Building Resilience

CREATING STRONG AND SUSTAINABLE CITIES AND COMMUNITIES

xylem
Let's Solve Water

Building Resilience

Communities must anticipate, prepare for, respond to, and recover from external shocks.

Ensuring Water Security

One-third of the world's population experiences water scarcity at least one month per year. In the face of growing needs and increasingly variable supply, communities must turn to innovative solutions to ensure water security.

Strengthening Critical Infrastructure

Around the world, cities face unprecedented pressures and rising risks. By creating robust, intelligent systems that are designed to withstand variability, cities can proactively protect members of their growing populations for years to come.

Driving Response and Recovery

By responding quickly and methodically in the aftermath of natural disasters, communities can save lives, time, and money. Rapid dewatering, diligent emergency services, and innovative reconstruction efforts can help cities 'build back better.'

Engaging Community Stakeholders

By involving the public in resiliency decisions and planning, communities are empowered to withstand unexpected climate events that affect their livelihoods and access to water.

Letter from Xylem's President and CEO

Cities around the world frequently face environmental challenges and natural disasters that threaten human lives and the natural world upon which we all depend. In the midst of rapid urban growth, cities also confront increases in exposure to water scarcity, changes in weather patterns, and other risks. Today's municipal leaders must work harder than ever to make their cities more resilient.

Fortunately, community leaders do not stand alone. As outlined in the United Nations' Hyogo Framework for Action, the private sector has an essential part to play in disaster risk reduction. Companies like Xylem are working to help communities anticipate, prepare for, respond to, and recover from natural disasters and environmental challenges. By ensuring the continuity of critical services, no matter the circumstance, Xylem seeks to play an integral role in creating resilient cities.

Increasing the resilience of cities is one of the most complex challenges facing public leaders around the world. According to the United Nations, 66 percent of the world's population will live in urban areas by 2050, posing a distinct need to create resilient urban centers. What's more, research by scientists at the International Panel on Climate Change indicates global economic losses from disaster events have increased significantly, further underscoring the need for communities to improve their ability to withstand such events. This growing concentration in both population and economic impact means urban centers are acutely exposed to natural disaster risk.

Many of the world's most destructive natural disasters involve water, whether through flooding (too much water in the wrong places); drought (not enough water in the right places); or contamination (unusable or hazardous water). These phenomena threaten human lives, endanger property and livelihoods, and inflict environmental damage. In the midst of any disaster, natural or otherwise, ensuring the supply of clean and safe drinking water to affected populations can become an urgent challenge. Xylem seeks to be a trusted provider of innovative and reliable technologies that meet this challenge by managing water sustainably across its entire cycle – from the headwaters of rivers to cities and farms and back to the oceans. Our tagline, "Let's Solve Water," points to our commitment to addressing the world's most pressing water challenges through partnership and collaboration.

This material provides real-life examples of products, services, and solutions that Xylem offers as part of our contribution to building resilience. We hope these stories will serve as a conversation starter. We are here to listen and participate in the discussion, and we stand ready to share our global experience with leaders around the world as they seek to build more resilient and sustainable cities.

Patrick Decker
President and Chief Executive Officer
Xylem Inc.

Introduction

Resilience – the ability to anticipate, prepare for, respond to, and recover from external shocks – can be increased in several ways.

Xylem breaks down resilience-building strategies into four categories of actions: ensuring water security, strengthening critical infrastructure, driving response and recovery, and engaging community stakeholders. These actions, based upon the needs and current trends of the water sector, combine to offer a holistic solution that considers the nuanced needs of urban areas, which can vary based on geography, population size, or governmental structure, among other metrics.

The first, ensuring water security, addresses the dire need for cities to supply clean water to the public continuously and reliably in all conditions. The scope of the challenge is vast: approximately one-third of the globe experiences water scarcity at least one month per year. Increasing water security is incumbent upon all stakeholders in the water sector.

The second, strengthening critical infrastructure, includes pragmatic solutions to the new and unprecedented pressure upon critical systems to support the needs of a growing population amidst unpredictable weather events. Populations are booming, urban density is increasing, infrastructure is underdeveloped or in need of an upgrade; a new set of disasters – both natural and man-made – is putting these vital centers at greater risk. By creating smart, robust systems that are designed to withstand variability, cities can preemptively protect members of their growing populations for years to come.

Thirdly, taking action to drive response and recovery efforts can lessen the severe impacts of disasters. Between 2000 and 2012, natural disasters caused $1.9 trillion in damage globally. By responding quickly and methodically in the aftermath of these disasters, communities can save lives, time, and money. Rapid dewatering, diligent emergency services, and innovative reconstruction efforts contribute to the efficient restoration of cities to their pre-disaster status – and even allow them to come back stronger.

Finally, cities must bring all stakeholders to the table in order to devise complete and effective solutions that meet the needs of all parties involved in the resilience discussion. By including multiple groups – including the public – in resiliency decisions and planning, communities are empowered to withstand unexpected climate events that affect their livelihoods and access to water.

Ensuring Water Security

One-third of the world's population experiences water scarcity at least one month per year. In the face of growing needs and increasingly variable supply, communities must turn to innovative solutions to ensure water security.

Of the many challenges facing communities around the world, water scarcity is perhaps the most pervasive. Municipal authorities are well aware of the highly visible dangers of floods, mudslides, tsunamis, and storm surges that have captured headlines around the world. However, the silent, creeping threat of water scarcity is just as dangerous to the future of a city.

The challenge of water scarcity is clear, present, and growing. In 2000, 150 million people lived in cities facing perennial water shortages, where available supply per person is less than 100 liters a day. Almost 900 million more lived in areas that faced seasonal shortages, where available supply dipped below this level at least one month each year. By 2050, these numbers are expected to grow to 1 billion and 3.1 billion people, respectively. Over half of the 6 billion urban dwellers predicted by 2050 will face critical water scarcity in their cities. As climate change produces variations in rainfall, these challenges could intensify in nearly every region of the world.

Cities are especially vulnerable to water shortages because their populations are highly concentrated and require reliable water supplies from their environs to maintain their intense pace of human and economic activity. For many cities, resilience means managing water variability and declining availability. Even minor, temporary disruptions of supply can affect millions of people and economic output. Longer-term disruptions can be fatal to a city's growth prospects.

A water secure future will require a range of solutions, including economic incentives, regulatory measures, and technological advancements. The following case studies focus on technology-based solutions, highlighting innovations that are helping cities address water scarcity today. The stories focus on Xylem's work in water recycling, reuse, and water resource optimization – and on the partnerships that make resilience possible.

By investing in solutions like these, cities can move toward a water secure future. Investments in resilient water infrastructure can help cities meet growing needs and reduce vulnerability to water variability and drought. While building resilience will be challenging, the good news for municipal leaders is that they are not alone.

All around the world, Xylem's employees are committed to applying our distinctive water technologies, proven expertise, and innovative thinking to create solutions for a water-scarce future. From wastewater reuse to aquifer recharge to desalination, the following stories demonstrate the breadth and depth of our experience in addressing water scarcity. As a trusted partner in countries around the world, Xylem is ready to help cities become more resilient by "solving water."

Aquifer Storage and Recovery in Wichita, Kansas

Challenge

Optimizing water supply sometimes requires more than measuring and monitoring – it can also call for physical management of water resources. Underground aquifers are an important water source for many cities around the world, especially when rainfall is scarce and surface water becomes unavailable. They can also serve as storage sites to save water for the future. But many aquifers face challenges such as over-exploitation, saltwater intrusion, and industrial pollution.

Location	Wichita, Kansas, USA
Challenge	Saltwater intrusion and micro-pollutants in aquifer
Solution	Aquifer recharge through treated freshwater injection
Product	Wedeco PDO ozone generators

These are the very problems that Wichita, Kansas faces in the Equus Beds Aquifer. In the last fifty years, this historically plentiful source of water has come under threat. First, the brackish Little Arkansas River is intruding into the aquifer, making salty what was once fresh. Second, nearby energy production has led to brine intrusion from oil fields, raising chloride levels in the aquifer to dangerous levels. Third, continual overdraft by the 1,620 wells in the region has led to steadily declining groundwater levels. At current withdrawal rates, the aquifer will fail to meet projected city water needs by the year 2100.

Local leaders, in concert with the U.S. Department of the Interior's Bureau of Reclamation, reacted to this trend by devising a plan to replenish and restore the aquifer. They decided to pursue aquifer recharge, which involves the injection of surface water into underground aquifers to restore water levels, dilute residual minerals, and resist the incursion of brackish water. To succeed, they needed to ensure the recharge water was of the highest possible quality, since injecting the aquifer with impure water could pollute the entire groundwater resource.

Solution

To accomplish these goals as well as counter water shortages due to population growth, the City of Wichita developed a multi-phase project that draws excess water from the Little Arkansas River. That water is treated and then pumped into the Equus Beds Aquifer for future residential, agricultural and commercial use.

The project includes incentives to save water for the future. By building up reserves, local and federal officials can work to ensure the City of Wichita's water supply will not run dry. "The water that we inject into the aquifer, we get credits for that water. Like a savings account, it allows us to build those credits up to use them sometime in the future when we need them," Don Henry, Assistant Director of Public Works and Utilities for the City of Wichita, said.

For the $247 million project, the City of Wichita ensured that recharge water would be stringently treated to prevent groundwater contamination. Together with partners Air Products and Chemicals, Inc. and APT Water, Wichita selected Xylem's Wedeco ozone generators as part of a complete Advanced Oxidation Process (AOP) solution to remove micro-pollutants such as endocrine disrupting compounds (EDCs), which can affect hormone function in humans and other animals. EDCs can often be traced to disposal of pharmaceuticals, personal care products, and runoff of agricultural chemicals. Wichita's leaders also designed this project specifically to address atrazine, a pesticide used in local farms.

