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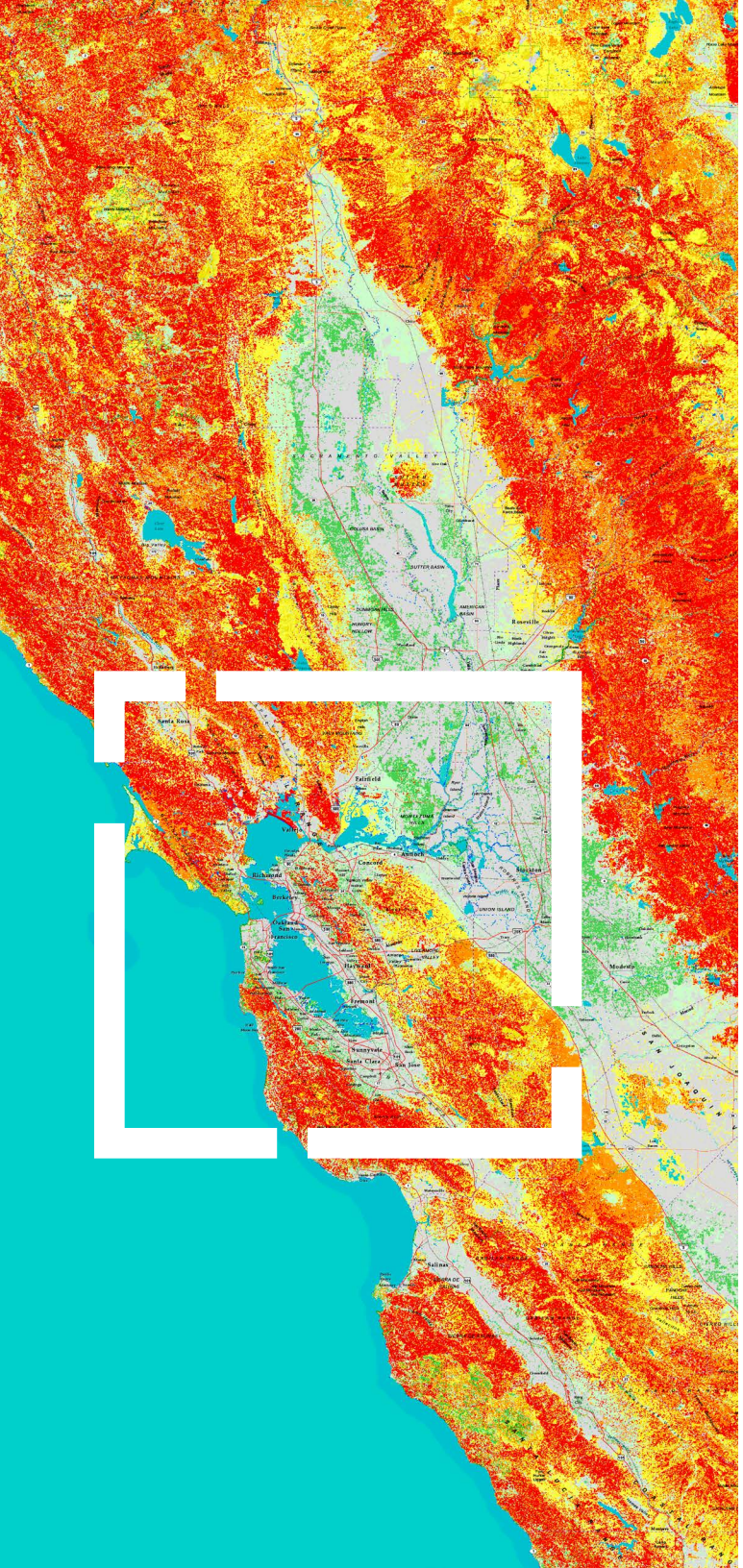
CALIFORNIA WILDFIRES & FOREST RESILIENCE:

APPLYING ANALYTICS AND REAL-TIME AWARENESS

How Location Intelligence Can Advance Prediction and Adaptability



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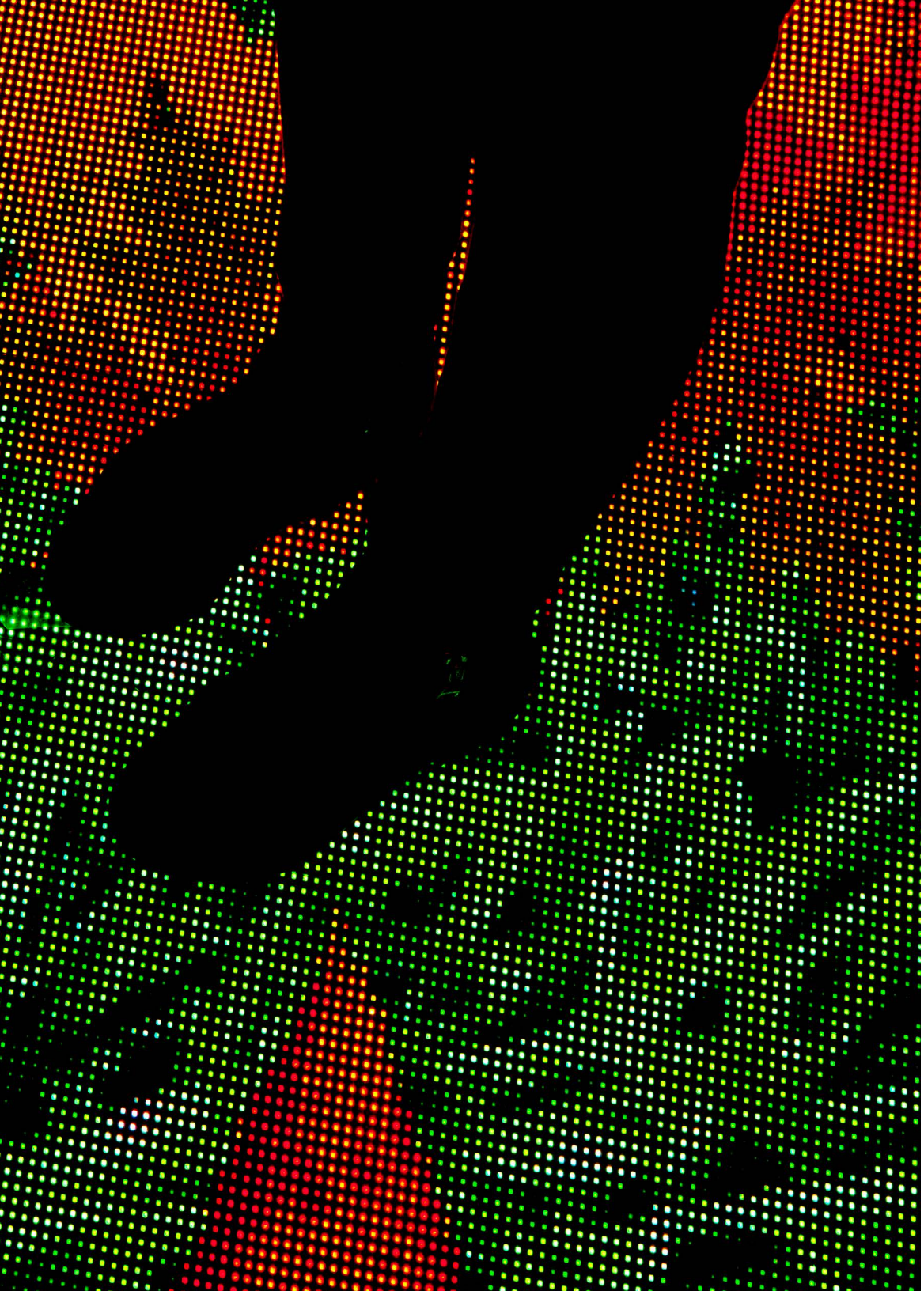


Executive Summary

The Need and the Capabilities

The Big Idea

Around the world, complex organizations are applying apps, drones, artificial intelligence (AI), machine learning, spatial analytics, and the Internet of Things (IoT) to populate a real-time view of assets and people on a shared map. A modern geographic information system (GIS) combines data collection, analysis, and sharing to achieve operational intelligence. With these tools, organizations gain an edge on complicated challenges because they can see trouble coming and manage decisively around it. For natural resource agencies and wildfire response management leaders, this means using dynamic real-time data and interactive maps to make tactical decisions amid dynamic conditions. ▶

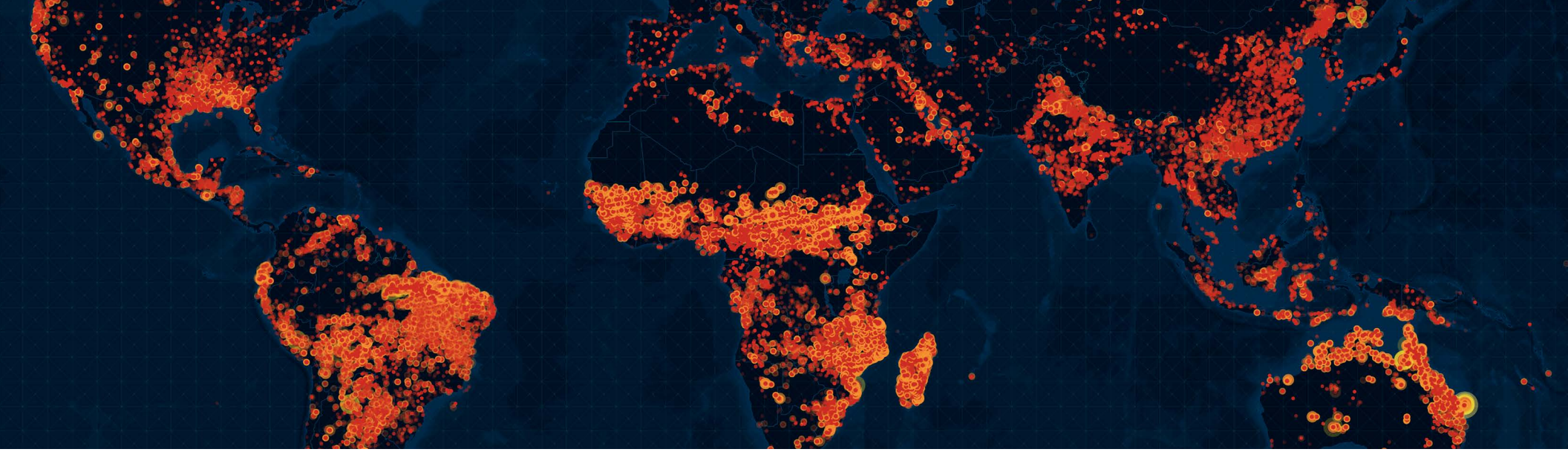
Here's the *Why*

Climate change is causing havoc in forests worldwide. The 2020 California wildfire toll exceeded all prior metrics in this era of modern wildfire management. There were nearly 10,000 fires that burned more than 4.2 million acres–roughly four percent of the state's land. The 2020 August Complex Fire began on August 16 when lightning strikes started 38 separate fires that crossed seven counties and burned more than one million acres, making it the first gigafire. A series of fire tornadoes–twisters of smoke and flame–hit Lassen County, California, prompting the National Weather Service to issue its first-ever warning for this extreme fire behavior. Few will forget the crimson skies in San Francisco. Remarkably, the 2021 fire season has been worse, if "seasons" truly exist anymore.

