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Geophysical Pilot Test Technical Memorandum

NERT Remedial Investigation – Downgradient Study Area
Nevada Environmental Response Trust Site
Henderson, Nevada

Final

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Responsible Certified Environmental Manager (CEM) for this project

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state and local statutes, regulations and ordinances.

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Downgradient Study Area Project Manager

October 24, 2017
Date

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List of Acronyms and Abbreviations

AFE	analog front end
bgs	below ground surface
CSAMT	Controlled-source audio-frequency magnetotellurics
EM	electromagnetics
ERI	Electrical resistivity imaging
FGSP	Full-Scale Geophysical Survey Plan
ft/s	feet per second
GPT	geophysical pilot test
GPTP	Geophysical Pilot Test Plan
Hz	hertz
kg	kilogram
kHz	kilohertz
LVW	Las Vegas Wash
MASW	multi-channel array surface wave
NDEP	Nevada Division of Environmental Protection
NERT	Nevada Environmental Response Trust
ohm-m	ohm meter
PEG	propelled energy generator
PVC	polyvinyl chloride
RI	Remedial Investigation
ReMi	Refraction Microtremor
TDEM	time-domain electromagnetic
UMCf	Upper Muddy Creek formation
USBR	United States Bureau of Reclamation
V(s)	Shear wave velocity
2D	two-dimensional

1.0 Introduction

This technical memorandum (memo) describes the results of the geophysical pilot test (GPT) conducted for the Nevada Environmental Response Trust (NERT) Remedial Investigation (RI) - Downgradient Study Area in Henderson, Nevada (site) (**Figure 1**). This memo has been prepared as an interim deliverable in advance of the forthcoming NERT RI Report. Except as noted in this memo, the work was conducted per the procedures and methods described in the Geophysical Pilot Test Plan (GPTP)[1] approved by Nevada Division of Environmental Protection (NDEP) on July 11, 2016.

The overall objective of the Downgradient Study Area investigation is to identify subsurface pathways within the Downgradient Study Area through which perchlorate-impacted groundwater is entering the Las Vegas Wash (LVW). The GPT program is being conducted to aid in meeting that objective. The location of paleochannels, as well as other potential preferential flow pathways, is important to the understanding of perchlorate mass flux to the LVW outside of the NERT RI Study Area. While limited geophysical surveys have been conducted in the area, uncertainties remain as to the locations of these channels in the vicinity of the LVW. The GPT consisted of evaluating three geophysical systems, including the feasibility of employing the systems under constrained access conditions, their cost effectiveness, and their effectiveness at identifying the top of the Upper Muddy Creek formation (UMCf) and paleochannel geometry. The GPT results will serve as the basis for the forthcoming Full-Scale Geophysical Survey Plan (FGSP) to select the optimal approach for a full-scale geophysical survey of reaches of interest along the LVW within the Downgradient Study Area.

The data quality objectives, methods and procedures, and sampling plan for the GPT are described in the GPTP, which was designed to answer the following study questions:

- What geophysical methodology returns the most accurate interpretation of paleochannel geometry?
- Can the geophysical data identify and segregate coarse- and fine-grained sediments within the overlying alluvial fan deposits?
- Can geophysical data be verified with existing or new soil boring data?
- What geophysical method(s) can readily be implemented considering restrictions on access to property and biologically sensitive areas?

[1] AECOM, 2016. Geophysical Pilot Test Plan. NERT Remedial Investigation – Downgradient Study Area, Nevada Environmental Response Trust Site, Henderson, Nevada. Final. July.

2.0 Geophysical Pilot Test

Four potential locations for the GPT survey lines were selected based on the review of available data and access considerations; however, two of these locations were back-up locations in case access issues or logistics made one or two of the preferred locations infeasible. The four potential GPT locations are shown on **Figure 2**. Two GPT survey line locations, GPT-2 and GPT-4, (**Figure 2**) were selected for the testing of the geophysical systems. In addition, two verification borings were drilled at each of the two selected GPT lines to verify the results of the geophysical surveys. GPT-2 and the associated verification soil borings are located on United States Bureau of Reclamation (USBR) and Clark County Wetlands Park properties, and GPT-4 and the associated verification soil borings are located on Clark County Wetlands Park and LandWell Company L.P. (LandWell) properties (**Figure 3**). Subsurface geophysical field activities were conducted on October 17, 2016, through November 18, 2016. Drilling of the verification borings was conducted from February 13 through February 18, 2017.

2.1 Pre-Field Activities

A site-specific Health and Safety Plan was developed for the Downgradient Study Area, including the planned field work for the GPT activities (utility clearance, land survey, biological clearance survey, geophysical survey and drilling). Property owners were contacted to obtain permission for access to conduct the geophysical surveys and possible vegetation trimming. Access was granted by USBR[2], Clark County Wetlands Park, and LandWell. Copies of the entry permits are provided in **Appendix A**.

Prior to the utility clearance survey, a field reconnaissance of the GPT locations was conducted to verify the location, accessibility, and physical conditions along each 830-foot-long survey line. GPT-1 was located in an area that had been revegetated and where vegetation was dense. Therefore, to avoid clearing vegetation, GPT-1 was taken out of consideration as a potential survey line. GPT-4 was moved approximately 150 feet to the north due to dirt mounds, roads, and an earthen fill embankment measuring approximately 20 feet in height along the proposed survey line. Prior to drilling activities, the locations of the verification borings were adjusted slightly to avoid vegetation and uneven terrain.

2.1.1 Utility Clearance

A subsurface utilities clearance survey was conducted prior to final selection of the GPT survey lines to avoid crossing or being in close proximity of any subsurface utilities. The utility clearance was conducted using a magnetometer, ground penetrating radar and a utility locator along GPT-2 and the relocated GPT-4 (as discussed in Section 2.1). The originally proposed location of GPT-2 was along a dirt road directly adjacent to a paved road. This location was selected because of the lack of vegetation; however; the utility survey identified a water line and sewer line in the adjacent road. In addition, two well boxes, 3-foot-tall bollards, and an electrical box were identified near the western end of the GPT-2 during the utility clearance, and the line was also bisected by a paved road on the west end of the line. To avoid interference from these metallic or electrical-related objects, GPT-2 was moved approximately 230 feet to the north. The utility clearance survey at the relocated GPT-2 and GPT-4 locations did not identify any subsurface utilities. GPT-1 and GPT-3 were not cleared for utilities because GPT-2 and GPT-4 were determined to be the most feasible locations for performing the GPT.

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[2] USBR, 2016. Request for Right of Use, Non-invasive Geophysical Pilot Test and Installation of Transducers (Project), Nevada Department of Environmental Protection (NDEP), Contract No. 16-07-30-0850, Robert B. Griffith Water Project (Your Letter Dated August 12, 2016), October 6.

A second subsurface utilities clearance survey was conducted prior to the drilling of the verification borings. No utilities were detected at the four verification boring locations.

2.1.1 Rationale for GPT Survey Lines

Based on the initial field reconnaissance and utility clearance, the relocated lines for GPT-2 and GPT-4 were selected as the two preferred geophysical survey lines. These locations were selected based on the following reasons:

- They were mostly clear of vegetation
- No subsurface utilities were present along the lines
- Soil borings or wells had previously been drilled near these lines providing soil stratigraphy data that could support evaluation of the GPT results
- Suspected paleochannels had been mapped across these lines making them ideal locations to conduct the subsurface GPT surveys

2.1.2 Biological Clearance Surveys and Monitoring

A biological clearance survey was conducted on November 1, 2016, at GPT-2 and GPT-4 prior to the start of vegetation trimming and the GPT survey activities. According to the field biological survey that AECOM performed on November 1, 2016, the location of GPT-2 would cause minimal impacts on the local vegetation because the majority of the line is located in areas with no vegetation. The location of GPT-4 is highly disturbed with dirt roads and brush piles. A restoration area is located on the northwestern portion of the line, and tamarisk trees are located at the northwestern end of the line, just after the end of the line. As such, significant biological constraints were not identified at the two GPT locations.

A biological clearance survey was conducted on February 12, 2017, prior to the drilling activities at GPT-2 and GPT-4. Each verification boring location and the access routes with a 100-foot buffer area were surveyed. No sensitive biological resources were observed at these locations. Per the USBR entry permit, a biological monitor was present during drilling activities. Each day, prior to commencing field activities, a biological clearance survey of the work areas was conducted (February 13 through February 17, 2017). Field crews and equipment stayed within areas and routes cleared and approved for work by the biologist. Borings were covered at the end of each day to prevent wildlife from falling into them. Motorized vehicle speeds in the work areas did not exceed 15 miles per hour.

Minor disturbance of vegetation occurred at the NERT-CB3 soil boring location (**Figure 4**). Existing roads were used as much as possible; however, some saltbrush bushes were driven over to access the drilling location. To minimize disturbance, the ingress and egress paths for the equipment and motor vehicles were the same.

2.1.3 Land Survey

The two GPT survey lines and four verification borings were surveyed by a State of Nevada-licensed land surveyor. The positions of each line were surveyed and referenced to the State Plane Coordinate System, and elevations were referenced to the North American Vertical Datum (NAVD) of 1983 for the Nevada East Zone (2701) with vertical datum based on NAVD of 1988 (NAVD 88) referenced to the City of Henderson Benchmark network. The end points and 100-foot intervals were staked and surveyed along the GPT survey lines, and labeled as described in Section 5.1 of the GPTP. Station 000 was labeled at the east (GPT-2) and southeast (GPT-4) ends of the lines with increasing station numbers to the west and northwest. The land survey for the GPT survey lines was conducted from October 17 through 19, 2016 and the survey for the verification soil borings was conducted on February 17, 2017. Elevation of the ground surface and polyvinyl chloride (PVC) casings in the verification soil borings were also surveyed on February 17, 2017.

2.1.4 Trimming of Vegetation

Minimal trimming of vegetation was conducted at GPT-4 so that the GPT survey line equipment could be laid out and the survey measurements could be obtained. Vegetation was trimmed to create an approximately 6-foot-wide path. The vegetation roots were left intact to encourage regrowth. Areas cleared along GPT-4 were located at approximate survey station 120 to 140 feet, 340 to 450, and 800 to 825 feet. No trimming of vegetation was conducted at GPT-2.

2.2 Geophysical Systems Evaluation

The objective of the investigation was to determine the effectiveness of several geophysical methods to map subsurface geologic/hydrologic features such as the contact between unconsolidated sediments and the UMCf and possible paleochannels cut into the UMCf. Three types of systems were tested: seismic, electrical resistivity, and electromagnetic. Within these systems, five geophysical methods were evaluated:

1. Seismic surface waves: consisting of the active-source Multi-Channel Analysis of Surface Wave (MASW) method supplemented with the passive-source Refraction Microtremor (ReMi – passive source) method;
2. Compression (P) -wave seismic refraction – seismic refraction;
3. Electrical resistivity imaging (ERI) – electrical resistivity;
4. Time-domain electromagnetic (TDEM) – electromagnetic (EM); and
5. Controlled-source audio-frequency magnetotellurics (CSAMT) – EM.

The locations and lengths of each of these surveys are shown on **Figure 5** and **Figure 6**. The seismic methods were applied to determine if they could be effectively utilized to map the top of the UMCf. The ERI, TDEM, and CSAMT methods were used to determine whether the methods may be effective at mapping the lateral variability of the subsurface and the top of the UMCf. Detailed information of each procedure is presented in the GPT report prepared by GeoVision (**Appendix B**). A Sokkia C300 auto level was used to measure relative elevations along each GPT survey line. The relative elevation survey was tied to the elevation recorded by a licensed surveyor (Section 2.1.3).

2.2.1 Seismic Methods

Seismic methods involve introducing acoustic energy into the subsurface by an impulsive energy source such as a sledgehammer or weight drop impacting a metallic plate, a vibratory energy source; or use of ambient vibrations. The acoustic waves propagate through the subsurface at a velocity dependent upon the density and stiffness of the material through which they travel. Two seismic methods were tested as part of the GPT, surface waves and P-wave seismic refraction. Detailed information on the methods is provided in Section 2 and Section 3 of the GeoVision Report (**Appendix B**).

2.2.1.1 *Surface Wave Methods*

The surface wave methods are used for determining shear wave velocity profiles. Active-source surface wave data were acquired using the MASW method. These measurements were augmented with passive-source surface wave data acquired using the ReMi method.

MASW equipment used during this investigation consisted of two Geometrics Geode signal enhancement seismographs, 4.5-Hertz (Hz) vertical geophones, seismic cable with 10-foot take outs, a 3-pound hammer, a 10-pound sledgehammer, a 20-pound sledgehammer, a 40-kilogram (kg) propelled energy generator (PEG), and an aluminum plate. The active soundings were acquired along a linear array of 48 geophones spaced 5 feet apart, placed from stations 300 feet to 535 feet along GPT-2 and GPT-4 (**Figures 5 and 6**).

Shot points (i.e., seismic signal created by hammers and PEG impinging on the aluminum plate) were located 5, 20, 50, and 100 feet from the geophone at the end of each GPT line. Multiple shot points were located in the interior of the array. The 3-, 10-, and 20-pound sledgehammers were used for the 5-foot offset source locations. The 10-pound sledgehammer was used at the interior offset source locations, including the center shot. The 3-pound hammer was also used at the center shot. For quality control purposes, the test at the center shot location was repeated using the 10-pound sledgehammer on each array. The PEG was used for the 20-foot and greater offset locations. Data from the impact sources were averaged 10 times to improve the signal-to-noise ratio.

The passive soundings were collected coincident with the P-wave refraction survey which is described in the next section (**Figures 5 and 6**). The passive surface wave data were collected using the two Geometrics Geode signal enhancement seismographs that recorded 40, 30-second noise records using a 2-millisecond sample rate. Data were processed as noted in Section 2.3 of the GeoVision report (**Appendix B**).

2.2.1.2 *P-Wave Seismic Refraction Method*

Seismic refraction methods involve analysis of the travel times of the first energy to arrive at the geophones. These first arrivals are from either the direct wave (at geophones close to the source), or critically refracted waves (at geophones further from the source). The data acquisition system used for the P-wave seismic refraction survey consisted of the same equipment used to collect the surface wave data. The 48, 4.5-Hz geophones were spaced 10 feet apart.

The P-wave soundings were placed at stations 180 feet to 650 feet along GPT-2 and GPT-4 (**Figures 5 and 6**). Approximately 17 shot point locations were sounded: end shots at geophones 1 and 48, multiple off-end shots, and interior shots at regular intervals between every fourth station. For quality control purposes, the center shot was repeated. Data from the impact sources were averaged 10 times to improve the signal-to-noise ratio. Data were processed as noted in Section 3.3 of the GeoVision report (**Appendix B**).

2.2.2 ERI Method

ERI involves the measurement of the apparent resistivity of subsurface sediments and rock as a function of depth and/or lateral offset. The resistivity of soils and rock is a function of porosity, permeability, presence and ionic content of the pore fluids, and clay mineralization.

Electrical resistivity surveys are conducted by applying an electrical current across a pair of current electrodes, while measuring the potential difference (voltage) between one or more pairs of potential electrodes. For a two-dimensional (2D) resistivity survey, the current and potential electrodes are generally arranged in a linear array. Measured voltages are used to calculate the apparent resistivity of the subsurface.

The ERI lines were placed along the entirety of the two GPT survey lines, from stations 0 feet through 830 feet (**Figures 5 and 6**). The 2D electrical resistivity data were acquired along the survey line using an Advanced Geosciences Inc. SuperSting R8/IP 112-electrode system. The SuperSting was programmed to acquire data in multiple passes to increase data density and minimize potential cultural noise. ERI data were collected using the inverse Schlumberger and strong gradient array configurations. Detailed information on the ERI methods is provided in Section 4 of the GeoVision Report (**Appendix B**).

Electrodes were spaced every 10 feet to allow high-resolution imaging of the near surface and a depth of investigation in excess of 120 feet. Contact resistance measurements were recorded prior to data acquisition. Electrodes exhibiting abnormally high contact resistance were treated with a saline solution and checked for good contact. The saline solution minimizes contact resistance between the electrode stake and the surrounding soil.

For quality control purposes, two cycles are run for each line of the command file. A command file is used by the ERI system to consistently run through the various combinations of current and voltage electrodes for each array. The repeated cycles are checked internally for repeatability. If a low repeatability (high error) occurs, the specific command line is automatically recollected to obtain acceptable repeatability. If the recollected cycles still exhibit a low repeatability (high error), the measurement is flagged. Data were processed as noted in Section 4.3 of the GeoVision report (**Appendix B**).

2.2.3 EM Method

An EM system consists of a transmitter loop and a receiver coil. The transmitter loop consists of a square loop of insulated wire placed on the ground surface. The receiver coil is placed in the center of the transmitter loop (central loop sounding) but may be placed outside of the transmitter loop (offset loop sounding). The EM-47 transmitter operates at three user-selectable repetition frequencies of 285-315, 75, and 30 Hz and is synchronized to the PROTEM receiver using a reference cable. Depending on the required resolution and depth of investigation, the dimensions of the transmitter loop may be changed. Larger loops allow deeper investigation depths and reduced noise level but with some loss of resolution.

2.2.3.1 *TDEM Method*

A Geonics EM-47 transmitter high-frequency receiver loop and a PROTEM digital receiver were used to conduct the TDEM soundings. The 100-watt, battery-powered EM-47 transmitter, placed centrally along one side of each wire loop, was used to drive current pulses through the wire. Generally, transmitter currents of 1 to 3 amperes were used for the 285-315, 75, and 30-Hz repetition rates, respectively.

Seven soundings were collected at each GPT survey line. The center of each sounding was placed at stations 100, 200, 300, 400, 500, 600, and 700 feet (**Figures 5 and 6**). Using pre-marked wire loops, 40-meter by 40-meter loops were established. For each sounding, the receiver coil was placed at the center of the loop. Detailed information on the TDEM methods is provided in Section 5 of the GeoVision Report (**Appendix B**).

The data acquired at each sounding center consisted of measurements at several different receiver gain settings for the three transmitter frequencies, in order to assure data quality and to obtain data over the largest possible time interval. Each frequency was recorded twice for quality control purposes. Data were processed as noted in Section 5.3 of the GeoVision Report (**Appendix B**).

2.2.3.2 *CSAMT Method*

A CSAMT system consists of a controller/receiver, an analog front end (AFE) for analog signal conditioning, an electric field kit, a magnetic field kit, and a vertical dual-loop transmitter with an operating range of 1 kilohertz (kHz) to 70 kHz. For data collection, the AFE is placed at the center of the sounding. Two electrical dipoles are then set up over the center of the sounding, in the specified x and y directions. These dipoles are referred to as Ex and Ey. Magnetic dipoles, Hx and Hy, are placed on a level location at least 2 meters apart and perpendicular to each other. The controller/receiver unit is placed outside of the sounding area.

The system measures the electrical impedance at the earth's surface by recording a series of simultaneous measurements of the local electrical and magnetic field fluctuations using the orthogonal electric and magnetic fields (natural and controlled). The depth of investigation is determined by the resistivity of the subsurface and frequencies encountered.

The CSAMT instrument used during this investigation consisted of a Geometrics Stratagem EH4. For each sounding, the electric and magnetic dipoles in the x direction (Ex and Hx) were placed in line with each GPT survey line. The electric and magnetic dipoles in the y direction (Ey and Hy) were placed perpendicular to the x dipoles and the GPT transect. The electric dipoles were placed using a length of 30 meters to accommodate the station spacing without overlap. The external transmitter was placed to the south of GPT-2 and northeast of GPT-4 at a distance of 600 feet or more. Both the AFE and the transmitter were grounded using stainless steel electrodes.

Seven soundings were collected at each GPT survey line. The center of each sounding was placed at stations 100, 200, 300, 400, 500, 600, and 700 feet (**Figures 5 and 6**). Three frequency bands were collected for each sounding: Band 1 (low), Band 4 (mid), and Band 7 (high). For each sounding collected, the instrument was manually gained to ensure the signal was strong enough while ensuring that it was not clipping out of range. Detailed information on the CSMAT methods is provided in Section 6 of the GeoVision Report (**Appendix B)**.

For quality control purposes, measurements at soundings GPT-2-CSAMT-700 and GPT-4-CSAMT-100 were repeated. Before the soundings on GPT-2 and after the soundings on GPT-4 were collected, parallel tests were conducted. The parallel tests were used to ensure coherence on all channels by placing the electrical dipoles on the same electrodes in the x direction and by placing the magnetic dipoles in the y direction. Data were processed as noted in Section 6.3 of the GeoVision report (**Appendix B**).

2.3 GPT Survey Results

2.3.1 Seismic

The results of the seismic surveys are shown on **Figures 7 through 10**. For the surface wave survey, the shear wave velocity (V_s) of subsurface sediments is generally a function of depth of burial and associated overburden pressure, degree of cementation, age of the sediments and to a lesser degree, soil type. For similar aged sediments under similar confinement, clays can have lower velocity than sands which can have lower velocity than gravels. At GPT-2, the estimated depth of the surface wave survey is about 100 feet. The data showed an increase in V_s with depth, which is to be expected. A direct, depth-dependent relationship between V_s and formation type is not possible to predict. At GPT-2, the top of the UMCf is estimated to occur at the layer boundary interpreted at a depth of 57 feet bgs (**Figure 7**) based on the assumed contact observed in the ERI data (about 60 feet) and the TDEM (about 60 to 70 feet bgs). It should be noted that the data inversion process does not yield a unique solution. The layer boundary interpreted in the surface wave survey may be shifted within 20 percent of depth and compensated for by adjusting the other parameters in the analysis, especially the V_S of the nearby layers..

At GPT-4, the estimated depth of the survey is about 200 feet; however, a thick, shallow, stiff zone – possibly caliche – impacted the ability to interpret shear wave velocities at depth. The surface wave test indicated that the possible cemented zone (caliche) extends from 15 feet below ground surface (bgs) to about 55 feet bgs (**Figure 9 and Figure 10**).

The P-wave seismic refraction survey at GPT-2 identified the saturated zone, where P-wave velocities exceed 4,000 feet per second (ft/s). The top of this saturated zone appears at an approximate depth of 16 to 20 feet bgs, shown on **Figure 8** as a dashed black line at 4,000 ft/s. The UMCf contact was masked by the saturated zone; therefore, it was not detected using this survey method. At GPT-4, the top of the interpreted caliche zone (P-wave velocities at about 8,000 to 9,000 ft/s contour) appears at an approximate depth of 14 to 18 feet bgs (**Figure 10**). Lower velocity sediments below the caliche layer could not be imaged because of the high P-wave velocities associated with the caliche layer that masks any underlying geologic structure. For the same reason, the depth to groundwater at GPT-2 could not be estimated from the seismic refraction data. The decreased P-wave velocity between 200 feet and 300 feet offsets is likely related to disturbed soil from activities related to the soil berm in this area rather than a paleochannel.

2.3.2 ERI

The results of the ERI survey are shown in **Figures 11 and 12**. Three resistivity units were identified by the ERI surveys (**Figure 11**). At GPT-2, the uppermost unit, with high resistivity (red colors), was interpreted as unsaturated sands and gravels that extend from the surface to an approximate elevation of 1,515 feet. This unit is underlain by a unit with intermediate resistivity (green colors) that extends to an approximate elevation of 1,460 feet and is interpreted as saturated sands and gravels. This unit is underlain by a unit with low resistivity (blue colors) that is interpreted as the saturated finer-grained UMCf. The UMCf in this area may be composed of silts that are less conductive which make it more difficult to identify the contact between the saturated sands and gravels and the UMCf using ERI methods.

There is no significant resistivity structure indicative of a large paleochannel carved into the top of the UMCf. Near the LVW, the driving force for channel erosion would have been much lower than upgradient on steeper slopes and thus paleochannels would be expected to be shallow and not easily discernable. Therefore, paleochannels in this area would be expected to be interpreted through coarser-grained channel sediments or zones of higher resistivity. Several areas with slightly elevated resistivity in the intermediate units could be associated with coarser-grained sediments. The most significant of these features was detected at 300 feet offset.

Similar results were observed at GPT-4, with the exception of a thin, lower resistivity unit in the near surface. No anomalies were detected at this location (**Figure 12**). This zone of consistently high resistivity may be associated with the caliche unit postulated in the seismic refraction and surface wave models.

2.3.3 EM

The results of the TDEM survey are shown in **Figures 13 and 14**. Geoelectric sections were developed for both the one-dimensional (1D) smooth and 1D layered TDEM models (**Figure 13**). Three resistivity units were identified, similar to those identified in the ERI surveys. At GPT-2, the uppermost unit, with resistivity greater than about 20 ohm-meter (ohm-m), was interpreted as unsaturated sands and gravels that extend down to an elevation of approximately 1,525 feet (shown in orange, red and pink). The middle unit, with resistivity ranging from 5 to 7 ohm-m, is interpreted as saturated sands and gravels (shown in light blue and green). The top of the lower unit, located at an elevation of about 1,440 to 1,460 feet, with resistivity of less than 1.3 ohm-m, is interpreted as saturated finer-grained UMCf (shown in darker blues). No anomalous resistivity zones that may be related to a paleochannel were detected during the TDEM survey; however, the interpreted top of the UMCf is slightly deeper in the western end of the line.

Similar results were observed in GPT-4, with the exception that the uppermost unit was interpreted as unsaturated sands and gravels and/or caliche. This unit extends to an approximate elevation of 1,520 feet (**Figure 14**). There was no lateral variability in the depth of the units indicating the presence of paleochannels in this area.

Useful CSAMT data could not be recovered at GPT-2 due to an unknown source of electrical noise (e.g. radar system, microwave tower, transmission tower). Good quality CSAMT data were recovered at GPT-4. This method has much lower near-surface resolution than the ERI and TDEM methods. A near surface unit above an approximate elevation of 1,510 to 1,520 feet is interpreted to be unsaturated sands and gravels and/or the caliche unit (yellow and red colors) (**Figure 15**). This unit is underlain by a unit of intermediate resistivity between approximate elevations of 1,510 feet and 1,420 feet, and interpreted to be saturated sands and gravels or possibly the saturated silty member of the UMCf (green colors). The lower unit (below an elevation of approximately 1,450 feet) shows lower resistivity (blue colors) and is interpreted as the saturated, clayey member of the UMCf. It should be noted that a silt/clay boundary within UMCf might have a stronger EM signature than the top of UMCf.

2.3.4 Quality Control

Quality control measures for all of the methods showed consistent results with initial measurements for both of the GPT survey lines. Results of the quality control measures are presented in Appendix B of the GeoVision GPT report (**Appendix B**).

2.3.5 Rationale for GPT Verification Boring Locations

Two GPT verification soil boring locations were drilled at each of the GPT survey lines based on the seismic, ERI, and EM method results. Boring locations were placed in areas where anomalies were observed or to verify the units identified by the GPT surveys. Surface vegetation was considered when choosing the boring locations so that disturbance of the surface vegetation would be minimized. Where possible, the soil borings were placed in areas that are sparsely vegetated and along existing dirt roads. The locations of the verification soil borings locations along GPT-2 and GPT-4 are shown on **Figure 4**.

At GPT-2, one verification soil boring was originally proposed to be drilled at station 300 feet to investigate the higher resistivity anomaly shown by the ERI results. This boring location was moved to station 348 feet due to a hilly area at the original locations that would have made it difficult for the drill rig to maneuver to the original location. The second boring along GPT-2 was drilled at station 540 feet to confirm the depths of the units identified by the seismic, ERI, and TDEM surveys.

Along GPT-4, one verification soil boring was drilled at station 230 feet to investigate the possibility of a paleochannel being located at a deeper depth than what is shown on the ERI survey (**Figure 12**). The second verification soil boring was drilled at station 390 feet to confirm the depths of the units identified by the seismic, ERI, TDEM, and CSAMT surveys.

2.4 Verification Borings

Verification borings were drilled along each GPT survey line to verify the results of the GPT surveys. The rationale for the verification soil boring locations is discussed in Section 2.3.5. The locations of the four borings drilled are shown on **Figure 4**.

2.4.1 Drilling, Soil Sampling, and Analyses

Sonic drilling methods were used to advance each of the GPT verification soil borings. A truck-mounted LS600 rig and support vehicle were used to advance the 8-inch-diameter soil borings. Each boring was drilled to a depth of 75 feet below bgs. Soil cores produced by the sonic drilling methods were logged by a geologist using the Unified Soil Classification System. Approximate depth to groundwater was noted for each soil boring and ranged from 17 feet bgs to 24 feet bgs. Boring logs for each soil boring are presented in **Appendix C**.

A 3-inch blank PVC casing was installed in each soil boring down to its total depth. The casing was installed to prevent the borehole from collapsing and to facilitate induction logging. Casing was set loosely and un-grouted with no bottom cap. After the casing was installed the top of the soil boring was covered to prevent wildlife from falling into the hole. The total depth of the cased borehole varied slightly from the total depth drilled.

Bulk soil samples were collected from each soil boring for soil property testing. One soil sample from each boring was collected from the unsaturated zone and two to five samples were collected from the saturated zone. At least one sample was collected from the UMCf (saturated zone). Samples were collected at the discretion of the field geologist but, in general, were from soils that were representative of the overall range of lithology. Soils were tested for:

- Grain Size Analysis via ASTM Method D422M, sieve method;
- Moisture Content via ASTM Method D2216; and
- Atterberg Limits via ASTM Method D4318.

A summary of the soil property results are provided on **Table 1** through **Table 3**. Detailed soil property results are presented in the laboratory report (**Appendix D**).

2.5 Soil Boring Logs

Soil boring logs showed that the upper 50 to 60 feet of sediments consists of saturated and unsaturated interbedded silts, sands, and gravels with the UMCf below these sediments. The UMCf was identified based on the lithology (silt, high density, and the characteristic green or blue-green color. At GPT-2, groundwater was observed at 17 and 24 feet bgs, with the deeper groundwater at NERTCB1 (west). The UMCf was observed at 48 feet bgs at NERTCB1 and deepened toward the east to 66 feet bgs at NERTCB2. At GPT-4, groundwater was observed at 17 and 20 feet bgs, with the deeper groundwater at NERTCB4 (southeast). No caliche was observed in the two soil borings along GPT-4. The UMCf was observed at 53 and 52 feet bgs. Logs for each soil boring are presented in **Appendix C**.

2.6 Geophysical Logging of Soil Borings

A review of the geophysical survey results indicated that EM induction logging of the soil borings could be beneficial to tie electrical resistivity structure in the ERI and TDEM models to geologic observations in the soil boring logs, and to better calibrate the values measured to the subsurface features of interest. The four GPT verification soil borings were logged using dual-induction logging methods. A copy of the EM logging report is provided in **Appendix E**.

2.6.1 EM and Natural Gamma Induction Logging Procedures

Each verification soil boring was logged using dual-induction data collection techniques. Measurement procedures were conducted per the following ASTM standards:

- ASTM Method D5753-05 (Re-approved 2010) – Standard Guide for Planning and Conducting Boring Geophysical Logging;
- ASTM Method D6274-10 – Standard Guide for Conducting Boring Geophysical Logging, Gamma; and
- ASTM Method D6726-01 (Re-approved 2007) – Standard Guide for Conducting Boring Geophysical Logging- Electromagnetic Induction Logging.

Conductivity and natural gamma data were collected using a Robertson Geologging, Ltd. dual-induction probe. This data collection method is most often used to assist with bed boundary identification, strata correlation between borings, and strata geometry and type.

An EM induction probe consists of a transmitter coil and a receiver coil. The probe was 7.5 feet long and 1.5 inches in diameter. An alternating current is applied to the transmitter coil, causing it to radiate primary and secondary EM fields. The secondary EM field which is measured as an alternating current in the receiver coils is proportional to formation conductivity. Conductivity is inverse with respect to resistivity.

Natural gamma measurements register small quantities of radioactive material contained in soil and rock that emit gamma radiation as they decay. This radiation is detected by scintillation, which is the production of a tiny flash of light when gamma rays strike a crystal of sodium iodide. The light is converted into an electrical pulse by a photomultiplier tube and is counted by the probe's microprocessor. This measurement is useful because radioactive elements are concentrated in certain soil and rock types (e.g., clay or shale, and depleted in others, e.g., sandstone or coal).

To prevent the borehole from collapsing during EM logging, each borehole was fitted with 3-inch PVC blank casing to total depth. Casing was set loosely and un-grouted with no bottom cap. The total depth of the cased borehole varied slightly from the total depth drilled.

Logging consisted of lowering the EM induction probe through the casing to the bottom of the boring, then returning it to the surface while acquiring data. Typically, probe ascent is approximately 15 feet per minute, collecting data continuously at 0.05-foot spacing. For quality assurance, logs were run twice in each boring. Natural gamma measurements were made continuously to a depth of approximately 66 feet bgs.

2.6.2 EM Induction and Natural Gamma Logging Results

GPT-2

Data from the two boreholes along GPT-2 demonstrated a similar pattern (**Figure 16 and 17**). The upper 12 to 14 feet exhibited low conductivity which corresponds to dry sands observed during drilling activities. Between 12 to 14 feet and approximately 32 feet bgs, elevated conductivity was detected which corresponds to finer-grained silts and sands as well as the groundwater table. Below 32 feet bgs to about 48 feet bgs (at NERT-CB1) and 66 feet bgs (at NERT-CB2), conductivity is lower than the zone above, and fairly uniform. At 48 and 66 feet bgs, conductivity increases significantly, corresponding to the top of the UMCf.

A comparison of the two coil spacings (long and short) showed that, overall, differences within each soil boring were fairly small suggesting lateral homogeneity in sediment conductivity. Differences were larger for NERT-CB1 than for NERT-CB2.

The natural gamma results correlate weakly with the sediment type and grain size noted by the soil boring logs. Gamma counts are highest in the upper 6 to 8 feet, in the unsaturated coarse-grained sediments. Fluctuations of the counts are stronger for NERT-CB1 than for NERT-CB2. Gamma values increase significantly at the UMCf contact.

Overall, the dual-induction logging from both boreholes showed similar patterns, indicating that sediments are fairly uniform along GPT-2. The main difference between the two soil boring locations is the interpreted depth to the UMCf, which is shallower on the west in NERT-CB1.

GPT-4

Data from the two soil borings along GPT-4 demonstrated a similar pattern between the two soil borings (**Figures 18 and 19**). The upper 44 to 48 feet of the induction logs showed a fairly flat response with overall lower conductivity (higher resistivity). An uptick representing the water table is not observed in the induction logs. Starting at 44 feet (NERT-CB4) and 48 feet (NERT-CB3), conductivity values increase substantially. Based on the soil boring logs, the conductivity values increase approximately 6 to 8 feet above the UMCf contact.

A comparison of the two coil spacings showed that, overall, differences within each soil boring were fairly small, suggesting lateral homogeneity in sediment conductivity. Differences were slightly larger for NERT-CB4 than for NERT-CB3.

The natural gamma results correlate weakly with the sediment type and grain size noted by the soil boring logs. Gamma counts are highest in the upper 10 feet, in the unsaturated coarse-grained sediments. NERT-CB4 shows an anomalous spike between 10 and 16 feet. This spike corresponds to a thinly layered sandy silt-sand-silt with gravel sequence in the boring log, above the groundwater table. Between 20 and 30 feet, values are slightly but consistently higher in NERT-CB4 than in NERT-CB3, which is consistent with expectations due to differences in sediment type. Between 42 and 55 feet, counts are relatively low in both borings, just above the UMCf contact.

3.0 Conclusions

Of the five geophysical methods tested, seismic methods were found to be most effective in locating groundwater or caliche, whichever is shallower; however; they were not successful in mapping deeper sediments, including the top of the UMCf, paleochannels, and they were not able to identify or segregate coarse- and fine-grained sediments within the overlying alluvial fan deposits. The refraction method could have limited use in areas where groundwater information is not available but it would not provide sufficient detail needed to map deeper units and it is not a cost effective method for large-scale surveys.

Both ERI and TDEM methods were found to be effective for mapping subsurface structure at GPT-2 and GPT-4; however, they were not able to identify or segregate coarse- and fine-grained sediments within the overlying alluvial fan deposits. There was no conclusive evidence of large paleochannels in the top of the UMCf at either GPT line. It should be noted that the GPT survey lines tested might not have had sufficient lateral variability for paleochannels to be detectible. These tests indicated that subsurface structures are oriented relatively horizontal beneath each GPT survey line; however, there may be a gradual deepening of a low-resistivity zone, likely associated with the saturated clay of the UMCf, at the western end of GPT-2. ERI and TDEM methods may be successfully utilized to characterize subsurface geologic/hydrologic conditions, including sufficient data to be able to interpret paleochannel geometry. Selected seismic, ERI, and TDEM survey line results for GPT-2 and GPT-4 are shown on **Figure 20 and 21**.

ERI methods can be used in areas with limited access (i.e., dense vegetation) or that cross subsurface pipelines, whereas TDEM methods are better suited for areas that are easily accessible (i.e., sparse vegetation or on an existing dirt road) and not near electromagnetic noise sources that could interfere with data collection. Brush trimming requirements are different for ERI and TDEM methods. Although minimal brush trimming will be required for ERI methods in areas with light to moderately dense vegetation, it may be possible to acquire TDEM data without brush trimming, making it an easier and a more cost-effective method than ERI.

CSAMT is capable of imaging greater depths than ERI and TDEM methods but it does not provide the level of near surface resolution that ERI and TDEM do. In addition, CSAMT data could not be collected at GPT-2 due to heavy interference by what is believed to be an outside cultural noise source, such as a microwave tower or transmission tower. Although CSAMT methods may provide sufficient data at depth for the interpretation of top of the UMCf and paleochannels, these methods are susceptible to interference from cultural noise sources. For this reason, CSAMT methods are not proposed for the full-scale geophysical survey.

Verification soil borings together with dual-induction and natural gamma logging of the soil boring provided verification of the geophysical methods tested, collecting physical data of the subsurface sediments. In general, sedimentary units identified in soil boring logs corresponded with the dual-induction and gamma logs. EM induction and gamma logs help to increase the confidence of soil core visual observations because they are an independent source of hard data to verify observations. Soil property analysis from samples collected from the verification soil borings provided information on plasticity, grain size, and moisture content. This independent data can also be used to confirm observations made during logging of the borings; however, these data will be most useful for the future design of remediation systems.

4.0 Recommendations

Results of the geophysical methods tested were evaluated to see if the objectives of this investigation were met. The GPT study showed that geophysical methods vary in capabilities (i.e., investigation depth, resolution, and ease of deployment) and are tools best used in concert with each other. The following combination of geophysical methods together with drilling and logging of verification soil borings is recommended to maximize survey coverage and obtain sufficient subsurface details in the full-scale geophysical survey.

1. EM Methods for screening – After reviewing the results of the GPT survey and taking into account the large amount of proposed linear feet (13,000 feet) to be surveyed for the FSGS, GeoVision recommends using EM methods for an initial screening of proposed full-scale geophysical survey lines. These methods (Geonics EM-31 and EM-34XL) were not used in the GPT investigation but are recommended as a reconnaissance tool that can be utilized to identify areas for focused ERI and TDEM surveys. Geonics EM-31 equipment would be used to map near surface features, such as pipelines, that may interfere with other EM measurements. EM-34XL would be used to map lateral variability, ideally to indicate paleochannels. These EM methods are non-contact (31) and minimally-contacting (34) devices, and are very efficiently deployed in the field. The cost to run these methods are about 30 percent less that the more sophisticated ERI and TDEM methods for comparable coverage area but do not provide sufficient detailed information at depth. Therefore, ERI or TDEM methods would still be needed to characterize possible anomalous features.
2. ERI and/or TDEM Methods – These methods returned the highest resolution (laterally and vertically) in the upper 100 feet.

   ERI methods are very time- and labor-intensive to conduct on a large scale; therefore, where possible, TDEM methods are recommended for the more detailed surveys. The approach to using this method would be to acquire TDEM data at 500-foot intervals where EM-34XL data indicate only gradual variation in subsurface electrical structure and at 100- to 200-foot intervals in areas where the EM-34XL indicates anomalous subsurface electrical structure. ERI would be used only in areas with anomalous EM-34XL data where electromagnetic interference or site access conditions are not suitable to TDEM acquisition.
3. Seismic Methods – Limited seismic refraction surveys (e.g., end shots only) can be acquired, as needed, in areas where groundwater depth information is not available but needed to facilitate ERI or TDEM interpretation. The labor-intensive surface wave surveys are not recommended.
4. Verification Soil Borings – Verification soil borings are reliable for determining subsurface lithology, soil properties and to verify the geophysical data. However, soil borings are costly and impractical for investigating large survey areas. Two verification soil borings are recommended for each full-scale geophysical survey line.
5. Soil Property Testing – Soil properties testing is recommended for each verification soil boring to verify observations on the soil boring logs and for later use in the design of remedial systems for the NERT RI. At least one sample should be collected from the unsaturated zone and two to five samples should be collected in the saturated zone. Each sample should be analyzed for grain size analysis (ASTM Method D422; sieve method), moisture content (ASTM Method D2216), and Atterberg limits (ASTM Method D4318).
6. In-hole EM Induction and Natural Gamma Logs – Electrical logging of the verification soil borings is recommended to collect detailed lithologic information, to verify lithological observations from logging of the soil boring, and to accurately tie in electrical resistivity structure in the TDEM or ERI models to

geologic observations in the verification soil borings. EM induction logging is recommended for each verification soil boring. Verifications soil borings will be cased with PVC to prevent collapse of the hole during electrical logging.

These proposed investigation methods can be readily implemented at the site for the full-scale geophysical survey. These recommended geophysical methods coupled with limited drilling and logging of verification soil borings would be minimally invasive and protective of culturally and biologically sensitive areas.

The objective of the full-scale geophysical investigation along the LVW is to identify subsurface pathways or structures through which perchlorate-impacted groundwater is entering the LVW. Paleochannels are thought to be preferential pathways for perchlorate-impacted groundwater entering the LVW. To assess the location of these paleochannels, the full-scale geophysical survey would need to cover approximately 13,400 linear feet using several geophysical survey methods and the drilling of soil borings to verify the geophysical data. Implementation of the full-scale geophysical survey is estimated to be $1.2 million.

In addition, paleochannels near the LVW are broad structures and additional detailed investigations may have to be conducted to identify a more precise location where perchlorate-impacted groundwater is entering the wash. The costs for these additional investigations are not included in the $1.2 million estimated for the full-scale geophysical survey. Based on the broad nature of the full-scale geophysical survey and the high cost to implement, AECOM does not recommend implementing the full-scale geophysical survey. However, consideration should be given to fiber-optic distributed temperature sensing (DTS) technology to evaluate groundwater-surface water interaction along the LVW.

DTS installations provide a direct measurement of the water temperature along the streambed. This method can provide a robust data set to delineate groundwater discharge zones because groundwater temperature is relatively stable in nature and the contrast between groundwater and surface water temperatures would isolate areas of groundwater inflow. Temperature data collected from DTS technology would focus future surface water and groundwater sampling events, as well as other investigations, in areas along the LVW where groundwater inflow is suspected.

Three surface water investigations in the Downgradient Study Area have been completed between May 2016[3] and February 2017.[4] The results of these investigations indicate that there are two reaches that show increases in perchlorate with no obvious source of perchlorate input. Concentrations of perchlorate increase upgradient of Calico Ridge Weir and upgradient of Three Kids Weir. It is assumed the perchlorate is entering the LVW via groundwater in these reaches. DTS technology could be deployed in these areas to identify the location of groundwater inflow to the wash. A focused surface water sampling event could then be conducted to determine if the areas of groundwater inflow are contributing perchlorate.

DTS deployments involve laying a thin fiber-optic cable on the streambed, typically in the same general direction as the stream flow. Temperature measurements are performed at approximately every 1 meter along the cable, at regular time intervals, typically every 15 minutes for the duration of the survey. The cable is attached to an operating unit, which requires a very small footprint adjacent to the stream to operate, minimizing any landscape

[3] AECOM 2016. Surface Water and Seep Grab Sampling Technical Memorandum, NERT Remedial Investigation, Downgradient Study Area, Nevada Environmental Response Trust Site, Henderson, Nevada, Final, November.

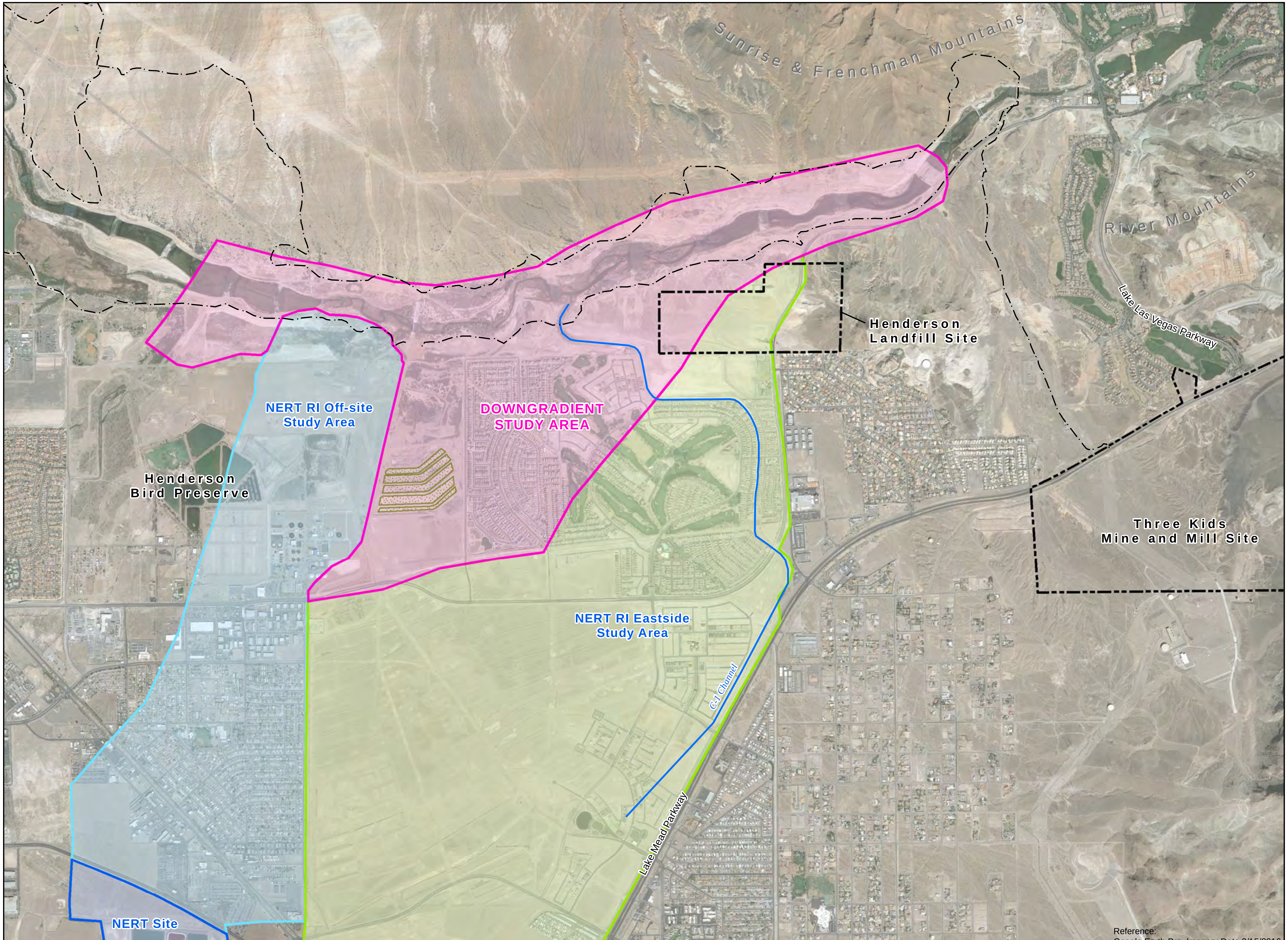
[4] AECOM 2017. Surface Water Investigation Technical Memorandum, NERT Remedial Investigation, Downgradient Study Area, Nevada Environmental Response Trust Site, Henderson, Nevada, Preliminary Draft, June.

impacts. This method is minimally invasive, ideal to use in ecologically sensitive environments, and provides a robust dataset.

Conducting a fiber-optic DTS survey to delineate locations of groundwater flow to the LVW would cost significantly less than implementing a full-scale geophysical survey because survey lengths would be shorter, the methods are minimally invasive and the field time is significantly less. The estimated cost to investigate the two reaches suspected of groundwater inflow is estimated to be approximately $220,000 or 80 percent less than the full-scale geophysical investigation. Therefore, an investigation using DTS technology is recommended to provide a more accurate location of groundwater inflow to the LVW. This recommendation is also included in the Surface Water Investigation Technical Memorandum, currently in preparation.[5]

[5] AECOM 2017. Surface Water Investigation Technical Memorandum, NERT Remedial Investigation, Downgradient Study Area, Nevada Environmental Response Trust Site, Henderson, Nevada, Preliminary Draft, June.

Figures



Legend

- Wetlands Trail
- C-1 Channel
- US Bureau of Reclamation Property
- Northern Rapid Infiltration Basins
- NERT RI Downgradient Study Area
- NERT RI Off-site Study Area
- NERT Site
- NERT RI Eastside Area Study Area

0 2,000
Feet
Scale 1:24,000
1 inch = 2,000 feet
NORTH

NERT RI
Downgradient Study Area

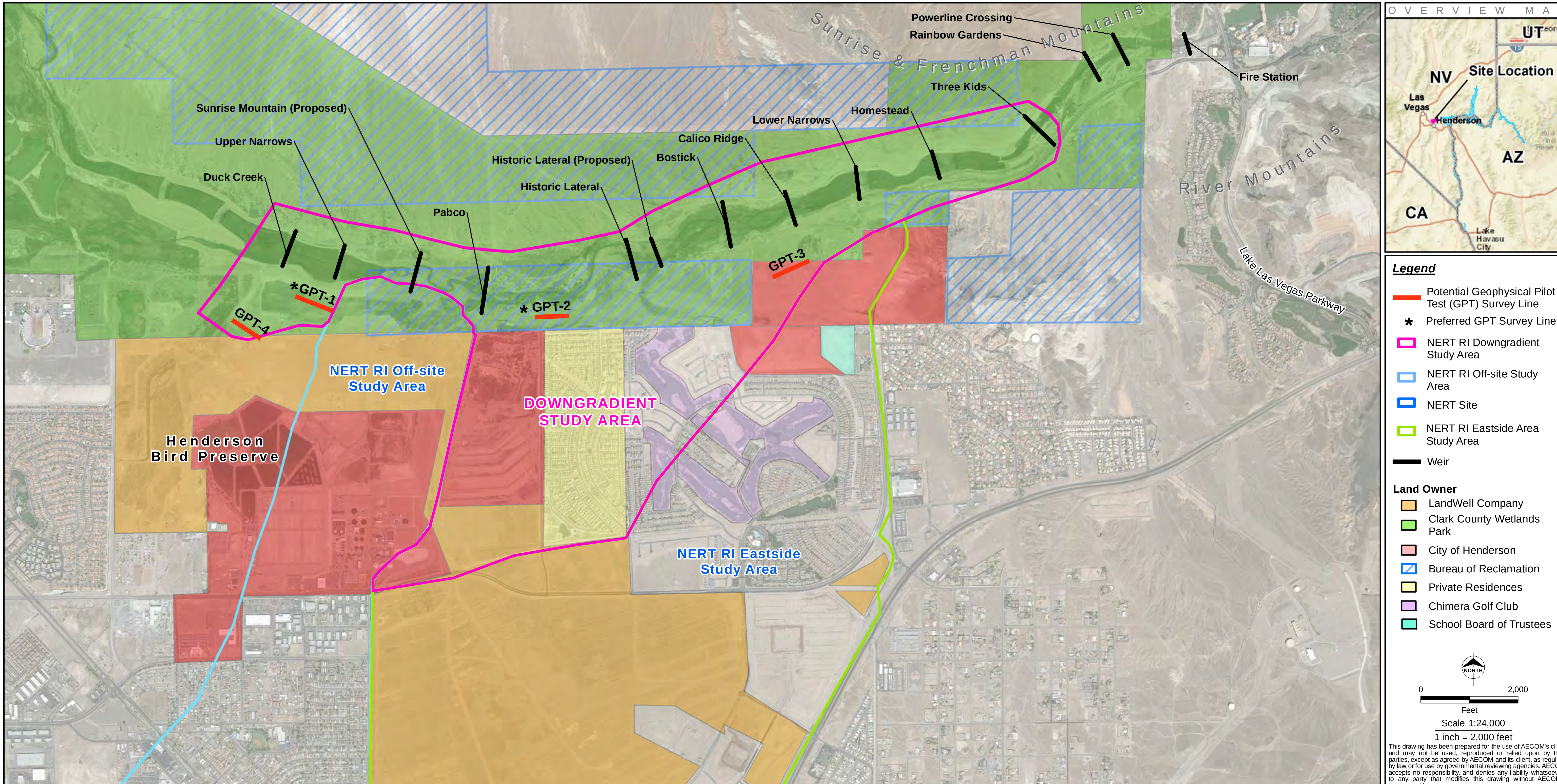
DOWNGRADIENT STUDY AREA LOCATION MAP

Date:6/5/2017 Project: 60477365

AECOM

Figure 1

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Geophysical\GPT Tech Memo\Fig1 Vicinity Map.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1



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NERT RI
Downgradient Study Area

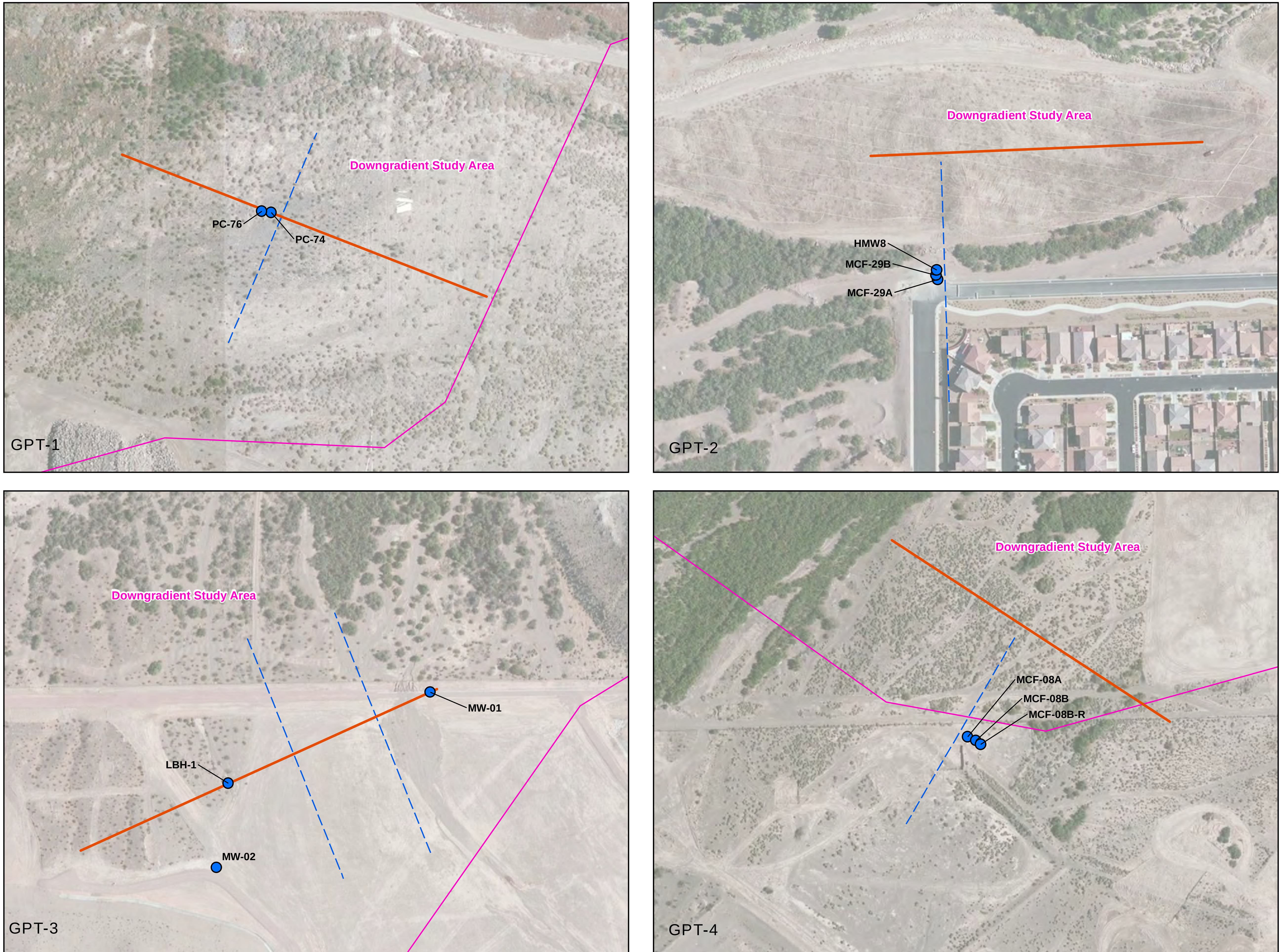
PROPERTY OWNERSHIP MAP WITH POTENTIAL GPT SURVEY LINE LOCATIONS

Date: 8/25/2017 Project: 60477365

AECOM

Figure 2

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Geophysical\GPT Tech Memo\Fig2 Proposed_Geophysical_Locations.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community; AECOM (2015)

OVERVIEW MAP

Legend

- Potential Geophysical Pilot Test (GPT) Survey Line
- Approximate Paleochannel Location
- NERT Downgradient Study Area Boundary
- Existing Well Location or Previously Drilled Soil Boring Location

NORTH

0 200
Feet

Scale 1:2,400
1 inch = 200 feet

NERT RI
Downgradient Study Area

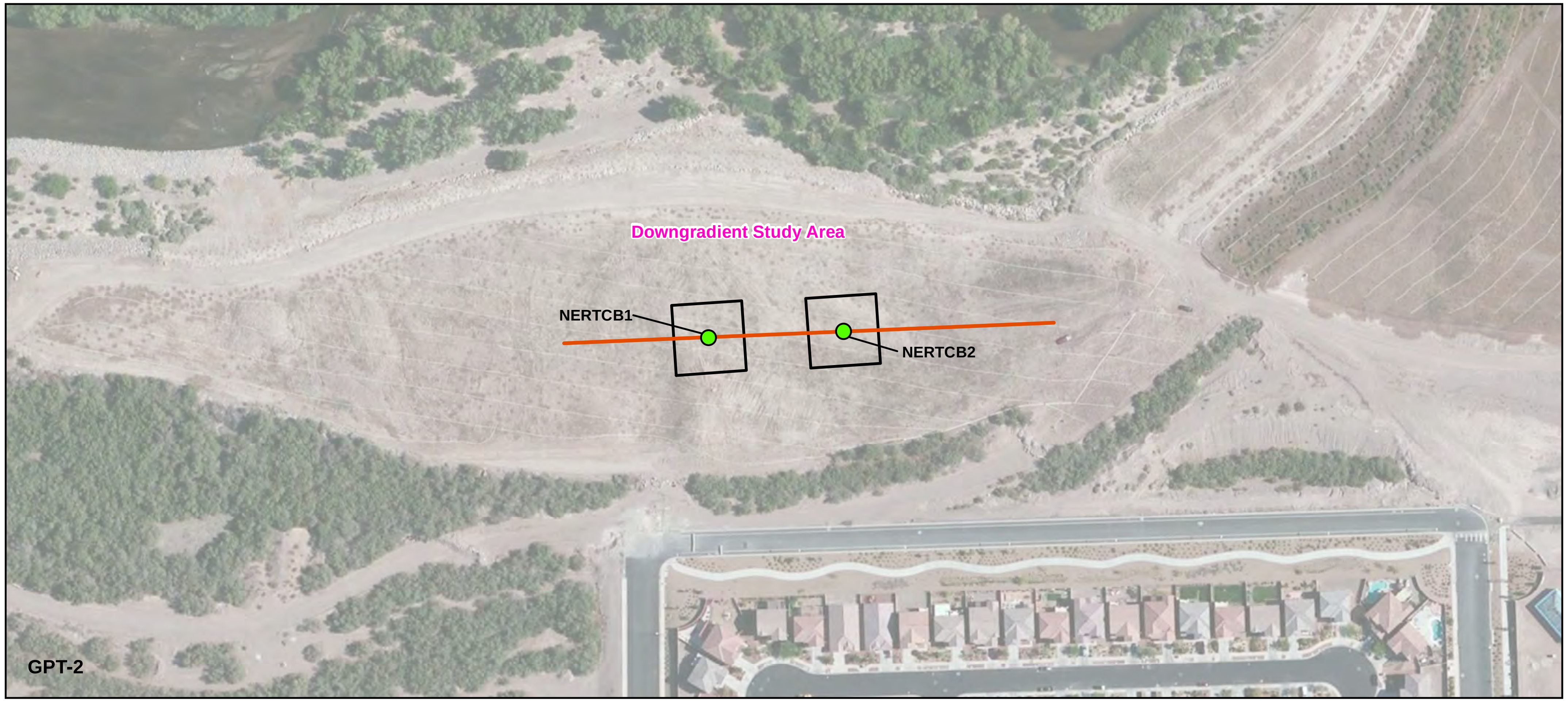
DETAILED VIEWS OF POTENTIAL GPT SURVEY LINE LOCATIONS

Date: 6/21/2017 Project: 60477365

AECOM

Figure 3

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Geophysical\GPT Tech Memo\Fig3 GPT_closeup Locations.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: scopm1



Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

OVERVIEW MAP

Legend

- Geophysical Pilot Test (GPT) Survey Line
- Verification Soil Boring Location
- NERT Downgradient Study Area Boundary

NORTH

0 200
Feet

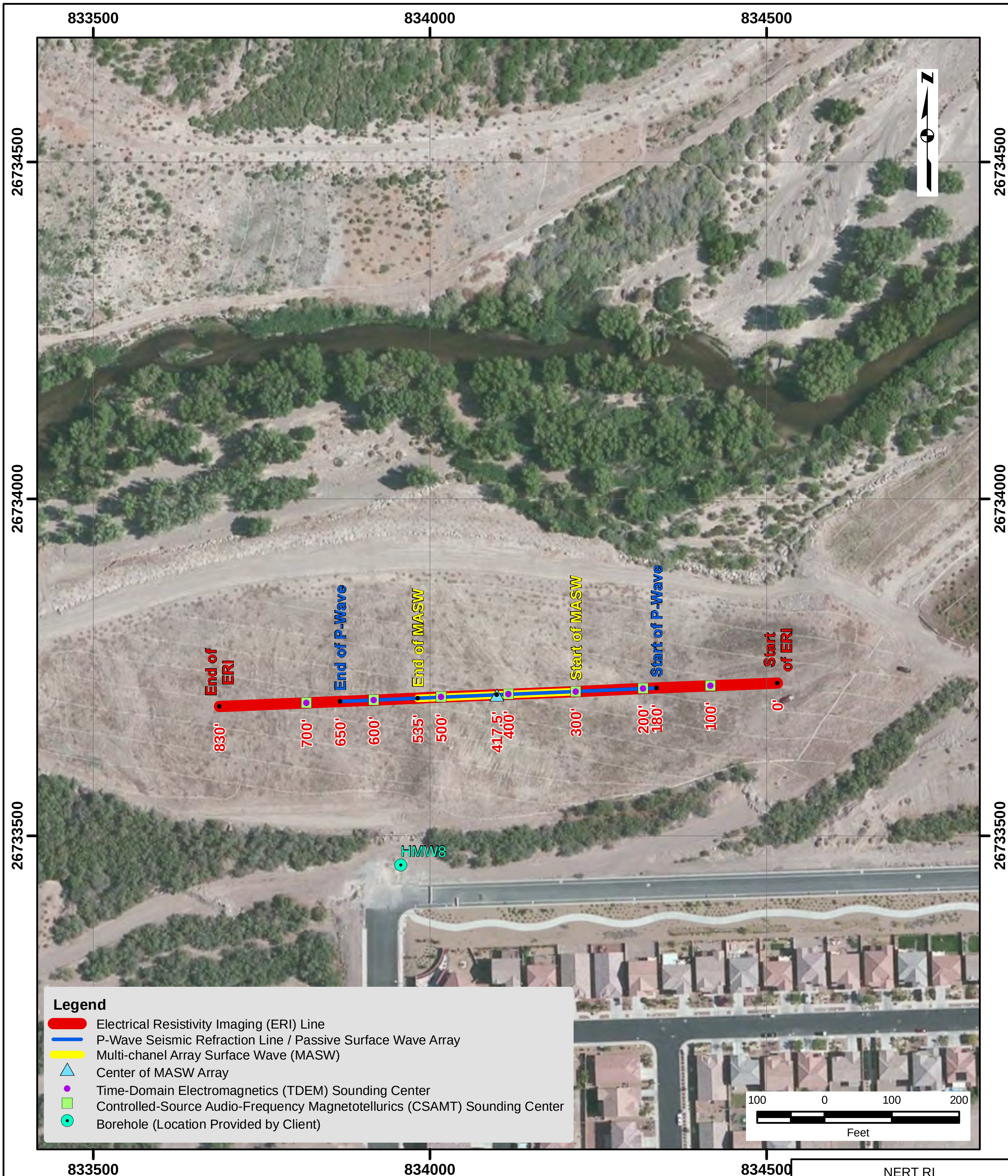
Scale 1:2,400
1 inch = 200 feet

NERT RI
Downgradient Study Area

VERIFICATION SOIL BORING LOCATIONS AT SURVEY LINES GPT-2 AND GPT-4

Date: 6/21/2017 Project: 60477365

AECOM **Figure 4**



NOTES:
1. Nevada State Plane Coordinate System, NAD 83, East (2701), US Survey Feet
2. Base map source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Source:
Figure modified from GEOVision, *2017, Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, January 4.*

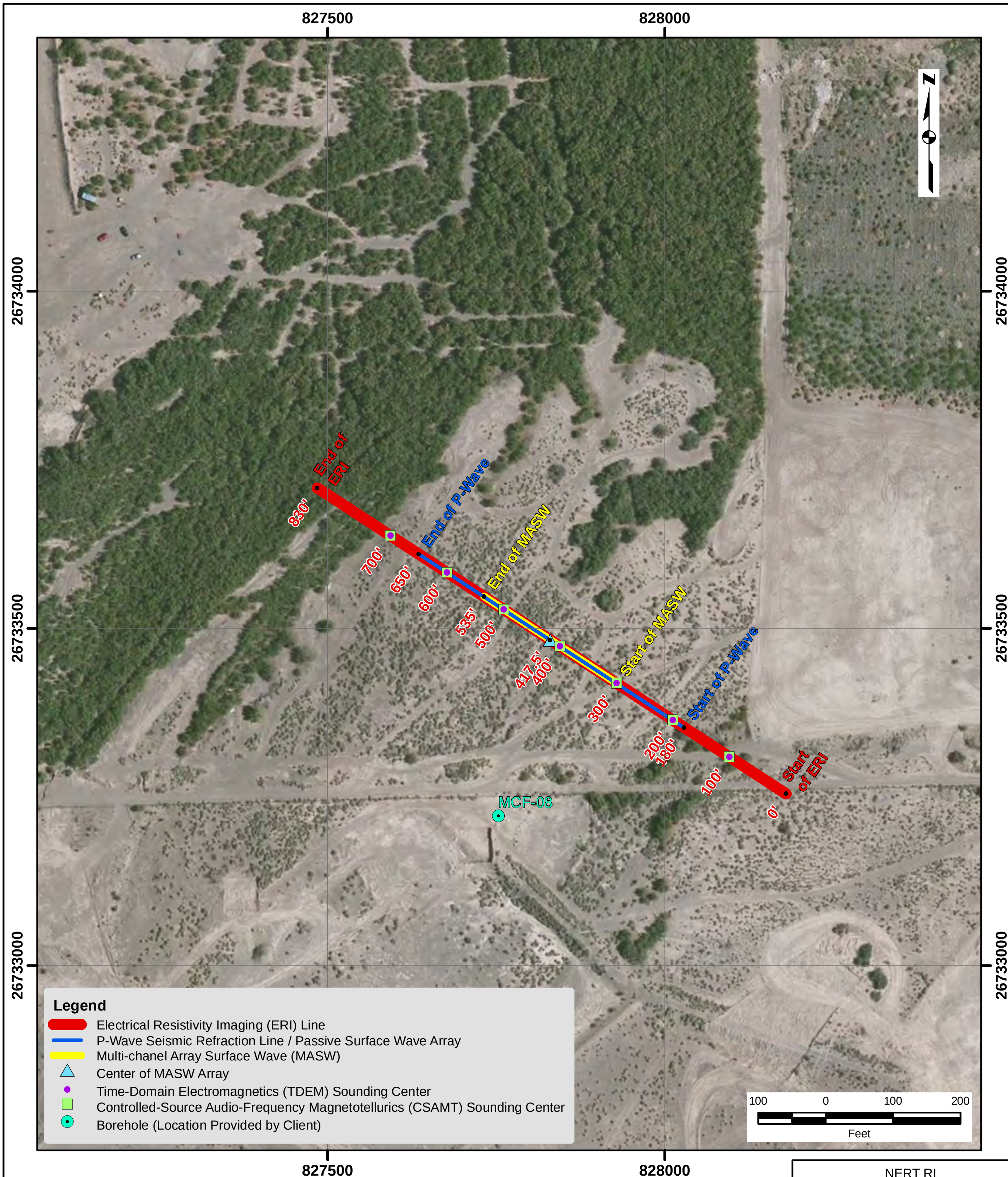
NERT RI
Downgradient Study Area

LINE LENGTHS OF GEOPHYSICAL SYSTEMS TESTED AT GPT-2

Date: 6/21/2017 Project: 60477365

AECOM

Figure 5



NOTES:
1. Nevada State Plane Coordinate System, NAD 83, East (2701), US Survey Feet
2. Base map source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Source:
Figure modified from GEOVision, *2017, Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, January 4.*

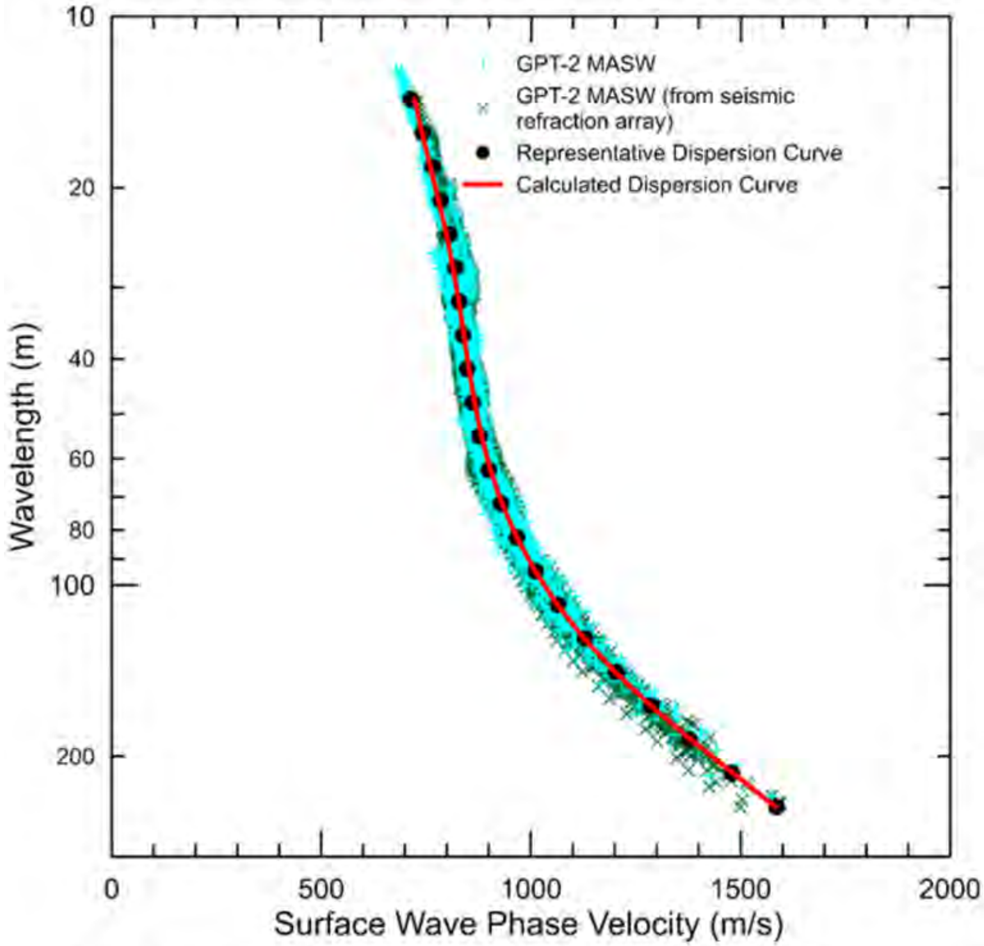
NERT RI
Downgradient Study Area

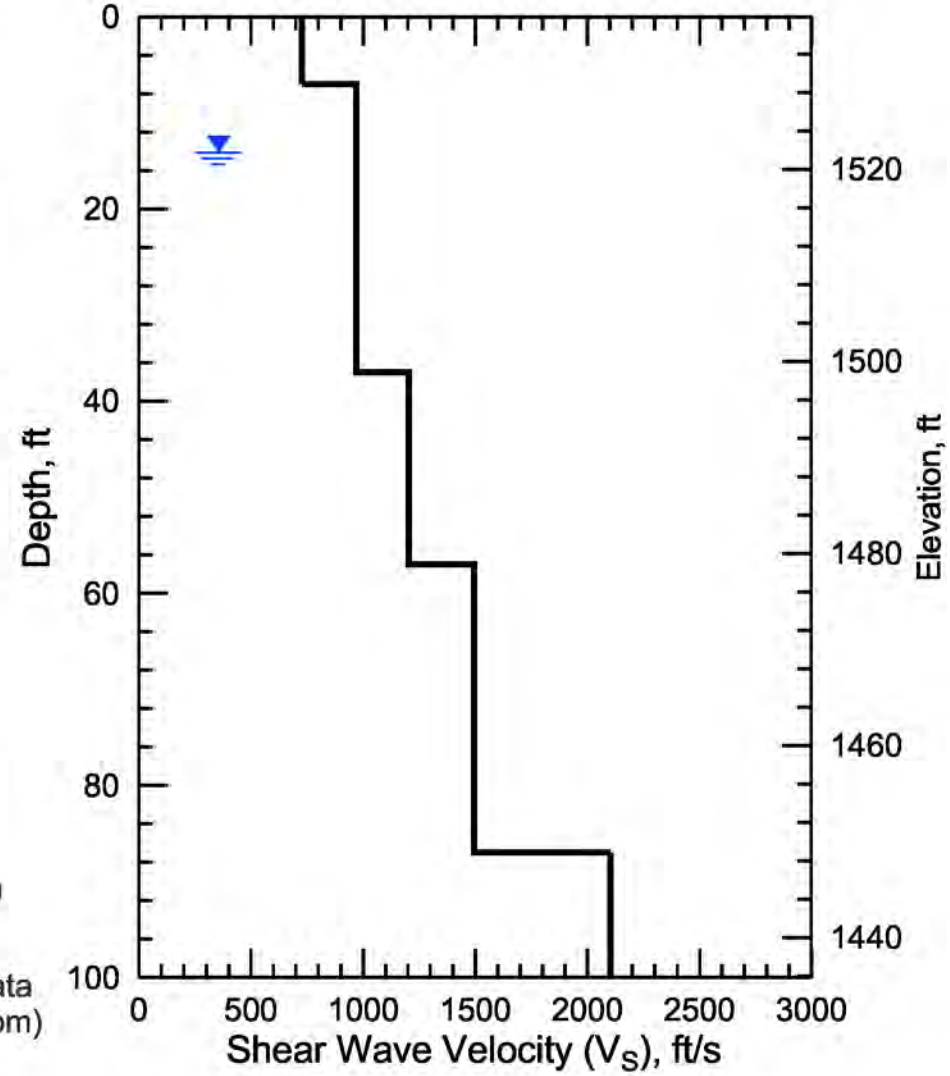
LINE LENGTHS OF GEOPHYSICAL SYSTEMS TESTED AT GPT-4

Date: 6/21/2017 Project: 60477365

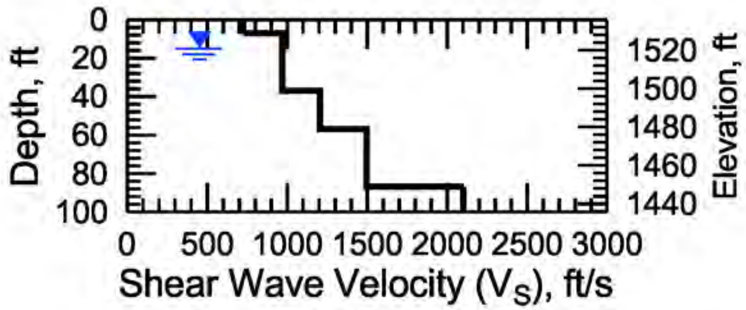
AECOM

Figure 6





Field, representative and calculated surface wave dispersion data (left) and associated V_s model (5x scale right and 1x scale bottom)



Source:
Figure modified from GEOVision, 2017, Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, January 4.

