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Environmental Data from the Field to the Map

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INTRODUCTION

Environmental investigation and remediation projects are inherently complex. At the same time expectations for data management are growing rapidly, while budget pressures require you to do more with less. Tools to better gather and manage environmental data are now affordable and have a high return on investment. We will look at examples of using this technology on environmental projects.

An environmental management system (EMS) is a key part of a company's environmental stewardship. Procedures and practices to continually improve environmental performance can provide great benefits in operating the company. Managing site environmental quality data is a key component of this. An environmental data management system (EDMS) is an important element of the EMS for environmental projects, providing project staff with the information that they need to make decisions that can have a significant impact on public health.

Improvements in computers, data communications, and transfer formats have made it much easier to implement an integrated EDMS program for gathering, managing, selecting, and displaying data from the field and the lab. Software now lets users define sampling plans, create files for field data entry, and print chains of custody and bottle labels. Laptop and handheld computers facilitate field data entry and may provide automated communication back to the office. Most labs can now create usable electronic data deliverables (EDDs). QC checks and limit comparisons can be largely automated. The result is organized data that can be efficiently used for reporting, graphing, and mapping, to better understand project issues.

The process of gathering and managing environmental data is shown in Figure 1. This process is broken into four parts: 1) planning your events; 2) field and lab activities; 3) managing data; and 4) analyzing and displaying data. These parts will be described, along with several other data management issues.

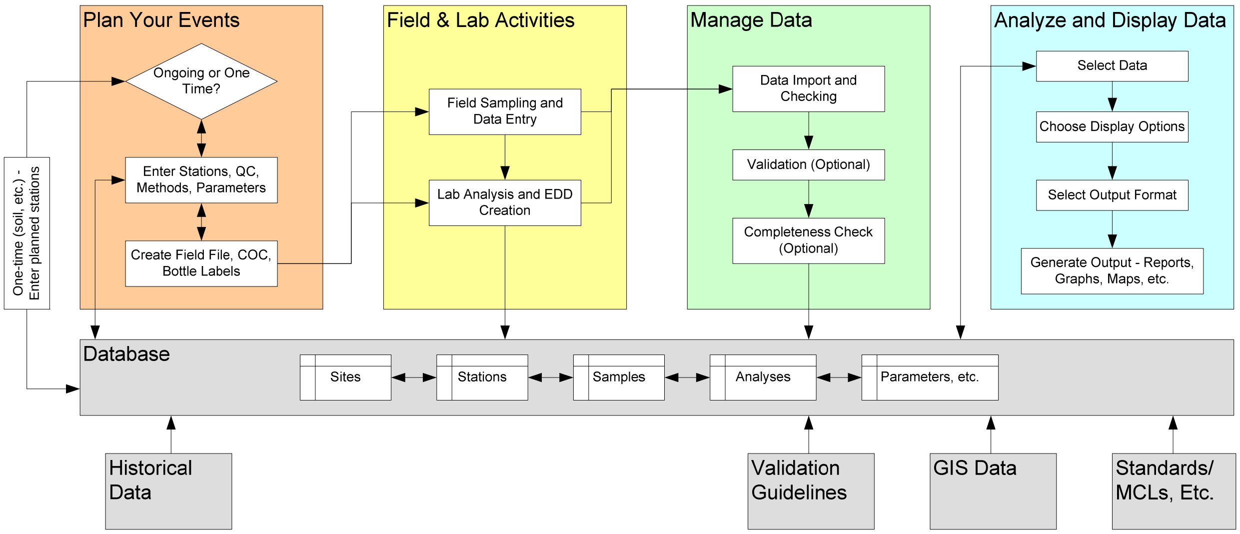


Figure 1 - Overview of environmental data gathering and management

An example of a display from a modern integrated environmental data management system (EDMS) is shown in Figure 2. This technology puts high quality, organized data in the hands of the project staff.

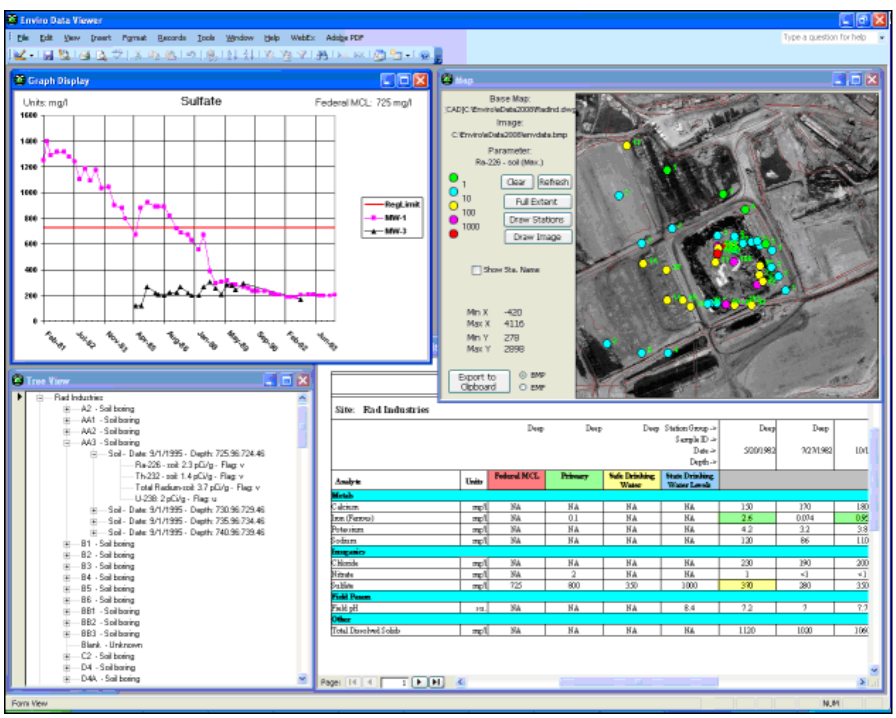


Figure 2 - Example screen from an integrated data management system

PLANNING SAMPLE EVENTS

The process of gathering and managing quality environmental data should start in the office (or trailer) with creating a sample plan, and then generating individual sample events. An example of data management software being used to set up and track a sample event is shown in Figure 3.

SETTING UP THE EVENT

On this form the user is selecting the stations (locations such as monitoring wells, soil borings, etc.) to be added to the Event. If the stations are already in the database, such as for an ongoing program, they can select them from the list. If the stations will be newly created by the event, such as one-time soil samples, they will need to enter the station information, at least as much as they have, such as a name, prior to adding it to the event. For stations that will have multiple samples, such as by depth, this needs to be entered.

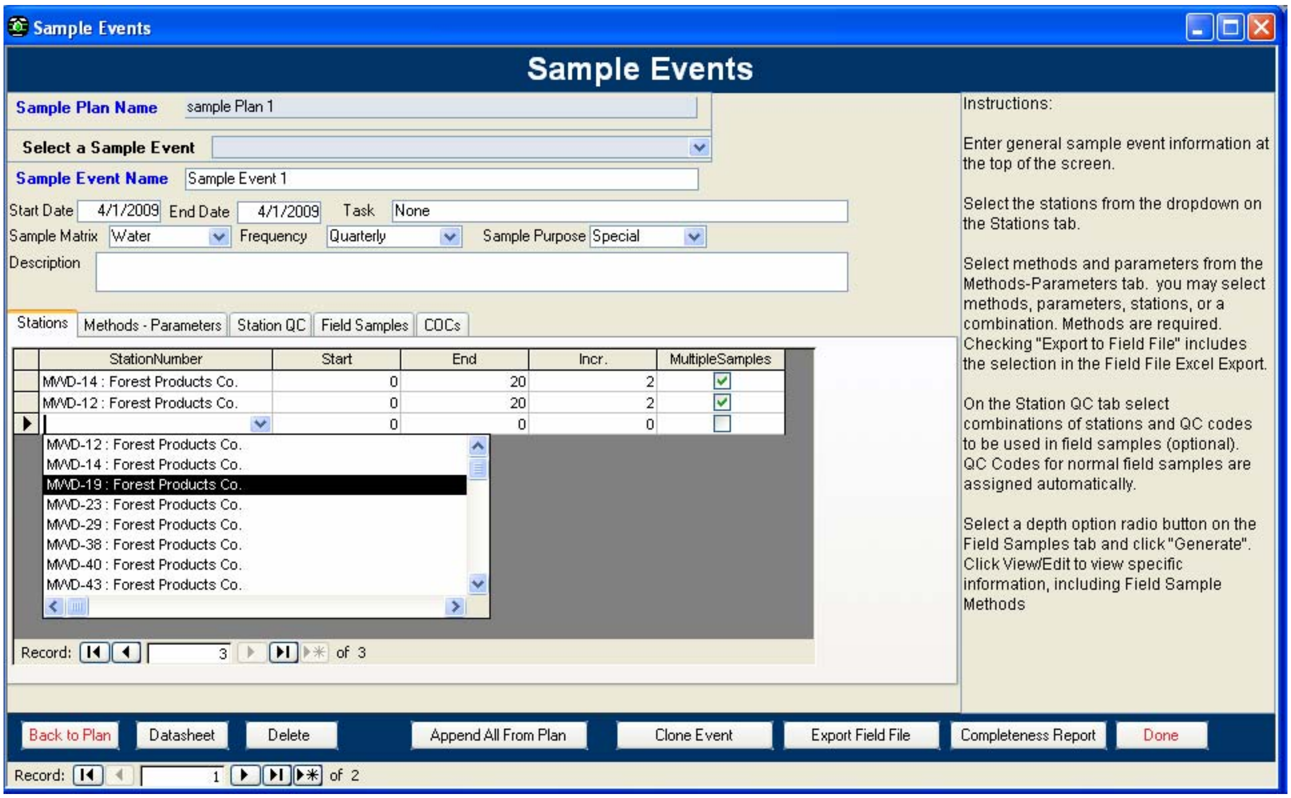


Figure 3 - Entering stations for a sample event

Next, the user will enter the methods and parameters to be used as shown in Figure 4. Each event may need to have analytic methods, parameters, or both. Also, many events will contain both field and laboratory methods and parameters. The field methods/parameters will need to be exported to the field file as discussed below, while the lab methods/parameters will need to go on one or more chains of custody. Some projects may require different methods and parameters to be applied to different stations, and this must be accommodated. The user may also want to add field QC samples as shown in Figure 5.

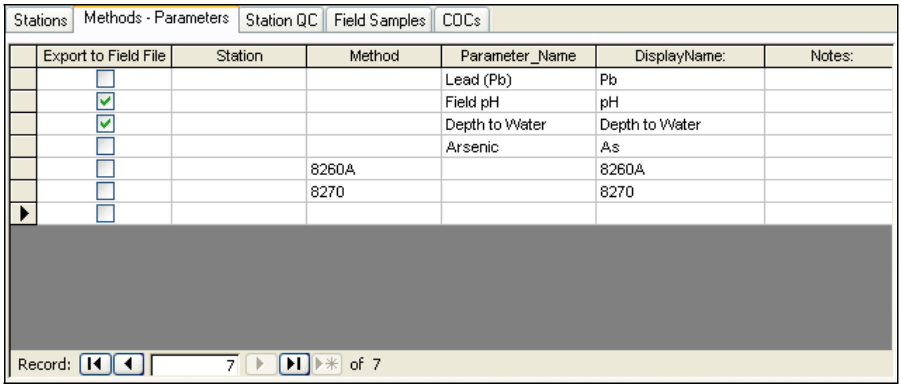


Figure 4 - Entering methods and parameters for a sample event

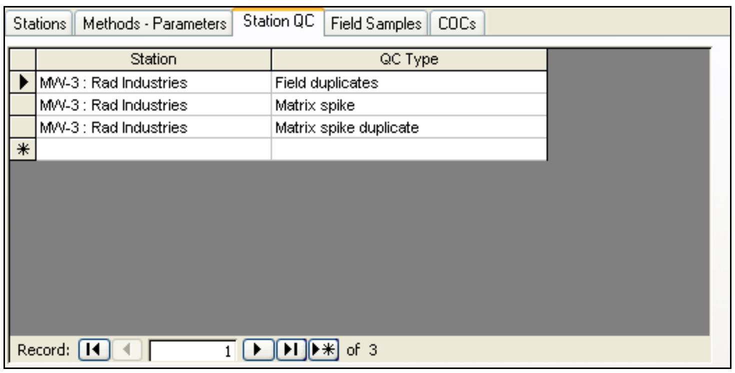


Figure 5 - Entering station QC for a sample event

After entering the station and QC information, the field samples can be generated as shown in Figure 6.

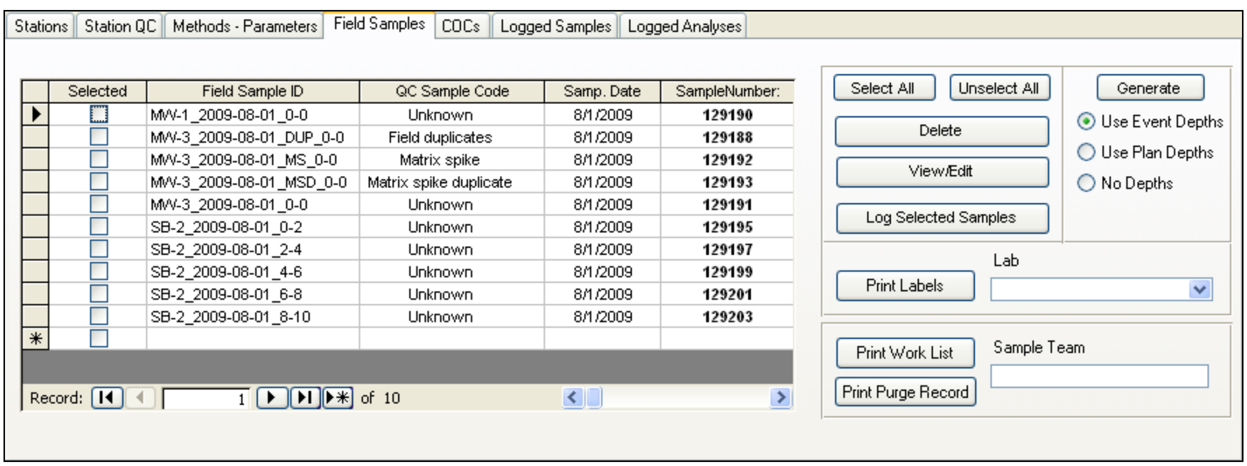


Figure 6 - Generating field samples for a sample event

CREATING CONTAINER LABELS

The information entered in the planning tool can then be used to create container labels. The user should select the samples for labels, and the lab, and then the labels can be created as shown in Figure 7. These can be printed on standard Avery labels. Note that some containers have multiple fractions.

