



Environment

Conservation

Sustainability

Equity and Social Justice

Smart Planning

Climate Action

Public Safety

Infrastructure

Humanitarian Assistance

MAPPING THE NATION

Creating the World We Want to See



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Foreword

Geographic Understanding Creates a Better Future

I often say that sustainability starts with geography. Geography holds the key to helping us better understand and manage our world, which faces compounding crises. In fact, I believe our future depends on it. We must be more coordinated and concentrated in taking action where it is needed the most if we are to create a world that is healthy, prosperous, equitable, peaceful, secure, and in balance with nature. In other words, geography will help us ensure a more sustainable future for all.

A Foundation for Understanding

A geographic approach provides a way of thinking and problem solving that integrates and organizes all relevant information in the crucial context of location. In much the same way that geography integrates the physical, biological, and social sciences, geographic information system (GIS) technology integrates the knowledge that is needed to understand the complex challenges facing our world.

GIS provides a means to examine and explore the dimensions of every challenge, prioritizing what to do where and when based on evidence and analysis. With GIS, layers of domain-specific intelligence can be draped over maps. They can be combined and modeled to reveal new relationships and hidden connections across space and time.

Leaders make more informed decisions using GIS to see these patterns and trends, model different scenarios, and craft solutions. They use maps to better communicate and collaborate—providing a shared understanding of the issues at hand. With GIS, government agencies, companies, and institutions around the globe are using the power of geography to guide their course toward a better future.

Toward a National GIS

It is clear that creating a better future requires us to work collaboratively, connecting our organizations to truly understand our world. GIS has become more interconnected than ever before. Systems link organizations and agencies together to share millions of datasets among a diverse set of users. Users with expertise and knowledge use this data and GIS to create billions of maps every day. This has created ripple effects of positive impacts on the world, from biodiversity protection to safer and more inclusive communities.

Technological advancements have enhanced the utility of GIS and expanded its impact. The latest GIS-powered solutions thrive on endless data from a growing constellation of Earth-observing satellites and ground-based sensors. The increased number and frequency of observations are now processed using cloud computing and artificial intelligence (AI) to enhance knowledge about our planet in near real time.

A greater flow of data between and within organizations has reduced siloed information and broadened interdisciplinary collaboration. A shared

map provides the conduit for integrating and exchanging knowledge and information—building a national and global GIS that fosters a shared understanding and allows everyone to chart our progress together.

Building Digital Twins

With a national GIS, we can truly start to model and understand our world in new ways. Building a GIS-based digital twin of our planet using reality capture and real-time data shows not only what's happening now but allows us to simulate what might be. A living digital twin tracks everything that moves and changes in the landscape and models performance and stresses on systems. With this GIS-based digital twin, we gain new insight into how every part of a system affects the others, pinpointing problems and addressing challenges as they arise.

It fills me with hope to see digital twins and open science used to conserve more land and ocean, to identify inequities, and to address the impacts of climate-related threats. We need more evidence-based guidance to improve the balance on our planet and meet the urgency of the moment. With digital twins, we have an opportunity to advance science at an accelerated pace.

Mapping the Nation

Within this book are stories that describe the work of technical and scientific experts, civil servants, policymakers, designers, and many more stakeholders who make the world better using GIS.

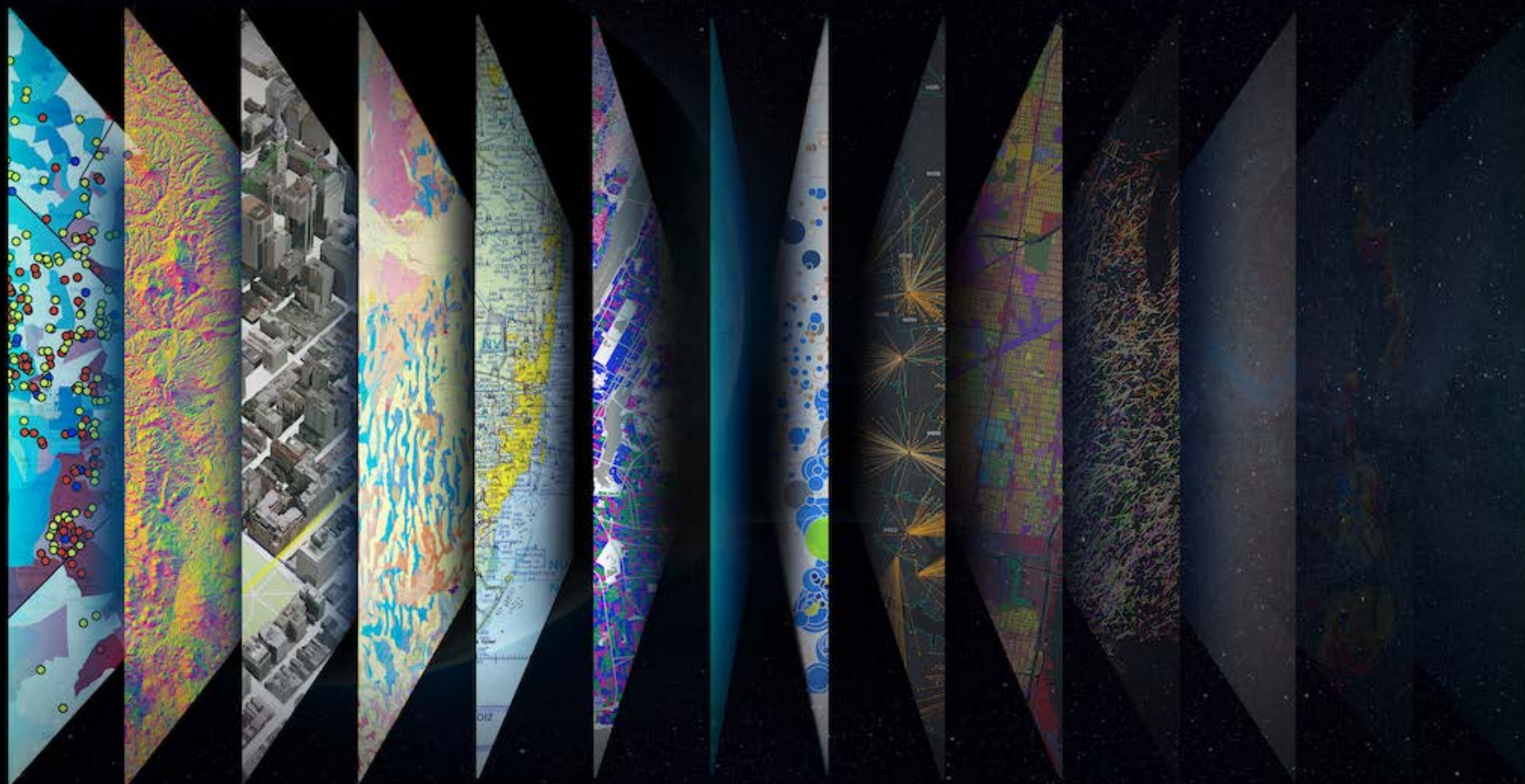
Mapping the Nation: Creating the World We Want to See continues a long series of books that acknowledge the contributions of GIS users by showcasing their work. These stories illustrate how geography and a geographic approach guide important decisions around the globe. We're continuously amazed by the depth of GIS activity and how its use measurably improves organizations and communities. Using GIS, professionals advance science, design with nature in mind, make communities more livable and efficient, improve public safety, secure nations, protect natural spaces, enhance human health, and mitigate social conflicts.

Now is the time to strengthen the stewardship of our world. At Esri®, we're dedicated to enhancing knowledge to create the world we all want to see. Sustainability starts with geography.

Warm regards,



Jack Dangermond



Introduction

Creating the World We Want to See

Despite growing evidence that humankind lives beyond its means, we have easy choices and many chances to create a more sustainable world. The same science, technology, and cultural forces that have led to the success of humans as a species can guide us toward a more balanced and livable planet.

Using GIS, we can collectively imagine and design solutions that can be implemented widely. A modern GIS facilitates data collection, analysis, and sharing to achieve coordinated responses. Using these tools, organizations gain an edge on complicated challenges because they can see trouble coming and take action to decisively avoid it. For cities, regions, and nations, these tools provide awareness through maps and dashboards to ensure that everyone can participate in building more sustainable approaches.

As organizations that use GIS to address complex problems already know, the science of geography fosters ground truths. By creating a shared picture for everyone involved, it leads to quicker and more decisive action. With the use of GIS, initiatives can be formulated, priorities emerge, and progress can be made.

Within this book, you will read of organizations that took a proactive approach to climate action, equity and social justice, the environment, conservation, humanitarian assistance, public safety, smart planning, infrastructure, and sustainability. Through the familiar frame—problem, solution, result—you will learn of organizations and individuals who are making an impact with GIS by applying a geographic approach to their challenges.

At Esri, we like to think of GIS as a geospatial nervous system for the planet, one that can help guide an effort such as climate resilience by empowering organizations to take the pulse of climate pressures. We are committed to helping our users design a better, more sustainable future. And we're confident that the collaborative nature of GIS will foster important connections among and within organizations.

Partnerships and collaborations, such as the one between the United Nations (UN) and Esri around quantifying the UN's Sustainable

Development Goals (SDGs), can help everyone on the planet. Mobile field data applications, coupled with analytic capabilities, can support the ambitious goals of ending poverty and hunger and all the other important aims of a modern and inclusive society.

GIS provides tools to better manage the natural environment and safeguard wild and biodiverse places. Many communities have gone too far in extracting resources to the detriment of species and ecosystems. Nature is inherently resilient though, and land managers have employed GIS to return vibrancy. GIS guides rewilding and rejuvenation programs that enhance habitat and return locally extinct species to reclaim balanced ecosystems.

Humanitarian-aid organizations use GIS to address some of their most common challenges, such as helping where needs are the greatest and finding safe routes to deliver relief services. In public safety, GIS reveals where to focus efforts to prevent, protect against, and mitigate complex threats and hazards. With real-time data-driven insights aiding mission-critical decisions, responders can quickly recover from events and threats that pose the greatest risk of destabilizing communities.

Geodesign provides a smart planning approach to designing with nature rather than against it. This powerful method has been used to create new developments that bring important amenities to communities, including enhanced proximity to nature and increased shade to combat climbing temperatures. GIS has been used to make communities more livable while reducing risks from more extreme storms due to climate change.

The global GIS vision that was once imagined by pioneers of the technology has gradually come about through our collective work.

When we all can see the benefits of our actions, we can accelerate changes to create a world we all want to see. Together, we can leave future generations with blueprints and solutions that create balance. We owe it to the planet, and all the species that live on it, to map the change we want to see.



Climate Action

A geographic approach has helped revolutionize how communities adapt to climate impacts and mitigate damages by adopting resilience strategies.

The Florida Division of Emergency Management (FDEM) has transformed its previous 500-page hazard mitigation plan into an engaging, interactive map-based experience. This innovation came about after the state surveyed counties and municipalities about the data and tools they needed.

Local jurisdictions “told us they didn’t find the previous plan useful, which is a dagger to our heart for this huge five-year effort,” said Kristin Lentz, the mitigation planning manager at FDEM.

To provide a more user-friendly and intuitive plan, Lentz and her team used GIS technology to analyze hazards, climate, and social vulnerability and incorporated digital maps into their planning. Local jurisdictions in Florida now have the data they need to devise effective mitigation strategies and employ techniques to improve resilience.

Geospatial modeling provided a detailed picture of flood risks in Los Angeles. Researchers simulated flooding at much finer spatial resolution. This level of detail allowed them to create a more comprehensive and accurate flood risk map.

Director of the Flood Lab at the University of California, Irvine, Brett Sanders, explained, “Existing models for doing accurate local inundation mapping in the past haven’t let modelers study a region the size of Los Angeles County at once at this resolution.” The researchers used the model to identify the populations facing the biggest flood risks. The Los Angeles Board of Supervisors were so impressed with the model and its consideration of vulnerable populations that they passed a new measure to consider equity for all flood mitigation projects.

In Atlanta, the city has recognized that trees play an important role in making the city more livable as the weather heats up. Trees Atlanta, a nonprofit

organization, is using GIS technology to record, map, and track its work in maintaining Atlanta’s 48 percent tree canopy coverage. This effort is crucial as Georgia faces the fastest urban tree loss in the nation.

The data manager at Trees Atlanta, James Moy, highlighted how GIS technology has enhanced their capabilities, sharing how GIS “really expanded the possibilities for how we could record our planting locations, what kind of information we could record, and the quality of care we could give each tree.”

Trees Atlanta has fostered a community-led tree-planting effort in places where they will be well received and cared for by the community.

New York City officials are working on a revision to flood maps to include projections of how climate change will impact the city’s neighborhoods. The city is also using GIS technologies to provide residents with interactive maps that show current flood hazards and how they are likely to increase due to climate change. This is a part of the city’s efforts to fill in the public’s understanding of flood risk and guide infrastructure planning to reduce the impacts of climate-related hazards.

To address rising air pollution, the US EPA and Forest Service have collaborated to create the AirNow Fire and Smoke Map, a mapping tool that combines official air quality data with readings from a network of low-cost sensors run by volunteers. This map aids Americans overall in understanding and planning around worsening air quality conditions.

The map combines data from various sources, including official AirNow monitors, temporary monitors set up by state or federal agencies, and homemade air sensors run by members of the public. President Joe Biden has called the enhanced map “an important tool.”

If we can better track the impacts of climate change and the solutions to combat it, we might be better at protecting our communities and our planet. Dynamic maps of changing conditions will encourage more people to participate.

In Florida, Interactive Maps Tell the Story of Modern Risk Mitigation

Every US state has had to update its five-year hazard mitigation plan—now with priorities around community vulnerability and climate forecasts. Mitigation managers in Florida are meeting this Federal Emergency Management Agency (FEMA) mandate in a new way, through interactive maps to make their plan more user-friendly.

We met with local jurisdictions, and they told us they didn't find the previous plan useful, which is a dagger to our heart for this huge five-year effort.

—Kristin Lentz, mitigation planning manager, Florida Division of Emergency Management or FDEM



Retirement communities dot the coasts of Florida, with many right on the water. This poses hazards from hurricanes, high tides, and sea level rise.

So Lentz and her team at FDEM used GIS technology to build a more engaging experience. What was once a 500-page PDF is now a website with data-rich maps and insightful narratives.

To meet FEMA's directive by the August 2023 deadline, the FDEM team applied GIS analysis of hazards, climate, and social vulnerability. Then, to make the plan more intuitive, Lentz worked with Dan Rydl, GIS manager at FDEM, on incorporating digital maps. They built the site using ArcGIS® Hub to organize information and ArcGIS StoryMaps stories for narratives. They will continue to update the site's open data and analytical guides for counties and municipalities.

Mitigation Projects through a Lens of Vulnerability

Hazard mitigation projects encompass retrofitting critical facilities such as schools and hospitals to better withstand hazards such as high winds, flooding, and extreme heat. The work entails hardening infrastructure such as electric and telecommunications networks to uphold power and internet connections. Other eligible projects include stormwater mitigation to increase drainage and, in some cases, elevating homes in areas that experience repeat flooding.

After a major event, FDEM assesses damages to determine how mitigation projects reduced property loss and saved people from harm.

"The loss avoidance reports help us with storytelling and getting buy-in for more projects," Lentz said. "In mitigation, projects utilize effective resilience techniques to improve future outcomes, which can be highlighted through these reports."

In a similar way, FDEM uses maps to show communities in need of more help and areas where hazard risks are highest.

"We mapped risks and hazards and draped social vulnerability on top of that," Rydl said. "Almost everybody that looks at the hazard vulnerability map pauses and wants to talk about it because they understand hazard risk in a new way."

With more mapping, a more comprehensive picture of risk in Florida emerged. For instance, analysis of some natural

hazards, such as extreme heat, revealed social vulnerability in the central spine of the state. "Diving deeper to ask, 'Why is that?' was helpful for us on the planning side," Lentz said.

"Regardless of the hazard, it opens your eyes to the more challenged and impoverished areas," Rydl said. "People assume that the coast is the most vulnerable, but that's not always the case."

Forecasting and Collaboration Make a Path Forward

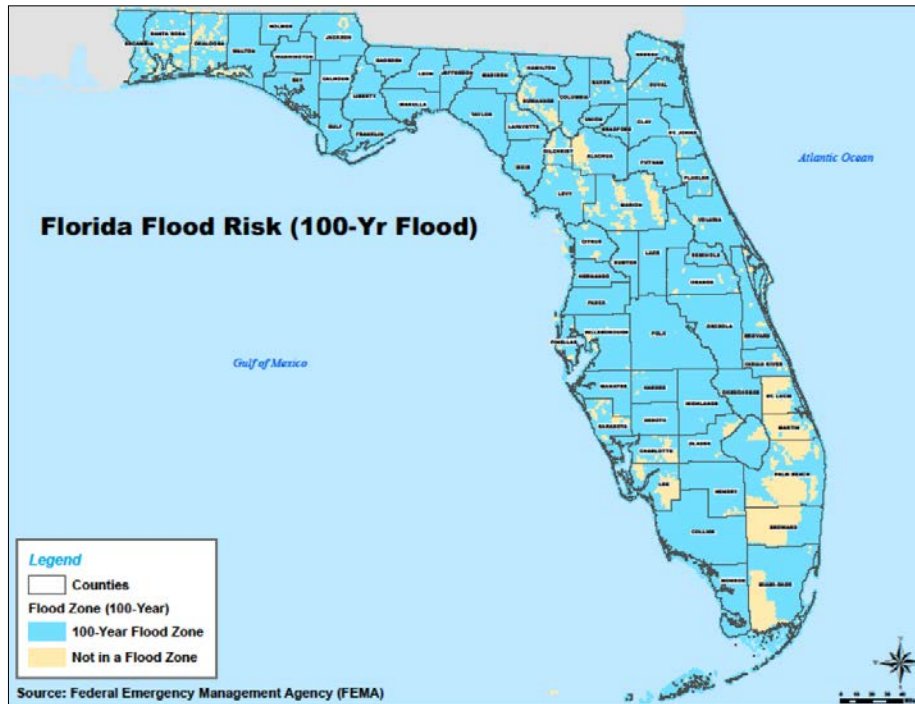
On the previous five-year plan, Rydl and the FDEM GIS team provided maps. This time, he taught Lentz and her mitigation planning team how to make maps. They met every week for two years. Rydl trained the team on GIS basics, and they applied the technology to all of FEMA's requirements.

Along the way, talents emerged on the combined GIS and planning teams. Some members were more comfortable making maps, others focused on narratives, and a few took on web development. "We picked up on that and built a really fun collaborative environment," Rydl said.

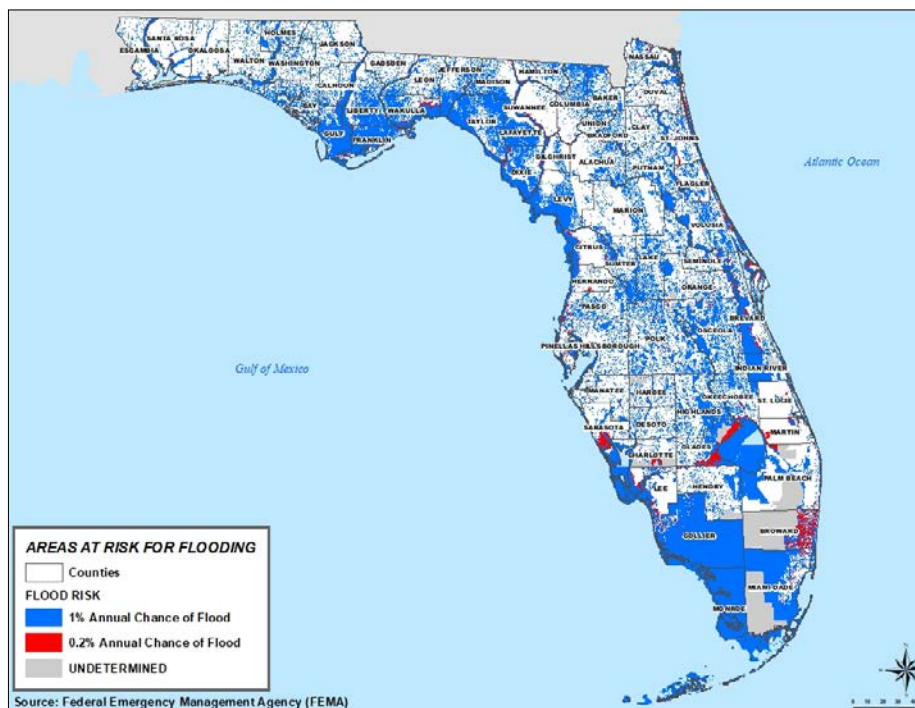
One area of focus was climate vulnerability. Florida currently feels increased impacts from more frequent and intense natural hazards. These hazards include wildfires, extreme heat, drought, storms, heavy precipitation, and sea level rise.

The state sees more natural disasters than most, particularly during hurricane season, which runs June 1 through November 30. For 2023, forecasters expected less activity than normal for the first time in seven years, after an upward trend as extreme hurricanes were on the rise from 2018 to 2023.

Hurricane Ian, which devastated southwest Florida in September 2022, is a sobering example. It caused \$113 billion in damages and 152 deaths. A report from 2022 ranks it as the third-costliest storm in US history. Without existing measures to mitigate damage, it could have been worse. And the damage that was felt is now guiding further mitigation.



Florida flood risk map from 2018 shows most of the state in a 100-year flood zone.



The flood risk map in the 2023 report corrects mapping errors made previously, and shows FEMA special flood hazard areas.

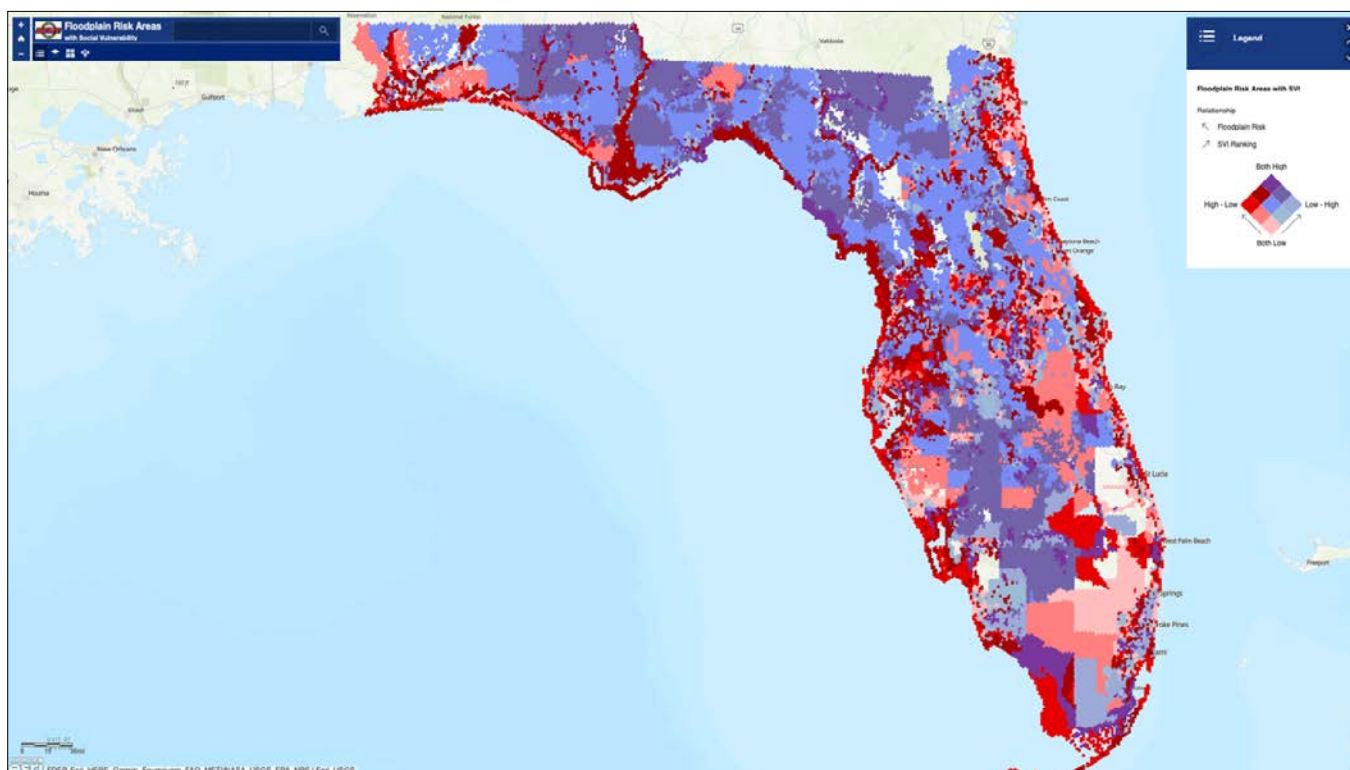
Although many states have considered climate forecasts in their hazard plans in the past, the FDEM team knows how tightly mitigation aligns with climate resilience.

“We’ve done the research to understand impacts, but I think we can improve on visualizing what future conditions will look like here in Florida,” Lentz said.

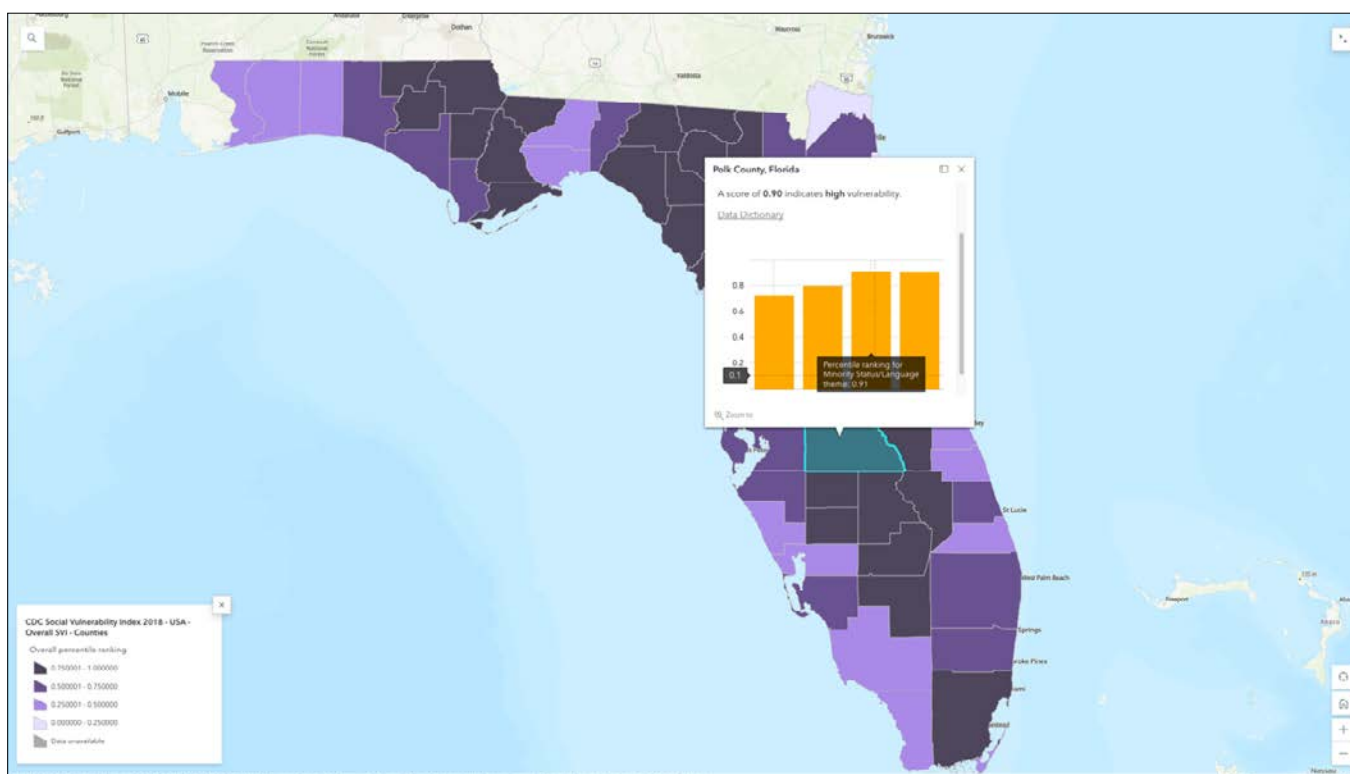
Rydl is looking into risk forecast models to understand what’s coming. Meanwhile, Lentz and her staff are on their way to becoming GIS experts. “I think the GIS team has become a little more mitigation-y, and I think mitigation got a little more GIS-y,” Rydl said.

For 2023, the FDEM team was confident it had built a product that’s more useful to the counties and municipalities that design mitigation projects.

“We created a tool that allows local jurisdictions to ask where dollars will best be spent,” Lentz said. “They can look at how successful projects are, but also at where they haven’t yet implemented mitigation.”



The bivariate risk map of Florida flood risk for the 2023 State Hazard Mitigation Plan relates the Social Vulnerability Index from the Centers for Disease Control and Prevention overlaid with hazard risk to reveal where help is needed most.



Zooming into Census Tract 124.10 in Polk County, Florida, the flood risk score of .68 and social vulnerability score of .65 place this tract at moderate to high vulnerability for both in the 100-Year Floodplain.

Mapping LA's Flood Risk Reveals Hidden Harm in Vulnerable Communities

In 2023, Californians endured a relentless barrage of atmospheric river systems, the massive volumes of water vapor that snake across the Pacific and unleash copious precipitation when they reach land. Tropical Storm Hilary drenched areas of Los Angeles with as much as six inches of rain in late August. Street flooding occurred downtown, and numerous roads were washed out in the surrounding mountains. The deluge boosted historically low water levels, ending the state's

severe drought. But the flooding and landslides that the systems bring severely test infrastructure and endanger lives and livelihoods, illustrating the many ways climate change increases risk to communities around the world.

California's "weather whiplash," the rapid swings between dry and wet spells, is also worsening. Cities such as New York and Miami face risks from coastal and urban flooding,



Brett Sanders, director of the University of California, Irvine, Flood Lab, standing in the LA River.

but cities in California have compounding risks. They face increasing flood risks while also managing drought and wildfires.

“You look back at the last few years in this state — it’s been fire to ice, and no warm bath in between,” Governor Gavin Newsom said during a news briefing on March 15, 2023, in Pajaro, the Monterey County town flooded by a levee breach. The flooding displaced hundreds of people in the primarily migrant town and raised concerns about crop yields in the agricultural region.

If anyone has any doubt about Mother Nature and her fury—if anyone has any doubt about what this is all about in terms of what’s happening to the climate and the changes that we’re experiencing—come to the state of California.

— Governor Gavin Newsom

In California, as elsewhere, the challenge is compounded by a basic problem: inadequate understanding of flood risk.

One study of flood exposure in Los Angeles that appeared in the journal *ScienceAdvances* in August 2022 suggests that the population exposed to dangerous flooding, or a flooding event with 1 percent annual probability, is between 10 and 40 times greater than US government maps show.

The study, published in November 2023 in *Nature Sustainability*, estimates that 425,000 people and \$36 billion of assets would be exposed to dangerous floods rising to a height over 30 cm within the 100-year flood zone. The study also shows that the current 1 percent annual probability flood cannot be contained by existing flood infrastructure such as levees.

The numbers of at-risk Angelenos surprised even the researchers. “We double- and triple-checked our models and tried to figure out, Did we make a mistake?” said

Brett Sanders, director of the Flood Lab at the University of California, Irvine.

To make their estimates, Sanders and his colleagues used an innovative geospatial modeling approach specifically designed for high-performance computing, allowing them to achieve an unprecedented level of mapping detail.

Initially, the researchers set out to learn which Angelenos face the biggest flood risks by combining new hazard maps with census data.

As they expected, they found an inequality along socioeconomic lines, with the more disadvantaged half of the population shouldering 65 percent of the composite flood hazard.

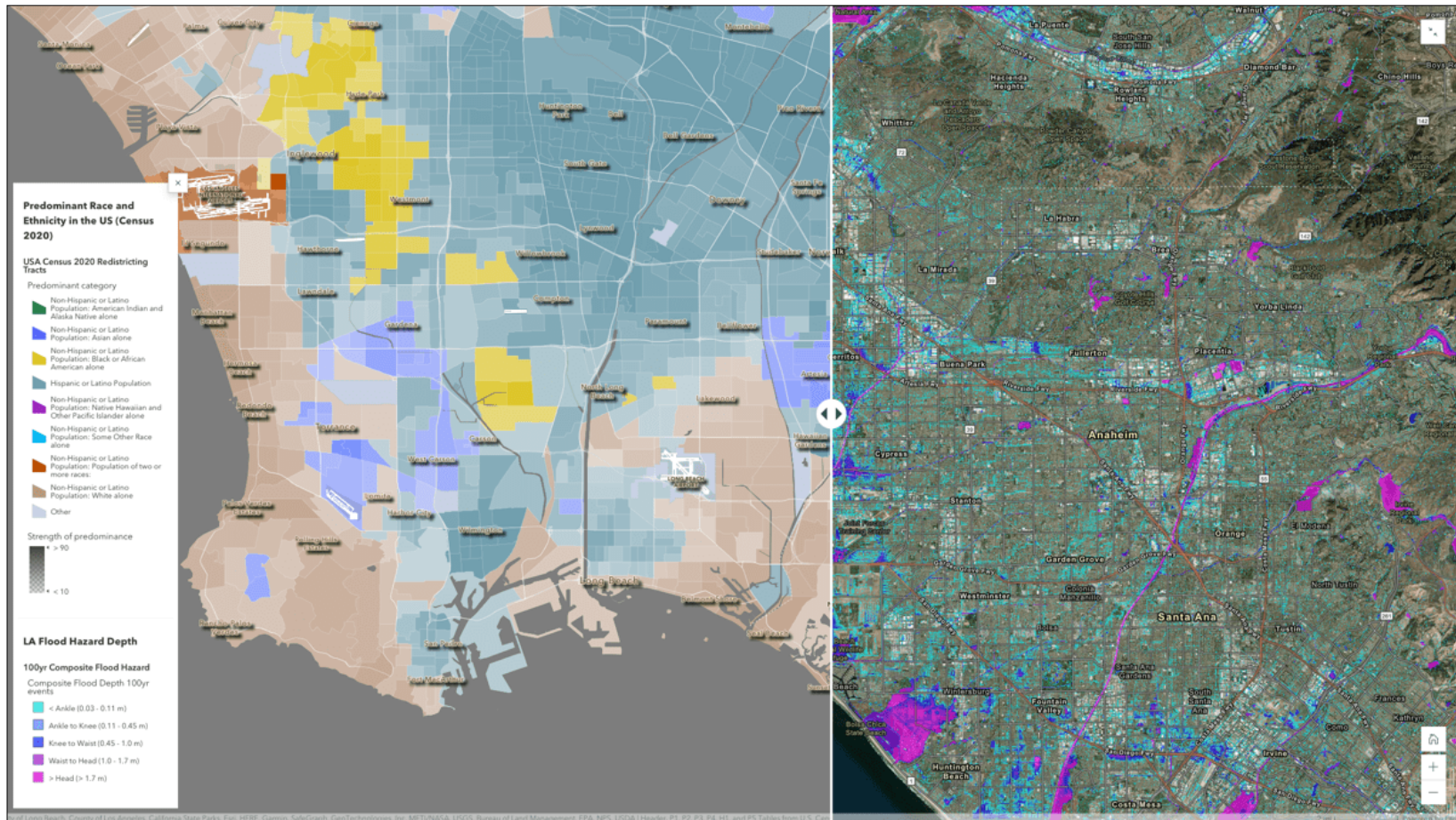
But the strongest disparity they found was racial. Although non-Hispanic White communities were disproportionately likely to suffer coastal flooding, Black, Hispanic, and Asian residents were 79 percent, 17 percent, and 11 percent more likely than White populations, respectively, to be exposed to dangerous flooding, particularly from river floods.

The racial and economic disparities, previously unacknowledged in federal flood risk maps, are exacerbated by the fact that disadvantaged communities tend to receive less government support for flood risk reduction and disaster recovery compared with more affluent communities.

Left unaddressed, these risks only grow, leaving communities not only unprepared but less capable of bouncing back after a storm, says Sanders. The six most expensive natural disasters in the world in modern history were all the result of tropical storms such as Hurricane Katrina.

And years later, some communities are still recovering from previous disasters even as they try to prepare for future storms.

“New Orleans tells the story of cities that don’t recover, neighborhoods that are forever changed after the flood, that don’t bounce back,” Sanders says.



This map visualizes a side-by-side comparison of the spatial distribution of flood depth (right panel) and the spatial distribution of population for non-Hispanic Black, Hispanic, non-Hispanic Asian, and non-Hispanic White populations (left panel).

The Importance of Up-to-Date, and Accurate, Maps

In the US, the National Flood Insurance Program (NFIP) is designed to assist owners of property within the 100-year flood zone in rebuilding after a damaging flood. But the maps that FEMA uses for the program—and that many rely on to determine risks—aren't required to include rainfall hazards, or the often-immense impervious surfaces of cities where rainfall runoff can't be contained by street gutters.

The FEMA maps also rely on hydrologic and hydraulic modeling (of flood peaks and channel capacity) that is often decades out of date, and out of step with dramatic changes to population and the urban landscape.

Although the maps cover coastal and river flooding, Sanders said, "They don't ask, 'Well, if it rains really hard and the water hits the ground and runs into the streets and it can't drain fast enough, where's it going to pond, and who's it going to flood?'"

Even alternative efforts meant to improve on FEMA's maps don't properly estimate urban flood risks, says Sanders. Large-scale flood risk models used in nationwide studies offer relatively low accuracy in urban areas, since they typically lack data about urban drainage infrastructure and the condition of flood channels, levees, and dams. They also rely on geographic and computational grids that are too coarse to

depict the complexities of flooding as runoff spreads across city landscapes.

For their study of Los Angeles, Sanders and colleagues built a numerical model capable of simulating flooding at a spatial resolution of three meters across the nearly 7,000-square-kilometer area of greater Los Angeles. “Existing models for doing accurate local inundation mapping in the past haven’t let modelers study a region the size of Los Angeles County at once at this resolution,” he says.

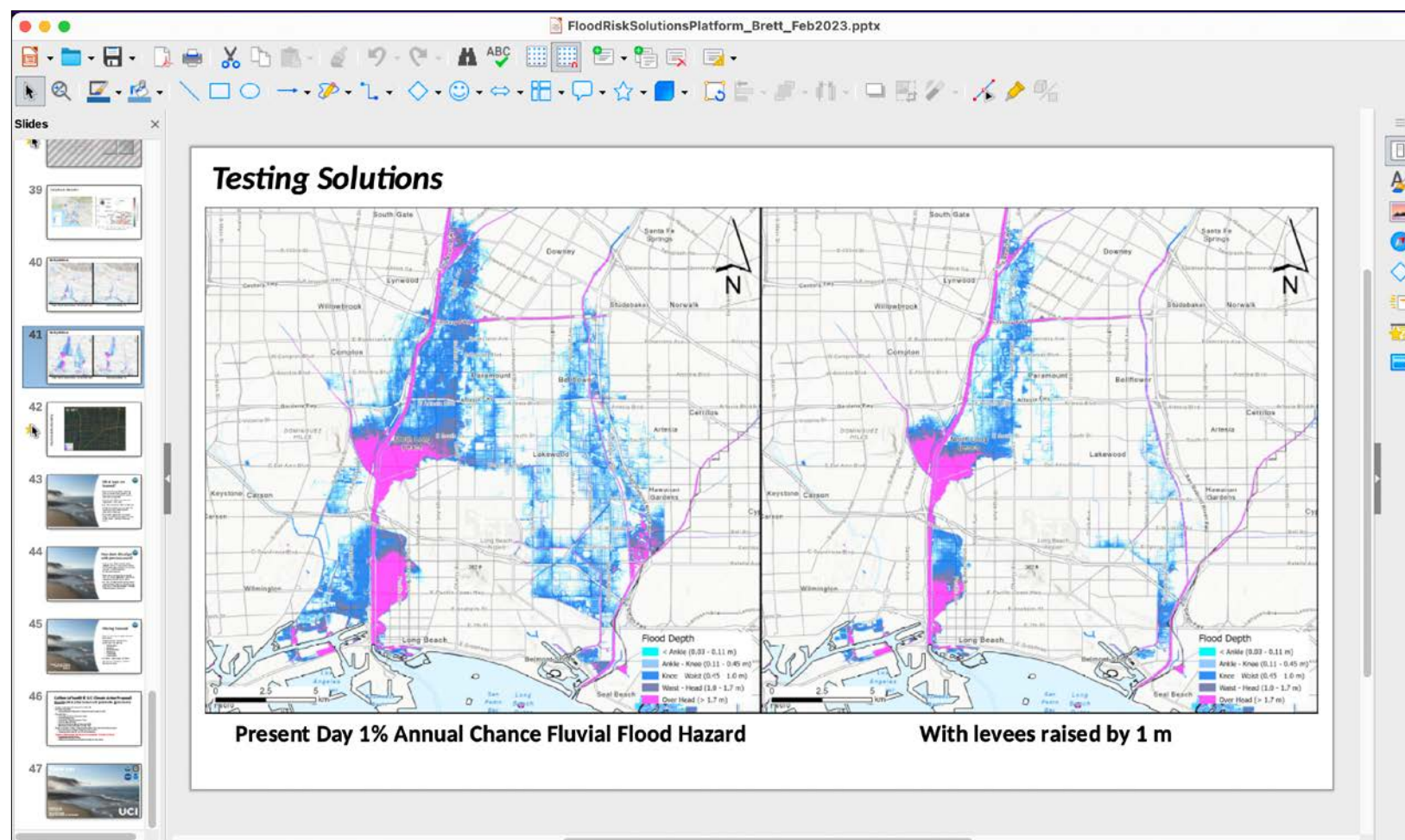
They began building their map with topographic data and digital elevation models (DEM) based on aerial lidar or photogrammetric surveys. “It’s fine enough that we can

resolve a road and how low the road is and how much water might run down a road.”

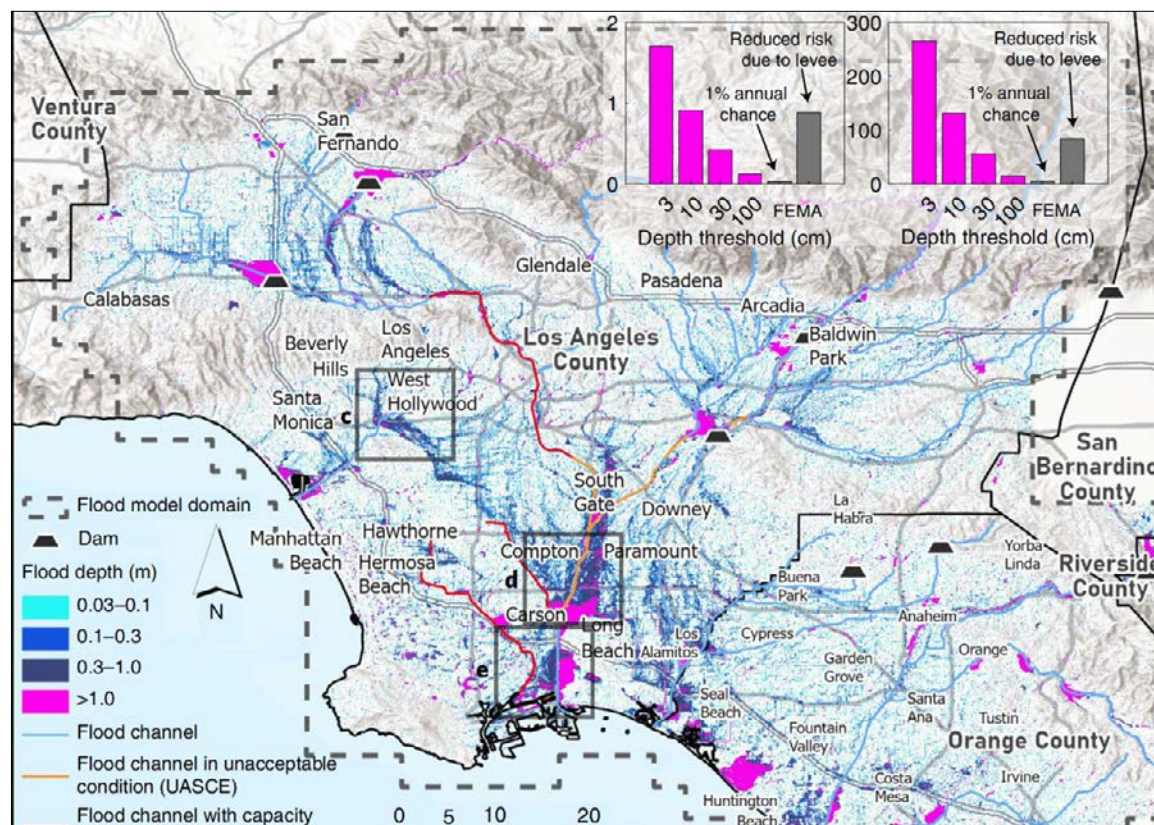
Still, the surface data misses all the complexity underground, such as pipes and culverts. Sanders and his colleagues turn to local governments for ancillary datasets, such as shapefiles for stormwater infrastructure and path lines for pipes.

From there, they “hydrocondition” the data to represent the functional effects of the infrastructure on the map and simulate different kinds of floods.

Running these simulations demands the supercomputing powers of parallel servers, but this introduces its own



The Parallel Raster Inundation Model, or PRIMo, is designed for whole-city-scale hazard modeling.



The new model allows the UCI Flood Lab to test scenarios and show the effect of various mitigation measures.

bottlenecks. So the researchers developed a more efficient flood inundation model, the Parallel Raster Inundation Model, or PRIMo. Designed specifically for whole-city-scale hazard modeling, the model uses a new way to represent infrastructure, says Sanders, and “strikes a balance between the amount of detail you put into the model and your ability to model a large area.”

Gathering Community Feedback

Sanders and his team also held workshops with city agencies, environmental groups, and some of the community groups most likely to be impacted to hear Angelenos’ biggest flood concerns, from sea level rise to levee failures to heavy rain. Using ArcGIS technology and ArcGS StoryMaps developed by Jochen Schubert at the UCI Flood Lab, they

shared data with stakeholders to get early input into the flood model. Sanders thinks the process can help deepen understanding and trust.

“We know from experience that getting stakeholders involved early in a process is really important, so that when results are finally finalized, there’s more buy-in that this model has some validity and it’s sharing something that makes sense and is actionable,” Sanders said.

The new maps are now helping improve flood understanding in vulnerable areas, such as along the LA River, and sparking fresh discussions about adaptation. The system can be updated to account for possible infrastructure projects, including new levees, channel

widening, green infrastructure, and even changes to land-use and building codes.

“We can run different scenarios like, Well, what if we widen the river? What if we raise levees? What if we invest in parks and green spaces? ... Can we slow down the water before it gets to the river and capture it and store it? I think a lot of people would like to do that.”

Addressing Heightened Risk Elsewhere

Next, Sanders and his team want their model to be used by other US cities where flood risk remains undermapped, harnessing the power of big data, machine learning, and new aerial sensors. Better flood risk maps can help identify projects that will address inequities while reducing risks for everyone,

and possibly addressing other risks, too. One example: Governor Newsom ordered the use of flood waters to fill aquifers, to battle the state's ongoing drought.

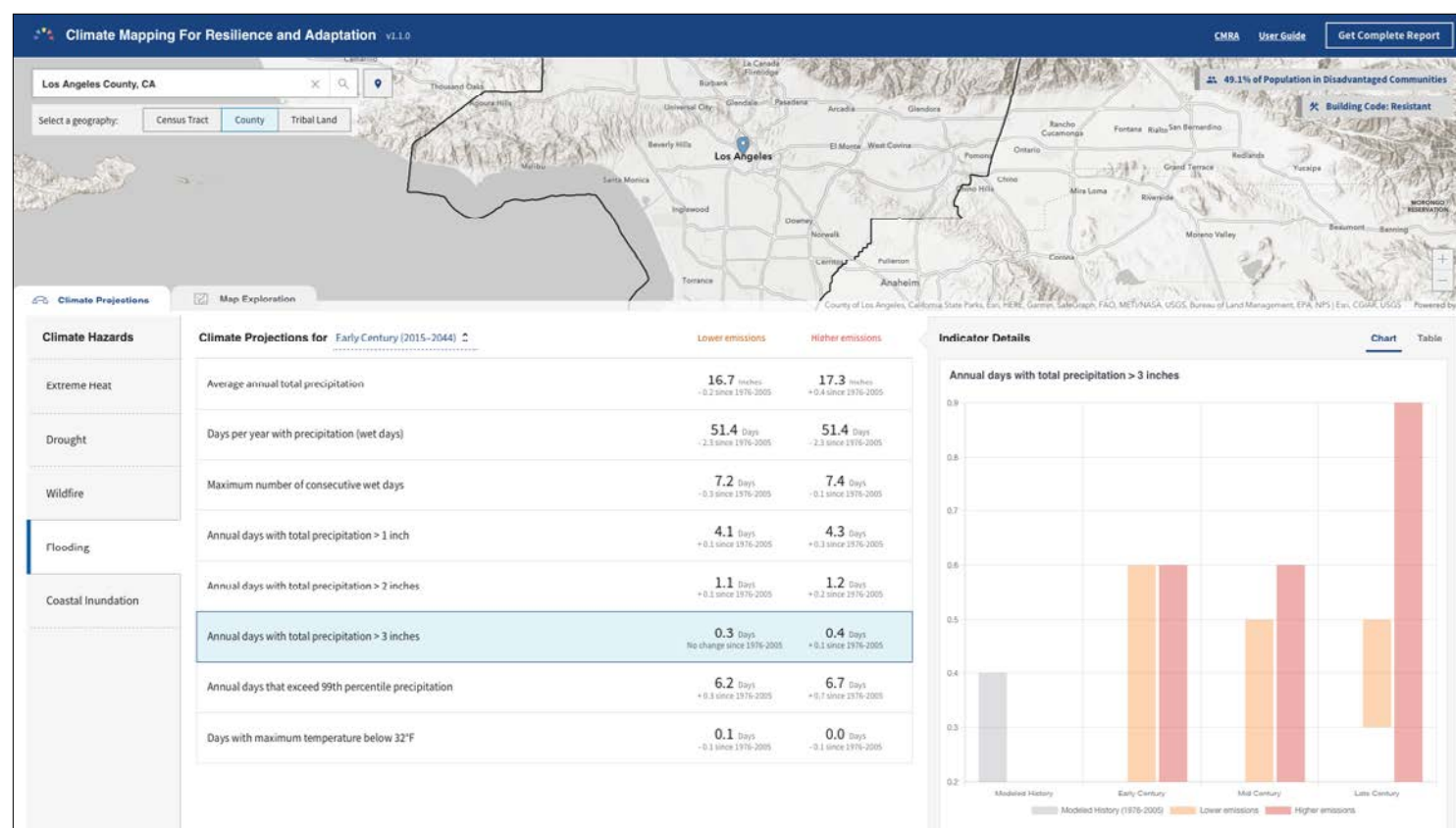
For climate adaptations, says Sanders, "you want to have something that's good for water conservation and good for ecosystems and good for flood risk management and good for social equity."

The White House has also emphasized the need for better, more public climate risk mapping, especially as it prepares to distribute historic sums for local infrastructure projects. The Climate Mapping for Resilience and Adaptation (CMRA) tool that was developed in 2022 uses maps and data from more than a dozen federal agencies to help communities

better understand their risks and seek resources accordingly. Sanders hopes his team's approach will eventually inform tools such as this, too, for instance, by helping FEMA improve its flood risk models.

Already, the maps are leaving their mark on Los Angeles. Following the study's publication in October 2022, the county Board of Supervisors passed a motion in December 2022 directing the city's public works department to develop a plan to address flood risks and inequities, while improving the city's water conservation and drought measures.

It's an "impact that you could only dream of," says Sanders, "seeing your work immediately register with leaders who say we need to act on this problem."



The Climate Mapping for Resilience and Adaptation tool combines extensive federal hazard data that can be used at national, regional, and local levels to monitor flooding conditions and explore trends.

To Protect Trees, Atlanta Nonprofit Maps and Measures Benefits

There's a running joke that in Atlanta, all navigation prompts include "Peachtree Street," because 71 roads all have some form of that name. But with the city's tremendous growth—adding two million residents between 1996 and 2014—actual live trees were becoming a rarity in and around Atlanta. In the 1990s, 27 acres of tree canopy coverage per day were lost during the construction boom brought on by the 1996 Olympic Games.

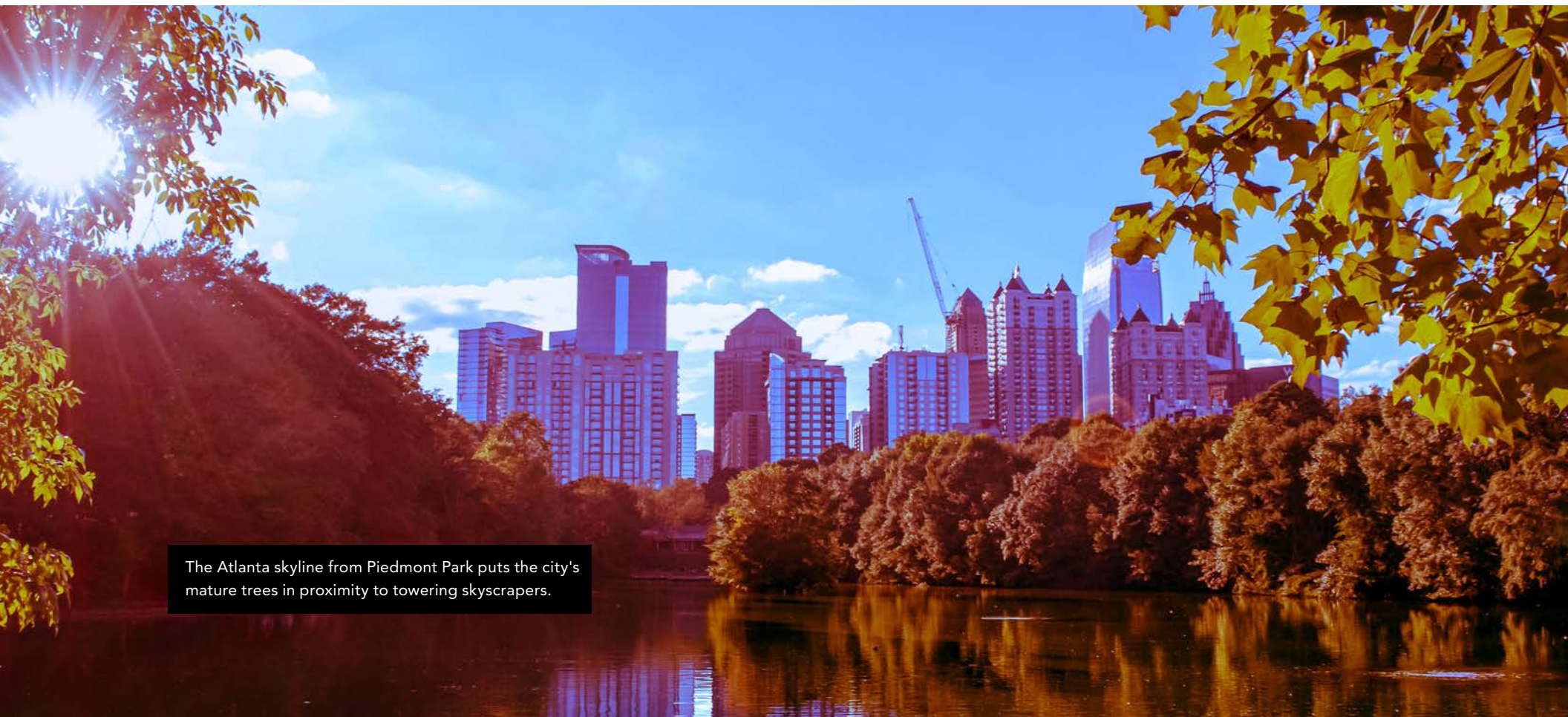
Trees Atlanta works to mitigate the city's tree loss and increase downtown tree canopy through planting, education, and conservation. The nonprofit is a community of employees and volunteers who recognize the benefits of trees and green space. The efforts to revive Atlanta's roots in nature put Trees

Atlanta on the map for redefining what urban spaces can look like. The nonprofit uses GIS technology to record, map, and track its work to keep Atlanta green.

Trees Atlanta has had success in safeguarding the reputation of Atlanta for being a "city in a forest," with its 48 percent tree canopy coverage. But there's an uphill battle statewide; the US Forest Service has singled out Georgia for the fastest urban tree loss in the nation.

Growing from Paper-Based Maps to GIS

Before implementing GIS, the Trees Atlanta team members could not gather a full picture of their work in specific neighborhoods or throughout the city. But now, from start



The Atlanta skyline from Piedmont Park puts the city's mature trees in proximity to towering skyscrapers.

to finish, the workflow of Trees Atlanta tracks the steps that accomplish its mission. Fifty employees and dozens of volunteers use GIS to log activities.

“That really expanded the possibilities for how we could record our planting locations, what kind of information we could record, and the quality of care we could give each tree,” said James Moy, data manager for Trees Atlanta.

Moy has trained his coworkers to use a suite of GIS products in their daily workflows. Coordinators use GIS maps to plan and prioritize planting projects. Places where trees are needed are scouted, and plans are shared with government officials and the surrounding community to gather feedback and gain approvals. Mobile workers use GIS apps to navigate and track where they need to prune and water trees as well as where to treat trees that may be infested with invasive pests. GIS data collection tools provide mobile workers a place to track their hours, and GIS dashboards show them the acres of trees they have conserved.

Coordinators use the same maps to select appropriate species that fit the conditions of specific areas. Volunteers are given access to the maps so they know where to plant trees, and the system tracks where and when to maintain the trees until they reach maturity.

Understanding that Community Conservation Begins with Education

To date, Trees Atlanta has planted and cared for more than 150,000 trees. To choose sites, the organization uses maps to understand the socioeconomic conditions in neighborhoods and engages with community members to gain their support.

“When you get into community forestry, you realize that humans are a part of the ecosystem, especially in an urban place,” Moy said. “The most important thing for choosing tree planting sites is whether they are going to be well received by the people.”

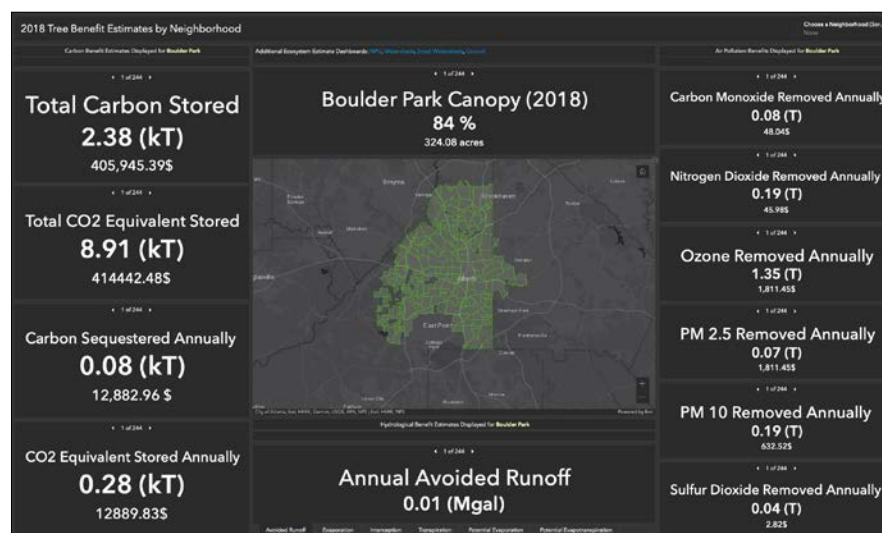
Starting in 2020, the organization analyzed the factors leading to tree survival. Staff found that when an active community group participated in planting, trees flourished.

About one-third of the tree planting sites are requested by community members. Another third of the sites are agreed on by the nonprofit’s employees and volunteers, who return to communities year after year, answering the question, “Where are we going next?” The final third are selected by coordinators who use spatial analysis and satellite imagery in GIS to determine where trees are needed most.

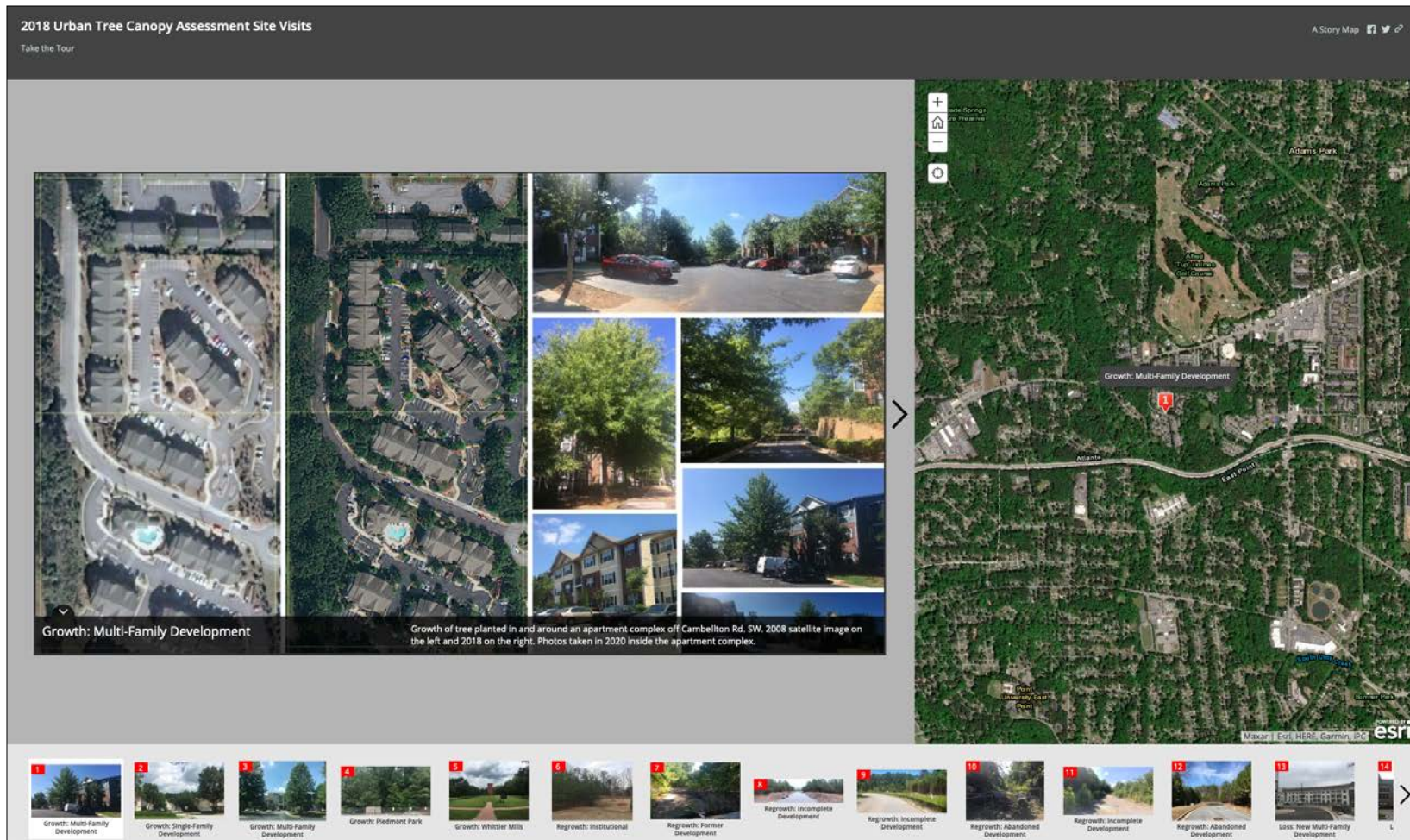
Choosing the Right Tree for the Right Place

Looks nice and growing well aren’t the only criteria for determining which trees get planted. Of the 7,000 trees planted in 2022, 83 percent were native species. More native species have been planted because the public has a greater interest in supporting plants that occur naturally in the region and adapt well to changes in climate.

Trees Atlanta brings in information from the USDA Plant Hardiness Zone Map to determine which trees have the most



The Tree Benefit Dashboard displays Atlanta’s 244 neighborhoods as well as the benefits of their tree canopy, which includes decreases in carbon emissions, annual stormwater runoff, and air pollution.



Part of the data-validation process used for the 2018 tree canopy update involves field verification of changes since 2008.

adaptability. “We’re looking more into native adaptive trees that have evolved in a slightly warmer climate farther south from Atlanta, with warmer winters and hotter summers,” Moy said.

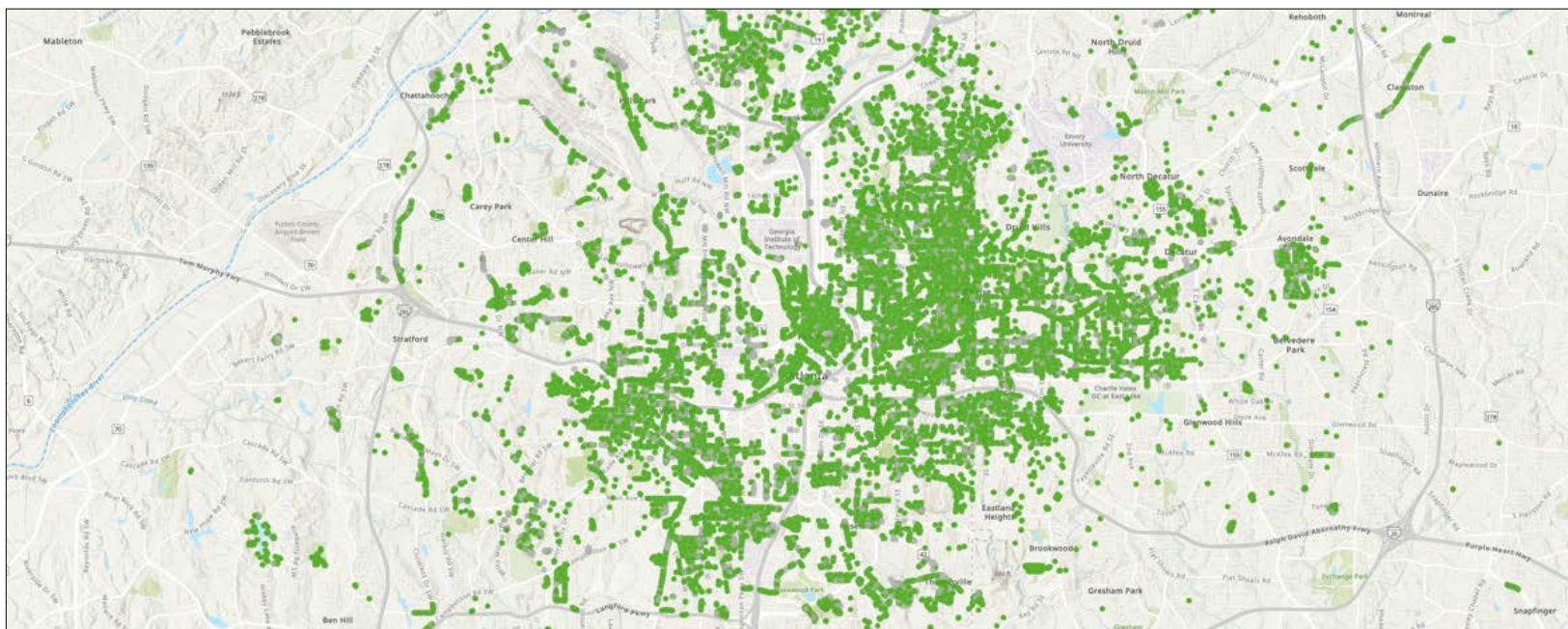
The trees planted early in the organization’s history are now becoming mature, and communities are seeing the benefits.

“Those mature trees provide a lot of shade, and that turns into better health outcomes. We’ve also seen animals moving back to places where they haven’t been seen in a long time,” Moy said.

As far as beneficial health impacts, a Clemson University study of a region in Northern California found that annual average health-care costs were \$374 lower for those living near green space.

Filling in Food Deserts

In addition to health benefits, trees provide food beyond that of the ubiquitous peach tree. Trees Atlanta was instrumental in the creation of the Urban Food Forest at Browns Mill, the country’s largest edible-foods forest on public land, with 7.1 acres of land ripe with 2,500 pesticide-free edible and medicinal plants.



Trees Atlanta has planted and cared for more than 150,000 trees, which are shown on this tree inventory map.

Food from the forest is grown under a model of agroforestry, a method of growing trees and shrubs to provide nourishment and an ecologically resilient landscape. Ten minutes away from Atlanta's bustling airport, the expansive forest was once a small family farm. But unrealized property development brought blight and neglect to the Lakewood and Browns Mill neighborhoods, where many residents live in poverty and the closest grocery store is a 30-minute bus ride away.

"The Urban Food Forest at Browns Mill is a resource that anyone can use to enjoy green space, harvest food that was collectively grown by the community, and learn techniques to grow food," Moy said. "The forest demonstrates practices of permaculture to mimic the growing practices of Indigenous peoples."

Protecting the Future of Green Space

Since 2001, Atlanta's Tree Protection Ordinance has been a critical tool to preserve the city's tree canopy. But the ordinance hasn't been enough to protect trees against a

wave of development. To remove a tree, a permit needs to be approved by the city, but illegal removal still occurs, creating threatening conditions for the oldest trees.

Trees Atlanta has been working with the Georgia Institute of Technology on tree canopy assessments to continue to innovate and find ways to maintain Atlanta's status as a "city in a forest."

Analysis of the benefits of the forest is guiding decision-making as the climate continues to change. Atlanta mayor Andre Dickens, elected in November 2021, is committed to the city's trees, and he ties tree canopy protection directly to climate change impacts in his environmental and clean energy plan.

In response to a question about rising temperatures in the city, Dickens replied, "The reduction of the tree canopy only enhances the urban heat island effect and the rising energy costs that make it more expensive to keep our homes cool. The first effort from the City of Atlanta needs to be in the protection of our tree canopy."

NYC: Few Cities Are Doing More to Map and Respond to Rising Waters

New Yorkers are tough, but they're no match for an ever-weirder, ever-fiercer climate. It took only 48 hours for Hurricane Sandy to overwhelm coastal neighborhoods, killing 44 people, damaging or destroying 70,000 housing units, and leaving behind \$19 billion in damages. The ferocious remnants of Hurricane Ida dropped more than three inches of rain in an hour, submerging streets and subways, and killing 11 people in flooded basement apartments.

These impacts underscore the growing threat that climate change poses to cities such as New York, especially to their most vulnerable residents.

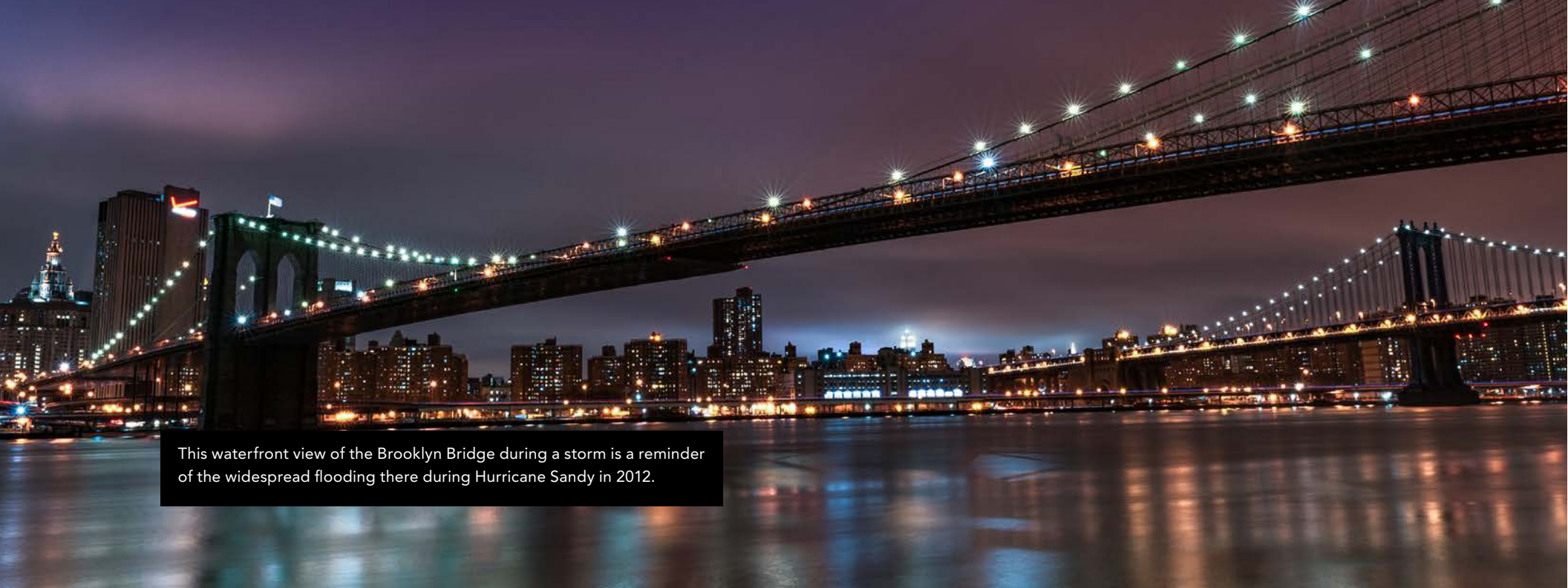
In the US, 90 percent of natural disasters involve a flood, according to FEMA, making flooding the most frequent and the most expensive natural disaster in the country. Estimates suggest that by the 2050s, sea level rise and inland floods could impact 1 of every 10 people on Earth and cost cities more than \$1 trillion.

Now, as the US federal government engages in a historic nationwide infrastructure buildout, researchers, nonprofit organizations, and GIS specialists are harnessing new technology to improve understanding of where flooding is likely and to better rank investments in resiliency. These include advances in real-time flood sensor systems, sophisticated hydrological models, and high-resolution satellite monitoring.

In New York City, officials are preparing a decades-in-the-making revision to federal flood maps that will, for the first time, include projections that show how climate change will impact the city's neighborhoods.

Mapping Risks and Vulnerability

Communities across the US need better risk mapping. The White House recognized this need and created the Climate Mapping for Resilience and Adaptation, or CMRA, tool in 2022 to surface projected exposure to climate hazards. Similarly, the National Oceanic and Atmospheric Administration (NOAA)



This waterfront view of the Brooklyn Bridge during a storm is a reminder of the widespread flooding there during Hurricane Sandy in 2012.

created the Digital Coast Mapper to aggregate a range of data—on coastal flooding, storm surge, and long-range inundation impacts—using a method of visualizing climate risk that was initially developed for New York in the wake of Hurricane Sandy.

Anywhere along the New York waterfront ranks high for flood risk, and nearly 1.5 million New Yorkers live in the federally designated 100-year floodplain, threatened by once-in-a-hundred-year extreme storms. Maintained by FEMA as part of the National Flood Insurance Program, or NFIP, floodplain maps are meant to define mortgage risks, set insurance rates, and establish building and land-use regulations. But in New York and elsewhere, the actual risks of floods and storms reach farther than most people think, and farther than the prevailing federal flood maps have described.

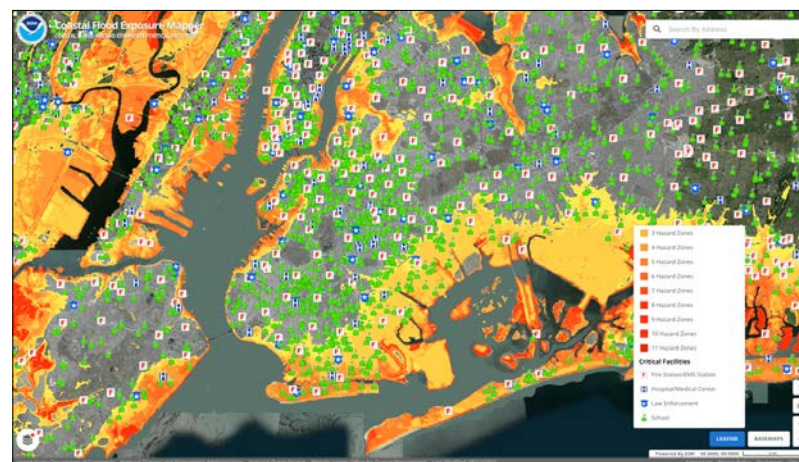
In a study published in February 2023 in the journal *Nature Climate Change*, researchers found that on federal maps, the underestimations of flood risks missed about eight million homes and overvalued the housing market by about \$200 billion. The analysis, by researchers from the Environmental Defense Fund and the nonprofit organizations Resources for the Future and the First Street Foundation, found that many overvalued properties are concentrated in coastal counties with no flood-risk disclosure laws and where there is less concern about climate change. The unpriced flood risks endanger the stability of the housing market, local governments, and homeowners, particularly in low-income areas.

The old floodplain maps don't account for sea level rise, rainfall, or riverine flooding, and they can be hampered by outdated data and models. They can also create a false sense of security, by focusing on whether a property is inside or outside of a floodplain, without addressing risk to individual properties. And FEMA hasn't significantly updated many of its maps for decades.

In cities such as New York, billions of dollars in property values and government revenue are at stake, to say nothing of lives and livelihoods. By the year 2050, according to a report published by the city's comptroller in October 2022, rising tides and more frequent storms will put significant essential infrastructure and properties amounting to upward of \$242 billion in current market value at risk of coastal flooding.

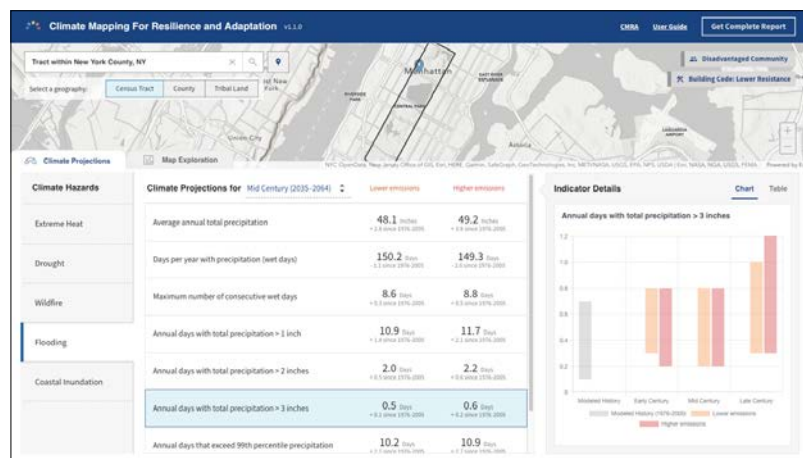
Sobering Statistics

The consequences of geospatial data gaps can be devastating. When Hurricane Harvey dumped up to 47 inches of rain in Harris County, Texas, in 2017, more than two-thirds of the homes that flooded were outside FEMA's Special Flood Hazard Area, which designates areas where flood insurance coverage is mandatory. This means that most of those homeowners were uninsured or heavily underinsured.



NOAA created the Coastal Flood Exposure Mapper to help communities kick-start conversations about coastal risks. The mapper enables users to explore maps that show people, places, and natural resources exposed to coastal flood hazards.

