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Authentic Intelligence:

AUTOMATED DECISION-MAKING THROUGH GTSM

ANYTHING THAT MOVES OR CHANGES OVER TIME CAN BE STUDIED USING GEOSPATIAL TIME-SERIES MANAGEMENT, A TOOL THAT LIFTS ALL CURRENT DATA-GATHERING TOOLS AND COLLECTED INFORMATION TO A LEVEL OF TRUE EFFECTIVENESS.

During the past several years, there has been an increase in one type of posting on water agency bulletin boards—retirement party announcements. Key management and engineering staff who have dedicated 30-plus years to the industry are heading out for a well-deserved rest.

Despite hours spent in meetings intended to limit the effects of this turnover, the younger, less-experienced staff who will be left behind know that they're in for some serious nail-biting. How can they hope to match the decision-making experience of their retiring counterparts? Will they be able to offer customers a seamless transition, or will customers feel every bump along the learning curve?

When the entire industry is considered, more questions arise. Will anyone be able to gain the knowledge of these retirees when few employees stay at one agency long enough to even receive a 10-year service pin? If not, can high-level water resource experience be replicated?

The answers may be found in geospatial time-series management (GTSM), the next logical progression from existing applications such as geographic information system (GIS) mapping, automated data collection tools such as supervisory control and data acquisition (SCADA), and modeling programs such as hydrologic and hydraulic modeling (H&H). GTSM integrates the data that most water agencies already collect, yielding information framed to a particular time and space. The result is highly relevant data that can be used to predict drinking water supplies, manage water storage reservoirs, measure environmental restoration progress, and prevent flooding.

MANAGED DATA HELP DRIVE DECISIONS

Common tools have limitations. A typical water agency collects and stores an abundance of data. Utilities have made significant investments in "must-have" tools and applications to handle such data. For example:

INSIDE THE GTSM FRAMEWORK

The ability to link time-series data to a global information system (GIS) is a key component of geospatial time-series management's (GTSM's) power. The GTSM system stores water bodies and streams with their cross sections, watersheds, structures, and monitoring points in a spatial database with key attributes. Taking advantage of relational database design, the GTSM system goes a step further and identifies the relationships between these features.

As a result, the GIS recognizes that a particular monitoring point is, for example, on the headwater side of a structure where it controls water levels in one specified water body that flows into another specified water body downstream. The entire drainage system is defined as a network with centerlines, called "hydro-edges," that represent flow running through the entire system. All the other features of the GIS related to the network are at user-defined points of interest called "hydro-junctions." The watersheds, water bodies, and hydro-points (structures and monitoring points) are connected to the hydro-network using relationships with the hydro-junctions.

Retirement parties are becoming more commonplace events in the water industry as experienced decision-makers embark on a new phase of their lives. One way utilities can bridge the resulting knowledge gap is by using integrated data generated by geopsatial time-series management to predict supplies, manage reservoirs, and prevent flooding.

- GIS is used to digitize and access as-builts, watershed maps, and service-area grids.
- H&H modeling has been widely applied to better understand the range of conditions in water resources and facilities.
- SCADA is now the industry standard for collecting real-time operating data.

None of these applications, however, is a predictive tool in itself. Data points—even when collected using SCADA—are just data points, nothing more. GIS is but a spatial frame of reference for those data points. Some water industry professionals also suggest that H&H modeling is not an absolute measurement and that models can be flawed or manipulated to modify results. Ultimately, these applications fall short of predicting outcomes because they yield limited information.

Record-keeping also limited. Water data have been collected for a relatively short period of time. Most communities have only 50 years of rain data, although some of the nation's oldest official rain gauges are about 100 years old. Fifty-plus years may sound like a long time, but even 100 years of data make for a very small data sample when evaluating an entire watershed or a single lake or river. Water resources experience many changes over the course of decades and centuries. Judging future water supplies by examining existing historical rain data is like a doctor spending one second with a patient and then making a final diagnosis.

Data collected and stored are not useless. However, the industry must find a way to manage all of the information and use the data to make decisions, not merely to report on what has already happened. GTSM is such a solution. It lifts all current tools and collected information to a level of true effectiveness.

ASSESSING THE BIG PICTURE

The creation of an automated decision-making tool is a major step. To date, computer applications in the water industry have fallen far short of replacing human intelligence. H&H modeling, GIS mapping, and SCADA have not eliminated the need for experienced eyes to review the data.

In the past, veteran water agency employees were able to predict outcomes by evaluating modeling and operational data. They drew on their own experiences of water and weather trends, gathered over time, as well as their detailed knowledge of a facility's or watershed's physical configuration.

Time and space were the key elements that veteran employees applied to transform data into a decision-making tool. In other words, the information needed is not typically a single point, such as a reservoir level or a rainfall total. "Time-series" information is key (e.g., variation of reservoir levels, rainfall, or water quality markers over time).

