# Innovation & Environmental Stewardship

## *Review of Significant Water Industry Trends*

*This report reviews a number of significant trends in the water industry and demonstrates how American Water's Innovation & Environmental Stewardship program is addressing these issues.*

### Climate Change and Energy Efficiency

The effects of climate change will shape the nature of the water industry in profound ways. Table 1 lists just a few of the expected impacts; however, these impacts are not completely unknown. Water utilities have always lived with variations in climate – floods and droughts have been tracked for decades. The difference is that in the future these will happen at a more rapid rate – a 100-year flood happening every 20 years, or a 20-year drought occurring every five years. The main driver of climate change is an increasing amount of greenhouse gases, which contribute to global warming.

**Table 1: Impacts of Climate Change**

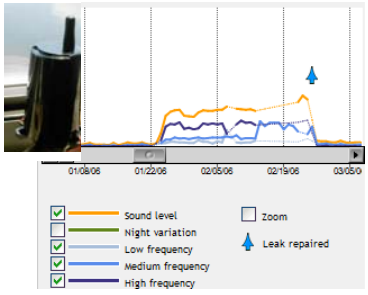
- Changing weather patterns
- Higher surface air temperatures
- Melting of polar ice caps
- Longer, more frequent droughts
- Shorter, higher intensity rainy seasons
- Variation in water quality, contaminant loading
- Rise in ocean levels causing salt water intrusion

Water utilities contribute substantially to greenhouse gas production using an average 4 percent of the nation's electric production and up to 20 percent of the electricity in some regions. For American Water, nearly 93 percent of its greenhouse gas footprint comes from the use of electricity – with nearly 90 percent of that used in pumping water.

In December 2009, American Water made a commitment through the U.S. Environmental Protection Agency (USEPA) Climate Leaders program to reduce its greenhouse gas intensity by 16 percent by 2017. American Water will achieve the reduction through a combination of increasing pump efficiencies, purchasing cleaner generated energy sources, reducing the number of vehicles, and increasing the use of on-site solar and other alternative energy-producing methods. Optimization of energy use is not only important from an environmental sustainability perspective, but it's also essential for economic prosperity.

### Investigating Infrastructure Integrity

There is a tremendous need to invest in and upgrade America's drinking water infrastructure. According to a 2007 USEPA survey, the 20-year capital investment need for public water systems is estimated at $334.8 billion. The American Society of Civil Engineering reports that each day, approximately 7 billion gallons of treated drinking water are "lost" primarily due to leaks in drinking water pipeline throughout the United States. This represents approximately 15 percent of the nation's total daily water production. Because climate change will put increased stress on the availability of water supplies, it is essential that water utilities rescue this lost supply – not only because it is an increasingly scarce supply but also because of its embedded energy and the greenhouse gas footprint that it represents. American Water is responsible for more than 45,000 miles of main, so this is an important issue for the company.

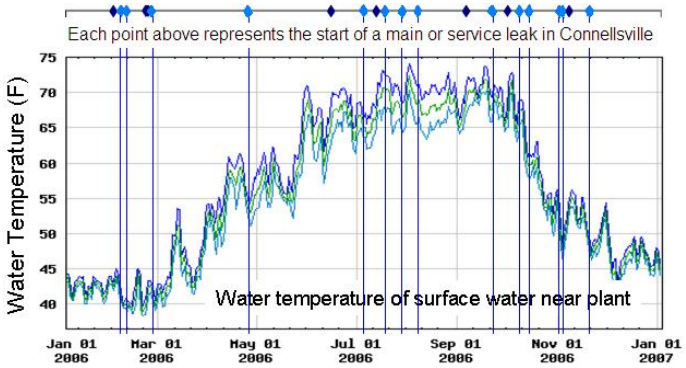



An acoustic profile of a leak. Arrows indicate the repair. Inset; the MLOG device.

The development of low-cost acoustic leak detectors (e.g., MLOG) that can be permanently deployed throughout a distribution system now permits water utilities to survey for pipeline leaks every day. The acoustic monitor is installed on the service line next to the water meter and can relay the data back through the automatic meter reading telemetry system to a central computer. The computer can process the data and alert the system operator when suspected new leaks have been detected.

