Virginia Department of Mines, Minerals and Energy
Automated Mapping Facilities Management System (AM/FM)[1]

by

Doug Mullins and Terry Stockner[2]

Abstract. The Virginia Department of Mines, Minerals and Energy realized the need exists to create a digital database that will provide improved mining and geologic information needed for the permitting and reclamation of coal mines; for reclaiming abandoned mine sites; for coal reserve and coal quality studies and for engineering studies related to subsidence, mine blowouts, and underground mine development. The Coalbed Mapping Project (CBM) and Automated Mapping Facilities Management System (AM/FM) were initiated to meet this need. The Coalbed Mapping Project's main goal is to create a set of base maps that show underground-mining extents of each coalbed in each quadrangle in the Southwest Virginia Coal fields. The AM/FM System is comprised of integrated digital coverages of surface mine permits, water monitoring data, Abandoned Mined Land (AML) problem areas, complaint investigation information, and U.S.G.S. 7.5' digital topographic maps. It is clear that advances in automation technology permit us to access and utilize data as never before. This allows us to maximize the use of decreasing resources available to both industry and government. By making information available in the form of AM/FM and other digital systems, both access and ease of analysis are facilitated.

Introduction

There has been a long history of coal mining in Southwest Virginia, much of which occurred before the creation of regulatory agencies. The Virginia Department of Mines, Minerals, and Energy (VA DMME) has collected a vast amount of coal mine information and mapping in performing its regulatory requirements. However, there is a tremendous amount of coal mining data and mapping not yet collected or readily usable. The need to collect, catalog, and use this source of knowledge in a timely manner became important to VA DMME as resources became less available. Filling this need would not only benefit the Department, but everyone involved with coal mining

as data became more readily available. The Department created two solutions; the Coalbed Mapping Project (CBM) and the VA DMME Automated Mapping and Facility Management System (AM/FM).

Coalbed Mapping Project

The Coalbed Mapping Project was created to map the location of all known underground coal mining in Southwest Virginia. The efforts were concentrated on those mines that operated before the existence of regulatory agencies. Maps and information for these mines are the most difficult to acquire and easily lost. Many of these maps are being made available to the Department by coal companies.

The maps are created by collecting, scaling, placing and outlining all known mines for each seam for each U.S.G.S 7.5' Topographical Quadrangle in the coalfields. If the mine operated from the 1950s onward, the underground mine index number is recorded along with dates of operations, mine name, and company name. If the mine operated prior to the 1950s or if no information is known about the mine, it is given an old mine number, omxxxx, for reference and any known information is still gathered. Some mine maps showed surface and/or

---

augered features that altered the coal seam outcrops. These areas were also captured for general reference. (see Figure 1.)
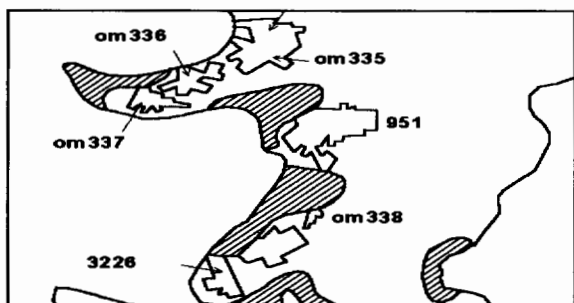

Figure 1: A portion of the Blair seam showing the identification of all known mine works. Shaded areas depict where coal outcrops have been altered by surface mining.

When the project started in 1991, a set of mylar overlays were the final output. After reaching the second phase of the project in 1996, the data is now being provided in a digital format. Digital files are provided in AutoCAD® and Arc/Info® export formats in both raster and/or vector versions.

In the second phase of the project, the increased power and affordability of the personal computers and workstations has made the creation of a digital mine map repository possible and usable. The mine maps are scanned by a large-format scanner. Currently, over 1000 mine maps have been scanned, showing over 3,000 mines. Much of this is performed on location in the file rooms and vaults of the coal companies providing access to the maps. These digital maps are then placed into the VA State Plane Coordinate System (NAD27) by the best means possible. Most companies still in operation have company grids and the conversions to the VA State Plane Coordinate System. However, the older mines were mostly surveyed in a mine-specific coordinate system. For these older maps, the only method of location is by using any visible surface feature drawn on the map for comparison to U.S.G.S. Topographic maps. (see Figure 2.) Work is still ongoing to capture underground mine maps in a digital format.

