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

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Abstract

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

Introduction

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

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

Data usability

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

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

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

**Site 1**

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

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

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

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

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

![Landfill Site Photo](image)

**Figure 1: Landfill Site Photo.**

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

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

- **Startup of Gas Extraction System**
- **Final Capping of East Cell**
- **Ponding at MW-3**
- **Creation of Retention Pond**

*Water Levels in MW-2*
Soon after the installation of the cap the water levels start to drop, but do not return to their original level. Bicarbonate concentrations increase coincidentally with the increasing water levels. However, these bicarbonate concentrations do not decrease with the water levels, although their concentrations no longer continue to rise. The methylene chloride concentrations do not start to rise at the same time as the bicarbonate and water levels (Figure 4). The organic constituents begin to increase with the start of construction of the final cover. The organic chemical concentrations start to drop at the installation of the gas extraction system.

![Methylen chloride concentrations vs. time in MW-2](image)

**Figure 4: Methylene chloride Concentrations vs. Time in MW-2**

A number of conclusions can be reached from this case study. The first is that the elevation of the bicarbonate concentrations is not related to the capping of the landfill but is, instead, connected to the elevated water levels. In the relatively arid climate of Colorado, an elevation of alkalinity is often observed in wells where the water level rises dramatically above the previous saturated zone. The elevated water levels appear to be caused by the presence of the retention pond that was expanded in the summer of 1996. It also appears that the installation of the cap and the removal of the retention pond removed the source for the rise in water level elevations and, coincidentally, stopped the rise in bicarbonate concentration.
The concentrations of methylene chloride and other organic contaminants do not appear to be directly related to the rise in water levels. The rise appears to start before the installation of the cap, but may be related to the placement of a temporary cap previous to the placement of the final cap. The gas extraction system is having a beneficial effect exhibited by a decrease in the concentrations of the organic contaminants. This lends support to the option of letting the facility continue to use it as a remediation method.

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

Site 2

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

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

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

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

Laboratory results of the samples collected showed that groundwater was contaminated at the facility. Based on the cross-sections it was determined that a bedrock high was situated to the south and west of the site and the bedrock surface greatly influenced groundwater flow direction. This was also apparent in contour plots of the bedrock elevations and the groundwater gradient. This high prohibited the flow of groundwater toward the stream. Therefore, the site did not affect the water quality of the stream and river. The drinking water supply was safe. The groundwater contour map showed that groundwater flow was to the northwest and that the drinking water well was not down gradient of the contamination (Figure 5). Groundwater contamination, though present, attenuated and was below regulatory limits at the site boundary to the northwest.
Although there was residual contamination at the site, this study showed that it did not warrant further remedial action. The results of this study allowed the EPA and state RCRA group to lift the corrective action order from the site and open the site for redevelopment.

Site 3

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

Due to its size, all of the data from Rocky Flats has not yet been completely loaded into EQuIS. As of the end of 1999, geologic and well completion information has been input. Approximately 1300 borings, of which 1200 are wells, have been entered. As more borings are being drilled at this site, these are being uploaded into the system. There are 22,000 water level measurements for these wells. Chemical data is being migrated into the system from two older databases. Data from an older state system are being loaded to help personnel evaluate the quality of remediation efforts taking place at the site.
From this data a groundwater model was constructed to help evaluate groundwater activity. See Figure 6 for the bedrock tin created for the model. The database was shared with site personnel. This sharing of data allows for the better evaluation of activities at the site. The integrated EQuIS data management system facilitates a better understanding of the geology and hydrogeology of the site. Once complete, the full system will permit better public access to information.

Conclusion

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

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