A second critical piece is knowledge of what these variations mean in terms of managing specific water resources and watersheds. A picture in the form of a GIS image truly

Geospatial time-series management translates data into the correct units and format to integrate time and spatial data and shares results within a single geographic information system–driven resource that is instantaneously accessible to team members.

paints a thousand words. GTSM translates water industry data into the correct units and format to operate within a single GIS-driven resource (Figure 1). All team members have instantaneous access to time-varying data. In short, GTSM can be used to examine anything that moves or changes over time. (See the sidebar on page 76 for details on how this data translation occurs within the application).

GTSM TRANSLATES WATER DATA

GTSM was developed by the consulting firm PBS&J, in collaboration with the University of Texas Center for Research in Water Resources, the Environmental Systems Research

AWARD-WINNING APPLICATION

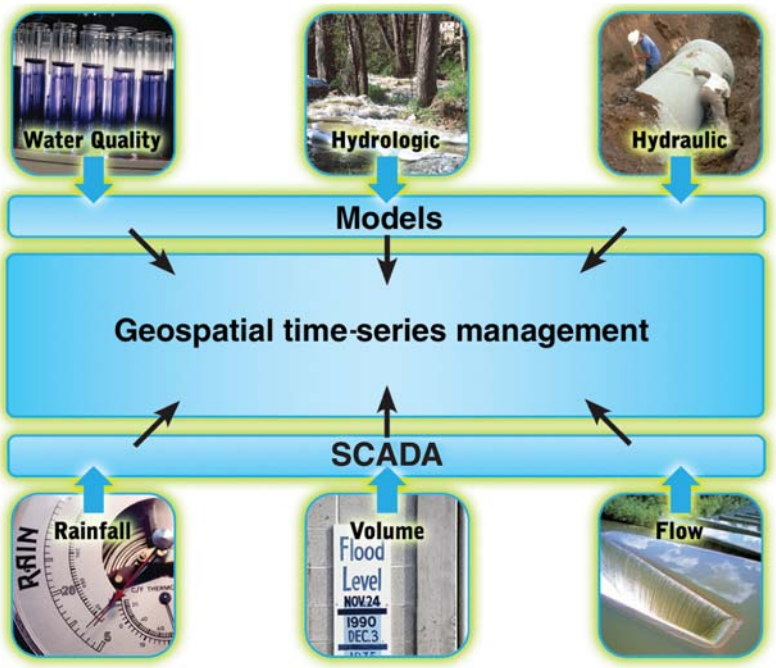
Gives SFWMD Decision-makers Timely, Accurate Data

GTSM is the next natural step up from the Arc Hydro Enterprise Database developed by the South Florida Water Management District (SFWMD), University of Texas Center for Research in Water Resources, and PBS&J. Arc Hydro was developed to give SFWMD decision-makers timely, accurate data about South Florida's hydrologic and hydraulic (H&H) systems. The resulting water resources, GIS model, and associated tools have addressed watershed management, hydro-period analysis, operational decision-making, and H&H modeling for South Florida and the Everglades. In 2004, the database won a Florida Institute of Consulting Engineers Engineering Excellence Award.

Because it integrates spatial data with time-series data, Arc Hydro is a way to manage modeling programs—such as WATER—in GIS, not just in a pure H&H framework. In addition, Arc Hydro standardizes data to reduce redundancies. The application can also standardize and track project data or information such as permit updates. Data quality can be tracked for better science. This integrated decision support and adaptive management platform leads to better decision-making.

For South Florida, the design team developed a common data structure for several different project types, so that data and results can be shared through a regional enterprise GIS. A unique relational database environment was formed in which the natural connections between natural water bodies, control structures, monitoring points, and drainage basins are linked to the large quantity of time-series data stored. Procedures and "hooks" are included, allowing the GIS to be used with time-series data for hydrology, heads and flows, system state, system projections, water balancing, and adaptive management.

FIGURE 1 Geospatial time-series management



SCADA—supervisory control and data acquisition

Geospatial time-series management integrates the data collected from applications such as SCADA and hydrologic and hydraulic modeling, providing information framed to a particular time and space.

Institute (ESRI), and DHI Water and Environment. The application evolved from the Arc Hydro Enterprise Database, an application developed to meet specific project needs for the South Florida Water Management District (SFWMD). (For more information about Arc Hydro, see the sidebar on page 77).

The Arc Hydro Geodatabase and tools are the accepted GIS data models for hydrology across the United States. Time-series concepts developed for the project have influenced ESRI to extend core data structures. Spinning off from Arc Hydro, GTSM translates water-related data into a single, accessible, GIS-driven resource. Data such as those collected by SCADA, are integrated into ESRI's Arc Hydro Geodatabase, and raw data are converted into a common set of units and a uniform format within a GIS framework.

GTSM DATA SUPPORT DECISION-MAKING

With so many data-collecting and mapping applications in the water industry's arsenal, GTSM was the natural next step toward making the data more useful and relevant. For example:

- SCADA yields instantaneous information about the activities of system components in the present, then stores the information. GTSM offers a way to use the saved data to evaluate system performance.
- Time-varying data such as rainfall, stream flow, and water level can be fed into an H&H model, a water quality modeling program, or the operational data sets collected by SCADA. GTSM links the data to GIS elements and characteristics, allowing for time-series calculations.

