hydro line

Esri • Winter 2011/2012

GIS for Water Resources

Geodesign Improves Water and Land-Use Planning

By Gustavo Arciniegas, PhD, Researcher, Institute for Environmental Studies, VU University Amsterdam

Editor's Note: Planners apply the geodesign process to optimize their land-use plan. Geodesign methodology employs technology that shows users, during the design stage, the impact a given action could have on people and nature. Planners can see how various what-if scenarios play out in meeting design objectives as well as how they will impact the whole scheme of resource management of biodiversity, the landscape, human need, and future resources. By bringing geographic information system (GIS) technology into the geodesign process, land-use plans more closely follow a watershed's natural systems to benefit people and the environment.

The Dutch are familiar with polders—low tracts of land typically enclosed by dikes—and their characteristic hydrologic and land-use challenges. The Bodegraven polder, located in the province of South Holland, is a low-lying peat meadow area of some 4,672 hectares in the Netherlands, where water tables are controlled to enable multiple land uses. Although the Bodegraven polder has been predominantly used for commercial dairy farming, it is also important for its natural, cultural, and historical value.

Current land use within the Bodegraven polder is not sustainable because it negatively impacts ground subsidence, peat meadow landscape, water management, water quality, and the economics of dairy farming. Stakeholders wanted a new land-use plan.

The project study area is the Bodegraven polder, located in the province of South Holland in the Netherlands (photo copyright Frank Stroeken from Terra Incognita).

In This Issue

These stakeholders included the local water board, the City of Bodegraven, the Province of South Holland, farmers' organizations, and nature conservation organizations, as well as individual farmers, residents, and recreational visitors. They had conflicting objectives. The solution called for a geodesign approach that considered their needs and helped them reach a consensus.

The provincial authorities began a planning process to review and adjust both water management practices and land uses in the area. The Spatial Analysis and Decision Support Department of the Institute of Environmental Studies provided a project team that worked with stakeholders to develop and test participatory tools to support integrated land-use planning and water management.

The project team structured the planning process for the Bodegraven polder into three geodesign workshops for stakeholders: design, analysis, and negotiation. In the design workshop, the team defined three reference plan alternatives, stakeholder objectives, and evaluation criteria. For scenario planning, the team used ArcGIS and CommunityViz, an ArcGIS extension, extensively during the analysis and negotiation workshops to visualize maps and scenarios.

During the analysis workshop, team members used a touch table that interfaced with GIS to present thematic maps about the region. They also set up a separate screen to

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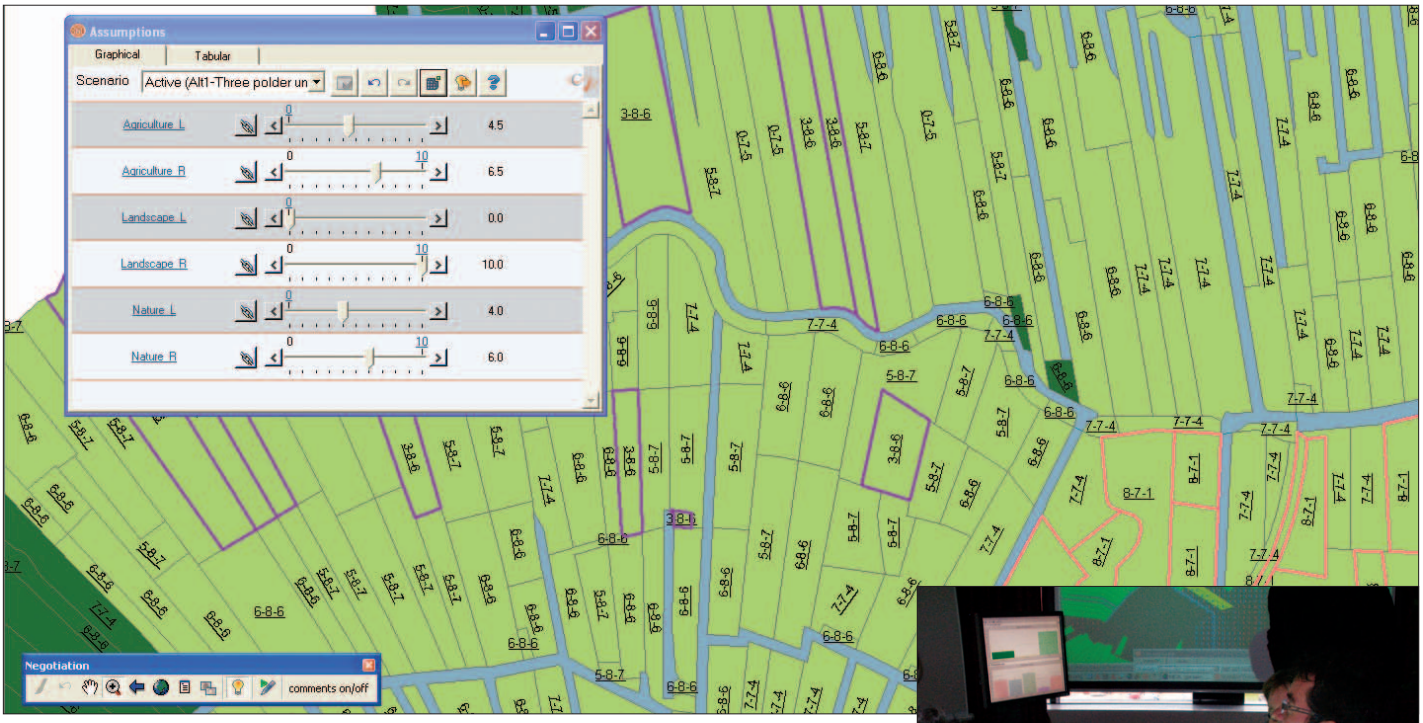
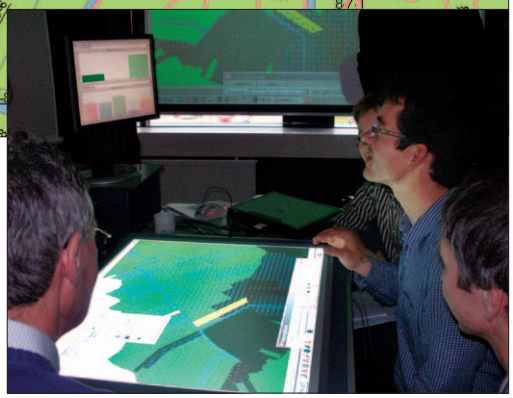


During the planning stage, a scenario tool enables stakeholders to change criteria values using slide bars and see the change on a map.



