Environmental
OBSERVER

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GIS for Environmental Management Solutions

European Environmental Map Services Move to Cloud

By Barbara Shields, Esri Writer

The European Environment Agency (EEA) is one of the first European Union agencies to offer Web mapping services in the cloud. EEA sees its service as an information product and a way to promote its message of sustainable environments. Its Shared Environmental Information System (SEIS) initiative helps environment data providers share methodologies, ideas, standards, and technologies. SEIS is a means for exchanging data from local to global level. ArcGIS is an important component to build SEIS; recently, EEA began moving its Web mapping services to the cloud using ArcGIS Server and ArcGIS.com.

Cloud GIS offers data storage, end-user Web applications, and focused computing services. It costs less, is always available, has faster application delivery, is flexible, and has improved business continuity. This helps EEA better coordinate its many programs such as the European Environment and Observation Network (Eionet), an initiative that has 450 participating institutions. Map services allow participants to better collaborate in community computing for easier and faster information sharing via SEIS.

Several European initiatives that contribute to SEIS are transitioning to the cloud environment, wherein technological capabilities are commonly maintained off-premises and delivered on demand as services via the Internet. These participants include

- Infrastructure for Spatial Information in Europe (INSPIRE)—A European Union directive to create a spatial data infrastructure that enables sharing geospatial data among European public-sector organizations and with the public
- Global Monitoring for Environment and Security (GMES)—A collaboration between the European Commission and the European Space Agency to establish a European capacity for earth observation from space and in situ that supports sustainable development and global governance
- Water Information System for Europe (WISE)—EEA and European Commission's Internet tool that informs citizens about water quality and EU water policy
- Ozone Web—EEA portal for near real-time ozone information
- Eye on Earth—EEA's two-way communication platform, which brings together scientific information with feedback and observations of millions of ordinary people via social networking sites
- Biodiversity Information System for Europe (BISE)—A Web portal for data and information on biodiversity in the European Union

Eye on Earth data for bathing water quality is mapped with ArcGIS. This map service has a high rate of access by vacationers during the summer. A blue color means the water is safe for swimming.

An advocate of cloud computing, EEA executive director Jacqueline McGlade noted, "Our community has a great appetite for all kinds

continued on page 2

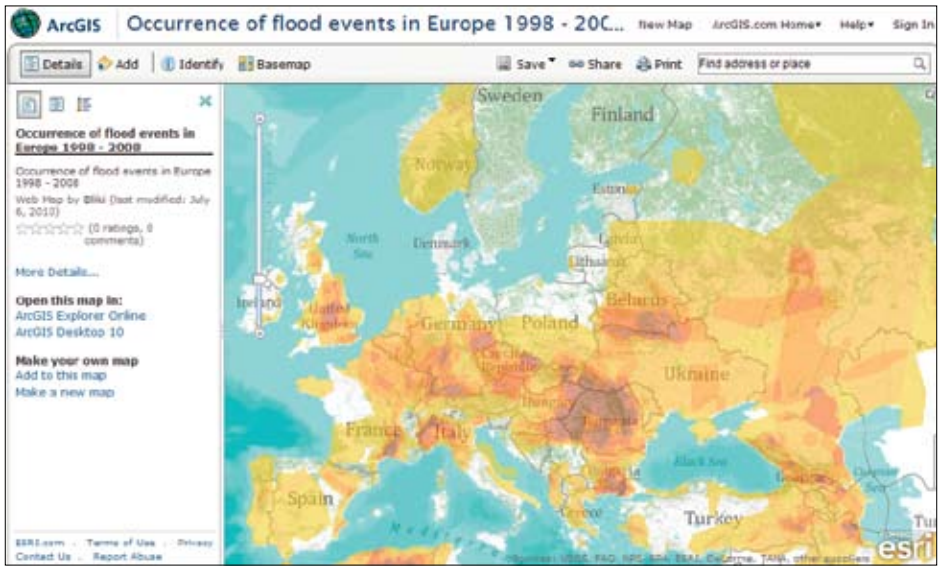
In This Issue

continued from cover

European Environmental Map Services Move to Cloud

of applications, and we can move these in and out of the cloud as needed. Every time we add a new service that has a transaction element, we see the access numbers go up and up. We have to accommodate the fact that the more information we put on the Web, the more people want to look at it. We anticipate that people want to do their own startups and their own applications out of the reference data that we are creating."

"We want our users to be able to access multiple layers, do their own mashups, and create their own applications," continued McGlade. "GIS technology is moving rapidly ahead. In our latest discussions with Esri, we talked about crowdsourcing and mashing possibilities and getting data into the working environment so that people in the field can use GIS for analysis. Esri's providing the way to make this happen."



A flood map of Europe for 1998–2008 was created by EEA using data from Dartmouth Flood Observatory and an ArcGIS Online world topo map.

Initially, the EEA's map service platform was built using ArcIMS for deploying 100 percent of its service's Internet mapping software functionality. Now, EEA's GIS team is migrating these map services to ArcGIS Server, a move that is improving the system's stability.

EEA's project officer of geospatial developments, Jan Bliki, gave a strong case for migrating from ArcIMS to ArcGIS Server. "ArcGIS Server is very stable," Bliki explained. "It allows us to isolate our services in a well-defined way. A poorly behaving map service won't bring down the rest of the infrastructure."