The Coalbed Mapping Project has been a tremendous asset in increasing the knowledge of paste mining activity. Although it is not expected that every deep mine that has ever operated will be input into the system, continuous efforts to expand
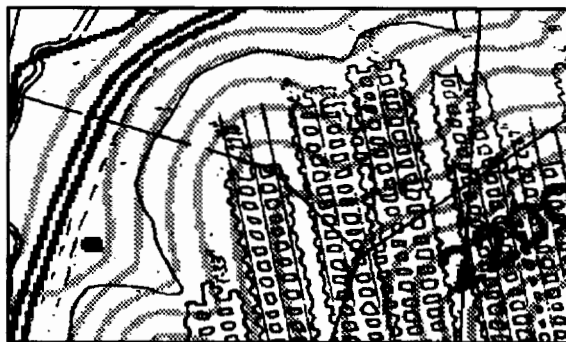

Figure 2: An example of a scanned mine map placed on a U.S.G.S Topographic map.

the project have made this a valuable tool for the future of coal mining in Southwest Virginia. The data generated by the project provides improved mining and geologic information needed for the permitting and reclamation of coal mines; for coal reserve and coal quality studies; and for engineering studies related to subsidence and underground mine development.

Automated Mapping and Facility Management

The VA DMME Automated Mapping and Facility Management System (AM/FM) was created to transform the current manual mapping system into a digital database usable by anyone. The system was created in 1993. The first goal was to record the VA Division of Mined Land Reclamation (DMLR) coal mining surface permit boundaries. Every mine in Virginia must show the surface area it plans to disturb and discuss plans for reclamation. Over 800 permits were digitized from the permit application maps, creating over 1,200 polygons. Every polygon is assigned by permit number. This permit number is then related to a database containing information about the operation.
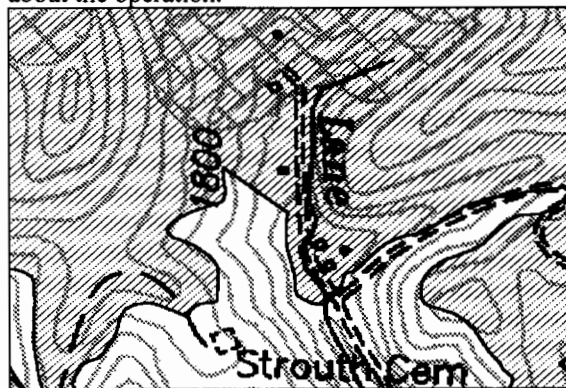

Figure 3: The southern portion of a DMLR surface permit is shown shaded and outlined

458

The mine status, operating company, acreage permitted, dates, etc. can be accessed by a single click on the screen. (see figures 3 and 4.)

Permit	1101537
Applic	102084
Apprv	Y
Date	19950706
Status	A
Statcde	1
Typecde	1
App_acread	656.000000
Rel_to	0
Rel_from	1100503
Comment	also reling from 1200105 & 1101353
Applic	102084
Company	VIRGINIA IRON, COAL & COKE COMPANY
Status	A
Statcde	1
Statdate	19950914
Typecde	1

Figure 4: Lists some of the information that the AM/FM system can provide with a single click of the mouse.

The surface permit boundaries are updated as coal mine operators amend and revise the permit plans. This keeps the data current as possible and usable for industry when new permits are being considered.

The speed and accessibility of digital information has increased the need to have all geographic related information converted from a paper/manual system to the AM/FM digital system. New data currently being converted from paper to digital form are the Proposed Mining Underground (PMU) boundaries, Abandoned Mine Land (AML) inventory, and Water monitoring locations.

The PMUs will be the second "layer" of information to be added to the system. The boundaries show the projections of each underground mine by outlining and addressing areas that will be mined in the near future. Being able to access this data quickly will allow permit reviewers to address possible impacts in a more timely fashion.

Virginia's Abandoned Mine Land Program is responsible for mitigating problems caused by pre-regulatory mining. The areas are inventoried and shown on U.S.G.S. Topographic maps. Knowing the location of problem areas can vastly aid in the handling of newly-developing problems as events sometimes cascade and create further environmental problems.

Surface and ground water quality is a concern for everyone. Monitoring is a tool used in the prevention of water supply degradation. Water monitoring efforts are costly and can be easily duplicated when the location of monitoring points relative to each other is not readily available. There are literally thousands of monitoring points, and when the water monitoring AM/FM "layers" are completed, industry and government will be able to manage this information much better to prevent over-monitoring. Monitoring points too close to each other only serve to add cost with no added value to the data collected. These costs could be redirected to other expenses. The inverse, however less likely, could be discovered; where an area may not be monitored sufficiently to prevent problems which, when identified, could be corrected.

There are few limits to how much data can be captured in a system such as this. The main concern is maintenance and updates. Information that changes rapidly must be maintained constantly and resources must be allocated to make this possible.

