GIS in Occupational Health and Safety Services

Sergio B. Henricy, M.S.
Senior GIS Specialist
Applied Information Systems
Clayton Group Services, Inc.

Ed Stewart
Senior Project Manager
Clayton Group Services, Inc.

Abstract

The environmental health and safety (EHS) services industry generates large quantities of data. Data originates mainly from asbestos inspections, and industrial noise and air quality monitoring events. The typically non-integrated methods commonly used to manage EHS data, including paper forms, spreadsheets, and word processing applications, are time consuming, prone to error, and costly.

The application of relational databases and Geographic Information Systems (GIS) to EHS information management can resolve shortcomings of traditional methods and provide enhanced functionality. Among the benefits are greater data integrity, more defensible data, improved capacity to gather and manage more data with less effort and cost, better reporting capabilities, ease of access by EHS managers, and new visualization and analysis tools. This paper describes a typical EHS data management scenario and outlines an integrated solution that utilizes a GIS linked to a central database and support modules.

A Typical EHS Data Management Scenario

Asbestos, noise, and air monitoring data are collected using a variety of methods.

Asbestos inspections typically require recording locations and descriptions of asbestos suspect materials (ACM), as well as collecting material samples to determine asbestos content. Chain of custody (COC) forms, required to track samples, are filled out manually with information from the inspection forms. The COC accompany collected samples as they are sent to laboratories for analysis. Finally, returning laboratory analytical sample results must be matched with corresponding inspection record information for analysis and reporting.

Noise data is collected using meters placed throughout an industrial facility to record noise levels in specific areas over the course of a normal work shift, after which inspectors return to record instrument readings.

Indoor air quality data is collected from using air-monitoring devices placed on personnel and areas to determine exposure to airborne pollutants over a period of time after which, once again, inspectors return to record instrument readings.

Often, all asbestos inspection, and noise and air monitoring data are manually recorded on paper forms in the field.

Back in the office, data is, once again, manually entered into electronic documents, such as spreadsheets or text documents, for storage. Data stored in these various, disconnected document formats, is later retrieved for analysis and reporting. Data is also often manually entered or plotted on paper maps or CAD drawings.

Analysis of EHS data generally involves the review of analytical results and readings to determine if sampled or inspected facility locations exceed specific compliance levels.

In a non-integrated system, a consultant will typically examine the various data files in which the data is stored and compile results tables on which the conclusions of a final report will be based.

Major problems identified with this common scenario are:

- Lack of data integrity enforcement – a piece of paper will accept anything!
- It allows non-standardized data entry among inspectors/projects, which makes it more difficult to spot errors
- Forces data to be re-entered, sometimes twice after first recorded: one to fill out the Chain of Custody form (COC, as in the case of Asbestos samples) and yet another time back at the office (all three systems)
- It increases probability of input errors
- It increases data entry and access cost/time
- It facilitates loss or misplacement of data files
- It makes it difficult to access data efficiently and accurately
- It allows multiple copies of each data file/document to exist
- Analysis of EHS data stored in non-centralized systems is time-consuming, costly, and difficult to reproduce
- The previous point is exacerbated in cases involving several facilities, each one with its own set of documents, inspection records, and results
- Additional data/information needs, such as life safety equipment, training records, equipment calibration, and others, would make this scenario unsustainable
- It decreases responsiveness to inquiries
- It increases probability of erroneous reports due to data transcription and/or retrieval errors
- It makes it impossible to implement any type of automated response or warning system
- It limits analysis capabilities to a manual review of tabular results and manual input on CAD maps

With decreasing budgets, tighter deadlines, and demand for producing better results faster, EHS managers and consultants experiencing any of the situations described in the previous scenario will increasingly find themselves in need of a better solution that will allow them to do more, with less.

A GIS-enabled EHS Data Management System

An overall solution to EHS data and information management that addresses the above-described issues will make EHS data and information management more efficient and cost effective. However, it can also enable managers and consultants to take advantage of GIS-based information, visualization, and analysis technology that would enhance data access, presentation, and analysis.