The GIS shop consists of three in-house staff and some GIS consultants. EEA has 100 map applications running over 65 map services. In the past, this was very difficult to manage, and the team often worried that the servers would go down when demand was high. After the migration to ArcGIS Server, the service had no crashes or other major problems. Bliki explained, "One day we had a huge peak of demand. In four hours, 35,000 visitors hit one map service. That is about two million map requests. The system worked through it without any problem. We could have easily withstood 50,000 visitors and been fine."

Esri is working with EEA to discuss and define environmental layers to enter into the community basemap. EEA receives huge amounts of data on a weekly basis. ArcGIS.com is an important piece of EEA's infrastructure. ArcGIS.com is a Web site for finding and sharing GIS content, organizing data into groups, and building communities. Site visitors can freely access ready-to-use projects and post their own projects and applications for community use. Community members can feed their data into a data template and post it on ArcGIS.com.

"We find that ArcGIS.com is a new way to promote map services and give nondevelopers mashup capabilities they never had before," Bliki said. "It is a place where our members and anybody else can share data and compare environmental messages with each other. The concept of map services as a product for the public rather than for developers is a new way of thinking. I believe it will totally change the reusability of our information."

Because ArcGIS Server is based on open geospatial and IT standards, EEA can serve data to anybody. "Most of the other GIS products don't provide that," noted Bliki. "We serve a full packet for open source, Google, Bing Maps, and Esri ArcGIS products. Once we set up the service, it is very easy to serve it to everybody." EEA SEIS users can consume data on Web browsers, mobile devices, and desktop systems.

"We have already moved most of our services from ArcIMS to ArcGIS Server," continued Bliki. "The applications were a bit harder to move over because we had to establish the best approach. Now that we have it set up, we can make map services available on the Internet in a few days rather than what used to be weeks."

The GIS team considers the whole design process to be faster and much more dynamic when it uses ArcGIS Server. "Previously, I had to ask a developer to help with high-level tasks," said Bliki. "Now I can divide these tasks more easily between cartographers, database managers, and developers and create very stable and reliable service products."

Many people use EEA's integrated spatial information system to access relevant themes and products. They can easily search and view data and download functions that help them with analysis and policy making. "EEA's Web site [discomap.eea.europa.eu] makes it possible for people to reuse our map services together with their own data," concluded Bliki. "We believe that the new approach of ArcGIS.com and map services seen as a product to everyone is going to change the international approach of serving environmental data."

Visit EEA's map service at eea.europa.eu. See the bathing water map at dataservice.eea.europa/map/BathingWater/.

For more information about this solution, contact Guenther Pichler, Esri (e-mail: gpichler@esri.com).

GIS-Enabled Brownfields Remediation

By Robin Smith, PhD, Esri Environmental Industry Manager

Urban life is dynamic. On any day, you can turn a corner in your town and see a business starting up, changing hands, or closing its doors. It is the urban cycle of life. Businesses that once caused your city to economically flourish eventually become a part of its urban blight problem. Then, somehow, some way, someone such as a city planner will get an idea, do an assessment, and get a grant award and other stakeholder funding so the city can remediate that blight area and turn it into a green space, an emerald necklace, a boardwalk, a tourist center, or a soccer field. A property that had become a health threat is remediated and sold anew, perhaps to a business that brings new jobs and revenue.

Brownfield remediation funding is available from the U.S. Environmental Protection Agency's (EPA) Brownfields and Land Revitalization program. The program offers local governments support through a variety of grants including those for area-wide planning pilot programs, revolving loans, cleanup, job training, training research, technical assistance, and targeted brownfields assessments. Each of these grants is described on the brownfields page on the EPA Web site at epa.gov.

You may well qualify for an EPA grant to kick-start your GIS brownfields project. Once your brownfields inventory is in place, you can once again use GIS to quickly access that data to apply for other grants.

GIS can help cities inventory, characterize, assess, and conduct planning for their brownfields management programs and get community and stakeholder involvement in the process. GIS helps you see on a map areas that need remediation and prioritize them in the context of environmental and health risk, available and/or required funding, property values, market potential, and other criteria you decide are important to assess. It can also help you pinpoint where to best place your resources for the best return. Furthermore, GIS can be used in the next steps of planning, implementation, job tracking, and goal completion. But even more promising is that GIS can help you continuously evolve and grow your urban planning and economic development strategies for the twenty-first century.

Your local government may already use ArcGIS, thereby allowing you to tap into its data and applications. This way, you can share applications and collaborate on projects. Use ArcGIS for brownfields management to visualize and analyze

- Location and status of brownfields
- Proximity to nearby businesses, residences, and transportation
- Area growth trends
- Vicinity's residence and business demographics
- Similarities of local neighbors and prospects spending
- Environmental remediation operations
- Zoning areas and projected restrictions
- Local real estate market values
- Return on investment potential
- What-if scenarios

We are presenting two brownfields-related GIS stories in the next section. To read other stories, go to esri.com/brownfields.