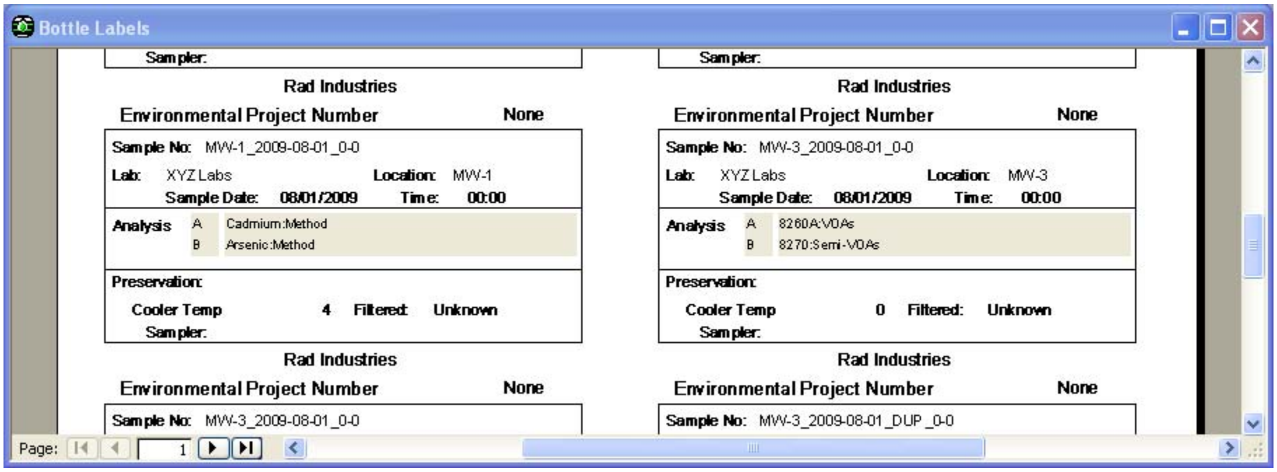
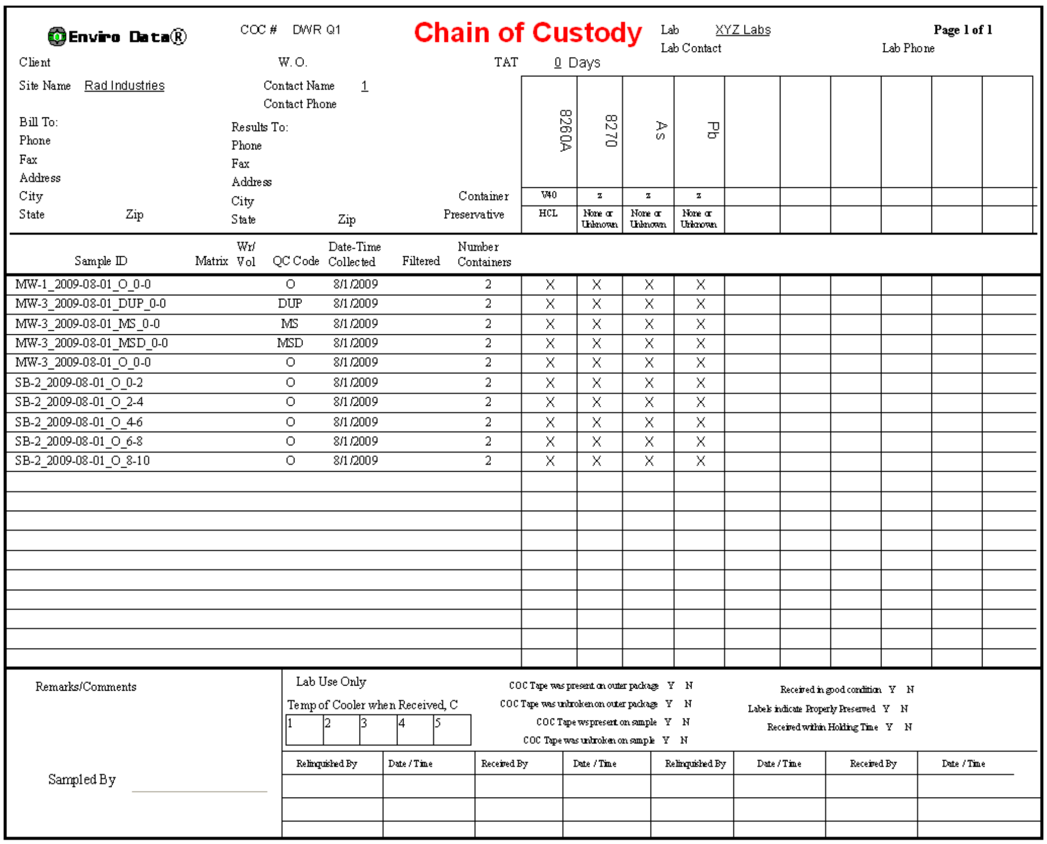


Figure 7 - Generating sample containers for a sample event

CREATING THE CHAIN OF CUSTODY

The samples and methods/parameters can then be assigned to one or more chains of custody, as shown in Figure 8. They might also have the software generate a field file as discussed in the next section.



Enviro Data® COC # DWR Q1 **Chain of Custody** Lab XYZ Labs Page 1 of 1
Lab Contact Lab Phone
Client W.O. TAT 0 Days
Site Name Rad Industries Contact Name 1
Contact Phone
Bill To: Phone Fax Address City State Zip
Results To: Phone Fax Address City State Zip

Sample ID	Matrix	Wt/ Vol	QC Code	Date-Time Collected	Filtered	Number Containers	8260A	8270	As	Pb
Container							V40	z	z	z
Preservative							HCL	None or Unknown	None or Unknown	None or Unknown
MW-1_2009-08-01_O_0-0			O	8/1/2009		2	X	X	X	X
MW-3_2009-08-01_DUP_0-0			DUP	8/1/2009		2	X	X	X	X
MW-3_2009-08-01_MS_0-0			MS	8/1/2009		2	X	X	X	X
MW-3_2009-08-01_MSD_0-0			MSD	8/1/2009		2	X	X	X	X
MW-3_2009-08-01_O_0-0			O	8/1/2009		2	X	X	X	X
SB-2_2009-08-01_O_0-2			O	8/1/2009		2	X	X	X	X
SB-2_2009-08-01_O_2-4			O	8/1/2009		2	X	X	X	X
SB-2_2009-08-01_O_4-6			O	8/1/2009		2	X	X	X	X
SB-2_2009-08-01_O_6-8			O	8/1/2009		2	X	X	X	X
SB-2_2009-08-01_O_8-10			O	8/1/2009		2	X	X	X	X

Remarks/Comments
Sampled By
Lab Use Only
Temp of Cooler when Received, C 1 2 3 4 5
COC Tape was present on outer package Y N
COC Tape was unbroken on outer package Y N
COC Tape ws present on sample Y N
COC Tape was unbroken on sample Y N
Received in good condition Y N
Labels indicate Properly Preserved Y N
Received within Holding Time Y N

Relinquished By	Date / Time	Received By	Date / Time	Relinquished By	Date / Time	Received By	Date / Time

Figure 8 - Chain of Custody form generated by the Sample Planning tool

FIELD AND LAB ACTIVITIES

Management of the groundwater, soil, and related data next moves to the field, both with taking physical samples to send to the laboratory, and with gathering field data such as fluid levels, temperature, pH, and other field parameters. Recent improvements in field equipment have made it easier to gather data directly in the field, either using portable measuring tools, or through manual entry at the site.

FILLING OUT THE FIELD FILE

Figure 9 shows an example of gathering field data using a spreadsheet file on a computer or on paper, while Figure 10 shows an example of data entry in the field using a Windows Mobile PDA phone. The data has been entered into an Excel spreadsheet, which can be emailed to the office, or synched to the desktop upon return. The field data is then imported into the database, and associated with the analytical data when it arrives from the laboratory. The data management system should help with all phases of this process.

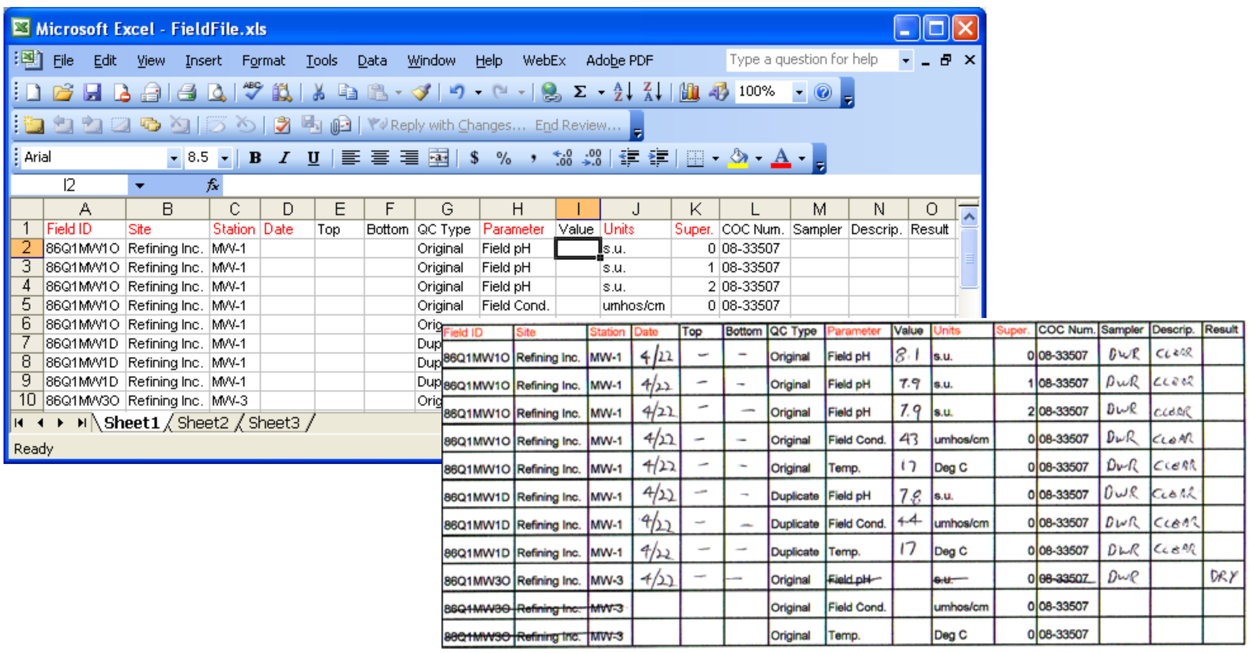


Figure 9 - Example of data gathering using a spreadsheet file on a computer or on paper

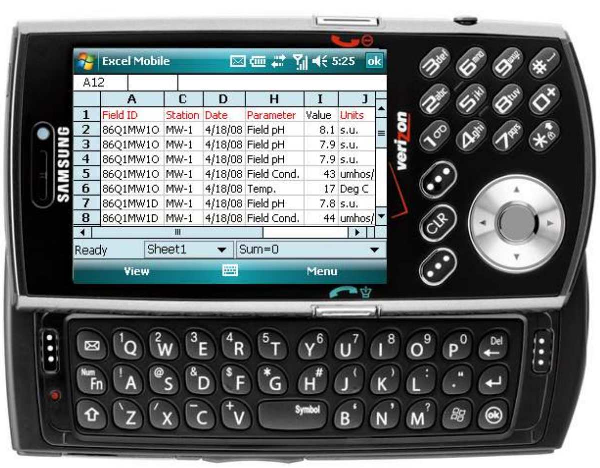


Figure 10 - Example of data gathering using a Windows Mobile PDA phone

SUBMITTING SAMPLES TO THE LAB

After the field measurements are taken, the samples are taken and sent to the lab along with the chain of custody.

MANAGING DATA

There are many different aspects of quality control that apply to managing environmental data, many of which can be made more efficient through effective use of data management software. The first step is to have a comprehensive data management plan, either as part of quality control planning, or as a separate document. The next step is to obtain the data in a suitable format. The data elements in the selected format must then be mapped to the data elements in the receiving application.

IMPORT FORMATS

A significant problem over the years has been coming to agreement on one or more common formats for data providers and data consumers to use for transferring data, especially laboratory data. Traditionally, each data consumer, either an agency or software program, has defined a data transfer format to satisfy its particular needs. This has resulted in laboratories and data management professionals often needing to deal with dozens or even hundreds of different formats in their daily work. Recently the USEPA, Army Corps of Engineers, and others have worked to develop a standard data transfer format for environmental data. This format, called SEDD (Staged Electronic Data Deliverable) is based on an industry standard, self-documenting format called XML (eXtensible Markup Language.) This format is capable of handling the hierarchical relationships inherent to environmental data. While this format is not as easy to work with as simpler flat-file formats, tools are increasingly becoming available to create and accept data in this format. While having a standard format like SEDD can help significantly with expediting data transfer, other data quality issues, such as consistency and reasonableness, must still be addressed. Several of these formats are shown in Figure 11.

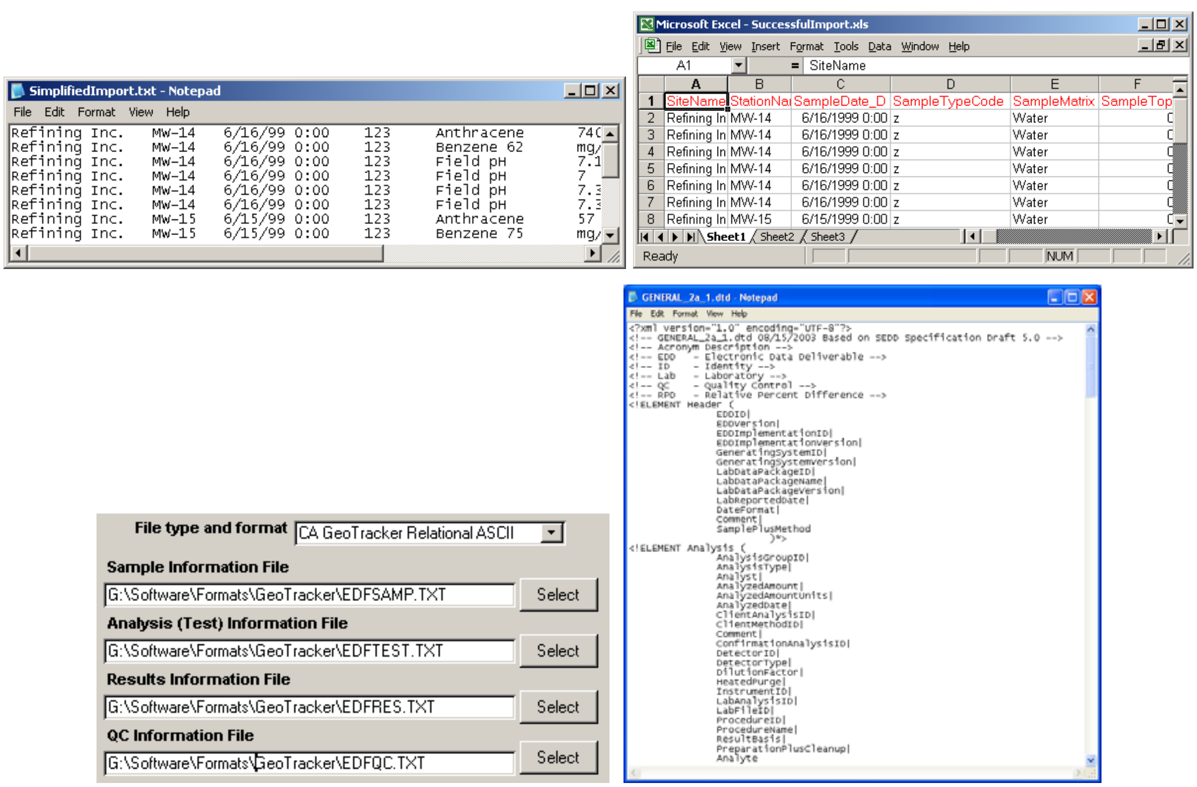


Figure 11 - Example data formats: ASCII, Excel, multi-file (GeoTracker) and SEDD XML

All data must be checked for consistency in order to fit into an effective relational data management system, and consistency problems must be resolved accurately and efficiently. Unfortunately this is usually a manual process, since the common errors such as variations in spelling and punctuation in location and parameter names generally require human judgment to resolve. An example of this problem resolution process is shown in Figure 12.

CHECKING DURING IMPORT

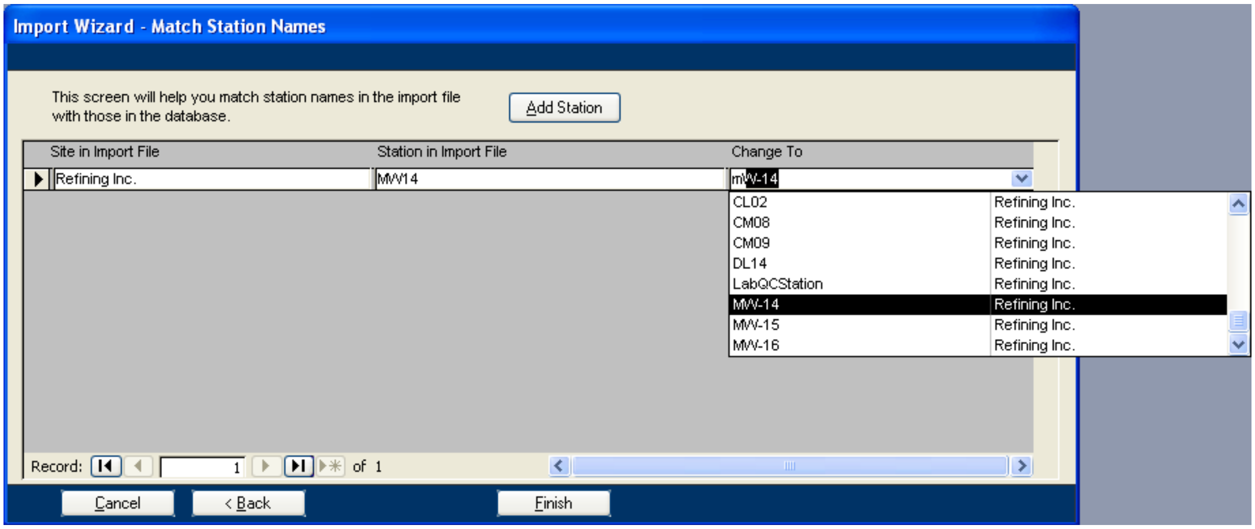


Figure 12 - Data management software being used to enforce data consistency during import

DATA VALIDATION ASSISTANCE

Beyond consistency checking, the amount of quality control effort may vary from project to project, depending on the expected use of the data. The software can help with simple statistical tests such as outlier and charge balance calculations. For more rigorous checking, the software can check holding times, spike recoveries, QC sample frequencies, and other more traditional "validation" activities before the validator makes the final determination of suitability for use. Figure 13 shows an example of a form for setting up a software assisted data validation task. Figure 14 shows a statistical outlier report comparing recent data with historical data.

