EPA/540/R-02/503
May 9, 2002

EarthSoft, Inc.
Environmental Quality Information System - EQuIS®

Innovative Technology Evaluation Report

National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

NOTICE

The U.S. Environmental Protection Agency (EPA) through its Office of Research and Development under the auspices of the Superfund Innovative Technology Evaluation (SITE) Program funded the research described here under Contract No. 68-C5-0036 to Science Applications International Corporation (SAIC). It has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

The EPA is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for reducing risks from pollution that threatens human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

ABSTRACT

This project consisted of an evaluation of the Environmental Quality Information System (EQuIS) software designed by EarthSoft, Inc. as an environmental data management and analysis platform for monitoring and remediation projects. In consultation with the EQuIS vendor, six primary modules were tested in this evaluation. These were: Chemistry, Geology, ArcView Geographic Information System (GIS) Interface, Data Verification Module (DVM), CrossTab Report Writer, and Electronic Laboratory Data Checker (ELDC). These modules were chosen for testing because they are the most commonly used. As a part of this evaluation, a demonstration of the technology was conducted by the SITE Program at Science Applications International Corporation's (SAIC) offices in Cincinnati and Columbus, Ohio and McLean, Virginia. The purpose of the demonstration was to determine whether the software performs the functions claimed by EarthSoft, Inc. and to assess the accuracy of the EQuIS output. In addition, demonstration results and other sources of cost information were used to develop detailed cost estimates for full-scale application of the technology.

The primary objectives for the EQuIS software evaluation were to:

1. Verify that all system functions were fully operational and had no significant programming errors. A significant programming error was defined as: the inability of a software function to execute properly (e.g., a fatal error) or a software function which produced an erroneous result (e.g., incorrect statistical calculation).

2. Determine the conformance of the EQuIS system's input and output functions to data exchange standards. Data import was tested by comparing values in the EQuIS database with input files to ensure data were not corrupted. Similarly, data export involved a comparison of EQuIS output files with values in various commercial-off-the-shelf (COTS) software to which EQuIS exports data.

The secondary objective of the system evaluation was to:

1. Estimate the cost of implementing, using, and maintaining the system for a "typical" hazardous waste site data management program.

In general, major system functions of the six modules tested performed as claimed by the vendor, with the exception of several functions of the DVM module which impacted the usefulness of this module. Other modules exhibited minor problems with system functionality, but none of these impacted the overall utility of the software. Most system functions were easy to use for anyone familiar with Microsoft Windows.

The software demonstrated the ability to adhere to data exchange standards while importing data from and exporting data to a variety of COTS software. Data exchange was not always straightforward and frequently required support from EarthSoft's help desk or an operator experienced with data exchange related to other databases.

The total cost for a large-scale, multi-user implementation of the software, based on experience at the New Jersey Department of Environmental Protection (NJDEP), was estimated to be $190,500. At the time of the demonstration, NJDEP had a 40-user license and had received over 16,000 submissions from hazardous waste sites throughout the state. This estimate assumed the equivalent of two full-time staff to manage the program and operate the software. Data entry was performed by the equivalent of three full-time student co-op students. This estimate included:

- site preparation
- equipment (software and hardware purchase/upgrades)
- startup and fixed costs
- first year operating costs (primarily labor)
- supplies
- maintenance

Total costs for a smaller-scale, multi-user application were estimated at $45,000 based on information from the Colorado Department of Health. This estimate assumed part time operation by two permanent employees and data entry by temporary employees.

The cost to implement this technology will be highly site specific depending upon the number of modules and users required, the current availability of computer equipment, the amount of data processed, and the familiarity of personnel with basic scientific software. The cost estimates do not include operating costs for successive years.

The reader is cautioned that, due to the rapid nature of software development, the versions of EQuIS modules utilized during this demonstration have since been superceded. The developer claims that many of the minor problems noted during this demonstration have been corrected or rendered moot because of changes to the software (see the Vendor Claims in Appendix B) . In some cases, these changes were reportedly ongoing or completed by the time this evaluation was completed. Due to scheduling and budgetary constraints, the SITE Program was unable to verify these claims. However, as part of its routine sales operations, EarthSoft provides software demonstrations. Such demonstrations can be used as an opportunity for potential customers to verify that the vendor has upgraded the system as claimed.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

ARAR	Applicable or Relevant and Appropriate Requirement
ATTIC	Alternative Treatment Technology Information Center
BDAT	Best Demonstrated Available Technology
CAA	Clean Air Act
CDPHE	Colorado Department of Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLU-IN	Cleanup Information
COTS	Commercial off-the-shelf
CWA	Clean Water Act
DVM	Data Validation Module
EDD	Electronic Data Deliverable
ELDC	Electronic Laboratory Data Checker
EM	electromagnetics
EPA	U. S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
EVS	Environmental Visualization System
FTE	full-time employee
GB	gigabyte
Ghz	gigahertz
GIS	Geographic Information System
GIU	graphic interface utility
GMS	Groundwater Modeling System
GPR	ground penetrating radar
HVAC	heating, ventilation, and air conditioning
ITER	Innovative Technology Evaluation Report
LDRs	Land Disposal Restrictions
MB	megabyte
MCL	maximum contaminant level
mHz	megahertz
NAAQS	National Ambient Air Quality Standards
NJ	New Jersey
NJDEP	New Jersey Department of Environmental Protection
NPDES	National Pollutant Discharge Elimination System
NRMRL	National Risk Management Research Laboratory
ORD	Office of Research and Development

ACRONYMS AND ABBREVIATIONS (Continued)

OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PC	personal computer
PCB	polychlorinated biphenyl
POTW	publicly-owned treatment works
PPE	personal protective equipment
ppm	parts per million
PTE	part-time employee
QAPP	Quality Assurance Project Plan
QA	quality assurance
QC	quality control
RAM	random access memory
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RPM	remedial project manager
SAIC	Science Applications International Corporation
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SITE	Superfund Innovative Technology Evaluation
SVOCs	semi-volatile organic compounds
TBC	to be considered
TER	Technology Evaluation Report
TSCA	Toxic Substances Control Act
UPS	universal power supply
VISITT	Vendor Information System for Innovative Treatment Technologies
VOCs	volatile organic compounds
WAM	Work Assignment Manager
2D	2-dimensional
3D	3-dimensional

ACKNOWLEDGMENTS

This Superfund Innovative Technology Evaluation (SITE) Program report was prepared under the direction and coordination of Richard Eilers, U.S. Environmental Protection Agency (EPA) National Risk Management Research Laboratory (NRMRL) Work Assignment Manager (WAM).

This report was prepared for EPA's SITE Program by the Energy and Environment Group of Science Applications International Corporation (SAIC) in Hackensack, New Jersey and Cincinnati, Ohio under Contract No.68-C5-0036. This report was written by Jim Rawe, the SAIC WAM, with assistance from Evelyn Meagher-Hartzell, Ravi Kanda, Steve McBride, and Bill Samuels of SAIC, the software evaluator(s). The author is grateful to Izak Maitin of the New Jersey Department of Environmental Protection (NJDEP) for providing data sets for use in this evaluation, and to Rita Schmon-Stasik and Joe Evans of SAIC who performed quality reviews.

EXECUTIVE SUMMARY

This document presents an evaluation of the Environmental Quality Information System (EQuIS) software and the ability of this data warehouse to import, review, utilize, and export chemical and geological data during a Superfund Innovative Technology Evaluation (SITE) demonstration conducted by the U.S. Environmental Protection Agency (EPA). This software receives chemical and geologic data via manual input or electronic data deliverables (EDDs). EDDs are checked for formatting errors utilizing the Electronic Lab Data Checker (ELDC). Data in the Chemistry module can receive a limited validation using the Data Verification Module (DVM). EQuIS links to Microsoft Office® allowing the user to generate custom formats for graphing and reporting. Custom reports can also be generated with the CrossTab Report Writer. EQuIS contains an ArcView Interface that allows data to be queried from both the Geology and Chemistry modules, and 3-dimensional (3D) visualization to be accessed. Finally, EQuIS data can be exported from Chemistry, Geology, or the ArcView Interface to a variety of commercial off-the-shelf (COTS) software for 3D visualization, production of well logs and geologic cross-sections, and other graphical representations.

During the SITE demonstration, data from the Martin Aaron site in Camden, New Jersey were utilized to evaluate the software capabilities. The primary objectives for the EQuIS software evaluation were to:

1. Verify that all system functions were fully operational and had no significant programming errors. A significant programming error was defined as: the inability of a software function to execute properly (e.g., a fatal error) or a software function which produced an erroneous result (e.g., incorrect statistical calculation). Major system functions in the Chemistry, Geology, ArcView Interface, DVM, CrossTab, and ELDC modules were executed to verify operability.

2. Determine the conformance of the EQuIS system's input and output functions to data exchange standards. EQuIS interfaces with several COTS packages. These include Groundwater Modeling System (GMS), Rockworks, LogPlot, Environmental Visualization System (EVS), Surfer, and ArcView. The data exchange between EQuIS Chemistry, Geology, and ArcView Interface was tested for interoperability with this list of select COTS products.

The secondary objective of the system evaluation was to:

1. Estimate the cost of implementing, using, and maintaining the system for a "typical" hazardous waste site data management program.

A Category II Quality Assurance Project Plan (QAPP) was developed for this project. No samples were collected nor were any analyses performed. Therefore, standard quality assurance (QA) objectives for data quality indicators (precision, accuracy, etc.) do not apply to this project. Project QA efforts centered on documentation of various tests performed to support conclusions regarding the evaluation of software functionality and data exchange. In addition, the QA review evaluated the completeness of planned testing and the impact of any QAPP changes. Overall, test results were well documented and complete. QAPP modifications, arising from efforts to limit redundancy, address project financial constraints, correct test plan errors, or remove obsolete or seldom used software functions, were fully described and justified in project documentation. Functions that were not evaluated were not considered crucial to the overall system functionality. These deviations from the QAPP did not impact overall project objectives.

The EQuIS demonstration results indicate that five of the six modules performed successfully. For these five modules, the majority of system functions performed as claimed by the vendor. Minor problems with system functionality were discovered, but none of these impacted the overall utility of the software. Most system functions were easy to use for anyone familiar with Microsoft Windows. The evaluation of the sixth module (DVM) indicated the successful performance of most major functions, but performance problems with the application of three of the functions tested. The Precision and Blank Ratio functions performed inconsistently. The Flag Order function did not perform as expected. These problems have a significant impact on the application of the software for data verification tasks.

The software also demonstrated the ability to adhere to data

exchange standards while exporting data to a variety of COTS software. Data exchange was not always straightforward and frequently required support from EarthSoft's help desk or an operator experienced with data exchange related to other databases. Table ES-1 presents the summary results for the two primary objectives as they relate to each of the modules.

Table ES-1. Summary Results for Primary Objectives

EQuIS Module	System Fully Functional/ No Significant Programming Errors	Conformance to Data Exchange Standards
ELDC	YES	NA
Chemistry	YES	YES
DVM	PARTIAL[1]	NA
Geology	YES	YES
ArcView Interface	YES	YES
CrossTab Report Writer	YES	NA

[1] = The system was partially functional; however, some key functions did not operate as claimed by the vendor. This had a significant impact on the application of the software for data verification tasks.
NA = Not applicable

The total cost for a large-scale, multi-user implementation of the software, based on experience at the NJDEP, was estimated to be $190,500. At the time of the demonstration, NJDEP had a 40-user license and had received over 16,000 submissions from hazardous waste sites throughout the state. This estimate assumed the equivalent of two full-time staff to manage and operate the software. Data entry was performed by the equivalent of three full-time student co-ops. This estimate included:

- site preparation
- equipment (software and hardware purchase/upgrades)
- startup and fixed costs
- first year operating costs (primarily labor)
- supplies
- maintenance

The total time to implement this technology, including setup and training, is estimated to be at least 1 year, although this number will vary greatly depending upon the resources allocated to system setup and the experience of the personnel involved.

Total costs for a smaller-scale, multi-user application were estimated at $45,000 based on information supplied by the Colorado Department of Health. This estimate assumed part time operation by two permanent employees and data entry by temporary employees.

The cost to implement this technology will be highly site-specific depending upon the number of modules and users required, the current availability of computer equipment, the amount of data processed, and the familiarity of personnel with basic scientific software. The cost estimates do not include operating costs for successive years.

The reader is cautioned that, due to the rapid nature of software development, the versions of most EQuIS modules utilized during this demonstration have since been superceded. The developer claims that many of the minor problems noted during this demonstration have been corrected or rendered moot because of changes to the software (see Appendix B - Vendor Claims). In some cases, these changes were reportedly ongoing or completed by the time this evaluation was completed. Due to scheduling and budgetary constraints, the SITE Program was unable to verify these claims. However, as part of its routine sales operations, EarthSoft provides software demonstrations. Such demonstrations can be used as an opportunity for potential customers to verify that the vendor has upgraded the system as claimed.

The EQuIS software was also evaluated based on the nine criteria used to evaluate technologies in the Superfund feasibility study process. Table ES-2 presents the results of this evaluation.

Table ES-2. Superfund Feasibility Study Evaluation Criteria for the EQuIS Software [a, b]

Evaluation Criterion	Performance
Overall Protection of Human Health and the Environment	• Does not directly impact this criterion; however, cost-effective data management and assurance of data quality may result in overall protection of human health and the environment.
Federal ARAR [c] Compliance	• Does not apply. However, the software may be a useful tool in managing data required to demonstrate compliance with ARARs. As of March 2002, EPA Regions 1 through 5 were using this software to assist in managing their hazardous waste site data.
Long-term Effectiveness and Permanence	• Does not directly impact this criterion; however, cost-effective data management and assurance of data quality may result in the long term effectiveness of monitoring programs associated with remediation projects.
Reduction of Toxicity, Mobility, and Volume through Treatment	• Does not apply.
Short-term Effectiveness	• Implementation of the EQuIS data management system may result in improvements in the short term effectiveness of monitoring programs and remediation efforts.
Implementability	• Software impementability appears to be straightforward and well-supported by the EarthSoft help desk. As with any complex software, at least one user with significant computer software experience will be required to manage the implementation of each application. In addition, initial and some ongoing user training will be necessary for all software users.
Cost [d]	• The cost of using this technology, for a multi-user license, is estimated at between $45,000 and $190,000 [e] including startup and fixed costs (e.g., insurance), software and hardware purchases (costs can vary significantly depending upon current availability at the user's facility), training, data entry (use of EDDs for current data will reduce this cost, although historical data will typically require manual entry), supplies, and system operation and maintenance (only first year operating costs are included). The cost for a single-user aplication (e.g., small environmental consultant), with a license for the six EQuIS applications evaluated during this demonstration, would be approximately $11,000 for the software. Assuming that the consultant had the necessary hardware, the only additional costs would be vendor-supplied training costs, labor for implementation of the system, and any applicable overhead costs.
State Acceptance	• The willingness of vendor to perform software demonstrations should increase acceptability. Currently, the EQuIS software is being utilized by 10 [f] states to manage environmental data for hazardous waste cleanup sites.
Community Acceptance	• Use of the software to provide graphical representations of site data should assist site managers in raising community awareness and acceptance regarding selected remediation approaches.

a Based on the results of the SITE demonstration using data from the Martin Aaron site in New Jersey.
b Information contained in this table should not be used without examining all other parts of this evaluation report.
c ARARs = Applicable or Relevant and Appropriate Requirements
d Actual cost of the technology is site-specific and dependent on the characteristics of the site data and upon the qualifications of the personnel implementing the technology.
e These cost estimates are based on information supplied by two states: Colorado and New Jersey. Colorado has a license for five users (additional details on the use of the software are provided in Section 3.4). New Jersey has a 40-user license and has received over 16,000 submissions from hazardous waste sites throughout the state (additional details are also supplied in Section 3.4).
f As of March 2002. These states are: Colorado HMWMD, Delaware NREC, Florida DEP, Mississippi DEQ, Nebraska DEQ, Nevada DEP, New Jersey DEP, New York DEC, Pennsylvania DEP, Rhode Island DEM, and West Virginia DEP.

SECTION 1

INTRODUCTION

An evaluation of the Environmental Quality Information System (EQuIS) software system was conducted by the U. S. Environmental Protection Agency (EPA) National Risk Management Research Laboratory (NRMRL) under the Superfund Innovative Technology Evaluation (SITE) Program. EarthSoft, Inc., the developer of the EQuIS data management system, was responsible for providing the software and training of evaluation personnel during the demonstration. Science Applications International Corporation (SAIC) was the SITE Program contractor for the implementation of this demonstration and conducted the evaluation of the EQuIS software and report writing activities in support of this effort.

This introduction provides an overview of (1) the SITE Program, (2) the purpose of this Innovative Technology Evaluation Report (ITER), (3) the EQuIS software, (4) the data set utilized for the evaluation, (5) demonstration activities, (6) demonstration results, and (7) additional sources of information on the SITE Program and the demonstration. Section 2 presents an applications analysis for the technology. Section 3 discusses the results of an economic analysis of the technology. Section 4 presents the results of the demonstration. Section 5 discusses requirements to be considered when using the technology. Section 6 discusses the status of the technology. Appendix A contains case studies. Appendix B contains vendor claims for the technology.

1.1 BRIEF DESCRIPTION OF PROGRAM AND REPORTS

In 1986, the EPA Office of Solid Waste and Emergency Response (OSWER) and the Office of Research and Development (ORD) established the SITE Program to promote the development and use of innovative technologies to clean up Superfund sites across the country. Now in its fifteenth year, the SITE Program is helping to provide the treatment technologies necessary to implement new Federal and State cleanup standards aimed at permanent remedies rather than quick fixes. The SITE Program is composed of four major elements: the Demonstration Program, the Emerging Technology Program, the Measurement and Monitoring Technologies Program, and the Technology Transfer Program.

The major focus has been on the Demonstration Program, which is designed to provide engineering and cost data for selected technologies. To date, the Demonstration Program projects have not included funding for technology developers. EPA and developers participating in the program share the cost of the demonstration. Developers are responsible for demonstrating their innovative systems at chosen sites, usually Superfund sites. EPA is responsible for sampling, analyzing, and evaluating all test results. The final product of each demonstration is an assessment of the technology's performance, reliability, and cost. This information is used in conjunction with other data to select the most appropriate technologies for the cleanup of Superfund sites.

Developers of innovative technologies apply to the Demonstration Program by responding to EPA's annual solicitation. EPA also accepts proposals any time a developer has a Superfund waste treatment project scheduled. To qualify for the program, a new technology must be available as a pilot- or full-scale system and offer some advantage over existing technologies. Mobile technologies are of particular interest to EPA. This is the second SITE demonstration of a data management system.

Once EPA has accepted a proposal, EPA and the developer work with the EPA regional offices and State agencies to identify a site containing waste suitable for testing the capabilities of the technology. EPA prepares a detailed sampling and analysis plan designed to evaluate the technology thoroughly and to ensure that the resulting data are reliable. The duration of a demonstration varies from a few days to several years, depending on the length of time and quantity of waste needed to assess the technology.

The second element of the SITE Program is the Emerging Technology Program, which fosters the further investigation and development of treatment technologies that are still at the laboratory scale. Successful validation of these technologies can lead to the development of a system ready for field demonstration and participation in the Demonstration Program.

The third component of the SITE Program, the Measurement

and Monitoring Technologies Program, provides assistance in the development and demonstration of innovative technologies to improve characterization of Superfund sites.

The fourth component of the SITE Program is the Technology Transfer Program, which reports and distributes the results of both Demonstration Program and Emerging Technology Program studies through ITERs and abbreviated bulletins. A Technology Evaluation Report (TER) was also developed for the EQuIS SITE demonstration. The TER provides greater detail on the demonstration and presents a complete package of measurement results. The TER is on file at EPA NRMRL.

1.2 PURPOSE OF THE ITER

The ITER provides information on the EQuIS software and includes a comprehensive description of the demonstration and its results. The ITER is intended for use by EPA remedial project managers (RPMs) and on-scene coordinators, contractors, and others involved in the remediation decision-making process and in the implementation of specific remedial actions. The ITER is designed to aid decision makers in determining whether specific technologies warrant further consideration as applicable options in particular cleanup operations. To encourage the general use of demonstrated technologies, EPA provides information on the applicability of each technology to specific sites and wastes. The ITER includes information on cost and site-specific characteristics. It also discusses advantages, disadvantages, and limitations of the technology.

Each SITE demonstration evaluates the performance of a technology in treating a specific waste, or in this case, in managing environmental data. The environmental data at other sites may differ from those examined during this demonstration. Therefore, successful demonstration of a technology for these site data does not necessarily ensure that it will be applicable at other sites. Results from the demonstration may require extrapolation to estimate the operating ranges in which the technology will perform satisfactorily. Only limited conclusions can be drawn from a single demonstration.

1.3 TECHNOLOGY DESCRIPTION

The EQuIS software is designed as an advanced environmental data management and analysis platform for monitoring and remediation projects. According to EarthSoft's web page at the time of the demonstration, the EQuIS system consists of 7 applications, 5 modules, and 12 interfaces which link with commercial off-the-shelf (COTS) packages that perform a variety of graphical and 3-D visualization functions. In consultation with the EQuIS vendor, a total of six primary applications, modules, and interfaces were tested in this evaluation. These were: Chemistry, Geology, ArcView Geographic Information System (GIS) Interface, Data Verification Module (DVM), CrossTab Report Writer, and Electronic Laboratory Data Checker (ELDC). In order to simplify the discussion, these six software applications, modules, and interfaces are all referred to as modules in this text.

These modules were chosen for testing because they are the most commonly used. A brief description of each software module, and the functions that the vendor claims the module performs, is presented below. A schematic diagram of the system that was evaluated is presented in Figure 1. For the EQuIS modules tested, the entire project database is generated as a Microsoft Access database which can be queried using standard MS-Access or SQL commands. The vendor states that an Oracle database can be substituted for the MS-Access database without affecting module functionality.

EQuIS Chemistry (version 3.3) offers a user interface and Microsoft Access relational database that can be used to organize and manage sampling information and chemical analytical data generated in the field or by commercial laboratories. Sample information, test data, and results can be input manually or imported into the EQuIS Chemistry database. From the database, queries can be generated and data can be interfaced with other analytical software for visualization, graphing, and reporting.

EQuIS Geology (version 2.3) is a companion module that manages geological and geotechnical information. Soil boring and sample data can be entered manually or imported directly into a project database. Site information is categorized by location. Data may be exported for reporting, 3-dimensional (3D) visualization, contouring, borehole logging, solid modeling, or groundwater flow modeling. It should be noted that version 2.3 was a beta version; the vendor opted to have a beta version with better capabilities evaluated, knowing that an increased likelihood of system errors was likely.

The **EQuIS ArcView GIS Interface (version 1.6)** has features that allow users to query and view EQuIS Chemistry and Geology data inside of the ArcView environment (see next page for a description of the ArcView Software). This GIS Interface consists of linked tables, the EQuIS Location View, and a menu system that supports a number of activities. The module tested was based on ArcView version 3.2. As of March 2002, EarthSoft's EQuIS for ArcGIS, built upon ESRI's ArcGIS 8.1 platform, had been released. However, due to schedule and financial constraints, this module could not be evaluated as part of the SITE demonstration.

The **ELDC (version 2.6)** allows users to check electronic deliv-

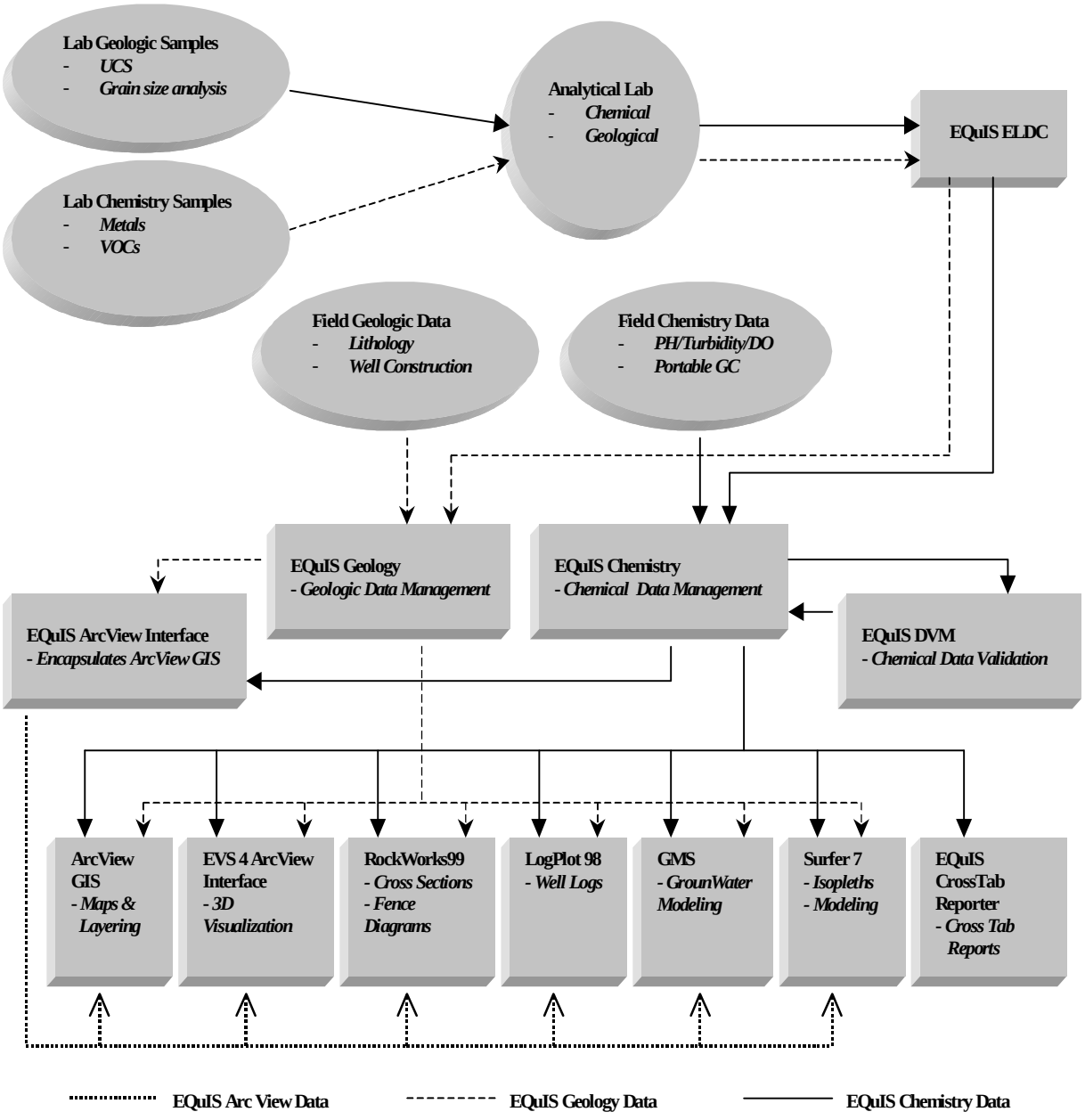


Figure 1-1. Flow diagram for data through the EQuIS software

erables before they are incorporated into a database. It is designed to identify electronic data deliverable (EDD) problems before data are used. The ELDC checks data against a defined EDD format; no computations or data validation are performed.

The **EQuIS DVM (version 1.2)** provides data review and partial validation in accordance with selected EPA Guidelines (e.g., CLP program) and analytical program requirements from other agencies. It should be noted that in late 2000, subsequent to initiation of the demonstration, this module was replaced by EarthSoft with the Data Quality Management (DQM) module. Due to schedule and financial constraints, the DQM could not be evaluated as part of the SITE demonstration. (See the Vendor Claims in Appendix B for the vendor's rationale for replacing the DQM).

The **EQuIS CrossTab Report Writer (version 1.6)** is a tool that can be used in conjunction with the EQuIS Chemistry module to design and create various complex cross tab reports without having to re-key or cut and paste data.

In addition to the six EQuIS modules described above, the interface to six commercial-off the shelf (COTS) packages that are integrated with EQuIS, were also evaluated. These packages were:

- ArcView (version 3.2);
- GMS (Ground Water Modeling System);
- Surfer (Contouring, Gridding, and Surface Mapping Package);
- LogPLot98 (well log data plotting);
- Rockworks99 (geologic mapping tools); and
- EVS (Environmental Visualization System).

ArcView is a desktop mapping and analysis tool that allows users to visualize, explore, query, and analyze data spatially. ArcView works with geo-spatial data, both vector and raster formats. The system can perform both spatial and tabular queries. It can be customized to change the graphic interface utility (GIU) automate a series of functions, and add new functions.

The Department of Defense Groundwater Modeling System (GMS) integrates and simplifies the process of groundwater flow and transport modeling by integrating a number of tools. GMS supports the following models: MODFLOW, MODPATH, MT3D, FEMWATER, SEEP2D, and RT3D.

Surfer is a contouring and 3D surface plotting program that runs under Microsoft Windows and has extensive variogram modeling capabilities. Surfer converts data into contour, wireframe, vector, image, shaded relief, and post maps. Maps can be customized to produce user-specific output.

The LogPlot98 program is the newest version of the log plotting software published by RockWare, Inc. It reads user-created data files that contain descriptive, quantitative, and other data, and plots these data as graphic strip logs. The format or "blueprint" of the logs (the components and their locations) is designed within the LogDesign program, included with LogPlot98.

The RockWorks99 program is a Windows application that reads a variety of data types (stratigraphic formation elevations, XYZ data, lineations, etc.) from a built-in spreadsheet-style data window. It offers graphic output of a variety of maps (point, contour, color-filled, and 3D surface maps), strip logs, hole-to-hole cross sections, fence diagrams, 3D stratigraphic diagrams, 3D solid model diagrams, general data plots, rose and stereonet diagrams, and more. RockWorks also offers isopach, volume, and trend surface residual computations that are presented as reports. Advanced 2-dimensional (2D) and 3D volumetrics include thickness, overburden, and data filters.

EVS has been designed to provide streamlined reproducible methods to complete visualization and analyses. The modular structure of the program allows the user to graphically construct his/her own visualization programs, which can be saved as applications for subsequent use with the same or different data sets.

1.4 DESCRIPTION OF THE DEMONSTRATION DATA

In order to properly evaluate the EQuIS software, a comprehensive data set was required to ensure that all major system functions were utilized and evaluated. The data set from the Martin Aaron site in New Jersey was selected because it was a comprehensive data set that was already available in an electronic format compatible with EQuIS. NJDEP had previously input data into its data management system and prepared an EDD. This file was then forwarded to EarthSoft for review and correction of data entry and data formatting errors. The corrected file was then supplied to SAIC for use in evaluation of the EQuIS software.

Available site data consisted of information presented in the Draft Final Remedial Investigation (RI) Report dated February 1999. Summary chemical analytical data were provided in tables. These data included positive analytical results for VOCs, SVOCs, metals, pesticides/polychlorinated biphenyls (PCBs), and dioxins/furans in surface and subsurface soils as well as both shallow and deep groundwater wells. Additional information, including well boring logs and water level measurement data, were provided in the appendices to this RI.

