

ArcUser

The Magazine for Esri Software Users

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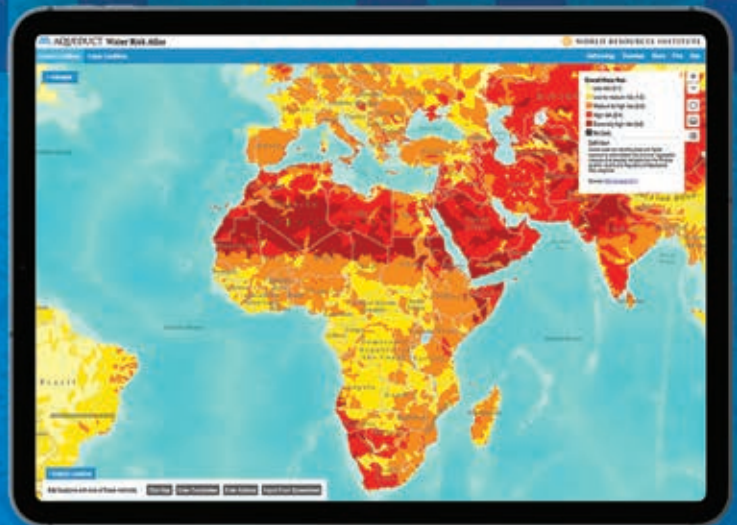
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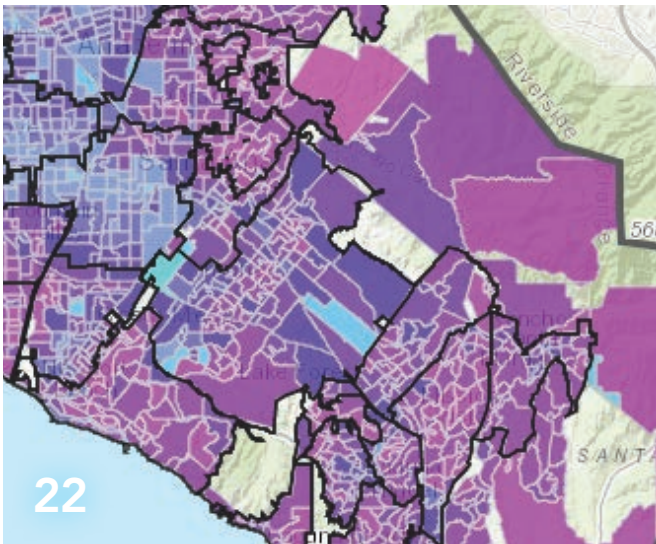
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Partner of the Year



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On the Cover

The cover image shows a relative elevation model (REM) of current and former channels of the Sauk River in Skagit and Snohomish Counties in the state of Washington. REMs reveal where river channels have migrated and are better for visualizing fluvial features than aerial photography or standard digital elevation models (DEMs) in flooding studies. Daniel Coe of the Washington Geological Survey converted a lidar-derived DEM to this REM. The image appears in Coe's chapter in *GIS for Science* from Esri Press.

Something Old That's New

The 2019 Esri User Conference was an occasion for Esri not only to celebrate its 50-year anniversary but, more importantly, the principles that it has adhered to during those five decades: focusing on the success of its users, constantly pushing the limits of GIS technology, and advancing GIS science.

As Esri president Jack Dangermond introduced the conference theme, GIS: The Intelligent Nervous System, he noted that this is both an old and a new idea. It incorporates a view of the Earth that has been foundational to Esri's approach to GIS. As Dangermond said during his plenary address, "This notion is built on the metaphor of the human nervous system." He stressed that the Earth resembles a living organism that is complex, interconnected, self-healing, resilient, and constantly changing.

The User Conference is an event for sharing and celebrating the work of GIS professionals. On the plenary stage, GIS users from businesses, government agencies, and nonprofits shared how they are applying The Science of Where to meet challenges such as the loss of biodiversity and the creation of smarter and more resilient communities.

This annual gathering of the GIS world is also an occasion for unveiling how Esri has extended the integrative, analytical, and visualization capabilities of GIS. As digital technology rapidly changes the world, GIS technology is coevolving and incorporating trends in mainstream IT—artificial intelligence, real-time data, and 3D modeling—just to name a few.

In plenary presentations by both users and Esri staff, advances in the science of GIS and the science in GIS were apparent. From the work done by African Parks detecting poachers through tracking and analyzing elephant movements to the analysis by insurance provider USAA using fire perimeter imagery and ArcGIS Pro's deep learning to classify damage to thousands of buildings in minutes rather than weeks, GIS at scale is making stunning changes in what can be done.

"The geospatial revolution is just beginning. It is going to profoundly transform our world," concluded Dangermond. "Together we have the power to choose the way forward. We have the power to *SEE WHAT OTHERS CAN'T*."



Monica Pratt
ArcUser Editor

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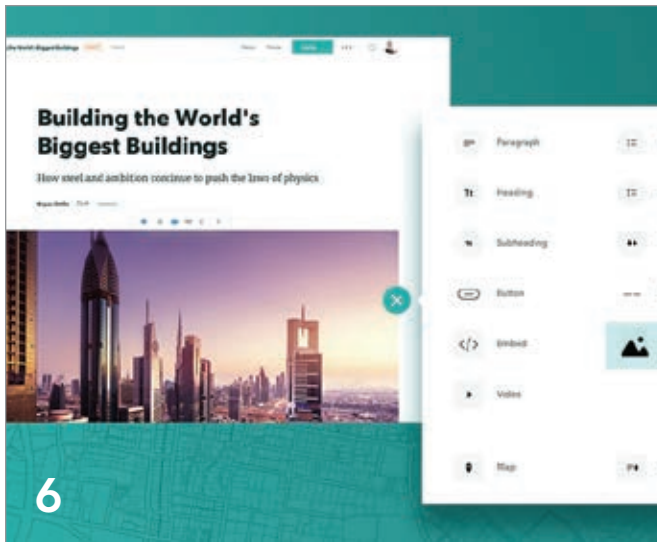
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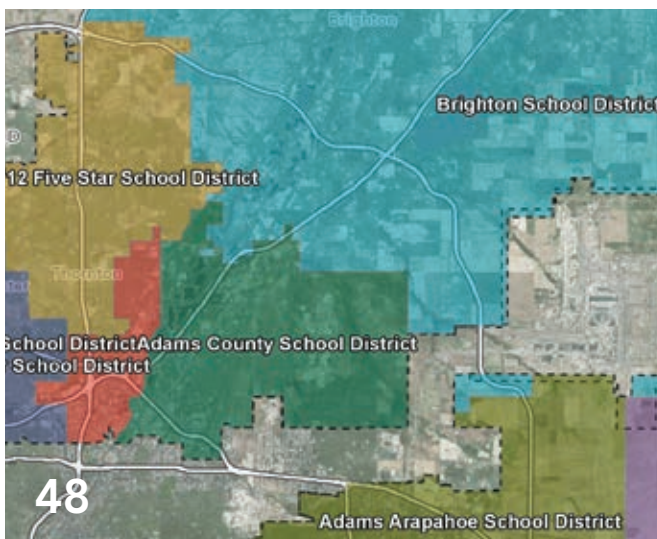
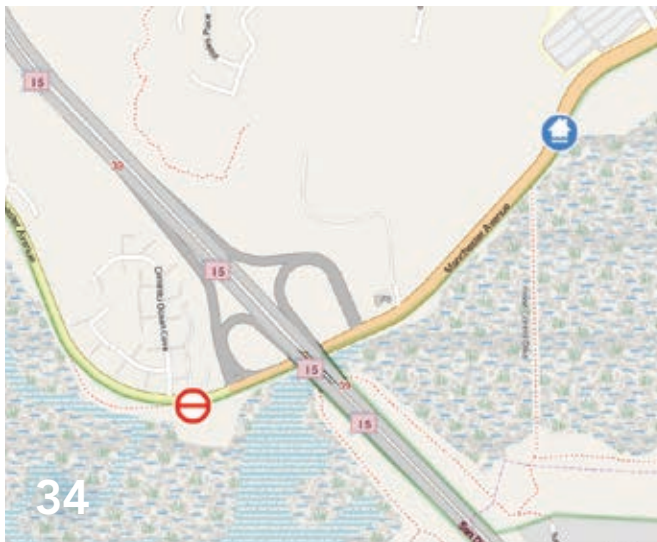
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ArcGIS StoryMaps

Revolutionize the Way You Tell Stories

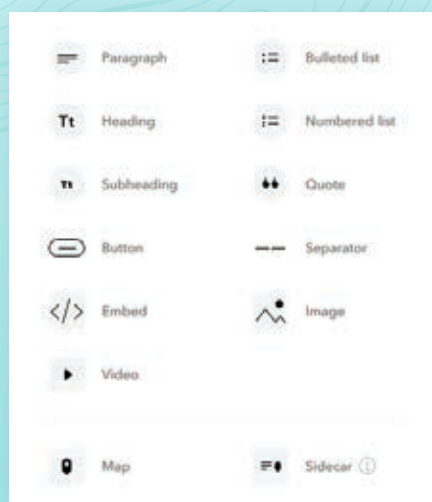
By Allen Carroll

You've got a blockbuster of a story to tell that includes marvelous maps, fabulous photographs, and a riveting narrative. To help you tell your story simply, powerfully, and with style, Esri has developed ArcGIS StoryMaps (esri.com/storymaps).

