Abstract

As residential communities expand, developers and local officials are faced with construction in areas where zoning issues and past use activities have complicated the development process. Some of the most desirable and available tracks of land in and around Richmond, Virginia, are located in abandoned coal mine areas. The first commercial coal production in the United States was active in the Richmond area from the mid 1700s to well into the 1800s. What remains today is an undocumented network of mine shafts and tunnels and prospecting pits that pose a threat of future subsidence. Citizens and County officials have become sensitized to these risks as a result of dropouts in the ground surface within lots and below structures, requiring expensive remediation.

There are a number of technical methods available to engineers for subsurface exploration. The paper describes how geologic mapping, site reconnaissance, and research into historical records, combined with standard geotechnical drilling, air track drilling, and resistivity surveys were used to delineate abandoned mine hazards in the development phase of the property. The geology of the coal measures and research into the available records formed the basis for layout of the exploration studies. Profiles of the resistivity surveys provided continuity between borings and identified the locations of possible mine shafts. Air track drilling and resistivity profiles were used to categorize various surface features such as depressions associated with mine shafts and/or subsidence resulting from collapsed mine tunnels and determine the most appropriate remediation method. The result was a development plan that reflected an efficient approach to development in and around abandoned mine features and also incorporated a treatment plan for archeological data recovery.

Introduction

The first documented discovery of coal within the Richmond Basin was in 1701 (Traver et al. 1988:9). This discovery resulted in the purchase of several tracts of available land along the southern boundary of the James River approximately 12 miles upstream of Richmond. The production of coal and coke began in earnest in 1720 and marks the first commercial production in the United States. The production was mainly from surface mine operations; however, strip mining gave way to deep mining operations using drift or slope mines, shaft mining, and pit mining (reference Figure 1)
Throughout the early part of the 18th century, land development, the economy, and the cultural landscape of this area of Virginia were dominated by tobacco production. Consequently, development of infrastructure necessary to transport coal to market was delayed until the revolutionary war when the tobacco market was seriously impacted and the demand for coal increased. The early 1800’s saw the development of both public and private railroads and roadways to transport coal to markets in Washington, New York, and Philadelphia. However, by that time, the coal industry in Pennsylvania had developed and the coal remaining in this area was thought to be non-competitive. As a result, coal production from the site was effectively over by 1850.

Today, this section of the Richmond Coal Basin has transitioned into a fast-growing community of single-family residential developments and supporting retail businesses.

**Project Development**

The project site consists of a 750-acre tract of land that borders the south side of the James River. Approximately 20 percent of the property along its north and east boundaries contains evidence of the past mining activities which include mounds of coal waste or overburden soils or isolated depressions at the ground surface. These “cone-like” depressions vary in size and depth and are generally associated with varying amounts of tailings around the perimeter of the depression (reference Figure 2).
Some of the depressions appear randomly scattered throughout the mined area; however, many of the depressions are grouped and aligned in generally north-south and east-west directions (reference Figure 3). From a development standpoint, the economic viability of the site hinged on the amount of property that could be developed less the allowances for floodplains, wetlands, and ecological zones and setbacks around streambeds; all of which were readily discernable early on in the project. Less understood was the amount of land that may need to be excluded as a result of the previous mining activities and the problems associated with future subsidence. Another concern was the extent of remediation that would be necessary to satisfy both state and local agencies.
Preliminary Studies

The first part of the site exploration studies primarily involved characterization and quantification of the mining features. The archeological data recovery effort was part of an agreement between the developer, Virginia SHPO, and the U. S. Army Corps of Engineers for mitigation of adverse effects during site construction as dictated in Section 106 of the National Historic Preservation Act of 1966. The archeological work identified three separate mining operations that were suspected to have been present on site. Aside from just a general location of the mines, little information exists as to which coal seams were mined and the type of mining operations that may have been performed. It is generally understood that as many as three coal seams may have been present on site. The beds generally dip to the west 20 degrees and trend to the north 15 degrees. The most prevalent type of mining for that time period was shallow pits and trenches both of which were evident at the site. Little surface evidence was present to suggest more extensive operations. No evidence of timber shoring, brick or stone buildings, or equipment was noted. The archeological data gathering compiled records of the cultural features associated with the mine works as well as provided insight into the type and extent of mining activity on site.