The system described below was developed to address common EHS data management needs and to incorporate geographic information systems (GIS) for data collection, visualization, and analysis. The following characteristics were emphasized during design:

- Use of a central, standardized database to store all required EHS data
- Clear separation between user interface and underlying database
- Modularity: data collection, data entry, import, analysis, and reporting, and GIS
- Web-compatibility
- Secure and controlled user access
- Ease of use
- Scalability and integration with other systems

The system consists of a central database, and data collection, GIS, laboratory data upload, reporting, and analysis modules. The GIS component is utilized in the data collection, visualization, analysis, and reporting.

Centralized Storage: The Database

The central database is the centerpiece of the enterprise EHS solution and it supports all data processing modules. The system is designed to manage asbestos, noise, and air monitoring data and information generated during periodic facility inspections. The database format used is Microsoftâ SQL Serverâ, but it can also be implemented in Microsoftâ ACCESSâ, for a non-enterprise solution. In addition to system tables used to manage project-specific information and control access to the data, the main features of the database are the survey inspection and analytical results data tables.

The inspection tables are used to store all information and data collected during the inspection or survey event. Each record of survey or inspection (which may be an actual sample record in the case of Asbestos) is attributed with a unique identifier that is used to tie the record to its GIS location and, later on, to its analytical results, in the case of a sample record, and other documents related to the record (e.g., digital photograph of the sample location).

Data captured using the data collection module is moved periodically to the inspection tables for centralized storage.

Data Collection and the GIS

The system uses a data collection module designed to work with ArcPadâ on a personal digital assistant (PDA) or hand-held computer. This module generates periodic uploads to the central system.

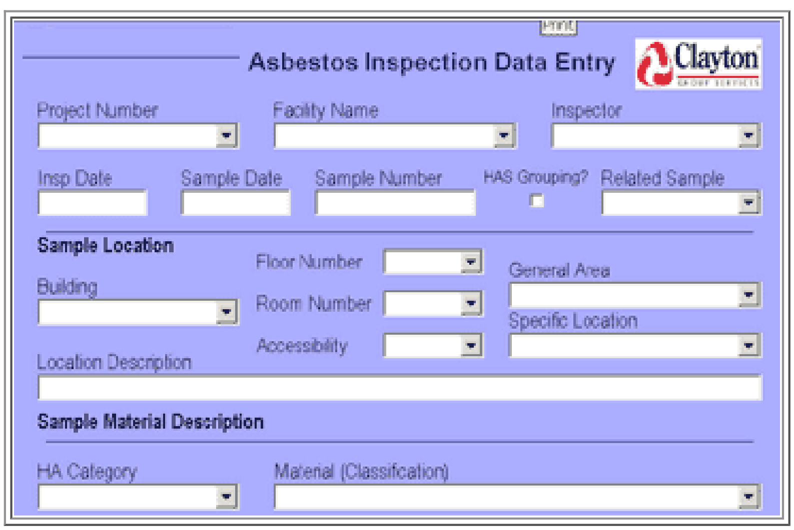
The first application of GIS in EHS data management is in the attribution of locations to sample or inspection points within a facility. Because Global Positioning System (GPS) is often disabled indoors, this is best accomplished by using floor plan layers embedded in the ArcPadâ data collection system and registered to a common coordinate system.

In the field, inspectors bring up the appropriate floor plan and data collection points layers and create data collection point features by tapping on the desired location within the floor plan displayed on the screen. These points are given unique identifiers using the same conventions established for naming sample or inspection locations in the project work plan. After creating a new location, the system prompts the user to continue entering information in subsequent data entry forms, using the unique ID to identify the new data record to which the new point is related. The result of this operation is a new GIS point feature linked to a unique information record stored in the survey table by means of the unique ID.

Creating Sample Locations in ArcPad.