Fires have been occurring year-round. This year, California is reeling from extreme drought with foliage moisture at record lows, according to the US Drought Monitor. There have been 900 more wildfires in 2021 so far than during the same period a year before. This frightening trend prompted Governor Gavin Newsom to double an already record-setting budget request–from $1 billion to $2 billion–for wildfire mitigation.

"Clearly we recognize we need to step up our efforts here in the state of California," Newsom said.

Decision-makers and operations officials require a real-time management tool that enables them to see the current condition of forests and use that information to make choices about resources, people, and assets. They need to see these conditions, not just as they are now, in the moment, but also how they are likely to shift in an hour, a day, or a week. They need a tool that provides a visual means to understand the full context of natural areas and the wildland-urban interface. They need a technological solution to see what's happening and to seek answers by querying data across space and time to make crucial resource management decisions, acting proactively rather than reactively. ▶



Modern GIS technology can accomplish these interwoven objectives, with a suite of tightly integrated tools that can achieve several goals simultaneously:

- **Collect, Analyze, and Share Data—**Use purpose-built, location-based apps to collect data and optimize the efficiency of field activities. Then use GIS in the office to store, map, and analyze data points to see challenges in their totality. The data, map products, and analytical results can all be shared internally, across departments, with partners, and pushed back and forth to and from the field.
- **Spatially Enable Operations—**Operational awareness delivered by GIS lets supervisors see what is happening in the field; track teams with an awareness of where they are and what they're doing; improve efficiency to reduce the strain on people and equipment; and push routes and directions directly to the field to simplify communications and speed a coordinated response.
- **Achieve Real-Time Intelligence—**Ingest massive volumes of real-time data feeds and perform fast queries and analyses to understand movement and change. Firefighters are combining in-depth models that predict the behavior of fires, as well as tactical tools that aggregate information about weather conditions and the location of crews. This real-time awareness allows users to see such things as a crew in need of support, the houses and buildings that are in danger, and the places where there are gaps in coverage.
- **See the Totality of the Situation with Great Clarity—**Because a modern GIS contains tools to understand people, assets, natural systems, and processes, it provides unique context and intelligence. This transparency empowers people to reach consensus and collectively create a smart forest management plan, empowered by hand-held devices, giving everyone correct answers fast and achieving consensus quickly.
- **Bring Stakeholders Together for Shared Solutions—**By continuously collecting and storing data and providing the means to visualize it on maps, GIS allows decision-makers to note historical patterns and devise solutions. Using machine learning and other AI tools, planners can forecast outcomes. Managers can also use GIS to organize people and the data they collect and analyze around specific initiatives. GIS workflows underpin good decision-making by helping users analyze the data, mobilize action, and then monitor progress.

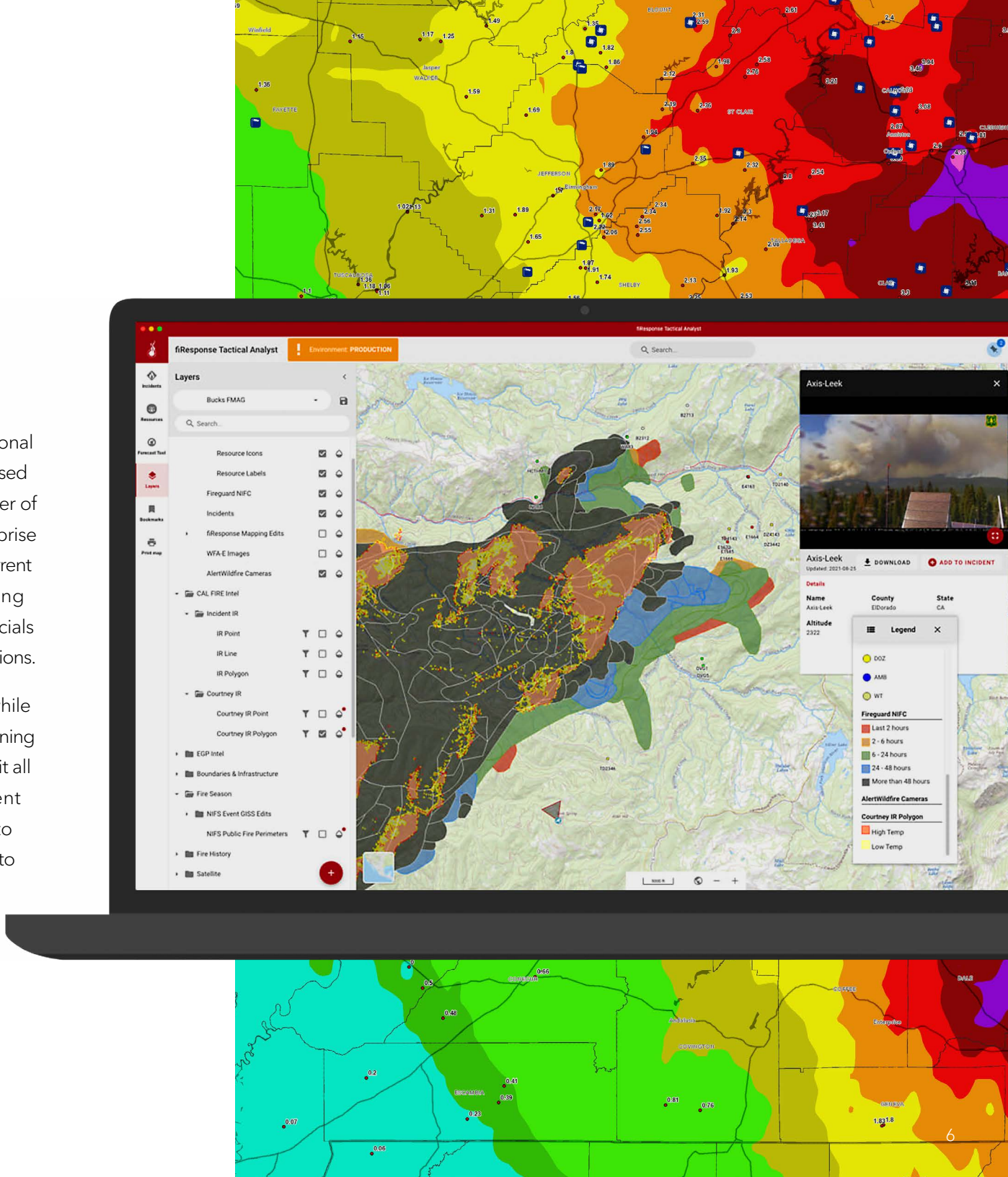
GIS manages this level of complexity while simplifying the communication of crucial information. It affords a dual visibility, illuminating problems and highlighting progress toward the sustainability goals that define a resilient forest for the 21st century. ■

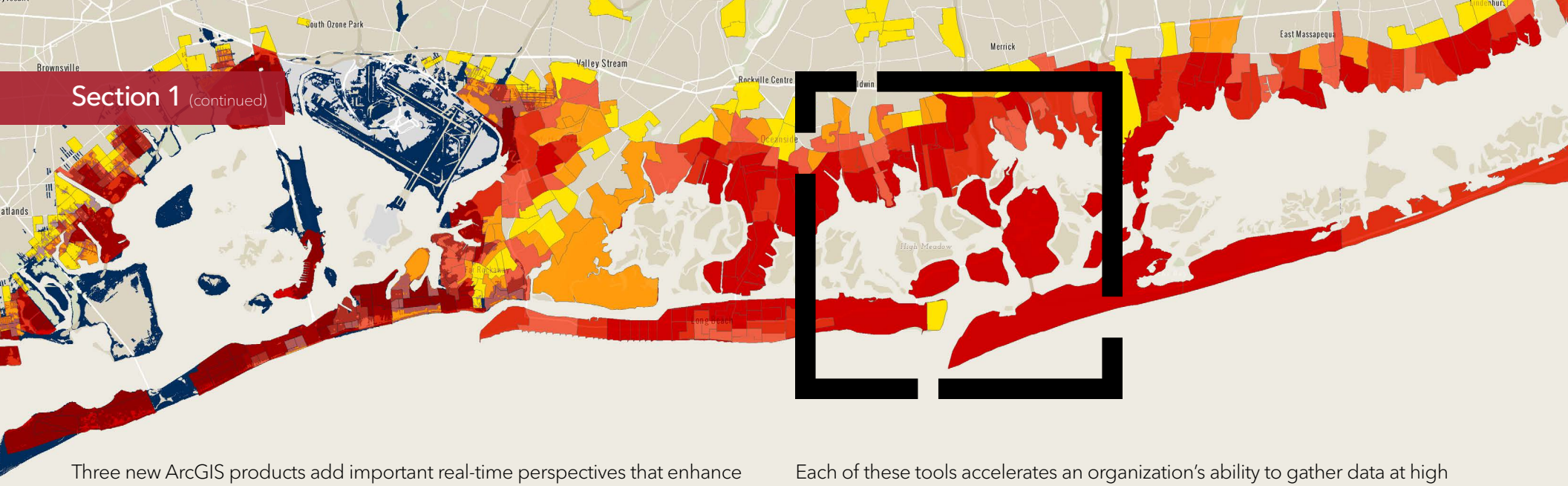
SECTION 1

REAL-TIME FEEDS FOR MANAGEMENT

Managing natural resources effectively requires situational awareness for problem-solving in the moment. A GIS-based operational intelligence system gives officials the power of a shared map that incorporates the totality of its enterprise information repositories. Real-time data connects the current situation with the events unfolding around it. Seeing operations data and current status on a map gives officials the confidence they need to make proactive forest decisions.

GIS can bring data together from disparate sources, while smart maps offer a comprehensive view of what's happening now. Weather reports, incidents, construction activity—it all comes together to provide full awareness of current conditions and ways to improve them. With access to historical data, trends and patterns can be uncovered to guide decisions. Armed with location intelligence, management can proceed at peak performance levels and achieve service excellence. ▶





Three new ArcGIS products add important real-time perspectives that enhance an organization's situational awareness:

ArcGIS VelocitySM is a cloud-native software as a service for ArcGIS Online that allows organizations to ingest data from IoT platforms, data brokers, and third-party APIs. It helps users process, visualize, and analyze real-time data feeds; store them as big data; and perform fast queries and analysis. This capability adds an awareness that brings clarity to essential operational decisions, allows for remote monitoring of important assets, and provides key inputs to achieve predictive maintenance and process optimization.

ArcGIS Tracker is a mobile app that enables organizations to monitor where field staff are and analyze where they have been. Knowing where personnel are enhances safety, allows organizations to dispatch the closest personnel to respond to unplanned events, ensures adequate coverage, and lets managers check if field personnel are on task. Observable patterns give decision-makers the ability to examine productivity and create efficiencies in field activities.

ArcGIS Field Maps integrates the ability to capture data with easily configured forms; combines position and locations on a map to find assets and routes to the work; and improves transparency between the field and office by seeing tasks alongside the location of the workforce.

Each of these tools accelerates an organization's ability to gather data at high volumes to provide context. GeoAI—a combination of GIS and artificial intelligence programs—helps fill in data gaps and automate analytics to tease out information from dataflows. Using deep learning models, GeoAI performs three crucial functions. It sorts through large image caches, recognizing and categorizing the depicted objects by using pattern detection algorithms; discerns change and trends amid enormous amounts of data; and makes authoritative predictions based on current conditions compared to historical data.

GeoAI allows cities to be even more proactive. Just as deep learning programs can recognize shapes and objects, they can also sense patterns in the data that are not otherwise apparent. This kind of analysis gives operational leaders advance warning of unfolding events.

