

# ArcUser

The Magazine for Esri Software Users

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Protects People  
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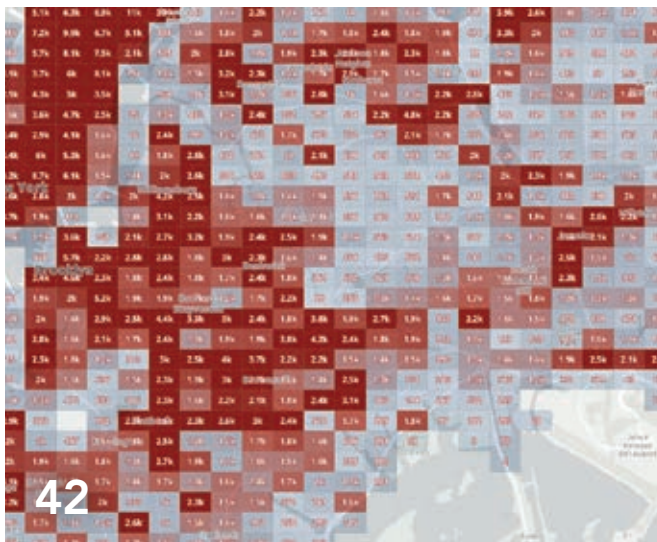
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# What Is Needed

In March, the Esri Developer Summit returned as an in-person as well as a virtual event. As Esri president Jack Dangermond noted in his opening remarks, Esri recognizes that developers are critical to extending GIS to meet the myriad challenges faced by society and the Earth because they possess “the creativity and knowledge of what is needed.”

An article in this issue demonstrates how developers applied GIS to a basic, world-wide challenge: providing safe drinking water. According to the Division for Sustainable Development in the United Nations Department of Economic and Social Affairs, 26 percent of the world’s population lacked access to safely managed drinking water in 2020. Five student developers tackled this problem. Using simple, low-cost sensors, cloud data storage, artificial intelligence, and GIS, they devised Saaf water, a system that can be widely deployed to improve the health and even save the lives of millions. Their solution was the grand prize winner of IBM’s Call for Code Global Challenge.

In collaboration with partners around the world, Esri is building tools, models, and datasets that will form the geospatial infrastructure essential to understanding an interconnected and interdependent Earth. For example, Esri has been working with the POPGRID Data Collaborative to develop a better global, high-resolution gridded representation of human settlement that is being shared via ArcGIS Online.

A geospatial framework enables a holistic approach for creating a more sustainable world. Whether building livable cities, more effectively responding to disasters, or addressing the twin problems of the world’s energy needs and climate change, the intrinsically geographic approach of GIS leads to innovative solutions. A nonprofit, The Ray, is using GIS to identify the previously overlooked solar power potential of land adjacent to the nation’s 47,000 miles of interstate highway. In Iowa, analysis revealed 38,000 acres that were prime spots for solar installation that could potentially produce five million megawatt-hours per year, valued at \$400 million.

Two things that previously constrained the application of GIS—scarcity of data and time-intensive analysis—have been upended in the last decade. An abundance of data from satellite imagery, remote sensing, drone acquisition, Internet of Things (IoT) sensors, crowdsourcing, and the data-sharing platforms of government agencies and businesses has been unleashed. At the same time, GIS furnishes far more tools for deriving information from data quickly, including automated machine learning techniques and real-time processing.

In addition, while its capabilities are markedly increasing, the cost of GIS—like other IT technologies—is substantially decreasing. There has never been a better time for applying GIS to problems at any scale, from local to global.

Monica Pratt  
ArcUser Editor

# ArcUser

Spring 2022 Vol. 25 No. 2

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## Editorial

Editor Monica Pratt

Contributors Matthew Lewin, Jim Baumann, Citabria Stevens

Technical Adviser Paul Dodd

Copyediting Allan Mendiola

## Design

Creative Director James Hitchcock

Designer Doug Huibregtse

Illustrator Dan Gill

Photographers Eric Laycock, Rachel Kinney

Print Coordinator Lilia Arias

## Advisory Board

Corporate Marianna Kantor

Products Damian Spangrud

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## Editorial Inquiries

Monica Pratt, ArcUser Editor  
380 New York Street  
Redlands, CA 92373-8100 USA  
[arcuser\\_editor@esri.com](mailto:arcuser_editor@esri.com)

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ISSN 1534-5467

ArcUser is published quarterly by Esri at  
380 New York Street, Redlands, CA 92373-8100 USA.  
ArcUser is written for users of Esri software and  
distributed free of charge to registered users.



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# Briefly Noted

## → Everyone Has a Story to Tell

StoryMaps is a new personal storytelling tool that can help anyone share and explore important ideas and experiences as compelling interactive content that features maps, video, images, and audio clips. Whether it is sharing an epic road trip or a passion for gardening, StoryMaps is designed for individuals. With the StoryMaps mobile apps for iOS and Android, storytelling can happen anywhere. It lets travel bloggers, hobbyists, foodies, craftspeople, family genealogists, influencers, small business owners, and others engage, inspire, and connect with their world.

StoryMaps is available only from StoryMaps.com and is built separately from the ArcGIS system. It differs from ArcGIS StoryMaps, Esri's enormously popular professional storytelling tool that allows organizations to give context to complex ArcGIS work and is part of the ArcGIS system.

The tools provided by StoryMaps simplify and enhance story creation. Use prebuilt layouts and easily incorporate videos, images, and audio clips for an immersive experience. Since every story has a place, use Esri mapping technology to provide content using maps, illustrate trends, or provide an interactive tour. Set the mood for a story with ready-to-use themes or create custom themes by choosing background colors, fonts, and button styles. Use rich text editing capabilities and simple drawing and annotation tools. Once a story is finished, sharing it on social media, embedding it in a website, or providing access to it via a URL is simple and easy because Esri hosts StoryMaps stories.

StoryMaps is available at two levels: a no-cost Basic level and the monthly subscription Premium level with enhanced storytelling capabilities. Try StoryMaps ([storymaps.com](https://storymaps.com)) for free with a 30-day trial and get access to Premium plan features.



↑ StoryMaps is a new personal storytelling tool that can help anyone share and explore important ideas and experiences as compelling interactive content.



## → Deprecation of the U.S. Survey Foot

The National Institute of Standards and Technology (NIST), the National Geodetic Survey (NGS), National Ocean Service (NOS), and National Oceanic and Atmospheric Administration (NOAA) have acted collaboratively to deprecate use of the US survey foot. Effective January 1, 2023, the US survey foot should not be used and will be superseded by the international foot, which is defined as 1 foot equal to 0.3048 meter exactly in all applications. The international foot, currently used throughout the US for most applications, is typically referred to as simply the foot. Either foot or international foot may be used for clarity in technical applications.

## → Vexcel Image Services for ArcGIS

ArcGIS users, without any proprietary plug-ins, can access informative layers or derive location insights with confidence using imagery captured with award-winning and market-leading camera sensor technology from the UltraCam suite, designed and manufactured by Vexcel Imaging. Vexcel operates the world's largest aerial imagery program, and this new service provides fast and easy access to its massive imagery library in the Esri ArcGIS system. By directly providing high-quality imagery in ArcGIS, end users can make more accurate and informed decisions with greater authority. With optimized access to Vexcel's vast library of imagery directly in ArcGIS, end users can benefit from access to the world's largest aerial imagery program, which collects imagery from more than 20 countries.

## → Changes to Basemaps

Esri will retire select older basemaps and offer new basemap replacements in 2022. Once the basemaps are retired, they will no longer be available for use in maps and apps. Users can anticipate a round of basemap updates in summer 2022. Version 1 of vector basemaps and the original Ocean basemap are scheduled for retirement in December 2022. Please visit the default map galleries section of ArcGIS products for a listing of actively maintained basemaps. Visit "Notification that old Esri Vector Basemaps will be retired in 2022" (<https://bit.ly/3ro3ZtJ>) for more information.



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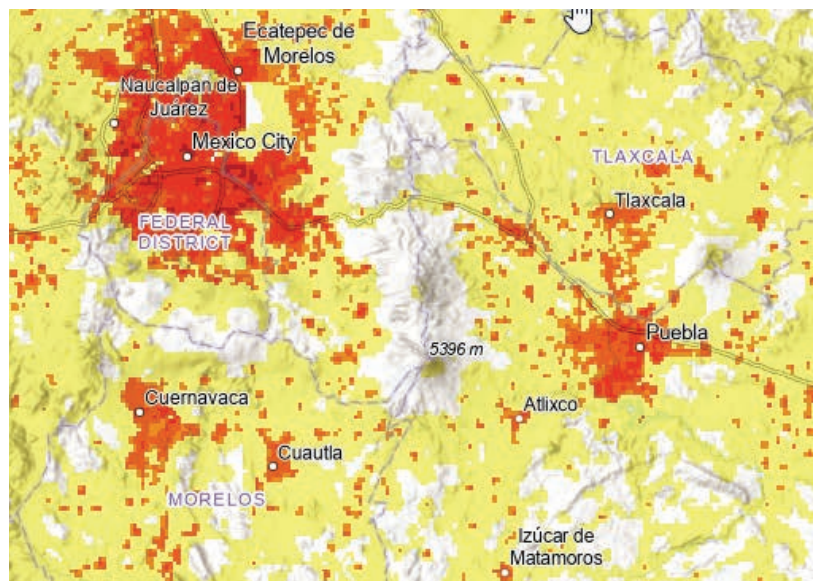
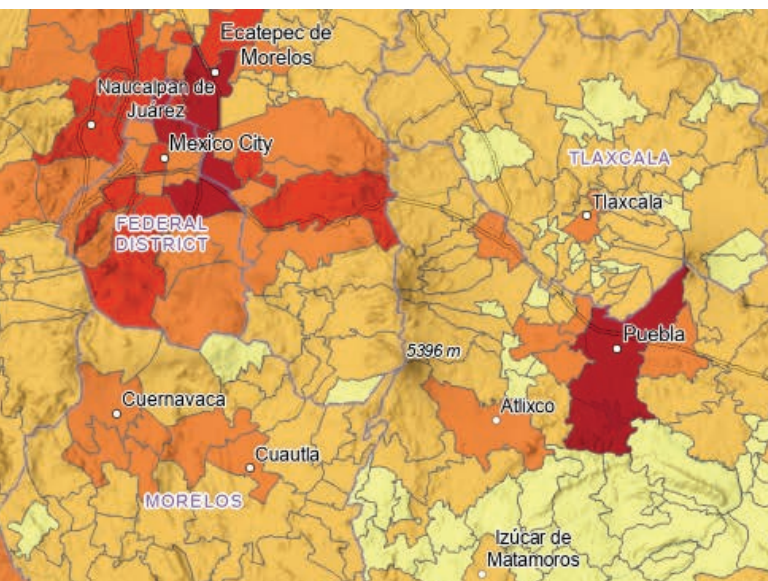




# A First Glimpse

## into the Future of Population Data

By Charlie Frye



For the last 30 years a growing number of experts and analysts have developed, validated, and lately are popularizing what appears to be a better way to represent where people are located. Specifically, this better way is based on a global high-resolution gridded representation of human settlement.

Such population models estimate statistical surfaces of population density and can be used directly to estimate population, or as a basis to apportion population from polygons representing census tabulation areas. The resultant gridded population estimates provide a sharpened focus on where these populations live or engage in daily activities.

For the last several years organizations, including Esri, have been participating in the POPGRID Data Collaborative ([popgrid.org/](http://popgrid.org/)) to work together to improve methods, outcomes, and the overall value of gridded population.

In addition to the goal of increasing the general understanding of the value of gridded population estimates, POPGRID.org is organizing and expanding the international community of data providers, users, and sponsors of georeferenced data on population, human settlements, and infrastructure. The organization seeks to improve data access, timeliness, consistency, and utility. It supports data use and interpretation through identifying and addressing pressing user needs. POPGRID works to reduce duplication and user

↑ On the left, polygons represent municipios in the vicinity of Mexico City and display census population counts with one color per polygon. On the right, 1-km resolution gridded population data shows estimates of population density. Places where people are unlikely to live are symbolized with no color.

confusion and encourages innovation and cross-disciplinary use.

POPGRID.org regularly meets with the organizations that most need reliable population data. The mission-driven work of various United Nations agencies such as the Office for the Coordination of Humanitarian Affairs (OCHA) and the United Nations Population Fund (UNFPA), the Gates Foundation, The World Bank, and others provides requirements for justifying the use of and requirements for producing trustworthy verifiable, geospatial analysis outcomes with gridded population products.

One of these requirements is a global collection of high-resolution annual population estimates capable of illustrating local changes in total population and five-year age and sex cohorts. In

December 2021, Esri and WorldPop.org announced the release of such a collection in the ArcGIS Living Atlas of the World. WorldPop.org is part of the University of Southampton. The datasets, funded by the Bill and Melinda Gates Foundation, resulted from collaborations with the Center for International Earth Science Information Network (CIESIN) and the University of Louisville.

This collection is available as three layers that are freely available for use anywhere in the ArcGIS system or via http and REST. These layers are unique and remarkable for many reasons. Foremost is the composition of the collection: 21 globally complete annual estimates of 38 global population variables beginning in 2000 through 2020.

In raw form, WorldPop.org makes this data available by country by variable. This data, which covers 249 countries and 38 variables and spans 21 years, is contained in nearly 200,000 TIFF files that anyone can download. These files were combined into global extent rasters that represent total population, population density, and five-year age and sex cohorts. Instead of making 798 image services, a relatively new technology was used—multidimensional raster storage in Esri's Cloud Raster Format (CRF). This technology allows this data to be made available in just three image services.

The initial release contained 1-km resolution datasets for total population, population density, and population cohorts.

**WorldPop Total Population 2000–2020 1 km**—Annual estimates of total population per cell for the years 2000–2020 at 30 arc-second resolution (approximately 1 km at the equator).

**WorldPop Population Density 2000–2020 1 km**—Annual estimates of population density in persons per square kilometer for

the years 2000–2020 at 30 arc-second resolution (approximately 1 km at the equator).

**WorldPop Population Cohorts 2000–2020 1 km**—Annual estimates of age and sex population cohorts per cell for the years 2000–2020 at 30 arc-second resolution (approximately 1 km at the equator).

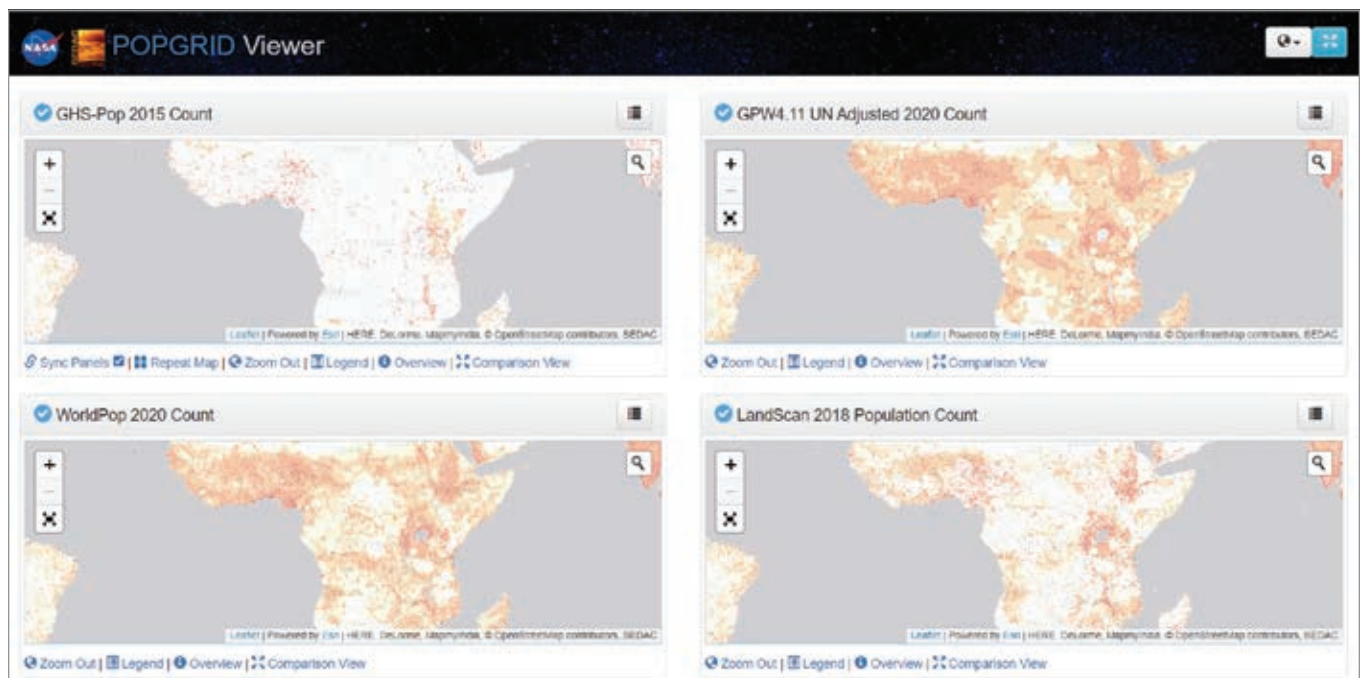
These layers all represent the coarsest resolution of unconstrained gridded population data from WorldPop. *[Unconstrained gridded population data is estimated over all land grid squares globally.]* WorldPop.org and Esri are currently working to make the finer, 100-meter resolution, data available later this year. Esri plans to add each new year of population estimate data as it is produced by WorldPop.

However, there are limitations to the methods and many uncertainties within the data. For instance, all countries of the world do not conduct their censuses in the same way or at the same time. Learn more about gridded population and the challenges in producing global population estimates by reading “WorldPop gridded population estimate datasets and tools: How are they different and which should I use?” (<https://bit.ly/3GMotRP>) and “The spatial allocation of population: a review of large-scale gridded population data products and their fitness for use” (<https://bit.ly/3Jlur1>). Use the POPGRID Viewer (<https://bit.ly/3sA6edf>) to compare different gridded population datasets.

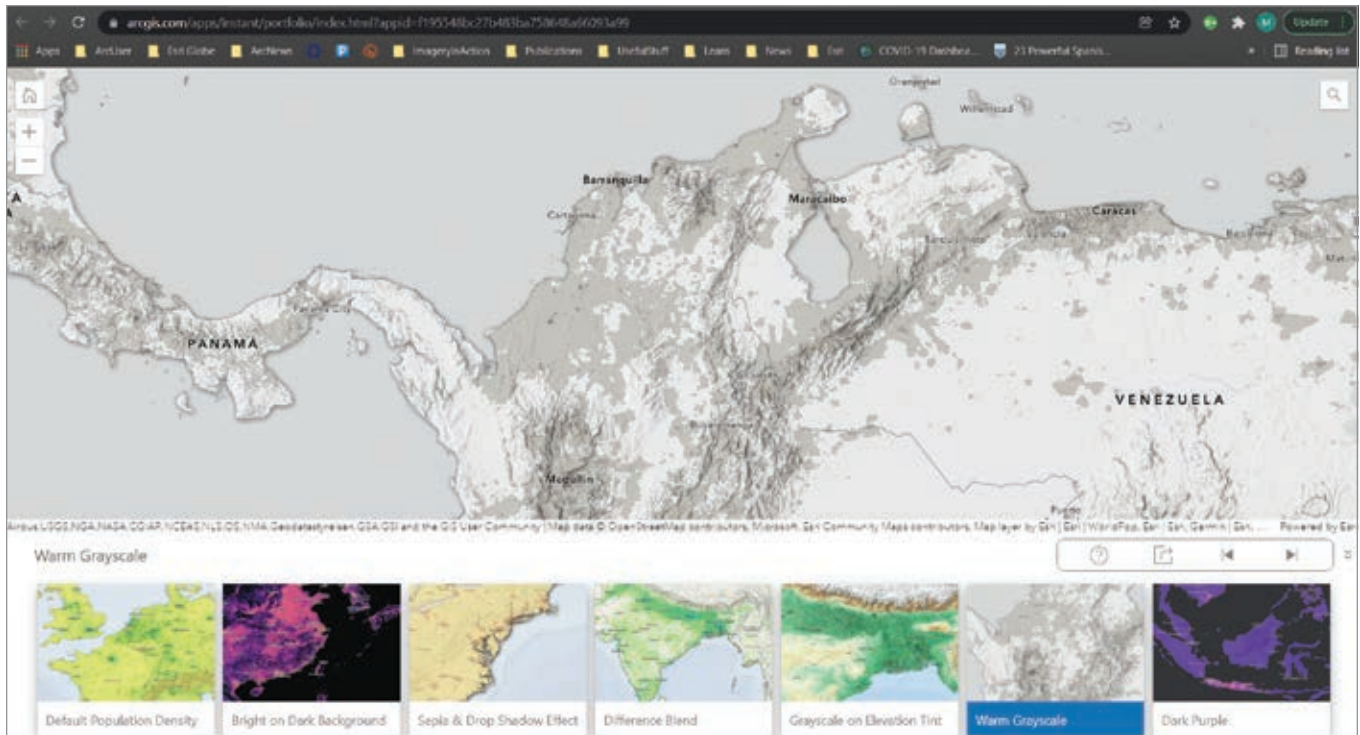
## Gridded Population Layers in ArcGIS Online

The Population Density layer is the best way to show population because values at each location are normalized to units of persons

↓ The POPGRID Viewer (<https://bit.ly/3sA6edf>) can be used to compare different gridded population datasets.







↑ This web app (<https://bit.ly/3LtfCBx>) illustrates seven different techniques for displaying the WorldPop layers.

per square kilometer. Without this normalization, even raster datasets can present misleading density-like depictions when showing total population, leading readers to interpret higher densities than actually exist the further they pan or zoom away from the equator.

To show the variety of ways population density can be used in a web map, the author created a web app that illustrates seven different techniques for displaying the Population Density layer (<https://bit.ly/3HKvRi3>). Click one of the tiles at the bottom of the app, and then click the info icon on that tile to show examples, information, and a link to the instructions on reproducing that style.

## Performing Analysis in ArcGIS Pro

While many analysis tasks are possible with this data, zonal statistics in ArcGIS Pro is one of the most common. This analysis finds the sum of the population estimated to live within the area of any given polygon.

To get started, open ArcGIS Pro with a project that has a map. On the Map tab, click Add Data.

On the left side of the Add Data window, expand the Portal node and choose Living Atlas.

In the upper right of the Add Data window, enter WorldPop into the Search text box. This will result in three options.

Select WorldPop Total Population 2000–2020 1km and click OK.

In the map's Contents, select the WorldPop Total Population 2000–2020 1 km layer. This will cause the multidimensional tab to appear. Click on this tab to show the tools for working with multidimensional layers.

In the Multidimensional tab, starting from the left side, the Variables list should contain Total Population. Then StdTime is a dimension for these layers, and each year of data will be shown as

a choice. This can set the layer to use All (default), just one year, or a range of years. On the right side of the Multidimension tab are tools.

The most common task with gridded population data is to find out how many people living in a given area would be impacted by an event such as an epidemic or natural disaster. The Zonal Statistics as Table tool is the fastest way to learn how many people live in an area or zone.

To use this tool, a polygon layer with a feature or features representing the area of impact is also needed. The tool will produce a table containing rows for each feature in the input polygons, and columns for the unique ID of each feature, and population.

Use ArcGIS Online or ArcGIS Pro to explore the WorldPop Total Population 2000–2020 1 km (<https://bit.ly/3Bflqze>), WorldPop Population Density 2000–2020 1 km (<https://bit.ly/3sAwgx1>), and WorldPop Population Cohorts 2000–2020 1 km datasets (<https://bit.ly/3gJvh8h>), available from ArcGIS Living Atlas of the World

## Acknowledgments

The author would like to acknowledge the work and support of WorldPop leadership and staff he has collaborated with to create these services, particularly Andrew Tatem, Alessandro Sorichetta, and Maksym Bondarenko.

## About the Author

**Charlie Frye**, the chief cartographer at Esri, manages the Cartographic Projects Group on the content team. He has been with Esri since 1994. Currently, Frye is the author of Esri's Ecological Land Unit services, global ecological content, and World Population Estimate Services. Contact him at [cfrye@esri.com](mailto:cfrye@esri.com).



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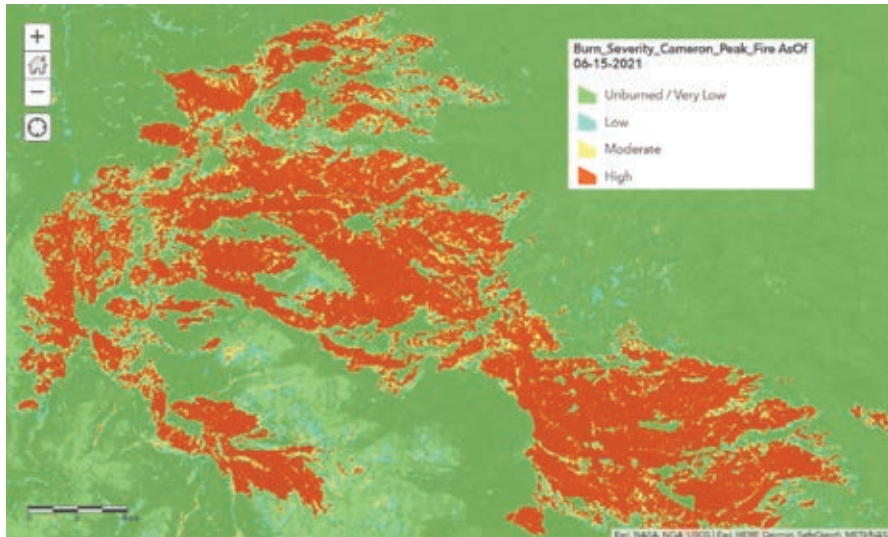
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# Actionable Information from Imagery

By Jeff Liedtke and Thomas O. Sweet, Jr.



← This map shows the burn severity of the 2020 Cameron Peak Fire in Colorado. Burn severity maps are crucial for determining slope stability, public safety response, mitigation measures, and water quality.

Most GIS professionals know that the value of imagery goes way beyond a backdrop for GIS layers. The information contained in most maps and GIS layers is derived from imagery to create or revise maps and GIS layers. Actionable information can be derived from imagery. Detecting, identifying, and mapping change for a wide variety of applications is a primary function of many organizations.

For example, burn severity maps can guide wildfire response activities such as public safety efforts, assessing landslide risk, and mitigation measures. Imagery is a critical component in creating those maps, but imagery must be current and analyzed, and the results shared appropriately with the organizations that can take action.

ArcGIS Image for ArcGIS Online (ArcGIS Image), part of the ArcGIS Image suite, is a cloud-based product for hosting, managing, and analyzing collections of imagery. This integrated system of capabilities can extract information from imagery for decision support in operational environments.

ArcGIS Image Online provides access to an extensive collection of raster tools and functions. Because it is a software as a service (SaaS) solution, ArcGIS Image Online eliminates not only the need to manage and maintain IT infrastructure, but also the requirement to manage and update imagery collections. Because ArcGIS Image Online is cloud-based, it has the advantages of cloud computing power, storage, and scalability. Deployment in the cloud also adds efficiency to analysis of imagery by bringing analysis capabilities to hosted imagery, rather than moving large collections to process them.

## Store Once, Use Continually

To use ArcGIS Image Online, transfer your imagery from local storage media to the cloud. Hosting your imagery and raster collections in ArcGIS Image Online is straightforward. Add your imagery as a tiled imagery layer or a dynamic imagery layer, depending on the intended use for the layer.

Use a tiled imagery layer to host a single mosaicked image layer, or one or more individual image layers in a tiled format for fast performance, image processing, and analysis. Use a dynamic imagery layer to host an image mosaic layer or collection of images that will allow you to manage, process, and analyze the individual images that populate a mosaic or collection. [For detailed information on imagery layers, see “A Guide to Sharing Imagery and Raster Data” in the winter issue of *ArcUser* (<https://bit.ly/3OwLcLt>).]

When hosting imagery to the cloud, choose to configure the image as one image, one mosaicked image, multiple imagery layers, or as an image collection. Drag and drop locally stored imagery into the dialog window and specify properties. The image is uploaded to the cloud. Imagery is published to your folder in the cloud with its own item page and URL. On the item details page, you will specify the settings for the image file, processing, display, and sharing.

## Analyze Imagery in the Cloud

Tools and functions in ArcGIS Image Online transform remotely sensed imagery and multidimensional raster data into a smart image. Hosted tiled and dynamic imagery layers can be analyzed and actionable information extracted for operational decision support. Map Viewer and Map Viewer Classic support visual analysis of imagery and raster layers. Enhance imagery with renderers such as Stretch and Colormap and apply any number of standard or custom raster function templates (RFTs) published with the image layer.

Quantitatively analyze imagery in three ways with Map Viewer Classic, using:

- Standard tools on the Raster Analysis pane.
- Standard raster functions using on-the-fly processing.
- Custom RFTs and processing chains built in the Raster Function Editor pane and shared with members inside and outside your organization.

Both dynamic and tiled imagery layers support all the bands, bit depth, and other characteristics of the source imagery, and they are suitable for accurate image analysis and processing. Both imagery types can be analyzed using tools on the Raster Analysis pane. In addition, dynamic imagery layers support server side

on-the-fly processing using functions and raster function chains.

### Using the Raster Analysis Pane

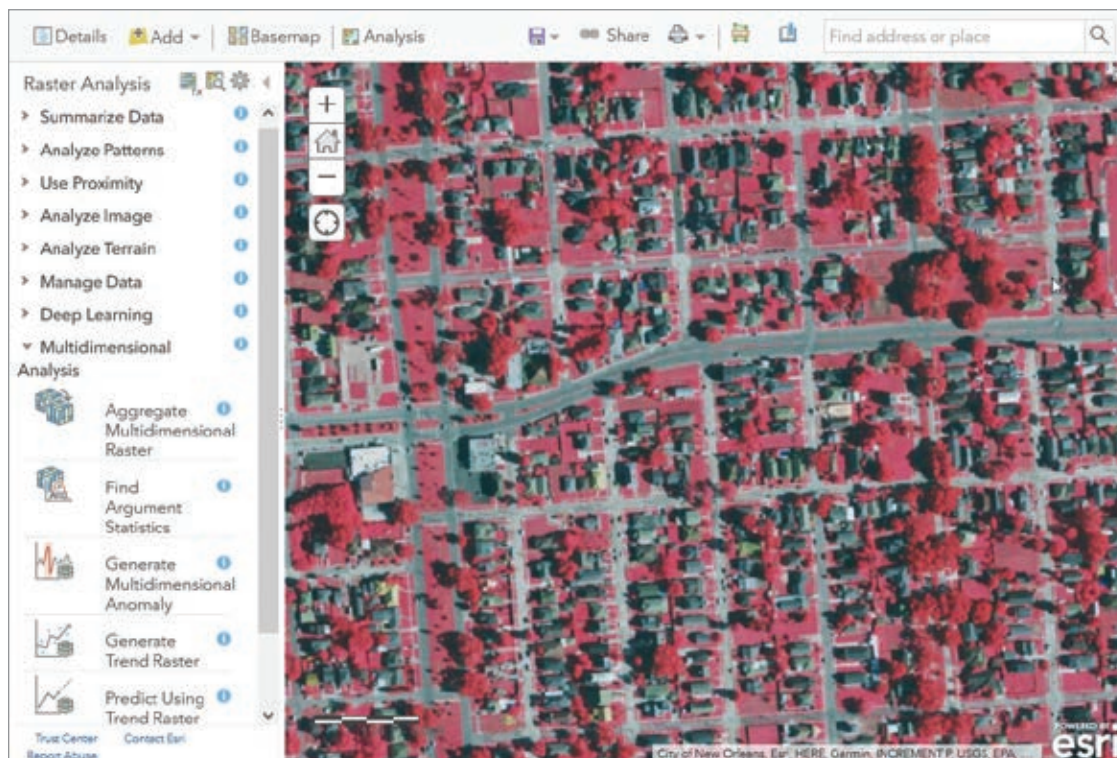
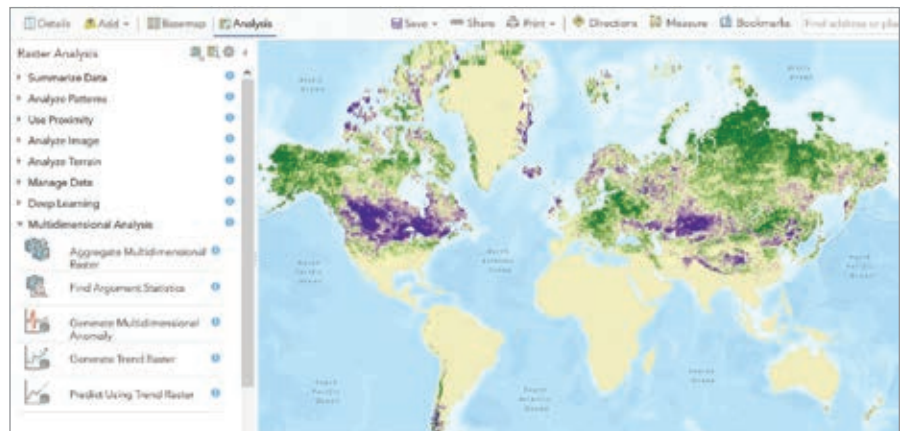
The Raster Analysis pane in Map Viewer Classic includes more than 25 raster processing tools contained in functional categories. These tools produce a new raster analysis layer that can be saved to the cloud. See ArcGIS Image Online documentation (<https://bit.ly/3tes47z>) for a detailed description of these tools.

