New Data and Techniques for Evaluating Subsidence from Abandoned Underground Mines in Ohio

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ABSTRACT

Subsidence due to the collapse of abandoned underground mines is a geologic hazard that can affect buildings, highways, and infrastructure, potentially endangering lives and property. Further, damages from mine subsidence can cost millions of dollars. Between 2008 and 2011, the Ohio Department of Natural Resources (ODNR), Division of Mineral Resources Management invested more than $2.4 million to complete 87 projects related to abandoned underground mines. The costs of mine subsidence are expected to rise as abandoned underground mines age and deteriorate and as further development occurs across the Ohio landscape.

The ODNR Division of Geological Survey (the Survey) has been responsible for mapping the locations of abandoned underground mines since 1977. The mapping process involves creating and managing a geographic information system (GIS) of abandoned underground mines in Ohio. A recently developed custom GIS application allows Survey staff geologists to quickly gather any geologic data on file at the Survey that is relevant to a subsidence complaint. Once the information has been gathered into the GIS, a geologist writes a report summarizing the data and noting critical information. The report is submitted to either the Division of Mineral Resources Management or a consulting engineering company assigned to the complaint for further evaluation, site inspection, and potential remediation. The GIS software application provides easy access to digital geologic information for evaluation and potential property remediation.

New datasets also are being developed as part of the ongoing mapping program. The Survey is the archive for all final abandonment mine maps, which are scanned at a high resolution and georeferenced to existing ground control. Using georeferenced mine maps, the elevation, thickness, and information on the condition of each mine is captured into the GIS. These datasets, in addition to new statewide LiDAR and other digital geologic datasets, are used to identify areas at high risk due to potential mine subsidence. Variables analyzed as part of this study include age of a mine, depth to a mine, amount of unconsolidated overburden, and roof rock lithology. The new datasets will provide a better understanding on the variables controlling mine subsidence from abandoned mines.

INTRODUCTION

Underground mining for coal in Ohio was first reported in 1800 (Crowell, 1995). The majority of the underground mining takes place in coal- and clay-mining areas of eastern and southern Ohio (fig. 1). Other commodities have been mined underground within Ohio, including salt, gypsum, limestone, shale, and even peat. Geologists have estimated that over 8,000 mines have been in operation over the last 200 years (Delong, 1988). With such a large number of mines being developed over a long period of time, there is an increasing probability that mines will collapse and subside as they age and deteriorate and as development occurs across the Ohio landscape.

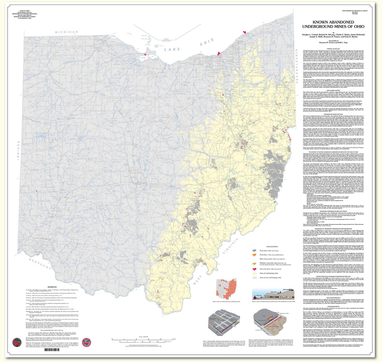

FIGURE 1.—*Known Abandoned Underground Mines of Ohio* (modified from Crowell and others, 2008). The majority of abandoned underground mines are associated with coal and clay mining in eastern Ohio.

FIGURE 2.—Aerial photograph showing location of mine subsidence in Youngstown, Ohio. In 1941, a property was inventoried by Fuller and Sturgeon (1941) as containing an abandoned mine shaft of the Foster #1 mine, which was abandoned in 1884 and was the most productive mine on the south side of Youngstown. Fuller and Sturgeon also noted that in 1876, a block of sandstone measuring 4' x 4' x 7' was taken out of the shaft and exhibited at the Centennial Exposition in Philadelphia. It won a gold medal for the best stone block on exhibition. In 1977, a garage collapsed into a mine shaft on a nearby property (Crowell, 1980; DeLong, 1988).

FIGURE 3.—Collapse of Interstate 70, near Cambridge, Ohio caused by mine subsidence (Crowell, 1995).

FIGURE 4.—Damage to a house from mine subsidence. Sugarcreek Township, Tuscarawas County, Ohio.