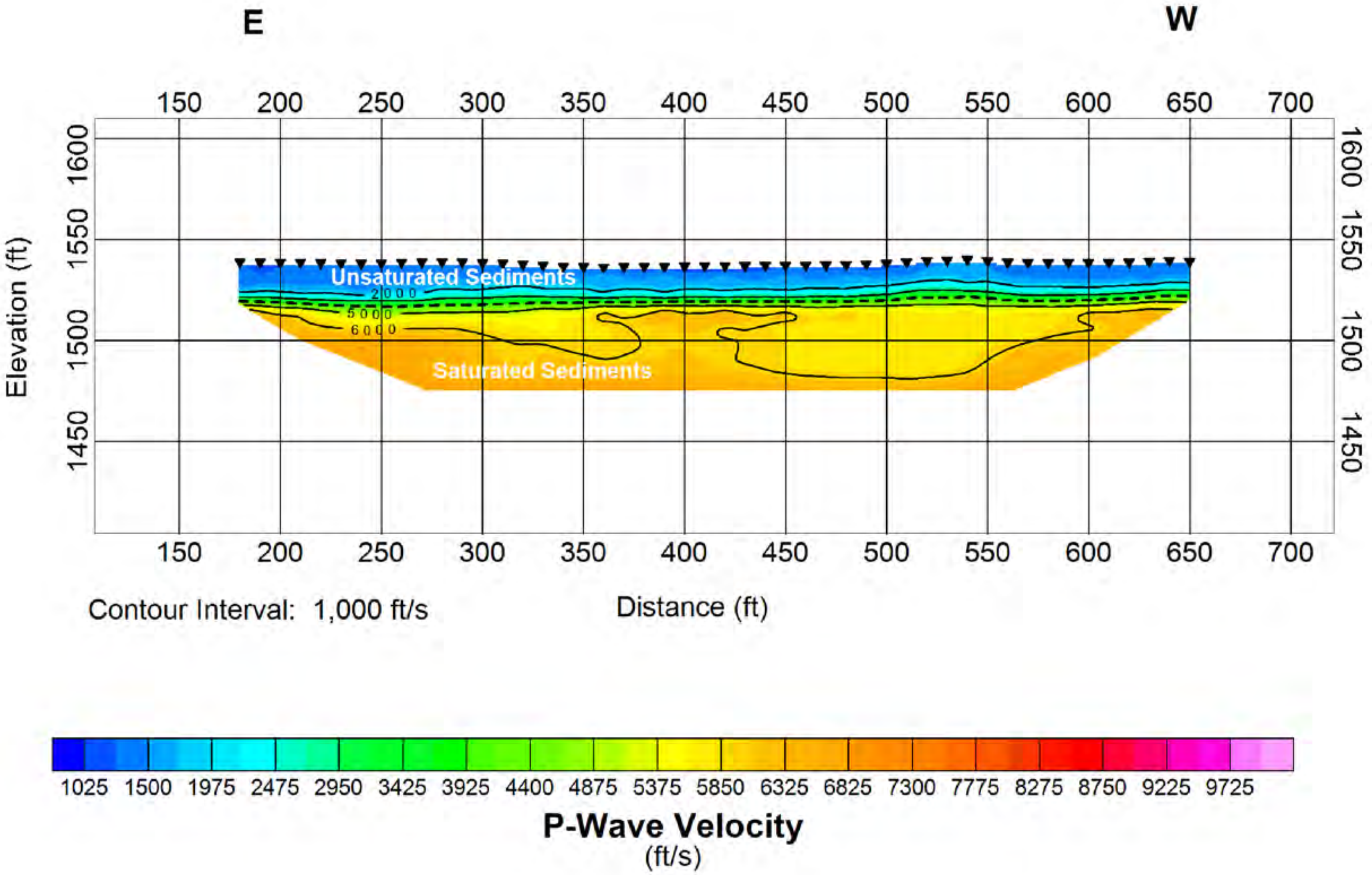
NERT RI
Downgradient Study Area

EXAMPLE OF MASW RESULTS AT ONE STATION ALONG GPT-2

Date: 6/23/2017 Project: 60477365

AECOM

Figure 7

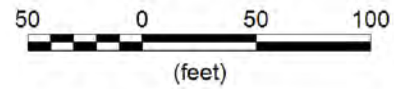


Legend

▼ Geophone Location

—— Wave Velocity Contour

– – Interpreted Groundwater Interface



NERT RI
Downgradient Study Area

RESULTS OF P-WAVE SURVEY - GPT-2

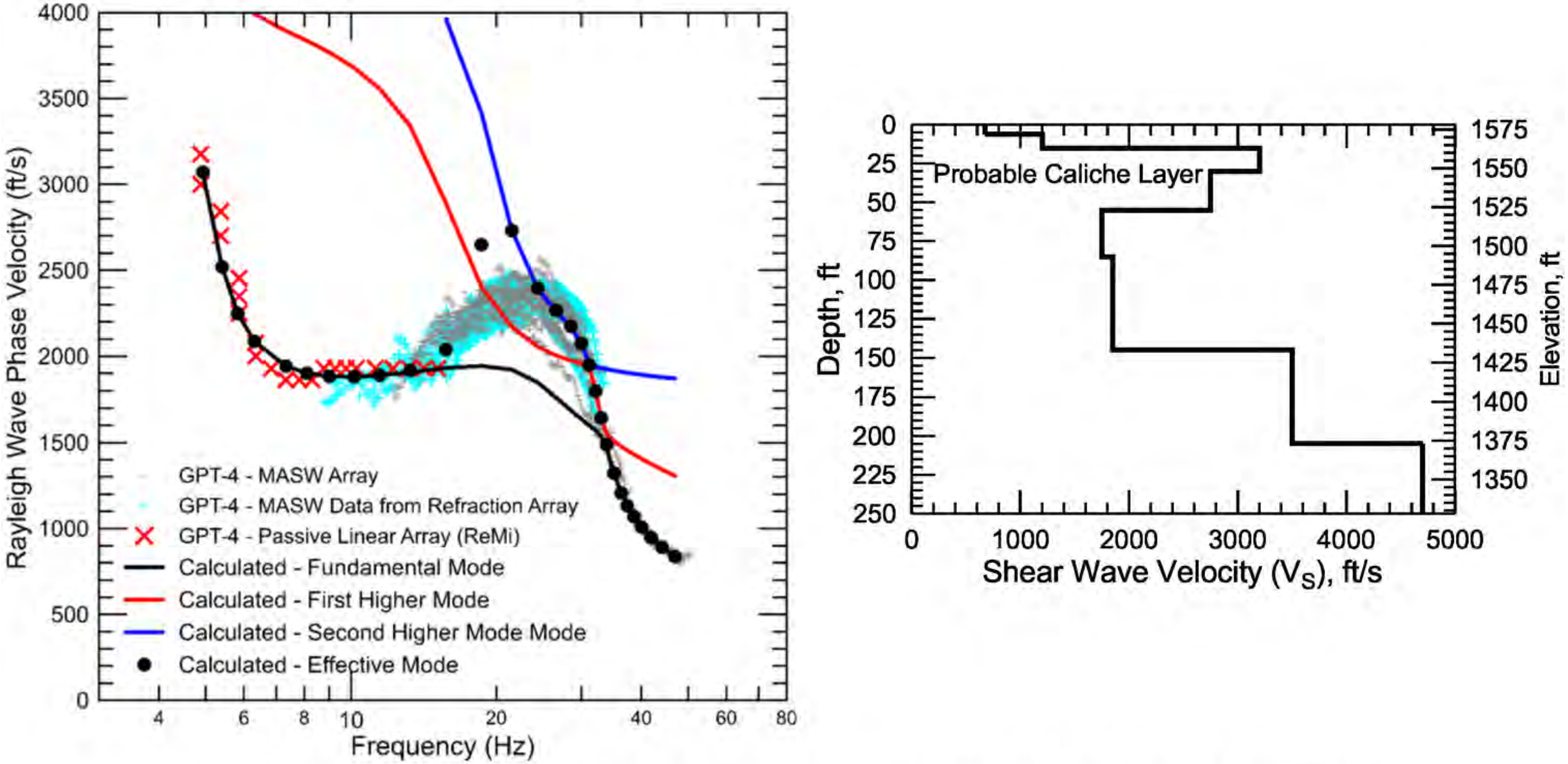
Date: 6/21/2017 Project: 60477365

AECOM

Figure 8

Source:
Figure modified from GEOVision, 2017, *Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, January 4.*

Note: Cross section is a mirror image of the cross section shown on Figure 4.



Field, representative and calculated surface wave dispersion data (left) and associated V_s model (right)

Source:
Figure modified from GEOVision, 2017, Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, January 4.

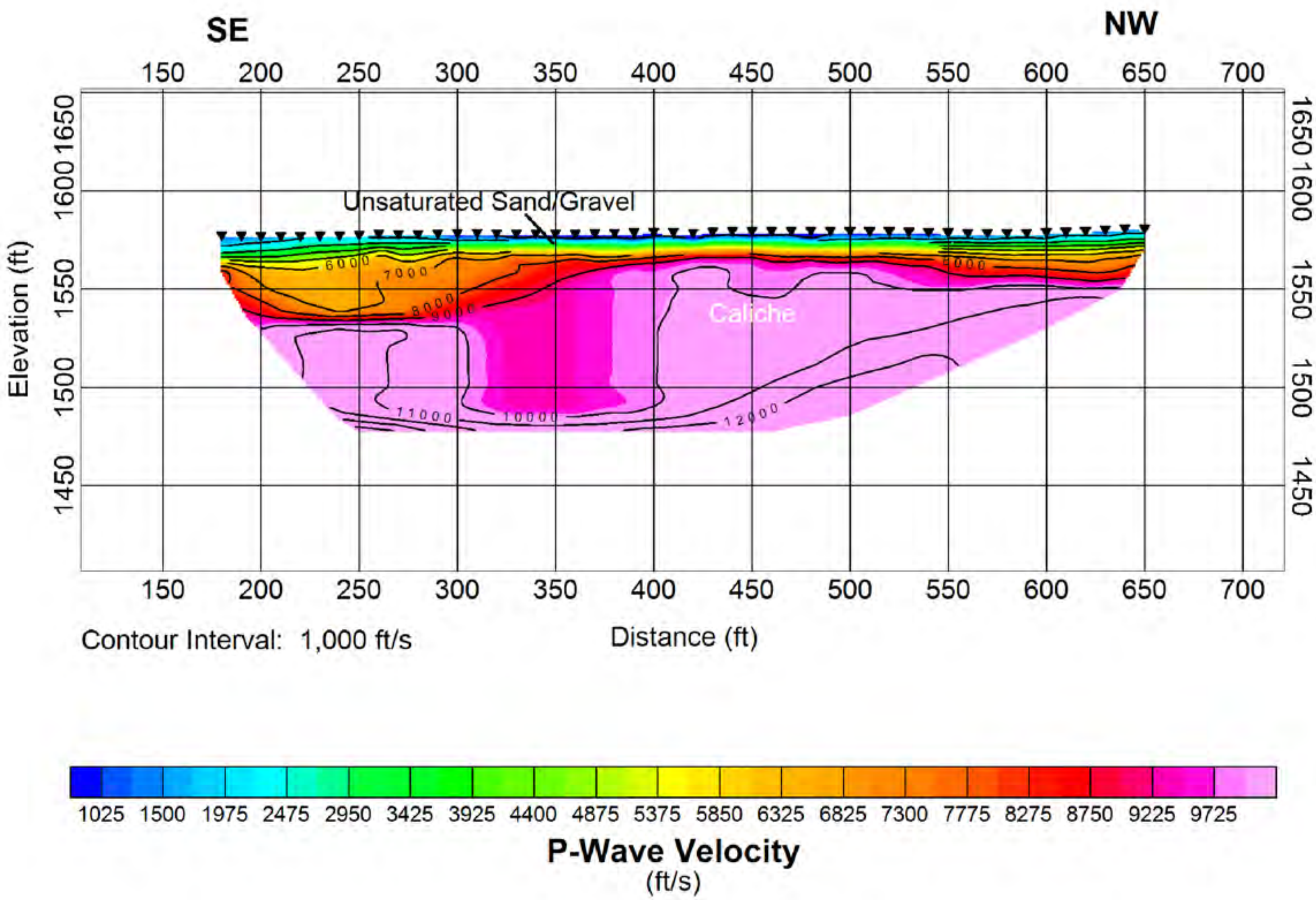
NERT RI
Downgradient Study Area

EXAMPLE OF SURFACE WAVE SURVEY RESULTS AT ONE STATION ALONG GPT-4

Date: 6/23/2017 Project: 60477365

AECOM

Figure 9



Legend

- ▼ Geophone Location
- —— Wave Velocity Contour
- – – Interpreted Groundwater Interface

50 0 50 100
(feet)

NERT RI
Downgradient Study Area

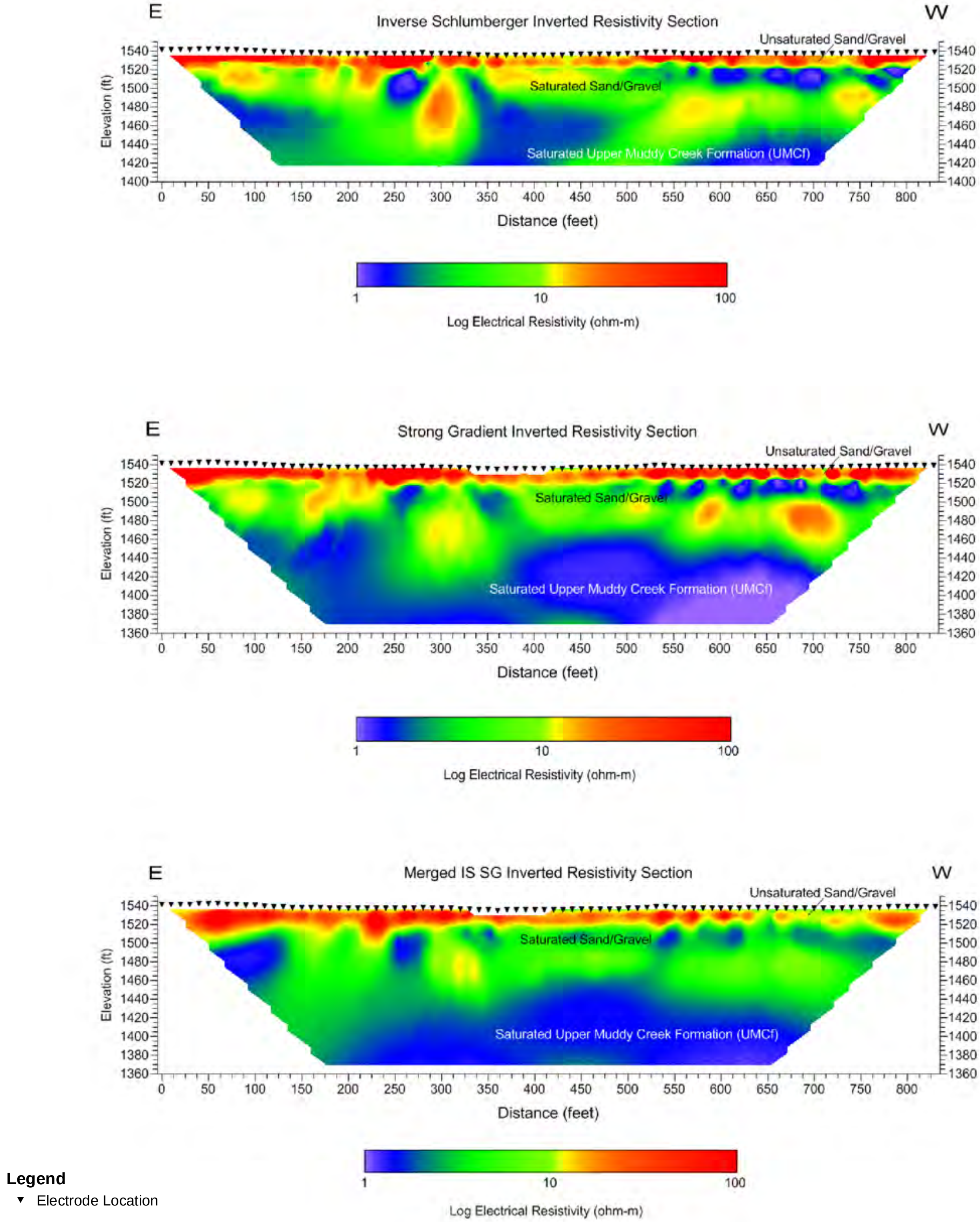
RESULTS OF P-WAVE SURVEY - GPT-4

Date: 6/21/2017 Project: 60477365

AECOM **Figure 10**

Source:
Figure modified from GEOVision, 2017, *Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, January 4.*

Note: Cross section is a mirror image of the cross section shown on Figure 5.



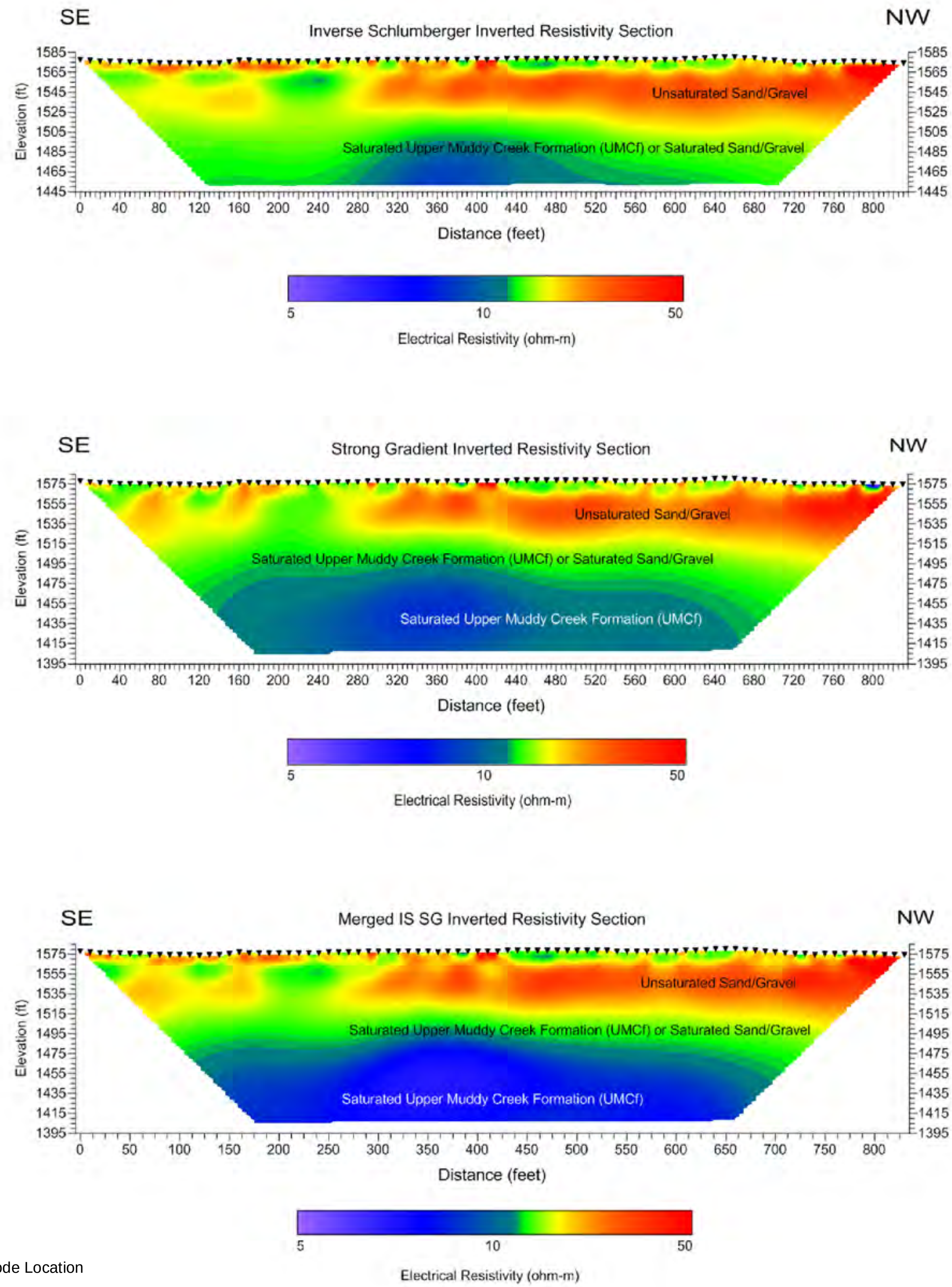
NERT RI
Downgradient Study Area

RESULTS OF ERI SURVEY - GPT-2

Date: 6/13/2017 Project: 60477365

AECOM **Figure 11**

Source:
Figure modified from GEOVision, 2017, *Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, January 4.*



Legend

▼ Electrode Location

NERT RI
Downgradient Study Area

RESULTS OF ERI SURVEY - GPT-4

Date: 6/13/2017 Project: 60477365

AECOM

Figure 12

Source:
Figure modified from GEOVision, 2017, *Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, January 4.*

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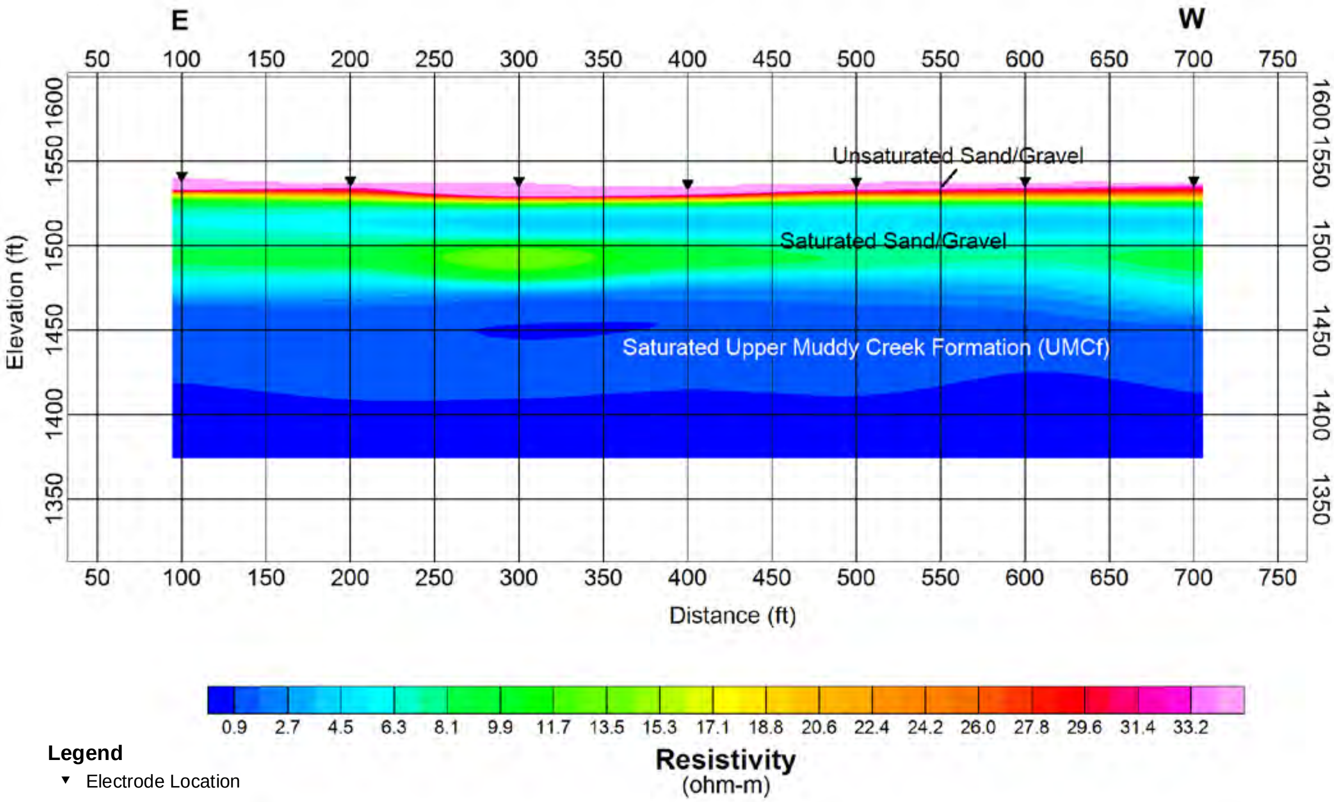
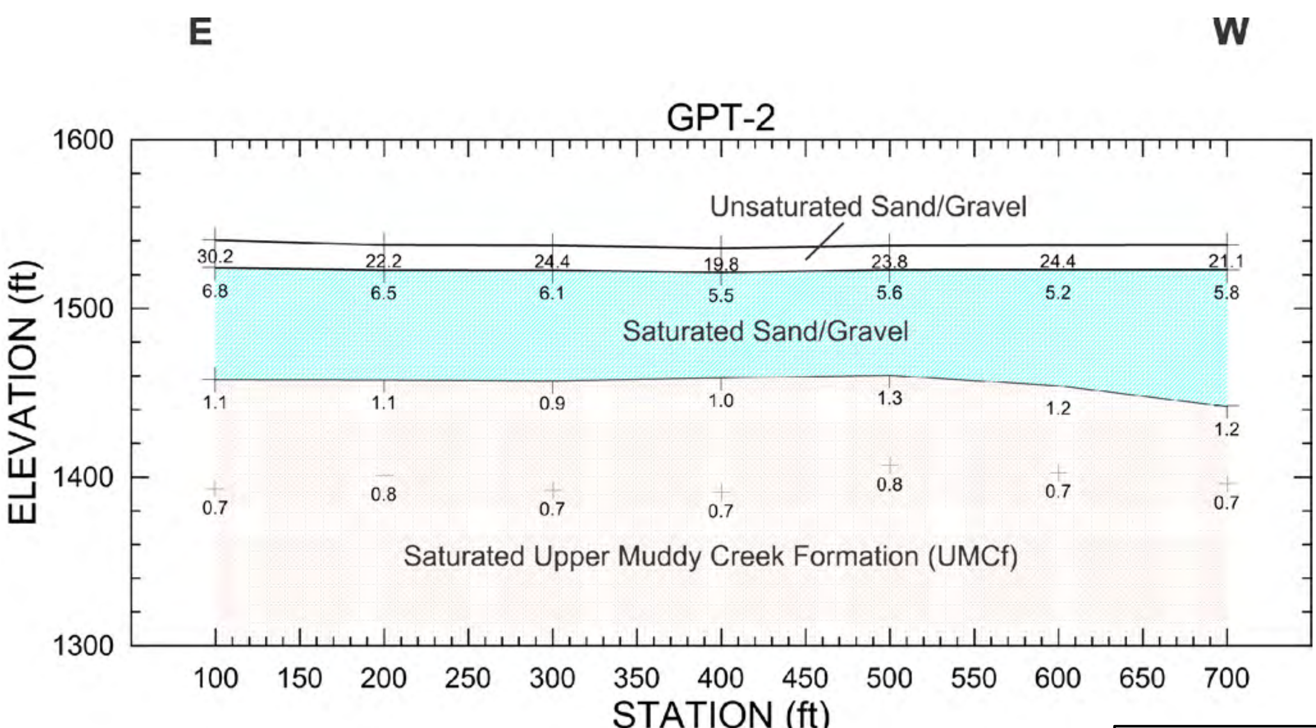




NERT RI
Downgradient Study Area

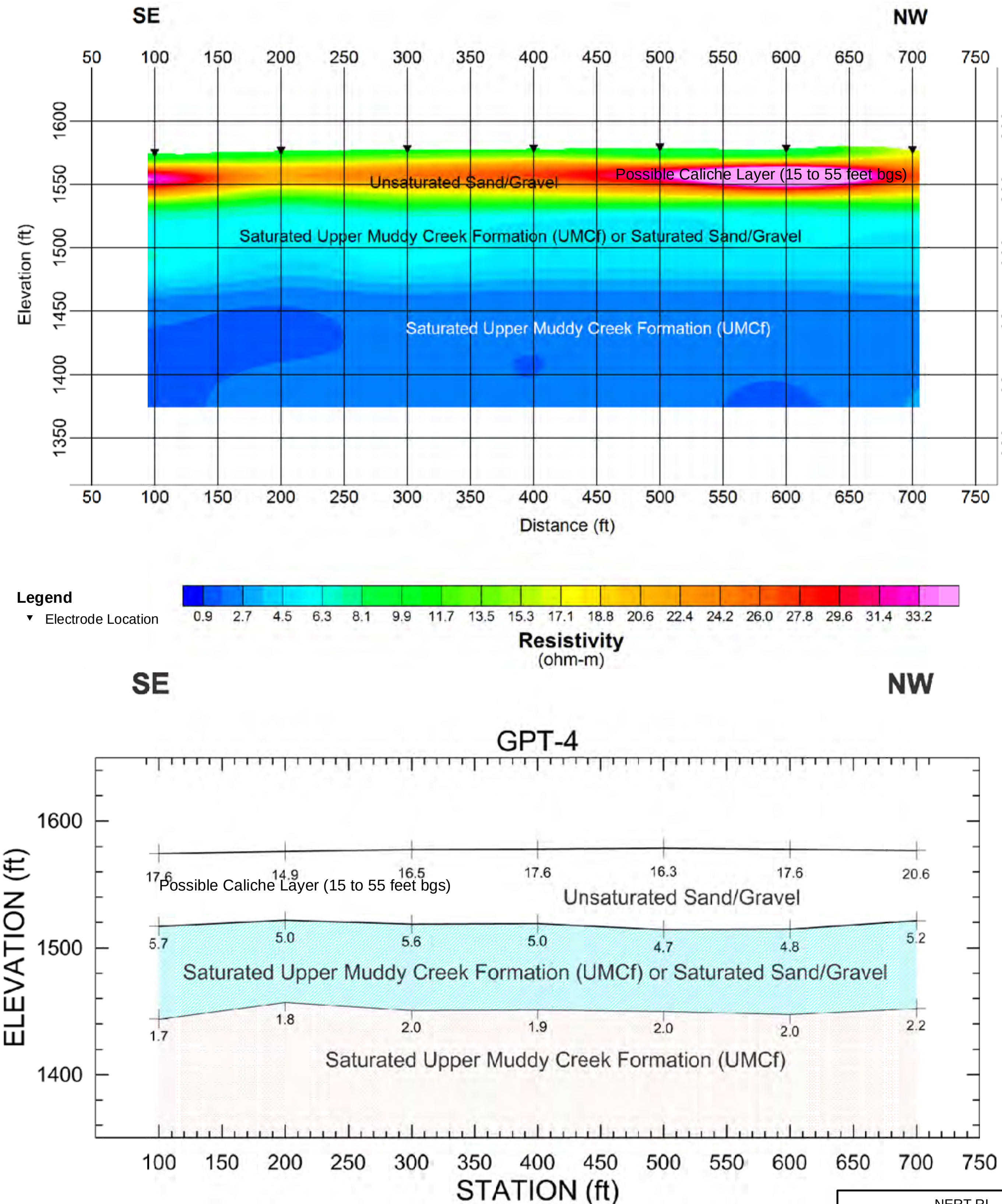
RESULTS OF TDEM SURVEY - GPT-2
(SMOOTH AND LAYERED MODELS)

Date: 6/13/2017 Project: 60477365

AECOM **Figure 13**

Source:
Figure modified from GEOVision, 2017, *Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, January 4.*

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Geophysical\GPT Tech Memo\Fig12.mxd | Coordinate System:



NERT RI
Downgradient Study Area

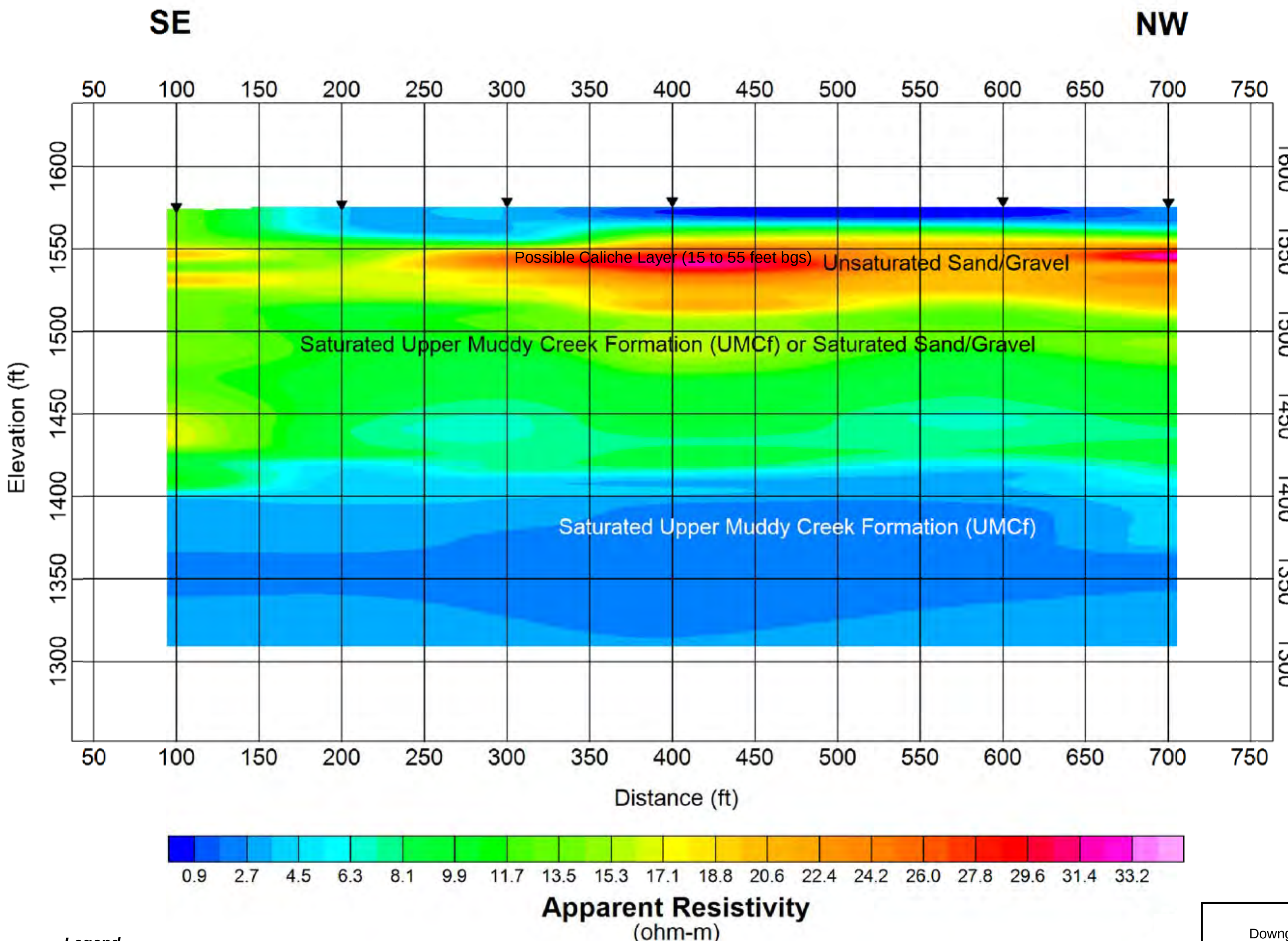
RESULTS OF TDEM SURVEY - GPT-4
(SMOOTH AND LAYERED MODELS)

Date: 8/21/2017 Project: 60477365

AECOM **Figure 14**

Source:
Figure modified from GEOVision, 2017, *Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, January 4.*

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Geophysical\GPT Tech Memo\Fig13.mxd | Coordinate System:



Legend

▼ Geophone Location

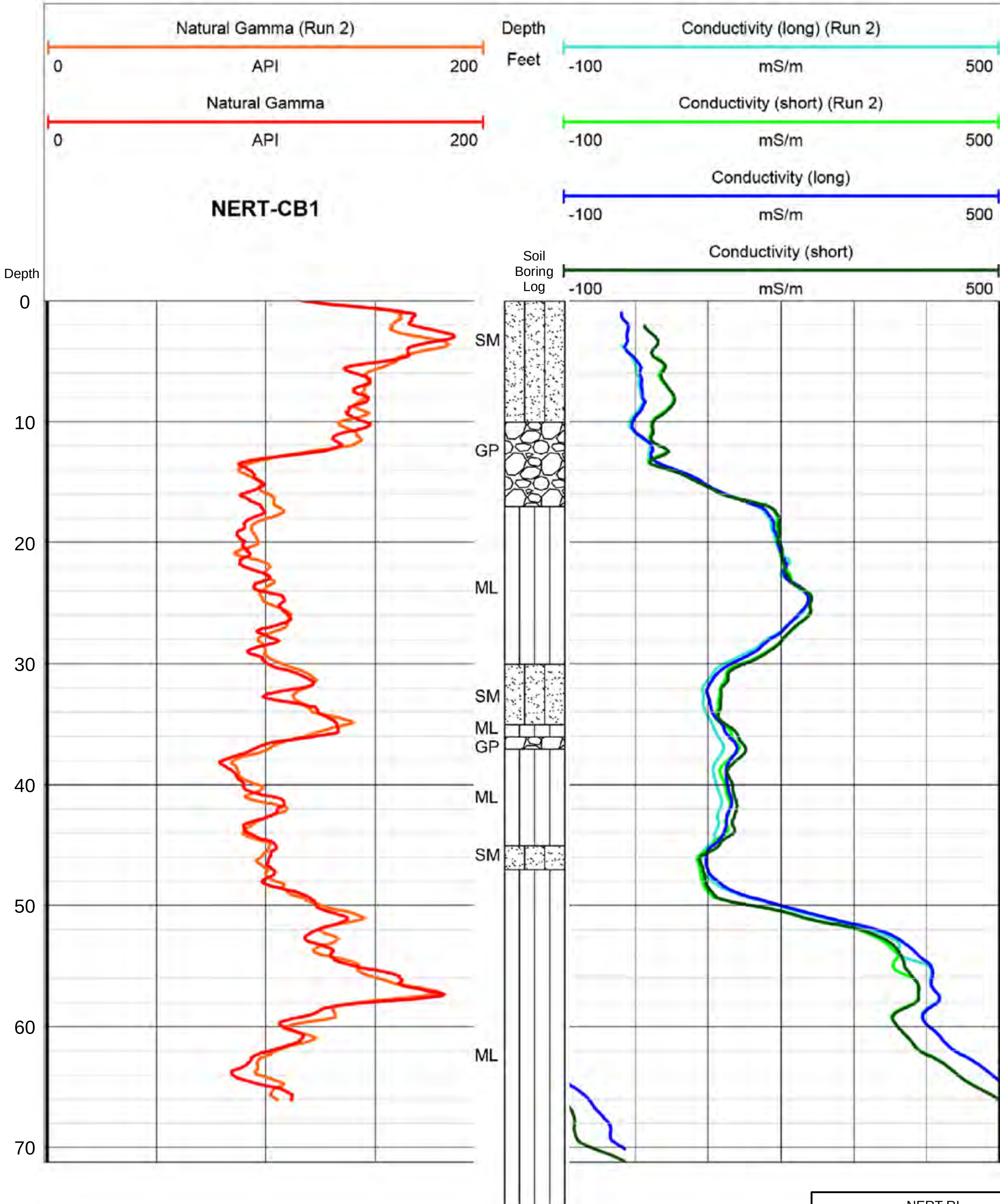
Source:
Figure modified from GEOVision, 2017, *Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, January 4.*

NERT RI
Downgradient Study Area

RESULTS OF CSAMT SURVEY - GPT-4

Date: 6/21/2017 Project: 60477365

AECOM **Figure 15**



Note:
For detailed soil boring log see Appendix C of the GPT Technical Memorandum.

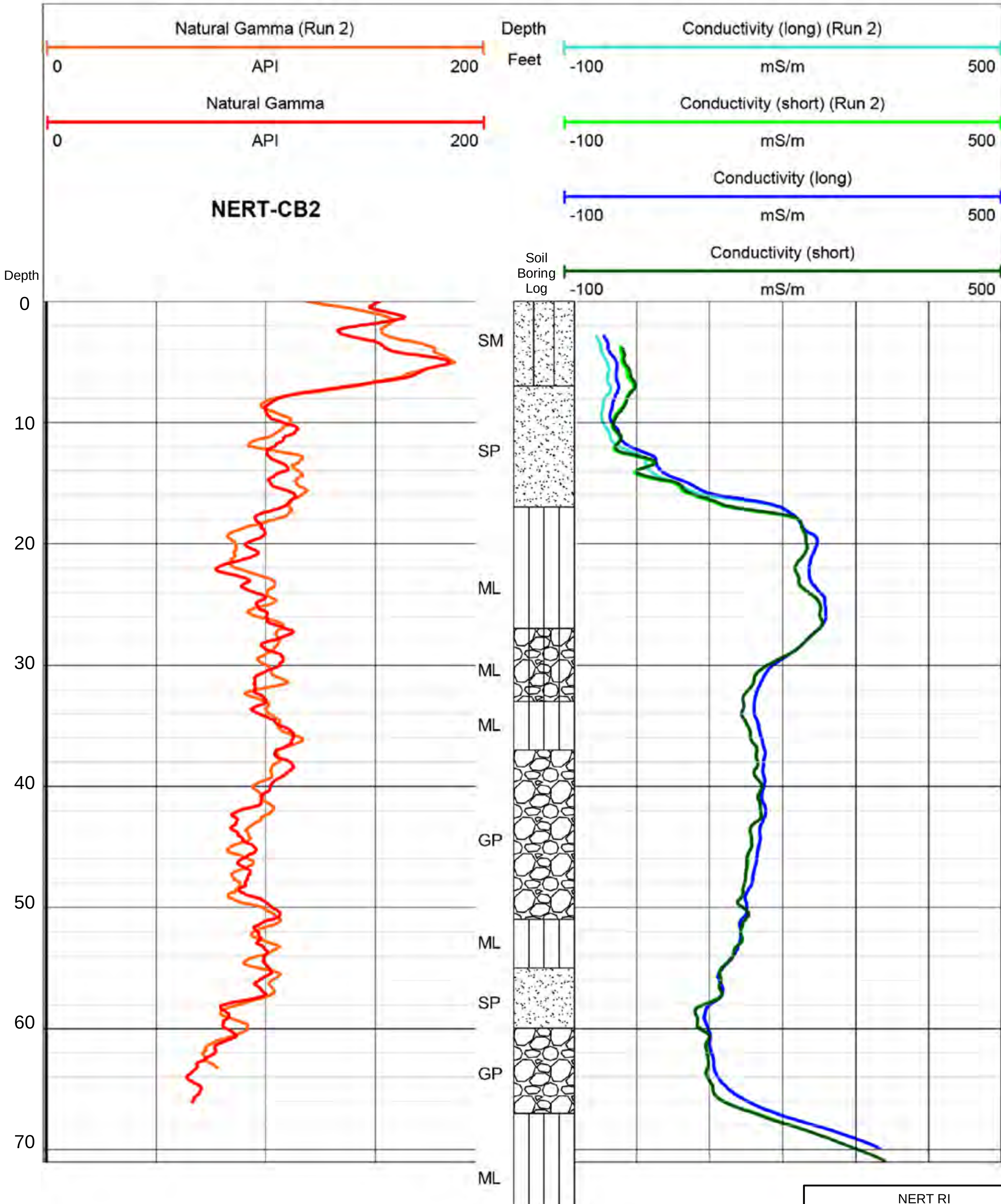
Source:
Figure modified from *GEOVision 2017, NERT Remedial Investigation - Downgradient Study Area, Borehole Geophysis, Las Vegas Wash, Henderson, Nevada, June 20.*

NERT RI
Downgradient Study Area

DUAL INDUCTION LOG
NERT-CB1

Date: 6/21/2017 Project: 60477365

AECOM **Figure 16**



Note:
For detailed soil boring log see Appendix C of the GPT Technical Memorandum.

Source:
Figure modified from *GEOVision 2017, NERT Remedial Investigation - Downgradient Study Area, Borehole Geophysics, Las Vegas Wash, Henderson, Nevada, June 20.*

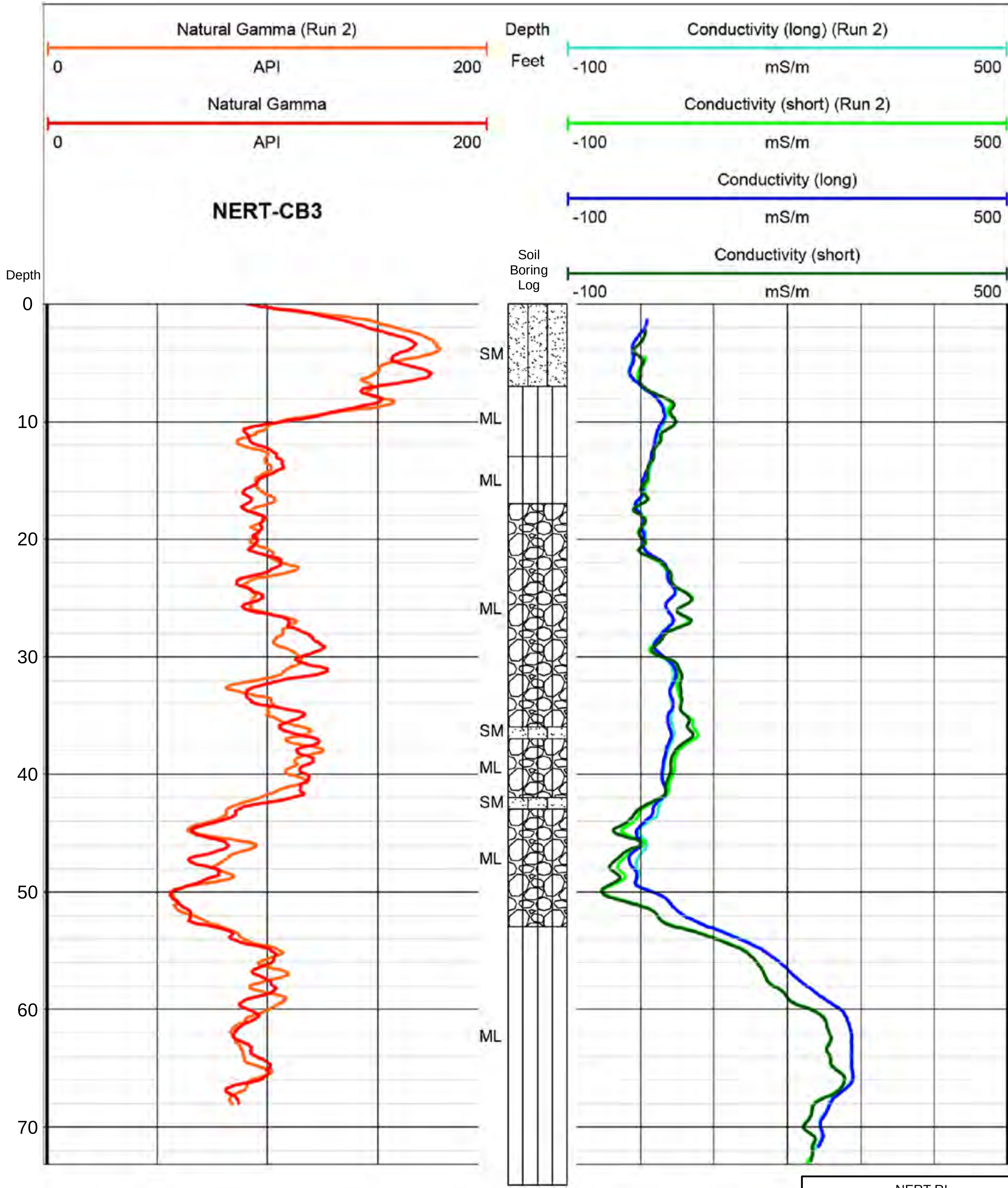
NERT RI
Downgradient Study Area

DUAL INDUCTION LOG
NERT-CB2

Date: 6/21/2017 Project: 60477365

AECOM **Figure 17**

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Geophysical\GPT Tech Memo\Fig17.mxd | Coordinate System:



Note:
For detailed soil boring log see Appendix C of the GPT Technical Memorandum.

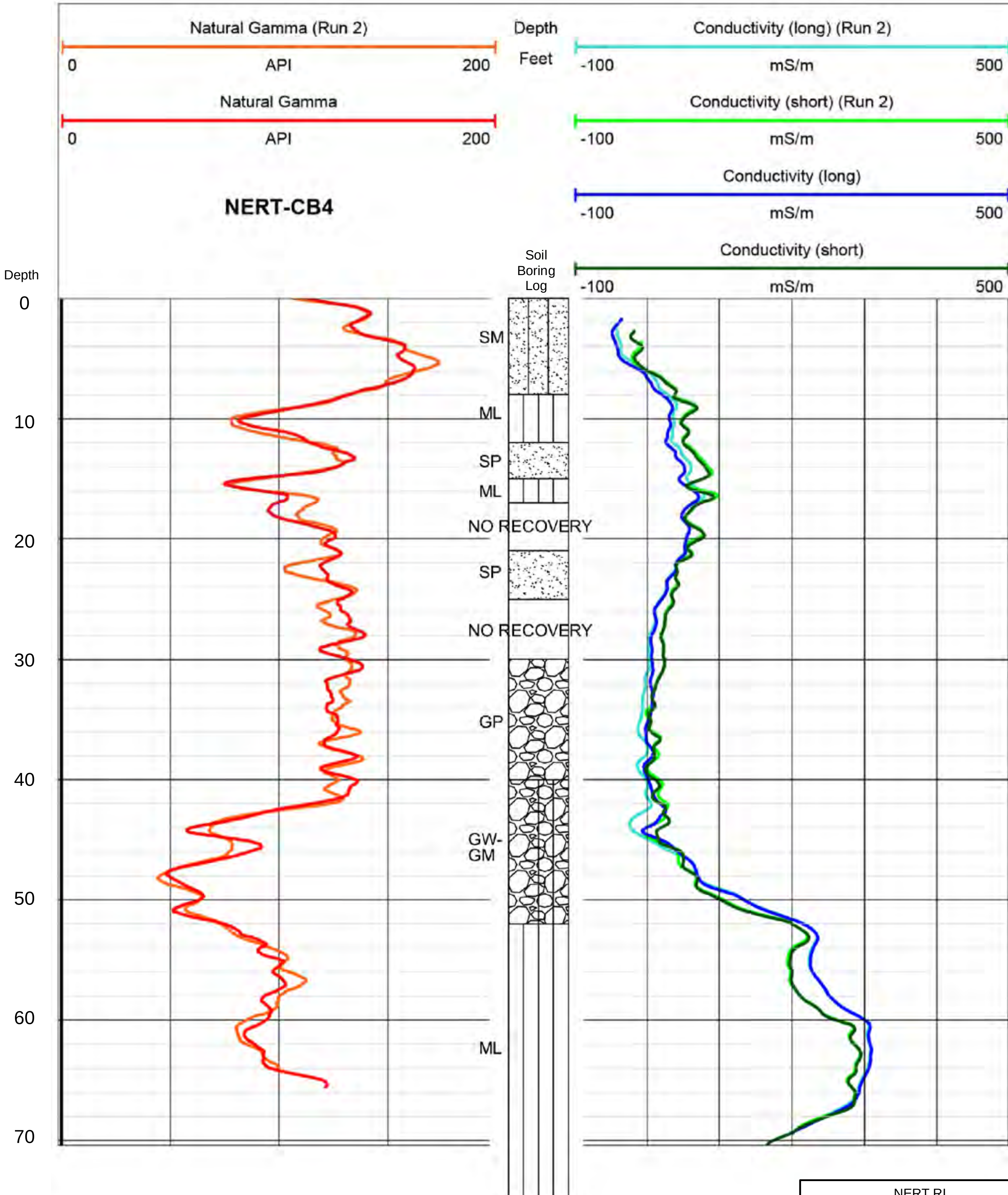
Source:
Figure modified from *GEOVision 2017, NERT Remedial Investigation - Downgradient Study Area, Borehole Geophysis, Las Vegas Wash, Henderson, Nevada, June 20.*

NERT RI
Downgradient Study Area

DUAL INDUCTION LOG
NERT-CB3

Date: 6/21/2017 Project: 60477365

AECOM **Figure 18**



Note:
For detailed soil boring log see Appendix C of the GPT Technical Memorandum.

Source:
Figure modified from *GEOVision 2017, NERT Remedial Investigation - Downgradient Study Area, Borehole Geophysis, Las Vegas Wash, Henderson, Nevada, June 20.*

NERT RI
Downgradient Study Area

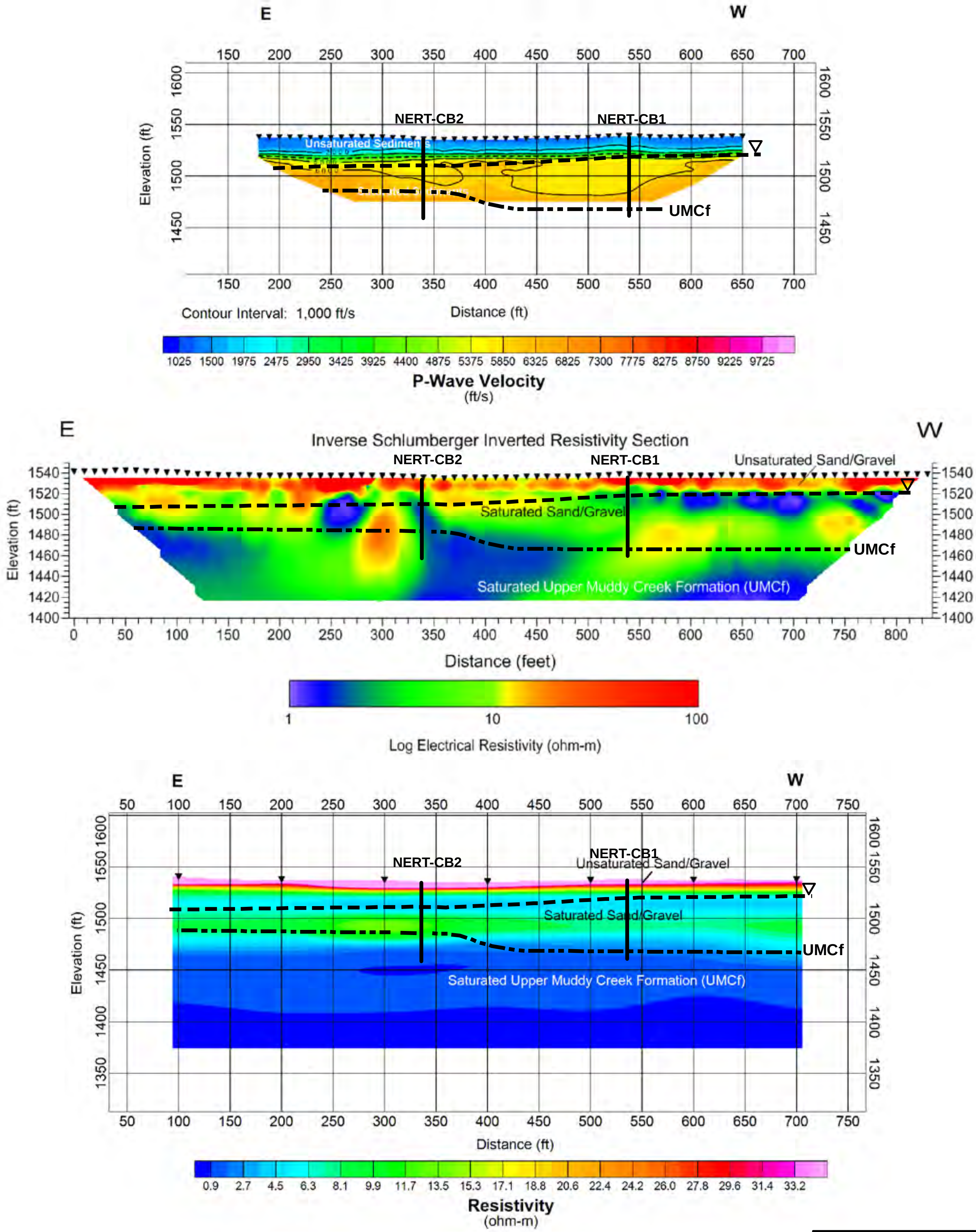
DUAL INDUCTION LOG
NERT-CB4

Date: 6/21/2017 Project: 60477365

AECOM

Figure 19

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Geophysical\GPT Tech Memo\Fig19.mxd | Coordinate System:



Legend

▼	Geophone Location
——	Wave Velocity Contour
– – –	Interpreted Groundwater Interface
∇ – – –	Static Groundwater Level
UMCf – · – · –	Top of Upper Muddy Creek formation

Note:
Groundwater levels and contact of the UMCf are based on observations made in the verification soil borings.

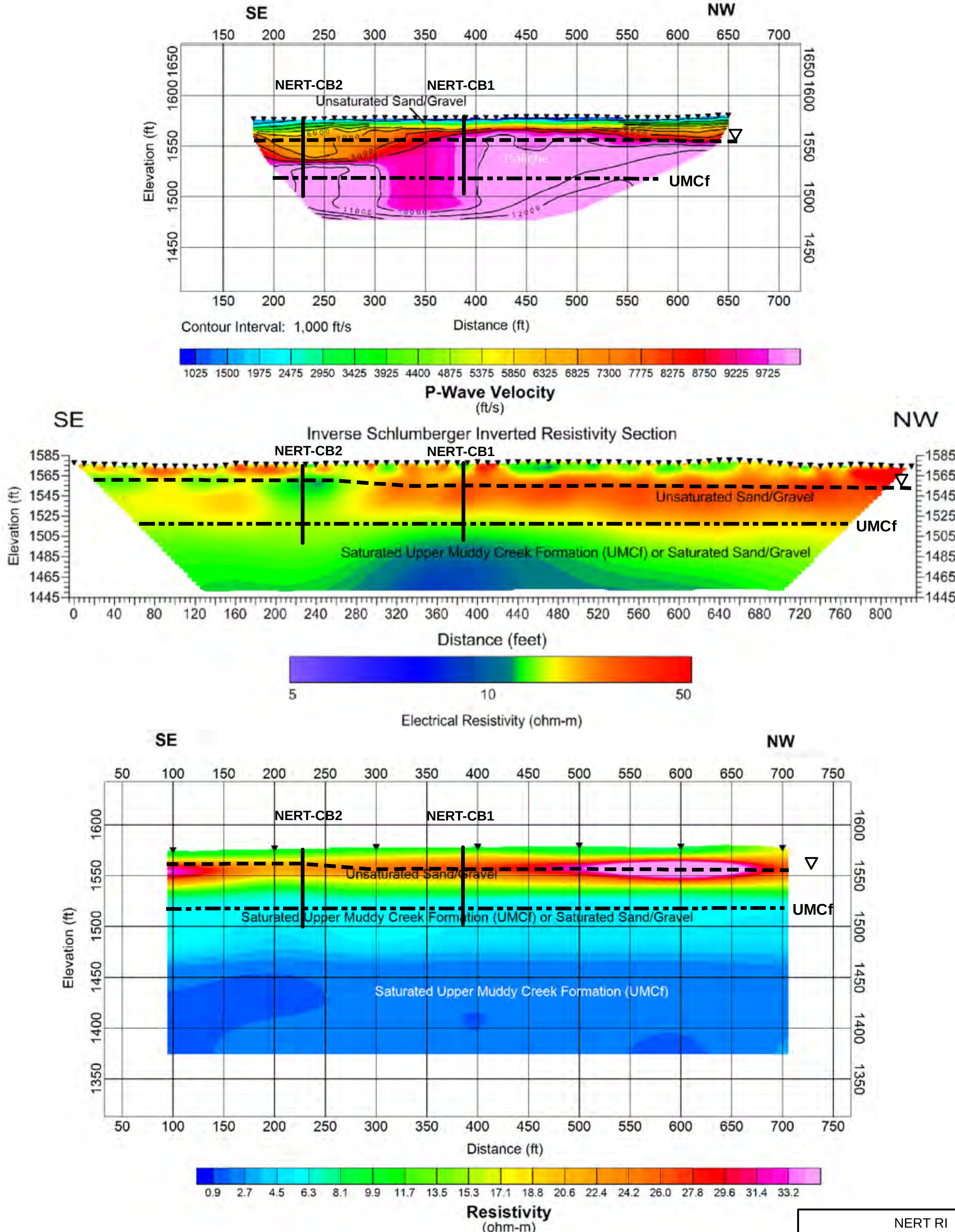
Source:
Figure modified from *GEOVision, 2017, Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, June 20.*

NERT RI
Downgradient Study Area

SEISMIC, ERI & TDEM COMPARISON
GPT-2

Date: 6/21/2017 Project: 60477365

AECOM **Figure 20**



Legend

▼ Geophone Location

– – – Interpreted Groundwater Interface

▽▬ ▬ ▬ Static Groundwater Level

UMCf ▬·-·- Upper Muddy Creek Formation

Note:
Groundwater levels and contact of the UMCf are based on observations made in the verification soil borings.

Source:
Figure modified from *GEOVision, 2017, Geophysical Pilot Test, NERT Remedial Investigation- Downgradient Study Area, Las Vegas Wash, Henderson, Nevada, June 20.*

NERT RI
Downgradient Study Area

SEISMIC, ERI & TDEM COMPARISON GPT-4

Date: 6/21/2017 Project: 60477365

AECOM **Figure 21**

Tables

Table 1. Summary of Grain Size Analysis
NERT Downgradient Study Area, Henderson, Nevada

Sample Identification	Sample Identification	Depth (feet)	Mean Grain Size Description USCS/ASTM (1)	Median Grain Size (mm)	Particle Size Distribution (weight percent) (2)				
						Sand Size			
					Gravel	Coarse	Medium	Fine	Silt/Clay
GPT-2	NERT-CB-1-15	15	Gravel	9.889	59.94	8.10	14.50	15.05	2.40
GPT-2	NERT-CB-1-28	28	Fine sand	0.210	2.29	6.00	28.13	42.99	20.59
GPT-2	NERT-CB-1-35	35	Gravel	6.092	54.8	13.67	15.00	10.40	6.13
GPT-2	NERT-CB-1-42	42	Fine sand	0.096	0.00	0.14	8.30	52.97	38.58
GPT-2	NERT-CB-1-52	52	Fine sand	0.316	0.00	1.09	40.69	38.47	19.74
GPT-2	NERT-CB-1-70	70	Fine sand	0.335	0.00	1.39	43.05	51.45	4.11
GPT-2	NERT-CB-2-7'	7	Gravel	4.07	47.92	10.63	17.06	17.38	7.00
GPT-2	NERT-CB-2-18'	18	Fine sand	0.072	0.00	0.2	5.65	43.09	51.06
GPT-2	NERT-CB-2-27'	27	N/A	7.606	55.85	8.86	16.71	11.32	7.26
GPT-2	NERT-CB-2-38'	38	Gravel	5.116	51.88	19.4	20.20	7.01	1.52
GPT-2	NERT-CB-2-70'	70	Fine sand	0.361	0.00	0.17	23.72	73.51	2.59
GPT-4	NERT-CB-3-10	10	Gravel	2.075	33.59	17.11	27.64	17.94	3.72
GPT-4	NERT-CB-3-33	33	N/A	8.079	55.99	8.34	14.84	15.22	5.60
GPT-4	NERT-CB-3-55	55	N/A	23.148	60.08	6.43	16.31	9.70	7.48
GPT-4	NERT-CB-4-15	15	Fine sand	0.229	1.92	3.47	17.68	62.41	14.52
GPT-4	NERT-CB-4-30	30	Coarse sand	2.234	29.63	23.33	32.07	11.40	3.58
GPT-4	NERT-CB-4-50	50	Fine sand	0.110	0.00	0.52	13.6	52.8	33.07
GPT-4	NERT-CB-4-71	71	Medium sand	0.339	10.87	4.99	28.04	42.29	13.81

Notes:

(1) Based on Mean from Trask; USCS: Unified Soil Classification System

(2) Grain Size Analysis via Method D422M, sieve method

ASTM: ASTM Method D422M, sieve method

N/A: Mean grain size could not be calculated using Trask method because there was no 25 weight percent fraction of material in the sample.

mm: millimeters

Table 2. Summary of Moisture Content Analysis
NERT Downgradient Study Area, Henderson, Nevada

GPT Survey Line	Sample Identification	Collection Date	Depth (feet)	Moisture Content [(1)]
GPT-2	NERT-CB-1-15	2/14/2017	15	4.8
GPT-2	NERT-CB-1-28	2/14/2017	28	18.2
GPT-2	NERT-CB-1-35	2/14/2017	35	11.2
GPT-2	NERT-CB-1-42	2/14/2017	42	29.6
GPT-2	NERT-CB-1-52	2/14/2017	52	91.3
GPT-2	NERT-CB-1-70	2/14/2017	70	55.2
GPT-2	NERT-CB-2-7'	2/13/2017	7	5.0
GPT-2	NERT-CB-2-18'	2/13/2017	18	37.7
GPT-2	NERT-CB-2-27'	2/13/2017	27	23.8
GPT-2	NERT-CB-2-38'	2/13/2017	38	9.0
GPT-2	NERT-CB-2-70'	2/13/2017	70	63.6
GPT-4	NERT-CB-3-10	2/16/2017	10	6.8
GPT-4	NERT-CB-3-33	2/16/2017	33	13.8
GPT-4	NERT-CB-3-55	2/16/2017	55	37.8
GPT-4	NERT-CB-4-15	2/15/2017	15	11.9
GPT-4	NERT-CB-4-30	2/15/2017	30	12.2
GPT-4	NERT-CB-4-50	2/15/2017	50	53.1
GPT-4	NERT-CB-4-71	2/15/2017	71	33.1

Notes:

(1) ASTM Method D2216. Moisture Content is in percent of dry weight.

Table 3. Summary of Atterberg Limits Analysis
NERT Downgradient Study Area, Henderson, Nevada

GPT Survey Line	Sample Identification	Depth (feet)	Analysis Date	Atterberg Limits (1)			USCS/Plasticity Chart Symbol (Fines: <#40 Sieve)
				Liquid Limit	Plastic Limit	Plastic Index	
GPT-2	NERT-CB-1-15	15	3/7/2017	14.4	Non-Plastic		ML
GPT-2	NERT-CB-1-28	28	3/7/2017	26.1	16.6	9.5	CL
GPT-2	NERT-CB-1-35	35	3/7/2017	16.8	Non-Plastic		ML
GPT-2	NERT-CB-1-42	42	3/7/2017	26.7	Non-Plastic		ML
GPT-2	NERT-CB-1-52	52	3/7/2017	139.8	85.9	53.9	MH
GPT-2	NERT-CB-1-70	70	3/7/2017	68.9	34.8	34.1	MH
GPT-2	NERT-CB-2-7'	7	3/3/2017	15.9	Non-Plastic		ML
GPT-2	NERT-CB-2-18'	18	3/3/2017	38.3	19.7	18.6	CL
GPT-2	NERT-CB-2-27'	27	3/6/2017	29.7	15.5	14.2	CL
GPT-2	NERT-CB-2-38'	38	3/6/2017	5.2	Non-Plastic		ML
GPT-2	NERT-CB-2-70'	10	3/6/2017	71.1	32.8	38.3	CH
GPT-4	NERT-CB-3-10	10	3/9/2017	12.5	Non-Plastic		ML
GPT-4	NERT-CB-3-33	33	3/10/2017	14.2	Non-Plastic		ML
GPT-4	NERT-CB-3-55	55	3/10/2017	66.0	39.7	26.3	MH
GPT-4	NERT-CB-4-15	15	3/9/2017	10.0	Non-Plastic		ML
GPT-4	NERT-CB-4-30	30	3/9/2017	3.6	Non-Plastic		ML
GPT-4	NERT-CB-4-50	50	3/9/2017	53.8	32.8	21.0	MH
GPT-4	NERT-CB-4-71	71	3/9/2017	46.3	34.2	12.1	ML

Notes:

(1) ASTM Method D4318. Silt assumed as fine fraction for Non-Plastic samples.

USCS: Unified Soil Classification System

CH: Inorgainc clays of high plasticity, fat clays

CL: Inorganic clays of low to medium plasticity, gravelly calys, sandy clays, silty clays, lean clays

MH: Inorgainc silts, micaceous or diatomaceous fine dandy or silty soils, elastic silts

ML: Inorgainc silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight palsticity

Appendix A

Entry Permits

United States Department of the Interior

BUREAU OF RECLAMATION
Lower Colorado Regional Office
P.O. Box 61470
Boulder City, NV 89006-1470

OCT 06 2016

IN REPLY REFER TO:
LC-2517
LND-6.00

HAND DELIVERED

Mr. Carlton Parker, P.G.
Supervisor Environmental Scientist
Nevada Department of Environmental Protection
2030 East Flamingo Road, Suite 230
Las Vegas, NV 89119

Subject: Request for Right of Use, Non-invasive Geophysical Pilot Test and Installation of Transducers (Project), Nevada Department of Environmental Protection (NDEP), Contract No. 16-07-30-L0850; Robert B. Griffith Water Project (Your Letter Dated August 12, 2016)

Dear Mr. Parker:

We are enclosing for your files the fully executed duplicate original license which authorizes NDEP to execute the Project on Bureau of Reclamation lands withdrawn for the Robert B. Griffith Water Project in Henderson, Nevada.

If you have questions or need further information, please call Mr. Brandon Barrow, Realty Specialist, at 702-293-8171.

Sincerely,

for
Marc Maynard, Chief
Resources Management Office

Enclosure

United States Department of the Interior

BUREAU OF RECLAMATION
Lower Colorado Regional Office
P.O. Box 61470
Boulder City, NV 89006-1470

IN REPLY REFER TO:
LC-2517
LND-6.00

OCT 0 6 2016

HAND DELIVERED

Mr. Carlton Parker, P.G.
Supervisor Environmental Scientist
Nevada Department of Environmental Protection
2030 East Flamingo Road, Suite 230
Las Vegas, NV 89119

Subject: Request for Right of Use, Non-invasive Geophysical Pilot Test and Installation of Transducers (Project), Nevada Department of Environmental Protection (NDEP), Contract No. 16-07-30-L0850; Robert B. Griffith Water Project (Your Letter Dated August 12, 2016)

Dear Mr. Parker:

This letter transmits the offer by the Bureau of Reclamation of a license which will authorize NDEP to execute the Project over, across, and under lands withdrawn by the Bureau of Reclamation for the Robert B. Griffith Water Project. Enclosed are an original and duplicate original of the license.

If the license is acceptable, NDEP may sign both documents in the spaces indicated and return both documents to the Bureau of Reclamation, Attn: Mr. Brandon Barrow, LC-2517, P.O. Box 61470, Boulder City, NV 89006. The signature should be dated and acknowledged by a notary public. Upon our receipt of the signed documents from you, they will be dated, signed by Reclamation, and the duplicate original returned to you.

If you have questions or need further information, please contact Mr. Barrow, Realty Specialist, at 702-293-8171 or bbarrow@usbr.gov.

Sincerely,

Edward Seum

Edward Seum, Manager
Lands Group

Enclosures – 2

DUPLICATE ORIGINAL

Contract No. 16-07-30-L0850

ENTRY PERMIT

NON-INVASIVE SURFACE GEOPHYSICAL PILOT TEST AND INSTALLATION OF TRANSDUCERS IN EXISTING WELLS

NEVADA DEPARTMENT OF ENVIRONMENTAL PROTECTION

ROBERT B. GRIFFITH WATER PROJECT

This Entry Permit is made pursuant to the Act of Congress of June 17, 1902 (32 Stat. 388), and acts amendatory thereof or supplementary thereto, all of which acts are commonly known and referred to as the "Federal Reclamation Laws," and particularly pursuant to the Act of Congress approved August 4, 1939 (53 Stat. 1187), as amended August 18, 1950 (64 Stat. 463); the Act of Congress approved October 22, 1965 (79 Stat. 1068), as amended; and pursuant to the regulations found at 43 CFR 429, between the Bureau of Reclamation, hereinafter referred to as "Reclamation," represented by the Chief, Resources Management Office, hereinafter referred to as "Authorized Officer," and Nevada Department of Environmental Protection, hereinafter referred to as "Permittee."

By letter dated August 12, 2016, Permittee requested permission to conduct non-invasive surface geophysical pilot test and installation of transducers in existing wells (Project) on lands withdrawn by Reclamation for project purposes.

This action has been determined to be excluded from National Environmental Policy Act documentation by Categorical Exclusion No. LC-16-34, dated October 3, 2016.

Subject to the following stipulations, Reclamation grants Permittee, or its authorized agents or representatives, permission to enter Federal land under Reclamation jurisdiction to conduct cultural and paleontological resources investigations on the following-described lands.

By accepting and signing this Entry Permit and using the permitted areas, Permittee agrees to be bound by the Terms and Conditions, attached hereto as Exhibit A and made a part hereof, and the stipulations listed below.

1. Activities shall be performed in compliance with all Federal, State, and local laws and regulations applicable, and substantially as described on Exhibit B, which is attached hereto and made a part hereof.

2. This permission is subject to all prior existing rights. Prior to commencing the investigations, Permittee shall coordinate all activities with any other entities holding valid existing rights or having any applicable jurisdiction on the subject land.

3. The permission granted covers activities performed on Reclamation land withdrawn for the Robert B. Griffith Water Project in sections 28, 29, and 30 T. 21 S., R. 63 E., MDM, Clark County, Nevada, as generally described and depicted on Exhibit B.

4. While conducting the permitted activity Permittee shall be particularly alert to take all reasonable and necessary precautions to protect and preserve any and all antiquities or other objects of archaeological, cultural, historic, or scientific interest on or adjacent to lands of the

United States under this Entry Permit. Should sites, ruins, or artifacts be discovered during these operations, Permittee shall immediately suspend work involving the area in question, and contact the Authorized Officer at 702-293-8130. Permittee shall follow up with a written report of their finding(s) to the Authorized Officer within 48 hours. Objects under consideration include, but are not limited to, historic or prehistoric ruins, human remains, funerary objects, and artifacts discovered as a result of activities under this Entry Permit. Construction shall not resume until all mitigative measures developed in consultation with the State Historic Preservation Officer have been completed. All objects of antiquity recovered from the above-described lands of the United States are the property of the United States and shall be turned over to the Bureau of Reclamation.

5. A maximum speed of 15 miles per hour shall be maintained while using the permitted areas to reduce dust and allow personnel to observe desert tortoises in the road.

6. All activities shall be confined to the minimum area necessary.

7. Permittee shall at all times keep the permitted area, including storage areas used by Permittee, free from accumulations of waste materials or rubbish. Prior to completion of the permitted activity, Permittee shall remove all rubbish and other like material belonging to Permittee or used under Permittee's direction during the permitted activity.

8. Permittee shall be responsible for compliance with all applicable dust abatement and air quality standards in the permitted areas.

9. Permittee shall immediately notify the Authorized Officer at 702-293-8130, as well as the Clark County Health Department at 702 383-1027, of any release of hazardous substances, toxic substances, or hazardous waste on or near the areas authorized by this Entry Permit.

10. NDEP shall provide Reclamation with monitoring data for the work surrounding the geophysical pilot testing phase. In addition, data associated with the transducers shall be provide to Reclamation following the completion of the pilot test.

11. Should vegetation clearing be needed, a field survey of the site shall be conducted by a biologist prior to clearing, to verify that no sensitive flora or fauna species are present. Areas with suitable avian habitat shall be surveyed by a biologist prior to clearing. If breeding activities are occurring, work shall cease until the young have fledged.

12. If a desert tortoise is observed on or near any roads or well sites, all travel on the road and all associated work shall cease until the tortoise has moved out of the area of its own volition.

13. Permittee shall be responsible for obtaining all required permits prior to commencement of the activities authorized on lands of the United States under this Entry Permit.

14. All on-site personnel in the permitted areas shall be personally instructed by Permittee or its designated agent or representative, regarding the Terms and Conditions set forth in Exhibit A and the above-listed stipulations. All on-site personnel shall have a copy of this permit in possession while in the permitted areas.

15. This permission shall not be construed as a grant of permanent interest for a right of way or as an abandonment of the United States use and occupancy of the premises described herein.

16. This Entry Permit is temporary and is for the purpose of authorizing non-invasive surface geophysical pilot test and installation of transducers in existing wells for the Project.

17. Non-compliance with any Entry Permit stipulation shall be grounds for termination of this authorization.

18. This authorization shall be effective upon the date of execution by Reclamation, and it will terminate on March 1, 2017.

BUREAU OF RECLAMATION

By: For Marc Maynard — 6 OCT 2016

Chief, Resources Management Office
P.O. Box 61470
Boulder City, NV 89006-1470

Date

NDEP

By: ______ — 6 Oct 2016

Supervisor Environmental Scientist
NDEP
2030 E. Flamingo Road, Suite 230
Las Vegas, NV 89119

Date

Contract No. 16-07-30-L0850

ACKNOWLEDGMENT

STATE OF NEVADA)
) ss.
COUNTY OF CLARK)

On this 6th day of October, in the year 2016, before me, Nancy Rolfe, A Notary Public in and for said County and State, personally appeared John Ladd, Acting, Chief, Resources Management Office, Lower Colorado Region, Bureau of Reclamation, United States Department of the Interior, known to me to be the person described in the foregoing instrument, and acknowledged to me that he executed the same on behalf of the United States of America in the capacity therein stated and for the purpose therein contained.

Nancy Rolfe

Notary Public in and for the County of
Clark, State of Nevada

My Commission Expires: March 27, 2019

NANCY ROLFE
Nevada
My App. Expires March 27, 2019

NANCY ROLFE
Notary Public-State of Nevada
APPT. NO. 07-2499-1
My App. Expires March 27, 2019

Contract No. 16-07-30-L0850

ACKNOWLEDGMENT

STATE OF Nevada)
) ss.
COUNTY OF Clark)

On this 6th day of October, in the year 2016, before me,

Nancy Rolfe, A Notary Public in and for said County and State,

personally appeared

Name J. Carlton Parker,

Title Supervisor Environmental Scientist,

known to me to be the person described in the foregoing instrument, and acknowledged to me

that he/she executed the same on behalf of

Name of Company NDEP,

in the capacity therein stated and for the purpose therein contained.

Nancy Rolfe

Notary Public in and for said County and State

My Commission Expires: March 27, 2019

NANCY ROLFE
Notary Public-State of Nevada
APPT. NO. 07-2499-1
My App. Expires March 27, 2019

ENTRY PERMIT
TERMS AND CONDITIONS

1. HOLD HARMLESS: Permittee agrees to indemnify the United States for, and hold the United States and all of its representatives harmless from, all damages resulting from suits, actions, or claims of any character brought on account of any injury to any person or property arising out of any act, omission, neglect, or misconduct in the manner or method of performing any construction, care, operation, maintenance, supervision, examination, inspection, or other activities of Permittee.

2. TERMINATION: Reclamation may, at any time and at no cost or liability to the United States, terminate this Entry Permit:

a. in the event of a natural disaster, a national emergency, a need arising from security requirements, or an immediate and overriding threat to public health and safety; or

b. if Reclamation determines that Permittee has failed to use this Entry Permit for its intended purpose; or

c. if Permittee fails to comply with all applicable Federal, State, and local laws, regulations, ordinances, or terms and conditions of this use authorization, or to obtain any required permits or authorizations; or

d. if any activity is deemed to be illegal on Federal lands.

3. RESERVATION: There is reserved to the United States the right of its officers, agents, employees, contractors, licensees, and permittees, acting within the scope of their authority, at all times and places freely to have ingress to, passage over, and egress from all of said lands for the purpose of exercising, enforcing, and protecting the rights reserved herein.