A deep learning program can also integrate historical data to help users make informed predictions. The system can integrate data from remote sensors, leveraging big data and IoT to improve asset management as part of a smart natural resources approach. ■

CASE STUDY

CAL FIRE

Applying New Predictive and Tactical Tools to Fight Destructive Fires

The Situation

California is experiencing the most destructive fires in its history. Owing to dryness and fuel loads, the current blazes generate their own weather, adding another layer of unpredictability among the chaos. Thunder clouds have massed above, causing lightning strikes that spark spot fires ahead of advancing flames.

The Caldor and Dixie fires and other recent blazes mark a pattern of rapidly expanding wildfires with erratic and unusual behavior, fueled by a growing number of too-dry forests and severe drought conditions. The drumbeat of nearly constant blazes year-round can be overwhelming and leaves little room for rest and recovery.

The Challenge

California Department of Forestry and Fire Protection (CAL FIRE) officials—who say they have never seen so many acres burn with such intensity—are trying to be ready for what the fires will do next.

The size and number of wildfires demand many people and assets. Every day, CAL FIRE officials must continuously reprioritize resources for new and emerging fires. On a single day—August 16, 2021—the agency was fighting 10 wildfires with 10,700 firefighters, 795 fire engines, 192 hand crews, 265 bulldozers, 276 water tenders, and 45 helicopters. CAL FIRE wanted to know where these crews and equipment were at all times to improve efficiency and better coordinate response. ▶

The Solution

CAL FIRE couples FireGuard USA with Technosylva's wildfire analysis and tactical products built on Esri® ArcGIS technology. Firefighters are now using imagery, smart maps, and computer simulations to monitor and forecast fire behavior.

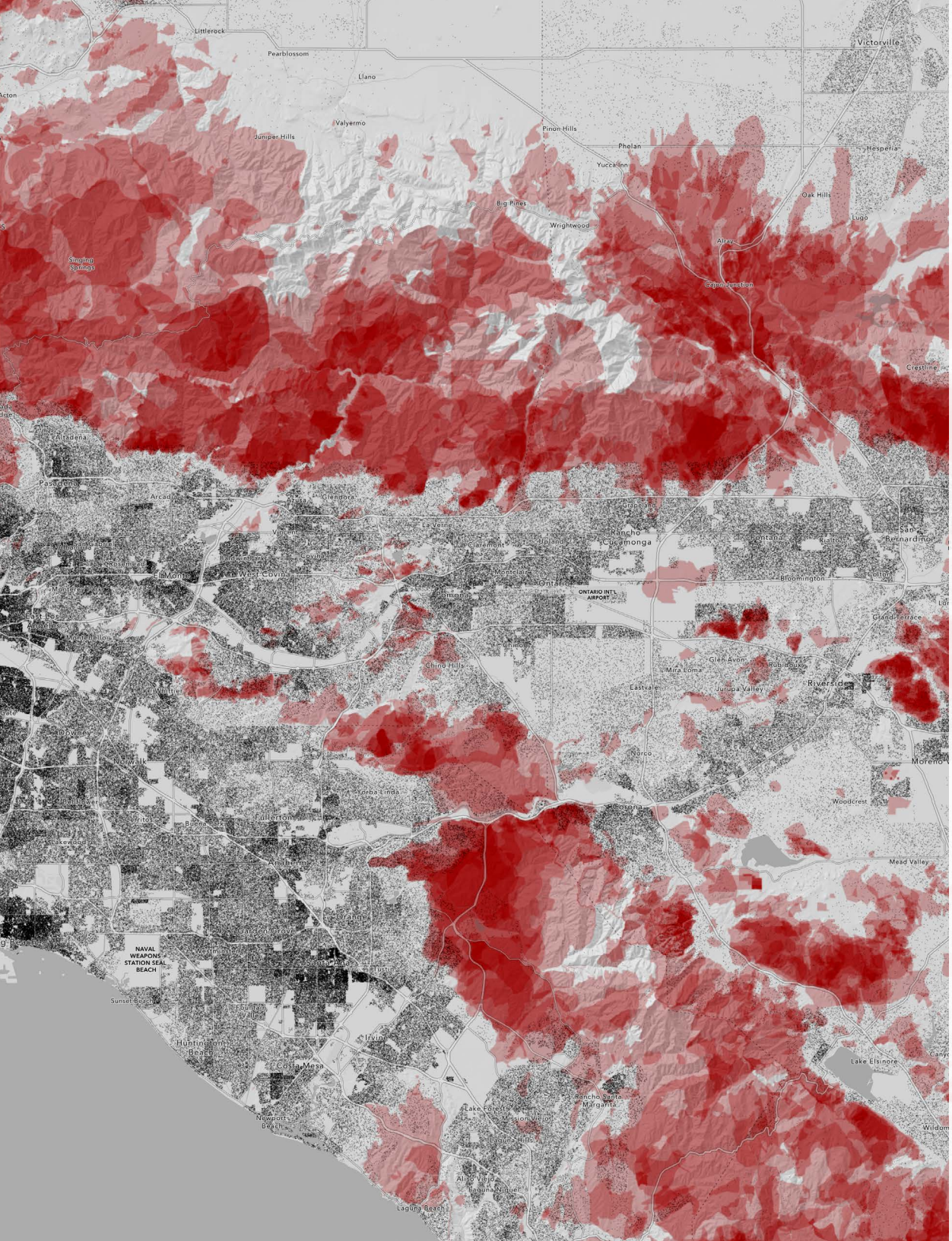
Analysts with CAL FIRE can now run simulations; plan actions; and locate all firefighters, engines, helicopters, and other resources on the map. In the field, firefighting crews can look at their mobile devices for alerts and fire activity awareness.

As more fires occur, the situation continues to personally impact more people in the fire service. It has pushed CAL FIRE and other agencies to have a greater understanding of the effects of incidents.

CAL FIRE uses Technosylva's Wildfire Analyst tool to understand the impacts of a fire's predicted spread. Everyone can see dots for structures on the map and a corresponding table that indicates when the fire may reach these buildings. With this detailed simulation, CAL FIRE can quickly understand the potential for the fire and make better decisions on response and suppression options.

CAL FIRE uses Tactical Analyst from Technosylva to provide the common operational picture of all firefighting activity. The tool combines multiple datasets that are shared on a single map, allowing CAL FIRE to understand all aspects of an active wildfire, such as the affected area; near real-time infrared imagery showing fire fronts and fire intensity; camera views; and full incident details that can be explored and replayed across space and time.

This fire season represents the first time an incident commander has had a shared map with input and visibility from every crew. A bulldozer driver, for example, can see on a map where someone is scouting ahead and the locations, in real time, of arriving engines. The tool allows individuals and teams to see their objectives, capture their work, and witness their edits as they go onto the map. ▶



CAL FIRE (continued)

"These are cascading disasters. The first phase is the fire itself. The second is the recovery—removing hazards, planting new trees, rerouting electrical lines and roads, and rebuilding."

– Phillip SeLegue, CAL FIRE Deputy Chief of Intelligence

The Results

CAL FIRE has found that the shared map helps provide a sense of understanding and accomplishment; and the awareness of the work of others helps encourage the use of the technology.

The teams in the field have benefitted from receiving input from analysts in the office who provide forecasts of fire behavior and updates on incoming weather. The dialogue between the office and the forest also helps prioritize the use of assets and the activities of crews to contend with changing conditions, such as spot fires. ■

SECTION 2

MEASURING AND MODELING TO PREDICT FIRE BEHAVIOR

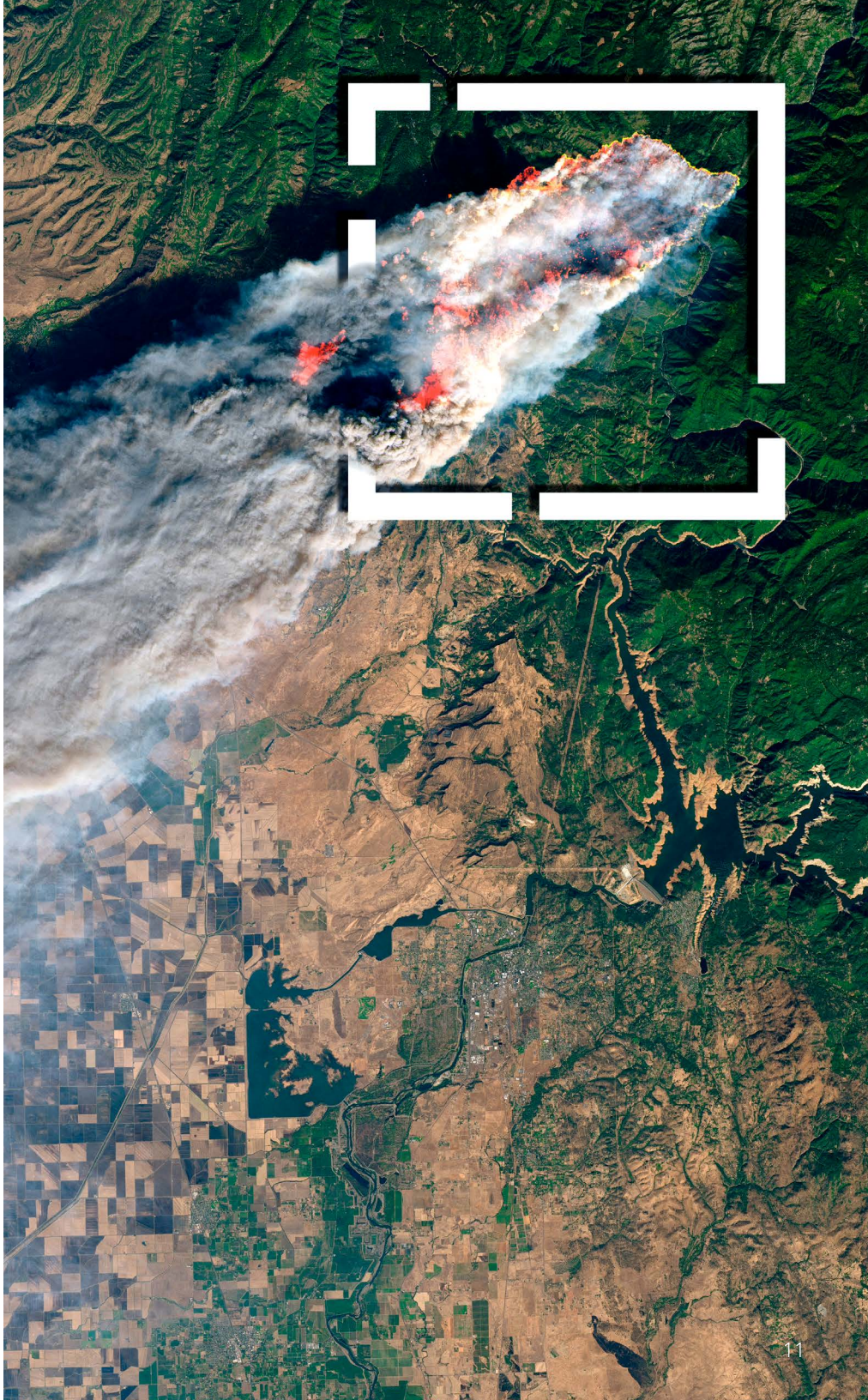
> "Here's what we see. Here's our crystal ball. Here's what fires have done here in the past. That's not going to appease everybody, but helping the public understand things that are scary is going to buy us something. I just have to hope that, because fire is here to stay."
>
> – Casey Teske, US Fish & Wildlife Service Fire Management Analyst

