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## **Groundwater Monitoring Report Streamlining Techniques – 15305**

Ashley Shull, Natalie López

Savannah River Nuclear Solutions LLC, Savannah River Site (SRS) Aiken, South Carolina,  
29808

### **ABSTRACT**

Compliance with national and state environmental regulations (e.g. RCRA and CERCLA [SuperFund]) requires Savannah River Site (SRS) to extensively collect and report groundwater monitoring data, with potential fines for missed reporting deadlines. Large reports, which may contain dozens to hundreds of monitoring stations, are especially challenging to present data in a way that is quick and easy to interpret. Initially analyzing hundreds to thousands of records of data to be summarized in the report can be daunting, and producing maps can be extremely time consuming. Several utilities have been developed at SRS to facilitate production of the regulatory reports which include data tables, charts, maps, and cross-sections. Components of each report are generated in accordance with complex sets of regulatory requirements specific to each site monitored. SRS developed a relational database to incorporate the detailed reporting rules with the groundwater data, and created a set of automation tools to interface with the information and generate the report components. Maps produced with ArcGIS use a technique that can be repeatedly used to display data very quickly and in a consistent form. Cross-sections developed with RockWorks provide a more technical and geological analysis and representation of well and boring data, while allowing for automated data placement. These process improvements have streamlined the repetitive job of creating data tables, charts, maps, and cross-sections. It has also enhanced report quality and consistency by centralizing the information, and has reduced manpower and production time through automated efficiencies.

### **INTRODUCTION**

Reporting is an integral part of waste management. When waste has impacted groundwater, monitoring reports must be submitted to regulatory agencies on a scheduled frequency until contaminants in the groundwater decline below required limits, typically with a minimum expectation of 30 years. Components of each report are generated in accordance with complex sets of regulatory requirements specific to each waste site monitored. Non-compliance with the reporting schedule or required content can result in significant fines to the waste generator. Faced with long term, high-volume reporting commitments, shrinking resources and stiff penalties for failure, SRS turned to automation to optimize the ability to produce and submit accurate and timely groundwater monitoring reports to the USEPA and the governing state agencies.

Automation of the groundwater reporting process presented multiple challenges. One challenge was to migrate the complex set of waste-site-specific monitoring and reporting requirements into an electronic format that could be integrated with report production tools. At the onset of

reporting, the regulatory requirements only existed in text format stored in multiple locations. Users needed to be able to edit and update report specifics through a common input interface to keep up with revisions to waste site permits and the groundwater regulatory program.

Monitoring data collected throughout SRS for a variety of media and to meet a variety of objectives are stored in a general environmental database. The groundwater reports need only a subset of these data that are stored in the general environmental database referred to as the Environmental Restoration Data Management System (ERDMS), an Oracle database. The challenge was to extract data specific to each report and perform calculations before being transferred to a relational database designed specifically to automate groundwater reporting. A key aspect of the extraction application was that it be linked to the reporting requirements particular to each waste site. The data extraction method needed be a fast, menu-driven application that could be executed by the user, without dependence on computer programmer staff.

Once having accomplished the task of extracting, preparing and transferring the data into the relational database designed for groundwater report automation known as the 'GRIP' database (the Groundwater Report Information Processor database), multiple applications were developed to facilitate production of the report components generally common to all groundwater reports such as: graphs showing the trends in contaminant concentrations over time; graphs showing the trends in water elevation over time; tables comparing the results of groundwater analyses against health-based concentration limits pertinent to each waste site; and maps and cross-sections showing the extent of contamination and the groundwater flow directions.

In addition to providing overall consistency and standardization, the reporting tools needed to be fast and flexible enough to accommodate the nuances of the individual requirements for each report. The primary improvement needed for map production was a process that would replace manual placement of sampling results at well locations which could range from as few as a dozen to as many as several hundred locations per map. There are as many as 45 maps and cross-sections in some reports, with multiple reports generated in a single year, calling for a mass production process. The original manual labeling process and volume of maps kept a drafting staff of 5 busy throughout the year. The automated process eventually reduced mapping staff to 1 person.

