Environmental
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GIS for Environmental Management Solutions

Soil Remediation Assessed with GIS

By Jeffrey M. Laird, GIS Manager, Badger Army Ammunition Plant

Historically, resources for the environmental remediation of contaminated soils have been limited. Therefore, excavation should be focused only on those areas where it is necessary, minimizing the removal of surrounding collateral uncontaminated soil. Environmental managers and geologists use GIS software to build 3D models for decision making and presentation tasks inherent in defining a project with an accurate scope and budget. Project managers use GIS to create baseline maps for evaluating contractor bids. GIS can document processes and provide spatially accurate models for projecting the cubic yards of earth and concrete that need to be removed in remediation efforts.

GIS technology proved to be a mission-critical element of remediation activities at the Badger Army Ammunition Plant (AAP) in Baraboo, Wisconsin. Built in 1941, the plant produced ammunition, ordnance, gunpowder, and propellant for the United States Army until 1975. In the late 1990s, the government decided to decommission Badger AAP and transfer the land to other government agencies. Subsequent surveys detected various hazardous compounds in the site's structures, soil, and groundwater. These needed to be remediated to Wisconsin Department of Natural Resources (WDNR) and federal Environmental Protection Agency (EPA) guidelines. This remediation process is ongoing.

Contamination site map has orthorectified images set at 30 percent transparency to depict underground contamination, concrete footings and columns, and concrete structures on top of the slabs. Circular and square meshes are concrete supports for storage tanks, which were long since removed. This map makes it easy for anyone to understand where excavation must be done.

A GIS project was established at Badger AAP in 1999 to support scientists and engineers involved in the site remediation. GIS also supported army and contractor staff in communicating spatial information to management, command personnel, and concerned citizens groups and providing sophisticated spatial modeling and analysis tools, decision-making tools, and mapping products for the user community.

The Badger GIS is composed of ESRI's ArcGIS Desktop, ArcIMS, ArcGIS 3D Analyst, and ArcPad 7 software. The entire GIS operation is outsourced to Grand Terre GIS of Frankfort, Kentucky, an ESRI business partner.

One, nine-acre remediation area has been demolished to its concrete foundations with the exception of a few remaining buildings. Although soil contamination is relatively shallow, it is near hard-to-access locations of concrete slabs, support columns, and footings.

It is most cost-effective for the army to have only the contaminated soils removed. However, where concrete foundations exist within the contaminated areas, the concrete must also be removed, which is more expensive than soil removal. Some concrete foundations were as

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GIS for Environmental Law

The use of GIS in both the creation and enforcement of environmental legislation is increasing. One of the driving forces of this increase is the availability of satellite imagery at a resolution sufficient to highlight compliance infractions. Environmental modeling of the potential ramifications of new laws cannot be accurate without integrating other information outside the scope of environmental studies. GIS provides this integrating and modeling framework.

Environmental law cases, for example, pollution source prosecution, use GIS as a means to deliver evidence to legal professionals and jurors. GIS visualization tools can now be used to illustrate evidence in a manner previously impossible. Learn more about how GIS is used to manage the environment at www.esri.com/environment.

ESRI International User Conference Set for June 2007

The Twenty-seventh Annual ESRI International User Conference (UC) will take place June 18–22, 2007, at the San Diego Convention Center in San Diego, California. This gathering is for those who use ESRI's GIS solutions to manage and share geospatial data and analysis capabilities on the desktop, across the enterprise, in mobile devices, and through Web-based services. A comprehensive offering of sessions, workshops, and exhibits will help both experienced and novice users of GIS expand their knowledge and further their skills in deploying geospatial data and workflows at all levels of government, in business operations, and in society.

The conservation group will hold meetings during the conference to update members on GIS projects and data-sharing opportunities for conservation and environmental management.