Each ozone generator produces 2,100 pounds of ozone per day. This energy-efficient, fully instrumented system utilizes Wedeco EFFIZON® HP electrodes and variable frequency power supply technology to ensure reliable and cost-effective production of ozone that oxidizes harmful compounds, including atrazine. The AOP solution is also capable of killing pathogens and mitigating bromate formation as a carcinogenic by-product.

Sustainable Impacts

Shaun Porter, water industry specialist at Air Products said, "We are extremely pleased with our arrangement with Xylem to provide a cost-effective contaminant removal solution. The advanced oxidation system can help meet disinfection requirements while also destroying trace contaminants and minimizing the formation of by-products, such as bromate, making it ideal for drinking water applications, as well as water reuse and process water clean-up."

Since beginning operation in 2013, this project draws 30 million gallons of excess water each day from the Little Arkansas River, treats it, and injects it into the underground aquifers to ensure that wells in the surrounding area will continue to supply clean water to Wichita residents. Since the project's inception, the aquifer's levels have increased by nearly 15 percent and it is now 95 percent full. Xylem is proud to have partnered with the City of Wichita to renew its water supply.

The Little Arkansas River running through downtown Wichita, Kansas.

Innovative Water Reuse Solutions for the City of Los Angeles

Challenge

In the four year period between fall 2011 and fall 2015, the state of California experienced its worst drought on record since 1835. The drought was brought on by a combination of record-low precipitation levels and record-high temperatures; in fact, 2014 and 2015 were the two hottest years in California's recorded history.

In May 2015, in an effort to mitigate negative effects of the drought on the area's population and economy, California's state water board approved emergency drought regulations that aimed to slash water use in urban areas by 25 percent. The measures called for cities and water agencies to reduce water usage by eight to 36 percent.

Solution

To meet these requirements, water professionals have turned to water reuse as an essential and sustainable solution that will help secure the state's water needs. Soon after the water board's decision, Xylem was commissioned to deliver a unique water reuse system to increase the supply of purified, recycled water in Los Angeles. The proposed system, to be a part of the city's Terminal Island Water Reclamation Plant (TIWRP), includes a groundbreaking expansion of the Advanced Water Purification Facility (AWPF) that treats non-potable reuse water. Xylem's Wedeco MiPRO photo Advanced Oxidation Process (AOP) will ensure that the City of Los Angeles' TIWRP complies with California's stringent groundwater recharge regulations for indirect potable reuse in the safest, most cost-effective way possible.

Xylem's Wedeco MiPRO photo AOP solution will be installed as a final barrier against pathogens and contaminants that cannot be removed by other treatment technologies. The MiPRO photo system is part of a plant expansion at the AWPF, which includes microfiltration and reverse osmosis prior to AOP. The customized solution, validated through extensive pilot-scale testing, will be the first greenfield AOP design using ultraviolet (UV) light with chlorine for indirect potable reuse.

Location	Los Angeles, California, USA
Challenge	Unprecedented drought across California
Solution	Wastewater treatment and recycling for industrial use
Product	Wedeco MiPRO Advanced Oxidation Process (AOP) and Sanitaire aeration system

"This application of UV with chlorine as an AOP process is a significant breakthrough in treatment to make water reuse more sustainable and cost-effective," said Keel Robinson, North America Water Reuse Leader for Xylem. "The use of UV with chlorine for AOP will enable the Terminal Island Water Reclamation Plant to utilize their existing chlorination facility without having to add any new chemicals, and it will significantly reduce the life-cycle cost relative to the other types of AOP, such as UV with hydrogen peroxide."

The Terminal Island plant currently treats wastewater from more than 130,000 residents and 100 businesses in the Los Angeles harbor area, including the communities of Wilmington, San Pedro and a portion of Harbor City. The plant purifies the tertiary effluent to potable water quality levels for use in industrial applications. Additionally, the purified water is also used for recharging the stressed drinking water aquifers – which is particularly important in the wake of the drought. Through aquifer recharge, the recycled water serves as a barrier against seawater intrusion to protect the groundwater against increased salinity.

Sustainable Impacts

Construction for the second phase expansion began in 2015 with operation expected to commence in mid-2017. Upon completion, the plant will provide 12 million gallons per day of highly purified water

The Terminal Island Water Reclamation Plant (TWIRP), located in Los Angeles.

for beneficial use. "Los Angeles Sanitation is pleased to partner with Xylem as we continue to identify ways to increase recycled water capacity at our water reclamation plants. This effort will allow us to contribute more to groundwater recharge in the face of a historic drought," commented Traci Minamide, Chief Operating Officer of LA Sanitation. "The innovative technology – advanced oxidation process – aids in our commitment as environmental stewards to protect our most precious resource."

Additionally, Xylem will be supplying a Sanitaire aeration system to the Terminal Island Water Reclamation Plant for enhancing the performance of the existing wastewater biological treatment system. The Sanitaire fine bubble aeration grids will consist of Silver Series II membrane disc diffusers and ceramic disc diffusers to enhance oxygen transfer, reduce energy costs, and improve the quality of the water feeding the Advanced Water Purification Facility. Xylem has now provided fine bubble diffused aeration to all the Los Angeles Sanitation's wastewater treatment plants.

Water reuse technology will bring multiple benefits to Los Angeles, such as meeting growing water demands, safeguarding existing water supplies, and producing high-quality water at a lower life-cycle cost than developing a new water supply. These aspects will combine to deliver a resilient, drought-resistant water source with valuable economic and environmental benefits for the AWPF.

Mumbai's Metro Rail System

Challenge

Few countries face a water-scarce future as severe as India's, home to 16 percent of the world's population but only four percent of the world's fresh water. India's spectacular growth has fueled a population and consumption boom, which has resulted in an increased demand for municipal, industrial and agricultural water.

Mumbai, with a population of 20 million people, is India's financial capital. As with other cities of its size, Mumbai faces complex water challenges, ranging from efficient water use in municipal transportation operations to ensuring adequate water supply. Xylem is helping Mumbai manage its growth by making its mass transportation system more sustainable and water-efficient.

Solution

When Mumbai began designing its metro rail project, planners included a water reuse and recycling system in design requirements. They realized Mumbai would need a reliable treatment system that could turn the metro system's nearly 1.2 million liters of wastewater used daily into clean water for new uses, such as washing and irrigation, in a cost-effective way.

To turn this vision into reality, Mumbai's metro rail team selected advanced wastewater treatment solutions from Xylem, including the Sanitaire continuous flow Intermittent Cycle Extended Aeration System (ICEAS) process, which had already been utilized in nearly 1,000 sewage and treatment installations around the world. ICEAS treats water by aerating, settling, and decanting the water in a single system with reliable, energy-efficient, and cost-effective technologies, followed by integrated disk filtration and disinfection. Xylem's engineering capabilities ensured this compact water reuse plant would fit in the small space available by customizing it for the metro system's needs.

"This is a unique application where state-of-the-art process technologies are system-integrated in a very limited footprint," said Raveendra Bhat, Director of Treatment and Dewatering for Xylem India. "It is the most cost-effective way to produce non-potable reusable water for the Mumbai Metro Rail authorities."

Location	Mumbai, India
Challenge	Inefficient water use in public transit in a water-scarce region
Solution	Integration of non-potable reuse in the metro system's infrastructure
Product	Sanitaire Intermittent Cycle Extended Aeration System (ICEAS)

A metro train passes through Mumbai, India.

Reach Farther

In addition to the metro rail system, another Xylem initiative underway in India is the country's first water reuse plant to turn wastewater into potable drinking water, located in Vadodara, Gujarat. The plant integrates the ICEAS process with ultra-filtration membranes and a UV disinfection system to produce clean drinking water. By recycling water, the plant makes a necessary contribution to the creation of a water-secure future for India.

"It is critical for governments and private companies to make forward-looking investments in water reuse," says Colin Sabol, Xylem's Senior Vice President and President of Xylem's Analytics business. "If they have doubts about the viability of high quality water reuse, we can point to this plant and say, 'Yes, you can.'"

India's government recently identified infrastructure as the critical bottleneck to India's future, pointing to the need to ensure delivery of vital services that will underpin growth and human development. Cities around the country are facing severe water shortages and Xylem is eager to support them in meeting the challenge. "India's cities need to be looking closely at water reuse," says Sabol, "and we'll be there to help them make it a cost-effective reality."

Pre-treatment in Saudi Arabia

Challenge

In Saudi Arabia, surface water is scarce and rain is infrequent. Below ground, Saudi Arabia's deposits of crude petroleum fuel economic activity in the country, but groundwater resources are increasingly depleted by the needs of the crude oil industry, human consumption, and food security. Experts around the world estimate Saudi Arabia's groundwater supply will be completely depleted in mere decades.

However, the country's long coastlines provide access to plentiful seawater, and to solve its water supply challenges, Saudi Arabia has turned to desalination technologies. In 1927, Saudi Arabia installed its first desalination facility. Since then, the nation has increased its desalination production from 300 million liters per day to more than five billion liters per day today. When Saudi Arabia's second largest city, Jeddah, located on the western Red Sea coast, began to face the dangerous combination of water scarcity and growing water demand, the city's leaders turned once again to seawater desalination as a solution.

Solution

The Jeddah Phase 3 Plant, which is owned by the Saline Water Conversion Corporation, Kingdom of Saudi Arabia, produces 690 million liters per day of potable water to quench the city's thirst. The water is treated by reverse osmosis (RO) membrane technology, which extracts salt from seawater, creating high quality potable water. RO membranes are intended for removing salt and dissolved ions, but seawater is a soup of debris, silt, microscopic aquatic life, and other materials that can rapidly clog membranes, increasing energy consumption or even outright stopping membrane function. Pre-treatment technologies are critical to ensure that reverse osmosis systems function reliably and efficiently over time.

