https://doi.org/10.1002/opfl.1802

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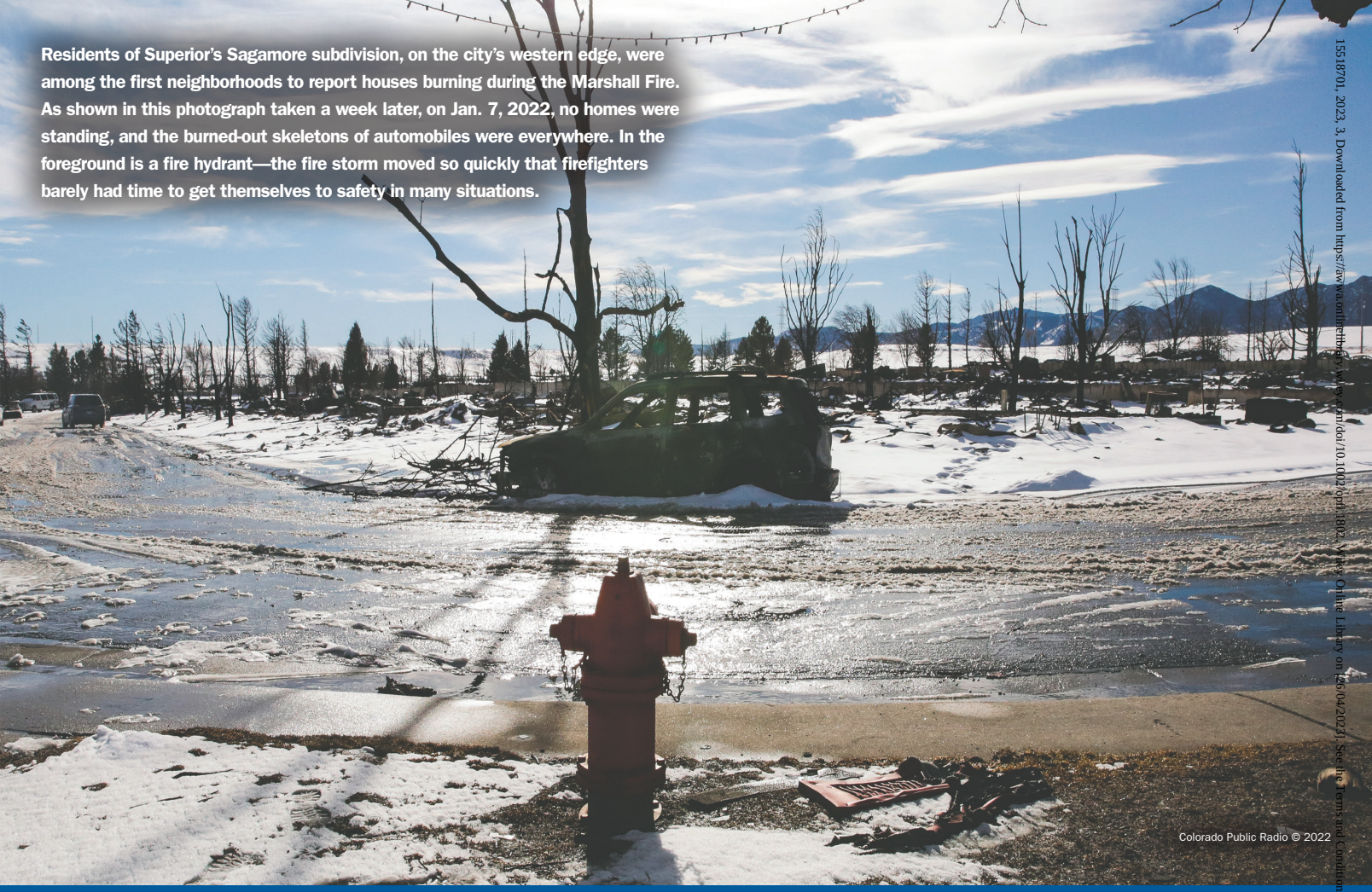
From system assessment to recovery, a water utility's staff went beyond the call of duty to respond to the most destructive structural wildfire in Colorado history.