A pilot study of the system in Connellsville, Pa., was very successful, reducing the lost water from over 20 percent to around 10 percent within six months, saving an estimated $140,000 in lost revenue, with a payback for the technology of less than two years. The units now have been installed in systems in California and New Jersey and additional trials of the next generation of monitors are underway in Illinois and West Virginia. Cost models for automatic meter reading and acoustic monitoring have been made available to all state operations.

The acoustic monitors can be used for more than just detecting leaks, however; they can indicate the condition of the pipe and demonstrate the factors that contribute to leak formation. Approximately two-thirds of the main breaks in Connellsville were preceded by evidence of pipe leakage. Rapid detection and repair of the failing main can prevent collateral damage and overtime costs associated with a main break. Because the monitors can now detect when a leak first starts, rather than when it "surfaces," an accurate determination of leak-initiating factors can be made. The effect of changes in water temperature is shown in the figure below where leaks were associated with both rapid decreases and increases in water temperature. The optimum time for leak surveys is in the fall, when rapid changes occur in surface water temperatures.

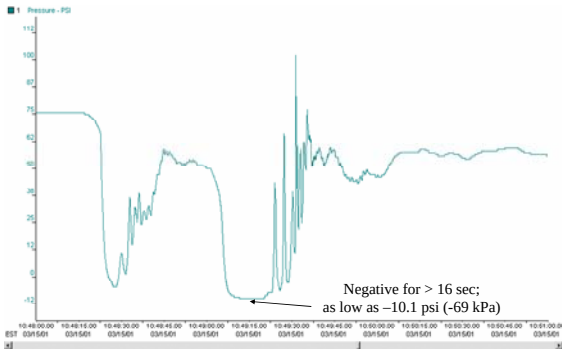



Relationship between changes in water temperature and the start of a main leak/break (in diamonds along the top).

## Ensuring Distribution System Integrity

The National Research Council defined distribution integrity as "the ability to provide a reliable water supply at an acceptable level of service" — addressing demands for adequate pressure, fire protection and reliability of uninterrupted supply. Critical in preserving this integrity is maintaining adequate pressure and reliability of supply. Pressure transients are pressure waves that can be formed whenever there is a rapid change in water velocity (such as the rapid shutdown of a high-service pump). Negative pressure transients formed in water systems can cause intrusion of contaminants through cross connections and pipeline leaks. A study of 65 soil and water samples conducted at water main repair sites revealed fecal indicator microorganisms, and enteroviruses were immediately adjacent to the exterior of distribution system pipelines. Leaking sewer lines or failing septic systems were thought to be the source of contamination.

Evidence for backflow of contaminants into the distribution system can come from the automatic meter reading system. The systems can be programmed to send an alert through a fixed network telemetry system whenever the meter flows backwards. Like the MLOG data, an e-mail or text message can be sent to the operator whenever this occurs. Ongoing studies show that approximately 2 percent of the meters in various systems demonstrate such backflow and in some locations, such events occur every several days. The challenge to water utilities is to understand and control such events to maintain system integrity and protect public health.




Example of a negative pressure transient following a pump shutdown.

All nonresidential American Water customers are required to determine if they need to take steps to prevent cross connections and the possibility of backflow to the water system. These steps typically consist of the installation of an approved backflow prevention device and routine testing of the device. In some cases, residential customers are also required to install backflow prevention devices (i.e., new service connections, permanently installed fire sprinklers and permanently installed lawn sprinklers). Failure to comply can result in water service disconnection.

## Water Quality Risk Modeling

Quantitative Microbial Risk Assessment (QMRA) is a powerful tool for organizing and assessing microbial data. According to an American Academy of Microbiology report, the greatest value in microbial risk assessment is in the development of the model, not necessarily in the final answer. Proper application of microbial risk assessments can be valuable in guiding the selection and application of treatment processes, determining sensitivity analyses and organizing research needs. The key, however, is that the microbial risk assessment process is iterative – there is no single start or ending point, and therefore, it is always striving to improve on itself.