1.5 DESCRIPTION OF DEMONSTRATION ACTIVITIES

A kickoff meeting was held on January 11, 2000 to verify the vendor claims, to define the demonstration project objectives,

and to discuss a software training session to be provided by the vendor. The preliminary project objectives were re-defined based upon input provided by EarthSoft. These initial project objectives were used by EPA's contractor to prepare the Quality Assurance Project Plan (QAPP) after the software training was completed.

EarthSoft customized its standard training module based upon the qualifications of SAIC's evaluators. In late February 2000, training was provided to four evaluators, SAIC's Work Assignment Manager, and one other staff member assisting with the project. EarthSoft supplied a training manual and demonstration versions of its software and that of key COTS products. EarthSoft staff demonstrated important functions of all software to be tested while SAIC staff utilized the software to mimic the actions of the trainer.

Subsequent to completion of software training, SAIC staff intermittently utilized the software to gain further expertise in software capabilities. Based upon knowledge of the software functions, SAIC developed a QAPP which contained the test plan (a series of matrices that identified key functions and their purpose or capabilities, summarized a procedure to test the identified function, presented the rationale for determining whether the test was a success or failure, and provided a template for entering test results in the electronic file). During the QAPP development process, the project objectives were modified based upon evaluator observations and input from the vendor. The draft QAPP was first submitted to the vendor for review and comment, and then to the EPA QA Program. Comments were incorporated, and the QAPP was finalized on November 3, 2000.

Over the next six months, SAIC evaluated each of the modules designated for testing. Results were recorded in the electronic matrices; additional documentation was assembled in two forms: 1) electronic copies of input screens and results (output tables and reports, error message screens, and other documentation of results), and 2)handwritten notes on procedures (including any modifications that were required) and results that were recorded in bound notebooks with numbered pages.

At the beginning of the evaluation of each module, all results were forwarded to SAIC's project QA Coordinator for a review. This review evaluated completeness of documentation, whether the results adequately addressed project objectives as stated in the test matrix, and consistency among the four evaluators. The QA Coordinator also reviewed any changes in evaluation procedures to determine whether there was an impact on the ability to evaluate project objectives. After this initial review, the QA Coordinator randomly reviewed a percentage (approximately 5 to 10 percent) of the evaluation results to ensure completeness and consistency. The evaluation was completed in early April 2001.

1.6 SUMMARY OF DEMONSTRATION RESULTS

The results obtained in support of the primary objective are:

- In general, the EQuIS ELDC, Chemistry, Geology, ArcView Interface, and CrossTab Report Writer system functions were fully operational and had no major programming errors. For these five modules, major system functions were successfully tested. A few functions did not operate as expected, but these functions were either obsolete (had been removed or were planned for removal in future software modules) or were judged by the evaluators to be minor functions that did not impact the overall usability of the software. The DVM module was only partially functional; several key functions did not perform as claimed by the vendor. Most system functions for all six modules were easy to use for anyone familiar with Microsoft Windows.

- Based upon the limited testing planned under this demonstration, the EQuIS Chemistry, Geology, and ArcView Interface modules were determined to be in conformance with data exchange standards, as judged by the ability to import data and export data to other commercial software.

The results obtained in support of the secondary objectives are:

- The total cost for a large-scale, multi-user implementation of the software, based on experience at the New Jersey Department of Environmental Protection (NJDEP), was estimated to be $190,500. At the time of the SITE demonstration, NJDEP had a 40-user license and had received over 16,000 submissions from hazardous waste sites throughout the state. This estimate assumed the equivalent of two full-time staff to manage and operate the software. Data entry was performed by the equivalent of three full-time student co-ops. This estimate included site preparation, equipment (software and hardware purchase/upgrades), startup and fixed costs, first year operating costs (primarily labor), supplies, and maintenance. Total costs for a smaller-scale, multi-user application were estimated at $45,000 based on information from the Colorado Department of Health. This estimate assumed part time operation by two permanent employees and data entry by temporary employees.

The cost estimates do not include operating costs for successive years. The cost to implement this technology will be highly site specific depending upon the number of modules and users

required, the current availability of computer equipment, the amount of data processed, and the familiarity of personnel with basic scientific software. For example, the cost of a single-user application (e.g., a small environmental consulting firm) with a single license for each of the six EQuIS applications evaluated during this demonstration, would be approximately $11,000 for software. Assuming that the consultant had the necessary hardware, the only additional costs would be vendor-supplied training costs, labor for implementation of the system, and any applicable overhead costs.

The reader is cautioned that, due to the rapid nature of software development, the versions of EQuIS modules utilized during this demonstration have since been superceded. The developer claims that many of the minor problems noted during this demonstration have been corrected or rendered moot because of changes to the software. In some cases, these changes were reportedly ongoing or completed by the time this evaluation was completed (see Appendix B, Vendor Claims, for additional information). Due to scheduling and budgetary constraints, the SITE Program was unable to verify these claims. However, as part of its routine sales operations, EarthSoft provides software demonstrations. Such demonstrations can be used as an opportunity for potential customers to verify that the vendor has upgraded the system as claimed.

- The Alternative Treatment Technology Information Center (ATTIC) is a comprehensive, automated information retrieval system that integrates data on hazardous waste treatment technologies into a centralized, searchable source. This data base provides summarized information on innovative treatment technologies. The modem access number is (513) 569-7610. Voice assistance is available at (513) 569-7272. The TelNet number is CINBBS.CIN.EPA.GOV.

- Version 5.0 of the Vendor Information System for Innovative Treatment Technologies (VISITT) data base contains information on 346 technologies offered by 210 developers. VISITT can be down-loaded from www.prcemi.com/visitt. Technical assistance or a disk copy of VISITT can be obtained by calling (800) 245-4505.

- The OSWER Cleanup Information (CLU-IN) electronic bulletin board contains information on the status of SITE technology demonstrations. The system operator can be reached at (301) 589-8268. Modem access is available at (301) 589-8366 or www.clu-in.com.

Technical reports can be obtained by contacting EPA-NRMRL's Technology Transfer Branch, 26 West Martin Luther King Drive, Cincinnati, Ohio 45268 at (513) 569-7562.

1.7 KEY CONTACTS

Further information concerning the EQuIS software described in this report can be obtained by contacting the individuals listed below:

1. EPA Project Manager for the SITE Demonstration:
   Richard Eilers
   U.S. Environmental Protection Agency
   National Risk Management Research Laboratory
   26 West Martin Luther King Drive
   Cincinnati, Ohio 45268
   Phone: (513) 569-7809
   Fax: (513) 569-7676
   E-mail: eilers.richard@epa.gov

2. Technology Developer Contact:
   Mitch Beard, President
   EarthSoft, Inc.
   Cantonment, FL
   Phone: (800) 649-58855
   E-mail: mbeard@EarthSoft.com

Information on the SITE Program is also available through the following on-line information clearinghouses:

SECTION 2

TECHNOLOGY APPLICATIONS ANALYSIS

This section provides information on the ability of the EQuIS software to meet regulatory and operational requirements associated with the remediation of Superfund sites. Subsection 2.1 presents a discussion of the considerations associated with seven major regulatory programs. The operability, applicability, key features, availability, site support requirements, and limitations of the system are discussed in Subsections 2.2 through 2.8.

2.1 REGULATORY CONSIDERATIONS

For typical treatment technology evaluations, this subsection discusses seven major regulatory programs, starting with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). CERCLA requires compliance with all applicable or relevant and appropriate requirements (ARARs), providing the entrance point for the other regulations discussed in this subsection. Other regulatory programs include CERCLA, and the Resource Conservation and Recovery Act (RCRA), Clean Air Act (CAA), Safe Drinking Water Act (SDWA), Clean Water Act (CWA), Toxic Substances Control Act (TSCA), and Occupational Safety and Health Act (OSHA). Each statute can have corresponding State or local laws that are more stringent or broader in scope than analogous Federal regulations.

However, the EQuIS software does not treat hazardous materials; rather it is used to manage data from liquid and solid-phase materials. Therefore, EQuIS is only applicable for data management and reporting requirements under these statutes.

2.2 OPERABILITY OF THE SYSTEM

The EQuIS software is described in detail in Subsection 1.3. The core component of the system is the environmental chemistry data management system. It is written in Visual Basic and uses the Microsoft Access database engine. EQuIS Chemistry offers a user interface and relational database warehouse to organize chemical field and lab data. Data can be input manually or imported directly into EQuIS Chemistry's database. Once data have been entered, queries can be generated and data interfaced with industry-standard products for visualization, graphing, and reporting. An interface with ArcView is also available.

EQuIS Geology offers a relational database warehouse to organize geologic, geotechnical, and hydrogeologic data. Soil boring and sample data can be entered manually or imported directly into the project database. Once data have been entered, queries can be generated and data interfaced with several different industry-standard products for visualization, modeling, boring logs, cross sections, fence diagrams, and reporting. EQuIS Geology currently interfaces with the following systems:

- GMS - Department of Defense (developed by Brigham Young University)*
- LogPlot98 - Rockware*
- Rockworks98 - Rockware*
- Surfer - Golden Software*
- Groundwater Vistas - Environmental Simulations
- EVS - C-Tech*
- gINT
- ArcView GIS - ESRI*

* - these were evaluated in this demonstration

Site information is categorized by location. At each location, well construction and transient water level measurement information may be defined. Additionally, stratigraphy and continuous vertical trace sample data such as CPT data may be stored and modified. Point parameters such as porosity, hydraulic conductivity, and organic carbon content may be specified for discrete samples at any number of vertical locations. All data may then be exported for visualization and analysis, such as contouring, borehole logging, solid modeling, or groundwater flow modeling.

The EQuIS ArcView Project Interface permits users to view EQuIS project data in the ArcView environment. It also allows users to query and view EQuIS Chemistry and Geology data inside of ArcView. The Interface consists of linked tables, the

EQuIS Location View, and a menu system that supports a number of activities.

The EQuIS ELDC is designed to assist in checking EDD (Electronic Data Deliverable) files to ensure smooth importing into the EQuIS Chemistry module. It can be useful for labs that are submitting deliverables to users, as well as to the users who are importing the files. ELDC can check for common data loading problems including duplicate data, data of the wrong type, and required data that are missing. It can also check selected fields against a predefined list of allowed values. ELDC performs most of the same checks as EQuIS Chemistry does in its Import function. ELDC includes on-line help, including context sensitive help.

The EQuIS DVM provides data review and validation in accordance with quantifiable sections of the EPA Functional Guidelines and CLP programs, as well as other analytical program requirements from other agencies. Data in the EQuIS Chemistry module are reviewed and MS Word or HTML reports for contamination blanks, precision, accuracy, detection limits, and surrogate recoveries are produced. Flags are written back to the Chemistry data management system. All logic and rules are documented and editable. (Note: as mentioned in Section 1, the DVM has been replace with a new module, the DQM.)

The EQuIS CrossTab Report Writer is a tool that can be used in conjunction with EQuIS Chemistry. The interface allows users to create complex cross tab reports - using data from existing EQuIS Chemistry project databases. The EQuIS CrossTab Report Writer allows users to design various types of cross tab reports using pull-down menus to select column and row content.

2.3 TECHNOLOGY APPLICABILITY

The applicability of the technology is fairly well established. According to the developer, more than 2,000 units (one or more software modules each) have been purchased since its first release in 1996. As of the publication of this document, the vendor asserts that the EQuIS software is being utilized by EPA Regions 1 through 5; the states of Colorado, Delaware, Florida, Mississippi, Nebraska, Nevada, New Jersey, New York; Pennsylvania, Rhode Island, and West Virginia. In addition, the software is reportedly being applied by numerous environmental consulting firms throughout the U.S. and several DoD and DOE facilities, including Argonne, Rocky Flats, several Naval Shipyards, Warner Robbins AFB, several Port Authorities, and Army Corps of Engineers Districts in Sacramento and Korea.

Case studies in Appendix A summarize the results of the use of the technology at different sites. Appendix B contains vendor claims for the technology. These case studies and many of the vendor claims have not been independently evaluated by EPA-NRMRL or SAIC.

2.4 KEY FEATURES OF THE EQuIS SOFTWARE

EarthSoft's EQuIS software is an environmental data management platform written in Visual Basic. It is designed to warehouse and manage chemical, geologic, geotechnical, and hydrogeological data, including field sampling data and field and laboratory analytical results. Other important features of the software include:

- Uses Microsoft Access as a relational database to organize and query data
- Provides a limited data verification and validation function to document data quality
- Offers a user interface to import and export data for visualization, graphing, and reporting through a number of existing commercial software products
- Allows users to view and manipulate data in the ArcView environment

Specific functions of various modules were described in Section 2.2.

2.5 AVAILABILITY OF THE TECHNOLOGY

The EQuIS software is readily available and can be obtained directly from EarthSoft's web site. A number of environmental consulting firms also provide EQuIS software, as well as support for the installation, customization, and utilization of the software, under agreements with EarthSoft. It should be noted that EarthSoft no longer supports the DVM. It has been re-written as the DQM.

2.6 EASE OF USE

In general, the software is easy to use. Most system functions were easy to use for anyone familiar with Microsoft Windows. The ease of use of the functions tested was facilitated by the graphical user interface. Most operations were point and click. Many operations had confirmation messages, informing the user that a particular operation was about to take place and providing the option to not proceed on with the operation. Some were helpful and some were not. Additional information regarding the ease of use of specific modules and functions is reported in Section 4.3.

2.7 SITE SUPPORT REQUIREMENTS

No significant additional site support requirements will be needed for the typical application of EQuIS by a consulting firm or government agency. Complex applications and efforts to integrate existing data may require additional commitment of resources or outside expertise to implement.

2.8 LIMITATIONS OF THE TECHNOLOGY

The EQuIS software, like most comprehensive data management systems, requires personnel familiar with, or who can be trained in, the use of MicroSoft Windows or similar menu-based software. In addition, anywhere from three full days to several weeks of training will be required (depending on user experience and aptitude, as well as the complexity of the application) to adequately implement this software. Again, based on the experience of the evaluators, this is consistent with other complex environmental data management software.

Some important data verification and validation procedures are not addressed by the DVM version tested. Among these are chain of custody reviews, temperature of samples as received by the laboratory, instrument performance data, internal standards, external standards, retention time windows, interference results, serial dilutions, appropriate selection of constituent data from subsequent dilutions, and selection of best results for samples re-extracted and /or re-analyzed due to QC performance problems. These items would still have to be addressed by a person performing a manual review of the project data. Limitations of this and other specific software functions are described in Section 4.3.

Program or site-specific trials are recommended to determine the effectiveness of software for each application.

2.9 REFERENCES

1. CERCLA/Superfund Orientation Manual. U.S. Environmental Protection Agency. EPA/542/R-92/005, October 1992.

2. Superfund LDR Guide #5 Determining When Land Disposal Restrictions (LDRs) are Applicable to CERCLA Response Actions. U.S. Environmental Protection Agency. OSWER Directive 9347.3-OSFS, July 1989.

3. Guidance on Remedial Actions for Superfund Sites with PCB Contamination. U.S. Environmental Protection Agency. EPA/540/G-90/007, August 1990.

SECTION 3

ECONOMIC ANALYSIS

3.1 INTRODUCTION

The primary purpose of this economic analysis is to estimate the costs for using the EQuIS software on a commercial scale for advanced environmental data management and analysis regarding monitoring and remediation projects.

3.2 BASIS OF ECONOMIC ANALYSIS

The cost analysis was prepared by breaking down the overall cost into a subset of the 12 standard SITE cost categories. The cost categories and the areas that each of them generally comprise are listed in Table 3-1. The basis for the economic analysis was derived from two sources: the New Jersey Department of Environmental Protection and the Colorado Department of Health and Environment (CDPHE). These two sources reflect, respectively, a large- and small-scale, multi-user implementation of EQuIS with associated cost estimates at the high and low end. Because some of the cost categories are very site specific, costs for these categories should be used with caution. Values presented in this section have been rounded to a realistic number of significant figures.

Costs for a single-user license for the six EQuIS modules evaluated during the SITE demonstration would be approximately $11,000 for software. Assuming that the consultant had the necessary hardware, the only additional costs would be vendor-supplied training costs, labor for implementation of the system, and any applicable overhead costs.

3.3 ISSUES AND ASSUMPTIONS

This subsection summarizes the issues and assumptions of the economic analysis for this study. Subsections 3.3.1 through 3.3.12 describe assumptions that were made in determining project costs for the 12 cost categories. Because this evaluation was performed on a software product, several cost categories typically used for a physical or chemical process were deemed not applicable to the economic analysis for an environmental

Table 3-1. Twelve Cost Categories for the EQuIS SITE Demonstration

1. Site Preparation	7. Consumables
2. Permitting and Regulatory • Not applicable	8. Effluent Treatment/Disposal • Not applicable
3. Equipment • Computer hardware and software	9. Residuals • Not applicable
4. Startup and Fixed Costs • Working capital • Insurance • Contingencies	10. Analytical services • Not applicable
5. Operating Costs • Labor • Management costs • QA labor	11. Modifications, repair, and replacement • System maintenance • Software upgrades • Hardware upgrades
6. Supplies • Operating supplies	12. Site demobilization • Not applicable

information management system. These included: (3.3.2) permitting and regulatory costs; (3.3.8) effluent treatment and disposal; (3.3.9) residuals and waste shipping, handling and transport; (3.3.10) analytical services; and (3.3.12) site demobilization. The remaining cost categories are discussed in detail below.

Additional issues and assumptions regarding data management costs are described below. These were derived from a private consulting firm's experience with EQuIS as well as the experience of the CDPHE.

According to one consulting firm's experience with EQuIS, with respect to data management costs, there is some time involved with establishing business practices to take advantage of the software defining standards, data flow, etc. That can be brief or very lengthy depending on the organization or use. Once that is determined, for new data with perfect lab EDDs and using the checking tools it should take no longer than 5 to 15 minutes to load a data package.

This firm prefers to manually enter the chain-of-custody information. They report the use of DVM and ELDC significantly reduces (50 – 75 percent) the amount of time spent doing data quality assessments from the old-fashioned way.

For loading historical data, it is assumed that the data are either not in digital form or are in a digital form that will require significant reformatting before data migration. Conversion can take quite a bit of time unless it's already in a relational database format (anywhere from 2 to 20 hours to do the conversion). Most data entry/conversion time is related to finding information not readily available (What is the sample date? Which location does it belong to? What's the CAS number). As a rule though, it takes about one-half of an hour per sample. It should be noted that these same issues will apply to any other electronic database, not only EQuIS.

The division in CDPHE using EQuIS consists of 120 people regulating Superfund, RCRA, Solid Waste, Voluntary Cleanup, and State CERCLA. CDPHE implemented EQuIS two years ago with one individual devoted mainly to the database administration. This individual is a geologist and Visual Basic programmer. CDPHE has implemented EQuIS on a site-by-site basis. Historic data are loaded on a site-by-site basis by student interns at $11/hour from local universities who have advanced knowledge of geology, chemistry, or GIS to enter the data.

CDPHE has not fully implemented an Electronic Data Deliverable throughout the Division's regulated sites, but have gotten a full EDD submittal implemented from several of their main labs. They are implementing EQuIS on a distributed basis where the project managers/scientists are responsible for learning the use of the system and the evaluation of their own data. They have focused on a power user approach, training first those with the proven aptitude and enthusiasm and with projects ready to utilize the system.

3.3.1 Site Preparation Costs

Since EQuIS is a computer-based environmental information management system, the potential site preparation costs associated with EQuIS could range from simply setting up a single computer in an office to run EQuIS to the establishment of a computer facility to house servers, data storage devices, workstations, network equipment, and peripherals (printers, plotters). In the simple case, there may be no preparation cost at all since the system could be easily set up in an existing office with no special requirements. In the case of establishing a new computer facility, the costs of setting up a computer room would involve: 1) proper environmental controls (i.e., temperature and humidity), 2) establishment of telecommunication infrastructure (voice and data lines), 3) purchase of furniture for setting up the computers and peripherals, and 4) purchase of universal power supply (UPS) equipment. According to McKinsey and Company, Inc., twenty percent of the costs for hardware is for retrofitting -- electrical and heating, ventilation, and air conditioning (HVAC) upgrades.[1]

3.3.2 Permitting and Regulatory Costs

The costs associated with permitting and complying with environmental regulations are not applicable to this SITE study. No permits are required to set up or run EQuIS.

3.3.3 Equipment

The equipment costs associated with EQuIS are broken down into two major components: software and hardware. Software costs are separated into two categories: 1) EQuIS products and 2) third-party products that interface with EQuIS. Presented below are exhibits that summarize the costs of these two categories of software. This is followed by a discussion of hardware costs.

3.3.3.1 EQuIS Products

A series of exhibits are presented below; these summarize the costs of the EQuIS applications, modules, and interfaces. EQuIS applications operate independently of other software, although they can be integrated with other software. Modules operate on EQuIS data to generate certain output which can be imported by, or functions linked to, other software packages. Interfaces provide a direct link to other software packages and utilize EQuIS data within these software packages.

These costs were obtained from the EarthSoft website (http://www.EarthSoft.com/products/prices.php3) as of

February 2001.[2] The costs shown in these figures are for a single user license. EarthSoft provides discounted costs with multi-user purchases.

3.3.3.2 EQuIS Applications

Figure 3-1 summarizes the costs associated with these EQuIS applications: Chemistry, Geology, ELDC, Hydrology, DMR, DUMPStat, and Carstat. For this project, only the Chemistry, Geology, and ELDC modules were evaluated.

3.3.3.3 EQuIS Modules

Figure 3-2 shows the costs for the following EQuIS modules: ArcView Interface, DVM, SiteMaster, CrossTab Report Writer, and Completeness Checker. For this project, only the ArcView Interface, DVM and CrossTab Report Writer were evaluated.

3.3.3.4 EQuIS Interfaces

Figures 3-3 and 3-4 below show the costs of EQuIS interfaces to a variety of third-party software packages including: GMS, EVS, STATISICA, RockWorks, DUMPStat, Brio, DMR reports, Groundwater Vistas, Logplot, gINT, Earthvision, CARStat, and NJDEP Import/Export. These costs are for the interface only; they do not include the cost for the third party software. For this project, only the interfaces to GMS, EVS, Rockworks, and LogPlot were evaluated.

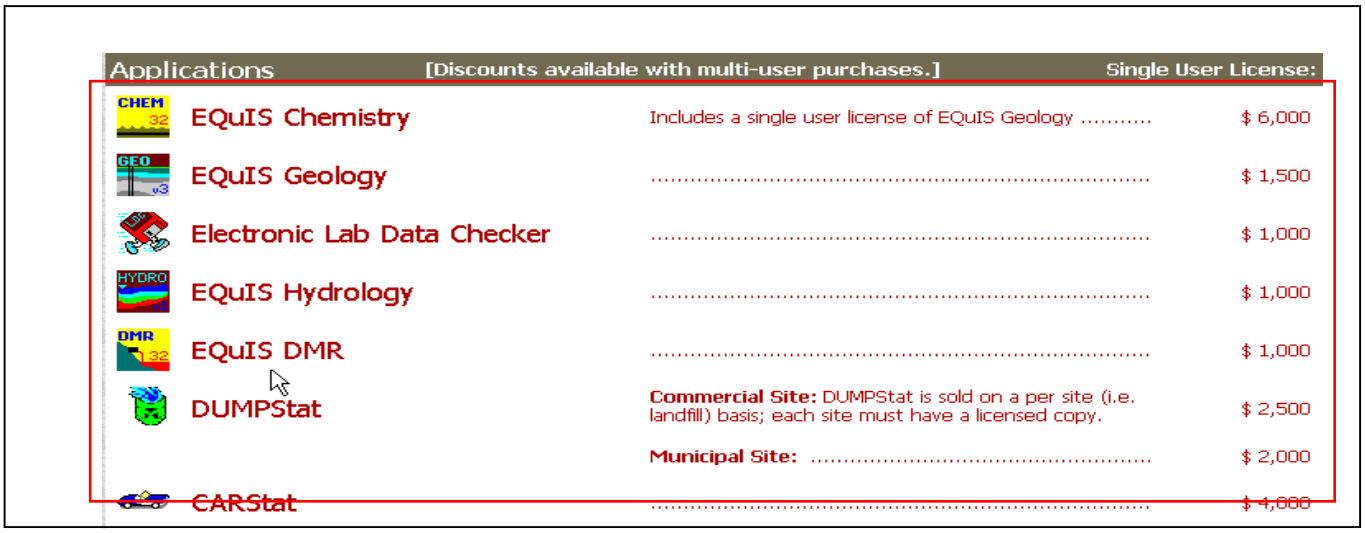


Figure 3-1. Cost of EQuIS applications

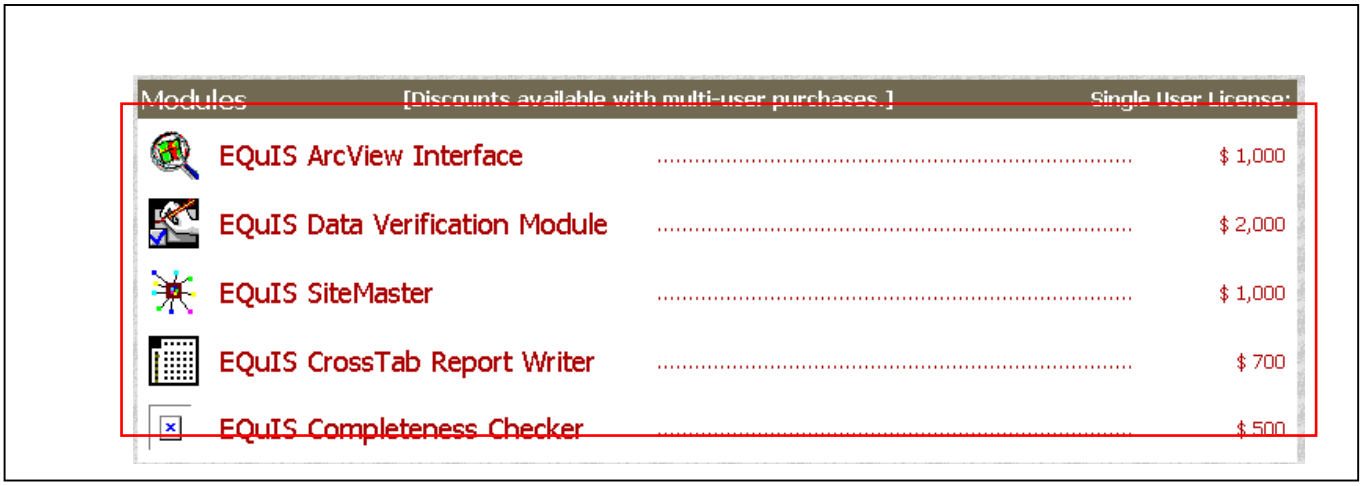
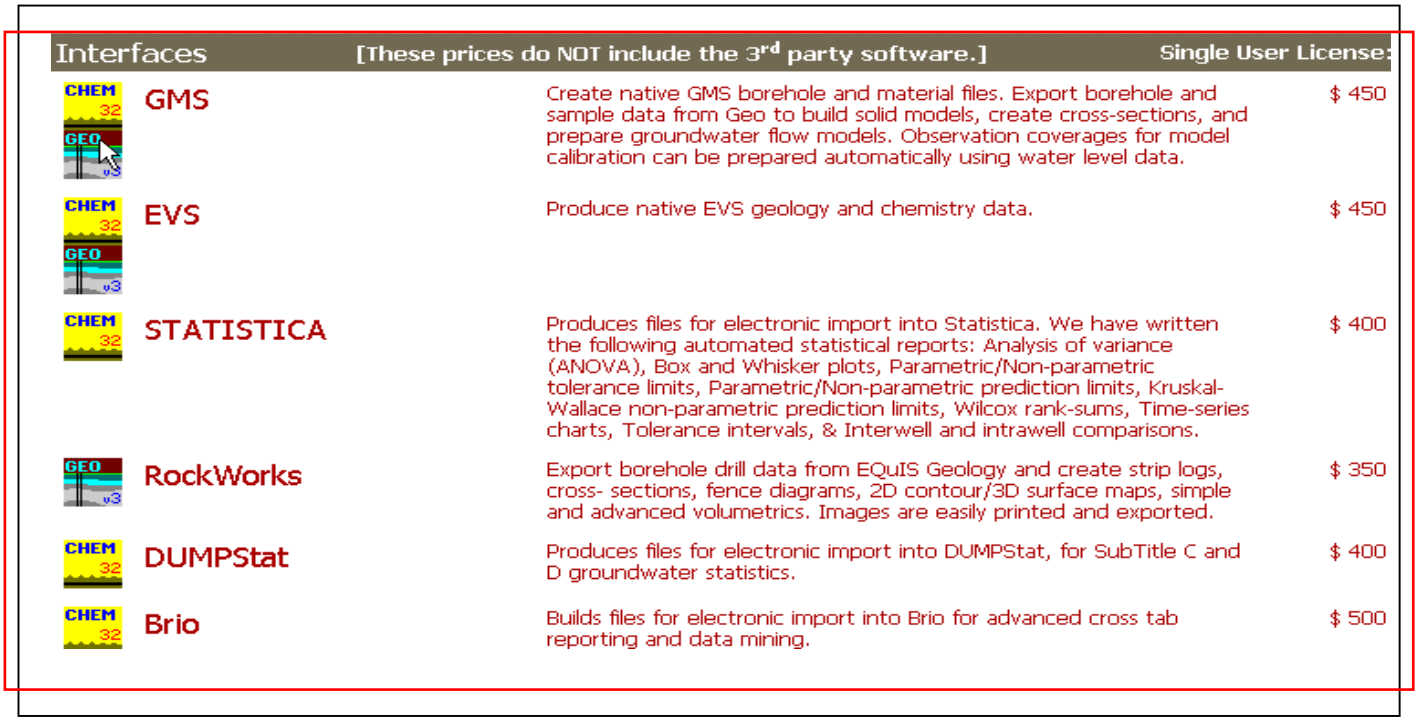


Figure 3-2. Cost of EQuIS modules



Interfaces	[These prices do NOT include the 3rd party software.]	Single User License:
GMS	Create native GMS borehole and material files. Export borehole and sample data from Geo to build solid models, create cross-sections, and prepare groundwater flow models. Observation coverages for model calibration can be prepared automatically using water level data.	$ 450
EVS	Produce native EVS geology and chemistry data.	$ 450
STATISTICA	Produces files for electronic import into Statistica. We have written the following automated statistical reports: Analysis of variance (ANOVA), Box and Whisker plots, Parametric/Non-parametric tolerance limits, Parametric/Non-parametric prediction limits, Kruskal-Wallace non-parametric prediction limits, Wilcox rank-sums, Time-series charts, Tolerance intervals, & Interwell and intrawell comparisons.	$ 400
RockWorks	Export borehole drill data from EQuIS Geology and create strip logs, cross- sections, fence diagrams, 2D contour/3D surface maps, simple and advanced volumetrics. Images are easily printed and exported.	$ 350
DUMPStat	Produces files for electronic import into DUMPStat, for SubTitle C and D groundwater statistics.	$ 400
Brio	Builds files for electronic import into Brio for advanced cross tab reporting and data mining.	$ 500

Figure 3-3. Cost of EQuIS interfaces

DMR Reports	A collection of various reports written by EarthSoft. $1,000 for the complete library.	$ 250
Groundwater Vistas	Export geologic sample data parameters to Groundwater Vistas for groundwater flow model preprocessing.	$ 350
LogPlot	Build LogPlot data files including stratigraphy, CPT-type data, geologic samples, and well construction.	$ 350
gINT	The new EQuIS Geology interface with gINT will make bore logs and fence diagrams even easier. EarthSoft developers have collaborated closely with gINT developers to produce a "live link" interface. That means that once you have created the "live link" from your EQuIS project to gINT, the data virtually exports itself. Any new data entered into EQuIS Geology will automatically appear for reporting in gINT. Just a few minor ODBC issues are being resolved before we can release this exciting interface.	$ 500
EarthVision	Export EQuIS data to EarthVision.	$ 800
CARStat	The new EQuIS Chemistry interface with CARStat will make statistical reporting even easier. The interface will allow the user to create a "live link" from CARStat to the EQuIS database. Any new data entered into EQuIS will automatically be available for reporting in CARStat.	$ 400
NJDEP Import/Export	Interface directly with NJDEP.	$ 350

Figure 3-4. Cost of EQuIS interfaces

3.3.3.5 Third-Party Products

Software prices were obtained only for the third-party packages tested in this evaluation. These include: GMS, ArcView, LogPlot, Rockworks, EVS, and Surfer.