A single report can have hundreds of pages of graphs showing changes in water elevations or contaminant concentrations over time. A charting tool was needed that could create hundreds of graphs in a short period of time, and include options that could be tailored to include multiple wells, contaminants and concentration limits on the same chart. Originally the graphs were produced by transferring data to MSExcel spreadsheets, setting up the parameters and manually configuring the charts to specify the contaminants to display for each sampling location. It was preferable to develop a charting tool to derive data and report specifics directly from the GRIP database, reducing data transfer errors, user errors and improving speed and data integrity.

Another requirement common to the groundwater reports was to provide groundwater sampling and analysis results in tabular format. A large report could contain nearly 1,000 pages of tabular data that were difficult if not impossible to review for determining critical impacts. A tool was developed to access the database and create data tables in a matrix format, using reporting criteria to select multiple wells and contaminants to be displayed on the same page. These 'data

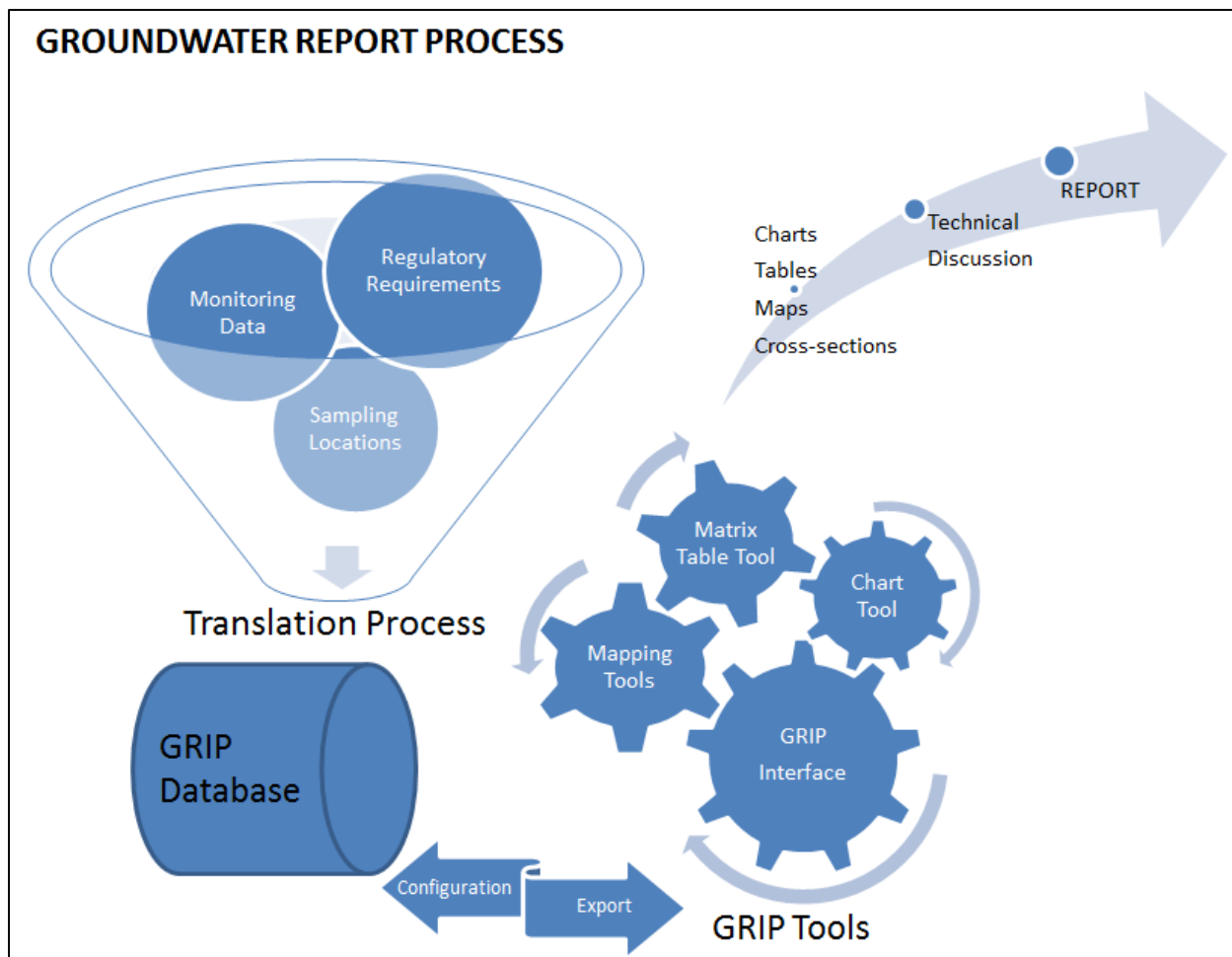
matrix tables' use color coding to identify results that exceed report specific concentration limits contained in the database. The color coding and the matrix table format greatly facilitate data interpretation as well as significantly reducing the number of pages needed to provide the information.