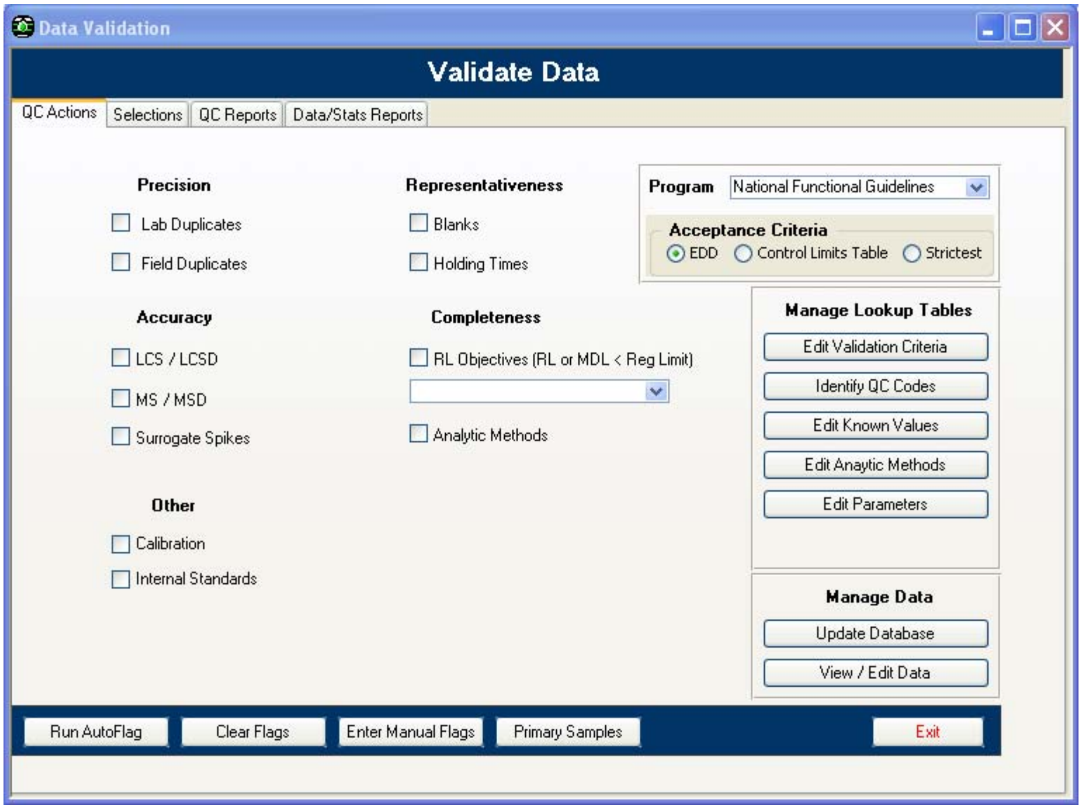


Figure 13 - Software being used to assist with data validation using EPA CLP-type procedures

Data Comparison and Evaluation — **Report Date: December 5, 2001**

SAMPLE NO: LAB NO: STATION:MW-1

PARAMETER	11/21/85 RESULT	COMPARISON PERIOD OF DATA	QC Code	N	# OF DET	MIN	MAX	MEAN	MEDIAN	SD	# OF SD'S FROM MEAN
Calcium (TOT) (mg/l)	160	02/26/81-05/18/94	O	53	53	105.0	210.0	145.3	131	33.4	0.4
Iron (Ferrous)(TOT) (mg/l)	2.3	02/26/81-05/18/94	O	52	52	0.0	5.5	1.1	1.3	1.8	0.7
Potassium (TOT) (mg/l)	6.6	02/26/81-05/18/94	O	53	53	1.1	48.0	5.3	5.2	6.3	0.2
Sodium (TOT) (mg/l)	410	02/26/81-05/18/94	O	53	53	96.6	550.0	239.2	290	164.3	1.0
Chloride (mg/l)	220	02/26/81-05/18/94	O	53	53	120.0	380.0	181.7	190	60.6	0.6
Nitrate (mg/l)	< 4	02/26/81-08/18/93	O	50	53	120.0	380.0	181.7	190	2.1	0.6
Sulfate (mg/l)	920	02/26/81-05/18/94	O	53	53	190.0	1400.0	503.3	670	410.9	1.0
Field pH (s.u.)	7.1	02/26/81-05/18/94	O	53	53	7.0	8.0	7.4	7.4	0.3	1.1
Total Dissolved Solids (mg/l)	2070	02/26/81-05/18/94	O	53	53	850.0	2813.0	1505.2	1630	714.7	0.8

Figure 14 - Example statistical report for analyzing data quality

It can also be useful to run a "completeness report" at the end of each data gathering event to confirm that all the expected data was received, or missing data explained. Figure 15 shows an example of one of these reports.

Enviro Data® COC # DWR Q1 **Completeness Report** Lab XYZ Labs **Page 1 of 1**

Client W.O. TAT 0 Days Lab Contact Lab Phone

Site Name Rad Industries Contact Name 1

Contact Phone

Bill To:	Results To:
Phone	Phone
Fax	Fax
Address	Address
City	City
State Zip	State Zip

Sample ID	Matrix	Wt/ Vol	QC Code	Date-Time Collected	Filtered	Number Containers	8260A	8270	As	Pb
						Container	V40	z	z	z
						Preservative	HCL	None or Unknown	None or Unknown	None or Unknown
MW-1_2009-08-01_O_0-0			O	8/1/2009		2	97	63	1	1
MW-3_2009-08-01_DUP_0-0			DUP	8/1/2009		2	97	63	1	1
MW-3_2009-08-01_MS_0-0			MS	8/1/2009		2	97	63	0	0
MW-3_2009-08-01_MSD_0-0			MSD	8/1/2009		2	97	63	0	0
MW-3_2009-08-01_O_0-0			O	8/1/2009		2	97	63	1	1
SB-2_2009-08-01_O_0-2			O	8/1/2009		2	97	63	1	1
SB-2_2009-08-01_O_2-4			O	8/1/2009		2	97	63	1	1
SB-2_2009-08-01_O_4-6			O	8/1/2009		2	97	63	1	1
SB-2_2009-08-01_O_6-8			O	8/1/2009		2	97	63	1	1
SB-2_2009-08-01_O_8-10			O	8/1/2009		2	97	63	1	1

Figure 15 - Example completeness report for analyzing data quality

ANALYZING AND DISPLAYING DATA

Once the data has undergone the appropriate level of review, it is stored in a central repository, usually in a normalized relational data model. The user interface of the data management system should provide selection and display tools that provide a good level of flexibility, while still being easy to use. This can be a difficult balance to achieve. As data management systems move from use by experts to project personnel, ease of learning and use become increasingly important.

There are three parts to outputting data. These are: 1) data selection; 2) display options; and 3) output format. Once the selection and display options have been determined, the data can be displayed in the database, a geographic information system (GIS), other graphics and analysis programs, or some combination. For some projects, display (or even management) of data via the Internet could be important. Also for some projects, management and display of geological and engineering data can be important. Some examples will be shown in later sections.

DATA SELECTION

The first step in working with data is to select the data to be retrieved. There are a number of ways to do this. In a database management program like Microsoft Access, it can be done using query tools such as SQL and the query grid to specify and retrieve data as shown in Figure 16.

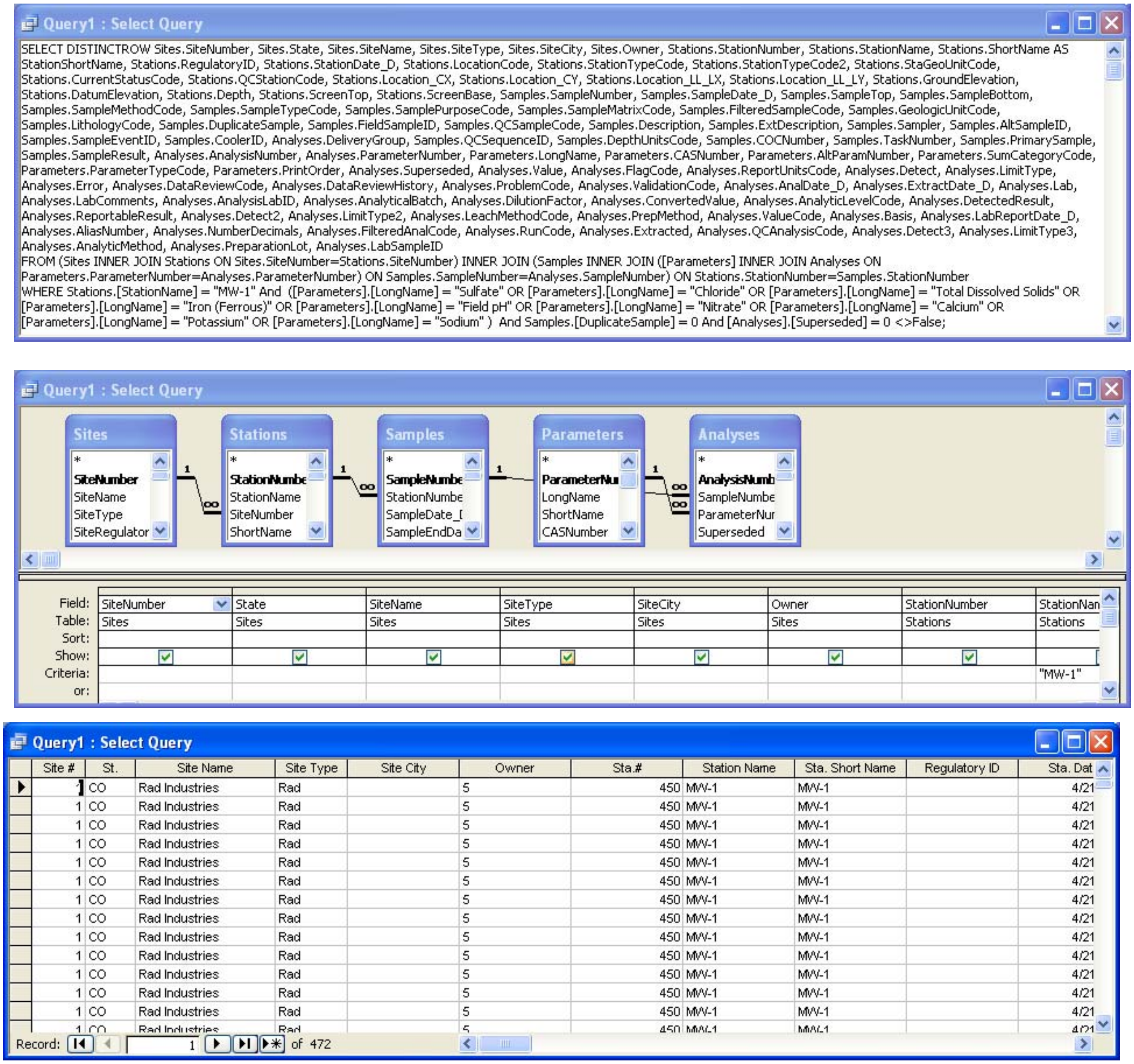


Figure 16 - Microsoft Access query in SQL, grid and datasheet views

Commercial tools for managing environmental data provide an easier and more intuitive way to select data as shown in Figure 16.

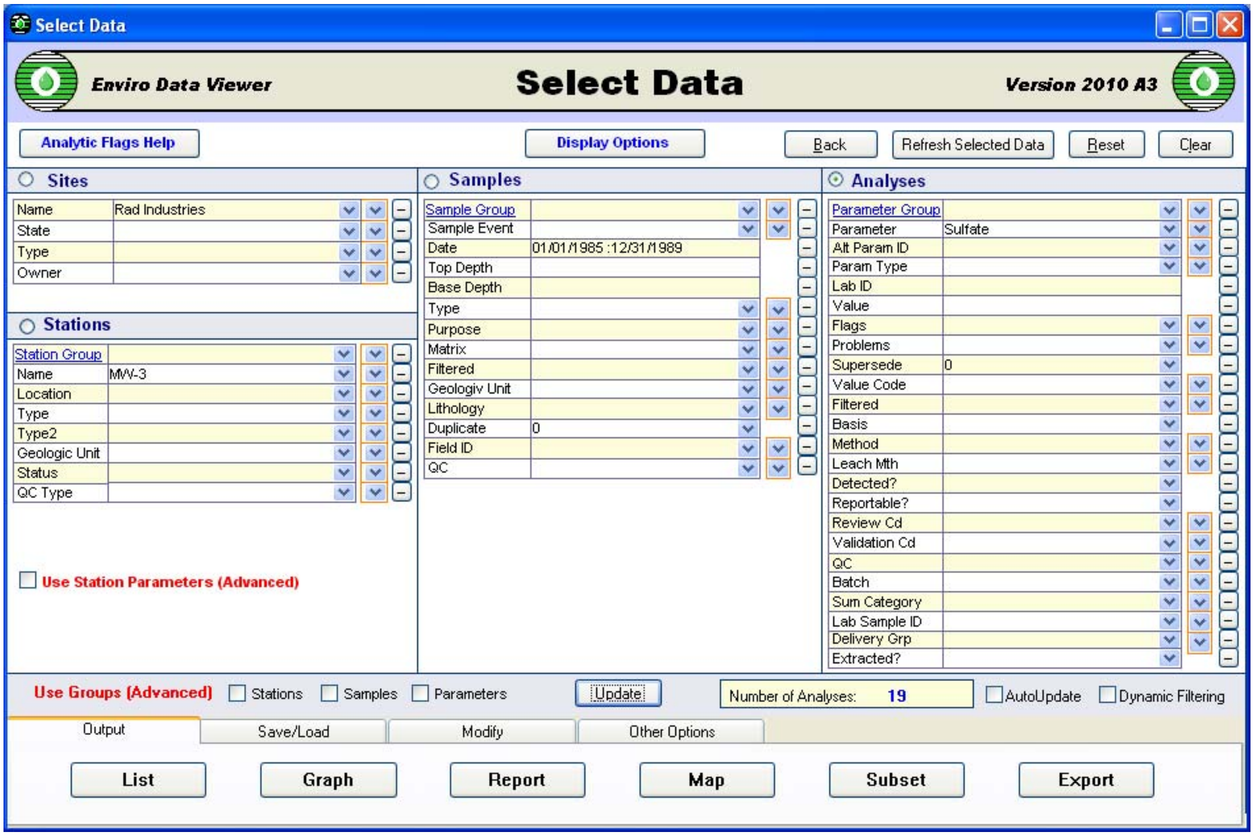


Figure 17 - Screen for selecting data

With this tool the user picks items to be used in the selection from drop-down lists. It handles complex relationships between the tables, including one-to-many and many-to-many relationships while hiding the complexity from the user.

DISPLAY OPTIONS

Environmental data has a number of subtleties that complicate the storage, retrieval, and display of the data. A number of these are described in a later section. Also, each project has its own way of displaying the data. In order to satisfy as many of these needs as possible, the software should let the user specify a variety of display options to fine-tune the output. Examples of these options include how to handle flagged data (including non-detects), whether to convert to consistent units, how to handle regulatory limits, whether to display only "hits" (either detections or exceedences), how to handle large numbers, and whether to display calculated parameters. An example of a screen to specify these options is shown in Figure 18.