This new story builder gives you intuitive tools to add maps, pictures, and videos to your narrative; incorporate stylish design; and choose from among predesigned themes that harmonize your story's visual elements.

Why add a new storytelling builder to the repertoire of popular Esri Story Maps app

↓ The block palette contains every element needed to assemble a narrative including regular paragraph text, headings and subheadings, story dividers, quotes, maps, images, and videos.



templates like Story Maps Tour, Story Maps Cascade, and Story Maps Journal?

Well, here's the story.

Esri has been enabling place-based multimedia storytelling for more than seven years, providing everyone—from GIS professionals to journalists and from conservationists to scientists—with the app templates to tell compelling stories about their work. Almost one million stories have been produced using the classic templates.

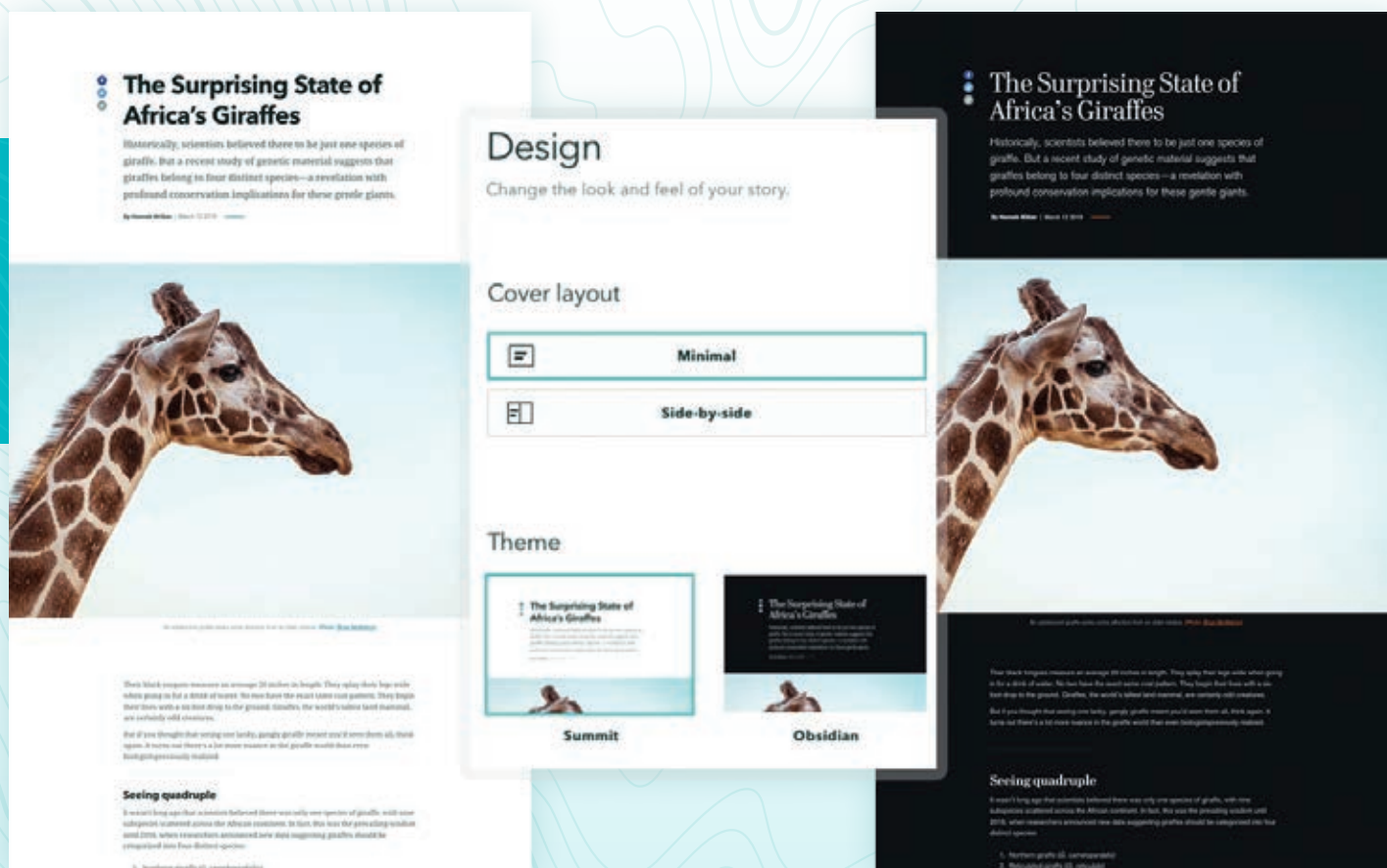
But time and experience taught members of Esri's StoryMaps team—who develop and test the builders and make story maps themselves—that changes needed to be made. The project to design a next generation product launched in 2018. It quickly became clear that to incorporate new features and improved performance capabilities, the team needed to create a new resource rather than continuing to incrementally upgrade the existing storytelling templates. The key benefit of this decision is that you can create a variety of story formats within a single builder.

Based on lessons learned by the team and feedback received from thousands of people across the large Esri Story Maps community, ArcGIS StoryMaps was developed to include the following features:

- A single, unified builder allows you to mix and match the various formats and user experiences from Esri's classic templates and several new formats.
- A new themes function lets you refine the look and feel of your story with a single click.
- With Express maps, you can make simple maps in mere minutes.
- New publishing workflows let you make changes to a shared story but publish your edits only when you are ready.
- A completely redesigned mobile experience minimizes load times and maximizes ease of reading.

Of course, thousands of people use the classic app templates and will want to continue using them. Although the classic apps will be available for some time, try ArcGIS StoryMaps because this new storytelling builder makes it easier and more enjoyable than ever to create rich multimedia narratives.

"The new story map template will allow users to mix and match different classic functionalities, all in a one-stop-shop template," said Amanda Huber, a Minnesota-based GIS technician who helped test ArcGIS StoryMaps before its release. She liked how ArcGIS StoryMaps combines the



↑ Each theme has its own combination of colors, fonts, and basemaps. The first release has two themes: the light background (Summit) and the dark background (Obsidian).

feel of the Story Maps Tour template with the scrolling flow of a Story Maps Cascade template.

Tell a Story Using ArcGIS StoryMaps

The heart of the new ArcGIS StoryMaps is the story builder, and its main feature is a block palette. In the block palette, you can find every element you need to assemble a narrative: regular paragraph text, headings and subheadings, story dividers, quotes, maps, images, videos, and more.

The block palette includes some special items that you should find particularly useful. You can use the embed block to insert web pages, Tweets, and other external web content, either as fully interactive items or as compact cards with titles, thumbnail images, and links.

