Evolution of Enterprise GIS within Title IV and V Mining Programs at the West Virginia Department of Environmental Protection[1]

L. Keith Evans[2]

Abstract. Inability of the Agency's non-spatial Inspection and Enforcement (I&E) Oracle-based client server application, the Environmental Resources Information System (ERIS), to answer spatial questions about Mountain Top Mining resulted in the Bragg litigation and associated costs (> $4,000,000). This case created momentum within the Division of Mining and Reclamation (DMR) to support development of an enterprise Geographic Information System (GIS). This paper examines a published definition of "enterprise GIS" and a list of its benefits correlated with recent rapid evolution of GIS within Title V and Title IV mining programs in the West Virginia Department of Environmental Protection (WVDEP).

Rapidly increasing numbers of GIS users supported via a Citrix infrastructure running custom built ArcObjects applications can, for the first time, retrieve and associate spatial graphics with tabular data from ERIS, from the Office of Abandoned Mine Lands & Reclamation's client server relational data base referred to as their Resource Information Management System (RIMS) and from the Agency's environmental sampling results relational data base known as the Environmental Quality Information System (EQuIS). Geographically remote GIS users can now access all spatial data in the Agency's archive. For the first time, CAD users are beginning to access GIS data. A September 2003 flight using InterMAP's Learjet platform X band radar sensor produced a high accuracy IFSAR elevation dataset in ten counties in West Virginia's southern coal field. This higher resolution elevation data allows both DMR and Office of Abandoned Mine Lands & Reclamation (OAML&R) to generate pre-construction five foot contour mapping. Multispectral imagery collected from our Bell Jet Ranger helicopter is beginning to be used to monitor permitted activities and to observe landscape change over time. Finally, new ArcGIS capabilities allowing spatial data to be checked out and back in the GIS and the potential to engineer similar check out/in processes from ERIS and other enterprise relational databases using small, inexpensive HP iPAQ devices is being investigated.

Additional Key Words: Mountain Top Mining, spatial, Citrix, ArcObjects, IFSAR, elevation, airborne imaging.

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Introduction

In the early 1990s most legal challenges facing West Virginia's active mining program were site specific in nature: use of technology based water quality limits, localized surface and groundwater hydrologic impacts, structural damage from subsidence and blasting, dust, and aesthetics. Development and implementation of an Oracle-based client server computer application known internally as the Environmental Resources Information System (ERIS) was mandated by a 1992 agreement with the Office of Surface Mining (OSM). ERIS' focus was also site specific, recording day-to-day I&E activities at active mine sites. Both Division of Mining and Reclamation (DMR) management and OSM relied entirely on this non-spatial technology to support permitting actions and related legal challenges. During the 1990's, the State's active mining program invested most of its Information Technology (IT) budget for outside consultants able to code in PowerBuilder, the programming environment used to create ERIS desktop components.

Without funding, the Agency's Geographic Information System (GIS) development lagged significantly behind the ERIS implementation. Spatial extent and complexity of permitted mining operations was represented as a longitude and latitude coordinate pair in ERIS. This crude spatial representation was the only data initially available to represent mining sites in the Agency's GIS. Early GIS activities also included investigating spatial accuracy of all coordinates in ERIS for the first time. This was accomplished by comparing where mining site coordinates in ERIS plotted with respect to ERIS' data fields containing county and 1:24,000 scale United States Geological Survey (USGS) topographic map name. After excluding all sites with no geographic coordinates and sites having longitude and latitude values entered as zero, more than 15 percent of the mining sites did not plot in the same quad or in some instances the same county as shown in ERIS.

With the filing of the Bragg litigation late in 1998, the Agency had to answer basic spatial questions about the number and distribution of Mountain Top Mining sites in West Virginia's watersheds, the number of constructed versus proposed valley fills, and the number of miles of streams lost because of constructed valley fills. This represented a radical departure from site specific issues. ERIS was unable to provide these basic spatial data and Bragg litigation cost

more than $4,000,000 in legal fees. Additional county, regional, and watershed issues after Bragg included lands unsuitable, total maximum daily loads (TMDLs), cumulative hydrologic impact analysis (CHIA), and anti-degradation implementation.

Development of an Appropriate Geospatial Database Model for Active Mining Sites

Defending the litigation required the West Virginia Department of Environmental Protection (WVDEP) to participate in an inter-agency task force charged with producing an Environmental Impact Statement (EIS). An action item from this group lead to initial funding ($75,000) for development of a multi-layer geospatial data model in which features are correctly represented as polygons, vectors and points. This spatially correct data model could be queried for basic answers to county, regional, and watershed-level environmental questions. Therefore, a second round of funding was approved.

As this second round work (converting mapping of all Mountain Top Mining sites from paper to digital data) neared completion, additional quality control checks were performed on the geographic coordinates stored in ERIS. Results showed that 46% of points based on ERIS coordinates did not fall within the spatial extent of the permit's new boundary stored in the GIS data model.

In 2001, a special funding allocation from OSM supported the last work phase converting paper mining maps to digital GIS layers. These monies funded tasks collectively known as the Program Enhancement Cooperative Agreement (PECA). Receiving PECA funding was the keystone event that escalated development of the Agency's GIS to enterprise level tasks discussed below.

Within PECA, the paper map to digital data conversion task included capture of deep mine extents for the first time. This third, very large addition to the active mining spatial data extended back in time to include permits considered active as long ago as 1982.

It is not unusual to have more than a dozen layers now represent a single mining site over the duration of a permit. It is also not unusual for the number of layers to change during the life of a mining project. Figure 1 shows a subset of the 14 possible data layers used to accurately represent active mining operations in West Virginia today.

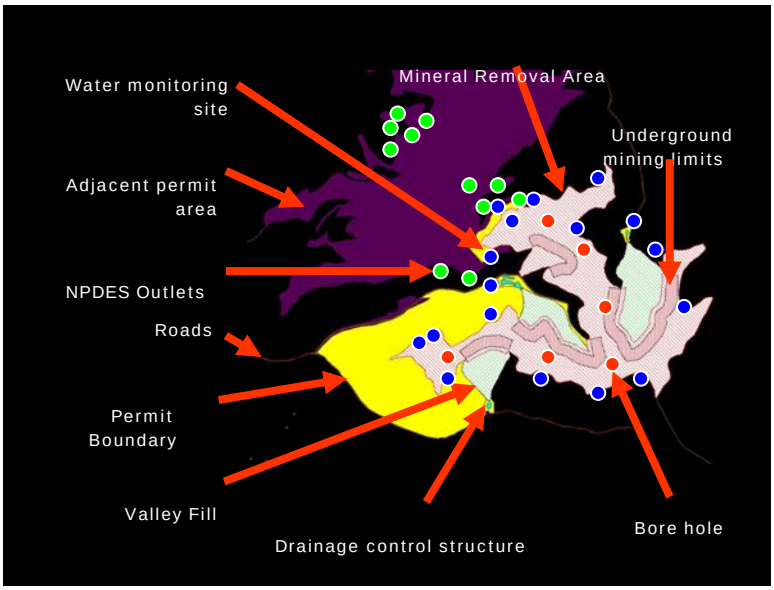


Figure 1. A typical mine site represented in DMR's new geospatial data model. All layers may not exist for a given mine site (i.e., surface mines lack an underground mining limits layer, etc.).