BY KURT KOWAR

UTILITY STAFF MOUNT A HEROIC RESPONSE TO AN URBAN WILDFIRE

ON DEC. 30, 2021, communities in Boulder County suffered through the Marshall Fire, the most destructive structural wildfire in Colorado history. An unusually wet spring followed by an unusually warm and dry summer and fall created abundant dry grass. This, combined with the lack of snow so far that winter, created ideal weather conditions for the fire. Additionally, wind gusts up to 115 mph rapidly spread the fire.

Louisville, Colo., was devastated by the Marshall Fire. During the fire, staff who operated water treatment and distribution systems became first responders and the backbone of a massive firefighting effort. After the fire, they had to become experts on the emerging science of recovering contaminated water systems affected by fire. Water system staff, with help from neighboring systems and external technical experts, stabilized the infrastructure, found and removed the contamination, and restored services. Their efforts earned them the 2022 AWWA Heroism Award for aiding others while placing themselves at great personal risk.



Residents of Superior's Sagamore subdivision, on the city's western edge, were among the first neighborhoods to report houses burning during the Marshall Fire. As shown in this photograph taken a week later, on Jan. 7, 2022, no homes were standing, and the burned-out skeletons of automobiles were everywhere. In the foreground is a fire hydrant—the fire storm moved so quickly that firefighters barely had time to get themselves to safety in many situations.

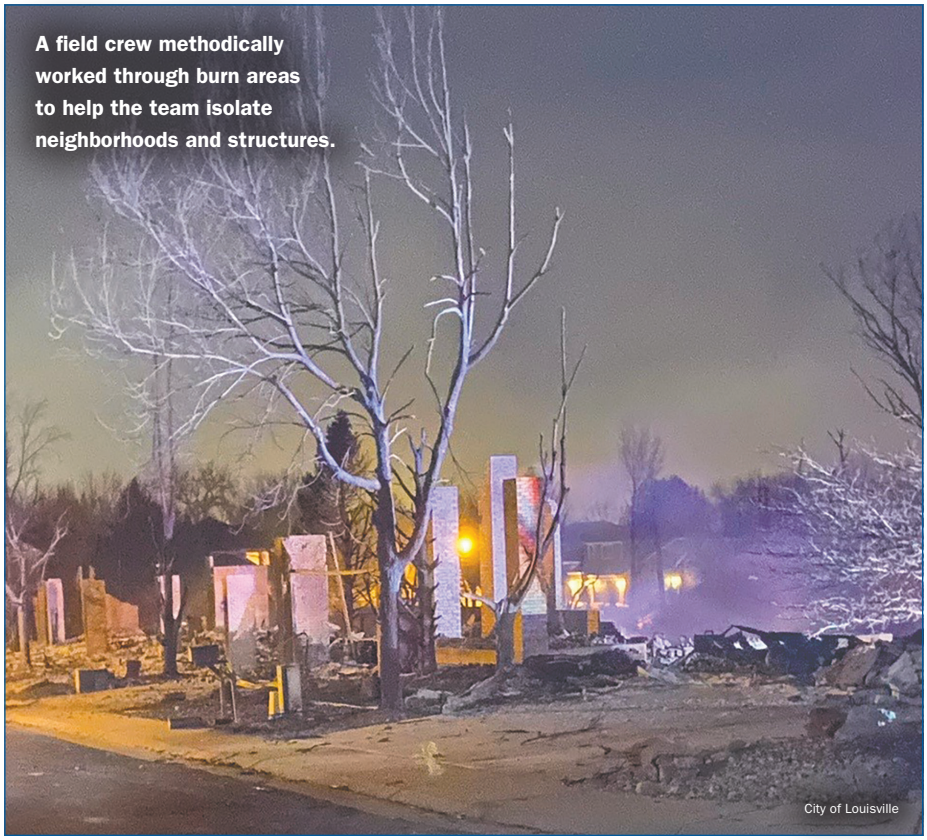
A photograph taken of the same Sagamore corner on Dec. 29, 2022, with the same fire hydrant now buried in snow, offers a view of new home construction rather than burned-out homes and cars.

WATER UTILITY RESPONSE

From a utility perspective, there were many lessons learned and disaster preparedness activities validated during the Marshall Fire (see sidebar, "Lessons Learned During the Marshall Fire"). In general, the staff's training to do the right thing, do it right the first time, and fail forward (i.e., use failure to find success) allowed many small miracles to happen during the event that saved homes and possibly lives.

