THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

Oak Ridge National Laboratory

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**ENVIRONMENTAL DECISION SUPPORT SOFTWARE**
APPLICATION:	**INTEGRATION, VISUALIZATION, SAMPLE OPTIMIZATION, AND COST-BENEFIT ANALYSIS OF ENVIRONMENTAL DATA SETS**
TECHNOLOGY NAME:	**Groundwater*FX***
COMPANY:	**Decision*FX*, Inc.** **310 Country Lane** **Bosque Farms, NM 87068**
PHONE:	**(505) 869-0057**
WEBSITE:	**www.decisionFX.com**

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 (SCMT), 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 (DOE's) Environmental Management (EM) program, NERL selected a team from Brookhaven National Laboratory (BNL) and Oak Ridge National Laboratory (ORNL) to perform the verification of environmental decision support software. This verification statement provides a summary of the test results of a demonstration of Decision*FX*'s Groundwater*FX* environmental decision support software product.

DEMONSTRATION DESCRIPTION

In September 1998, the performance of five decision support software (DSS) products were 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 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 team performed a baseline analysis for each problem to be used as a basis of comparison.

Decision*FX* staff chose to use Groundwater*FX* to perform all three endpoints using data from the Site B and Site S sample optimization and cost-benefit problems. For both problems, Groundwater*FX* was used to define sample locations to characterize the extent of groundwater contamination above specified contaminant threshold concentrations. The software generated two-dimensional (2-D) base maps containing site features that were overlain with maps of concentrations or of probability of exceeding contamination threshold levels. Groundwater*FX* was also used to estimate the volume of water contaminated above the specified threshold concentrations and to provide exposure concentrations at specified locations for use in human health risk calculations. The estimates for volume and concentrations were done using probabilistic simulation. This permitted the analyst to provide statistical estimates of the confidence in the software's volume and concentration estimates. Details of the demonstration, including an evaluation of the software's performance, may be found in the report entitled *Environmental Technology Verification Report: Environmental Decision Support Software—DecisionFX, Inc., GroundwaterFX,* EPA/600/R-00/037.

TECHNOLOGY DESCRIPTION

Groundwater*FX* is a decision support system intended to provide decision makers and analysts a means of evaluating environmental information related to the nature and extent of contamination in groundwater. Key attributes of the product include the ability to delineate, provide visual feedback, and quantify uncertainties in the nature and extent of groundwater contamination (e.g., concentration distribution, probability distribution of exceeding a groundwater cleanup guideline); to provide objective recommendations on the number and location of sampling points; and to provide statistical information about the contamination (e.g., average volume of contamination, standard deviation, etc.). Groundwater*FX* runs on Windows 95 and 98 or NT platforms and on the Power Macintosh operating system.

VERIFICATION OF PERFORMANCE

The following performance characteristics of Groundwater*FX* were observed:

Decision Support: Groundwater*FX* is a probabilistic-based software designed to address 2-D and three-dimensional (3-D) groundwater contamination problems, including optimization of new sample locations and generation of cost-benefit information (e.g., evaluation of the probability of exceeding threshold concentrations). The software generated 2-D maps of the contamination and of the probability of exceeding a specified threshold concentration. Cost-benefit curves of the cost (volume) of remediation vs. the probability of exceeding a threshold concentration were generated in Excel using Groundwater*FX* output files. The software provided estimates of current and future exposure concentrations for use in human health risk calculations. The interpretations of statistical data permit the decision maker to evaluate future actions, such

as determining sampling locations or developing cleanup guidance, on the basis of the level of confidence placed in the analysis.

Documentation of the GroundwaterFX Analysis: Decision*FX* staff generated a report that provided an adequate explanation of the process and parameters used to analyze each problem. Documentation of data transfer, manipulations of the data, and analyses were included. The criteria used to select models for the simulation and the parameters for conducting the probabilistic assessment were provided in standard ASCII text files that are exportable to a number of software programs. Output files from the simulations were also provided for review.