New maps, delayed again in September 2023, will likely show Harris County's 100-year floodplain growing from around 150,000 acres to 200,000 acres. The maps, built in consultation with the county, will be FEMA's first to depict urban flooding and will incorporate new rainfall estimates from NOAA, data that had not been updated since the 1960s.



The Climate Mapping for Resilience and Adaptation tool combines extensive federal hazard data that can be used at national, regional, and local levels to monitor flooding conditions and explore trends.

Still, although the analysis includes data up to 2017, it will not consider projections for how climate change will impact future storms.

“One of the fatal flaws of FEMA flood maps is that they are largely backward-looking,” Rob Moore, director of the Natural Resources Defense Council’s water and climate team, told the *Houston Chronicle* last month. “The only place I’m aware of where they’re attempting to include future conditions in flood maps is New York City.”

When Hurricane Sandy devastated parts of New York in 2012, city residents were relying on FEMA flood-risk maps that hadn’t been significantly updated since 1983. In 2016, after a city review found errors with FEMA’s maps, the agency and the city agreed to work on a new map.

The delayed FEMA flood-risk map that was promised in 2023 will factor future flood risk, based in part on maps made by the city’s panel on climate change that use a projection of 30 inches of sea level rise by 2050.

According to a separate analysis by First Street, New Yorkers can expect a 20 percent increase in flood risk by the year 2050,

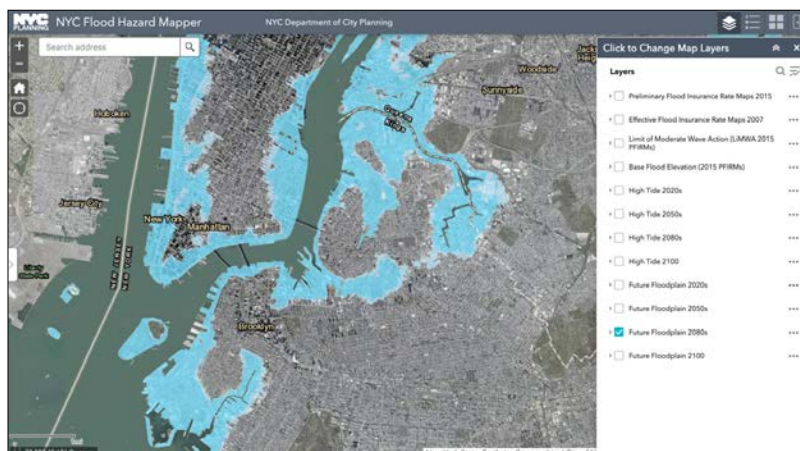
impacting thousands of residents currently unaddressed in the federal data. A 2022 report by the city’s comptroller found that by then, rising tides and more frequent storms will put upward of \$242 billion in property value at risk of coastal flooding, a 38 percent increase from today.

The new maps from the city and FEMA have been promised in 2023 and 2024, respectively. When they are put in place, the city, and its residents, will still face challenges.

The city anticipates thousands more residents will be required to pay for flood insurance, a burden many will undoubtedly struggle to meet. Updates to the city’s building code will likely increase costs for developers in flood-prone areas. And many New Yorkers may not see the maps: A state law, which passed in 2022, finally mandates that landlords warn renters about flood risk before they put down a deposit, but the law doesn’t extend the same protection to buyers.

In the meantime, ahead of the new maps becoming available, the city has been finding other ways to fill in the public’s understanding of flood risk. The Department of City Planning made an interactive map that lets residents see current flood hazards as well as how they are likely to increase with climate change. In 2022, the mayor’s office released a map New Yorkers can use to check their future risk from flashfloods during a moderate event (a storm with two inches of rain an hour) as well as during an extreme stormwater flood, given expected rises in sea level by 2050 (2.5 feet) and 2080 (4.8 feet).

New York City is already using its new flood risk projections for its climate resilience design guidelines, which inform development as well as the planning of infrastructure projects aimed at reducing the impacts of climate-related hazards. To help residents and officials track the progress of the mitigation projects, the city’s Office of Emergency Management is mapping them. And the Department of Environmental Protection built an ArcGIS StoryMaps story in September 2021 to illustrate the city’s stormwater resiliency plan, which involves finding ways to make the Big Apple more “spongy.”



The NYC Flood Hazard Mapper provides a comprehensive overview of the coastal flood hazards that threaten the city today, as well as showing how these flood hazards are likely to increase in the future with climate change.

Future-Looking Maps and Future-Proof Strategies

Geospatial analysis is also guiding the biggest mitigation project of all.

In 2022, the US Army Corps of Engineers unveiled a proposal to build movable sea gates—designed to protect against once-in-a-hundred-year storms—across the mouths of major bays and inlets along New York Harbor.

The plan—which also calls for more than 30 miles of land-based levees and sea walls and nature-based solutions such as wetland restoration and shorelines built out of sand, oyster shells, and plants—is estimated to cost \$52.6 billion. But a geospatial cost-benefit analysis—a central tool for the corps—showed that without the protections, average annual damages to the region would amount to \$5.1 billion by 2030 and \$13.7 billion by the end of the century. Conversely, the corps estimates its efforts would generate a net benefit of \$3.7 billion each year over the next 50 years.

In meetings with community members and environmental groups, maps that show the benefits, drawbacks, and uncertainties of the corps’s plan have been helping the corps incorporate public feedback into its analyses. Once the plans are finalized, and if Congress approves them, construction

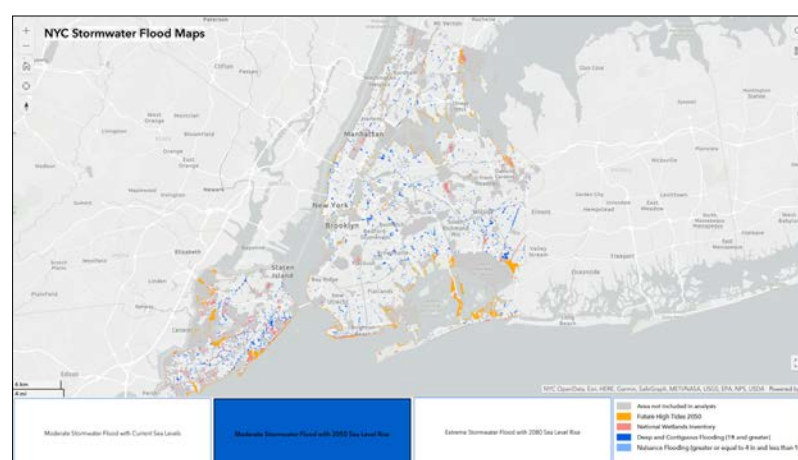
could begin in 2030 and end by 2044, with some projects completed sooner.

Even this may not be enough, according to some experts, who argue that the government will likely need to buy out and relocate residents in at-risk areas.

In light of rising seas, New York City should create a “predictable, community-informed buyout program” that prioritizes individuals in areas at the highest risk, says a report published in December 2022 by actuarial consultancy Milliman and the nonprofit Rebuild by Design.

The report’s authors recommend that New York invest massively to protect shoreline communities and build affordable housing in inland neighborhoods, since the areas most vulnerable to floods are home to people of color in low-income communities.

“It is important to think about not only who is being impacted by climate change now, but who will be impacted as existing climate pressures worsen,” said Molly Barth, a GIS consultant at Milliman, in a statement. “Using geospatial and demographic data, municipalities can better understand the risk to local populations and use that data to make more informed community decisions.”

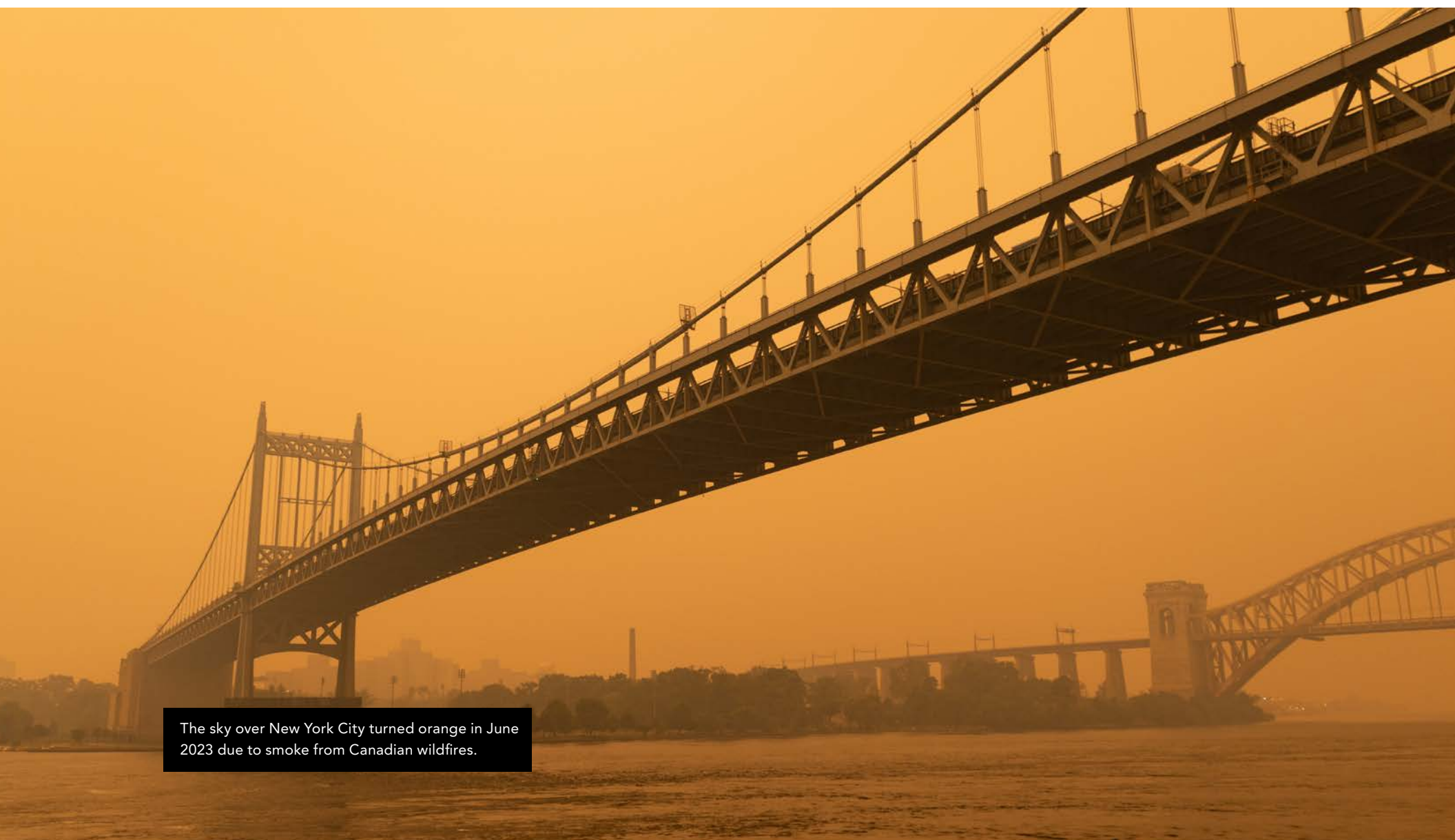


To help New Yorkers understand and prepare for flooding risk, the city has created three rainfall-based flooding maps. The maps show moderate stormwater flooding scenarios under current and future sea level rise conditions, as well as an extreme stormwater flooding scenario under future conditions.

To Build a New Pollution Map, the US Turned to Thousands of Volunteers

You didn't need an app to know something was wrong. In vivid oranges and yellows, the skies over New York City this summer—the result of Canadian wildfires hundreds of miles away—repeated a stark truth about our changing climate: the impacts of wildfires and other natural disasters are growing more intense, and even at a distance, it's getting harder to escape them.

Still, an array of apps and geospatial data are helping Americans better understand their air, whatever color it is, and plan accordingly. Public health officials are increasingly interested, too. Research from the Centers for Disease Control and Prevention (CDC) has identified that people with asthma or other cardiovascular conditions, as well as poorer communities, elderly people, and those working outdoors, face the highest risk from air that's heavy in fine particulate matter (PM) and



The sky over New York City turned orange in June 2023 due to smoke from Canadian wildfires.

ozone. Fine particulate matter measuring 2.5 microns or less in width (PM2.5) ranks as one of the most concerning toxic air pollutants.

In 2020, the US Environmental Protection Agency (EPA) and the US Forest Service (USFS) collaborated to release the *AirNow Fire and Smoke Map*, a first-of-its-kind map powered by GIS technology that combines official data on fine particulate matter with more granular readings from a vast network of low-cost sensors run by volunteers. Compared with older government air maps, the new map increased the total number of PM2.5 monitoring locations almost fivefold, to more than 900 cities. President Biden has called the enhanced map “an important tool,” and in early June 2023, a day after White House press secretary Karine Jean-Pierre mentioned AirNow.gov during a White House briefing, a record 12.4 million people visited.

“It’s really important for EPA to be able to deliver this information,” John Millett, communications director for the EPA’s Air and Radiation Office, which runs AirNow.gov, told *The Washingtonian* at the time. The AirNow app, he added, “was actually able to edge out TikTok for highest number of downloads for a little while.”

Enter your location at fire.airnow.gov, and you’ll likely see a map sprinkled with icons. Flames indicate reported fires, circles represent official AirNow monitors, triangles show temporary monitors set up by state or federal agencies, and squares indicate air sensors run by members of the public. Colors, from green to dark purple, indicate the quality of the air at that location, from good to hazardous. Click on any sensor and a pop-up box reveals more details.

When the air quality index (AQI) value is above 100 for more than 24 hours, the air is considered unhealthy, according to the EPA, at first for certain sensitive groups of people, then for everyone as AQI values get higher. A reading of 300 or higher means the air quality is hazardous. In that case, cautions the map, “Avoid all physical activity outdoors.”

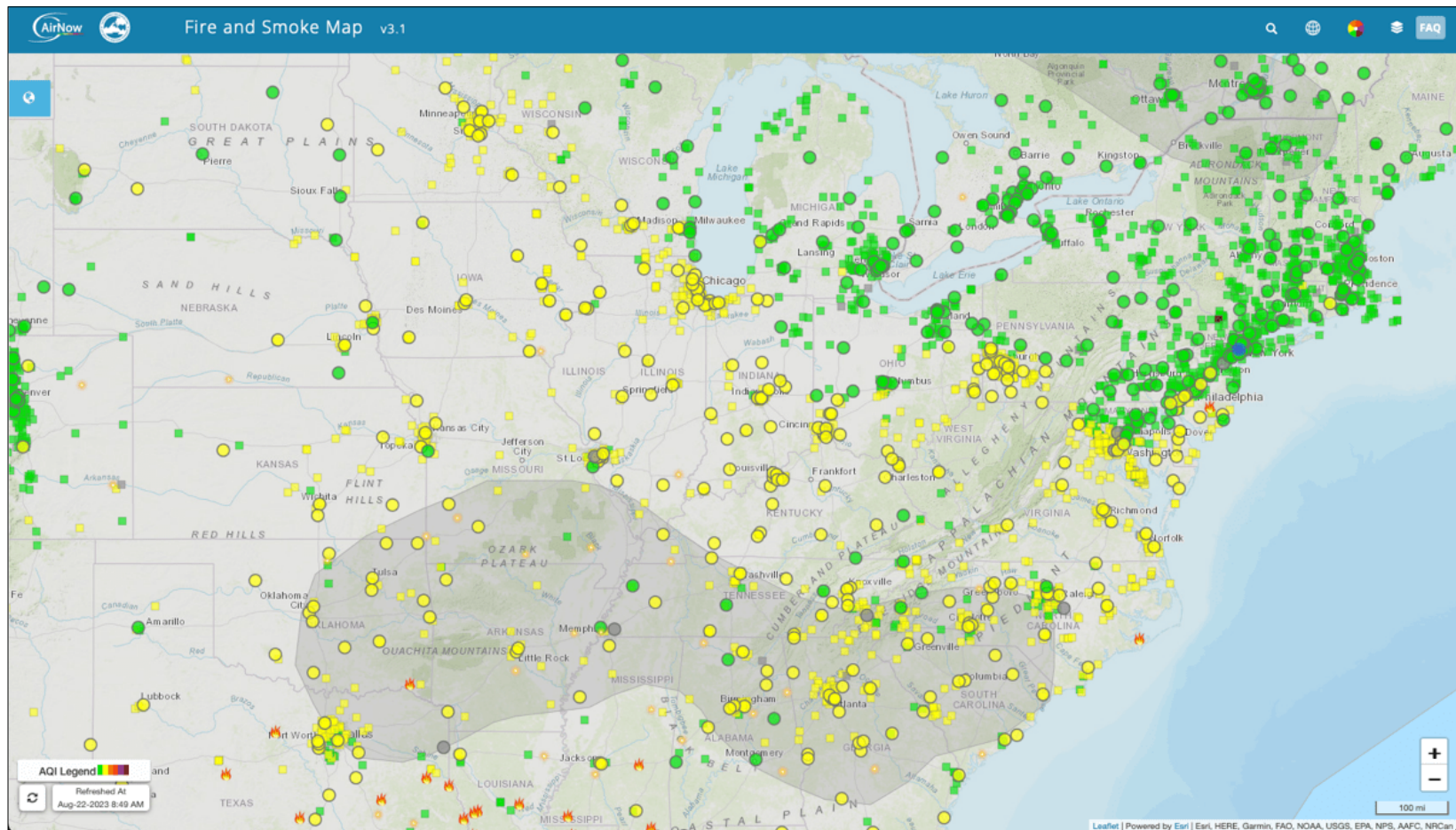
The Rise of PurpleAir and Crowdsourced Air Quality Data

Though it looks simple, the new map was a complex undertaking and built on a national air monitoring system, which was decades in the making. Under the Clean Air Act, a partnership led by the EPA and state and federal agencies, along with Canada and Mexico, built and maintains a network of air sensors now numbering in the thousands. Data from these monitors appears on the standard map at the EPA’s airnow.gov site and mobile app and informs 24-hour air quality forecasts developed by NOAA.

But since 2020, air monitoring has undergone a technological revolution, led in part by a small company called PurpleAir. The company was born after a self-proclaimed tech geek named Adrian Dybwad grew worried about the choking dust blowing into his town of Draper, Utah, from a nearby gravel pit. Like many places, Draper has historically lacked extensive sensor networks to monitor airborne particulate matter; even big cities such as New York and San Francisco only have about a dozen government-managed sensors in the AirNow network. Checking the AirNow map didn’t help much.

Buying his sensors was also out of the question: the systems on the market cost thousands of dollars and weren’t designed to quickly detect the effects of dust and smoke particulate matter. So Dybwad built his device, using low-cost circuit boards, PVC pipe, and lasers. He found enough volunteers around the Salt Lake Valley willing to host the homemade sensors and started building a small network before officially launching PurpleAir in 2015. The company, which now sells three models from \$199 and up, has shipped more than 30,000 devices over the past five years. Users have the option of sharing their data with PurpleAir to enrich its real-time map.

Like AirNow, PurpleAir by default uses the EPA’s AQI, which measures levels of pollution on a scale from 0 to 500. The index governs the five pollutants regulated by the Clean Air Act—particulate matter, ground-level ozone, carbon monoxide, sulfur dioxide, and nitrogen dioxide. PurpleAir’s sensors only measure PM2.5.



On the East Coast on August 22, 2023, air quality was good, despite being sandwiched between smoke to the north and south.

Although its data isn't as reliable as the readings provided by the more sophisticated devices in AirNow's network, air quality specialists have found PurpleAir's cheap, plentiful devices hard to resist. After a successful trial run by environmental officials in Southern California in 2016, Dybwad was soon fielding requests for the devices from air quality groups and academics across the country. During wildfires, local firefighters and the EPA's air resource advisors have begun turning to PurpleAir's sensors to help guide the placement of temporary air monitoring devices and to provide more immediate data to municipalities and emergency responders.

How AirNow and PurpleAir Connected

In 2019, Congress signed the Dingell Act into law, which for the first time mandated a better way to protect Americans from wildfire smoke. Soon, fire specialists at the USFS Research and Development unit and Interagency Wildland Fire Air Quality Response Program began a partnership with colleagues at the EPA. In the interest of better tracking fast-moving wildfire smoke, they wondered if they could integrate PurpleAir's vast data into the official AirNow map.

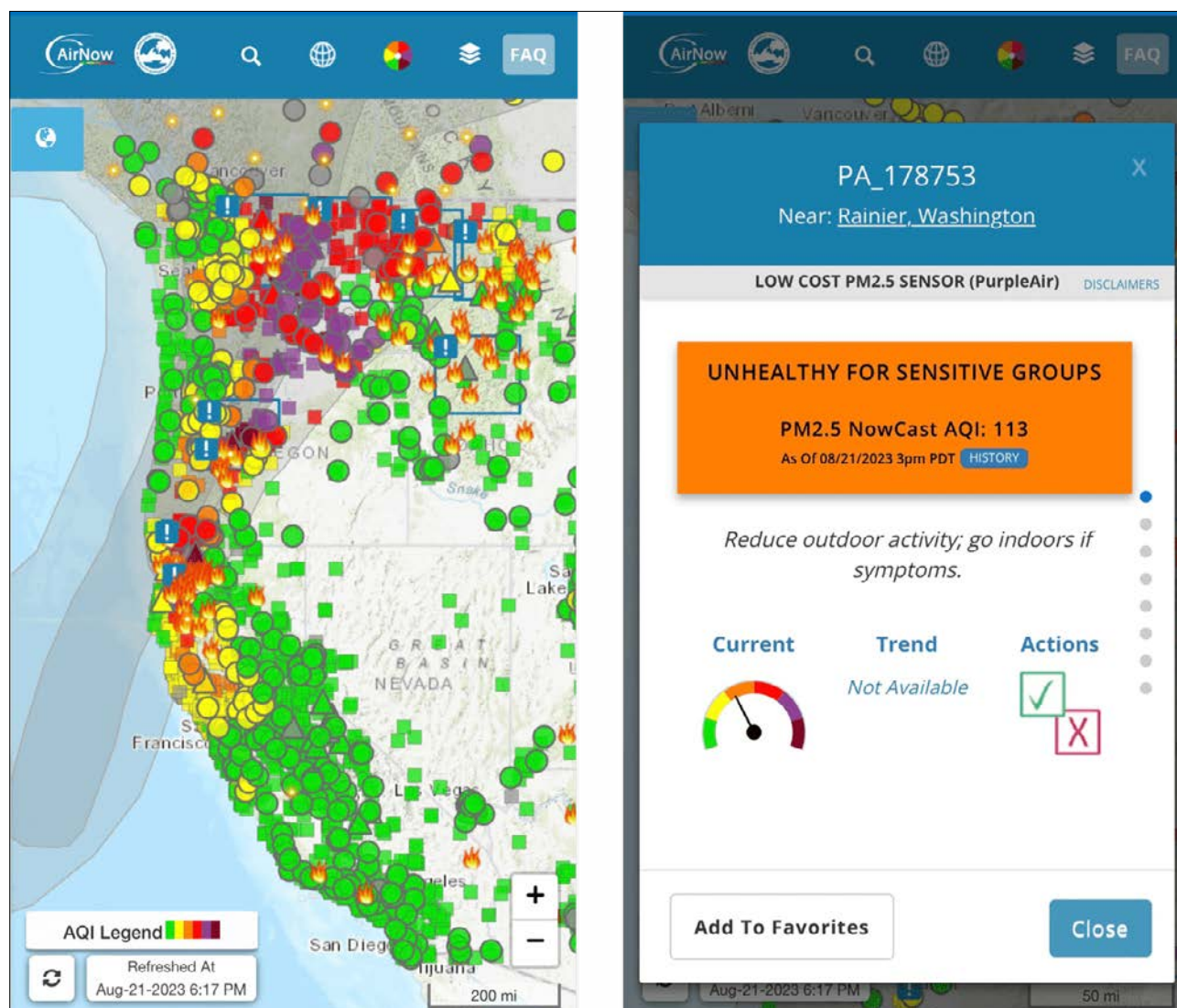
Because of differences among the sensors, they knew combining the two streams of data would be complicated. Researchers noticed that PurpleAir devices were problematic on smoky days, at times dramatically overestimating readings of PM2.5. Woodsmoke particles have a different density from gravel dust or other pollutants, which can confuse PurpleAir's sensors.

By contrast, the government's more delicate sensors are costly, state regulated, regularly calibrated by scientists, and can more accurately measure fire pollution. Unlike the PurpleAir machines, which use a laser to estimate the concentration of PM2.5 in an air sample, the official devices measure particulate matter by drawing air through a filter and then weighing the filter once an hour.

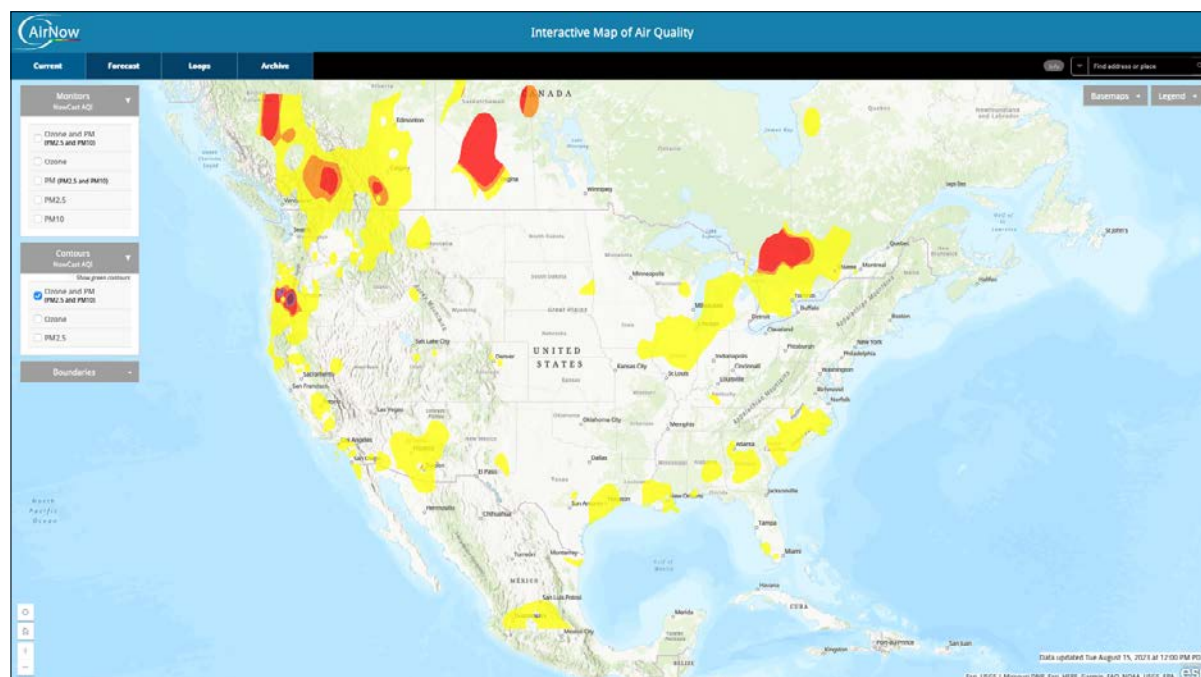
Placement is another problem. It's hard to know, for instance, if a PurpleAir sensor has been placed next to a park or inside a chimney. AirNow sensors are installed according to more stringent and transparent rules to not bias the measurements.

(Of course, even official assurances should be checked: in the runup to the Beijing Olympics in 2008, officials dramatically improved the city's air quality readings simply by moving the pollution sensors to areas outside the city limits; in response, the US Embassy began publicizing its own AQI numbers.)

To start, researchers at EPA and dozens of state, local, and tribal partners began installing PurpleNow sensors nationwide, side by side with the official monitors. Armed with months of



Users of the AirNow app can see smoke and air quality across North America and zoom in on health recommendations based on current conditions.



The Air Quality Aware app, available in ArcGIS Living Atlas of the World, combines air quality data with Census Bureau data about vulnerable populations.

that data, EPA scientist Karoline Barkjohn and a team at the Pacific Northwest Research Station then built a correction equation to make the PurpleAir data more accurate, leveraging data from co-located sensors as well as local historical temperature and relative humidity measurements.

The final *Fire and Smoke Map*, built using ArcGIS software, applies a range of filters to the open data it gets from PurpleAir. It removes questionable data when sensor readings disagree, applies the correction equation, and displays the single AQI score, which is averaged over time using an EPA formula called NowCast. Flame icons indicate where fires are reported to be burning, based on data from the US National Interagency Fire Center and automated satellite fire detection. Fire data also appears in NOAA's Hazard Mapping System as well as the *Active Wildfire Map* by Esri, which uses weather and wind models to track and forecast smoke.

Click on any sensor reading on the *Fire and Smoke Map* and a pop-up box appears, showing the AQI for PM2.5 at that location. Users can scroll to see data that can help them plan outdoor activities and receive suggested actions to consider taking based on the AQI. In some cases, indicators and graphs show whether air quality is improving or worsening. On smoky days, the site may remind people to wear masks, close windows, or stay indoors.

The Future of Air Mapping

The hybrid approach of the *Fire and Smoke Map* suggests other tantalizing combinations.

For instance, the Air Quality Aware app, available in ArcGIS Living Atlas of the World, combines air quality data with Census Bureau data, which could help local leaders locate vulnerable populations, such as asthma sufferers, and adjust public health efforts accordingly. Others are also tapping into PurpleAir's data to map air quality risks and find new insights.

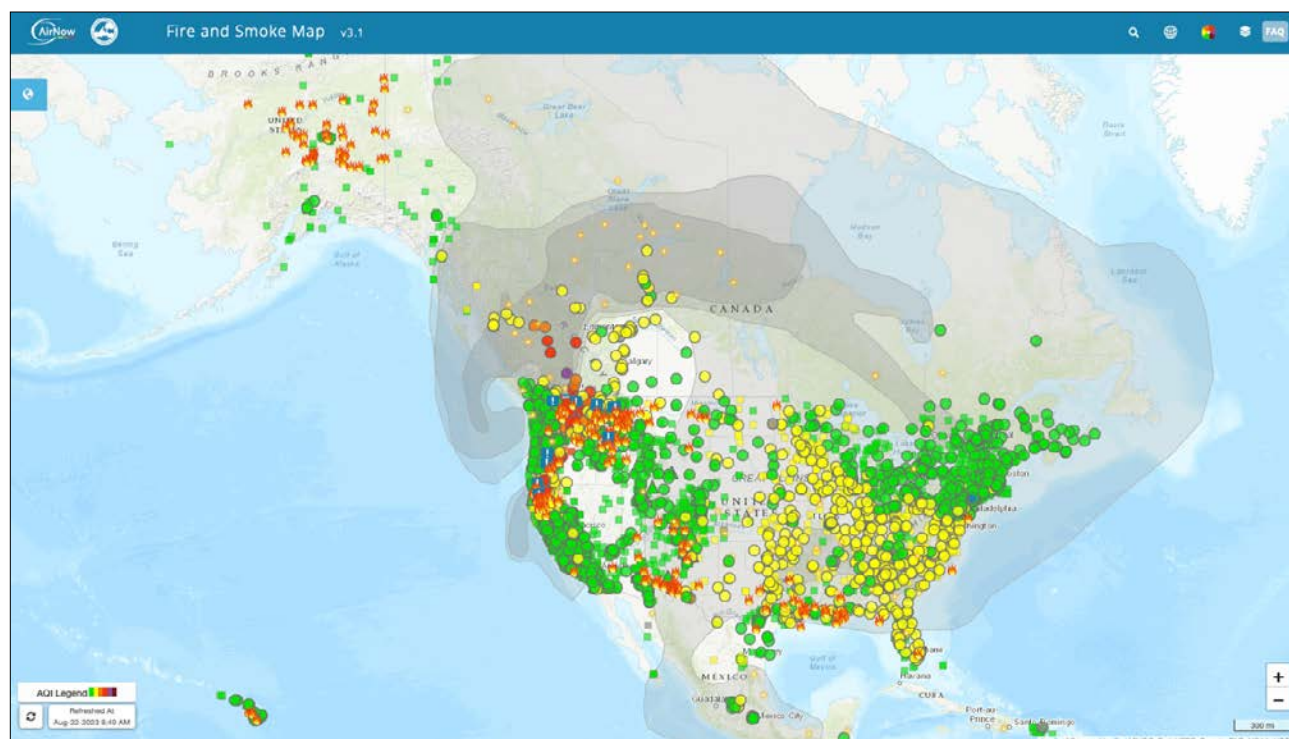
In 2022, Esri solution engineers used ArcGIS Velocity, the big data analysis capability of ArcGIS Online, to build a proof of concept map that can send out air hazard alerts, helping school officials plan outdoor activities on smoggy days. After combining PM2.5 information from PurpleAir and EPA's AirNow on a map of the Bay Area, the team added elementary schools, using a layer from ArcGIS Living Atlas. With the incident detection tool in Velocity, the team then set up email notifications that are triggered when PM 2.5 concentrations around any of the schools reach unhealthy levels.

By adding data from CalEnviroScreen 4.0, a landmark mapping tool created by the California Office of Environmental Health Hazard Assessment, the map allowed the team to visualize the vulnerable populations that may be adversely affected by poor air quality. By animating historical pollution data, for instance during the July 4th holiday, they could also depict the impacts that fireworks smoke may be having on certain populations.

EPA and USFS researchers continue to improve their maps. Last year, the agencies enhanced the sensor data correction equation, added a Spanish version, and included a feature called ColorVision Assist, which makes the map accessible to color-blind people. Users can now save sensors to a “favorite” list and see fire perimeters on the map when they click on a fire incident.

In addition to improving the public’s understanding of air quality conditions during wildfires, the map and the correction equation are helping PurpleAir improve its data. The EPA has encouraged other air quality device makers to continue improving their systems and hinted at the possibility that their data could also appear on the map.

When this snapshot of the Fire and Smoke Map was captured on August 22, 2023, widespread haze can be seen from Canadian wildfires and fires in the Southeast and Pacific Northwest.



The agency is also pushing for even better national coverage of air quality and for more monitoring on the local, municipal, and tribal level. As researchers at the University of California, Irvine, found, PurpleAir’s sensors tend to be more common in wealthier communities with lower air pollution. To help fill in the gaps, in 2022, the agency began distributing air quality monitors to 132 underserved localities, as part of an historic \$53 million federal investment in local air monitoring.

Wildfires are becoming more frequent and more intense, powered by warming conditions that allow for more fuel to burn. As the fires on Maui demonstrated, the effects can be deadly, wiping a whole town off the map. But the impacts from smoke extend far beyond fires. During the wildfire season of 2020, more than half of California’s population spent a month or more breathing in “unhealthy” or “hazardous” air. If we can better track the smoke and smog, researchers hope, we might be better at protecting our communities. Dynamic maps of changing conditions may encourage more people to purchase sensors to fill in data gaps, too.



Equity and Social Justice

GIS technology aids in identifying areas where equitable services are needed and where unjust practices leave people vulnerable.

In Louisville, Kentucky, traffic safety improvements are being made in underserved communities first. GIS technology was used to identify high-risk locations based on crash analysis and roadway design. These locations were subsequently compared with data on community vulnerabilities, revealing that disadvantaged areas suffered higher rates of harm. This data was crucial in securing a \$21 million implementation grant from the US Department of Transportation (USDOT) for safety improvements in the city's most hazardous corridors.

"GIS analysis is woven through the work that we do. It's the foundation for a lot of our decision-making," said Amanda Deatherage, the transportation planner supervisor for Louisville Metro Government. This analysis led to the development of the Safe Streets and Roads for All (SS4A) grant application, which ultimately resulted in funding for planned changes.

The Environmental Justice Index (EJI), developed by the Centers for Disease Control and Prevention (CDC), is a unique geospatial tool that measures the cumulative impacts of social and environmental factors on communities. Each census tract in the US receives a single score representing these cumulative impacts, allowing for a comprehensive understanding of the challenges faced by different locales.

"What's more important," said Benjamin McKenzie, project coordinator for the EJI, "is that you can click on an individual community, and you can actually see what is driving those impacts." The tool lets users view the map and its score through each of the 36 individual indicators, providing a detailed context for each location's score.

The National Association for the Advancement of Colored People (NAACP) is using GIS technology to highlight and address systemic inequalities. By using smart maps and advanced analytics, the NAACP can identify patterns of discrimination and disadvantage to inform their advocacy work.

"We are embracing this idea that as technology moves, so goes the world," said Yumeka Rushing, the NAACP's chief strategy officer. By infusing more data and data science into their research and programs, the NAACP can offer more authoritative insights into racial injustice.

Los Angeles County uses GIS technology to document and address racial disparities. Following the declaration of racism as a public health issue, the county conducted a study using GIS technology to understand the conditions affecting the health and well-being of Black residents.

In the inaugural report on the *State of Black Los Angeles County*, maps and data science laid bare the unequal reality faced by Black residents. Despite living in one of the most prosperous counties in the nation, Black residents were found to be more likely to experience disparities in family stability, health, education, employment, economic opportunity, public safety, criminal justice, and housing.

The 2022 educational endeavor supported by the National Geographic Society—*2892 Miles to Go: Geographic Walk for Justice*—uses GIS technology to reexamine history and issues concerning justice, race, and equity. This social justice collaboration among educators, change-makers, and leaders focuses on place-based storytelling and maps that highlight layers of injustice and the humanity of those who walked before us.

Ashley Lamb-Sinclair, a National Geographic Explorer and founding partner of the project, emphasized the role of GIS technology in telling these narratives. "How do you add layers to amplify and connect the dots both in terms of visuals and data? How do you show the story of a family in Jackson dealing with a water crisis and connect it to a family in Baltimore who is dealing with a different type of water crisis—and to a family in Flint?" she said.

GIS provides insight into patterns of inequality and can provide common understanding across communities to effect positive change.

Vision Zero: Maps Fuel Funding for Equitable Traffic Safety in Louisville

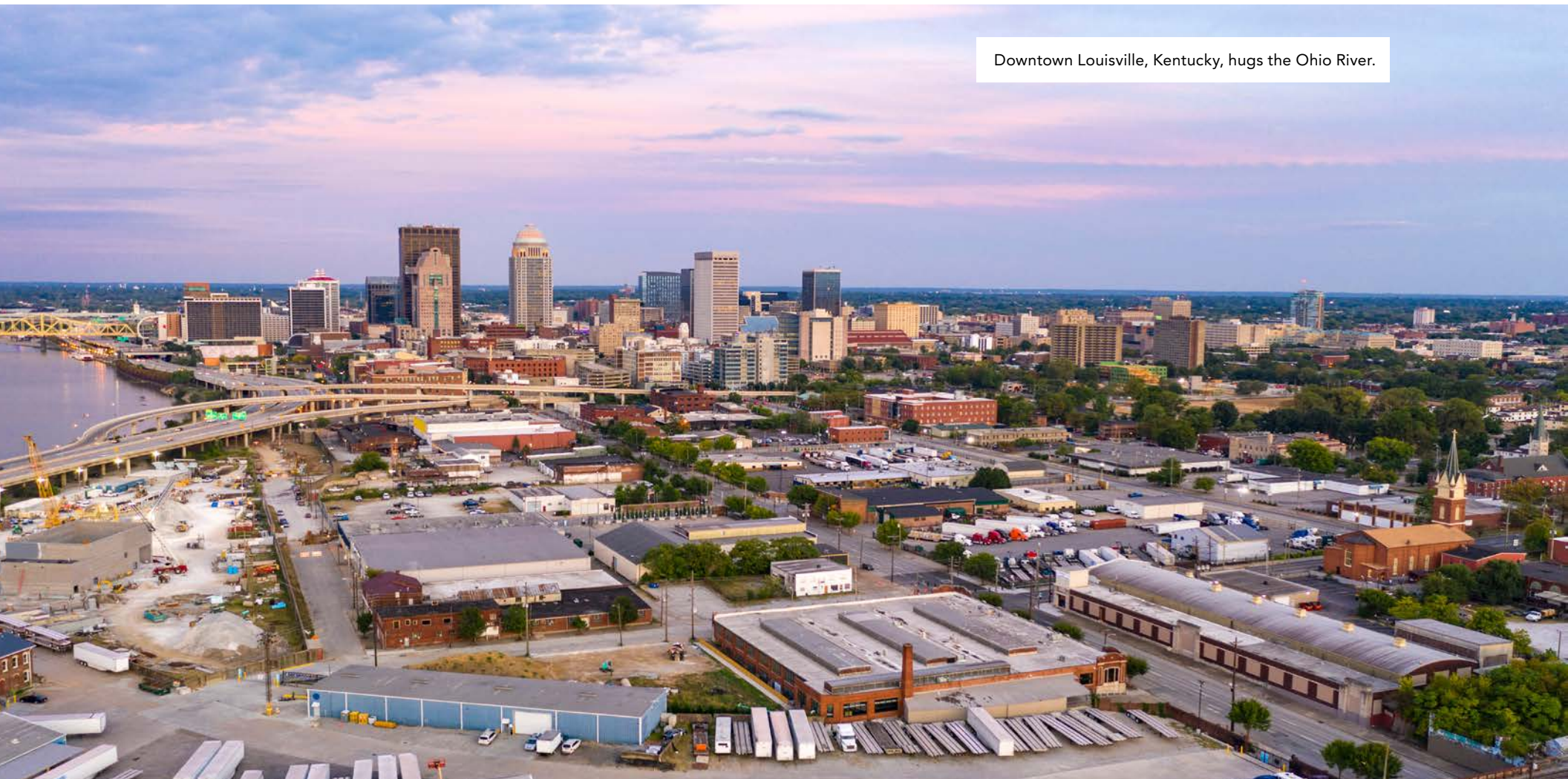
Avoiding automobile crashes starts with attentive drivers. But there's also a growing call to reengineer streets where fatalities and serious injuries chronically occur.

Road safety is a national priority. "Traffic crashes cost tens of thousands of American lives a year—a national crisis on our roadways—and everyone has an important role to play in addressing it," said US secretary of transportation Pete Buttigieg in February 2023 at the launch of a call to action. "Today we are asking all Americans—including private industry, nonprofit and advocacy organizations, and every level of government—to join us in acting to save lives on our roadways."

In Louisville, Kentucky, the government has made a commitment to end road fatalities by 2050. To start this initiative, staff used GIS technology to identify high-risk locations based on crash analysis and roadway design. These locations were then compared with data on vulnerabilities in communities. The conclusion: Harm has happened at higher rates in disadvantaged areas.

This data and accompanying maps then became Louisville's call to action. The analysis appeared in the city's Safe Streets and Roads for All (SS4A) grant application, developed in partnership with the Kentucky Transportation Cabinet and Palmer

Downtown Louisville, Kentucky, hugs the Ohio River.



Engineering. The city now has a \$21 million implementation grant from USDOT to put planned changes in place.

The projects tackle the 10 corridors where safety improvements will have the greatest impact.

“The work to prioritize those projects was all a GIS exercise,” said Amanda Deatherage, the transportation planner supervisor for Louisville Metro Government. “GIS analysis is woven through the work that we do. It’s the foundation for a lot of our decision-making.”

Larger Government, Greater Awareness

When Louisville merged with Jefferson County in 2003, Kentucky’s largest city doubled its population, and its area grew sixfold. GIS helped the government come to terms with its larger size. The GIS team gathered data to provide the new picture of residents and services.

The city’s department of public works mapped traffic fatalities and suspected serious injuries. It found that more than 900 people had lost their lives on Louisville’s roadways since 2014, including 185 pedestrians. Staff then looked at hot spots and patterns.

This awareness of fatalities and serious injuries led the city council to pass its Vision Zero Louisville ordinance. It marked a shift from the conventional reactive approach to traffic incidents. Instead, the city used the ordinance to look at the many layers of protection it could provide to both prevent crashes and reduce injuries.

Our early Vision Zero work focused on educating the public about where fatalities were happening, using GIS. Now, we want to build support for projects to improve the transportation network and reduce the likelihood of crashes happening at all.

—Amanda Deatherage, transportation planner supervisor for Louisville Metro Government

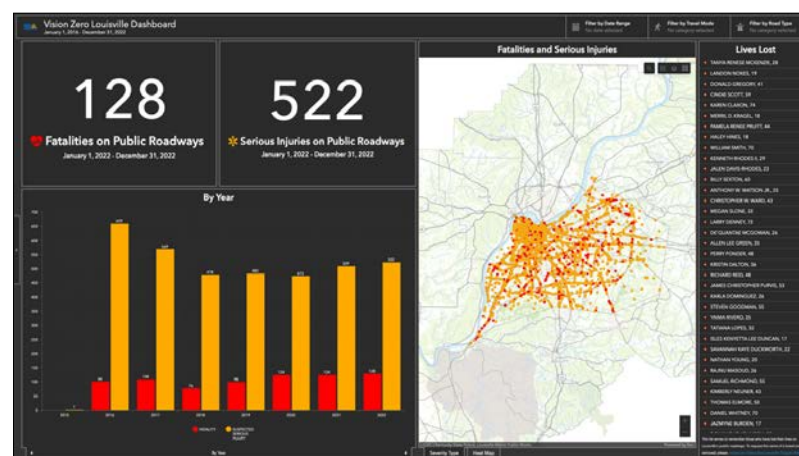
The 10 roadway corridors included in the SS4A-funded project will benefit from an array of safety improvements, including the addition of better lighting, medians, and bicycle lanes. All project locations will be rightsized (e.g., converting a four-lane roadway into a three-lane roadway). Rightsizing is a Federal Highway Administration proven safety countermeasure that promotes safer speeds. It often adds a dedicated left-turn lane and provides enhanced mobility and access for all road users.

Priority Projects

When the Vision Zero Louisville ordinance passed in 2022, Claire Yates, a transportation planner, became the first program manager dedicated full time to Vision Zero. Early on, she placed an emphasis on communicating using maps and visualizations.

She mapped 16 priority locations, using maps to help leadership understand the changes needed. Louisville staff wanted to modernize how they tell the story of where incidents occur. Crash data is critical, but it doesn’t encompass the entire story. GIS seeds solutions by providing greater context.

“We have a lot of elected leaders to answer to and a lot of priorities,” Deatherage said. “We can’t fund everything at



The Vision Zero Louisville Dashboard displays crash data to provide an accessible data-driven approach to address the causes.



Intersection modifications, new sidewalks, pedestrian signals, and better lighting should reduce pedestrian injury crashes along Algonquin Parkway.

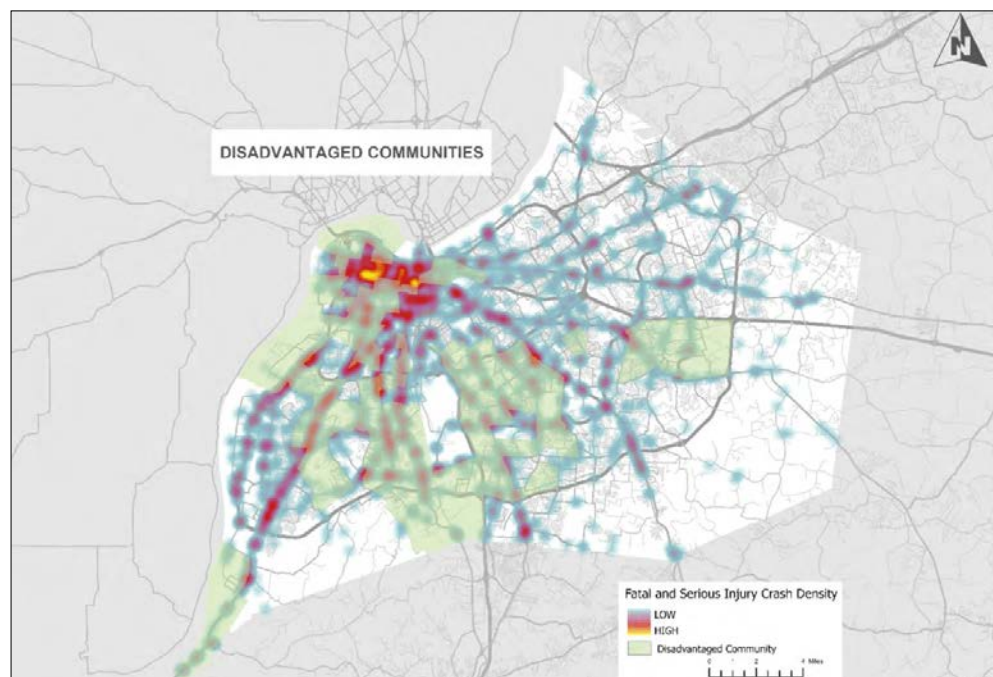
once. We're trying to leverage technology in a way that helps us be more transparent to the public. We also want the public to give input on what we should focus on."

Data analysis of potential road safety projects incorporated data from USDOT, the Kentucky Transportation Cabinet, and internal sources. Social vulnerability data from ArcGIS Living Atlas gave Louisville the data it needed to focus on supporting the Justice40 Initiative. The initiative seeks to address chronic underinvestment in disadvantaged communities, with at least 40 percent of federal funding dedicated to closing gaps. Of

Louisville's 10 safety improvement projects, 6 focus on disadvantaged places.

Safety Measures to Save Lives

USDOT's call to action came a year after the National Roadway Safety Strategy was released in January 2022. This document defined a five-pronged safe system approach to reducing roadway fatalities. It includes safer people, safer vehicles, safer speeds, safer roads, and postcrash care.



Map analysis reveals where fatal and serious injury crash density (2013–2017) corresponds with USDOT disadvantaged census tracts.

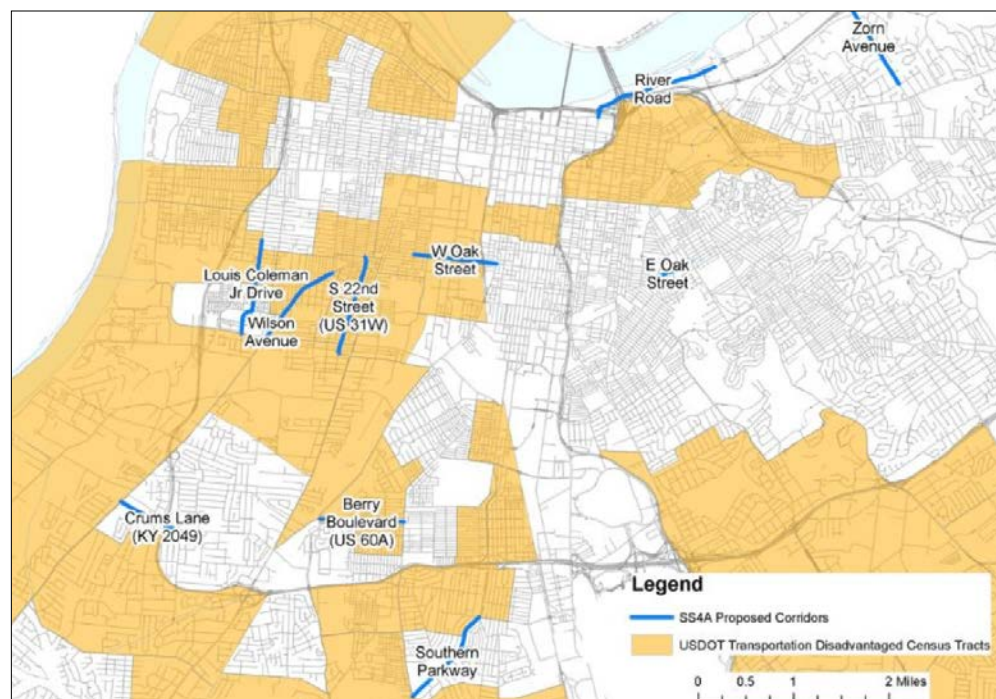
“We must do everything in our power to make our roads safer for everyone, regardless of how you travel,” said Louisville mayor Craig Greenberg in a statement. “Vision Zero is a new way of thinking, and it is achievable.”

With projects in place to construct safer roads, Vision Zero Louisville next focused on safer speeds.

“We identified and filtered the highest posted speed limits and evaluated them for crash reduction,” Yates said. A preliminary audit identified seven stretches where the posted speed limit was above 35 miles per hour. From 2016 to 2022, four people were killed and 27 people were seriously injured

on those stretches. The city is now going through the process of reducing speeds on those roadways.

As transportation safety advocate Janet Heston of Matthew’s Bridge noted at Louisville’s inaugural commemoration of World Day of Remembrance for Road Traffic Victims, “No reset button can be pressed to bring back those killed. The best way to honor them is by making our streets safer.”



Louisville identified 10 project corridors in disadvantaged census tracts in need of traffic safety attention.

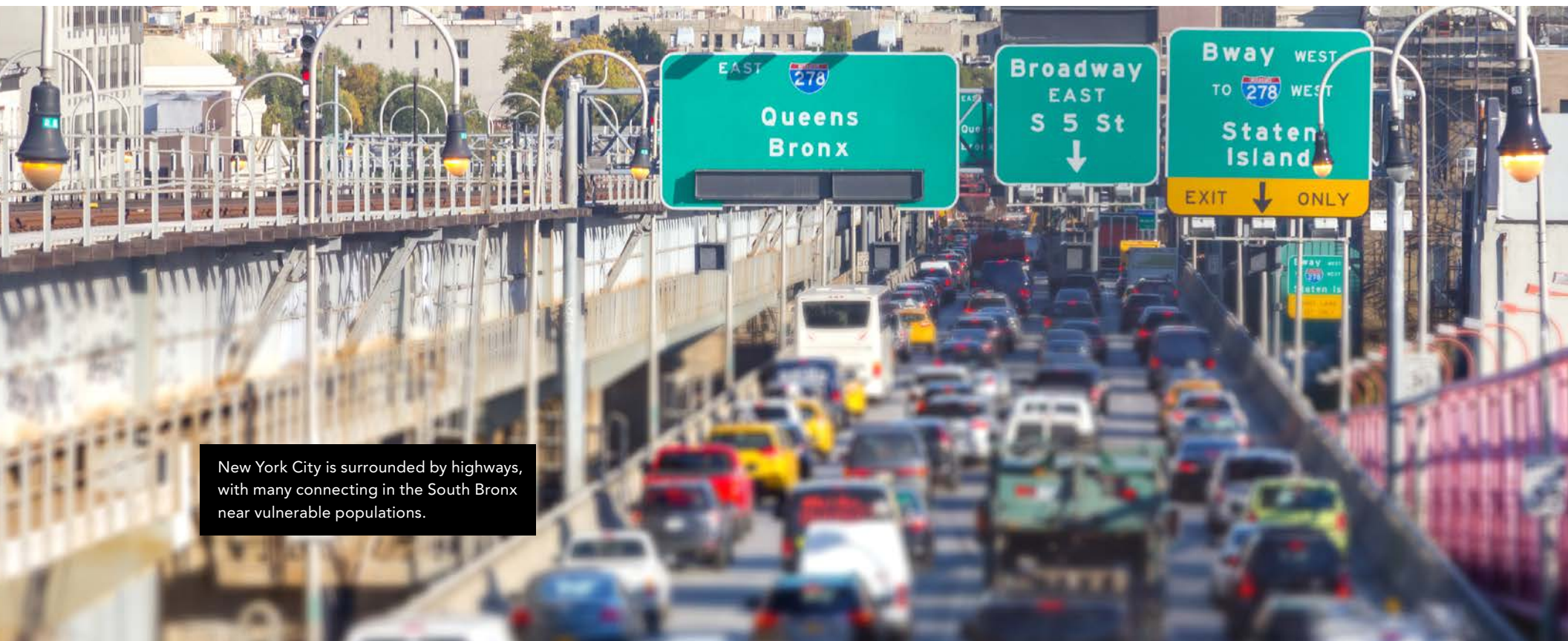
How Unjust Is Your Environment? The CDC's New Map Will Show You

When New York City passed a law in 2019 that would charge a fee to motorists who drive into Manhattan south of 60th Street, one of the world's most traffic-clogged business districts, climate advocates hailed it as a historic win for the health of New Yorkers and the environment. But if you zoomed out on the map from Manhattan, things looked more complicated. Forecasts showed that truck drivers seeking to avoid congestion pricing would end up driving more through areas outside the tolling zone.

"All tolling scenarios will increase heavy-duty truck trips in neighborhoods along the Cross Bronx Expressway, worsening emissions and associated harms to health," wrote Rachel Levine, President Biden's assistant secretary for health, in a letter in November 2022 to the Metropolitan Transportation Authority (MTA) and other agencies behind the plan.

Referencing full-color maps of the South Bronx, she urged measures to counteract the additional traffic, such as prioritizing nearby schools for air filtration systems and deploying zero-emissions buses. She added, "These communities likely breathe more diesel [particulate matter] than 98 percent of communities nationwide."

Her concerns echoed long-standing local calls for a fairer environment and were rooted in a new federal mapping tool, the Environmental Justice Index (EJI), which ranks communities across the US according to environmental health risk. Built by the CDC alongside the US Department of Health and Human Services' (HHS) new Office of Environmental Justice, EJI is the first national geospatial tool to measure the cumulative impacts of social and environmental factors, including preexisting chronic health conditions and built-environmental



New York City is surrounded by highways, with many connecting in the South Bronx near vulnerable populations.

factors such as proximity to hazardous-waste sites. On the EJI Explorer, a map-based portal available at eji.cdc.gov, each census tract in the US receives a single score representing cumulative impacts.

Revealing the Cumulative Impacts of Pollution

On the EJI Explorer, the neighborhoods along the Cross Bronx Expressway—first proposed in the 1940s by Robert Moses over the protests of locals—not only rank high for toxic air, cancer risk, and poverty but also suffer from a high prevalence of chronic health conditions, such as asthma and diabetes, that can worsen with the impacts of air pollution. “Cumulatively,” Levine wrote, “the burden of social, environmental, and underlying health factors in these neighborhoods ranges from the 90th to 99th percentile nationwide, according to the EJI.”

This is precisely what the tool was designed for, said Benjamin McKenzie, project coordinator for the EJI.

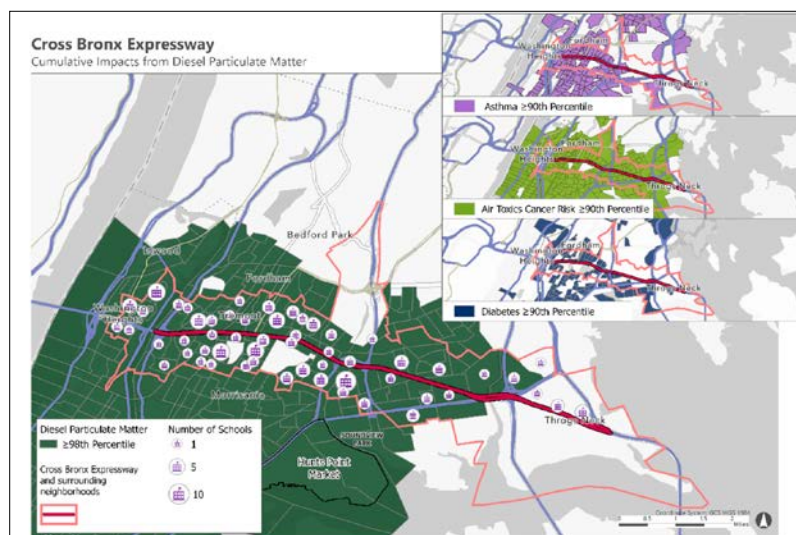
“Part of what we’re trying to do is to raise awareness of how all these factors interconnect,” said McKenzie, an epidemiologist who uses GIS technology “to study the contextual factors causing or contributing to a disease or negative health outcome, including the social determinants of health that make location a key factor in our well-being.”

The EJI is one of a growing number of government tools that help communities and policymakers pinpoint environmental, social, and health vulnerabilities at the level of a neighborhood, and sometimes a city block. The tools fit into the Biden administration’s environmental justice agenda, which includes Justice40, an executive order from January 2021 that calls for distributing 40 percent of climate, clean energy, and infrastructure investments to “disadvantaged communities,” as identified by the Climate and Economic Justice Screening Tool. The initiative will inform how federal and local agencies spend billions in annual investment from the Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA).

Informing Local Remediation Decisions

Apart from helping implement federal programs, tools such as the EJI can empower action at the local level, too. Policymakers and state agencies can use the EJI to ensure that the proper percentage of funded initiatives are allocated to those most in need. Community members can use the EJI to point to specific burdens, such as high levels of air pollution or toxic sites, that might be affecting people’s health. The tool could also be a boon to public health professionals, helping make it easier to estimate local impacts, especially when personnel and resources are scarce.

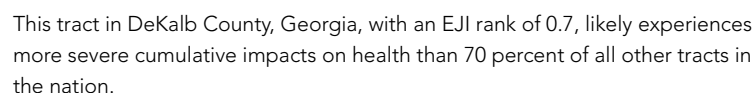
The EJI is different from other geospatial environmental justice tools in one key aspect: for each census tract, a county subdivision for which the US Census collects data, the EJI shows the combined risk people there face resulting from a wide range of environmental, social, and health burdens. The tool shows a single score, based on a percentile ranking system. “Measuring cumulative impacts, as opposed to just a set of scores, is precisely the thing we bring to the table,” McKenzie said.



Rachel Levine, President Biden’s assistant secretary for health, referenced these maps of the South Bronx to urge measures to reduce their pollution burden. Map courtesy of Rachel Levine, US Department of Health and Human Services.

Crucially, the tool lets users view the map and its score through each of the 36 individual indicators, including factors such as proximity to highways, the prevalence of chronic disease, and lack of health insurance. This information is critical because it makes the tool flexible enough to answer a variety of general or specific questions without having to use a separate index. Links on a separate page lead to the underlying raw data resources used to create the index. These originate from the CDC, the Census Bureau, the EPA, and the Mine Safety and Health Administration.

For years, public health professionals have explored these factors through portals such as the EPA's EJScreen or



He offers the example of two similar-sized communities with similar levels of air pollution.

In a lower-income community, McKenzie added, “People don’t have the same level of access to insurance, and a lot of people might already have underlying medical conditions.”

The two communities with similar levels of air pollution may have the same levels of truck traffic, he said, “but one of them is going to end up having more extreme health effects.”

McKenzie said the EJI, like the SVI, is already helping some CDC researchers answer basic questions at the outset of public health emergencies.

The tool is also helping inform other efforts at HHS, which have made health equity a priority in various regulatory

initiatives. In October 2023, the Centers for Medicare & Medicaid Services incorporated several equity measures in its payment rules for Medicare, hospitals, and nursing facilities. The agency also advises that the EJI can be used to achieve Justice40 goals, along with tools such as the White House's CMRA portal and Climate Economic Justice Screening Tool and its associated data layers, to pinpoint and prioritize disadvantaged communities for environmental justice programs.

The EJI is already being used at the local level, too. In Cook County, Illinois, officials are using the map to help prioritize support for suburban municipalities in developing its Climate Resiliency Plans. Under the program, priority is given to communities that experience the most severe cumulative impacts to health and may have the fewest resources to build climate resilience.

I think as a nation, we started to realize that environmental justice is absolutely critical to achieving health equity. So much of our health is impacted by contextual considerations.

—Benjamin McKenzie, Project Coordinator for the EJI

The COVID-19 pandemic only brought those factors into sharper relief. “That definitely brought more attention to the fact that we need to be addressing those disparities,” he said.

Realizing the Impacts around Manhattan

In early 2023, McKenzie and his team held community workshops to share ideas on how to use the tool and gather local feedback that can help improve the index. More than 900 people have registered so far, says the CDC, and since the EJI went public in August 2022, the website received more than 110,000 site visits in the first year.

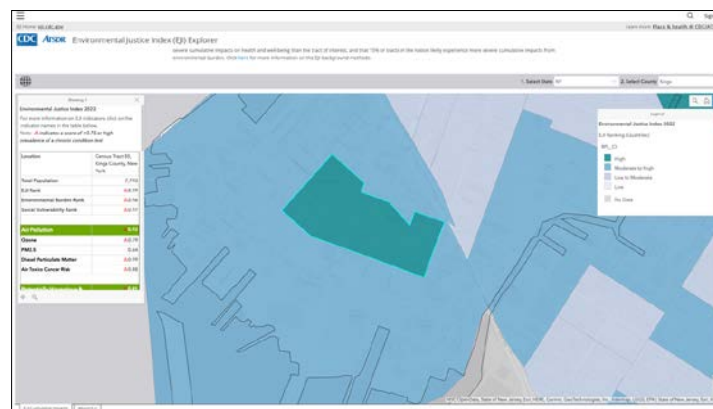
“We’ve definitely seen people who just hadn’t thought about the fact that social factors or health factors might

play a role in how the environment affects their health,” McKenzie said.

The EJI has put new investment on the map. In New York City, Levine and a chorus of local leaders and community members pointed to the air quality risk from MTA’s congestion pricing plan, especially on already-burdened communities. The MTA told the federal government that it would spend tens of millions to mitigate those impacts in the Bronx and elsewhere.

Those efforts helped bring the mitigation plan over the finish line: In late June 2022, final approval was granted by the Federal Highway Administration giving MTA a green light to start the program as early as May 2024. The scenario may still face headwinds: a lawsuit filed by the state of New Jersey in July 2023 warns of similarly increased pollution impacts on Bergen County and notes that although the MTA has proposed \$130 million in mitigation efforts for increased congestion in the Bronx, it has offered none for New Jersey.

For McKenzie, the MTA’s moves and a growing conversation around environmental justice underscore the value of tools such as the EJI and show why it’s critical to find even better ways to highlight places on the map that have long been forgotten. “Advocates can now use this data to point to that and to say, ‘This is a community that deserves attention,’” McKenzie concluded.



The neighborhood around the Gowanus Canal ranks high in the EJI for its environmental burden and social vulnerability.

The NAACP Sees Digital Maps as Tools for Modern Civil Rights Action

America's oldest and largest civil rights organization, the NAACP, uses the power of maps to oppose and prevent systemic inequalities.

Maps and geography have played a central role in furthering discriminatory policies and practices that deny some people equal opportunities. Redlining in mortgage lending and redistricting to tilt elections and public school assignments are some examples of map-driven tactics that support unfair treatment.

Now, using smart maps and advanced analytics from GIS technology, the NAACP has repositioned itself as a monitor of inequality in an increasingly complex world where the strategies for creating privilege and, conversely, inequity are evolving. A geographic approach has gained importance in the civil rights movement because data-driven maps can help leaders identify and prioritize the most harmed places.

"We are embracing this idea that as technology moves, so goes the world," said Yumeka Rushing, the NAACP's chief



March for Our Lives was a student-led demonstration in support of gun control legislation. It took place in Washington, D.C., on March 24, 2018, with more than 880 affiliated events throughout the US. Image courtesy of NAACP.

strategy officer, who is charged with accelerating the shift toward innovation. “We’ve got to be a part of that movement in leveraging new technologies to open up windows of opportunity.”

As awareness of systemic discrimination and racism grows, society and public policy are slowly changing. Although racial discrimination still exists, leaders at the NAACP say there is a greater sense of will and purpose to confront racial injustice. In part, this is because the data being uncovered by the NAACP and other justice organizations is hard to ignore.

Thanks to the efforts of individuals and community organizers, the nation is seeing more action against practices such as dumping harmful waste in Black neighborhoods and denying access to the ballot.

Meanwhile, through the Justice40 executive order from January 2021, the White House is directing 40 percent of federal infrastructure investments to communities of color—where public and private investments have lagged or been diverted or withheld, causing generational disparities. That redistribution of investments will expand broadband internet to communities where it is lacking, many of them Black. And there are growing demands for greater corporate accountability, including targeted advocacy toward companies that create toxic air pollution disproportionately impacting the health of people in Black communities.

The need for community organizing informed by authoritative, place-based research, data science, and mapping has never been more important. That’s why the NAACP has embraced GIS as a strategic tool for making its activism more personal, relevant, engaging, and effective.

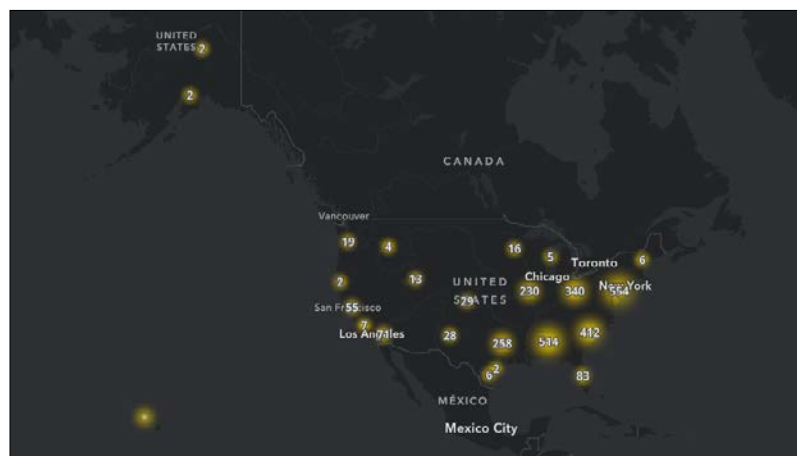
Quantifying Human Experience through Data

The NAACP’s civil rights advocacy and activism, much of it carried out through local chapters, aims to improve life expectancy and other outcomes for African Americans. Programs and initiatives focus on protecting voting rights and pushing for economic inclusion, environmental and

climate justice, and access to world-class education, as well as opportunities that help develop the next generation of leaders. Protecting the lives and interests of Black people also requires identifying and eradicating harmful and devaluing messaging and imagery about people of color.

For decades, the NAACP’s organizers and members have used maps to visualize the landscape and pinpoint hot spots where injustice is happening. Maps supported legal action aimed at protecting voting rights in the Georgia and Florida elections in 2021. Maps helped tell the story of how government disinvestment left residents with contaminated water in Flint, Michigan, and Jackson, Mississippi—documenting the geographic reach of negative health outcomes and loss of life due to irresponsible policies.

When residents in Flint turned on their taps and received water from a contaminated river in 2014, they complained about the discoloration and stench, and reported related health problems. Tragically, consumption of water from the Flint River has been linked to a 12 percent drop in fertility rates and a 58 percent increase in fetal deaths in affected neighborhoods, according to a report from the National Partnership for Women & Families.



A map of NAACP office locations shows how the network of advocates spans the nation.

Providing the geographic context to turn such lived experiences into actionable information has become a compelling part of the NAACP's work. Maps and geospatial data quantify the scope of discrimination's damage in specific locations. Linking personal experiences to those locations on a map can reveal patterns and trends across time and space.

"We know that the oral tradition and the narrative tradition matter in communities of color," Rushing said. "How do you add layers to amplify and connect the dots both in terms of visuals and data? How do you show the story of a family in Jackson dealing with a water crisis and connect it to a family in Baltimore who is dealing with a different type of water crisis—*ecoli* in the water—and to a family in Flint? How do we connect this to civic engagement? How do we link this to supportive policies and institutions?"

NAACP leaders look to infuse more data and data science into the organization's research and programs to bring stories

of injustice to light more accurately and authoritatively. They also see storytelling with maps as a powerful means of shifting policies and countering deficit narratives—those that place Black people as caricatures or victims instead of presenting a complete history that includes accomplishments and a true representation of the diversity within African American communities.

With maps and the ability to aggregate lived experiences, the stories themselves become the thing that shapes public policy, and the public policy becomes the narrative of the people.

—Yumeka Rushing, NAACP's chief strategy officer

Mapping the Movement

The NAACP has begun modernizing with GIS technology's visually engaging maps, web apps, data analysis tools, dashboards, and digital surveys. These tools give the organization a knowledge-generating, location-aware

infrastructure for fine-tuning its business operations and racial justice work. Evolving piece by piece, NAACP's Mapping the Movement strategy will be implemented across four focus areas:

1. Improve strategy and impact. Compiling location data to guide planning and decision-making will help the NAACP, and partners in other racial justice organizations and programs, understand how to effectively move resources to where they are needed most and measure the impact of their programs and work.



The water crisis in Jackson, Mississippi, began in late August 2022 after the Pearl River flooded and infrastructure failed. Here volunteers pass out water to residents left without a safe source. Image courtesy of NAACP.

2. Increase and amplify community engagement.

Communication is an essential part of the organization's work on behalf of members and partners to build support for programs and policies. This includes keeping constituents aware of relevant work taking place in racial justice organizations and issuing calls to action against policies and conditions that have the potential to create widespread or localized harm. Maps and data analysis resources will guide understanding as leaders develop strategies and tactics in specific areas. Leaders will use the same tools to highlight successes that others can replicate elsewhere.

3. Develop the next generation of GIS leaders. Rushing and her innovation team want to inspire justice leaders to be users and advocates of geospatial technology. By stepping into roles as creators, managers, and analysts, the NAACP's members and staff can bring depth, nuance, and unique perspective to conversations about race and justice.

4. Use mapping to imagine and move toward a racially just future. Data science calls for outlining goals, marking a starting point, and monitoring outcomes and progress over time. Monitoring makes it easier to recognize and address problems by location, detect changes and regional patterns, and document outcomes or accomplishments. Having this type of command over data can be used to compel other organizations and business leaders to invest more thoughtfully,



Volunteers work phones and social media to mobilize voters across the country. Image courtesy of NAACP.

partner in justice work, and contribute resources to support mutually beneficial programs and initiatives.

A New Framework for Racial Equity Work

Leaders at the NAACP believe the organization's long, well-documented history of successful civil rights activism makes it an especially important partner in the digital age. They see digital maps and data science as the right tools for more effective engagement for justice, equity, corporate responsibility, and climate action.

By continuing to enrich its racial justice work through data science, the NAACP's leaders can offer more authoritative insights to partners and stakeholders. The process begins with using maps to show where people are experiencing unbalanced conditions such as limited access to a quality education and unequal access to opportunities for home- or landownership. With a map-based frame of reference, the NAACP can help partners and policymakers evaluate locations to better understand how to invest in ways that address past disparities while improving or contributing to racial equity.

Voter Incident Report Form		
Incident*		
(* indicates a required field)		
☐ Polling place issue	☐ Poll Worker/ election official issue	☐ Polling place or ballot accessibility
☐ Voter intimidation / Misinformation	☐ Voting machine / equipment / balloting issue	☐ Prevented from voting/ mail-in ballot issue

The Voter Incident Report Form provided a map-based visualization of any voting incident throughout Election Day to remove any impedances to citizens' right to vote. Image courtesy of NAACP. [Long description.](#)

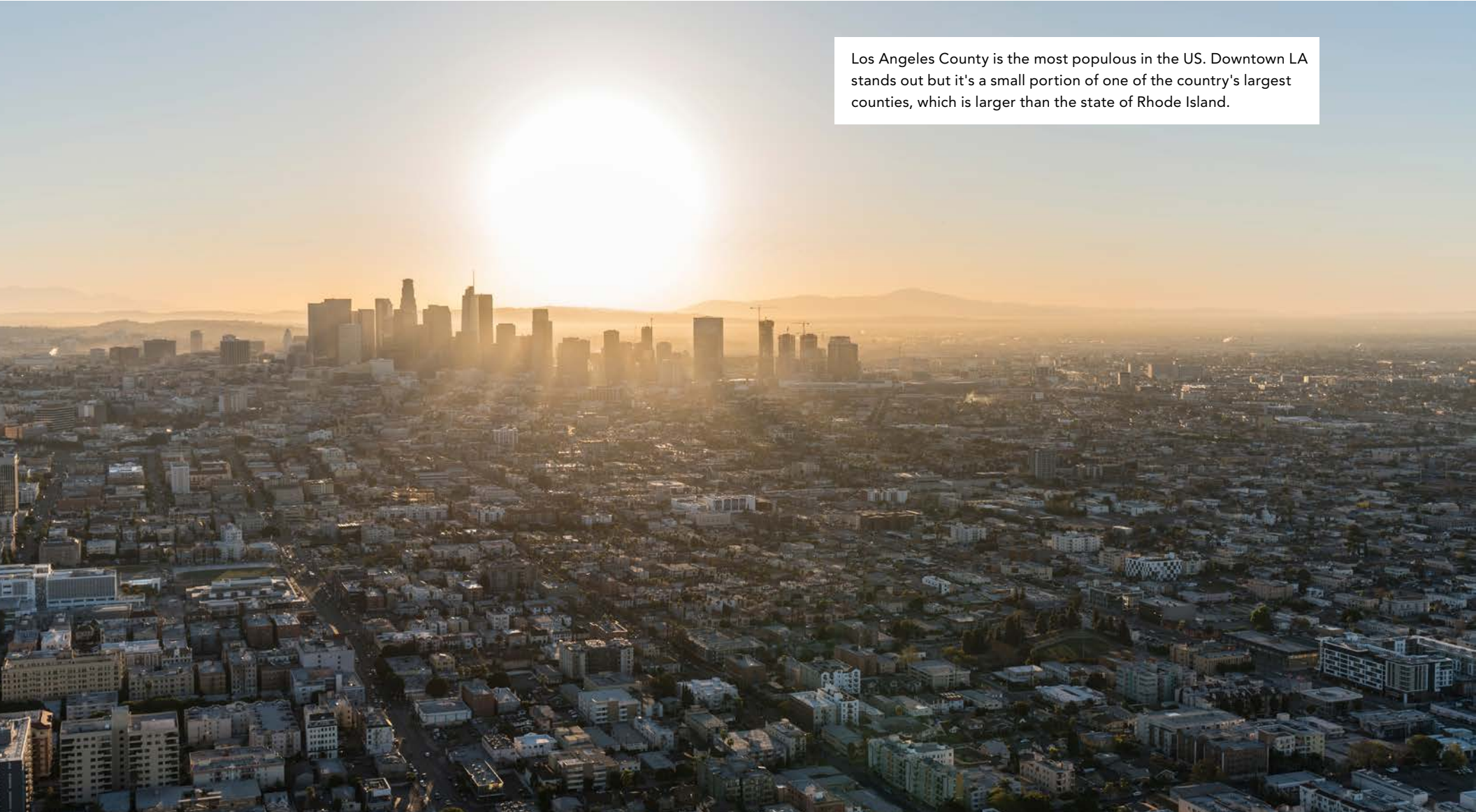
LA County Documents and Addresses Racial Disparities Using GIS Technology

In 2020, against a backdrop of national protests over the killing of an unarmed Black man, George Floyd, by police in Minneapolis, the Los Angeles County Board of Supervisors joined other counties and cities in declaring racism a matter of public health. The board said racism against Black people was at crisis levels.

“As a nation, we had reached an inflection point which demanded that every institution in this nation—including Los

Angeles County—publicly and collectively confront the myriad injustices faced by Black people in this country,” the board wrote.

As the most populous and racially/ethnically diverse county in the US—serving approximately 10 million people—leaders here are especially motivated to adopt innovative strategies and approaches to end systemic and normalized racism.

An aerial photograph of Los Angeles, California, taken during the "golden hour" of sunset. The sun is a large, bright, glowing orb in the upper center of the frame, casting a warm, orange-gold light across the entire scene. The city's skyline is visible in the middle ground, with several prominent skyscrapers silhouetted against the bright sky. The foreground and middle ground are filled with a dense, sprawling urban landscape of residential and commercial buildings, streets, and green spaces. The overall atmosphere is one of a vast, bustling metropolis under a dramatic, hazy sky.

Los Angeles County is the most populous in the US. Downtown LA stands out but it's a small portion of one of the country's largest counties, which is larger than the state of Rhode Island.

The supervisors called for a study to help them better understand conditions that negatively affect the health and well-being of Black residents in LA County. In the inaugural report on the *State of Black Los Angeles County*, maps and data science lay bare this unequal reality.