4. NONDISCRIMINATION: The Permittee hereby agrees as follows:

a. To comply with Title VI (section 601) of the Civil Rights Act of July 2, 1964 (78 Stat. 241), which provides that "...no person in the United States shall, on the ground of race, color, sex, or national origin be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the City receives financial assistance from the United States...," and to be bound by the regulations of the Department of the Interior for the effectuation thereof, as set forth in 43 CFR 17.

b. To obligate its subcontractors, subgrantees, transferees, successors in interest, or any other participants receiving Federal financial assistance hereunder, to comply with the requirements of this provision.

c. In the event that a final decision of a hearing examiner or of the Director, Office of Hearings and Appeals, pursuant to 43 CFR 17, provides for termination of or refusal to grant the authorization provided for in this Entry Permit, the Authorized Officer may terminate this Entry Permit and revoke the grant. This provision shall be a covenant running with the land during the period in which the property is used for a purpose for which the Federal financial assistance is extended or for any other purpose involving the provisions of similar services or benefits.

d. To comply with Section 504 of the Rehabilitation Act of 1973, Public Law 93-112, as amended which is designed to eliminate discrimination on the basis of disability in any program or activity receiving Federal financial assistance, and to obligate its subcontractors, subgrantees, transferees, successors in interest, or any other participants receiving Federal financial assistance hereunder, to comply with the requirements of this provision.

e. To comply with the Age Discrimination Act of 1975, as amended, 42 U.S.C. 6101, et seq., and the general age discrimination regulations at 45 CFR 90 which are designed to prohibit discrimination on the basis of age in programs and activities receiving Federal financial assistance, as set forth in 43 CFR 17, and to obligate its subcontractors, subgrantees, transferees, successors in interest, or any other participants receiving Federal financial assistance hereunder, to comply with the requirements of this provision.

5. EQUAL OPPORTUNITY: During the performance of this Entry Permit, Permittee agrees as follows:

a. Permittee shall not discriminate against any employee or applicant for employment because of race, color, religion, sex, or national origin. Permittee shall take affirmative action to ensure that applicants are employed, and that employees are treated during employment, without regard to their race, color, religion, sex, or national origin. Such action shall include, but not be limited to the following: Employment, upgrading, demotion, or transfer; recruitment or recruitment advertising; layoff or termination; rates of pay or other forms of compensation; and

EXHIBIT A

selection for training, including apprenticeship. Permittee agrees to post in conspicuous places, available to employees and applicants for employment, notices to be provided by the Authorized Officer setting forth the provisions of this nondiscrimination clause.

b. Permittee shall, in all solicitations or advertisements for employees placed by or on behalf of Permittee, state that all qualified applicants shall receive consideration for employment without discrimination because of race, color, religion, sex, or national origin.

c. Permittee shall send to each labor union or representative of workers with which it has a collective bargaining agreement or other contract or understanding, a notice, to be provided by the Authorized Officer, advising said labor union or workers' representative of Permittee's commitments under section 202 of Executive Order 11246 of September 24, 1965, as amended, and shall post copies of the notice in conspicuous places available to employees and applicants for employment.

d. Permittee shall comply with all provisions of Executive Order No. 11246 of September 24, 1965, as amended, and of the rules, regulations, and relevant orders of the Secretary of Labor.

e. Permittee shall furnish all information and reports required by said amended Executive Order and by the rules, regulations, and orders of the Secretary of Labor, or pursuant thereto, and shall permit access to its books, records, and accounts by the Authorized Officer and the Secretary of Labor for purposes of investigation to ascertain compliance with such rules, regulations, and orders.

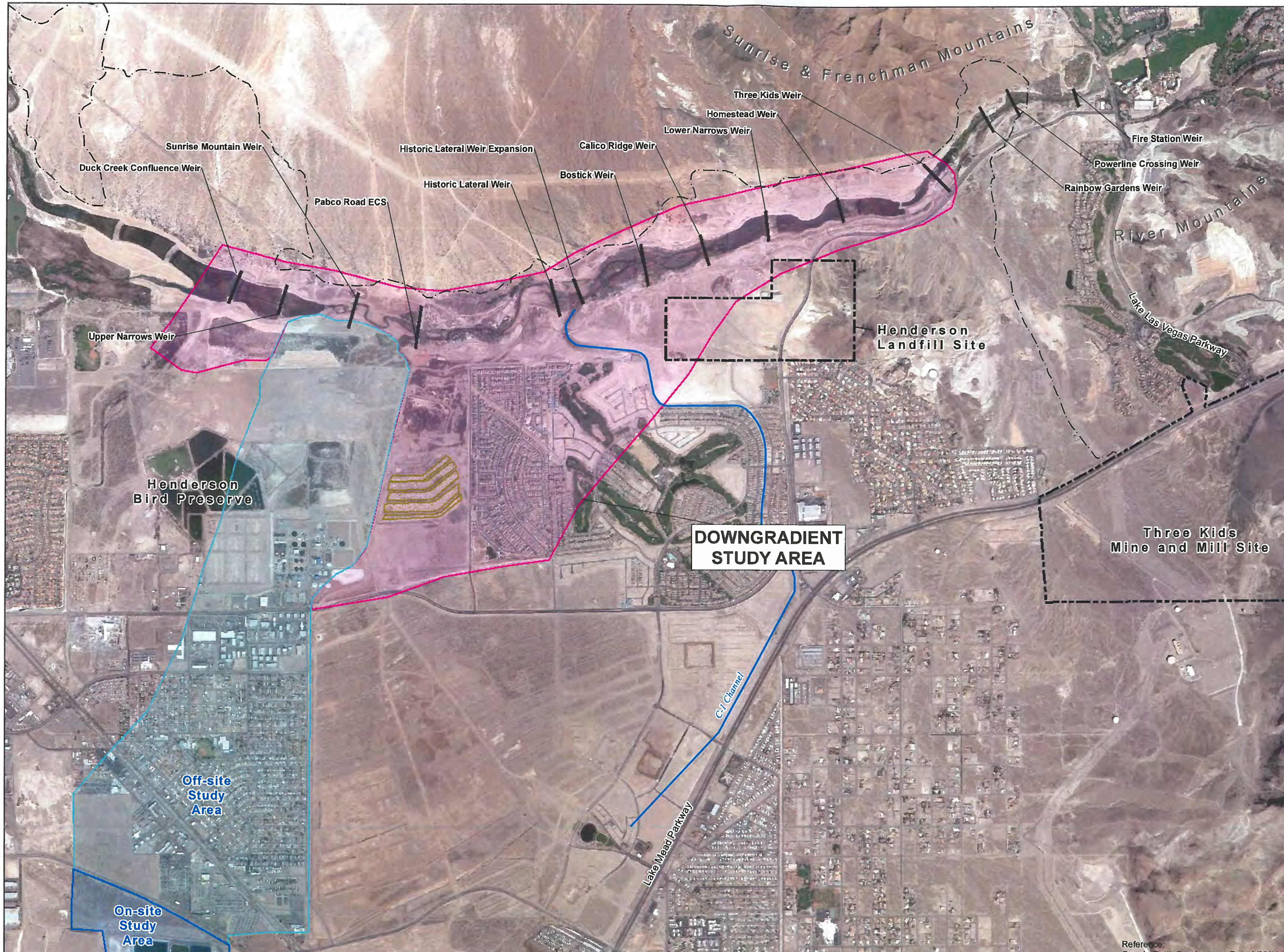
f. In the event of Permittee's noncompliance with the nondiscrimination clauses of this Entry Permit or with any of such rules, regulations, or orders, this Entry Permit may be canceled, terminated, or suspended, in whole or in part, and Permittee may be declared ineligible for further Government contracts in accordance with procedures authorized in said amended Executive Order, and such other sanctions may be imposed and remedies invoked as provided in said amended Executive Order, or by rule, regulation, or order of the Secretary of Labor, or as otherwise provided by law.

g. Permittee shall include the provisions of paragraphs a. through g. in every subcontract or purchase order unless exempted by rules, regulations, or orders of the Secretary of Labor issued pursuant to section 204 of said amended Executive Order, so that such provisions shall be binding upon each subcontractor or vendor. Permittee shall take such action with respect to any subcontract or purchase order as may be directed by the Secretary of Labor as a means of enforcing such provisions, including sanctions for noncompliance; provided, however, that in the event Permittee becomes involved in, or is threatened with, litigation with a subcontractor or vendor as a result of such direction, Permittee may request the United States to enter into such litigation to protect the interests of the United States.

6. OFFICIALS NOT TO BENEFIT: No member of or delegate to Congress or resident commissioner, and no officer, agent, or employee of the Department of the Interior shall be admitted to any share or part of this Entry Permit or to any benefit that may arise therefrom, but this restriction shall not be construed to extend to this Entry Permit if made with a corporation or company for its general benefit.

7. SEVERABILITY: Each provision of this use authorization shall be interpreted in such a manner as to be valid under applicable law, but if any provision of this use authorization shall be deemed or determined by competent authority to be invalid or prohibited hereunder, such provision shall be ineffective and void only to the extent of such invalidity or prohibition, but shall not be deemed ineffective or invalid as to the remainder of such provision or any other remaining provisions, or of the use authorization as a whole.

EXHIBIT A



Legend

- Wetlands Trail
- Channels
- Northern Rapid Infiltration Basins
- NERT Downgradient Study Area
- NERT Off-site Study Area
- NERT On-site Study Area

Exhibit B

NORTH

0 2,000

Feet

Scale 1:24,000

1 inch = 2,000 feet

NERT
Regional Groundwater
Downgradient Study Area

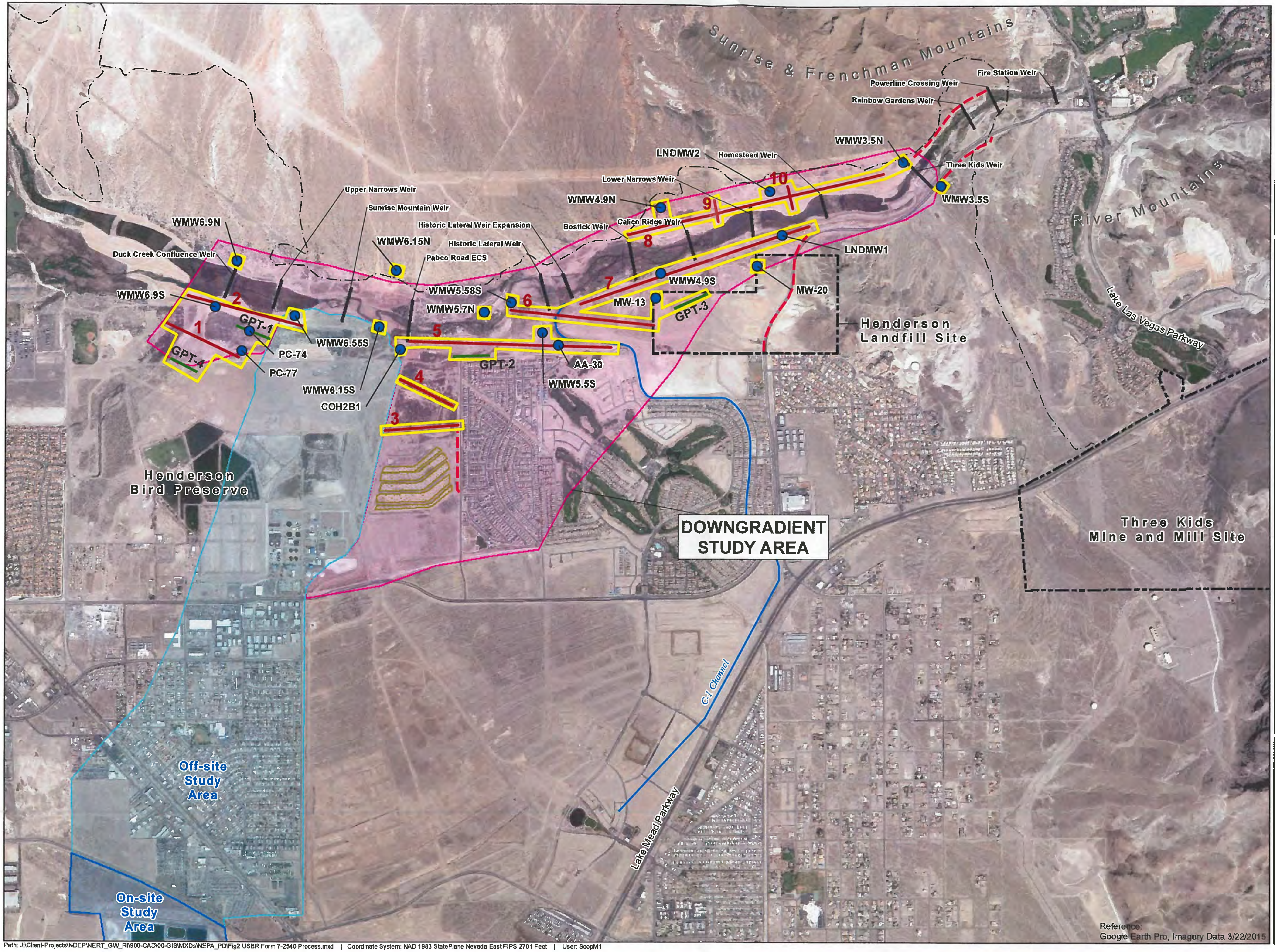
DOWNGRADIENT STUDY AREA LOCATION MAP

Date: 8/8/2016 Project: 60477365

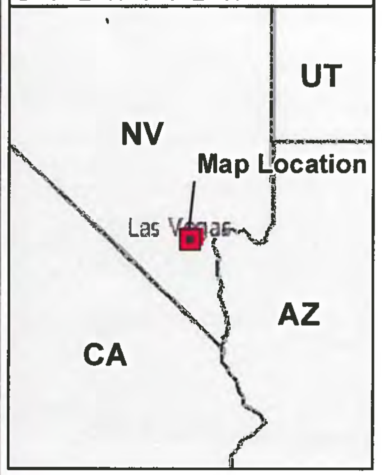
AECOM

Figure 1

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\NEPA_PD\Vicinity Map.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: ScopM1



OVERVIEW MAP



Legend

- Transucer Installation in Well
- Full-Scale Geophysical Survey Line
- Geophysical Pilot Test (GPT) Survey Line
- Channels
- Northern Rapid Infiltration Basins
- NERT Downgradient Study Area
- NERT Off-site Study Area
- NERT On-site Study Area
- Wetlands Trail
- Project Area
- Access Route

NORTH

0 2,000
Feet

Scale 1:24,000
1 inch = 2,000 feet

NERT
Regional Groundwater
Downgradient Study Area

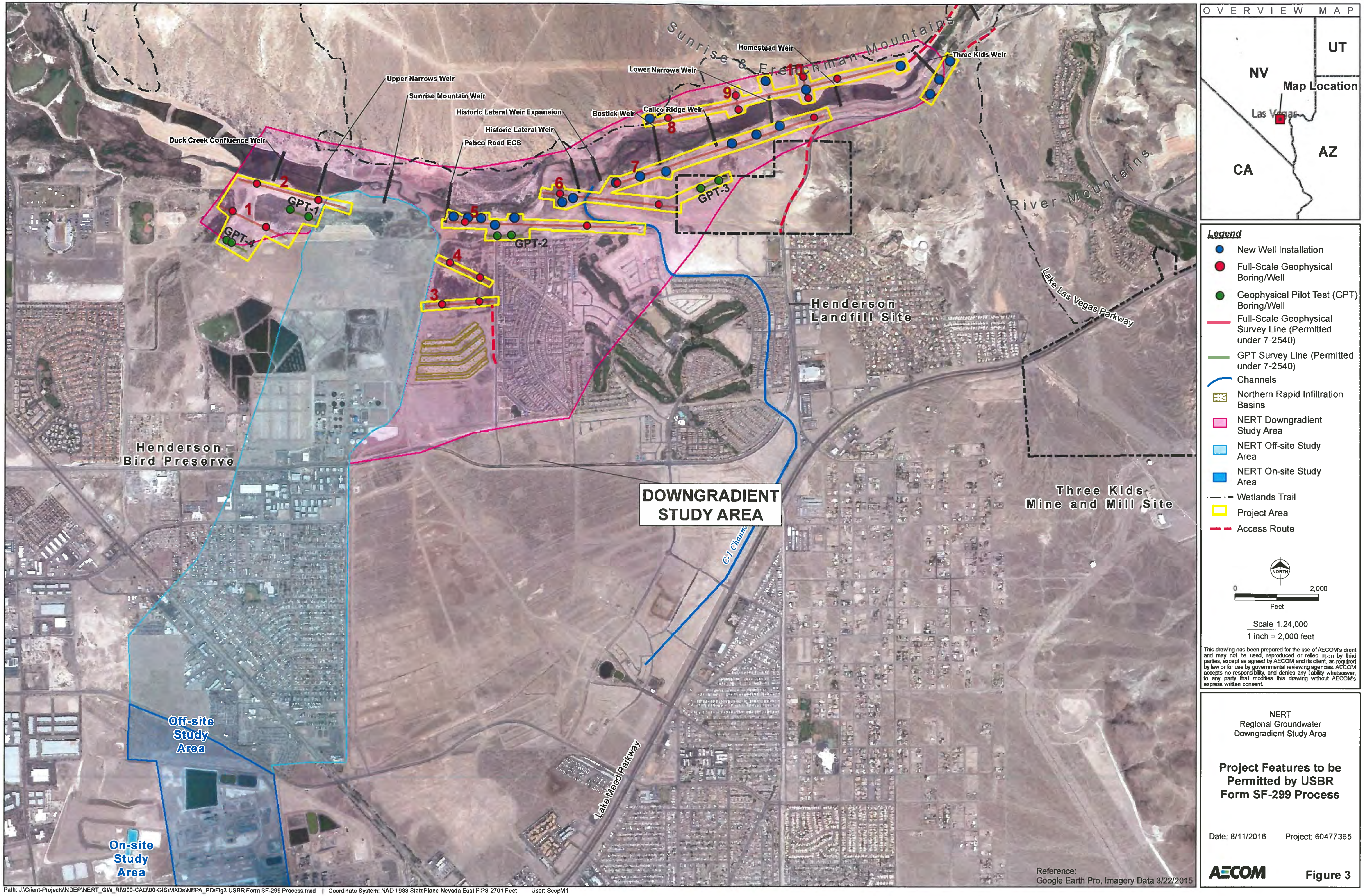
Project Features to be Permitted by USBR Form 7-2540 Process

Date: 8/11/2016 Project: 60477365

AECOM

Figure 2

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\NEPA_PD\Fig2 USBR Form 7-2540 Process.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: ScopM1



Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\NEPA_PD\Fig3 USBR Form SF-299 Process.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: ScopM1

OVERVIEW MAP

Legend

- Potential Geophysical Pilot Test (GPT) Survey Line
- * Preferred GPT Survey Line
- 50-ft Buffer Project Area
- Disturbance Footprint
- Pilot Test Boring/Well Location
- Approximate Paleochannel Location
- NERT Downgradient Study Area Boundary

NORTH

0 200
Feet

Scale 1:2,400

1 inch = 200 feet

NERT
Remedial Investigation
Downgradient Study Area

CLOSE UP OF GPT LINES AND VERIFICATION SOIL BORINGS

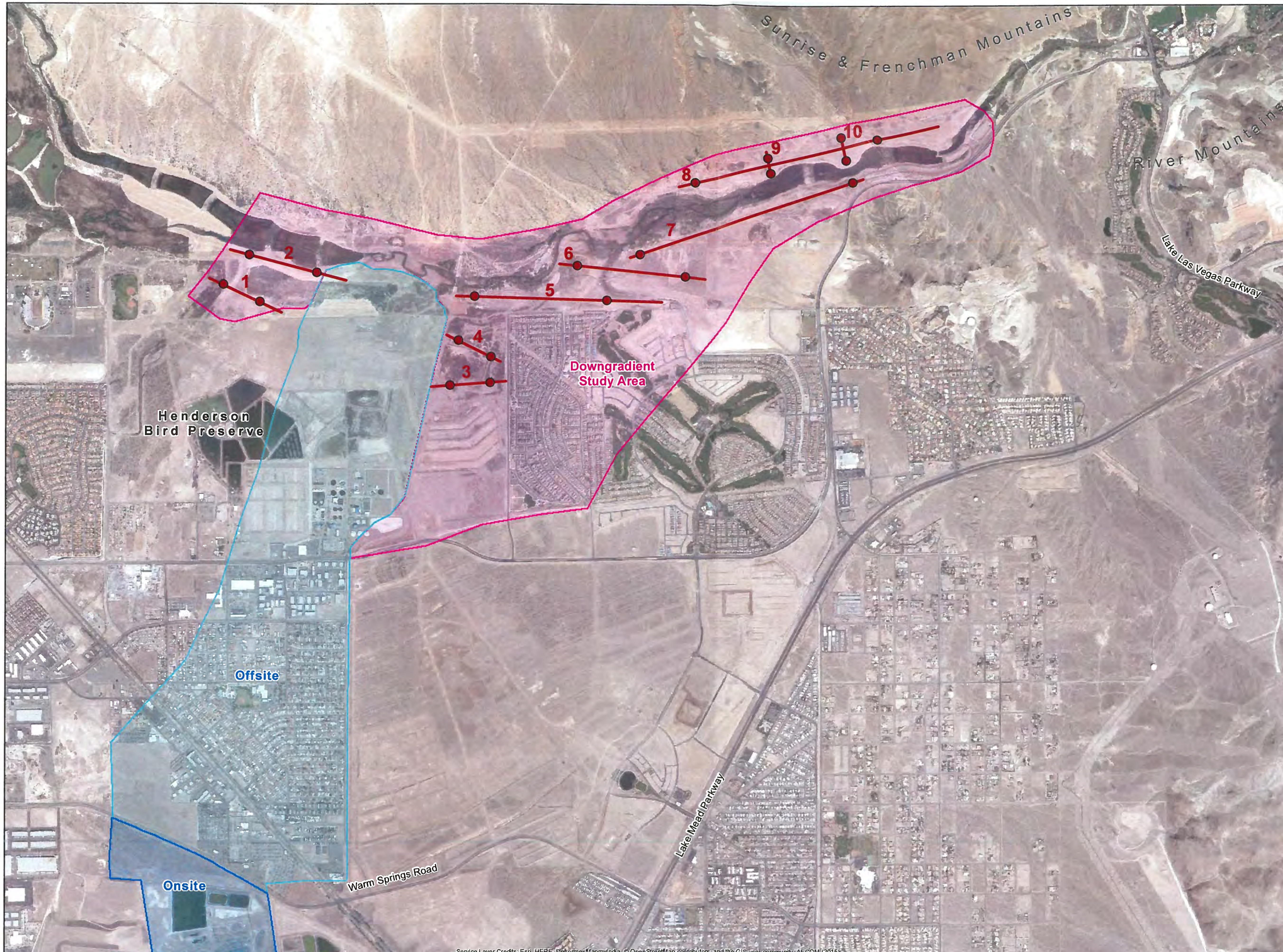
Date: 8/11/2016 Project: 60477365

AECOM

Figure 4

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\NEPA_PD\Fig4_GPT Lines closeup Locations.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: ScopM1



Legend

- Full-Scale Geophysical Survey Line
- Full-Scale Geophysical Verification Boring
- Northern Rapid Infiltration Basins
- NERT Downgradient Study Area
- NERT Off-site Study Area
- NERT On-site Study Area

NORTH

0 2,000

Feet

Scale 1:24,000

1 inch = 2,000 feet

NERT
Remedial Investigation
Downgradient Study Area

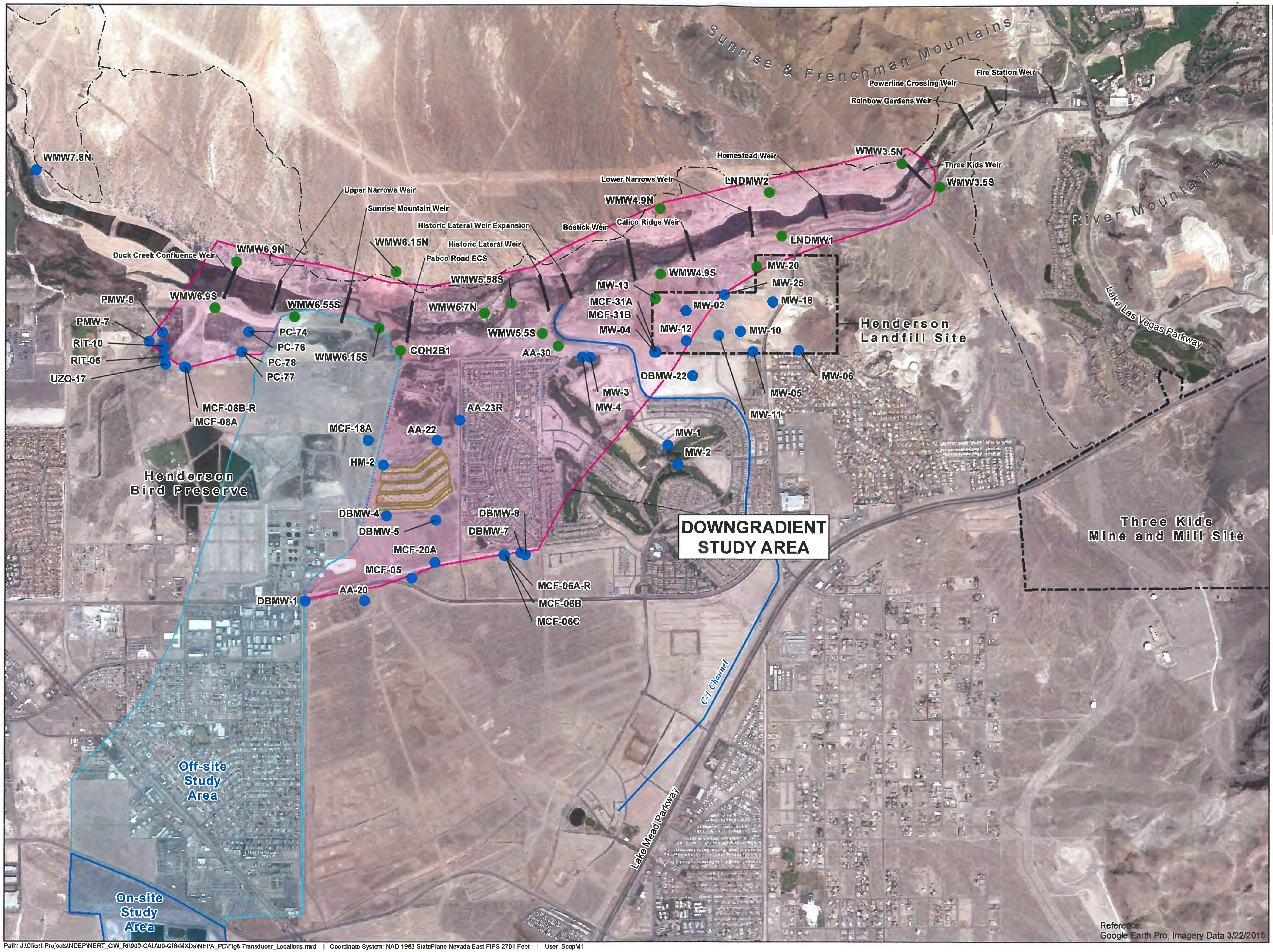
FULL-SCALE GEOPHYSICAL SURVEY LINE LOCATIONS MAP

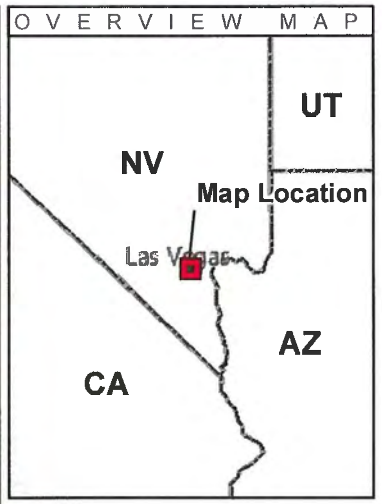
Date: 8/11/2016 Project: 60477365

AECOM

Figure 5

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\NEPA_PD\Fig5-Full-Scale Geophysical Lines.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: ScopM1





Legend

- Transducer Installation in Well
- Existing Groundwater Monitoring Well
- Channels
- Northern Rapid Infiltration Basins
- NERT Downgradient Study Area
- NERT Off-site Study Area
- NERT On-site Study Area
- Wetlands

NORTH

0 2,000
Feet

Scale 1:24,000
1 inch = 2,000 feet

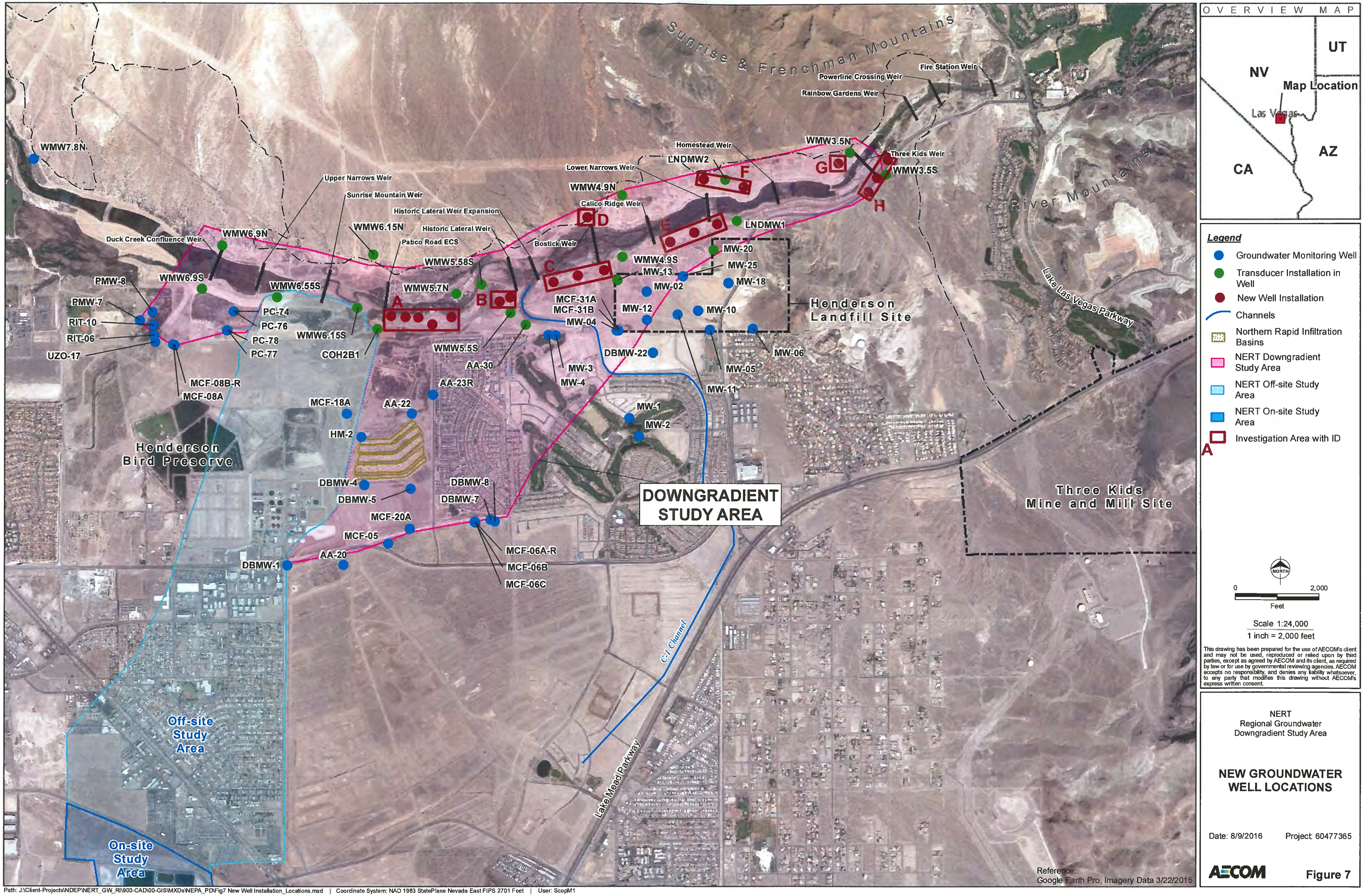
NERT
Regional Groundwater
Downgradient Study Area

TRANSDUCER INSTALLATIONS IN EXISTING WELLS

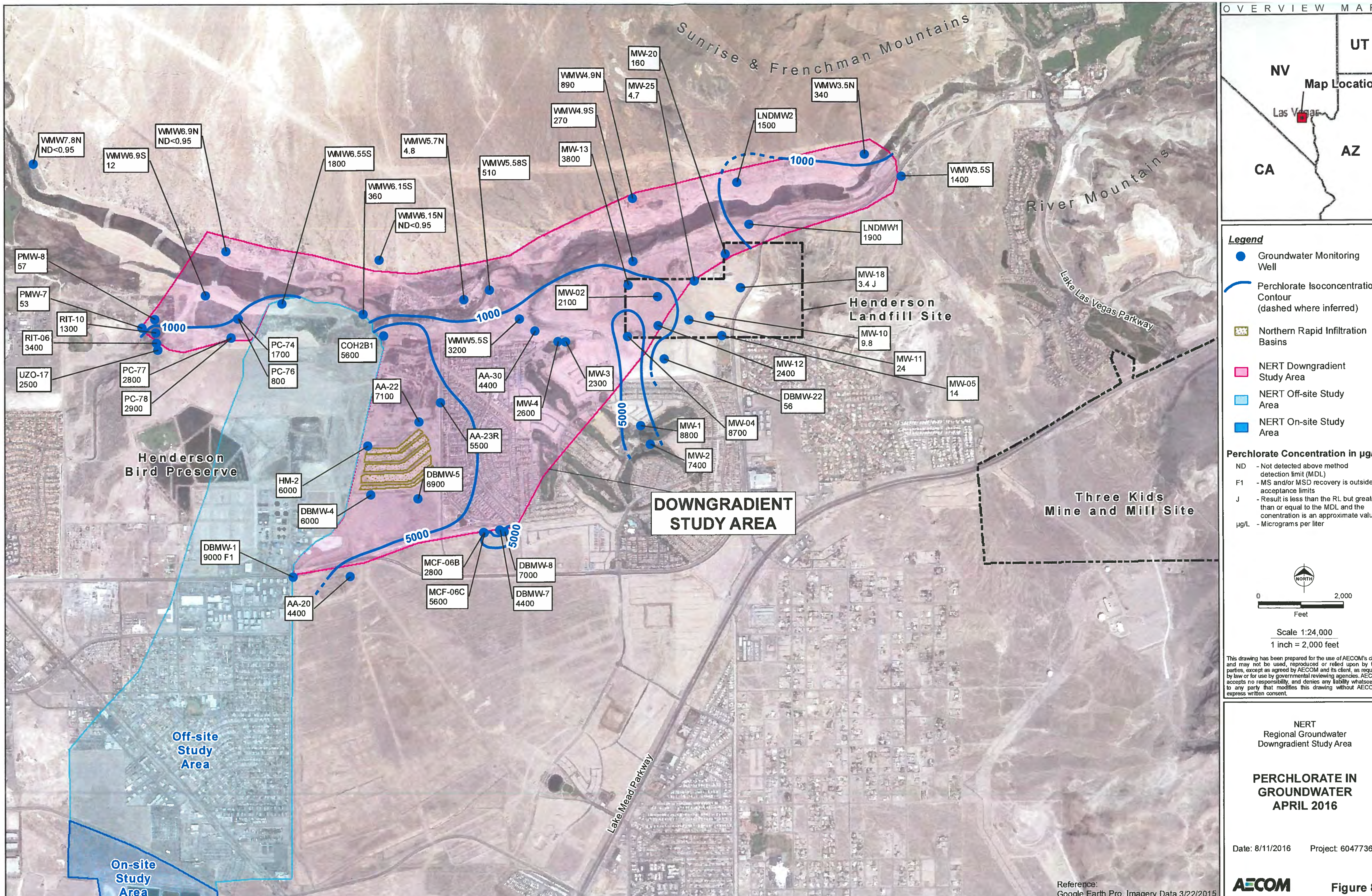
Date: 8/11/2016 Project: 60477365

AECOM

Figure 6



Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\NEPA_PD\Fig7 New Well Installation_Locations.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: ScopM1



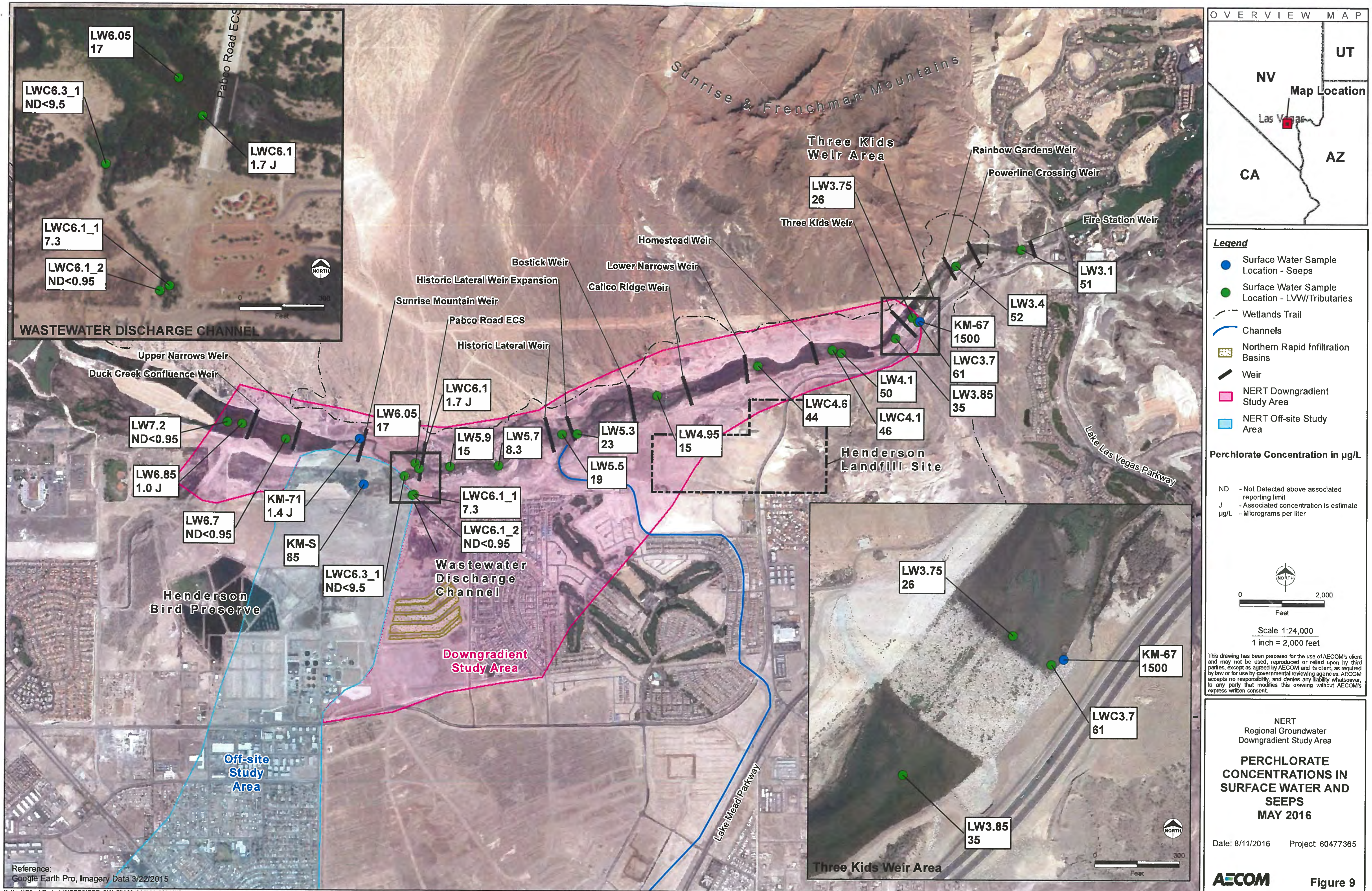
NERT
Regional Groundwater
Downgradient Study Area

PERCHLORATE IN GROUNDWATER APRIL 2016

Date: 8/11/2016 Project: 60477365

AECOM Figure 8

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\NEPA_PD\Fig8 GW_Sampling_perchlorate.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: ScopM1



WASTEWATER DISCHARGE CHANNEL
LW6.05 17
LWC6.3_1 ND<9.5
LWC6.1 1.7 J
LWC6.1_1 7.3
LWC6.1_2 ND<0.95
Pabco Road ECS
NORTH
0 300 Feet
Sunrise & Frenchman Mountains
Three Kids Weir Area
Rainbow Gardens Weir
Powerline Crossing Weir
Fire Station Weir
LW3.75 26
Three Kids Weir
Homestead Weir
Bostick Weir
Lower Narrows Weir
Historic Lateral Weir Expansion
Calico Ridge Weir
Sunrise Mountain Weir
Pabco Road ECS
Historic Lateral Weir
Upper Narrows Weir
Duck Creek Confluence Weir
LW3.1 51
LW3.4 52
KM-67 1500
LWC3.7 61
LW3.85 35
LW4.1 50
LWC4.1 46
LWC4.6 44
LW4.95 15
LW5.3 23
LW5.5 19
LW5.7 8.3
LW5.9 15
LWC6.1 1.7 J
LW6.05 17
LW7.2 ND<0.95
LW6.85 1.0 J
LW6.7 ND<0.95
KM-71 1.4 J
KM-S 85
LWC6.3_1 ND<9.5
LWC6.1_1 7.3
LWC6.1_2 ND<0.95
Henderson Landfill Site
Lake Las Vegas Parkway
Wastewater Discharge Channel
Henderson Bird Preserve
Downgradient Study Area
Off-site Study Area
Lake Mead Parkway
Three Kids Weir Area
LW3.75 26
KM-67 1500
LWC3.7 61
LW3.85 35
NORTH
0 300 Feet
Reference:
Google Earth Pro, Imagery Data 3/22/2015
OVERVIEW MAP
UT
NV
Map Location
Las Vegas
AZ
CA
Legend
Surface Water Sample Location - Seeps
Surface Water Sample Location - LVW/Tributaries
Wetlands Trail
Channels
Northern Rapid Infiltration Basins
Weir
NERT Downgradient Study Area
NERT Off-site Study Area
Perchlorate Concentration in µg/L
ND - Not Detected above associated reporting limit
J - Associated concentration is estimate
µg/L - Micrograms per liter
NORTH
0 2,000
Feet
Scale 1:24,000
1 inch = 2,000 feet
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NERT
Regional Groundwater
Downgradient Study Area
PERCHLORATE CONCENTRATIONS IN SURFACE WATER AND SEEPS
MAY 2016
Date: 8/11/2016
Project: 60477365
AECOM
Figure 9
Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\NEPA_PD\Fig9_SW Perchlorate.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: ScopM1

Caceres-Schnell, Carmen

From: lfarris landwellco.com <lfarris@landwellco.com>
Sent: Tuesday, October 18, 2016 3:47 PM
To: Caceres-Schnell, Carmen
Cc: mparis landwellco.com
Subject: RE: Geophysical Survey for NDEP

Youre good

Lee C. Farris, P.E.
Vice President
The LandWell Company and Basic Remediation Company
875 West Warm Springs Road
Henderson, Nevada 89011
702-567-0400 (o)
702-568-2888 (d)
702-523-2920 (c)

-----Original Message-----
From: Caceres-Schnell, Carmen [mailto:Carmen.Caceres-Schnell@aecom.com]
Sent: Tuesday, October 18, 2016 2:02 PM
To: lfarris landwellco.com
Cc: mparis landwellco.com
Subject: RE: Geophysical Survey for NDEP

Hi Lee,

Were you able to speak with your team about access for the geophysics survey on the LandWell property? We'd like to be out there tomorrow morning if possible.

Thank you,

Carmen Caceres-Schnell
Scientist V, Remediation
D +1-805-764-4031   M +1-818-517-3126
Cisco +270-4031
carmen.caceres-schnell@aecom.com

AECOM
1220 Avenida Acaso
Camarillo, CA 93012, United States
T +1-805-388-3775
aecom.com

-----Original Message-----
From: lfarris landwellco.com [mailto:lfarris@landwellco.com]
Sent: Thursday, October 13, 2016 3:36 PM
To: Caceres-Schnell, Carmen
Cc: mparis landwellco.com
Subject: Re: Geophysical Survey for NDEP

If you need access next week have to assessed if you'll be clearing brush or just surveying? I think this area is clear.

Also can you clarify what utility clearance means.

You may call me on cell to discuss. 7025232920.

Sent from my iPhone

> On Oct 13, 2016, at 5:33 PM, Caceres-Schnell, Carmen <Carmen.Caceres-Schnell@aecom.com> wrote:
>
> Farris,
>
> Thank you for responding. Currently we would possibly need to access LandWell property on Tuesday or Wednesday of next week. If we talk on Monday, will that be enough time for you to make a decision on this?
>
> Regards,
>
> Carmen Caceres-Schnell
> Scientist V, Remediation
> D +1-805-764-4031   M +1-818-517-3126
> Cisco +270-4031
> carmen.caceres-schnell@aecom.com
>
> AECOM
> 1220 Avenida Acaso
> Camarillo, CA 93012, United States
> T +1-805-388-3775
> aecom.com
>
> Built to deliver a better world
>
> LinkedIn Twitter Facebook Instagram
>
>
> -----Original Message-----
> From: lfarris landwellco.com [mailto:lfarris@landwellco.com]
> Sent: Thursday, October 13, 2016 3:29 PM
> To: Caceres-Schnell, Carmen
> Cc: mparis landwellco.com
> Subject: Re: Geophysical Survey for NDEP
>
> Carmen. I'll call you Monday to discuss.
>
> Sent from my iPhone
>

>> On Oct 13, 2016, at 5:24 PM, Caceres-Schnell, Carmen <Carmen.Caceres-Schnell@aecom.com> wrote:
>>
>> Mark,
>>
>> I got an out of office message from Lee saying that he is unavailable so I'm hoping you can help. Please see email below. If you prefer to discuss over the phone I please give me a call.
>>
>> Thank you,
>>
>> Carmen Caceres-Schnell
>> Scientist V, Remediation
>> D +1-805-764-4031   M +1-818-517-3126
>> Cisco +270-4031
>> carmen.caceres-schnell@aecom.com<mailto:carmen.caceres-schnell@aecom.com>
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>> Camarillo, CA 93012, United States
>> T +1-805-388-3775
>> aecom.com<http://www.aecom.com/>
>>

>>
>>
>> From: Caceres-Schnell, Carmen
>> Sent: Wednesday, October 12, 2016 3:29 PM
>> To: 'lfarris@landwellco.com'
>> Subject: Geophysical Survey for NDEP
>>
>> Lee,
>>
>> AECOM will be conducting a geophysical survey in support if the NERT Regional Groundwater Downgradient Study Area investigation. The USBR has issued a permit (7-2540) to conduct this work on federal lands but the proposed work includes an alternate survey line (GPT-4) partially located on Landwell property (see attached figure). GPT-4 located on Landwell property, will be surveyed only if the two preferred lines are found to be unsuitable for the study.
>>
>> The proposed work is non-invasive and consists of utility clearance, minimal clearing of vegetation if necessary, a land survey to mark the survey lines, and the surface geophysical investigation. The purpose of the study is to test three geophysical systems to evaluate which system returns the best subsurface information. The location of GPT-4 was chosen as an alternate based on a paleochannel mapped at this location and the soil borings that have been previously drilled near this location.
>>
>> In February 2016, Landwell granted AECOM access to existing wells for the purposes of collecting groundwater samples. The agreement is valid for 360 days. If Landwell is amenable to the proposed geophysical survey to be conducted on their property, could the existing access agreement be used to access the site? I would be happy to discuss this with you further if you have any questions.
>>
>> Thank you,
>>

>> Carmen Caceres-Schnell
>> Scientist V, Remediation
>> D +1-805-764-4031   M +1-818-517-3126
>> Cisco +270-4031
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>> T +1-805-388-3775
>> aecom.com<http://www.aecom.com/>
>>
>> Built to deliver a better world
>>
>> LinkedIn<http://www.linkedin.com/company/aecom_15656> Twitter<http://twitter.com/AECOM>
Facebook<http://www.facebook.com/AecomTechnologyCorporation> Instagram<http://instagram.com/aecom>
>>
>>
>> <Figure 2a USBR Form 7-2540 and land Ownership.pdf>
>> <16 03 07 LandWell access agreement.pdf>

Clark County
Parks & Recreation Department

2601 E Sunset Rd • Las Vegas NV • 89120-3515
(702) 455-8200

Jane Pike, Director
Mindy Meyers, Assistant Director

January 21, 2017

Carmen Caceres-Schnell
AECOM
1220 Avenida Acaso
Camarillo CA 93012

Dear Carmen Caceres-Schnell:

Clark County has reviewed your request for authorization to drill for soil borings per the request dated January 10, 2017.

Based on the information provided, land owner authorization has been approved on County lands and concurrence is provided by County for activities on US Bureau of Reclamation lands as described in the attached Use Permission Form and contingent upon AECOM obtaining all applicable permits, maintaining compliance with all local, state and federal laws and in accordance with the Historic Preservation Programmatic Agreement (PA) for the Wetlands Park. Further, AECOM shall abide by the following stipulations:

Provide County before and after photographs of construction of surface water stations in digital format.

Notify County of start and conclusion of installation construction activity as well as timeframe that vehicles will be traversing the trails and roads for installation and construction activities.

Vehicular traffic shall remain on existing roads and take measures to limit access on concrete trails and take action to protect concrete trails by heavy equipment.

Extreme caution should be maintained by vehicles to protect park visitors within the Wetlands Park.

Any native vegetation that is impacted by the construction and installation of the surface water stations shall be documented and replaced by AECOM.

AECOM shall provide County a brief synopsis of the project appropriate for use by County on Wetlands Park webpage and social media. Additional photos of the project are appreciated.

Sincerely,

Elizabeth Bickmore
Senior Program Administrator, Wetlands Park

cc: Jane Pike, Director, Parks and Recreation
cc: Darren R. Daniels, Manager, Real Property Management
cc: Brandon Barrow, Realty Specialist, U.S. Bureau of Reclamation
cc: Todd Tietjen, Regional Water Quality Manager, SNWA

Appendix B

Geophysical Pilot Test Report by GEOVision, June 2017

SUBMITTAL

GEOPHYSICAL PILOT TEST
NERT REMEDIAL INVESTIGATION – DOWNGRADIENT STUDY AREA

LAS VEGAS WASH
HENDERSON, NEVADA

GEO*Vision* Project No. 16374

Prepared for

AECOM
1220 Avenida Acaso
Camarillo, CA 93012
(805) 764-4031

Prepared by

GEO*Vision* Geophysical Services
1124 Olympic Drive
Corona, CA 92881
(951) 549-1234

Report 16374-01 Rev 0

June 20, 2017

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1 INTRODUCTION

A geophysical investigation was conducted from November 7th to 11th, 17th, and 18th, 2016 at two (2) locations, GPT-2 and GPT-4, in the Las Vegas Wash located near Henderson, Nevada. The objective of the investigation was to determine the effectiveness of several geophysical techniques to map geologic/hydrologic features such as the contact between unconsolidated sediments and the Upper Muddy Creek formation (UMCf) and possible paleochannels cut into the Upper Muddy Creek formation (UMCf).

Six (6) geophysical methods were evaluated during this investigation: active and passive surface waves, P-wave seismic refraction, electrical resistivity imaging (ERI), time-domain electromagnetic (TDEM), and controlled-source audio-frequency magnetotellurics (CSAMT).

Locations for GPT-2 and GPT-4 are shown on the Figures 1 and 2, respectively. The active and passive surface wave and P-wave seismic refraction techniques were applied to determine if they could be effectively utilized to map the top of the Upper Muddy Creek formation (UMCf). The ERI, TDEM, and CSAMT techniques were used to determine whether the techniques may be effective at mapping the lateral variability of the subsurface and the top of the Upper Muddy Creek formation (UMCf). The approximate locations of GPT-2 and GPT-4 are provided in Table 1.

The following sections include a discussion of geophysical methodology, equipment and field procedures, data processing, interpretation of the geophysical data, and conclusions.

2 ACTIVE AND PASSIVE SURFACE WAVE INVESTIGATION

2.1 *METHODOLOGY*

A discussion of active and passive surface wave methods is provided in the technical note included as Appendix A. The active surface wave technique used includes the multi-channel array surface wave (MASW) method. The passive surface wave technique used includes the array microtremor method.

The basis of surface wave methods is the dispersive characteristic of Rayleigh waves when propagating in a layered medium. The phase velocity, V_R, depends primarily on the material properties (V_S, mass density and Poisson's ratio or compression wave velocity) over a depth of approximately one wavelength. Waves of different wavelengths, λ, (or frequencies, f) sample different depths. As a result of the variance in the shear stiffness of the layers, waves with different wavelengths travel at different phase velocities; hence, dispersion. A surface wave dispersion curve, or dispersion curve for short, is the variation of V_R with λ or f.

The MASW methods are in-situ seismic methods for determining shear wave velocity (V_S) profiles. Surface wave techniques are non-invasive and non-destructive, with all testing performed on the ground surface at strain levels in the soil in the elastic range (< 0.001%). MASW testing consists of collecting multi-channel seismic data in the field and applying a wavefield transform to obtain the dispersion curve and data modeling.

Ground motions are recorded by 24 or more geophones typically spaced 1 to 3 m apart and aligned in a linear array and connected to a seismograph. A wavefield transform, such as the f-k, τ-p or phase shift transform, is applied to the time history data to isolate the surface wave dispersion curve.

The array microtremor technique uses 4 to 48 receivers aligned in a 2-dimensional array. Triangle, circle, semi-circle and "L" shaped arrays are commonly used, although any 2-dimensional arrangement of receivers can be used. Receivers typically consist of 1 to 4.5 Hz geophones. The triangle array, which consists of several embedded equilateral triangles, is often used as it provides good results with a relatively small number of geophones. With this array the outer side of the triangle should be at least equal to the desired depth of investigation. The "L" array is useful at sites located at the corner of perpendicular intersecting streets. Typically 20, or more, 30-second noise records are acquired for analysis. The surface wave dispersion curve is estimated using the extended spatial autocorrelation (ESAC) technique

The dispersion curves generated from the active and passive surface wave soundings are generally combined and modeled using an iterative, inverse modeling routine where a V_S profile is found whose calculated dispersion curve is a close fit to the field data.

The theoretical model used to interpret the dispersion assumes horizontally layered, laterally invariant, homogeneous-isotropic material. Although these conditions are seldom strictly met at a site, the results of active and/or passive surface wave testing provide a good "global" estimate of the material properties along the array. The results may be more representative of the site than a borehole "point" estimate.

2.2 *EQUIPMENT AND FIELD PROCEDURES*

2.2.1 Survey Control

The active and passive surface wave soundings were established by **GEO***Vision* for GPT-2 and GPT-4. The soundings were placed in a centralized location for each GPT. The active (MASW) soundings were placed at 300 ft to 535 ft along GPT-2 and GPT-4. The passive soundings were collected coincident with the P-wave refraction survey which was placed at 180 ft to 650 ft along GPT-2 and GPT-4. Geophone locations for the seismic soundings were marked using a 300 ft tape measure using the provided surveyed locations for spatial control. A Sokkia C300 auto level was used to measure relative elevations along the active soundings for use in P-wave refraction processing as well. The relative elevation survey was tied to real-world elevations using coordinate data provided by AECOM, Inc. All elevation data were reduced in a spread sheet.

The position of each sounding for GPT-2 and GPT-4 are shown on Figures 1 and 2, respectively. The coordinate locations of each sounding's end point and channel spacings are summarized in Table 1.

2.2.2 Active and Passive Seismic Surface Wave Survey

Active surface wave data were acquired using the MASW technique. Passive surface wave data were acquired using the array microtremor method.

A typical MASW field layout is shown in Appendix A. MASW equipment used during this investigation consisted of two Geometrics Geode signal enhancement seismographs, 4.5 Hz vertical geophones, seismic cable with 10-foot takeouts, a 3 lb hammer, a 10 lb sledgehammer, a 20 lb sledgehammer, a 40 kg propelled energy generator (PEG), and an aluminum plate. MASW data were acquired along a linear array of 48 geophones spaced 5 ft apart. Shot points were located 5, 20, 50, and 100 ft from the end geophone locations and multiple shot points were located in the interior of the array. The 3 lb hammer, and the 10 lb and 20 lb sledgehammers were used for the 5 ft offset source locations. The 10 lb sledgehammer was used at the interior offset source locations, including the center shot. The 3 lb hammer was also used at the center shot. The center shot location was repeated using the 10 lb sledgehammer on each MASW array for QC purposes (Appendix B). The PEG was used for the 20 ft and greater offset locations. Data from the impact sources were averaged 10 times to improve the signal-to-noise ratio. MASW data were acquired in a manner to also allow P-wave seismic refraction analysis. Photographs of typical MASW equipment are presented in Appendix A. All field data were saved to hard disk and documented on field data acquisition forms.

Array microtremor measurements were made along a linear array of 48, 4.5 Hz geophones with a 10 ft geophone spacing coincident with each P-wave refraction line. A typical field layout is shown in Appendix A. The passive surface wave array consisted of two Geometrics Geode signal enhancement seismographs that were used to record forty, 30 second noise records using a 2 millisecond (ms) sample rate. Data were stored on a laptop computer for processing and field geometry and associated files names were documented in field data acquisition forms.

2.3 *DATA PROCESSING*

The MASW data were reduced using the software Seismic Pro Surface V6.0 developed by Geogiga using the following steps:

- Input seismic record into software.
- Enter receiver spacing, geometry and wavelength restrictions, as necessary.
- Apply wavefield transform to seismic record to convert the data to phase velocity – frequency space.
- Identify and pick dispersion curve.
- Repeat for all shot records and merge dispersion curves.
- Convert dispersion curves to WinSASW format for modeling.

The array microtremor data were reduced using the software PICKWIN95 developed by Oyo Corporation using the following steps:

- Input all seismic records into software.
- Enter receiver spacing, geometry and wavelength restrictions, as necessary.
- Calculate the spatial autocorrelation (SPAC) coefficients for each seismic record and average.
- For each frequency calculate the degree of fit of a first-order Bessel function to the SPAC coefficients for a multitude of phase velocities.
- Identify and pick dispersion curve as the best fit of the Bessel function for each frequency.
- Convert dispersion curves to required format for particular modeling software utilized.

The surface wave dispersion curves from the active and/or passive surface wave data were used for modeling. An iterative inverse modeling process was used to generate an S-wave velocity model for the sounding. During this process an initial velocity model was generated based on general characteristics of the dispersion curve. The theoretical dispersion curve was then generated using the fundamental mode Rayleigh wave dispersion assumption and compared to the field dispersion curve. Adjustments were then automatically made to the thickness and velocities of each layer and the process repeated until an acceptable fit to the field data was obtained.

Data inputs into the modeling software included layer thickness, S-wave velocity, P-wave velocity, and mass density. P-wave velocity and mass density only have a very small influence (i.e. less than 10%) on the S-wave velocity model generated from a surface wave dispersion curve. However, realistic assumptions for P-wave velocity, which is impacted by the location of the bedrock, and mass density will slightly improve the accuracy of the S-wave velocity model.

During data modeling, the compression wave velocity, V_P, of unsaturated soils was estimated using a Poisson's ratio, ν, of either 0.30 or 0.33 and the relationship:

$$V_P = V_S\,[(2(1-\nu))/(1-2\nu)]^{0.5}$$

3 SEISMIC REFRACTION INVESTIGATION

3.1 *METHODOLOGY*

When conducting a seismic survey, acoustic energy is input to the subsurface by an energy source such as a sledgehammer or weight drop impacting a metallic plate, vibratory source, or explosive charge. The acoustic waves propagate into the subsurface at a velocity dependent upon the elastic properties of the material through which they travel. When the waves reach an interface where the density or velocity changes significantly, a portion of the energy is reflected back to the surface, and the remainder is transmitted into the lower layer. Where the velocity of the lower layer is higher than that of the upper layer, a portion of the energy is also critically refracted along the interface. Critically refracted waves travel along the interface at the velocity of the lower layer and continually refract energy back to surface. Receivers (geophones) laid out in linear array on the surface record the incoming refracted and reflected waves. The seismic refraction method involves analysis of the travel times of the first energy to arrive at the geophones. These first arrivals are from either the direct wave (at geophones close to the source), or critically refracted waves (at geophones further from the source).

Analysis of seismic refraction data depends upon the complexity of the subsurface velocity structure. If the subsurface target is planar in nature, then the slope intercept method can be used to model multiple horizontal or dipping planar layers. A minimum of one end shot is required to model horizontal layers and reverse end shots are required to model dipping planar layers. If the subsurface target is undulating (i.e., bedrock valley), then layer-based analysis routines such as the generalized reciprocal method, delay time method, time-term method, plus-minus method and wavefront method are required to model subsurface velocity structure. These methods generally require a minimum of 5 shot points per spread (end shots, off-end shots, and a center shot). If subsurface velocity structure is complex and cannot be adequately modeled using layer-based modeling techniques (i.e., complex weathering profile in bedrock, numerous lateral velocity variations), then Monte Carlo or tomographic inversion techniques are required to model the seismic refraction data. These techniques require a high shot density (typically every 2 to 4 stations/geophones). Generally these techniques cannot take advantage of off-end shots to extend depth of investigation, so longer profiles are required.

Errors in seismic refraction models can be caused by velocity inversions, hidden layers, or lateral velocity variations. At sites with steeply dipping or highly irregular bedrock surfaces, out of plane refractions (refractions from structures to the side of the line rather than from beneath the line) may severely complicate modeling. A velocity inversion is a geologic layer with a lower seismic velocity than an overlying layer. Critical refraction does not occur along such a layer because velocity has to increase with depth for critical refraction to occur. This type of layer, therefore, cannot be recognized or modeled, and depths to underlying layers would be overestimated. A hidden layer is a layer with a velocity increase, but of sufficiently small thickness relative to the velocities of overlying and underlying layers, that refracted arrivals do not arrive at the geophones before those from the deeper, higher velocity layer. Because the seismic refraction method generally only involves the interpretation of first arrivals, a hidden layer cannot be recognized or modeled, and depths to underlying layers would be underestimated. A subsurface velocity structure that increases as a function of depth rather than as discrete layers will also cause depths to subsurface refractors to be underestimated, in a manner very similar to that of the hidden layer problem. Lateral velocity variations that are not adequately addressed in the seismic models will also lead to depth errors. Tomographic imaging techniques can often resolve the complex velocity structures associated with hidden layers, velocity gradients, and lateral velocity variations. However, in the event of an abrupt increase in velocity at a geologic horizon, the velocity model generated using tomographic inversion routines will smooth the horizon with velocity being underestimated at the interface and possibly overestimated at depth.

3.2 *EQUIPMENT AND FIELD PROCEDURES*

3.2.1 **Survey Control**

The P-wave seismic refraction lines were established by **GEO***Vision* for GPT-2 and GPT-4. Lines centrally were placed along each GPT starting at 180 ft and ending at 650 ft along each traverse. Geophone locations for the P-wave refraction line were marked using a 300 ft tape measure and the provided surveyed locations for spatial control. A Sokkia C300 auto level was used to measure relative elevations along the line. The relative elevation survey was tied to real-world, approximate elevation using data provided by AECOM, Inc. All elevation data were reduced in a spread sheet.

The P-wave seismic refraction lines at GPT-2 and GPT-4 are shown on Figures 1 and 2, respectively. The coordinates of each line and channel spacing are summarized in Table 1.

P-wave seismic refraction data were coincident with the passive surface wave arrays. Details on the passive surface wave arrays are found in Section 2.

3.2.2 **Seismic Refraction Survey**

The seismic data acquisition system used for the P-wave seismic refraction consisted of two 24-channel Geometrics Geode signal enhancement seismographs combined to form a 48-channel system and a laptop computer running Geometrics Seismodule Controller Software. Other seismic equipment utilized during this investigation consisted of 4.5 Hz vertical geophones, seismic cable, trigger extension cables, a 40 kg propelled energy generator (PEG), and aluminum plates.

Each line consisted of 48 geophones spaced 10 feet apart for line lengths of 470 ft. Seventeen (17) or more shot point locations were occupied: end shots at geophones 1 and 48, multiple off-end shots, and interior shots at regular intervals between every fourth station. For QC purposes, the center shot was repeated (Appendix B).

The PEG was used as the energy source for each shot point. A hammer switch attached to the aluminum plate and coupled to a trigger extension cable was used to trigger the seismograph upon impact. The final seismic record at each shot point was the result of stacking 10 shots to increase the signal to noise ratio. All seismic records were stored on a laptop computer. Data files were named with the sequential line, spread, and shot number and a “.dat” extension (i.e. data file 1105.dat is the seismic record from line 1, spread 1, shot 5). Data acquisition parameters, file names, and leveling data were recorded in a field log, which is retained in project files.

3.3 *DATA PROCESSING*

Seismic refraction data were modeled using the tomographic analysis technique with a smooth and layered starting model. The layered starting model was created using the time-term processing method for each line.

The first step in data processing consisted of picking the arrival time of the first energy received at each geophone (first arrival) for each shot point. First arrival times were selected using the automatic and manual picking routines in the software package SeisImager™ (Oyo Corporation) by a **GEO***Vision* geophysicist. First arrival times were picked on all seismic records. First arrival times were saved in an ASCII file containing shot location, geophone locations, and associated first arrival time. Relative elevations for each geophone location were calculated from the leveling data using a spreadsheet and converted to elevations using data provided by AECOM, Inc. Data quality was affected by factors such as transient noise and geologic conditions. Attempts were made to minimize transient noise as much as possible by waiting for passing air traffic during shots.

3.3.1 **Tomographic Analysis Technique**

Seismic refraction data were modeled using the tomographic analysis technique available in the SeisImager™ Plotrefa software package, developed by Oyo Corporation. Refraction tomography techniques are often able to resolve complex velocity structure (e.g. velocity gradients) that can be observed in bedrock weathering profiles, but are not well suited to accurately resolving layered structures. Conversely, layer-based modeling techniques such as the generalized reciprocal method can accurately model layered structure, but are not able to accurately model the velocity gradients that can be observed in weathered bedrock.

Tomographic inversion techniques will model a smooth velocity gradient even if a sharp velocity boundary exists. The use of layer-based starting models for tomographic inversion will generally sharpen the contact between geologic units with large velocity variation, if present. The layer-based tomographic inversions were used to obtain the expected, abrupt velocity contacts present in the geologic section while also modeling the slight velocity gradients that may be present in the sections.

The tomographic inversion was conducted as outlined in the following steps. The first arrival and elevation data were loaded into the software package and a 20 layer initial model was defined with velocity smoothly increasing with depth. The velocity range in the initial model was based on the general characteristics of the travel time data. For the layer-based starting models, layers were assigned in the travel time data and an initial time-term starting model was generated. The time-term model was used as the initial model for the tomographic routines. The velocity models were extended to permit the use of off-end shot points during the inversion with the goal of improving the accuracy of the seismic refraction models near the ends of the lines. A minimum of 50 iterations of non-linear raypath inversion were then implemented to improve the fits of the travel time curves to near-surface sediments/rock. Final tomographic velocity models for each seismic line were exported as ASCII files and imported into the Geosoft Oasis montaj® v9 mapping system where the velocity models were gridded, contoured and annotated for presentation.

4 ELECTRICAL RESISTIVITY INVESTIGATION

4.1 *METHODOLOGY*

Electrical resistivity imaging (ERI) involves the measurement of the apparent resistivity of subsurface soil and rock as a function of depth and/or position. The resistivity of soils and rock is a complicated function of porosity, permeability, ionic content of the pore fluids, and clay mineralization.

To conduct an electrical resistivity survey an electrical current is applied to a pair of current electrodes and the potential difference (voltage) is measured between one or more pairs of potential electrodes. For a 2D resistivity survey, the current and potential electrodes are generally arranged in a linear array. Common array types include the pole-pole, pole-dipole, dipole-dipole, Schlumberger, and Wenner arrays.

Measured voltages are used to calculate the apparent resistivity of the subsurface. The apparent resistivity is the bulk average of all soils and rock influencing the applied current. It is calculated by dividing the measured potential difference by the input current and multiplying by a geometric factor specific to the array being used, as well as electrode spacing. Apparent resistivity is typically run through an inverse modeling algorithm to generate a geoelectric section of the subsurface directly beneath the profile.

In general, for 2D electrical resistivity surveys, resolution and depth of investigation are inversely proportional. High resolution is typically obtained by using relatively small electrode spacing. However, using small electrode spacing reduces investigation depth. Conversely, large electrode separation will typically provide greater depth of investigation, but sacrifices resolution.

4.2 *EQUIPMENT AND FIELD PROCEDURES*

4.2.1 **Survey Control**

Each ERI line was established by **GEO***Vision* for GPT-2 and GPT-4. The lines were placed along the entirety of each GPT transect. Electrode locations for the ERI lines were marked using a 300 ft tape measure using the provided surveyed locations for spatial control. A Sokkia C300 auto level was used to measure relative elevations along the line. The relative elevation survey was tied to real-world approximate elevation using coordinate data provided by AECOM, Inc. All elevation data were reduced in a spread sheet.

The position of each ERI line for GPT-2 and GPT-4 are shown on Figures 1 and 2, respectively. The coordinates of each line and channel spacing are summarized in Table 1.

4.2.2 **Electrical Resistivity Survey**

2-D electrical resistivity data were acquired along the geophysical traverses using an Advanced Geosciences, Inc. (AGI) SuperSting R8/IP 112-electrode system. A 10 ft electrode spacing was used to allow high resolution imaging of the near surface and a depth of investigation in excess of 120 ft. Additionally, the SuperSting was programmed to acquire data in multiple passes to increase data density and minimize potential cultural noise. A salt water solution was added to electrode locations staked in surface soil to minimize contact resistance between the electrode stake and the surrounding soil, as necessary. Contact resistance measurements were recorded prior to data acquisition. Electrodes exhibiting abnormally high contact resistance were treated or retreated with saline solution and checked for good contact.

ERI data were acquired using the dipole-dipole, inverse Schlumberger, and strong gradient arrays. The SuperSting was programmed with the appropriate acquisition parameters and set to record automatically along each 84 electrode spread. For QC purposes, normal field operation uses two cycles for each line of the command file. The repeated cycles are then checked internally for repeatability. If a low repeatability (high error) occurs, the command line is automatically recollected to obtain an acceptable repeatability. If the recollected cycles still exhibits a low repeatability (high error), the measurement is flagged. A repeat set of command lines are presented for each GPT in Appendix B.

Resistivity data were stored in the internal memory of the SuperSting R8/IP and downloaded to a laptop computer upon completion of the field investigation. Field data files were assigned a name that included profile number and array type.

4.3 *DATA PROCESSING*

Dipole-dipole, inverse Schlumberger, and strong gradient data were modeled separately using the program EarthImager 2D v2.4.0 by Advanced Geosciences, Inc. A smooth model inversion algorithm using a finite element mesh with surface topography was selected to generate the 2D earth model of resistivity versus depth/elevation, called a geoelectric section. The starting model for the inversion was based on the average apparent resistivity of the acquired data. Additionally, the inverse Schlumberger and strong gradient data were merged before inversion. The combined model can provide the near surface resolution of the inverse Schlumberger array and the depth of the strong gradient array. Inversion output was saved as an ASCII format XYZ file containing position, elevation, and resistivity. The data were imported into Golden Software, Inc. Surfer for gridding, contouring, and final presentation. All files generated during processing are archived.

5 TIME-DOMAIN ELECTROMAGNETIC INVESTIGATION

5.1 *METHODOLOGY*

The time-domain electromagnetic (TDEM) instrument used during this investigation consisted of a Geonics EM-47 transmitter, high-frequency receiver coil, and a Protem digital receiver. This system is designed to image to a maximum depth of about 100 m, whereas other systems such as the Geonics EM-57 and EM-37 are designed with larger transmitters and lower-frequency coils to image to greater depth.

A TDEM system consists of separate transmitter (Tx) and receiver (Rx) coils. The Tx coil generally consists of a square loop of insulated wire laid on the surface. The Rx coil is generally placed in the center of the Tx loop (central loop sounding) but may be placed outside the Tx loop (offset loop sounding). The EM-47 transmitter operates at three user-selectable repetition frequencies of 285-315, 75, and 30 Hz and is synchronized to the PROTEM receiver using a reference cable.

Depending on the required resolution and depth of investigation, the dimensions of the transmitter loop may be changed. In the central loop sounding mode, 30 by 30 m to 100 by 100 m Tx loops can be used with the EM-47 transmitter. Larger loops allow deeper depths of investigation and reduced noise level, at some loss of resolution.

The 100 watt battery-powered EM-47 transmitter is used to drive a modified square-wave current through the Tx loop. One period of the transmitted waveform (33.3 milliseconds for the 30 Hz repetition frequency) consists of two current-on (time-on) and two current-off (time-off) cycles. At the end of the first time-on cycle, the current is abruptly switched off for a quarter period using a rapid linear ramp. During the following time-on cycle, the current flows in the opposite direction. The abrupt termination of the current induces a short-duration voltage pulse in the ground in accordance with Faraday's Law of Induction. This voltage pulse gives rise to a current loop in the ground in the immediate vicinity of the Tx loop. The location of the maximum current intensity diffuses downward and outward with time, thereby providing information on the electrical properties of successively deeper materials. The diffusing current system produces a time-varying secondary magnetic field, which is measured as a voltage induced in the receiver coil. The Geonics PROTEM receiver measures the decaying secondary magnetic field at 20 logarithmically-spaced gates during the transmitter time-off cycle only. Many hundreds to thousands of measurements are stacked to improve data quality. The measurements are converted to apparent resistivity by calculating the resistivity of a uniform half-space that would give rise to the measured voltage.

5.2 *EQUIPMENT AND FIELD PROCEDURES*

5.2.1 Survey Control

Each TDEM sounding was established by **GEO***Vision* for GPT-2 and GPT-4. Seven (7) soundings were collected in each location for a total of 14 soundings. The center of each sounding was placed at locations of 100, 200, 300, 400, 500, 600, and 700 ft for each GPT. Using pre-marked wire loops, the corners of each loop were established using approximately 40 m on a side. The receiver loop was placed at the center of the transmitter wire loop for each sounding.

The center of each TDEM sounding for GPT-2 and GPT-4 are shown on Figures 1 and 2, respectively.

5.2.2 **Time-Domain Electromagnetic Survey**

A Geonics EM-47 transmitter (Tx), high-frequency receiver coil and a Protem digital receiver (Rx) were used to conduct TDEM soundings. The TDEM soundings were conducted in the central-loop sounding mode where the receiver coil is placed inside of the transmitter loop during data recording.

At each sounding location, a transmitter loop consisting of insulated 12-gauge copper wire was placed on the ground in a square loop with approximate 40 m sides. The receiver coil was placed at the center of the Tx loop. The receiver coil was connected to the PROTEM Receiver and a reference cable between the transmitter and receiver synchronized the system.

The 100 watt battery-powered EM-47 transmitter, placed centrally alone one side of each wire-loop, was used to drive current pulses through the wire. The EM-47 transmitter was operated at repetition frequencies of 285-315, 75, and 30 Hz. Generally, transmitter currents of 1 to 3 amperes were used for the 285-315 to 30 Hz repetition rates, respectively. The current pulses induced eddy current flow in the subsurface. The receiver coil positioned in the center of the wire-loop is used to record the decay of the secondary magnetic field due to the eddy currents induced in the subsurface. The Geonics PROTEM receiver measured the decaying secondary magnetic field at 20 logarithmically-spaced gates during the transmitter time-off cycle only. The data acquired at each sounding center consisted of measurements at several different receiver gain settings for the two transmitter frequencies, as needed. This was accomplished in order to assure data quality and to obtain data over the largest possible time interval. The measurements were converted to apparent resistivity by calculating the resistivity of a uniform half-space that would give rise to the measured voltage. The data from each sounding were stored in solid-state memory in the receiver and transferred at the end of the day to a computer for processing. Each frequency was recorded twice to account for QC requirements (Appendix B).

5.3 ***DATA PROCESSING***

The TDEM field data collected for the 14 soundings were transferred from the Geonics PROTEM receiver to a PC for editing and processing. All processing and modeling of the TDEM data was performed with the software package TEMIX XL (Interpex Ltd.). The initial step in processing was to input all of the soundings into the program. During data input, the measurements made at the various amplifier gains and frequencies for each sounding were combined to produce one voltage decay curve (transient). Next, the data were transformed into apparent resistivity versus recorded time gate. The apparent resistivity curve was modeled by inversion to obtain a one-dimensional (1D) geoelectric section that most closely matches the observed decay curve. Two types of inversion routines can be utilized: a 1D layered model inversion and a 1D smooth model inversion. The TEMIX XL 1D layered model inversion routine requires an initial model of the geoelectric section, which includes the number of layers and the thickness and resistivity of each of the layers. The inversion program then adjusts these parameters so that the model curve converges to best fit the curve formed by the field data. The inversion program does not change the number of layers within the model curve, but allows all other parameters to change freely or they can optionally be made constant. To determine the influence and best fit of the number of layers on the solution, separate inversions with different numbers of layers are run. The model with the fewest number of layers, which best fits the data is used in the final interpretation. This inversion approach is best suited for developing geoelectric cross sections. The TEMIX XL smooth model inversion routine requires the user to specify the number of layers (typically 10 to 19), the thickness of the first layer, and the depth of the final layer. Optionally, the program can calculate a default thickness of the first layer and depth of the final layer. The program increases layer thickness with depth to account for loss of vertical resolution with depth. The smooth model inversion routine is then run using fixed layer thickness to develop a model of resistivity versus depth where resistivity varies smoothly with depth. This inversion approach is best suited for presentation of geoelectric sections as color images.

The interpreted geoelectric section derived from each TDEM sounding is not unique. The magnitude of each individual layer resistivity and thickness can normally be varied within a limited range with no significant change to the fit of the geoelectric model of the field data. This variation in fit parameters is termed equivalence and is a problem faced by most surface geophysical techniques. An equivalence analysis was performed for each of the TDEM soundings to estimate a range of models that fit the field observations almost as well as the best fit model. Another form of analyzing equivalence is in the total number of layers used in the inversion model. In the TEMIX XL program, the interpreter sets a fixed number of layers. During the inversion process, the program adjusts the layer resistivity and thickness so the model best fits the field data. Generally, a minimum number of layers are used in the modeling program. This is determined by increasing the number of layers in the model, until additional layers do not significantly improve the fit of the model to the field data. Inversion models with three to four layers were generally used for the TDEM data collected during this investigation.