As companies submit additional paper maps for a given permit and they are converted to digital data by the Technical Applications and Geographic Information System Unit (TAGIS), a site chronology is built into the GIS. A given active permit changes both shape and area permitted during the course of the mining operation. For example, Landsat scenes in Figure 2 depict how a large area surface mine changed in Boone County, WV from 1994 to 1998. With closure of the mining operation, the whole history showing how the site changed over time can be played back by sequentially displaying the layers in DMR's geospatial data model based on map date.

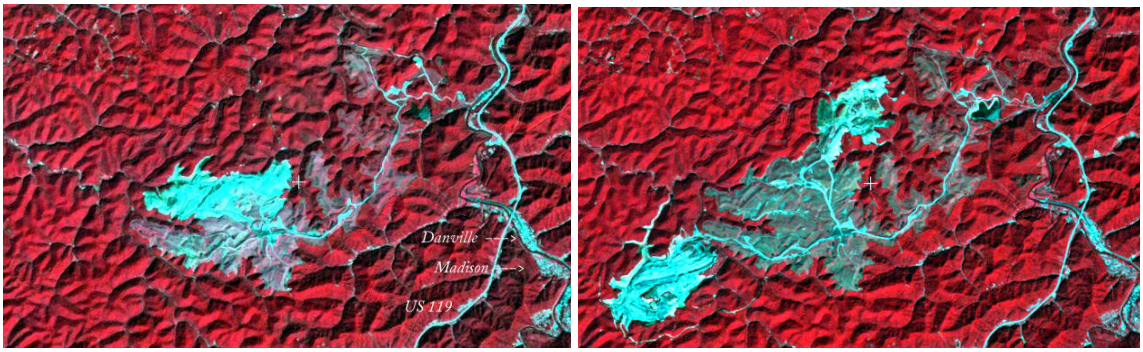


Figure 2. Change over time as mining progresses at a large area surface mine in Boone County, West Virginia. The left image is clipped from a 1994 Landsat image while the right image of the same area is from 1998.

Definition and Benefits of Enterprise GIS

The Agency's working definition of enterprise GIS begins with a Geospatial Information & Technology Association (GITA) presentation titled "Enterprise GIS-Building a Strong Foundation" (Landrum, 2001). Landrum's definition of an Enterprise GIS includes the following (not listed in their original sequence and with an identifying number affixed at the end of each bullet but not found in Landrum's original publication):

- Provides desktop access to all users (1);
- Provides access to other information systems in the organization by using a map or application as the integrator of the organization's information (2);
- Supports applications that are easy to use and understand (3);
- Well organized and well managed (4);
- Integrates geographic data across multiple departments and serves the entire organization (5);
- GIS is supported by all departments and management (6).

The experiences gained in supporting a GIS at several DMR regional offices necessitated adding a seventh bullet:

- Provides access to geospatial data regardless of the user's geographic location (7)

This last element reflects the difficulty keeping regional offices geographically isolated from our primary IT infrastructure in Charleston, West Virginia and field personnel equipped with the most current GIS data. Time and effort required to replicate large raster data sets to multiple locations where disk storage space for GIS data was severely limited proved problematic even with T1 telecommunication lines between the remote locations and our central GIS data archive.

To identify for WVDEP management and Agency GIS users the tangible benefits of investing time and monies into development of an enterprise GIS, a search for known benefits was conducted. "The What and Why of Farallon's Enterprise GIS Approach" (Farallon Geopraphics, Inc. 2004) lists the following as benefits of enterprise GIS (not listed in their

original sequence but with an identifier affixed at the end of each benefit and also not found in the original publication):

- Each department uses its preferred software and data types while working from a shared database (the best [right] tools for the job [A]);
- Eliminates time wasted converting or translating data and eliminates out-of-sync data or errors (increases productivity [B]);
- All users and key decision makers have quick access to the most accurate and up-to-date data (increases data accessibility [C]);
- All independent systems communicate quickly and effectively, regardless of data format (improves communications among departments [D]);
- Storing spatial data in a central database, your organization will maintain secure, high-quality data (increases data security [E]);
- Enhances speed, reliability and uptime [F];
- Enables easy web-based access for data sharing and community participation [G].

How recent projects relate to development of enterprise GIS and identifying subsequent benefits of these activities make up the remaining sections of this paper.

Custom Spatial Applications and Growing Numbers of GIS Users

At the beginning of the first quarter of 2003, WVDEP's Title IV and Title V programs had approximately sixty-five GIS users in four categories: power users, frequent users, occasional users, and new users (Figure 3). The 65 estimated users is based on the number of staff that had GIS training provided by either OSM's Technical Innovations and Professional Services (TIPS) program, by WVDEP's TAGIS, or directly by ESRI or ESRI's Authorized Training Centers; by the number of desktops that GIS was installed on and by the number of calls logged for GIS support. The 65 users represent the degree of success the Agency had implementing GIS technology by simply giving potential users basic GIS software training and access to the GIS data archive then expecting them to use the technology from that point on during normal working hours.

During 2003, significant numbers of staff moved toward the power user category (i.e., some new users became occasional users, etc.). The total GIS user community at the end of 2003 was

estimated at 130. The increased usage, primarily Title V staff, was a direct result of TAGIS creating a custom ArcGIS application to support DMR's permitting and I&E workflows.

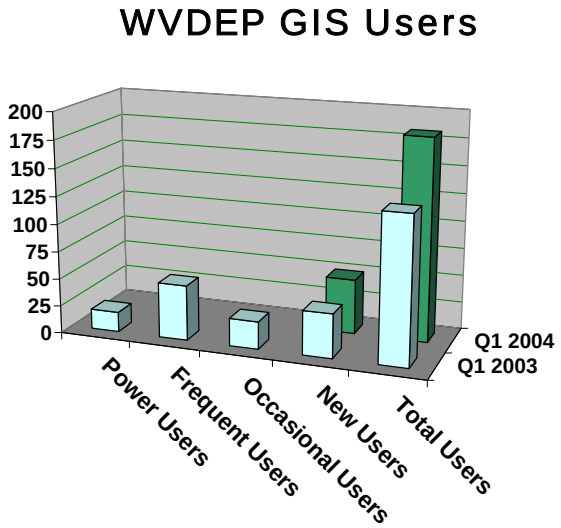


Figure 3. Increasing numbers of GIS users from 2003 – 2004.