ESRI on the Road

Eye on Earth Consortium
November 2010
Abu Dhabi, United Arab Emirates
eyeonearthsummit.net

COP 16 United Nations Climate Change Conference
November 29–December 10, 2010
Cancun, Mexico
cc2010.mx

Esri Federal User Conference
January 19–21, 2011
Washington, D.C., USA
esri.com/feduc

National Council for Science and the Environment
11th National Conference
Our Changing Oceans
January 19–21, 2011
Washington, D.C., USA
ncseonline.org/conference/Oceans/

Esri Developer Summit
March 7–10, 2011
Palm Springs, California, USA
esri.com/devsummit

Esri International User Conference
July 11–15, 2011
San Diego, California, USA
esri.com/uc

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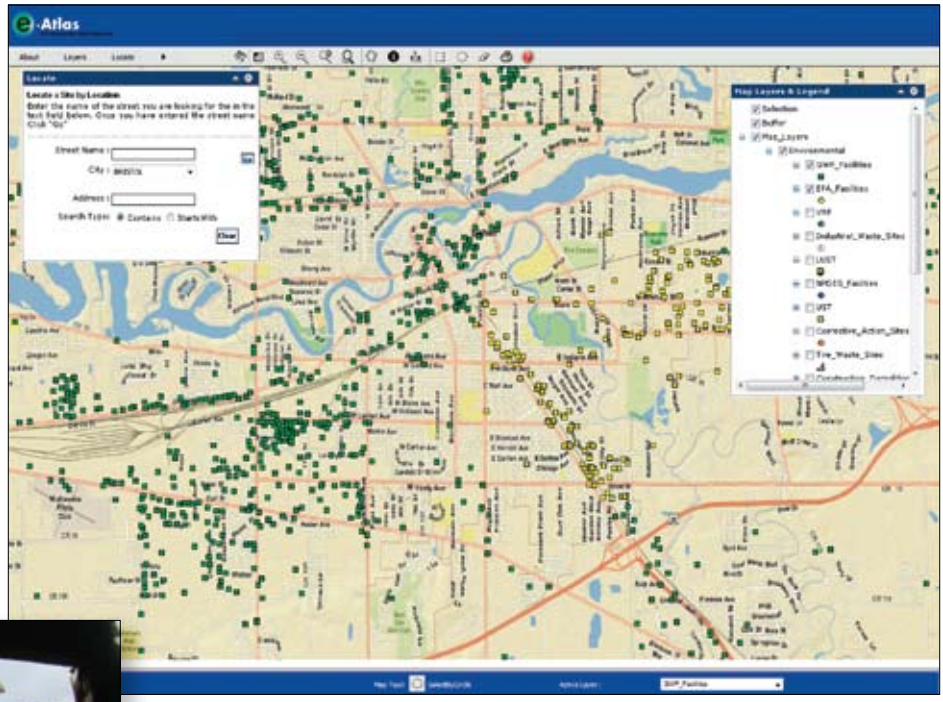
County's Brownfield Locations Available on Its Public Mapping Service

The County of Elkhart, Indiana, is using Esri's ArcGIS software to map brownfield sites, understand their histories, and rate their risk and impact to the environment. The Elkhart County Health Department invited Symbiont, a full-service engineering and consulting firm headquartered in West Allis, Wisconsin, to help expand its current database of environmental events and create a public Web site that allows citizens to search data, see it on a map, and understand their proximity to potential at-risk areas.



Elkhart's e-Atlas, built on ArcGIS Server, is a Web-based brownfield inventory tool that shows environmental concerns such as abandoned facilities, leaking underground storage tanks, and tire waste sites.

Data is key to a successful environmental management program. In 1989, Elkhart initiated the Groundwater Protection Ordinance program with the purpose of preventing contamination of its water resources from industrial chemical activity. The county built a paper-based database containing environmental concerns.

Discarded factories lower adjacent property values. They can also be toxic.

In 2006, the county sought to reduce urban sprawl by redeveloping its brownfields and other underused sites and existing infrastructure. It applied for an EPA brownfields assessment grant and was able to create a data management solution. Symbiont and Elkhart's GIS team designed a brownfields inventory. For the foundation of the inventory database, the task team used the existing county groundwater protection data. It contained property information of facilities involved with hazardous materials and environmental records of the most contaminated and neglected sites. The team continued to build the database to include an inventory scope of the past 20 years for 5,000 facilities.

The most important component of GIS is data. Converting a paper system to a computer data management system can be an arduous task. Faced with 44 file drawers filled with inspection records, correspondence, complaints, state and federal actions, and miscellaneous information, the team converted 200,000 pages of paper-based records to digital format. The conversion process involved determining an index structure for cataloging and digitizing records. These documents were integrated with GIS by geocoding the facilities by their addresses.

Another step in the conversion process was to put these digitized records in a document management system that was integrated with a Web-based system. The team used Esri's ArcGIS Server technology to create a Web application that combines the inventory information with GIS for mapping and analysis. This makes it possible for the user to view all the sites that could be potential brownfields. The user selects a site and is provided with links to records stored in the document management system for that facility. The application greatly improves the efficiency of researching and viewing data.

The value of a geodatabase for a brownfields analysis is the accumulation of attributes about geographic events such as natural geological events of slope, soil porosity, and hydrology, as well as human introduced events such as chemicals, industrial facilities, wells, and tanks. With a GIS, all of these environmental attributes can be visualized on a map.

The system conversion has improved the efficiency of Elkhart's Groundwater Protection Ordinance program because GIS generates a

GIS is useful for site remediation to see underground and aboveground tanks, stained soils, and other site hazards.

