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COVER
Rising waters from wet weather require water and wastewater utilities to find creative solutions. Houston Water turned a flooded service area into a test bed for decentralized, mobile treatment options. Read more on p. 28.

Testing a mobile treatment option

The City of Houston's emergency wastewater response to Hurricane Harvey

Aisha Niang, Shannon Dunne, Devin Sloane, Peter Brooks, Michael Warady, and Scott Schaefer

On Aug. 26, 2017, Hurricane Harvey made landfall in Texas. During the following days and weeks, more than 1270 mm (50 in.) of precipitation fell in the greater area around the City of Houston. This wet weather led to significant flooding and disruption or failure of utility service for several communities.

To guard against this type of disruption in the future, Houston Water, a division of the City of Houston Public Works, solicited requests for proposals to develop decentralized, grid-independent, mobilized wastewater treatment capacity operated by licensed wastewater operation professionals. Houston Water extended this request via the Texas-based water technology hub, Accelerate H2O. This solution is meant to prevent service interruptions even if some of Houston Water's water resource recovery facilities (WRRFs) become inundated again. Along with testing which technologies worked best in this situation, the utility also developed techniques and procedures to deploy these mobile units.

◀ **These relatively small emergency systems can be brought to the site of facilities that are damaged – here they are sitting alongside the Turkey Creek Wastewater Treatment Plant – or they can be set up in remote locations that lack stand-alone treatment systems.** waterTALENT LLC

Project parameters

Houston Water developed and executed this project during and immediately following the hurricane's landfall. Because of the hurricane, the utility's existing WRRFs were insufficient to meet treatment requirements. At the height of the storm flooding, 18 of 39 WRRFs were flooded. Two WRRFs – Turkey Creek and West District – remained offline for several weeks.

To help alleviate this, Houston Water sought mobile wastewater treatment units able to manage flow demands ranging from 190 to 1140 L/min (50 to 300 gal/min). The utility wanted the units to handle influent with unknown water quality to serve as a bypass to existing WRRFs and wastewater lift stations. These units also could support the cleanup of other low-lying, flooded, or otherwise affected areas.

The request for proposals generated a lot of interest. More than 20 entities responded to Accelerate H2O's solicitation; however, upon further examination, most were deemed unable to mobilize available treatment trains.

Another complicating factor for this project was its unclear end. Compared to a tornado or brief seismic event, Hurricane Harvey resulted in flooding in and of itself, and was further exacerbated by unprecedented emergency releases from regional water storage, resulting in flooding that continued for far longer than was expected with lasting consequences beyond any recent hurricane.

For this project, Houston Water ultimately partnered with a water and wastewater project development and technology company; a provider of licensed, experienced water and wastewater operators; and a specialized water and wastewater engineering consultant.

The project afforded the opportunity to gather data and evaluate the systems against such criteria as cost, readiness, operational demands, and, of course, treatment performance. Costs examined included both asset rental or purchase costs as well as costs associated with utilities, freight, personnel hours (licensed operators), and consumables required. Readiness was measured qualitatively by looking at the local or regional availability of equipment, site preparation required, and the experience level required of operators. Operational demands were measured qualitatively as well by looking at the ease of ongoing use, monitoring, and optimization. Treatment performance was based on effluent concentration.

The results of this effort have implications for wastewater utilities' ability to increase resilience to unforeseen shocks to their system. These findings can inform the disaster response and recovery components of the Prepare-Absorb-Respond-Recover-Adapt infrastructure resilience framework as shown in the figure on p. 31. This project straddles both the Respond and Recovery phases.

Mobile unit makeup

The project deployed two independent mobile treatment train configurations with teams of experienced, licensed operators to supplement existing treatment works and support overall disaster response and recovery efforts. The project put a series of constraints on the treatment solutions to ensure that they would have the best chance of success:

- The assets had to be able to arrive in a matter of days given the urgency of the emergency.
- The solutions needed to be mobile, skid-mounted, or otherwise easy to transport.
- The flow requirement range was set at 190 to 1140 L/min (50 to 300 gal/min).
- Effluent had to meet regulatory requirements for biochemical oxygen demand (BOD), total suspended solids (TSS), and ammonia.
- Licensed operators had to be available to manage system processes around the clock.