The increase in GIS users from 2003 to 2004 was approximately 50 additional staff. Most of these users were in the new user category bringing the total number of all Title IV and V users to approximately 180. Most of this new group of fifty were Title IV people added because TAGIS developed a second custom application to support Office of Abandoned Mine Lands & Reclamation's (OAML&R's) day-to-day activates. Both the Title V and Title IV applications were designed to simplify use of the GIS; reducing the learning curve for new users. The lesson clearly learned, after evaluating the impact of creating these two spatial applications, is that rapidly growing numbers of new GIS users in WVDEP required developing customized spatial applications that make use of the technology much easier.

Custom applications fielded within Title IV and V programs are written in Visual Basic using ArcObjects (Wu, 2004). The DMR application provides users with many powerful capabilities: 1. the ability to pull data from their ERIS application by clicking on a specific mine site (GIS graphic's key field matches up with ERIS client server application key field); 2. pop up scans of original mine maps to see specifications and notes not captured in GIS layers; and 3. loads a display tool allowing them to page through digital field photographs (i.e., valley fills) easily

without having to know where these files are located in the IT infrastructure or how to write Structured Query Language (SQL) queries.

Likewise, the OAML&R application enhances the ability to access their Office's client server application called the Resource Information Management System (RIMS). This function is performed by clicking on a specific abandoned mine land (AML) site (GIS graphic's key field and RIMS key field both set to problem area description number) that loads a display tool for accessing AML digital field photographs, etc.

Based on Landrum's definition of enterprise GIS, these activities provide desktop access to all users (1), provide access to other information systems in the organization by using a map or application as the integrator of the organization's information (2) and support applications that are easy to use and understand (3). The primary benefit of developing custom applications for WVDEP is the elimination of wasted time in converting or translating data and eliminates out-of-sync data or errors (increases productivity [B]). The applications also provide all users and key decision makers quick access to the most accurate and up-to-date data (increases data accessibility [C]).

Using ArcSDE to Scale to Enterprise GIS

Almost all Title IV and V point, vector, and polygon spatial data have been migrated to ArcSDE. Additionally, quadrangle-based raster data have been compiled into seamless ArcSDE raster mosaics; allowing user access to topo information without the need to know the quad name. A Digital Ortho (DO) statewide layer was the first raster mosaic built (see Figure 4).

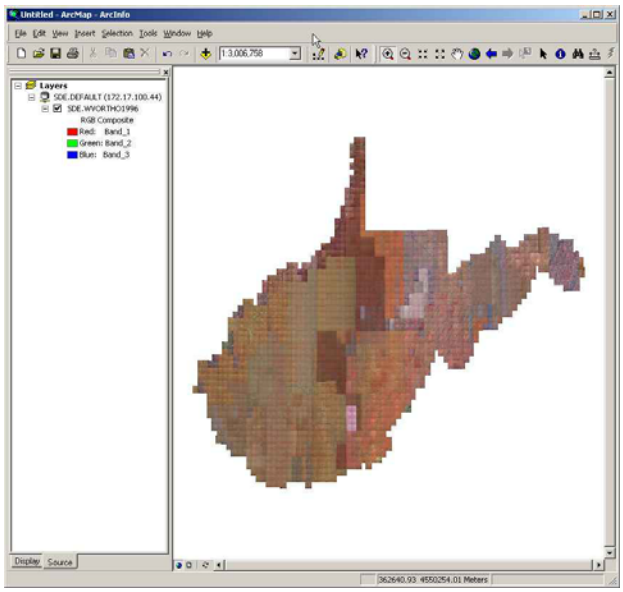


Figure 4. Screen capture of a very large raster mosaic created from all 1996-98 DOQQs in ArcSDE

In addition to a mosaic built from one meter 1996-1998 DOQs, an ArcSDE raster mosaic of all Digital Raster Graphics (DRGs) has been constructed. The largest single ArcSDE dataset is a raster image catalog containing all scanned mining maps; currently exceeding 37 million rows in Oracle. GIS users routinely access these raster image mosaics in both DMR and OAML&R. This project, according to Landrum's enterprise GIS definition, moves WVDEP closer to an organized and well managed GIS (4). The primary benefit of building these image catalogs is that they enhance speed, reliability, and uptime (F).

AutoCAD Map Users Accessing ArcSDE

Because Title IV and V employees also utilize AutoCAD Map, TAGIS was interested in how well commercial CAD software products could read and write to ESRI's binary file formats. Over the years, a convergence of CAD and GIS technologies resulted in production of GISConnect, an AutoCAD Map add on product that fully supports accessing and editing ESRI's data formats including geodatabases, shapefiles, coverages and feature classes. GISConnect also allows access to ArcSDE data directly from AutoCAD.

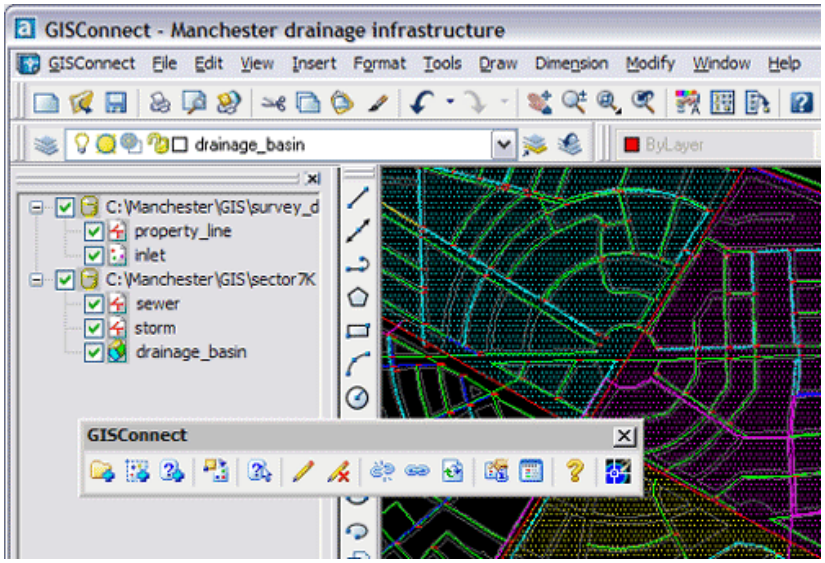


Figure 5. GISConnect's toolbar in AutoCAD Map

Discovery of this tool integrates geographic data across multiple departments and serves the entire organization (5). This enterprise tool benefits WVDEP because, with its use, all independent systems communicate quickly and effectively, regardless of data format (improves communications among departments [D]).

