Project No. 031019
RFP MSHA #J53R1011
Account No. B2532538
July 2006

D'APPOLONIA

FINAL REPORT
DEMONSTRATION PROJECT - MINE VOID DETECTION
DC RESISTIVITY SURFACE GEOPHYSICAL METHOD
LOTS BRANCH TAILINGS IMPOUNDMENT SITE
PRENTER, WEST VIRGINIA

Lots Branch Tailings Impoundment

Prepared for

MINE SAFETY AND HEALTH ADMINISTRATION
ARLINGTON, VIRGINIA

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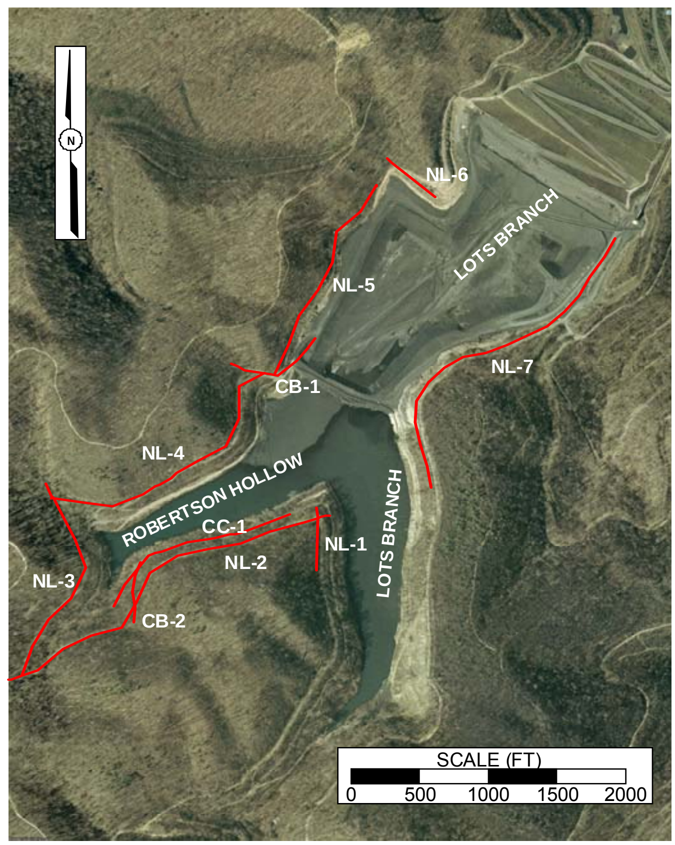
EXECUTIVE SUMMARY

This Report presents the results of a demonstration project of the DC resistivity surface geophysical method and the subsequent verification of the geophysical interpretation based on borings and imaging of parts of mine workings at the Lots Branch tailings impoundment site in Prenter, West Virginia. In addition to the DC resistivity surveying, time domain electromagnetic (TDEM) data were also obtained, the results of which are presented in a separate report.

The overall concept exploited for both DC resistivity and TDEM techniques is that mine workings can be identified on the basis of conductive mine water, which will stand out as being more conductive than natural ground. In the case of the DC resistivity technique, the possibility also existed that dry mine workings would stand out because of their low conductivity/high resistivity with respect to natural ground.



Lots Branch coal refuse facility with location of DC resistivity survey lines

The Lewiston Coal is the seam that outcrops in the portion of the valley that will eventually be filled with fine tailings (fine coal refuse slurry). Knowledge of the mining within this seam was known on the basis of mine maps. Further refinement in terms of relating the mine maps to the ground surface was obtained using a downhole laser imaging system developed by Carnegie Mellon University and commercialized by Workhorse Technologies, Inc. of Braddock, PA.

This demonstration project focused on the ability to detect mine workings which may be in close proximity to an impoundment, where the potential exists for a breakthrough of tailings into the workings. In such a setting, the continuity and width of coal barriers are critical parameters in the subsequent engineering evaluation of the potential for a breakthrough. The DC resistivity method offers a surface technique which can detect underground voids using portable equipment which could readily be deployed at a mine site.

The Lots Branch impoundment is approximately 100 acres in size with a depth of impounded fine refuse of nearly 200 feet. The impoundment is situated in the central portion of Lots Branch and extends upstream and includes Robertson Hollow. Future development of the impoundment is planned to result in disposal of fine refuse slurry above the level of the Lewiston coal seam, which has been underground mined throughout the perimeter of the impoundment, a length of approximately 15,000 feet. Thus, the presence and continuity of the outcrop coal barrier is a factor in evaluating the potential for impoundment breakthrough to the abandoned mine workings. A geophysical method such as DC resistivity has the potential to be an effective tool to gather information on the coal barrier and mine voids. Considering that the project objectives included distinguishing between mined and un-mined areas, the smallest target of the geophysical method is an entry (void in the shape of a tunnel) of the order of 15- to 25-feet in width and about 6-feet in height, or parallel entries separated by coal pillar(s) which could represent a target of approximately 75-feet in width. Areas of more extensive mine workings represent a larger target. If the mine voids are sufficiently conductive as a result of mine water, they represent a significant contrast in conductivity relative to the intact rock.

The DC resistivity surveying was conducted with a Syskal Junior 48-electrode measurement system manufactured by Iris Instruments of Orleans, France. Nine profiles were obtained over mined areas in the Lewiston seam. The setup of the electrode system was designed to yield resistivity measurements through and beneath the Lewiston Coal, typically at a depth of 40 to 60 feet. An additional profile (CC-1) was obtained as an experiment along the outcrop of the Lewiston Coal at the southern edge of Robertson Hollow.

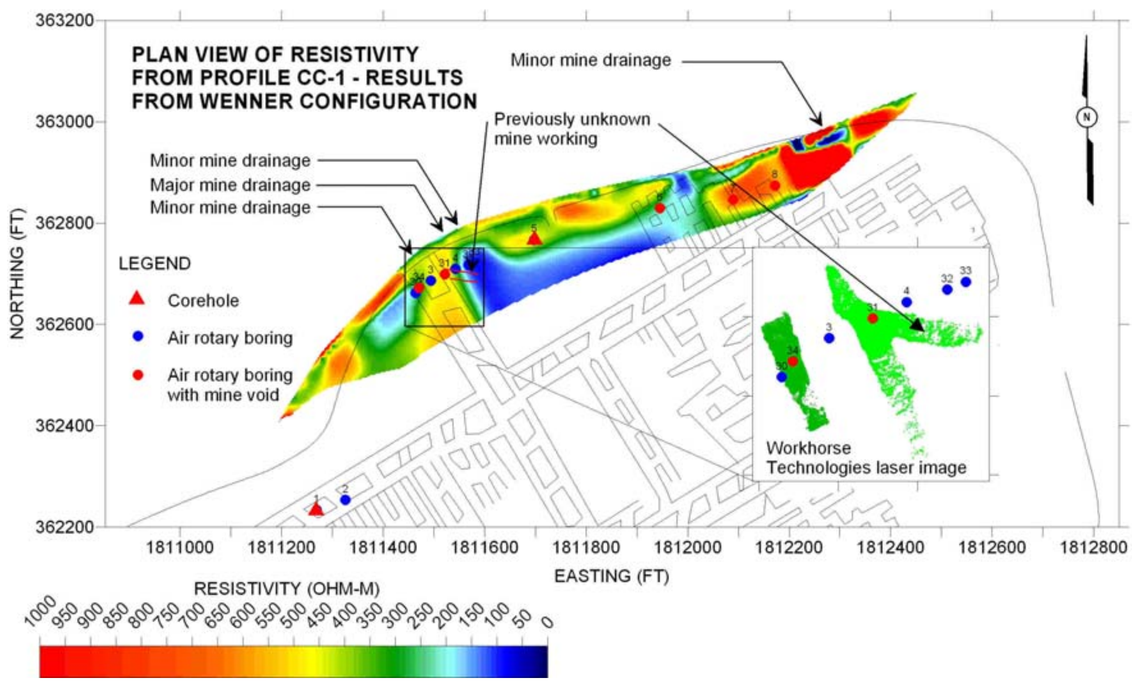
The DC Resistivity surveys were conducted as two-dimensional (2-D) surveys along existing access roads located over coal barriers and workings of the Lewiston seam at the impoundment perimeter. The alignment of mine entries that extend to the outcrop of the coal seam are approximately perpendicular to these access roads, and thus underlie the resistivity line and can be represented as a two dimensional target. Other mine workings are adjacent the resistivity line, and tend to be concentrated on only one side of the line. These conditions introduce three dimensional aspects to the survey. Upon processing of the resistivity data, two dimensional cross sections are developed showing the variation in resistivity of subsurface materials along the survey line. The stratigraphy of the overburden and coal is generally in continuous layers, interrupted by mine workings. Accordingly, the 2-D cross sections are interpreted by evaluating resistivity anomalies and variations. Causes of such anomalies and variations include conductive mine water either in flooded workings or along entry floors that can result in resistivity "lows," or non-conductive dry air which can result in resistivity "highs" relative to the coal and overburden strata. Based on theoretical considerations, it was anticipated that the DC resistivity measurements would be able to detect wet or flooded workings, which underlie the survey line or may be located adjacent to the line, but the detection of anomalously high resistivity that could indicate the presence of dry workings might not be practical.

The test profiles were located to traverse mine workings in the Lewiston Coal under varying degrees of flooding. The Lewiston Coal seam ranges in thickness from about 4 to 6 feet and dips to the northwest at about 1.5 degrees. As such, the mine workings on the north side of the impoundment dip away from the valley wall and are dry. The workings on the south side of the valley dip towards the impoundment and mine water seeps into the valley. Flooded or partially flooded workings were expected to be encountered where mine workings terminate at barrier coal on the southern edge of the impoundment. The actual degree of flooding would depend on the efficiency of the natural drainage barrier along these mine workings or if a constructed drainage is present.

These probable differences in flooding allow for the Lots Branch site to be grouped into three basic areas, as discussed below:

Southern side of Robertson Hollow

Five survey profiles were obtained on the southern side of Robertson Hollow, four conventional 2D vertical profiles as well as the experimental coalcrop line (CC-1) interpreted as a plan view of the Lewiston seam. Based on the dip of the coal seam and

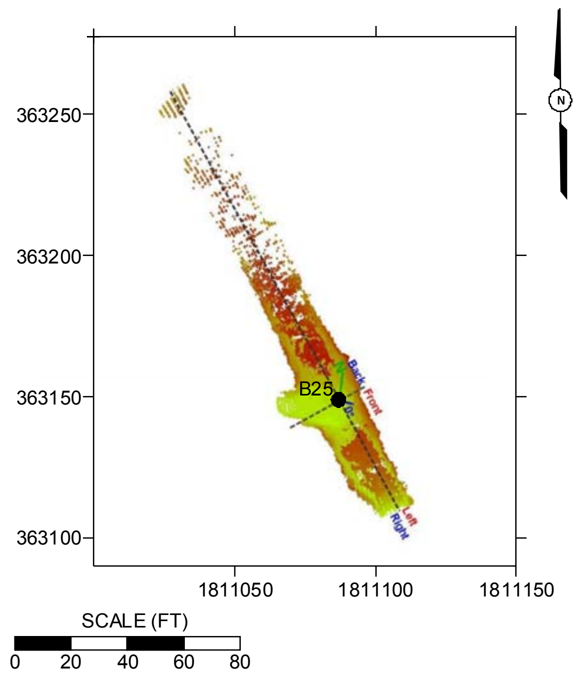


Results of coalcrop survey line CC-1 compared with laser imaging obtained by Workhorse Technologies – the results indicate the presence of previously unknown workings in the Lewiston Coal. All illustrations in this executive summary are color-coded the same.

the mine map, these lines were anticipated to encounter flooded or partially flooded workings. The results indicate the presence of a resistivity low suggestive of at least partially flooded mine workings. The resistivity highs associated with the two entry tunnels indicate the tunnels are probably dry, being drained at the observed seeps. The resistivity low interpreted as unmapped workings that may be flooded or partially flooded. Exploration borings and the laser imaging provides confirmation of the location of the two entry tunnels indicated on the mine map, which allow for the definition of 140 feet of open tunnel associated with the northern entry and 80 feet of tunnel associated with the southern entry. In addition, the results image 80 feet of an undocumented tunnel extending from the northern entry towards the east. This is the same area that the resistivity results indicate that additional mine workings are likely to be present.

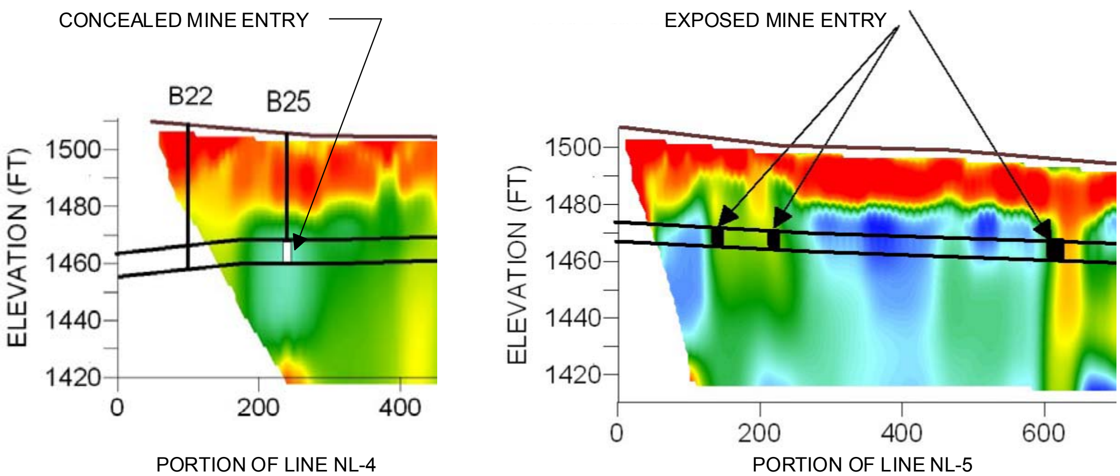
The northern side of Robertson Hollow merging into the northern side of Lots Branch

The northern side of Robertson Hollow and including the northern side of Lots Branch is located where mine water would tend to drain away from the coalcrop. It was therefore expected that mine workings on this side of the valley would be dry. Five survey profiles were obtained on the northern side of Robertson Hollow and Lots Branch: NL-3, NL-4, NL-5, NL-6, and CB-1. Borings from this side of the valley that encountered both dry workings and workings with limited water were imaged by Workhorse Technologies. One of the images from Boring B25 where limited water was encountered on the mine floor was able to map more than 200 feet of concealed entry tunnel.



Georeferenced top-down laser image of a concealed mine entry penetrated by Boring B25 and surveyed by Workhorse Technologies

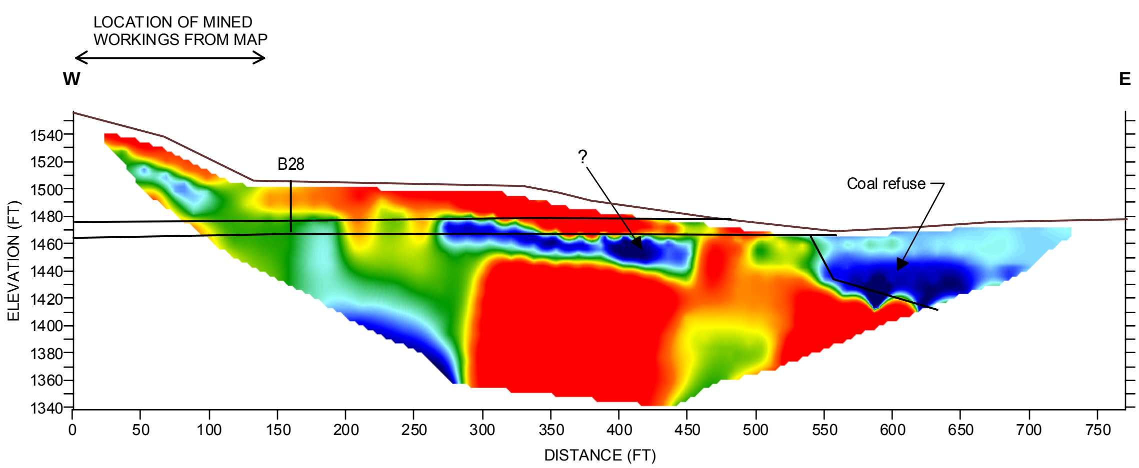
The geophysical profiles indicate variable results over what are assumed to be dry workings. In nearly all cases, the known mine workings are marked by geophysical anomalies, but in some cases they are resistivity lows and in others they are resistivity highs. The observed dry entries clearly appear as resistivity highs, but apparently sufficient moisture is present at the entry imaged from Boring B25 because it is marked by a resistivity low. It is speculated that the warm, moist air present in the mine at the location of Boring B25 influences the



Results of DC resistivity profiles over exposed and concealed entries on the northern side of Lots Branch – the results indicate that exposed workings are marked by a resistivity high whereas the concealed entry is marked by a resistivity low. It is speculated that warm, moist air in the entry penetrated by Boring B25 somehow influences the results.

electrical properties of the mine workings, perhaps by coating the surfaces with a wet, conductive layer.

An interesting result from the northern side of Lots Branch is the coal barrier profile CB1. The results indicate that there is a high conductivity zone in the vicinity of the line. While coal refuse saturated by the impoundment is present at the eastern end of the



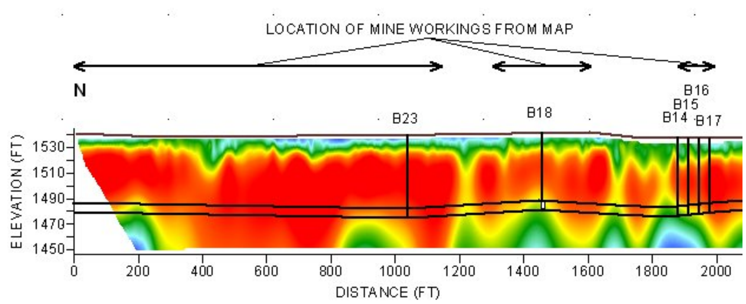
Results of DC resistivity profile CB1 – a pronounced resistivity low that is as intense as the coal refuse at the eastern edge of the profile is suggestive that the profile is over or near flooded workings. The top and bottom of the coal are depicted in the cross sections based on the results of the exploratory borings (e.g., B28 is Boring B28, which indicated the presence of solid coal).

line, the anomalous low located between about 275 and 450 feet in the above image appears partially below the level of the coal. This type of strong anomaly is associated with flooded mine workings or conductive refuse. Because of access limitations, an exploratory boring that disclosed solid coal could only be located west of this anomaly.

The basic conclusion from the data collected above dry workings is that it might be possible to identify dry voids, but the interpretation of the results is much more subtle than when they are at least partially flooded. Except where there are resistivity highs where openings are known to be crossed because they are visibly exposed, the main anomalies that appear to be mine related are those where it is possible that the mine is partially flooded.

The southern side of Lots Branch

The southern side of Lots Branch is another area where it was anticipated that the mine workings would be at least partially flooded. The actual results along Line NL-7 do not indicate that the mine is flooded. Low resistivity anomalies reflective of flooded mine workings were limited in occurrence, and more typically high resistivity zones were detected in areas where partially flooded workings were anticipated. This may be due to the workings being well drained. Where observed in the field at an exposed entry located near Boring B23, the mine appears to discharge limited seepage or is dry. The only boring that encountered mine workings and all borings that encountered solid coal in this area were observed to be dry to the level of the Lewiston seam.



Results of DC resistivity surveying over mine workings on the southern side of Lots Branch along Line NL-7 – the results indicate that the workings are not flooded as there is no strong indication of low resistivity at the level of the Lewiston Coal. However, at one location of relatively low resistivity, Boring B18 did encounter mine workings.

Summary

The abandoned mine workings in the Lewiston seam of the Lots Branch site, when explored, contained air filled voids or saturated gob. The presence of flooded workings were limited to shallow water (a few inches, and suspected to be more in adjacent areas imaged from the boreholes) on the mine floor, unless the workings contained gob where greater levels of mine water were detected. Flooded, open workings were not encountered. The following summarizes the conditions encountered at Lots Branch and the results obtained with the DC Resistivity method:

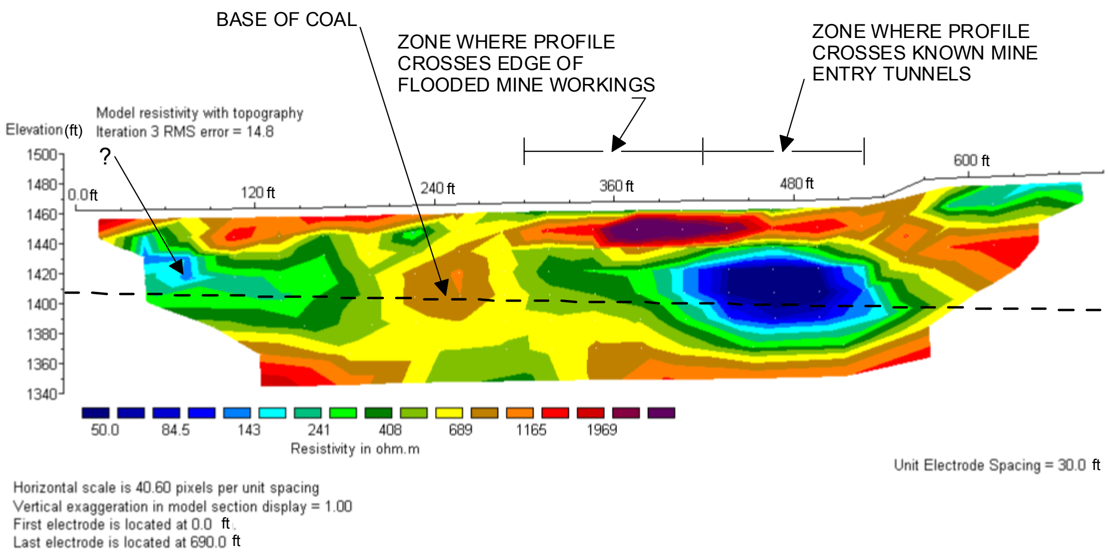
- Unmined Coal – Unmined coal conditions determined from borings or inferred from the mine map exhibited variable resistivity, typically ranging from 250 to greater than 1000 ohm-meters. In some cases, the coal seam did not exhibit significant contrasts from the overburden rock.

- Shallow Water on Open Mine Floor – Where water pooled, or is suspected to pool on the mine floor, a resistivity low of less than 250 ohm-meters was detected. Resolution varied from detection of a set of entries as lows (Line NL-4) to areas of suspected more extensive workings exhibiting as intermittent lows which are probably not reflective of individual rooms.

- Saturated Gob within Mine – Saturated gob in-filling the mine workings (Line NL-2) exhibited resistivity lows of similar magnitude as detected at locations of shallow water on open mine floor.

- No Obvious Water on Open Mine Floor – Where no obvious evidence of ponded water was detected on the mine floor, the resistivity surveys indicated lows in some areas, variable resistivity values in some areas, and highs at locations of entries which were open to the atmosphere. It is possible that moisture in the air and possibly condensate on the walls is present in mine workings where there is no obvious water observed on the mine floor at the exploration boring.

While flooded mine workings were not encountered at Lots Branch, such conditions have been encountered at the Weisner Hollow site in Pennsylvania. Based on the results of a limited DC Resistivity survey over flooded workings at the Weisner Hollow site, as well as other working experience, flooded workings can exhibit a strong resistivity low with high resolution of the workings. Commercially available DC resistivity technology can distinguish individual flooded rooms and pillars to depths as great as about 30 – 40 feet. Beyond a depth of about 40 feet the technique can resolve the presence or absence of mine workings, but cannot resolve individual rooms and pillars. For workings deeper than about 100 feet, the method has the potential to be effective, but theoretical models and practical experience demonstrate that the target size/depth ratio needs to be favorable and the required length of the resistivity profile to acquire deep images is often limited by surface interference.



Results of DC resistivity measurements taken over fully flooded mine workings at a coal refuse facility located at Weisner Hollow in Jefferson County, PA. In this case, the workings traversed by the resistivity profile are clearly delineated.

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1 INTRODUCTION

This Report presents the results of a demonstration project of the DC resistivity surface geophysical method and the subsequent verification of the geophysical interpretation based on borings and imaging of parts of mine workings within the Lewiston Coal at the Lots Branch tailings impoundment site in Prenter, West Virginia (Figures 1 and 2). The Lewiston Coal is the seam that outcrops in the portion of the valley that will eventually be filled with fine tailings (fine coal refuse slurry), as shown in a sectional view on Figure 3. In addition to the DC resistivity surveying, time domain electromagnetic (TDEM) data were also obtained. The results of the TDEM measurements are presented in a separate report (D'Appolonia, 2006). Imaging of portions of the mine workings was obtained using a downhole laser system developed by Carnegie Mellon University and commercialized by Workhorse Technologies, Inc. of Braddock, PA.

This demonstration project focused on the ability to detect mine workings which may be in close proximity to an impoundment, where the potential for a breakthrough of tailings into the workings exist. In such a setting, the continuity and width of coal barriers are critical parameters in evaluating the potential for a breakthrough. The DC resistivity geophysical method offers a surface technique which can detect underground mine voids and thus, assist in verifying the continuity of coal outcrop barriers and mine entry locations. The objectives of applying the geophysical method at a mine demonstration site included:

- Detection of mine workings interpreted from resistivity anomalies associated with a contrast between the mine environment and intact rock.

- Mapping of mine entries if sufficient resolution of the resistivity results can distinguish separate individual targets such as two entries separated by a coal pillar.

- Assessment of the continuity of coal barrier pillars through interpretation of intact rock resistivity.

A mine map was available to aid in the design of the geophysical program, providing a general location and depth for the investigation of voids. An exploration drilling and mine void imaging program was incorporated into the project to assist in validation of the results of the geophysical surveys.

The project consisted of the following tasks:

- A Work Plan was prepared presenting the proposed location and limits of the geophysical surveys on the Lots Branch impoundment, along with survey procedures, the exploration drilling program to verify the surveys, and special access and safety requirements. Prior to preparation of the Work Plan, short test surveys were performed to help establish procedures and view potential results from the DC resistivity method. The work Plan was submitted in April 2005.

- The main geophysical survey was performed in May 2005 and consisted of ten traverses covering 16,000 feet of line. Concurrent with the geophysical surveys, location and elevation surveys were performed to accurately locate the traverses, mine entries, coal outcrop, and mine discharges.

- The geophysical surveys were processed and interpreted to identify resistivity anomalies for comparison with the available mine map and for targeting confirmatory borings.

- A drilling program was prepared and implemented consisting of four cored holes to retrieve samples for characterization of the site stratigraphy, and 24 air rotary borings to explore coal seam and mine conditions for verification of the geophysical surveys. As part of the exploration program, the larger mine voids encountered were subjected to laser imaging to identify entry alignment and dimensions.

The Lots Branch impoundment is approximately 100 acres in size with a depth of impounded fine refuse of nearly 300 feet. As shown in Figures 1 and 2, the impoundment is situated in the central portion of Lots Branch and extends upstream and includes Robertson Hollow. Future development of the impoundment is planned to result in disposal of fine refuse slurry to El. 1495, exceeding the level of Lewister coal seam which outcrops between Elevation 1460 and 1540. The Lewiston seam has been underground mined throughout the perimeter of the impoundment, a length of approximately 15,000 feet. Thus, the presence and continuity of the outcrop coal barrier is a factor in evaluating the potential for impoundment breakthrough to the abandoned mine workings.

The DC resistivity surveying was conducted with a Syskal Junior 48-electrode measurement system manufactured by Iris Instruments of Orleans, France. As shown on Figure 2, nine profiles were obtained over mined areas in the Lewiston seam. The setup of the electrode system was designed to yield resistivity measurements through and beneath the Lewiston Coal, typically at a depth of 40 to 60 feet. An additional profile was obtained as an experiment along the outcrop of the Lewiston Coal at the southern edge of Robertson Hollow.

The test profiles were selected to take advantage of access accounting for terrain and alignment constraints, as well as mine equipment (haul truck) interference. The profiles were also located to traverse mine workings in the Lewiston Coal under varying degrees of flooding. The Lewiston Coal seam ranges in thickness from about 4 to 6 feet and dips to the northwest at about 1.5 degrees (Figures 3 and 4). As such, the mine workings on the north side of the impoundment dip away from the valley wall and are dry. The workings on the south side of the valley dip towards the impoundment and mine water seeps into the valley. Flooded or partially flooded workings were expected to be encountered where mine workings terminate at barrier coal on the southern edge of the impoundment. These probable differences in flooding allow for the Lots Branch site to be grouped into three basic areas:

- The southern side of Robertson Hollow – in this area mine workings were expected to be at least partially flooded.

- The northern side of Robertson Hollow merging into the northern side of Lots Branch – in this area the workings were expected to be dry. Three entries in the Lewiston seam labeled are exposed along the northern edge of Lots Branch.

- The southern side of Lots Branch – in this area the workings were expected to be at least partially flooded. One mine entry is exposed on this side of the valley.

The DC resistivity surveying was conducted along the entire perimeter of the impoundment, where abandoned mine workings are present at elevations below the ultimate level of fine coal refuse slurry.

Subsequent sections of this report present the theory of the DC resistivity method (Section 2), the basic background of the Lots Branch site (Section 3), field procedures covering the geophysical surveying, as well as the drilling and imaging of the mine voids (Section 4). Section 5 provides the results of the DC resistivity surveying with observations regarding the application of the DC resistivity technique in an environment such as the Lots Branch Tailings Impoundment. Section 6 provides conclusions and recommendations.

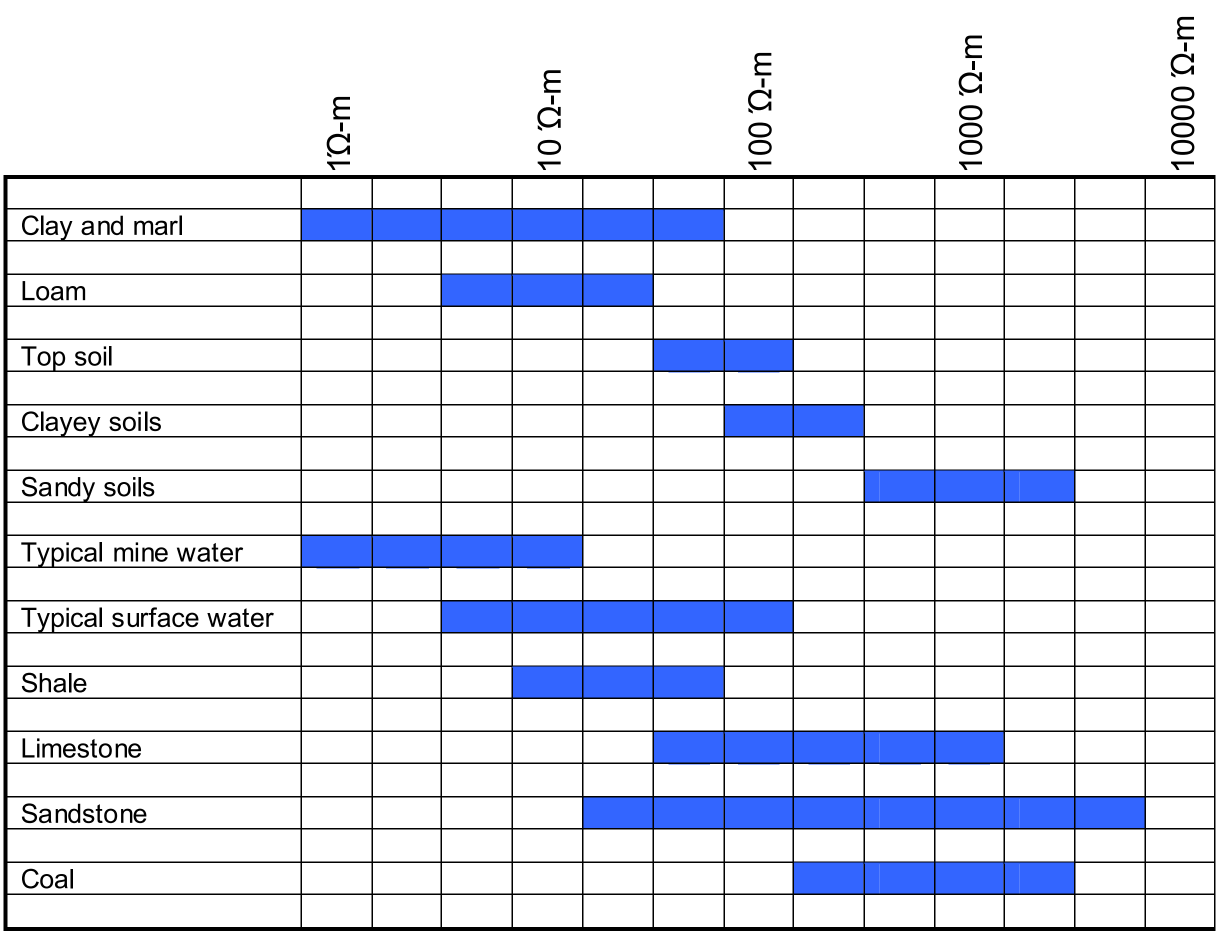
2 BACKGROUND THEORY OF DC RESISTIVITY TECHNIQUE

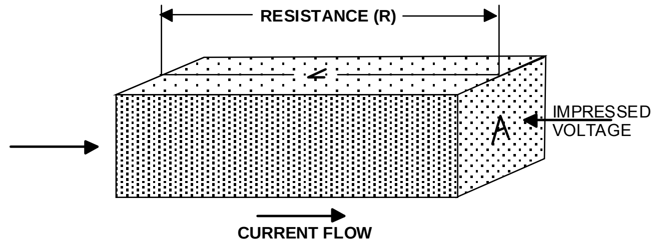
The starting point of any geophysical investigation must be basic physics. Geophysics will be effective only if a target of interest has a physical contrast with the surrounding ground. For example, a mine entry containing metal tracks could be an easy target for a magnetic survey, but if the tracks are not present, the magnetic response of the entry might be too subtle to recognize. Another important consideration is if the geophysical contrast of the target can be distinguished from other features with similar contrasts – what geophysicists call the signal to noise (S/N) ratio. A mine entry might be relatively easy to identify with a gravity survey that can detect a void space as a zone of low density, but if the target is located in an area of rugged topography, the errors associated with the topographic corrections can easily mask the response from the mine workings. Notwithstanding the above difficulties, mine workings can be associated with measurable physical contrasts.

The DC resistivity method depends on being able to detect mine workings on the basis of their electrical properties. Coal itself usually has a high resistivity compared to other sedimentary rock types as shown in Table 1 (modified after Benson (1988)). This property has formed the basis for detecting coal from borehole logs and DC resistivity surveying was used as a tool for exploring for coal as early as 1934 (Ewing et al., 1936). Multi-electrode systems were developed in the 1970s and in the 1980s were applied by the Bureau of Mines for locating abandoned mines (Burdick et al., 1986). The detection of voids depends on whether or not the void has a physical contrast with the surrounding rock. If the void is dry, the void will be difficult to detect with electrical measurements. Air does not transmit an electrical current, but unless the coal is of an unusually low resistivity, it could be difficult to distinguish high-resistivity coal from a void.

Mine water with conductivity (the reciprocal of resistivity) in the range of typical surface water could be about 500 micro-Siemens/centimeter (μS/cm), which corresponds to a resistivity of 20 ohm-meters. If the mine water is more acidic, the conductivity could approach 5,000 µS/cm, which corresponds to a resistivity of 2 ohm-meters. In either case, the contrast between a flooded or even a partially flooded mine compared to a typical coal resistivity of 500 to 1,500 ohm-meters will approach two orders of magnitude. In the case of the Lots Branch site, the average conductivity of ground water from the Lewiston Coal based on the results of the boring program is about 800 µS/cm, which corresponds to an average resistivity of about 12 ohm-meters, although the overall variability is large, with the range in conductivity measured to range from as low as 100 µS/cm to greater than 2,000 µS/cm.

TABLE 1 – TYPICAL RANGE OF EARTH MATERIALS IN OHM-METERS (modified from Benson, 1988)





Sketch of parameters to define resistivity

The purpose of a DC electrical survey is to determine the subsurface resistivity distribution of the ground, which can then be related to physical conditions of interest such as lithology, porosity, the degree of water saturation, and the presence or absence of voids in the rock. The basic parameter of a DC electrical measurement is resistivity. Resistivity is not to be confused with resistance. Resistance (R), measured in ohms, is the result of an electrical measurement, where according to Ohm's Law:

$V = IR$ or $R = V/I$

where V = voltage in volts and I = current in amps.

Resistivity of a material is a fundamental physical property related to the ability of a material to conduct electricity. If R is the resistance of a block of conductive material having length L and cross-sectional area A (see sketch), then resistivity is given as:

$\rho = RA/L$

Resistivity measurements of the ground are normally made by injecting current through two current electrodes and measuring the resulting voltage difference at two potential electrodes. From the current (I) and voltage (V) values, an apparent resistivity (ρa) value is calculated.

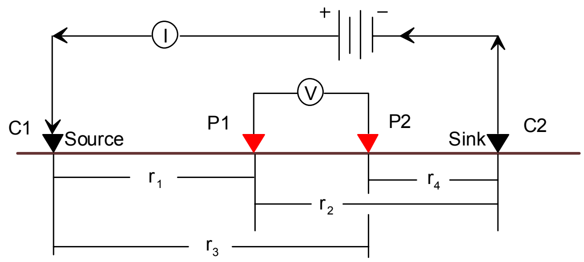
$\rho a = kV/I$

where k is the geometric factor which depends on the arrangement of the four electrodes.

The "k" value can be calculated for any four-electrode configuration according to the generic formula:

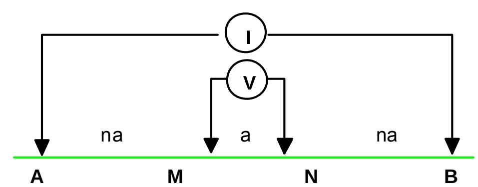
$$k = 2\pi\,[1/(1/r_1 - 1/r_2 - 1/r_3 + 1/r_4)]$$

where the subscripted "r" values are distances as defined in the adjacent sketch.



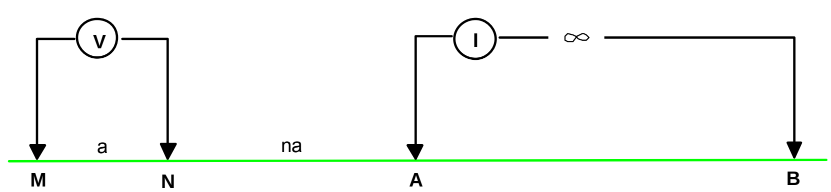
Geometry of generic four-electrode configuration

Three electrode configurations are most commonly applied for general application, the Wenner Schlumberger, dipole – dipole or the pole - dipole configurations. With the Wenner – Schlumberger electrode array, the current electrodes are located on both sides of the two voltage electrodes at multiples of the "a" spacing between the voltage electrodes. With this configuration, the signal to noise ratio is generally favorable and vertical contrasts are enhanced.



Setup for Wenner-Schlumberger survey

With the dipole-dipole configuration, two electrodes are separated by a constant spacing called the "a" spacing and are used to inject current into the ground. Two additional electrodes also separated by the "a" spacing are moved along the survey line at distances from the current electrodes that are multiples of the "a" spacing. The pole – dipole configuration is similar, except that one of the current electrodes is sufficiently far from the other three such that it can be considered to be at an "infinite" distance from the other three. In most cases the pole – dipole has proven to be preferable to the dipole – dipole configuration because the depth of penetration is relatively greater for the same "a" spacing and the "noise" level is reduced. Field experimentation has demonstrated that the most important aspect of data acquisition is the signal to noise ratio, with the best results achievable with the Wenner-



Setup for pole-dipole survey

Schlumberger and pole-dipole configurations. The Wenner-Schlumberger relationship has the advantage of providing the best vertical resolution, but the disadvantage of this configuration is that the full depth of penetration is not achieved except near the middle of a spread of electrodes. The pole-dipole configuration does not have the same vertical resolution as the Wenner-Schlumberger, but has generally better lateral resolution and the full depth of penetration is obtained closer to the end of the line. Given that each array has good signal to noise ratio and the ability to image the subsurface in somewhat different manners, both were applied for the Lots Branch survey.

It is necessary to distinguish between the various expressions for resistivity to avoid confusion throughout this report. The term "apparent resistivity" applies to field values calculated from measurements of voltage and current, with the appropriate geometric correction applied. "Apparent resistivity" values assume a homogenous earth. The "apparent resistivity" values are used as input for the inversion software and have not been used in any of the figures. "True resistivity" is the actual resistivity in the ground and is often the term applied to the results of the inversion process, as the resistivity model generated by the inversion is an approximation of the true resistivity. Throughout this report, the output of the inversion software has been used to create all the resistivity cross section images and is referred to as just "resistivity" except in the following paragraph where we use "true resistivity" to distinguish it from "apparent resistivity".

The measured values of apparent resistivity need to be converted to true resistivity for actual conditions in the ground to be interpreted. This is a complex process that restricted the application of DC electrical surveys until the development of software capable of being run on a PC. The conversion of apparent resistivity as a function of electrode spacing to true resistivity as a function of depth can be conducted for 2D profiles with the RES2DINV program (Geotomo Software, 2004). This program automatically determines a 2D resistivity model for the subsurface from the data obtained from electrical imaging surveys. A forward modeling subroutine is used to calculate the apparent resistivity values and a non-linear optimization technique is used for the inversion routine. The program supports both finite difference and finite element forward modeling techniques.

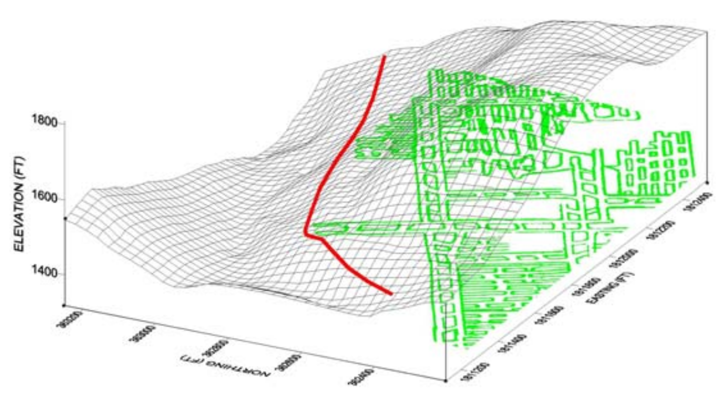
The inversion routine used by the RES2DINV program is based on a smoothness-constrained least-squares method (deGroot-Hedlin and Constable, 1990; Loke and Barker, 1996). One advantage of this method is that the damping and flatness filters can be adjusted to suit different types of data. For the data sets obtained at Lots Branch, natural earth layering is enhanced with a vertical filter that enhances horizontal layering. Conversely, the targets of interest, the mine voids, are of discrete lateral extent, which would be enhanced by selecting a vertical flatness filter that would enhance lateral variations. As a compromise, the processing was conducted with an equal weight assigned to both horizontal and vertical data components.

The 2D model generated by the RES2DINV program divides the subsurface into a number of rectangular blocks and the purpose of the program is to determine the resistivity of the rectangular blocks that will produce an apparent resistivity pseudosection that agrees with the actual measurements. For the Wenner-Schlumberger array, the thickness of the first layer of blocks is set at half of the electrode spacing. For the pole-dipole array this thickness is 0.6 times the electrode spacing. The optimization method reduces the difference between the calculated and measured apparent resistivity values by adjusting the resistivity of the model blocks. A measure of this difference is given by the root-mean-squared (RMS) error, which was less than 10% with the Lots Branch data sets.

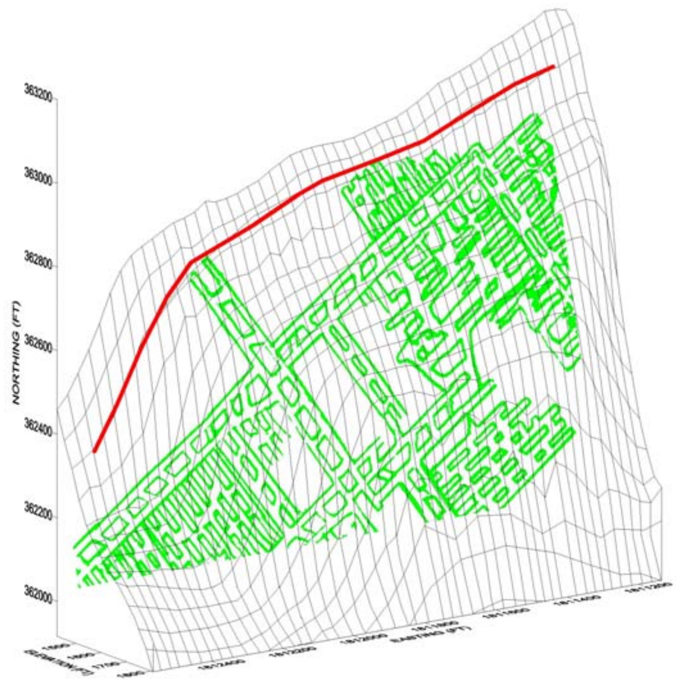
Forward modeling of coal workings offers the possibility of determining the resistivity measurements that would theoretically be made in the field with different electrode configurations. The means to effectively conduct forward modeling is also a relatively recent innovation. The RES2DMOD program developed by Loke (2002) offers the possibility of calculating theoretical apparent resistivity measurements for different subsurface conditions that can then be used as input to the RES2DINV program based on either finite element or finite difference modeling. The results depict what electrical cross sections generated by the inversion process in RES2DINV should look like for different subsurface conditions. These theoretical electrical cross sections can then be compared to the original model to determine how well the process has imaged the subsurface and facilitate the interpretation of real subsurface conditions. A discussion of 2D forward modeling with a comparison to actual case histories is presented in Appendix B.

Project experience with DC electrical measurements presented in Appendix B demonstrates that commercially available technology can be effective, especially for the rapid mapping of mine workings at depths up to about 100 feet. For deeper workings, the method has the potential to be effective, but theoretical models and practical experience demonstrate that the target size/depth ratio needs to be favorable and the required length of the resistivity profile to acquire deep images is often limited by surface interference. Additional details of some of the case histories presented in Appendix B can be found in Johnson (2003a,b); Johnson and Snow (2002) and Johnson, Snow and Clark (2002). None of the case histories presented in Appendix B or discussed in the above-referenced publications were obtained from dry mine workings.

A limitation to gathering DC resistivity data along linear profiles is that the images obtained are not necessarily from directly beneath the profile. A means to verify where the electrical images should be located spatially is to conduct the survey in three dimensions(3D). 3D surveys



3D topographic image depicting mine workings in the Lewiston Coal and location of experimental coalcrop profile CC-1 can be conducted by simultaneously processing parallel profiles with the RES3DINV program (Loke, 2003). Unfortunately, the steep terrain and/or logistical constraints did not allow for the placement of the necessary number of parallel lines such that the data could be processed in 3D. Nevertheless, this "limitation" to the 2D survey allowed for the experimental deployment of the electrodes along the Lewiston coalcrop line in an effort to image into the coal seam, rather than beneath it. The assumption of this deployment was that if horizontal position could be processed as if it were topography, nearby conductive bodies within the coal seam would appear at their correct horizontal position as long as the strata above and below the coal are uniform.



Rotated 3D ground surface and mine workings depicting the assumption followed for processing CC-1 northing is assumed to be elevation. The coal workings are imaged as long as there are no other conductive bodies near the profile.

The concept of detecting flooded workings not directly beneath the survey line was evaluated on the basis of 3-D modeling. A model simulating 2-D profiles passing over and near flooded mine workings was generated with the RES3DMOD program (Loke, 2005). The details of this modeling are presented in Appendix B. The basic result of this modeling confirms that flooded workings that are not directly beneath a 2-D profile will still appear on the profile, but at a depth that is deeper than the vertical depth to the coal seam. In essence, conductive bodies appear on the profile at their actual distance to the profile line, which is greater than the depth to the coal seam if the workings are off to the side. In the case of the coalcrop profile CC-1, the implication of this 3D modeling is that coal workings can effectively be mapped in plan view in terms of their distance to the coalcrop.

3 SITE BACKGROUND

The Lots Branch tailings impoundment is currently being developed by the Pine Ridge Coal Company (a Division of Peabody Energy). The proposed elevation of fine coal refuse is at Elevation 1495 feet, which will cover exposed workings of the Lewiston Coal seam (Figures 2 and 3). The Lewiston seam was underground mined from the 1930s through the 1950s and is found at an elevation of about 1540 feet near the upstream limits of the impoundment to about Elevation 1460 near the northwest abutment of the embankment. Approximately two-thirds of the overall area of the tailings impoundment will eventually cover the Lewiston Coal. The general dip of this seam is about 1.5 degrees towards the northwest (Figure 4) and the seam ranges in thickness from about 4 to 6 feet. Geologically, the Lewiston Coal (also called the Stockton – Lewiston Coal) is part of the Pennsylvanian age Kanawha Series and is overlain by the Homewood Sandstone and underlain by the Coalburg Sandstone, also of the Kanawha Series. The Homewood Sandstone is consistently present as a massive, competent unit in all of the borings. In addition, immediately above the Lewisburg Coal a layer of interbedded coal stringers and carbonaceous shale is consistently present with an average thickness ranging from six to nine feet (the average thickness south of Lots Branch is about six feet; north of Lots Branch it is about nine feet thick; and south of Robertson Hollow it is about eight feet thick). A thin layer of shale/underclay is intermittently present beneath the Lewiston Coal. Appendix C provides the boring logs from the coreholes and air rotary borings.

Chemical testing consisting of pH, conductivity and temperature measurements was conducted if water was encountered during drilling, as well as from seeps and surface water. Table 2 presents these results. The pH varies from 4 to 7 and the conductivity ranges from 100 µS/cm to >1,990 µS/cm.

The mine map of Lewiston Coal workings was provided by Pine Ridge Coal Company as presented in a permit application prepared by Alliance Consulting, Inc. One of the goals of this investigation was to verify the fit of the mine map to the ground surface and this was achieved by surveying exposed entries and also from the results of mine imaging conducted by Workhorse Technologies.

