

MAPPING HYDROLOGICALLY SIGNIFICANT CATEGORIES OF SPOIL DEPOSITS ACROSS BROAD AREAS FOR PURPOSES OF LAND-USE MANAGEMENT, WARRICK COUNTY, INDIANA¹

by

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Abstract. Surface mining has disturbed approximately 180,000 acres of Indiana. Because many management issues require understanding of how groundwater moves through spoil, practical methods need to be developed for mapping hydrologically significant categories of spoil across broad areas. As part of a pilot study involving cooperation between several state agencies, spoil deposits in Warrick County were targeted for mapping. The Indiana State Department of Health (ISDH) had conducted a preliminary investigation of mine spoils and suggested evaluation criteria for such materials. In consultation with members of a working group on spoil characterization, four categories of soil replacement were selected for mapping, based on the presence or absence of grading and thickness of soil cover. The Indiana Geological Survey (IGS) compiled post-mining land-use maps in digital and paper form. Where uncertainties existed, mapping was conducted by IGS, in consultation with the Indiana Department of Reclamation (IDOR), using aerial photographs and topographic maps. The final product consists of a geographic information system (GIS) containing map layers showing the distribution of the four hydrologically significant categories of spoil, together with other layers of hydrologic interest. Users can view these maps in conjunction with map layers showing infrastructure, aerial photographs and topographic quadrangle maps.

Additional Key Words: Spoil Characterization, Geographic Information Systems, GIS

Introduction

Spoil, which is the cast overburden resulting from surface mining, does not resemble soil and hence can not be evaluated by soil scientists for septic-field suitability using conventional methods of inspecting natural soil horizons. Spoil is comprised of a variety of rocks and minerals with different chemical and physical characteristics and in varying proportions and sizes. But despite spoil's compositional heterogeneity, certain categories can be identified on the basis of mining and reclamation techniques that were employed at the time of the spoil's creation, as well as the character of the overburden from which the spoil was derived. In order to evaluate sites for septic-field suitability, guidelines are needed that incorporate readily available (or cheaply attainable) information.

Surface mining has disturbed approximately 180,000 acres of Indiana. Surface-mining and reclamation methods have evolved through the years. The earliest mine operators created steep, ungraded spoil ridges, which were often planted with trees. After 1967, the State of Indiana established standards for leveling peaks and ridges on land to be used for row crops, pasture, and forest. In 1977, Congress enacted the federal Surface Mining Control and Reclamation Act (SMCRA), establishing performance standards dealing with topsoil, hydrology, contour of the land, and revegetation following mining. After passage of the Act, coal operators were required to incorporate soil replacement into their reclamation activities for all reclamation that occurred after May 3, 1978. In areas where prime farmland existed prior to mining, operators were required by the Act to make provisions for stockpiling soil from such areas and restoring it to an equivalent (though not necessarily the same) area during reclamation. The Indiana Soils/Prime Farmland Team (1998) discussed prime and non-prime farmland soil-replacement requirements and exemptions.

Much of this reclaimed land has distinct aesthetic advantages for residential development, such as forests, lakes, and (or) rolling terrain. Pressure for development in areas of mine has recently been increasing. Substantial parts of some counties (as much as 50 percent of Warrick County) is now comprised of spoil, and some suburban areas are encroaching on mined lands. The use of residential septic fields in mine

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spoil has been questioned by ISDH; however, little is known regarding the fate of septic leachate in such man-made materials. Some states have effectively banned the use of septic fields in mine spoil. Practical criteria are needed by field investigators of the ISDH to evaluate various mine-spoil areas for installation of septic fields throughout the Indiana coal field to protect groundwater and surface waters. By removing uncertainties regarding the hydrologic suitability of such areas, a potential obstacle to the development of these large tracts of real estate will have been eliminated.

The preliminary investigation by ISDH of mine spoils suggested special evaluation criteria for such materials (Dunn, 1994). The criteria recognized four distinct landforms produced by different reclamation methods: (1) pre-1967 reclamation; (2) 1967 to 1977 reclamation; (3) post-1977 prime farmland reclamation; and (4) post-1977 non-prime farmland reclamation. Broad qualitative guidelines were offered regarding the suitability for on-site sewage disposal within these different landforms.

ISDH requested that IGS conduct preliminary mapping of mine spoil to assist local health departments in evaluating the suitability of sites on for on-site sewage disposal. Detailed characterization and mapping of mine spoil on the basis of all potentially relevant physical, chemical, and engineering factors would be prohibitively costly and time-consuming. The purpose of this paper is to describe the development of a GIS that can be used in the preliminary phases of investigations that require hydrologic characterization of mine spoil deposits.