Dec. 30, 2021: Afternoon. As the fire quickly grew, the local power utility, Xcel Energy, was forced to shut down power and gas lines not already destroyed, disrupting many support systems in the process. Water treatment plants supported by diesel and natural gas generators, previously thought of as reliable, quickly became damaged or unusable. Midday, the Town of Superior's diesel generator was operating but in an unhardened wood enclosure. That wood structure was readily engulfed by flames, along with the diesel generator. One of the two Louisville water treatment plants that relied on natural gas backup power generation was unable to come on line for treatment.

Power Systems Under Fire. After the fire, it became apparent that communities should evaluate their fuel sources, locations, and enclosures in relation to backup generator reliability and vulnerability. With generators failing, Superior's water treatment plant was unable to supply water, and Louisville had only one of two treatment plants on line due to low winter demands. However, Louisville staff were able to make their way through the fire to activate an interconnect valve. With flaming power poles teetering above them, they fought to keep Superior supplied with water during the peak of the firefighting. Louisville and Superior staff practice operating the interconnect annually and were able to perform the task quickly when the need became critical. The interconnect, installed only a few years before the wildfire, was a result of the communities working together to proactively provide a level of redundancy for each other.



A field crew methodically worked through burn areas to help the team isolate neighborhoods and structures.

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Manual Water Storage Tank Inspections. Without power, the supervisory control and data acquisition (SCADA) and communications systems failed, rendering Louisville staff blind to the levels and pressures in the city's distribution system. This required operators to undertake, in firestorm and hurricane-force winds, manual inspection of water tank levels throughout the fire zone.

Climbing ladders and army-crawling against wind and smoke along the tops of tanks to inspect water levels through hatches, operators realized Louisville could run out of water. This was a shocking discovery, as the city had its sole operating treatment plant running at full capacity at 8 mgd on what would normally be a 2-mgd day. Reflecting on this experience has led to planning for low-tech improvements to easily verify system status when high-tech systems, which are often taken for granted, aren't available. Activities that may be quick or easy to accomplish, such as manually checking a tank level, can become time-consuming and dangerous when performed during a natural disaster.

The near-empty water storage tanks prompted Louisville staff to open a large-intake raw water valve, allowing water to flow freely through the powerless water treatment plant and into the distribution system to maintain whatever pressure possible. What was once a potable water supply quickly became a dedicated tool to fight fire, protect property, and save lives. With raw water now in the system, Louisville staff also needed to manage a communitywide boil water order and faced systemwide flushing for recovery, with temperatures forecasted to go below zero the following week.

The team did the best it could to give the community a chance to fight the flames.

Getting Systems Back on Line. Through many calls with the power company, and with priority support of the event's incident command system, power was restored to Superior's water treatment plant, and large trailers of compressed natural gas were transported into the fire zone to the Louisville water treatment plant to fuel its natural gas backup power systems. As teams cut into the Louisville plant's gas supply lines to plumb in the trailers, which were essentially mobile bombs, houses in flames exploded nearby. Operators synchronized in the darkness throughout the plant, preparing systems to come back on line by hand and without SCADA. As the generator fired up and the plant came back into commission, staff manually set systems to provide treated water. Louisville staff practices running treatment plants by hand without SCADA for disaster-planning purposes, and this practice and knowledge proved invaluable during the Marshall Fire.

Dec. 30, 2021: Midnight. Nearing midnight of a long, disastrous day, Louisville's staff felt a brief sense of accomplishment. Both of the city's water treatment plants were on line and treating at full combined capacity of 13 mgd, and Superior's water treatment plant was operational. However, it didn't take long for the team to realize the distribution system wasn't gaining pressure.