The sidecar block, the first of several immersive blocks added to the builder, combines a scrolling narrative panel on one side (accommodating text and multimedia

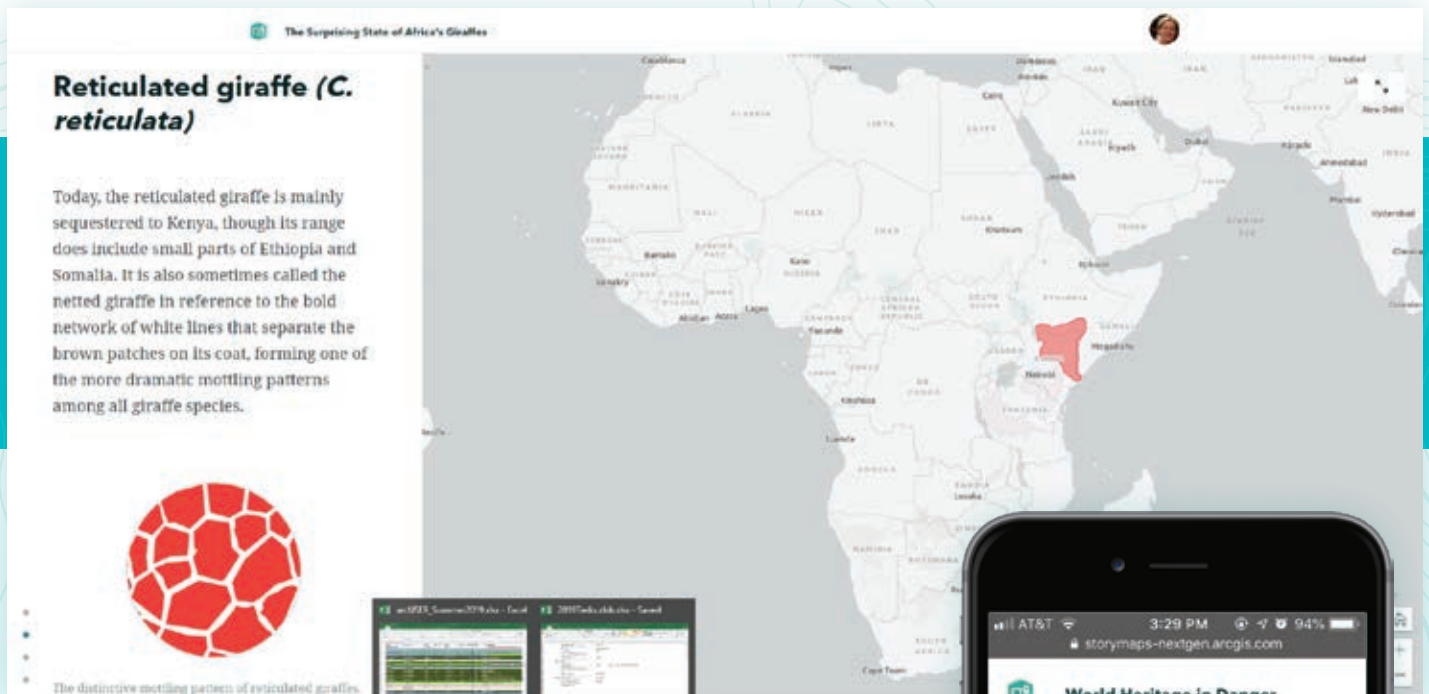
items) with a stationary media panel on the other side to add a unique reading experience to your scrolling story. You can create a series of these pairs, or slides, within a sidecar block, resulting in an experience that closely resembles the classic Story Maps Journal template. Soon, you will see a block that emulates (and improves on) Story Maps Tour.

You can build your story, block by block, using the palette—and you can insert new blocks between the ones you've already created. All the while, your story is saved automatically, eliminating the risk that a browser crash or other mishap will result in lost work.

People are increasingly using story maps as a dynamic, easily updated alternative to Microsoft PowerPoint for giving presentations. With that in mind, Esri will soon introduce a new feature that will let you replace the vertical scroll of the current ArcGIS StoryMaps (and the classic Story Maps Cascade) with a horizontal scroll through a series of slides.

Yet another cool feature of ArcGIS StoryMaps is a design panel that lets you change the theme—the look and feel—of your story with a single click. Each theme has its own combination of colors, fonts, and basemaps. Initially the builder offers themes with a light background (Summit) and a dark background (Obsidian). In the future, new themes will be added. Capabilities will also be added to give you greater flexibility in customizing your stories to match your tastes and your organization's visual style.

The new storytelling builder also makes editing and publishing easier and more flexible. You can create drafts and publish stories for your organization or the public. You can also make extensive edits to a published story. Your edits will be saved as unpublished changes until you're ready to have them appear in the published story. As a final touch, the ArcGIS StoryMaps builder automatically generates a pre-populated panel or card, with title and



↑ ArcGIS StoryMaps introduces express maps so you can quickly create simple, beautiful maps featuring one or a series of points, lines, and areas.

thumbnail image, that appears in social media posts.

Remember—all these features will be available within a single builder. You'll be able to mix and match them in fun and creative ways.

Incorporate Web Maps, Web Scenes, and Express Maps

Shame on me for coming this far having barely mentioned maps! Maps, after all, are what make Esri's storytelling tools uniquely useful and powerful. ArcGIS StoryMaps lets you seamlessly integrate the web maps and 3D web scenes that you've created—or that you've discovered on ArcGIS Living Atlas of the World—into your narrative. Both will work beautifully within the new story maps, even on mobile devices.

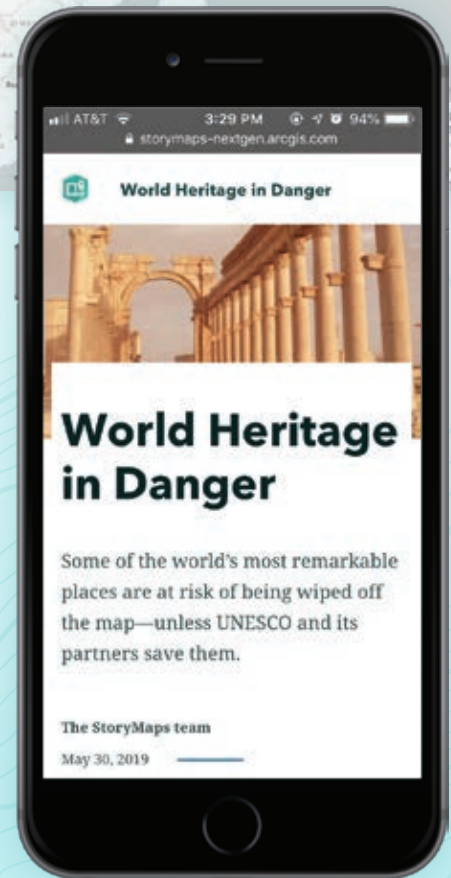
ArcGIS StoryMaps introduces a new mapping alternative: express maps. With express maps, you can quickly create simple, beautiful maps featuring one or a series of points, lines, and areas. You can

create pop-ups with images, titles, and descriptions, and you can add helpful annotations like text and arrows.

Storytelling for Everyone

Story maps have become a kind of *lingua franca* of the geospatial realm. ArcGIS StoryMaps will be even more useful for geospatial professionals and help make place-based storytelling easy and accessible for everyone. Students, researchers, designers, public affairs professionals, and hobbyists all want to tell stories, and they stand to benefit from a product that makes creating highly polished multimedia narratives easy.

These are challenging times. It's more important than ever to use the tools of the digital age to inform the public about issues that affect the health and well-being of individuals, communities, and our planet. Story maps can play an important role in raising awareness; increasing understanding; inspiring people to action; and, ultimately, telling the story of the earth.



↑ ArcGIS StoryMaps stories look great on mobile devices.

About the Author

Allen Carroll is the program manager for storytelling at Esri. He founded the Esri Story Maps team. Prior to joining Esri in 2010, he worked at National Geographic for 27 years in a variety of positions, including art director of *National Geographic* magazine and chief cartographer at National Geographic Maps.

esri.com/storymaps

Become the 2019 StoryMapper of the Year

Everyone loves a good story. The new ArcGIS StoryMaps is a great way to tell one.

Demonstrate your storytelling skills using this next generation story builder by entering the 2019 StoryMapper of the Year Contest sponsored by Esri.

A Simple but Powerful Map Builder

Many government organizations have been using classic Esri Story Maps apps to create stories on many topics, including social issues, the environment, agriculture, sports, health, and tourism. Esri Story Maps apps use templates to combine maps, text, and multimedia content to tell stories.

“Esri Story Maps has evolved tremendously over the past eight years, but this is our biggest leap forward yet,” said Allen Carroll, program manager for storytelling at Esri. “We’ve taken the feedback provided by our storytelling community to create this next generation storytelling tool and deliver a great new experience for our users. Our goal is to enable tens of thousands of people to create sophisticated, map-driven narratives that rival the *New York Times*, the *Guardian*, and the *Washington Post*.”

ArcGIS StoryMaps is a simpler way to tell your story. With ArcGIS StoryMaps, you no longer need templates—you can build stories using the new builder block palette. Mapping is also much simpler. Easy-to-create express maps can be made within the builder itself.

Other major enhancements include one-click design themes that make your content look polished and professional and responsive design that means your content will look beautiful on any mobile device. It’s now possible to author stories from a tablet.

A New Kind of Contest

The 2019 StoryMapper of the Year Contest will work differently than previous story map contests. It adds a community

service dimension. In addition to an ArcGIS StoryMaps entry, participants will be asked to describe how they would use a \$5,000 donation from Esri to make a positive impact on their community through storytelling.

For example, you might want to purchase laptops for seventh graders at a local school and host a classroom workshop on GIS or story maps. Or you could work with a nonprofit to empower the homeless to tell their stories. Your entry will be judged on the merit of your \$5,000 donation idea as well as the story map you submit.