These process improvements have improved quality and consistency by centralizing the information, and have reduced manpower and production time through automated efficiencies.

## **INTEGRATED PROCESSING SYSTEM**

The Groundwater Reporting Information Processing (GRIP) relational database was developed to manage the various groundwater permit and reporting requirements. Report and permit requirements are configured in GRIP through a user interface. The GRIP database is integrated with a suite of tools used in extracting and analyzing data and creating products for the final reports (time versus concentration charts, time versus groundwater elevation charts, data tables, statistical analysis, and map/cross section drawings).

The actual data from groundwater monitoring is managed along with the results of other monitored media in an Oracle database called the Environmental Restoration Management System (ERDMS). However, the general environmental database does not address the groundwater reporting requirements (which stations get sampled on what frequency for what analytes, and what are the analyte limits for reporting purposes, etc.). Therefore, groundwater data is extracted from the general environmental database, translated and transferred into the GRIP database. The extraction tool is integrated with the reporting requirements stored in the GRIP database. Data is selected and extracted from the general database based on association with the sampling locations of the report being prepared. As part of the extraction process, the raw data goes through a process of standardization, filtration, calculation and presentation. Figure 1 provides an overview of the integrated process.



**Fig. 1. Overview of the GRIP Integrated System**

### **Relational Database**

The tables in the GRIP database contain the relationships of key groundwater report elements. The elements common to all reports/permits were identified for incorporation in the design of the database.

- Report to permit association
- Sampling locations, types and regulatory categories
- Sampling depths (i.e. aquifers)
- Analytes (i.e. contaminants) to be monitored
- Analyte concentration limits
- Analyte types
- Analyte groupings (suites and subsuites)

- Sampling intervals
- Results from sample analyses
- Required outputs (i.e. time vs data charts, data tables, statistics, maps and cross sections)

## **Design**

The GRIP Interface presents the permit/report data elements using a Tree structure. The permit/report data is best presented this way because the data is easily organized into a hierarchy type structure:

Report (contains one or more Permits)

    Permit (contains Suites and/or Well Types)

        Suite (contains SubSuites and/or Analyte Types)

            SubSuite (contains Analyte Types)

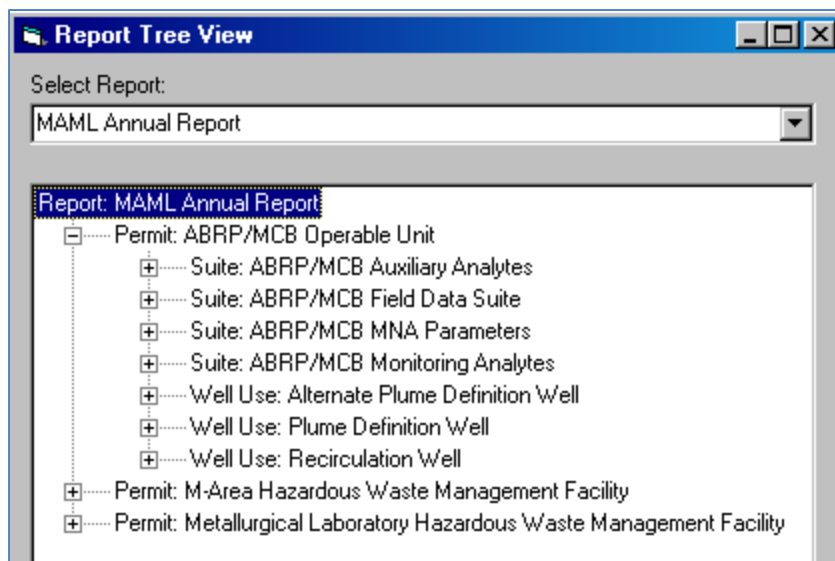
                Analyte\_Type (contains Analytes)

        Well Use (contains Wells)

The Suite/SubSuite/Analyte Type/Well Uses can be thought of as “groupings” of the Permit data used for easier data organization/presentation. This also enables the occurrence of repeating data. For example, an Analyte may appear more than one time, each for a different purpose, in the same Permit (e.g. Appendix IX and Compliance Monitoring Constituents).

