West Virginia GIS Technical Center
West Virginia University
Department of Geology and Geography · Eberly College of Arts and Sciences

WV DOT GIS Implementation Study – August 2002 Report

In cooperation with [Rahall Transportation Institute], Marshall University, this preliminary study identifies steps that should be undertaken by the West Virginia Department of Transportation (WV DOT) to implement geographic information system (GIS) technologies. As part of this strategic implementation plan, the [WV GIS Technical Center] focused on accessible, accurate geo-spatial information available to transportation decision-makers. A demonstration project created a GIS county highway map using the best available digital data and extended the value of the cartographic map with spatial analysis of a proposed expressway. It is hoped that the data development and coordination issues discussed in this report will encourage WV DOT to utilize existing spatial data to create a digital mapping base rather than digitize cartographic features from their paper county highway map series.

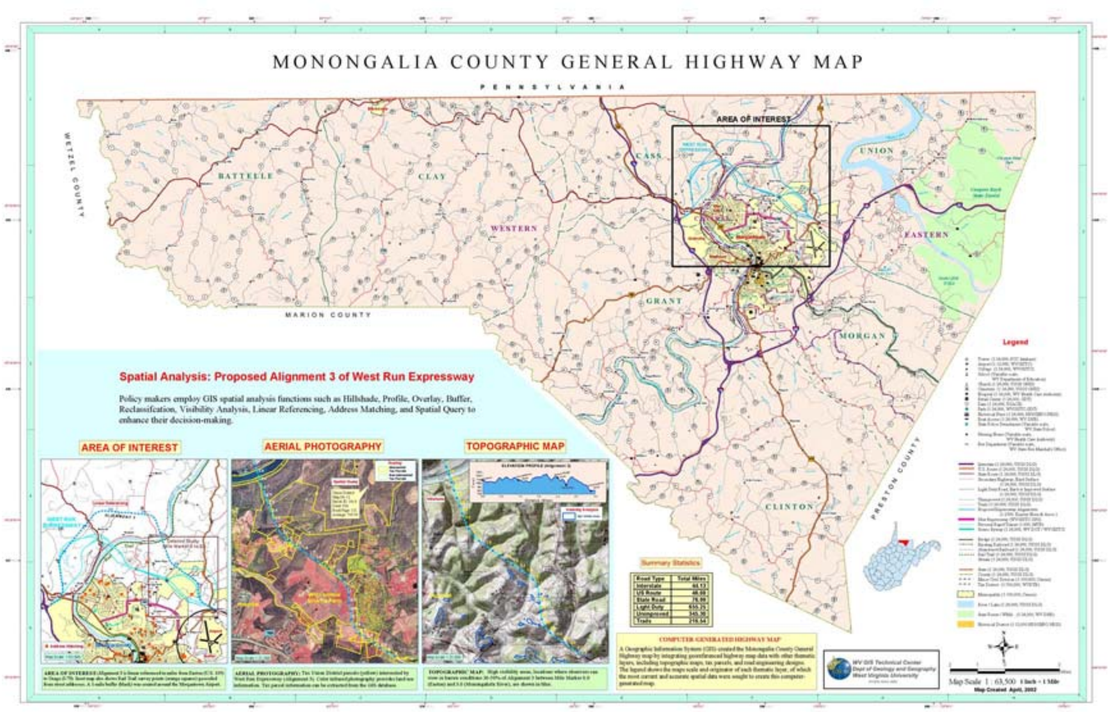


Figure 1: Main Map: GIS computer-generated general highway map for Monongalia County, West Virginia. Inset maps: Spatial analysis of proposed West Run Expressway (Alignment 3).

I. INTRODUCTION

Geographic information is a valuable national resource. It is estimated that approximately 80% of all government information has a geographic or spatial component, so the availability of suitable spatial data lies at the core of any transportation project. The 2002 GIS-Transportation survey reveals that 83% of state DOTs participate in geo-spatial data sharing activities with other state agencies or organizations (Appendix E). The ability to share spatial databases utilizing geographic information systems (GIS) not only reduces data redundancy and inconsistency, thus saving an organization time and money, but also provides users with valuable analytical and visual tools for enhancing transportation studies. To demonstrate this concept, georeferenced highway data and other thematic layers were integrated to create a computer-generated highway map (Figure 1) similar to the current WV Department of Transportation's Monongalia County General Highway paper map. In addition to generating an electronic highway county map, spatial analysis was done for Alignment 3 of the West Run Expressway, a new road proposed north of Morgantown in Monongalia County, WV.

II. GIS TRANSPORTATION FRAMEWORK DATA

GIS transportation data incorporates multimodal transportation networks and facilities to include roads, trails, railroads, waterways, airports, bridges and tunnels. Ideally, it is collected to a known level of spatial accuracy and currency, properly attributed, documented in accordance with established metadata standards, and accessed through data clearinghouses at little or no cost and free of restrictions on use. Spatial transportation data can then be incorporated into robust, enterprise-wide GIS system that provide road and rail network topology for routing applications and other functions such as indirect location referencing systems for locating features like bridges, signs, pavement conditions, and traffic incidents. To implement a successful geographic information system, WV DOT must *appraise* the current West Virginia Spatial Data Infrastructure, *identify* cost-sharing partnerships to build a suitable digital mapping base, and then *design* a system that *integrates* and *shares* geo-spatial data originating from multiple sources.

SPATIAL DATA INFRASTRUCTURE

The National Spatial Data Infrastructure (NSDI) encompasses policies, standards, and procedures for organizations to cooperatively produce and share the "best" available geographic data throughout all levels of government, the private and non-profit sectors, and the academic community. One of the core "framework" layers identified by the Federal Geographic Data Committee is transportation, since a map or GIS application almost always incorporates some type of road information. Transportation and other commonly used framework data form the backbone of both the West Virginia and National Spatial Data Infrastructures.

The State GIS Technical Center periodically publishes a framework report on data development and coordination issues specific to West Virginia. This report focuses on the best geographic data available to the statewide geo-spatial community. It provides the status for eight core themes (hydrography, *transportation*, orthoimagery, elevation, cadastral, geodetic control, governmental units, topographic maps) used by most GIS applications and six applications-specific data themes (soils, geology, land cover, critical structures, flood mapping, and economic development). For each framework data theme there is a brief description, mapping status, ultimate mapping goal, and data producer information, including originator(s) of data, resolution, currency, and data availability. Table 1 depicts the transportation section of the report.

DIGITAL TRANSPORTATION BASE

A digital transportation base serves as the critical foundation for which linear referencing systems and GIS applications are built upon. Therefore, the positional accuracy, currency, completeness, and availability of data are important factors in determining the best transportation base. Both national and state level base mapping viewpoints are discussed below.

National Perspective: Most federal transportation databases adhere to national standards and are accessible to the public (Table 2). In the past, transportation data was produced at the national level and disseminated to state and local government. Now federal agencies such as the U.S. Geological Survey, U.S. Census Bureau, and Federal Highway Administration are implementing programs to incorporate state and local transportation databases of suitable spatial and temporal scale into their national databases. Recently the Geography Division, U.S. Census Bureau, entered into several long-term contracts and partnerships in order to improve the accuracy of the information in its Master Address File (MAF) and associated Topologically Integrated Geographic Encoding and Referencing (TIGER) database. In June 2002 the Census Bureau awarded Harris Corporation an eight-year contract, valued in excess of $200 million, for the Master Address File/Topologically Integrated Geographic Encoding and Referencing Accuracy Improvement Project (MAF/TIGER AIP). The Master Address File (MAF)/TIGER Accuracy Improvement Project will create a complete and current list of all addresses and locations where people live and work. The Census modernization program also will update the TIGER digital database transportation features previously collected at 80-meter accuracy to a much greater spatial accuracy of 3 meters for the entire nation by FY 2008. Likewise, the Federal Highway Administration (FHWA) is incorporating higher resolution data with its existing 1:100,000-scale National Highway Planning Network (NHPN). In addition, national mapping initiatives (Appendix G) like the The National Map and Geospatial One-Stop propose to establish a seamless, continuously maintained, high-resolution transportation mapping database for the nation.

Other State DOT Perspective: Over 95% of the state DOTs have some operational GIS capability (Figure 3), and recent trends show that 89% of state highway departments now use a base mapping scale of 1:24,000-scale or better (Figure 4; Appendix E). State DOTs and their business partners have identified the need for higher spatial resolution transportation data for their mapping and analytical applications and thus are in the process of upgrading their mapping databases to a scale of 1:24,000 (1 inch = 2000 feet) or larger (Appendix F). Until a few years ago, most state DOTs built their digital transportation databases from 1:24,000-scale USGS topographic maps, but now the 1:24,000-scale standard (+/- 40 feet accuracy) is being superceded with geographic data collected from detailed photography or from Global Positioning System (GPS) centerlines (< 2 meter accuracy). State DOTs such as Pennsylvania, New Jersey, and North Carolina are using aerial photography, collected at mapping scales of 1:12,000 or larger, to revise their topographic-based linear transportation features, while Kentucky is implementing an accuracy improvement program utilizing GPS (Appendix F).

WV DOT Perspective: WV DOT should follow the national trend of building comprehensive, statewide transportation databases with more accurate spatial data. In addition to high-resolution digital data (i.e., GPS, engineer surveys) collected by the WV DOT highway survey crews and its subcontractors, the WV DOT should consider both (1) topographic-based and (2) address-based transportation databases as a framework for its digital map base (Table 3). Two *topographic-based* transportation databases, U.S. Geological Survey Digital Line Graphs (DLG) and U.S. Forest Service Cartographic Feature Files (CFF), are very similar geometrically in that they are digital representations of roads, trails, bridges, exit ramps, tunnel portals and other detailed transportation features derived from 1:24,000-scale topographic maps. At present, digital transportation features from 1:24,000-scale topographic maps are available for 85% of the state from the WV GIS Technical Center. The WV GIS Technical Center may complete the remaining 15% topographic-based, digital transportation files by summer 2003.

To access highly accurate road centerline data, consideration should be given to incorporating *address-based* transportation databases currently being developed in West Virginia. E-911/local government transportation datasets usually are more current and spatially accurate than other transportation databases, although each county has unique mapping standards and data sharing agreements. Often the local assessor and E-911 director do not collaborate or cost-share but produce independent transportation databases. Another barrier is that county governments may not release their transportation databases without cost-sharing agreements to recover data development and maintenance costs. With the advent of new mapping programs, the address-based transportation databases in West Virginia could become more uniform and accessible. To improve the delivery of emergency services in the state, the Legislature in 2001 established a Statewide Addressing and Mapping Board to provide city-style addresses for every identifiable structure in the rural areas of West Virginia. The board has formed a $15 million partnership with Verizon to map the state and create E-911 addresses. Another program already mentioned, the Census Bureaus' Master Address File (MAF)/TIGER Accuracy Improvement Project, will also make current transportation addressing and mapping databases more spatially accurate. Although specific details regarding the data collection and coverage extent have not been released, these two important programs could lead to a single, uniform addressing and mapping transportation database for the state.

DATA INTEGRATION AND SHARABILITY

Presently there is no single agency that *integrates* all transportation information nationwide, nor likely will there ever be one. In most states, including West Virginia, transportation data is developed and maintained at different spatial and temporal accuracies by federal, state and local entities to support their existing business requirements for information, reporting, and management of their road network system. As more accurate transportation data becomes available, it is very challenging to integrate transportation data of different positional accuracies (Figure 2), detail, coverage, and currency, while retaining the value of existing data investments.

Geographic data must not only be available and in a seamless, consistent format, but it must be adequately attributed and *sharable* with other computer systems. Because over 84% of state DOTs use more than one software product for their GIS applications, with ESRI GIS the most popular, followed by Intergraph/Microstation and TransCad, transportation databases must be properly designed to exchange attribute information. At the North Carolina DOT, for example, the Mapping Section uses Microstation software to develop and maintain digital county, urban, and state travel maps; while the GIS Programming & Analysis Section uses ESRI ArcGIS software to create specialized analytical map products. So information could be easily shared accross different software platforms, the North Carolina DOT GIS Unit implemented an appropriate database design along with a set of conversion programs.

Unfortunately, some state highway computer mapping systems are like "islands" of technology because these systems cannot share information, either "horizontally" across DOT databases or "vertically" with other federal, state, and local government transportation databases. One reason for multiple, disparate transportation mapping systems is that no universal spatial data model exists for sharing information among organizations. To overcome this problem, the federal government and some states are developing core data standards. The federal government is developing a conceptual spatial identification standard (Appendix H) while some states like Kentucky and Utah already have developed core consensus data standards (Appendices F).

COST-SHARING

Although integrating and sharing transportation data is challenging, this should not prevent WV DOT from utilizing existing digital transportation data, especially road centerline geometry, as it is very expensive to create a fully developed digital road network system. To date, federal, state, regional and local governments have invested millions of dollars in *cost-sharing* programs to create digital transportation data for West Virginia. The U.S. Geological Survey, U.S. Forest Service, and the state have contracted 2.5 million dollars to collect and maintain topographic-based transportation databases for West Virginia. It is estimated the WV E-911 agencies and county tax assessors of West Virginia counties have spent 4 million dollars to develop local transportation databases. In the immediate future both the U.S. Census ($200 million) and Verizon ($15 million) will allocate 215 million to fund address-based transportation databases in West Virginia.

Table 1: WV Transportation Framework Data – June 2002 Status

TRANSPORTATION

DESCRIPTION: Transportation networks and facilities to include roads, trails, railroads, waterways, airports, bridges and tunnels. Road centerlines should incorporate street address ranges for geocoding applications and a linear referenced system for routing applications.

COORDINATION: Coordination between WV DOT and other transportation data producers in the state are necessary to establish core content standards and business relationships. Through such coordination will foster formal/informal agreements for sharing, creating, and maintaining statewide transportation data.