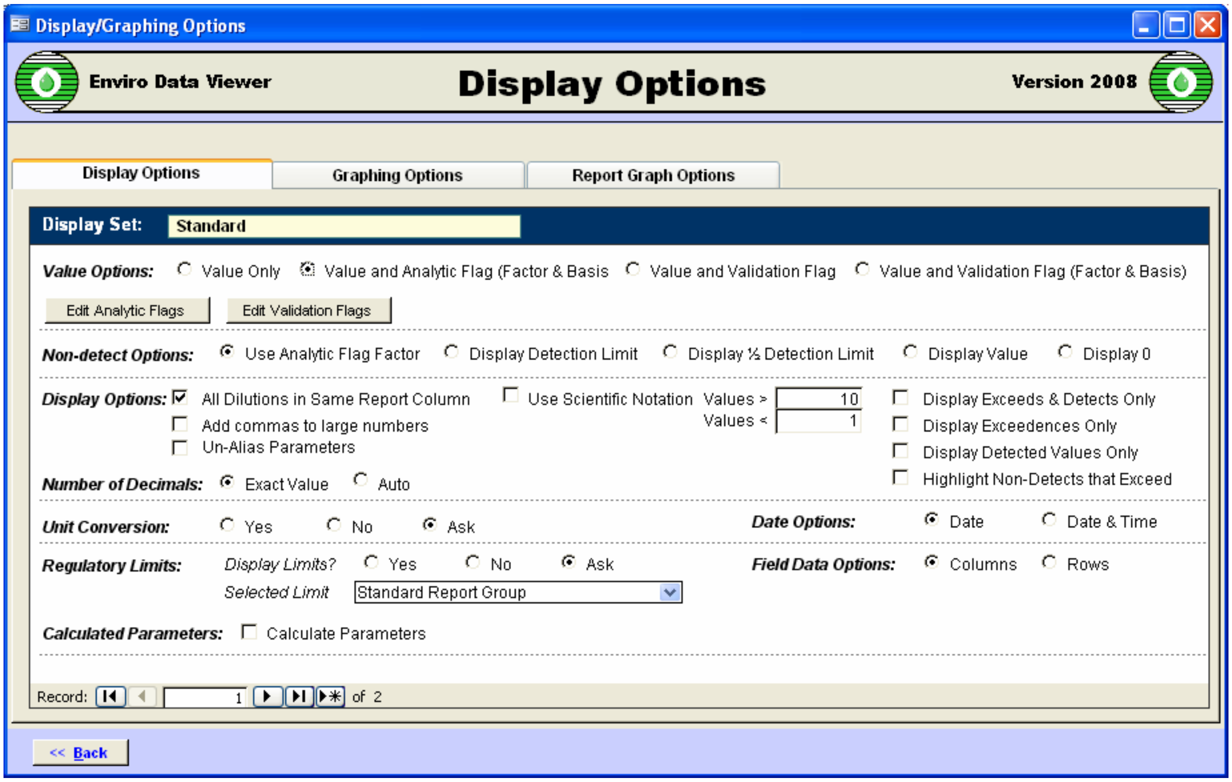


Figure 18 - Screen for specifying display options

DISPLAYING DATA IN THE DATABASE

In the past, the primary deliverable for project data has been the tabular report. This type of display remains important, and software features such as flexible and automated formatting of results, and automatic comparison to target levels, can make this process much more efficient. With the data stored in a comprehensive data management system, other displays such as maps and time-sequence graphs, also with comparison to limits, are easy to generate, and can tell you quite a bit about the site.

In some cases the data retrieval needs are very simple, such as looking up one or a handful of results. The TreeView display shown in Figure 19 is an example of this.

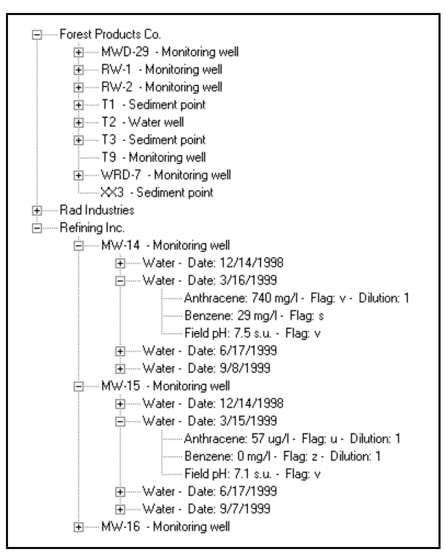


Figure 19 - TreeView display for individual results

Sometimes it is necessary to compare results to multiple target levels. Figure 20 is an example of a report comparing each result to four target levels, color-coding which level the result exceeds. This aspect of environmental data management is becoming increasingly complex. For example, some permits for discharge of water have different maximum contaminant levels for different times of the year, such as irrigation versus non-irrigation season. And some cleanup projects need to compare to different levels to determine potential use of remediated properties.

Validated Results (Test Site)

Site: AA

					Cluster ->	ZZ	ZZ	ZZ	ZZ
					Sample ID ->	AA-BB-003	AA-BB-005	AA-BB-006	AA-BB-006
					Date ->	10/9/2001	10/25/2001	10/17/2001	1/14/2002
					Depth ->				
Analyte	**Units**	**Base Background**	**BTAG Sediment**	**Industrial Sediment RBCs**	**Residential Sediment RBC**				
Pesticides									
4,4'-DDD	ug/kg	8.3	16	NA	NA	**29 v / 20**	**60 U / 60**	**50 J / 7.5**	-
4,4'-DDE	ug/kg	11	2.2	NA	NA	**37 v / 20**	**60 U / 60**	**31 v / 7.5**	-
4,4'-DDT	ug/kg	15.4	1.58	NA	NA	**20 U / 20**	**60 U / 60**	7.5 U / 7.5	-
ALDRIN	ug/kg	NA	NA	340	38	10 U / 10	29 U / 29	3.7 U / 3.7	-
ALPHA-BHC	ug/kg	NA	NA	NA	NA	10 U / 10	29 U / 29	3.7 U / 3.7	-
ALPHA-CHLORDANE	ug/kg	5	NA	NA	NA	10 U / 10	29 U / 29	3.7 U / 3.7	-
BETA-BHC	ug/kg	NA	NA	NA	NA	10 U / 10	29 U / 29	3.7 U / 3.7	-
DELTA-BHC	ug/kg	NA	NA	NA	NA	10 U / 10	29 U / 29	3.7 U / 3.7	-
DIELDRIN	ug/kg	NA	NA	360	40	20 U / 20	60 U / 60	7.5 U / 7.5	-
ENDOSULFAN I	ug/kg	NA	NA	NA	NA	10 U / 10	29 U / 29	3.7 U / 3.7	-
ENDOSULFAN II	ug/kg	NA	NA	NA	NA	20 U / 20	60 U / 60	7.5 U / 7.5	-
ENDOSULFAN SULFATE	ug/kg	NA	NA	NA	NA	20 U / 20	60 U / 60	7.5 U / 7.5	-
ENDRIN	ug/kg	NA	NA	610000	23000	20 U / 20	60 U / 60	7.5 U / 7.5	-
ENDRIN ALDEHYDE	ug/kg	NA	NA	NA	NA	20 U / 20	60 U / 60	7.5 U / 7.5	-
ENDRIN KETONE	ug/kg	NA	NA	NA	NA	20 U / 20	60 U / 60	7.5 U / 7.5	-
gamma-BHC (Lindane)	ug/kg	3.14	NA	NA	NA	10 U / 10	29 U / 29	3.7 U / 3.7	-
GAMMA-CHLORDANE	ug/kg	NA	NA	NA	NA	10 U / 10	29 U / 29	3.7 U / 3.7	-
HEPTACHLOR	ug/kg	3.14	NA	1300	140	10 U / 10	29 U / 29	3.7 U / 3.7	-
HEPTACHLOR EPOXIDE	ug/kg	NA	NA	630	70	10 U / 10	29 U / 29	3.7 U / 3.7	-
METHOXYCHLOR	ug/kg	NA	NA	1E+07	390000	100 U / 100	290 U / 290	37 U / 37	-
TOXAPHENE	ug/kg	NA	NA	52000	580	200 U / 200	590 U / 590	74 U / 74	-
PCBs									
AROCLOR-1016	ug/kg	NA	22.7	82000	5500	20 U / 20	29 U / 29	37 U / 37	-
AROCLOR-1221	ug/kg	NA	22.7	2900	320	20 U / 20	29 U / 29	37 U / 37	-
AROCLOR-1232	ug/kg	NA	22.7	2900	320	20 U / 20	29 U / 29	37 U / 37	-
AROCLOR-1242	ug/kg	NA	22.7	2900	320	20 U / 20	29 U / 29	37 U / 37	-

Figure 20 - Regulatory report comparing to multiple limits at once

Being able to make time-sequence graphs is one of the big benefits of a centralized data management system relative to storing data from each event in a separate file. An example of a graph with comparison to a target level is shown in Figure 21. The user has selected a point to display additional information.

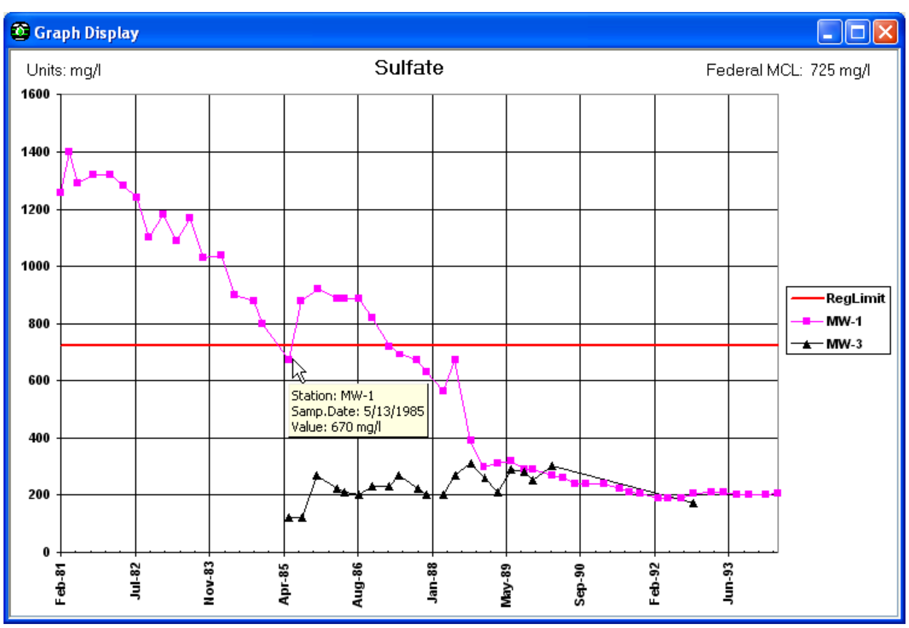


Figure 21 - Time-sequence graph showing relationship to a regulatory limit

A graph display with multiple graphs on a page is shown in Figure 22.

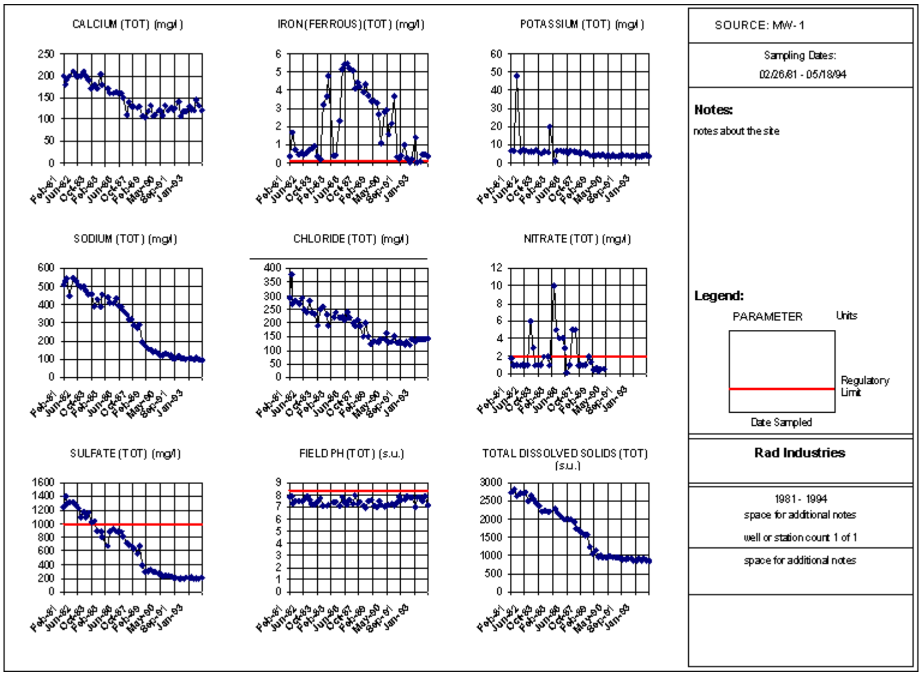
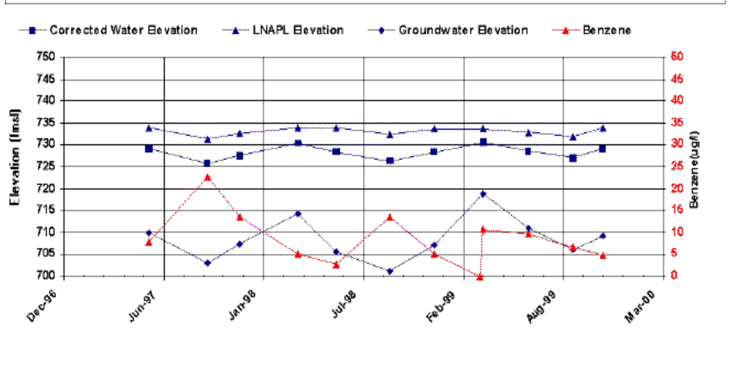


Figure 22 - Formatted report with multiple graphs on a page

For situations such as remediating fuel spills it is often useful to display a dissolved constituent (such as benzene) as a function of water and non-aqueous phase liquid (NAPL) levels, as shown in Figure 23.

Water and Product Level Observations

SampleDate	Depth to Water	Corrected Depth to Water	Corrected Water Elevation	LNAPL Thickness	Groundwater Elevation	Benzene	Depth to LNAPL
		ft	ft	ft	fmsl	ug/l	ft
5/20/1997	26.35	19.24	729.14	24.05	709.90	7.8	2.3
9/16/1997	33.25	22.76	725.76	28.45	703.00	22.8	4.8
11/19/1997	28.95	20.28	727.58	25.35	707.30	13.6	3.6
3/14/1998	22.05	16.04	730.24	20.05	714.20	5	2
5/31/1998	30.55	22.60	728.30	28.25	705.70	2.8	2.3
9/14/1998	34.85	24.76	726.16	30.85	701.40	13.4	3.9
12/14/1998	29.15	21.16	728.26	26.45	707.10	5.2	2.7
3/15/1999						0	
3/21/1999	17.35	11.80	730.70	14.75	718.90	10.6	2.6
6/20/1999	25.35	17.64	728.54	22.05	710.90	9.8	3.3
9/16/1999	30.25	21.00	727.00	26.25	706.00	6.7	4
11/16/1999	26.95	19.72	729.02	24.65	709.30	4.8	2.3



Site:
Refining Inc.
Station:
MW-15
Notes:
Water level example with Benzene

Envirodata®

Figure 23 - Graph displaying a dissolved constituent (benzene) as a function of water and NAPL levels

The spatial component of data distribution is key to understanding the project. While sophisticated data displays are generally created in a GIS, it can be convenient to view the data in the database, as shown in Figure 24, if the software provides that capability.

