Underground mining impacts as experienced by the North Carolina Department of Transportation: Two case histories.

David T. Hering, L.G., P.E.
North Carolina Department of Transportation
Geotechnical Engineering Unit

The mining industry in North Carolina has changed dramatically over its more than 200 year history. The vast majority of the commercial mining operations in North Carolina over the past 60 years have been open pit operations for the purpose of gravel, sand, and dimension stone and are easily recognized during highway planning. However, since the 1700's there have been numerous well documented mining operations including many with underground works. Unfortunately, there have also been many poorly documented or undocumented underground mine works during this same time period.

The North Carolina Department of Transportation (NCDOT) has been fortunate not to have experienced problems with underground mine workings until the recent past. Typically, a mined area was either well known and could be avoided, or was an open pit operation without a major impact on the Highway. However, since 1999 there have been two projects where mining operations were present under proposed highways without the knowledge of the Highway Planners.

<u>Site 1: R-0617C, Lincoln County, NC</u>

This project consists of a four-lane divided highway at a new location that will be part of a bypass around the City of Lincolnton. The project is located in the western Piedmont of North Carolina in an area known as the King's Mountain Belt. This area has been the source of many of the metallic minerals mined in North Carolina.

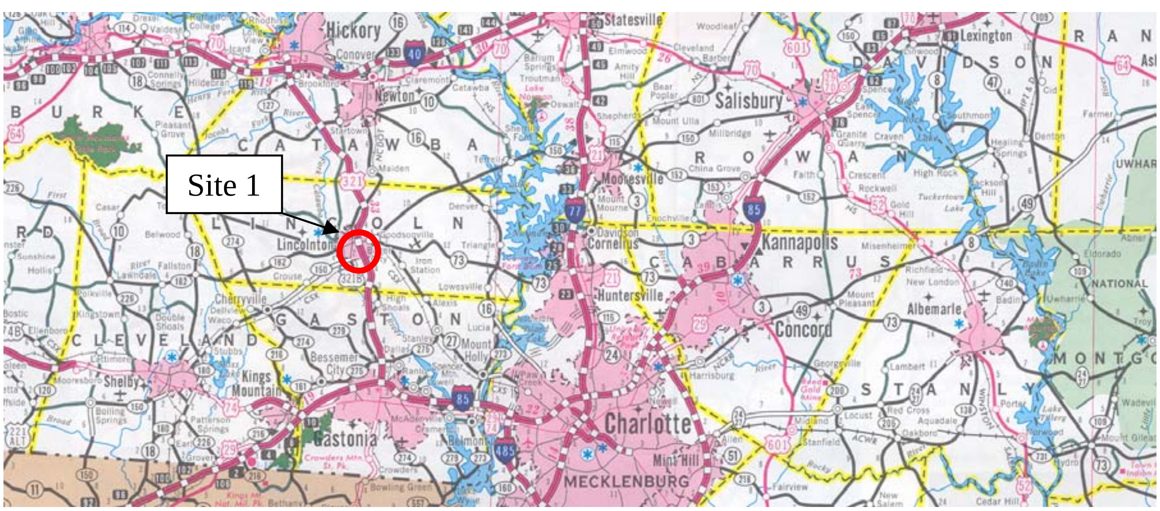

Figure 1: Site vicinity map for Site 1

During the corridor study for this project, the presence of mine workings was not discovered even though there was some documentation of their presence. While contacting property owners for this project, a NCDOT geologist was informed that a former tin mine was present on one of the properties. A search of literature found that cassiterite was first discovered in the area in 1883 and the first prospecting was done in 1885. The cassiterite occurs primarily in the pegmatite and associated greissens that formed during the intrusion of Cherryville Granite into the surrounding parent rocks. The cassiterite is typically found in the highest concentrations near the contact of the pegmatite and the greissens. Numerous development-mining operations worked in the area from the late 1880’s through the 1940’s and included open pits, trenches, shafts, and tunnels. However, none of these operations became commercially viable.