MAPPING STATUS:

1) **Environmental Systems Research Institute (ESRI):** ESRI, a geographic information software company, is sponsoring a transportation data model consortium that will enable geographic information system (GIS) users to take greater advantage of ArcGIS 8 and the new geodatabases. http://www.esri.com/news/releases/00_4qtr/unetrans.html

2) **Federal Geographic Data Committee (FGDC):** The Ground Transportation Subcommittee (GTS) promotes the coordination of geo-spatial data for ground transportation related activities. The Subcommittee is sponsoring the development of a conceptual data model standard (NSDI Framework Transportation Identification Standard) for identifying road segments as unique geo-spatial features independent of cartographic or analytic representation. http://199.79.179.77/gis/fgdc/

3) **National Park Service (NPS):** The Rivers & Trails Program of the National Park Service is in the process of compiling state trails at a nominal scale of 1:100,000. http://wvgis.wvu.edu/data/data.php (search on trails)

4) **U.S. Census Bureau (Census):** Harris Corporation has been awarded an eight-year contract, valued in excess of $200 million, by the U.S. Census Bureau for the Master Address File/Topologically Integrated Geographic Encoding and Referencing Accuracy Improvement Project (MAF/TIGER AIP). The objectives of this program are to align existing 1:100,000-scale roads, hydrography, railroads, structures, landmarks, pipelines, power lines and other TIGER database features to a much greater locational accuracy (3-meter horizontal accuracy) for all of the nation's 3,232 counties by FY 2008. http://www.census.gov/geo/mod/maftiger.html

5) **U.S. Department of Transportation (US DOT):** The Federal Highway Administration (FHWA) is in the process of enhancing the National Highway Planning Network (NHPN), a comprehensive network database of the nation's major highway system. The current 1:100,000-scale geographic database consists of over 400,000 miles of the nation's highways comprised of Rural Arterials, Urban Principal Arterials and all National Highway System routes (http://wwwcf.fhwa.dot.gov/hep10/gis/gis.html). The National Transportation Atlas Data (NTAD) is a set of transportation-related geospatial data for the United States compiled by the Bureau of Transportation Statistics (BTS). The data consist of transportation networks such as the NHPN, transportation facilities, and other spatial data used as geographic reference. http://www.bts.gov/gis/ntatlas/index.html

6) **U.S. Geological Survey (USGS):** The USGS partnerships with the WV GIS Technical Center to collect digital vector representations of roads, trails, bridges, exit ramps, tunnel portals and other detailed transportation features derived from USGS 1:24,000-scale topographic maps. A USGS unit compiles information from state and local agencies for map revisions. USGS Digital Line Graph (DLG) road attribute data is limited to road classification and federal/state highway route numbers. http://wvgis.wvu.edu/data/data.php (search on roads)

7) **U.S. Forest Service (USFS):** The Monongahela National Forest maintains a trail and road geographic database for 3,300 miles of roads (http://wvgis.wvu.edu/data/data.php, search on roads). The spatial databases originated from 1:24,000-scale USFS Cartographic Feature Files and are linked to Oracle INFRA attribute tables which include linear referencing measures for event themes. http://www.fs.fed.us/eng/road_mgt/documents.shtml

8) **WV Department of Transportation (WV DOT):** The Division of Highways plans, designs, builds and maintains more than 34,000 miles of state roads. Only paper maps of transportation data are accessible to the public from WVDOT. Refer to http://www.wvdot.com/7_tourists/7d1_availablemaps.htm. The Appalachian Transportation Institute (ATI) at Marshall University and the WV GIS Technical Center at WVU are developing a GIS-Transportation strategic plan for WV DOH. Project Number TRP 99-32 (http://www.marshall.edu/ati/research/projects.htmlx).

9) **Statewide Addressing and Mapping Program:** Governor Wise has appointed a Street Addressing and Mapping Board to implement a statewide E-911 mapping project funded by Verizon. The goal is to provide a city-style address for every identifiable structure in the rural areas of West Virginia to improve delivery of emergency services.

DATA PRODUCERS:

DATASET NAME	*ORIGINATOR(S)*	*SCALE*	*MAP UNIT*	*% WV*	*CURRENCY*
TIGER	U.S. Census	1:100,000	County	100	2000
National Transportation Atlas	U.S. DOT	1:100,000	State	100	2001
County Highway Maps (Not Vector)	WV DOT	1:63,500	County	100	Variable
Digital Line Graphs (DLG)	USGS	1:24,000	7.5 Min. Quad	70	1950-1997
Cartographic Feature Files (CFF)	USFS	1:24,000	7.5 Min. Quad	15	1995
E-911 Road Centerlines & Addresses	WV E-911 Council	1:1200 to 1:100,000	County	5(?)	1999-present
Local Road Databases	County/City Govts.	1:1200 to 1:4800	Jurisdiction	?	Variable
New Roads	WV DOT / Contractors	Survey-scale	Planned Route	N/A	Variable
Major Trails	NPS, WV DNR, USFS	GPS to 1:100,000	Jurisdiction	90	Variable

ULTIMATE GOAL: Statewide 1:24,000 or larger scale mapping database of core transportation features.

DATASET	SOURCE	SCALE	PROS	CONS
TIGER/Line	U.S. Census	1:100,000	Attributes Standards Statewide Coverage	Spatial Accuracy
NHPN NTAD	FHWA BTS	1:100,000 1:100,000	Linear Reference System Standards Statewide Coverage	Spatial Accuracy
DLG	USGS	1:24,000	Standards Spatial Accuracy	Attributes Currency Partial Statewide coverage
CFF	USFS	1:24,000	Standards Spatial Accuracy	Attributes National Forest areas only
E-911/ local government	County	1:4800 or larger	Currency Geocoding Spatial Accuracy	No public access to data No uniform standards Partial statewide coverage Road centerlines only

Table 2: GIS transportation datasets available to WV DOT (sorted by scale). The table lists some of the most common GIS transportation datasets available to WV DOT and the principal advantages and disadvantages of each transportation dataset.

Common Functionality	Originator / Digital Product Name or Project	% WV
Addressing and Mapping (Geocoding)	Census MAF/TIGER Accuracy Improvement Project	0
	WV State Addressing and Mapping Project	0
	County E-911 / Tax Assessor Mapping Projects	8
1:24,000-Scale Topographic Maps	USGS Digital Line Graph (DLG)	71
	USFS Cartographic Feature Files (CFF)	15
Highway Planning Databases	FHWA National Highway Planning Network (NHPN)	100
	WV DOT transportation databases	?

Table 3: GIS transportation datasets grouped by common functionality and percentage of digital product completed for State. Tax assessor transportation databases may not always have an addressing component.

III. PAPER VERSUS COMPUTER-GENERATED MAPS

WV DOT HIGHWAY MAP SERIES

The WV Department of Transportation publishes state and county general highway maps. A county map (Type A format) consists of one to seven 18” x 36” (height x width) sheets at a scale of 1 inch = 1 mile (1:63,500) and is printed in black or 2-3 colors (Figure 5a). The paper maps contain a rich source of cartographic information, including transportation, boundary, cultural, and environmental features. These paper maps are continuously updated and are a snapshot at the time of creation. Paper highway county maps that have been scanned and then georeferenced are useful as a mapping guide but should not be digitized because other, more spatially accurate digital data, like the DLG, E-911, and GPS road network data, already exist (Appendix B).

OTHER STATE DOTs

With the advent of new computer mapping technologies, more and more state highway offices have moved from paper-generated to computer-generated maps (Figure 5b). Furthermore, the 2002 GIS-T survey reveals that more state transportation departments are publishing computer-generated highway maps on their Internet sites in either a PDF or TIFF file format (Table 4). An official with the Pennsylvania DOT remarked that paper map sales actually increased after making their digital maps available on the Internet; and the only reported problem was that the Internet maps were made available to the public sooner than the printer could produce the paper maps. Many state DOTs also make their GIS transportation data files available for free download to the public. Pennsylvania DOT uses the Pennsylvania Spatial Data Access system (PASDA), Pennsylvania's official geo-spatial information clearinghouse, to provide widespread sharing of transportation GIS files.

State DOT	Map files (County or State)	Public Data Files
KY	Click here	Click here
OH		Click here
NC	Click here	Click here
NJ	Click here	
PA	Click here	Click here

Table 4: Computer-generated GIS maps and data files accessible via the Internet.

For comparative analysis, digital county highway maps were downloaded from state DOT Internet sites of Kentucky, New Jersey, North Carolina, and Pennsylvania (Table 4; Appendix F). Except for Kentucky DOT, which used ESRI ArcView 3.2 software, the other DOTs developed digital county maps using Microstation. After reviewing other state DOT digital highway maps, it was apparent that the feature density, page size, mapping scale, map projection, as well as overall cartographic quality varies from state to state. For instance, the Pennsylvania DOT (PENNDOT) publishes two county map products: County Type 10 and Type 3 Maps (Figure F1). The 1:65,000-scale County Type 10 Maps are full-color, include all public roads, and are designed for 36" x 49" printing; whereas the simplified County Type 3 Maps show only the major roads and features in two colors, and are published at a smaller pager size and mapping scale. To support the different map types, PENNDOT maintains more than one road network file: a spatially accurate master road file for analytical applications and artistically modified cartographic files for digital highway map products. After reviewing other digital DOT county maps, it also was discovered that most DOTs publish Internet county highway maps as single sheets. State DOTs like Kentucky, New Jersey, and Pennsylvania publish their county highway maps as a single sheet, whereas North Carolina DOT produces multiple-sectioned county maps generated at a constant scale.

ADVANTAGES OF DIGITAL MAPS

Digital highway maps have many advantages over manually generated traditional paper maps. Computer-generated maps integrate existing or new digital geographic data more quickly and accurately than manual procedures that scribe geographic data onto paper maps. Digital map files are much easier to edit and revise than paper maps. More printing options are available too, from printed hardcopy to dynamic Internet maps. In a digital environment, spatial analysis and visualization tools extend computer mapping beyond the value of visually appealing cartographic maps. To demonstrate this, the GIS Technical Center utilized geographic information software to create a digital county highway map for Monongalia County, WV, and then conducted spatial analysis of a proposed county expressway (Appendix A).

IV. DIGITAL DATA ACQUISITION – MONONGALIA COUNTY GENERAL HIGHWAY MAP

To save time and money, the first step in creating digital county highway maps is to locate existing GIS data layers. For the Monongalia County highway map demonstration project, most of the digital datasets were downloaded from the WV GIS Technical Center's Data Clearinghouse, the largest repository of geo-spatial data specific to West Virginia. The Data Clearinghouse is accessed primarily by searching the Technical Center's website (http://wvgis.wvu.edu/data/data.php). Presently the Technical Center provides free Internet access to over 180 spatial datasets, and is continually publishing more current and spatially accurate datasets as they become available.

Data originated from a wide range of governmental agencies, academic institutions, and private companies. In fact, over 30 different thematic datasets originating from 17 agencies were processed to create the GIS highway map of Monongalia County (Table 5). Except for the local Morgantown Utility Board, no extensive mapping databases existed at the county government level or from the Region VI Planning and Development Council that serves Monongalia County. Instead, almost all the datasets, including the road network, were collected from state and federal sources. In the future, however, more local government mapping databases should become available, since Metropolitan Planning Organizations, Regional Planning and Development Councils, and county governments like Brooke, Cabell, Hancock, and Kanawha are beginning to develop and maintain comprehensive geographic databases for their localities.

Selected digital datasets for the computer-generated highway map of Monongalia County were a snapshot of the best available geographic data. To compile quality geo-spatial data, an evaluation of each dataset's currency, spatial accuracy, and completeness (geometry and attributes) was made. Where possible, geographic information was collected from the originator or data producer since this data generally was the most current and accurate. Although a majority of the datasets were derived from 1:24,000-scale USGS topographic maps, spatial accuracy of data ranged from highly accurate Global Positioning System (GPS) road data and local 1:600-scale Morgantown Utility Board data to less accurate 1:500,000-scale tax district boundary data. Higher spatial resolution data was preferred because it permitted the viewing of detailed areas, allowed for more accurate linear referencing of the proposed new road, and in most cases, reduced incompatibility errors between different data themes. Certified datasets like USGS Digital Line Graphs (DLG) were chosen because quality-checked data usually adhere to uniform standards as well as being geometrically and topologically clean; clean datasets were easier to integrate with other datasets and across political and collection area boundaries. Lastly, the completeness and number of attributes associated with each data theme were an important consideration for querying subsets of geographic data and for creating map annotation.

Organization Type	**Dataset and Source**
Federal Government	*U.S. Geological Survey* - roads, trails, bridges, railroads, state/county boundaries, rivers/lakes, churches, cemeteries, populated places; *National Park Service* – historic districts and places; *U.S. Census* – minor civil divisions and municipalities; *U.S. Army Corps Engineers* – dams; *Federal Communications Commission* – towers
State Government	*Health Care Authority* – hospitals, nursing homes; *State Fire Marshal's Office* – fire departments, *State Police* – police detachments; *Department of Education* – schools; *Department of Natural Resources* – boat access, state parks and wildlife management areas; *Department of Tax and Revenue* – tax district boundaries; *Department of Transportation* – scenic byways; *Higher Education Policy Commission* – colleges; *WV GIS Technical Center* – new road (Route 705); airport runway
Local Govt.	*Morgantown Utility Board* – personal rapid transit
Commercial	*Geographic Data Technologies* – parks, retail centers; *Kimley-Horn & Associates* – proposed West-Run Expressway; *National Business Database* - businesses

Table 5: Geographic datasets utilized for digital county highway map. Refer to the GIS Technical Center's Data Clearinghouse for more information on individual datasets.

The most important dataset for highway maps is the road network. Existing USGS DLG transportation data files were chosen for their spatial accuracy and attributes, and because no E-911 digital road data existed for Monongalia County for comparison. Drawbacks of the DLG transportation data for general highway maps are its currency, limited road classification scheme and missing county route numbers. Because existing DLG transportation data is not always current, new roads such as State Route 705 were collected utilizing GPS. Proposed new roads such as the West Run Expressway, a northern outer loop around Morgantown connecting I-68 with I-79, were captured electronically from scanned highway plans provided by the engineering firm Kimley-Horn and Associates.

GIS datasets are available for most features depicted on the paper highway maps except for individual dwellings, farms, and businesses; although these structures are capable of being mapped upon completion of a statewide E-911 addressing and mapping file. While Table 5 reveals that numerous governmental and private agencies are sources for spatial data, occasionally geographic data is not available for certain features. If no existing data source is available, then heads-up digitizing from other reference data sets is an option. Reference data sets also are important for verifying existing geographic data. Two of the most valuable reference datasets utilized for base mapping in this pilot project were "digital" USGS 1:24,000-scale topographic maps and 1:12,000-scale aerial photos valued a 2 million dollars. Only because federal and state agencies formed cost-sharing partnerships are these reference geo-spatial datasets available to the public for free.