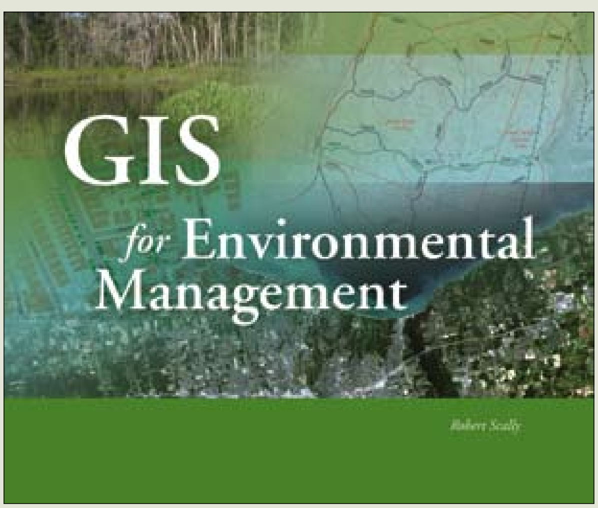
The 2007 conference will feature a one-day Plenary Session covering highlights in development work by ArcGIS product teams. The conference week will include technical workshops and user presentation sessions. Workshops will cover ArcGIS software and extensions in detail, benefiting GIS users and development teams. User presentations, organized by topic and industry tracks, will enable users to discuss their applications and share lessons learned with others who share their goals and objectives for GIS.

New for 2007 will be the Benefits of GIS track, designed for managers and senior executives to discuss the value of, and achievements in, GIS technology within government and utilities as well as private sector organizations. The 2007 ESRI UC will feature a comprehensive exhibits area, offering direct access to hundreds of ESRI business partners and information on the products and services that are available to support GIS users.

GIS users of all skill levels will benefit from attending the 2007 ESRI International User Conference and concurrent events. Dates, deadlines, and other conference details are now available at www.esri.com/uc.

GIS for Environmental Management

Complex environmental challenges increasingly demand sophisticated solutions. *GIS for Environmental Management* outlines the ways that GIS is fulfilling the need of humanity to better manage, protect, and preserve the environment. Topics covered range from biodiversity and pollution to coastal zone management and change detection. Order this book from ESRI Press at www.esri.com/esripress.



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much as eight feet deep, which complicated the process of ascertaining an approximate cost for excavation.

Managers needed to see a three-dimensional view of both contamination and concrete. Contamination data was overlaid onto the concrete foundations data and volume information so the amount of concrete and soil to be removed could be calculated. Then costs and level of effort for the project could be projected.

To determine the extent of contamination, the geologists needed to see where the contaminated area boundaries were and how the concentrations were distributed. They installed multiple borings and took soil samples at several depths. The positions of the borings were recorded using ArcPad on a Thales MMCE GPS with submeter accuracy. These points were supplied to the GIS manager who plotted them against a basemap of the site. When sample results came back from the lab, the geologists evaluated them and attached values to the borehole points as attributes.

The ArcGIS 3D Analyst extension was used to create a TIN of the site area. Then a surface of contamination was created using the depths of the samples with contaminant "hits." Next, a nearest-neighbor algorithm within ArcGIS 3D Analyst was used to determine the contaminated area based on the boreholes and their resultant values. The results were projected onto the contaminant surface TIN and assigned a thematically colored legend based on concentration value. Values below the WDNR threshold for remediation were discarded, and the final result was a spatially accurate three-dimensional model of the extents of contamination. As a last step, geologists decided that because no contamination results were deeper than two feet, and two feet was the maximum depth to which an excavation would go, it was not necessary to project onto a contaminant surface TIN. It was easier to assign the contaminant model a uniform offset of negative two feet off the site surface TIN. All this was modeled and viewed using ArcInfo and ArcGIS 3D Analyst.

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Data Model Is Grassroots Effort

U.S. Fish and Wildlife Service

U.S. FWS National Wildlife Refuge System Waterfowl Production Area

U.S. FWS National Wildlife Refuge System Clark Salyer National Wildlife Refuge

The ideal situation for constructing a successful GIS is to develop a well-devised plan prior to implementation. The key is knowing ahead of time what information products GIS will deliver, then planning a project that takes advantage of them. In the real world of federal governance, however, the ebb and flow of personnel, data, funding, and regulatory compliance have resulted in a meandering development of some agencies' GIS.

