

The Evolution and Roadmap of Chemical Data Display in Environmental Investigations

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Presented at the Twenty-fourth Annual ESRI User Conference, San Diego, CA
August 9–13, 2004

Abstract

Historically, maps were hand drawn and annotated with peel-and-stick labels and pushpins. In the 1980s, color-coding and manual symbolization gave us maps that attempted to provide an efficient visualization of the data. However, the artistic result was better than the data interpretation that was intended. This paper presents the advances of GIS technology and various ways to present chemical data in a more efficient and usable fashion. With the use of ArcGIS and the 3D Analyst extension, in conjunction with an Oracle database, data are now queried and displayed in a desktop tool that provides a more efficient visualization.

Introduction

Environmental investigations provide critical information about the concentration of specific contaminants in the soil and groundwater that require monitoring and/or remediation. Samples are collected and analyzed for concentrations that exceed established reporting limits. Project team members have the need to be able to view these analytical data spatially in order to evaluate investigation sites. This has been accomplished in a number of ways in the past, and the methods continue to evolve as GIS technology advances.

Methods of Data Display Prior to GIS Technology

Prior to the current technology, paper maps were utilized to display and analyze analytical data. Survey data may or may not be available for sampling locations. If sampling locations were not surveyed, their geographic locations were estimated based on features on a topographic map. The sample locations and corresponding laboratory analytical results were drawn on paper maps by hand to allow for spatial analysis (Figure 1). The use of pushpins and peel-and-stick labels for color-coding symbolization proved useful in making these maps more communicative. Drafting departments housed large flat drawer file cabinets for the storage of 7 ½ minute quadrangle topographic maps. The storage system was cumbersome, space consuming and less than efficient.



Figure 1. Paper topographic map annotated by hand; stick-on label designates area of concern.

The implementation of Computer Aided Drafting (CAD) provided the capability for standardized electronic base maps to be digitized, edited and printed. Sample locations could be placed and text could be typed onto the electronic maps to display data. CAD was a useful tool for drafting departments since maps were now standardized and could be printed in-house rather than purchased from outside vendors. Color printers were not cost effective, therefore stick-on labels and pushpins continued to be the means for presentation of chemical data.

GIS Implementation

The implementation of GIS opened many new doors for the display and analysis of chemical data. Unlike the prior CAD applications, spatial data were now stored within the GIS in real-world coordinates (i.e. latitude/longitude or any of a number of other coordinate systems), and could be converted from one

coordinate system to another. This allowed for scaled maps to be generated and printed. It allowed for topological analysis, i.e. the manner in which spatial features relate to one another. Attributes of spatial features could be assigned, managed, displayed on maps and used for querying and analysis. Digital aerial photographs could be georeferenced and displayed along with vector data to assist in evaluating contaminant sources and remediation techniques. As a desktop tool, users could accurately measure distance between features within the GIS and could link features to documents that reside outside of the GIS, such as photographs, reports, scanned sample collection logs, etc.

GIS and Relational Databases

GIS technology presented connectivity to an external relational database. This allowed users to query an existing database for spatial and attribute data. Tables could be linked or imported into the GIS and then joined or related to provide for the display of various categories of attribute data.

In the early versions of GIS, users could query a relational database for spatial data (i.e. sampling location's geographic coordinates) and display them with other spatial data. Essentially, these coordinates were queried, and a coverage of point features was generated in ArcInfo. Text labels, such as location names, could be stored in the coverage. Updates to the coverage were still an issue at this time because the connection was of a "query and download" nature, therefore if coordinates for a location were modified, or if new locations were added, those changes were not automatically reflected in the point coverage. Users were left with two options to manage these updates, 1) generate a new coverage each time updates were made to the database, or 2) develop an ArcInfo AML script to scan newly downloaded files for updates and make the necessary changes or additions to the existing coverage. The first option involved redundant annotation editing, but the second option allowed the retention of the existing annotation in the coverage and only the new or modified locations required annotation editing.

Currently, ArcGIS delivers "live-link" database connectivity with the capability of annotation being linked to spatial features. The benefit of this is that each time an ArcGIS database connection is opened, the existing layer for any features that are derived from the database are updated on the fly. If a new feature has been added to the database, it now exists in that ArcMap layer. If attribute(s) are linked to features, and the attribute(s) have changed, those updates are also reflected in ArcMap.