TABLE 2 – RESULTS OF CHEMICAL TESTING FROM BORINGS, SEEPS AND SURFACE WATER

Boring or other identified location	*Specific conductance (µmho/cm)*	*Resistivity (Ohm-m)*	*pH*	*Temp-erature (ºF)*	*Depth of GW from surface (ft)*	*Depth of GW (ft)*	*Comments*
B1							Corehole, caved at 7.1 ft
B2	790	12.7	7	68	46.15	2.95	Opaque with coal fines
B3	1020	9.8	6	68	42.2	4.9	Opaque with coal fines
B4	1250	8	6	62	42.2	4.9	Opaque with coal fines
B5					32.1		Corehole, caved at 5.7
B6	1420	7	5	68	42.1	3.4	Opaque with coal fines
B7					40.9	0.3	Caved at 41.2
B8	> 1990	<5	5	68	40.85	2.26	Opaque with coal fines
B9	310	32.3	6	71	45.35	3.0	Gray color
B11							Dry
B12							Dry
B13					40.6	0.1	Caved at 40.7 ft
B14							Dry
B15							Dry
B16					33.3		Corehole - Water level not representative of water in coal
B17							Dry
B18							Dry
B20	140	71.4	6	61	46.95	2.55	Clear
B22	100	100	6	63	45.06	0.75	Black
B23	410	24.4	6	59	65.33	1.87	Opaque with coal fines
B25					38.7	0.1	
B28							Dry
B29							Corehole, caved at 7.1 ft
B30	320	31.3	6	68	42.55	2.55	Opaque with coal fines
B31							Dry
B32	1020	9.8	6	59	39.7	1.05	Opaque with coal fines
B33	1060	9.4	6	59	39.25	2.08	Opaque with coal fines
B34					42.5	0.2	Caved at 42.7

TABLE 2 – Continued

Boring or other identified location	*Specific conductance (µmho/cm)*	*Resistivity (Ohm-m)*	*pH*	*Temp-erature (ºF)*	*Depth of GW from surface (ft)*	*Depth of GW (ft)*	*Comments*
Impoundment water	600	16.7	6		n/a	n/a	Measured at two location in impoundment
Entry "D"	530	18.9	6		n/a	n/a	Estimated flow 1-2 gpm in 5/05
Seep 19m west of Line CC-1	130	76.9	5		n/a	n/a	Measurement made from point ~ 12 ft below Lewiston Coal
Seep along Line CC-1, 450 ft from west end	960	10.4	5		n/a	n/a	From Lewiston Coal, flow estimated at 40-50 gpm in 5/05
Seep along Line CC-1, 525 ft from west end	1380	7.2	4.5		n/a	n/a	From Lewiston Coal, flow estimated at 100-120 gpm in 5/05 and combines seepage from 450 and 558 ft
Seep along Line CC-1, 558 ft from west end	1370	7.3	4		n/a	n/a	From Lewiston Coal, flow estimated at 20-30 gpm in 5/05
Seep along Line CC-1, 1280 ft from west end	590	16.9	5		n/a	n/a	From Lewiston Coal, flow estimated at 10-20 gpm in 5/05

Within the area of the proposed impoundment, four main entries corresponding to the mine map within the survey area and designated as Entries A, B, C and D (Figure 2) are still open, although they are observed to be partially collapsed. These were surveyed and the results of the laser imaging by Workhorse Technologies from Boreholes B13, B25, B31 and B34 were also incorporated to define a "fit" of the mine map to the ground surface shown on Figure 2. Based on registering the mine map, surveys, and the surface topographic map, the mine map should be shifted 50±5 feet east and 25±5 feet north of the position shown on previous maps, which assume that the coordinate system for the mine map is the same as the modern topographic map. This fit required correcting some distortions in the mine map that were possibly introduced when the mine map was scanned. By slightly rotating the mine map (0.2 degrees clockwise), matching the grid lines to the modern grid lines to make sure that the scale was correct, and then shifting the map to match mine entries and the results of the drilling and imaging program, the final fit was established by shifting the mine map 50±5 feet east and 25±5 feet north of the modern map coordinates. This correlation can be seen on Figure 2 by comparing the surface topographic map grid (shown in black) with the mine map grid (shown in green). It is possible that some further adjustment in the registration of the maps could result from surveying the other entries, but it is expected that the fit of the mine map shown on Figure 2 is essentially correct.

The dip of the coal seam (Figure 3) controls the drainage of mine water. Along the southern side of Lots Branch and the southern side of Robertson Hollow the entries are frequently locations where mine drainage occurs. Unless the coal fracturing allows for good natural drainage or the miners left drains, it was expected that the mine workings away from these entries could be fully or partially flooded. None of the borings drilled in September 2005 that penetrated mine workings along the southern side of Lots Branch or the southern side of Robertson Hollow encountered water and the amount of water that may have been present at the time of the geophysical surveying in May 2005 is not known. Nevertheless, it is reasonable to assume that at least some water was present in these portions of the mine at the time of the survey. At the time of the geophysical surveying four seepage points were mapped along Line CC-1 (Figure 7), one with a flow of more than 100 gal/minute, assumed to originate from a concealed entry. The other seeps were less than about one tenth of the flow of this main seep in May 2005. At the time of the laser imaging in September 2005, the highest flow was less than 10 gal/minute and it may be that there was not enough water in the mine to pond at that time, although water was observed to flow into the bottom of Boring B30, expected to be only a few inches from a dry entry tunnel. For this reason, it is assumed that the miners used an engineered drainage to keep the floor of the mine dry, probably with a drain on the northern side of the northern entry tunnel based on the geophysical results.

The coal on the northern side of Lots Branch dips towards the northwest, away from the valley. The mine workings on this side of the valley are therefore expected to be dry, which is what is observed at the exposed entries and also from the borings that penetrated mine voids - B11, B13 and B25.

The shape of the Lots Branch Valley is also controlled by the mining of another coal seam located above the Lewiston seam, the Five Block Coal. The Five Block seam is located stratigraphically approximately 30 - 50 feet above the Lewiston. This coal was also underground mined and the workings can be observed where a strip mine bench has been developed along the southern side of the tailings impoundment. This strip bench is currently being used as a road for hauling coarse coal refuse to the back of the impoundment. Room and pillar workings and augering of this coal are also observable in the area of Robertson Hollow.

The Five Block Coal has been reported in the past to be on fire. Smoke can be observed to emanate from the ground along geophysical survey line CB-1 and the eastern end of NL-4 (Figure 2). This situation may influence conditions in the Lewiston mine workings. Air temperatures in mine voids were noted during drilling as shown in Table 3 and the temperature of groundwater from within the Lewiston Coal is indicated in Table 2.

TABLE 3 – AIR TEMPERATURE RECORDED IN MINE VOIDS

Boring No.	Air Void Thickness (ft)	Elev. Base of Lewiston Coal (ft)	Temperature (ºF)
B6	1.0	1480.16	68
B7	2.2	1491.97	70.2
B8	0.3	1484.17	68
B11	6.7	1463.76	82.1
B13	5.7	1465.21	72.6
B18	4.1	1481.2	66.5
B25	8.0	1462.73	75.4
B31	6.0	1473.8	Not recorded*
B34	5.8	1475.54	Not recorded*

* Temperature of water from B30, immediately next to mine workings penetrated by B31 and B34, was 68 ºF.

Air and groundwater temperatures from the Lewiston Coal are not natural. The boring with the highest recorded air temperature is B11, which is near an observed area of smoke along the Five Block seam. This boring emitted warm, moist air throughout the survey. Warm moist air was also observed to emit from mine openings A, B and C along the western side of Lots Branch. As discussed subsequently, temperature may affect the conductivity of the Lewiston Coal.

The Coalburg Coal seam underlies the Coalburg Sandstone beneath the Lewiston seam at approximately El. 1350 – 1370 in this area. This is the coal seam currently being mined. Although this coal outcrops in the Lots Branch valley that has already been filled with tailings, the coal barrier is several hundred feet in width. The closest point of the existing room-and-pillar workings to the tailings impoundment when it is completely full is located in the portion of the impoundment designated as Robertson Hollow (Figure 2) and the workings are greater than 200 feet horizontal distance away. Because of its depth below the ground surface and the fact that the mine is dry, this seam has not been considered a viable target for the geophysical surveying.

The Hernshaw (El. ~924) and Dorothy (El. ~1270) coal seams also exist in the Lots Branch area, but no underground mining is reported for either seam in this area.

The coal refuse disposal plan for the Lots Branch impoundment includes constructing the embankment with a maximum crest level of El. 1530 with a maximum tailings level (fine coal refuse) at El. 1495. Accordingly, the continuity and integrity of the Lewiston seam coal barrier is of interest along a substantial portion of the impoundment perimeter, along with a limited section of the Coalburg seam in the upstream, southern end of the impoundment.

4 FIELD PROCEDURES

The DC resistivity survey was conducted in two phases using a Syskal 48-electrode system manufactured by Iris Instruments. An initial survey consisting of three lines was conducted between December 1 -5, 2004 and the results presented in the April 2005 Work Plan. The main geophysical survey presented in this report took place from May 4 – 20, 2005 and consisted of 9 conventional survey lines and an additional experimental line obtained along at the outcrop of the Lewiston Coal (the "coalcrop"). Based on the results of the geophysical surveying, 4 coreholes and 24 air rotary borings were drilled between September 15 – 21, 2005. Six boreholes encountering mine voids were selected for laser imaging by Workhorse Technologies. Of these, it was practical to laser image mine workings from four of these borings between September 19 – 21, 2005. These field efforts are discussed separately.

4.1 Initial Field Survey

The purpose of the initial geophysical surveying was to assess procedures and to evaluate site-specific results at the Lots Branch tailings impoundment. The surveying was conducted between December 1 and 5, 2004. Three profiles were selected for testing on the basis of the diversity of conditions that were expected to be encountered within the Lewiston Coal. Line 1 was located such that the profile would traverse three exposed entries on the northwestern side of the impoundment. The entries were dry and offered the challenge of determining the effectiveness of the techniques in locating a dry mine void. Line 2 was located along the southern perimeter of the tailings impoundment in an area with workings along the entire length of the line to evaluate the variability of the geophysical signature over what was expected to be flooded or partially flooded workings. Line 3 was located in an area where a portion of the line was expected to be underlain by flooded workings.

The main results of this initial surveying were that the DC resistivity surveying was expected to benefit from reducing the electrode spacing from 5 meters to 2.5 meters to improve the resolution and that surface topographic surveying would be required to achieve the accuracy necessary for locating borings and relating the results to the mine map. GPS measurements were found to be too imprecise for acceptable field location (horizontal and vertical), because valley walls and/or tree coverage restricted satellite reception.

4.2 Main Geophysical Survey

The main geophysical survey presented in this report took place from May 4 – 20, 2005 and consisted of 9 conventional survey lines and an additional experimental line obtained along at the coalcrop of the Lewiston Coal. The DC resistivity profiles (Figure 2) were obtained with the Syskal 48-electrode measurement system manufactured by Iris Instruments of Orleans, France. As discussed in Section 2.0, from a conceptual standpoint, it was expected that the pole-dipole configuration would have a better lateral resolution than the Wenner-Schlumberger configuration, but the Wenner-Schlumberger configuration would have a better vertical resolution. The data were processed as 2D cross sections with the RES2DINV program (Geotomo Software, 2004). All of the survey results obtained were of excellent quality, with RMS errors all less than 10% and usually less than 5%.

The overall goal of the geophysical demonstration was to identify the continuity of barrier coal at the outcrop and if there are areas where the data indicate the possibility of encountering unmapped workings within the barrier coal. Identification of breaches in the barrier coal was best accomplished by conducting the survey along profiles over the top of and more or less parallel to the line of the barrier coal and seven profile lines were obtained in this manner, NL-1 through NL-7 (Figure 2). This procedure was able to take advantage of the situation that trails and haul roads for impoundment access usually follow along surface contour lines, thus minimizing the need for corrections to be applied to the geophysical data for surface topography. The test profiles were selected to take advantage of access accounting for terrain and alignment constraints, as well as mine equipment (haul truck) interference. All of these profiles were conducted with both pole-dipole and Wenner - Schlumberger configurations with the 48 electrodes separated by 2.5 meters.

An additional interest of the geophysical demonstration program was the detection of the width of the barrier coal for comparison with the width indicated on the available mine map. Two profile lines (CB-1 and CB-2 shown on Figure 2) were conducted as close as practical to be perpendicular to the topographic contour lines to allow for the development of profiles from near the coal seam outcrop to central areas of the mine workings. These profiles were conducted with an electrode spacing of 5 meters to allow for a sufficient depth of penetration where the profiles went above the level of the Five Block seam.

The experimental coalcrop survey line CC-1 was surveyed by placing the transect in close proximity to the coalcrop of the Lewiston seam and a 5-meter electrode spacing was used to maximize the extent of penetration into the hillside. Under the assumption that the coalcrop line was "seeing" horizontally into the hillside, the horizontal position rather than elevation was used for the "topographic" correction during the data processing and it was necessary to locate each electrode with a subsequent ground topographic survey. Otherwise, the survey procedures were the same as for the other profiles.

Surface control in terms of site coordinates and elevation was provided with the location of benchmarks by Cornerstone Consulting and Design, Inc. of Danville, WV. D'Appolonia extended this surveying to specific geophysical lines and borehole locations.

4.3 Selection of Boring Locations

Based on the results of the DC resistivity surveying, the locations of a total of 19 boring locations were initially selected to characterize key points of the mine within the Lewiston Coal. All of these borings were targeted to encounter mine workings, in particular where the mine map indicated workings to be present at the location of the DC resistivity anomalies. The four coreholes (B1, B5, B16 and B29) were also placed with the hope of encountering mine workings, but their main function was to obtain representative stratigraphy across the entire survey area, primarily to determine the position and thickness of the Lewiston Coal, as well as to determine the lithology of the rock above the coal. Because of uncertainties in relating the mine map to the ground surface, it was anticipated that not all boreholes would encounter their intended targets and that it would be necessary to make field decisions regarding where to place the borings and coreholes. In actuality, 24 air rotary borings were drilled of which nine borings encountered mine workings as listed in Table 3 in Section 3. The rationale for the selection of the location of borings and coreholes is described below on the basis of their location along DC resistivity survey lines:

Line NL-2 – From west to east, B1 (corehole) and B2 (air rotary) were drilled with the intention of encountering mine workings and to define the configuration of the Lewiston Coal. As further discussed in Section 5.1, these borings were not expected to encounter flooded workings, as they were located over anomalously high resistivity at the level of the Lewiston Coal. Borings B3 and B4 were intended to encounter the entry on the south side of Robertson Hollow. Both of these borings encountered solid coal. As this entry was an important reference point to position the mine map with respect to the ground surface, Borings B30 and B31 were drilled to encounter the entry. B31 did encounter one of the entry tunnels and the results of imaging by Workhorse Technologies identified a cross-cut tunnel trending towards the east. It was therefore important to understand if this cross-cut tunnel represented a portion of the mine not included on the mine map, or if this tunnel connected to the second entry tunnel and was consistent with the mine map. Borings B32, B33 and B34 were therefore drilled. The second entry tunnel was encountered in B34 and showed that the cross-cut tunnel was something not depicted on the mine map. Farther east, Boring B5 (corehole) was drilled in the area of a resistivity anomaly where mine workings were not shown to exist on the mine map. This boring encountered solid coal. Borings B6, B7 and B8 were targeted to encounter mine workings in an area where there were resistivity anomalies and the mine map indicated that workings would be present. All three encountered gob-filled workings.

Line NL-3 – Boring B20 was drilled at a point where the mine map indicated that workings would be present and where the DC resistivity results indicated that, if workings were encountered, they would be dry. Solid coal was encountered.

Line NL-4 – Borings along this line were intended to encounter workings and to investigate resistivity anomalies. From west to east, Boring B22 was intended to encounter workings, although after the final best fit of the mine map was established, this boring was located outside of the area of mining and solid coal was encountered. Boring B25 was located in an area where there was a resistivity low (unexpected because workings were expected to be dry) and also where an entry was mapped. This boring did encounter the entry and there was a small amount of water in the mine at that location. Borings B9, B11, B12 and B13 were all targeted where the resistivity at the Level of the Lewiston Coal was anomalously low and also where mine workings were mapped. Borings B11 and B13 did encounter mine workings.

Line CB1 – Boring B28 was targeted over a resistivity low at the level of the Lewiston Coal where, based on the mine map, workings were not anticipated. Strong resistivity low values were encountered in the eastern half of the profile. The air rotary rig could not set up over the zone of lowest resistivity and B28 was located as the closest point with good access. This boring encountered solid coal.

Line NL-5 – Boring B29 (corehole) was targeted to provide information where the resistivity results indicated complex conditions and where the line crossed mapped workings. This corehole encountered solid coal.

Line NL-7 – From north to south, Boring B23 was targeted to better characterize workings immediately behind Entry D, which was hoped to better define the correlation of the mine map to the ground surface, but mine workings were not encountered. B18 was located to be at the central point of one of the mains in the Lewiston Coal and also to correspond to a resistivity low. This boring encountered mine void. Borings B14, B15, B16 and B17 were all targeted to encounter a mapped entry, but all encountered solid coal.

The details of the interpretation of the DC resistivity profiles in terms of the location of the borings is presented in Section 5.

4.4 Drilling

Based on the results of the geophysical surveying, 4 coreholes and 24 air rotary borings were drilled between September 15 – 21, 2005. Both the coreholes and air rotary borings were drilled by L. G. Hetager Drilling, Inc. of Punxsutawney, PA. The location of these coreholes and air rotary borings is provided on Figure 2. Boring Logs are provided in Appendix C.

NX size core (2 1/8 inch core from a 3 inch hole) was obtained from the four coreholes. The air rotary borings were drilled such that 6 inch diameter holes were obtained. A few of these holes were reamed out to 8 ¾ diameter holes and cased with 6 inch PVC casing in anticipation that the downhole equipment from Workhorse Technologies would require casing. In actuality, the cuttings from the reaming process proved to be an interference to the work conducted by Workhorse Technologies and a field decision was made by Workhorse Technologies personnel to conduct their surveying from uncased 6 inch holes.

Upon completion of the boreholes, they were sounded with an M-scope water level indicator to detect and measure the depth to ground water. The results of the water level monitoring are summarized in Table 2 and on the boring logs in Appendix C. In mine voids, the bottom of the void was encountered without detecting a measurable water surface and therefore was characterized as “dry.” However, based on M-scope response and visual observation of sediments, the bottom of the mine voids was moist to wet.

Boreholes were grouted on September 27th and 28th (except for Borings B16 and B17 which were grouted during the week of September 19th). Borings were grouted with Type II Portland cement grout by personnel of Hetager Drilling under the direction of D'Appolonia field personnel. Borings that did not encounter mine voids were filled with grout. Wooden or PVC pipe spacers were used to accomplish the grouting of borings that encountered mine voids. PVC pipe was used to span mine voids in borings that were partially or entirely reamed to 8 ¼ inches or more in diameter (Borings B11, B13, and B31). These borings were first sounded, and then a length of nominal 6 inch diameter PVC pipe, cut so that the top of the pipe would extend at least 1.5 feet above the top of the void, was lowered to the bottom of the boring. The PVC pipe was then filled with grout. A machined wooden plug was then placed in the top of the pipe, and plastic and paper were added to hold bentonite chips in place above the wooden plug. Approximately 1 to 2 feet of bentonite chips was then placed in the boring. Grout was pumped into the remainder of the boring above the bentonite chips. Due to concern that the bell-joints in the 6 inch diameter PVC pipe would become stuck in the upper portions of 6 ¼ inch diameter borings with mine voids (Borings B6, B7, B8, B18, B25, and B34), solid wood tree trunks of 4 to 5 inches in diameter were used to span the distance from the bottom of these borings to a distance at least 1.5 feet above the top of the mine void. Machined wooden plugs, retention material, and bentonite were then placed on top of the spacer prior to pumping grout into the remainder of the boring. Grout was allowed to settle for at least 3 hours and was then topped off. A schematic showing the grouting procedures is provided with the boring logs in Appendix C.

4.5 Imaging of Mine Voids

Imaging of portions of the mine workings was obtained using a down-the-borehole dry hole laser range based geometric scanner called a Ferret, developed by Carnegie Mellon University and commercialized by Workhorse Technologies, Inc. of Braddock, PA. If flooded workings had been encountered, an imaging tool called the Submersible Ferret that utilizes a sonar scanning system would have been used. As only dry workings were encountered, the laser-based Ferret scanner was deployed.

Close-up of Ferret tool showing the laser and laser tilt axis with borehole camera below.

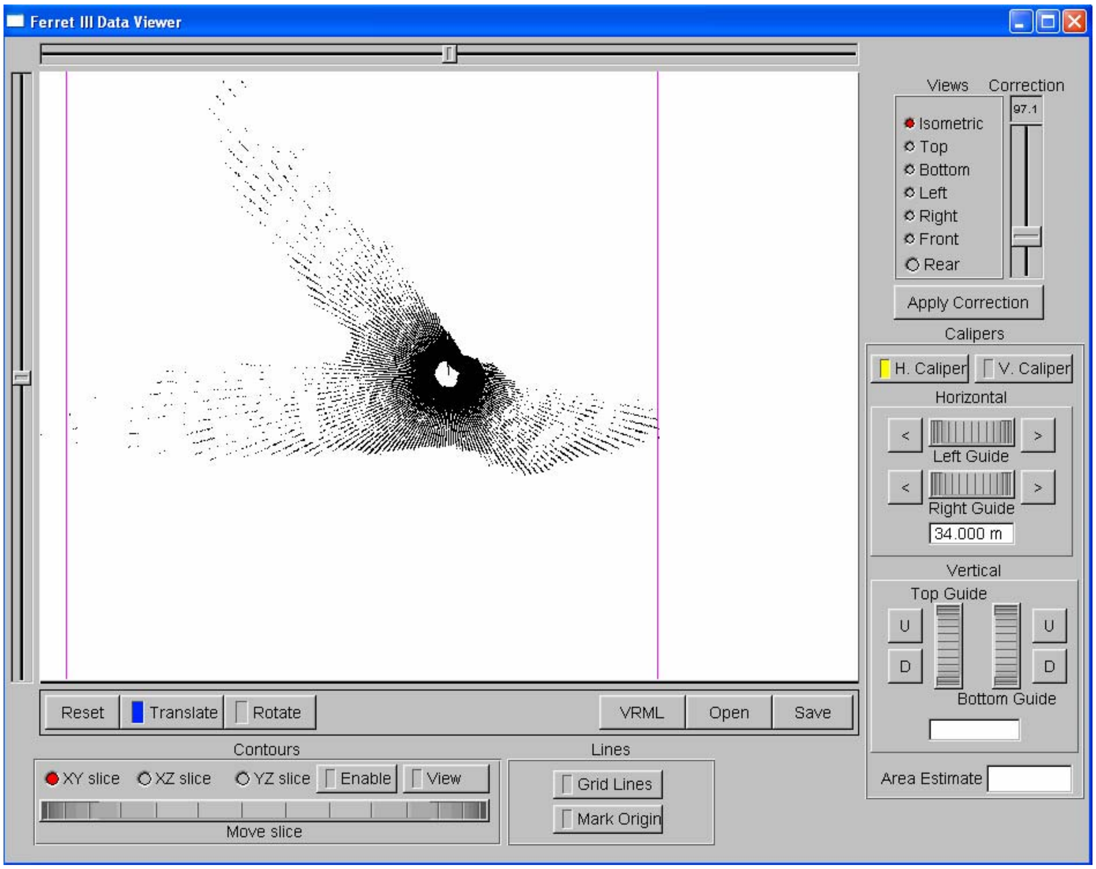
The Ferret is operated by being lowered on a cable down a borehole into a mine void. Once deployed into a void space the operator initializes a pan and tilt sequence to produce a scan of the void. Ferret is capable of collecting angular data to 0.1 degree increments and range data to 65 meters while maintaining accuracies to within 10mm. In the field, the collected data set is converted into a 3 dimensional point cloud model of the void. The point cloud is then converted into a mesh model allowing the client and operator to view a user-friendly 3-D model of the underground space. Video data are also collected during the scan using a low light camera. These data are post-processed to produce plan views, sectional views, and volume estimations.

Close-up of the Ferret tool and deployment at the Lots Branch site hanging from a tripod entering into an uncased hole – B18

Six boreholes encountering mine voids were selected for imaging. Of these, it was practical to image mine workings from four of these borings between September 19 – 21, 2005. Boreholes B13, B25, B31 and B34 were surveyed. Borehole 11 could not be surveyed because drill cuttings in the mine prevented the Ferret from having sufficient space to rotate within the mine void and Borehole B18 could not be entered because the imaging sonde could not fit past an obstruction in the borehole.

The Ferret fits down a 6 inch diameter hole and for the shallow depths encountered at the Lots Branch site mechanical linkage was maintained between the instrument and the surface to provide a surface referenced orientation. The mine voids were first viewed with the video camera and the operator made decisions as to what angular range would effectively image each void. Preliminary scans were obtained to quickly obtain rough images of each void and then the operator would select the final scanning parameters to obtain a satisfactory resolution of the mine void. By examining the data in the field informed decisions could be made as to what supplemental scans were needed to map a void. Three-dimensional images of a single scan were viewed in the field using software developed at Carnegie Mellon University specifically for the Ferret tool.

Surveyed locations and elevations of the boreholes were not available to Workhorse Technologies in the field, so each hole was locally referenced. Elevations were referenced as negative depth in feet from the surface. The zero azimuth for the scans at each hole was referenced to a predominant physical surface feature such as the centerline of the road or another borehole and defined as an azimuth with respect to magnetic north. In the laboratory a single composite model was generated for each hole with all the points from all scans. The zero azimuth of the model was referenced to magnetic north and a file containing all of the points was then prepared to display in X, Y, Z coordinates. By summing the point file with surveyed hole coordinates the models were georeferenced by D'Appolonia as shown on Figures 7, 12 and 14.



Field display of laser imaging from Borehole B31 – this image can be manipulated in the field such that the physical characteristics of the mine void can be reviewed in real time.

5 RESULTS

The DC resistivity profiles were located to traverse mine workings in the Lewiston Coal under varying degrees of flooding. As discussed in Section 3, the mine workings on the north side of the impoundment dip away from the valley wall and are dry. The workings on the south side of the valley dip towards the impoundment and mine water seeps into the valley. Flooded or partially flooded workings were expected to be encountered where mine workings terminate at barrier coal on the southern edge of the impoundment. The actual degree of flooding would depend on the efficiency of the natural drainage barrier along these mine workings or if a constructed drainage is present. These probable differences in flooding allow for the Lots Branch site to be grouped into three basic areas:

- The southern side of Robertson Hollow – in this area mine workings were expected to be flooded. There is a drainage seep that appears to correspond to a concealed entry, such that there is some control for the location of the mine map with respect to ground surface. The approximate coalcrop of the Lewiston Coal has been benched to create an access road for loggers.

- The northern side of Robertson Hollow merging into the northern side of Lots Branch – in this area the workings were expected to be dry. The approximate coalcrop of the Lewiston Coal has been benched along the length of Robertson Hollow. Along Lots Branch, the Lewiston is exposed and the three entries labeled A, B and C have been identified. In places smoke can be observed to emanate from above the Five Block Coal, especially in the area where Robertson Hollow merges with Lots Branch (Figure 2).

- The southern side of Lots Branch – in this area the workings were expected to be at least partially flooded. Control for the location of the mine map is available from only one location (Entry D on Figure 2).

These three areas are reviewed separately.

5.1 Southern side of Robertson Hollow

The southern side of Robertson Hollow was surveyed with resistivity lines NL-1 and NL-2, the coal outcrop line CC-1, and a line intended to evaluate the coal barrier CB2. Thirteen control borings were drilled in this area. Three borings (B6, B7 and B8) encountered relatively small voids and soft material interpreted to be mine gob; two borings (B31 and B34) encountered dry mine workings interpreted to correspond to the known concealed mine entry (Figure 2). The size of the voids and the presence of mine gob were not conducive to the imaging of the mine from Borings B6, B7 and B8, but Boreholes B31 and B34 did offer suitable conditions and were imaged by Workhorse Technologies. The results of the boring program and imaging from B31 and B34 allow for the development of the "fit" of the mine map to the ground surface shown on Figures 2 and 4.

Profile NL-1 is not interpreted to be directly over mine workings, but workings likely to contain some water are interpreted to be present at the southern end of the line (Figure 5). The two resistivity profiles corresponding to the pole-dipole and Wenner-Schlumberger configurations indicate the presence of low resistivity values in the southern half of the line, but at an apparent depth beneath the Lewiston Coal. This is interpreted to indicate that workings are near, but not directly beneath the southern half of the profile, consistent with the available mine map. The DC resistivity measurements not only respond to changes in the ground just beneath the profile, but also to the sides.

Profile NL-2 exhibits substantial variation of resistivity values at the depth of the Lewiston Coal, for which the 13 borings along this profile now provide good constraint for its location (Figure 6). Along the eastern end of Profile NL-2, Borings B6, B7 and B8 were targeted to encounter workings based on specific resistivity low anomalies observed with both the pole dipole and Wenner-Schlumberger configurations. These borings targeted along this part of Line NL-2 show that mine workings are associated with resistivity lows at the level of the coal and solid coal is present where relatively high resistivity values are present, consistent with what would be expected if the workings were at least partially flooded at the time of the survey. All of these borings did encounter mine workings, but they contained gob such that they were not candidates for imaging by Workhorse Technologies. The Wenner-Schlumberger configuration results depict resistivity lows extending farther east than the profile obtained with the pole-dipole configuration and the reason for this is not apparent.

Evidence of a resistivity low from the pole-dipole configuration was explored at Boring B5 and solid coal was encountered. The resistivity low at this location was not as significant as detected in the eastern portion of the line.

A main target of Profile NL-2 was the mine entry associated with mine drainage along the Lewiston Coal bench near the tailings impoundment. This entry was encountered by Borings B31 and B34 and imaged by Workhorse Technologies such that the mine map can be conclusively related to the ground surface. Both electrode configurations indicate anomalies at the location of the entry as indicated by the two borings with voids on Figure 6, although the Wenner-Schlumberger configuration results show a stronger anomaly than the pole dipole results. Several borings were required to locate the entries shown on the map and imaged with the DC resistivity survey.

Two borings, B1 and B2, were targeted along Profile NL-2 to explore resistivity highs at mine workings indicated to be present on the mine map and anticipated to be dry. Both encountered solid coal at the pillars adjacent to the workings.

If Profile NL-2 is reviewed as a whole, the strongest resistivity lows are where there appears to be a concentration of workings in the eastern half of the line, but there are other anomalies along the line that could also be interpreted to possibly be workings. This interpretation is further enhanced with the results from the experimental coalcrop profile.

<u>Profile CC-1</u>, the experimental coalcrop profile (Figures 7 and 8) was generated on the assumption that an electrical survey could detect conductive mine workings off to the side of the line. The survey was conducted along a bench where there was physical evidence that the bench was excavated along the Lewiston Coal (coal was occasionally exposed). This bench is perched between about 30 to 50 feet above the water level in the impoundment. The assumption of the survey was that the DC resistivity measurements would detect nearby conductive bodies, regardless of their spatial position with respect to the line. If it can be assumed that the nearby conductive bodies are from mine workings, rather than some other source, the position of the workings can be

determined if their distance to the resistivity profile can be determined. This distance can be determined if horizontal position is processed as if it were topography. Because the conductive bodies associated with mine workings are confined to a planar surface, the result is that distances from the line to these conductive features can be assumed to represent an image of the mine in plan view. The uncertainty of this along CC-1 was the presence of conductive water in the impoundment at a depth of 30 – 50 feet beneath the profile. If CC-1 had imaged the water in the impoundment, it would have appeared at a constant apparent depth beneath the profile. As this was not the case, the results have been interpreted to represent conductive bodies within the Lewiston Coal.

The results from CC-1 are particularly indicative that there could be workings in the barrier coal not mapped on the available mine map. The correlation of the mine map to the results from CC-1 shows that the resistivity low values begin at the edge of the eastern entry. The western entry is not well defined and it is speculated that drainage within the two entry tunnels was engineered to flow along the eastern edge of the eastern tunnel. The elevation of the Lewiston Coal based on the borings crossing the entry tunnels shows that the coal reaches a low point about 50 feet east of the eastern entry tunnel. The largest seep is located approximately this distance from the entry tunnels and the axis of the resistivity low on CC-1 appears to follow this low point in the coal. The presence of this pronounced resistivity low would be best explained if unmapped mine workings were present towards the east such that water could pool. The results of the laser imaging by Workhorse Technologies allows for some additional insight into the presence of unmapped workings.

As noted above, the results of the laser imaging by Workhorse Technologies allow for the definitive location of the entry tunnels associated with the seepage along the southern side of Robertson Hollow. The results of the laser imaging from Borings B31 and B34 are compared with the results of the coalcrop survey on Figure 7 and different three-dimensional views of the coal mine workings from these boreholes are presented on Figure 9. The results define the location of the two entry tunnels at a location consistent with the mine map. The laser imaging allows for the definition of 140 feet of open tunnel associated with the northern entry and 80 feet of tunnel associated with the southern entry. In addition, the results image 80 feet of an unknown tunnel extending from the northern entry towards the east. This previously unknown mine working may represent a conduit for mine water to flow eastward from the mine entry tunnels such that it can pool in the area of lowest coal, which is the same area that the resistivity results indicate that additional mine workings are likely to be present.

The geophysical survey was performed in May when wetter conditions prevailed than encountered at the time of the drilling program in September. At the time of the geophysical surveying four seepage points were mapped along the coalcrop line, one with a flow of more than 100 gal/minute. The other seeps were less than about one tenth of the flow of the main seep. At the time of the laser imaging in September 2005, the highest flow was less than 10 gal/minute and the mine voids did not encounter water in them, although water flowed into the bottom of Boring B30, only inches away from a dry entry tunnel. For this reason, it is assumed that an engineered drainage was used to keep the floor of the mine dry, probably with a drain on the northern side of the eastern entry tunnel. As the lowest point in the coal is about 50 feet east of the entry tunnels and previously unknown workings have been identified, it is assumed that drainage was established such that the main drainage outfall at the surface was set to be at this lowest point in the coal, which is the location of the largest seep.

Profile CB2, intended to characterize the barrier coal shows that it is practical to trace a coal seam from its outcrop position into a slope (Figure 10). Overly steep slopes or highwalls made it impractical to obtain profiles that did not closely follow the topographic contours over most of the survey area, but it was possible to follow one logging trail that connected a bench constructed at or near the Lewiston Coal with the bench constructed over the Five Block seam. A resistivity low is present at an apparent depth that is slightly below the level of the coal near the coalcrop, especially well defined with the pole-dipole configuration, which suggests that the profile is not immediately above flooded workings, but that the workings are close. Access was not possible for exploration of this area with a drill rig. At the southern end of the line, the resistivity low suggests the presence of mine workings consistent with the mine map.

5.2 The Northern Side of Robertson Hollow and Northern Side of Lots Branch

The northern side of Robertson Hollow and including the northern side of Lots Branch is located where mine water would tend to drain away from the coalcrop. It was therefore expected that mine workings on this side of the valley would be dry. Good control was established for the location of workings within the Lewiston Coal on the basis of both borings and observed entries at three locations immediately beneath the southern half of NL-5.

<u>Profiles NL-3 AND NL-4</u>: Where traversed by NL-3 (Figure 11), there is the suggestion of mine workings with anomalies that have relatively low resistivity values, but the values are not as low as would be expected from flooded workings and there is no obvious correlation with the mine map. Conversely, the DC resistivity survey conducted in May indicates that NL-4 (Figure 12) does have resistivity low values at locations where the mine map indicates that workings are present. The two entries penetrated by Borings B25 and B13 in September are both marked by resistivity lows, contrary to the observation from these borings that indicate limited water on the mine floor or otherwise dry conditions in the mine. The laser imaging of the mine entries (Figures 13 and 14) suggests that the mine floor could pond water, particularly during wetter seasonal conditions. Boring B11, which encountered a dry mine void in September, is marked by relatively high resistivity with the Wenner-Schlumberger profile, less clearly marked with the pole-dipole configuration. The mine workings in the Lewiston Coal traversed by NL-4 appear to be best imaged as resistivity lows, suggestive that the configuration of the mine at this location does not facilitate good drainage and the mine workings have a relatively high moisture content, even though the location of the workings is on the upgradient side of the Lewiston Coal and the borings did not encounter standing water. M-scope readings from the open voids did detect the presence of moisture, although standing water was not detected. Warm, moist air emanated from the borings in this area, especially in the northeastern part of the profile. This area is near where the 5-Block seam is on fire, so it is assumed that ground water is heated up when it percolates through the zone on fire and this heat is passed on to the Lewiston Coal by means of this groundwater infiltration.

The results of the laser imaging provides good confirmation of the spatial location of the mine workings in the Lewiston Coal, consistent with the interpretation provided on Figure 2. The results from Boring B25 (Figure 13) and Boring B13 (Figure 14) define the presence of entry tunnels consistent with the mine map. More than 160 feet of a NNW trending entry tunnel were imaged from Borehole B25. There is an indication of the presence of a crosscut tunnel extending westward from B25, but this tunnel appears to be collapsed. Although the warm, humid air emanating from Borehole B13 made the imaging difficult, the results define more than 90 feet of NNW trending dry entry tunnel also consistent with the mine map. If there are any lateral tunnels, they are collapsed or were not detected from the position of the borehole.

Profile CB1 intended to image the coal barrier is difficult to interpret. At the eastern end of the profile, the more conductive response of the saturated coal refuse is evident, with the Wenner-Schlumberger profile providing the better vertical resolution. The results seem to indicate that there could be flooded workings at between 150 and 200 feet on the profile, where B28 was drilled into solid coal (Figure 15.) The strongest resistivity low is located between about 275 and 450 feet on the Wenner-Schlumberger configuration and centered on 375 feet on the pole dipole profile. The anomaly is consistent with typical images of flooded workings, but this would require that the coal at this location have a local dip that does not fit with the regional pattern.

The anomalously low resistivity in the middle of CB1 in what should otherwise be solid rock is as low or lower than the coal refuse. Unless CB1 is above or near flooded mine workings, the intensity of this anomaly is difficult to explain. This area is where smoke is emitted from the hillside next to the profile (Figure 2). Because an increase in temperature would promote the generation of acidity in the presence of moisture and the conductivity of acidic water dramatically increases with increasing temperature, it is noted that the heat may be affecting the conductivity of the moisture within the Lewiston Coal (air temperature at the bottom of B28 was measured at 77.7 ºF). Thus, the coal seam in this are may exhibit anomalously low resistivity.

Line NL-5 (Figure 16) traverses three exposed entries that are visibly dry. These openings appear as resistivity highs on both the pole-dipole and Wenner-Schlumberger profiles. The profile is not suggestive that there could be other entries along this profile, except possibly at about 1220-1250 feet along the profile. Elsewhere along the profile, resistivity lows are observed at varying elevations above and below the coal seam. Because coal refuse and mine spoil is graded to higher elevations than the coal seam, in close proximity to the survey line, its conductance may influence the results. The northern 500 feet along NL-5 crosses at the edge of mine workings, according to the mine map, but there is no obvious difference in the characteristics of the resistivity results to suggest that workings are near. Boring B29 explored an area of highly variable resistivity, but encountered solid coal.

Line NL-6 (Figure 17) is the last profile taken on the north side of Lots Branch where coal workings are expected to be dry. Mine spoil and coal refuse are present immediately adjacent to the line. This line does not indicate a pattern that would suggest the presence of workings. The overall resistivity of this profile is relatively low compared to the others and it is suspected that the results are responding to the lower resistivity (higher conductivity) of mine spoil and coal refuse placed up to the general area of the line (the line was buried by mine spoil the day after the data were acquired).

The basic conclusion from the profiles taken where workings are dry is that it might be possible to identify dry voids, but the interpretation of the results is much more subtle than when they are at least partially flooded. Except where there are resistivity highs where openings are known to be crossed because they are visibly exposed, the main anomalies that appear to be mine related are those where it is possible that the mine is partially flooded.

5.3 The Southern Side of Lots Branch

The southern side of Lots Branch is another area where it was anticipated that the mine workings would be at least partially flooded. Surveying of Entry D indicates that this portion of the map correlates well with the rest of the map and the fit on Figure 2 is a reasonably good registration of the mine structures to the ground surface. In this case, the coalcrop contour drawn on the mine map is not accurate and actually shows the coalcrop line to be inside the area of workings immediately north of the beginning of line NL-7, which is not possible. Ignoring the depiction of the coalcrop on the mine map, the workings appear to be well located.

The resistivity results along Line NL-7 (Figure 18) are not readily interpretable in terms of relating the results to the mine map. Where workings are crossed from the northern end of NL-7 to about 1120 feet along the profile, the resistivity values at the level of the Lewiston Coal are uniformly higher than would be associated with even partially flooded mine workings. Based on the resistivity measurements from both electrode configurations, workings would not be expected to be present unless they are dry. The single boring in this area, B23, encountered water only at the base of the coal within intact coal. Where observed in the field, Entry D exhibits only very low seepage, less than 1- 2 gpm as observed in May 2005. In September, no flow was observed from Entry D, although water was still ponding in front of the entry. The second zone of mapped workings from about 1260 to 1620 feet along the profile also exhibits resistivity values at the level of the Lewiston Coal that are higher than would be associated with mine workings containing water. The single boring in this area, B18, encountered dry mine workings that could not be imaged because of an obstruction in the boring. The lowest resistivity values encountered along the survey line are centered at about 1850 feet along the profile, best defined with the Wenner-Schlumberger results, at a location immediately north of the mapped entry where the borings reveal a low point in the Lewiston Coal. This may be a location where water accumulates, but the borings that attempted to intersect the entry (B14, B15, B16 and B17) did not encounter water at the elevation of the Lewiston Coal, although water did appear in the corehole B16 within the Homewood Sandstone above the Lewiston Coal. The basic observation from the results from NL-7 is that the mine workings are sufficiently well drained to prevent their being electrically imaged and the data would not be suitable for defining a correlation of the mine map to the ground surface.

6 CONCLUSIONS AND RECOMMENDATIONS

The demonstration project illustrated the application of the DC resistivity surface geophysical method along the entire Lewiston seam coal barrier at the Lots Branch impoundment perimeter that may be subject to slurry deposition. Approximately 15,000 feet of survey line were obtained along the impoundment perimeter in about three weeks. Following processing and interpretation, twenty eight borings were targeted to explore resistivity anomalies, obtain data on the stratigraphy, and allow laser imaging of selected mine workings. The laser imagery provided information on the entry alignment and dimensions. These data assisted in orienting the mine map with the surface topographic map, generally correlated the definition of the mine workings shown on the mine map, and identified one location of suspected additional workings not indicated on the map.

The forward modeling presented in Appendix B illustrates the benefits and limitations of the electrical resistivity method at detecting mine workings in an environment like Lots Branch. Because the depth to the mine workings was typically between 40 and 60 feet, detection of individual entries was not anticipated, but flooded workings were expected to show strong anomalies of low resistivity corresponding to the elevation of the mine.

Considering the objectives of the demonstration project at Lots Branch, the DC resistivity method achieved the following:

- Detection of mine workings in areas that contained water.
- Mapping of mine workings, that is distinguishing between entries and pillars, was not achieved for the conditions present (attributed to the depth of the workings and the limited or no evidence of water in the workings).
- Assessment of the continuity of barrier coal pillars was effective in areas that contained water, but of restricted value in areas where mine water was not present.

The demonstration surveys conducted at Lots Branch encountered mine workings with limited presence of water. Perimeter surveys (NL-1 through NL-7) conducted to explore the continuity of coal barriers and confirm the presence of mapped mine workings identified resistivity lows at the mine level that were confirmed to be associated with a variety of mine conditions, including:

- Saturated mine gob at resistivity lows along NL-2 (at Borings B-6, B-7 and B-8).
- Shallow water (observed or suspected ponding based on imaging data) on open mine floor at resistivity lows along NL-4 (at Borings B-13 and B-25).
- No observed water on open mine floor at resistivity lows along NL-7 (at Boring B-18).

Because of the limited presence of water in the mine workings, the strong, low resistivity anomalies anticipated from the forward modeling and encountered at the alternative site (Appendix B) indicative of flooded workings were not encountered except along experimental coal crop Line CC-1 on the south side of Robertson Hollow. Laser imaging of the mine workings from a borehole penetrating one of the main entries which was dry (B-31) indicated unmapped workings at a lower elevation and thus suspected to pond water.

Resistivity highs were encountered at the coal seam level in a few instances and related to mine workings, primarily associated with entries in direct connection with the atmosphere (along NL-5 over Entries A, B and C).

Two dimensional surveys to develop profiles over the barrier pillars and mine workings can be deployed efficiently when access is available such as at Lots Branch, and the method is capable of identifying potential locations of mine voids. Mine workings along the perimeter of Lots Branch contained only limited water or were relatively dry, which resulted in more subtle anomalies. While still useful in evaluating the coal barrier continuity and width, the more limited contrast between workings and coal resulted in more numerous target areas for confirmatory drilling.

In addition to DC resistivity survey lines deployed along the hillside contour over the barrier pillars and workings of the Lewiston seam, survey lines were also deployed transverse to the contour in an effort to detect mine workings and the width of the coal barrier at the seam outcrop. The steep terrain at Lots Branch limited this deployment to the locations where logging roads provided access, and resulted in survey line alignment being at an angle to the contour as opposed to perpendicular. Additionally, the length of such lines were limited by old high walls encountered for the 5-Block seam, and thus, limited the extent of subsurface profiles over the Lewiston workings. While topographic corrections were applied during processing of the profiles, the three dimensional effects and potential of influence from nearby conductive zones not directly beneath the profile (at the outcrop or towards the mine) make interpretation of the data more complex. Coal Barrier Line CB-1, while suggestive of nearby mine workings, could not be verified and was likely influenced by other environmental factors (heat and humidity from a previously reported fire in the 5-Block seam). Coal Barrier Line CB-2 on the south side of Robertson Hollow detected low resistivity anomalies, although the stronger anomalies appeared to be associated with the seam outcrop. These factors make deployment, processing and interpreting in an environment like Lots Branch complex with low potential for efficient application.

An experimental deployment of the DC resistivity survey along the Lewiston seam outcrop in Robertson Hollow was performed in an attempt to develop horizontal profile of the seam and location of workings (Line CC-1). While still subject to the three dimensional effects from nearby conductive zones, the low resistivity anomaly observed in an area of barrier pillar, was subsequently determined to be an unmapped working with suspected flooded conditions. Thus, it appears useful to consider coal crop surveys for evaluations of barrier conditions.

Limitations were encountered in deploying and interpreting the DC resistivity survey at Lots Branch:

- The steep terrain and required topographic corrections introduce greater complexity in the interpretation.

- The presence of conductive coal refuse and mine spoil at the outcrop can influence the resistivity measurements and limit the ability to detect mine workings (i.e., Lines NL-5 and NL-6). It is difficult image mine workings beneath coal refuse, because most of the electrical current will travel through the coal refuse, rather than the ground beneath this material.

- Environmental factors such as heat and associated humidity probably influence the resistivity measurements in unexpected ways adding some uncertainty to the interpretations.

- Workings where there is limited presence of water will result in more subtle resistivity anomalies, and thus, require more extensive drilling exploration to confirm possible targets.

DC resistivity surveying has demonstrated that where there is at least some water in a mine it is practical to image shallow (< 100 foot depth) mine workings at a tailings impoundment environment as zones of anomalously low resistivity. At Lots Branch, the targeted mine working were between 40 and 60 feet deep and well within range of the method.

One of the most useful applications of the DC resistivity technique proved to be the deployment of electrodes along the coalcrop. This portion of the surveying was intended to be experimental, but the results of DC resistivity surveying along the coalcrop of the Lewiston Coal allowed for the best identification of zones where unknown workings were likely to be present. This situation was field verified by the imaging conducted by Workhorse Technologies.

The results of DC resistivity surveying over mine workings known to be relatively dry was that some of the known entries could be imaged as resistivity highs. Nevertheless, the basic conclusion from the profiles taken where workings are dry is that it might be possible to identify dry voids, but the interpretation of the results is much more subtle than when they are at least partially flooded. Except where there are resistivity highs where openings are known to be crossed because they are visibly exposed, the main anomalies that appear to be mine related are those where it is possible that the mine is partially flooded or contains moisture (such as observed as warm moist air emanating from boreholes into the mine).

Demonstration of the ability of electrical measurements to image mine workings would benefit from conducting additional surveys where the workings are fully flooded. The visual impact that can be achieved from the imaging of fully flooded mine workings in a tailings impoundment environment is provided on Figure B7 in Appendix B obtained from the Weisner Hollow impoundment site in Jefferson County, Pennsylvania. It is expected that additional useful data for demonstration purposes could be obtained from this site, or some other location.

Another conclusion from the Lots Branch demonstration survey is the quality and usefulness of the laser imaging of the mine workings conducted by Workhorse Technologies, Inc. This technology allows the measurement of void dimensions and entry orientation along with the qualitative understanding of the mine conditions which contribute to orienting the mine map with surface features, and interpreting the geophysical surveys.

Respectfully submitted,

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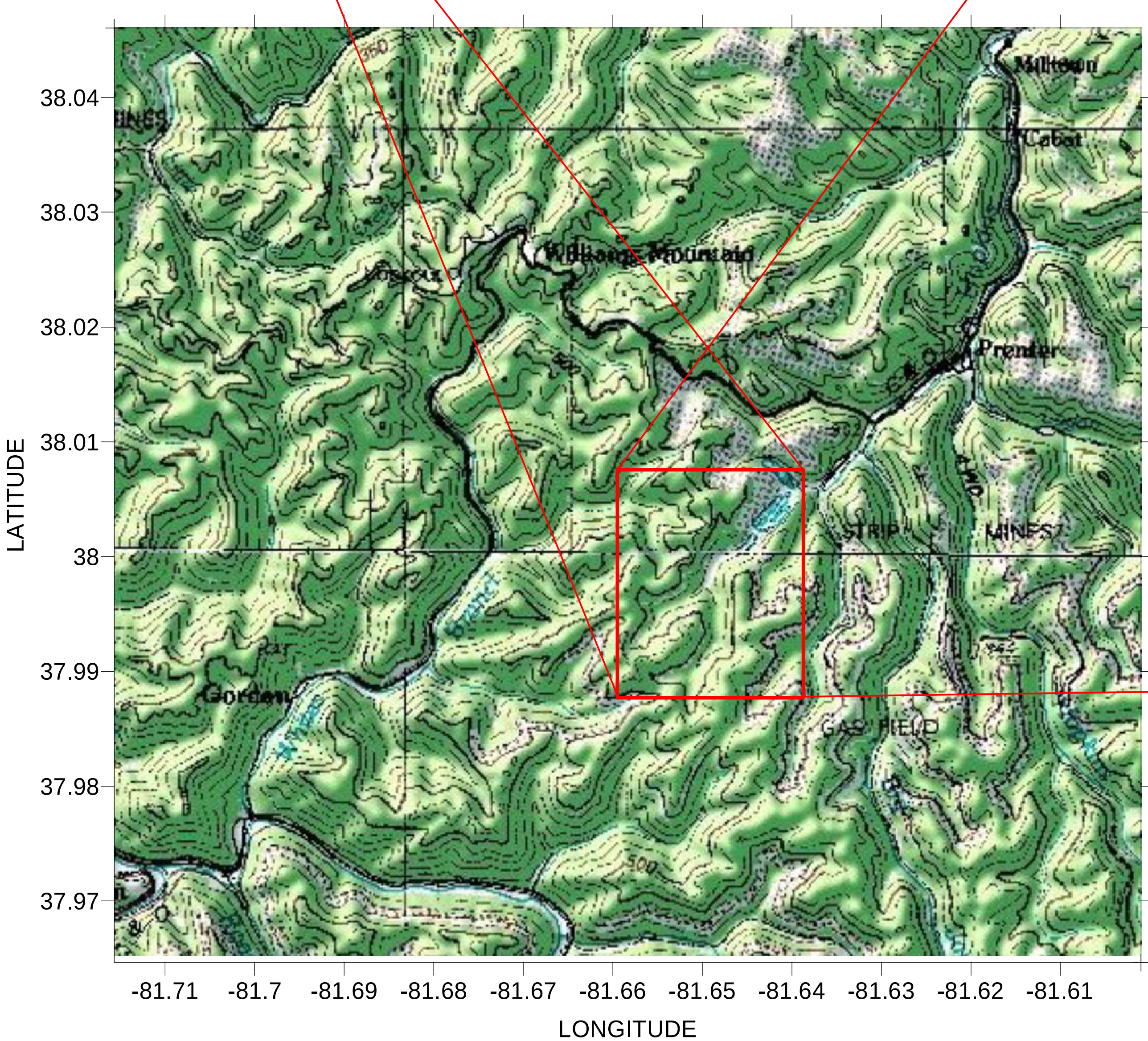
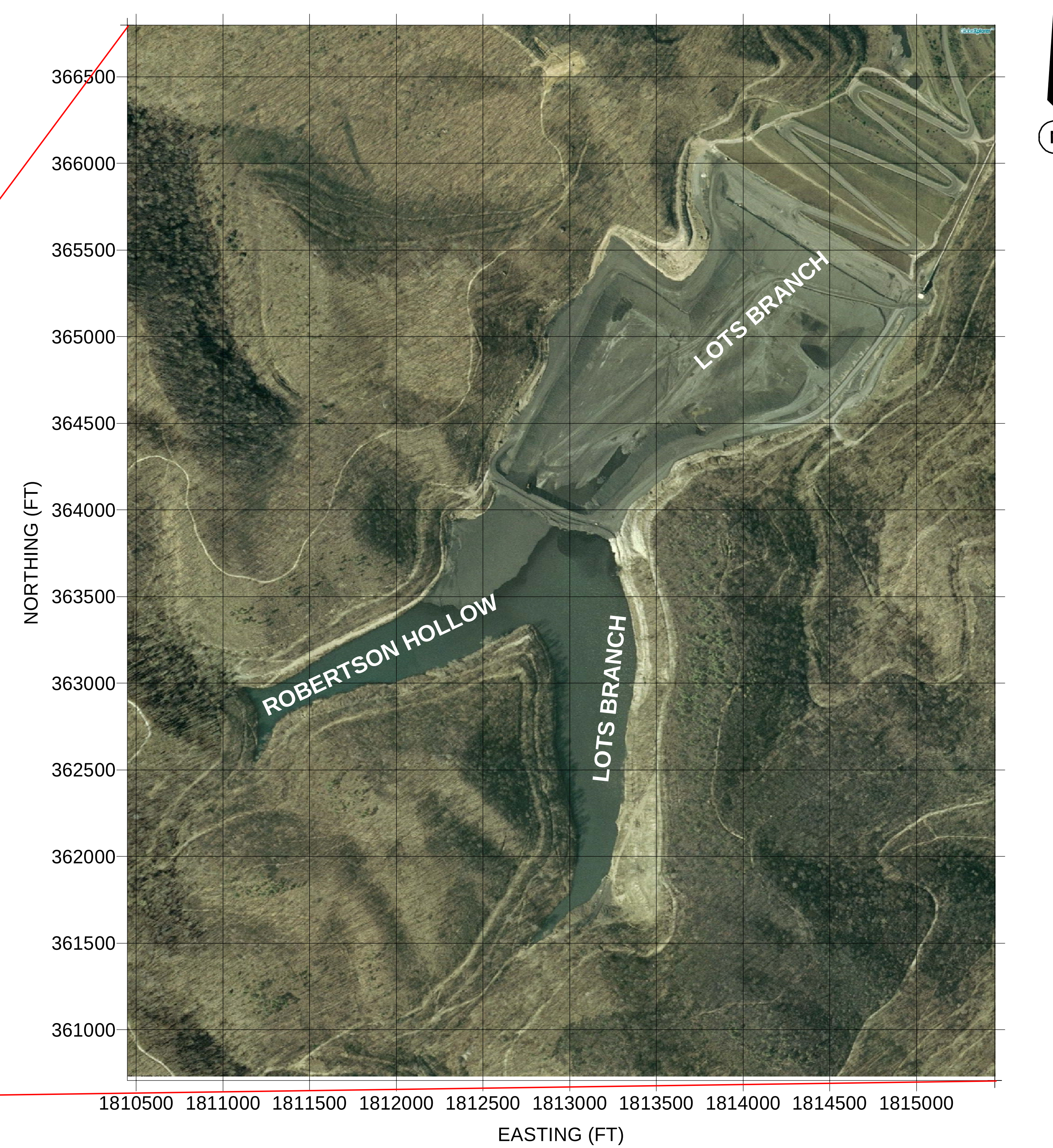
FIGURES

NOTES:

Aerial photograph taken March 15, 2003 at a best resolution of two feet and obtained from Terraserver imagery. The topographic map is from the USGS dated Jan 1, 1972.