Comparison with Baseline Analysis and Data: Decision*FX* used Groundwater*FX* to perform the visualization, sample optimization, and cost-benefit aspects of problems from Sites B and S. The analysis performed by Groundwater*FX* did not provide an adequate match to the data on either test problem. For Site B, the locations of wells in some simulations were incorrectly plotted on the site map. The maps of contaminant concentrations were generally consistent with the data near the source of contamination. However, the software did not represent the leading edge of the plume accurately. The maps showing the probability of exceeding a contaminant threshold were inconsistent with the baseline data, and the estimate of the volume of the plume was three to five times smaller than that obtained in the baseline analyses. The estimates of exposure concentrations for risk calculations were too low by a factor of 2 to 3 as compared to the baseline analyses. For Site S, Groundwater*FX*'s estimates of contaminant concentrations were an extremely poor match to the data and baseline analysis. As a result, estimates of the volume of contaminated groundwater and of exposure concentrations for risk calculations were substantially different from those suggested by the data and baseline analysis. In addition, the Groundwater*FX* estimates of exposure concentrations supplied for risk calculations were inconsistent with the contaminant concentration maps generated by the software.

Multiple Lines of Reasoning: The foundation of the Groundwater*FX* approach is a Monte Carlo simulator that produces multiple simulations of the distribution of contamination that are consistent with the known data. From these simulations, concentration and probability maps were produced to assist in evaluating the extent of contamination. This permits the decision-maker to evaluate future actions, such as determining sampling locations or developing cleanup guidance, on the basis of the level of confidence placed in the analysis.

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

Ease of Use: Groundwater*FX* is a sophisticated flow and transport code that incorporates Monte Carlo simulation in a 3-D framework. A high level of skill and experience is required to use it effectively.

Several features of Groundwater*FX* make the software package cumbersome to use. These include the need for a formatted data file for importing location and concentration data, the need to have all units of measurement in meters (USGS and state plane coordinates systems are typically measured in feet), the need to have all graphic files imported as a single bitmap (which prohibits the use of multiple layers in visualizations and requires coordinates of the bitmap to be provided when the bitmap is used as a base map for visualization), the inability to edit graphic bitmap files, and the absence of on-line help. Visualization output is limited to bitmaps of screen captures that can be imported into other software for processing. Overcoming these limitations to perform an analysis requires more work on the part of the software operator.

Groundwater*FX* exports text and graphics to standard word processing software directly. Graphic outputs are generated as bitmaps, which can be imported into other software to generate .jpg, and .cdr graphic files. Groundwater*FX* generates data files from statistical analysis and concentration estimates in ASCII format, which can be read by most software.

Efficiency and Range of Applicability: Two problems were completed and documented with 12 person-days of effort. However, the technical team concluded that the analyses were, at best, a first pass through the

problem; the procedure would need to be repeated several times to improve the accuracy of the analysis. The incomplete analysis was due primarily to the combination of the sophisticated approach of the software—e.g., Monte Carlo simulation of 3-D flow and transport—and the time constraints of the demonstration. Substantially more time would be required to properly analyze the problem. Groundwater*FX* provides the flexibility to address problems tailored to site-specific conditions.

Operator Skill Base: To use Groundwater*FX* efficiently, the operator should be knowledgeable in probabilistic modeling of groundwater flow and contaminant transport. Knowledge pertaining to conducting sample optimization analysis and performing cost-benefit problems would be beneficial.

Training and Technical Support: An analyst with the prerequisite skill base can be using Groundwater*FX* after three days of training. A users' manual is available to assist in operation of the software. Technical support is available through e-mail and over the phone.

Cost: Decision*FX* plans to sell Groundwater*FX* for $1000 for a single license. It will be supplied at no cost to state and federal regulators.

Overall Evaluation: The main strength of Groundwater*FX* is its technical approach using Monte Carlo simulation of flow and transport processes to address variability and uncertainty in groundwater contamination problems. The use of groundwater simulation models should be a better approach to sample optimization designs than the use of purely statistical or geostatistical simulation models. However, the analysis performed by Groundwater*FX* did not provide an adequate match to the data on either test problem. Thus, it was not possible to determine whether Groundwater*FX* can accurately estimate the extent of groundwater contamination. The technical team also concluded that the many ease-of-use issues identified above make the software cumbersome to use. In particular, visualization capabilities are limited, and the ability to import graphic files only in bitmap format can lead to problems in the analysis.

The credibility of a computer analysis of environmental problems requires good data, reliable and appropriate software, adequate conceptualization of the site, and a technically defensible problem analysis. The software can address these components of a credible analysis. However, other components, such as proper conceptualization and use of code, depend on the analyst's skills. 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.

Gary J. Foley, Ph.D.
Director
National Exposure Research Laboratory
Office of Research and Development

David E. Reichle
ORNL Associate Laboratory Director
Life Sciences and Environmental Technologies