Click on a tool in the Raster Analysis pane to display the tool and adjust parameters,

including output name and location to save the new raster layer in the cloud, then click Run Analysis. When analysis is complete, a new raster item will be created, and you can add information such as definitions or specify sharing conditions to its item description.

### Using Raster Functions

You can find the raster functions in the Custom Analysis Tools and Raster Functions pane. ArcGIS Image Online provides raster functions (<https://bit.ly/3u50jOh>) for analysis, appearance, classification, conversion,



↑ An analysis of the change in monthly worldwide snow cover from 2000 to 2020 using MODIS data was analyzed with the Multidimensional Analysis tools in the Raster Analysis pane. Purple areas show a net increase and green areas show net decrease in snow cover.

← Raster Analysis pane in the Map Viewer Classic. (Imagery: QuickBird, © 2010 Maxar Technologies)





correction, data management, distance hydrology, math, statistical, and surface to process and analyze dynamic imagery and raster data. These functions process multispectral and hyperspectral imagery, multidimensional scientific data, and temporal data for time series analysis.

Dynamic imagery layers can be processed on the fly using raster functions that are applied as you pan and zoom imagery in the map display. Because image processing calculations are only performed on the pixels that are visible in your map, results can be viewed and analyzed immediately. This allows you to adjust parameter

settings as needed to visualize and optimize your results. After you fine-tune your parameter settings, you can publish your final results to the cloud.

### Using and Building RFTs

More than 150 raster functions can be used to process dynamic imagery or chained together to create RFTs, which can be saved and shared with your organization and applied to different sets of imagery to standardize processing, results, and products.

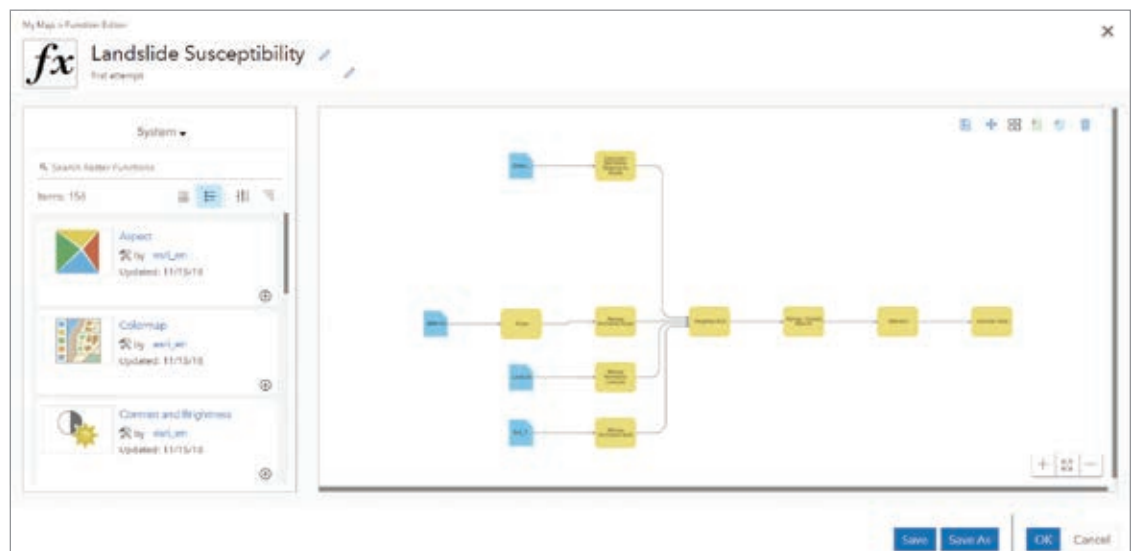
RFTs are built or modified in the Raster Function Editor, a visual programming interface for building imagery and raster

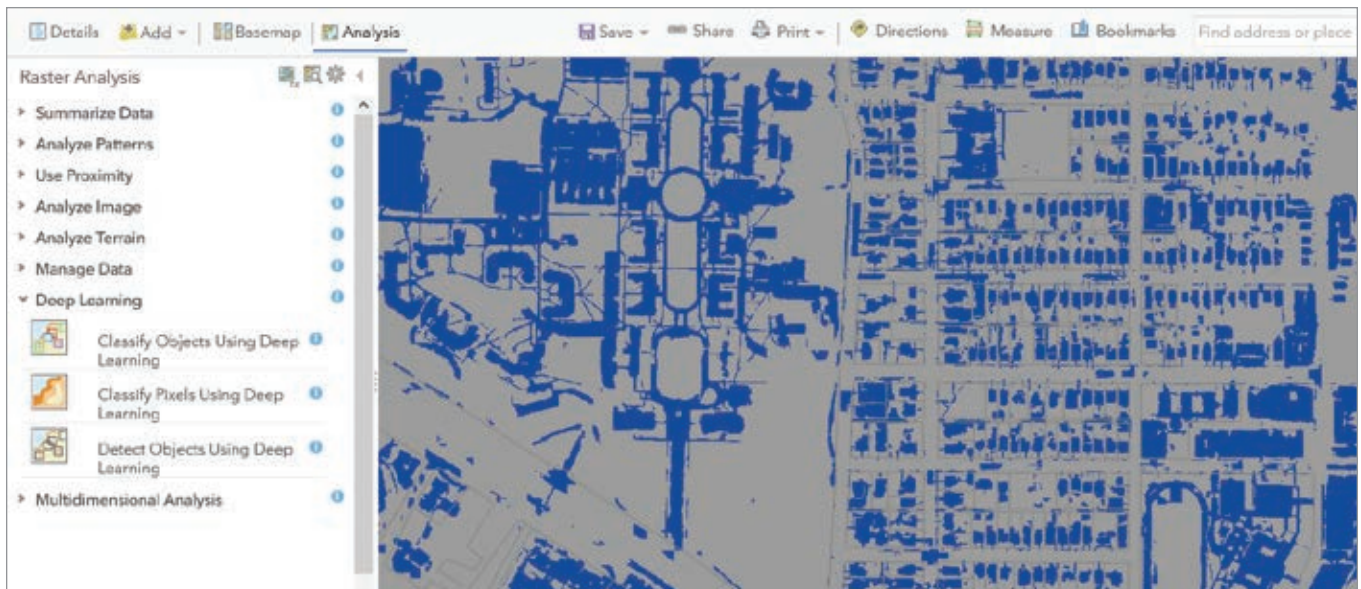
analysis processing chains. Function chains are represented as diagrams in which functions are chained together, using the output of one or more functions as the input to another function. These raster function chains can be saved as RFTs, which you can reuse to automate your image analyses and processes. You can publish source imagery with any number of RFTs, which will render different products and visualizations in the map viewer.

For example, you can publish a collection of Sentinel satellite images with RFTs that use different band combinations, ratios, and math operators, which

↑ This landslide susceptibility map was derived using an RFT to identify areas prone to slope failure for emergency planning and mitigation.

→ Landslide susceptibility RFT in the Raster Function Editor pane.





allows members in your organization to use results of your custom algorithms. For instance, employing RFTs, others in your organization can view imagery as an ortho-image mosaic, visualize land-cover classes, detect stressed vegetation, and assess burn severity.

### About Using Credits

Your organization is charged credits for the storage and processing of imagery. The number of credits charged to store hosted imagery layers depends on the layer type, number of images, and size. The number of credits charged to process imagery depends on the complexity and CPU resources required. After specifying the tool and function parameter settings, the estimated number of credits needed to process your imagery is calculated before you click Run. Refer to the ArcGIS Online documentation (<https://bit.ly/34Qm3os>) for more information about credit usage.

### Accessibility with Security

Projects often involve different stakeholders from different departments, external organizations, or the public. These stakeholders have different needs and permissions to view, edit, analyze, publish, and share imagery layers and information products and ArcGIS Online ensures data is properly managed and can be securely accessed at different levels. Proper sharing of imagery layers and derived products is

important for effective communication, operations, and governance.

### Imagery Analysis Benefits across ArcGIS

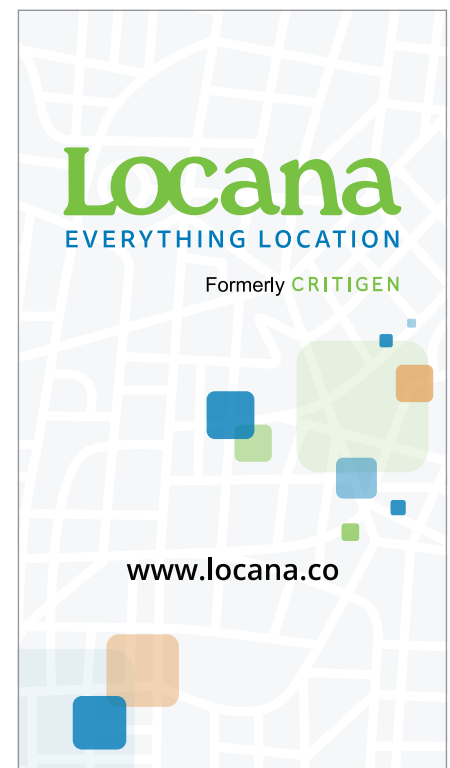
Because it is part of the ArcGIS Online ecosystem, the output of ArcGIS Image Online analysis can be incorporated into information products and shared in a controlled fashion. Data and products can also be integrated with ArcGIS Pro, ArcGIS Enterprise, ArcGIS extensions, field apps, and dashboards. Image analysis is no longer just the domain of the remote sensing scientist. With ArcGIS Image Online, GIS practitioners can analyze imagery—either visually or computationally—and benefit from the insight it can provide.

### About the Authors

**Jeff Liedtke**, a product engineer and documentation lead for the raster team at Esri, has a background in remote sensing, photogrammetry, and image processing. Applying remote sensing techniques to provide valuable information for operational decision support applications is his passion.

**Thomas O. Sweet, Jr.**, a member of the imagery and remote sensing team, has more than 30 years of experience in the field. His work applying cost effective GIS technologies has been recognized by federal agencies, governors, and the White House.

↑ This impervious feature map was derived from 4-band multispectral aerial imagery using deep learning tools in ArcGIS Image Online. Impervious feature maps are used for activities such as flood planning.





# Understand and Mitigate Risks *on a Global Scale*

By Jim Baumann

**Organizations across the world** are leveraging earth observation (EO) data and GIS to understand the impacts of disaster events and better mitigate them.

These organizations, including the Group on Earth Observations (GEO), Esri, Geoscience Australia, and the Committee on Earth Observation Satellites (CEOS), are collaborating to integrate Digital Earth Africa (DE Africa) imagery into the Africa GeoPortal and develop tailored applications and training materials that focus on reducing disaster risks on the continent of Africa.

This is just one example of the work being spearheaded by GEO, a partnership of governments and organizations that promotes the availability, access, and use of earth observations (EO) from both surface and satellite data. GEO was established in 2005 by the Third Earth Observation Summit, with the United Nations Office for Disaster Risk Reduction (UNDRR) being one of GEO's initial participating organizations.

GEO's objective is to highlight the value and usefulness of earth observations for research, policy, decision-making, and action. Using the data gathered from EO, decision-makers can better understand things such as population density in different parts of the world and socioeconomic information including where vulnerable populations live.

↓ Rising tides flood infrastructure in Easton, Maryland.  
(Photo courtesy of David Borges.)



Today, the GEO community includes 113 countries, the European Commission, more than 700 national government agencies, 135 international participating organizations, and 17 GEO Associates. GEO Associates are commercial and nonprofit organizations that have demonstrated commitment to GEO's mission and are recognized as official GEO collaborators. Esri is a GEO Associate, and 30 Esri staff members are currently participating in 34 different GEO Work Programme activities. They work in areas such as capacity development, climate action, and disaster risk reduction.

Along with collaborating on projects with Esri, GEO is using Esri software to create geospatial solutions for its disaster risk-reduction and resilience efforts. "Earth observations are inherently spatial, and the analytic capabilities of Esri technologies make that data more accessible and understandable," said David Borges, a physical scientist with the National Aeronautics and Space Administration (NASA) Earth Science Division's Applied Sciences Program, in the Disasters program area. Borges also cochairs the recently formed GEO Disaster Risk Reduction Working Group (GEO DRR-WG). Borges continued, "GIS serves as a bridge between the scientific research communities and decision-makers."

The goal of the GEO DRR-WG is to support policies such as the UNDRR Sendai Framework for Disaster Risk Reduction 2015–2030, and the group serves as the primary GEO liaison to UNDRR. According to the United Nations Office for Disaster Risk Reduction, the framework focuses on the following priorities:

- Understanding disaster risk
- Strengthening disaster risk governance
- Investing in disaster risk reduction for resilience
- Enhancing preparedness for effective disaster response and to "Build Back Better" in recovery, rehabilitation, and reconstruction

"The framework calls for a substantial reduction of disaster risk and the subsequent losses in lives, livelihoods, and health," Borges said. It also considers the economic, social, cultural, and environmental impact of disasters. "[At GEO], we are helping expand the use of EO insights to achieve the Sendai Framework goal to increase the number of countries with national and local disaster risk reduction strategies," said Borges. "EO data and knowledge can complement the data that governments already have access to, such as disaster risk trends over time. Taken together, the compiled data can help them better understand and visualize their specific vulnerabilities and exposure."

Esri software also is being used to help the GEO Work Programme, which facilitates collaboration of activities that members, GEO Associates, and other organizations are working on to fulfill GEO's mission. Realizing the need to coordinate the expansive geospatial data gathering efforts required for the 64 GEO Work Programme activities, the Disaster Risk Reduction, Capacity Development, and



Climate Change working groups collectively implemented ArcGIS Survey123 to standardize the process.

América Álvarez, a GIS technical lead at the US Geological Survey (USGS) Office of International Programs, worked on the project. "Once the groups finalized the survey questions, we created 64 unique survey links [one for each GEO Work Programme activity]," Álvarez said. "With the appropriate settings, we were able to have more than one individual complete or update a single survey per activity. We then brought the survey results from the 64 accounts into a single master dashboard, which has helped us coordinate our efforts in disasters, climate change, and capacity development."

The three GEO working groups are distributing the surveys to the various activity leads around the world. As each survey is completed and submitted, results are automatically aggregated and reflected on a dashboard created using ArcGIS Dashboards.

"ArcGIS Survey123 has proven to be a very useful tool that meets the specific needs of our working groups, including the critical ability to capture and communicate the inherently spatial aspect of GEO's efforts and impact around the world. For the GEO DRR-WG, the collected data informs us where we should focus our efforts during the coming year," Borges said.

Esri also is involved, along with the GEO DRR-WG and UNDRR, in codeveloping the Earth Observations Risk Toolkit for Disaster Risk Reduction. According to the GEO website, the toolkit will be composed of open-source services and tools that will provide information on risk vulnerabilities, hazards, and exposures. This information will be provided to emergency response agencies at the local and national levels, mainly in low- and middle-income nations often beset by hazards such as tsunamis, floods, and dry conditions that cause wildfires. Humanitarian and economic development organizations also will find the toolkit's resources useful.

Because the Earth Observations Risk Toolkit is fundamentally geospatial, it is

being built using a hub site. The hub site, created using ArcGIS Hub, is hosted by UNDRR using its Esri account. This approach will make it easier for UN partners to collect, access, and apply multidimensional risk data and analytics to help address disasters and climate change.

All the work that's being done by GEO, its members, UNDRR, Geo Associates, and other partners is critical to reducing and responding to risks caused by disasters. "These activities, made possible through international partnerships, are critical," Borges said.

"To reduce the impacts of intensifying disaster events in the future, national authorities must fully understand the real geographic and sectoral extent and effect of current disasters. The GEO community, in partnership with UNDRR and Esri, is working tirelessly to ensure that users can leverage earth observations as much as possible to accomplish the objectives of the Sendai Framework and prevent future loss of life and infrastructure."

## About the Author

**Jim Baumann** is a longtime employee at Esri. He has written articles on GIS technology and the computer graphics industry for more than 30 years.

↓ The GEO Disaster Risk Reduction Working Group used ArcGIS Survey123 and ArcGIS Dashboards (pictured) to better understand stakeholder engagement activities. (Image courtesy of AmeriGEOSS.)







# Identifying the Solar Potential Next to America's Highways

By Terry Bills

An hour out of Atlanta and halfway to Alabama, the southbound I-85 freeway crosses US Highway 27. Unless your destination is LaGrange, Georgia, you'll likely blow right past exit 14.

If you do take exit 14 after nightfall, you could easily miss the five-acre, one-megawatt array of solar panels that fills the grassy area of the diamond-shaped interchange. It powers the 50 LED streetlamps on this previously unlit stretch of asphalt, and excess electricity goes directly to Georgia Power's grid. The Ray, an Atlanta-based nonprofit that partially underwrites this installation, hopes it serves as a guiding light for America's sustainable energy future.

The exit 14 solar project exists on land

that transportation planners call a highway right-of-way, or ROW. These are the buffer spaces—including shoulders, medians, rest stops, and turnoffs—that provide breathing room on high-speed thoroughfares.

A movement is under way to transform typically shade-free highway ROWs that sit outside the safety zone (at least 30 feet from the roadway) into sites for generating solar power. Georgia, Iowa, Oregon, and Massachusetts are among the states that have launched pilot projects that take advantage of the secure borders of freeway ROW, which are typically adjacent to electrical infrastructure and easy to access for maintenance.

The Ray, which promotes the use of

ROW land for solar panel arrays, estimates many states have enough federal interstate freeway ROW land to support thousands of acres of solar arrays. Interchange acreage alone, like the ROW used for the exit 14 project, could generate 36 terawatt-hours of electricity, which is enough to fully charge 12 million electric vehicles each year.

## ROWs Upon ROWs

The first step is locating and evaluating possible locations, specks within the hundreds of thousands of miles of highways in the country—over 47,000 miles in the interstate system alone.

Solar arrays require specific conditions, and their sheer size can be disruptive. To





← The five-acre diamond-shaped parcel at the interchange where the southbound I-85 freeway crosses US Highway 27 in Georgia now hosts a one-megawatt array of solar panels. This previously unlit stretch of asphalt now generates power for 50 LED streetlights and sends excess electricity to Georgia Power's grid.

↓ The Ray used a tool developed by Esri to conduct geospatial analysis of Iowa's 238,000 acres of highway right of way to identify and rank potential sites for solar panels.

help find the perfect spots for arrays, The Ray used a tool developed by Esri to conduct geospatial analysis with a GIS, an approach it hopes becomes widely adopted by other organizations and transportation departments.

While working with open data from the Iowa Department of Transportation, The Ray began by using GIS to identify and display the state's 238,000 acres of highway ROW. Various map layers revealed other attributes of interest for choosing the best sites, such as electrical lines.

The geospatial tool then allowed analysts to eliminate land they didn't want to use, such as protected areas and high-density regions. Anything too close to railroad tracks or pipelines—or too far from electrical lines—was also automatically subtracted from the map.

The analysis returned the results of potential sites. The tool could then rank possible locations by suitability, considering such variables as solar radiation, a calculation derived from a 3D terrain model that showed elevation and trees that cast shadows.

The net result was 38,000 acres of prime solar-ready land. Based on the tool's calculations, arrays on those polygons could produce five million megawatt-hours per year, worth about \$400 million.

"The GIS analysis lets transportation agencies move from what they could do to

what they should do," said Allie Kelly, The Ray's executive director.

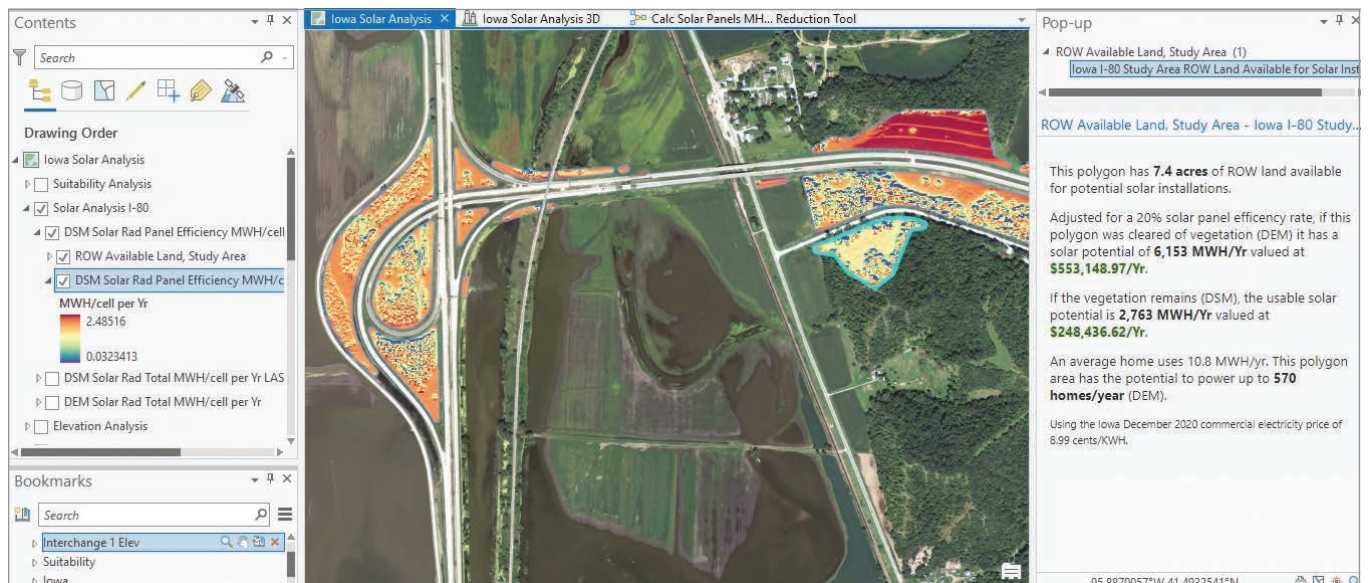
## Wall-to-Wall Sustainability

The Ray takes its name from Ray Anderson, a former Georgia Institute of Technology (Georgia Tech) football player who founded Interface, Inc., a company that pioneered the manufacture of carpet tiles for office spaces, in 1973.

Throughout the 1970s and 1980s, Anderson grew Interface into an industry giant. In the early 1990s, inspired by Paul Hawken's book, *The Ecology of Commerce*, Anderson looked for ways to clean up the petroleum-heavy industrial processes that are involved in making his company's products.

"He called it Interface's 'mission zero,'" Kelly said. "The goal was zero waste to landfill, zero carbon, and zero fossil fuels." Anderson became an early adopter of what we now call a circular economy.

Anderson later cochaired President Bill Clinton's Council on Sustainable Development; advised President Barack Obama on climate change; and funded an endowed chair at Georgia Tech to support research in natural systems, energy, climate, and sustainability. Following Anderson's death in 2011, Harriet Anderson Langford, his youngest daughter, founded The Ray. The nonprofit charity functions as a proving







↑ The Ray encourages transportation departments to plant flowering perennials as ground cover for solar sites that provide a haven for bees, butterflies, and other pollinators, many of them threatened species.

ground for sustainable transportation technology on the Ray C. Anderson Memorial Highway, a designation Langford successfully acquired in her father's honor.

## Understanding the Benefits

Highway ROWs are not The Ray's only focus. Exit 14 lies at one end of a stretch of I-85 nicknamed The Ray Highway, a living testbed for the organization's transportation-related projects. But as an example of looking for ways to wring useful efficiency out of underused land, the ROW project best exemplifies Anderson's vision.

The Ray is currently discussing 10 projects for sites across the country, including Austin, Texas, and Charleston County, South Carolina. Making these projects happen requires negotiations with local governments, contracted tollbooth and turnpike operators, and state-level transportation departments.

## The Bees' Needs

A ROW is—for practical purposes—land that exists to exist. It is a necessary blank space in the highway fabric. Solar arrays not

only add economic value to those lands but also provide a crucial, though less quantifiable, public service.

The Ray encourages transportation departments to plant flowering perennials as ground cover for these sites. The plantings provide a haven for bees, butterflies, and other pollinators, many of them threatened species.

The GIS-powered tool The Ray developed to evaluate ROW land can show how much sunlight will reach the ground. Besides generating energy for people, a ROW can then also become a source of solar power for symbiotic flora and fauna.

"You end up preserving pollinator habitat for decades," said Kelly. "These arrays take land that was producing nothing and transform it into something special."

To illustrate the scope and benefits of ROW solar projects, The Ray uses a GIS-based digital twin of a highway area. The detailed visualization, which includes a 3D representation of the landscape and the solar panels, helps stakeholders gain a direct contextual understanding of a project.

"Transportation engineers know about

asphalt, concrete, bridges, and signage," Kelly said. "When we start talking about solar panels, this is infrastructure that isn't native to them. The digital twin normalizes it."

The twin can provide an exact replica, including the size of the panels and the width between rows. It can take the viewer down to the ground level, and even show how the array will look from various vantage points.

"It allows a transportation department to get comfortable with a solar array, but it also allows transportation departments to think ahead to the community's perspectives," Kelly explained. A rise in the land, for instance, might mean that the solar arrays will impact local viewsheds. The tool can even show what someone of a given height might see when standing at a certain point.

## Seeing Risk and Reward

The digital twin tool can also provide real quantitative data to assess the economic value of ROW arrays. How much sun will the site receive, based on weather data? How much will the generated electricity be worth, based on local rates?

These questions are crucial, because a ROW solar array effectively puts a transportation department into the electricity business. A department might, for example, work out a power purchase agreement with a local utility. Perhaps some of the power could be used to increase the number of electric vehicle charging stations.

"Trying new things in transportation is just inherently risky," Kelly said. "This tool is designed to mitigate those risks. It's all about values and equivalencies."

## About the Author

**Terry Bills**, the global transportation industry director at Esri, is responsible for all transportation infrastructure segments worldwide. He has more than 25 years of experience in transportation, working on planning, policy development, information technology, and GIS. He has been a principal planner for a large regional planning agency, as well as the president of a GIS and transportation consulting firm. He earned two master's degrees from the University of California, Los Angeles, where he was also a doctoral candidate.



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# Mapping the Geography of Underground Ecosystems

By Michael Jones

The National Cave and Karst Research Institute (NCKRI) used hydrogeology, biology, and GIS to safeguard endangered species living below the surface. NCKRI is dedicated to promoting sustainable management of caves.



↑ *Tartarocreagris texana*, the Tooth Cave pseudoscorpion (Photo by Dr. Jean Krejca, Zara Environmental LLC.)

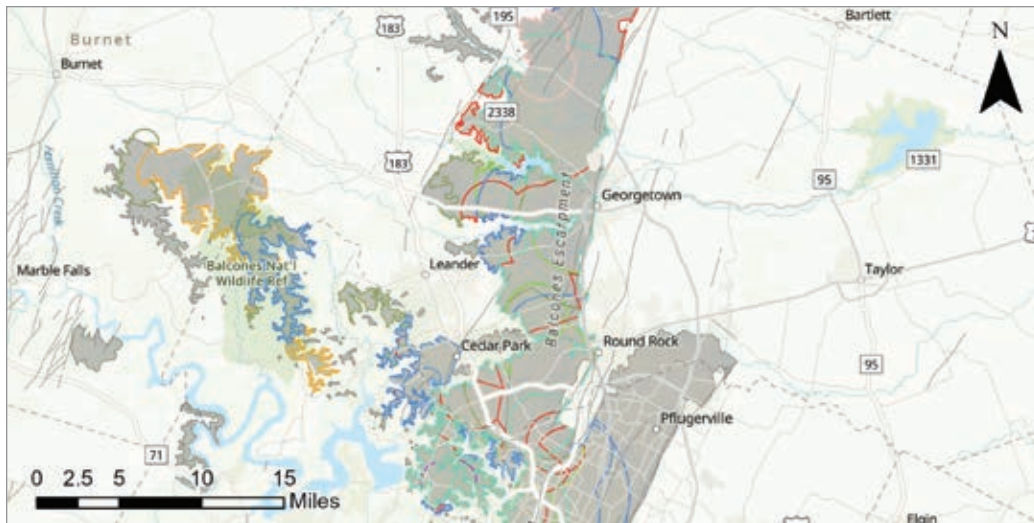
**How do you map** a primarily unknown and poorly defined terrain? Mapping the distribution of rare and endangered species hidden in caves was the challenge presented to NCKRI. The US Fish and Wildlife Service (USFWS) contracted NCKRI to redefine the distribution of federally listed, endangered karst invertebrate species in the Austin, Texas, region. The resultant maps would help USFWS prevent the degradation and destruction of interconnected underground ecosystems that are unseen from the surface.

Because the underground landscape is mostly inaccessible to humans, NCKRI proposed a GIS model to predict likely species distributions and possible restrictions and barriers to their distribution. NCKRI selected ArcGIS Pro for modeling. The ArcGIS Spatial Analyst extension provides advanced modeling and statistical tools that allow users to perform comprehensive, raster-based spatial analysis to solve complex problems.

Models of species ranges identify the probability of encountering the subject species. As a result, GIS provides USFWS with valuable

information for various regulatory needs such as managing and setting recovery standards. In addition, range maps help guide development away from sensitive areas, allowing opportunities to purchase or enhance the regulation of those areas.

Previous studies of the Austin karst species used simple and broad statistical methods to define their distribution. (Karst refers to landscapes usually characterized by caves and other cavities.) However, as new localities and additional information for the species became available, the earlier maps became out-of-date. Therefore, in 2021, NCKRI performed a more robust statistical analysis of species distribution in ArcGIS Pro. This study updated the karst fauna region (KFR) and karst zone predictive area boundaries established initially by the USFWS nearly 30 years ago and updated in 2007. (KFRs are regions with the same group of karst species.) *[Karst zone areas are delineated based on the presence or probable presence of endangered karst species. They are defined as: Zone 1—areas known to contain*



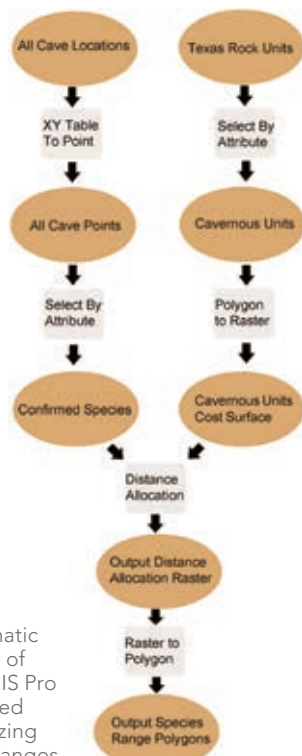
← The range of *Troglobitic* species, which are restricted to caves, are depicted clustered at the range margins along Brushy Creek but show no clustering along the south fork of the San Gabriel River.

endangered cave fauna; Zone 2—areas having a high probability of suitable habitat for endangered or other endemic invertebrate cave fauna (refined now to only endangered cave fauna); Zone 3—areas that probably do not contain endangered cave fauna; and Zone 4—areas which do not contain endangered cave fauna.]