The smooth model 1D inversions and the layered 1D inversions were combined for each GPT. The smooth model 1D inversions were then input into the Geosoft Oasis montaj® v9 mapping system where the 1D inversions were gridded, contoured, and annotated for presentation. The layered 1D inversions were plotted in Grapher 12 and then converted to Corel Draw for presentation, interpretation, and annotation.

6 CONTROLLED-SOURCE AUDIO-FREQUENCY MAGNETOTELLURICS

6.1 *METHODOLOGY*

The controlled-source audio-frequency magnetotellurics (CSAMT) instrument used during this investigation consisted of a Geometrics Stratagem EH4 using two electric dipoles (Ex, Ey), two magnetic dipoles (Hx, Hy), and an external transmitter (Tx) for high frequency output. The Stratagem EH4 operates on the principle of natural and controlled source tensor magnetotellurics. This allows for deeper investigations using natural magnetotelluric fields and shallower investigations using controlled magnetotelluric fields via an external transmitter. This system is designed to image to depths of 10 to 500 m using a wide frequency range. However, this instrument is most effective for locating deep structures (greater than 100 m).

A Geometrics Stratagem EH4 system consists of a controller/receiver, an analog front end (AFE) for analog signal conditioning, electric field kit, magnetic field kit, and a vertical dual loop transmitter with an operating range of 1 kHz to 70 KHz. The electric field sensor kit consists of four buffered, active high-frequency dipole cables and 4 stainless steel electrodes. The magnetic field sensor kit consists of two 10 Hz to 100 kHz range sensors with cables. The Stratagem EH4 has a frequency range of 10 Hz to 92 KHz and operates using three (3) frequency bands for acquisition. Band 1 (low) operates from 10 Hz to 1 KHz, Band 4 (mid) operates from 500 Hz to 3 KHz, and Band 7 (high) operates from 750 to 92 KHz. Depending on the target of the investigation and onsite conditions, a specified number of time-series segments are collected for each band utilized during the survey. Typically, only Band 1 (low) and Band 7 (high) are collected during a survey since the frequency ranges already overlap with Band 4 (mid).

For data collection, the AFE is placed at the center of the sounding. Two electrical dipoles are then set up over the center of the sounding, in the specified x and y directions. These dipoles are referred to as Ex and Ey, respectively. The specified x and y directions do not necessarily have to be placed along west to east and south to north directions. The electrical dipoles may be aligned in any direction as long as the Ex and Ey directions are perpendicular to each other, within 1 to 2 degree tolerance. The dipoles length is typically determined by the maximum space allowable by the survey. A longer dipole may result in increased magnitude of signal depending on geologic and electrical conditions. The lengths of the electric dipoles have no bearing on the depth of investigation. The depth of investigation is determined by the resistivity of the subsurface and frequencies encountered. The magnetic dipoles, Hx and Hy, are placed anywhere within the range of the cables. The magnetic dipoles are also placed on a level location at least 2 meters apart and perpendicular to one another within a 1 to 2 degree tolerance. Hx and Hy are placed parallel with the directions of Ex and Ey, respectively. The controller/receiver unit is placed outside the sounding area and run with a 12 volt battery. The dual loop transmitter (Tx) is placed within the transmitters far-field. Generally, the far-field begins at a distance of three skin depths from the measurement site to the transmitter where the skin depth **δ** (m) for earth resistivity **ρ** (ohm-m) at frequency ***f*** (Hz) is given by:

$$\boldsymbol{\delta} = 500 \sqrt{(\boldsymbol{\rho}/ \boldsymbol{f})}$$

The earth resistivity **ρ** is the estimated bulk resistivity between the transmitter and measurement site and the frequency ***f*** is the lowest operating frequency utilized.

The Stratagem system measures the electrical impedance at the earth's surface by recording a series of simultaneous measurements of the local electrical and magnetic field fluctuations using the orthogonal electric and magnetic fields (natural and controlled). The magnetic fields are detected with two perpendicular Hx and Hy sensors. The electric fields are detected by measuring the differential voltage between the two electrodes of the electric dipole (Ex or Ey). The response of the Ex and Ey sensors is amplified and filtered by the AFE and transmitted to the console for analog-to-digital conversion and digital signal processing. During data collection, a specified band of frequencies (Band 1 (low), Band 4 (mid), and Band 7 (high)) are collected using the placed electric and magnetic dipoles. For Band 1 and Band 4, the natural magnetotelluric field fluctuations are recorded. For Band 7, the external transmitter is used to supplement the magnetotelluric field by producing a specified range of frequencies in the far-field. Numerous time-series segments or stacks, are collected for each band utilized and vary depending on the response encountered at each site. For Band 7, 15 time-series segments or stacks, are preferably used in order to synchronize with each of the 15 frequencies output by the external transmitter. The external transmitter is set to transmit each of its 15 frequencies for 20 seconds when activated. All field measurements are made over a period of several minutes; Fourier transformed, and stored as a power spectra. The resulting data is recorded as a raw file, cross powers (calculated) file, and calculated impedance curve of resistivity versus depth file.

6.2 *EQUIPMENT AND FIELD PROCEDURES*

6.2.1 **Survey Control**

Each CSAMT sounding was established by **GEO***Vision* for GPT-2 and GPT-4. Seven (7) soundings were collected at each location for a total of 14 soundings. The center of each sounding was placed at locations of 100, 200, 300, 400, 500, 600, and 700 ft for each GPT using the provided survey coordinates for spatial control.

The position of each CSAMT sounding for GPT-2 and GPT-4 are shown on Figures 1 and 2, respectively.

6.2.2 **Controlled-Source Audio-Frequency Magnetotellurics Survey**

A Stratagem EH4 was used to collect the CSAMT soundings. For each sounding, the electric and magnetic dipoles in the x direction (Ex and Hx) were placed in line with each GPT transect. The electric and magnetic dipoles in the y direction (Ey and Hy) were placed orthogonal to the x dipoles and the each GPT transect. The electric dipoles were placed using lengths of 30 m (100 ft) to accommodate the station spacing without overlap. The electric dipoles were placed using a 100 m surveyors' rope and a Brunton compass. The magnetic dipoles were placed using a Brunton compass and a carpenter's level. The external transmitter was placed south of GPT-2 and northeast of GPT-4 at a distance of 600 or more feet. Both the AFE and the transmitter were grounded using stainless steel electrodes.

Three (3) frequency bands were collected for each sounding: Band 1 (low), Band 4 (mid), and Band 7 (high). Band 1 was collected using 10 time-series segments, Band 4 was collected with 5 time-series segments, and Band 7 was collected using 15 time-series segments. For each sounding collected the instrument was manually gained to ensure the signal was high enough and to also ensure that the signal was not clipping out of range.

All measurements for GPT-2-CSAMT-700 and GPT-4-CSAMT-100 were repeated for QC purposes (Appendix B). Before the soundings on GPT-2 and after the soundings on GPT-4 were collected, a parallel test was conducted. The parallel test was used to ensure coherence on all channels by placing the electrical dipoles on the same electrodes in the x direction (Ex0/Ey0 attached to electrode Ex0 and Ex1/Ey1 attached to electrode Ex1) and by placing the magnetic dipoles in the y direction (Hx/Hy parallel in the Hy direction). The Stratagem is then used with Band 1 and Band 7 with reduced time-series segments and without the external transmitter. The resultant data curves are then checked for coherence between the dipole readings to ensure the instrument is functioning properly.

6.3 *DATA PROCESSING*

The CSAMT field data collected for the 14 soundings were transferred from the Stratagem receiver to a PC for editing and processing. All processing and modeling of the TDEM data was performed with the software package Imagem (Geometrics). The initial step in processing was to input all of the soundings into the program. Each time-series segment for each band range was then manually checked for errors encountered during collection (i.e. transient spikes from vehicle traffic), as necessary. Segments that have poor quality data may be removed from the band collected. Afterwards, all the data from each sounding for each GPT were merged into one section and output to an ASCII file containing position, depth, and apparent resistivity readings. The depths were then converted to elevations and input into the Geosoft Oasis montaj® v9 mapping system where the sections were gridded, contoured, and annotated for presentation.

7 RESULTS

The active and passive surface waves, P-wave seismic refraction, electrical resistivity imaging (ERI), time-domain electromagnetic (TDEM), and controlled-source audio-frequency magnetotelluric (CSAMT) methods were evaluated at GPT-2 and GPT-4 (Figures 1 and 2).

The active and passive surface wave figures for GPT-2 are presented as Figures 3 and 4. The active and passive surface wave figures for GPT-4 are presented as Figures 11 and 12. Figures 3 and 11 show the ReMi velocity image and active/passive dispersion data for GPT-2 and GPT-4, respectively. Figures 4 and 12 show the S-wave velocity model for GPT-2 and GPT-4, respectively.

The P-wave seismic tomography models for GPT-2 and GPT-4, developed using a layer-based starting model, are presented as Figures 5 and 13, respectively. Smooth starting seismic models were also utilized, but did not provide any additional information, and were, therefore, considered redundant. The color scheme used on the seismic tomography images consist of blue-green, yellow-orange, and red-pink representing low, intermediate, and high velocities, respectively. The transition from blue to green occurs at a velocity of 2,500 ft/s and the transition from green to yellow occurs at a velocity of 5,300 ft/s. The transition from orange to red occurs at 7,300 ft/s. The velocity contours and colors shown on each tomography image represent the average seismic velocity in the area. Tomographic inversion techniques will typically model a gradual increase in velocity with depth even if an abrupt velocity contact is present. Therefore, if velocity gradients are not present, tomographic inversion routines will overestimate and underestimate velocity above and below a layer contact, respectively, with the actual layer contact tracing a velocity contour between that of the two layers.

The electrical resistivity models for GPT-2 and GPT-4 are presented as Figures 6 and 14, respectively. Three arrays were collected for each GPT: dipole-dipole, inverse Schlumberger, and strong gradient. The dipole-dipole arrays for each GPT contained a high amount of errors likely due to electrical noise and other factors. Therefore, the dipole-dipole arrays are not presented. For each GPT, the inverse Schlumberger and strong gradient arrays were inverted and presented. Also, a merged inverse Schlumberger and strong gradient section was also inverted. The arrays were merged to combine the near surface resolution of the inverse Schlumberger array and the depth of investigation of the strong gradient array. The color scheme used on the electrical resistivity images is a log scale to enhance the contrast between high and low resistivities. The color scheme consists of blue-green, yellow-orange, and red-pink representing low, intermediate, and high resistivity, respectively.

The time-domain electromagnetic (TDEM) figures for GPT-2 and GPT-4 are presented as Figures 7 through 10 and Figures 15 through 18, respectively. Figures 7 and 15 show example 1D smooth TDEM models for GPT-2 and GPT-4, respectively. Figures 8 and 16 show example 1D layered TDEM models for GPT-2 and GPT-4, respectively. Figures 9 and 17 present a 2D geoelectric section of the smooth TDEM models for GPT-2 and GPT-4, respectively. Figures 10 and 18 present a 2D geoelectric section of the 1D layered TDEM models for GPT-2 and GPT-4, respectively.

The controlled-source audio-frequency magnetotellurics (CSAMT) gridded section for GPT-4 is presented as Figure 19. Due to cultural, electromagnetic noise interference (e.g. radar system, microwave tower, transmission tower) on the day of testing, the CSAMT data were unusable and are not presented for GPT-2.

The electrical resistivity of sediments is primarily a function of clay content, porosity, and the specific conductance of the pore water. Clays have low resistivity relative to dry sands and gravels. Saturated sands and gravel have lower resistivity than unsaturated sands and gravel, with the resistivity being a function of the total dissolved solids content of the pore water. At this site we expect that the clay member of the Upper Muddy Creek formation (UMCf) will be an excellent target for electrical or electromagnetic methods. The silt member of the Upper Muddy Creek formation (UMCf) may not be as easily imaged depending upon clay content and whether the overlying sediments are saturated or not. A nearby geologic log indicates that the Upper Muddy Creek formation (UMCf) may be the silt member in the area of the pilot study. Electrical and electromagnetic methods will also be sensitive to lateral changes in the specific conductance of groundwater across the site.

Two borehole logs were provided by AECOM, Inc., HMW8 near GPT-2 (Figure 1) and MCF-08 near GPT-4 (Figure 2). However, each borehole is located roughly 250 ft from each respective GPT and may not provide accurate ground truth estimates for the geophysical interpretation.

7.1 *GPT-2*

7.1.1 Active and Passive Surface Waves

The surface wave dispersion curve recovered from MASW data collected at GPT-2 were modeled using the fundamental mode Rayleigh wave assumption. The surface wave dispersion data recovered from the passive linear array using the ReMi technique were not used for site characterization as the dispersion data were not considered reliable at small frequencies (long wavelengths). The fit of the theoretical dispersion curve to the experimental data collected at the site and the modeled V_S profile for the surface wave sounding is presented as Figure 4. The resolution decreases gradually with depth due to the loss of sensitivity of the dispersion curve to changes in V_S at greater depth. During surface wave modeling, high Poisson's ratio saturated sediments were anchored at a depth of 17 ft based on P-wave seismic refraction, TDEM, and ERI models. The estimated depth of investigation for the combined active and passive surface wave sounding is about 100 ft.

The S-wave velocity model developed from the surface wave dispersion data (Figure 3) shows a gradual increase in V_S with depth from about 725 ft/s at the surface to 2,100 ft/s at a depth of about 87 ft. The S-wave velocity of subsurface sediments is generally a function of depth of burial and associated overburden pressure, degree of cementation, age of the sediments, and, to a lesser degree, soil type. For similar aged sediments, clays can have lower velocity than sands which can have lower velocity than gravels. At this site, the finer-grained Upper Muddy Creek formation (UMCf) is older than the overlying sands and gravels and, therefore, the relationship between V_S and formation type is not possible to predict without borehole velocity measurements. The possibility cannot be discounted that the V_S layer at a depth of 57 ft is associated with the top of the Upper Muddy Creek formation (UMCf); however, it should be noted that this layer can likely be shifted within 20% of depth and compensated for by adjusting the V_S of the bounding layers.

7.1.2 P-wave Seismic Refraction

The P-wave seismic refraction line for GPT-2 was modeled using a tomographic inversion routine with a layer based starting model and is presented as Figure 5. The line is presented as east to west to match the survey distance markers as placed by a subcontractor for AECOM, Inc. The primary feature identified by the seismic refraction survey was the saturated zone, where P-wave velocity is expected to exceed 5,000 ft/s. The interpreted groundwater interface is marked with a black dashed line at the 4,000 ft/s contour on the tomography model and is about 16 to 20 ft deep beneath the line. A deeper unit, such as the Upper Muddy Creek formation (UMCf), was effectively masked by the shallow saturated sediments and, therefore, was not imaged beneath this line.

7.1.3 Electrical Resistivity Imaging

The ERI model for GPT-2 is presented as Figure 6 and presents the variation of electrical resistivity with distance and depth along the profile. The line is presented as east to west to match the survey distance markers as placed by a subcontractor for AECOM, Inc. The ERI data were modeled using a smooth model inversion routine; therefore, the model will show smoothly varying resistivity even if abrupt layer contacts are present.

There are three primary units in the ERI sections (Figure 6). A highly resistive unit (red colors) extends from the surface to an elevation of about 1,515 ft and is interpreted as unsaturated sands and gravels. This unit is underlain by an intermediate resistivity unit (green colors) with resistivity generally in the 5 to 10 ohm-m range, which extends to an elevation of about 1,460 ft and is interpreted as saturated sands and gravels. This unit is underlain by a low resistivity unit (blue colors) with resistivity generally in the 1 to 3 ohm-m range, which is interpreted as saturated finer-grained Upper Muddy Creek formation (UMCf) sediments. The contact between the saturated sands and gravels and Upper Muddy Creek formation (UMCf) may not be well defined if the uppermost portion of the Upper Muddy Creek formation (UMCf) consists of silt with little to no clay, which may have similar electrical properties to sand.

There is no significant resistivity structure indicative of a large paleochannel cut into the Upper Muddy Creek formation (UMCf). There are, however, several areas with slightly elevated resistivity in the intermediate resistivity unit (interpreted saturated sands and gravels) that could be associated with coarser grained sediments. The most significant of these features is located at a position of about GPT-2-300 in both the Inverse Schlumberger and strong gradient resistivity sections but is not as clear in the combined resistivity section. Although this feature, which only has a width of several tens of feet, is not associated with a large paleochannel, it does have an anomalous resistivity of unknown source and could be considered a potential target for drilling.

7.1.4 Time-domain Electromagnetics

Geoelectric sections were developed for both the 1D smooth and 1D layered TDEM models along GPT-2 and are presented as Figures 8 and 10, respectively. An example of the smooth TDEM model for GPT-2-TDEM-200 before being combined with the other models for gridding is presented as Figure 7. An example of the layered TDEM for GPT-2-TDEM-200 before being combined with the other models for presentation is shown as Figure 9. Three resistivity units are identified in the TDEM geoelectric sections that are similar to those identified in the ERI models. The uppermost unit, interpreted as unsaturated sands and gravels, has resistivity greater than about 20 ohm-m that extends to an elevation of about 1,525 ft. The electrical properties of this unit are not well defined, as it does not extend to great enough depth to be resolved by the Geonics EM-47. The middle unit has resistivity in the 5 to 7 ohm-m range and is interpreted as saturated sands and gravels. The top of the lower unit is located at an elevation of about 1,440 to 1,460 ft. This unit has resistivity of less than 1.3 ohm-m and is interpreted as saturated finer-grained Upper Muddy Creek formation (UMCf) sediments. It is evident in both the smooth and layered geoelectric sections that there are no anomalous resistivity zones that may be related to a large paleochannel (e.g. significant deepening of the low resistivity unit). It should be noted, however, that the top of the interpreted finer-grained Upper Muddy Creek formation (UMCf) may be slightly deeper at the western end of the line. The line would have to be extended to the west to determine if this is the edge of a geologic structure of interest.

7.1.5 Controlled-Source Audio-Frequency Magnetotellurics

No models or data are presented for the CSAMT for GPT-2. All data collected on the day of the survey for GPT-2 experienced heavy interference by what is assumed to be an outside cultural noise source, such as a microwave tower or other transmission tower. The noise source interfered directly with the electrical y dipole (Ey) and partially with the electrical x dipole (Ex). Sufficient data were unable to be mined from the collected soundings and, therefore, GPT-2 could not be modeled with CSAMT. It is possible that data collection on another day may produce useable results. However, time constraints of the pilot test study did not allow for extra data collection on a separate day during the survey.

7.2 *GPT-4*

7.2.1 Active and Passive Surface Waves

Surface wave propagation at GPT-4 is very complicated due the presence of a probable, high-velocity caliche layer. The presence of such geologic units severely diminishes the application of both P-wave seismic refraction and surface wave techniques at the site. The high velocity layer induces dominant higher mode Rayleigh waves in the surface wave dispersion data, which can only be modeled using multi-mode and/or effective mode modeling routines. Due to the presence of the high velocity layer, it was challenging to reduce surface wave dispersion data from the MASW data. Additionally, surface wave dispersion data reduced from the linear passive array using the ReMi technique may not be reliable.

The surface wave dispersion curve recovered from MASW and ReMi (small frequencies only) data collected at GPT-4 was modeled using the effective mode Rayleigh wave assumption. Due to a high-velocity caliche layer significantly impacting the quality of the data and limiting the application of the resulting V_S model to mapping the Upper Muddy Creek formation (UMCf), only a preliminary model was developed. The fit of the theoretical dispersion curve to the experimental data collected at the site and the modeled V_S profile for the surface wave sounding is presented as Figure 12. The resolution decreases gradually with depth due to the loss of sensitivity of the dispersion curve to changes in V_S at greater depth. The higher frequency segment of the dispersion curve appears to be associated with the fundamental mode and first and second higher mode Rayleigh waves; whereas the low frequency segment of the dispersion data is associated with the fundamental mode. The estimated depth of investigation for the combined active and passive surface wave sounding is 200 ft; however, the accuracy of the model at depth is dependent upon the accuracy of the dispersion data interpreted from ReMi analysis of the linear passive array, which does not appear to be very reliable.

The S-wave velocity model developed from the surface wave dispersion data (Figure 12) shows an abrupt increase in V_S to about 3,200 ft/s at a depth of 15 ft, which is likely associated with the top of a caliche layer. The thickness of this layer is not well resolved, but appears to extend to a depth of about 55 ft where V_S decreases to between 1,750 and 1,850 ft/s. V_S increases to over 3,500 ft/s at a modeled depth of 145 ft, which could be associated with another caliche unit or rock. It should be noted that the V_S model may not be very reliable at depth due to both the presence of the high velocity caliche layer at shallow depth and uncertainty in the dispersion curve interpreted from the linear passive array using the ReMi technique.

7.2.2 **P-wave Seismic Refraction**

The P-wave seismic refraction line for GPT-4 was modeled using a layer based, time-term starting model and is presented as Figure 13. The line is presented as southeast to northwest to match the survey distance markers as placed by a subcontractor for AECOM, Inc. As evidenced in the surface wave data, there appears to be a near surface caliche layer at about 14 to 18 ft bgs. The caliche has a P-wave velocity as high as 10,000 ft/s and appears to track the 8,000 to 9,000 ft/s contour in the velocity model. The seismic refraction technique requires that a layer velocity increases if it is to be resolved. Therefore, any lower velocity layer underlying the caliche cannot be imaged using the refraction method. Another words, the high velocity suspected caliche layer effectively masks any underlying geologic structure. The depth of the model shown does not reflect the actual thickness of the caliche. It should be noted that there is a more gradual increase in velocity between GPT-4-REFR-200 and GPT-4-REFR-300. A more conductive zone is also imaged in that area in the ERI sections for GPT-4 (Figure 14) as well. This area is likely related to disturbed soil rather than a paleochannel. Due to the presence of the possible caliche zone, depth to groundwater could not be estimated from the seismic refraction data.

7.2.3 **Electrical Resistivity Imaging**

The ERI model for GPT-4 is presented as Figure 14 and presents the variation of electrical resistivity with distance and depth along the profile. The line is presented as southeast to northwest to match the survey distance markers as placed by a subcontractor for AECOM, Inc. The ERI data is modeled using a smooth model inversion routine; therefore, the model will show smoothly varying resistivity even if abrupt layer contacts are present.

There are four primary units in the ERI sections (Figure 14). A thin, highly variable resistivity unit associated with near surface soils of variable type is underlain by a relatively high resistivity unit that extends to an elevation of about 1,520 ft. The high resistivity unit is likely associated with unsaturated sands and gravels and/or the caliche unit identified in seismic refraction and surface wave models. Resistivity gradually decreases with depth from about 15 to 8 ohm-m from an elevation of about 1,520 ft to an elevation between 1,450 ft and 1,475 ft, in what is likely saturated sands and gravels or the saturated silt member of the Upper Muddy Creek formation (UMCf). Below an elevation of 1,450 ft to 1,475 ft, resistivity is in the 5 to 7 ohm-m range, in what is likely saturated Upper Muddy Creek formation (UMCf) sediments. The electrical sections show mostly laterally homogenous geoelectrical structure with no anomalous features than could be identified with a large paleochannel.

The borehole log for MCF-08 near GPT-4 does encounter the silt member of the Upper Muddy Creek formation (UMCf) at a depth of about 67 ft deep. However, MCF-08 is roughly 250 away from GPT-4 and a hard caliche layer was not identified in the borehole log.

7.2.4 **Time-domain Electromagnetics**

Geoelectric sections were developed for both the 1D smooth and 1D layered TDEM models along GPT-4 and are presented as Figures 16 and 18, respectively. An example of the smooth TDEM model for GPT-4-TDEM-200 before being combined with the other models for gridding is presented as Figure 15. An example of the layered TDEM for GPT-4-TDEM-200 before being combined with the other models for presentation is shown as Figure 17.

Three resistivity units are identified in the TDEM geoelectric sections. The uppermost unit, interpreted as unsaturated sands and gravels and/or caliche, has resistivity greater than about 15 ohm-m that extends to an elevation of about 1,520 ft. The geoelectric section from the smooth TDEM models (Figure 16) also has a thin surficial layer with slightly lower resistivity, that is too thin to be accurately resolved by the Geonics EM-47. The middle unit has resistivity in the 4.5 to 6 ohm-m range and is interpreted as saturated sands and gravels or, possibly, the saturated silt member of the Upper Muddy Creek formation (UMCf). The top of the lower unit is located at an elevation of about 1,450 ft. This unit has resistivity of generally less than 2 ohm-m and is interpreted as saturated finer-grained Upper Muddy Creek formation (UMCf) sediments. Although there is reasonable correlation in geoelectric units between the ERI and TDEM sections, resistivities are generally higher in the ERI sections. There is no lateral variability in the depth of any geoelectric unit that could be associated with a large paleochannel.

7.2.5 **Controlled-Source Audio-Frequency Magnetotellurics**

The CSAMT section for GPT-4 is presented as Figure 19. The section is similar to the smooth model of the TDEM for GPT-4 (see Figure 16). A higher resistivity layer is imaged in the near surface above elevations of 1,510 to 1,520 ft which is likely related to unsaturated sands and gravels and/or the caliche unit. An intermediate resistivity zone is imaged between an elevation of about 1,510 ft and 1,420 ft, which is likely associated with saturated sands and gravels and/or the saturated silty member of the Upper Muddy Creek formation (UMCf). A more conductive (less resistive) zone is imaged below an elevation of about 1,420 ft, which is likely associated with a saturated, clayey member of the Upper Muddy Creek formation (UMCf). The same unit was imaged at a higher elevation of 1,450 ft in the higher resolution TDEM models. Although the CSAMT is capable of imaging to much greater depth than the ERI or TDEM survey using a Geonics EM-47, it does not have the level of surface resolution as the other techniques.

8 DISCUSSION AND RECOMENDATIONS

A geophysical feasibility study was conducted in the Las Vegas Wash near Henderson, Nevada. The objective of the investigation was to determine the effectiveness of several geophysical techniques to map geologic/hydrologic features such as the contact between unconsolidated sediments and the Upper Muddy Creek formation (UMCf) and possible paleochannels within the Upper Muddy Creek formation (UMCf). Two (2) sites were used for testing six (6) geophysical techniques. These sites were designated as GPT-2 and GPT-4 (Figures 1 and 2). The six (6) geophysical methods that were tested for this pilot study include: active and passive surface waves, P-wave seismic refraction, electrical resistivity imaging (ERI), time-domain electromagnetics (TDEM), and controlled-source audio-frequency magnetotellurics (CSAMT). The electromagnetic induction technique, which offers a cost effective means of evaluating large areas, was not utilized during the pilot study because geophysical data were only acquired along short profiles.

The P-wave seismic refraction technique (Figures 5 and 13) was found to be useful for mapping approximate depth to the saturated zone, but only in areas without caliche layers in the shallow subsurface. Although the technique cannot map the depth to the Upper Muddy Creek formation (UMCf), knowledge on groundwater depth is useful when interpreting electrical resistivity and electromagnetic data. Therefore, limited seismic refraction surveys in areas without borehole information may be useful in future investigations. Surface wave techniques (Figures 3, 4, 11, and 12), which are used to map S-wave velocity, were not found to be particularly effective during the feasibility study, especially at GPT-4, which has a shallow caliche layer. The utilization of surface wave techniques for site characterization should not be revisited unless borehole velocity measurements were to show a definitive correlation between S-wave velocity and the Upper Muddy Creek formation (UMCf).

Both the electrical resistivity imaging (ERI) (Figures 6 and 14) and time-domain electromagnetic (TDEM) (Figures 7-10 and 15-18) methods were found to be effective for mapping subsurface electrical structure at GPT-2 and GPT-4. There is no conclusive evidence of large paleochannels cut into the Upper Muddy Creek formation (UMCf) at either site. The electrical techniques indicate subsurface electrical structure relatively horizontal beneath each profile. However, there may be a gradual deepening of a low resistivity zone, likely associated with a saturated, clay member of the Upper Muddy Creek formation (UMCf), at the western end of GPT-2. Although significant geologic structures were not detected beneath GPT-2 and GPT-4, the electrical resistivity models at each site are markedly different indicating that the ERI and TDEM methods may be successfully utilized to characterize subsurface geologic/hydrogeologic conditions. Each of these two methods has different and often complementary strengths and limitations. The TDEM method is more cost effective at covering large areas, providing a 100 or 200 ft station spacing is utilized. ERI, however, has better spatial resolution when using a 10 to 20 ft electrode spacing, which would be utilized in this environment. The TDEM method is more effective at imaging into a conductive medium, such as clay, but is more susceptible to noise from electrical transmission lines and surface/buried metallic objects; whereas, in some cases, it can be possible to acquire ERI data in areas with pipelines and fences providing the profile is orthogonal to the surface/subsurface features. Brush clearance requirements are also different for each method as well. Minimal brush clearance will be required for both methods in areas with light to moderate density of low height scrubs. It may also be possible to acquire TDEM data without brush clearance in areas where the ERI technique requires light clearance along a profile. The ERI method will be more cost effective in areas with very dense brush where it is not possible to walk through the brush, as it is only necessary to clear a narrow, linear corridor.

The CSAMT method (Figure 19) was not as successful as the electrical resistivity and TDEM methods. Useful CSAMT data could not be recovered at GPT-2 due to an unknown source of electrical noise (e.g. radar system, microwave tower, transmission tower) on the day of testing. Good quality CSAMT data were recovered at GPT-4; however, the technique has much lower near surface resolution than the ERI and TDEM techniques.

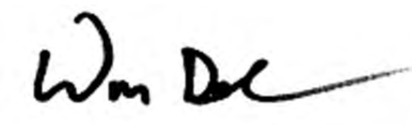
A future exploration approach for geophysical site characterization may be as follows:

- An electromagnetic induction survey (Geonics EM-31 and EM-34XL) along profiles or grids to map lateral variation in subsurface electrical structure that could be associated with paleochannels. The cost of these techniques is only about 20% of that of the more sophisticated electrical resistivity imaging and TDEM methods for comparable coverage area. Therefore, the techniques provide an excellent reconnaissance tool that can be utilized to identify areas for focused electrical resistivity and/or TDEM surveys. The Geonics EM-31 would be utilized to map near surface features, such as pipelines, that may interfere with EM-34XL measurements. EM-34XL data would be acquired using a 40 m coil spacing to map lateral variability in electrical structure over a depth range that encompasses the expected depth of paleochannels. These techniques do not provide detailed depth information and, therefore, it would still be necessary to acquire ERI or TDEM data to characterize possible anomalous features; however, measurements can be focused in areas of possible interest. Appendix A – Time Domain Electromagnetic Method, presents example EM-31 and EM-34XL and TDEM models from a site south of the current investigation area where the Upper Muddy Creek formation (UMCf) is finer-grained. This image demonstrates that the EM-34XL measurements identified all structures that then were later modeled in detail using TDEM data.
- ERI and/or TDEM soundings to characterize subsurface electrical structure. TDEM soundings could be used in areas that are easily accessible and not near EM noise sources. ERI can be conducted in areas with more limited access or that cross subsurface pipelines. A possible approach would be to acquire TDEM data at 500+ ft intervals where EM-34XL data indicates that there is only gradual variation in subsurface electrical structure and at 100 to 200 ft intervals in areas where the EM-34XL indicates that there is anomalous subsurface electrical structure. ERI would be acquired in areas with anomalous EM-34XL data where site access conditions are not suitable to TDEM acquisition.
- Limited seismic refraction surveys (e.g. end shots only) can be acquired in areas where groundwater depth information is not available but needed to facilitate ERI or TDEM interpretation.
- EM induction logs should be conducted in PVC cased monitoring wells to accurately tie electrical resistivity structure in the ERI or TDEM models, to geologic observations in the borehole logs. It should be noted that the EM induction logging technique cannot image through stainless steel casing or screen.

9 CERTIFICATION

All geophysical data, analysis, interpretations, conclusions, and recommendations in this document have been prepared under the supervision of and reviewed by a **GEO***Vision* California Professional Geophysicist.

Prepared by



June 20, 2017

William Dalrymple — Date

California Professional Geophysicist, P.Gp. 1072

GEO*Vision* Geophysical Services

and

June 20, 2017

Antony J. Martin — Date

California Professional Geophysicist, P.Gp. 989

GEO*Vision* Geophysical Services

This geophysical investigation was conducted under the supervision of a California Professional Geophysicist using industry standard methods and equipment. A high degree of professionalism was maintained during the project from the field investigation and data acquisition, through data processing interpretation and reporting. Original field data files, field notes, and observations, and other pertinent information are maintained in the project files and are available for the client to review for a period of at least one year.

A professional geophysicist's certification of interpreted geophysical conditions comprises a declaration of his/her professional judgment. It does not constitute a warranty or guarantee, expressed or implied, nor does it relieve any other party of its responsibility to abide by contract documents, applicable codes, standards, regulations, or ordinances.

TABLES

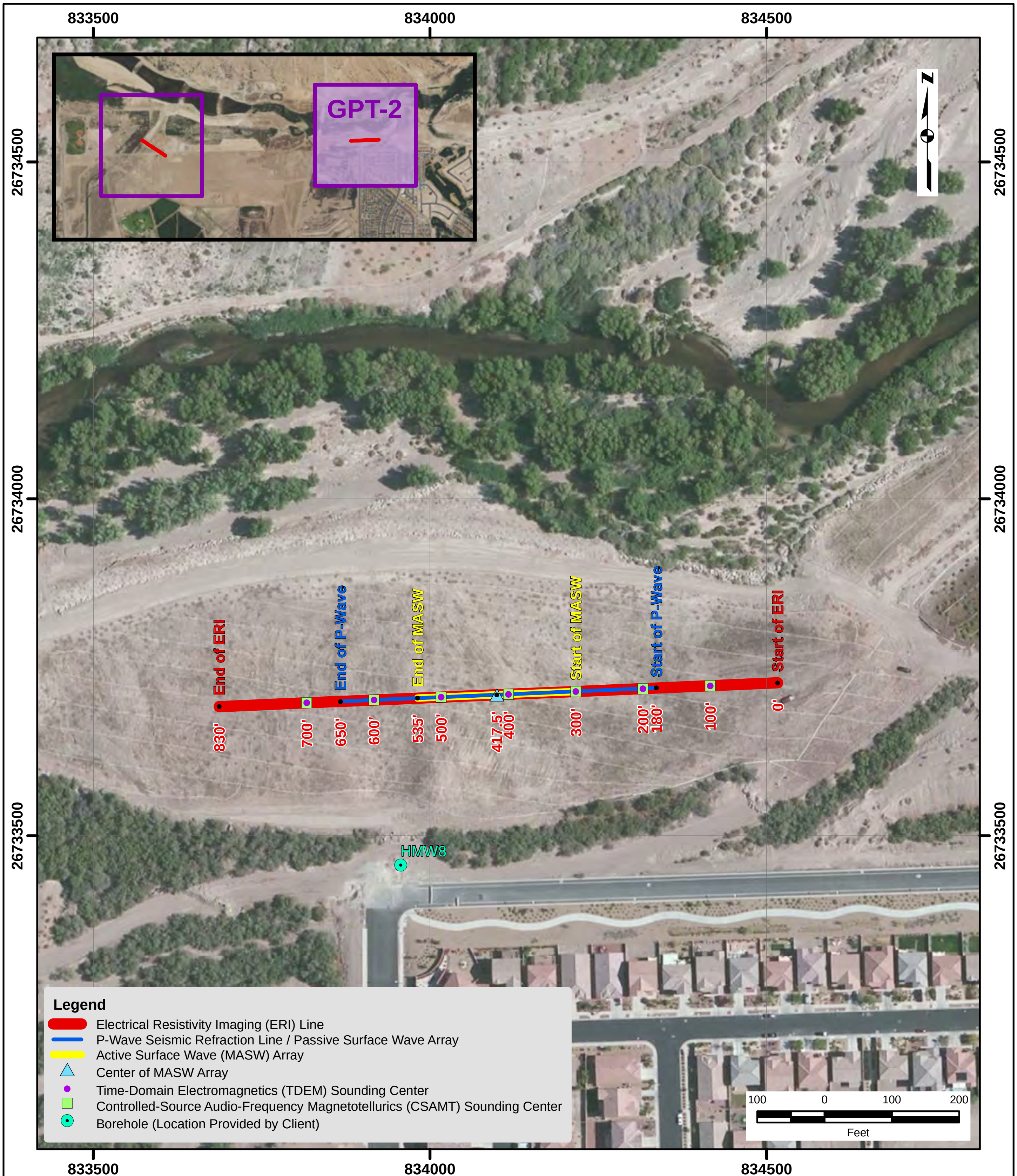
Table 1 Geophysical Line Locations

Name	Type	Spacing (ft)	No. of Channels	Location (ft)	Easting (US Feet)	Northing (US Feet)
GPT-2	MASW	5	48	300	834,217	26,733,714
				535	833,982	26,733,704
GPT-2	P-Wave	10	48	180	834,336	26,733,719
				650	833,817	26,733,697
GPT-2	ERI	10	84	0	834,516	26,733,727
				830	833,687	26,733,692
GPT-4	MASW	5	48	300	827,929	26,733,418
				535	827,732	26,733,547
GPT-4	P-Wave	10	48	180	828,029	26,733,353
				650	827,636	26,733,610
GPT-4	ERI	10	84	0	828,180	26,733,254
				830	827,485	26,733,708

Notes:

1. Coordinates in NV State Plane, Zone East (2701), NAD83, US Survey Feet.
2. Coordinates calculated from data provided by AECOM, Inc.

FIGURES



NOTES:
1. Nevada State Plane Coordinate System, NAD 83, East (2701), US Survey Feet
2. Base map source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

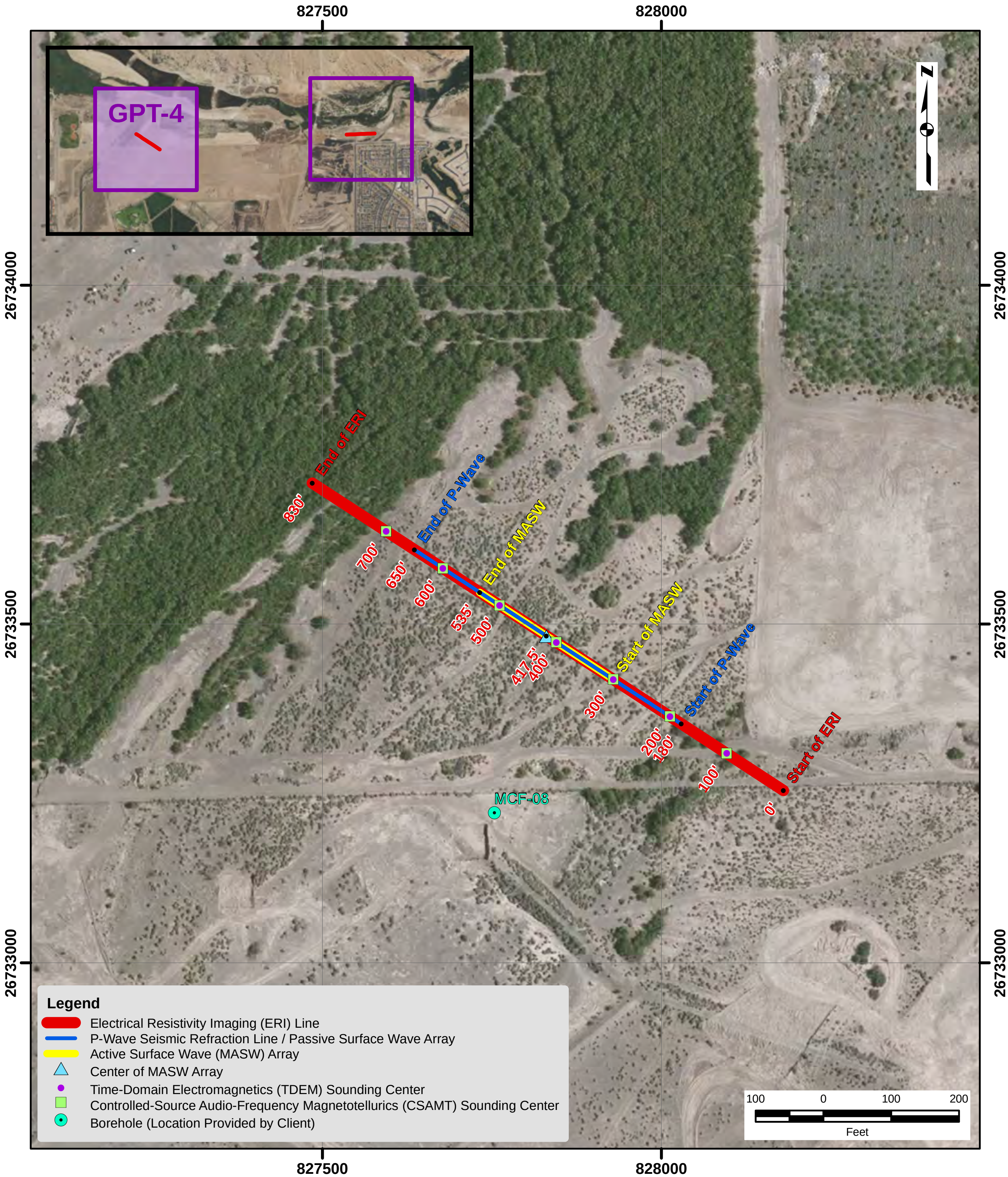
GEOVision geophysical services

Date:	11/28/2016
GV Project:	16374
Developed by:	W Dalrymple
Drawn by:	T Rodriguez
Approved by:	A Martin
File Name:	16374_1.MXD

FIGURE 1
SITE MAP
LOCATION OF GPT-2

GEOPHYSICAL PILOT TEST
LAS VEGAS WASH
HENDERSON, NEVADA

PREPARED FOR
AECOM, INC.



NOTES:
1. Nevada State Plane Coordinate System, NAD 83, East (2701), US Survey Feet
2. Base map source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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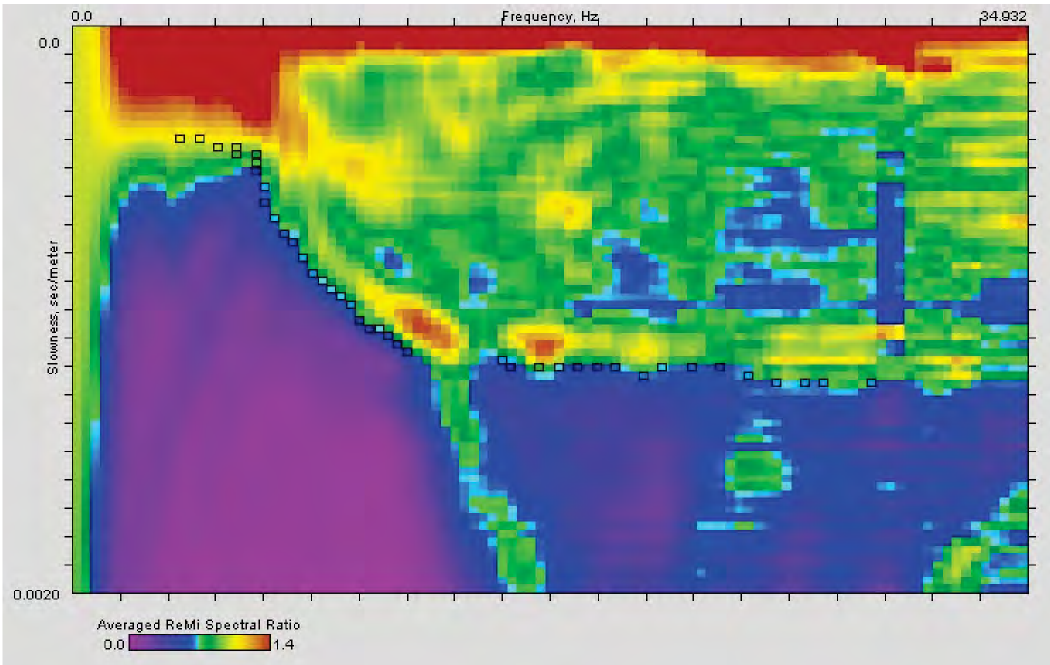
File Name:	16374_1.MXD

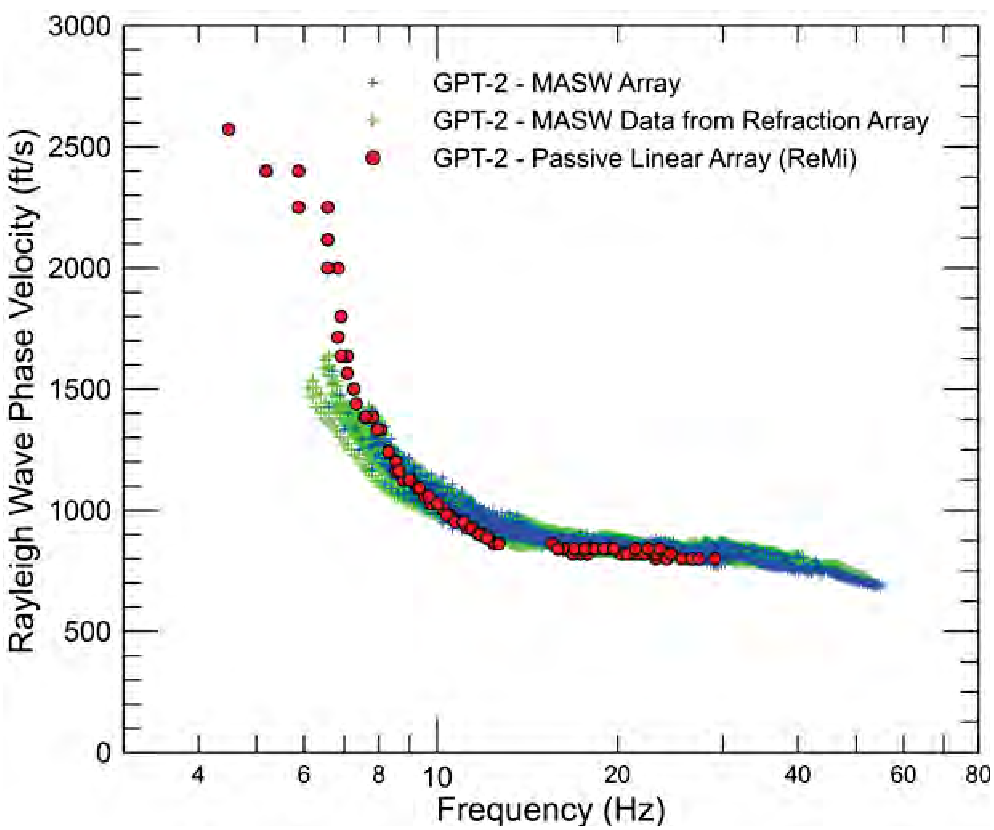
FIGURE 2
SITE MAP
LOCATION OF GPT-4

GEOPHYSICAL PILOT TEST
LAS VEGAS WASH
HENDERSON, NEVADA

PREPARED FOR
AECOM, INC.

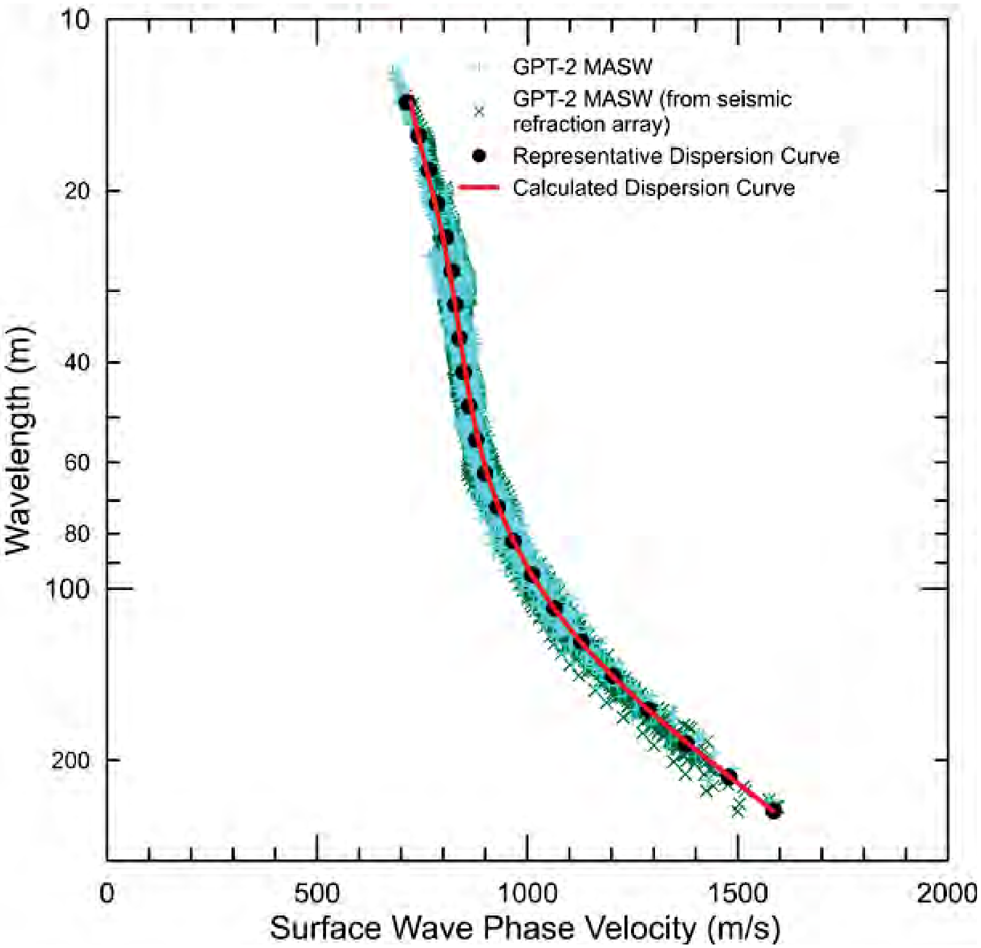


Analysis of ReMi data collect into the P-wave refraction line

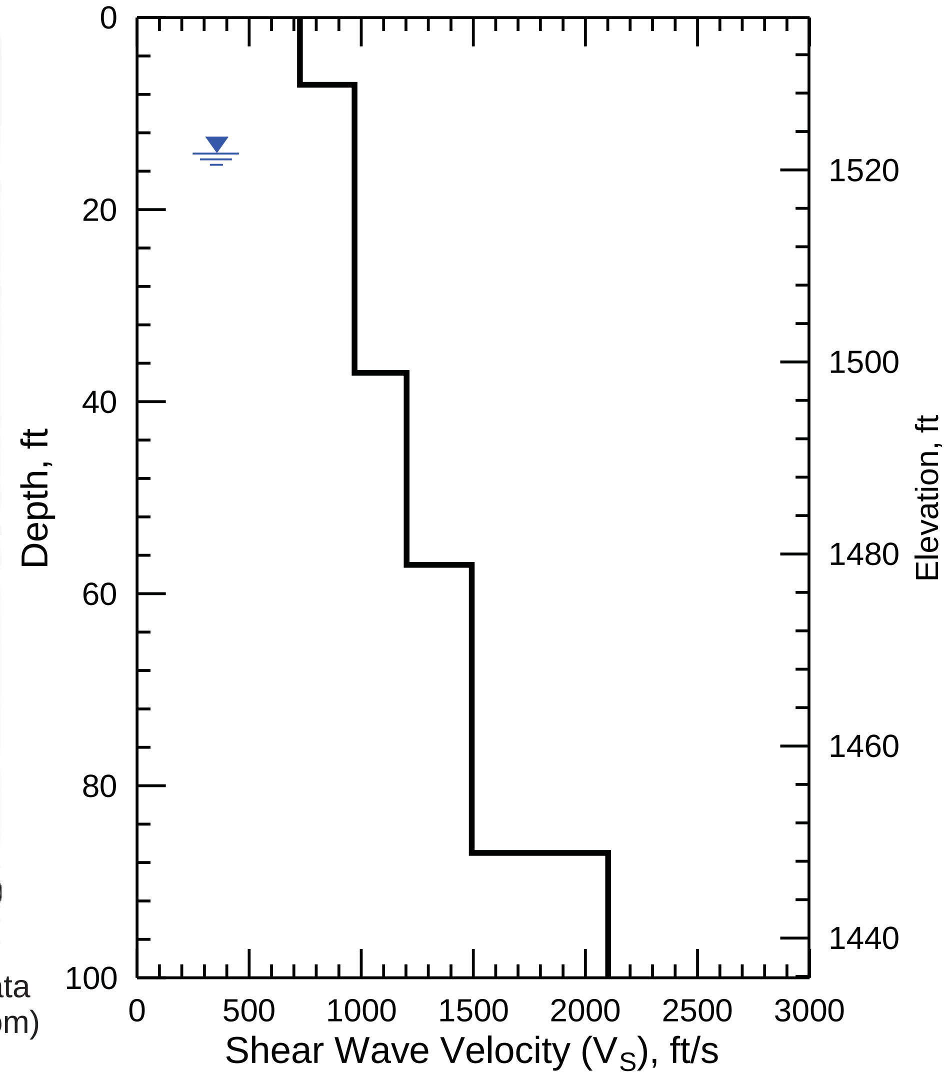


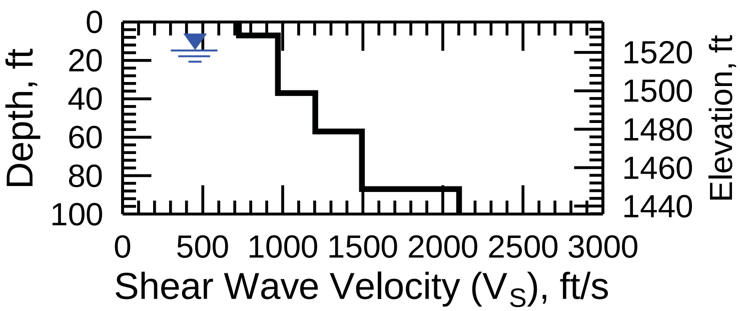
Comparison of active source (MASW) and passive source (ReMi) surface wave dispersion data

GEOVision geophysical services	FIGURE 3 GPT-2: REMI VELOCITY IMAGE AND ACTIVE/PASSIVE DISPERSION DATA
Project No. 16374	LAS VEGAS WASH HENDERSON, NEVADA
Date: DEC 5, 2016	
Drawn By: DALRYMPLE	PREPARED FOR AECOM, INC.
Approved By: MARTIN	
File P:\2016\16374 - AECOM...\F03.cdr	



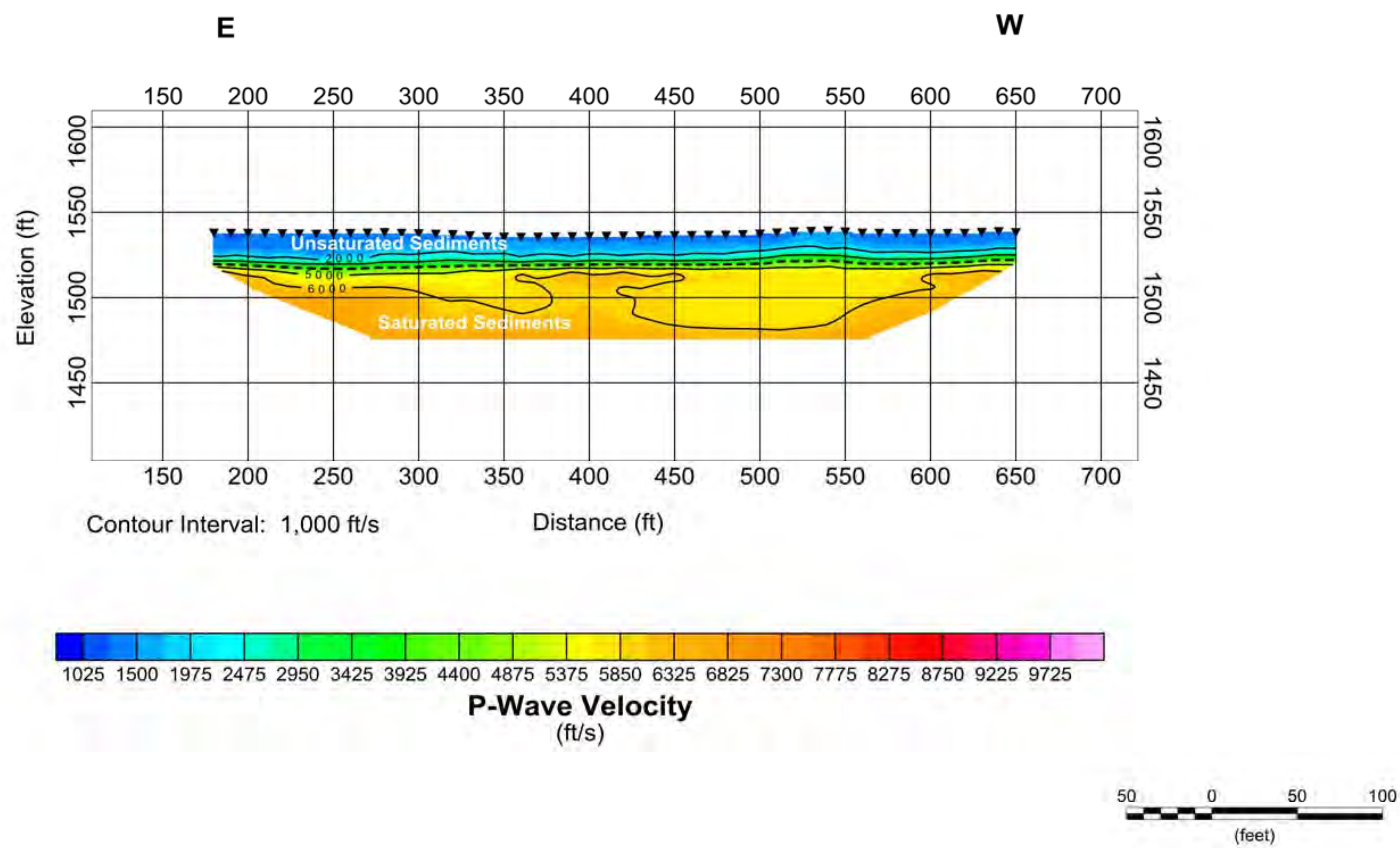
Field, representative and calculated surface wave dispersion data (left) and associated V_s model (5x scale right and 1x scale bottom)





GEOVision geophysical services

Project No. 16374	FIGURE 4 GPT-2: MASW DISPERSION DATA AND VS MODEL
Date: JAN 3, 2017	LAS VEGAS WASH HENDERSON, NEVADA
Drawn By: DALRYMPLE	
Approved By: MARTIN	PREPARED FOR AECOM, INC.
File P:\2016\16374 - AECOM...\F04.cdr	



LEGEND

▼ Geophone Location

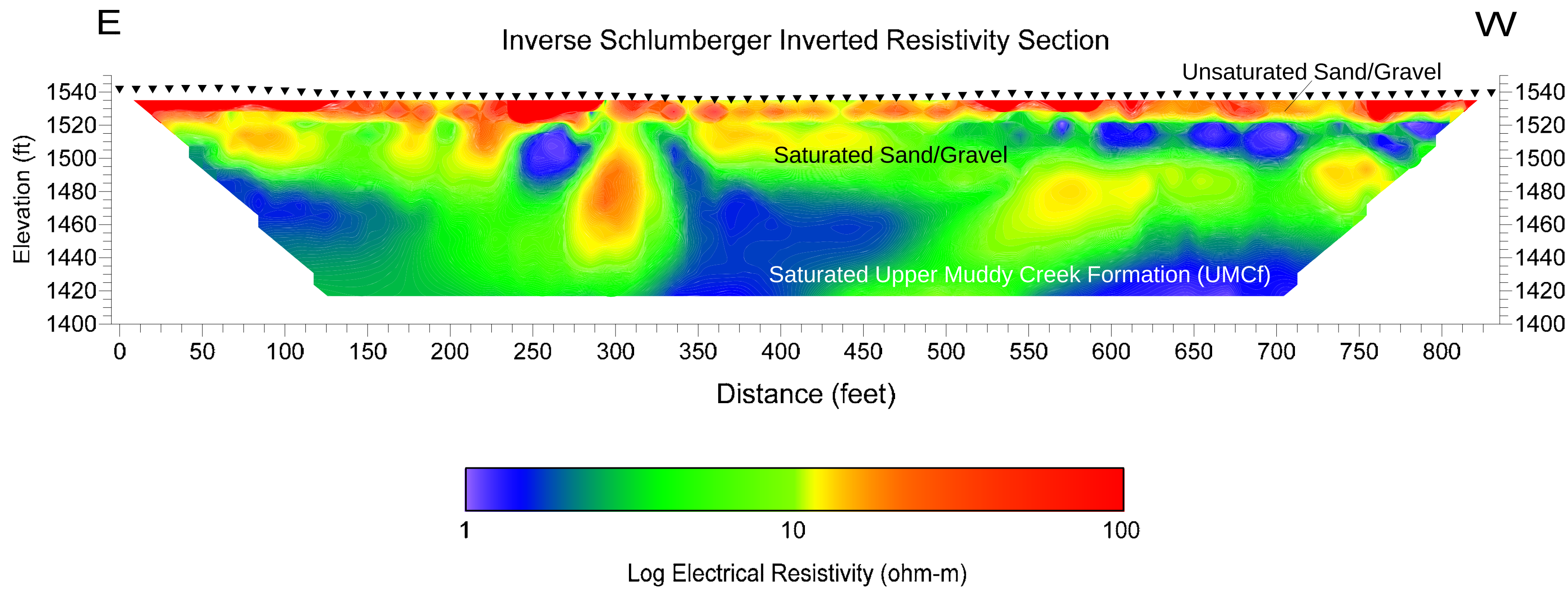
GEOVision geophysical services

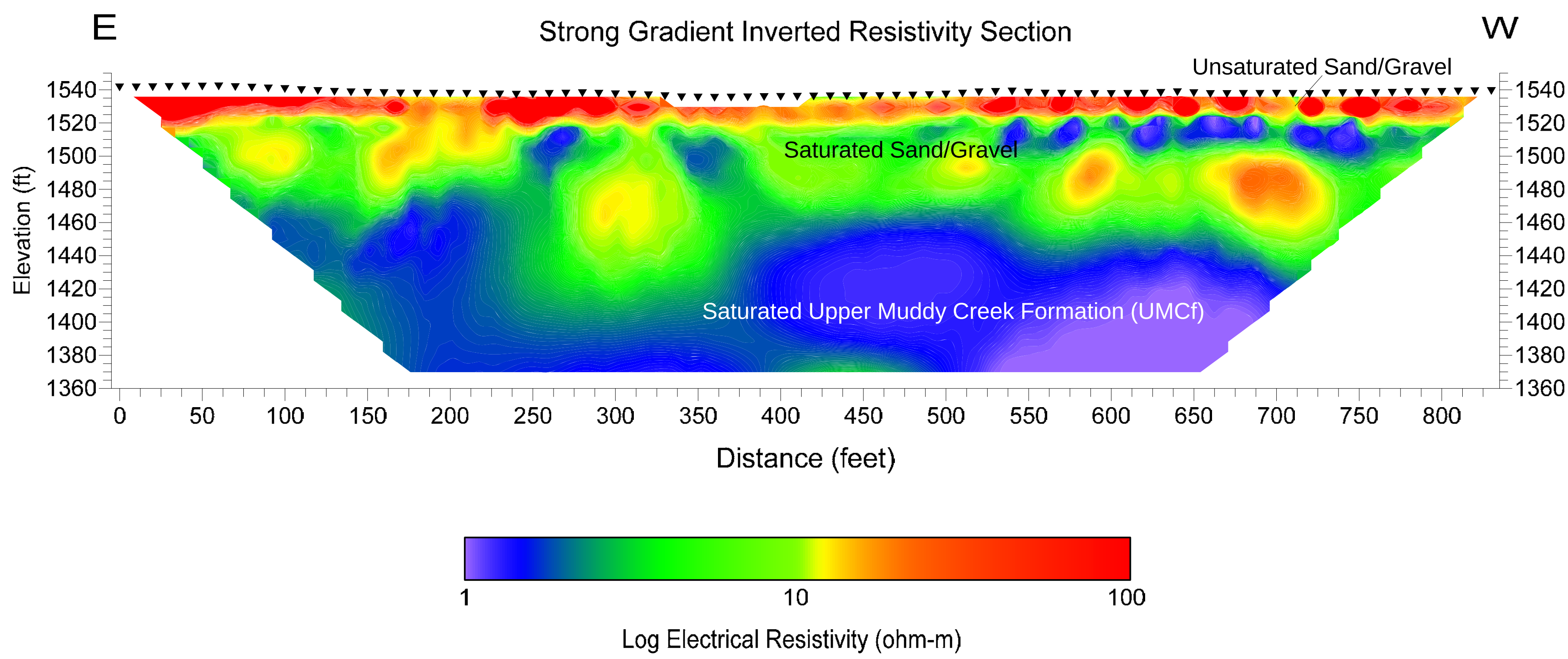
Figure 5

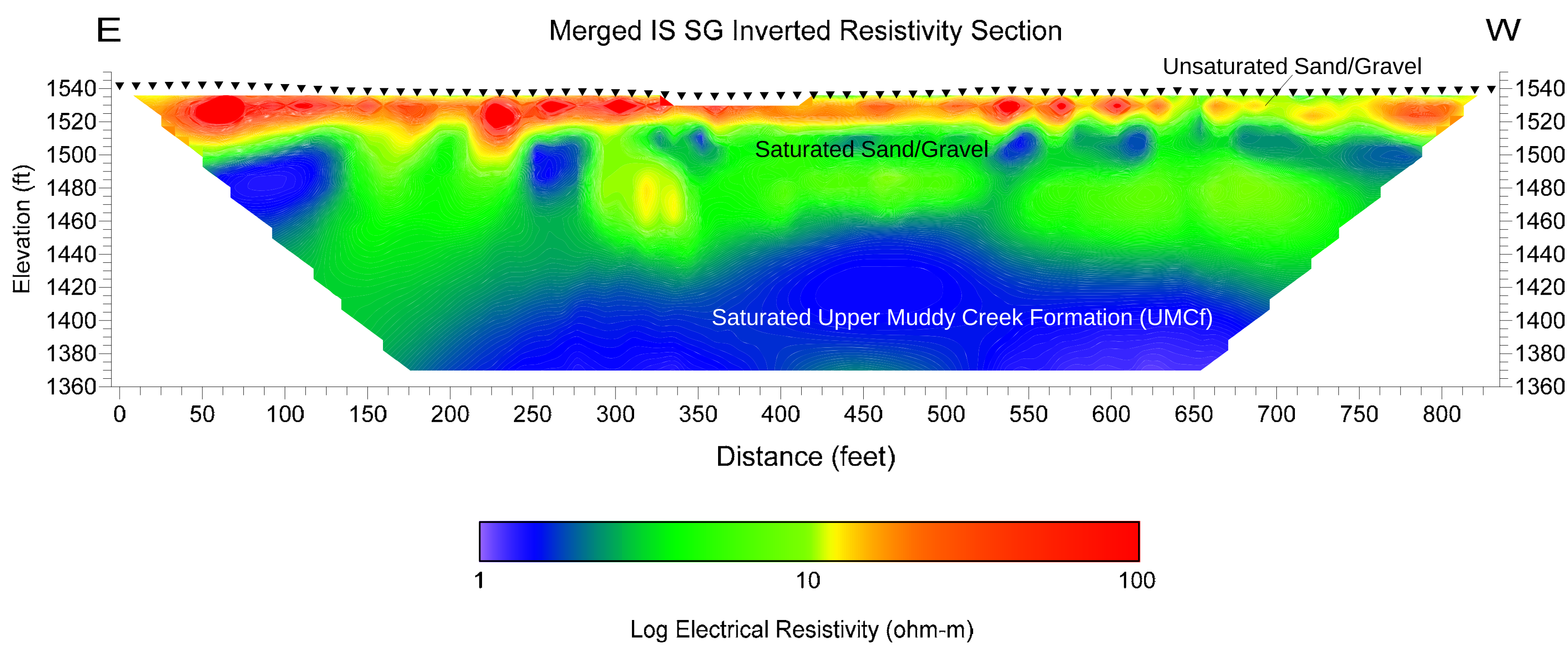
GPT-2: Time-Term Seismic Tomography Model
GV Project No. 16374

Las Vegas Wash
Henderson, Nevada

Prepared for AECOM, Inc.







Legend

▼ Electrode Location

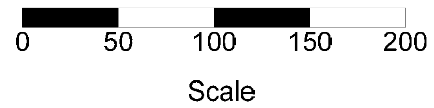


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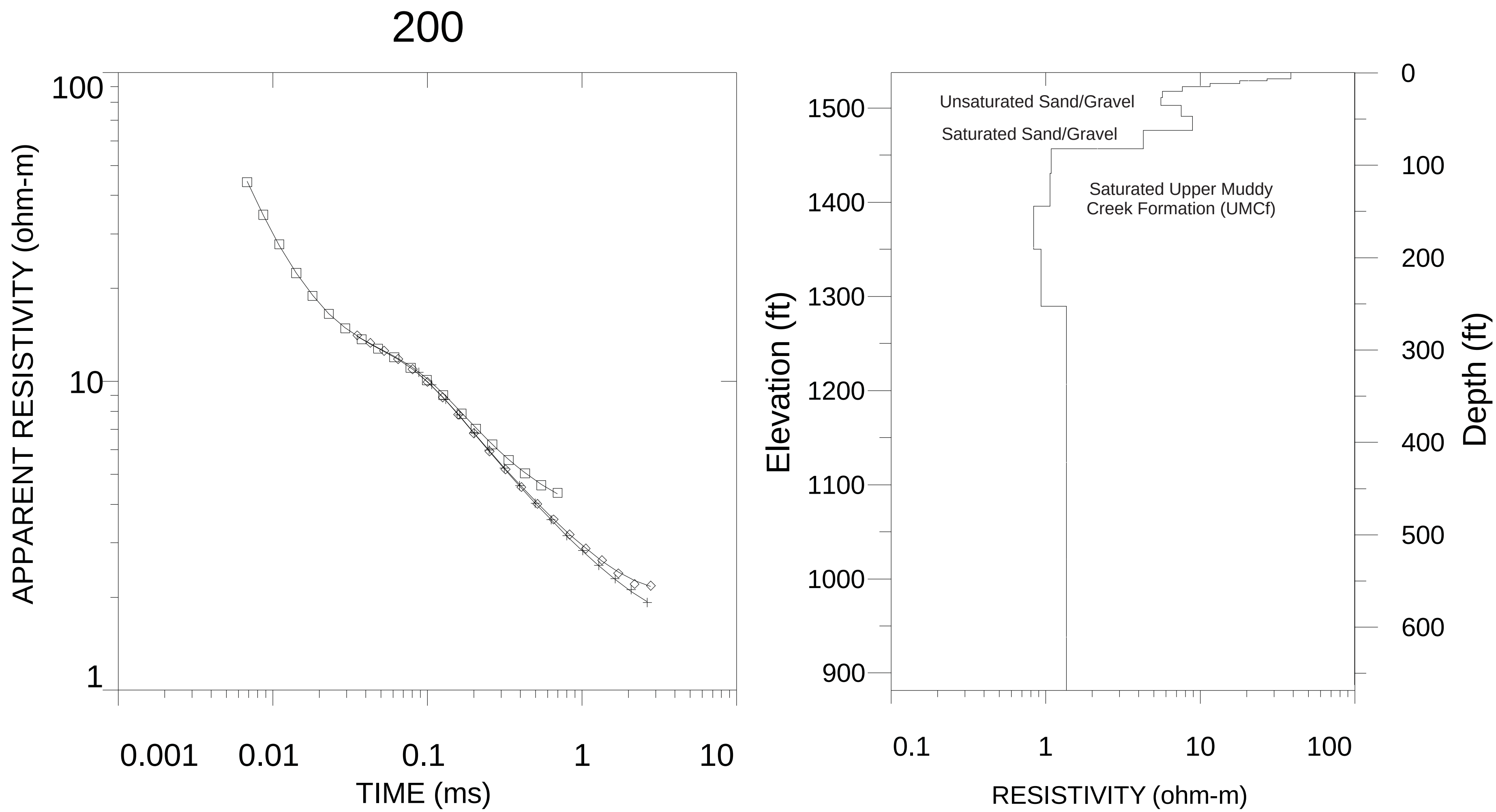
Figure 6

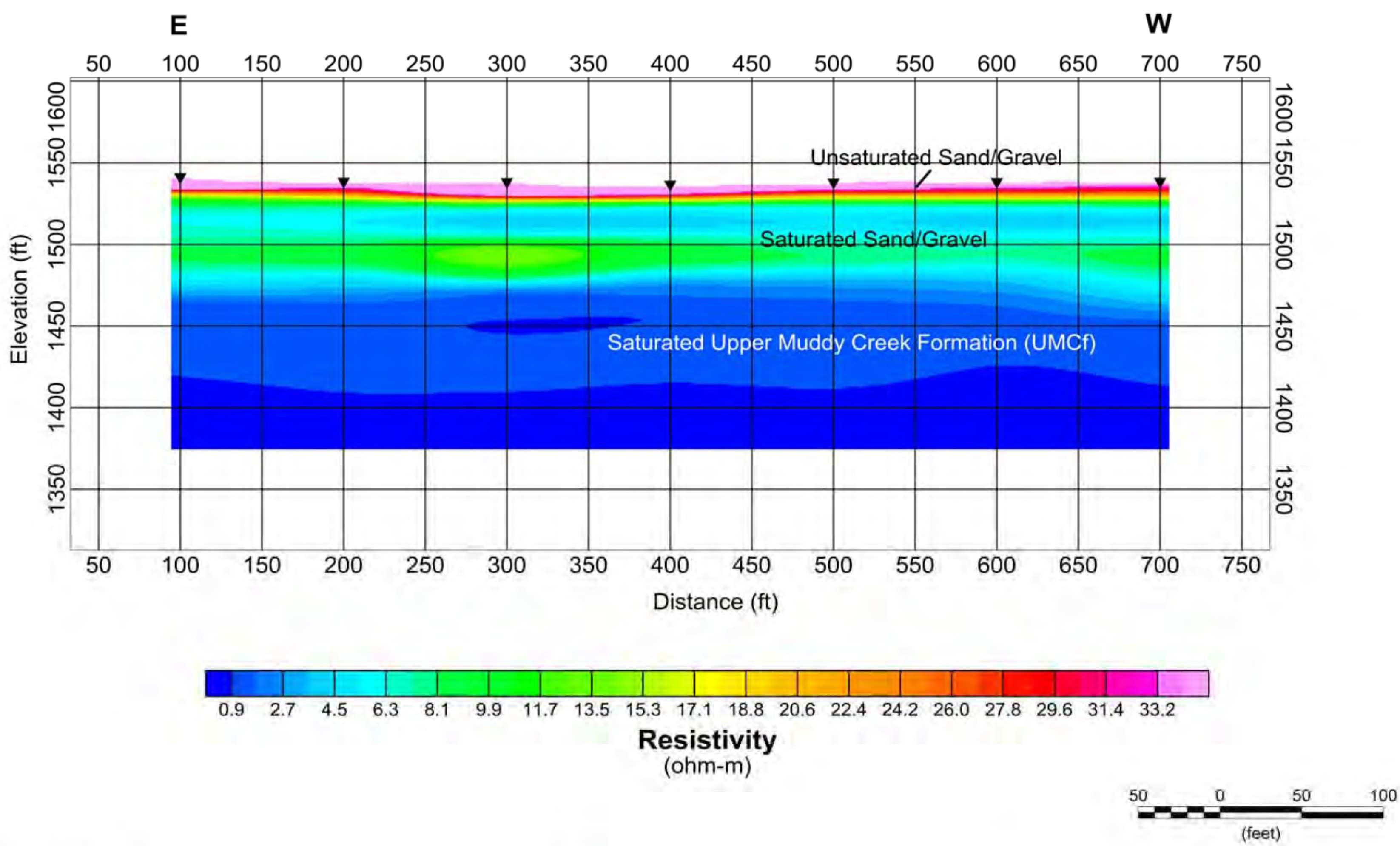
GPT-2 Resistivity Model Sections
GEO*Vision* Project No. 16374

PROJECT SITE
HENDERSON, NV

Prepared for AECOM



GEOVision geophysical services	FIGURE 7 EXAMPLE 1D SMOOTH TDEM MODEL: GPT-2-TDEM-200
Project No. 16374 Date: JAN 3, 2017	LAS VEGAS WASH HENDERSON, NEVADA
Drawn By: DALRYMPLE Approved By: MARTIN File P:\2016\16374 - AECOM...\F07.cdr	PREPARED FOR AECOM, INC.