V. GIS MAP CREATION – MONONGALIA COUNTY GENERAL HIGHWAY MAP

A computer-generated highway map of Monongalia County was created by integrating georeferenced highway map data with other thematic layers, including topographic maps, aerial photography, tax parcels, and road engineering design drawings. The map includes a general view of the county highway system along with detailed views of the proposed West Run Expressway (Appendix A). A legend shows the map scale and originator of each thematic layer.

The digital county map was created utilizing Environmental Systems Research Institute's (ESRI) ArcGIS 8.2 software. ArcGIS 8.2 is a popular desktop GIS and mapping software that provides data visualization, query, analysis, and integration capabilities along with the ability to create and edit geographic data. During map processing all data were referenced to the Universal Transverse Mercator (UTM) coordinate system, the preferred coordinate system for statewide datasets in West Virginia. To eliminate multiple section maps, the computer-generated map was produced as one section and at the same scale of paper highway maps (1:63,500; 1" = 1 mile). Inset maps of the proposed West Run Expressway were created to show specific areas of interest in more detail. Final processing included adding to the map margin a legend, county location map, and three computer-generated grids: latitude/longitude graticule, measured UTM grid, and reference grid. In addition to printing the computer-generated map on paper, an electronic 41" x 26" Adobe PDF file was made for web publishing.

Map annotation is a vital component of highway maps and is impacted by display scale, feature density, and symbol shape and size. For this pilot project, annotation was computer generated from feature names that existed in attribute tables. This is the most efficient way of creating annotation instead of creating labels manually. Highway shields and route number labels were created automatically from GIS coverage attributes where present. Overpasses were created as a separate coverage to show the proper overpass/underpass road sequencing.

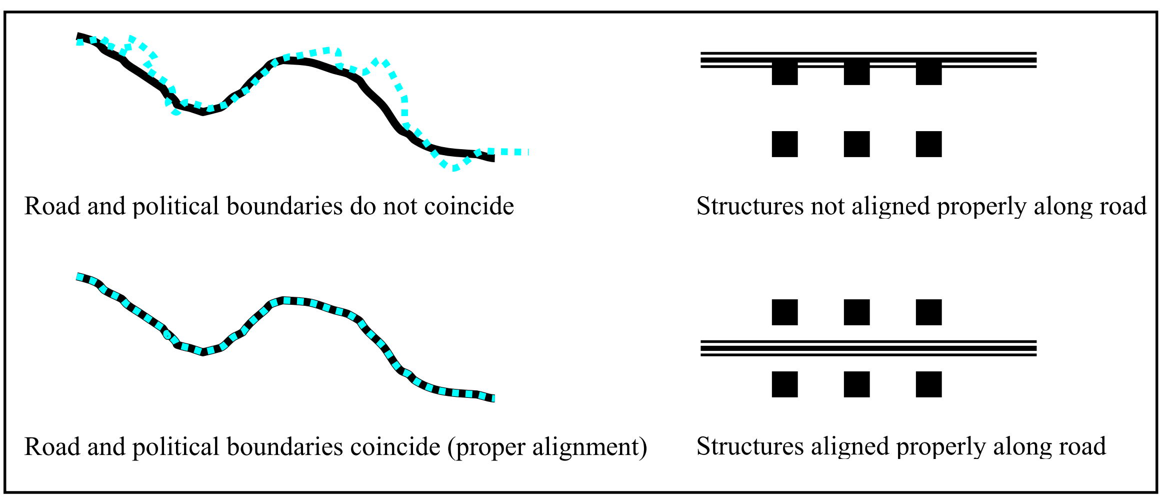


Figure 2: Consistency of road network among other data themes. Data compatibility issues arise when combining multiple themes collected at different positional accuracies.

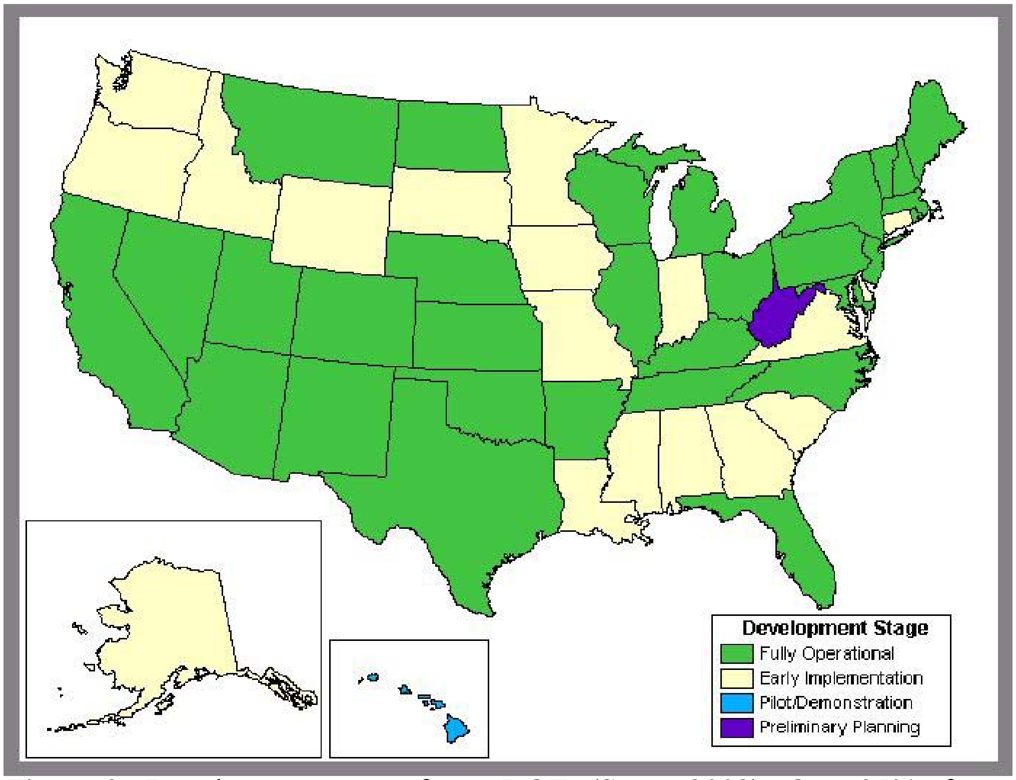


Figure 3: Development stage of state DOTs (Spear, 2002). Over 95% of state DOTs have some operational GIS capability.

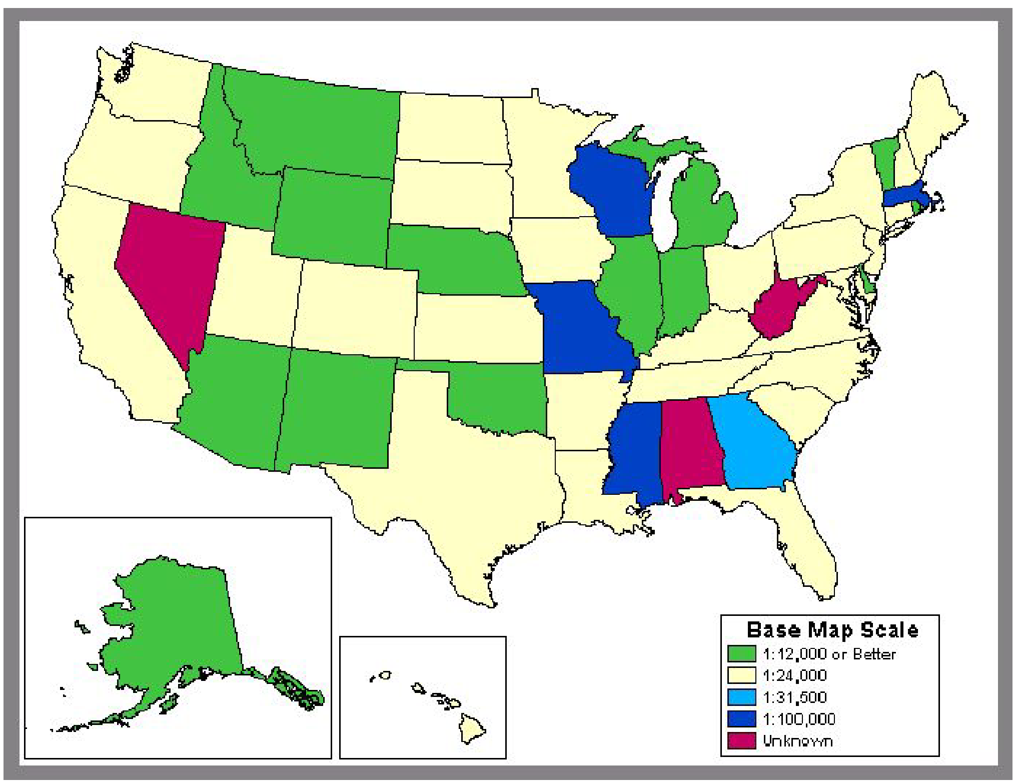


Figure 4: Base map scale of state DOTs (Spear, 2002). 89% of state DOTs use a base mapping scale of 1:24,000-scale or better.

Figure 5a: Current Monongalia County General Highway Map (Non-digital)

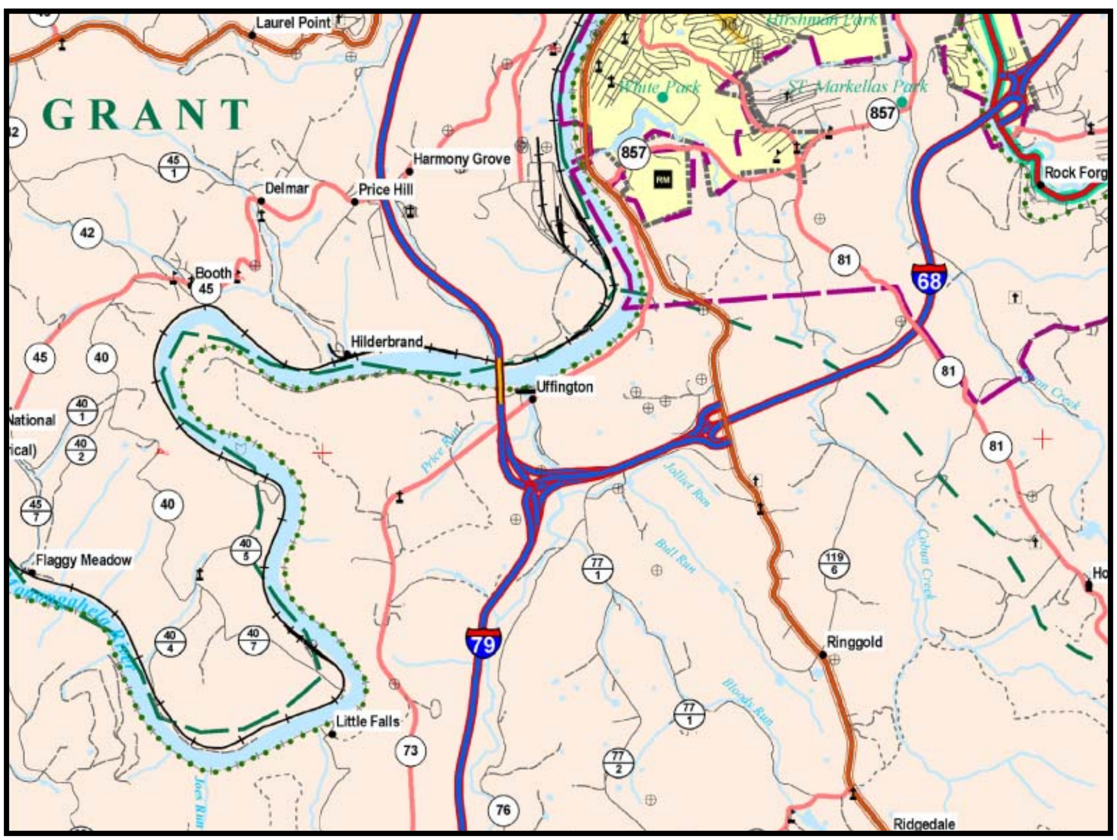


Figure 5b: Computer-generated County Highway Map, Monongalia County.

VI. RECOMMENDATIONS

(1) Establish an interagency transportation task force and lead agency to coordinate data sharing and to implement a transportation framework for the state.

- *Transportation Task Force:* Many states have organized a task force of transportation data producers and users to determine an optimum model for data creation, maintenance, and distribution. The task force should include selective members from county government, Metropolitan Planning Organizations, Planning and Development Councils, WV Department of Transportation, Rahall Transportation Institute, State GIS Technical Center, Statewide Addressing and Mapping Board, Monongalia National Forest, Federal Highways Administration, and U.S. Census Bureau. Transportation mapping experts from the private sector should also be consulted.

- *Data Exchange among Multiple Transportation Databases*: The proposed interagency task force should review technical and business relationships of independently maintained transportation databases at the federal, state, and local levels, and determine if these databases are fully capable of transferring attribute and geometric data between corresponding segments in each of the datasets. If an "interoperability scheme" can be incorporated for multiple datasets while retaining the value of existing data investments, then mapping guidelines that support a common transportation framework for the state should be established. This will be a challenging task since no transportation model exists that is compatible with all standards. At a minimum, the task force should (1) review the Federal Geographic Data Committee's NSDI Framework Transportation Identification Standard (Appendix H) as a guide to provide a conceptual data model for identifying unique road segments which are independent of cartographic or analytical network representation; (2) review core content standards and business relationships implemented by other states for sharing data among multiple transportation datasets (Appendix F); (3) identify successful, economical methods for conflating or exchanging geometric and/or attributes between transportation databases; (4) evaluate indirect referencing systems to include linear referencing (Appendix I) and geocoding (address matching); (5) identify other data themes that are compatible with transportation datasets; and (6) review mandates and other legislation from states like Minnesota that require local governments to provide road information.

- *Area Integrator at State Level:* No federal agency such as the U.S. Geological Survey or U.S. DOT is taking the lead to develop a comprehensive road network transportation dataset, probably because most state DOTs already have developed detailed, high resolution transportation databases and because no universal data model exists. Although local governments will create transportation data, as they are most familiar with what is in their locality, a central coordinating agency at the state level should act as an "area integrator" and "data steward" to coordinate the integration of multiple, often incompatible transportation databases for West Virginia; the coordinating agency also will conduct the quality control necessary to insure data accuracy and completeness as well as to make the data accessible to government and private agencies.

(2) Identify existing and future digital transportation data to form the "framework" for WV DOT's GIS transportation network and facilities mapping base.