The GRIP Interface uses a tabbed control to enable the user to navigate around the various components for the tool. The buttons on each of these tabs simply call ‘\_click’ events that begin the noted functionality.

The Reports Tab provides the ability to Add/Update a Report Definition. All reports must be defined here before they are accessible in the rest of the GRIP Interface. Drop-down lists show the reports once they are defined. Multiple permits may be associated with a single report. Clicking on the a View By Report button of the Reports Tab allows the user to Select a Report using a drop down menu and provides a tree view of the associated permits, analytes, sampling locations and all their assorted subcategories as displayed in Figure 2.



**Fig. 2. Assortment of Report Elements Configured through GRIP Interface**

The tree structure has been designed to provide context sensitive menus that show the user what operations are appropriate at this point. For example, by right-clicking over the appropriate tree entry, the user has the option to Add or Delete a well, or an analyte.

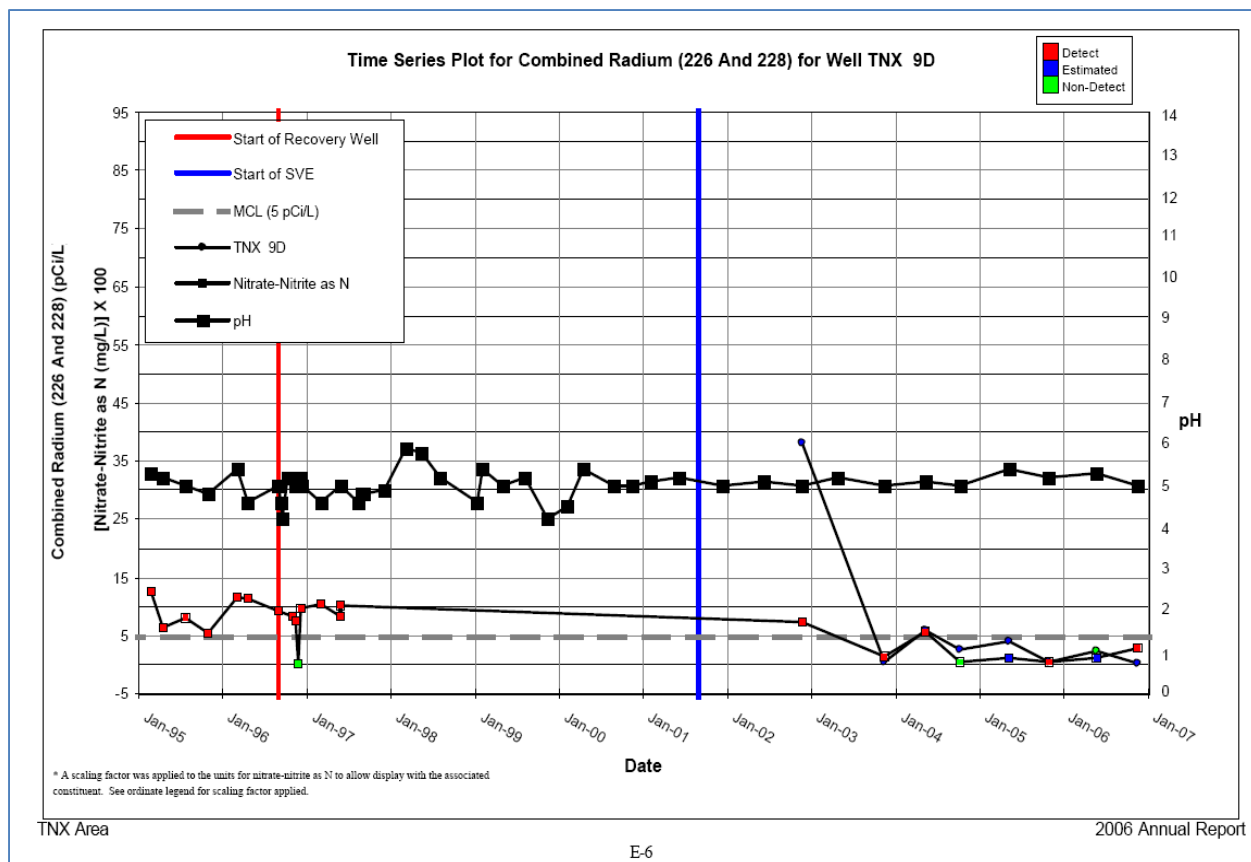
By right-clicking over an analyte suite, the user has a variety of configuration options to choose from by placing ‘flags’ in an Excel style matrix of sampling locations and analytes. This form is called when the user chooses to set sampling flags, mapping flags, or charting flags. By right-clicking over an analyte, the user can configure the concentration limit mandated by the permit. Similarly, right-clicking over a well allows the user to configure the attributes of the well such as the aquifer zone, regulatory use and type. All these settings are incorporated by the GRIP tools during automated production of the maps, charts and tables, saving valuable time and providing accuracy and consistency with permit requirements.