Computing Infrastructure Improvements

Figure 6 demonstrates the challenges incurred in replicating GIS data and the potential benefit incurred by WVDEP regional office personnel allowing access to GIS data from their desktops. The late 1990s distributed file services implementation did not work well because regional offices remained resource challenged and did not have adequate disk space to store an appropriate subset of all data in the GIS archive. This distributed approach was replaced late in 2002 with a centralized concept (Figure 7) using a SGI Origin 2000 IRIX-based server, 1 terabyte RAID, and two IBM rack mounted 8 processor Citrix computers (funded by PECA). The Origin 2000 provided network file services (NFS) to access mining coverages and shapefiles along with Oracle RDMS services for ERIS and ArcSDE. The databases were read by the two Citrix computers via fast Ethernet local area network (LAN). Sixteen simultaneous DMR field office and headquarters users (16 total CPUs in the Citrix servers) ran ArcGIS 8.3 with these IT assets. For the first time, regional office users had access to all GIS data resources. As the user

base grew, performance became an issue because the Citrix systems were powered by older Pentium III CPUs running at 700 megahertz. The existing fast Ethernet LAN provided inadequate bandwidth for both file services and server-based access via ArcSDE in conjunction with limited infrastructure which limited GIS users to a maximum of sixteen.

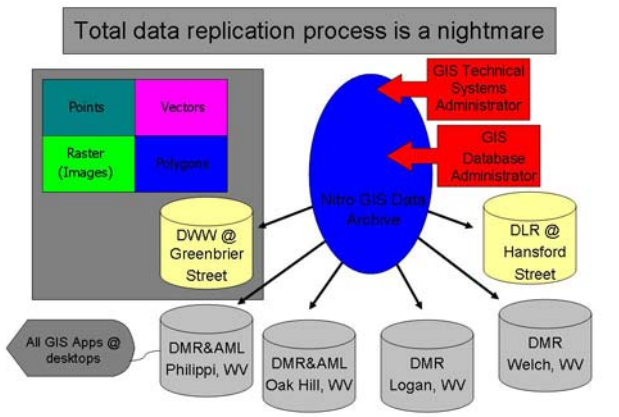
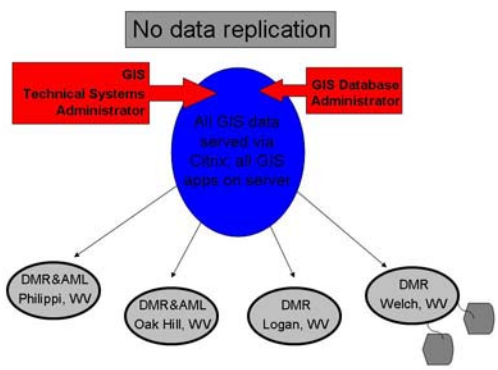


Figure 6. GIS data replicated to remote facilities



GIS data no longer replicated. Figure 7.

In this last quarter of 2004, the Citrix environment has grown into a farm (partially PECA funded) which significantly improved field office access speed by moving to faster IBM blade servers (see Figure 8) connected at gigabit networking speed to Oracle blade servers that are part of the same blade center. Storage was expanded from the 1 terabyte redundant array of inexpensive disks (RAID) to over 5 TB on a Storage Area Network (SAN) attached to the blade center at the same gigabit speed. Each blade has two Pentium IV CPUs running at 2.8 gigahertz and provides each GIS user sufficient random access memory (RAM) to run ArcGIS plus extensions like 3-D Analyst. ArcGIS 9.0, with most extensions installed, is accessible to both Title IV and Title V staff via OSM's TIPS program.

Figure 8. IBM Blade Servers

Addressing the Need for High Accuracy Elevation Data

Shank (2000) evaluated the extent of surface mining activity in Upper Mud River, Lower Little Coal River, Coal River, Spruce Creek, Upper Pond Fork, Guyandotte River Direct Drains, Island Creek and Buffalo Creek watersheds in southern West Virginia. His 1998 findings showed that, of the eight watersheds, Upper Pond Fork had the least disturbance (5.36% of the total watershed) and Guyandotte River Direct Drains had the most disturbed area (10.61%). Therefore, the ability to accurately represent today's topography in West Virginia's southern coal field must reflect the terrain altered by surface mining. Both Title IV and V mining programs perform daily work which benefit from accurate Digital Terrain Model (DTM) of disturbed sites.

Because Digital Line Graph (DLG)-based hypsography from that region of the State was based on aerial photos that ranged from 1955 to 1969 (Shank, 2004), an accurate DTM based on existing DLG's was impossible to produce. This 35+ year old elevation data incorrectly represented extensive Mountain Top Mining areas in southern West Virginia as undisturbed.

Another elevation dataset, the National Elevation Dataset (NED), is based on 30 meter resolution Digital Elevation Model (DEM) data broken into 7.5 minute tiles with a vertical accuracy of ± 16 meters. The NED exists for all southern West Virginia coal producing counties. Like the DLG-based hypsography, NED data from that part of the State does not show elevation changes resulting from Mountain Top Mining.

In early 2004, the USGS began producing new 10 meter resolution quadrangle-based datasets. These data were based on the 1996-1998 National Aerial Photography Program (NAPP) flights that were subsequently converted into the first statewide Digital Ortho Quarter Quads (DOQQs). While these new data are a substantial modernization representing Mountain Top Mining sites, they are still six to eight years out of date.

Using PECA funds, WVDEP contracted InterMAP Technologies to produce a contiguous higher resolution elevation dataset of Boone, Clay, Fayette, Kanawha, Logan, Mingo, McDowell, Nicholas, Raleigh and Wyoming Counties. InterMAP flew a STAR-3i IFSAR sensor on a modified Learjet Model 36 collecting data exceeding the contracted zone in September of 2003. The Learjet typically flies these missions at over 450 mph at elevations exceeding 30,000 feet. The X band sensor images a 10 km swath of ground in a single pass. The delivered elevation dataset is a grid of elevations at 5 meter intervals with a root mean square error (RMSE) of 1.0 meter vertically. An orthorectified radar image (ORI), resembling a black and white aerial photo, was also produced. An ORI shows the intensity of radar returns. This product has a 1.25-meter pixel size and are part of InterMAP Technologies NEXTMap product (specifications documented in Table 1).