To solve the pre-treatment challenges of the Jeddah plant, Doosan Heavy Industries and Construction Company, the prime contractor, selected Xylem's Leopold filter technology. The 28 Leopold FilterWorx filters, which consist of Leopold Type S underdrain, washwater troughs, penstocks, air blowers, and filter

Location	Jeddah, Saudi Arabia
Challenge	Severe water scarcity
Solution	Pretreatment for seawater desalination
Product	Leopold FilterWorx

Racks of filters in a desalination plant.

media, pre-treat source water from the Red Sea by removing debris and contaminants that could disrupt the final stage of treatment. By optimizing plant function, Xylem's reliable and durable Leopold pre-treatment filters are helping Jeddah meet the needs of a thirsty and growing population.

Reach Farther

Since the inception of the Jeddah plant, Xylem has continued to contribute to solving Saudi Arabia's water scarcity challenges. In April 2017, Xylem announced the opening of an office in Riyadh, Saudi Arabia, as a part of Xylem's $35 million investment commitment to Saudi Arabia and the Middle East North Africa (MENA) region. This expansion includes providing localized products and expertise for these water-scarce nations.

"The opening of our Saudi Arabia office is an important milestone for our regional investment and supports our long-term strategy of providing sustainable water technology solutions to help solve the region's water challenges. The new office enables us to be closer to our customers and develop smarter, bespoke solutions that fit their unique needs, which also allows us to increase our capabilities," said Vincent Chirouze, Regional Director, Xylem Middle East and Africa. "Our new Saudi Arabia office extends our legacy of providing the same high-quality service and products our partners and customers have come to expect from Xylem."

Ecuador's Largest Irrigation Project

Challenge

"When there was a drought, there was no water for the animals, for the pasture, or for irrigating the produce we consumed and much less for crops for sale," an Ecuadorian citizen lamented in an interview with the World Bank. Ecuador, a country that is home to diverse biomes of desert, alpine, dry forest, and rainforest, is often subjected to both drought and flood conditions. This variability makes farming difficult, especially without irrigation systems, which can help provide a steady supply of water to crops. "It's heart-breaking, living so close to the river and yet having no water for the fields, having to rely on rains for the harvest to yield," another resident added.

Crews look below to the newly installed Flygt pumps for the Transvase Chóngon-San Vicente project.

Location	Javita River Valley, Ecuador
Challenge	Arid farming region cannot access water outside of rainy season
Solution	Irrigation system allows water access for farms
Product	Flygt AC Custom Pumps

Conditions worsened in 2011, when Ecuador experienced a severe drought. Estimated losses from the drought were over $200 million; according to the Emergency Operations Center of Ecuador, five provinces declared a state of emergency. After the drought, the Ecuadorian government took action, implementing new, multifaceted projects to reduce the impacts of the drought through the Integrated Project for Sustainable Environmental and Social Development in Ecuador (PIDAASSE) initiative.

Solution

The Transvase Chóngon-San Vicente project in the Javita River Valley, a part of the PIDAASSE initiative, was the largest irrigation project in Ecuador. It was spearheaded by Hidalgo & Hidalgo, the largest

Construction crews, city officials, and citizens celebrate the opening of the new system.

contractor in Ecuador and Xylem's local Flygt representative, Ivan Bohman Cia, who worked in concert with the Ecuadorian Water Secretariat, Senagua. To support this endeavor, Xylem supplied Flygt Custom Pumps with A-C customized hydraulics for optimum efficiency. These custom pumps now enable the irrigation of an arid region of 7,700 hectares in the Javita River Valley, transforming it into viable agricultural land. The $39 million project will meet both drinking water and irrigation needs of the river valley's residents for years to come.

The large-scale project involves pumping water from the Chongón canal over a distance of 50 kilometers to the San Vicente dam. Water is then pumped to the 500,000 cubic meter capacity Leoncito reservoir, where the four large Flygt AC Custom Pumps, each with a pumping capacity of 20,000 gallons per minute (GPM), drive the water to a tank 220 metres up 'La Strawberry' hill on the Chongón-Colonche range. From there, the water is discharged by gravity into the Camarona estuary and finally to the San Vicente dam.

The Javita River Valley's 85,000 inhabitants benefit from this system, which brings a reliable supply of drinking and irrigation water to an area where it was only previously available by water tanker or precipitation. Local farmers in the province of Santa Elena are now able to consistently grow crops including onions, cocoa, peppers, corn, and plums.

Reach Farther

The new irrigation system was officially inaugurated by the President of Ecuador, Rafael Correa, in November 2014. Since its inception through the PIDAASSE program, the Ecuadorian Ministry Coordinator of Strategic Sectors has reported encouraging results. The Ministry stated that the area's unemployment rate was reduced from 85 to 5.5 percent and emigration from the region decreased from 50 to five percent. Land value also rose by 30 percent. Today, six more irrigation projects are in the planning stages. The systems, which require an investment of more than $600 million, will provide water to a total of 200,000 hectares of land in Ecuador.

Tomas Brannemo, Senior Vice President and President of Xylem's Transport business said, "At Xylem, we work hard to deliver innovative products and solutions to solve customers' water challenges. We are delighted to be a part of this project which is making such a positive difference in the standard of living in this area."

Strengthening Critical Infrastructure

Around the world, cities face unprecedented pressures and rising risks. By creating robust, intelligent systems that are designed to withstand variability, cities can proactively protect members of their growing populations for years to come.

Urban infrastructure relies on a number of distinct networks to supply city dwellers with food, water, energy, transportation, and other services. These infrastructure networks are vital to the life of modern cities, and when they are damaged, human health, welfare, and the economy are jeopardized. Unfortunately, many cities are confronting a "new normal" of increased natural hazards, weather volatility, and aging networks that threaten to impair and overwhelm the critical infrastructure upon which lives depend.

In the United States, the U.S. Department of Homeland Security defines critical infrastructure as "assets, systems, and networks, whether physical or virtual, so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof." Other countries have articulated similar concepts. Protecting these vital systems amidst variable threats, such as disaster and disrepair, requires cities to become as innovative – and resilient – as possible.

Increasing the resilience of critical infrastructure is a multi-dimensional challenge, but at its root is the need to protect a city's most vital systems from harm and enable them to bounce back quickly when they are impaired. Effective water management plays an important role in urban resilience, as floods and contaminated water can significantly damage the performance of essential networks, such as those that support transportation, energy, and wastewater services.

Beyond the challenge of disasters, cities and rural areas alike must face the consequences of aging infrastructure. The breakdown of critical networks due to disrepair can be just as damaging as an unforeseen natural disaster. Unlike disasters, however, the threat of aging infrastructure is certain and constant. According to the Value of Water Campaign, only one-third of infrastructure repair needs are currently met in the United States. For water and wastewater infrastructure alone, the American Society of Civil Engineers estimates necessary repairs in the U.S. will total $105 billion by 2025; in Asia, the Asian Development Bank estimates $800 billion in infrastructure investments will be needed by 2030.

Investments in the resilience of critical systems can help cities reduce losses, ensure operational continuity, and save lives. By prioritizing the development of intelligent infrastructure, including the installation of systems equipped with the ability to monitor water quantity and quality, cities can prepare themselves to weather any storm that may come.

Effective water management stands at the heart of infrastructure resilience, as floods and contaminated water can impair the performance of essential networks, such as those supporting transportation, energy, and wastewater services. The following case studies outline how Xylem works with partners to build resilience in urban transportation, water, and power infrastructure.

Leak Detection and Environmental Monitoring with Smart Systems in Singapore

Challenge

In Singapore, smart water management is a national priority. With few domestic water resources of its own, Singapore has invested in innovative ways to manage its water supply. Currently, water demand is met by a combination of desalination, reuse, imported water, and local catchment systems.

The island city-state's Public Utilities Board (PUB) estimates that by 2060, total water demand will nearly double. To sustain this rapid growth, Singapore continues to seek new ways to ensure water flow to citizens remains uninterrupted. One area it has aggressively targeted is leak detection and remediation, since unresolved leaks waste significant amounts of precious water and energy each year in municipal water systems.

Location	Singapore
Challenge	Supporting the management of a critical water supply infrastructure nationwide
Solution	Utilizing smart monitoring systems
Product	YSI EXO sensors, Visenti's smart water platform

Solution

In partnership with Singapore's PUB, Xylem brands Visenti and YSI teamed up to develop and implement an end-to-end real-time monitoring Smart Water Grid. This grid was designed to optimize energy consumption, water quality, and leakage detection. Implementation of the project began in December 2013 and included the deployment of 210 wireless sensors to collect real-time data on water quality, pressure, flow, and acoustic emission from the water supply network through Visenti's smart water platform.

YSI EXO multi-parameter sondes, which serve as the grid's wireless sensors, link to the PUB's supervisory control and data acquisition (SCADA) system, where data is stored in cloud servers. These sensors and software provide PUB's water operations and planning teams with decision support services including detection of leaks and bursts, system modeling, demand prediction, and operational simulation, all accessible through the cloud.

Since its installation, the system has successfully detected more than 100 pipe bursts. It has also enabled real-time trouble-shooting via immediate feedback, which helps isolate low pressure zones in high consumption areas and saves time and frustration. In one instance, a commercial customer notified PUB of low water pressure at their facility, prompting a field team to begin a search for leaks in the surrounding area. Pressure tests collected by a nearby sensor did not show any unusual activity, allowing the field team to discern there was no leak or burst in the vicinity. The team soon discovered the commercial building's tank was too small to provide adequate supply for the demand during peak consumption.

By using the Smart Water Grid to respond to customer's needs, the PUB can now quickly and accurately determine the source of water supply problems. Moreover, PUB also has the ability to monitor water quality in the system through smart water technology.