Groundwater Modeling System (GMS)
The costs associated with obtaining the GMS software are shown in Figures 3-5 through 3-7. Figure 3-5 shows costs for various GMS packages. Figure 3-6 shows costs forindividual GMS modules. Figure 3-7 shows costs for workstation and NT Server hardware locks.

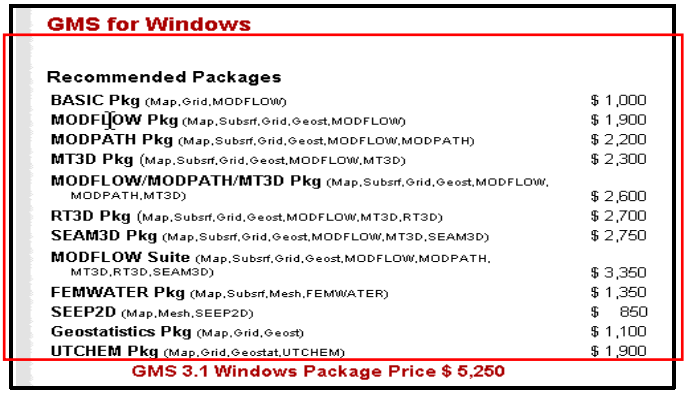


Figure 3-5. Costs for GMS packages

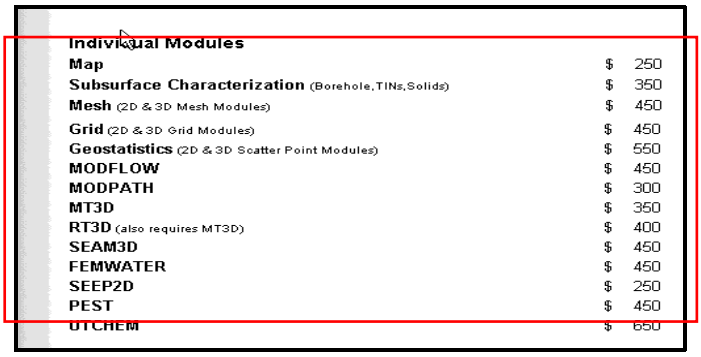


Figure 3-6. Costs for GMS Individual Modules

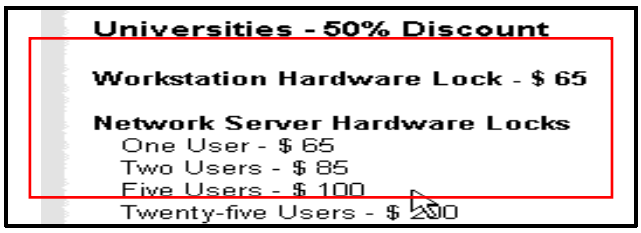


Figure 3-7. GMS costs for workstation and NT Server hardware locks

ArcView
The costs for the ArcView software are shown in Table 3-2. The ArcView GIS shrink-wrap license agreement allows for network use. Network use is limited to the number of seats that the user has purchased.

Table 3-2. Costs for the ArcView software

Quantity	Standard/Volume List Price ($)	Federal List Price	Reseller Cost ($)
1-5	1,195	956	717
6-25	1,076	861	646
25-50	956	765	574
51-100	837	670	502
101-500	657	526	394
501+	598	478	359

LogPlot
The costs for the LogPlot software are shown in Figure 3-8.

Rockworks
The costs of the Rockworks software are shown in Figure 3-9.

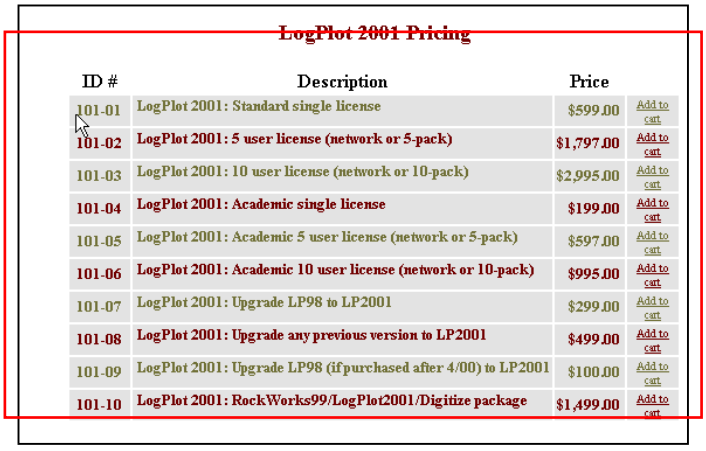


Figure 3-8. Costs of the LogPlot software

Environmental Visualization Software (EVS)
The costs of the EVS is shown in Figure 3-10.

Surfer

The costs of the Surfer software are shown in Figure 3-11.

RockWorks99 Pricing

ID #	Description	Price	
100-01	RockWorks99: Standard single license	$899.00	Add to cart
100-02	RockWorks99: Standard 5-user license (network or 5-pack)	$2,697.00	Add to cart
100-03	RockWorks99: Standard 10-user license (network or 10-pack)	$4,995.00	Add to cart
100-04	RockWorks99: Academic single license	$399.00	Add to cart
100-05	RockWorks99: Academic 5-user license (network or 5-pack)	$1,197.00	Add to cart
100-06	RockWorks99: Academic 10-user license (network or 10-pack)	$1,500.00	Add to cart
100-07	RockWorks99: 3D Visual Pro - single user	$999.00	Add to cart
100-08	RockWorks99: 3D Visual Pro - 5 pack license (network not available)	$2,997.00	Add to cart
100-09	RockWorks99: 3D Visual Pro - 10 pack license (network not available)	$4,995.00	Add to cart
100-10	RockWorks99: Academic 3D Visual Pro - single user	$599.00	Add to cart
100-11	RockWorks99: Academic 3D Visual Pro - 5 pack license (network not available)	$1,797.00	Add to cart
100-12	RockWorks99: Academic 3D Visual Pro - 10 pack license (network not available)	$2,995.00	Add to cart
100-13	RockWorks99: Upgrade: RockWorks98 to RockWorks99	$199.00	Add to cart
100-14	RockWorks99: Upgrade: Any previous version to RockWorks99	$499.00	Add to cart
100-15	RockWorks99: Upgrade: RockWorks98 to 3D Visual Pro	$449.00	Add to cart
100-16	RockWorks99: Upgrade: Any previous version to 3D Visual Pro	$749.00	Add to cart
100-17	RockWorks99: RockWorks99/LogPlot2001/Digitize package	$1,499.00	Add to cart

Figure 3-9. Costs of the RockWorks software

EVS For ArcView	EVS for ArcView is a subset of EVS Standard, plus an AV 3.1/3.2 extension that provides dozens of 3D volumetric visualization and analysis tools for the mapping professional. These tools are EVS applications that are launched directly from ESRI's ArcView GIS, yet provide the supreme functionality of EVS gridding, estimation and visualization modules. Use GIS queries or read in ASCII data to make 3D volumetric models.	$2,495
EVS For ArcView RENTAL	Monthly rental rate for EVS For ArcView. Rate does not include refundable $100 deposit for Software Key.	$495
EVS Standard	Environmental Visualization System modular analysis and visualization software (under Windows NT/95/98) for the high-end environmental, geologic or mining engineer. EVS provides user friendly kriging routines to create fully three-dimensional models of chemical distributions by geologic layer. Directs site assessment efforts by identifying locations of highest uncertainty and lowest statistical confidence. Representations can be isovolumes, colored surfaces, grids, arbitrary slices, visualization of vector data such as streamlines of potential flow, isolines, etc. Volumes and masses of chemical plumes can be calculated for the total system or by geologic layer. Also creates three-dimensional fence diagrams displaying geologic layers and chemical concentrations with up to eight separate fence cross-sections simultaneously displayed. DXF files can be imported and overlayed along with colored and labeled axes and a color legend. Includes a statistics module and a fully functional EVS Viewer. Includes one year of software maintenance, upgrades, and technical support.	$4,995

Figure 3-10. Costs of the EVS

	Price
Surfer	$599
Grapher	$299
MapViewer	$249
Didger	$329
Demo CD-ROM (includes all products) No shipping charges or DOWNLOAD **FREE** demos from the Internet - www.goldensoftware.com	$ 10

Upgrades (Requires serial number from any previous version)	Serial #	Price
Surfer		$139
Grapher		$ 99
MapViewer		$ 79
Didger		$ 89

Figure 3-11. Costs of the Surfer software

3.3.3.6 Hardware Costs

Any standard business personal computer (PC) in the price range of $900 - $2,000 is capable of managing the EQuIS applications. To use the other modules and interfaces that EQuIS takes advantage of, such as ArcView or GMS, one should consider the NT operating system and have at least 256 megabytes (MB) random access memory (RAM). Table 3-3 shows a comparison of typical PC costs from a leading manufacturer. Naturally, the speed of the processor, along with available RAM, and other specifications, impact the rapidity with which software functions can be performed. During the demonstration, no attempt was made to determine the most cost-effective hardware configuration. The size of the data set, the labor rate for data entry and management, and a host of other factors impact this determination. Therefore, the selection of the most cost-effective hardware configuration must be determined on a site-specific basis.

The specific configuration associated with one of the systems listed in Table3-4 (Pentium III, 866 MHz) is shown in Figure 3-12. This system was selected as a low-cost configuration that exceeded the basic software requirements.

3.3.4 Startup and Fixed Costs

Startup and fixed costs include the costs for training, working capital, insurance, taxes, monitoring and contingencies.

Table 3-3. Comparison of PC Typical Costs (data from a leading manufacturer)

Processor	Speed	Cost
Intel Celeron	700 MHz	$ 878
Pentium III	866 MHz	1,028
Pentium III	933 MHz	1,462
Pentium 4	1.3 GHz	1,887
Pentium 4	1.4 GHz	2,037
Pentium 4	1.5 GHz	2,237

The cost associated with on-site EQuIS training is $1200/day. There are three categories of training offered; these are listed below.

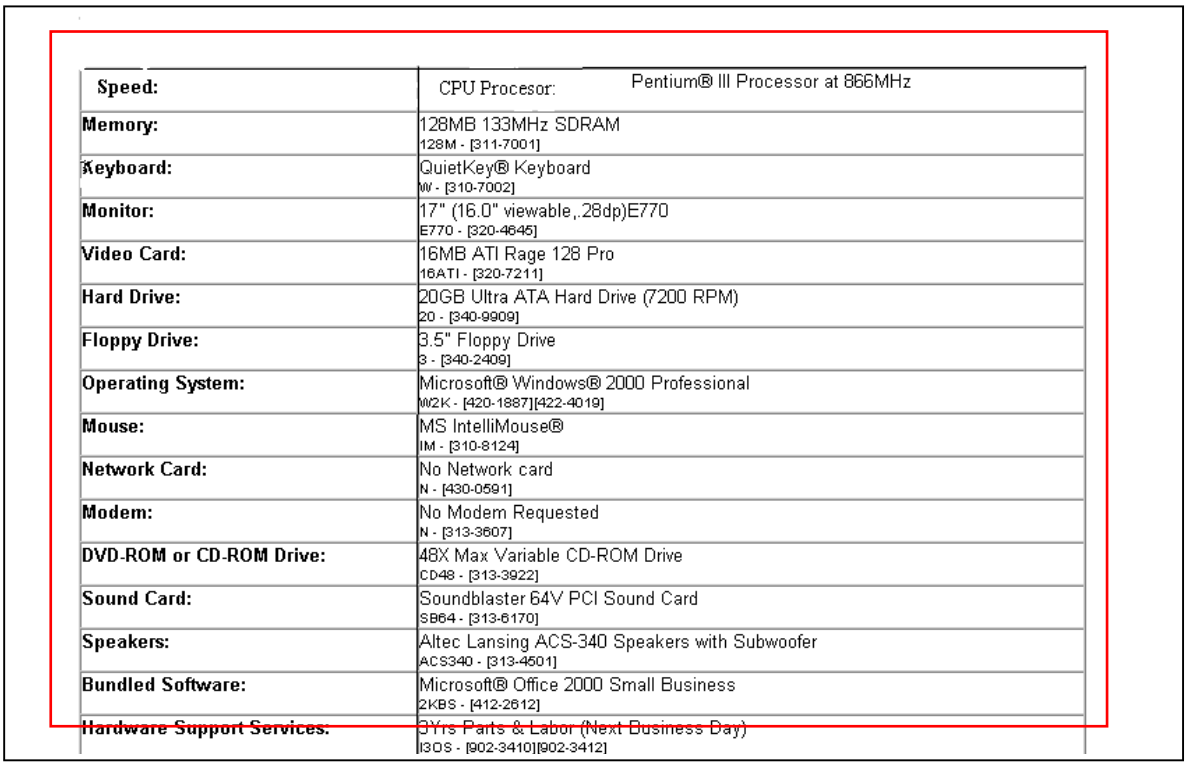
CONSULTANT/INDUSTRY TRAINING
- on site typically 3 days (for initial training, subsequent trainings vary)
- generally less than 10 students
- 1-2 instructors

PUBLIC SECTOR (EPA/STATE) TRAINING
- on site or at a central location
- typically 2 days, casual user
- 20, sometimes more students
- typically 2 instructors

OPEN TRAINING
- open to anyone, central location
- 2-3 days
- 10-30 students
- 2-3 instructors.

Working capital consists of the costs of borrowing capital for operating supplies, utilities, and labor necessary to keep EQuIS operating without interruption due to financial constraints. The working capital for this system is based on maintaining 2 months of payroll for labor and 1 month of inventory for supplies. Based on the operating costs listed in the next section (total of $119,000 per year), the working capital costs would be approximately $ 21,000 (1/6 of 119,000 = $ 20,000 + $ 1,000 for supplies).

A contingency cost is included to cover additional costs caused by unforeseen or unpredictable events, such as strikes, storms, floods, and price valuations. The project contingency cost is estimated to be 10 percent of the operating cost. Based on the NJDEP experience, the operating cost is estimated to be $119,000 per year (see Section 3.3.5); thus the contingency cost is estimated to be $12,000.



Speed:	CPU Procesor: Pentium® III Processor at 866MHz
Memory:	128MB 133MHz SDRAM 128M - [311-7001]
Keyboard:	QuietKey® Keyboard W - [310-7002]
Monitor:	17" (16.0" viewable,.28dp)E770 E770 - [320-4645]
Video Card:	16MB ATI Rage 128 Pro 16ATI - [320-7211]
Hard Drive:	20GB Ultra ATA Hard Drive (7200 RPM) 20 - [340-9909]
Floppy Drive:	3.5" Floppy Drive 3 - [340-2409]
Operating System:	Microsoft® Windows® 2000 Professional W2K - [420-1887][422-4019]
Mouse:	MS IntelliMouse® IM - [310-8124]
Network Card:	No Network card N - [430-0591]
Modem:	No Modem Requested N - [313-3607]
DVD-ROM or CD-ROM Drive:	48X Max Variable CD-ROM Drive CD48 - [313-3922]
Sound Card:	Soundblaster 64V PCI Sound Card SB64 - [313-6170]
Speakers:	Altec Lansing ACS-340 Speakers with Subwoofer ACS340 - [313-4501]
Bundled Software:	Microsoft® Office 2000 Small Business 2KBS - [412-2612]
Hardware Support Services:	3Yrs Parts & Labor (Next Business Day) I3OS - [902-3410][902-3412]

Figure 3-12. Sample configuration for the Pentium III (866 MHz) listed in Table 3-4

3.3.5 Operating Costs

Operating costs can vary widely depending on the project, the state of the data (hardcopy vs. digital), the data format, and data integrity. The operating costs presented in this subsection are based on the NJDEP experience. The operating costs are summarized below.

FTE*	$60,000	Manage HAZSITE program
PTE*	$25,000	Co-manage HAZSITE program
PTE	$10,000	Manage HAZSITE help-desk
PTE	$12,000	Interns - 3 positions - total 20-40 hours/week year round
PTE	$5,000	Prepare software for distribution
Task	$4,000	Develop tools to support processing
Task	$3,000	Develop tools to support processing

* FTE/PTE - full/part time employee, part may designate a FTE working on more than one initiative.

The total operating cost is $119,000 per year - almost all salary. This total does not consider the hour contributed by up to 10 bureau representatives that meet every two weeks as the EDS Committee. Nor does it consider the time for senior managements' involvement in the HAZSITE effort. This would be accrued at the Section Chief, Bureau Chief, and Assistant Director levels. Also absent are costs associated with staff support by OIRM - computer setup, internal help desk, network and server configuration/security.

3.3.6 Supplies

For this project, supplies consist of printer paper, ink cartridges, plotter paper, floppy disks, zip disks, and CD-ROMs. Annual operating supplies costs are estimated to be one percent of the operating costs, which is approximately $1200.00

3.3.7 Consumables

This project involved the evaluation of a computer software system. There were no consumables (other than supplies) related to this project.

3.3.8 Effluent Treatment/Disposal

EQuIS is an environmental information management system. It does not produce any effluent. Therefore the cost of effluent disposal and treatment are not applicable.

3.3.9 Residuals

EQuIS is an environmental information management system. It does not require the storage, transportation, or treatment of residuals or wastes. Therefore the cost of residuals and waste shipping, handling, and transport is not applicable.

3.3.10 Analytical Services

EQuIS is an environmental information management system. It does not require a sampling or analytical program to be established. Therefore the cost of analytical services is not applicable.

3.3.11 Modifications, Repair, and Replacement

The costs associated with EQuIS modifications, maintenance, repair, and replacement are listed in Figure 3-13. Training costs were previously discussed in Section 3.3.4.

3.3.12 Site Demobilization

EQuIS is an environmental information management system. The costs associated with site demobilization are not applicable.

3.4 RESULTS OF THE ECONOMIC ANALYSIS

This subsection summarizes the results of the economic analysis of the EQuIS technology as applied to the environmental data collected by two environmental agencies, the NJDEP and the CDPHE.

The NJDEP reflects a large-scale, multi-user implementation of EQuIS. NJDEP has received over 16,000 submissions to date and moves approximately 500 files into EQuIS at a time. NJDEP currently has a 40-user license. The storage requirements are estimated to be 4-6 GB/year for receiving submissions and making EQuIS data available. Based on the NJDEP experience and the hardware/software costs presented in this report the overall costs for implementing and operating EQuIS are listed in Table 3-4.

The CDPHE represents a small-scale, multi-user implementation of EQuIS. In Colorado, EQuIS is operated by two staff: a GIS/geologist and a VB programmer/geologist. Historic data are converted on a site by site basis by student interns at $11/hour from local universities who have advanced knowledge of geology, chemistry, or GIS to enter the data. Data uploading and quality checks are performed by the VB programmer/geologist. Staff commitment is approximately 15-20 percent. An Electronic Data Deliverable is not fully implemented throughout the Division's regulated sites, but a full EDD submittal has been implemented from several of the main labs. EQuIS is being implemented on a distributed basis where the project managers/scientists are responsible for learning the use of the system and the evaluation of their own data. Training is supported. The focus is on a power user approach, training first those with the proven aptitude and enthusiasm and with projects ready to utilize the system. Based on this operational setting, it is assumed that the small- scale operating cost = 10% of the large scale operating cost ($119,000, see Table 3-4) = $ 11,900. The costs estimated for a small-scale implementation of EQuIS are shown in Table 3-5.

3.5 REFERENCES

1. McKinsey & Company, Inc. 2000. Identifying Costs and Sources of Funding. Website URL, http://www.Benton.org/Library/

2. EarthSoft Inc., 2000. EarthSoft products and prices. Website URL, http://www.earthfoft.com

3. Putnam , S. Weaver , C. Thompson and M. Beard, 2000. The power of EQuIS in environmental management and decision analysis: case studies in Colorado, Website URL, http://www.EarthSoft.com/news/articles.php3

4. Defina, J., Maitin, I., and Gray, A., 1998. New Jersey Uses GIS To Collect Site Remediation Data, Arcuser April-June, 1998, Website URL, http://www.esri.com/news/arcuser/arcuser498/newjersey.html

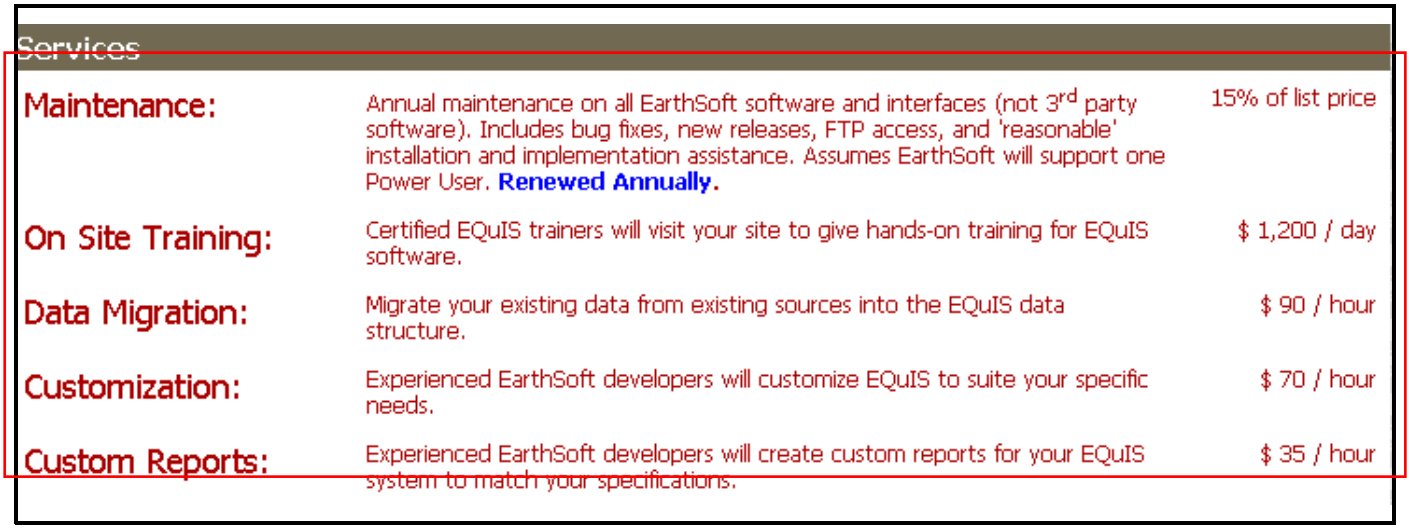


Figure 3-13. Cost of EQuIS services

Table 3-4. Costs Estimate for a Large-Scale, Multi-User Implementation of EQuIS

Item	**Cost ($)**	**Percent of Total Cost** (%)
Site Preparation (2)	4,994	2.6
Permitting and Regulatory	Not applicable	Not applicable
Equipment (1)	24,973	13.1
Startup and fixed (3)	36,600	19.2
Operating costs	119,000	62.4
Supplies (4)	1,190	0.01
Consumables	Not applicable	Not applicable
Effluent treatment and disposal	Not applicable	Not applicable
Residuals and waste shipping, handling and transport	Not applicable	Not applicable
Analytical services	Not applicable	Not applicable
Modification, repair and replacement (5)	3,746	2.0
Site demobilization	Not applicable	Not applicable
Total operating costs	190,503	100.0

Notes:

(1) Software:

EQuIS Software	($)	EQuIS Interfaces	($)	Third Party Software	($)
Chem	6000	GMS	450	GMS (basic)	1000
Geo	1500	EVS	450	ArcView	1195
ELDC	1000	Rockworks	350	Rockworks	2495
ArcView	1000	LogPLot	350	LogPLot	899
DVM	2000				599
CrossTab	700				
Total	12,200	Total	1,600	Total	6,787

Hardware: 3 Pentium III (933 MHz) = $4,386

Total Equipment Costs = $12,200 + $1,600 + $6,787 + $4,386 = $24,973

(2) Site Preparation = 0.20 x Equipment Cost = $4994

(3) Training = 3 days x $1,200 per day = $3600; Working capital = $21,000; Contingency = $12,000

(4) Supplies = 0.01 x 119,000 = $ 1,190

(5) Maintenance = 15% of equipment costs (0.15 * $ 24,973 = $3,746)

Table 3-5. Costs Estimate for a Small-Scale, Multi-User Implementation of EQuIS

Item	Cost ($)	Percent of Total Cost (%)
Site Preparation (2)	4,904	9.7
Permitting and Regulatory	Not applicable	Not applicable
Equipment (1)	22,049	48.6
Startup and fixed (3)	3,600	7.9
Operating costs (4)	11,900	26.2
Supplies (5)	119	0.3
Consumables	Not applicable	Not applicable
Effluent treatment and disposal	Not applicable	Not applicable
Residuals and waste shipping, handling and transport	Not applicable	Not applicable
Analytical services	Not applicable	Not applicable
Modification, repair and replacement (6)	3,307	7.7
Site demobilization	Not applicable	Not applicable
Total operating costs	45,384	100.0

Notes:

(1) Equipment; Software = $ 20,587; Hardware: 1 Pentium III (933 MHz) = $ 1462
Total Equipment Cost = $ 20,587 + $ 1,462 = $ 22,049

(2) Site Preparation = 0.20 x Equipment Cost = $ 4409

(3) Training only = 3 days x $1,200 per day = $3600

(4) Small scale operating cost = 10% of large scale cost ($ 119,000) = $ 11,900

(5) Supplies = 0.01 x 11,900 = $ 119

(6) Maintenance = 15% of equipment costs (0.15 * $ 22,049 = $3,307)

SECTION 4

TECHNOLOGY EFFECTIVENESS

This section discusses the effectiveness of the EQuIS software in managing data during the SITE demonstration. Subsection 4.1 contains background information on the demonstration, including a discussion of predemonstration activities and a list of the three demonstration objectives. Subsection 4.2 contains a brief description of the methodology employed during SITE demonstration testing. Subsection 4.3 summarizes the demonstration results.

4.1 BACKGROUND

4.1.1 Data Review

The Martin Aaron data set was examined to become familiar with the data fields that were essential to testing the functionality of the various modules. The data, as received, were reviewed with respect to the test plan to determine whether all functions could be evaluated or whether the data required alteration or the use of a new data set for completion of all aspects of the evaluation. Missing data were identified and alternative data were identified for all applicable tests.

4.2 METHODOLOGY

The primary objectives were:

1. Verify that all system functions were fully operational and had no significant programming errors. A significant programming error was defined as: the inability of a software function to execute properly (e.g., a fatal error) or a software function which produced an erroneous result (e.g., incorrect statistical calculation). Each system function in the Chemistry, Geology, ArcView Interface, DVM, CrossTab Report Writer, and ELDC modules were executed to verify operability.

2. Determine the conformance of the EQuIS system's input and output functions to data exchange standards. EQuIS interfaces with several COTS packages. These include GMS, Rockworks, LogPlot, EVS, Surfer, and ArcView. The data exchange between EQuIS and each COTS product was tested for interoperability.

The secondary objective of the system evaluation was:

1. Estimate the cost of implementing, using, and maintaining the system for a "typical" hazardous waste site data management program. Costs were broken out as follows: software maintenance, hardware maintenance, data management, and training. The results of this cost estimate were presented in Section 3.

4.2.1 System Functionality

System functionality (Primary Objective No. 1) tests were performed for each of the following modules: ELDC, Chemistry, DVM, Geology, ArcView Interface, and CrossTab Report Writer. Tests involved execution of key features identified in the test plan. Items that were investigated included:

- Project file directory structure
- Intuitive design of software features
- Default values for data entry
- Sequential data entry
- Pop-up or online reference data
- Other features specifically designed to ease repetitive or time-consuming practices performed during management of environmental data.

System functions were evaluated using the method and rationale for success/failure identified in the respective test matrices in the QAPP. Comments were also noted for software elements that, in the opinion of the evaluator, were particularly easy or very difficult or akward to implement. This was a qualitative evaluation.

4.2.2 Conformance of Input and Output With

Data Exchange Standards

Conformance to data exchange standards was evaluated for input to and output from EQuIS Chemistry, Geology, and ArcView Interface with GMS, Rockworks, LogPlot, EVS, Surfer, and ArcView. The general test procedure consisted of data exchange between the applicable EQuIS modules and each associated COTS product to test for interoperability. Input sample data were created in User-Defined Import Format and GMS Data format. Data import functions were tested with these sample inputs. This testing consisted of comparison of values in the EQuIS database (Chemistry, Geology, and ArcView Interface modules) and the respective input file to ensure that values were not corrupted during the import process. Output sample data were created for export to GMS, Rockworks, LogPlot, EVS, Surfer, and ArcView. Data export functions were tested with these sample outputs. Using the test data set, EQuIS passed data to each of the COTS packages listed above. The outputs produced by the respective COTS packages were compared to values in the EQuIS Access database to ensure that data integrity was maintained during the export and display process.

4.3 DEMONSTRATION RESULTS

This subsection contains results for the demonstration. Subsection 4.3.1 presents the results of the software evaluation with respect to Primary Project Objective No. 1. Subsection 4.3.2 presents the results of the evaluation with respect to Primary Objective No. 2. The cost analysis (Secondary Objective No. 1) was presented in Section 3.0.

4.3.1 Functionality Test Results

The functionality results for each of the six modules evaluated are reported, in the order originally presented in the QAPP, in subsections 4.3.1.1 through 4.3.1.6.