The Esri StoryMaps team and three guest judges will select the top five finalists. The guest judges are geography and storytelling all-stars: Alex Tait, the geographer at National Geographic; Michael Goodchild, professor emeritus and geographer at the University of California, Santa Barbara; and James Fallows, a staff writer for *The Atlantic*.

Once the top five entries are selected, they will be featured on the StoryMapper of the Year Contest website and—starting October 21, 2019—online voting will begin by the public to choose a favorite. Contest participants and the finalists are encouraged to invite their friends and followers to share their favorite entries and vote for the grand prize winner. The entry that gets the most votes receives the grand prize and the entrant becomes the StoryMapper of the Year.

The winners will be announced by Esri president Jack Dangermond on GIS Day (November 13, 2019).

- The grand prize winner will receive
- \$5,000 for use in partnership with a local government entity, school, or nonprofit organization.
 - One Esri Technical Certification exam voucher valued at US\$250.
 - One ArcGIS for Personal Use license valued at US\$100.
 - A certificate of recognition.

The four runners-up will each receive \$1,000 for use in partnership with a local government entity, school, or nonprofit organization plus the same voucher, license, and certificate of recognition described previously. Esri will also promote the finalists on esri.com and on the company’s social media sites.

To start creating your own story map, visit ArcGIS StoryMaps (esri.com/storymaps). For more information on classic Esri Story Maps and how to switch to ArcGIS StoryMaps, visit the ArcGIS StoryMaps product road map page (storymaps.arcgis.com).

The StoryMapper of the Year Contest started July 8, 2019, and the deadline for submission is 5:00 p.m. (PDT), September 30, 2019.

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DEEP LEARNING + GIS = OPPORTUNITY

By Rohit Singh

The field of artificial intelligence (AI) has progressed rapidly in recent years, matching or, in some cases, even surpassing human accuracy at tasks such as image recognition, reading comprehension, and translating text. The intersection of AI and GIS is creating massive opportunities.

AI, machine learning, and deep learning are helping us make our world better by increasing crop yields through precision agriculture, fighting crime by deploying predictive policing models, and predicting when the next big storm will hit so we can be better equipped to handle it.

Broadly speaking, AI is the ability of computers to perform tasks that typically require some level of human intelligence. Machine learning is one type of engine that makes this possible. It uses data-driven algorithms that learn from data to give you the answers that you need. One type of machine learning that has emerged recently

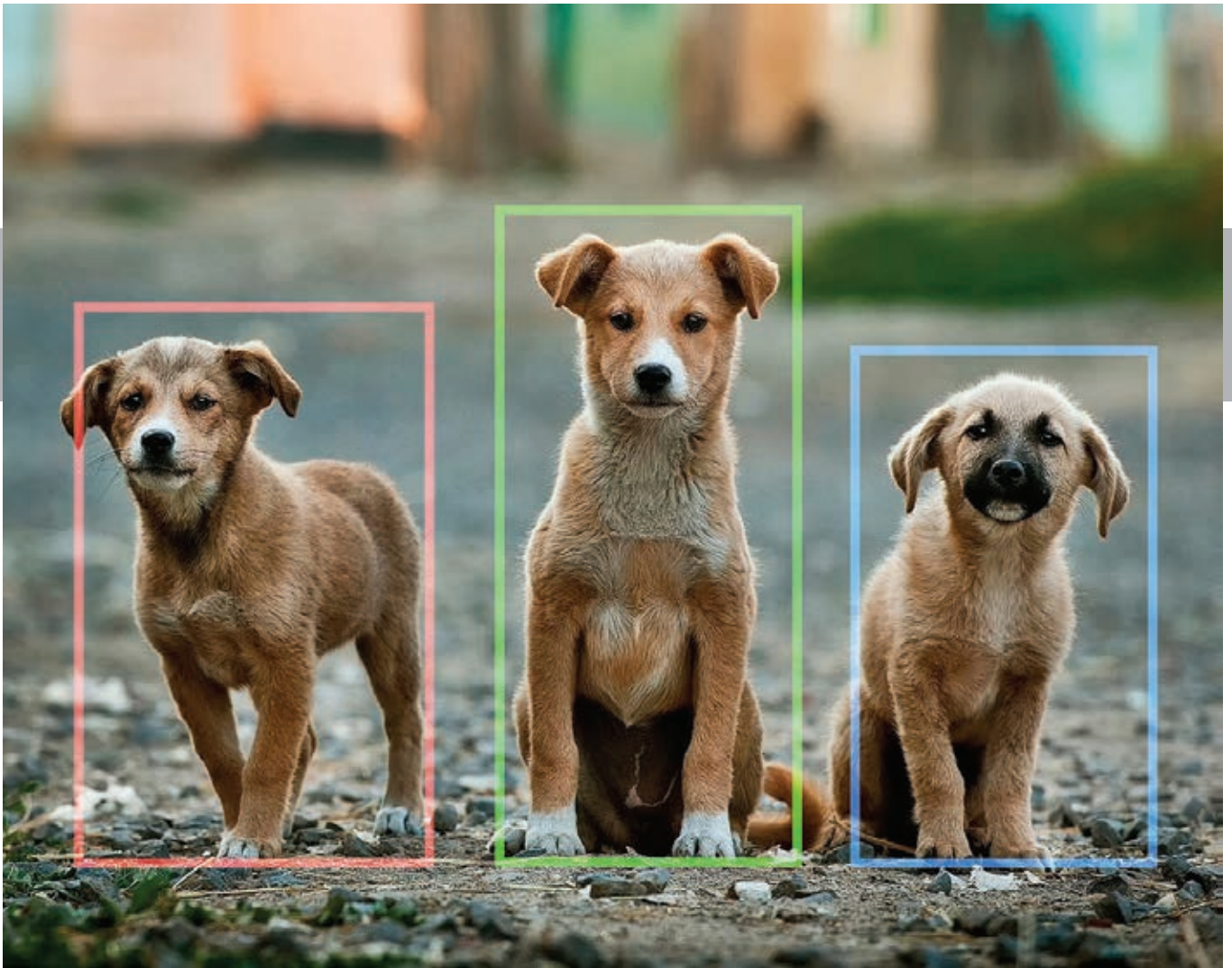


← ↑ In image classification, the computer assigns the label “cat” to an image of a cat (left). The computer classified the image above as a dense crowd.

is deep learning. Deep learning uses computer-generated neural networks, which are inspired by and loosely resemble the human brain, to solve problems and make predictions.

MACHINE LEARNING IN ArcGIS

Machine learning has been a core component of spatial analysis in GIS. Its tools and algorithms have been applied to geoprocessing



↑ → In object detection, the computer finds objects within an image (above) as well as the objects' location (right).

tools to solve problems in three broad categories: classification, clustering, and prediction. With classification, you can use vector machine algorithms to create land-cover classification layers. Clustering lets you process large quantities of input point data, identify the meaningful clusters within this data, and separate meaningful clusters from the sparse noise. Prediction algorithms, such as geographically weighted regression, give you the ability to model spatially varying relationships. These methods work well in several areas. Their results are interpretable, but they need experts to identify or include those factors (or features) that affect the outcome being predicted.

THE RISE OF DEEP LEARNING

Wouldn't it be great if the machine figured out what those factors/features should be just by looking at the data? That's where deep learning comes in. In a deep neural network, there are neurons that respond to stimuli and are connected to each other in layers. Neural networks have been around for decades, but it has been a



challenge to train them.

The advent of deep learning can be attributed to three primary developments in recent years—availability of data, fast computing, and algorithmic improvements:

DATA: We now have vast quantities of data, thanks to the Internet, the sensors all around us, and the numerous satellites that are imaging the whole world every day.

COMPUTING: With cloud computing, we have powerful computational resources. Graphics processing units (GPUs) have become more powerful than ever and gone down in price, thanks to the gaming industry.

ALGORITHMIC IMPROVEMENTS: Finally, researchers have now cracked some of the most challenging aspects of training deep neural networks through algorithmic improvements and network architectures.

APPLYING COMPUTER VISION TO GEOSPATIAL ANALYSIS

One area of AI where deep learning has done exceedingly well is computer vision, or the ability for computers to see. This is particularly useful for GIS because satellite, aerial, and drone imagery is being produced at a rate that makes it impossible to analyze and derive insight through traditional means.

Image classification, object detection, semantic segmentation, and instance segmentation are some of the most important computer vision tasks that can be applied to GIS. The simplest task is image classification. For example, the computer assigns the label “cat” to an image of a cat. In GIS, this classification is used to categorize geotagged photos. Another image, classified as “dense crowd,” can be used by GIS for pedestrian and traffic management planning during public events.