Properties designated as brownfields are ugly and dangerous and health threats to the community.

community-wide picture. Health Department staff can easily pull up data layers about current land use and community wells' proximity to brownfields to quickly see potential threats to water resources. Additionally, facility relocations and transitions can be managed to provide the appropriate inspection frequencies. Queries can be conducted determining the need for inspections by township or municipality, thus improving time management in the program.

Another value is the reduction in staff time spent locating documents and records. What once took hours of searching through files now takes seconds in the GIS. The user simply types in an address or selects a location on the map and receives in-depth information about that location. In addition, the user can run a query that brings up all similar sites or lay different data layers atop each other to easily view relationships. These capabilities set the foundation for putting GIS to work for a host of other county projects.

Building the project on Esri's ArcGIS allows the system to be scalable, flexible, integrated, and accessible. It has become a centralized resource for managing data and retrieving information. Users can rank and prioritize brownfield inventory sites throughout the county and see land-use history and environmental status. Elkhart County's brownfields inventory has the potential of becoming a repository of economic development opportunities.

"Working with ArcGIS Server, we were able to create an application out of the box," notes Ryan Eckdale-Dudley, GISP and Symbiont's GIS coordinator. "By using ArcGIS Server Manager, we were able to efficiently create an application that did not require complex programming. Updates to the application can be performed without the need for a software developer."

The team dubbed the model e-Atlas and is leveraging the data to expand to additional projects in the county. They integrate other datasets with the GIS e-Atlas, including Sanborn maps, tax information, spills not associated with industrial facilities, and planning and zoning overlays.

"Managing the information generated by the groundwater protection program, along with requests for information from the public, had become an increasingly time-consuming task," states John Hulewicz, Elkhart County's environmental health supervisor. "Our resources were stretched thin, and work performance was suffering. Field staff were spending more time in the office than conducting inspections. E-Atlas has refocused our ability to do the actual fieldwork and make more productive use of our time. I dreamed of the day this would happen, and thankfully it has!"

The local health department used e-Atlas to build the countywide What's in My Back Yard (WIMBY) program. This program provides online information via a GIS-enabled Web site that shows community brownfields as well as other community threats such as sexual offenders' residences and operational meth lab sites. This is a transparent government that gives citizens insight for intervention in their communities.

"GIS delivers accessible brownfields inventory that really helps our customers with their Environmental Protection Agency grant applications," concludes Eckdale-Dudley. "They can easily bring up information required for creating a case that qualifies them for project funding."

For more information, contact John Hulewicz, environmental health supervisor (e-mail: jhulewicz@elkhartcounty.com, telephone: 574-875-3391) or Ryan Eckdale-Dudley, GISP, GIS coordinator, Symbiont (e-mail: Ryan.dudley@symbiontonline.com, telephone: 414-755-1131).

Learn more about Esri's GIS solutions for brownfields management at esri.com/brownfields.

City Prioritizes Brownfield Redevelopment Spending

Seeking to revitalize its commercial corridors, the City of South Bend, Indiana, had set aside city funds for the job and procured an assessment grant from the U.S. Environmental Protection Agency's (EPA) Brownfields Program for a redevelopment study. As part of the EPA study, the city used GIS to create a brownfields inventory. The primary goals of the inventory project were to understand the distribution of brownfields within the city, identify the best properties on which to spend redevelopment funds, and create and maintain a database for future projects. The inventory has been useful in applying for additional EPA Brownfields and Land Revitalization program funding and for economic development planning.

South Bend's GIS department has been using Esri's ArcGIS software since 1999 to manage geographic data and generate maps for different city projects. "Various departments in the City of South Bend have embraced using GIS technology to enhance services provided to its citizens," explains Deb Kuehn, South Bend's GIS manager. "Examples are hot spot mapping of crime, tracking of basement flooding, showing utility inventory, and posting basic maps that support various city festivals and events. We have taken existing data housed by departments and put it into a standardized format and centralized repository where anyone within the city can find it."

Teaming with a consultant, Hull & Associates, Inc., city planners and the GIS department designated the commercial corridors they wanted to include in the project and began creating attribute categories about them for the database. The consultant identified assets and liabilities and, based on the city's criteria, ranked them by priority, thereby helping the city target remediation resources.

Managing and Seeing Data

Initially, the scope of the pilot study included 20,000 parcels for assessment. Today, the project has grown to include data for 46,000 parcels. The database contains ownership and tax information, parcel identification numbers, and zoning maps acquired from county records. Staff uses GIS to process data that represents real-world objects and dynamically links it to an on-screen map. When the data in the database changes, GIS updates the map to reflect these changes. This means South Bend's parcel and environmental data can be easily maintained and kept current for timely reporting.

In the early years of South Bend's GIS department, much of this information was still in paper form and had to be prepared for computer use. Now the city's database includes digitized data about utilities, zones, parcels, and so forth. Good data is essential for analysis, and the project team considered data quality, quantity, source, and completeness when compiling data from local and state government resources. The team also captures information at the site, which members verify and log into the geodatabase. A geodatabase is a collection of geographic datasets for use by ArcGIS.