Product	**Orthorectified Radar Imagery**	**Digital Surface Model**	**Digital Terrain Model**
Abbreviation	ORI	DSM	DTM
Pixel size	1.25 meters		
Product type		II	II
Root mean square error (RMSE)	2.0 Meters	1 Meter	1 Meter
95%		2.0	2.0
Mean & standard deviation		0.7	0.7

Table 1. IFSAR Specifications

Figure 9 - 12 illustrate the importance of the IFSAR product for WVDEP. The four images have the same map extent (part of the Williams Mountain, WV 1:24,000 scale topographic quadrangle) but differ with regard to their source data. The elevation data presented in the left

two images is the NED. They show the area undisturbed by mining. The right two images are based on the September 2003 IFSAR flight. These images show significant changes on the site resulting from mining activities.

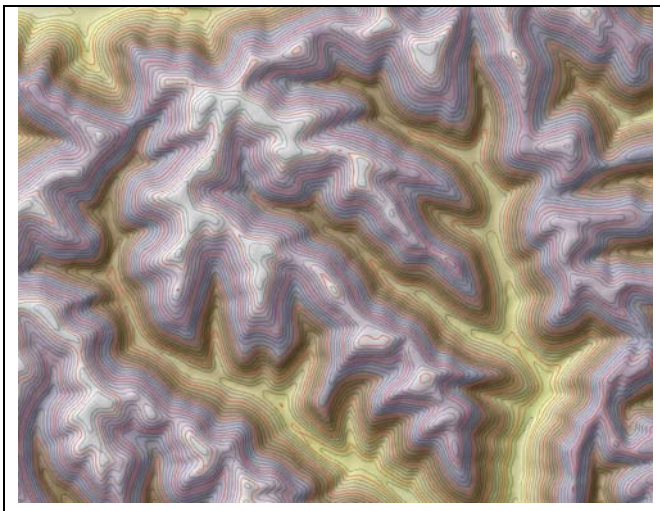


Figure 9. A hillshade with 10 foot contours based on NED

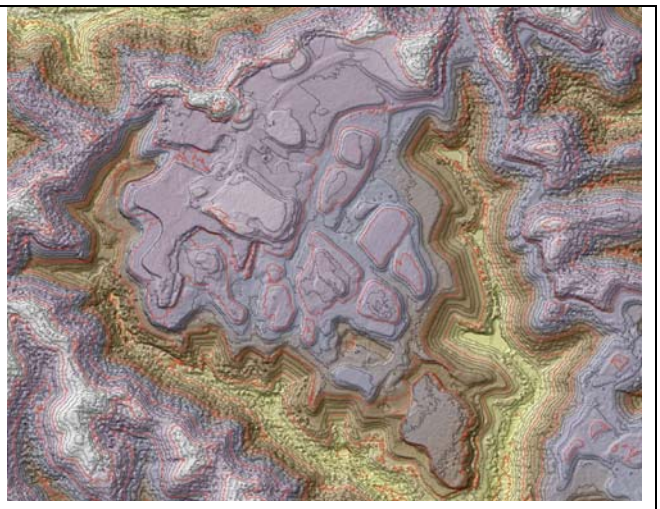


Figure 10. A hillshade with 10 foot contours based on September 2003 IFSAR flight

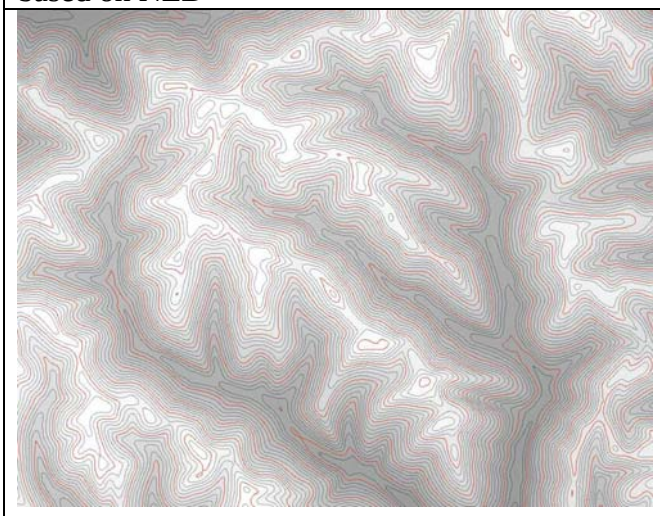


Figure 11. Ten foot contours based on NED

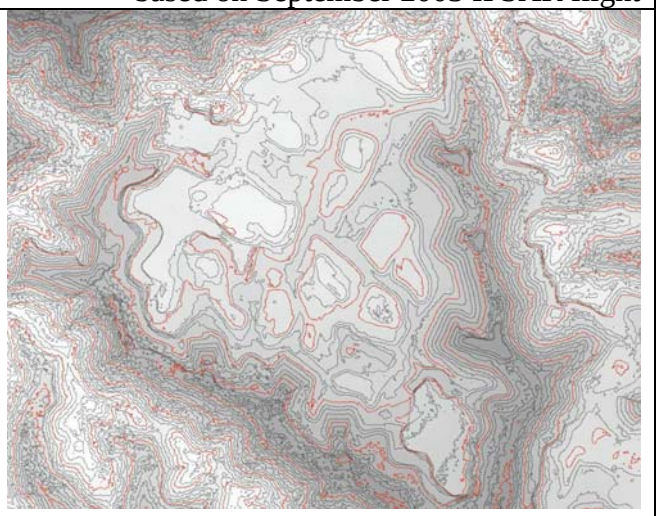


Figure 12. Ten foot contours based on the September 2003 IFSAR flight

The 10 foot contour lines have a red index contour every 50 feet. Changes in the post-mining topography make hydrologic modeling based on the two elevation datasets generate significantly different results. Accurate Cumulative Hydrologic Impact Assessments (CHIAs) requires realistic representations of both topography and land use.

Quality control checking of the IFSAR data by TAGIS involved comparison of IFSAR data with limited areas in southern West Virginia where recent Lidar data exists. In addition to terrain visualization, IFSAR elevation data is adequate to generate a 5 foot contour map of disturbed mining sites. This resolution is sufficient for rough estimation of cut and fill quantities for site remediation cost estimation and preliminary planning of earthworks projects. The ten county IFSAR data products were also cost effective with a price roughly equal to the cost that the Federal Emergency Management Agency (FEMA) paid for Lidar data for Wyoming County.

Using Landrum's definition, this data integrates geographic data across multiple departments and serves the entire organization (5). The benefit to WVDEP from the IFSAR data collection best fits the concept of all users and key decision makers having quick access to the most accurate and up-to-date data – increasing data accessibility (C).