With object detection, the computer needs to find the objects within an image as well as their location. This is a very important task in GIS because it finds what is in a satellite, aerial, or drone image, locates it, and plots it on a map. This task can be used for infrastructure mapping, anomaly detection, and feature extraction.

Another important computer vision task is semantic segmentation. Each pixel of an image is classified as belonging to a specific class. In GIS, semantic segmentation can be used for land-cover classification or the extraction of road networks from satellite imagery.

An early example of the use of semantic segmentation and its impact is the success the Chesapeake Conservancy has had in combining Esri’s GIS technology with the Microsoft Cognitive Toolkit (CNTK) AI tools and cloud solutions to produce the first high-resolution land-cover map of the Chesapeake watershed. This work is available on GitHub (github.com/Azure/pixel_level_land_classification) and can be deployed on a Microsoft Data Science Virtual Machine (DSVM) on Azure. [Read “Tackling a Monumental Project” in the Spring 2018 issue of *ArcUser* to learn more about the Chesapeake Conservancy project.]

Another type of segmentation is instance segmentation. You can think of this as a more precise object detection in which the precise boundary of each object instance is marked out. Instance

segmentation can be used for tasks like improving basemaps. This can be done by adding building footprints or reconstructing 3D buildings from lidar data. Esri recently collaborated with NVIDIA to use deep learning to automate the manually intensive process of creating complex 3D building models from aerial lidar data for Miami-Dade County in Florida.

DEEP LEARNING FOR MAPPING

In working with satellite imagery, one important application of deep learning is creating digital maps by automatically extracting road networks and building footprints. Imagine applying a trained deep learning model on a large geographic area and producing a map containing all the roads in the region, then having the ability to create driving directions using this detected road network. This can be particularly useful for developing countries that do not have high-quality digital maps or in areas where newer developments have been built.

Good maps need more than just roads—they need buildings. Instance segmentation models like Mask R-CNN are particularly useful for building footprint segmentation and can help create building footprints without any need for manual digitizing. However, these models typically result in irregular building footprints that look more like masterpieces by the Spanish architect Antoni Gaudí than regular buildings with straight edges and right angles. Using the Regularize Building Footprint tool in ArcGIS Pro can help restore the straight edges and right angles necessary for an accurate representation of building footprints.

INTEGRATING ArcGIS WITH AI

ArcGIS has tools to help with every step of the data science workflow including data preparation and exploratory data analysis; training the model; performing spatial analysis; and finally, disseminating results using web layers and maps. To add context and depth to your analyses, you can use content from Esri’s ArcGIS Living Atlas of the World. This large collection of Esri-curated and partner-provided imagery can be critical to a deep learning workflow.

ArcGIS Pro includes tools for helping with data preparation for deep learning workflows and has been enhanced for deploying trained models for feature extraction or classification. ArcGIS Image Server in the ArcGIS Enterprise 10.7 release has similar capabilities, providing the ability to deploy deep learning models at scale by leveraging distributed computing.

The `arcgis.learn` module for ArcGIS API for Python on GitHub (<https://bit.ly/2Wv750F>) enables GIS analysts and data scientists to train deep learning models with a simple, intuitive API. ArcGIS Notebooks provides a ready-to-use environment for training deep learning models.

ArcGIS includes built-in Python raster functions for object detection and classification workflows using CNTK, Keras, PyTorch, fast.ai, and TensorFlow. Additionally, you can write your own Python raster function that uses your deep learning library of choice or specific deep learning model/architecture. See a handy



← ↓ In semantic segmentation, each pixel of an image is classified as belonging to a specific class (left). Semantic segmentation can be used for extracting road networks from satellite imagery (below).

guide on GitHub at <https://bit.ly/2EGUY6W> to get started.

Deep learning is a rapidly evolving field that allows data scientists to leverage cutting-edge research while taking advantage of an industrial-strength GIS. Python, chosen as the primary programming language of popular libraries such as TensorFlow, PyTorch, and CNTK, has emerged as the *lingua franca* of the deep learning world. ArcGIS API for Python and ArcPy, a Python site package, are a natural fit for integrating with these deep learning libraries that





← ↓ Instance segmentation is a more precise type of object detection. The precise boundary of each object instance is marked out. It can be used for improving basemaps by adding building footprints.

give you more capabilities.

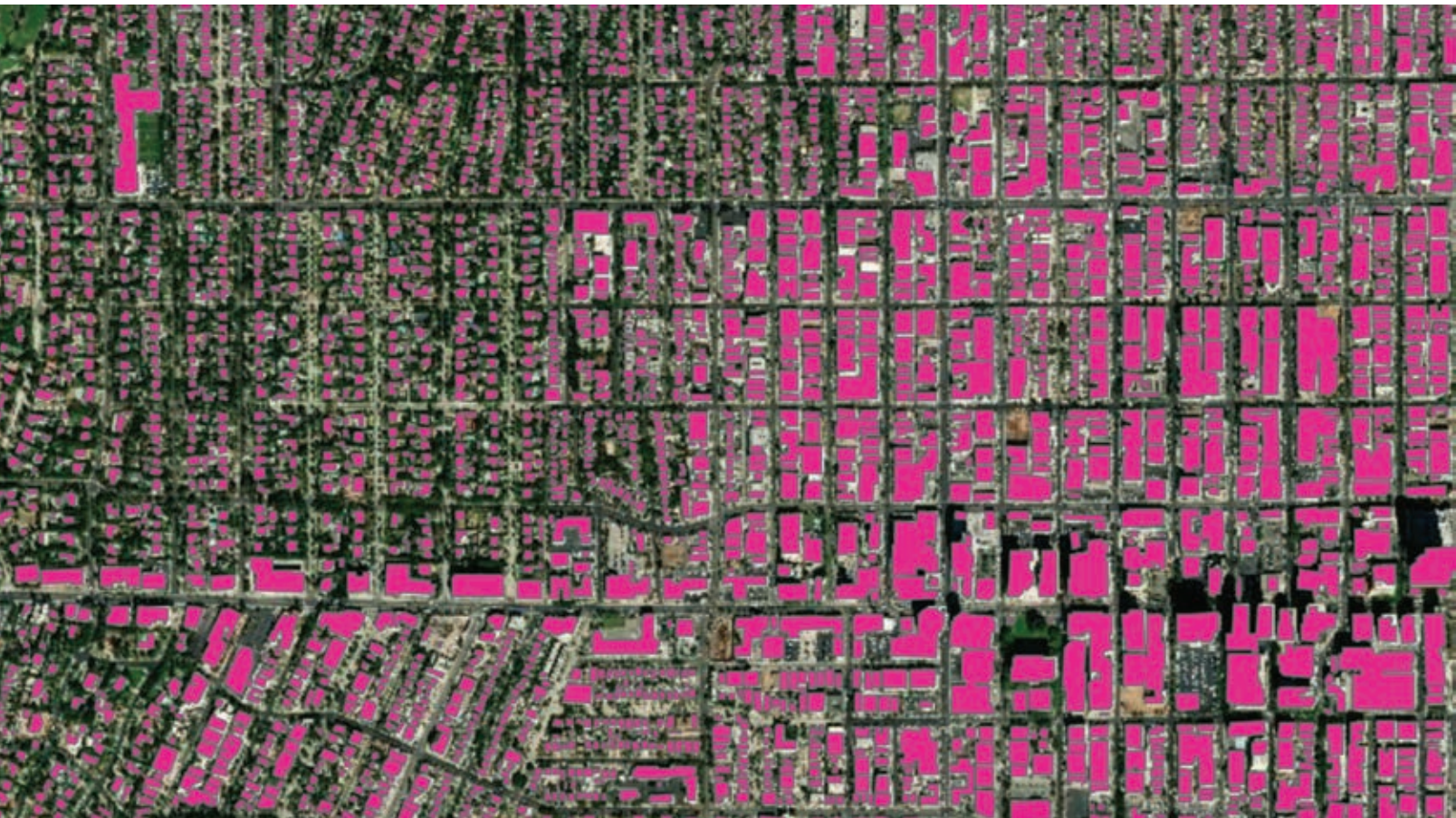
While the examples in this article have focused on imagery and computer vision, deep learning can be used equally well for processing large volumes of structured data such as observations from sensors or attributes from a feature layer. Applications of such techniques to structured data include predicting the probability of accidents,

sales forecasting, and natural language routing and geocoding.

Esri is investing heavily in these emerging technologies and has started a new R&D center in New Delhi, focused on AI and deep learning on satellite imagery and location data.