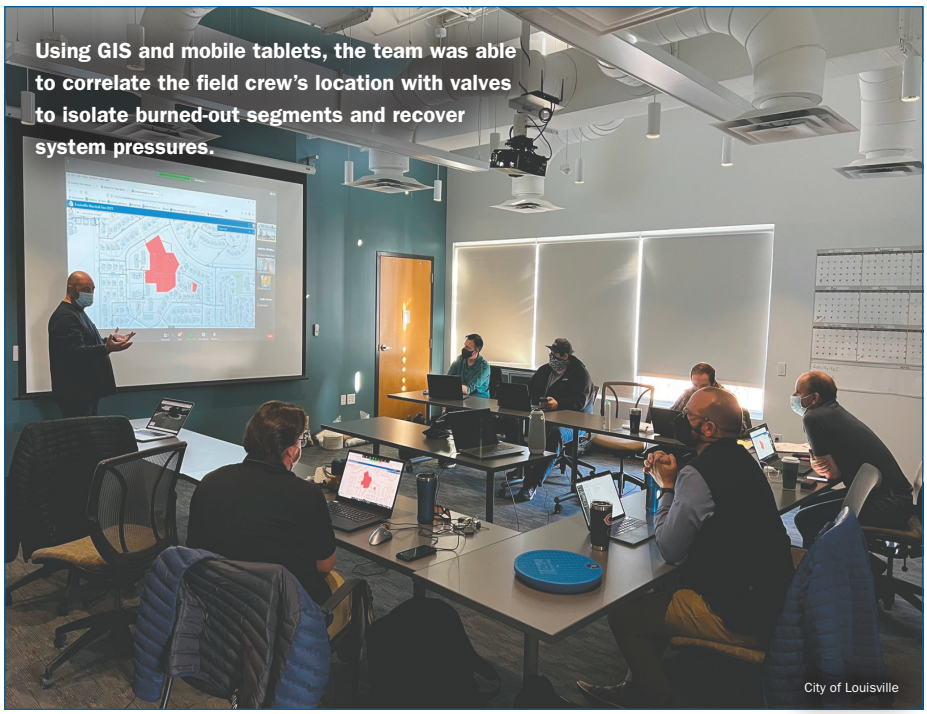
Gauging Water Loss. Information wasn't readily available about where homes had burned or how many structures were affected. The team had limited information, so it had to make best guesses on what was happening because of the need to maintain and recover system pressures. Assuming any structure that burned was spewing water from an open ¾-inch service line, it was estimated that there could be significant water loss from system leakage in addition to firefighting efforts. Rough, midnight, brain-fried math led the team to the general conclusion it could be losing twice as much water as it was producing. This wasn't a sustainable position with crews still fighting fires and structures still burning.

Gathering Information. Shortly after midnight, the team had a crew make its way to the incident command location to request damage location reports and begin the process of locating the water loss. At incident command, burned-structure information was limited, and only generalized fire limits were available on a map. Regardless, the team used the map and began the process of methodically working through burn areas and isolating whole neighborhoods or structures. The landscape looked like a war zone, with fire everywhere and everything covered in debris or ash. Hardly anything could be recognized in the dark.

Digital Mapping. Using geographic information system (GIS) mapping technology and mobile tablets, the team was able to correlate the field crew's location with valves to isolate segments of the system. This approach also allowed the team to send screenshots to incident command to coordinate where firefighting was still happening and verify if water needed to stay on or could be shut off—a task that would have been nearly impossible with paper maps. Over a period of seven hours, surrounded by burning foundations, smoke, and various explosions, the team isolated gushing commercial fire systems and residential service lines that were spewing significant amounts of water that the team had previously only speculated about. Slowly, through the night, as the team isolated each service or block, the city's tank levels began to rise, and system pressure increased.

Dec. 31, 2021: Fatigue and Shock. After 35 hours of struggling to keep Louisville's water system on line, some of the city's crews slept. Others now responded to below-freezing temperatures and 12 inches of snow removal.

Thinking Proactively. The unthinkable often happens during disasters, so it's important to learn to think ahead of what might possibly happen next. Throughout those 35 hours, the team



Using GIS and mobile tablets, the team was able to correlate the field crew's location with valves to isolate burned-out segments and recover system pressures.