ArcView Avenue Script Database Queries

One of the key milestones in data visualization resulted from database connectivity and ArcView Avenue scripts that were used to query and group chemical data that was managed in an Oracle database.

During a Phase 1 Investigation, hundred of samples, both soil and groundwater, were to be collected using direct push equipment. The primary concern at this site consisted of a list of 23 Volatile compounds (VOCs), which were grouped, in an Oracle database, as an “analyte group”. The initial samples were analyzed at a local laboratory, on a contract that required results to be reported within 24 hours of sampling. The results of these analyses were submitted electronically on a daily basis. Upon receipt, the data were loaded into an Oracle database. After the data were loaded into Oracle, an Avenue script was executed that queried the database using “group by” and “having” functionality. This query returned a table that consisted of the name and geographic coordinates of each sampling location, and a Yes/No column that reflected whether any of the 23 compounds were detected above established reporting limits at that location. The resulting table was displayed as an event theme in ArcView and symbolized in one color at locations where analytes were detected, and another color at locations where no analytes were detected (Figure 2). This presentation allowed on-site personnel to plan the next round of sampling locations by quickly viewing the results of the initial sampling. Prior to the development of this procedure, an effort such as this would have been prolonged by days or even weeks. Using ArcView, Avenue and Oracle, decisions were now made and implemented daily, demonstrating a cost savings of thousands of dollars.

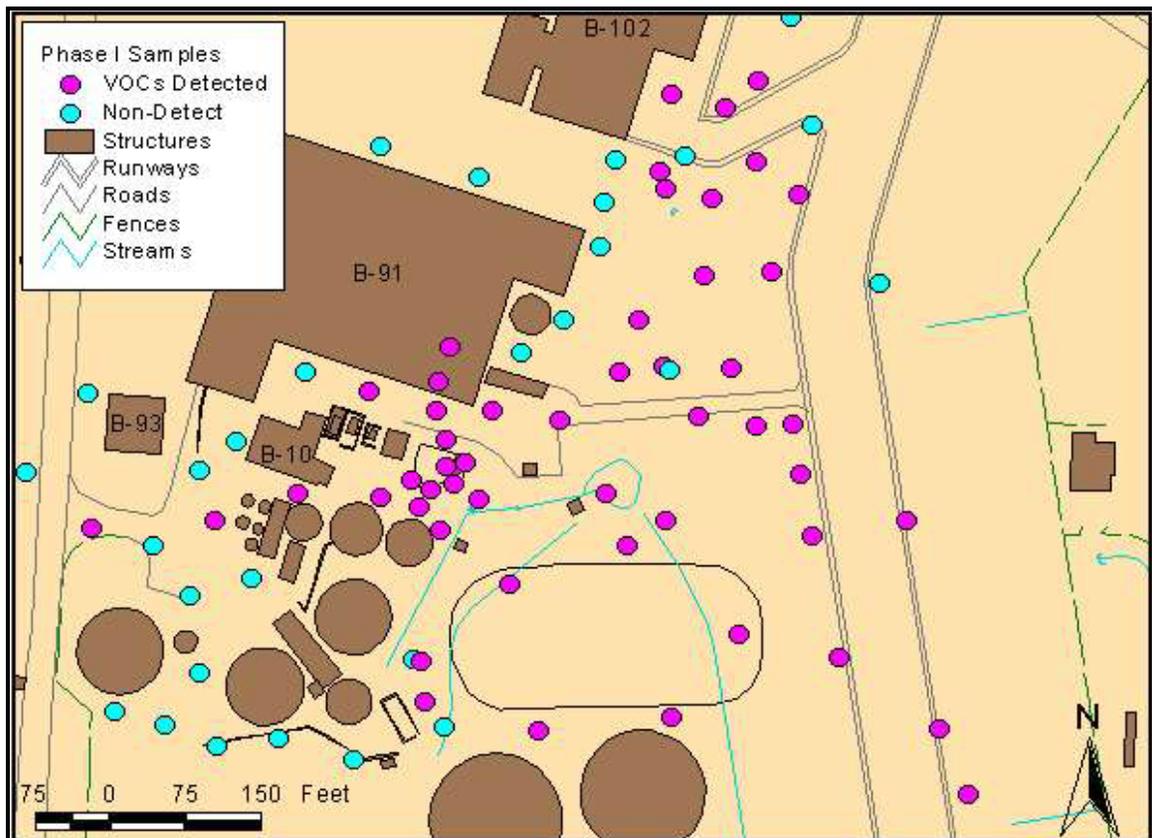


Figure 2. Avenue script used to group results and display sample locations based on whether any analytes in the group were detected above reporting limits.