## RESULTS

Once all the data has been loaded into the GRIP database, and all the reporting and permit requirements have been configured, the suite of report automation tools read the settings, extract the data and produce the report components. The tools allow the user to produce report components without needing to know the database structure or query language.

### Charting

A GRIP Tool, such as the Charting Tool for example, reads the settings from the database so it will produce a set of charts for the right wells and analytes defined in a permit, and at what value to place a concentration limit line. The user operates the GRIP Chart tool to tailor the parameters such as the date range for the charts, the template to be used, scales to be used, headers, footers, page numbers and variety of other options. An example of one of the more complex charts produced by the Grip Chart tool is shown in Figure 3.



**Fig. 3. Complex Chart with Multiple Analytes, Multiple Scales and Vertical Time Lines**

### Data Tables

The GRIP Matrix Table tool presents groundwater monitoring results in a format that has proven to be highly effective for communicating the most amount of information in the least amount of space. The results are presented in a matrix of wells and analytes, then color coded to highlight values exceeding limits that may merit compliance review or corrective action (Figure 4). This format also aids in comparing contamination variability between aquifers and identification of outliers. Conventional data tables that took up to hundreds of pages can now be supplied in as little as one large matrix table. The technical team as well as regulators and the public can easily interpret the data, compare tables from previous reports, or recognize trends.



**Table B-1. SLF, Corrective Action/ACL/MZ Constituent Results, First Half 2010**

Station			Field Data							1. SLF Corrective Action/ACL MZ Constituents						1.b. Non-Hazardous ACL/MZ Constituents			
			1.a. 261 Appendix VIII/264 Appendix IX Hazardous Constituents							1.a. 261 Appendix VIII/264 Appendix IX Hazardous Constituents						1.b. Non-Hazardous ACL/MZ Constituents			
			Inorganic							Organics						Radioisotopes			
			Co-constituent							MERCURY						COMBINED RADIUM (226 AND 228)			
day-month-year	PH	PC	SC	TU	VP	WT	FC	Co-constituent	Unit	ACL/MZCL	5	7	5	5	5	5	5	15	20
day-month-year	pH	ft	us/cm	NTU	gal	degC			ug/L								pCi/L	pCi/L	pCi/mL
LFW 29	Background Well	SPAU	20-Jan-2010	4.2	161.3	22	0.4	23	19.5										
LFW 43B	Background Well	SPAU	20-Jan-2010	4.3	161.4	20	0.2	36	19.2										
LFW 43C	Background Well	SPAU	20-Jan-2010	4.5	161.5	30	0.2	47	19										
LFW 43D	Background Well	SPAU	20-Jan-2010	4.5	161.5	19	0.4	15	18.5										
LFW 23R	Point of Compliance Well	SPAU	25-Jan-2010	4.8	150.03	45	0.7	11	19.7										
LFW 36R	Point of Compliance Well	SPAU	25-Jan-2010	6.7	146.38	327	4.1	11	20.1										
LFW 41R	Point of Compliance Well	SPAU	25-Jan-2010	4.7	144.47	36	0.8	9	19										
LFW 48C	Point of Compliance Well	SPAU	25-Jan-2010	5.7	148.38	59	0.9	23	19.3										
LFW 48D	Point of Compliance Well	SPAU	20-Jan-2010	4.3	148.4	28	0.7	17	19.4										
LFW 57B	Point of Compliance Well	SPAU	26-Jan-2010	4.1	143.7	53	0.6	105	18.7										
LFW 59C	Point of Compliance Well	SPAU	26-Jan-2010	4.9	143.2	51	0.1	60	19.1										
LFW 59D	Point of Compliance Well	SPAU	26-Jan-2010	4.5	145	25	0.3	23	20.2										
LFW 61C	Point of Compliance Well	SPAU	26-Jan-2010	6.3	143.3	216	2.3	43	21										
LFW 61D	Point of Compliance Well	SPAU	27-Jan-2010	5	147.3	31	3	25	20.4										
LFW 62B	Point of Compliance Well	SPAU	26-Jan-2010	4.1	142.44	49	0.4	106	19.2										
LFW 62C	Point of Compliance Well	SPAU	26-Jan-2010	5	143.25	54	0.8	49	20										
LFW 62D	Point of Compliance Well	SPAU	26-Jan-2010	NS	127.2	NS	NS	60	NS										
SWSP-5	Point of Exposure	SPAU	NS	NS	NS	NS	NS	NS	NS										