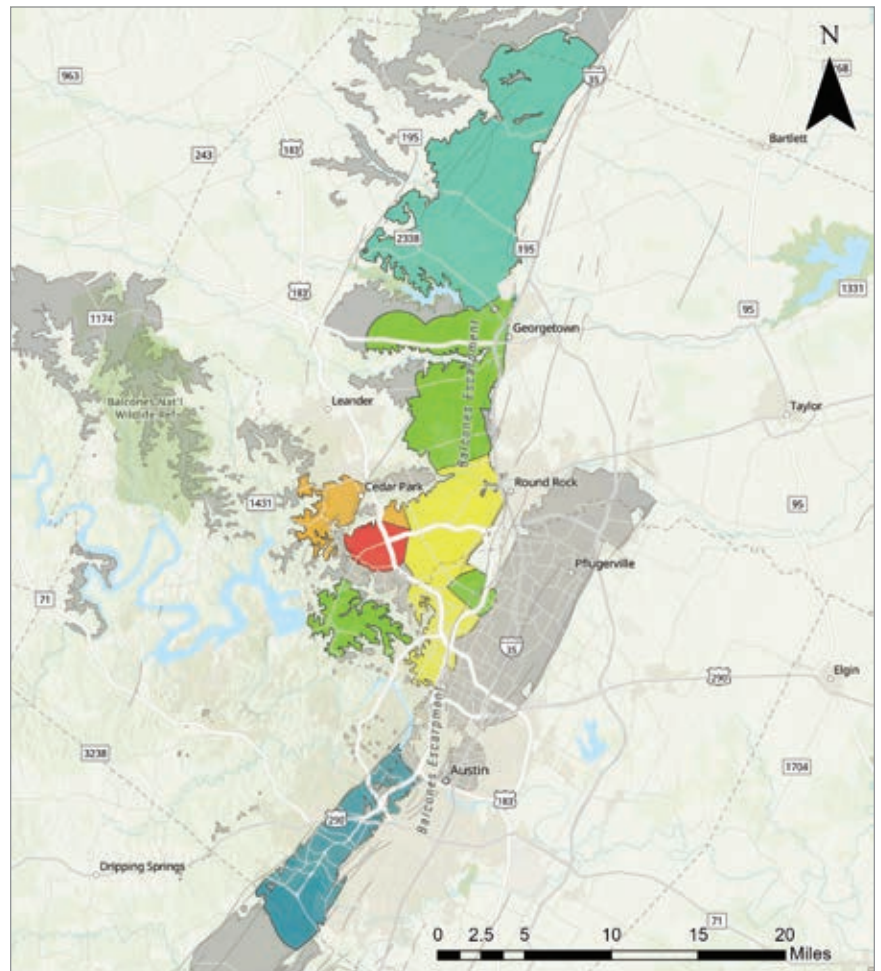
How can GIS be applied to mostly hidden underground ecosystems? It comes down to knowing the nature of the geospatial data and using appropriate modeling constraints. NCKRI attempted multiple methods to identify the most

accurate means of evaluating species distribution. Geology, hydrology, climate, vegetation, and soils are potential factors affecting species distribution. However, NCKRI did not incorporate all these methods and elements due to a lack

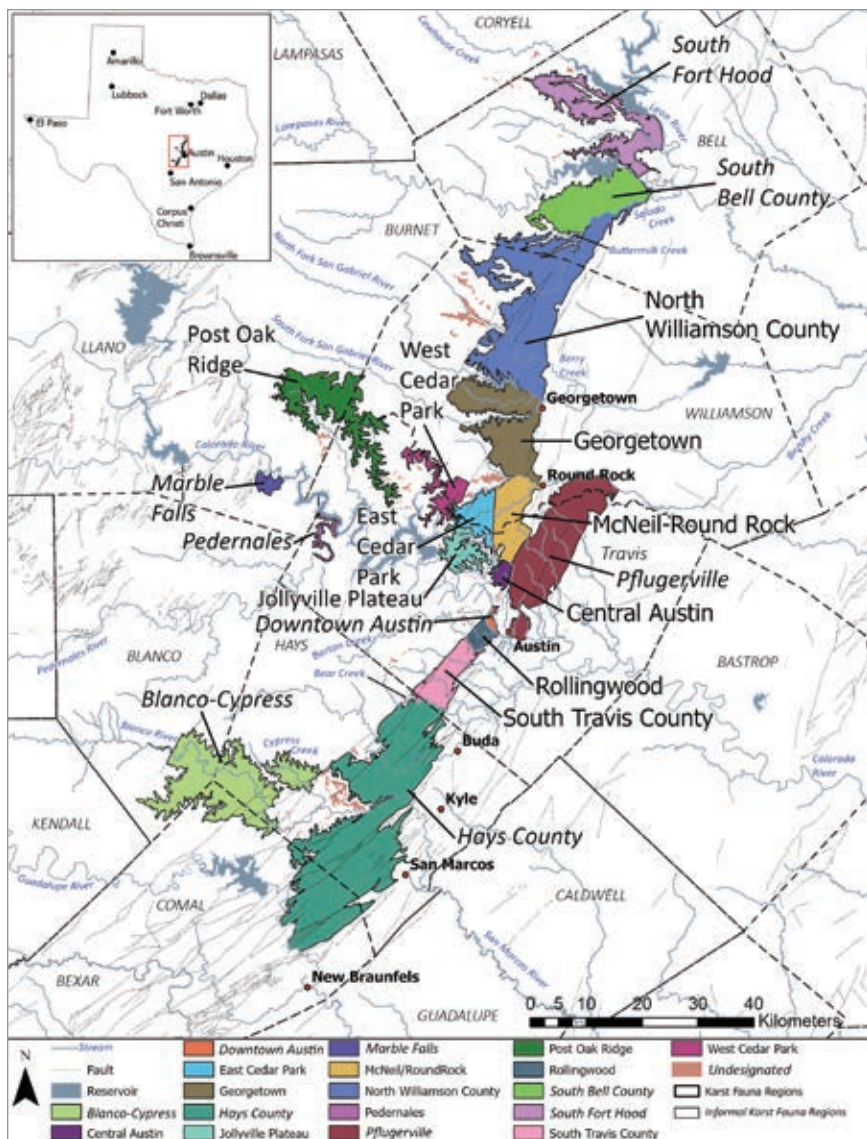
↘ This map shows the modeled distribution of six troglitic carabid *Rhadine* species beetles in the Austin, Texas, area. The areas in bright colors represent each species, and the gray area is the cavernous unit.



→ Schematic workflow of the ArcGIS Pro mode used for analyzing species ranges.







↑ Karst fauna regions (KFRs) as revised by this study.

of data with sufficiently high resolution.

Following an extensive evaluation, NCKRI determined the best modeling method was to reverse the GIS analysis. Rather than model the effects of various physical conditions on the species' distribution, NCKRI analyzed the distribution range of each species.

The investigation used hydrogeologic and biological data to create a GIS model that mapped the ranges of the 7 listed species and 32 nonendangered species from 479 caves in the study area. The 39 species used in the study—which included beetles, harvestmen, millipedes, pseudoscorpions, and spiders—were all fully adapted to their dark surroundings and do not occur on the surface. In addition, the 32 nonendangered but endemic species occupy the same ecological niches as the endangered species. Therefore,

NCKRI used the additional information and layers of other potentially relevant data to constrain the distribution of the endangered species.

The clustering of multiple modeled species range margins within a limited area reflects the possible presence of a barrier or restriction to species distributions. NCKRI then carefully examined geologic factors, such as formation contacts, faults, streams, soils, and other factors, to determine if they create a barrier or restriction of the species' distribution. In some instances, NCKRI found no hydrogeological explanation for a cluster of range margins and assumed that subsurface ecological conditions beyond the investigation's scope created the restrictions or barriers.

After evaluating the newly available geospatial tools and biological data in ArcGIS Pro, NCKRI initiated a series of five repeatable steps to perform statistical analysis to revise endangered karst species distributions along the Balcones fault zone in Texas:

- Describe a set of cavernous geologic units as the potential habitat of the endangered karst species.
- Combine the cavernous units to create a rasterized cost surface at a 1-meter resolution.
- Assign each pixel a value of 1 as the cost distance a species would have to travel to distribute itself throughout the cavernous unit.
- Analyze the possible geographic ranges for each species using the Distance Allocation tool to model their boundaries.
- Compare the modeled ranges for each species and genus with previously established KFRs and karst zones to update those boundaries as needed.

The GIS modeling identified 15 range margin clusters as potential KFR boundaries. Of the eight original KFR boundaries, the GIS analysis supported five, modified three, and eliminated one. Additionally, the analysis established two new boundaries, dividing an existing KFR into two. Further, the investigation created eight informal KFRs for the regions that constrain the distribution of the endangered species.

The GIS model also suggested modifications to the karst zones. Biospeological surveys reported more localities for the listed endangered species since the previous karst zone revision in 2007. Zone 1, where endangered species are known to occur, grew to fill many of the former Zone 2 areas, which had a high probability for their presence. In addition, the number of karst

zones expanded from the previous four to include two subzones for zones 3 and 4. These subzones were needed to identify their biological status more precisely than previously defined so that their ecosystems can be better managed.

NCKRI based the subzones on their potential for different, nonendangered ecological communities versus potential cave and karst occurrence. In addition to the new localities, the GIS distribution modeling proved a valuable tool in revising the karst zones. The GIS modeling provided a more quantifiable justification for the location of the boundaries throughout the study area, especially where little or no geologic or other potential boundary condition was apparent.

Since the completion of this report, released as NCKRI Report of Investigation 10 (available for free download from [www.nckri.org/publications/reports-of-investigation/](http://www.nckri.org/publications/reports-of-investigation/) with all the project's details), USFWS has updated its endangered species management guidance based on the new results. In addition, the modeling method is described in detail in the report for use as a template for objectively and statistically delineating the ranges of karst troglobites in other areas. (Karst troglobites is a species that lives only in caves and associated cavities.)

For more information, go to the USFWS website ([www.fws.gov/office/austin-ecological-services](http://www.fws.gov/office/austin-ecological-services)). For more information about the modeling methods, contact George Veni at [gveni@nckri.org](mailto:gveni@nckri.org).

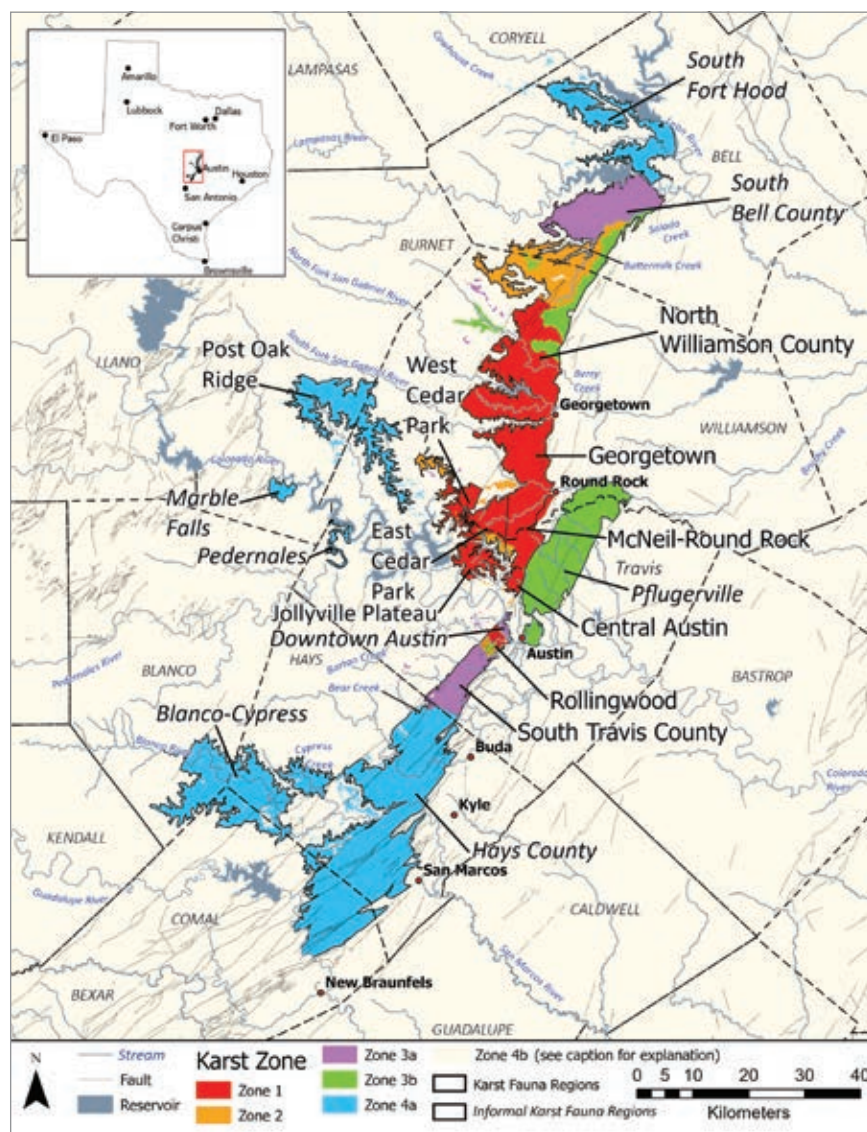
## Acknowledgments

This research was funded by USFWS and supported by exceptional technical assistance from Jenny Wilson, USFWS karst invertebrate lead. James Reddell provided the species data and a wealth of information that made this project possible. The Texas Speleological Survey provided invaluable access to its files for cave location and other crucial information. Special thanks go to Bernard Szukalski, David Johnson, and the rest of the Geo Experience Center team of Esri, who generously provided the repeatable Python workflow Jupyter Notebook to speed up multiple geoprocessing commands during the GIS modeling, and an independent in-depth analysis of the model. Additionally, many others supplied data and insights that improved the quality of this study.

## About the Author

**Michael Jones** is a graduate assistant at the Center for Advanced Spatial Technologies (CAST) at the University of Arkansas. He was the cave and karst science specialist at NCKRI when this project was carried out. Jones holds a bachelor's degree in geography water resources from Texas State University in San Marcos and is working toward earning his master's degree focusing on carbon dioxide dynamics within Earth's carbonate critical zone. His passion for the science and protection of karst critical zones comes from his appreciation for the various ecosystem goods and services provided by caves and karst.

↓ Karst zones as revised by this study. Due to the broad area and its complexity, Zone 4b, as shown, includes some Zone 4a areas with the intent that only areas adjacent to the KFRs with endangered karst species are Zone 4b.





# Expanding the Capabilities of Cell Image Analysis with GIS

By Jim Baumann

Russ Butler and Craig Gillen, along with a team of undergraduate research assistants at AdventHealth University (AHU), have been applying GIS technology on the micro scale to add image classification to spatiotemporally stamped human health data.

**Butler and Gillen** are not the first to apply GIS to analyzing the human body. Eric J. Topol, an American cardiologist, scientist, and author, proposed a human GIS in “Individualized Medicine from Prewomb to Tomb,” an article published in the March 27, 2014 issue of *Cell*. Topol’s theoretical human GIS model incorporated layers of human health information from individual biological molecules in context with environmental conditions.

According to Butler, who is the director of the Center for Population Health Research (CPHR) at AHU, the relationship between human health and well-being corresponds to factors that range from the molecular to the global scale. “We are spatiotemporal beings, and GIS has the inherent capacity to capture these layers. GIS can provide us with a more comprehensive view of a patient for both treatment and prevention,” said Butler.

Embedded in GIS systems are powerful image classification tools. These tools, in conjunction with Human GIS layers, could provide a unique way to visualize patient medical information. To augment practitioner diagnoses, imaging data such as bio-sensors, X-rays, MRIs, mammography, and sonograms could be classified in ways that make the data machine readable, analysis ready, and ultimately more useful.

Moreover, all this information can be linked to a patient’s geographic coordinates. The places where people live, work, and play are known to affect life expectancy,

wellness, and health. The image classification abilities of GIS, together with its amazing capacity for almost limitless data layering and analyses from molecules to environment, could provide novel insight into understanding the complex factors determining human health and wellness.

Present-day electronic health records (EHR) systems compile extensive patient-related information. But, EHRs do not currently integrate all pertinent patient information, such as classified patient imagery and allied health notes on neighborhood characteristics, physical and occupational therapy, rehabilitation, and dietary and nutrition services.

Butler and Gillen are performing spatial analyses at the micro-GIS level by modeling cellular distributions to better understand *Mycobacterium tuberculosis*—the bacteria that causes tuberculosis (TB)—a disease that has infected humans for millennia. The World Health Organization (WHO) noted that 1.5 million people died from TB in 2020, making it the second-leading infectious killer after COVID-19.

“TB is a difficult disease to treat. One of its intractable features is the formation of multiple cellular masses within the lungs called granulomas,” said Butler. “TB granulomas are small masses formed during infection that develop and grow through a dynamic process between the host immune response and mycobacteria. It is well-known that granuloma-scale

outcomes, are related to disease severity.”

Using micro-GIS to quantitatively assess granuloma structure, Butler believes this research can significantly contribute to understanding TB and lead to better treatment outcomes. Butler, in collaboration with researchers from the University of Michigan and the University of Pittsburgh, has published several papers about the use of micro-GIS to examine granulomas.

“Using the power of ArcGIS classification algorithms and by applying Cartesian coordinate systems, we are among the very first to create a novel pipeline for spatioquantitatively defined cellular patterns within granulomas,” said Butler. Several different image classification techniques were used—support vector machine (SVM) and random tree—on a variety of granuloma images. These supervised machine learning techniques require training sample files. These training files were created by selecting as many as 100 sample sites of the different cell types.

Researchers were interested in two to three different cell types for any given image or project. The analysis used geoprocessing tools, often the Classification Wizard, to produce classified images that provided feedback about the distributions of different cell types.

This also showed that staining techniques often resulted in cellular debris being misclassified as cells. The use of geoprocessing tools helped to develop

→ Using ArcGIS classification algorithms and applying Cartesian coordinate systems, AHU researchers are among the first to create a novel pipeline for spatially quantitatively defined cellular patterns within *Mycobacterium tuberculosis* granulomas.

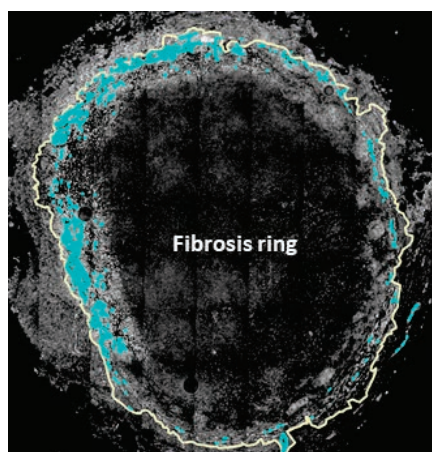
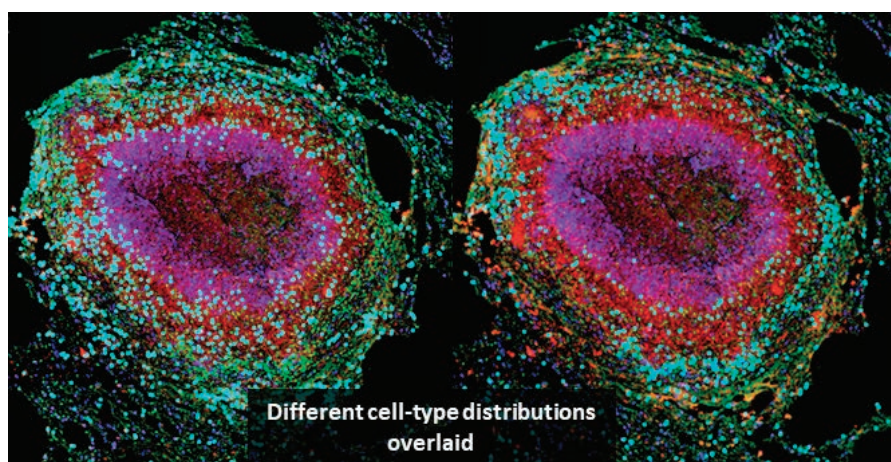
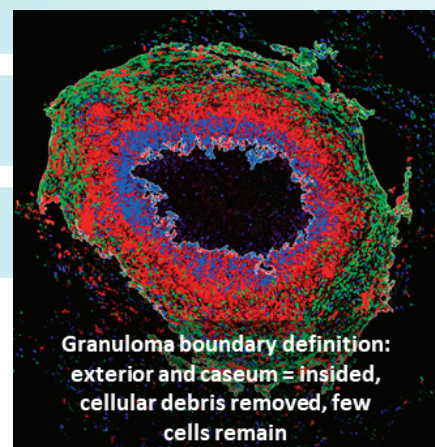
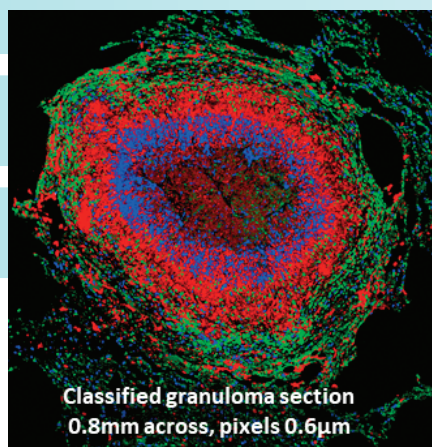
an unsupervised classification process, which greatly helped separate stained cells from merely stained cytoplasm. Classified images compared to the same stained biological samples revealed the cellular nuclei.

Researchers used knowledge gained through these runs and applied it to unsupervised runs. These classifications produced subsequent category collapsing to identify the desired cell types.

"This is a very complex process where human input and machine classifications are iterative, with the human input the final arbiter," said Butler. "For example, unlike, say, a forest classified from satellite imagery, our images have depth." A tissue section of a cell could be angled from deep in the cell to its surface, which would vary the expression of staining.

This process is much more complex than classifying a forest on a slope because the samples the team works with—tissue, intracellular matrix, or other cells—are more difficult to handle. As a result, Butler noted that, "It is virtually impossible to produce an undamaged tissue sample that is only one cell thick. We have been working on this for five years now and appreciate the advice and support that Esri staff members have provided us."

Extending the micro-GIS capabilities for cell image analysis to human imaging modalities, such as X-ray, MRI, CT scans, and ultrasound—when combined with immunology, microbiology, histology, and/or



epidemiology—could lead to a significant reduction of the global burden of disease concluded Butler.

### About the Author

**Jim Baumann** is a longtime employee at Esri. He has written articles on GIS technology and the computer graphics industry for more than 30 years.

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# ML Aids Geospatial Assessment for Disaster Response

By Akshaya Suresh and Vinay Viswambharan

In 2021, Esri partner Dewberry was asked to identify temporary housing locations for disaster survivors displaced from their homes in Louisiana following Hurricane Ida. Locations close to the original communities were preferred because that would support faster revitalization of the affected region's economy.

Dewberry, an architectural and engineering firm, combined its damage assessments with tools provided in the ArcGIS Network Analyst extension for ArcGIS Pro and added in parcel data and damage assessment information to display hot spots where damage occurred. The analysis also identified unaffected large parcels of land where temporary housing sites could be placed.

Hurricanes, tropical storms, and other natural disasters can cause structural devastation. For affected communities, it is vital to quickly determine the impacts on building structures to keep residents safe. Assessments of structural damage provide important information needed by federal, state, and local emergency responders to make critical decisions regarding resource allocation during recovery and rebuilding efforts.

Dewberry performs geospatial damage assessments for government clients following natural disasters. Advancements in the field of machine learning (ML) are playing an increasingly important role in performing damage assessments because these capabilities are also being used for proactive disaster response.

## How ML Supports Geospatial Damage Assessments

The predictive benefits of ML begin with data collection. Dewberry collects post-event imagery in areas that have sustained damage from hurricanes and other natural

disasters. The company obtains this data from providers such as the National Oceanic and Atmospheric Administration (NOAA), Civil Air Patrol, and the National Insurance Crime Bureau. After the data is uploaded to ArcGIS Image Server, Esri's imagery data management system, it is added to a compilation of imagery from previous natural disasters and then uploaded into a repository of data across various geographies.

ArcGIS provides end-to-end deep learning capabilities, enabling users to label features, train models, and perform feature

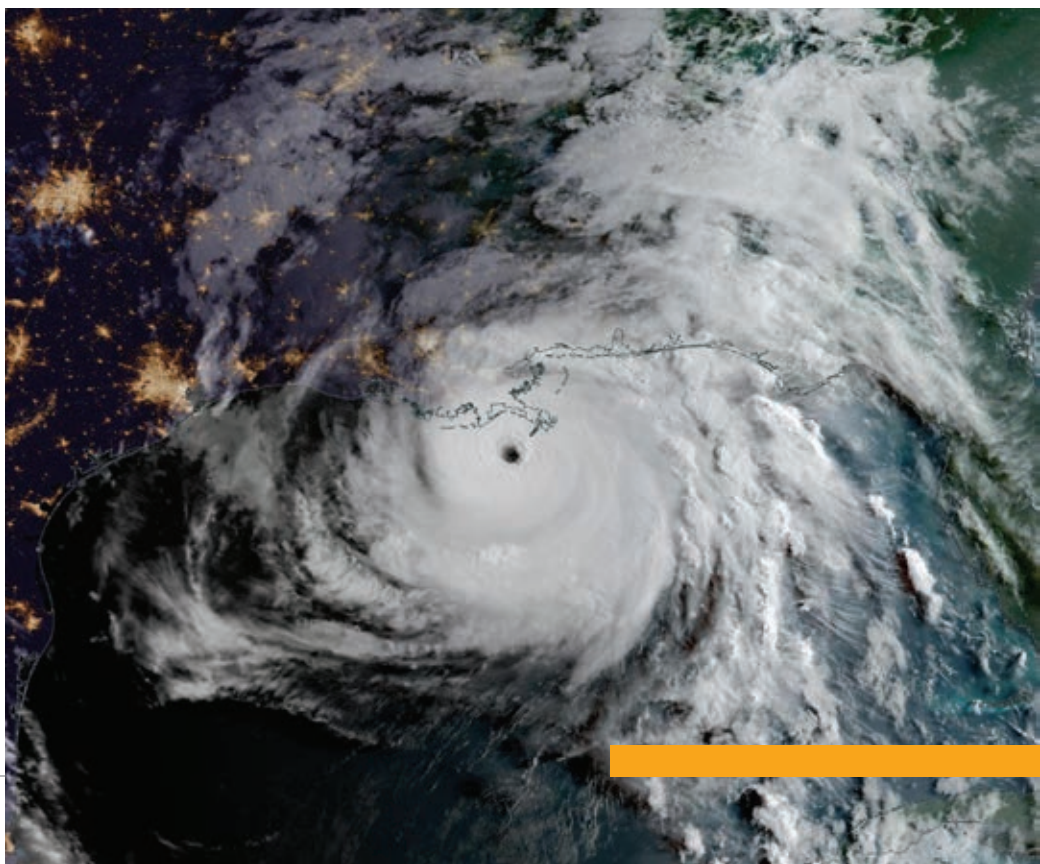
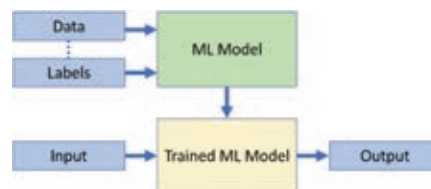
extraction on imagery. Using ArcGIS Image Analyst extension for ArcGIS Pro, deep learning models are trained to detect specific (and relevant) features within the imagery. The training data feeds the ML model, which learns to identify patterns of disaster damage to help predict which structures will be affected by future disasters.

## Training Deep Learning Models

Prior to training a deep learning model, training samples using high-resolution imagery must be created to represent

→ Damage assessment machine learning model training workflow

↓ Dewberry was asked to identify temporary housing locations for disaster survivors displaced from their homes in Louisiana following Hurricane Ida.



Predicted Classification: Minor



← Model classification used to predict damage.

features of interest. Using the labeling capabilities in ArcGIS Pro, features of interest, such as downed trees, building classifications (damaged and undamaged), and tarps covering holes in roofs are digitized and labeled. Those labeled features are added to a feature class so they can be referenced in training the model.

Once training samples are collected, models are trained relevant to the problem set using the Train Deep Learning Model geoprocessing tool in the Image Analyst toolset for ArcGIS Pro. Key models Dewberry has trained include:

- An object detection model to identify damaged tree stumps.
- An object detection model to identify blue tarps.
- An object classification model to classify structures according to the severity of the damage sustained.

The ground truth labels are compared to the model classification results to get a quick qualitative idea of how well the model performed.

## Performing Damage Assessments

Before Esri's ML technology was available, a Dewberry analyst visually interpreted postevent imagery, performing an average of 100 damage assessments per hour. Using trained deep learning models, Dewberry can now complete 410,000 automated assessments per hour. This significant improvement confirms that ML is beneficial for both interpreting data with greater efficiency and increasing the ability to extract a variety of data points.

Using the trained models with the inferencing tools in ArcGIS Pro, Dewberry identifies damaged property structures and classifies the severity of the damage. This information is communicated to the Federal Emergency Management Agency (FEMA) for downstream analytical applications. Once feature extraction with damage classification is complete, the results are reported to FEMA. Subsequently, FEMA shares the results through operational dashboards to provide actionable insights that enable multiple stakeholders to make timely and informed decisions.

Users of these dashboards can assess the damage and proactively dispatch necessary aid. ArcGIS goes beyond just extracting features using artificial intelligence (AI). It enables users to leverage the power of a complete suite of geospatial tools and applications to perform further downstream analysis.

The damage classification of disaster sites performed by Dewberry is paving the path for additional analyses. For example, after a tornado outbreak struck Kentucky in 2021, Dewberry reviewed information generated from damage assessments and input it into a debris estimation model. The model enabled analysts to determine approximately how much debris was generated from the damaged structures. Using ModelBuilder and Summarize tools in

ArcGIS Pro, the data was aggregated and provided to the county to aid in allocating resources for debris removal.

## Summary

Dewberry is leveraging powerful geospatial tools and ML capabilities to facilitate efficient response and recovery in times of critical need. Using ML-powered geospatial damage assessments, it is developing and implementing action plans to help communities better equip themselves to respond to future natural disasters. With upcoming enhancements, such as the ability to identify damaged power lines, roads, and bridges, and support for other types of disaster events, Dewberry is maximizing the potential of ML.

## About the Authors

**Akshaya Suresh** is a product marketing manager on the imagery and remote sensing team at Esri with a passion for artificial intelligence (AI) and big data analytics.

**Vinay Viswambharan** is a product manager on the imagery and remote sensing team at Esri who has zeal for remote sensing and everything imagery.

Dewberry staff members **Catherine Bohn**, **Paul Dean**, and **Siddharth Pandey** are subject matter experts who contributed to this article.

↓ This heat map shows the density of damaged housing. Blue polygons indicate undamaged areas that are suitable for temporary housing.





# A GEOGRAPHIC APPROACH TO PLANNING

By Keith Cooke

**IT'S NO SECRET** that geography is a key factor in all things related to planning and community development. Sometimes it's an influencing factor. Sometimes it's the main driver for a project and the reason why the public embraces or opposes it.