Shadow Box Maps

The majority of professionals in the industry were accustomed to viewing analytical results from several analytes for each sampling location on a map. GIS users created shadow box maps (see Figure 3) that presented analytical results from any number of analytes. While these maps displayed the data that were needed for evaluation, they were difficult to read, and rather time consuming to create.

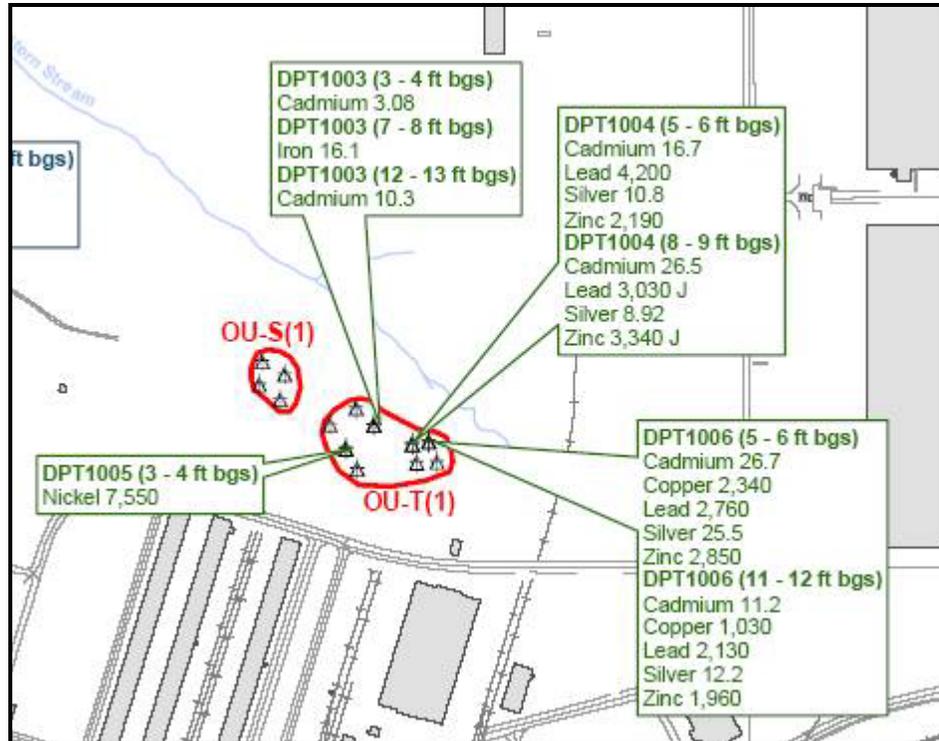


Figure 3. Shadow Box Map

GIS offers several alternatives to these awkward maps. Using pie chart and bar chart symbology, the percentages of various chemical concentrations can be depicted graphically for ease of interpretation.

In Figure 4, TCE is the primary contaminant of concern at this site; Dichloroethene (DCE) and Vinyl Chloride are degradation products, therefore the concentrations of those must also be evaluated. An Oracle database table contains columns of analytical results for the three analytes, along with the sampling location name and geographic coordinates. A database connection is established in ArcCatalog. Features in this table can be now displayed as an ArcMap layer. Several options for symbolizing features are found on the Symbology tab, in the Layer Properties. Using the Chart option, sampling locations can be symbolized as pie charts or bar charts that represent the concentration of several analytes (Figure 4).