In addition to responding to customer reports and monitoring quality, the system has provided PUB with up-to-the minute data about demand in the network. This insight helps system operators optimize long-term reservoir maintenance activities. Furthermore, PUB engineers have used the system's simulation interface to test-run numerous scenarios and complex crises to better prepare for future risks.

Reach Farther

Outside of the municipal water grid, Xylem and Singapore's PUB have partnered to expand the country's ability to monitor its surface water supply. The PUB uses YSI water quality sensors and Visenti software to measure dissolved oxygen, turbidity, chlorophyll, pH, conductivity, and other parameters in lakes and reservoirs before water enters treatment plants for processing. These water quality sensors are also used to ensure the health and safety of water in rivers and harbors.

Since the installation of the municipal and surface water monitoring systems, Singapore's PUB has lowered the percentage of unaccounted-for-water (UFW) in the system to approximately five percent, a rate significantly lower than most countries' average UFW of 10 to 30 percent. By combining YSI's sensor technology and Visenti's software, national UFW is reduced, the life of Singapore's water system infrastructure is extended, pipe bursts are reduced, assets can be rehabilitated quickly, and time and money are saved. From the municipal grid to the surrounding environment, Xylem is partnering with Singapore to help manage precious water resources, saving money and securing the country's future.

Smart Urban Development in Kuala Lumpur

Challenge

Malaysian citizens are no strangers to heavy rainfall – the nation is annually subjected to major rainfall events from monsoons during the summer months. Historically, monsoons have caused severe flooding in Malaysia, especially in areas near water bodies, which swell to unusually high levels during storms. Located at the confluence of the Klang and Gombak rivers, Greater Kuala Lumpur is one such area prone to serious flooding. As the nation's capital and the home to more than seven million people, flooding can cause the bustling metropolis to skid to a halt. As the city continues to develop, growth has placed additional pressure on its drainage system's ability to cope with flash floods. Following a series of devastating storms and subsequent flooding in the early 2000s, Kuala Lumpur needed relief.

Solution

In 2004, the Stormwater Management and Road Tunnel (SMART) project was commissioned by the Malaysian government as a solution to control unwanted water in the capital. The innovative system was designed to redirect floodwater before it entered the city center through a 9.7-kilometer long tunnel. The $600 million project includes several elements: a holding basin with a floodwater storage capacity of 600,000 cubic meters, a reservoir with a capacity of 1.4 million cubic meters, and a bypass tunnel. It also includes a control center for managing, operating, and maintaining the SMART system.

Location	Kuala Lumpur, Malaysia
Challenge	Urban flooding and overcrowding
Solution	Adaptable, multiuse tunnel for floodwater storage and traffic movement
Product	SonTek Argonaut Doppler, Flygt pumps

Perhaps the tunnel's most innovative feature is its three-kilometer "double-decker" motorway. During drier periods, vehicles can use SMART's second lower motorway (as depicted in the diagram), thus relieving traffic on the city's main highways.

Sensors also form an important part of the SMART system by providing information to control center operators, allowing them to manage the tunnel and motorway system. The SMART tunnel uses 16 of Xylem's SonTek brand Argonaut acoustic Doppler current meters, each positioned at specific heights in the water. The meters offer real-time data on water level and velocity. As river levels rise, the SMART control center uses this information from Xylem's Argonaut acoustic Doppler units to guide decisions.

Pumps also play a critical role in floodwater control. With 23 pump stations currently installed in the SMART system, all floodwater in the tunnel can be dewatered within 24 hours. To power these stations, the SMART team reviewed a vast array of pump offerings from multiple manufacturers; 76 of Xylem's Flygt pumps were selected due to their superior performance and quality.

The main pumps were installed next to the tunnel gate, where strong turbulent flow occurs as the floodwaters hit the gate. Before starting the project, Xylem evaluated several calculations to minimize power requirements and ensure maximum strength and efficiency. In addition, special concrete walls and inlet openings – designed with the help of Xylem technical support – protect the main pumps. Large inlet pumps were also installed in the long tunnel to dry the dewatering pumps.

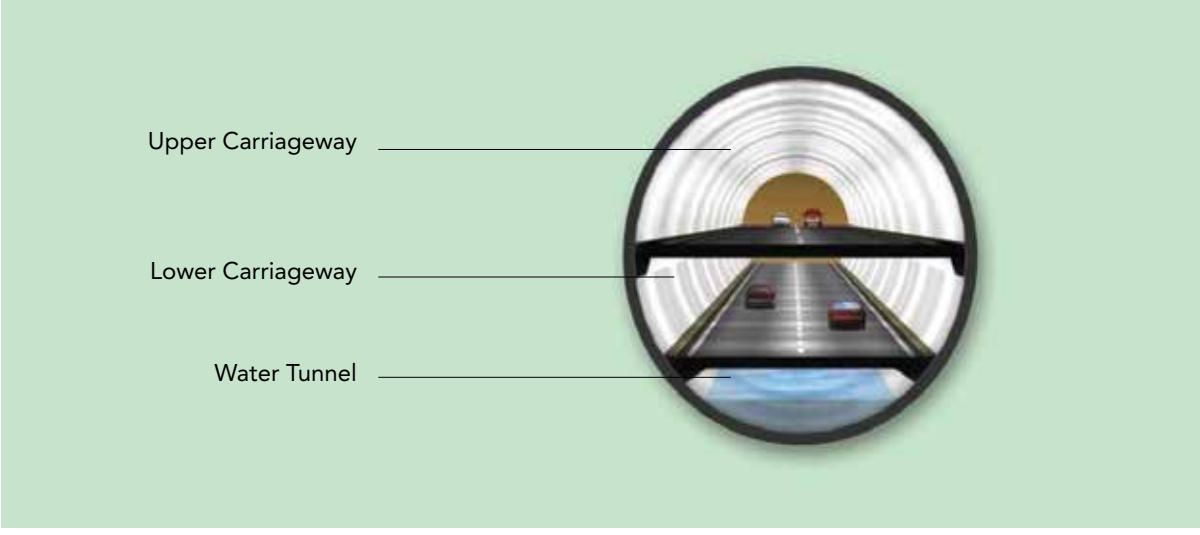
Xylem also manages all maintenance for pumps in the tunnel. "We have a very strong partnership with the customer and work closely with them, providing training and maintenance know-how for their staff," says William Choong, Transport Lead Manager for Xylem Greater Asia, who was involved in the SMART contract.

Sustainable Impacts

After nearly four years of combined effort from the 6,700 people involved in the project's design and construction, SMART opened to traffic in 2007. To date, the tunnel has been used nearly 50 times to divert floodwater and has successfully prevented the city of Kuala Lumpur from further serious flooding. Each day, approximately 40,000 vehicles use the SMART tunnel.

The project is a novel example of a public-private partnership to improve the functionality and affordability of resilient urban water systems. Since its inception, SMART has been recognized with considerable media coverage and several international engineering awards. The National Geographic Channel dedicated an episode of its "Megastructures" series to the SMART system.

Representatives from other cities facing similar flooding issues, such as Singapore and Jakarta, have also visited the SMART tunnel to inform the evaluation of similar projects to manage storm water issues in their own communities. "When the idea for the tunnel was first suggested, there were a lot of skeptical voices; it has since proven to be a model that works and supports the resilience of this dynamic city," concludes Choong.



A diagram of the SMART system.

Flygt Submersible Pumps in Sims Bayou

Challenge

Sims Bayou begins near Missouri City, Texas, and meanders northeast until it reaches Buffalo Bayou. After significant flood events in the Sims Bayou watershed, the Federal Emergency Management Agency called for federal and regional flood damage reduction projects and a major floodplain remapping effort in May 2016. The project's success would bring multiple benefits to the City of Houston's suburbs that lie within the Sims Bayou watershed. Not only would the communities be at a significantly lower risk of flooding, property owners would also profit from significant flood insurance rate reductions. However, the Sims Bayou project quickly proved to be a complicated one.

One of the City of Houston's major proposed improvements in Sims Bayou involved the installation of a new wastewater lift station. Due to large variations in total daily head – a static head of 46 feet but reaching as high as 138 feet – pump selection was difficult. The concern centered on the need for net positive suction head when only one pump was running. The consulting engineer, Klotz Associates, had ruled out the use of variable frequency drives. The City of Houston also preferred to build a "Station in the Round" to lower construction costs. To meet these needs, Klotz Associates proposed a 42-foot diameter, 46-foot deep wet well to accommodate five to six pumps. Klotz then contacted Xylem, knowing the project would require a team effort.

Solution

Based on Klotz Associates' design, Xylem distributor Hahn Equipment recommended six Flygt 280-horsepower submersible pumps for use at Sims Bayou. Xylem engineers then conducted a computational fluid dynamics (CFD) study to analyze potential fluid flow problems at the station. The CFD study revealed problems with flow distribution at the approach to the proposed pumps. Several of the pumps would suffer from excessive swirl and uneven velocity distribution. After careful analysis and consideration of the CFD findings, six Flygt pumps were selected over competitive equipment, which offered higher horsepower units.

Location	Houston, Texas, USA
Challenge	Improving a wastewater treatment plant and reducing flood risk
Solution	Meeting variable needs by engaging the client, consultant, and distributor
Product	Xylem Flygt pumps and computational fluid dynamics study

Based on the Xylem team's CFD assessment, Hahn Equipment advised the City of Houston that the total horsepower of the six Flygt pumps would be less than five competitive pumps, resulting in a lower cost solution to this pumping challenge.

After selecting Flygt, the stakeholders, including the project manager, consulting engineer, and Hahn Equipment, met to develop pump customizations that could offer a resolution to problems outlined by the CFD. Suggested modifications to the pumps included enlarged inlet ports as well as guide vanes inside the ports and the inlet chamber. These changes significantly improved the hydraulic conditions. Through collaboration, the team was able to avoid costly future modifications to the project.