Mine subsidence in Ohio has been a problem that only has been recognized in the last 40 years. In 1977, a mine shaft collapsed 110 feet within a 230 feet shaft underneath a garage in Youngstown, Ohio (fig. 2). This incident led to the Survey mapping the detailed locations of abandoned underground mines (DeLong, 1988). Other prominent incidents have occurred, such as the collapse of Interstate 70 near Cambridge, Ohio (fig. 3; Crowell, 1995), and the recent subsidence underneath a house in Sugarcreek, Ohio (fig. 4). The cost associated with the remediation of abandoned mines is high. The repair of the collapse of I-70 near Cambridge cost approximately $3.8 million (Crowell, 1995). As of 2005, the Ohio Department of Transportation had spent approximately $14.3 million to repair highway damage caused by mine subsidence. In 2008, the ODNR Division of Mineral Resources Management invested more than $1.3 million to complete 32 projects related to abandoned-underground mines (Gordon, 2009). As abandoned underground mines age and deteriorate, we expect the costs associated with remediation of the abandoned mines to increase.

Most homeowner insurance policies do not cover damages from mine subsidence. In Ohio, the Mine Subsidence Insurance Fund gives property owners the opportunity to purchase mine-subsidence insurance. In order to assist the Ohio Mine Subsidence Insurance Underwriting Association (OMSIUA) with the evaluation of insurance claims, the Survey has entered into an agreement with OMSIUA to provide geologic information and preliminary evaluation of the validity of the mine subsidence claims. When officials from the OMSIUA receive a claim from a property owner, Survey geologists are given the claim for further evaluation. The geologists automatically gather all digital geologic maps and documents for the claim location using a GIS software application. Once all the information is gathered into the GIS, the geologists evaluate the potential of an underground mine to underlie the property and then write a claim report. The claim report is submitted to a consulting engineering company for further evaluation and potential remediation. The GIS software application provides easy access to digital geologic information for insurance claim processing and potential property remediation.

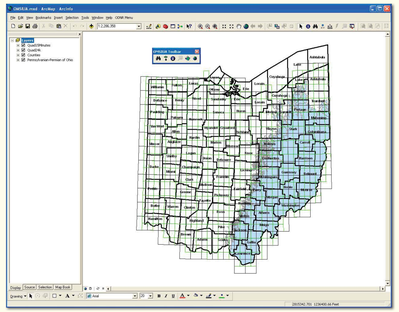

FIGURE 5.—OMSIUA Toolbar.

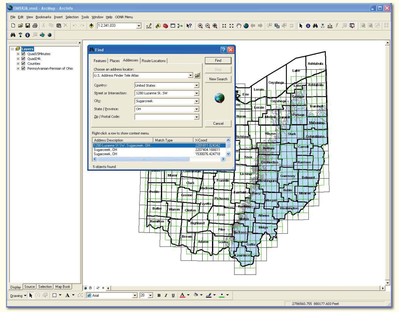

FIGURE 6.—Find tool on the OMSIUA Toolbar. The Find tool and the ESRI Address Locator are used to locate insurance claims based upon the claim address.

OMSIUA GIS APPLICATION

The OMSIUA GIS application consists of a toolbar with a number of tools. The tools contain a mixture of native ArcGIS tools and custom-designed tools using VBA for ArcObjects (fig. 5).

To locate mine subsidence claims, two tools are used to zoom into the claim location and load all geologic maps and documents. The toolbar contains the native ArcGIS Find tool (fig. 6). This tool is used to locate insurance claims based upon the Address Locator function in the Find tool. The second tool on the toolbar is mine-subsidence Select Location tool (fig. 7). This tool will load all known digital geologic maps and all geologic GIS data into the ArcMap document for that location. Some of the GIS datasets include the abandoned underground mines, the permitted surface mines, the 1:24,000-scale bedrock geology, and the 1-foot resolution digital orthophotography. One of the most important historical records is the 15-minute thematic geologic maps. These maps have been scanned and indexed. The Select Location tool will identify all the scanned maps within a mile radius and load them into the ArcMap (fig. 8).

Once the information is loaded, the geologist can conduct a preliminary mine-subsidence analysis. The Underground Mine Information form (fig. 9A) will present the attribute information on abandoned underground mines. Using the form, the georeferenced abandoned mine maps can be loaded into the ArcMap (fig. 9B). Documents can be accessed using the native ArcGIS Hyperlink tool (fig. 10). Some of the documents that can be accessed are the measured stratigraphic sections, core descriptions, and oil-and-gas well completion cards. These three types of documents can have a description of a coal bed within them and possibly the notation that an underground mine is nearby.

After the analysis is completed, portions of the preliminary mine subsidence report can be automated. A tool will export thematic, page-size, PDF maps (fig. 11A). The page-size maps are generated with the correct titles (fig. 11B). The PDF maps, along with all the geologic documents within a half-mile of the site, will be exported to a temporary directory (fig. 11C). The geologist can then ZIP the files together and send them to the consulting engineering company for further analysis.