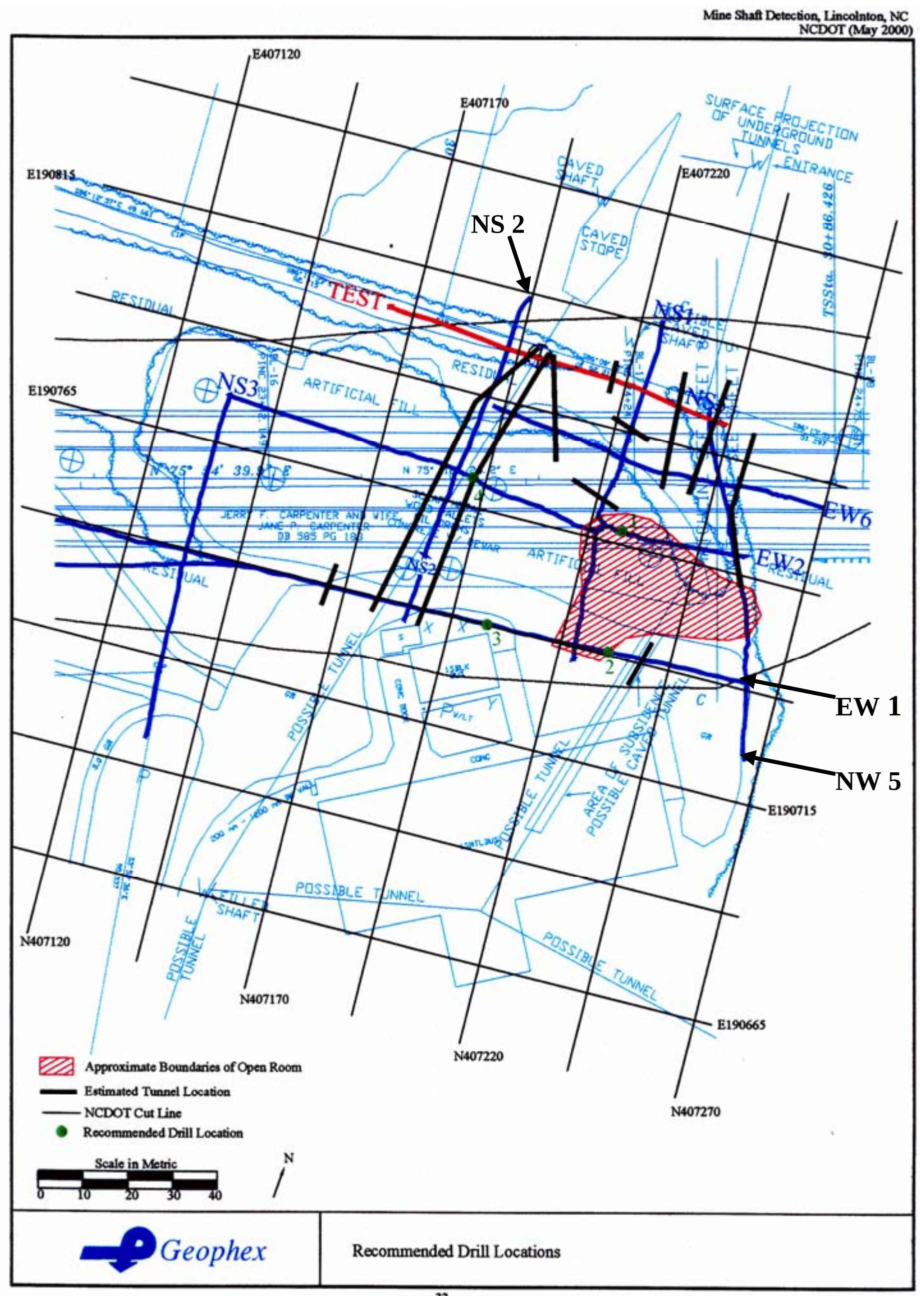

Figure 2: Geophysical Survey lines in the area of known tunnels

A site reconnaissance before drilling began revealed an open tunnel entrance and several caved vertical shafts still visible on the property. In December 1999 borings were performed in the area of known mining to determine shaft locations. This investigation had little success. In May 2000 a geophysical investigation was conducted to supplement the borings. The area of the property that had an open tunnel entrance was chosen to evaluate the effectiveness of six different geophysical methods (Figure 2). These methods were electromagnetic (EM), total field magnetic, ground-penetrating radar (GPR), gravity, DC resistivity, and seismic refraction.

The tunnel was estimated to be 5 meters below the ground surface and air-filled at the location of the proposed testing. The center of the testing was approximately 15 meters from the tunnel entrance. Only DC resistivity and seismic refraction showed any evidence of the tunnel at the test location and therefore were chosen for testing the remainder of the area. It was determined later that the tunnel was actually caved at the test location and not air-filled.

The second geophysical investigation centered on the northeastern corner of the property where documents indicated the mining had been heaviest. Eleven DC resistivity lines ranging from 81 m to 291 m long and five 72 m long seismic refraction lines were run in this area (figure 2). Several anomalies were located with most being interpreted as filled/caved tunnels as well as two potential air-filled tunnels. However, one area was interpreted as a probable air-filled room of considerable size (figure 2 and 3).

Eleven borings were performed in July 2000 to try to confirm some of the targets identified in the geophysical investigation. None of the targets were determined to be open and air-filled as assumed, although some were soft soil that may indicate a caved tunnel.

Another investigation utilizing borings was conducted in June 2002 (figure 4). Three of these borings encountered an air filled void (figure 5). These three borings were performed approximately 12 meters west of the anomaly believed to be an open room. A down hole camera was used to verify the size and condition of the void. The video showed a fairly significant open chamber that connected between and continued beyond the boring locations. Other borings conducted at this time did not find any evidence of caved tunnels at suspected locations.

Overall the geophysical investigation at this site does not appear to have defined areas of open tunnels very well. Although some caved tunnels may have been located, the open tunnels were found purely with conventional borings.

This project should be let for construction in January 2005. The current plan is to perform another geophysical investigation and more borings after the gross excavation is completed. Any old tunnels or chambers that are exposed or discovered at shallow depths will be excavated and backfilled with riprap and/or grout.