Inventory, Classification, and Rank

The brownfields project database includes

GIS generated a parcel redevelopment ranking map that shows ranking and weighting factors for helping city planners prioritize parcels in need of remediation.

structural and environmental data. For example, underground storage tank locations and ownership had been previously recorded on a spreadsheet. The project team reused this data by adding it to the geodatabase and generating an underground tank data layer. Numerical environmental risk-level ratings of "High," "Moderate," or "Not an environmental issue" were applied to each tank location in the geodatabase. Once location information is added to the geodatabase, it is available for analysis. The user runs a query and visualizes the result on a map.

The project team uses various criteria for ranking parcels in need of remediation and weighting them for prioritizing remediation. If a property is attached to cross-referenced environmental data found in any of 16 government databases, such as the EPA's Resource Conservation and Recovery Act Information (RCRAInfo), the Comprehensive Environmental Response Compensation and Liability Information System (CERCLIS), and the National Response Centers' Spills and Accidents Database (previously called ERNS), it is ranked accordingly. Parcels attached to ecological concerns, such as wetlands with unique and endangered species, are factored into the ranking.

Additional considerations are classifications for surface water (flood zones, water quality), groundwater resources (potential resources, use wells, existing wells, land use), general industrial activities (foundries, machine shops), and pollution potential. Community support is essential. Therefore, community acceptance of redevelopment, community input on specific properties, city and county support of redevelopment, and existing owner and outside investor interest are also ranked and weighted. ArcGIS calculates these ranking and weighting factors and generates a parcel redevelopment ranking map that uses a color scale to highlight redevelopment needs.

Support for Economic Development and City Services

The site analysis has also been useful for developing city services such as adding a fire station. But South Bend also needs to attract business. Large businesses that are prospecting for franchise sites use GIS technology to consider a site's location value such as proximity to target markets, transportation, and commercial zoning. Because the city uses GIS, it can share data with these investors, thereby helping them make their decisions. Moreover, the city can support developers with their own efforts in applying for remediation project funds.

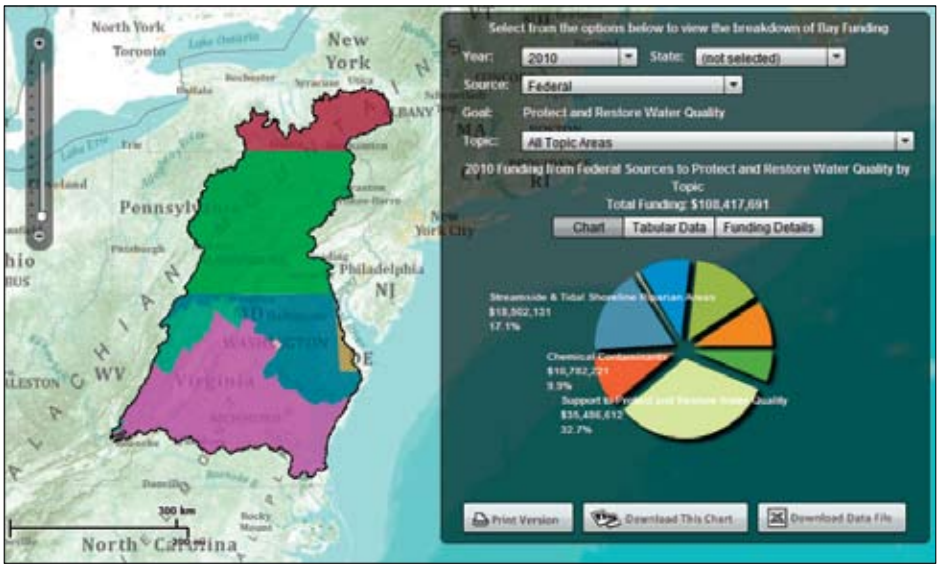
Read about other GIS brownfields projects and learn more about Esri's GIS solutions for brownfields management at esri.com/brownfields. Learn more about urban redevelopment with Hull & Associates, Inc., at hullinc.com.