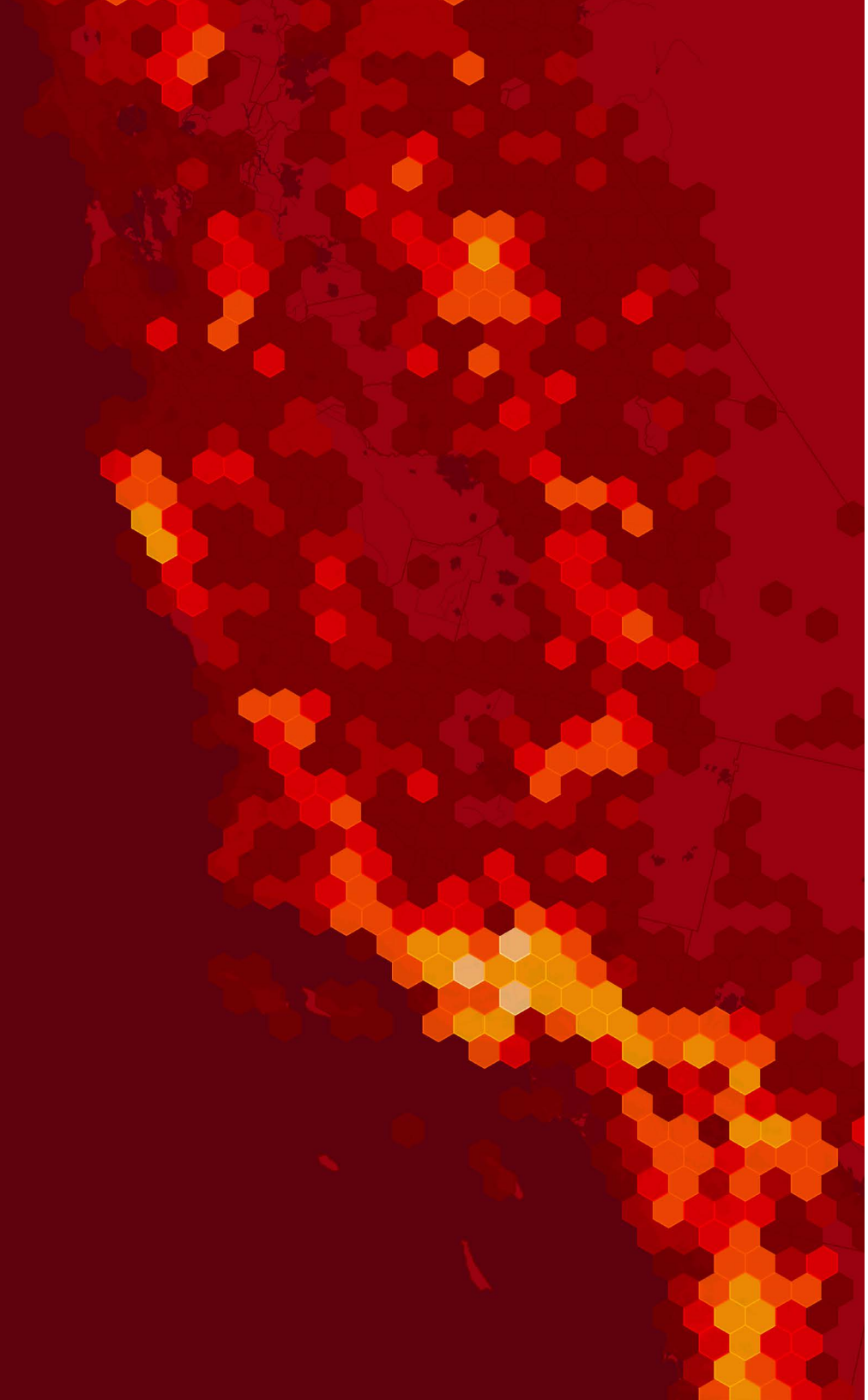
The saying that someone "can't see the forest for the trees"–when they overlook the big picture by focusing too much on the details–isn't really true of forest management. Modern wildfire suppression is increasingly complex. Ensuring fire-prone forests are prepared for the next threat requires seeing the aerial view and the finer points as well as everything tying them together.

There's no magic button or machine that can fully, and with complete accuracy, predict where a volatile fire will spread or how it will react. There are tools, though, that can help fire analysts better understand what may happen next in a wildfire and the environmental factors affecting its trajectory, such as what suppression efforts may have taken place previously in an area or the known whereabouts of beetle-rotted trees that make for a powerful fuel and knowing what shape the trees are in.

That's where predictive analytics and a geographic approach can come into play.

Weather forecasts, satellite imagery, and information about moisture levels in an area, can be overlayed on a map of existing fires, helping to illustrate possible contingencies. ▶





Section 2 (continued)

Algorithms and machines are not omnipotent. They require a solid backbone of human knowledge. Consider what happened to Geoff Marshall, an analyst with CAL FIRE. The modeling program was showing a swiftly moving fire in the middle of a calamitous season, racing through an area called Big Creek. He knew that path was largely filled with dead trees—eaten through by bark beetles and drained by drought—that would make for more volatile fuel. He warned his supervisors, and later the fire did what he had expected, including jumping a river. His analysis facilitated evacuations and possibly saved lives.

Much of firefighting in this new era is rethinking forest management.

Before a fire even starts, modeling can help firefighters visualize the data layers of a fire-prone area, using such variables as topography, prior fire-suppression and prescribed burn efforts, tree species, and the location of nearby homes and businesses.

The US Forest Service Forest Inventory and Analysis program keeps track of the country's wilderness by taking an annual sample of 350,000 plots of land, each about the size of a football field.

The program's BIGMAP uses cloud-computing processing to ingest an immense amount of data, including tens of trillions of pixels of satellite imagery, to produce analysis in days. Among the maps the agency has been openly publishing for the public are those showing forest stocking levels in the nation's "wood basket" as well as forests that are particularly susceptible to wildfires. The term *wood basket* refers to an organization's harvest area as well as whole southern states, which have been producing lumber for centuries. The wood basket region stretches from eastern Texas to Maryland, and it produces 60 percent of the country's wood products.

The agency is using data visualized in maps to also make decisions about where to focus planting to have the least adverse impact—where threats are low, productivity is high, and where forests aren't fully stocked.

The tool helps leaders make decisions about what to keep, what to plant, what to clear out, and what should be allowed to burn to prevent worse fires later. ■

CASE STUDY

US FISH & WILDLIFE SERVICE

A Journey from Firefighter to Researcher and Back

The Situation

Fire management analyst Casey Teske has experience as both an operational firefighter and an analyst who uses data to help predict a fire's behavior. While working toward an advanced degree in fire ecology, she learned how to use GIS technology and location intelligence to understand how fires start and spread. During summer breaks, she fought fires to earn money for her studies.

The Challenge

With both physical and analytical experience in fighting fires, Teske wanted to find better ways to make the jobs of firefighters easier and safer, aiming to apply computer modeling to anticipate a fire's path and predict its intensity. She hoped to link firefighters in the field with the useful insights that GIS delivers.

Noticing that housing developments continued to move into fire-prone areas, she wondered how agencies could more proactively create better systems for managing volatile situations. ▸

US Fish & Wildlife Service (continued)

The Solution

Teske pointed to the way aerial infrared imagery can make the firefighting process more efficient. "Instead of just going to where you were yesterday and doing what you were doing, now you have increased situational awareness, which is important for developing tactics and strategies," she said. Combining the infrared information with GIS mapping and modeling can produce informed predictions of *where* and *how*. The process can also show where the effects of previous treatments may reduce fire behavior or give firefighters a tactical advantage.

Drones also hold potential to help users observe and stream data in real time. Artificial intelligence and machine learning can bolster those real-time insights, improving post-fire analysis.

The Results

GIS enables all data related to fires to be analyzed in context. Scientists and firefighters can quickly determine whether the threatened ecosystem is a forest or a prairie, and learn the relevant humidity, wind, rainfall, and snowfall patterns. They can see the frequency of lightning strikes, identify the number of fire-resistant trees and plants thriving in comparison to invasive species, and find historic trends for each variable. ▸

Sidebar Intensifying Forest Management Practices

Funds are being applied in California to expand forest management practices to improve resilience against wildfires and the impacts of climate change. An operational intelligence system powered by ArcGIS provides opportunities to streamline the flow of field activities—eliminating friction that slows service delivery, synchronizing workflows, and compounding incremental savings into large reductions in time and costs.

One key contribution of an operational intelligence system is around mobility. The system can be applied to a fleet of vehicles and used to route workers and crews to where they are needed. Applying a workforce management tool saves money by using GIS to both manage field operations and improve fragile ecosystems. Return on investment (ROI) is measured in fuel saved and less cost for vehicle maintenance. More intangible savings comes from time saved and the added benefit of shared visibility.

CAL FIRE's effort not only to expand the crews tasked with fuel management but also to scale up treatment to 500,000 acres annually by 2025 will require a great deal of coordination. The job of thinning the forest and applying prescribed fire will require synchronous actions from a large number of specialists. The visibility of all actions on a shared map can aid collaboration. A "single-pane-of-glass" fosters collective awareness of individual actions.

The restoration of land requires coordinated input to get the balance right for current and future landscapes as well as for the benefit of all endemic species. There is also an urgency to restore an area quickly to help prevent further danger to life, property, and natural resources.

Ecologically based strategies benefit from a shared platform for communication and data sharing among all stakeholders. The added analytical capability of GIS fosters input from scientists and other experts to focus forest management practices—increasing carbon storage, protecting biodiversity, and addressing climate resilience. ■

SECTION 3

APPLYING DRONES TO SENSE RISKS AND HELP THE VULNERABLE

In the air or on the ground, there are some places humans can't or shouldn't venture during a cataclysmic event. In a vast, rapidly changing emergency, a bird's-eye view can make a significant difference when weighing strategies in the face of threats and hazards, but conditions often deter the use of piloted aircraft. From the vantage point of a drone or satellite, an entire forest—and a racing wildfire—can be observed through imagery captured in or near real time.

The viewpoint can reveal what's happening beneath the smoke and canopy that might help in firefighting or rescue efforts, using thermal imaging to follow a fire's path or determine where the wind is blowing. Quickly stitching together imagery of burn areas into a high-definition mosaic view can provide a shareable, updated reference point for those needing the big picture and the ability to zoom in.

Drone-led modeling and simulation may ultimately provide an early warning to firefighters on the ground who find themselves in dangerous positions, as one US Department of Agriculture (USDA)-funded test hopes to show by first sending autonomous drones above prescribed burns. ▶

Section 3 (continued)

In the summer of 2021, as fires brutalized the Northern California landscape, GeoAcuity used Site Scan for ArcGIS to collect, process, and analyze imagery from its drones, and it used ArcGIS Online to plan flights and share information among multiple agencies helping in recovery efforts, including more than 30 law enforcement agencies across five counties. ArcGIS Dashboards and ArcGIS Web AppBuilder facilitated the visualization of data that was shared and collected. Hundreds of gigabytes of data collected daily were processed and available to decision-makers within 24 to 48 hours. That quick turnaround was necessary in prioritizing where to send help and where to focus rebuilding efforts.