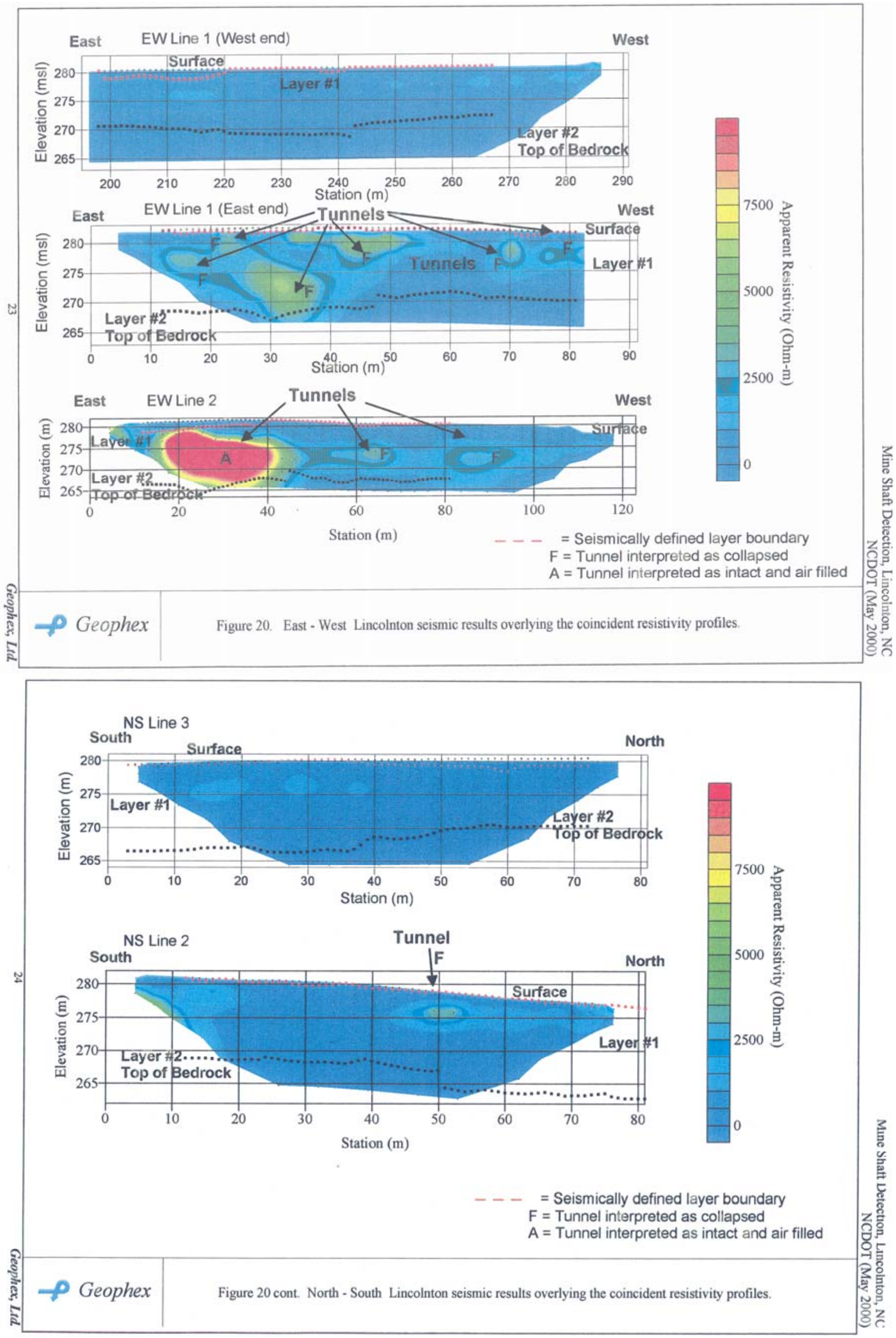

Figure 3: Interpretation of geophysical lines in the area of known mining

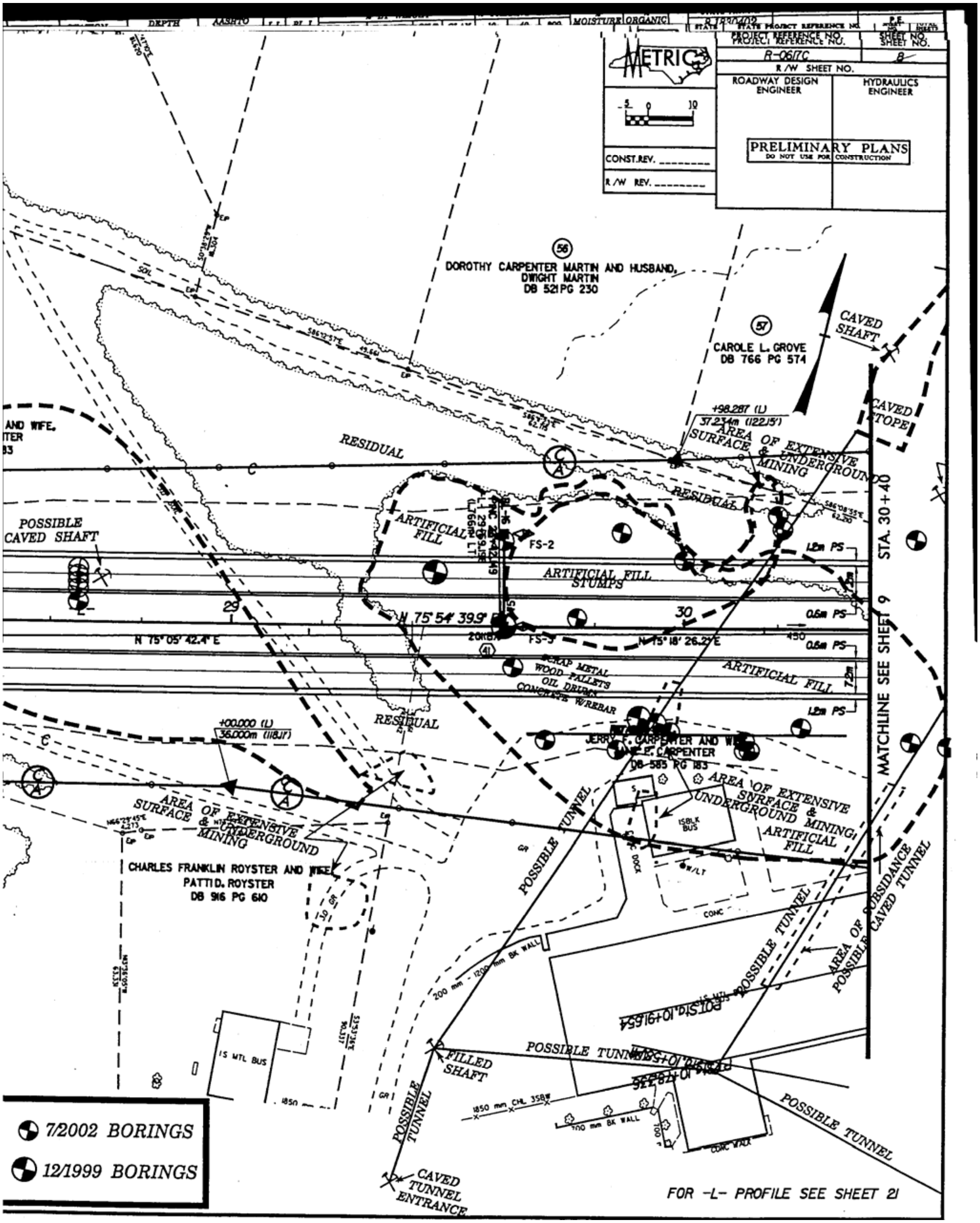

Figure 4: Borings from 2002 investigation and some from 1999

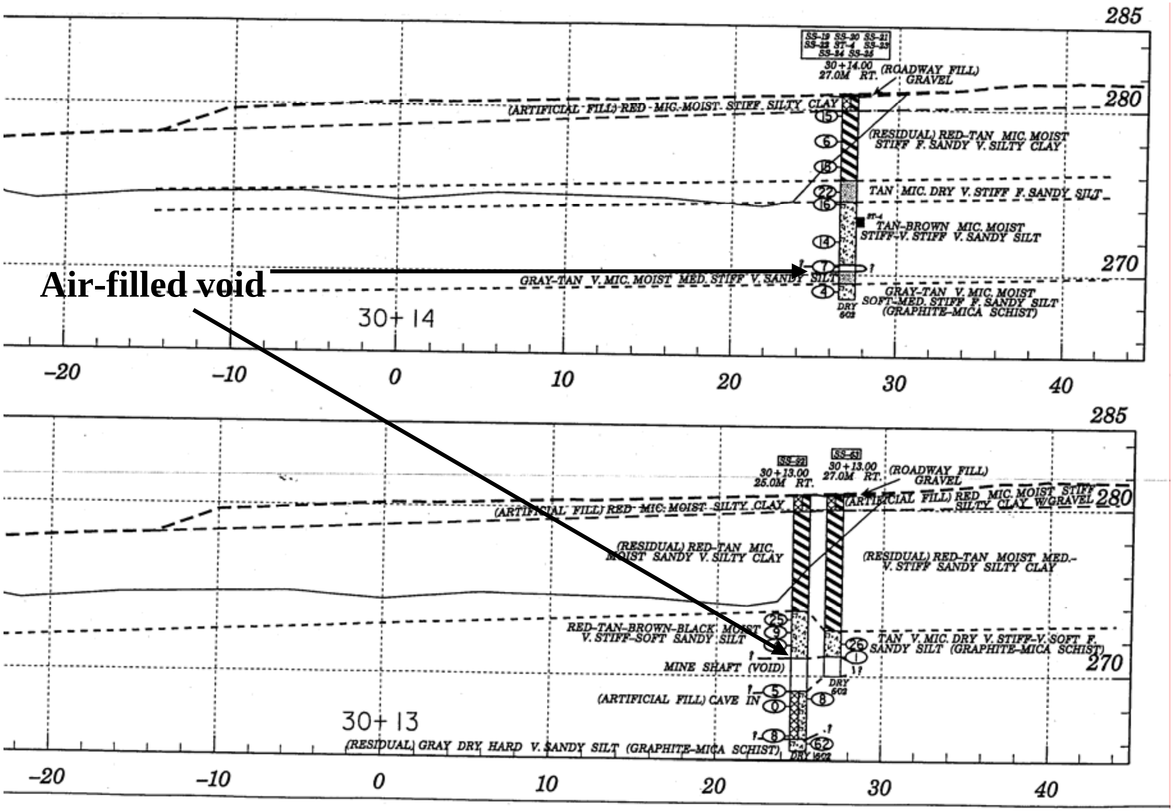

Figure 5: Borings from 2002 investigation that intercepted an air-filled tunnel

Site 2: R-2610A Chatham County, NC

The project consists of a two-lane widening of US 421 on location parallel to the existing road. The project is located in the eastern Piedmont of North Carolina in the Sanford Triassic Sub-basin. No evidence of a mine was encountered during the roadway investigation that was performed in the fall of 2001. However, while drilling for the end bent foundation of the structure crossing the AC&W Railroad, a mineshaft was discovered.