Most agencies' GIS systems grow over a span of years, from the ground up, with disconnected desktop approaches designed for specific, local office projects. Now that geospatial technologies have become effective in connecting databases, federal agencies are taking major steps to expand their databases and improve accessibility of data and GIS solutions. Within the Refuges and Wildlife Program at the U.S. Fish and Wildlife Service (FWS), a data model holds the promise for the refuge system's next generation of GIS data management.

For many years, FWS has used GIS at the grassroots level for research and field station projects. FWS manages the 96-million-acre National Wildlife Refuge System, which encompasses 545 wildlife refuges, thousands of Waterfowl Production Areas, and other special management areas. In the late 1990s, the FWS Division of Refuges began an organized effort to build a data model for Wetland Management Districts in Region 3. Resource managers, biologists, and GIS specialists began to collaborate on the development of standardized databases and content using ArcView 3.x. In 2001, Region 6 revised the Region 3 data model and ArcView tools to encompass approximately 25 themes and associated data tables. The result was the Refuge Lands GIS (RLGIS).

With the release of ArcGIS software, managing highly robust datasets became easier, so Region 6 began to work with Regions 1 and 2 on expanding the RLGIS databases. Representatives from the three regions, called the Spatial Information Management (SIM) team, embarked on a nine-month, two-times-each-week conference call collaborative effort to define a comprehensive database to capture and store spatial information about features, land definitions, and management that are owned and managed by the FWS Refuge System.

The group worked closely with managers and biologists at field stations, coaxing from them the information needs required to perform their work by asking the simple question, "What do you want to know about what you do?" People from many parts of the country were asked to review the content of the data model, an effort that resulted in an expanded scope of the model. As a result, SIM has expanded to include representatives from each of the FWS regions.

SIM organized the resulting information into three major data categories: real property and other features, vegetation and habitats, and resource management. SIM also compiled a data dictionary that contains 219 pages of documentation about geodatabases, feature classes, fields, relationship tables, pick list/domain content, field widths, and field types. From this, it created 69 feature classes and 26 relational tables with thousands of fields. The data definitions were constantly referenced to FWS service standards and existing databases when possible.

The data model became immense, and help was needed to ensure the data model's efficiency, structure, and organization would work. The SIM team called on ESRI's Professional Services Group to provide expert support in developing the data model. Professional Services performed a comprehensive evaluation on the efficiency of the data model. Using Microsoft Visio, Professional Services created a UML model to define feature classes, relationships between feature classes, lookup tables, and domain values. Using the ArcCatalog schema wizard, end users can import the data model to build the structure into their databases. ESRI customized data input forms that make it easier for people to assign attributes to the features in their database and to manage related tables. ESRI is in the process of building interfaces for desktop applications to interact with the data model, which helps users get to the right data in the easiest way possible. It also is developing field data collection solutions that incorporate GPS and ArcPad field GIS software for capturing data when using a relational database structure.

Following ESRI's recommendation, the RLGIS data model was divided into three topic-oriented geodatabases. The first contains feature classes specific to real property, facilities, infrastructure, management unit, and monitoring inventory. The second consolidates upland and wetland vegetation mapping as well as invasive plants. These two geodatabases do not utilize a relational database structure. The third geodatabase houses information related to resource management, utilizing the relational data structure available in a geodatabase, and ranges from land management, disease, and invasive species to public use.

FWS users will access these geodatabases to manage a wide range of spatial information needs including vegetation and weed management, water management, wildfires and prescribed burns, hunting and trapping, fences, signs, and a host of others. RLGIS will be available to any interested refuge field station, and support and delivery will be managed regionally. Users in the field will select the portion of the data model that relates to them and use it to collect and maintain data for their local areas. Because the data model is comprehensive, data can be rolled up to regional and, ultimately, a national level, as needed. The end result of the data model effort will be that data becomes more accurate and retrieved more easily.