Stakeholders use tools on a GIS-enabled touch table to discuss land-use possibilities.

show additional information, charts, and tables. Next, the team used CommunityViz Scenario 360 to create scenarios. Each scenario consisted of a polygon-based suitability map in which the weights of each criterion were set according to participants' values. Participants could change the weights interactively using the touch table to adjust assumption settings in the software.

As the weights were changed, the results were dynamically updated and presented both on the touch table as a map and on the separate screen as a bar chart showing aggregated scores for various criteria and objectives the participants had established. A set of weights and the corresponding set of value maps constituted the main product of this phase.

To support negotiation, the project team used a multiple criteria method to show trade-offs among stakeholder objectives. Stakeholders adjusted qualitative and quantitative trade-offs. Qualitative trade-offs were identified by selecting polygons that were "very suitable" or "very unsuitable" for each potential land-use type based on their summed area and ranked criteria analysis (RCA) values. Quantitative trade-offs were identified by selecting polygons that would profit from a land-use change based on MCA value.

GIS graphs scenario outcomes.

Using the GIS-enabled touch table, participants identified quantitative trade-offs by selecting polygons and using sketch tools to change land-use patterns and discuss them. A land-use palette allowed participants to assign different land uses to target parcels. Once participants agreed on land-use changes, MCA value changes were instantly updated and displayed as bar charts on the separate screen.

Ton Verdoorn, project manager, province of South Holland, said, "The combination of GIS and planning tools made it possible to quickly and clearly see both spatial and numerical consequences of changing variables on the map."

The workshop facilitated discussion and collaboration in devising a plan for changing the current land-use pattern of the polder that met shareholders' needs. This project ran for four years, from 2006 to 2010, and ended with a positive result that satisfied all the project stakeholders. The combined use of GIS mapping and scenario planning tools allowed the team to bring expert knowledge and stakeholder perspectives to the land-use decision process.

For more information, contact Gustavo Arciniegas, PhD, researcher, Institute for Environmental Studies, VU University Amsterdam (e-mail: Gustavo.Arciniegas@ivm.vu.nl).

Water Sampling in a Rain Forest

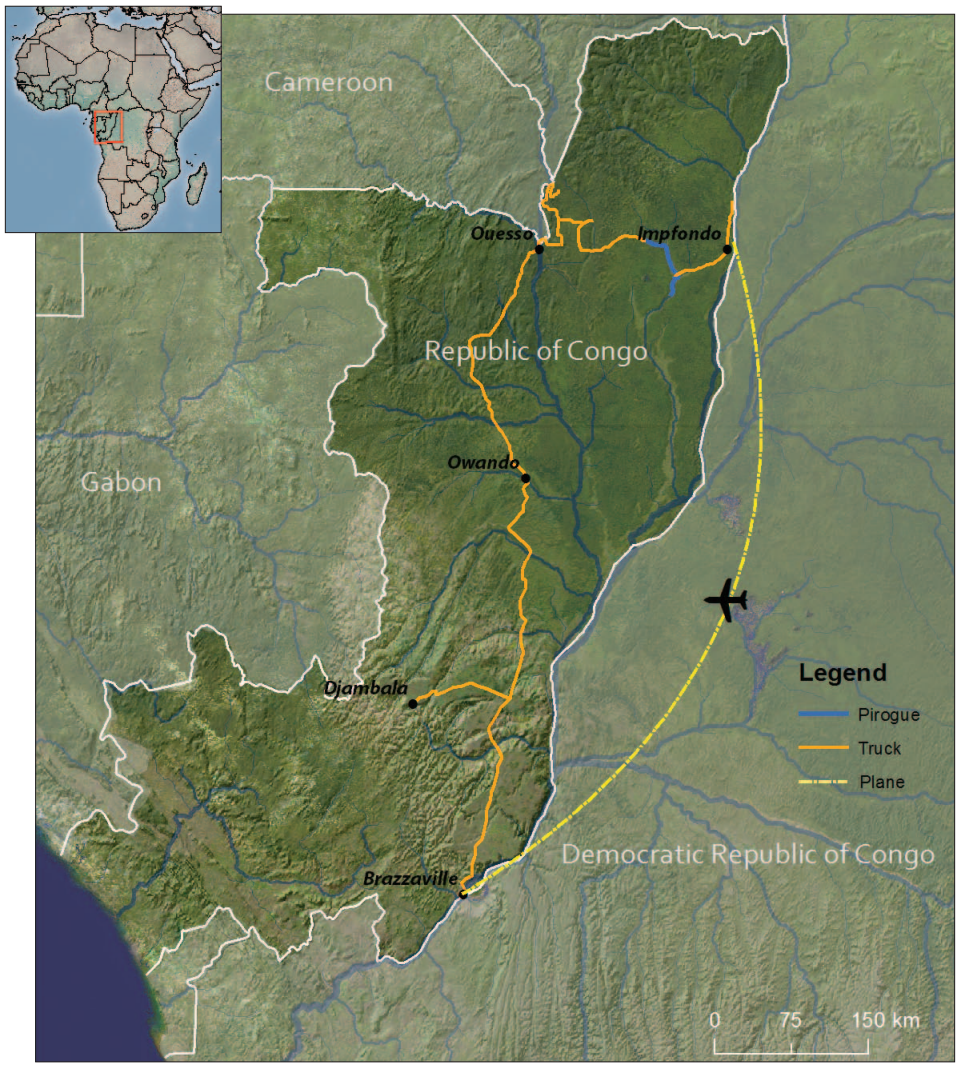
By Barbara Shields, Esri Writer

Scientists from the Woods Hole Research Center (WHRC) embarked on an expedition to collect water data from the Congo River Basin, the world's second-largest river system and one of utmost importance for understanding the global carbon budget. Greg Fiske, WHRC's GIS manager and researcher, was part of the team. He was there, armed with vast quantities of spatial data, to ensure that the team stayed on the route during the expedition and to contribute to the sampling goals.