Reach Farther

By operating directly in the liquid being pumped, Flygt submersible pumps do not require special structures to support them, considerably reducing construction costs. They are smaller than their non-submersible counterparts because the motor and hydraulics are integrated into one compact unit, resulting in pumping stations that are less complex to build. Finally, they take up less space and eliminate noise and cooling problems due to submerged operation.

The Sims Bayou project was designed and constructed in an environmentally responsible manner; an increasing number of birds and wildlife can already be seen along completed segments of

the bayou and at the stormwater detention basins. Moreover, citizens residing in neighborhoods adjacent to Sims Bayou now have a lower risk of flooding than in the past; property owners benefit from reduced flood insurance rates.

Working closely together, the client, consultant and distributor pooled their knowledge to bring a challenging project to successful completion. In the words of Whit Kelley, Hahn Equipment Sales Manager, "I believe the main reasons that we were successful on this project were three fold. First, Flygt's willingness and ability to help with design; secondly, Flygt's ability to witness test the pumps in the U.S.; thirdly, the fact that Hahn Equipment has had a long and successful track record with Klotz Associates, Inc. and the City of Houston." In the end, the City of Houston, Klotz Associates, Xylem, and Hahn Equipment worked arm-in-arm to deliver a successful lift station for the communities near Sims Bayou.

Disaster Recovery with Sensus FlexNet System in Alabama

Challenge

Storm events are common for most utilities, and Alabama Power Company is no exception. However, on April 27, 2011, the tornado and corresponding storm that ripped through Tuscaloosa County and surrounding areas was anything but typical – before the skies cleared it would become the most powerful, destructive event in the area's recorded history, damaging or destroying many utility assets.

Location	Huntsville, Alabama, USA
Challenge	Severe storms and tornadoes
Solution	Quick restoration via outage management systems and advanced metering
Product	Sensus FlexNet™® communication network

A tornado-damaged home in northern Alabama after the 2011 disaster.

More than 400,000 Alabama Power Company customers lost power. The National Weather Service determined the path length of the violent tornado to be 80.3 miles, with a maximum damage path width of 1.5 miles. Reports from Tuscaloosa indicated 43 people were killed, with over 1,000 injured.

Solution

Alabama Power Company had been preparing for severe weather to hit the state long before the morning of April 27, 2011. The utility's parent, Southern Company, began laying the groundwork for response management and system modernization by requiring its utilities to integrate their current outage management systems (OMS) with advanced metering infrastructure (AMI) systems. By fall 2010, Alabama Power had successfully merged a proprietary OMS with Xylem's Sensus FlexNet™® communication network, a multi-application, fixed-base, two-way wireless communications network. The FlexNet system brought a number of key benefits, including real time situational analysis and grid stabilization.

The ability to collect data from smart meters and deliver it over the FlexNet system added a new dimension to operations. The new information available from it could be used to enhance the utility's outage estimation systems. Before using the FlexNet system, the Alabama Power Company's OMS could estimate where service is out, but couldn't reflect where service was back on, or more importantly, what locations could actually take power. That, according to Derl Rhoades, Alabama Power Company's AMI Network Operations and Translation Team Leader, is critical in major outage events.

"Let's say there are 500 residences connected to one switch. We can know the switch is open either through the SCADA system indicating the switch is open or by pinging the affected meters. But if the switch is closed, the utility can't know the status of those 500 customers." This issue was solved when the OMS was integrated with the FlexNet system, allowing Alabama Power Company greater situational awareness during outages.

Upon installation, the Sensus advanced meters were able to alert the utility of the signal outages sooner than customers could call the utility to report the outage. With these messages, the OMS can specify critical loads, typically hospitals, fire stations or traffic signals, for priority restoration. "The meter data carried by the FlexNet system is able to provide enough clues to give us the information about individual premises that the legacy OMS can't," Rhoades explained.

An important consideration in selecting the FlexNet system was that it required far less infrastructure, reducing exposure to damage. Thousands of miles of transmission and distribution lines and structures could be lost in a storm, leaving alternative communication systems vulnerable because downstream meters may not be able to communicate their status in an outage.

Sustainable Impacts

Durability in a storm was a significant factor in selecting an AMI technology several years ago, but no one at Alabama Power could have anticipated the magnitude of destruction from the storm that hit the southeast that day in April. The Sensus FlexNet system remained largely intact after the storms blew through, save for one tower: its top 40-foot section was bent a full 180 degrees down toward the ground. The antenna from the crippled tower, however, was still transmitting a signal.

Eight days after the storms, Alabama Power reported that most of the critical infrastructure had been repaired. With the OMS and FlexNet combination, the utility could ensure power was on without having to dispatch personnel. This allowed restoration work to be prioritized for the most affected areas and bring daily life back to normal as quickly as possible.

Alabama Power's Rhoades reported that most service was restored two days faster than what had been experienced in the region's worst storms up to this point, including Hurricane Katrina. "It's tough to say outright what the FlexNet AMI system contributed to the speed of restoration," said Rhoades, "but there's no question that it was a contributing factor to effective response management by continually presenting up to the minute data."

Driving Response and Recovery

By responding quickly and methodically in the aftermath of natural disasters, communities can save lives, time, and money. Rapid dewatering, diligent emergency services, and innovative reconstruction efforts can help cities 'build back better.'

When disaster strikes, the first questions to go through the minds of city managers and municipal leaders are often about water: do we still have access to water? Is there flooding? Has our water been contaminated? The dual challenge of delivering clean water to citizens and removing wastewater and stormwater runoff safely becomes one of a city's top priorities after a disaster.

In recent years, city officials have found themselves facing these challenges increasingly more often. The last five years have brought a large number of unpredictable, devastating natural disasters around the world. Global natural disasters created losses of $45 billion in 2013 - on the heels of $72 billion in losses in 2012. In total, a 2016 study by the World Bank asserts global annual consumption losses from natural disasters are equivalent to $520 billion; this forces approximately 26 million people into poverty each year.

Intelligent recovery processes can drastically reduce these statistics. Given the critical importance of basic infrastructure services, every hour gained in restoring services can prevent millions of dollars or more in losses. Investments include technologies, insurance, systems, and services that accelerate infrastructure repair or restoration to minimize downtime before services resume.

After storms strike, flooding can be immediate, destructive, and even fatal. To cope with the onset of water pouring into streets, homes, commercial buildings, and subway tunnels, cities need resilient drainage systems powered by reliable and powerful pumps. They also need 24/7 drainage assistance to "dewater" flooded areas quickly during and after the crisis.

From emergency sewer bypass systems that allow wastewater infrastructure to continue to operate in crises, to pump station backups, to the emergency water technologies that get clean water where it needs to be, Xylem provides innovative solutions and services to help cities increase resilience. By assessing post-disaster resilience alternatives, cities can create new systems that allow them to withstand the damage of natural disasters. From disaster onset to recovery, Xylem works to adequately equip our customers to handle any events that come their way.

Dewatering Argentina's Cities After a Massive Storm

Challenge

A massive rainstorm swept through Buenos Aires Province on April 1, 2013, causing extensive flash floods that washed away cars and resulted in the loss of over 60 lives. In the province's capital of La Plata, 40 centimeters of rain fell in just two hours, overwhelming drainage systems and nearly submerging homes. The Argentine government called the storm an "unprecedented catastrophe." More than 3,000 people were evacuated from their homes during the storm, and tens of thousands were left without electricity.

Location	Buenos Aires, Argentina
Challenge	Major flooding after an unprecedented storm
Solution	Dewatering buildings and infrastructure
Product	Xylem dewatering team with Godwin pumps

The downpour also caused a power outage and fire at Ensenada Station, Argentina's largest oil refinery, operated by YPF. YPF's President and CEO, Miguel Galuccio, said in a press conference that while the plant's drainage systems could process and properly dispose of 95,000 cubic meters of rainfall in six hours, the April 2013 storm flooded the plant with 315,000 cubic meters of water, over three times its capacity. Stormwater rose to 1.7 meters in some areas of the plant.

Godwin pumps dewatered approximately 30,000 cubic meters of water in Buenos Aires.

Solution

During and after the storm, Buenos Aires city officials and private customers contacted Xylem for help in removing floodwater from buildings, underground parking lots, and supermarkets. A staff of six people from Xylem's Rental & Aftermarket division provided 24-hour service throughout the entire crisis. Since Xylem's dewatering pump products are designed to work in any environment on a range of power sources, including gas, diesel, and in some cases, even car batteries, the dewatering team was able to respond even in areas experiencing power failure.

"Our Godwin pumps dewatered approximately 30,000 cubic meters of water in Buenos Aires city," says Osvaldo Greco, who at the time was Managing Director of Xylem's business in Argentina. "In the flooded neighborhood of Barrio Privado San Andrés, Tigre, the operational flow was 29,000 cubic meters, and in Pasionaria, San Isidro, our Flygt equipment transported water amounting to 9,000 cubic meters."

Xylem was also called in to dewater the Ensenada oil refinery in La Plata. "We drained 4,000 cubic meters from the refinery's pump house and 205,000

cubic meters from the area around the plant," says Gustavo Ortega, Head of Aftermarket and Rental. "We began our technical assistance at the plant on April 2nd and finalized our work on April 4th, though our equipment continued to operate after that. Overall, we have learned a lot from this experience and have now formed a crisis committee for these kinds of emergencies."

Reach Farther

A year after successfully removing the flood water from the Ensenada oil refinery, the plant elected to purchase specialized dewatering equipment from Xylem. After Xylem's quick response during the storm, YPF purchased 15 high-power Godwin dewatering pumps in order to be prepared for future flooding emergencies and reduce long-term risk.