Institutionalizing Airborne Imaging to Monitor Landscape Change over Time

In 1992, TAGIS recognized the need to acquire and retain digital imagery in support of permitting activities and site-specific litigation. The need to periodically recall the shape and spatial extent of a permitted site at different times in site history was one lesson learned during Bragg. Initial use of satellite imagery in WVDEP's mining programs was limited by: 1. funding to buy commercially available scenes; and 2. by the number of commercial sources of satellite imagery available at that point in time. Early assets consisted of a few Landsat and SPOT satellite scenes. The first statewide imagery was a 10 meter SPOT mosaic from 1994–1995. An additional statewide panchromatic SPOT coverage was obtained in 2000. While use of these statewide resources verified the value of digital imagery, their lack of resolution left some potential uses unrealized.

The best resolution imagery the Agency can currently access, for areas larger than a single watershed, is one meter resolution aerial photography covering all of West Virginia. From 1996 to 1998, the National Aerial Photography Program (NAPP) gathered color infrared photography that was then converted to Digital Ortho Quarter Quads (DOQQs).

Newer, high resolution satellite-based systems such as Ikonos, QuickBird, and OrbView-3 are a very cost effective solution particularly in the western United States were operations tend to be huge but very few in number. In the east, however, WVDEP currently deals with 2,090

active, permitted mining operations ranging in size from 0.02 to 3,113 acres. Because of the number of smaller permits in West Virginia, the need for more detailed resolutions is not yet commercially available.

PECA provided funding to purchase an appropriate imaging system light enough in weight and low enough in power to be attached to the Bell Jet Ranger 206-B3 helicopter. After an extensive search of commercially available systems that ranged from single digital cameras to hyperspectral sensors, a system was purchased. The Agency has succeeded in mounting an Airborne Data Systems four band, 2k x 2k pixel system on its older rotary wing aircraft. This system consists of a yoke mounted device allowing the pilot to fly planned flight lines, and contains two electronics packages: a camera pod containing red, green, blue and near infrared digital cameras that mount on the belly of the helicopter and a data acquisition console installed in the rear passenger area (see Figure 13 – 15 below).

Figure 13. Two electronic packages that make up the imaging system

Figure 14. Fabricated camera mount attaching camera pod to the helicopter

Figure 15. Data acquisition module in passenger area of aircraft

Airborne imaging has been used to provide the Agency with 0.25 to 0.5 meter resolution photography. The similarity between airborne imaging and space-based sensors is shown in Table 2 below. The system is currently being used to evaluate permitted refuse impoundments and to allow DMR to evaluate sites resulting from recent forfeitures.

Units are µm.	**WVDEP's Airborne Imaging System**	**Space Imaging's Ikonos Satellite**		**SPOT-6**		**Landsat ETM+**	
	Range	Min	Max	Min	Max	Min	Max
Blue	0.44-0.52	+0.01	0.00	-0.01	-0.05	+0.01	0.00

Green	0.51-0.62	0.00	-0.02	-0.01	-0.03	+0.01	-0.02
Red	0.61-0.71	+0.02	-0.01	0.00	-0.03	0.02	-0.02
Near Infrared	0.65-1.07	+0.11	-0.22	+0.14	-0.18	+0.11	-0.17

Table 2. Comparison of sensors

Figure 16 below shows a single frame from the system that has been orthorectified and laid over the statewide DOQ layer. With proper front-to-back and side-to-side overlap, stereo visualization of sites is possible.

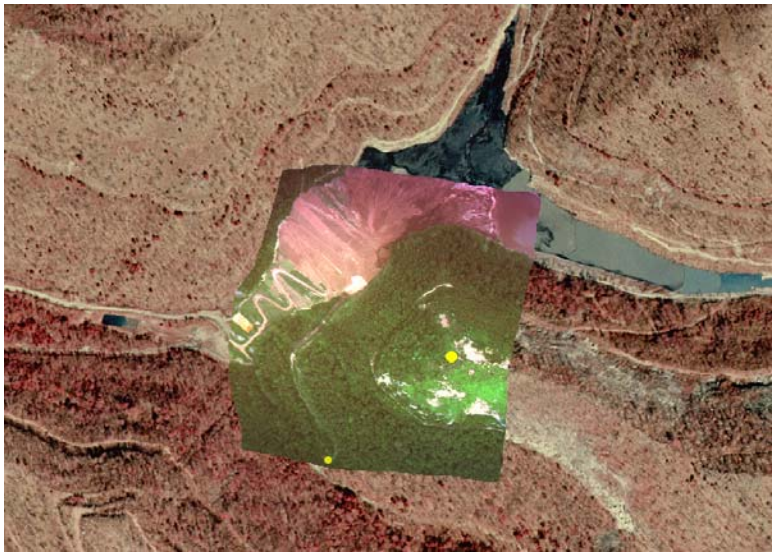


Figure 16. The 1996 – 1998 statewide, near infrared film-based DOQQ layer overlaid by a single, natural color airborne imaging scene also orthorectified.

Airborne imaging provides desktop access to orthorectified imagery of sites selected for all WVDEP GIS users (1). Timely, high resolution imagery is part of a well organized and well managed (4) GIS. Because progression of mining needs to be known by WVDEP's Division of Water and Waste, airborne imaging can be used across multiple departments; serving the entire organization (5). All users and key decision makers have quick access to the most accurate and up-to-date data (increases data accessibility [C]) when given recent airborne imaging.

Integrating GIS Spatial Data and ERIS/RIMS Tabular Data with GPS in the Field

In a manner reminiscent of the effort to provide access to GIS data for remote regional office users, a similar challenge existed to assure timely access to GIS data for field staff. Significant progress has been made in the past eighteen months with the evolution of HP iPAQ hardware and ArcGIS software's ability to check out and in spatial and tabular data. Based on responses from our field staff regarding an ideal field computing environment, technology has very nearly caught up with imagination. Our employees want a small, but very fast field computer with a color, high resolution display readable in direct sunlight. They have come to expect onscreen moving map layers (ESRI's ArcPAD software) with an indication of their current position (accomplished by pairing a cordless, Bluetooth, WAAS enabled GPS receiver with the iPAQ). They also want onsite access to ERIS and RIMS data when visiting field sites.