- Establish Data Sharing Partnerships: It would be costly for a single agency to create and maintain a digital, spatially accurate road network base for the entire state. Consequently, the WV DOT should form statewide road data partnerships with other agencies that maintain highly accurate transportation data.

- Avoid Digitizing WV DOT County Highway Paper Maps: Do NOT create a digital mapping base from existing WV DOT general highway reference maps (1:63,500; 1" = 1 mile; Figure 5a) because these maps are spatially inaccurate, incompatible with more accurate geographic datasets, and not seamless across sheet and county boundaries.

    - Spatially Inaccurate: In many cases the current WV DOT general highway map features are cartographic or artistic in nature and not of true mapping accuracy (Figure B2). If cartographic coverages (streams, roads, etc.) must be made for map-making purposes, first develop and maintain spatially accurate master GIS datasets for analytical and referencing applications. Then derive visually appealing cartographic files from these spatially accurate master GIS datasets.

    - Incompatible with other Data Themes: The positional accuracy of digitized WV DOT road centerlines would be inconsistent with other, more accurate data themes. Coincidental features like roads and political boundaries would not share the same geographic space, nor would geocoded structures like schools and churches be positioned properly along roads (Figure 2).

    - Edge-Matching Errors: Road centerline gaps occur when edge-matching digitized WV DOT road centerlines of cartographic maps across county and sheet map boundaries (Figure B1).

- Create a New, Highly Accurate Digital Transportation Base: Besides high-resolution digital data (i.e., GPS, engineer surveys) already collected by the WV DOT highway survey crews and its subcontractors, the WV DOT should consider spatially accurate (1) topographic-based and (2) address-based transportation databases as a framework for their digital map base (Table 3). The WV DOT digital road network base should include ALL public roads for analytical applications and linear referencing systems.

(3) Employ GIS technologies to store, maintain, and publish both paper and electronic highway maps. As WV DOT migrates to a digital mapping environment, it can achieve major cost savings through overhauling the design, content, and printing process of its current county highway map series. Suggestions for revamping the county general highway map series:

- MAP DESIGN

  - *GIS Personnel and Software:* Consider organizational impacts of requiring technically advanced staff and equipment to implement a GIS mapping system. GIS software and its application can be complex and not always intuitive.

    - Personnel: An expert mapping/applications team can involve several technical specialties, including cartographers, GIS analysts and programmers, and system/database administrators. Computer-generated highway maps and analytical applications should be done by experienced professionals or outsourced to the private sector.

    - Software: Most likely more than one software application will be required for cartographic maps and analytical applications. Computer-Aided Design (CAD) software such as Microstation or AutoCAD should be complemented with ESRI ArcGIS 8.2 to implement a robust GIS mapping program.

  - *Best-Available Data*: Choose the best-available data for making digital highway maps. Where possible, data should be collected in a GIS format from the originator or maintainer of that particular dataset (Table 5). The best available geographic data can be collected from existing digital databases, new data sources via GPS, engineering and survey design files, or from reference digital map sources such as digital aerial photography and topographic maps. Desirable data should be accessible, seamless, and consistent among themes, as well as certified and documented to prescribed metadata standards.

  - *Database Development:* Properly designed, fully attributed transportation databases will serve as a critical foundation for cartographic maps and analytical applications. Review functional requirements for road centerline databases (cartography, geo-referencing, network application) and sharable databases. Develop a road network database so that attributes can be transferred or cross-linked between different software applications. Where economical, conflate or transfer road surface types, county highway route numbers, and other useful road attribute features from suitable sources to the selected digital road network base. Migrate from existing legacy (non-graphical) databases to geographic information systems.

  - *Coordinate System:* Reference map data to the Universal Transverse Mercator (UTM) Coordinate System, Zone 17 North, North American Datum of 1983, with map units in meters. The UTM Zone 17 projection, which covers almost the entire geographic extent of West Virginia, is the preferred coordinate system of most state agencies.

- *Geographic Extent of Data*: Maintain and update master road files at county level or higher to provide flexibility for creating both statewide and county general reference highway maps. Coverage extent of major highway routes should be statewide. When creating digital county highway maps, statewide GIS coverages should be clipped to the county extent with existing annotation attached to the updated coverages.

- MAP CONTENT

  - *Reduce Map Content*: After the road network, prioritize which datasets are absolutely necessary on general highway maps.

    - Road Network: Reduce the number of surface types (i.e., bituminous road and soil surfaced roads) depicted on general highway maps. Leave detailed road classifications for internal WV Department of Transportation maps.

    - Individual Structures: Eliminate individual dwellings like houses and farms that are exaggerated, cartographic representations on the map and do not represent true map scale. (Only for specialized maps capture individual structures using digital aerial photography or address databases.) Landmark features like churches, schools, or major buildings should be sufficient.

  - *Page Size, Map Scale, and Feature Density:* Re-evaluate page size, map scale, and feature density of county highway maps series, as this adversely affects the map content and visual appearance of the map. If a constant scale/multiple sections format is chosen, the maximum number of paper sections should not exceed two.

  - *Map Annotation:* Automatically generate map annotation from feature names that exist in the attribute tables. Annotation for large counties like Randolph County must be big enough to be readable if reduced to a standard page size for publishing.

- MAP PUBLISHING

  - *Single Sheet County Maps:* Publish county highway maps to a single, standard page size instead of using a multiple sections format (Appendix D). Map rescaling is easily accomplished in a computer environment.

  - *Export Map to other Software:* Export digital highway maps to other software in a variety of formats. For example, GIS maps can be exported to vector-graphics software like Freehand or Illustrator in case cartographic enhancements are needed.

  - *Public Access:* Make computer-generated maps available free to the public in PDF format (D or E paper size) via the Internet. In addition, transportation GIS files used to generate these maps should be made available to the public (Table 4).

(4) Extend computer mapping beyond value of cartographic maps.
Geographic Information Systems can do more than just make pretty maps. As demonstrated with the West Run Expressway inset maps, GIS software allows users to perform spatial analysis along transportation corridors. Transportation corridors can be dynamically segmented and referenced to mile markers for traffic accidents or pavement conditions. Street addresses for bridges or street intersections can be geocoded or converted to geographic locations. Visibility analyses can determine viewshed areas impacted by a proposed highway. A proposed highway can be buffered to a specific right-of-way distance and then intersected with tax parcels to determine which property owners are affected. Spatial statistics can quickly sum the different highway surface types. In summary, there are a broad range of GIS applications, from asset management and inventory, visualization of features and event, to complex spatial analysis applications.

(5) Develop a multi-phased modular approach to implementing GIS similar to Pennsylvania DOT's GIS Strategic Plan (Appendix F).

- Incorporate the GIS Strategic Plan into other WV DOT automated technology plans.

- Avoid sinking into big "money pits." As evident by the State DOT Roll Call, each DOT has unique goals and interests and is in different stages of GIS development. Some DOTs have been developing their GIS capabilities for 10-15 years, and now are undertaking complex, enterprise database integration and application projects. Also consider that it may be cheaper to migrate to new database solutions than to incorporate "legacy" databases into GIS applications.

- Early implementation of GIS should focus on pilot/demonstration projects, base map development, data integration, and a few, targeted applications such as planning, road inventory, federal reporting, or general highway map production. Identify a few applications that allow WV DOT to work cheaper and faster, thus realizing the benefits of GIS. Follow the stages of GIS development as defined in the 2002 GIS-T State DOT Survey (Figure 3 and Appendix E).

    1. ***Preliminary Planning*** (no operational GIS capability, but evaluating other states' programs, talking with software vendors, etc.)

    2. ***Pilot/Demonstration*** (no officially recognized GIS unit(s), but one or more GIS demonstration projects underway)

    3. ***Early Implementation*** (one or more officially recognized GIS units, primary focus on base map development, data integration, and a few, targeted applications)

    4. ***Fully Operational*** (widespread use of GIS throughout the agency, core GIS functions include base map maintenance, training, technical support, and intra-agency coordination)

GENERAL REFERENCES:

(1) NSDI Framework Transportation Identification Standard (Appendix H)

(2) State I-Team Plans posted at http://www.fgdc.gov/I-Team/ (Appendix F)

(3) Spear, Bruce; Federal Highway Administration, Washington, DC; presented at the 2002 AASHTO GIS-T Symposium, Atlanta, GA (Appendix E)

APPENDICES:

APPENDIX A: Spatial Analysis – Proposed West Run Expressway

APPENDIX B: Scanned WV DOT General Highway County Paper Maps

APPENDIX C: Relationship between WV DOT General Highway Map Symbols and DLG Codes

APPENDIX D: Map Scale, Page Size, and Sheet Number of State DOT County Series Maps

APPENDIX E: GIS-T 2002 State DOT Survey and GIS Trends/Barriers

APPENDIX F: State DOT GIS Implementation Plans (Excerpts from Kentucky, Maryland, New Jersey, Pennsylvania, and Utah plans)

APPENDIX G: National Mapping Initiatives

APPENDIX H: Federal Identification and Core Content Transportation Standards

APPENDIX I: Linear Referencing Systems (LRS)

APPENDIX A: SPATIAL ANAYSIS – PROPOSED WEST RUN EXPRESSWAY

For transportation studies, GIS software provides a variety of indirect location referencing systems and spatial analysis tools to enhance the decision-making process. Some of these GIS functions were used to evaluate the proposed Alignment 3 of West Run Expressway, a northern bypass located north of Morgantown between I-68 and I-79.

Area of Interest Inset Map: The Area of Interest Map (Figure A1) demonstrates how a zoomed-in view of the proposed expressway can be displayed without having to create a totally new map. The inset map also demonstrates how road networks provide the basis for several indirect location referencing systems to locate point or linear features like bridges, signs, pavement conditions, and traffic incidents. Two referencing methods utilized in the mapping project are address geocoding and linear referencing, both shown on the Area of Interest inset map. Geocoding converts street addresses of a road network file into geographic coordinates. The Area of Interest inset map demonstrates how street addresses of respondents for a local rail-trail recreational survey were converted to a point GIS coverage. Spatial statistics can now be conducted on the survey variables. Another type of location referencing system uses measured routes created by dynamic segmentation to depict geographic information. In ArcGIS the linear route-measure system builds upon ARC/INFO's arc-node topological model to provide a linear route-measure system for modeling and analyzing linear features. Transportation attributes can be defined along a route spanning many arcs or a route that spans part of a single arc. For example, Alignment 3 of the proposed expressway was dynamically segmented into mile markers for easier referencing, beginning with mile marker 0 (Easton) and ending at mile marker 3.0 (Monongahela River). Point attributes like proposed signs at mile markers 1.2 and 3.5 could be indirectly referenced to the expressway. The Area of Interest Map also demonstrates how the spatial analysis buffer function created a 1-mile exclusion zone around the municipal airport.

Topographic Map Inset Map: The map inset labeled Topographic Map (Figure A2) depicts three spatial functions based upon 10-meter digital elevation data: profile, hillshade, and visibility. An elevation profile of Alignment 3 shows change in surface elevation between Easton and the Monongahela River. The hillshade function creates a shaded relief map to enhance the topography of the area. A visibility analysis on the elevation grid generates high visibility areas, locations on the ground where observers can view, in barren conditions (no trees or houses blocking view), 30-50% of Alignment 3 between mile markers 0.0 (Easton) and 3.0 (Monongahela River). As expected, much of the proposed expressway will be visible to observers located on hilltops positioned close to the proposed expressway.

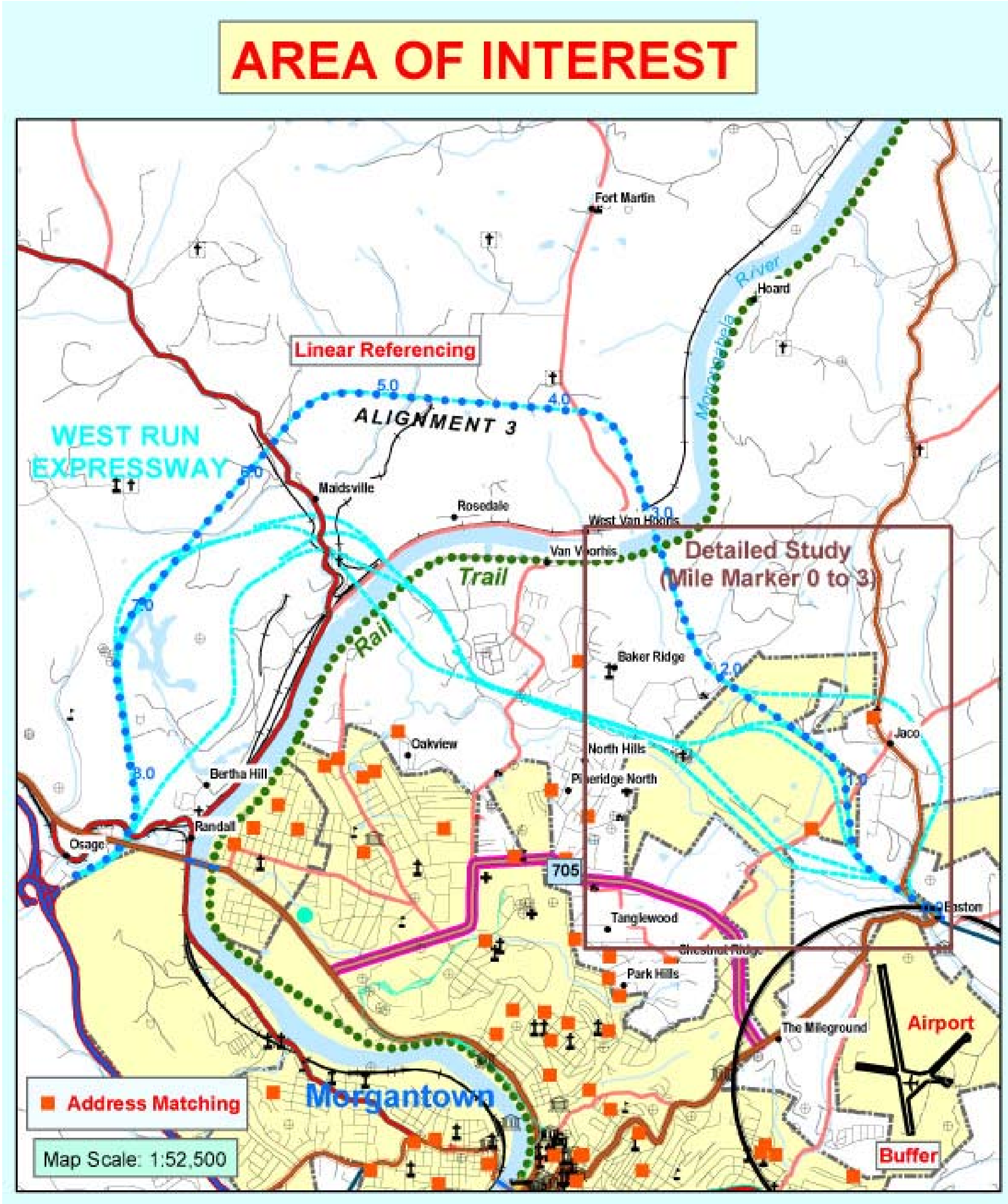
Aerial Photography Inset Map: Color-infrared aerial photography serves a variety of purposes, from information about land use to field references for transportation studies. In this map inset (Figure A3), the spatial analysis overlay function intersects Alignment 3 with the tax parcel polygons to determine which properties the proposed highway directly affects. A spatial query demonstrates how to identify the name of the owner or any other relevant information for a particular parcel.