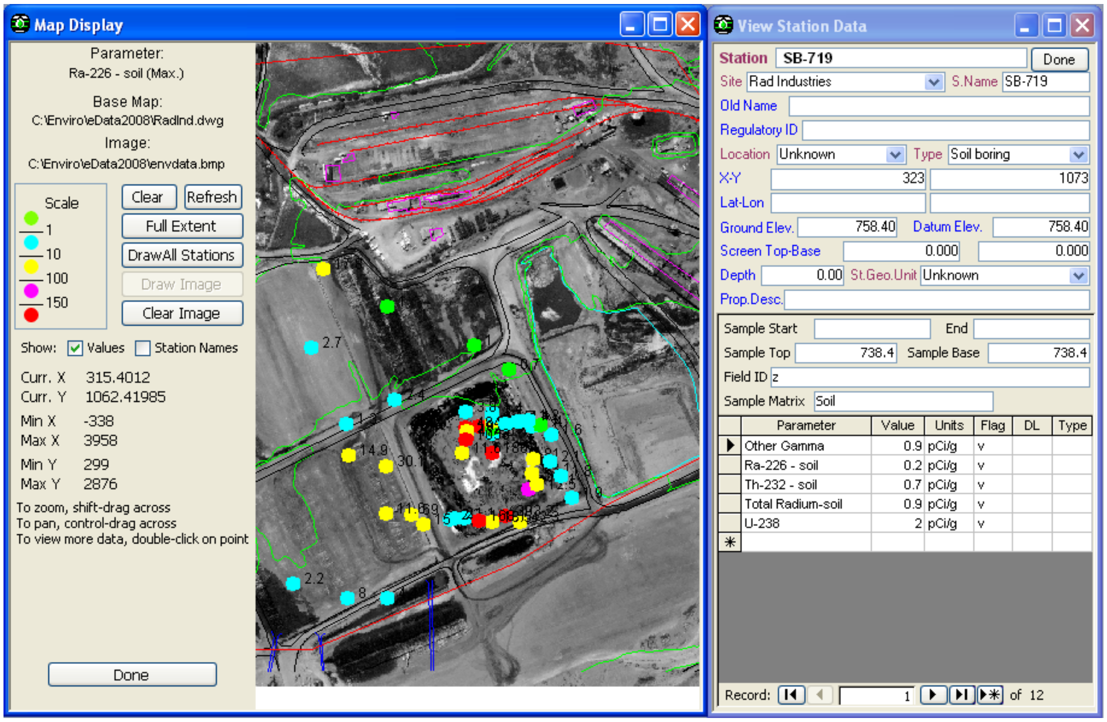


Figure 24 - Map within the database showing additional data for the selected station

The more of these analyses and displays that can be done automatically by the software the less the opportunity for error. For example, if the data management system does the regulatory limit comparisons, which are then used for reporting and mapping, then if a result is red on the report, it will also be red on the map.

DISPLAYING DATA IN GIS

The spatial component of contaminant distribution can be a critical factor in understanding and addressing site issues. This spatial component is very difficult to visualize from tables and graphs, but often can be easily understood with one or more maps. Tight integration between the data management system and the GIS is the key to efficiently generating good maps, and ensuring that the quality of the data is not degraded in the process. GIS software such as ArcGIS from ESRI provide a number of features for displaying environmental data in useful ways, as shown in Figure 25 and Figure 26. Note that in Figure 26 one of the locations has a red dot indicating a high value, but the label indicates that it was not a detected value, with the exceedence caused by an elevated detection limit for one reason or another.

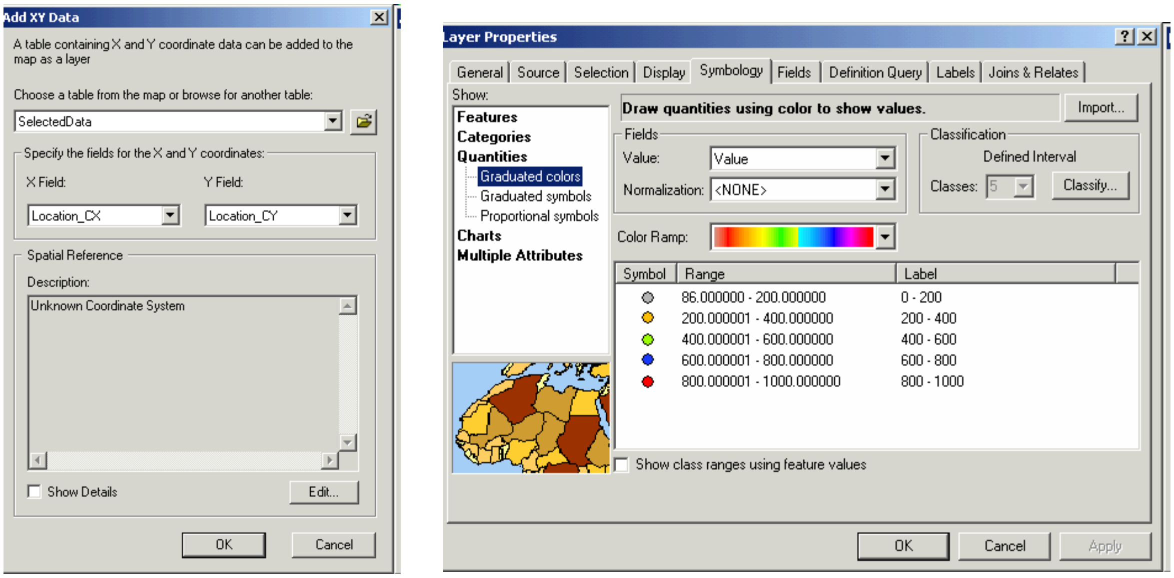


Figure 25 - Configuring the display of environmental data using features in ArcGIS

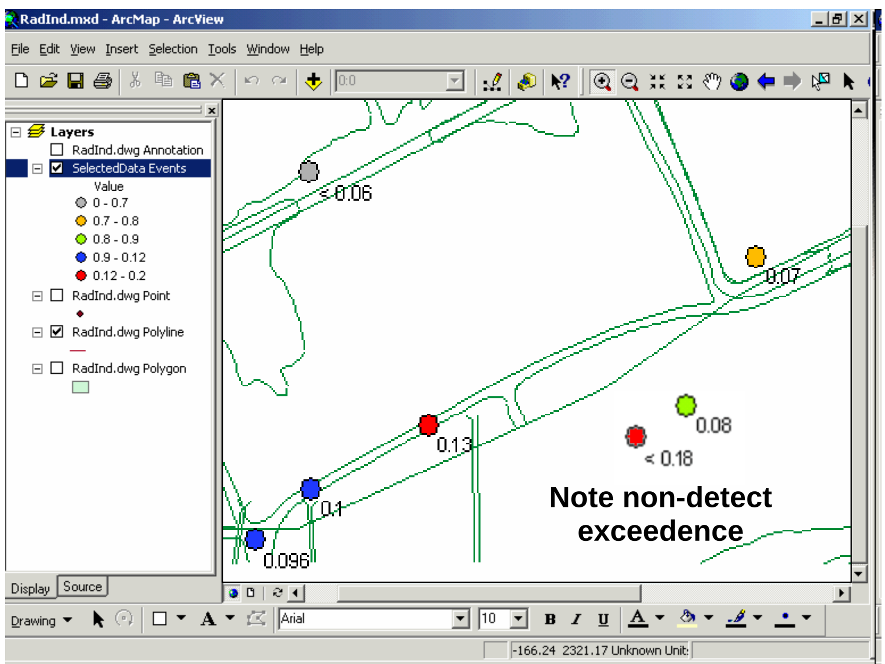


Figure 26 - Displaying environmental data using features in ArcGIS

Graphically rich displays such as callouts (data tables on the map, Figure 27 and Figure 28), graphs on the map (Figure 29), and Stiff water quality diagrams (Figure 30), can aid greatly in understanding site conditions and making project decisions, however they require a GIS plug-in to automate their display.

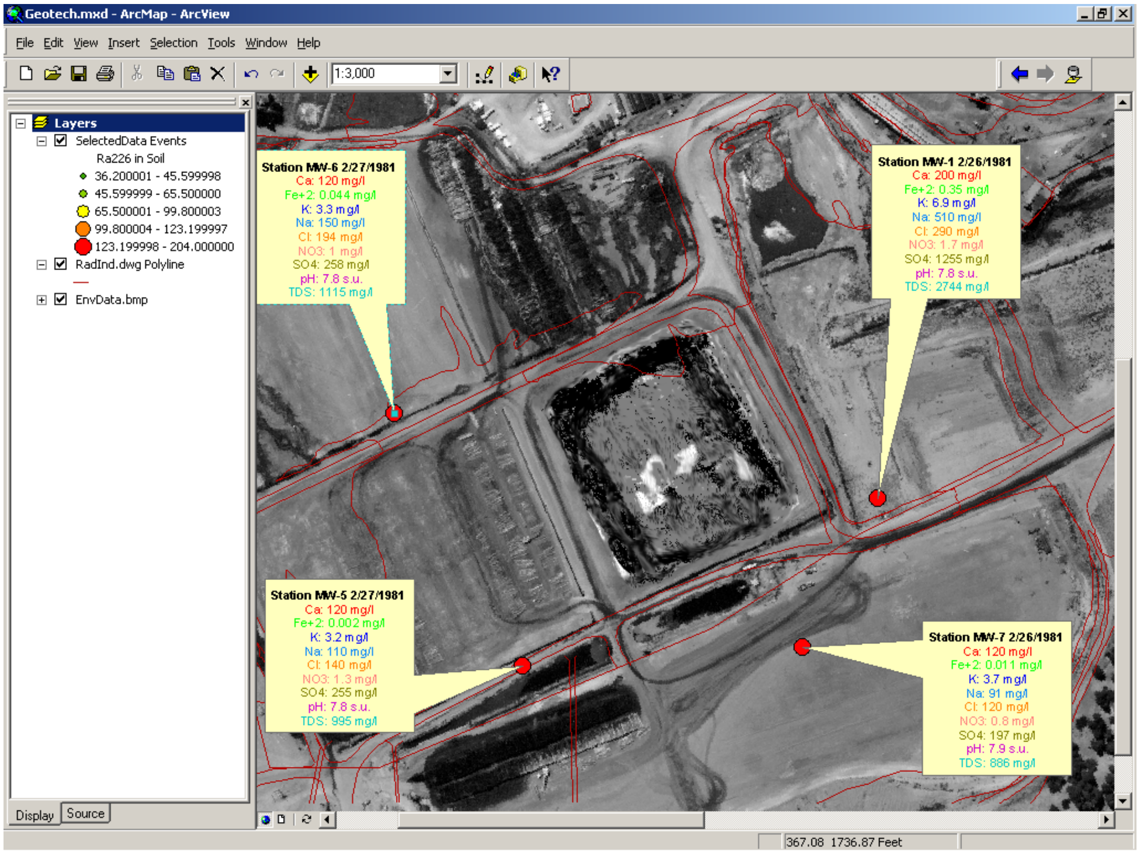


Figure 27 - GIS map with automatically generated callout boxes

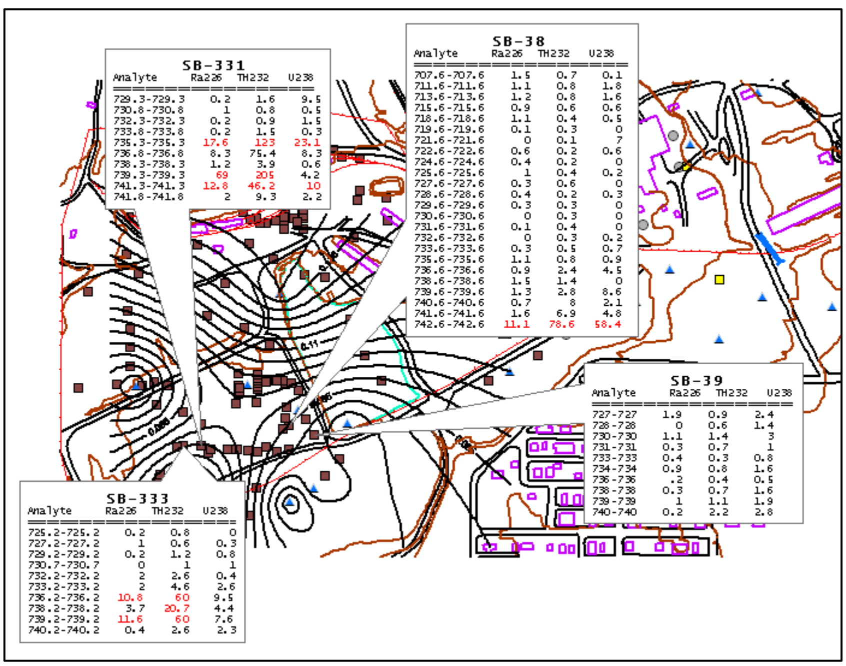


Figure 28 - Advanced callouts with crosstabs and highlighted exceedences

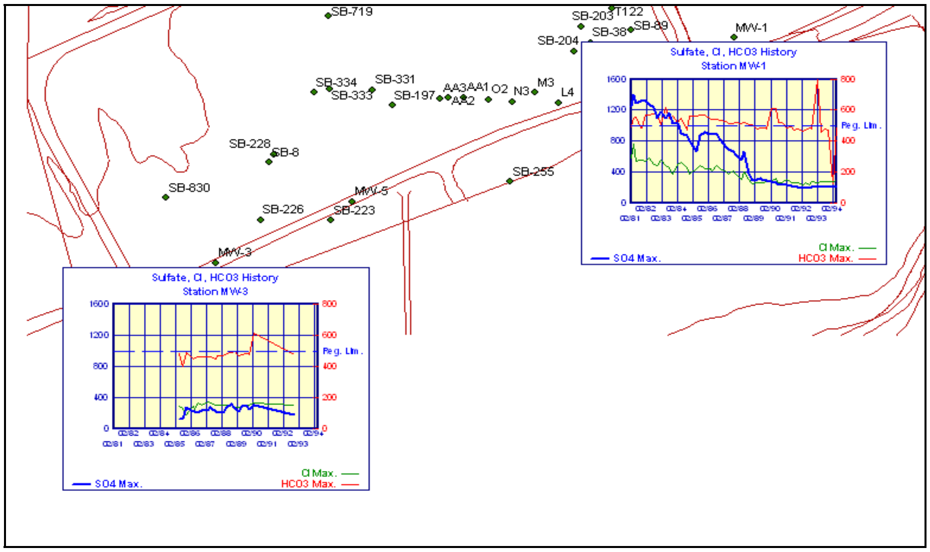


Figure 29 - Time-sequence graphs drawn automatically on a GIS map

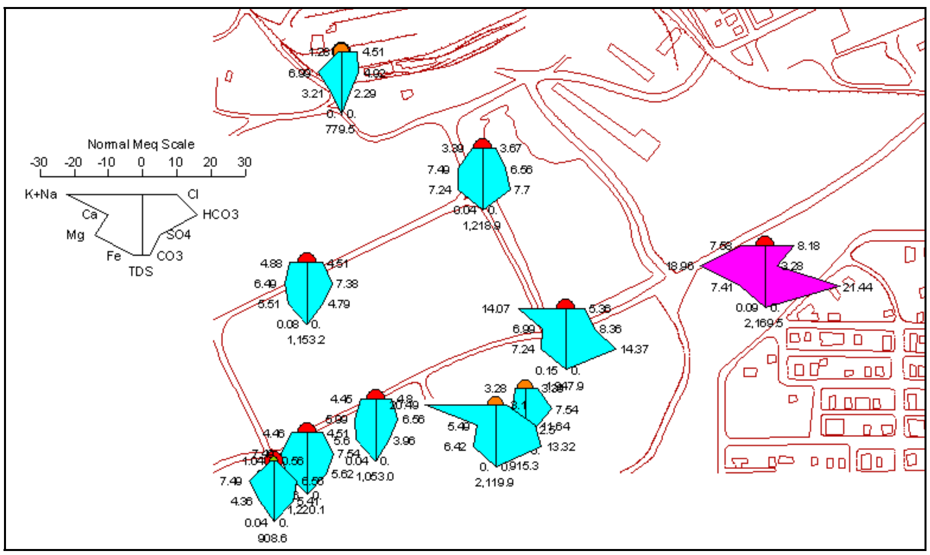


Figure 30 - GIS map with automatically generated Stiff water quality diagrams

As GIS tools become more sophisticated, the software can perform a greater role in making project decisions. For example, in Figure 31 the GIS has been used to create "Radar Plots", which are specialized graphs that can show constituent concentrations as the points of a polygon, similar to wind roses, with the distance out from the center to each point of the polygon representing concentration. By drawing these plots at the corresponding locations of the samples on the map, it is possible to see the distribution of concentrations across the site. In this case, the user has drawn the concentration of the several metals of concern at several locations. This can be useful in analyzing the spatial distribution of the constituents to help with decisions about potential remediation options. Other ways that this can be used include investigation of degradation of BTEX organics across a site, or tracking radioactive decay.