LEGEND

▼ TDEM Sounding Location

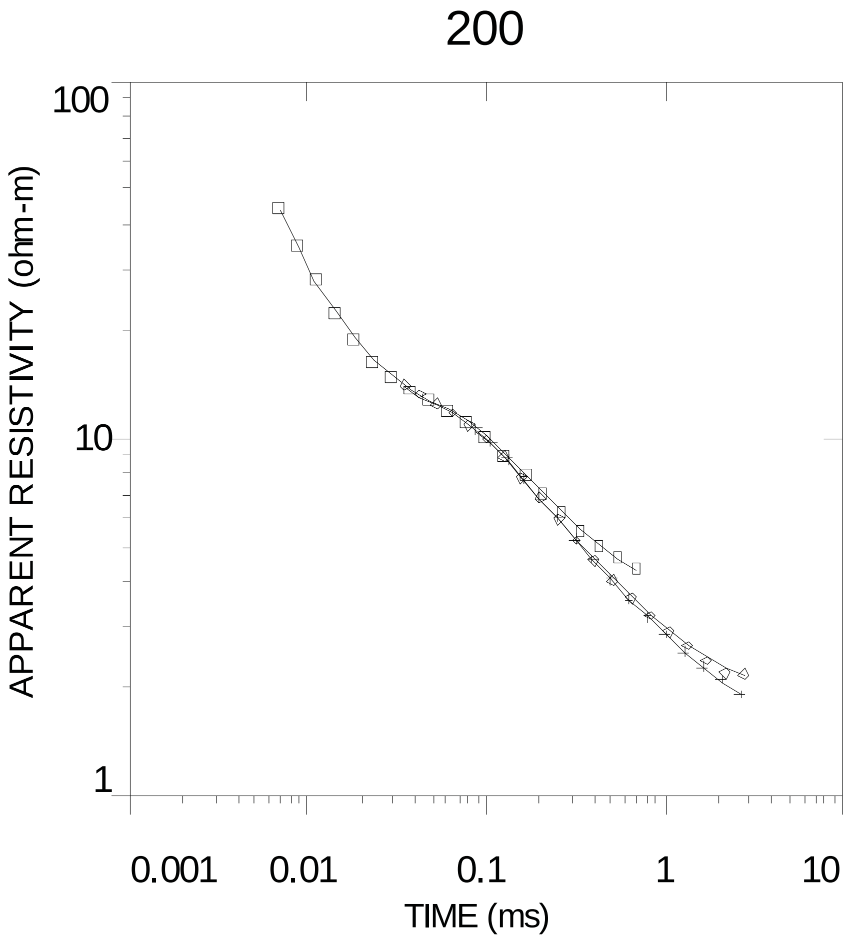
GEOVision geophysical services

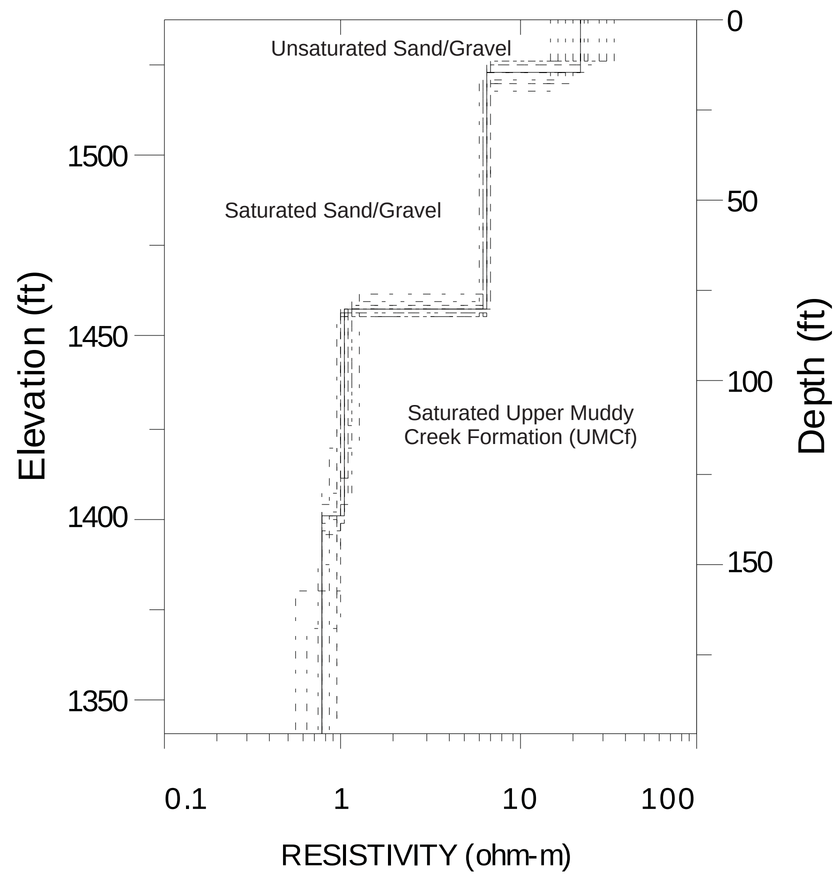
Figure 8

GPT-2: Geoelectric Section From 1D Smooth TDEM Model
GV Project No. 16374

Las Vegas Wash
Henderson, Nevada

Prepared for AECOM, Inc.





GEOVision geophysical services	FIGURE 9 EXAMPLE 1D LAYERED TDEM MODEL: GPT-2-TDEM-200
Project No. 16374	LAS VEGAS WASH HENDERSON, NEVADA
Date: DEC 30, 2016	
Drawn By: DALRYMPLE	PREPARED FOR AECOM, INC.
Approved By: MARTIN	
File P:\2016\16374 - AECOM...\F09.cdr	

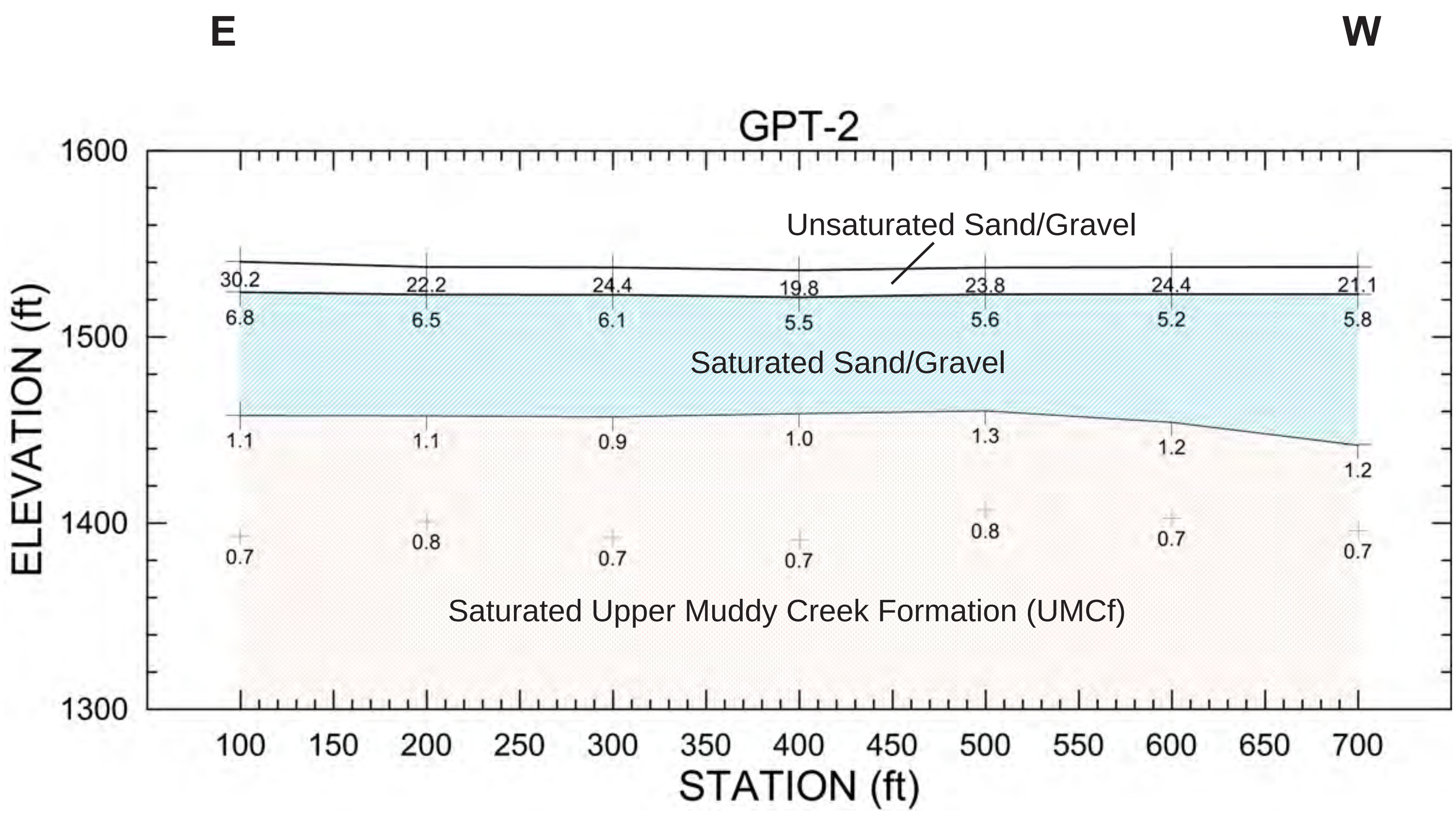


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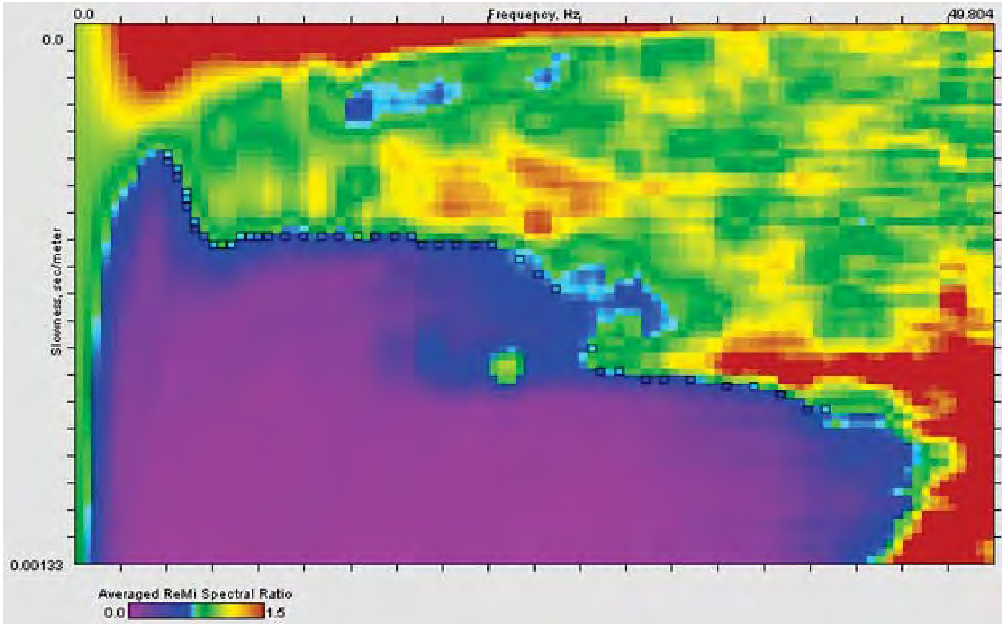
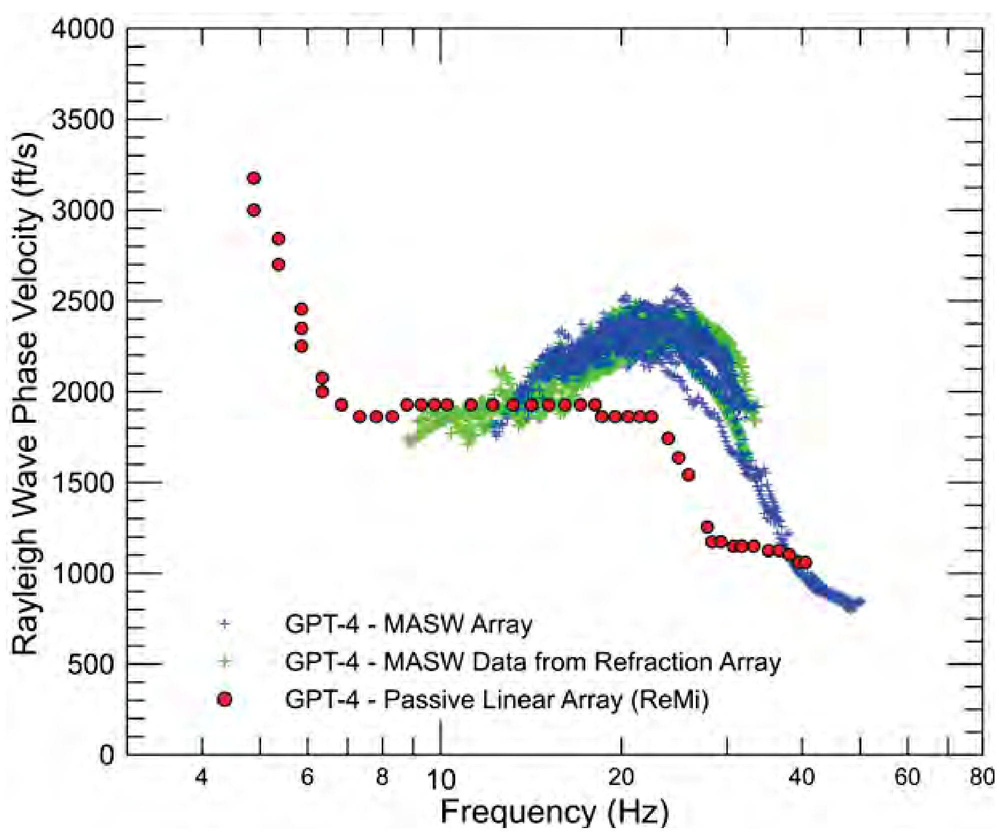
FIGURE 10
GPT-2: TDEM 1D LAYERED MODEL INVERSION

Project No. 16374	LAS VEGAS WASH HENDERSON, NEVADA
Date: DEC 30, 2016	
Drawn By: DALRYMPLE	PREPARED FOR AECOM, INC.
Approved By: MARTIN	
File P:\2016\16374 - AECOM...\F10.cdr	



Analysis of ReMi data collect into the P-wave refraction line



Comparison of active source (MASW) and passive source (ReMi) surface wave dispersion data

GEOVision geophysical services

FIGURE 11
GPT-4: REMI VELOCITY IMAGE
AND ACTIVE/PASSIVE DISPERSION DATA

Project No. 16374

Date: DEC 5, 2016

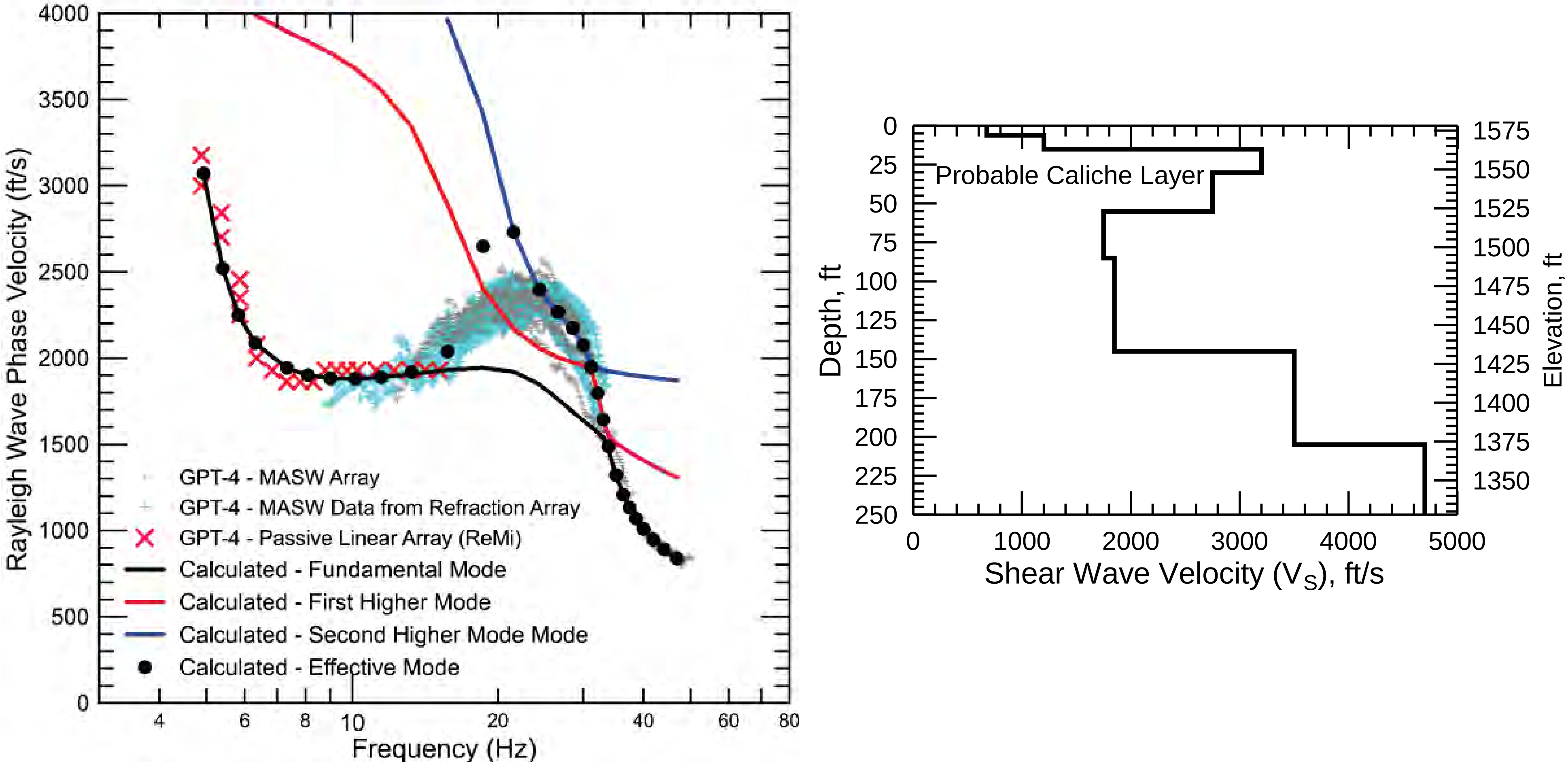
Drawn By: DALRYMPLE

Approved By: MARTIN

File P:\2016\16374 - AECOM...\F11.cdr

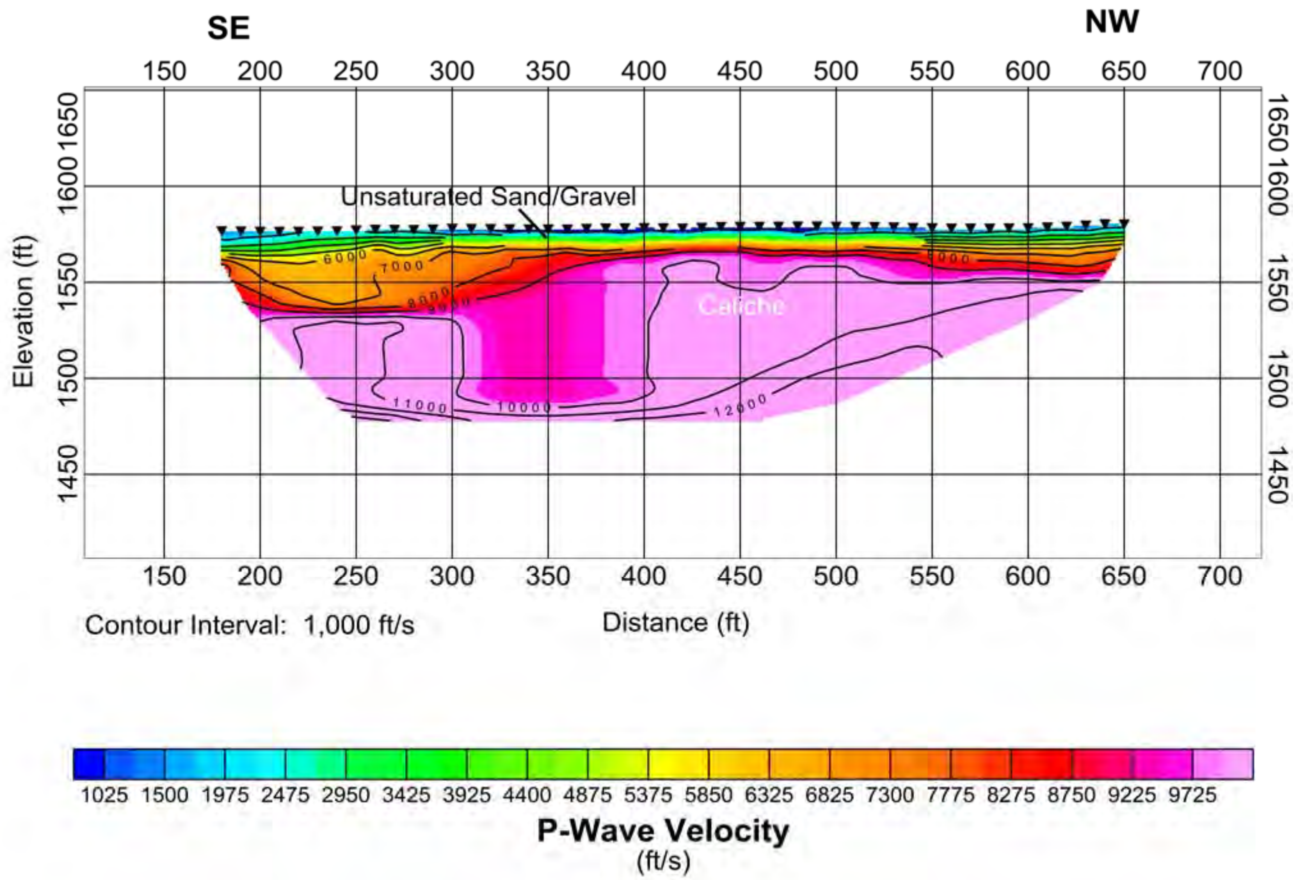
LAS VEGAS WASH
HENDERSON, NEVADA

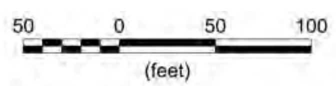
PREPARED FOR
AECOM, INC.



Field, representative and calculated surface wave dispersion data (left) and associated V_s model (right)

GEOVision geophysical services	FIGURE 12 GPT-4: MASW DISPERSION DATA AND VS MODEL
Project No. 16374 Date: JAN 3, 2017	LAS VEGAS WASH HENDERSON, NEVADA
Drawn By: DALRYMPLE Approved By: MARTIN File P:\2016\16374 - AECOM...\F12.cdr	PREPARED FOR AECOM, INC.





LEGEND

▼ Geophone Location

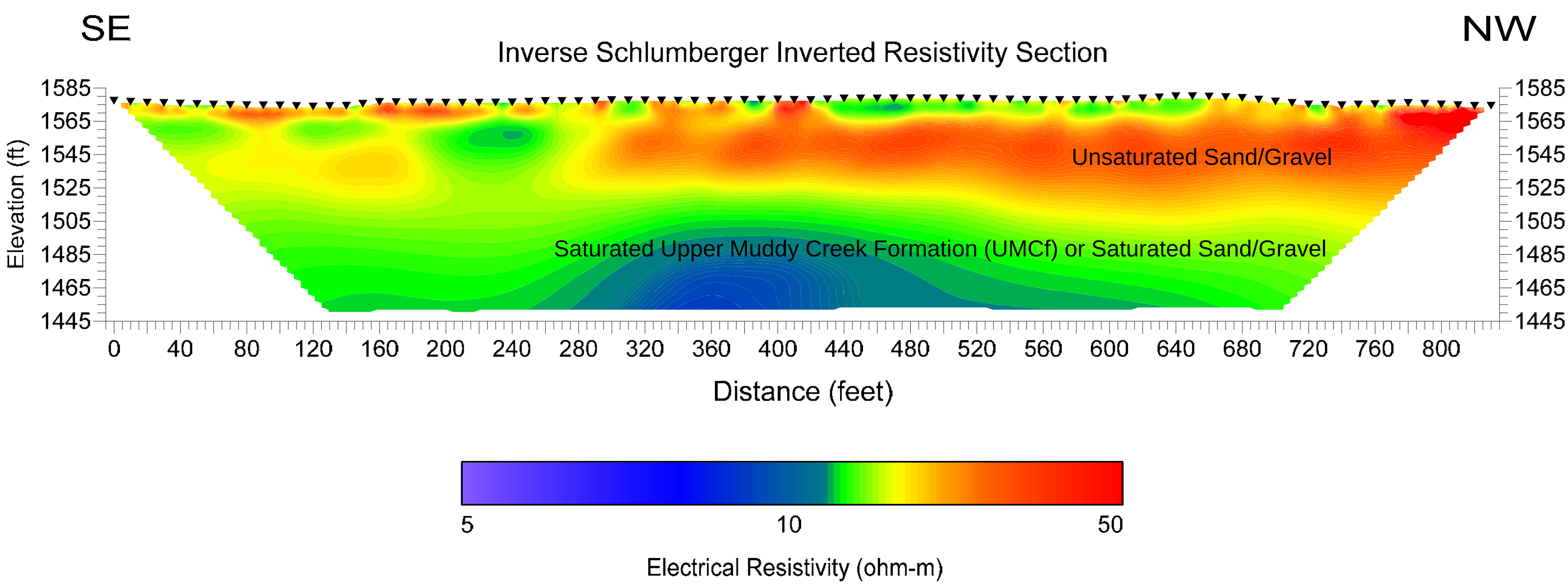
GEOVision geophysical services

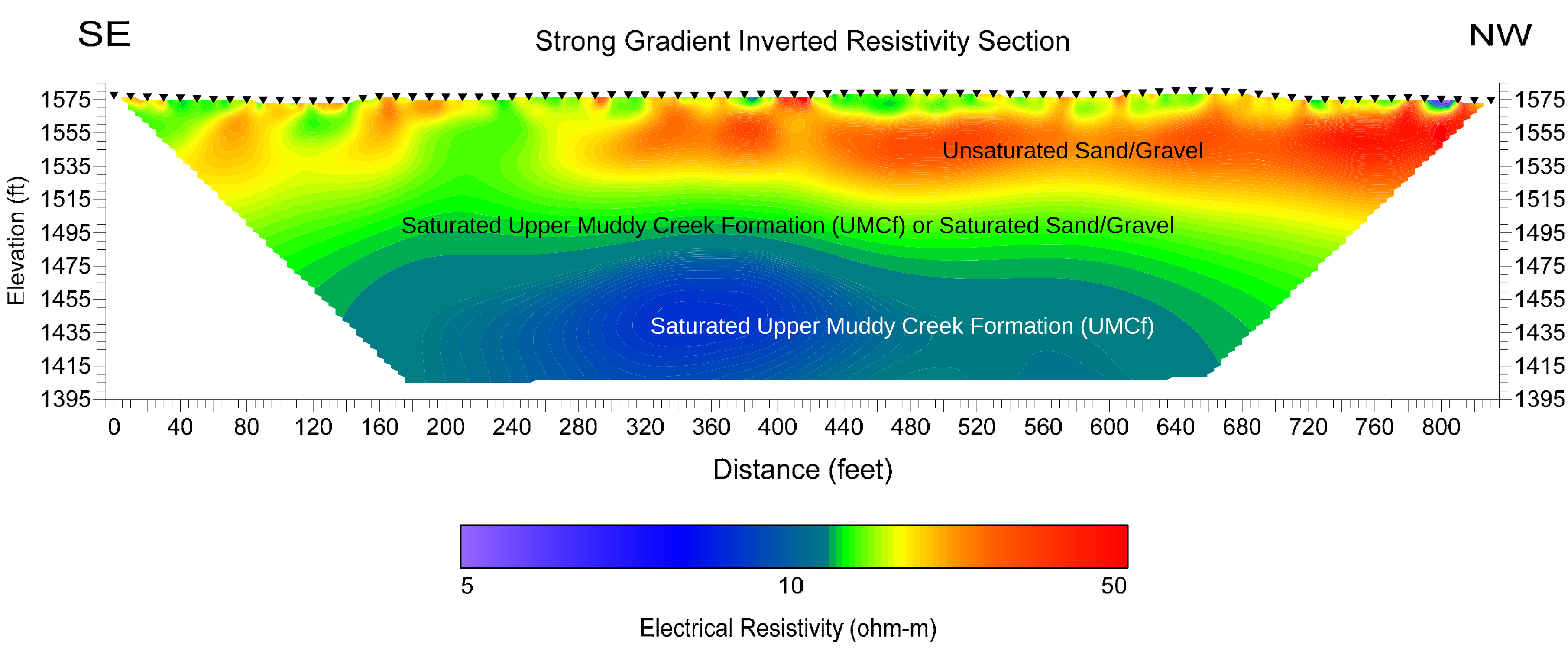
Figure 13

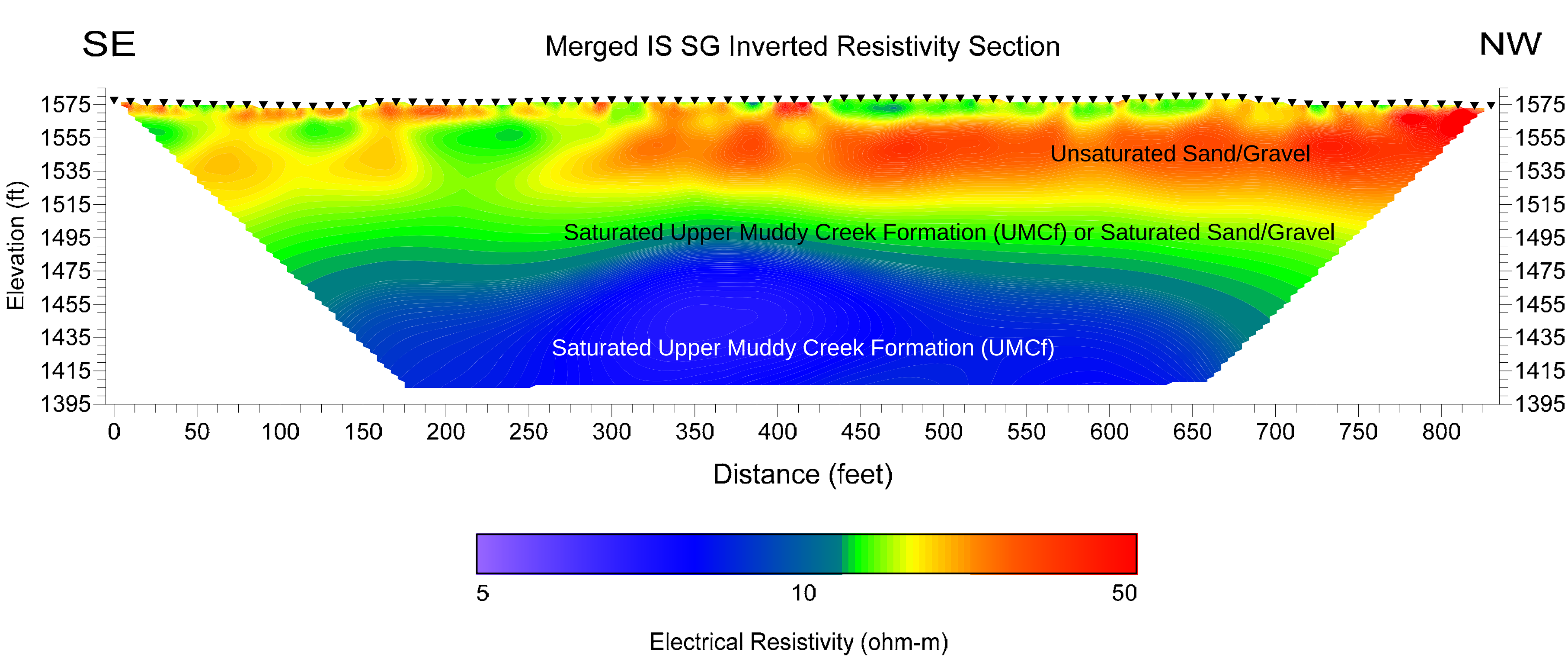
GPT-4: Time-Term Seismic Tomography Model
GV Project No. 16374

Las Vegas Wash
Henderson, Nevada

Prepared for AECOM, Inc.

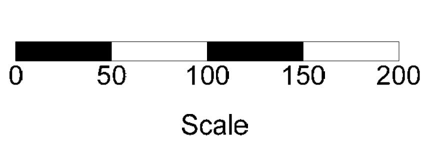






Legend

▼ Electrode Location



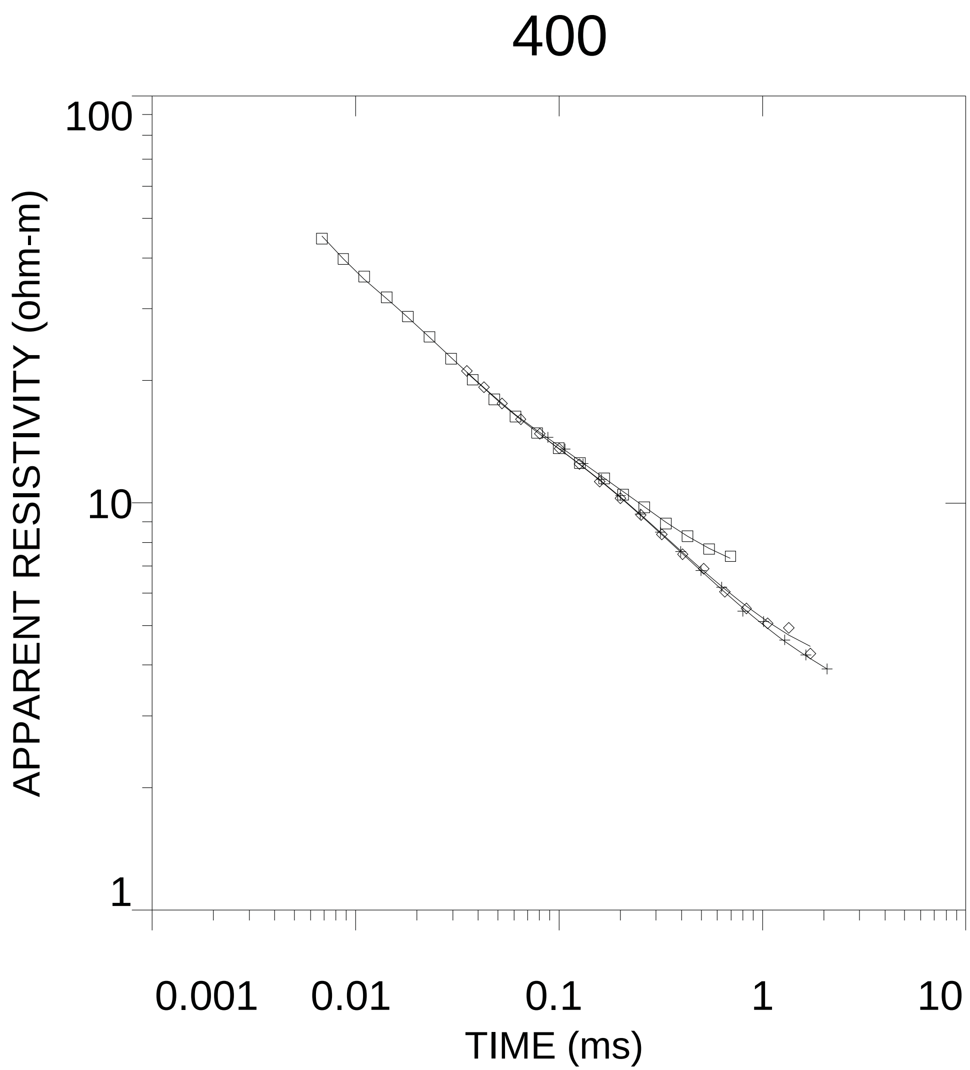
GEO*Vision* geophysical services

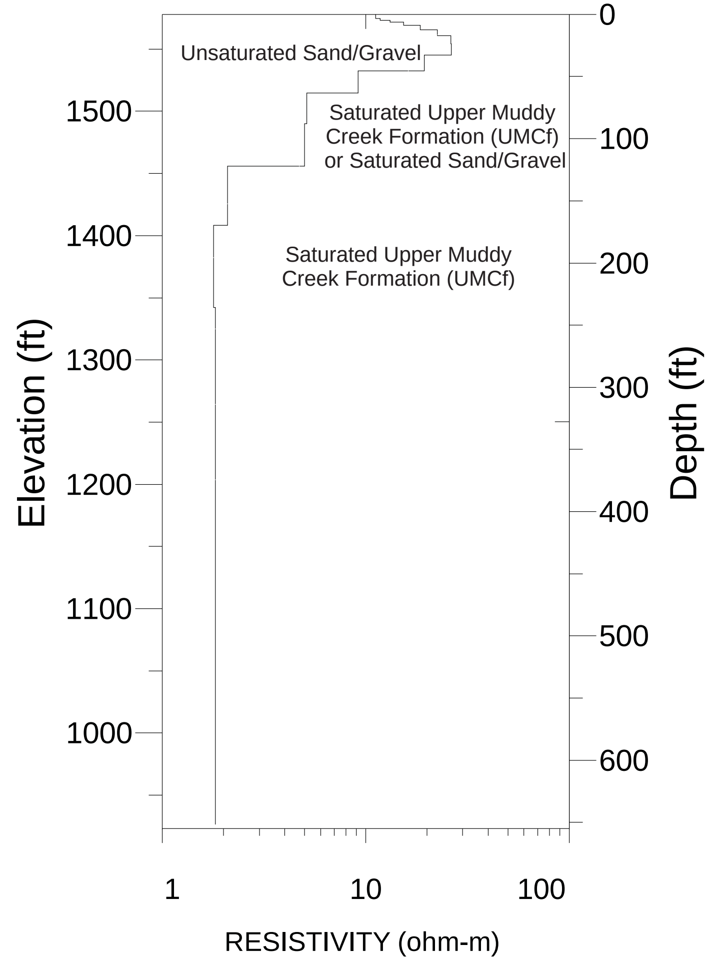
Figure 14

GPT-4 Resistivity Model Sections
GEO*Vision* Project No. 16374

PROJECT SITE
HENDERSON, NV

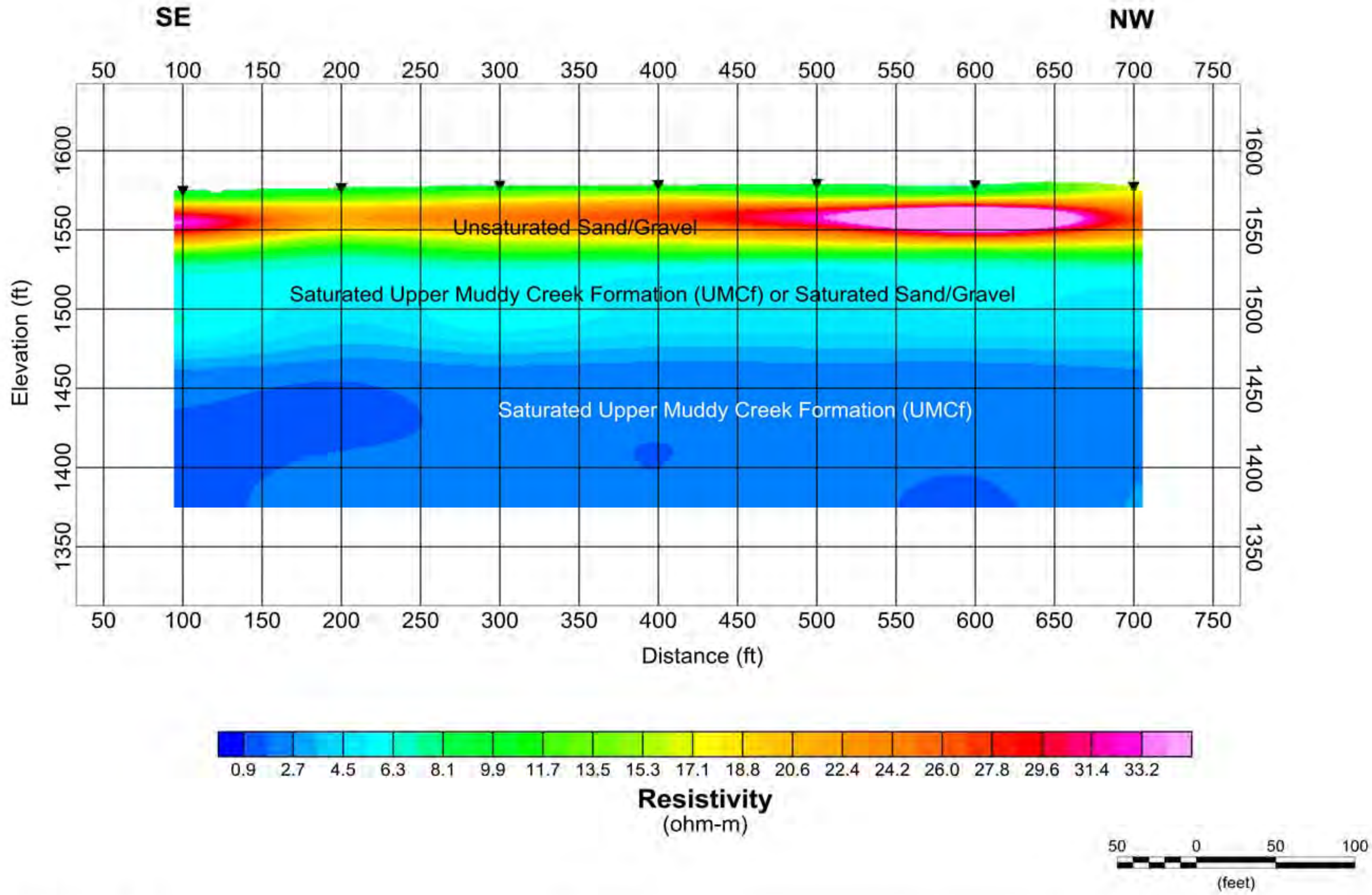
Prepared for AECOM





GEOVision geophysical services

Project No. 16374	FIGURE 15 EXAMPLE 1D SMOOTH TDEM MODEL: GPT-4-TDEM-400
Date: JAN 4, 2017	LAS VEGAS WASH HENDERSON, NEVADA
Drawn By: DALRYMPLE	
Approved By: MARTIN	PREPARED FOR AECOM, INC.
File P:\2016\16374 - AECOM...\F15.cdr	



LEGEND

▼ TDEM Sounding Location

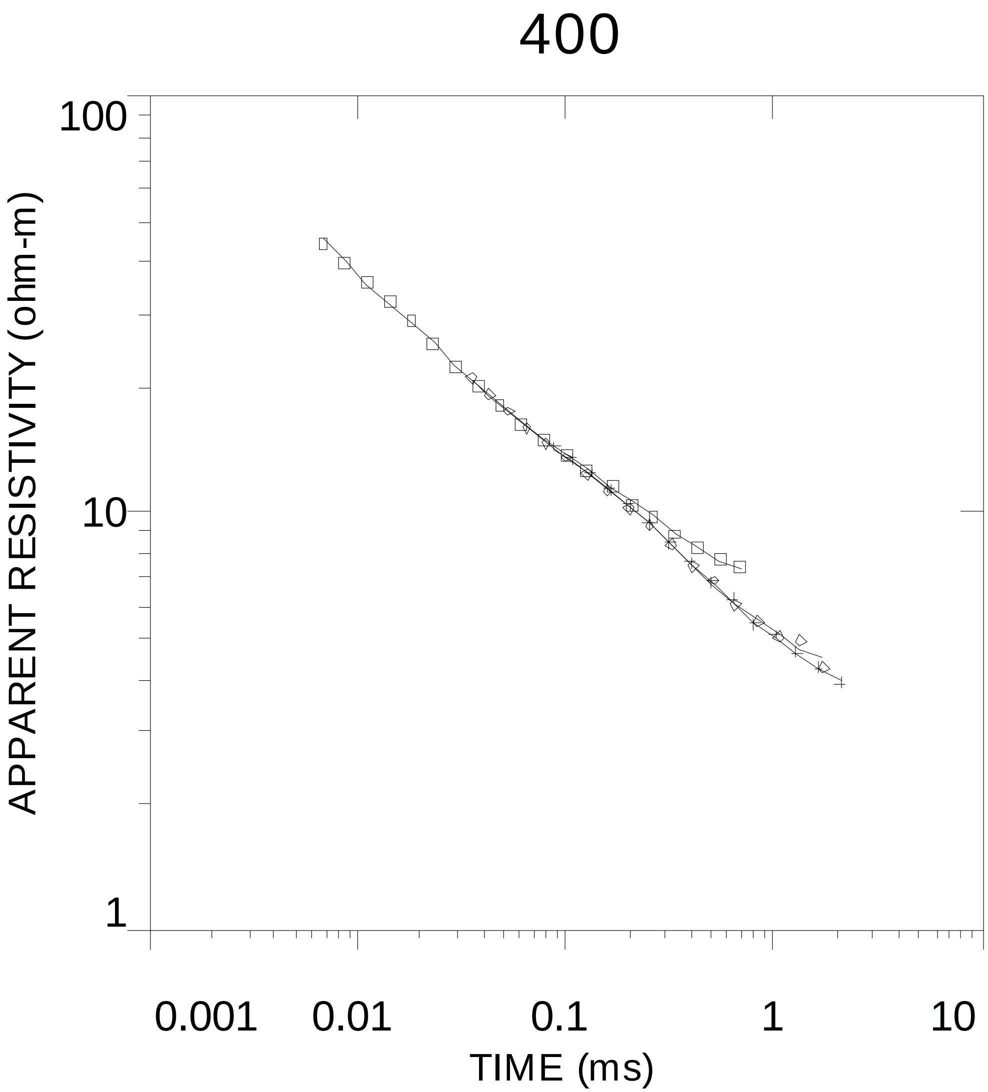
GEOVision geophysical services

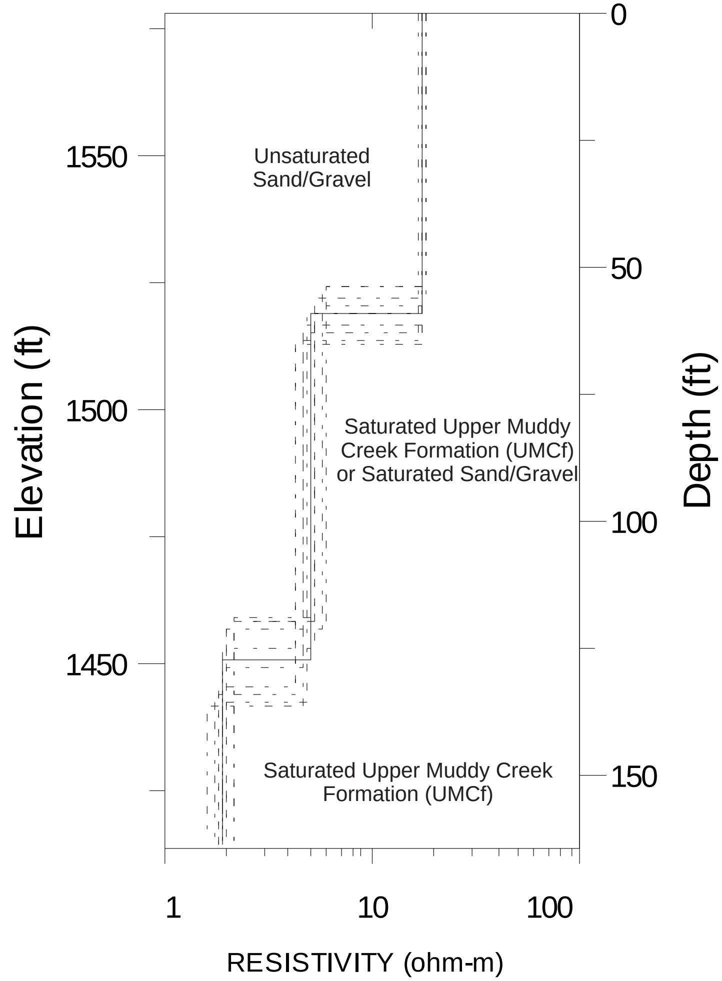
Figure 16

GPT-4: Geoelectric Section From 1D Smooth TDEM Model
GV Project No. 16374

Las Vegas Wash
Henderson, Nevada

Prepared for AECOM, Inc.





GEOVision geophysical services

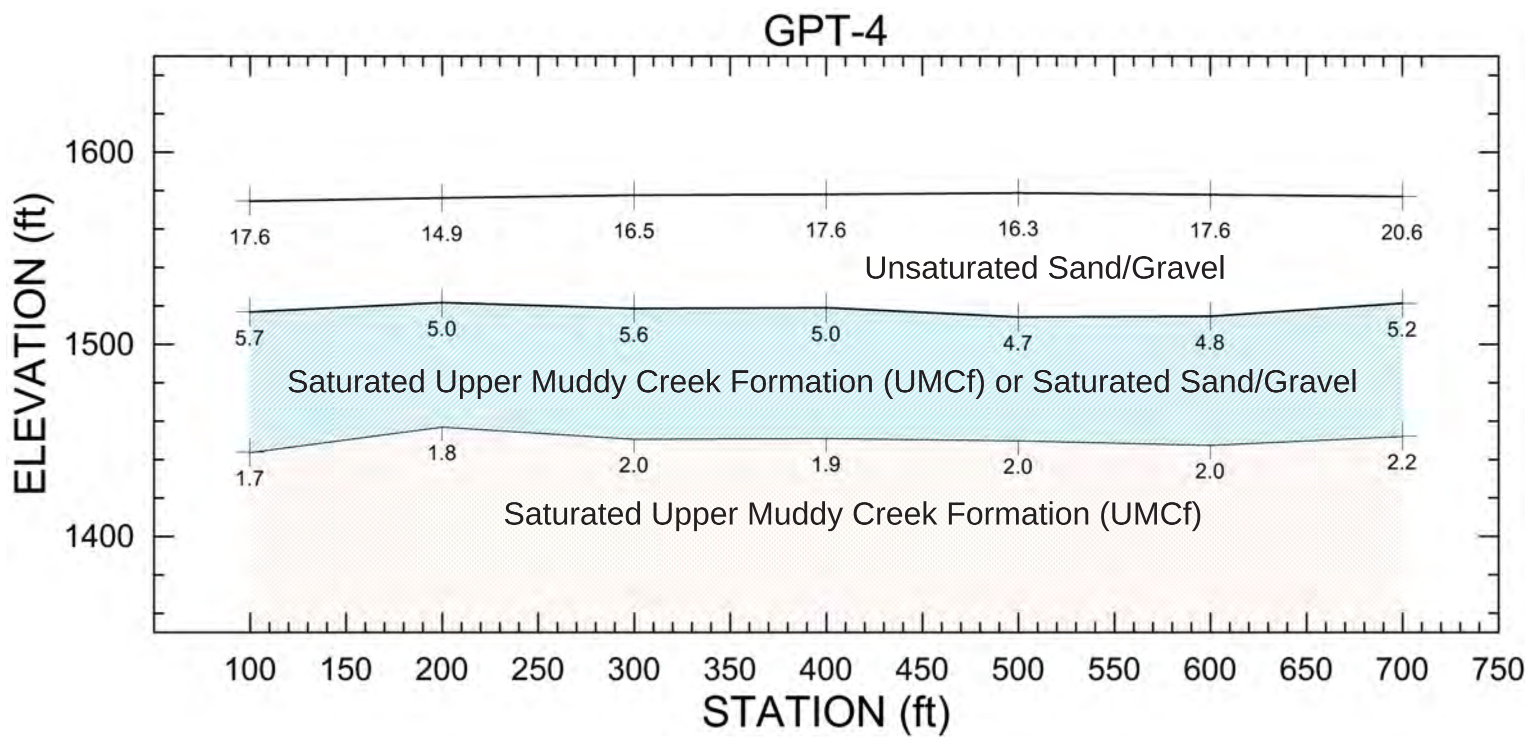
FIGURE 17
EXAMPLE 1D LAYERED TDEM MODEL:
GPT-4-TDEM-400

Project No. 16374
Date: DEC 30, 2016
Drawn By: DALRYMPLE
Approved By: MARTIN
File P:\2016\16374 - AECOM...\F17.cdr

LAS VEGAS WASH
HENDERSON, NEVADA

PREPARED FOR
AECOM, INC.

SE NW



GEOVision geophysical services

Project No. 16374	FIGURE 18 GPT-4: TDEM 1D LAYERED MODEL INVERSION
Date: DEC 30, 2016	LAS VEGAS WASH HENDERSON, NEVADA
Drawn By: DALRYMPLE	
Approved By: MARTIN	PREPARED FOR AECOM, INC.
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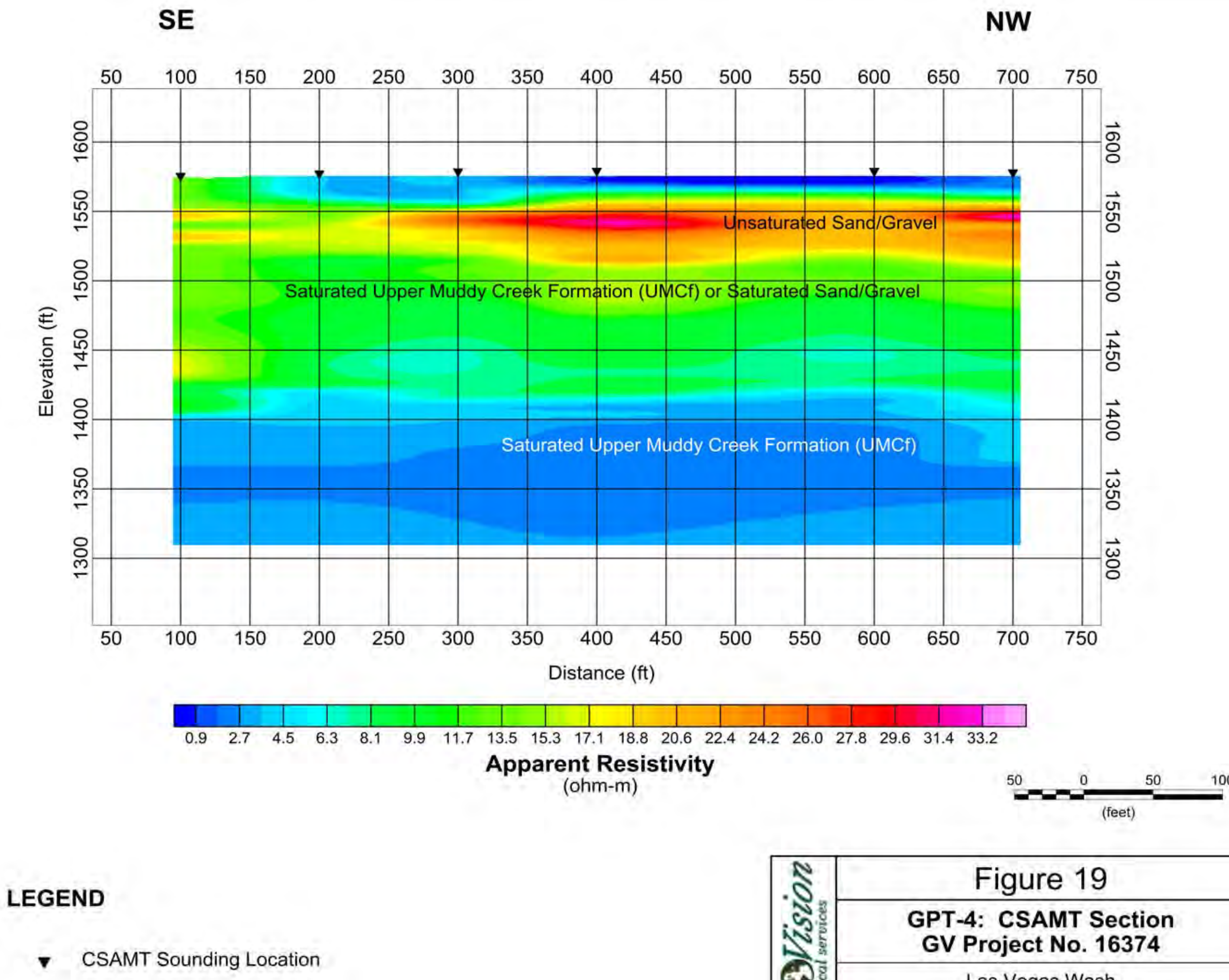

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Figure 19

GPT-4: CSAMT Section
GV Project No. 16374

Las Vegas Wash
Henderson, Nevada

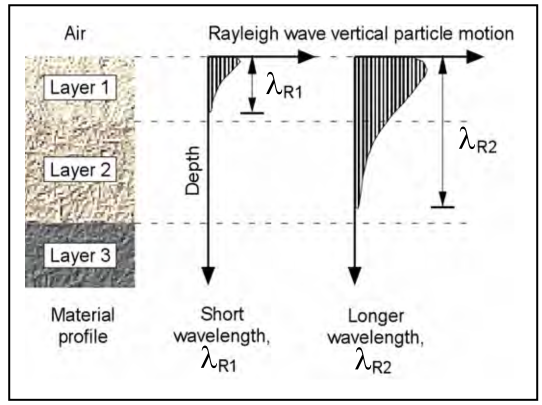
Prepared for AECOM, Inc.

APPENDIX A
Technical Notes

ACTIVE AND PASSIVE SURFACE WAVE TECHNIQUES

Overview

Active and passive surface wave techniques are relatively new in-situ seismic methods for determining shear wave velocity (V_S) profiles. Testing is performed on the ground surface, allowing for less costly measurements than with traditional borehole methods. The basis of surface wave techniques is the dispersive characteristic of Rayleigh waves when traveling through a layered medium. Rayleigh wave velocity is determined by the material properties (primarily shear wave velocity, but also to a lesser degree compression wave velocity and material density) of the subsurface to a depth of approximately 1 to 2 wavelengths. As shown in the adjacent diagram, longer wavelengths penetrate deeper and their velocity is affected by the material properties at greater depth. Surface wave testing consists of measuring the surface wave dispersion curve at a site and modeling it to obtain the corresponding shear wave velocity profile.



Active Surface Wave Techniques

Active surface wave techniques measure surface waves generated by dynamic sources such as hammers, weight drops, electromechanical shakers, vibroseis and bulldozers. These techniques include the spectral analysis of surface waves (SASW) and multi-channel array surface wave (MASW) methods.

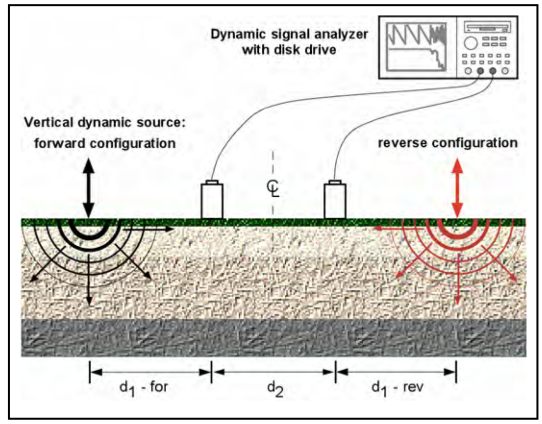
Hammer Energy Sources

Accelerated Weight Drop

Electromechanical Shaker

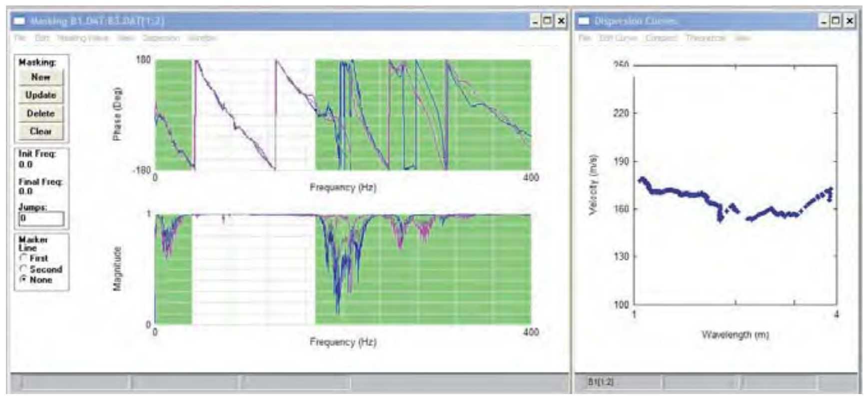
Bulldozer Energy Source

The SASW method is optimized for conducting V_S depth soundings. A dynamic source is used to generate surface waves of different wavelengths (or frequencies) which are monitored by two or more receivers at known offsets. An expanding receiver spread and optimized source-receiver geometry are used to minimize near field effects, body wave signal and attenuation. A dynamic signal analyzer is typically used to calculate the phase and coherence of the cross spectrum of the time history data collected at a pair of receivers. During data analysis, an interactive masking process is used to discard low quality data and to unwrap the phase spectrum, as shown in the figure below. The dispersion curve (Rayleigh wave phase velocity versus frequency or alternatively wavelength) is calculated from the unwrapped phase spectrum.



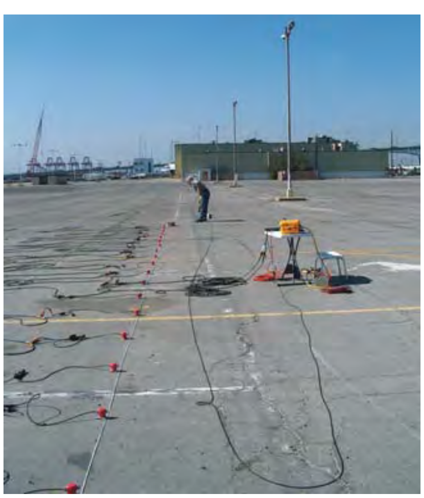
SASW Setup

HP Dynamic Signal Analyzer

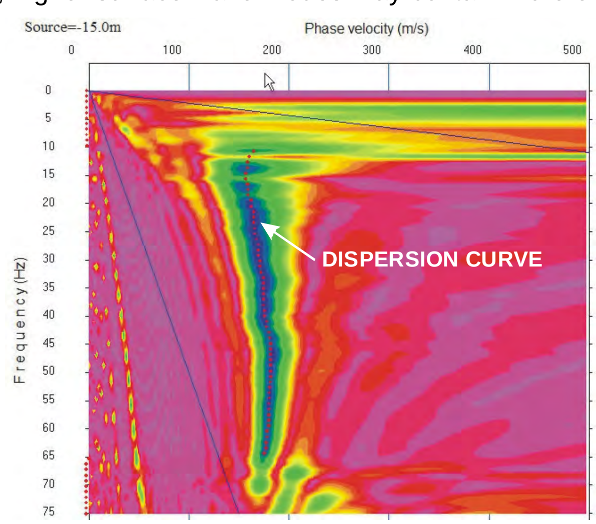


Masking of Wrapped Phase Spectrum and Resulting Dispersion Curve

The MASW field layout is similar to that of the seismic refraction technique. Twenty four, or more, geophones are laid out in a linear array with 1 to 2m spacing and connected to a multi-channel seismograph as shown below. This technique is ideally suited to 2D V_S imaging, with data collected in a roll-along manner similar to that of the seismic reflection technique. The source is offset at a predetermined distance from the near geophone usually determined by field testing. The Rayleigh wave dispersion curve is obtained by a wavefield transformation of the seismic record such as the f-k or τ-p transforms. These transforms are very effective at isolating surface wave energy from that of body waves. The dispersion curve is picked as the peak of the surface wave energy in slowness (or velocity) – frequency space as shown. One advantage of the MASW technique is that the wavefield transformation may not only identify the fundamental mode but also higher modes of surface waves. At some sites, particularly those with large velocity inversions, higher surface wave modes may contain more energy than the fundamental mode.



MASW Field Setup

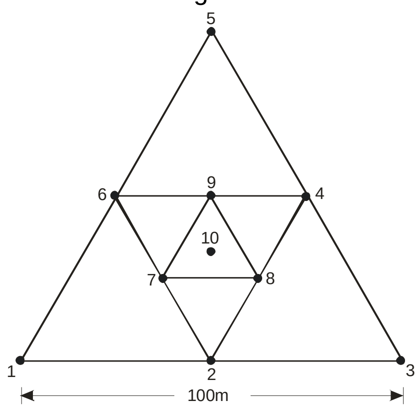


Wavefield Transform of MASW data

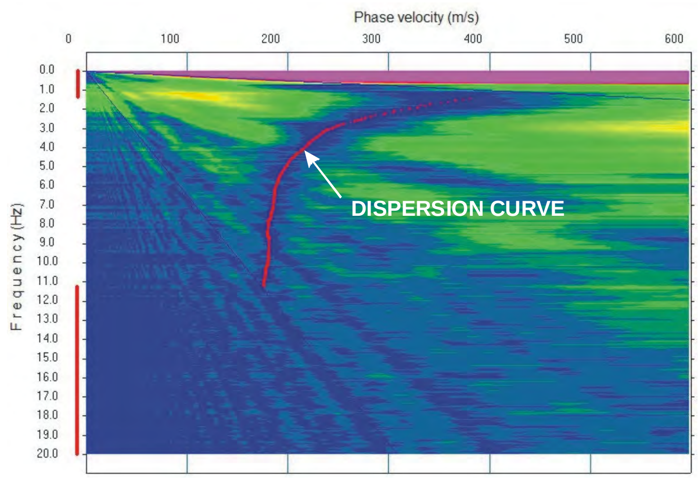
Passive Surface Wave Techniques

Passive surface wave techniques measure noise; surface waves from ocean wave activity, traffic, factories, etc. These techniques include the array microtremor and refraction microtremor (REMI) techniques.

The array microtremor technique typically uses 7 or more 4.5- or 1-Hz geophones arranged in a two-dimensional array. The most common arrays are the triangle, circle, semi-circle and "L" arrays. The triangle array, which consists of several embedded equilateral triangles, is often used as it provides good results with a relatively small number of geophones. With this array the outer side of the triangle should be at least as long as the desired depth of investigation. Typically, fifteen to twenty 30-second noise records are acquired for analysis. The spatial autocorrelation (SPAC) technique is one of several methods that can be used to estimate the Rayleigh wave dispersion curve. A first order Bessel function is fit to the SPAC function to determine the phase velocity for particular frequency. The image shown below shows the degree of fitness of the Bessel function to the SPAC function for a wide range of phase velocity and frequency. The dispersion curve, is the peak (best fit), as shown in the figure below.

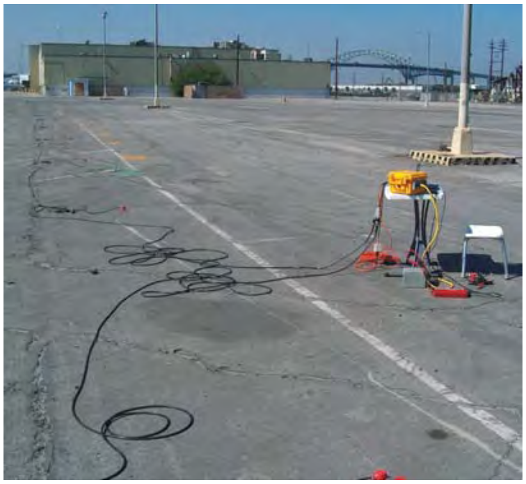


Triangle Array Geometry

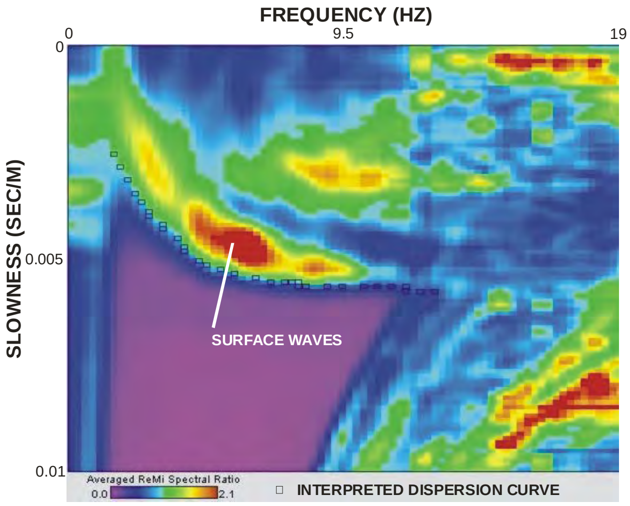


Dispersion Curve from Array Microtremor Measurements

The refraction microtremor (REMI) technique uses a field layout similar to the seismic refraction method (hence its name). Twenty-four, 4.5 Hz geophones are laid out in a linear array with a spacing of 6 to 8m and fifteen to twenty 30-second noise records are acquired. A slowness-frequency (p-f) wavefield transform is used to separate Rayleigh wave energy from that of other waves. Because the noise field can originate from any direction, the wavefield transform is conducted for multiple vectors through the geophone array, all of which are summed. The dispersion curve is defined as the lower envelope of the Rayleigh wave energy in p-f space. Because the lower envelope is picked rather than the energy peak (energy traveling along the profile is slower than that approaching from an angle), this technique may be somewhat more subjective than the others, particularly at low frequencies. The SPAC technique can also be used to extract the surface wave dispersion curve from linear array microtremor data providing there are omni-directional noise sources.



Refraction Microtremor Array Layout



Wavefield Transform of REMI Data

Depth of Investigation
Active surface wave investigations typically use various sized sledge hammers to image the shear wave velocity structure to depths of up to 15m. Weight drops and electromechanical shakers can often be used to image to depths of 30m. Bulldozers and vibroseis trucks can be used to image to depths as great as 100m. Passive surface wave techniques can often image shear wave velocity structure to depths of over 100m, given sufficient noise sources and space for the receiver array. Large passive arrays, utilizing long-period seismometers with GPS clocks have been used to image shear wave velocity structure to depths of several kilometers.

Combined Active and Passive Surface Wave Testing
The combined use of active and passive techniques may offer significant advantages on many investigations. It can be very costly to mobilize large energy sources for 30m/100ft active surface wave soundings. In urban environments, the combined use of active and passive surface wave techniques can image to these depths without the need for large energy sources. We have found that dispersion curves from active and passive surface wave techniques are generally in good agreement, making the combined use of the two techniques viable. It is not recommended that passive surface wave techniques be applied alone for UBC/IBC site classification investigations. Microtremor techniques do not generally characterize near surface velocity, which may have a significant impact of the average shear wave velocity of the upper 30m or 100ft and so should always be used in conjunction with SASW or MASW. An SASW sounding to a depth of 30m requires at least a 60m linear array. If sufficient space is not available for this, it may be possible to use a 45m triangle array on the site or place a 100-200m long REMI array along an adjacent sidewalk or an "L" array at an adjacent street intersection.

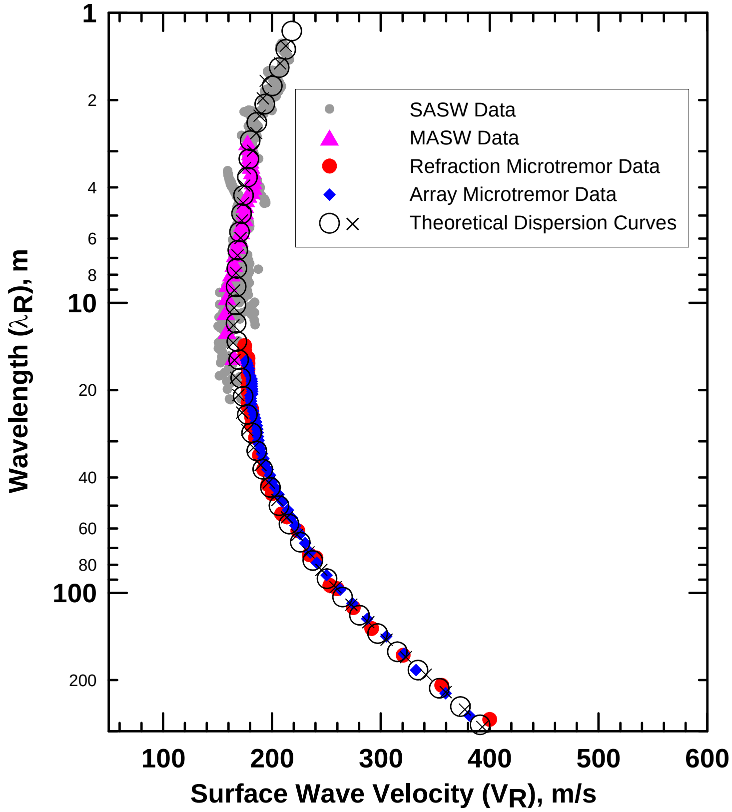
Microtremor Measurements along Sidewalk

Modeling
There are several options for interpreting surface wave dispersion curves, depending on the accuracy required in the shear wave velocity profile. A simple empirical analysis can be done to estimate the average shear wave velocity profile. For greater accuracy, forward modeling of fundamental-mode Rayleigh wave dispersion as well as full stress wave propagation can be performed using several software packages. A formal inversion scheme may also be used. With many of the analytical approaches, background information on the site can be incorporated into the model and the resolution of the final profile may be quantified.

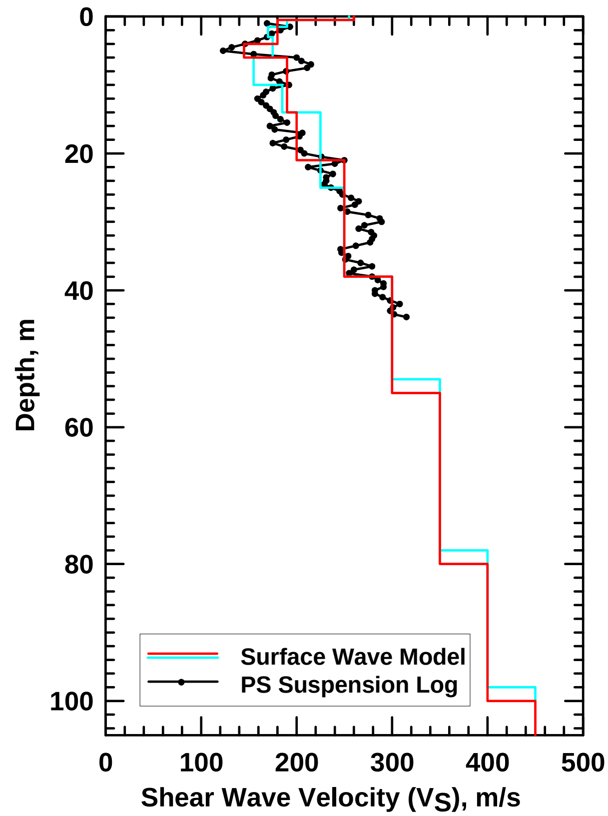
Applications
Active and passive surface wave testing can be used to obtain V_S profiles for:

- UBC/IBC site classification for seismic design
- Earthquake site response
- Seismic microzonation
- Liquefaction analysis
- Soil compaction control
- Mapping subsurface stratigraphy
- Locating potentially weak zones in earthen embankments and levees

Case History
The figures below show the surface wave dispersion curves and alternative shear wave velocity models for a site in Los Angeles, California. All of the previous figures illustrating SASW, MASW, array and refraction microtremor techniques were from this site. The dispersion curves from all four methods are shown on the left along with the theoretical dispersion curves for alternative S-wave velocity versus depth models on the right. Conditions at this site were very poor for active surface wave techniques because of the presence of very low velocity hydraulic fill. In fact, with active surface wave techniques it was only possible to image to a depth of about 12.5m with energy sources typically capable of imaging to 30m. There is excellent agreement in the dispersion curves generated from all of the methods over the overlapping wavelength ranges. The minor differences probably result from variable velocity of the hydraulic fill within the sampling volume of the specific methods. Two Vs versus depth models were generated to illustrate the difficulty modeling the highly variable, near surface velocity structure evident in the PS log. The two surface wave models yielded similar values for the average shear-wave velocity of the upper 30m (V_S30), 201 and 202 m/s, illustrating that Vs30 is much more tightly constrained than the actual layer thicknesses and velocities in the models. V_S30 estimated from the PS log (194 m/s) is within 4% of that estimated from the two surface wave models (201 and 202 m/s). The small differences in V_S30 between the two methods may easily result from the different sampling regimes (borehole versus large area) rather than errors in either of the methods.



Field Data and Theoretical Dispersion Curve



V_S Model

In contrast to borehole measurements which are point estimates, surface wave testing is a global measurement, that is, a much larger volume of the subsurface is sampled. The resulting profile is representative of the subsurface properties averaged over distances of up to several hundred feet. Although surface wave techniques do not have the layer sensitivity or accuracy (velocity and layer thickness) of borehole techniques; the average velocity over a large depth interval (i.e. the average shear wave velocity of the upper 30m or 100ft) is very well constrained. Because surface wave methods are non-invasive and non-destructive, it is relatively easy to obtain the necessary permits for testing. At sites that are favorable for surface wave propagation, active and passive surface wave techniques allow appreciable cost and time savings.

SEISMIC REFRACTION METHOD

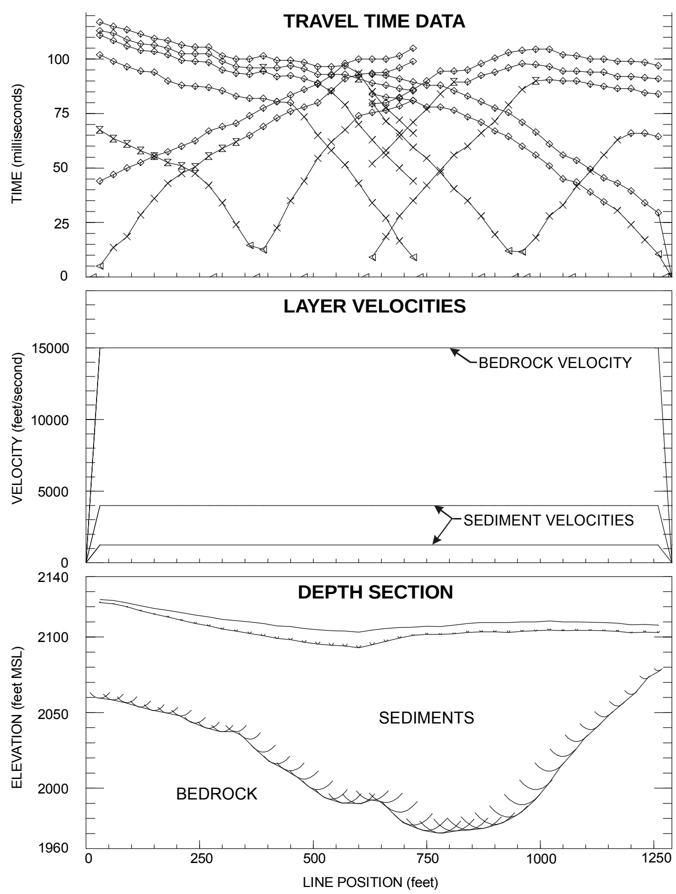
GEO*Vision* geophysicists conduct high-resolution seismic refraction surveys in support of a variety of engineering, environmental, and hydrogeologic investigations.

When conducting seismic surveys, acoustic energy is input to the subsurface by an energy source such as a sledgehammer impacting a metallic plate, weight drop, vibratory source, or explosive charge. The acoustic waves propagate into the subsurface at a velocity dependent upon the elastic properties of the material through which they travel. When the waves reach an interface where the density or velocity changes significantly, a portion of the energy is reflected back to the surface, and the remainder is transmitted into the lower layer. Where the velocity of the lower layer is higher than that of the upper layer, a portion of the energy is also critically refracted along the interface. Critically refracted waves travel along the interface at the velocity of the lower layer and continually refract energy back to surface. Receivers (geophones), laid out in linear array on the surface, record the incoming refracted and reflected waves. The seismic refraction method involves analysis of the travel times of the first energy to arrive at the geophones. These first arrivals are from either the direct wave (at geophones close to the source), or critically refracted waves (at geophones further from the source). The seismic reflection method involves the analysis of reflected waves, which occur later in the seismic record.