The latest HP iPAQ hx4700 (see Figure 17) increases display resolution from 240 x 360 pixels (all previous iPAQ models) to VGA's 480 x 640 pixel count. Color depth remains 16 bit and the device is very readable in direct sunlight. While the current version of ArcPAD is not optimized for this new display resolution, ESRI is working on a version that takes full advantage of this advanced color screen. Likewise, the newest HP has a quicker CPU (Intel® PXA270 processor running at 624 MHz) and 192 MB total memory (128 MB ROM and 64 MB SDRAM). Internal storage provides, for the first time without a cumbersome expansion sleeve, both integrated SD slot (supports 1-bit and 4-bit SDSDIO/MMC cards up to the maximum storage currently commercially available in this format, 1 gigabyte [GB.]) and a compact flash slot (Type II card) tested by TAGIS up to 4 GB. With a capacity of 5 GB of solid state storage, this device can carry and operate on, large spatial and tabular datasets.

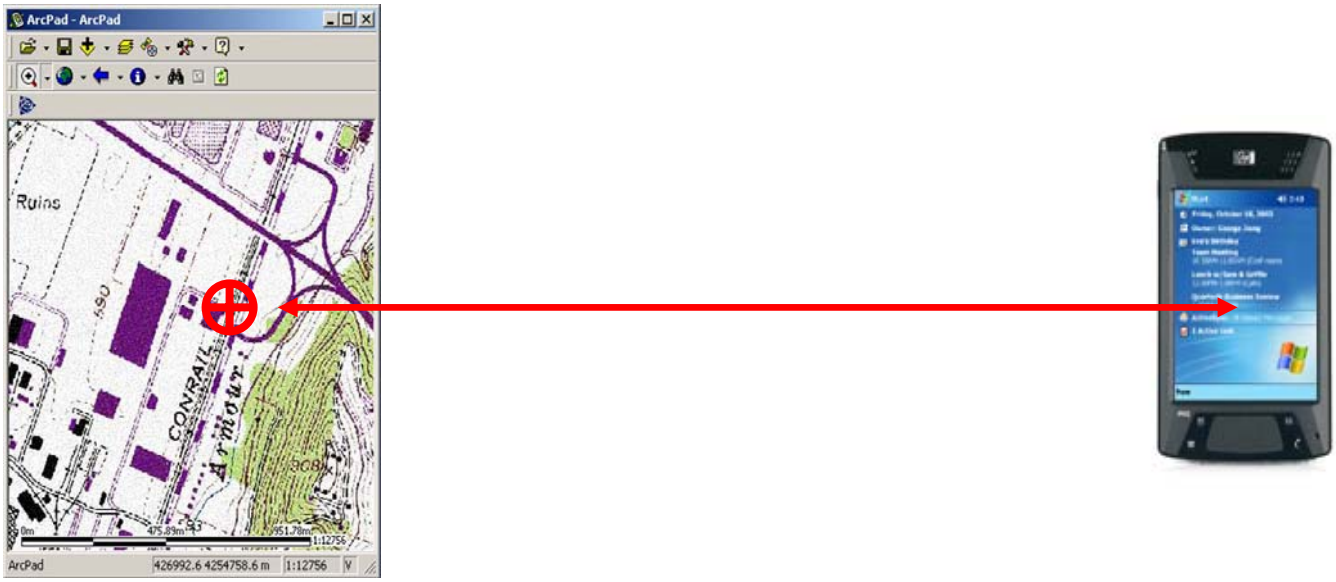
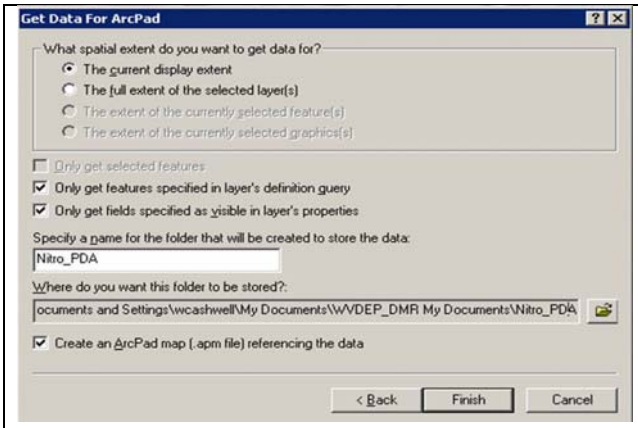


Figure 17. Screen capture from ArcPAD of a scrolling Digital Raster Graphic (DRG) overlaid by a cursor indicating one's current position.

Beginning with version 8.3, ArcGIS provides check out and in capability (see Figures 18 and 19 below) that allows end users to take spatial and tabular data for a specific area to the field for both site assessment and information updating. This process has been optimized to work with ArcPAD. Based on Landrum, this work provides access to other organizational information systems by using a map or application as the integrator of the organization's information (2). It also provides access to geospatial data regardless of the user's geographic location (7 [added in this paper]). This new field computing environment allows all users and key decision makers to have quick access to the most accurate and up-to-date data – increasing data accessibility (C).



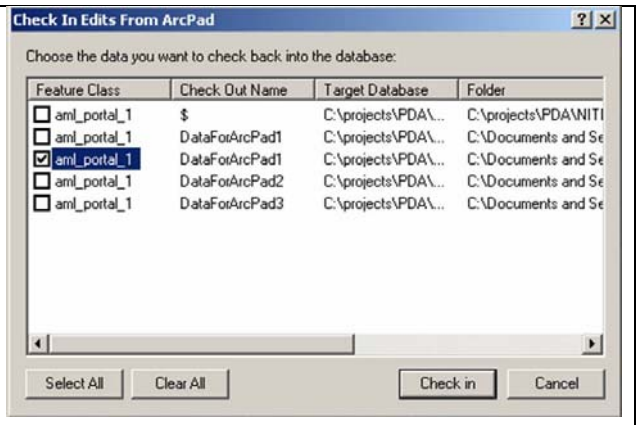


Figure 18. ArcGIS screen capture of the ArcPAD data checkout screen

ArcGIS check in screen. Figure 19.

EQuIS

Another PECA task also early in implementation, is the Agency's Environmental Quality Information System (EQuIS). This Oracle database's table structure is designed to store environmental sampling results and is a commercial product of EarthSoft, Inc.

WVDEP is initially populating EQuIS' tables with chemical data but will also someday house the Agency's geologic sampling results. Over 1 million sampling results have been entered by DMR staff and commercial laboratories submitting analytical results electronically via the World Wide Web (WWW). Analytical results in EQuIS can be retrieved and analyzed by custom programs and by a number of commercial applications provided by the OSM TIPS program. Figure 20 shows an example of a groundwater data query and retrieval from an EPA superfund site with several sampling locations (points) from EQuIS. Using EQuIS for ArcGIS, a custom tool bar created by EarthSoft, contour lines showing concentrations of a specific groundwater pollutant are plotted.

DMR historical permit data (last five years) and trend station data make up most of the analytical results currently in EQuIS. In the fall of 2004, the Agency's Special Reclamation Program and OAML&R also began entering their analytical results.