ABOUT THE AUTHOR

Rohit Singh is the managing director of the Esri R&D Center in New Delhi, India. He leads the development of data science, deep learning, and geospatial AI solutions in the ArcGIS platform. He is passionate about deep learning and its intersection with geospatial data and satellite imagery. Singh has been recognized as an Industry Distinguished Lecturer for the IEEE Geoscience and Remote Sensing Society (GRSS).



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Briefly Noted

→ Jane Goodall Institute and Esri to Provide Community Mapping Tools That Will Protect Nature

“Conservation at the community level is essential to sustaining our natural world,” said Jack Dangermond, Esri founder and president. “Protecting global ecosystems cannot work on a global scale unless it starts locally, which is why we are honored to work with our friend and partner, the Jane Goodall Institute, on this collaboration, leveraging their years of experience working at the local scale in pursuit of conservation, balanced with the needs of human communities.”

The partnership with the Jane Goodall Institute (JGI) will jointly develop a set of tools to help communities map and manage local ecosystems using a collaborative design and planning approach aided by GIS. These tools will help communities map, monitor, and better manage natural resources such as community forests, wildlife reserves, water catchment and flood control areas, human settlements, agricultural lands, and agroforestry spaces.

JGI’s community-centered conservation approach, called TACARE, partners with local communities and governments to create sustainable livelihoods while planning for and advancing environmental protection. “A key component of our success is that we work to help villagers find ways to make livelihoods that do not destroy the environment and help them understand that protecting the environment not only conserves wildlife, but *[also]* their own future. The geospatial technologies that Esri provides will enable us to scale up our projects so that we cover hundreds of villages, ensuring that information is actionable and relevant to decision-makers to help design and manage landscapes that better support people’s livelihoods, as well as wildlife,” said Dr. Jane Goodall, DBE, founder of the JGI, and a United Nations Messenger of Peace.



→ View Crops over Time

The United States Department of Agriculture (USDA) supports American agriculture by gathering statistics of cultivated land cover, tracking what crops are planted and where they are growing, and making that data available in the USDA National Agricultural Statistics Service (NASS) CropScape cropland layer of the United States (nassgeodata.gmu.edu/CropScape/). For the first time, CropScape has been published as a time series in the ArcGIS Living Atlas of the World under the service name USA Cropland. In 2008, the first year all 48 conterminous US states were produced in one piece under the CropScape name, Esri obtained the layer and now has assembled all 11 CropScape growing seasons since 2008 into a one-year-per-frame series that is ready for both analysis and animated display.



→ Esri Commits Technology and Expertise to Initiative Protecting Biodiversity

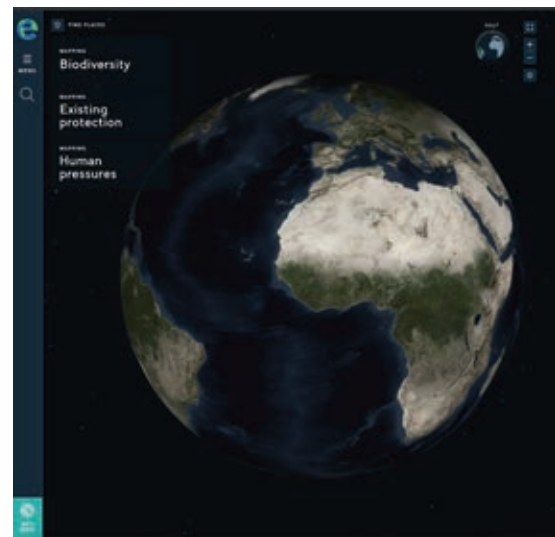
Esri has partnered with the E.O. Wilson Biodiversity Foundation to support the Half-Earth Project with ArcGIS mapping and analytics capabilities. The goal of this initiative is to conserve half the earth's lands and seas to reverse the species extinction crisis currently threatening the planet. The goal of the project is to map global species distribution in unprecedented detail and use this information to identify conservation priorities that will safeguard species diversity. The Half-Earth Map will provide decision-makers and communities with the information they need to make informed conservation management decisions that meet the needs of both people and biodiversity.

Esri will provide its geospatial cloud, ArcGIS Living Atlas of the World, and significant geospatial and geoscience expertise, as well as financial support. In addition, Esri is asking its global user community to share biodiversity data to support the ongoing Half-Earth Project mapping and analytic efforts. "By working together, we believe it will be possible to accelerate efforts worldwide to identify not just species at risk but also the areas of the planet that must be set aside and protected for long-term conservation of biodiversity. My personal belief is that this effort is critically important for the earth's future," said Jack Dangermond, Esri founder and president.

To learn more about how Esri is helping preserve the earth's ecosystems, visit go.esri.com/half-earth.

→ Esri and Mobileye Collaboration Expands Access to High-Definition Map Data

The collaborative agreement between Esri and Mobileye, a leading provider of advanced driver-assistance systems software, will bring Mobileye's advanced real-time, high-definition mapping and location data collection capabilities into Esri's platform as native services. Esri customers will be able to visualize and analyze mapping and location data streamed from vehicle sensors equipped with Mobileye technology, enabling a new type of living, dynamic map on the Esri platform. The new agreement vastly expands the existing relationship between Esri and Mobileye, an Intel company, bringing advancements in both safety and data collection. The agreement enlarges the scope and makes this data more accessible to Esri customers. The dynamic nature of this new data source will enable better decision-making and greater automation for Esri customers.





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Preserving Voter Rights with the Help of GIS

By Jeremy Byrum

For Native Americans living in North Dakota, GIS technology has helped address a significant question: How can their voting rights be preserved in the face of a new, statewide voter identification law?

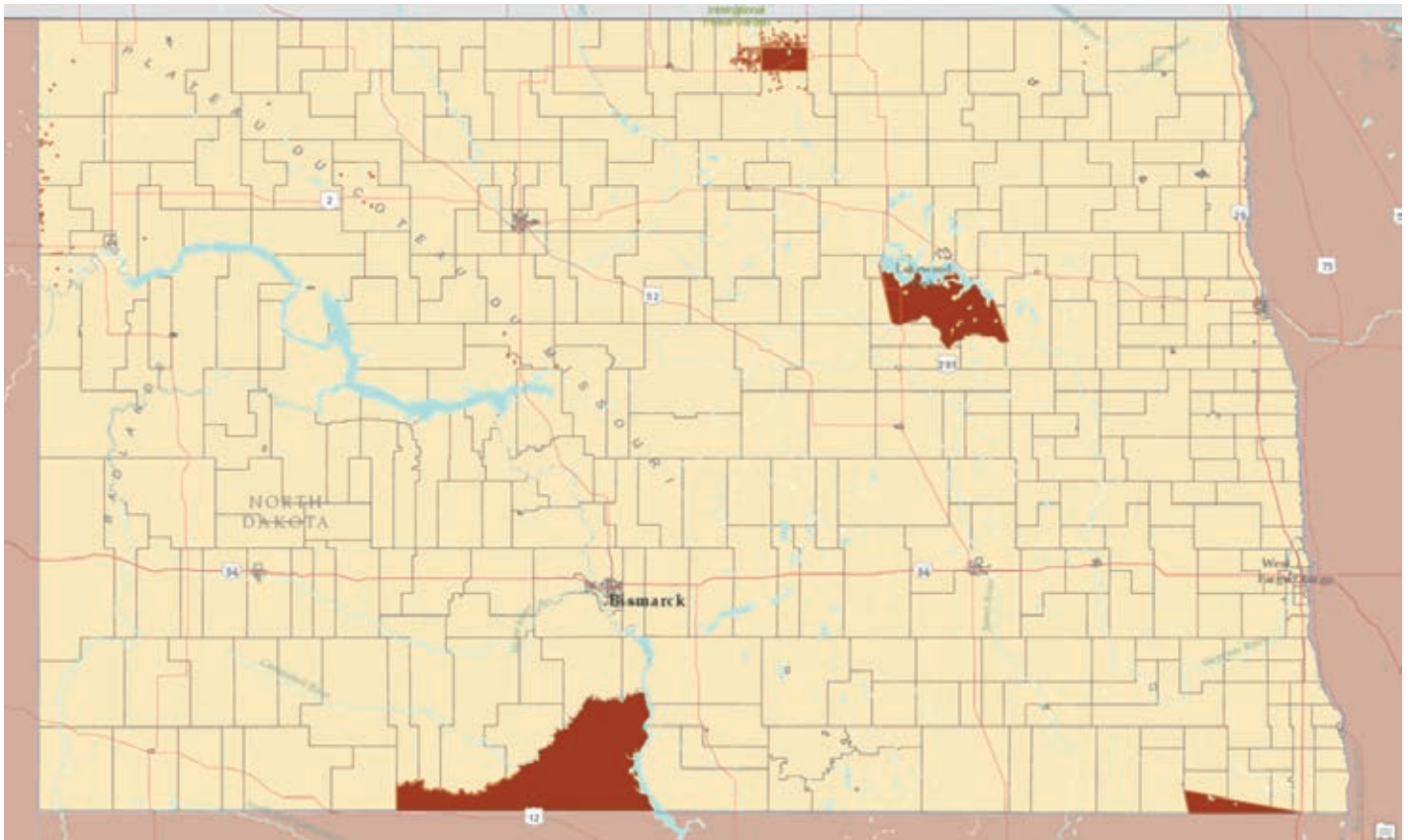
Just weeks prior to the 2018 midterm elections, the US Supreme Court voted not to intervene and let stand a lower court decision upholding a state law that requires that all North Dakota residents present identification with a street address before being allowed to vote.