Seismic Refraction Survey in the Borrego Valley

GEO*Vision* **geophysicists use the seismic refraction method to:**

- **Map bedrock topography**
- **Map faults in bedrock**
- **Characterize landslides**
- **Estimate depth to groundwater**
- **Estimate bedrock rippability**
- **Evaluate rock properties**



Seismic Refraction Survey to Map Bedrock Topography

GEO*Vision* seismic refraction equipment includes:

- 96-channel Oyo DAS-1 seismograph
- two 24 channel Geometrics Geode seismographs
- seismic refraction cables with 15 to 50-foot takeouts
- 4.5, 8 and 10-Hz geophones
- two accelerated weight drop energy sources
- Betsy downhole percussion firing rod
- Radio trigger and high-voltage blaster

"a bold new vision in geophysical services"

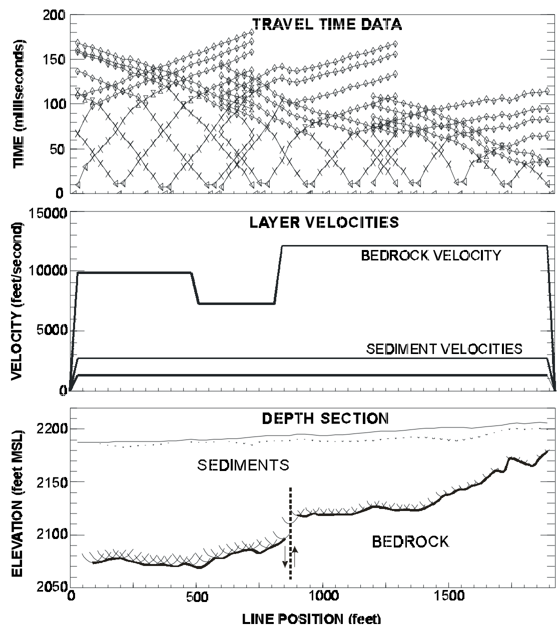
GEO*Vision* maintains several software packages to process seismic refraction data. These software packages include:

- FIRSTPIX™ by Interpex, Ltd.
- IXRefraX by Interpex, Ltd.
- VIEWSEIS™ by Viewlog Systems, Ltd.
- SeisImager by Geometrics Inc./Oyo Corporation
- Rayfract™ by Intelligent Resources, Inc.
- SeisOpt Pro ™ by Optim LLC

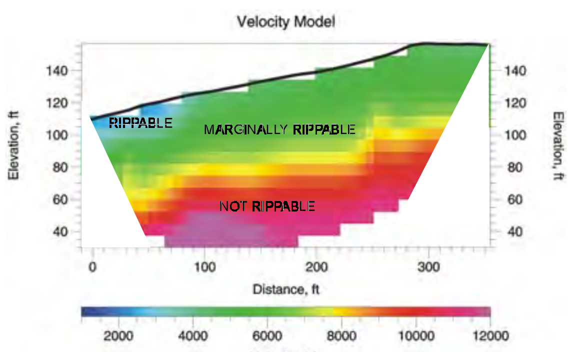
Accelerated Weight Drop Energy Source

These software packages allow us to process seismic refraction data using the following layer-based and velocity gradient (smooth model) techniques:

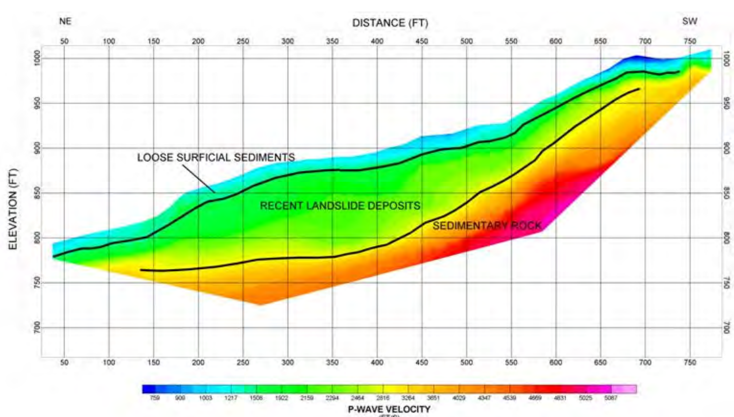
- Generalized reciprocal method (GRM)
- Reciprocal method/Delay time method
- Time-Term method
- Plus-Minus Method
- Wavefront Method
- Monte Carlo based inversion
- Delta t-V tomographic inversion
- Wavepath Eikonal Traveltime tomographic inversion
- Nonlinear traveltime tomographic analysis



Seismic Refraction Survey to Map Fault



Seismic Refraction Survey to Map Ribbability



Seismic Refraction Survey Characterize Landslide

ELECTRICAL RESISTIVITY METHOD

GEO*Vision* *geophysical services*

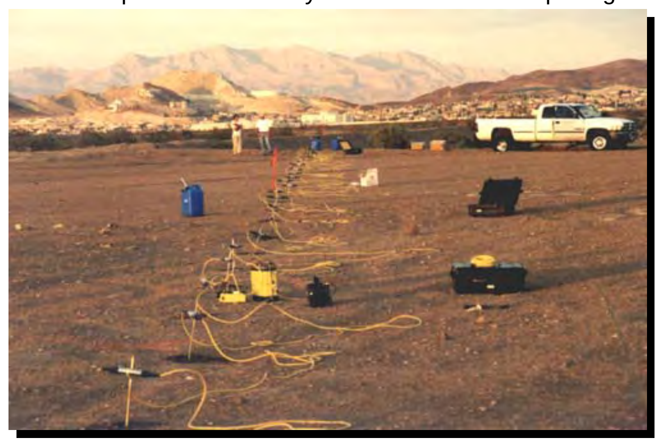
The electrical resistivity method involves measuring the apparent resistivity of soils and rock as a function of depth or position. The resistivity of soils is a complicated function of porosity, permeability, ionic content of the pore fluids, and clay mineralization. The most common electrical methods used in hydrogeologic and environmental investigations are vertical electrical soundings (resistivity soundings) and resistivity profiling.

During a resistivity survey, current is injected into the earth through a pair of current electrodes, and the potential difference is measured between a pair of potential electrodes. The current and potential electrodes are generally arranged in a linear array. Common arrays include the dipole-dipole array, pole-pole array, Schlumberger array, and the Wenner array. The apparent resistivity is the bulk average resistivity of all soils and rock influencing the current. It is calculated by dividing the measured potential difference by the input current and multiplying by a geometric factor specific to the array used and electrode spacing.

In a resistivity sounding, the distance between the current electrodes and the potential electrodes is systematically increased, thereby yielding information on subsurface resistivity from successively greater depths. The variation of resistivity with depth is modeled using forward and inverse modeling computer software.

GEO*Vision* applies resistivity sounding techniques to:

- Characterize subsurface hydrogeology
  - Determine depth to bedrock/overburden thickness
  - Determine depth to groundwater
  - Map stratigraphy
  - Map clay aquitards
  - Map saltwater intrusion
- Map vertical extent of certain types of soil and groundwater contamination
- Estimate landfill thickness



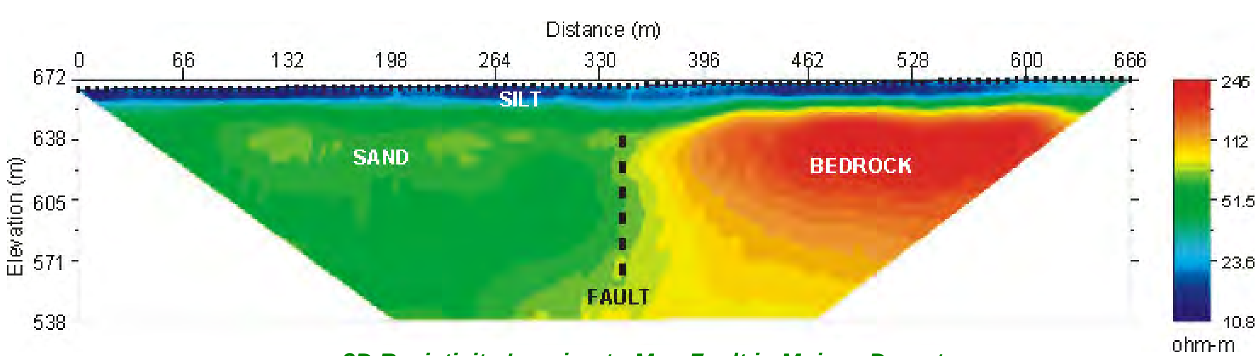
AGI Resistivity Imaging System

In resistivity profiling, the electrode spacing is fixed and measurements are taken at successive intervals along a profile. Data are generally presented as profiles or contour maps and interpreted qualitatively.

When information on both the horizontal and vertical extent of a subsurface feature is desired, it is common to combine the sounding and profiling techniques. This technique is commonly referred to as resistivity imaging. Automated data acquisition systems gather all of the desired combinations of current and potential electrodes using arrays programmed by the geophysicist. The resistivity data is then downloaded to a computer and modeled using forward and inverse modeling software. The applications of 2-D and 3-D resistivity techniques are effectively the combined applications of the 1-D sounding and profiling methods discussed above. The 3-D resistivity technique is best applied when the target of interest is truly three-dimensional in nature, such as certain types of contaminant plumes, karst features, etc.

GEO*Vision* applies resistivity profiling techniques to:

- Map faults
- Map lateral extent of conductive contaminant plumes
- Locate oil field sumps and mud pits
- Locate voids and karsts
- Map heavy metals soil contamination
- Delineate disposal areas
- Map paleochannels
- Explore for sand and gravel
- Map archaeological sites

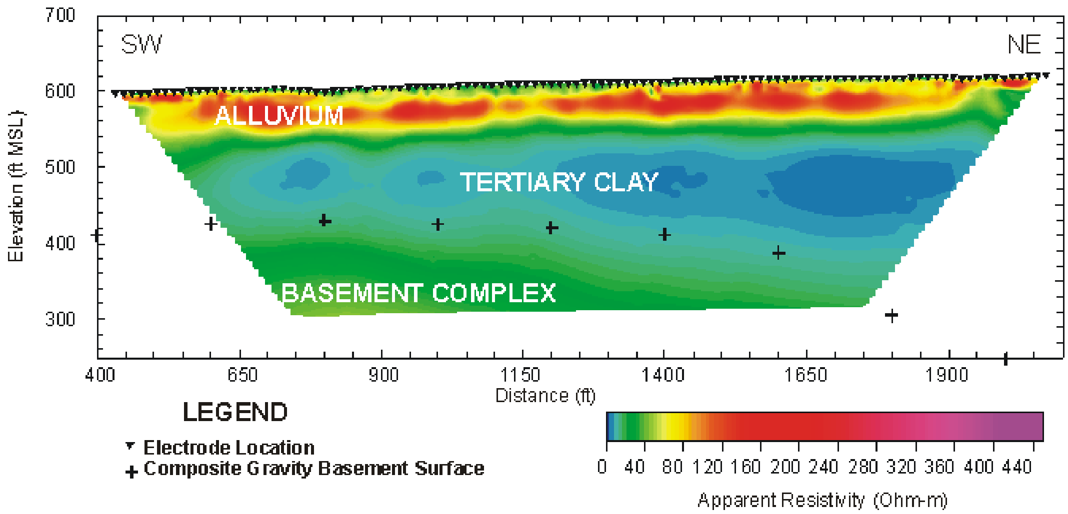


2D Resistivity Imaging to Map Fault in Mojave Desert

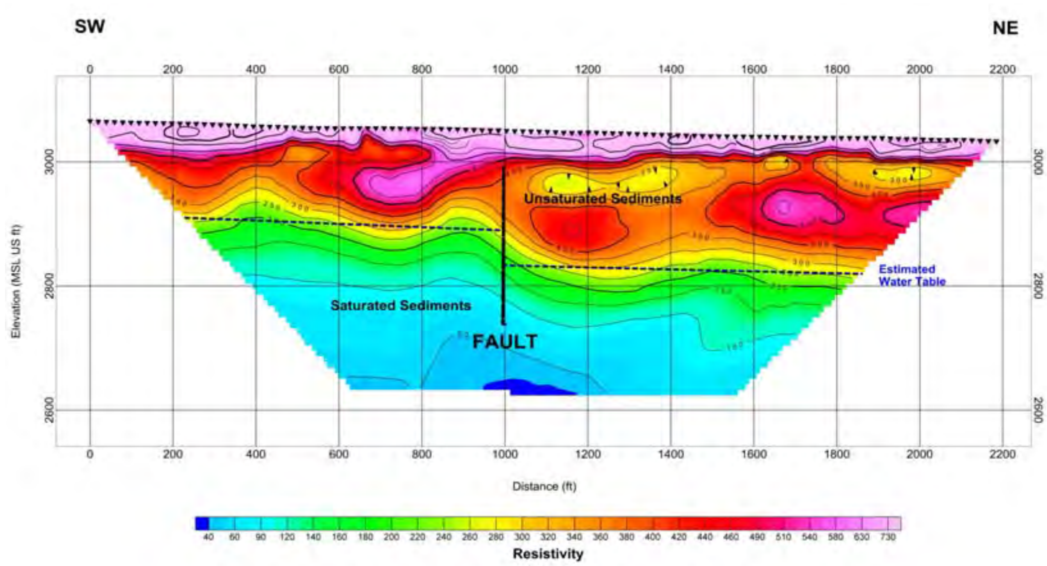
1124 Olympic Drive, Corona, California 92881 ph 951-549-1234 fx 951-549-1236 www.geovision.com

AGI SuperSting R8 112 Electrode Resistivity System

2D Resistivity Imaging to Map Geology in Imperial Valley

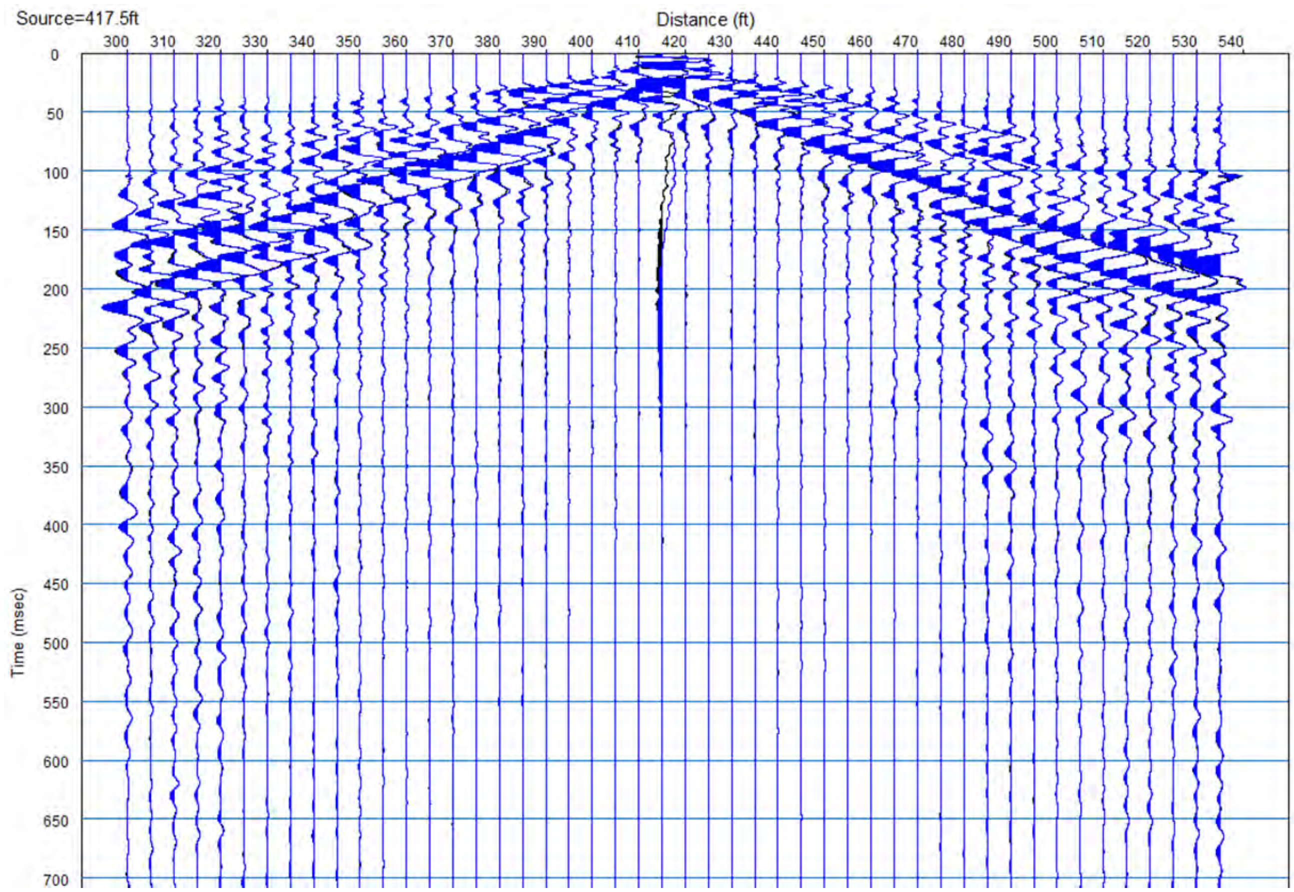


2D Resistivity Imaging to Map Depth to Tertiary Clay Unit and Basement Rock



2D Resistivity Imaging to Map Fault Forming a Groundwater Barrier

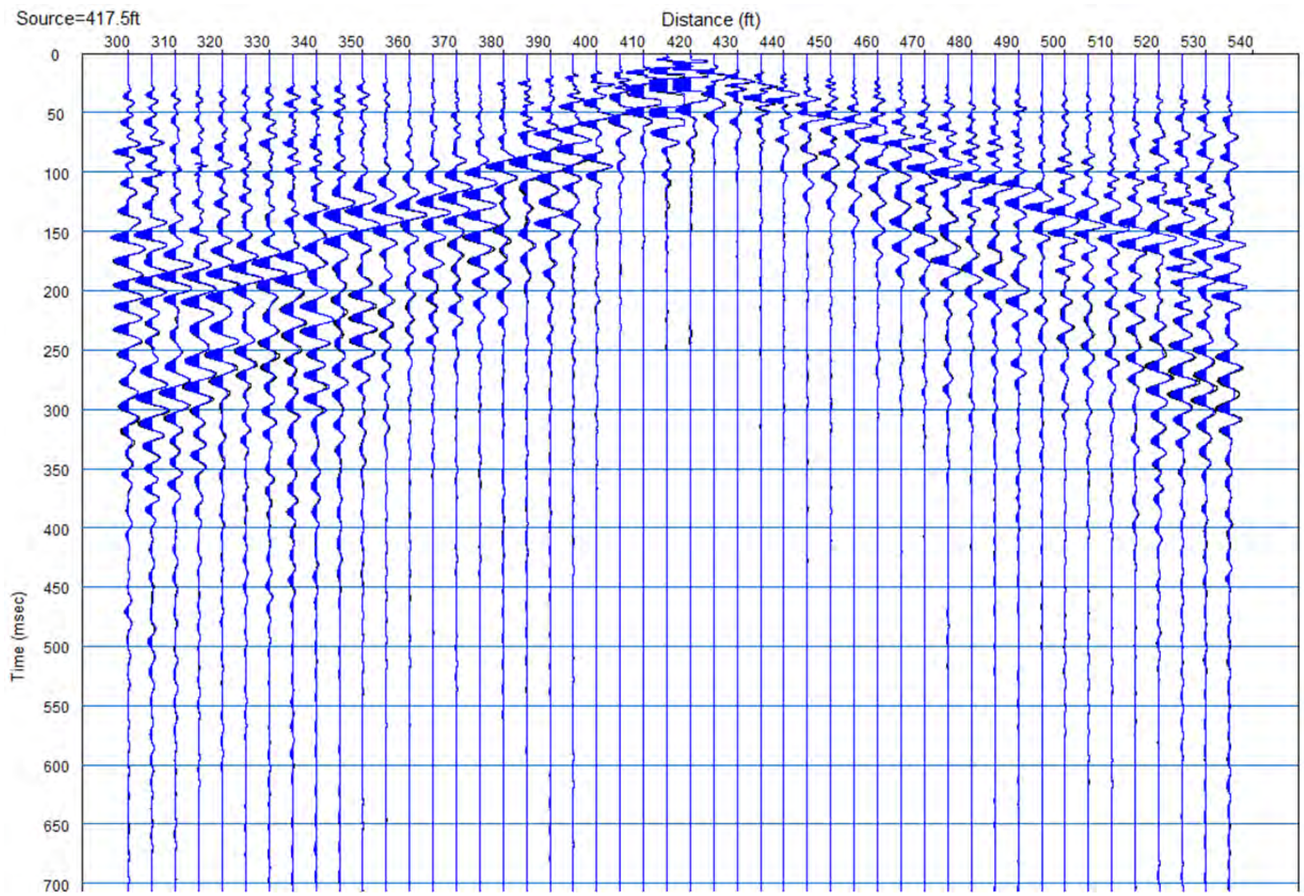
APPENDIX B
Quality Control Results



GPT-2 Multichannel Analysis of Surface Waves (MASW) QC Comparison Overlay
File 2209: GPT-2-MASW-417.5 (Black), File 2210: GPT-2-QC-MASW-417.5 (Blue)

Note:

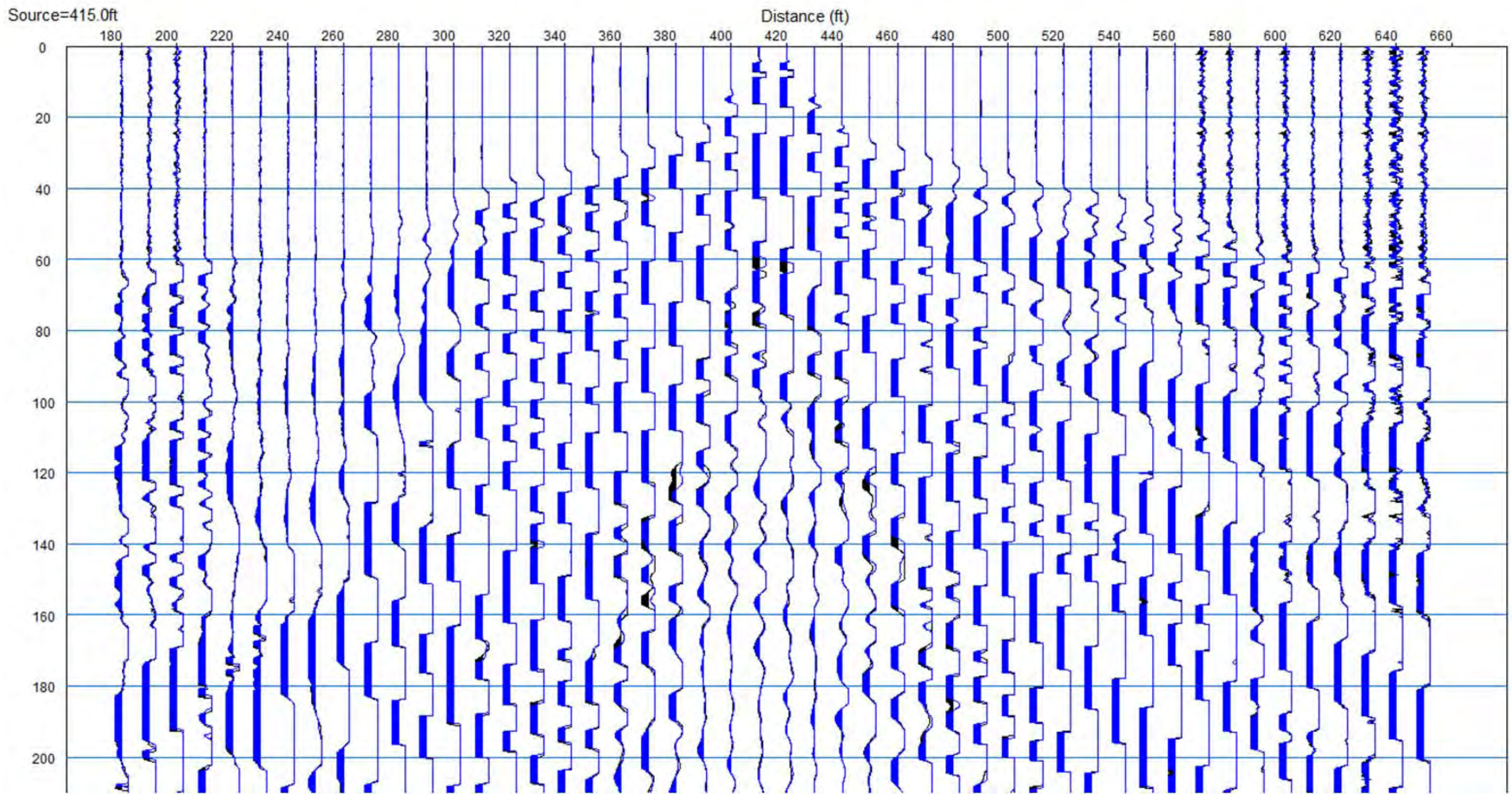
1. Data are consistent between the two files.



GPT-4 Multichannel Analysis of Surface Waves (MASW) QC Comparison Overlay
File 4209: GPT-4-MASW-417.5 (Black), File 4210: GPT-4-QC-MASW-417.5 (Blue)

Note:

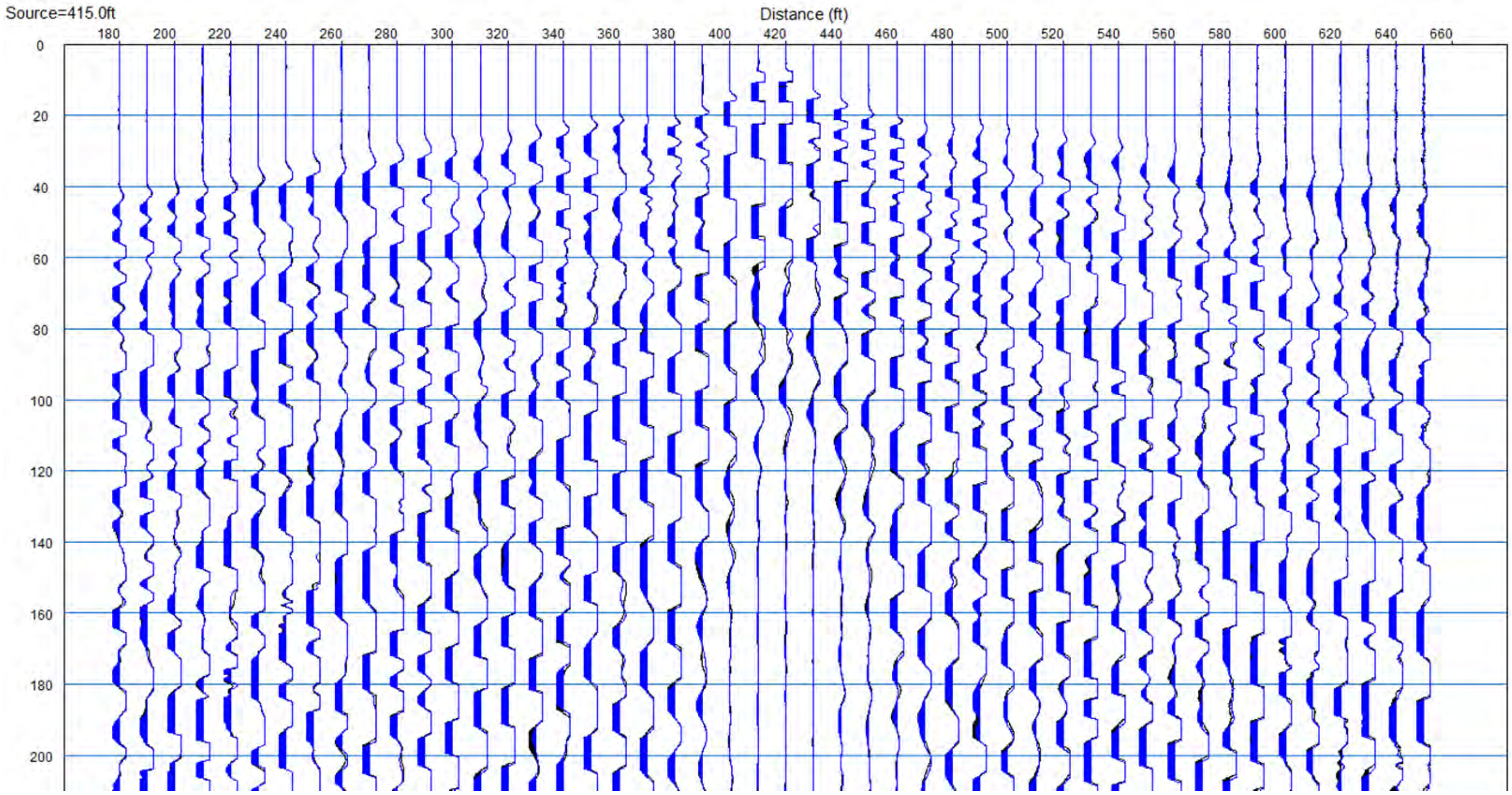
1. Data are consistent between the two files.



GPT-2 Seismic Refraction QC Comparison Overlay
File 2109: GPT-2-REFR-415 (Black), File 2110: GPT-2-QC-REFR-415 (Blue)

Note:

1. First arrival data are consistent between the two files.



GPT-4 Seismic Refraction QC Comparison Overlay
File 4110: GPT-4-REFR-415 (Black), File 4111: GPT-4-QC-REFR-415 (Blue)

Note:

1. First arrival data are consistent between the two files.

TX Index	RX Index	Apparent Resistivity (ohm-m)	QC Apparent Resistivity (ohm-m)	Difference (ohm-m)	Percent Difference
1	2	15.28	15.21	0.07	0.46
1	2	10.84	10.84	0.00	0.00
1	2	6.27	6.32	-0.05	0.76
1	2	3.82	3.83	-0.01	0.14
1	2	3.21	3.23	-0.02	0.47
1	2	3.62	3.62	0.00	0.03
1	2	4.88	4.88	-0.01	0.11
1	2	8.11	8.14	-0.03	0.32
3	2	13.96	13.96	-0.01	0.04
3	2	10.98	11.04	-0.07	0.60
3	2	5.88	5.88	0.00	0.06
3	2	2.93	2.93	0.00	0.01
3	2	2.19	2.18	0.01	0.59
3	2	2.27	2.29	-0.01	0.62
3	2	2.65	2.65	0.00	0.09
3	2	4.78	4.78	0.00	0.07
4	2	10.31	10.30	0.00	0.04
4	2	6.52	6.53	-0.01	0.10
4	2	4.47	4.47	0.00	0.01
4	2	2.74	2.71	0.02	0.91
4	2	2.27	2.27	0.00	0.06
4	2	2.18	2.18	0.00	0.18
4	2	2.57	2.58	-0.01	0.41
4	2	3.30	3.31	0.00	0.10

GPT-2 Electrical Resistivity (Strong Gradient Array) QC Repeat Measurements

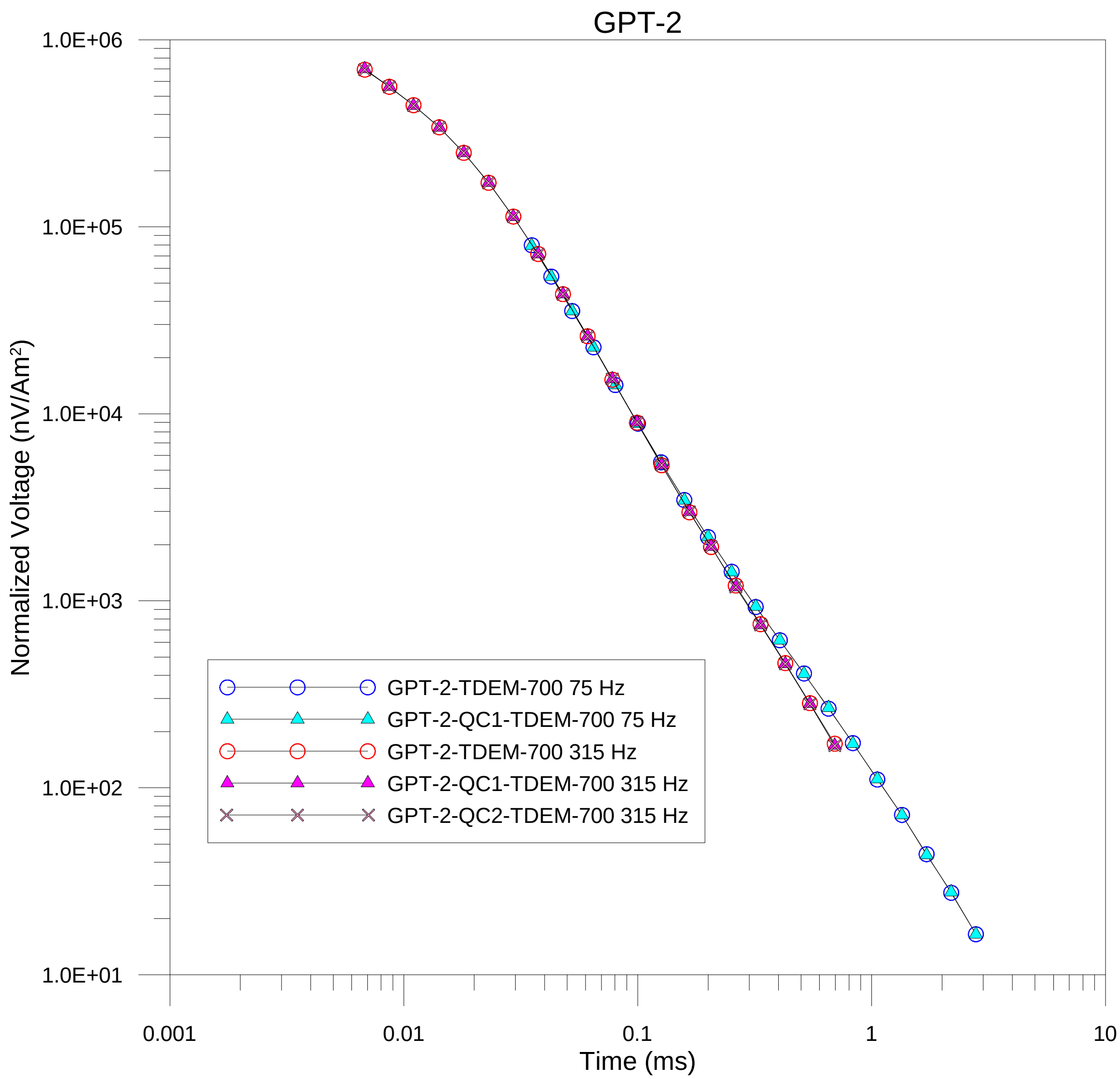
Note:
1. Data between the two measurement sets are consistent.

TX Index	RX Index	Apparent Resistivity (ohm-m)	QC Apparent Resistivity (ohm-m)	Difference (ohm-m)	Percent Difference
1	2	1.70	1.70	0.00	0.08
1	2	1.37	1.37	0.00	0.34
1	2	1.47	1.47	0.00	0.18
1	2	1.57	1.56	0.00	0.13
1	2	1.79	1.79	0.00	0.18
1	2	2.05	2.05	-0.01	0.39
1	2	1.89	1.89	0.00	0.00
1	2	2.02	2.01	0.01	0.36
3	2	1.81	1.81	0.00	0.02
3	2	1.96	1.95	0.00	0.16
3	2	2.22	2.21	0.02	0.85
3	2	2.20	2.20	-0.01	0.36
3	2	2.14	2.14	0.00	0.23
3	2	1.76	1.75	0.00	0.28
3	2	1.74	1.74	0.01	0.33
3	2	1.97	1.97	0.00	0.06
4	2	2.28	2.28	0.00	0.05
4	2	2.16	2.16	0.00	0.02
4	2	1.96	1.96	0.00	0.14
4	2	1.83	1.83	0.00	0.26
4	2	1.91	1.91	0.00	0.03
4	2	2.29	2.29	0.00	0.17
4	2	2.00	2.01	0.00	0.10
4	2	2.22	2.23	-0.01	0.36

GPT-4 Electrical Resistivity (Strong Gradient Array) QC Repeat Measurements

Note:

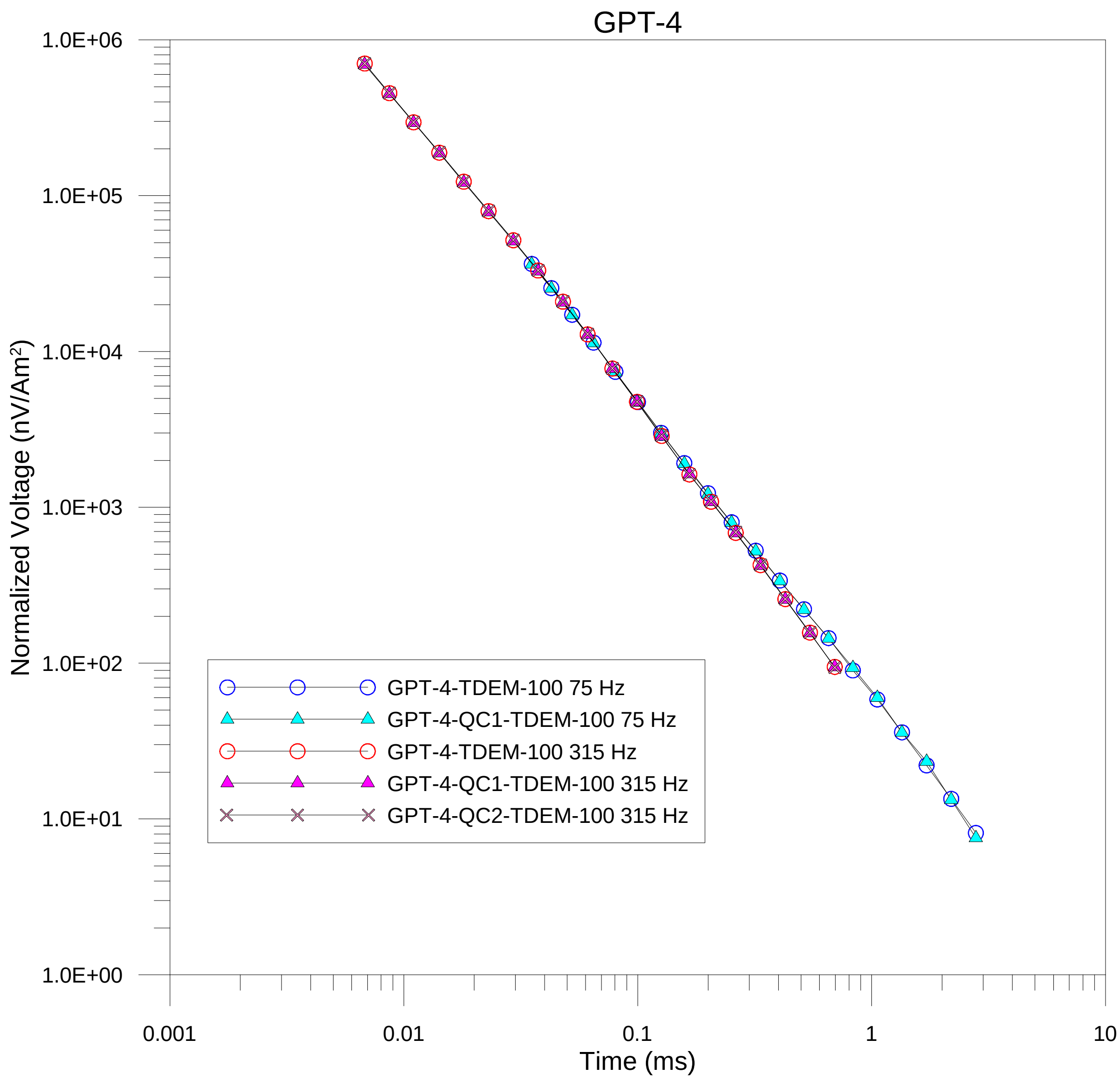
1. Data between the two measurement sets are consistent.



GPT-2 Time-Domain Electromagnetic QC Comparison Overlay

Note:

1. Observed values are consistent between the data sets.



GPT-4 Time-Domain Electromagnetic QC Comparison Overlay

Note:

1. Observed values are consistent between the data sets.

Depth (m)	Apparent Resistivity (ohm-m)	QC Depth (m)	QC Apparent Resistivity (ohm-m)	Depth Difference (m)	Percent Depth Difference	Apparent Resistivity Difference (ohm-m)	Percent Apparent Resistivity Difference
0.6	13.0	-	-	N/A	N/A	N/A	N/A
0.6	13.0	0.6	78.6	0.0	0.0	65.7	83.5
0.7	13.0	0.7	78.6	0.0	1.4	65.7	83.5
0.8	13.0	0.8	78.6	0.0	1.3	65.7	83.5
0.9	13.0	0.9	78.6	0.0	0.0	65.7	83.5
1.0	13.0	1.0	78.6	0.0	0.0	65.7	83.5
1.1	13.0	1.1	78.6	0.0	0.9	65.7	83.5
1.3	13.0	1.3	78.6	0.0	0.8	65.7	83.5
1.4	13.0	1.4	78.6	0.0	1.4	65.7	83.5
1.6	13.0	1.6	78.6	0.0	0.6	65.7	83.5
1.8	13.0	1.8	78.6	0.0	0.6	65.7	83.5
2.0	13.0	2.0	78.6	0.0	0.5	65.7	83.5
2.2	13.0	2.2	78.6	0.0	0.4	65.7	83.5
2.5	13.0	2.5	78.6	0.0	0.8	65.7	83.5
2.8	13.0	2.8	78.6	0.0	0.7	65.7	83.5
3.2	13.0	3.2	78.6	0.0	0.6	65.7	83.5
3.6	13.0	3.5	78.6	0.0	0.8	65.7	83.5
4.0	13.0	4.0	78.6	0.0	0.5	65.7	83.5
4.5	13.0	4.4	78.6	0.0	0.9	65.7	83.5
5.0	13.0	5.0	78.6	0.0	0.6	65.7	83.5
7.6	18.0	7.6	18.0	0.0	0.7	0.1	0.4
8.9	19.4	8.8	18.3	-0.1	1.0	-1.1	5.7
9.9	12.9	9.6	13.3	-0.4	3.9	0.4	3.0
13.8	19.4	13.7	19.6	0.0	0.3	0.3	1.3
15.0	14.3	13.8	15.7	-1.2	8.8	1.4	8.7
17.5	13.6	15.3	14.9	-2.2	14.3	1.3	8.9
19.9	13.5	18.0	14.2	-1.8	10.1	0.7	5.0
22.2	13.3	19.8	13.8	-2.4	12.2	0.5	3.6
26.2	14.2	22.4	14.4	-3.8	17.0	0.2	1.3
30.0	12.3	25.8	12.8	-4.2	16.2	0.5	3.9
43.2	16.8	29.4	11.7	-13.9	47.1	-5.1	43.7
45.8	9.8	33.5	14.4	-12.3	36.6	4.6	31.7
51.4	10.2	36.2	11.5	-15.2	41.9	1.4	11.7
52.4	4.5	38.4	10.0	-14.0	36.4	5.5	54.9
55.2	4.0	44.0	9.3	-11.2	25.4	5.3	56.7
55.4	2.7	47.5	8.9	-8.0	16.8	6.2	70.0
62.4	3.1	51.2	8.7	-11.2	21.9	5.6	64.3
63.8	2.6	52.6	4.6	-11.3	21.4	2.0	44.1
75.6	2.8	55.9	4.1	-19.7	35.3	1.2	30.2
143.4	6.9	64.2	3.3	-79.3	123.6	-3.6	110.3
153.7	16.2	73.3	2.7	-80.3	109.6	-13.5	500.7
219.3	22.1	162.6	17.1	-56.7	34.9	-5.0	29.4
250.0	3.4	191.7	30.5	-58.3	30.4	27.1	88.9

GPT-4 Controlled-Source Audio-Frequency Magnetotellurics (CSAMT) QC Comparison
Location: GPT-4-QC-CSAMT-100
Original Data: File 003 QC Data: File 004

Notes:
1. Measurements depths do not fully match between soundings.
2. Outside and/or transmitter interference appears to have affected the near surface data (upper 5 m).
3. Mid depths (7 to 25 m) have roughly consistent resistivity values.
4. Differences in depths where measurements were taken may attribute to greater error at greater depths.

TIME DOMAIN ELECTROMAGNETIC METHOD

GEOVision geophysical services

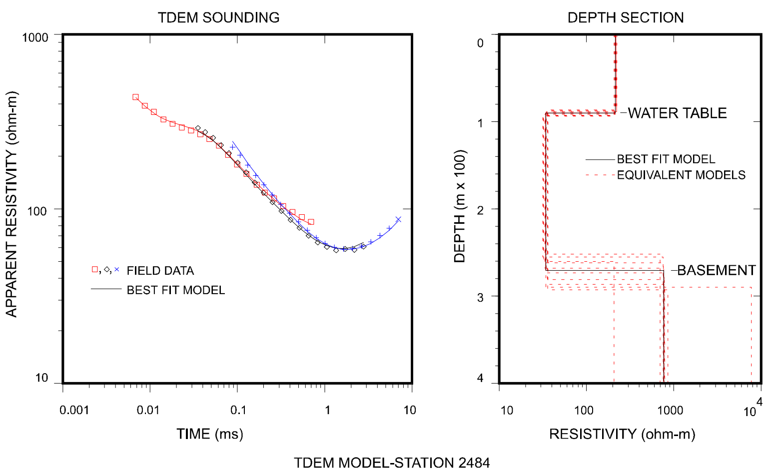
Time-domain electromagnetic (TDEM) surveys are conducted to map changes in resistivity or its inverse, conductivity, with depth. This method is, in effect, an EM equivalent of the resistivity sounding method. TDEM soundings can be made at stations along a profile to yield two-dimensional models of the resistivity structure of the subsurface.

TDEM data are generally modeled using computer inversion techniques, and output is a model of resistivity as a function of depth. These techniques can be used to explore depths ranging from about 30 feet to over 5,000 feet, depending on methodology used.

Geonics TDEM System

Common applications of TDEM methods include:

- Mapping geologic structure
- Mapping large fracture zones
- Imaging deep conductive contaminant plumes such as oil field brines and acid-mine drainage
- Characterizing salt-water intrusion
- Determining depth to groundwater and groundwater resources
- Mapping subsurface stratigraphy
- Characterizing mineral resources



TDEM Sounding to Map Depth to Groundwater and Bedrock

Advantages of TDEM compared to Frequency Domain EM soundings are:

- Lower sensitivity to geologic noise, such as variation in overburden thickness and lateral changes in overburden conductivity
- Greater depths of penetration than conventional FDEM instrumentation
- Smaller transmitter-receiver separation for equivalent depth
- More suited to mapping variation of electrical resistivity versus depth
- Minimal land survey requirements because the method is less sensitive to topographic relief

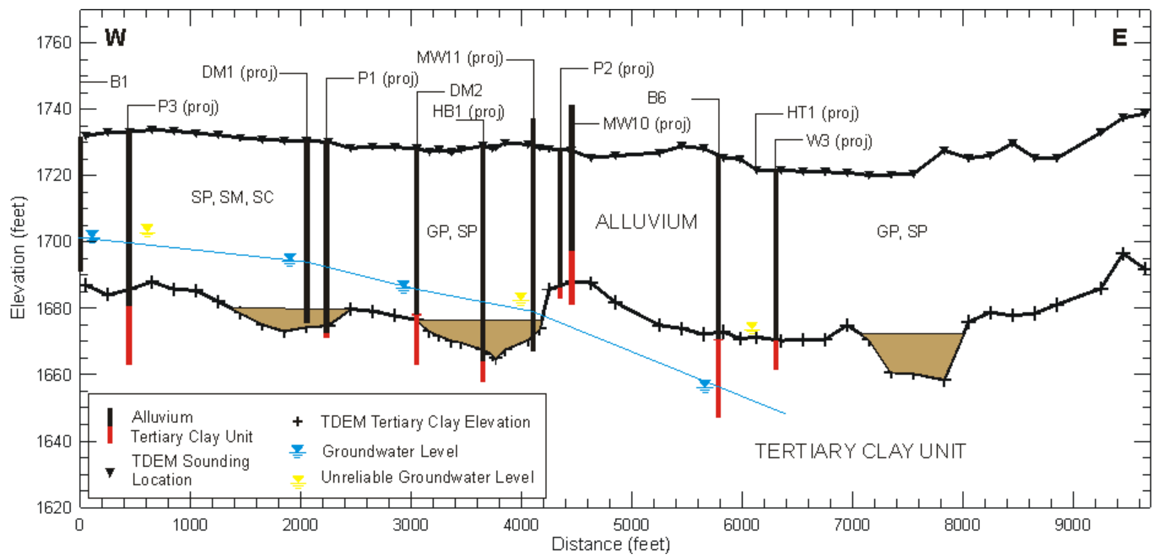
Advantages of TDEM compared to DC resistivity are:

- Has better lateral and vertical resolution for deeper targets
- More rapid data collection
- Electrode stakes are not necessary for electrical contact, meaning that there are no problems injecting current into a resistive surface area
- Better depth of investigation with portable equipment
- Better at mapping conductive targets, such as clay

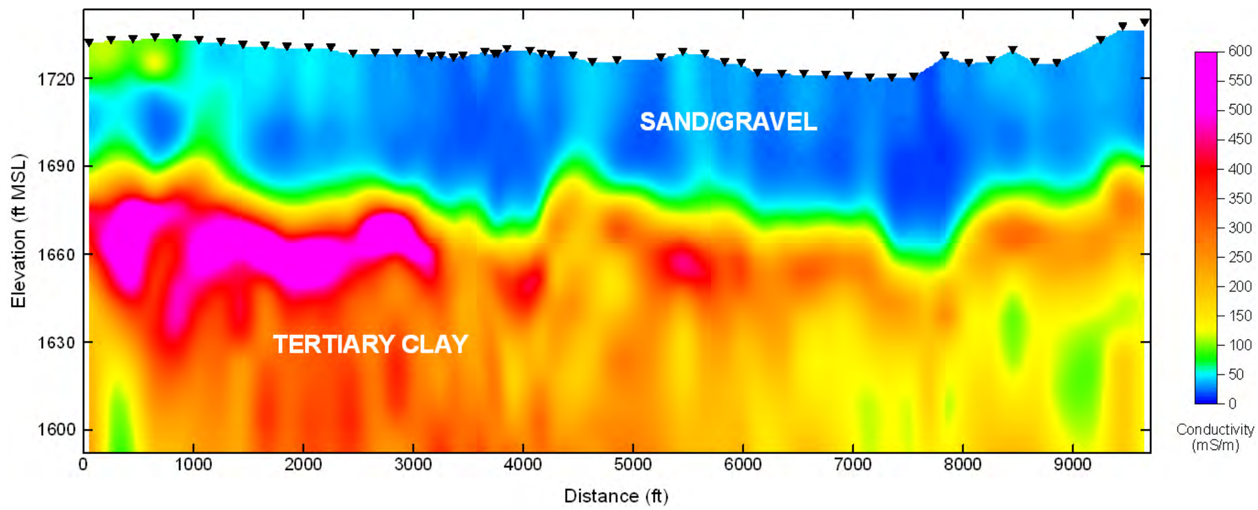
Limitations of the TDEM method include:

- Slower data collection than conventional FDEM instrumentation
- Like all surface geophysical methods, suffers from equivalence/nonuniqueness where multiple earth models may fit the field data
- Highly resistive areas limit signal strength at depth
- Unable to image upper 5m
- Not as good as DC resistivity at mapping resistive targets

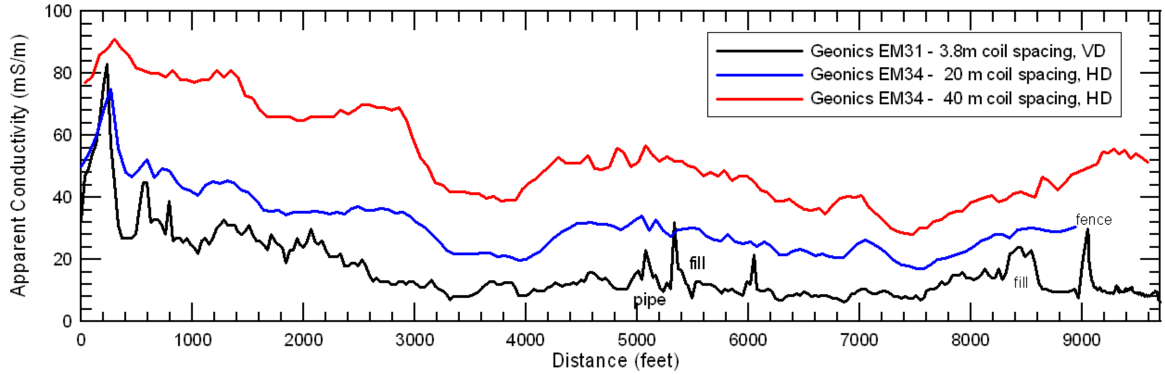
1124 Olympic Drive, Corona, California 92881, ph. 951-549-1234, fx. 951-549-1236, www.geovision.com



TDEM Survey to map paleochannels in a Tertiary clay unit. Geologic cross-section derived from 1-D TDEM layer based models at 200 ft intervals along the profile.



2-D image of electrical conductivity derived from 1-D smooth model inversions of TDEM data above.



EM induction profile (Geonics EM-31 and EM-34) along same line presented above. Note that the EM-34, 40 m coilspacing data detects paleochannels identified above.

Appendix C

Verification Soil Boring Logs

AECOM

1220 Avenida Acaso
Camarillo, CA 93012
(805) 388-3775
www.aecom.com

Boring No. NERT-CB1

Client: NDEP		
Project Number: 60477365, 2015-160B-01		
Site Description/Location: NERT Downgradient Study Area, Henderson, NV		*Ambient PID Reading:* NA
Coordinates: 26733704.37; 834023.03	*Elevation:* 1536.91 *Datum:*	*Sheet:* 1 *of* 3
Drilling Equipment/Method:/Sonic	*Weather:* sunny and warm	*Monitoring Well Installed:* No
Sample Type(s): Continuous	*Boring Diameter:* 8 IN.	*Screened Interval:* - ft.
Approved By: C. Caceres-Schnell	*Logged By:*S. Piper / *Date/Time Started:* 02-14-17	*Depth of Boring:*75 feet bgs
Drilling Contractor: Cascade	*Backfill:* / *Date/Time Finished:* 02-14-17	*Water Level:* Approximately 24 feet bgs

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"/RQD	Recovery (ft)	PID Reading (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay), description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
0						SM		SILTY SAND, brown (7.5YR 5/3), 70% fine-grained sand, 20% silt, 10% gravel, subangular, dry, poorly graded, fine- to medium-grained gravel (max size 4"), volcanic clasts, gravel calsts are volcanic possibly rhyolite.	3" PVC Casing
5									
10									
15	NERT-CB-1-15	X		0.5				-*PTS Classification: Gravel	
17						ML		SILT, light olive brown (2.5YR 5/3), 100% silt, dense, moist, poorly graded, mica grains are visible	
20									
23								-moist to wet	
25									
26								-Increase sand and gravel: brown (7.5YR 4/3), moist, fine to medium-grained gravel w/ max gravel size 2"	
28	NERT-CB-1-28	X		0.5				-*PTS Classification: Fine Sand	
30									

Notes: Hand auger to 5 feet
* PTS Laboratories Inc., physical soil properties results; March 7, 2017

AECOM 1220 Avenida Acaso Camarillo, CA 93012 (805) 388-3775 www.aecom.com	Client: NDEP	Boring No. NERT-CB1
	Project Number: 60477365, 2015-160B-01	
	Site Description/Location: NERT Downgradient Study Area, Henderson, NV	Ambient PID Reading: NA
	Coordinates: 26733704.37; 834023.03 Elevation: 1536.91 Datum:	Sheet: 2 of 3
	Drilling Equipment/Method: /Sonic Weather: sunny and warm	Monitoring Well Installed: No
	Sample Type(s): Continuous Boring Diameter: 8 IN.	Screened Interval: - ft.
Approved By: C. Caceres-Schnell	Logged By: S. Piper Date/Time Started: 02-14-17	Depth of Boring: 75 feet bgs
Drilling Contractor: Cascade	Backfill: Date/Time Finished: 02-14-17	Water Level: Approximately 24 feet bgs

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"/RQD	Recovery (ft)	PID Reading (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay), description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
						SM		SILTY SAND, light brown (7.5YR 6/3), 70% fine-grained sand, 20% medium-plastic silt, 10% fine- to medium-grained gravel (max size 1"), subangular, dense, wet, poorly graded	3" PVC Casing
								-increase in gravel	
35								-*PTS Classification: Gravel	
	NERT-CB-1-35	X		0.5		ML		SILT, brown (7.5YR 4/3), 80% silt, 20% high-plastic clay occurring as separate lenses, dense, moist	
						GP		POORLY GRADED GRAVEL WITH SILT AND SAND, brown (7.5YR 4/3), 60% fine- to medium-grained gravel (max size 1"), 30% sand, 10% silt, subangular, wet, poorly graded volcanic gravel clasts	
						ML		SILT, brown (7.5YR 4/3), 90% silt, 10% medium-plastic clay occurring as separate clay lenses, dense, wet	
40								-80% silt, 15% high-plastic clay occuring as separate lenses, 5% fine-grained gravel, weak red (2.5YR4/2), mottled	
	NERT-CB-1-42	X		0.5				-*PTS Classification Fine Sand	
45						SM		SILTY SAND, weak red (2.5YR 4/2), 70% sand, 20% silt, 10% poorly graded gravel, wet	
						ML		SILT, light olive gray (5Y 6/2), 90% silt, 10% high-plastic clay occurring as separate clay lenses, loose to very dense, moist, distinctive green color	
								-Upper Muddy Creek formation	
50									
	NERT-CB-1-52	X		0.5				-*PTS Classification: Fine Sand	
55									
								dark gray (2.5YR 4/1), 75% silt, 20% fine-grained gravel, 5%high-plastic clay occurring as clay lenses, dense, moist to wet, blue gray color with a strong organic reduced odor	
60									

Notes: Hand auger to 5 feet.
*PTS Laboratories, Inc. physical soil data results March 7, 2017

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	Project Number: 60477365, 2015-160B-01	
	Site Description/Location: NERT Downgradient Study Area, Hednerson, NV	*Ambient PID Reading:* NA
	Coordinates: 26733704.37; 834023.03 *Elevation: 1536.91* *Datum:*	*Sheet:* 3 *of* 3
	Drilling Equipment/Method:/Sonic *Weather:* sunny and warm	*Monitoring Well Installed:* No
	Sample Type(s): Continuous *Boring Diameter:* 8 IN.	*Screened Interval:* - ft.
Approved By: C. Caceres-Schnell	*Logged By:*S. Piper *Date/Time Started:* 02-14-17	*Depth of Boring:* 75 feet bgs
Drilling Contractor: Cascade	*Backfill:* *Date/Time Finished:* 02-14-17	*Water Level:* Approximately 24 feet bgs

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"/RQD	Recovery (ft)	PID Reading (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay), description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
						ML15		SILT, light olive gray (5Y 6/2), 90% silt, 10% high-plastic clay occurring as separate clay lenses, loose to medium dense, moist, distinctive green color, very dense *(continued)*	3" PVC Casing
65								-increase in gravel	
70	NERT-CB-1-70	☒		0.5				-*PTS Classification: Fine Sand	
								-70% silt, 20% low-plastic clay occurring as separate clay lenses, 10% fine-grained gravel (max size < 1/4"), wet, subangular	
75									

Total Depth = 75 feet Boring terminated Target depth achieved PVC casing down to 70 feet

Notes: Hand auger to 5 feet.
*PTS Laboratories, Inc. physical soil data results March 7, 2017

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Boring No. NERT-CB2

Client: NDEP			*Ambient PID Reading:* NA
Project Number: 60477365, 2015-160B-01			*Sheet:* 1 *of* 3
Site Description/Location: NERT Downgradient Study Area, Henderson, NV			*Monitoring Well Installed:* No
Coordinates: 26733698.39; 8344214.96	*Elevation:* 1535.46	*Datum:*	*Screened Interval:* - ft.
Drilling Equipment/Method: /Sonic	*Weather:* sunny and warm		
Sample Type(s): Continuous	*Boring Diameter:* 8 IN.		
Approved By: C. Caceres-Schnell	*Logged By:* S. Piper	*Date/Time Started:* 02-13-17	*Depth of Boring:* 75 Feet bgs
Drilling Contractor: Cascade	*Backfill:*	*Date/Time Finished:* 02-13-17	*Water Level:* Approximately 17 feet bgs

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"/RQD	Recovery (ft)	PID Reading (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay), description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
0						SM		SILTY SAND WITH GRAVEL, brown (7.5YR 4/3), 70% fine-grained sand, 15% medium- to coarse-grained gravel (max size 2"), 15% non-plastic silt, subangular, loose, dry, poorly graded, gravel clasts are volcanic	3" PVC Casing
5								-max gravel size 3", volcanic, grantic mica grains visible	
								-*PTS Classification: Gravel	
7	NERT-CB-2-7	X		0.5		SP		POORLY GRADED SAND WITH GRAVEL, brown (7.5YR 4/3), 55% fine- to medium-grained sand, 40% fine- to coarse-grained gravel (max size 3"), 5% non-plastic silt, subangular, loose, dry, poorly graded, volcanic clasts	
10									
15									
17						ML		SILT, yellowish brown (10YR 5/4), 75% silt, 20% high-plastic clay occurring as separate clay lenses, 5% fine-grained gravel, subangular, dense, moist to wet, water in core barrel	
18	NERT-CB-2-18	X		0.5				-*PTS Classification: Fine Sand	
20								-moist, max gravel size <1/4"	
25									
27	NERT-CB-2-27	X		0.5		ML		GRAVELLY SILT, brown (7.5YR 5/4), 70% non-plastic silt, 30% medium- to coarse-grained gravel (max size 6"), subangular, loose, wet, volcanic	
30									

Notes: Hand auger to 5 feet.
*PTS Laboratories, Inc. physical soil data results; March 7, 2017

AECOM	Client: NDEP	Boring No. NERT-CB2
1220 Avenida Acaso Camarillo, CA 93012 (805) 388-3775 www.aecom.com	Project Number: 60477365, 2015-160B-01	
	Site Description/Location: NERT Downgradient Study Area, Henderson, NV	Ambient PID Reading: NA
	Coordinates: 26733698.39; 834214.96 Elevation: 1535.46 Datum:	Sheet: 2 of 3
	Drilling Equipment/Method:/Sonic Weather: sunny and warm	Monitoring Well Installed: No
	Sample Type(s): Continuous Boring Diameter: 8 IN.	Screened Interval:- ft.
Approved By: C. Caceres-Schnell	Logged By:S. Piper Date/Time Started: 02-13-17	Depth of Boring: 75 feet bgs
Drilling Contractor: Cascade	Backfill: Date/Time Finished: 02-13-17	Water Level: Approximately 17 feet bgs

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"/RQD	Recovery (ft)	PID Reading (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay), description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
						ML		GRAVELLY SILT, brown (7.5YR 5/4), 70% non-plastic silt, 30% medium- to coarse-grained gravel (max size 6"), subangular, loose, wet, volcanic (continued) -decrease in gravel, increase in silt	3" PVC Casing
						ML		SILT, brown (7.5YR 5/4), 80% silt, 15% high-plastic clay occurring as separate clay lenses, 5% fine- to medium-grained gravel (max size 1/2"), subangular, dense, moist, poorly graded, volcanic gravel	
35									
	NERT-CB-2-38	X		0.5		GP		POORLY GRADED GRAVEL WITH SAND, (5YR 4/3), 70% fine- to coarse-grained gravel (max size 2"), 30% sand, subangular to subrounded, wet, poorly graded, volcanic, possibly sedimentary clasts as well -*PTS Classification: Gravel	
40									
45								-increase in silt -70% fine- to coarse-grained gravel (max size 3"), 20% fine-grained sand, 10% silt, volcanic clasts (mica)	
50									
						ML		SILT, brown (7.5YR 5/4), 100% low-plastic silt, dense, moist -increase sand and gravel	
55						SP		POORLY GRADED SAND WITH GRAVEL, dark brown (7.5YR 3/3), 70% fine-grained sand, 30% fine- to medium-grained gravel (max size 1/2"), subangular to subrounded, soft, wet, poorly graded	
60									

Notes: Hand auger to 5 feet.
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Boring No. NERT-CB2

Client: NDEP		
Project Number: 60477365, 2015-160B-01		
Site Description/Location: NERT Downgradient Study Area, Henderson, NV		*Ambient PID Reading:* NA
Coordinates: 26733698.39; 834214.96	*Elevation:* 1535.46 *Datum:*	*Sheet:* 3 of 3
Drilling Equipment/Method:/Sonic	*Weather:* sunny and warm	*Monitoring Well Installed:* No
Sample Type(s): Continuous	*Boring Diameter:* 8 IN.	*Screened Interval:* - ft.
Approved By: C. Caceres-Schnell	*Logged By:* S. Piper / *Date/Time Started:* 02-13-17	*Depth of Boring:* 75 feet bgs
Drilling Contractor: Cascade	*Backfill:* / *Date/Time Finished:* 02-13-17	*Water Level:* Approximately 17 feet bgs

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"/RQD	Recovery (ft)	PID Reading (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay), description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
						GP		POORLY GRADED GRAVEL WITH SAND, reddish brown (5YR 4/3), 70% medium- to coarse-grained gravel (max size 2" to 3"), 20%fine-grained sand, 10% silt, subangular to subrounded, wet	3" PVC Casing
65									
						ML		SILT, dark gray (2.5Y 4/1), 90% silt, 10% high-plastic clay occurring as separate clay lenses, dense, moist, blue/gray color, strong organic reducing odor -Upper Muddy Creek formation	
70	NERT-CB-2-70	X		0.5				-*PTS Classification: Fine Sand	
75									

Total Depth = 75 feet Boring terminated Target depth achieved PVC casing down to 64 feet

Notes: Hand auger to 5 feet.
*PTS Laboratories, Inc. physical soil data results March 7, 2017

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Client: NDEP		**Boring No. NERT-CB3**
Project Number: 60477365, 2015-160B-01		
Site Description/Location: NERT Downgradient Study Area, Henderson, NV		*Ambient PID Reading:* NA
Coordinates: 26733474.82; 827845.09	*Elevation:* 1577.9 *Datum:*	*Sheet:* 1 *of* 3
Drilling Equipment/Method:/Sonic	*Weather:* sunny and warm	*Monitoring Well Installed:* No
Sample Type(s): Continuous	*Boring Diameter:* 8 IN.	*Screened Interval:* - ft.
Approved By: C. Caceres-Schnell	*Logged By:*S. Piper / *Date/Time Started:* 02-16-17	*Depth of Boring:* 75 feet bgs
Drilling Contractor: Cascade	*Backfill:* / *Date/Time Finished:* 02-16-17	*Water Level:* Approximately 17 feet bgs

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"/RQD	Recovery (ft)	PID Reading (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay), description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
0						SM		SILTY SAND, brown (7.5YR 5/2), 70% fine-grained sand, 20% silt, 10% medium- to coarse-grained gravel (max size 1"), subangular, soft, dry, poorly graded, boulder size also >4" volcanic clasts	3" PVC Casing
5								-increase in silt	
7						ML		SANDY SILT, brown (7.5YR 4/2), 60% low-plastic silt, 30% fine-grained sand, 10% medium- to coarse-grained poorly graded gravel (max size 4"), subangular, dense, moist to dry	
10	NERT-CB-3-10	X		0.5				-*PTS Classification: Gravel	
								-increase in silt & clay	
13						ML		SILT, brown (7.5YR 5/2), 75% silt, 15% medium-plastic clay occuring as separate clay lenses, 10% medium- to coarse-grained gravel (max size 2"), subangular, dense, moist to wet	
15								-increase in gravel	
17						ML		GRAVELLY SILT, gray (7.5YR 5/1), 60% silt, 40% medium- to coarse-grained poorly graded gravel (max size 3"), subangular to subrounded, soft, wet	
23								-dark volcanic cobbles, very difficult drilling, driller added water.	
27								-low-plastic silt, brown (7.5YR 5/3), moist to wet, dry, subrounded gravel, difficult drilling. Drilled through large cobble inside	
30									

Notes: Hand auger to 5 feet.
*PTS Laboratories, Inc. physical soil data results March 7, 2017

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Client: NDEP		**Boring No. NERT-CB3**
Project Number: 60477365, 2015-160B-01		
Site Description/Location: NERT Downgradient Study Area, Henderson, NV		*Ambient PID Reading:* NA
Coordinates: 26733474.82; 827845.09	*Elevation:* 1577.9 *Datum:*	*Sheet:* 2 *of* 3
Drilling Equipment/Method:/Sonic	*Weather:* sunny and warm	*Monitoring Well Installed:* No
Sample Type(s): Continuous	*Boring Diameter:* 8 IN.	*Screened Interval:* - ft.
Approved By: C. Caceres-Schnell	*Logged By:* S. Piper / *Date/Time Started:* 02-16-17	*Depth of Boring:* 75 feet bgs
Drilling Contractor: Cascade	*Backfill:* / *Date/Time Finished:* 02-16-17	*Water Level:* Approximately 17 feet bgs

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"/RQD	Recovery (ft)	PID Reading (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay), description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
						ML		GRAVELLY SILT, gray (7.5YR 5/1), 60% silt, 30% medium- to coarse-grained gravel (max. size > 6"), 10% sand, subrounded, dense, wet, more difficult drilling, added water, volcanic cobbles	3" PVC Casing
	NERT-CB-3-33	☒		0.5					
35									
						SM		SILTY SAND, brown (7.5YR 4/3), 80% fine-grained sand, 20% silt, soft, wet	
						ML		GRAVELLY SILT, dark brown (2.5YR 8/2), 60% silt, 20% fine- to medium-grained gravel (make size > 1/2"), 10% fine-grained sand, soft, wet	
40									
						SM		SILTY SAND, brown (7.5YR 4/3), 80% sand, 20% silt, soft, moist	
						ML		SANDY SILT WITH GRAVEL, brown (7.5YR 4/3), 60% silt, 20% fine-grained sand, 20% fine- to medium-grained gravel, subrounded, soft, wet	
45	NERT-CB-3-45	☒		0.5					
								-gray (7.5YR 6/1), wet	
50									
								-silty fine- to medium-grained gravel	
						ML		SILT WITH GRAVEL, brown (7.5YR 4/4), 80% silt, 15% fine-grained gravel (max size 1/4"), 5% low-plastic clay occurring as separate clay lenses, subrounded, dense, moist	
55								-Upper Muddy Creek formation	
60									

Notes: Hand auger to 5 feet.
*PTS Laboratories, Inc. physical soil data results March 7, 2017

AECOM 1220 Avenida Acaso Camarillo, CA 93012 (805) 388-3775 www.aecom.com	*Client:* NDEP	**Boring No. NERT-CB3**
	Project Number: 60477365, 2015-160B-01	
	Site Description/Location: NERT Downgradient Study Area, Henderson, NV	*Ambient PID Reading:* NA
	Coordinates: 26733474.82; 827845.09 *Elevation: 1577.9* *Datum:*	*Sheet:* 3 *of* 3
	Drilling Equipment/Method: Sonic *Weather:* sunny and warm	*Monitoring Well Installed:* No
	Sample Type(s): Continuous *Boring Diameter:* 8 IN.	*Screened Interval:* - ft.

Approved By: C. Caceres-Schnell	*Logged By:* S. Piper	*Date/Time Started:* 02-16-17	*Depth of Boring:* 75 feet bgs
Drilling Contractor: Cascade	*Backfill:*	*Date/Time Finished:* 02-16-17	*Water Level:* Approximately 17 feet bgs

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"/RQD	Recovery (ft)	PID Reading (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay), description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
						ML		SILT WITH GRAVEL, brown (7.5YR 4/4), 80% silt, 15% fine-grained gravel (max size 1/4"), 5% low-plastic clay occurring as separate clay lenses, subrounded, dense, moist *(continued)* -max gravel size 1/2", poorly graded	3" PVC Casing
65								-85% silt, 15% clay, light brownish gray (2.5Y 6/2)	
								-brown (7.5YR 4/4), mottled with green & brown 67 to 69 feet	
70									
75									

Total Depth = 75 feet Boring terminated
Target depth achieved PVC casing down to 75 feet.

Notes: Hand auger to 5 feet.
*PTS Laboratories, Inc. physical soil data results March 7, 2017

AECOM		
1220 Avenida Acaso Camarillo, CA 93012 (805) 388-3775 www.aecom.com	*Client:* NDEP	**Boring No. NERT-CB4**
	Project Number: 60477365, 2015-160B-01	
	Site Description/Location: NERT Downgradient Study Area, Henderson, NV	*Ambient PID Reading:* NA
	Coordinates: 26733374.43; 827990.15 *Elevation:* 1575.36 *Datum:*	*Sheet:* 1 *of* 3
	Drilling Equipment/Method:/Sonic *Weather:* windy, cool , some rain	*Monitoring Well Installed:* No
	Sample Type(s): Continuous *Boring Diameter:* 8 IN.	*Screened Interval:* - ft.
Approved By: C. Caceres-Schnell	*Logged By:* S. Piper *Date/Time Started:* 02-15-17	*Depth of Boring:* 75 feet bgs
Drilling Contractor: Cascade	*Backfill:* *Date/Time Finished:* 02-15-17	*Water Level:* Approximately 20 feet bgs

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"/RQD	Recovery (ft)	PID Reading (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay), description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
0						SM		SILTY SAND, strong brown (7.5YR 4/6), 60% fine-grained sand, 30% silt, 10% coarse-grained gravel (max size 8"), subangular, soft, dry, poorly graded, volcanic gravel	3" PVC Casing
5									
								-increase in silt	
8						ML		SANDY SILT, brown (10YR 4/3), 70% low-plastic silt, 30% sand, moist	
10									
12						SP		POORLY GRADED SAND, (7.5YR 5/3), 100% fine-grained poorly graded sand, soft, moist, mica grains, volcanic and sedimentary clasts	
								-*PTS Classification: Fine Sand	
15	NERT-CB-4-15	X		0.5		ML		SILT WITH GRAVEL, brown (7.5YR 4/3), 75% silt, 10% fine- to medium-grained gravel (max size 2"), 5% fine-grained sand, subangular, soft, moist, poorly graded	
17								NO RECOVERY-Could not get a sample, large boulder in core barrel	
20									
21						SP		POORLY GRADED SAND WITH GRAVEL, 80% sand, 20% gravel (max size 2") < 5% silt, subangular, soft, wet, poorly graded, high water zone	
25								NO RECOVERY-Very wet zone, lost sample and water from core barrel as it was retrieved.	
30	NERT-CB-4-30							-*PTS Classification: Coarse Sand	

Notes: Hand auger to 5 feet bgs.

* PTS Laboratories, Inc physical properties data results, March 7, 2017

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Boring No. NERT-CB4

Client: NDEP	
Project Number: 60477365, 2015-160B-01	
Site Description/Location: NERT Downgradient Study Area, Henderson, NV	*Ambient PID Reading:* NA
Coordinates: 26733374.43; 827990.15 *Elevation:* 1575.36 *Datum:*	*Sheet:* 2 *of* 3
Drilling Equipment/Method:/Sonic *Weather:* windy, cool, some rain	*Monitoring Well Installed:* No
Sample Type(s): Continuous *Boring Diameter:* 8 IN.	*Screened Interval:* - ft.
Approved By: C. Caceres-Schnell *Logged By:* S. Piper *Date/Time Started:* 02-15-17	*Depth of Boring:* 75 feet bgs
Drilling Contractor: Cascade *Backfill:* *Date/Time Finished:* 02-15-17	*Water Level:* Approximately 20 feet bgs

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"/RQD	Recovery (ft)	PID Reading (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay), description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
30–40				0.5		GP		POORLY GRADED GRAVEL WITH SAND, dark grayish brown (10YR 4/2), 65% medium- to coarse-grained gravel (max size 5"), 30% fine-grained sand, 5% silt, subrounded, soft, wet, well graded, pink, light and dark fedlpar grains in larger cobbles	3" PVC Casing
40–52						GW-GM		WELL GRADED GRAVEL WITH SILT AND SAND, very dark gray (7.5YR 3/1), 60% fine- to coarse-grained gravel (max size 6"), 30% fine-grained sand, 10% silt, subrounded, dense, moist, well graded, cobbles >6"	
~43								-gray (10YR 6/1)	
~48								-increase in silt	
50	NERT-CB-4-50			0.5				-*PTS Classfication: Fine Sand	
52–60						ML		SILT, brown (7.5YR 4/4), 100% low-plastic silt, dense, moist	
								- Upper Muddy Creek formation	

Notes: Hand auger to 5 feet.
*PTS Laboratories, Inc. physical soil data results March 7, 2017

AECOM 1220 Avenida Acaso Camarillo, CA 93012 (805) 388-3775 www.aecom.com	*Client:* NDEP *Project Number:* 60477365, 2015-160B-01 *Site Description/Location:* NERT Downgradient Study Area, Henderson, NV *Coordinates:* 26733374.43; 827990.15 *Elevation:* 1575.36 *Datum:* *Drilling Equipment/Method:*/Sonic *Weather:* windy, cool, some rain *Sample Type(s):* Continuous *Boring Diameter:* 8 IN.	**Boring No. NERT-CB4** *Ambient PID Reading:* NA *Sheet:* 3 *of* 3 *Monitoring Well Installed:* No *Screened Interval:* - ft.
Approved By: C. Caceres-Schnell	*Logged By:* S. Piper *Date/Time Started:* 02-15-17	*Depth of Boring:* 75 feet bgs
Drilling Contractor: Cascade	*Backfill:* *Date/Time Finished:* 02-15-17	*Water Level:* Approximately 20 feet bgs

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"/RQD	Recovery (ft)	PID Reading (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay), description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
						ML		SILT, brown (7.5YR 4/4), 100% low-plastic silt, dense, moist *(continued)*	3" PVC Casing
								-olive gray (5Y 5/2), mottled color	
65								-increase sand	
								-brown (7.5YR 4/4), very dense "blockey and crumbley" texture.	
70									
	NERT-CB-4-71	⊠		0.5				-*PTS Classification: Medium Sand	
								-brown (7.5YR 4/4) & light gray (5Y 5/1), mottled, "less crumbley"	
75									

Total Depth = 75 feet Boring terminated Target depth achieved PVC casing down to 72 feet

Notes: Hand auger to 5 feet bgs.