Los Angeles County has the third-largest Black population nationally. The report found that despite living in one of the most prosperous counties in the nation, Black residents are more likely to experience large disparities in family stability, health and mental wellness, education, employment, economic opportunity, public safety, criminal justice, and housing. Black residents also experience higher rates of homelessness, incarceration, and rent burden. These conditions combine with a higher risk than other groups for dying younger, earning less, and being denied a home loan.

County officials hope the report, with its many maps that show where disparities exist, will “guide, govern, and increase the county’s ongoing commitment to fighting racism.”

The county’s research for the report drew on data analysis, digital mapping from GIS technology, and firsthand accounts. Findings in the report indicate that racism in Los Angeles County has existed through decades of disinvestment in Black communities, unfair hiring practices, and discrimination in college admissions.

“We want this report to be a model for other counties and cities to think about how they assess the impact of their policies and procedures,” said Dr. Tolu Wuraola, data analyst and racial equity consultant for the Anti-Racism, Diversity, and Inclusion (ARDI) Initiative.

A Call to Action

Los Angeles Supervisors unanimously adopted a motion to establish an Anti-Racism County Policy Agenda on July 21, 2020. After Minneapolis police officers killed George Floyd, an unarmed Black man, on May 25, 2020, the board said it had a responsibility to act and address centuries of structural racism.

The following year, in 2021, the board voted unanimously in a separate action to return the waterfront property known as Bruce’s Beach. The property was illegally taken from Black entrepreneurs nearly a century earlier. When fixing this historic injustice, LA County leaders said that more can be done.

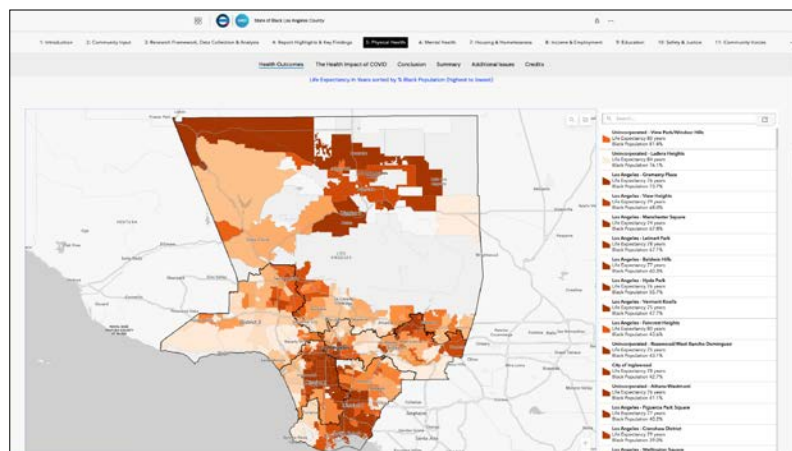
The *State of Black Los Angeles County* report provides the social and historical context that explains why racial disparities exist. The report’s maps allow county officials to see the number and location of neighborhoods where disparities exist.

The Board of Supervisors passed a motion in July 2020 to establish the ARDI Initiative. The team supporting this initiative worked with key stakeholders to develop the county’s Racial Equity Strategic Plan. According to the 10-year plan, which was passed in 2023, “The disparate geographic landscape of opportunity yields very different life outcomes for those raised in neighborhoods of affluence compared to those raised in neighborhoods of disadvantage.”

Through this plan, the county is coordinating its departments to improve opportunities for education, full-time employment for individuals, and incomes above the poverty level for families. The county is also working to prevent infant deaths and first-time felony convictions for adults.



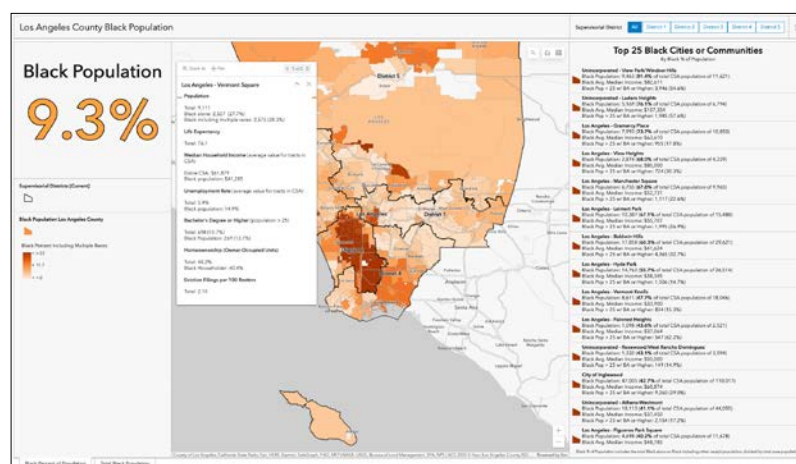
Los Angeles County’s racial equity strategic plan has a set of goals and a dashboard to track progress.



This map shows the life expectancy of Los Angeles County's Black population, with darker colors indicating a lower lifespan.

Since 2020, the county has also added new departments that focus on improving outcomes for some of the county's most vulnerable populations. The departments include Aging and Disabilities; Youth Development; Justice, Care, and Opportunities; and Economic Opportunity. County officials expect that these programs will provide the resources that are needed to meet or exceed their larger equity and anti-racism goals.

To ensure the county is making progress toward these goals, the ARDI team will continue to collect and analyze data with GIS and report on outcomes.



Black resident population map shows a population of 9.3 percent and details on the top 25 Black cities or communities.

Coming to Terms with the Data

Los Angeles County is an economic powerhouse. Its gross domestic product is the largest nationally for a county, at \$712 billion or 3.8 percent of the US economy in 2021, according to the Bureau of Economic Analysis. Yet wealth is lacking in Black communities.

The 2023 *State of Black Los Angeles County* report indicates that 30 percent of the county's homeless population is Black, although this group is just 9.3 percent of the county's population. Blacks in Los Angeles County have a higher rent burden (62 percent) and rates of eviction (1.6 evictions per 100 renter households), according to the report.

Black applicants are less likely to have a mortgage application approved (61.9 percent) compared with Whites (69 percent), Asians (69 percent), and Latinos (64 percent). The average value of a home owned by Black residents in the county is approximately \$200,000 less than the county average and more than \$450,000 below the average value for homes owned by Whites.

However, there were bright spots. Among the counties in the country with the highest number of Black residents, Los Angeles ranked second on Black college degree attainment (28.4 percent), though still significantly trailing White and Asian residents within Los Angeles County.

Also, more Black Angelenos now have access to health care with an estimated 93.6 percent having health insurance, compared with 95.5 percent of whites. The county also saw a 16 percent reduction in the rate of Black Angelenos incarcerated in the county jail system. One of the biggest bright spots, however, was the data on Black people and mental health treatment. It showed that—both before and after the onset of the pandemic—Black people in the county were more likely than any other group to receive treatment for self-reported mental/emotional issues.

Science for Deeper Understanding

The county's ARDI team partnered with researchers from California State University, Dominguez Hills, Claremont Graduate University, and Capacity to Impact, a research and evaluation firm. The study design called for an examination of Black outcomes at smaller geographies.

As part of its research, the ARDI team worked with the county's Internal Services Department using GIS technology to compile data about the well-being of Black residents. The research focuses on physical and mental health, housing and homelessness, income and employment, education, and criminal justice.

Organizing the data on GIS-based digital maps by location allowed the researchers to see patterns. Stacking data layers over the maps has shown, for example, that segregation, health disparities, poverty, and lower property values tend to follow historical patterns for redlining. For decades, mortgage lenders used this practice to deny loans to Black applicants. Maps were drawn to designate communities from which loan applications would be refused.

In its work to address such inequities and show the distinctiveness within the county's Black communities, the ARDI team also examined inequities at the city and neighborhood levels. By doing so, the researchers could compare differences in life expectancy, median household income, unemployment rates, homeownership rates, and more across the county.

For example, although the Black median household income was \$51,259 in 2022 at the county level, the (average) Black median household income is \$107,354 in unincorporated Ladera Heights (which is 76 percent Black) and \$38,345 in unincorporated Hyde Park (which is 56 percent Black). Countywide, the Black homeownership rate is 33.5 percent, but 73.3 percent in Ladera Heights and 36.9 percent in Hyde Park.

It was critical for us to evaluate how residents were doing at the neighborhood level since we are aware of the relationship between race and place, the legacy (and ongoing occurrence) of residential segregation, and the lack of access to resources in certain geographical areas.

—Tolu Wuraola, data analyst and racial equity consultant for the ARDI Initiative

Sharing the Lessons Learned

Hyperlocal location intelligence—authoritative information about a specific place or places—guides decision-makers in many areas of business and government. GIS mapping and data analysis tools support many of the county's equity initiatives. Examples include the county's Equity Explorer tool and the Los Angeles County GIS for Equity web page.

Many organizations in Los Angeles County and elsewhere are working toward similar goals for equity. For that reason, the ARDI team expects other organizations and foundations to benefit from its work.

“To date, we have made some progress in our collective struggle for equity, but we know we need to do so much more,” said Hilda Solis, chair of the Los Angeles County Board of Supervisors when the 2021 budget was released. “We are in this marathon together, and we will see this through to the finish line.”

Today, technology offers powerful tools for ensuring that all residents are healthy, experience justice, and thrive. The work carried out in Los Angeles County is evidence of this. As in that community, other jurisdictions will need courage, commitment, and resources to address disparities in life outcomes and public investment.

The History of Justice, Race, and Equity— Educators Create Maps to Foster Unity

Some 2,892 miles separate the two furthest points in the continental United States, and exploring each of those miles presents an opportunity to reexamine history and issues

concerning justice, race, and equity. That's according to a 2022 educational endeavor supported by the National Geographic Society—*2892 Miles to Go: Geographic Walk for Justice*. As

In the Greenwood neighborhood of Tulsa, a sign commemorates Black Wall Street. This area, with mostly black-owned businesses, was thriving prior to the violence and destruction of the 1921 Tulsa Race Massacre.



the creators of the project's storytelling platform assert, "It is long past time to walk these miles together."

A social justice collaboration among educators, change makers, and leaders, *2892 Miles to Go* focuses on place-based storytelling and maps that bring to light, in the words of the project's founding partner Ashley Lamb-Sinclair, "layers of injustice" and the "humanity of the people who walked before us."

Lamb-Sinclair, a National Geographic Explorer, said she was inspired to start 2892 after attending a healing ceremony hosted by Black Lives Matter Louisville in 2020. It was there she first learned about historical events, injustices, and activists within her community.

The project uses ArcGIS StoryMaps software to blend custom web maps with digital media to create an online collection of resources.

The Route So Far

Project participants first select a route in their community. Then they walk it to collect experiences, photos, videos, and conversations. Using GIS technology, they connect stories to locations on a map.

So far, storytellers have published five collections that highlight Louisville, Kentucky; Saint Paul, Minnesota; Route 66; Tulsa, Oklahoma; and

Hawaii. Each collection contains interactive stories with videos, artwork, podcasts, and interviews. The collections also include guided assignments called 2892 Living Textbooks that give students an exercise to learn from and contemplate their own lived experiences.

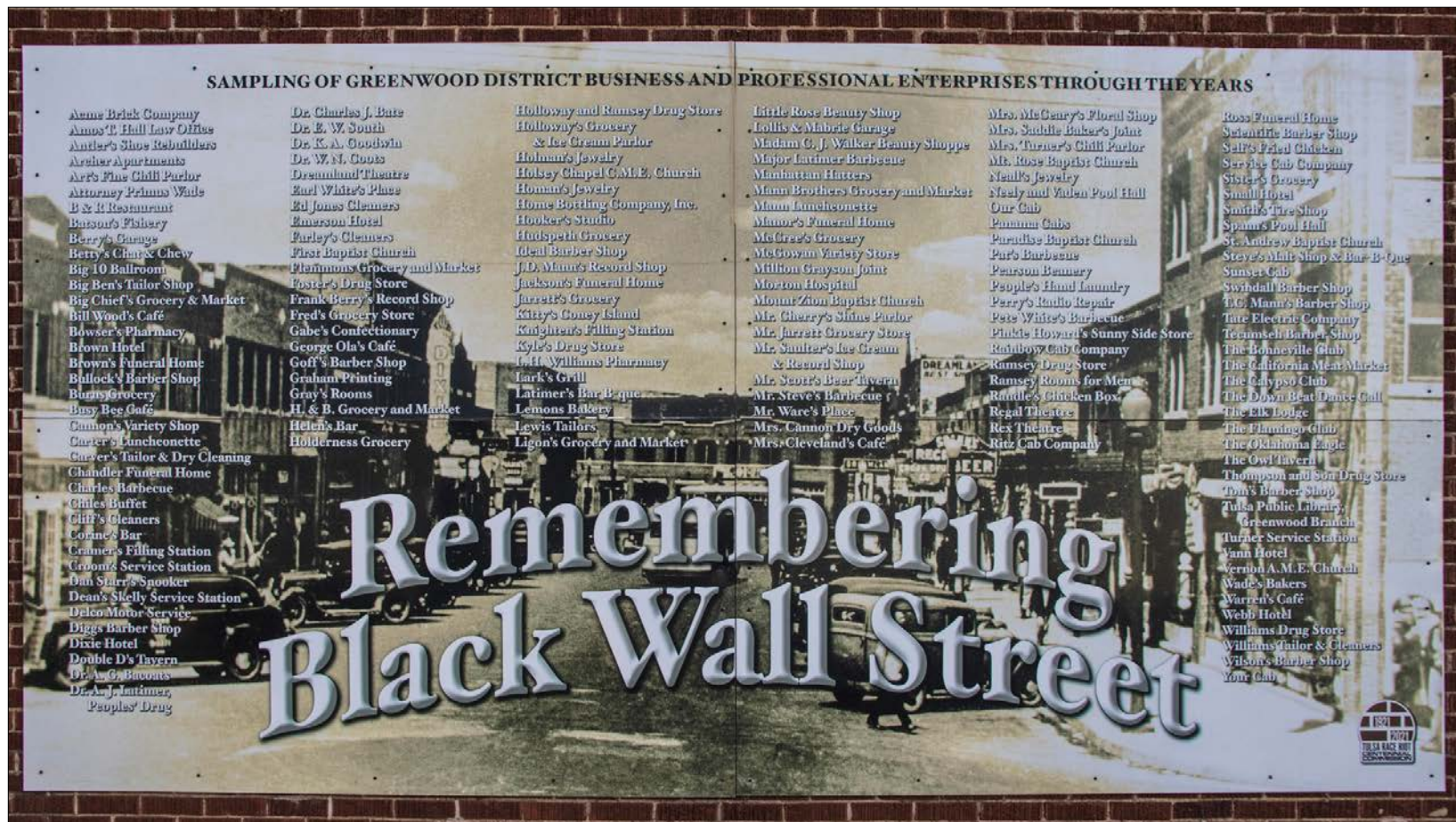
The 2892 Louisville collection of stories offers narratives about the city's past and present. The stories relate the perspectives of people of color to give everyone an understanding of the status quo and the chance to acknowledge the past and heal, and they provide opportunities for community members to move forward with empathy.

Lance G. Newman II narrates a video tour that relates how a housing project in Louisville's West End has been replaced with condos, displacing residents experiencing poverty.

In Saint Paul, Minnesota, six storytellers engage residents by uncovering the Rondo community's rich history of Black



The project home page sends a simple message about the importance of considering justice, race, and equity now.



A sign commemorates the continued legacy of Black owned businesses in Tulsa that were harmed by violence but not shut down.

excellence. The community was destroyed in the mid-1960s when I-94 was built, displacing thousands of African Americans.

Tulsa, Oklahoma, storytellers share a part of the city's history that's often unacknowledged: the Historic Greenwood District, a prosperous Black neighborhood destroyed during the 1921 Tulsa Race Massacre. Hundreds of Black people were killed and years of Black success erased. In the following decades, cover-ups and government actions such as the federal highway program, urban renewal projects, and the assertion of eminent domain spurred generational wealth loss and ongoing trauma for descendants.

Along Route 66, storytellers examined the iconic route's impact on residents in Amarillo, Texas, and Albuquerque, New Mexico. "I thought I knew most of what there was to know about this landscape," wrote Dr. Shanna Peebles in her blog post. "But what would happen if I slowed down and began to try to develop new eyes for this old road?" The Route 66 storytellers sought to explore the intersection of race, culture, mobility, and oil and gas development from the perspectives of the Indigenous, Black, and Hispanic communities impacted by Route 66.

The 2892 Miles to Go project has expanded to include the contingent United States. Hawaiian storytellers have joined

with an ongoing project that explores learning through the lens of āina, referring to land and earth and all that thrive there (humans, animals, plants, and fungi).

The Journey Ahead

Each interactive 2892 story collection asks learners to consider hard questions, seek out hidden histories, and retell previously misleading or long ignored stories in their own communities.

For 2892 storytellers, exploring communities has paved the way to celebrate cultures and reclaim their spaces.

The *2892 Miles to Go: Geographic Walk for Justice* project continues, with more communities using ArcGIS StoryMaps stories to compile resources and create community collaborations. There is an open call for participation for anyone interested to tell their community's stories.

In the Rondo community in St. Paul, stories have become part of the landscape through the Rondo Commemorative Plaza—an outdoor park featuring this memorial wall. Image courtesy of TEN x TEN Studio.





Environment

Professionals use GIS to enhance environmental health and eliminate harmful contaminants.

The Trust for Public Land (TPL) used GIS technology to demonstrate the fiscal impacts and economic benefits of parks in New York City. They found that parks not only mitigated harmful environmental outcomes but also boosted health, property values, and tourism. Their report provided a compelling financial incentive for policymakers to increase funding for the creation, protection, and maintenance of public parks.

"We wanted to make sure people understand that, in addition to having a nice place to play and a break from the urban experience that a park offers, there are other indirect benefits in relation to air quality, stormwater management, and wildlife habitat. We wanted to prove that we can make the most of limited funding and meet multiple needs with parks, because they're a big part of what makes a community healthy," said Mitch Hannon, TPL GIS program director. The report was instrumental in influencing policymakers' short- and long-term funding decisions.

The Los Angeles (LA) County Department of Parks and Recreation continues to assess equity and prioritize parks and recreational amenities where the most vulnerable people live. More parks are coming to LA County, many of them in neighborhoods where more green space is greatly needed. LA County Parks has begun restoring degraded lands—brownfields, landfills, and oil fields—as future parkland.

Clement Lau, departmental facilities planner with LA County Parks, spoke to the growing opportunities to remediate land for parks. "At the county, we're emphasizing the need for restoring degraded lands, especially in park-poor communities. We've developed parks on brownfields before and are working on converting a landfill into a regional park in Puente Hills. There are also opportunities to convert oil fields into additional parkland in Baldwin Hills."

Wildlife Conservation Society Canada (WCS Canada) is using GIS technology to protect Canada's peatlands, which hold a staggering 150 billion tons of carbon. The organization uses GIS to measure peatland cover and carbon storage, record the lands' protected status and risks from development, inform fieldwork, and prioritize conservation efforts.

"Over the past couple of decades, GIS has become a useful tool for peatlands work, especially for these large landscapes," said Lorna Harris, director of the Forests, Peatlands, and Climate Change Program at WCS Canada.

The Wisconsin Department of Natural Resources (DNR) has developed the Wisconsin PFAS Interactive Data Viewer to visualize the occurrence of per- and polyfluoroalkyl substances (PFAS) across the state. The tool allows them to map contamination sites while also recording locations where remediation efforts are under way.

"PFAS have been around for almost 100 years," Johnson said. "Two or three years ago [in 2020], there were about 3,000 chemicals that we knew about, and now we're at 10,000. We're learning something new every day—learning how they behave in the environment, and how they impact our health. We're starting to understand a lot more about the science behind them and what we can do to mitigate their impact." This initiative has been crucial in gaining stakeholder support to tackle PFAS, not only at the state level but also nationally.

Drones, water sampling, and GIS technology are being used by the Tahoe Environmental Research Center (TERC) to record conditions and address the problem of algal growth and the invasive Asian clam in Lake Tahoe. The use of drones has proven effective in tracking the algae growth around the 72-mile shoreline of the lake.

"Previously, we had to track the growth of algae based off small sub-samples," Berry said. "Now, with the drone work, we can track algae much more spatially. We're capturing sites with hundreds of meters of shoreline, and it's easier to track algae growth." In addition to routine monitoring, TERC's research also focuses on more specific areas, such as invasive species control, lake currents, sediment resuspension dynamics, lake food webs, landslide risk, and wetlands performance. GIS is used to guide this work to monitor problem areas and enhance understanding.

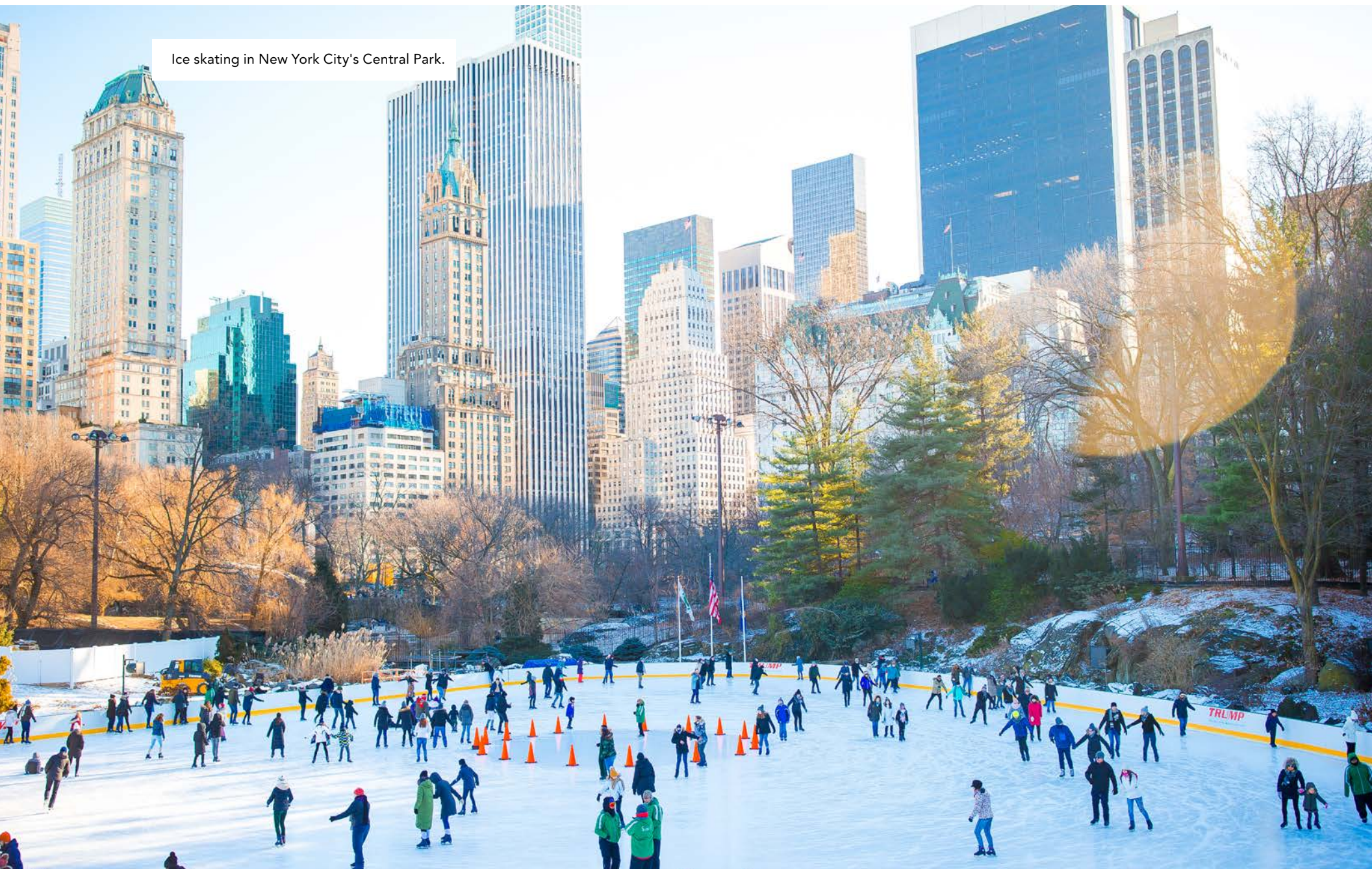
Using GIS, communities create maps that help maintain a healthy balance between humans and nature.

NYC: The Economic Value of Parks

"What is common to the greatest number gets the least amount of care," Aristotle stated in 350 BCE. In 1968, ecologist Garrett Hardin expanded on this idea, coining it "the tragedy of the commons." Hardin argued that, when it comes to using Earth's natural resources, individuals will always act in their own best interest.

The Trust for Public Land (TPL) promotes the benefits of the commons, combating the defeatist sentiment of Hardin's statement that all shared spaces are overused. TPL passionately works to catalyze communities to be healthier, more livable, and more connected through parks and public lands.

Ice skating in New York City's Central Park.



Although the tragedy of the commons may help explain some negative results of modern life—unsustainable development, air pollution, carbon emissions, depleted water supply—TPL uses data to show how parks and public lands not only mitigate these harmful outcomes but also create shared, positive outcomes. TPL used conservation economics in its 2023 report to prove that public parks—an often underfunded public good—provide a myriad of benefits that have monetary value.

To publish *The Economic Benefits of Parks in New York City*, a team of economists, specialists, and research partners used GIS technology to measure the fiscal impacts of city, state, and federal parks within New York City. The report explains how parks lower health-care costs for people who exercise there, provide natural air and water filtration, increase property values, and promote tourism while serving as a place for people to connect with nature.

The report—the first of its kind to study the city’s integrated park system—reveals that policymakers have extraordinary financial incentive to increase funding for the creation, protection, and maintenance of public parks, because parks provide an economic engine for the city.

Choosing the Right Tool

TPL is a national nonprofit that works with communities to create parks and protect land. For more than 10 years, TPL’s ParkScore index has used information about access, amenities, investment, acreage, equity, and a GIS model to rank how well the 100 largest US cities are meeting the need for parks. Currently, 99 percent of New York City’s nearly 8.5 million residents live within a 10-minute walk of a park.

ParkScore measures accessibility, but TPL needed a way to measure the intangible benefits that come from park proximity. An understanding that the economy, social systems, and the natural environment are intertwined prompted team members to ask the following: How can the public health advantages be quantified? How can the benefits of the natural environment be valued?

There’s a growing global interest to put a value on ecosystem services—the many life-sustaining benefits we receive from nature—but nobody had made these calculations across New York City’s urban park system.

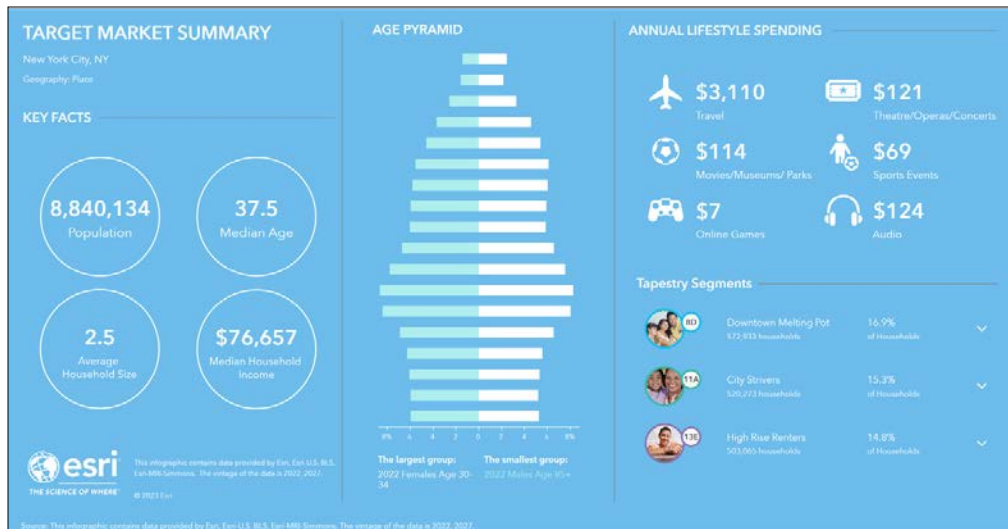
We wanted to make sure people understand that, in addition to having a nice place to play and a break from the urban experience that a park offers, there are other indirect benefits in relation to air quality, stormwater management, and wildlife habitat. We wanted to prove that we can make the most of limited funding and meet multiple needs with parks, because they’re a big part of what makes a community healthy.

—Mitch Hannon, GIS program director at TPL

The project was no small task. New York City maintains more than 48,000 acres of parkland across the city’s five boroughs, making parks a valuable public asset and a critical part of the city’s infrastructure. New York State also maintains important recreational assets such as Shirley Chisholm State Park; the National Park Service oversees iconic places such as Liberty Island and Grant’s Tomb; and there are many multi-jurisdictional parks such as Governors Island and Hudson River Park. “Valuing ecosystem services and outdoor recreation is a challenge because the information can be so dispersed,” said Jennifer Clinton, TPL senior parks and conservation economist.

To analyze and appraise such a vast resource, Clinton, Hannon, and their partners looked to geospatial tools, such as ArcGIS Business Analyst, which provided location-driven market insights. Business Analyst contains data on consumer behavior, leisure, and business activities in a geographic context, which helped the team estimate how recreation spending contributes to the local economy.

“On a local level, Business Analyst is an obvious tool because of its ability to analyze market potential,” Clinton said. “It gave us a way to figure out how residents were spending their money, how often they’re participating in certain activities, and the estimates of spending in different



The Target Market Summary for New York City looks at the demographics of city residents. [Long description.](#)

categories. We were able to articulate data in a way that allowed us to speak to local policymakers in a way we hadn't been able to before."

Adding Up Billions in Benefits

The three sections of TPL's report—human health, nature's services, and economic impact—outline billions of dollars in benefits and savings that New York City parks give residents, businesses, and visitors each year. Some of the most impressive figures include the \$9.1 billion in recreational value, \$2.43 billion in avoided stormwater treatment costs, and \$17.9 billion in tourism spending that the New York City park system generates.

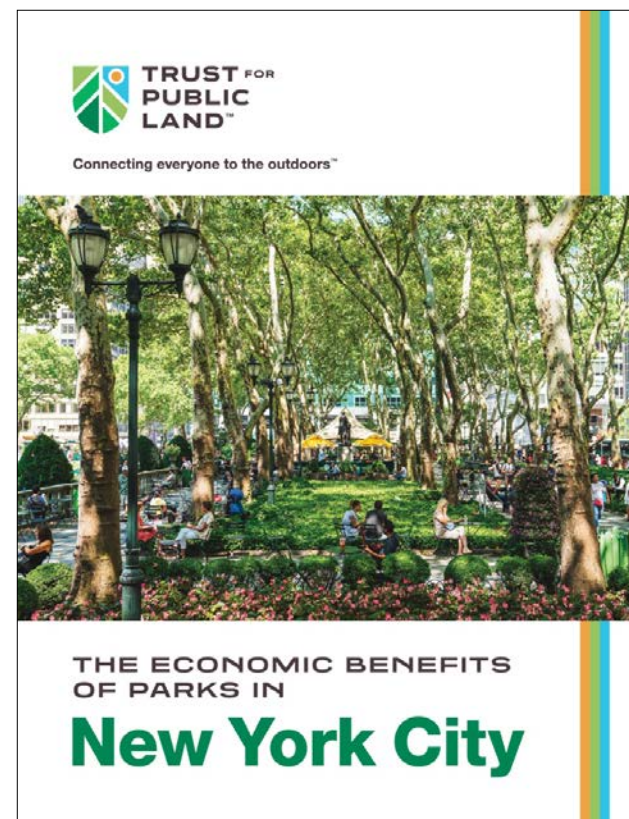
"Even though we believe these values are present in our work, we're always a little blown away by the valuations we find in some of these reports. Billions of dollars are reflected in the work of conservation. It's a lot more than people would imagine, in terms of environmental services and economic impact," Hannon said.

For policymakers, the report is timely. The passage of the Great American Outdoors Act in 2020, the bipartisan Infrastructure Investment and Jobs Act of 2021, and the

introduction of the Community Parks Revitalization Act in 2022 show that parks are a national priority. Communities are well-positioned to use federal funding to reduce the effects of climate change, improve collective health, and boost their local economies by maintaining and creating parks.

The TPL report provides a framework that TPL will replicate elsewhere to quantify the vast potential benefits of parks as well as inspire imagination and motivation to continue and expand park funding.

Because the report's analysis was limited to the years before the COVID-19 pandemic, it



Cover of the report, The Economic Benefits of Parks in New York City.



The Trust for Public Land has turned many school playgrounds into parks.

serves as a conservative baseline. The TPL team knows that there was a substantial rise in park use in 2020, because they were among the few places where people could escape. Clinton is hopeful that the increase is sustained and continues to generate value and engagement with nature.

Establishing a Framework for the Future of Parks

Since its publication in March 2022, *The Economic Benefits of Parks in New York City* has influenced policymakers' short- and long-term funding decisions. "Our most immediate need was securing short-term funding for cleaning and maintaining parks that saw record use during the pandemic. But to meet long-term goals of park equity and climate resiliency, we also need to build and maintain new parks. The big structural challenge is finding strong and dependable funding for parks," said Carter Strickland, TPL's vice president for the mid-Atlantic region and New York State director.

New York City mayor Eric Adams pledged to devote 1 percent of the city's budget to funding public parks

and broke ground on 104 previously paused park projects in March 2023. In addition to connecting residents to nature, parks appeal to tourists and give business leaders a reason to establish an office or storefront nearby.

"There's a dual benefit to parks—they help bolster the economy and they're essential for residents' quality of life," Strickland said.

Strickland, Hannon, and Clinton are optimistic about the role of parks in economic recovery, especially in the wake of the pandemic. Appraising the often unseen but important benefits of these spaces provided a critical foundation for their creation, protection, and maintenance. Hannon said this analysis couldn't have been done without GIS.

"It's so powerful to look at a map and see where you need to work," he said. "It's not just theoretical. You're there—right there."

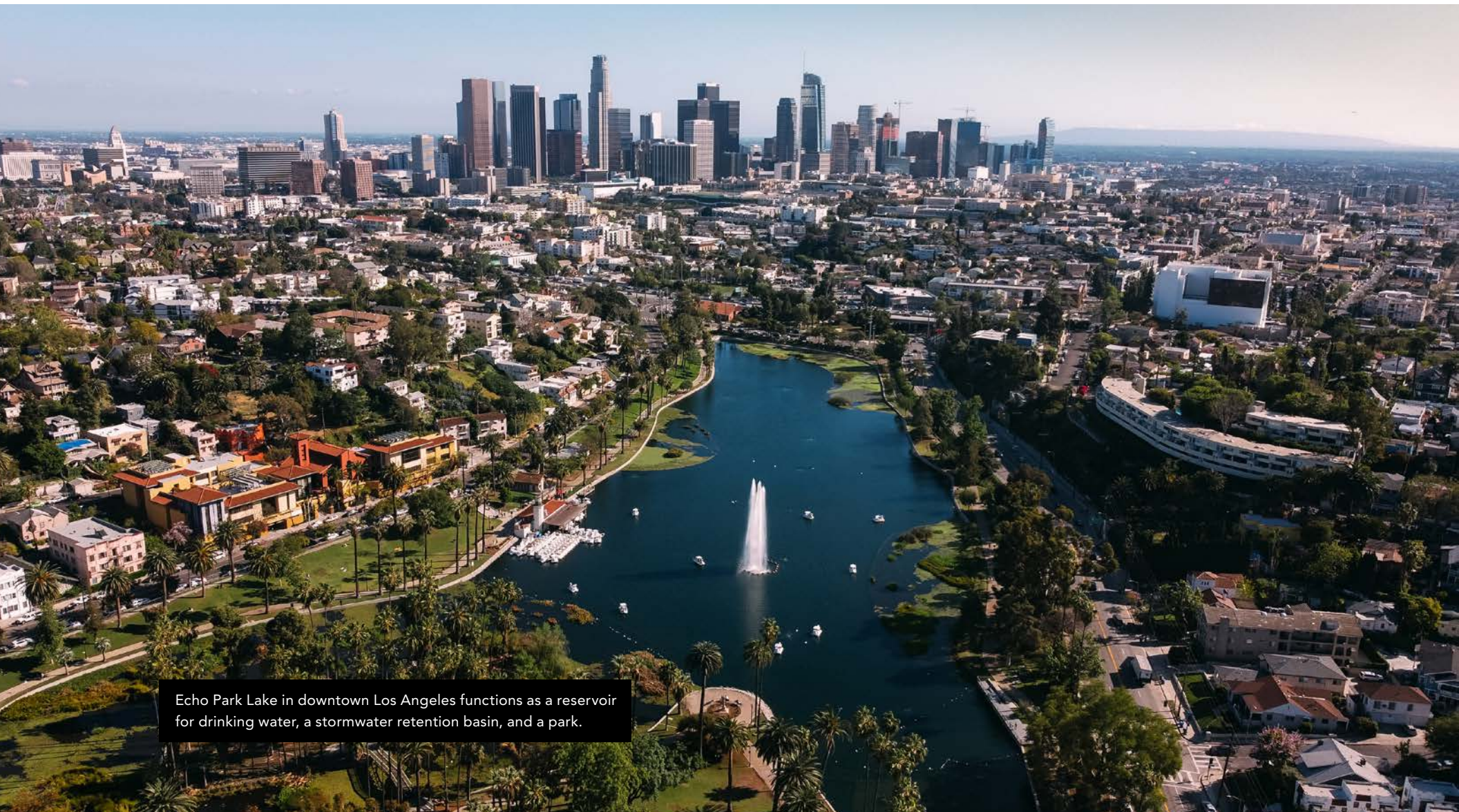


The Trust for Public Land used Esri Tapestry Segmentation to analyze New York City neighborhoods into demographic and socioeconomic segments for market and park customer analysis.

LA County Maps Equitable Access to Nature, Remediates Degraded Lands

More parks are coming to Los Angeles County, many of them in neighborhoods where more green space is greatly needed. The Los Angeles County Department of Parks and Recreation began restoring degraded lands—brownfields, landfills, and oil fields—as future parkland in 2023. These former industrial sites are part of the county's 2023 pledge to conserve 30 percent of lands and waters by 2030, what's known as the 30×30 Initiative.

The county's 30×30 plan, called the Parks Needs Assessment Plus (PNA+), builds on efforts by the State of California, the Biden administration, and nations around the world. The commitment aims to improve environmental health and biodiversity in this time of rapid habitat loss due to climate change. In LA County, the plan will also address the needs of vulnerable populations, including people who live in places deprived of nature.



Echo Park Lake in downtown Los Angeles functions as a reservoir for drinking water, a stormwater retention basin, and a park.

To determine which areas should be prioritized for environmental conservation and restoration and regional and rural recreation—using equity as a guide—LA County Parks relies on GIS technology.

“In the 30×30 Initiative, the focus is more on traditional conservation, which involves protection of additional natural lands,” said Clement Lau, departmental facilities planner with LA County Parks. “At the county, we’re emphasizing the need for restoring degraded lands, especially in park-poor communities. We’ve developed parks on brownfields before and are working on converting a landfill into a regional park in Puente Hills. There are also opportunities to convert oil fields into additional parkland in Baldwin Hills.”

Lau noted that communities of color are overrepresented in areas in need of restoration.

“There’s certainly an environmental justice angle to it,” Lau said. “Supervisor Holly Mitchell referred to our underserved communities as unfinished. They’re a work in progress—in need of more attention—to have the infrastructure like parks and recreational services they deserve.”

Pioneering an Equity-Based Funding Model

LA County Parks’ planners pioneered an equity-based approach in 2016. Their needs assessment used GIS technology to map existing facilities and identify demand for parks in communities countywide. They found that Los Angeles has the least amount of accessible park space among major US metropolitan areas, with the worst access to parks in communities of color.

The analysis of park equity helped fuel the passage of Measure A in January 2020, a tax on property improvements that now funds park improvement and development projects in perpetuity. Measure A mandates that dedicated funding be set aside and allocated to very high and high park need areas.

“Since we did the needs assessment, the whole county has been more equity driven,” Lau said. The pioneering work now

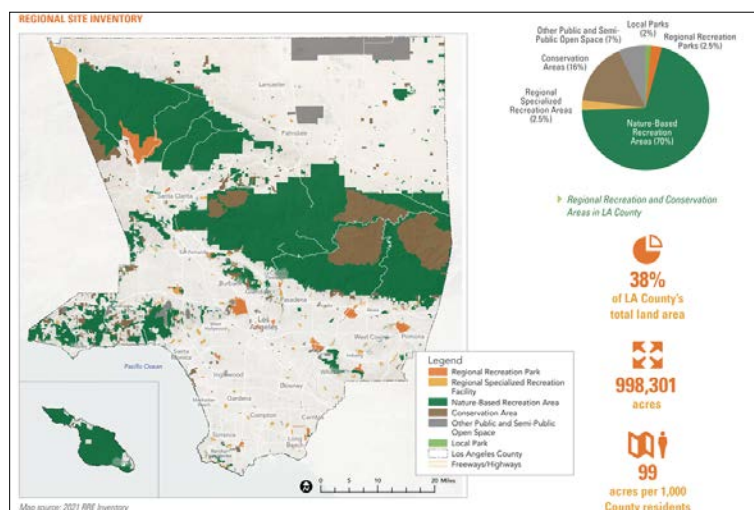
has a follow-on focus to review the needs of rural communities, look at park needs regionally, and identify priority areas to conserve and restore land for parks and open space.

In December 2022, the LA County Board of Supervisors adopted the final report, *PNA+*, that analyzes and maps land conservation, rural recreational needs, and restoration priorities along with transit options to parks.

“We mapped health indicators, access to public transit or personal vehicle, and the combination of those things in the rural north of the county,” Lau said. “These communities are land rich, but park amenities poor. They are surrounded by open land but do not have the things urban folks take for granted, like swimming pools, splash pads, playgrounds, and ball fields. That analysis gave us a much better understanding of rural recreational needs.”

Mapping Needs and Vulnerabilities

Melissa Erikson, principal and director of Community Design Services at MIG, the planning firm that LA County Parks contracted with to conduct the GIS analysis, credits the *PNA+* report with an expanded view of conservation.

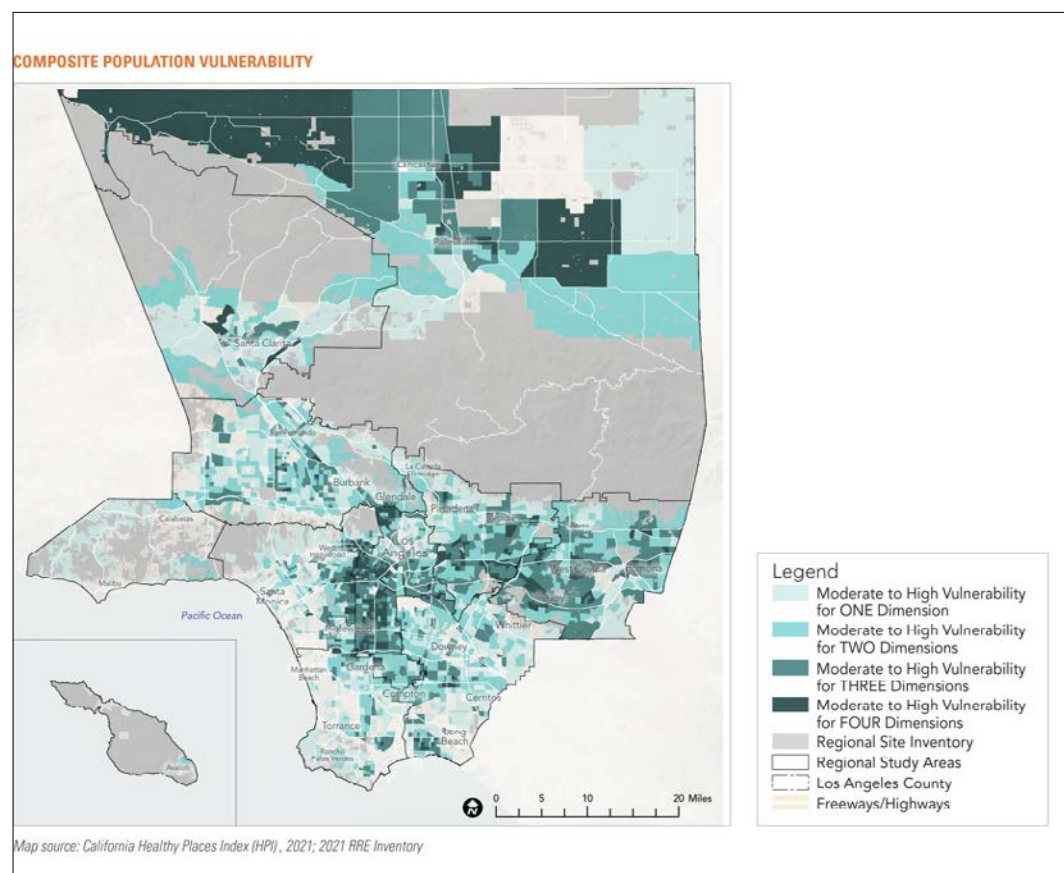


The regional site inventory maps the various parks, recreation facilities, and conservation areas that are open to the public. Map courtesy of LA County Department of Parks and Recreation and MIG.

Erikson and her team gathered an inventory of parkland in rural parts of the county and conducted proximity analysis to transit stops, driving distances, and biking options.

LA County is divided west to east by the San Gabriel Mountains, contained mostly within the Angeles National Forest. The Santa Monica Mountains mark the northern boundary. And the Mojave Desert begins in the northeastern part of the county. In these northern rural regions, it gets cold in the winter, which limits the distance people are willing to walk or bicycle.

“Many people in LA County don’t have cars,” Erikson said. “If it takes you two and a half hours to get to the beach using public transit, that’s a pretty big burden and barrier to access.”



The PNA+ report focused on population vulnerability, going beyond population density to ensure that everyone in Los Angeles County has access to nature and recreational facilities. Map courtesy of LA County Department of Parks and Recreation and MIG.

Analysis of anonymized cell phone data was used to see who visits park facilities, regional parks, trails, beaches, and open spaces. “The snapshot showed that visitors are predominantly wealthy and White,” Erikson said.

That’s one of the reasons that remediating degraded lands looks so attractive—to create parks near people of color who disproportionately live near those lands.

“LA County wants to address land where people live,” Erikson said. “That’s smart, because how can someone appreciate the need to conserve some pristine location if they have no connection to nature?”

Adopting Degraded Lands for Parks

Considering who visits parks changed some of the strategies of the PNA+ report.

“Originally this was just the regional and rural edition of the park needs assessment,” Erikson said. “But as we started digging into these disconnects, it allowed us to ask, ‘Why just look at traditional conservation?’ There are some significant improvements that can be made on degraded lands to counter the conditions.”

LA County has expanded the idea of creating parklands by adopting utility corridors and looking for opportunities to create small parks on vacant land.

“Typically, where powerlines are fenced off, they become places where people dump their trash,” Lau said. “We see those areas as win-win opportunities because if they’re not a park, they’re a nuisance, and a lot of that land is located in areas that lack parks.”

The Puente Hills Landfill Park received funding in July 2023 to restore 140 acres and become the first new regional park in more than 30 years in the county. That's because most of the vacant land in the county is owned or in need of cleanup.

"We need to figure out the level of remediation needed," Lau said. "We're moving toward a parcel-by-parcel analysis to determine which sites should be prioritized."



The concept design to convert portions of a landfill into a regional park in Puente Hills is now undergoing community review. Image courtesy of LA County Department of Parks and Recreation and Studio-MLA.

Saving Canada's Peatlands to Help Stabilize the Climate

Canada's 1.1 million square kilometers of peatlands—one of Earth's largest natural carbon stores—are a little-known but crucial aspect of the country's wildfire crisis across the boreal forest region. In 2023, between January and mid-July, more than 24.7 million acres of forest burned, spanning from Alberta to Quebec. The wildfires were so expansive, the smoke blanketed most of the East Coast of North America, from Nova Scotia all

the way south to Florida. The worst air pollution in the world on June 6, 2023, was in New York City. The health impacts of the wildfires across Canada sent a clear signal about the costs of climate change.

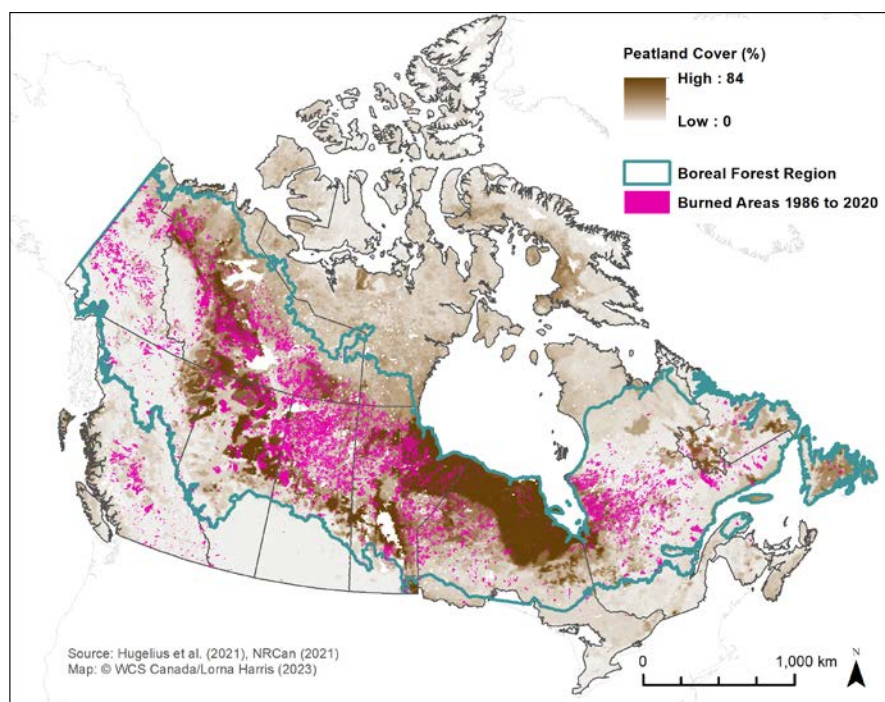
Peatlands are wetland ecosystems where waterlogged conditions capture plant material and keep it from fully



Aerial photo of peatlands in the Hudson Bay Lowland, Photo courtesy of Lorna Harris.

decomposing. Peat is essentially young coal. When wildfire approaches, if the ground is wet and spongy—as it is when healthy—it can slow or stop the fire. But when it dries out, it can do the opposite and be a potent fuel for fires. Many degraded and disturbed peatlands across Canada have been drying for some time, extending the firefighting challenge.

Remarkably, Canada contains 25 percent of the world's peatlands, which hold a stunning 150 billion tons of carbon. Because of human encroachment, industrial disturbances, and the ongoing impacts of climate change, the critical carbon storage and climate-mitigation capabilities of peatlands are in danger. Permafrost thaw and greater fire frequency and intensity add to the threats to these vital but vulnerable lands.



This map shows all burned areas across Canada between 1986 and 2020, with an overlay of peatlands. Map by WCS Canada with data from Natural Resources Canada.

Wildlife Conservation Society Canada (WCS Canada) is working to ensure peatlands continue to serve an essential climate change mitigation function. The organization applies

GIS technology to foster a fundamental shift in how peatlands are assessed and managed in Canada.

“Over the past couple of decades, GIS has become a useful tool for peatlands work, especially for these large landscapes,” said Lorna Harris, director of the Forests, Peatlands, and Climate Change Program at WCS Canada. “Having an idea of the different peatland types, where they are, and how they connect can help us understand where the water is flowing across the landscape and what plant communities are within an area.”

WCS Canada uses GIS to measure peatland cover and carbon storage; record the lands’ protected status and risks from development, such as mining claims; inform fieldwork; and prioritize conservation efforts. Researchers take maps into the field to verify map accuracy and add on-the-ground observations in a process that achieves what is called ground truth.

An Irreplaceable Global Ecosystem

Only 13 percent of Canada’s peatlands are protected. The remaining 87 percent are at constant risk from development and industrial activities such as peat extraction, logging, and mining.

The Hudson Bay Lowlands, which spans the northern portions of Manitoba, Ontario, and Quebec, is the second-largest peatland complex in the world, and it’s under pressure. Within the Hudson Bay Lowlands sits the Ring of Fire, a vast mineral-rich region with deposits of chromite, nickel, copper, gold, zinc, and other minerals. Mining in this region is subject to ongoing debate, with the possible economic benefits being weighed against globally significant environmental concerns and the rights of Indigenous communities.

Indigenous peoples have been the stewards of the vast peatland landscapes across Canada from time immemorial and are working to establish research and community-based monitoring programs to continue this work.

Peatlands across Canada are part of cultural landscapes of importance to many First Nations. In recognition of this essential connection, there's a push to expand Indigenous Protected and Conserved Areas (IPCAs) across Canada's northern peatlands.

Peatland destruction causes the loss of carbon and takes away the future carbon-absorbing capacity. It turns the world's best carbon sink into a carbon source. And peatlands can't rebound like forests.

We can't re-create peatlands. You can restore them, but you often get something completely different, and you can't recover the lost carbon. Peatlands have taken thousands of years to absorb all that carbon and build it up. Even if you give it 10, 20, 30 years, that's nothing in the lifetime of a peatland.

—Lorna Harris, director of the Forests, Peatlands, and Climate Change Program at WCS Canada

Canada's peatlands can keep that carbon stored for many thousands of years. That's much longer than other carbon sinks,

such as rain forests, which can release carbon relatively quickly—over decades and centuries.

Monitoring Changes across Vast Wilderness

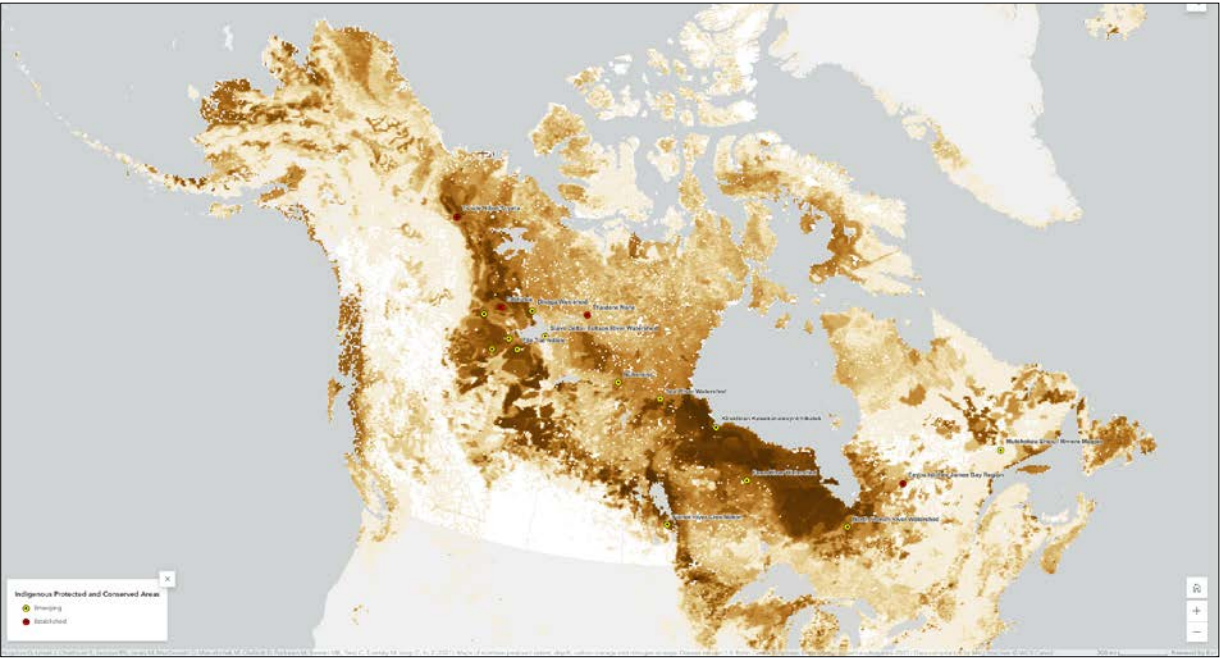
WCS Canada's goal is to work with partners in the Hudson Bay Lowlands to track changes as they happen, including mining activities, permafrost thaw, and wildfire damage. The data collection will give a clearer idea of what's happening across Canada's peatlands, an area too vast for achieving comprehensive ground truth.

Building this knowledge is a challenge; the areas are distant and secluded. "There aren't research stations," Harris said. "The only settlement is small communities, hunting camps, mining camps."

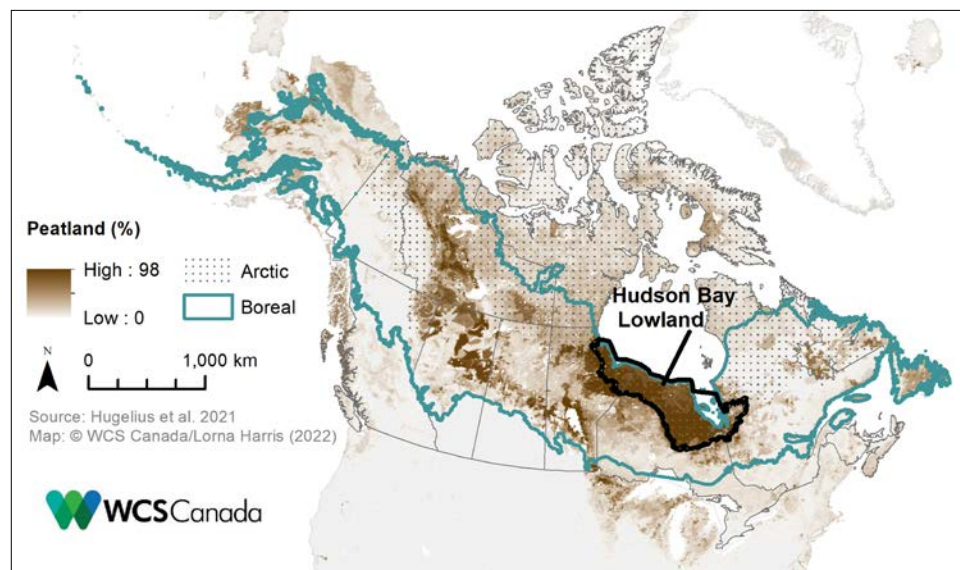
Even maintaining a charged battery for a computer, tablet, or mobile phone is nearly impossible. "It's a very difficult place to work," Harris said. "It's swarming with bugs most of the time, blackflies and mosquitoes, so we're all in the peat bog with our bug jackets, sealing up any gaps so they can't get through."

The expense of reaching these remote regions is high. The annual cost of using a helicopter to cover even a small lowland area starts at \$60,000. "That makes it very challenging to get baseline data, do the monitoring, and get back," Harris said.

WCS Canada is working with partners to set up remote monitoring, using sensors and satellites to learn more about peatlands across Canada and make the most of the organization's limited budget. WCS Canada plans to expand



This map by WCS Canada shows established Indigenous Protected and Conserved Areas (IPCAs) across Canada as well as potential ones.



Canada is home to the world's largest concentration of peatlands.

its use of technology to track peatlands, including the use of drones, aerial imagery, and lidar data.

"We're determining what's going on in each area based on the data we have available," said Meg Southee, lead geospatial data analyst at WCS Canada. "We're using remotely sensed data, and we're modeling based on that."

A Conservation Journey

Canada still has a long way to go to protect the vulnerable forests and peatlands of the boreal region.

"I'm currently looking at oil sands expansion in northern Alberta and a fen [a type of peatland] that's taken close to 8,000 years to develop and could be destroyed in an instant," Harris said. "Some restoration would be possible with a lot of work, but you can't get back these landscapes that are thousands of years old."

In WCS Canada's 2023 policy brief on protecting northern peatlands, GIS-driven opportunities for conservation action are described, including

developing a complete inventory of current peatlands and potential dangers. This effort to enhance the mapping and monitoring would include tracking relevant industrial activity to develop a full picture of what's happening to the peatlands and where.

With the rampant wildfires in summer 2023, Canada's vulnerability to climate change is at the forefront. WCS Canada is working with global partners to get peatland conservation on the global climate action agenda to free up funds to tackle this important challenge.

"The United Nations Environment Programme has been working to bring all the major peatland countries together," Harris said. "Peatlands only cover about 3 percent of earth's land surface, but they store nearly 30 percent of the total soil carbon. It's a very small area relative to forests, but they store more carbon than all the world's forests combined."



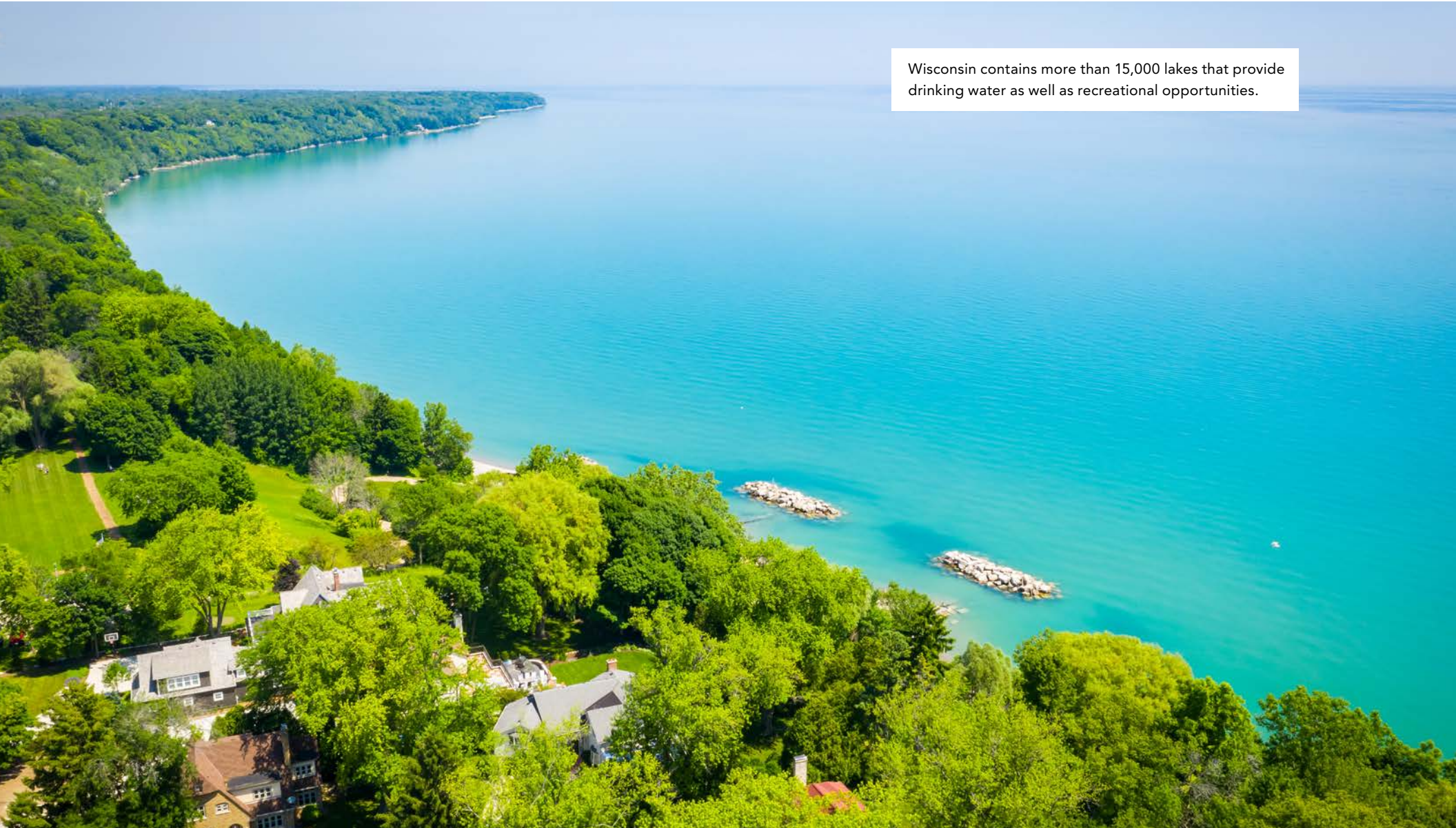
Burned peatlands in northern Alberta. Courtesy of Lorna Harris.

Wisconsin: Using Maps to Tackle 'Forever Chemicals'

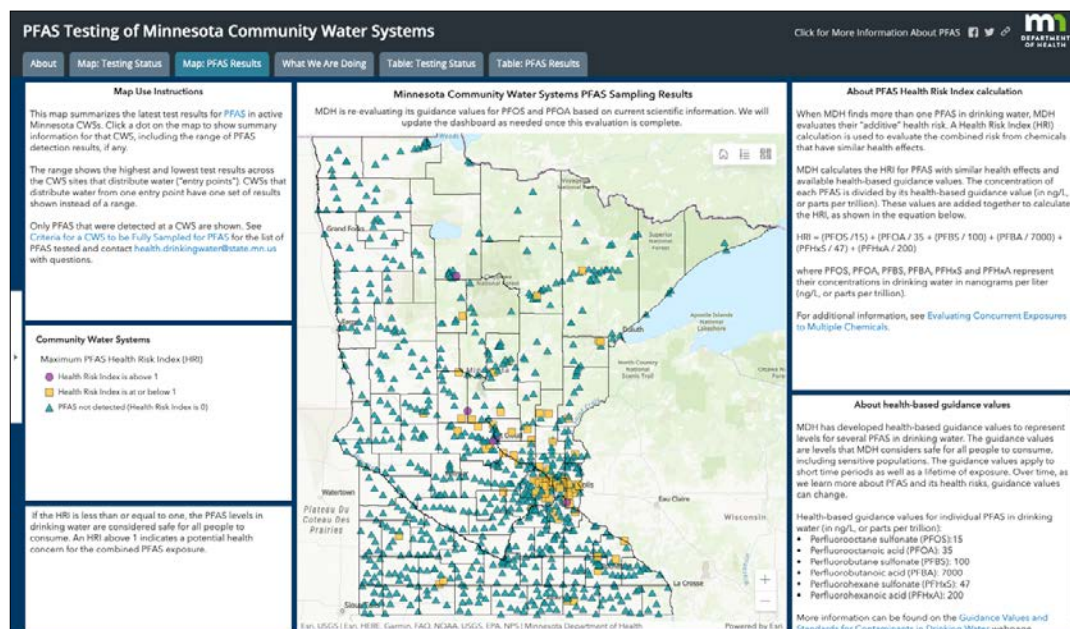
The thought of so-called forever chemicals coursing through bodies of water or across the earth's surface paints an ominous picture. Substantial efforts are now under way to combat PFAS, a notoriously pervasive class of contaminants. In Wisconsin, teams are mapping the prevalence of these dangerous chemicals in drinking water supplied by two of the world's largest lakes.

"We all have PFAS in our blood at this point," said Melanie Johnson, director of the Office of Emerging Contaminants at the Wisconsin Department of Natural Resources (DNR). "We're all kind of dealing with it."

Since the 1940s, toxic chemicals have been used to create a multitude of industrial and consumer products, including firefighting foam and household cleaners. PFAS have traveled

An aerial photograph of a Wisconsin lake. The water is a vibrant turquoise color. The shoreline is lined with dense green trees. In the foreground, several houses with grey roofs are visible, surrounded by lush greenery. Two small rocky islands are in the water.

Wisconsin contains more than 15,000 lakes that provide drinking water as well as recreational opportunities.



Minnesota tests and maps evidence of PFAS in community water systems. When the Minnesota Department of Health finds more than one PFAS in drinking water, analysts evaluate and communicate the added health risk.

through water systems, poisoning wildlife and people. Health-care professionals have tied these chemicals to liver and immune system issues in both humans and animals. Researchers continue to study the damaging effects of long-term exposure.

As the understanding of the risks associated with PFAS continues to grow, governments around the world are sampling water and mapping PFAS concentrations using GIS technology. The maps provide target areas to address the presence of these enduring chemicals.

After Wisconsin DNR identified PFAS contamination levels that exceeded health recommendations in five communities, staff began implementing measures to address the problem.

Spearheaded by Johnson and her colleague Jesse Papez, section supervisor for the GIS Data Analysis and Integration Section, Wisconsin DNR developed the Wisconsin PFAS Interactive Data Viewer to visualize the occurrence of PFAS across the state.

"PFAS have been around for almost 100 years," Johnson said. "Two or three years ago [in 2020], there were about 3,000 chemicals that we knew about, and now we're at 10,000. We're learning something new every day—learning how they behave in the environment, and how they impact our health. We're starting to understand a lot more about the science behind them and what we can do to mitigate their impact."

Addressing PFAS in the Water Worldwide

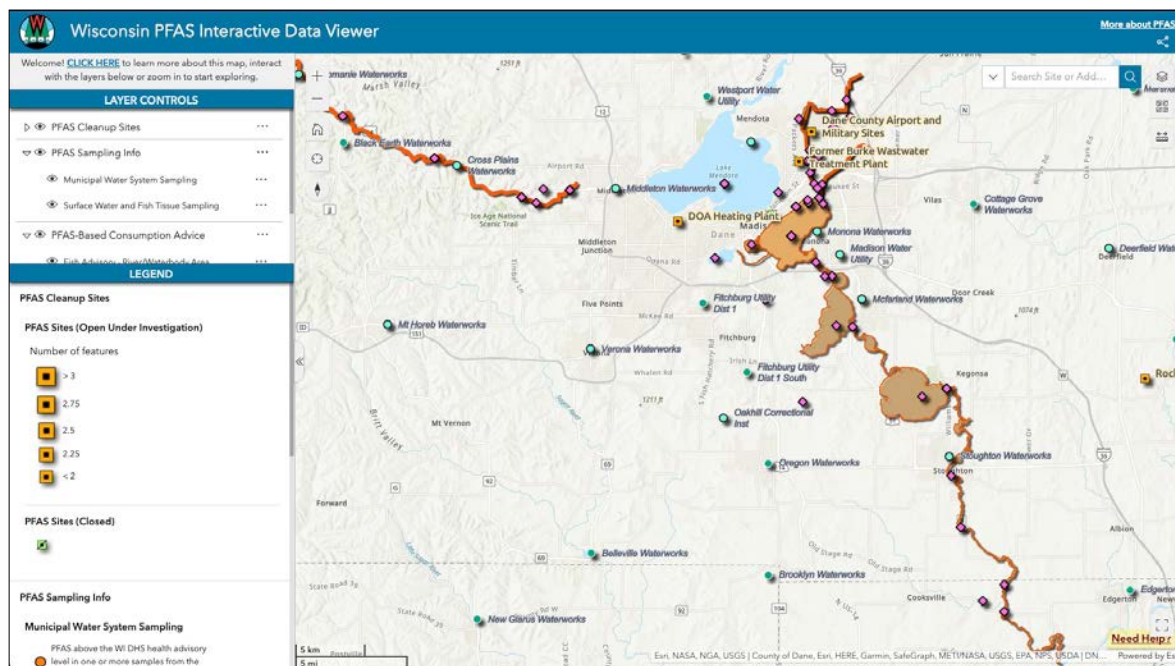
Companies that create and use PFAS are under intense scrutiny. They also face lawsuits for contributing to water pollution.

The European Union has proposed a ban on the production, use, and sale of about 10,000 of these substances. In Japan, the government focused on improving water quality after a group of residents in Okinawa had high levels of PFAS in their blood. The US EPA proposed the first-ever national drinking water standard for six PFAS in 2023. With the funding, the EPA plans to help communities on the front line of the fight against forever chemicals.

Wisconsin is one of several Great Lakes states that have made PFAS a priority to keep their residents and abundant water resources safe. They do this by increasing testing, setting clear standards, and openly sharing their progress.

Wisconsin is bordered by two of the world's largest lakes, Lake Superior and Lake Michigan. With more than 1.6 million residents depending on these lakes for their drinking water, lowering PFAS levels has become a critical health priority.

For Johnson and her team, GIS provides a better view of PFAS pollution and the health of water systems that are contaminated and most in need of ongoing cleanup.



Waterways in and around Madison, Wisconsin, have shown signs of concerning PFAS levels coming from industrial sites.

“I think there’s great value in visualizing it,” Johnson said. “One of the things we really wanted to visualize is the drinking water results.”

Communicating and Collaborating

With the help of the PFAS data viewer, the Wisconsin DNR team can map contamination sites as well as locations where remediation efforts are under way. By visualizing and integrating this extensive location-based data, the team can effectively plan strategies, allocate resources, and share information.

Initially, Wisconsin DNR focused on remediation sites while conducting statewide sampling of surface water and wastewater treatment plants. Staff aim to broaden their understanding of fish and wildlife contamination by sharing data and collaborating with neighboring states.

“If we’re studying a specific fish, we share that data with the other states and they share their data,” Johnson said.

Wisconsin DNR led the effort to study the smelt found in Lake Superior and issued a public advisory not to eat more than one meal of fish per month because of high levels of PFAS. That finding was confirmed by studies conducted in Michigan and Minnesota, and those states followed up with their own warnings.

One of Wisconsin DNR’s primary objectives is to ensure effective communication with the public. Through the Wisconsin PFAS Interactive Data Viewer, the team aims to provide a user-friendly interface

for essential information. Anyone can navigate the PFAS data viewer to determine if there is any contamination within their area. Stakeholders, including those interested in detailed raw data or the history of a contaminated site, can delve deeper.

“We had a design goal of keeping it as intuitive as possible, yet as information rich as possible so the learning curve would be minimal,” Papez said, adding that the goal included “providing as much data as we could without it being overwhelming or requiring data science skills.”

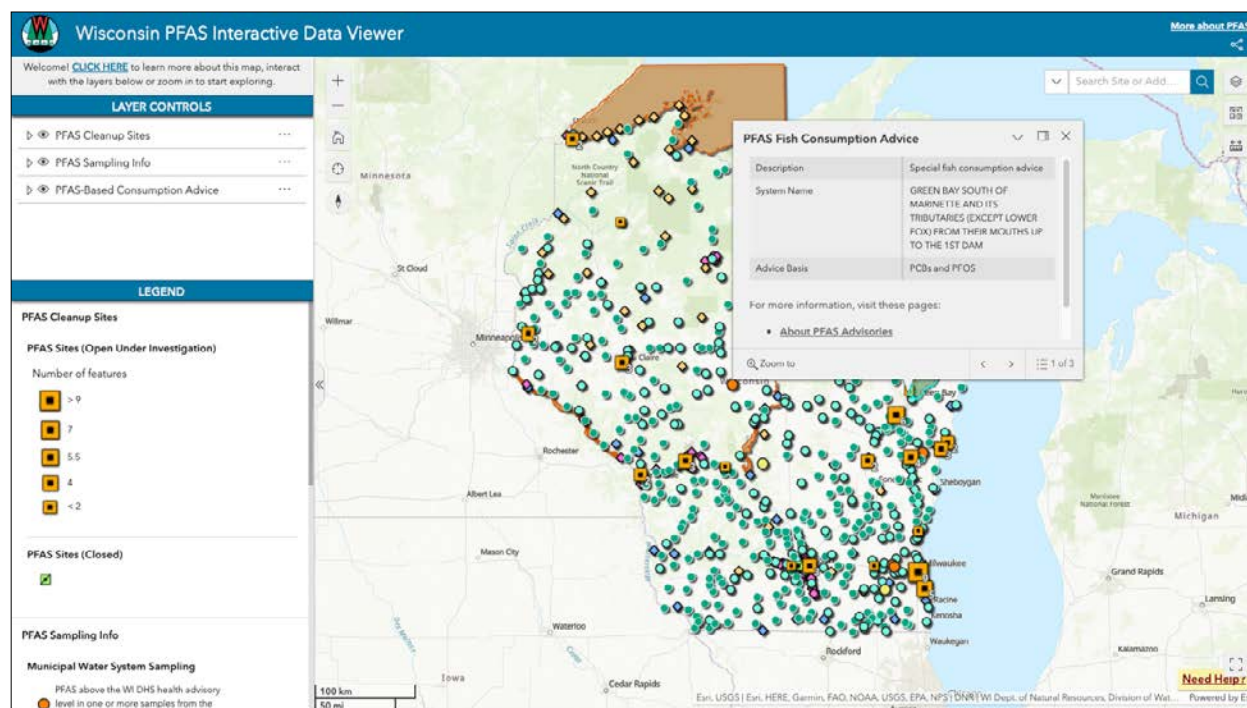
Bridging the Divide

Wisconsin DNR received funds from the Infrastructure Investment and Jobs Act in 2023 to address emerging contaminants and ensure excellent water quality. Johnson and her team believe that tools such as the Wisconsin PFAS Interactive Data Viewer will play a crucial role in gaining stakeholder support to tackle PFAS, not only at the state level but also nationally.

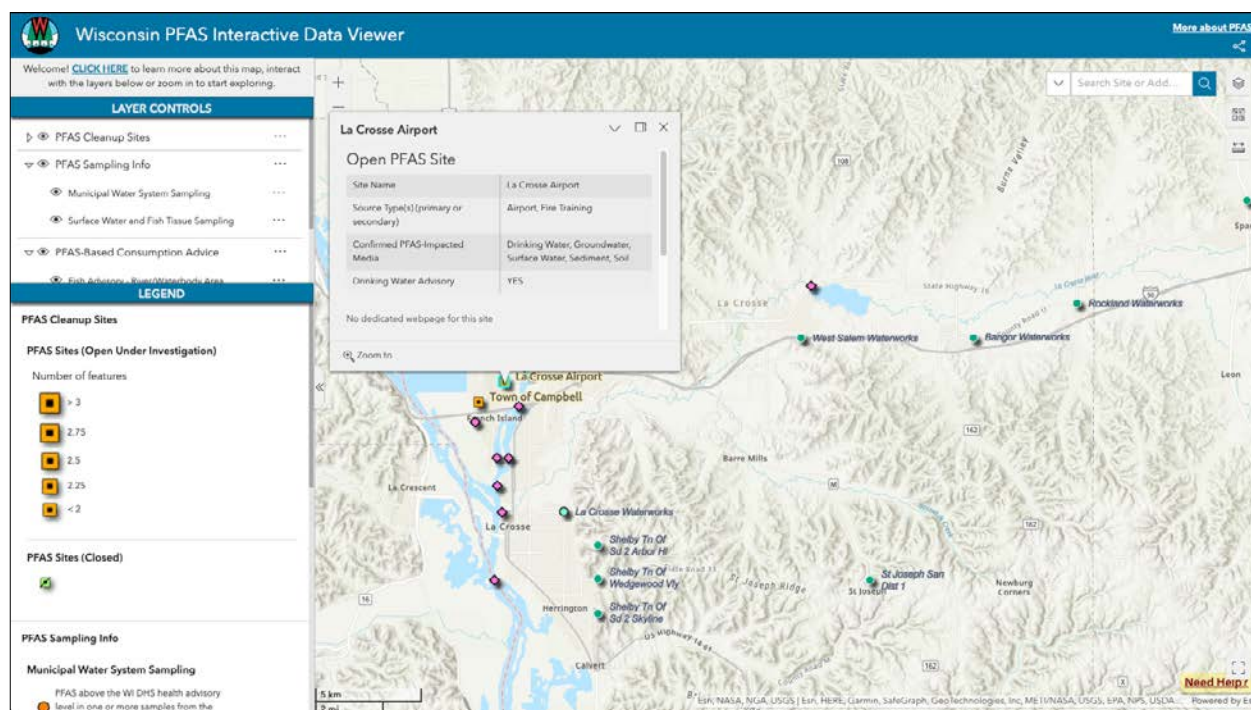
“This tool can be very helpful for legislators to understand

if PFAS contamination has been detected in their districts and how it impacts their constituents," Johnson said. "As more communities witness the impact of PFAS, it will become more of a unifying issue."