Integration of a QMRA with a distribution system hydraulic model is being performed to examine the public health impact of negative pressure transients. The advantage of this approach is that an extremely difficult situation to monitor (because of the transient nature of the event) can easily be modeled and mitigation approaches examined. For example, in the transient contamination scenario, the duration of the event was shown to have the strongest influence on risk because it determines the coincidence of consumption of the slug of contaminated water by customers. That is, the shorter the duration of the event, the lower the probability that someone would actually consume the contaminated water. The analysis could provide the basis for future regulations where prolonged events would be restricted. In the future, much greater emphasis will be placed on development of QMRAs as a cost-effective means of studying a problem and evaluating multiple solutions.

## Wastewater Infrastructure


Leaking sewer lines threaten potable water supplies.

The physical condition of the nation's 16,000 wastewater treatment systems is poor due to a lack of investment in plant, equipment and other capital improvements. Aging waste-water management systems discharge an estimated 850 billion gallons of untreated sewage into U.S. surface waters each year. Sanitary sewer overflows caused by blocked or broken pipes result in the release of as much as 10 billion gallons of raw sewage yearly. The EPA estimates the nation must invest $390 billion over the next 20 years to replace existing systems and build new ones to meet increasing demands.

What does this have to do with safe drinking water? One of the greatest challenges of the next century will be for water utilities to develop an integrated approach to water and wastewater management. Recognizing that deteriorating wastewater collection systems are a threat to potable supplies is a starting point.

American Water has examined novel technologies for examining wastewater infrastructure. Electroscan technology measures the electrical resistance of sewer lines, which are typically clay tile or cement pipes, where leaks are detected as a decrease in resistance. The technology was found to be 1.7 to 21 times more effective in detecting defects compared to the conventional closed-circuit television technique, 50-80 percent less expensive and 30-50 percent more productive (e.g., more pipes can be scanned). Moreover, because the results are quantitative, they can be put into a cost model that balances the cost of repairs against the decreased treatment cost of the infiltrated water. Because capital resources will continue to be scarce for utilities, such decision models will be important to maximize the effectiveness of repairs.

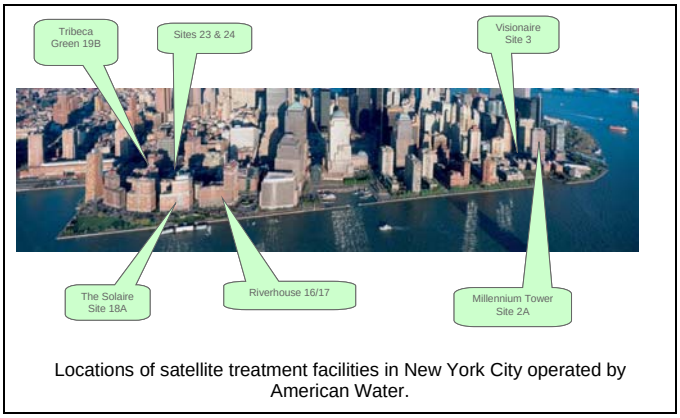
## Reuse of Treated Wastewater

Use of reclaimed wastewater is already a large and growing practice in the U.S., and nationally, it is estimated that 1.7 billion gallons per day of wastewater is reused. Reclaimed water use on a volume basis is growing an estimated 5 percent per year. In 2002, Florida reclaimed 584 million gallons per day (MGD) and California ranked second with 525 MGD. Other leading states include Texas, Arizona, Nevada, Colorado, Georgia and Washington. Constraints on water resources will continue the trend with increasing effects of climate change.

The challenge in increasing the use of reclaimed water is the lack of a pipe network to distribute the water, particularly in urban settings where the cost of installing dedicated networks would be enormous. Satellite wastewater treatment facilities "scalp" or "mine" wastewater from a sewer collection system and reuse the treated effluent for local recycling applications while returning the process residuals to the collection system for subsequent processing at the centralized treatment facility. The term "sewer mining" is particularly appropriate because it conveys a sense of value in that precious resources are mined.