Methods and Results

The principal task was to create a map layer showing major categories of spoil landform type (fig. 1). Four categories were recognized: (1) Category 1A, where spoil was left ungraded and there was no soil replacement, (2) Category 1B, where the spoil was graded, but there was no soil replacement, (3) Category 2, where spoil has been graded and subsequently covered with less than 30 inches of soil replacement, and (4) Category 3, where spoil has been graded and subsequently covered with greater than 30 inches of soil replacement ("prime farmland"). The principal factor governing the distribution of spoil landform types is the date of reclamation, particularly with respect to the enactment and phased implementation of SMCRA in 1977, which promulgated more stringent rules regarding grading and capping of the spoils.

Information about dates of mining was derived from map legends, reports of the Indiana State Mine Inspector, dates of aerial photography, the Preliminary Coal Map series of the IGS, and coal mine datasets of IGS. The databases associated with these coverages were used to differentiate where mining ceased during or prior to 1977, and where mining ceased at some time between 1978 and 1982. For the former, it was assumed that no soil was replaced during reclamation, so that those areas are comprised solely of Categories 1A or 1B; for the latter, it was assumed that reclamation involved either Categories 1A, 1B, or 2, but that there was no Category 3. Also, IDOR assisted with differentiation of Categories 1A, 1B, and 2 for some of the mines that operated between 1977 and 1982.

Actual mined areas where mining occurred prior to 1982 were obtained as digital coverages from the Indiana Coal Mine Database of the IGS. These coverages were compiled from affected area maps of IDOR (source scale is typically 1:4,800), aerial photographs of the U.S. Department of Agriculture (USDA) (source scale = 1:20,000 and 1:40,000), original maps of coal-mining companies (typically 1:4,800), previous studies of the IGS (various scales, but predominantly 1:24,000), and county soil-survey maps (source scale = 1:15,840

For areas mined since 1982, the situation is more complex, and there is no single source of digital maps showing permitted areas, affected areas, and mined areas, or proposed or actual post-mining land use. Prior to mining, mine operators must submit applications for permits to mine to IDOR. As part of their permit applications, they must provide maps showing where prime farmland exists and the areas that will be affected by mining. Once a permit to mine has been granted, the mine operator may periodically submit applications for variances in the proposed mining plan. Upon completion of reclamation, the operators must submit maps showing final "soil replacement" or "post-mining land use." For mining operations that are still ongoing, maps associated with the original permit application and for interim variances can be used to determine the likely disposition of soil-replacement categories. For mining operations that have finished, the final post-mining land use map can be used to determine the actual distribution of soil-replacement categories.

The various coal companies may (or may not) possess maps in digital form, but such information is submitted only in paper form to IDOR, which is the central repository of such information. Consequently, efforts were made to obtain digital maps from several coal companies, including Amax Coal Company and

United Minerals, Inc. In addition to digital data obtained from coal companies, permit boundaries for selected areas were obtained in digital form from the IGS; for some of these areas, soil replacement categories were identified with the assistance of IDOR.

For areas from which digital data was not available, copies of paper maps were obtained from IDOR; features such as the "May 3rd Line" (certain requirements of SMCRA came into effect on May 3, 1978) and "prime farmland" were identified with the assistance of IDOR. The paper maps were then converted into digital form at the IGS.

Aerial photographs were inspected to identify and map boundaries between graded and ungraded spoil without soil cap. This series of photographs was taken in 1980 and IDOR reviewed these boundaries. Those photographs have been registered to the TIGER road files of the U.S. Census Bureau (source scale = 1:100,000); because of distortions in the photographs and because of the large source scale of the TIGER files, displacements of features (such as road intersections) may appear when the photographs are viewed in conjunction with the TIGER roads or with digital raster graphics files of 7.5-minute topographic quadrangle maps. Such displacements are typically (but not always) less than 50 m.

Finally, all areas for which maps existed were overlaid on USGS 7.5-minute topographic quadrangle maps. The photorevisions of these maps (typically shown as a purple stipple pattern and based on aerial photographs taken in the late 1970's or 1980's) indicated that in some areas mining had extended beyond the areas covered by all of the maps that had been collected to-date. Consultation with IDOR indicated that some of the photorevisions represent mined areas, while others appear to be errors that do not represent any mining activity. Because field checking of these areas was beyond the scope of this project, these areas were designated as "indeterminate."