After the inspection or survey is over, the PDA is synchronized with the office central database and GIS and all records and point features collected are transferred to the central system. A basic implementation of the system will accomplish this by direct USB connection (i.e. cradling the PDA) back at the office. A more sophisticated implementation can accomplish this directly from the field using a wireless solution that enables the PDA to connect to the central server via secure Internet connection.

A manual data entry module is also available for users who wish to hold off on the implementation of electronic data collection.



Asbestos Data Entry Module.

The GIS Module

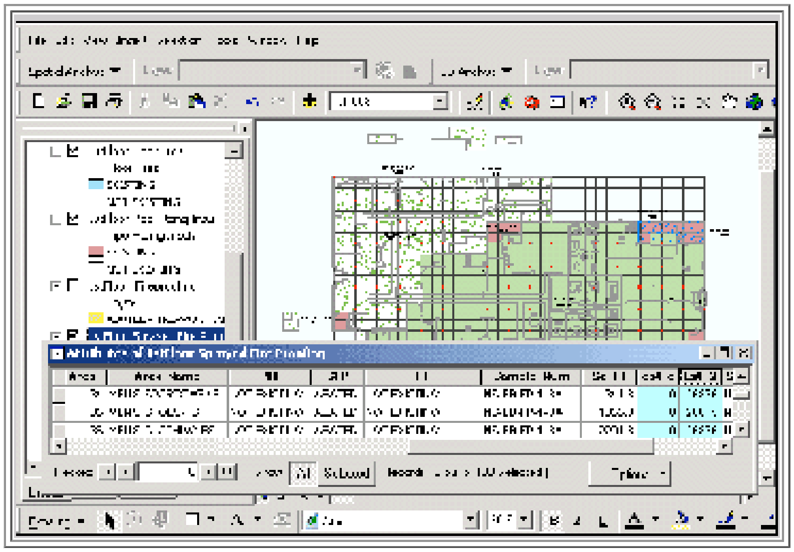
Naturally, a GIS must be implemented before any of this can happen. This system uses ArcGISâ to interact with the central database via a direct connection. The geodatabase format is recommended due for integration with external databases.

In order to enable GIS-enhanced data collection, floor plans of the facility are brought into the GIS and registered to a common coordinate system. The approach to this varies with the availability of floor plan data. The best floor plan sources are electronic CAD files, but many times all that is available are scanned or PDF files, or even just hard-copy drawings. There are many approaches to importing non-GIS data, registering layers to coordinate systems, and developing new features. Any GIS professional will be able to determine the best approach for a given data source, and we will not try to describe the different processes. However, the important point here is that the end result is a set of floor plan GIS layers that are registered to a common coordinate system and which describe the different facility floors. Once in the GIS, the floor plan layers are incorporated in the electronic data collection module.

The GIS also includes pre-defined, blank data collection point layers for the different types of data (asbestos, noise, and air).

A basic GIS module will consist of data point layers (e.g. asbestos sampling locations) displayed over common floor plan layers. Additionally, water lines and other system diagrams may be incorporated into the GIS, if applicable and available.

Each floor plan layer is used by different data-modules depending on the type inspection event. The link established between each data collection record and its corresponding GIS point feature is used to access all inspection and analytical data related to the point from the GIS. This enables users to apply GIS visualization and analysis tools.



Sample Location Distribution and Linked Data for Inspection Points.