Chesapeake Bay Restoration Made Transparent to Public

Esri and Chesapeake Bay Program Build Web-Based Accountability Tool

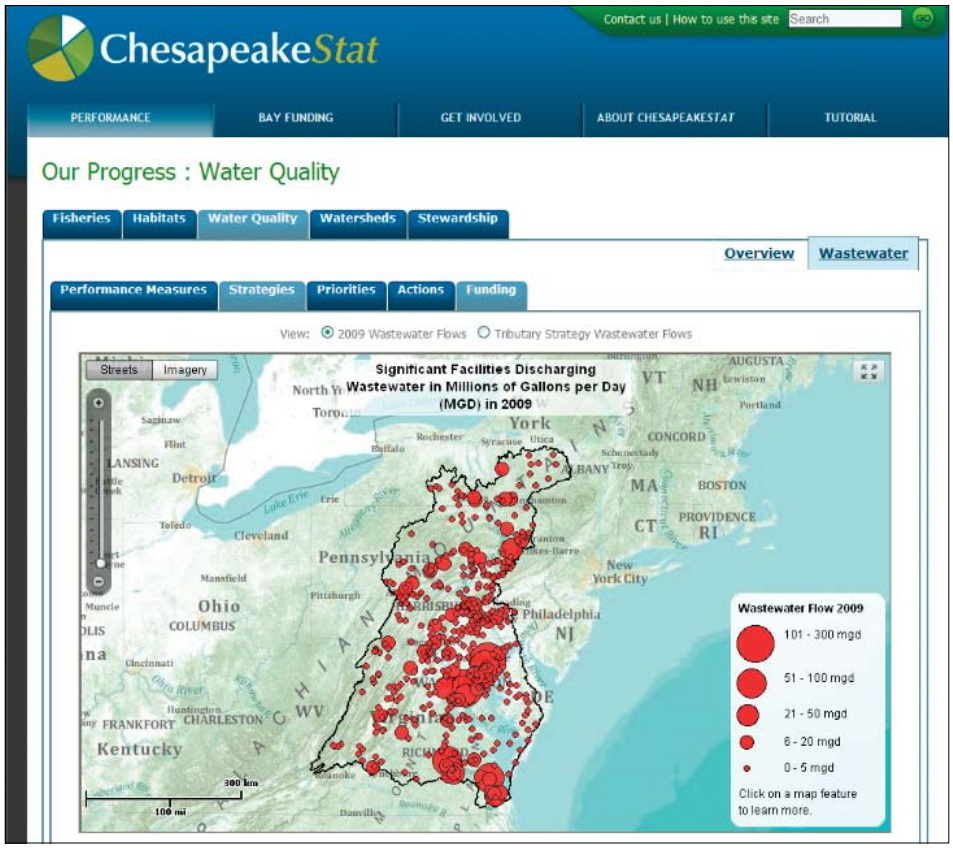
The Chesapeake Bay Program (CBP) team worked with Esri and others to build the online Web mapping application, known as ChesapeakeStat, that allows the public, Congress, restoration stakeholders, and project managers to follow the progress, status, and funding allocations of the bay's restoration program.

"ChesapeakeStat is a geoaccounting tool," explains John Wolf, U.S. Geological Survey (USGS) and GIS team leader of CBP. "Esri has been instrumental in developing the successful StateStat and BayStat models that were implemented under the leadership of Maryland's governor Martin O'Malley. It was a natural step to work with Esri staff in the design of our project, which takes it a step further. People can see in a geographic context how an agency's goals, strategies, and outcomes are being accomplished."



ChesapeakeStat shows the breakdown of federal funding for restoration of riparian areas, remediation of chemically contaminated areas, and the protection and restoration of water quality.

ChesapeakeStat is built, in part, on Esri's ArcGIS Server and the ArcGIS API for Flex. This makes it easy for site visitors to zoom in to an area and locate restoration activities, then drill down into smaller watershed units to see what is happening in a specific area. The Web site is the first one-stop GIS project to improve accountability for all partners in this restoration effort. Eventually, the public will be privy to all bay and watershed restoration activities, funding levels, and progress toward goals.



GIS applications give ChesapeakeStat users insight into pollutant and remediation activities. A wastewater application built with the ArcGIS API for Flex accesses and displays wastewater discharge data.

ChesapeakeStat's design is closely related to the CBP Strategic Framework; describes how federal, state, and other partner funding will be used during each fiscal year; and includes a database of project information. GIS has made this database user-friendly so the public can visualize the information geographically. ChesapeakeStat organizes information around the CBP goal areas of sustainable fisheries, healthy habitats, water quality, healthy watersheds, and Chesapeake stewardship. Each category contains a suite of environmental and performance indicators.

The ChesapeakeStat tool supports an adaptive management approach, which is CBP's management strategy that encompasses setting goals, defining strategies, setting priorities, taking actions, monitoring results, and making management adjustments. This means that beginning from the overall goal level, users will

ultimately be able to drill into detailed scientific data and analysis that supports decision making.

CBP's goals and strategies are included in the design of the Web site dashboards that interactively present performance and environmental information organized by strategic topics. The database includes management activities for conservation and restoration throughout the watershed and in the estuary. The ChesapeakeStat application accesses a geodatabase that contains the spatial and tabular information that is visualized on the Web site. Content is organized by operational stages of measuring progress, taking action, and developing priority areas for targeting activities.

Community members can share photos on the Web site such as this one (above) of an osprey on the Chesapeake in Jug Bay, Maryland. Photos are accessible from the map.

Topic-based navigation includes five major program areas that relate directly to the business goals of CBP:

1. Sustainable Fisheries (crabs, oysters, striped bass, etc.)
2. Healthy Habitats (fish passages, bay grasses, wetlands)
3. Water Quality (wastewater treatment, agriculture, storm water)
4. Healthy Watersheds (land conservation and protection)
5. Chesapeake Stewardship (public access, environmental education, citizen and community action)

Starting at these program areas, users can drill into the level of detail they need to see. These CBP business goals are categorized in the application. For example, a resource manager can select the Water Quality goal category, select the topic Wastewater, and quickly understand the collective issues and initiatives dealing with this topic throughout the partnership.

A Performance Measure tab leads to a tool that allows the user to see how well restoration efforts are meeting the goals set by the CBP partnership. A goal may be a stated level in terms of nitrogen or phosphorus pollutant load reductions achieved basinwide. In many cases, goals are attached to geography. In the future, the user will be able to drill into a geographic area on the map to get a more comprehensive understanding of pollution source sectors. The user will be able to access one indicator measure for the entire bay area, such as dissolved oxygen, then compare this same indicator among other watersheds. For a single watershed, the user can explore different pollution indicators for that particular geographic area.