Continued sampling will improve understanding the need to reduce PFAS contamination levels and break the cycle of forever contamination.



The Wisconsin PFAS Interactive Data Viewer maps cleanup sites, water samples, and fish consumption advice.



Airports often land on the PFAS contamination list, as do fire training sites.

In the US, the Great Lakes states have been quick to act on PFAS, given their role as stewards of 95 percent of the fresh surface water in North America. More states are taking on this problem, starting with testing and putting test results on a map. As PFAS contamination becomes more understood and strategies emerge, maps will be central to the worldwide cleanup effort.

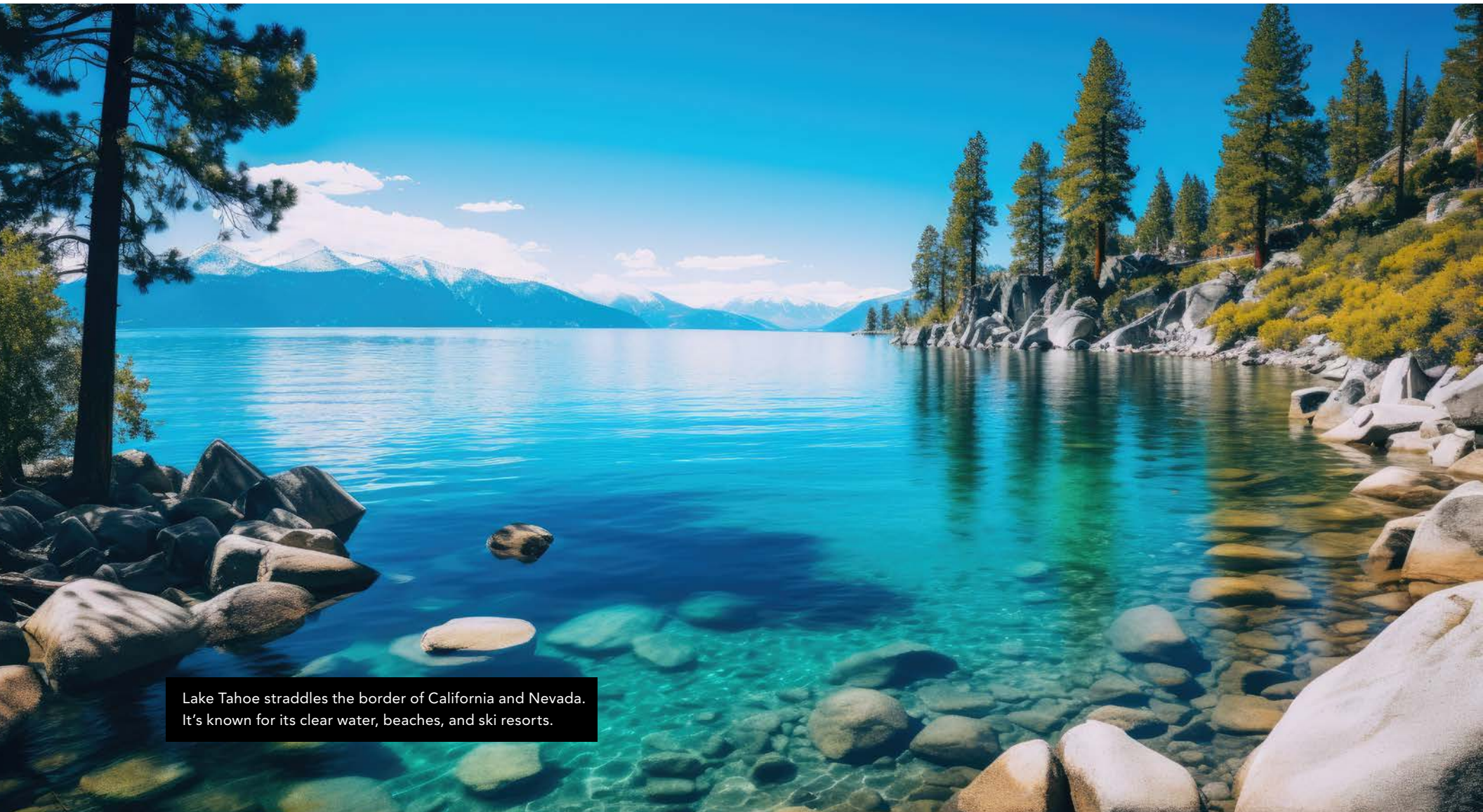
Drone Monitoring Tackles Growing Algae Threat to Lake Tahoe

Brandon Berry has an enviable job. In the morning, he flies a drone to survey Lake Tahoe shores, and in the afternoon, he dives into the lake to sample water quality. This hands-on research has its fitness benefits, and it's hard to imagine a more beautiful office.

It's a year-round job, though. "In the wintertime when the water is freezing cold and it's snowing, I think my colleagues are less envious," Berry said.

As ecological researcher for the Tahoe Environmental Research Center (TERC), his work has advanced scientific understanding of algal growth and the invasive Asian clam. Both contribute to degradation of the nearshore in the historically clear mountain-ringed lake.

Berry began the drone program at TERC five years ago. He's used the combination of drones, water sampling, and GIS technology to record conditions and address Lake Tahoe's



Lake Tahoe straddles the border of California and Nevada. It's known for its clear water, beaches, and ski resorts.

metaphyton problem—free-floating, nuisance algae that forms mats above the bottom of the lake. Dependent on currents and wave patterns, the algae can wash onshore, where it rots.

“We’ve discovered that metaphyton is heavily linked to the Asian clam, which are about the size of a quarter when mature, and microscopic as juveniles,” Berry said. These filter feeders take in water and excrete nutrients that cause big blooms of algae.

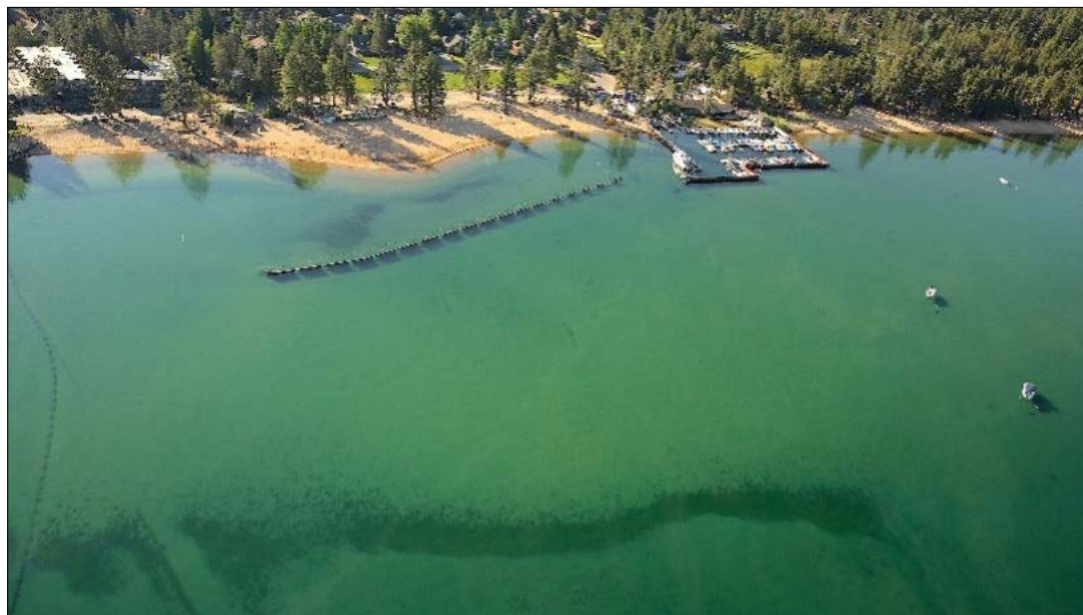
Lake Tahoe is so large that it visibly dips toward the center due to the curvature of the earth. With drones, Berry captures imagery to record the clarity of the lake and the presence of algae around its 72-mile shoreline.

After flying test plots that ring the lake, he dives in to scoop and sample sand to count the number of clams. Data is processed and analyzed with GIS to communicate conditions and collaborate with other scientists to gain an overall understanding of the lake. This data records changing conditions and informs testing of management techniques to address the problem.

“Tahoe is a popular lake, and the majority of people interact with it right along the shoreline,” Berry said. “When there’s rotting algae on beaches, it causes concern. Right now, aesthetics is one of the main concerns.”

Sensing to Inform Science

TERC is an offshoot of the University of California, Davis. It was established in 1968 to monitor Lake Tahoe to support state agencies in both California and Nevada, which have jurisdiction for different parts of the lake. For more than 50



A band of metaphyton (unattached algae) appears offshore in this drone image taken at a site in South Lake Tahoe. Photo by Scott Hackley, courtesy of Tahoe Environmental Research Center.

years, TERC has recorded warming water temperatures and earlier peak snowmelt. Monitoring has shown changes to the food chain in response to the changing climate.

TERC observes this complex ecosystem with a combination of sensors and systems, including a network of water sensors that provides real-time reads on quality. Researchers then go out with data capture tools to verify changes. They analyze that data in the office using GIS and other tools to determine the causes of changing conditions.

When Berry began the drone program, it was uncertain if it would work to see through water and quantify algae volumes. It has proven effective, but there were lessons. For instance, drone flights take place in early morning now, when winds are calm (reducing obscuring ripples) and the sun doesn’t glint off the water.

Berry considers many factors to optimize the quality of the data he collects. He avoids strong winds to ensure safe takeoffs and landings. It’s the trickiest part of each flight,

so he keeps a close eye on the wind forecasts. “Ninety-five percent of our flights are over water, and I haven’t lost a drone to the water yet,” he said. “It’s nothing short of a miracle at this point.”

To process and aggregate drone images, Berry uses the cloud-based drone mapping software Site Scan for ArcGIS. After he completes each flight, he uploads images to the cloud while he’s driving to the next site. “By lunchtime, photos are ready to look at and share with the rest of the group,” Berry said.

The team is building a test for machine learning in hopes of automating classification and change detection.

It’s really nice to have the imagery. It’s easy to write reports, do science experiments, or analyze data. When you see these big green mats on pristine beaches—bigger than two years ago—it’s got a shock value.

— Brandon Berry, ecological researcher at TERC

Tracking More Clearly

What started with a few drone tests turned into a sizable drone program.

“Previously, we had to track the growth of algae based off small sub-samples,” Berry said. “Now, with the drone work, we can track algae much more spatially. We’re capturing sites with hundreds of meters of shoreline, and it’s easier to track algae growth.”

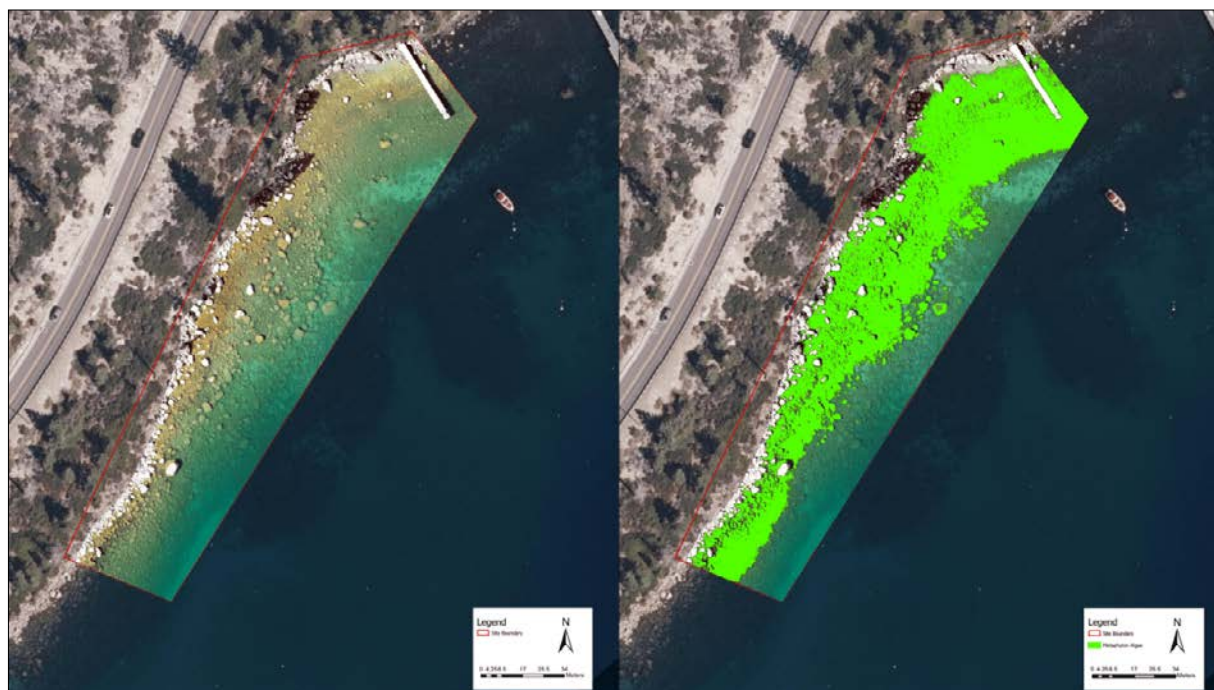
With the success of monitoring metaphyton,

the program expanded to monitor attached algae known as periphyton. The periphyton grows on rocks and other objects near shore.

“We’ve tested drones and have proven they work,” Berry said. “We’re now combining everything into a big nearshore monitoring program.”

The program uses a helicopter to regularly fly around the perimeter of the lake, which it can do in an hour. That flight gives the team data about the entire shoreline to pick out any problem spots where algae has popped up. The drone flights monitor specific sites with high-resolution imagery to track the rate of algae growth.

In addition to routine monitoring, TERC’s graduate students, post-doctoral scholars, visiting scientists, and professional staff conduct ongoing research funded by national and state agencies. Research topics include invasive species control, lake



These drone-derived image maps taken on the north shore of Lake Tahoe show the periphyton (attached algae) problem. On the left is an orthomosaic created with Site Scan for ArcGIS. On the right is a classified image with periphyton in bright green. Photo by Brandon Berry, courtesy of the Tahoe Environment Research Center.

A TERC research diver surveys a patch of metaphyton algae found near a growing Asian clam population in Lake Tahoe. Photo by Brandon Berry, courtesy of Tahoe Environmental Research Center.

currents, sediment resuspension dynamics, lake food webs, landslide risk, and wetlands performance.

The drone effort, for now, is primarily to monitor and understand the algae problem.

"There has been a huge increase in tourism and an increasing amount of concern for algae growth in the near shore," Berry said. "If mitigation or management becomes a priority, then the monitoring will continue to inform those practices."



Metaphyton algae washes onto shore and degrades the historically pristine beaches of Lake Tahoe. Photo by Katie Senft, courtesy of Lake Tahoe Environmental Research Center.



Conservation

Conservation professionals tackle biodiversity preservation efforts with maps and apps. Conservationists use GIS to gain insights into complex environmental challenges to better understand the interdependencies of native species and human activity and mitigate threats from climate change.

In the Congo Basin, the Baka people's deep Indigenous knowledge is being leveraged for sustainability efforts across Central Africa. Thomas Smith, a professor of ecology and evolutionary biology at the University of California, Los Angeles (UCLA), has been working with local Baka experts since the mid-1980s, helping to capture this knowledge using GIS technology.

"There's really a vast perceptual difference in the way they see the forest," said Smith. He established the Congo Basin Institute to further the collaboration and advance conservation. The Baka guides learned about mapping tools and conservation practices and have since been instrumental in recording their knowledge.

The field notes from Baka guides, which encompass knowledge about local plants, wildlife, and seasonal cycles, are integrated with other data on GIS maps. Smith noted, "The Baka people are our interpretive guides to understand what direction to go."

Melanie Smith, the program director for the Bird Migration Explorer at the National Audubon Society, has been working to tell the complex story of bird migration with the help of GIS technology. She and her colleagues aggregated research data from hundreds of institutions and designed an accessible platform that visualizes the annual journeys of more than 450 bird species.

"Birds are important ecological indicators," Smith said. "They tell us about the health of the environment because what birds need and what humans need are very similar: clean air, clean water, open space, access to food, and shelter."

The Explorer uses species, location, and conservation challenge maps to combine bird banding, tracking, abundance, and genetic data with geography.

In Kenya, the Elephants and Bees Project for Save the Elephants has developed a nature-based solution to human-elephant conflict. Beehive fences, equipped with wire and treated poles, are constructed around farms. When elephants strike the fence wires, bees are alerted, and their buzzing scares the elephants away.

To monitor farms and fences, a team of GIS officers initially visited farmers with handheld GPS devices and manually recorded information about human-elephant conflicts. This process was transformed when the officers deployed ArcGIS Survey123, a GIS app that works on smartphones and tablets, allowing real-time data collection.

The data collected is visualized using ArcGIS Dashboards, which allows the team to understand and monitor elephant interactions with the ecosystem. This project highlights how technology, combined with traditional ecological knowledge, can contribute to the conservation of endangered species.

During Catherine Ressijac's pursuit of a master's degree in conservation medicine, her continued connection with Imire Rhino & Wildlife Conservation proved helpful to her research. Her work to apply GIS to fill in data gaps about the species on the preserve became a skill she could give back to the community.

"I had this aha moment that I could hand a mobile app to a ranger with deep ecological knowledge, and they could capture data in the field in such an easy way. And then someone far away like me could access, manage, and draw insights from it," Ressijac said.

In Argentina's Iberá National Park, Rewilding Argentina is working to repopulate the jaguar, a species that was declared locally extinct more than 70 years ago. Carlos De Angelo, a professor and jaguar researcher, advised researchers on using GIS-powered maps and analysis to track jaguar movements and measure their impact on the ecosystem.

De Angelo and his team monitored other animal populations, inspecting predator-prey relationships to understand ecosystem health and stability. They mapped numbers and locations of prey to determine suitable jaguar habitats.

"Rewilding Argentina has the power to do more dynamic work," De Angelo said. He emphasized the impact of adopting a combination of GIS mobile apps and dashboards that has brought an expansive conservation effort to life.

As humankind's impact drives disruption to the natural resources that sustain life, communities and local people around the globe are mobilizing to become better stewards of the world around them. Adaptive community-based conservation planning employs GIS to help community members better understand the importance of nature and protected areas and leads to informed sustainable actions.

Indigenous Knowledge Captured on Maps Aims to Protect Congo Basin Diversity

The Baka people in the Congo Basin have an interconnected view of their forest. They think of nature as a network. They know how species influence each other and how weather influences everything. This deep Indigenous knowledge is vital to sustainability efforts across Central Africa and the world.

“There’s really a vast perceptual difference in the way they see the forest,” said Thomas Smith, professor of ecology and evolutionary biology at UCLA.

Smith has worked with local Baka experts since the mid-1980s. He founded the Congo Basin Institute (CBI) in part



A village in the Democratic Republic of Congo sits next to one of the world's most biodiverse forests.

to further the collaboration and advance conservation. Baka guides learned about mapping tools and conservation practices, and now these “professors of the forest” work alongside Smith and his team, recording their knowledge using GIS technology.

The field notes from Baka guides share locations of plants and wildlife as well as seasonal cycles and interactions. This Indigenous knowledge comes together on GIS maps along with data from government ministries, university researchers, conservation organizations, and other local experts. For Baka guides, maps help them inform future generations about the interconnectedness of the forest. For scientists, the Indigenous knowledge fills important gaps and advances the need for protections.

As weather patterns become more intense and species move, the data-driven maps will help efforts to preserve the forest, especially in places where species will relocate to adapt to new climates.

“The forest faces fundamental challenges,” Smith said. “The Baka people are our interpretive guides to understand what direction to go.”

Preserving Places for Future Evolution

Smith is an evolutionary biologist. His early work in the late 1980s with the estrildid finch revealed how bill size in this species was not distributed or determined by sex, age, body size, or geographic origin. In contrast to Charles Darwin’s famous finches, these birds differed in ways that seemed to favor ongoing evolution.

Over Smith’s 40-plus years in Africa, he has continued to study how rain forest species evolve. In research from 2022, the CBI team discovered that transition zones between rain forest and savanna are critical because these contact zones are where evolution happens. These places not only preserve species but generate them.

Unfortunately, these places are also where humans want to settle, on the edge of the forest, not within it. By losing crucial pieces of land where ecosystems mix—called ecotones—plant and animal species lose areas that support adaptation.

I realized that we’re doing conservation wrong in Africa. We’re preserving the pattern of biodiversity—species hot spots—but we’re not preserving the processes that produce and maintain biodiversity.

— Thomas Smith, professor of ecology and evolutionary biology at UCLA

The work of CBI team members focuses on the conservation of process, not just pattern. That means their science centers on the biotic processes that underlie and maintain the biodiversity of the forest.

Finding the Way

The Congo Basin comprises more than 10,000 species of tropical plants, with 30 percent unique to this iconic forest. The area is home to endangered wildlife, including forest elephants, chimpanzees, bonobos, and lowland and mountain gorillas. Often called “the lungs of Africa,” the Congo Basin



This photo of an early expedition crew in Cameroon in 1993 shows Thomas Smith (top center) alongside two graduate students and six professors of the forest. Image courtesy of Thomas Smith.



A young Baka girl records a lecture by a Baka elder. CBI's School for Local and Indigenous Knowledge is assisting Baka communities in preserving their oral histories in this way. Photo courtesy of the Congo Basin Institute.

absorbs more carbon than the Amazon rain forest and provides an essential lifeline to an incredible web of life over an area larger than Alaska.

Anthropologists think the Baka people have inhabited the Congo Basin for 200,000 years, living as hunter-gatherers and getting to know the forest. They use GIS to create and interpret maps, but in the forest, Baka guides rely on the maps they hold in their minds.

"One of my favorite things to do was to go trekking with [Baka guides] for three weeks," Smith said. "I would have no clue where I was, and they would know exactly where they were. We'd be walking for three days, and they would stop and say, 'Hang on, I want to check a tree over there to see if it has ripe fruits.'"

Maps of species and resources are part of the Baka guides' neural networks. Their ability to sense in the deep rain forest

has led to many discoveries and a more accurate inventory of the forest.

"When we're doing wildlife census work, it's largely by sound because you can't see far in the rain forest," Smith said. "The Baka guides can tell by the sound of a twig cracking on the forest floor whether it's a chimpanzee or a duiker."

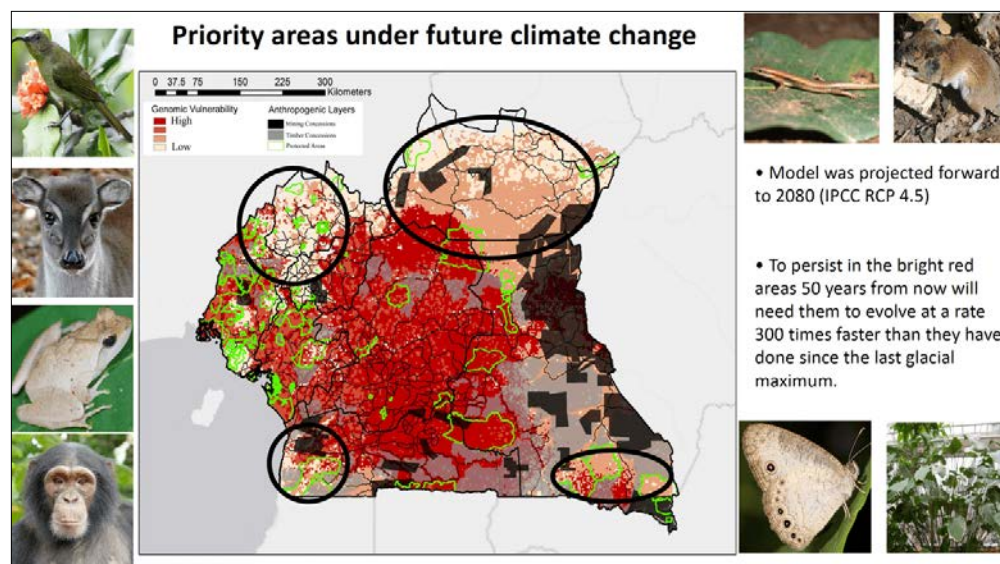
The treks Smith took with local guides covered extensive distances, often on animal tracks rather than established trails. Smith related how the Baka guides always knew their location,

the distances to their destination, and how long it would take to get there. He witnessed how they read the landscape through sound, animal tracks, insects, or the sky. They knew what wildlife they would encounter, and exactly what the forest would look like up ahead.

"When I go into the forest with them, my perception is heightened," Smith said. "We've had so many experiences. . . . I was in an area with a lot of gorillas, and the Baka guide said there was a silverback and a female carrying a baby on her back. I was skeptical, but sure enough, we walked another 100 meters, and there they were in a clearing."

Smith has been so enthralled with their knowledge that he couldn't help testing its limits.

"I'm asking questions all the time, 'What about this?,' 'When are we going to see that?,'" Smith said. "At one point, I asked, 'Do you think it's going to rain?,' and it was a guide named Augustine who said, 'I'm not God.'"



The Congo Basin Institute has mapped areas important for protection from the pressures of climate change.

Capacity Building

The Congo Basin Institute has partnered with universities around the world to build higher education resources in Central Africa. People from local villages are trained in ecological research techniques, such as wildlife surveys, and hired at a professional wage to work on conservation projects.

The aim is to gather traditional ecological knowledge about this critical natural area. "The Baka know 300 species of tree, the seeds from those trees, and they can identify the seedlings from those trees," Smith said. "We now have professors of the forest who not only know the Baka names but all the Latin names. They are a phenomenal resource for anyone trying to do conservation work in the Congo Basin."

CBI aims to extend the network of field research stations in the Congo Basin to improve monitoring and preservation efforts. There are just a handful of stations now, in contrast

to the hundreds that dot the Amazon in South America. Yet this region holds similar biodiversity value and the critical climate-stabilizing role of carbon sequestration.

CBI started a school for young people in 2020. There, the professors of the forest transmit their knowledge to future generations. Maps play an important role in the classroom to show interconnections that can be reinforced in the forest.

Already, the partnership is seeing benefits to the local natural world. When the Zoological Society of London set out to study the giant pangolin, a 70-pound endangered species

closely related to the most-trafficked mammal, they had difficulty finding any.

"They asked me if the Baka guides could help," Smith said. "Our trained crew quickly found 20 burrows, set up camera traps, and captured the first images of a giant pangolin coming out of its burrow."



Professors of the forest teach children about plants and wildlife and their interactions.



The Audubon Society tracks the movement of more than 450 bird species across the Americas.

National Audubon Society Maps the Wondrous Routes of Bird Migration

Each summer, Melanie Smith notices the small, brown birds that take up residence in her backyard in Talkeetna, Alaska. As the program director for the Bird Migration Explorer, a trained ornithologist and a lifelong birder, she knows that these creatures are Swainson's thrushes. She learned that they migrate from as far as Argentina in the spring to spend the summer nesting near her home.

"When you see birds in your backyard or out in your local park, it feels like they're your birds," Smith said. "But they're many people's birds. They go from community to community, and a lot of them are spending three-quarters of their time outside the United States."

Beginning in 2019, Smith and her colleagues at the National Audubon Society have been working with founding partners

and hundreds of researchers to tell the complex story of bird migration using GIS technology. The process required aggregating research data from hundreds of institutions and designing an accessible, beautiful, and dynamic platform.

Using millions of location data points, the newly launched Bird Migration Explorer allows users to visualize on maps the incredible annual journeys made by more than 450 bird species across the hemisphere. The free, interactive digital platform—available in English and Spanish on desktops and tablets—connects birds to locations across the Americas and reveals the extraordinary challenges they face in flight. Such insight is invaluable and timely: In the past 50 years, we’ve lost more than 2.5 billion migratory birds from North America.

“Birds are important ecological indicators,” Smith said. “They tell us about the health of the environment because what birds need and what humans need are very similar: clean air, clean water, open space, access to food, and shelter. When we see their populations declining, we have to wonder what’s causing that and how we can remedy it.”

A Data-Driven Approach to Conservation

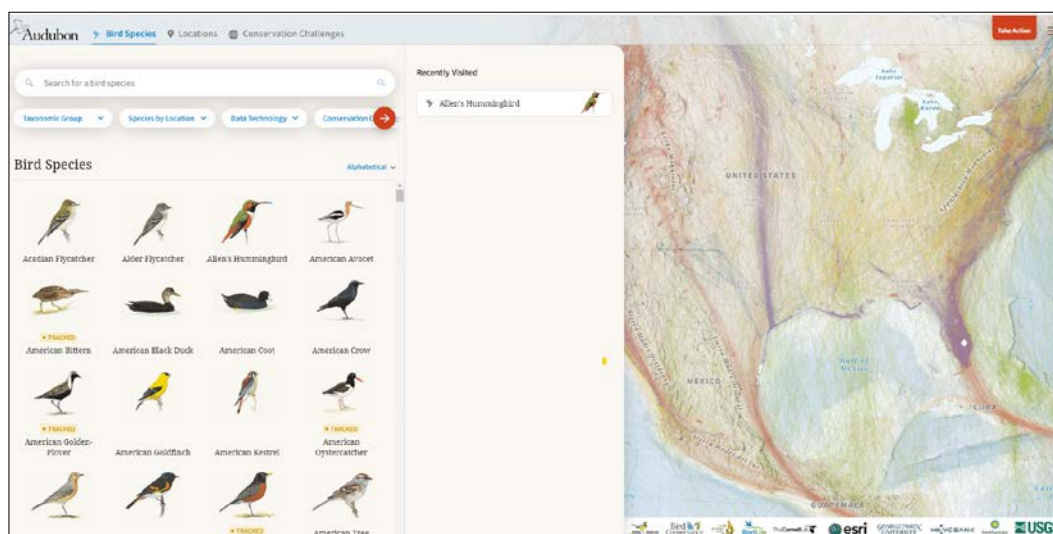
In late 2018, Audubon established the Migratory Bird Initiative and its focus was multifaceted: identify places that migratory birds need and protect the ones that matter most, reduce threats to birds, and engage people from diverse communities in the joy of birds and the wonder of migration. With this mission in mind, Smith and her team asked: How can we use data to drive conservation efforts? By mapping when and where

birds face challenges, such as suburban development or climate change, Audubon can investigate root causes of decline and engage with communities and local organizations to reverse the decline and preserve biodiversity.

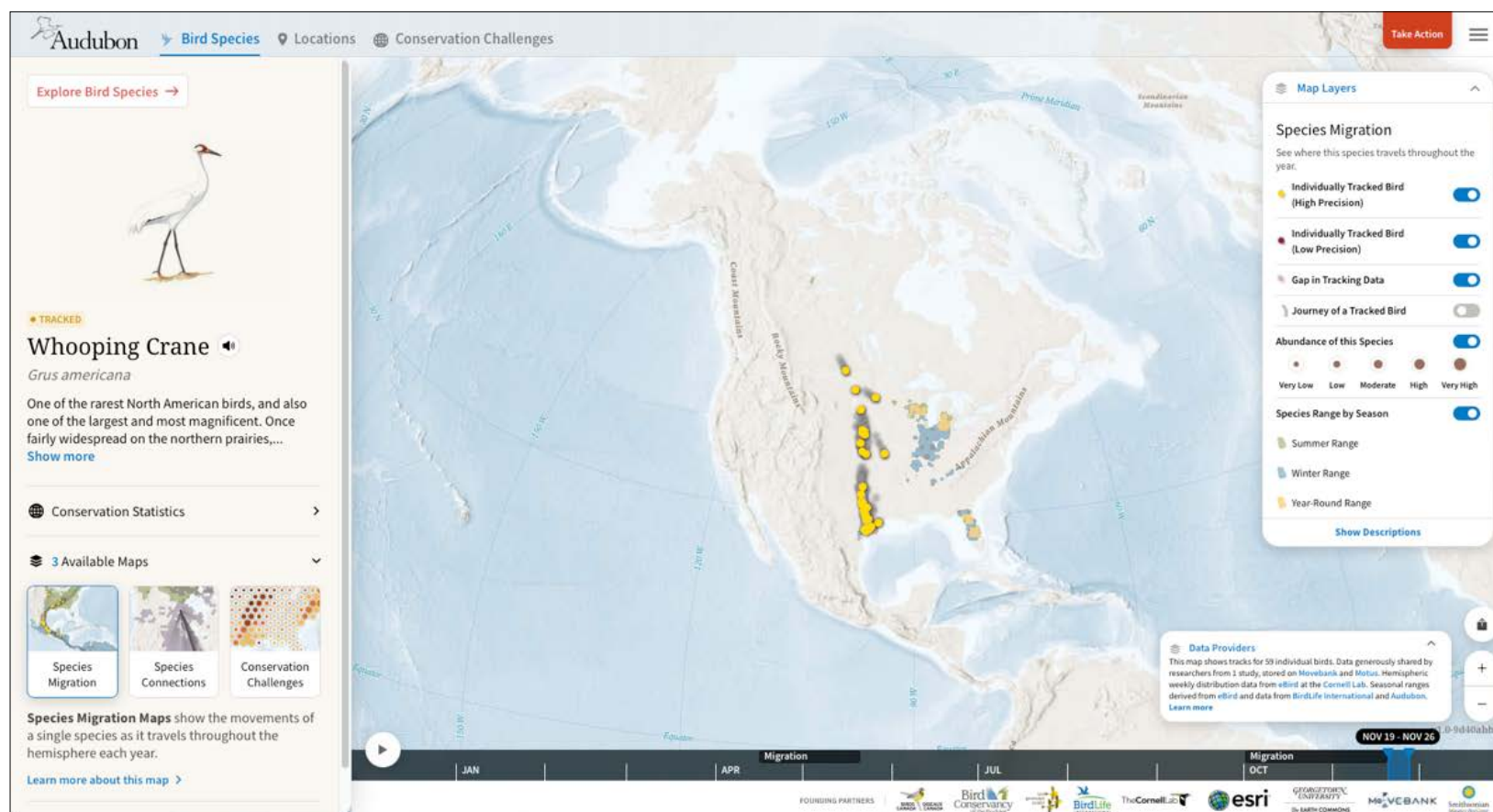
Presented using three types of maps—species, locations, and conservation challenges—the Explorer combines bird banding, tracking, abundance, and genetic data with geography. Intricate illustrations of each species, a custom basemap built by Esri, and well-crafted storytelling help the Explorer appeal to multiple audiences, from conservationists and advocates to birders and the casually curious.

The platform’s eye-catching design is fueled by troves of data that were identified, processed, and published to ArcGIS Online. Each of the partners listed on the Explorer home page provided aggregations of migration science. Tracking data was the exception, because individual scientists owned that information. And to secure it, Smith and her team contacted each one of them.

The data was then combined in Movebank, an online platform that helps researchers manage, share, and analyze



The Bird Migration Explorer was made possible through the generous contributions of tracking data submitted by hundreds of researchers across many organizations working throughout the Western Hemisphere.



The Whooping Crane was brought to the brink of extinction in the 1940s, but strict protection has brought the wild population back to well over 100.

animal-tracking information. In total, 283 institutions have contributed to the Bird Migration Explorer.

Collaborating to Create a Complete Picture

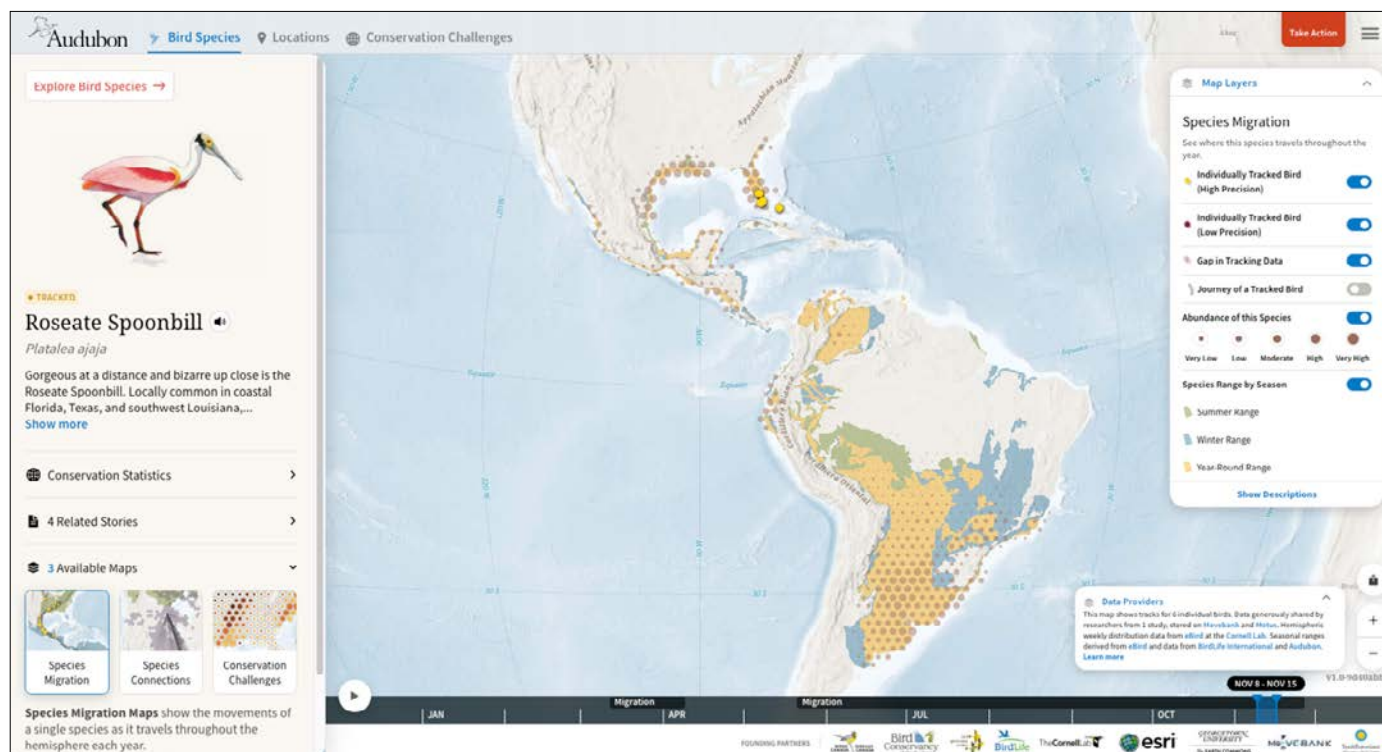
Smith worked with staff members across Audubon, contractors, and partner organizations to ensure that the bird migration science was accurately and meaningfully depicted. Audubon director of enterprise GIS Connor Bailey facilitated the integration of cutting-edge GIS capabilities with the project's broader vision.

"Early on, we had to find the right technology and work closely with Esri to make sure that our underlying infrastructure could handle the immense amount of information we were bringing together," Bailey said.

Bailey and his team partnered with Esri partner Blue Raster—a company that creates an array of dynamic web and mapping solutions—and other organizations to build a fully functional application. With a two-decade-long career in enterprise GIS for nonprofit organizations and conservation initiatives, Bailey said that the Bird Migration Explorer is the largest project he's worked on. More than 100 people were involved in the development stage alone.

The Explorer launched in September 2022, but Smith, Bailey, and the rest of the Audubon team know their work isn't finished. "This is an ongoing project that will continue to live," Bailey said. "We're looking forward to building out more capabilities and processes for long-term maintenance, because this is intended to be a living, breathing, interactive

Roseate spoonbills are locally common in coastal Florida, Texas, and southwest Louisiana. They are usually found in small flocks, often associating with other waders.



atlas and repository where all of this migration information can come together in one place.”

GIS technology is integral to conservation initiatives because it allows scientists to make informed decisions that will affect biodiversity and the planet.

Each of the datasets provides a different knowledge system. By combining them, it doesn't necessarily mean we have all the answers, but it does mean we have the most complete picture, and we will use that to inform smart conservation.

—Melanie Smith, program director for the Bird Migration Explorer

Smith is quick to note that the 458 species included in the Bird Migration Explorer account for less than 5 percent of all bird species in the world. In the future, she looks forward to adding datasets and more species. A simplified experience for

mobile users is in the works as well.

The mobile version of the Explorer will join other portable birding resources, such as Audubon's Bird Guide app—which contains the organization's complete *Field Guide to Birds*—and the Cornell Lab of Ornithology's eBird app. These in-the-field resources give naturalists, birders, and first-time explorers access to authoritative data that makes the birding experience more rewarding and enlightening.

Even though the Explorer is just one piece of Audubon's conservation strategy, Smith and Bailey anticipate finding more ways to use a geographic approach in their work. "GIS allows us to visualize and understand problems we face from a geographic perspective," Bailey said. "That's important because we need to be able to understand our landscape in order to actually make changes that benefit humans, biodiversity, and birds."



Elephants drink from the river along one of their migration routes.

Mapping a Nature-Based Solution to Human-Elephant Conflict

An ancient African folktale tells of elephants that are afraid of honeybees. In 2006, researchers proved that tiny insects can indeed affect—and help save—the world's largest land mammal.

Lucy King, head of the Elephants and Bees Project for Kenya-based Save the Elephants, had the idea to play recordings of swarming African honeybees near elephant

herds and saw how the huge animals quickly run away. Her findings are the foundation of a creative solution that saves elephants' lives by using beehives to redirect elephants before they interact with humans.

In Kenya, the majority of wildlife live outside protected areas. Elephants can become a nuisance for farmers, who suffer devastating crop raids when the hungry giants trample their

fields, often at night. The two come into conflict—farmers want to protect their livelihoods, homes, and families and elephants want to provide for their herds.

King and her team developed a nature-based solution—beehive fences made of wire and treated poles with beehives hanging between them. When elephants strike the fence wires, bees come out buzzing, which scares the elephants away. The team worked with farmers to install them around their fields. Farmers gain further benefits from bees pollinating their crops and selling honey from the hives—and they sleep soundly knowing the African honeybees are active at night.

Elephants are afraid of honeybees and avoid them as much as possible because bees swarm and sting them, especially around sensitive areas such as their trunk, eyes, and inside their ears.

Today, beehive fences protect farmland in 23 countries. As the project has grown, researchers have used GIS technology and remote sensing—the process of using satellite or other aerial images to monitor characteristics of the earth’s surface—to monitor effectiveness. Simplifying data collection gives program staff not only a better picture of elephant behavior so they can anticipate future problems but also more time to focus efforts on new initiatives.

Creating a System within a System

Founded in 1993, Save the Elephants has used geospatial technology to track elephant movement across African landscapes for more than two decades. Today, the organization hosts Africa’s largest elephant-tracking database. But as GIS capabilities have evolved, so have the organization’s goals and practices.

“When we started working with Esri’s tools, we were putting elephant tracks on a map. Over time, we were able to do advanced analysis to understand migration corridors and use models to see where elephants are most likely to be at certain times of the year,” said Festus Ihwagi, a senior scientist and research manager.

Tsavo National Park, Kenya’s largest national park, is home to the country’s largest elephant population, with more than 12,000 residing there. Save the Elephants staff are in constant communication with the farmers who live between the east and west sections of the 8,000-square-mile park. Once beehive fences are built around farms, staff visit to make sure that the fences are working and to spot maintenance issues, and catalog elephant encounters. These data collection processes allow for ongoing research, monitoring, and problem-solving.

To monitor farms and fences, a team of GIS officers initially visited farmers with handheld GPS devices and manually recorded information about human-elephant conflicts. That information, which sometimes included hand drawings of elephant movements into and around the farms, was digitized at the office.

“There was a lot of work that went into data collection between the handhelds and digitizing and maintaining all the other records that come with that data,” said Gloria Mugo, a GIS officer and remote sensing scientist who joined the Elephants and Bees Project in 2016.



The Save the Elephants Bee team (Derick, Emmanuel, Nashon, and Titus) look at a dashboard of data collected from the field. Image by Robyn Brown, courtesy of Save the Elephants.



Gathering details from farmers is now done with ArcGIS Survey123, eliminating duplicate data entry. Image by Sarah Kunkel, courtesy of Save the Elephants.

Mugo and the other officers saved time by deploying ArcGIS Survey123, a GIS app that works on smartphones and tablets. After digitizing their questionnaires, the officers could visit farmers and collect data in real time. The result, Mugo said, was transformative. “It slashed our working time from around 80 hours a month to about 16 hours.”

As data comes into the office from the field, staff ensure that records are properly analyzed and stored. Reporting is also much easier, giving staff more time for analysis rather than data entry.

Data collected with Survey123 is then visualized with ArcGIS Dashboards. Together, these tools convey information about elephant movement, crop raids, and beehive fence maintenance. The collected data is hosted and visualized with a single system, making it easier to see which regions might need enhanced support and optimal locations to expand the program. As a result, the Elephants and Bees Project increased the number of farms in the beehive fence

program. They’re now protecting 47 farms in Sagalla—a community in Voi, Kenya—up from 30 farms.

Exploring New Methods of Understanding Elephant Migration

With the time saved by using geospatial tools, Mugo and the Elephants and Bees Project staff can focus on other important work. While beehive monitoring is still key to their efforts, officers have also trained farmers in conservation agriculture methods, built a women’s enterprise center where local women weave baskets and knit bee suits and bags to generate alternative income, packaged “elephant-friendly” honey and other products,

and developed an elephant conservation curriculum and have produced a Human-Elephant Coexistence Toolbox.

The toolbox is a wealth of knowledge for communities hoping to resolve human-elephant conflict and includes strategies from across Africa. “The toolbox has instruction manuals for many methods you can use to deter elephants—not just beehives. Other places are dealing with these conflicts, and we’ve been able to communicate to a wider audience so that people can learn from these tools and methods. No one method will work everywhere, and new learnings from the field will feed back into the toolbox,” Mugo said.

The toolbox includes details on elephant behavior and why they’re an important species as well as farm protection methods, elephant-compatible farming practices, habitat information, and guidance on living near elephants.

To benefit elephant diets, Mugo is researching whether specific plants are attractive to elephants, using imagery and remote sensing technology. She published a paper in 2022



Monitoring beehive fences, which safeguard crops and elephants, now incorporates a digital workflow, saving time and improving awareness. Image by Naiya Raja, courtesy of Save the Elephants.



Beehive fence monitoring with pen and paper needed to be digitized back in the office. Photo by Derick Wanjala, courtesy of Save the Elephants.

confirming that Sentinel 2A imagery can be used to visualize vegetation species distribution.

“We’ve been able to overlay elephant tracking data that was collected with a handheld GPS, and we can see that wild African bulls walk a particular path for a specific plant they love eating. Family groups will walk paths that lead to plants that females and young calves prefer. When they move together, they walk paths that ensure there’s something for everyone,” she said.

Remote sensing expands research possibilities because officers don’t have to be on-site to collect data. Ihwagi and Mugo see its application as a promising way to understand the nuances of elephant behavior continent-wide. Paired with GIS, it gets them one step closer to realizing their dreams of seeing Africa’s elephants repopulated and understood as a crucial species of the continent’s biodiversity.

The communities, people, governments, and stakeholders who are involved in trying to protect these elephants need to visually see data and information, which is something we can’t do without GIS. It helps us get to a point where we have a higher understanding of all the systems that are interconnected.

— Gloria Mugo, GIS officer and remote sensing scientist with the Elephants and Bees Project

How Do You Help Rhinos Thrive in the Wild?

Give Rangers a Data Collection App

Ask Catherine Ressijac what inspired her career and pursuit of a PhD in conservation biology, and she will tell you it started with an undergraduate trip to a conservancy in Zimbabwe. "Like most people who have experienced a safari or a deeply hands-on experience in a savanna ecosystem, it's easy to have your heart captured."

The experience led Ressijac to work at Imire Rhino & Wildlife Conservation for two years before returning to graduate school. During her tenure, she learned about the conservancy community, conducted research, and monitored species. Early on, she recognized a need to fill in gaps in the data collection process at Imire.



A new baby rhino continues Imire's breeding success. More than 16 endangered rhinos have been born at the conservancy in the last 20 years. Photo courtesy of Imire.

During her pursuit of a master's in Conservation Medicine from Cummings School of Veterinary Medicine, a GIS course unlocked a path forward.

I had this aha moment that I could hand a mobile app to a ranger with deep ecological knowledge, and they could capture data in the field in such an easy way. And then someone far away like me could access, manage, and draw insights from it.

— Catherine Ressijac, GIS solution provider for Imire Rhino & Wildlife Conservation

When she returned to Imire for her master's thesis, she worked with rangers to implement ArcGIS Survey123, an easily configured GIS app for phones and tablets. The data that came back made her eager to access more of the knowledge rangers have gleaned observing wildlife.

"Not only should we be harnessing their knowledge and inviting them to participate in the more formal or systematic scientific process, but we should also be celebrating and crediting rangers for their contributions to conservation science," Ressijac said.

Black rhinos are central to Imire's identity. The preserve was awarded custody of seven rhinos in 1987. Conservancy rangers and staff have successfully bred 16 rhinos in the last 20 years, with the most recent calf born in February 2023. Still, the animals are critically endangered because of poaching for their horns. There are only 5,500 left, according to the World Wildlife Fund.

"Scientifically, we don't know much about rhino behavior and movement ecology. But with the Imire rangers patrolling them daily, they have a uniquely intimate understanding of Imire's individual rhinos, their habits and personalities, how they use the landscape they occupy, and how they interact with each other and other species," Ressijac said.

Data Collection and Conservation Management

While Ressijac sees rangers as "dynamic field scientists who provide a key data resource," she notes a common challenge in conservation management: the ability to sustain data collection and scientific research. Some scientists don't share their findings with rangers or managers. In addition, they may bring technologies that are not useful for conservancy staff.

So Ressijac sat down with rangers to test how well Survey123 could fill their data gaps. "I asked them exactly what questions they had about rhinos, about the information they wanted to be captured, how they wanted to collect it, and they had great ideas constantly for me."

The fact that Survey123 works offline was an important capability for rangers who collect data in areas without internet access. Pinning the data to where it was collected allows it to be mapped and visualized by anyone on the Imire staff.

As rangers worked with Ressijac to build the surveys and reports, the collaboration helped adapt the app to meet conservancy needs and gave rangers more autonomy over the data collection process. Improvements included an in-app function to capture photos and add them to their reports. They also removed tedious questions such as those about weather reports and thoughtfully added questions about rhino behaviors.

The first collaborative surveys collected data on the black rhino diet; behaviors such as walking, lying down, resting time, eating, scent marking, and defecating; and social cues such as movements and mating events.

Ressijac's first foray into rhino data collection for her master's thesis allowed her to provide management with insights into rhino habitat use, seasonal dietary trends, and individual behavior. The initial surveys she created proved to be a powerful tool for capturing mother-baby dynamics and milestones for the calf, such as suckling, playing, eating, and exploring.



Rangers confer over data they have collected in the survey app.
Photo courtesy of Imire.



A ranger stands watch in a bid to monitor and protect rhinos.
Photo courtesy of Imire.

Tangible Impact on the Conservancy

Ressijac has continued to develop surveys well beyond the initial work for her thesis at Tufts University. The workflows have quickly caught on, and the surveys have transformed into a meaningful tool for rangers and managers to capture wildlife data and gain insights.

Now, Imire rangers and staff use GIS maps and analysis to communicate capacity needs, track territorial overlaps or fights, and understand their rhino population. "Having this deeper understanding helps us determine where to relocate a rhino or if we have space for others and how these changes impact the conservancy over time," Ressijac said.

A map of grazing resources showed that the white rhino population could be expanded, solidifying plans to translocate six new white rhinos to Imire in 2023. When the rhinos arrived, they were added to the survey system to see how they established and interacted with existing white rhinos.

Since deploying the first survey in 2019, Ressijac has seen

staff buy in and has received many requests for customized reports. Most importantly, the technology has gained support for a data-driven, adaptive management style.

"Data provides an insurance policy in many ways for any manager, whether you're at a small reserve or a national park, to back up why you make decisions the way you do," Ressijac said.

Ressijac is proud of what they have been able to accomplish. "Imire is unique because it's like a living laboratory where rangers make it possible to really learn about rhino ecology through monitoring and data collection. Looking back over a decade, I can see how Imire has adapted and how I have evolved as a conservationist by working together in this dynamic environment."

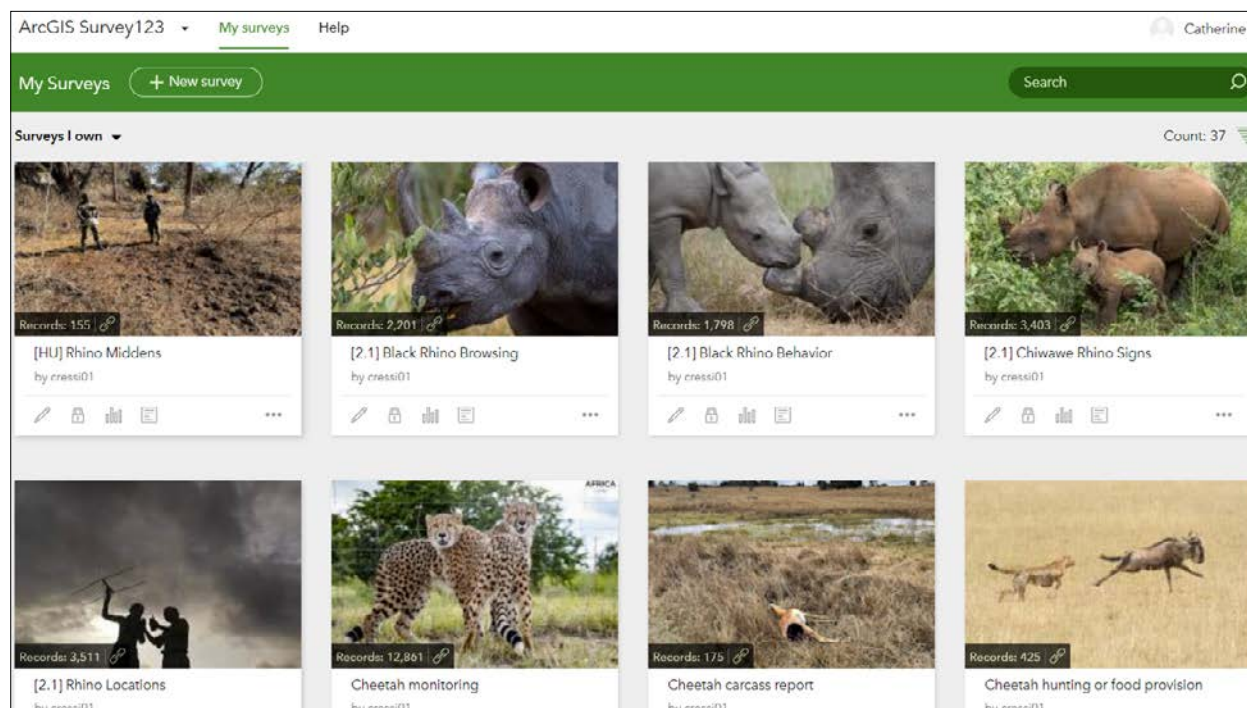
In the short term, she hopes to continue developing custom wildlife monitoring surveys based on what the conservancy needs, such as the introduction of new animal species. She also wants to connect the program to a Zimbabwean

academic institution to have an on-the-ground point person for research. This shift would allow rangers to better balance their daily anti-poaching and wildlife monitoring duties.

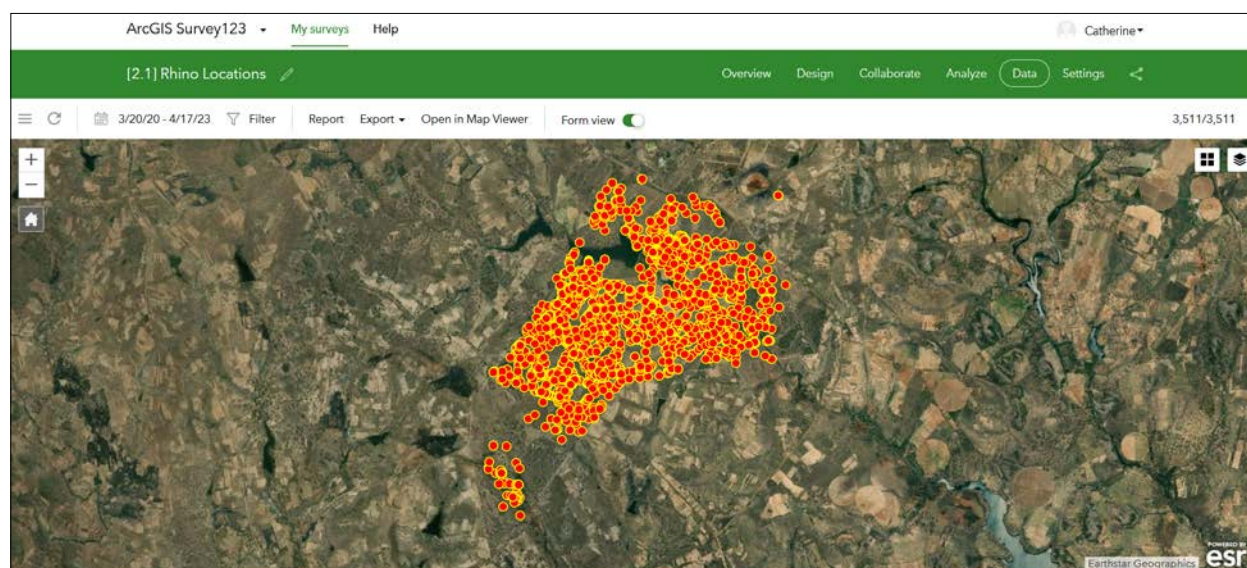
Looking to the future, Ressijac hopes to take her passion for collaboration to more conservation organizations.

"The most rewarding part of my journey has been the perspective gained from long-term involvement in a conservation initiative. We have a lot to learn from one another, and there are so many large problems in conservation that will only be tackled by working together."

— Catherine Ressijac, GIS solution provider for Imire Rhino & Wildlife Conservation



Many purpose-built apps capture a variety of rhino and cheetah behaviors. Screenshot by Catherine Ressijac, courtesy of Imire.



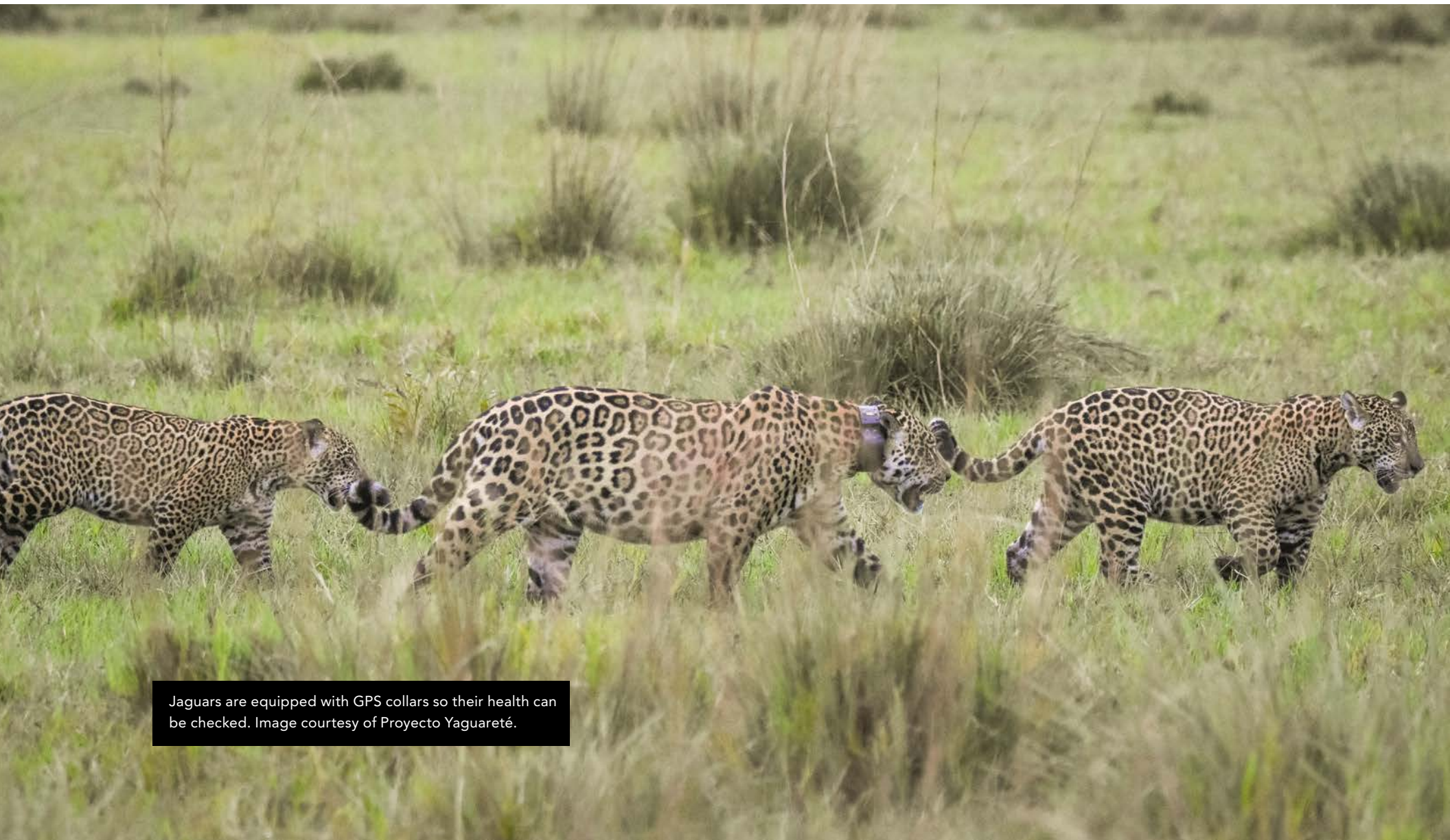
Rhino locations centered in a common area. Screenshot by Catherine Ressijac, courtesy of Imire.

Jaguar Conservation: Smart Maps Guide Ecosystem Revitalization in Argentina

A vast, lush grassland stretches to the horizon in Argentina's Iberá National Park. The gate of a large chain-link enclosure opens, and a jaguar wearing a GPS collar strides into the wilderness for the first time, leading her two cubs. In a nearby office, people beam at the unfolding scene, watching camera feeds from all angles around the jaguar reintroduction center. The release marks another remarkable milestone in Rewilding

Argentina's ambitious effort to repopulate the jaguar—something experts said was impossible.

"This is the first time jaguars have been reintroduced anywhere," said Carlos De Angelo, a professor, jaguar researcher at Proyecto Yaguareté (CeIBA-CONICET), and the project's GIS technology adviser. "It was an enormous effort."



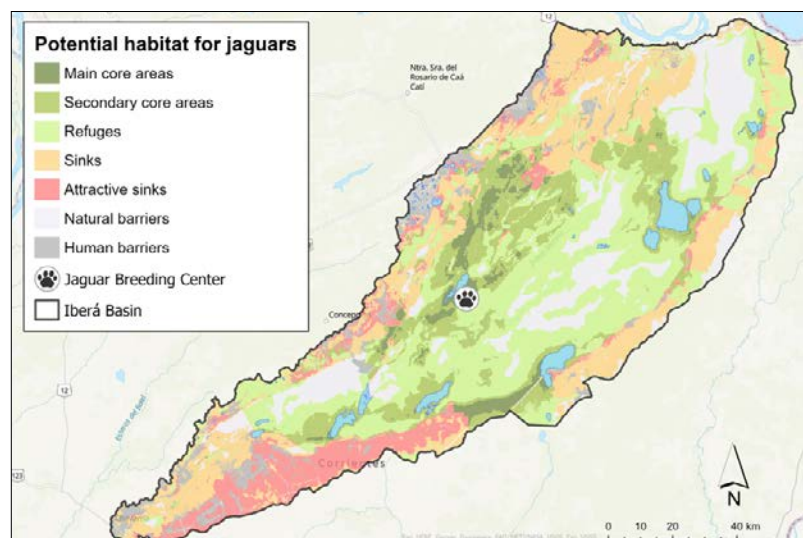
Jaguars are equipped with GPS collars so their health can be checked. Image courtesy of Proyecto Yaguareté.

The largest cats in the Americas and a keystone species, jaguars were declared locally extinct in Argentina's Corrientes province more than 70 years ago. Now, Rewilding Argentina is relocating captive jaguars, getting them acclimated to living in the wild, and releasing them to resume their natural roles in Iberá. De Angelo advised researchers on using GIS-powered maps and analysis to track jaguar movements and measure their impact on the ecosystem.

A Deeper Understanding

Together, Iberá National Park and Iberá Provincial Park form the largest protected area in the country. The parks are home to 4,000 plant species and a diversity of birds, reptiles, amphibians, and mammals.

Part of the legacy of Tompkins Conservation and its mission to protect and rewild the earth, Rewilding Argentina has reintroduced anteaters, pampas deer, red and green macaws, and peccaries since its founding in 2010. Tapirs and the giant otter are the next to be reintroduced. Each time, GIS has been critical to the process. The technology provides a snapshot of the ecosystem before species are released. Then it supports monitoring of distribution, behavior, and interactions once the animals are in the wild.



A map reveals the areas—shaded in dark and light green—that are most suitable for jaguars in Iberá National Park. Map by Carlos De Angelo/Proyecto Yaguareté, courtesy of Rewilding Argentina.

Adding the jaguar—the region's top predator—required a deep understanding of the area's complex ecological systems. The team relied on GIS technology to help answer essential questions: Where should the jaguars live? Will they be able to hunt natural prey? How many jaguars can the park support?

De Angelo and his team began by monitoring other animal populations. By inspecting predator-prey relationships, they saw patterns critical to ecosystem health and stability. The researchers also mapped numbers and locations of marsh deer, capybaras, and other prey to determine suitable jaguar habitats.

Mapping the Connections

The first jaguars were released into the park in 2021. Leading up to their release, De Angelo collected jaguar data from the Pantanal, a similar wetland ecosystem in Brazil, to model ideal habitats and predict behavior.

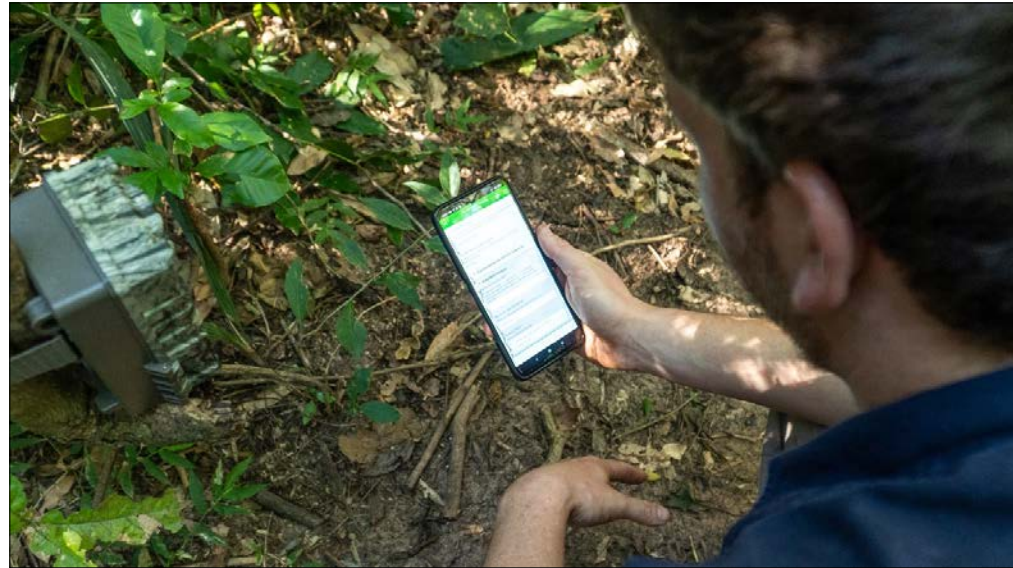
Rewilding researchers use this data as a baseline to draw comparisons and insights about jaguars released in Iberá National Park. They take mobile devices into the field to record information and images with GIS apps such as ArcGIS Survey123, ArcGIS QuickCapture, and ArcGIS Field Maps. The collected data syncs to the team's GIS database and populates interactive maps. Researchers then use GIS analysis to understand and monitor jaguar interactions with prey, vegetation, and other animals.

De Angelo leveraged this data to create a risk map for capybaras, the jaguars' main source of food. Capybaras had been living in Iberá without a predator for decades. What used to be a place for them to freely forage, relax, and sleep is now an area where they need to be strategic amid a predatory threat.

Drone imagery syncs to GIS maps, giving the research team a bird's-eye view. When the map shows capybaras clustered together—a behavior adopted to protect themselves—the team knows that's an area where they feel threatened.

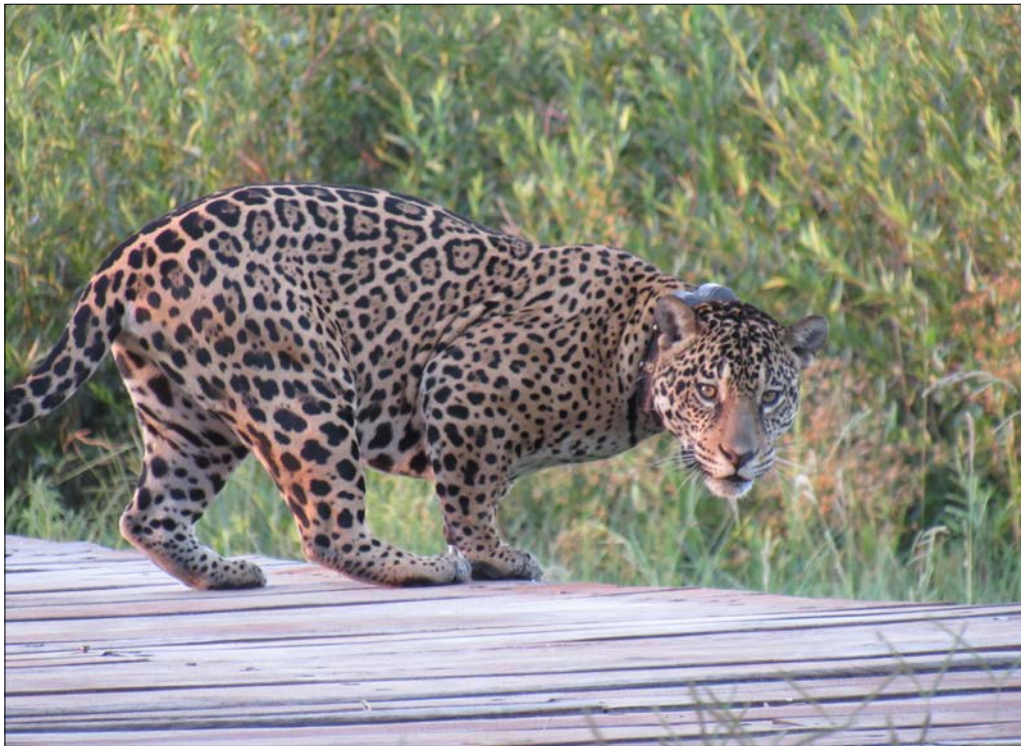
This approach delivers a holistic understanding of the jaguars' impact. "This risk map will help us understand how the capybaras are perceiving risks and how they may change their behavior. That will change the shape of these areas because they will stop eating there and then eat more in other places," De Angelo said.

To complement inputs collected with drones and mobile apps, researchers set up a variety of camera traps across the park. These cameras collect valuable data about the animals that don't wear GPS devices. When an animal wanders into a camera's field of vision, the movement is recorded and can be analyzed with GIS.



Researchers easily input information about animal behavior into ArcGIS Survey123. That data is then synced to a map to show where it was collected. Image courtesy of Rewilding Argentina.

"We are using all these technologies to make the process very quick," De Angelo said. "Every 20 days or so, we analyze everything. We go into the field to corroborate the number of animals that were the prey of the jaguars. This is useful for two main things—knowing that reintroduced jaguars are doing well and understanding their impact and role on the Iberá ecosystem."

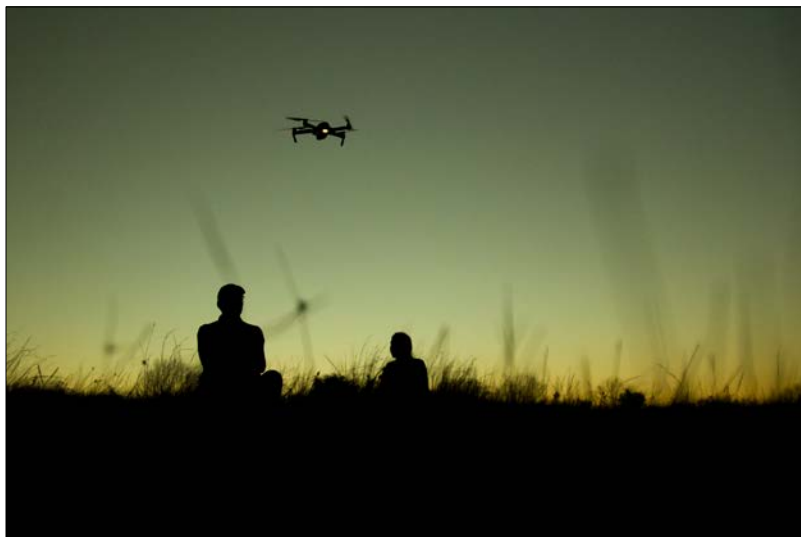


Jaguars like to live near water and are very good swimmers. They are most active at dawn and dusk.

A Strategy for Long-Term Ecosystem Management

Eleven years into the jaguar project, Rewilding Argentina staff are seeing its benefits. Local pride rooted in a reverence for nature has blossomed along with a robust ecotourism industry in communities along the Iberá National Park perimeter.

"Jaguars are a very charismatic species that are good for tourism. A new economy has been built surrounding the local traditions and the conservation of nature," De Angelo said.



Drone flights at night, using thermal sensors, provide a means to monitor nocturnal predators. (Photo by Constanza Pasián, courtesy of Proyecto Yaguareté)

For centuries in South America, jaguars were widely respected and viewed as icons of godlike power. Now, according to Diana Frete, the vice mayor of the nearby town of Colonia Carlos Pellegrini, these mighty felines are “symbols of living culture.” Residents have respect for and take pride in the nature of the region. Young people are more likely to stay in their hometowns and participate in the local economy by becoming guides and artisans.

Rewilding Argentina staff members will continue to monitor the surrounding environment, ensuring it will thrive. They are already using GIS to track invasive species, such as feral pigs and deer. Gauchos (cowboys) have been enlisted to keep an eye out for the animals, recording sightings with QuickCapture. That data feeds into the team’s GIS dashboard.

Jaguars have begun to have cubs in the wild. As the jaguar population grows, there is hope that their presence will naturally balance the Iberá ecosystem. A similar project reintroduced

gray wolves to Yellowstone National Park and had cascading ecological effects. As the wolves preyed on the overpopulation of elk, which had overgrazed the land and eroded riverbanks, other species—bears, pollinators, birds, and fish—returned to their natural habitats.

In Iberá, jaguars prey on medium-sized predators that have freely hunted birds, lizards, and rodents for decades. De Angelo and his team hypothesize that, as the medium-sized predator population returns to its natural size, smaller animals, such as endangered bird species, will be saved from extinction.

With GIS technology, De Angelo can manage an expansive conservation effort. By adopting a combination of GIS mobile applications and dashboards, “Rewilding Argentina has the power to do more dynamic work,” he said.

Watching the jaguar project unfold has been a rewarding process for De Angelo. He remembers the first conversations about it in 2005: “When the idea was presented, everybody was saying, ‘Yeah, sounds nice, but it’s almost impossible.’ More than 15 years later, now jaguars are there. And the process is working.”



Wildlife radio telemetry is used to track the movement and behavior of the jaguar. Image courtesy of Proyecto Yaguareté.



Humanitarian Assistance

Humanitarian organizations around the world apply GIS to analyze and plan missions, mobilize and implement field teams quickly, and monitor and evaluate their effectiveness and sustainability, and they do it in real time.

The 2018 Thai cave rescue, which trapped 12 boys and their coach underground, was a testament to the power of collaboration and the use of GIS for the sake of good. Maps became a central tool in this rescue mission, coordinating swift action under stressful conditions, and helping devise a plan that eventually led to the successful rescue of the team.

As the mission shifted from search to rescue, maps provided near real-time readings of oxygen levels and changes in water depth. The maps kept everyone focused on the immediate tasks at hand.

The Food and Agriculture Organization (FAO) of the United Nations (UN) uses satellite imagery, field data, and advanced spatial analysis and mapping to understand and combat food insecurity. The FAO's Data in Emergencies (DIEM) team created the DIEM Hub using GIS technology and remote sensing to monitor food vulnerability and identify the needs of farmers.

"People are living in situations where they are constantly being hit by something," said Neil Marsland, head of the DIEM team in the Office of Emergencies and Resilience at FAO in Rome. The DIEM Hub analyses, maps, and stores the 150 indicators collected during each survey in countries such as Afghanistan, Lebanon, Yemen, Burkina Faso, Mali, Sudan, and Colombia. The populations in these countries are "telling us they need food, but also other things," Marsland added.

In the ongoing conflict in Ukraine, GIS technology has been a significant tool in identifying the presence of explosive remnants of war along with the damage to infrastructure and homes. The HALO Trust, the largest demining organization in the world, uses GIS to detail the impacts and ongoing dangers in conflict regions.

"What we do is critical to reconstruction and resettlement post-conflict, because you cannot just deal with the damage straight away," said Luan Jaupi, head of information and communications technology at The HALO Trust. "We enable other humanitarian organizations and national authorities to safely conduct their activities by informing them where it's safe to go and making places safe by clearing the explosives that are littered around."

When the conflict in Ukraine began in February 2022, MapAction dispatched GIS professionals to neighboring Poland within 24 hours of a request to support agencies involved in delivering humanitarian aid.

In their day jobs, MapAction volunteers use GIS to help governments, businesses, and other organizations maximize efficiency and improve decision-making. During a crisis, MapAction's GIS professionals do the same, providing location intelligence products that create a common operating picture. This helps crisis response teams better understand and navigate unfamiliar territories and avoid duplication of effort.

"It's a privilege to have been there in the early days of MapAction, and I'm really impressed at the impact subsequent teams have made with it," said Olivier Cottray, a founder of MapAction. "It was at the forefront of the sector now known as humanitarian GIS and has become a mainstay in humanitarian response. It's impossible to quantify that impact. How many lives did the availability of an up-to-date map help to save? They are countless."

The Royal Geographical Society (with the Institute of British Geographers) (RGS-IBG) conducted a five-year field research study in collaboration with partners in Colombo, Sri Lanka; Dhaka, Bangladesh; Harare, Zimbabwe; and Hargeisa, Somaliland, to understand the lives of migrants after they move to urban communities.

"Research into migration in response to conflict or disasters highlights the fact that since people expect the situation at home to improve, they also expect to return," said Michael Collyer, professor of geography at the University of Sussex and principal investigator of the study.

Researchers used novel methods combining satellite imagery, GIS software to create maps, and personal interviews to identify geographic factors—environmental hazards, lack of local resources, and mobility barriers—that prevent migrants from thriving.