An inventory of the surface features revealed approximately 160 suspect former mining features were located on the property. The majority of the features consisted of conical-shape depressions ranging in size from 3 to 56 feet in diameter with the depth of the cones extending 1 to 16 feet below the surrounding ground surface. The features were roughly grouped into three clusters, suggesting the presence of the three historical mining operations.
Once the features were located, an initial exploratory study was initiated to define the limits of the previous mining activities on the ground. The study consisted of 33 geotechnical borings and approximately 16,000 feet of electrical resistivity survey. The purpose of the borings was to explore the subsurface stratigraphy within and immediately adjacent to the mining features searching for evidence of lateral mine shafts within the subsurface, and subsidence of overburden resulting from subsurface collapse. The purpose of the electrical resistivity surveys was to provide a “larger” view of the subsurface in and around the mine areas. Surveys were performed through both features and borings to provide a means a “calibrating” the geophysical measurements.

The earth resistivity tomography technology is based on the conventional resistivity survey principles. It involves the measurement of the apparent resistivity of the earth. The dipole-dipole array was used, where an electric current is applied to the ground via two electrodes and the potential difference created at the surface is measured between two other electrodes. The apparent resistivity value is then calculated by dividing the difference by the current and applying a geometric factor based on the electrode configuration. In the tomographic survey, resistivities are measured from many groups of four electrodes selected systematically from up to 84 electrodes. The end result, obtained through iterative inverse modeling of the apparent resistivity values, is a resistivity profile showing resistivity contours in the units of Ohm-meters. Differences in resistivity values can be used to infer changes in the type of rock or soil at different locations along the profile.

Figure 4 is a resistivity profile of the subsurface in the area of one of the major mine features. Fill was placed in the surface depression to access the boring location at its center. The resistivity plot shows relatively low resistivity through the shaft area which is consistent with the soils encountered in the boring. Another notable inference from Figure 4 is the area of high resistivity (red to purple colors) immediately adjacent to the mine. The high resistivity could be interpreted as indicative of rock strata. This is consistent with the results of a boring drilled along the perimeter of the feature.

The results of the preliminary studies provided:

- **A defined “area of previous mining activity”**. The developer was able to go forward with development outside the limits set defining the mining area.

- **A general sense of the geometry of the mining features**. An absence of interconnected subsurface horizontal shafts associated with the mining features suggested that the surface depressions were primarily isolated vertical shafts. Only one area of surface topography revealed evidence of subsurface collapse from a lateral tunneling operation.
As development progressed in areas outside the designated mine area, development plans were prepared for areas within the mined areas that attempted to minimize the impact of known mine features. Lot boundaries were established that placed the majority of the mine features within areas of the site designated as “open space”. House locations were oriented such that known features were outside the proposed limits of any structure footprint. An attempt was also made to keep roadways and potential pathways of pipelines and drainage features removed from the feature locations.

Once a preliminary development plan was prepared for a section of the mine area, an exploration plan consisting of geotechnical borings, geophysical profiling, and air track drilling was initiated. The purpose of the development phase studies was to both define the near surface soil conditions for design of foundations and placement of infrastructure and also to develop the methodology for remediation of the mine features.

Protocols were developed for each of the exploration techniques. The protocols were developed on visual evidence of mine activity at the surface with the presumption that shafts or voids in the subsurface would originate from what could be seen on the surface. Except for some past logging activities, most of the site was essentially undisturbed. Geotechnical borings were drilled at the proposed house corners. Borings were terminated at auger refusal or 50 feet. Geophysical profiling was performed through the proposed house locations or between the house location and any known feature on the lot. Air track borings were drilled first at the center of each feature to terminate in rock at the base of the pit. Four to eight borings were drilled at the perimeter of each feature to a similar depth to identify the existence of horizontal subsurface tunnels.

The results of the development phase studies revealed that the features were predominately vertical pits without lateral subsurface tunnels.
was encountered, the shafts were six to eight feet in height. Partial collapse of the tunnels was reflected in subsidence of the ground surface along the alignment of the tunnel.

The value of utilizing several exploratory techniques was shown in one area of the site where surface evidence of past mining was not present. The resistivity survey in this area indicated low resistivity and the possible presence of a mine pit that had been filled in the recent past. Subsequent geotechnical drilling confirmed the presence of a pit requiring relocation of the proposed house.

**Remediation**

The methodology for remediation of the mine features has yet to be finalized. It is anticipated that variations of capping and filling the features may be possible based on size, location, and depth. The area of subsidence will be stabilized by either collapsing the shaft from the surface or filling the shaft in place.

**Conclusions**

Development within previously mined areas requires a cooperation of efforts at several levels. Preserving the cultural history of the past can be part of future development and in fact can be an important resource in determining the most appropriate exploration techniques to be applied. A combination of exploration techniques provides a clearer and more comprehensive picture of the unknown. The cultural site history is another tool that can be utilized to predict the scope and nature of features to be explored resulting in a more cost effective approach of site development.

**References**

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