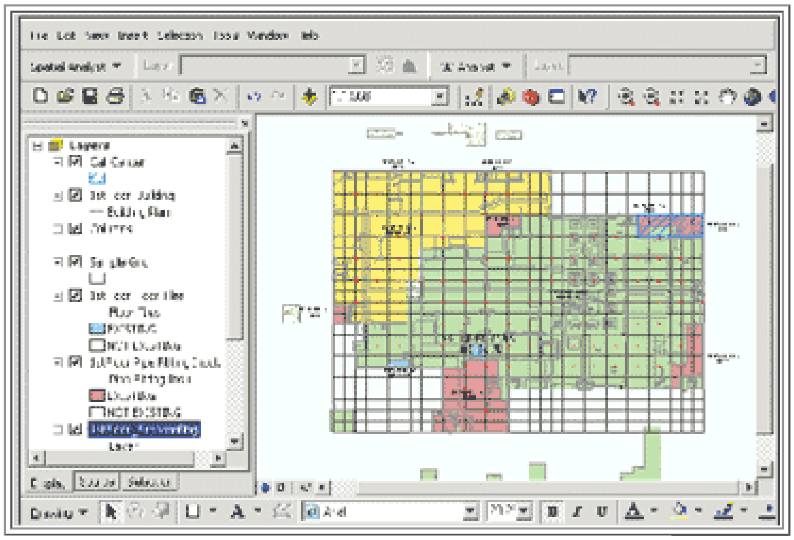
GIS-Enhanced Functionality

Enabling GIS in an EHS data management system allows users to take advantage of GIS unique functionality for data visualization, analysis, and more.

Visualization

An immediate benefit of linking a GIS to EHS data is the ability to quickly visualize the results from different types of inspections.

An asbestos inspection will generally identify homogeneous sampling areas (HSA) of asbestos suspect materials and sample locations within each HSA. Because each HSA usually encompasses a defined area within a facility floor (e.g. a room, adjacent rooms, hallways, etc.), a properly designed floor plan layer can be used to identify these areas and produce theme maps that describe HSA distribution at a glance.



Asbestos Homogeneous Sampling Areas Distribution.

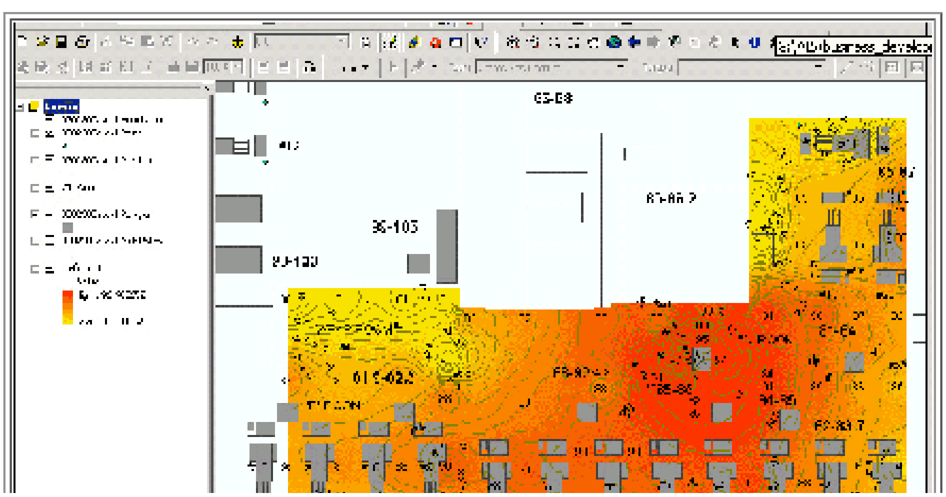
Moreover, the HSA map can be used to plan future sampling events.

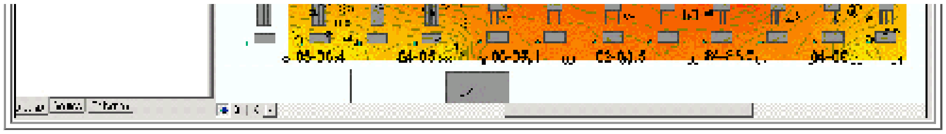
A map of sampling locations can also be produced for each floor plan/facility and help the OHS consultant, or manager, visualize sample distribution over the project area. Asbestos, noise, air sampling location maps can be quickly generated or use as visualization tools and for data analysis.

Analysis

Because sampling or inspection location points in the GIS are linked to analysis results, users can apply GIS analysis tools to produce new information based on the linked data and the spatial distribution of the points over the project area. This system uses ArcGIS, and Spatial Analyst and 3D Analyst extensions tools to analyze inspection results.