Humanitarian aid organizations use GIS to help address some of their most common challenges such as where to prioritize recovery efforts.

"Thirteen Lives": How the Thai Cave Rescue Exemplifies Collaborative Action

Ron Howard's film *Thirteen Lives* documents the plight of 12 boys, aged 11 through 16, and their 25-year-old coach trapped in a remote underground cave in Thailand in June 2018. During the response, people from different countries, cultures, disciplines, and backgrounds came together to save them. In fact, more than 10,000 volunteers joined forces to conduct an awe-inspiring rescue. The film spotlights an important truth that by working together, we can overcome complex challenges in our world.

The story is also a remarkable tale of using GIS for good. Maps play a central role in the 2022 film because they helped coordinate swift action during a stressful time. The monsoon season added pressure because heavy rain threatened to make the cave impassable. Using maps, rescuers collaborated closely and combined their knowledge about the cave system and cave diving to devise a plan that ultimately freed the team.

The Tham Luang cave complex is a cave system in northern Thailand.



Finding a Common Language

Early on, the Thailand Department of Mineral Resources (DMR) brought together GIS and mapping experts from Esri Thailand and GIS Co. Ltd. to create a portfolio of maps to help locate the trapped boys. Using GIS, different organizations involved in the search and rescue added their data and insights to build a holistic picture of the challenge. The maps showed the complete context of the cave from different perspectives from both above and below.

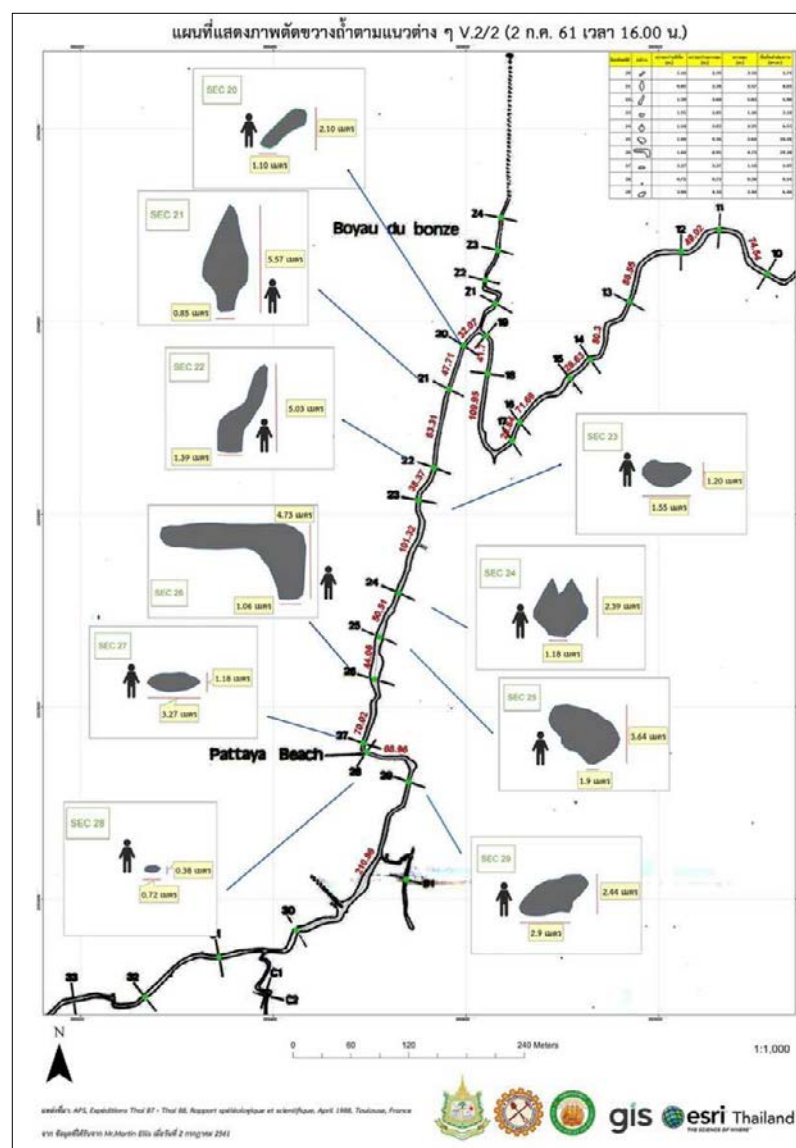
Staff from the Royal Irrigation Department surveyed the area's geology using electrical resistivity techniques to determine the source of the water that was flooding the cave. Mapping experts interpreted the data to find sinkholes that might be acting as water funnels, and they created 3D maps to show where aboveground streams stopped and went underground.

With this range of maps, responders modeled the terrain and determined where diversions could be built to reduce the flow of water into the cave. A collaborative team comprising engineers from the Department of Royal Irrigation, experts from the Department of National Parks, Wildlife, and Plant Conservation, and soldiers from the Royal Thai Army worked together to construct dams and install pipes that diverted water onto nearby rice paddies. Despite incessant rain, water levels within the cave started to drop.

As rescuers journeyed into the cave in search of where the trapped team was located, they marked their progress on a map, recording the maze of passageways and chambers to make sure they did not miss an area of the cave in their search.

Rescue divers used maps of the cave system to study all the twists and turns and guide them through murky water to reach the trapped team.

As the mission shifted from search to rescue, maps relayed near real-time readings of oxygen levels and changes in water depth. These maps kept everyone focused on the immediate



From June 30 to July 1, 2018, rescue teams created this map to provide real-world dimensions of cave passages and distances between sections. The dive team used this map for context when planning and operating the search mission.

tasks at hand. As the story riveted people around the world, it became a matter of national pride to use the maps to show how many people were working together and how their collaborative action achieved a remarkable outcome.



On July 2, 2018, the 12 kids and their coach were found within the cave in the area called Nom Sao Hill. Experts gather around a map to discuss strategy.

Achieving Common Ground

In the Thai cave rescue, a dedicated group of professionals put their mapping skills to the test and marveled at how the maps quickly became the universal language for a coordinated response. The rescuers have shown us how maps enhance understanding and speed collaborative action, both vital powers when addressing today's urgent challenges.

Shared maps have a way of simplifying complex matters, and they provide a way to coordinate decisions while ensuring that diverse perspectives are considered. The shared map isn't your map or my map, it's *our* map. It provides a common ground for us to work from and a way to prioritize what we want to achieve.

We see this same scenario with maps in the response to oil spills, earthquakes, floods, hurricanes, wildfires, famine, social unrest, and pandemics. With climate change, many communities are facing new extremes that are exacerbating racial and social inequities. Maps are helping plan, adapt, and add resilience, providing insight into more equitable approaches that help those in greatest need.

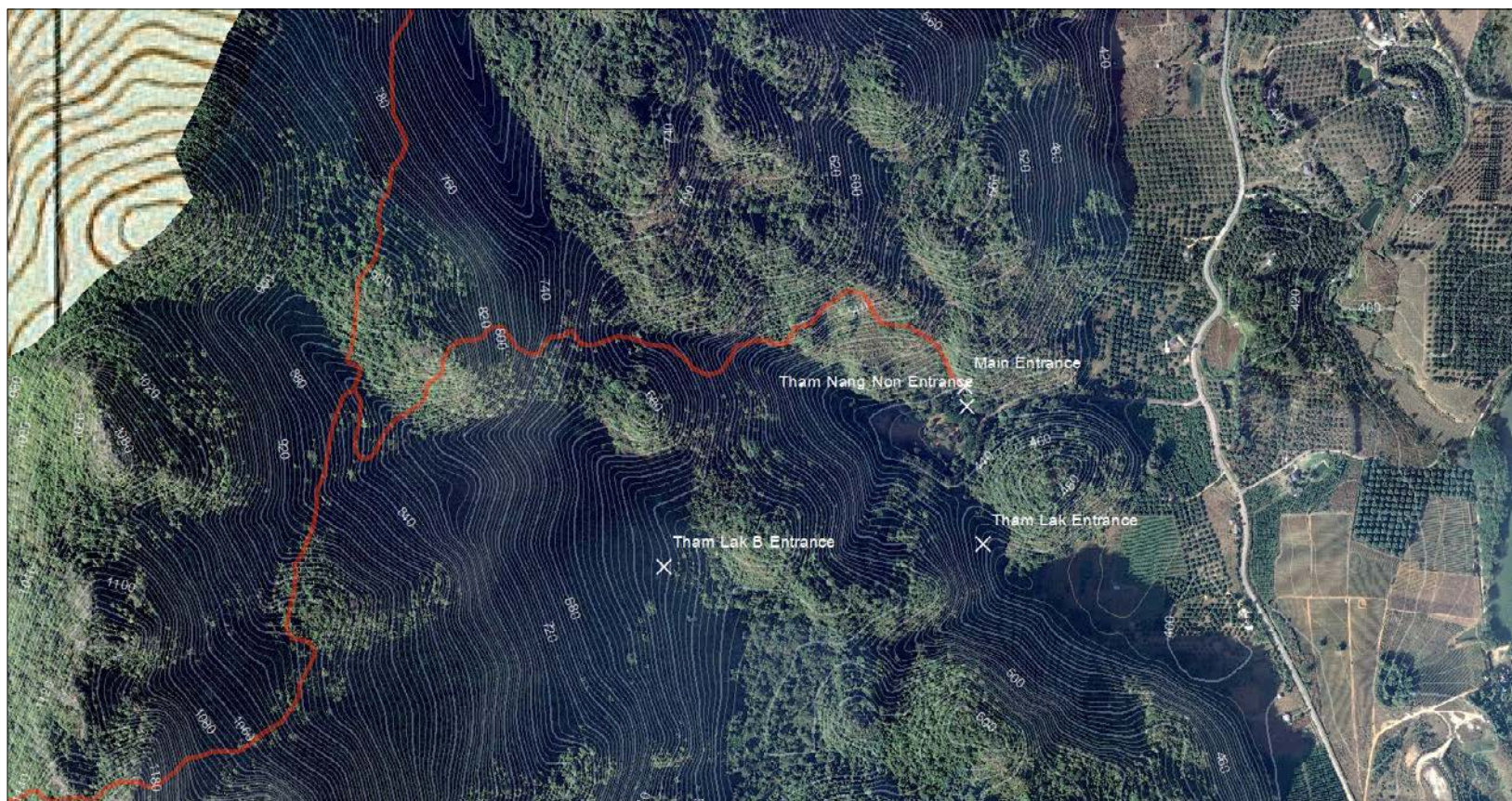
Using a geographic approach, we can look across the social, economic, and natural systems at play to devise methods to address complex challenges. Maps help gather diverse perspectives to find common ground that moves us toward a more sustainable future.

The geographic approach is being taught in schools, so future generations know more about their community and the importance of using maps to collaborate and guide better outcomes. Charities and mission-driven organizations use the geographic approach to amplify the impact their programs have within a community. And conservation organizations are using maps to determine where nature-based solutions can reduce future risk and how a geographic approach can help address a loss of biodiversity.

Thirteen Lives shows that in a time of great need, selfless people come together, each providing their perspective and expertise, each making their contribution to a map that has a profound impact on the outcome. We work best when we work together, and together we have the chance to maximize our positive impact on the world.



The war room at the Geohazard Operation Center became the epicenter for map creation and map-based discussions.



June 28, 2018: This traditional topographic map puts 3D heights and distances into context.



Enumerators and local residents in the northwest of the Syrian Arab Republic assess the damage following a devastating earthquake. @FAO

Assessing the Needs of the World's Most Food-Insecure Countries

In 2022, it was the onset of the ongoing conflict in Ukraine. In 2023, it was extreme heat across many countries and fall armyworms munching maize crops across southern Africa. These leading causes of food insecurity are just a few of the crises in focus for the Food and Agriculture Organization of the United Nations (FAO). The Data in Emergencies (DIEM) team uses satellite imagery, data collected from the field, and advanced spatial analysis and mapping to investigate root

causes and mitigation strategies to reduce food insecurity.

People are living in situations where they are constantly being hit by something. You can have a flood followed by a livestock disease outbreak and, at the same time, have conflict breaking out and the currency plunging.

—Neil Marsland, head of the DIEM team at FAO in Rome

FAO kicked off a data-driven monitoring program in 2020—during the pandemic—to assess rising agricultural stresses in countries where food insecurity has become chronic. To monitor food vulnerability and survey the needs of farmers, the team created the DIEM Hub using GIS technology and remote sensing.

Food scarcity has historically been connected to government instability. According to the World Food Programme, more than 80 percent of UN mobilized resources went to conflict areas in 2022. The most war-torn countries face perpetual cycles of hunger and instability.

“Famines are pretty rare, thankfully, but we do have many situations where people are rapidly depleting their assets in order to get access to food,” Marsland said. “They’re engaging in what we call negative coping strategies, such as selling off their last productive animal or migrating away from the household in a desperate attempt to find work.”

Working Where the Need Is Greatest

Marsland and the DIEM team monitor 27 countries facing food crises and analyze the connections among climate change, conflict, migration, geopolitics, and economics. Analysts on the team use satellite imagery and GIS technology to create models that can detect livestock hardship and crop stress. Inputs from a network of in-country enumerators add perspective on agricultural production and the impact of storms or pests, helping the team determine what producers may need. When it’s too dangerous to go door to door, assessments are completed through computer-assisted telephone interviews.

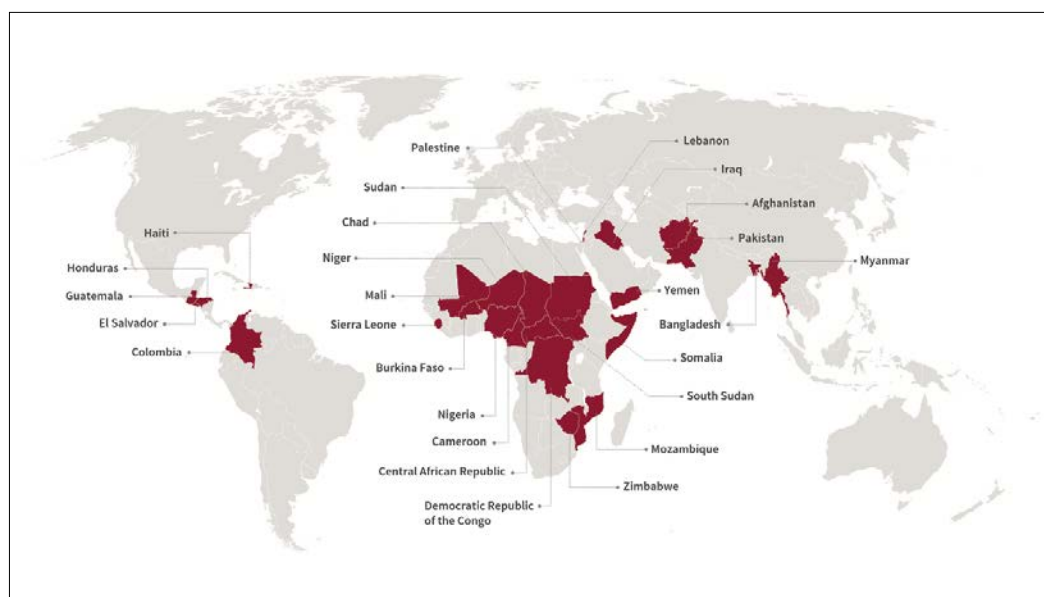
“They’re telling us they need food, but also other things,” Marsland said. “They need seed to plant the next crop and

vaccinations to keep their animals from dying. With GIS, we’re able to map and display this data very clearly. We can compare needs within a country, across time, and look at the needs of all countries.”

The DIEM Hub analyzes, maps, and stores the 150 indicators collected during each survey in countries such as Afghanistan, Lebanon, Yemen, Burkina Faso, Mali, Sudan, and Colombia. The surveys of approximately 150,000 households each year—performed every two to six months—provide an accurate picture of food production trends and volatilities.

Since the DIEM Information System was launched, the team has extended its network of partners, including national government agencies in the countries it monitors.

Before 2020, the UN did not receive regular updates on how and where food-insecure regions were impacted by crises. Now, through DIEM’s DIEM-Impact, analysts can provide initial impact assessments within 72 hours. This has been helpful in



The number of hungry and malnourished people in the world had been declining before it began rising in 2016. The setback came with an increase in extreme storms and conflicts. This map shows the 27 countries the DIEM Information System monitors and several more where impacts are assessed. ©FAO.



The DIEM team examined satellite images to understand flooding in Libya after the passage of storm Daniel in September 2023. ©FAO.

understanding events such as the flooding in Libya, the destruction of the Kakhovka dam in Ukraine, tropical cyclone Mocha in Myanmar, and the fall armyworm infestation in Burkina Faso. These reports, often built using ArcGIS StoryMaps stories, present compelling and actionable details.

Survey apps on mobile phones help streamline data collection. Automation and cloud computing enable rapid data processing. Digital workflows validate data and speed government approvals. And the DIEM Hub, an open data site, shares information and stories instantly.

Analyzing the Cascading Impacts of Conflict

The DIEM Information System has evolved since operation began in 2020. Analysis conducted in the Sahel region of West Africa helped transform the team's mission when they were able to provide accurate data and quantify the complex factors leading to food insecurity across the region—extending beyond monitoring to show causes and effects.

"We've been able to analyze ongoing conflict in the Sahel and the impact of seasonal flooding that has become more frequent and severe with climate change,"

Marsland said. "We provide a really good set of tools to analyze the impacts affecting marginalized individuals and communities that depend on growing crops and taking care of livestock."

Reports include analysis of satellite images, including radar images to see through clouds, and all the local knowledge the team collects about agricultural conditions and impacts.

When Ukraine's Kakhovka dam was breached, for instance, the immediate concern was that the nearby farms would be flooded. But then analysts began to look more closely at the effects of the emptying reservoir.

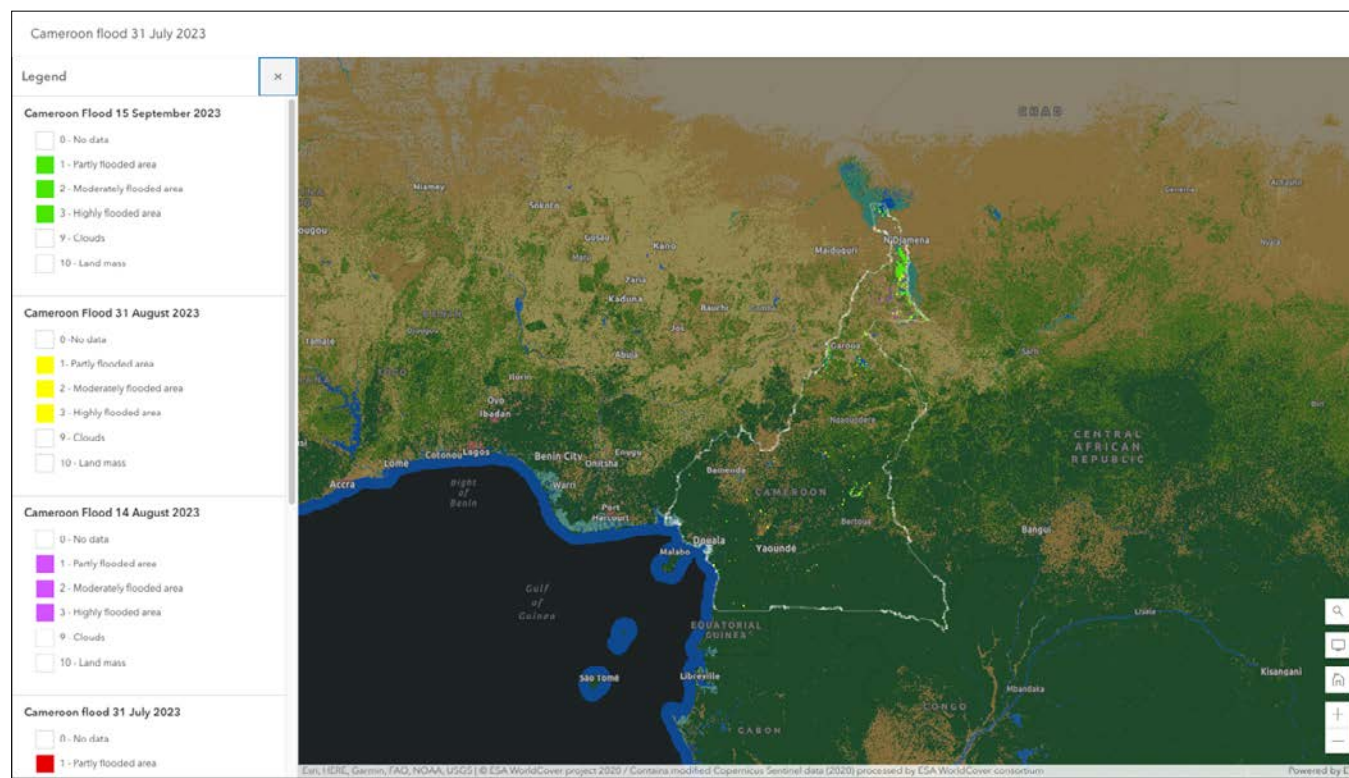
"We realized the main problem was the irrigation channels," said Andrea Amparore, data manager for DIEM. "There are three irrigation systems—among the biggest in the world—that were fed by the reservoir. The loss of water will have a huge impact on agricultural production in Ukraine and Russian-occupied territories until the dam can be rebuilt."

Knowing the food-related impacts on people helps the network of providers prioritize relief work and devise longer-



The DIEM team trains enumerators in El Paraíso, Honduras, in November 2022. ©FAO/Humberto Mejia

The DIEM team uses ArcGIS StoryMaps stories to communicate analytical findings and creates interactive maps such as this one about the extent of flooding across the Sahel region of Africa from July through September 2023. Zooming into each country displays the flood extent to gauge the level of disruption.



term strategies—such as determining how to fill the gap in grain caused by the ongoing conflict in Ukraine.

Expanding the Reach

Analysts at Cornell University and local universities such as Marondera University in Zimbabwe also use the data stored in the DIEM Hub to examine root causes of food insecurity and to come up with strategies to mitigate hunger.

“Professors and their students investigate possible connections between shocks and food insecurities,” Amparore said. “They explore the factors that can increase or decrease the resilience of certain households compared to others.”

To further extend analytical capabilities, the DIEM team is investigating how artificial intelligence–based machine learning can process imagery and further automate answers to questions.

DIEM quickly gained momentum and a growing appreciation from the community of food providers it serves. The work appeared in the world’s leading multidisciplinary science journal *Nature* in 2023. The team has visits planned to the various DIEM regions to build awareness of the available data and encourage local investment in the initiative.

In its ongoing work, DIEM will continue to build awareness of the tool to support sustainable and sustained food monitoring. The ultimate goal is to foster stability in the countries prone to multiple shocks.

“What we hear in the headlines is people being given emergency food, which is clearly a critical intervention,” Marsland said. “What we’re trying to understand in more detail is what that does to people’s lives—their families—and as importantly, what to do about it.”

Ukraine: The HALO Trust Maps Land Mines and Explosive Remnants of War

During the conflict in Ukraine, a growing number of humanitarian assistance organizations have gathered in Rzeszow, Poland, to aid displaced people and rebuild after the war.

Rather than just wait, many have been mapping the damage to prioritize the reconstruction and resettlement necessary to safely return millions of Ukrainians to their homes. Over the

first month of the conflict alone, more than 4 million people fled the country, and an estimated 6.5 million people were internally displaced.

For The HALO Trust (HALO), the largest demining organization in the world, the mapping effort is focused on identifying the presence of explosive remnants of war as well as damage to homes and infrastructure.



HALO Trust experts document unexploded ordnance in Ukraine.

A geographically dispersed team is using a GIS to detail the impacts and the ongoing dangers.

“What we do is critical to reconstruction and resettlement post-conflict, because you cannot just deal with the damage straight away,” said Luan Jaupi, head of information and communications technology at The HALO Trust. “We enable other humanitarian organizations and national authorities to safely conduct their activities by informing them where it’s safe to go and making places safe by clearing the explosives that are littered around.”

Accessing Open-Source Information

Unlike past conflicts where the aggressor had the element of surprise, social media and commercial satellite imagery have allowed the world to see and document Russia’s invasion of Ukraine. These so-called open-source intelligence sources differ from classified intelligence that can only be shared through diplomatic channels.

“We’re collecting information from internet sources such as Twitter, Telegram, and Facebook,” said Jesse Hamlin, global GIS and database officer at The HALO Trust. “We’re finding lots of tanks and armored personnel carriers that have been destroyed, and they’re potentially booby-trapped with land mines around them. We’re also seeing mines being littered across a road and vehicles just driving past them, because there’s a panic to get out.”

HALO’s explosive ordnance experts review a variety of datasets flowing into its database from social media and news outlets, verify whether the data is relevant to the mine action sector, identify the model of the munitions if possible, and then place the dangers on a smart map to be shared with others.



A dynamic web map captures updates of conflict and damage in Ukraine.

“We’re finding lots of bridges that have been blown up by both sides, which means you may have been able to cross that bridge at one point, either to leave Ukraine or to come back in after the conflict is finished, but now you physically can’t cross the bridge until it is repaired,” Hamlin said. “This will impact the delivery of aid and the return of the people to their communities.”

Putting Evidence on the Map

The HALO team has worked to streamline the steps of geolocating an event on social media and speed the flow of information. Experts can now go through a stream of evidence and filter out just the events they feel need to be investigated, rather than manually searching the internet for social media and news articles.

“Looking at the map, the areas in red show the line of contact, where Russians are pushing forward and getting pushed back on a daily basis,” Hamlin said. “The dots show events we pulled from social media that are color coded

for unexploded ordnance, land mine, improvised explosive device, cluster munitions, and other bomb types.”

Each social media post is explored by HALO’s explosive ordnance disposal experts, who examine the image to see what they will be dealing with. “They know right away if it’s a FAB-500 aircraft bomb, which provides an evidence point we can investigate in the future,” Hamlin said.

Mapping the bombs and bomb types has helped HALO educate the public in Ukraine about the munitions being dropped.

“We’re interested in cluster munitions for one, because they’re dispersed over large areas and children often pick them up and play with them,” Hamlin said.

HALO has also received evidence of a new Russian land mine called the POM-3, with sensors that detect human footfall rather than being triggered when disturbed. This new type of mine is launched by rocket and falls to the ground by

parachute. When it senses a person, it detonates an explosive that spreads fragments in a circle 50 yards across.

The POM-3 adds great complexity and danger to the demining effort because it will require bomb squad robots to dismantle them at a distance, and HALO will need to acquire that technology.

Automating Damage Detection

HALO first did this advanced mapping work in Tripoli, Libya, in 2019, for a conflict that lasted a year.

“We asked ourselves what we could be doing during the conflict to aid our post-conflict intervention, and we decided to record and map the presence of explosive ordnance,” Jaupi said. “We learned a lot of lessons, and we’re doing things a lot better now.”

In some of the cities in Ukraine, such as Mariupol, imagery showed massive damage from excessive and constant shelling. An effort is under way to apply the AI approach of machine

learning to train computers to detect the damage from the imagery. HALO has been working for some time with machine learning experts at Esri to analyze the damage in countries such as Sri Lanka, Afghanistan, and Libya. Being able to detect damage programmatically helps HALO understand where to find unexploded bombs and land mines.

Work is still in progress to refine the dataset and maps that will be shared with other humanitarian organizations and the



Local experts on unexploded ordnance deal with rocket remnants in Mykolaiv, Ukraine. Photo by Anastasia Prokofyeva.

international community. As HALO continues to process and refine the dataset, this will provide more clarity on the contamination inside Ukraine.

Returning to a War-Torn Land

HALO has more than 8,000 explosive ordnance disposal experts operating in 28 countries. It has been active in the Donbas region of Ukraine since 2016, removing explosive remnants of war from the 2014 conflict. And now there's a much larger job ahead because the conflict spans much of the country—the second-largest in Europe, behind Russia.

When the situation begins to de-escalate, HALO will use the map to prioritize its work and keep its own staff safe. A simple GIS-based form is being developed that Ukrainians will be able to use to report what they find and where it is located so that experts can follow up and dispose of it. And HALO mappers plan to continue monitoring social media.

"Our goal is to ensure families can return and rebuild their lives in safety, and maps help us do this," Hamlin said.



Red Cross and press gather in Mariupol, Ukraine, during a lull in the bombing.



Much of the destruction in Ukraine surrounds civilian areas, such as this damaged apartment building in Kyiv.

When Crisis Ensues, MapAction Volunteers Map the Road to Safety

When the conflict in Ukraine began in February 2022, an exodus of more than five million people ensued, with many more later. In the initial surge, crisis response organizations immediately mobilized to bring humanitarian aid to those who were displaced, most of them women and children. As the deadly campaign unfolded, staff and volunteers from nonprofit MapAction—all of them skilled in the use of GIS technology—also deployed. For two months, they equipped response teams with digital maps and geographic analysis that helped guide efforts to save lives and reduce suffering.

In operation since 2002, MapAction dispatched GIS professionals to neighboring Poland within 24 hours of a request to support agencies involved in delivering humanitarian aid.

In their day jobs, MapAction volunteers use GIS to help governments, businesses, and other organizations maximize efficiency and improve decision-making. During a crisis, MapAction's GIS professionals do the same, providing location intelligence products that create a common operating picture.



Family members embrace after being reunited after fleeing Russia's invasion of Ukraine.

This helps crisis response teams better understand and navigate unfamiliar territories and avoid duplication of effort.

It's a privilege to have been there in the early days of MapAction, and I'm really impressed at the impact subsequent teams have made with it. It was at the forefront of the sector now known as humanitarian GIS and has become a mainstay in humanitarian response. It's impossible to quantify that impact. How many lives did the availability of an up-to-date map help to save? They are countless.

—Olivier Cottray, a founder of MapAction



MapAction's overview map shows major settlements, transport links, and physical features of Ukraine and the region.

MapAction volunteers created dynamic maps in Ukraine to show population movement and monitor border crossings, transportation systems, supply routes, and refugee reception centers. The volunteers and staff quickly became part of a humanitarian coalition, helping relief organizations use technology to improve collaboration and information sharing.

"Essentially, what we're trying to do is build a picture of what's going on that we can share with the organizations responding," said Jonny Douch, MapAction acting Emergency Operations director.

Civilian Life Is Upended under Conflict

Thousands of Ukrainians have died, and even more have been injured as the conflict progresses. Civilians have seen their homes and communities destroyed across a nation that approaches the size of Texas. By March 1, 2022, more than a

half million people had crossed Ukraine's border to escape. Most headed west.

"In addition to the grave situation inside Ukraine, hundreds of thousands are seeking refuge in neighboring countries," said Filippo Grandi, head of the Office of the United Nations High Commissioner for Refugees (UNHCR), at a briefing for the United Nations Security Council. "They need safety and protection, first and foremost, but also shelter, food, hygiene, and other support; and they need it urgently."

Women and children made up 90 percent of the refugee population, UNHCR reported. They faced risks such as gender-based violence and sexual exploitation. Also vulnerable were senior adults, unaccompanied minors, and people with disabilities that made it difficult for them to escape from high-risk areas.

For a time, the displaced found themselves in obscurity, with aid organizations unable to account for their whereabouts or safety.

GIS Critical to Global Response to Ukrainian Crisis

UNHCR's initial goals included setting up and managing logistics, a necessary step for a coordinated response on behalf of refugees. The United Nations Office for the Coordination of Humanitarian Affairs (OCHA), one of the United Nations bodies involved in humanitarian response, has long worked with MapAction and asked for assistance for Ukraine. MapAction's Emergency Operations director reached out to the 80 GIS professionals on the organization's volunteer roster to see who was available to help.

"I got a phone call asking if we could send some people to Poland," Douch said. "I sent an alert out by text to the

volunteers, who then sign in and say what their availability is, or they phone me back."

Early in crisis response planning, digital maps created with GIS technology can provide answers necessary to coordinate timely and well-executed interventions. GIS technology can integrate volumes of data about geographic regions, their populations, and human movement. Frequent updates to maps give response teams near real-time awareness of changing conditions. Equally important, maps created with GIS are easy to share, which is valuable when multiple organizations need to work in tandem.

MapAction Volunteers Mobilize

When OCHA contacted MapAction's operations director for help, eight staff and volunteers deployed, some of them almost immediately, heading to crisis response centers across Europe.

Gemma Davies, a former MapAction volunteer and now head of Geospatial Services, was among the first of MapAction's team to arrive, assisting teams from the World Food Programme and other organizations as they staffed a logistics cluster from a hotel conference room in Krakow, Poland.

"It was about the speed that we were getting there," Davies said. She and the volunteers helped with "a lot of that early decision-making where people have no maps and no context, and they needed to just sit down in a meeting with something in front of them. Because we were out early, we were able to get maps into people's hands."



As the conflict in Ukraine displaced people, MapAction worked to understand where they were going.

MapAction volunteers also provided maps that identified dozens of locations where service organizations could initiate contact with refugees.

Humanitarian Response Spreads across Europe

After about 10 days in Krakow, the World Food Programme and other global relief organizations were mobilizing their own GIS teams to sustain operational awareness and collaboration. MapAction volunteers moved to other locations. Claire Byrne, a spatial data scientist with the EPA in Ireland and a MapAction volunteer for more than 10 years, traveled to Moldova. She and Chris Jarvis, who also represented MapAction, assisted the International Federation of Red Cross and Red Crescent Societies (IFRC), which were working to support the Moldovan Red Cross.

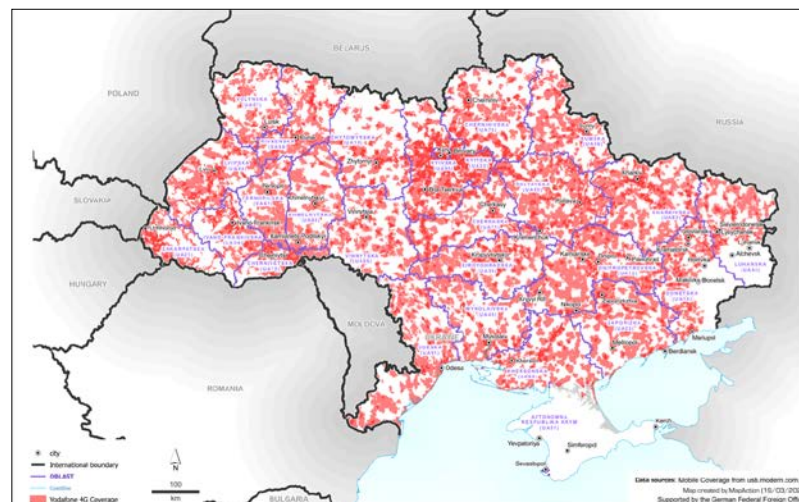
“Since the start of the emergency, about 300,000 people crossed the border into Moldova,” Byrne said. “Around 98,000 had remained in Moldova, but only about 5 percent of those had stayed in reception centers. So the majority of them had gone to host families, but there wasn’t a clear, central picture of where they were and who they were with and what they needed and also what the host families needed.”

Byrne and other responders worked with the IFRC to establish a needs assessment survey that would collate all information into a centralized information system that would allow Moldovan Red Cross headquarters staff to coordinate with the IFRC to serve the needs of refugees and host families.

Relying on the data management capabilities of GIS software, MapAction volunteers created a map of border crossings. UNHCR released a dashboard in mid-April 2022 that continues to provide border crossing data. Finally, the world had a way to understand the scale of the exodus.

Calculating the Value of Volunteer Support

MapAction concluded its two-month-long support efforts on April 5, 2022. Volunteers created more than 30 digital map products that conveyed the breadth and scale of the



MapAction mapped the preconflict availability of 4G connections across the country to relate the most developed and most populated parts of the country.

emergency. Volunteers also assisted with data and analysis, computer programming scripts, and other forms of support for more than 25 organizations.

“We had positive feedback from some of the NGOs saying, ‘It made a massive difference having that context in our planning meeting,’” Davies said.

The displaced Ukrainians may never know that eight MapAction volunteers traveled far from home to mobilize on their behalf at a tragic time in Ukraine’s history. The volunteers serve for reasons other than recognition. Instead, they wanted to make a difference for tens of thousands of strangers who’d lost sight of the dream for peace that most of humanity clings to.

“We’re often there at the start of something, and then we’re gone,” said Byrne, “But the analysis and visualization products we provide during that emergency phase can be invaluable in shaping the humanitarian response.”

Sri Lanka: How Geography Shapes Life for Migrants

Although large-scale patterns in human migration can tell us why people leave home and where they go, data about what happens next is notoriously poor. The Royal Geographical Society (with the Institute of British Geographers) (RGS-IBG) set out to fill in knowledge gaps about migrants' lives after they move. The insights are contained in a five-year field research study with partners in Colombo, Sri Lanka; Dhaka, Bangladesh; Harare, Zimbabwe; and Hargeisa, Somaliland. The knowledge researchers gathered using a geographic approach will be key to informing initiatives that support the sustainable integration of new migrants into urban communities.

As of 2008, for the first time, more than half of the world's population lived in urban areas. That number is expected to rise to nearly 70 percent by 2050—growth fueled largely by migration from rural areas, as more people leave crisis-afflicted and climate-pressured areas in search of safety and economic opportunity. Despite this trend, however, many global cities lack policies and infrastructure to support an influx of new residents.

Colombo experiences significant in-migration from rural areas, according to the results of the RGS project *Migrants on*



Colombo is the most populous city in Sri Lanka.

the Margins. More than 50 percent of Colombo's population lives in underserved settlements, the study reports, and migration and displacement are a particular challenge in these underresourced communities.

"Research into migration in response to conflict or disasters highlights the fact that since people expect the situation at home to improve, they also expect to return," said Michael Collyer, professor of geography at the University of Sussex and principal investigator of the study. But Colombo's census data suggests that migrants more often stay within the metro area, largely in poorly resourced, low-income neighborhoods.

Using novel methods combining satellite imagery, GIS software to create maps, and personal interviews, the researchers identified geographic factors—environmental hazards, lack of local resources, and mobility barriers—that prevent migrants from moving forward.

Migrant Communities Take Root in High-Risk Areas, Satellite Imagery Shows

Colombo is uniquely influenced by its geography. The coastal capital of an island nation, its location on the Indian Ocean cemented its status as the region's largest port centuries ago. The metro area accounts for nearly 50 percent of the nation's gross domestic product (GDP). For rural Sri Lankans leaving home, the city's prosperity promises jobs and income.

But Colombo's waterfront setting also means that its streets sit near sea level, intertwined with offshoots of the neighboring Kelani River—as a result, they are prone to flooding. Comparing satellite imagery of the city taken over the past few decades, the RGS team saw significant growth of migrant communities in some of the highest-risk floodplains where local regulations typically prevent construction.

"In some of these settlements, there was an initial plan for formal development," said Sakeena Alikhan, a researcher and GIS specialist at the Sri Lanka-based nonprofit Centre for

Migration Research and Development (CMRD). "But the city found illegal encroachment near the riverbanks and canals, so it stopped building and people started to settle there informally."

The satellite imagery shows one case where land was cleared for construction, but then was quickly covered by informal settlements. "You see communities infilling near the water, and you get a sense of the precarity of these environments," said Catherine Souch, head of research and higher education at RGS. Annual floods can leave swaths of these settlements in disrepair, forcing residents to relocate and preventing them from establishing permanent homes.

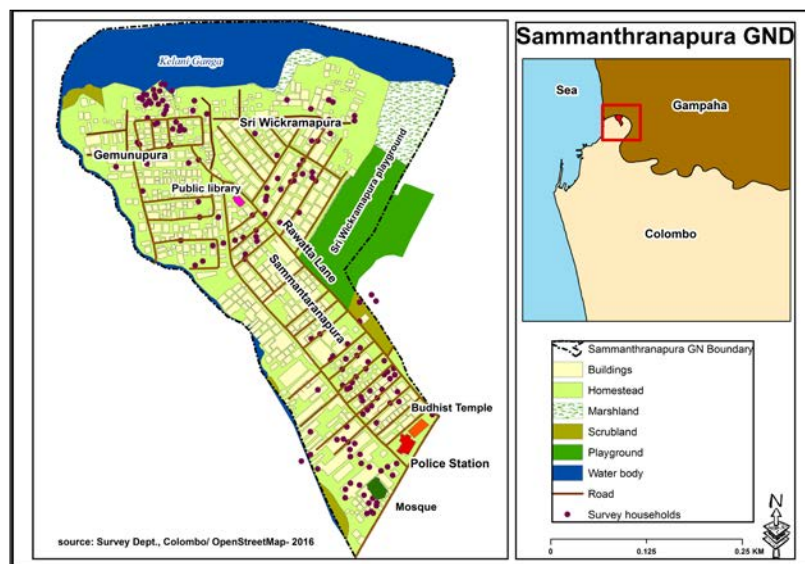
"There is a temporary nature to these neighborhoods," said Danesh Jayatilaka, research team chairman at CMRD. "People can't get their feet on the ground and then can't afford to move to a safer area or leave the city."

Mapping a Lack of Local Resources

The informal origins of Colombo's migrant settlements have impacts beyond housing security. Businesses and city services are usually underdeveloped, with neighborhoods lacking critical infrastructure such as water supply and sewage, community institutions such as churches and schools, and public places such as government offices and police stations.

Working with GIS data from the Survey Department of Sri Lanka, the team created digital maps of several settlements in Colombo. "The GIS tools helped us document what kinds of resources these areas have," Alikhan said. "The maps illustrate how specific communities access basic services, and whether people need to visit other areas for necessities."

The resource maps showed a wide gap in services, largely depending on the settlement's geographic proximity to more developed neighborhoods. For example, Sammanthranapura—a small, dense community with a population of approximately 10,000 people—offers residents a public library, a police station, and two religious centers.



The Sammanthranapura informal settlement is bounded on two sides by water, increasing flood risk and limiting how residents can access other parts of the city. Source: Survey Department, Colombo and Open StreetMap 2017, © Sakeena Alikhan.

Sammanthranapura is also bounded on the north and west by flood-prone waterways that limit connectivity to other parts of the city and borders only one other neighborhood by land. A settlement in Colombo's Kirulapana suburb, however, is within reach of public transit, government buildings, schools, and a waste disposal facility.

The team noted that physical access to resources, although important to document for conversations with policymakers, was not always an indicator that migrant communities had stable housing and opportunity for social mobility. Rather, the research points to inclusion in social and political protections as being key to better outcomes.

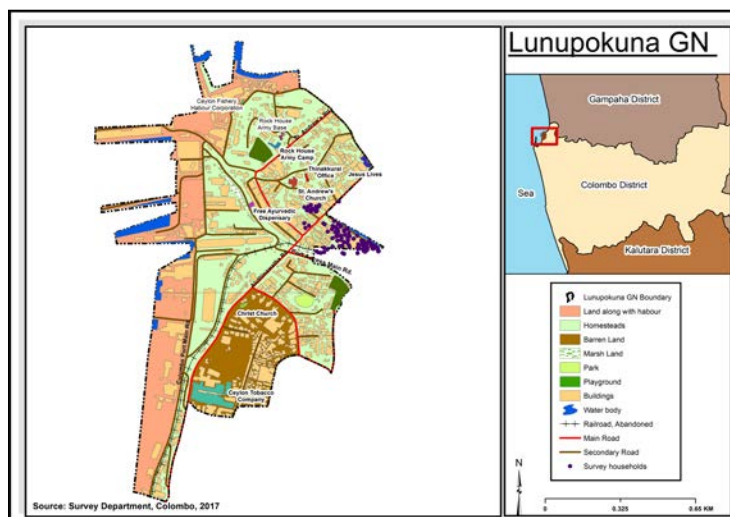
"We've shown that these populations live, not necessarily on the geographical margins of cities, but on the margins in an economic, political, and social sense," Collyer said. "Some of these communities are actually right in the center of cities, and yet they are excluded from systems like tenants' rights and fair wages, and so people there become trapped."

Stories Highlight Links between Physical and Social Mobility

In addition to exploring the regional and local geographies of Colombo's migrant communities, the research team set out to learn more about migrants' own experiences moving into and within the city. The team used a novel personal mapping method to interview residents of informal settlements, filming individuals as they drew a map of their migration journey. Then, some of the drawings were transferred to GIS.

The personal maps revealed that people often moved between several informal living situations in pursuit of stable housing and income. "We learned that, while many of these individuals first left home as teenagers, it would take nearly 30 years for them to settle in one place," Alikhan said. Although job changes and family needs were cited as reasons for relocating, many interviewees also reported moves resulting from forced evictions.

The researchers found that such evictions had a lasting, negative impact on migrants' physical and social mobility. Physically, as evidenced in interviews and personal mapping exercises, evictions set individuals back as they relocated



Researchers use GIS to map every informal settlement in Colombo, Sri Lanka. A settlement in Lunupokuna is bounded on one side by wetlands and a landfill on the other. Source: Survey Department, Colombo and Open StreetMap 2017, © Sakeena Alikhan.

from one informal settlement—where they had established an income source and a support system—to another. Socially, the study introduces the idea of “evictability”—the fear of eviction, which contributes to individuals’ reluctance to invest in their home and participate in local politics.

Ultimately, Souch said, “Giving people security in a place to live is absolutely core and fundamental to their life chances once they’ve moved.”

Maps Create a Common Language for Change

Migrants on the Margins provides insight into how governments can sustainably support migrant communities after people arrive in cities. Existing policies in Colombo, and the other cities the project visited, approach migration as a problem to be addressed. Efforts in Sri Lanka have previously sought to reduce migration, and an urban regeneration program in 2022 aimed to remove settlements and rehouse residents in high-rise apartments.

“Root causes for people leaving home are very difficult to deal with; they include long-term problems such as war, conflict, political instability, or climate change,” Collyer said. And, Jayatilaka said, “It makes sense on paper to put people in apartments; it’s safe, more solid, and doesn’t have floods.



Comics helped the researchers teach young students about migration patterns, urban growth, and spatial inequalities in cities. (Image courtesy of RGS, © Positive Negatives) [Long description](#).



Researchers meet with the community in a crowded room.

But you take people away from their world—they have lives in these communities, and that is lost and changed when they have to move.”

One of the study’s key findings centered around individual invisibility versus collective visibility—how worries of eviction prevent individuals from seeking recognition in their community while migrant communities as a whole face public scrutiny. This leaves migrant voices out of policy and planning discussions, the study found, and results in policies that harm migrants and migrant communities. The critical next step of this research is to open the lines of communication for mutual understanding between migrant communities and their neighboring formal settlements.

Since the study’s release, the team has held exhibitions and workshops with policymakers, leveraging the imagery and maps to communicate and provide visual evidence of migrants’ lived experiences in Colombo’s informal settlements. “A map can be read by anyone,” Alikhan said. “These maps give citizens and governments a common reference point to communicate not only about geographical features or physical infrastructure, but also people’s connections to each other and to their environment.”



Public Safety

Agencies around the world manage public safety, emergency response, fire, wildland fires, and public events from beginning to end using location intelligence derived from GIS software. Land managers, emergency managers, firefighters, and law enforcement officers use dynamic maps and GIS tools to identify risks and craft mitigation strategies. During events, mobile data collection tools and map-based dashboards with live data feeds inform decisions that save lives and property.

Alexandre Penha, operations deputy at Portugal's National Authority for Emergency and Civil Protection (ANEPC), reflected on the changes made since 2017, when wildfires killed 66 people and injured 200 in Portugal. In response, the country passed laws to reduce risk and better respond to emergencies. ANEPC added five new regional operational commands, hired more firefighters, and added aerial assets.

Penha highlighted the digital transformation within ANEPC, which now uses advanced wildfire mapping technology, including an early warning system and real-time maps powered by GIS technology. According to Penha, the improved technology has led to significant results: "The results were huge, not only for the flow of information but also our ability to predict the evolution of each fire."

Jennifer Lana, the GIS manager at Cobb County Government in Georgia, highlighted how dynamic data was made accessible for Major League Baseball's technical team during the 2021 World Series. They used advanced mapping to plan for a massive victory celebration, with just 35 hours to organize a party for 350,000 guests.

"We have 50 different datasets on the map from the footprint of the stadium, all the businesses, the lights and cameras, the traffic data feed, 911 calls, traffic from Uber and Lyft rideshare, and the location of Cobb County vehicles," Lana said. With that foundation of awareness established, Cobb County law enforcement could feel confident that they could keep peace and safety during a complex event.

The City of Frisco, Texas, has developed an innovative and collaborative emergency response platform called SAFER, for Situational Awareness for Emergency Response, that delivers real-time situational awareness of assets and staff across departments. Susan Olson, assistant director of IT for Frisco, Texas, shared how GIS technology has kept up with the city's rapid growth from 30,000 to 230,000 residents between 2000 and 2023. "We built the reliance on SAFER over time on a foundation of accurate data, strong

integrations, and being responsive to needs." The system now integrates with more than 30 other systems and holds dozens of GIS data layers.

Frisco's police chief, David Shilson, noted how the digital twin system improved responses: "In larger scenes, incident commanders can look at where units are in order to quickly set perimeters and direct incoming resources."

In response to Hurricane Ian in Florida in September 2022, federal and state urban search and rescue teams used a suite of tools that allowed all actions to be tracked on a shared map. More than 20 search and rescue teams used a suite of tools called the Search and Rescue Common Operating Platform (SARCOP) to collect more than 108,000 field observations.

The toolset enabled them to segment search areas to be covered in 12-hour shifts, show tracks where each team had been, and drop icons to indicate what was found or done. The situational awareness gave each team as well as coordinators at the state and federal levels the means to stay informed and adjust quickly to cover places where people might be found.

Jared Doke, a program manager for SARCOP, spoke to efficiency gains from seeing where other teams were operating. "Before we had the ability to draw segments on a map, teams were overlapping, not knowing others were there until they'd bump into them on the streets," he said.

Mike Sena, director for the Northern California High Intensity Drug Trafficking Area (HIDTA) and president of the National Fusion Center Association (NFCA), underscored the importance of better information sharing among federal, state, local, tribal, and territorial government and law enforcement. He shared a vision for a next-level geographic approach to crime fighting, capable of identifying and understanding public safety threats across all public safety and security information fusion centers in America.

Sena expressed excitement about a pilot project that combines mapping and collaboration tools to enhance information sharing: "We can share data and visualizations with 25,000 people in real time. Fusion centers have never had that capacity before."

Whether you are a first responder, analyst, investigator, or fusion center director, you need information to quickly gain awareness and understanding of events across multiple jurisdictions. GIS provides the tools to collect, integrate, analyze, and disseminate information quickly and easily.

Portugal Revamps Wildfire Resilience after Devastating Fires

Territory maps cover a wall in Alexandre Penha's office, providing a constant reminder of how much has changed since he became operations deputy at Portugal's National Authority for Emergency and Civil Protection (ANEPC).

Seventeen days after Penha took over the post in 2017, the country experienced its deadliest wildfires. Drought, high temperatures, and strong winds combined to spread 156 fires

that June. Blazes burned 100,000 hectares, killed 66 people, and injured 200. Fast-moving flames destroyed enough crops and livestock to impact the country's economy. Many people lost everything.

In response, Portugal passed laws to reduce risk and better respond to emergencies. Penha's organization, ANEPC, redesigned its territories, adding five new regional operational

Portugal deploys rugged fire engines to fight fire in rural hills.



commands. The added areas are designed to improve response times and the capacity to cope with increasing risks. ANEPC hired more firefighters, added aerial assets (helicopters and airplanes), purchased fire engines, and equipped firefighters with more protective equipment.

Penha looks at the wall maps to remember redrawn district lines that took effect in 2022: “There were 18 district commands and now there are 24 subregions, and each has a new name. It’s not an easy test to remember each one yet.”

These are some of the only paper maps he looks at these days because ANEPC has undergone a digital transformation. Penha now uses advanced wildfire mapping technology, including an early warning system aided by satellite and radar data to quickly detect wildfires. Real-time maps—powered by GIS technology—provide a live operational view of every fire. Drones and helicopters populate maps with high-resolution images for up-to-the-minute awareness of fire locations and behavior.

Sharing Data, Seeing the Same Map

After the 2017 fires, upgrading the decision support system was the top priority. “At that time, information flowed in a text system, and someone was always trying to put that information on a map,” Penha said.

Now a shared map captures incidents and activity so regional, subregional, and local stakeholders can see current conditions. The civil protection authority, the National Guard, the Forestry Institute, local authorities, and more provide input and gain awareness through ArcGIS Online. Firefighters and the National Guard collect data on smartphones using ArcGIS Survey123. Helicopter crews use ArcGIS QuickCapture to gather images and make updates about fire behavior.

“They can send important information to the fire analyst—the type and inclination of the smoke, the wind, the type of fuel,” Penha said. “The results were huge, not only for the flow of information but also our ability to predict the evolution of each fire.”

The system provides a national overview along with a view of each subregion. It reports the events of the last few days, shows where fires are occurring, and tallies the energy released by each fire.

Right now, on my screen, I have one fire with crews that have been dispatched, one where crews are working, one that has been contained, and one we’re watching,” Penha said. “I can keep an eye on each one. I can see how many men are there, how many trucks, how many aerial assets.

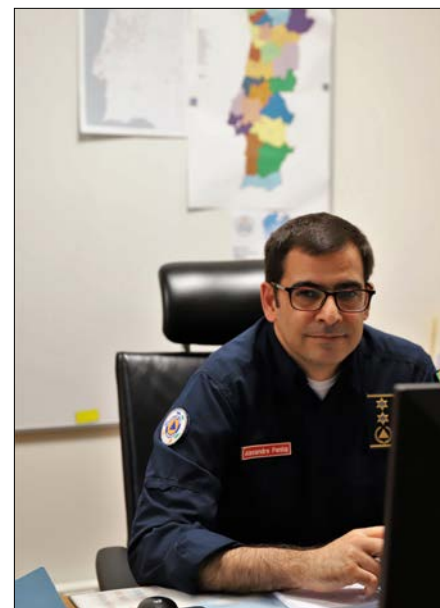
—Alexandre Penha, operations deputy at ANEPC

The map view integrates with other operational platforms, including weather predictions and dispatch centers. When a fire crew is sent to help, they know what to expect, and they can use the system to report their work. Later, administrative and financial details are added so all aspects of response can be assessed after each fire.

Reducing Risk by Reducing Fuels

One of the first laws to pass after the 2017 fires was a mandate that farmers must clear their fields after harvest. The National Guard maps each farmer’s preparations for the fire season.

“National Guard teams go from field to field to collect data,” Penha said. “On the one hand, this work compels farmers to clean their fields. It also gives us an overview of what vegetation and fuels are present, so we know what to expect if fires occur.”



Alexandre Penha at his desk.



Accurate information is mandatory for the safety of firefighting crews on the ground. The QuickCapture app has large buttons and intuitive workflows to make data capture easy.

In forests, prescribed burns reduce fuel loads. The mapping system identifies areas that should be burned and, in real time, supports firefighters in keeping each burn under control.

Penha was a firefighter in the Lisbon Fire Brigade for 20 years before coordinating a national response. With his new job, he has gained a national awareness of what's needed—beyond the use of high-tech maps.

"We have a huge problem in that the people who care for the forest are getting too old," Penha said. "Younger people want a different life. Even if the government has the money, if there's nobody there, nobody will take care of the forest."

Penha sees this problem not only with fires, but also with floods. Without people in rural areas to keep an eye on things, the pace of climate change overwhelms land managers.

Experiencing the Worst and Helping Others Deal with It

Regions with a Mediterranean climate are among the first threatened by growing wildfires. Portugal collaborates closely with other European countries, especially Spain, France, Italy, and Greece, as each has suffered major fires. But the threat is spreading.

"In 2022, Italy deployed aerial assets to Germany and Romania because they are starting to suffer from climate

change and have big fires,” Penha said. “In 2019, we sent planes to Sweden, one of the countries that we never expected to have problems with forest fires. That’s the way things are now.”

Drought and winds continue to plague forests in South America, as they do in Europe. In March 2023, ANEPC sent a team to Chile as the country was dealing with several big fires during its summer months. Portugal’s firefighters arrived equipped with the command-and-control system on smartphones. The 140 firefighters used QuickCapture to collect images and share information.

In Portugal, the summer of 2022 was difficult. Fires burned from July through October, inflicting widespread damage. Hundreds of people were injured, and hundreds



A shared map helps local command oversee and plan wildfire operations



of structures were destroyed. The military was called to help with firefighting.

In preparation for summer 2023, ANEPC developed AI workflows to help determine where best to apply its resources. Teams anticipated a need to battle between 80 and 120 forest fires a day.

“The number of fires will certainly not be fewer, and we won’t have more firefighters,” Penha said in advance. “We’ll have some new sensors on our reconnaissance airplanes that will give us more information and we have to do a rapid analysis of it. We’re always moving volunteers and firefighters from the coast to the interior of the country and from the south to the north. If we don’t have timely evidence, the places in need won’t have firefighters.”

The Emergency and Civil Protection Special Force (FEPC) uses the data that is collected to work on the lines.

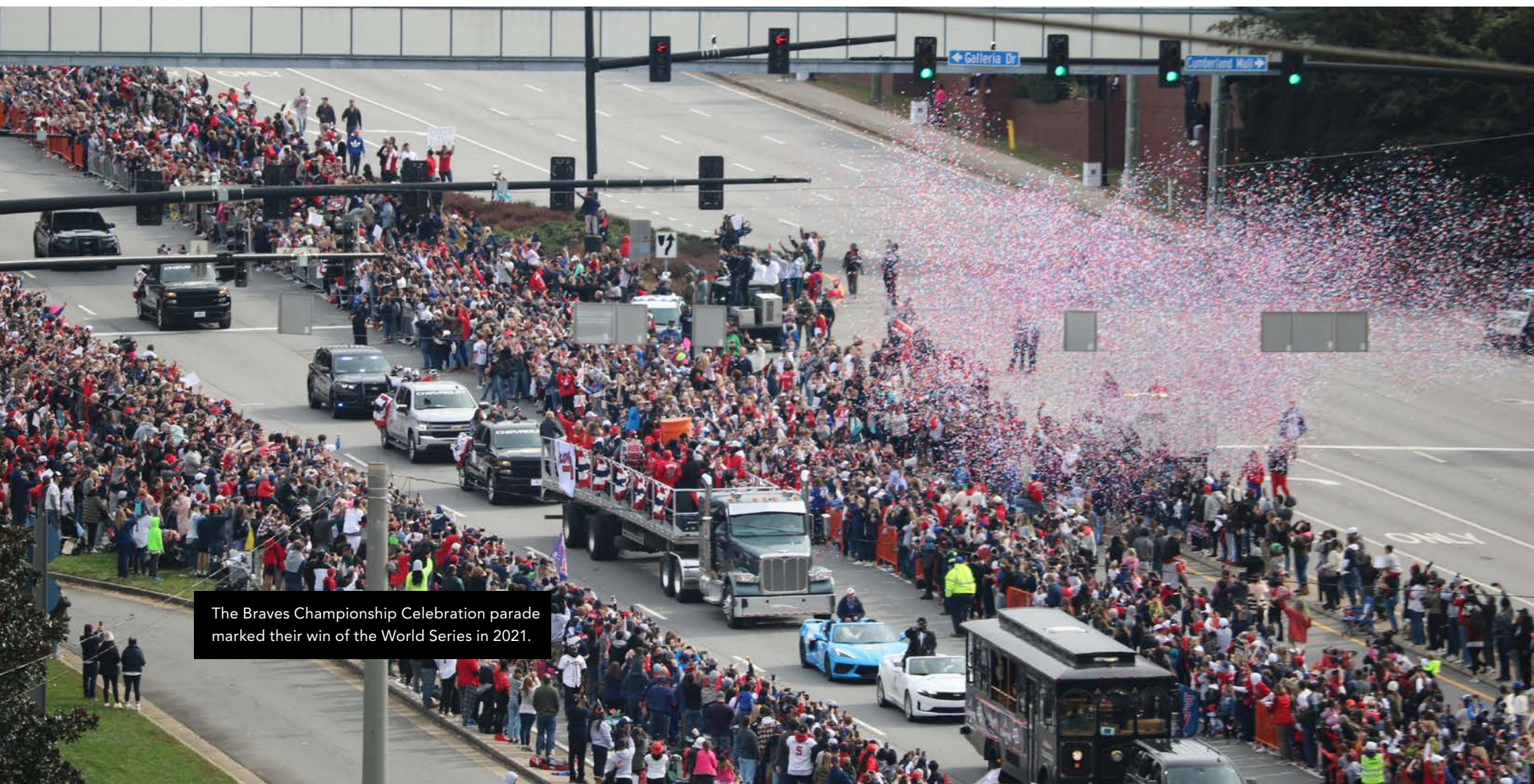
Cobb County Secures World Series with Real-Time Location Technology

By the time the World Series came to Cobb County, Georgia, in fall 2021, the technology and expertise demonstrated by the staff orchestrating public safety couldn't help but win the attention of Major League Baseball's technical team.

They could walk into any conference room, and with just a click, they could see dashboards with maps showing the location of security staff, live traffic, and 911 calls. They hadn't seen dynamic data that was so accessible before.

—Jennifer Lana, GIS manager at Cobb County Government

Yet as the Atlanta Braves took control of the seven-game series the week of November 1 and county officials wanted to plan for a massive victory celebration, preparations had to be delayed. There's a long-standing superstition in baseball that planning a celebration before the World Series concludes invites bad luck. So once Braves relief pitcher Will Smith's 97 mph four-seam fastball was grounded out to end game six on Tuesday, November 2, ending the series, that meant officials in Cobb County had only 35 hours to organize a party for 350,000 guests.



The Braves Championship Celebration parade marked their win of the World Series in 2021.

It had been a while since the Braves were world champions. The last time was in 1995 when the team was in a different stadium and a different jurisdiction. So there were no set plans or knowledge about how to accommodate championship crowds.

However, Cobb County's investment in sophisticated mapping and monitoring technology and staff have been tried and tested during big events. This includes home games of professional baseball's National League Division Series, the National League Championship Series, the World Series, and security for the National Football League's 2019 Super Bowl in Atlanta.

This time the huge celebration would include a parade procession that would wind through downtown Atlanta and culminate at the Braves' home ballpark, Truist Park.

Jeremy "J. D." Lorens, a lieutenant in charge of traffic management at the Cobb County Police Department, handled parade security using up-to-date maps and remote control of traffic lights. For home games at the ballpark, Lorens had already worked with a team of GIS specialists to apply mapping for crowd control, security, and traffic management. Now, Lorens needed the same detailed maps—outside the stadium—to create the parade route.

The GIS team provided tools to help the Braves organization as well as state and county officials define and approve the route. Next, Lorens gathered barricades to match the narrow three-lane map he devised to reduce roadway width and put the crowd in proximity to players. "I knew there would be families with little kids," he explained. "I wanted to get them as close to the parade as possible."

During the parade, GIS maps displayed the location of every officer along the route, allowing incident commanders to see where each asset

was located in case of an emergency. The smooth operation of the parade allowed Lorens to craft an efficient plan for barricade removal when the procession was halfway through its route.

Advanced Stadium Technology

Before Truist Park opened in 2017, Cobb County authorities invested in advanced traffic management technology to move fans quickly and easily to and from the ballpark that sits near the intersection of two interstate highways. They wanted to make sure the stadium location improved rather than added to Atlanta's traffic congestion.

Lorens oversees traffic management at the ballpark and runs the control center with live feeds of 70 cameras monitoring pathways and "The Battery" entertainment district. Thirty more cameras monitor critical intersections. GIS allows Lorens and the team to visualize the location and condition of every traffic light and camera. Using these inputs and controls, he and his officers synchronize the flow of vehicle and pedestrian traffic during regular games.

Cobb County's Public Safety departments use GIS dashboards and data on a regular basis to ensure citizen



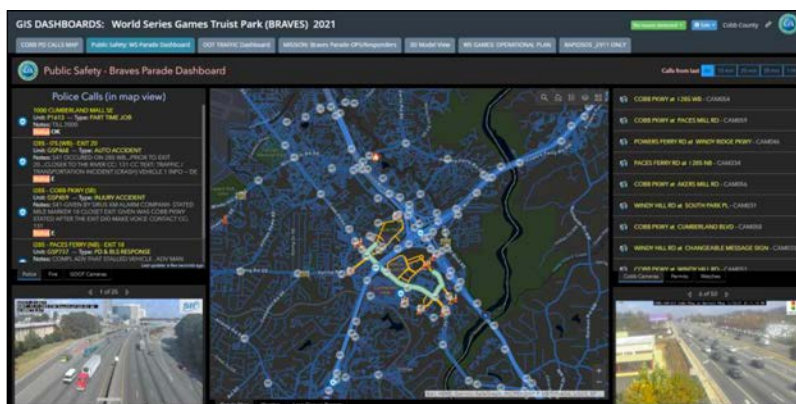
The Braves Championship Celebration parade route wove around the stadium.



The operations center office featured a view of the field.

safety. These seasoned GIS users trust and know how to use the data, maps, and dashboards as location intelligence. These trained users then became the trainers as more personnel were added during the playoff run.

For the 2021 World Series games, the number of police officers roughly doubled that of a typical game to handle larger crowds and longer hours. Officers were organized in three main groups: inside the stadium, traffic and operations,



The public safety dashboard combined feeds from camera and traffic centers for the security of the World Series Games at Truist Park in Cobb County, Georgia, in 2021.

and overall campus security. The groups relied on GIS for real-time information and communication.

“We normally see 40,000 people in the stadium and another 5,000 people in The Battery,” Lorens said. “For the World Series games, we had 100,000 people on a 100-acre footprint, and we saw traffic start at 11 a.m. for a 7 p.m. game.”

Location is also critical for the county’s AI system used to analyze foot traffic from the video feeds. GIS and AI technologies combine to inform changes in traffic light sequences to keep people and vehicles flowing.

“We have 50 different datasets on the map from the footprint of the stadium, all the businesses, the lights and cameras, the traffic data feed, 911 calls, traffic from Uber and Lyft rideshare, and the location of Cobb County vehicles,” Lana said. “We have built that awareness over time, so we didn’t have to change much for the World Series, but there were modifications.”

Lorens has learned that each game has a distinct traffic pattern, and he developed specific maps for day versus night games or weekday versus weekend games. When it came to the playoffs though, he could not count on prior predictability.

“Once you get to a championship series, it doesn’t matter what day the game falls on, because everyone takes off work,” Lorens said. “You go to the most robust map you have, and you use that.”

Dashboards and Real-time Tracking

Having a well-provisioned stadium security setup has helped Cobb County deal with the unanticipated nature of professional baseball planning. As the team worked its way

through the playoffs, each subsequent win and series ratcheted up interest and attendance at the games.

The primary GIS toolset Cobb County relied on includes ArcGIS Mission; it tracked the location of roving plainclothes officers working throughout The Battery. With command-and-control software, the incident commanders in the operations center could make tactical resource assignments and get real-time updates from the field, and then share information across teams. The fact that the app could be accessed on a smartphone was key to the stealth requirements of the operation.

“Undercover officers are in a unique situation because they don’t have radios,” Lana said. “But everyone on the planet has a smartphone, and nobody is going to think twice about someone looking at a map on their phone. On the app, officers could see each other and where a dangerous situation was happening, and in the command center, we knew no officer could get lost in the crowds.”

Other smartphone features also came in handy.

“Our analysts,” Lorens said, “could look up a license plate tag or provide background information. When it’s just a text,



The operations center combined personnel from all emergency service agencies who used maps for awareness and to guide activity.

that can get siloed between two people, and here everybody was able to see it and add to it if needed.”

Putting the Wraps on a Stellar Season

For Cobb County’s World Series games, the use of Mission was tactical, guiding public safety response to incidents involving unruly behavior. “There were a lot of drunk people everywhere,” Lana said. “Each time the Braves won, the crowds got bigger and crazier.”

For Lorens, and his public safety team, a map was key to keeping control of rowdy situations. “We were able to see where our people are and put them in places so everybody else saw them,” he said. “For commanders, we could make sure we had coverage so that nothing critical happened.”

Lorens and his team applied GIS in a more integrated way for the victory parade where the ability to track officers and floats in real time was critical, ensuring safety and easing traffic disruptions. It’s a method the county will employ moving forward. “Now we’ve got a blueprint,” Lana said.

Lorens added, “I plan to build out the map of where we had bottlenecks and where we responded with more staff, and I’ll keep that in my back pocket.”



A detailed dashboard of traffic around the stadium helped traffic managers keep traffic moving during the games.



The SAFER system supports the needs of all first responders, including this firefighter who can see the location of other units responding to the same incident.

Frisco, Texas, Finds Success with a Public Safety Digital Twin

Frisco, Texas, has a live map of public safety incidents and personnel locations shared across police, fire, and transportation departments. This map, a public safety digital twin, extends inside schools, allowing responders and staff to see live video of hallways. If traffic backs up, the live map is viewed by transportation engineers who can remotely change traffic signals. When incidents occur, fire and police staff use the digital twin to route themselves to calls and coordinate response.

After 15 years of continuous evolution, numerous examples exist of how the Situational Awareness for Emergency Response (SAFER) platform lives up to its name.

Frisco's use of GIS technology, the underpinnings of SAFER, has grown, keeping up as the city grew from 30,000 to 230,000 residents between 2000 and 2023. Safety has become a big selling point for the city. For 2022 and 2023, Frisco was recognized as the safest city in the US due to its low rates of property and violent crime.

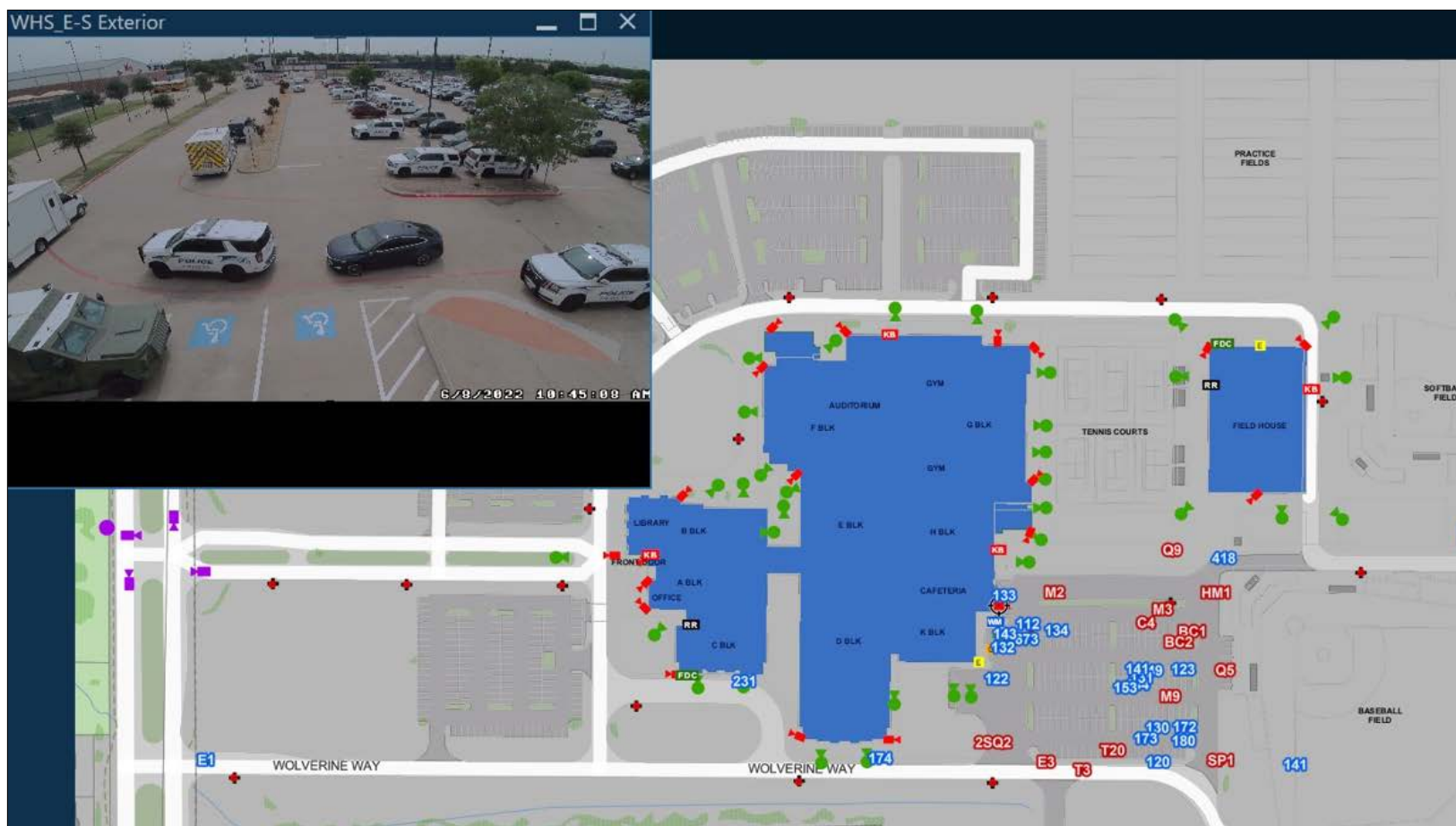
"Back when I started in 2001, we didn't have an IT department, but city leadership embraced the power of GIS," said Susan Olson, assistant director of IT, and lead for GIS and SAFER. "I was told, 'We need GIS because we can't grow without understanding our city.'"

Frisco police chief David Shilson likes how SAFER provides access to information in the field for faster responses and resolutions. "In simple calls like minor accidents, dispatchers and responding officers can pull up traffic cameras through links in SAFER and determine the best approach. In larger scenes, incident commanders can look at where units are in order to quickly set perimeters and direct incoming resources."

SAFER has gained daily use across multiple city departments, increasing collaboration among city staff. When problems occur, it provides clarity, allowing first responders to get critical information fast.

Meeting Needs and Finding Champions

Today, SAFER supports the needs of all first responders and has become a passion project for Olson, who pioneered the system. She now oversees all enterprise GIS for the city. Olson first earned the trust of public safety professionals by using GIS to make sure all city roads and addresses—even those still in the planning phase—were accurately mapped.



SAFER started with the school district. One of the first steps was integrating school floor plans with links to cameras aimed at school hallways and access points.

"Often accidents and crime happen when sites are under construction," Olson said. "We put new roads on the map when there's a plan so everyone has awareness of where new development is happening."

With every call for service, having the right location improved response times and outcomes. Olson then spent years delivering on the original vision of SAFER to create one shared system to respond to all calls. The system accrued a long wish list: requirements to add, data to capture, systems to integrate, staff to train, partnerships to forge.

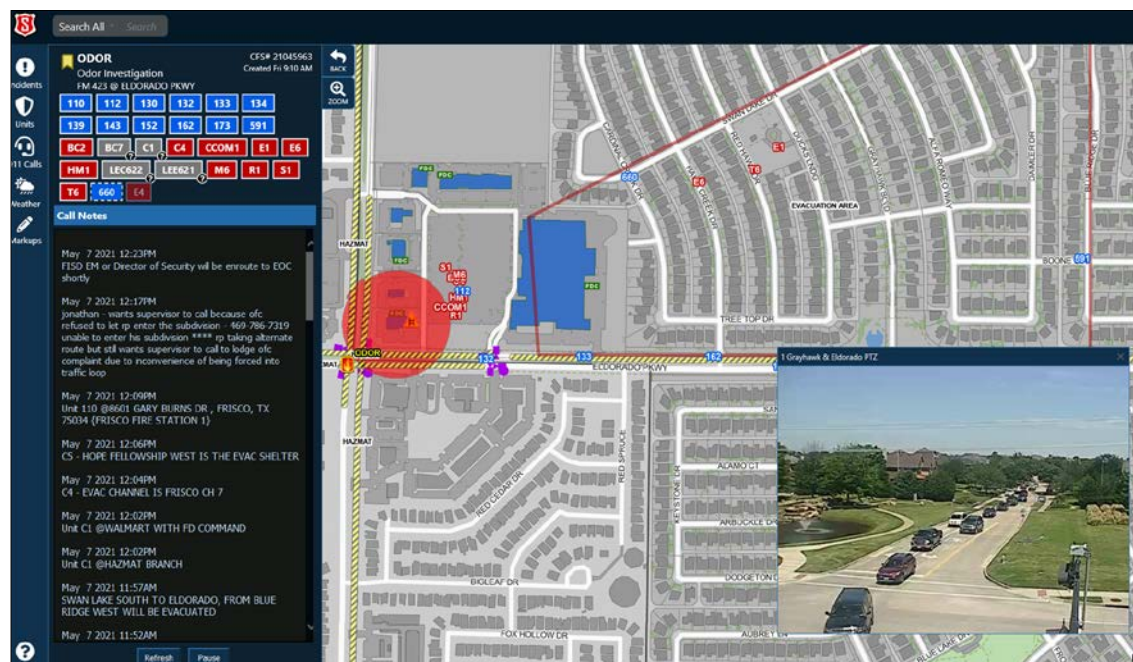
The SAFER team refreshed and modernized the user interface and application code in 2023. They worked with other city IT staff to improve responsiveness and sustainability.

SAFER is used at all 78 Frisco schools, serving more than 66,000 students. Jon Bodie, the director of emergency management for the Frisco Independent School District (FISD), compares first responders using SAFER to an orchestra working from the same sheet of music. "Campus incidents and emergencies range from routine calls to lockdowns and threat investigations," he said. "With access to over 4,000 FISD camera feeds and floor plans, SAFER allows Frisco agencies to coordinate resource support for these emergencies in real time, ensuring students and staff stay safe."

The Frisco Fire Department schedules yearly visits to every school to ensure that school information is up-to-date in SAFER. "The firefighters and school administrative staff work together during a fire drill to critique and identify areas of



During the hosting of the Academy of Country Music Awards, the operations center viewed camera feeds and maps on a large video wall.



The SAFER system shows the location of events, an image, and the location of emergency personnel.

"We built the reliance on SAFER over time on a foundation of accurate data, strong integrations, and being responsive to needs," Olson said.

Daily, city residents use a crime map app that's an offshoot of the SAFER system. "Our residents are very engaged and aware of their surroundings, and they let us know if the data doesn't look right," Olson said.

The success GIS has seen hasn't been limited to public safety, it has also helped fuel Frisco's growth and entice corporations to make the city their home. "When our Economic Development Corporation staff

improvement," said William Clay Carpenter, deputy chief of the Frisco Fire Department. "Through this collaboration, staff from both agencies get to know one another better and strategize student safety."

are trying to attract a company, they work with our GIS team," Olson said. "We've built web apps for companies to show them all Frisco has to offer."

Always Updating, Adapting, Integrating

Scaling SAFER to keep pace with the city's massive growth has required diligent attention and communication across departments. The system now integrates more than 30 systems, including live links to traffic cameras throughout the city and real-time traffic from HERE, and it holds dozens of GIS data layers.



When a construction crew ruptured a six-inch gas line near a school, SAFER was used to coordinate first responder actions.

Lasting Lessons in Search and Rescue from Hurricane Ian Response

After Hurricane Ian swept through Florida in September 2022, first responders, the US Coast Guard, the National Guard, and Urban Search and Rescue (US&R) teams rushed

in, going door to door to rescue and assist more than 2,500 people. The category 4 storm reduced many beachfront towns to rubble, and storm surge flooded large swaths of the state.



Fort Myers Beach, Florida, was devastated by Hurricane Ian in September 2022.

Thousands of people living aboard boats posed an early concern, because the storm surge coincided with the highest tide that month, and hundreds of boats were pushed deep into the mangroves.