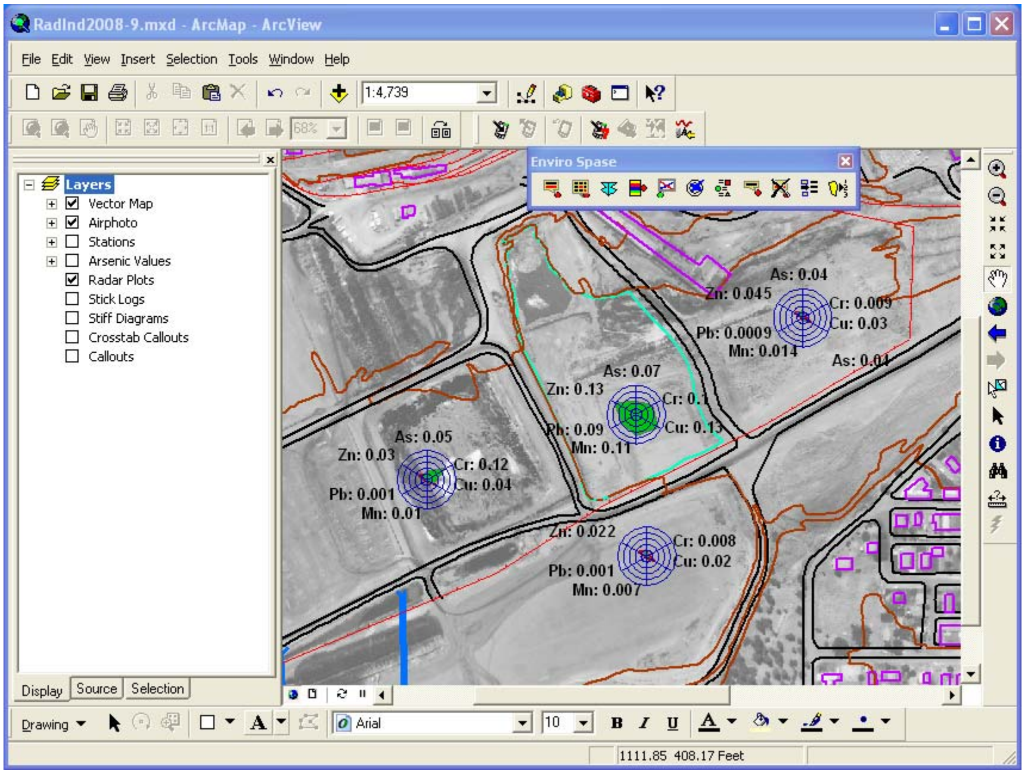


Figure 31 - Radar plots showing the distribution of metals at different locations

DISPLAYING DATA IN OTHER GRAPHICS PROGRAMS

Some software can create specialized displays, such as 2-D contour maps and 3-D plume displays that exceed what can be done easily in the GIS. Examples of this include Surfer and Voxler from Golden Software (Figure 32 and Figure 33,) EVS from C Tech and Enviro Insite

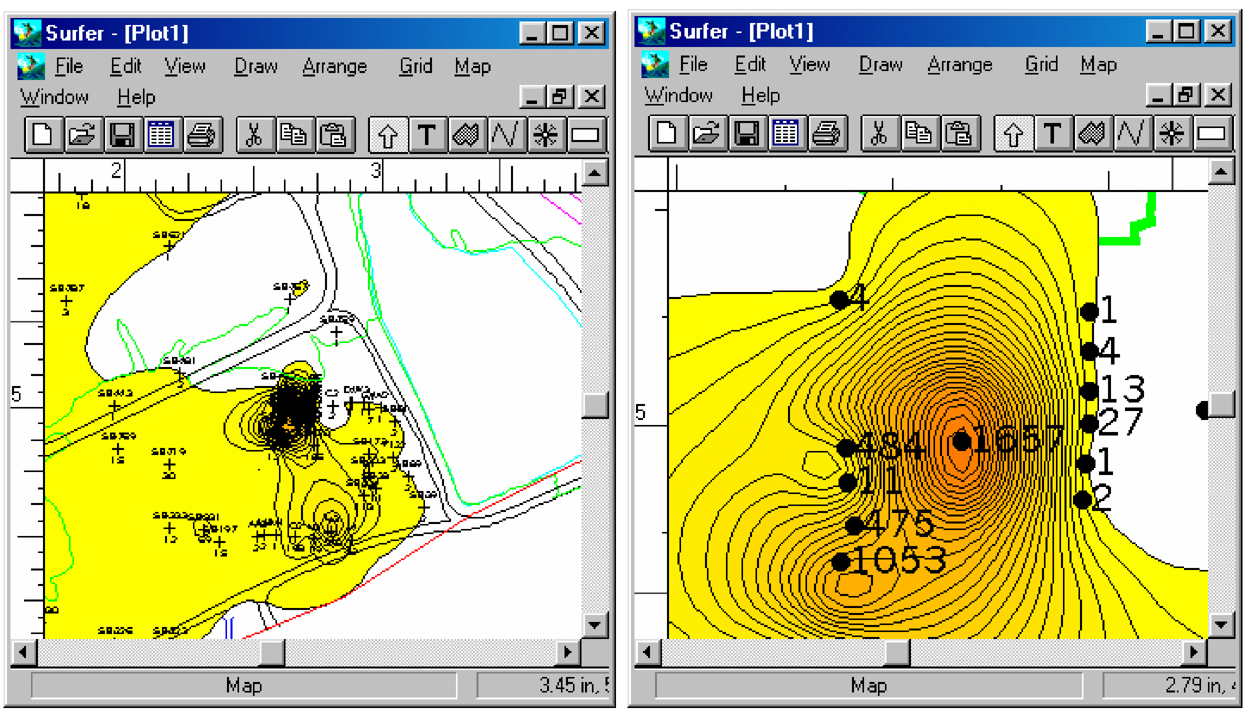


Figure 32 - 2-D contour maps from Surfer using data from the database

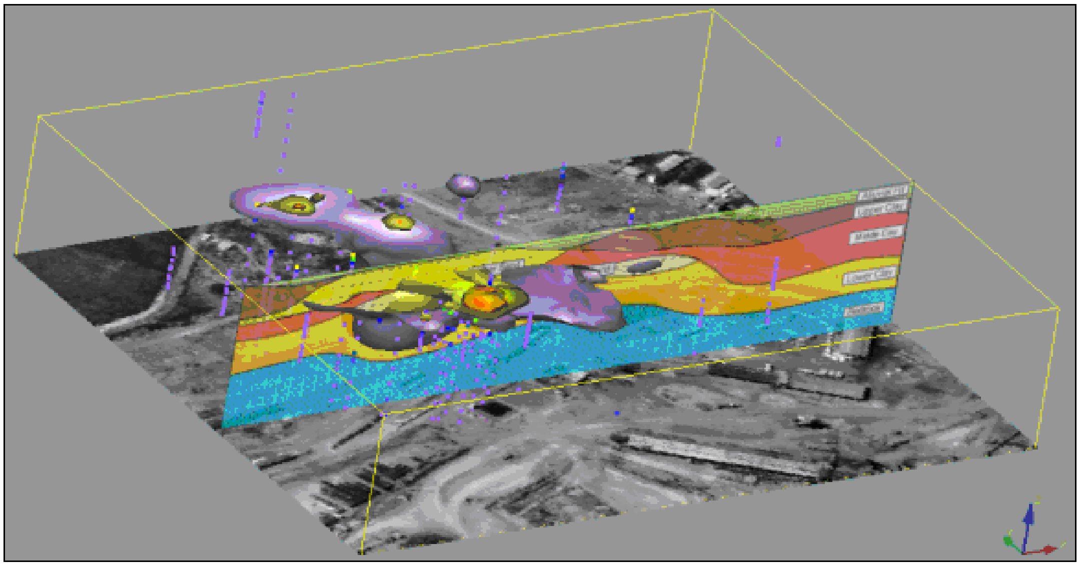


Figure 33 - 3-D view by Voxler of contaminant plume and geology with data from the database

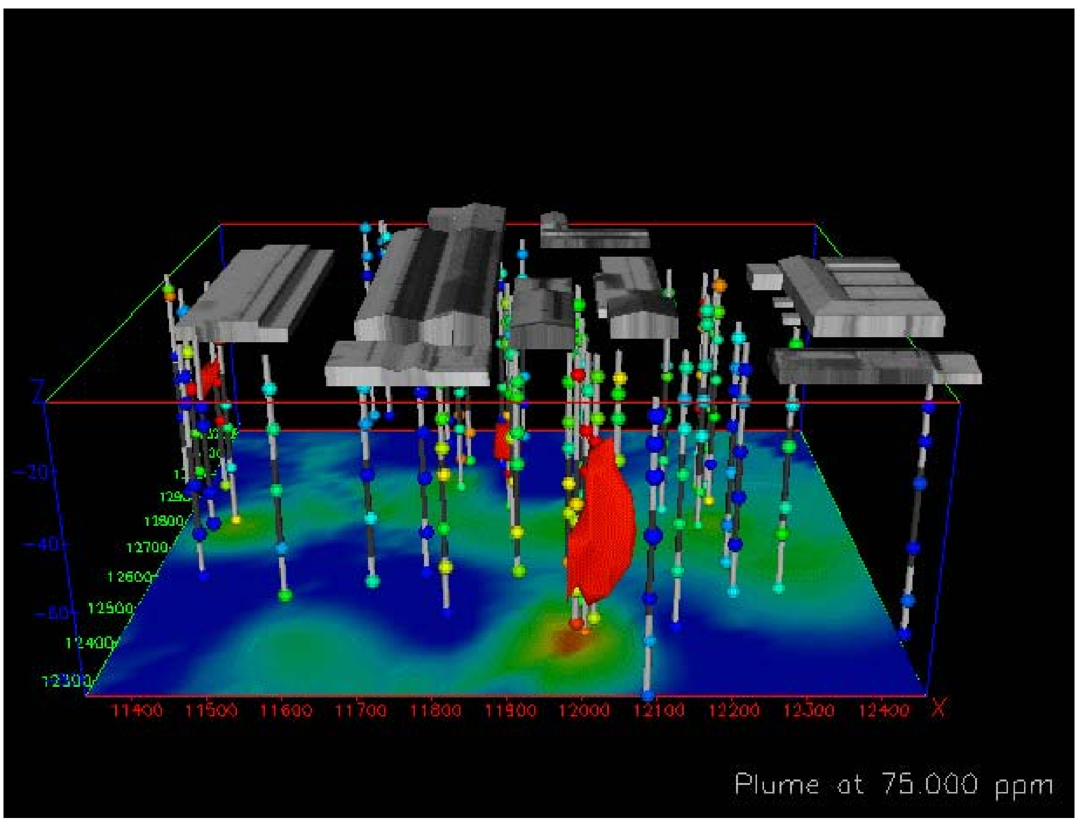


Figure 34 - 3-D view by EVS of contaminant plume and geology with data from the database

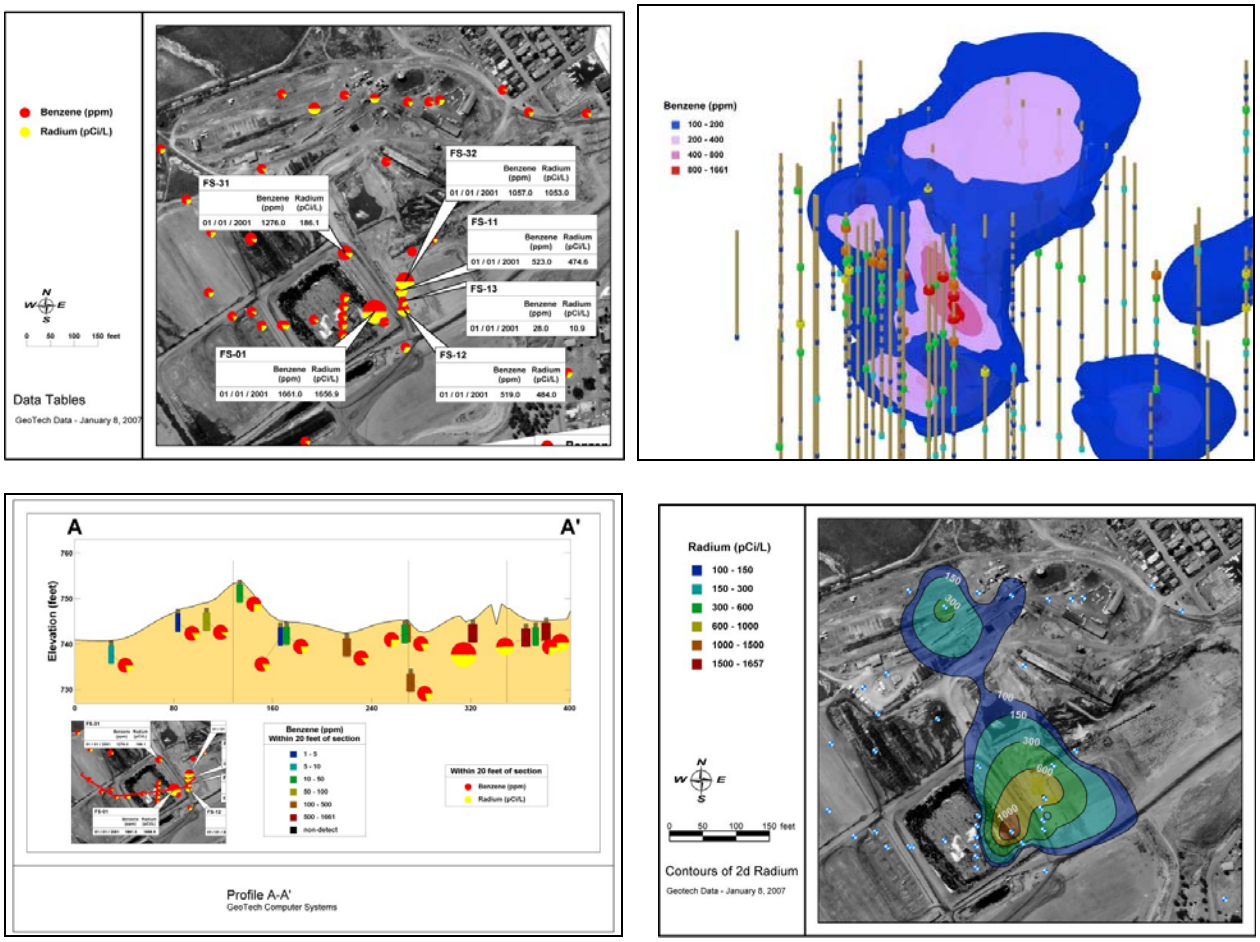


Figure 35 - Multiple displays created with Enviro Insite with data from the database

In all cases, the database plays a key role in preparing the data for the graphics, merging laboratory data with location coordinates, enforcing consistent units, managing flagged data, and so on.

DISPLAYING DATA VIA THE INTERNET

For some projects it is important to provide data access to people at multiple locations. This can be done via a direct connection to the data tables over a wide area network, which provides good security, or via the Internet, which could provide better performance. Internet data access can be set up as a host-based system for delivering the complete database interface across the Internet, for internal and external users. This option, which can be implemented a number of ways, is good where identified users need the full software functionality. Another option is to provide the data interface as a native browser application. This can be easily customized to suit project needs. This option is good where you need to provide simple selection and display capabilities to a large number of users. Two screens for a browser-based system are shown in Figure 36 and Figure 37.