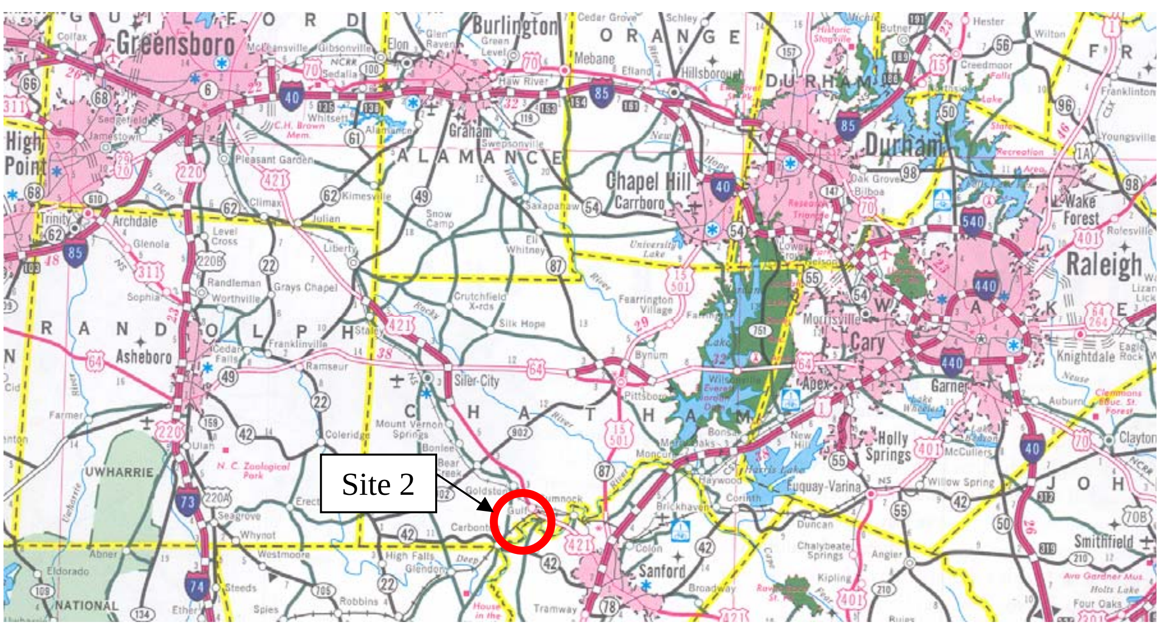

Figure 6: Site vicinity map for Site 2

Research was done to determine if there was any record of a mine at this location. Literature showed three test pits and a known mine within a 0.5 mile radius of the encountered mineshaft (figure 7). One of these test pits appears to be less than 500 feet from the shaft location. However, there was no documentation of a mine at the location of the bridge. The area 1.5 to 2 miles east and west of the bridge location has several locations where the seam of coal intersects the surface (figure 7 and 8).

The coal in this region appears to have been first noted in 1755 and was pit mined mainly for use at forges in the area. By 1850 a system of dams and locks was begun on the Deep River to allow shipping of commerce along the river. At that time, interest in commercial operations for mining and shipping the coal began. At least 2 deep shafts (up to 460 feet) were in place by 1853. Railroads finally reached the area in 1860 just in time for the Civil