Supported by the National Science Foundation, the project, known as the Global Rivers Project, is a collaboration of several institutions around the world and focuses on six globally significant river systems: the Congo, Yangtze, Brahmaputra, Ganges, Kolyma, and Fraser. Fiske contributes his GIS skill and expertise to work with a selection of scientists, including geologists, geochemists, hydrologists, engineers, and remote-sensing experts, to explore the relationship between river chemistry and large-scale land-cover characteristics.

Within the Republic of Congo, the team traveled by four-wheel-drive truck on a southwest–northeast transect, covering 1,400 kilometers (roughly the distance from Massachusetts to North Carolina) through rough terrain, poor roads, insects, and days of soggy weather countered by days of stifling heat. November is the rainy season in the Congo, which was the main reason the trip was planned for that time. High-flowing rivers and wetlands at their peak created an ideal contrast between the sampled water chemistry from this trip and that from previous excursions taken in the dry season.

One of the key measurements was dissolved organic carbon (DOC), which is a generalized term for those organic components dissolved in marine and freshwater ecosystems. It is a key indicator of land disturbance and land-cover changes worldwide. As a doctor may take a sample of your blood to divulge information about the health and well-being of your internal systems, so too can scientists characterize the conditions of the land within a watershed by taking detailed chemical samples of rivers and streams. And DOC isn't alone. Scientists have an elaborate quiver of water chemical metrics that may define land-related changes within our world's major watersheds. In addition to DOC, water samples were analyzed for a variety of other constituents including dissolved and particulate forms of nitrogen and phosphorus, as well as temperature, salinity, pH, and a selection of dissolved gases.



The Global Rivers Project Congo expedition trekked more than 1,400 kilometers through rough terrain.

As with any statistical modeling, diversity is important in the sample set. GIS was used to find easily accessible major waterways where the areas of contribution (upstream watershed) covered the most diverse set of land-cover types available in the Republic of Congo. Latitude-longitude coordinates for each sample point were captured using a Garmin GPS and mapped regularly.

The Congo River Basin has the largest swamp forest in the world. It is where the team spent the majority of time collecting data. Team members traversed these forests in a pirogue (wooden dugout canoe), sampling water along the way. Despite the hardship of the journey, they were happy to encounter a variety of land-cover types: grasslands and croplands in the south; sparse forest areas in the nation's midsection; dense humid forests in the north; and, finally, swamp forests in the northeastern area of the country.

The team's goal was to collect data on each land-cover type in the basin as well as samples from tributaries feeding those areas. In prepa-

continued on page 4

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Water Sampling in a Rain Forest

ration for the trip, Fiske loaded spatial data onto his laptop, which the team used for indicating specific land-cover types that were important to analysis. He also created some GIS scripts to assess the upstream area and produce a selection of land-cover metrics within that area based on key remotely sensed GIS layers.

At the end of each day, Fiske uploaded the geocoded water sample data to his laptop running Esri's ArcGIS software. He overlaid water sample and land-cover type attributes on the remote-sensing data so the team could immediately see the results of its work and affirm that it was in the appropriate location. GIS brought together, on the fly, the sample points/locations and the spatial data. GIS displayed an area's tree cover, its biomass/carbon, high-resolution natural color imagery, and more. For the Congo area, important data layers include the percentage of swamp forest and seasonal inundation. (Other watersheds around the world may need different GIS data layers.)

Over the side of a pirogue, researchers collect water samples in the swamp forest.

Fiske also made good use of the ArcGIS Hydrology toolbox for a lot of the work on the project. This made work in the field easier. Between these tools and the custom scripts, at the river's edge, the team could click a button and query the GIS about the size of the upstream contributing area or the percentage of tree cover or other key land-cover types.

The challenge that made mapping difficult, and sometimes made fieldwork impossible, was the intense rain and the river waters. Fiske and other members of the team were constantly concerned about dropping gear into the river or losing it to the water in the bottom of a flooded pirogue. Sensitive gear was protected in waterproof bags and Pelican hard cases. Data was backed up on a USB-powered Passport external hard drive that was well secured in a watertight case.

The team had other duties besides data collection. As part of the National Science Foundation grant, some project funding is designated for outreach and education. The team visited schools in two communities in the Congo River Basin on this trip and distributed art supplies to the students. The children were asked to put pen to paper and describe, through art, the importance of their local river. Their pictures and drawings will become part of the My River, My Home exhibition, joining nearly 100 other pieces from students in Siberia and Canada. The exhibition will travel to galleries, and a virtual collection will be posted on the WHRC website.

In addition, the team worked with local people and trained them to collect water samples and metrics. This would allow the scientists to retrieve critical time-series information on the tributaries of the Congo. Because WHRC staff and partners worked with local students, teachers, and community leaders who live in the towns and villages within watersheds, they built partnerships for sustainable solutions.

Upon returning to the United States, the team provided data and samples to associates who would use them to further study the attributes and relationships within the basin. Collectively, the members hope to reveal just how important dissolved organics and other key elements can be in detecting the impacts humans have on the land of the Congo River Basin. Their findings will provide the basis for understanding the health of a watershed and directing future watershed management.

Fiske is currently the GIS adviser for the Global Rivers Project. Using tools such as Esri's cloud map service ArcGIS.com, he has been able to share data with others and distribute commonly used base layers. He chose the Esri service because it is free and user-friendly, so even those with no GIS experience can use it. He posts project-wide base layers, such as stream networks, sample locations, and watershed boundaries, on ArcGIS Online so that scientists and others can download maps and data directly into their own GIS projects. It is essential that the various river projects all use the same version of these layers. ArcGIS.com is also used to make maps of sample locations and other important layers that are shared among colleagues.