Using the example of rainfall data, GTSM distributes the data, in inches, over the catchment area to calculate rainfall accumulation or volume over a particular time period.

The rainfall level is no longer just a number—it becomes a value applied to a specific location for which the effects of the rainfall on the location can be ascertained. This information can help measure flooding potential or available water resources.

For water level information, GTSM relates the data to a specific water body, converts the data into a water volume, and provides remaining capacity and stage-storage information. Again, water level becomes a value related to a specific body of water with a known capacity.

- When utilities use GTSM, stream flow data can be related to how the data progress through a specific water body with effects of control structures or natural contours and barriers. The flow data can be used to calculate changes in stream volume. Model or gauge data are converted to flood-depth contours by applying hydrographs and digital terrain models.

Although H&H modeling and GIS have been combined before, they have not been applied over a time series. Typically, the model considers a peak flood at only one point in the time series to make the flood map. With GTSM, however, the entire hydrologic curve can be considered.

GTSM DATA HELP MAXIMIZE RESOURCES

Its time-series information component makes GTSM useful to water managers in myriad ways. In the scientific or environmental decision-making arenas, for example, applications include

- adaptive management and environmental restoration, including inundation mapping for minimum flows and levels;
- total maximum daily load/National Pollutant Discharge Elimination System water quality applications and contaminant tracing; and
- flood mapping and flood hazard identification.

Possible management and decision-making situations that can benefit from GTSM also include:

Sensitive environmental restoration projects such as in the Everglades, Fla., already make use of geospatial time-series management. Time-series data are related to specific water structures to better determine system status and projections, water balancing, and adaptive management options.

- displaying the current state of the water network—levels, flows, and volumes—in GIS terms;
- calibrating systems using a rapid comparison of modeled versus measured sources and accumulating net changes to detect measurement errors;
- tracking and predicting water movement to prepare water budgets;
- predicting storage requirements in the short and long term for the region or for one water body using network flow and volume transfer rates; and
- evaluating historical responses (natural or operational) to changing conditions.

For regional water management and water supply agencies, GTSM is valuable for short- and long-range planning. It can support operational decisions such as reservoir management and water allocation, short-term and long-term system-state predictions, and system planning. These decision-making capabilities address the growing concern of water agencies nationwide—maximizing their available water resources.

EFFECTIVE RESOURCE MANAGEMENT IS AN INDUSTRYWIDE CONCERN

GTSM's most significant use may, in fact, be in addressing how a water agency can best manage its limited quantities of freshwater. This issue, once largely limited to western states, is now seen as a growing concern across the country. The application's refined capabilities will help water managers better assess water budgets for a given area or predict water storage requirements for the short and long term. Time-series data allow water managers to track water movement with more accuracy and use existing water resource conditions to look ahead to future conditions based on predicted rainfall.

With GTSM, water managers can conduct accurate experiments to see the effect of moving water resources around a service area map; for example, if moving 2 in. (50 mm) of water from one location to another translates into a net gain of 6 in. (150 mm) in the new spot. GTSM makes this possible because the time-series data for flows and levels are linked to the GIS intelligence, so the data are treated as volumes.

GTSM IN ACTION IN SOUTH FLORIDA

The SFWMD is currently operating a conceptual framework for GTSM. PBS&J has linked the water agency's SCADA measurement points to its enterprise GIS. This yields intelligence about what is being measured in what units and how that information relates to the inflow or outflow of water to lakes, canals, control structures, monitoring points, and drainage basins. The spatial data are linked to time-series data, resulting in a way to use GIS with time-series data for hydrology, heads and flows, system status and projections, water balancing, and adaptive management.

GTSM is available for water agency use. If GIS is already in place at a particular agency, GTSM can be designed and brought online in as few as three months. In addition to the resource management possibilities, managers and water agency boards who have authorized expenditures on countless data collection and mapping programs will finally see their collection of investments transformed into a true decision-making tool.

Although no automated application can fully replace the water industry's retiring staff, GTSM will bring an agency's newer staff closer to matching their predecessors' performance—and make all those retirement parties feel far less bittersweet.

ABOUT THE AUTHORS

John (Woody) Wodraska, *to whom correspondence should be addressed, is the national director of water resources for PBS&J, 3230 Commerce Pl., Ste. A, West Palm Beach, FL 33407; e-mail woody@pbsj.com. Wodraska is a nationally known water resource expert with bicoastal insights on water issues. During his 30 years in the industry, he has worked with sensitive water management issues as executive director of the South Florida Water Management District and as general manager and chief executive officer of the Metropolitan Water District of Southern California. Jack Hampson has more than 20 years' experience in process automation and automated mapping software. He has been actively involved with water resources in GIS since 1992.*

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