"The Ensenada plant is a significant facility with the capacity of refining 188,000 barrels of oil on a daily basis," said Gustavo Chaab, YPF refinery manager. "It is crucial that a plant of this size have the ability to restore plant operations quickly following an incident. The Godwin pumps that we purchased will ensure that we are fully prepared for such an event in the future."

Post-Disaster Reconstruction in China

Challenge

Lushan County is located on the upper reaches of Qingyi River in the northeast of Ya'An area and on the west side of the mountains surrounding the Sichuan Basin in China. Covering an area of over 1,350 square kilometers, Lushan County is connected with Wenchuan County on the north and Chongzhou City on the northeast. In April 2013, a 7.0-magnitude earthquake jolted Lushan, making the remote town in west Sichuan the subject of nationwide focus.

The Lushan earthquake attracted great attention from Chinese leadership on national, provincial, and city levels. Just one month after the earthquake, Xi Jinping, the President and Chairman of China, accompanied by Zhang Gaoli, the Vice-Premier of the State Council, visited Lushan to offer condolences to the masses in the earthquake-stricken area and oversee earthquake relief work. President Xi encouraged all involved to "carry out scientific reconstruction as quickly as possible."

Location	Lushan, Sichuan, China
Challenge	Destruction from a 7.0 magnitude earthquake
Solution	A new integrated, resilient wastewater pump station
Product	Flygt TOP Pump Station

Lushan, Sichuan, China.

The only visible aspect of the underground system in Lushan.

Solution

Since the earthquake, the devastated area has recovered rapidly. After learning of the disaster, Xylem's Flygt engineers quickly contacted the client and drove to Lushan for a face-to-face discussion about how Xylem could contribute to the rebuilding of the city. Upon hearing the local government's desire to build a sewage pump station as quickly as possible, they recommended a newly developed solution: Flygt's the optimum pump (TOP) integrated pump station. The station, which could be concealed underground, would integrate well with the city's newly built scenic area.

Integrated pump stations avoid key drawbacks of traditional pump stations, such as long planning and construction cycles, because most the station is pre-fabricated. This process shortens the construction period, ensures project quality, and does not require construction of a pump room, thus leaving scenic areas undisturbed. Moreover, the underground pump station can operate unattended thanks to the advanced automation technology, which also minimizes maintenance needs.

The post-disaster reconstruction of Lushan was a significant task, with engineering and infrastructure construction operations carried out under tight schedules. In addition to stringent project quality requirements, the integrated pump station had to be delivered to the site within four weeks. Thanks to the joint efforts of Xylem's sales and technical engineers, the Flygt TOP integrated pump station was successfully delivered, installed, and commissioned ahead of schedule.

Sustainable Impacts

The new pump station delivers Lushan's wastewater, collected in the Hanjiang Ancient Town, through a pipeline buried under the river to a wastewater treatment plant five kilometers away. With the exception of an elegant control cabinet that sits on a piece of lawn (pictured), all other structures of the pump station are concealed underground. Manager Li of Sichuan Huaxi, General Contractor, embraced the design concept of the integrated pump station. "Local residents cannot imagine at all that a pump station is hidden right underground when they walk in the scenic area as there's neither sound of water pump operation nor pungent odor."

The integration with the surrounding environment of the scenic area, combined with the stable operation of Flygt integrated pump station, serves as a testament to Lushan's ability to collaborate and rebuild. Now, the restored Hanjiang Ancient Town is striving to become a national AAAA-grade tourist attraction.

A well-hidden access point to the underground system in Lushan's scenic area.

Coastline Protection along the New Jersey Shore

Challenge

Route 35 isn't just a road winding down the New Jersey shore. Along one stretch, it's the transportation lifeline for island towns like Bay Head and Mantoloking, which sit on a sliver of land between the ocean and bay in New Jersey.

In 2012, Superstorm Sandy tore through these towns and ripped up Route 35. The historic storm, which affected more than nine states on the Atlantic Coastline, caused $36.8 billion in damage to New Jersey alone. o Much of this destruction was to the state's infrastructure; for residents of Bay Head and Mantoloking, the damage to route 35 prevented much-needed emergency services from accessing their towns.

Solution

The New Jersey Department of Transportation made immediate stopgap repairs to reopen the road. After the initial fix, the Department of Transportation began planning a long-term repair and redesign of Route 35. They selected Xylem's technology as a part of the rebuilt roadway. Xylem pumps and controllers are key elements in creating a safer and stronger highway. "This road is now ready to withstand even the worst of the worst-case scenarios," says Chuck Narod, a Xylem sales representative in the United States.

Location	New Jersey, USA
Challenge	Rebuilding after historic destruction from Superstorm Sandy
Solution	Creative road redesign with below-ground pump stations
Product	Flygt Slimline pumps and MultiSmart controller

The road redesign includes improvements to the pavement, utilities and landscaping, but a new drainage system featuring Xylem's unique submersible products is the key to storm-proofing this vulnerable stretch of Route 35. As part of the $265 million reconstruction project, Xylem supplied nearly 50 powerful Flygt Slimline submersible propeller pumps and another 27 smaller submersible pumps in nine pump stations along the 12-mile section of the road that was hardest hit during Superstorm Sandy. The Xylem pumps – located in concrete-encased pump stations underneath the road – are capable of working underwater, and each

Destruction from Superstorm Sandy in Mantoloking, NJ.

Slimline propeller pump can move 9,000 gallons of water a minute. If a storm overwhelms the regular drainage sewers, Xylem's pumps will kick in and push the excess water back into the bay.

"There's not a lot of room for these pump stations under the road, so the unique small-footprint design of our Flygt Slimline pumps was a big plus for the contractors working on this project," says Mark Umile, Manager of the Xylem sales branch located in Malvern, Pennsylvania, about 100 miles from the New Jersey coast. "It allowed them to design smaller concrete vaults for the pump stations," thereby reducing capital costs even further.

Each pump station is connected to a control panel – located 12 feet above the ground level to protect it from storm surges. The role of the control panel is to coordinate the operation of the multiple pumps inside each station. Again, Xylem had the right product for this part of the job: Xylem's MultiSmart controller. The MultiSmart is a pre-programmed controller that can run multiple pumps without complication.

"You don't need to hire someone to control the pumps or create a custom control system for each pump station," says Narod. "For this job, one MultiSmart controller can be programmed quite easily to run the multiple Xylem pumps down in the pump station to ensure we're getting out as much water as possible, as fast and efficiently as possible."

Sustainable Impacts

For Narod and Umile, both long-time industry veterans, this project has a little more meaning than most. It's not just that they are helping New Jersey recover and rebuild from Superstorm Sandy, it's that they are helping the state in ways that will not be fully realized for years to come.

"Our company doesn't just sell products and walk away from the job," says Umile. "We're an industry leader with a large service department that's going to be here when we're needed. So while we're solving a problem for the state today, New Jersey is also going to find out years from now that we are still here to help them out. They might not know it today, but they'll find out tomorrow when another huge storm hits and they need somebody they can depend on to help them get through it. That's where we come in. And that feels good."

Route 35 after Superstorm Sandy made landfall.

Emergency Bypass in New York City's Wastewater Treatment Plant

Challenge

At around 11:20 AM on July 20th 2011, one of the hottest days of the year in New York City, a catastrophic pump fire broke out at the North River wastewater treatment plant. The fire caused a shutdown of the plant's five main sewage pumps, resulting in severe environmental consequences.

Located on the banks of the Hudson River, the North River plant in Manhattan is one of the city's 14 sewage treatment plants, treating about 125 million gallons of wastewater every day. After the shutdown, that wastewater was no longer being treated. Instead, it built up in the North River plant's sewer system. Over a period of 52 hours, between 215 and 260 million gallons of raw sewage spilled over directly into the Hudson and Harlem Rivers, creating an immediate and highly visible emergency.

Solution

As firefighters fought to bring the four-alarm blaze under control, officials from the New York City Department of Environmental Protection (NYC DEP) moved quickly. One of the first calls the NYC DEP made was to Pumping Services, Inc., a New Jersey-based representative for water and wastewater equipment and a distributor for Xylem's Flygt branded submersible pump products. John Corkery, Pumping Services' municipal sales manager, remembered receiving the call. "After understanding the situation, I immediately contacted the Xylem team and confirmed that we had numerous large Flygt submersible pumps available to help fix the situation – but they were hours away in Ohio and Georgia," he said.

With the plant's main pumps out of service, Corkery recommended an emergency "pump-around" to transport raw sewage to the plant's primary treatment equipment, a necessary but complex undertaking. "We were being asked to lift wastewater 65 feet, so it immediately became a submersible pump application," said Corkery. That's when he called his colleagues who handle Xylem's Godwin portable dewatering pumps. While the Flygt submersible pumps were being sourced, Xylem's Godwin pumps team moved into action.

Location	New York City, New York, USA
Challenge	Fire at a wastewater treatment plant causes sewage discharge
Solution	Emergency 'pump around' to redirect sewage to treatment facility
Product	Xylem dewatering team with Godwin and Flygt pumps

Xylem began to organize equipment and logistics required for immediate shipment. Sales engineer Ryan Booth recalled, "We immediately began to mobilize the high density polyethylene pipe (HDPE) required for the pump-around." Approximately 9,000 feet of HDPE, fusion machines, and operators were required to get the plant up and running again. "The critical issue was getting the pipe here immediately," said Booth. "The pumps are no good without the pipe."

Once the NYC DEP authorized the emergency equipment on Thursday night, Xylem trucks hit the road from as far west as Ohio and as far south as South Carolina and began arriving on site on Friday morning, about 10 hours after the notice to proceed with Flygt and Godwin pumps. Xylem's Scott Myers took the wheel of one truck, driving through the night from Ohio to bring the pumps to New York. By Friday morning, in record-breaking heat, Xylem personnel began building the pump-around; the team also set up a 24-hour operations center to channel information to the DEP and other contractors working at the plant.