Summary Statistics Table: Statistics are generated easily from the road network database tables to summarize road surfaces in total miles (Table A1).

Summary Statistics

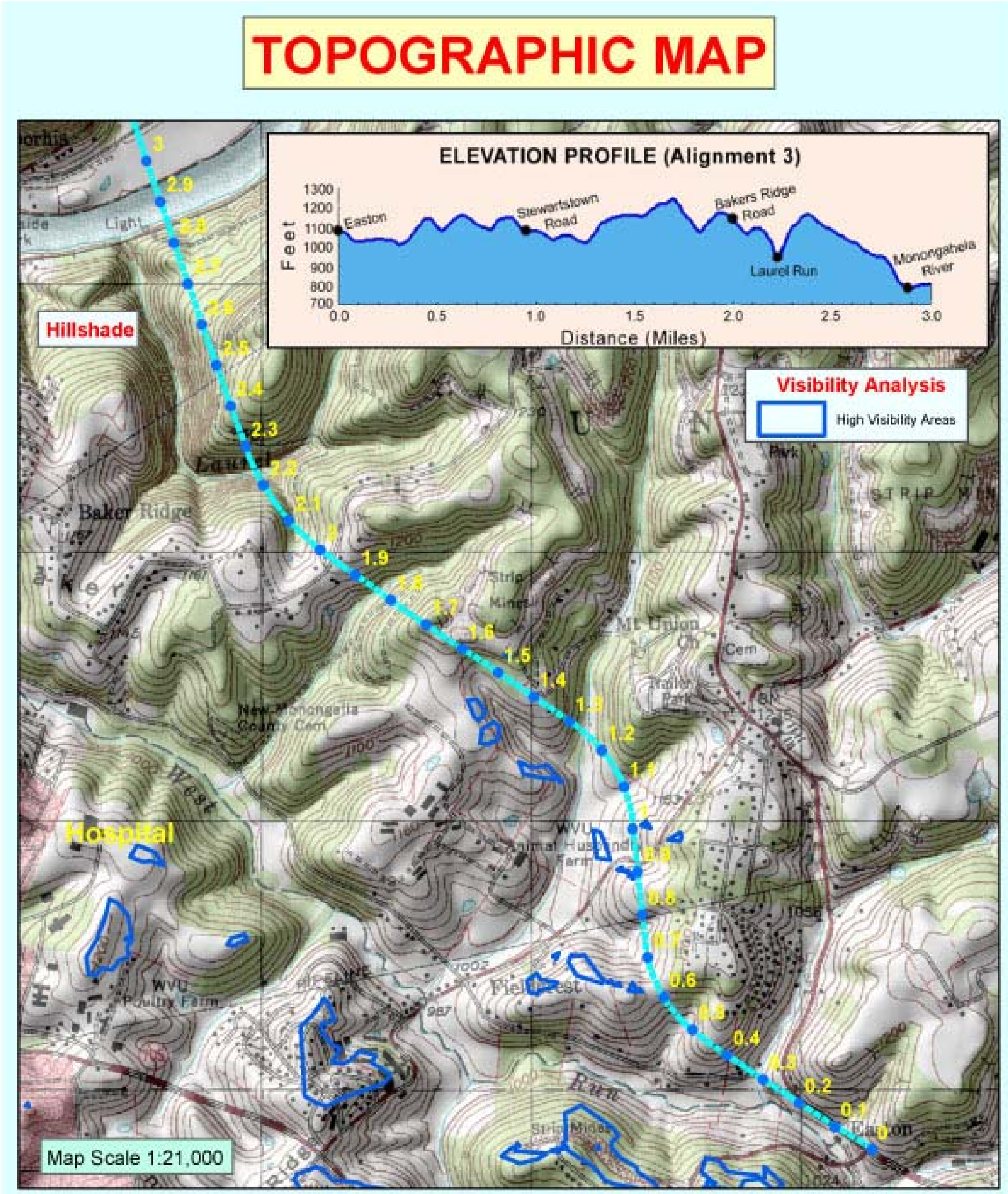
Road Type	Total Miles
Interstate	44.13
US Route	46.08
State Road	76.99
Light Duty	655.25
Unimproved	345.30
Trails	216.54

Table A1: Summary Statistics. Spatial analysis of proposed West Run Expressway.



AREA OF INTEREST: Alignment 3 is linear referenced in miles from Easton (U.S. 119) to Osage (I-79). Inset map also shows Rail Trail survey points (orange squares) geocoded from street addresses. A 1-mile buffer (black) was created around the Morgantown Airport.

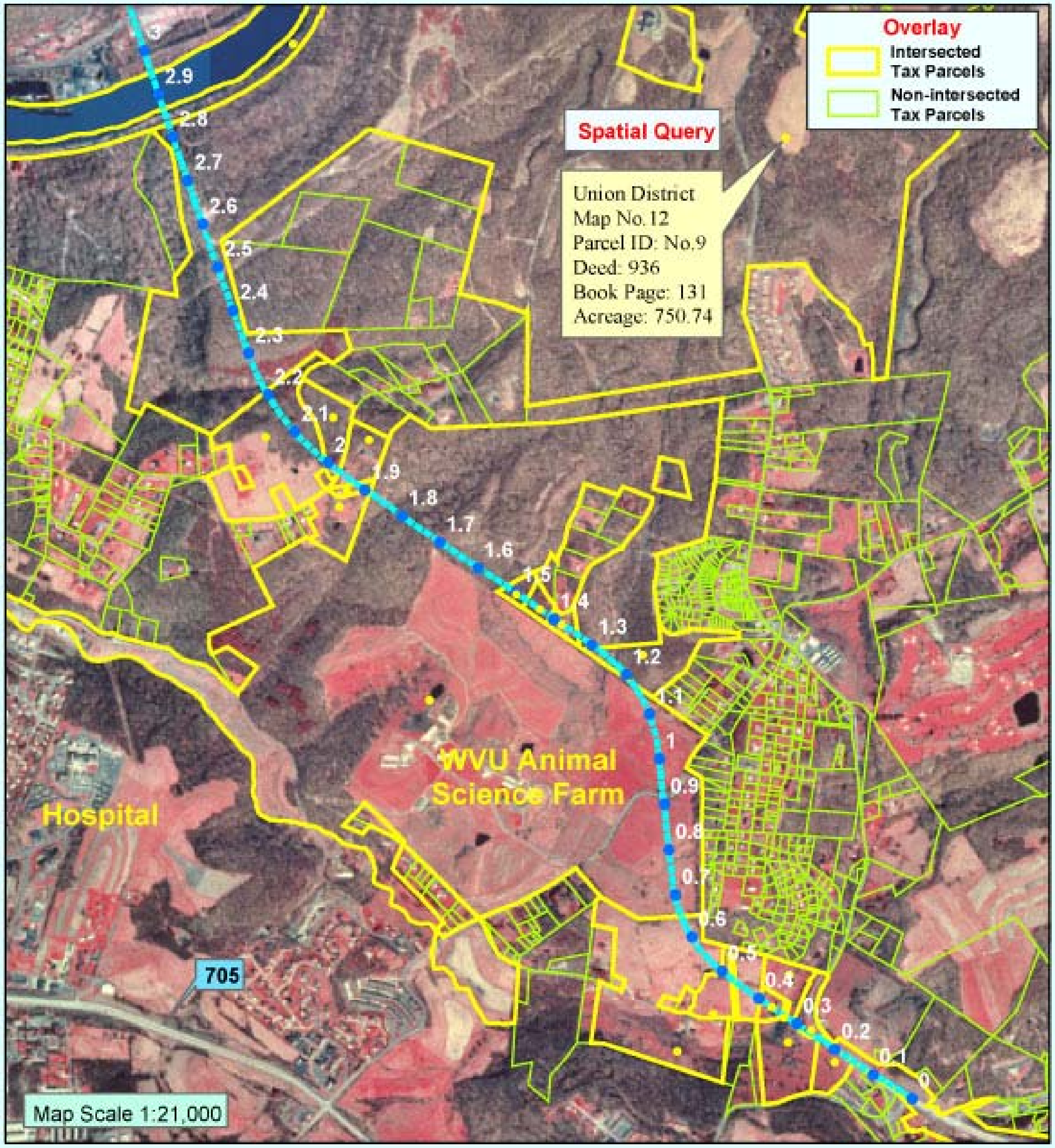
Figure A1: Area of Interest Inset Map. Spatial analysis of proposed West Run Expressway.



TOPOGRAPHIC MAP: High visibility areas, locations where observers can view in barren conditions 30-50% of Alignment 3 between Mile Marker 0.0 (Easton) and 3.0 (Monongahela River), are shown in blue.

Figure A2: Topographic Map Inset. Spatial analysis of proposed West Run Expressway.

AERIAL PHOTOGRAPHY



AERIAL PHOTOGRAPHY: Tax Union District parcels (yellow) intersected by West Run Expressway (Alignment 3). Color infrared photography provides land use information. Tax parcel information can be extracted from the GIS database.

Figure A3: Aerial Photography Inset Map. Spatial analysis of proposed West Run Expressway.

APPENDIX B: Scanned WV DOT General Highway County Paper Maps

Utilize WV DOT Paper Highway Maps for Reference Only: Paper highway county maps that have been scanned and then georeferenced to become GIS images are useful as a mapping *reference* guide but should not be digitized to serve as a base map because other, more spatially accurate digital data, like the DLG, E-911, and GPS road network data, already exist. Not only are the 1:63,500-scale county highway maps spatially inaccurate, these maps do not always edge-match correctly across sectional and county boundaries, nor are they spatially compatible with other themes that are more accurate and current (Figures B1-B3). Consequently, georeferenced, scanned images of county highway maps should only be used as *reference* layer for content and map symbology.

Figure B1: Scanned and georeferenced general county highway maps converted to GIS mapping files for three counties, Monongalia, Marion, and Taylor, and overlaid onto 10-meter panchromatic SPOT satellite imagery. Edge matching is a problem across sheet and county boundaries.

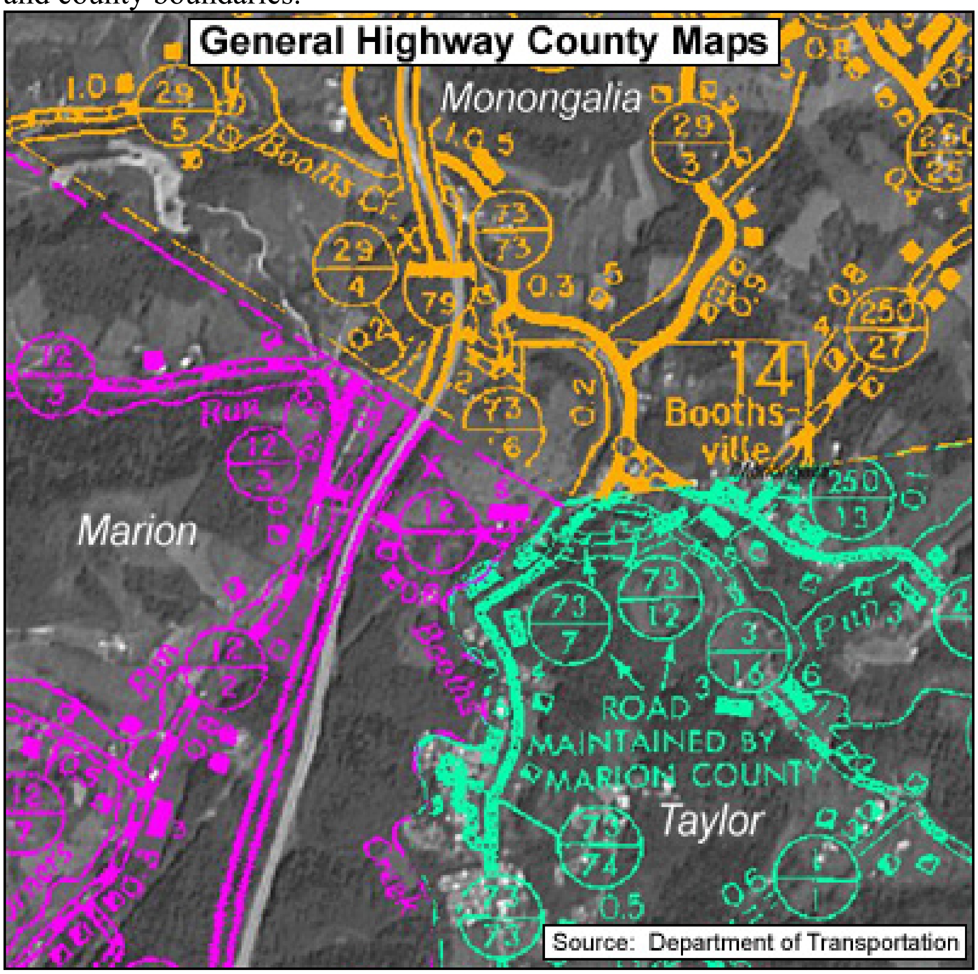


Figure B2: Scanned and georeferenced general county highway maps converted to GIS mapping files for Monongalia County, overlaid onto 1:24,000-scale USGS topographic map. Cartographic representation of man-made features like houses and buildings are exaggerated when compared to true horizontal scale. At true map scale, for example, individual houses cover the geographic area of a city block. The positional spatial accuracy of paper general highway maps is not suitable for detailed mapping projects (note offset of airport and I-68; houses represent city blocks).