Fiske and others are also designing spatial models to show correlations of certain land-cover types and water chemistry variables in hopes of being able to extrapolate the rules defined by the Congo analysis to other portions of tropical Africa—places that would be much more difficult to go to and physically sample.

Expedition member Paul Mann greets students at a local school and talks to them about their river.

Map Rallies Support for Open Space Initiative

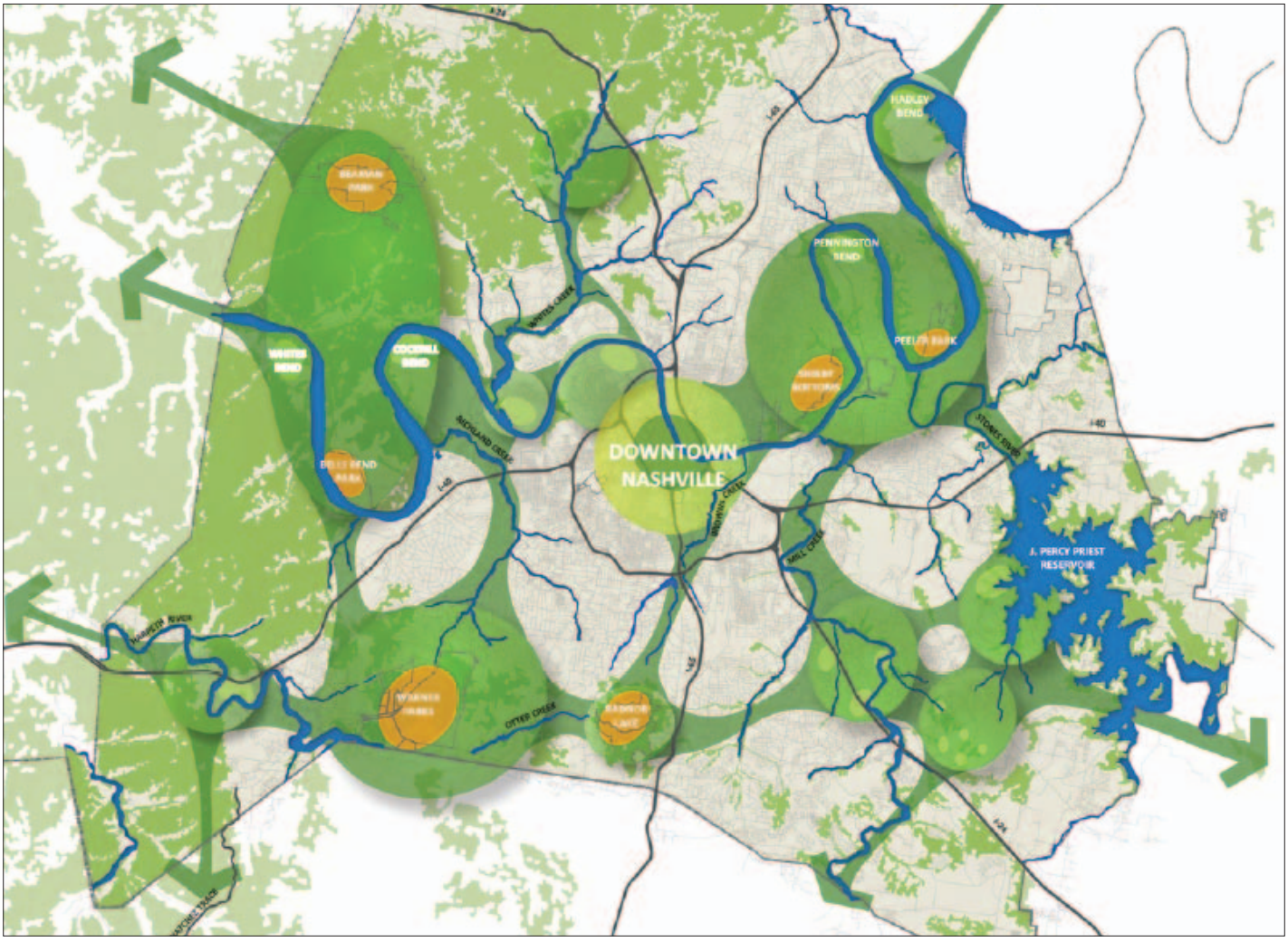
Proposed Green Infrastructure to Connect Community, Forests, Land, and Water

Nashville, Tennessee, experienced a major flood in May 2010. The public needed to understand the value of natural systems and regulated floodways, floodplains, open water, and the Mill Creek watershed as well as how conservation opportunities could mitigate future flood hazards.