4.3.1.1 EQuIS ELDC Functionality Test Results

The ELDC is a tool designed to assist laboratories in checking that the electronic data deliverables, or EDDs, they produce will be acceptable to their clients. Alternately, when a laboratory does not provide this service, it is run as a "stand-alone" product to do an initial scan of EDDs prior to loading the data into the EQuIS Chemistry Module.

The ELDC evaluation was performed on four major functions: 1) EDD Data Check, 2) Error Logs, 3) Created Test Data, and 4) Historical and Y2K Data. The ELDC passed each of the major functionality tests performed. The ELDC ran quickly and smoothly. Data errors in the EDD were correctly identified in its reports. The identified errors were systematically corrected by the evaluator and the EDD was rerun after each correction. The error logs always acknowledged that the corrections had been made. Correcting EDD errors was often time consuming, but would usually be done by the laboratory that generated the data. The time required for this process appears to be dependent on the EDD as supplied by a laboratory, not a function of the ELDC. However, this length of time could be shorter if the ELDC identified the specific error location within the EDD records. In this version, only the type of error and total number of each error type was reported.

The following subsections summarize the ELDC performance for
the four functions tested. The first two subsections summarize results using the Tutbasic EDD. Some functions were not originally tested with this data set due to the lack of pertinent data to evaluate the functions in question. A second data set was created to test these functions; the results of these evaluations are reported in the final two subsections.

EDD Data Check

The ELDC imports project data from laboratory generated EDDs written by a laboratory in a format or file structure defined by the client. The ELDC checks various items against a defined EDD format and makes simple data comparisons. The ELDC makes no computations using the project data. Its output information alerts its user as to types of errors it has found and identifies their general location within the EDD file structure.

This evaluation verified that the ELDC checked the EDD and produced an Error Log. Items that were originally tested by the Tutbasic EDD were: Required Fields; Duplicates Records; and Values Out Of Range. Text fields were not tested because they already use dashes. The Tutbasic EDD loaded quickly and the ELDC performed functions in about 10 to 15 seconds. Longer run times should be expected based on the file size of the EDD (numbers of samples, methods, and analytes per method). The EDD used during the evaluation had 7 samples, 1 analytical method, and 44 total analytes.

Error Log

When the ELDC checks the EDD, an error log is produced to document data not in the defined format or meeting simple data requirements defined by the user.

This part of the test verified that the ELDC Error Log that was generated was accurate. The EDD was successfully corrected, using information the in Error Log, to a "no error status". A warning remained (non-critical) in reference to lab name (MendoLab). This was not a problem since this data field (lab_name_code) was not a required field.

Created Test Data

The Tutbasic EDD did not contain data to evaluate all portions of the EDD data check. This evaluation verified accurate Error

Log generation for items that were not tested in the initial testing of the Tutbasic EDD.

Items newly tested (not tested in the initial run) under this section that produced errors as expected were: CAS number errors, wrong chemical method numbers, and unit changes (reference values) that replaced letters with numbers. Items tested under this section that did not produce errors as initially expected are: misspelled chemical names, negative numerical results, and the use of future years. There are no vendor claims for these categories. They were originally included as part of the Test Plan Matrix under the general concept of testing reference values. However, they are not reference values. The fact that these items did not produce errors is acceptable and actually makes the software more versatile.

Historical and Y2K Data

The vendor claimed that the ELDC properly handles older data and data that span the Y2K period. This section of the test verified the ELDC's ability to work with historical data and that it is Y2K compliant.

All aspects of this test were successful. Samples with collection dates of both 5 and 10 years ago were properly processed. Likewise, samples with collection data of December 1999 and extraction dates of January 2000 were properly handled.

4.3.1.2 EQuIS Chemistry Functionality Test Results

The Chemistry module functionality evaluation was divided into five major sections: 1) System Administration and Maintenance, 2) EQuIS User Functions, 3) Data Entry, 4) Editing and Viewing Data, and 5) Reporting and Graphing. Each of these sections consisted of a number of functions for which the results are described below. Each of the five major functions generally performed as claimed by the vendor. However, at least one individual function in each of the major functional categories failed to perform as claimed. In some cases, these failures were minor (had little impact on system functionality) or were contrived situations that are unlikely to occur during normal software operation. In other cases, the failures were more significant, ranging from problems that made the system more difficult to use to failures that could potentially result in data errors. None of these failures, however, impacted the overall performance of the software.

System Administration

System Administration worked well to allow the set up of, and provide the security necessary to maintain, multiple users with different levels of access. There were three major elements to this evaluation: User Administration and Maintenance, Project Administration and Maintenance, and Communication With External Applications.

User Administration and Maintenance - User Administration and Maintenance is used to maintain data security within EQuIS Chemistry. Each user must be entered through System Administration, and have a unique name and password with which they may log into the EQuIS Chemistry system. Users may be created, edited, or deleted through System Administration. EQuIS's User Administration system is hierarchical in design, allowing for multiple users with varying levels of access to particular projects and the system in general. The levels of access granted to various users should be determined by the types of data management functions they perform. An important consideration in determining user access levels is identifying those users who should have, or will need, access to the System Administration functions. System administration functions include assigning user and project passwords; designating user access levels; importing, exporting, and merging data; and performing system database maintenance activities. There are four levels of system access built into the system for various combinations of users and projects. Access levels determine what functions EQuIS will allow each user to perform and what applications he/she can run. The access levels are listed in Table 4-1. Each level can also perform all of the functions associated with the previous level.

Table 4-1. EQuIS User Access Levels

User Access Level	Accessible Functions
Casual	View graphics and reports; export data
Operator	Casual user functions plus: import data; manually enter data
Power	Operator functions plus: merge data; edit reference tables, data tables, and groups
Super	Power user functions plus: project and user setup

The User Administration functions worked as claimed by the vendor with only minor exceptions. After entering the System Administration as a Super User, access was easily given to the Power User, Casual User, and Operator. The Password, User Name, User's Directory, and Administration Access for a Casual User, an Operator, a Power User, and a Super User were successfully modified and deleted using the appropriate menus. As claimed by the vendor, the User Login Name could not be duplicated. On the other hand, User Directories could be accidentally duplicated, indicating the potential for improper duplication of information. However, the likelihood of such duplication seems remote based on the lengths to which the evaluator had to go to create this scenario.

Project Administration/Maintenance - The EQuIS Chemistry

data module is based on projects. Projects contain chemical data from single or multiple sites. The data for each project are stored in a Microsoft Access© database. The System Administrator needs to consider several things when creating and setting up projects, including file management, database organization, and data security. Before a project can be opened in EQuIS Chemistry, it must be created through System Administration. When a project is created, the system administrator enters a project name, project code, and path to the project's database. Other information (including project start date, site, client, and project manager) may also be included when creating a project. The system administrator may also choose which users may have access to that project, and what type of access those users have to the project data. Existing projects may also be modified (except for the project code) or deleted through System Administration or from EQuIS Chemistry. The System Administrator can also copy reference tables between EQuIS projects.

New projects were easily created; no significant time lags occurred. System Administration worked as claimed by preventing new projects from being set up using the same database as an existing project; however, new projects could be assigned to inactive project databases. This result indicates the potential for improper duplication of project information although, as with User Administration, the likelihood appears to be remote. Project access worked as expected. Project maintenance was successfully accessed and utilized from the Edit and File menus. System Administration prohibited the duplication of a project. The evaluator was able to remove users, add a new user, and edit a current user status. However, the evaluator was able to remove the Super User from the list of User Names displayed by the Project Maintenance screen. The system would be improved by including a statement cautioning the user that she/he is planning to remove the only project Super User. Projects were easily deleted from the Project Maintenance screen with no time lags.

Communication With External Applications - EQuIS allows system administrators to change the home directories of external software applications accessed from the tools menu. As well as allowing various access privileges to built-in functions, EQuIS Chemistry also allows the user to access external applications.

Communication with external software generally worked well, although a minor problem was identified. Changes to the ProgPath were appropriately retained after exiting and re-entering the Applications Location Maintenance screen. The program also did not allow the evaluator to delete any external software applications which were considered "system entries"; other applications could be deleted. It also did not allow the user to change the ProgName for any of the applications. However, the system did not prevent the evaluator from changing or assigning the ProgPath of an existing application to a path that did not exist (e.g., by deleting one letter from the path) or to a directory which did not contain anything but an *.exe file. This portion of the software did not perform as claimed by the vendor; however, this problem was not considered critical to proper function of the software's System Administration.

EQuIS User Functions

EQuIS User Functions were evaluated in six parts: 1) Getting Around, 2) Data Grids, 3) Drop Down List, 4) List Box 5) Selecting Data, and 6) Querying Data. Each basic User Function, and the corresponding evaluation result, is described in one of the following sections.

Getting Around - Within the program there is a general pattern followed on most screens. Logic flow proceeds from the upper left panel to the upper right panel and then to the bottom panel. The upper left panel generally contains identification information such as the project name and sample ID. Gray fields are simply display fields, whereas white fields can be edited. The upper right and bottom panels are for data entry and modification. The mouse or the <TAB> key may be used to move from field to field on the EQuIS Chemistry system screens.

Screen logic was verified to flow from upper left to right and then to the bottom.

Data Grids - Many modules within EQuIS Chemistry use data grids to display data. These grids are a flexible interface between user and data. When using a data grid, the user may:

- Change the order of the columns
- Change the width of the columns
- Select an individual record (row)
- Select multiple records
- Enter or edit data within the grid cells for select modules
- Select a field value from a drop-down list (when applicable)
- Choose a value from a drop-down grid in select fields.

Actions that could and could not be performed with data grids were appropriate.

Drop-Down List - A drop-down list is signified by a down arrow at the right of a data field. When this down arrow is clicked, the list appears. To select an item from the list, simply click on the desired item.

Drop down lists were easy to use and worked as expected.

List Box - A list box is a box that lists one or more columns of data items. If the list of items is too long for the box, then scroll bars allow the user to access the entire list. When selecting multiple items from a list box, pressing <CTRL> while selecting allows multiple, non-adjacent selections. Pressing <SHIFT> while selecting from the list selects everything from the first click to the next click.

The <SHIFT> and <CTRL> keys were successfully used to select

items from list boxes.

Selecting Data - Many functions of EQuIS Chemistry allow the user to select specific data. There are three different methods with which the user can select data: Single Location, Location Groups, or Select From Map. When using Select From Map, data may be selected singly or in groups with a polygon or circle.

Data were selected by single locations and a report was successfully generated. Location group data were used to generate a plot and an export file. The deselect function also worked as claimed. The Select From Map function worked well except that single locations could not be selected. While this can be an inconvenience, it is not a major obstacle to the software functionality since unwanted locations from a group can be easily deleted.

Querying Data - Before using the Query Tool, the user must determine the purpose of the query. For example, the user may want to query a table for records that contain a certain range of dates. Once the purpose of the query has been determined, the user must decide which data fields will be used in the query. Once a query has been outlined by the user, the Query Tool is used to perform the query.

The basic query function (set up, run, and show queries) also worked well; however, queries are not designed to be saved and re-used by EQuIS Chemistry.

Data Entry

EQuIS provides two means for transferring or importing data into the system: Manual Data Entry or Electronic File Import. If the data to be loaded into EQuIS are only available in hardcopy format, the data can be entered manually into the system through the manual data entry screens or the data can be entered into spreadsheet templates and imported into EQuIS. Alternatively, if the data are already resident in an electronic database or spreadsheet, or if corresponding Electronic Data Deliverables (EDDs) have been provided for the field sampling and laboratory analysis work, these data can be imported directly into EQuIS. It should be noted that the electronic data format will need to be EQuIS compatible (e.g., IRPIMS or similar format or equivalent). In the event the data format is non-standard, (or unknown) the instructions in the Importing Data Electronically section will need to be followed to correlate the data to the EQuIS database fields. However, EQuIS is not a fixed format. New formats can be created and custom EDDs are available from many sources.

Data for import into EQuIS can be prepared in several ways:

- Using the MS Excel© spreadsheet templates. EQuIS provides spreadsheets that have been set up as import file templates. The columns are labeled with the field names, data types, and width. Columns are also color-coded to indicate which are required. The user selects the appropriate worksheets according to the type of data. Each set of worksheets includes an information sheet explaining the available templates. After loading the worksheet templates with data, each worksheet is saved as a separate text file (tab or comma delimited) to be imported into EQuIS. The text files are imported into EQuIS, not the spreadsheet itself.

- Using an editor to create ASCII files (i.e. DOS files, not word processing files). Each text line must end with a CR-LF (carriage return-line feed) and each data element must be separated by a tab or a comma. See the EDD Format Definitions located in the EQuIS\Doc directory on EarthSoft's web page for a detailed description of each format.

- Using an outside database system. Use that system's export or reporting capabilities to either create ASCII files or to load data into one of the many EQuIS spreadsheet templates. If the data from the other system do not match column-for-column with the selected spreadsheet, the data will not import into EQuIS. However, new spreadsheet formats can be created to match other databases.

The Data Entry function evaluation consisted of six areas: 1) Data Templates, 2) Data Import Preferences, 3) Error Log, 4) Import Rollback, 5) Temporary and Permanent Databases, and 6) Merging the Database.

EQuIS Data Templates - EQuIS provides several templates for loading data. These templates are provided as MS Excel© workbooks. Each workbook includes an information sheet that explains the templates included in that workbook. Each template is a single worksheet and represents an available EQuIS data import format. The column headers on the worksheet represent field names in various tables of the EQuIS database. The columns have been named according to requirements in the database. The second row headers indicate the order, field data type, and size. If the columns are moved out of order, the import will be rejected. The column names that represent fields whose data are required (cannot be empty) in the database are highlighted in yellow.

Field sampling, test method, and analytical result data were entered into MS Excel worksheets which were imported into EQuIS Chemistry. Data completeness, correctness, and order were maintained during import.

Data Import Preferences - The Preferences section of the Import Data File screen contains the following options.

- Require Parent Records - the import requires that all data entered have the appropriate parent records, which prevents any orphan data in the Temporary database. For example, information must exist in the TEST table for

result records to import. The import will check for parent records in both the Temporary and the Permanent databases. When this field is checked, the Create Missing Records option is grayed-out and is unavailable. If the data have no parent record, an error log will be generated. The error log messages are not generated during merge.

- Create Missing Parents. If checked, missing parent records are automatically created in the Temporary database as the data are loaded, thereby making it easier to load without needing to manually create parent records. If this field is checked, then the Require Parent Records field is unavailable. Only key field or skeletal information is created for the parent. Additional information may be desired before merging the record to the Permanent database. This option should be used with caution because a single typographical error in the imported data could result in the creation of an unwanted parent record.

- Overwrite Existing Data. If checked, the new data can overwrite existing data when an overlap occurs as the data are being loaded into the Temporary database. This option does not affect data in the Permanent database.

- Add New Reference Values to Lookup Tables. If checked, when the data are loaded into the Temporary database, reference (look-up) data are automatically added to the Permanent database reference tables. This option should be used with caution because a simple typographical error in the new data could result in the creation of an unwanted reference value.

- Use Default If Missing. If checked, default values are loaded to replace missing data as the data are imported into the Temporary database.

Click on each option to select. Unavailable options display in gray.

The system successfully identified an intentional error and prevented the import of test data without a field sample parent record in the temporary database. The system was able to create the missing parent records required for data import. Reference values and default values were added to those already present in the system.

Error Log - The error log shows errors that occurred while importing data into the Temporary database. The error log is an ASCII file describing errors encountered, (i.e. missing reference value, etc.) and whether it is an error, warning, or other information. Records with errors will not be loaded into the Temporary database. Records with warnings or other messages will be loaded into the Temporary database. The file name for the error log is the same as the file selected for import. If the import file name is filename.txt, then the default error log name would be filename.ERR.

An Error Log listing errors and explanatory messages was generated; its configuration agreed with that described in the EQuIS literature. This log could be sorted by row, field, and error, or could be displayed as a summary of errors only.

Import Rollback - Each time data are imported electronically, these data are assigned a unique batch identification. This identification is written into the IBatch field of each record imported into an EQuIS data table (any table beginning with dt_). The Rollback function allows the user to remove all records with a particular IBatch number from the project's Temporary database. The Rollback function is available from the Edit menu on the Import screen. Selecting the function displays a form with a drop down box from which can be selected an IBatch number for a particular import to 'rollback'. The imports are listed with the IBatch number, the type of import, the date that the import was completed and the number of records imported. The results of the Rollback are shown in a text box on the form. The number of records deleted from each affected table are reported.

The Import Rollback function successfully removed data entered during a previous step.

Temporary and Permanent Databases - Each manual data entry window has a Search Temp DB check box. Select this box to enter or edit data in the Temporary database. Data entered into the Temporary database must be merged into the Permanent database. Data in the Permanent database can be edited and deleted, but new records cannot be entered directly into the Permanent database. New records must be entered into the Temporary database and merged into the Permanent database. When adding (or editing) data in the Temporary database, the drop-down lists for each applicable field (such as sys_loc_code) display values from the Temporary and Permanent databases. When editing data in the Permanent database, the drop-down lists display data only from the Permanent database. The manual data entry window allows the user to enter field data, lab sample data, and test data. (Note: Entering result data can be done in two different ways. The first method allows the user to enter data one result at a time. The second method allows the user to use parameter groups to enter multiple results.)

Field and analytical result data were successfully entered and viewed in Temporary and Permanent Databases. Although the system prevented the entry of invalid dates, times, and invalid codes for certain fields, it did not generally check and prevent the entry of anomalous data such as negative depths or shipment and receipt dates which predated sampling events.

Merging the Database - The Merge function in EQuIS moves data from the Temporary database to the Permanent database. It allows

a System Administrator to move single records or groups of records from single tables or groups of associated tables, based on user specified options. When records are successfully merged from the Temporary to the Permanent database, they are removed from the Temporary database. The merge function can only be performed by users with Super or Power access privileges. The two Merge types are available in EQuIS are New and Update. The new merge is used to put data into the Permanent database that did not previously exist in the Permanent database. The Update merge is used to update existing records in the permanent database. The Update merge does not overwrite any existing data, it only updates empty fields in the Permanent database with data from the Temporary database. The merge function creates new records in the Permanent database from data stored in the Temporary database. The selector allows the user to specify what data are to be merged. One of the follow0ing merge options may be used: by table, by sample, by location, by borehole, by well or all tables.

The Merging the Database function merged data tables from temporary to permanent databases without error.

Editing and Viewing Data

Six functional categories were evaluated under Editing and Viewing Data: 1) Data Table Maintenance, 2) Reference Table Maintenance, 3) Table Indexer, 4) Database Table Record Counts, 5) Group Maintenance, and 6) Data Screens Overview.

Data Table Maintenance - Data tables contain the dynamic or project data and are maintained in the Temporary and the Permanent database. These data can be edited or viewed using data table maintenance. User access levels determine editing capability. The Select Table drop-down list on the Data Table Maintenance screen has three columns. The first column shows the common name of the table, the second column shows the actual table name (within the database), and the third column shows the parent table (if any).

Changes that were made to data tables in the permanent and temporary databases were retained by the system after exiting and reentering the Data Table Maintenance screen to view the modified tables. In addition to editing cell contents using the cursor, data were also copied, cut, and pasted between cells within the same column and cells within different columns. Rows from the data tables in the permanent and temporary databases were also deleted. As claimed by the vendor, it was not possible to change a data entry in a key field in a data table located in the permanent database. However, data in a key field in a data table located in the temporary database were modified. These changes were made using the cursor and by pasting the contents from one cell over the contents in another cell in a data table. Furthermore, the changes were retained by the system after exiting and re-entering both the EQuIS Chemistry and the Data Table Maintenance screen. Although it is possible that the system will detect and remove these problems during normal use, this could not be confirmed. Therefore, this portion of the test was not a success. In another test, users without access to the NJ Demo Test Project were appropriately prevented from opening a project when logging into EQuIS Chemistry or by using the Edit...Open Project function. As a result, they were prevented from accessing the Data Table Maintenance screen. Also, Casual users and Operators with access to the project were unable to access the Data Table Maintenance screen from the Edit menu since this function was greyed out.

Reference Table Maintenance - Reference data are maintained in the Permanent database only in the reference tables. These tables provide the information contained in the drop down lists of look up information in the system and are edited by system administrators and users with edit privileges. The Table drop-down list on the Reference Table Maintenance screen has three columns. The first column shows the common name of the table. The second column shows the actual table name (within the database), and the third column shows the parent table (if any).

In addition to editing cell contents using the cursor, data were also copied, cut, and pasted between cells within the same column and cells within different columns. Rows from the reference table were also deleted. In general, EQuIS Chemistry appropriately prevented a user from changing an entry in a reference table key field. However, when working with the Unit Conversion Factor table, it was possible to improperly cut and paste, or copy and paste, a value (e.g., cm) from one cell in the Reported Unit column over the value in another cell in the Reported Unit column (e.g, over ft) if the value in the adjacent column (key field Default Unit) also contained the same value being pasted (e.g., cm). Furthermore, these changes were retained by the system when the user exited and re-entered the Reference Table Maintenance screens. Therefore, although EQuIS Chemistry has been set up to a prevent a number of modifications to the fields, there was one instance where the system did not prevent a change(s) to a key field(s) in the reference tables. It should be noted that these modifications introduced as part of the evaluation would not necessarily be the result of casual use and that, in general, a user would need to be trying to make these changes in order for them to occur. In another part of the test, users without access to the NJ Demo Test Project were appropriately prevented from opening this project when logging into EQuIS Chemistry or by using the Edit...Open Project function. As a result, they were also prevented from accessing the Reference Table Maintenance screen. In addition, Casual users and Operators with access to the project were appropriately prevented from accessing the Reference Table Maintenance screen from the Edit menu since this function was greyed out.

Table Indexer - The Table Indexer is a tool that allows the user to add indexes to tables in the Temporary and Permanent databases. The user may also view existing table indexes using the Table Indexer. The Temp Db box allows the user to choose tables from the Temporary database (checked) or the Permanent database (unchecked). The user may also choose to hide the default indexes

that are read-only. This is done by checking the Hide Read-Only Indexes box. Casual users are prevented from editing data, and some key system features are reserved for Power users.

Indexes were successfully added to tables, viewed, and modified in both the temporary and permanent databases. Furthermore, it was confirmed that the indexes were properly retained by the system, as entered, after closing and reopening the EQuIS Chemistry - Indexer screen. Finally, the evaluator was appropriately prevented from creating an index in which the same field was selected twice. Since the evaluator was unable to select any of the fields in the Field in Index box, no changes could be made to read-only indices associated with tables in either the permanent or temporary databases. The evaluator also confirmed that the fields in the read-only index appeared gray. Users without approved access to the NJ Demo Test Project were unable to open this project when logging into EQuIS Chemistry or by using the Edit...Open Project function. As a result, they were appropriately prevented from accessing the EQuIS Chemistry - Indexer screen. Also, Casual users and Operators with access to the project were unable to access the EQuIS Chemistry - Indexer screen from the Edit menu since this function was greyed out.

Database Table Record Counts - The user may see a summary of the number of records in each data table of the Permanent or Temporary databases by using the Database Table Record Counts.

The record counts obtained for data tables in the permanent and temporary databases remained consistent during repeated access of the Table Record Counts window and changed by an appropriate amount after the evaluator removed records between viewings of the Table Record Counts window.

Group Maintenance - There are three general categories of Group Maintenance; Using Groups, General Group Maintenance, and Analytical Group Maintenance.

- **Using Groups** - Group maintenance allows the user to save a selection, or group of samples, locations, analytes, or wells (etc.) for reporting and graphing. For example, instead of selecting individual samples every time a report is created, the group maintenance feature allows the user to create reports using a previously saved group of samples. Selecting and saving groups (or samples from the same locations) for reporting and graphing functions ensures that precisely the same samples are reported each time; preventing the accidental omission of any component of the group. Group maintenance is managed by EQuIS in two pairs of tables. Each pair consists of a parent table containing user-defined names of groups, and a child table containing the members of each group.

- **General Group Maintenance** - The user may create groups for use within a project. The possible group types (Boreholes, Excavations, Field Samples, Soil Gas, Lab Samples, Site Locations, Other Areas, Product Thickness, Samples, or Wells) are listed in rt_group_type. Each group is a selection of records from one data table. If a field sample group is created, all members of the group must reside in the Field Sample table and records from different tables cannot be combined into the same group. However, any record can be part of many groups created in the same table. The groups can be used for most reporting and graphing. Within reporting and graphing, wherever a location is selected, a location group is also selected. The same holds true for all possible group types.

- **Analytical Group Maintenance** - The Method Analytical Group and the Method Analytical Group Member tables select records from the reference table Analytes. Within reporting and graphing, wherever an analyte is selected, an analyte group can also be selected. This grouping mechanism does not allow data from the Sample Parameter Measurement, Geotechnical Result, or Biological Result data tables to be grouped; this grouping works only to retrieve data from the Result data table. The functionality of this pair is similar to the Group pair; a group member (an analyte) can be in many Method Analyte groups. Groups were created with relative ease.

Existing group information was edited, saved, and later successfully viewed after exiting the system. Deletion of a group was easily performed and was confirmed in the Analyte Group Maintenance screen.

Data Screens Overview - The screens used to enter data manually may also be used to edit or view data. Data stored in the Temporary database or Permanent database may be viewed using the View menu for those who do not have Edit privileges. All users can view field sample collection data, corresponding lab sample information, analytical tests conducted, and the corresponding analytical results. (Note: Users may not delete a single sample and all of its dependent records in a single operation in a project's Temporary database. In the Permanent database there is some capability for cascading deletes of dependent records.)

After field sample and result data were viewed and edited, the evaluator re-entered the respective Manual Data Entry screens and confirmed that the changes were retained. Changes were made from the different tabbed views; when a change was made to one tabbed view, it was saved to the other views when Apply was selected. Changes that were made from the Result tab view could only be observed in the Data View tab if Apply was first selected. Changes could not be made to the data displayed from the Data View tab view.

Reporting And Graphing

Once data have been entered into the EQuIS Chemistry database

(either manually or by electronic import), the user can use the data in a variety of ways. EQuIS Chemistry can provide detailed reports and graphs tailored to the needs of the user. The user may use any subset of data to create a report or graph. When reporting, graphing, and exporting, only data that have been approved by the user are eligible. This is done by entering 'Yes' in the reportable_result field of dt_result - allowing the user to validate each record. The reportable_result field may be accessed either through Manual Result Data Entry or by using Data Table maintenance. Data imported using the ESBasic EDD can use a default value for the reportable_result field. Once the data have been entered and indicated as reportable, they can be accessed for reporting, graphing, or exporting.

Three types of functions were tested under Reporting and Graphing: production of reports, creation of various plots and exporting data. A total of seven functions were evaluated (these were judged by the evaluator to be representative of the functions most likely to be used by software users); all were successful.

Reporting Data - EQuIS offers three different reporting formats to give users a variety of tools readily available to view and report data.

- **Quick Reports**: Provides a report for a single table or a single predefined query of the data.
- **Standard Reports**: EarthSoft provides these predefined reports, which link to either MS Excel© or Crystal Reports.
- **Custom Reports**: Reports that a system administrator creates and links to EQuIS for use on their project or within the company. This option allows the user to create or install any reporting application. If an executable file name cust_rpt.exe exists in the main executable directory, then this menu option will start the application. EQuIS's ability to generate Custom Reports will not be evaluated during the demonstration

Three Quick Reports were developed from a data source, a reference source, and a query source. Each was successfully viewed in MS Excel. An attempt was also made to generate a Quick Report using unapproved data. This test was not successful. According to EarthSoft's documentation only data that have been approved by the user and contain a "Yes" in the reportable_result field of dt_result are eligible for use in a report generated from a data table. However, after changing the reportable_result field for a result to "No" using Data Table Maintenance, the affected result was inappropriately included in the resulting Quick Reports. An Analytical Concentration Standard Report was created and saved in MS Excel. A printout was compared to the data grid displayed by the Worksheet tab in the Report Criteria screen; all results matched. An attempt was made to generate an Analytical Concentration Standard Report using unapproved data. The data were appropriately screened out by the software.

Creating Graphs From Within EQuIS - EQuIS provides links to third party applications for further analysis and modeling of the data. The current applications linked are Surfer by Golden Software and Microsoft Excel. Surfer is used to create contours; Excel is used to create graphs. There are five types of graphs that can be created from within EQuIS (only Trend and Dot Plots were evaluated.

- **Trend Plot**: This is a 2D plot completed in Grapher. User can select/filter data from the project database.
- **Map**: This is a 3D plot using Surfer. User can select/filter data from the project database.
- **Trend Plot from File**: Automates Trend Plots with data from a user-specified data file (CSV type).
- **Map from File**: Automates maps with data from a user-specified data file (CSV type).
- **Dot Plot:** 3D standard dot plot/posting using Surfer. Users can select and filter data from the project database.

Trend Plots and Contour or Dot Plots were successfully created, saved, and viewed. The saved files were re-opened and matched the original plots.

Exporting Data - Data can be exported to other EQuIS modules (e.g., ELDC) or COTS software (e.g., EVS) for reporting and graphing.

A reference file was exported and successfully opened in ELDC; the data structure and content were unchanged and the number of rows in the export file remained the same as had been in the original file. Data were exported to a tabular scatter point 3D file (*.xyz) and then successfully imported into GMS 3.0. The original *.xyz files was saved as an *.sp3 file and then imported into EQuIS Chemistry; the data structure and content were unchanged during export.

4.3.1.3 EQuIS DVM Functionality Test Results

The EQuIS DVM is linked to the EQuIS Chemistry module and imports project file data maintained in the Chemistry module. The imported data are subjected to an array of verification/validation functions. The DVM reports data qualifiers or "flags" relative to pre-set Quality Control (QC) criteria. Preset criteria are written into the DVM software as previously established by USEPA Guidelines or specified in the pertinent analytical method; these can be edited. System Administration Functions maintain defined users and user levels. The module also provides access protection for users without system authorization to the Chemistry module. As claimed by the vendor, some important data verification and validation procedures are not performed by the DVM version tested. Among these are chain of custody reviews, temperature of samples as received by the

laboratory, instrument performance data, internal standards, external standards, retention time windows, interference results, serial dilutions, appropriate selection of constituent data from subsequent dilutions, and selection of best results for samples re-extracted and /or re-analyzed due to QC performance problems. These items still need to be addressed by a person performing a manual review of the project data.

Overall, the system performed several tasks well. However, three functions either performed inconsistently (Precision function and Blank Ratio) or did not perform as expected (Flag Order function). These problems have a significant impact on the application of the software for data verification tasks. The software was easy to use. Data loaded to the DVM using specified project code from Administration (project setup) and verified data quickly with the module (depending on test data involved), with a range of 55 seconds to 7 min and 45 seconds. Nine DVM functions were tested: 1) System Administration, 2) Analytical Methods Table, 3) The Hold Time Function, 4) The Blank Ratio Function, 5) The Flag Order Function, 6) Accuracy Function, 7) Precision Function, 8) Semivolatile (SVOA) Analytes, and 9) Settings/Default. The DVM functions tested and the corresponding results are described in the following subsections.