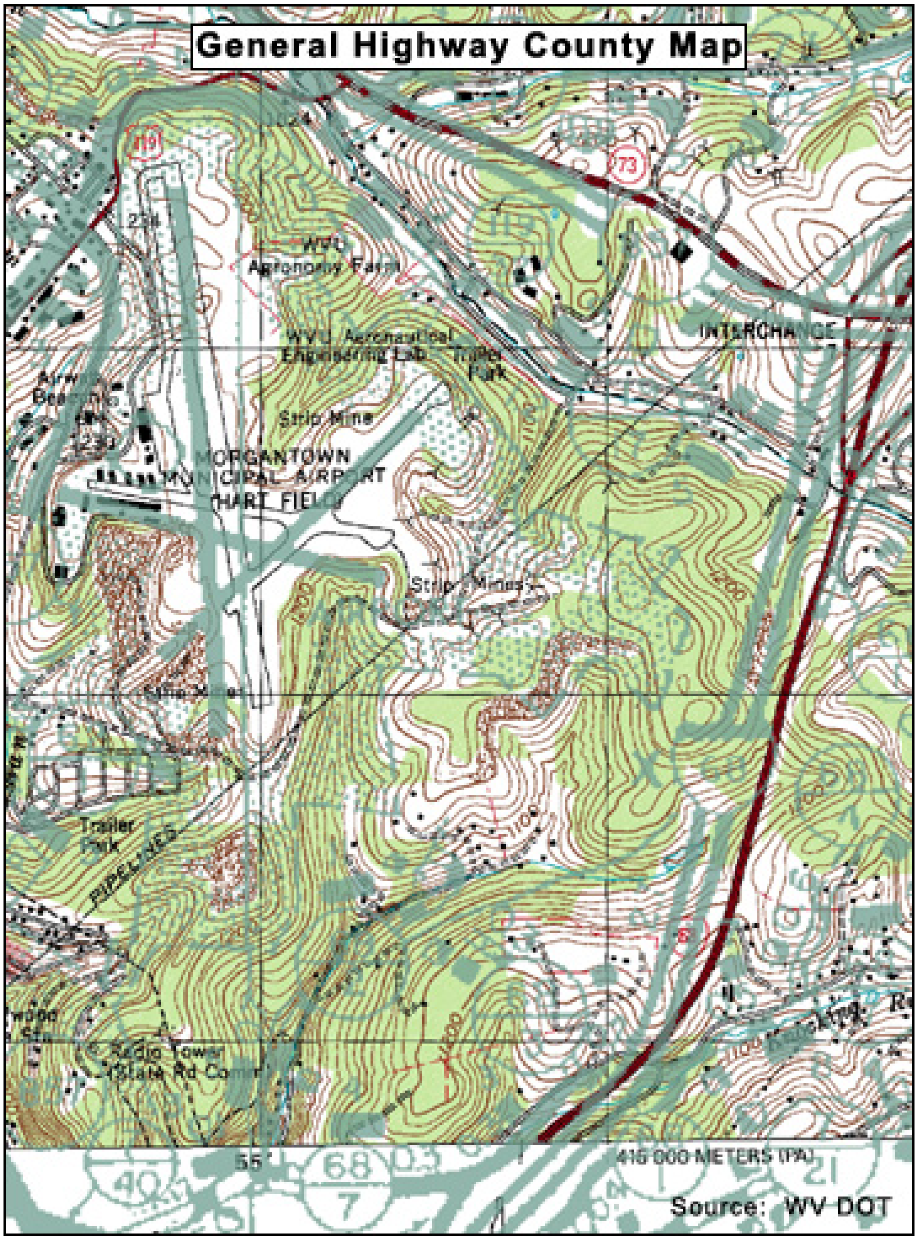


Figure B3: Scanned and georeferenced general county highway maps converted to GIS mapping files for Monongalia County, overlaid onto 1-meter color-infrared digital orthophoto.

How Paper Highway Maps were Georeferenced: District 4 Headquarters of the WV Department of Transportation provided scanned images (~ 200 dpi) of the paper 18" x 36" General Highway County Maps (Type A--Flat maps). The GIS Technical Center mosaicked the county sections together into a single county image, erased all information outside of the county border (insets, legend, etc.), and then georeferenced the image to a computer-generated 5-minute latitude / longitude grid. To make other datasets viewable underneath the digital scanned county highway map, the background white color was made transparent.

APPENDIX C: Relationship between WV DOT General Highway Map Symbols and USGS DLG Codes

None of the existing topographic or address-based GIS databases identified in Table 3 will satisfy current attribution requirements of WV DOT's highway map series. The geometry or digital vector representations are suitable if current and complete but in most cases the attribution is lacking or insufficient. Non-WV DOT transportation databases have different road classification schemes and thus are difficult to merge with WV DOT's scheme. Another problem is that other non-WV DOT databases lack the comprehensive county route numbers typically found on WV DOT highway paper maps. The following discussion explores the different road classification schemes of USGS Digital Line Graphs and WVDOT county highway maps.

The USGS Digital Line Graph (DLG) files are digital representations of roads, trails, bridges, exit ramps, tunnel portals and other detailed transportation features derived from USGS 1:24,000-scale topographic maps. All DLG data distributed by the USGS are DLG - Level 3 (DLG-3), which means the data contain a full range of attribute codes, have full topological structuring, and have passed certain quality-control checks. Numeric DLG attribute codes describe the physical and cultural characteristics of DLG node, line, and area elements. Each DLG element has one or more attribute codes composed of a three-digit major code and a four-digit minor code, and follow the legend classification located on USGS topographic maps. A Spatial Data Transfer Standard (SDTS) format of these codes was chosen because it combines the major and minor codes into a unique feature identification code that allows for easier classification.

DLG files do not contain the detailed surface types and county numbers that are found on the WV Division of Highway's County General Highway maps. Consequently, DLG road surface types cannot be satisfactorily matched to the surface types denoted on the general highway maps. Table C (DLG_STDS_Codes.xls) shows the correlation between the DLG codes and highway map symbols for road surfaces, signage systems, railroads, and structures. For example, the DLG code 1700209, for "light duty, hard or improved road," represents four WV general highway map road surface classifications: bituminous road, gravel or stone road, soil surface road, and graded and drained road. In addition no county route numbers are collected as DLG attributes.

Since it is difficult to create surface types from DLG attributes, in this pilot mapping project we created separate GIS coverages for Interstates, federal, and state highways from the signage or route number attribute field. It is assumed that these roads have similar road surfaces. Secondary highways (hard surface), light duty roads (hard or improved surface), unimproved roads and trails were classified according to DLG surface type codes.

Table C: Comparison of WV DOT highway map and USGS DLG symbology

Relationship between DOT General Highway Map Symbology and DLG Codes For the Monongalia County, West Virginia, Highway Map		
DOT Symbol Type/Name	**DLG Code(s) in SDTS**	**DLG Code Explanation**
Roads and roadways		
Trail	1700212 or 1700211	211=regular; 212=4 wheel drive
Impassable Road	No match	
Primitive Road	1700210	unimproved road, generally dirt
Unimproved Road	1700210	unimproved road, generally dirt
Graded and Drained Road	1700209	light duty, hard or improved
Soil Surfaced Road	1700209	light duty, hard or improved
Gravel or Stone Road	1700209	light duty, hard or improved
Bituminous Road	1700209	light duty, hard or improved
Paved Road	1700205 or 1700201	205=hard surface secondary highway, undivided; 201=hard surface primary highway, undivided
Divided Highway	1700203 or 1700201	203=hard surface primary highway, divided; 201=hard surface primary highway, undivided--will depend on scale collected
Sign Systems		
Interstate Route	SR ###	DLG code is 172.xxx, but in SDTS they translated
U.S. Numbered Highway	I ##	DLG code is 173.xxx, but in SDTS they translated
WV Numbered Highway	US ###	DLG code is 174.xxx, but in SDTS they translated
Railroads		
Railroad	1800201	181.x added to encode number of tracks when multiple track symbol used
Narrow gauge railroad	1800201 and 1800606	606 added to 201 when symbology is narrow gauge
Railroad station	1800400	Node or point, depending on location
Railroad bridge	vertical=O	On bridge 1800602 is added to 201, in SDTS have depicted as O
Railroad Tunnel	?	In tunnel 1800601is added to 201, in SDTS not known how shown
Structures		
Bridge, General	vertical=O	On bridge for road layer=1700602, added to road code; SDTS uses a vertical field
Dam	?	Collected on hydro 0500406, not known how show in SDTS
Tunnel	?	For roads, in tunnel 1700601 is added to road code, in SDTD don't know how show
Ford	?	On road layer 1700606 is added to road code; don't know how shown in SDTS
Other DLG Codes		
	Bridge abutments	1700001 on roads layer; points collected where bridge abutments cross roads
	tunnel portals	1700002 on roads layer; points collected where tunnel portals cross roads
	rest area	1700223 on road through rest area
	ramp in interchange	1700402 on ramp

APPENDIX D: Map Scale, Page Size, and Sheet Number of State DOT County Series Maps

State DOTs use either a (1) variable scale/constant page size/single sheet, (2) constant scale/variable page size/single sheet, or (3) constant scale/constant page size/multiple sheets format for their county highway map series. WV DOT presently uses format 3: the county map (Type A format) consists of one to seven 18" x 36" (height x width) sheets at a scale of 1 inch = 1 mile (1:63,500), printed in black or 2-3 colors.

Most state DOTs publish on the Internet single sheet maps, not multiple sheets, because it is a more desirable format for the public to download and view. Single sheet maps can include detailed city inset maps in the map margins. WV DOT should also publish single sheet maps, either at a variable scale/constant page size or constant scale/variable page size. If the constant scale/variable page size option is chosen, in a digital environment, computer-generated maps can be easily rescaled to a standard page size as long as the map annotation and symbols remain legible. In West Virginia, if single sheet maps are generated at a constant map scale of 1:63,500, then the approximate page size for Randolph County would be 54 x 76 inches, Monongalia County 48 x 36 inches, and Hancock County 18 x 24 inches. Unlike paper maps, the larger county maps like Randolph County could be reduced to a smaller page size for publication purposes.

Table D: File and page sizes of other state highway maps.

Producer	File name	File size	Page size
PA DOT	allegheny_GHSN.pdf (Type 10)	7907 KB	36.24 x 49.25 in
	indiana_GHSN.PDF (Type 10)	5338 KB	36.15 x 49.17 in
	lycoming_GHSN.pdf (Type 10)	4275 KB	38.6 x 29.79 in
	allegheny_T3.pdf (Type 3)	2714 KB	23.99 x 18 in
	indiana_T3.pdf (Type 3)	1977 KB	20.02 x 25.47 in
	lycoming_T3.pdf (Type 3)	1376 KB	24.09 x 18.31 in
NJ DOT	atlantic.pdf	1857 KB	22.65 x 20 in
	essex.pdf	1190 KB	20 x 20.85 in
	sussex.pdf	2769 KB	20.97 x 20 in
	hudson.pdf	604 KB	18.21 x 20.29 in
	cumberland.pdf	1628 KB	20.18 x 20 in
KY DOT	adair.pdf	621 KB	27.64 x 16.78 in
	anderson.pdf	456 KB	27.6 x 16.78 in
	barren.pdf	961 KB	27.58 x 17 in
	edmonson.pdf	473 KB	27.65 x 16.78 in
	hardin.pdf	614 KB	18.5 x 28.13 in
NC DOT	alexa_plt01tif600.tif	969 KB	30.187 x 17.5 in
	alexa_plt02tif600.tif	879 KB	30.187 x 17.5 in
WVGISTC	County_highway_map_demo_41x26ls.pdf	4248 KB	41 x 26 in

APPENDIX E: GIS-T 2002 State DOT Survey and GIS Trends/Barriers

Source: Bruce Spear, Federal Highway Administration, Washington, DC; presented at the 2002 AASHTO GIS-T Symposium, Atlanta, GA.

- *2002 Summary of State DOT GIS Activities*
- *2002 summary spreadsheet and survey form sent out to state DOTs*
- *2002 Roll Call of State DOT Activities*
- *What is GIS-T? Beyond the State DOTs*

GIS-T 2002 Survey of State DOTs

- GIS Capability: Over 95% of state DOTs have some operational GIS capability.
- GIS Budget: 30% of state DOTs have GIS budgets over $1 million.
- GIS Core Staff: Full-time GIS core staff members are usually located in either the Information Services or Planning Divisions. The number of GIS professionals employed at state DOTs range from none to 52 (North Carolina), with a national average of 7 GIS professionals assigned to each state DOT.
- Digital Mapping Base: 95% of state DOTs have a digital mapping base, of which 36% of these mapping bases include all public roads.
- Base Mapping Scale: 89% of state DOTs use a base mapping scale of 1:24,000-scale or larger.
- Data Sharing: 83% of state DOTs participate in geo-spatial data sharing activities with other state agencies or organizations.
- GIS Software: Over 84% of state DOTs use more than one GIS software product, with ESRI GIS the most popular, followed by Intergraph/Microstation and TransCad.
- Database Software: Most DOTs utilize Oracle or Access for database management software.

Trends of GIS use in State DOTs

- Locating GIS core staff in Information Services
- Increasing budgets for GIS activities
- Decentralizing GIS applications to end users throughout the agency
- Making transportation databases more accurate and accessible to public
- Sharing of geographic data between county and state agencies
- Significant growth in web-based GIS
- Migrating to enterprise data integration systems

Barriers to GIS use in State DOTs

- Benefits not well articulated
- High costs for geo-spatial data development or conversion
- Competing non-GIS “legacy tools”
- No standard feature / attribute definitions
- Different accuracy / detail requirements for network database

Current GIS Applications

- Road feature inventory
- Highway asset management
- Safety management / crash analysis
- Highway project locations
- Traffic incident monitoring
- Road conditions / weather
- State highway map / atlas
- Road construction / detours
- Truck permitting / routing
- Environmental impact analysis conversion
- Competing non-GIS “legacy tools”
- No standard feature / attribute definitions
- Different accuracy / detail requirements for network database

APPENDIX F: State DOT GIS Implementation Plans (Excerpts from Kentucky, Maryland, New Jersey, Pennsylvania, and Utah plans)

Every state is unique in its mapping guidelines, digital base map development, database architecture, data sharing protocol, mapping project(s)/application(s), and stage of GIS development. Just from reviewing other state's county highway maps (Figures F1-F4), it is evident that variables such as the feature density, page size, mapping scale, map projection, as well as overall cartographic quality varies among state DOTs.