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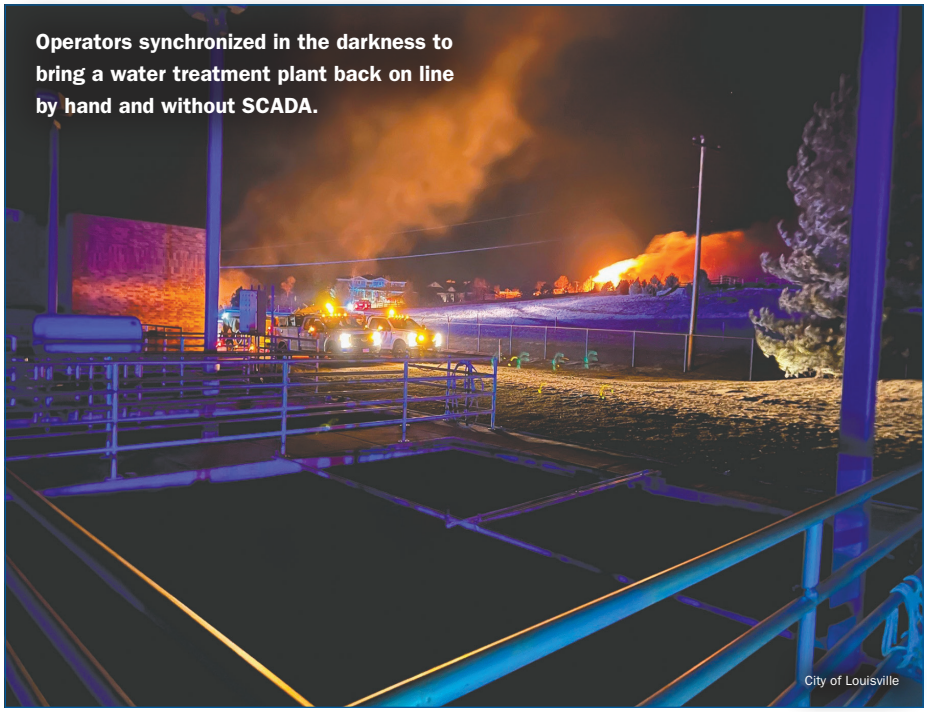

Operators synchronized in the darkness to bring a water treatment plant back on line by hand and without SCADA.

constantly thought about the next steps it could take to stay ahead of the event. The team had to rethink what the purpose of a distribution system was on the fly and redefine what public health and safety meant in critical moments.

Doing It Right. Ultimately, every team member understood what the right thing to do was at any given moment, but it took courage to do the right thing to make a difference. There were many moments in which the team members weren't sure of their safety or job security given the unorthodox risks taken. Through it all, the team did the best it could to give the community a chance to fight the flames.

Jan. 2, 2022: Recovery Begins. With winter conditions finally arriving, water system staff faced the looming task of flushing the entire water system in near- or below-freezing temperatures. A task that would normally take many months in the summer with dedicated crews needed to be done as soon as possible. Then another miracle happened. Slowly, calls and emails offering assistance began coming in. The team was able to organize and schedule incoming resources, with the assistance of the City of Boulder Utilities and other surrounding utility agencies.

Flushing in Freezing Weather. Internally, the team had set a goal to flush the entire water system—120 miles of pipeline—in one week. This was an aspirational goal that was only possible with a 24-7 effort, and it was met internally and externally with extreme skepticism given the conditions.

The flushing crews experienced a brutal first night in freezing temperatures but came in the next morning with hope. Over the course of two more days, against all odds, the end was in sight. However, Mother Nature had other plans, and another blizzard was forecasted to move in. But with their momentum going, the flushing crews decided to keep flushing through the night and the storm. Although lives weren't on the line, pride, accomplishment, and restoring daily life to a ravaged community were. The skill and dedication of the utility crews were on full display.

Boil Water Order Lifted. Ultimately, on the evening of January 5, just four days after starting and a week after the fire, flushing was completed. System sampling results were confirmed, and the boil water order was lifted for Superior and unburned areas within Louisville. What was viewed as impossible became possible through the unified power of utility crews throughout Colorado's Front Range.

EMERGING SCIENCE

Parallel to flushing and immediately after the fire, utility staff also began corresponding with the Colorado Department of Public Health & Environment (CDPHE) to assess the condition of the fire-affected public water systems and determine protocols to bring them back on line. Science and regulations are clear on what to do after a boil water order. However, in the case of water systems contaminated by wildfire, emerging science presented red flags for volatile organic compound (VOC) contamination in the distribution system from superheated gases and backflow during depressurization.

New Protocols. CDPHE provided guidance needed to manage each property or burned area of the Louisville water system under cross-connection control guidelines that required staff to develop protocols to safely bring water mains and individual services back on line while attempting to reinstate unaffected areas from the boil water order. It was a unique challenge to be in the middle of a disaster and to have to develop new protocols with emerging science to recover a water system under tight deadlines.