Methods, Hardware, and Software Solutions

The Coalbed Mapping Project and the AM/FM System use the same methods to produce results. Therefore, there are several design considerations that have guided, and continue to guide, their development.

First, the information must be in a usable, familiar, and widely-accepted form. The hardware and applications used must be readily available and mainstream. The digital processes must be equivalent to current methods. Access and distribution of the data must be simple and easily accomplished. The system must be kept to a "size" such that the workload to update and maintain does not devour all available resources.

Our first task was to talk to the people involved with the coal industry to see what software programs were being used, what file formats they supported, and seek the most suitable ones for our needs. If we had created our own data file formats that no other program could read or was not widely supported, our efforts would be less effective. Two software lines were chosen to create the base or the language of our system: AutoCAD® by Autodesk and Arc/Info® by Environmental Sciences Research Institute (ESRI).

AutoCAD® is the drafting package most widely used by the coal industry in Southwest Virginia. Almost every industry or government agency we interact with uses this program or its file formats for drafting. We needed to maintain this compatibility at all cost. The largest sources of preexisting digital data are coal operators or consultants, and they use AutoCAD®

Arc/Info® is one of the most widely used and powerful AM/FM systems. ESRI has software packages ranging from the powerful Arc/Info® to the more user friendly Arcview®, and was one of the first companies to bridge into the area of CAD/GIS compatibility with its ArcCAD® product. This bridge allowed us to build an AM/FM system that could go into CAD or GIS systems easily and allow for full data exchange. Less work would be duplicated this way. By supporting both Arc/Info® and AutoCAD® we could guarantee data compatibility and usability for some time. Of these two software lines, the file formats used are both raster and vector.

Vector (line) data and raster (image) data are both utilized. For the vector side, we use Arc/Info® coverages and AutoCAD® drawings. For the raster side, Tiff and RLC file formats are used. Raster information is used heavily for a quick and easy way to capture data and be sure everything shown on the map is present. The files are nothing more than digital photographs that can be overlaid for visual analysis. Vector data is line data that database entries can be assigned to; thus allowing the software to analyze the data whenever possible (this decreases time, especially in searching). Finding the location of one permit out of over 800 takes only a couple of seconds.

Hardware needed to create the data and run the software has improved dramatically. Five years ago, this type of system would consist of several UNIX® workstations at some considerable cost. Presently, with the creation of the Intel® Pentium line, a steady migration from UNIX® to the Microsoft® operating systems is taking place. We currently use one Silicon Graphics UNIX® workstation. However, the bulk of the workstations and PC's are Pentium Processors in the 120 - 133 MHz range. The amount of Random Access (RAM) memory on these computers ranges from 32 to 128 Megabytes(Mb). We found that the volume of the data made the amount of RAM, as opposed to faster CPUs, more critical in data processing. Increasing both RAM and CPU speed is the best option.

Scaleable Pentium Pros® with 128-plus Mb RAM would be the preferred choice at the present.

For geographic data entry, we use Global Positioning System receivers, digitizers and scanners.

The GPS receivers we use range in post-processed accuracy from 5 meters to sub-meter. The Department has several Trimble Geoexplorers® and Geoexplorer II® to locate large generalized features. Accuracy of these receivers are less than or equal to 5 meters after processing. A Trimble Pathfinder Pro XL® is used for the specific sub-meter needs. GPS is used for field-checking the accuracy of, or adding to, existing mapping data. The Department maintains its own GPS base station for use in the Southwest Virginia area. The base station is located in the Big Stone Gap office in Wise County, VA. Base station data is available to the public.

Bulk digitizing jobs are sometimes contracted out, rather than processed in-house, when creating the basic map layers. However, updating is still performed in-house. Our work load has required four digitizers, three of which measure three by four feet and are accurate to one-hundredth of an inch. The fourth has a four by five feet active area and is accurate to a thousandth of an inch.

For raster files, we have one large format gray scale scanner with an optical resolution of 400 dpi and a 36-inch scan area. We have smaller scanners with color capability that scan documents up to 11 x 17 inches at 200 dpi optical and 8 x 11 up to 2700 dpi optical. A color slide and negative scanner is available mostly for reports, but are sometimes used for data entry.

Old mine maps are difficult to scan. The quality of the maps can vary greatly. This tends to make the work involved too costly to contract out. The purchase of scanners and performing quality control ourselves has been far more feasible.

All hardware items are now being purchased from well-known companies that have been in their respective businesses for sometime. We experienced numerous problems in going with lesser known companies in an effort to save money.