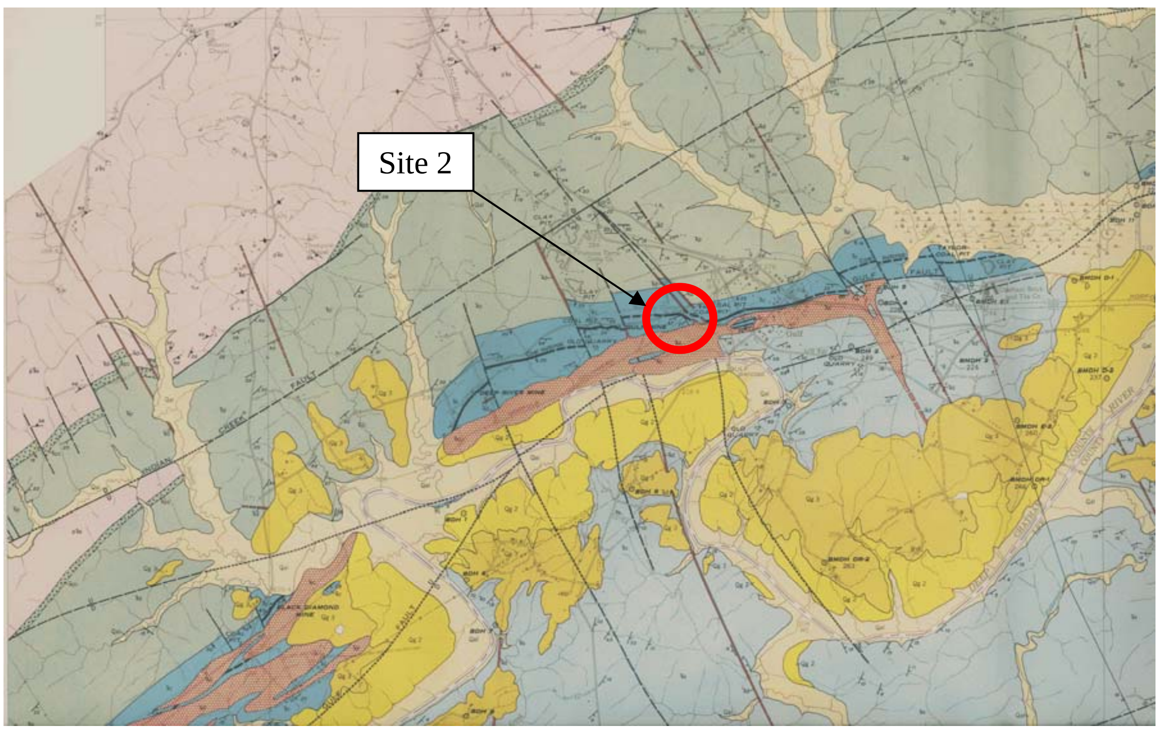

Figure 7: Geology of Chatham and Lee Counties in area of mine shaft

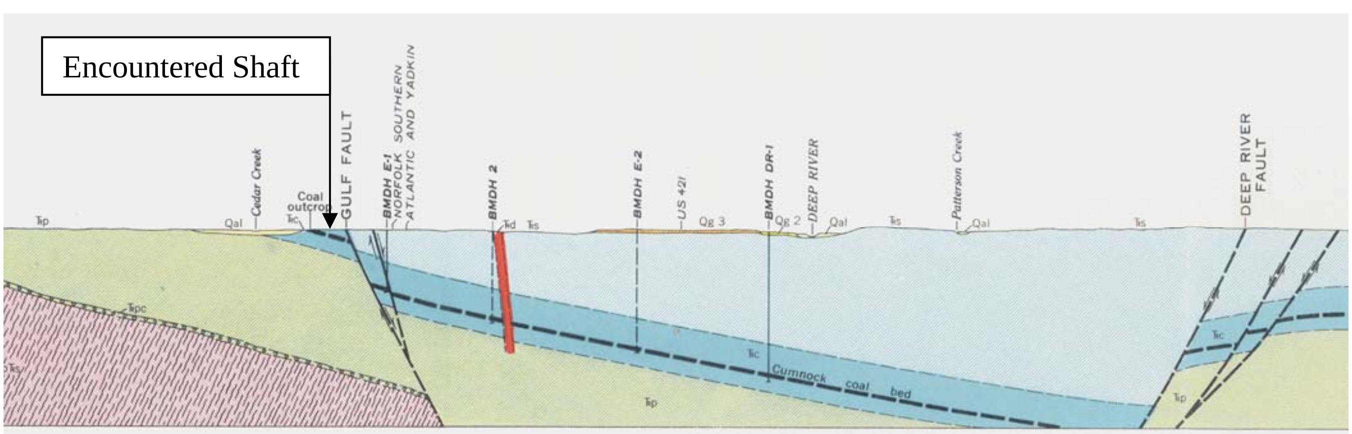

Figure 8: Profile through part of Deep River Basin

War. Mining continued through the war and sporadically thereafter. Unfortunately, there has never been a great quantity of coal taken from this region due to the complex faulting of the coal beds and intrusions of diabase.

The boring that encountered the shaft was performed at the end bent of the proposed bridge and coincidentally at the base of the existing roadway embankment. There was an existing depression approximately 1 foot deep and 4 feet in diameter at the location drilled. After drilling the boring, it was assumed that caving within the shaft caused the depression. There was also some minor sloughing of the existing embankment slope at this location attributed to the caving. Within the boring, wood was encountered in split spoon drives from 7 to 20 meters depth and was assumed to be from timbers placed for support in the mine.

After allowing this hole to stabilize for a week, a down hole camera was used to determine the lateral extent of the shaft. Unfortunately, the water was still too cloudy to see more than a few inches. In an attempt to help determine the lateral extent of the shaft, an inclined hole (figure 9) was drilled to intercept the shaft at depth. During the drilling of the inclined hole, water flowed back into the original drill hole thereby showing a connection between the borings. Wood was also encountered in the inclined hole indicating that parts of a shaft were intersected.