Coordinated System Recovery. With the city's flushing teams nearing completion, the team reached out to academic experts for assistance. An ad hoc water system recovery meeting was created over the course of a day with experts flown in overnight. A meeting of epic regulatory proportions convened on January 4, with representatives from Louisville,

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Superior, City of Boulder, CDPHE, Colorado Environmental Protection Agency (EPA), California EPA, Oregon EPA, US EPA, Purdue University, Oregon State University, University of Colorado, and Corona Environmental. The team quickly facilitated and assimilated various perspectives and knowledge bases into next steps and protocols to return Louisville's water systems to normal in a safe, transparent manner for the general public.

Data-Driven Decision-Making. In the end, testing protocols were developed with the partners that allowed for data-driven decision-making to reintroduce water mains and homes back into the systems safely. The number of tests and scale at which testing was undertaken, along with the speed at which results were desired, quickly stretched the laboratory capacity of mutual aid partners and private labs. Testing proved to be the largest constraint during the process of recovering and reintroducing pieces of the system. It also became an extremely large cost in the recovery, nearing $700,000 and coming close to the cost of the system's physical infrastructure damage.

As tests results and data became available to validate safety and compliance, the boil water order was lifted; over weeks and months, isolated neighborhoods and habitable homes were brought back on line. To provide transparency and ongoing feedback to residents for service recovery, Louisville provided online mapping that provided near real-time distribution system and property-level test results for contaminants. This proactive approach helped city officials and residents understand where service had been restored and allowed for more individualized communication with properties that still needed to be cleared by testing before being reintroduced to the system. It also instilled public confidence that the city was safely recovering the water system.

During flushing and compliance coordination, GIS was a critical tool in providing clear communications. GIS could quickly coordinate data, establish reasonable expectations, and create a common visual language to communicate succinctly with technical and nontechnical stakeholders alike who were affected by the event. In the weeks and months after the fire, the GIS continued to support damage assessments in a common format for consistent reporting at county, state, and federal levels.

REBUILDING STRONGER

As of this writing in early 2023, Louisville is well on its way to rebuilding. More than a year later, the water system is just now reaching a point where it may be able to discontinue water system testing for VOCs as part of ongoing contamination monitoring. However, water system staff still test each service line as homes are reconnected during the rebuild process to ensure a safe system, peace of mind, and data to support protocols for future disasters. To better understand decisions, resources, expertise, and response limitations during and after the wildfire, read "The Marshall Fire: Scientific and Policy Needs for Water System Disaster Response," a case study recently published in *AWWA Water Science* at https://doi.org/10.1002/aws2.1318.

LESSONS LEARNED

MARSHALL FIRE DISASTER RESPONSE INSIGHTS

Looking back on the events of Dec. 30, 2021–Jan. 2, 2022, the City of Louisville's water systems staff learned several important lessons during and after the Marshall Fire that may help other water utilities with their emergency response efforts. Consider the following:

- Disaster preparedness, in the form of annual training and system redundancy improvements where possible, can be invaluable.
- Review personal protective equipment that may be needed for wildfire response.
- Prior understanding of an incident command structure, as well as local or regional disaster chain of command and support system structures, can help utilities quickly respond to and recover from a disaster. Consider running tabletop exercises for various potential emergency scenarios.
- Review the vulnerability of backup power systems to natural disasters with internal staff and local energy providers.
- Don't be afraid to acknowledge what's known and unknown. Find experts and get them on-site to help as quickly as possible.
- High-tech systems are great but quickly become low-tech during a disaster. Water utilities need to understand how to run their systems in a low-tech way.
- GIS has a high cost of entry but pays for itself over the long run—especially during a disaster. Time is money, and common visual communications are critical to expediting large-scale disaster recovery.
- Set aspirational goals. Don't focus on what can't be done. Utilities can accomplish impossible tasks and timelines given the right culture and by building strong relationships with neighboring communities.
- Contamination is expensive. Flushing and testing take significant time and money. Be sure to consider testing resources and turnaround times in advance of an emergency.
- High-risk wildfire areas should consider remote shutoff valves during any type of meter replacement program. Proactive isolation and contamination prevention for one large event could potentially save significant cost and time of recovery. Given the knowledge gained over many fires in many states, contamination will happen, testing will be required, and recovery with contamination will be expensive.