GIS is the tool that helps us measure, analyze, and visualize geography. For most of its early years, GIS was out of the reach of many planning professionals because it required expensive hardware, client-side software, and usually multiple weeks of training. It was an investment many planners couldn't make, particularly if they had access to a GIS professional in their organization. But when you have people who aren't subject matter experts in planning involved in planning-focused analysis, it's very easy for information to get lost in translation.

The emergence of web-based GIS has evolved the role of planners so that they can efficiently access and utilize tools to make better, more sustainable, data-driven decisions. Simultaneously, this frees up GIS staff to work on other crucial projects. A modern geographic approach helps planners understand neighborhood characteristics, derive business intelligence, generate sustainable policies, support civic inclusion, and design sustainable scenarios.

## UNDERSTANDING NEIGHBORHOOD CHARACTERISTICS

"A map is a pattern made understandable, and understanding precedes action," is an often-repeated quote of Richard Saul Wurman, founder of the TED conferences. GIS helps us understand the demographics, socioeconomic characteristics, housing situation, and other aspects of individual neighborhoods. Instead of relying on anecdotal or dated information, GIS provides access to thousands of authoritative variables to generate a clear picture of the aspects, resources, and needs of a community.

Within the Esri platform, this is accomplished using ArcGIS Business Analyst Web App. This web-based approach provides an easy way to not only view and analyze data, but also collaborate with colleagues, property developers, elected officials, and the public, so that

→ Business intelligence can be derived from the permitting system outputs by using ArcGIS Insights, a web-based app.

everyone is working off the same authoritative content.

Two of the app's outputs are infographics (both template based and customized) and reports. These provide valuable complements to maps that help drive decisions such as locating businesses, identifying community needs, understanding the local workforce, and accessing consumer spending behavior.

## DERIVING BUSINESS INTELLIGENCE

The permitting system is almost always the system of record in a planning department. Although data entry and analysis are usually done by a relatively small group within the organization, planners, administrators, and elected officials need to derive business intelligence from the data gathered by the permitting system. This can be challenging with a legacy system, a not uncommon situation given the cost of permitting systems.

Within the Esri platform, this business intelligence can be derived by using ArcGIS Insights, a web-based app. With simple outputs from the permitting system, ArcGIS Insights can be used to answer questions such as:

- How do the number of permits this month or this year compare to those from last month, last year, or five years ago?
- Where is the most activity occurring? How do developments in one council district compare to those of a neighboring district?
- Which neighborhoods and types of permits have received the most stop work orders?

In the end, this kind of business intelligence helps efficiently generate additional value from the permitting system for a city that has probably already invested hundreds of thousands of dollars in it over the years.



→ Infographics, one of the two outputs of the ArcGIS Business Analyst Web App, complements maps and helps drive decisions.

## GENERATING SUSTAINABLE POLICIES

Increasingly, the role of planners has moved from simply reviewing site plans and subdivision plats to influencing policy development for cities and counties. That influence can be found in comprehensive plans, housing policies, or economic development (which are all usually intertwined). As with understanding neighborhood characteristics, policy development works best with a data-driven approach. Esri Maps for Public Policy ([livingatlas.arcgis.com/policy/overview/](http://livingatlas.arcgis.com/policy/overview/)) is a free resource dedicated to raising the level of spatial and data literacy used in creating public policy that addresses topics from economic opportunity and social equity to transportation and infrastructure and public safety. The site provides curated maps that can help generate more sustainable and more justifiable policies. This content can exist on its own and can be simply viewed in a browser or collected and added to another app within the ArcGIS environment.

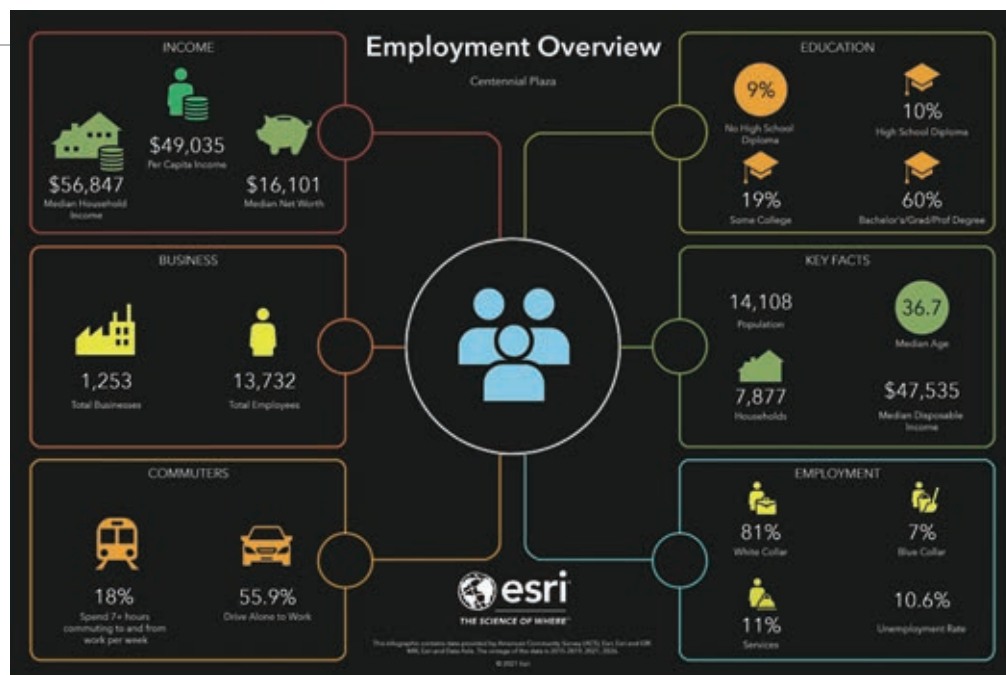
## SUPPORTING CIVIC INCLUSION

Virtually everyone cares about the neighborhood in which they live. In the past, when residents wanted to voice their concerns, a public planning commission hearing or an even more infrequent town hall meeting was their only option. However, just because someone couldn't show up for a planning commission meeting on a Tuesday evening didn't mean they didn't care about the community.

Today, cities and counties must be more inclusive. They must find new ways for the public to engage with—and be engaged by—their government. Location is at the heart of most planning activities, so GIS remains a key component in civic inclusion. ArcGIS Hub provides a focused, initiative-driven approach to providing open data, delivering information, and receiving feedback. That feedback can be a survey, freeform comment, or map markup showing the location of a proposed park. This approach to civic inclusion is less about simple notification and more about developing a genuine partnership between the government and the public.

## DESIGNING SUSTAINABLE SCENARIOS

With an understanding of neighborhood characteristics, policy development, and civic inclusion in place, planners can more effectively design the types of plans and projects that meet the needs of



the community. This can be done collaboratively with developers or proactively by demonstrating how a community's needs can be met with a specific design or land-use plan.

ArcGIS Urban provides the 3D and 2D web-based tools that planners can use to develop multiple scenarios quickly and efficiently. They can view and measure the impact of scenarios on population, jobs, utilities, traffic, tax revenue, and other aspects. Administrators, developers, and the public can review these scenarios.

In many cities, zoning reform is being demanded to meet a city's modern housing needs. Without spending tens of thousands of dollars on consultants, ArcGIS Urban allows planners to play out and compare different zoning scenarios to show how many people and jobs could be accommodated with a new proposed zoning classification. It's an effective way to streamline changes in dated codes that stifle the growth and development of neighborhoods.

Because ArcGIS Urban is part of the ArcGIS system, 3D web scenes created when planning scenarios can be shared with others and integrated into ArcGIS CityEngine to provide a photo-realistic view of a proposed development.

GIS is no longer a luxury for planning departments. It's a mission-critical system. It provides apps and tools that are more accessible to planning professionals. The geographic approach enabled by GIS empowers data-driven decision-making, policy development, and design that meets the needs of modern communities.

## ABOUT THE AUTHOR

**Keith Cooke** is the global industry manager for community development at Esri. A graduate of Auburn University, he has been a GIS professional since 1994 and has worked for planning and community development agencies at the regional and municipal levels in Alabama and North Carolina. Prior to his current role, Cooke was an account executive at Esri for 15 years who worked with more than 100 local governments.



# Supercharge ArcGIS Online Organization Management with Reports

By Jennifer Wrightsell-Hughes

As an organization administrator, you may be looking for more efficient and effective ways to manage members, content, credits, and activities in your ArcGIS Online organization.

For example, you may want to compare member credit usage to help with credit budgeting. Or, if your goal is to reduce storage costs, you may need to monitor file and feature storage to identify unusually large items.

The organization status dashboard, accessible from the Organization page Status tab, provides a good overview of your organization. But if you need more detailed, on-demand information that you can easily download and share, administrative reports are your best option.

This article describes the four report options in ArcGIS Online and explains how to create, find, and use them. The article also shows you how to get the most out of administrative reports by scheduling them to run automatically.

## Types of Reports

ArcGIS Online has four report types—member, item, credit, and activity. They are generated as comma-separated value (CSV) files that can be opened and sorted

using a spreadsheet program such as Microsoft Excel.

## Member Report

This report generates a comprehensive list of members in your organization at the time the report is created. The member report includes details about each member, such as their assigned user type and role, username, available credits, and add-on apps.

## Item Report

An item report provides a snapshot of all the content items in your organization at the time you run the report. For example, you can see the name of the item, the item owner, its share level, and storage size, as applicable.

## Credit Report

A credit report lists the number of credits consumed by each member in your organization throughout a specified week or month. Credit usage is broken down by credit-consuming tool, such as geocoding, geoenrichment, and spatial analysis.

## Activity Report

An activity report shows changes made to your organization members' groups and

content for a day, week, month, or year you specify. It provides details about added, created, updated, shared, or deleted items, and other item information. The activity report also provides details about member management actions—for example, updated member roles, password resets, and group assignments.

## Create Reports

Now that you understand the different types of reports available, it's time to create a couple of reports.

## Create a Credit Report

Suppose you're interested in credit usage in the month of December.

1. Go to Organization > Status > Reports and click Create report.
2. Choose Credit as the Report type. Select Month for the Duration and choose 2021 for Year and December for Month. Keep the default report name and click Create report.

While your report is being generated, the pending reports indicator is displayed. Once the report appears in your list, you can download it from the Reports tab or from its item page, since each report is automatically saved as an item in your content.

↓ Generate reports that help manage ArcGIS Online organizations by monitoring the number and storage size of files and features.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Title	Item ID	Item URL	Item Type	Date Created	Date Modified	Content C	View Count	Owner	File Storage Size	Feature Storage Size	Share Level	# of Group Tags	Number of Items Hosted		
2	3.3 demo template copy	e71a3a559fa44620bc	Web Experience	Thu Sep 2	Thu Sep 24 18:43:35		0	Shelly_Rives_doc		22	0	private	0	0	FALSE	
3	Admin Dashboard	7a5ea46e22774ea6b	Dashboard	Thu Jun 21	Thu Jun 25 20:12:24		1	Theo_Gaskell_doc		167400	0	private	0	[Readlines]	0	FALSE
4	Alberta crown land boundaries	723305c9f	https://se	Feature Set	Tue Feb 1	Tue Jul 27 11:39:24		6	Gita_Oden_doc	983040	0	public	0	[crown re]	0	FALSE
5	ArcGIS Online March Update Vide	e16d8308790c46db	Dashboard	Thu Mar 1	Tue Mar 24 17:44:39		14	Shelly_Rives_doc		2833	0	private	0	[ ]	0	FALSE
6	Assignments	e1419ebf7	https://se	Feature Set	Thu Jun 21	Thu Jun 25 20:10:44		0	Theo_Gaskell_doc	0	0	private	0	[Elections]	0	TRUE
7	Attachments_Table	7ce8cd55d27b4bbdb	File Geod	Mon Jun 2	Mon Jun 29 15:47:20		1	Shelly_Rives_doc		4110095	0	private	0	[table]	0	FALSE
8	attachement_test_url_params	444fad87b	https://dc	Web Map	Fri May 07	Fri May 07 16:50:22		41	Shelly_Rives_doc	648	0	public	0	[test]	0	FALSE
9	Auto Carousel template 1	861aa9d3e1c4c5a8	Web Experience	Thu Sep 2	Thu Sep 24 18:21:43		1	Shelly_Rives_doc		22	0	private	0		0	FALSE
10	Blue Whale Habitats	1b0d426124654749b	Shapefile	Wed Feb 1	Wed Feb 19 15:00:43		12	Kleth_Waldow_doc		4935108	0	private	0	[marine, v	0	FALSE
11	Blue Whale Habitats	7ae445331	https://se	Feature Set	Wed Feb 1	Wed Feb 19 15:06:10		12	Kleth_Waldow_doc	0	7053312	public	3	[marine, v	0	TRUE
12	Campsites layer	4cfc4860	https://se	Feature Set	Wed May	Wed Dec 13 18:30:34		40	Gita_Oden_doc	0	4933584	org	2	[campsite]	0	TRUE

→ You can create reports for specific time periods.

↓ You can automatically generate reports at specified intervals that are produced on selected days.

**Note:** If another administrator has already run the same report, you cannot run it again. You can download the existing report on the Reports tab.

3. Open the report's item page.
4. Click Download and open the report. Optionally, you can update the item details and share the report with your organization or a group.

### Create an Item Report

Now suppose you want to identify which file and feature layer items are taking up the most storage space in your organization.

1. On the Reports tab, click Create report.
2. Select Item for Report type, accept the default report name, and run the report.
3. Download and open the report.

Scan the storage size columns—File Storage Size and Feature Storage Size—to see which items are largest in terms of

storage. If there are many items, you can sort on either column to easily see which are the largest files or features. Storage size is reported in bytes, but you can apply a mathematical formula— $/(1024 * 1024)$ —to convert bytes to megabytes.

### Find Existing Reports

You can find existing reports on the Status tab of the Organization page. Choose Reports on the Status tab. To help you find a report, you can search or filter by report type or date created.

### Schedule a Report

For organization activities and actions your organization wants to monitor on a regular basis, consider scheduling your reports to run automatically.

On the Reports tab, click Create report. Set the report parameters and turn on the Schedule reports toggle button.

Choose a cadence, start date, and optional end date for the report.

Click Create report.

Now the report will run automatically without any further effort on your part!

### Learn More

Read best practices for ArcGIS Online organization administrators in this blog, "Time-saving tips for managing members in ArcGIS Online" (<https://bit.ly/3BI0Uho>).

Check out the latest resources for ArcGIS Online, including discovery paths, blog articles, and help documentation (<https://bit.ly/3RozQEF>).

Download this guide to essential tasks and best practices for setting up ArcGIS Online (<https://bit.ly/3oQJq8a>).

Join the Esri Community and visit the ArcGIS Online section to exchange ideas, solve problems, and build relationships with the ArcGIS Online community (<https://bit.ly/3JxjgPH>).

### About the Author

Jennifer Wrightsell-Hughes is the documentation lead for ArcGIS Online. She has a bachelor's degree in journalism and more than 20 years of experience writing and editing product documentation, lessons, and other content. In her spare time, she enjoys practicing yoga, painting, and spending time at her cottage.

To learn more about creating administrative reports in ArcGIS Online, see <https://bit.ly/3rLylqi>.

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# Performance Tips for ArcGIS API for JavaScript

By Rene Rubalcava and Julie Powell

**One of the goals** of a web developer is to build performant web applications. Notice, that we said one of the goals. As developers, we shouldn't overprioritize performance optimization and neglect other user expectations. Users drive what we do. We should meet user needs while staying as performant as possible. These strategies can help make your web applications built with the ArcGIS API for JavaScript work better.

## Before You Begin

The rendering logic in JavaScript API is already optimized. Because the software fetches data efficiently, you should test the app on various devices first to understand its performance before diving into optimization. API performance is constantly being improved—in terms of CPU and memory usage—so using the most current release of the API can benefit your application's performance. If you start noticing performance issues when many features are in the map view, or if your app needs many visible layers, consider the recommendations in this article.

## Designing Your Map for Performance

Whether using the ArcGIS Online or Enterprise Map Viewer to create a map and then loading it into your app, or constructing your map manually using JavaScript code, it's important to design the map for performance. This is where web mapping application optimization starts. A map designed for performance is one that loads only the data needed to make a meaningful visualization, at the right time. If you really understand both your data and your user's requirements for interacting with it, you can design a map that optimizes both performance and experience. Let's explore some tips to consider for accomplishing this.

### Reduce the Number of Features Displayed

With the fast rendering pipeline used by JavaScript API and the smart client-server implementation of feature services, you can render a shocking amount of data with speed that is often comparable to that of a desktop application. Often end users access applications on very resource-constrained devices or with limited network bandwidth, so it is important for some developers to optimize applications for this scenario. The following strategies will reduce the amount of data your application is working with, which can reduce network latency, rendering time, and the application's memory footprint.

- Establish the minimum and maximum scale.
- Preprocess data when appropriate.
- Limit the map to the layers needed by the application.

- Use definition expressions to filter data displayed by layers.
- Only load the attributes you need.

### Establish the Minimum and Maximum Scale

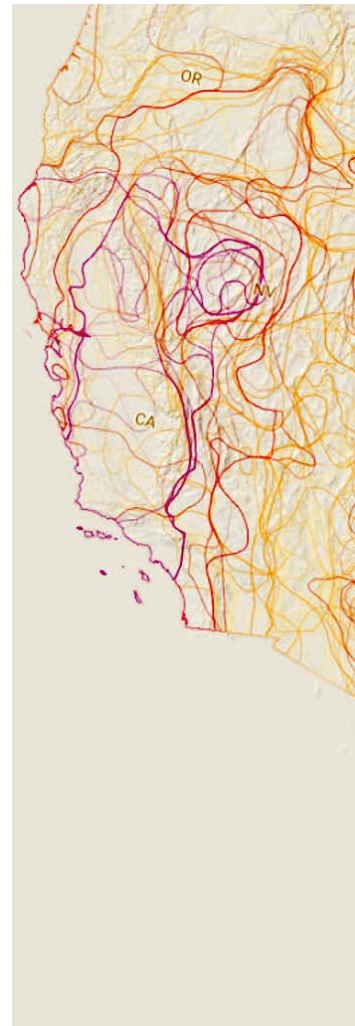
The number of features displayed impacts performance, especially on memory-constrained devices. When you set a minimum and maximum scale (also referred to as the visible scale range), a layer's features are displayed when the zoom level is within the set range. What layers should you show at each scale? When configuring the visible scale range of each layer, think about what features make sense to view at small and large scales. Can users distinguish between features at small scales? As you zoom out, it may become difficult to see more detailed information, or as you zoom in, information may become too coarse. Often the best way of determining the visible scale is by playing around with it and looking at the data through your end user's eyes.

### Preprocess Data When Appropriate

Use the ArcGIS system to preprocess your data for display at small scales. At the country, state, or county level, it may be more useful to display the data as aggregated polygons as opposed to individual points. There are multiple ways to summarize data within polygons. Polygons can either be a standard geography such as a state boundary or they can be regularly divided into a grid or hexagons. If it is meaningful to summarize your data at a standard geography, calculate the summary statistic for each geography and thematically map each polygon according to its value.

If it doesn't make sense to summarize at a standard geography, an alternative is binning. Binning aggregates large amounts of point features into polygons called bins. A single bin represents all features within its boundaries and appears wherever at

→ Figure 1: This layer represents five years of drought in the western US. It consists of more than 100,000 complex polygons. The map shows areas of intense drought, so it is somewhat useful, but it requires loading lots of vertices.



least one feature lies within it. For layers that contain thousands or millions of point features, binning vastly improves layer drawing performance. You can use ArcGIS Pro or ArcGIS Online to aggregate data and create summary layers. Use a scale dependency to display the summarized data at small scales and display individual features as the user zooms in. This approach only makes sense if your data is not constantly changing because each time your data changes, you will need to process the data again.

### Limit the Map to the Key Layers Needed

Avoid authoring web maps with a dozen or more layers. A web map with many layers is usually a web map trying to address too many user needs in a single application. Breaking the content into different maps to build focused applications will better meet specific user needs. A good approach for doing this is to categorize your users into groups based on their role and data and application requirements. Then design maps for users with similar needs and create clean and easy-to-use mapping applications that target their use case. These applications can often streamline users' workflows while providing better performance because they work with less data.

If you must create a map with many layers, you may be able to squeeze a bit more performance out of it by loading the layers

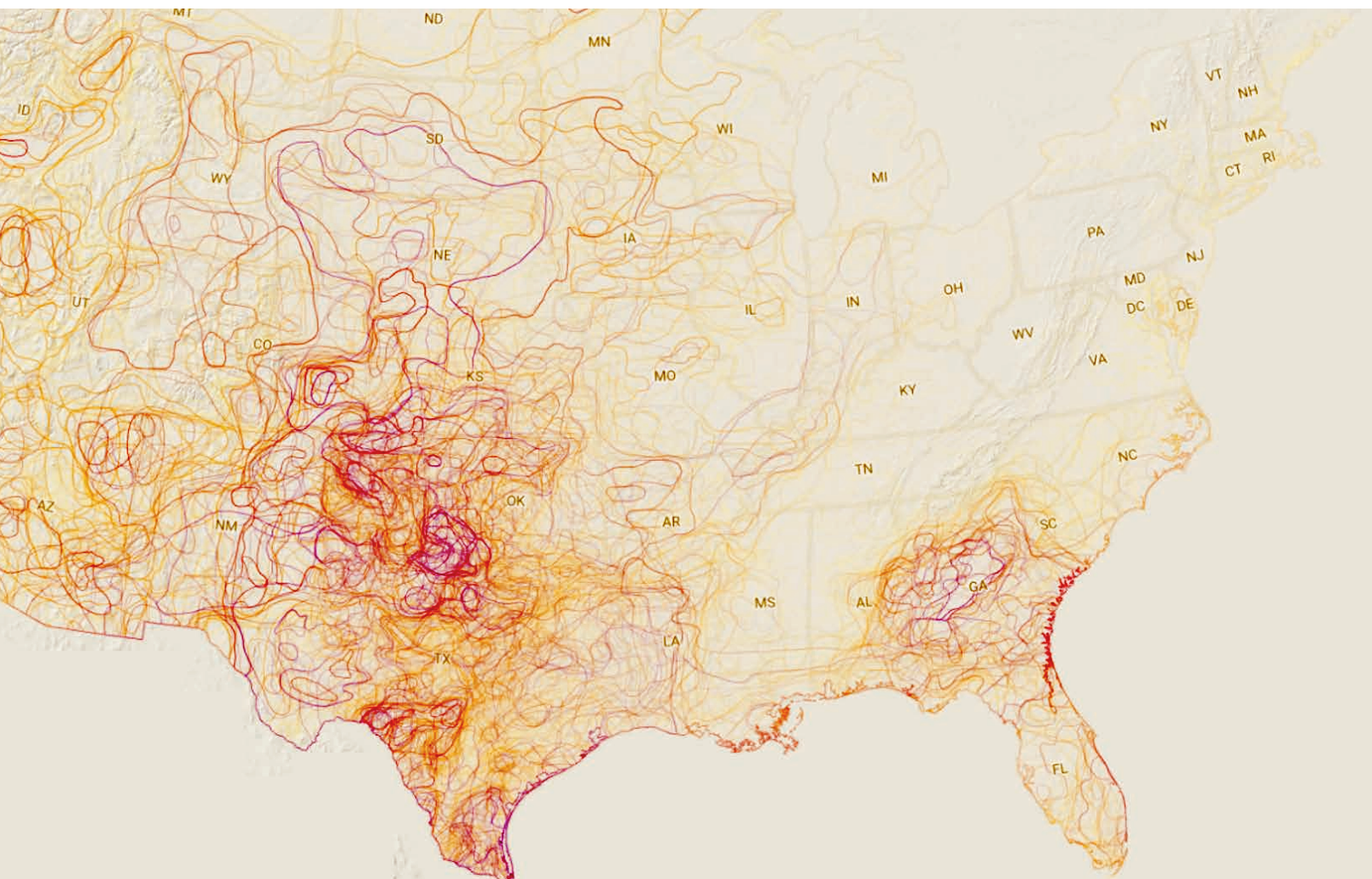
```
const webmap = new WebMap(portalItem);
await webmap.load();
await webmap.loadAll();
const layers = webmap.layers.filter(filterLayers);
const map = new ArcGISMap({
  basemap: webmap.basemap,
  layers
});
```

↑ Listing 1

in your application as needed. Listing 1 shows how you could accomplish that. It loads the map, finds the layers needed when the application loads, and then loads the other layers as required.

### Use Definition Expressions to Filter the Data Displayed

If your application requirements are met using only a subset of the layer's features, set a definition expression on the layer. Definition expressions set on the layer are different from defining a client-side filter. When a definition expression is set on the layer, the server will only return the needed features.





### Load Only the Attributes Needed

By default, JavaScript API will only load the attributes it needs for visualization. This is done for performance reasons, because many datasets have a lot of attributes that are not used by the application. Sending many attributes to the client and storing them in memory can degrade map loading time. However, the application may need attributes in addition to the ones needed for display. For example, if you are building workflows that include client-side filtering, querying, or statistical calculations, you'll need all corresponding attributes available on the client. Developers sometimes make the mistake of using an asterick (\*) to set the layer's `outFields`, which means all attributes are loaded. Instead, determine exactly which attributes are needed and explicitly set those attributes as `outFields`.

## Optimize Services

Improve the performance of your application and the services it uses by employing the following techniques:

### Enable Control Cache

One of the best performance enhancements for public feature services is to enable the control cache. The JavaScript API uses a concept called feature tiles, which is like raster tiles but works with features rather than precooked images. It allows the JavaScript API to do cacheable queries when requesting data, so both the server-side data fetch and client-side display operations can be extremely efficient. Feature services hosted in ArcGIS Online can be cached, so requests do not have to go to the back-end database. (The ability to enable a similar cache will come to ArcGIS Enterprise in a future release.) Caches can be configured to be valid for between 30 seconds and 5 minutes. If data doesn't change frequently, set the cache to the maximum time so data can be retrieved as fast as possible.

### Precook Features into Vector Tile Layers

Feature services often load as fast as vector tile layers when loaded using a laptop. That surprising fact is due to the fast rendering engine in JavaScript API and client-server optimizations for feature services. Displaying feature services—as opposed to vector or raster tile layers—is ideal because it allows you to build interactive workflows in your app. This is because all feature geometries and attributes are available on the client for use in any geometric, querying, filtering, or statistical operation.

However, if end users are on more limited devices, you may not have the luxury of loading all features. To preserve a crisp display at any scale and minimize memory consumption, you can pre-cook features into a vector tile layer. Interactivity will depend on a feature service used behind the scenes. Queries will go to the server rather than a client-side feature layer, but the display will be handled by the vector tile layer. When end users are using very resource-constrained devices or in low network bandwidth situations, consider precooking raster tiles as opposed to vector tiles. However, this will come at a cost. The raster tiles will not display as crisply as vector tiles and are not dynamic. For example, as the user rotates the map, the labels won't rotate.

## Optimize Application Design

There are several methods you can use to optimize your web mapping applications with a custom build geared toward your application. The PRPL pattern is a common method for making applications performant, especially on low-end devices and in regions with poor Internet connectivity.

- Push critical resources
- Render as soon as possible
- Pre-cache assets
- Lazy load as needed

### Push Critical Resources

You want to be able to push critical resources to your web application as soon as possible. These resources include JavaScript, CSS, images, fonts, or other assets needed up front for your application. You can leverage the `rel="preload"` attribute in your script and style tags. The browser will prioritize loading of these assets. Some build tooling will let you designate bundles with this attribute for the output HTML file. Most modern build tooling will create bundles for you so that your application will only request the required bundles on load.

### Render as Soon as Possible

A side effect of pushing critical resources when an application starts is loading and rendering the initial route as soon as possible. This is also an area where you can leverage an app shell. An app shell is the minimum amount of HTML and CSS needed to display your page right away. It might not have the detailed layout but would display the bare minimum of the application. If the map takes up a significant region of your initial page, you could have an image of a map or globe displayed until the map loads. It does not have to be an exact image of the map you want the application to display; the placeholder can just indicate where a map will appear.

→ Figure 2: To optimize the performance of the layer in Figure 1 on the web and achieve a more meaningful map, the data was preprocessed, and a 30 kilometer hexagonal net was used to aggregate all instances of drought within each hexagon zone so they could be summarized. The map was styled so the center point of each zone showed the intensity and duration of drought. The set of bivariate points shows proportional time spent in drought, while color characterizes the cumulative intensity of that drought. At finer scales, point symbols are replaced with specific information on drought characteristics. This produced a more meaningful and performant map that allows more granular data to be viewed at large scales. Learn more by reading John Nelson's ArcGIS StoryMaps story (<https://bit.ly/3hKARaS>).



### Precache Assets

Ideally, you want to limit the number of requests made to a server. Service workers, a script that runs in the background of the user's browser, can help with this. You can configure a service worker to cache resources, such as JavaScript, CSS, images, and fonts, so that on the next load, your application doesn't need to make extra requests. After the initial load, this means faster page loads on subsequent visits.

### Lazy Load

Once you have preloaded and cached critical resources in your application, you may want to lazy load the remaining resources. This doesn't necessarily need to be an initial route, but there are portions of your application—such as charts, or even the map—that are loaded at runtime.

For example, an application might display a list of locations by name. When a location is selected, a map is loaded displaying that location. In this case, you want to render that list as soon as possible, but you can lazy load the resources for the map later. This can be accomplished in a few ways including using dynamic imports of modules for when they are needed. You don't want to overuse dynamic imports because this could result in code being repeated in the bundles generated by dynamic imports.

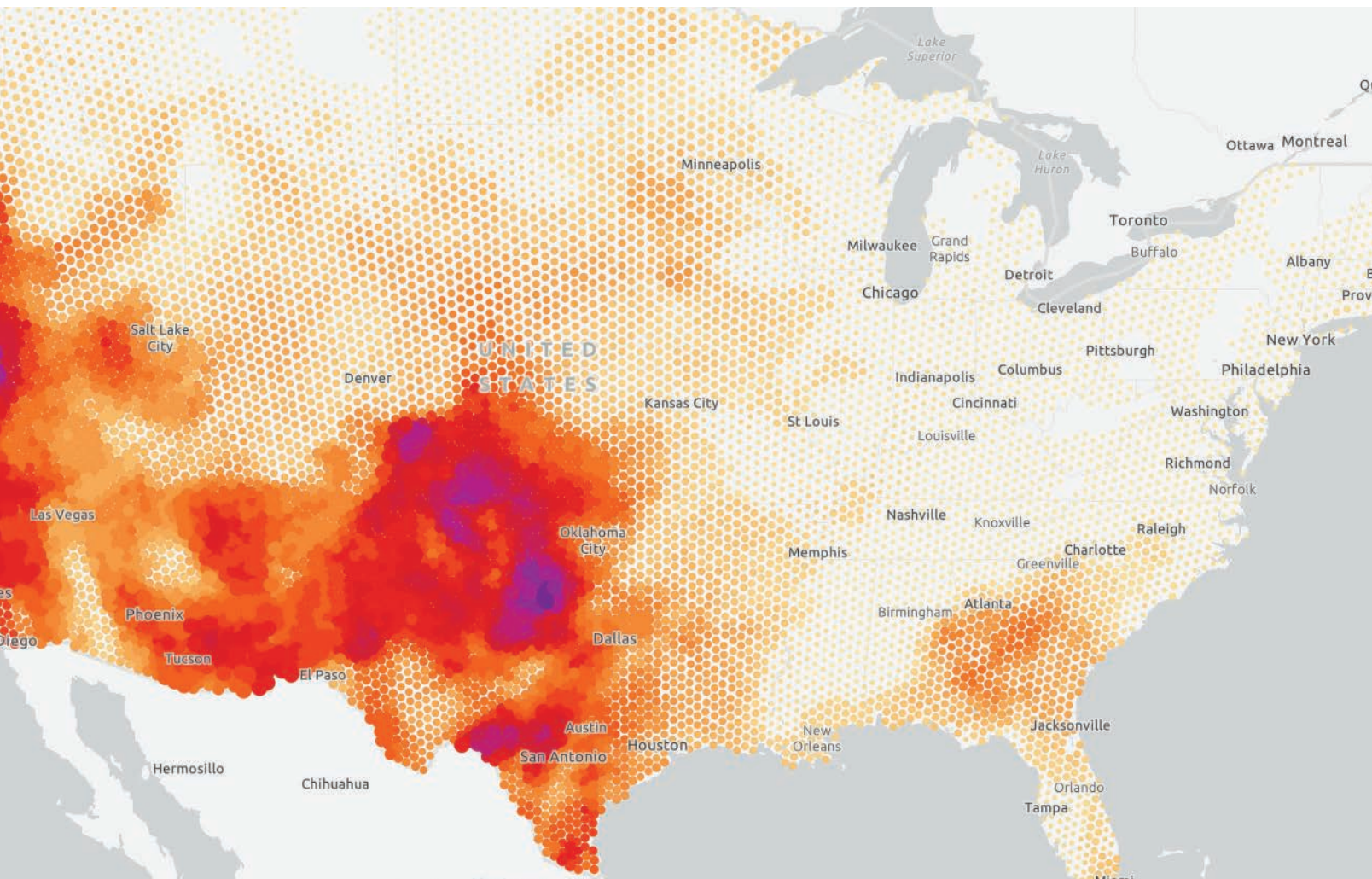
### Conclusion

The best applications are built by developers that truly understand their end users and optimize their application's experience to focus on their users' requirements—no more and no less. Using the techniques in this article, you can tune your map, the services it uses, and your application design to create the happy intersection of a good user experience and optimized performance. Learn more by reading the ArcGIS API for JavaScript documentation at <https://js.arcgis.com>.