After creating the map layer of spoil landform types, it was incorporated into a GIS that included other potentially relevant map layers. For example, in addition to surface mining, there has been considerable underground mining of coal in Warrick County. Where such mines are very shallow, they have sometimes been used in the past for residential septic disposal. For this reason, undermined areas were also included in the GIS. These were obtained from pre-existing digital files of the IGS, whose source scale was 1:24,000.

Other pre-existing map layers that are included in the GIS are (1) deposits of coal-preparation refuse

("gob" and "slurry"), which can be important source of acidic mine drainage, (2) water-well logs and gamma-ray logs, which are important sources of geologic information, (3) coal bed crop lines, (4) aerial photographs, and (5) topographic quadrangle maps.

The GIS uses ArcExplorer™ software as a data browser. ArcExplorer™ has been developed by the Environmental Systems Research Institute, Inc. (ESRI; <http://www.esri.com>) and is freely distributed. Users can interactively view and query the map of spoil landform types and its relationship to other pertinent hydrologic, geologic, and landuse features.

Conclusions

As population and associated development continues to expand into mined areas, information concerning hydrologic properties underlying such areas will become increasingly important. In Indiana, reclaimed areas consist of an intricate patchwork of landform types that were created over more than seven decades, as a result of evolving technology and regulations. As discussed in the companion paper (Olyphant *et al.*, in review), these landform types appear to have distinctly different hydrologic regimes. Proper environmental decision-making will require further elucidation of the hydrologic characteristics of each of these landform types. However, for the present, an approach that involves the linkage of hydrologic investigations with GIS mapping and analytical tools would seem to provide the most expeditious basis for making land-use decisions.

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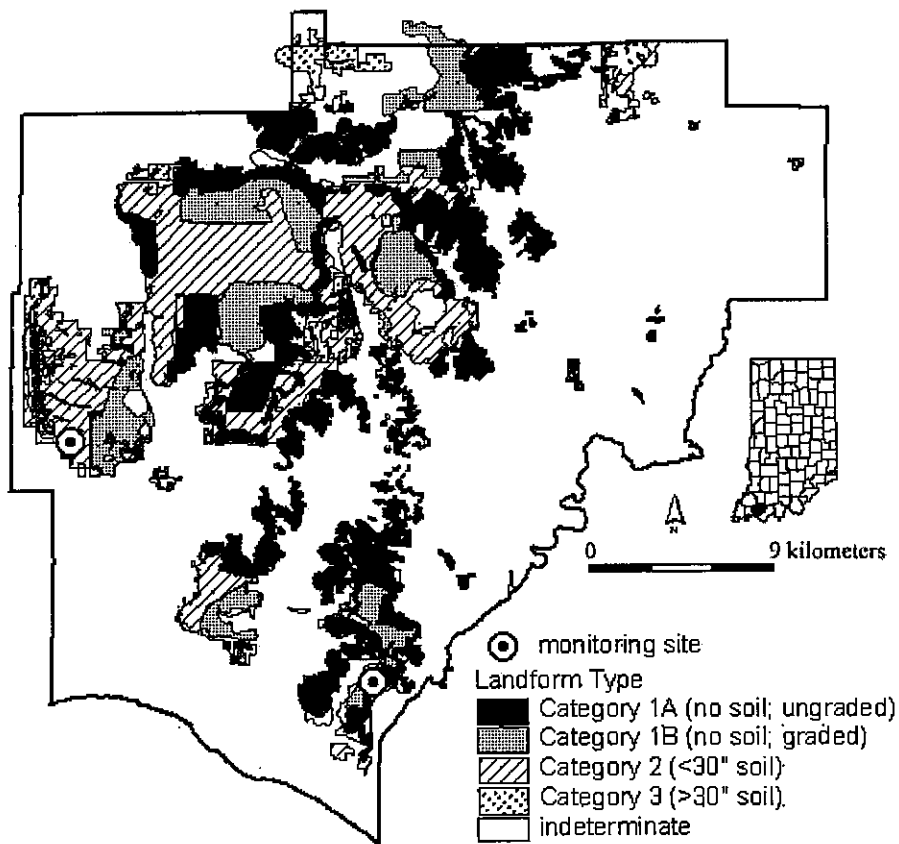


Figure 1. Map of Warrick County, Indiana, showing categories of spoil landform types. Intensive monitoring of hydrologic conditions in spoil are being conducted at the monitoring sites.