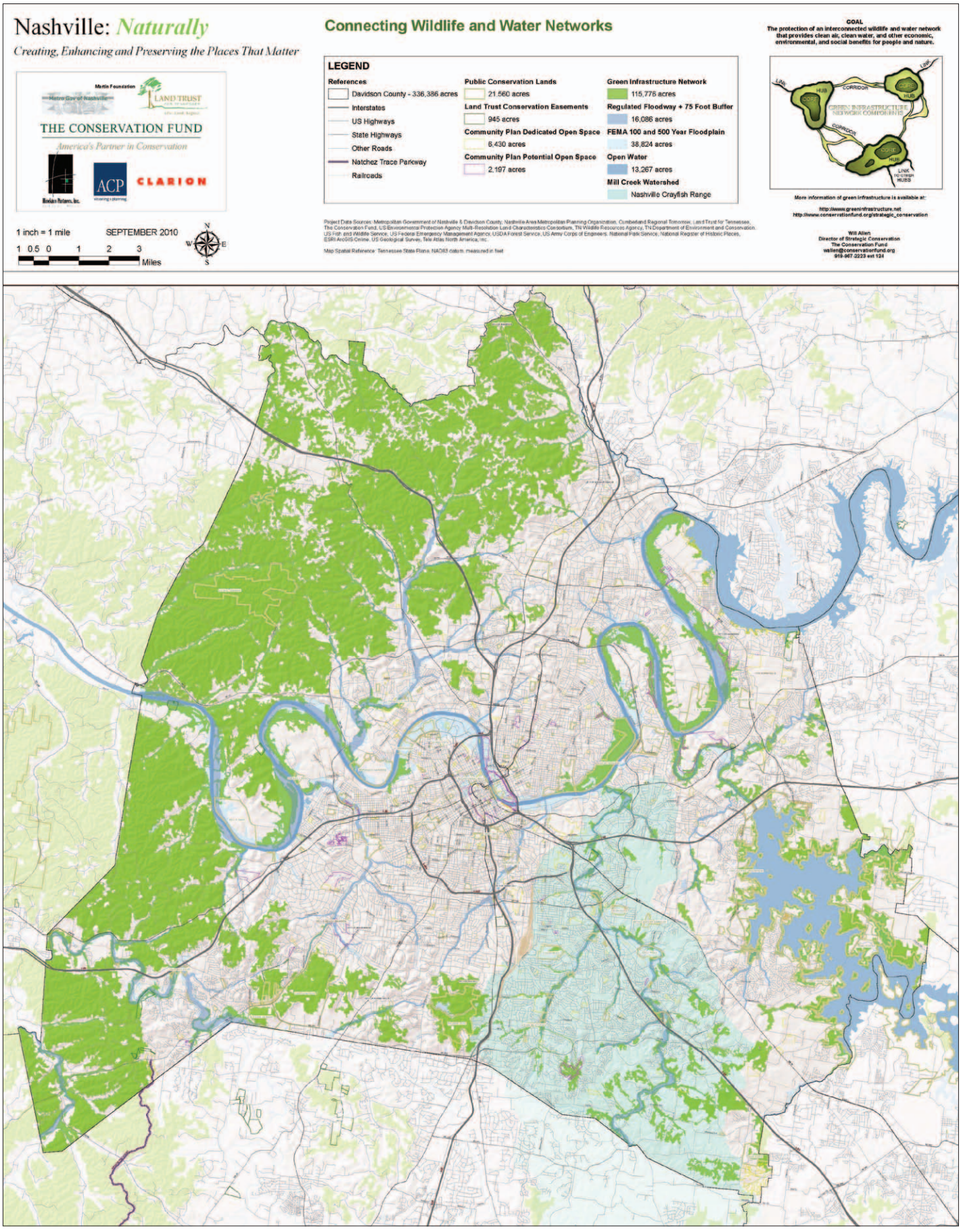
Nashville-Davidson County citizens worked with Nashville: Naturally to set resource priorities and identify four key themes to be included in an open space plan: water and wildlife networks, recreation, farming, and historic/iconic concerns.

Map designers created a green infrastructure network GIS layer for representing an interconnected network of land and water areas that are needed for clean air; clean water; and other economic, environmental, and social benefits for people and nature. These areas were designated as the most suitable for protection. To show the connection of water and wildlife networks, designers used ArcGIS to model how hubs and core forests, wetlands, and aquatic systems are linked by corridors. The map combines data from more than a dozen disparate sources and creates inventories of existing open space, flood-sensitive areas, and the green infrastructure network. Mapmakers highlighted Davidson County within the context of surrounding landscape by using the ArcGIS Online shaded relief map service and adding transparency to the green infrastructure network layer. Applying a transparency mask outside the Davidson County boundary served to lighten but not remove the areas outside the county.

More information on the green infrastructure network design approach is available at www.greeninfrastructure.net.



The Open Space Vision for Floodwater Management



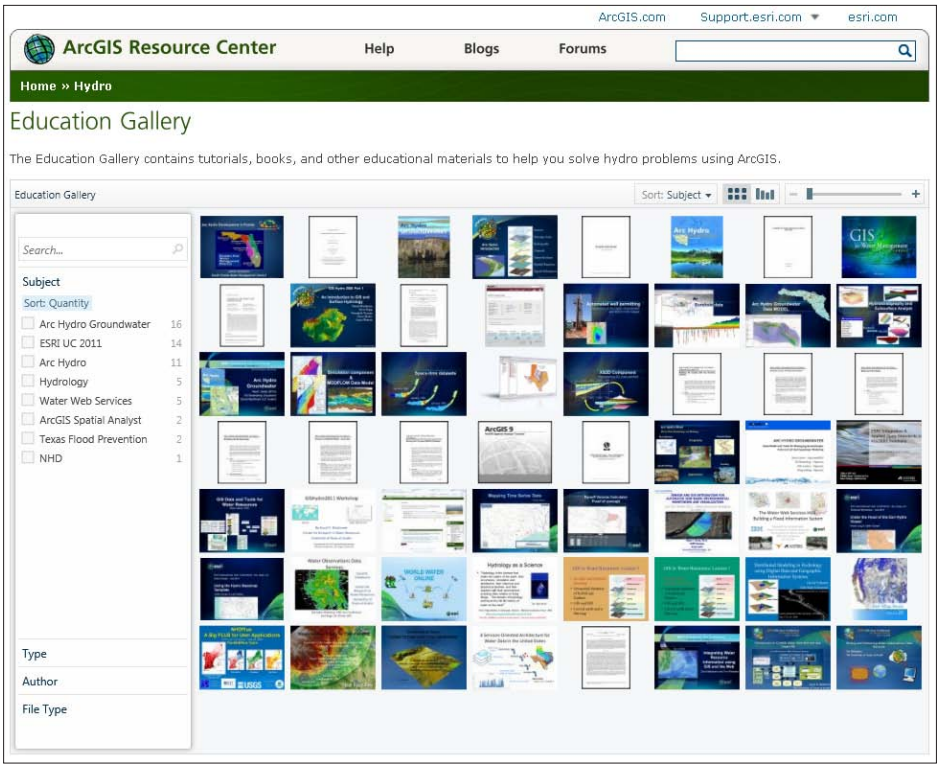
Map by Will Allen and Jazmin Varela, the Conservation Fund, Chapel Hill, North Carolina, USA