The AM/FM system has to conform with current methods of manual drafting for two main reasons: 1.) The laws and regulations that govern

coal mining in Virginia dictate the minimum base and permit map requirements. 2.) People who use the data are familiar with the current standard. The fastest way to go from manual to computer mapping is to keep the new system as familiar to the user as possible. The manual mapping system required the U.S.G.S topographic maps as the base upon which all data was drafted by hand. The AM/FM system required a set of base maps that would be "replicas" of the paper U.S.G.S. maps.

The Department looked at several forms of low-cost base maps that were available off-the-shelf. Most varieties were advertised for less than $100 per map; however, they were not suitable for two main reasons: 1.) the data did not accurately duplicate the U.S.G.S. maps currently used; 2.) the copyrights were not sold with the data. This placed major restrictions on sharing our data with our customers. A full data exchange had to be maintained with industry, local, and federal governments. The solution was for the Department to have the U.S.G.S. maps converted.

The Department contracted out the digital conversion of 50 U.S.G.S topographic maps in the VA State Plane South NAD 27 coordinate system. More topographic maps are being purchased. The maps are in both raster and vector form with one restriction regarding distribution. The data is public domain and may be freely distributed but can not be resold as is by any other group other than the original contractor and VA DMME. Fees collected by the Department for the base maps are meant to cover the cost of distribution only. It took more than two years to acquire base maps which met our specifications. This now allows all individuals who interact with the Department to use the same base maps, significantly reducing confusion and discrepancies.

The vector data is in AutoCAD® release 12 drawing format. The digital base maps maintains a layer scheme for each data type. Contours within each quad are attributed for their elevations; thereby allowing three-dimensional models. AutoCAD® to Arc/Info® conversion of the line data is possible. However, both programs use slightly different font files. For the Arc/Info® side, the drawing files were digitally converted to TIF files. Line and point features are converted as need. For general overlays of data onto base maps, raster data is used for speed of display over the vector files. However, the vector maps have a major advantages, such as the ability to

customize what is to be seen. Also, changing the viewing scale does not degrade the quality of the work for the vector files. The data does not become more accurate when enlarged. However the print quality does not degrade for vector files. Raster files will degrade in quality when enlarged by becoming jagged or grainy. By using both raster and vector base maps, the weakness of one file format is compensated by the strengths of the other.

By keeping our existing mapping standard, the AM/FM data can be understood easily by any user currently familiar with U.S.G.S. mapping. The only new information the user needs to become familiar with is the coal-related data produced by the Department.

The database created is meant to be used by anyone anywhere. The best and simplest means of distribution have been employed to make this possible. The digital base maps can be purchased for less than $50 on a compact disc. The disc contains 50 U.S.G.S. topographic maps in AutoCAD® release 12 format. The base maps as well as the coal mine data to be overlaid onto the base maps can also be downloaded via the Internet. The Department has an Anonymous FTP site set up with the assistance of the Federal Office of Surface Mining. The address is FTP://pulaski.mme1.state.va.us for a World Wide Web browser such as Netscape or Internet Explorer. If access is by another type of FTP software, it is necessary to use *Anonymous* as the login name and a full name or email address as a password. Anonymous accounts have restricted privileges and their activity is monitored. Because of the large size of the base maps, downloading is not recommended. The CBM or AM/FM data has a far smaller file size and is updated as needed, making downloading the method of choice.

Summary and Conclusions

As with any new project or direction taken by business or government, care must be used to manage the growth of the project. As the information added to the system increases, so does the work needed to maintain what is being added. By considering the initial work load of data creation and the frequency the data changes, the maintenance workload can be visualized. This work load must not be concentrated too heavily in one area. Many people in the Department continue to have an active roll in data creation, which constitutes the largest initial work load. Once the system is created, specific

personnel are designated to maintain specific portions of the AM/FM system. This spreads the work load over many people to keep things running smoothly. If a problem is discovered in creating a particular data layer, the entire system is not affected. Although many are involved in the data creation and entry, fewer are involved in maintaining the over all focus of the system. This provides a constant direction for expansion.

The best way we found to expand the information covered has been to visualize the goal, lay out the steps and achieve each step one at a time. This sounds obvious. However, as the system developed, the desire to do everything the new way at once was realized and controlled. By completing small portions and building slowly over the past several years, a sound digital database has been developed.

The Virginia Department of Mines, Minerals, and Energy has made a dedicated effort in creating a digital geographic database. This database is usable not only by the Department but is heavily accessed by industry, the general public, and local and federal governments. The new database has helped to establish a free exchange of mining information to and from everyone involved in coal mining. The Automated Mapping and Facility Management system and the Coalbed Mapping Project have created the means to help meet the needs for future coal mining in Southwest Virginia.