Explanation

- [##] EPA Functional Guideline Code of 'J' was applied to the result, indicating an estimated quantity.
- <EQL(##) Constituent was below detection. The sample-specific Estimated Quantitation Limit is in parentheses.
- Result exceeds applicable limit.
- REJ Result Rejected
- Result is less than the applicable limit and without EPA Functional Guideline qualifiers.
- NS Requested to be sampled but was not. See comments as to why not.
- Blue Text Not a required sample analysis.

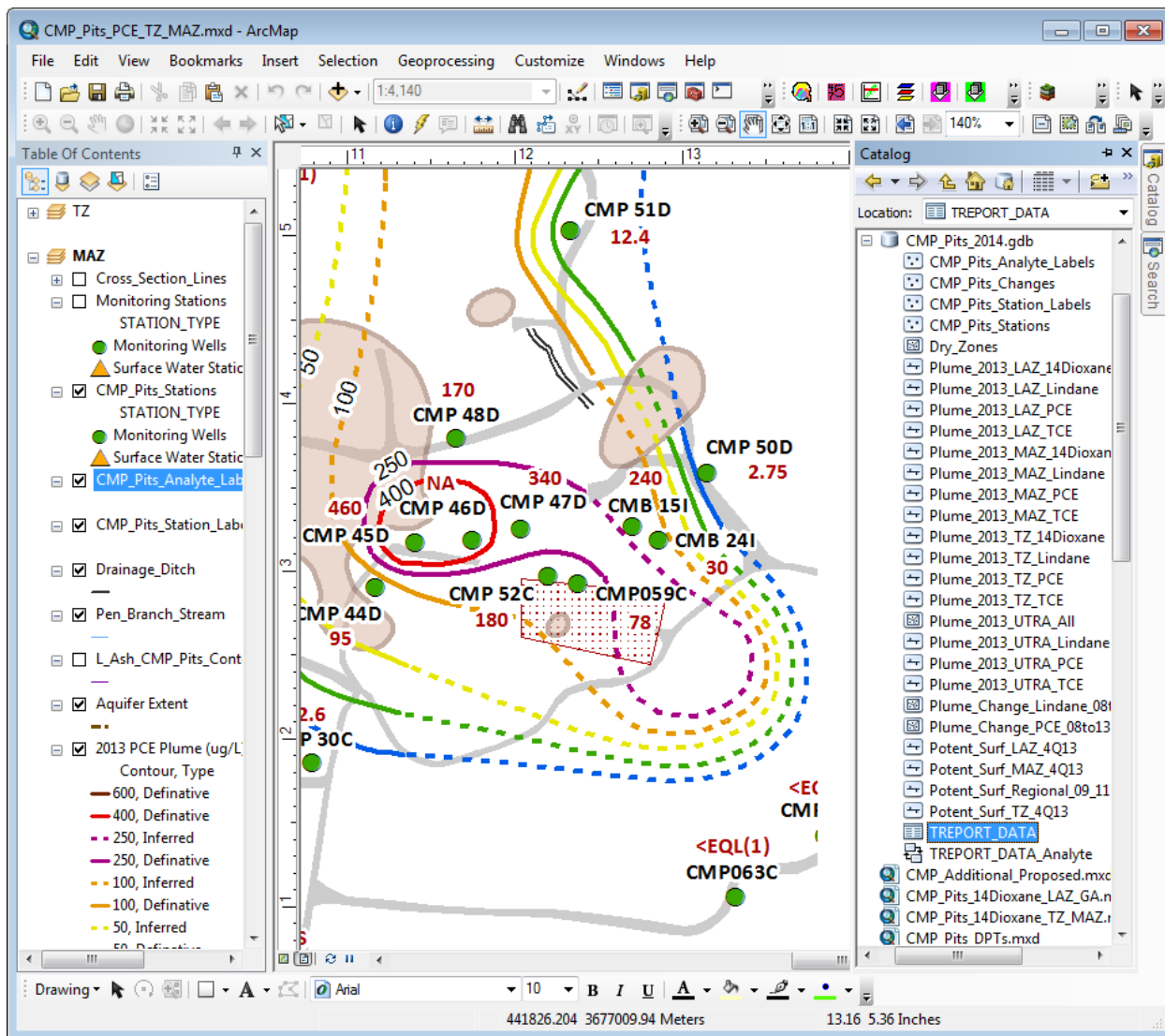
**Fig. 4. Color-coded Matrix Table Yields Maximum Information in Minimum Space**