Aerial photograph in West Virginia State Plane Coordinates in feet.





SCALE (FT)

0 500 1000 1500 2000

FIGURE 1

LOCATION AND AERIAL PHOTOGRAPH OF LOTS BRANCH TAILINGS IMPOUNDMENT SITE

PREPARED FOR

MINE SAFETY AND HEALTH ADMINISTRATION
ARLINGTON, VIRGINIA

D'APPOLONIA

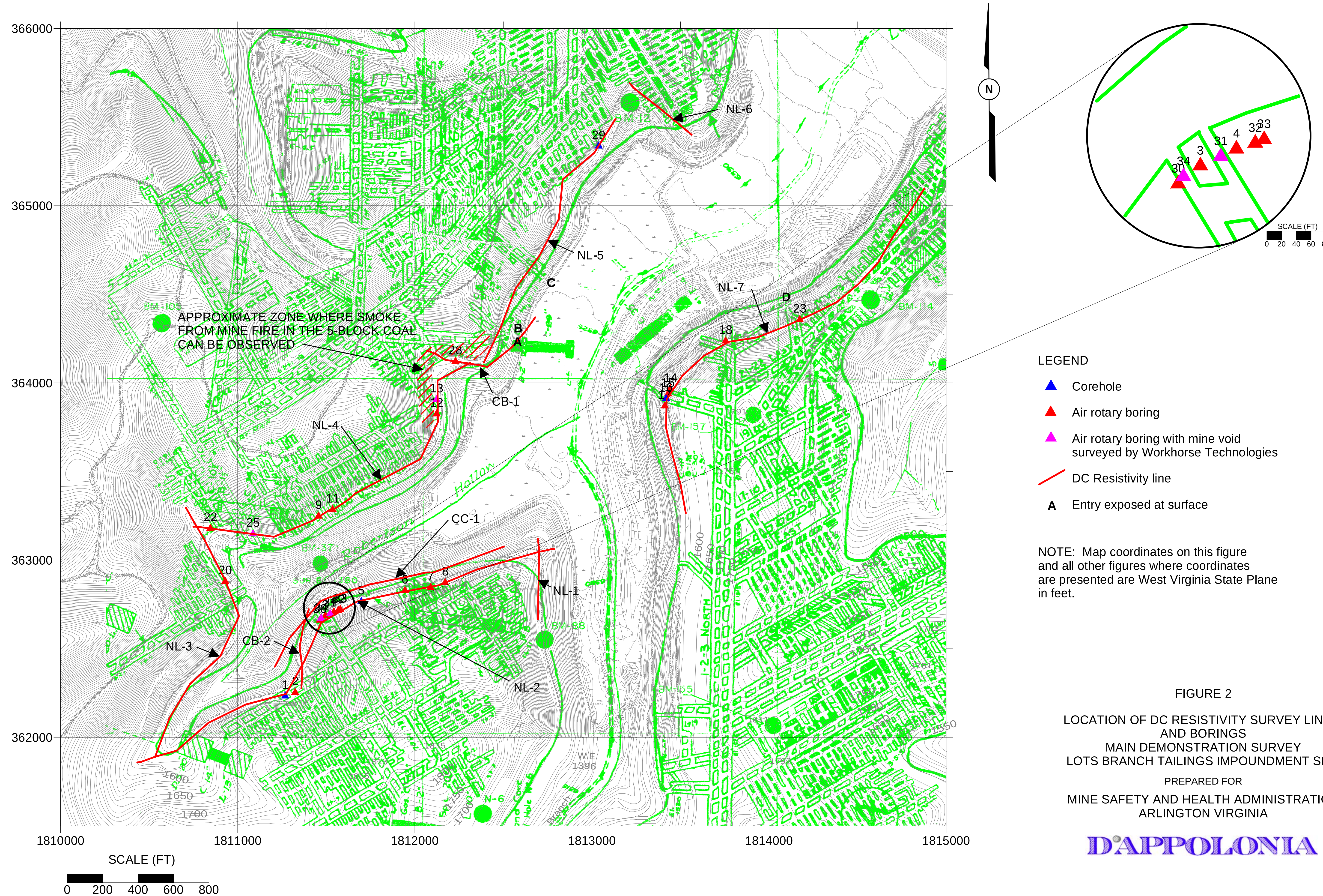


FIGURE 2

LOCATION OF DC RESISTIVITY SURVEY LINES
AND BORINGS
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

PREPARED FOR

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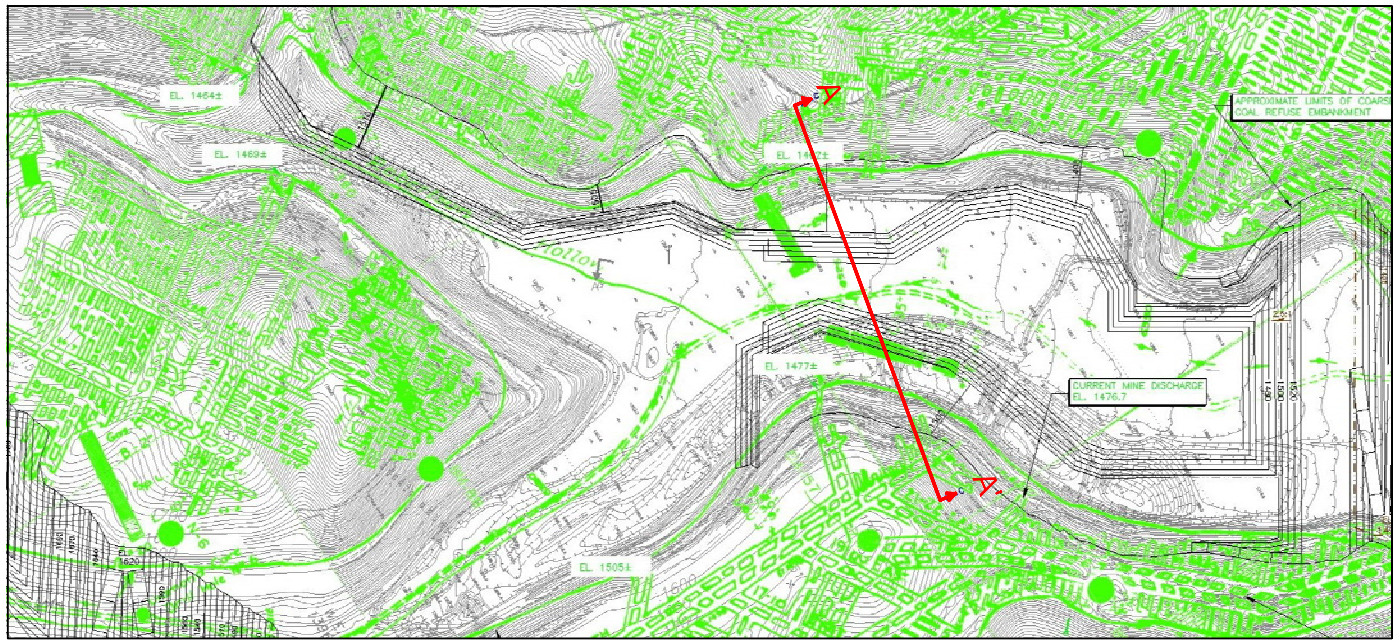
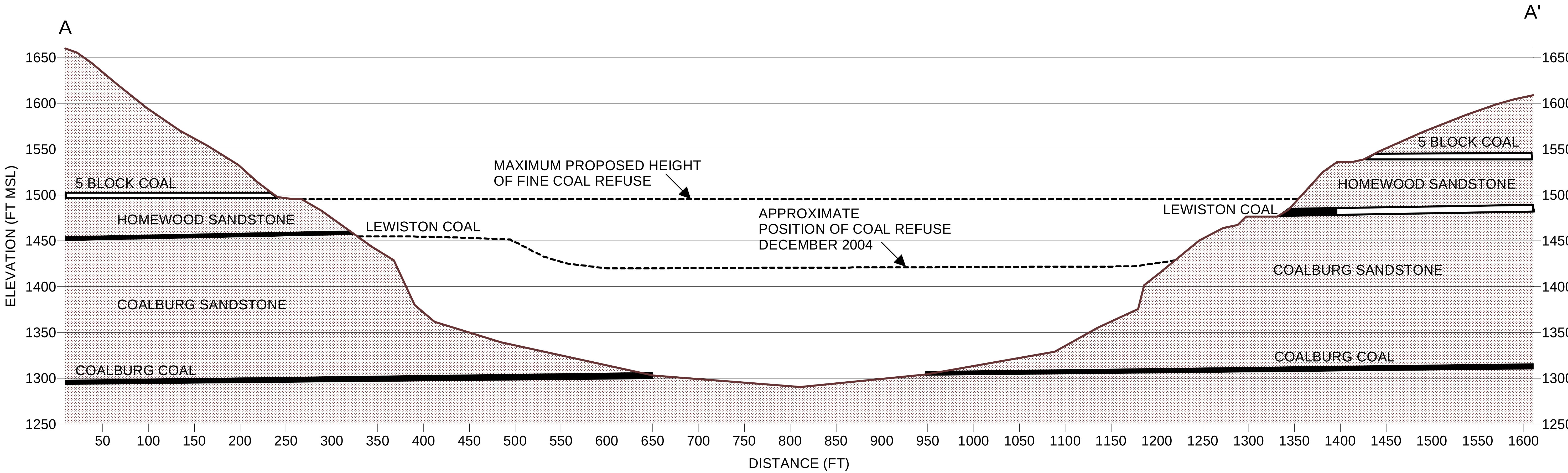


MAP OF LOTS BRANCH TAILINGS IMPOUNDMENT
WITH OVERLAY OF LEWISTON COAL SEAM

SCALE (FT)
0 500 1000 1500 2000



NOTES: Topography taken from aerial photograph
taken April 7, 1986

Mine map provided by Pine Ridge Coal Company
and georeferenced by Alliance Consulting

Section presented with no vertical exaggeration

FIGURE 3

SECTION THROUGH LOTS BRANCH TAILINGS IMPOUNDMENT
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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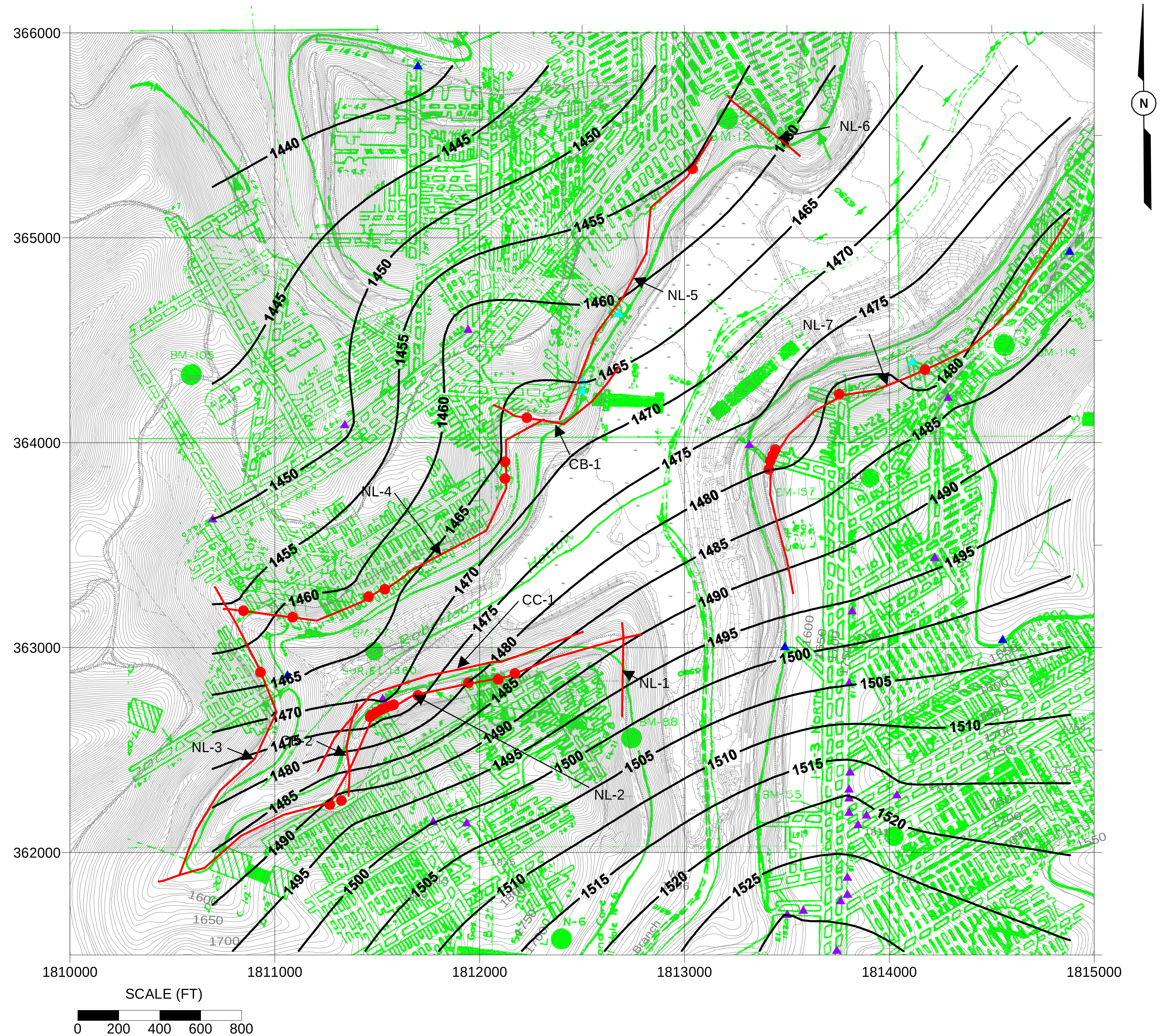

LEGEND

- ▲ Elevation from mine map
- ▲ Elevation from other sources shown on Alliance maps
- ▲ Elevation measured in the field by D'Appolonia
- ● Boring location

FIGURE 4

STRUCTURE CONTOUR MAP
LEWISTON COAL SEAM
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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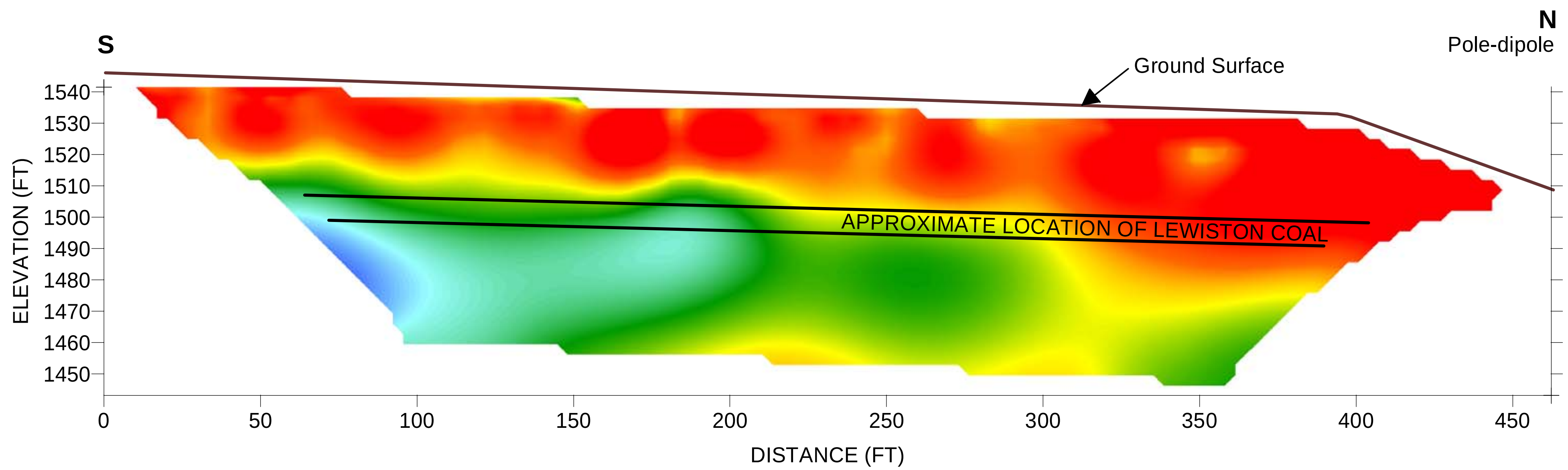

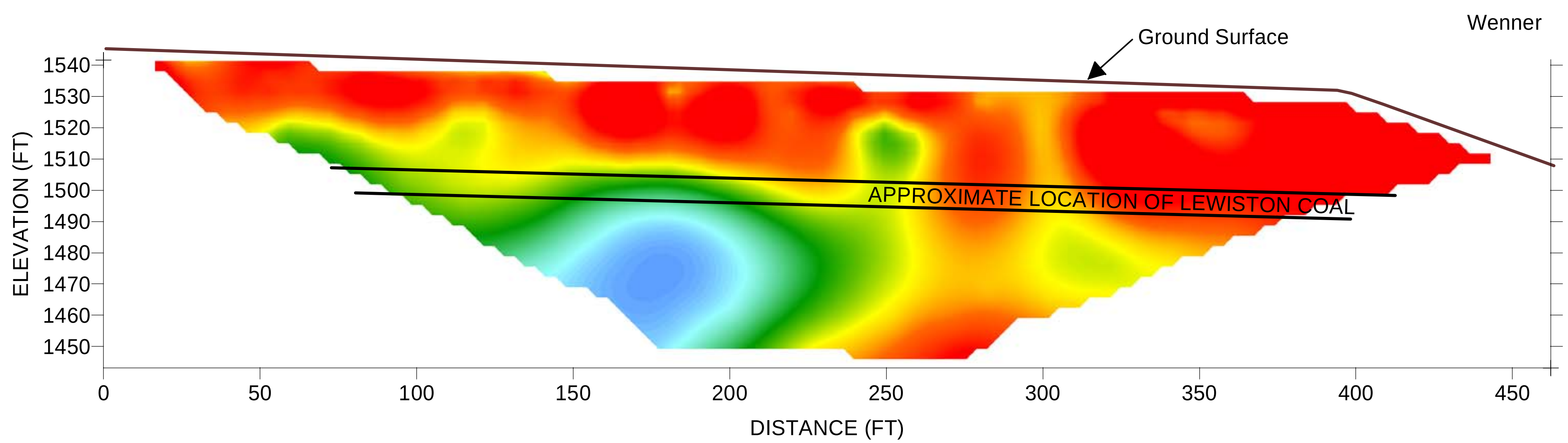

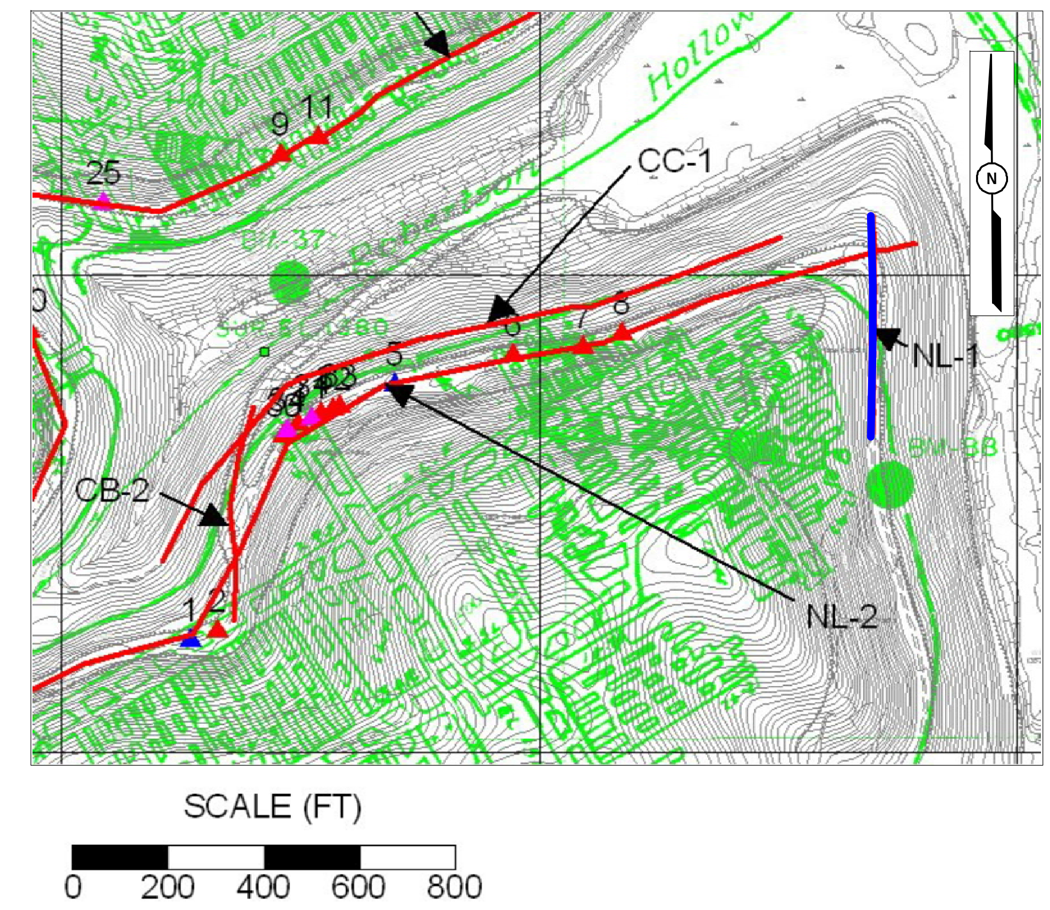

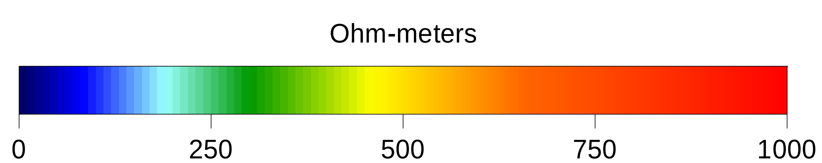

FIGURE 5

DC RESISTIVITY RESULTS ALONG LINE NL-1
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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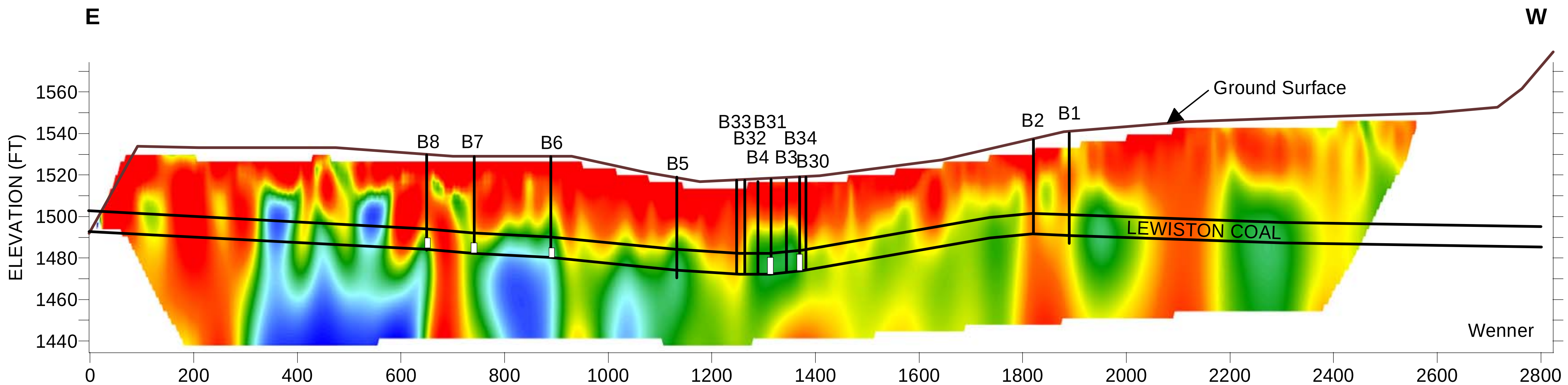

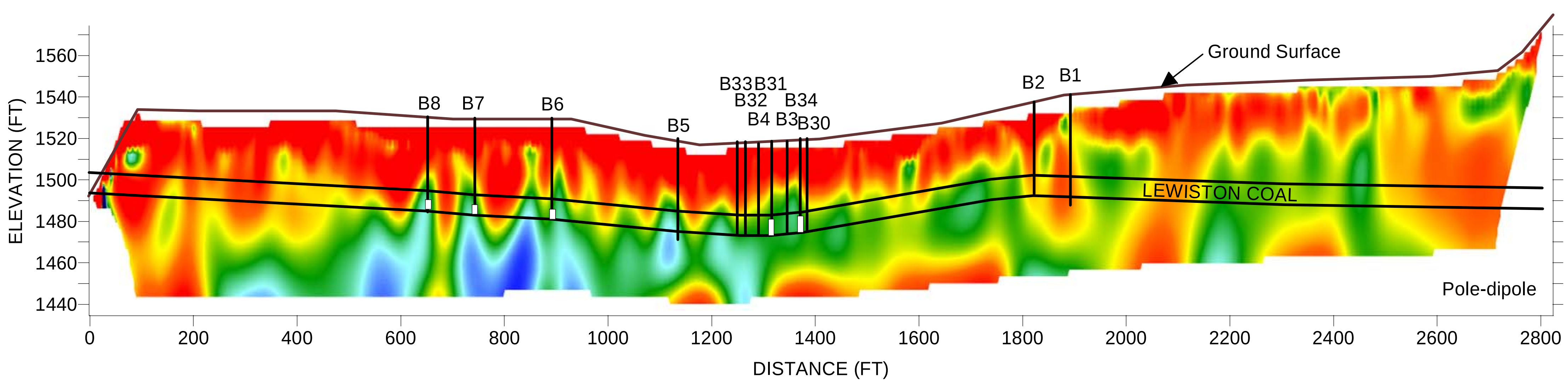

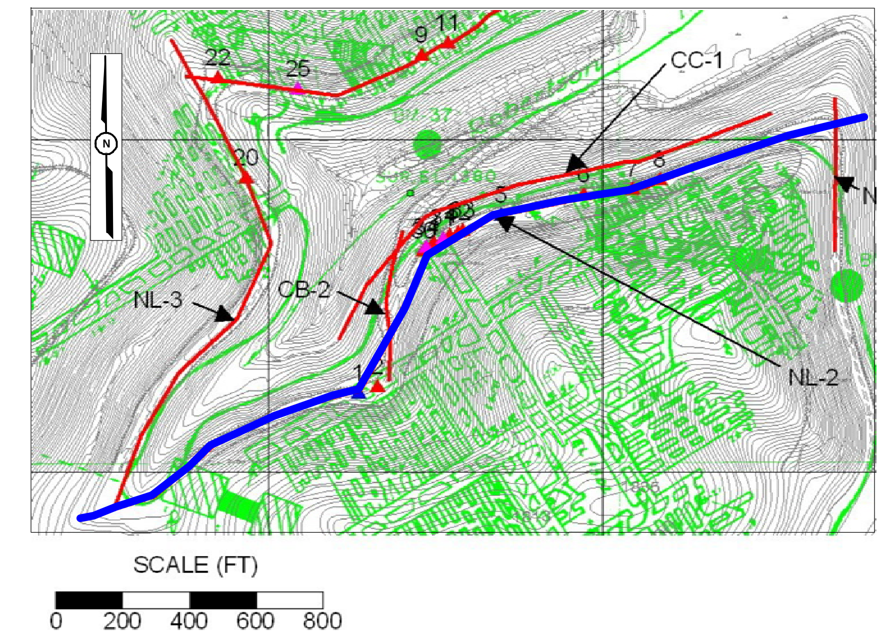

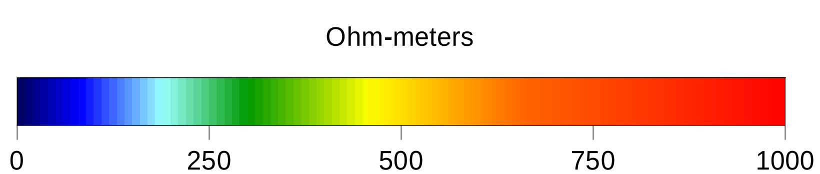

LEGEND

B8 Boring - voids depicted with white rectangle; otherwise solid coal encountered at level of Lewiston Coal

FIGURE 6

DC RESISTIVITY RESULTS ALONG LINE NL-2
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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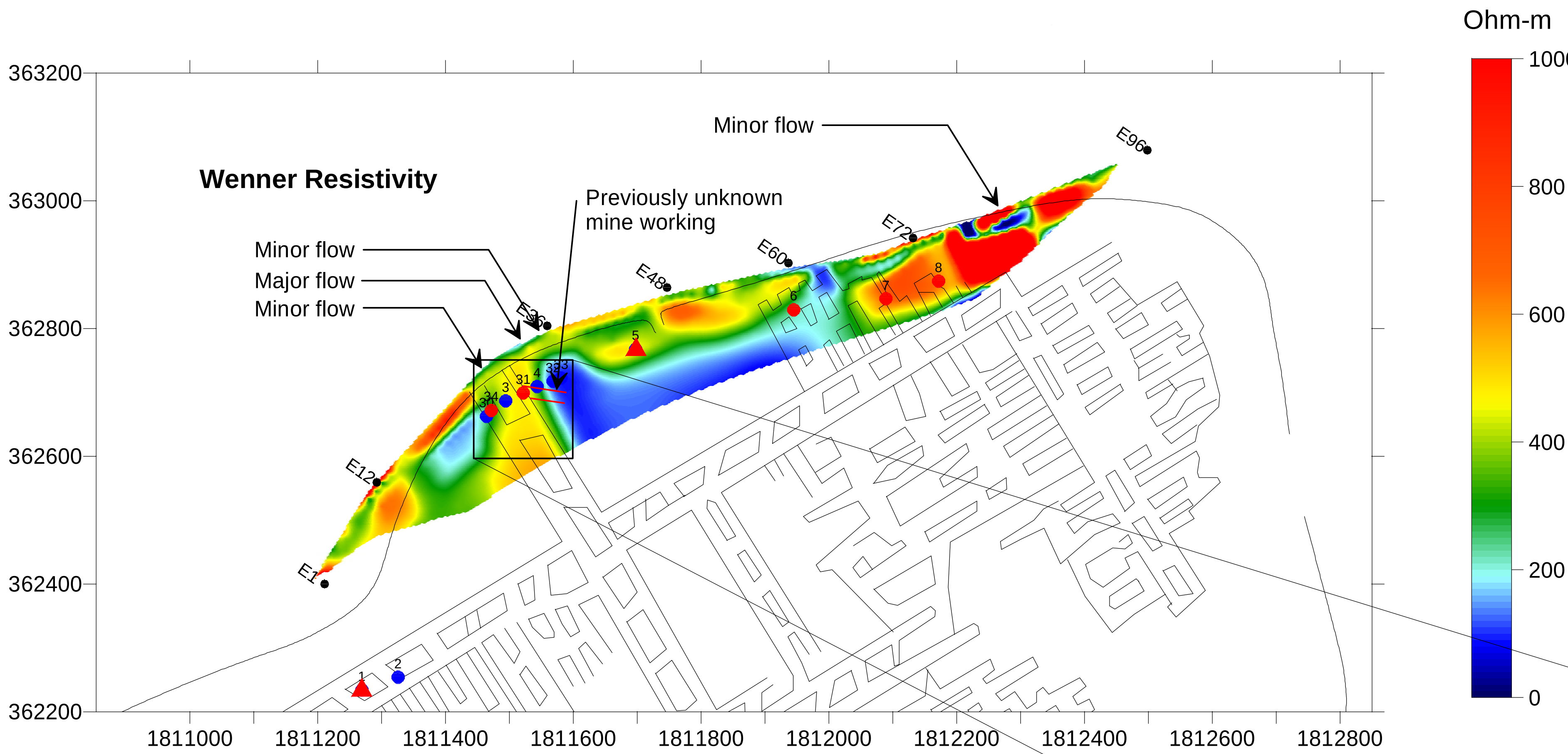

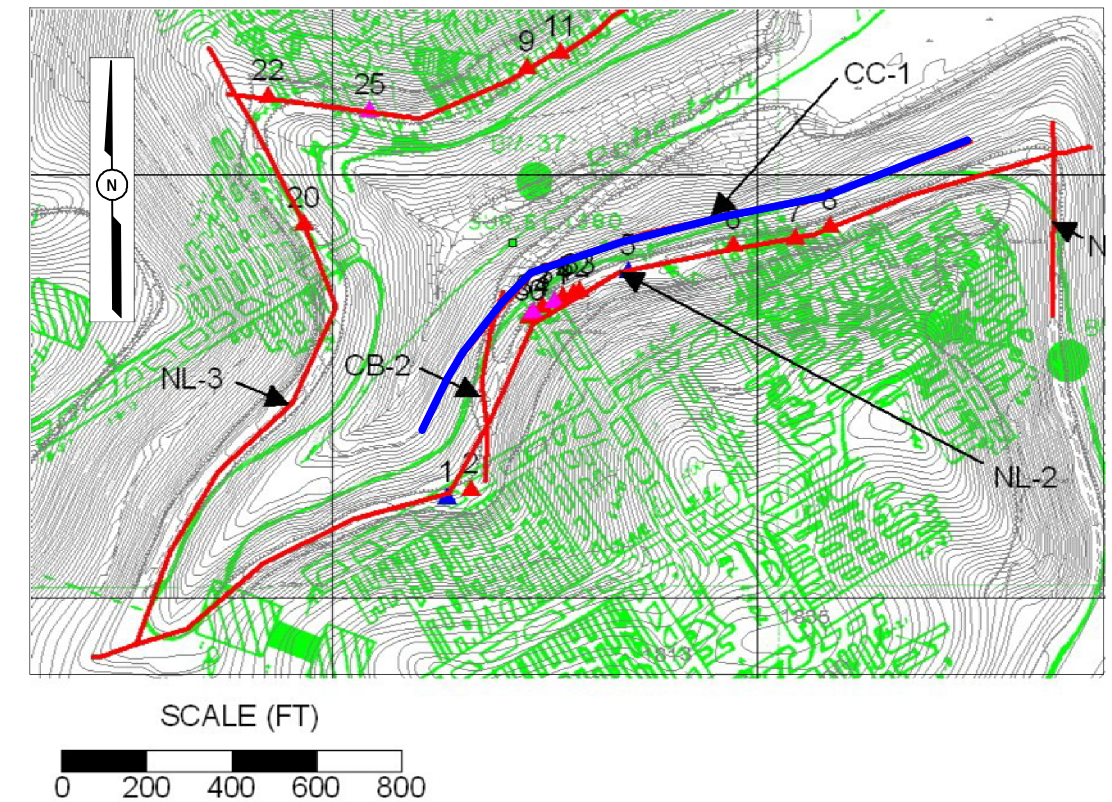

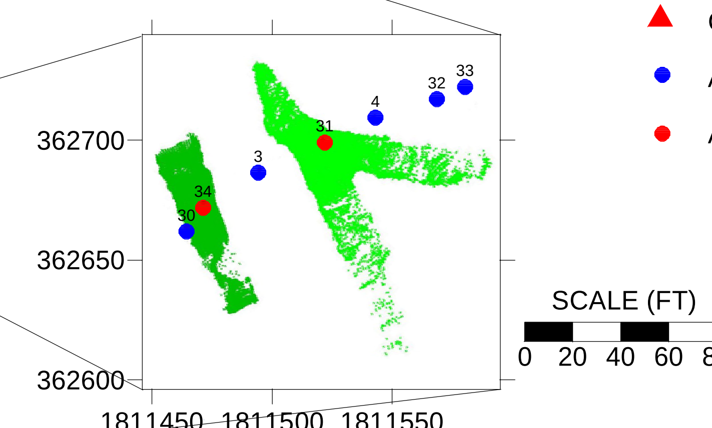

Layout of mine entry from laser imaging system surveyed by Workhorse Technologies - note that results identify a previously unknown tunnel extending into area of resistivity anomaly.

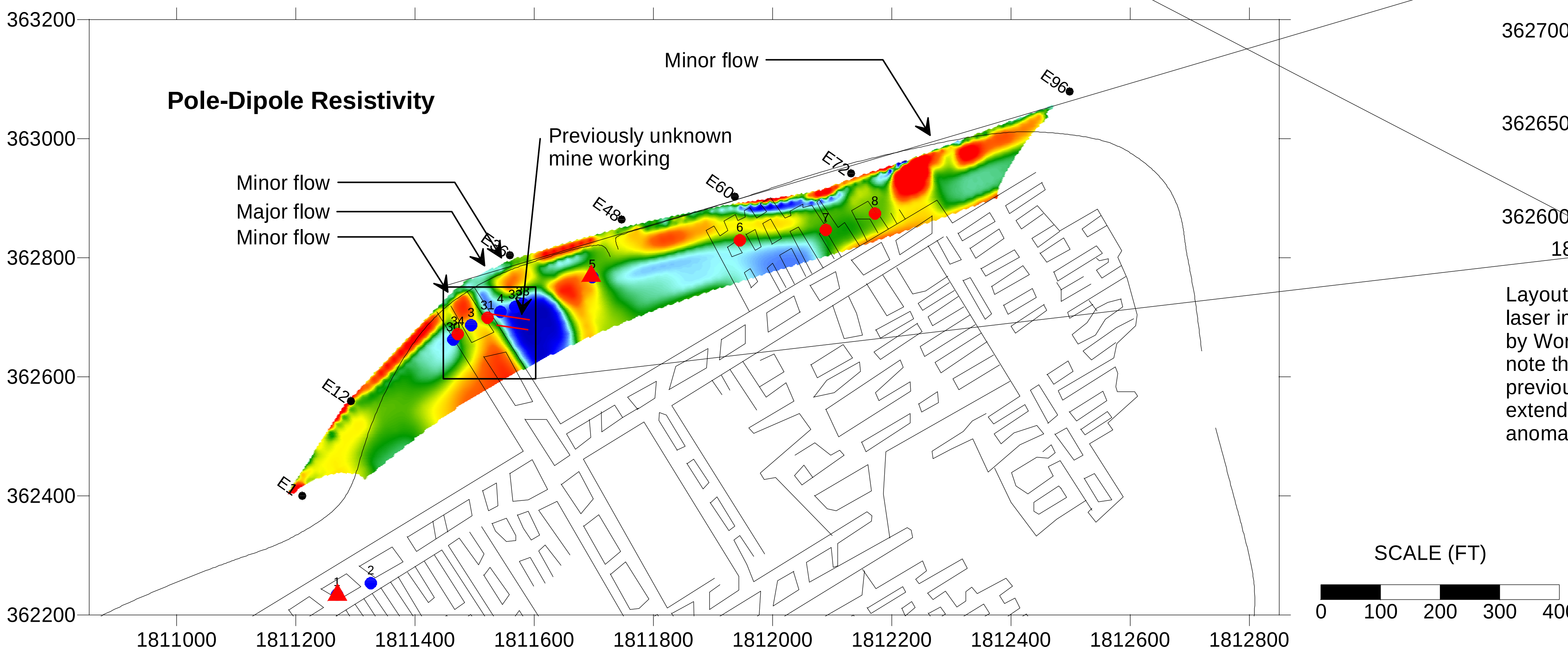

FIGURE 7

DC RESISTIVITY RESULTS AT THE "COALCROP LINE"
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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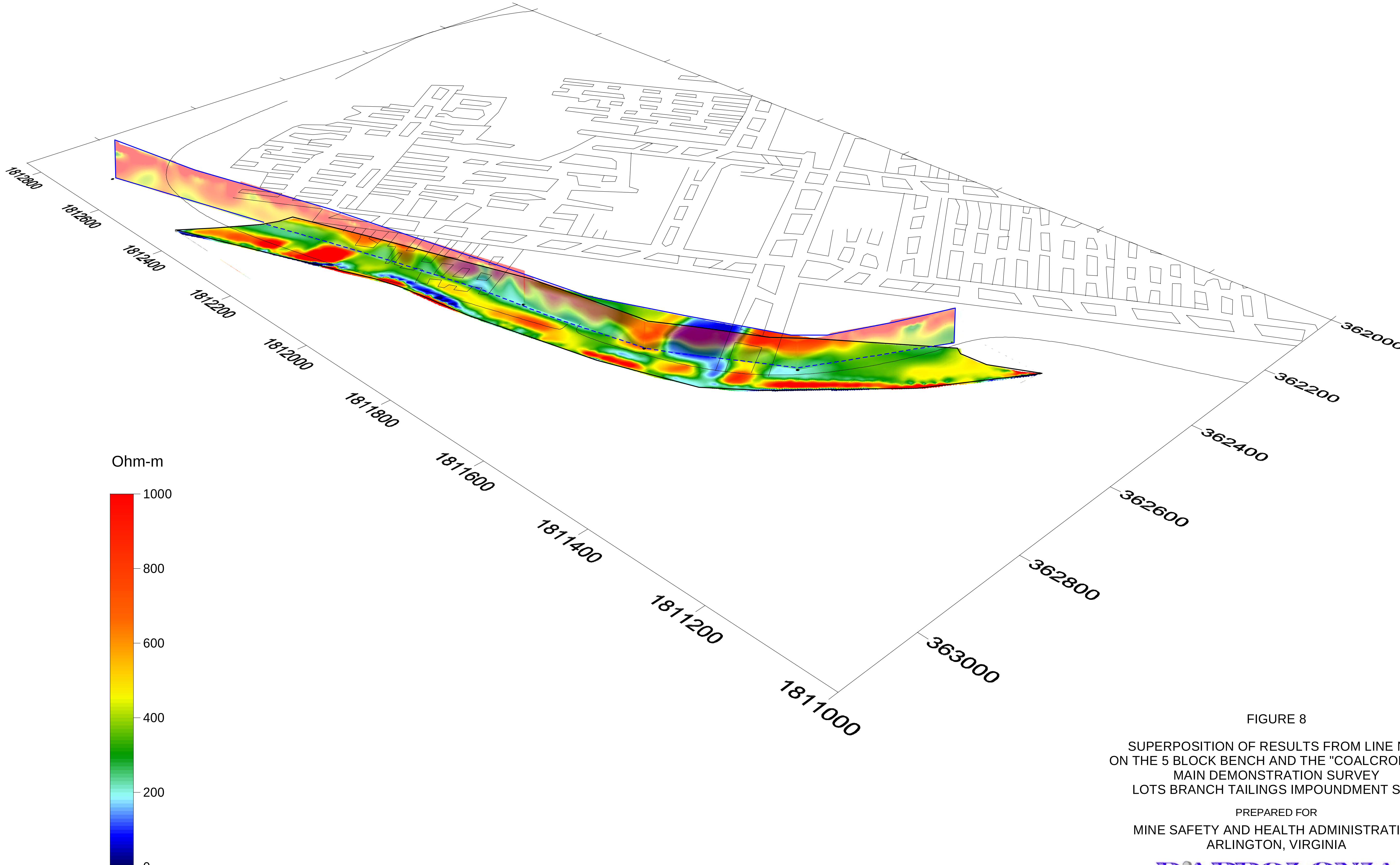

FIGURE 8

SUPERPOSITION OF RESULTS FROM LINE NL-2
ON THE 5 BLOCK BENCH AND THE "COALCROP LINE"
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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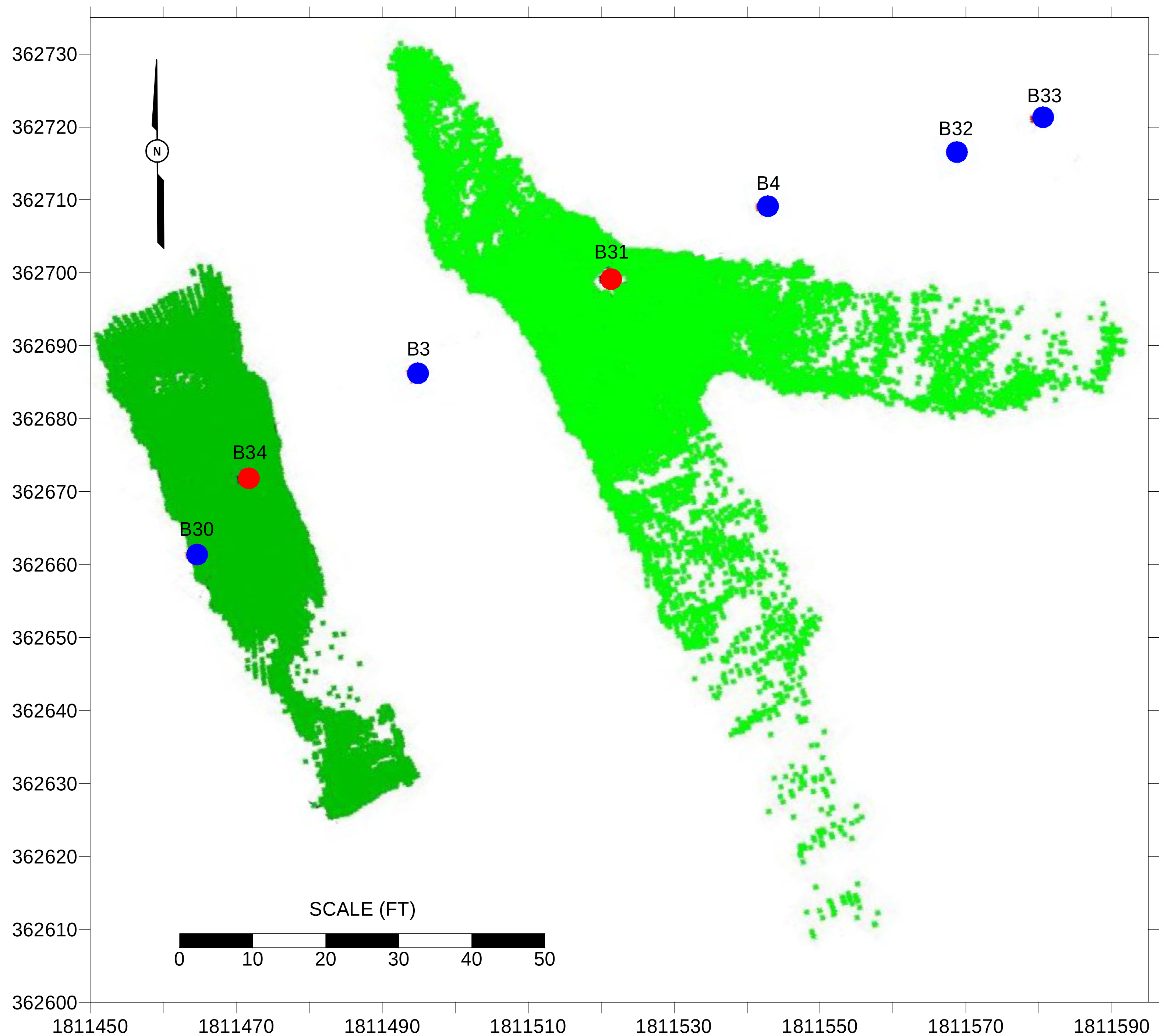
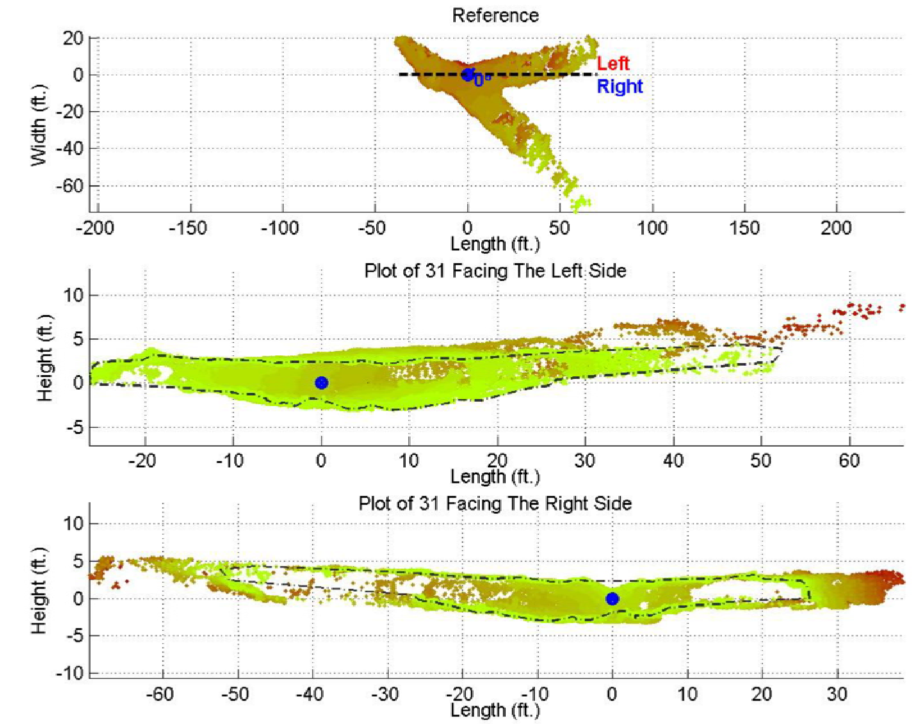
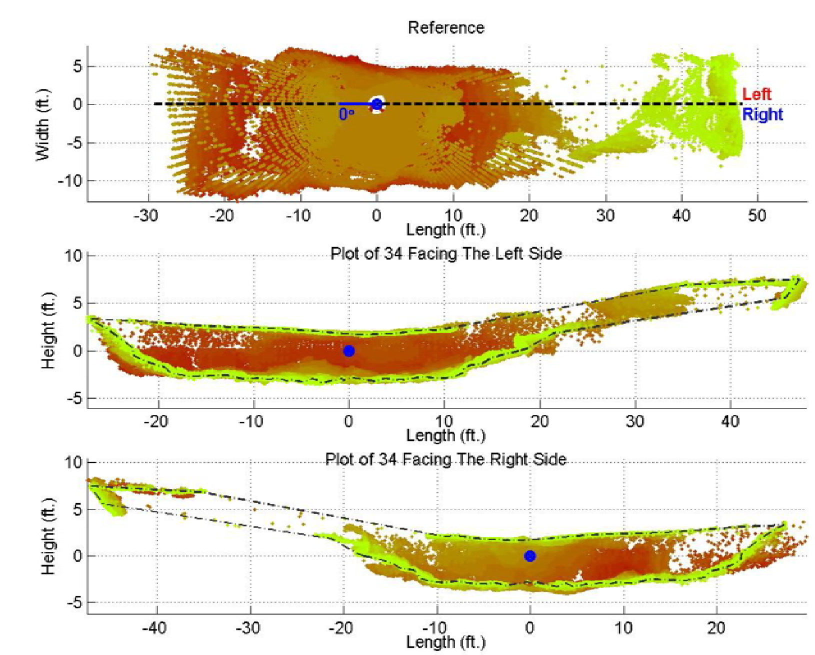


TOP-DOWN VIEW OF COMBINED LASER IMAGING FROM BORINGS B31 AND B34



TOP-DOWN AND LONGITUDINAL SECTIONS FROM BORING B31



TOP-DOWN AND LONGITUDINAL SECTIONS FROM BORING B34

LEGEND

- (blue circle) Air rotary boring encountering intact coal
- (red circle) Air rotary boring encountering mine void and imaged by Workhorse Technologies

NOTE:

Color coding of laser imaging relates to the depth of a point beyond an arbitrary cut line and is intended for visualization purposes only, to show the relationship of a section to the rest of the points. The range for each plot varies.

