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Expressway to the Future: GIS and Advanced Metering Infrastructure

Utilities are finding themselves in a changing financial, regulatory, and meteorological environment. As a result, managers are being forced to make more complex decisions about the management of their system, but without improved information to support their decision-making. If the Internet is the information highway, then geographic information system (GIS) enterprise asset management and advanced metering infrastructure are the expressways to the future for utilities to transform data into intelligence necessary to make informed operational and capital decisions. Utilities of the future will require technological investments in GIS-centric asset management programs and advanced metering infrastructure.

GIS: THE RIGHT TECHNOLOGY AT THE RIGHT TIME

Revving your engine. In a 2009 article the "father of GIS," Roger Tomlinson, explained that development costs of GIS are estimated to be one tenth the price of just five years ago. In addition, the hardware and software capabilities are also much greater. The typical core or central processing unit is 40% more powerful than the equivalent computer the year before. The data are also now more often available in digital format that significantly increases the speed at which it can be obtained. "I'm very positive about the future of GIS. It's the right technology at the right time," Tomlinson stated in the article. "When I think of all the major problems that we face throughout the world today—overpopulation, food shortages, reduced agricultural production, adverse climate change, poverty—these are all quintessentially geographic problems. These problems are all concerned with the human relationship to the land, and this is where GIS can make its biggest contribution. GIS is the technology of our times and is uniquely suited to assist in solving the problems that we face" (Baumann, 2009).

Picking up speed: Trends in GIS. In 2010 the results of a study by Bartlett and West were published to provide a resource for public works professionals, offering insights into how their colleagues in the United States and Canada are using and supporting GIS. A total of 1,375 public works professionals responded. The following was compiled from their responses:

- A total of 89% of respondents indicated their organization has implemented GIS, with 46.1% indicating their organization's GIS programs are tied to another entity—for example, a county.
- Of the utilities that have not yet implemented GIS, 40.6% intend to do so within the next five years.
- Of the 11% that have not yet implemented GIS, 18.2% have no plans to do so and rely on paper files, spreadsheets, and databases to manage capital projects, permits (e.g., building or utility permits), utility maintenance (e.g., pipe replacement, sewer cleaning, meter replacements), and complaints (e.g., potholes, drainage).

• Respondents who have implemented GIS programs report using the technology for a variety of purposes, from base maps to infrastructure and utility management, planning, demographic analysis, incident tracking, and other uses. This is true for all but the smallest entities and in every region.

• Of those respondents currently using GIS, 47% reported that it was accessible to the public. The larger the population served by the entity, the more likely this was to be true.

• More than 60% of larger entities report they have incorporated GIS into daily management of infrastructure, with that percentage tapering off sharply for populations of fewer than 50,000. Those reporting use of GIS as a public works management tool most commonly cite project and maintenance management as primary uses (Bartlett & West, 2010).

THE ENGINE IS THE GEODATABASE

GIS as a transformation technology can be used as the unifying framework to apply geospatial information to a host of applications and integrated as a core component of the utility information technology (IT) structure. GIS is not just about mapping, it is also the backbone of the utility this is used to capture critical asset data and perform spatial and system analyses to discover risks, strengths, and weaknesses in all water systems (water, sewer, storm, reuse).

Shifting gears: GIS mapping to GIS managing. Mapcentricity must move from drafting tables and computer-aided design technologies to asset data deposited into the GIS geodatabase that is then shared seamlessly with all other mission-critical applications. The US water industry needs to move toward common data sharing and open standards between the areas of utility asset data knowledge, geographical and environmental dependencies, meteorological and climate variability monitoring, and regulatory and governmental data collection programs. This data-gathering and asset knowledge–sharing approach requires the GIS geodatabase to be the authoritative asset-data repository that leverages the benefits of being an open and shared database.

Setting the course: Defining GIS-centric. A certified GIS-centric solution does not have redundant asset-data storage with reliance on views, links, data mapping, or database triggers. The data model should be customizable and user-defined without unnecessary vendor support. The asset-data structures should be nonproprietary for field names, types, tables, relationships, and other data design elements. The data design should be configured to allow for other GIS-centric solutions to concurrently use the asset data. All assets should be structured in a way to enable the full power of GIS analysis and modeling tools in addition to preserving the integrity of the geodatabase relationships, domains, and data types (NAGCS, 2010).