Even though Hurricane Harvey put the Turkey Creek Wastewater Treatment Plant out of commission for an extended period, the facility's operators were onsite to help set up and operate the mobile treatment systems that Houston Water sought out to ensure treatment. waterTALENT LLC

These six frac tanks combined with a pre-screening and clarification technology provided a treatment method capable of handling up to 1140 L/min (300 gal/min). waterTALENT LLC

As stated, the project assessed these two treatment trains in terms of cost, readiness, operational demands, and treatment performance.

Costs. Train No. 1, being composed of simple pre-screening, blowers, field-expedient coarse air diffusers, and a lamella plate settler was less costly than Train No. 2, which included pre-screening, pure oxygen, and the ballasted-floc polishing unit. Train No. 2 also was more expensive on an operating basis.

Readiness. Train No. 2 had more novel components with longer lead time, particularly related to the proprietary polymer required for optimal performance. Furthermore, the ballasted-flocculation requirements of a pressurized potable water supply, tighter pre-screening requirements, proprietary polymers, and sand (ballast) inputs, made it a more challenging technology to deploy. Also, Train No. 2's requirement of a level site to support the hydraulics of the unit made it more challenging.

Operational demands. Operating Train No. 1 was a challenge as it was run entirely manually. Operators performed frequent sampling and testing to optimize treatment processes and chemical dosing and Train No. 1 required around the clock operational monitoring. Train No. 2, on the other hand, was more automated. However, it required a specialized software technician to start up and continue to troubleshoot and operate the system.

Treatment performance. Train No. 2 demonstrated up to 97% TSS removal (501 to 15 mg/L), 99% BOD removal (539 to 5.8 mg/L), and 98% ammonia removal (30 to 0.5 mg/L). It achieved this effluent quality 2 days after start up. However, extended operation and sampling was not possible given project limitations and site constraints.

Train No. 1 achieved similar results after 3 days in operation. But Train No. 1 then regressed slightly for days 4 through 9, before finally stabilizing at low double-digit or single-digit effluent concentrations for TSS and BOD and negligible ammonia concentrations.

Considering these constraints, Houston Water tested two different types of treatment processes, each with a different philosophy of response to emergency wastewater treatment requirements. The two options differed in terms of aeration processes, biological seeding techniques, and clarification and polishing technologies.

Treatment Train No. 1. This option treats 570 L/min. It uses an aeration blower, off-the-shelf biological growth enhancement, coarse-bubble aeration tanks, clarification tanks, return activated sludge pumping, and lamella tube settler for clarification/polishing.

Treatment Train No. 2. This option treats 760 L/min. It uses drum filter screening, pure oxygen delivery, activated sludge seed from a WRRF, aerated equalization, return activated sludge pumping, and ballasted-floc settling for clarification and polishing.

Performance under pressure

Upon deployment, these two treatment trains were employed at two different WRRFs. Given the emergency response nature of the project, the project did not lead to a rigorous controlled scientific method comparison. However, during the response and study, these treatment trains experienced several anticipated and unanticipated situations common to natural disasters. These included

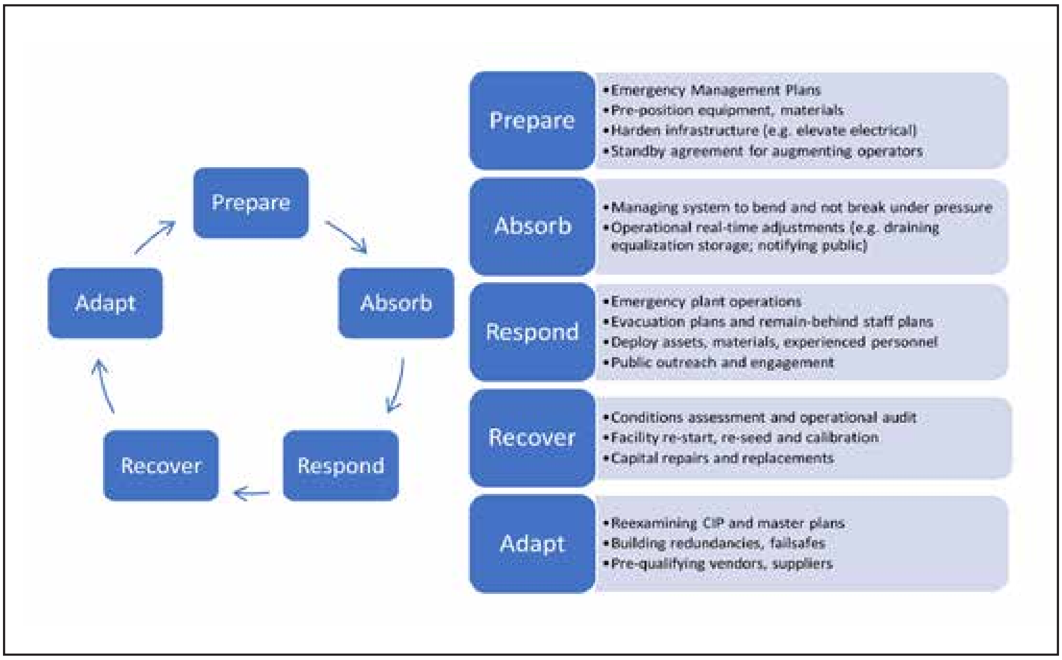
- unexpected influent variation of both quality and volume, including the observation of low organic load water (*i.e.* floodwater) as well as non-municipal industrial and commercial loadings;
- minor equipment failure, power outages, and component supply shortages;
- site footprint constraints from topography to layout optimization;
- the requirement to demobilize an assembled asset, move, and reassemble at a different site; and
- such logistics challenges as a shortage of housing and transportation for first responders and licensed operators.