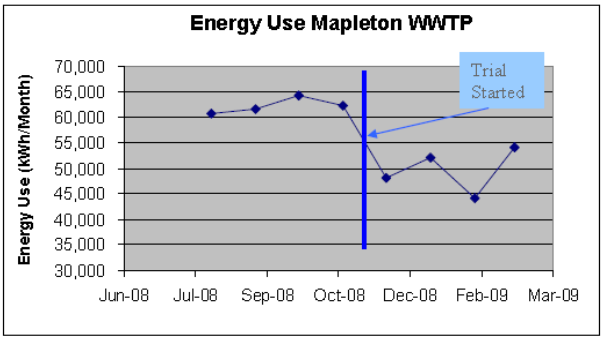
Sewer mining is advantageous because it enhances collection system capacity, helping to avoid the sanitary overflows mentioned above. Using reclaimed water instead of tap water also helps to increase the capacity of the drinking water supply. Because reclaimed water is treated and used on-site, it minimizes the infrastructure requirements and keeps distribution requirements at a minimum. Moreover, because "sewage flows downhill," reclaimed water processed at the final sewage treatment plant has to be pumped back to the community. Use of satellite treatment saves on pumping costs of reuse water and therefore reduces greenhouse gas production and enhances sustainability. Finally, because the satellite treatment can be tailored to the specific reuse application, it can reduce treatment cost and provides planning, operating and capital investment flexibility.

American Water operates more than 80 reclaimed water systems and annually recycles more than 2.6 billion gallons – mostly for irrigation but also for toilet flushing and cooling systems. The company has conducted a number of studies on reclaimed water quality and found that membrane bioreactors (MBRs) produce the best water quality. Importantly, MBRs combined with ultraviolet disinfection produced water with low levels of assimilable organic carbon, a nutrient that stimulates bacterial growth. MBR technology also provides an effective barrier for viruses and *Cryptosporidium* oocysts.




Locations of satellite treatment facilities in New York City operated by American Water.

One downside of MBR treatment is that it is typically more energy-intensive than conventional processes. Research conducted at Applied Water Management's Mapleton plant in Columbus, N.J., however, reduced the energy intensity by 40 percent and improved the effluent quality for nitrogen and phosphorus removal. American Water researchers are now looking into obtaining a patent for the process.




Reduction in energy use at the Mapleton MBR facility

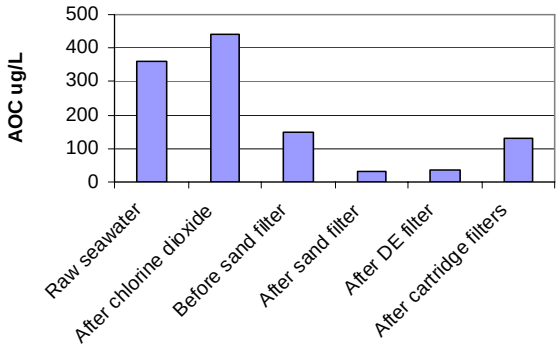
## Desalination Research

Worldwide, the desalination market is growing 15 percent per year as more water-scarce areas are turning to salt water as a source of drinking water. In the U.S., desalination is gaining growing attention since over 50 percent of its population lives in coastal areas where production and disposal is more feasible. Frost & Sullivan report the "U.S. Desalination Pretreatment Market" will double between 2005 and 2012.

Desalination processes, however, face challenges including brine disposal, pretreatment optimization, energy conservation and overall productivity of the membrane system. In coastal areas, the brine is typically disposed into the ocean or nearby estuary, but obtaining regulatory approvals can be time consuming and expensive. Inland locations can dispose of the brine in saline aquifers (if available) or concentrate the solution and recover the salt. The processes are energy- intensive, so attention to energy conservation is important. To make the process more energy-efficient, the desalination facility can be co-located next to a power plant and use the heated cooling water as the intake to the desalination facility. The warm water requires less energy to process through the membrane; however, the higher temperatures increase scale and biofilm formation.

Assimilable organic carbon (AOC) in drinking water is the portion of natural organic matter that is associated with growth of biofilm bacteria. The conventional AOC test is a bioassay using two well-characterized bacteria, which, when added to a pasteurized water sample, will grow with a known cell yield. Based on this yield, the concentration of AOC can be determined and compared to a known standard curve (typically acetate carbon). AOC is typically composed of small molecular-weight, easily biodegradable organic compounds that can readily pass through treatment barriers.