High-resolution aerial imagery can be used by the public too, including homeowners needing to show proof of damage to relief organizations and insurance companies.

That imagery lives on to help communities in preparing for the next threat, using it as a reference point to see how forests may have changed since the last fire. ■

CASE STUDY

HAWAII VOLCANO

Drones Deployed to Monitor Erupting Kilauea Volcano

The Situation

Kilauea, on the Big Island of Hawaii, is one of the world's most active volcanoes. For more than three decades it continuously erupted, with few moments of reprieve. In 2018, lava spewed out of vents in a residential neighborhood, eventually destroying more than 700 homes.

The Challenge

The US Geological Survey typically sends in-person surveyors to capture the GPS coordinates of the leading edge of the lava flow as it moved. But the flows can imperil crews, including emergency responders. In addition, for their own safety, pilots were barred from flying helicopters overhead at night, so visibility from above was hindered. Smoke rising from the lava was also preventing a clear view. ▶

Hawaii Volcano (continued)

The Solution

Drones could fly above the eruption to monitor lava paths and respond to requests where ground truth was needed during the emergency response. The Center for Robot-Assisted Search and Rescue (CRASAR) sent a five-person team of highly trained volunteers, deploying their drones for what was believed to be the first use of unmanned aerial vehicles in a disaster response to a volcano eruption. Using GIS, the team was able to visualize the eruptions in real time on a digital map after images were automatically tagged with their locations.

During a six-day period, from May 14 to May 19, the team flew 44 drone flights, including 16 at night. Outfitted with thermal sensors, the drones captured clear images of the lava below and even identified a new fissure. To determine the lava's speed, a drone would hover above the front edge of the lava flow and capture a geotagged image. Several minutes later, it would follow that leading edge to where it traveled and repeat the process. The drones also performed remote sensing tasks, mapped fissures, and detected sulfur dioxide emissions.

The Results

The work of drones obviated the need to manually map and geocode the lava's leading edge. The machines could also quickly respond to emergencies, including one that involved a resident possibly trapped in an isolated home. The team's expertise allowed them to all speak the same operational language as they involved scientists and emergency responders. The drones' aerial view also came at a lower cost than piloted helicopter flights. ■

SECTION 4

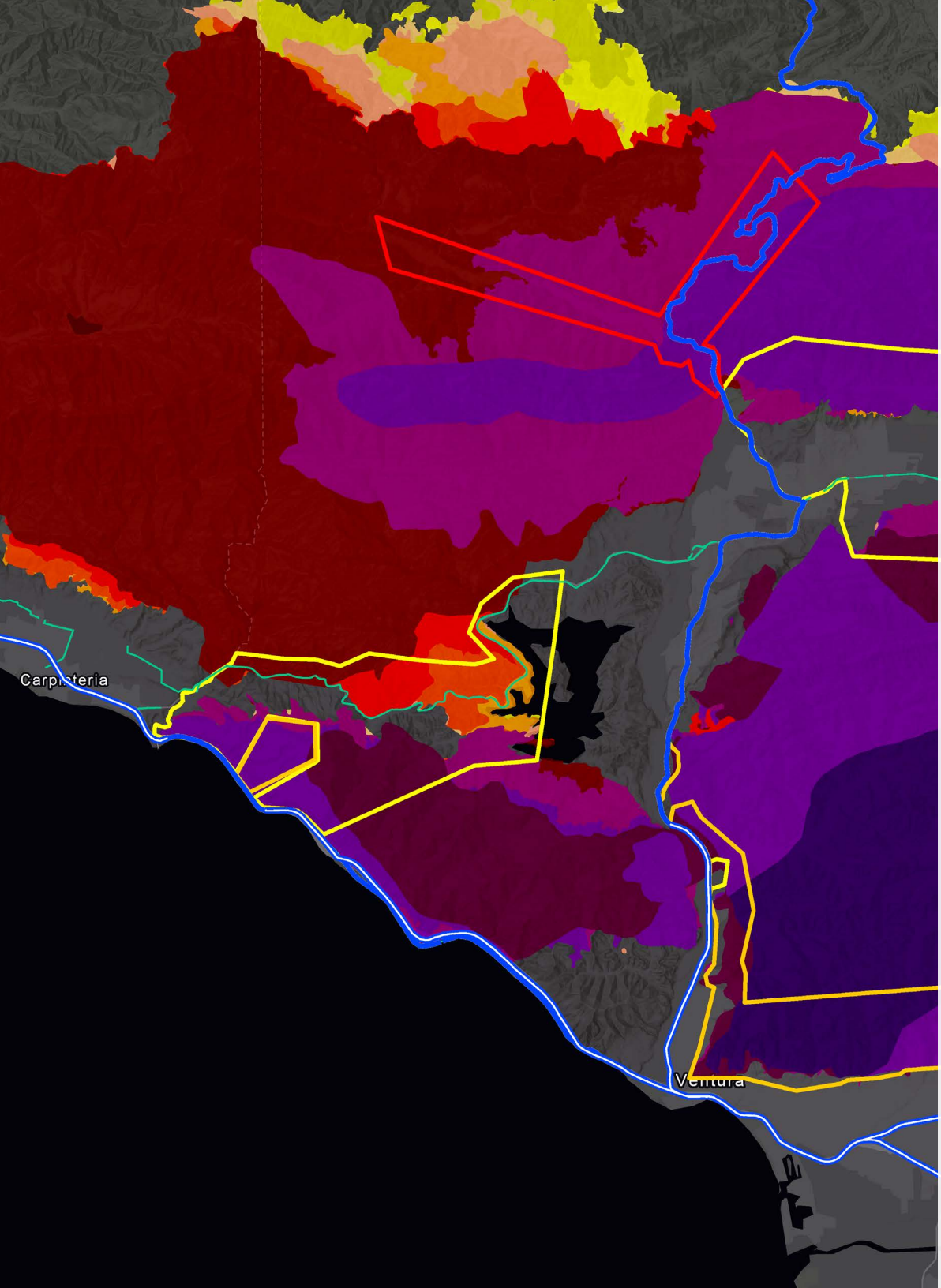
GUIDING MITIGATION MEASURES FOR NATURAL RESOURCES

Building resilience to catastrophic fires requires restoring the health of forests and diverse landscapes as well as strengthening wildfire preparation within communities.

True operational intelligence helps managers see and communicate about incidents and changing conditions. An optimal system includes communication channels between agencies, government and residents, and government and businesses as well as between governments. The system provides advisories and alerts, so businesses and residents can make alternative plans, avoid certain areas, or take special precautions. It also provides the backbone of information and communication to coordinate effective mitigation efforts as well as firefighting actions.

For both fire response and mitigation measures, the system provides critical feedback loops. Responders gain access to data to assess the situation, understand where to act, and then note progress. For fire mitigation, homeowners get alerts and details about issues they need to address to safeguard their property and become active participants to prevent impacts. Both groups benefit from a shared map-based view.

The operational intelligence system taps into real-time data from sensors to gauge conditions. The system processes data that is compared to past patterns to recommend changes. And the real-time situational awareness helps identify priority activities that need more attention as well as those that are working well. With all of these inputs, responders can make more informed decisions. ▶



Section 4 (continued)

A GIS-powered operational intelligence system allows managers to see incidents in their full context. The combination of GIS and AI—GeoAI—can power a system that detects patterns and hot spots that are not immediately evident by looking at the map. While the manager looks at the big picture and determines what to do across the workforce, individual workers can be sent automated messages to begin dealing with impacts.

A GIS-powered operational intelligence system can serve as a geographically aware information conduit. It can channel incident reports to the right managers, using a location intelligence approach. When there is a spot fire over the ridge, for example, the assignment can be sent to the nearest crews. A report of a downed power line can be routed to power company crews in the right area and checked by fire crews to make certain nothing has been ignited. Together, these workers can take on the assignment and provide status updates to everyone. ▶

Section 4 (continued)

Managers who embrace GIS to direct their field workforce gain app-powered operational intelligence that provides a full picture of productivity. The common view between the field and office helps ensure that the right measures are implemented when and where they need to. It empowers mobile workers with real-time awareness and the right inputs—putting institutional intelligence into smartphones to enhance worker knowledge and efficiency. Apps that tackle workflows have proved to reduce errors, boost productivity, and save money. The more the tools are used, and the more collected data there is, the better the data and decisions become.

With the increasing frequency and intensity of catastrophic wildfires around the world, land use and forest management practices have necessarily begun to evolve in order to reduce the magnitude of damage.

The evolution of GIS technology now means that GIS not only can continuously gather information but also can empower quick analysis and real-time responses. It's a system that enables situational awareness—continuous knowledge that is highly actionable and shareable.

GIS strengthens the relationship between natural resource managers, first responders, businesses, residents, and government departments. It creates a more engaged community and shows the general public that it has a genuine stake in the pursuit of operational intelligence. ■

CASE STUDY

National Park Service Resource Advisors

On-the-Ground Experts Work to Minimize Impacts Before and After Fires

The Situation

During wildfires and other hazardous events, emergency responders and public safety personnel have their hands full dealing with the conditions and the threats to people and property. The value of natural and cultural assets are a major concern, but a first responder may not know what's there or what safeguarding measures to take.

The Challenge

First responders rely on National Park Service Resource Advisors (READs) to provide guidance on natural and cultural assets during an incident. These advisers can be biologists, hydrologists, archaeologists, tribal liaisons, or specialists from other disciplines who, during an incident, focus on minimizing the impact of disaster response and recovery operations on ecosystems, archaeological sites, and protected species.

This is painstaking work during and after an incident. With heightened damages from recent fires that have burned millions of acres in California, the scale of the work is also large. To date, many READs have relied on paper maps and PDFs, without a digital version to share with firefighters and first responders. The READs team members needed a better way to capture their work and share their recommendations in a way that fostered collaboration. ▸

The Solution

Using a combination of ArcGIS Online and the mobile mapping app ArcGIS Collector, recent READs efforts have streamlined data gathering and sharing. The move to digital workflows transformed a once cumbersome process with near real-time GIS collaboration.

For the first time, during a recent fire, the READs team had access to a frequently updated map in ArcGIS Collector, rather than a static poster-sized wall map. The live view allowed the team to toggle through various layers on the map and to see vulnerable sites in the context of current conditions.