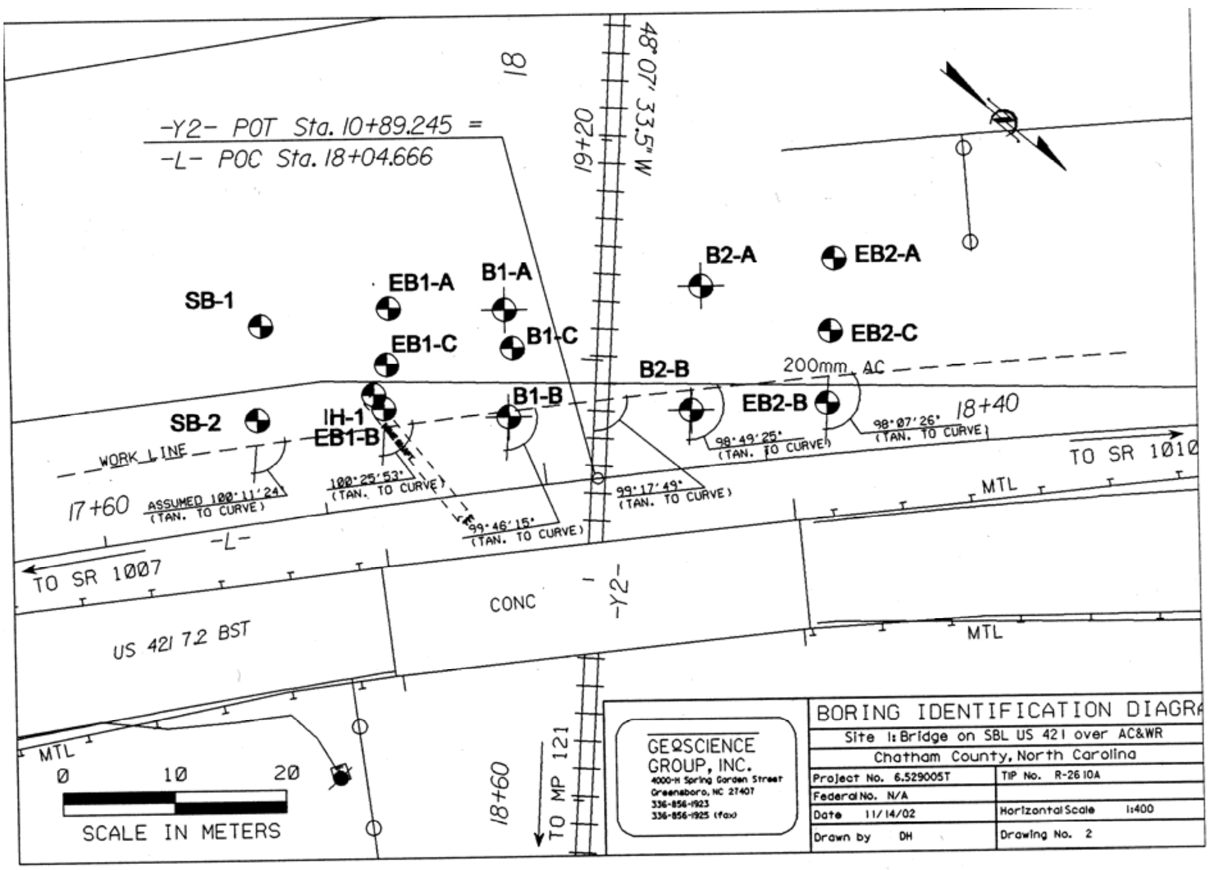

Figure 9: Original sequence of borings before the Geophysical survey

The down hole camera was attempted again, this time pumping water out of the boring while using the camera. It was determined that the inclined hole had intercepted a side tunnel that was open for a length of approximately 2 meters. Unfortunately, the original boring was blocked by debris at 5.5 meters depth. This material apparently washed into the hole during the drilling of the inclined hole.

Additional borings were drilled within the footprint of the proposed road and at End Bent 1 to try to locate any other shafts in the area. No other shafts were found with the borings. It was then decided to use geophysics to help determine the extent of the one shaft that was encountered as well as determine if any other shafts were present.

It was proposed by the Geophysical firm hired that electromagnetic (EM) and DC resistivity methods were the most appropriate based on the site conditions. The geophysical surveys were constrained by the existing roadway embankment and the railroad tracks. A 34.5 by 40-meter survey grid was laid out for the EM data collection (figure 10). Data was collected along parallel tracks at 1.5 meters spacing using five different frequencies simultaneously. Although some conductivity anomalies were present they did not show a pattern that indicated a tunnel or shaft.

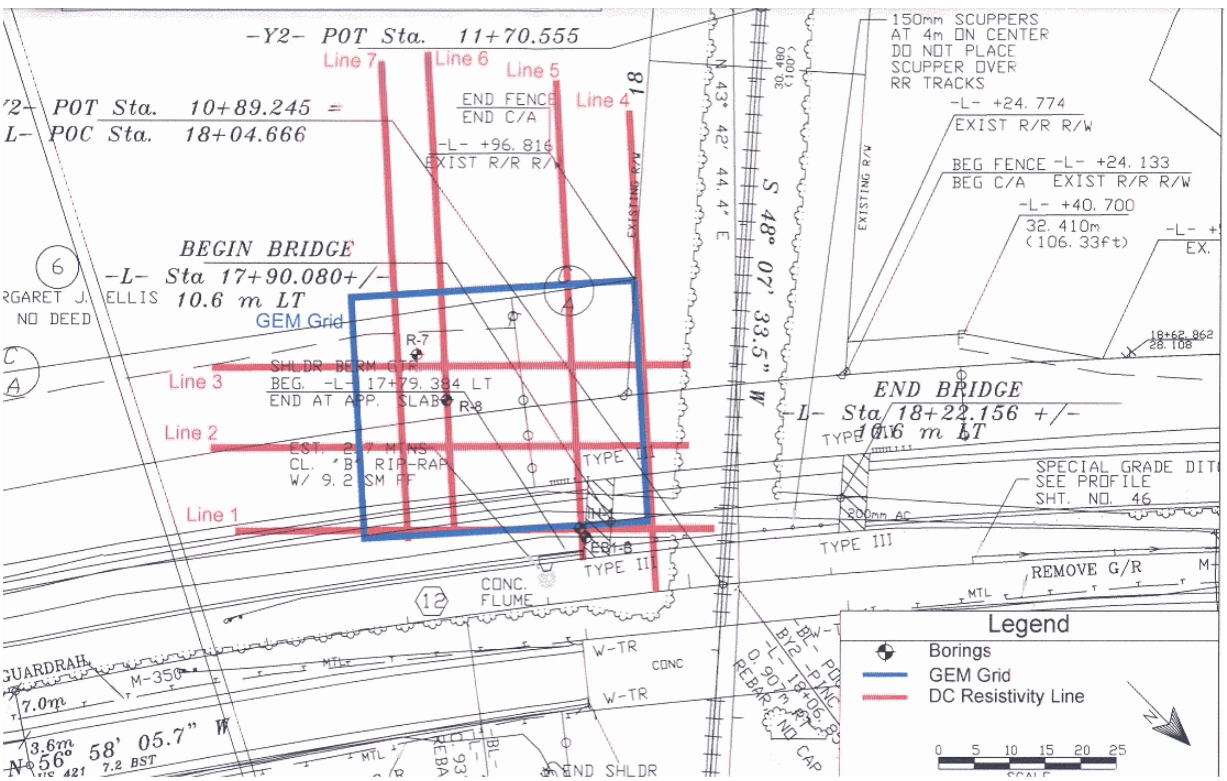

Figure 10: Plan view of site showing Geophysical lines

Seven DC Resistivity lines were run, three from SE to NW, and four from SW to NE (figure 10). All the lines were 67.5 meters long with the electrodes spaced at 1.5 meter intervals. The resistivity across the site was relatively low with a range of less than 80 ohm-m. This was attributed to the fine grained soils and high water table at the site. However, several higher resistivity targets were identified as potential tunnels. Borings were performed at two of the strongest targets. These targets were determined to be harder zones of rock rather than mine tunnels.