FIGURE 9

RESULTS OF LASER IMAGING INTO ENTRY TUNNELS ON THE SOUTH SIDE OF ROBERTSON HOLLOW MAIN DEMONSTRATION SURVEY LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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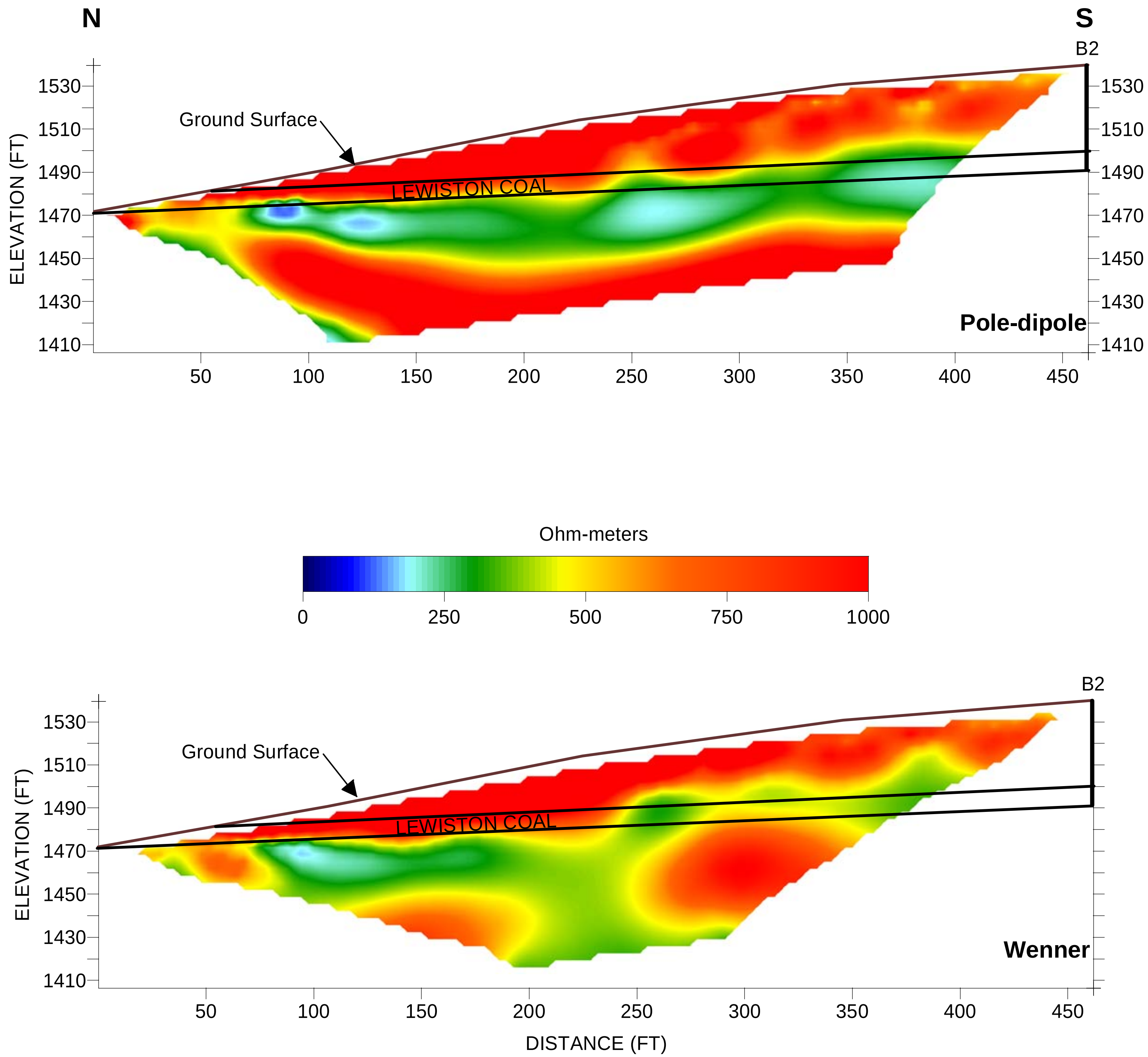

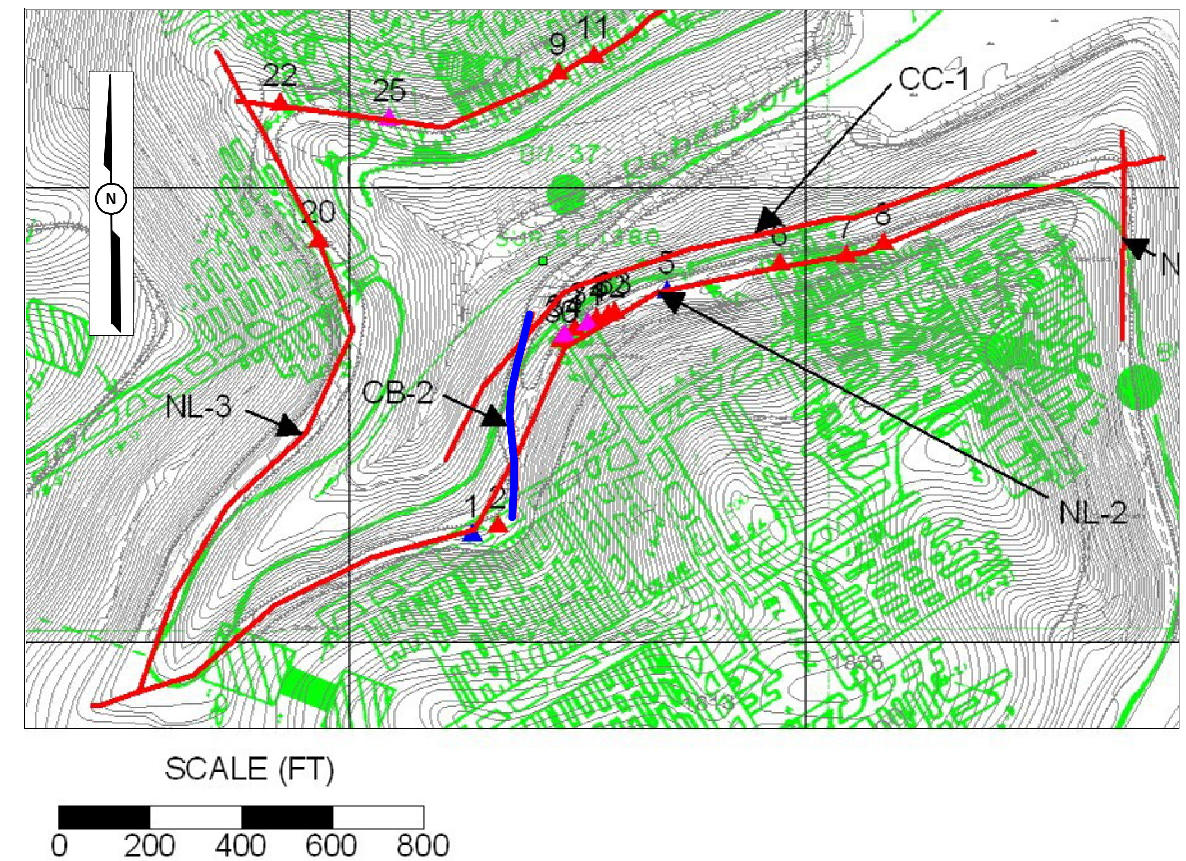

FIGURE 10

DC RESISTIVITY RESULTS
ALONG COAL BARRIER LINE CB-2
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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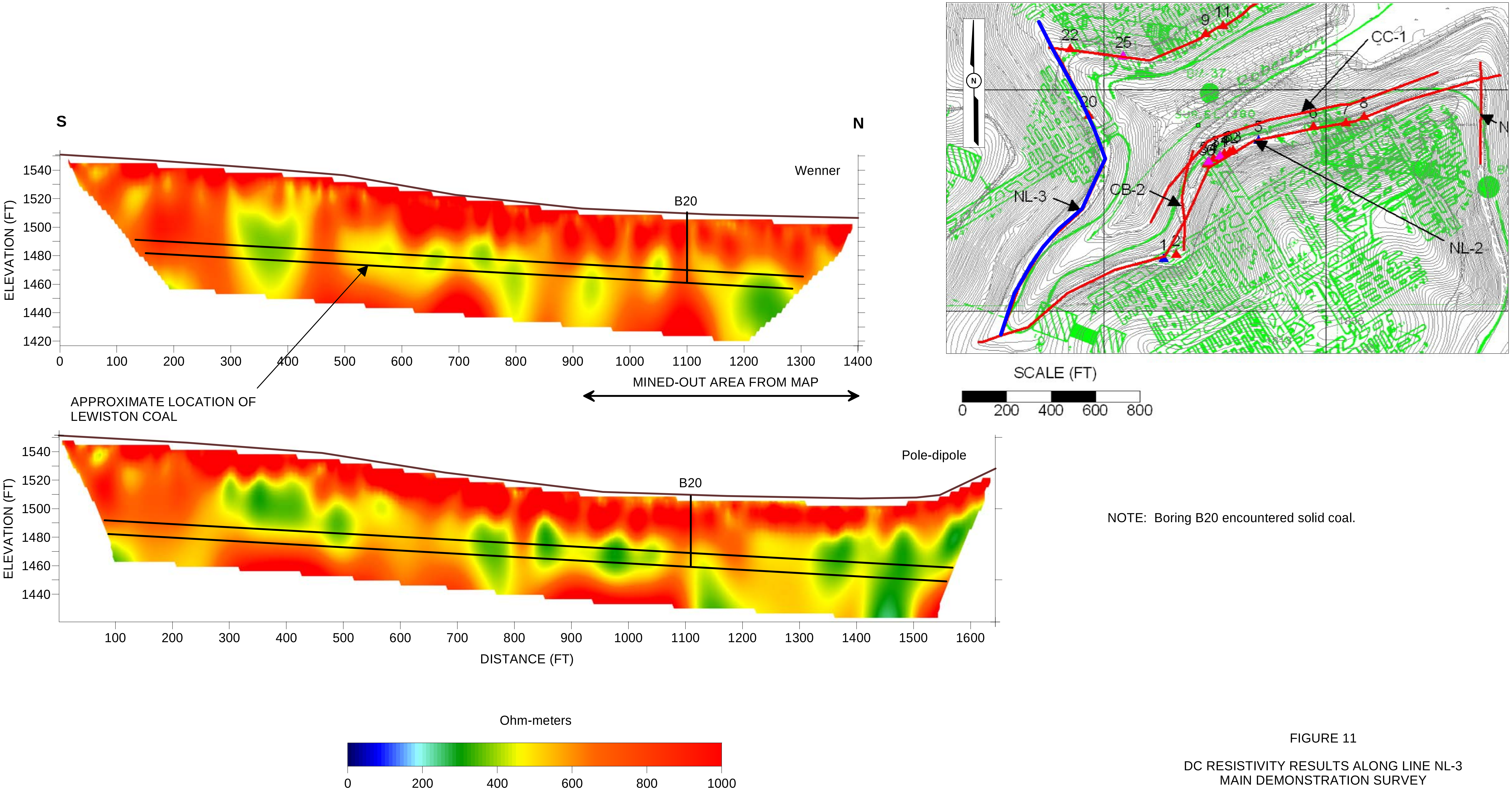

FIGURE 11

DC RESISTIVITY RESULTS ALONG LINE NL-3
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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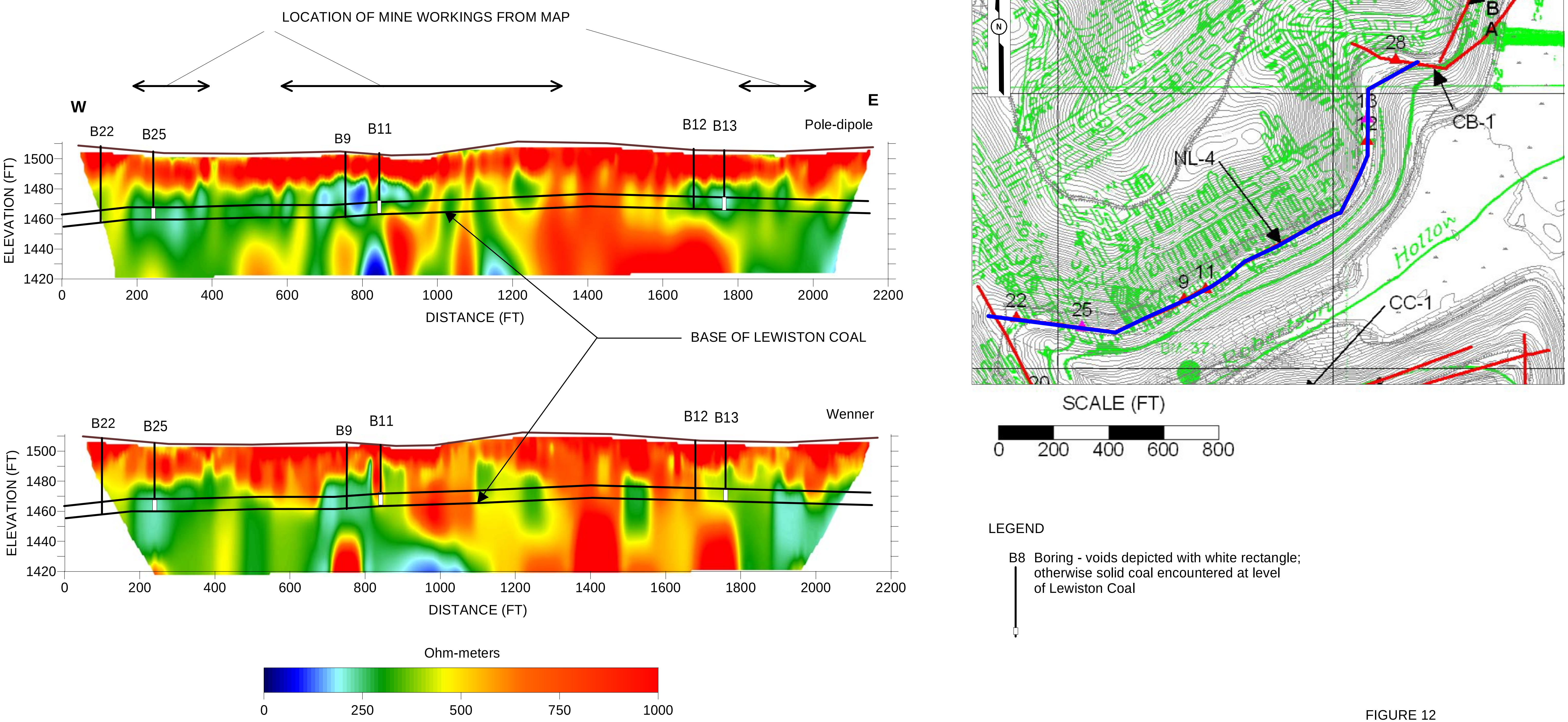

FIGURE 12

DC RESISTIVITY RESULTS ALONG LINE NL-4
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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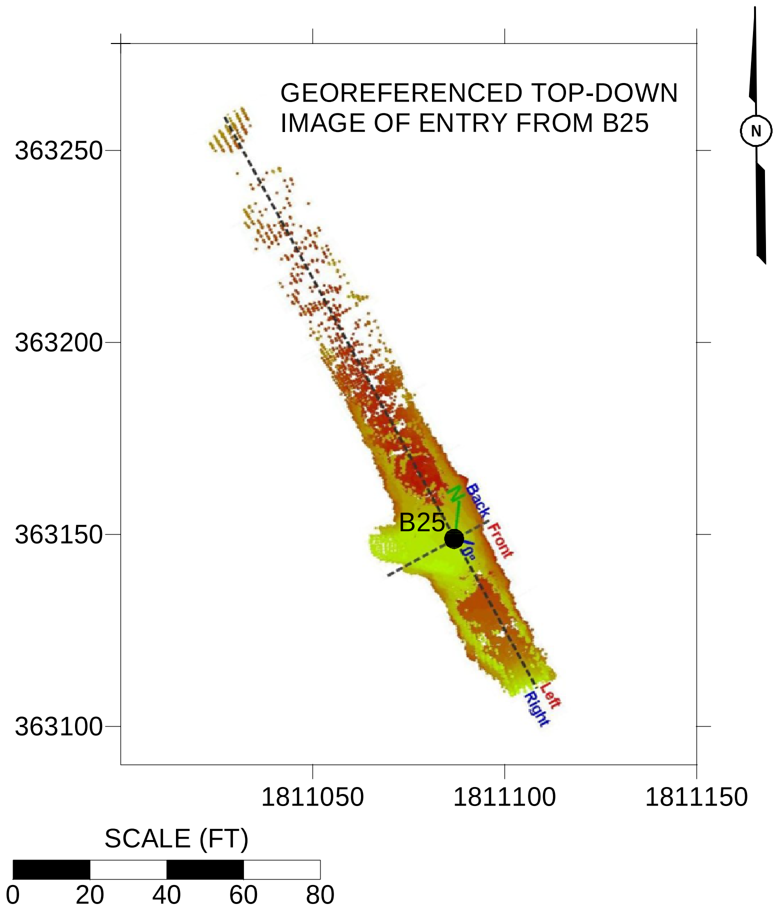

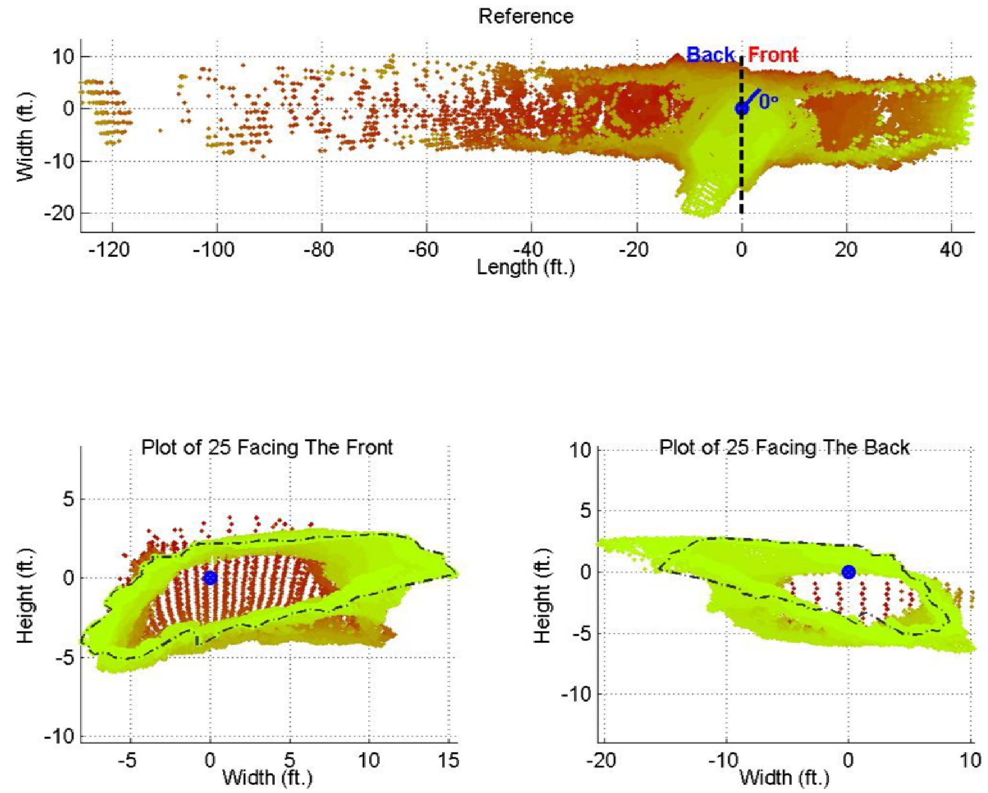

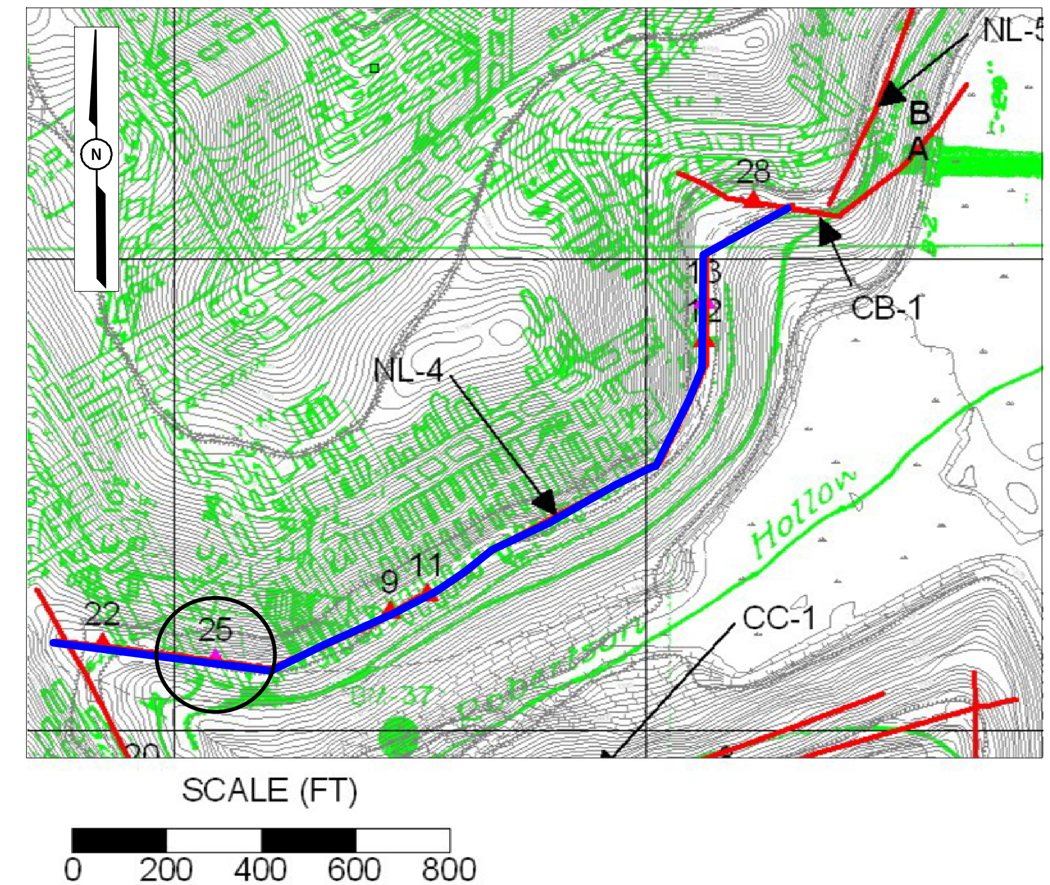

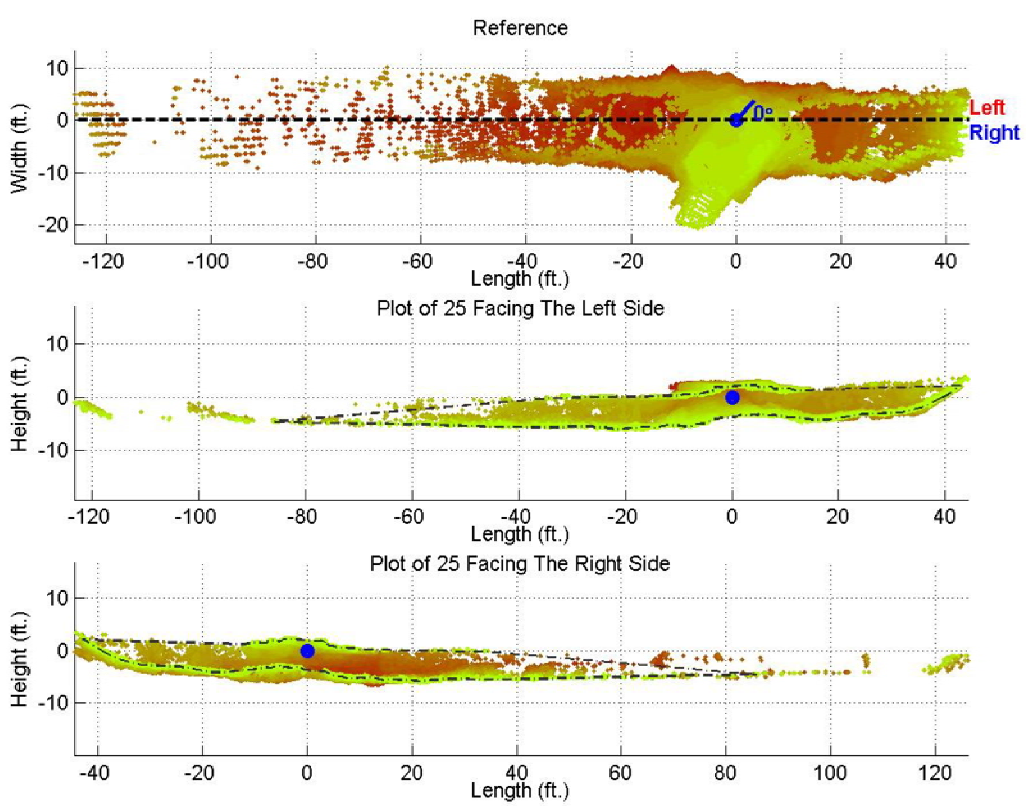

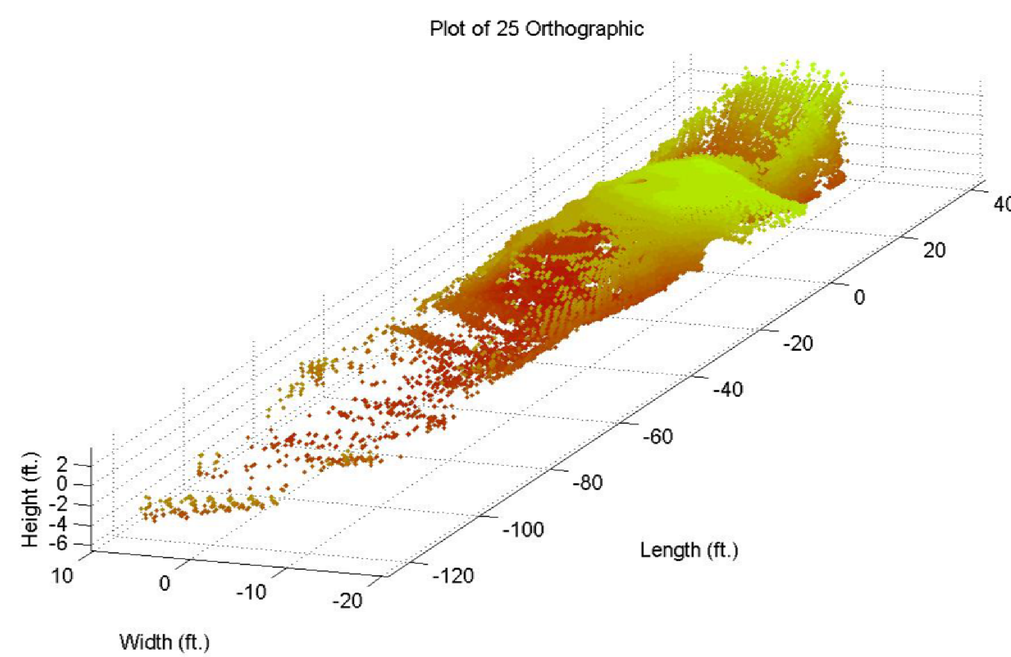

NOTE:

Color coding of laser imaging relates to the depth of a point beyond an arbitrary cut line and is intended for visualization purposes only, to show the relationship of a section to the rest of the points. The range for each plot varies.

FIGURE 13

RESULTS OF LASER IMAGING INTO ENTRY TUNNELS
ON NORTH SIDE OF ROBERTSON HOLLOW FROM B-25
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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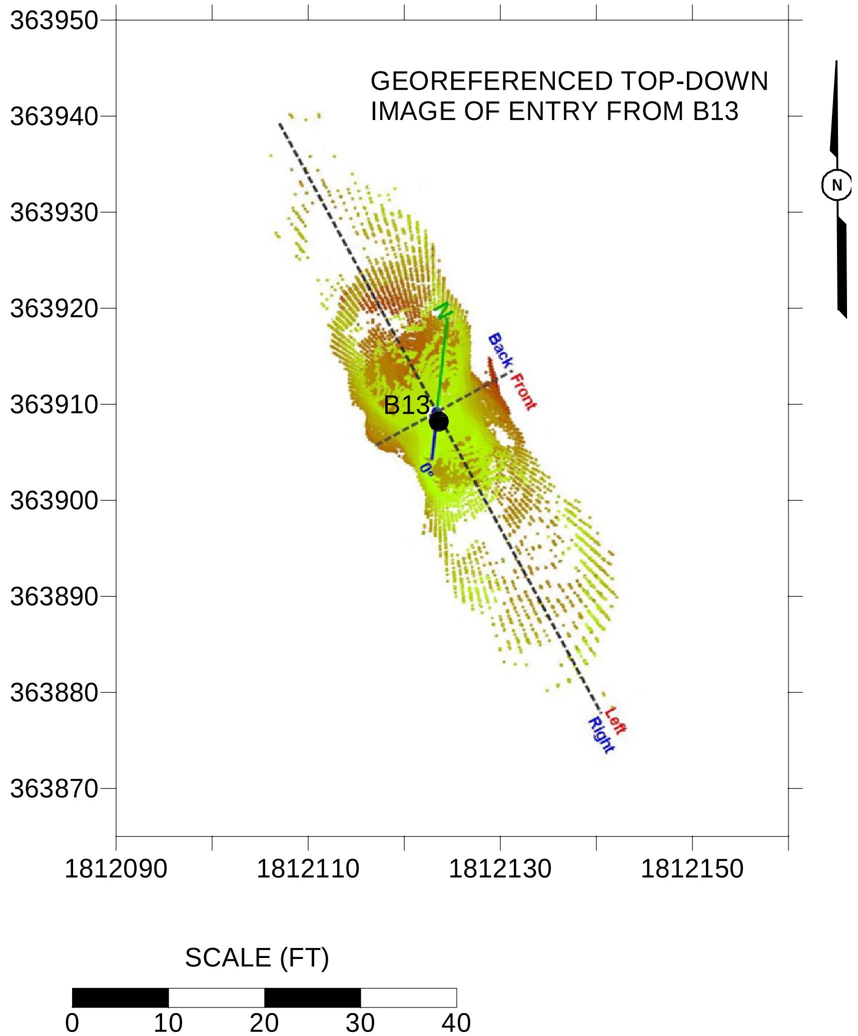

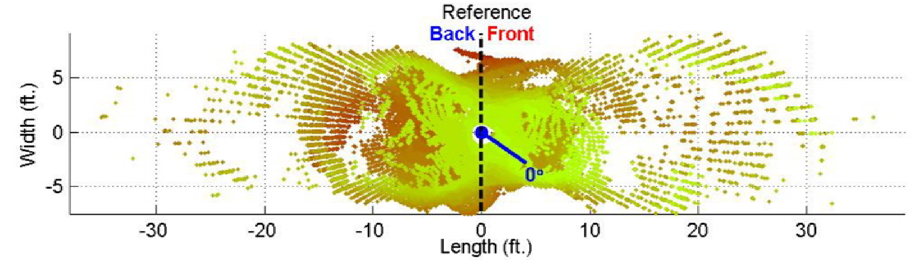

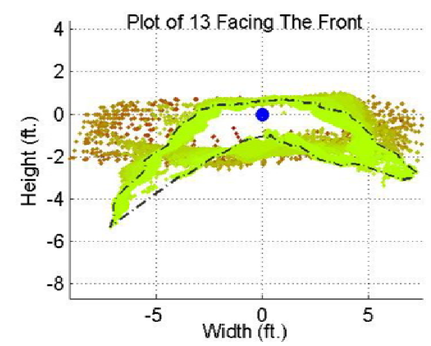

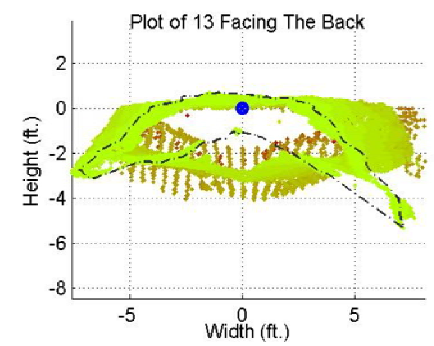

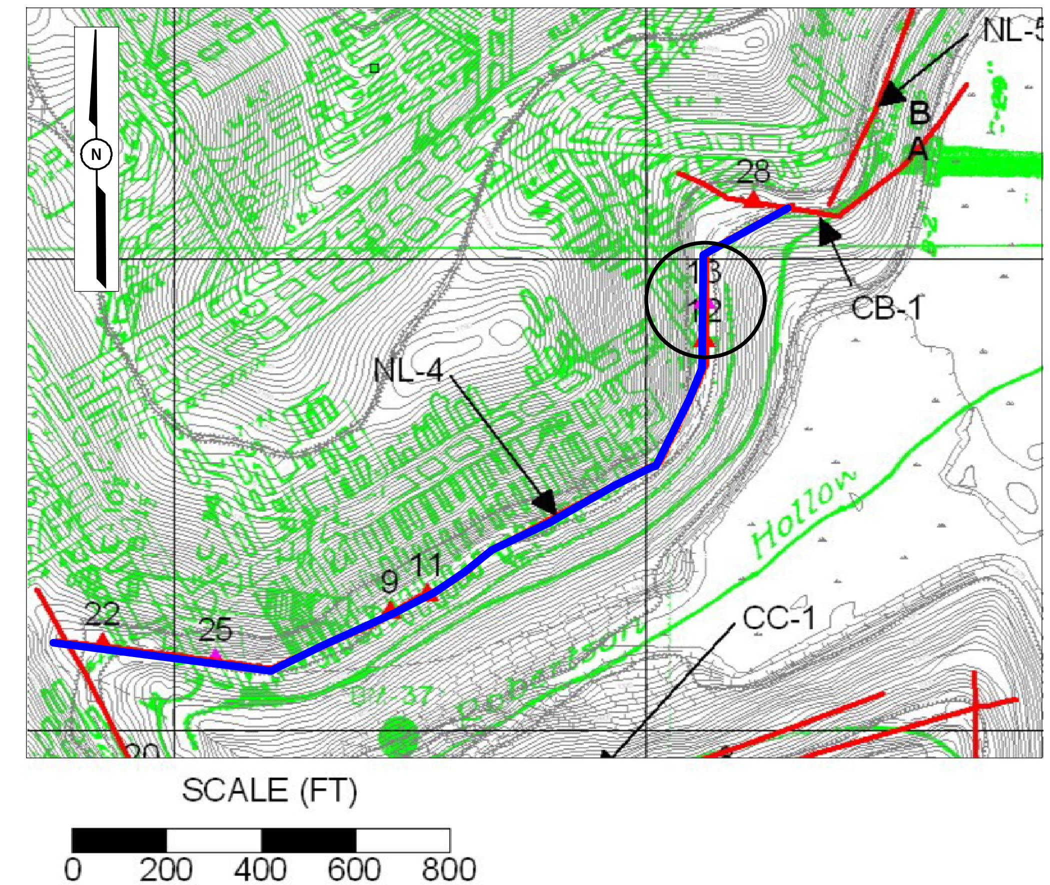

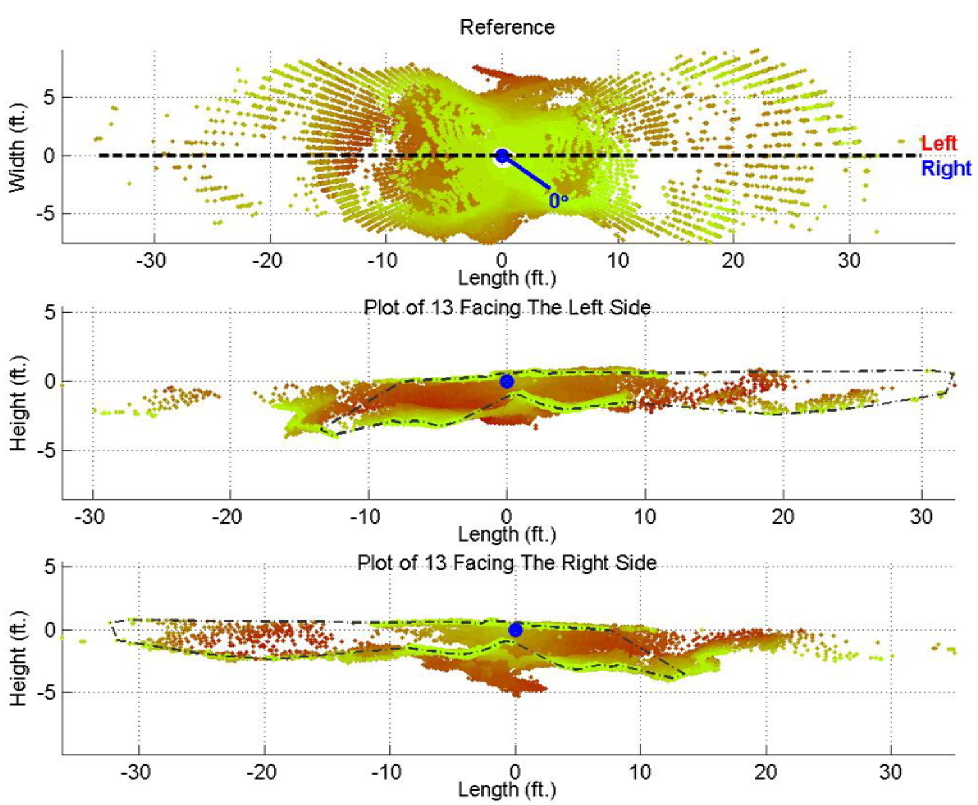

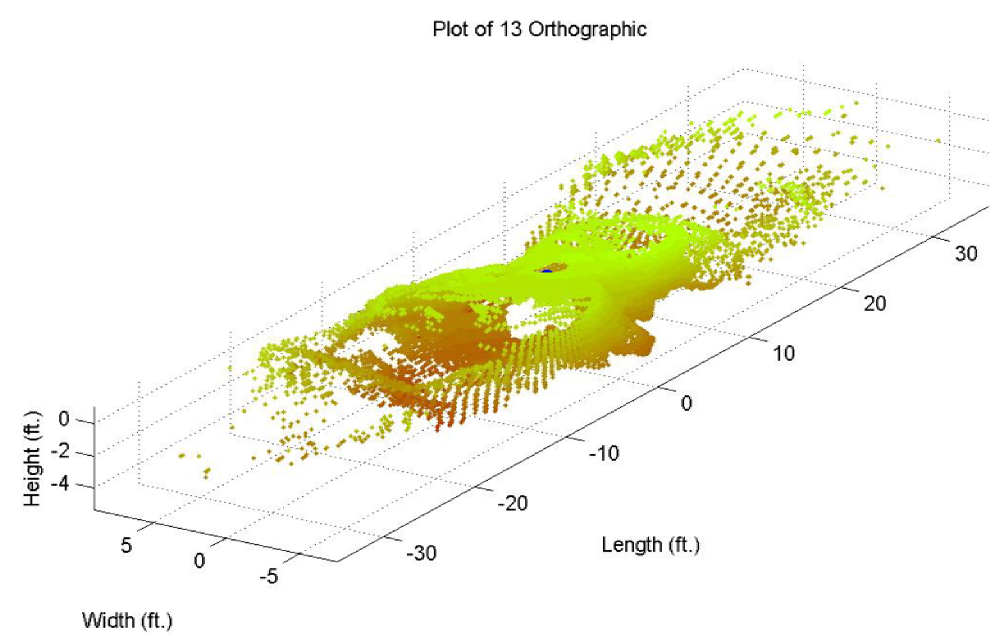

NOTE:

Color coding of laser imaging relates to the depth of a point beyond an arbitrary cut line and is intended for visualization purposes only, to show the relationship of a section to the rest of the points. The range for each plot varies.

FIGURE 14

RESULTS OF LASER IMAGING INTO ENTRY TUNNELS
ON NORTH SIDE OF ROBERTSON HOLLOW FROM B-13
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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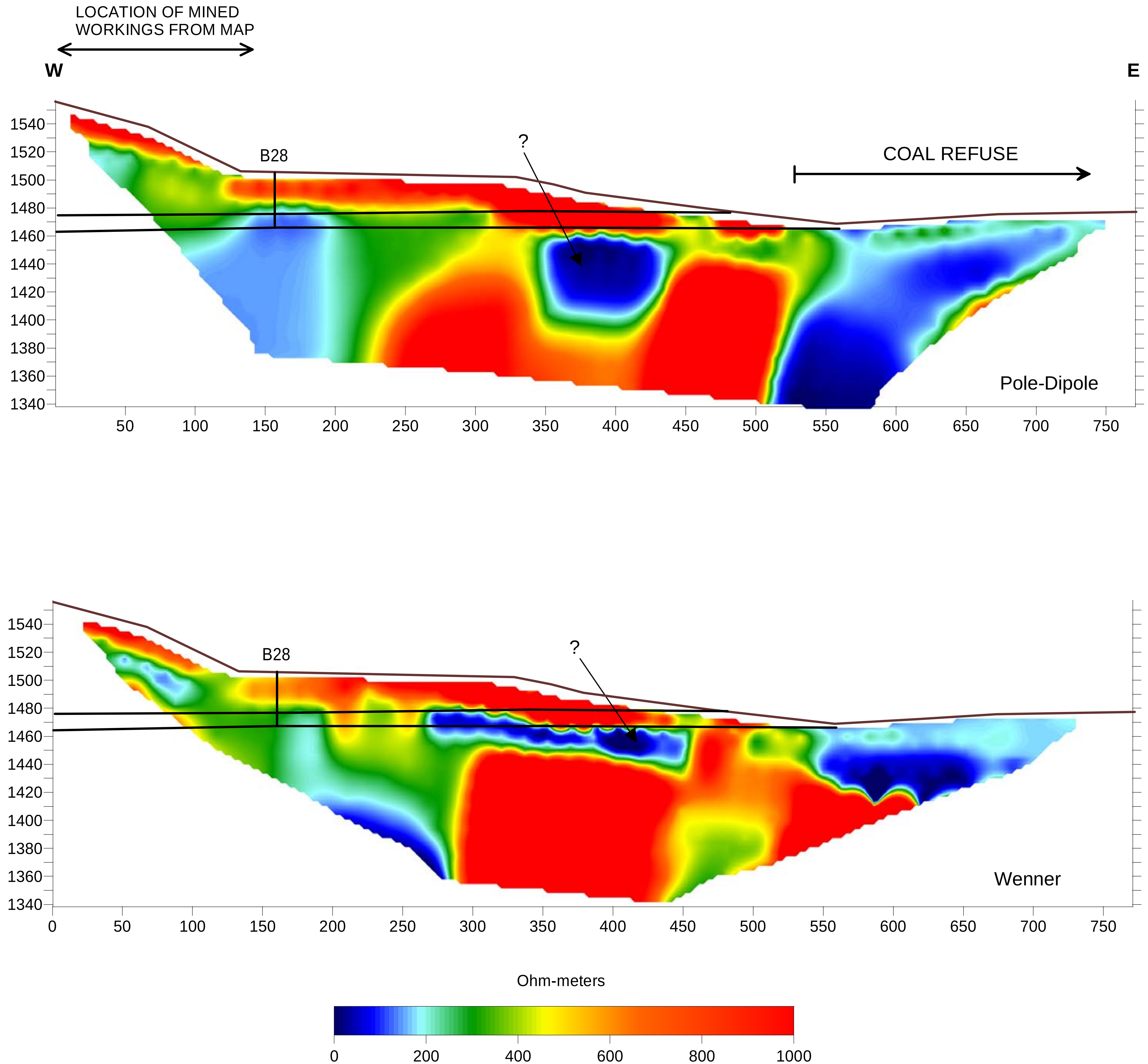

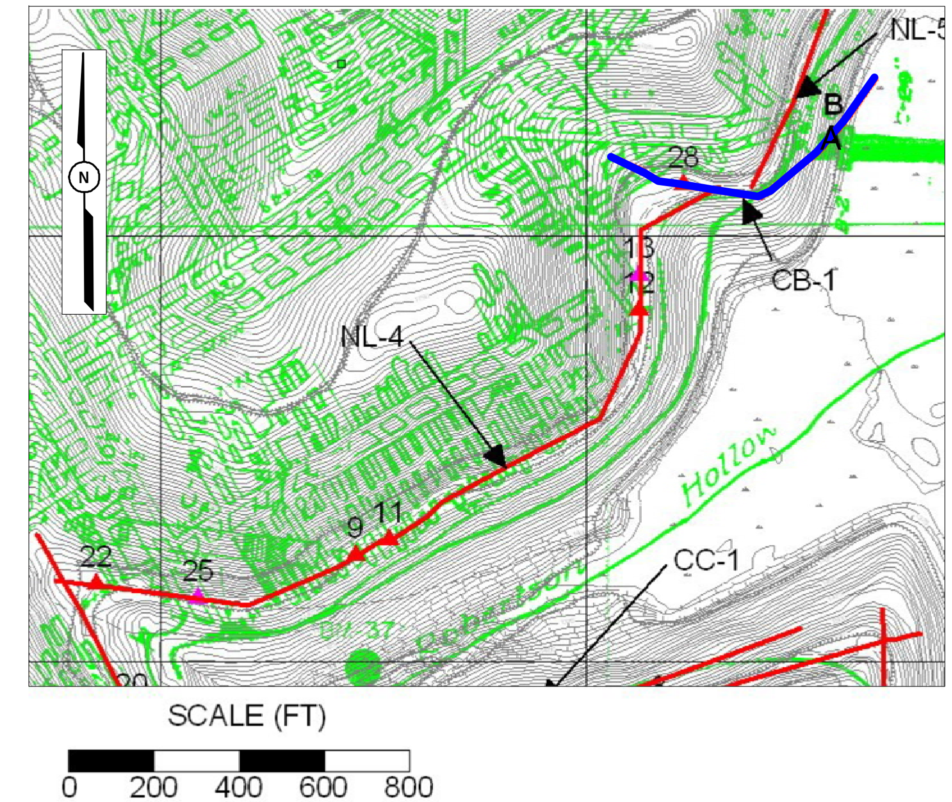

NOTE: Boring B28 encountered solid coal.