Noise monitoring results are used to generate noise-level contour maps that highlight high-decibel areas or areas with noise levels beyond regulatory limits.



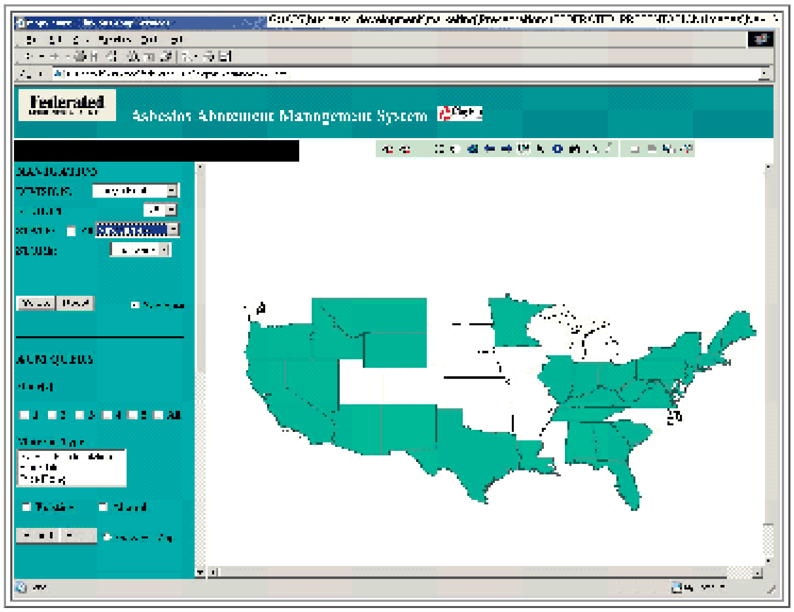


Noise Level Contouring Using Spatial Analyst.

Air quality readings can also be used to generate contour maps of reading concentrations.

Other Applications

In a web-based application of the system, clients use an ArcIMS map to access EHS data and information for different locations in different states.



Web-enabled EHS Data Access Using ArcIMS.

In this case, the GIS interface is used as a portal to access the integrated GIS and EHS data management system. The user is able to access analytical thematic maps reflecting results of different inspection types, such as noise level contours.

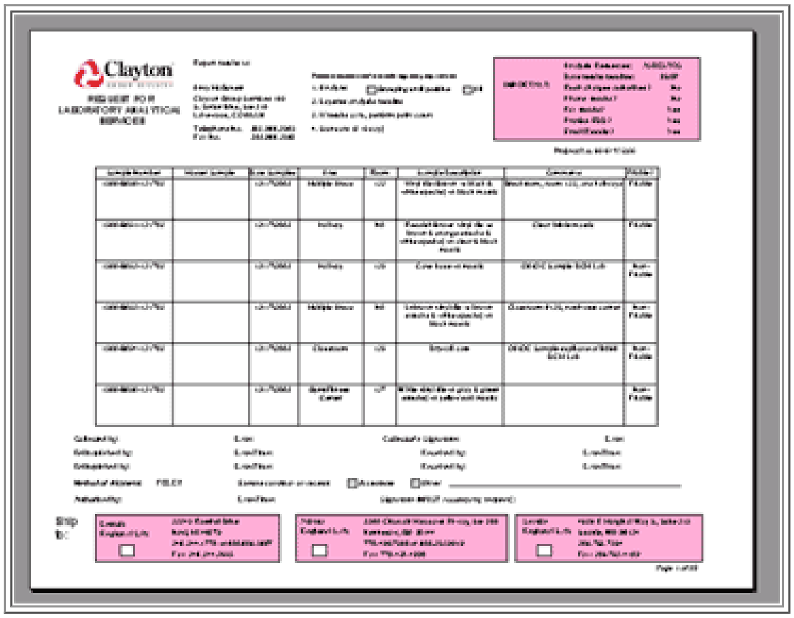
Support Modules

In order to maximize returns on the GIS-enabled EHS data management system, we developed basic data management support modules that ensure the EHS-GIS is always working with the latest and most accurate information available. Key components are automated electronic data deliverables (EDD), chain of custody (COC), laboratory data import, and data reporting.

