THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**ENVIRONMENTAL DECISION SUPPORT SOFTWARE**
APPLICATION:	**INTEGRATION AND VISUALIZATION OF ENVIRONMENTAL DATA SETS**
TECHNOLOGY NAME:	**ArcView GIS Version 3.1 using ArcView Spatial Analyst and ArcView 3D Analyst extensions**
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The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification Program (ETV) to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations and stakeholder groups consisting of regulators, buyers, and vendor organizations, with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The Site Characterization and Monitoring Technologies Pilot, one of 12 technology areas under ETV, is administered by EPA's National Exposure Research Laboratory (NERL). With the support of the U.S. Department of Energy's Environmental Management program, NERL selected a team from Brookhaven National Laboratory (BNL) and Oak Ridge National Laboratory to perform the verification of environmental decision support software. This verification statement provides a summary of the test results of a demonstration of Environmental Systems Research Institute's (ESRI's) ArcView® environmental decision support software (DSS) and its extensions ArcView Spatial Analyst® and 3D Analyst™.

DEMONSTRATION DESCRIPTION

In September 1998, the performance of five DSS products was evaluated at the New Mexico Engineering Research Institute located in Albuquerque, New Mexico. In October 1998, a sixth DSS product was tested at BNL in Upton, New York. Each technology was independently evaluated by comparing its analysis results with measured field data and, in some cases, known analytical solutions to the problem.

Depending on the software, each was assessed for its ability to evaluate one or more of the following endpoints of environmental contamination problems: visualization, sample optimization, and cost-benefit analysis. The capabilities of the DSS were evaluated in the following areas: (1) the effectiveness of integrating data and models to produce information that supports the decision, and (2) the information and approach used to support the analysis. Secondary evaluation objectives were to examine the DSS for its reliability, resource requirements, range of applicability, and ease of operation. The verification study focused on the developers' analysis of multiple test problems with different levels of complexity. Each developer analyzed a minimum of three test problems. These test problems, generated mostly from actual environmental data from six real remediation sites, were identified as Sites A, B, D, N, S, and T. The use of real data challenged the software systems because of the variability in natural systems. The technical evaluation team performed a complete baseline analysis for each problem. These results, along with the data were used as a baseline for comparison with the DSS results.

ESRI staff used ArcView GIS Version 3.1 and its Spatial Analyst and 3D Analyst extensions to perform the visualization endpoint using data from Sites A, B, and N. The Site A test problem, a three-dimensional groundwater cost-benefit problem, required an analysis of remediation volume as a function of cleanup levels for two volatile organic compounds (perchloroethene and trichloroethane). Data were supplied at a series of wells for one representative period. Within each well, data were collected on a 5-ft vertical spacing from the top of the water table to the confining bedrock. The Site B test problem was a two-dimensional groundwater contamination sample optimization problem for three contaminants (trichloroethene, vinyl chloride, and technetium-99). Developers were provided with a series of wells containing contaminant concentrations and were asked to specify additional locations in which to collect more data to better define the nature and extent of contamination. The Site N test problem was a two-dimensional soil contamination cost-benefit problem. This problem included three heavy metal contaminants (arsenic, cadmium, and chromium). The objective was to define the cost (area) of remediation as a function of two cleanup levels for each contaminant.

The intent of the ArcView analyses was to demonstrate the capability to integrate large quantities of data into a visual framework to assist in understanding a site's contamination problem. For the Site N analysis, ArcView was used to estimate the area and costs associated with cleanup to different threshold levels. Sample optimization components of the test problems were not performed.

Details of the demonstration, including an evaluation of the software's performance, may be found in the report entitled *Environmental Technology Verification Report: Environmental Systems Research Institute, ArcView GIS Version 3.1 using ArcView Spatial Analyst and ArcView 3D Analyst Extensions*, EPA/600/R-99/094.

TECHNOLOGY DESCRIPTION

ArcView GIS version 3.1 is a geographic information system (GIS). One function of the software is to help environmental professionals quickly and comprehensively characterize, manage, and visualize information relevant to understanding environmental contamination problems. The ArcView GIS integrates common database operations, such as query and statistical analysis, with the visualization and geographic analysis benefits offered by maps. The Spatial Analyst extension was developed to solve problems requiring that distance or other continuous surface modeling information be considered as part of the analysis. The 3D Analyst extension permits the creation of three-dimensional surface models and

assists users with three primary tasks—surface model construction, analysis, and display. ArcView and its extensions operate on Windows 95, 98, and NT platforms.

VERIFICATION OF PERFORMANCE

The following performance characteristics of ArcView GIS Version 3.1 and its extensions Spatial Analyst and 3D Analyst were observed:

Decision Support: ArcView GIS version 3.1 was able to quickly import data on contaminant concentrations, geologic structure, and surface structure from a variety of sources with different formats and integrate this information on a single platform. It was able to place the information in a visual context that supports data interpretation.

Documentation of the ArcView Analysis: ArcView generated reports that provided an adequate explanation of the process and parameters used to analyze each problem. Documentation of data transfer, manipulation of the data (e.g., how to treat contamination data as a function of depth in a well), and analyses were included. Model selection and parameters for contouring were also provided in the exportable documentation. ArcView generated graphical output in . jpg format and incorporated this directly into a Microsoft Word file.