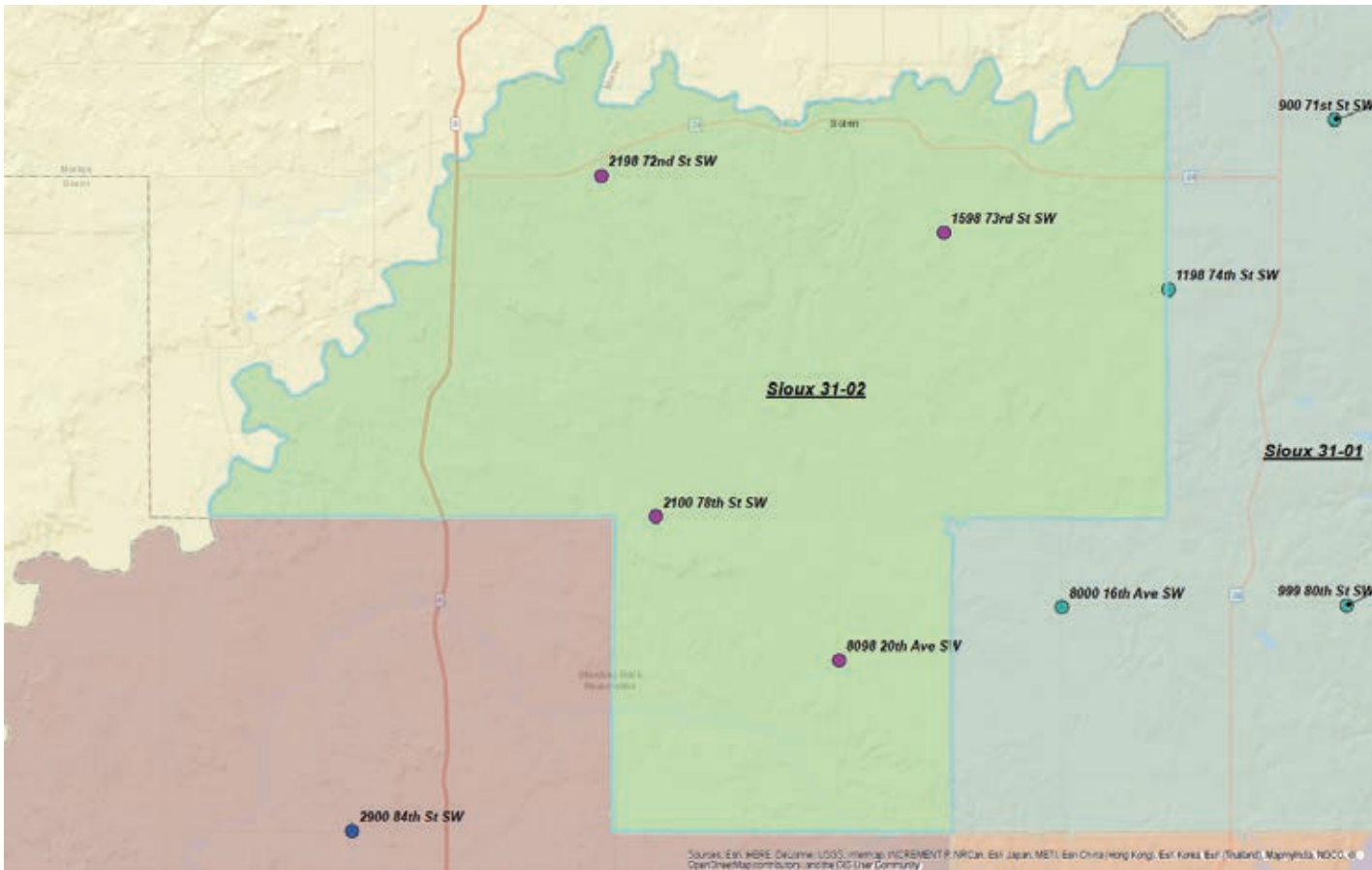
Many of the state's nearly 30,000 Native Americans live on reservations and do not have street addresses. Reservations have dirt roads, streets without signs, and nearby structures identifiable by their features, not numbers. Instead of addresses, many residents use post office boxes.

But the use of post office boxes is no longer acceptable under this new legislation, which went into effect 30 days before the November 2018 midterms. Even though supporters of the law said it was necessary to prevent voter fraud at the ballot box, the law also threatened to prevent many residents on reservations from exercising their right to vote.

Four Directions, a Native American voter rights advocacy group that has been fighting against that law's restrictive impact since its inception, reached out to Jean Schroedel, a professor of politics and policy at Claremont Graduate University (CGU). Having worked

↓ Brian Hilton obtained the voting precincts in North Dakota and selected the precincts that intersected the Standing Rock, Turtle Mountain, and Spirit Lake reservations.





↑ After splitting the precincts that intersected reservations into four areas, Hilton identified locations suitable for an address, created a new point, and assigned a street and address to it.

on Native American voting rights (and with Four Directions) in the past, Schroedel was poised to find a solution for the affected residents of the Standing Rock, Turtle Mountain, and Spirit Lake reservations in North Dakota.

Schroedel turned to her colleague Brian Hilton for help. Hilton is a specialist in GIS in the university's Center for Information Systems & Technology, director of the advanced GIS lab, and a longtime user of Esri technology. The two had worked together on a related matter several years prior regarding the court case *Wandering Medicine vs. McCulloch*. That case dealt with voter access for members of isolated tribes in Montana. Hilton had helped illustrate with geographic data that voter turnout was significantly impeded due to travel distance, geographic obstacles, and other socioeconomic factors.

This time, with the midterms drawing near, the project required haste. With just two weeks to Election Day, Hilton went to work. After obtaining shapefiles of the voting precincts in North Dakota

from the Harvard Election Data Archive, he selected the precincts that intersected the Standing Rock, Turtle Mountain, and Spirit Lake reservations. He split those precincts into four roughly equal areas. He identified locations in each precinct quadrant that were not on an existing house but were on a physical road that had a name (e.g., 35th Avenue SW).