GIS Hydro Resources Are Online

By Caitlin Scopel, Esri Mapping Center Team Member

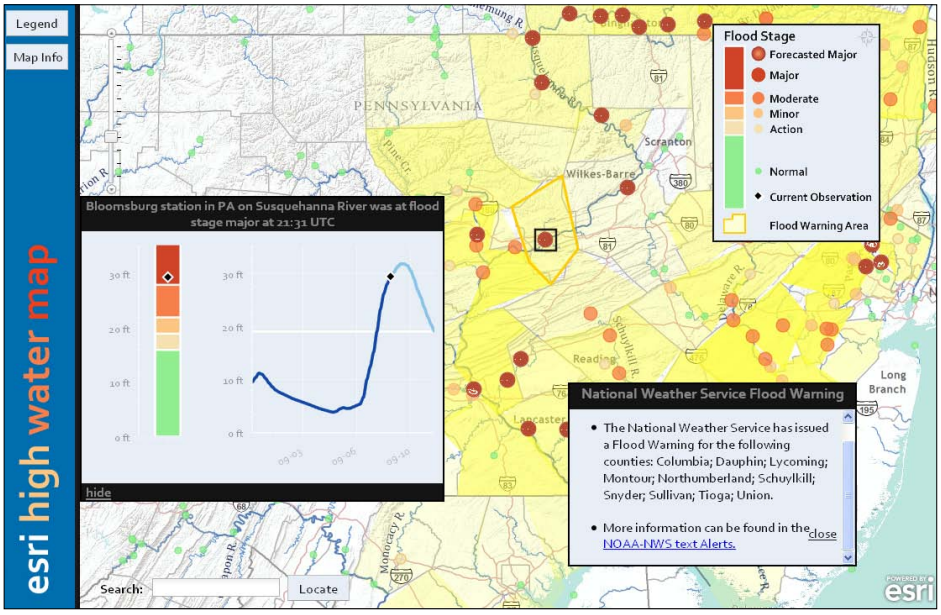
During the 2011 Esri International User Conference, more than 30 managers and users working in the water/wastewater industry attended the GIS Hydro 2011—Water Resource Workshop. Working with the workshop's theme, The Future of Water on the Web, the Esri Mapping Center team presented web resources, maps, and applications designed for Esri's natural resources community.

Hydro Resource Center: The Hydro Resource Center provides resources to help ArcGIS users solve surface water and groundwater problems and create great hydro maps and applications, which can be found in the Education Gallery, the Map & App Gallery, and the Video Gallery. In addition, the Hydro Resource Center helps users connect with each other and Esri staff through its blog and forums. All the presentations from the Water Resource Workshop are now available in the Education Gallery. Visit the Hydro Resource Center at resources.arcgis.com/content/hydro.



Hydro Resource Center Education Gallery Showing All Presentations from GIS Hydro 2011—Water Resource Workshop

US High Water Application: Esri High Water Map provides a snapshot for the general public of current water levels and flood forecasts across the United States. The application uses Esri's Hydro Reference Overlay cached map service, data from NOAA's National Weather Service (NWS)—Advanced Hydrologic Prediction Service (AHPS), and the NWS flood warning areas. The map shows current flood warning areas and water levels at more than 4,000 US gauge locations. To interact with the map, users click on the gauges or flood warning areas or use the Locate tool. Flood warning areas are linked to NWS flood warning text alerts. When clicked, stream gauge points return a graph of the current water level, flood stage levels, and past and future water levels. View the High Water Map at http://hydro_bm.esri.com/HighWater/highwater.html.



Esri High Water Map displays floods in eastern Pennsylvania.

Soil Maps: Hydro-related soils web maps of the United States from the Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) dataset are on ArcGIS Online. These maps include Hydrologic Group, Hydric Classification, Drainage Class—Dominant Condition, Drainage Class—Wettest, and Water Table Depth. These dynamic maps draw from the cloud and are projected on the fly. They are enabled with pop-up windows. Esri will release more soils maps in the near future.

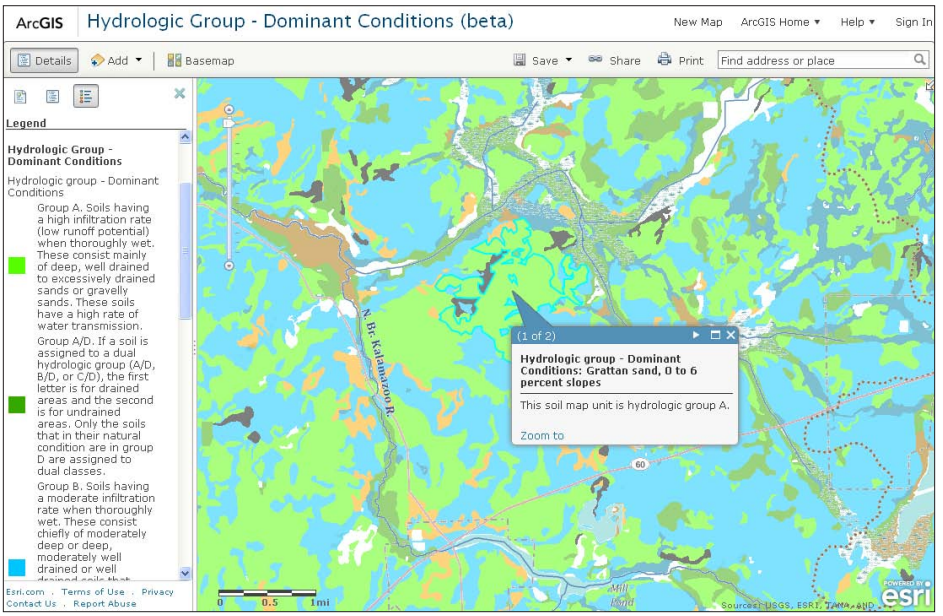
Runoff Volume Calculator: Enter precipitation values and intervals of time for a location, and the prototype application calculates the corresponding runoff at the HUC 12 watershed level. Runoff is calculated using the

Soil Conservation Service (SCS) method that requires a curve number, which is computed using the hydric soil property and the available water content information from SSURGO and land-cover information from National Land Cover Database. The runoff volume calculator is a proof-of-concept prototype. Esri plans to incorporate additional functionality into the application that will show how changes in land cover can affect runoff. The tool will also perform porosity calculations and pedologic transfer functions.