* PTS Laboratories, Inc physical properties data results, March 7, 2017

Appendix D

Soil Property Laboratory Report

PTS Laboratories, Inc.

8100 Secura Way • Santa Fe Springs, CA 90670
Telephone (562) 347-2500 • Fax (562) 907-3610

March 20, 2017

Carmen Caceres-Schnell
AECOM
1220 Avenida Acaso
Camarillo, CA 93012

Re: PTS File No: 47098
Physical Properties Data
NDEP Downgradient Study Area; 60477365 Task 2015-160-10

Dear Ms. Caceres-Schnell:

Please find enclosed report for Physical Properties analyses conducted upon samples received from your NDEP Downgradient Study Area; 60477365 Task 2015-160-10 project. All analyses were performed by applicable ASTM, EPA, or API methodologies. The samples are currently in storage and will be retained for thirty days past completion of testing at no charge. Please note that the samples will be disposed of at that time. You may contact me regarding storage, disposal, or return of the samples.

PTS Laboratories appreciates the opportunity to be of service. If you have any questions or require additional information, please give me a call at (562) 347-2502.

Sincerely,
PTS Laboratories, Inc.

Michael Mark Brady, P.G.
Laboratory Director

Encl.

PTS Laboratories

Project Name: **NDEP Downgradient Study Area**
Project Number: **60477365 Task 2015-160-10**

PTS File No: 47098
Client: AECOM

TEST PROGRAM - 20170221

CORE ID	Depth ft.	Core Recovery ft.	Grain Size Analysis ASTM D422	Moisture Content ASTM D2216	Atterberg Limits ASTM D4318			Comments
		Plugs:	Grab	Grab	Grab			
Date Received: 20170221								
NERT-CB-2-7'	7	N/A	X	X	X			
NERT-CB-2-18'	18	N/A	X	X	X			
NERT-CB-2-27'	27	N/A	X	X	X			
NERT-CB-2-38'	38	N/A	X	X	X			
NERT-CB-2-70'	70	N/A	X	X	X			
NERT-CB-1-15	15	N/A	X	X	X			
NERT-CB-1-28	28	N/A	X	X	X			
NERT-CB-1-35	35	N/A	X	X	X			
NERT-CB-1-42	42	N/A	X	X	X			
NERT-CB-1-52	52	N/A	X	X	X			
NERT-CB-1-70	70	N/A	X	X	X			
NERT-CB-4-15	15	N/A	X	X	X			
NERT-CB-4-30	30	N/A	X	X	X			
NERT-CB-4-50	50	N/A	X	X	X			
NERT-CB-4-71	71	N/A	X	X	X			
NERT-CB-3-10	10	N/A	X	X	X			
NERT-CB-3-33	33	N/A	X	X	X			
NERT-CB-3-55	55	N/A	X	X	X			
TOTALS:	**18 Bags**	**N/A**	**18**	**18**	**18**			**18**

Laboratory Test Program Notes
Contaminant identification:
Standard TAT for basic analysis is 10-15 business days.
Grain Size Analysis - ASTM D422: Dry sieve only method; includes tabular data, graphics and statistical sorting in Excel format.
Hydrometer analysis must be requested prior to initiating tests, additional costs would apply.

PTS Laboratories

PTS File No: 47098
Client: AECOM
Report Date: 03/20/17

ATTERBERG LIMITS DATA - FINE FRACTION < No. 40 SIEVE

(Methodology: ASTM D4318)

Project Name: NDEP Downgradient Study Area
Project No: 60477365 Task 2015-160-10

SAMPLE ID.	DEPTH, ft.	ANALYSIS DATE	ATTERBERG LIMITS (1) LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	USCS / PLASTICITY CHART SYMBOL (Fines: <#40 Sieve)
NERT-CB-2-7'	7	20170303	15.9	Non-Plastic		ML
NERT-CB-2-18'	18	20170303	38.3	19.7	18.6	CL
NERT-CB-2-27'	27	20170306	29.7	15.5	14.2	CL
NERT-CB-2-38'	38	20170306	5.2	Non-Plastic		ML
NERT-CB-2-70'	70	20170306	71.1	32.8	38.3	CH
NERT-CB-1-15	15	20170307	14.4	Non-Plastic		ML
NERT-CB-1-28	28	20170307	26.1	16.6	9.5	CL
NERT-CB-1-35	35	20170307	16.8	Non-Plastic		ML
NERT-CB-1-42	42	20170307	26.7	Non-Plastic		ML
NERT-CB-1-52	52	20170307	139.8	85.9	53.9	MH
NERT-CB-1-70	70	20170307	68.9	34.8	34.1	MH
NERT-CB-4-15	15	20170309	10.0	Non-Plastic		ML
NERT-CB-4-30	30	20170309	3.6	Non-Plastic		ML
NERT-CB-4-50	50	20170309	53.8	32.8	21.0	MH
NERT-CB-4-71	71	20170309	46.3	34.2	12.1	ML
NERT-CB-3-10	10	20170309	12.5	Non-Plastic		ML
NERT-CB-3-33	33	20170310	14.2	Non-Plastic		ML
NERT-CB-3-55	55	20170310	66.0	39.7	26.3	MH

(1) Silt assumed as fine fraction for NON-PLASTIC (NP) samples.
USCS: Unified Soil Classification System

PARTICLE SIZE SUMMARY

(METHODOLOGY: ASTM D422M)

PROJECT NAME: NDEP Downgradient Study Area

PROJECT NO: 60477365 Task 2015-160-10

Sample ID	Depth, ft.	Mean Grain Size Description USCS/ASTM (1)	Median Grain Size, mm	Particle Size Distribution, wt. percent				
				Gravel	Sand Size			Silt/Clay
					Coarse	Medium	Fine	
NERT-CB-2-7'	7	Gravel	4.070	47.92	10.63	17.06	17.38	7.00
NERT-CB-2-18'	18	Fine sand	0.072	0.00	0.20	5.65	43.09	51.06
NERT-CB-2-27'	27	N/A	7.606	55.85	8.86	16.71	11.32	7.26
NERT-CB-2-38'	38	Gravel	5.116	51.88	19.40	20.20	7.01	1.52
NERT-CB-2-70'	70	Fine sand	0.361	0.00	0.17	23.72	73.51	2.59
NERT-CB-1-15	15	Gravel	9.889	59.94	8.10	14.50	15.05	2.40
NERT-CB-1-28	28	Fine sand	0.210	2.29	6.00	28.13	42.99	20.59
NERT-CB-1-35	35	Gravel	6.092	54.80	13.67	15.00	10.40	6.13
NERT-CB-1-42	42	Fine sand	0.096	0.00	0.14	8.30	52.97	38.58
NERT-CB-1-52	52	Fine sand	0.316	0.00	1.09	40.69	38.47	19.74
NERT-CB-1-70	70	Fine sand	0.335	0.00	1.39	43.05	51.45	4.11
NERT-CB-4-15	15	Fine sand	0.229	1.92	3.47	17.68	62.41	14.52
NERT-CB-4-30	30	Coarse sand	2.234	29.63	23.33	32.07	11.40	3.58

(1) Based on Mean fromTrask

PTS Laboratories, Inc.

AECOM

PTS File No: 47098

PARTICLE SIZE SUMMARY

(METHODOLOGY: ASTM D422M)

PROJECT NAME: NDEP Downgradient Study Area

PROJECT NO: 60477365 Task 2015-160-10

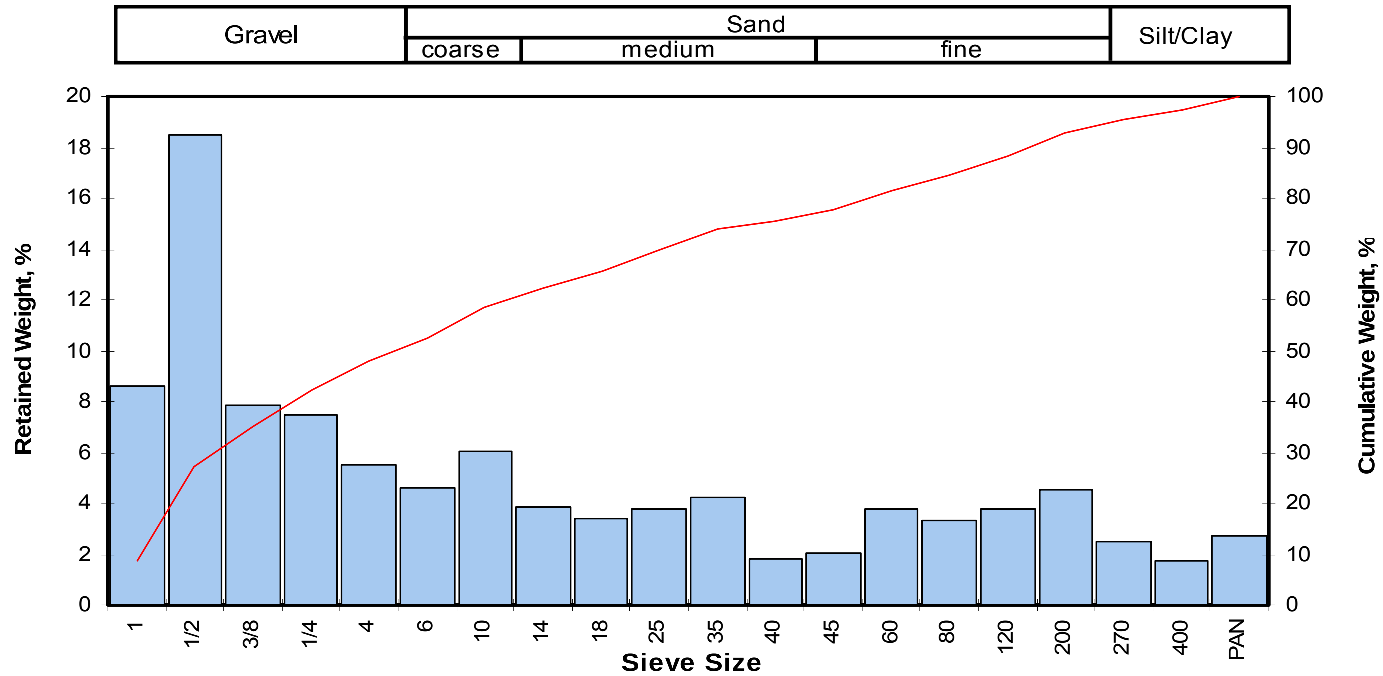
Sample ID	Depth, ft.	Mean Grain Size Description USCS/ASTM (1)	Median Grain Size, mm	Particle Size Distribution, wt. percent				
				Gravel	Sand Size			Silt/Clay
					Coarse	Medium	Fine	
NERT-CB-4-50	50	Fine sand	0.110	0.00	0.52	13.60	52.80	33.07
NERT-CB-4-71	71	Medium sand	0.339	10.87	4.99	28.04	42.29	13.81
NERT-CB-3-10	10	Gravel	2.075	33.59	17.11	27.64	17.94	3.72
NERT-CB-3-33	33	N/A	8.079	55.99	8.34	14.84	15.22	5.60
NERT-CB-3-55	55	N/A	23.148	60.08	6.43	16.31	9.70	7.48

(1) Based on Mean fromTrask

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-2-7'
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	7



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	28.79	8.58	8.58
0.4922	12.501	-3.64	1/2	62.09	18.50	27.08
0.3740	9.500	-3.25	3/8	26.40	7.87	34.94
0.2500	6.351	-2.67	1/4	25.09	7.48	42.42
0.1873	4.757	-2.25	4	18.47	5.50	47.92
0.1324	3.364	-1.75	6	15.48	4.61	52.54
0.0787	2.000	-1.00	10	20.21	6.02	58.56
0.0557	1.414	-0.50	14	12.95	3.86	62.42
0.0394	1.000	0.00	18	11.46	3.41	65.83
0.0278	0.707	0.50	25	12.74	3.80	69.63
0.0197	0.500	1.00	35	14.07	4.19	73.82
0.0166	0.420	1.25	40	6.03	1.80	75.62
0.0139	0.354	1.50	45	6.75	2.01	77.63
0.0098	0.250	2.00	60	12.57	3.75	81.37
0.0070	0.177	2.50	80	11.03	3.29	84.66
0.0049	0.125	3.00	120	12.78	3.81	88.47
0.0029	0.074	3.75	200	15.20	4.53	93.00
0.0021	0.053	4.25	270	8.48	2.53	95.52
0.0015	0.037	4.75	400	5.79	1.73	97.25
			PAN	9.24	2.75	100.00
TOTALS				335.62	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5			
10	-4.57	0.9333	23.705
16	-4.24	0.7454	18.933
25	-3.76	0.5320	13.514
40	-2.86	0.2849	7.235
50	-2.02	0.1602	4.070
60	-0.81	0.0692	1.757
75	1.16	0.0176	0.446
84	2.40	0.0075	0.189
90	3.25	0.0041	0.105
95	4.15	0.0022	0.056

Measure	Trask	Inman	Folk-Ward
Median, phi	-2.02	-2.02	-2.02
Median, in.	0.1602	0.1602	0.1602
Median, mm	4.070	4.070	4.070
Mean, phi	-2.80	-0.92	-1.29
Mean, in.	0.2748	0.0746	0.0962
Mean, mm	6.980	1.894	2.444
Sorting	5.504	3.321	
Skewness	0.603	0.332	
Kurtosis	0.277		
Grain Size Description (ASTM-USCS Scale)	Gravel (based on Mean from Trask)		

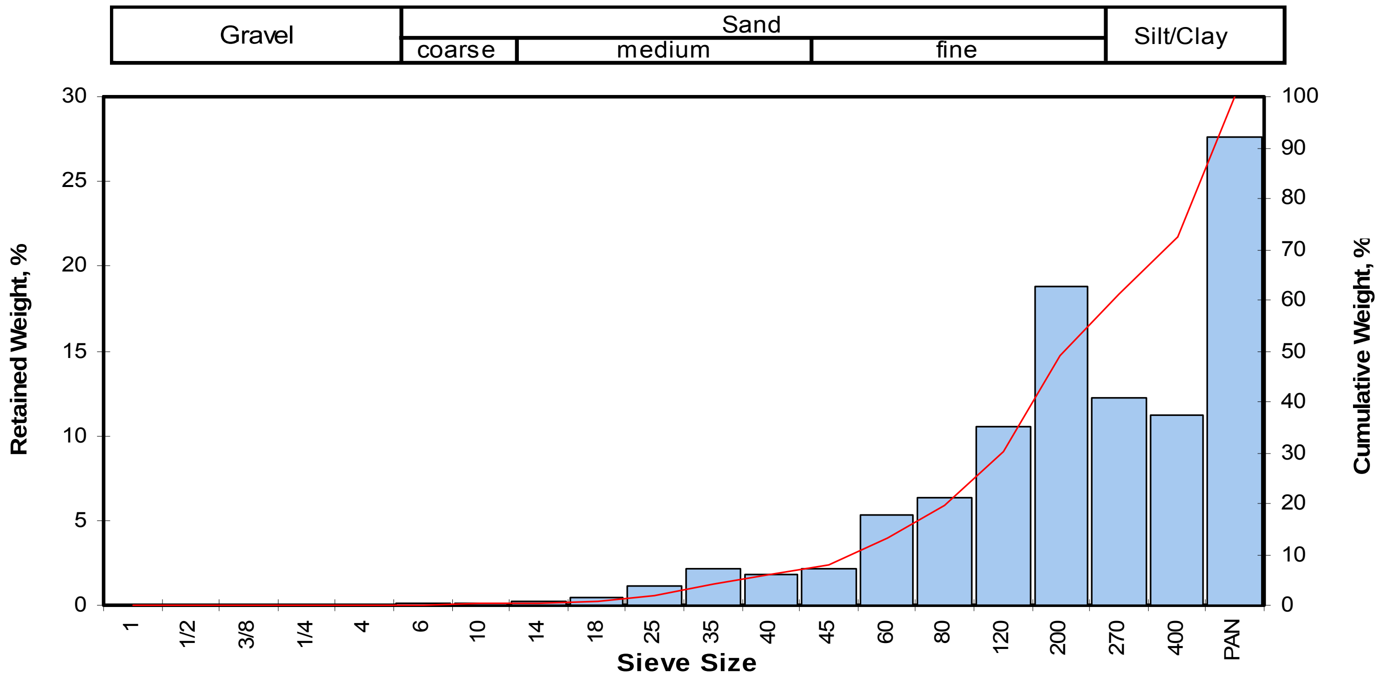
Description	Retained on Sieve #	Weight Percent
Gravel	4	47.92
Coarse Sand	10	10.63
Medium Sand	40	17.06
Fine Sand	200	17.38
Silt/Clay	<200	7.00
	Total	100

Phone: (562) 907-3607 Fax: (562) 907-3610

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-2-18'
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	18



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	0.00	0.00	0.00
0.4922	12.501	-3.64	1/2	0.00	0.00	0.00
0.3740	9.500	-3.25	3/8	0.00	0.00	0.00
0.2500	6.351	-2.67	1/4	0.00	0.00	0.00
0.1873	4.757	-2.25	4	0.00	0.00	0.00
0.1324	3.364	-1.75	6	0.14	0.13	0.13
0.0787	2.000	-1.00	10	0.08	0.07	0.20
0.0557	1.414	-0.50	14	0.21	0.19	0.39
0.0394	1.000	0.00	18	0.49	0.44	0.83
0.0278	0.707	0.50	25	1.19	1.08	1.91
0.0197	0.500	1.00	35	2.38	2.16	4.07
0.0166	0.420	1.25	40	1.97	1.79	5.85
0.0139	0.354	1.50	45	2.32	2.10	7.96
0.0098	0.250	2.00	60	5.85	5.30	13.26
0.0070	0.177	2.50	80	7.00	6.34	19.60
0.0049	0.125	3.00	120	11.66	10.57	30.17
0.0029	0.074	3.75	200	20.72	18.78	48.94
0.0021	0.053	4.25	270	13.45	12.19	61.13
0.0015	0.037	4.75	400	12.35	11.19	72.32
			PAN	30.54	27.68	100.00
TOTALS				110.35	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	1.13	0.0180	0.457
10	1.69	0.0122	0.309
16	2.22	0.0085	0.215
25	2.76	0.0058	0.148
40	3.39	0.0037	0.095
50	3.79	0.0028	0.072
60	4.20	0.0021	0.054
75			
84			
90			
95			

Measure	Trask	Inman	Folk-Ward
Median, phi	3.79	3.79	3.79
Median, in.	0.0028	0.0028	0.0028
Median, mm	0.072	0.072	0.072
Mean, phi			
Mean, in.			
Mean, mm			
Sorting			
Skewness			
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Mean from Trask)

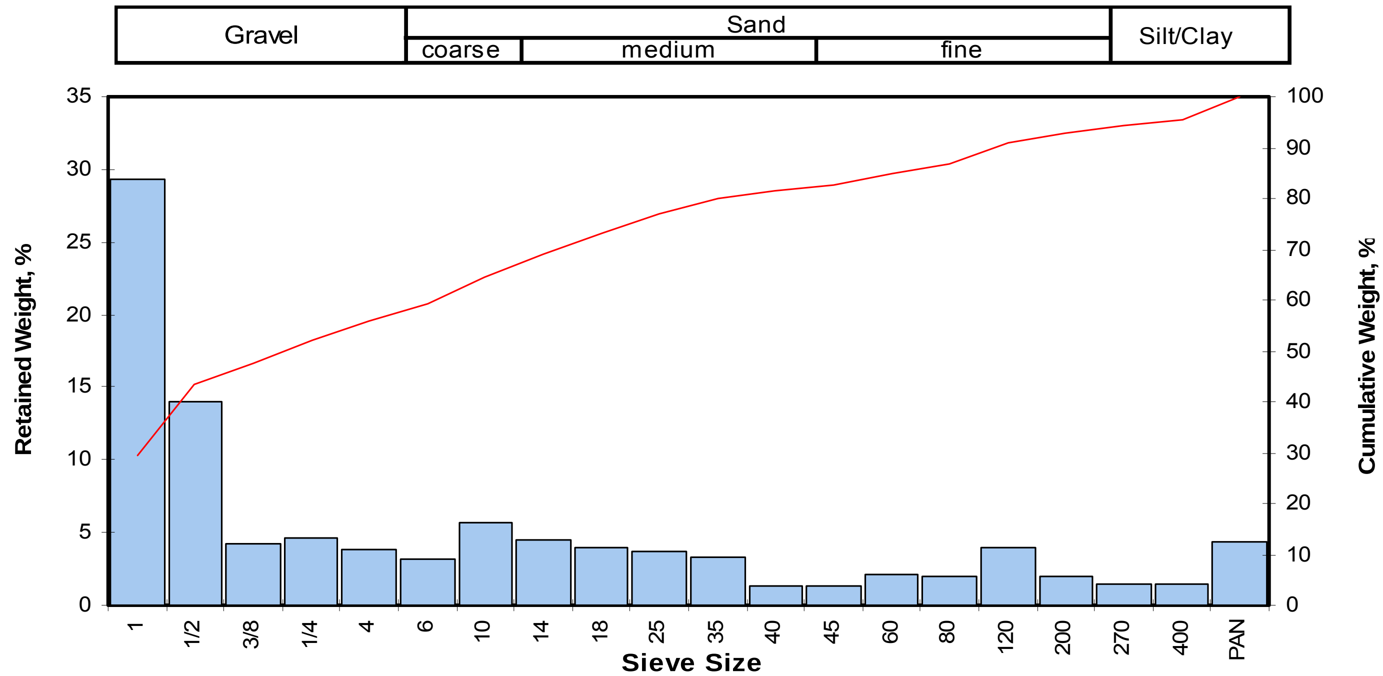
Description	Retained on Sieve #	Weight Percent
Gravel	4	0.00
Coarse Sand	10	0.20
Medium Sand	40	5.65
Fine Sand	200	43.09
Silt/Clay	<200	51.06
	Total	100

Phone: (562) 907-3607 Fax: (562) 907-3610

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-2-27'
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	27



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	90.48	29.32	29.32
0.4922	12.501	-3.64	1/2	43.11	13.97	43.29
0.3740	9.500	-3.25	3/8	12.89	4.18	47.46
0.2500	6.351	-2.67	1/4	14.17	4.59	52.06
0.1873	4.757	-2.25	4	11.70	3.79	55.85
0.1324	3.364	-1.75	6	9.98	3.23	59.08
0.0787	2.000	-1.00	10	17.35	5.62	64.70
0.0557	1.414	-0.50	14	13.79	4.47	69.17
0.0394	1.000	0.00	18	12.18	3.95	73.12
0.0278	0.707	0.50	25	11.47	3.72	76.83
0.0197	0.500	1.00	35	10.07	3.26	80.10
0.0166	0.420	1.25	40	4.07	1.32	81.42
0.0139	0.354	1.50	45	4.08	1.32	82.74
0.0098	0.250	2.00	60	6.71	2.17	84.91
0.0070	0.177	2.50	80	6.13	1.99	86.90
0.0049	0.125	3.00	120	12.08	3.91	90.81
0.0029	0.074	3.75	200	5.94	1.92	92.74
0.0021	0.053	4.25	270	4.44	1.44	94.18
0.0015	0.037	4.75	400	4.42	1.43	95.61
			PAN	13.55	4.39	100.00
TOTALS				308.61	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5			
10			
16			
25			
40	-3.88	0.5794	14.716
50	-2.93	0.2995	7.606
60	-1.63	0.1216	3.090
75	0.25	0.0330	0.839
84	1.79	0.0114	0.289
90	2.90	0.0053	0.134
95	4.54	0.0017	0.043

Measure	Trask	Inman	Folk-Ward
Median, phi	-2.93	-2.93	-2.93
Median, in.	0.2995	0.2995	0.2995
Median, mm	7.606	7.606	7.606
Mean, phi			
Mean, in.			
Mean, mm			
Sorting			
Skewness			
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	N/A (based on Mean from Trask)

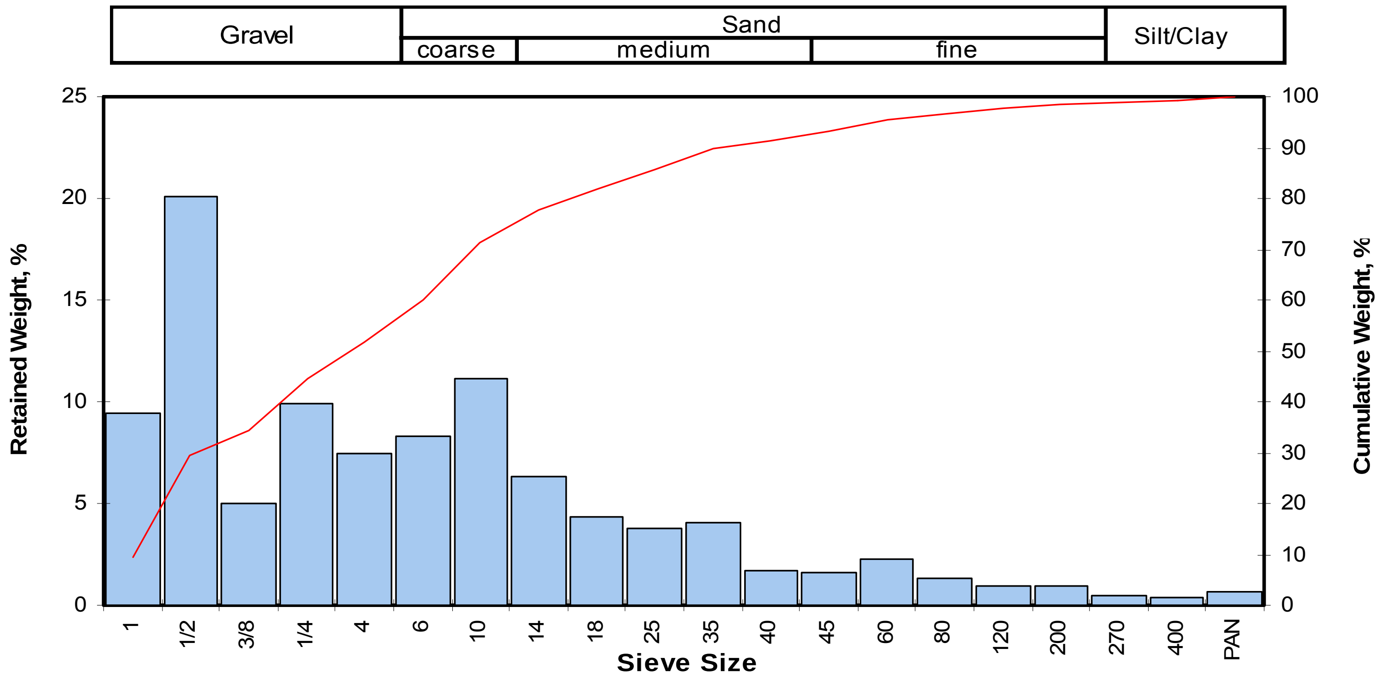
Description	Retained on Sieve #	Weight Percent
Gravel	4	55.85
Coarse Sand	10	8.86
Medium Sand	40	16.71
Fine Sand	200	11.32
Silt/Clay	<200	7.26
	Total	100

Phone: (562) 907-3607 Fax: (562) 907-3610

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-2-38'
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	38



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	45.07	9.45	9.45
0.4922	12.501	-3.64	1/2	95.78	20.09	29.54
0.3740	9.500	-3.25	3/8	23.68	4.97	34.51
0.2500	6.351	-2.67	1/4	47.17	9.89	44.40
0.1873	4.757	-2.25	4	35.66	7.48	51.88
0.1324	3.364	-1.75	6	39.52	8.29	60.17
0.0787	2.000	-1.00	10	52.97	11.11	71.28
0.0557	1.414	-0.50	14	30.28	6.35	77.63
0.0394	1.000	0.00	18	20.76	4.35	81.99
0.0278	0.707	0.50	25	18.11	3.80	85.79
0.0197	0.500	1.00	35	19.15	4.02	89.80
0.0166	0.420	1.25	40	7.99	1.68	91.48
0.0139	0.354	1.50	45	7.54	1.58	93.06
0.0098	0.250	2.00	60	10.77	2.26	95.32
0.0070	0.177	2.50	80	6.21	1.30	96.62
0.0049	0.125	3.00	120	4.54	0.95	97.57
0.0029	0.074	3.75	200	4.34	0.91	98.48
0.0021	0.053	4.25	270	2.35	0.49	98.98
0.0015	0.037	4.75	400	1.84	0.39	99.36
			PAN	3.04	0.64	100.00
TOTALS				476.77	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5			
10	-4.62	0.9660	24.535
16	-4.32	0.7853	19.947
25	-3.87	0.5757	14.622
40	-2.93	0.2991	7.598
50	-2.35	0.2014	5.116
60	-1.76	0.1334	3.388
75	-0.71	0.0643	1.633
84	0.26	0.0328	0.832
90	1.03	0.0193	0.490
95	1.93	0.0103	0.263

Measure	Trask	Inman	Folk-Ward
Median, phi	-2.35	-2.35	-2.35
Median, in.	0.2014	0.2014	0.2014
Median, mm	5.116	5.116	5.116
Mean, phi	-3.02	-2.03	-2.14
Mean, in.	0.3200	0.1604	0.1731
Mean, mm	8.128	4.074	4.396
Sorting	2.993	2.292	
Skewness	0.955	0.143	
Kurtosis	0.270		

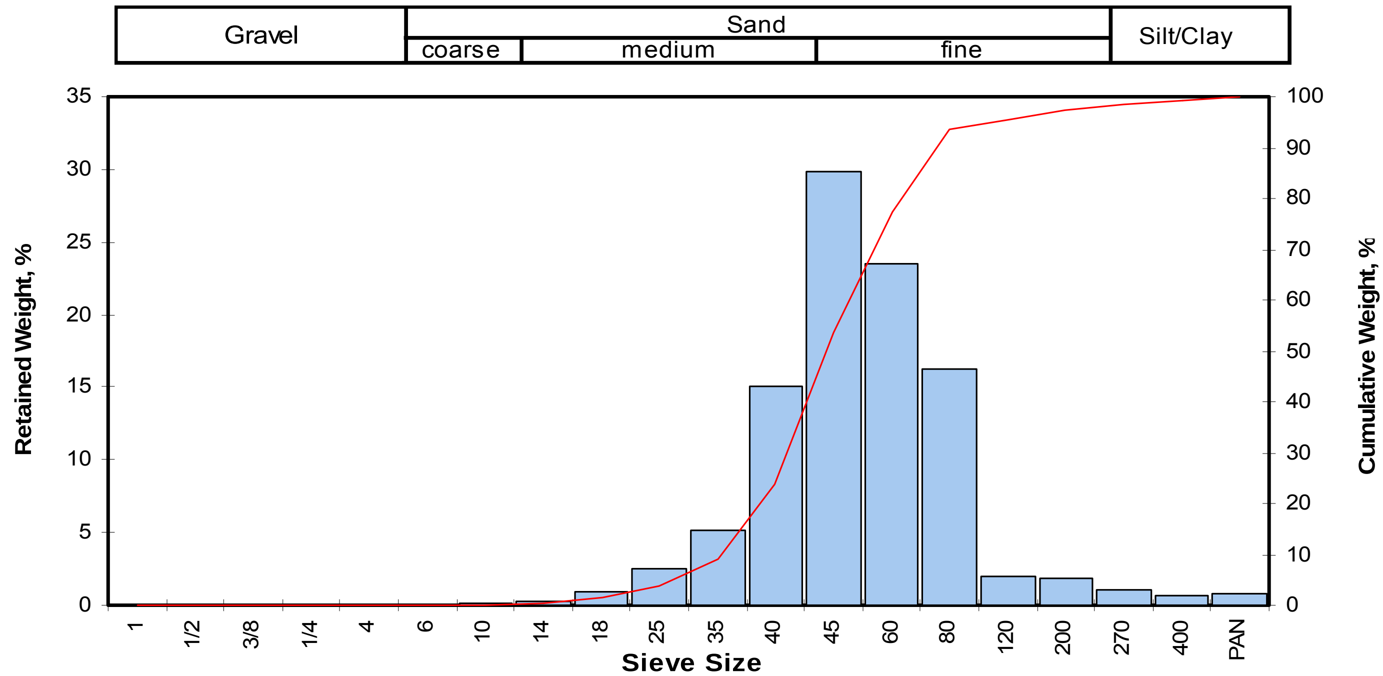
Grain Size Description (ASTM-USCS Scale)	Gravel (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	51.88
Coarse Sand	10	19.40
Medium Sand	40	20.20
Fine Sand	200	7.01
Silt/Clay	<200	1.52
	Total	100

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-2-70'
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	70



Opening		Phi of	U.S. Sieve	Sample Weight	Incremental Weight,	Cumulative Weight,
Inches	Millimeters	Screen	No.	grams	percent	percent
0.9844	25.002	-4.64	1	0.00	0.00	0.00
0.4922	12.501	-3.64	1/2	0.00	0.00	0.00
0.3740	9.500	-3.25	3/8	0.00	0.00	0.00
0.2500	6.351	-2.67	1/4	0.00	0.00	0.00
0.1873	4.757	-2.25	4	0.00	0.00	0.00
0.1324	3.364	-1.75	6	0.00	0.00	0.00
0.0787	2.000	-1.00	10	0.13	0.17	0.17
0.0557	1.414	-0.50	14	0.21	0.28	0.45
0.0394	1.000	0.00	18	0.65	0.87	1.32
0.0278	0.707	0.50	25	1.84	2.46	3.78
0.0197	0.500	1.00	35	3.82	5.10	8.88
0.0166	0.420	1.25	40	11.24	15.01	23.90
0.0139	0.354	1.50	45	22.31	29.80	53.70
0.0098	0.250	2.00	60	17.57	23.47	77.17
0.0070	0.177	2.50	80	12.19	16.28	93.45
0.0049	0.125	3.00	120	1.53	2.04	95.50
0.0029	0.074	3.75	200	1.43	1.91	97.41
0.0021	0.053	4.25	270	0.76	1.02	98.42
0.0015	0.037	4.75	400	0.54	0.72	99.15
			PAN	0.64	0.85	100.00
TOTALS				74.86	100.00	100.00

Cumulative Weight Percent greater than			
Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	0.62	0.0256	0.651
10	1.02	0.0194	0.494
16	1.12	0.0181	0.461
25	1.26	0.0164	0.418
40	1.39	0.0151	0.383
50	1.47	0.0142	0.361
60	1.63	0.0127	0.322
75	1.95	0.0102	0.258
84	2.21	0.0085	0.216
90	2.39	0.0075	0.190
95	2.88	0.0054	0.136

Measure	Trask	Inman	Folk-Ward
Median, phi	1.47	1.47	1.47
Median, in.	0.0142	0.0142	0.0142
Median, mm	0.361	0.361	0.361
Mean, phi	1.57	1.66	1.60
Mean, in.	0.0133	0.0124	0.0130
Mean, mm	0.338	0.316	0.330
Sorting	1.272	0.546	0.615
Skewness	0.909	0.358	0.303
Kurtosis	0.263	1.070	1.333

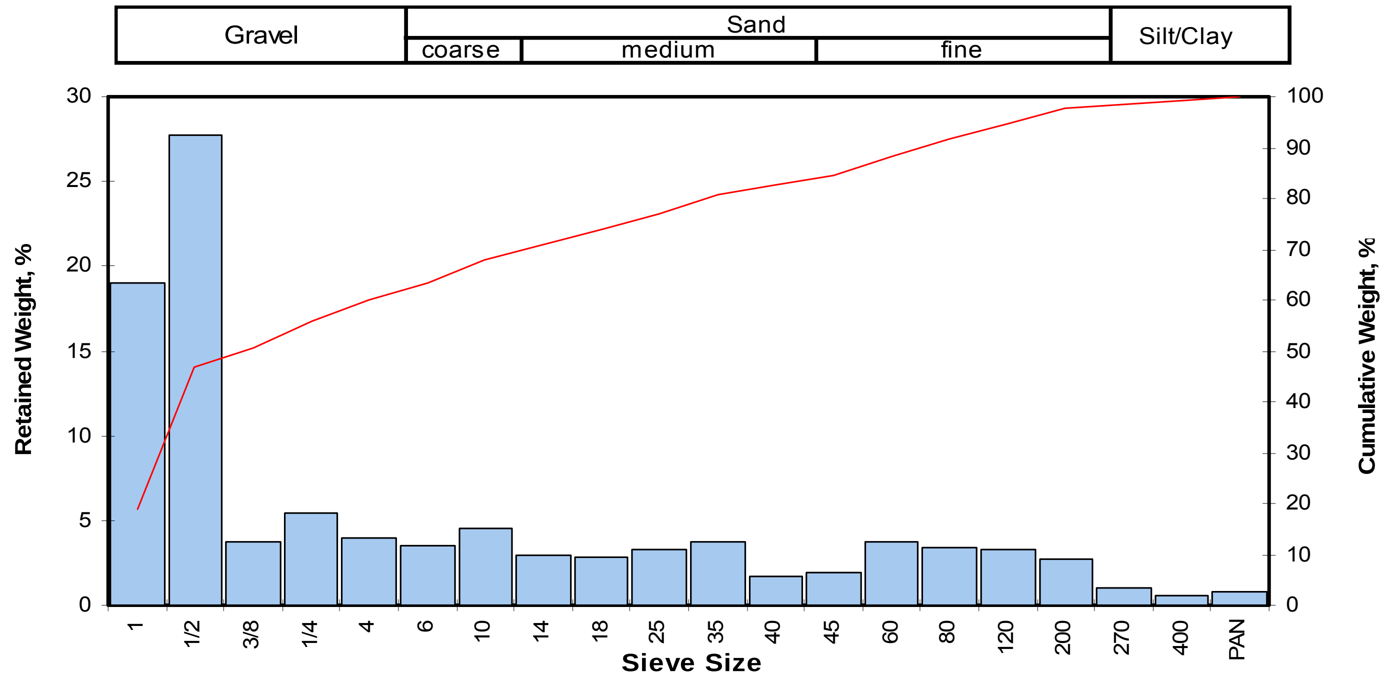
Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.00
Coarse Sand	10	0.17
Medium Sand	40	23.72
Fine Sand	200	73.51
Silt/Clay	<200	2.59
	Total	100

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-1-15
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	15



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	68.98	19.05	19.05
0.4922	12.501	-3.64	1/2	100.34	27.72	46.77
0.3740	9.500	-3.25	3/8	13.69	3.78	50.55
0.2500	6.351	-2.67	1/4	19.76	5.46	56.01
0.1873	4.757	-2.25	4	14.24	3.93	59.94
0.1324	3.364	-1.75	6	12.79	3.53	63.48
0.0787	2.000	-1.00	10	16.52	4.56	68.04
0.0557	1.414	-0.50	14	10.73	2.96	71.00
0.0394	1.000	0.00	18	10.20	2.82	73.82
0.0278	0.707	0.50	25	11.78	3.25	77.08
0.0197	0.500	1.00	35	13.57	3.75	80.82
0.0166	0.420	1.25	40	6.22	1.72	82.54
0.0139	0.354	1.50	45	7.15	1.98	84.52
0.0098	0.250	2.00	60	13.45	3.72	88.23
0.0070	0.177	2.50	80	12.14	3.35	91.59
0.0049	0.125	3.00	120	11.86	3.28	94.86
0.0029	0.074	3.75	200	9.90	2.73	97.60
0.0021	0.053	4.25	270	3.83	1.06	98.65
0.0015	0.037	4.75	400	2.18	0.60	99.26
			PAN	2.69	0.74	100.00
TOTALS				362.02	100.00	100.00

Cumulative Weight Percent greater than Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5			
10			
16			
25	-4.43	0.8483	21.548
40	-3.89	0.5830	14.808
50	-3.31	0.3893	9.889
60	-2.24	0.1863	4.731
75	0.18	0.0347	0.882
84	1.43	0.0146	0.370
90	2.26	0.0082	0.208
95	3.04	0.0048	0.122

Measure	Trask	Inman	Folk-Ward
Median, phi	-3.31	-3.31	-3.31
Median, in.	0.3893	0.3893	0.3893
Median, mm	9.889	9.889	9.889
Mean, phi	-3.49		
Mean, in.	0.4415		
Mean, mm	11.215		
Sorting	4.943		
Skewness	0.441		
Kurtosis			

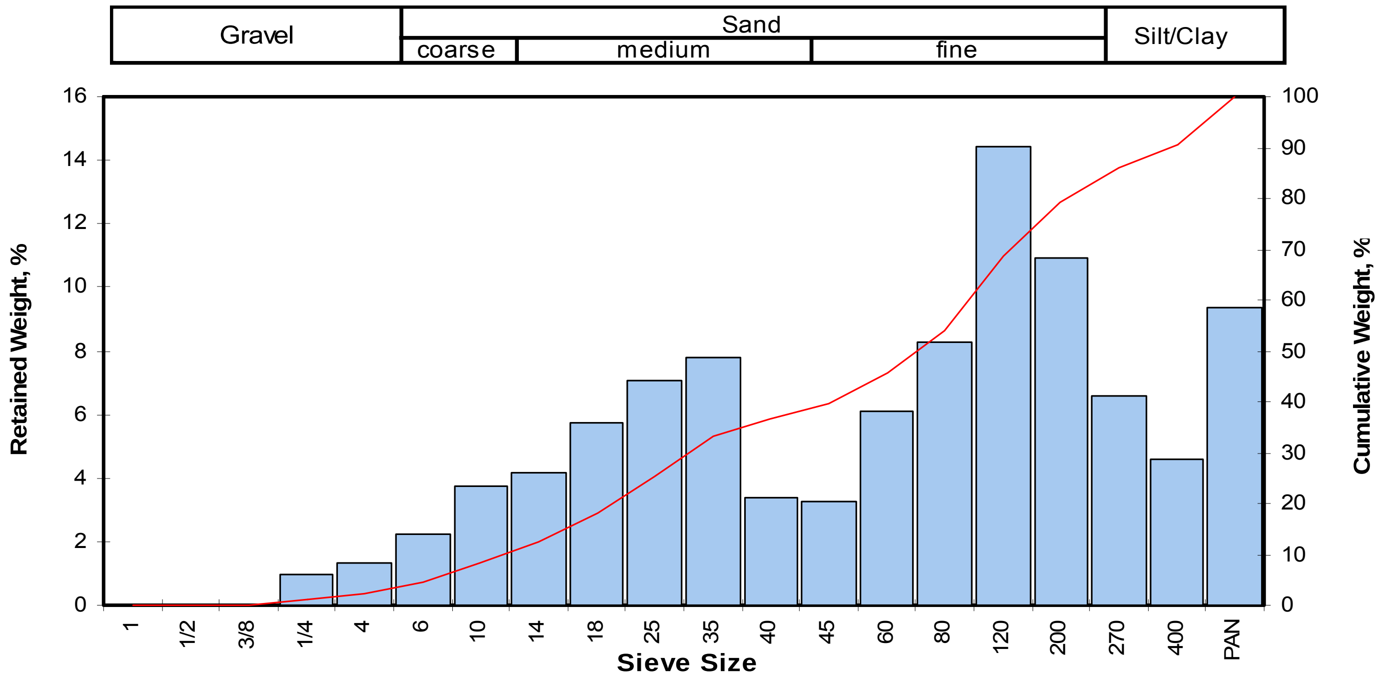
Grain Size Description (ASTM-USCS Scale)	Gravel (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	59.94
Coarse Sand	10	8.10
Medium Sand	40	14.50
Fine Sand	200	15.05
Silt/Clay	<200	2.40
	Total	100

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-1-28
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	28



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	0.00	0.00	0.00
0.4922	12.501	-3.64	1/2	0.00	0.00	0.00
0.3740	9.500	-3.25	3/8	0.00	0.00	0.00
0.2500	6.351	-2.67	1/4	1.53	0.97	0.97
0.1873	4.757	-2.25	4	2.08	1.32	2.29
0.1324	3.364	-1.75	6	3.52	2.23	4.52
0.0787	2.000	-1.00	10	5.95	3.77	8.29
0.0557	1.414	-0.50	14	6.57	4.16	12.45
0.0394	1.000	0.00	18	9.09	5.76	18.22
0.0278	0.707	0.50	25	11.17	7.08	25.30
0.0197	0.500	1.00	35	12.26	7.77	33.07
0.0166	0.420	1.25	40	5.29	3.35	36.42
0.0139	0.354	1.50	45	5.16	3.27	39.69
0.0098	0.250	2.00	60	9.63	6.10	45.79
0.0070	0.177	2.50	80	13.07	8.28	54.08
0.0049	0.125	3.00	120	22.75	14.42	68.50
0.0029	0.074	3.75	200	17.21	10.91	79.41
0.0021	0.053	4.25	270	10.43	6.61	86.02
0.0015	0.037	4.75	400	7.28	4.61	90.63
			PAN	14.78	9.37	100.00
TOTALS				157.77	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	-1.65	0.1239	3.148
10	-0.79	0.0683	1.735
16	-0.19	0.0450	1.143
25	0.48	0.0282	0.717
40	1.53	0.0137	0.347
50	2.25	0.0083	0.210
60	2.71	0.0060	0.153
75	3.45	0.0036	0.092
84	4.10	0.0023	0.058
90	4.68	0.0015	0.039
95			

Measure	Trask	Inman	Folk-Ward
Median, phi	2.25	2.25	2.25
Median, in.	0.0083	0.0083	0.0083
Median, mm	0.210	0.210	0.210
Mean, phi	1.31	1.95	2.05
Mean, in.	0.0159	0.0102	0.0095
Mean, mm	0.405	0.258	0.241
Sorting	2.797	2.145	
Skewness	1.223	-0.140	
Kurtosis	0.184		

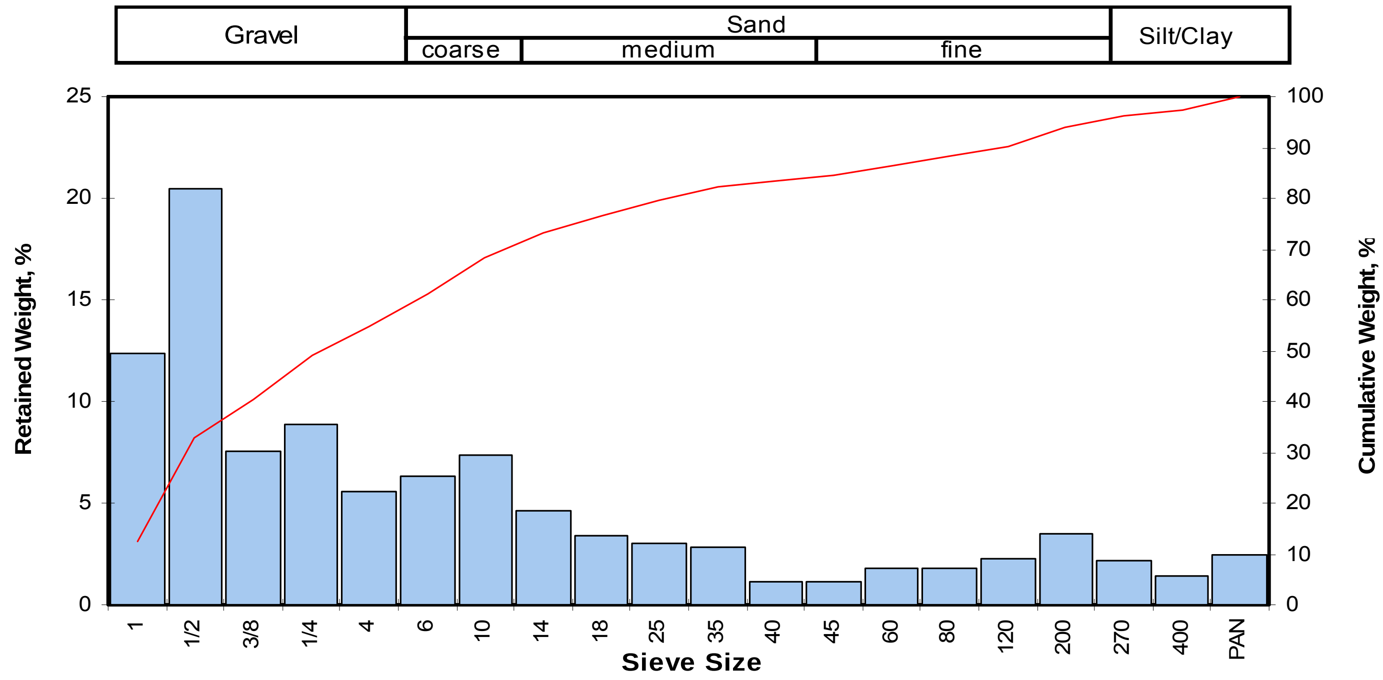
Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	2.29
Coarse Sand	10	6.00
Medium Sand	40	28.13
Fine Sand	200	42.99
Silt/Clay	<200	20.59
	Total	100

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-1-35
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	35



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	49.92	12.37	12.37
0.4922	12.501	-3.64	1/2	82.46	20.43	32.79
0.3740	9.500	-3.25	3/8	30.31	7.51	40.30
0.2500	6.351	-2.67	1/4	35.91	8.89	49.19
0.1873	4.757	-2.25	4	22.64	5.61	54.80
0.1324	3.364	-1.75	6	25.47	6.31	61.11
0.0787	2.000	-1.00	10	29.72	7.36	68.47
0.0557	1.414	-0.50	14	18.84	4.67	73.14
0.0394	1.000	0.00	18	13.67	3.39	76.52
0.0278	0.707	0.50	25	12.34	3.06	79.58
0.0197	0.500	1.00	35	11.24	2.78	82.36
0.0166	0.420	1.25	40	4.47	1.11	83.47
0.0139	0.354	1.50	45	4.49	1.11	84.58
0.0098	0.250	2.00	60	7.18	1.78	86.36
0.0070	0.177	2.50	80	7.08	1.75	88.12
0.0049	0.125	3.00	120	9.08	2.25	90.36
0.0029	0.074	3.75	200	14.15	3.50	93.87
0.0021	0.053	4.25	270	8.93	2.21	96.08
0.0015	0.037	4.75	400	5.74	1.42	97.50
			PAN	10.08	2.50	100.00
TOTALS				403.72	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5			
10			
16	-4.47	0.8701	22.101
25	-4.03	0.6411	16.284
40	-3.26	0.3781	9.604
50	-2.61	0.2398	6.092
60	-1.84	0.1407	3.575
75	-0.22	0.0460	1.169
84	1.37	0.0152	0.387
90	2.92	0.0052	0.132
95	4.01	0.0025	0.062

Measure	Trask	Inman	Folk-Ward
Median, phi	-2.61	-2.61	-2.61
Median, in.	0.2398	0.2398	0.2398
Median, mm	6.092	6.092	6.092
Mean, phi	-3.13	-1.55	-1.90
Mean, in.	0.3436	0.1152	0.1471
Mean, mm	8.726	2.925	3.736
Sorting	3.733	2.917	
Skewness	0.716	0.363	
Kurtosis			

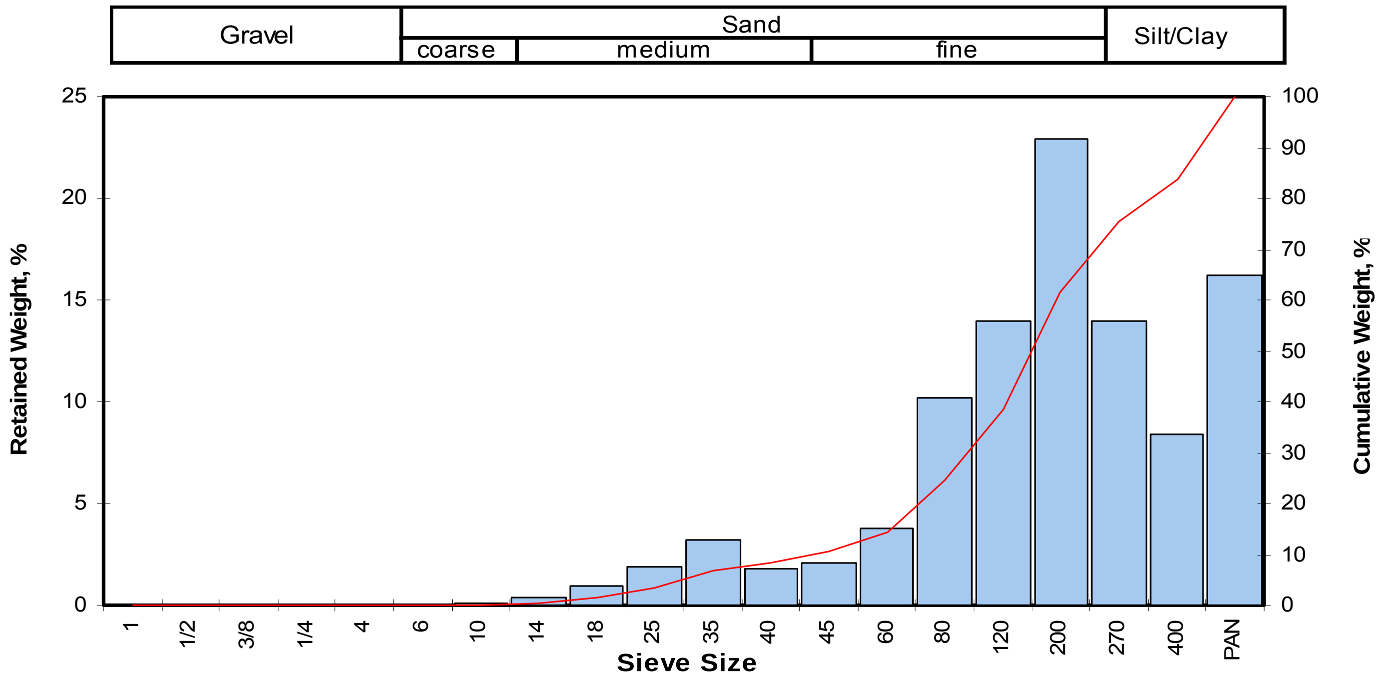
Grain Size Description (ASTM-USCS Scale)	Gravel (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	54.80
Coarse Sand	10	13.67
Medium Sand	40	15.00
Fine Sand	200	10.40
Silt/Clay	<200	6.13
	Total	100

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-1-42
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	42



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	0.00	0.00	0.00
0.4922	12.501	-3.64	1/2	0.00	0.00	0.00
0.3740	9.500	-3.25	3/8	0.00	0.00	0.00
0.2500	6.351	-2.67	1/4	0.00	0.00	0.00
0.1873	4.757	-2.25	4	0.00	0.00	0.00
0.1324	3.364	-1.75	6	0.00	0.00	0.00
0.0787	2.000	-1.00	10	0.20	0.14	0.14
0.0557	1.414	-0.50	14	0.54	0.38	0.52
0.0394	1.000	0.00	18	1.41	0.99	1.51
0.0278	0.707	0.50	25	2.73	1.91	3.42
0.0197	0.500	1.00	35	4.58	3.21	6.63
0.0166	0.420	1.25	40	2.59	1.81	8.44
0.0139	0.354	1.50	45	2.95	2.07	10.51
0.0098	0.250	2.00	60	5.35	3.75	14.26
0.0070	0.177	2.50	80	14.59	10.22	24.48
0.0049	0.125	3.00	120	19.98	14.00	38.47
0.0029	0.074	3.75	200	32.75	22.94	61.42
0.0021	0.053	4.25	270	19.92	13.95	75.37
0.0015	0.037	4.75	400	11.95	8.37	83.74
			PAN	23.21	16.26	100.00
TOTALS				142.75	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	0.75	0.0235	0.596
10	1.44	0.0145	0.369
16	2.09	0.0093	0.236
25	2.52	0.0069	0.174
40	3.05	0.0048	0.121
50	3.38	0.0038	0.096
60	3.70	0.0030	0.077
75	4.24	0.0021	0.053
84			
90			
95			

Measure	Trask	Inman	Folk-Ward
Median, phi	3.38	3.38	3.38
Median, in.	0.0038	0.0038	0.0038
Median, mm	0.096	0.096	0.096
Mean, phi	3.14		
Mean, in.	0.0045		
Mean, mm	0.114		
Sorting	1.814		
Skewness	0.999		
Kurtosis			

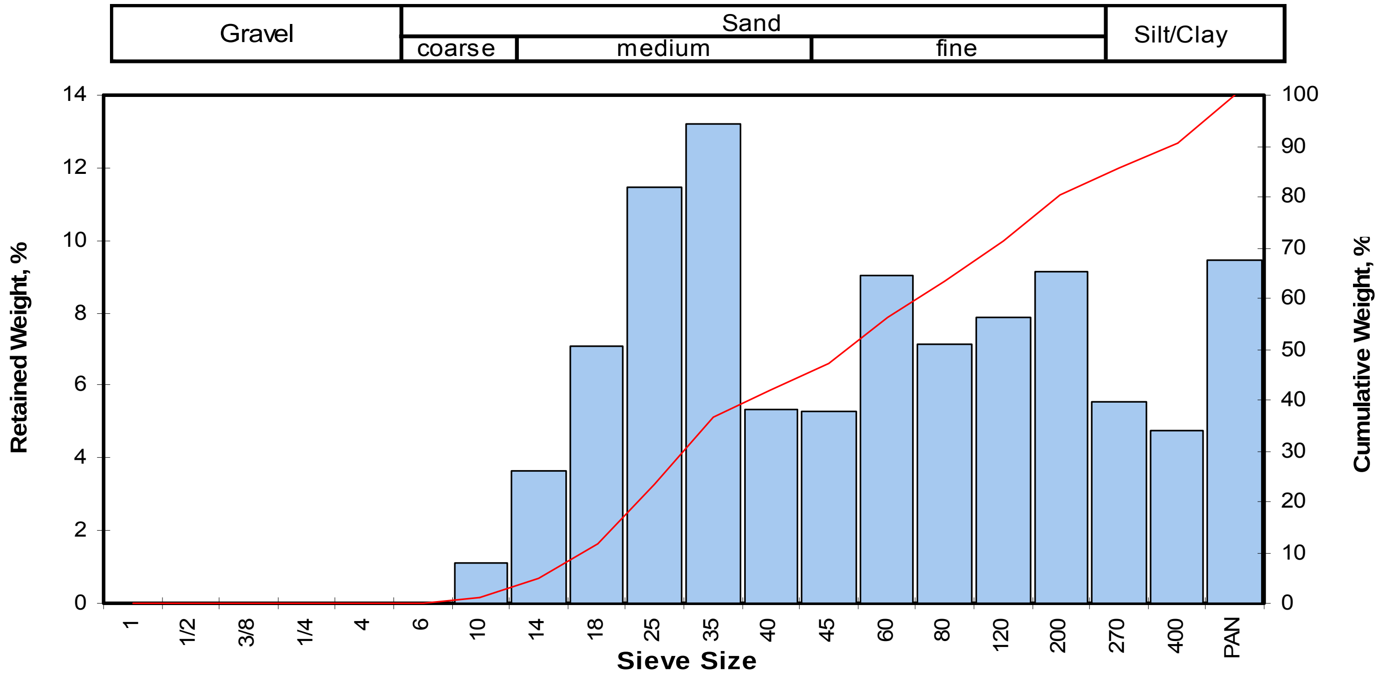
Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.00
Coarse Sand	10	0.14
Medium Sand	40	8.30
Fine Sand	200	52.97
Silt/Clay	<200	38.58
	Total	100

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-1-52
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	52



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	0.00	0.00	0.00
0.4922	12.501	-3.64	1/2	0.00	0.00	0.00
0.3740	9.500	-3.25	3/8	0.00	0.00	0.00
0.2500	6.351	-2.67	1/4	0.00	0.00	0.00
0.1873	4.757	-2.25	4	0.00	0.00	0.00
0.1324	3.364	-1.75	6	0.00	0.00	0.00
0.0787	2.000	-1.00	10	0.76	1.09	1.09
0.0557	1.414	-0.50	14	2.54	3.66	4.75
0.0394	1.000	0.00	18	4.90	7.06	11.81
0.0278	0.707	0.50	25	7.95	11.45	23.25
0.0197	0.500	1.00	35	9.17	13.20	36.46
0.0166	0.420	1.25	40	3.70	5.33	41.79
0.0139	0.354	1.50	45	3.67	5.28	47.07
0.0098	0.250	2.00	60	6.29	9.06	56.13
0.0070	0.177	2.50	80	4.95	7.13	63.25
0.0049	0.125	3.00	120	5.48	7.89	71.14
0.0029	0.074	3.75	200	6.33	9.11	80.26
0.0021	0.053	4.25	270	3.86	5.56	85.82
0.0015	0.037	4.75	400	3.29	4.74	90.55
			PAN	6.56	9.45	100.00
TOTALS				69.45	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	-0.48	0.0550	1.397
10	-0.13	0.0430	1.093
16	0.18	0.0347	0.881
25	0.57	0.0266	0.675
40	1.17	0.0175	0.446
50	1.66	0.0124	0.316
60	2.27	0.0082	0.207
75	3.32	0.0039	0.100
84	4.09	0.0023	0.059
90	4.69	0.0015	0.039
95			

Measure	Trask	Inman	Folk-Ward
Median, phi	1.66	1.66	1.66
Median, in.	0.0124	0.0124	0.0124
Median, mm	0.316	0.316	0.316
Mean, phi	1.37	2.13	1.98
Mean, in.	0.0153	0.0090	0.0100
Mean, mm	0.388	0.228	0.254
Sorting	2.595	1.952	
Skewness	0.824	0.242	
Kurtosis	0.273		

Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Mean from Trask)

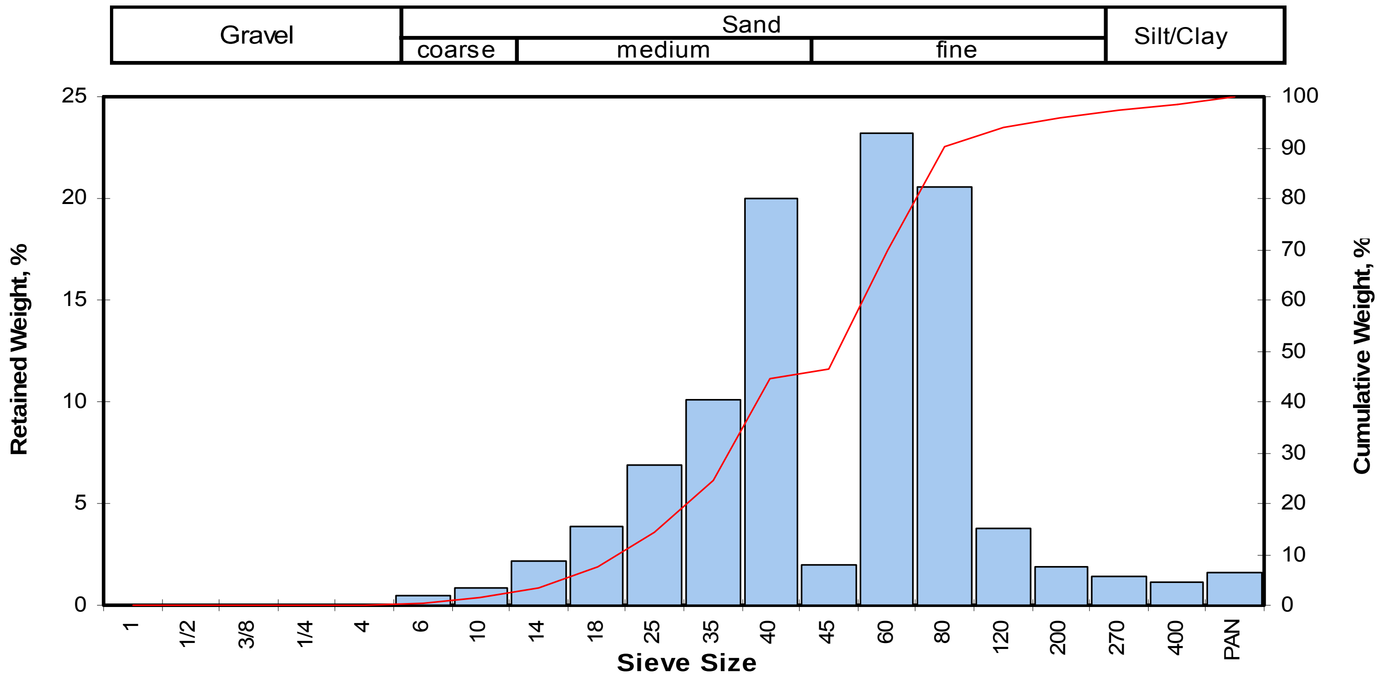
Description	Retained on Sieve #	Weight Percent
Gravel	4	0.00
Coarse Sand	10	1.09
Medium Sand	40	40.69
Fine Sand	200	38.47
Silt/Clay	<200	19.74
	Total	100

Phone: (562) 907-3607 Fax: (562) 907-3610

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-1-70
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	70



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	0.00	0.00	0.00
0.4922	12.501	-3.64	1/2	0.00	0.00	0.00
0.3740	9.500	-3.25	3/8	0.00	0.00	0.00
0.2500	6.351	-2.67	1/4	0.00	0.00	0.00
0.1873	4.757	-2.25	4	0.00	0.00	0.00
0.1324	3.364	-1.75	6	0.35	0.51	0.51
0.0787	2.000	-1.00	10	0.61	0.89	1.39
0.0557	1.414	-0.50	14	1.48	2.15	3.54
0.0394	1.000	0.00	18	2.65	3.85	7.40
0.0278	0.707	0.50	25	4.76	6.92	14.31
0.0197	0.500	1.00	35	6.98	10.14	24.45
0.0166	0.420	1.25	40	13.76	19.99	44.44
0.0139	0.354	1.50	45	1.37	1.99	46.43
0.0098	0.250	2.00	60	16.00	23.25	69.68
0.0070	0.177	2.50	80	14.18	20.60	90.28
0.0049	0.125	3.00	120	2.57	3.73	94.01
0.0029	0.074	3.75	200	1.29	1.87	95.89
0.0021	0.053	4.25	270	0.95	1.38	97.27
0.0015	0.037	4.75	400	0.80	1.16	98.43
			PAN	1.08	1.57	100.00
TOTALS				68.83	100.00	100.00

Cumulative Weight Percent greater than			
Weight percent	**Phi Value**	**Particle Size Inches**	**Particle Size Millimeters**
5	-0.31	0.0488	1.241
10	0.19	0.0346	0.878
16	0.58	0.0263	0.667
25	1.01	0.0196	0.498
40	1.19	0.0172	0.437
50	1.58	0.0132	0.335
60	1.79	0.0114	0.289
75	2.13	0.0090	0.229
84	2.35	0.0077	0.196
90	2.49	0.0070	0.178
95	3.39	0.0037	0.095

Measure	Trask	Inman	Folk-Ward
Median, phi	1.58	1.58	1.58
Median, in.	0.0132	0.0132	0.0132
Median, mm	0.335	0.335	0.335
Mean, phi	1.46	1.47	1.50
Mean, in.	0.0143	0.0143	0.0139
Mean, mm	0.363	0.362	0.353
Sorting	1.475	0.882	1.003
Skewness	1.006	-0.126	-0.073
Kurtosis	0.192	1.100	1.353

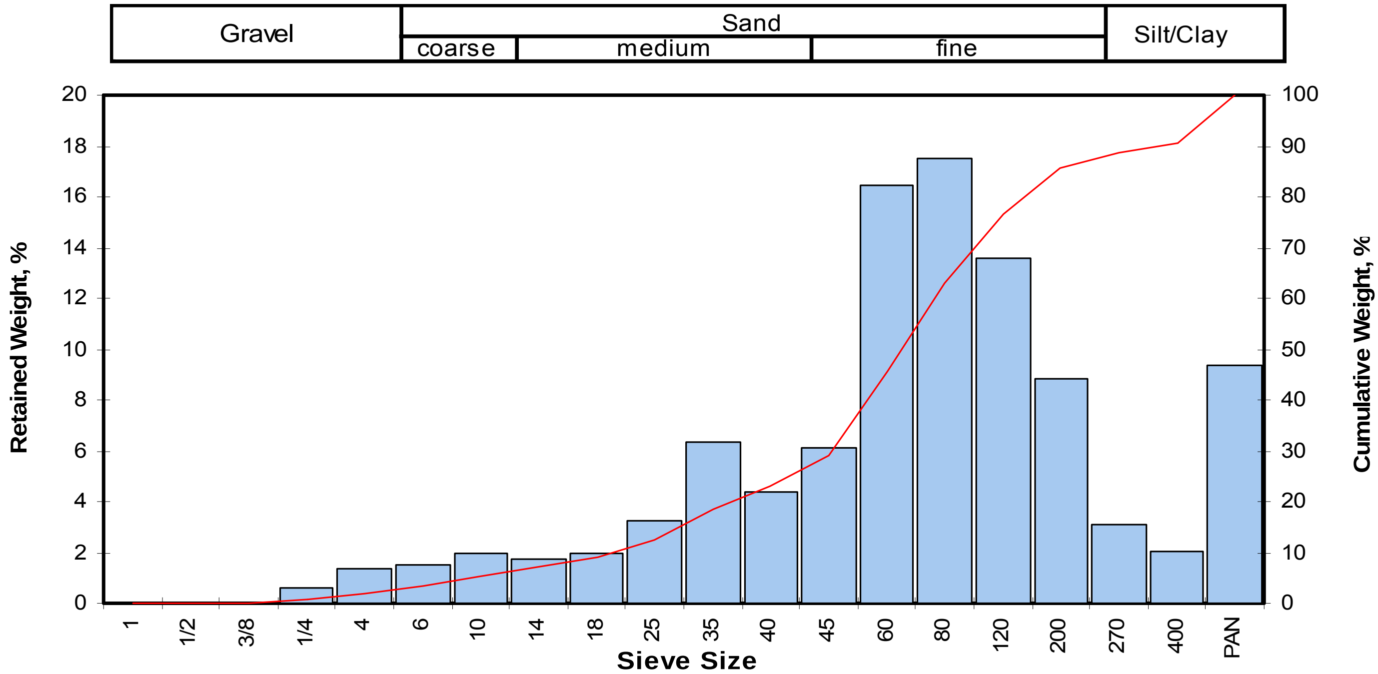
Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.00
Coarse Sand	10	1.39
Medium Sand	40	43.05
Fine Sand	200	51.45
Silt/Clay	<200	4.11
	Total	100

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-4-15
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	15



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	0.00	0.00	0.00
0.4922	12.501	-3.64	1/2	0.00	0.00	0.00
0.3740	9.500	-3.25	3/8	0.00	0.00	0.00
0.2500	6.351	-2.67	1/4	1.37	0.58	0.58
0.1873	4.757	-2.25	4	3.13	1.34	1.92
0.1324	3.364	-1.75	6	3.49	1.49	3.41
0.0787	2.000	-1.00	10	4.63	1.98	5.39
0.0557	1.414	-0.50	14	4.07	1.74	7.13
0.0394	1.000	0.00	18	4.57	1.95	9.08
0.0278	0.707	0.50	25	7.57	3.23	12.31
0.0197	0.500	1.00	35	14.86	6.34	18.65
0.0166	0.420	1.25	40	10.34	4.41	23.07
0.0139	0.354	1.50	45	14.33	6.12	29.18
0.0098	0.250	2.00	60	38.45	16.42	45.60
0.0070	0.177	2.50	80	40.93	17.47	63.07
0.0049	0.125	3.00	120	31.77	13.56	76.64
0.0029	0.074	3.75	200	20.71	8.84	85.48
0.0021	0.053	4.25	270	7.21	3.08	88.56
0.0015	0.037	4.75	400	4.80	2.05	90.61
			PAN	22.00	9.39	100.00
TOTALS				234.23	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	-1.15	0.0872	2.215
10	0.14	0.0357	0.906
16	0.79	0.0228	0.578
25	1.33	0.0157	0.398
40	1.83	0.0111	0.281
50	2.13	0.0090	0.229
60	2.41	0.0074	0.188
75	2.94	0.0051	0.130
84	3.62	0.0032	0.081
90	4.60	0.0016	0.041
95			

Measure	Trask	Inman	Folk-Ward
Median, phi	2.13	2.13	2.13
Median, in.	0.0090	0.0090	0.0090
Median, mm	0.229	0.229	0.229
Mean, phi	1.92	2.21	2.18
Mean, in.	0.0104	0.0085	0.0087
Mean, mm	0.264	0.216	0.221
Sorting	1.748	1.417	
Skewness	0.994	0.058	
Kurtosis	0.155		

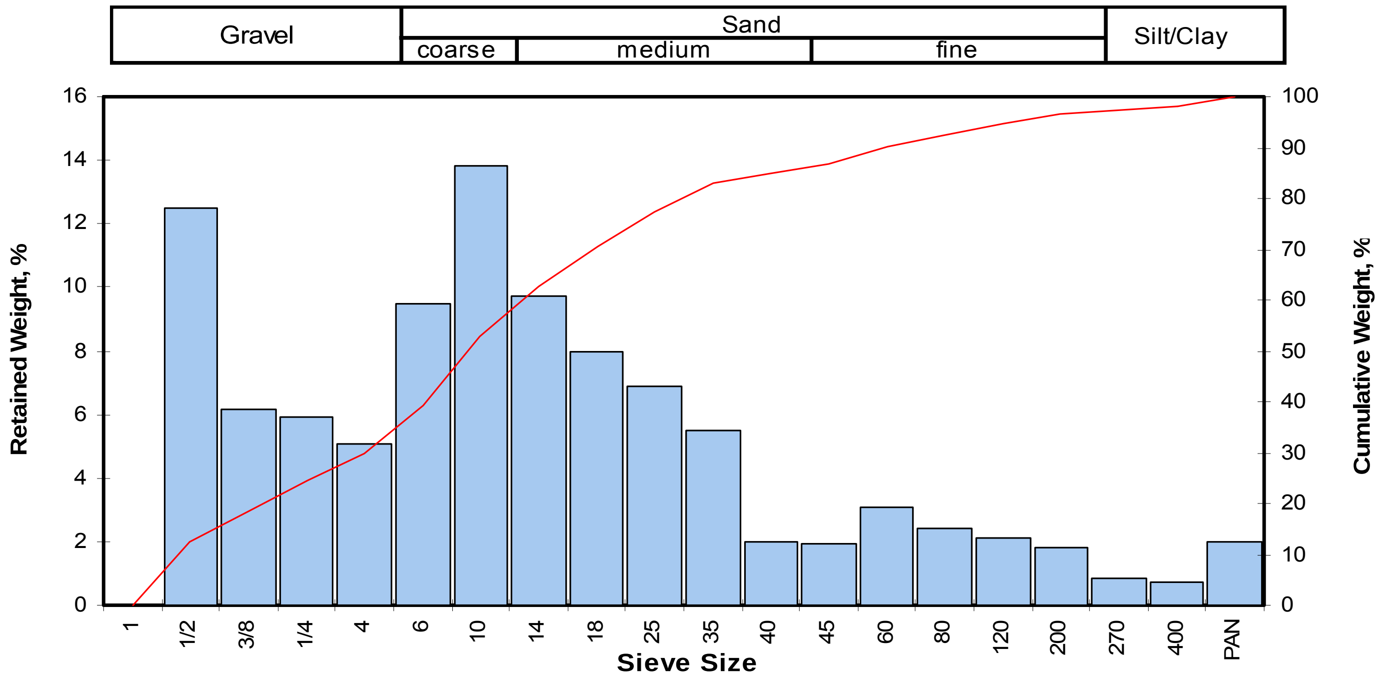
Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	1.92
Coarse Sand	10	3.47
Medium Sand	40	17.68
Fine Sand	200	62.41
Silt/Clay	<200	14.52
	Total	100

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-4-30
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	30



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	0.00	0.00	0.00
0.4922	12.501	-3.64	1/2	37.97	12.50	12.50
0.3740	9.500	-3.25	3/8	18.67	6.15	18.64
0.2500	6.351	-2.67	1/4	17.94	5.90	24.55
0.1873	4.757	-2.25	4	15.43	5.08	29.63
0.1324	3.364	-1.75	6	28.79	9.48	39.10
0.0787	2.000	-1.00	10	42.08	13.85	52.95
0.0557	1.414	-0.50	14	29.54	9.72	62.68
0.0394	1.000	0.00	18	24.14	7.95	70.62
0.0278	0.707	0.50	25	20.93	6.89	77.51
0.0197	0.500	1.00	35	16.71	5.50	83.01
0.0166	0.420	1.25	40	6.10	2.01	85.02
0.0139	0.354	1.50	45	5.85	1.93	86.94
0.0098	0.250	2.00	60	9.33	3.07	90.01
0.0070	0.177	2.50	80	7.41	2.44	92.45
0.0049	0.125	3.00	120	6.49	2.14	94.59
0.0029	0.074	3.75	200	5.55	1.83	96.42
0.0021	0.053	4.25	270	2.63	0.87	97.28
0.0015	0.037	4.75	400	2.19	0.72	98.00
			PAN	6.07	2.00	100.00
TOTALS				303.82	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	-4.24	0.7460	18.947
10	-3.84	0.5653	14.359
16	-3.42	0.4209	10.691
25	-2.63	0.2437	6.190
40	-1.70	0.1280	3.252
50	-1.16	0.0880	2.234
60	-0.64	0.0612	1.556
75	0.32	0.0316	0.802
84	1.12	0.0181	0.459
90	2.00	0.0099	0.250
95	3.17	0.0044	0.111

Measure	Trask	Inman	Folk-Ward
Median, phi	-1.16	-1.16	-1.16
Median, in.	0.0880	0.0880	0.0880
Median, mm	2.234	2.234	2.234
Mean, phi	-1.81	-1.15	-1.15
Mean, in.	0.1376	0.0872	0.0875
Mean, mm	3.496	2.215	2.222
Sorting	2.778	2.271	2.259
Skewness	0.997	0.005	0.087
Kurtosis	0.191	0.632	1.031

Grain Size Description (ASTM-USCS Scale)	Coarse sand (based on Mean from Trask)