FIGURE 15

DC RESISTIVITY RESULTS ALONG COAL BARRIER LINE CB-1
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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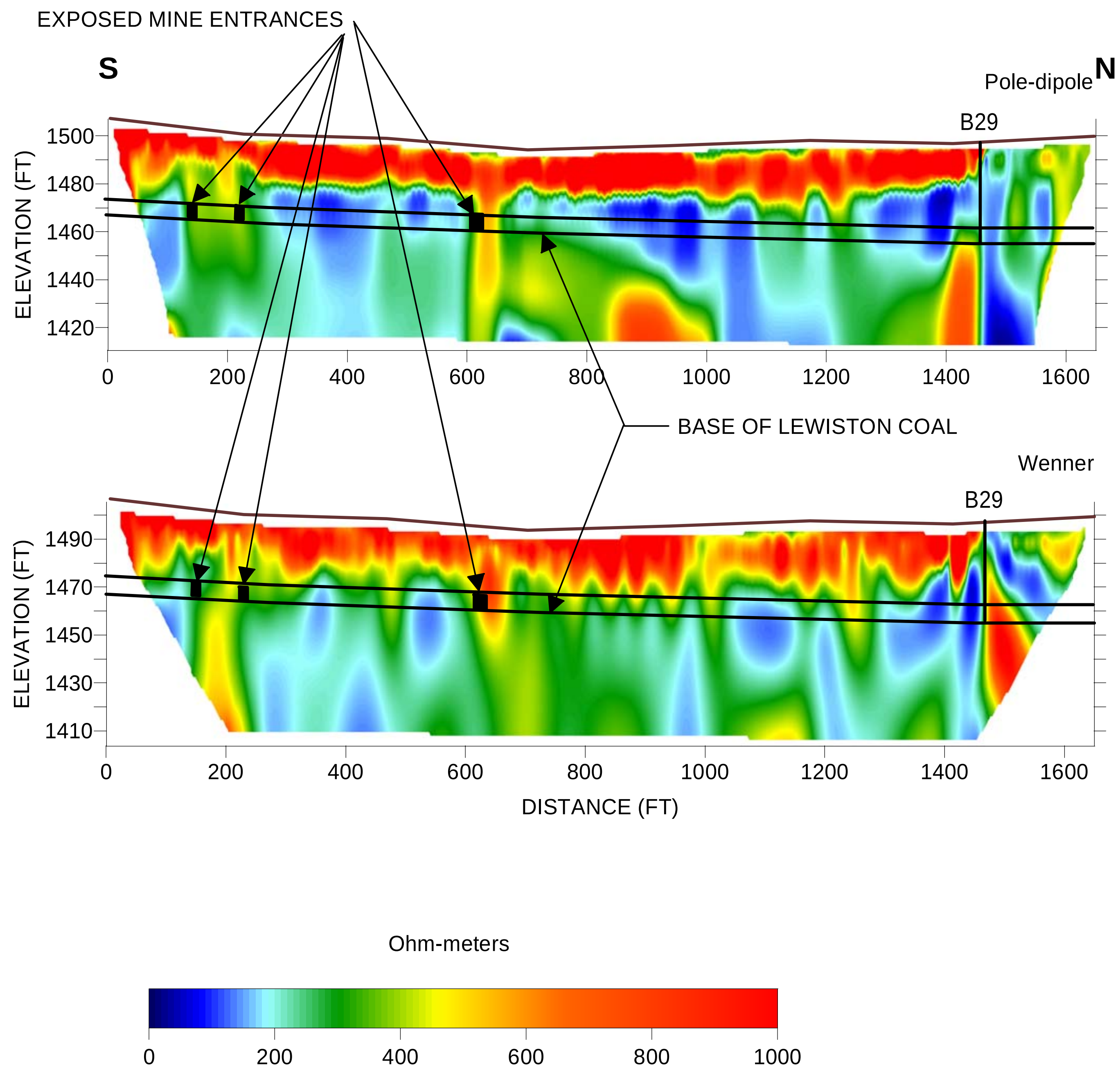

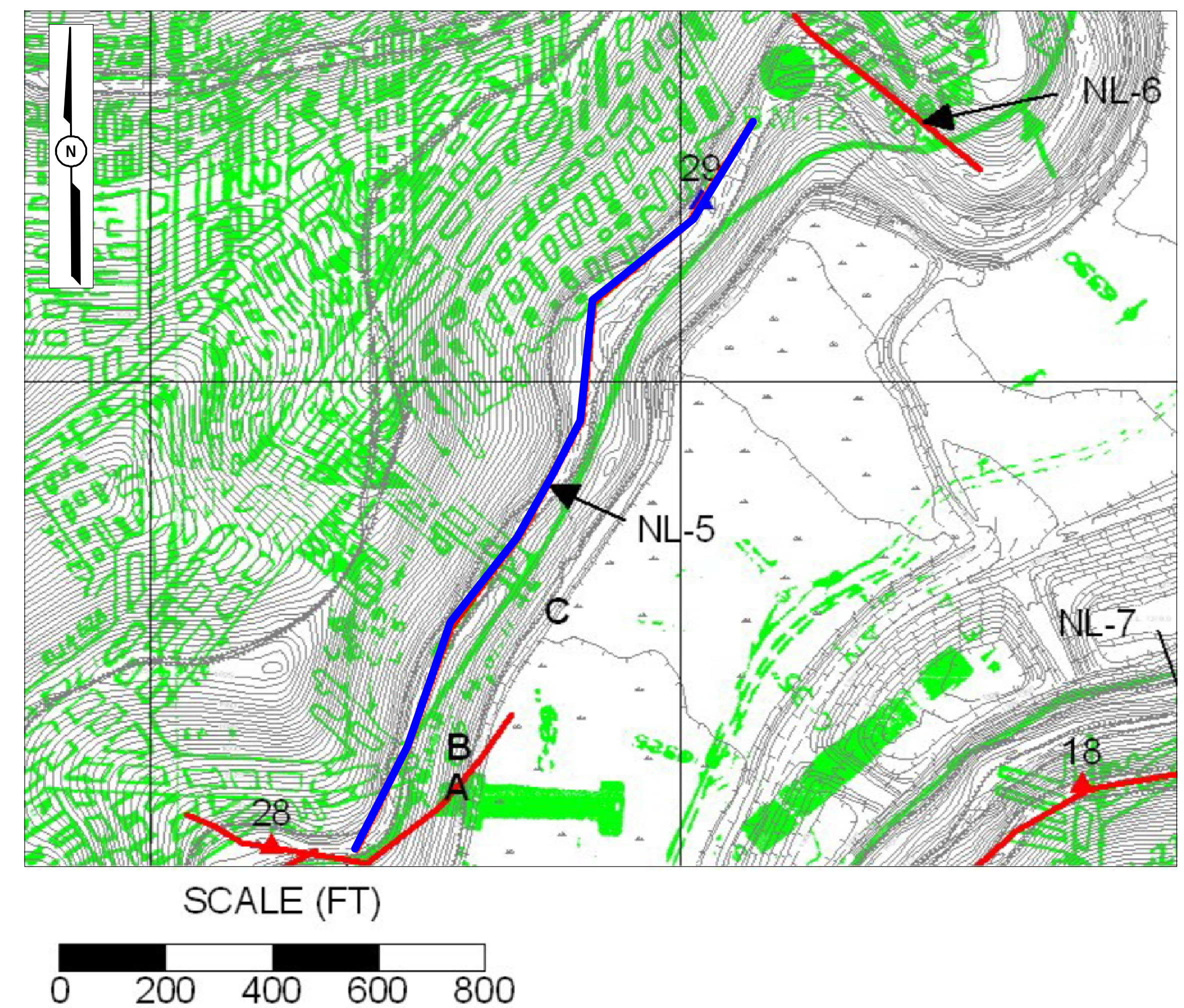

NOTE: Boring B29 encountered solid coal.

FIGURE 16

DC RESISTIVITY RESULTS ALONG LINE NL-5
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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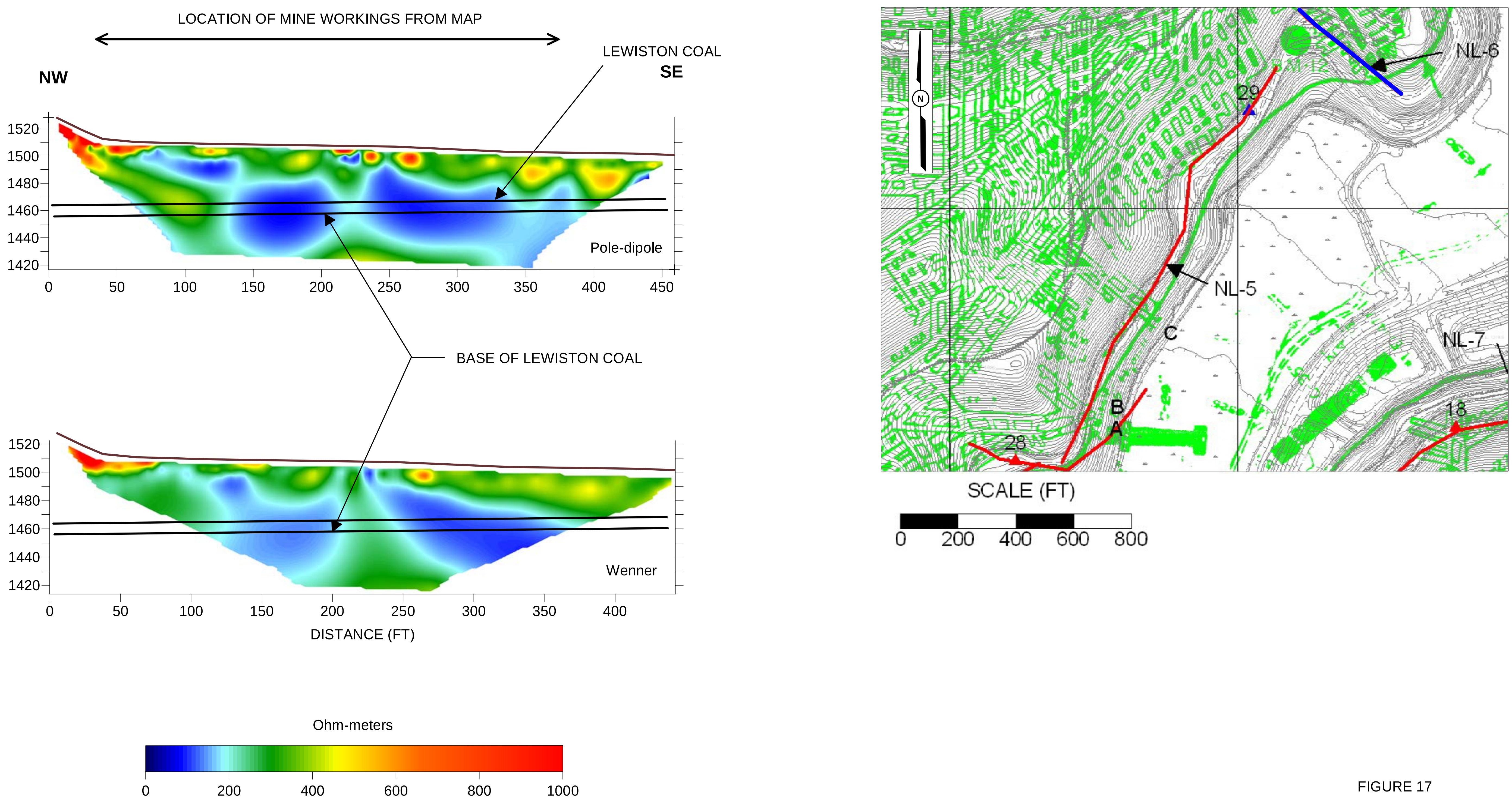

FIGURE 17

DC RESISTIVITY RESULTS ALONG LINE NL-6
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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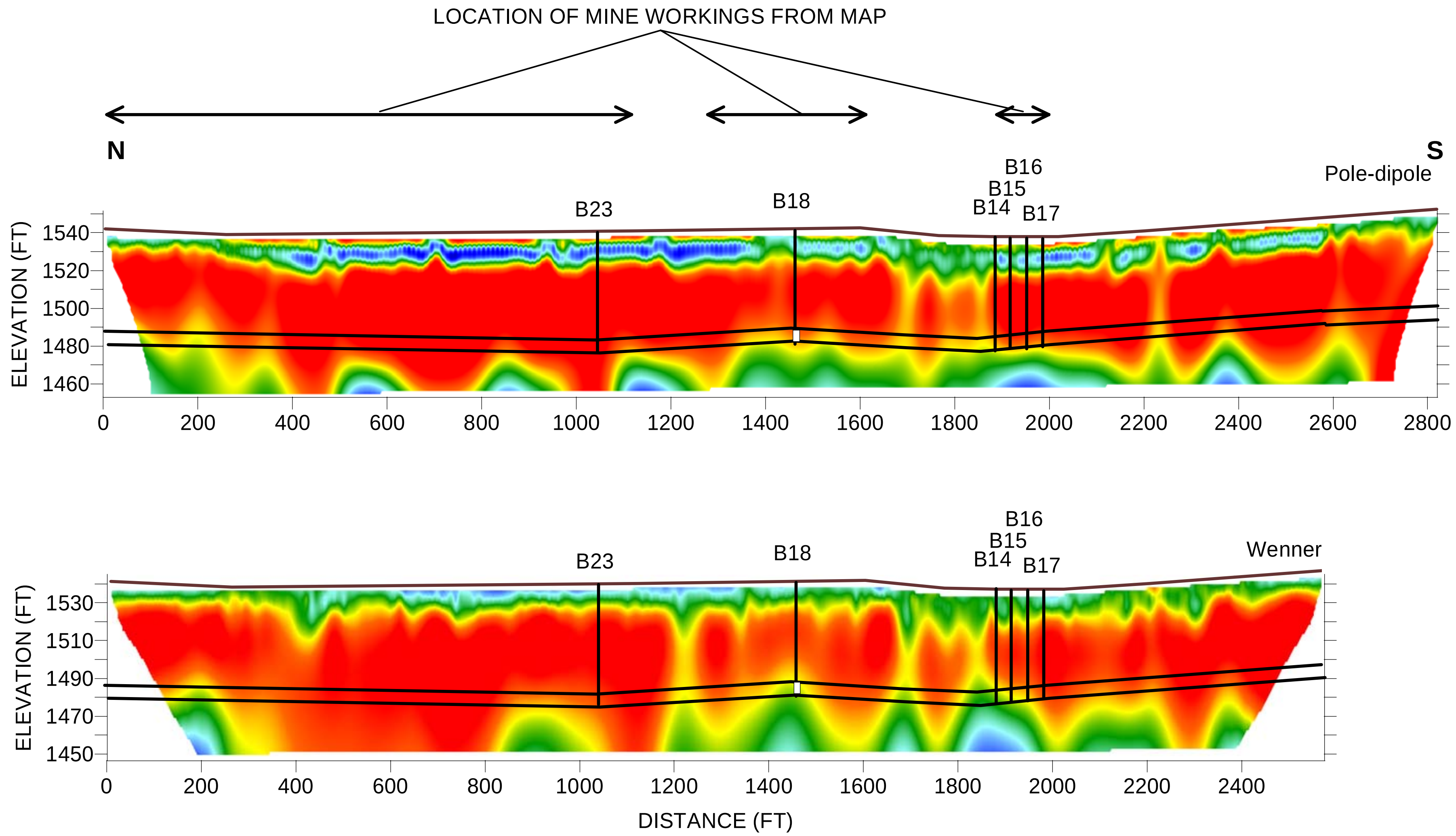

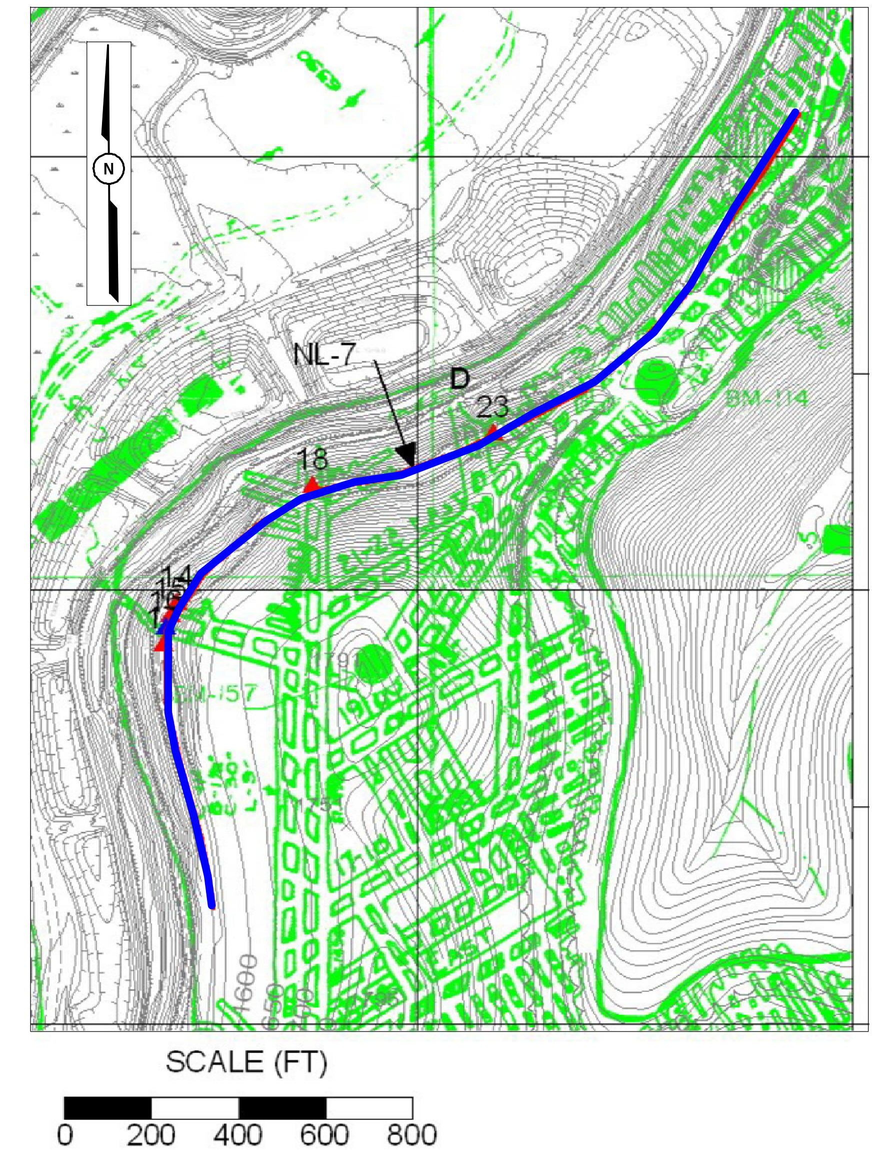

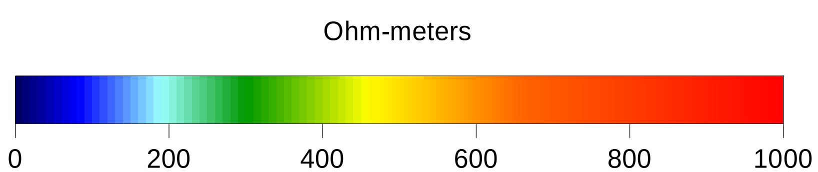

LEGEND

B18

Boring - voids depicted with white rectangle; otherwise solid coal encountered at level of Lewiston Coal

FIGURE 18

DC RESISTIVITY RESULTS ALONG LINE NL-7
MAIN DEMONSTRATION SURVEY
LOTS BRANCH TAILINGS IMPOUNDMENT SITE

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APPENDIX A – WORKHORSE TECHNOLOGIES REPORT

Lots Branch Impoundment, West Virginia Mine Mapping Investigation

Prepared for:

D'Appolonia
275 Center Road
Monroeville, PA 15146-1451

Release Date: **October 14, 2005**

Project No: **031019**

Prepared by:

Workhorse Technologies, Inc.
484 West 7th Avenue
Homestead, PA 15120

Warren (Chuck) Whittaker
Operations Manager

William (Red) Whittaker
Chief Scientist

Introduction

Workhorse Technologies, LLC, conducted laser mapping of the dry voids associated with old coal mine workings at the Lots Branch Impoundment of Pine Ridge Coal Company located near the town of Prenter in Boone County, West Virginia. The investigation is in support of the D'Appolonia demonstration project "Mine Void Detection with DC Resistivity and TDEM Surface Geophysical Methods" for the U.S. Department of Labor, Mine Safety and Health Administration.

4 voids associated with old coal mines were mapped and modeled. Figure 1 shows the orthographic representations of the modeled voids associated with coal mines accessed through holes 13, 25, 31, and 34.

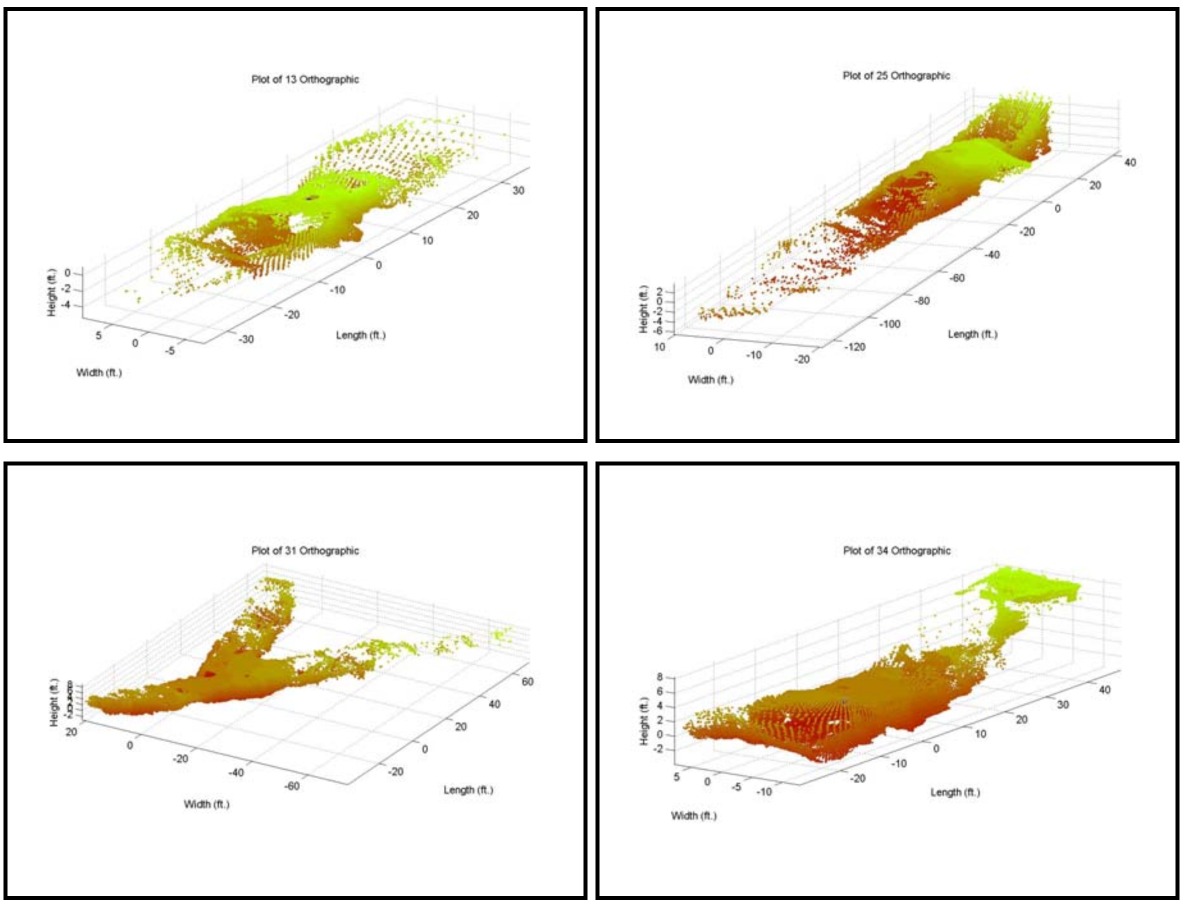


Figure 1: Orthographic views of mine void models for holes 13, 25, 31, and 34

The field work was conducted on September 19, 20, and 21, 2005 with D'Appolonia and MSHA personnel present. Many holes were drilled for verification of D'Appolonia's investigations. Of these, 6 holes were selected to be modeled of which 2 could not be modeled due to conditions encountered in the holes.

Ferret Laser Scans

The data was obtained using the Ferret, a tool developed for subterranean mapping. The Ferret uses a survey quality point laser range finder on a pan and tilt unit to take measurements. Figure 2 shows Ferret with rigid deployment at a typical site hanging from a tripod entering into the casing of a hole. Ferret fits down a 6 inch diameter hole and for the shallow depths encountered at this site mechanical linkage was maintained between the instrument and the surface to provide a surface referenced orientation. Using Ferret point distant measurements and pan and tilt angles are recorded in data sets called scans. Ferret is capable of collecting angular data to 0.1 degree increments and range data to 65 meters while maintaining accuracies to within 10mm. Figure 3 shows a screen capture of a raw scan for review in the field. By examining the data in the field informed decisions are made on what supplemental scans are needed to completely map a void or plan a next hole.

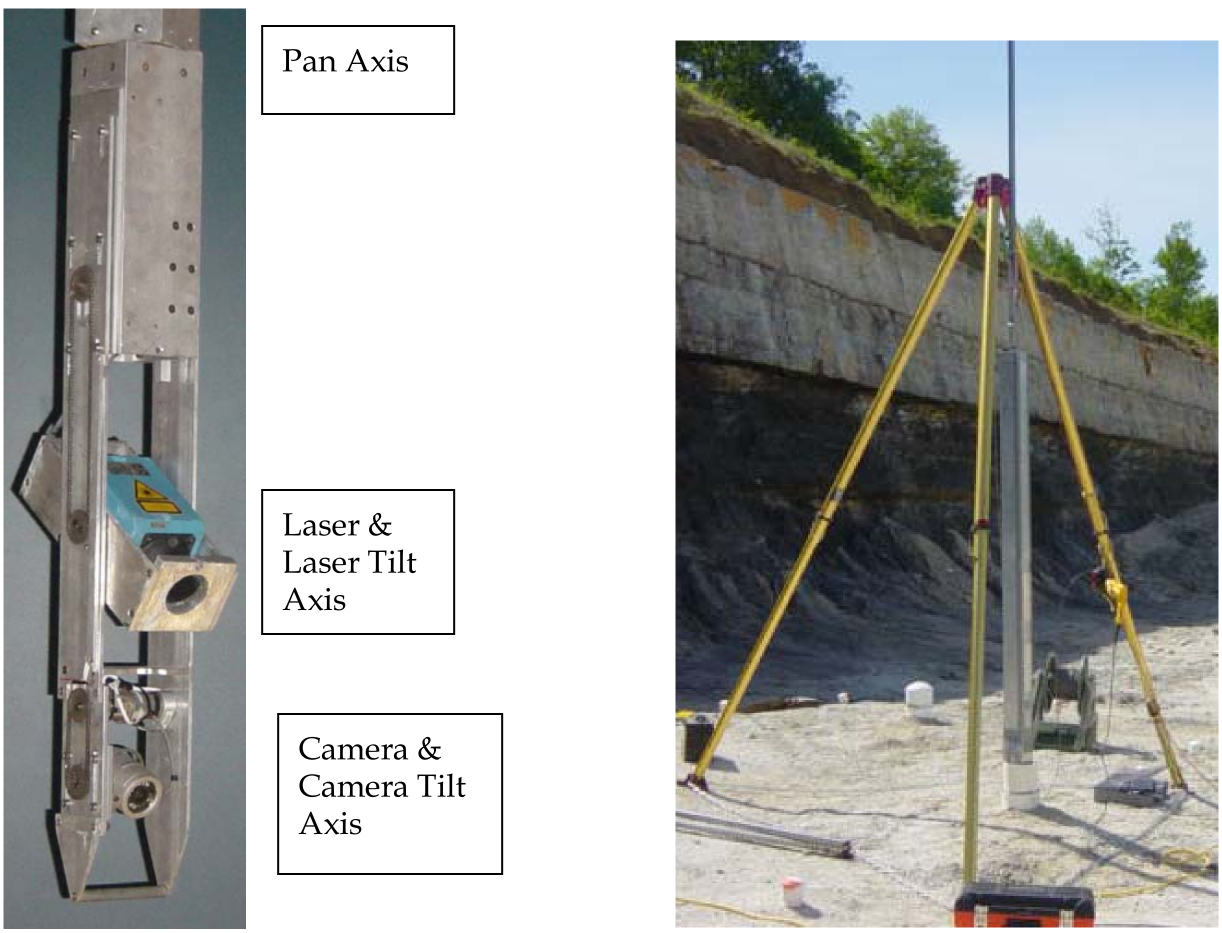


Figure 2: Ferret close-up (left) rigid deployment from tripod (right)

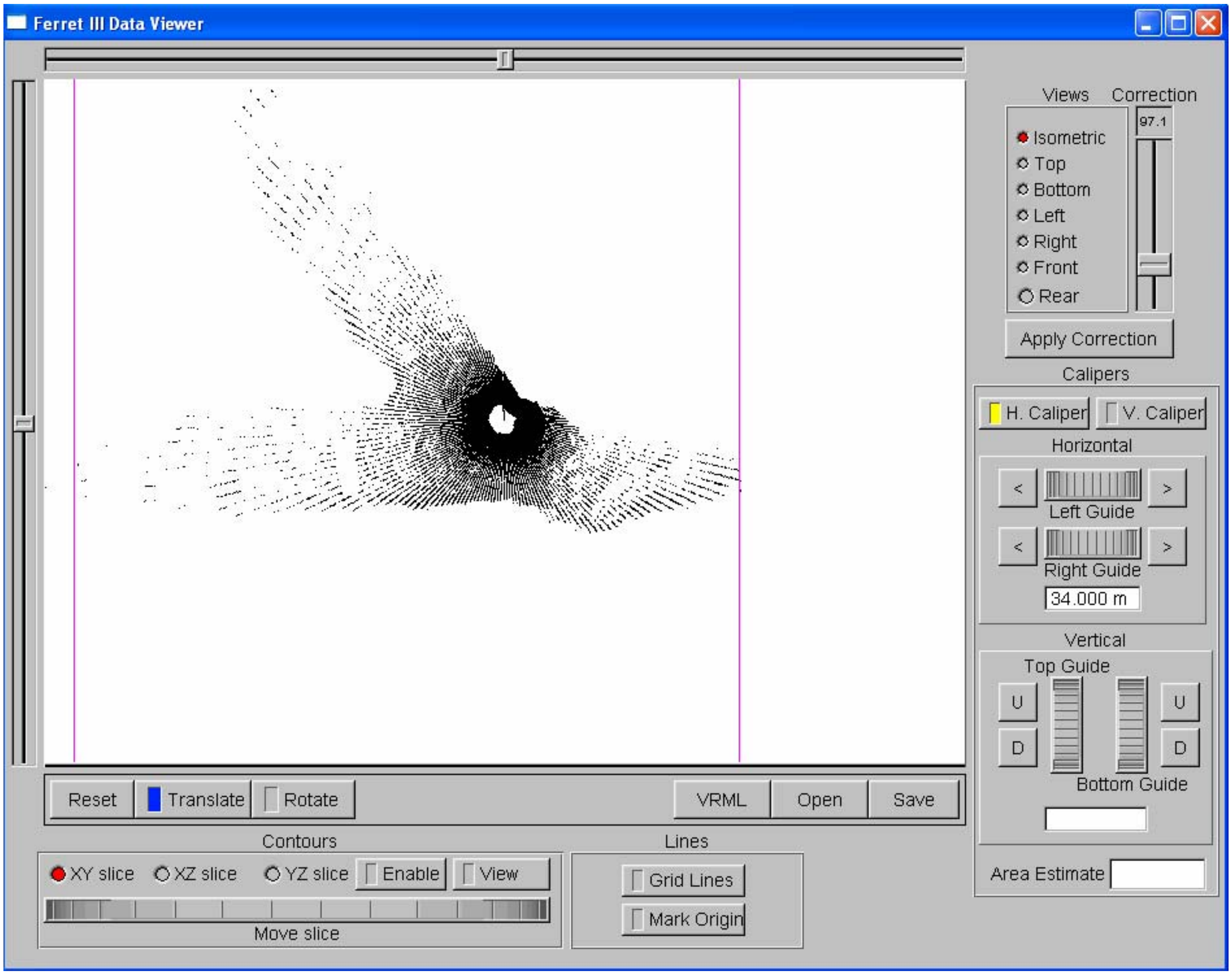


Figure 3: Field review of raw scan at hole 31

Survey of hole locations

Surveyed locations and elevations of the boreholes were not provided so each hole is locally referenced. Elevations are referenced as negative depth in feet from the surface. The zero azimuth for the scans at each hole is referenced to a predominant physical surface feature such as the centerline of the road or another borehole. For each hole a single composite model is generated which containing all the points from all scans. The zero azimuth of the model is referenced with North and a file containing all of the points is displayed in X, Y, Z coordinates. North referenced used are listed in the borehole descriptions below. These point files are found in the results section of the electronic data. By summing the point file with surveyed hole coordinates and surface elevation the models can be geo-referenced.

Boreholes

For each borehole there are statistics, volume, a north referenced horizontal plot, orthographic view of the model, and sectional views of the model. Additionally for each model there are files on the data disk with the x,y,z points, and point cloud models. The orthographic, top, side, and front plots give good representations of the model but viewing the model with a 3-D viewer offers the investigator greater insight into understanding the features from the old mines. For instance careful examination of the borehole 25 model reveals old mine posts. Individual borehole data follws:

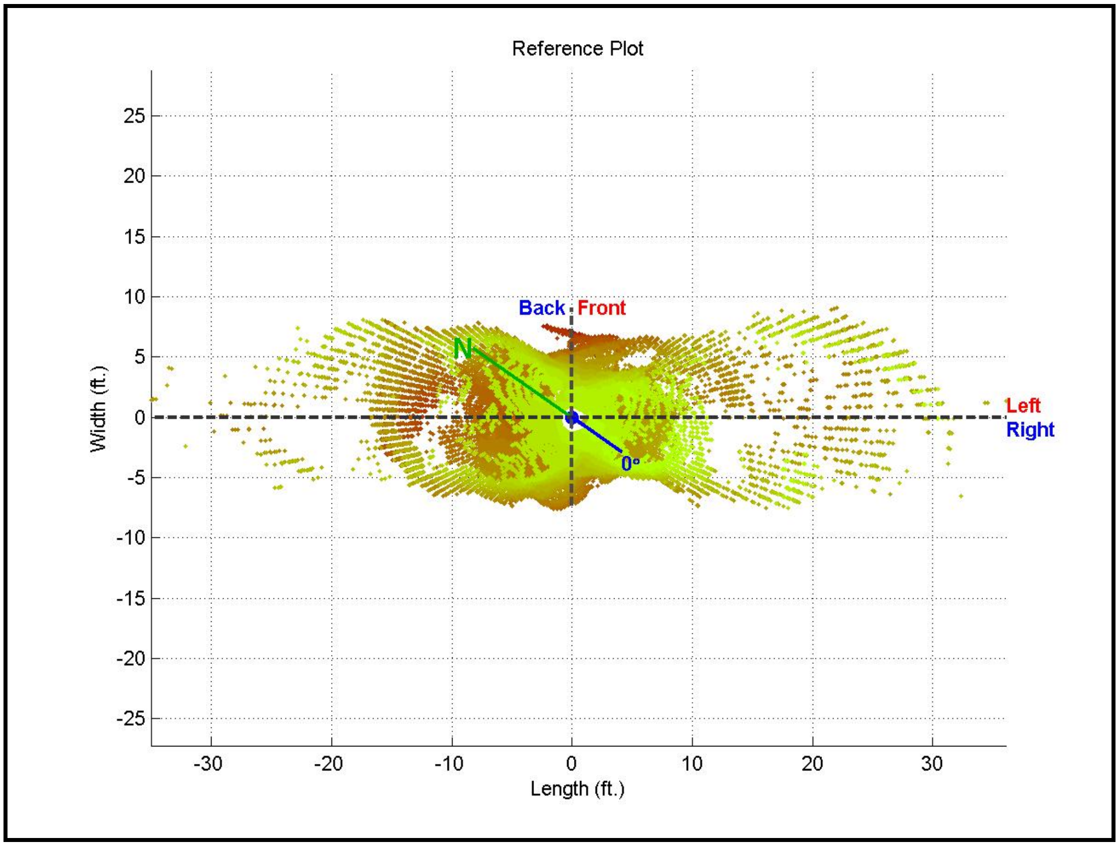
Borehole 11

September 19, 2005	
Top of void depth	32.6 ft
Bottom of hole	38.2 ft

Only video data was collected at this location. There was not enough clearance for deploying the laser due to the build up of drill cuttings in the floor of the mine. No laser data was collected for this hole. The drill cuttings formed a volcano shaped cone which stands to within a foot of the bottom of the casing leaving an opening just big enough for the camera scan.

Borehole 13

September 19, 2005	
Top of void depth	25.6 ft
Bottom of void depth	27.8 ft
Volume of void	2145 cu ft
Azimuth reference	0 was in line with the road facing South


Reference Plot
Back
Front
N
0°
Left
Right
Width (ft.)
Length (ft.)
25
20
15
10
5
0
-5
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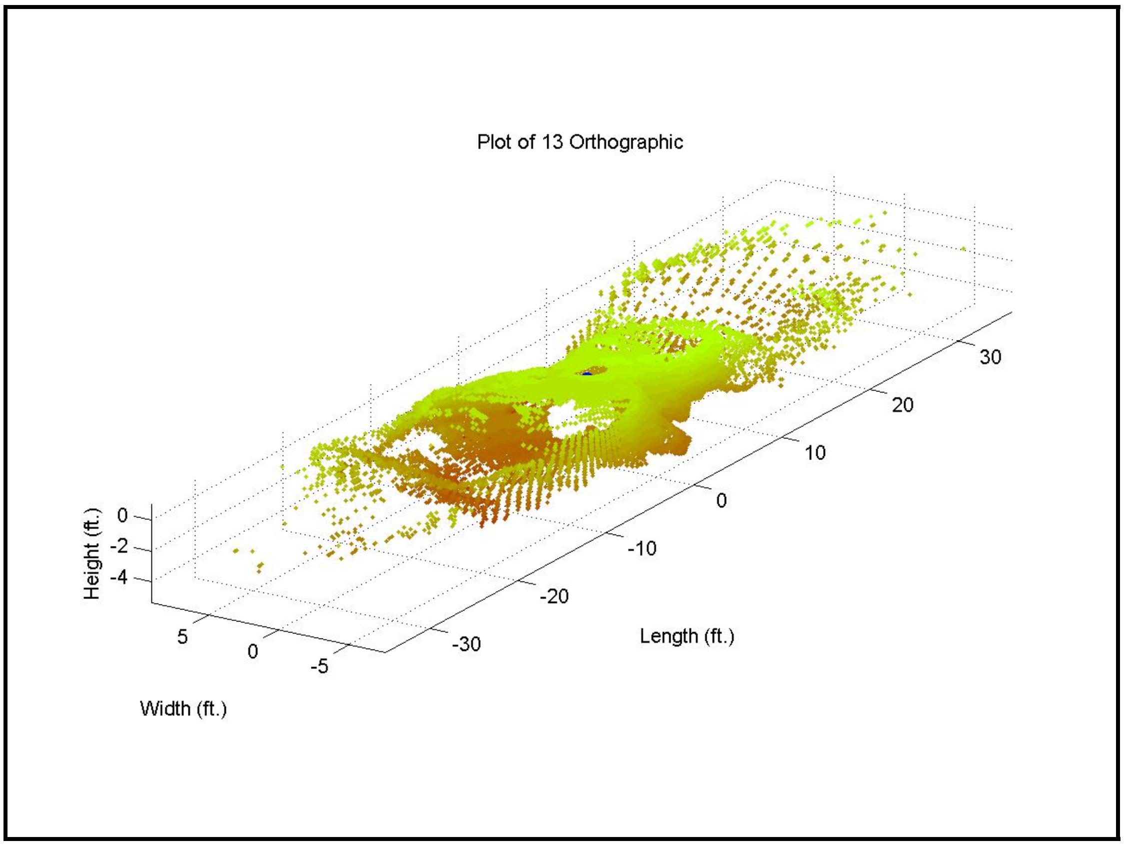
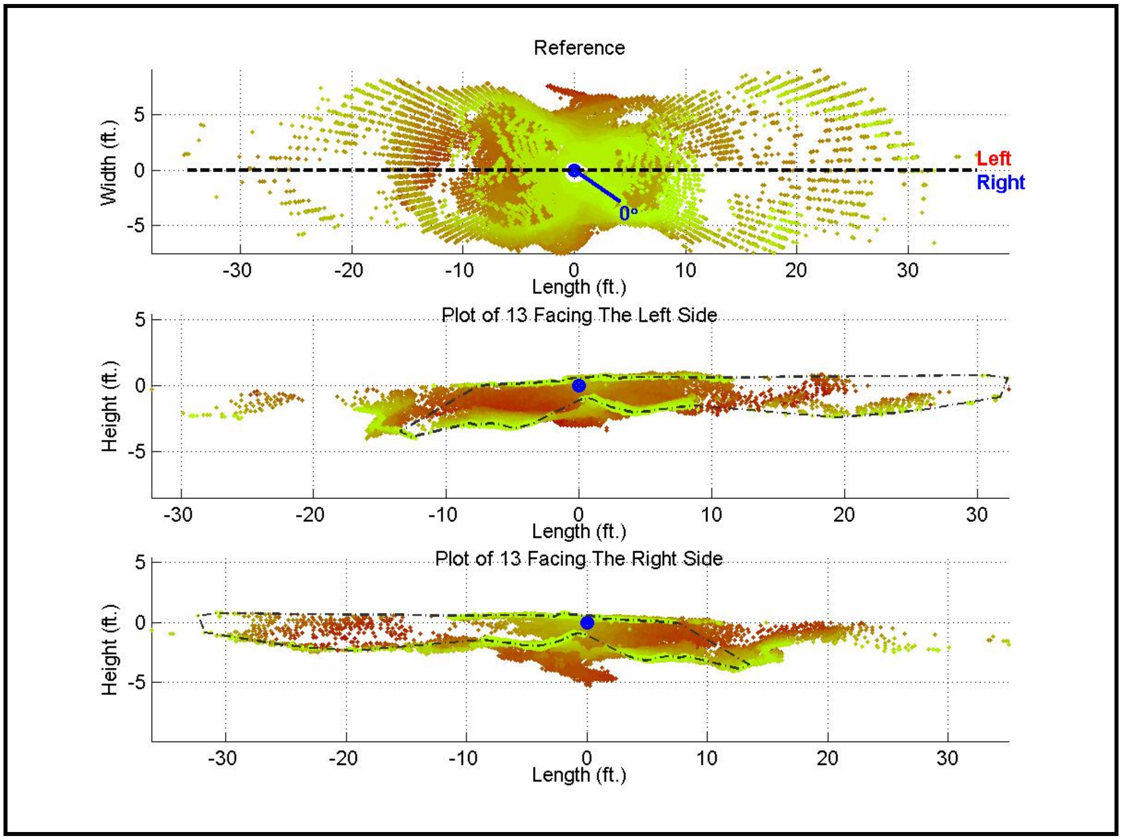
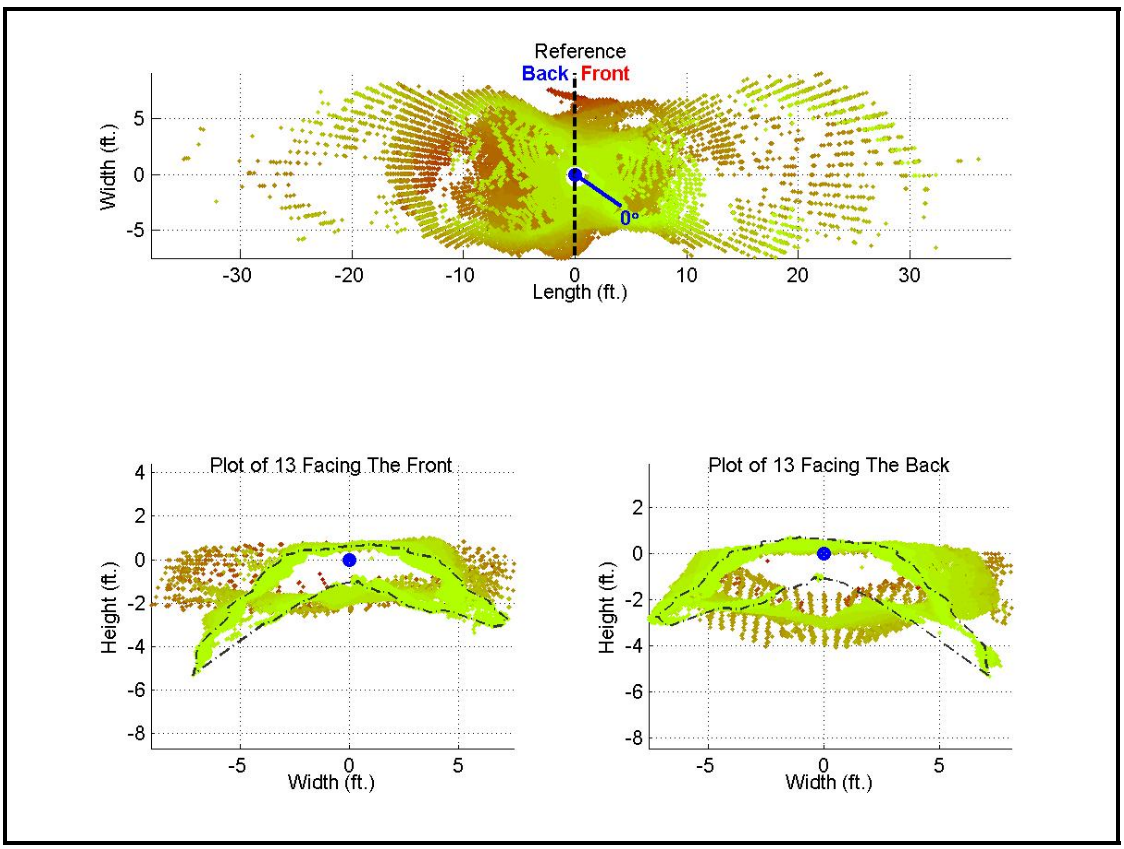
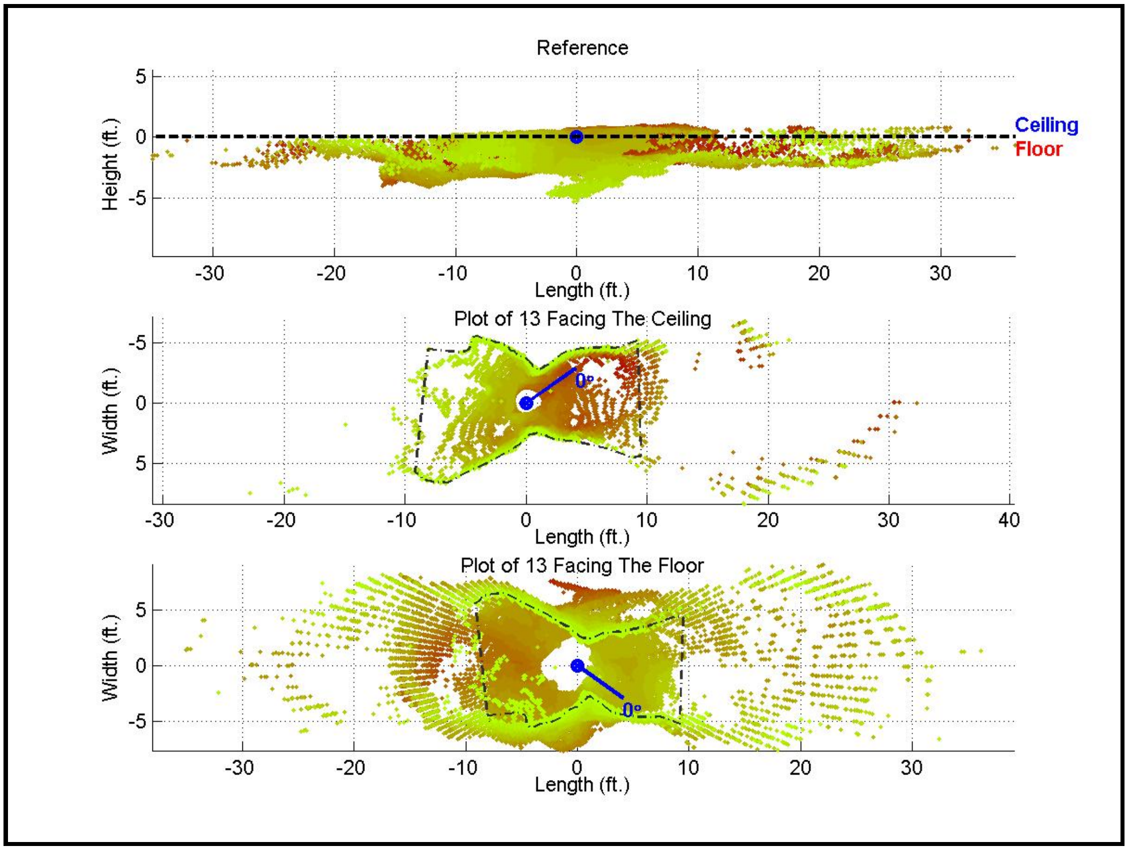
-10
0
10
20
30


Plot of 13 Orthographic
Height (ft.)
0
-2
-4
Width (ft.)
5
0
-5
Length (ft.)
-30
-20
-10
0
10
20
30


Reference
Left
Right
0°
Width (ft.)
Length (ft.)
Plot of 13 Facing The Left Side
Height (ft.)
Length (ft.)
Plot of 13 Facing The Right Side
Height (ft.)
Length (ft.)


Reference
Back
Front
0°
Width (ft.)
Length (ft.)
Plot of 13 Facing The Front
Height (ft.)
Width (ft.)
Plot of 13 Facing The Back
Height (ft.)
Width (ft.)



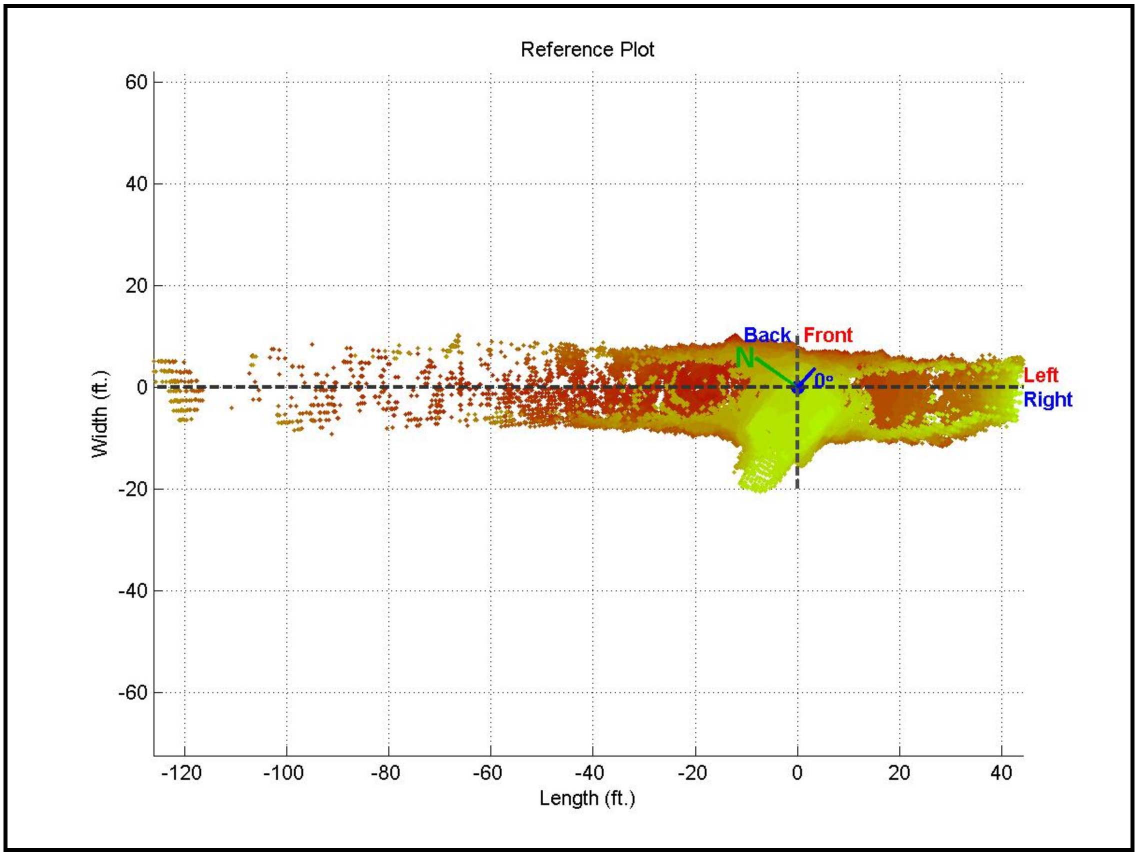
Borehole 18

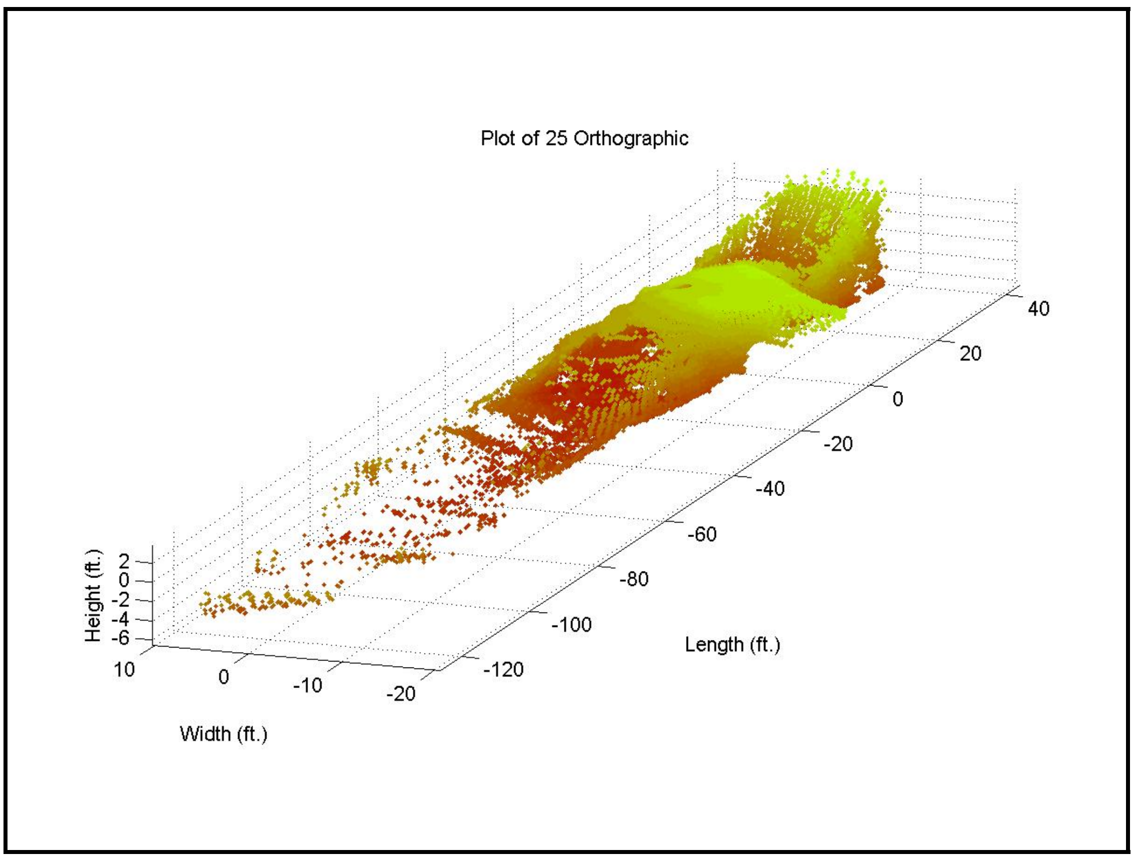
Only video data was collected at this location. There was not enough clearance in the hole to allow ferret to be lowered more than 24ft. The video shows the scrapings along the wall of the hole where the instrument was stopped. It is indeterminate whether the hole narrowed or was misaligned.