System Administration

System administration was tested to verify security measures were in place to prevent unauthorized access through the DVM into the Chemistry module (see Section 4.3.2.3 for a detailed description of System Administration). Three items were designated for testing: 1) access to the database with a fictional ID, 2) operation of the system at a higher user level than defined, and 3) access to the system as a deleted user.

Overall, the System Administration provided adequate security for a controlled implementation of the DVM and Chemistry modules.

Database Access Using a Fictional ID - This test was designed to verify security from unauthorized access using an incorrect or fictional identification.

The system performed as claimed by the vendor; access was denied using the fictional ID.

System Operation at a Higher Lever Than Defined - This test was designed to evaluate whether a user could operate the system at a level higher than previously defined for that user level.

This test was not attempted since the tutorial software already operates at the highest user level.

Database Access Using a Deleted User - This test was designed to verify security from unauthorized access using a deleted user identification.

The system performed as claimed by the vendor; access was denied to the deleted user.

Analytical Methods Table

The Analytical Methods Table provides a list of standard analytical methods. The table was tested to verify that the table could be used and modified as expected. Four specific functions were tested: 1) methods were compared to those in DVM Data 2) a new method was added to the table, 3) a method was deleted from the table, and 4) the deleted method was added back to the table.

Overall, the Analytical Methods Table provided adequate versatility for the use of a wide variety of project data. The table was easy to use. Specific results are as follows.

Compare Methods to the DVM Data - This test verified whether the Analytical Methods Table functioned correctly with respect to the evaluation using DVM Data (Martin Aaron site).

All method references were verified as correct.

Add a New Method to the Table - This procedure tested the ability to update the list of methods with new or revised methods not currently included.

Method numbers 8280 and 8290 for dioxins/furans were successfully added to the Analytical Methods Table.

Delete a Method from the Table - This evaluation verified the ability to remove methods that are no longer used.

Method numbers 8280 and 8290 for dioxins/furans were successfully deleted from the Analytical Methods Table.

Replace a Deleted Method In the Table - This test evaluated the ability to replace a method that had been accidentally deleted or to re-instate an outdated method to accommodate the use of historical data. Method number 8290 for dioxins/furans was successfully added back to the Analytical Methods Table.

The Hold Time Function

The Analytical Methods Table also provides criteria fields for the evaluation of holding times and maintains the necessary fields for sample-specific data (date fields) relative to holding time calculations. Data imported from EQuIS Chemistry were evaluated against these reference fields for holding time violations. The Hold Time Function was tested to verify that holding time violations, historical data, and Y2K sensitive data would be reported accurately. This function performed as expected and was easy to use.

Hold Time - This test evaluated DVM's hold time determination function for information accuracy.

Test method 9060 has a Technical Holding time of one day. The DVM correctly flagged data from a sample that had a lapse time of 18 days between collection and analysis. During the evaluation for older project data, the sampling date was successively changed to 5 and then 10 years before the sample preparation date. The DVM reported the 5 and 10 year lapse between sampling and preparation as a holding time violation and correctly flagged the affected results.

Historical Data - This procedure evaluated the ability of DVM to accurately handle data and information from older projects (defined as before 1/1/00).

Sample date fields were populated with sampling dates of 8/20/94 and 8/20/89. The DVM used the dates correctly.

Y2K Compliance - This test evaluated whether data that bridged the Y2K threshold were appropriately handled.

A sampling date of 12/21/99 was used and an analysis date of 1/2/00. These dates were used correctly and reported accurately indicating Y2K compliance.

The Blank Ratio Function

The Blank Ratio Function records blank contamination and assesses the impact to associated environmental samples with respect to the USEPA 5x/10x rule. This rule establishes an analyte specific factor (ratio) by which the blank contamination is multiplied. This process sets a QC screening action level below which the analyte is considered an artifact due to the observed chemical contamination and the affected result is flag U (non-detect). The Blank Ratio Function was tested to verify that the DVM would: 1) correctly report contamination present in a blank, 2) accurately report analyte-specific action levels, and 3) correctly assess and report the affect on sample results. This testing was accomplished using a variety of methods, analytes, blank contamination levels, and variations of target compound concentrations in the affected field samples.

During the EQuIS Demonstration Project the DVM, reported both false positive and false negative data. False positive data were represented by many analytes (VOCs, SVOCs, pesticides, and metals) with concentrations below the QC action level that should have been flagged by the DVM but were not. False negatives were represented by heptachlor and chlordane, each with a concentration of 26 µg/kg and flagged U. The Blank Ratio (5x) action level for these compounds is reported correctly by the DVM as 25 µg/kg for the observed contamination of 5 µg/kg. This means that no sample result greater than 25 µg/kg should be qualified. In the case of metals, no data were flagged in any of the samples and the DVM reports did not indicate the presence of contamination in the blanks. The original EarthSoft DVM data had low level contamination in the blanks that were not acknowledged. The SITE EQuIS Demonstration test data placed a high level of lead contamination in the blank and an equal concentration in the field samples with the same result. Populating the database for metals used the same procedure as for organics with the exception that laboratories do not flag metal data with a B for blank contamination. Accordingly, B flags were used for organic data but not for metals. This is in keeping with USEPA guidance and analytical laboratory industry standards. The failure of metal data to register at all appears to be relational. These determinations are critical in that investigation data should not have false positive or false negative data. Mismanagement of data at the validation level may have expensive downline consequences with respect to risk assessments and remediation decisions.

As this function is one of several useful features of the DVM module, these problems are considered to have a fairly severe impact on the software's usefulness.

The Flag Order Function

One important goal of data validation is to determine the degree to which project data are compromised by any observed problems. The correct ranking and application of QC problems is essential in achieving this goal. In assessing all applicable review items, the most appropriate flag for a given data point, indicative of the most serious quality issue associated with the sample data, can be determined. This test evaluated the ability of the Flag Order Function to ascribe the most stringent flag applicable to a result where multiple flags of different severity were indicated by the supporting QC data. For example, a J flag qualifies a sample result as an estimate and an R flags indicates data were not usable. To reject data (R) is the more severe determination and should be the most stringent flag assigned.

In the test of the created test data, estimated DDT and heptachlor were flagged with a U as a result of blank contamination and were later appropriately flagged with the U instead of a J in the precision summary. This was the expected outcome. However, in a second DVM report DDT and heptachlor were flagged with a U for blank contamination and later (in the surrogate summary), flagged with a J (less severe) instead of the U. This outcome was not correct according to the flag order. These failures indicate that this function did not perform as claimed.

Accuracy Function

The Accuracy Function was tested to verify the correct use of certain QC criteria percent recovery data and proper qualifier application to the affected sample data.

Pesticide tests used various high and low percent recovery data, including 1 percent under the low QC criteria and 1 percent above the high QC criteria. The test also used percent recoveries below 10 percent (non-detects were correctly flagged R) and equal to 10 percent (non-detects were correctly flagged UJ).

Precision Function

Precision is a measured comparison of substantially similar data

points using the RPD as the indicator of their closeness. The correct application and reporting of precision data is important to interpretations of the current project data and decisions concerning potential additional data needs. The Precision Function was tested to verify the correct use of certain QC criteria (relative percent difference or RPD) and proper qualifier application to the affected sample data.

Several concerns were noted during the evaluation. The RPD did not appear to be calculated correctly (the unspiked sample was compared to the spiked sample result). While the DVM report flagged sample results impacted by outlier RPD values, the wrong RPD value was used. In addition, the DVM report column used to present RPD data was missing the appropriate results. These failures indicate that this function did not perform as claimed.

Semivolatile (SVOA) Analytes

The Semivolatile (SVOA) Analytes function was tested to verify the correct use of surrogate percent recovery criteria and ensure proper qualifier application to the affected sample data. Semivolatile compounds are segregated into one of two groups. The groups, acid and base, are named for the type of sample preparation that is performed to maximize the extraction efficiency of distinct chemical classes.

The DVM correctly flagged SVOA results according to acid/base fraction assignments for out of control surrogate recoveries.

Settings/Default

Tab 1 was tested to verify the correct use of dilution factors and appropriate application of volatile surrogate QC data. The Tab 1 setting provides a function for allowing "out of control" surrogate recoveries in a diluted sample. The Test Plan was written to test a 5:1 dilution threshold. (Dilutions of 5:1 and greater were believed to be the DVM criteria.) The dilution threshold actually starts at 6:1 per EarthSoft DVM Manual.

Three reports were generated. Dilutions of 10:1 and 5:1 were set in the first two reports with the Tab 1 option selected and not selected, respectively. The system passed the test at 5:1 (the DVM flagged data for out of control surrogates). On a re-test at 6:1, the DVM passed as it did not flag data for out of control surrogates with the Tab 1 option selected, reflecting the impact of dilution on surrogate recovery.

4.3.1.4 EQuIS Geology Functionality Test Results

The EQuIS Geology Module consists of linked database tables, and a menu system that supports a number of functionalities. In total, eight functions were evaluated: 1) Getting Around, 2) Preferences, 3) Material and Material Groups, 4) Unit Calculator, 5) System Administration, 6) Manual Data Entry, 7) Editing and Viewing Functions, and 8) Quick Reports. The first four of these related to the customizability and ease of use of the user interface windows. System Administration is similar to what was described in Section 4.3.1.2; it consists of user and project administration and maintenance functions. Once a project has been created, the first step in using EQuIS Geology is getting data into the project. Data may be brought into EQuIS Geology either manually or electronically. If the data are available only in hardcopy format, they may be entered manually through data entry screens. However, if the data exist in electronic format either in text files, spreadsheets, or another database, data can be imported automatically. In most cases, electronic data import will be used at the outset of a new project. Where data currently reside in text files, they can be imported into the database. When data are present in spreadsheets, electronic data import requires only a properly formatted text file. Only Manual Data Entry was evaluated under Primary Objective No. 1, because data import to EQuIS Geology was evaluated under Primary Objective No. 2 (see Section 4.3.2.2.) The ability to accurately view and edit tables was evaluated for two groups of operations: Data Table Maintenance and Reference Table Maintenance. Finally, the reporting capabilities in EQuIS Geology were accessed through Quick Reports.

Getting Around

Several data management tools are used with the EQuIS Geology system. Understanding how to use the system helps the user avoid unnecessary errors.

This test consisted of an evaluation of the ease of use and functionality of four specific functions: 1) System Screens, 2) Data Grids, 3) Lists, and 4) Query Tool. The first three performed as claimed by the vendor; the fourth function had a mixed result, as described in the following paragraphs.

System Screens - Within the program there is a general pattern followed on most screens. Logic flow (and description in this manual) proceed from upper left panel to upper right panel to bottom panel.

The borehole, well, and sample data entry system screens were opened and verified that the logic flow proceeded from the upper left to the bottom right, as stated by EarthSoft.

Data Grids - Many modules within EQuIS Geology use data grids to display data. These grids are a flexible interface between user and data. When using a data grid, the user may: 1) change the order of the columns; 2) change the width of the columns; 3) select an individual record (row); 4) select multiple records; 5) enter or edit data within the cells of the grid (except when data are specified as read-only); or 6) select a field value from a drop-down list (when applicable).

Manipulation of the data grid and the data within it were very straightforward and logical.

Lists - Lists are used in system screens for choosing what table or

borehole data the user wants to display or edit, changing the units of depth, and selecting fields in a query. Basically, lists allow the user to choose a value or a record, where multiple values or records can be associated with a given field. There are two types of lists: drop down lists which allow the user to select only one value and list boxes which allow the user to select multiple values.

- **Drop-Down List** - A drop-down list is signified by a down arrow at the right of a data field. When this down arrow is clicked, the list appears. To select an item from the list, simply click on the desired item.

  Drop down lists were tested using the Borehole, Well, and Stratigraphy view screens. Selecting a borehole identification (ID) in the upper left panel changed the displayed data in the rest of the fields to those data associated with the selected ID. Drop down lists were also tested (as part of Materials & Material Group maintenance tests below), for changing the status flag for records, by choosing an accept or reject flag (A or R) for that field.

- **List Box** - A list box is a box that lists one or more columns of data (information). List boxes were tested in export screens for Surfer, GMS, and LogPlot.

  List boxes were used to select multiple (non-continuous as well as continuous) export records, and checked for navigation scroll bars when the entire list could not be displayed on a system screen. The lists performed as claimed by the vendor and the design was found to be intuitive. Even for a user without any spreadsheet or database experience, these lists will be easy to use because extensive online help is provided with the software.

Query Tool - This tool is available in Data & Reference Table Maintenance (under the Edit Menu), and in export screens (under the File/Export Menu) of the Geology module and can be accessed by clicking on the QueryTool button**.** Once a query has been outlined by the user, the Query Tool can be used to actually perform the query. The user can choose to display records according to his/her criteria, which could be easily specified in the bottom part of the Query Criteria screen.

A query was designed and saved to a file for later use; its SQL script was also displayed. The query tool functioned flawlessly in multiple queries that were performed. However, there was no option to recall or invoke a previously saved query in the Query Criteria screen. EarthSoft confirmed that this version, as well as subsequent versions, do not support this feature to prevent users (other than the SUPER user) from accidentally modifying the structure of the data or reference tables.

Preferences

EQuIS Geology allows the user to customize the program and databases for the users needs through preferences. Program preferences may be set in the Preferences screen, displayed by selecting Preferences from the File menu. After the user has selected the desired preferences, clicking OK will save and activate these preferences, whereas clicking Cancel will ignore the changes the user has made. The user can specify Screen Preferences, Unit Preferences, Import Preferences, and Miscellaneous Preferences; only the first two of these were evaluated.

Screen Preferences - Screen Preferences allow the user to change background color, select between two sizes for toolbar buttons, and to remove the toolbar entirely from the display.

All of these functions worked as stated by the vendor and changes were saved upon exiting the module.

Unit Preferences - Unit Preferences allow the user to specify length units for data being electronically imported or exported. They do not change the units of depth already entered (or manually entered) into the EQuIS Geology system.

It was verified that a chosen unit length was saved upon exiting the system.

Materials & Material Groups

EQuIS Geology is available with three standard material classifications (USCS, AASHTO, and USDA) and a fourth category that contains petroleum and mineral resources called Other. However, because these materials may not necessarily meet all of the required material definitions, other materials and material groups may be added. For each material a definition and color may be defined. Material groups allow the user to group materials that are common to a specific project or site. The user may create additional groups if needed for a specific project. User-defined groups may contain any combination of standard or user-defined materials and may be updated as needed.

During this test, new groups and new materials were successfully added, and then used during data entry. A new material group was created and both existing and new materials were added to that group. The evaluator verified that duplicate material groups, as well as duplicate materials, were appropriately rejected by the software. However, two problems were noted with the patterns used to denote material groups. First, no information was available in the EQuIS Geology module for patterns corresponding to various standard geologic materials. A list of default patterns corresponding to one or more standard geologic classifications systems would be useful. Secondly, although material properties for any geologic material can be assigned only globally, and cannot be different in different material groups for a given project (appropriately preventing inadvertent duplication of materials), this feature was not clearly explained on the Material Group Maintenance screen. These two issues deal primarily with ease of

use and, therefore, were judged to be minor; this function worked essentially as claimed.

Unit Calculator

The unit calculator is a simple tool to do unit conversions. This tool may be useful not only for users of EQuIS Geology, but also in any office, laboratory, or classroom setting where geologic, geotechnical, or hydrogeologic calculations are required. To access the Unit Calculator, select *Unit Calculator* from the Tools menu or type <*CTRL*> + <*U*>.

This Unit Calculator tool was tested, by carrying out two sets of conversions (English-Metric and vice versa) for each of seven entities: length, area, volume, mass, density, pressure, and temperature. These conversions were checked with a hand calculator for accuracy. The calculator tool provided with the EQuIS Geology module was found to be accurate and easy to use.

System Administration

Management of EQuIS Geology projects is carried out with the System Administration module. In System Administration new projects are created, users are established and assigned to various projects, and the location of third-party visualization and analysis tools is designated. Each user should have a unique name and password, with which they may log into the EQuIS Geology system.

Major User and Project Administration functions, including customizing user and project access for different levels of users were evaluated. Both functions essentially performed as claimed by the vendor, with the exception of part of the user access test (see details below). Overall, user administration was easy to use and could be implemented securely by any system administrator with super user access to the EQuIS Geology system.

User Administration/Maintenance - To maintain data security within EQuIS Geology, each user is established in System Administration. When a new user is created, a login name and password (as well as user name and directory) are recorded. When logging into the program, the user must use his/her login name and password to access EQuIS Geology. When a user is created, he/she may choose whether or not to give administration access. If they are given administration access, they can use System Administration to create, edit, or delete projects and users (see Section 4.3.1.2 for additional description of User Administration).

The User Administration Maintenance function worked as claimed. Four new users, called Casual-Martin, Operator-Martin, Power-Martin, and Super-Martin, were created with appropriate permissions to cover all four types of project access levels built into the EQuIS Geology module. The *User Administration* screen was very easy to use and followed the same upper left to lower right logic flow that was common to most EQuIS system windows. Super-Martin was used to add another user Casual – MA. This user was later deleted as part of the testing. It was noticed that deleting the user does not delete the user directories. This was, however, easy to do from the Windows Explorer screen, and does not affect the overall functionality of the module. It was also verified that a user without administration privileges could not add a new user. Overall, user administration was easy and could be implemented securely by any system administrator with super user access to the EQuIS Geology system.

Project and Database Maintenance - When a project is created, the system administrator will enter a project name, project code, and path to the project database. Other information such as project start date, site, client, and project manager may also be entered when creating a project. This information (except for the project code) may be changed later through System Administration. When a project is created, the system administrator may choose which users may have access to that project, and what type of access those users have to the project data. In addition to indicating which users can access each individual project, System Administration allows users to access project data with different access levels. Lower user access levels allow users to view and export data. Higher user access levels allow users to import and edit data in addition to viewing and exporting data. In addition to the business context of the data management plan being employed, there are also security considerations. EQuIS allows multiple levels of password-protected access in the system that are generally sufficient for stand-alone, single-system operations. For network environments with both local and modem access, additional security measures such as storing client data only on non-network accessible media may be in order if the user is unsure about the security of existing system "firewalls" and other protective devices. A consultation with the user's network system administrator is particularly useful in planning for secure operation of the system and protection of the data. Four functions were evaluated under Project and Data Maintenance: 1) File and Directory Organization, 2) Creating New Projects, 3) User Access to Projects, 4) Modifying Existing Projects, and 5) Editing/Deleting Projects.

- **File and Directory Organization** - EQuIS organizes data into directories that are set up through the system's administration and user registration processes. Naming and relationships established between the directories used should reflect the business context of the data that EQuIS is intended to manage. An example of project organization is to place all project files in directories named after the projects. (For example, c:\earthosft\geo\projectname).

  File and directory organization were tested. Changing program path field information and adding new programs was an easy process which was intuitively organized in the Applications Location Maintenance screen. The process involved replacing the path of the original application location with the new application path in the Applications Location Maintenance screen.

- **New Project** - Similar to the Chemistry module, the EQuIS Geology moduel is based on projects which contain geologic data. These data are stored in a Microsoft Access© database. Subsection 4.3.1.2 provides additional information on project administration.

  A new project was successfully created for this evaluation. As part of the EQuIS Geology SITE project, a database was created and filled with 34 records of borehole and well data. It was verified that a Template database was first copied over to the location of the Martin-Aaron project working directory, with the indicated database name. Users created through the User Administration test above were given access to this project, covering all possible access levels allowed in EQuIS Geology.

- **User Access** - User access to projects is controlled through System Administration to maintain data security. As with the Chemistry module (see Section 4.3.1.2), there are four user access levels: casual, operator, power, and super.

  The test of user access to projects yielded mixed results. The Martin-Aaron project was created by the SUPER user and project access was tested to confirm that it was governed by the accessibility hierarchy prescribed by the vendor. The evaluator verified that users could access only the projects to which he/she was assigned. In addition, only super users could access the System Administration module to be able to modify other users' access – Casual, Operator and Power users appropriately could not access the System Administration screen. However, several other parts of this function failed to perform as claimed by the vendor. First, the casual user (Casual-Martin) could modify the database even though permission had not been granted. Secondly, the operator user (Operator-Martin) could not import data, a function for which he/she was authorized. Finally, the Power and Super users (except the SUPER user) could neither edit nor view the data/reference tables or groups. All of these observations run contrary to the hierarchy prescribed by the vendor. EarthSoft claims that these issues have been rectified in later releases of the software; however, SAIC was not able to verify this claim due to schedule and monetary constraints on the project.

- **Modifying an Existing Project** - Projects can be modified by super users. This test was designed to verify that the modified project information was saved upon closing and reopening EQuIS Geology.

  Only the user SUPER and other super users can modify the status of an existing user, including other super users. However, since users at lower levels of hierarchy cannot even access the System Administration screen, they cannot modify any users. Therefore, this test was successful. This function was easy to use and was designed intuitively.

- **Edit/Delete** - Several controls are important to ensure that project edits are made only by authorized personnel. In addition, it is critical that project files can not be improperly duplicated or accidentally modified. The ability to edit/delete a project is available to only super users. Error messages are produced when a new project with the same name as an existing one is created or when an existing project database is specified for a new project.

  Editing and deleting projects was easy and straightforward to use; all functions worked as claimed by the vendor.

Manual Data Entry

Three main data 'objects' exist with the EQuIS Geology data structure: borehole, geologic sample, and well. Each object must have a unique ID. EQuIS Geology has four specific kinds of data inputs: borehole, well, sample and stratigraphy. The accuracy and ease of use of data entry functions for six types of geology data were evaluated in this portion of the test. The data types were: 1) borehole, 2) well, 3) water level, 4) well segment, 5) sample, and 6) stratigraphy.

Each of these functions performed the basic tasks claimed by the vendor for data entry. It should be noted, however, that there were two basic types of issues related to the use of each of these functions. First, several functions lacked QA checks where the evaluator thought them appropriate. Secondly, a number of functions provided no way to correct data entry errors, often resulting in the loss of data already entered. Overall, the data entry functions passed the test, but they could be modified to improve the user friendliness of the system and prevent simple data entry errors.

Borehole Data - Borehole data consists of X Coordinate, Y Coordinate, Surface Elevation, Longitude, Latitude, Confined Water Level, Unconfined Water Level, and Aquifer Zone. For every borehole location, construction and water table information may be directly associated. Additionally, the drilling or sampling method may be described and the stratigraphy defined for every borehole.

Borehole data entry was easy. All borehole data were entered, edited, and deleted from a screen that was dedicated to borehole data input. Entering an already existing borehole ID displayed all data on the existing borehole. If data did not exist, data fields remained blank. Saving the edits to a borehole saved the data when the borehole ID was pulled up after exiting and restarting the Geology module. Deleting a borehole ID removed all of the

daughter objects (well, sample, and stratigraphy data) for that ID. The user was prompted to make sure he/she wanted to delete the ID. If a user wanted to change only the name of the borehole without changing the rest of the information under it, he/she had to use the Access database to edit the borehole ID directly. Because the borehole name is a key field for most tables in the database, this change needed to be made in multiple Access tables. This was a time-consuming task and could be prone to user errors.

Well Data - As with borehole data, well data will typically consist of location, construction, and water table information. Since a well typically coincides with a borehole in the same location, they share the same unique ID, x, and y coordinates.

Entering well data was easy. All well data were entered, edited, and deleted from a screen dedicated to well data input. Entering an already existing well ID displayed all of the data on the existing well. If data did not exist, data fields remained blank. Data were successfully entered for about 16 wells in creating the MartAron.mdb database. It should be noted that changing well data did not change borehole data because the borehole was the parent object, and its information was grayed out and uneditable from the well data entry window. The same issue that applied to changing only the borehole name applied to wells data entry. Deleting a well did not remove the borehole because the borehole was the parent object. The user was prompted to make sure he/she wanted to delete the ID. If the user accidentally deletes a well, there is no Undo option. All of the data have to be entered again, unless the user is deleting the well record from inside the Access database.

Water Level Data - Water level data include date and time of measurement, reference elevation, depth and elevation, technician, batch number, comment, and dry indicator.

Water level data were entered in the Well data screen by clicking on the Water Levels tab. The fields in this screen included date and time of measurement, water level depth and elevation, reference elevation, and technician. These fields could be edited from the Water Levels tab. Deleting a water level was accomplished by selecting a record to delete and clicking the delete button. There were a number of issues with this data entry window and, although they do not affect the module's overall functionality, they have the potential of wasting time by a) not checking for incorrect data entry format in some fields (data and time); b) not being specific in its error messages before it shuts down; c) shutting down the entire well data screen without giving the user a second chance; d) and lastly, by not prompting the user to save well segment data before moving on the water level data entry. In addition, there was no check to make sure that the depth to water level from the top of casing (TOC) and water level elevation sum up to the TOC elevation.

Well Segment - Well segment data include start depth elevation, end depth, inner diameter, outer diameter, material, and comment. Well segment data were entered in the Well data screen, by clicking on the Well Segments tab. Entering data was intuitive and the screen was easy to use. Deleting a well segment was accomplished by selecting a record to delete and clicking the delete button. There were two issues with the well segment data entry screen. First, if well segment data were not entered, the Well Data screen crashed after displaying an error message, and all data had to be re-keyed. The user did not get a second chance to re-enter a new well segment type. Secondly, the program did not check whether the inner diameter was less than the outer diameter and also did not check that the well start depth was less than the end depth.

Sample Data - A geologic sample is defined as a physical sample of the media taken from the borehole. This may be drill cuttings, or a pushed or driven sample; however, it is important to note that this is not sampling data used for analytical chemistry. Sampling and drilling parameters typically acquired in the field such as SPT blowcount and recovery may be associated with each sample. Additionally, laboratory parameters that typically come from geotechnical laboratory tests may be assigned to the same samples. These data (i.e. porosity, hydraulic conductivity, etc.) may then be used as input parameters in groundwater flow models. Samples may also be defined irrespective of location, such as material taken from the bucket of a loader in the construction of a road to be tested for quality control. EQuIS Geology allows the user to enter various types of sample data. These data may be entered, edited, or viewed from the Sample Data screen. The Sample Data screen displays information about the borehole that the current sample is associated with. This information cannot be edited.

Sample data were entered, edited, and deleted from a screen dedicated to sample data input. This screen could be accessed either from the Edit/Sample menu or from the Sample button from the EQuIS Geology screen tool bar. Deleting a sample was as simple as selecting the field value to be deleted and hitting the delete key on the keyboard. Two issues with this input screen: a) there were no data checks in place during the data entry process, for either the Sample Parameters, or for Static Props data, and b) if a sample ID existed, the corresponding records were pulled up. There was no way of editing just the sample ID while keeping the rest of the data fixed, unless the database was accessed directly from Access. That involved a cumbersome update of multiple linked tables in the database.

Stratigraphy - In addition to location information, each borehole ID may have an associated stratigraphic description. The stratigraphy may be defined on a layer-by-layer basis as well as on a larger scale geologic unit basis. The stratigraphy information may be used to create boring logs or for solid modeling. The X and Y coordinates may vary from layer to layer allowing non-vertical boreholes. The field immediately below the X and Y coordinate fields is used to indicate the top of the current stratigraphic layer either in depth or elevation (according to the entry option set in the Borehole Data screen).

- The Geologic Unit field allows the user to group lithologic layers together in units. The user may choose an existing geologic unit by selecting from the drop-down list. The user may also enter a new geologic unit by typing the name and clicking *Yes* when prompted to add a new geologic unit.

- The Material Group box allows the user to select the group from which available materials will be displayed. In addition to the four system groups (AASHTO, USCS, USDA, OTHER), the user may create custom groups to which he/she can assign any material. The user may also create new materials. The user may also change between groups for different layers in the borehole.

- The Description box allows the user to store a description of a lithologic layer. Each layer may have two separate text descriptions. A description may be entered while adding the layer. A description may also be entered (or edited) by selecting a layer in the grid and typing in the description.

Add Layer/Change Material is used to add a new layer to the stratigraphy or modify and existing layer. If the user has entered a new depth (or elevation), this button reads Add Layer. Delete removes the current layer from the defined stratigraphy. The top layer may not be deleted, only modified. When any succeeding layer is deleted, the material of the overlying layer is assumed where the deleted layer previously existed. Graph Labels On toggles the display of depth/elevation labels on the borehole graph. In cases where several layers exist within a short vertical interval, the labels may run together and it may be preferable to turn the graph labels off. This affects only the display of the Stratigraphy screen and has nothing to do with any logs that may be created. Geologic Units toggles the display of geologic unit labels on the borehole graph. The user may wish to view the graph with the geologic units labeled or the stratigraphy alone.

Stratigraphy data were entered, edited, and deleted from a screen dedicated to stratigraphy data input. That screen could be accessed either from the Edit/Stratigraphy menu or from the Stratigraphy button from the EQuIS Geology screen tool bar. Stratigraphy data were successfully entered for 34 boreholes in conjunction with other borehole data, while creating the MartAron.mdb database described in the data and borehole sections above. Data entry is very easy. Data flow was roughly from the top left to the bottom. New materials were added during the testing under Material groups above. The graphical display of colors was found to agree with the scheme chosen while creating the material and its group. Overall, the addition of stratigraphic levels was easy to perform using EQuIS.

Editing and Viewing Functions

The ability to edit tables accurately was evaluated for two groups of operations: Data Table Maintenance and Reference Table Maintenance.

Data Tables - Data tables contain dynamic or project data and are maintained in the project database (dt_tablename). These data can be edited or viewed using Data Table Maintenance. User access levels determine editing capability. The Table drop-down list on the Data Table Maintenance screen has three columns. The first column shows the common name of the table. The second column shows the actual table name (within the database), and the third column shows the parent table (if any). The View menu allows all users (all user access levels) to view data in the current project database. Data cannot be entered, modified, or deleted using any of the View menu options.

Accuracy of Data Tables was checked by opening them using MS Access. The Access Table was confirmed to display the same information as the Data Table. Viewing capability was tested for users of all levels and was found to be not accessible to anyone other than SUPER. The error was reportedly due to the fact that the evaluator's installation was an evaluation version of the software which does not support full security, as the full license version does. (It should be noted that the original software installation was made by EarthSoft). An observation regarding the Data Table Maintenance screen was that the data display window at the bottom of this screen could not be adjusted by itself. Its size was automatically adjusted in proportion to the window size. For large monitor screens, this wastes space that could otherwise be used to display additional data records. Logging in as the user SUPER, a new borehole "abc" was added to the database through the data table maintenance screen. The data table was closed, and then EQuIS Geology was closed. On restarting the module, the borehole was still in the data table. It was verified that casual and operator users cannot open the data tables for editing. But neither power nor super users other than the master user (SUPER) could access the data tables for editing in the evaluation version of the software. Also, none of the users created by the evaluator could even view the data tables as mentioned in the previous section, even though all users should have been able to do so. It was found that the safest way to add a new borehole is through the New Borehole screen (as discussed above) and the only way to edit an existing borehole is through the Borehole Data screen created by clicking on the Edit/Boreholes menu, instead of editing the data tables directly (due to the complexity of tracking all the key fields being modified in the affected tables). However, trying to change the key fields in a data table produced an error message. Therefore, editing data tables is convenient only when editing non-key fields.