The ArcGIS Server capabilities of ChesapeakeStat support scale dependency. As one drills into a selection, the accompanying map interface changes relative to the user-selected topic. For example, by selecting the Strategies tab, a user can see nitrogen pollution from wastewater sources throughout the bay watershed. Facilities that contribute more nitrogen to nearby receiving waters are shown with a larger symbol, regardless of the map scale selected.

A Priorities tab opens up a map that shows priorities for several programs focused on pollution reduction. An Actions tab opens a page that shows activities associated with each of the jurisdictions' progress in reaching short-term interim goals, or two-year milestones.

Finally, a Funding tab accesses information about the financial investments the partners are making to control pollution from various sources. The funding information can be sorted by year, state, source, goal, and topic.

ChesapeakeStat accesses other systems for data and information through Web services. For instance, CBP is leveraging the Environmental Protection Agency's (EPA) Enforcement and Compliance History Online (ECHO) data to tell the wastewater facilities story. In the future, ChesapeakeStat will be pulling data directly from Maryland's BayStat as well as other partner data resources.

Chesapeake Bay recovery prospects are not hopeless. Regulation, enforcement, best management practice implementation, education, citizen engagement, and a watchful eye can bring the estuary back to the state it was in 50 years ago.

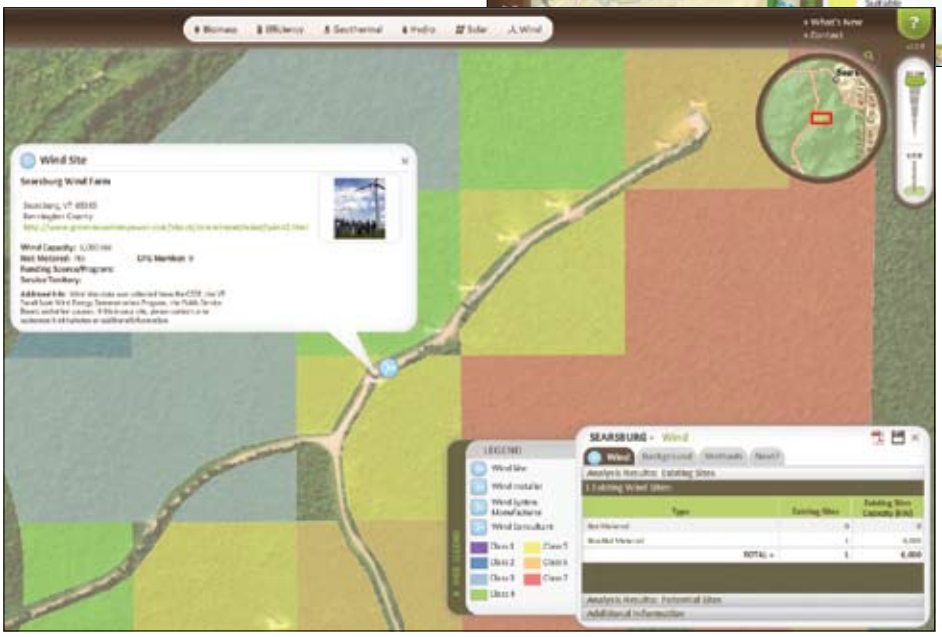
Read more about Esri's solutions for environmental management at esri.com/environment. Access the ChesapeakeStat tool from the Chesapeake Bay Program Web site at stat.chesapeakebay.net/.

Is Renewable Energy Doable Energy?

People from Vermont take pride in their state's scenic beauty and the heritage of their forests, rivers, and small towns. A grassroots response to the pressing need to cut energy costs, foster renewable energy generation, and lessen the state's contribution to global warming is emerging. Of Vermont's 255 towns, more than 100 now have energy committees.

Vermonters want to know where renewable resources exist and what they can do to use them. A new interactive Web site, the Renewable Energy Atlas of Vermont, makes it possible for every Vermont town and county to identify, visualize, and analyze data about existing and promising renewable energy opportunities using GIS.

An energy map shows an area's potential for biodiesel feedstocks. The application includes an analysis results panel.



Vermont Renewable Energy Web site users can select the energy type wind and see the current location of a wind farm and its kilowatt capacity.

Built on Esri's ArcGIS technology, the Renewable Energy Atlas of Vermont makes it possible for people to access data about biomass, efficiency, geothermal, hydroelectric, solar, and wind energy and use GIS to view existing sites and potential projects by area. Since its launch in April 2010, the site has received thousands of hits. Vermonters are using it as a reference for mounting thermal solar units on their homes. Other states are also taking note of the site. The Alaska Energy Authority is highly interested in building a similar tool.

The Renewable Energy Atlas was initiated by Vermont Sustainable Jobs Fund (VSJF), a nonprofit organization created by Vermont's legislature to accelerate the development of the state's green economy. VSJF provides early-stage grant funding and technical assistance to develop markets for sustainably produced goods and services such as renewable energy and local food systems.

"Energy is the key variable for transitioning toward sustainability," explained Scott Sawyer, research, evaluation, and communications coordinator at VSJF. "We were looking for a way to show Vermonters how to move away from nonrenewable energy by relocalizing renewable energy production. Site visitors can zoom in to a town or subtown level and look at the community's renewable energy and efficiency possibilities. Our goal was to make the Web site easy and fun. Robust GIS technology, tons of data, engaging design, and easy-to-use applications made this possible."