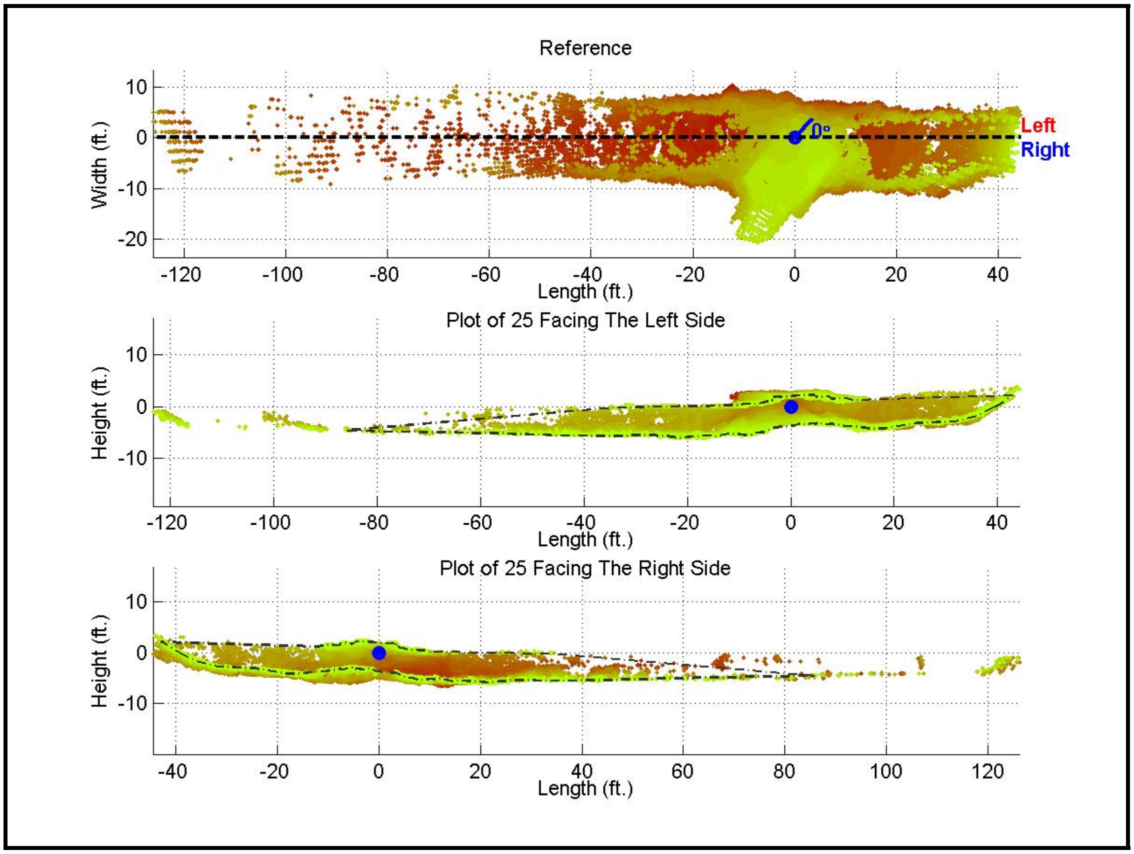
Borehole 25

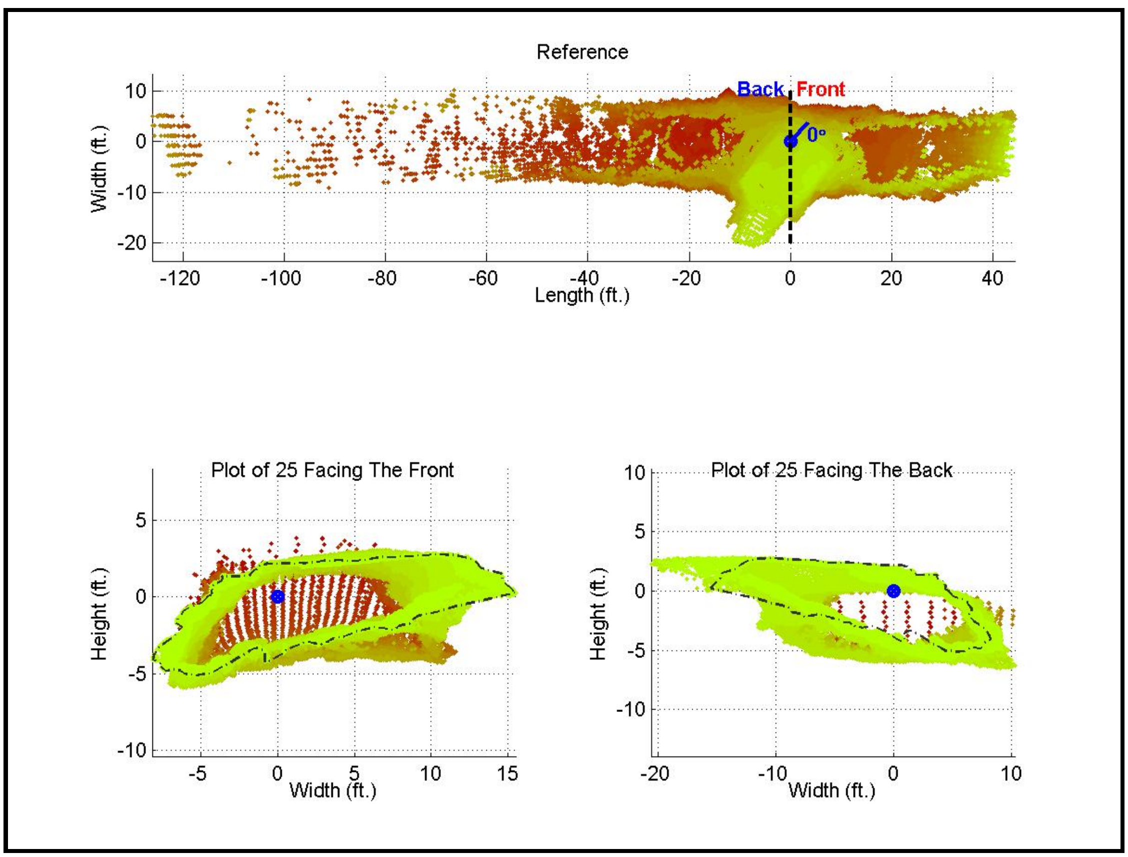
September 20, 2005

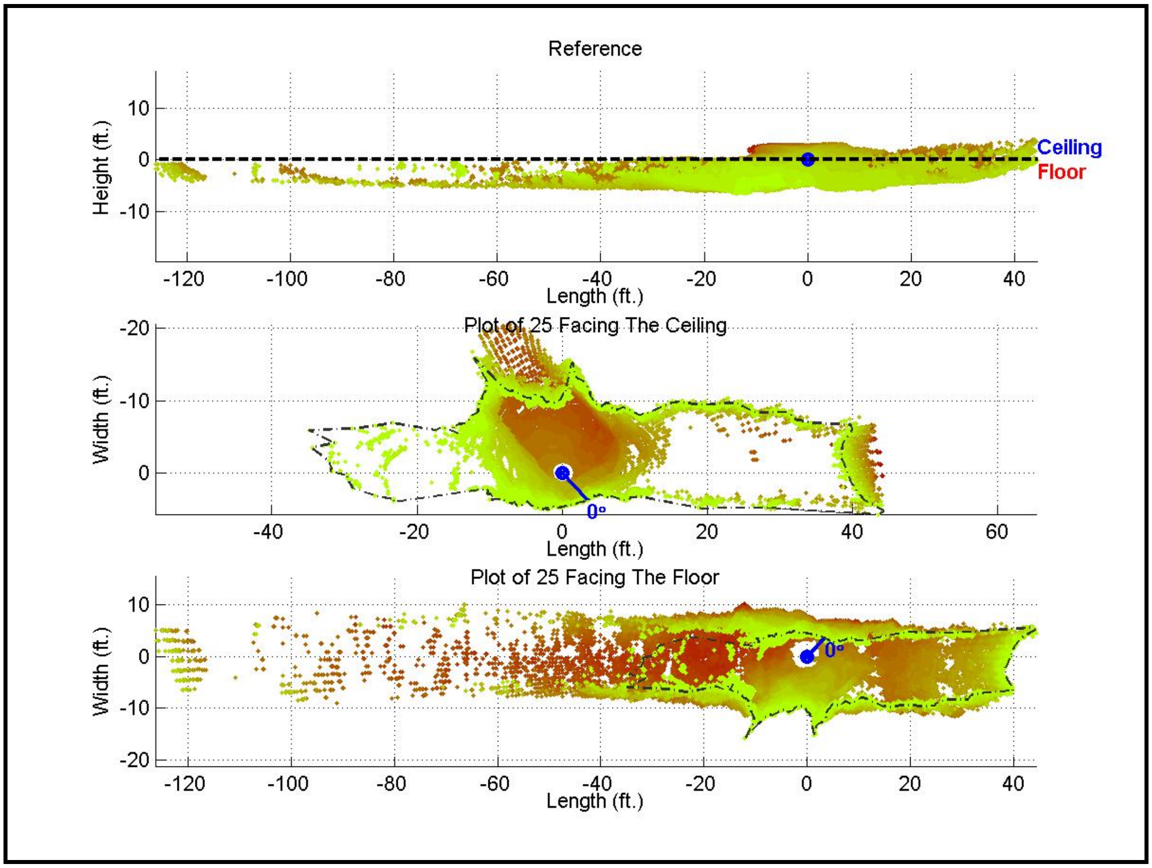
Top of void depth	29.9 ft
Bottom of void depth	36.3 ft
Volume of void	11034 cu ft
Azimuth reference	0 was directly opposite a line to hole 22


Reference Plot
Width (ft.)
Length (ft.)
Back
Front
N
0°
Left
Right
60
40
20
0
-20
-40
-60
-120
-100
-80
-60
-40
-20
0
20
40


Plot of 25 Orthographic
Height (ft.)
2
0
-2
-4
-6
10
0
-10
-20
Width (ft.)
Length (ft.)
-120
-100
-80
-60
-40
-20
0
20
40


Reference
Width (ft.)
Length (ft.)
Left
Right
0°
Plot of 25 Facing The Left Side
Height (ft.)
Length (ft.)
Plot of 25 Facing The Right Side
Height (ft.)
Length (ft.)

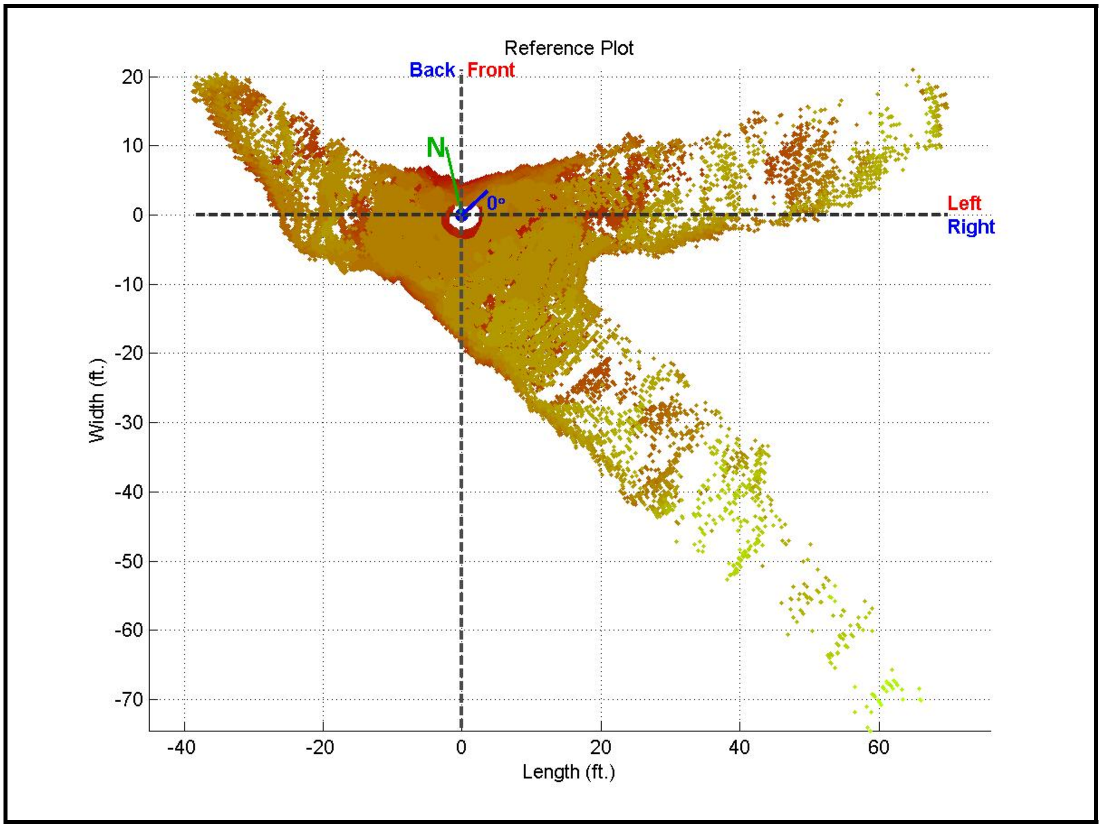

Reference
Width (ft.)
Length (ft.)
Back
Front
0°
Plot of 25 Facing The Front
Height (ft.)
Width (ft.)
Plot of 25 Facing The Back
Height (ft.)
Width (ft.)



Borehole 31

September 20, 2005

Top of void depth	36.4 ft
Bottom of void depth	40.8 ft
Volume of void	10679 cu ft
Azimuth reference	0 was aligned with the road bearing N60E


Reference Plot
Back
Front
N
0°
Left
Right
Width (ft.)
Length (ft.)
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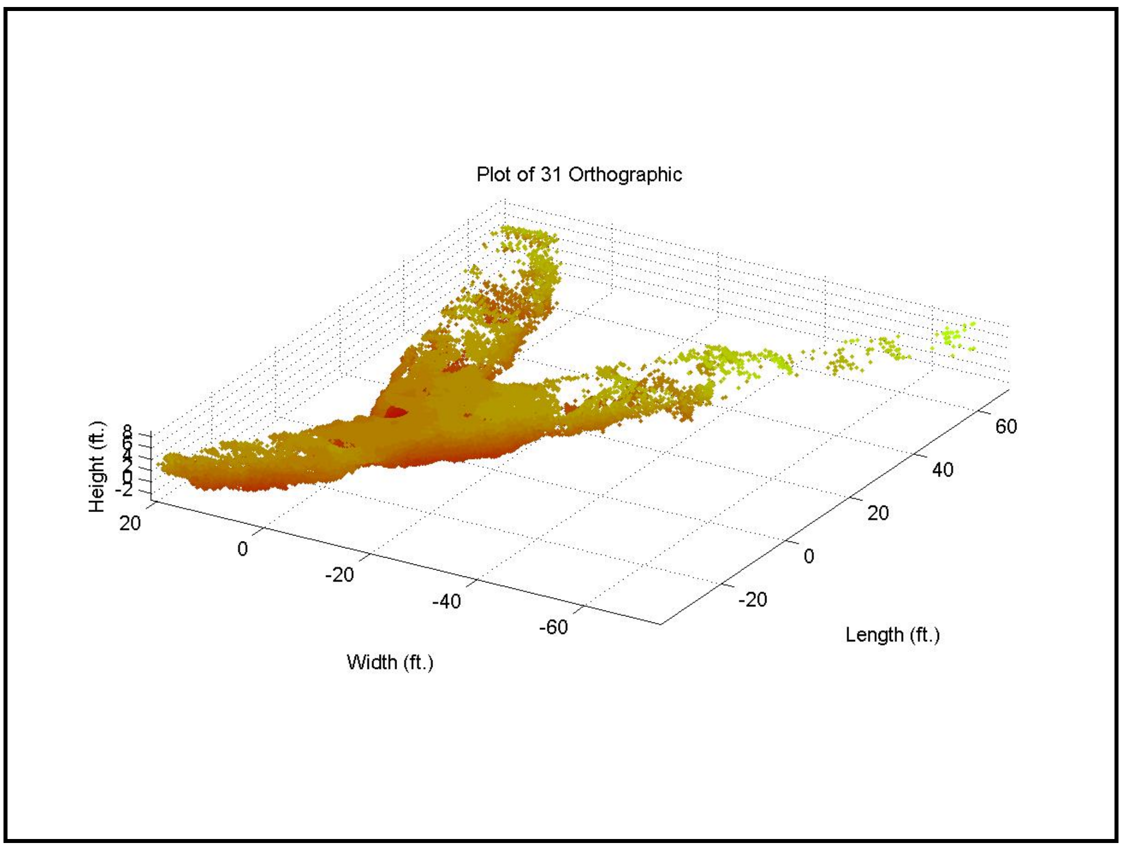
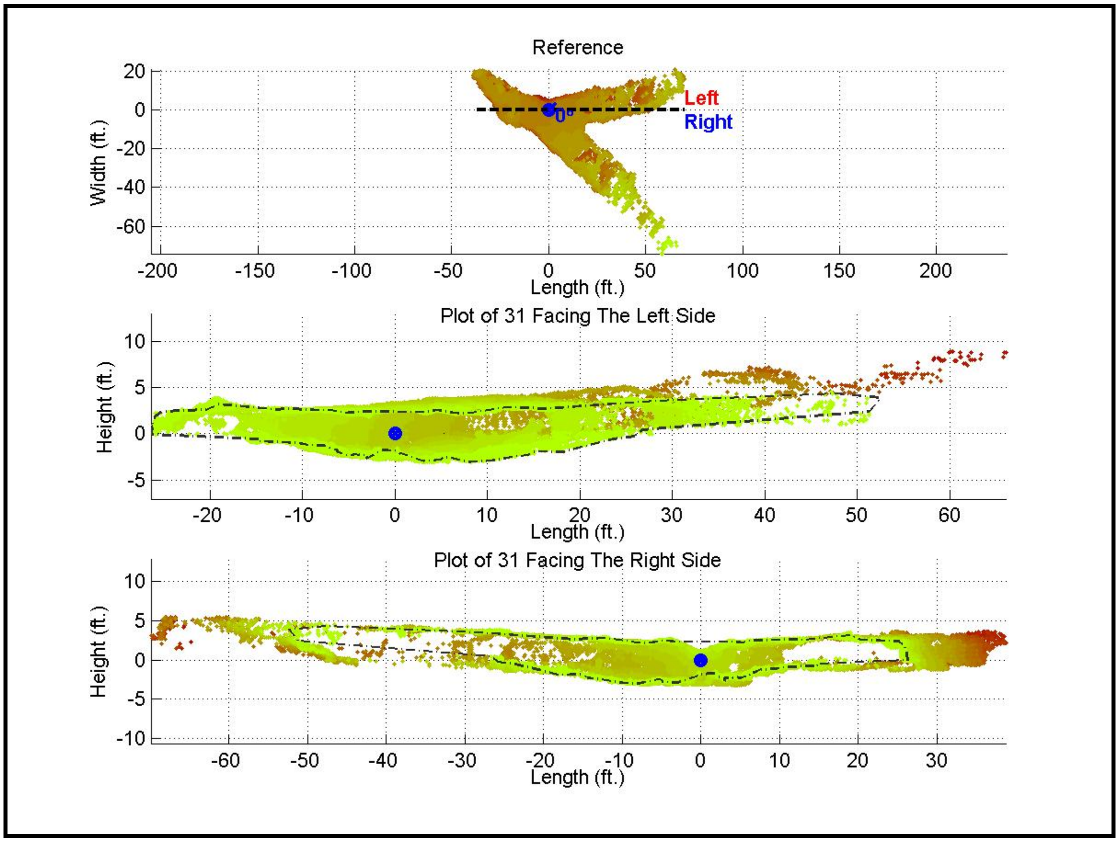
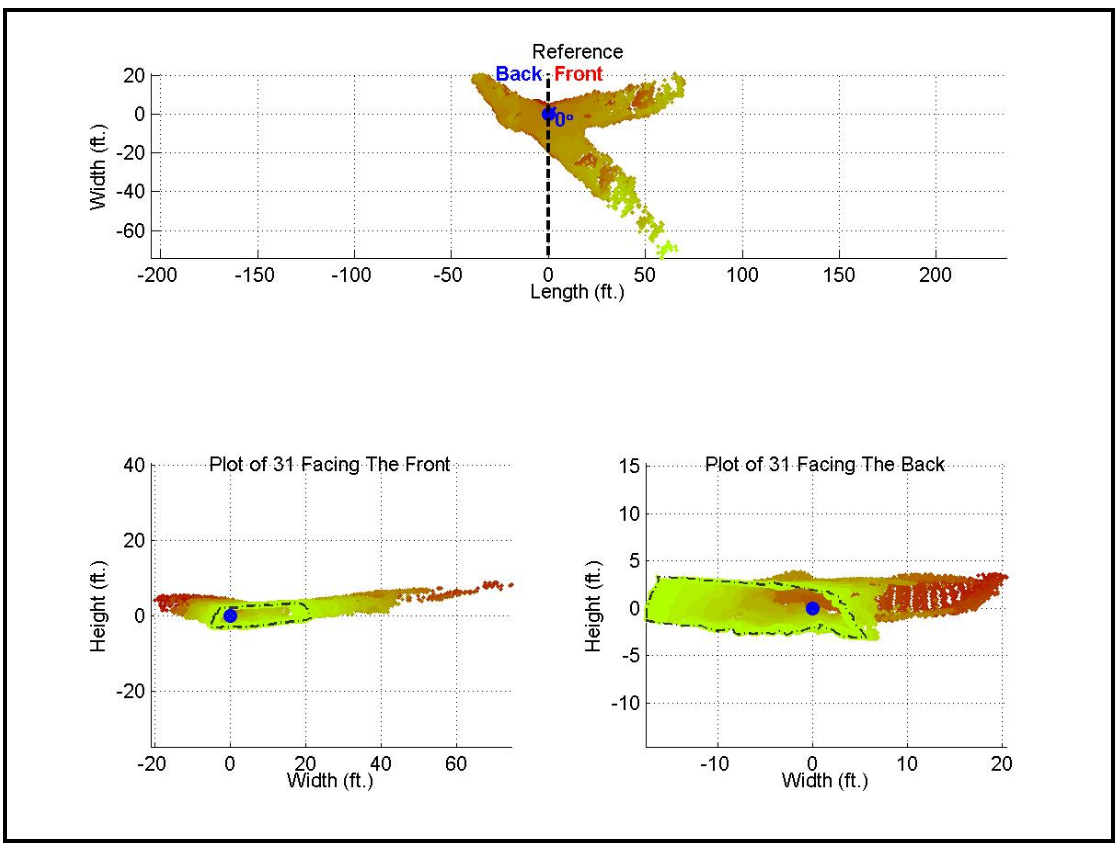
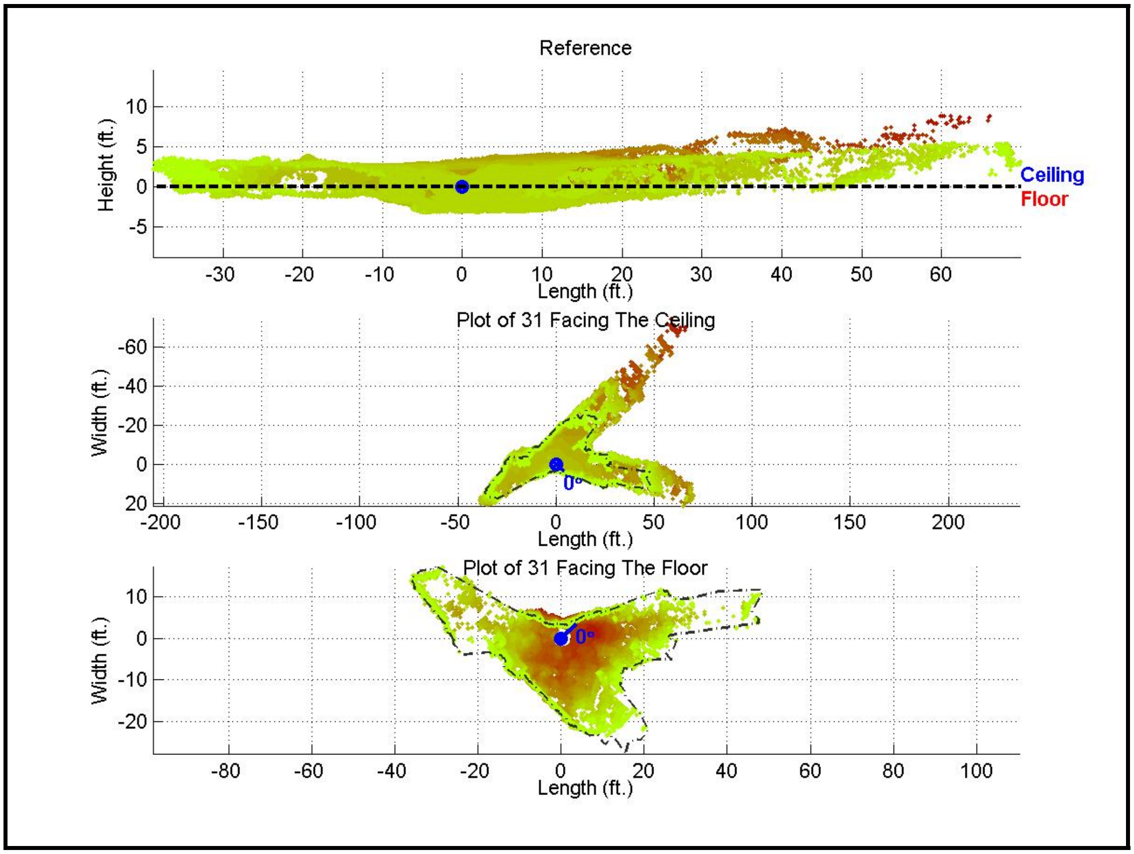
10
0
-10
-20
-30
-40
-50
-60
-70
-40
-20
0
20
40
60


Plot of 31 Orthographic
Height (ft.)
Width (ft.)
Length (ft.)
20
0
-20
-40
-60
60
40
20
0
-20


Reference
Left
Right
0°
Width (ft.)
Length (ft.)
Plot of 31 Facing The Left Side
Height (ft.)
Length (ft.)
Plot of 31 Facing The Right Side
Height (ft.)
Length (ft.)


Reference
Back
Front
0°
Width (ft.)
Length (ft.)
Plot of 31 Facing The Front
Height (ft.)
Width (ft.)
Plot of 31 Facing The Back
Height (ft.)
Width (ft.)



Borehole 34

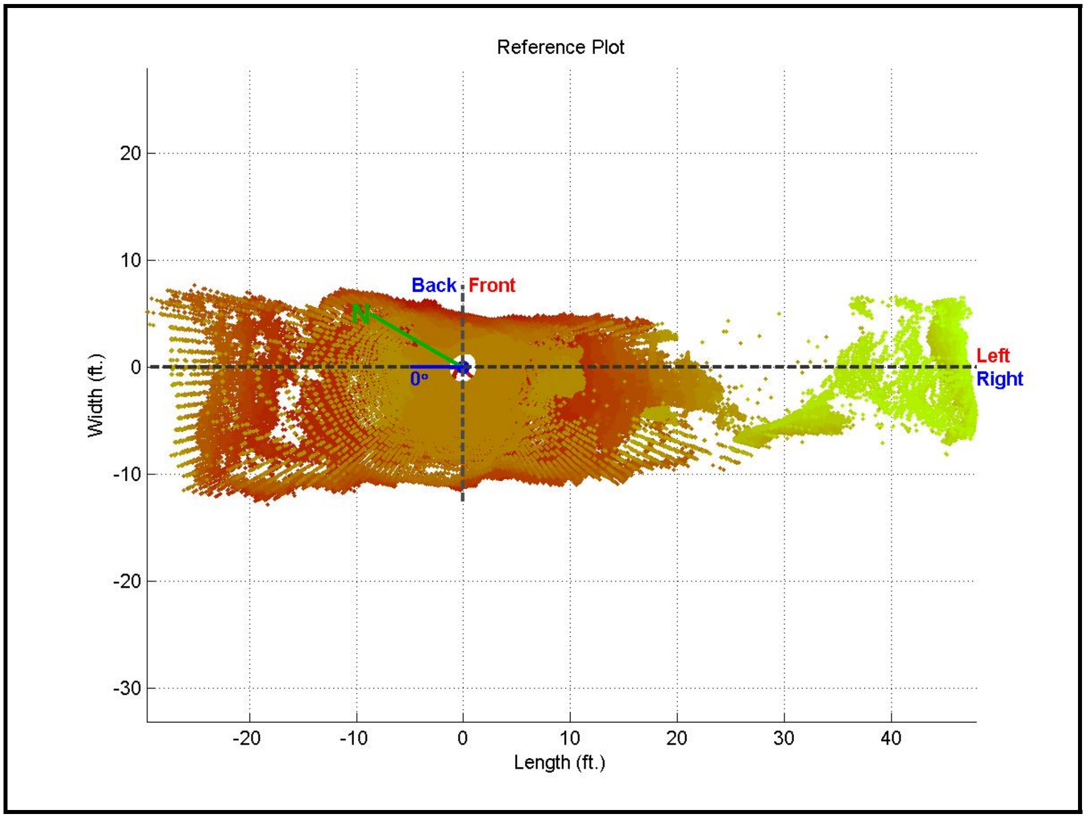
September 21, 2005

Top of void depth 36.2 ft

Bottom of void depth 41.6 ft

Volume of void 4297.9701 cu ft

Azimuth reference 0 was to be aligned with same bearing reference used for hole 31 however a blunder in matching the mechanical linkage resulted in a 90 degree shift in the reference.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N
0°
Left
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Length (ft.)
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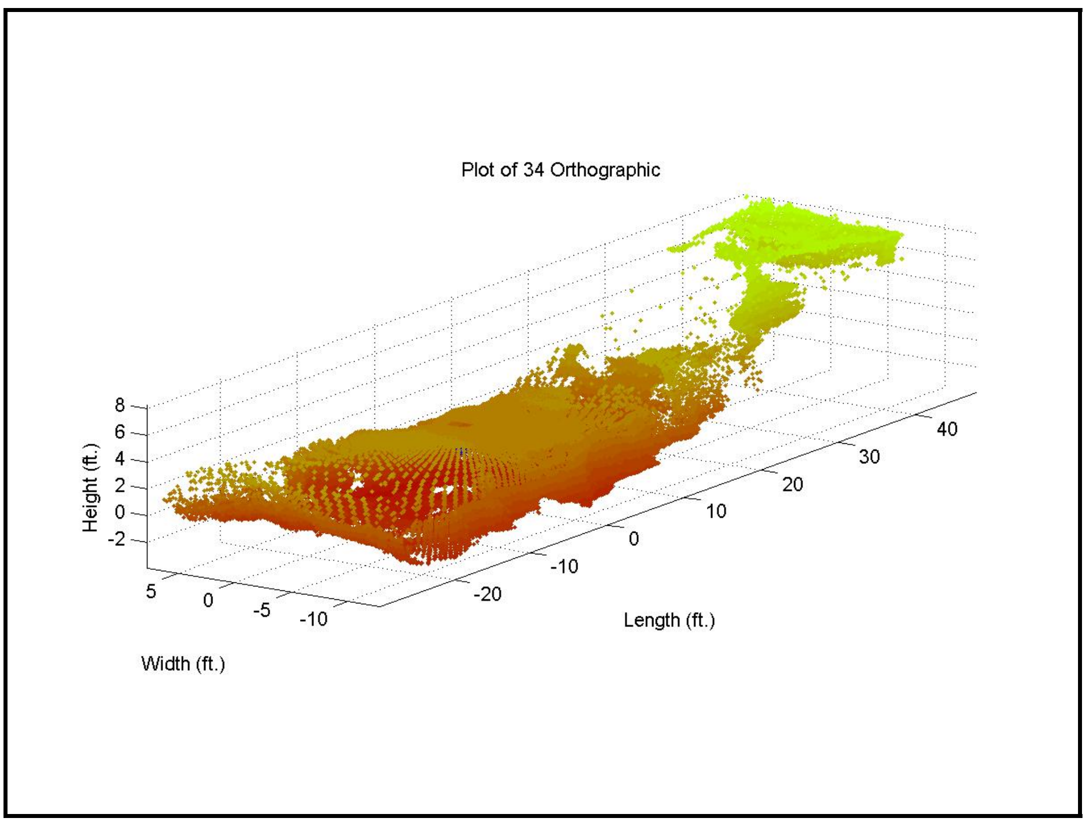
10
20
30
40


Plot of 34 Orthographic
Height (ft.)
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6
4
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5
0
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Width (ft.)
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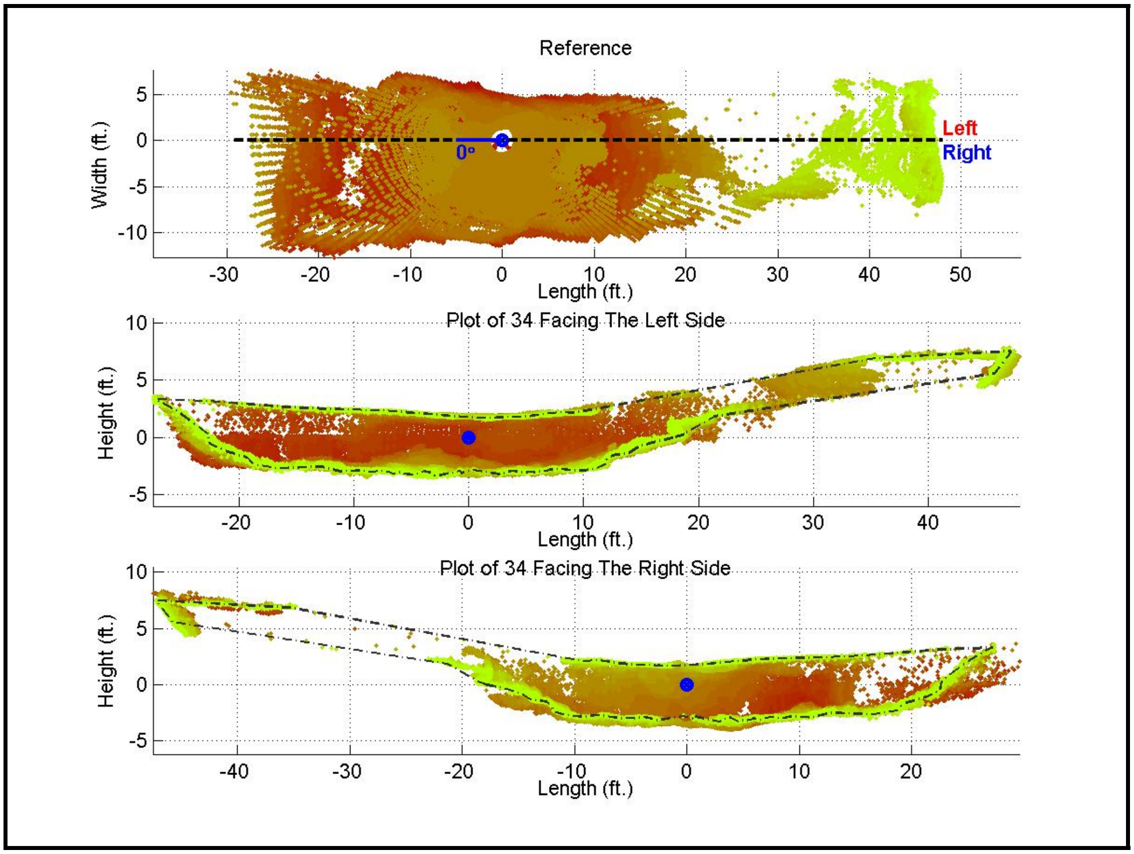
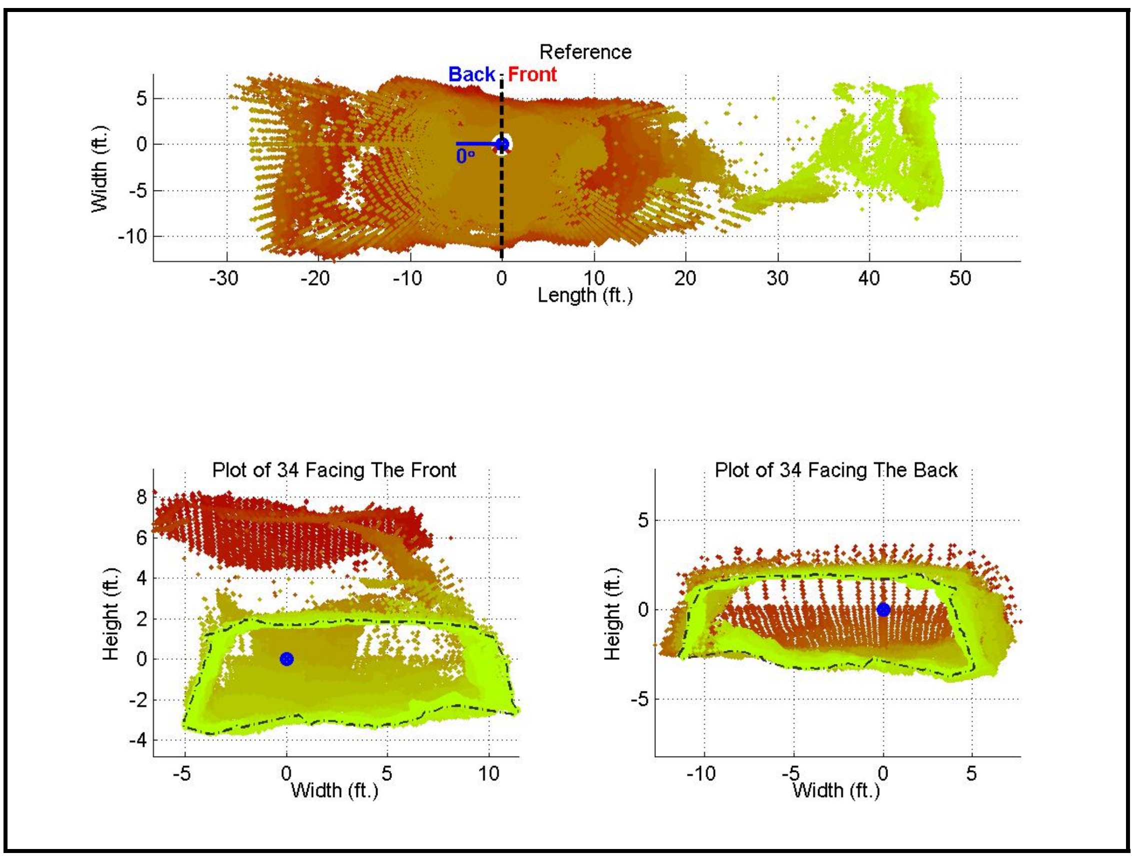
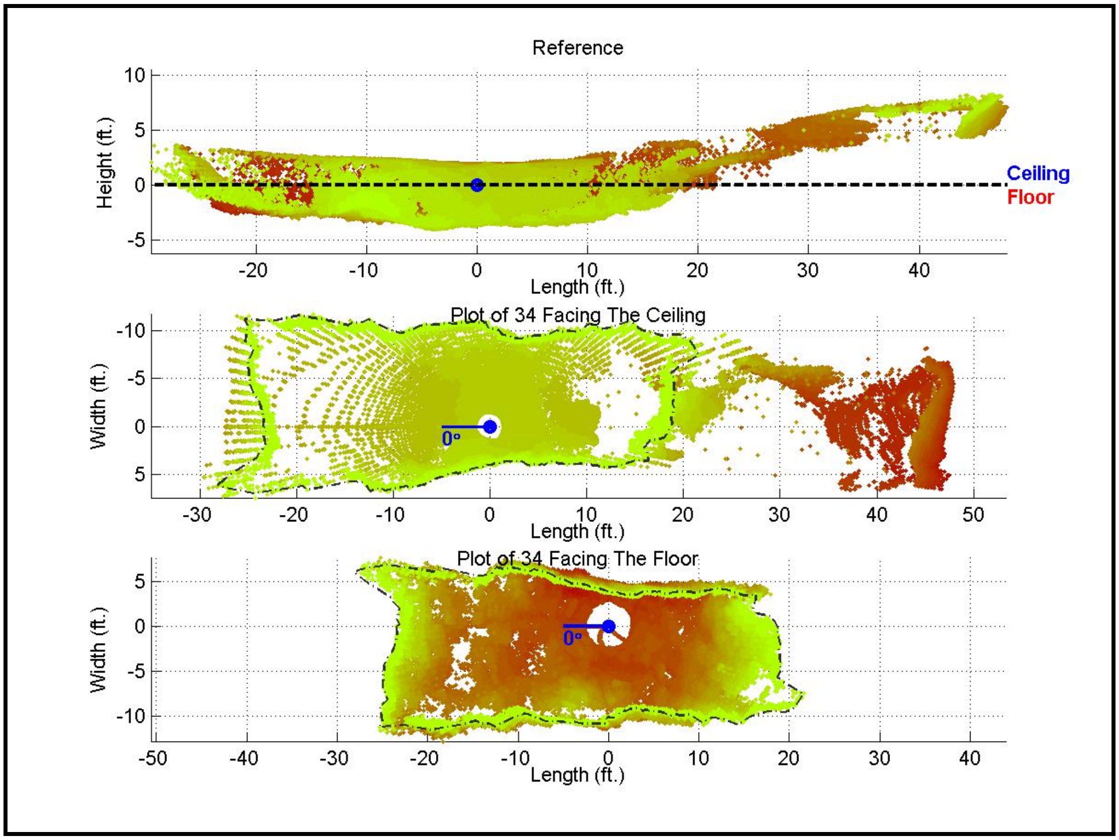
-10
0
10
20
30
40
Length (ft.)


Reference
Width (ft.)
Length (ft.)
0°
Left
Right
Plot of 34 Facing The Left Side
Height (ft.)
Length (ft.)
Plot of 34 Facing The Right Side
Height (ft.)
Length (ft.)


Reference
Back
Front
0°
Width (ft.)
Length (ft.)
Plot of 34 Facing The Front
Height (ft.)
Width (ft.)
Plot of 34 Facing The Back
Height (ft.)
Width (ft.)



Composite Plot and Survey

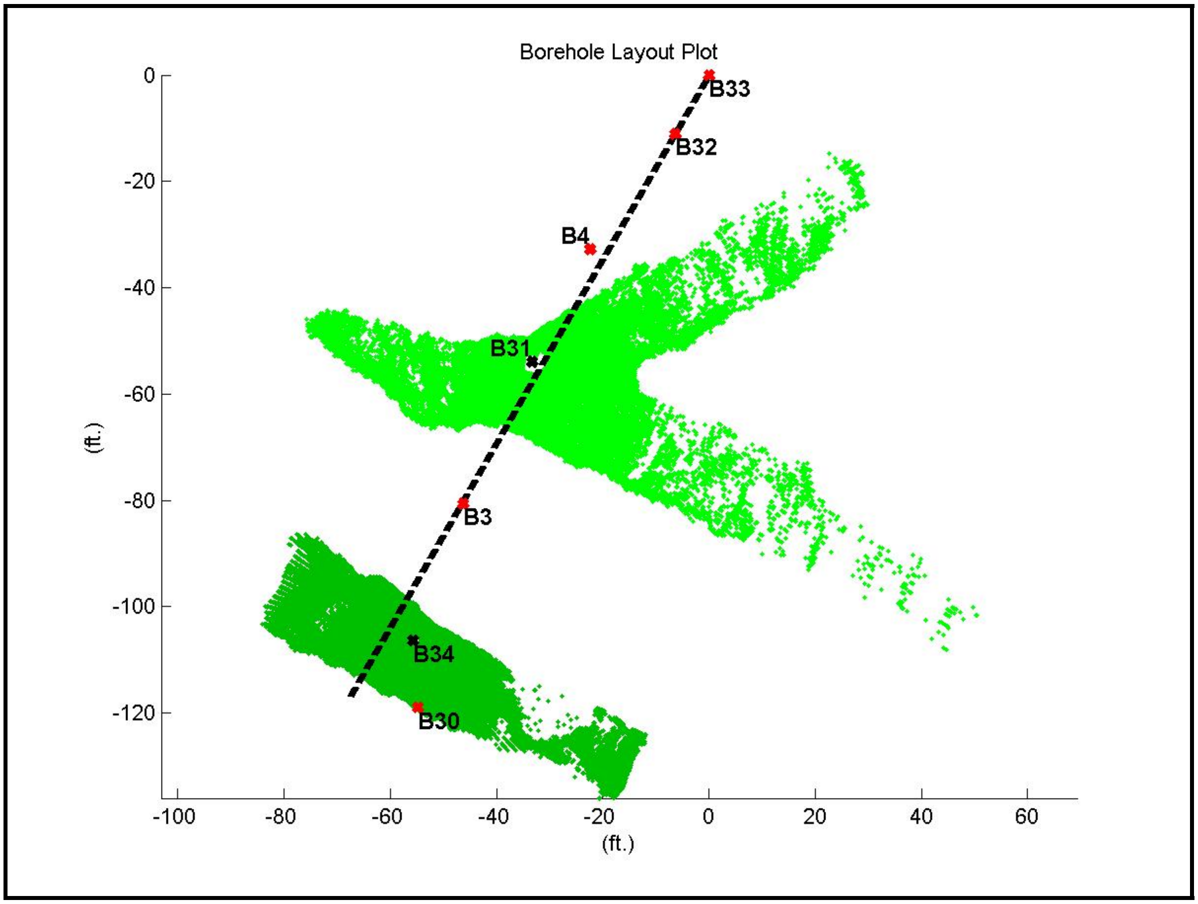
Several holes were drilled in the vicinity of boreholes 31 and 34. Following the Ferret work in hole 34 a localized layout survey was conducted in order to explain the coal and void records from the drilling logs. The survey and the resulting plot follows:

Hole Layout
September21,2005
Pine Ridge Coal Company
Lots Branch Impoundment

Hole #	Length	90 offset	direction	finding
B-33	0	On Line	x	coal
B-32	12'-9"	On Line	x	coal
B-4	39'-6"	(-36")	<	coal
B-31	63'-4"	(-22")	<	void
B-3	93'	3"	>	coal
B-34	120'	5'	>	void
B-30	130'-6"	12'	>	coal

x on line
< toward lake
> toward hillside

Bearing of tape measure 240 degrees from compass



Summary

The Lots Branch Impoundment void exploration provided a great opportunity for Workhorse Technologies, LLC to show the strength of Ferret's mapping capabilities. The voids accessed in the 4 boreholes at the site clearly define the localized pieces of the old coal mines.

Acknowledgements

Thank you to Bill Johnson of D'Appalonia and MSHA for your invaluable support, orientation, and expertise in the field.

Thank you to D'Appolonia and MSHA for this opportunity.

Electronic Data Files index
Index to the Electronic Data

The data and analysis is summarized in this written report however the electronic files accompanying this report contain the complete data sets, models and images relaying our investigation.

The electronic data is presented in several forms:

- 3 dimensional point files - Point files are a listing of coordinates that define the individual point measurements from a scan or model. These files are in a .txt form and a read me file document explains the form of the data. (x,y,z), or (horizontal angle, vertical angle, distance)
- 3 dimensional point cloud models – These files consist of a plot in space of all the collected data points and the resulting model is referred to as a point cloud. See Figure 4. The files are listed in a .wrl format and can be viewed by VRML web based data viewers such as Cortona found at www.parallelgraphics.com See Figure 5.

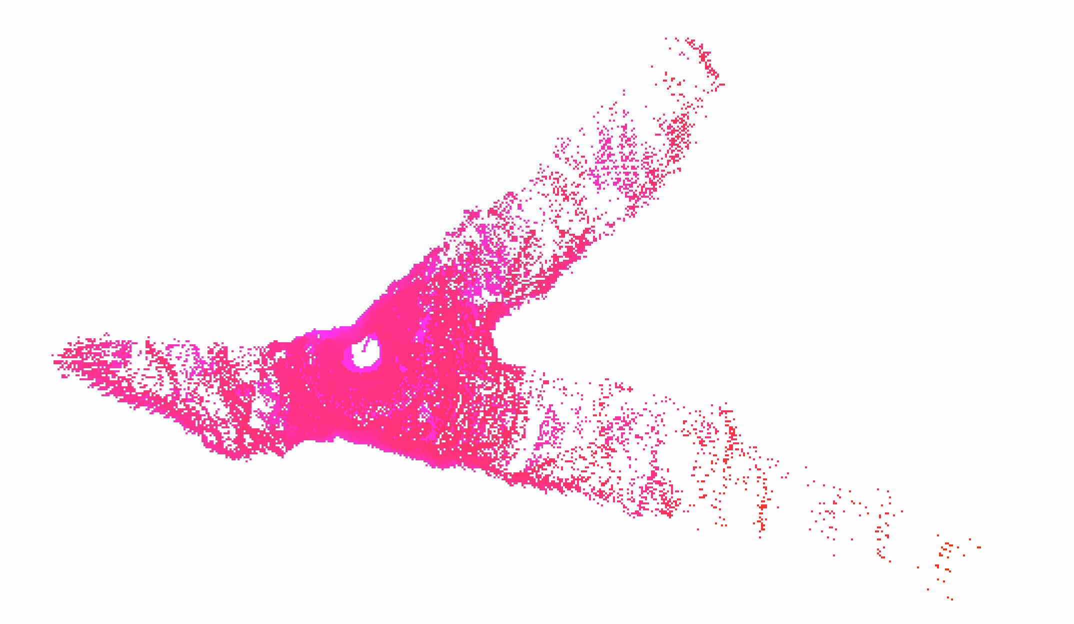


Figure 4: point cloud image from hole 31

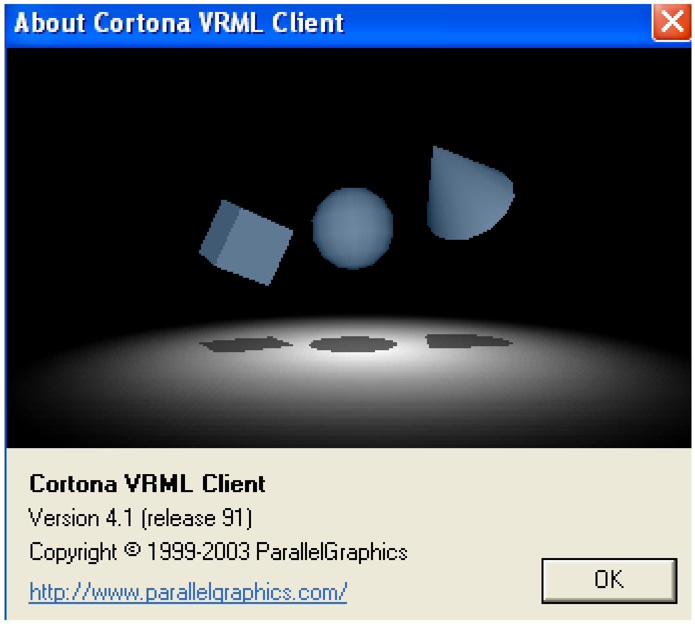
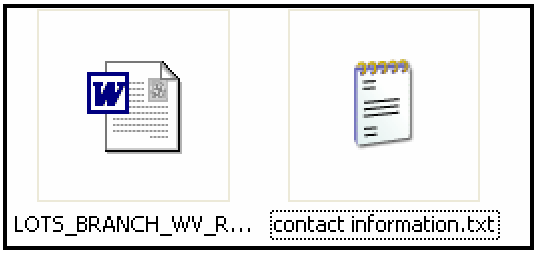
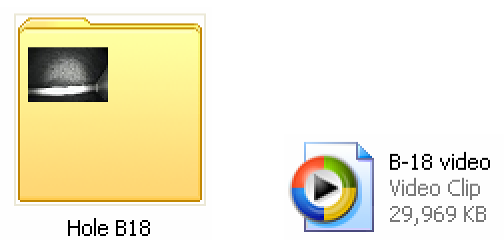


Figure 5: Cortona VRML viewer

- 2 dimensional plots – Plots of data in a single plane are presented in a .jpg format.
- Movies – Movies are compressed .avi files. To view these movies you will need to install DivX Codec by running DivXPlay.exe found on the disc. (for Windows XP). At http://www.divxmovies.com/codec/ you can find installs for other operating systems
- Scans - Individual scans are recorded in the field as a .scn file. This is Workhorse's raw data format and no viewer is provided

Following is the index of the files found on the accompanying DVD.