Reference Tables - Reference data are maintained in the database only in the rt_ tables. These tables provide the information contained in the drop down lists of look up information in the system and are edited by system administrators and users with edit privileges. The *Table* drop-down list on the Reference Table Maintenance screen has three columns. The first column shows the

common name of the table. The second column shows the *actual table name* (within the database), and the third column shows the parent table (if any).

Accuracy of Reference Tables was checked by opening them using MS Access. The Access table displayed the same information as the Reference table. Logging in as SUPER, accept status flags were added for some materials in the Materials table through the Reference Table Maintenance screen. The reference table was closed, and then EQuIS Geology was closed. On restarting the module, the status flags chosen were still in the data table. The same problems were experienced with Reference Tables as had been experienced with Data Tables.

Quick Reports

Quick Reports are a simple way to get data from the project database into Microsoft Excel. These data may then be used for creating plots or formatted for reporting. The top panel of the Select Quick Report screen provides three different types of Quick Report Sources: Data Table, Reference Table, and Query. The Data Table source option provides a single data table to produce a report from. The Reference Table source option provides a single reference (look up) table to report from. The Query source option provides a list of previously-defined queries to use to select data to report. View Report will launch the viewing application and allow the user to view the report.

All steps involved in generating a Quick Report (constructing and running a query, and generating a report from the query results) were successfully carried out as part of testing this functionality. An issue with this functionality was that a report could be generated only from one table at a time. Even the Query tool allowed the choice of only one table or query at a time, and that was sometimes a limitation of this function.

4.3.1.5 EQuIS ArcView Interface Functionality Test Results

ArcView GIS software was created by ESRI as an geographic information system to that can be used to create and integrate visualization functions (charts, spreadsheets, CAD drawings, pictures, etc.); maps (land use, topographic, etc.); spatial analysis; and other functions using new or existing data sets.

The EQuIS ArcView Project Interface permits users to view EQuIS project data in the ArcView GIS environment. The Interface consists of linked tables, the EQuIS Location View, and a menu system that supports a number of activities. A total of fourteen functions were tested covering all aspects of this Interface. Twelve out of the fourteen functions passed their respective test. One function (EQuIS ArcView Default Project) had mixed results and one function failed (Recreate the Default EQuIS ArcView Project). The tests covered: 1) EQuIS Default ArcView Project, 2) Recreate the Default EQuIS ArcView Project, 3) Create Custom Project, 4) EQuIS-ArcView Project, 5) EQuIS Chemistry Menu-Change Layout Views, 6) Selection Tool Functionality, 7) Permanent and Temporary Theme Test, 8) Create Chemical Themes, 9) Create Chemical Chart, 10) Post Data, 11) Add Location Data, 12) Toggle Tool Theme, 13) Advanced Labeling, and 14) Cross Tab Reporting. This Interface was invoked from both the Chemistry and Geology modules. An ArcView project (martin_aron.apr), built from data collected at a hazardous waste site in New Jersey was used for testing purposes. This project contained borehole data, groundwater monitoring data and GIS overlays of the site. Thus it could be used to test Interface functions related to both the Chemistry and Geology modules.

The ease of use of the functions tested was facilitated by the graphical user interface. Most operations were point and click. Many operations had confirmation messages, informing the user that a particular operation was about to take place and providing the option to not proceed with the operation. The use of the EQuIS ArcView Interface does not require extensive training in the operation of ArcView. The menus and dialogs added to the standard ArcView interface from the EQuIS Chemistry and Geology extensions were intuitive and provided for the automation of ArcView functionality which was tailored to the EQuIS data. For users trained in ArcView, all of the basic ArcView functions were also available for use.

EQuIS Default ArcView Project

The user ArcView Interface supports two types of ArcView projects, the default project located in the EQuIS root directory, and custom projects that have been created by the user.

The EQuIS.apr ArcView project was successfully opened and saved. However, when Test_site.apr was opened through ArcView, the EQuIS Chemistry and Geology extensions could not be loaded. Message screens appeared from ArcView indicating that EQuIS ArcView Interface extensions cannot be loaded into a project unless that project is called directly from EQuIS.

Recreate the Default EQuIS ArcView Project

The Default Project is included with the Interface installation. It is named EQuIS.apr and cannot be modified. Work done in the EQuIS.apr can be saved as another filename. If the default project is damaged or deleted by accident, it may be recreated by installing the EQuIS Interface extension into a New project and saving that project under the name "EQuIS.apr". This project must exist in the EQuIS "shared" directory, e.g. X:\EQuIS\ESShared.

This test evaluated the ability to open the EQuIS ArcView project directly from ArcView. The default file could not be successfully recreated through the steps associated with this test. When the EQuIS extensions attempted to load, the following message appeared, “The EQuIS ArcView Interface extensions cannot be loaded into a project unless that project is called directly from EquIS.” The fact that EQuIS ArcView project cannot be opened directly from ArcView rather than from EQuIS is only an

inconvenience, not a system failure.

Create Custom Project
Custom Projects may exist in any directory for which the user has write permission. The EQuIS Interface will create a work directory for the custom project APR called \Eqarcwrk. The user must have write privileges to the ArcView working directory.

A custom project was created. The EQuIS extensions were retained upon opening. The project opened cleanly in the EQuIS ArcView interface called through the Geology module. The steps required to create the custom project and open it are all menu driven and could be easily navigated to create and open the custom project.

EQuIS-ArcView Project
An EQuIS ArcView session is started through the 32-bit EQuIS for Windows application. The user will be prompted by the Connect EQuIS – ArcView dialog screen to use the EQuIS default project, or to select an existing ArcView project. A list of ArcView projects that have been associated with a specific EQuIS Chemistry or Geology project is presented. The ArcView project to be used with EQuIS must have the EQuIS GIS extensions(s) installed. Six operations were tested under this function: add, delete, and set default each for Chemistry and Geology projects. All of these procedures performed as claimed by the vendor and were very easy to use. All steps were menu driven and easy to navigate - all mouse clicks and menu selections. Keyboard input was minimal, just one entry for a 10 character name of the ArcView project.

Add New Chemistry Project - ArcView - An existing project is made compatible with EQuIS by installing the EQuIS Interface extension and then saving the project. EQuIS functionality will only be available when the project is launched through EQuIS. An EQuIS ArcView session is started through the 32-bit EQuIS for Windows application. The user is prompted by the Connect EQuIS - ArcView dialog screen to use the EQuIS default project, or to select an existing ArcView project. A list of ArcView projects that have been associated with a specific EQuIS Chemistry project is presented. The ArcView project to be used with EQuIS must have the EQuIS GIS extension(s) installed.

This test was invoked from the Chemistry module. Through the project maintenance tab, a new apr was added to the existing EQuIS project. When this project was open in ArcView, the ft_field samples and dt_location tables were open. The user needed some basic familiarity with ArcView to navigate to the Table GUI to verify that dt_locations and dt_field_samples exist.

EQuIS-ArcView Project-Delete Chemistry-ArcView Project - This is an EQuIS-ArcView interface maintenance task. This option deletes an ArcView APR - EQuIS Chemistry project association. the actual ArcView project is not deleted from disk.

This test confirmed that an existing ArcView project could be removed from the Chemical EQuIS project. The path to the selected ArcView project was deleted from the GUI menu. A nice feature was the confirmation message, "You are about to delete the path to the ArcView Project, Continue?"

EQuIS-ArcView Project-Set Default Chemistry-ArcView Project This is an EQuIS-ArcView interface maintenance task. Setting an ArcView project as default moves the project to the top position in the ArcView APR list box. In subsequent ArcView sessions, the Connect EQuIS- ArcView dialog screen will display with this project selected. Multiple ArcView projects may be associated with each EQuIS Chemistry project. EQuIS Chemistry and Geology projects will have different associations.

This test confirmed that an existing ArcView Project could be set to the default in the Chemical EQuIS module. The existing ArcView project, martin_aron.apr in the ESShared directory was added to the EQuIS project and set as the default. This project opened successfully through the EQuIS-ArcView interface.

EQuIS-ArcView Project-Add New Geology-ArcView Project - An existing project is made EQuIS compatible by installing the EQuIS Interface extension and then saving the project. EQuIS functionality will only be available when the project is launched using through EQuIS. An EQuIS ArcView session is started through the 32-bit EQuIS for Windows application. The user is prompted by the Connect EQuIS - ArcView dialog screen to use the EQuIS default project, or to select an existing ArcView project. A list of ArcView projects that have been associated with a specific EQuIS Geology project is presented. The ArcView project to be used with EQuIS must have the EQuIS GIS extension(s) installed.

This test showed that a new ArcView project could be added to the Geology EQuIS project. The martin_aron.apr ArcView project was selected from the project list and successfully opened through the EQuIS-ArcView interface invoked from the EQuIS Geology module.

EQuIS-ArcView Project-Delete Geology-ArcView Project - This is an EQuIS-ArcView interface maintenance task. This option deletes an ArcView APR - EQuIS Geology project association. The actual ArcView project is not deleted from disk.

This test confirmed that an existing ArcView Project could be removed from the Geology-ArcView EQuIS project. The path to the selected ArcView project was deleted from the GUI menu. A nice feature was the confirmation message,"You are about to delete the path to the ArcView Project, Continue ?"

EQuIS-ArcView Project-Set Default Geology-ArcView Project - This is an EQuIS-ArcView interface maintenance task. Setting an ArcView project as default moves the project to the top position in the ArcView APR list box. In subsequent ArcView sessions, the Connect EQuIS - ArcView dialog screen will display with this

project selected. Multiple ArcView projects may be associated with each EQuIS Geology project. EQuIS Chemistry and Geology projects will have different associations.

This test verified that an existing ArcView Project could be set to the default in the Geology EQuIS module. The existing ArcView project, martin_aron.apr in the ESShared directory was added to the EQuIS project and set as the default. This project opened successfully through the EQuIS-ArcView interface.

EQuIS Chemistry Menu-Change Layout Views

When the EQuIS project is invoked the menu bar will display the EQuIS Chem options. Selecting either menu option will produce a dropdown menu containing EQuIS ArcView functions. The functions for the EQuIS Chem menu are described below:

- Full Data View - This menu option calls the default window configuration for working with EQuIS data - this consists of three windows containing the tables dt_location and dt_field_sample, and the EQuIS Location View.

- Full Location View - Selecting this option maximizes the EQuIS Location View and removes all tabular record data from the screen.

This test confirmed that Screen Views may be changed in the Chemistry application. The records selected on the map (63 out of 140) matched the records selected in the dt_locations table (63 out of 140). Upon invoking the clear selection tool, all records in the table as well as features on the map were deselected. This tool was easy to use; however, it did require the user to have some familiarity with the basic ArcView tools, menus, and buttons.

Selection Tool Functionality

EQuIS locations are selected by using standard ArcView methods. The Select Feature tool is applied to dt_location theme and the active theme. The clear selection tool clears all currently selected records and features.

This test compared selected features in the view with selected records in the dt_location table. The records selected on the map (63 out of 140) matched the records selected in the dt_locations table (63 out of 140). Upon invoking the clear selection tool, all records in the table as well as features on the map were deselected. This tool was easy to use; however, it did require the user to have some familiarity with the basic ArcView tools, menus, and buttons.

Permanent and Temporary Theme Test

To support the creation of chemical themes, each new chemical theme is identified as "Condition: Temporary" in the themes comment section under Properties. The condition of a theme, temporary or permanent may be toggled through the EQuIS menu. Both temporary and permanent themes may be manipulated using any standard ArcView tool or Avenue script - the user is not limited to the analytical capabilities provided by the EQuIS Interface.

This test verified that permanent and temporary themes were saved with projects. Two chemical data themes were created: query1_qry and heptachlor_qry. Query1_qry was toggled to be permanent. After saving the project and re-opening it, only the permanent theme, query1_qry was listed in the table of contents. This function was relatively easy to use but required knowledge of the interface to build a chemical data theme. However, this interface was entirely menu driven, and thus, easy to manipulate. A nice feature was the information screen that allowed the user to go back and toggle additional themes to permanent status prior to exiting this function. A temporary chemical data theme was created (styrene_qry). The attribute table for this theme was opened and a chart was made for the start depth variable. The project was saved, ArcView was exited, and then the project was re-opened. The temporary chemical data theme, styrene_qry was present in the table of contents. Creating the temporary chemical data theme was straightforward using the EQuIS Chemistry menu item. The user needed basic ArcView knowledge in order to create the chart. Prior to saving the project, the user was warned that associated charts and attribute tables would be deleted upon saving and exiting, unless the skip button was pressed.

Create Chemical Themes

The EQuIS GIS Interface provides a theme builder for working with chemical data. Building single chemical themes for analysis supports large EQuIS projects with a minimum of performance decay as file size increases. The "Building Chemical Data Themes" option invokes the Chemical Data Theme Builder window. The user is required to select the sample matrix, date range or task, total or dissolved, and a specific chemical. Non-required fields are set to represent the extremes for the samples and matrix selected; these include start and end depths and an all inclusive date range.

This test confirmed that chemical data themes could be created using several methods. The first chemical data theme was created from the ground water matrix, using endosulfan - all default values (35 out of 140 wells were selected). The second theme also used endosulfan with the start depth range as 10-40, end depth range 15-50, and the date range of 01/01/80 to 21/1/00 (1 out of 140 wells were selected). The third theme used toluene but reportable results and hits only were checked (14 out of 140 wells was selected). The fourth theme applied a color scale to the results. The screen for creating a chemical data theme was very easy to use. Check boxes and list boxes were a useful feature. The show SQL feature would be useful to programmers who require knowledge of the query statement built to create the chemical data theme. For testing screening levels, lindane was selected and GW screen level applied - 15 records were selected. For the second screening test, the GW screen was applied to the entire set of chemicals - 556 records were selected. The chemical data theme builder was easy to use - list boxes and check boxes were used to select screen criteria. It took

about 15 seconds to perform the screen against all the chemicals.

Create Chemical Chart
Using the ArcView charting function, the data in a chemical theme table can be displayed in one or more chart types (bar chart, histogram, scatter diagram, etc). If a Chemical Data Theme has been used to construct a chart, and this theme is to be deleted, the user will be presented with a dialog screen requesting that a decision be made about the theme. It may be "skipped" or deleted along with related charts and tables.

This test confirmed that data could be modified in the chemical charting function. Two charts were created from different chemical data themes - one chart for Lindane, one chart for a subset of all screened chemicals. After selecting the delete chemical themes item, the dialog box was displayed indicating the associated charts and attribute tables that would be deleted along with these themes. All temporary themes were then deleted from the view. An easy-to-use dialog box, indicating associated charts and tables to be deleted, was a helpful informational message. The user had the option to skip the deletion of these charts as an option.

Post Data
Selecting this option will produce a drop down list that permits the user to select the data field they would like to post. Data may be posted for the dt_location theme and all query themes. ONLY those locations currently selected will be posted. If no locations are selected, all locations will be posted. The Clear Posted Information tool clears all labels from the EQuIS Location View for all visible themes.

This test verified that data can be posted. From the chemical data theme query1_qry, sys_loc_code values were posted for all wells in the table. Two wells were selected from the attribute table. The sys_loc_code for the selected wells matched the sys_loc_code posted on the view. All posted values were deleted after selected the clear posted values menu item. It was extremely easy to use this menu item. It required only one mouse click, then the selection of an attribute from a list box. The only drawback to the GUI was that the attribute names appear to be truncated in the list box.

Add Location Tool
The Add Location capability permits users to create a new EQuIS Chem or Geo location by selecting a point in the EQuIS Location View. The Add Location tool is available while the EQuIS Location View is active. New locations are included and the dt_location legend updated after saving the ArcView project.

Two locations (t1 and t2) were added to the view and the dt_locations table using the add location tool. The presence of two additional records in the dt_locations table was verified. This was a very simple tool to use - the user placed the cursor on the map where the location was to be added, then a dialog box popped up prompting the user to add in the attribute information such as sys_loc_code, description, elevation, etc.

Toggle Theme Tool
Themes may be toggled between "temporary" and "permanent" by selecting the Toggle Theme tool. After this tool has been selected, highlighting a theme's legend will produce a dialog window that allows the user to modify the theme condition. Multiple themes may have their status changed before closing this window.

The chemical data theme query1_qry was toggled from permanent to temporary. The project was saved, then exited. Upon re-opening, query1_qry was not in the table of contents. The toggle tool was easy to use - one mouse click changes status from permanent to temporary and vice versa. A dialog box was displayed providing information about what associated objects (i.e., tables, charts) would also be deleted. The user had the option to skip these deletes.

Advanced Labeling
The advanced labeling tool allows the user to select a location from the current theme, drag a leader to the position for the label, then identify those fields to be included in a feature label.

Using the advanced labeling tool, two fields were checked on for display (sys_loc_code and primary site code). These fields were posted on the map and verified in the associated attribute table. For the site selected, two features were co-located, a soil boring and a monitoring well - both were labeled correctly. This tool was easy to use - check boxes enabled the display of user selected attributes. The use of a leader was helpful to offset the label from the feature.

Cross Tab Reporting
The cross-tabular report tool allows the user to produce a report window detailing chemical data for a selected location. Reports are created by selecting the cross-tab report tool then selecting a location from the EQuIS Location View. Data from the active theme are used. Chemical data themes that have been created using the Screening Level option include the threshold value applied to each chemical.

A chemical data theme was created for ethylbenzene. The cross-tab tool was selected and locations were selected from the view. A comparison of the cross-tab report and the attribute table for the chemical data theme showed that the same stations were selected in each window. It was not intuitive that the cross-tab tool is also used as the selection tool for the stations.

4.3.1.6 EQuIS CrossTab Report Writer Functionality Test Results

The EQuIS CrossTab Report Writer is a tool that can be used in conjunction with EQuIS Chemistry. The interface allows users to quickly create complex cross tab reports - using data from existing EQuIS Chemistry project databases. The versatality of the EQuIS

CrossTab Report Writer allows users to design various types of cross tab reports with this interface. The CrossTab Report Writer module functionality evaluation was divided into four major sections: 1) Initial User Access; 2) Open a Project; 3) Close a Project; and 4) Open, Submit, and Save a New Query and Generate/Save a CrossTab Report Developed From That Query. The results for each of these sections is described below. All functions that were tested performed as claimed by the vendor.

Initial User Access
As with the Chemistry and Geology modules, it is important to assign and control user access. User access to the data within the Chemistry module is critical to the creation of cross-tab reports.

After system log on was successfully completed using Login Name "SUPER" and Project Code "NJ Demo Test" the CrossTab Report Writer screen appeared This function was easy to use and performed as claimed by the vendor.

Open a Project
The ability to open projects is a basic function necessary to use chemistry data to create cross-tab reports.

The "tutor" project was successfully opened by selecting File . . . Open Project and then selecting "tutor" from the Project Code drop-down displayed by the EQuIS CrossTab Report Writer Login screen. After the tutor project was selected, "EQuIS Project = "tutor"" was displayed on the bottom left corner of the EQuIS CrossTab Report Writer screen. This function was easy to use.

Close a Project
The ability to close projects is a required function to maintain project security and integrity.

The "tutor" project was successfully closed by selecting File . . . Close Project from the main menu. After the tutor project was closed, "no active EQuIS project" was displayed on the bottom left corner of the EQuIS CrossTab Report Writer screen.

Open, Submit, and Save a New Query and Generate/Save a CrossTab Report Developed From That Query
The query function is integral in the preparation of cross-tab reports. Queries allow the user to identify and pull into CrossTab Report Writer specific data required for certain reports.

The results of a new query containing arsenic soil data were opened, submitted, and viewed. After the results of the query were saved as a MicroSoft Excel file, a cross-tab version of the report was generated and saved as an Excel file. The saved query was re-opened in the CrossTab Report Writer and the two Excel files containing the query results and the cross-tab results, respectively, in Excel. A comparison of the different files indicated that these files retained their original content and structure, although, as expected, additional formatting (e.g., changes to the column widths and shading) would be needed in order for the format of the Excel files to match the format displayed by the CrossTab Report Writer for this and all additional queries.

A new query containing arsenic soil data *sorted by analyte* group was opened, submitted, and the results viewed. After the results of the query were saved as an Excel file, a cross-tab version of the report was generated and then saved as an Excel file. The saved query was re-opened in the CrossTab Report Writer and the two Excel files containing the query results and the cross-tab results, respectively, in Excel. A comparison of the different files indicated that these files retained their original content and structure.

Two new queries were opened, submitted, and the results viewed, the first using Sample Results (groundwater) and the second using Sample Results (soil). The queries erroneously displayed no results. Changes were required, under the direction of EarthSoft, to the cross-tab.mdb file. This allowed query results to be obtained and saved as an HTML file. The saved query in the CrossTab Report Writer and the HTML files, containing the cross-tab results in Netscape Navigator, were reopened. A comparison of the different files indicated that these files retained their original content and structure.

A new query using Sample Results (soil), was opened, submitted, and the results viewed. After the results of the soil query were saved as a user defined text file called "Sample Results (soil) - Arsenic", the evaluator then generated a cross-tab version of the report. (Note: The strings in the user defined text file were separated by commas and used quotation marks as delimeters.) The cross-tab report generated with the soil results was saved as a user defined file. The saved query in the CrossTab Report Writer and the user defined text files containing the query results and the cross-tab results in MS Excel was re-opened. A comparison of the different files indicated that these files retained their original content and structure.

The operator did not attempt to generate a CrossTab Report by opening a water level query, since the NJ Demo Test data set does not contain water level data.

4.3.2 Conformance to Data Exchange Standards Test Results

The subsequent three subsections summarize the results for Primary Objective No. 2 - Conformance to Data Exchange Standards for the Chemistry, Geology, and ArcView Interface modules, respectively. The purpose of these tests was to determine the conformance of the EQuIS system's input and output functions to data exchange standards.

4.3.2.1 EQuIS Chemistry Conformance to Data Exchange Standards Test Results

Data Entry/Import

EQuIS provides two means for transferring or importing data into the system: Manual Data Entry or Electronic File Import. If the data to be loaded into EQuIS are only available in hardcopy format, the data can be entered manually into the system through the manual data entry screens or the data can be entered into spreadsheet templates and imported into EQuIS. Alternatively, if the data are already resident in a database or spreadsheet, or if corresponding Electronic Data Deliverables (EDDs) have been provided for the field sampling and laboratory analysis work, these data can be imported directly into EQuIS. (Note: The electronic data format will need to be EQuIS compatible (e.g., IRPIMS or similar format or equivalent). In the event the data format is non-standard, (or unknown) the instructions in the Importing Data Electronically section will need to be followed to correlate the data to the EQuIS database fields.)

Data for import into EQuIS can be prepared in several ways:

- MS Excel© Spreadsheet Templates - EQuIS provides spreadsheets that have been set up as import file templates. The columns are labeled with the field names, data types, and width. Columns are also color-coded to indicate which are required in the EQuIS data model. The appropriate worksheets are selected according to the type of data. Each set of worksheets includes an information sheet explaining the available templates. After loading the worksheet templates with data, each worksheet is saved as a separate text file (tab or comma delimited) to be imported into EQuIS. The text files are imported into EQuIS, not the spreadsheet itself. Loading data using templates is explained in EarthSoft's documentation.

- ASCII Files - Using an editor to create ASCII files (i.e. DOS files, not word processing files). Each text line must end with a CR-LF (carriage return-line feed) and each data element must be separated by a tab or a comma.

- Outside Database - Use that system's export or reporting capabilities to either create ASCII files or to load data into EQuIS spreadsheet templates. If the data from the other system do not match column-for-column with the spreadsheet, the data will not import into EQuIS.

Additional information on data entry and import functions can be found in the documentation located in the EQuIS/Doc directory on EarthSoft's web page. Two functional groups were evaluated: 1) EQuIS Data Templates and 2) Data Import Preferences.

EQuIS Data Templates - EQuIS provides several templates for loading data. These templates are provided as MS Excel© workbooks. Each workbook includes an information sheet that explains the templates included in that workbook. Each template is a single worksheet and represents an available EQuIS data import format. The column headers on the worksheet represent field names in various tables of the EQuIS database. The columns have been named according to requirements in the database. The second row headers indicate the order, field data type, and size. If the columns are moved out of order, the import will be rejected. The column names that represent fields whose data are required (cannot be empty) in the database are highlighted in yellow.

Field sample, test, and result data were entered into three MS Excel worksheets. The evaluator then saved the worksheets as text files and imported them into the dt_sample, dt_field_sample, dt_test, and dt_result data tables located in the temporary database within EQuIS Chemistry. A comparison of the MS Excel worksheets and the data tables displayed by the Data Table Maintenance screen indicated that data completeness, correctness, and order were maintained during the import. The evaluator also used MS Explorer to confirm that import summaries were added to the Import.log file. An Import Summary was also added to the Import.log file in the global ESShared directory on the completion of Check and Load.

Data Import Preferences - The five parameters that were evaluated under Data Import Preferences were 1) Require Parent Records, 2) Create Missing Parents, 3) Overwrite Existing Data, 4) Add New Values to Lookup Tables, and 5) Use Default if Missing.

- **Require Parent Records** - The import requires that all data entered have the appropriate parent records, which prevents any orphan data in the Temporary database. For example, information must exist in the TEST table for result records to import. The import will check for parent records in both the Temporary and the Permanent databases.

  The system successfully identified an error and prevented the import of a row of test data for a sample/test without a field sample parent record in the temporary database. An error log was also created which showed that the parent table record was missing for a sample. The system later allowed the import of the test data when the import was attempted after the "Create Missing Parents" parameter was selected.

- **Create Missing Parents** - If checked, missing parent records are automatically created in the Temporary database as the data are loaded, thereby making it easier to load without needing to manually create parent records. If this field is checked, then the Require Parent Records field is unavailable. Only key field or skeletal information is created for the parent. Additional information may be desired before merging the record to the Permanent database.

The system successfully created missing parent records when importing result data for five samples which did not have parent records in dt_test in the temporary database. In addition to allowing the records to be imported into dt_result, the appropriate defaults were added for the missing parent records in dt_test, but not to dt_field_sample or dt_sample. A message was also written to the error log following the Import noting that parent records had been created.

- **Overwrite Existing Data** - If checked, the new data can overwrite existing data when an overlap occurs as the data are being loaded into the Temporary database. This option does not affect data in the Permanent database.

  This test was a success. The system successfully imported a text file containing new result_values for the five samples/results. An analysis of dt_result in the temporary database using the Data Table Maintenance screen indicated that the new results had replaced the previously imported results.

- **Add New Reference Values to Lookup Tables** - If checked, when the data are loaded into the Temporary database, reference (look-up) data are automatically added to the Permanent database reference tables.

  EQuIS successfully added a new reference value (TRG1) to the result_type_code field in the Result Type reference table as confirmed in the Reference Table Maintenace screen. The new reference value was added during the import of result data for five samples.

- **Use Default If Missing** - If checked, default values are loaded to replace missing data as the data are imported into the Temporary database.

  The system successfully added a default value (T) to the "T/D" column in the dt_result data table in the temporary database as confirmed in the DataTable Maintenace screen. The default value was added during the import of result data for five samples.

Exporting Data

The export functions within EQuIS Chemistry enable easy retrieval of data from the databases. Export functions send the data to a file for use in other applications. The File Export functions associated with each type of report are described below. EQuIS Chemistry allows export of data to multiple products such as EQuIS Geology, EQuIS Site Master, EQuIS CrossTab Report Writer, EarthSoft Lab Data Checker, IRPIMS, DUMPStat, STATISTICA, GMS, MTech, gINT, GTGS and New Jersey HazSite etc. Data export to the ELDC module and two COTS software packages (GMS and Surfer) was tested; the results follow.

Export to ELDC RefVals - The ELDC RefVals Export is a part of the standard EQuIS Chemistry product. It is designed to provide the user's set of reference values in a format that can be used by the labs that are using the EarthSoft Lab Data Checker. It allows selection of any or all of the reference tables. It also provides the ability to export sample numbers or locations. The use of this information would require some additional setup on the part of the Lab Data Checker user, but would then allow the lab to check to be sure that the location and sample codes they are providing in the EDD file are acceptable to the EQuIS Chemistry user receiving the data.

A reference file (rt_action_level_type) was exported to a **.dat* file and then successfully opened in ELDC. It was confirmed that the data structure and content were unchanged and that the same number of rows saved during the export were transferred during the import.

Export to GMS - The GMS Export is an optional interface that may be purchased separately and used with EQuIS Chemistry. This interface allows export of data to the Department of Defense's Groundwater Modeling System (GMS), published by the Brigham Young University.

Monitoring well arsenic records from a single sampling event were exported to a tabular scatter point -3D file (**.xyz*) and then successfully imported into GMS 3.0. Since the evaluator was unable to determine how to view a data table containing the imported data in GMS 3.0, the original **.xyz* file was saved as a **.sp3* file and then imported into EQuIS Chemistry in order to confirm that the data structure and content were unchanged during the export.

Exporting to Surfer - Surfer is directly linked to EQuIS Chemistry. When the Plot tab is selected during a graphing operation, EQuIS opens Surfer and exports two files (a griding and a *.csv file), which Surfer uses to plot the graph. EQuIS stores these files in the current user's directory (e.g., EQuIS/Tutor/Users/Super for a Super user working with the Tutor database). The files are named in ascending order as follows: Temp0001.grd and Temp0001.csv for the first plot; Temp0002.grd and Temp0002.csv for the second plot; and so forth.

A Dot Plot and a Contour were successfully plotted and viewed in Surfer using analytical concentration soil data from the NJ database. The plots were viewed in Surfer, exported to a **.csv* file, and saved from Surfer to a **.sfr* file. The configurations for these plots were also saved and the **.csv* and Surfer files were later opened and the evaluator confirmed that the Contour and Dot Plot were recovered as entered. An examination of the **.csv* file in MS Excel indicated that data completeness and order were maintained during the export. Also, no errors where identified when originally plotting the graphs in Surfer from EQuIS and when attempting to open the file.

4.3.2.2 EQuIS Geology Conformance to Data Exchange Standards Test Results

Once a project has been created, the first step in using EQuIS Geology is getting data into the project. Data may be brought into EQuIS Geology either manually or electronically. If the data are available only in hardcopy format, the user will need to enter them manually through data entry screens. However, if the data exist in electronic format either in text files, spreadsheets, or another database, data can be imported automatically, often with little or no modification of the original files. The method used for transferring data into EQuIS Geology depends on the data media, the quantity of data, and the objective. In most cases, electronic data import will be used at the outset of a new project. Where data currently reside in text files, they can be imported often with no modifications into the database. When data are present in spreadsheets, electronic data import requires only a properly formatted text file.