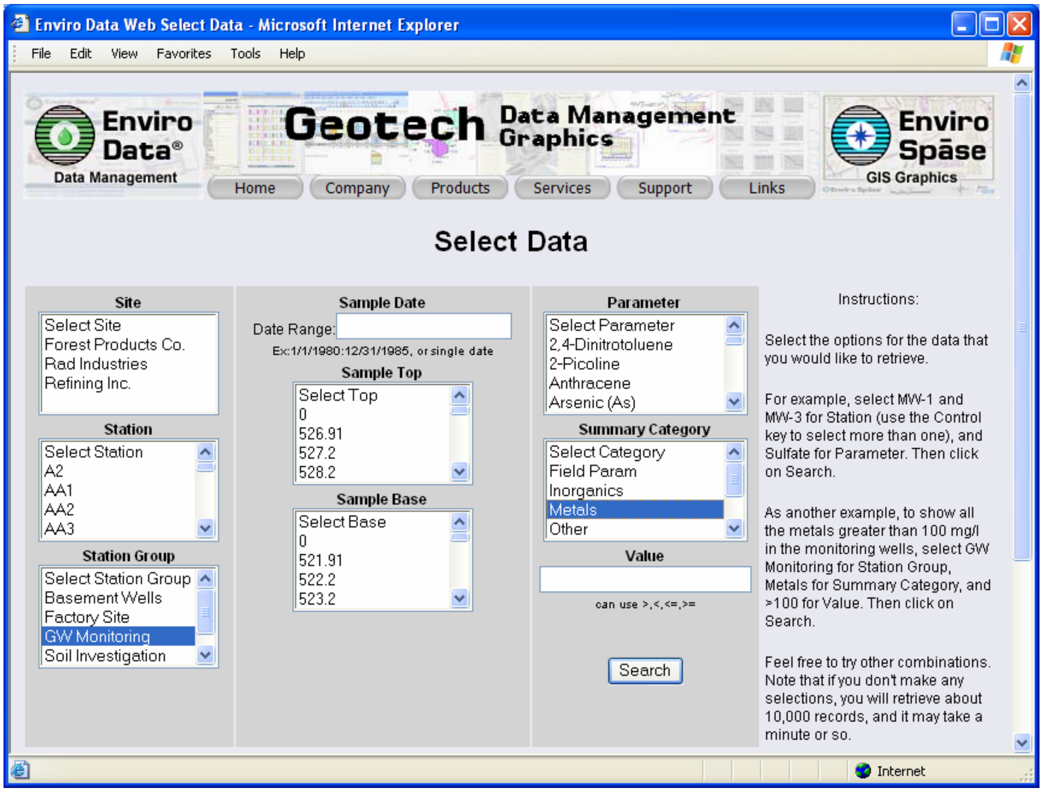


Figure 36 - Browser-based data selection screen

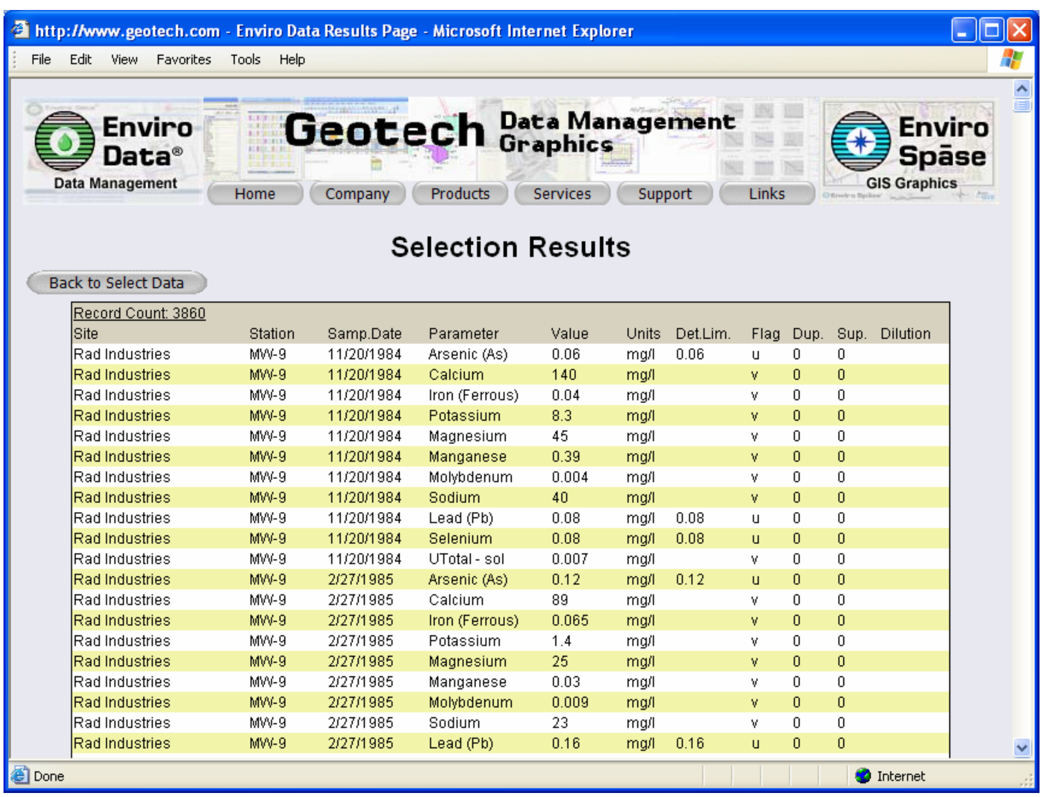


Figure 37 - Data table delivered via the Internet

ANALYZING DATA IN OTHER PROGRAMS

Some environmental projects require using the data in more advanced ways, such as groundwater, surface water, and air modeling. Free tools to do this are available from various government agencies, and commercial vendors such as Aquaveo provide nice graphical interfaces to make the models easier to use. The database plays an important role in this, helping organize the data and exporting it in the necessary formats.

MANAGING BULK DATA

While much environmental data fits well in the model of stations, samples, and analyses, sometimes it is necessary to handle bulk data of various kinds. The goal is to provide a repository and tools for handling data that is inappropriate for storage in the sample/analysis table structure, but that could have connections to the rest of the database as necessary. Examples of the data that could be handled by this system include water level and other physical data from loggers, two- and three-dimensional soil surveys, air quality data such as stack or similar data, equipment operating data, and so on. It should also be able to handle surface and downhole direct sensing, geophysical and similar data. Note that, given the large amount of data anticipated, this feature will work best with data storage in Microsoft SQL Server or Oracle, rather than Access. A screen should be provided to select data for further processing. It could look something like this:

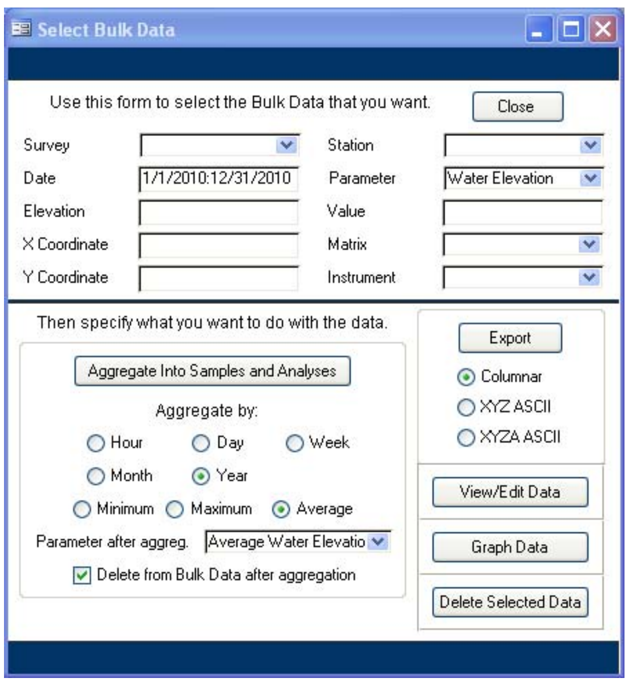


Figure 38 - **BULK DATA** form

This example can aggregate by date in a variety of ways, but the capability to aggregate by depth or over a volume can also be useful.

MANAGING AND DISPLAYING SITE GEOLOGY

Management of site geology, either by itself or in conjunction with field and lab analytic results, can be a challenge for investigation and remediation projects. Geology can be stored in several ways. One is to assign a geologic unit and lithology code (along with other data) to each physical sample. In this way analytical results can be easily associated with the geology. Another way is to have the formation "tops", also known as stratigraphy or a site conceptual model, stored by location, but separately from the samples. This often better represents actual site conditions, since formation boundaries rarely coincide with two foot sample intervals. A diagram of these two options is shown in Figure 39.

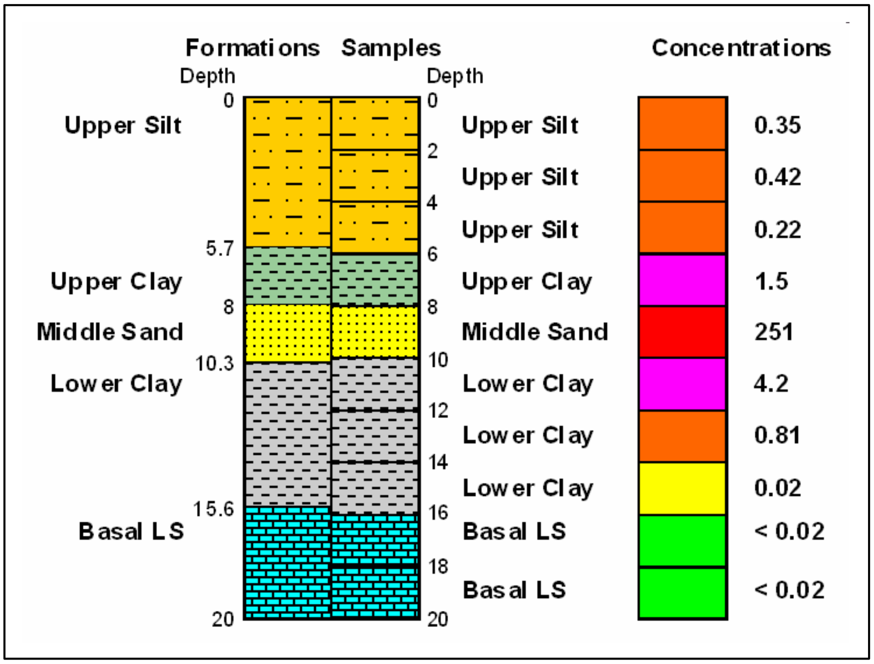
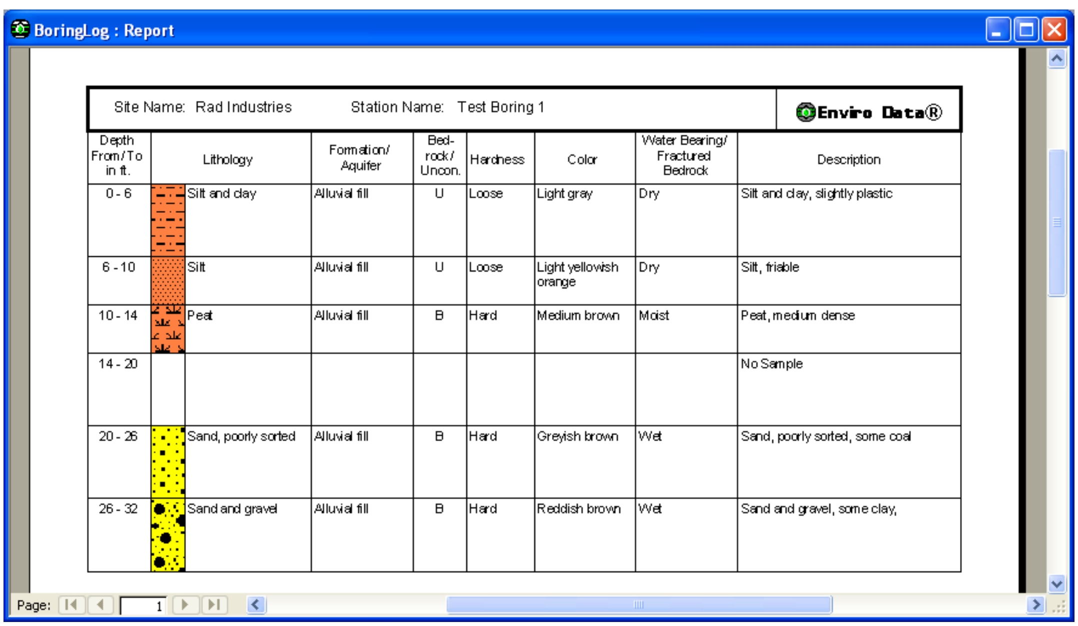


Figure 39 - Model of stratigraphy (left) and sample-based geology (right), and lab results

The geological data can be displayed in a variety of ways, either by itself or with analytical data. Figure 40, for example, shows a lithology log drawn by the database software for one boring. Figure 41 shows a display of stick logs showing lithologies and concentrations drawn on a GIS map.



Depth From/To in ft.	Lithology	Formation/ Aquifer	Bed-rock/ Uncon.	Hardness	Color	Water Bearing/ Fractured Bedrock	Description
0 - 6	Silt and clay	Alluvial fill	U	Loose	Light gray	Dry	Silt and clay, slightly plastic
6 - 10	Silt	Alluvial fill	U	Loose	Light yellowish orange	Dry	Silt, friable
10 - 14	Peat	Alluvial fill	B	Hard	Medium brown	Moist	Peat, medium dense
14 - 20							No Sample
20 - 26	Sand, poorly sorted	Alluvial fill	B	Hard	Greyish brown	Wet	Sand, poorly sorted, some coal
26 - 32	Sand and gravel	Alluvial fill	B	Hard	Reddish brown	Wet	Sand and gravel, some clay,

Figure 40 - Lithology log created by a database system

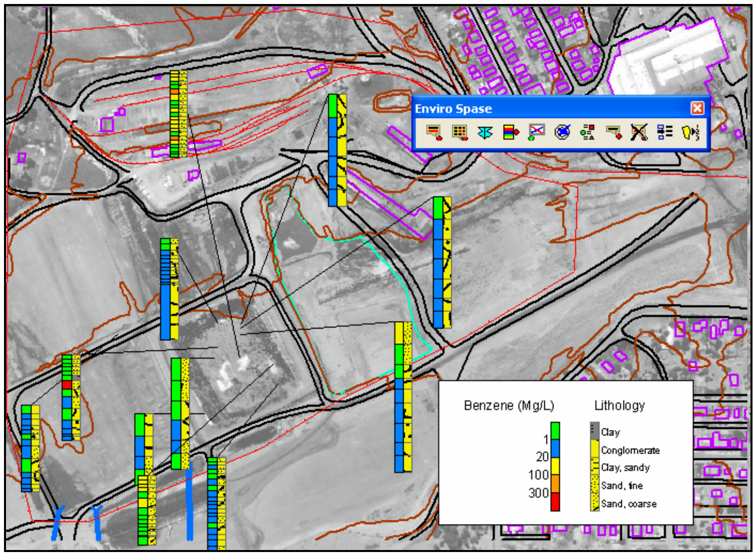


Figure 41 - Stick log display in the GIS showing geology and analytic results

Having the ability to create these types of output easily integrated with the database and GIS make it much easier to create displays as necessary to make project decisions.

IMPLEMENTATION CHALLENGES

Managing the technical data for investigation, remediation, and monitoring of mining projects has traditionally been done on an event-by-event basis. Moving all of the data for a project into a centralized data management system provides many technical and financial benefits over the older approach. With desktop data management systems easily able to handle all of the data for one or more projects, and server systems with the capacity to store data for a whole enterprise, these benefits are now available to any organization. All of the data for soil, groundwater, surface water, and other matrices for a project can easily be stored in one database. This makes it easy to use a consistent set of tools for selecting data, creating reports, generating graphs, and making geographic information system (GIS) maps of various types. Easily creating this consistent output can result in better decision making, more efficient project performance, and significant cost savings.

However, this process does have a set of challenges to successful implementation, some of which are technical and some of which involve business issues.

TECHNICAL CHALLENGES

Environmental projects face several technical challenges that significantly complicate managing project technical data. It is important that the design of the database provide ways of handling these issues by storing the data in multiple data fields, and by providing tools for the user to choose the display options at retrieval time. These are in addition to the usual data management technical challenges of gathering and transferring lab and field data, quality control, storage and retrieval, report and map creation, and GIS map display. Some of the technical challenges include:

Non-detects - Often the display of non-detected results needs to vary based on the output requirements. For example, for reporting it might be necessary to show the result as “ND” for not detected, or “<0.01” showing “less than” and the detection limit. In other cases, the result might need to be reported as a zero to force a zero line on a contour map, or ½ the detection limit for statistical calculations.

Other flagged data - Often data is flagged by the lab or the validator, impacting the use of the data on reports. Flagged results, especially rejected and estimated data, require special display capabilities, and often special numerical handling for statistical and other outputs.

Multiple results for one analyte - Handling of multiple results due to dilutions, reanalyses, and so on also require adequate design and functionality support.

Radiological data - Handling of this data requires special features for converting activities to concentrations, and for storing counting error data.

Complicated regulatory limits - Many projects often compare to multiple, and often complex, regulatory limits and target levels.

The system for storing, retrieving, and displaying the data must be able to handle these and many other data issues. As with so many other things, the devil is in the details.

BUSINESS CHALLENGES

Implementing an EDMS or a GIS is a business decision that will provide both tangible financial benefits as well as intangible technical and subjective benefits. This document highlights some of the benefits that users have seen from implementing an environmental database and GIS system such as Geotech's Enviro Data and Enviro Spase. We will first report specific cost savings that have been reported by clients, and apply these financial benefits to several scenarios. We will then discuss the intangible benefits, both technical and subjective, of installing an EDMS or GIS system. Finally, we will help you calculate the specific financial benefits for your company, and provide thoughts about recovering the cost.