Simple systems, expert operators

The project demonstrated that a simple, flexible system with fewer site preparation requirements and process steps is preferred for a short-term, emergency response. The operational ease (following startup), effluent quality, and long-term durability of Train No. 2 were outweighed by the difficulty in mobilizing, assembling, and starting up the system.

Given the number of variables outside the control of the utility in a disaster response bypass treatment – such as location, topography, influent concentrations/variability,

Prepare-Absorb-Respond-Recover-Adapt infrastructure resilience framework



equipment supplies and availability – having a system with greater tolerances, flexibility, and implementation speed is preferable for future emergency deployments.

The successful implementation of the project for both trains was due in large part to access to full-time, around-the-clock, experienced, licensed operators provided by waterTALENT (Los Angeles) and Houston Water along with the support of on-call engineering support, local contractors, suppliers, electricians, and other support staff. By having top-flight operators responsible for the basic operations and maintenance of the systems, process decision-making and adjustments were made in real time without a lengthy review or approval process. This was a critical value given the variability in influent water quality. In the project's after-action report, the most commonly cited key to success was having senior operators with delegated responsibility for process control and process decision-making.

Furthermore, the extensive experience of the operators allowed for the application of tradecraft gained over decades of operations and emergency response scenarios. This included several clever fixes:

- The operators used dog food as a biological growth enhancement when activated sludge was either unavailable or risky to transport and other seed sources were in short supply.
- They used low-cost microscopes to determine microbiological progress without lab testing for real-time process control.
- The on-the-job skills gained in rising through the ranks of the operator occupation, such as heavy equipment operations, electrical/mechanical skills, and basic pump and generator maintenance were vital to emergency response work.

Lessons from Houston

Houston Water learned several critical conclusions from this project that any wastewater utility can benefit from. Chief among these conclusions are the following.

Be prepared. Wastewater utilities need to proactively maintain a set of service providers, tools, assets, and materials that are shelf-stable, low-cost, mobile, and readily available prior to the onset of a natural disaster. These plans, processes, and suppliers need to be included in the utility emergency management plans and should be rehearsed from time-to-time prior to the onset of an emergency.

Plan ahead. Depending on the region and location of an emergency, these support assets may be difficult or impossible to locate. Fortunately, Houston has a significant industrial base of equipment suppliers who had equipment and contractors available, but utilities lacking a major industrial base need to plan accordingly and pre-qualify vendors or pre-purchase equipment within a reasonable radius of the vulnerable and disaster-prone regions of a utility service area.

Observe the situation. The treatment train and assets should be selected based on the stage of the disaster the utility is experiencing. A simple, durable system may be suitable for a short-term temporary emergency response but may struggle with longer-term operations. Conversely, a more sophisticated treatment technology may struggle during the highly variable immediate disaster aftermath but may perform more consistently in the longer-term recovery effort. And most importantly, the best overall strategy for response is to have a durable, recoverable, and redundant collection system and WRRFs which, if they fail, can come online again quickly.

Trust your operators. Equally critical to selecting technologies is having experienced operators managing these projects, preferably those with disaster response experience. Sub-par technology operated by above-average operators will outperform the best technologies in a dynamic, uncertain, and ever-changing disaster scenario. As is the case with most disasters, utilities are exposed to losing key members of their operational staff who may be attending to their own personal needs, so standby operations agreements with staff sourced from areas outside the disaster zone will offset this exposure.

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