EQuIS Geology interfaces with several COTS products, including GMS, LogPlot, Rockworks, EVS, and Surfer. The data exchange (import and export) between EQuIS and each of the above COTS product was tested for interoperability. These third-party geoscience software products may be accessed from the EQuIS Geology module and are configured using EQuIS Administrator module. The geological data used for these tests were developed from the Martin Aaron hazardous waste site data provided by the NJDEP.

Electronic Data Import - EQuIS Geology provides a method for importing electronic data into the database. Currently supported imports include gINT databases, GMS borehole and material files, and a user-defined text file format. After the import type has been selected, the user need only select any options, indicate the file type, and indicate the number of header lines before importing the file. If the user has defined a Geologic Sample/Stratigraphy import, the user must indicate which he/she is actually going to import. The default number of header lines is 1. If the user indicates more header lines than are actually in the file, data will be omitted from the import. If the user indicates fewer header lines than are in the data file, the import may not function correctly. Only file types with the specified extension (.txt for tab delimited, .csv for comma delimited) will be displayed. Thus, the user has to make sure that his/her file has the appropriate extension. For comma delimited only, text strings do not need to be enclosed in quotes. Thus, if the user intends to import names or comments, it is preferable to use the comma delimited format. If any of the data are unable to be imported, an error log called import.err is created that will show the date, time, file, line number, offending field, offending value, and error.

The data import test was organized into three major sections: 1) Import Preferences, 2) GMS Data, and 3) User Defined Formats, which include data for location, cone penotrometer (CPT), geologic sample/stratigraphy, water levels, and well segments.

Import Preferences - In order to streamline data import, several import options may be set in the Preferences screen. Selecting either comma or tab delimited import determines which delimiter will be selected when the user defines an import format. If the user consistently uses one type of delimiter, making it the default will eliminate one step in defining import formats, which is preferable. The user may check import data for invalid characters such as apostrophes. If the user is unfamiliar with the data he/she is importing, or if text fields are lengthy and varied it is wise to check the imported data. However, if the user is certain the dataset contains no apostrophes or it is very simple (e.g. one-word description), bypassing the data check may accelerate data import. When fields that require a valid entry in a reference table (aquifer zone, phase, drilling subcontractor, engineering subcontractor) are imported, the reference table is checked to see if the value being imported exists. If the value exists in the reference table, the import continues. If the value is not found in the reference table, it must be added to the reference table.

Importing data was easy. Data flow was intuitive and logical, and creating a template was as easy as selecting, dragging, and dropping the fields required in the order needed. Twenty borehole ID's were created for each of the two types of import file formats (csv and tab-delimited). Two other files with arbitrarily placed apostrophes were also created from these files (Comma1-a.csv & Tab1-a.dat) to test the software's ability to identify inappropriate data. Location data import configuration was stored in a file. The Skip Column function was found to perform as claimed. All imports were based on a Location Data template, which was created for this evaluation by clicking on the Define button of the Import screen. Imported data were verified from within EQuIS. The program accurately identified all apostrophes that were deliberately introduced into the Comma1-a.csv and Tab1-a.dat files and created an error log for them. The file import function performed as expected.

GMS Data - EQuIS Geology works side-by-side with the Department of Defense Groundwater Modeling System, GMS. In addition to exporting borehole stratigraphy to GMS, native GMS borehole files can be imported directly. Borehole data are used in GMS for solid models and cross-sections. Sample parameters can be used to interpolate to a grid for a flow model, and water level measurements can be utilized for automatic creation of an observation coverage for model calibration. Borehole files are used to describe borehole data. Multiple holes can be defined in a single file. Each hole is defined by a list of contacts representing the boundaries between different materials. The contacts are defined by xyz coordinates. In the case of a vertical hole, the xy locations of all of the contacts are identical. A hole can also have a name and a water table elevation associated with it.

A GMS input file martaron-GMS-Import.bor was created. The corresponding *.mat file was also renamed martaron-GMS-Import.mat and both were put in the same directory. The borehole

information in the *.bor file and the material information in the *.mat file were both successfully extracted into EQuIS. Some of the imported boreholes were randomly checked (visually) to make sure the import was successful and it was found to be so. When the file format was correct, this function was extremely easy to use. However, in spite of the ease of use of this functionality, the evaluator wasted time not knowing that a *.mat file defining all materials in the *.bor file should accompany the latter, and both should be in the same directory. This is not obvious either from the error message or from the online help provided with the program.

User Defined Formats - The user-defined import format is the most flexible of all EQuIS Geology imports. The first step in defining an import format is determining what type of data the user wants to import. The import types include Location Data, Cone Penetrometer Data (CPT), Geologic Samples/Stratigraphy, Water Level Data, and Well Segments. Each data type has different requirements. Once the user has selected the appropriate data import format, he/she must define the parameters which actually exist in the data file. This is done by selecting each parameter in the Available Parameters list and dragging it to the Selected Parameters list. The user may also select multiple parameters in the Available Parameters list (by holding down the <CTRL> key) and then click the right arrow to move the selected parameters to the Selected Parameters list. If the user assigns an incorrect field by dragging the wrong parameter, he/she may delete that parameter by selecting it in the Selected Parameters list and clicking the left arrow to remove it from the list.

The evaluation of User Defined Formats included data for 1) location, 2) CPT, 3) geologic sample/stratigraphy, 4) water levels, and 5) well segments. Imports of all of these data types were successful.

- **Location Data** - For Location import, the example parameters that can be defined include ID, X Coordinate, Y Coordinate, Latitude, Longitude, Total Depth, Surface Elevation, Start Date, End Date, Driller, Aquifer Zone, Measured Depth, and Stickup Height.

  Importing location data was carried out successfully, including using *Skip Column*, and retrieving saved templates for importing data.

- **CPT Data** - The CPT-type data format is used for a series of any number of linear (typically vertical) points and any number of parameters describing the linear profile. In addition to the borehole ID being in the first column, this data format requires that depth be included (in any position in the template). However, before any parameters will be available to be selected, they must first be entered in the CPT Parameters reference table using Reference Table Maintenance.

  CPT data were added at one depth for all boreholes defined in the Tab1.dat file, and the new file renamed as InputData.csv. The hydraulic conductivity parameter was added to the CPT Reference Table. Upon importing the csv file containing the hydraulic conductivity data, these values were viewed from the CPT data table. Imported data were compared to the original and were found to be correct. CPT data were imported successfully.

- **Geologic Samples/Stratigraphy** - The Geologic Samples/ Stratigraphy format is used when parameters are assumed to be constant over a discrete interval. These data are sometimes termed "From-To" samples where some property is constant "From" one depth "To" another depth. In addition, this format requires that both From Depth and To Depth are included in the import template. Although the data format is the same for both geologic samples and stratigraphy, it is unlikely that the user will use the same file for both types of data. If the user is importing stratigraphy, his/her intervals will probably be continuous (0 to 14, 14 to 41, 41 to 53, ...) whereas geologic samples are more likely to be taken at distinct intervals (10 to 11, 20 to 21 feet, 30 to 31 feet, ...). Data types for Geologic Sample/ Stratigraphy import include Atterberg Limit data, compaction, fluid flow, weight volume, and other sampling data.

  More columns were added to the file InputData.csv to include compaction (weight-volume) data: moisture content and porosity. This file was renamed InputData2.csv. This import was representative of imports through this window (Atterberg limits, compaction data, other weight-volume data, etc.). The data were successfully imported from the input file ImportData2.csv and were verified to be identical to the original data. Geologic sample and stratigraphy data were successfully imported into EQuIS Geology. When sample ID was not part of the import, EQuIS set default names for all future samples based on borehole ID. This function has multiple categories of sample properties from which to choose and an input file can have these in any order without confusing EQuIS. This format offers flexibility in importing data from any source into EQuIS.

- **Water-Level Input** -Water Level Input format allows the user to import data files containing water level measurements. Each line of the data file represents a unique water level measurement. The available import fields allow the user to import date and time measurement, as well as other information.

  Water level data were imported successfully from the input file ImportData3.csv. It is important to include Date and Time fields with any water level import since EQuIS

looks for them during data import or entry. The imported data were checked to make sure they were identical to the original data, by viewing them from the data table. This function was easy to use especially since it deals with only one list.

- **Well-Segment Data** - Well segment data format allows the user to import dat files containing well construction data. Each line of the data file represents a well segment. Available import fields include inner and outer diameter, segment top and segment base, as well as other well segment information.

  Well Segment data were imported successfully from the input file ImportData4.csv. It is important to make sure to include Segment base and Segment top data with any well segment import as EQuIS looks for them during data import or entry. The imported data were checked to make sure they were identical to the original data. This function was easy to use as it dealt with only one list.

Electronic Data Exports

Much of the utility of EQuIS Geology comes in utilizing the export capabilities to:

- create solid models and cross sections
- produce boring logs and well construction diagrams
- view contour plots or 3D surfaces
- use data in pre-processing for groundwater flow models
- create reports

In some cases, data is communicated directly to a target database; for other applications, data is exported to a flat-file ASCII format that can be read by the destination program.

The Export screen is designed to facilitate exporting all types of data. The Select Export Type drop-down list allows the user to select either Borehole Data (stratigraphy), Sample Data or Water Level Data. The tabs in the lower portion of the screen display the data that can be selected for export. The Locations tab displays the location (boreholes) that can be selected for export. The user may select a specific combination, or use the Select All locations box to export all boreholes. The user may also use the Query Tool to further refine the locations of interest, such as querying for all locations where the surface elevation is greater than 2200 feet. The Data sets tab displays the CPT data sets that are available for export. If no data sets have been defined, then no data sets will be available for export. The Samples tab displays geologic samples and parameters that are available for export. This tab is only available if the user is exporting sample data. The tab allows the user to query for samples of certain depths by entering the boundary depths and clicking Refresh. The user may select any specific combination of samples to export, or use the Select All Samples box to export *all* samples. The user must also select which desired parameters are to be exported. The Data Options and File Options buttons allow the user to choose various export options. This makes it possible to tailor each exported data file precisely to the input format of the destination program. Error Log will be enabled if any of the selected data caused an error during export. The user may click the button to view a text file that describes, in detail, each error that occurred. If no errors occurred during export, the Error Log button will not be enabled.

Data export tests were organized by the five COTS programs to which data were being exported: GMS, LogPlot, RockWorks, EVS, and Surfer. Borehole data were exported to all fives COTS programs. Sample and water level data were additionally exported to both GMS and Surfer.

Export to GMS - Borehole data, sample data, and water level data can be exported to GMS. Borehole data include stratigraphy and CPT-type sample data. Borehole files exported to GMS are opened in GMS as borehole files. Sample data include discrete locations samples where any of the following parameters may be defined at each sample location: moisture content, optimum moisture content, specific gravity, saturation, void ratio, minimum void ratio, maximum void ratio, porosity, hydraulic conductivity, unit weight, dry unit weight, saturated unit weight, minimum dry unit weight, maximum dry unit weight, relative density, relative compaction, and organic carbon.

All 35 boreholes that were part of the MartAron site data were successfully exported to GMS. Accuracy of data exported was visually checked by picking three boreholes at “random” in both Notepad and the GMS Viewer. The GMS project was saved as MartAron-Final.gpr. Seven borehole samples were created and successfully exported to GMS as 2D scatter point data. Accuracy of data exported was visually checked by picking three samples at “random”, in both Notepad and the GMS Viewer. The GMS project was saved as MartAron-Samples.gpr. Thirty-five boreholes were exported as a scatter point File. Accuracy of exported water levels was visually confirmed by picking three samples at “random” in both Notepad and the GMS Viewer.

Export to LogPlot - Stratigraphy, CPT-type sample data, sampled intervals and well construction data can be exported to LogPlot for boring log plotting. EQuIS Geology creates an import file which is directly read into LogPlot. Data Options allows the user to define specific data options for the export. The user can select whether to export stratigraphy as individual layers, or as geologic units. Four other options are also available when creating a LogPlot data file:

- Stratigraphy - exports the material and any descriptive comment for each layer (or geologic unit).
- Sampled Intervals - exports sample point as the top of sample and sample thickness as the length of sample recovered.
- Well Construction - exports well construction elements to

produce well construction diagram.

- CPT-type Data - exports CPT-type sample data for each data set selected.

The Data sets tab allows the user to select which CPT data sets will be exported. After selecting the desired options, choose the appropriate boreholes and data sets.

Thirty-five boreholes were exported to LogPlot, along with representative well segment information. After entering well segment data for well SB-24, the data were re-exported to LogPlot as SB-24(MW-2M).dat file. A Log was compiled for this well and exported as a JPEG image, which was consistent with the data exported. Accuracy of exported borehole data was visually checked by picking three boreholes at "random" in both Notepad and the LogPlot spreadsheet screens.

Export to RockWorks - EQuIS Geology will export a text file in the borehole stratigraphy (*.atd) input format used by RockWorks. The file contains stratigraphy information for each of the select boreholes. These files allow to view cross sections, fence diagrams, and other complex visualizations within RockWorks. Data Options allows the user to export either stratigraphy or geologic units. The user may also choose to automatically create a reference borehole, or select a reference borehole from the available list. A manually selected reference borehole may or may not be included in the export. If the Include box is checked, then the stratigraphy of the reference borehole will be included in the export file. Otherwise, the reference borehole information will be used only as reference and will not be included in the export file.

Seven boreholes (with two wells amongst them) were exported from EQuIS Geology to RockWorks, along with a Reference Borehole. The corresponding master RockWorks file was martinaron.atd. The data in RockWorks spreadsheets were compared to data that were exported and were found to be accurate. Lithologies were preserved during the export. This was checked using the stratigraphy screen in the Create Cross Section screen of RockWorks. During this export, the evaluator found that exporting data to RockWorks was not straightforward, and depended on the exact set of boreholes being exported (in order to create a Reference Borehole). When an accurate Reference Borehole was not created or if it was absent, data export was not successful.

Export to EVS - EQuIS Geology will export a text file in the borehole geology (*.geo) input format used by EVS. The file contains stratigraphy information for each of the selected boreholes. This file can be opened in EVS and used for complex 3-dimensional geologic modeling. Data Options allows the user to export either stratigraphy or geologic units. The user may also choose to automatically create a reference borehole, or select a reference borehole from the available list. A manually selected reference borehole may or may not be included in the export. If the Include box is checked, then the stratigraphy of the reference borehole will be included in the export file. Otherwise, the reference borehole information will be used only as reference and will not be included in the export file. If any of the boreholes the user has selected do not have stratigraphy to be exported to EVS, he/she will be notified and an error log will be created.

Borehole data, along with a reference borehole, were exported from EQuIS Geology to EVS readable martaron.geo file. An option for importing geology data existed in EVS; however, the demo version of the software being used for the SITE demonstration did not allow viewing files other than those supplied with that version. Exporting data to EVS appeared to be straightforward; however, this could not be confirmed because the evaluation team was provided with a demo version without this capability. Data Options to be chosen were straightforward to use.

Export to Surfer - Both borehole stratigraphy data and sample data may be exported to Surfer. Where stratigraphy is constant or relatively simple, layer contacts may be interpolated to define, for example, bedrock surface elevation over a two-dimensional field. Sample data parameters can be interpolated to a grid and then used in groundwater flow model pre-processing.

- **Exporting Boreholes to Surfer** - There are no Data Options or File Options when exporting borehole stratigraphy data to Surfer. The stratigraphy for selected boreholes will be exported in a comma delimited text file with the x and y coordinates first, followed by the elevation of each material interface proceeding up the borehole. If a borehole with no defined stratigraphy is exported, the surface elevation and total depth of the borehole follow the x and y coordinates. Some thought must be exercised in exporting boreholes to Surfer. **NOTE:** If boreholes with differing numbers of layers are exported in the same file, the data will be difficult to interpret in Surfer as a given column will contain one material interface for one boring and a completely different interface for another boring.

  Borehole data were exported to Surfer input format as martaron.csv. Three records were picked at "random" to check the integrity of this data export. It has to be kept in mind that plotting borehole stratigraphy in Surfer is meaningless unless all boreholes have the same number and type of layers which was not the case with the SITE demonstration data. Therefore, a stratigraphy plot was not made. However, this visualization was not a requirement of this test and data were successfully and accurately exported to Surfer.

- **Exporting Samples to Surfer** - To create a surfer data file, select all of the samples to export. The user may query for samples of a specified depth. After selecting the desired samples, choose the parameters to export from the

parameter list on the right side. Neither Data Options nor File Options are available when exporting sample data to Surfer.

Sample data export to Surfer was a one step process (no data options or file options required) and was easily and successfully accomplished. Only one sample parameter could be exported to Surfer at a time. When multiple parameters were exported, they were input into the same third column (the first two being the location coordinates (X and Y), leading to mismatch of records across columns. Moisture content data for all of the samples were exported to martaron-samples-moisture.csv. Accuracy of exported data was confirmed by visual comparison of three records chosen at "random". Exporting samples was easy - it was as simple as first picking all of the samples that the user was interested in and then picking the sample parameters that the user wished to export. However, there was a problem with exporting multiple sample parameters to Surfer. Although this problem does not affect the overall export functionality to Surfer, it might be inconvenient to users who want to export all sample data at once (instead of one at a time) and then use Surfer to plot one parameter at a time. Borehole water level data were exported to Surfer input format as martaron.csv. Accuracy of exported data was checked by visual comparison of three records chosen at "random". These data were also plotted in Surfer. Data export to Surfer was successfully accomplished in one step (no data options or file options required), and was easy to complete.

4.3.2.3 EQuIS ArcView Interface Conformance to Data Exchange Standards Test Results

If the ArcView Interface has been invoked through EQuIS Geology, or an EQuIS Chemistry project has a complimentary Geology project, the EQuIS Geology menu options will be available. EQuIS Chemistry and EQuIS Geology projects are considered complimentary when they are have the same project code, e.g. TUTOR - TUTOR. It is expected that not only the names will be the same, but that the projects share a set of common locations. A number of geoscience software products may be accessed using the EQuIS-ArcView Interface. Third-party products are configured using EQuIS Administrator module. It is important that paths and file locations be correctly entered prior to invoking the interface.

Geological Data Test

If the ArcView Interface has been invoked through EQuIS Geology, or an EQuIS Chemistry project has a complimentary Geology project the EQuIS Geology menu options are available. The View Stratigraphy option is invoked by selecting a location from either the dt_location table or the current display. Invoking this menu option calls the stratigraphy screen for the selected location. Once this screen is visible, users may use the drop down list to review lithology and sample descriptions for other locations having this information.

The Site Test Project was opened in the Geology module, the ArcView interface was invoked, and the boreholes were displayed in the view. A single borehole was selected and the view lithology menu item was invoked. All features were then selected and the view 3D lithology menu item was selected. A 3D scene was generated. This function was easy to use. The user needed to know the ArcView select tool to perform this function. If a feature was not selected, an informational message appeared indicating that a feature must be selected.

Log Plot

This menu invokes Rockware's LogPlot application. By selecting a single location and selecting the Boring Log menu option the user is able to automatically produce a boring log using data that are managed in EQuIS Geology. All rules regarding the template and formatting of the log must be managed through LogPlot directly.

This function performed as claimed and required only two operations. Borehole SB-67 was selected from the ArcView interface. The Create LogPlot Log menu item was invoked from the EQuIS Geology menu. The data were automatically passed to the LogPlot software and the log was created.

Fence Diagram

Selecting a group of locations and applying this menu option exports data to RockWorks. The user is presented with a configuration screen that allows the modification of the parameters that will be used to produce the fence diagram. Once this has been completed the user moves to a second screen where locations may be connected to create a facet of the fence. This is accomplished by clicking on one location and then a second location. Repeat this process for each facet to be displayed. Continuing beyond this screen will create a fence diagram in the RockWorks product.

Boreholes were selected through the EQuIS ArcView Interface. These data were automatically passed to Rockworks. The create fence diagram menu item was selected from Rockworks, then boreholes were selected from the map interface. Several error and warning messages appeared having to do with no intervals available. These messages were due to the lack of data for certain depth intervals in some site boreholes, not a system failure. The end result was a fence diagram.

Cross Section

Selecting a group of locations and applying this menu option exports data to RockWorks. The user is presented with a configuration screen that allows the modification of the parameters that will be used to produce the cross-section. Once this has been completed the user moves to a second screen where locations may be connected to create each segment of the cross-section. This is

accomplished by clicking on one location and then a second location. Repeat this process for each facet to be displayed. Continuing beyond this screen will create a cross-section in the RockWorks product.

Nine boreholes were selected from the ArcView interface. Then the Create 2D cross section menu item was invoked. The data were successfully passed to Rockworks and Rockworks was invoked. Boreholes were selected from the Rockworks interface to produce the cross section. Two warning messages appeared: 1) "Attempting to plot numeric data" and 2) "Unable to find the file E:\Site|EQuIS\Eqarcwrk\183.42 file. All log files must reside on the same directory as the spreadsheet file". This is a minor functional failure, resulting in inconvenience for the user in relocating files after the fact.

Export Borehole Data to GMS
Boreholes are exported to the Groundwater Modeling System (GMS) using this menu option. The user first selects a set of locations for export. Next, by selecting this option data are exported and made available for manipulation within GMS.

Eight boreholes were selected from the EQuIS-ArcView interface and these were successfully passed to the GMS application. This interface was easy to use - it involved only the EQuIS selection tool and the GMS menu option.

Export Borehole Data to EVS
Export of borehole data to EVS is similar to Log Plot, except that the Launch EVS Application menu options is selected.

This function performed unsuccessfully. An error message appeared from the EQuIS ArcView interface. The EVS application was never launched. Even though the test was unsuccessful, the user interface was easy to use - similar to exporting data to GMS - one selection tool, then invoking the Launch EVS menu option.

Export/Import data to Surfer
Data can be exported to Surfer from EQuIS through a number of industry standard data exchange formats including *.dxf and *.wmf files. Surfer functionality, such as 3-D wireframe displays, and grid and contour functions, can be applied to the data.

An *.wmf file was exported to the Surfer sample directory. This file was successfully imported to Surfer through the basemap option. This procedure required knowledge of ArcView functionality to export a view.

Chemical Data Statistics Button
Activating a chemical data theme allows the user apply the chemical data theme statistics button. A statistical summary window is produced for the active theme. When a set of locations is selected only chemical records belonging to these locations will be included in the analysis.

A chemical theme table was created for toluene. The chemical theme statistics menu item was invoked. The statistics generated showed a sample size of 48, which matched the number of selected records in the query1_qry chemical theme table. This function was easy to use - once the chemical theme table is created, the user selects the chemical theme statistics item from the Geology menu.

4.4 QUALITY ASSURANCE/QUALITY CONTROL

QA may be defined as a system of activities the purpose of which is to provide assurance that defined standards of quality are met. A QA program is a means of integrating the quality planning, quality assessment, QC, and quality improvement efforts to meet user requirements. However, standard QA objectives for data quality indicators (precision, accuracy, etc.) do not apply to this project. For this evaluation of the EQuIS Software, QA efforts centered primarily

on the documentation of the various functionality tests performed for each of the software modules. In addition, QA efforts assessed the impact that changes to and deviations from the test plan had on the achievement of project objectives, and an evaluation of the completeness of the testing planned in support of the project's primary and secondary objectives

4.4.1 QA/QC Conclusions and Data Quality Limitations

Primary objectives for the evaluation of the various modules of the EQuIS software were achieved through the execution of the test plans described in the QAPP. Modifications to the test plan, arising from efforts to limit redundancy, address time and financial constraints, correct errors in specific function directions, or remove from evaluation seldom used or obsolete functions, were documented in the evaluation tables through use of redline strikeout and highlighted edits. While some of these modifications resulted in certain functions not being evaluated, in general these functions were not considered critical to the overall functionality of the modules affected. Two minor procedures of the Chemistry module evaluation (one in the Administration and one in the Data Entry function tests) were not performed as planned; other test procedures for these functions provided an overall evaluation. Overall, test results were well documented and complete, and modifications to and deviations from the test plan were described and justified, and did not impact overall project objectives.

4.4.2 QA Efforts and Results

As part of the QA oversight for this evaluation, the results recorded on the various test matrices were reviewed as the evaluation of each

software module began. This initial review centered on the completeness of the documentation, whether the conclusions drawn were supported by the test results recorded, and whether any changes to the test protocols were described, explained, and/or justified. Changes were made to future entries into the test matrices as needed. QA review of the results entered onto the test matrices was performed periodically throughout the evaluations, as well as on a random sampling of results at the conclusion of the evaluation for each module. The review of the completed test matrix for each software module is summarized below.

4.4.2.1 QA/QC - ELDC Functionality Test Results

Deviations from the original test plan centered on the data set provided, along with a minor change in the Y2K test sequence. These deviations had no impact on the achievement of project objectives since the data set used could be manipulated to allow evaluation of all desired functions as described in the QAPP. All tests planned in the assessment of this module of the software were executed as described in the test matrix.

4.4.2.2 QA/QC - Chemistry Functionality Test Results

Numerous edits and revisions to the test procedures were required and were documented in project files. Specific review comments about each of the evaluation subcategories are provided below.

During the evaluation of the Chemistry module system administration functions, the ability to create new projects was tested. The creation of the new projects was confirmed through the System Administration function, as per the test plan. However, projects were not opened in EQuIS Chemistry to confirm that new project information created in System Administration was retained and could be reopened in both System Admin and EQuIS Chemistry.

Among the EQuIS Chemistry data entry functions tested were functions to allow for manually entering lab sample data. The initial test procedure was revised, to avoid redundant tests. However, manual entry of lab sample data was not performed since lab sample data were not part of the database used ("NJ Demo Test"). However, it should be noted that all other types of data entry procedures (field data, test data, and result data) were successful, while parameter group entry was not performed due to time and resources constraints.

4.4.2.3 QA/QC - DVM Functionality Test Results

Results for the evaluation of the Data Verification Module of the EQuIS software indicated that, with minor modifications, all test procedures were performed as described in the QAPP.

4.4.2.4 QA/QC - Geology Functionality Test Results

The evaluation of the EQuIS Geology module was completed in accordance with the test plan presented in the QAPP. Reasons for the modifications to the test procedures were clearly described as results were entered onto the evaluation table.

4.4.2.5 QA/QC - ArcView Interface Functionality Test Results

No modifications were required to the test plan and all procedures were performed in accordance with the steps given in the summary table.

4.4.2.6 QA/QC - CrossTab Report Writer Functionality Test Results

Minor modifications to the evaluation test plan did not impact the overall assessment of the software functions.

4.4.2.7 QA/QC - Chemistry Data Exchange Test Results

A second primary objective of the evaluation for the Chemistry module was to determine ability of the software to perform data exchange functions. Several tests of this function were not performed due to time and financial constraints.

4.4.2.8 QA/QC - Geology Data Exchange Test Results

The Geology module was evaluated to determine the ability of the module to perform import/export functions as part of the second primary project objectives. One new test procedure was added to the original test plan to assess a function not previously included. All other tests were performed and recorded as per the test plan.

4.4.2.9 QA/QC - ArcView Interface Data Exchange Test Results

The test plan for the evaluation of the second primary objective for the GIS ArcView Interface was followed. The automatic data exchange functions were tested as planned without modification.

4.5 RESIDUALS

Because EQuIS is not a treatment technology, no processing residuals will be generated.

SECTION 5

OTHER TECHNOLOGY REQUIREMENTS

5.1 ENVIRONMENTAL REGULATION REQUIREMENTS

There are no regulatory requirements on the software itself. The content and format of reported data may be defined by applicable Federal, state, and local regulations. Data query and cross-tab reporting functions offer the versatility to meet many of these requirements.

5.2 PERSONNEL ISSUES

Personnel issues related to this software center on the capabilities of staff to learn and implement the EQuIS software. The software is complex in that there are several modules and numerous functions within each module. In addition, the use of COTS software may require further specialized expertise. However, these factors are also what provides the software with power to perform the required tasks. During the demonstration, personnel with experience in Windows-based products and basic spreadsheet and word processing software were able to learn and apply the major functions after a fairly short learning curve. Based on the experience of the evaluators, it is believed that anyone can learn to be a basic user of this software. Obviously, it is expected that the time required to learn and utilize the system will, to some extent, be impacted by the degree of experience of the users. A typical application will, however, require one staff with experience in using basic scientific software. Full utilization of COTS software will require an individual with more experience (e.g., GIS software, databases, and 3D modeling programs) or a significant commitment and aptitude to learn to fully utilize these programs. In addition, a knowledge of various reporting requirements will be needed to ensure that data are managed and reported in a manner consistent with applicable regulatory requirements.

5.3 COMMUNITY ACCEPTANCE

Community acceptance of a technology is affected by both actual and perceived hazards. The only aspect of the EQuIS technology that may uniquely affect community acceptance is that this technology may assist site managers in demonstrating site activities to local communities through the use of data management, quality assurance, and visualization functions.

Two Visitors' Days were held: one on June 21, 2000 in Philadelphia, Pennsylvania and the second on November 14, 2000 in Seattle, Washington. Presentations were made by EPA-NRMRL, the developer, and various software users. Brief overviews of the SITE Program and the software were provided. During each Visitor's Day, interactive technology demonstrations were available from EarthSoft and a number of environmental consultants which have partnered with EarthSoft. Participants in Visitor's Day included regulatory personnel, remediation contractors, and members of the general public. This is an example of an activity to inform the public and improve community acceptance.

SECTION 6

TECHNOLOGY STATUS

Prior to the SITE demonstration, the EQuIS software had been implemented at several state and Federal offices to manage environmental data from the regulated community. According to EarthSoft, EQuIS is currently being used in 10 states and 5 EPA Regions (see Table 6-1).

Representative case studies are discussed in greater detail in Appendix B.

Table 6-1. End Users of EQuIS.

STATE/REGION	POINT OF CONTACT	TELEPHONE NUMBER	E-MAIL ADDRESS
STATES			
Colorado HMWMD	Candy Thompson/ Andy Putnam	(303) 692-3424	Andrew.Putnam@state.co.us
Delaware NREC	Steve Johnson	(302) 395-2622	sjohnson@dnrec.state.de.us
Florida DEP	Kathleen Lurding	(850) 921-9823	kathleen.lurding@dep.state.fl.us
Mississippi DEQ	William McKercher	(601) 961-5731	Willie_McKercher@deq.state.ms.us
Nebraska DEQ	Steve Kemp	(402) 471-0803	Steve.Kemp@NDEQ.State.NE.US
Nevada DEP	Bill Story	(775) 687-4670	bstory@ndep.carson-city.nv.us
New Jersey DEP	Izak Maitin / Irene Kropp	(609) 777-1763	imaitin@dep.state.nj.us
New York DEC	Koon Tang	518-402-9549	kstang@gw.dec.state.ny.us
Pennsylvania DEP	Mike Arnold	(717) 783-9475	miarnold@state.pa.us
Rhode Island DEM	Joe Martella	(401) 222-2797 x 7109	jmartell@dem.state.ri.us
West Virginia DEP	Rick Doneghy	304-558-7763	rdoneghy@MAIL.DEP.STATE.WV.US
Also, we have received a verbal agreement to purchase a Five User License from the California DTSC, and think we will sell systems in the near future to the Maine DEP and Texas NRCC.			
EPA Regions			
Region 1	Carolyn Casey	(617) 918-1368	Casey.Carolyn@epamail.epa.gov
Region 2	Andy Crossland	(212) 637-4436	crossland.andy@epamail.epa.gov
Region 3	Matt Mellon	(215) 814-3168	mellon.matthew@epa.gov
Region 4	David Jenkins	NA	Jenkins.Dave@epamail.epa.gov
Region 5	David Wilson	312-886-1476	WILSON.DAVID@epamail.epa.gov
EQuIS is also being used by several DoD and DOE facilities, including Argonne, Rocky Flats, several Naval Shipyards, Warner-Robins AFB, several Port Authorities, and several Army Corps Districts including Sacramento and Korea.			