Taking the lead. The township of Waterford, Mich., was founded in 1834. It is in the center of Oakland County with a population of more than 73,000 and, with 34 lakes, is known to many as "Lakeland's Paradise." By simply driving through this typical, midsized, US town it may not be obvious that its municipal services have been fortified by a powerful GIS backbone structure since 1998. This town reflects a simple vision for leveraging a GIS investment to build a network of GIS-centric applications to advance the return on investment and cost savings. Township officials realized that by selecting the correct technology they could balance workforce challenges with a better allocation of resources, as well as balance increasing material and equipment costs with enhanced performance and optimization. Waterford has added to its GIS backbone a computerized maintenance management system (CMMS) that meets the town's GIS-centric criteria to better manage its assets (Cityworks, 2010). The asset data are captured for reference in the event of employee turnover and retirements as well as for future disasters. The asset-condition data and work-history collections form a treasure trove, rich with asset maintenance and predictive failure data.

According to Haslam (2010), robust asset-maintenance history built over time and stored in the CMMS provides a predictive standard for when similar assets may fail and how assets typically fare in the given region and climate, as well as other important local factors. For many assets, the clustering, frequency, and costs of unplanned maintenance activities alone—analyzed and visualized using GIS tools—provide enough evidence to make an intelligent investment decision of when, where, and how maintenance and rehabilitation should take place. Often, unique attributes (or characteristics) of the asset stored in the geodatabase (such as type and the contractor) contribute more insight than age or expected life with regard to the likelihood of failure. For high-risk assets, maintenance history and GIS analytical tools can provide insight and help prioritize where to use limited budgets for increased inspection, monitoring, and condition assessment (Cityworks, 2010).

The automation associated with a robust GIS is speeding up Waterford's work cycle, resulting in cost savings and better decision-making. In addition, Waterford engaged the services of a GIS-centric provider of wet infrastructure modeling and simulation software for water and wastewater utilities (Simonsen, 2010). The incorporation of a GIS is not just beneficial to Waterford's water and wastewater divisions. The public works department expanded the use of GIS to include the facilities and operations division, cemeteries, parks,

and even the police department. The seamless integration of GIS-centric applications has improved the response times and has saved additional money in utility locating services (Cityworks, 2010).

Engaging the pit crew. Utilities require many different software applications. The billing, financial, payroll, human resources, and supervisory control and data acquisition are all examples of systems that are not necessarily GIS-centric or GIS-enabled and therefore require another integration strategy.

Using all available tools. According to Przybyla (2010), many such strategies have been used over time, starting with file transfers and progressing to point-to-point automated data transfer-style interfaces. Often, the number of connections and the complexity of managing change became overwhelming to the users—because these solutions are based on importing files or directly updating databases, they have many challenges. For example, if an application changes because of an upgrade, the point-to-point connections often have to be reconstructed. A better approach is based on the service-oriented architecture (SOA) concept. With SOA, services talk directly to other services and exchange data based on a loosely coupled concept. A set of orchestration tools connect the services and monitor the data exchanges. The use of standards maximizes the ease of integrating off-the-shelf products, and orchestration services facilitate easy monitoring and recovery if problems occur. Because the services are typically built into newer applications, they shield the data exchanges from changes in the underlying data structures or changes because of upgrades. Once the framework is built, incremental applications can be easily added.

Electric and gas utilities are ahead of the water industry in their work with SOA and integrated planning, customer maintenance, asset-condition monitoring, and asset-information management. The SOA approach combined with GIS and advanced metering infrastructure (AMI) in the future holds the ability for utility general managers to monitor both the financial and operational performance of the water system in real time.

Basic steps to consider when developing a GIS-centric enterprise asset management system include:

(1) Determine an integration architecture appropriate for your organization.

(2) Develop a GIS-centric asset database structure.

(3) Select GIS-centric applications where available.

(4) Select non-GIS-centric applications with open architecture and web services.

(5) Use SOA to integrate loosely coupled concepts.

Staying informed of the conditions. GIS solutions are being developed and are resulting in increased productivity and cost savings in many places in North America. The approach is not solely data-centric but also gathers and collects data critical for asset management decision-making. When these data are shared across independent silos of municipal operations, the benefits of the GIS backbone extend to land-use planning, wastershed and sewer outfall management, regional cooperation in addressing storm-drain run-off, and integrated sustainability planning. A shared GIS approach allows for the holistic analysis of geographic relationships that produce tangible and tactical implementation plans to quickly address water challenges in a collaborative manner. GIS is a critical tool to help analyze, understand and visualize complex spatial relationships, and answer complex questions using data that do not appear to be related other than by proximity or spatial connectivity. As a result, GIS is used for long-term planning studies, environmental management, customer analytics, logistics support, and capital decision-making (Dangermond & Meehan, 2007). Many times the breakdown in cooperation around watersheds is not the result of disagreement about the issues or a lack of willingness to participate in finding solutions, but the justification and allocation of costs. This financial disconnection can be eased into the planning process by using GIS analytical tools and applying new regional cost-allocation methodologies.