### About the Authors

**Rene Rubalcava** is a product engineer on the ArcGIS API for JavaScript team. Follow him on Twitter @odoenet.

**Julie Powell** is a principal product manager, focusing on ArcGIS API for JavaScript and Esri's design system. She works with a wide user community and contributes feedback to development teams to help ensure users can be successful. Powell presents GIS technology trends and innovative solutions at conferences worldwide. She brings 19 years of experience in delivering a variety of software solutions for both the enterprise and consumer markets.





# Together Again at DevSummit

"It's nice to be back, isn't it?"

**With those words**, Jack Dangermond, Esri president and founder, welcomed attendees back to Palm Springs, California, to the first in-person Esri Developer Summit (DevSummit) in two years. With added health and safety protocols in place, Esri staff members were excited to interact with more than 1,000 attendees during the event, which was held March 8–11, 2022.

In addition to attending workshops and sessions, DevSummit was an opportunity for attendees to meet face-to-face with Esri staff members for one-on-one sessions and network with other developers, who came from more than 700 organizations.

DevSummit also had a virtual incarnation. One legacy that carried over from the completely virtual versions of DevSummit held during the COVID-19 pandemic was the multiple plenary session format. This year, all three Plenary Sessions and a selection of technical sessions were livestreamed during the event and available as recordings after sessions concluded.

The Plenary Session that opened the summit, Building Apps, set the tone for the event. Dangermond noted that GIS and geospatial technologies have been evolving for many years, and the purpose of DevSummit is to share the next steps in that evolution. Esri technology has been evolving within a framework that supports developers and end users and creates an infrastructure that Esri is scaling up.

While he sees this process—which has been unfolding over the last 50 years—as a wonderful history, he also sees it as just the beginning of a field that will be used to address all the major challenges that the world faces. Esri builds the tools that developers, with their creativity and knowledge of what is needed and wanted, use to make geospatial technology come alive.

Dangermond sees the evolution of GIS and geospatial technology as being driven by three things: the evolution of core technologies such as computing platforms; the demands of consumers of this technology; and great people “who are playing hard” to develop solutions. By sharing how developers at Esri work, think, and create, DevSummit lets developers get to know the people behind the scenes who build Esri technology.



After opening remarks by Dangermond, David Cardella, Esri product manager for developer technology, took the stage as the master of ceremonies and commented on the high energy level in the room. “You engage us and provide us feedback so we can improve our product. You challenge us to do more and do better,” he said.

## Web Apps

The Plenary Session moved on to demonstrations that shared how to employ Esri tools and services to make web apps. Product manager Jianxia Song demonstrated how ArcGIS Experience Builder is used to quickly create polished, interactive web apps without coding. Presentations by members of the ArcGIS API for JavaScript team showed recently added capabilities in 3D mapping and web editing, and the new animated FlowRenderer. Matt George demonstrated the substantial improvements made in visualizing massive datasets at various scales. Any render field changes are reflected in the display in real time, owing to the new mesh processing pipeline, which decreases total load time and can draw partial results faster.

Esri’s technology continues to acknowledge the real-world needs of developers. It is now easy to bring ArcGIS location services into existing open-source mapping applications to improve the end-user experience. For example, the ArcGIS REST JS is a wrapper library for working with Esri services that can be used to add ArcGIS location services to an application built with Leaflet to enrich the content and improve the usability of apps.

Julie Powell, a principal product manager for ArcGIS API for JavaScript and Esri’s Calcite Design System, showed how developers can take advantage of Calcite to create full-scale apps that are beautiful and easier to use. The new Map Viewer for ArcGIS Online is just one example of Calcite in use. Developers can use Calcite to build clean applications that provide consistent user experiences with minimal effort.

## Building Native Apps

"ArcGIS Runtime can put the right map in the right app, on the right device," said Divesh Goyal, product lead for the ArcGIS Runtime SDK for .NET team, who kicked off sessions about the development of native apps using the ArcGIS Runtime SDKs. Demonstrations highlighted improvements in visualization, augmented reality, and other functionalities as well as widgets and filters that support building apps that meet specific needs.

Presenters in this segment of the Plenary Session demonstrated enhancements to ArcGIS Runtime SDKs over the past year such as improvements in 2D and 3D visualization, the addition of display filters for features, and the ability to scale features by a factor or by applying an ArcGIS Arcade expression. Mark Bockenbauer, product engineer for the ArcGIS Runtime team, showed two new ways developers can use location in their apps: geotriggers and the ArcGIS IPS, Esri's indoor positioning service. Geotriggers use the device location to generate a notification or other action based on the proximity of a user to a feature and can be configured to work completely offline. ArcGIS IPS can be used for indoor mapping applications that update in real time to tell users exactly where they are located.

Runtime samples can be explored by downloading several viewer apps: ArcGIS Runtime SDK Sample Viewer (for Android devices, available from Google Play), ArcGIS Runtime SDK Samples (for iOS devices, available from the Apple Store), and ArcGIS Runtime SDK for .NET Samples (WPF) (available from the Microsoft Store).

Developers can incorporate the realism of game engine visualizations in interactive solutions with the ArcGIS Maps SDK for Game Engines. Devin Lavigne, a developer with Houseal Lavigne, demonstrated how his company uses ArcGIS SDK for Unreal Engine and ArcGIS CityEngine to bring an immersive and impactful experience to

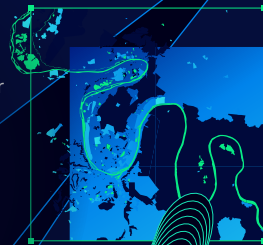
redevelopment presentations his company makes to cities. Lavigne summarized the value of integrating GIS with gaming engines by saying, "the SDK for game engines really allows us to unify the familiar world of GIS with the beautiful world of game engines."

## Exploring the ArcGIS System

Presentations in the second Plenary Session focused on how ArcGIS is integrating and leveraging developments in the larger world of computing and science. It was introduced by Sud Menon, Esri director of software development. He characterized ArcGIS Pro, ArcGIS Enterprise, ArcGIS Online, and ArcGIS Platform as the pillars of the ArcGIS system. Menon provided an overview of the ArcGIS system that supplied context for new capabilities that incorporate developments in big data, artificial intelligence (AI), cloud data warehouses, knowledge graphs, and imagery acquisition and analysis.

Of special interest to developers was Menon's comments on ArcGIS Platform, a developer-focused platform as a service (PaaS) offering that provides access to spatial analysis, geocoding, search, and routing capabilities; maps, data, geoenrichment, and basemaps; data hosting; and ArcGIS mapping APIs and open-source libraries. He also described the distributed global architecture

← David Cardella, Esri product manager for developer technology, welcomed attendees to the first Plenary Session saying, "You engage us and provide us feedback so we can improve our product. You challenge us to do more and do better."



live  
by  
the  
code

```
const env = new Env({
  container: "ArcGIS",
  env: "dev",
  environment: "development",
  logLevel: "debug",
  logDestination: "console"
});

const app = new ArcGISRuntime({
  env: env,
  logLevel: "debug",
  logDestination: "console"
});
```



underlying ArcGIS Online and ArcGIS system that allows data hosting in three regions in multiple data analytic hives. Each has colocated compute and storage for all the kinds of data that GIS needs to manage. This large system is built on both Microsoft Azure and Amazon Web Services (AWS).

## Analysis of Big Data in the Cloud

"ArcGIS is a comprehensive data analysis system for performing integrated and synergetic analytics between different types of data," noted Menon. Cloud data warehouses, which have become increasingly popular for processing big data and large workloads without infrastructure expense, can be accessed by ArcGIS. Eugene Yang demonstrated how the analytical capabilities of ArcGIS Pro can be combined with the processing power of Google's BigQuery. ArcGIS Pro can also work with cloud data warehouses in Snowflake and Amazon Redshift. Another presentation by Art Haddad and Linda Beale showed how ArcGIS Insights can use Snowflake to analyze massive datasets. ArcGIS Insights is a self-contained, web-based geovisual analytics product that works in the cloud or behind a firewall as part of the ArcGIS system of analysis.

ArcGIS GeoAnalytics Server, which has been available in ArcGIS Enterprise and integrated with ArcGIS Pro, is now available in a new cloud product. ArcGIS GeoAnalytics On Demand Engine is a stand-alone spatial analysis system for use on data lakes. It can be used independently of ArcGIS and leverages Apache Spark native technology in the cloud. Currently in beta, ArcGIS GeoAnalytics On Demand Engine uses a consumption-based business model.

Graph analytics is a new area of analysis. ArcGIS Knowledge is a services-based product that combines spatial and graph analytics to evaluate and understand highly dependent systems such as supply chains and assess the impacts of specific events or conditions on a system. It brings together structured and unstructured data, spatial and nonspatial data, and new graph analytics. Because it is available through Esri's REST API, developers can build custom web applications and use the connected data in the graph to enrich other GIS data.

ArcGIS Image for ArcGIS Online is an extension of ArcGIS Online that harnesses the tremendous power of the cloud to host, access, process, and visualize data. During his presentation, senior product manager Shea Shelby used ArcGIS Image and ArcGIS API for Python, pretrained deep learning models, and the object detection raster function to generate building footprints for the entire country of Grenada. Venay Viswambaran, a product manager on the imagery team, showed how ArcGIS Image could generate a land-cover classified map using deep learning tools and one of the pretrained classification models available through the Python API. With that map and other data land characteristics, he used chained raster functions to produce a landslide susceptibility map that could be visualized in 2D and 3D. (For more information on ArcGIS Image, read "Actionable

Information from Imagery" in this issue.)

ArcGIS Velocity is a software as a service (SaaS) offering that can provide real-time visualization and analytics of smart sensor data that adds the power of location to the Internet of Things (IoT). Esri has expanded the types of sensor data that can be ingested and analyzed for increased awareness and improved operations management.

## Extending ArcGIS

Now in its 17th year, DevSummit has made a lot of developer history. "And at my age, I remember all of it," quipped Jim McKinney, Esri chief technology officer, who was the master of ceremonies for the third Plenary Session. This session focused on extending and automating ArcGIS and applying new, more robust spatial analysis tools.

Developers have two options for extending ArcGIS Pro: Python and ArcGIS Runtime SDK for .NET. When using Python, developers can access more than 2,000 geoprocessing tools and use ModelBuilder, libraries, script tools, ArcGIS API for Python, and ArcGIS Notebooks.

With the comprehensive ArcGIS Runtime SDK for .NET, developers can choose from four development patterns: add-ins, configurations, plug-in data sources, and corehost. Add-ins is the primary development pattern used to develop new tools and custom workflows, and customize the ArcGIS Pro UI. Configurations are like add-ins but allow for a deeper level of UI customization. Plug-in data sources are used to integrate custom or proprietary datasets into ArcGIS Pro. Corehost is the pattern used to develop stand-alone applications and console apps on top of the ArcGIS Pro geodatabase and geometry APIs.

## Automation Strategies

ArcGIS delivers an enterprise-ready automation platform that can be implemented using APIs and no-code and low-code options in addition to using SDKs. On the enterprise level, ArcGIS automation can be extended through integrating custom functionality across business processes, through extending services to give users new functionality, or through infusing geoprocessing or AI models into the geospatial infrastructure.

The many types of automation available in ArcGIS include robotic process automation that distills expertise into workflows; collaborations that help fill gaps in organizational knowledge; and continuous integration/continuous delivery (CI/CD), a set of processes that automate code change delivery. ArcGIS has extensive tools for automating GIS administration, deployment, and content management. Automation processes can also be triggered by events or scripted and delivered at a certain time interval using the ArcGIS API for Python.

Enterprise GIS is a mission-critical system that benefits from automation in a cloud-native manner. ArcGIS Enterprise on Kubernetes, which was delivered



last year, is automation ready and microservices and standards based so it works with IT standards. Because of its highly scalable nature and intelligent updating, ArcGIS Enterprise on Kubernetes has great value for some organizations.

### Spatial Analytics Platform

The ArcGIS system includes tools for spatial analysis, data science, and applying machine learning and deep learning techniques. Valid analysis requires the right data that has been prepared for analysis. Esri has a geoinformation model that makes it easy to prepare a constantly expanding list of data types for analysis and visualization.

Lauren Bennett, program manager for spatial analysis and data science at Esri, introduced demonstrations of the new and expanded spatial analysis tools in ArcGIS by observing that, "Spatial data science encompasses all the work we do to do great analysis." This includes data engineering and visualization, sharing, and collaboration. However, this work goes beyond applying algorithms and tools. "It's about applying the geographic approach to solve the complex challenges that our organizations, communities, and the world face. Applying the geographic approach is absolutely critical for tackling these complex, deeply interconnected challenges that we face," said Bennett.

Spatial science is the foundation of ArcGIS. The demonstrations in this final segment highlighted two recent advancements in spatial statistics: presence-only prediction and change point detection over

time. Presence-only prediction eliminates the need to collect data on where something isn't and is valuable for applications such as ecological modeling and land mine detection. Change point detection finds time steps when trends significantly change. Change points can be important indicators of policy changes or underlying problems.

Analysis of multidimensional raster analysis is another important area of spatial analysis. Raster team principal software product engineer Hong Xu demonstrated a new principal component analysis tool that can help understand the spatial and temporal patterns in time series imagery data.

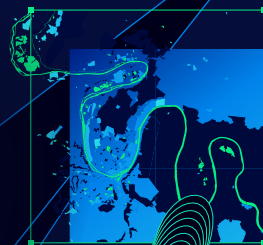
### Based on Developer Priorities

In concluding the third Plenary Session, McKinney thanked attendees and hoped that these new capabilities would aid developers in using the ArcGIS system to meet their needs in innovative ways and drive the important work of developers.



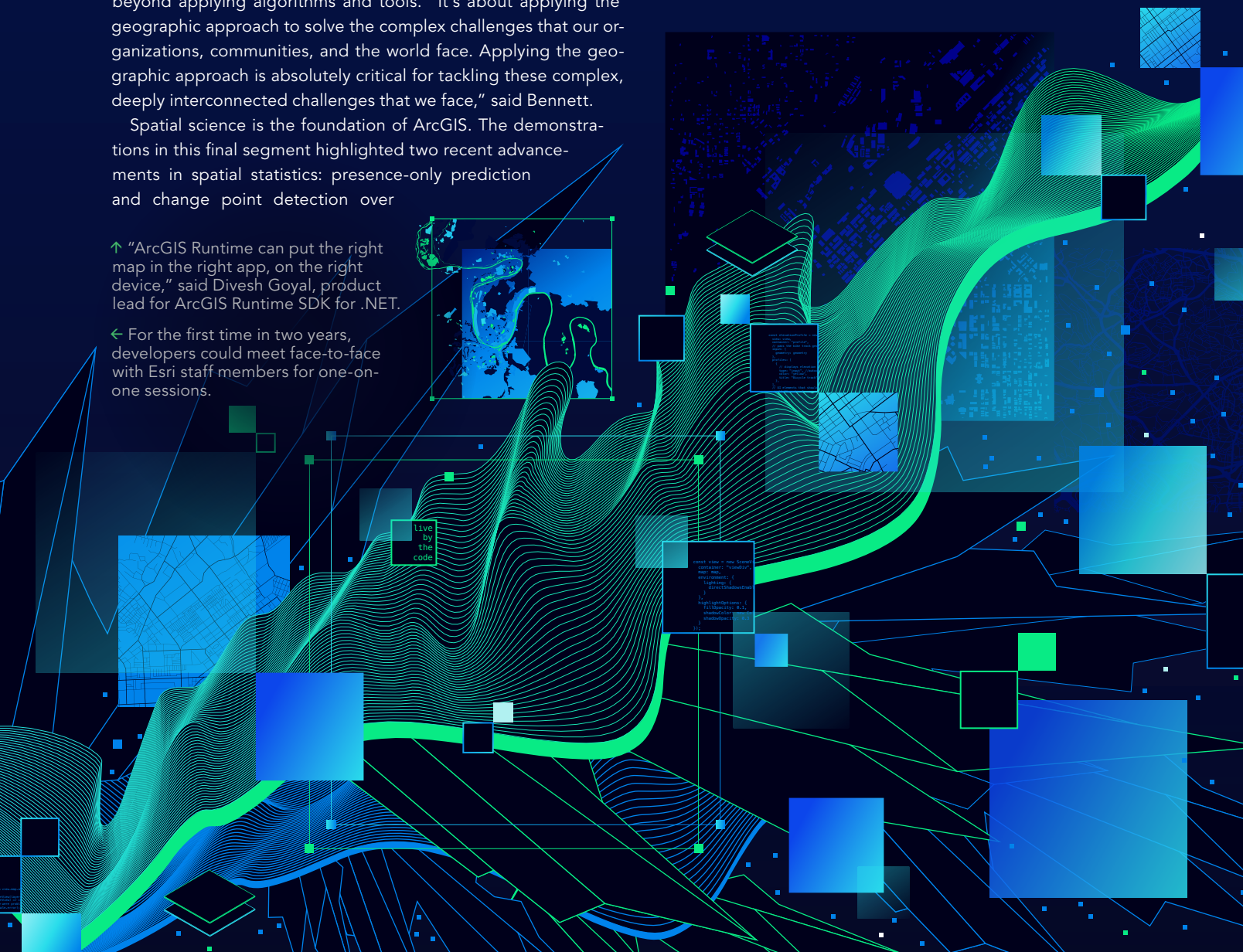
↑ "ArcGIS Runtime can put the right map in the right app, on the right device," said Divesh Goyal, product lead for ArcGIS Runtime SDK for .NET.

← For the first time in two years, developers could meet face-to-face with Esri staff members for one-on-one sessions.



live  
by  
the  
code

```
const client = new OpenLayersClient({
  container: 'map',
  map: new OpenLayers.Map(),
  layers: [
    new OpenLayers.Layer('Map')
  ]
});
```





# The Simple Economics of Modern Geospatial Technology

By Matthew Lewin

When you look at the big technology successes of recent decades, you'll notice they all have one thing in common—they make an important activity cheaper.

**Take the internet.** Despite its status as the most transformative technology of our lifetime, the internet provides a simple economic benefit—it makes searching for information and communications cheaper. Artificial intelligence (AI)—the hottest technology on the block—has equally simple economics. It lowers the cost of prediction and diagnosis. And although blockchain is still an emerging technology, its economics are clear. It reduces transaction verification costs and the cost of operating a marketplace without a central authority.

Cheap creates demand. Cheap drives opportunities. Economics tells us that when the price of something drops, we tend to use more of it. And if that something is particularly valuable, it can have a dramatic impact. That's why understanding a technology's basic economics is such a great way to cut through the hype. It distills the value proposition to its essence—sharpening our understanding of how a technology impacts people and organizations.

It's through this lens that I examine geospatial technology. Today we're seeing an explosion of interest in digital maps and spatial analytics. Just look at the proliferation of map-based dashboards and contact-tracing apps that have surfaced in response to COVID-19. But pandemic-induced hype aside, there's currently a real and material surge of interest across the board for geotech. In fact, *2020 Location Intelligence Market Study*, a report by the Dresner Advisory Services, noted that half of organizations consider geospatial technology a critical or very important enabler of their business agenda. The mobile mapping market, for instance, has seen particularly strong growth and is set to grow by 15 percent per year to over \$40 billion by 2024, according to research done by Global Market Insights, Inc. And that's just one segment of the geospatial industry.

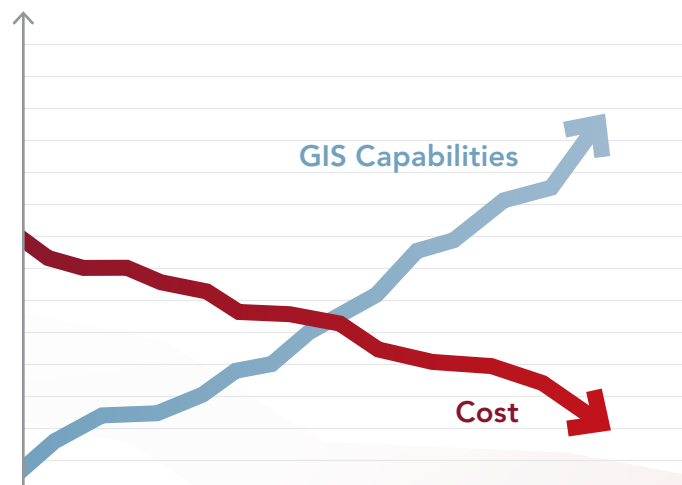
It begs the questions: What are the economics behind the growth? What valuable activity or ability does geospatial technology make cheaper? And what are the implications for people and organizations?

## Cost of Spatial Awareness

Geospatial technology is a catchall for the range of modern tools that enable mapping and spatial analysis. These include established technologies like GIS, GPS, GNSS, and remote sensing, as well as the new wave of digital technologies that acquire, consume, and process location-based data. Given that it is generally asserted that 60 to 80 percent of all data contains a spatial element, the extent of geospatial technology is vast.

The key insight is that geospatial technology provides something quite simple—spatial awareness. It helps people understand where things happen, where they might happen next, and why they happen where they do.

On a personal level, spatial awareness is obviously important. We all need some level of geographic understanding to participate in society and go about our day. Whether it's getting to work,



deciding where to live, or detecting potential hazards, spatial awareness is an important ability.

For organizations, however, spatial awareness is important on another level. The interests and assets of virtually any organization vary significantly by location. Whether it's customer spending habits or shipping routes, the factors that impact a company's fortunes differ in character and complexity from place to place. Spatial awareness is critical to the viability and long-term sustainability of essentially any organization—or society, for that matter. Without technology, spatial awareness is difficult, to say the least. The manual effort required to compile information about customers, competitors, suppliers, society, and the environment, and then analyze and map the spatial relationships is arduous, complicated, and time-consuming. All this to say, it's very costly. Geospatial technology overcomes these challenges.

In simple economic terms, geospatial technology makes spatial awareness cheaper.

## Cost Drivers: Data + Machine Learning

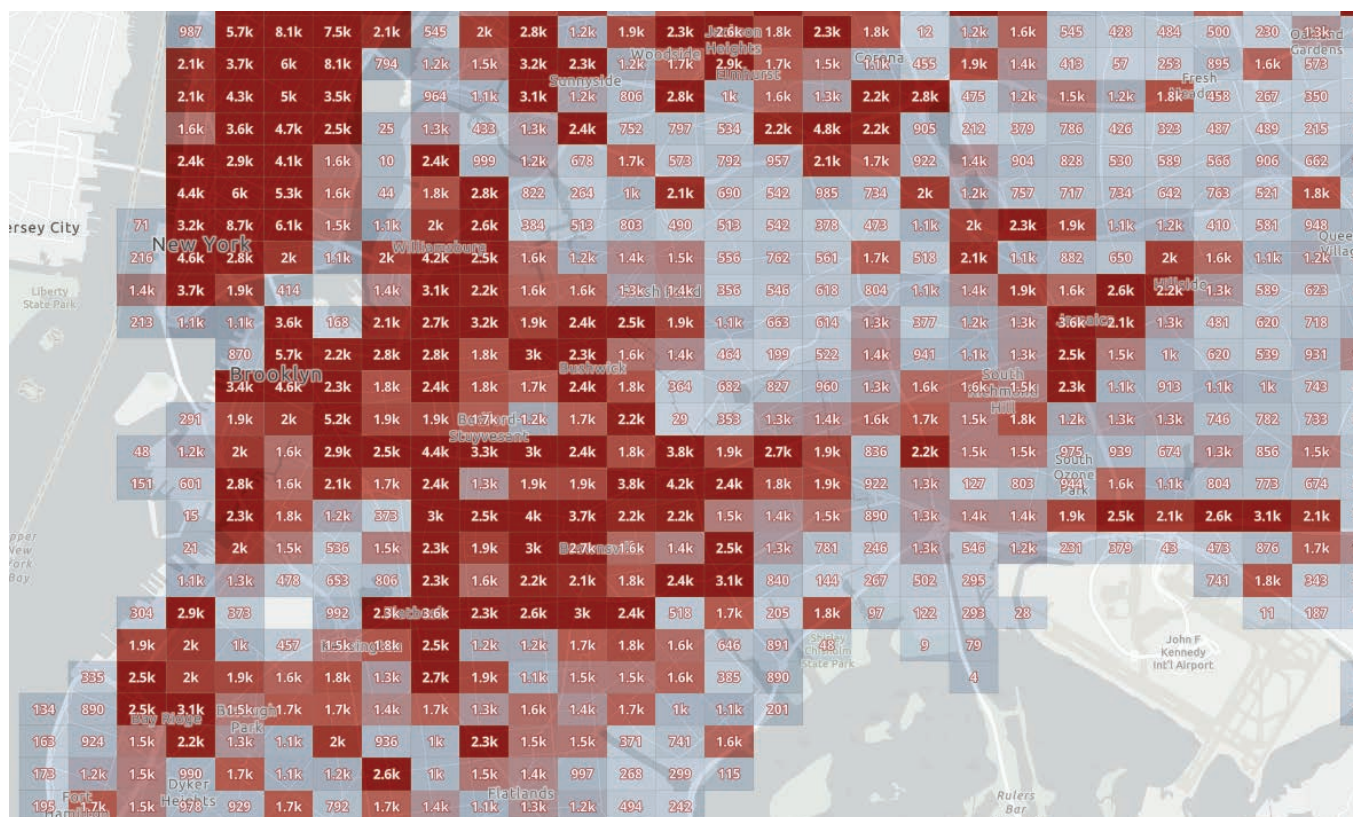
What's driving the recent surge in demand? Geospatial technology has been around a long time, so this recent uptick suggests that certain new advances are accelerating the drop in the cost of

spatial awareness. In fact, that's exactly what's happening, and two recent developments stand out: the explosion of accessible spatial data and the rise of machine learning.

Humankind's current rate of data creation is staggering. Some projections have the world's data doubling every two years, and by 2025 doubling every 12 hours. That's a mind-boggling amount of information, and most of it is spatial. Several factors are contributing to the growth:

- Advancements in traditional spatial data acquisition methods such as satellite imagery, aerial photography, surveying, and remote sensing
- Innovations in new acquisition technology such as drones and vehicle trackers
- Growth of in-situ sensor technology (the so-called Internet of Things)
- A massive influx of crowdsourced data generated by mobile mapping solutions and social media applications (including geotagged photos, videos, and text messages)
- The emergence of open data platforms from government agencies and businesses, allowing for the creation and sharing of raw spatial data as well as derived works such as thematic maps and analytics dashboards, which themselves become sources of spatial data

↓ More readily available spatial data and faster, more sophisticated spatial analysis methods are providing locational awareness at a lower price.





The net effect is that access to spatial data is byte-for-byte easier and cheaper than ever. And on that basis alone, we're seeing people and businesses take advantage of this. But data is only one side of the equation. The other side relates to how spatial data is analyzed. This is where AI and machine learning enter the picture.

Machine learning gets around the problem of human involvement in analysis. I don't say that to sound flippant, but certain aspects of spatial analysis are intractable—specifically, selecting variables. Machine learning uses prediction-based techniques to identify the most relevant variables to include in its statistical models. This is done based on how closely the variables produce an expected outcome derived from a training dataset. A great example is how insurance companies are using machine learning to identify property damaged in a storm. The machine learning model is fed a series of datasets containing images of damaged and undamaged properties. The AI then develops a pattern recognition model built from variables of its choosing. Based on the model, the AI predicts which properties appear to be damaged and which don't. For a human to do this, it would be very time-consuming. AI makes this process a snap and is usually much more accurate.

When you put these benefits together—more readily available spatial data and cheaper, faster AI-driven spatial analysis—you get better spatial awareness at a better price.

## Implications for People and Organizations

What does cheaper spatial awareness mean for people and organizations? When something valuable gets cheaper, economics tells us two things happen: (1) people start using it in nontraditional ways, and (2) other factors change in value depending on whether they're complements or substitutes.

## The Expanded Role of Spatial Awareness

As new machine learning techniques and ubiquitous spatial data lower the barriers to spatial awareness, we'll start to see a deeper application of geography to long-standing problems. Consider human movement. Understanding why people travel from one location to another is notoriously difficult. Much of this understanding depends on scale—are we interested in short-term, localized movements, or longer-term, regional migration patterns. In both cases, the motivating factors are varied and complex. That's why predicting where people will travel to is so hard.

Recently, we've seen advances in both cases. On the local scale,

researchers have developed spatial AI models to monitor street cameras and adjust traffic lights to help disperse crowds after live public events. Traditional methods of planning exit routes are burdened by trying to account for all the possible reasons people

go one direction or another, and on-the-ground crowd control tactics can be inefficient and quickly overwhelmed. The new approach analyzes real-time video to detect areas where crowds are forming and predicts which routes would best ease congestion. Controllers can then adjust traffic lights accordingly. The AI provides a much more dynamic level of spatial awareness, and actively enables public safety.

On the global scale, researchers have—for the first time—developed models that predict international migration patterns resulting from climate poverty. The models incorporated environmental, socioeconomic, and political factors into different climate scenarios that could affect regions of Central America. Included in the models were factors like carbon concentrations, gross domestic product (GDP), and border management. Over 10 billion data points were fed to a supercomputer, which developed predictions of how different populations would respond to different climate change scenarios. The models were compared against historical migration patterns to assess and refine their accuracy.

The result was five migration projections that illustrate the profound impact of climate change on population migration—specifically how it could drive the displacement of huge populations in the next 50 years. In the past, projections like these were impossible considering the cost of computing and data acquisition, and the relative immaturity of spatial modeling algorithms. In short, the price of spatial awareness was just too high. In the future, we will almost certainly see more of these breakthroughs.

## Complements and Substitutes

When the cost of something important—like spatial awareness—changes economics tells us that the value of its complements and substitutes also changes.

Complements are goods or services that experience joint demand. Generally, as demand for one thing increases, demand for its complement also increases. Think of the way apps increase in popularity in conjunction with the rise of smartphones, or how pasta sauce demand goes up when demand for the pasta itself increases.

An obvious complement to AI-driven spatial awareness is the judgment-based skills needed to capitalize on the analysis

When you put  
them together—  
more readily  
available spatial  
data and cheaper,  
faster AI-driven  
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spatial awareness  
at a better price.

it generates. In the future, activities such as sophisticated cartographic visualization, geodesign, data quality assurance, and spatial storytelling will be in high demand as organizations focus on making decisions informed by improved awareness. Also, there will be demand for the applications of ethics, social justice, and economic impact analysis, as these require deep consideration of subtle relationships that are currently the domain of human cognition.