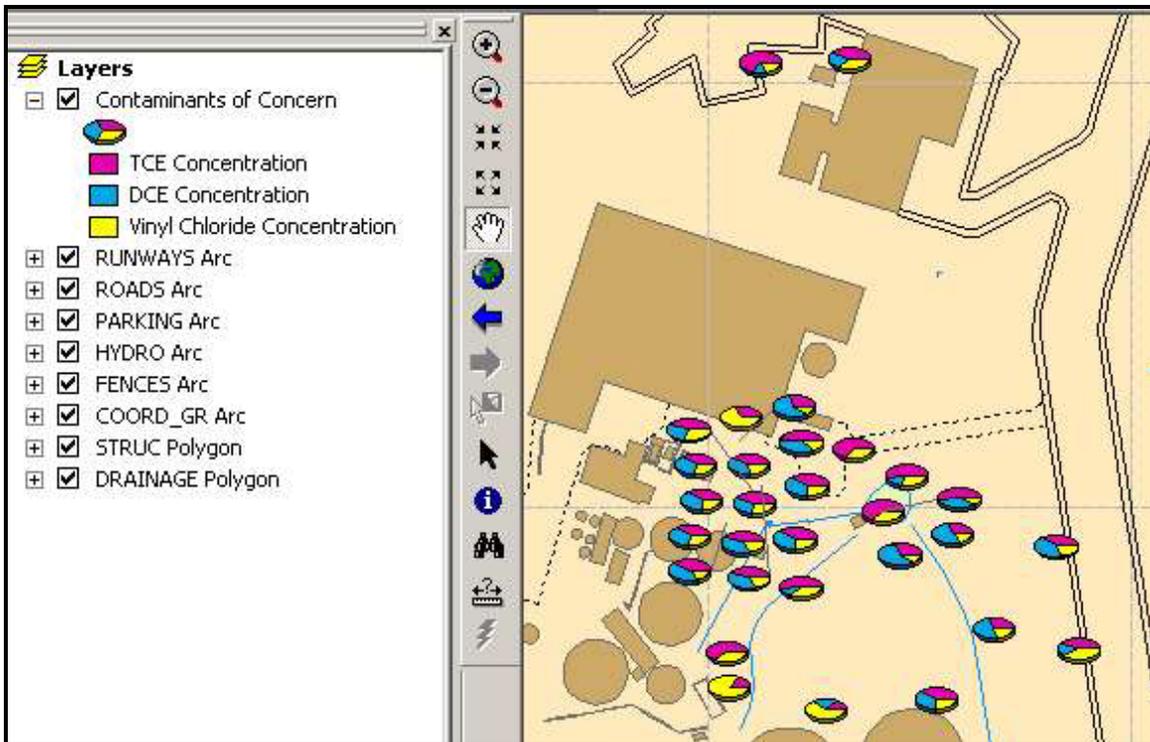


Figure 4. Pie chart symbolization to display three analytes per sampling location.

Another representation that is significant in environmental investigations is a map showing the total of the concentrations of all analytes within a particular predetermined Analyte group. In the example below, the concentration of VOCs was being assessed. Laboratories report individual results for each of the 23 VOC compounds being analyzed. In Oracle, totals of those individual concentrations were calculated for each sampling location. The totals were then plotted using different colored symbols, in graduated sizes, to communicate areas with high concentrations that required additional step-out sampling and/or remediation (Figure 5).