GIS technology and applications are available on desktops, in networks, on the web, and even in "the cloud." The beauty of GIS is its scalability. The power of data and analysis can be used with many programs, from Microsoft Access geodatabases and shapefiles on the small end to large enterprise geodatabases running in Oracle or similar enterprise databases. GIS can be leveraged to make businesses more efficient, more intelligent, more profitable, and more sustainable (Williams, 2010).

Sharing the win. Many small or rural utilities do not have the IT or GIS capacity to support these activities. In such cases the county or a larger nearby utility could partner via web-enabled solutions to provide this mission-critical service. This should be considered a high priority for federal, state, and county grants and special needs funding. Many times the argument that these technologies are not affordable is based on labor-intensive and costly manual processes. These costs may be alleviated by introducing and investing in new technology.

Fine-tuning the engine. GIS-secured asset data can be developed at the local level and passed up to the regional, county, and state levels for big-picture analysis and review. This would be similar to the watershed approach, which uses natural rather than political boundaries. The development of asset management plans and integrated sustainable plans requires collaboration at every level. Developing ongoing monitoring and performance plans based on the condition of all assets—aboveground treatment plants and hydrants to belowground pipes and valves—comprise our management duties and public expectations. Hydraulic models can be created from the GIS data and analyzed using advanced genetic algorithms that examine tens of thousands of scenarios to produce the best solution and lowest cost option for operational efficiency and capital and replacement decisions. Water distribution, wastewater collection, and even irrigation systems could benefit from a comprehensive optimization process periodically, but especially during master planning activities and definitely before rates, charges, and fees are calculated and implemented. Optimization used to explore ways to decrease costs while still meeting social policy and technical requirements should always be part of the path toward long-term affordability planning.

PREPARING FOR THE NEXT CHALLENGE: GIS AND DEMAND-SIDE MANAGEMENT

As the twenty-first century has seen the drinking water industry landscape become increasingly rocky, AWWA has expanded its role to help water utilities meet new challenges. In general, these challenges are a declining workforce, aging infrastructure, regulatory compliance, water scarcity, source protection, and climate change. These elements are captured under the planning umbrella of sustainable integrated resource planning (AWWA, 2007). Within the arena of water resource planning the critical data of the demand forecast and demand management are required first in order to evaluate the need for new supply development.

Public water supply systems cannot be made entirely "drought-proof" through supply development and augmentation. There are limits to such traditional supply-side approaches, including increasing costs of supply development, concern over environmental impacts, and, in many cases, political controversy. As a result, water demand must be managed just as supplies must be managed (AWWA, 2002).

Demand-side management can be a powerful tool in reducing future water needs, and if the effort is sustainable, it can be treated as an additional source of water supply. Demand-side management has a cost, a yield, and environmental considerations and needs to be closely evaluated just as any new supply project would.

Many water departments may have a water resource group searching for and planning new water supply projects extending 50 years into the future. On the other side of the department, a conservation group may be working with the metering team to manage a demand-side conservation program. Such programs use advertisements such as Denver Water's "Use Only What You Need" campaign, offer natural landscaping workshops, and promote incentive programs to reduce residential lawn sizes and replace older toilets. Many organizations offer summertime water audits and sell smart readers so customers can better predict and manage their water use and therefore their water bill. Although it would be nice to imagine these activities are all motivated by resource conservation–oriented attitudes and behaviors, the main motivation is usually the price signal issued each month in the form of a water bill.

Legislative policies are another driving force behind more demand-side management practices. Examples of these policies include three-day watering restrictions for residential customers set forth by the local water board or city council, or California's SB7x-7 calling for a 20% water reduction per capita by 2020. Many times because of departmental silos within utilities, the demand-side planning, analysis, and results are not shared consistently with those working on the supply-side effort. The interactive and ongoing nature of sustainable integrated resource planning ensures the information will continue to be updated and flow to the correct parties.

AMI: Taking conceptual design to testing. Because of the importance of demand management and the need to shift from voluntary conservation to operational control, technology will continue to be developed and implemented. Demand-management technology will help inform the utility and customers of issues, send real-time price signals, run leak-management programs, reduce manual processes, and minimize operational costs. With GIS as the backbone, the demand-management tools will include AMI such as smart meters, sensors, advanced control devices, and improved communication equipment. For some years the electricity-metering industry has been developing smart meters for various applications. Water metering technology has always lagged behind (Crowson, 2010). For the electric industry, the development and combination of AMI and GIS have resulted in predictive demand and fewer service disruptions. In Europe the investment in smart electricity metering is well-advanced and supported by many demand-management policies. Smart water metering (SWM) has not been developed to nearly the same extent, but the past decade has seen progress in the concepts of advanced or smart metering. Because of investments made by the electricity industry, metering has evolved from interval meters with simple communications to advanced, or smart, metering with an increased range of functionality.