Hole B25

b25-000
SCN File
11,124 KB

b25-001
SCN File
450 KB

b25-002
SCN File
15,275 KB

b25-000
Text Document
3,914 KB

b25-001
Text Document
150 KB

b25-002
Text Document
5,213 KB

B-25 video
Video Clip
223,038 KB

Hole B31

b31-000
SCN File
15,660 KB

b31-001
SCN File
223 KB

b31-002
SCN File
10,043 KB

b31-000
Text Document
5,244 KB

b31-001
Text Document
81 KB

b31-002
Text Document
3,010 KB

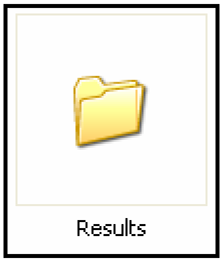
B-31 video
Video Clip
216,125 KB

Hole B34

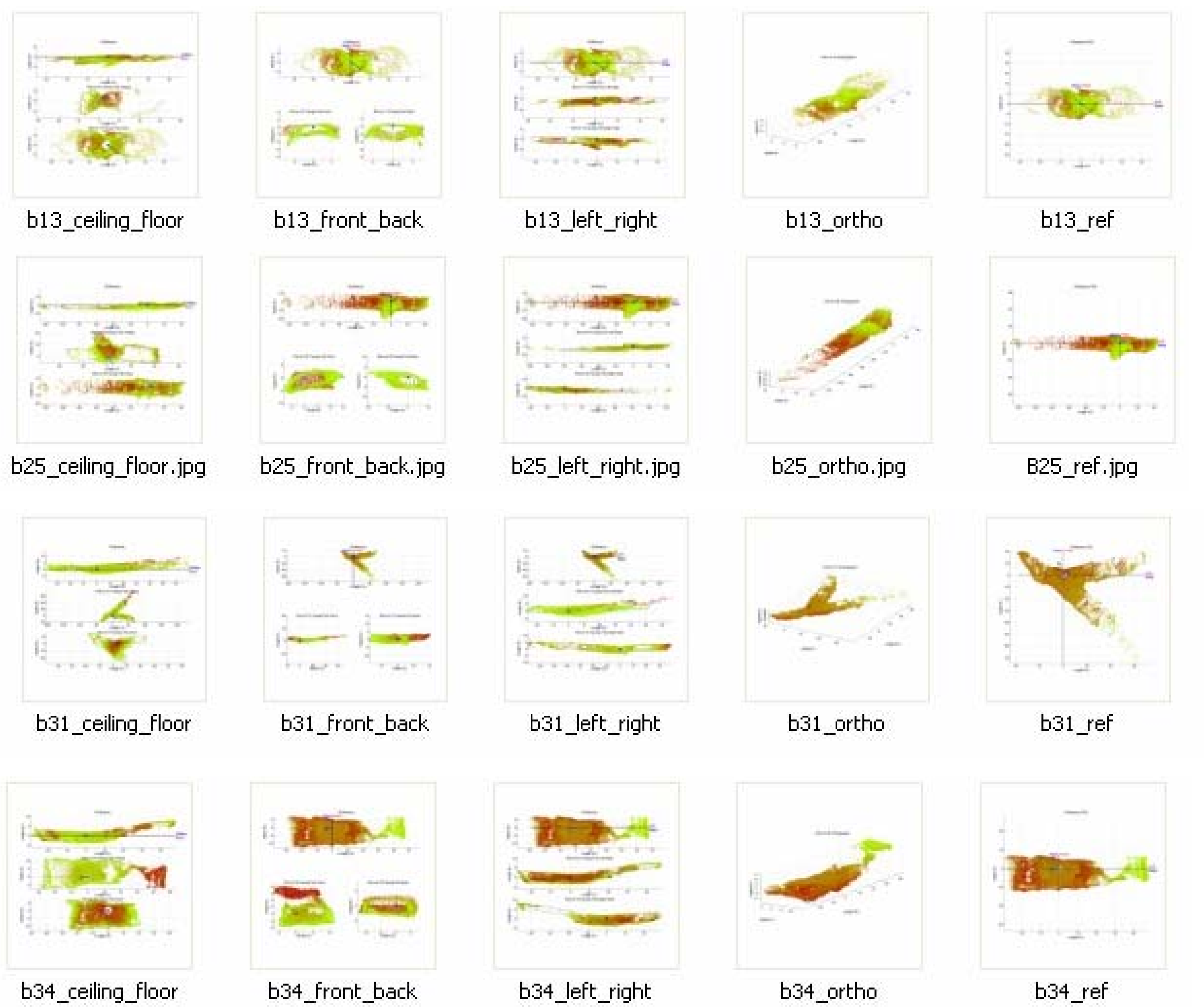
b34-000 SCN File 10,967 KB	b34-001 SCN File 27,209 KB	b34-002 SCN File 1,106 KB
b34-003 SCN File 3,331 KB	b34-004 SCN File 2,204 KB	
b34-000 Text Document 3,877 KB	b34-001 Text Document 3,569 KB	b34-002 Text Document 69 KB
b34-003 Text Document 1,184 KB	b34-004 Text Document 802 KB	
B-34 video Video Clip 246,348 KB		

DivXPlay.exe

Readme.txt


Results


Cross Section Plots


b13_ceiling_floor
b13_front_back
b13_left_right
b13_ortho
b13_ref
b25_ceiling_floor.jpg
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b25_left_right.jpg
b25_ortho.jpg
B25_ref.jpg
b31_ceiling_floor
b31_front_back
b31_left_right
b31_ortho
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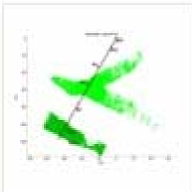
b34_left_right
b34_ortho
b34_ref

Extra Plots



Layout

Point Files

B13_pts B25_pts B31_pts B34_pts Readme

Volume Estimates

Readme
Text Document
1 KB

volumes
Text Document
1 KB

VRML Files

B31_B34 BH13 BH25 BH31 BH34

APPENDIX B
FORWARD MODELING OF THE RESPONSE OF THE DC RESISTIVITY TECHNIQUE TO MINE WORKINGS

APPENDIX B – FORWARD MODELING OF THE RESPONSE OF THE DC RESISTIVITY TECHNIQUE TO MINE WORKINGS

For any geophysical technique to be effective, the target of interest must have a physical contrast with surrounding material such that it can be distinguished. For the purpose of modeling coal mine workings, the assumption has been made that the mine is at least partially flooded. As discussed in the results of the Lots Branch survey, the possibility does exist to image dry workings, but the presence of water greatly enhances the possibility that electrical measurements can detect mine workings.

Mine water at Lots Branch ranges from 100 µS/cm to >1,990 µS/cm. The average of the measured values is approximately 800 µS/cm. The contrast between a flooded or even a partially flooded mine compared to a typical coal resistivity of 500 to 1,500 ohm-meters will approach two orders of magnitude.

Forward modeling of coal workings offers the possibility of determining the resistivity measurements that would theoretically be made in the field with different electrode configurations. The means to effectively conduct forward modeling is also a relatively recent innovation. At the time of the start of the demonstration project, two-dimensional (2-D) modeling was the current state-of-the-practice. During the course of the demonstration project, three-dimensional (3-D) modeling became commercially available. This discussion presents the results of both 2-D and 3-D modeling in terms of defining the capabilities and limitations of the DC resistivity technique for imaging abandoned mine workings.

2-D MODELING

The RES2DMOD program developed by Loke (2002) and available at no cost from from Geotomo Software at www.geoelectrical.com offers the possibility of calculating theoretical electrical measurements for different subsurface conditions that can then be used as input to the RES2DINV program based on either finite element or finite difference modeling. The results depict what electrical cross sections should look like for different subsurface conditions. These theoretical electrical profiles can then be compared to real-world profiles and facilitate the interpretation of real subsurface conditions. Figure B1 depicts the process of calculating an electrical profile from a theoretical model.

The example depicted in Figure B1 illustrates a model corresponding to a 2-meter (6.6-foot) thick coal seam whose base is at a depth of 10 meters (33 feet). Although the average measured value of mine water from Lots Branch was approximately 800 µS/cm, a value of 500 µS/cm, which corresponds to a resistivity of 20 ohm-meters, was used for modeling given the wide range of measured values, with some as low as 100 µS/cm. The sandstone rock encountered both above and below the Lewiston Coal ranges in resistivity from about 500 to 1200 ohm-meters and for the purpose of modeling has been assumed to have a resistivity of 800 ohm-meters. The coal has been assumed to have a resistivity of 1,000 ohm-meters, which is typical of coal, but is not a contrast that would be expected to be readily distinguishable from the surrounding sandstone, which is the case with the results from Lots Branch. The mine openings and the pillars separating them are assumed to be 5 meters (16 feet) in width. The resistivity measurements are defined for the Wenner-Schlumberger configuration with an electrode separation of 2.5 meters (8 feet).

With this typical model, the RES2DMOD program calculates theoretical readings, which in turn form the basis for the calculation of a theoretical cross section with the RES2DINV program, as depicted on Figure B1.

In the example shown on Figure B1, the mine workings are easy to recognize, but it is not practical to distinguish individual room and pillars. If the mine workings had been shallower and/or the individual rooms had been wider, it would have been practical to image individual rooms and pillars. Figure B2 depicts the same model as shown on Figure B1, except that the rooms have been widened to be 7.5 meters (25 feet) wide, rather than the 5 meters (16 feet) assumed for the model shown on Figure B1. With rooms 7.5 meters wide the mine workings are easy to recognize, as are the pillars separating them. It should be noted that the coal itself does not stand out as a separate layer, as proved to be the case at Lots Branch. If the actual depth of the coal had not been not known in advance, it would have been difficult to precisely define the position of the coal.

In contrast to the coal, the modeling strongly defines the water-flooded mine openings. A problem with the interpretation of the voids is that it is difficult to determine the thickness of the void as the zone of low resistivity appears to extend both above and below its actual position. If the mine is only partially flooded (Figure B3), the results still appear similar to Figure B1, except that the overall contrast is weaker and the vertical uncertainty in the position of the void increases. Again, a correct interpretation of the model requires that the position of the coal be defined in advance.

The modeling from the Lewiston seam confirms the basic observation that when the depth to the coal seam increases, resolution quickly decreases, primarily because of the need to increase the electrode spacing to achieve the depth of interest. Figure B4 depicts the variation of theoretical response of a typical coal mine model, placing the coal seam and voids at increasing depths. With the initial depth of 10 meters (33 feet), the rooms and pillars are easy to resolve, but the deeper models depict only a single anomaly for the mined-out area and it is not practical to distinguish individual rooms and pillars. The anomaly associated with the mine workings at a depth of 18 meters (60 feet) is readily discernable, although it is necessary to know the position of the coal as the resistivity low associated with the mine workings extends many meters above and below the actual voids. The shape of the anomaly for the workings at 28 meters (92 feet) appears similar to the form from 18 meters, but the intensity of the anomaly is significantly less and is only a factor of about three less than that of the background rock. This contrast could be difficult to measure under field conditions if the data are noisy or there are other factors such as variable topography to interfere with the data acquisition. The resistivity contrast associated with mine workings at a depth of 50 meters (164 feet) is less than a factor of two below that of the background rocks. Although theoretically detectable, field conditions would make the detection difficult. The model from a depth of 100 meters (328 feet) is effectively undetectable, even from the theoretical model.

An important practical difficulty defined by the models is the length of the profile necessary to image to different depths. The length of a pole-dipole profile necessary to image a 70-meter wide target at a depth of 10 meters is about 130 meters (425 feet). The length of the line necessary to image to 50 meters would be about 400 meters (1,300 feet), which could be impractical at many locations.

One of the difficulties in detecting deeper mine workings from the theoretical model is that ratio of the depth of the target to the total width of the target (70 meters in the model) increases with increasing depth. The model indicates that reliable results are obtained when the depth/target width ratio is greater than 2. Figure B5 depicts a comparison of the ability to detect two targets at a depth of 50 meters (164 feet), one that is 70 meters (230 feet) wide and another that is 160 meters (525 feet) wide. When the mine workings are 160 meters wide, they are much more easily detectable, although it still necessary to have equipment that will be able to put enough current into the ground such that the workings can be imaged.

Comparison of Theoretical 2-D Models with Actual Abandoned Mine Workings – Examples not at Lots Branch

Several case histories in addition to the case histories developed at Lots Branch can be used to compare theoretical models with actual abandoned mine workings. These case histories are useful as they offer examples of the geophysical response of mine workings containing more water than encountered at Lots Branch. The details of some of these case histories have been previously presented and are not repeated here (Johnson, 2003; Johnson and Snow, 2002 and Johnson, Snow and Clark, 2002).

Base of Coal at Approximately 10 Meters (33 feet)

A case history depicting conditions where the base of the coal mine workings is at a depth of approximately 10 meters is at the Regency Park Subdivision, Plum Borough, Pennsylvania. The Regency Park subdivision is located over shallow mine workings associated with the Plum Creek Mine operated in the late 19th and early 20th century. The subdivision has been the location of numerous foundation failures over the past several decades since the homes were constructed. The results shown on Figure B6 define a series of resistivity lows that bottom out near the bottom of the Pittsburgh Coal seam at a depth of about 30 feet as known from available mine maps and the results of borings drilled along the profile. Where borings were drilled within 5 feet of the profile, the resistivity lows were found to correspond to mine voids (partially collapsed) and the zones of relatively high resistivity between the lows was found to contain coal. The mine is not completely flooded. Typically, there is no more than about two feet of water in the mine.

Figure B6 compares the actual Regency Park profile with a predictive model of a partially flooded mine. Model constraints indicate that the mine water must be fairly acidic, as a 2,500 µS/cm conductivity, which corresponds to a resistivity of 4 ohm-meters, best fits with a model that is close to the actual results. In both the actual and theoretical models, the electrical measurements exaggerate the thickness of the flooded portion of the mine.

Base of Coal at Approximately 20 meters (66 feet)

A case history that depicts conditions where the base of the coal mine workings is at a depth of approximately 20 meters is from a survey conducted next to a mine tailings impoundment in Jefferson County, Pennsylvania. A single profile was conducted with the pole-dipole technique with a 20-meter electrode spacing over known mine workings at a depth of approximately 20 meters (64 feet). In this case the mine was also known to be fully flooded. The results shown on

Figure B7 indicate the presence of a pronounced resistivity low in the area of the known mine entries. The results do not distinguish separate rooms and pillars, as predicted from the theoretical modeling, but the extent of the known mine openings is clear. The results also indicate the probable presence of unknown workings.

Figure B7 compares the actual Jefferson County profile with a predictive model of a completely flooded mine consistent with the known mine workings at this location. Model constraints indicate that the mine water should be close to 1,200 µS/cm conductivity (8 ohm-meters), as this value best fits with a model that is close to the actual results. In both the actual and theoretical models, the electrical measurements exaggerate the thickness of the flooded portion of the mine. The probable unknown mine workings were not modeled.

Base of Coal at Approximately 30 meters (98 feet)

An example from SW Indiana offers the possibility of comparing theoretical versus actual data from a mine near a depth near 30 meters in a complex setting. The property is underlain by two coal seams, the No. 7 seam at an approximate depth of 9 meters (30 feet) and the No. 6 seam at about 27 meters (90 feet). The shallower of the two seams was partially surface mined and the available mine map indicates the presence of some auger workings extending from the former highwall. The deeper seam was mined underground.

In terms of a resistivity target, the deep mine workings represent a much more complicated target than the previous two case histories, considering both depth and the complex conditions above the seam, including strip mining and auger mining of a shallower seam. The survey was conducted with an "unconventional" pole-dipole configuration with an electrode spacing of 10 meters. The pole-dipole survey applied for this survey is considered "unconventional" because the "infinite" electrode was not placed in a remote position on the ground, but was located within the deep coal seam.

The results of the single test line provided two useful pieces of information. The results depict the presence of shallow augering of coal from the former strip mine highwall in an area where it was not known to exist. Also, the existing mine map appears to be a good representation of the deep mine workings. The survey results indicate the presence of a resistivity low across the area where deep workings were known to exist.

Figure B8 compares the actual SW Indiana profile with a predictive model of a fully flooded deep mine that also includes shallow auger workings and mine spoil. Model constraints indicate that the mine water must be very acidic, as a 5,000 µS/cm conductivity, which corresponds to a resistivity of 2 ohm-meters, best fits with a model that is close to the actual results. In both the actual and theoretical models, the electrical measurements do not resolve the vertical extent of the mine voids and the results are useful only in defining the lateral extent of the workings and it is necessary to know the depth of the coal. The mine spoil and the augering of the base of the strip mined seam are well defined.

Base of Coal at Approximately 50 meters (164 feet)

An attempt was made to image mine workings at a depth of 50 meters at a location in Harmar Township, PA over workings of the Harwick Mine in the Upper Freeport Coal. This mine was operated in the late 19th and early 20th century and the entire survey area was essentially mined out except for a 100 x 100 foot block of coal surrounding an old oil or gas well. The purpose of the survey was to determine if this block of coal was still remaining as part of a geotechnical study to evaluate subsurface stability.

The survey was conducted with a pole-pole configuration with a 20-meter electrode spacing, which is different than the previous examples. With the pole-pole configuration one current electrode and one voltage electrode are placed at an "infinite" distance from the survey profile. The other two electrodes are moved along the profile at multiples of the 20-meter spacing up to a factor of 8 (160-meter electrode separation). The pole-pole configuration was used to improve the signal to noise ratio and obtain the maximum depth of penetration, but the drawback to this technique is that resolution is lost. The results of this survey indicate that sufficient resolution was not obtained (Figure B9). The results do not appear to have any relationship to the coal seam, but it is noted that the highest resistivity values are immediately above the anticipated coal pillar. It is speculated that the survey is actually responding to a less fractured rock above the unmined coal, which would be expected to have a relatively higher resistivity than the saturated fractured rock over the mined out portions of the Harwick Mine, assuming some mine subsidence has occurred. No attempt was made to model this field survey.

Conclusions from 2-D Modeling

Efforts to delineate underground mine workings typically rely on available maps and confirmatory boreholes and the characterization of regions between boreholes is uncertain. Electrical resistivity measurements can be used to supplement the borehole data and reduce the uncertainty of the interpretation. Furthermore, electrical measurements can be used to optimize the number and locations of the boreholes.

Project experience with DC electrical measurements demonstrates that commercially available technology can be effective, especially for the rapid mapping mine workings at depths up to about 100 feet. For deeper workings, the method has the potential to be effective, but theoretical models and practical experience demonstrate that the target size/depth ratio needs to be favorable and the required length of the resistivity profile to acquire deep images is often limited by surface interference. The method is therefore usually most effective for mine subsidence applications, rather than in evaluating the proximity of relatively deep active mines to abandoned, flooded workings, but local conditions can allow for this technique to be effective for deeper targets.

3-D MODELING

The following discussion presents the results of 3-D model with the intent of simulating conditions encountered at Lots Branch. Resistivity data are typically interpreted with the assumption that subsurface conditions represented by the data are 2-dimensional. This is because resistivity data are not often collected with sufficient density to permit processing by software that transforms raw (observed) data to 3-dimensional resistivity models. The process of converting observed measurements into a resistivity model of the subsurface is called inversion. This discussion presents the results of 2-D inversion of data generated from a 3-D model.

The software used to generate the 3-D model is RES3DMOD (Loke, 2005). It is provided at no cost from Geotomo Software at www.geoelectrical.com. The model consists of 17 layers, with each layer consisting of 130 x 94 cells. The program assumes there are 2 cells between each electrode, so each layer consists of a grid of 66 x 48 electrodes. The model is based on a 3-meter electrode spacing. The area of desired coverage was too large to be included in a single model so it was generated as two separate models (Figure B10). The results were combined to create depth sections, each of which is 320 meters long. It is not possible to include topography in models used with the RES3DMOD program.

The depth to the bottom of each layer is as follows:

1	0.0875 m	10	19.25 m
2	1.75 m	11	24.0 m
3	2.75 m	12	30.0 m
4	4.00 m	13	39.0 m
5	5.50 m	14	50.0 m
6	7.25 m	15	65.0 m
7	9.50 m	16	85.0 m
8	12.25 m	17	110.0 m
9	15.50 m		

The coal layer is layer 9, and is therefore located between depths of 12.25 and 15.5 meters. Three resistivities were used for the model. The layers above and beneath the coal were assigned 1000 ohm-meters. The unmined coal was assigned 300 ohm-meters and the mined areas were assigned 10 ohm-meters.

The output of the model was a 3-D set of observed resistivity values for specified electrode configurations. In this case, the resistivity values were determined for pole-dipole and Wenner configurations. Data from specific east-west transects were extracted from each 3-D set and used as input in the 2-D inversion software RES2DINV. The inversion was performed for transects 21, 30, 42, and 51 meters south of the north edge of the model. These are shown in Figure B11 as Lines A, B, C and D, respectively.

Pole-Dipole Configuration

The results of the 2-D inversion of the pole-dipole data is shown in Figure B12. A response from the mine tunnels is seen in all 4 transects, including Line A which is 12 meters north of the end of the tunnels. In Line A, the depth to the top of the tunnels appears to be about 15 meters. The depth to the top of the tunnels appears to be about 13 in Line B, 11 meters in Line C and 10 meters in Line D. The actual depth is 12.25 meters. Additional workings are starting to appear at a depth of about 17 meters between 210 and 250 meters in Line D. The actual depth here also is 12.25 meters.

Wenner Configuration

The Wenner results are shown in Figure B13. The Wenner configuration did not detect the mine tunnels at Line A and only weakly at Line B, where they appear to be at a depth of about 12 meters. The tunnels show up well in Lines C and D, where they appear to be at a depth of about 8 meters. As above, the actual depth is 12.25 meters. The mine working between 210 and 250 meters were not detected.

Conclusions from 3-D Modeling

The primary question to be answered by this effort was to determine whether the interpreted depth would be deeper if the transect were off to the side of (or off the end of) the targeted mine workings. This work has shown that, in fact, the workings would appear deeper if data were collected along transects that were off to the side of workings. This was true whether the Wenner or pole-dipole configuration was used. The modeling effort also indicates that the pole-dipole configuration is able to detect the workings at a greater distance from their limit than the Wenner configuration.

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Johnson, W. J. and R.E. Snow, 2002, *Geophysical Methods for the Detection of Underground Mine Workings*, Association of State Dam Officials (ASDSO), Tailings Dams 2002, Las Vegas, Nevada, April 29 – May 1.

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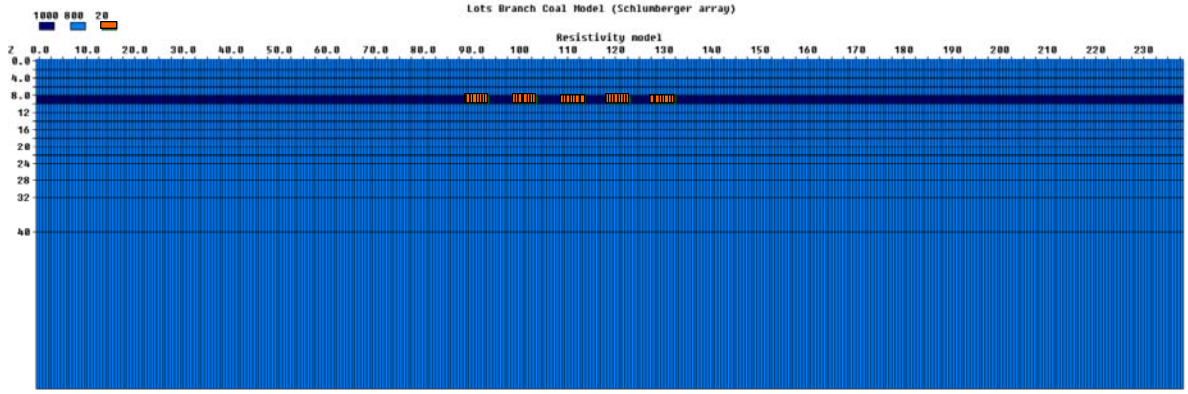
Loke, M. H., 2002, *RES2DMOD, Rapid 2-D Resistivity Forward Modeling Using Finite-Difference and Finite-Element Methods*, published at www.geoelectrical.com

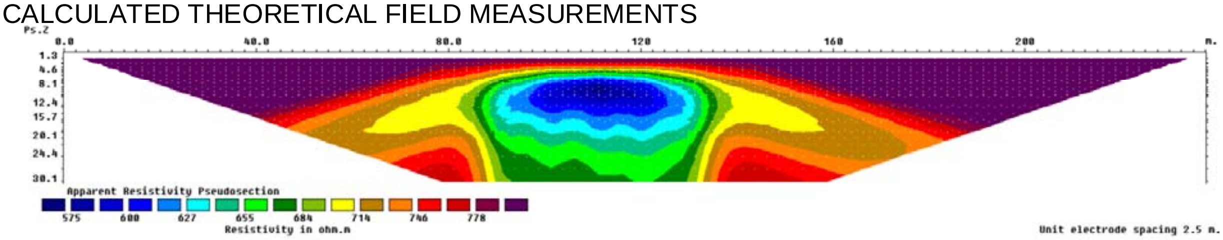
Loke, M. H., 2000, *A Practical Guide to 2-D & 3-D Electrical Imaging Surveys*, published at www.geoelectrical.com

Loke, M. H., 2005, *RES3DMOD ver. 2.14, 3-D resistivity & IP forward modeling using the finite-difference and finite-element methods*, published at www.geoelectrical.com

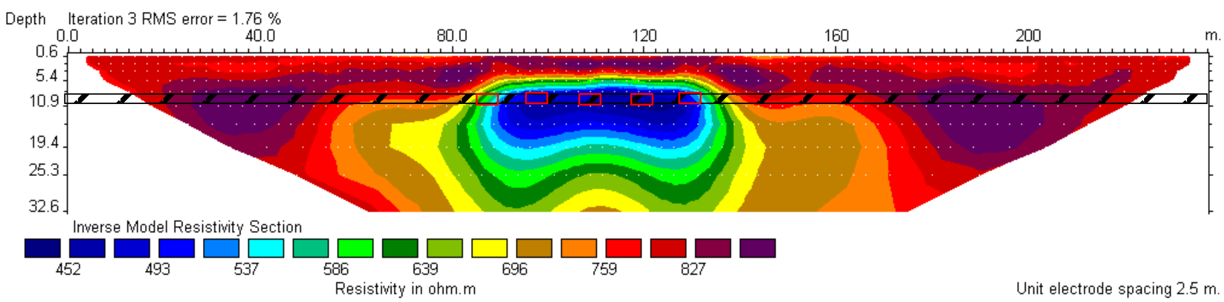
SUBSURFACE MODEL USED AS INPUT TO RES2DMOD PROGRAM



CALCULATED THEORETICAL FIELD MEASUREMENTS

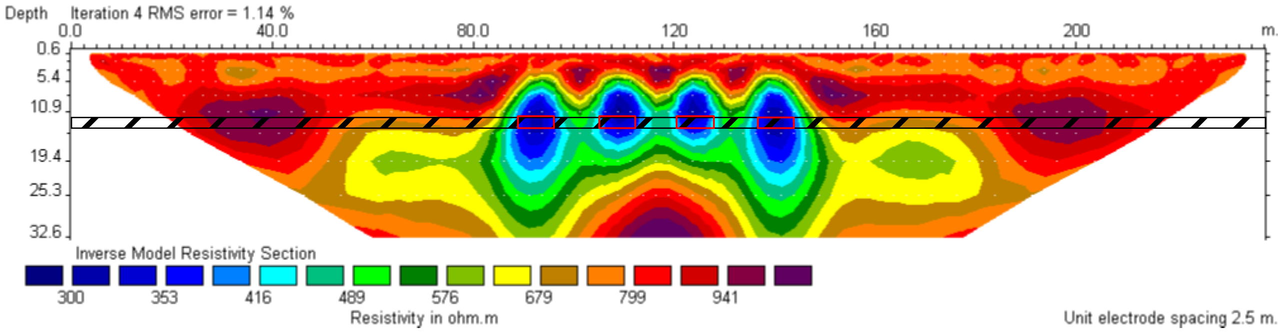


CROSS SECTION FROM RES2DINV PROGRAM BASED ON THEORETICAL FIELD MEASUREMENTS



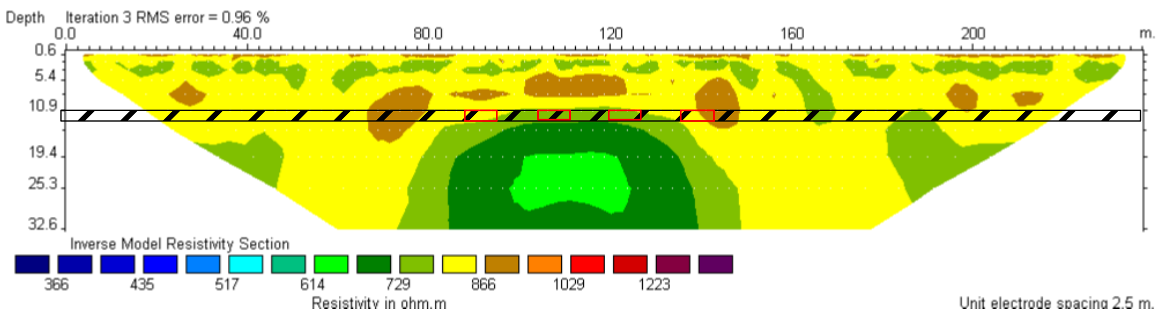
NOTE: Mine workings assumed to be flooded. Width of mine workings assumed to be 5 m (16 ft). Coal assumed to have a resistivity of 1000 ohm-meters; mine water assumed to have resistivity of 20 ohm-meters; and sandstone above and below the Lewiston Coal assumed to have a resistivity of 800 ohm-meters.

FIGURE B1 - DEPICTION OF MODELING PROCESS FOR
2M THICK FLOODED WORKINGS AT A DEPTH OF 10 M
WITH CHARACTERISTICS OF LEWISTON COAL WORKINGS



NOTE: Mine workings assumed to be flooded. Width of mine workings assumed to be 5 m (16 ft). Coal assumed to have a resistivity of 1000 ohm-meters; mine water assumed to have resistivity of 20 ohm-meters; and sandstone above and below the Lewiston Coal assumed to have a resistivity of 800 ohm-meters.

FIGURE B2 - RESULTS OF MODELING 2M THICK FLOODED WORKINGS AT A DEPTH OF 10 M WITH CHARACTERISTICS OF LEWISTON COAL WORKINGS, EXCEPT THAT THE WIDTH OF THE ROOMS HAS BEEN EXPANDED FROM 5 METERS TO 7.5 METERS



NOTE: Mine workings assumed to be partially flooded. (0.5m water) Width of mine workings assumed to be 5 m (16 ft). Coal assumed to have a resistivity of 1000 ohm-meters; mine water 20 ohm-meters; air void 10,000 ohm meters; and sandstone above and below the Lewiston Coal 800 ohm-meters.

FIGURE B3 - RESULTS OF MODELING 2M THICK PARTIALLY FLOODED WORKINGS AT A DEPTH OF 10 M WITH CHARACTERISTICS OF LEWISTON COAL WORKINGS

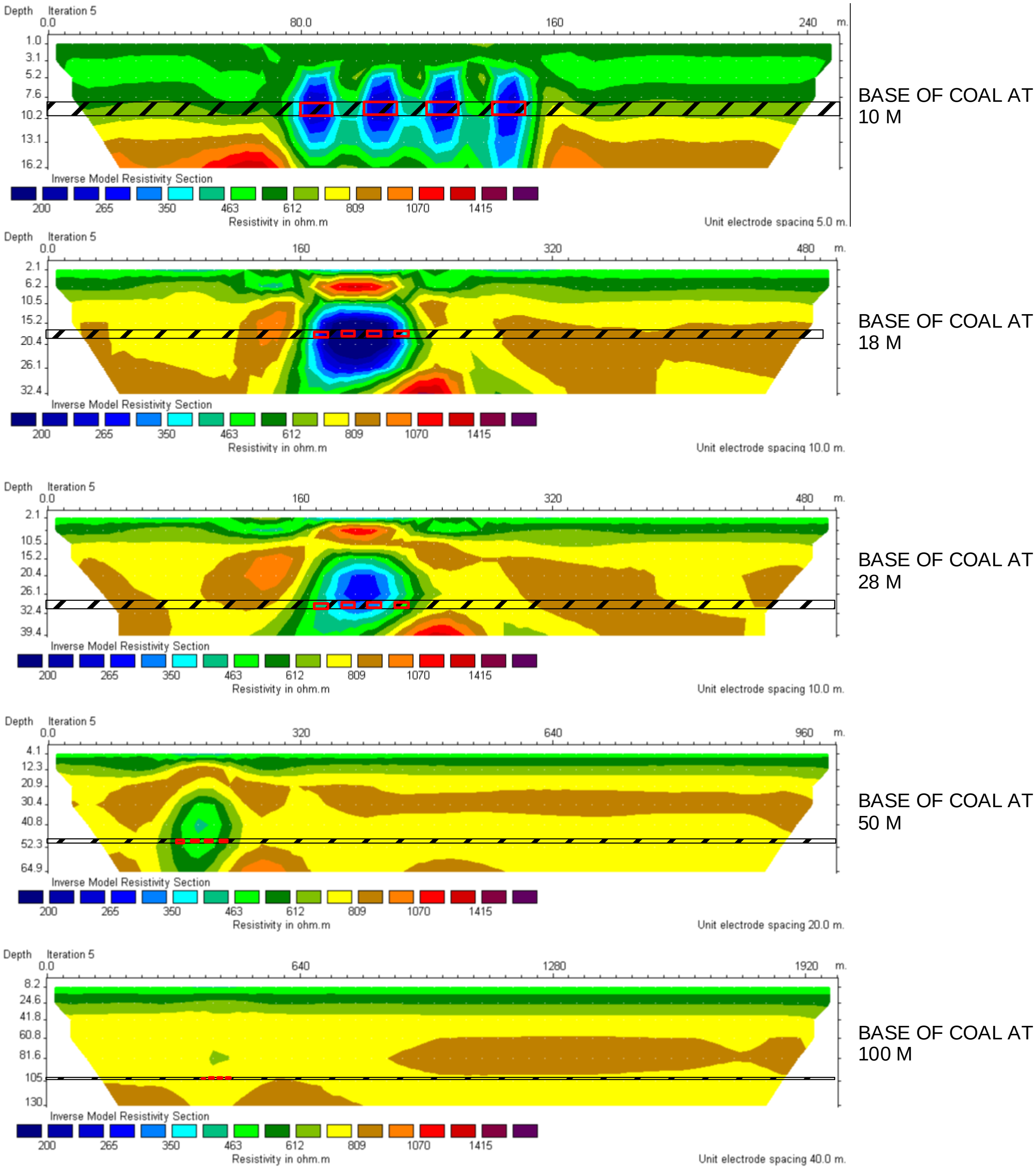
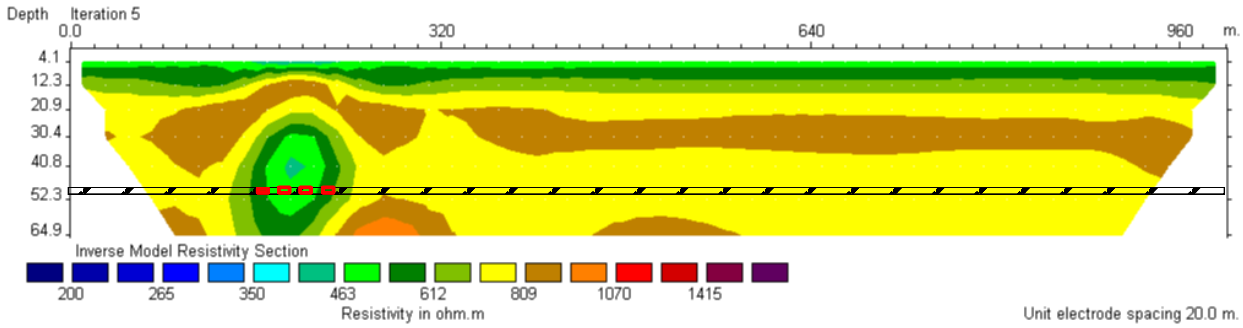
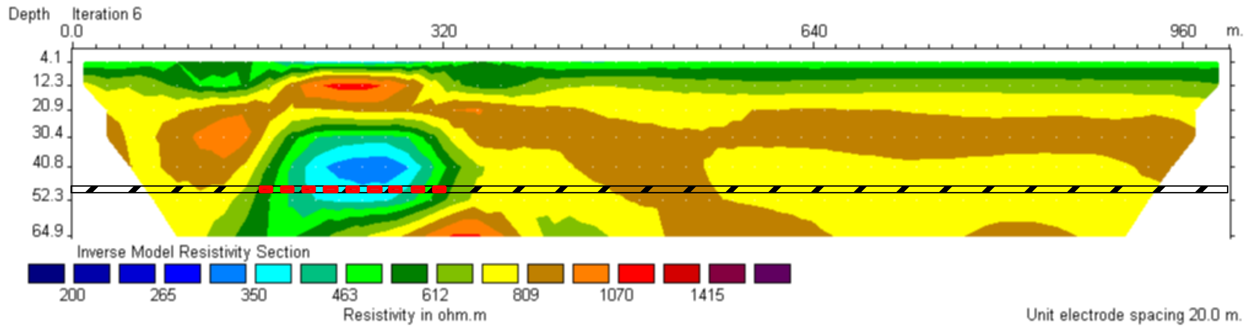


FIGURE B4 - MODEL RESULTS FOR FLOODED COAL WORKINGS AT DIFFERENT DEPTHS (COAL SEAM 2M THICK)



COAL MINE WORKINGS 70 M (230 FT) ACROSS



COAL MINE WORKINGS 160 M (525 FT) ACROSS

FIGURE B5 - MODEL RESULTS FOR FLOODED COAL WORKINGS OF DIFFERENT LATERAL EXTENTS, BOTH AT A DEPTH OF 50 M (COAL SEAM 2MTHICK)

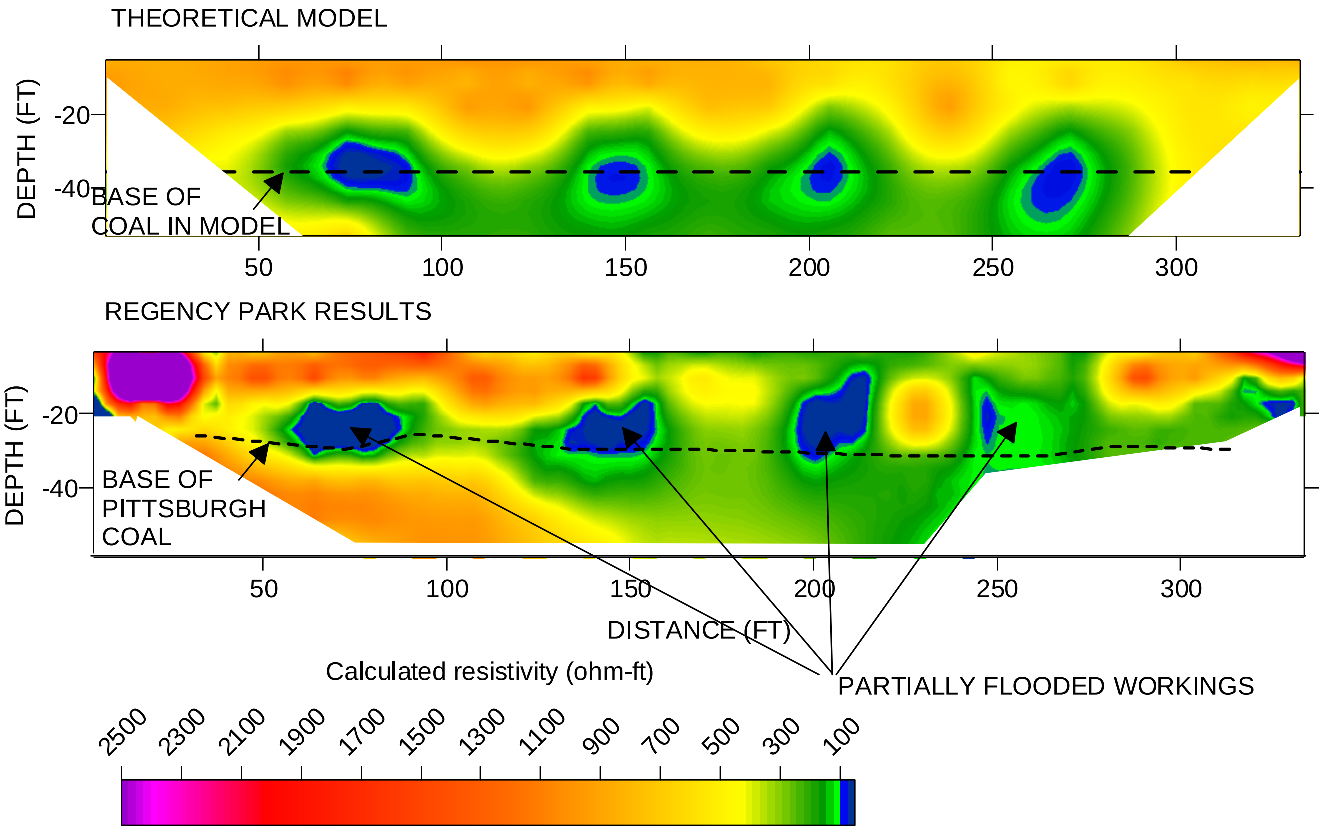
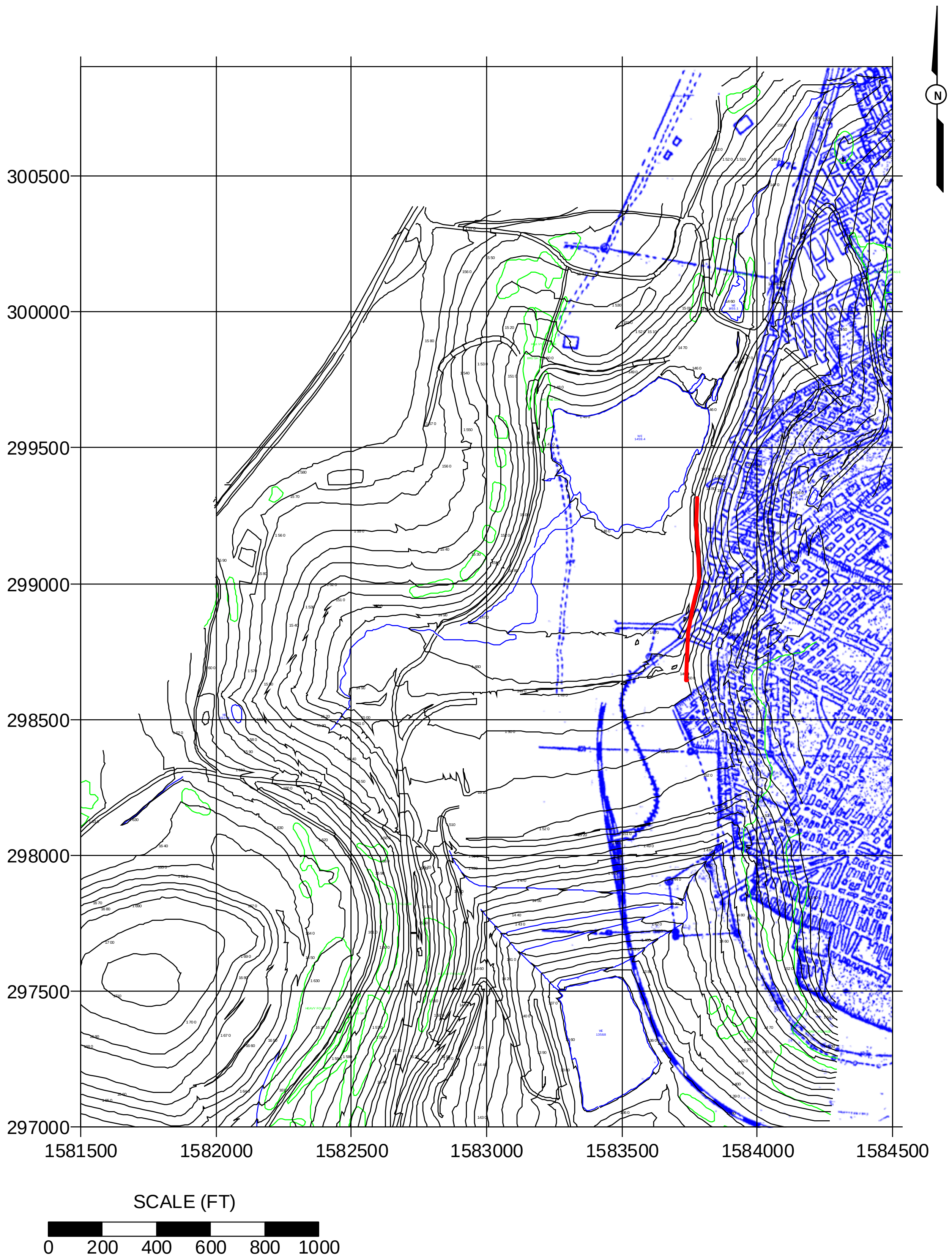


FIGURE B6 - PREDICTED AND ACTUAL RESULTS OF POLE-DIPOLE SURVEY OVER PITTSBURGH COAL SEAM AT REGENCY PARK, PA



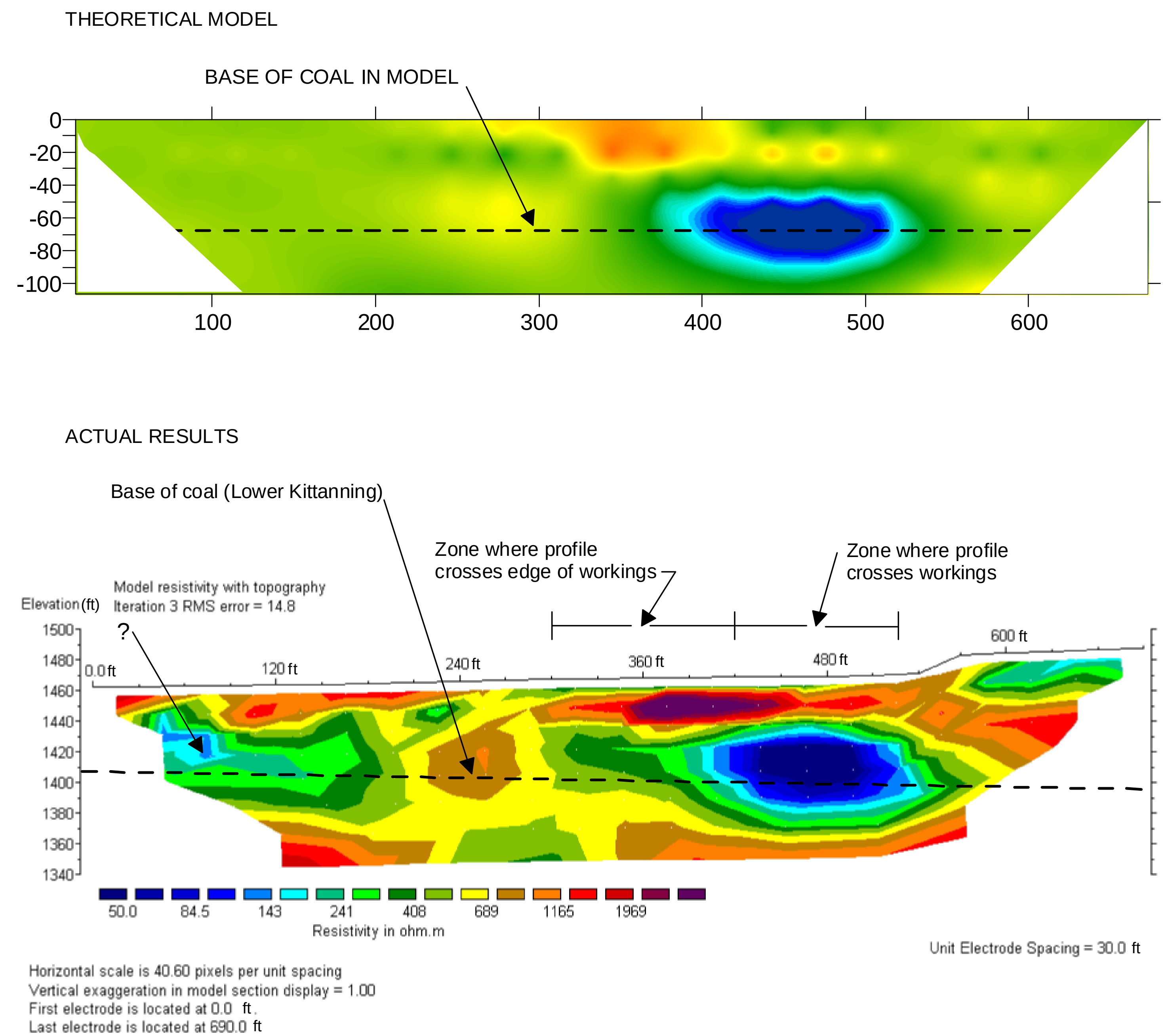


FIGURE B7 - PREDICTED AND ACTUAL RESULTS APPLYING THE POLE-DIPOLE ELECTRODE CONFIGURATION FROM TEST PROFILE NO. 1 AT THE WEISNER HOLLOW SITE