The conventional method to detect AOC was time consuming and cumbersome, until recently when American Water developed a bioluminescent assay by inserting the lux gene into the *Pseudomonas* P17 and *Spirillum* NOX strains. The assay is much faster and can be partially automated using a sensitive photon-counting luminometer. This biolumin-escence AOC test has been successfully used to monitor the biostability of reclaimed water and the method was published in the December issue of Applied and Environmental Microbiology.




A variation of the test has been developed for salt water using the naturally bioluminescent marine bacterium *Vibrio harveyii,* and the assay is being used to measure the concentration of AOC in salt and brackish water. This test can evaluate the effectiveness of desalination pretreatment processes to prevent biofouling on reserve-osmosis desalination membranes. Because biofouling is a major operational problem – increasing trans-membrane pressures, operational costs and increased energy use – it is anticipated that the saltwater AOC test could help to define pretreatment requirements for salt and brackish water desalination.

## The Energy/Water Nexus

Increasingly, it is being recognized that the production of energy and water are inextricably linked. Water is needed to produce energy and energy is needed to produce water. Moreover, this link is vital to U.S.

security and economic health. The ability to continue to provide both clean, affordable energy and water is being challenged, however, by climate change, limited water resources, increased water treatment requirements and pollution from energy exploration. Because the energy required for treatment and delivery of water accounts for as much as 80 percent of its cost, an insufficient supply of affordable energy will have a negative impact on the price and availability of water. Likewise, the electricity industry is second only to agriculture as the largest user of water in the United States. Electricity production from fossil fuels and nuclear energy requires 190,000 million gallons of water per day, accounting for 39 percent of all freshwater withdrawals in the nation, with 71 percent of that going to fossil-fuel electricity generation alone. Increasing water quality regulations typically require technologies that use more energy (like membranes, UV, ozone, etc.).

The options for reducing energy usage include wind, solar and bioenergy and may already be available to utilities. Solar energy has an advantage in that electrical production is the greatest from noon to 2 p.m. – typically when the cost of power is the greatest. American Water's Canal Road and Raritan-Millstone Water Treatment Plants in New Jersey used available land near the plants to build a ground-mounted photovoltaic system that in 2008 produced 818,000 kWh kilowatts of energy. The Yardley (Pa.) Water Treatment Plant in 2008 purchased 1,394,304 kWh of wind energy to meet 100 percent of its electrical demand. Combined, the three plants reduced their carbon dioxide emissions by 1,150 metric tons of CO2e.

Bioenergy, either from digestion of wastewater biosolids or from landfill gasses, is a renewable source that may already be under the control of the utility. In 2009, American Water researchers assisted its water companies in evaluating the use of methane from several nearby landfills. In addition, we are pursuing commercial bioenergy projects where wastewater solids are converted into methane that can be used to produce heat or electricity, or be compressed to operate the utility's fleet of vehicles.

## Improving Corrosion Control, Reducing Costs

American Water provides phosphate-based chemicals at more than 100 water treatment facilities. Many of those facilities use orthophosphate-based corrosion inhibitors, and over 70 percent of the corrosion inhibitors include zinc. Zinc orthophosphate (ZOP), however, is expensive and excessive concentration of zinc in wastewater discharge or sludge is an environmental concern. If all American Water facilities converted to nonzinc alternatives, more than 220 tons of zinc would be kept out of the environment.

American Water, working in conjunction with Virginia Tech, conducted studies at five sites in the company's system consisting of side-by-side pipe loops using ZOP with high zinc concentrations, low zinc concentrations and a nonzinc orthophosphate. The studies showed the nonzinc alternative was as effective for lead and copper corrosion control as the ZOP for the same phosphate dose. For cement (and asbestos-cement) pipes, zinc may play a role in stabilization of the cement through the formation of zinc silicates. Work is currently ongoing to determine if removing zinc from an existing corrosion control program will have an effect on the stability of existing corrosion-inhibiting scales.

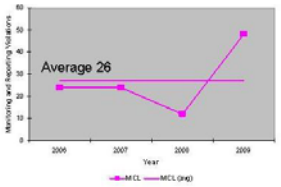
When measured on a phosphate basis, phosphoric acid is much cheaper than ZOP. Based on 2007 pricing, costs have the potential to be reduced substantially by converting from 1:3 ratio of ZOP to concentrated (75 percent) phosphoric acid. Cost savings may increase due to the increasing costs of zinc and transportation. Actual savings, however, will be highly variable due to local chemical bid prices and volumes used. Systems in Indiana, New Jersey, West Virginia and Illinois have either already converted to reduced or nonzinc orthophosphate or are planning to do so in the near future.