Twelve additional holes (R-9 through R-20) were then drilled at close spacing (5 to 8 feet), attempting to determine if the shaft or side tunnels extended even a short distance under the proposed bridge or roadway (figure 11). No additional shafts or even soft soils were discovered.

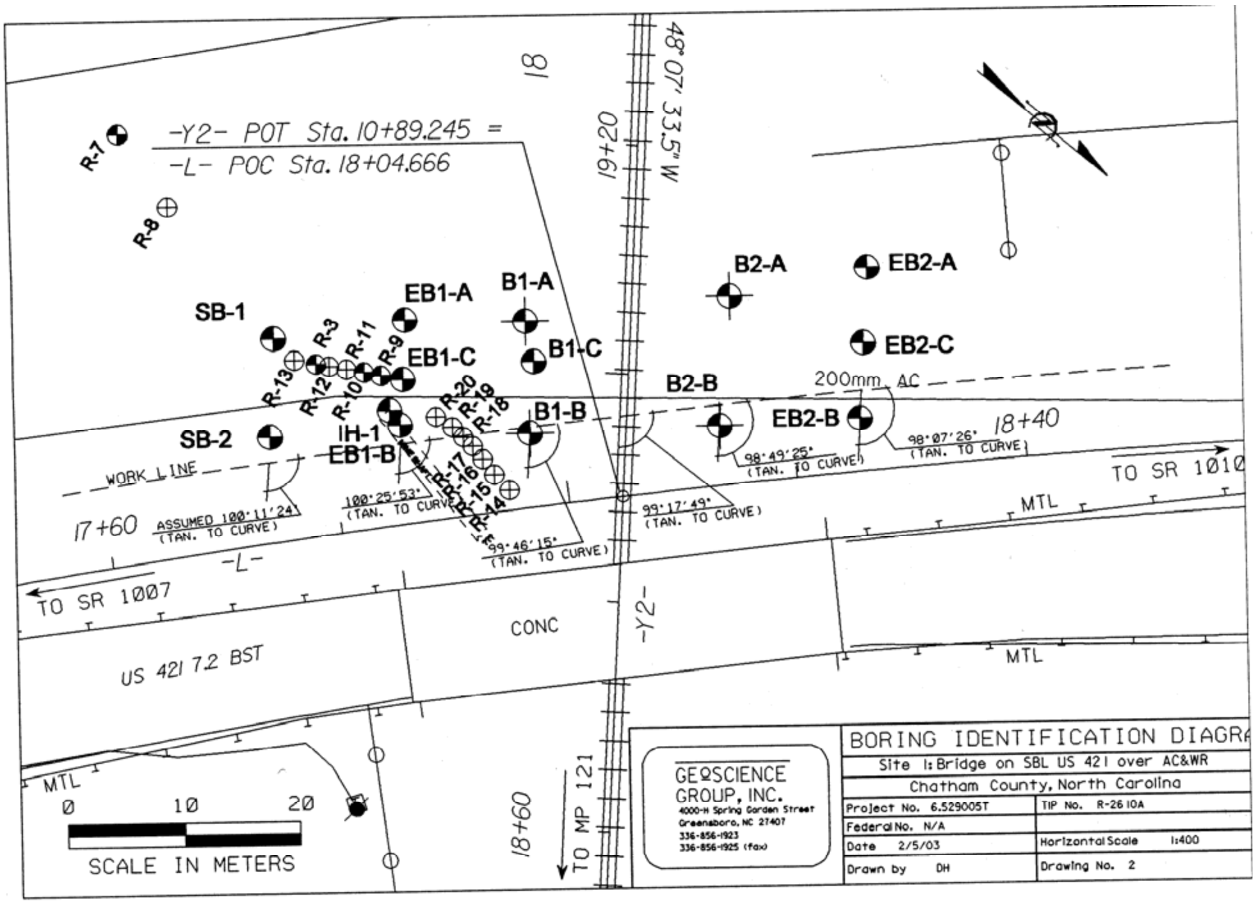

Figure 11: Plan view of site 2 showing additional boring locations

The recommended solution for this site is to extend the length of the bridge such that the abutment will be beyond the known extent of the shaft and the new interior bent will fall within the limits of the located shaft. Drilled piers will be used at the interior bent and they will be fully encased to the bottom of the mineshaft and socketed into rock a sufficient distance to overcome the unsupported length.

It is assumed from evaluating all available data that the remainder of the mine extends under the existing roadway embankment that has been in place for almost 50 years. It appears at this site that geophysics did not have a chance to locate the shaft due to physical constraints limiting the area to be tested. However, the interpretation of the geophysical data at this site may have been influenced by the hope of success. The low level of resistivity across the site appears to have indicated a fairly uniform subsurface with the "higher" resistivity anomalies only indicating slightly harder rock.

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