“That kind of search was never done before,” said Mike Zielonka, a captain on Orange County Fire Rescue, Florida Task Force 4 (FL-TF4). “Searchers sent up a drone when they got close to each boat to see if it was even inhabitable. That way we wouldn’t sacrifice a person wading through really hazardous conditions if a search wasn’t needed.”

FL-TF4 focused on large liveaboards, ranging from billion-dollar yachts to shrimp boats, conducting hundreds of searches in hard-to-reach places. Zielonka and team used postimpact aerial images to drop way points indicating the next boats to search and forwarded a live map to teams that spread out by boat and bushwhacked through mangrove thickets. “The map helped us make sure we covered our bases so we could be very accountable for the areas we searched,” Zielonka said.

The FL-TF4 team and more than 20 other search and rescue teams used a suite of tools called the Search and Rescue Common Operating Platform (SARCOP) to collect more than 108,000 field observations. The toolset enabled them to segment search areas to be covered in 12-hour shifts, show tracks where each team had been, and drop icons to indicate what was found or done. The situational awareness gave each team as well as coordinators at the state and federal levels the means to stay informed and adjust quickly to cover places where people might be found.

“It made for a better use of teams, not duplicating efforts,” Zielonka said. “I have a long list of the names of the storms I’ve been to over the years, but as far as severely impacted coastal areas, Fort Myers, south Sanibel, and south Pine Island had the most damage I’ve ever seen. The storm wiped the sand clean of structures, leaving behind just piles of sticks.”

People, Process, Technology

SARCOP has been 10 years in the making, with a team made up of GIS practitioners from the National Alliance for Public Safety GIS (NAPSG) Foundation, funding and support from the US Department of Homeland Security Science and Technology (DHS S&T), FEMA, and solution engineers from Esri who refined the toolset over the course of many disaster events.

SARCOP takes a people, process, technology approach to search and rescue. It pulls together ArcGIS mobile apps—including Survey123, QuickCapture, Field Maps—and ArcGIS Online in a wrapper built with ArcGIS Experience Builder to capture search and rescue workflows. SARCOP provides a system that’s ready to go, works right away, and is designed for use throughout a wide-area-search incident, such as floods, hurricanes, and tornadoes.

“There have been a lot of smaller deployments, like in Texas where they used SARCOP more than three different times in 2022 for wildfire, tornadoes, and flash floods,” said Paul Doherty, emergency management specialist (geospatial) at FEMA. “Those no-notice events are important because there is less time to prepare, so having a common system ready to go really makes a big difference for first responders.”

For Hurricane Ian, Florida’s whole US&R system adopted SARCOP for the wide-area search that took two weeks. The local adoption is a key to the success because each disaster starts and ends locally. FEMA coordinates with others and lends support, but it doesn’t lead the response to disasters. Over the years, FEMA has invested in SARCOP and worked alongside the NAPSG Foundation, the International Association of Fire Chiefs, and others to create a common platform to enable all search and rescue responders who don’t have the ability or funding to build something like this themselves.

Jared Doke, who works closely with Doherty as a program manager for the NAPSG Foundation through a grant from DHS S&T, explained efficiency gains and how the tool has evolved.

Several years ago in Louisiana, we had a state team and a federal team that were drawing search and rescue segments over each other, going to the same places, and we didn't know that until the data started showing up. Before we had the ability to draw segments on a map, teams were overlapping, not knowing others were there until they'd bump into them on the streets.

—Jared Doke, program manager at NAPSG Foundation

During 2023 recovery events, with SARCOP adopted by more teams, the search was done much faster because there's little overlap.

"You can spend a lot of time just asking someone where they are, but when you can see everyone on the map, it removes a lot of that time-consuming chatter," Doherty said. "Hurricane Ian was a breakthrough for us, because we had, in one map, live tracking of both federal and state teams across a wide area."

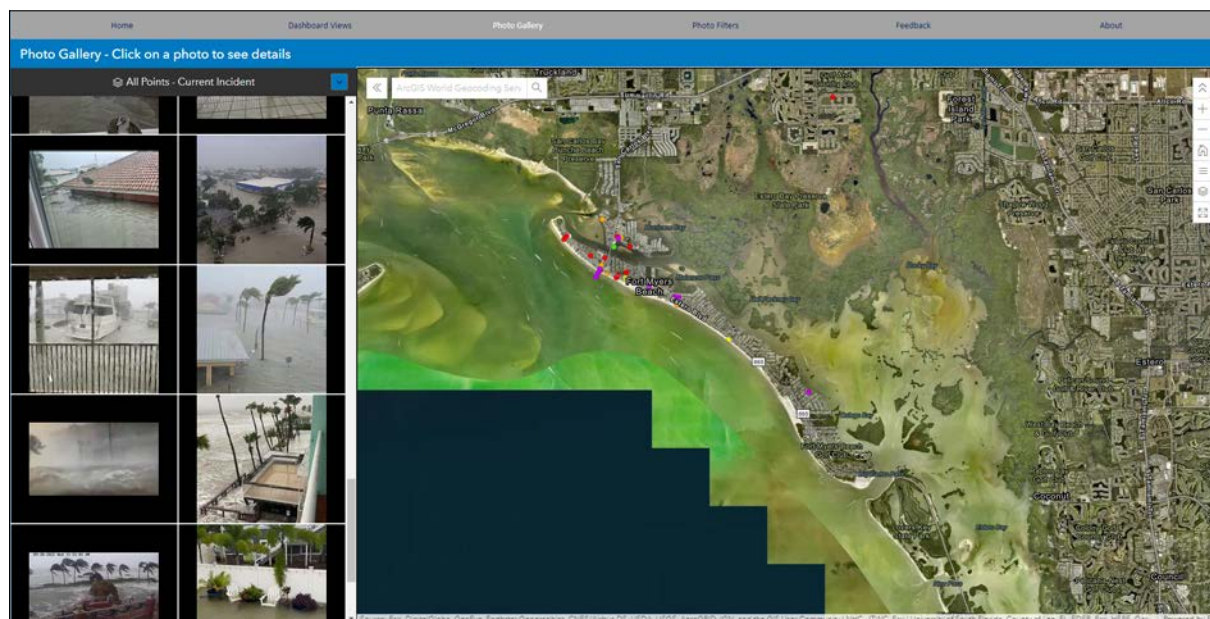
US&R Incident Support

Lexi Passaro deployed to Florida for Hurricane Ian as a situation unit leader on FEMA's Blue Incident Support Team, which coordinated US&R operations, including strategic and tactical planning. She has been involved with SARCOP's evolution, using a predecessor tool and then the 2022 iteration on missions to the Champlain Towers building collapse in Florida, floods in Kentucky, and now Hurricane Ian.

"In just a year, it has matured and evolved," Passaro said. "We came up with an intel cell concept, which is even now maturing into a Search and Rescue Intelligence Group concept. When the data and imagery is combined with human intelligence and remote sensing like unmanned aerial systems images, video, thermal imaging, and other technologies, we can make science- and data-based decisions on search planning. The technology has been there for a while, but now we're getting to use it in more beneficial ways."

Members of US&R task forces are certified for their skills, such as structural collapse, wide area search, swiftwater rescue, confined spaces, hazmat, and other specialties. Passaro relishes her role as a "translator", to analyze data and information coming from SARCOP and distill it into an informed search plan the Incident Support Team then uses to guide specialists.

"A lot of our members are very skilled at technical rescue, which involves power tools to break and cut concrete, which is really hard hands-on work," Passaro said. "These are folks who



Some of the first evidence of storm damage is collected from a crowdsourcing cadre of #PhotoMappers from GISCorps who take images posted on social media and place them on a map.



Virginia Task Force One travels by boat to search the offshore islands that were cut off when Hurricane Ian destroyed the bridges.

day to day are often running into burning buildings, which doesn't involve computers. They appreciate how easy the tool is to document what they just did, because the data helps all of us. It's a culture of problem-solving and helping, and just getting done what needs to be done."

Data-Driven Preparation and Response

Before Hurricane Ian made landfall in southwest Florida, FEMA's response geospatial office provided models of where homes might be damaged. The modeled data drives response, knowing where and how many families will need help. It's also useful for coordinating and clustering search and rescue teams where the most help will be needed.

FEMA's Tool for Emergency Management and Prioritizing Operations (TEMPO) uses the Priority Operations Support Tool (POST) algorithm to provide predictions for areas of greatest social vulnerability, looking at conditions that would cause people not to evacuate, such as non-English language speakers, financial hardship, or lack of transportation.

The US&R teams use this information to plan searches in the hardest-hit areas first, to do what's called a hasty search, moving fast to get people out quickly. Once that is completed, they then go door to door—this is when the SARCOP map fills in, with first a primary search and then a secondary search to find people who may be trapped.

During the Hurricane Ian response, internet connectivity was supported by the federal program FirstNet, which supplies mobile telecommunications infrastructure for first responders, and by the satellite-based internet company Starlink. Connectivity ensured response teams could access and make use of photos US&R collected in QuickCapture, as well as other imagery and video captured from drones.

Always Improving

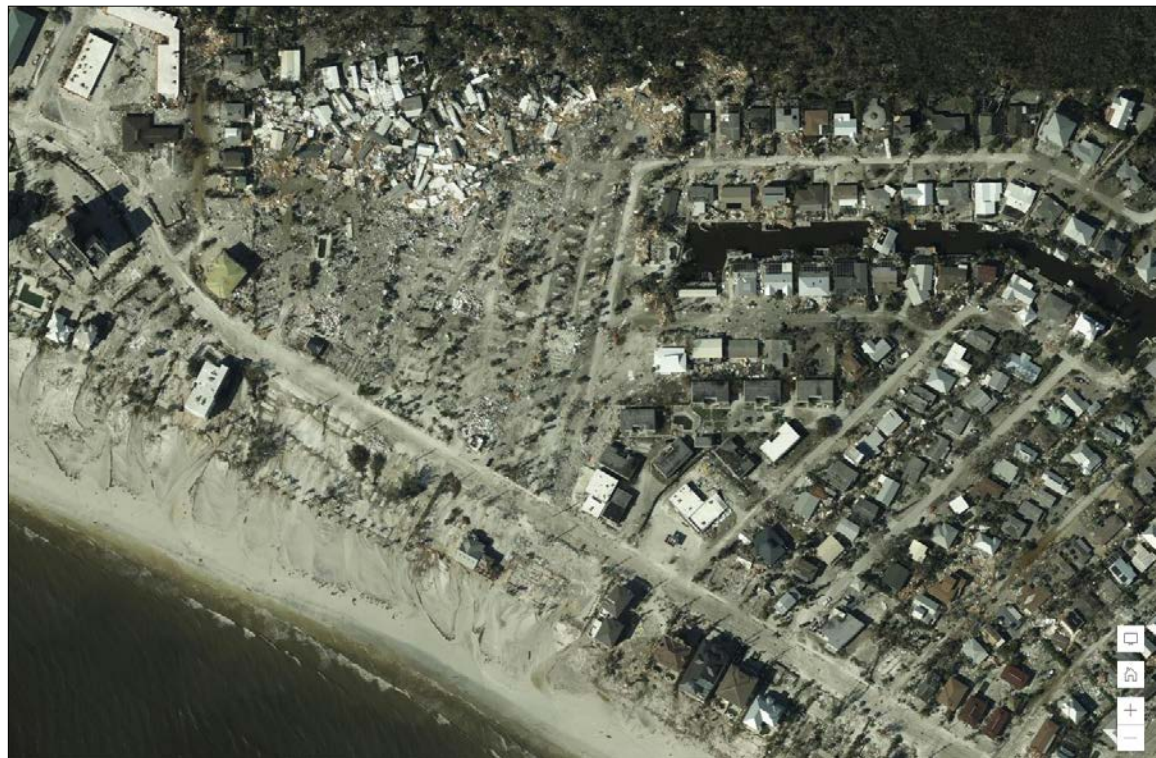
Future goals with SARCOP are to apply a Search and Rescue Intelligence Group concept, using its agile framework to pull data together and see it in different views for different groups.

A preincident image of Fort Myers Beach is easily compared with the next image of post-incident damage to see what has changed.

Another objective is to predict how long it will take to search an area, based on factors such as population density, distance traveled, and severity of impact. This leap will help leaders allocate the right number of resources for the task ahead, whether the mission is in a city or rural area. The ability will build on past performance to know what teams are capable of accomplishing.

Tablets and phones were used on the Hurricane Ian response, and both will continue to be supported for SARCOP. But with GPS and data capture tools in use, better battery charging systems are needed to keep devices powered during dynamic searches. Internet access is key to collaboration, and continuing to improve connectivity is a high priority.

The post-incident image of Fort Myers Beach shows the extent of the damage.



The SARCOP damage map classifies buildings in red for major damage and purple for destroyed.

The outreach continues with states, cities, counties, and agencies, such as the US Coast Guard, to spread the word about SARCOP and welcome wider participation. The more people who use it, the more effective it can become. With greater information sharing at the outset, the stage can be set for a swifter recovery.

"We're there for two weeks, mostly to protect and save lives," Doherty said. "At the end, we package up the information to give it to the local agency to help them plan the recovery. Recovery is the long game, because that will last months and years, and we're happy to help them get off to a good start."

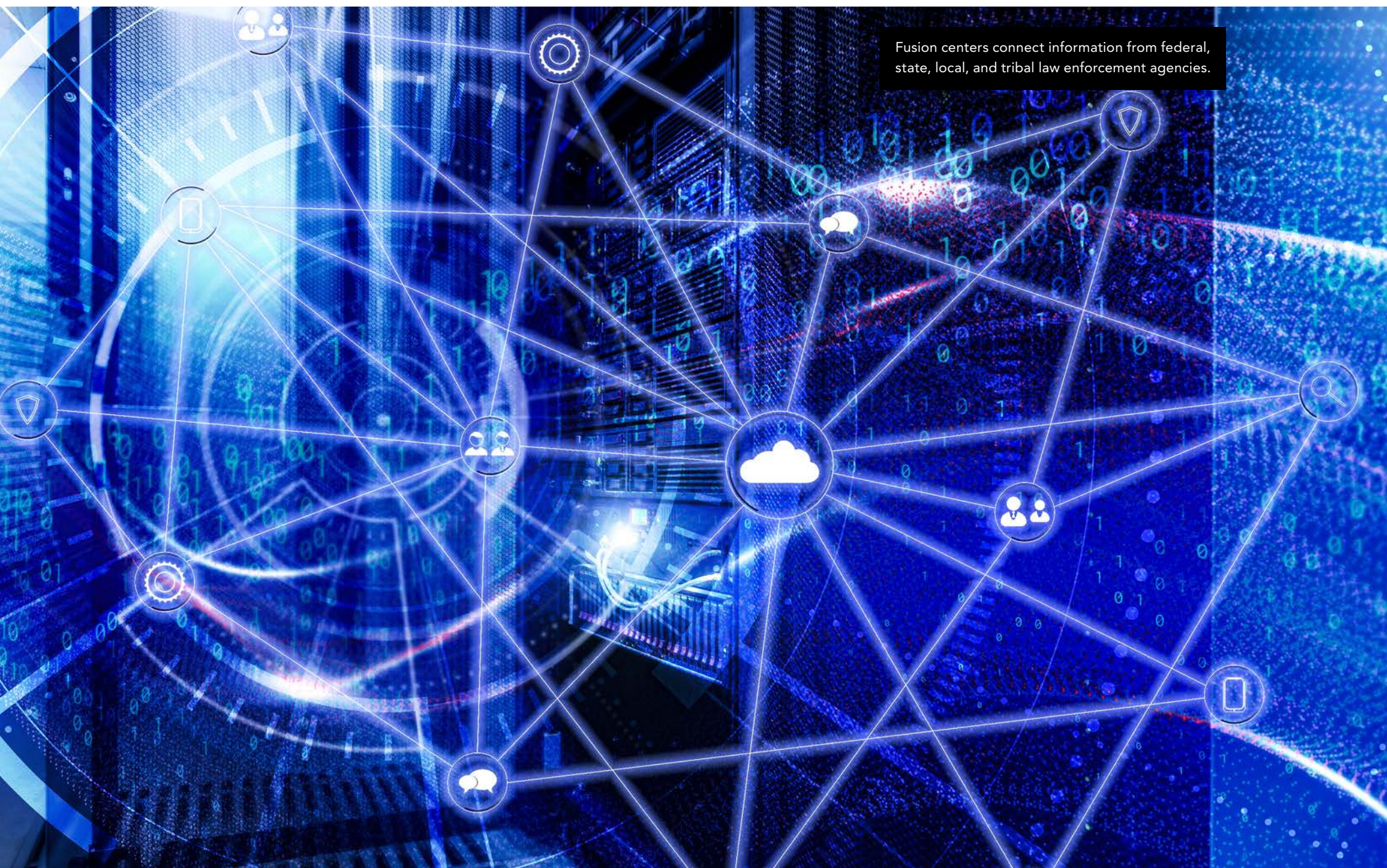
The maps for tracking the path of teams begin to look like scribbled crayon marks, showing where people have been and where there are gaps in coverage.



Fusion Center Concept Evolves with Streamlined Data Sharing

Following the terrorist attacks of September 11, 2001, a consensus in federal, state, local, tribal, and territorial government and law enforcement formed around the need for better information sharing.

The result was the creation of a network of information clearinghouses called fusion centers and the organization of the US Department of Homeland Security. Today, 80 fusion centers across the US and its territories use high-tech technology to integrate and share data.



Fusion centers connect information from federal, state, local, and tribal law enforcement agencies.

These centers have helped identify suspicious acts related to both violent crime and terrorist activity. They form a vital network of thousands of experts—police and firefighters, emergency medical services, and narcotics enforcement agents—working with private-sector owners of critical infrastructure and federal, state, and local authorities. Cities and counties with real-time crime tracking capabilities connect their data and camera feeds, adding a granular awareness from Real-Time Crime Centers that work with their fusion centers. GIS and other IT staff support the efforts by analyzing data and creating information products to guide decisions.

A lot of information fusing takes place. But ask almost anyone in these agencies, and they'll likely say they could collaborate and share more.

"America operates law enforcement through 18,000 individual agencies that are islands," said Mike Sena, director for the Northern California HIDTA and president of NFCA.

Sena has a vision for a next-level geographic approach to crime fighting to not only create maps but also provide an up-to-date shared awareness of the location of public safety threats to all fusion centers and their partners across America. He cites the example of a school threats dashboard he created using GIS technology that revealed wide-scale incidents that investigators have repeatedly determined were hoaxes.

"One day we had over 200 threats to schools around the country," Sena said. "We never would have seen the scale without visualizing input from nationwide data collectors. People were reporting threats in near real time, and we could see it on the map to figure out the extent of the problem." Though the incidents still required a response, the ability to see the widespread pattern helped police officers take a measured approach—investigating and information gathering rather than immediately activating heavily armed responses.

Dealing with the Fentanyl Crisis

Sena has navigated the complexity of data sharing across jurisdictions and domains in dealing with the drug overdose

crisis. He currently works with a team investigating a large fentanyl distribution network in San Francisco with more than 260 dealers that move large quantities every day.

The operation involves multiple agencies and undercover officers who share a common operating picture to break up this nefarious network. Analysts use GIS to map key locations, such as where dealers live, where they sell drugs, and where they have been arrested.

I see GIS as a giant multilevel chessboard. But we're often playing checkers in law enforcement. We see the immediate target, and we jump on that, but we're not going for the queen . . . the pieces that matter.

— Mike Sena, director of the Northern California HIDTA

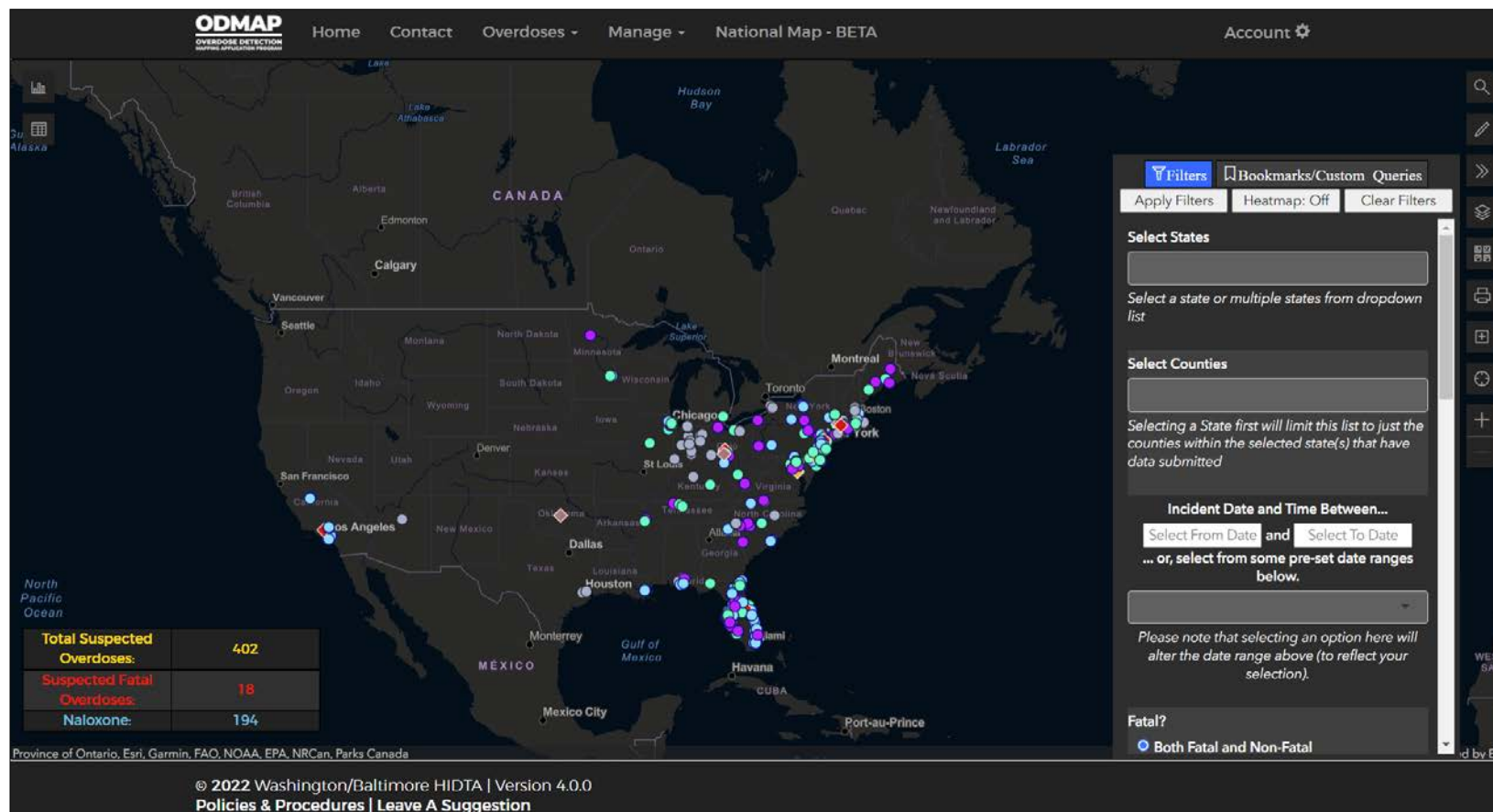
As Sena sees it, GIS technology gives law enforcement an information edge.

"We're dealing with organizations and groups of people that have unlimited amounts of money and know how to raise funds quickly with illicit substances," Sena said. "We need to organize ourselves better."

Sena learned from the experience of Director Tom Carr and Deputy Director Jeff Beeson at the Washington/Baltimore HIDTA as they deployed the Overdose Detection Mapping Application Program (ODMAP) across the nation. The map provides near real-time suspected overdose data across jurisdictions to support public safety and public health efforts. It has proven effective in mobilizing an immediate response to a sudden increase, or spike, in overdose events. The same type of map-based alerts, Sena said, could be used for responding to shootings, robberies, organized retail theft, and burglaries.

Seeing Violence and Crime

Sena aims to take the school threats and overdose dashboards to the next level. He envisioned a system for fusion centers to connect additional threat-related dashboards, adding alerts, collaborative tools, and even video



The Overdose Detection Mapping Application Program, or ODMAP, links first responders and relevant record management systems to a mapping tool to track overdoses to stimulate real-time response and strategic analysis across jurisdictions. It was developed by the Washington/Baltimore High Intensity Drug Trafficking Area, or HIDTA.

conferencing. He reached out to Esri and Microsoft—companies that engineer two of the core technologies all agencies possess—to combine the best of Esri’s GIS map visualization capabilities with the collaborative tools of Microsoft Teams.

They created the Threat Reporting Exchange, or T-REX, as a proof of concept. It brings Esri and Microsoft platforms together in a collaborative space with a shared dashboard, an area for analysis, and a way to see real-time trends across the nation.

“We can share data and visualizations with 25,000 people in real time,” Sena said. “Fusion centers have never had that capacity before.”

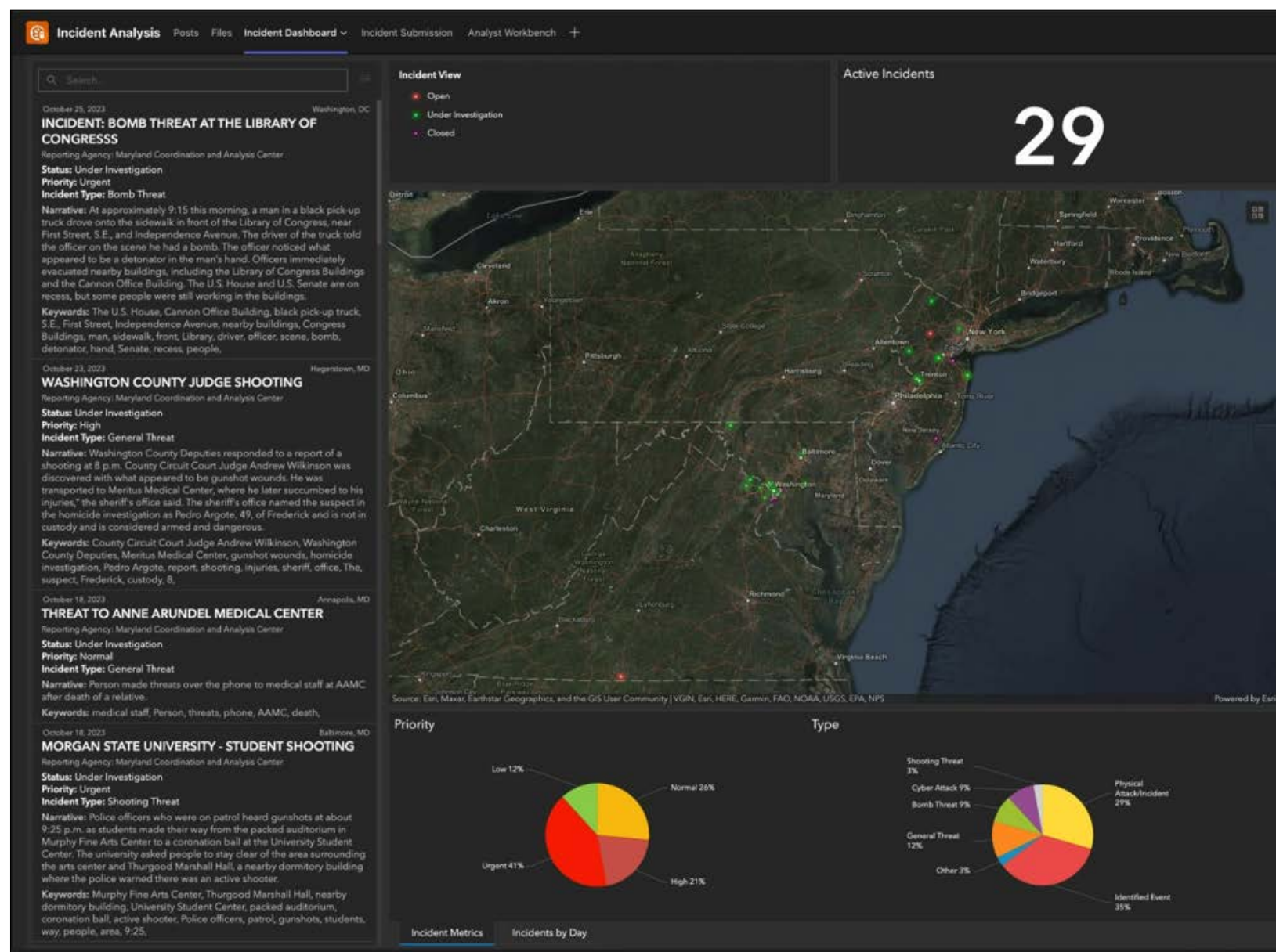
Sena hopes to continue to refine T-REX and expand it to 100,000 concurrent users, with the ability to conduct real-time briefings for all fusion centers and their stakeholders in local law enforcement.

“The goal is to ingest data from whatever sources and pull it onto maps,” he said. “Ultimately, we hope to identify anyone who is causing harm to the community and a way to both see the threats and understand how to defeat them.”

Criminologists have shown that violent crime leads to more violent crime. The nationwide spikes in drug use, gun violence, and robberies are complex and interrelated. Sena would love to map all the dimensions of these issues—putting it all on a multilevel chessboard that all fusion centers, HDTAs, and their partners can share.

“Mapping threats helps us connect all those islands with bridges of information,” Sena said.

The T-REX dashboard integrates Esri's geospatial tools with Microsoft Teams for collaborative threat management.





Smart Planning

Effective and efficient smart planning uses a location-based, data-driven approach and prioritizes the human element in community design. Urban and community planners are achieving critical strategic goals through location intelligence.

Digital twins are becoming a key tool in urban development and planning, helping to visualize the future of cities and regions. They provide a clear and interactive view of proposed developments, helping planners make informed decisions and encouraging public participation.

In southeast Michigan, Jeff Nutting, forecast coordinator for the Southeast Michigan Council of Governments (SEMCOG), highlighted the importance of digital visualization in planning. “We wanted to show the potential of a site ... We needed something we could see and share, beyond just our imagination,” he said. This approach has allowed SEMCOG to create detailed, realistic models to visualize future developments and infrastructural changes.

Planners in Kauai, Hawaii, sought ways to preserve the character of a historic Hawaiian neighborhood called Kaumakani. The planning department for the County of Kauai used maps and GIS technology to help record and protect Kaumakani’s unique character. A survey of the area gathered details and incorporated them in a new type of building code, protecting Kaumakani’s roots from cultural erosion.

“To write the code, we made a lot of measurements, took photos of everything, and put together a series of features,” said Alan Clinton, an administrative planner for the county.

As the map was developed, it revealed patterns that helped the planning department define the formal elements the landowners needed to include in their structures.

In Montgomery County, Maryland, GIS technology is being used to create a dynamic digital twin. This allows developers to accurately identify potential opportunities and helps the public understand future community development.

Montgomery County’s Thrive 2050 plan also prioritizes dense, sustainable housing. The plan emphasizes transit-oriented development and ensures racial equity and climate resilience. “We know we need to satisfy more residential development to keep housing affordable,” said Chris McGovern, manager of the Information Systems/Geographic Inventory System at Montgomery Parks and Planning. This focus on sustainability and resilience allows for a balanced approach to urban development.

A key theme emerging from urban planning discussions is the prioritization of sustainability and resilience. Cities are increasingly focusing on reducing emissions, promoting energy efficiency, and preparing for the impacts of climate change.

In Vienna, Austria’s, aspern Seestadt development, an ambitious commitment to lower environmental impact has been incorporated into the project’s comprehensive plan. “This gives every member of Wien 3420 the possibility of seeing a complete picture. ... Our goal is for every member of the organization to directly access it in their work,” explained Petr Bocharnikov, a digital strategist with the Swiss firm Sokigo, stressing the importance of a sustainable and resilient urban vision.

Brownfield redevelopment, or the process of repurposing previously used or contaminated land, is emerging as a crucial approach to urban revitalization. By identifying, assessing, and remediating these sites, cities can create new housing opportunities, generate businesses and jobs, and improve the overall livability of urban areas.

In Bridgeport, Connecticut, the Connecticut Metropolitan Council of Governments (MetroCOG) created a map-based Brownfields Inventory Site Selector tool to tackle the challenge of redeveloping formerly industrial sites. “We’re trying to eliminate as many impedances as possible,” said Patrick Carleton, deputy director at MetroCOG. “Getting information out there and accessible makes an easier path forward for redevelopment.”

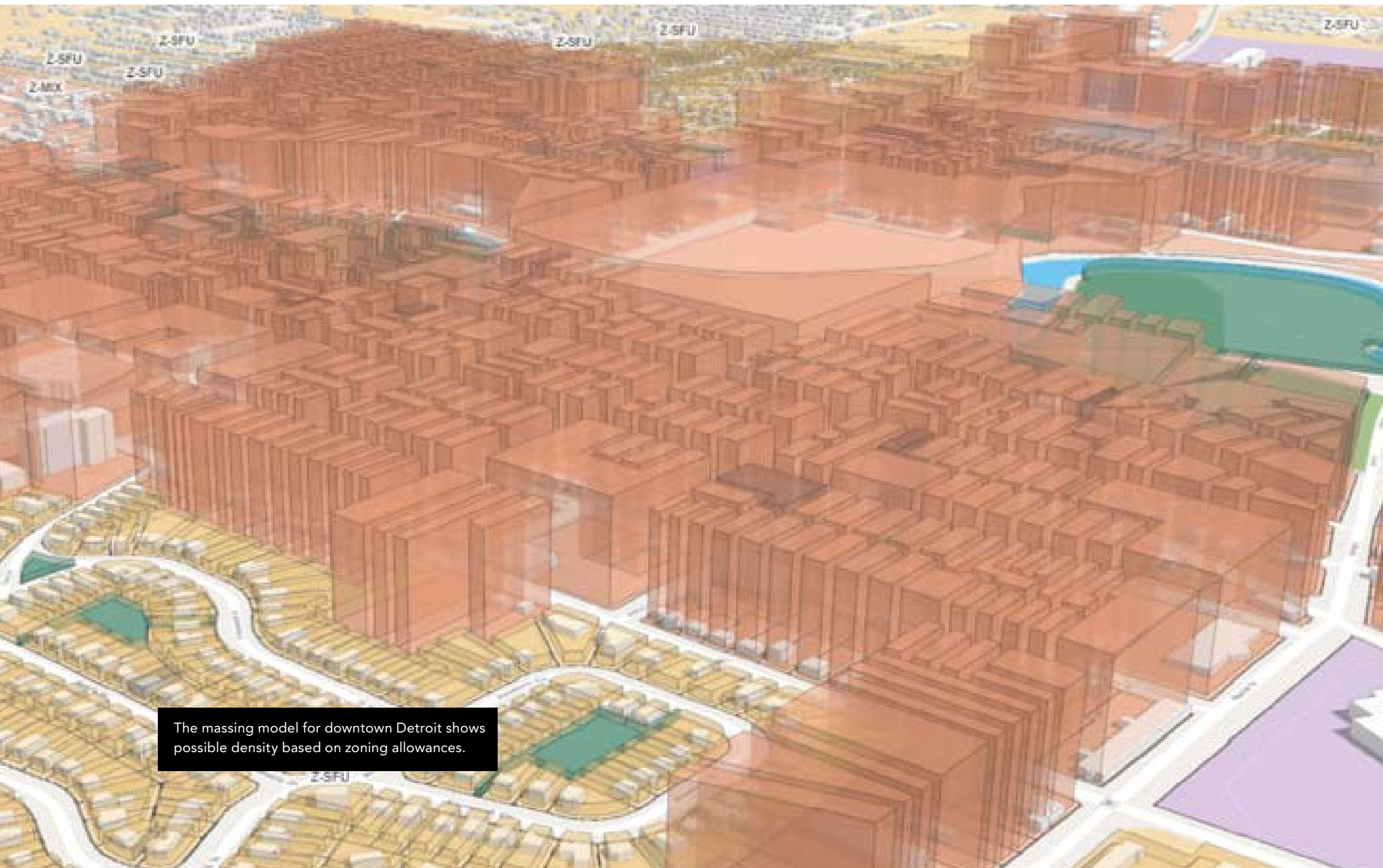
“With all the growth that’s happening, our plan is to divide the region into places that we talk to every year, instead of every three to five years,” said Matt Fulda, executive director at MetroCOG.

Using GIS technology, planners determine how, when, and where their designs can have the greatest impact.

Digital Twin Provides Clear Picture of Detroit Region's Revitalization

The Detroit region is growing and thriving. The people there benefit from connected small towns, dynamic urban centers, active waterfronts, diverse neighborhoods, leading educational institutions, and abundant agricultural,

recreational, and natural areas. SEMCOG, a seven-county regional planning organization serving the 5 million people in the metro Detroit region, has its eye on all these elements. It helps local governments and residents see how each of these assets are vital parts of what makes the region so livable.



The massing model for downtown Detroit shows possible density based on zoning allowances.

Detroit has some of the most visible signs of transformation. A large open lot in central downtown—the result of the 1998 teardown of the flagship Hudson’s department store—is being filled by what will be the city’s second-largest building, set to contain a dynamic mix of event space, stores, restaurants, hotel rooms, offices, and residences.

Evidence of the rich mix of the area’s assets and revitalization are now available for anyone to see in 3D maps showing not only the city’s present but also the entire region’s future. Development plans for the next 30 years in Detroit and a couple hundred surrounding communities are now clearly visible, thanks to what’s being recorded in the GIS used by planners and municipal leaders in southeast Michigan.

“We wanted to show the potential of a site, even if all we had was a city mayor saying, ‘We’re going to get this developed, and it’s going to have a hotel, restaurants, and condos.’ We needed something we could see and share, beyond just our imagination,” said Jeff Nutting, forecast coordinator for SEMCOG.

Seeing the Long-Range Future

Using GIS to compile details and conduct analysis every five years, Nutting oversees SEMCOG’s 30-year forecast of population, housing, employment, and land-use changes.

The forecast supports spending decisions on infrastructure management—such as water, sewer, and transportation projects—including what roads and bridges to widen or repave.

For the agency’s 2050 forecast, SEMCOG asked 232 communities in the region for their development plans in fine detail. Instead of simply asking how many units were planned for a specific parcel, SEMCOG captured site and concept plans that show how roads and buildings are laid out, how tall the buildings will be, and how much square footage they will have. The site plans also convey the amount of pavement

planned, which informs impervious-surface calculations for stormwater planning.

“We thought, if we used planning documents, it would be something they already have and we would be speaking their language,” Nutting said.

More than 200 communities contributed plans and data in the 2022 round, compared with fewer than 100 in 2016.

Most planners in the region are so busy managing developments, they don’t have time to calculate growth. SEMCOG envisioned a new kind of outcome. By inputting plans, the forecasting team would provide a detailed and realistic model to visualize what was coming.

If the planner didn’t have a site plan for a planned development, Nutting and his team used ArcGIS Urban to design a concept plan for the site. The planner was presented with some option of development type, and then a rules-based model showed what that would look like.

SEMCOG processed 800 development site plans as part of the forecast process creating a digital twin of the region. Rather than points on a map, the new map shows what kind of growth is planned, including the building footprints of all multifamily housing projects or single-family homes, and gives planners an awareness of regional development patterns.

“It’s much easier for communities to double-check what we’ve put together,” Nutting said. “We’re giving them a map of current and future buildings.”

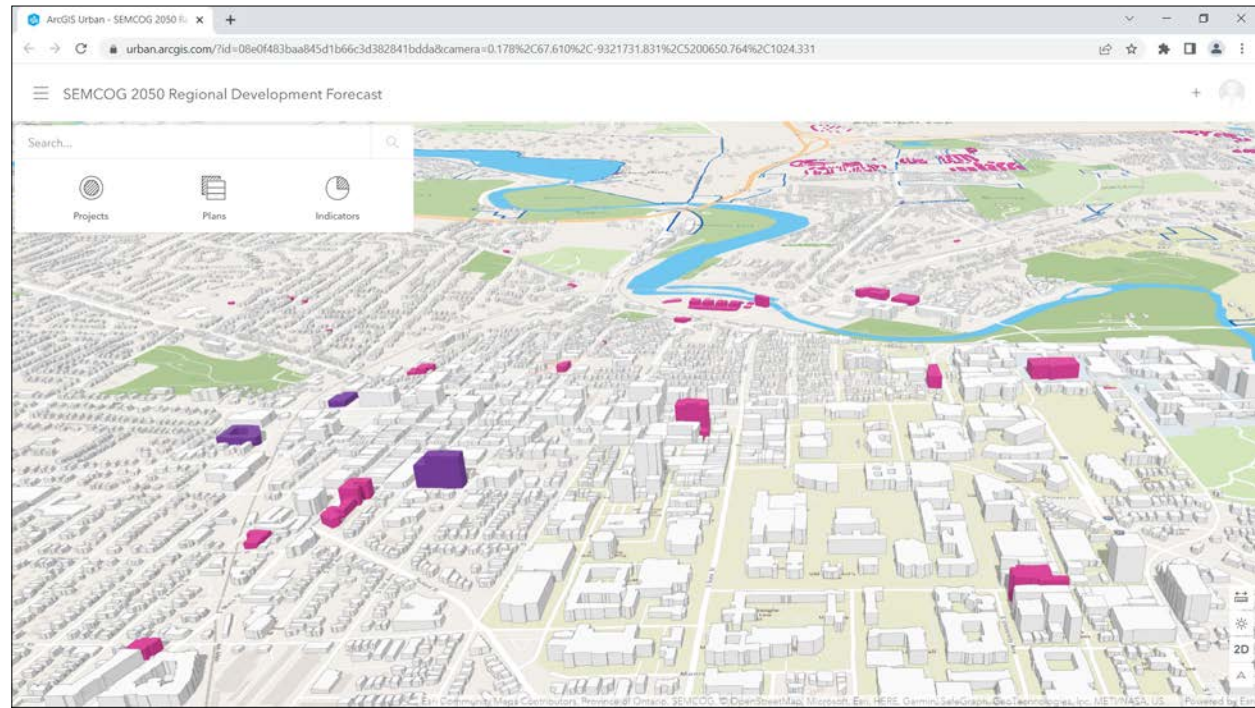
Watching the Detroit Region Expand

Putting all the data on a map helps SEMCOG see what things look like regionally and triggers questions about where development will go next.

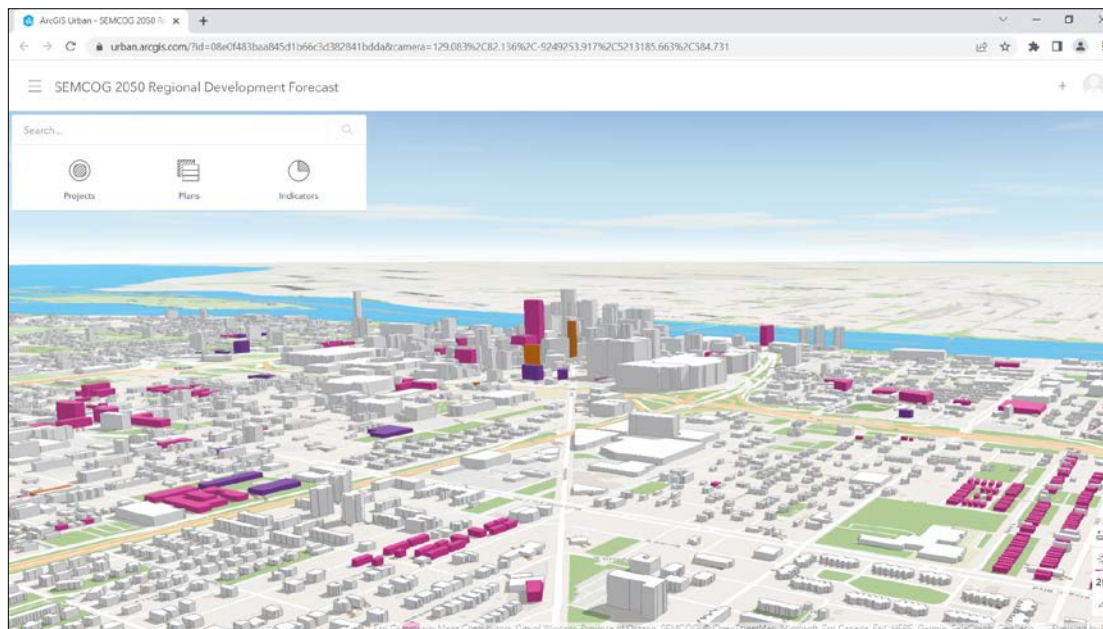
One of the things that the forecasters have seen are fewer planned storefronts and office buildings.

“We’ve had a number of former office towers that have been gutted and turned into housing or offices, or typically both,” Nutting said. “Schools that are 50 to 100 years old are being converted, and there is more multifamily development than in the past.”

The map also helps anticipate future trends, such as whether development is trending more toward infill lots and smaller projects or whether developers are jumping to the exurbs where they can create whole subdivisions.



These infill projects show how housing is being added in older neighborhoods.



Looking toward neighboring Windsor, Ontario, you can see that development is planned in and around Detroit’s downtown.

Informing Individual Plans

The aim of all this information gathering is to project the patterns of growth far into the future for an accurate SEMCOG forecast, and also foster collaboration between planners in neighboring communities.

“Our hope for the forecast is that communities will use it in their own planning work and that they will consider the zoning and master plans of their neighboring communities to make planning more seamless and integrated,” Nutting said.

The map of building footprints has color coding for 26 different building



Many communities in Detroit are growing at a fast pace, including downtown.

“With all the growth that’s happening, our plan is to divide the region into places that we talk to every year, instead of every three to five years,” Nutting said. “That way when we get to this point in five years, the model will largely be in place already.”

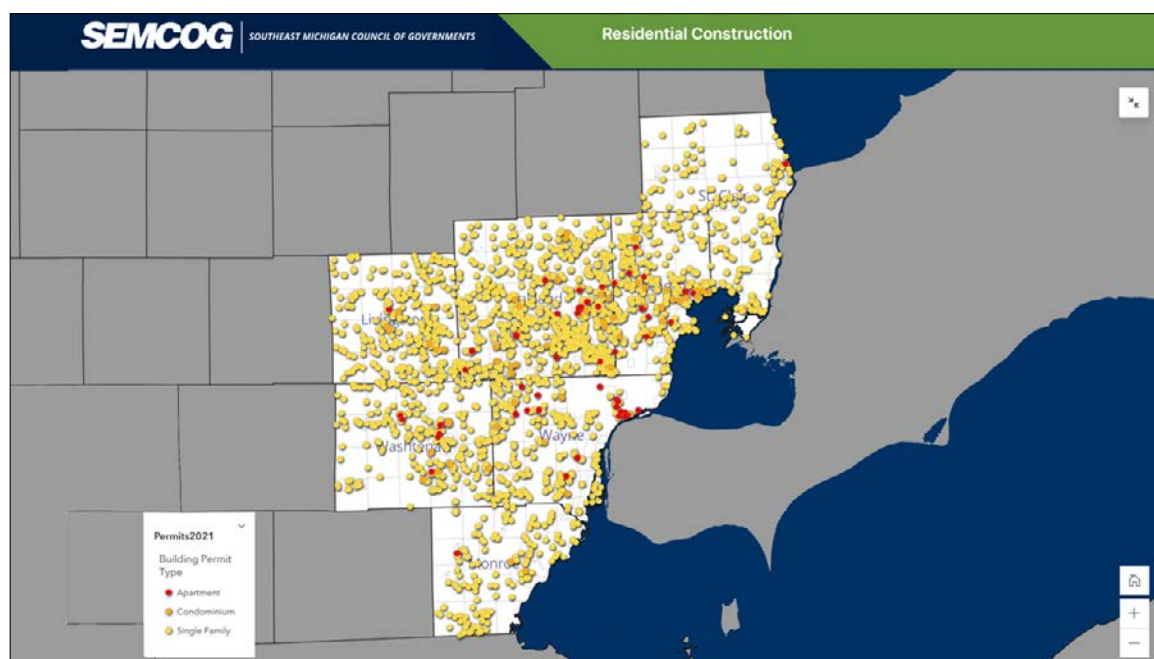
The regional plan also serves to show residents that their region is well into its rebound.

“There have been a lot of changes, particularly in the city of Detroit where city leaders have a plan, they’re following it, and it’s working,” Nutting said.

types, including four residential and 22 nonresidential types that align to major employment categories in the region.

Many planners who have seen the visual result were quick to ask if they could share it with their planning commissions, township boards, and communities.

Nutting hopes that municipalities will start to require building information models as part of their planning process because that would make pulling the details together much easier.



Map of residential construction in Southeast Michigan shows 2021 building permits across the region.

Can a Historic Kauai, Hawaii, Community Modernize without Losing What Makes It Unique?

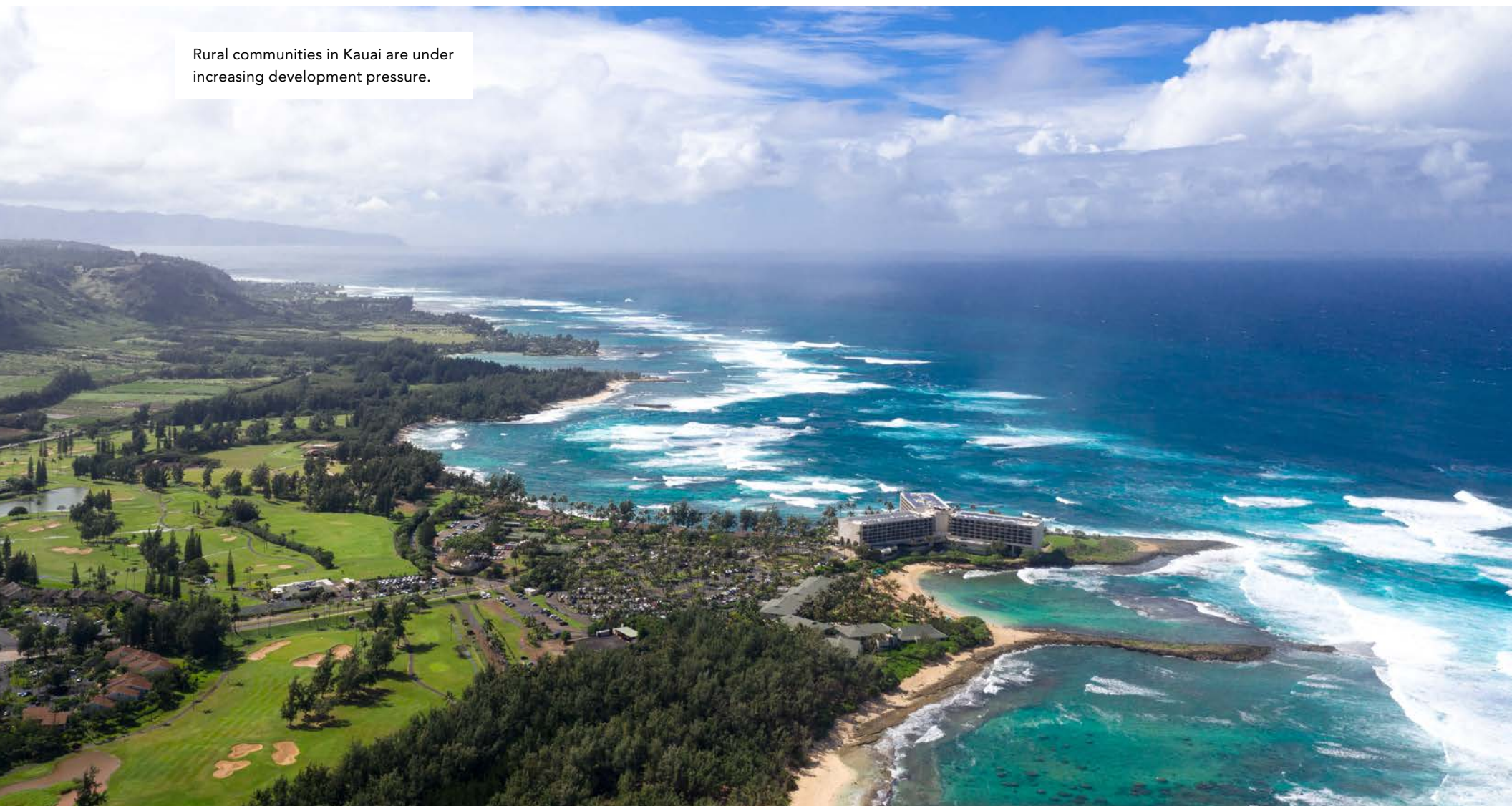
Kaumakani, a name that translates from the Hawaiian language as “place in the wind,” is a former sugar plantation camp founded in the late 19th century on the island of Kauai.

Kauai, known as the Garden Isle because of its lush landscapes, is the fourth largest of the Hawaiian Islands and has served as the backdrop of numerous films, including *Jurassic Park* and *Avatar*. Kauai is home to less than 5 percent of Hawaii’s people, and the population of Kaumakani—around 720 people—is less than 1 percent of Kauai’s.

On any given day, nearly one-third of the people on Kauai are tourists. They have no lasting stake in Kauai’s future, but their connection to Hawaii’s major economic driver can slant the island’s power dynamics, stifling the voice of Kauai’s permanent population.

A small rural settlement such as Kaumakani is especially vulnerable. That’s one reason the planning department for the County of Kauai uses maps and GIS technology to help protect Kaumakani’s unique character. A survey of the area in 2022

Rural communities in Kauai are under increasing development pressure.





Planners looked at the character of infill development with medium-density residential building types for limited retail and service uses.

gathered details and enshrined them in a new type of building code, protecting Kaumakani's roots from cultural erosion.

Island Camps

Sugar is no longer a viable industry on Kauai, but several of the plantation camps it generated still survive as contemporary housing. As the County of Kauai's Planning Department noted in its 2018 general plan—which received the American Planning Association's most prestigious award—the camps occupy a unique place in the island's history and culture.

Their location, surrounded by sugar cane fields, “created a greenbelt that differentiated towns from agricultural and natural areas,” the report noted. “This relationship between built areas and surrounding natural or agricultural lands heavily influences [the island's] character [and] rural identity.”

The pedestrian-oriented scale of the camps fostered walkable communities, even with the rise of the automobile. That communal feel remains today. However, the camps' relative isolation and paucity of services—Kaumakani has a single, small retail area—make residents largely car dependent.

The general plan includes a commitment to “revitalize, restore, and celebrate these characterful towns that promote healthy economies and community life.” Kaumakani appears in the plan as one of five priority equity areas, considering its makeup of largely low-income neighborhoods and communities of color. Planners had to navigate the tension between preservation and adaptation.

Past and Present

Most of Kaumakani's modest homes—relatively low-cost rentals—were built in the 1940s, before the sugar plantation changed ownership. In 2022, Kaumakani's current owners

expressed an interest in demolishing and replacing some of the unoccupied homes that had fallen into disrepair. The owners also wanted to build new structures on the camp's mostly vacant fourth quadrant.

Planners had to look closely to determine what the landowners would be allowed to do—and to detail how they would be allowed to do it.

“The thing that's so unique about this area, and which required a different approach, is that it's just one big property with no lot lines, built before there were any complex zoning ordinances,” said Alan Clinton, an administrative planner for the county.

The planning department would have to start from scratch, formulating a code that would articulate what makes Kaumakani Kaumakani.

County planners walked the streets, observing the form and layout of the neighborhood. They carried mobile devices loaded with QuickCapture to gather relevant details and

place them on a shared map. All information—pictures, notes, data—populated this map.

“To write the code, we made a lot of measurements, took photos of everything, and put together a series of features,” Clinton said.

As the map developed, it revealed patterns that helped the planning department define the formal elements the landowners needed to include in their structures. The code was appended to the 300-page West Kauai Form-Based Code.

Besides describing how the homes should look to conform to the plantation architectural style, the planners also wanted to preserve the way private housing and public street life were closely intertwined in Kaumakani. The new code defined the allowed frontage, the maximum amount of space between a building’s facade and the street.

Carport Confidential

The map, and the building forms within it, revealed fascinating details about the essential characteristics of Kaumakani that would likely have gone unnoticed otherwise.

Clinton pointed to an aerial view provided by the department’s Kaumakani map. “You’ll notice that all these homes have a main central body and a carport on the side,” he said. Close observation and an understanding of local culture helped the planners understand the carports’ significance.

“Oftentimes, planners will say parking in the front is bad,” Clinton said. “But these carports are really more like outdoor living spaces. They’re places where people eat, or even live. They’re kind of extensions of the houses’ interior space.”

The carports were never part of the original design of the houses. They had appeared organically, added to the properties over the years by individual tenants.

The property owner, which had already begun to build some of the replacement homes, had missed the carports’ significance.

“We told them, ‘Sorry, guys, but this is part of the form and character of the camp,’” Clinton said. “The carports are a defining element that we wanted to make sure was included.”

Clinton pointed to another interesting detail from the map. On one quadrant, the homes had been built with a vertical orientation to the street, while in another, they varied, forming a neat pattern that alternated between vertical and horizontal. As carports had been added over the years, tenants had followed these patterns.

The lack of formal lot lines made this all the more remarkable. The patterns had emerged without guidance and likely without discussion among tenants. They are now part of Kaumakani’s building code.

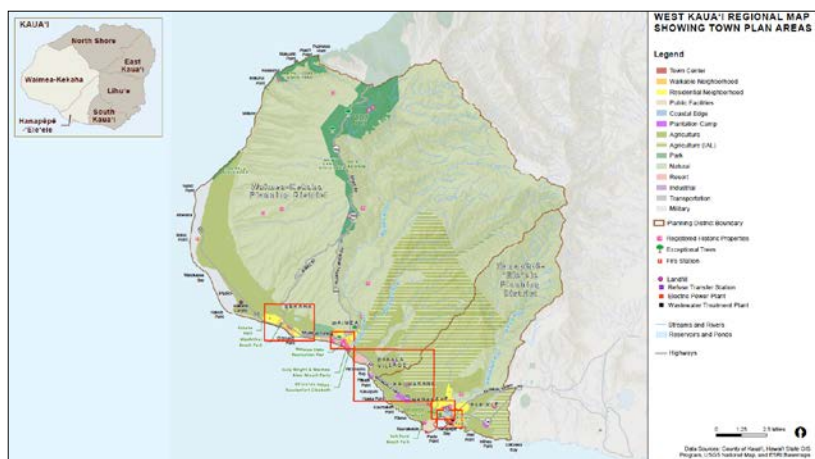
The Move to Foreground Form

In Hawaii, the concept of land planning taps into a unique historical and cultural vein. In the Indigenous Hawaiian belief system, the concept of land—or *aina*—implies not just the ground itself but also the connection between people and place. The concept of *aloha aina* (love of the land) is a deeply rooted tenet with connotations of patriotism. The local word used to describe a resident of Hawaii—*kamaaina*—translates literally as “child of the land.”

The general plan for the island reflects the department’s understanding of these ideals. It was assembled with extensive community input, including informal “talk story” sessions, a local term that refers to casual conversation.

These sessions influenced the planners’ approach to applying zoning ordinances to plantation camps such as Kaumakani. Feedback from camp residents included the importance of community childcare centers and the interest in adding yurts or tiny homes to increase the amount of living space.

One way the department demonstrates its respect for a historically rich neighborhood such as Kaumakani is through a



The West Kauai Community Plan conveys the vision of how local people would like the area to evolve and manage change in the coming years.

modern approach that runs counter to traditional urban and regional planning orthodoxy.

“Planners have usually divided land into usage categories—like, this area is for industrial purposes; that one is for single-family homes,” Clinton said. “But over the years, focusing on use hasn’t always supported the historic areas people love and enjoy.”

The alternative approach—form-based zoning codes—retains usage categories while adding humanist considerations. Function, to varying degrees, follows form.

Form-based codes highlight form and character over use. We create a whole new zoning code that focuses on building types, how structures interact with the street, and how the form and character of buildings fit an area.

— Alan Clinton, an administrative planner with the County of Kauai

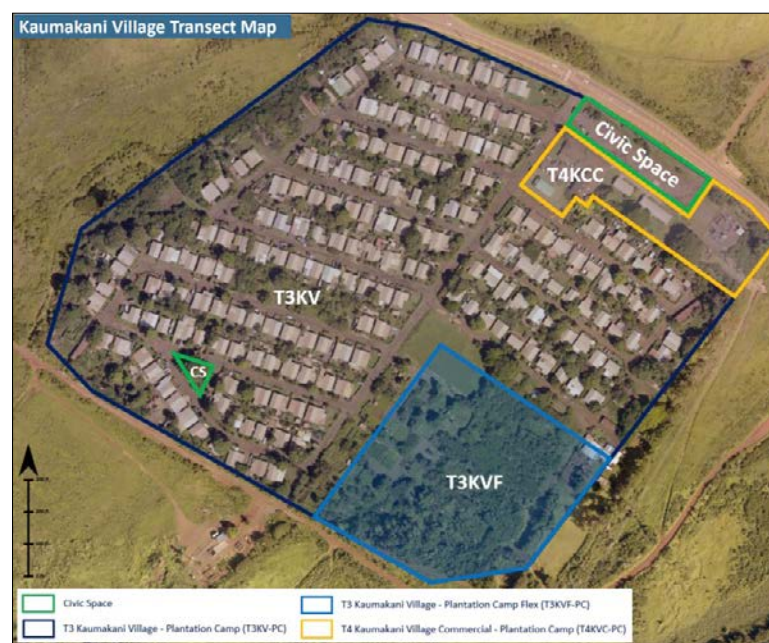
The philosophy is similar to that of the geodesign movement, which advocates close analysis—often using large amounts of data. The goal is to understand and predict how people will experience a built environment and to minimize human impact on the natural world. Not coincidentally, both approaches adopt GIS as a way to gather and process information.

Form-based codes can seem baffling to developers accustomed to thinking solely in terms of usage categories. Now, anyone building land—or making changes to an existing structure—covered by the West Kauai Form-Based Code can click on parts of the map to understand which aspects of the document relate to a particular structure or area.

Clinton said that his department has been approached by groups interested in form-based codes as a means of restoring and preserving other Kauai towns and settlements. Since many of the original structures are gone, historic photos will form the foundation of the new codes.

The planners also intend to make GIS maps a bigger part of the community outreach process. They want to use maps to help locals articulate what they consider essential form and character.

“If we were to just dictate usage, it wouldn’t create the kind of developments that communities want,” Clinton said. “Form-based codes take more work on our part, but we’re OK with that.”



For the evolution of Kaumakani Village, civic and commercial spaces have been designated by planners, and work has been done to capture the character of the place.

Digital Twin Boosts Growth, Sustainability Planning in Maryland County

Montgomery County, Maryland, has pioneered many urban planning firsts, including preserving open space.

Montgomery County, Maryland, has pioneered many urban planning firsts, including preserving open space. sustainability goals. The result: This dynamic digital twin gives developers an accurate picture of potential opportunities. It also helps the public understand what their community—down to a single block—will look like in the future.



Montgomery County, Maryland, has pioneered many urban planning firsts, including preserving open space.

Many of Montgomery County's 1.06 million residents live in Bethesda and Silver Spring, urban enclaves just outside the nation's capital. Like urban areas across the US, planners there contend with balancing affordable housing and an interest in preserving forests and farms.

Montgomery County officials have pioneered new ways to manage these issues for decades. To address affordable housing in 1974, the county implemented the nation's first successful moderately priced dwelling unit program. In 1980, the county established the Agricultural Reserve by preserving 93,000 acres—almost a third of its land resources. A few years later, density placement was transformed by the Optional Method of Development, which allowed higher densities in urban areas in exchange for added public amenities or increased land preservation in rural areas.

To keep pace with changing demographics and housing demand, Montgomery Planning staff have embraced GIS technology. The county uses GIS to increase transparency, keeping developers and the public informed about projects while speeding regulatory processes. They digitize 2D plans, integrate them with 3D modeling software, and share them online. The dynamic digital twin that keeps pace with plans gives developers an accurate picture of potential areas of opportunity.



A new feature in ArcGIS Urban allows planners to add “ghost” buildings to distinguish between the plan being reviewed, what exists (in white), and other plans in the vicinity (out of focus).

Montgomery County's Thrive 2050 plan prioritizes dense, sustainable housing. It concentrates growth in downtown areas, emphasizes transit-oriented development, and insists on racial equity and climate resilience. Passed with a unanimous planning board vote, the award-winning plan has officials optimistic that it will address housing needs far into the future.

We know we need to satisfy more residential development to keep housing affordable. By focusing growth along certain transit corridors near metro stations, we're giving developers an incentive to build a missing middle housing solution where duplexes, triplexes, and infill development can grow.

— Chris McGovern, manager of the Information Systems/Geographic Inventory System at Montgomery Parks and Planning

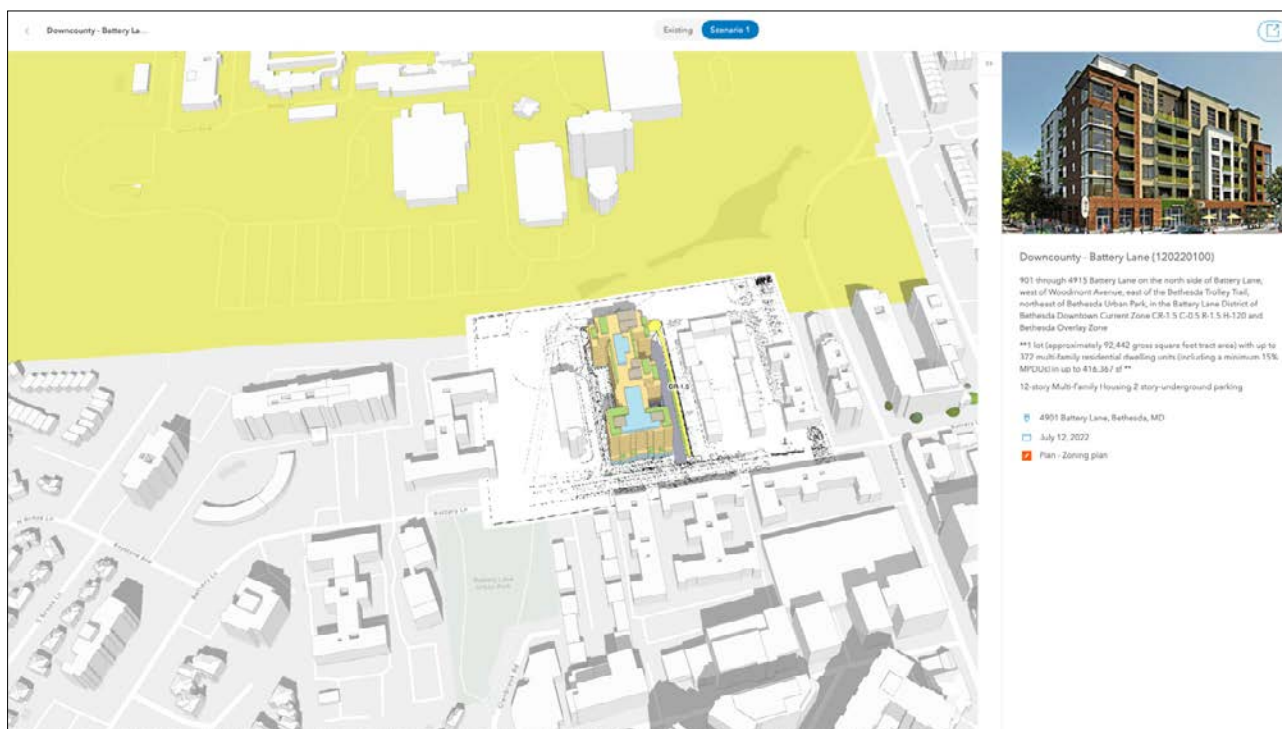
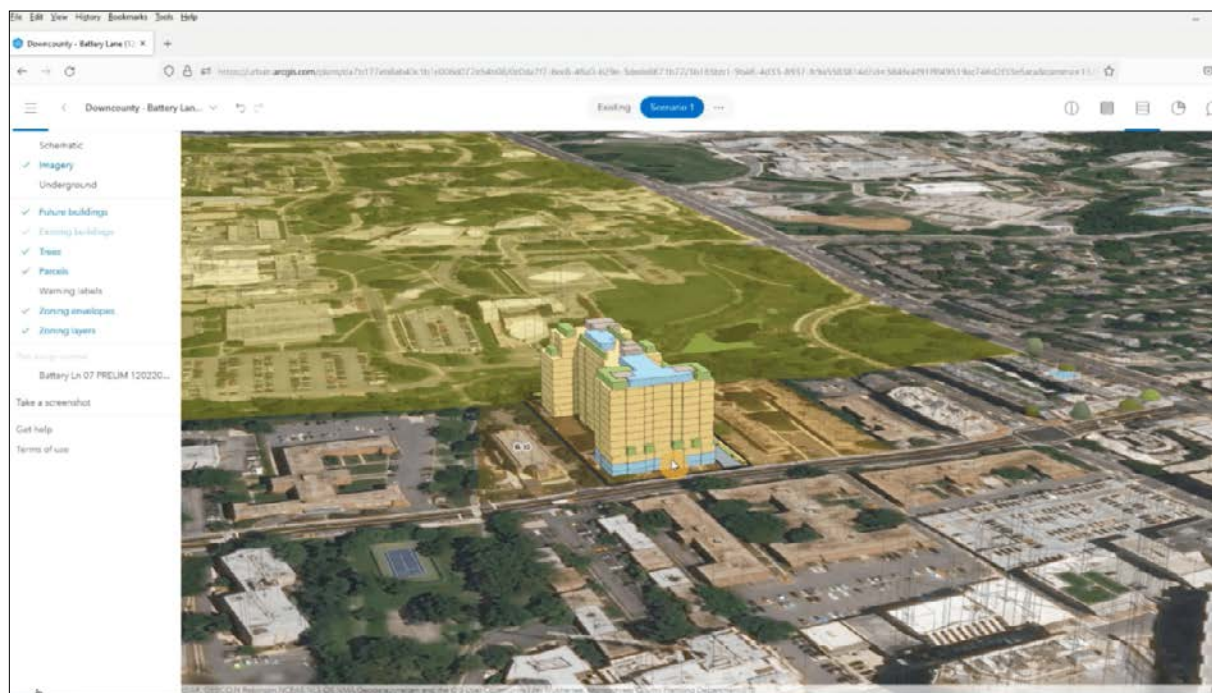
A Blueprint for Progress

The department has used digital tools to inform the public for years. The Development Activity Information Center (DAIC) indexes project descriptions, maps, drawings, and other information. The MCAtlas map viewer for Montgomery County displays related data—county and election boundaries, priority funding areas, and opportunity zones. An interactive Development Activity map outlines developments by type and tracks progress.

Even with this robust set of resources, the county's city planners and GIS specialists knew they could offer a more intuitive view of planned growth. “The DAIC is where we convey our regulatory information to the public so that they have visibility on the process and take part in our meetings,” McGovern said. “But we wanted to 3D render those projects, so they'd be able to understand what we're talking about without having to look at two-dimensional architectural drawings.”

This, McGovern said, is where smart city planning software came in to create a countywide planning digital twin. Specialists combine 2D drawings and documents to generate a 3D model in ArcGIS Urban. Layers such as building footprints

Adding imagery below 3D buildings reveals added details about vegetation, parking lots, roads, and amenities.

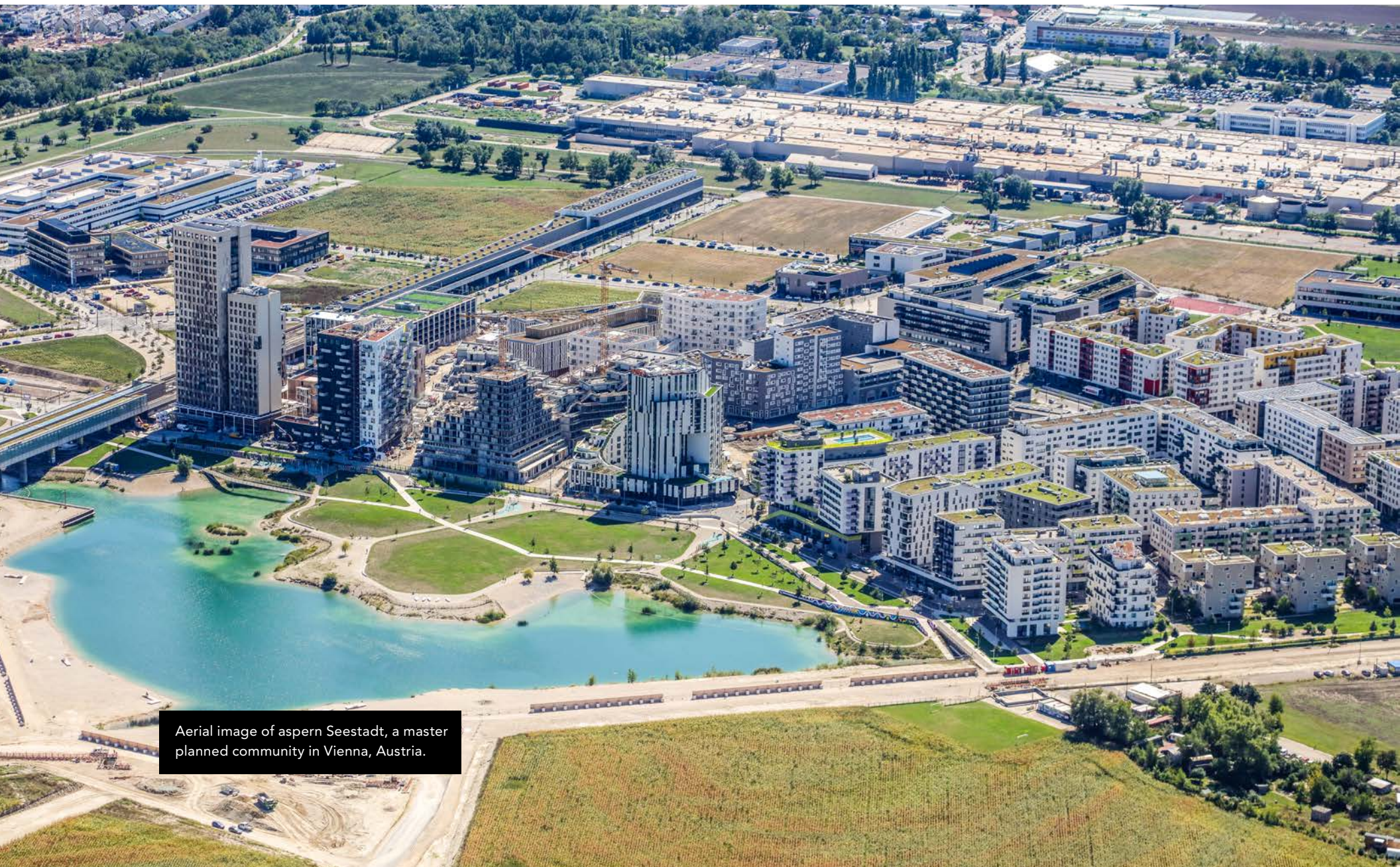


Montgomery County planners use ArcGIS Urban to capture a digital twin of all proposed developments. Battery Lane plans are moving forward for a new 10-story luxury apartment building.

Inside One of Europe's Largest Urban Developments

Vienna is a city in a bind. Austria's capital, home to nearly two million people, is one of the European Union's largest and fastest-growing cities. Vienna held the top spot on *The Economist's* annual rankings of the world's most livable cities four consecutive years from 2020 to 2023.

But a city can only remain livable if there are enough places for people to live. Vienna's leadership has used the challenge of creating more housing as an opportunity to envision a new pattern of neighborhood planning and placemaking throughout Vienna—a city within a city.



Aerial image of aspern Seestadt, a master planned community in Vienna, Austria.

The result: aspern Seestadt, which reclaims a brownfield area to create a development that embraces new urban ideals while retaining the classical urban structure of old Vienna.

As aspern Seestadt has evolved, it has emerged as one of Europe's most dynamic planned communities and an incubator for smart city initiatives. GIS technology helps planners implement clean energy and low-emission strategies and aids the long-range planning and implementation to ensure that aspern Seestadt achieves a unique balance of sustainability and livability.

A New Life for an Old Airfield

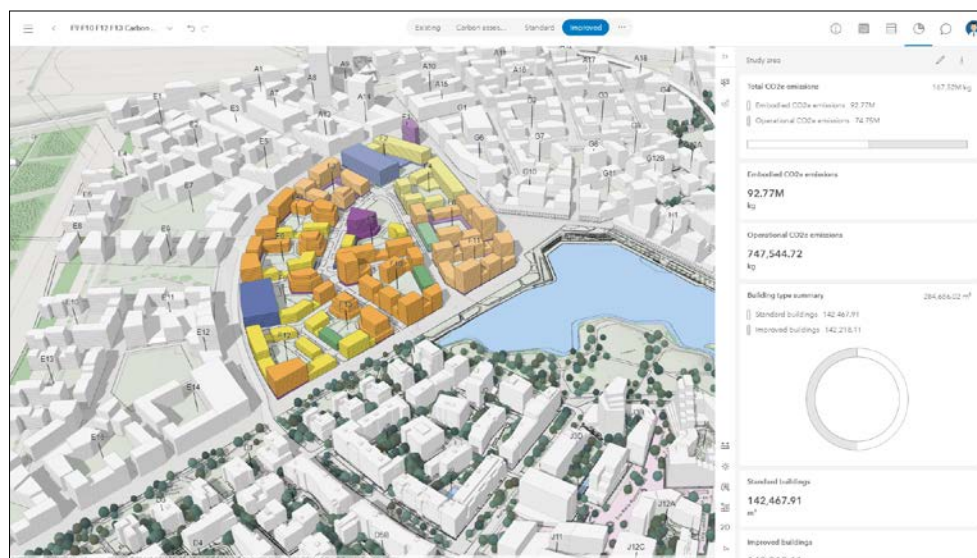
In the early 2000s, following a period of stagnation and slow growth, Vienna's population began to skyrocket. Since then, it has increased by 25 percent. The city is projected to add 200,000 new residents by 2030.

As far back as the 1990s, Vienna's political and civic leaders foresaw the strain population growth would place on the city's housing stock. Political realities complicated the problem. Vienna is both a city and one of Austria's nine provinces, surrounded by another, Lower Austria.

"It's just not possible for Vienna to grow on the outside," said Carina Huber, an urban planner with the development agency Wien 3420 AG, the corporation responsible for overseeing aspern Seestadt's development. "The only opportunity is to adapt unused areas within the city."

Casting around for land to develop, officials settled on the former site of Aspern Airfield. A major civil and military aviation facility for more than 50 years, Aspern had closed in 1977, just as Vienna was reaching its postwar population low.

When construction began in 2007, the site was a derelict former airport. Today, aspern Seestadt is a thriving community



The total embodied CO2e emissions relates building performance from the original efficiency standard as well as a more stringent standard that was developed when building technology improved. Screenshot courtesy of Wien3420.

spread over 800 acres. When it is completed in 2030, it will be home to more than 25,000 people and 20,000 workplaces.

Everything Old (City) Is New Again

To begin to understand the scope of aspern Seestadt's achievement, consider that this former brownfield now contains a swimmable artificial lake at its heart.

The lake is its own circular economy. A plant converts the gravel from the lake excavation into road base and aggregate for concrete. To date, 1 million tons of recycled material have been delivered. Keeping the material on site has saved 280,000 truck trips and 6,000 tons of emissions.