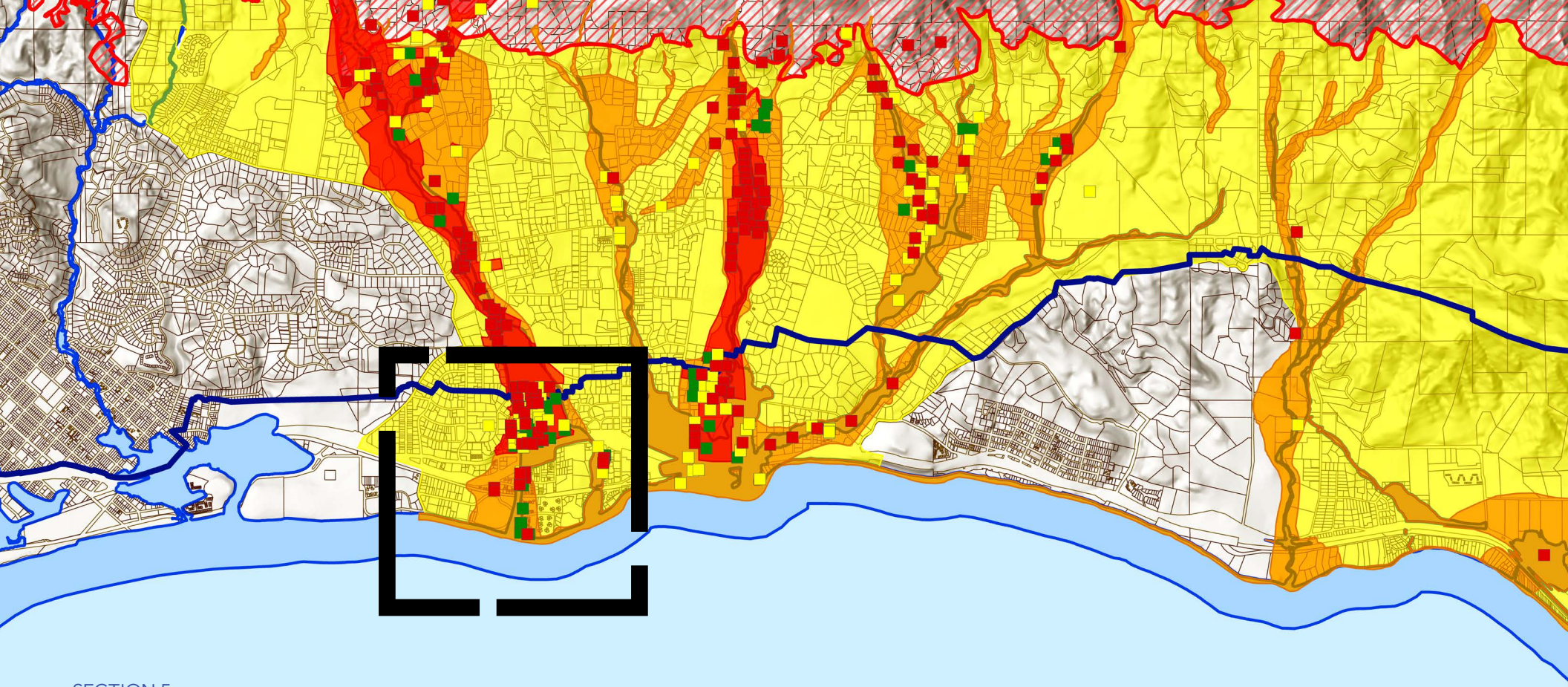
The Results

Having access to the shared map and the data behind it allowed the READs team to spend less time making maps and more time analyzing the impact of the fire. It freed the team from the time-consuming tasks of digitizing data and downloading GPS files. With access to shared data, team members could move on to analysis sooner and improve the timeliness of their recommendations.

The shared common data platform made it far easier for the READs team to collaborate and communicate with incident, agency land, and public information managers about the status of sensitive habitats, historic sites, and other important resources that required remediation.

The workflow of having a shared map and dashboard also greatly improved communication. Instead of answering questions as they came up, this combination gave incident managers a way to filter map layers and see the status of repair projects, including the allocation and availability of specialized equipment needed to do the repairs.

With both the fires and the people fighting them so widely dispersed, the ability to access data remotely was a significant time-saver. Whatever their location, workers could access the same geospatial information, and sync any information they gathered, without having to travel anywhere. Regular updates from everyone kept the whole team current across the entire fire zone. ■



SECTION 5

HELPING HARD-HIT COMMUNITIES REBOUND

Much of emergency response has been rooted in a defensive posture. Agencies prepare as best they can, but ultimately it's a matter of responding to each urgent need as it crops up and recovering afterward, until the cycle starts over.

Current conditions are forcing us to adopt new methodologies. Weather events are now powerful enough to create their own storm systems, a factor largely driven by climate change. Fierce and relentless natural threats—and the calamities they create—are causing a distressing feedback loop. Exhausted responders, depleted mitigation resources, and decimated communities limit the efficacy of the old methods, setting the stage for the inevitable new disasters to cause even more damage.

We need to rethink how we approach these events, beginning with how we prepare for them.

3D-rendered modeling can calculate possible outcomes, providing an early view of what a future disaster could look like. A digital terrain model can be augmented to show an area's population, emergency shelters, and the locations of vulnerable residents. Planners can get ahead of events, conducting simulations of even the most extreme scenarios. ▶

Section 5 (continued)

Esri's Damage Assessment solution assists with the cataloging of razing and repairs required after severe events. Sharing damage assessments online, with workers documenting damage in the field and sending the information back to those cataloging it, can speed the process, helping communities rebuild.

The communities themselves—the people who endure the emergencies—can also better inform preparations before potentially calamitous outcomes occur. No one knows the risks better than those who endure them.

Municipalities and relief agencies have sought the input of those who know where the floodwater flows, where tidal floods persistently creep up, and where the forest just past a backyard has been felled by beetle infestations. Providing focused investment to address the problems most often seen by impacted communities—rather than spreading limited resources far and wide—can pay significant dividends in anticipating the next disaster. In some places, relief groups have taught local residents how to build their own floodwalls or irrigation canals to keep rising waters at bay. The residents' sense of ownership helps in maintaining their incentive for mitigation.

With so many emergencies—and only so much assistance—it helps to focus attention on the greatest need and coordinate both among responders and with the affected communities. ■

CASE STUDY

RED CROSS | American Red Cross and Relief Groups Work from One Shared Map to Reach People in Crisis

The Situation

As a global health pandemic was leaving many in the US out of work and unable to afford meals, the operators of food banks and other community-based nonprofit relief groups were finding themselves stretched thin, especially as a series of natural disasters, including wildfires, demanded their attention. The need for food aid increased by as much as 500 percent across the country.

The Challenge

It can be difficult for aid organizations to know where to focus their attention. Aid response amid wildfire conditions can be challenging. Instead of there being a single place to deliver aid, affected residents flee or are evacuated to other locations. Relief organizations then must find a way to find those affected, who may now be in another county or state, and get the aid to them. The global pandemic also emphasized the need for relief staff to be able to work effectively from home or in a mobile capacity, limiting access to shared software or programs that weren't in the cloud. ▶

The Solution

The American Red Cross, with funding support from Walmart and the Walmart Foundation, built the Disaster Partner Hub. The shared online space has brought together more than 70 relief organizations to coordinate responses to emergencies in four key areas: feeding operations, call center data, damage assessment, and shelter operations. Data has been automatically pulled into a shared dashboard view so that each agency can monitor conditions. A Daily Feeding Activity app can be sorted by disaster, allowing users to zoom in on an interactive map of the US and see all activities at that moment. The Partner Feeding dashboard shows the numbers of meals produced, meals served, and boxes of food delivered across the country.

The hub is also accessible anytime, anywhere, as software-as-a-service. Partner organizations have created more than a dozen event-specific situational awareness briefs shared through ArcGIS StoryMaps to update the larger group.

The Results

A pilot project intended for use from April to June 2020 turned into a daily operational tool used by the partner food aid organizations. The shared data has also been used beyond pandemic-related food aid assistance to help hurricane victims.

"We can see what each other is trying to do and can fill in any gaps with resources," said Patrick Colley, director of member engagement at Feeding America. ■

SECTION 6

PLANNING FOR RESILIENCE: SHIFTING FROM REACTIVE TO PROACTIVE

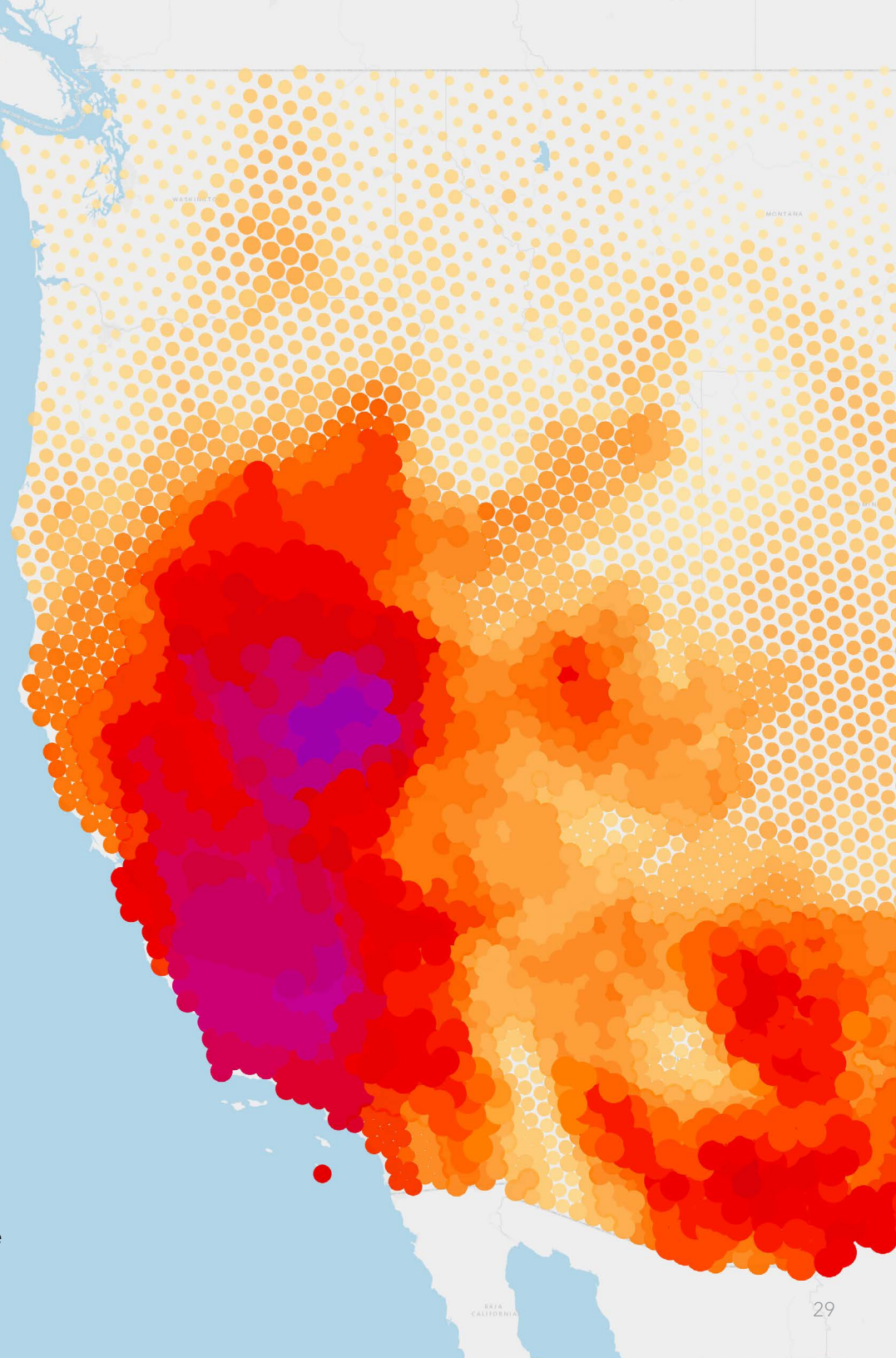
Thinking with a map gives a bird's-eye view. It adds the spatial relationship, where communities can consider their level of vulnerability and pinpoint structural weaknesses to harden and be more resilient in the face of future disasters.

Anticipatory action is one of the latest buzz phrases in the response sector. The thinking is simple: If you can plan for the disaster before it hits, you can save lives and limit costs.