Per Landrum, EQuIS provides access to other information systems in the organization by using a map or application as the integrator of the organization's information (2). In the near

future EQuIS will insure that all users and key decision makers have quick access to the most accurate and up-to-date data – increasing data accessibility (C).

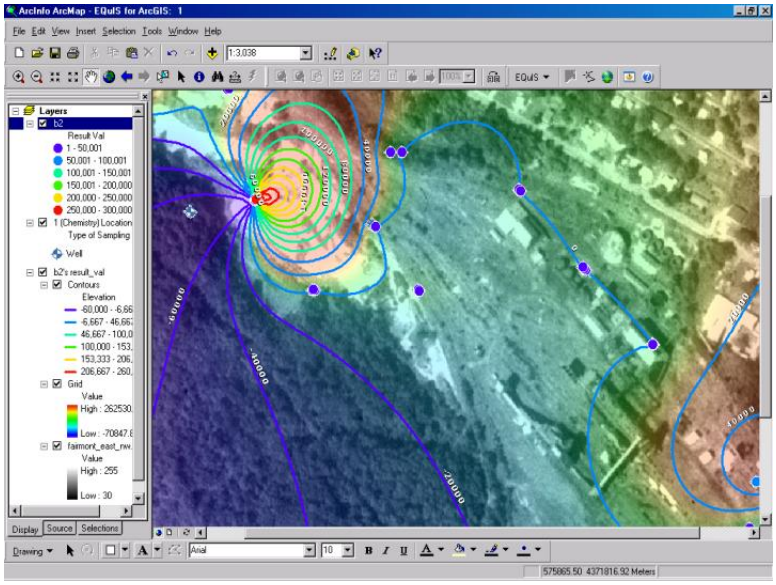


Figure 20. Screen capture from ArcGIS showing groundwater pollution concentrations at an EPA superfund site

Interactive Mapping via the Net

WVDEP had one of the first WWW sites offering interactive mapping of environmental data with a statewide spatial extent. WVDEP's interactive mapping capability predates all exiting commercial products (ESRI's ArcIMS, Intergraph's Geomedia product, etc.).

Prior to most federal and state initiatives providing public access to Agency data via the WWW, WVDEP's TAGIS Unit created the Agency's Public Empowerment Program (PEP) that served such a purpose but was somewhat limited by early Internet technologies. Evolution of technologies has resulted in recent strides in our WWW interactive mapping capabilities. From May 27, 2004 to November 3, 2004 (160 days) current technology generated 233,216 total maps (1,457 per day). The site's address is http://gis.wvdep.org.

Noteworthy recent development activities in interactive mapping includes being able to access the 1996 – 1998 DOQQ layer (when zoomed in to a reasonable map extent) as a basemap layer. Spatial analysis capability has also been expanded significantly. Figure 21 shows the

beginning spatial analysis screen that provides access to a Geographic Names Information System (GNIS) tool, a new tool to zoom to one of the state's fifty-five counties and a new tool that automatically tallies the number of Toxic Release Inventory (TRI) and AML sites in a selected spatial extent. The results of clicking on Boone County are shown in Figure 22. The mapping extent is now zoomed to Boone County; showing two links dynamically built-in that either popup a page showing data from the Agency's TRI database or a page providing access to RIMS information.

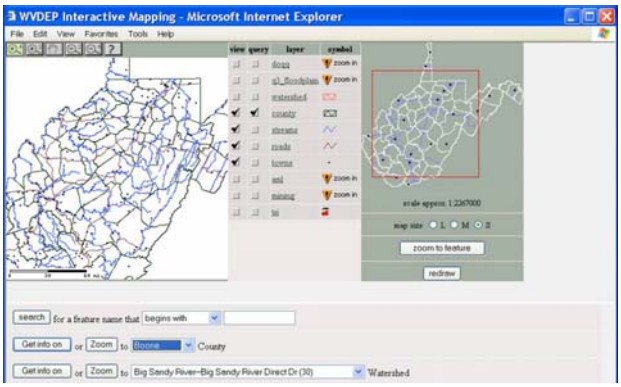
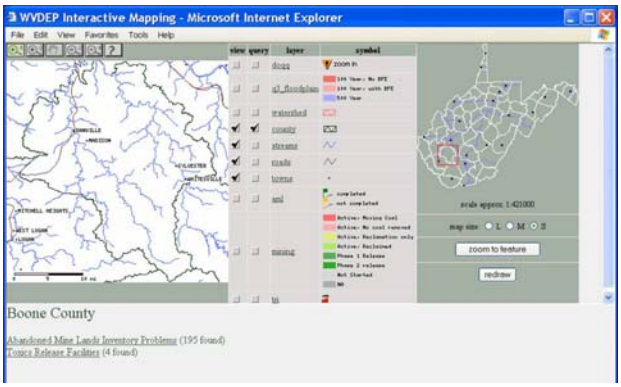


Figure 21. The spatial analysis interactive mapper window.



The link to database results window. Figure 22

From Landrum's enterprise GIS definition, these WWW enhancements provide desktop access to all users (1) and provide access to other information systems in the organization by using a map or application as the integrator of the organization's information (2). The most significant benefit of this GIS enterprise work is that it enables easy web-based access for data sharing and community participation (G).

Conclusions

Failing to fund GIS development, representing spatially complex mining sites only as points, and lack of quality control checking coordinates stored in ERIS was costly to WVDEP. OSM's PECA was the keystone event necessary to move GIS toward the enterprise structure by funding numerous activities.

Adding significant numbers of new GIS users required creating custom built spatial applications that allow new users to productively use the technology with very little training. ArcSDE's ability to build huge raster image catalogs also simplifies novice users successfully utilizing the GIS archive. ArcSDE scales to large number of users and works well with Citrix to deliver GIS to remote desktops at regional offices. CAD users, for the first time, have begun to access and edit ArcGIS data including ArcSDE data assets.

Topography changes as a result of surface mining and must be accurately represented to do hydrologic modeling, terrain visualization, earthworks, etc. How mining sites change the landscape over time is highly important information to archive. Having up to date spatial and tabular data when on site is challenging but is becoming practical with the evolution of HP iPAQ hardware, ArcGIS' checkout/check in screens and ArcPAD. Chemical data is important for both Title IV and V programs and WVDEP's EQuIS is becoming an archive for this data. Over time, the decision support process will benefit greatly from ArcGIS and other TIPS applications being utilized to analyze both chemistry and geology sample information by querying analytical results in EQuIS. Finally, interactive mapping enhancements continue to encourage private and corporate citizens to access Agency data via a mapping interface.

Literature Cited

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