Aspern Seestadt has made an ambitious commitment to lower its impact on residents and the environment. The aspern climate-fit standard was developed with the goal to meet a greenhouse gas-neutral economy by 2040, with high-efficiency buildings, maximum use of renewable energy sources, e-mobility, and mitigating extreme heat in the summer.

This balanced approach permeates the comprehensive plan that governs the project's development. The plan emphasizes



Shops and eateries are located at the center of the residential area, within walking distance. Image courtesy of Wien3420, © Luiza Puiu.

ambitious emissions requirements, both in the construction and everyday functioning of aspern Seestadt. Fifty percent of the area must be kept as undeveloped green and open spaces, with paths and treelined streets. At the same time, the area's population density is nearly twice that of Vienna as a whole.

From the beginning, the City of Vienna saw aspern Seestadt as a test bed for smart city concepts, including a deemphasis on cars. The plan called for a 40-40-20 transportation infrastructure concept: 40 percent public transit, 40 percent walking and cycling, and 20 percent personal vehicles.

Before any structures were built, the city built two metro rail stations in aspern Seestadt and extended the metro line to reach the site. It's a 25-minute ride to reach Vienna's city center, 15 kilometers away on the other side of the Danube River. Since 2018, metro and railway lines meet at the transfer station Aspern Nord on the north side of the development, which makes for a 17-minute trip to Vienna's central train station.

"What makes Seestadt unique, I would argue, is that it maintains the transportation mode split of the inner city," said Petr Bocharnikov, a digital strategist with Sokigo, the Swedish

firm that together with Sweco has developed and deployed new GIS tools for aspern Seestadt. "Historic city centers to this day allow for a significant share of travel with public transport, cycling, and walking, but new developments are much more car-oriented."

A Comprehensive Plan and a Malleable Map

Something else unique about aspern Seestadt is the way its overall urban philosophy has evolved and flourished. Instead of being a top-down vision emanating from officials of the City of Vienna, it is the product of an ongoing long-term collaboration among diverse public and private stakeholders.

This approach reflects what spatial planners Astrid Krisch and Johannes Suitner, in their analysis of aspern Seestadt, call "the switch from government to governance" in city planning. The priority is nurturing the emergent ideals rather than dictating them.

For this reason, Wien 3420 AG was created as a public-private partnership with the City of Vienna and two additional shareholders in 2003. The agency serves to coordinate all the inputs, a task aided by GIS.

In the early days of planning and construction, Wien 3420 AG used GIS primarily to print updated maps that displayed the project's progress. As aspern Seestadt has taken shape, GIS has become a powerful integrated tool for planners and architects. GIS now provides a common virtual meeting space for project-related data and creates a foundation for including detailed infrastructure drawings (CAD) and building information models (BIM).

The agency uses GIS to create an unfolding visual documentation of the plan. People involved with the project can take parts of the map relevant to their duties and integrate them into workflows for planning, constructing, operating, and marketing the development.

Huber referenced one of the earliest aspern Seestadt maps, depicting the comprehensive plan for the development. “It’s been with us from the very beginning,” she said. “It shows all the usages and open spaces. It’s the most used map in the whole company.”

Over time, the map has been augmented by dashboards that show aspern Seestadt’s progress. These help all project stakeholders understand whether the project is meeting its goals. For example, it can provide information about total emissions of proposed buildings based on the building function and expected construction standard. It also helps everyone involved understand the schedule for completing various phases of the development.

“We can combine 2D information with the 3D model we now have,” she said. “We can picture an already constructed building block, and we can load in contracts and PDFs.”

A Digital Twin Keeps Pace with Development

As aspern Seestadt has progressed, GIS technology has advanced along with it. The result is a realistic vision of the town that would have been impossible when the project was first conceived. As Bocharnikov wrote in a 2022 project update, “We’re transforming traditional GIS into a project information model and, ultimately, a digital twin.”



From the 3D interface, users can choose to view projects, plans, and indicators. Screenshot courtesy of Wien3420.



The lake provides a natural focal point and fuels a healthy lifestyle to relax, play, and swim. Image courtesy of Wien3420, © Luiza Puiu.

This geospatial digital twin, built using ArcGIS Urban, serves an important purpose in documenting the present and the past. But the twin also holds enormous importance as a way to understand the future and tweak the comprehensive plan accordingly. The town has always had goals related to climate change—both in terms of building the development with a minimum carbon footprint and ensuring heat mitigation strategies. The twin guides the planners in making data-driven decisions to reach these objectives.

The twin also provides a record that lets planners change tactics in new parts of the development based on lessons learned from earlier phases. Stricter energy efficiency standards were applied in 2023 to the next phase of development. The digital twin provides visual communication of the change as well as quantifying gains in efficiency. It keeps aspern Seestadt focused on its goal of being a new sustainable and forward-thinking energy-efficient development in Europe.

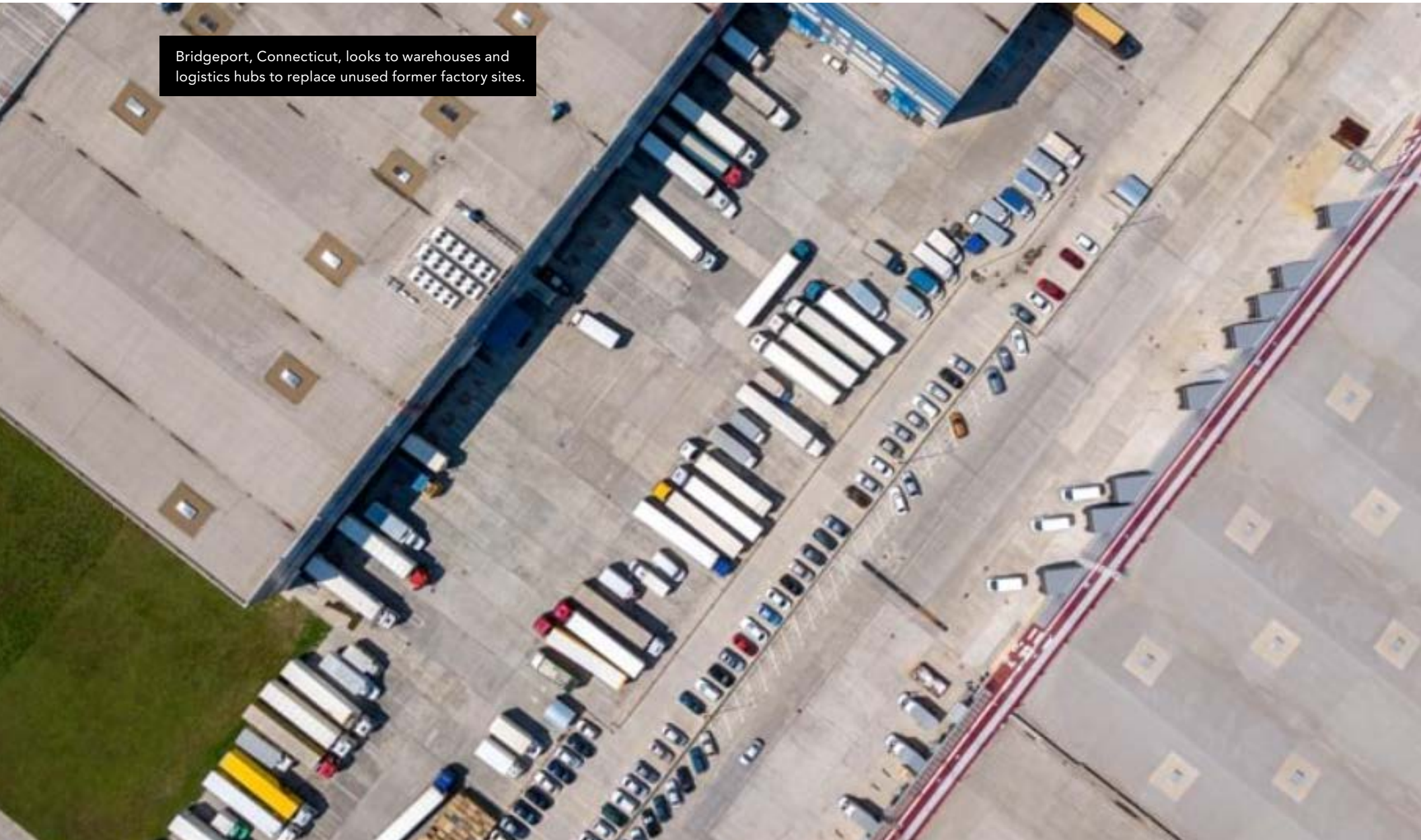
“This gives every member of Wien 3420 the possibility of seeing a complete picture, including completed buildings, the master plan, modifications of the master plan, and architectural projects that are being refined,” Bocharnikov said. “Our goal is for every member of the organization to directly access it in their work. That’s very valuable for collaboration within the agency.”

Connecticut: How Maps of Past Contamination Focus Redevelopment in Cities

In Bridgeport, Connecticut, properties once bustling with manufacturing are now prime sites for warehouses and other logistic and transportation uses, taking advantage of the city's strategic location between New York City and Boston. At least that's the city's plan, in response to growing demand to shore up supply chain gaps in the US. However, many of the abandoned or rundown factories could still be hazardous

because of past industrial uses so officials must determine where turnaround can happen quickly.

"Connecticut has a very rich industrial past, which was great in the early to mid-1900s, but it left a significant contamination issue we're still struggling to climb out of," said Matt Fulda, executive director at MetroCOG. "Bridgeport had Remington,

An aerial photograph of a large industrial facility, likely a warehouse or logistics hub, in Bridgeport, Connecticut. The facility features a long, dark blue roofline. A vast parking lot is filled with numerous semi-trailers, mostly white and blue, parked in neat rows. To the right of the trailers, there are several rows of cars parked. A red double-track railway line runs diagonally across the lower right portion of the image. The surrounding area appears to be a mix of industrial and possibly residential or commercial land, with some greenery visible in the bottom left corner.

Bridgeport, Connecticut, looks to warehouses and logistics hubs to replace unused former factory sites.



With success visualizing in 3D, MetroCOG invested in ArcGIS Urban to create such projects as this virtual reality model of a village district on a commercial corridor in the region.

and other munitions and heavy industrial activities, which has left a lot of the city undevelopable.”

In fact, Fulda notes that roughly 30 percent of the city’s land parcels are vacant or underused. City planners and developers are working to understand the opportunity cost of so-called brownfield redevelopment sites, guided by a map-based Brownfields Inventory Site Selector tool, which is loaded with all relevant data.

Developers at MetroCOG created the tool to fill in knowledge gaps, using GIS technology. City planners use the tool to visualize, analyze, and prioritize sites based on factors such as contamination levels, connectivity to freight and transit hubs, and climate resilience.

“We’re trying to eliminate as many impedances as possible,” said Patrick Carleton, deputy director at MetroCOG. “Getting information out there and accessible makes an easier path forward for redevelopment.”

Reconnecting along the Northeast Corridor

Brownfield redevelopment provides a potential win-win situation for municipalities both by addressing environmental

contamination and generating new businesses and jobs that produce tax revenue. And removing brownfields provides a psychological value—to show a city isn’t mired in its past.

MetroCOG has a history of transforming brownfield sites, having secured grants from the US EPA and state agencies for both assessment and remediation for many sites in the region.

The scale of remediation varies dramatically across different properties. Some just need removal of contaminated soils or building asbestos. Other sites are far more complex, with different industries on the same property over the course of 100 years, and require millions of dollars to fully remediate all sorts of legacy contaminants.

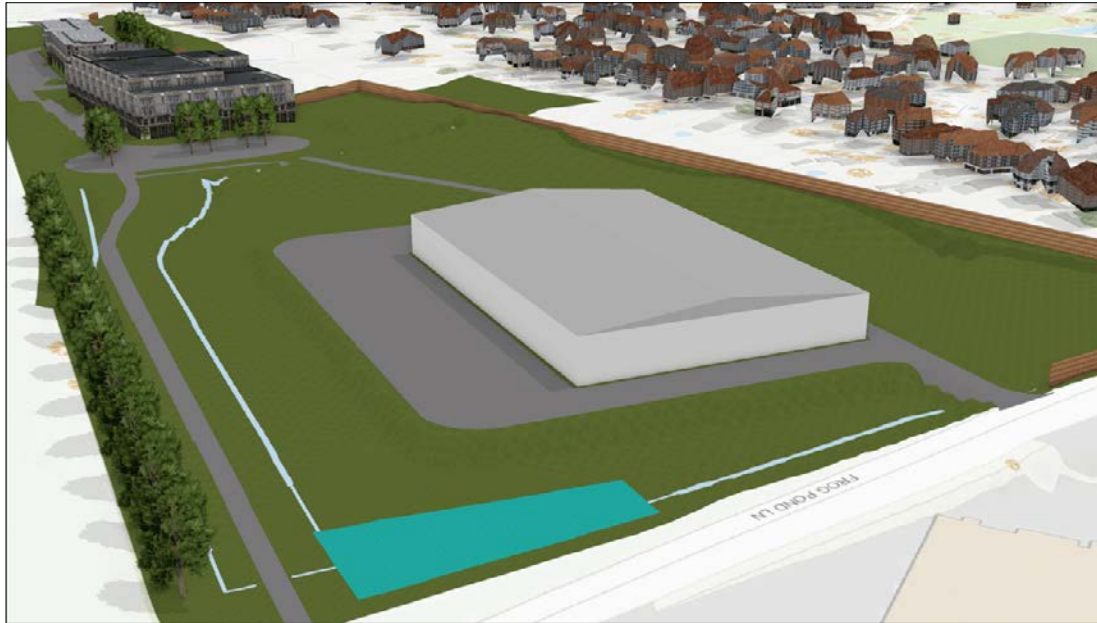
— Matt Fulda, executive director at MetroCOG

The first step involves inventorying sites. So MetroCOG staff members started by gathering background details and adding those to the inventory map. They scanned documents from municipal and state records pertaining to past facilities that occupied each site, with information such as type of contaminants and likely location of hazardous materials.

The MetroCOG team then conducted spatial analysis to determine where remediation work would have the most impact across the region. The team’s work factored in environmental justice issues as residents around some sites experience persistent poverty and disparities in education and health.

“We’ve tried to target specific corridors in Bridgeport and Stratford, the two most urbanized and disadvantaged communities in our region, and with the most problematic sites,” Carleton said.

Next, MetroCOG hired environmental remediation experts to sample and analyze the soil, groundwater, and any remnants



MetroCOG used ArcGIS 3D Analyst to create these views of the site of a former metal plating facility in Stratford, generating interest by visualizing the context and what could be built there.

Showing Redevelopment Potential

Brownfields aren't the only focus of MetroCOG. The council also administers cooperative planning for issues related to transportation, land use, housing, public facilities, open space, environment, energy, and economic development. Increasingly, staff members have been applying and promoting their GIS capacity to member communities of Bridgeport, Easton, Fairfield, Monroe, Stratford, and Trumbull. This includes building issue-oriented tools similar to the brownfield site selector and creating 3D visualizations to help city planners see the changes they want to foster.

of structures to measure contamination and make cleanup plans for priority sites. GIS is a common technology for this type of collaboration, used for mapping where the work needs to be done and reporting where and to what extent each site is contaminated.

Finally, MetroCOG's brownfield site selector tool made available all the historical records—many of which were previously only available on paper and tucked away in file drawers—and provided access to the latest environmental assessment reports.

In Stratford, MetroCOG worked with municipal staff to showcase development options for



MetroCOG used ArcGIS 3D Analyst to create these views of the site of a former metal plating facility in Stratford, Connecticut, generating interest by visualizing the context and what could be built there.



An abandoned factory is ready for reinvention in Bridgeport, Connecticut.
Image courtesy of MetroCOG

the site of a former metal plating facility currently going through cleanup. Using 3D tools in ArcGIS to visualize the area, MetroCOG staff created a digital twin of the site. The immersive model displayed several redevelopment scenarios. Accompanied by the deep-dive details in the brownfields tool, the work impressed the EPA, which showcased the project during its 2019 National Brownfields Training Conference.

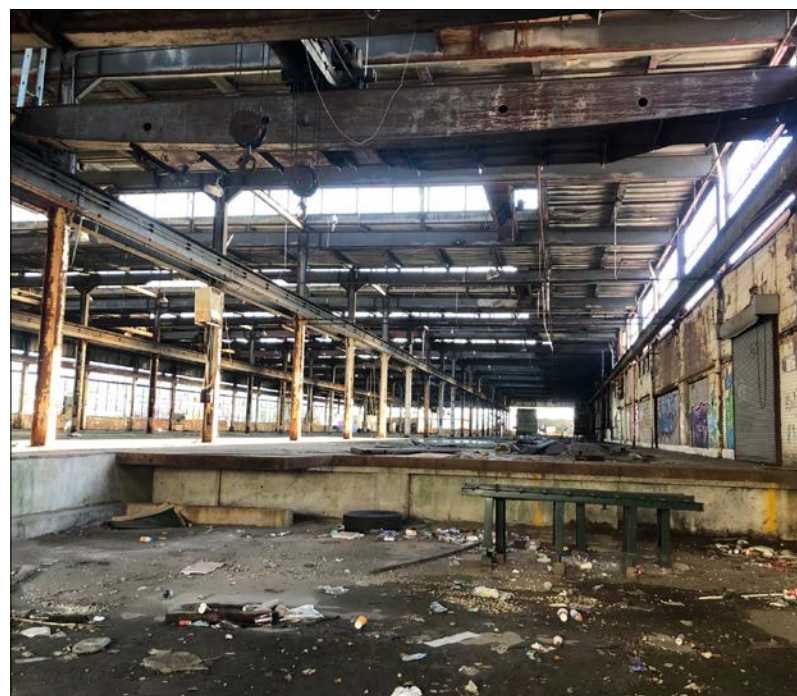
“The metal plating site in Stratford is next to another site undergoing extensive remediation with the help of US EPA,” Carleton said. “They are both close to the interstate and close to commercial and industrial corridors within the town, and the visualization helps the town market those properties.”

Meeting Industrial Demands

A 2022 MetroCOG economic development survey identified industrial space as being the highest in demand for real estate. The survey cites a growing need for space from companies in the transportation, logistics, and supply chain industries.

With a port, an interstate, and a state highway that originates in Bridgeport and moves north to connect to Interstate 84, the region is well-positioned for advanced manufacturing. Defense contractors, such as Sikorsky Aircraft headquartered in Stratford, reinforce the viability of the area. With more than 300 manufacturers—ranging from small to multinational—in the region, MetroCOG and the municipalities it serves are hopeful that new industrial uses will lead to renewal and drive the economy forward.

“Mapping the vacant or underutilized parcels in the region has helped us work with our municipalities and with developers to prioritize locations for remediation,” Fulda said. “We’re hopeful those locations will have a cascading effect, to get more properties cleaned up, advertised, and developed so they will attract other developments.”



Gutted industrial building interior. Image courtesy of MetroCOG.



Infrastructure

Organizations use GIS for infrastructure management to model, connect, and enable relationships of the built, social, and natural worlds with advanced visualizations and analytics across the entire infrastructure life cycle.

Vodafone created a high-resolution digital twin of its network coverage in the UK using GIS technology. Originally aimed at producing a better map, it has evolved into a more effective planning tool for engineers and the company as a whole.

“Initially, it was purely a question of producing a better map,” said Boris Pitchforth, lead architect at Vodafone. “Now it has become a much smarter way for us to plan.” Rebecca King, GIS lead at Vodafone, shared that the digital twin not only allows for better signal propagation modeling across coverage areas but also helps mitigate issues caused by physical obstructions such as tree growth.

Vodafone’s digital twin allows the company to plan for future expansions such as new housing, shopping centers, and sports venues. The Vodafone digital twin for Britain—representing 245,000 square kilometers—contains various levels of immersive 3D detail that give anyone at the carrier the ability to see the invisible signals the company creates and sells.

The team responsible for designing the first underground railway in Australia’s fastest-growing city, Brisbane, created a detailed and up-to-date 3D model of the project and the city above it using GIS. This digital twin has been instrumental in visualizing the project, guiding the construction process, and facilitating stakeholder engagement.

Russell Vine, Cross River’s chief innovation officer, shared the advice they received from the Crossrail project in London: “They basically said, ‘We would have built a bigger, better 3D digital model sooner.’” Consequently, Cross River implemented a federated BIM model, integrating BIM information into a single file that depicts the entire project. This digital twin has been instrumental in visualizing the project, guiding the construction process, and facilitating stakeholder engagement.

The US Army Corps of Engineers has developed a digital twin to manage the complex task of maintaining the waterways of the Mississippi River.

The Mississippi River’s volatile water levels often cause national concern as it is the primary route for most grain exports and other key commodities. The US Army Corps of Engineers, to better manage and anticipate these changes, has developed a digital twin system known as NavPortal. This system uses GIS technology to monitor river conditions, operations, and vessel traffic.

Ned Mitchell, a research civil engineer at the US Army Engineer Research and Development Center and NavPortal product manager, said, “We’ve got hundreds of dredge locations nationwide, and we need a tool like NavPortal to be our early warning indicator. We need to see the worst trouble spots forming before they become full-blown emergencies.” The NavPortal system combines cloud computing, ship tracking, and AI to process and present huge volumes of data, providing an operations-wide digital twin.

Miami International Airport (MIA), the 10th-busiest airport in the US, decided to transition to an all-digital workflow in 2022. It did this by replacing a paper-based inspection process with tablets running apps built with GIS technology. Maurice Jenkins, MIA’s division director of Information Systems and Telecommunications, emphasized the benefits of this transition.

Jenkins stated, “It’s clear-cut, it’s concise. No one has to worry about deciphering an inspector’s cryptic notes or interpreting what that individual meant when they made that notation. There’s no paper to worry about—it can save hundreds of trees—and there’s no wait for someone to input the data. There are so many benefits, but mainly it’s about the processing speed and the increased accuracy that allow us to focus on what’s taking place on the airfield.”

Virginia’s SMART SCALE program uses GIS technology to prioritize infrastructure projects based on factors such as safety, congestion, accessibility, land use, the environment, and economic development. The program has been instrumental in enabling Virginia to embark on one of the country’s largest transportation projects—the expansion of the Hampton Roads Bridge-Tunnel.

“People are realizing that we need to attack transportation problems in a fundamentally different way,” said Chad Tucker, SMART SCALE project manager. “There’s a lot of great data sources that we have now that we can rely on to focus on the real problem areas and try to move the needle from a performance standpoint.”

The GIS-powered SMART SCALE approach ensures continuity across project description, features, sketch, and estimate. It provides a public dashboard for stakeholders to follow progress locally or across the state.

Modern infrastructure management requires holistic thinking on both micro and macro scales. A geographic approach to planning and operations helps leaders understand how infrastructure projects relate to surrounding environments. GIS is the nervous system for modern infrastructure management, connecting systems, workforces, organizations, and communities.

Vodafone Creates Country-Scale Digital Twins to Engineer Better Networks

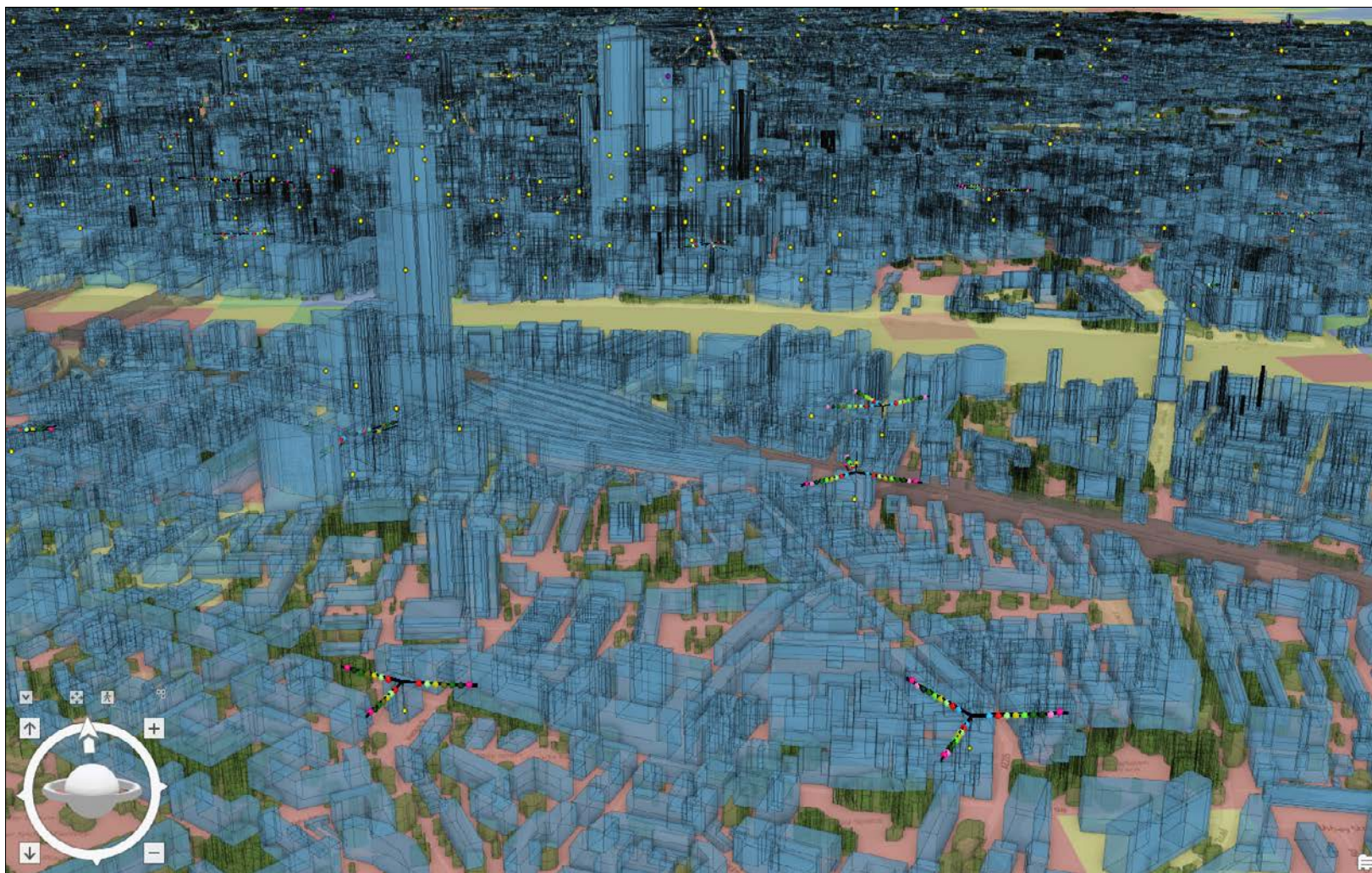
All mobile network operators offer a coverage map that allows anyone to see where signals reach, the quality of coverage (2G, 3G, 4G, 5G), and if the signal is strong indoors and out. At Vodafone, a high-resolution digital twin provides a far more granular understanding of the network than previously possible.

“Initially, it was purely a question of producing a better map,” said Boris Pitchforth, lead architect at Vodafone. “Now it has become a much smarter way for us to plan.”

The Vodafone digital twin for Britain—representing 245,000 square kilometers—was created using GIS technology. It



A training session is guided by a projection of the company's digital twin on a video wall. Image courtesy of Vodafone.



Vodafone's digital twin guides maintenance and upgrades to the network. Image courtesy of Vodafone.

contains various levels of immersive 3D detail that give anyone at the carrier the ability to see the invisible signals the company creates and sells.

For engineers, the digital twin enables signal propagation modeling across coverage areas to guide constant maintenance and upgrades that strengthen signals and increase coverage area.

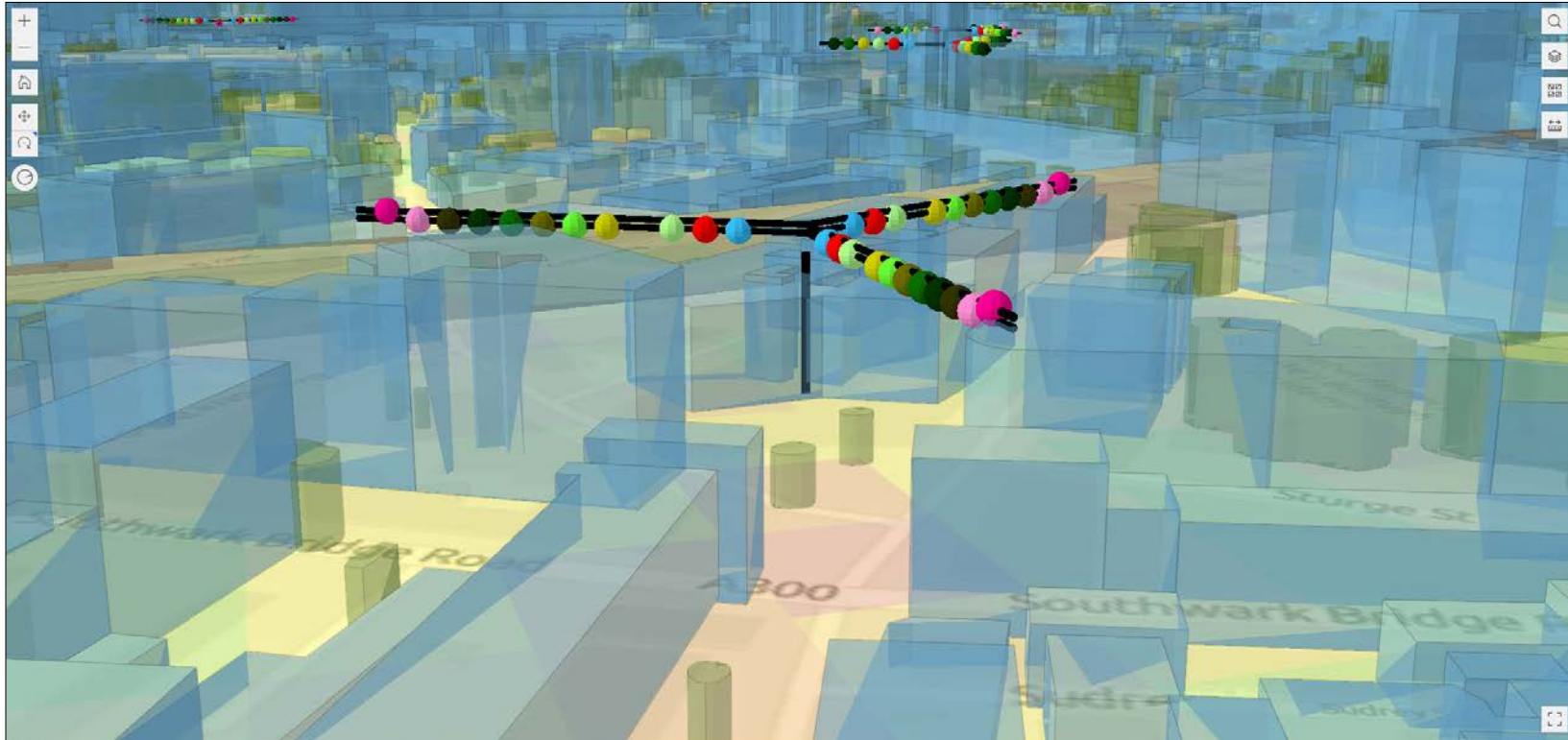
Vodafone's digital twin enables the company to stay on top of plans for developments, such as new housing, shopping

centers, and sports venues. This helps ensure Vodafone's signal is strong wherever demand is growing.

The UK has been Vodafone's test ground for its pioneering digital twin. The company is now looking to adapt this approach to cover the millions of customers Vodafone serves in 12 countries across Europe.

Signals Diminish Wherever There's Clutter

In the beginning, Pitchforth and his team used the digital twin to combat clutter—objects that obstruct cellular signal.



For engineers, the digital twin enables signal propagation modeling to tune the signal to the neighborhood and user demand. Image courtesy of Vodafone.

Trees were an early consideration, especially tree growth. To model tree growth, the team has acquired tree data spanning many years, with details about seasonal changes that impact signal.

“We don’t know individual tree types,” said Rebecca King, GIS lead at Vodafone. “It might be unrealistic to think we could capture whether each tree is an oak, hazelnut, or conifer across the whole country, but we would capture that if we could.”

Vodafone’s 360-degree view of the network and signal strength is stored in the Amazon Web Services (AWS) cloud; attributes are cataloged and visualized using ArcGIS Enterprise.

The country-scale details about clutter include more than 40 million environmental features. Network features, such as towers and equipment, add another 500,000 records. Network performance data adds billions of rows of data to the database

to depict signal strength across space and time. And keeping track of population volumes, such as how many people are on the road or travel through each train station, allows Vodafone to conduct capacity planning.

Engineers Gain Awareness

The digital twin has become instrumental to planning. With details about topography, cell towers, and the equipment on each tower, engineers can preplan for work on individual towers or whole sections of the network. They can look at how a new tower could fill a gap in coverage, or model how adding or removing a component might impact signal strength.

The digital twin also enables engineers to measure infrastructure remotely, which saves time and money because they don’t need to go to the field every time to take a measurement. It can also be used to direct them to the cell



The digital twin captures some things at higher levels of detail than others, such as this cell tower captured along with the complex urban environment around it. Image courtesy of Vodafone.

tower in the middle of a field or in a dense urban environment, where finding the path or access road can be tricky.

With the digital twin, major landmarks—such as London’s Paddington Station with railway lines, skyscrapers, a canal, a bridge, and a busy road—are modeled in fine detail.

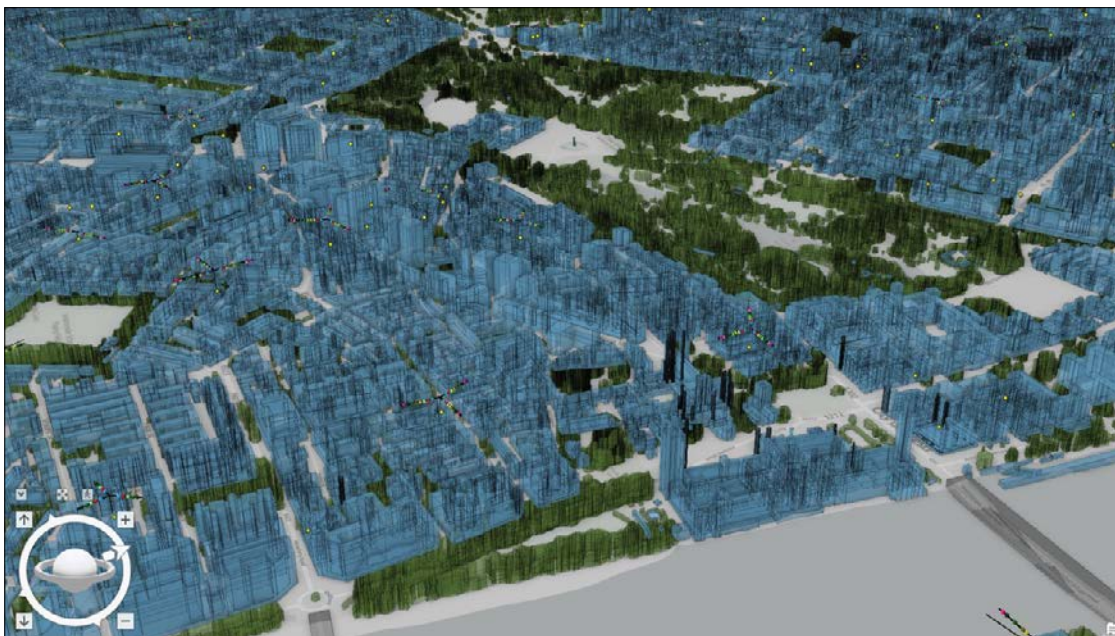
This Is a Tool Every Vodafone Employee Can Use

The amount of place-, equipment-, and signal-related data that the digital twin integrates is staggering. But as Pitchforth points out, no digital twin is perfect. Vodafone has built its digital twins so that

people across the company can correct inaccuracies and fill in missing information. “The more people who see the network and know the network, the more people who can report any gaps,” he said.

The digital twin also contributes to Vodafone’s pledge to ensure that its UK operations achieve the goal of net-zero carbon emissions by 2027.

“We’ll always need engineers to go out—there’s no way around that. But we want to reduce multisite visits,” Pitchforth said. “Instead of driving all those trips, the digital twin allows an engineer to visit the site virtually while sitting at a desk. It’s surprising how the emissions savings add up.”



Vodafone’s digital twin needed to capture all the trees in the parks around Westminster because leaves can obstruct the signal. Signals on 5G networks transmit at a higher frequency than older networks but this decreases the signals’ range and lessens their ability to penetrate obstructions. Image courtesy of Vodafone.

In Australia's Fastest-Growing City, a Digital Twin Guides Rail Expansion

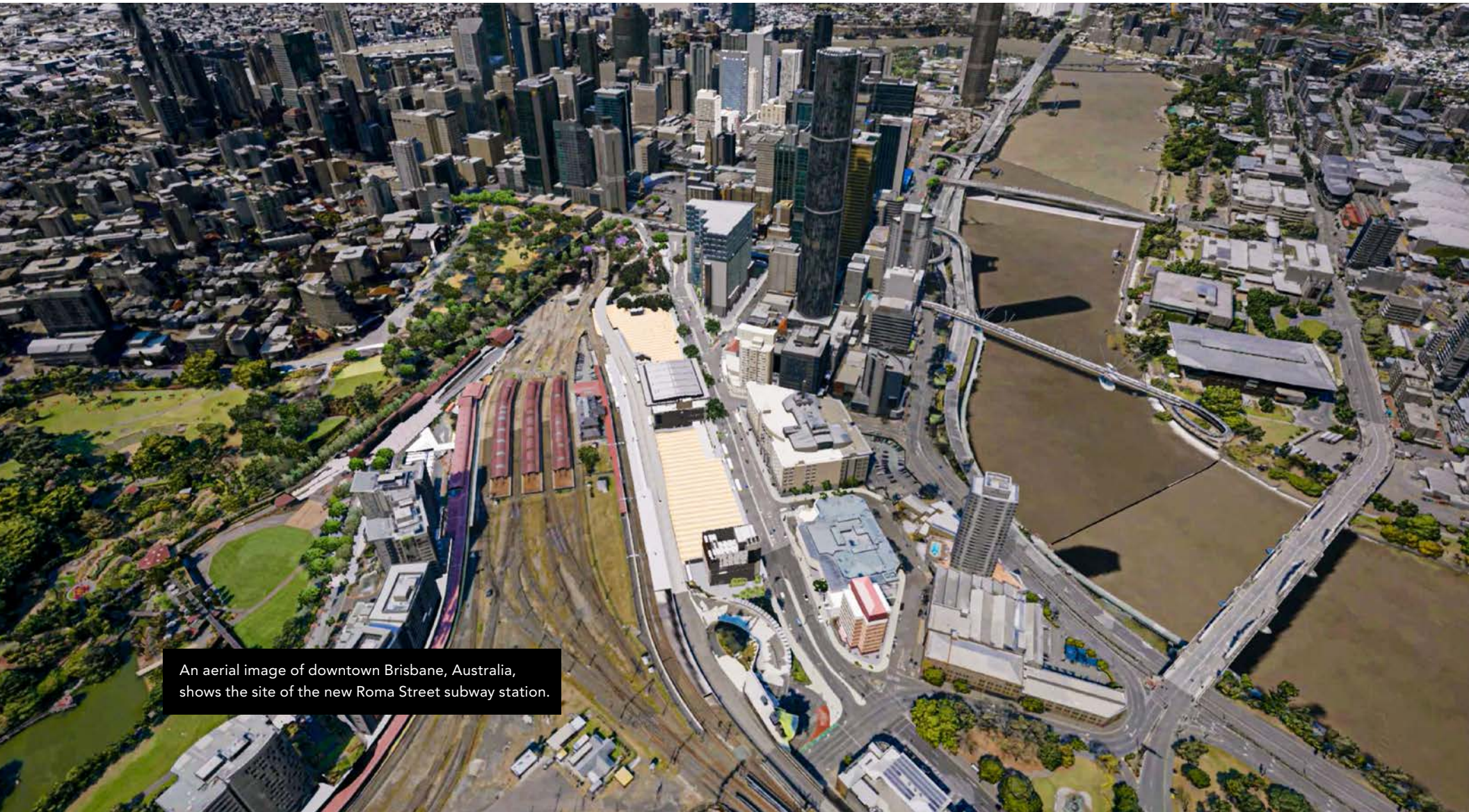
The team tasked with designing the first underground railway under the heart of Australia's fastest-growing city knew it would be a delicate task, fraught with infrastructural peril. Tunneling several stories under Brisbane's teeming metropolis, constructing expansive subterranean stations—what could go wrong?

At the outset with service beginning in 2023, nobody knew that the effort would involve an ingenious application of a GIS,

creating a detailed and up-to-date 3D model of the project and the Queensland capital city above it, and an immersive digital twin that brings the project to life.

A Rapidly Growing Queensland

The Queensland government conceived the Cross River Rail project as a way to alleviate population pressures. By 2036, the South East Queensland metro area is projected to add another 1.5 million residents (a number that by itself would



An aerial image of downtown Brisbane, Australia, shows the site of the new Roma Street subway station.

make it Australia's fifth-largest city), pushing the region's total population to nearly 5 million.

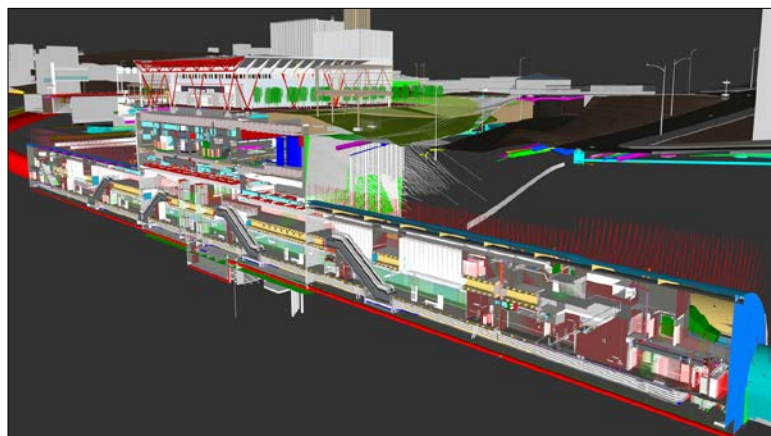
Most of these new arrivals will live outside of Brisbane, but within commuting distance. Many of the new jobs, however, will be in the Brisbane central business district (CBD), on the north bank of the Brisbane River.

Current rail infrastructure is insufficient to handle the necessary increase in CBD-bound train traffic. Cross River Rail will add 6 kilometers of twin tunnels under the river and four new underground stations.

A Bigger, Better Model

Soon after the project was announced, the Cross River Rail Delivery Authority, the overseeing agency created by the Queensland government, sought advice from colleagues on the other side of the world. The Crossrail project in London, launched in 2009, has similar aims, creating new tunnels and 10 new underground stations throughout Central London.

Crossrail involves construction beneath a metro area even denser than Brisbane's, with extremely narrow margins to avoid damaging existing underground infrastructure. "They're like our big brother that we idolize," said Russell Vine, Cross River's chief innovation officer.



A BIM model of Wgabba Station shows the level of detail required to guide construction.

By the time Cross River's plans were beginning, Crossrail had been under construction for almost seven years. The Cross River team contacted their British counterparts and asked what, if anything, they would do differently if they could start over.

"They basically said, 'We would have built a bigger, better 3D digital model sooner,'" Vine said. The big brother then offered three steps for how to build the perfect GIS-driven digital twin:

1. Create a common data environment.
2. Stipulate that all contractors use the same standards in their 3D architectural models so that they can all combine into a single model for the project.
3. Make the model immersive.

An Expansive Mission

For starters, Crossrail recommended that Cross River create a common data environment for all work. Any project-related dataset, no matter what the format—GIS, BIM, volumetric, photogrammetry (a three-dimensional coordinate measuring technique that uses photographs), everything—should be in a central repository.

This was useful advice. GIS technology has become adept at integrating BIM models and other project-related data formats into a GIS environment.

BIM models are 3D architectural models. They describe and depict the actual things being built or dug, whereas GIS adds contextual awareness.

Rather than just consider the BIM models as inert objects floating in space, people involved in a project can visualize what's around them. In GIS, they can see how each structure fits into the infrastructure above ground (such as paths, roads, and light poles), underground (the pipes and lines that connect utility services), and to the natural world (landscaping,



Workers enter the Roma Street cavern to conduct an inspection.

groundwater, and even wildlife and biodiversity considerations).

The advice also helped Cross River handle a broad mandate. When Queensland's government created the Cross River Rail Delivery Authority, it required the agency to be responsible not just for the railway itself, but also for planning and assessing the project's economic impact.

There was a good reason to include this mandate in the agency's charter. Although Cross River's aim anticipates future developments in the region, its location means Cross River will also *influence* those developments.

"Cross River Rail is going right under the CBD, so the area around the stations is already prime land where the city will grow next," Vine said.

Everything In Federation

Crossrail's second piece of advice related to BIM data coming from the project's many contractors and subcontractors. Create a "federated" BIM model, the Brits advised.

That meant combining the disparate BIM information into a single BIM file that depicts everything. For that to happen, Cross

River needed to ensure that every contracting entity was using exactly the same data formats, standards, and protocols.

"What the Crossrail team didn't realize until it was too late is that all their contractors were telling Crossrail how they were going to submit their BIM models—it was baked into the contracts," Vine said. "They told us, 'We indulged them, and we shouldn't have.'"

Rail Games

Crossrail's third recommendation is "the party piece, the one everybody loves," Vine said, because it's about making the model immersive. "They told us they should've put all their data into a game engine and turned it into virtual reality."

The Australian team did just that, using Unreal Engine, a 3D gaming tool, to tie it all together, so anyone sitting anywhere could be transported inside the place they were set to build.

So we have a federated BIM model of all the stations and all the tunnels, and GIS land mapping in 3D. But then we put it all into Unreal, crank the magic gaming engine handle, and it gives us back a single virtual reality.

— Russell Vine, chief innovation officer at Cross River

The result is 17 kilometers of immersive railway infrastructure that can be explored, similar to a first-person game, on a screen manipulating a web scene or with a virtual reality (VR) headset. The Cross River team even built a VR theater using a five-way projection system, so that many people can explore the project together.

The VR component transcends mere flash, providing a way for nontechnical stakeholders—people not directly involved in the design and construction of Cross River—to view the project as it proceeds. It also gives those who are part of the design team the kind of visual assessments that even the most detailed 3D BIM model cannot provide. As one example, Vine points to the Roma Street station, where teams are experimenting with ways to install a massive art exhibition

space on a concourse wall, trying and testing different ideas virtually before they finalize the design and build it.

The Digital Twin Expands to Capture All of Brisbane

Cross River's commitment to the common data environment (step one of the three-point plan recommended by the Brits) signaled a shift in the usual relationship between GIS and BIM on this kind of large infrastructure project. In the past, GIS would have served as a crucial support player, a context-adding host for the 3D architectural BIM renderings. But considering the mandate to document economic development around the train stations, Cross River elevated the importance of GIS. To depict those aboveground areas, Cross River required skillful 3D maps, including data gathered by lidar sensors to capture engineering-grade measurements.

That, in turn, led to another requirement. The aboveground data would also require context.

If the goal was to understand how the stations would affect economic development in the CBD, it didn't make sense to map just the area around them. You needed a map of the entire CBD. And everything had to be layered perfectly, so that anything underground (stations, tracks, tunnels, cables, and pipes) lined up in every respect with what was above it.

The result is a 3D land layer that shows lots, utilities, and other pertinent visual information. Cross River's use of 3D even includes material designed in consultation with Brett Leavy, a self-described "cultural heritage digital Jedi" who uses advanced VR technology to re-create precolonial Brisbane. Leavy's input, Vine explained, has helped ensure that the project honors and remains respectful of a First Nations perspective.

"We went from 'it's all about building a railway' to 'ah, it's also about rebuilding the city,'" he said. "We ended up making a 3D model of Brisbane, because it was impossible to do one without doing the other."

A Twin without End

The Cross River digital twin is a continuous work in progress. As designs are finalized and construction proceeds, a staircase or tunnel that existed as a single item in a contractor's initial BIM submission becomes one with thousands of individual components in the federated BIM model.

Beyond just the Cross River project, there's no reason the digital twin can't continue to grow in perpetuity, evolving with Brisbane itself. "We have a running joke about Cross River Rail, that the more you look at it, the bigger it gets," Vine said, noting that after the project began, the city was selected to host the 2032 Summer Olympic Games. "We have an opportunity to take what we've done here as part of building a railway line and stretch it to include everything we're going to need to build for the Olympics."

Vine even foresees the twin being a tool for operating the system in addition to its value in design, construction, and project management. "We realized we've built a digital twin that will help run the railway," he said. "So there's almost a whole second chapter waiting to be written."



Cross River Rail project map, with four new stations: Roma Street, Albert Street, Woolloongabba, and Boggo Road.

A Digital Twin of Ports and Channels Helps Army Corps Maintain US Waterways

The Mississippi River, America's most important inland waterway, moves essential commodities to market, including most grain exports, at lowest cost. Wild shifts in this mighty river's water levels have often caused national concern and uncertainty. But a newly crafted digital twin, designed to monitor and simulate river behavior and operations, reveals trouble spots.

In 2019, record precipitation kept the river above flood stage for more than 235 days. Then in summer 2022, water levels fell 11 feet below average because of protracted drought. Low levels caused barges to run aground and forced vessels to carry less cargo. Trucks had to take on loads in some spots. As freight costs rose, difficulties moving goods to market drove down the domestic price of grain and farmers faced losses.



A Mississippi River barge passes the famous arch in downtown Saint Louis, Missouri.

To help keep barge traffic and commerce flowing, the US Army Corps of Engineers (USACE) directed crews to dredge the river around the clock. For six straight months, they worked to maintain the nine-foot-deep channels that barges require. They managed this endeavor—keeping an eye on river conditions, operations, and vessel traffic—using GIS technology.

To monitor this work, the corps uses many purpose-built GIS-powered systems that monitor conditions and analyze vessel traffic. A new navigation portal, NavPortal, combines these data inputs to provide an operations-wide digital twin. NavPortal combines cloud computing, ship tracking, and AI to process and present huge volumes of data. It shows current channel conditions and compares that information to river traffic.

“We’ve got hundreds of dredge locations nationwide, and we need a tool like NavPortal to be our early-warning indicator,” said Ned Mitchell, a research civil engineer at the US Army Engineer Research and Development Center and NavPortal product manager. “We need to see the worst trouble spots forming before they become full-blown emergencies.”

Achieving Operational Awareness

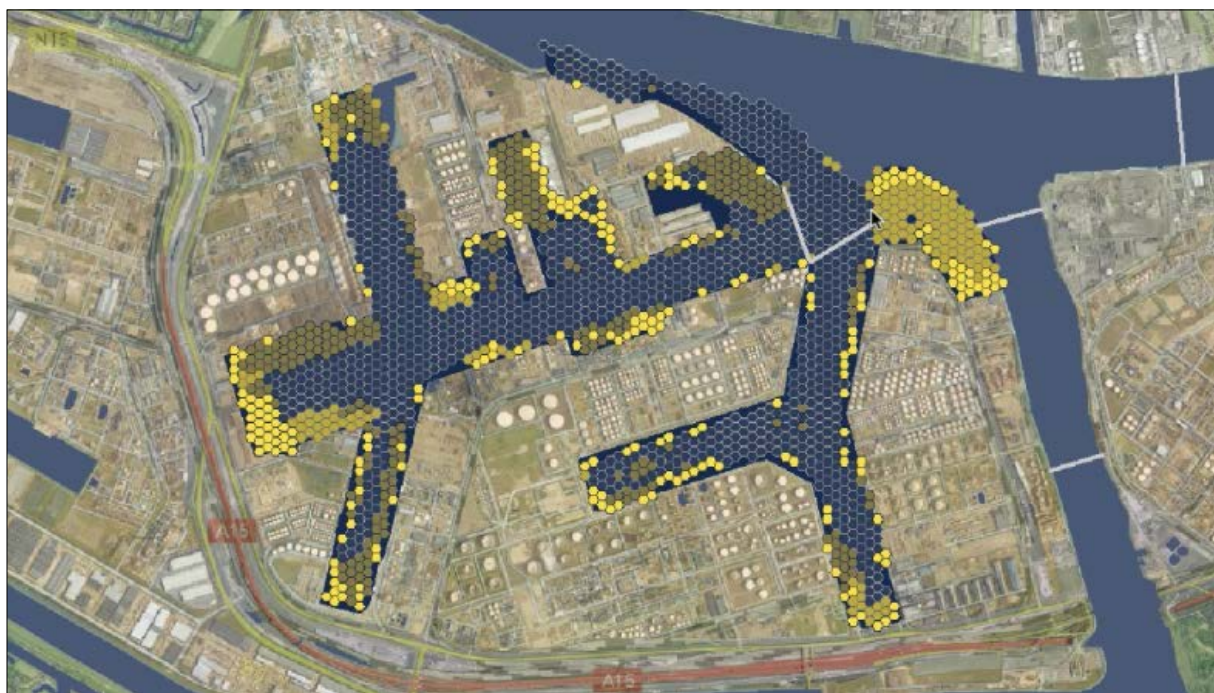
Along the Mississippi are six corps districts from Saint Paul, Minnesota, to New Orleans. Each district manages a stretch of river with a mix of dams, locks, levees, and dredged channels. In all, there are 4,200 miles of channels, 62 locks, 51 shallow-draft ports, and 7 deep-draft ports. That’s a lot to maintain. Complexity

increases with flood or drought, particularly at harvest time when river traffic spikes.

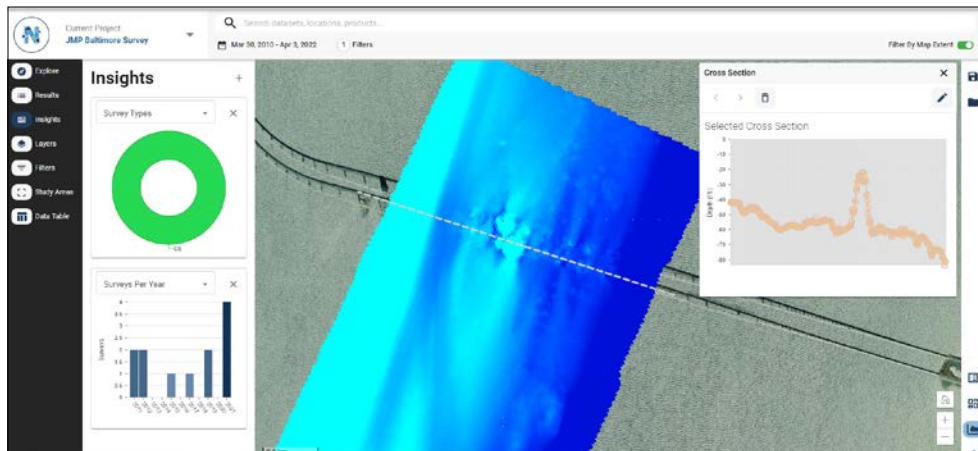
Drought conditions in October 2022 caused a backup of 3,000 barges. The delayed loads could have filled more than 200,000 semitrailer trucks (if that many were available). Farmers were able to move only half the volume of corn shipped the previous year. Shipments of fuel, chemicals, and building materials also stalled.

Congress stepped in, directing funds to address the inherent knowledge management problem that results from so many data feeds tracking so many volatile parameters. That’s when the NavPortal team created the operations digital twin using a federated systems approach, combining feeds from legacy systems that each play a part.

“The people we work for need all these inputs in one view right in front of them,” Mitchell said.



NavPortal helped determine the areas in the most need of dredging, shown in yellow.



Zooming in, NavPortal users can see channel surveys and cross sections to see where obstructions are building.

Now NavPortal provides clarity. It affords each corps district a current view of its stretch, along with the entire river. When there's little time to gather data and conduct in-depth analysis, NavPortal delivers ongoing awareness. It empowers staff to identify problems and plan fixes before channels clog.

Dealing with Volatility

The corps's project engineers have a tough job to understand channel depths and sediment buildup. In the

midst of drought, for instance, intermittent rains can make any stretch of the river viable for barges one day and impassable the next. "Trying to chase the bottlenecks in a system like that is a real challenge," Mitchell said.

Some veteran project engineers know intuitively how the river will change. But with more volatile weather because of shifting climate patterns, river behavior can defy even the sharpest instincts. And for novice engineers, surprising shifts over just a few years have set no reliable patterns.

NavPortal reveals the dynamic nature of the situation. "Now we have a digital twin to lay it all out for them," Mitchell said.

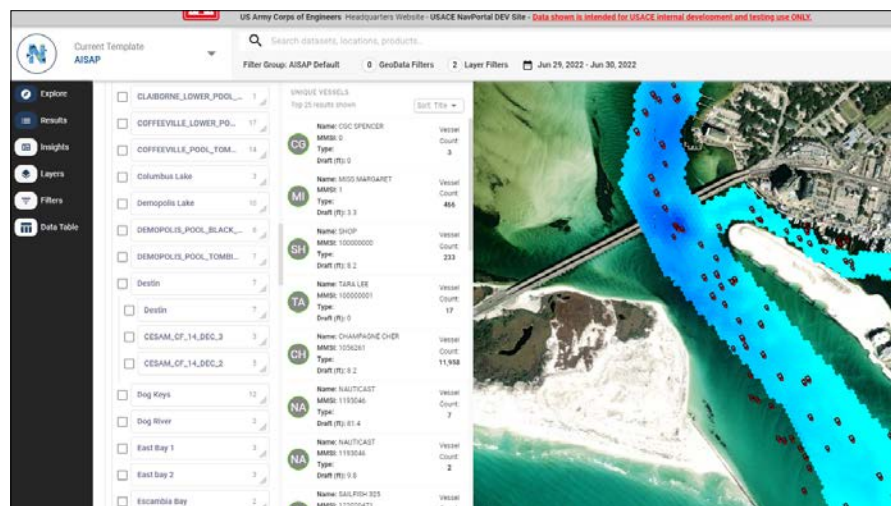
The portal's mix of map visualizations, charts, and graphs provides a holistic view of navigation projects and alternatives. "The idea is to make all the data accessible and understandable," said Josh Pritchard, a GIS and NavPortal manager for the USACE Mobile, Alabama, district office.

This comprehensive resource proves crucial as channel blockages can multiply quickly, with one or two choke points turning into dozens across many states. It gives engineers insight into current and historical patterns, plus predictions about what's likely to happen.

"NavPortal lets us see trends through time," Mitchell said. "We can plot time series charts at particular locations where we've seen trouble before. And we can anticipate seasonal shoaling events that tend to create trouble."

Awareness Lowers Costs

The corps spends roughly \$1.5 billion each year on its hundreds of maintenance dredging projects across the country. Shippers want greater depth at ports to carry more cargo per voyage. Producers need open



The ability to view current vessel traffic and depth data creates a living map that can be queried to provide new levels of awareness about volatile parameters.



Seven dredges moved nine million cubic yards of material at 70 different locations along 300 miles of river channel in the US Army Corps of Engineers' St. Louis District in 2022. A normal average is three to four million cubic yards with just two dredges working. Photo courtesy of USACE, photo by Janet Meredith.

with areas that need the dredged material, such as eroded beaches or shrinking wetland habitat. Another strategy maintains channels at depths greater than required for shipping to allow for more time between dredging.

These complex constraints and opportunities provide a lot to consider when the conditions can't wait. The NavPortal digital twin helps corps analysts account for more variables, allowing them to test and iterate before committing to a plan.

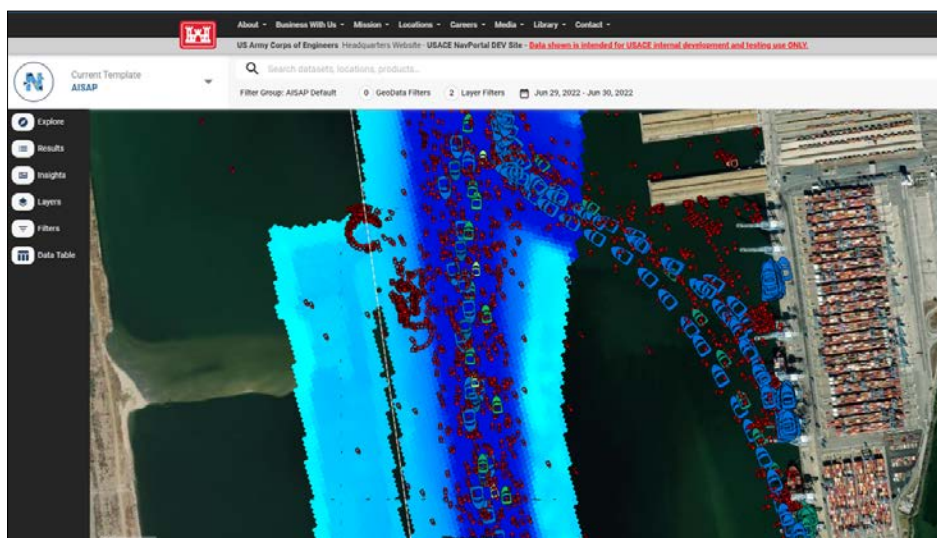
waterways to get their goods to market. And funds are never enough to cover all areas in need of upkeep.

NavPortal helps surface the most cost-effective maintenance strategies. The digital twin approach of scenario planning can consider more variables and answer more complicated questions.

Timing is critical. The corps owns some dredges, but most projects involve contractors. It's a time-consuming, multistep process to procure a dredge. Each permit undergoes environmental review. And most places have months when they can't dredge because of threatened species, such as sea turtles. Sediment will accumulate and channels can become impassable if there are delays with dredge contracting or if infill rates exceed historical norms.

Better coordination with awareness of conditions can make the most of each investment. By sequencing projects based on proximity, the engineers become proactive rather than reactive. They can also align projects

"We're hoping data can inform and, in some cases, change some long-standing ways of thinking," Mitchell said. "Now that we have data and quantitative trends, we can look at the life cycle equation. We can follow where the data leads to know if new approaches are cost-effective."



The ability to view current vessel traffic and depth data creates a living map that can be queried to provide new levels of awareness about volatile parameters.

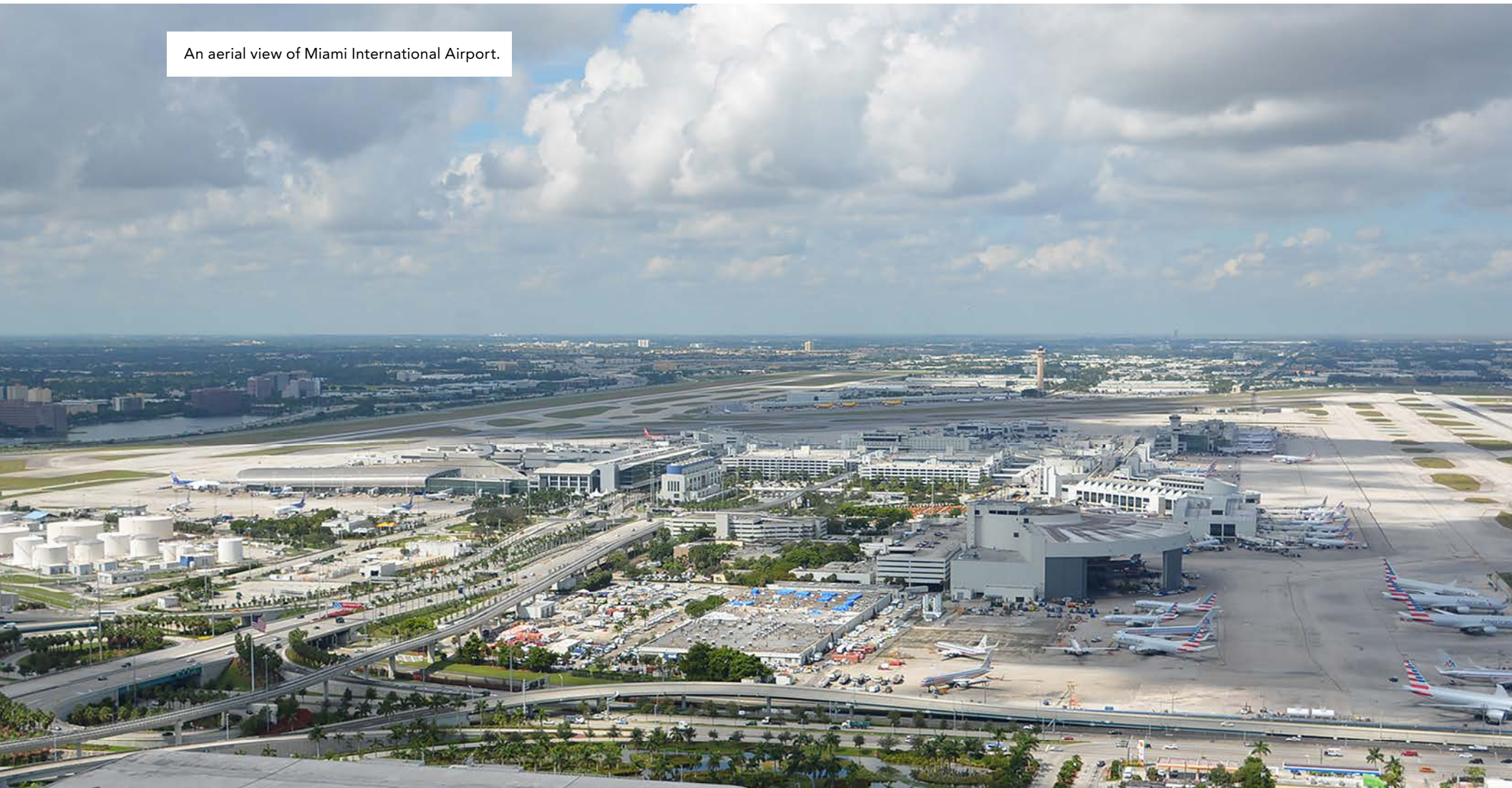
Miami International: Digital Transformation of Airport Inspections

MIA serves 1,000 daily flights to 176 destinations—moving more than 140,000 passengers daily—which makes it the 10th-busiest airport in the US. For international travel and cargo, it's the top US gateway. MIA's flow of people and goods creates a critical economic engine for Miami-Dade County and the state of Florida.

Considering the importance of keeping all that commerce and tourism in motion, MIA prioritizes quick mitigation of any issue involving any of its four runways.

Crews work in shifts all day, every day, to inspect, maintain, and clear the airfield—including all paved areas where planes take off or maneuver—of even the tiniest piece of loose pavement; trash; or a part, such as a lug nut, that came off an airplane. The Federal Aviation Administration (FAA) calls these hazards foreign object debris (FOD), and FOD is a central element of FAA Part 139 inspections. FAA conducts regular reviews of airfield maintenance and can levy large fines if an airport fails to conduct regular inspections and keep detailed records.

An aerial view of Miami International Airport.



“We can’t fail,” said Maurice Jenkins, MIA’s division director of Information Systems and Telecommunications. “So we make sure to have all the tools and resources available to ensure we rapidly address, respond to, deal with, and mitigate any disruptions in the most efficient and effective manner.”

MIA adopted an all-digital workflow in 2022, replacing a paper-based inspection process with tablets running apps built with GIS technology. The apps capture the location of every data entry, use pull-down menus to streamline recordkeeping, and can append a photo to text descriptions.

It’s clear-cut, it’s concise. No one has to worry about deciphering an inspector’s cryptic notes or interpreting what that individual meant when they made that notation. There’s no paper to worry about—it can save hundreds of trees—and there’s no wait for someone to input the data. There are so many benefits, but mainly it’s about the processing speed and the increased accuracy that allow us to focus on what’s taking place on the airfield.

— Maurice Jenkins, division director of Information Systems and Telecommunications at MIA

A Change to Streamline Airfield Maintenance

Jim Murphy, the airport supervisor who oversees Part 139 inspections at MIA, has been involved in airfield inspections there for 40 years.

“We were getting ready for my first FAA inspection, and my supervisor asked me to look at the grass areas adjacent to the runways to make sure there weren’t any holes,” Murphy said. “And I found a vault with a wood roof over it that was rotting away. When I think of how far we’ve come, that’s my starting point.”

Over the years of daily inspections, Murphy and his crews have conducted inspections at increasingly finer detail, creating a safer airfield.

“The regulations may not change much, but the level of what’s acceptable keeps getting tighter and tighter,” Murphy said.

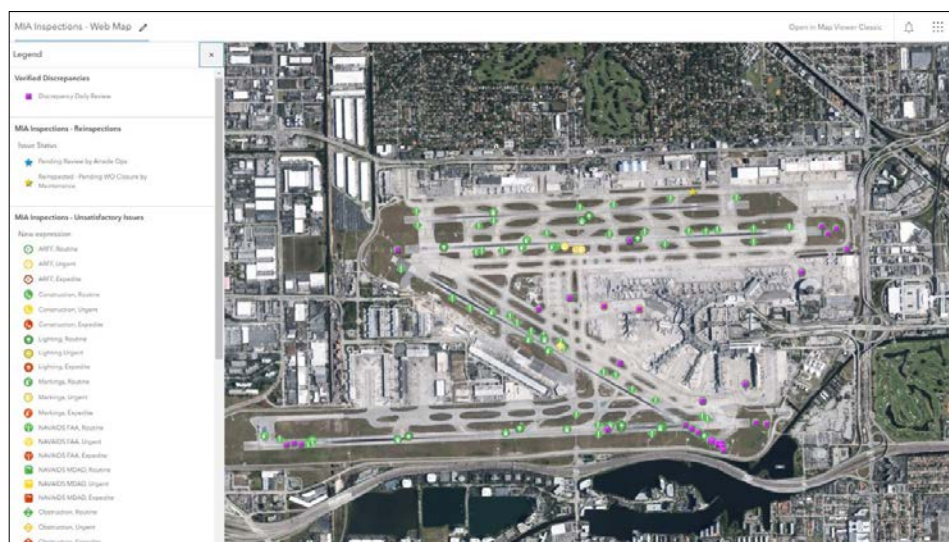
Before the digital tools, Murphy wouldn’t see an inspection report until the next day, but now, he can see the data as it comes in. “The output from this inspection tool allows us to drill down further, focus more, track better,” Murphy said.

With the change from paper to iPads, there’s more flexibility for anyone to record any foreign objects they pick up during daily rounds. It’s a quick process. “That’s the flexibility we wanted for FOD because if we’re traveling across the airfield for a meeting and see anything, like a plastic bottle, we stop and pick it up,” Murphy said.

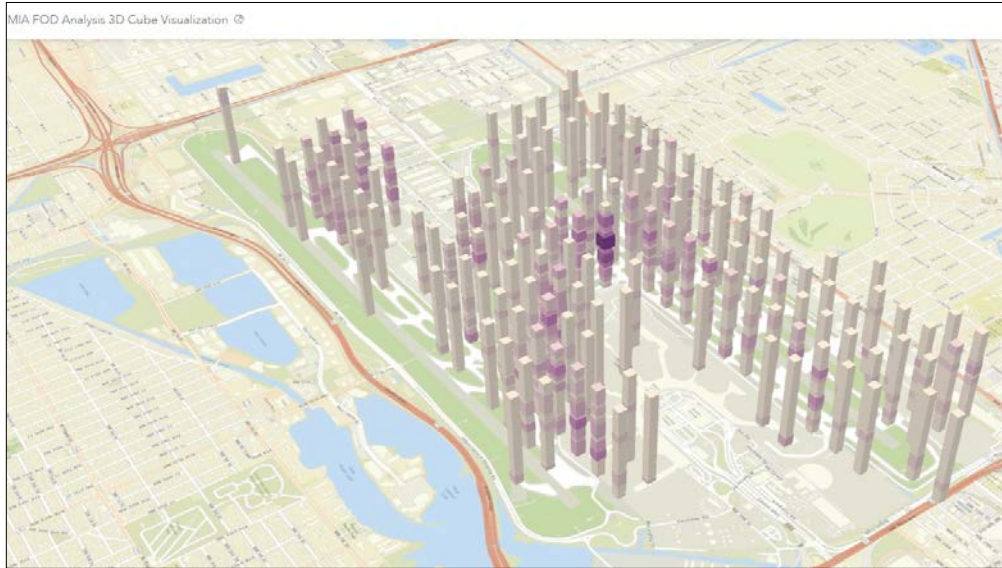
Inspection Improvements Lead MIA’s Digital Transformation

The digital transformation of MIA’s Part 139 inspections was implemented and refined by Miami-Dade County’s Enterprise GIS team, who configured components of ArcGIS, including ArcGIS Online, Survey123, and Dashboards to create shared maps.

“With process change, getting a better map is always key,” Jenkins said. “If I’m looking at a map, I’m getting the detail to



All the elements found during inspections get added to the MIA Inspections web map.



A 3D cube analysis shows where the density of debris has a tendency to grow or decrease related to certain events.

know what we're dealing with. And dashboards give senior management a great level of visualization to know what's going on as well. Everyone can engage and comment at one time rather than getting data later on, and we're all working off the same sheet of music, so to speak."

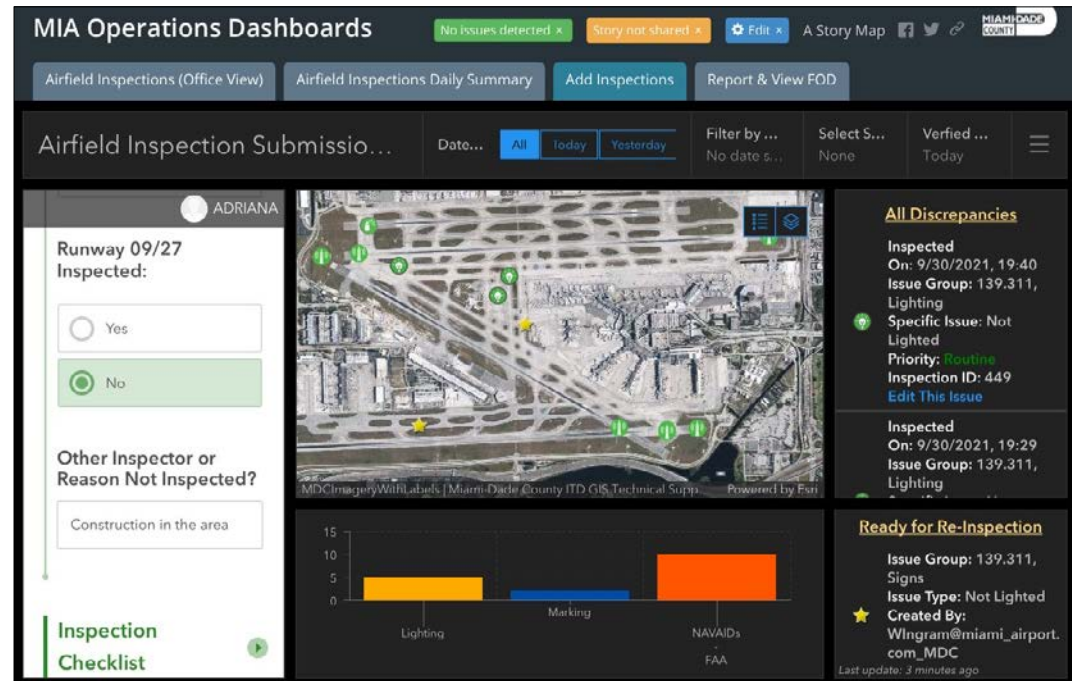
Miami-Dade County has been a GIS leader for more than 30 years, pioneering enterprise GIS approaches such as the sophisticated asset management system for the Miami-Dade Water and Sewer Department, which maintains the largest water network in the southeastern US. Before the inspection apps, MIA used GIS for planning and land-use decisions but not for operations.

Adriana Sanchez, the senior software developer and GIS analyst from Miami-Dade County's Information Technology

Department who led the implementation, shared that she's learned a lot about airports and the complex and rigorous workflows that are required. Staff at MIA had learned about the predefined airfield inspection tool that other airports are using and asked the county to investigate.

"We want to leverage all of the innovation possible to get a good, strong, integrated model of the airport footprint to maximize the delivery of our services," Jenkins said.

Before the latest digital tools, a few prior attempts to replace paper didn't work out. Although that led to frustration, it captured an inventory of the different areas of the airfield, which meant the GIS-based inspection tool could be implemented more quickly.



The MIA Operations Dashboards offer multiple views, including a summary of airfield inspection submissions.



Crews work around the clock to inspect the vast expanse of paved airfield at MIA.

Being able to visualize the data captured with Part 139 inspections has been a great help. When the FAA visited MIA for its twice-yearly review of inspections, instead of poring over papers to review inspections, the auditors could view all inspections in ArcGIS Online, look at inspections for any day, and conduct their review more efficiently.

“Nobody likes having to sit there and read a lot of paper,” Jenkins said. “Having a visual representation and seeing everything within a dashboard lets us do better empirical decision-making on the fly to improve our operational efficiency.”

And with these results, there’s momentum to apply GIS to other challenges at MIA.

As Jenkins said, “We want to dive deeper, get training, and develop a GIS strategy for the airport.”

Airport Modernization Fuels Digital Twin Approach

Big changes are coming to MIA to meet its continuing growth and projected demand of 77 million passengers and 5 million tons of freight annually by 2040.

In 2019, the Miami-Dade Board of County Commissioners approved a \$5 billion airport improvement plan to take place through 2035. The plan includes

concourse improvements, the construction of two on-site hotels, and the expansion of the airport’s cargo capacity.

To monitor the complex and carefully sequenced construction and renovation work, MIA has been developing a GIS-based digital twin to create a single source of truth for information and digital models.

“As we look at the digital twin, we’re going to go from 2D to 3D, 3D to 4D (adding time and scheduling), and potentially 5D (cost estimates and budget analysis),” Jenkins said. “We’re focused on getting rid of one-off solutions and mitigating disparate systems to tightly integrate business processes. We can create the go/no-go model to look at everything.”

Virginia Ahead of the Curve on Prioritizing Infrastructure

With \$110 billion flowing to states and local governments across the US to repair and rebuild roads and bridges as part of President Biden's infrastructure bill, deciding how to prioritize work will present its own unique challenge. At least one state will know exactly where to start, though. Virginia's geographic approach to prioritizing infrastructure projects has already enabled the state to embark on one of the largest transportation projects in the country: expanding a busy 3.5-mile, four-lane bridge-and-tunnel system.

The Office of Intermodal Planning and Investment has partnered with the Virginia Department of Transportation (VDOT) and the Virginia Department of Rail and Public Transportation to develop a way to score projects across six main categories: safety, congestion, accessibility, land use, the environment, and economic development. The approach, known as SMART SCALE, uses a GIS to visualize and analyze all relevant data in the context of location.



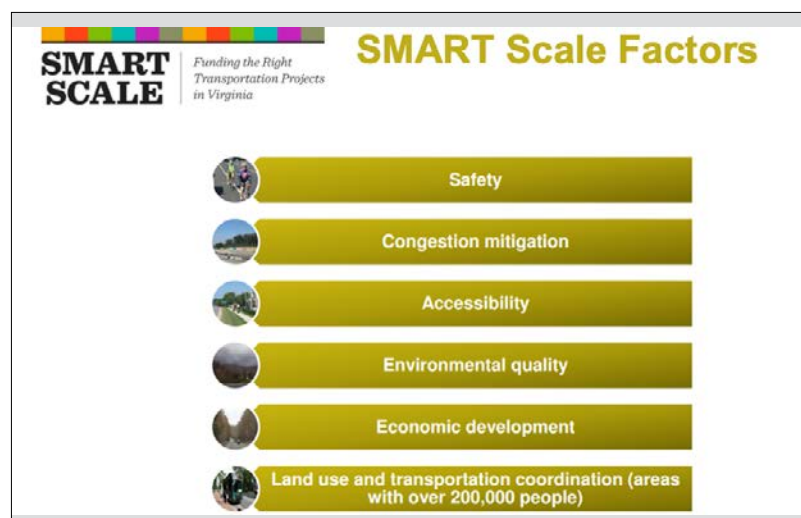
The towns and cities in the Tidewater Region of Virginia are connected by a series of bridges and causeways.