Emergency management and disaster response planners are emphasizing the need to understand an area's systemic risk. When severe weather events like high winds, wildfires, and floods repeatedly impact the same location, residents are left more vulnerable and in constant recovery mode. A deeper understanding of the dynamics of an area can improve mitigation and adaptation strategies.

As the climate changes, more extreme and frequent disasters are hitting communities that haven't previously had to deal with catastrophic emergencies. In California, communities are reeling from droughts and floods—Sonoma County was hit by both in quick succession.

Government officials use GIS for gaining a deeper understanding, analyzing the vulnerability of people, and monitoring the effectiveness of policies. Business leaders rely on GIS to analyze facilities, supply chains, and customer activity to know when and where to reduce or ramp up activity to withstand storms. Staff at nonprofits perform spatial analysis with GIS to guide the delivery of services where they are needed most. ▶

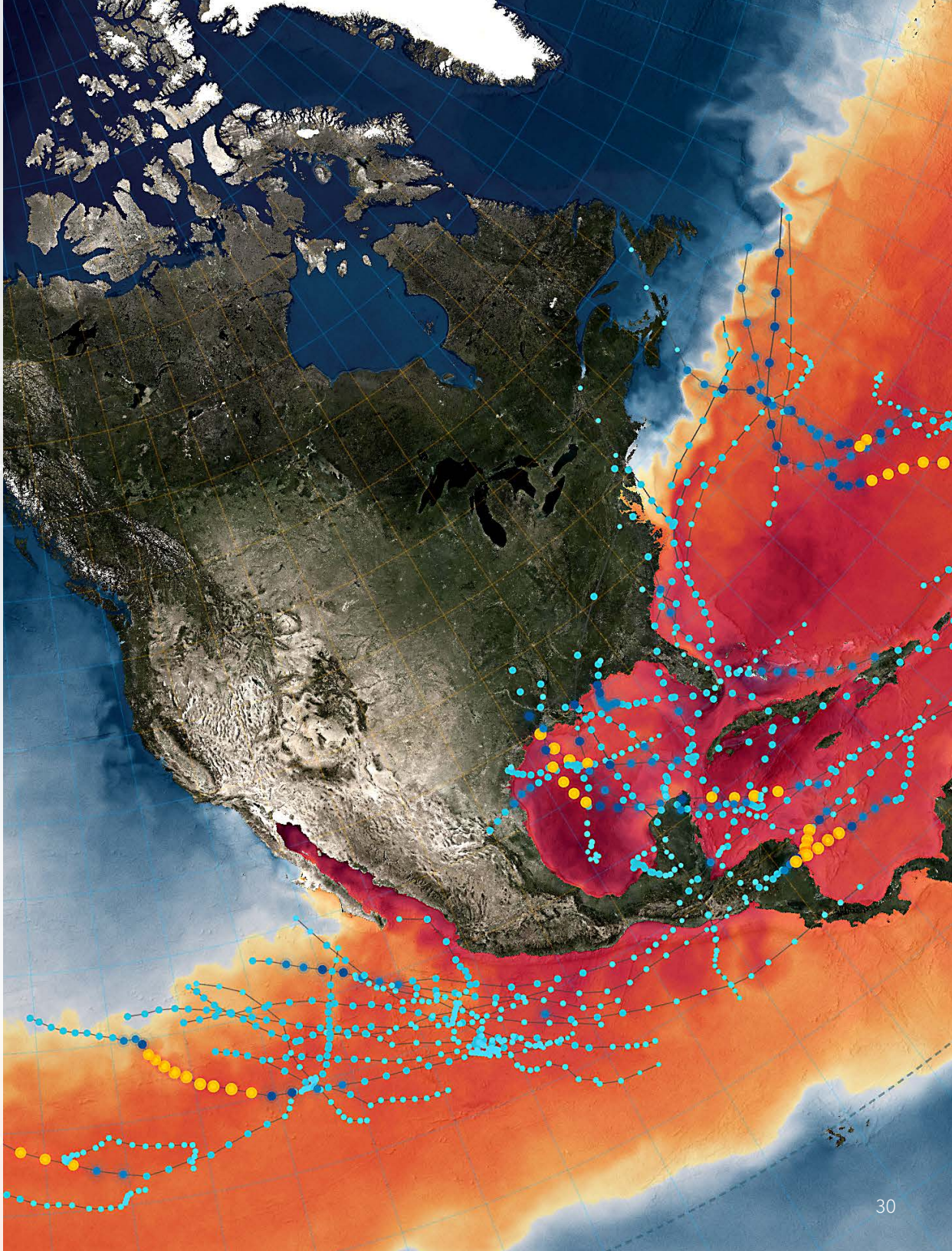


In places frequently struck by hurricanes or tornadoes, preparedness is a way of life. However, extreme storms brought on by climate change are also impacting communities unaccustomed to high winds, flooding, or other extreme weather events. And emergency managers are increasingly tasked with coordinating response to natural, technological, and human-made hazards. In short, preparedness for all types and sizes of crises has become key to building resilience.

CalEnviroScreen is a screening methodology that helps identify communities disproportionately burdened by multiple sources of pollution. This same mapping application can help planners identify existing vulnerabilities and environmental burdens in a community that might be exacerbated due to climate change.

Planners can analyze census and demographic data, examine critical infrastructure such as schools and hospitals, visualize weather patterns, and note historical hazard impacts across space and time. With that information, responders can decide where to prioritize resources now and in the future.

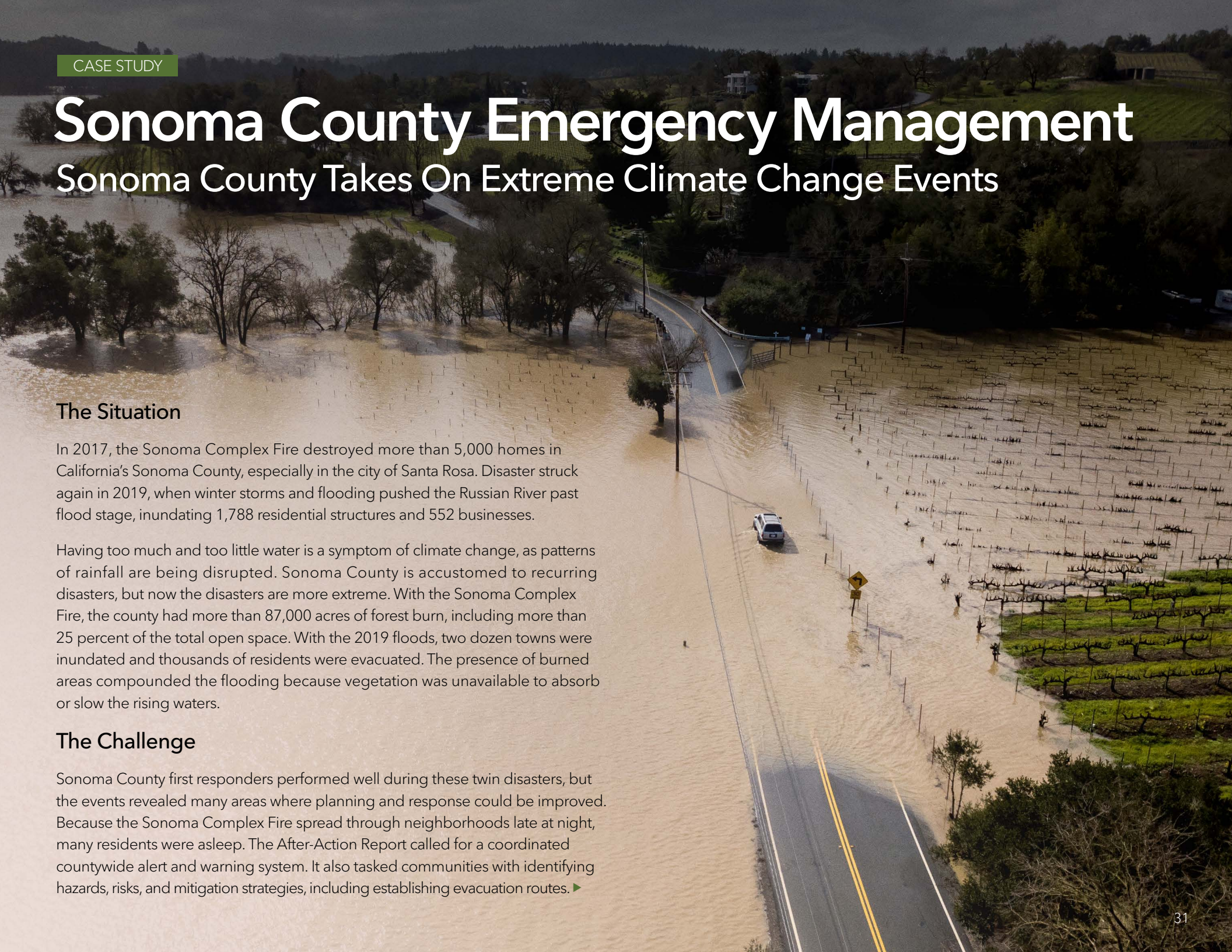
The challenges we face require unprecedented collaborative strategies. GIS has the power to connect disparate groups, enabling them to act together from remote locations. The same capability that is critical to coordinating response when disaster strikes is also valuable when considering priorities and long-range plans to enhance resilience. ■



CASE STUDY

Sonoma County Emergency Management

Sonoma County Takes On Extreme Climate Change Events



The Situation

In 2017, the Sonoma Complex Fire destroyed more than 5,000 homes in California's Sonoma County, especially in the city of Santa Rosa. Disaster struck again in 2019, when winter storms and flooding pushed the Russian River past flood stage, inundating 1,788 residential structures and 552 businesses.

Having too much and too little water is a symptom of climate change, as patterns of rainfall are being disrupted. Sonoma County is accustomed to recurring disasters, but now the disasters are more extreme. With the Sonoma Complex Fire, the county had more than 87,000 acres of forest burn, including more than 25 percent of the total open space. With the 2019 floods, two dozen towns were inundated and thousands of residents were evacuated. The presence of burned areas compounded the flooding because vegetation was unavailable to absorb or slow the rising waters.

The Challenge

Sonoma County first responders performed well during these twin disasters, but the events revealed many areas where planning and response could be improved. Because the Sonoma Complex Fire spread through neighborhoods late at night, many residents were asleep. The After-Action Report called for a coordinated countywide alert and warning system. It also tasked communities with identifying hazards, risks, and mitigation strategies, including establishing evacuation routes. ▶

Sonoma County (continued)

The Solution

After the 2017 fires, the Sonoma County Board of Supervisors laid the groundwork for a new alert system. The county implemented a new cloud-based public website that included live maps created with GIS, as well as plans for the public. The site was designed for high traffic and optimized for mobile devices. County agencies installed a high-definition camera network for the early detection of fires in the Lake Sonoma watershed. A system of stream/rain gauges were installed downstream of the burn areas to enhance Sonoma County's ability to monitor potential dangers during rainstorms.

The Results

Sonoma County Department of Emergency Management now has a state-of-the-art spatial awareness platform for local emergencies. Evacuation zones have been mapped and residents can look up routes and receive alerts. A new site even adds a countywide map of road closures and delays to further aid in routing. This alert system was tapped for the pandemic, with a county-level dashboard of COVID-19 cases and vaccination rates. For victims of the 2017 fires and 2019 floods, maps are being used to share property cleanup status and organize rebuilding efforts.