## Water Quality and Customer Communications

Producing high-quality water is paramount to the mission of American Water and across the company, more than 200 professionals are dedicated to ensuring that our product meets or surpasses state and federal drinking water standards. American Water scores greater than 99 percent compliance for both water and wastewater standards. Over the past three years, the company has averaged 26 times better than industry averages (as reported by the USEPA) for drinking water quality compliance, and 260 times better in

meeting monitoring and reporting standards. Our wastewater performance was double the national rate for systems without any discharge exceedances.

American Water is 26 times better than industry average for compliance with water quality standards (Maximum Contaminant Levels)

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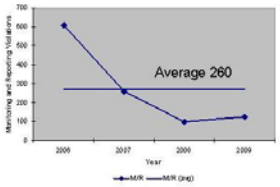


This high level of performance has been achieved through root cause analysis on past environmental violations, a strong focus on achieving compliance through robust Environmental Management Plans, identification of potential problems in advance through the environmental audit program, teamwork through routine conference calls and meetings, and direct technical assistance as needed.

Surveys have consistently shown that American Water customers highly value water quality and environmental stewardship. It is important, therefore, to effectively communicate our message of outstanding environmental performance. The annual Consumer Confidence Report is one tool to convey this message, with more than 3 million reports sent to American Water customers. Over the past three years, we've saved more than $75,000 by more efficiently producing these reports and reducing the number that are direct mailed. A substantial update to the Internet site added additional information on American Water's environmental program, stewardship activities and environmental protection. By entering their zip code, customers will be able to find answers to commonly asked questions by accessing water quality information specific to their system. Other activities to communicate our environmental message have included development of an environmental sustainability poster, newspaper and magazine articles, and several TV appearances.

## Innovation Development Process

In September, American Water announced the creation and staffing of the Innovation Development Process (IDP) Program, a mechanism to leverage American Water's market position and brand to enhance efficiency and reliability of service to customers and value to shareholders through technological innovation. Through the program, new technologies will be evaluated to both drive additional efficiencies into American Water and help grow the business.

The IDP's primary objective is to look for innovations that enhance the company's operational efficiencies and cost reduction, increase water and wastewater services, and position American Water for growth in the areas of reuse, desalination, wastewater and bioenergy. The program will also identify and pursue collaborations that could lead to new revenue streams and accelerate new technology adoption. During the first three months, 66 ideas were reviewed and four have proceeded to the Stage 2 level, where a preliminary business case is being prepared. Discussions are underway with venture capital partners who can bring startup capital, but value American Water's position and experience in the industry.

## Industry Leadership

By its very nature, American Water's research and environmental program is highly visible and provides an opportunity for thought leadership within the water industry. In 2009, the staff of the Innovation & Environmental Stewardship (I&ES) Department gave, on average, at least one presentation per week at local, regional, national or international conferences. Staff members serve in leadership positions on more than a dozen water industry committees or work groups, and have provided consultation to agencies such as the USEPA, Canadian Institute of Health and World Health Organization. American Water researchers help set the research plans for all of the major water funding agencies, thereby influencing the future direction of the water, wastewater and reuse water industries for the benefit of customers and shareholders. I&ES scientists serve as editors or peer reviewers for most of the major water publications while also mentoring students through college internships and high school science fairs.

It is important that American Water's research and environmental program has such high visibility because such openness promotes confidence, credibility and trust in the quality of work we do. In 2009, there was increased emphasis on knowledge transfer within the company through weekly updates, monthly webcasts, and periodic reports and presentations at company meetings. This internal technology transfer is increasingly important as fewer operating personnel attend national conferences due to shrinking travel budgets.

## For Additional Information

See also the American Water Internet site (www.amwater.com) for additional resources. For all questions or inquiries, please contact Dr. Mark LeChevallier at 856-346-8261, or mark.lechevallier@amwater.com.