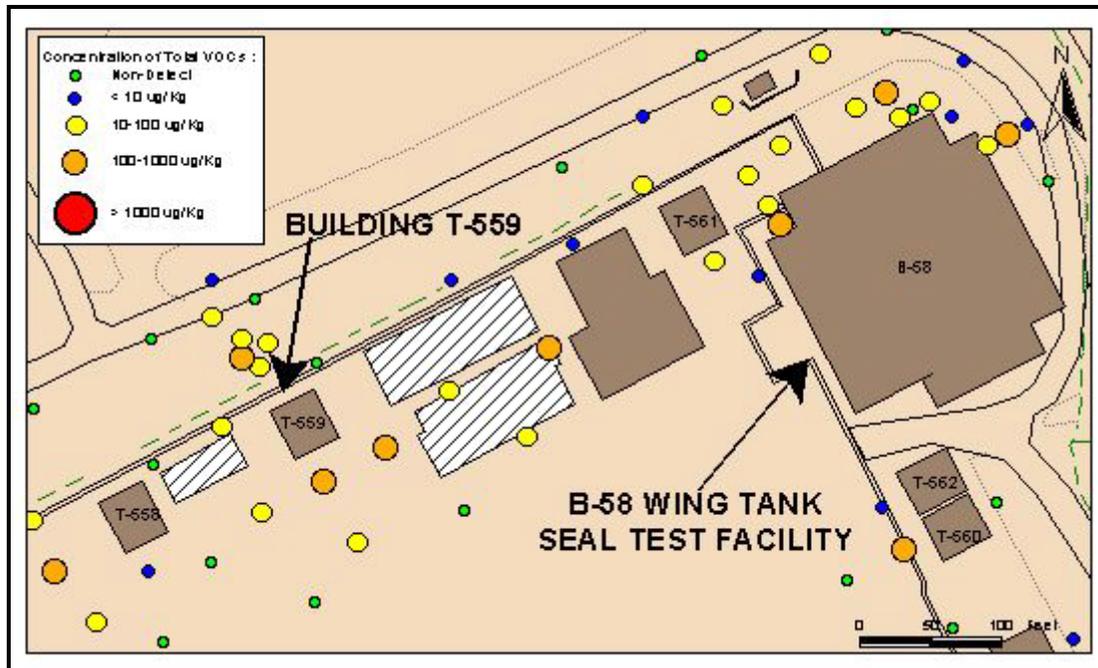


Figure 5. Sampling locations symbolized based on total of all VOCs analytical results.

3D Analyst Data Display

ArcGIS 3D Analyst extension provides effective visualization tools. One example represents a site with several samples collected at various depths. The results of an analyte (Trichloroethene, or TCE) are displayed, using different colored symbols, at the depth from which they were collected. A TIN is created, using 3D Analyst, to show the ground surface. The sample locations are plotted at their surface location, and those symbols are extruded to the sample depth (Figure 6). This gives a good depiction of the vertical extent of contamination at the site and supports the evaluation of remediation techniques.

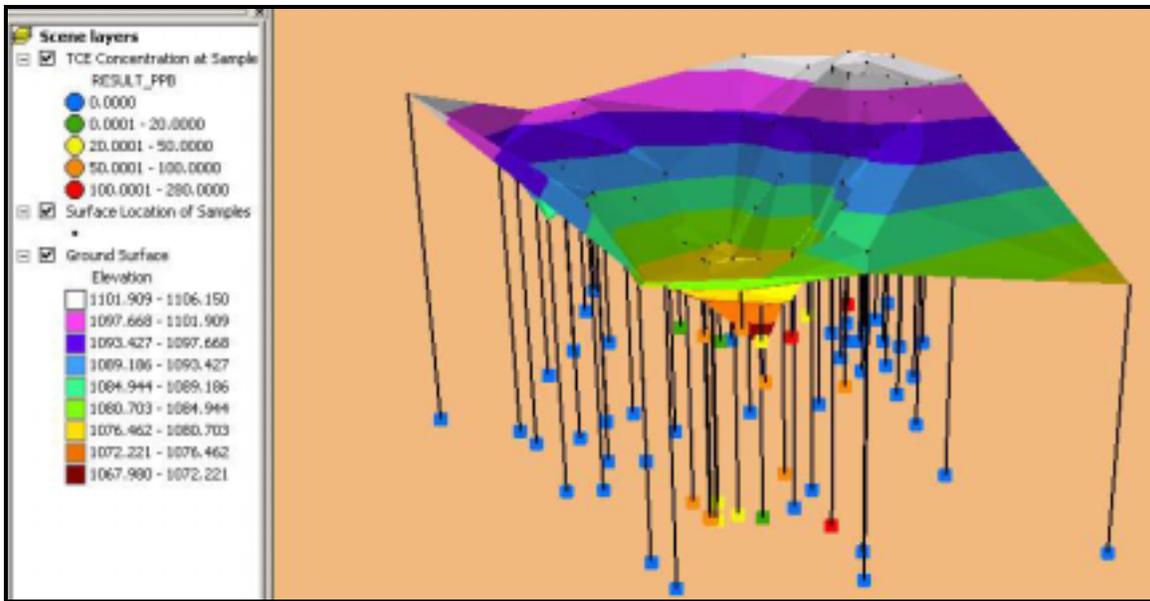


Figure 6. Sample locations at various depths symbolized based on concentration of TCE.