On the other hand, demand for some activities will almost certainly decrease as machine-based analysis and data processing increases in popularity. These are called substitutes in economic parlance. As geospatial technology evolves, we'll likely see a decline in roles that are readily substituted by the AI-driven model. These include manual, labor-intensive tasks like field data collection and basic map production, as well as spatial analyses that are outperformed by automated machine learning methods. Essentially any activity in a spatial workflow that doesn't require human reasoning is facing replacement by AI.

Understanding the economics of geospatial technology isn't a crystal ball, but it does help surface some possible implications.

Specifically, the increasing availability of spatial data and the speed and accuracy of machine learning will dramatically enhance an organization's location intelligence. This will lead to a much richer understanding of its business dynamics. In turn, demand will grow for competencies and tools that help managers develop business strategies that better reflect spatial reality. It's an exciting time for the geospatial industry. Your best move is to avoid the hype and get prepared.

### About the Author

**Matthew Lewin** is the director of management consulting for Esri Canada. His efforts are focused on helping management teams optimize and transform their businesses through GIS and location-based strategies. As a seasoned consultant, Lewin has provided organizations in the public and private sectors with practical strategies that enable GIS as an enterprise business capability. His interests lie at the intersection of business and technology, and he thrives on helping organizations bridge the gap between the two to achieve their most challenging GIS ambitions.



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# Connect to Excel Files in ArcGIS Pro

By Elaine Evans

You are working with more data than ever before. There are many data types, data collection methods, and data storage formats, and there's an infinite amount of data available for use, including data from Microsoft Excel files. This article answers the following four questions about using Excel files in ArcGIS Pro:

- 1 Do I need to have Microsoft products installed to connect to an Excel spreadsheet?
- 2 How do I know which Microsoft Access Database driver to install?
- 3 How do I know if a silent install is needed?
- 4 How do I complete a silent install of the Microsoft Access Database Engine driver?

## 1 Do I need to have Microsoft products installed to connect to an Excel spreadsheet?

The short answer is no. Excel tables may be used directly in ArcGIS Pro. Neither Excel nor Microsoft Office have to be installed on the same machine with ArcGIS Pro. The only requirement is that the correct Microsoft Access Database Engine 2016 Redistributable driver is present. Without this driver installed, attempts to expand or add an Excel spreadsheet to ArcGIS Pro will generate the ArcGIS Pro error message "Required Microsoft driver is not installed."

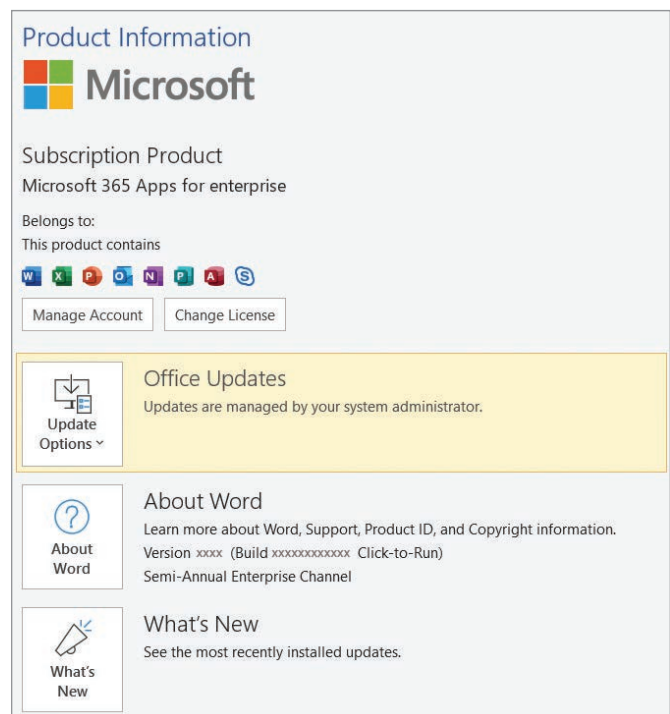
## 2 How do I know which Microsoft Access Database driver to install?

To answer this question, you need to first understand and verify a few things. First, why do you need to install the Microsoft Access Database Engine driver? Microsoft Access Database Engine technology helps bridge communication and data transfers between files that are proprietary to the Microsoft Office system and other non-Microsoft Office applications such as ArcGIS Pro.

There are two Microsoft Access Database drivers:

1. Microsoft Access Database Engine 2016 Redistributable 32-bit driver
2. Microsoft Access Database Engine 2016 Redistributable 64-bit driver

Prior to installing the driver, you need to know if any Microsoft products are already installed on your machine and if these



↑ Determine whether your Microsoft Office install is MSI or CTR using Word by going to File > Account. Under Product Information, in the About Word section, look at the end of the line containing the version and build numbers. If the CRC installer, used, Click-to-Run will be displayed, as shown here. If there is nothing displayed after the build number, then it's an MSI install.

products have been installed using either the Click-to-Run (CTR) technology or a Microsoft Installer (MSI).

Microsoft Office is installed using either MSI or CTR. MSI (more recently referred to as a Windows Installer file) is typically one large

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## Microsoft® Word for Microsoft 365 MSO (16.0.13127.21886) 64-bit

License ID: XX

Session ID: BD37FFF4-3E71-4711-8CAE-572EBDFA9D3B

→ To determine the bit level, open the About Microsoft Word window. The top line contains the combined version and build number followed by either 64-bit or 32-bit.

download file that contains both the installer and all Office components. CTR, an alternative to the traditional MSI installer method, uses streaming and virtualization technology to install and launch Office products faster.

Knowing the type of installer used is important because if your Microsoft Office products were installed using CTR, (such as Microsoft Office 365), Microsoft's side-by-side detection will prevent the installation of either the 32-bit or 64-bit driver from proceeding.

You also need to know the bit level installed for these Microsoft products. This information is important because if you try to install the downloaded AccessDatabaseEngine.exe file (32-bit driver) on a machine that already has a Microsoft 64-bit application, you will get an error message saying you can't install it because you currently have 64-bit Office products installed. A similar error message will display if you try to install the AccessDatabaseEngine\_X64.exe file on a machine that already has a Microsoft 32-bit application.

If you encounter either of these issues, don't despair. There's a simple workaround, which involves performing a silent installation of the downloaded Microsoft Access Database Engine 2016 driver.

Now that you have identified the appropriate driver for your

configuration, let's verify three key points before you download that driver.

## Point 1

Are any Microsoft Office products currently installed on the client machine on which ArcGIS Pro is installed?

→ If the answer is no, skip down to 3. How do I know if a silent install is needed?

→ If the answer is yes, proceed to Point 2 below.

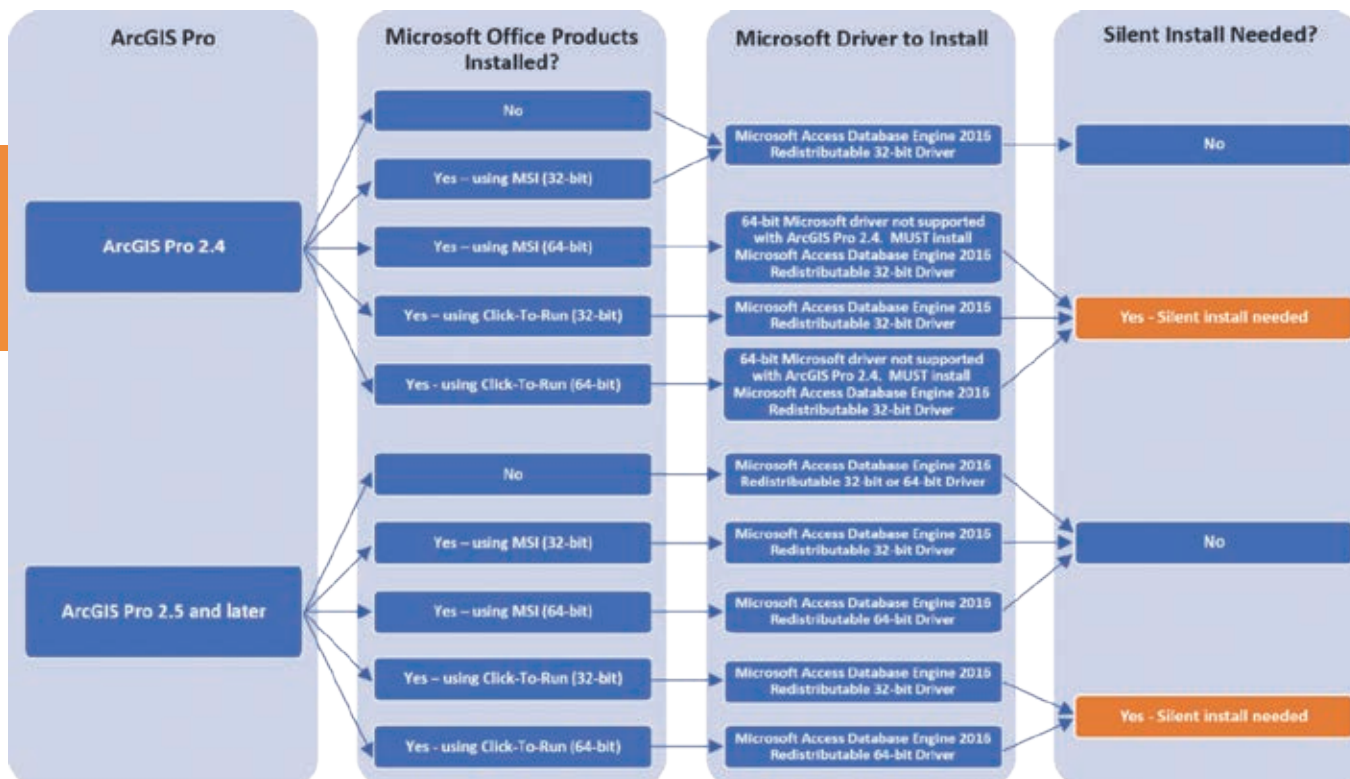
## Point 2

How do you tell whether your Microsoft Office install is MSI or CTR?

**Note:** These instructions are applicable for any Office app (e.g., Word, Excel), but this example uses Word.

In Word, Go to File > Account. On the right side, under Product Information, in the About Word section, look at the end of the line containing the version and build numbers. If the CTR installer used, Click-to-Run will be displayed. If there is nothing after the build number, then it's an MSI install.

↓ Figure 1: This decision tree will help you determine the appropriate Microsoft Access Database Engine driver to install.





### Point 3

Which Microsoft Office bit level is installed, 32 bit or 64 bit?

It's easy to tell if the bit level of your installation is 32 bit or 64 bit. These instructions are applicable for any Office app (e.g., Word, Excel), but this example uses Word. In Word, Go to File > Account and click About Word. This will open the About Microsoft Word window. The top line contains the combined version and build number followed by either 64-bit or 32-bit.

## 3 How do I know if a silent install is needed?

Based on your answers to the previous questions, use the decision tree in Figure 1 to help you determine the appropriate Microsoft Access Database driver to install and determine if a silent install is needed.

If you do not need a silent install, use the instructions at <https://bit.ly/3sqSTVQ>.

If you do need a silent install, use the steps under 4. How do I complete a silent install of the Microsoft Access Database Engine driver?

**Important:** If you are not sure whether a silent install is needed or if you have both 32-bit and 64-bit Microsoft products installed, download the Microsoft Access Database Engine 2016 Redistributable 64-bit driver (AccessDatabaseEngine\_X64) from <https://bit.ly/3sqSTVQ>. To complete a silent install of this driver, follow these steps outlined under 4. How do I complete a silent install of the Microsoft Access Database Engine driver?

→ In the Windows taskbar Search box, type cmd into the search box and click the Run as administrator option displayed on the right side of the Search window.

## 4 How do I complete a silent install of the Microsoft Access Database Engine driver?

Before beginning the following steps to complete a silent install of the Microsoft Access Database Engine driver, ensure that ArcGIS Pro is closed.

### Step 1

To download the Microsoft Access Database Engine 2016 Redistributable driver, go to <https://bit.ly/3sqSTVQ>.

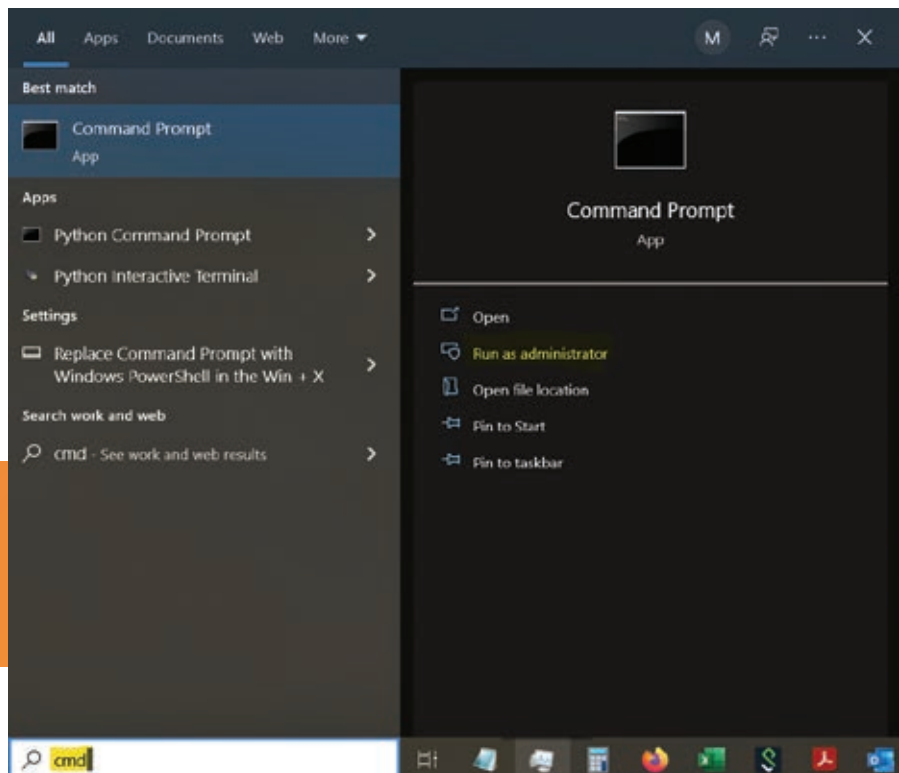
Check the box next to `accessdatabaseengine.exe`, if your Office app is 32bit. Check the box next to `accessdatabaseengine._X64.exe`, if your Office app is 64 bit.

Click Next to begin the download.

On the local machine where ArcGIS Pro resides, create a new folder named `MS_Driver` off the root directory of the drive. Example: This PC > OSDisk (C:) > `MS_Driver`.

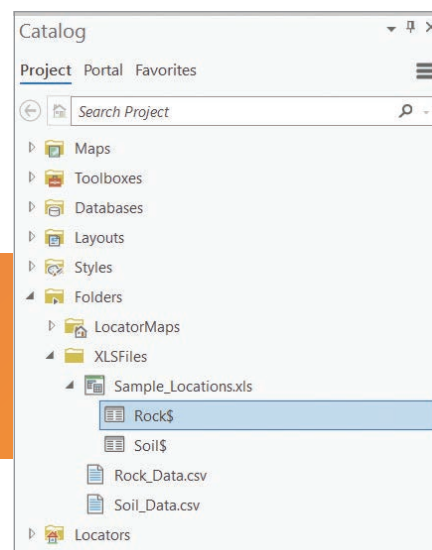
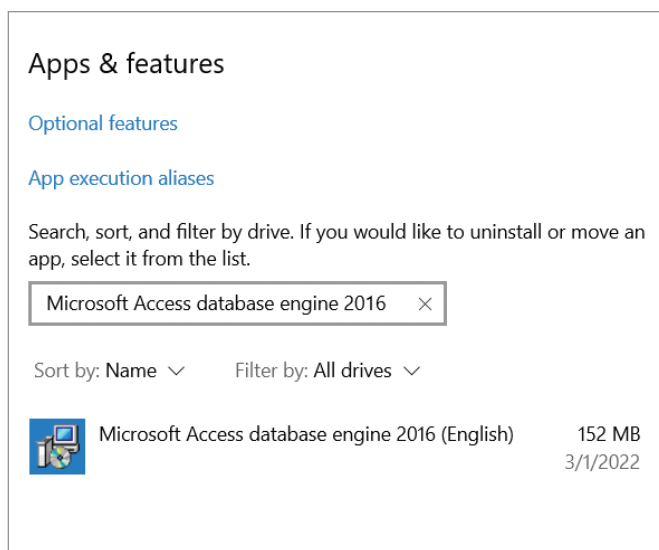
### Step 2

In the Windows taskbar Search box, type `cmd` into the search box. You will see Command Prompt appear in the Search window. Click the Run as administrator option displayed on the right side of the Search window.



→ After running the executable file for the correct Microsoft Access Database Engine 2016 driver, search in Apps & features to ensure it has been installed.

→→ With the driver installed, you can make a folder connection in ArcGIS Pro to the folder containing the Excel files you want to use and expand the Excel workbook to display one or more worksheets.



### Step 3

From the Command Prompt, provide the full path of the Microsoft Access Database Engine driver .exe file stored locally on your machine and add /quiet. Hit the Enter key to run this as a silent install.

In this example, the full path of the 32-bit driver .exe file run as a silent install would be

```
C:\MS_Driver\accessdatabaseengine.exe /quiet
```

In this example, the full path of the 64-bit driver .exe file run as a silent install would be

```
C:\MS_Driver\accessdatabaseengine_X64.exe /quiet
```

### Step 4

To verify that the driver was installed successfully, in the taskbar search box, type Add or remove programs and select Add or remove programs System settings from the search results. In the Apps & features pane, search for Microsoft Access database engine 2016 to locate the driver and verify that it has been installed.

### Step 5

Open ArcGIS Pro. From the Catalog pane, click and expand Folders. Right-click Folders and select Add Folder Connection. Browse, type, or copy the full path to the folder on your local or network computer that contains the Excel files you want to display in ArcGIS Pro. Click OK. The folder connection appears in the Catalog pane in the Folders category.

### Step 6

Click an Excel (.xlsx) file to expand the workbook and display one or more worksheets.

**Tip:** When accessed from ArcGIS Pro, a worksheet is shown as a separate table with a dollar sign (\$) displayed at the end of the worksheet name. Spaces in worksheet names will be replaced by underscores.

### Some Final Notes

Remember, when creating and maintaining data in Excel that you will use in ArcGIS Pro, some data preparation is typically necessary

to ensure that data is correctly identified by ArcGIS Pro. Read the documentation at <https://bit.ly/3C12LZu> to learn the limitations of this data source and <https://bit.ly/3C4djY4> to learn best practices when using data in Excel files. Now that you can work with Excel files in ArcGIS Pro, an entirely new treasure trove of data has been opened to you. What will you do with your newfound powers?

### About the Author

**Elaine Evans** is a product engineer on the geodatabase team at Esri who has worked with the geodatabase in various capacities at Esri since 2001.

Evans is passionate about finding opportunities to add valuable and creative content for the geodatabase technology that empowers ArcGIS users. Southern born and bred, she's a mom, weather enthusiast, aficionado of fine teas, baking, bagpipe music, and lover of all things pineapple.

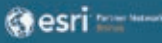

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# Five Ways Arcade Enhances Maps Using American Community Survey Data

By Steven Aviles



✦ The ACS Household Income Distribution Variables layer in ArcGIS Living Atlas of the World provides income ranges such as \$0 to \$14,999 and \$15,000 to \$20,000. ArcGIS Arcade allows you to combine those fields.

✦ Listing 1: This Arcade expression will combine the income ranges in the ACS Household Income Distribution Variables layer to answer questions about households that make less than \$50,000 a year.

✦✦ With the statements in Listing 1 added, the pop-up now displays information that aggregates information about income ranges.

Often you find that the layers you own—and especially layers you don't own—don't meet all your mapping needs. You may want to calculate new values for fields, spruce up your pop-ups with data from additional layers, or summarize your data based on geometry. You could copy datasets and join them to produce a third dataset that you would then have to manage. Instead, you could use ArcGIS Arcade, which allows you to calculate new data values on the fly.

For example:

- Make basic calculations, such as calculating a percent.
- Use functions, such as ABSOLUTE VALUE, ROUND, and logical statements.
- Create an index or ratio.
- Manipulate text or resize symbols based on map scale.
- Use geometry-based functions.
- Perform data cleanup such as fixing fields

that contain incorrect values or typos.

If you're brand new to Arcade, read "Your Arcade Questions Answered" (<https://bit.ly/370S3XD>) to learn more.

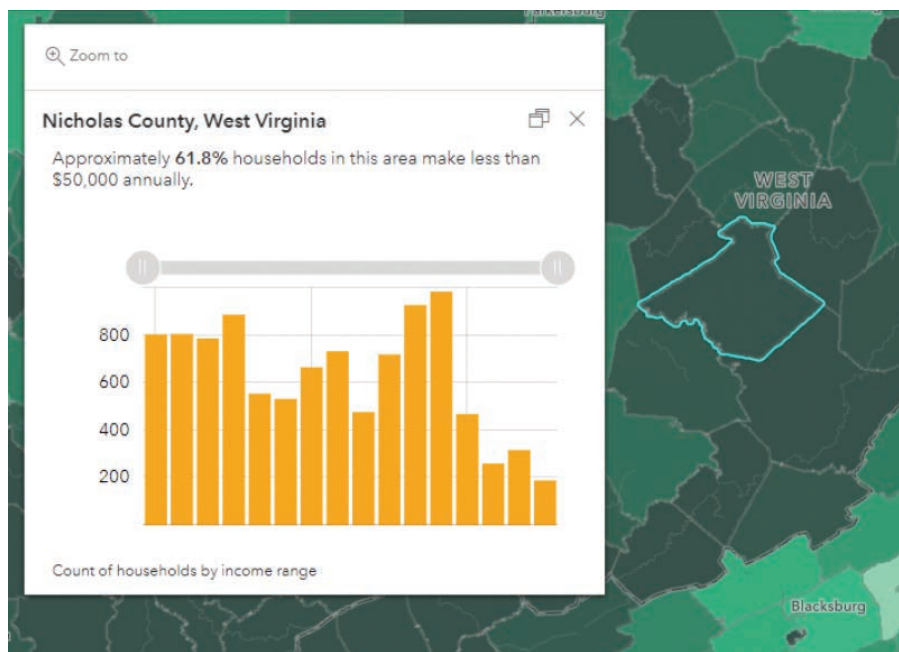
```
var Percent_Below_50k = round((%Household_B10001_005F + %Household_B15001_014F) + %Household_B15001_014F + %Household_B15001_014F + %Household_B15001_014F + %Household_B15001_014F + %Household_B15001_014F) / %Household_B10001_005F * 100;
return Percent_Below_50k;
```

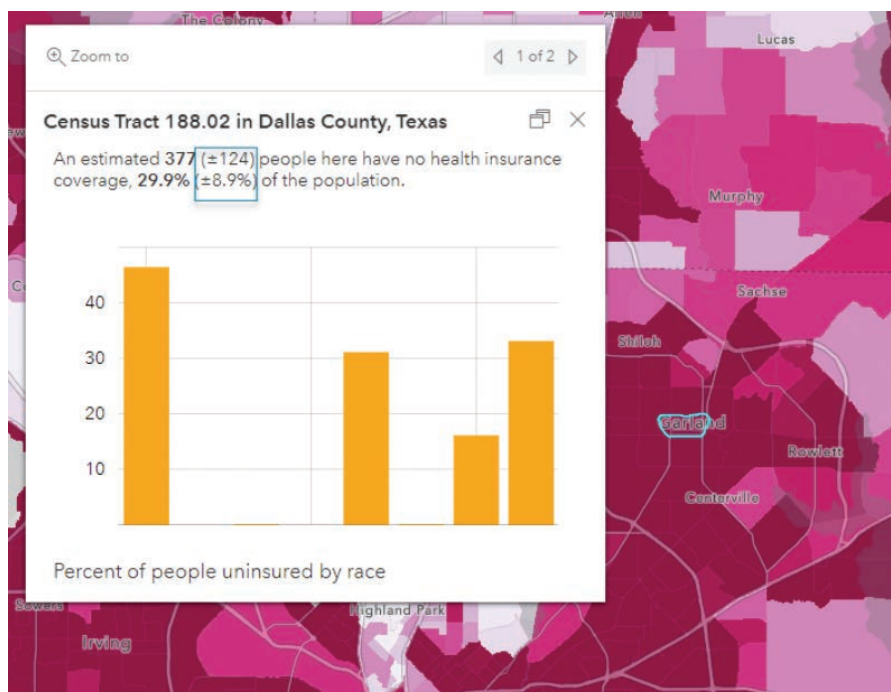
Listing 1

## What Exactly Is Arcade?

Arcade is a portable, lightweight, and secure expression language written for use in the ArcGIS system. Like other expression languages, it can be used to perform mathematical calculations, manipulate text, and evaluate logical statements. It also supports multistatement expressions, variables, and flow control statements. Arcade was designed specifically for creating custom visualizations and labeling expressions in the ArcGIS system. It allows users to write, share, and execute custom expressions in ArcGIS Pro, ArcGIS Runtime, ArcGIS Online, and the ArcGIS API for JavaScript.

Arcade allows you to access feature geometry, store constants and variables, and provide access to attribute values. You can use the broad functionality in Arcade to calculate new data-driven values.





## Using Census Data from ArcGIS Living Atlas and Arcade

ArcGIS Living Atlas of the World contains US Census Bureau American Community Survey (ACS) layers that are quick and easy to use when mapping demographic topics in the US. Combining Arcade and ACS layers can save time and enhance your maps.

The ACS provides a lot of interesting data points from social, economic, housing, and demographic characteristics about the US population every year. This data can be used to make important public and business decisions that clearly identify issues and opportunities and help more effectively allocate resources.

ArcGIS Living Atlas of the World contains layers of the most current ACS five-year estimates that are curated, free to use, and ready to go. The layers are updated annually to reflect the most current data values and geographical boundaries. Layers contain data for state, county, and census tract geographies. Each layer contains single or multiple ACS tables, grouped by topic, and each topic is available as boundaries and centroids. Many layers include precalculated fields such as sums and percentages. Coastlines and water features are clipped to meet cartographic needs. Field aliases and long descriptions bring metadata directly into the user experience.

## 1 Construct New Values to Map

A lot of valuable fields are given in ACS data, but often you may want to combine fields and construct new values to map. For instance, if you want to map the percentage of households with income below \$50,000, you can use the ACS Household Income

← All ACS layers contain margins of error fields that are displayed in pop-ups. This pop-up from the ACS Health Insurance by Age by Race Variables layer shows the margin of error for those without health insurance.

Distribution Variables layer in ArcGIS Living Atlas of the World and Arcade to calculate this attribute on the fly.

ACS offers the count of households within different income ranges such as \$0 to \$14,999 and \$15,000 to \$20,000. But if you want to combine those fields to identify households with incomes less than \$50,000, Arcade allows you to combine the different attributes and normalize them into a percentage as shown in Listing 1.

## 2 Spruce Up Your Pop-ups

Arcade allows you to quickly add new information to your pop-ups, such as new calculated fields, as well as writing conditional statements to provide information about your data. From the field calculations shown in Listing 1, you can simply copy and paste the Arcade expression as a new expression in the pop-up panel and re-create the percentage of households whose income was below \$50,000. In addition, Arcade allows you to bring in information from another layer, using FeatureSets, without having to run any join functions.

↓ Listing 2: Logical statements can be added to determine if a given census geography has reliable estimates for any given attribute by using the associated margin of error.

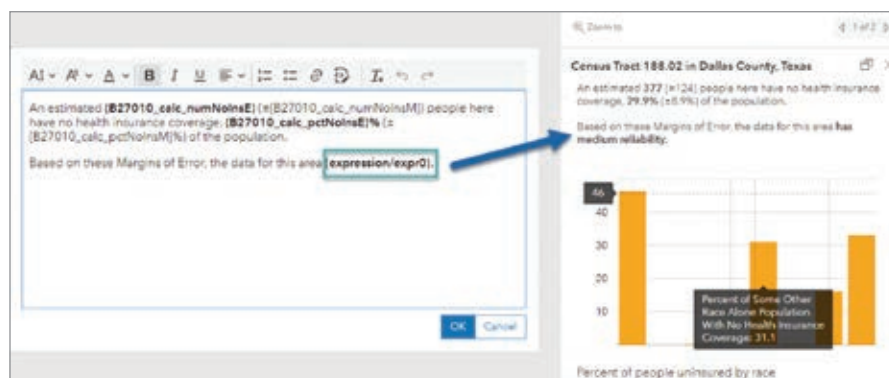
↓↓ The test in Listing 2 rates the reliability of the estimate.

Margin of Error Reliability Statement

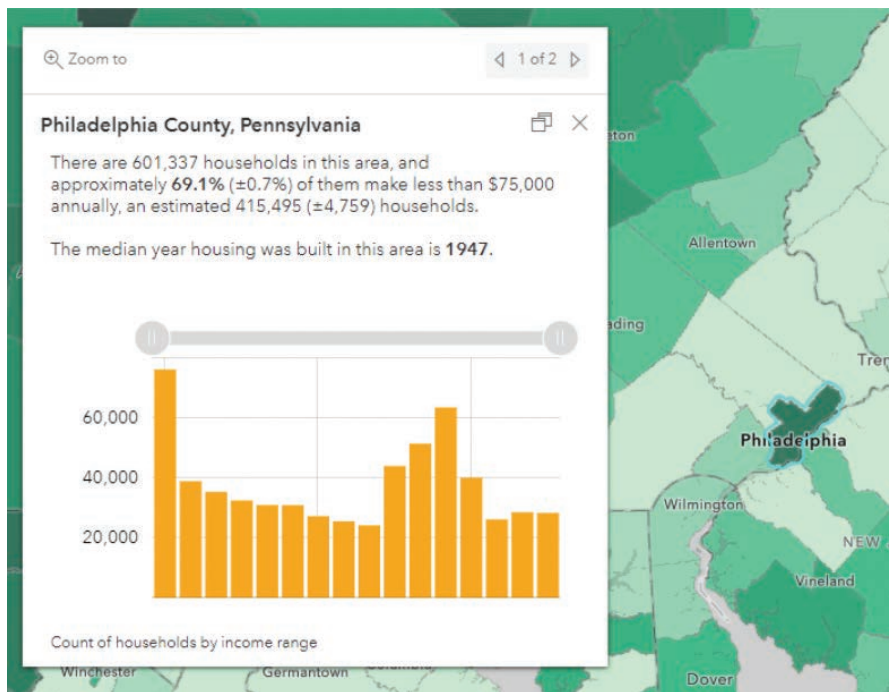
```
var estimate = $feature.B27010_calc_numNoInsM
var pop = $feature.B27010_calc_numNoInsM
var cv = ((1/2) * ($feature.B27010_calc_pctNoInsM)) * 100

When (cv < 40, "has low reliability",
  ($feature.B27010_calc_pctNoInsM) || "does not have enough information to determine reliability", "");
```

Listing 2







✦ Using FeatureSets provides more context for the information in this pop-up on household income.

✦ Listing 3: These statements use FeatureSets to bring data from the ACS Housing Units by Year Built Variables layer to the ACS Housing Costs Variables layer to provide context for a households by income map by displaying data about the median age of the housing.

## 4 Use Data from Other Layers

Often, you'll want to add additional information into a pop-up that resides in another layer. You could join the layers of interest together, but that requires additional time, credits, and some additional work. That's where Arcade's FeatureSets capability comes in.

FeatureSets are Arcade data functions you can use with feature layers. With FeatureSets, you can work with multiple features in a layer when authoring a pop-up or calculating fields. For a detailed explanation of FeatureSets, read "What's new with Arcade: Taking a stroll through FeatureSets (Part 1)" (<https://bit.ly/3lI0ips>).