“People are realizing that we need to attack transportation problems in a fundamentally different way,” said Chad Tucker, SMART SCALE project manager. “There’s a lot of great data sources that we have now that we can rely on to focus on the real problem areas and try to move the needle from a performance standpoint.”

For example, there’s a proposal to expand the Hampton Roads Bridge-Tunnel (HRBT) in coastal Virginia, ranked highest for its impact on congestion, access to jobs, multimodal and intermodal access, and travel time reliability. The commuter route links some of Virginia’s most populous cities separated by water and is an essential route for people living and working on opposite sides of the bay, lake, or river. Its ability to handle growing traffic meets a transportation need as well as an economic one, allowing local industry to continue to thrive.

These are the same needs so many other states, cities, and counties will consider with new funding on the horizon for fixes to roads and bridges.

In 2016, then-Virginia transportation secretary Aubrey Layne credited SMART SCALE for being one of the primary drivers to make the HRBT expansion happen, calling it a “keystone project” that tied together other transportation work in the region.



SMART SCALE factors weighed to determine priority projects.

Now, in another project in Virginia using the SMART SCALE program, nearly 10 miles of the I-64 corridor bridging the cities of Norfolk and Hampton, including the 3.5-mile stretch of the HRBT tunnel, will have double the lanes—eight—by 2025. Its \$3.8 billion total price tag makes it the largest transportation project in Virginia’s history.

Setting a Standard Criteria for Project Approval

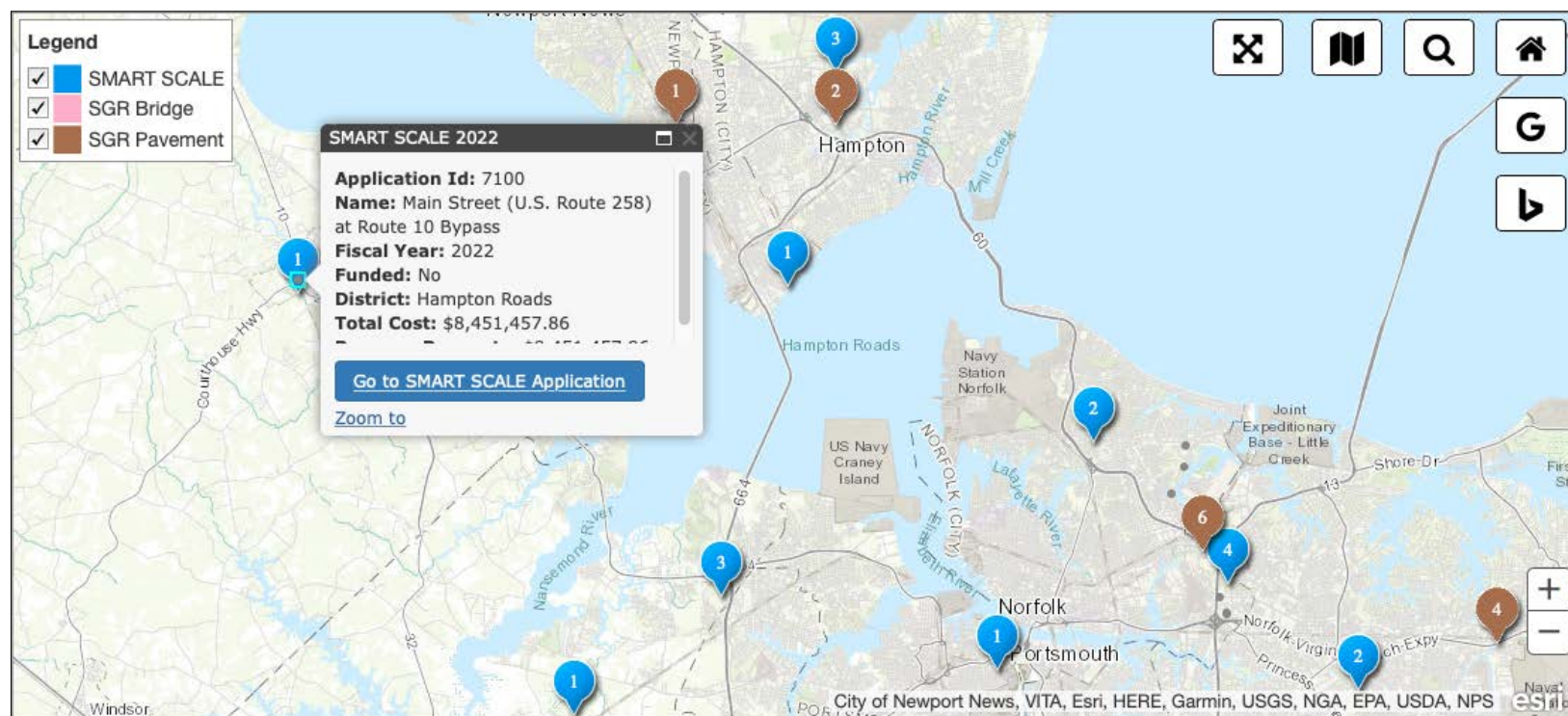
The process of vetting proposed projects for Virginia’s Transportation Plan (VTrans) begins with a multimodal needs assessment along the state’s transportation network, evaluating congestion, safety problems, and more. “There are plenty of needs. That’s the point,” said Brooke Jackson, senior engineer at VDOT, speaking about the carefully cataloged list of requirements that determine what projects are eligible. Jackson says there are always far too many projects to fit available funding, and this metrics-driven approach lends fairness and a scorecard approach that lets submitters see where their proposals succeeded or fell short.

Funding rounds are open to Virginia cities, counties, towns, and public transportation agencies on a two-year revolving schedule. If a proposed infrastructure project meets a need identified by VTrans and the SMART SCALE program’s readiness and eligibility criteria, the project can be considered and evaluated.

Before SMART SCALE was implemented in 2015, municipalities needed to get on a list kept by the governor. When a new administration came in, the project could be halted, money wasted, and no one held accountable.

Traditional funding mechanisms caused projects to take too long, and without having to prove the value of the investment, political will was at the core of prioritization. SMART SCALE sets out to remove politics and instead let data and expected outcomes drive decision-making.

“Everybody can see the data and what could be studied,” Jackson said. “It’s not about picking and choosing political



The map shows SMART SCALE bridge and pavement projects. The numbers relate the priority level of each project.

favorites. It's about providing benefits and improved system performance to help move people and goods."

Now, with a public GIS-powered dashboard, each project and project stakeholder have accountability. Anyone can see which projects have been selected for funding, why each project was selected, and furthermore, whether they are on schedule and on budget.

Addressing Equity and Showing Transparency

Projects are also monitored throughout their life cycle to ensure they are meeting goals. Of the approximately 400 applications submitted each year, fewer than half are selected for funding. Those chosen are expected to complete their projects within six years; the first six-year cycle wrapped up in 2022.

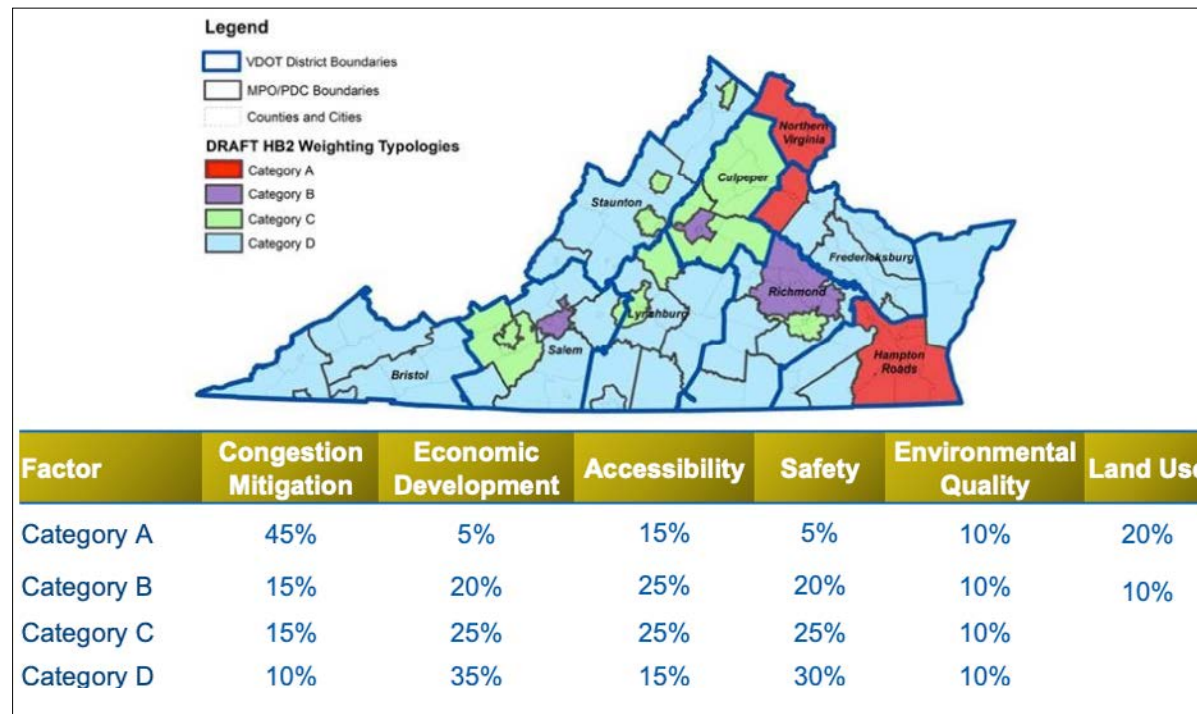
Managing each project during this cycle has been easier, with the GIS-powered SMART SCALE approach ensuring

continuity between project description, features, sketch, and estimate. Any stakeholder, including residents, can refer to the interactive map and dashboard to follow progress locally or across the state.

SMART SCALE is also helping to address infrastructure equity. Analysis of who benefits from projects is built into the process; this wasn't necessarily the case before SMART SCALE. Education and poverty levels are considered when scoring improvement projects. Accessibility, including access to public transit to connect people to jobs, is another key consideration for equitable mobility.

Whether projects are implemented by localities or by VDOT, their progress is tracked on the same public dashboard and held to the same standards. This transparency encourages participants to explain their mistakes—why it happened and how it will be fixed or prevented in the future—and to resist

Map of priority congestion mitigation projects across Virginia. [Long description.](#)



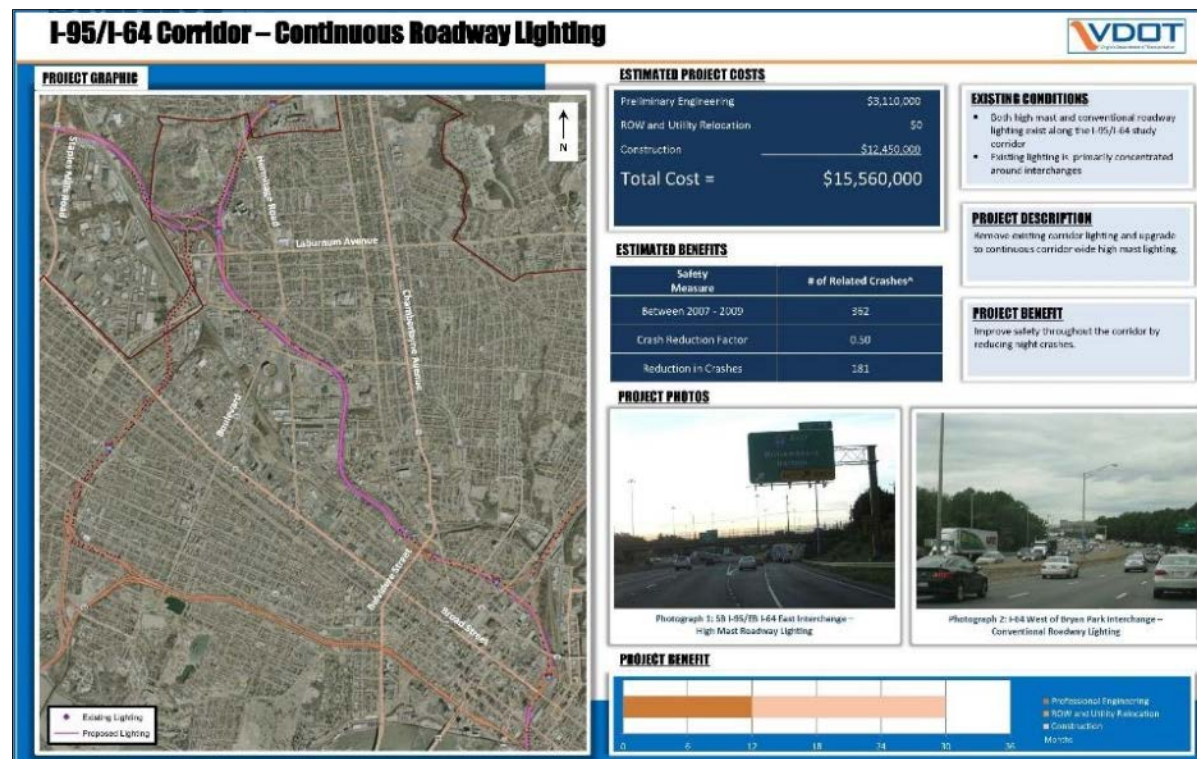
the urge to conceal failure, rather than learn from it.

To gain the public's trust and bolster the program's integrity, there are a few other rules, too: show your work and maintain communication after funding and throughout implementation.

"With SMART SCALE, you're getting all the money you ask for, and in six or seven years, we expect to see it built," Jackson said.

So far, the results in Virginia have been positive, and perhaps this will be a model for other states to emulate when prioritizing and managing upcoming infrastructure projects.

"Communication is better, investment into the system is better," Jackson said. "Working toward a bigger goal with a plan is important. We are getting a lot more projects completed start to finish in a faster time with a transparent process."



A Smart SCALE project map of roadway lighting improvements near Hampton, Virginia.



Sustainability

Throughout the world, GIS plays a central role in sustainability efforts by providing a comprehensive ecosystem for integrating and visualizing diverse environmental data. It enables stakeholders to make informed decisions by mapping and analyzing various sustainability factors. With the use of GIS, information on land use, biodiversity, water resources, and energy consumption can be overlaid on infrastructure assets and analyzed to identify patterns, relationships, and areas for improvement.

The white oak trees needed to make bourbon barrels have always been hard to find. White oak trees play a crucial role in bourbon production because of their unique cellular structure that permits an interactive exchange within the barrel, impacting the beverage's color and flavor.

Twenty years ago, finding the perfect white oak was as much an art as it was a science, relying heavily on the expertise and knowledge of experienced foresters. The introduction of GIS technology and a "bourbon barrel app" has significantly improved the process of locating these trees. The technology has empowered foresters to make better decisions about where to build a sawmill, based on factors such as the number and quality of local white oaks, available road and river transport, and the potential workforce.

The United Arab Emirates (UAE) has leveraged GIS technology to map its growth and quality of life over the past 50 years. The UAE's Federal Competitiveness and Statistics Centre (FCSC) used GIS technology to measure the country's progress from a predominantly oil-based economy to a more diversified one. The technology was used to modernize workflows and visualize the statistical indicators gathered for sectors such as health, education, the environment, and the economy. "We started by collecting detailed facilities datasets from ministries, like health and education facilities, and geoenabling statistics to map more than 70 national indicators," said Marwa Elkabbany, the GIS expert with FCSC.

The alarming rate of global pollinator decline has made habitat restoration a conservation priority, and Commonwealth Edison (ComEd) has been a longtime leader in doing its part by preserving native prairie habitats around its transmission lines. GIS technology has been instrumental in protecting the habitat of the endangered Hine's emerald dragonfly. The company used GIS maps to guide the relocation of some of its electric transmission towers, ensuring that the insects were not harmed during their dormant period. "Everything is marked in GIS so that our crews know exactly where they can and can't go," said Tom Ringhofer, manager of transmission vegetation management at ComEd.

Organic Valley, a national organic food brand and cooperative, has developed personalized data-driven reports and images that indicate the health of each paddock where dairy cows graze. The company provides this crucial information to farmers for important management decisions, such as how fast or slow to rotate the cows or when to cut grass and make hay.

"Many farmers have their standard rotation and adjust based on what they're seeing, but it can be difficult and time consuming to visually cover all those acres," said Phil Marty, GIS administrator at Organic Valley. Now, farmers complement conventional wisdom with insights from imagery to make data-driven decisions that have produced notable increases in pasture utilization.

Starker Forests, a family-owned land company, has been using GIS technology for decades to map holdings. However, the company has recently moved to a more collaborative approach, sharing data about the forest and its work. This transition was driven by changes in legislation, requiring forest landowners to share activities in near real time. "With the dashboard, the person responsible for each step can look and see when each process will be done for each unit so they can make sure a contractor is scheduled to move in when the prior work is finished," said Rick Allen, reforestation forester at Starker.

In addition to tracking the progress of its goals, Starker also uses GIS to monitor and report on actions the company takes for sustainability. It aims to improve tracking of sustainability metrics, such as seedling survival and growth, silvicultural treatments for young stands, and wildlife projects. This allows the foresters to identify areas for improvement and plan for future generations. "We identified early on that what we needed was more integration, moving from a culture of independent work by 12 people with 12 different workflows to a single repository where we can see the status of the forest and all our work," Allen said.

Increasingly, precision farmers use geoenabled smart devices and cloud computing to understand how no-till, cover crops, rotational grazing, and other sustainable practices contribute to better soil health, biodiversity, and CO₂ sequestration. Incorporating the power of location intelligence into regenerative farm management practices helps farmers gain new spatial insights, improve critical decision-making, and create more balanced outcomes.

The Mysteries of Bourbon: How Forestry, Mapping Support a Changing Industry

Even with careful environmental stewardship and well-managed forests, the white oak trees needed to make bourbon barrels have always been hard to find.

Twenty years ago, it was as much art as science—the best sleuths working to track down the trees that made ideal bourbon barrel staves. The quality and character of the wood matters because of its immense effect on the beverage's color and flavor.



Bourbon barrels must be made of white oak according to laws that guide the distillation and processing of the spirit.

There's a Kind of Magic in White Oak

Barrels made of white oak are not simply containers. They are crucial to the bourbon-making process. The internal structure of the white oak—its cellular makeup—creates an ongoing exchange within the barrel where the liquid is drawn into the wood and then pumped out without soaking through the barrel.

Ideally, the trees must be 80 to 100 years old and should be growing in a forest tract that has steady weather, neither too wet nor too dry. If those conditions aren't met, the heartwood doesn't possess the internal cellular structure that makes for the best liquid-tight barrels and the finest bourbons.

In the past, it was impossible to locate decades of weather records for rural, hilly, unpopulated areas to confirm historical patterns. So, even a trained forester, who was scouting trees for a big company, often relied on personal knowledge of the region.

Traditionally, the search for the best white oak was not only competitive among major distillers, but even had an air of secrecy. Just ask people like Bob Russell, a former forester who became something of a woodlands detective for the Brown-Forman distillery, makers of a variety of alcoholic spirits including Woodford Reserve and Jack Daniel's Tennessee Whiskey. In his role at Brown-Forman, Russell had to figure out ways to analyze large swaths of forest over most of the eastern half of the United States.

Twenty years ago, Russell often had to rely exclusively on his own eyes, his instincts for promising places, and paper-based censuses of trees done by the federal government. If a forest area looked favorable, he might also see if it could be a good location to build a sawmill. Often, he would visit a potential site without drawing attention to himself, looking for clues. He'd watch the roadways and count the logging trucks passing by to get a sense of the forestry activity, economy, and workforce.

He kept a low-key presence to avoid tipping off competitors about Brown-Forman's interest in the area. Recently retired, Russell had a career that spanned more than 40 years, including working as a forester, wood supply analyst, and, for lack of a better term, tree scout.

In his tenure at Brown-Forman, Russell was grateful for any tree census information the federal government could provide. Over the decades, he has seen the data and the analyses improve immensely with the help of GIS technology and the advent of what has been called a bourbon barrel app.

"Just knowing where to go helps a whole lot," Russell said of his early days in the industry. "And then seeing the Forest Service data and knowing how it's collected and how it's put together became a key in helping make those decisions."

Empowered with that knowledge and his own boots-on-the-ground observations, Russell could help guide and sometimes even reverse decisions about where to build a sawmill, based on the number and quality of local white oaks, available road and river transport, and potential workforce.

Bourbon Barrel Apps and GIS Aid in the Hunt

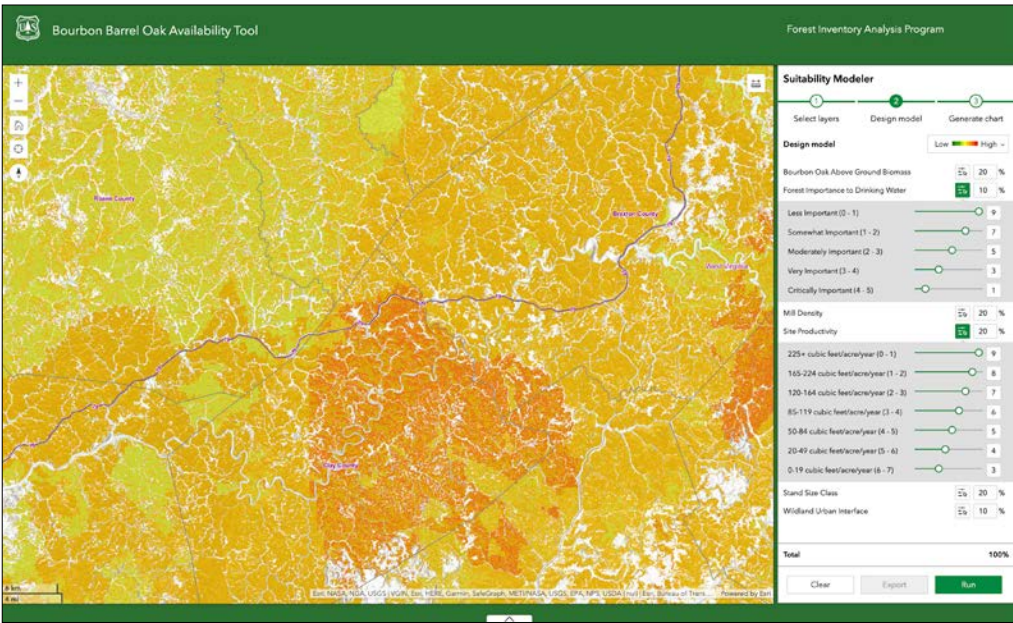
Today, the Forest Inventory and Analysis (FIA) Program of the US Forest Service has made its data more widely available online and more easily amenable to analysis by GIS. Developers from the US Forest Service and some in the spirits industry are creating apps to find stable areas of timber production and avoid places where the highly valued white oaks might become endangered from overcutting.

But even in the old days, the major producers knew they had to be careful to balance the need for white oak barrels with the need to ensure the survival of the slow-growing species. They realized early on that 80- to 100-year-old trees made the best barrel staves and had qualities that produced smoother, better-tasting bourbon. So, they could not afford to overharvest or create gaps in the staves supply line.

“They didn’t want to move into a landscape that was already being harvested pretty heavily and put even more pressure on the resource,” said Christopher M. Oswalt, a research forester for US Forest Service. “They have a long-term vision. They’ve got to keep these white oaks growing if they want to continue to produce the product that they do.”

Russell saw the spirits industry eventually gain better understanding of the multiple layers of data relevant to picking the right trees. But today, even with the help of the so-called bourbon barrel app that uses GIS to produce location intelligence and then plot those results on a map, the hunt for the perfect trees is still difficult. There are many reasons for that, including laws that say bourbon must be made in unused barrels. Later, after the bourbon is bottled, the barrels may be used to age other alcoholic beverages, such as Scotch whisky. But they cannot be reused for bourbon making. The law dictates that a fresh supply of white oak is needed, and it must keep pace with the popularity of bourbon and other spirits that use oak barrels.

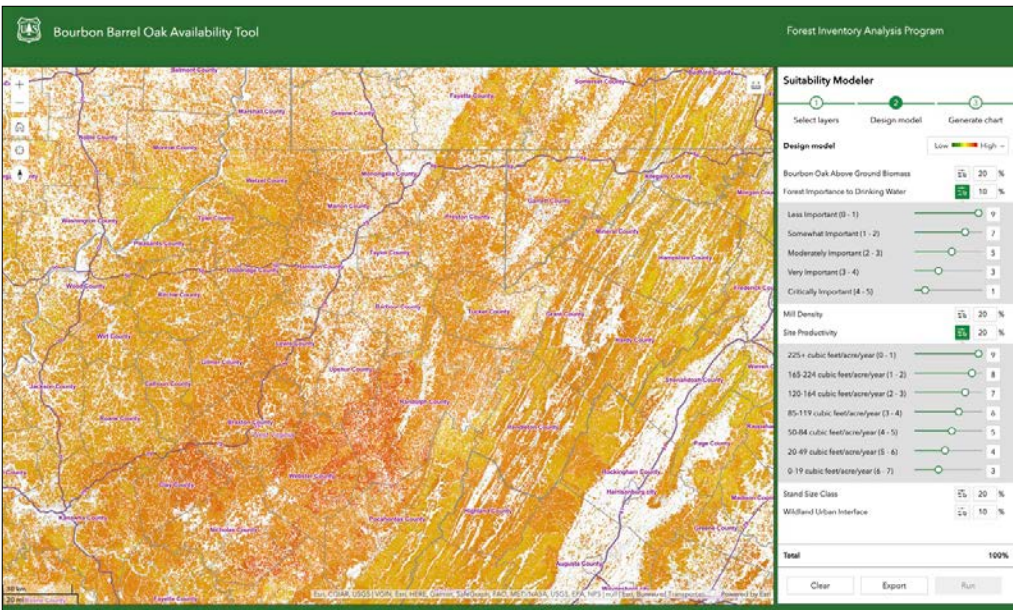
In response, company leaders can use GIS-based location intelligence to map and analyze key variables, such as the age of trees, numbers of trees, climate history and predictions, records of insect problems, invasive trees and plants that can crowd out white oak saplings, types and numbers of wildfires in the region, and the quality of staves made from wood in specific locales.



The suitability analysis allows users to adjust variables and see results on the map.

Raves about Staves

For the bourbon industry, staves are not simply the curved planks of a barrel. They have qualities that seem a bit mysterious to outsiders.



The Forest Inventory Analysis Program shows details of where white oak can be found.

White oak staves interact with the liquid, helping to age it properly while imparting sugars and flavors that create highly desired bourbons. Each company has its individual recipes, processes, and traditions for making bourbon that vary the way they char the inside of barrels to unleash flavors of caramelized sugars and vanillas from the wood.

The ongoing exchange imparts tastes, smoothness, and color that make up the distinct signature of bourbon.

Brown-Forman and others use nearly 100 percent of the white oak they purchase. They collect the bark to be used for fuel while the sawdust and wood chips are pressed into pellets to be used for cooking fires.

The Future of Bourbon Barrel Apps

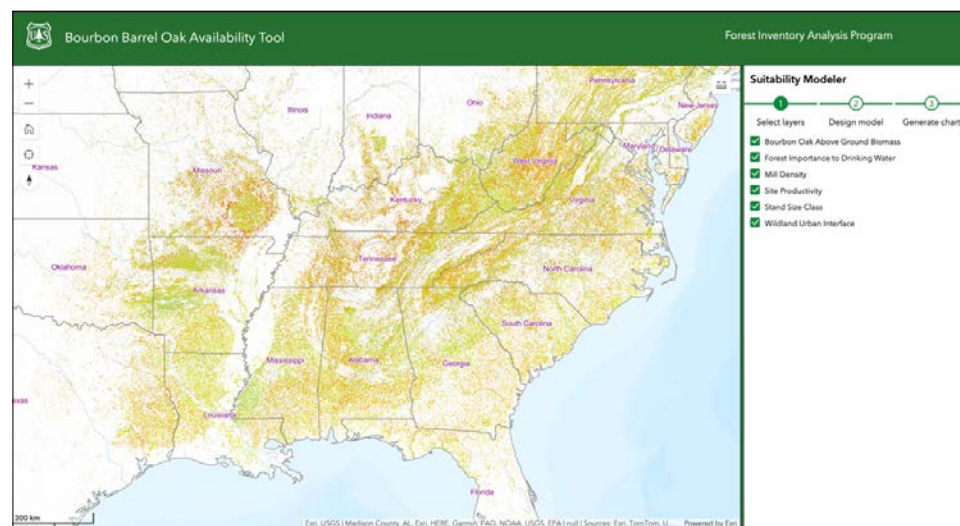
The US Forest Service handles data requests from many sectors—academia, the pulp and paper industries, and lumber companies. For distillers, they have been revamping the bourbon barrel app to reflect the multiple layers of data and type of analysis crucial to white oak logging and barrel-making purposes. The app gives an at-a-glance view of the available

resource, and users can adjust criteria to determine the most suitable locations that fit their needs.

“You could look for areas where white oak resources existed, where growth was positive in that white oak resource, and then also look where the density of mills was lowest,” Oswalt said. “And you could toy around with the different weights and so forth. Doing that highlights areas on the map that you might be interested in, and then you could click on the map and get a quick snapshot of what the resources within a 50- or 100-mile radius of wherever you clicked.”

With properly organized data and the ability to display the analyses spatially, the whole FIA database will open up to many related industries, Oswalt said.

“One of the things that we’re really interested in is bringing our national woodland owners’ survey information to bear to these questions,” he said. “We hope to bring that data together much more comprehensively, and do so spatially, so all of that information is available for each place at the same time.”



The Bourbon Barrel Oak Availability Tool allows users to explore many variables and to craft their own model to virtually visit places that may be suitable for harvest and milling of white oak.

Changing Methods for Changing Times

With airborne drone surveys also a possibility in some areas of forestry, the older types of intense boots-on-the-ground investigations may become a fading memory.

Russell has seen a wide arc of change in the industry, and he hopes to see white oak continue to thrive and supply bourbon makers.

“Well, right now, white oak is pretty rare and valuable,” Russell said. “The demand is far outrunning supply right now. And so that’s forced the price of logs up. It’s forced the price of lumber up So right now, it’s very precious. I’m expecting to see that crest and go back the other way. It always has over my last 43 years in the industry.”

Marking 50 Years, United Arab Emirates Maps Growth and Quality of Life

UAE has grown extraordinarily in the 50-plus years since it was formed in 1971, particularly in Abu Dhabi and Dubai, where the bulk of the country's population lives. Abu Dhabi has seen the most dramatic urban growth of the seven emirates. It's now a modern city with gleaming office towers, a complex multimodal transportation network, utility-scale renewable energy, and an education system that ranks in the top 20 in the world.

The UAE also stands out for diversifying its economy beyond oil, which required careful planning and great discipline.

In advance of the 50th anniversary of the country's founding, the UAE's FCSC mapped the country and its people, using GIS technology to quantify how far it has come.

FCSC adopted GIS to modernize workflows and visualize the statistical indicators it gathers for such sectors as health, education, environment, and the economy. GIS data feeds 1Map, which isn't one map, but rather the mapping capacity for the nation, with a collection of map layers, such as roads, facilities, and demographics about people. The information allows residents to see how the UAE is faring



The Palm Islands development in Dubai is indicative of the creativity and pace of growth in the United Arab Emirates.

and each ministry to see its strengths and weaknesses so investments can be made in the right places to improve quality of life for all residents.

“We launched our Geo-Stat geostatistical initiative in 2018,” said Marwa Elkabbany, the GIS expert with FCSC. “We started by collecting detailed facilities datasets from ministries, like health and education facilities, and geoenabling statistics to map more than 70 national indicators.”

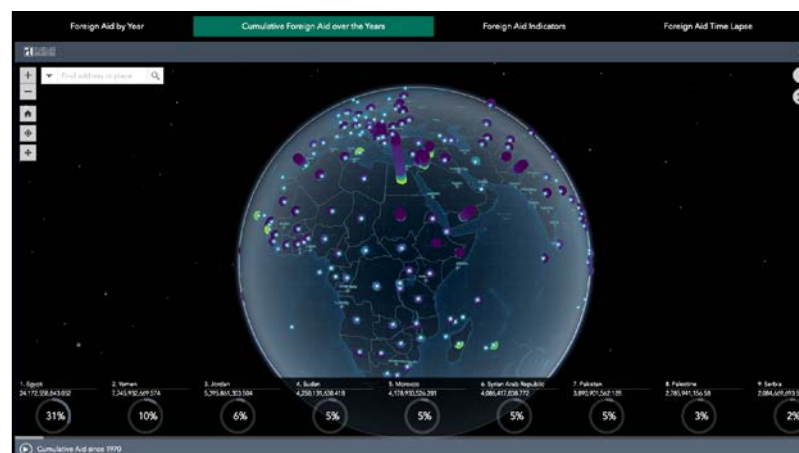
Setting Goals and Meeting Objectives

The discovery of oil in the 1950s fueled growth in the UAE, displacing pearls, fishing, and agriculture as key industries. Two decades ago, almost all the country’s economy was oil based. Now oil makes up less than 30 percent of gross domestic product (GDP). A series of plans have guided national investments away from oil dependency.

His Highness Sheikh Mohamed bin Zayed Al Nahyan, the third president of UAE, spoke in 2015 about this effort and the steady focus toward a future without oil. “In 50 years, when we might have the last barrel of oil, the question is, when it is shipped abroad, will we be sad?” he asked. “If we are investing today in the right sectors, I can tell you we will celebrate.”

UAE has diversified with investments in infrastructure, hospitality and tourism, and technology. There are three sovereign wealth funds in UAE that invest on behalf of the government, including Abu Dhabi Investment Authority with assets of nearly \$700 billion. This strategy of investment outside of oil aims to provide long-term returns from this nonrenewable resource.

Many of the investments are tied to both revenue diversification and improvements in quality of life, including the goal of being a destination for world-class health care, which illustrates how statistics drive societal advancements. First, the UAE needed to know the health of its people, and then it needed to compile details on health-care facilities.



As part of the 50th anniversary mapping project, FCSC mapped the cumulative foreign aid that UAE provided, which can be explored across time, country by country.

“We started the UAE Facilities Catalog by collecting the health facilities datasets along with the indicators such as how many are publicly owned, how many beds they have, and the number of medical staff and physicians,” Elkabbany said. “We mapped it to feed our geostatistical platform, then we overlaid facilities with our population and administrative maps to understand and evaluate their geographic distribution.”

Building a Modern Map

FCSC has been mandated by the Ministry of Cabinet Affairs to collect data from federal government entities in a seamless manner, including location data where applicable, while fostering best practices regarding data quality and standards. The 1Map name and branding by FCSC matches the country’s data integration goal, which fits the capabilities of modern GIS to tackle challenges across sectors.

The FCSC team came a long way from 2020 to 2023. It started by developing national foundational administrative maps for districts and subdistrict levels in addition to defining national urban areas. The process included setting national standards and data harmonization tasks to produce an up-to-date, authoritative geodatabase.

The FCSC GIS team has been working with federal and local

partners to implement a national collaborative geographic information portal that collects geospatial data from partners, processing the data to harmonize and standardize it, and then creating different applications and sites to serve the community and governmental partners through the one-stop 1Map portal.

The creation of the National Digital Data Ecosystem is a key priority for the UAE Government. FCSC has been working on a variety of projects as the lead federal entity for this effort, such as the Data Maturity Index, which aims to enable agencies to manage and administer their data in accordance with international standards and best practices to ensure accessibility and data flow, governance, and quality. Another example is the Emirates Data Network project, which supports the data exchange of federal administrative data contributing to a national knowledge hub.

At FCSC, the move to GIS started slowly with licenses for ArcGIS Pro and ArcGIS Online but soon expanded to ArcGIS Enterprise to enable integration across each ministry's ArcGIS implementation through the portal-to-portal collaboration capability. 1Map provides the foundational maps that each ministry builds on with its own data that it can share through ArcGIS Enterprise to maintain authority and security over the data it creates.

1Map datasets include population distribution; land use and housing; public facilities such as hospitals, schools, and cultural and religious destinations; and preserved natural areas and parks. This data is further broken down into component parts. For example, with population data, added demographic details include gender, citizenship, and age at different scales. Maps show each of these indicators as well as population density across the country.

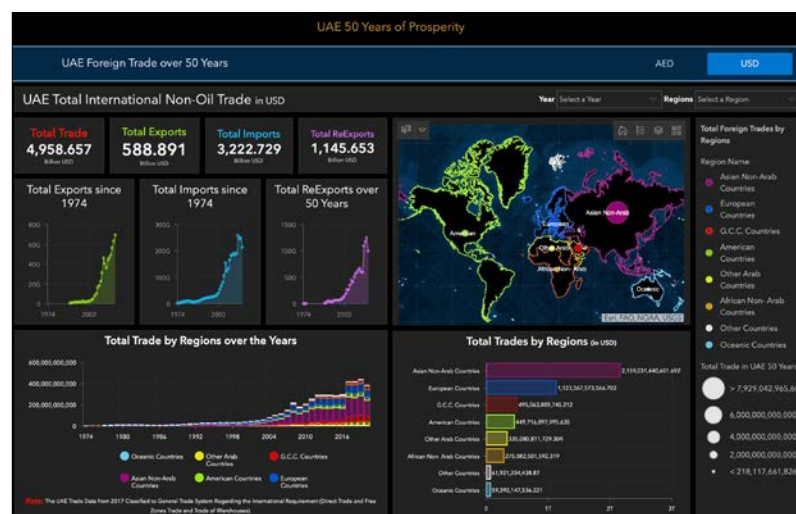
Much of the 1Map data is sensitive and restricted, so although some datasets are public, others are controlled with access only given to certain ministries or approved researchers.

The data is displayed in dashboards built with ArcGIS Dashboards to show progress on issues specific to a ministry's objectives and others for the nation. For instance, a public-facing dashboard gathers total international nonoil trade for the country. Narrative maps have been built using ArcGIS StoryMaps stories to better communicate with the public, such as a story that uses satellite images of Earth at night to illustrate urban growth in the country. Data is organized using ArcGIS Hub to indicate progress, including the 50 Years of Prosperity project. And data is further analyzed by experts to inform leaders and check on progress of policies—and to craft new ones—all focused on moving the country forward.

Measuring to Plan, Act, and Understand

Competitiveness on quality-of-life issues is central to the way FCSC operates. For instance, an initial calculation by international organizations about rural access to roads showed that just 76 percent of people living in rural areas had access to an all-season road within two kilometers.

"The roads in UAE are amazing, so it didn't make sense," Elkabbany said, relating how the World Economic Forum report in 2019 ranked UAE seventh in the world for quality of



As with many measures of UAE's modernization, the diversification of the country's economy away from oil dominance is carefully tracked. Dashboard screenshot courtesy of FCSC.

road infrastructure and the Legatum Institute ranked UAE as first in the world for satisfaction of roads and highways in its Prosperity Index Report.

“We looked at the dataset the international organization used to understand it, then we consolidated rural and urban boundaries from local municipalities, built a national population grid reflecting local statistics for population estimates, and overlaid all this data with the roads network according to the World Bank methodology,” Elkabbany said. “Now when we run this indicator, it shows 99.54 percent of rural-area residents have access to a road within two kilometers.”

This was one of many ways that the map helped verify the accuracy of the data and how the data helps verify the accuracy of the map. The road access indicator showed how rural and urban area delineation wasn't right and how population estimates were off. As Elkabbany notes, the climate and geographic conditions in the country favor urban development where housing is weather controlled and there's easy access to health care, schools, and other services.

Official statistics for the UAE, as with many nations, have long been maintained in spreadsheets, but there's a growing move to put these measurements on a map, thanks to the United Nations Sustainable Development Goals (SDGs) adopted in 2017. The SDGs recognize intertwining issues, such as how alleviating poverty goes hand in hand with improving health and education and spurring economic growth. Putting indicators on the map provides a crucial view to address inequalities and pinpoint where to limit the impacts of climate change.

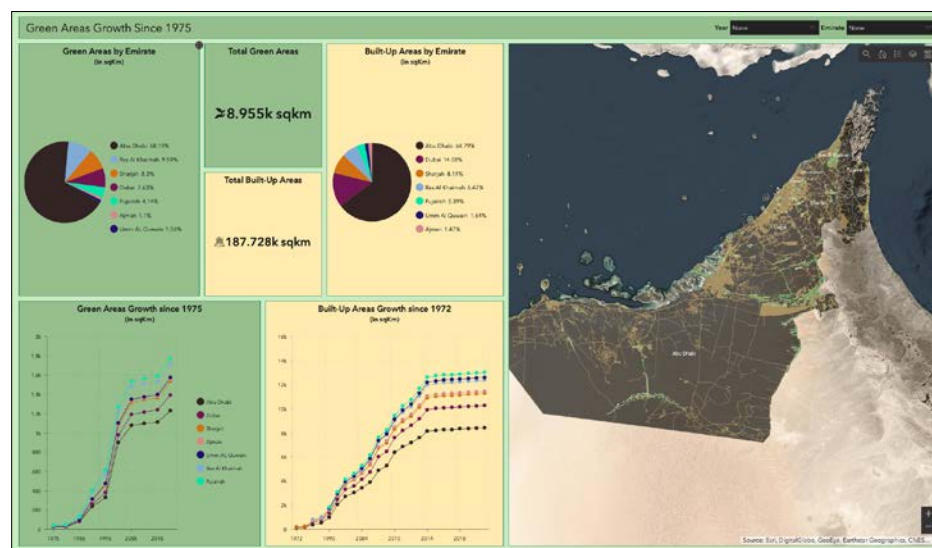
When the COVID-19 pandemic hit, FCSC had just launched maps of health facilities and population distribution. That data became critical to identify areas of risk and helped leaders

understand the critical importance of maps and geostatistics for crisis management.

“Government stakeholders are endorsing the use of GIS and geospatial intelligence capabilities across different sectors, with growing demand for map-driven meetings where geospatial dashboards are used as a decision support tool,” Elkabbany said.

Lately, FCSC has been using satellite imagery and machine learning to fill in data gaps. The team has collected all building footprints across the country and used smart meter data about electricity and gas consumption to derive population estimates for where people live and work. FCSC continuously looks at nontraditional data sources such as anonymized phone location data to understand the movement patterns of people. Analysis of movement patterns helps compare facilities and opportunities across different geographic areas, which is a great input for planning processes.

“We have to be ready. We must prepare our data, and we need to measure prosperity and competitiveness to ensure high quality-of-life standards are maintained and elevated,” Elkabbany said.



The growth in green and protected areas is another measurement tracked by FCSC.

Largest Organic Co-op Uses Custom Maps to Guide Grazing and Pasture Stewardship

At Organic Valley, a national organic food brand and cooperative of more than 1,650 small family farms spread across 35 states, grazing is more than a requirement, it's a point of differentiation and innovation. Its dairy farmers have always rotated cows across pastures, but now, with the help of data and maps, farmers are maximizing the productivity and sustainability in their grazing systems. With near-daily satellite images and custom mapping, Organic Valley provides accurate pasture condition reports to the farmer's inbox or mailbox. Though high tech behind the scenes, the delivered product is a simple report that anyone can use, including the

sizable percentage of Organic Valley's membership that is Amish or Mennonite.

These personalized data-driven reports and images indicate the health of each paddock, including details used to determine which should be grazed, cut, or left to grow.

The reports using satellite imagery, automated with GIS technology, contain precise information that's difficult to capture otherwise. This information is used to help feed and raise organic cows on lush pastures, furthering Organic Valley's sustainability efforts.



Cows graze in a lush green pasture as part of Organic Valley farming.

Enabling Farmers to Be More Efficient

Although Organic Valley dairies were already using rotational grazing, this program automates a precision pasture management approach that ensures cows will always be feeding on the best available forage with greater efficiency.

A critical component of the pasture reports is a “grazing wedge” that shows the estimated biomass availability for each paddock. Prior to this program, farmers who wanted this information had to estimate biomass with more manual methods. One approach involves walking paddocks with a plate meter to measure the height of the grass, recording figures in a notebook, and calculating grass cover alongside the amount of time the cows were left to forage. Such processes are difficult to repeat at regular intervals, so recordkeeping and implementation were inconsistent. Today’s pasture report automates this manual process, and the algorithms used to estimate biomass continue to improve through regular ground-truthing.

“Many farmers have their standard rotation and adjust based on what they’re seeing, but it can be difficult and time consuming to visually cover all those acres,” said Phil Marty, GIS administrator at Organic Valley. Now farmers complement conventional wisdom with insights from imagery to make data-driven decisions that have produced notable increases in pasture utilization.

The benefit of a well-informed rotational grazing system is often an increase in harvest efficiency, or the percentage of the forage that goes into the belly of the cow. And this efficiency can be realized without overgrazing. Overgrazing can negatively impact pastures, water retention, and ecosystem health.

On the pastures of an Organic Valley family farm, as many as 200 different types of plants grow, including clover, trefoil, brome, ryegrass, orchard grass, and timothy grass. As Organic Valley points out, it’s designed to be a salad bar for cows, ensuring proper nutrition and leading to the best quality of milk. With careful rotation, a critical balance of grasses and legumes is maintained, and cow manure is spread naturally, leading to healthy soil and a healthier herd.

With current pasture reports, biomass and what cows have eaten automatically calculate from satellite measurements, allowing farmers to balance supply and demand with less time and effort. The report gives farmers timely information for important management decisions, such as how fast or slow to rotate the cows or whether to cut grass and make hay.

Weekly Pasture Reports Made Possible with Imagery and GIS

Organic Valley first tapped Esri partner Planet in 2020 to see if its satellites could be used to monitor the health of each paddock. Paddock growth provides a constantly moving target, particularly in Wisconsin near the company’s headquarters where sunny days mixed with generous rains



The variability of growth across pasture and rangeland systems can be easily visible during certain seasons, such as in this image, but much harder when growth is greatest. Image courtesy of Organic Valley.

often create a tremendous amount of growth.

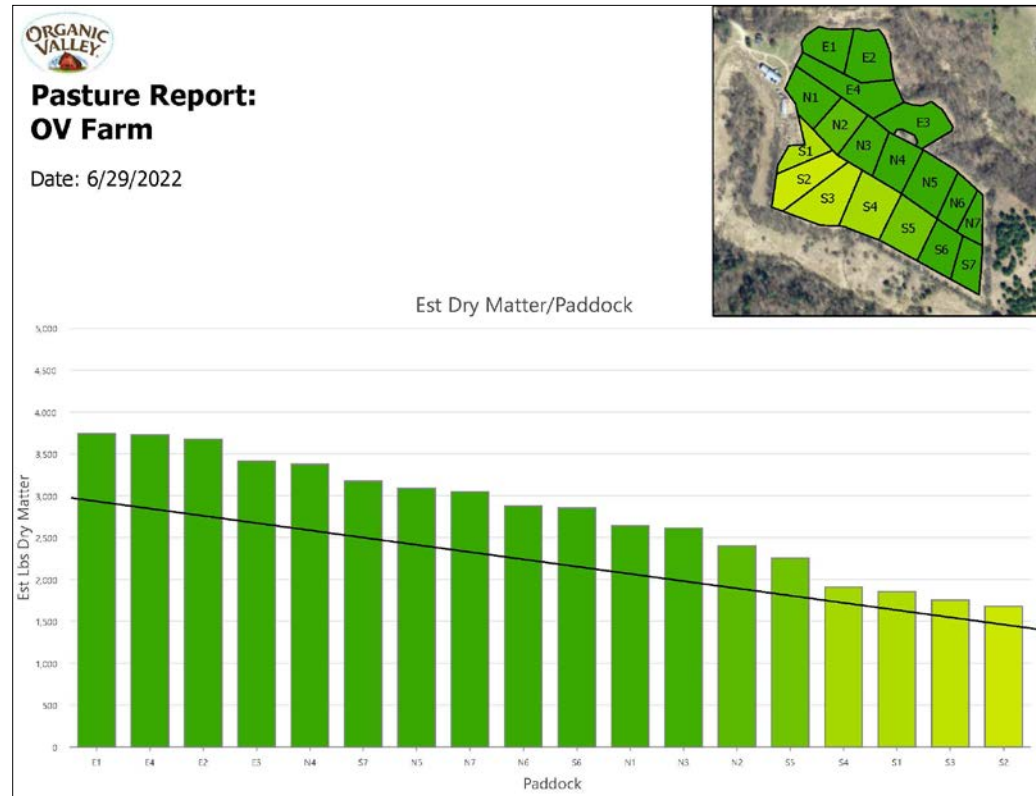
Satellites measure plant health by detecting the amount of chlorophyll in plants—the more chlorophyll, the greener the plants and the more biomass are in the images. Images that appear yellow to red have limited pasture available, indicating it is time to rotate cows off and rest those pastures, or sometimes it is indicative of something environmental such as excess or deficient moisture.

Planet was chosen because its constellation provides near-daily imagery at high resolution everywhere on Earth. Organic Valley piloted the approach on 20 farms, using ArcGIS Pro to analyze the imagery and automate custom reports for the farmers. For the first two years of the program, ground measurements were taken on a regular basis to compare against the analyzed Planet images. The initial 20 farms in the program demonstrated successful implementation, so Organic Valley expanded the program to nearly 100 farms in 2022.

For farmers, a superior degree of precision pasture feeding has the potential to fine-tune practices, tying what they see on their custom maps to what's in their milk tanks.

Farmers in the program have shared some of the things they can now see thanks to the high-tech approach, such as areas slow to bounce back that need more nutrients; areas irrigators are missing; weak areas of growth that might perform better with a different plant; and knowing when they can cut forage early to stockpile feed for winter months.

With positive proof demonstrated to date and automation in



The bar charts on the first page of the Pasture Report are what's called a grazing wedge. The height of the bars indicates the amount of biomass, and the greener color shows where growth is greatest. Image courtesy of Organic Valley.

place, Organic Valley started offering the precision grazing program in 2023 to any of the small family farms within the cooperative interested in the technology.

Organic Approaches to Improve All Outcomes

GIS is one of many enterprise systems at Organic Valley that keeps track of the variability of farming. The cooperative applies GIS to help determine the daily “assembly” side of the business, which encompasses hauling milk to processing plants as well.

Organic Valley contracts with a number of regional milk haulers, using GIS to determine the best routes to farms with volumes that will aggregate to a full truck. “This is a biological system, so if the grass withers up, milk dries up,” Marty said.

"It's a volatile supply and demand problem, so we're doing lots of vehicle routing, looking at volumes."

Grazing is a fundamental pillar in organic dairying. With regular refinement to monitoring and measuring efforts, Organic Valley is helping farmers innovate and steward the planet. One of its next aims is to quantify the amount of carbon that's being sequestered through rotational activity and perennial pasture systems.

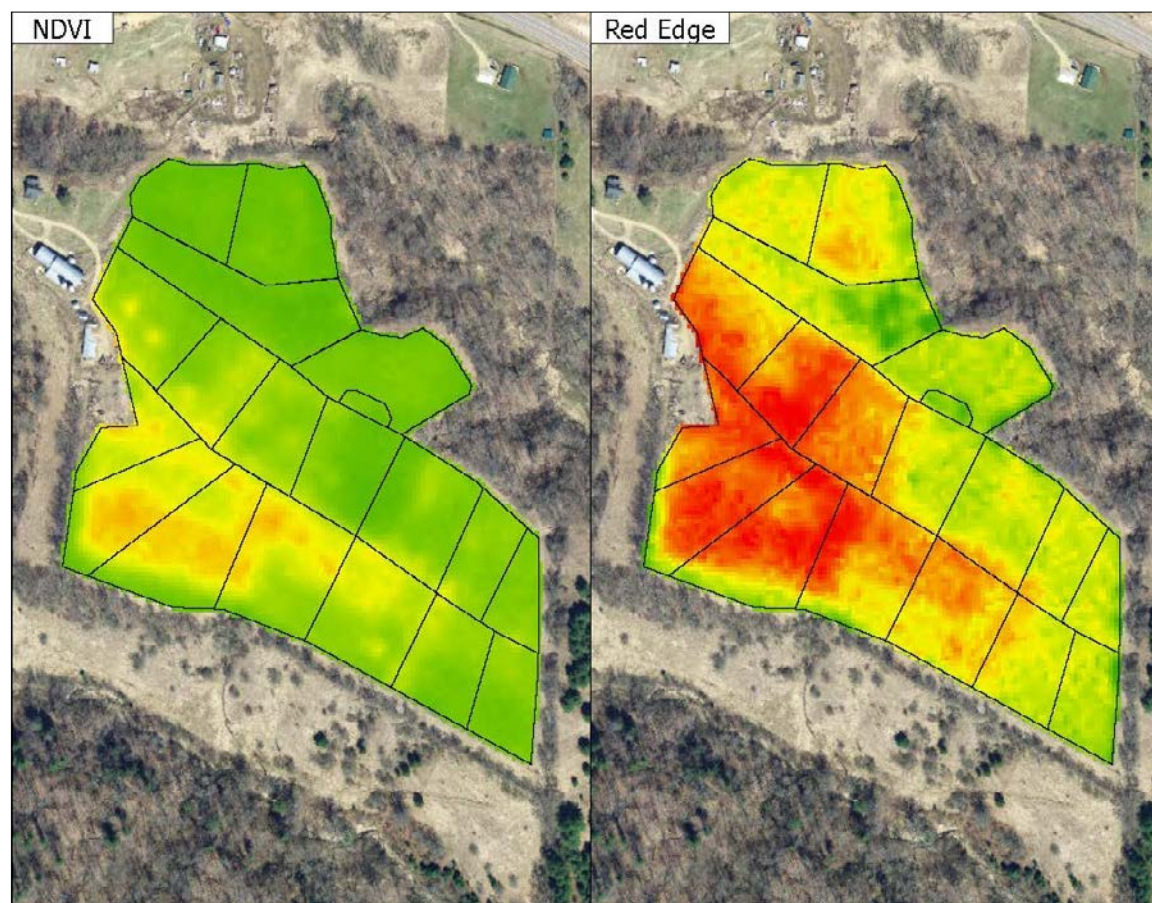
"If you just let a pasture grow up and it gets harvested one time, there's less carbon being sequestered than if it's continually grazed and regrowing," Marty said. The imagery insights help identify and monitor carbon sequestration capacity related to grazing, which could be a future source of revenue in a practice known as carbon farming.

In addition to putting actionable tools in the hands of dairy farmers and helping their grazing systems be more efficient and effective, optimizing carbon capture on working

lands holds great promise to return more value from the effort. This is part of a larger effort to facilitate climate smart farming across the cooperative.

Organic Valley was selected for an approximately \$25 million grant from the US Department of Agriculture to establish and measure on-farm practices that reduce greenhouse gas emissions. The funds will finance 1,200 new carbon reduction and removal projects on approximately 500 Organic Valley member farms over the next five years, and these projects will be monitored and analyzed to report on progress.

"Sustainability and carbon sequestration are things we should all be working on," Marty said. "We're happy to discuss what we do, it's in our cooperative mentality. We look forward to meeting and collaborating with others in this space."

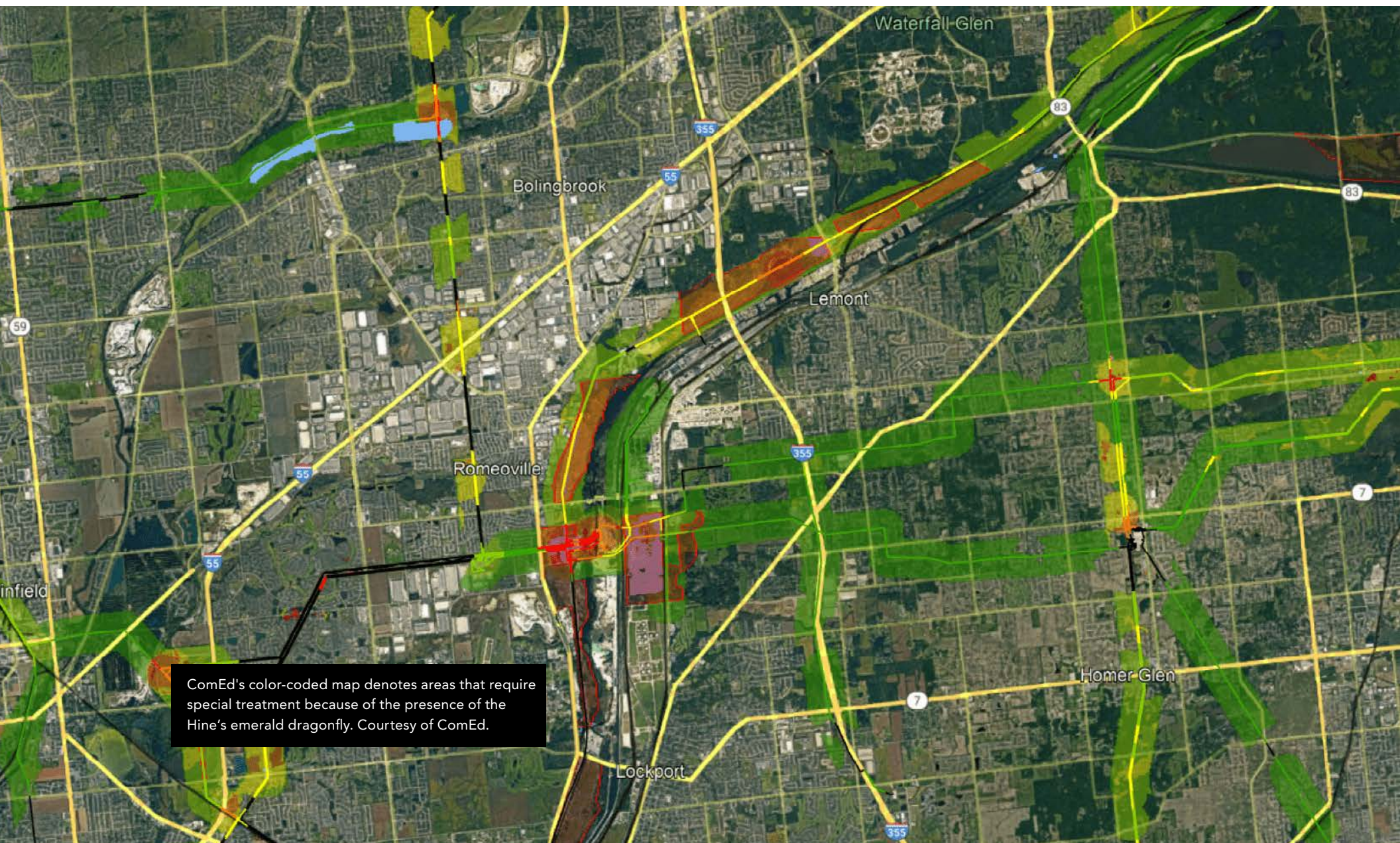


The satellite-derived Normalized Difference Vegetation Index (NDVI) image, left, quantifies vegetation health, with the healthiest plants shown in green, because they reflect green and near infrared light but absorb more red and blue light. The red-edge band, right, highlights stress and disease with great sensitivity to catch trends before lasting damage is done. Image courtesy of Organic Valley.

Illinois Utility Transforms Hundreds of Acres into Pollinator Habitat

Electric transmission lines in northern Illinois cut through the Lockport Prairie Nature Preserve, one of the few remaining habitats of the endangered Hine's emerald dragonfly. This rare insect stays underground for its first five years of life, making it

particularly vulnerable to changes on the land above. To keep utility maintenance from harming the dragonfly, staff at ComEd carefully crafted a habitat conservation plan that included the use of smart maps to remove lines to avoid conducting maintenance in sensitive areas.



ComEd's color-coded map denotes areas that require special treatment because of the presence of the Hine's emerald dragonfly. Courtesy of ComEd.

Avoiding land that the Hine's emerald dragonfly occupies helps the utility as well—eliminating the cost of complying with the strict protocols of the Endangered Species Act while simplifying land management.

ComEd's conservation efforts serve as an example of how organizations can use technology to be both profitable and sustainable.



The presence of milkweed is a necessity to attract monarch butterflies.

Protecting Prairies and Pollinators

ComEd's commitment to preserving habitat dates back to 1994, when the utility began planting prairie wildflowers and grasses, transforming hundreds of acres of land into native habitat. The restored prairie benefits local pollinators and other wildlife, whereas the plants' longer roots aid in resilience against drought and flood, increasing carbon sequestration and stormwater detention.

In 2017, ComEd's maps, loaded with data on utility assets and dragonfly habitat, supported an effort to relocate some of the company's electric transmission towers. Guided by maps made with GIS technology, the move was performed carefully during the insects' dormant season, and heavy cables were prevented from striking the ground where larvae rested.

Considering its pioneering conservation practices, ComEd has become a key collaborator with the Rights-of-Way as Habitat Working Group, reaching across industries and

organizations in North America to turn rights-of-way corridors into pollinator habitat.

The working group teamed up with the US Fish and Wildlife Service to protect the threatened monarch butterfly species through a Candidate Conservation Agreement with Assurances (CCAA). ComEd and more than 30 other organizations have signed the CCAA. Many of these companies share information on habitat areas they maintain to the Rights-of-Way as Habitat Geospatial Database and gain access to GIS tools for assessing sensitive areas. The data rolls into a public dashboard that tallies participants and tracks new pollinator habitat being created.

For the monarch butterfly, the key plant is milkweed. ComEd's program engages community groups that gather seeds, and the company hires contractors to plant them. More than two million milkweed seeds have been planted along rights-of-way corridors to meet ComEd's pledge to convert



Wildflowers growing under high-tension powerlines. Courtesy of ComEd.

more than 11,700 acres into high-value habitat for the monarch. ComEd managers use GIS to plan this work and then monitor impact on pollinators and other wildlife.

"We have standards, we have metrics, we have monitoring," said Sara Race, principal environmental program manager at ComEd. "We use GIS to understand where there are opportunities for prairie restoration and to prioritize projects."

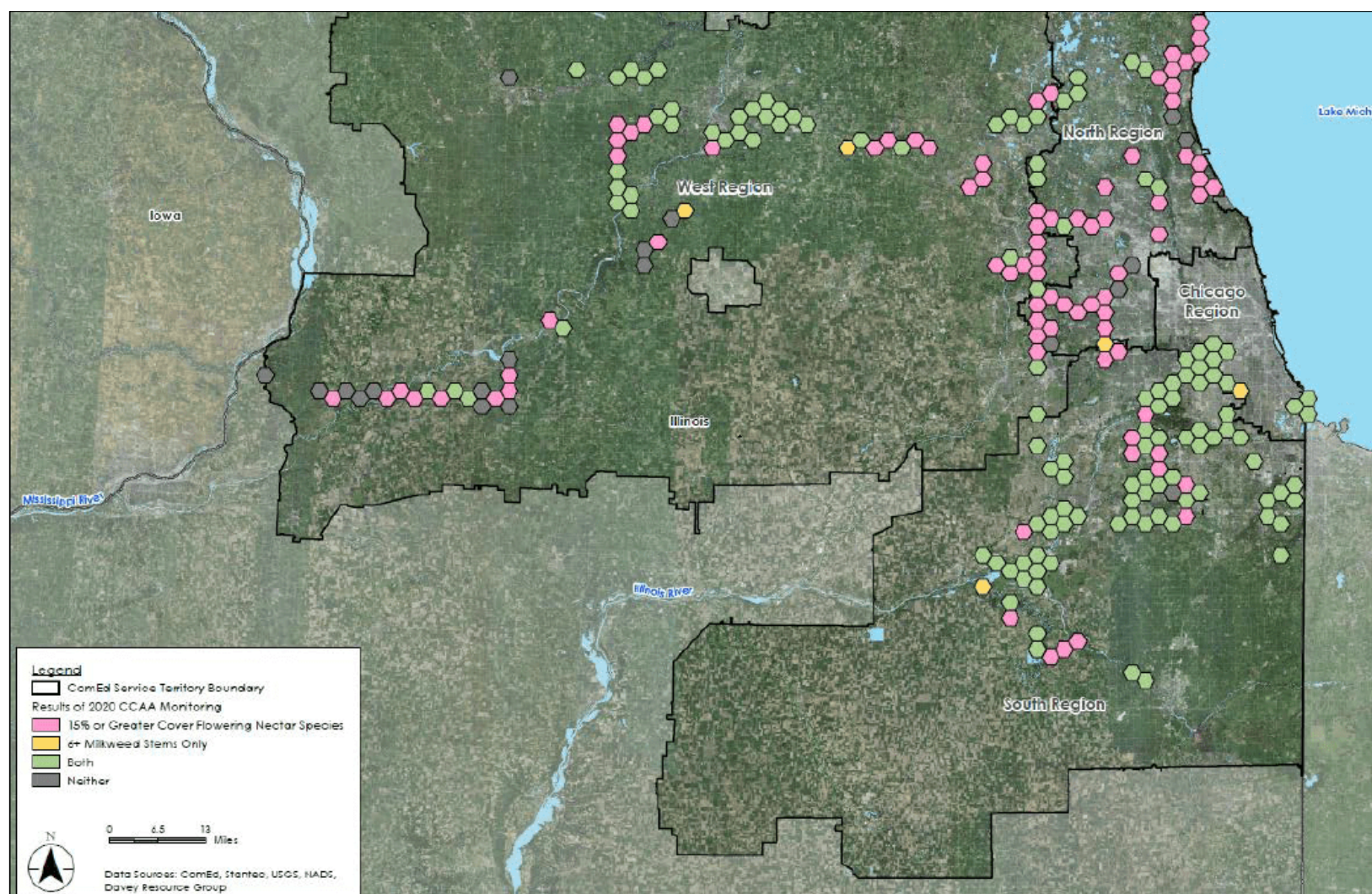
Focusing on Vegetation Management

It takes time and patient management practices to turn land into high-quality pollinator habitat.

At ComEd, vegetation management crews have made this work part of their ongoing efforts to keep the company's 43,000 miles of power lines clear from trees and tall shrubs—reducing outages and fire hazards. The utility's GIS maps track which rights-of-way corridors are transitioning to native plants and which are candidates for conversion.

"We have an annual inspection program to look at every span of transmission and make sure there's nothing growing past our limits," said Tom Ringhofer, manager of transmission vegetation management at ComEd.

Vegetation management teams collaborate closely with environmental restoration teams, using GIS to share data and communicate. Ringhofer says maintenance crews consult GIS maps to avoid endangered species and spot



Map of ComEd's territory denotes the prime pollinator habitat it monitors, along with each area's conservation status, to meet its agreement with the US Fish and Wildlife Service. Courtesy of ComEd.

protected areas where they can't apply herbicide. "Everything is marked in GIS so that our crews know exactly where they can and can't go," he said.

Ringhofer and his crews identify and clear invasive species—such as buckthorn and swamp willow—that grow too-tall thickets. In the 2020s, they encountered the Bradford pear, which has a weak branch structure and typically topples within 20 years. Clearing nuisance or hazardous vegetation gives native plants and animals room to grow. An area cleared of

buckthorn saw the return of wild indigo, wild bergamot, cup plant, and black-eyed Susan.

ComEd inspectors have been counting milkweed stems to see how many of those pollinator plants have taken hold, and then uploading their findings to the GIS. They also look for eagles' nests, Blanding's turtles, rusty patched bumblebees, and any other rare or endangered species.

"We're definitely seeing more diverse habitats and species on our rights-of-ways, including turtles," Ringhofer said.

Starker Forests Documents Workflows for Sustainable Forestry

When the forest-rich state of Oregon amended the Oregon Forest Practices Act through Senate Bill 1602 to regulate how and where herbicide and pesticide may be sprayed on private forestlands, it required forest landowners to share activities in near real time.

At Starker Forests, a fifth-generation family-owned land company in Corvallis, the regulation arrived as the business was implementing information technology updates. Foresters at the company have used GIS technology for decades to map their work, but it had been more of an individual tool without



A Starker Forests truck rests on a road near an area set for harvest.

much collaboration. With the reporting requirement, Starker decided to adopt Web GIS, with all foresters sharing data about the forest and their work.

There are a ton of possible systems, but so much of what we do is tied back to on-the-ground geography that no matter what we use to collect, store, and manage our activities data, we were still going to be using GIS.

—Rick Allen, reforestation forester at Starker

Centralizing the Mapping

Allen is one of several foresters at Starker Forests who are soon to retire, and the company was eager to make improvements to data collection systems. The idea had been to streamline the company's recording system to capture the institutional knowledge of this cadre of professionals—who, during their careers, had achieved sustainability certification from the American Tree Farm System—before they left the company.

Oregon's new rules reinforced the need to evolve from a paper-based process, which the company had used for decades, to a faster mode of recordkeeping. "We wanted to automate the process and eliminate how paper tends to stack up," Allen said.

Allen made the shift to take on the IT challenge after spending a career in reforestation, which includes managing forest site preparation, tree planting, and herbicide applications. Herbicides are used in the first few years of a forest plantation to hold back invasive species and other vegetation that competes for sunlight and moisture with planted seedlings. "The company prioritizes the reforestation process as an investment

for the future. Getting new trees in the ground within a year after harvest is the goal so that they're off to the races," Allen said.

With the legislation, the Oregon Department of Forestry extended buffer zones to keep the spray further away from homes, schools, and streams. Forestry is one of the most heavily regulated industries in the state. The extended buffer zones further protect people, drinking water, and fish habitat.

Allen sees the value of better spraying documentation for Starker's own purposes. This new system will allow any of the professional foresters to quickly locate and check the historical records for the herbicide applications.

"We found that trying to go back in time over paper records to figure out what nursery stock was planted and from which nursery, weather conditions, what chemicals were applied, and the application rates could be tedious and hard to figure out," Allen said.



Starker Forests uses clear-cutting on smaller areas than the industry average, noting its benefits for rodents, birds of prey, and elk and deer foraging. Image courtesy of Starker Forests.



Starker Forests follows the best management practices outlined by the American Tree Farm System. Signage helps signal management practices that lead to a healthy forest. Image courtesy of Starker Forests.

Advancing Enterprise Recordkeeping

Starker had investigated investing in an enterprise resource planning system—a large database—but opted to build new tools using GIS.

With the commitment to GIS, the Starker team worked with Esri to build field apps for specific workflows. The mobile-first approach meant that the tools would be used first in the forest to capture details specific to the different operational phases, from harvesting to reforestation.

Addressing end-to-end workflows with tailored tools often starts with Survey123, an app with simple forms that record data that can then be analyzed in the office. The data also feeds dashboards built with Dashboards to show progress toward goals such as the yearly planting of more than 500,000 trees.

Starker foresters manage more than 90,000 acres of coast range forests, including Douglas fir, Oregon white oak, western red cedar, western hemlock, ponderosa pine, Oregon ash, and grand fir. The company doesn't own a mill, or the mechanized equipment used to harvest trees. Instead, it uses contractors to harvest trees approximately 1,000 acres per year, with some thinning and clear-cutting.

With the new tools, the foresters have realized time savings for repeatable workflows and gained a better understanding of the health of the forest. Every year, hiring ramps up in the summer for forestry interns who take an inventory of portions of the forest.

They check for survival of the trees planted in previous years and gather details on competing vegetation that might trigger the need to apply herbicide to help the seedlings survive.

“A dashboard helps us quickly look at thousands of plots to see where we have issues,” Allen said. “We share that information with our board and use it to make management decisions.”

Managing Sustainable Harvesting Practices

Starker Forests is certified by the American Tree Farm System, which audits and validates the company's management practices. The certification process ensures that the company's management plan improves air, water, and soil quality while managing habitat for wildlife and cutting back on invasive species.

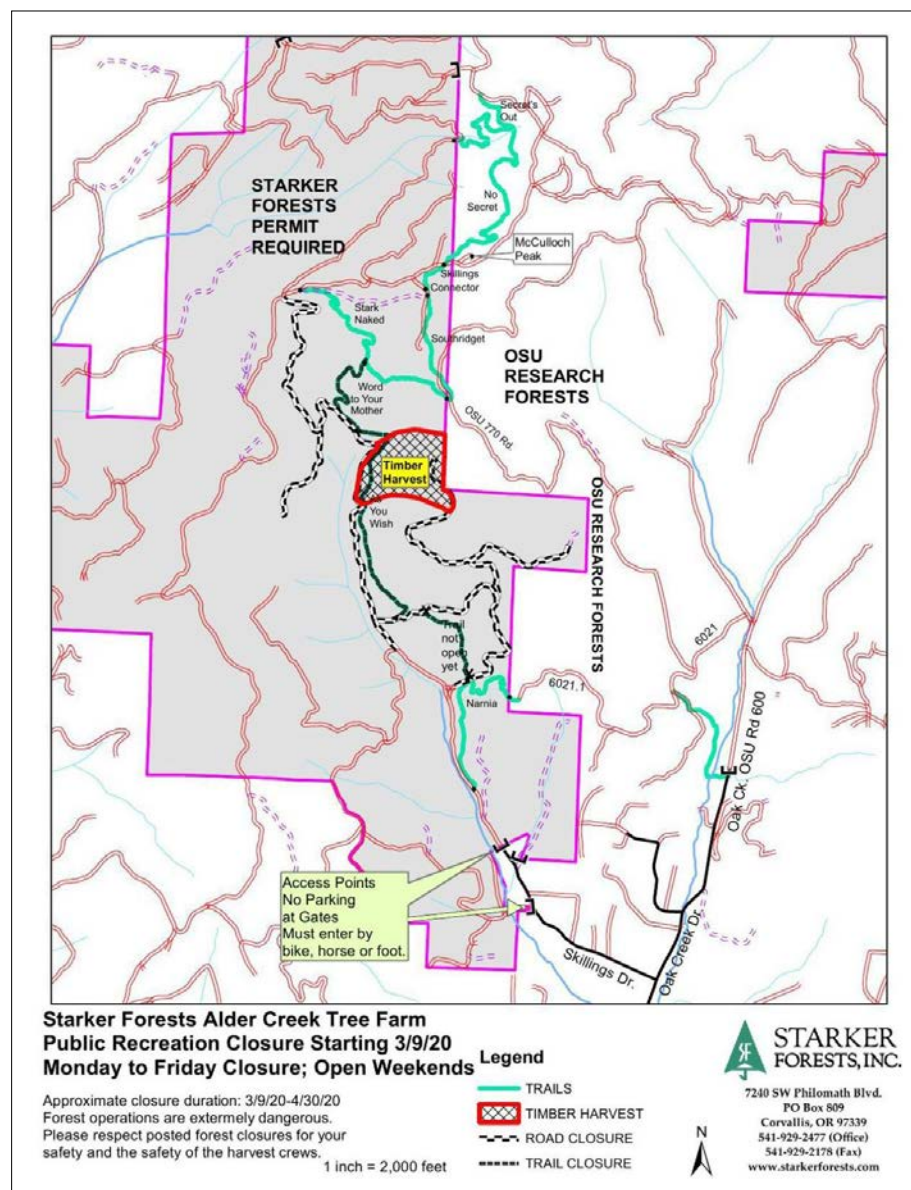
Water quality is one of many things that Starker carefully manages. The cable logging system the company uses pulls cut trees to the top of ridges and away from streams and wetlands. Road construction and maintenance are improved to minimize erosion to keep water clean. Buffers are maintained for spraying and harvesting to protect streams.

Allen and the IT team are working now on harvest planning and scheduling workflows to improve these processes.

“Everything starts with the harvest, and then all subsequent workflows follow—site preparation, spraying, tree planting, and thinning,” Allen said. “With the dashboard, the person responsible for each step can look and see when each process will be done for each unit so they can make sure a contractor is scheduled to move in when the prior work is finished.”

Starker has a long history of sustainable forest management and is focused on improving tracking of sustainability metrics, with a dashboard that tracks seedling survival and growth, silvicultural treatments for young stands, and wildlife projects. The dashboard and data it collects demonstrates sustainable growth and harvest levels across the acres it owns. This allows the foresters to identify areas for improvement and plan for future generations.

Under a stewardship agreement with the State of Oregon, a landowner that shows commitment to protecting natural resources, such as water and fish and wildlife habitat, can gain long-term regulatory certainty without fear of further restrictions by sharing evidence that it follows Forest Practices Act rules. Beyond better planning, the enterprise-level GIS that Starker has deployed makes it easier to monitor and report the actions the company takes.



Map marks public access for recreation and also illustrates Starker Forests' close connection to the forestry program at Oregon State University (OSU) where it sponsors a lecture series. Map courtesy of Starker Forests.

“It has been a process of awakening,” Allen said. “We identified early on that what we needed was more integration, moving from a culture of independent work by 12 people with 12 different workflows, to a single repository where we can see the status of the forest and all our work.”

Long Descriptions

Target Market Summary for New York City

The key facts are:

- Population: 8,840,134
- Median age: 37.5
- Average household size: 2.5
- Median household income: \$76,657

The 2022 age pyramid lists the largest group as females age 30–34 and the smallest group as males age 85 and over.

The annual lifestyle spending statistics are:

- \$3,110 for travel
- \$124 for audio
- \$121 for theater, operas, and concerts
- \$114 for movies, museums, and parks
- \$69 for sports events
- \$7 for online games

Several tapestry segments are also included.

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Comic

A young woman near railroad tracks says, “This time he took me and my older sister with him to the capital Dhaka. It was noisy, full of cars, swarming with mosquitoes. And once again, we lived near the railway tracks.”

An inset panel shows the young woman and her older sister meeting a potential employer. “You OK,”the employer tells the taller sister, and then turns to the young woman. “You too short. Come back in a year.” The young woman recalls, “I tried my best to find employment in a garment factory, but I was turned away wherever I went because I was still too small for the work.”

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Mitigation Projects in Virginia

The map includes the following table.

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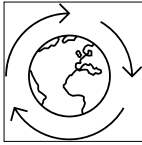
Factor	Congestion mitigation	Economic development	Accessibility	Safety	Environmental quality	Land use
Category A: Northern Virginia, Hampton Roads	45%	5%	15%	5%	10%	20%
Category B: Richmond	15%	20%	25%	20%	10%	10%
Category C: Culpeper	15%	25%	25%	25%	10%	–
Category D: Fredericksburg, Staunton, Lynchburg, Salem, Bristol	10%	35%	15%	30%	10%	–

Voter Incident Report Form

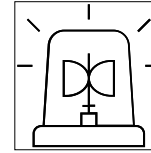
The listed incident types are:

- Polling place issue
- Poll worker/election official issue
- Polling place or ballot accessibility
- Voter intimidation/misinformation
- Voting machine/equipment/balloting issue
- Prevented from voting/mail-in ballot issue

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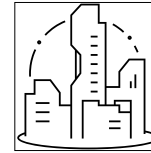
Climate Action



Public Safety



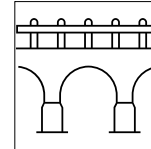
Equity and Social Justice



Smart Planning



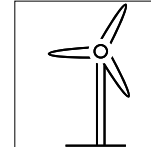
Environment



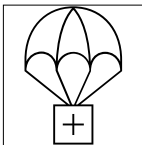
Infrastructure



Conservation



Sustainability



Humanitarian Assistance



For more information on GIS in the federal government, visit esri.com/federal.

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