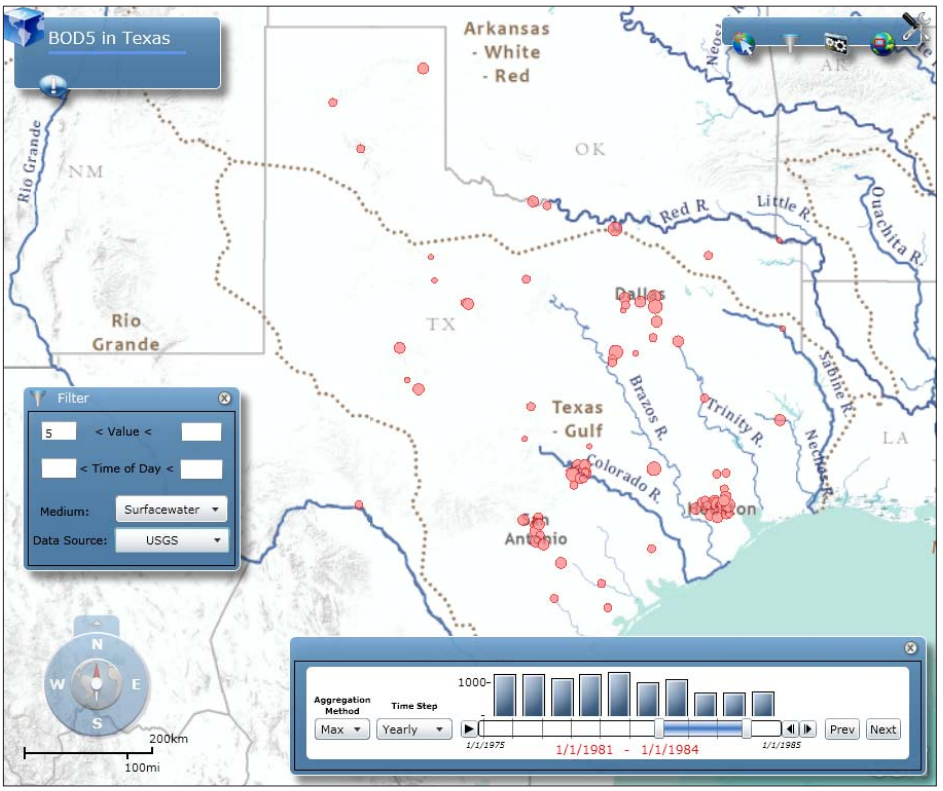
HIS Time Series Viewer: The Hydrologic Information System (HIS) Time Series Viewer is a web application, built on ArcGIS 10.1, that was created for sharing time series data. Rather than limiting map readers to viewing in one way, such as monthly average or extreme value, this prototype viewer allows users to aggregate and filter time series data on the fly. Consequently, users can ask complex questions of the data such as, What is the average summer temperature of river water when measured between 10:00 a.m. and 2:00 p.m., and How much variance is there between readings? The application shows how the answer varies between different watersheds.

World Water Online: World Water Online promotes a vision to leverage our world's amazing hydrology data in useful maps and applications. Esri has realized some of the best practices and patterns for creating web map applications. One such practice is to focus application development to do one useful task that meets a specific type of need. Simplifying an application decreases the number of information layers and services it requires, thereby making it easier to learn and use.

To move the World Water Online vision forward, Esri is working with data producers and subject matter experts to determine how best to host useful layers, maps, and applications. ArcGIS Online and Portal for ArcGIS are platforms for the water community to share and consume world hydrology information. A central online community will help the world hydrology community work together to share an understanding about data that is illustrated in maps and applications to make it useful.



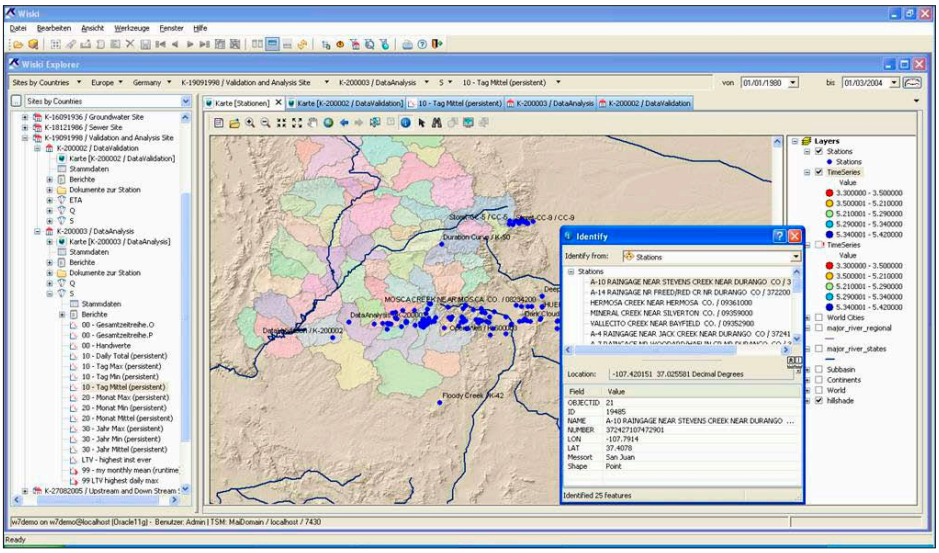
SSURGO Soils Hydrologic Group—Dominant Conditions in Lower Michigan



Biological Oxygen Demand 5 (BOD5) in Texas Time Series Viewer Aggregating Maximum Yearly Values, 1981–1984

Temporal Data Tools for Water Management

KISTERS' solution WISKI brings together spatial and temporal data for effective water resources management such as flood forecasting and warning; drought, snow, and ice monitoring; coast guard operations; groundwater monitoring; water and wastewater treatment; agricultural monitoring and irrigation; dam safety and operations; urban hydrology; and climate change records. WISKI excels at managing massive amounts of time series data with ease while giving clients access to integrated modules for water quality, data acquisition, task scheduling, modeling, and GIS mapping.