Listing 3 uses FeatureSets to bring data from one ACS layer into another.

```

// Aggregate expression for Housing Unit Year
// Built - Median QED
var AGC = FeatureSetByName($data, 'ACS Housing Units by Year Built Variables - Boundaries - County 4176a55330744696687');
var AGC_FeatureSet = AGC - AGC;
var county = AGC_FeatureSet[AGC_FeatureSet[0].COUNTY];
return county.F00535_00F
  
```

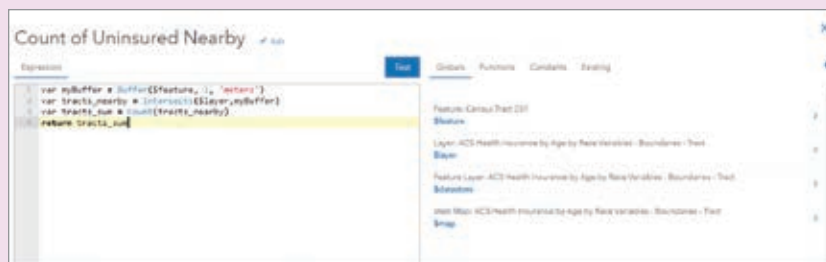
Listing 3

## 3 Writing Conditional Statements

Writing logic methods is useful for checking for empty values and writing conditional statements such as if/else logic and implementing switch-case statements. All ACS layers in ArcGIS Living Atlas of the World contain margins of error fields that are displayed in pop-ups. You can write logical statements in Arcade to determine whether a given census geography has reliable estimates for any given attribute by using the associated margin of error such shown in the Arcade statements in Listing 2. For an in-depth explanation on using Arcade to write statements for margins of error, read "Effective ways to communicate margins of error through pop-ups" (<https://bit.ly/35lQeUR>).

➔ With Arcade, you can use geometry functions such as Spatial Union, Intersection, Clip, Buffer, and Overlaps. In this example, surrounding census tracts are aggregated and displayed in the pop-up. The three expressions used to create this pop-up are shown on page 53.

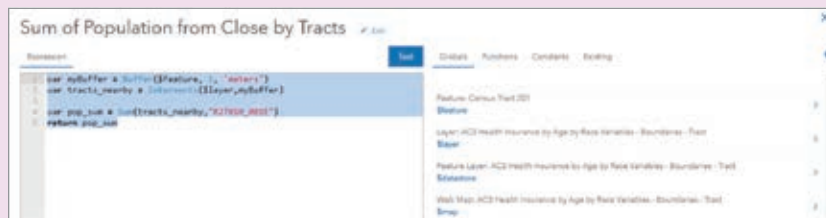




✦ The first expression uses buffer and intersect functions to sum the population in the adjacent census tracts.

✦ The second expression sums the uninsured population in the adjacent census tracts.

✦ The third expression determines the percent of uninsured population in the adjacent census tracts.



as Spatial Union, Intersection, Clip, Buffer, Overlaps, and more of your favorite spatial relationships.

For a more detailed description of geometry functions using Arcade, read "Use Arcade geometry functions with FeatureSets to provide spatial context" (<https://bit.ly/36Q2WLE>). For instance, you might want to aggregate areas based on an area of interest, such as a buffer. When dealing with margins of errors in ACS, you might want to aggregate surrounding census tracts to get values that are more reliable.

## Use Arcade to Enhance Any ArcGIS Map or App

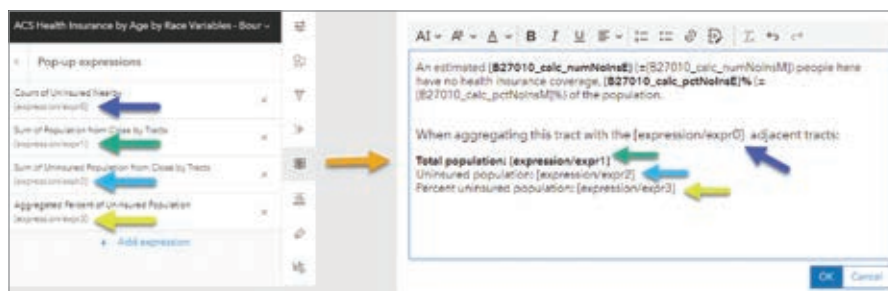
These are just some of the many ways that you can use Arcade to elevate ACS layers or any feature layer: calculating a new field to map an attribute of interest by sprucing up pop-ups with newly calculated fields and conditional statements or bringing in additional layers and displaying spatial relationships. Arcade makes working with ArcGIS Online, ArcGIS Pro, ArcGIS Dashboards, and web applications easier than ever.

Specifically, bringing data from the ACS Housing Units by Year Built Variables layer into the ACS Housing Costs Variables layer to bring in context about the median age of housing to households by income map. It uses the FIPS/GEOID field to find the matching record from the similar layer. This is an attribute-driven approach that is a lot like a join, which combines two tables based on a corresponding value. The FeatureSetByPortalItem() function allows you to pull data from another layer into a pop-up without adding the layer to your map. When retrieving data from a layer within your web map, use the FeatureSet function and access data with \$map. When retrieving data from a layer that isn't in your web map, use FeatureSetByPortalItem function.

## 5 Using Geometry Functions to Provide Spatial Context

While all the uses of Arcade described so far are awesome, when is the spatial in geo-spatial with using Arcade? Fear not, Arcade allows you to use geometry functions such

✦ The arrows indicate the Arcade expressions used to generate the information displayed in the pop-up.





# Create a Public Information App Using Experience Builder

By Jeff Baranyi and Jon Pedder

In today's world, the public has higher expectations for information sharing and transparency. Sharing information with the public is especially necessary for effective disaster response. Now during disasters, agencies share current information on critical features such as evacuation zones, incident information, road closures, and shelters—in other words, situational awareness information for the public, both those who are affected and those who are curious.

For many years, ArcGIS Web AppBuilder has been the tool of choice for GIS analysts looking to keep the public informed and safe. It provided simple functionality for the target audience; search by address, text communication by staff or public information officers, and the ability to share and embed maps have been key features.

As technology has evolved, the demand for information on mobile devices has dramatically increased. Recent updates to

ArcGIS Experience Builder are designed to meet these challenges. The Public Information Template for Experience Builder (<https://bit.ly/34ZVoH>) incorporates these updates and lessons learned.

The following tutorial will show how to:

- Create a new app using the Public Information Template for Experience Builder.
- Configure the template for use with your own map.
- Provide additional information on how to further configure this template to meet your needs.

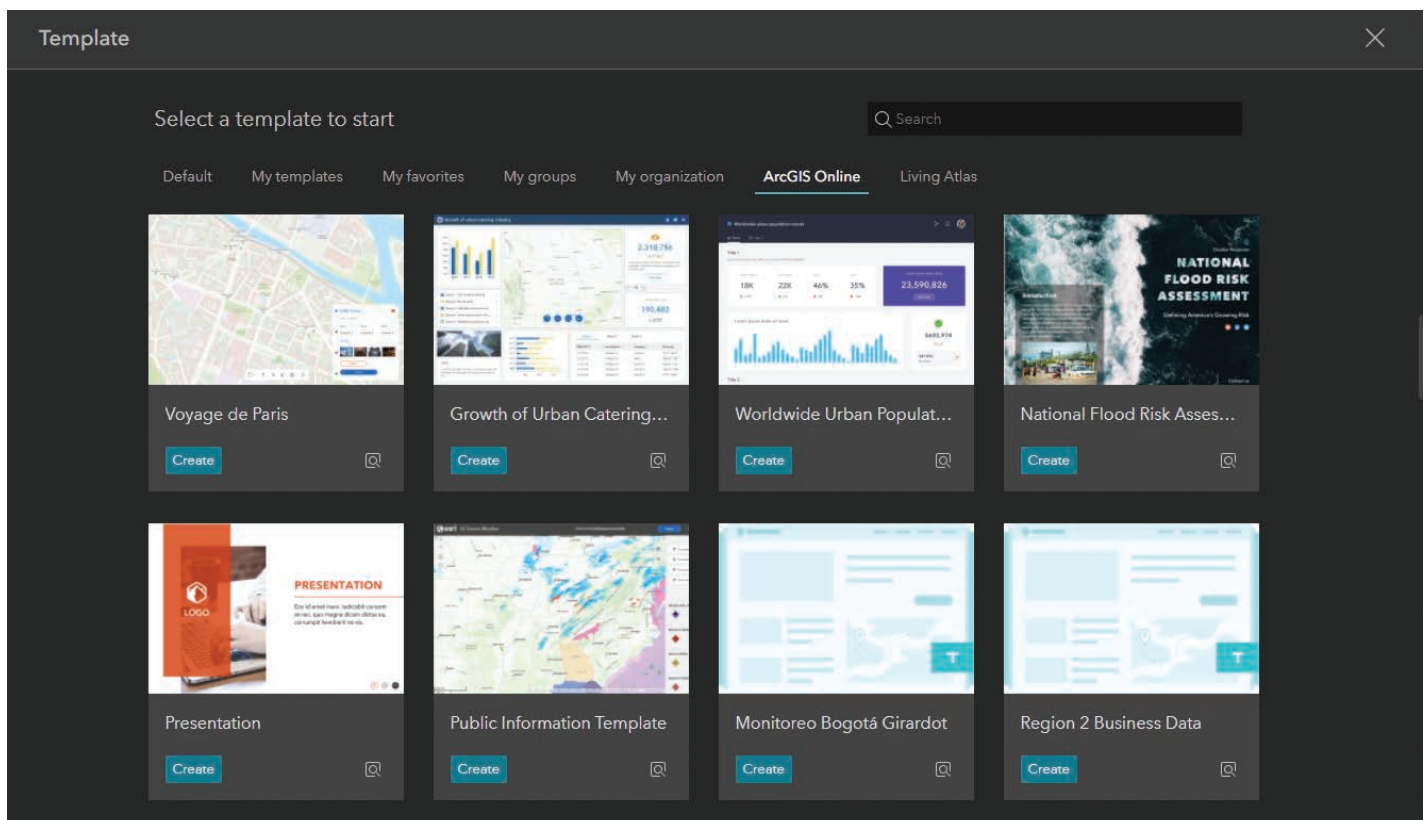
## Using the Public Information Template

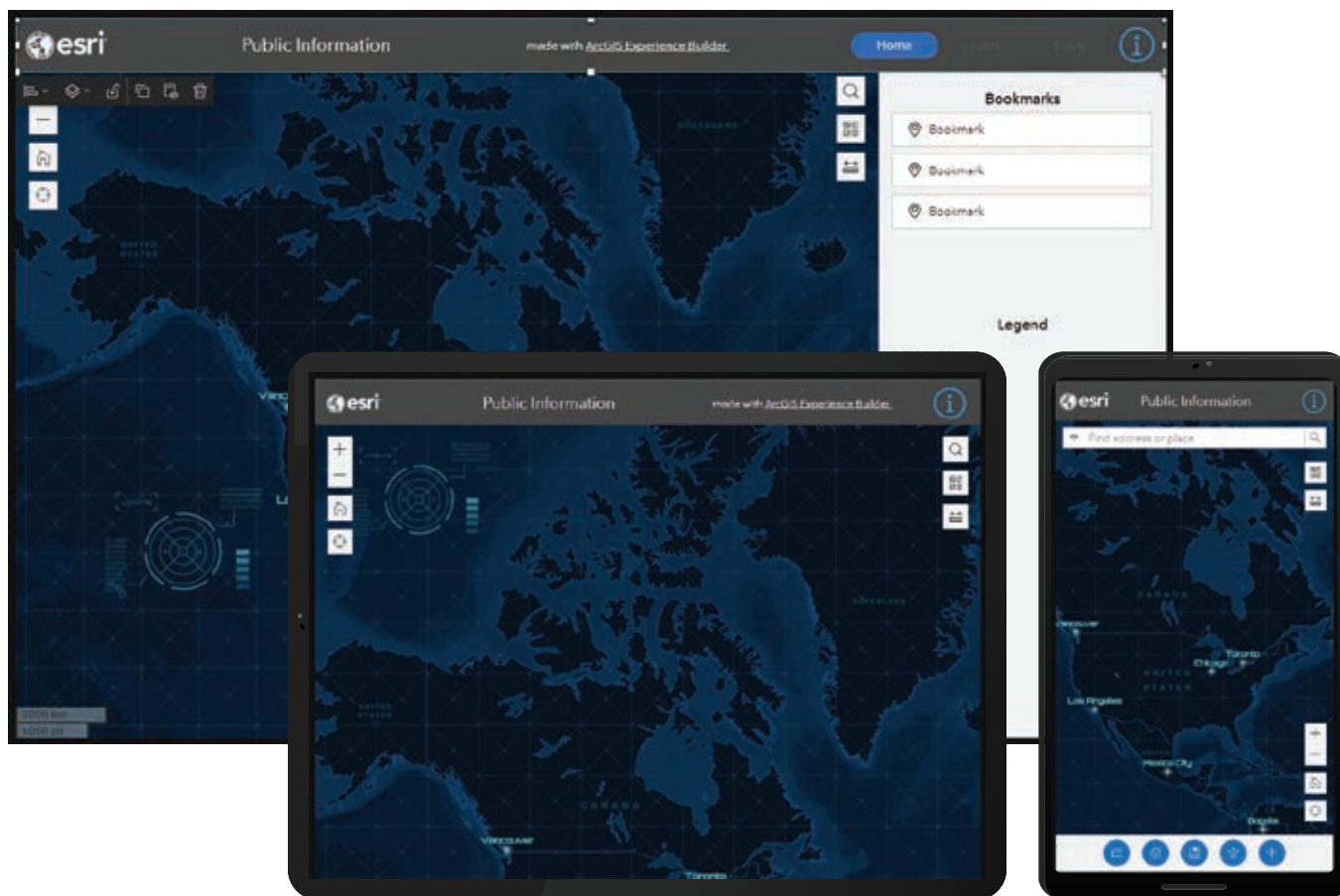
Sign in to your ArcGIS account, and open Experience Builder.

In ArcGIS Experience Builder, create a new app by clicking + Create new.

Browse for the template in ArcGIS Online by clicking the ArcGIS

↓ Locate the Public Information Template by clicking the ArcGIS Online tab and searching for the template.





Online tab, and then searching for the Public Information Template.

Explore the template. The Public Information Template is actually three apps in one—it contains specific configurations of the app for large-, medium-, and small-screen devices. Click the different screen icons across the top to toggle between the different device page layouts.

The layout for large-screen devices has three sections on the right. Each tabbed section—Home, Layers, and Share—has different widgets.

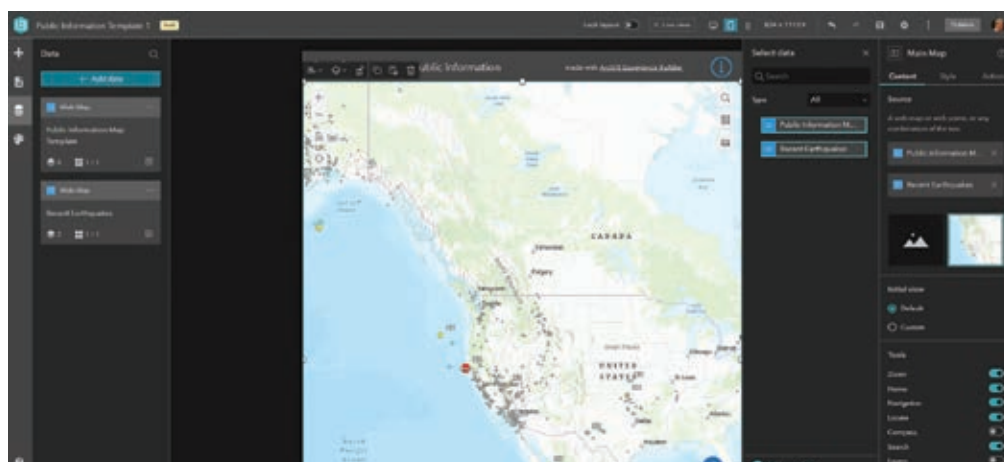
The layout for medium-screen devices, has buttons on the bottom right to access sections and modify them.

The layout for small-screen devices has buttons along the bottom to access sections and modify them.

Add your web map by clicking the Data icon on the left and clicking + Add data.

Browse or search for the web map you'd like to use and click Done.

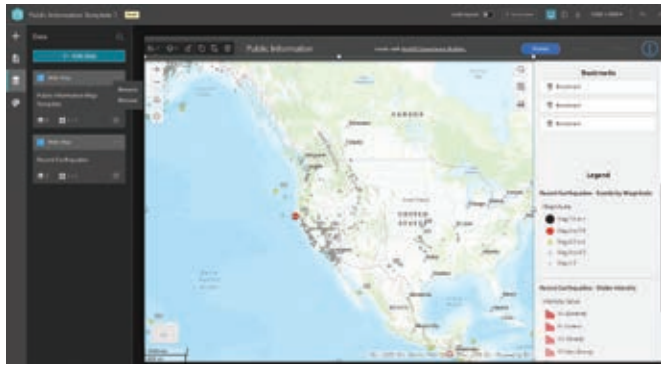
Configure the app to use your map instead of the default map.



↑ The Public Information Template is actually three apps in one. It contains specific configurations of the app for large-, medium-, and small-screen devices.

← Make sure that your web map is the only one selected and save the app by clicking the icon on the top right side of the interface.





← Remove the default map by going to the left side of the interface and under Data, click the ellipses next to Public Information Map and then click Remove.

## Learn More about Using the Template

See this new template in action on Esri's Disaster Response Program (DRP) page (<https://bit.ly/3HYvOPw>). Public Information Template apps for hurricanes, wildfires, flooding, severe weather, and earthquakes are embedded on this page. Access resource hubs provided by DRP at [esri-disasterresponse.hub.arcgis.com/](https://esri-disasterresponse.hub.arcgis.com/).

Some resources for learning more about Experience Builder are:

- ArcGIS Blogs (<https://bit.ly/3gUPOqx>)
- ArcGIS Learn Lessons (<https://bit.ly/3sKYwNA>)

The right section changes to Main Map. Click Select Map and then browse to locate and select the web map you just added.

Make sure that your web map is the only one selected and save the app by clicking the icon on the top right side of the interface. Remove the default map by going to left side of the interface and under Data, click the ellipses next to Public Information Map and then click Remove.

Now that your web map has been applied, you can configure the Information window. To do this, click the Page icon on the left, then Window > Information to configure this widget to meet your needs. Save the app when done.

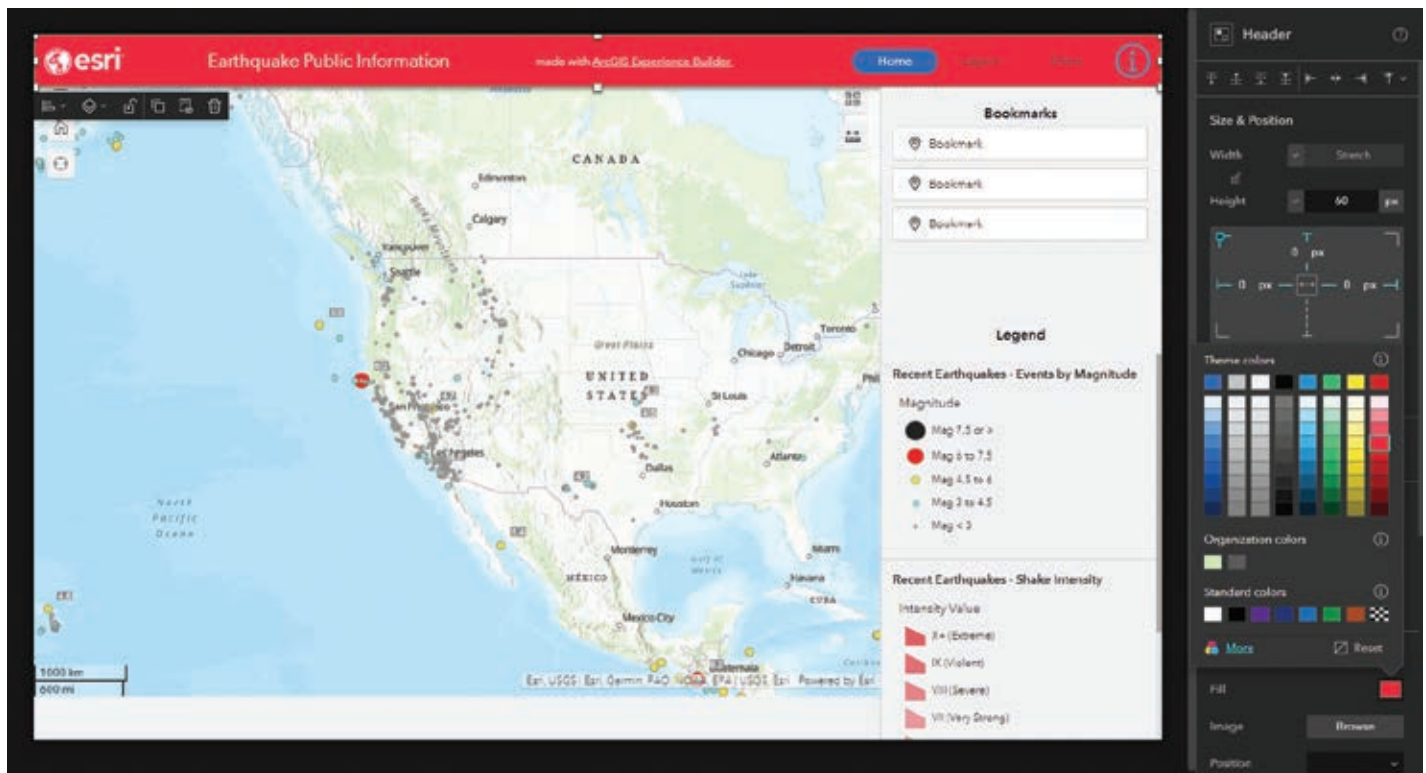
These are the basic steps needed to configure the Public Information Template for Experience Builder. You can further modify elements like the title, logo, brand, and color, as well as add in any additional widgets.

## About the Authors

**Jeff Baranyi** currently serves as the emergency management and fire technical lead on the Esri public safety team. He works closely with the public safety team and Esri's customers to define industry-focused solutions that promote the value of the ArcGIS system. Baranyi also is the technical manager for the DRP, who is responsible for ensuring the program is leveraging Esri technology effectively to support organizations and agencies impacted by complex emergencies and crises.

**Jon Pedder**, a GIS senior solutions engineer at Esri, has more than 20 years of experience supporting organizations worldwide to become crisis ready.

↓ You can further modify elements like the title, logo, brand, and color, as well as add additional widgets.



# GIS Bookshelf

## Thematic Mapping: 101 Inspiring Ways to Visualise Empirical Data

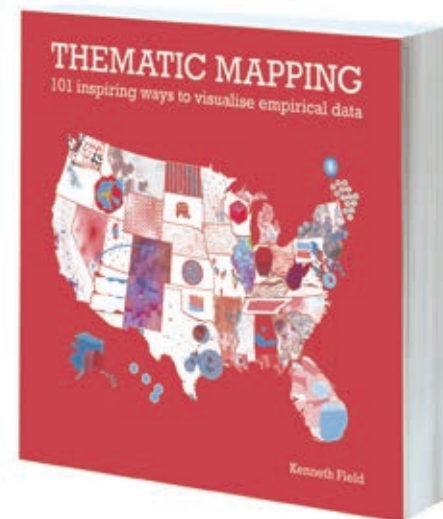
By Kenneth Field

In his second book on cartography, *Thematic Mapping: 101 Inspiring Ways to Visualise Empirical Data*, Kenneth Field explores the “many decisions, opportunities, constraints” that are involved in both making and reading maps. He uses the same dataset to create 101 thematic maps of various types that illustrate the strengths and weaknesses of each.

“This entire book is based on the fundamental idea that there are few maps that can be thought of as right or wrong,” Field wrote in *Thematic Mapping*. “They all tell different truths and different shades of the truth and what represents one person’s truth well may not chime with another person’s truth.”

Each map in this book uniquely portrays a single dataset using area, point, line, and 3D maps; cartograms; graphs; charts; and plots. The perception of the data has been influenced by the choice of colors, symbols, and other cartographic details. These maps illustrate the beauty and bane of cartography: There isn’t one objective and immutable way to make a map. This is the overarching message of the book.

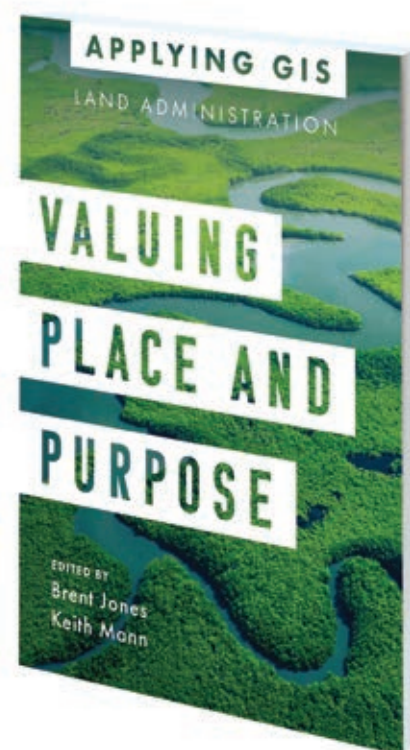
Field, whose cartographic practice includes both academic and commercial work, has won many awards for his maps and his writing. *Thematic Mapping* won a prestigious International Cartographic Association (ICA) award in 2021 for best education product. His previous book, *Cartography*, also won first-place honors for best education product from the ICA in 2019. Esri Press, 2022, pp. 296, print ISBN: 9781589485570, ebook ISBN: 9781589485587.



## Valuing Place and Purpose: GIS for Land Administration

By Brent Jones and Keith Mann

The availability of standardized, high-quality land data is vital to a successful economy. Land records and land management were some of the first applications of GIS. More recently, land data has become part of strategies that mitigate climate change and work toward social equity. *Valuing Place and Purpose: GIS for Land Administration* addresses all these applications of GIS to improve the creation, maintenance, and use of land data in a collection of real-world case studies. They describe the benefits of integrating GIS to modernize processes and information dissemination. They can serve as a guide for applying locational intelligence to common problems and societal challenges. (It is slated for publication in the third quarter of 2022.) Esri Press, 2022, pp. 120, print ISBN: 9781589487062, ebook ISBN: 9781589487079.





# Students' Solution Protects People from Contaminated Water

By Christa Campbell

**More a quarter** of the world's population—more than two billion people according to the United Nations (UN)—lack access to safe drinking water. And nearly all of them have no way of knowing if the life-sustaining liquid they draw from a village pump could make them deathly ill or even

kill them until it's too late.

But an enterprising group of young computer coders in India created Saaf water, a low-cost system that can go a long way to ensure that water—one of the most basic human needs—will not harm those who do not live near modern plumbing or have

access to purification methods.

The group—Hrishikesh Bhandari, Jay Aherkar, Satyam Prakash, Manikanta Chavvakula, and Sanket Marathe—built a water quality sensor and analytics platform that is accessible to people living in rural areas. Low-power, cellular-enabled

↓ More than two billion people lack access to safe water and have no way of knowing if the water from a village pump could make them deathly ill.







hardware monitors water quality parameters. The data collected is stored and disseminated using the IBM Cloud. The system uses artificial intelligence (AI) to predict circumstances that will degrade water quality so that it can alert people to the likelihood of contamination of the water they depend on for drinking, cooking, and cleaning.

Contamination spots and areas likely to become health risks are plotted on maps using GIS. The GIS dashboard, along with the color-coded and regularly updated smart maps, can keep residents aware of the quality of their drinking water in real time as well as make the data readily accessible and understandable to government entities.

Saaf water was chosen as the grand prize winner of IBM's 2021 Call for Code Global Challenge contest from a field of 500,000 developers who came from 180 nations. This first-place finish comes with a \$200,000 prize and the promise of expertise to guide

the group and help take the idea from proven prototype to widespread deployment as a working solution. According to *Indiatimes*, a mainstream news source in India, "The low-cost device could help save millions of lives in India if deployed on the large scale."

### A Mother's Illness Spurred Innovation

Bhandari's mother had become severely ill from contaminated water. It took three painful months for her to recover. This

↑ Members of the Saaf water group (left to right: Manikanta Chavvakula, Sanket Marathe, Jay Aherkar, Chintamani Shirodkar, Satyam Prakash, and Hrishikesh Bhandari)

→ The system uses simple hardware sensors that indicate the condition of the water source—green for safe water, yellow for water that has a high likelihood of being unsafe, and red to warn of confirmed contamination.





→ The GIS dashboard, along with the color-coded and regularly updated smart maps, can keep residents aware of the quality of their drinking water in real time as well as make the data readily accessible and understandable to government entities.

event set in motion a journey of discovery that may ultimately save many thousands of lives and relieve suffering.

Although parts of India are very modern, many areas still suffer from a lack of drinkable water and the treatment services to make water safe. The issue of contaminated water is complicated by the fact that areas without modern plumbing and treated water also have poorly managed garbage and human waste disposal systems. In fact, the UN report notes that 3.1 billion people—or 46 percent of the world's population—fall into this category.

After thinking about his mother's illness, Bhandari checked with his friends to see if anyone close to them also had suffered after ingesting tainted water from their village or neighborhood's traditional source. He found water-related illness to be common. Everyone seemed to have a relative or friend who was sickened at some point by contaminated water. As Aherkar, Prakash, Chavvakula, and Marathe did their research, they, too, were galvanized into action by what they found.

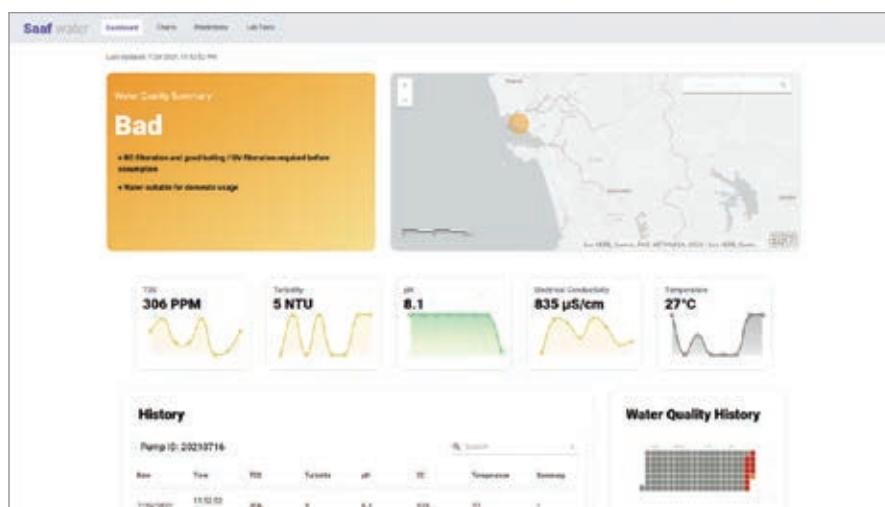
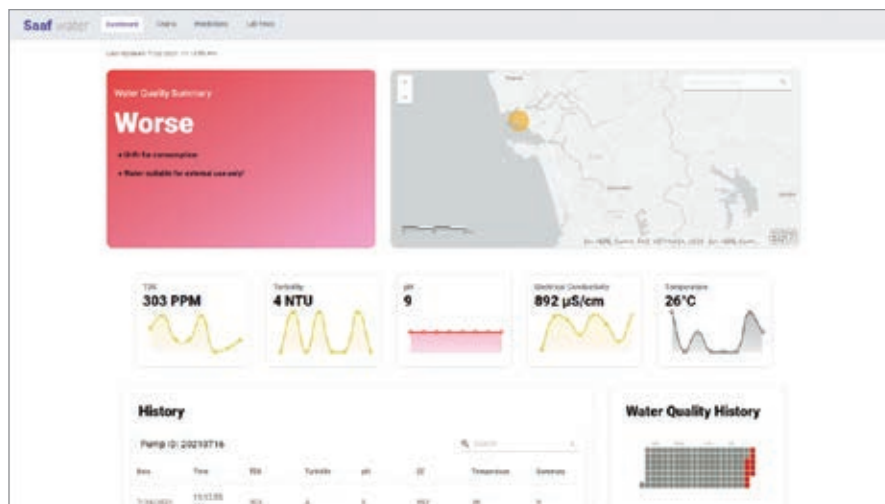
Bhandari said, "That's why we thought, 'Let's build a solution around this,' because it's not a problem that just we've encountered, but it is a problem that everybody is going to encounter in the future or is encountering currently."