Sidebar Forrester Research Recognizes Esri for Climate Risk Analytics Capabilities

Experts now rank climate change among the most significant threats we face, spurring demand for a new climate risk analytics market.

In *"The Forrester New Wave: Climate Risk Analytics, Q3 2020"* from independent analyst firm Forrester Research, the report's authors evaluated eight companies "that matter most" and noted there is growing scientific evidence of a climate that's changing faster than previously thought, making companies and governments increasingly concerned—and causing decision makers to pursue ways of mitigating damages.

Esri was among the leaders, with the report stating the company, "leads the pack with robust data, analytics, and visualization capabilities," and "applies spatial data visualization and advanced data and processing technologies to physical climate risk analysis."

Forrester, highly regarded for its analysis of the impacts of technology on business, had also made a bold call in 2011 that a new age of the customer had begun, with technology empowering consumers to demand more from businesses.

Many corporate leaders now recognize that location intelligence addresses risks tied to climate change. Natural resource managers have realized this too, and forest plans are now focusing on adaptation.

Given the pressures forests currently face, location intelligence is more important than ever, and the tools are up to the task. The modern GIS platform's ability to support different user types helps adapt the tool to fit many functions. This feeds data from the whole of operations to provide a more holistic understanding.

The geospatial approach spans science, technology, business, and governance. The new flexibility of the tools and data makes cross-sector integration possible, and new levels of collaboration have emerged. Location intelligence unites stakeholders around common causes.

As we navigate restoration from devastating fires, and observe how vegetation withstands the heat, or not, geospatial context is guiding a build-back-better plan in the face of climate pressures. Location intelligence is leading data-driven decisions that make sense of every place to create forests that can face a warmer future. ■

CONCLUSION

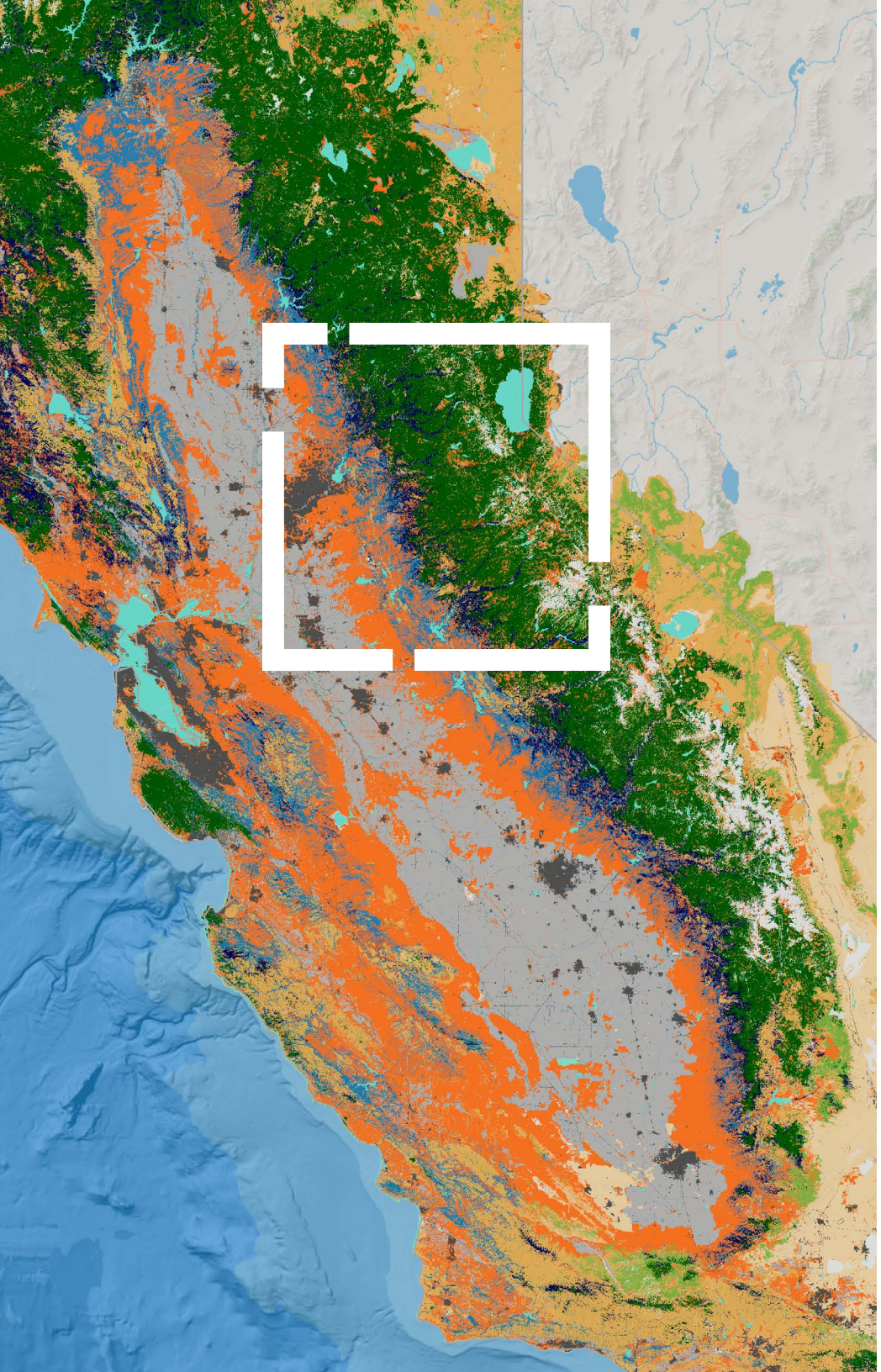
While the threat of wildfire is a stark reality, there are several ways to gain more control and strengthen planning, response, and prevention.

We know how to digitally catalog the types of trees in a forest, analyze the changes in landscape over time through drone and satellite imagery, and simulate scenarios including prescribed burns to diminish the fuel that feeds raging fires. We can observe fires in real time, monitoring their paths and using algorithms to support decision-making.

Advancements in mobile devices, sensors, and the Internet of Things have greatly increased the flow of data for emergency responses. The data proceeds from apps and dashboards to give everyone a real-time view of assets and people, displayed on a shared map. Field staff have an awareness of what to look for and can use their creativity to troubleshoot any situation alongside their peers. Workflows have been improved, with a unified live map for all departments.

GIS continues to advance, with streaming real-time data providing a current view of reality that greatly speeds understanding and wayfinding, and visualizations of historical patterns and trends. A growing suite of spatial analysis tools allow organizations to dive deeply into every incident to answer the *why* and the *now what* questions more quickly.

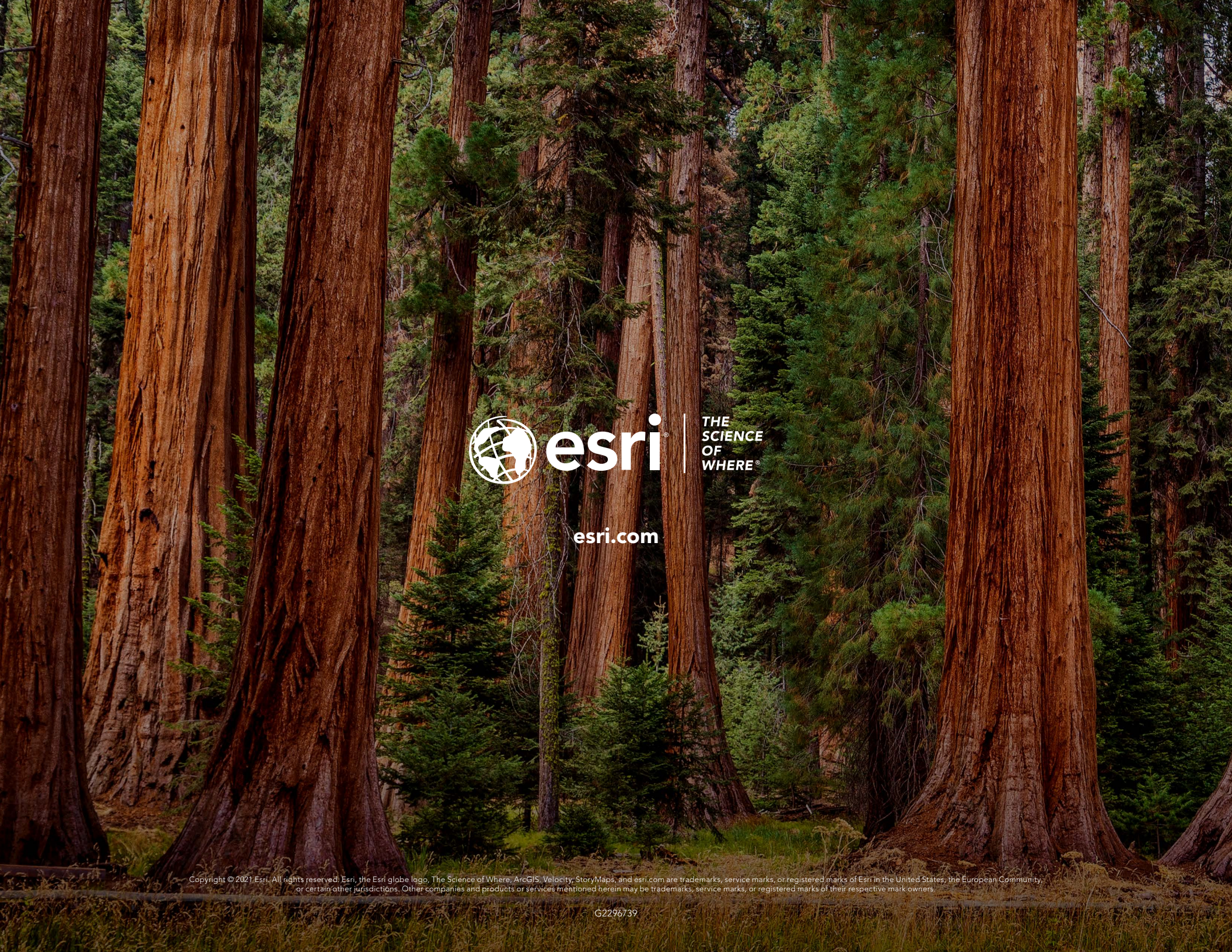
GIS makes it easier to tackle and understand challenging missions. By applying it in operations, the data gets better, the root causes and places to invest in become more apparent, and the analysis and communication necessary for achieving success on a daily basis grow clearer. GIS enables a common view and a way to share data and input from anyone: researchers, drone operators, residents, businesses, and relief organizations as well as firefighters and other emergency responders and government agencies. With shared operational intelligence, we all see the problem in its totality. We can collaborate to solve problems, streamline workflows to enhance efficiency, and create a path to effect continuous improvement and positive change. ■



Learn More

Esri, the global market leader in geographic information system (GIS) software, location intelligence, and mapping, helps customers unlock the full potential of data to improve operational and business results. Founded in 1969 in Redlands, California, USA, Esri software is deployed in more than 350,000 organizations globally and in over 200,000 institutions in the Americas, Asia and the Pacific, Europe, Africa, and the Middle East, including Fortune 500 companies, government agencies, nonprofits, and universities. Esri has regional offices, international distributors, and partners providing local support in over 100 countries on six continents. With its pioneering commitment to geospatial information technology, Esri engineers the most innovative solutions for digital transformation, the Internet of Things (IoT), and advanced analytics.

Register to attend, Wildfire & Forest Resilience: Preparing for What's Next
go.esri.com/wildfire-forest-resilience-event.



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