Cost Savings for an EDMS Imp.

One EDMS user at a large industrial company reported that their time to process electronic deliverables from laboratories decreased from 30 minutes to 5 minutes per file after they implemented and enforced a data transfer standard and a closed-loop reference file system so that the laboratories delivered clean data. Since the data administrator was handling about 300 files a year, this translates to 125 hours per year saved, for cost savings of almost $6,000 per year just for that one task. Additional savings were realized in increased efficiency in selecting and reporting data. Another client told Geotech that using the software for his reporting saves him 4-6 hours per day. He spends about half of his time doing data reporting, and bills at the rate of $80 per hour, so the software is saving him 650 hours per year, or $52,000 of project cost.

A second type of cost saving occurs when the data management work can be transferred to a less expensive employee after implementation of an easy-to-use data management system. For example, one client was able to transfer much of the data management work for a complex project from a high priced project manager to more economic tech and clerical staff members. This resulted in average savings of $25 per hour on about 40 hours per month, resulting in savings of $12,000 per year on a lump-sum project.

A third type of cost saving, and one that can provide the greatest value, is in using the database to justify cost savings on the project beyond the database system. One client routinely uses the EDMS to review their groundwater monitoring wells to identify ones where concentrations are consistently below regulatory limits. With a database of several hundred wells, they are able to identify about two wells per quarter that can safely be monitored less often. Each well that can be sampled annually instead of quarterly saves them about $3,000, and the database provides the documentation to take their case to the regulators. If they are successful on half of their requests, they can save $12,000 per year for the four wells, and these savings are cumulative from year to year.

Financial Benefits, Small Project

This example is based on feedback from several clients. Assuming 10 wells, quarterly monitoring, and 25 analytes, the time estimate for data management with spreadsheets and similar tools is likely to be about three days per monitoring event for data importing and reporting, or a cost of $7,680. As discussed above, using an EDMS has been shown to reduce the time to import an electronic data deliverable from 30 minutes to 5 minutes, a factor of 6. The time savings for reporting data has been reported to be as high as 50 to 75%. Using estimated overall project time savings of 50% of the data management time, this results in a dollar savings of $3,840 per year. If the cost to purchase the software and maintenance over a three year period is $6,400 ($4000 for software and $2400 for maintenance), the payback would be a factor of 1.8:1, and the investment would be paid back in the second year.

Another client at a top 20 consulting company who purchased an EDMS for large projects reported extreme timesavings on her small projects as well. For each data deliverable she needs to import the data, do basic data checking (verification but not a full CLP-like validation), and generate a regulatory report with comparison to multiple limits. Prior to the EDMS it took her about a day to do each deliverable at a project cost of $680. With the EDMS, once the database is set up for each project, each sample event now takes her one hour, at a cost of $85, a savings of $595 per event. She does about 10 of these per month, which saves more than the cost of one EDMS license per month. As they do a lot of lump sum projects, these savings go right to the bottom line.

Financial benefits, Large Project

A recent study performed by a Geotech client documented data management cost savings for a typical large Department of Defense project. They compared their estimated budget, based on their prior projects using previous methods, against actual costs after implementing the EDMS and field data module. The project had two staff members sampling 60 surface water sample locations, two samples per location, and 187 analytes, for a total of 22,400 results. Tasks for the project included pre-field sample preparation, field sample collection, post-field sample tracking and completeness check, incorporation of data validation flags, and database import and table formatting. Their estimated budget for the whole project was $56,520, and their actual cost was $25,728, a savings of $30,792 or 54%. The savings on one task, the database import and table formatting, was even more dramatic, with a decrease from $15,926 to $2,632, a savings of 83%. Including the $5,000 cost for software, this task still resulted in a savings of 46%.

Financial benefits, Corp. Solution

The calculation for a large corporate solution is based on a 40-office client company with about 100 large database projects. As discussed above, the data management cost for a large project is about $31,000 per year, of which $5,812 per year can be saved through data management. This results in an annual savings of $518,000 per year for 100 projects. The cost to implement a corporate system for 40 offices can be estimated based on the following cost items: software ($400,000, one time), maintenance ($80,000 per year), training ($40,000 one time), data conversion ($60,000 one time), and customization ($50,000 one time) for a total of $950,000 over five years. This comes to $190,000 per year, which is $4,750 per office or $1,900 per project. The cost saving results in a payback of 2.72:1. This result should scale linearly to smaller or larger implementations, as both the cost and the return vary directly with the number of offices and projects.

Cost Savings, GIS Implementation

A client reported the following results from implementing an EDMS and GIS solution. Once all analytical results had been received, it was necessary to post all detections and exceedences spatially in order to meet state agency and project requirements. Due to the size of the project site, the number of samples (almost 300), and the more than 5,000 detections needing to be shown spatially, a total of 16 E-sized maps were created. Typically, a single map can take as long as two days using traditional CAD drafting methods, due to the level of calculations and the amount of QA required. Using older internally-written GIS tools in the older version of ArcView 3, each map would have taken approximately 4 hours when all of the setup time is factored in. With updated tools, since the setup time and final QA needed is significantly less, each map took approximately 1 hour to complete. The savings of 16 maps and 15 hours per map totals 240 hours saved on that one project, easily enough to justify the cost of the software and learning curve.

Evaluating Your Benefits

What really matters is the cost savings for your company. Here is an example of how you might calculate your savings:

	Example	Your company
Cost items		
Software	$5,000	________
Support (3 years)	$3,000	________
Total cost	$8,000	________
Cost savings		
Data loading – save 50% of 10 days per year at $80 per hour, for 3 years	$9,600	________
Analysis – save 50% of 4 days per year at $80 per hour, for 3 years	$9,600	________
Reporting – save 50% of 4 days per year at $80 per hour, for 3 years	$9,600	________
Total savings	$28,800	________
Payback – $28,800 ÷ 8,000	3.6:1	________
Plus intangibles	Work quality	________
	Client satisfaction	________
	Staff morale	________

Recovering Your Investment

Consulting companies have several options for recovering their investment in EDMS and GIS tools. The money saved by projects could be kept, contributing directly to your bottom line. Or, some or all of the savings could be passed on to clients, making your company more competitive. For industrial companies or government agencies, all of the cost savings go to your bottom line. A challenge in many companies is how to pay for software that will be used on projects. The software can be purchased either with project dollars or overhead dollars. Using project dollars is usually easy to justify based on the numbers above, but requires implementation on a project-by-project basis.

Intangible Technical Benefits

While the dollars usually drive the purchase decision, the technical benefits are often the greatest contributors to the success of an EDMS or GIS implementation project. Building a comprehensive, centralized open database, and automating report and map display, can generate improved technical results in a variety of ways. The biggest technical benefit is the improved quality that results from removal of database fragmentation and excessive data handling. With an integrated system, people are always using the best data available, not an outdated piece of data, or data that was thrown together to answer a different question than the one they are currently answering. Related to this is improved communication on the project, because everyone is looking at the same data. This results in increased confidence in the data and in the decision making process for the project.

Another technical benefit is the ability to analyze the project better. Having a comprehensive database integrated with your GIS opens the door for better visualization and analysis, which can lead to a better understanding of the project, and a better ability to anticipate and remove problems before they become critical. This results in a process where projects are managed by the team, rather than the project managing the team with a series of crises and fire drills. The impact of these technical benefits on those outside the project, such as clients, upper management, and especially regulators, can be significant. If others develop confidence that the project team is staying on top of issues at the site, the result can be less scrutiny, and consequently less aggravation, for the project team. If they are finding and reliably dealing with issues as they come up, the project goes more smoothly for everyone.

Implementing a standardized corporate solution has benefits beyond a single project. All offices are using the same tool, minimizing training time, reducing software costs, and allowing sharing of work between offices.

Intangible Subjective Benefits

Some benefits derived from improved data management and display are subjective, but still contribute significantly to the overall success of the project. Data management and display can be the most tedious component of a project. Implementing an efficient system such as Enviro Data and Enviro Spase can significantly improve morale, which results in improved quality of output, less staff dissatisfaction and turnover, and in general a happier and more productive project team and client. There can also be expanded business development opportunities resulting from offering the best technology.

The Billable Hours Problem

A philosophy in many companies is that they make their money by billing hours, and buying and implementing new technology that decreases billed hours is perceived as decreasing revenue, which is a bad thing. So a new database implementation faces two obstacles: it costs money to implement the system, and then billed hours go down because of the increased efficiency provided by the software. The usual conclusion is that implementing this new system is a bad business decision.

Let's look at this technology model from a revenue-generating point-of-view for a consulting company. First, if your cost to deliver services to your client is higher than your competitor's cost (some of whom are already using Enviro Data and Enviro Spase, and cutting client costs), your client will use your competitor instead of you. Second, many of your clients are going to a unit cost basis for many types of work, such as routine monitoring tasks, so decreasing your internal cost goes directly to increasing your bottom line. Either way, increasing your efficiency improves revenue, client satisfaction, and employee performance, rather than hurting it. So if your company responds to suggestions of improving technology with the "billable hours" philosophy, it should be suggested to them that if they don't stay current with database technology and cut client costs, their competitors will, and revenue, clients, and employees may all be lost.

Buy vs. Build

Another issue that sometimes comes up is the decision of whether to buy a database system off the shelf, or build one internally. At first it may seem attractive to try to find a client to pay to build a system that you can then use on all your projects. You get the billable hours for doing the work, and don't have to pay license fees on the software. And you have control over the functionality that is developed. The attractiveness of this solution falls apart when you try to use the software for an extended period of time, or on other projects. Features developed specifically for one project may need to be rewritten for other projects, or as the needs of the original project evolve. And it is often difficult to find the time and money to find and fix bugs after the initial development has been done. This problem is compounded if the person or team that developed the software is no longer available.

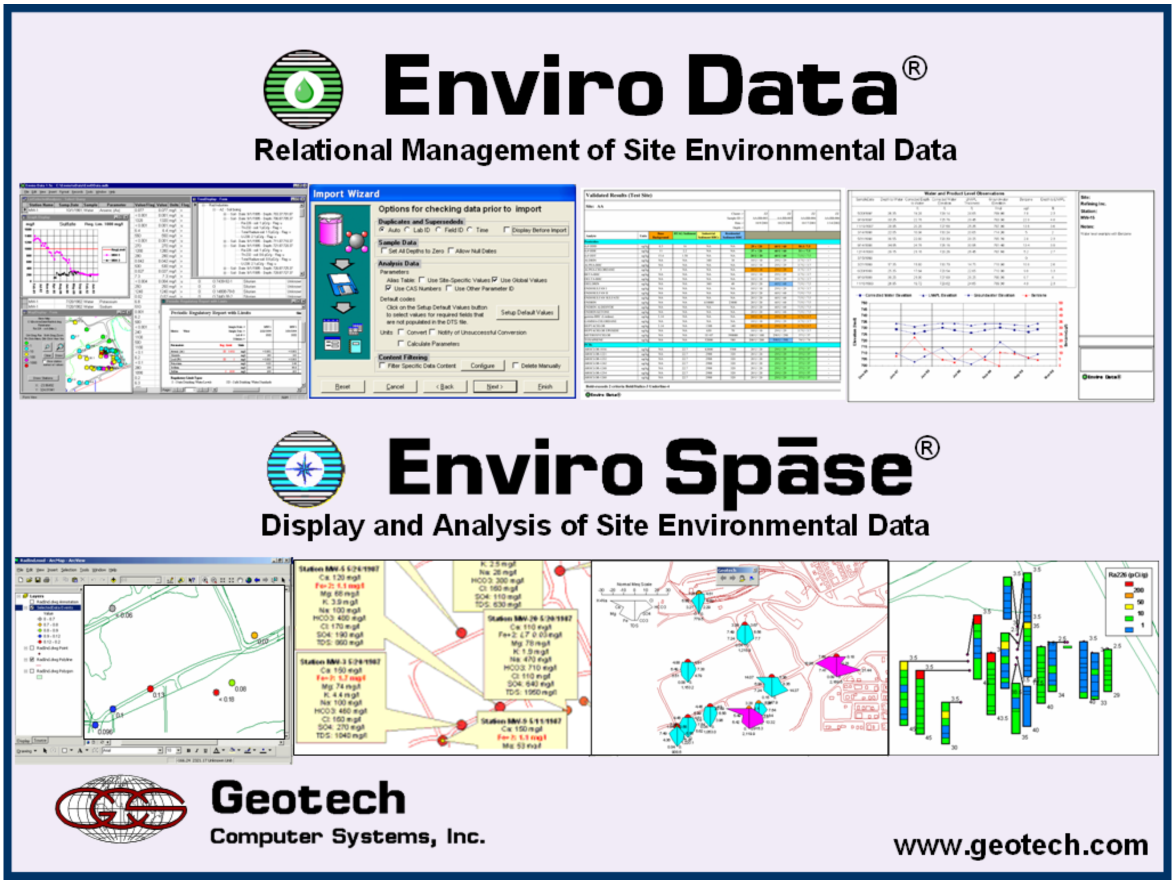
Commercial software like Enviro Data, on the other hand, has been developed from the ground up to support a wide variety of project requirements. Capabilities have been added over years of use by hundreds of clients so the software satisfies a much broader suite of needs than any in-house product could ever handle. Once you have purchased the software, a modest annual maintenance fee covers bug fixes and enhancements much more cheaply than you could do it with in-house staff. With concurrent use licensing, the software can be made available to many users at a surprisingly low cost. And with extensive support from laboratories around the country and a full set of exports for various purposes, project data will flow smoothly from start to finish.

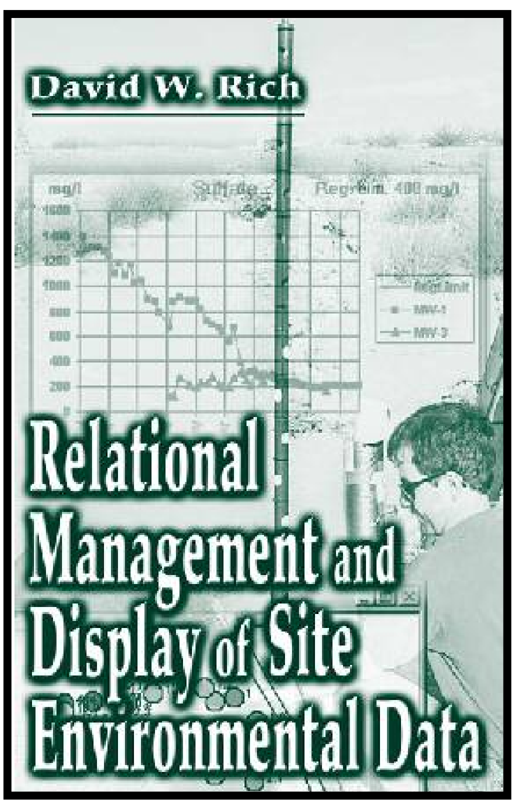
When it comes to buy vs. build, a commercial system like Enviro Data and Enviro Spase is the best of both worlds. You get the extensive and tested functionality of an off-the-shelf product, but, because the programs are open source, you get the configurability of a custom program. You also get a staff of seasoned developers and support technicians to help you make sure the software performs smoothly on your projects. The combination of Enviro Data and Enviro Spase is the low-risk solution to your data management needs.

Looking at the numbers confirms this. Geotech has about 25 programmer years in writing the software code, and over 15 years learning about and satisfying project needs. At an estimated overhead-loaded programmer cost of $60,000 per year, this comes to $1.5 million of programming time. The software has over 600 named features, counting imports, exports, reports, editing forms, map wizards, and so on. A typical client will use maybe a quarter of these, so your cost to create a program with the functionality your projects need would be about $375,000, assuming you can find a programmer with the industry experience necessary to do the development efficiently, and it will take you over six years to do it. For a lot less money you can have a fully workable, tested, industry-accepted solution now.

CONCLUSION

Each company's situation is different, but the time and cost savings from implementing an efficient EDMS and GIS system will, in most cases, provide a monetary payback in a short period of time, along with the many intangible benefits from using the best tools available. An important component of the approach suggested here is that manual handling of data is kept to a minimum. Using agreed-upon standard formats, as long as they are supported by software on both ends, makes it easy to obtain data from the field and the lab. Then, by implementing a full-featured data management and GIS system, users can receive the maximum benefit from their investment in sampling and analysis. The end result is more efficient and cost-effective projects, which is to everyone's benefit.





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