APPENDIX A

VENDOR CLAIMS

Background

Today, many companies can not make heads or tails of their data. They have little data consistency, poor data quality, and can make little use of the data to support decisions and analysis. Poor data lead to poor decisions. These decisions flow up from industrial client to state regulators to federal regulators. Without addressing data quality early in the process, far before the data are actually submitted to the EPA, little can be done to improve the EPA's decision making ability. Unfortunately, most EPA systems are only for the EPA, and are so large and expensive that they will never be very useful to industrial clients. Islands of Automation are the result, as systems are built that are unable to share data. By comparison, EQuIS can be used by small property owners, industrial clients, consultants, labs, and then by the regulatory community. EQuIS was not originally written for the regulatory community, but we have accidentally found that we can help. EQuIS can be used as a small local system, a regional departmental system, and as a large Enterprise system. In this manner, the data are high quality earlier in the process, and indeed, throughout the process. In fact, in many cases, the data are available from the industrial client in EQuIS, and can be submitted as is. Never before has this been the case. Never before has the EPA been able to obtain data from more than a site or two in the 'native' or original format, and been so able to immediately judge data quality and completeness.

EQuIS is today the most widely used subsurface data management system in the world. EarthSoft maintains that 'standards' are not set by committee, but rather by market forces and volume. The market has established EQuIS as the industry standard. What this means is that innovation is extensive and ongoing, because the large costs can amortized over a larger client base. Because of the large installed base of EQuIS users, continued innovation is guaranteed. Today, EPA Regions 1, 2, and 5 are large EQuIS users, and EPA Regions 3 and 4 are evaluating EQuIS. Today, the states of West Virginia, New Jersey, Colorado, Delaware, Nebraska, Nevada, and New York have multiple licenses of EQuIS. Several other states have one or two licenses of EQuIS, and several other states are either evaluating EQuIS, or we are 'in Purchasing' to procure EQuIS. Furthermore, almost all of the largest US consultants today have EQuIS, and worldwide, nearly 2,000 licenses of EQuIS have been purchased since its first release in 1996. Because EQuIS is not limited to use by just the EPA, States, the Army, Navy or Air Force, or the United States, EQuIS is ubiquitous in many projects around the US.

Because of EarthSoft's Open Systems business practices, a viable and active 'shareware' market is emerging for EQuIS modules and value added capability. Several new EQuIS modules are emerging that were not written by EarthSoft. And in the truest test of Open Systems, EQuIS clones are emerging.

Technology Advantages

The value of an electronic data management system such as EQuIS is that data are of reliable quality, and are readily available and easy to review, report, and utilize for model construction and analysis. Projects long completed and archived can be accessed in a fraction of the time that would be required for hardcopy reports or logs.

The EQuIS user interface provides an extensive suite of reporting tools and interfaces for sending data to many different visualization and analysis applications, the open system design also allows the development of custom interfaces without being bound by the cost and time requirements of the developer as is often the case with closed, proprietary systems. Another benefit of the open systems architecture is that the user is not locked into a specific visualization or analysis application. They may choose between any of several popular tools for creating borehole logs, groundwater models, solid models, or performing other types of analysis.

Furthermore, EarthSoft's Open Systems architecture provides the opportunity for a data manager to access data directly, outside of the user interface.

Caveat

As with any evaluation this complete and thorough, by the time the evaluation is completed, a new version of EQuIS is already released. Software is such a moving target that any single point in

time is not completely representative. We chose to evaluate EQuIS Geology Version 3 instead of Version 2, because of added new features, even though Version 3 was still in 'beta' status. EarthSoft, at the time of this writing, in Spring of 2002, is preparing for a major overhaul of the entire system, and a complete facelift of the user interface, in response to continued changes by Microsoft, ESRI, and our other development platforms and integrated third party products.

Upcoming developments include:

A shift to ArcGIS (ArcView 8) away from ArcView 3. This is a huge change for us since ArcView 3 used the unique and proprietary Avenue programming language, and ArcGIS uses the ubiquitous Visual Basic language. Since the rest of EQuIS is written in Visual Basic, our code can now be reused in the GIS interface, and functions need not be re-coded. This leads to our GIS interface being much more powerful, supportable, and Windows-like (i.e., easier to use)

- A complete re-write of the View module, producing a much simpler version (EZView) and an equally powerful but more modern version (QueryBuilder).
- A complete redesign and rewrite of the Data Verification Module (DVM). The new Data Qualification Module is a completely new product, replacing the DVM, which was too limited, restricted, rigid, and hard to use.
- The new EQuIS Enterprise is a Web-enabled, Oracle or SQL/Server system for organizations with a large number of users or a large number of projects, or wishing to easily run regional (i.e., Watershed wide) queries against the data.
- Many bug fixes, patches, and enhancements. We have released new versions of the ELDC, Rockworks interface, gINT interface, EVS interface, and the GMS interface, after the SITE Program testing started.
- EQuIS Air is now under design.
- The Field Data Checker, recently written at the request of an EPA Region, was not tested.
- The exciting new Pocket EQuIS was not available at the time of the evaluation. This PDA software supports electronic field data collection activities.
- A new 'Dashboard' is available that provides a link to Document Management, and allows for the posting of EQuIS databases on a private network or Intranet.
- A new module is nearly available to support Time Series Data is now available, that provides links to automatic data collection equipment, via manual or wireless data collection techniques, and provides data reduction capability such that continuously monitored locations can report a single value calculated a number of user-defined ways.

APPENDIX B

CASE STUDIES

The power of EQuIS in environmental management and decision analysis: case studies in Colorado

A. Putnam[1], S. Weaver[2] , C. Thompson[1], & M. Beard[2]
[1]*Colorado Department of Public Health & Environment, U.S.A.*
[2]*EarthSoft, Inc, U.S.A.*

Abstract

Selecting an optimal remediation strategy for environmental sites is never a straightforward, easy process. Successful management and decision analysis requires not only the availability of spatial, chemical, and geologic data, but also an integrated environmental quality information system which allows a project manager to utilize and analyze the data. EarthSoft's Environmental Quality Information System (EQuIS©) has been implemented by the Colorado Department of Public Health & Environment (CDPHE) to aid in achieving these data management and analysis objectives. EQuIS tightly integrates data management with industry-standard visualization and analysis tools resulting in an environmental management system that allows the user to easily investigate "What If...?" scenarios. The EQuIS solution is enabling CDPHE to conduct a more comprehensive and effective evaluation of environmental impacts, migration pathways, fate and transport mechanisms, appropriate remediation methods, effects of remediation, and compliance. Examples illustrate how CDPHE is using EQuIS and what benefits have been derived therefrom.

Introduction

The selection of an appropriate remediation methodology requires extensive field sampling. While data collection is a critical step in a site characterization effort, collection alone is not sufficient. Far too often, data painstakingly obtained from field investigation, particularly geologic data, cannot be located or easily used. Such data is often hardcopy instead of electronic, and may even be stored off-site in a nearly-forgotten repository. When the effort required to find and obtain data from a previous study is comparable to collecting the data in the first place, it is just as good as having no data to begin with!

The value of an electronic data management system such as EQuIS is that data is readily available and easy to review, report, and utilize for model construction and analysis. Even projects long completed and archived can be accessed in a fraction of the time that would be required for hardcopy reports or logs.

Data Usability

One scenario frequently encountered among environmental data managers today is the 'data hostage' situation. This problem may result not only from the use of a proprietary database that prevents 'back-door' access to data, but also from the *process* of storing data in a particular visualization or analysis application. The open systems architecture, upon which EQuIS is based, provides the opportunity for a data manager to access data directly, outside of the user interface. This philosophy is rapidly gaining wide acceptance as users are able to go directly into the database to build custom queries and write need-specific applications for reporting and formatting data. Whereas the EQuIS user interface provides an extensive suite of reporting tools and interfaces for sending data to many different visualization and analysis applications, the open system design also allows the development of custom interfaces without being bound by the cost and time requirements of the developer as is often the case with closed, proprietary systems. Another benefit of the open systems architecture is that the user is not locked into a specific visualization or analysis application. They may choose between any of several popular tools for creating borehole logs, groundwater models, solid models, or performing other types of analysis. This flexibility provides the opportunity to switch to a higher-level application if the currently used application is not adequate without migrating data to a new system. Many proprietary systems provide their own visualization and analysis tools and if these do not prove adequate, the user is at mercy of the developer or is required to migrate their data to a more suitable system. Proprietary evaluation tools are also often poorly documented as to the application of algorithms and are not generally accepted throughout the industry. This creates a situation where disagreement may occur between a facility and the regulating

entity as to the applicability of the evaluation tool.

The dangers of storing data in a specific visualization or analysis tool are illustrated by the hypothetical case of a project manager who has successfully used a groundwater modeling environment to produce the results needed by his client. However, when the client then needs borehole logs, cross-sections, or solid models in addition to the groundwater modeling, the manager is left in a quandary. Heretofore, the solution has been the costly investment not only in an additional product and the time required to learn the procedures necessary to produce the desired results, but also in understanding file formats and getting the appropriate data into the new application. EQuIS greatly simplifies this task by facilitating the creation of borehole logs, cross-sections, fence diagrams, reports, contours, groundwater models, solid models, and more all very quickly and easily…without having to understand the intricacies of specific file formats. This mechanism permits more time to be devoted to science and analysis rather than the overhead of a specific piece of software.

The Colorado Department of Public Heath and the Environment, Hazardous Materials and Waste Management Division has chosen EQuIS to facilitate better understanding of contaminated sites in Colorado and improve the decision making on cleanup of these sites

Site 1

An unlined municipal solid waste landfill composed of two separate areas has been in operation since 1968. The northernmost area is 60 acres in size; the southern area, slated for future expansion, is 259 acres.

The landfill began accepting waste in 1968. To comply with state regulations, a groundwater monitoring system was installed in 1990. This system consisted of 4 monitoring wells. Four more wells were installed in the expansion area to the south (See Figure 1). Monitoring well MW-4A serves as the background well and provides upgradient water quality data; MW-2 is the compliance/downgradient well for the existing 60-acre site.

Natural ponding started around MW-3 in October of 1995. The facility operator later created a retention pond out of the low area in the summer of 1996. A rising trend in water levels was seen in MW-2, downgradient of the retention pond, soon after. In November of 1997 the east cell of the landfill was capped and the retention pond was removed. At this point the rising trend of water levels in MW-2 reversed (See Figure 3).

A statistically significant trend of increasing bicarbonate and other inorganic constituents was observed in MW-2. This trend started in the first quarter of 1997. An increasing trend in the concentrations of certain organic compounds started in the second quarter of 1997. This is best illustrated by the concentration of methylene chloride over time. A theory was presented by site personnel that the capping of the landfill caused the increase of chemical constituents in MW-2 by restricting the volatile chemicals from escaping to the atmosphere and forcing them into a new migration path. Therefore, they proposed using an extraction system as an interim corrective measure. They also installed a new well, MW-9, to function as the downgradient, between MW-2 and the property line. A new upgradient well, MW-10, was also installed. These wells were installed in September of 1998. Elevated organic compounds have not been found in MW-9, the new downgradient well.

The Department began evaluating the landfill site using EQuIS in the fall of 1998. All available geologic data and chemistry information from 1994 was loaded into the database. For the geographic information system (GIS) display, topographic maps and historic and recent aerial photographs were obtained. Geospatial locations were obtained by taking GPS readings at a number of surficial features at the site. These data and geographic images allowed the project manager to perform more complex evaluations of the site geology and groundwater monitoring data.

The registration of all data, maps, and aerial photos into one coordinate system allowed a more sophisticated temporal, chemical and geologic depiction of the site. The 1968 aerial photo (pre-landfill) shows an old streambed directly underlying the main storage cells of the existing landfill (Figure B-1). It was expected that the alluvium underlying the stream system would create an area of high permeability. This was verified by the geologic cross-section (Figure B-2) seamlessly created by the integration of the warehoused data to a geologic visualization application. This former stream drainage makes an excellent path of migration for contaminants coming for the landfill. MW-9, the new well proposed to depict downgradient conditions, was set in the same drainage system, but was actually found to lie across the channel of the stream from MW-2 and not directly downgradient.

A group of time series plots were created from database queries to explain what is occurring at MW-2. Figure B-3 shows water levels vs. time at MW-2. There is a marked increase in the water levels after the installation of the retention pond.

Soon after the installation of the cap the water levels start to drop, but do not return to their original level. Bicarbonate concentrations increase coincidentally with the increasing water levels. However, these bicarbonate concentrations do not decrease with the water levels, although their concentrations no longer continue to rise. The methylene chloride concentrations do not start to rise at the same time as the bicarbonate and water levels (Figure B-4). The organic constituents begin to increase with the start of construction of the final cover. The organic chemical concentrations start to drop at the installation of the gas extraction system.

A number of conclusions can be reached from this case study. The first is that the elevation of the bicarbonate concentrations is not

related to the capping of the landfill but is, instead, connected to the elevated water levels. In the relatively arid climate of Colorado, an elevation of alkalinity is often observed in wells where the water level rises dramatically above the previous saturated zone. The elevated water levels appear to be caused by the presence of the retention pond that was expanded in the summer of 1996. It also

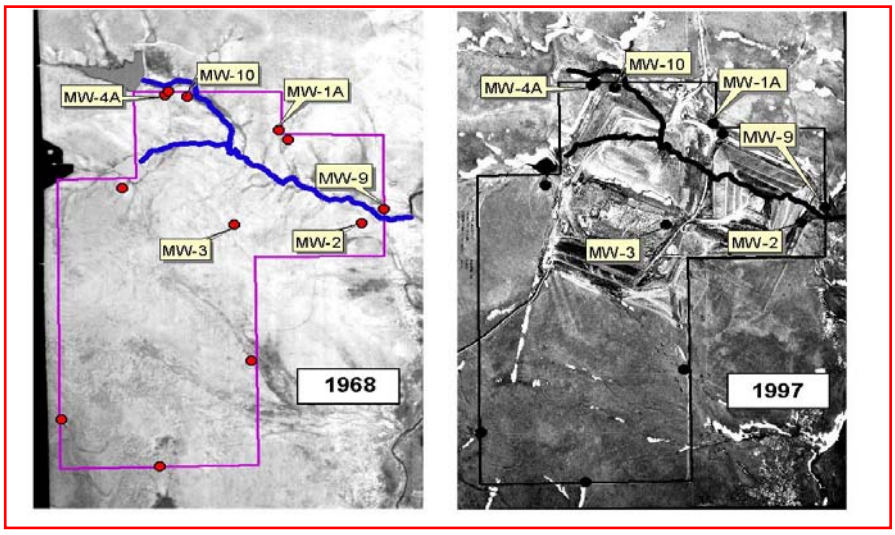


Figure B-1. Landfill site photo

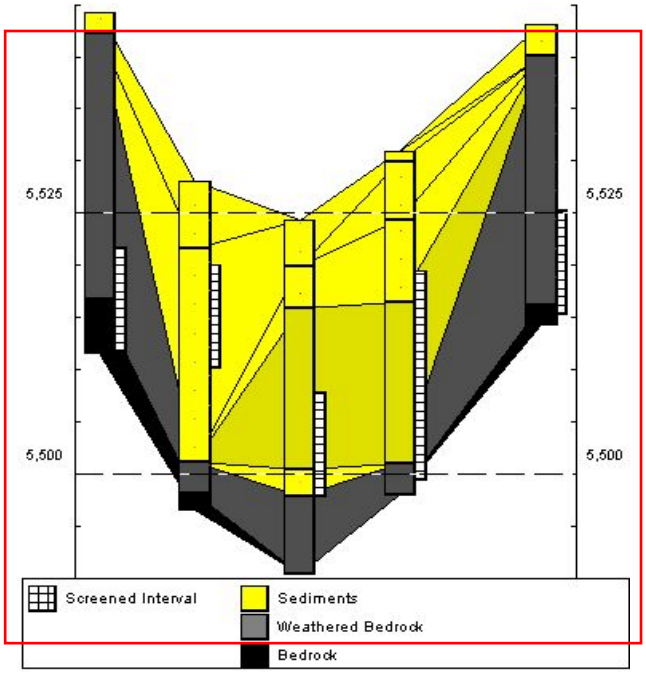


Figure B-2. Cross-section of old stream channel

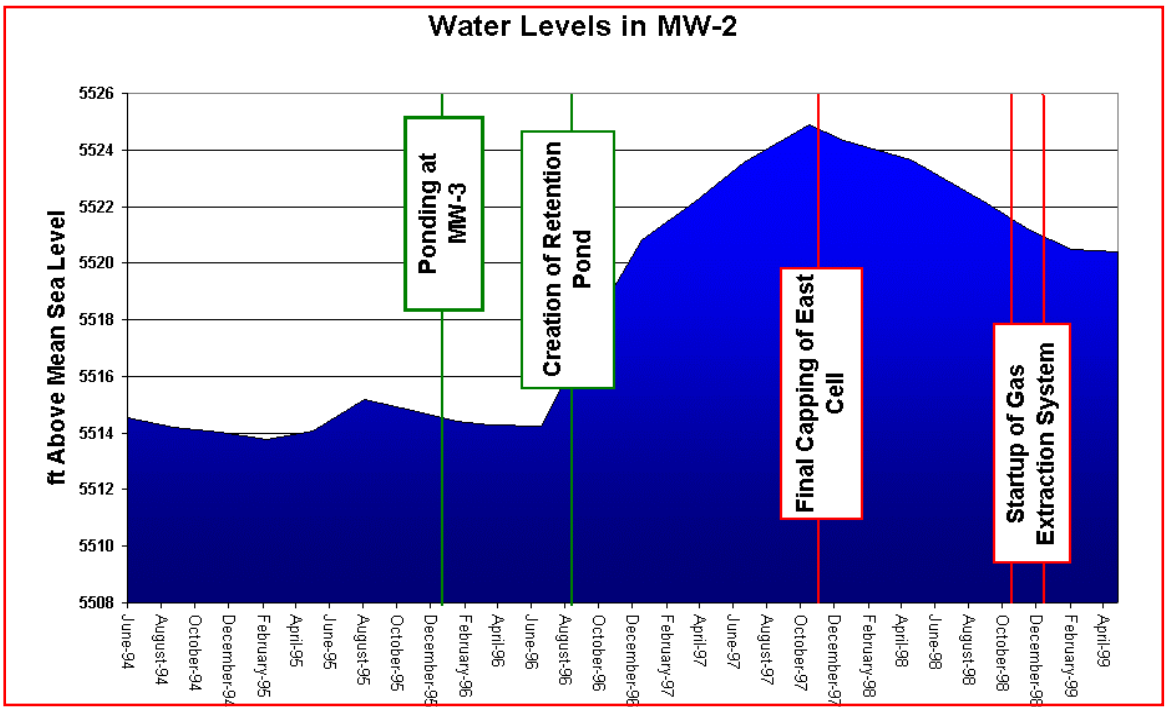


Figure B-3. Water Level vs. time at MW-2

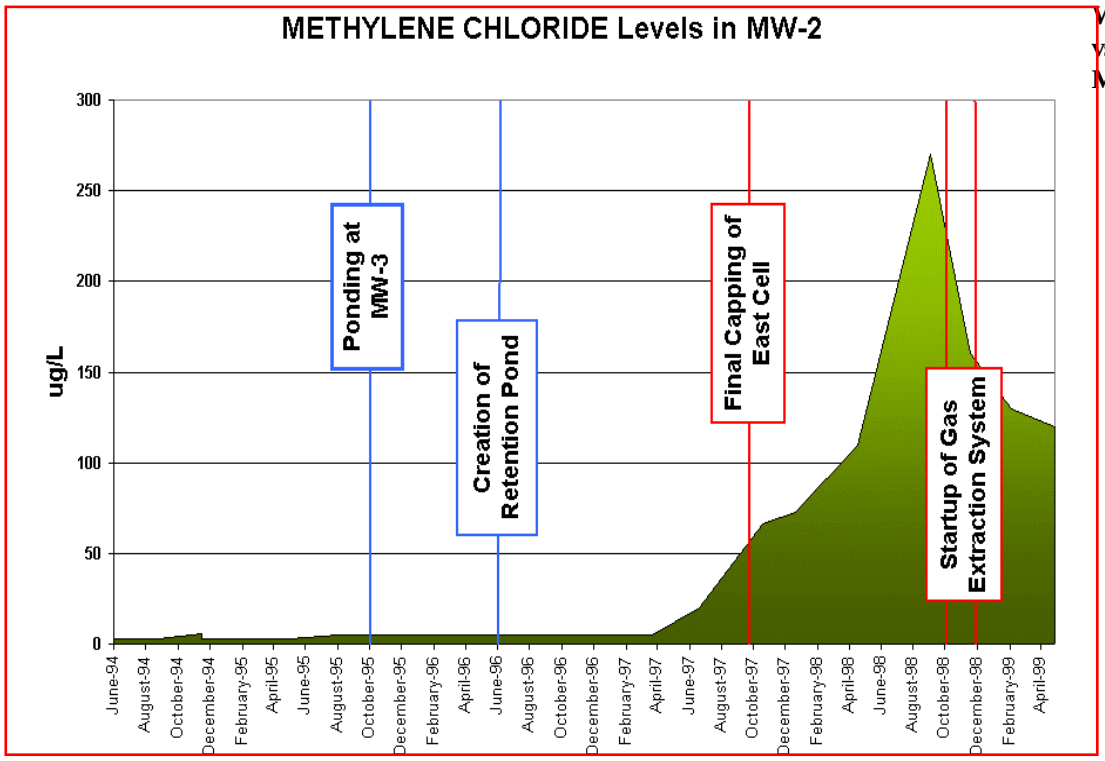


Figure B-4. Methylene chloride concentrations vs. time in MW-2

appears that the installation of the cap and the removal of the retention pond removed the source for the rise in water level elevations and, coincidentally, stopped the rise in bicarbonate concentration.

The concentrations of methylene chloride and other organic contaminants do not appear to be directly related to the rise in water levels. The rise appears to start before the installation of the cap, but may be related to the placement of a temporary cap previous to the placement of the final cap. The gas extraction system is having a beneficial effect exhibited by a decrease in the concentrations of the organic contaminants. This lends support to the option of letting the facility continue to use it as a remediation method.

Finally, the use of the integrated data system has brought up a question about the usefulness of the data from MW-9. MW-9 was put in place to monitor whether the plume of contamination was migrating off site. The location of this well is in the same sediments as MW-2, but because of the complex nature of alluvial sediments is probably not in direct hydraulic connection with the known area of contamination. A new well should be placed on the same side of the channel as MW-2 to determine if the plume is migrating off site.

Site 2

A defunct metal plating shop located in an industrial area was found to be out of compliance with numerous environmental regulations. These included the storage of hazardous waste onsite for a greater period of time then was allowed, multiple instances of poor housekeeping, unregulated discharge to the storm sewer, and the dumping of hazardous material on site. The site was closed by the Environmental Protection Agency (EPA) and local fire authorities in the early 1990s, and approximately 100 cubic yards of contaminated soil was removed from the south end of the building where the operators of the facility had been dumping waste. This was done as an emergency response to remove a potential source of groundwater contamination. The EPA also installed two monitoring wells on the site. Testing of water from these wells showed elevated concentrations of cyanide and certain metals. The EPA placed the site under a corrective action order that made it impossible for the property to be redeveloped due to the liabilities that were involved.

Several issues needed to be resolved prior to the corrective action order being removed. Since it was not known if all of the contaminated soil was removed initially, there may have been contaminated material still acting as a source for groundwater contamination. One possible location for this contaminated material was underneath the floor of the site building. Also, the direction of groundwater flow was not known at the site. It was possible that the contamination was moving into a stream nearby via shallow groundwater. This stream flowed into a river just below the site, and there was a municipal drinking water intake serving a population of approximately 30,000 people downstream of the confluence of these two surface water bodies. Additionally, there was a drinking water well within 90 feet of the property which produced water for a family of six.

Further investigation needed to answer certain questions. If groundwater was flowing toward the stream was the contaminated groundwater influencing water quality? If so, was the drinking water intake in jeopardy? Was the drinking water well already affected? Was there significant residual contamination under the building on site? A sampling plan was developed to answer these questions. To better understand the site, a GIS project was constructed and used in the development of the sampling plan.

Based on the sampling plan, 11 monitoring wells were installed around the site. Nine sub-slab borings were installed beneath the building to check for soil contamination. Samples were collected from the concrete floor and plating residue within the building and the soil beneath the building. Groundwater samples were collected from the 11 monitoring wells and the residential well. Surface water samples were collected from the stream and river. The elevations of the monitoring wells were determined by survey. Locations for the well points were collected using GPS. The lithology, well completion information, and water level readings were loaded into EQuIS. This allowed for the creation of cross-sections of the site and bedrock and groundwater contour maps.

Laboratory results of the samples collected showed that groundwater was contaminated at the facility. Based on the cross-sections it was determined that a bedrock high was situated to the south and west of the site and the bedrock surface greatly influenced groundwater flow direction. This was also apparent in contour plots of the bedrock elevations and the groundwater gradient. This high prohibited the flow of groundwater toward the stream. Therefore, the site did not affect the water quality of the stream and river. The drinking water supply was safe. The groundwater contour map showed that groundwater flow was to the northwest and that the drinking water well was not down gradient of the contamination (Figure B-5). Groundwater contamination, though present, attenuated and was below regulatory limits at the site boundary to the northwest.

Although there was residual contamination at the site, this study showed that it did not warrant further remedial action. The results of this study allowed the EPA and state RCRA group to lift the corrective action order from the site and open the site for

redevelopment.

Site 3

Rocky Flats has implemented EQuIS on a much larger scale. The Rocky Flats Environmental Technology site, owned by the U.S. Department of Energy (DOE), manufactured components for nuclear weapons for national defense until 1992. The plant is currently undergoing environmental cleanup, waste management, and decommissioning. The industrial complex of more than 100 buildings is located in the center of nine square miles of undeveloped land northwest of Denver. Rocky Flats stores the

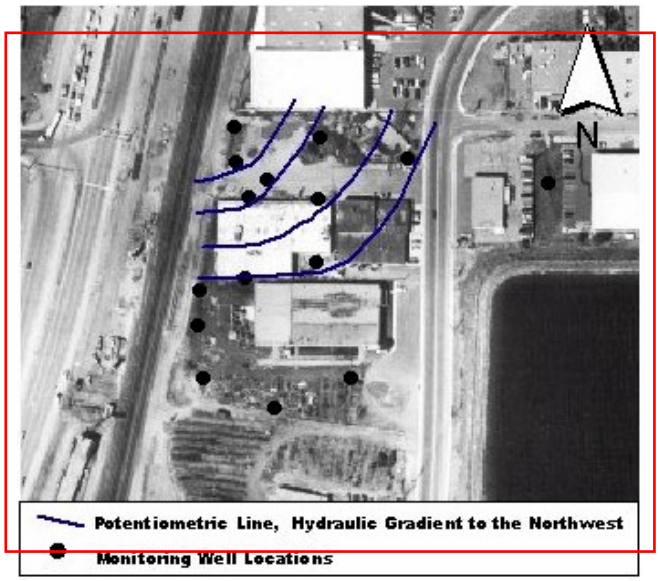


Figure B-5. Site plan and potentiometric surface map for metal plating site

largest quantity of radioactive and hazardous wastes in Colorado. Due to its size, all of the data from Rocky Flats has not yet been completely loaded into EQuIS. As of the end of 1999, geologic and well completion information has been input. Approximately 1300 borings, of which 1200 are wells, have been entered. As more borings are being drilled at this site, these are being uploaded into the system. There are 22,000 water level measurements for these wells. Chemical data is being migrated into the system from two older databases. Data from an older state system are being loaded to help personnel evaluate the quality of remediation efforts taking place at the site

From this data a groundwater model was constructed to help evaluate groundwater activity. See Figure 6 for the bedrock tin created for the model. The database was shared with site personnel. This sharing of data allows for the better evaluation of activities at the site. The integrated EQuIS data management system facilitates a better understanding of the geology and hydrogeology of the site. Once complete, the full system will permit better public access to information.

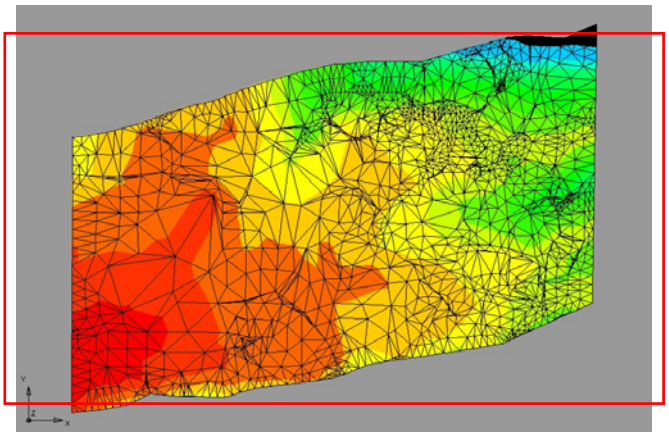


Figure B-6. Bedrock tin for Rocky Flats groundwater model

Conclusion

The sites discussed illustrate many of the advantages of implementing a database system such as EQuIS. With the storage of data in one centralized repository and the ability to export this data to many different evaluation tools, site characterization and analysis becomes quicker and more effective. Decisions can be made based on the data with much more confidence and reliability. Though the state has not fully implemented the system, benefits are already being seen. These include better understanding of the sites we regulate, improved data quality, easier design of sampling and remediation plans, and easier access to the data. The ease of data query and export to evaluation tools afforded by EQuIS allows project managers to test the sensitivity of different applications to the data. Also, several different statistical, contouring and groundwater modeling tools can be utilized with limited effort to check the validity of applying different algorithms to the problem.

A number of other uses are perceived in the future. As more sites are incorporated into the system it will be possible to use the data in the warehouse to help in the evaluation of newly discovered sites. Because of the standardized format, it will be easier to share data and conclusions with the general public.