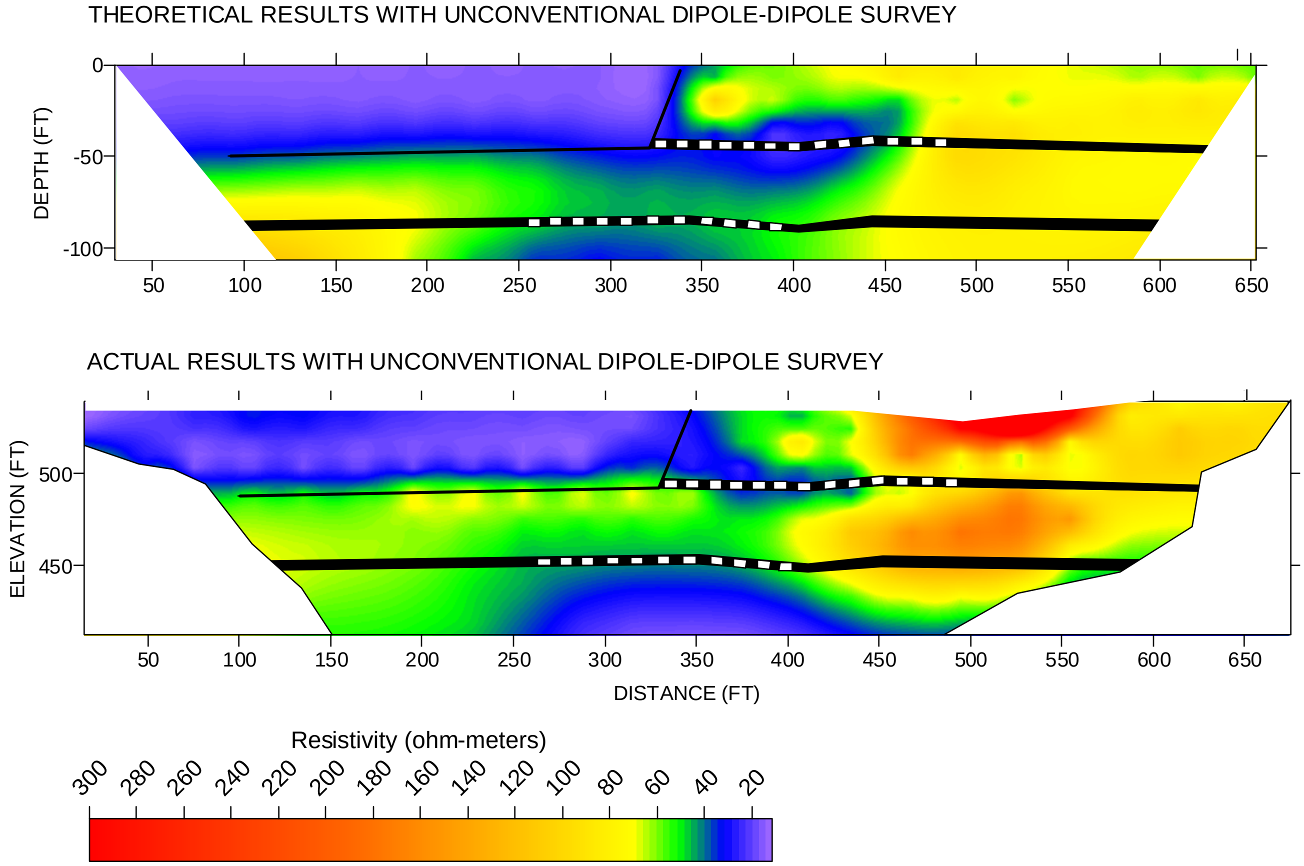


FIGURE B8 - PREDICTED AND ACTUAL RESULTS OF POLE-DIPOLE SURVEY OVER COAL SEAMS IN SW INDIANA

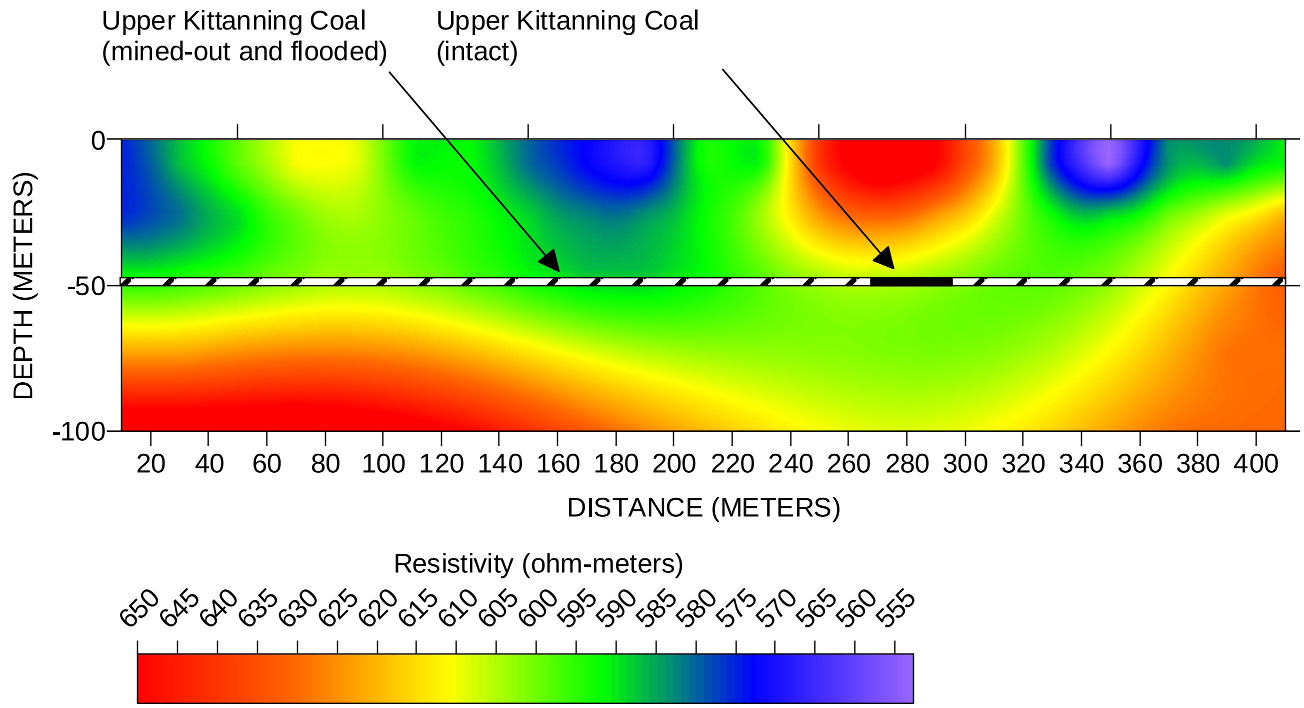


FIGURE B9 - ACTUAL RESULTS OF POLE-POLE SURVEY OVER HARWICK MINE IN HARMAR TOWNSHIP, PA

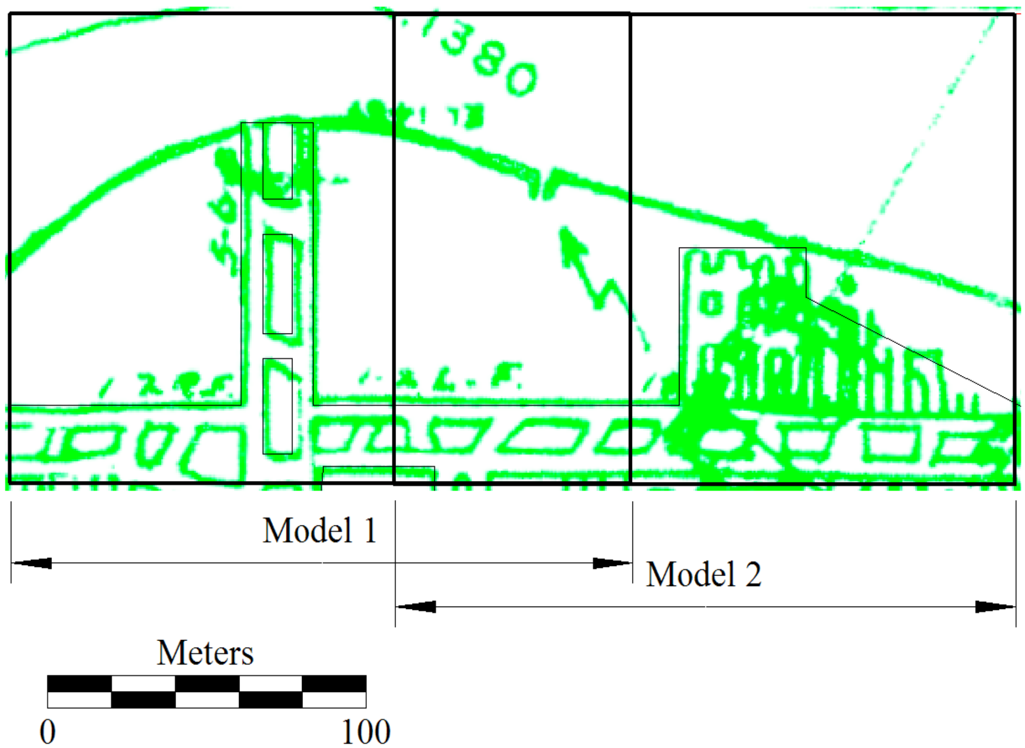


FIGURE B10 - BASIS OF 3-D RESISTIVITY MODELS.

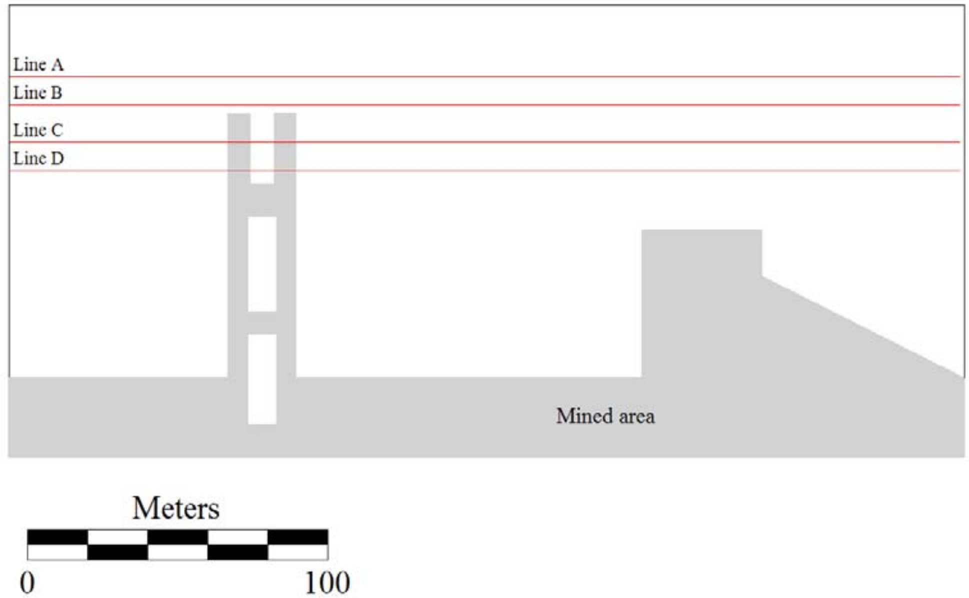


FIGURE B11 - TRANSECT LOCATIONS

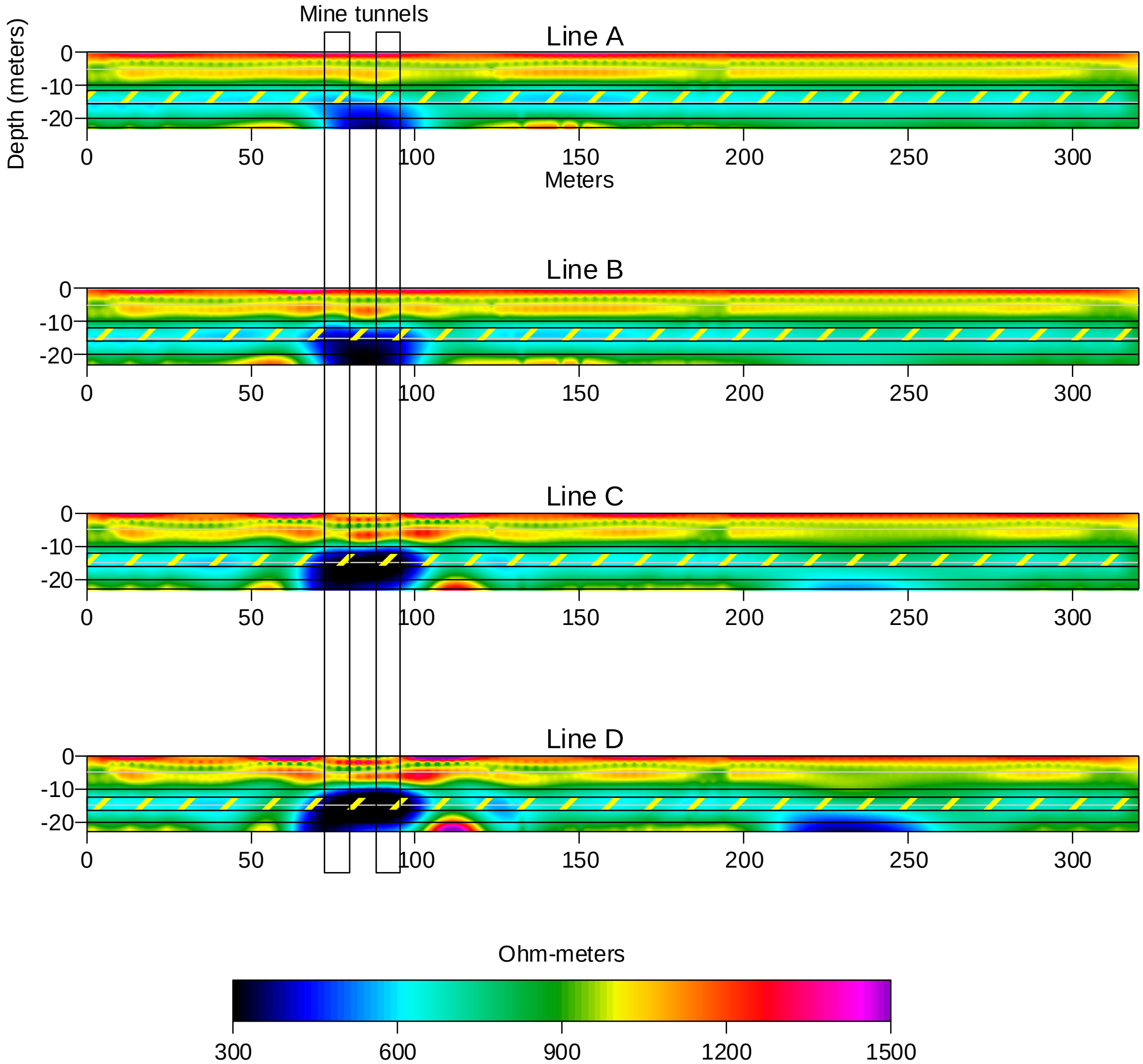


FIGURE B12 – 2D INVERSION FROM 3-D MODEL WITH POLE-DIPOLE CONFIGURATION

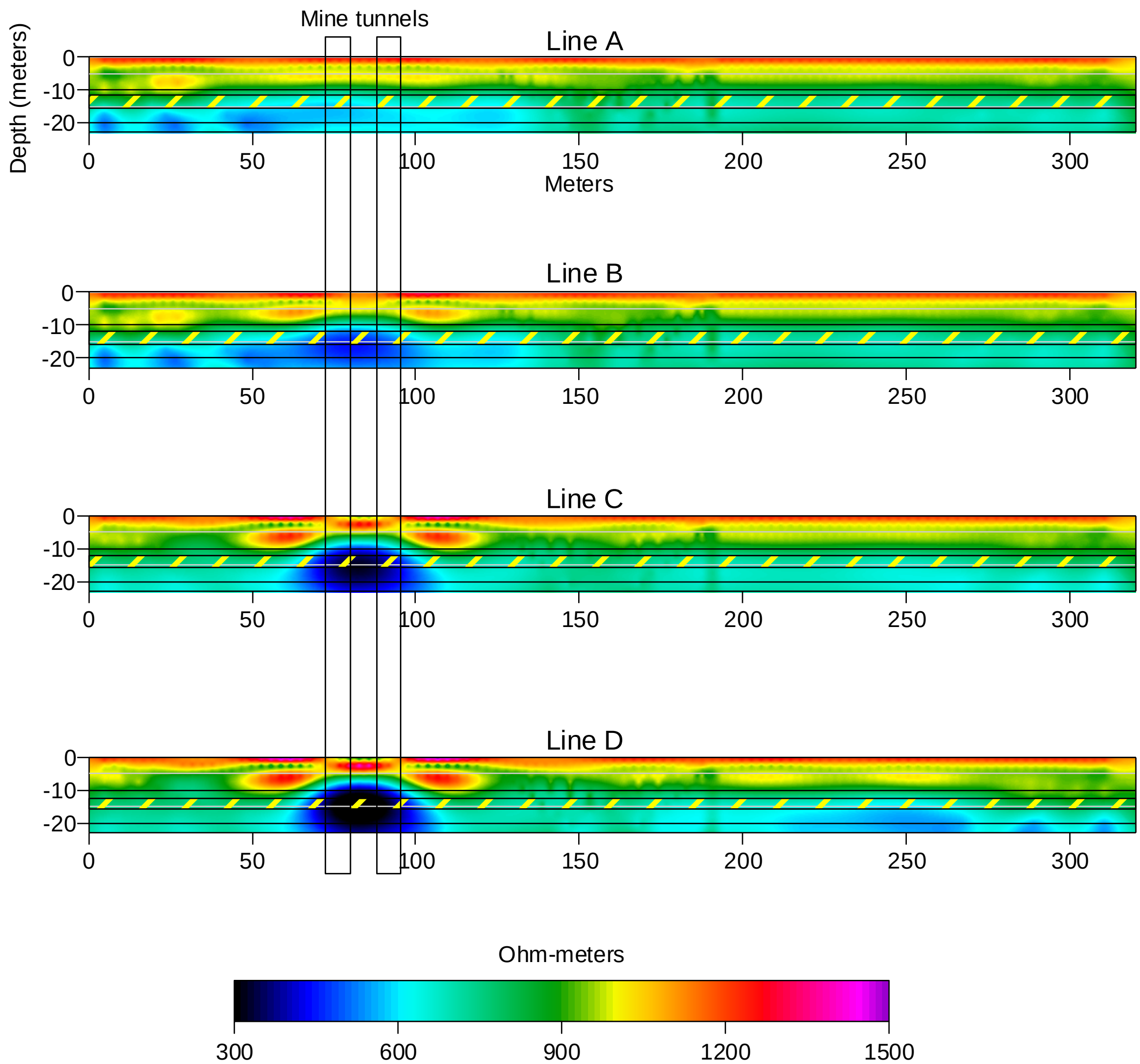


FIGURE B13 – 2D INVERSION FROM 3-D MODEL WITH WENNER CONFIGURATION

APPENDIX C
BORING LOGS AND GROUTING SCHEMATIC

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-1
	SHEET NO. 1 of 2	**DATE STARTED** 09-17-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-17-05
DRILLING METHOD Hetager track-mounted Rotary Drill with NX rock core (Wireline)	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)/ % REC.	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1540.57 GROUND WATER EL. 1533.46	COMMENTS:
0–5				**4-INCH DIAMETER CASING ADVANCED TO 4.9' THROUGH WEATHERED SANDSTONE** — 4.9'	
5	R-1	2.6 (100%)	8	SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)**	
10	R-2	5.0 (100%)	86		
15	R-3	5.0 (100%)	100		
20	R-4	5.0 (100%)	100		
25	R-5	4.8 (98%)	90		
30	R-6	5.0 (100%)	100		

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

[(1)]UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019 **SHEET NO.** 2 of 2	**BORING NO.** B-1 **DATE STARTED** 09-17-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-17-05
DRILLING METHOD Hetager track-mounted Rotary Drill with NX rock core (Wireline)	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)/ % REC.	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1540.57 GROUND WATER EL. 1533.46	COMMENTS:
	R-6 (CONT)	5.0 (100%)	100	SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **34.5'**	
35	R-7	5.0 (100%)	68	UNWEATHERED BROKEN TO UNBROKEN MEDIUM HARD DARK GRAY **SILTY SHALE** WITH BLACK COAL LENSES **36.9'**	
				SLIGHTLY WEATHERED VERY BROKEN SOFT TO MEDIUM HARD **BLACK COAL** **37.7'**	
40	R-8	5.0 (100%)	74	UNWEATHERED BROKEN TO UNBROKEN MEDIUM HARD DARK GRAY **SILTY SHALE** WITH BLACK COAL LENSES **42.9'**	
45	R-9	4.7 (94%)	0	SLIGHTLY WEATHERED VERY BROKEN TO BROKEN SOFT TO MEDIUM HARD **BLACK COAL** **(LEWISTON COAL FORMATION)** **49.8'**	
50	R-10	5.0 (100%)	56	UNWEATHERED UNBROKEN MEDIUM HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
55				**BOTTOM OF BORING B-1 AT 52.5'**	
60					

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

[(1)]UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-2
	SHEET NO. 1 of 1	**DATE STARTED** 09-16-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-16-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1540.27 GROUND WATER EL. 1494.12	COMMENTS:
0–32.2				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **32.2'**	
32.2–41.2				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **41.2'**	**NO AIR LOST**
41.2–46.5				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** **46.5'**	
46.5–48.3				INTERBEDDED SLIGHTLY WEATHERED SOFT BLACK **COAL** AND SLIGHTLY WEATHERED MEDIUM HARD DARK GRAY **SHALE** **48.3'**	
48.3–49.5				UNWEATHERED HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
				BOTTOM OF B-2 AT 49.5'	

Depth scale: 10, 20, 30, 40, 50, 60

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

(1)UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-3
	SHEET NO. 1 of 1	**DATE STARTED** 09-15-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-15-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1517.70 GROUND WATER EL. 1475.50	COMMENTS:
0–31.0				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **31.0'**	
				SLIGHTLY WEATHERED SOFT BLACK **COAL** **32.0'**	
				UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **39.1'**	**NO AIR LOST**
				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** **44.2'**	
				INTERBEDDED SLIGHTLY WEATHERED SOFT BLACK **COAL** AND SLIGHTLY WEATHERED MEDIUM HARD DARK GRAY **SHALE** **46.5'**	
				UNWEATHERED HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
				BOTTOM OF B-3 AT 49.5'	

Depth scale: 10, 20, 30, 40, 50, 60

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

(1) UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019 **SHEET NO.** 1 of 1	**BORING NO.** B-4 **DATE STARTED** 09-15-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-15-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1516.74 GROUND WATER EL. 1474.54	COMMENTS:
0 – 30.7'				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS** **SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **30.7'**	
30.7' – 32.5'				SLIGHTLY WEATHERED SOFT BLACK **COAL** **32.5'**	
32.5' – 39.8'				UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **39.8'**	**NO AIR LOST**
39.8' – 45.0'				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** **45.0'**	
45.0' – 46.5'				SLIGHTLY WEATHERED MEDIUM HARD DARK GRAY **SHALE** **46.5'**	
46.5' – 49.5'				UNWEATHERED HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
				BOTTOM OF B-4 AT 49.5'	

Depth scale: 10, 20, 30, 40, 50, 60

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

[(1)]UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-5
	SHEET NO. 1 of 2	DATE STARTED 09-16-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-17-05
DRILLING METHOD Hetager track-mounted Rotary Drill with NX rock core (Wireline)	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)/ % REC.	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1517.89 GROUND WATER EL. 1485.79	COMMENTS:
0–5.7				**4-INCH DIAMETER CASING ADVANCED TO 5.7' THROUGH WEATHERED SANDSTONE** **5.7'**	
5	R-1	1.3 (100%)	92	SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE**	
10	R-2	5.0 (100%)	72		
15	R-3	5.0 (100%)	90	**(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)**	
20	R-4	5.0 (100%)	100	**(HOMEWOOD SANDSTONE FORMATION)**	
25	R-5	5.0 (100%)	100		
30	R-6	5.0 (100%)	58	**29.5'** UNWEATHERED VERY BROKEN SOFT **BLACK COAL** **29.8'**	

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D'APPOLONIA

(1)UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-5
	SHEET NO. 2 of 2	DATE STARTED 09-16-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-17-05
DRILLING METHOD Hetager track-mounted Rotary Drill with NX rock core (Wireline)	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)/ % REC.	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1517.89 GROUND WATER EL. 1485.79	COMMENTS:
	R-6 (CONT)	5.0 (100%)	58	INTERBEDDED UNWEATHERED BROKEN TO UNBROKEN MEDIUM HARD DARK GRAY **SILTY SHALE** WITH SOFT **BLACK COAL** **32.9'**	
35	R-7	5.0 (100%)	70	UNWEATHERED BROKEN TO SLIGHTLY BROKEN MEDIUM HARD DARK GRAY **SILTY SHALE** **37.7'**	
40	R-8	5.0 (100%)	0	SLIGHTLY WEATHERED VERY BROKEN TO BROKEN SOFT TO MEDIUM HARD **BLACK COAL** **(LEWISTON COAL FORMATION)** **43.0'**	
				SLIGHTLY WEATHERED VERY BROKEN MEDIUM HARD DARK GRAY **SHALE** AND SOFT **BLACK COAL** **44.0'**	
45	R-9	4.8 (96%)	58	UNWEATHERED UNBROKEN HARD GRAY **LIMESTONE**	
50				**BOTTOM OF BORING B-5 AT 47.0'** UNWEATHERED UNBROKEN MEDIUM HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
55					
60					

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D'APPOLONIA

[1] UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-6
	SHEET NO. 1 of 1	DATE STARTED 09-15-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-15-05
DRILLING METHOD Driltech 40D Air Rotary Drill	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1530.36 GROUND WATER EL. 1488.26		COMMENTS:
10				HIGHLY TO SLIGHTLY WEATHERED SOFT TO MEDIUM HARD REDDISH-BROWN **SHALE**	10.5'	
20 30				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS** **SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)**	34.5'	
				SLIGHTLY WEATHERED SOFT BLACK **COAL**	35.5'	
				SLIGHTLY WEATHERED MEDIUM HARD GRAY **SHALE** WITH COAL LENSES	37.0'	
				SLIGHTLY WEATHERED SOFT BLACK **COAL**	38.0'	
40				SLIGHTLY WEATHERED MEDIUM HARD GRAY **SHALE** WITH COAL LENSES **(SANDY AREAS)**	42.0'	**AIR RETURN LOST: 42.7'** **VOID NOT OPEN ENOUGH TO MONITOR**
				SLIGHTLY WEATHERED SOFT BLACK **COAL**	42.7'	
				AIR-FILLED VOID	43.7'	
50				**MINE SPOIL-FILLED VOID**	50.2'	**BORING CAVED IN AFTER REMOVING BIT**
				UNWEATHERED HARD GRAY **LIMESTONE**		
60				**BOTTOM OF B-6 AT 54.5'**		

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D'APPOLONIA

[1]UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-7
	SHEET NO. 1 of 1	DATE STARTED 09-15-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-15-05
DRILLING METHOD Driltech 40D Air Rotary Drill	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1529.20 GROUND WATER EL. 1488.30	COMMENTS:
0–31.2				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **31.2'**	
				SLIGHTLY WEATHERED SOFT BLACK **COAL** **31.9'**	
				UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **36.3'**	**MINE TEMPERATURE 70.2°F**
				MINE SPOIL-FILLED VOID **40.5'**	**AIR RETURN LOST: 36.3'**
				AIR-FILLED VOID **42.7'**	**VOID NOT OPEN ENOUGH TO MONITOR**
				MINE SPOIL-FILLED VOID **47.0'**	**BORING CAVED IN AFTER REMOVING BIT**
				UNWEATHERED HARD GRAY **LIMESTONE**	
				BOTTOM OF B-7 AT 49.5'	

Depth scale: 10, 20, 30, 40, 50, 60

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D'APPOLONIA

[1] UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA		**PROJECT NO.** 031019	**BORING NO.** B-8
		SHEET NO. 1 of 1	**DATE STARTED** 09-15-05
BORING LOCATION SEE FIGURE		**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-15-05
DRILLING METHOD	Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1529.17 GROUND WATER EL. 1487.66		COMMENTS:
10				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)**		
20						
30					32.7'	
				UNWEATHERED SOFT GRAY **SHALE** AND SOFT BLACK **COAL**	33.8'	
				SLIGHTLY WEATHERED SOFTBLACK **COAL**	34.8'	
				INTERBEDDED SIGHTLY WEATHERED SOFT DARK GRAY **SHALE,** SOFT GRAY **CLAYSTONE** AND SOFT BLACK **COAL**	39.7'	**AIR RETURN LOST: 42.5'**
40				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)**	42.5'	**VOID NOT OPEN ENOUGH TO MONITOR**
				AIR-FILLED VOID	42.8'	
				SLIGHTLY WEATHERED SOFT BLACK **COAL AND MINE SPOIL**	45.0'	
				SLIGHTLY WEATHERED SOFT DARK GRAY **CLAYSTONE** AND MEDIUM HARD CARBONACEOUS **SHALE**	48.5'	**BORING CAVED IN AFTER REMOVING BIT**
				UNWEATHERED HARD GRAY **LIMESTONE**		
50				**BOTTOM OF B-8 AT 49.5'**		
60						

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D'APPOLONIA

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DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-9
	SHEET NO. 1 of 1	**DATE STARTED** 09-16-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-16-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1504.25 GROUND WATER EL. 1458.90	COMMENTS:
0–27.8				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **27.8'**	
27.8–37.3				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **37.3'**	
37.3–43.4				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** **43.4'**	**NO AIR LOST** **MINE TEMPERATURE 74.8°F**
43.4–49.5				UNWEATHERED HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
				BOTTOM OF B-9 AT 49.5'	

Depth scale: 10, 20, 30, 40, 50, 60

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D'APPOLONIA

[(1)] UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-11
	SHEET NO. 1 of 1	DATE STARTED 09-16-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-16-05
DRILLING METHOD Driltech 40D Air Rotary Drill	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1502.86 GROUND WATER EL. DRY	COMMENTS:
0–26.3				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **26.3'**	
26.3–32.4				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **32.4'**	
32.4–39.1				**AIR-FILLED VOID** **39.1'**	**AIR RETURN LOST: 32.4'**
39.1–42.7				UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** **42.7'**	**MINE TEMPERATURE 82.1°F**
42.7–45.0				UNWEATHERED HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
				BOTTOM OF B-11 AT 45.0'	

Depth scale: 10, 20, 30, 40, 50, 60

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D'APPOLONIA

[(1)]UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-12
	SHEET NO. 1 of 1	**DATE STARTED** 09-19-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-19-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1504.63 GROUND WATER EL. DRY	COMMENTS:
0–22.0				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **22.0'**	
22.0–32.0				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **32.0'**	
32.0–38.2				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** **38.2'**	**NO AIR RETURN LOST**
38.2–40.3				UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** **40.3'**	**MINE TEMPERATURE 65.9°F**
40.3–42.5				UNWEATHERED HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
				BOTTOM OF B-12 AT 42.5'	

Depth scale: 10, 20, 30, 40, 50, 60

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D'APPOLONIA

(1)UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-13
	SHEET NO. 1 of 1	**DATE STARTED** 09-19-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-19-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1505.51 GROUND WATER EL. 1464.91	COMMENTS:
0–25.5				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **25.5'**	
25.5–31.2				**AIR-FILLED VOID** **31.2'**	**AIR RETURN LOST: 25.5'**
31.2–40.3				**MINE SPOIL-FILLED VOID** **40.3'**	**MINE TEMPERATURE 72.6°F**
40.3–42.0				UNWEATHERED HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
				BOTTOM OF B-13 AT 42.0'	

Depth scale: 10, 20, 30, 40, 50, 60

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D'APPOLONIA

(1) UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-14
	SHEET NO. 1 of 1	**DATE STARTED** 09-19-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-19-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1535.63 GROUND WATER EL. DRY	COMMENTS:
				MINE SPOIL FILL FOR ROADWAY STABILIZATION **4.0'**	
10				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE**	
20				**(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)**	
30				**(HOMEWOOD SANDSTONE FORMATION)**	
40				**46.7'**	
50				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **53.8'**	**NO AIR RETURN LOST**
				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** **59.5'**	
60				SLIGHTLY WEATHERED MEDIUM HARD GRAY **SILTY SHALE** **BOTTOM OF B-14 AT 60.0'**	

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

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DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-15
	SHEET NO. 1 of 1	**DATE STARTED** 09-19-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-19-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1536.24 GROUND WATER EL. DRY	COMMENTS:
				MINE SPOIL FILL FOR ROADWAY STABILIZATION — 4.0'	
10 20 30 40				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** — 46.3'	
50				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** — 52.2'	
				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** — 58.5'	**NO AIR RETURN LOST**
60				SLIGHTLY WEATHERED MEDIUM HARD GRAY **SILTY SHALE** **BOTTOM OF B-15 AT 60.0'**	

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

[1]UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-16
	SHEET NO. 1 of 3	**DATE STARTED** 09-17-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-17-05
DRILLING METHOD Hetager track-mounted Rotary Drill with NX rock core (Wireline)	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)/ % REC.	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1536.50 GROUND WATER EL. 1503.20	COMMENTS:
0–4.5				**4-INCH DIAMETER CASING ADVANCED TO 4.5' THROUGH MINE SPOIL ROADWAY FILL**	
5	R-1	3.0 (100%)	73	**(SHALY AREAS TO 5.2')**	
10	R-2	5.0 (100%)	96	UNWEATHERED UNBROKEN MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE**	
15	R-3	5.0 (100%)	97	**(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)**	
20	R-4	5.0 (100%)	100	**(HOMEWOOD SANDSTONE FORMATION)**	
25	R-5	5.0 (100%)	90		
30	R-6	5.0 (100%)	97		

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D'APPOLONIA

[(1)]UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-16
	SHEET NO. 2 of 3	DATE STARTED 09-18-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-18-05
DRILLING METHOD Hetager track-mounted Rotary Drill with NX rock core (Wireline)	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)/ % REC.	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1536.50 GROUND WATER EL. 1503.20	COMMENTS:
	R-6 (CONT)	5.0 (100%)	97	SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **38.6'**	
35	R-7	5.0 (100%)	100		
40	R-8	3.3 (66%)	42	COMPLETELY WEATHERED VERY BROKEN SOFT DECOMPOSED RED **SANDSTONE AND CLAYSTONE** **41.1'**	
				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE (HOMEWOOD SANDSTONE FORMATION)** **45.3'**	
45	R-9	5.0 (100%)	54	INTERBEDDED SLIGHTLY WEATHERED VERY BROKEN SOFT TO MEDIUM HARD DARK GRAY **SILTY SHALE** AND **BLACK COAL** **51.2'**	
50	R-10	5.0 (100%)	56		
				SLIGHTLY WEATHERED VERY BROKEN SOFT **BLACK COAL** **(LEWISTON COAL FORMATION)** **57.4'**	
55	R-11	5.0 (100%)	10		
	R-12	4.7 (100%)	55	SLIGHTLY WEATHERED BROKEN TO SLIGHTLY BROKEN MEDIUM HARD GRAY **SILTY SHALE**	
60					

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

(1)UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-16
	SHEET NO. 3 of 3	DATE STARTED 09-18-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-18-05
DRILLING METHOD Hetager track-mounted Rotary Drill with NX rock core (Wireline)	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)/ % REC.	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1536.50 GROUND WATER EL. 1503.20	COMMENTS:
	R-12 (CONT)	4.7 (100%)	55	SLIGHTLY WEATHERED BROKEN TO SLIGHTLY BROKEN MEDIUM HARD GRAY **SILTY SHALE**	
				BOTTOM OF BORING B-16 AT 62.2'	
65					
70					
75					
80					
85					
90					

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D'APPOLONIA

(1)UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-17
	SHEET NO. 1 of 1	DATE STARTED 09-19-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-19-05
DRILLING METHOD Driltech 40D Air Rotary Drill	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1537.06 GROUND WATER EL. DRY	COMMENTS:
				MINE SPOIL FILL FOR ROADWAY STABILIZATION 4.0'	
10 20 30 40				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** 44.9'	
50				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** 51.0'	
				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** 57.1'	**NO AIR RETURN LOST**
60				SLIGHTLY WEATHERED MEDIUM HARD GRAY **SILTY SHALE** **BOTTOM OF B-17 AT 60.0'**	

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DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-18
	SHEET NO. 1 of 1	DATE STARTED 09-20-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-20-05
DRILLING METHOD Driltech 40D Air Rotary Drill	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1542.70 GROUND WATER EL. DRY	COMMENTS:
0–4.0				**MINE SPOIL FILL FOR ROADWAY STABILIZATION** 4.0'	
4.0–53.4 (10, 20, 30, 40, 50)				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** 53.4'	
53.4–57.4				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** 57.4'	**AIR RETURN LOST: 57.4'**
57.4–61.5 (60)				**AIR-FILLED VOID TO 61.5'** **BOTTOM OF BORING B-18 AT 61.5'**	

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D'APPOLONIA

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DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-20
	SHEET NO. 1 of 1	**DATE STARTED** 09-16-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-16-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1509.20 GROUND WATER EL. 1460.25	COMMENTS:
0–30.3				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **30.3'**	
30.3–39.9				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **39.9'**	**NO AIR LOST**
39.9–44.6				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** **44.6'**	**MINE TEMPERATURE 60.8°F**
44.6–45.8				INTERBEDDED SLIGHTLY WEATHERED SOFT BLACK **COAL** AND SLIGHTLY WEATHERED MEDIUM HARD DARK GRAY **SHALE** **45.8'**	
45.8–49.5				UNWEATHERED HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
				BOTTOM OF B-20 AT 49.5'	

Depth scale: 10, 20, 30, 40, 50, 60

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D'APPOLONIA

(1)UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-22
	SHEET NO. 1 of 1	**DATE STARTED** 09-16-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-16-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1503.79 GROUND WATER EL. 1457.74	COMMENTS:
0–33.2				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **33.2'**	
33.2–41.3				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **41.3'**	**NO AIR LOST**
41.3–45.9				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** **45.9'**	**MINE TEMPERATURE 69.8°F**
45.9–48.2				INTERBEDDED SLIGHTLY WEATHERED SOFT BLACK **COAL** AND SLIGHTLY WEATHERED MEDIUM HARD DARK GRAY **SHALE** **48.2'**	
48.2–49.5				UNWEATHERED HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
				BOTTOM OF B-22 AT 49.5'	

Depth scale: 10, 20, 30, 40, 50, 60

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D'APPOLONIA

[1]UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-23
	SHEET NO. 1 of 2	**DATE STARTED** 09-20-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-20-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1540.50 GROUND WATER EL. 1475.17	COMMENTS:
0–4.0				**MINE SPOIL FILL FOR ROADWAY STABILIZATION** 4.0'	
10 20 30 40 50				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** 52.6'	
				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** 59.3'	**NO AIR RETURN LOST**
60				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)**	

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D'APPOLONIA

[(1)]UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-23
	SHEET NO. 2 of 2	**DATE STARTED** 09-20-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-20-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1540.50 GROUND WATER EL. 1475.17	COMMENTS:
				SL SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** **67.1'**	
				SLIGHTLY WEATHERED MEDIUM HARD GRAY **SILTY SHALE**	
70				**BOTTOM OF BORING B-23 AT 68.5'**	
80					
90					
100					
110					
120					

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D'APPOLONIA

(1) UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-25
	SHEET NO. 1 of 1	DATE STARTED 09-20-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-20-05
DRILLING METHOD Driltech 40D Air Rotary Drill	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1501.53 GROUND WATER EL. 1462.83	COMMENTS:
0–25.5				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **25.5'**	
25.5–30.8				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **30.8'**	
30.8–38.8				**AIR-FILLED VOID**	**RETURN AIR LOST: 30.8'**
				BOTTOM OF B-25 AT 38.8'	

Depth scale: 10, 20, 30, 40, 50, 60

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D'APPOLONIA

[(1)] UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-28
	SHEET NO. 1 of 1	DATE STARTED 09-19-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-19-05
DRILLING METHOD Driltech 40D Air Rotary Drill	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1507.82 GROUND WATER EL. DRY	COMMENTS:
0–28.5 (10, 20)				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **28.5'**	
28.5–36.0 (30)				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **36.0'**	**NO AIR RETURN LOST**
36.0–40.7 (40)				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** **40.7'**	**MINE TEMPERATURE 77.7°F**
40.7–45.0				UNWEATHERED HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
45.0–60 (50, 60)				**BOTTOM OF B-28 AT 45.0'**	

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DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019 **SHEET NO.** 1 of 2	**BORING NO.** B-29 **DATE STARTED** 09-19-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-19-05
DRILLING METHOD Hetager track-mounted Rotary Drill with NX rock core (Wireline)	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)/ % REC.	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1488.14 GROUND WATER EL. NA	COMMENTS:
0–13.8				**4-INCH DIAMETER CASING ADVANCED TO 13.8' THROUGH COARSE COAL REFUSE**	
15	R-1	3.7 (100%)	71	SLIGHTLY WEATHERED TO UNWEATHERED BROKEN TO UNBROKEN MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** WITH SHALE AND COAL STREAKS **17.5'**	
				MODERATELY WEATHERED VERY BROKEN SOFT TO MEDIUM HARD DARK GRAY **SHALE** **18.1'**	
				SLIGHTLY WEATHERED VERY BROKEN SOFT **BLACK COAL** **18.6'**	
20	R-2	4.9 (98%)	74	INTERBEDDED UNWEATHERED UNBROKEN MEDIUM HARD GRAY **SANDSTONE AND SILTY SHALE**	
25	R-3	5.0 (100%)	86	**26.9'**	
30	R-4	5.0 (100%)	16	SLIGHTLY WEATHERED VERY BROKEN TO BROKEN SOFT **BLACK COAL (LEWISTON COAL FORMATION)**	

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[1]UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-29
	SHEET NO. 2 of 2	DATE STARTED 09-19-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-19-05
DRILLING METHOD Hetager track-mounted Rotary Drill with NX rock core (Wireline)	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)/ % REC.	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1488.14 GROUND WATER EL. NA	COMMENTS:
	R-4 (CONT)	5.0 (100%)	16	SLIGHTLY WEATHERED VERY BROKEN TO BROKEN SOFT **BLACK COAL** **(LEWISTON COAL FORMATION)** **31.5'**	
				UNWEATHERED VERY BROKEN MEDIUM HARD GRAY **SHALE** **32.0'**	
				SLIGHTLY WEATHERED VERY BROKEN TO BROKEN SOFT **BLACK COAL** **33.0'**	
35	R-5	4.8 (96%)	84	UNWEATHERED UNBROKEN MEDIUM HARD GRAY **SILTY SHALE**	
				BOTTOM OF BORING B-29 AT 37.5'	
40					
45					
50					
55					
60					

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D'APPOLONIA

(1) UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	**PROJECT NO.** 031019	**BORING NO.** B-30
	SHEET NO. 1 of 1	**DATE STARTED** 09-16-05
BORING LOCATION SEE FIGURE	**FIELD SUPERVISOR** R. Short	**DATE COMPLETED** 09-16-05
DRILLING METHOD Driltech 40D Air Rotary Drill	**CHECKED BY** W. Johnson	**DATE CHECKED** 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1518.23 GROUND WATER EL. 1476.43	COMMENTS:
0–31.8				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **31.8'**	
31.8–32.2				SLIGHTLY WEATHERED SOFT BLACK **COAL** **32.2'**	
32.2–38.8				UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **38.8'**	**NO AIR LOST**
38.8–43.8				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)** **43.8'**	
43.8–46.0				INTERBEDDED SLIGHTLY WEATHERED SOFT BLACK **COAL** AND SLIGHTLY WEATHERED MEDIUM HARD DARK GRAY **SHALE** **46.0'**	
46.0–50.0				UNWEATHERED HARD GRAY **SANDSTONE** **(COALBURG SANDSTONE FORMATION)**	
50–60				**BOTTOM OF B-30 AT 50.0'**	

Depth scale: 10, 20, 30, 40, 50, 60

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

(1) UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-31
	SHEET NO. 1 of 1	DATE STARTED 09-20-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-20-05
DRILLING METHOD Driltech 40D Air Rotary Drill	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1516.98 GROUND WATER EL. DRY	COMMENTS:
0–30.5				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **30.5'**	
30.5–31.5				SLIGHTLY WEATHERED SOFT BLACK **COAL** **31.5'**	
31.5–37.0				INTERBEDDED UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **37.0'**	
37.0–43.0				**AIR-FILLED VOID**	**RETURN AIR LOST: 37.0'**
				BOTTOM OF B-31 AT 43.0'	

Depth scale: 10, 20, 30, 40, 50, 60

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

(1) UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-32
	SHEET NO. 1 of 1	DATE STARTED 09-20-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-20-05
DRILLING METHOD Driltech 40D Air Rotary Drill	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1516.53 GROUND WATER EL. 1476.83	COMMENTS:
0–30.4				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **30.4'**	
30.4–31.5				SLIGHTLY WEATHERED SOFT BLACK **COAL** **31.5'**	
31.5–37.0				UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **37.0'**	
37.0–43.6				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)**	**NO AIR LOST** **MINE TEMPERATURE 59.8°F**
				BOTTOM OF B-32 AT 43.6'	

Depth scale: 10, 20, 30, 40, 50, 60

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

[1] UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-33
	SHEET NO. 1 of 1	DATE STARTED 09-21-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-21-05
DRILLING METHOD Driltech 40D Air Rotary Drill	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1516.40 GROUND WATER EL. 1477.15	COMMENTS:
0–30.1				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)** **30.1'**	
30.1–31.5				SLIGHTLY WEATHERED SOFT BLACK **COAL** **31.5'**	
31.5–38.4				UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL** **38.4'**	
38.4–45.1				SLIGHTLY WEATHERED SOFT BLACK **COAL** **(LEWISTON COAL FORMATION)**	**NO AIR LOST** **MINE TEMPERATURE 59.0°F**
				BOTTOM OF B-33 AT 45.1'	

Depth scale: 10, 20, 30, 40, 50, 60

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

(1)UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.

DEMONSTRATION PROJECT-MINE VOID DETECTION DC RESISTIVITY AND TDEM TECHNIQUES LOT'S BRANCH SLURRY IMPOUNDMENT SITE PRENTER, WEST VIRGINIA	PROJECT NO. 031019	BORING NO. B-34
	SHEET NO. 1 of 1	DATE STARTED 09-21-05
BORING LOCATION SEE FIGURE	FIELD SUPERVISOR R. Short	DATE COMPLETED 09-21-05
DRILLING METHOD Driltech 40D Air Rotary Drill	CHECKED BY W. Johnson	DATE CHECKED 10-03-05

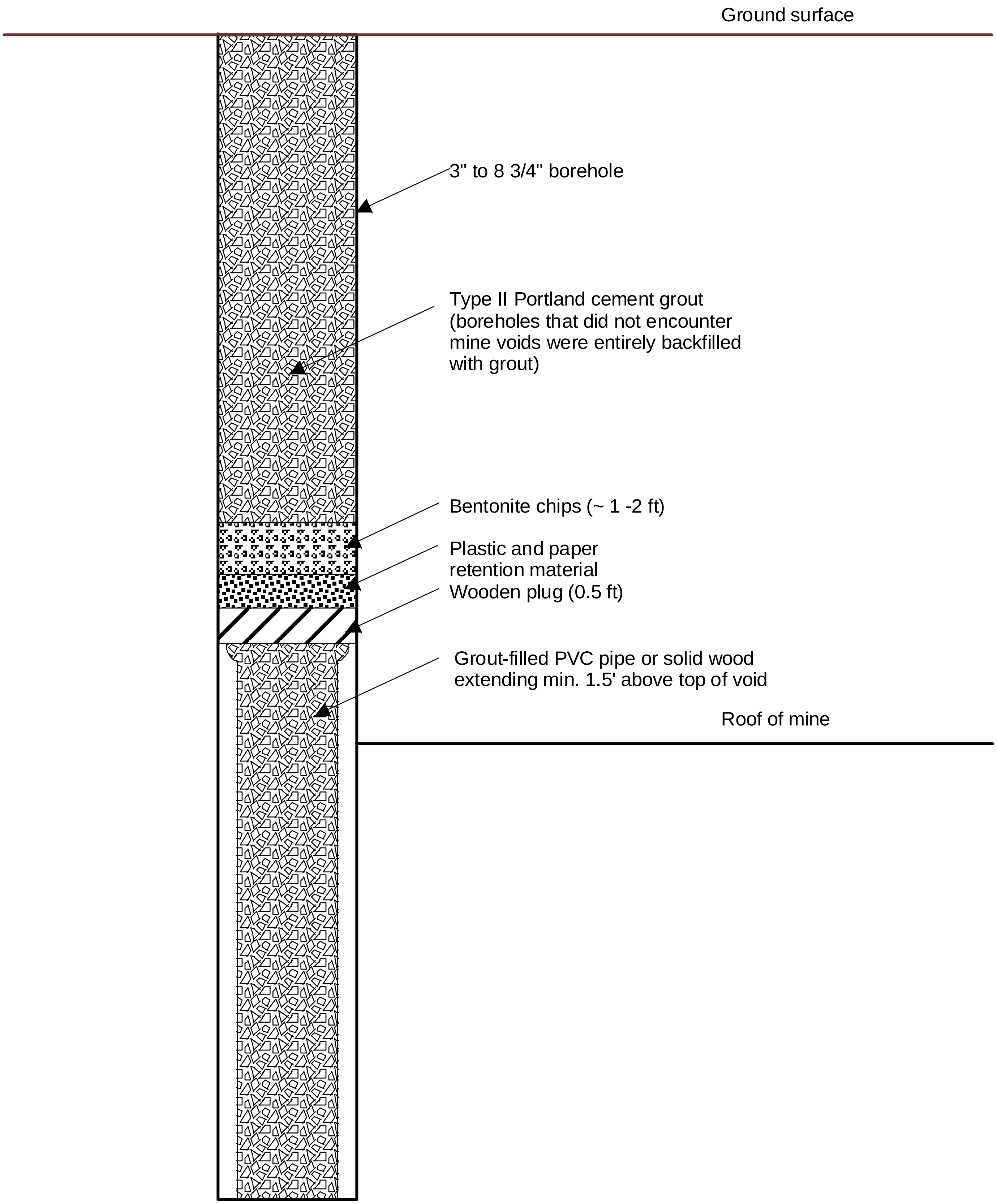
DEPTH (FT)	SAMPLE NO. OR TYPE AND RUN NO.	REC. (FT)	ROCK RQD (%)	DESCRIPTION OF MATERIAL SURFACE EL. 1518.24 GROUND WATER EL. 1475.74	COMMENTS:
0–31.3				SLIGHTLY WEATHERED TO UNWEATHERED MEDIUM HARD BROWN AND GRAY **MICACEOUS SANDSTONE** **(ISOLATED DARK GRAY CARBONACEOUS SHALE AND BLACK COAL STREAKS)** **(HOMEWOOD SANDSTONE FORMATION)**	
31.3'–**32.0'**				SLIGHTLY WEATHERED SOFT BLACK **COAL**	
32.0'–**37.9'**				UNWEATHERED SOFT TO MEDIUM HARD GRAY **SHALE** AND SOFT BLACK **COAL**	**RETURN AIR LOST: 36.9'**
37.9'–				**AIR-FILLED VOID**	
				BOTTOM OF B-33 AT 42.7'	

Depth scale: 10, 20, 30, 40, 50, 60

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

D'APPOLONIA

(1)UNCONFINED COMPRESSIVE STRENGTHS FOR SOIL SAMPLES BASED ON POCKET PENETROMETER TESTS. UNCONFINED COMPRESSIVE STRENGTHS FOR INTACT ROCK CORE BASED ON POINT LOAD TESTS.



GROUTING SCHEMATIC
(Not to scale)