3D Analyst is also used to generate TINs from the concentration values of a specific analyte. Contours can be generated from a TIN. ArcInfo Advanced Editing Tools now offer a technique to generalize and smooth these contours. This is a successful method of producing contours for a particular analyte as opposed to contours being drawn by hand and digitized. The 3D Analyst extension also includes a tool for calculating area and volume statistics for these TINs, which assists in preparation for remediation.

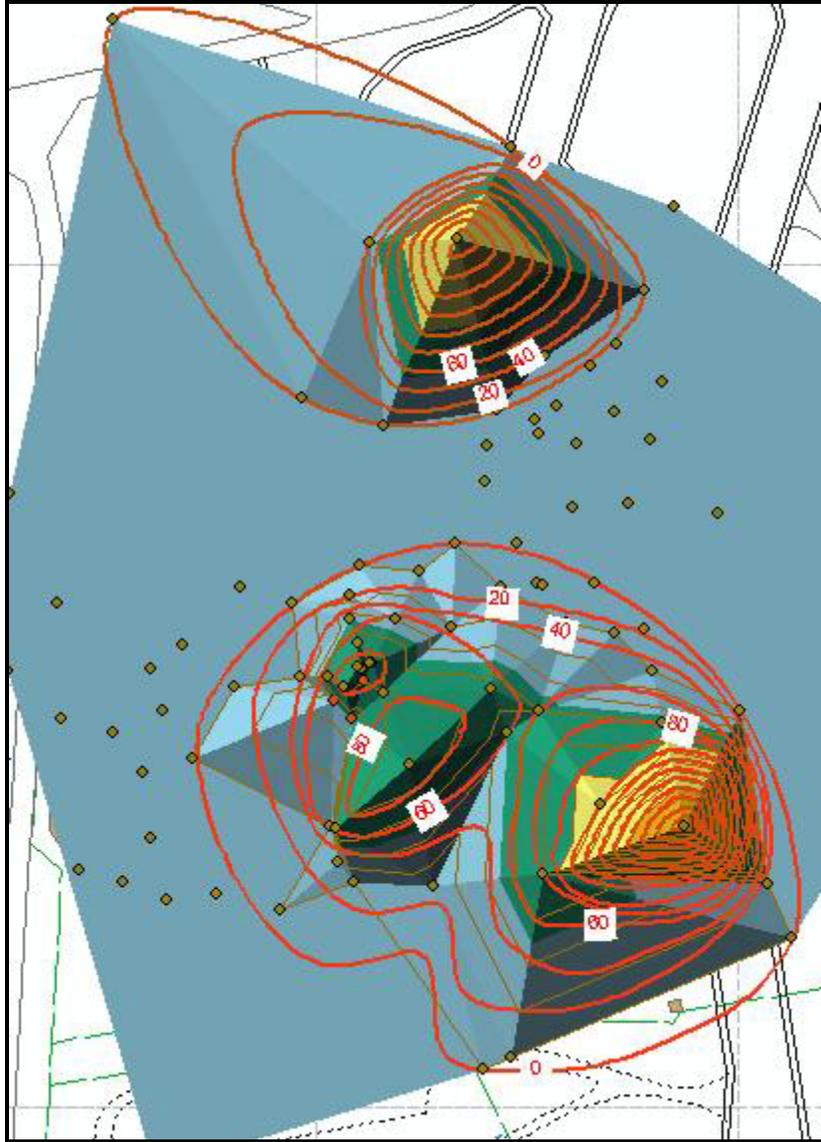


Figure 7. TINs and contours are generated based on concentrations of a particular analyte.

Conclusion

The display of chemical data in environmental investigations has evolved from handwriting on large paper maps and decorating maps with colored pushpins and stick-on labels. With the current technology afforded by ESRI products, data can now be presented in a number of other ways that are more conducive to environmental site evaluation. Professionals in the industry no longer have to sort through rows of values in a table, or attempt to interpret several values posted in shadow boxes. GIS users can now provide more clear and concise

maps for them to glean the information they need for their decisions. Thousands of dollars are saved in man-hours, storage space and the purchase of hard-copy maps.

Acknowledgements

Avenue scripts (used in Figure 2) were written by D. Randal Holtzclaw, Senior Systems Analyst, Shaw Environmental & Infrastructure, Inc.

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