Smart metering for the water industry will also extend beyond the capability of automated meter reading (AMR). Smart metering is expected to, at a minimum, establish more granular (i.e., within a day) water-use data, two-way communications between the water utility and the water meter, and potentially include communications to the customer (i.e., SWM). With respect to a customer's household, SWM could enable

- recording of daily water consumption,
- remote meter reading on a scheduled and on-demand basis,
- notification of abnormal use to the customer and/or the water utility,
- control of water consumption devices within a customer's premises, and
- delivery of messages to the customer.

Studies in Australia have found that the potential benefits of implementing smart metering to approximately 10 million electricity customers across Australia will outweigh the costs. These findings indicated a potential opportunity for the water industry to leverage the investment of the electricity sector and deliver benefits to customers of Australia's water sector. As a result, The Department of Sustainability, Environment, Water, Population and Communities conducted a study to investigate the potential costs and benefits of implementing SWM in Victoria (Victoria Water Trust, 2010). This study was driven by

- the need to respond to the variety of challenges arising from climate change, infrastructure investment, and population growth;
- an increased interest on the part of many electricity, gas, and water service authorities across the world in smart metering;
- the opportunity to significantly improve delivery of the urban water services and enhance other water efficiency initiatives by increasing customer awareness of their water use, empowering customers to better manage their consumption, and providing valuable demand information to stakeholders;
- the need to evaluate whether smart water metering has the potential to play an important role in stimulating innovation in water management and the achievement of longer-term water industry reform objectives; and
- an opportunity for the water industry to understand implications of the investment and capability of smart electricity metering.

One key element in the study considered the implementation options dealing with measurement and recording data. In general, it included pulse and interval methods.

Pulse. Where a metered consumption data point is recorded when a certain volume is consumed (e.g., 1–100 L) and at what time and date.

Interval. Where a metered consumption data point is recorded at specific time intervals (e.g., every 15 minutes, 30 minutes, hourly, or daily) and the volume of water consumed to that point.

Six implementation options were considered for the quantitative and qualitative analysis. These approaches were:

(1) weekly AMR services,
(2) weekly pulse meter data collection,
(3) weekly pulse meter data collection plus in-house display,
(4) daily pulse meter data collection using electricity AMI plus in-house communications,
(5) daily interval meter data collection using electricity AMI including in-house communications, and
(6) daily interval meter data collection using water AMI including in-house communications.

Although this type of study is difficult, the key findings of the quantitative analysis suggested that financially positive outcomes can be demonstrated for implementation options 1–4, which involve either more frequent collection of either simple accumulation-metering data from current meters or more frequent collection of pulse-metering data. Collection of interval metering data via implementation options 5 and 6 provided a financially negative outcome—the meters and associated systems are more expensive and it was determined that the information is no more valuable than the pulse information.

There is growing momentum and need for SWM pilots and programs in North America with recognition of water retailer benefits, including:

- identification and reduction of water leakage,
- improved asset management efficiency and effectiveness,
- reduced cost of retail operations, and
- changing consumer water efficiency and consumption attitudes and behavior.

The specific benefits listed for asset management included

- customer leaks management,
- network leaks management,
- capital efficiency for growth infrastructure,
- capital efficiency in replacement expenditure, and
- pressure management.

Smart meters do not increase the volume or security of water available to customers. However, they can empower customers with the information to manage their own consumption better than they can today and may facilitate an environment in which mandatory restrictions are replaced with a combination of price signals and voluntary water efficiency measures. A survey of Australian consumers highlighted their belief that ensuring adequate supplies of water for both consumption and the health of the environment is the most important issue in society. But the same results showed that 42% of individuals surveyed are unable to determine whether they are effective in reducing their own water use. It is still believed, therefore, that consumers are likely to benefit from technology that allows them to monitor and understand their water use, providing consumer education to establish a generational and societal change in attitudes toward water efficiency and consumption (Victoria Water Trust, 2010).

WHAT WILL DRIVE THESE ADVANCEMENTS IN THE UNITED STATES?

The water industry in the United States applies technology differently in almost every location. When it comes to metering, there are still several large geographic areas that do not have meters installed or do not read and bill according to the meters. Other jurisdictions have moved forward with AMR to reduce the manual and labor-intensive process of meter reading. Metering and monitoring advancements will continue in order to further meet water demand-management goals. GIS will continue to combine with other mission-critical systems to improve operational knowledge, control, and costs. A main focus will be on condition assessment and asset management programs to achieve operational and capital cost savings. In the near future, in order to meet community sustainability and affordability goals, water utilities will need to start collaborating with other electric, gas, telecommunications, and even transportation businesses to gain additional economies-of-scale, cost, and operational benefits in the advanced metering and monitoring infrastructure arena. GIS technology will create the common ground for each utility and industry to collaborate. The key drivers behind these advancements and the investments required include the three C's—crisis, costs, and curtailment, and the three S's—scarcity, security, and sustainability.

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