Chuck Loesch, an FWS wildlife biologist in Region 6, has been a key player in working on the project. From his involvement with building the data model, Loesch has gained insights he shares with others embarking on similar ventures. "People often resist the idea of collaborating, saying, 'Our situation is unique, and our work cannot be standardized.' Nobody is as unique as they think. We were able to find common ground, and that is the type of information we have included in this core data model. Another key to success is to build from the field up rather than initiate policy from the top down. If field people are involved in the design and content, they will get a product that is built for them. They are also more enthusiastic about contributing.

"Another important point is that end users do not care much about the structure—that is the developer's job. The field people want a tool that is useful for them, which means that the process or tools help them do what they need to do and they make sense. Finally, the applications need to be simple. If they are too convoluted, the user doesn't take or have the time to figure them out and will not use them. GIS applications have to work and look simple enough for the average field station employees. Users want a straightforward, easy-to-use product that works for them. Properly constructed GIS tools should be designed to make database complexities transparent to the user so that it is everybody's tool."

For more information about the Fish and Wildlife Service's RLGIS data model, send questions to Chuck Loesch at chuck_loesch@fws.gov.

Latest ArcGIS Software Release Makes It Easier to Author, Serve, and Use Geographic Knowledge

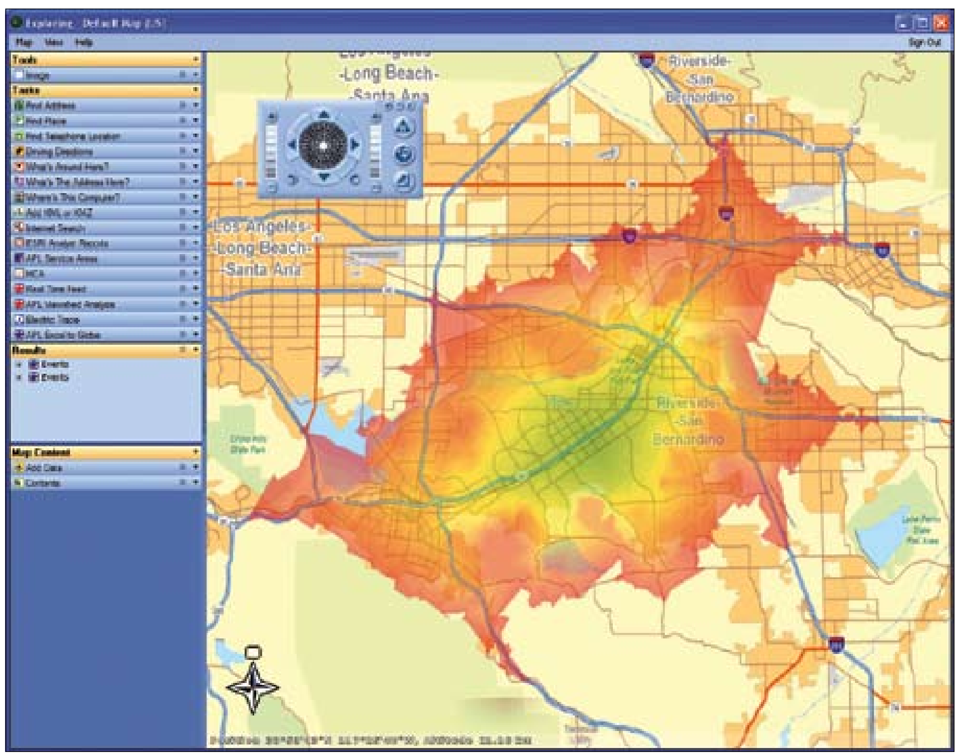
ESRI's ArcGIS 9.2 is a full release of ArcGIS Desktop (ArcInfo, ArcEditor, ArcView, and ArcReader), ArcGIS Engine, ArcGIS Server, and ArcIMS.