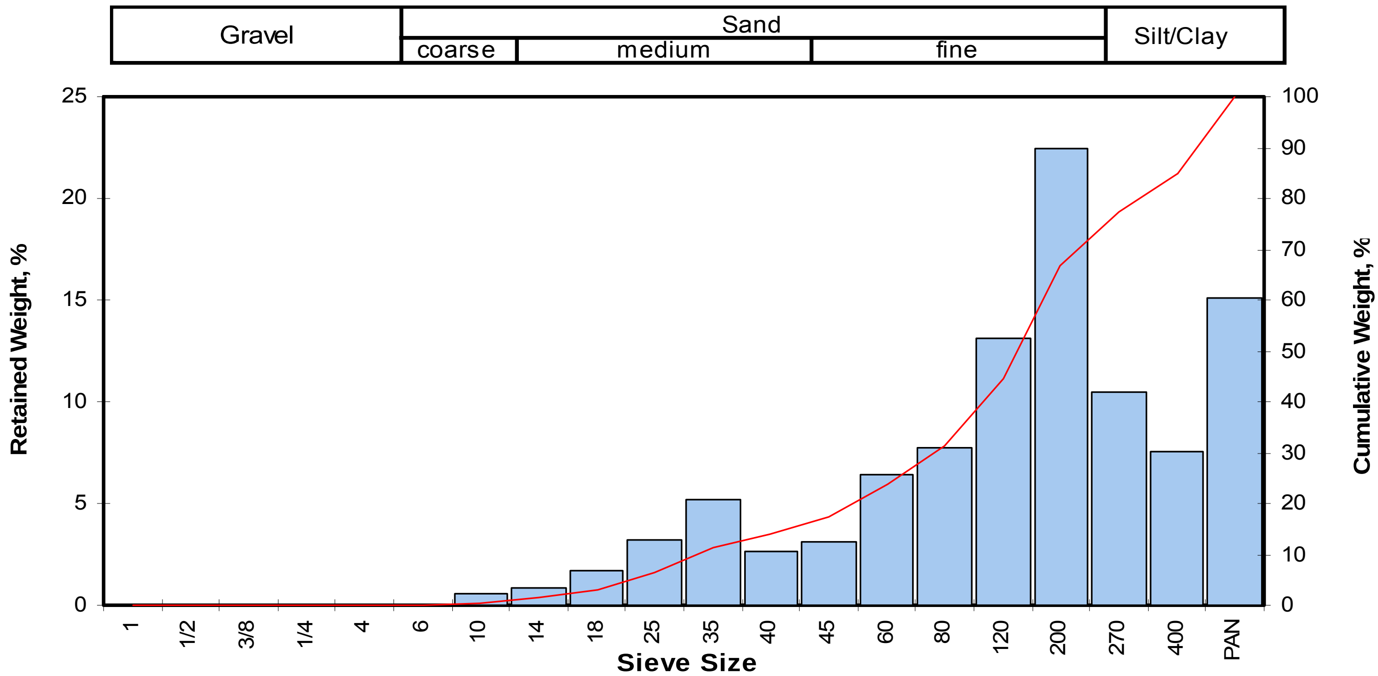
Description	Retained on Sieve #	Weight Percent
Gravel	4	29.63
Coarse Sand	10	23.33
Medium Sand	40	32.07
Fine Sand	200	11.40
Silt/Clay	<200	3.58
	Total	100

Phone: (562) 907-3607 Fax: (562) 907-3610

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-4-50
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	50



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	0.00	0.00	0.00
0.4922	12.501	-3.64	1/2	0.00	0.00	0.00
0.3740	9.500	-3.25	3/8	0.00	0.00	0.00
0.2500	6.351	-2.67	1/4	0.00	0.00	0.00
0.1873	4.757	-2.25	4	0.00	0.00	0.00
0.1324	3.364	-1.75	6	0.00	0.00	0.00
0.0787	2.000	-1.00	10	0.67	0.52	0.52
0.0557	1.414	-0.50	14	1.14	0.89	1.41
0.0394	1.000	0.00	18	2.16	1.69	3.10
0.0278	0.707	0.50	25	4.16	3.25	6.35
0.0197	0.500	1.00	35	6.60	5.15	11.50
0.0166	0.420	1.25	40	3.36	2.62	14.13
0.0139	0.354	1.50	45	3.98	3.11	17.24
0.0098	0.250	2.00	60	8.23	6.43	23.66
0.0070	0.177	2.50	80	9.89	7.72	31.39
0.0049	0.125	3.00	120	16.81	13.13	44.51
0.0029	0.074	3.75	200	28.70	22.41	66.93
0.0021	0.053	4.25	270	13.35	10.43	77.35
0.0015	0.037	4.75	400	9.64	7.53	84.88
			PAN	19.36	15.12	100.00
TOTALS				128.05	100.00	100.00

Cumulative Weight Percent greater than: Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	0.29	0.0321	0.817
10	0.85	0.0218	0.553
16	1.40	0.0149	0.379
25	2.09	0.0093	0.235
40	2.83	0.0055	0.141
50	3.18	0.0043	0.110
60	3.52	0.0034	0.087
75	4.14	0.0022	0.057
84	4.69	0.0015	0.039
90			
95			

Measure	Trask	Inman	Folk-Ward
Median, phi	3.18	3.18	3.18
Median, in.	0.0043	0.0043	0.0043
Median, mm	0.110	0.110	0.110
Mean, phi	2.77	3.05	3.09
Mean, in.	0.0058	0.0048	0.0046
Mean, mm	0.146	0.121	0.117
Sorting	2.035	1.645	
Skewness	1.051	-0.084	
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	Fine sand (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	0.00
Coarse Sand	10	0.52
Medium Sand	40	13.60
Fine Sand	200	52.80
Silt/Clay	<200	33.07
	Total	100

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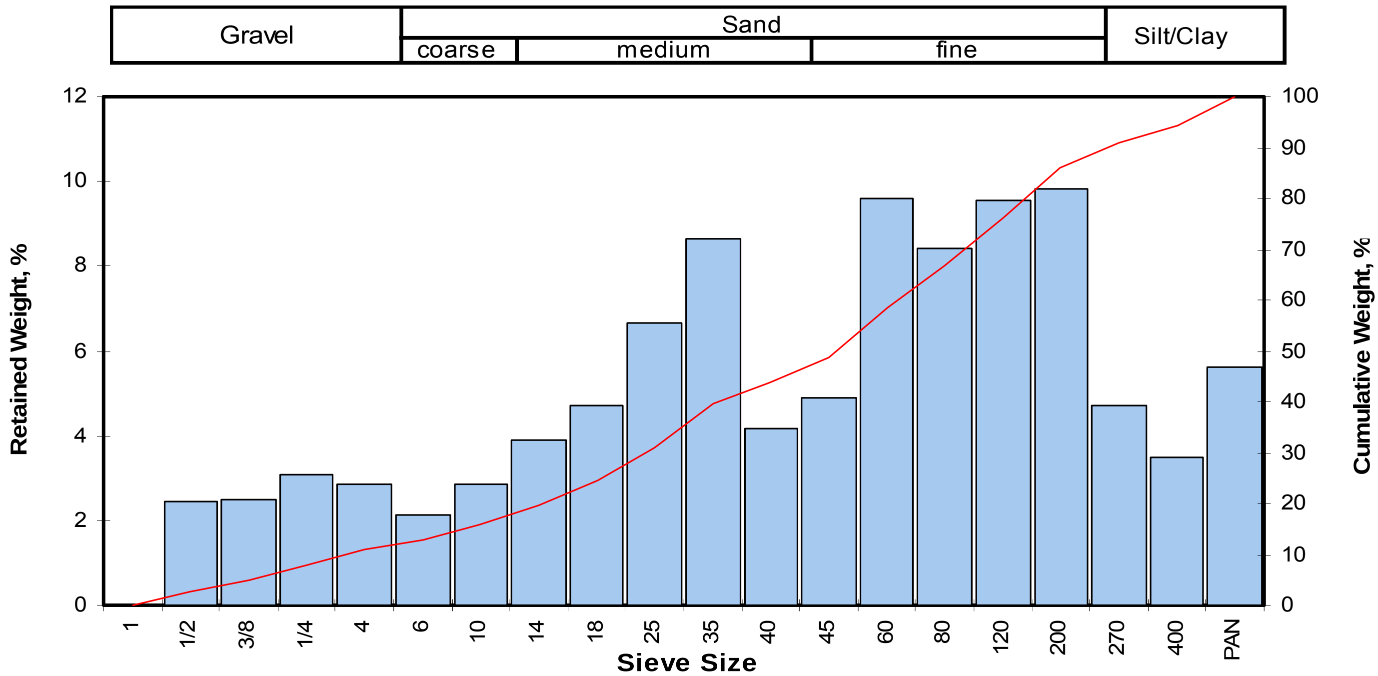
PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-4-71
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	71



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	0.00	0.00	0.00
0.4922	12.501	-3.64	1/2	3.91	2.46	2.46
0.3740	9.500	-3.25	3/8	3.93	2.48	4.94
0.2500	6.351	-2.67	1/4	4.87	3.07	8.01
0.1873	4.757	-2.25	4	4.55	2.87	10.87
0.1324	3.364	-1.75	6	3.38	2.13	13.00
0.0787	2.000	-1.00	10	4.55	2.87	15.87
0.0557	1.414	-0.50	14	6.15	3.87	19.74
0.0394	1.000	0.00	18	7.47	4.70	24.44
0.0278	0.707	0.50	25	10.60	6.68	31.12
0.0197	0.500	1.00	35	13.70	8.63	39.75
0.0166	0.420	1.25	40	6.60	4.16	43.91
0.0139	0.354	1.50	45	7.79	4.91	48.81
0.0098	0.250	2.00	60	15.21	9.58	58.39
0.0070	0.177	2.50	80	13.38	8.43	66.82
0.0049	0.125	3.00	120	15.15	9.54	76.36
0.0029	0.074	3.75	200	15.61	9.83	86.19
0.0021	0.053	4.25	270	7.46	4.70	90.89
0.0015	0.037	4.75	400	5.54	3.49	94.38
			PAN	8.92	5.62	100.00
TOTALS				158.77	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5	-3.24	0.3710	9.423
10	-2.38	0.2045	5.194
16	-0.98	0.0778	1.976
25	0.04	0.0383	0.972
40	1.02	0.0195	0.495
50	1.56	0.0133	0.339
60	2.10	0.0092	0.234
75	2.93	0.0052	0.131
84	3.58	0.0033	0.083
90	4.16	0.0022	0.056
95			

Measure	Trask	Inman	Folk-Ward
Median, phi	1.56	1.56	1.56
Median, in.	0.0133	0.0133	0.0133
Median, mm	0.339	0.339	0.339
Mean, phi	0.86	1.30	1.39
Mean, in.	0.0217	0.0160	0.0151
Mean, mm	0.551	0.406	0.382
Sorting	2.720	2.283	
Skewness	1.055	-0.115	
Kurtosis	0.082		

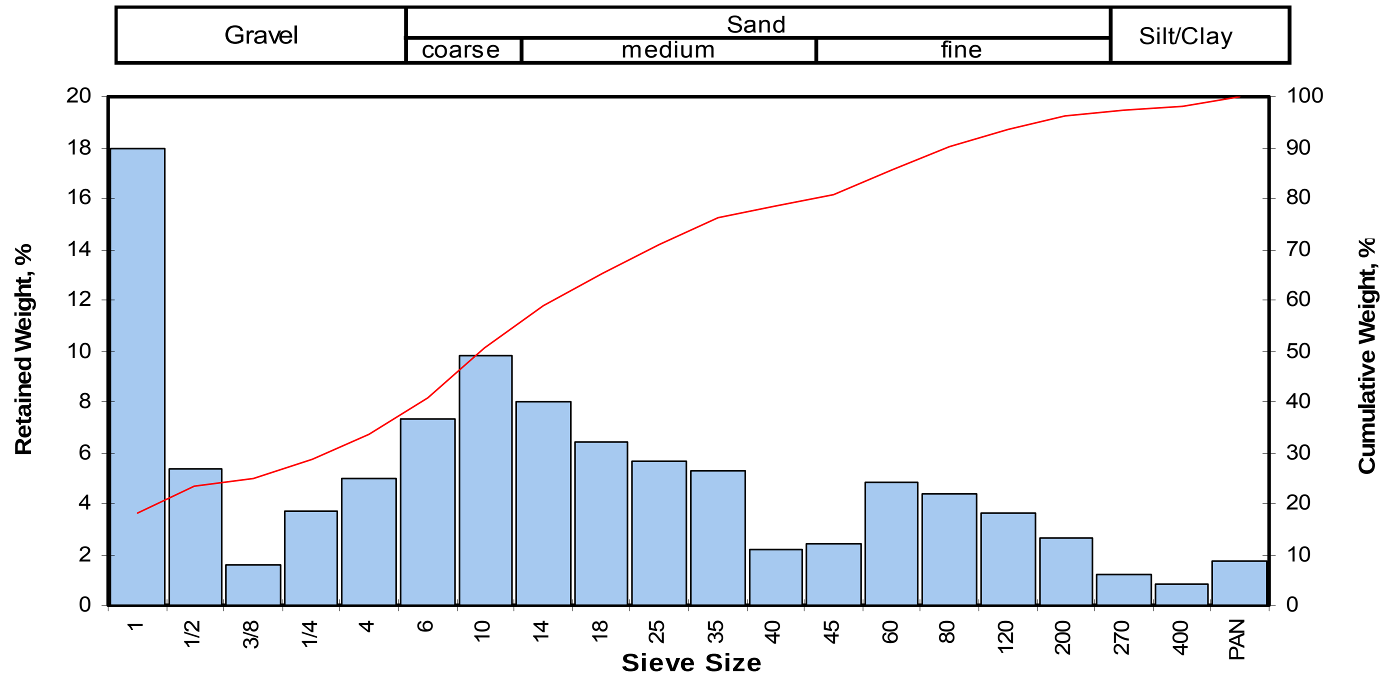
Grain Size Description (ASTM-USCS Scale)	Medium sand (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	10.87
Coarse Sand	10	4.99
Medium Sand	40	28.04
Fine Sand	200	42.29
Silt/Clay	<200	13.81
	Total	100

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-3-10
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	10



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	48.78	17.98	17.98
0.4922	12.501	-3.64	1/2	14.45	5.33	23.31
0.3740	9.500	-3.25	3/8	4.27	1.57	24.88
0.2500	6.351	-2.67	1/4	10.10	3.72	28.60
0.1873	4.757	-2.25	4	13.53	4.99	33.59
0.1324	3.364	-1.75	6	19.78	7.29	40.88
0.0787	2.000	-1.00	10	26.63	9.82	50.70
0.0557	1.414	-0.50	14	21.78	8.03	58.72
0.0394	1.000	0.00	18	17.49	6.45	65.17
0.0278	0.707	0.50	25	15.42	5.68	70.86
0.0197	0.500	1.00	35	14.30	5.27	76.13
0.0166	0.420	1.25	40	6.01	2.22	78.34
0.0139	0.354	1.50	45	6.62	2.44	80.78
0.0098	0.250	2.00	60	13.10	4.83	85.61
0.0070	0.177	2.50	80	11.94	4.40	90.01
0.0049	0.125	3.00	120	9.76	3.60	93.61
0.0029	0.074	3.75	200	7.25	2.67	96.28
0.0021	0.053	4.25	270	3.18	1.17	97.45
0.0015	0.037	4.75	400	2.26	0.83	98.29
			PAN	4.65	1.71	100.00
TOTALS				271.30	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5			
10			
16			
25	-3.23	0.3692	9.378
40	-1.81	0.1381	3.507
50	-1.05	0.0817	2.075
60	-0.40	0.0520	1.321
75	0.89	0.0212	0.538
84	1.83	0.0110	0.281
90	2.50	0.0070	0.177
95	3.39	0.0038	0.095

Measure	Trask	Inman	Folk-Ward
Median, phi	-1.05	-1.05	-1.05
Median, in.	0.0817	0.0817	0.0817
Median, mm	2.075	2.075	2.075
Mean, phi	-2.31		
Mean, in.	0.1952		
Mean, mm	4.958		
Sorting	4.173		
Skewness	1.083		
Kurtosis			

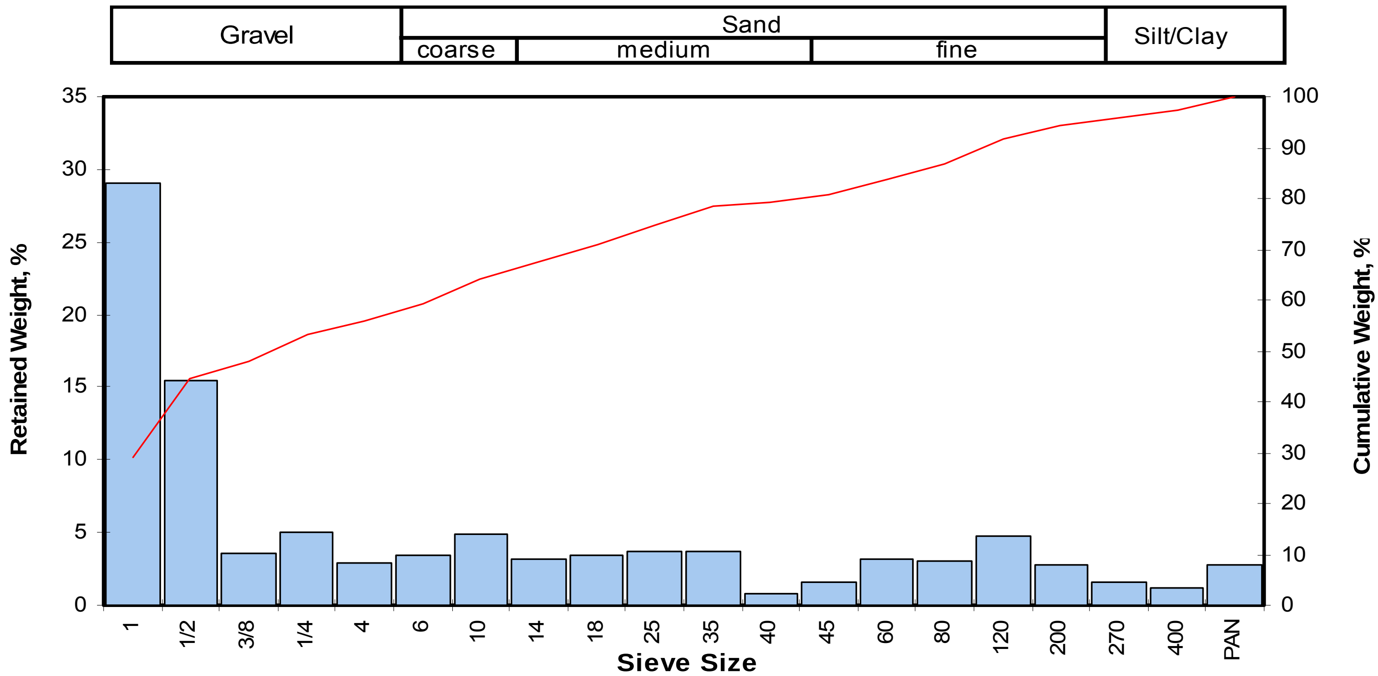
Grain Size Description (ASTM-USCS Scale)	Gravel (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	33.59
Coarse Sand	10	17.11
Medium Sand	40	27.64
Fine Sand	200	17.94
Silt/Clay	<200	3.72
	Total	100

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-3-33
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	33



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	154.58	29.01	29.01
0.4922	12.501	-3.64	1/2	82.15	15.42	44.43
0.3740	9.500	-3.25	3/8	18.83	3.53	47.97
0.2500	6.351	-2.67	1/4	26.94	5.06	53.02
0.1873	4.757	-2.25	4	15.81	2.97	55.99
0.1324	3.364	-1.75	6	18.32	3.44	59.43
0.0787	2.000	-1.00	10	26.13	4.90	64.33
0.0557	1.414	-0.50	14	16.77	3.15	67.48
0.0394	1.000	0.00	18	18.21	3.42	70.90
0.0278	0.707	0.50	25	19.70	3.70	74.59
0.0197	0.500	1.00	35	19.97	3.75	78.34
0.0166	0.420	1.25	40	4.42	0.83	79.17
0.0139	0.354	1.50	45	8.70	1.63	80.81
0.0098	0.250	2.00	60	16.73	3.14	83.95
0.0070	0.177	2.50	80	16.06	3.01	86.96
0.0049	0.125	3.00	120	25.11	4.71	91.67
0.0029	0.074	3.75	200	14.51	2.72	94.40
0.0021	0.053	4.25	270	8.55	1.60	96.00
0.0015	0.037	4.75	400	6.46	1.21	97.21
			PAN	14.85	2.79	100.00
TOTALS				532.80	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5			
10			
16			
25			
40	-3.93	0.6007	15.257
50	-3.01	0.3181	8.079
60	-1.66	0.1246	3.166
75	0.55	0.0268	0.681
84	2.01	0.0098	0.248
90	2.82	0.0056	0.141
95	3.94	0.0026	0.065

Measure	Trask	Inman	Folk-Ward
Median, phi	-3.01	-3.01	-3.01
Median, in.	0.3181	0.3181	0.3181
Median, mm	8.079	8.079	8.079
Mean, phi			
Mean, in.			
Mean, mm			
Sorting			
Skewness			
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	N/A (based on Mean from Trask)

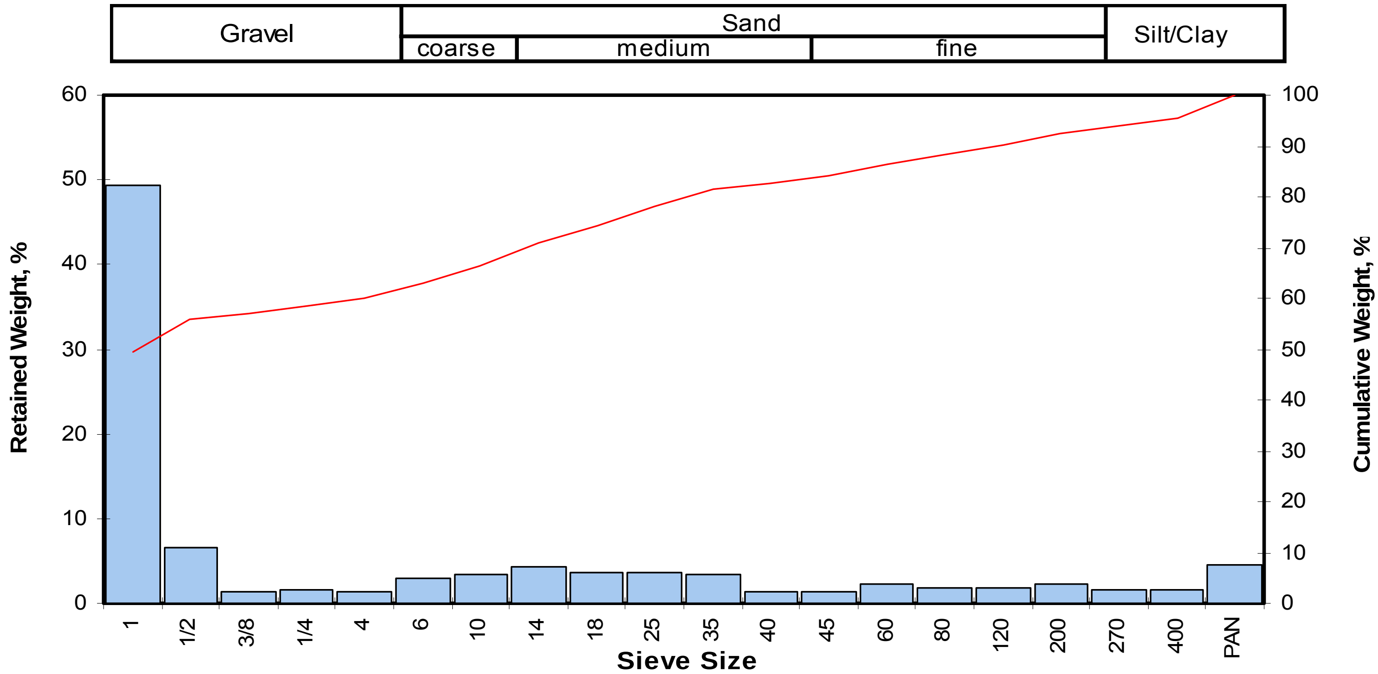
Description	Retained on Sieve #	Weight Percent
Gravel	4	55.99
Coarse Sand	10	8.34
Medium Sand	40	14.84
Fine Sand	200	15.22
Silt/Clay	<200	5.60
	Total	100

 Phone: (562) 907-3607 Fax: (562) 907-3610

PTS Laboratories, Inc.

Particle Size Analysis - ASTM D422M

Client:	AECOM	**PTS File No:**	47098
Project:	NDEP Downgradient Study Area	**Sample ID:**	NERT-CB-3-55
Project No:	60477365 Task 2015-160-10	**Depth, ft:**	55



Opening Inches	Opening Millimeters	Phi of Screen	U.S. Sieve No.	Sample Weight grams	Incremental Weight, percent	Cumulative Weight, percent
0.9844	25.002	-4.64	1	149.91	49.28	49.28
0.4922	12.501	-3.64	1/2	19.70	6.48	55.76
0.3740	9.500	-3.25	3/8	4.24	1.39	57.15
0.2500	6.351	-2.67	1/4	4.54	1.49	58.64
0.1873	4.757	-2.25	4	4.38	1.44	60.08
0.1324	3.364	-1.75	6	8.90	2.93	63.01
0.0787	2.000	-1.00	10	10.66	3.50	66.51
0.0557	1.414	-0.50	14	13.02	4.28	70.79
0.0394	1.000	0.00	18	11.17	3.67	74.46
0.0278	0.707	0.50	25	10.95	3.60	78.06
0.0197	0.500	1.00	35	10.30	3.39	81.45
0.0166	0.420	1.25	40	4.16	1.37	82.82
0.0139	0.354	1.50	45	4.21	1.38	84.20
0.0098	0.250	2.00	60	6.99	2.30	86.50
0.0070	0.177	2.50	80	5.40	1.78	88.27
0.0049	0.125	3.00	120	5.80	1.91	90.18
0.0029	0.074	3.75	200	7.11	2.34	92.52
0.0021	0.053	4.25	270	4.72	1.55	94.07
0.0015	0.037	4.75	400	4.53	1.49	95.56
			PAN	13.51	4.44	100.00
TOTALS				304.20	100.00	100.00

Cumulative Weight Percent greater than

Weight percent	Phi Value	Particle Size Inches	Particle Size Millimeters
5			
10			
16			
25			
40			
50	-4.53	0.9113	23.148
60	-2.27	0.1904	4.836
75	0.07	0.0374	0.950
84	1.46	0.0143	0.363
90	2.95	0.0051	0.129
95	4.56	0.0017	0.042

Measure	Trask	Inman	Folk-Ward
Median, phi	-4.53	-4.53	-4.53
Median, in.	0.9113	0.9113	0.9113
Median, mm	23.148	23.148	23.148
Mean, phi			
Mean, in.			
Mean, mm			
Sorting			
Skewness			
Kurtosis			

Grain Size Description (ASTM-USCS Scale)	N/A (based on Mean from Trask)

Description	Retained on Sieve #	Weight Percent
Gravel	4	60.08
Coarse Sand	10	6.43
Medium Sand	40	16.31
Fine Sand	200	9.70
Silt/Clay	<200	7.48
	Total	100

PTS Laboratories

PTS File No: 47098
Client: AECOM
Report Date: 03/20/17

WATER (MOISTURE) CONTENT OF SOIL OR ROCK BY MASS

(Methodology: ASTM D 2216)

Project Name: NDEP Downgradient Study Area
Project No: 60477365 Task 2015-160-10

SAMPLE ID.	DEPTH, ft.	ANALYSIS DATE	ANALYSIS TIME	MATRIX	TARE WEIGHT, grams	WET SAMPLE + TARE WT., grams	DRY SAMPLE + TARE WT., grams	MOISTURE CONTENT, % dry weight
NERT-CB-2-7'	7	20170303	1620	Soil	15.52	64.06	61.73	5.0
NERT-CB-2-18'	18	20170303	1620	Soil	15.33	78.34	61.10	37.7
NERT-CB-2-27'	27	20170303	1620	Soil	15.42	77.10	65.26	23.8
NERT-CB-2-38'	38	20170303	1620	Soil	15.51	98.81	91.90	9.0
NERT-CB-2-70'	70	20170303	1620	Soil	15.46	70.41	49.04	63.6
NERT-CB-1-15	15	20170303	1620	Soil	15.51	76.44	73.63	4.8
NERT-CB-1-28	28	20170303	1620	Soil	15.38	85.08	74.35	18.2
NERT-CB-1-35	35	20170303	1620	Soil	15.54	85.87	78.81	11.2
NERT-CB-1-42	42	20170303	1620	Soil	15.36	89.78	72.78	29.6
NERT-CB-1-52	52	20170303	1620	Soil	15.44	57.47	37.41	91.3
NERT-CB-1-70	70	20170306	1215	Soil	15.63	61.76	45.36	55.2
NERT-CB-4-15	15	20170306	1215	Soil	15.46	71.69	65.73	11.9
NERT-CB-4-30	30	20170306	1215	Soil	15.53	92.26	83.90	12.2
NERT-CB-4-50	50	20170306	1215	Soil	15.47	64.87	47.73	53.1
NERT-CB-4-71	71	20170306	1215	Soil	15.29	72.02	57.90	33.1
NERT-CB-3-10	10	20170306	1215	Soil	15.61	85.03	80.60	6.8
NERT-CB-3-33	33	20170306	1215	Soil	15.50	101.42	91.02	13.8
NERT-CB-3-55	55	20170306	1215	Soil	15.49	67.98	53.57	37.8

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CHAIN OF CUSTODY RECORD

PAGE 1 OF 2

COMPANY	AECOM
ADDRESS	1220 Avenida Acaso
CITY	Camarillo
ZIP CODE	93012
PROJECT MANAGER	Carmen Caceres-Schnell
email	carmen.caceres-schnell@aecom
PROJECT NAME	NDEP Downgradient Study Area
PHONE NUMBER	(805)764-4031
PROJECT NUMBER	60477365 Task 2015-160-10
FAX NUMBER	
SITE LOCATION	GPT Soil Borings, Henderson, NV
SAMPLER SIGNATURE	[signature]

PO#	86028
TURNAROUND TIME	24 HOURS ☐ 5 DAYS ☐ 72 HOURS ☐ NORMAL ☑
OTHER:	
SAMPLE INTEGRITY (CHECK):	INTACT X TEMP(F) 67.1
PTS QUOTE NO.	Q17-003
PTS FILE:	47098

ANALYSIS REQUEST

SAMPLE ID	DATE	TIME	DEPTH, FT	NUMBER OF SAMPLES	SOIL PROPERTIES PACKAGE	HYDRAULIC CONDUCTIVITY PACKAGE	PORE FLUID SATURATIONS PACKAGE	TCEQ/TNRCC PROPERTIES PACKAGE	CAPILLARITY PACKAGE	FLUID PROPERTIES PACKAGE	PHOTOLOG: CORE PHOTOGRAPHY	VAPOR TRANSPORT PACKAGE	POROSITY: TOTAL, AIR FILLED, WATER FILLED	POROSITY: EFFECTIVE, ASTM D425M	SPECIFIC GRAVITY, ASTM D854	BULK DENSITY (DRY), API RP40 or ASTM D2937	AIR PERMEABILITY, API RP40	HYDRAULIC CONDUCTIVITY, EPA9100/API RP40 or D5084	GRAIN SIZE DISTRIBUTION, ASTM D422 or 4464M	TOC: WALKLEY-BLACK	ATTERBERG LIMITS, ASTM D4318	VAPOR INTRUSION PACKAGE	FREE PRODUCT MOBILITY PACKAGE	Moisture Content, ASTM D2216		COMMENTS
NERT-CB-2 7'	2/13/17	1300	7																x		x			x		
18'	↓	1315	18																↓		↓			↓		
27'	↓	1330	27																↓		↓			↓		
38'	↓	1410	38																↓		↓			↓		
70'	↓	1515	70																↓		↓			↓		
NERT-CB-1 15	2/14/17	1003	15																↓		↓			↓		
28	↓	1046	28																↓		↓			↓		
35	↓	1046	35																↓		↓			↓		
42	↓	1115	42																↓		↓			↓		
52	↓	1115	52																↓		↓			↓		
70	↓	1338	70																↓		↓			↓		

1. RELINQUISHED BY	2. RECEIVED BY	3. RELINQUISHED BY	4. RECEIVED BY
[signature]	[signature]		
COMPANY AECOM	COMPANY PTS LABS	COMPANY	COMPANY
DATE 2/16/17 TIME 1600	DATE 2/21/17 TIME 1140	DATE TIME	DATE TIME

PTS Laboratories, Inc. CHAIN OF CUSTODY RECORD

PAGE 2 OF 2

COMPANY	AECOM
ADDRESS	1220 Avenida Acaso
CITY	Camarillo
ZIP CODE	93012
PROJECT MANAGER	Carmen Caceres-Schnell
email	carmen.caceres-schnell@aecom
PROJECT NAME	NDEP Downgradient Study Area
PHONE NUMBER	(805)764-4031
PROJECT NUMBER	60477365 Task 2015-160-10
FAX NUMBER	
SITE LOCATION	GPT Soil Borings, Henderson, NV
SAMPLER SIGNATURE	

PO# 86028

TURNAROUND TIME: 24 HOURS ☐ 72 HOURS ☐ 5 DAYS ☐ NORMAL ☑

OTHER: ____________

SAMPLE INTEGRITY (CHECK): INTACT X TEMP(F) 67.1

PTS QUOTE NO. Q17-003

PTS FILE: 47098

ANALYSIS REQUEST

SAMPLE ID	DATE	TIME	DEPTH, FT	NUMBER OF SAMPLES	SOIL PROPERTIES PACKAGE	HYDRAULIC CONDUCTIVITY PACKAGE	PORE FLUID SATURATIONS PACKAGE	TCEQ/TNRCC PROPERTIES PACKAGE	CAPILLARITY PACKAGE	FLUID PROPERTIES PACKAGE	PHOTOLOG: CORE PHOTOGRAPHY	VAPOR TRANSPORT PACKAGE	POROSITY: TOTAL, AIR FILLED, WATER FILLED	POROSITY: EFFECTIVE, ASTM D425M	SPECIFIC GRAVITY, ASTM D854	BULK DENSITY (DRY), API RP40 or ASTM D2937	AIR PERMEABILITY, API RP40	HYDRAULIC CONDUCTIVITY, EPA9100/API RP40 or D5084	GRAIN SIZE DISTRIBUTION, ASTM D422 or 4464M	TOC: WALKLEY-BLACK	ATTERBERG LIMITS, ASTM D4318	VAPOR INTRUSION PACKAGE	FREE PRODUCT MOBILITY PACKAGE	Moisture Content, ASTM D2216	COMMENTS
NERT-CB-4-15	2/15/17	1015	15																x		x			x	
30	↓	1136	30																						
50	↓	1400	50																						
71	↓	1430	71																						
NERT-CB-3-10	2/16/17	1115	10																						
33	↓	1230	33																						
55	↓	1345	55																↓		↓			↓	

1. RELINQUISHED BY	2. RECEIVED BY	3. RELINQUISHED BY	4. RECEIVED BY
[signature]	[signature]		
COMPANY AECOM	COMPANY PTS LABS	COMPANY	COMPANY
DATE 2/16/17 TIME 1600	DATE 2/21/17 TIME 1140	DATE TIME	DATE TIME

PTS Laboratories, Inc. • 8100 Secura Way • Santa Fe Springs, CA 90670 • Phone (562) 347-2500 • Fax (562) 279-1150

Appendix E

EM Induction Logging Report by GEOVision, June 2017

NERT REMEDIAL INVESTIGATION – DOWNGRADIENT STUDY AREA
BOREHOLE GEOPHYSICS

LAS VEGAS WASH
HENDERSON, NEVADA

GEO*Vision* Project No. 16374

Prepared for

AECOM
1220 Avenida Acaso
Camarillo, CA 93012
(805) 764-4031

Prepared by

GEO*Vision* Geophysical Services
1124 Olympic Drive
Corona, CA 92881
(951) 549-1234

Report 16374-02 rev 3

June 20, 2017

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APPENDICES

APPENDIX A **DUAL INDUCTION AND NATURAL GAMMA QUALITY ASSURANCE LOGS**

INTRODUCTION

Geophysical measurements were taken in four cased boreholes in two distinct areas of the Las Vegas Wash near Henderson, Nevada. Borehole geophysics was part of the Geophysical Pilot Test for the NERT Remedial Investigation - Down gradient Study Area. Data acquisition was performed on February 17, 2017. The work was performed for AECOM. Data analysis and report were reviewed by a **GEO***Vision* Professional Geophysicist or Engineer.

SCOPE OF WORK

This report presents the results of dual induction and natural gamma logs collected in four cased boreholes, as detailed in Table 1. The purpose of these studies was to supplement previously obtained surface geophysical and stratigraphic information.

Table 1: Borehole logging dates and locations

BOREHOLE DESIGNATION	DATES LOGGED	COORDINATES – DEGREES (1)	
		NORTHING	EASTING
NERT-CB1	02/17/2017	26733704.35	834023.60
NERT-CB2	02/17/2017	26733698.39	834215.55
NERT-CB3	02/17/2017	26733474.82	827845.09
NERT-CB4	02/17/2017	26733374.59	827990.52

Coordinates provided by AECOM(1)

INSTRUMENTATION

Induction / Natural Gamma Instrumentation

Formation conductivity and natural gamma data were collected using a dual induction (DUIN) probe manufactured by Robertson Geologging, Ltd (RG). The probe is 7.5 feet long, and 1.5 inches in diameter.

This probe is most often used to assist with

- Bed boundary identification
- Strata correlation between borings
- Strata geometry and type (shale indication)

The probe receives control signals from, and sends the digitized measurement values to, a RG Micrologger II (ML) on the surface via an armored cable. The cable is wound onto the drum of a winch and is used to support the probe. To provide probe depth data, cable travel is measured using a sheave of known circumference fitted with a digital rotary encoder. The probe and depth data are transmitted by USB link from the ML unit to a laptop computer where it is displayed and stored.

An electromagnetic (EM) induction probe consists of transmitter and receiver coils. An alternating current is applied to the transmitter coil, causing the coil to radiate a primary EM field. This primary EM field generates eddy currents in subsurface materials, which give rise to a secondary EM field. The secondary EM field is measured as an alternating current in the receiver coils, which is proportional to formation conductivity. The probe coil spacing is optimized to achieve high vertical resolution, minimal borehole influence and large radius of investigation. The RG dual induction probe has effective coil spacings of 1.6 and 2.6 feet, operates at a frequency of 39 kHz, has 1 millisiemens/meter resolution, and operates over a 5 to 3000 millisiemens/meter conductivity range.

Natural gamma measurements rely on small quantities of radioactive material contained in soil and rock to emit gamma radiation as they decay. Trace amounts of uranium and thorium are present in a few minerals; additionally potassium-bearing minerals such as feldspar, mica and clays will include traces of a radioactive isotope of potassium. This radiation is detected by scintillation, which is the production of a tiny flash of light when gamma rays strike a crystal of sodium iodide. The light is converted into an electrical pulse by a photomultiplier tube. Pulses above a threshold value of 60 KeV are counted by the probe's microprocessor. The measurement is useful because the radioactive elements are concentrated in certain soil and rock types, e.g. clay or shale, and depleted in others, e.g. sandstone or coal.

MEASUREMENT PROCEDURES

All borings were advanced using the sonic method at a nominal 8 inch diameter. Since geophysical logging was to occur at a later date, 3 inch PVC blank casing was set in each borehole to total depth, leaving a slight riser above ground. Casing was set loosely and un-grouted with no bottom cap, as it was merely to keep the borings open to total depth for geophysical logging, not for a permanent monitor point. As such, total depth of the cased boreholes (logged) varied slightly from depth drilled, as summarize in Table 2. The DUIN probe can acquire data in uncased and PVC cased boreholes without drilling fluid, thus ideal for this investigation.

Induction / Natural Gamma Measurement Procedures

Measurement procedures followed these ASTM standards:

- ASTM D5753-05 (Re-approved 2010), “Planning and Conducting Boring Geophysical Logging”
- ASTM D6274-10, “Conducting Boring Geophysical Logging – Gamma”
- ASTM D6726-01 (Re-approved 2007), “Conducting Boring Geophysical Logging – Electromagnetic Induction”

Prior to logging, measurement depths were referenced to ground surface. This was done by placing the top of the probe even with a stationary reference point, such as the top of the PVC riser, and the electronic depth counter set to the probe length minus the height of the reference point. The calculations were recorded on field logs. Offset distances between probe tip and measurement points are corrected by the data acquisition software. Initially, the probe was lowered to the bottom of the boring, stopped, then returned to surface while acquiring data. Typically, probe ascent is approximately 15 feet/minute, collecting data continuously at 0.05-foot spacing. For this investigation, logs were run twice in each boring for quality assurance. All logging runs are summarized in Table 2.

This probe is not calibrated in the field, as it is used to provide qualitative measurements, not quantitative values, and is used only to assist in picking transitions between stratigraphic units, as described in ASTM D5753-05 (Reapproved 2010), “Planning and Conducting Borehole Geophysical Logging”. However, functional test were performed prior to logging the first borehole and after logging the last borehole to ascertain functionality throughout the day. This is accomplished by securing a coil with an effective conductivity around the probe and then comparing and recording the output of the system.

Natural gamma is not calibrated in the field, as it is a qualitative measurement, not a quantitative value, and is used only to assist in picking transitions between stratigraphic units, as described in ASTM D6274-10, “Conducting Borehole Geophysical Logging – Gamma”.

At the completion of each logging run, the probe zero depth indication at the depth reference point was verified prior to removal from the boring.

DATA ANALYSIS

Induction / Natural Gamma Analysis

No analysis is required for these data; however depths to identifiable boring log features, such as distinct natural gamma transitions, were compared to verify consistent depth readings on all logs. Using WellCAD™ software version 5.1, data are shifted and trimmed, as need, then plotted as adjacent line logs. The final logs are then exported as LAS 2.0 format and saved as PDF.

RESULTS

Induction / Natural Gamma Results

Induction and natural gamma data for borings NERT-CB1 through NERT-CB4 are presented as Figure 1 through Figure 4, respectively. The repeat, second, or QA logs, plotted coincidently with the initial logs are presented as Figures A1 through A4 in Appendix A.

Depths on all figures and tables are referenced to ground surface. LAS 2.0 data (initial and QA) for each borehole as well as PDF files of initial and QA logs accompany this report.

SUMMARY

Discussion of Induction / Natural Gamma Results

Generally, all four borings produced good quality conductivity and natural gamma logs. Long and short conductivity profiles provide a good indication of interbedding or interfaces, showing changes in conductivity that correspond with changes in natural gamma. All four logs appear to terminate in a relatively more conductive zone starting at 50 to 60 ft bgs. Repeat logs are near identical to the initial logs, with minor variability mostly in natural gamma, which is expected. Results support the validity and functionality of the method applied.

Quality Assurance

These boring geophysical measurements were performed using industry-standard or better methods for measurements and analyses. All work was performed under **GEO***Vision* quality assurance procedures, which include:

- Use of standard field data logs
- Use of equipment functional testing prior to logging to ascertain tools are working within manufacturer specifications.
- Independent review of results by a California professional geophysicist or engineer.

CERTIFICATION

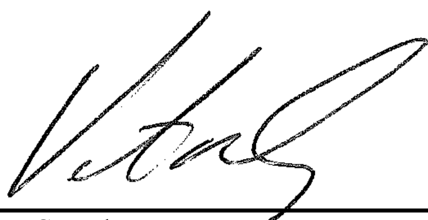
All geophysical data, analysis, interpretations, conclusions, and recommendations in this document have been prepared under the supervision of and reviewed by a **GEO***Vision* California Professional Geophysicist.

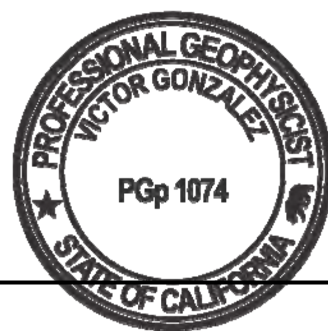
Prepared by:

April 17, 2017

J. Jonathan Jordan — Date
Staff Geophysicist
GEO*Vision* Geophysical Services

Approved by:





April 17, 2017

Victor Gonzalez — Date
California Professional Geophysicist, PGp. 1074
GEO*Vision* Geophysical Services

* This geophysical investigation was conducted under the supervision of a California Professional Geophysicist using industry standard methods and equipment. A high degree of professionalism was maintained during all aspects of the project from the field investigation and data acquisition, through data processing, interpretation and reporting. All original field data files, field notes and observations, and other pertinent information are maintained in the project files and are available for the client to review for a period of at least one year.

A professional geophysicist's certification of interpreted geophysical conditions comprises a declaration of his/her professional judgment. It does not constitute a warranty or guarantee, expressed or implied, nor does it relieve any other party of its responsibility to abide by contract documents, applicable codes, standards, regulations or ordinances.

Table 2. Logging dates and depth ranges

BOREHOLE DESIGNATION	TOOL AND RUN NUMBER	DEPTH RANGE (FEET)	DEPTH DRILLED (FEET)	SAMPLE INTERVAL (FEET)	DATE LOGGED
NERT-CB1	INDUCTION/NGAMMA 01	0.03 - 71.2	75	0.05	02/17/2017
NERT-CB1	INDUCTION/NGAMMA 02	0.03 - 71.2	75	0.05	02/17/2017
NERT-CB2	INDUCTION/NGAMMA 01	0.03 - 71.0	75	0.05	02/17/2017
NERT-CB2	INDUCTION/NGAMMA 02	0.03 - 71.0	75	0.05	02/17/2017
NERT-CB3	INDUCTION/NGAMMA 01	0.03 - 73.1	75	0.05	02/17/2017
NERT-CB3	INDUCTION/NGAMMA 02	0.03 - 73.1	75	0.05	02/17/2017
NERT-CB4	INDUCTION/NGAMMA 01	0.03 - 70.4	75	0.05	02/17/2017
NERT-CB4	INDUCTION/NGAMMA 02	0.03 - 70.4	75	0.05	02/17/2017

GEOVision geophysical services

CLIENT AECOM

LOG TYPE

Dual Induction
Natural Gamma

PROJECT	NERT Remedial Investigation
WELL	NERT-CB1
LOCATION	Henderson, NV
LOGGER	J. Jordan
DATE	Feb 17, 2017

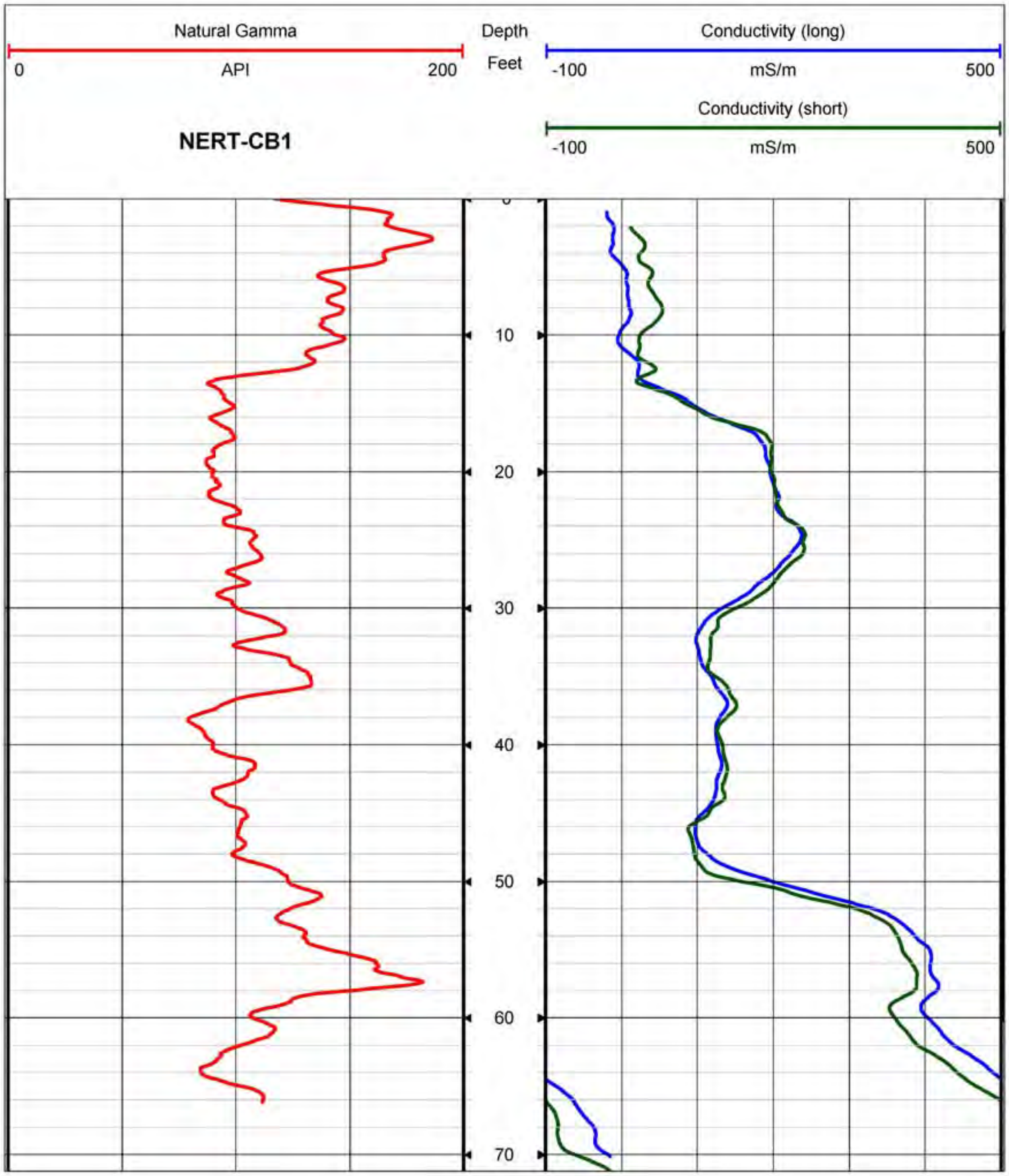


Figure 1: Borehole NERT-CB1 Dual Induction and Natural Gamma Logs

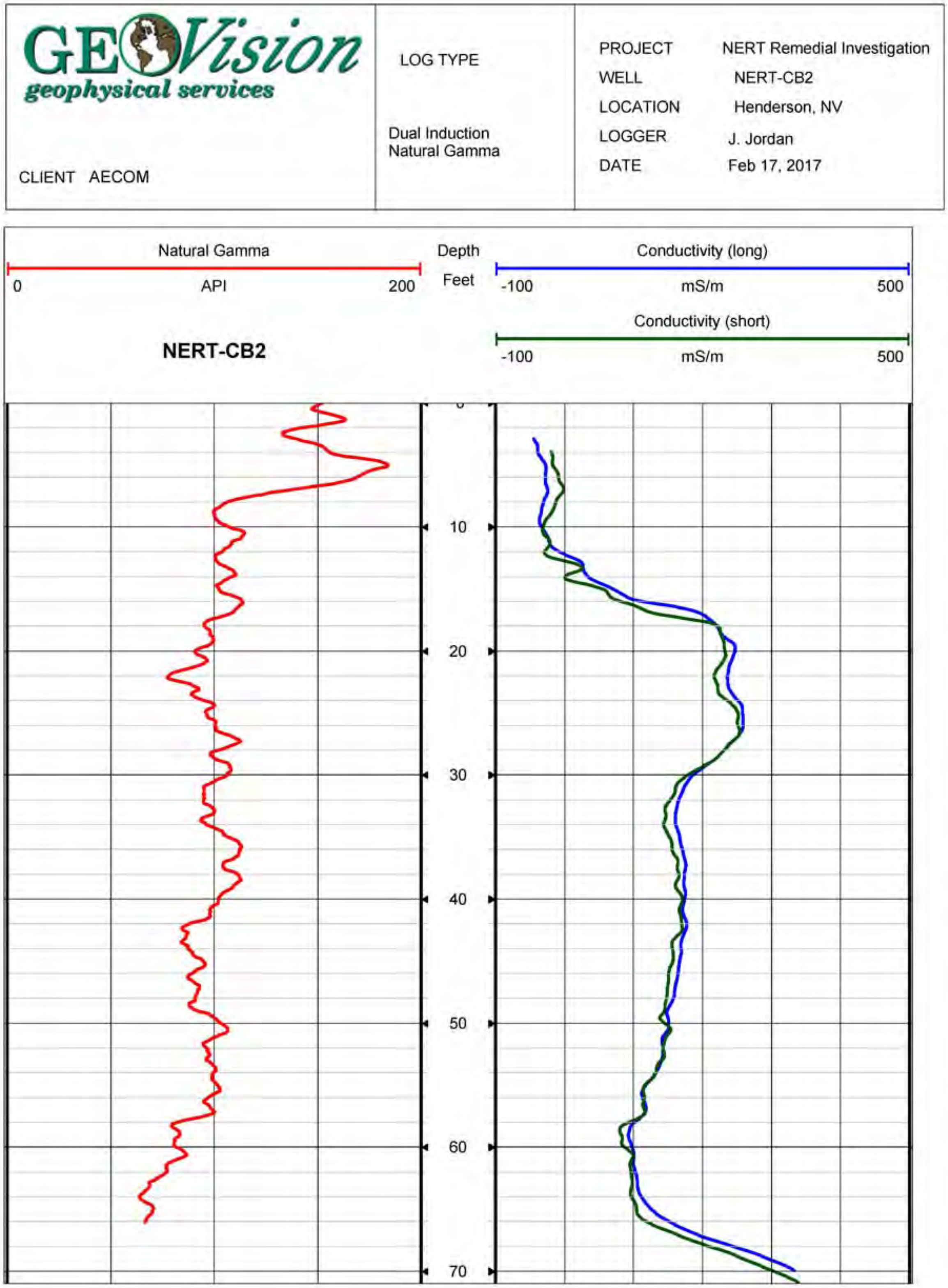


Figure 2. Borehole NERT-CB2 Dual Induction and Natural Gamma Logs

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CLIENT AECOM

LOG TYPE

Dual Induction
Natural Gamma

PROJECT	NERT Remedial Investigation
WELL	NERT-CB3
LOCATION	Henderson, NV
LOGGER	J. Jordan
DATE	Feb 17, 2017

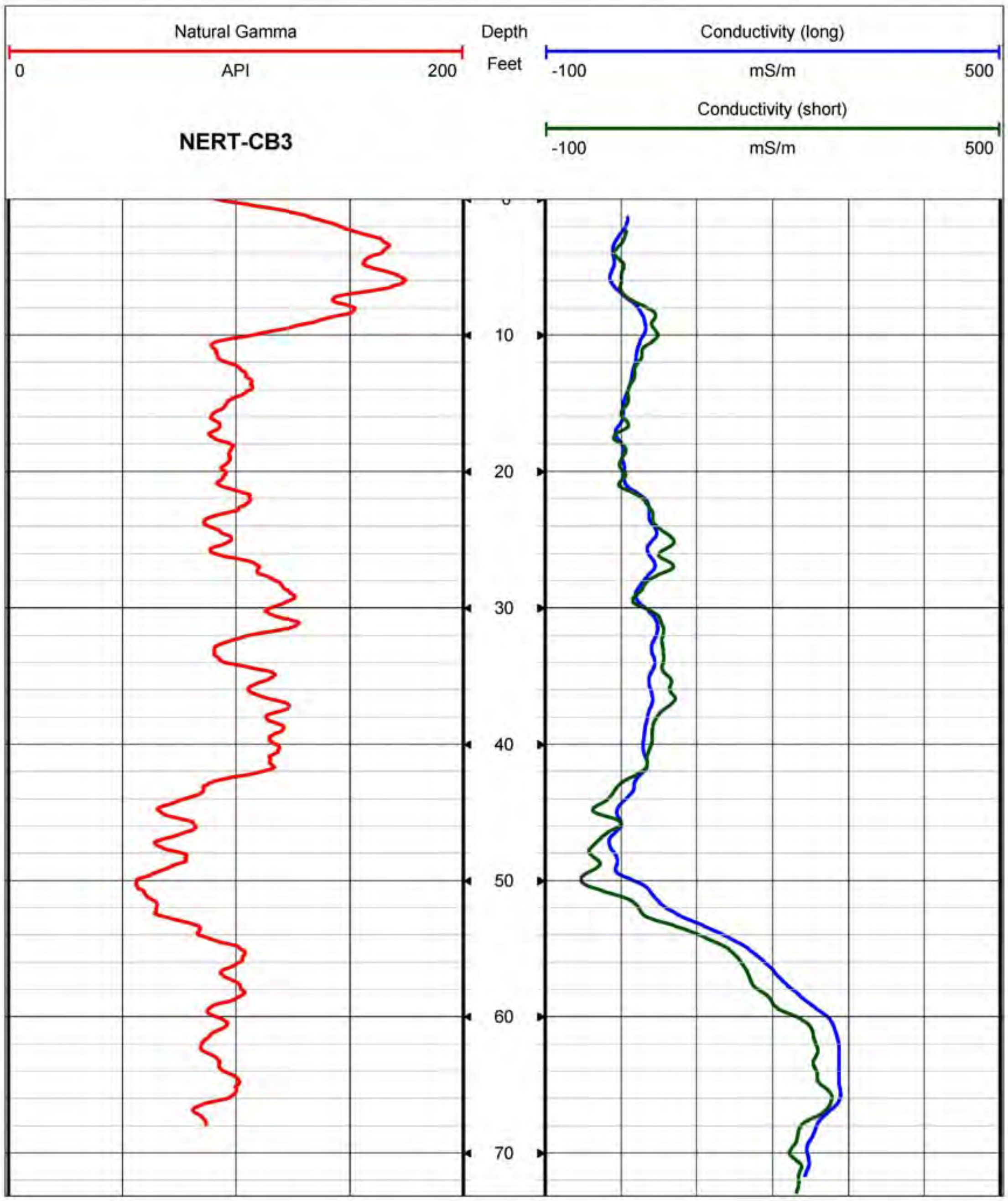

Figure 3. Borehole NERT-CB3 Dual Induction and Natural Gamma Logs

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CLIENT AECOM

LOG TYPE

Dual Induction
Natural Gamma

PROJECT	NERT Remedial Investigation
WELL	NERT-CB4
LOCATION	Henderson, NV
LOGGER	J. Jordan
DATE	Feb 17, 2017

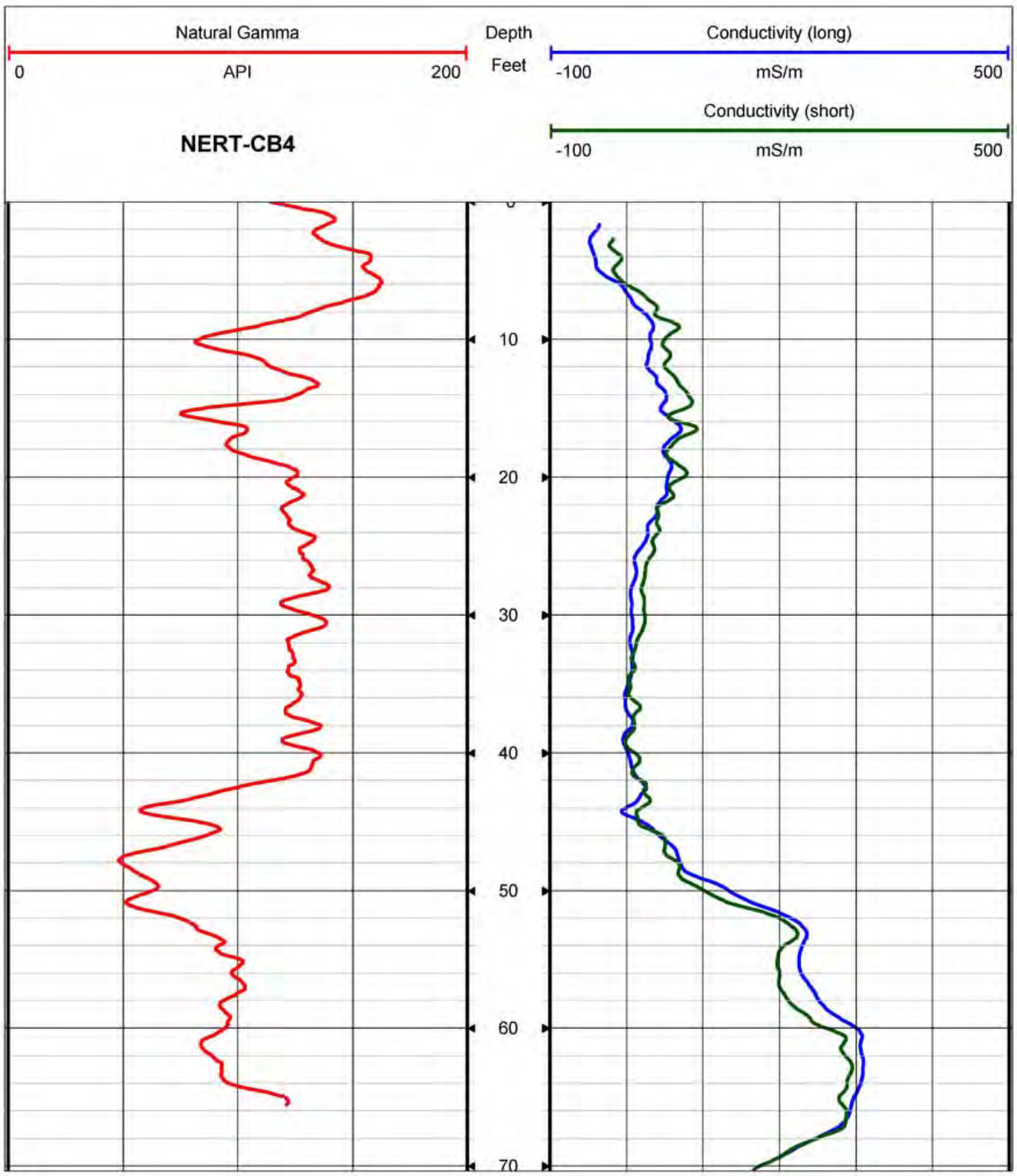

Figure 4. Borehole NERT-CB4 Dual Induction and Natural Gamma Logs

APPENDIX A

DUAL INDUCTION AND NATURAL GAMMA QUALITY ASSURANCE LOGS

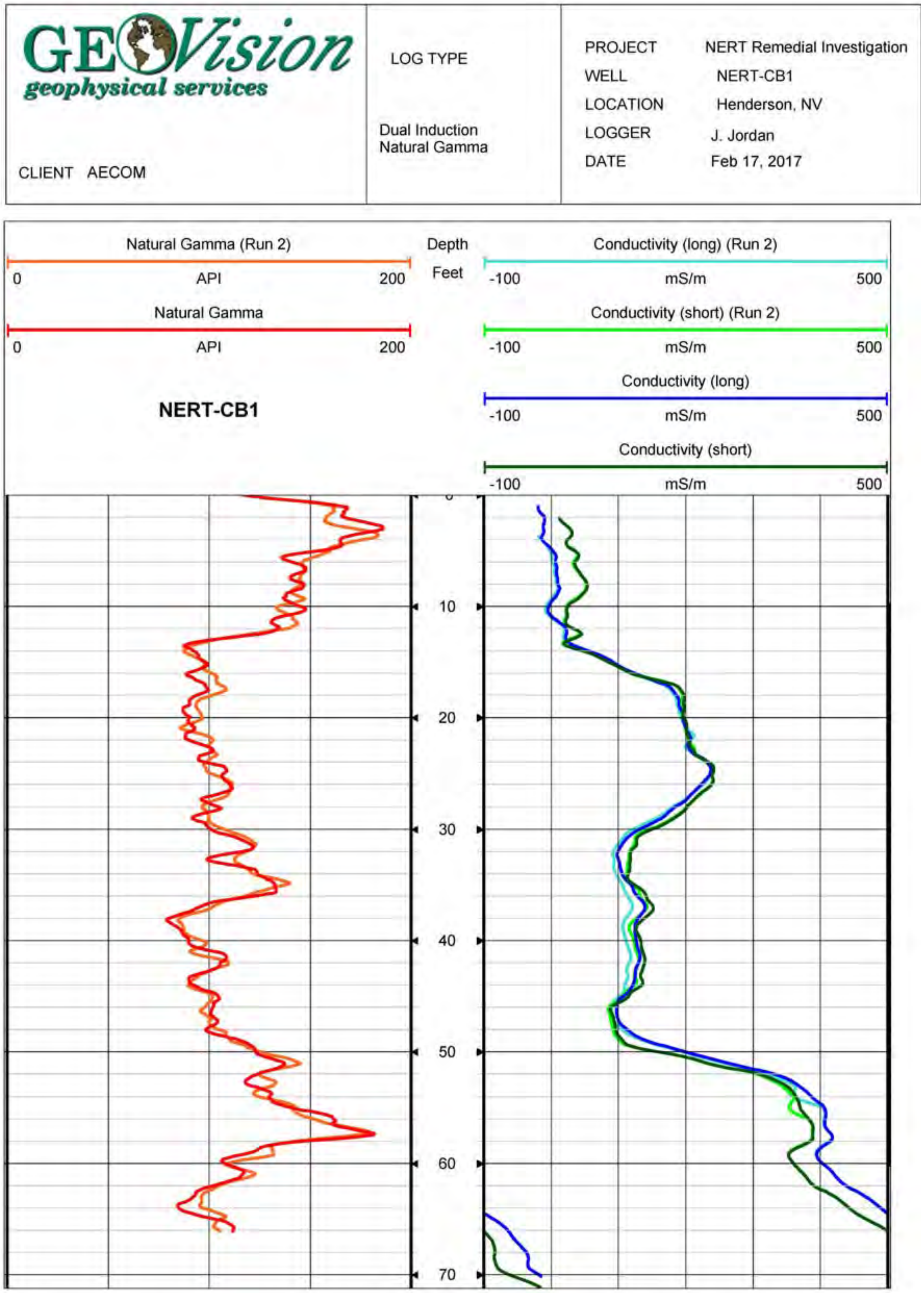

Figure A-1: Borehole NERT-CB1 Dual Induction and Natural Gamma QA Logs

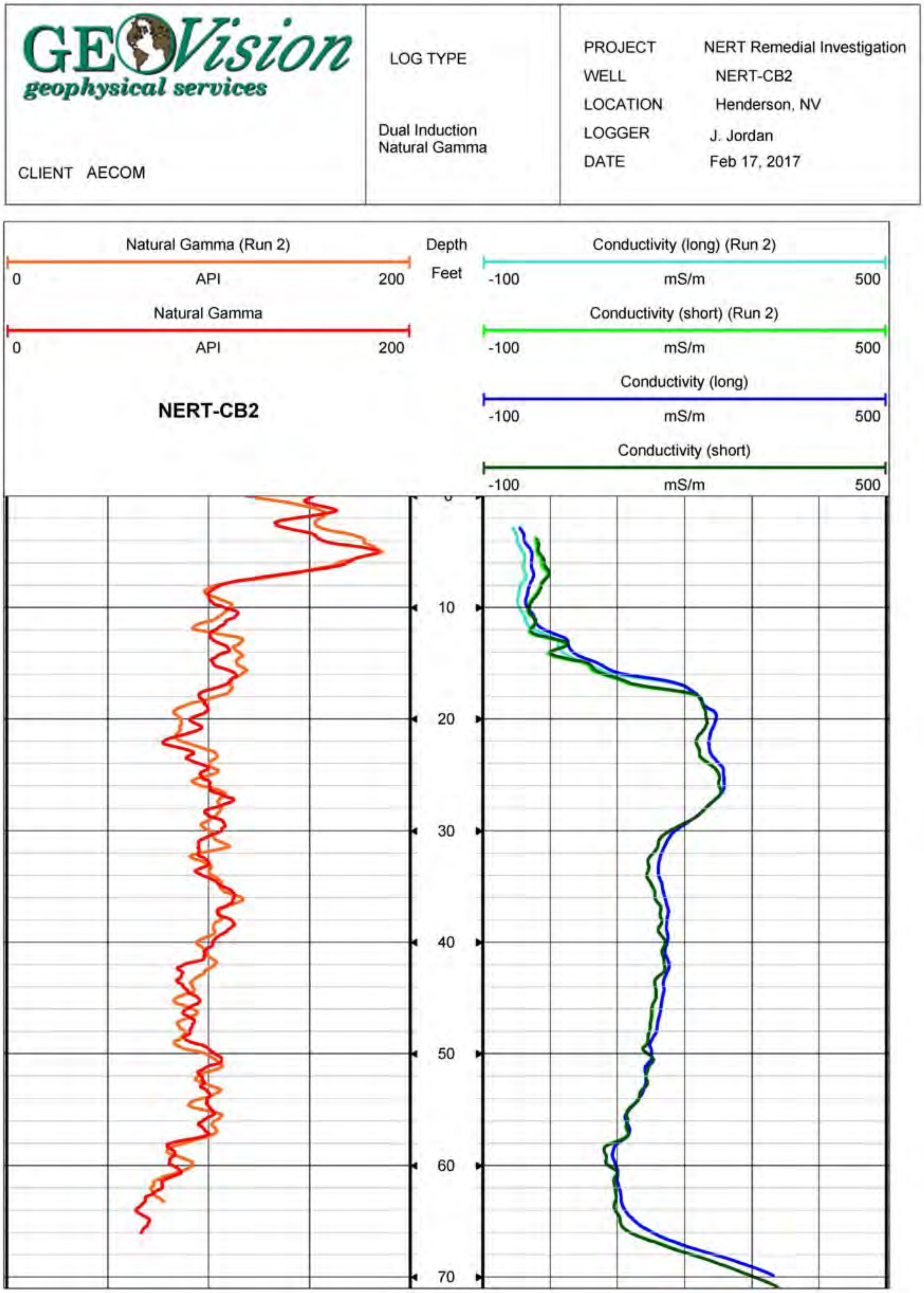

Figure A-2: Borehole NERT-CB2 Dual Induction and Natural Gamma QA Logs

GEOVision geophysical services

CLIENT AECOM

LOG TYPE

Dual Induction
Natural Gamma

PROJECT	NERT Remedial Investigation
WELL	NERT-CB3
LOCATION	Henderson, NV
LOGGER	J. Jordan
DATE	Feb 17, 2017

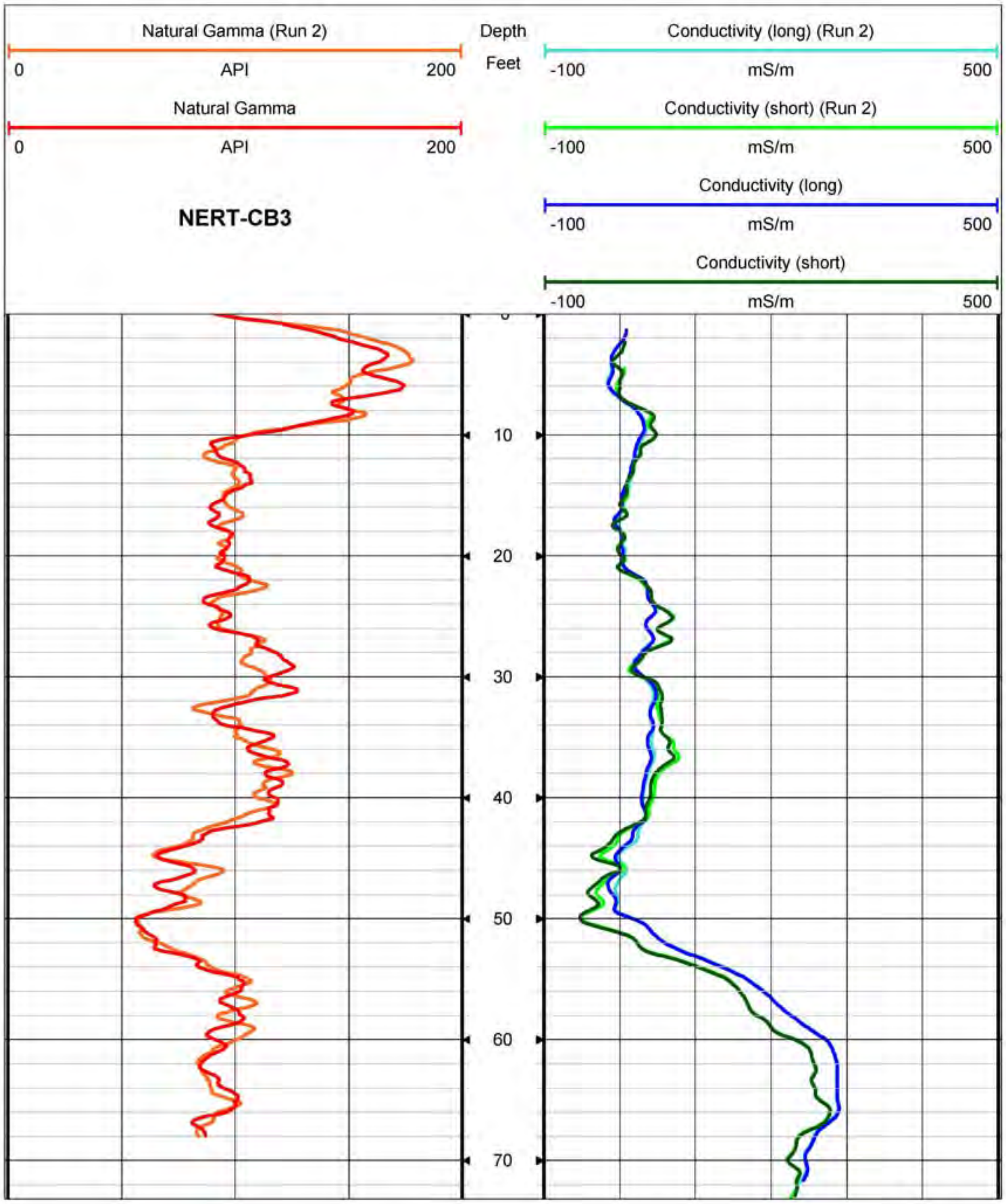

Figure A-3: Borehole NERT-CB3 Dual Induction and Natural Gamma QA Logs

GEOVision geophysical services	LOG TYPE	PROJECT	NERT Remedial Investigation
		WELL	NERT-CB4
		LOCATION	Henderson, NV
	Dual Induction Natural Gamma	LOGGER	J. Jordan
CLIENT AECOM		DATE	Feb 17, 2017

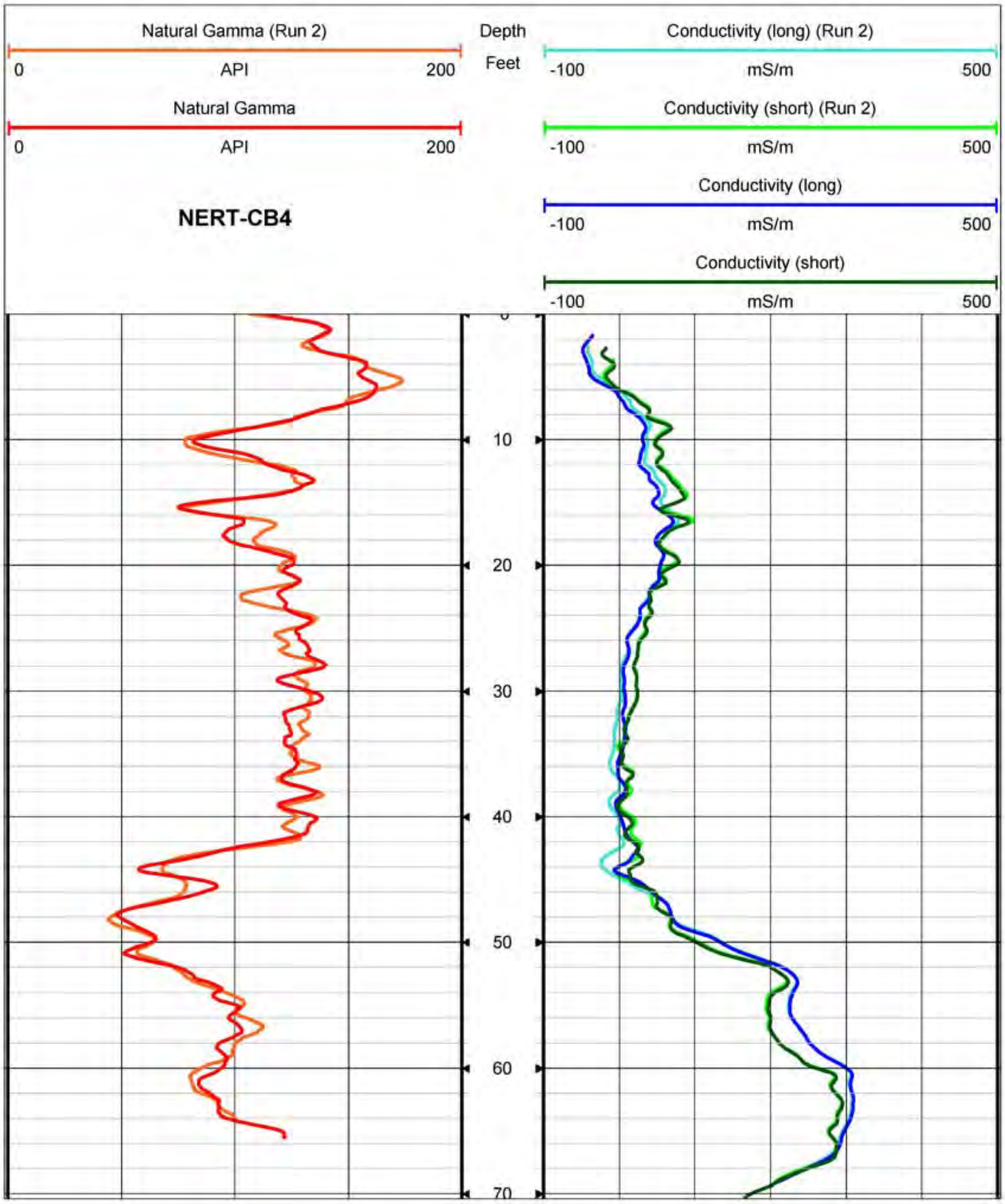

Figure A-4: Borehole NERT-CB4 Dual Induction and Natural Gamma QA Logs