(1) KENTUCKY

Kentucky DOT Centerline Standards

On December 20, 2001, the Geographic Information Advisory Council (GIAC) adopted the Kentucky Transportation Cabinet's standard for the development of a highly accurate road centerline dataset. This will support state and local level GIS development since transportation is a critical infrastructure layer. This standard (and its associate data) supersedes the existing 1:24,000 scale coverages, which were based from USGS topographic maps. The new data is available as individual county coverages or as part of a statewide coverage. The county level coverages are made available as they are completed, with all counties scheduled for completion near the end of calendar year 2003. The statewide coverages contain the new centerlines where available with the older version data to complete the statewide coverage. These datasets can be downloaded from the Office of Geographic Information web site… http://ogis.state.ky.us/

A comprehensive description of the collection standards and methodologies can be found here: http://giac.state.ky.us/giac_road_centerline_standard_v1_0.pdf (1.6mb file)

(2) MARYLAND

Maryland I-Team Plan (pages 51-52)

General Discussion: Maintenance of the Transportation layer is a good candidate for vertical data integration. In a vertical integration scenario, new features are added at the local level to a high level of spatial accuracy, then migrated through State and Federal government levels, generalizing as needed. Due to its dynamic nature, the transportation layer requires daily maintenance and a data architecture needs to be designed in a manner which encourages and enhances the effectiveness of this data stream while helping to fulfill the requirements of TBTP and Smart Growth. There are also requirements for the ability to query and display information about incidents in a real time environment from both the State (CHART) and from local governments (E-911) which demand accurate and timely data. From the standpoint of information flow, vertical integration of this data layer is already in place. Local governments annually provide information to the Maryland State Highway Administration on new roads within their jurisdictions. Similarly, the State provides information to the Federal Highway Administration through both electronic and paper transactions. For true vertical integration this process needs only to be standardized and applied uniformly.

Existing Product: The Maryland State Highway Administration maintains 1:24,000 scale transportation data as part of its GRID map series. The files are produced and maintained in CADD formats and converted, by others, to GIS formats as required. Data collected for Maryland's report on the Vertical Integration of Spatial Data shows that the State Highway Administration spent approximately $110.00 per square mile to create the road centerline file. This equals approximately $1,067,000 for the entire state. Again looking at the Vertical Integration of Spatial Data Report, they spend an additional $194,000 maintaining the file each year.

Product Specification: Digital vector graphic features representing transportation elements shall be captured from aerial photography. Photography used will be suitable for capture of road centerlines, medians, edge of pavement, edge of travelway, rail lines, airport facilities and other transportation features as needed. Data spatial accuracy shall meet the parameters of National map Accuracy Standards (NMAS) for 1" = 200' (1:2,400) scale mapping.

(3) NEW JERSEY

New Jersey I-Team Plan (Chapter 6)

To meet the immediate business needs of multiple state, regional, and local government agencies, the State of New Jersey plans to license a statewide commercial transportation dataset that includes street centerlines with address locating capabilities. Funding for this data has been included in the State of New Jersey, Office of Information Technology Fiscal Year 2002 Budget. Acquisition of a commercial street centerline dataset is intended to augment rather than supplant the NSDI transportation framework.

New Jersey DOT Mapping Summary (Word Document)

All base maps regardless of scale must meet a definable standard, such as the United States National Map Accuracy Standard (NMAS) referenced in this document. This will guarantee true positional accuracy of data layers. The NJDOT has produced a series of maps at quad (1:24000) scale which meet NMAS standards.

New Jersey DOT utilizes Intergraph GIS software and Bentley's Microstation for their GIS-Transportation system.

(4) PENNSYLVANIA

PENNDOT's GEOGRAPHIC INFORMATION SYSTEM

Initial Strategic Plan: In September 1991, a GIS Strategic Plan was adopted and incorporated into the Department's Automated Technology Strategic Plan. The plan proposed a phased modular approach to implementing GIS. This allowed tasks to be completed and applications to be developed as technology, funding, and resources became available. The success of this GIS project was attributed to close cooperation among the Bureau of Planning and Research, Bureau of Information Systems, and a

Department-wide GIS Steering Committee. The Committee was instrumental in exploring key GIS issues and ensuring the successful implementation of a Department-wide GIS. The Development and Demonstration Division contracted for a competitive selection of GIS software in 1993. A consultant was hired to sort through the vendors responding to a Request for Information and arranged demonstrations from the top contenders. Intergraph, already used extensively within PennDOT for engineering Computer Aided Drafting Design (CADD), was selected as the GIS software, along with ORACLE for the Database Management Software (DBMS).

Base Map Development: Routine base-map maintenance activities are a coordinated effort between the Geographic Information and the Cartographic Information Sections. Both GIS and cartographic activities use a single set of digital road centerline base maps first developed during the mid-1980s from USGS 1:24,000 scale quadrangle maps. Railroad centerlines, legislative districts, airports, school districts, soils, urbanized areas, and intermodal facilities have also been added to the spatial database. The map projection is polyconic; the map datum is 1983. PennDOT does not use Census TIGER files or most national spatial data, nor do they generally digitize new spatial data. The philosophy of the GID is not to create data; rather integrate data from existing sources. Other data provided for District Office use include Digital Ortho-photo Quarter Quads (DOQs) from the mid 1990's and Digital Raster Graphics (DRGs). Both sets of data are stored in MrSID format by county.

Linear Referencing System: A single linear referencing system (LRS) is used throughout PennDOT to link the corporate databases to the road centerline base maps. The LRS is defined in the Department's Roadway Management System (RMS) as a county-route-segment-offset address. Each segment is roughly one-half mile in length.

(5) UTAH

Utah I-Team Plan (Section 8)

Theme Description: The transportation layers often include many features of transportation networks and facilities. For the purpose of this initial plan, only roads are included. For transportation issues related to growth, economic development, disaster preparedness, emergency response (especially wildfires) and public land management, all roads must be included in the transportation framework.

There are multiple versions of roads data maintained in Utah. One is a comprehensive GIS version that is a collaboration of state, federal, and local government agencies which complies to the Utah Transportation Data Model. Another is a derivative of that, maintained by the Utah Department of Transportations that is used for network analysis of state and federal routes, and which carries some additional attributes. Utah's Automated Geographic Reference Center (AGRC), a Division of Information Technology Services (ITS) of the Department of Administrative Services, currently maintains a version of 1:24,000 scale roads derived from USGS Digital Line Graph (DLG) and Forest Service Cartographic Feature File (CFF) data, which will be replaced by the collaborative version described above. There is also the transportation data available from U. S. Census Bureau Tiger Files, which currently supplies the best version of address data for the state.

Data Sources: There are many sources for this data. The State of Utah, U. S. Geological Survey, Forest Service, and the Bureau of Land Management have cooperated over the last several years to complete the initial digitizing of roads from the 1:24,000 map sheets. This data, which has a nominal positional accuracy of 20 meters, meets the traditional needs of many state and federal agencies. Because many of these maps were 20 – 50 years old, a revision process has started to bring them up to date. Revising those old maps from DOQs and other photographic sources, has been necessary to make them more accurate, complete, and current.

State policy for GIS implementation has recognized that users close to the geographic features usually have first hand knowledge of the data and can provide more accurate and timely data. Many rural counties have not had the resources to fully participate and provide accurate credible data to this effort without assistance however. To that end, the State Legislature has provided funding for the counties to purchase GIS and GPS equipment and begin a process to inventory and map every road in the county. For a variety of county responsibilities, sub meter GPS generated roads centerline data is required. This data, which incorporates the Utah Transportation Data Model, will contribute to the State Geographic Information Database (SGID) and the NSDI. Even though state and federal agencies traditionally relied on the 1:24,000 data described above, this sub-meter fully attributed data will provide much more useful information for them. From the start, this process has adhered to the Framework principles initially defined by the FGDC. The most important concept being the use of the best available data for the NSDI.

The State is also working with the Utah Association of Counties and the Census Bureau to identify and integrate address information tied to transportation systems. The Utah Association of Counties has been instrumental in engaging the counties in a discussion about rural addressing standards relative to transportation. The Census Bureau has talked to state and local agencies about options for improvement and modernization of information about transportation features in TIGER.

Most Appropriate Data Steward: After many years of meetings in Utah about transportation data, we feel we have arrived on an optimum model for data creation, maintenance, and distribution. Our intention is to have local government create data, as they are most familiar with what is on the ground. AGRC will integrate this locally generated data and do the quality control necessary to insure accuracy and completeness. State and federal agencies will then have access to it to use in their products. An example of this is the Forest Service is currently using data from the counties in conjunction with their revision of the maps on the Fish Lake National Forest with AGRC doing the QA/QC. All current data will be catalogued, documented, and distributed through the SGID as outlined in the Data Sharing MOU.

Census must continue to update and maintain address ranges for their products but the primary custodian of this data should be local government. Since there is currently no federal agency that has overall responsibility for all roads features, it makes sense that the Census Bureau be given that responsibility through the revised OMB Circular A-16.

Figure F1-A: PA DOT Type 10 County Highway Map (digital). Created in Microstation.

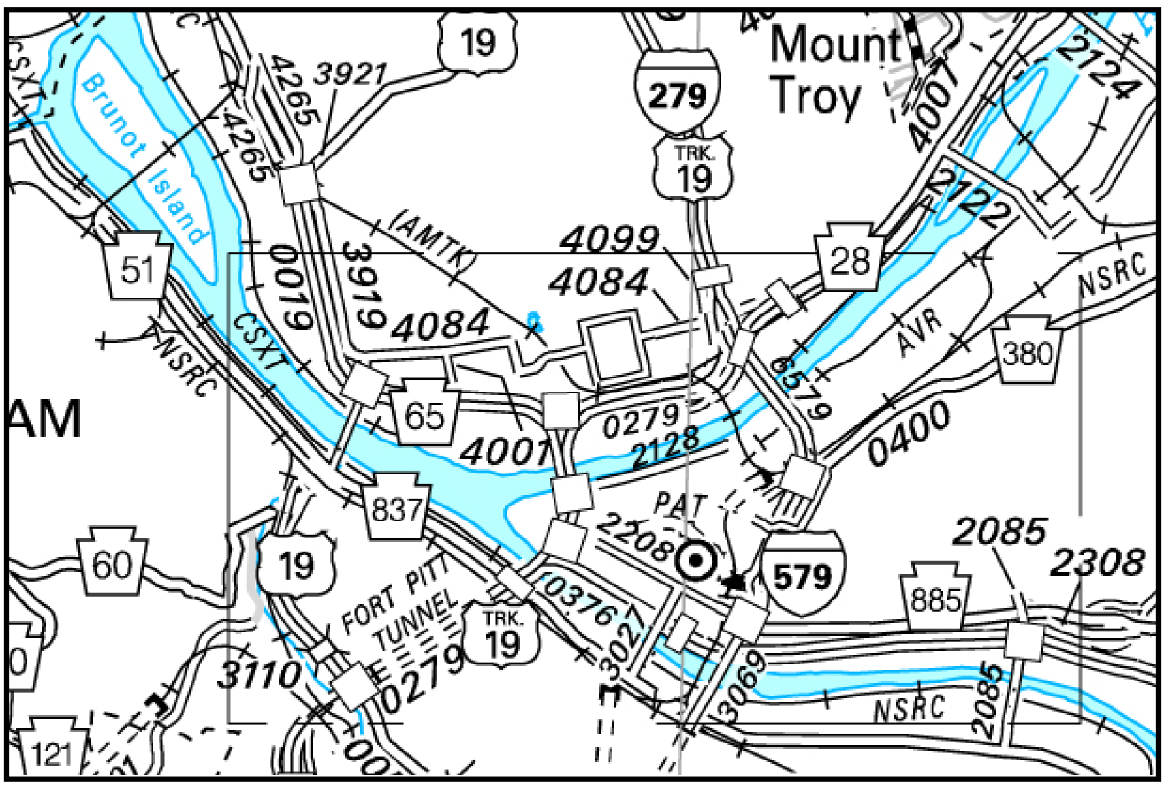


Figure F1-B: PA DOT Type 3 County Highway Map (digital). Created in Microstation.

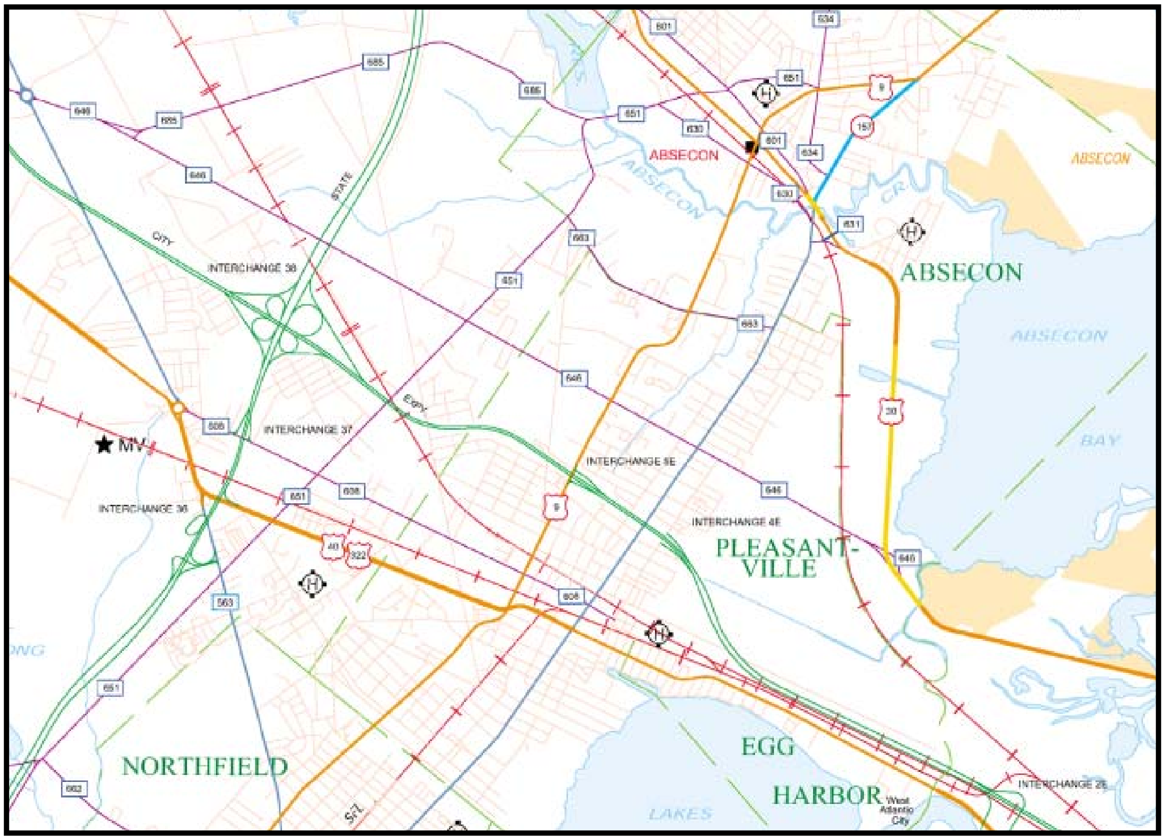


Figure F2: NJ DOT County Highway Map (digital). Created in Microstation.