ArcGIS 9.2 introduces a new way of sharing and accessing the rich geographic knowledge maintained in a traditional GIS to make users more productive.

Highlights of the ArcGIS 9.2 release include

- Usability and quality enhancements.
- A new method for storing cartographic representations in the geodatabase and a suite of advanced drawing and symbolization tools.
- Server-based GIS with ArcGIS Server, which allows you to serve models and applications authored with ArcGIS Desktop as GIS services.
- New visualization and analysis tools that allow you to create, play back, and export time-based animations and graphs of how processes evolve.
- New tools and wizards that make it easy to set up and manage a geodatabase. ArcGIS 9.2 also includes high-precision coordinate storage and greater flexibility in distributing your enterprise GIS data.
- Support for a growing array of open data standards. There is enhanced support for reading, exporting, and working with CAD drawings from AutoCAD and MicroStation.

All ArcGIS 9.1 users who are current on their maintenance will automatically receive ArcGIS 9.2 at no additional cost. For more information about ArcGIS 9.2, visit www.esri.com/whatsnew.



ArcGIS 9.2 lets you deliver GIS capabilities to large numbers of users over networks with server-based GIS.

Research Group Prepares GIS Data for Disaster Response Portal

Behind first responders facing physical obstacles during the aftermath of Hurricanes Katrina and Rita were dozens of government agencies providing information and support. One such agency was the National Institute of Environmental Health Sciences (NIEHS), a component of the National Institutes of Health responsible for understanding human health consequences associated with environmental contaminant exposures. Since NIEHS research and outreach programs focus on environmental hazards, it was uniquely positioned to provide information on potential sources of environmental contaminants and possible exposure impacts on both responders and hurricane victims.

Dr. David A. Schwartz, NIEHS director, recognized the agency's position and, before Hurricane Katrina made landfall, initiated a plan to provide information on local potential contaminants and health impacts. For best accessibility, the information would be available on the Web. To improve usability, it would have a GIS component to give users localized maps showing a combined picture of many different potential hazards in each area. For best impact, the GIS had to be available right away.

Schwartz called on William A. Suk, Ph.D., director of the Superfund Basic Research Program (SBRP), to help organize the GIS component. Under NIEHS, the SBRP supports research and outreach activities on environmental health issues associated with Superfund sites—national hazardous sites that have been identified by the Environmental Protection Agency as requiring remedial action. At least five SBRP-funded university research programs were already using GIS as a research tool and could contribute to the effort.

"We wanted to create a GIS that would initially help first responders to the hurricane. We could also see eventual use of the GIS to assist those at the state and local health and environmental levels and then eventually researchers trying to determine the health consequences associated with such an event," says Suk.

Within a day, the plan put a GIS team at the Children's Environmental Health Initiative (CEHI), an SBRP-funded program at Duke University, in charge of all data gathering and processing; tasked a group at the University of California San Diego (UCSD) Supercomputer Center with building the Web portal; and charged a San Diego State University (SDSU) group with providing the server interface. CEHI director Marie Lynn Miranda, Ph.D., coordinated activities with a core GIS production team of Andy Hull, Sharon Edwards, and Alicia Overstreet, with Jeff Davis acting as outreach coordinator. Many other volunteers from CEHI and other SBRP programs joined the effort.

"While we all sent in checks to emergency relief organizations, helping to construct the hurricane response Web site and working with first responders felt like good, hard, constructive work that we could do in the face of almost overwhelming destruction," says Miranda. Colleagues from Columbia University, the universities of Kentucky and Arizona, the Research Triangle Institute, UCSD, and SDSU helped track down data from their areas of expertise.

Target users were identified as the Centers for Disease Control and Prevention, American Red Cross, Federal Emergency Management Agency, and United States Department of Transportation. The GIS site had to support decision-making processes related to

- Identifying sources and routes of contaminants
- Evaluating the potential for immediate exposures to first responders
- Assessing human exposures that occurred in the immediate aftermath of the hurricanes
- Researching the short- and long-term health impacts associated with these exposures

Data was included in the Web portal about Superfund and Toxic Release Inventory (TRI) sites; oil production and extraction facilities, refineries, and pipelines; industrial facilities; agricultural operations; schools; and medical facilities for Alabama, Mississippi, and Louisiana (and later, Texas) as well as aerial imagery from the National Oceanic and Atmospheric Administration and the U.S. Geological Survey.