**Mapping**

Mapping data is prepared for posting using a module that is integrated with the GRIP Interface tool, using the 'Prepare Map Data Set' option. The module queries the results for an analyte and time frame selected by the user, without the user needing to know the database structure or query language. A predetermined result format is applied to create map labels that are easy to interpret. For example, a raw result of '0.5 U' would be converted to '<EQL', an abbreviation for 'less than the Estimated Quantitation Limit'. A specialized posting process places these labels on the map simultaneously, eliminating what used to take hours of manual label placement.

ArcMap is used to make maps and post data. A file geodatabase is used to store an exported portion of GRIP table which includes the pertinent data for the specific report. A 'basemap' is initially set up with a separate point feature class (layer) for the analytical result. This is also stored within the file geodatabase and uses stationary label placement for displaying the mapping

labels created with the ‘Prepare Map Data Set’ option mentioned above. Manual labeling of data can be very time consuming depending on the quantity of points and/or spatial density of points in the map. This point feature class acts as a placeholder for each well or station and allows for consistent display of the label’s position from map to map (Figure 5). A relationship class is utilized in ArcCatalog that links the GRIP data table to the point feature class using a common well identifier number. Definition queries are used to select the map specific data to be displayed (i.e. which analyte and/or which time period).



**Fig. 5. ArcMap Screenshot Showing Label Feature Class (red text) and Geodatabase (right side) with Data Table and Relationship Class**

After initially setting up the basemap with the point feature class for the mapping labels, the map can be copied and used for multiple analytes (multiple maps in the report) or the same map can be queried for different analytes to automatically display the data. After the initial basemap

setup, this process significantly reduces the time to produce maps, especially in following reports as all the key features and the mapping label placeholders are in place. Production of the next report's maps only require the GRIP data table to be replaced in the geodatabase, editing of contaminant plumes, isoconcentration lines, etc. based on the newly displayed data, and updating of any dates in legends or titles.

The result of using this process minimizes errors in displaying data, reduces time to produce the maps, and ensures the maps are consistent in their display from map to map and year to year. If needed, deletions or additions to the stations used can quickly be made by editing the point feature class.

### **Cross-sections**

Cross-sections were previously created in Microstation CAD software by other coworkers in a different group. This process entailed a lot of back and forth iterations before the cross-sections were finalized. To streamline the groundwater reporting process cross-section production was moved to RockWorks software and done by the person writing the reports or within the reporting group. This software is geologic based and has many applications including modeling. This is more beneficial than creating drawings using CAD since it directly models the geologic data and cross-sections can be changed or altered without having to start from scratch to make a CAD drawing. Many aspects and looks of the cross-sections can be made relatively quickly because all data associated with the wells and/or borings are saved within each project. Using CAD each piece will need to be manually made or edited.