WISKI Premium Map Module

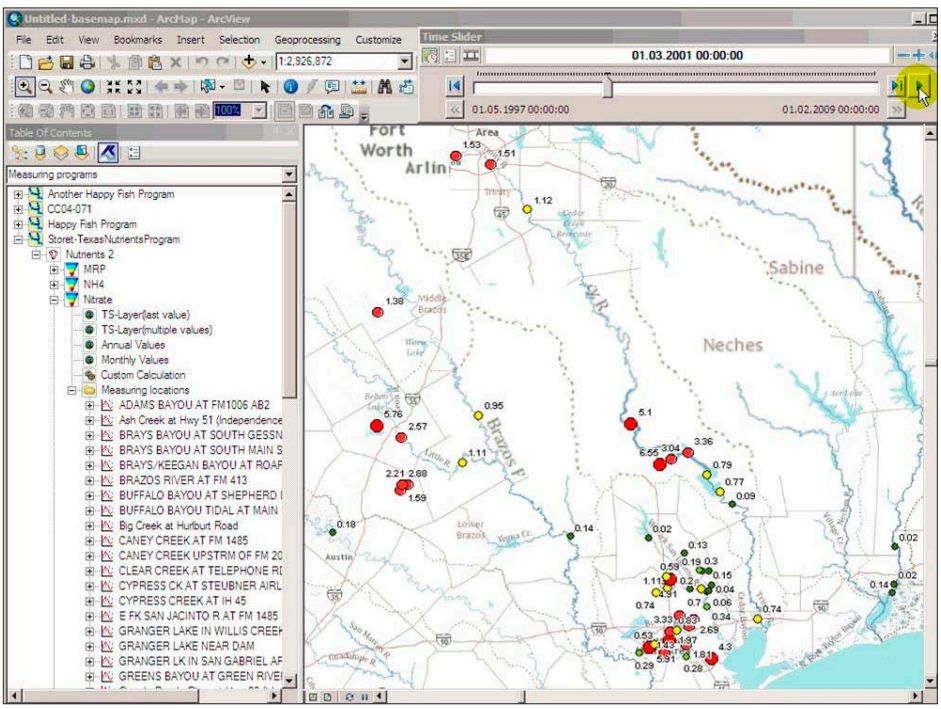
Integration with ArcGIS

KISTERS' solution is integrated with ArcGIS in three ways: The WISKI extension for ArcGIS runs on ArcGIS for Desktop. It enables users to access all time series and water quality sample data and metadata stored within the WISKI system. Users can create static and animated maps for reports, websites, or public presentations.

The WISKI Premium Map module is integrated directly into the graphic user interface of the WISKI desktop client application. It makes efficient use of the Esri ArcGIS Engine license and an .mxd basemap file. WISKI users can view, query, and perform complex operations on multiple stations at once using a condensed set of GIS navigation tools.

Lastly, WISKI Web Mapping uses ArcGIS API for JavaScript to provide high-quality mapping tools to the online client. Embed the TimeSlider widget for time-aware data.

In October 2011, KISTERS announced its new web interoperability solution, KiWIS (http://kiwis.kisters.de). Used in combination with WISKI or Hydstra, KiWIS is able to consume and publish real-time hydrologic data over the Internet using open standards such as WaterML 2.0 and Sensor Observation Service. This combination can also be placed on top of existing time series data archives, providing a quick and efficient method for disseminating and retrieving data from the Internet.



WISKI Extension for ArcGIS

For More Information

Sales inquiries: Phil Stefanoff, 1-905-531-WATR (9287) or phil.stefanoff@kisters.net

Product integration: Stefan Fuest, 49-241-967-1176 or Stefan.Fuest@kisters.de, or Michael Natschke, 49-241-967-1158 or Michael .Natschke@kisters.de

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Join the Water Resources Group

Esri's Water Resources Group is a network of water resource managers, geologists, environmental managers, and others interested in applying ArcGIS to their projects. User groups meet throughout the year to share information, data, tips on software usage, and project news. All users of Esri software are welcome. Learn more at esri.com/waterresources.

Esri International User Conference—A Resource for Water Resources

Esri invites you to the Esri International User Conference. At this conference, you will see how GIS helps you get the most out of your geological, environmental, and climatic data. GIS is used to develop climate change policy, create strategic flood maps, design disaster plans, and much more. Find the solution you need, from a desktop water analysis project to an enterprise-wide GIS implementation.

When: July 23–27, 2012
Where: San Diego Convention Center, San Diego, California, USA
Learn more and register: esri.com/uc

Join us and be inspired.

Hydrologic Analysis

ArcGIS Spatial Analyst contains specialized tools for working with and deriving new information from hydrologic and landscape data. Its toolset includes methods for describing hydrologic characteristics and tools to calculate flow across an elevation surface and derive features such as watersheds and stream networks.

With these specialized hydrologic tools and models, hydrologists can analyze temporal changes in the sedimentary process for a given terrain or build a flood forecasting model to find areas subject to flooding during a storm and then use the resultant flood map to identify affected parcels.

Hydro Blog

Become part of the water resources community. Visit the Hydro Blog. You will find information about tools, models, web maps, data visualization, and more.
esri.com/hydroblog

Save the Date

American Water Resources Association
March 26–28, 2012
New Orleans, Louisiana, USA
www.awra.org

SPAR International
April 15–18, 2012
Houston, Texas, USA
www.sparpointgroup.com/international

IFAT Entsorga
May 7–11, 2012
Munich, Germany
www.ifat.de/en/Home

IWA World Congress on Water, Climate and Energy 2012
May 13–18, 2012
Dublin, Ireland
iwa-wcedublin.org

World Environmental & Water Resources Congress
May 20–24, 2012
Albuquerque, New Mexico, USA
content.asce.org/conferences/ewri2012

American Water Works Association
June 10–14, 2012
Washington, D.C., USA
awwa.org/ace

Esri International User Conference
July 23–27, 2012
San Diego, California, USA
esri.com/uc

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