## Saaf water Was Born

As group members began to organize their thoughts and set up a plan to do something about the ongoing problem, they formed Saaf water. In Hindi, *saaf* means clean.

They decided that there had to be a way to help the situation. It might be an app or a device that could save lives, wouldn't cost a lot, and would be easy for the average person to understand and use. They realized that to be effective, the device and the system would have to be simple to operate and understand and low cost so it would be within the reach of low-income communities.

The system uses simple hardware sensors that indicate the condition of the water



source—green for safe water, yellow for water that has a high likelihood of being unsafe, and red to warn of confirmed contamination. Sensor information and layers of data gathered from weather patterns, seasonal correlation, population growth, local farming methods, and commercial development are used to assess trends affecting groundwater quality.

The goal of Saaf water is to put the hardware-software system in the communities that need it as soon as feasibly possible. That's why the team members, who were both excited and humbled by their win, are also anxious to deploy the solution and make good on their pledge to improve conditions for more than two billion people.

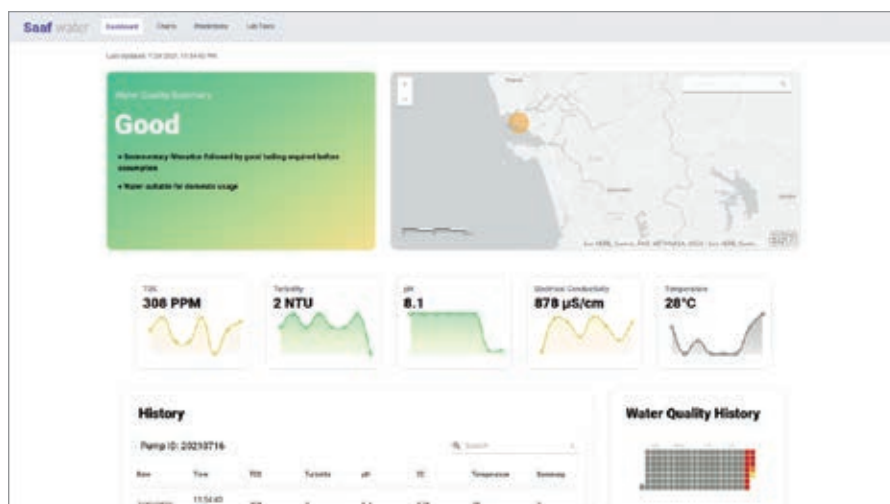
"My family felt proud," Marathe said. "For me, it's not about celebrating the win; it's about getting a long-term responsibility to apply things and to take things forward."

## Climate Change Complicates the Solution

It's not just a lack of proper human waste disposal or industrial runoff that causes biological and chemical contamination. Climate change adds another layer of complexity.

"Because climate change is on the rise, what is happening is sea level is rising and penetrating into groundwater. This pattern increases salinity and bacterial contamination," Bhandari said.

After winning the IBM global challenge, the five members of the group have continued to refine their system. They are trying to collect additional data, including data on historic weather patterns and current water quality. This data will help refine the algorithms that predict when contamination is likely to increase. Warnings can be sent out to those areas and local



group has created a way to alert people in neighborhoods and villages that the water they depend on may sicken them.

Learn more about how GIS is used to manage water quality (<https://bit.ly/3uA62xe>).

## About the Author

Christa Campbell is a director of water industry solutions at Esri. She is a water industry professional who has been successfully using and promoting technology to solve problems in the water industry for 20 years and is recognized for water industry thought leadership, strategic thinking, and building success with organizations across the globe. A passionate GIS advocate and lifelong learner, Campbell has a diverse background that includes digital transformation; remediation for Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) sites; managing GIS; and implementing new technology. She is a certified GIS professional and holds bachelor's degrees in geography and environmental studies and a master's degree in geography.

governments can be alerted to begin more thorough water testing.

## Visualizing the Analysis through Mapping

To make the information accessible to as many people as possible, the group recognized the power of plotting data on maps.

"With maps, what happens is we can create a spatial awareness system," Bhandari said. "Users will get a sense of depth. They'll get a sense of how water quality spreads across the landscape."

That helps governments see the larger picture and trends in contamination. It also can help neighborhoods, communities, and even regions develop a bond over water needs that could translate into the political will needed to solve the problem.

In addition to IBM resources, the group had assistance in creating maps that

allow users to visualize trends and problems. "With Esri India's help recently, we have brought spatial awareness to a new level, which provides our users a sense of what's happening in their neighborhood," Bhandari said.

The Saaf water system also has the capacity to suggest treatment and prevention options based on what the electronic sensors detect in the water. Bhandari's mother went through a terrible three months and seemed proud that her son's project may save others from illness and death.

"I didn't see her reaction in person," Bhandari said. "But from what I heard from her and my brother, she was literally crying when she heard that Saaf water had won [the IBM global challenge]."

Through simple water-testing devices, cloud-based data storage, machine learning, and GIS visualization, the Saaf water

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# Better Wayfinding on Campus with *Indoor Mapping*

Research by students and faculty members at two German universities led to the development of indoor mapping and routing apps that help students and staff members navigate complex campuses.

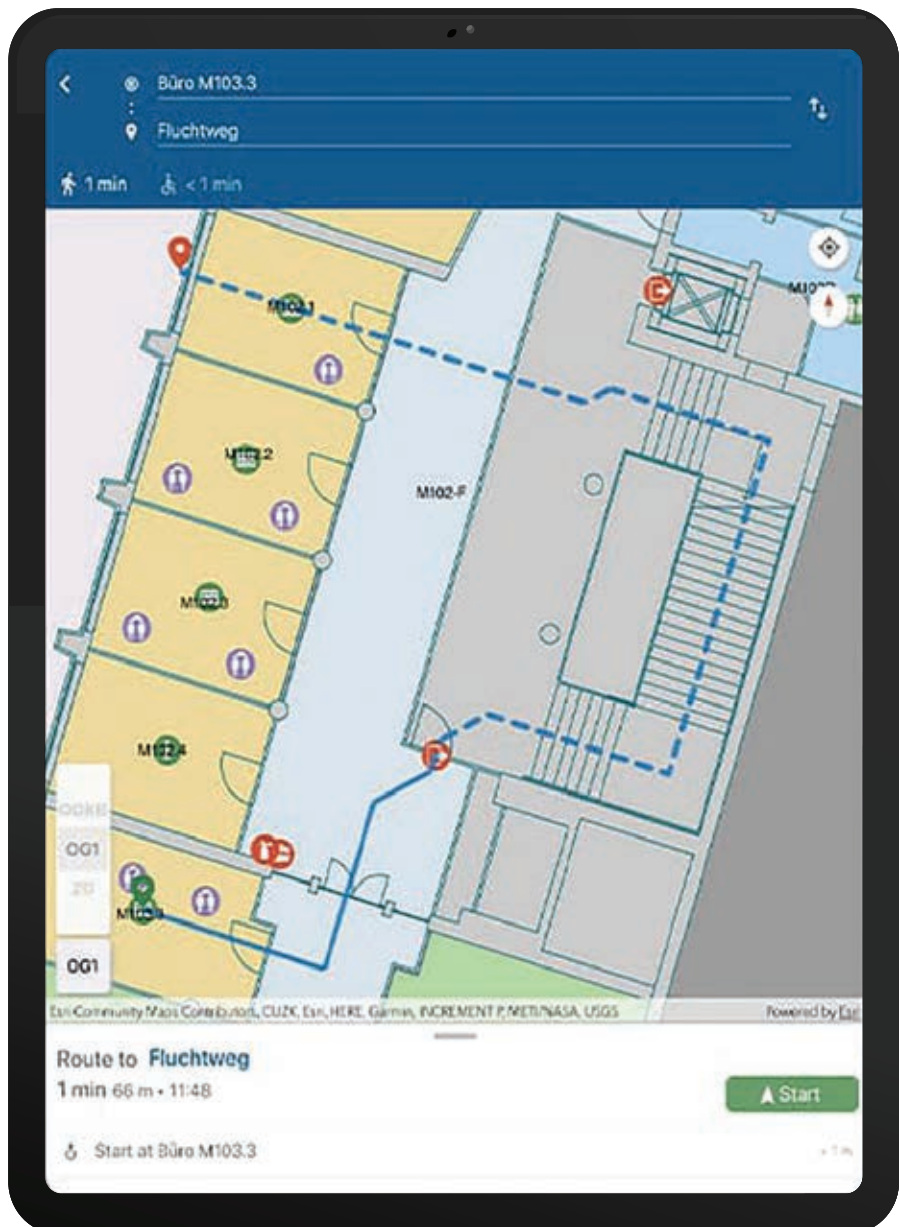
**As longtime** Esri institutional license users, both the University of Applied Sciences Würzburg-Schweinfurt (FHWS) and University of Applied Sciences Dresden (HTW) offer students geoinformation-related degree programs. Students from both universities explored the use of ArcGIS Indoors to create a common operating picture of university buildings for navigation, routing, and location sharing resources university-wide.

“Indoor mapping is a common topic for all universities, because we all have campuses where we spend a lot of time, especially indoors,” said Jan Wilkening, education coordinator for Esri Germany and a professor at FHWS since 2019. “And it is fun for students to cover this topic in a bachelor thesis, because they focus on their everyday life and not on something that is abstract or far away.”

## Exploring the Possibilities of Indoor Mapping

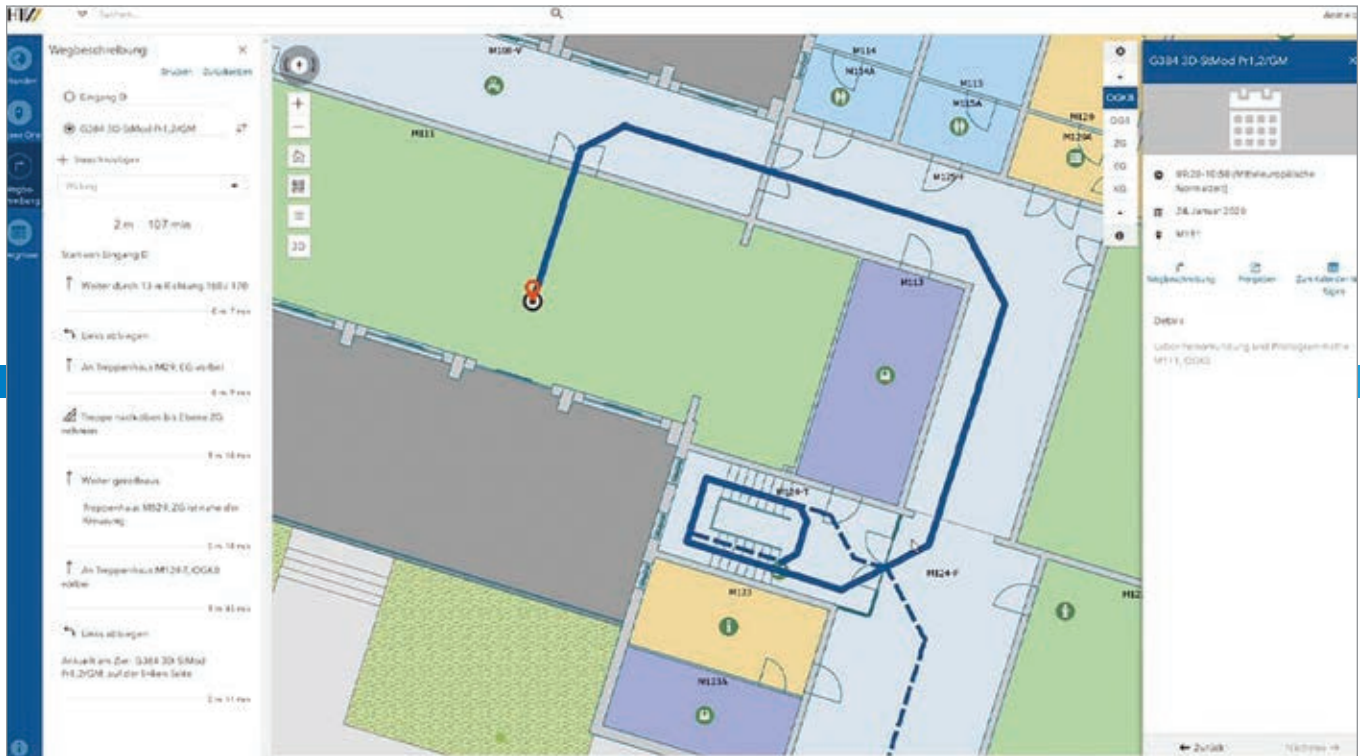
As campuses continue to grow, the universities will need to address indoor navigation demands for students and staff. One option is integrating a campus information system with ArcGIS Indoors. A project led by Rainer Schöffner, an engineer at FHWS, has been investigating techniques and applications for indoor navigation technology since 2014. He has developed a

→ Student Ricardo Roch designed the mobile app using ArcGIS Indoors. In this screenshot, the app is set to pedestrian navigation mode and shows emergency routing. (Screenshot courtesy FHWS/R. Schöffner © 2021 FHWS. All rights reserved.)



esri.com/arcuser Spring 2022 au 63





↑ Roch's app can display multiple layers of information, such as navigation and details for one-time events. For easy navigation, solid lines represent routes on a selected floor, while dotted lines indicate routes on other floors. (Screenshot courtesy of FHWS/R. Schöffner © 2021.)

challenging for students, faculty, and visitors. After seeing a presentation on ArcGIS Indoors, Roch realized the technology could be used to address the campus's navigational challenges.

Within a 10-week period, Roch created a web and mobile navigation app for a campus building. He explored CAD drawings, Revit models, and 3D buildings in different data formats to determine the best one for visualizing information and publishing it on ArcGIS Online so it could be used by desktop and mobile wayfinding applications. His thesis project tested indoor mapping in both 2D and 3D and looked for performance differences between desktop and mobile devices. He incorporated a unique routing system for emergency escape paths and identified wheelchair-accessible directions. Roch's work earned him the Esri Young Scholar Award Germany for 2020.

"It's really brilliant to get an experience like this, to use this software in a thesis, and I like it because it's a very intuitive tool," Roch said. "Now I think it's time to use this technology and to do more research on it. I see the future in indoor navigation

because we can get our position outside precisely, but we are kind of lost indoors. Therefore, it's time to use and prove these technologies."

Roch completed his bachelor's thesis in February 2020 and has entered a master's program with University of Applied Sciences Dresden. For his master's thesis, Roch plans to explore facility management with ArcGIS Indoors. He hopes that his bachelor's thesis can serve as a starting point for other students who see the value in indoor mapping and want to apply it more widely.

### Beyond Theory—What's Next for ArcGIS Indoors

Both Roch and Porzler presented theses that showed how indoor navigation technology could meet wayfinding challenges on campuses and be expanded for use in airports and hospitals.

"I think it's really good for collaboration and big research projects because ArcGIS Indoors has very good performance," Roch continued. "For other students, I can say it's so interesting to work with ArcGIS Indoors, and [I] recommend it. Don't be

afraid to use this software, because everything can work if you want it to, and if *[you need assistance]*, you have Esri contacts at your university who can help."

Porzler noted that if more universities explore ArcGIS Indoors for different projects, its functionality will grow as a result of student collaboration. But in a larger context, Porzler sees the technology growing beyond campuses, for business use as a cost- and time-saving tool.

"I think ArcGIS Indoors has a good possibility to improve building management and convenience for *[other buildings]* that many people pass through because of IPS—for example, airports, universities, conferences, hospitals, or train stations," Porzler said. "It is a great solution, especially if they are already using Esri technology, and I think there will be a lot more functions in ArcGIS Indoors in the *[coming]* months, years, and decades."

For now, both universities will continue to provide students with diverse research opportunities like indoor mapping as well as access to the latest GIS technologies to foster growth in the future of geoinformation and location-based sciences.

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# Cobb County Secures World Series in Real Time

By Carl Walter

By the time the World Series came to Cobb County, Georgia, in fall 2021, the technology and expertise demonstrated by the county 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," said Jennifer Lana, GIS manager at Cobb County Government. "They hadn't seen dynamic data that was so accessible before."

Yet, as the Atlanta Braves took control of the seven-game series the week of November 1, 2021, 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-miles-per-hour, four-seam fastball was grounded out to end game six and the series on November 2, officials in Cobb County, had only 35 hours to organize a party for 350,000 guests.

## Instantly Planning a Party

It had been a while since the Atlanta Braves had a world championship to celebrate. The last time was in 1995 when the team was in a different stadium and a different jurisdiction. Even though there were no set plans or knowledge about how to accommodate championship crowds, Cobb County's investment in sophisticated mapping and monitoring technology and staff have

been tried and tested during big events. This includes the 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 game in Atlanta. This time the huge celebration would include a parade 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, was assigned to handle 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. Lorens would need 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. Lorens gathered barricades that matched the narrow three-lane corridor he had mapped 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 the location of each asset in case of an emergency. The smooth operation of the parade allowed Lorens to craft an efficient plan for removing the barricades beginning 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. Truist Park is located near the intersection of two interstate highways, and authorities wanted to ensure that the stadium location lessened 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 Atlanta, an entertainment district. There are 30 more cameras at 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

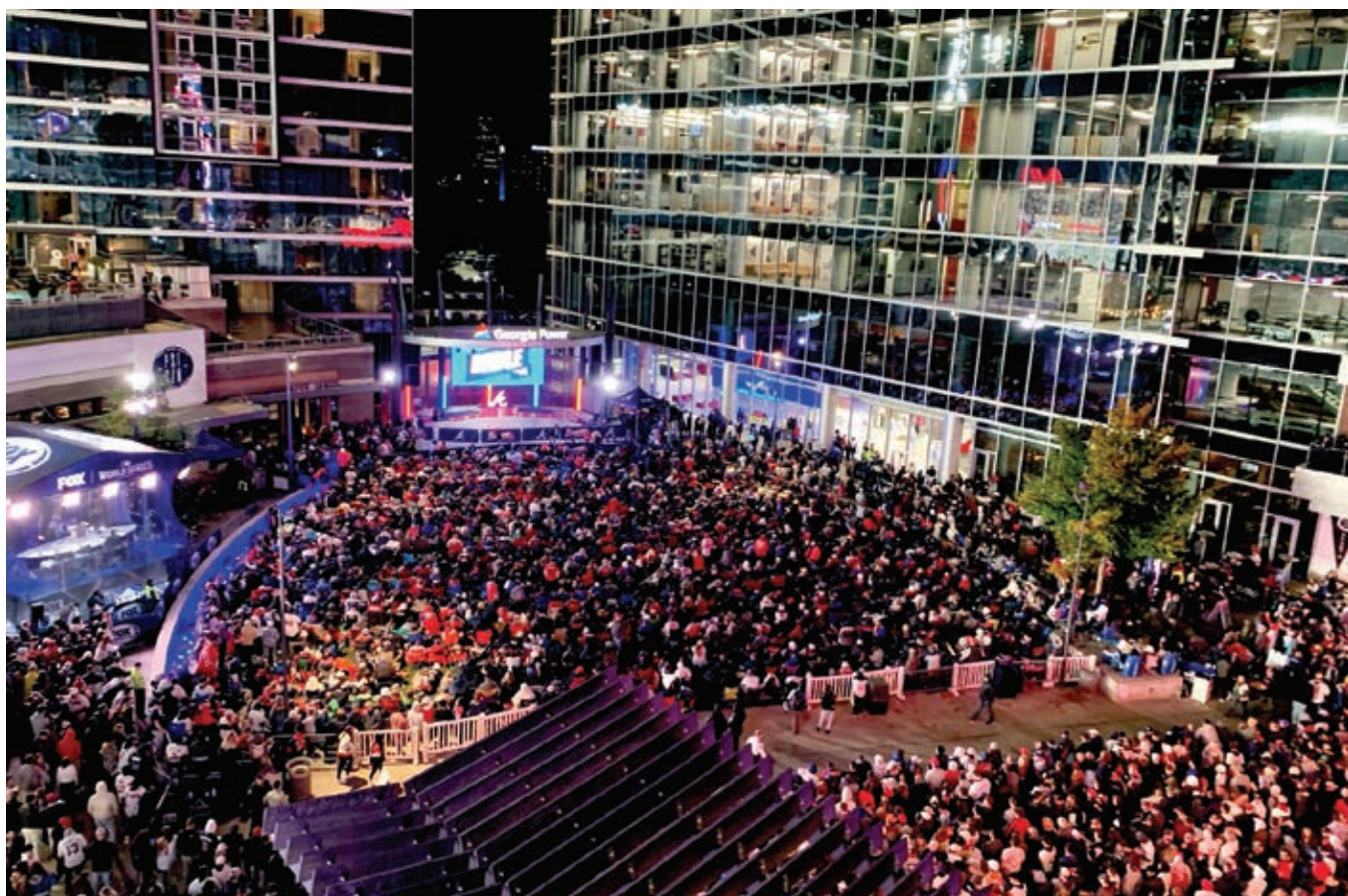
officers synchronize the flow of vehicle and pedestrian traffic during regular games.

Cobb County’s Public Safety departments regularly use GIS dashboards and data to ensure public safety. These seasoned GIS users trust and know how to use the data, maps, and dashboards and have seen how location intelligence helps them. 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 for a typical game was doubled to handle the larger crowds and longer hours. Officers were organized into three main groups: inside the stadium, traffic and operations, and overall campus security. The groups relied on GIS for real-time information and communication.

← Cobb County had to quickly plan a giant celebration after the Atlanta Braves World Series victory including a parade that would wind through downtown Atlanta and culminate at the Braves’ home ballpark, Truist Park.

↓ For the World Series games and the victory celebration, Cobb County Police Department had to ensure the safety of massive crowds.





"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 11:00 a.m. for a 7:00 p.m. game."

Location is also critical for the county's artificial intelligence (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.

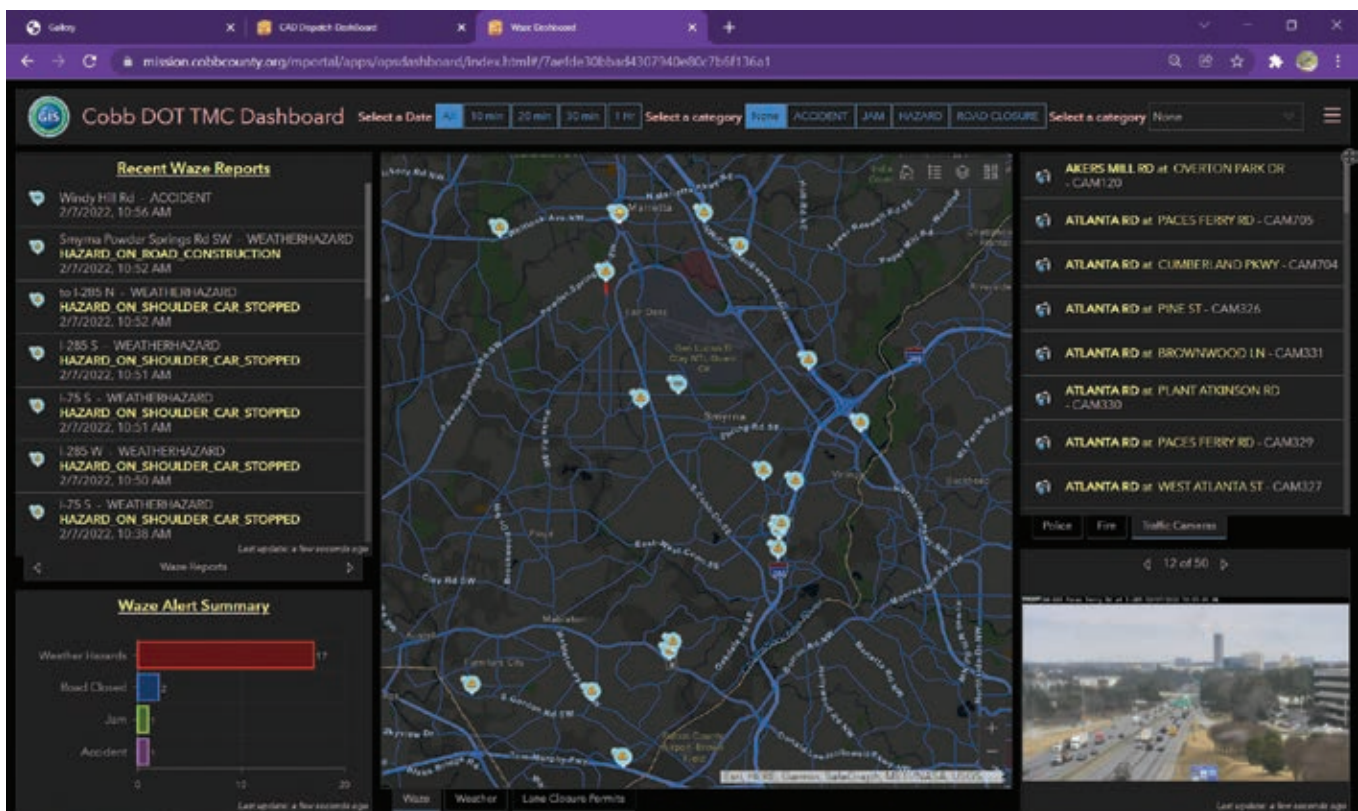
"We have 50 different datasets on the map from the footprint of the stadium, all the businesses, the lights and cameras, the traffic data feed, 911 calls, traffic from Uber and Lyft rideshares, and the location of Cobb County vehicles," Lana said. "We have built that awareness over time, so we didn't 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.

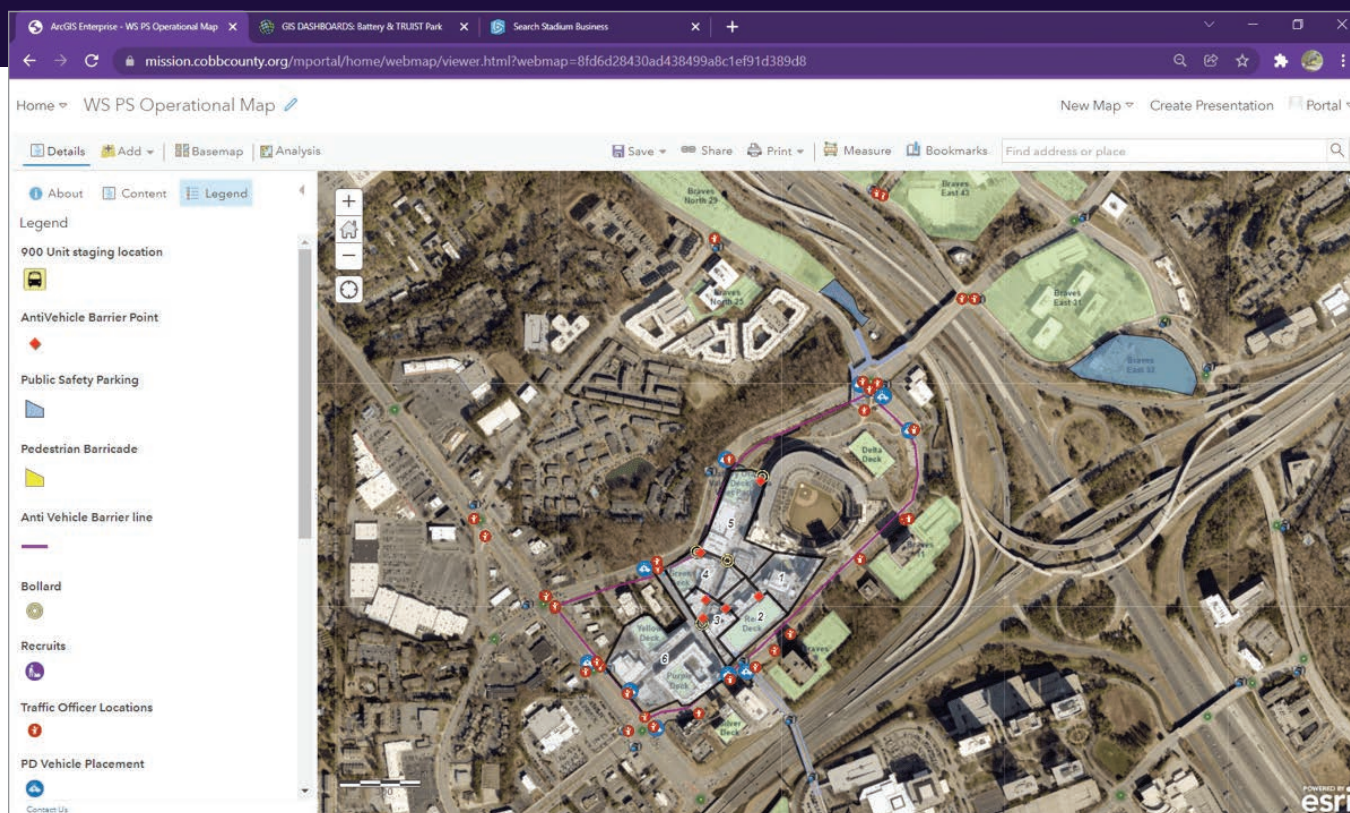
"Once you get to a championship series, it doesn't matter what day the game falls on, because everyone takes off work,"



↙↘ Before Truist Park opened in 2017, Cobb County authorities invested in advanced traffic management technology to monitor and move fans quickly and easily to and from the ballpark and maintain public safety.







↑ Cobb County relied on ArcGIS Mission to track the location of roving plainclothes officers working throughout the area surrounding Truist Park. This enabled the operations center to make tactical resource assignments and get real-time updates from the field, then share information across teams.

→ Managing the parade route required rapid and careful planning.

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 included ArcGIS Mission, which 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, 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, that can get siloed between two people, and here everybody was able to see it and add to it if needed.”





↑ With feeds from 30 cameras at critical intersections, the public safety team used GIS to visualize conditions at every traffic light location.

## Putting the Wraps on a Stellar Season

For Cobb County's World Series games, the use of ArcGIS 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. To ensure safety and ease traffic disruptions, the ability to track officers and floats in real time was critical. This is an operational methodology that 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."

With the Braves' core of young stand-out players, fans in and around Atlanta hope there will be cause for another World Series and parade, another opportunity for Cobb County officials to demonstrate their championship crowd expertise. But considering the age-old

baseball custom against preplanning for victory, they won't put plans in motion too far ahead.

## About the Author

**Carl Walter**, Esri's director of corporate security solutions, is responsible for directing Esri's outreach strategies as they relate to the use of analytical solutions within the homeland and national security markets globally. He joined Esri in 2010, after 20 years of increasing responsibility in law enforcement and intelligence operations. Shortly after the September 11 attacks in 2001, Walter was appointed director of the Boston Regional Intelligence Center, a US Department of Homeland Security designated intelligence fusion center. He embraced the new paradigm of intelligence sharing and established a decentralized security node in the Boston metropolitan area of responsibility, tasked with meeting regional intelligence needs while providing real-time information to help understand the national landscape of terrorist threats and criminal activity. On special assignment, Walter served as the planning section chief for the Democratic National Convention in Boston in 2004. He also served as the director, Bureau of Intelligence and Analysis, for the Boston Police Department. He holds a master's degree in criminal justice from the University of North Carolina at Charlotte, and a bachelor's degree in criminal justice from East Carolina University in Greenville, North Carolina.

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