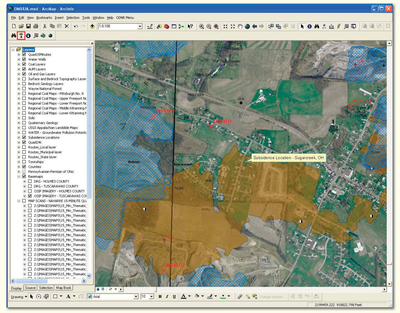

FIGURE 7.—Select Location tool. All geologic information is loaded into the ArcMap for the complainant location.

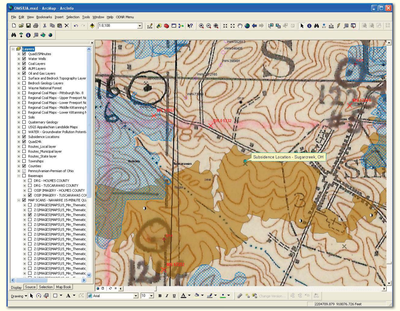

FIGURE 8.—Historic thematic 15-minute topographic map as a basemap. Map shows coal sample locations.

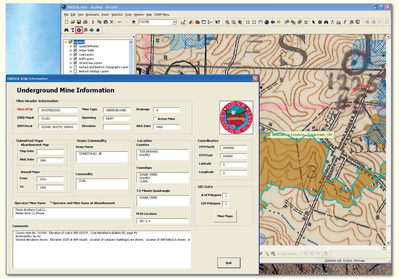

FIGURE 9A.—Underground Mine Information form.

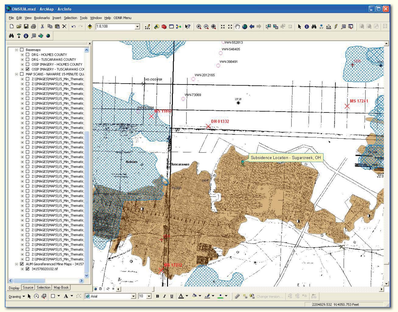

FIGURE 9B.—Georeferenced mine map can be loaded from the Underground Mine Information form.

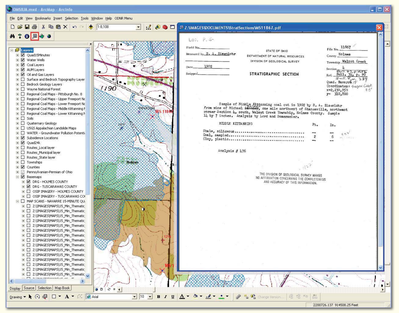

FIGURE 10.—Hyperlink to a Measured Section document.

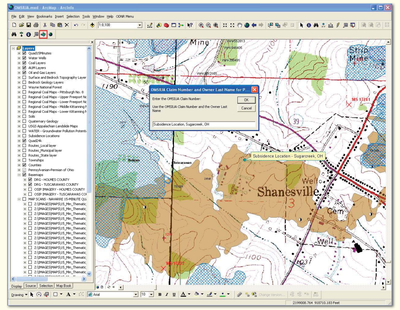

FIGURE 11A.—Automating the export of PDF maps.

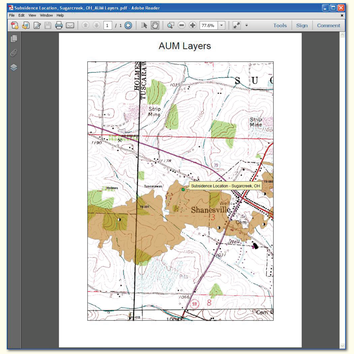

FIGURE 11B.—All automated PDF figures are generated with the correct titles.

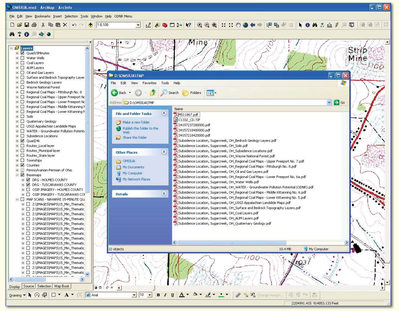

FIGURE 11C.—All documents within a half-mile radius and the PDF figures are copied to a temporary directory.