Electronic Data Deliverables and Chain of Custody

One of the key aspects of EHS data is the generation of Chain of Custody (COC) documents required to track the life of a sample, from the time the sample is taken in the field, until analysis results return to the consultant from the lab.

The integrated solution allows inspectors to print COC forms directly from the application. Moreover, it allows them to create an “electronic” version of the COC that can be ingested directly by the computerized laboratory system. Important benefits resulting from this automation are the maintenance of data integrity (data on the printed COC will reflect the information originally entered in the system during the inspection) and the reduction in time required to generate COC documents and upload the information at the laboratory (literally, from hours, to seconds).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Automated COC Form.

Laboratory Reporting and Data Import

We recognize the importance of working closely with the laboratories in order to expedite and improve data processing when analyses are needed. The integrated EHS solution ensures that all electronic data files delivered to the laboratory (e.g., electronic COC forms) are presented in a standard format that can be easily ingested by most laboratory information management systems (LIMS).

In turn, the application requires that laboratories adhere to a standard electronic data deliverable (EDD) format for reporting analytical results. This format is either a tab-delimited text file or a pre-formatted spreadsheet that is matched and automatically generated by the LIMS. When sample information, such as sample ID, date, description, etc., is uploaded to the laboratory system from electronic COC files, the match with existing inspection record data (back at the central database) is guaranteed. Moreover, each item of information is only entered only once during the entire process! It is estimated that this type of implementation reduces data processing time by as much as 40%, a much welcomed savings for tight project deadlines and budgets.

Data Reporting, and Analysis

Contact Information

Ed Stewart:
estewart@claytongrp.com

Sergio B. Henricy:
shenricy@claytongrp.com

C... a reporting and analysis tools are in place, in order to support the development c... tables. The integrated EHS data management solution incorporates f... review data and generate tables formatted to match required standards, as c... project. Ideally, there would be standard formats for all data tables and reports. In reality, these vary and the application must be adjusted to accommodate variations in report formats. However, once established, report formats are generally constant, making these adjustments a one-time event. Furthermore, the time spent performing these adjustments is more than offset by the ease with which reports can be generated afterwards.

Conclusions and Recommendations

Creating a GIS-enabled EHS data management system without automating other basic EHS data flow processes would be somewhat equivalent to using a diesel engine in a Formula One racecar. It would look good, but it would not perform to expectations!

Implementing a GIS solution to EHS data management should be the corollary of a series of implementation steps that culminate in a GIS-ready EHS data management system.

The following development steps can be identified:

- Establishing needs (target users, scope, objectives, and timelines)
- Implementing a centralized database/application that will store all EHS project field and laboratory data and which will support additional functionality modules
- Implementing successive functionality modules (GIS, data collection, laboratory data import, and basic reporting and analysis)

When choosing a model for an integrated EHS data management solution, consider the ultimate goals of the completed system. Managers should weigh if the system will be accessed internally (intranet or desktop) or externally (web-based), or whether the EHS information system will need to, eventually, be linked to other existing or planned systems within the organization. It is important that a solution be suitable for integration with other information systems to enable scalability of the system.

EHS data management systems that are well planned and implemented can generate substantial cost-savings. These savings are mostly in the form of dramatic reductions in data capture, manipulation and processing times. Additional savings are achieved by minimizing data errors and potentially avoiding missed deadlines.

Enabling GIS within an integrated EHS data management solution empowers managers and consultants with enhanced data visualization and analysis functionality not previously available to them. We have only mentioned a few immediate and important examples of application of GIS functionality to EHS data analysis. However, as it is usually the case when GIS technology is first applied in a field of work, it is likely that new and more ingenious applications of GIS in EHS data analysis will be developed.