Working with ArcGIS ArcView, the GIS team members used ArcMap to project latitude and longitude points from data they received in text format, assign common projections to all the data collected, and produce both the overview flat maps and detailed grid maps. They used ArcCatalog to update and maintain all the associated metadata.

Just two weeks after the site was up and running, Hurricane Rita arrived. Fortunately, connections between agencies had already been made and relevant data had already been collected. Adjustments were quickly made to include Rita impact areas based on previous lessons learned.

"Having a system such as this in place before a disaster happens is really important and so is cooperative collaboration—and everyone involved here was very willing to do the work," says Hull. Suk added that the group members remained flexible when confronted with enormous amounts of data and the short time frame. They quickly created a basic version offering preformatted maps and added functionality, such as interactive mapping capabilities, as they advanced. This enabled them to put an informative product online in one week.

Now, as efforts change from emergency response to cleanup and rebuilding, the GIS site continues to be relevant. "I think it is also going to point to needs for new and innovative technologies to help us better predict not only exposures from catastrophes but also exposures in general," says Suk.

For more information, contact hurricanegis@niehs.nih.gov.

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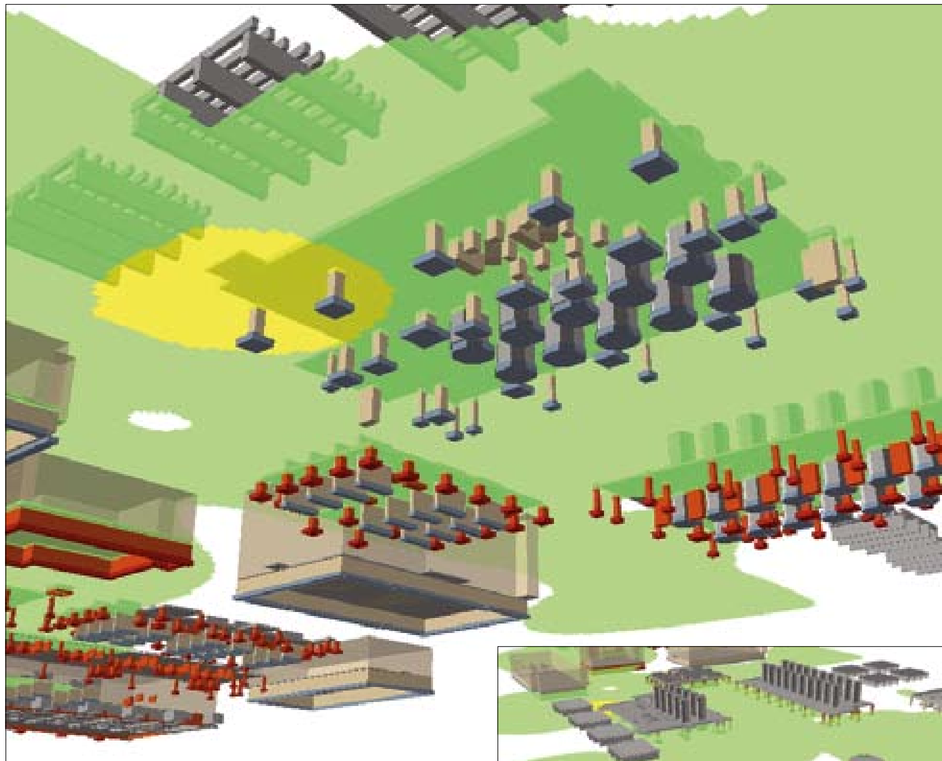
A model for concrete data also had to be created, and data needed to be digitized so that it could be used in the GIS. When the site structures were built in 1941–42, each structure was documented with an as-built engineering drawing done by civilian draftsmen working for the army at the time. These drawings still exist on paper and on microfiche, but both sources are very poor and in some cases illegible. These were the source maps for modeling the concrete. Foundation structures were categorized into three basic categories: slabs (including on-slab structures such as motor pads), support columns, and footings. Shapefiles were created for each category. Working from the as-built sources on a building-by-building basis, the two-dimensional geometries (length and width) were digitized using the ArcInfo precision entry tools. The length, width, and height values were then entered into the attribute records of each separate structure along with depth offset values. Other descriptive data about the building was also included in the model for future use. Digitizing data for the 16 buildings and 32 tanks in the project area took approximately 90 hours.