Similar to the creation of planar maps, a base cross-section is created. The same mapping label data is linked to the wells used in the cross-sections by the use of a cross-walk table. Cross-sections can be updated for following reports by linking the new data table. The mapping labels are automatically placed in the correct spots on the cross-sections based on the depth data saved with each well. This ensures the data is correctly labeled each time and removes much of the human error with manual label placement. Once the initial base cross-sections are set up, following reports are quickly updated. Only the query on the data table (the timeframe of the new data) and contaminant concentration lines and dates associated with titles and legends will need to be updated to produce the next report's cross-section.

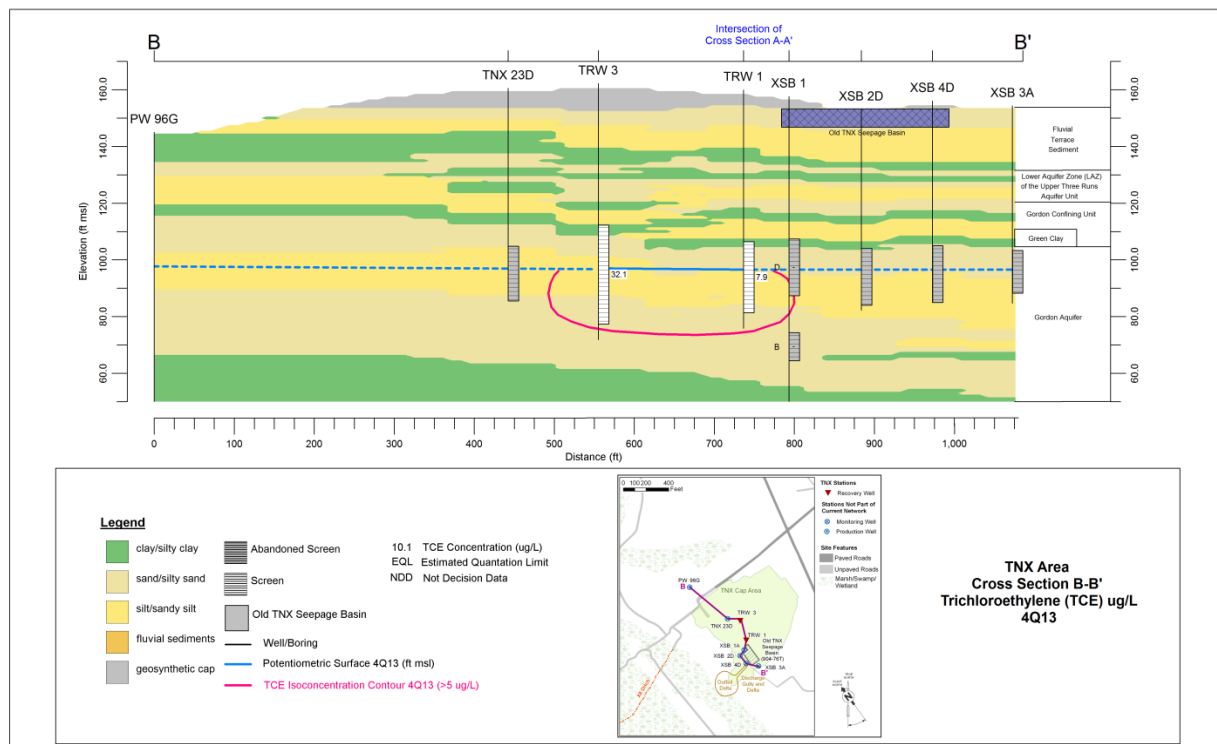


Fig. 6. Example of a Cross-section Created with RockWorks

## SUMMARY

Implementation of the relational database and associated automation tools was driven by the ongoing need for preparation of multiple reports required each year under strict regulatory schedules with severe penalties for missed deadlines. These process improvements have improved quality and consistency by centralizing the information, and have reduced manpower and production time through automated efficiencies, as much as 70% for some reports. Moving the production of the multiple applications, including use of the GRIP tools, mapping, and cross-section creation to the same people who write the report or to members within the same group have also further reduced costs and time. Initial setup for new reports in the GRIP tools, maps and cross-sections may take some time, but following reports are produced much faster. Using these processes has improved data analysis and reporting by having data visually displayed in different forms, provided a means to easily display data on maps and cross-sections, enables them to be reproducible from report to report, has reduced production times, and has reduced errors in creating all of these items.