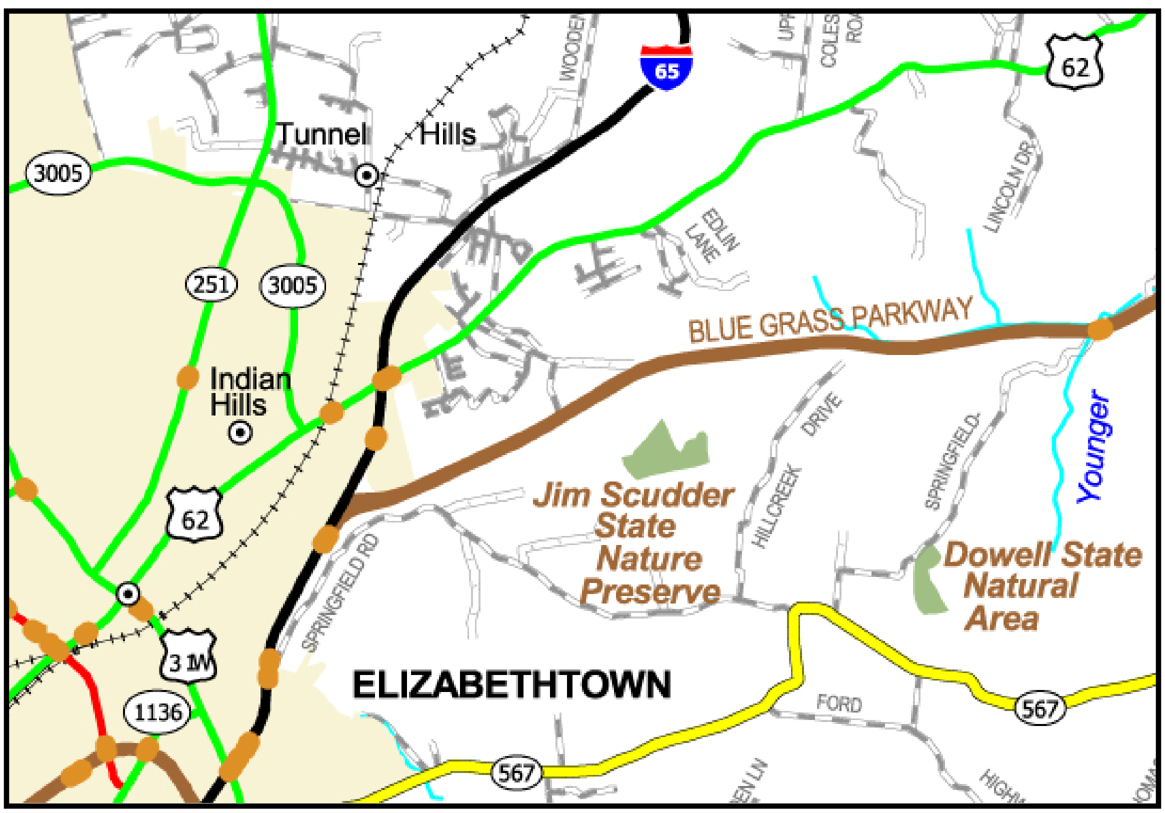


Figure F3: KY DOT County Highway Map (digital). Created with ArcView. Annotation must be redone for ArcGIS 8.2 software upgrade.

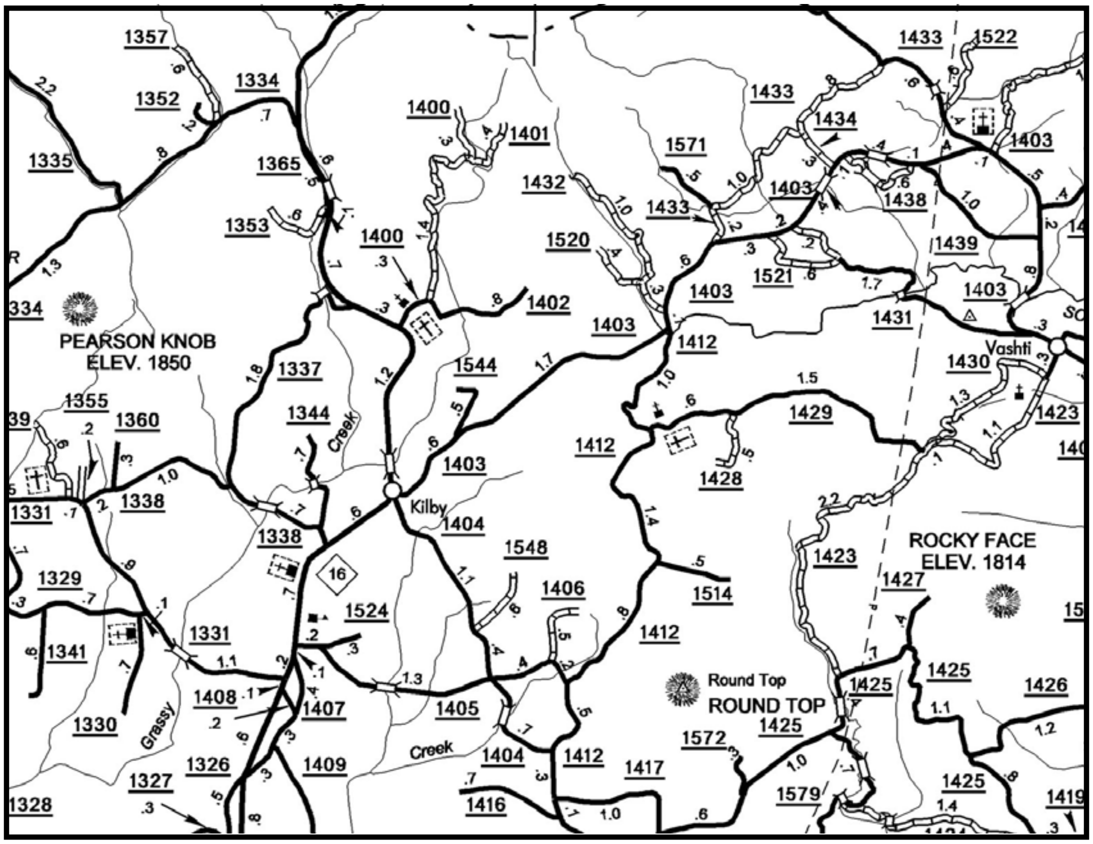


Figure F4: NC DOT County Highway Map (digital). Evident by mileages displayed on map, the NCDOT emphasizes linear referencing. Created in Microstation.

APPENDIX G: National Mapping Initiatives

(1) National Spatial Data Infrastructure (NSDI): The NSDI encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data. The 17 federal agencies that make up the Federal Geographic Data Committee (FGDC) are developing the NSDI in cooperation with organizations from state, local and tribal governments, the academic community, and the private sector. http://www.fgdc.gov/nsdi/nsdi.html

(2) I-Team GeoSpatial Information Initiative: The *I-Team Geospatial Information Initiative* (I-Team Initiative) is a joint project of the Federal Geographic Data Committee (FGDC), Federal Office of Management and Budget (OMB), the Council for Excellence in Government, Urban Logic, TIE, NSGIC, NACO, and other strategic partners. To build a National Spatial Data Infrastructure (NSDI), the I-Team Initiative addresses the institutional and financial barriers to development of the NSDI. It aims to offer a coherent set of institutional and financial incentives to make it easier for all levels of government and the private sector to collaborate in the building of the next generation of framework data. By aligning participant needs and resources, the I-Team Initiative will help all levels of government and the private sector to save money, migrate from existing legacy systems, make better user of existing resources, and develop the business case for additional public and private resources. http://www.fgdc.gov/I-Team/

(3) The National Map: Sponsored by the U.S. Geological Survey, *The National Map*, will be a seamless, continuously maintained set of geographic base information that will serve as a foundation for integrating, sharing, and using other data easily and consistently. http://nationalmap.usgs.gov/

(4) Geospatial One-Stop: The *Geospatial One-Stop* is a part of the new Office of Management and Budget (OMB) E-Government initiative to improve the effectiveness, efficiency, and customer service throughout the Federal Government. *Geospatial One-Stop* will revolutionize E-Government by providing a geographic component for use in all Internet based E-Government activities across local, state, tribal and federal government. http://www.fgdc.gov/geo-one-stop/index.html

Bureau of Transportation Statistics (BTS): Within the NSDI Transportation theme, the Bureau of Transportation Statistics will be responsible for coordinating the development of its content standard. Transportation is also unique since different modes use different transportation networks. This will be reflected in the development of content standards, in that a separate standard will be developed for each mode (highways, railways, air, and transit). http://www.bts.gov/gis/geospatial_onestop/index.html

Open GIS Consortiums (OGC): OGC is an international industry consortium of more than 220 companies, government agencies and universities participating in a consensus process to develop publicly available geoprocessing specifications. OGC Seeks Interested Parties for Geospatial One-Stop Transportation Pilot Activity.

APPENDIX H: Federal Identification and Core Content Transportation Standards

NSDI Framework Transportation Identification Standard

The FGDC Ground Transportation Subcommittee is sponsoring the development of a conceptual data model standard for identifying road segments as unique geo-spatial features which are independent of any cartographic or analytic network representation. These road segments will form the basis for maintenance of NSDI framework road data (through transactions and other means), and for establishing relationships between road segments and attribute data.

The BTS has identified four dominant transportation modes that comprise the NSDI Transportation layer: roads, rail, transit, and air. Because each mode is slightly different from each other, a separate standard will be developed for each.

Roads - Two standards are currently under development, the *NSDI Framework Transportation Identification Standard* (completed public review) and the Framework content standard for roads. The Identification Standard has been in development for approximately three years and was designed to enhance the sharing of data about transportation features. The Identification Standard was developed with little input from the vendor community and is technology and software neutral. Applications for the standard have not been developed nor has a mechanism to demonstrate its use and benefit been established. The FGDC Ground Transportation Subcommittee hopes to complete final modification and submit a final draft to FGDC by the summer of 2002.
The Framework content standard for roads will be designed to enhance data sharing. BTS has put out for bid a contract that will assist in the standard's development; also BTS is preparing to underwrite some expenses for application development and advertisement. Finally the USDOT is actively seeking individuals for participation in becoming either a Model Advisory Team member or joining the process in some other capacity.

Railroads, Transit, Air - The process for developing Framework content standards for the other transportation modes (Railroads, Transit, and Air) are just beginning. The USDOT is actively seeking individuals interested in contributing to the development of these standards.

For more information search FGDC and BTS websites:
(1) http://www.fgdc.gov/standards/status/sub5_7.html
(2) http://www.bts.gov/gis/fgdc/web_intr.html
(3) http://www.bts.gov/gis/fgdc/comments/index.html

APPENDIX I: Linear Referencing Systems (LRS)

A linear referencing system is a set of datums, networks, and linear referencing methods, whereby each point along a network can be identified uniquely by specifying the direction and distance form any known point on the network.

Linear reference systems, an essential component of transportation management applications, are complex, vendor specific, user specific, and difficult to transfer information between different computer mapping systems. Below are some articles about this subject and research on developing industry standards.

Roadway Inventory and Linear Referencing System
Identify a primary linear reference system (LRS) that can provide a valid platform for the Asset Management and TSIMS efforts. Identified a need for a "Best Practices" model for the Linear Reference System

On The Results of a Workshop on Generic Data Model for Linear Referencing Systems, Program (NCHRP), Project No. 20-27, Alan Vonderohe (editor), University of Wisconsin, Madison, WI, 1995. Summary of a workshop sponsored by the National Cooperative Highway Research

Guidelines for the Implementation of Multimodal Transportation Location Referencing Systems, National Cooperative Highway Research Program, Project 20-27(3), FY 1996. Further research is necessary to develop a comprehensive LRS data model that encompasses multimodal, multi-dimensional locations of stationary objects as well as moving vehicles.

(PDF] NCHRP 20-27(3) Multi-Modal Transportation LRS Data Model and Implementation Guidelines...
Administered by the Transportation Research Board (TRB) and sponsored by the member departments (i.e., individual state departments of transportation) of the American Association of State Highway and Transportation Officials (AASHTO), in cooperation with the Federal Highway Administration (FHWA), the National Cooperative Highway Research Program (NCHRP) was created in 1962 as a means to conduct research in acute problem areas that affect highway planning, design, construction, operation, and maintenance nationwide.

LINEAR REFERENCING SYSTEM REQUIREMENTS: Chapter V: HPMS Field Manual Chapter V HPMS Field Manual December 2000 CHAPTER V LINEAR REFERENCING SYSTEM REQUIREMENTS In the past, HPMS data has been analyzed and viewed as tables, charts, and graphs. Furthermore, any

[PDF] A Conceptual Design for the Iowa DOT Linear Referencing System
Iowa Department of Transportation LRS Development Project Page 7 Figure 2 LRS Operational

[PDF] GIS FOR TRANSPORTATION GIS FOR TRANSPORTATION
Understanding LRS. Linear Reference Systems by Geoanalytics

Support and Build the New LRS
NCDOT adopted a standard organizational LRS in 1998. Uses a single permanent LRS ID for each roadway length.

Functional Requirements for Road Centerline Databases
Cartography, georeferencing, network applications. Bruce Spear, Bureau of Transportation Statistics

LINEAR REFERENCING SYSTEMS 10/01/94 Report
FGDC Ground Transportation Subcommittee Position and Recommendations