In addition to the HDPE piping and valve equipment, submersible Flygt sewage pumps were in service on-site, each lowered into individual 8-foot by 70-foot deep trash-rack channels. Dewatering pumps were also used to remove several feet of residual firefighting water from the pump room. Xylem Pumping Services provided start-up services and training to NYC DEP personnel on the operation of this pump-around system.

By 9:30 p.m. on July 23, the NYC DEP reported the flow of sewage into the river finally ended. The Flygt pumps were operating smoothly, each performing at a rate of 10 million gallons per day.

Reach Farther

Thanks to rapid-response efforts, the Harlem and Hudson rivers were clean once again for the boaters, bathers and business owners who use New York City's waterways. Summing up the response to the emergency, Steve Askew, DEP Plant Superintendent for the North River facility, said, "It is really an impressive installation. The timetable that it took to get it here and get it up and running, from the thought process to operation, was literally just a few days. It really was quite a monumental effort." DEP Deputy Commissioner of Operations Kathryn Garcia echoed this sentiment in her official statement regarding the fire. "Because of [their] effort, the water quality impacts and associated recreational use restrictions were much more limited than might otherwise have been the case. DEP is very grateful to the employees and contractors who got North River up and running."

Disinfection after Legionnaires' Disease Outbreak in Germany

Challenge

In late summer 2013, hospitals in the German city of Warstein began seeing a surge of patients with Legionnaires' disease, a potentially fatal form of pneumonia contracted by breathing small airborne droplets of water contaminated with the *Legionella pneumophila* bacteria. By early September, more than 150 people were infected and two people had died from the disease in Warstein.

Location	Warstein, Germany
Challenge	Waterborne disease outbreak
Solution	UV treatment of contaminated wastewater effluent
Product	Wedeco LBX 1000 UV system

Legionella bacteria naturally live in fresh water, where they seldom cause illnesses that harm humans. However, problems arise when the bacteria enters a closed, man-made water system. *Legionella* outbreaks can occur in large contained water systems, such as in hospitals, hotels, or cooling towers. Upon entering the human body, the bacteria manifest into Legionnaires' disease. Because the disease is not contagious, the outbreak in Warstein alerted medical and environmental professionals that the outbreak was likely occurring in a city-wide system, resulting in many infections.

In an attempt to halt the frightening and fast-escalating outbreak, city officials and environmental regulators immediately turned their attention to Warstein's wastewater pathway. Since *Legionella* bacteria thrive in stagnant water, the first target was an industrial cooling tower that showed traces of the bacteria. The tower was shut down, but the rate of new infections didn't slow down. Attention quickly turned further upstream to a local wastewater treatment plant. Sure enough, the wastewater plant was emitting water with high levels of *Legionella* into the river that serves as the industrial cooling tower's water source.

Solution

Suddenly, the phones at Xylem's facility in Herford, Germany, were ringing off the hook. Located just 80 miles from Warstein, the Xylem site manufactures Wedeco ultraviolet (UV) disinfection systems for households, industries, and drinking water and wastewater treatment plants.

One call came from consultants, enlisted by regional regulators to help find a solution, who worked previously with the Herford team on solutions

for reducing pharmaceuticals and other micro-pollutants in wastewater treatment plant emissions. A second call came directly from the company that operated the Warstein wastewater treatment plant. "They were simple and urgent requests: help us find a treatment solution very fast," says Achim Ried, Chief Engineer of Higher Order Solutions for Xylem's Water and Wastewater Solutions business. "We had just a little information about the water matrix and the level of *Legionella* in the water, so we did a quick calculation and looked for a system that would be available right away."

The Xylem team was confident that ultraviolet light (UV) treatment was the right solution. Ultraviolet light directed at the water deactivates viruses and bacteria – including *Legionella* – by physically damaging their DNA. Within the hour, the team located a Wedeco LBX 1000 UV system in its Herford test site and pulled together a crew of experienced service technicians to deliver and install the system. By this point, the Warstein outbreak had become global news, and the pressure was on to find a quick solution.

"Usually, it would take weeks to find the right system for the situation and then get it ordered, delivered and installed," says Sven Baldig, managing director of Xylem Services. "But this was a case where quick action was vital, and we responded to the acute needs of the city."

In less than one day – cooperating closely with the wastewater treatment plant operators – the Xylem team had the system in place, with all the water piping and electrical connections complete.

Reach Farther

Since the speedy fix in early September, there have been no more reported cases of Legionnaires' disease in Warstein. The fast ultraviolet system installation from Xylem helped keep this dangerous outbreak from doing even more damage. In fact, the city of Warstein was so happy with the LBX UV's performance that one year later, the city purchased a Wedeco TAK 55 UV disinfection system, designed to match local site requirements with minimum footprint and minimum system life cycle costs. The new, permanently installed system fulfills Warstein's goal of >99-99.9% reduction of *Legionella* bacteria.

Unfortunately, the *Legionella* outbreak in Warstein is not an isolated incident. The United States Center for Disease Control (CDC) reported the number of people with Legionnaires' disease globally grew by four times from 2000 to 2014. In an effort to reverse this increase, Xylem has partnered with DC Water and Corona Environmental Consulting on a project to eradicate *Legionella* outbreaks in Washington, D.C. The objective is to create a scalable project that can be employed by cities around the world. The project includes testing for the bacteria at treatment plants, conducting focus groups, and surveys of utilities and building owners. By collaborating with cities and water professionals, Xylem hopes to continue making headway in the effort to eradicate Legionnaires' disease around the world.

Legionella pneumophila bacteria.

Engaging Community Stakeholders

By involving the public in resiliency decisions and planning, communities are empowered to withstand unexpected climate events that affect their livelihoods and access to water.

Societies' capacity to recover from disaster will be a defining factor in their ability to survive in a future marked by uncertain and severe weather. Surmounting this challenge requires building resilience with an all-hands-on-deck approach from public leaders, civic organizations, and the private sector. While water scarcity is a global problem, water issues are by their very nature deeply local, and the water scarcity challenge is in fact a vast array of local crises played out repeatedly around the world.

To sustainably and effectively manage these local water crises, all stakeholders, including citizens, governments, public water professionals, and the private sector, must play a role in developing a response plan. By including all groups in a community, resilience becomes a team effort – and a shared responsibility. At Xylem, we believe collaboration and cooperation are key ingredients to the development of resilient cities and healthy communities.

We collaborate with private, non-profit, and public organizations around the globe. One way this is achieved is through Xylem Watermark, the company's corporate citizenship program. Xylem Watermark supports humanitarian efforts to provide and protect clean water where it is needed most and to educate people on water issues. In partnership with several leading non-profits and other international and local partners, Xylem Watermark is helping large cities provide their most vulnerable residents with safe water.

City leaders need water solutions as diverse as the challenges they face, and Xylem aspires to be a helpful partner in "solving water." Around the world and over the years, Xylem has worked with cities and communities to manage water scarcity. Whether reusing and reclaiming wastewater, developing new supplies, identifying and preventing leaks and loss, improving efficiency, or monitoring the entire system, Xylem has the capability, know-how, and passion for understanding and solving water issues in partnership with public leaders, communities, and the private sector. Let's join together to confront these challenges.

Community Education in Atlántico, Colombia

Challenge

After torrential flooding in December 2010 and January 2011, nearly 90 percent of the southern area of the Department of Atlántico in Colombia was submerged by water; in some places, water reached the rooftops. The disaster, brought on by La Niña, caused the loss of 114 lives and displaced more than 100,000 people. It took three months for the water to recede and for residents to begin slowly trickling back to their homes.

Location	Atlántico, Colombia
Challenge	Torrential flooding in an unprepared community
Solution	Community education and flooding training programs
Product	ECOPAD from Xylem Watermark and MercyCorps

Solution

Mercy Corps, a Xylem partner, is a leading global organization empowering people to survive through crisis, build better lives, and transform their communities for good. Together, Mercy Corps and Xylem helped those who returned to Atlántico to prepare for future disasters. One of the methods employed was a flood simulation. As part of a water-related disaster risk reduction initiative (DRRI-Water), funded by Xylem Watermark, Mercy Corps trained and organized a group of community leaders, collectively referred to as ECOPAD ("Equipos Comunitarios para la Prevención y Atención de Desastre", or Community Teams for Disaster Prevention and Response) to work with the community on emergency response and prevention.

ECOPAD members participated in extensive disaster risk reduction trainings, and then went door to door talking with families about how and why to prepare for emergencies. The group helped community members develop emergency plans and kits, consisting of important documents, such as birth certificates, diplomas, and identification, as well as medicine, flashlights, and a change of clothes. The first community to enact a full-scale disaster simulation was Candelária. ECOPAD worked tirelessly to prepare residents, many of whom were refugees still living in makeshift housing, as their original homes remained uninhabitable.

Atlantico, Colombia.

Energy was high on a Friday morning in anticipation of the flood simulation. When the whistle blew, sounding the call to start the evacuation, residents gathered their emergency kits and walked calmly from their homes to the assigned meeting point on higher ground. When everyone reached the meeting point and was accounted for, members of ECOPAD thanked everyone for coming and after a round of applause, instructed everyone to return home in the calm and orderly way that they had come.

One participant remarked on the way back, "This exercise has educated us and prepared us for an eventual disaster should it come." The feeling of preparedness from the mock exercise helped reassure the community residents that they are now ready for whatever the future may bring.