Comparison with Baseline Analysis and Data: ArcView generated hydraulic head, ground surface elevation, bedrock elevation, and contaminant concentration maps. The maps ranged from posting of a marker at each data location, in which the size was proportional to the value of the parameter being represented (e.g., contamination level), to generation of concentration contours. Comparison of the contours of concentration and hydraulic head with the data and the baseline analysis showed that ArcView results were consistent with the measured values. ArcView accurately mapped wells, buildings, and site features. It accurately posted data to sample locations and hot-linked data to well locations. The Site N cost-benefit analysis performed using ArcView estimated the volume of contamination and the cost of remediation and was found to be consistent with the data and baseline analysis.

Multiple Lines of Reasoning: ESRI staff used ArcView, Spatial Analyst, and 3D Analyst to provide multiple interpretations of the data with different contouring algorithms and contouring parameters. The best fit to the data was provided for review. The multiple representations of the data permitted a better understanding of the extent of the contamination problem.

In addition to performance criteria, the following secondary criteria were evaluated.

Ease of Use: The demonstration showed that the basic features in ArcView were easy to use. An analyst with a background in environmental problems and a basic knowledge of database and GIS operations can use ArcView after one to two days of training. The ArcView platform has a graphical user interface with a logical menu structure to permit use of the options in the software package. ArcView supports data queries that permit evaluation of the data based on user-defined criteria, for example, using only trichloroethene data collected in 1999 for contouring. This query capability is a powerful data analysis tool. ArcView was demonstrated to accept a wide range of formats when importing data (e.g., database files, drawing files in .shp and .jpg formats) and can export files using a large number of formats. Use of advanced features, such as the Avenue scripting language, would require additional training and regular use.

Efficiency and Representativeness: ESRI staff completed three visualization problems and generated the report documenting the analysis with 12 person-days of effort. ArcView has a flexible database structure that supports multiple data input formats. This provides a platform that addresses problems efficiently and can be tailored to the problem under study. ArcView permits queries on any field (e.g., chemical

name, date, concentration, well identifiers) and also permits filtering (e.g., include only data between certain dates, maximum concentration at a location over a range of sample dates). The software has the capability to evaluate a wide range of environmental conditions (e.g., contaminant in groundwater, soil, multiple contaminants on a single site).

Training and Technical Support: ArcView offers several options for training and technical support. A detailed on-line help system is supplied with the software package, and a user's manual is available to assist in operation of the software. A step-by-step tutorial that covers the major features is provided with the software package. A one-day training course is available if desired. Technical support is available for a yearly maintenance fee.

Operator Skill Base: To use ArcView efficiently, the operator should have a basic understanding of the use of computer software in analyzing environmental problems. This includes fundamental knowledge about GIS and relational database files. In addition, knowledge about contouring environmental data sets is beneficial.

Platform: ArcView was demonstrated on a Windows NT 4.0 operating system. It requires a minimum of 128 megabytes (MB) of random access memory (RAM). During the demonstration, two machines were used. For Sites B and N, a 233-MHz Pentium II laptop with 128 MB of RAM, a 5-gigabyte hard drive and standard 1024×768 video monitor was used. The laptop was equipped with an internal CD drive, a 1-gigabyte Jazz drive, and a PCMCIA network adapter. For the Site A analysis, the computer contained a 300-MHz Pentium II processor with 128 MB of RAM and an Elsa Gloria XLM graphics card with 16 MB of video RAM and an Open GL chipset. This computer was equipped with an internal CD drive, a 1-gigabyte Jazz drive, an internal network adapter, and a 19-in. monitor.

Cost: Pricing varies for single stand-alone systems through enterprise-wide systems. Currently, the government price for the Windows version of a single stand-alone system of ArcView GIS Version 3.1 is $996; for Spatial Analyst and 3D Analyst, the Government Services Administration price is $2342 each. Prices for these products for private industry or for use on a UNIX-based operating system are slightly higher.

Overall Evaluations: The main strength of ArcView, Spatial Analyst, and 3D Analyst is their ability to easily integrate data and maps in a single platform to allow spatial visualization of the data. The visualization output was clear and easy to understand. The ability to sort and query data makes examination of a subset of the data easy to perform. ArcView's ability to manage data files from a wide range of sources makes it suitable for managing complex environmental contamination problems. The ease of use makes ArcView and its extensions accessible for the occasional user who wants to view the spatial correlation between data. For the more advanced user, the scripting language, Avenue, makes the ArcView products extremely flexible and customizable for problem-specific applications. ArcView is a mature product with a large customer base.

The technical team concluded that for visualization of environmental data sets, there were no major limitations in the ArcView set of programs. Minor problems noticed by the technical team included the inability to open some of the project files provided at the demonstration and, for a new user, the need to learn the terminology to understand the operation of ArcView (e.g., "scenes", "themes", "program files").

The credibility of a computer analysis of environmental problems depends on good data, reliable and appropriate software, adequate conceptualization of the site, and a technically defensible problem analysis. The results of the demonstration show that the ArcView software can be used to generate reliable and useful analyses for evaluating environmental contamination problems. This is the only component of a credible analysis that can be addressed by the software. The results of an ArcView

analysis can support decision-making. ArcView has been employed in a variety of environmental applications. Although ArcView has been demonstrated to have the capability to produce reliable and useful analyses, improper use of the software can cause the results of the analysis to be misleading or inconsistent with the data. As with any complex environmental DSS product, the quality of the output is directly dependent on the skill of the operator.

As with any technology selection, the user must determine if this technology is appropriate for the application and the project data quality objectives. For more information on this and other verified technologies visit, the ETV web site at *http://www.epa.gov/etv*.

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