When feature digitizing and attribution were finished, the three shapefiles were attached to the ArcGIS ArcScene application along with some road, building, and tank information that was clipped from the main feature classes residing in the Badger AAP geodatabase. The site TIN derived from contour and spot height elevations was added. The footings, columns, and slabs were then assigned the base height of the TIN and the individual features extruded according to their height values, beginning from their offset value in relation to the TIN's base height. Slabs were extruded in a positive direction and footings and columns were extruded in a negative direction, placing them below the surface. For example, a one-foot-high footing beginning at the end of a four-foot column would be offset four feet and extruded using a value of negative one. The column would be extruded negative four and not offset, since it starts at the bottom of the slab. The slab, normally six inches thick, would be extruded positively one-half foot and lie on top of the surface TIN.

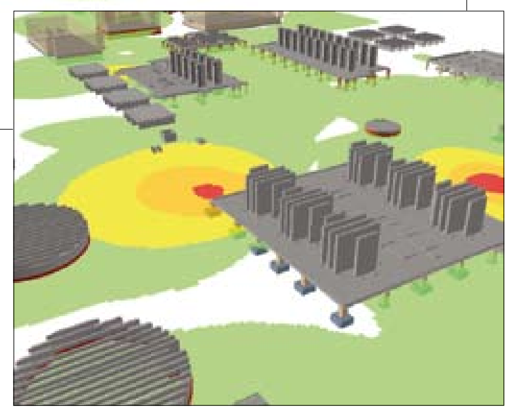


This fully rotatable model is an underground perspective looking up at the concrete and the contamination surface. Note where it intersects the features, which makes the features easy to select. Orange and red depict surrogate (best guess) data from buildings where the source as-builts were either lost, unavailable, or illegible.

In areas where the source maps were too poor to derive dimensions, surrogate data was used based on the geologist's knowledge of foundation construction. Where surrogate data was used, the subsurface features were assigned orange and red coloration.

The result of all this data input was a fully rotatable three-dimensional model of the subsurface foundations, spatially accurate and precisely to scale in ground units. Because each feature had length, width, and height attributes, the field calculator could be used to easily determine and populate a volume field. If features were circular or hexagonal, the relevant solid's geometry formula was used to derive volume.

The contaminant extents model was added to ArcGIS 3D Analyst to create maps that show where the contamination intercepted the concrete. These concrete features were then selected by location, and the sum of their volumes was added to the volume of contaminated earth to be removed. At that point, environmental management had the information it needed to compile a budget and a project description for the army to consider. It also was able to spatially illustrate concepts such as contaminant locations in relation to concrete subsurface features and slabs and provide views into the model from any angle at any scale.



This three-dimensional contaminant map shows the sulfuric acid concentrator building looking north toward the nitric acid recovery buildings (tall hexagonal columns). The meshes are storage tank foundations. The ghostly buildings at the top are building polygons with transparency set at 50 and indicate nonacid-related buildings such as storage and offices.

Jeffrey M. Laird is the GIS manager at Badger AAP and president of Grand Terre GIS. Laird is an ASPRS Certified Mapping Scientist; a GISCI certified GIS professional; and a member of ASPRS, URISA, and the National Association of Environmental Professionals. Learn more about Grand Terre GIS at www.grandterregis.com.

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