Visitors to the Renewable Energy Atlas site begin their research by selecting an area and an energy option. A biodiesel selection, for example, displays three subcategories: oilseed crops, waste vegetable oil, and potential algae-to-biodiesel locations. By selecting the waste vegetable oil category, the user can see the locations of all the restaurants that generate waste vegetable oil. The oilseed crops category shows agricultural soils suitable for growing oilseed crops. An analysis results panel then shows the energy potential such as the number of gallons of biodiesel fuel an acre of sunflowers could produce. With the solar photovoltaic (PV) option,

for instance, incoming solar radiation is modeled for nearly every building in the state. End users can then modify information about their specific site (e.g., PV system size, roof pitch) to arrive at an estimate of annual electricity output.

Collecting, organizing, and analyzing data and developing the Web interface for this project was a sizeable undertaking and took nearly two years from initial conceptualization to final Web site. For this, VSJF worked with the Vermont Center for Geographic Information (VCGI), which manages the Vermont Geographic Information System (VGIS) using Esri technology. During the past 25 years, VCGI has been operating the VGIS clearinghouse, developing statewide geographic base layers and providing GIS services to state agencies and local government.

Mike Brouillette, one of VCGI's senior GIS project managers, worked with VSJF to compile, model, and analyze the GIS data necessary for the project. "The overall objective was to build intelligence into the modeling process for each renewable energy layer that reflects the best overall public good for each resource site," he said. "Datasets for the major renewable energy options—biomass, efficiency, geothermal, hydroelectric, solar, and wind—were further broken down into multiple categories of data for specific renewable energy analysis. For example, the biomass option includes data for biodiesel, perennial grasses (for grass pellets), methane digesters, waste to energy, and woody biomass." VCGI worked with a wide range of experts in Vermont to identify and modify existing datasets, model new ones, and develop a methodology for each energy layer.

Once developed, these layers were further processed through a suitability framework for assessing the raw renewable energy resource based on practical considerations from the fields of conservation, ecology, natural resources, and recreational activities. This framework involves both masked (screened-out) areas unsuitable for development (rare and threatened species habitat or areas abutting rivers, lakes, and wetlands) and assigned rankings or relative suitability values to the remaining areas. These values can reflect the volume or quality of the raw resource, as well as societal values regarding the natural resource in question.

To build the functionality of the Renewable Energy Atlas, VSJF contracted with Fountains Spatial, a leading provider of GIS services including application architecture design and development, data design, training, and hosting. Fountains designed a leading edge, service-oriented ArcGIS Server software-based architecture that included ArcGIS Online services and the Esri Flex API for interface development.

"VSJF had some pretty high standards for this Web site," explained Fountains Spatial's Peter McAlenney, who managed the programming and interface design for the project. "It wanted the site to stand out and have a unique look and feel that breaks away from standard Web mapping applications. We raised the bar and, in so doing, faced challenges in building the look and feel of the user interface."

"For this application, we provided the capability to analyze, to varying degrees, more than 20 different renewable energy types," McAlenney said. "First we looked at the approach used by the very popular Boston Solar Web site. This application provided a simple yet powerful focused look into solar potential in the Boston area. We liked this approach and used it as inspiration and guidance for designing our solar process and the other renewable energy applications. Because each of the various energy types is unique, we needed to provide a wide range of interfaces for summarizing and displaying results. A wind power analysis is quite different than an evaluation of potential production of biodiesel from canola seeds. Designing these interfaces was one of the great challenges to developing the Renewable Energy Atlas."

In the project design methodology, Fountains Spatial documented analysis workflows from start to finish as well as key business logic. Its team created ArcGIS Server map (cartographic) and geoprocessing (analysis) services that consume the geodatabase provided by VCGI. Basemaps were mashed up from ArcGIS Online. ArcGIS Online is a common platform where ArcGIS users can directly connect to maps, layers, tasks, and tools published by Esri and other ArcGIS users.

The team used ArcGIS Desktop to author these maps and create the geoprocessing tools for performing tasks, such as running calculations, then published these via ArcGIS Server. The client front end and related business logic were implemented using the Flex API in Flex Builder. The design team added video tutorials to the site's help system and a content management system-driven information clearinghouse so users can access additional information such as photos and text.

"Esri's service-oriented architecture, including ArcGIS Server and ArcGIS Online, is fantastic," said Mark Haberle, senior project manager at Fountains Spatial. "It has provided us with the ability to consume massive amounts of free data and advanced services from ArcGIS Online. The system architecture allowed us to then layer our own raster and vector data over these map services. In turn, these were then mashed together with ArcGIS Online geocoding and locally published geoprocessing services, providing deep cartographic and analysis capabilities. Finally, these services, coupled with the rich Flex API, made it possible for us to build engaging, interactive, and powerful analysis tools. The Flex API also allowed creative, forward-thinking interface design to make the Web site easy to use and provide a unique brand. Using the Esri suite of technologies made this process seamless. Specifically, ArcGIS Online has been very efficient for us. We did not need to build any kind of basemap or geocoding services. You can't beat that."

"Our hope is that the atlas will assist town energy committees, funders, educators, planners, policy makers, and businesses in making informed decisions about renewable energies in their communities," said Sawyer. "These decisions will ultimately lead to successful projects, greater energy security, a cleaner and healthier environment, and better quality of life across the state."

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