Reach Farther

Through ECOPAD, Xylem Watermark and Mercy Corps empowered communities in Colombia to become more resilient to disasters. By focusing on citizen engagement and involvement, the ECOPAD program and others like it help to create communities that are prepared to stand strong against environmental challenges, armed with preparedness plans and situational knowledge.

Colombia is one of six countries included in the DRRI-Water projects implemented by Mercy Corps with funding from Xylem Watermark. The program in Colombia benefitted over 50,000 people.

Spanning six countries on three continents, Xylem Watermark's support for the Disaster Risk Reduction Initiative with Mercy Corps not only impacted more than 800,000 beneficiaries, but also helped to advance thinking about risk and resilience. In China, Colombia, Ethiopia, Indonesia, Nepal, and Tajikistan, the partnership generated field-based insights into the importance of engaging communities, forging strong government-community linkages, and incorporating sustainability into water-related DRR activities.

Waterkeepers at the Third Pole

Challenge

The Himalayan glaciers, which stretch east from northern Afghanistan, Pakistan, and India, through Nepal and Bhutan, and into the neighboring Tibetan Plateau and China, are the source of fresh water for nearly four billion people in Asia. Unfortunately, these glaciers, known as the 'third pole,' are rapidly melting.

Three major rivers – the Indus, the Ganges and the Brahmaputra – arise in the Himalayas, fed by glaciers, and flow directly into Pakistan, India and Bangladesh. The Yellow, Yangtze, Mekong, Irrawaddy and Salween Rivers also arise from the Tibetan Plateau and flow directly into China before continuing into Myanmar, Laos, Thailand, Cambodia, and Vietnam. These rivers are the source of water for drinking, washing, irrigation, fishing and industry.

The Indus and its tributaries sustain communities throughout Jammu and Kashmir, including the Indian city of Ladakh. Along its way, its river systems support temperate forests, plains, arid countryside, and countless communities. Unfortunately, the Indus, and the way of life of Himalayans, is under threat. There is little awareness of the dangers of plastic litter, which is migrating into the region's rivers and drinking water. Additionally, the glaciers are melting rapidly, endangering the springs and rivers used for drinking water.

Location	Ladakh, India
Challenge	Rapid glacial melt endangers water supply
Solution	Waterkeeper Alliance training exercises and monitoring
Product	YSI partnership with Xylem MercyCorps

Ladakh has also faced extreme weather events, including rare and catastrophic flash floods, worsened by rapid deforestation that has removed nature's flood-defense mechanisms. In August 2010, flash floods in Ladakh damaged over 71 towns and villages, claiming 225 lives. Floods in September 2014 killed more than 550 people in the Kashmir region and devastated the livelihoods of survivors. These incidences, which are expected to become more common, have been termed "Himalayan tsunamis."

A Waterkeeper tests the local water supply.

Solution

Through the Waterkeeper Alliance, a global network of grassroots leaders, 65 Waterkeepers and Affiliates are able to apply their passion and commitment to the health of river ecosystems in Ladakh and beyond. In January 2016, Waterkeeper Alliance launched an initiative to protect the Himalayan waters and its growing network in India, Nepal, and Bhutan, and work with Waterkeepers throughout the region – and across the globe – to protect the 'third pole.'

In July 2016, the Waterkeeper Alliance held their first training exercise in Ladakh, where Himalayan Glacier Waterkeeper has been leading communities and young people to protect the region's water resources. Himalayan Glacier Waterkeeper currently includes 20 Waterkeeper Affiliates based at Drukpa monasteries in streamside villages throughout Ladakh.

At the Druk Padma Karpo School, YSI experts trained the Himalayan Glacier Waterkeeper team and its 20 Affiliates on the use of water-quality monitoring field equipment. Drukpa nuns and students from the school were also trained on how to test water quality using monitoring kits. With these tools, the community is able to monitor the physical and chemical water quality conditions of their local waterways and advocate for the protection of clean water.

To launch the Himalayan Glacier Waterkeepers' water quality monitoring program, equipment from YSI (Professional Plus and pH10A) was used to measure dissolved oxygen (DO), conductivity, and pH. These instruments were supplemented with other tools to measure for nutrients, turbidity and E. coli. Ongoing water-quality testing will help establish baseline characteristics of these waterways and allow Waterkeepers to assess and address any changes that may occur.

Reach Farther

Beyond Ladakh, the Waterkeeper Alliance and YSI are also working in Bhutan, a small Himalayan kingdom east of Nepal. Last November, Waterkeeper Alliance staff traveled to Bhutan with a team of scientists to conduct physical, chemical and biological assessments of water quality in three Bhutanese rivers, the Thim Chu, Paro Chu, and Punakha Chu, as well as various streams. Working alongside Thim Chu Waterkeeper and partners from the National Environment Commission and the HydroMet Division of the Ministry of Economic Affairs, they installed the country's first three real-time water-quality monitoring sensors.

Protecting the Himalayan glaciers, rivers, and the countless communities that depend on them is a colossal challenge, but the Waterkeepers in the Ladakh, Bhutan, and Himalayan communities are optimistic.

Members of the Himalayan Glacier Waterkeeper team.

Disaster Risk Reduction in Far Western Nepal

Challenge

Kanchanpur District in the Far Western region of Nepal is witnessing a shift to more unpredictable and severe annual flooding. In the last decade, Western Nepal has been repeatedly hit by floods; record-setting floods occurred in September 2008 and again in June 2013. The damage to infrastructure, private property and livelihoods was substantial and the dangers seem to only grow more intense. "We're getting more droughts and fires during the dry season, and more floods and landslides during the monsoon season," explained Shreelal Pokharel, a local Disaster Risk Reduction Officer.

Additionally, health institutions in Nepal reported a dramatic increase of diarrhea during flood events due to inundated and contaminated water sources, lack of access to safe drinking water, and poor sanitation and hygiene practices. As a result, the effects of waterborne disease weigh heavy. In addition to microbiological quality, ingestion of arsenic-contaminated ground water was reported.

Location	Kanchanpur, Nepal
Challenge	Empowering Nepali citizens to withstand flooding
Solution	Engaging the community through mitigation work and preparedness planning
Product	DAWN from MercyCorps and Xylem Watermark

Solution

Mercy Corps, a leading global organization empowering people to survive through crisis, build better lives, and transform their communities for good, teamed up with Xylem Watermark to bring aid to Nepal through the creation of the Disaster Risk Reduction and WASH Interventions in Far Western Nepal (DAWN) program. The overall goal of the DAWN project was to increase Disaster Risk

Flooded fields in Nepal.

Reduction (DRR) and water, sanitation, and hygiene (WASH) interventions in Kanchanpur through community awareness, small-scale mitigation works, and disaster preparedness planning. The project encompassed multiple innovative strategies, including the involvement of the community's women to promote DRR and WASH practices. The project also utilized engineering initiatives to mitigate flood risks. Finally, DAWN included a community-established emergency and maintenance fund to sustain the area's water supply systems during future floods.

The project, built on the Nepali government's existing national program for community disaster risk management, is known as Disaster Management Committees. Mercy Corps and Watermark formed Water and Sanitation sub-committees, led by women, with a target of 75% female membership. Through these sub-committees, communities in Western Nepal can build an understanding of risk, vulnerability, and disaster management, with a focus on water and sanitation related to disasters.

Raising awareness about risk and its underlying factors is crucial to reducing a community's vulnerability. At the same time, increased public awareness of WASH behavior is also an important precursor to avoid or reduce water-borne disease outbreaks during emergencies. Public awareness campaigns for both DRR and WASH are being carried out in flood-prone communities through door-to-door outreach, street drama performances, and radio programs.

Reach Further

Beyond public outreach and training programs, the DAWN project also included initiatives to address water quality issues. In collaboration with the District Water Supply and Sanitation Division (DWSSD), DAWN identified local sites for elevated water access points. By installing hand pumps on platforms raised to the highest previous flood levels, the water points are resistant to contamination. In cases where arsenic-contamination was found, Mercy Corps responded by piloting low cost bio-sand arsenic filters. This innovative technology involves the filtration of water through sand, and gravel in either clay pots or plastic buckets.

Finally, DAWN established biological initiatives to reduce risks in communities that are settled along rivers and at risk of yearly flooding. By growing locally-available grasses, transplanting them to river banks, and then coupling them with deeply rooted plants on the slopes and top of the banks, the river banks' erosion is reduced – and, consequently, so is the community's flood risk. Shreelal Pokharel explains the concept's benefits: "The grass is called moorje. The people are starting their own nurseries to grow it, and then they plant it on top of the embankment. It stabilizes the soil — and it's also used to make rope."

In the future, DAWN plans to continue working with the community to build nurseries for growing moorje; such plants will be produced and managed by the women-led Water and Sanitation sub-committees. All together, the DAWN project benefitted close to 7,000 Nepali community members to increase their resilience to future disasters.

Xylem |'zīləm|

1) The tissue in plants that brings water upward from the roots;
2) a leading global water technology company.

We're a global team unified in a common purpose: creating advanced technology solutions to the world's water challenges. Developing new technologies that will improve the way water is used, conserved, and reused in the future is central to our work. Our products and services move, treat, analyze, monitor and return water to the environment, in public utility, industrial, residential and commercial building services, and agricultural settings. With its October 2016 acquisition of Sensus, Xylem added smart metering, network technologies and advanced data analytics for water, gas and electric utilities to its portfolio of solutions. In more than 150 countries, we have strong, long-standing relationships with customers who know us for our powerful combination of leading product brands and applications expertise, and a sharp focus on developing comprehensive, sustainable solutions.

For more information on how Xylem can help you, go to www.xylem.com

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xylem
Let's Solve Water

Xylem, Inc.
14125 South Bridge Circle
Charlotte, NC 28273
Tel 704.409.9700
Fax 704.295.9080
855-XYL-H2O1 (855-995-4261)
www.xyleminc.com