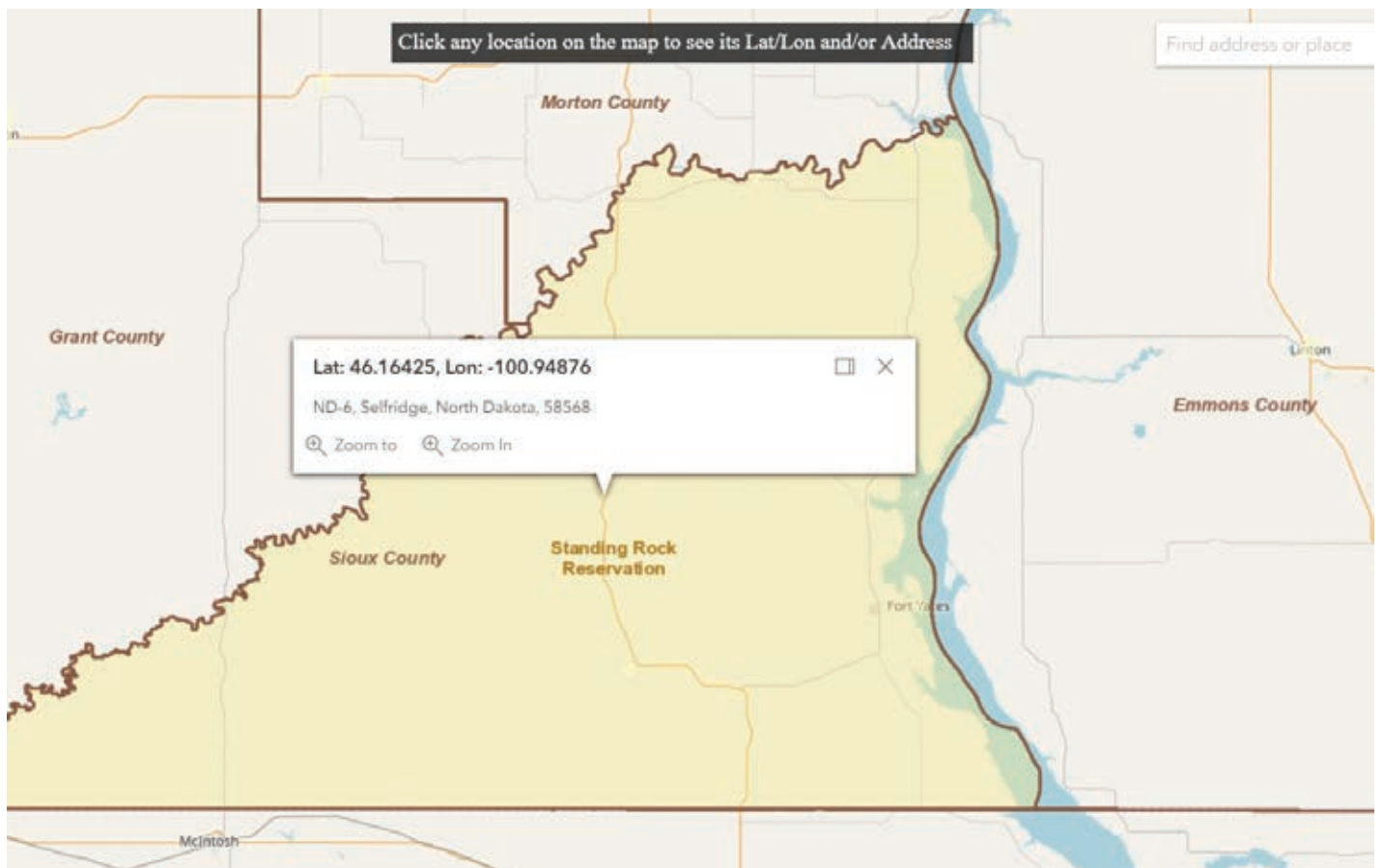
"It was somewhat laborious, as you have to zoom in and zoom out [of the map] and see if there are buildings or anything nearby to find a location that's suitable for an actual address," explained Hilton. It required that he use both ArcMap and ArcGIS Online to constantly consult Imagery, Streets, and OpenStreetMap basemaps.

At each location suitable for an address, he created a new point and assigned it a street

and address using the Burkle addressing system to determine the street number. *[The Burkle addressing system was devised for assigning road names and addresses in rural areas and is used in North Dakota to establish rural addresses for mail delivery and 911*

I can't think of another time where I felt that the research...mattered quite as much.

Jean Schroedel
Claremont Graduate University



↑ To demonstrate that address geocoding was not possible in many locations in the reservations, Hilton used the ArcGIS API for JavaScript to create an outline map that showed that addresses for many locations did not exist in the database.

response.] For each point, Hilton added address information to a spreadsheet and created corresponding maps of each precinct quadrant.

To demonstrate that address geocoding was not possible in many locations in the reservations, Hilton also used the ArcGIS API for JavaScript to create an online map that showed that addresses for many locations did not exist in the database. For many locations, the only information that could be provided was latitude-longitude coordinates. The tribes used the online map to explain why Hilton needed to create addresses for Native American voters living on the reservations.

The spreadsheets and PDF maps Hilton produced were sent to Four Directions. The organization then brought these materials to polling places so Native American voters could point to their residence and have an address given to them. Four Directions even funded the cost of printing new IDs with street addresses and helped shuttle residents to and from polling places.

The result? Voter turnout for the Standing Rock, Turtle Mountain, and Spirit Lake reservations was the highest ever recorded. It is anticipated that similar increases could occur if these methods were widely distributed to other places with similar challenges. If the issue of disenfranchisement based on a street address requirement arises again, the tools are now in place to combat it.

Hilton observed that Native Americans could further benefit from

this work, as it could provide first responders with a better method of identifying the location of 911 calls and other related emergencies. The impact of this work has also received extensive coverage including articles in *Time* magazine and the *New York Times*.

The collaboration of Schroedel and Hilton, which brought the university's politics and policy program and information science program together to find a solution to the problem, epitomizes CGU's emphasis on transdisciplinary efforts. The university's teaching philosophy is grounded in the belief that complex problems require scholars to transcend academic boundaries to find the best solutions to real-world challenges. As Schroedel said in an interview on CGU's YouTube channel, "I can't think of another time where I felt that the research...mattered quite as much."

For more information about CGU's use of Esri technology and the university's Center for Information Systems & Technology, contact executive director of Advancement Communications Nick Owchar at nick.owchar@cgu.edu.

To learn more about CGU's GIS program, visit <https://bit.ly/2Jzcq0m>. To read more about Schroedel's work related to Native American voter suppression, visit <https://bit.ly/2VxfL71>.

About the Author

Jeremy Byrum is an advancement writer in the Office of Advancement at Claremont Graduate University.

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OPTIMIZING ELECTIONS

Using GIS improves preparation and execution for county

By Monica Pratt

THE BURDEN of administering elections falls primarily on local government. The legal framework and some oversight for elections are provided by the federal and state governments, but counties do all the work of running every election. The enormity and complexity of this task are typically underappreciated. Local governments are responsible for elections held for administrative areas that range from the local to the federal, and cover school districts; special districts such as water, sewer, storm, sanitation, and community service areas; and municipal and county districts.

Ballots must be tailored based on where each voter lives, which is why the task of verifying voter addresses and precincts is so critical to the operations of a county elections office. In many cases, ballots must be provided in other languages, in addition to English. The Orange County Registrar of Voters (OCROV) provides translated ballots in Spanish, Vietnamese, Chinese, and Korean, and facsimile ballots in Tagalog

and Farsi (Persian). For each voter, the county elections office must identify the federal, county, state, municipal, and school district and any other jurisdictions in which that voter resides, determine how many of each type of the ballot to print, and distribute the ballots correctly.

OCROV is using GIS to improve how the county handles the complex tasks associated with running elections. In the 2018 General Election, it provide the appropriate ballot to every one of its 1.6 million voters. To that end, 385 ballot types were created.

The mission of OCROV is “To provide election services for the citizens of Orange County to ensure equal access to the election process; protect the integrity of votes; and maintain a transparent, accurate, and fair process.”

The individual at the helm of the OCROV is its registrar Neal Kelley. The process of optimizing OCROV efficiency and improving the voting experience has been championed by Kelley, who joined the county as Chief Deputy Registrar of Voters in 2004 and was appointed Registrar of Voters in 2006. Despite only having a staff of 65, the office tries to be at the forefront of elections departments at the state and national level by working with agencies such as the California Association of Clerks and Election Officials (CACEO), Department of Homeland Security (DHS), and the Federal Bureau of Investigation (FBI).

SMOOTHER OPERATIONS

Since 2016, OCROV has greatly expanded the use of GIS in its operations and planning for elections. The widespread use of GIS to improve election management, piloted in the 2016 election cycle and

refined in the 2018 cycle, has greatly enhanced the speed and efficiency of many operations at OCROV including verifying addresses.

In 2016, the OCROV GIS team was tasked to modernize all voter addresses by geocoding them and verifying the location of precinct boundaries in advance of the 2016 presidential election. This was not a trivial task.

Although some digital mapping of precincts had been done previously by OCROV, the list of voter addresses was based on paper reports. In the past, it could take months to review and verify voter addresses. By cross-checking voter addresses with address data maintained by the water department and assessor’s office, OCROV could verify that addresses were both valid and correct. Currently, OCROV maintains more than 800,000 addresses, and now the process of verifying them takes weeks, not months. This process has ensured OCROV would not face the problems other county registrars have experienced caused by inaccurate addresses that can lead to the nullification of election results.

In addition to assisting with verifying voter addresses, an internal ArcGIS Online tool identifies polling places that need volunteers and which polling places need language support. Other ArcGIS Online tools help OCROV track the delivery and return of equipment used at polling places. These tools allow OCROV staff to spot deficiencies and misallocations of resources.

GIS has been especially beneficial when OCROV is working under the time constraints imposed by special elections, which require preparing maps and materials for a subset of the county’s voters. In February 2019, OCROV needed to modify

■ GIS HAS IMPROVED NOT ONLY THE PREPARATION FOR ELECTIONS BUT ALSO THE COUNTY’S EXECUTION ON ELECTION NIGHT.

half the county's precincts in just a three- to four-week period. OCROV quickly accomplished these tasks for 300,000 voters—tasks that would have previously taken months.

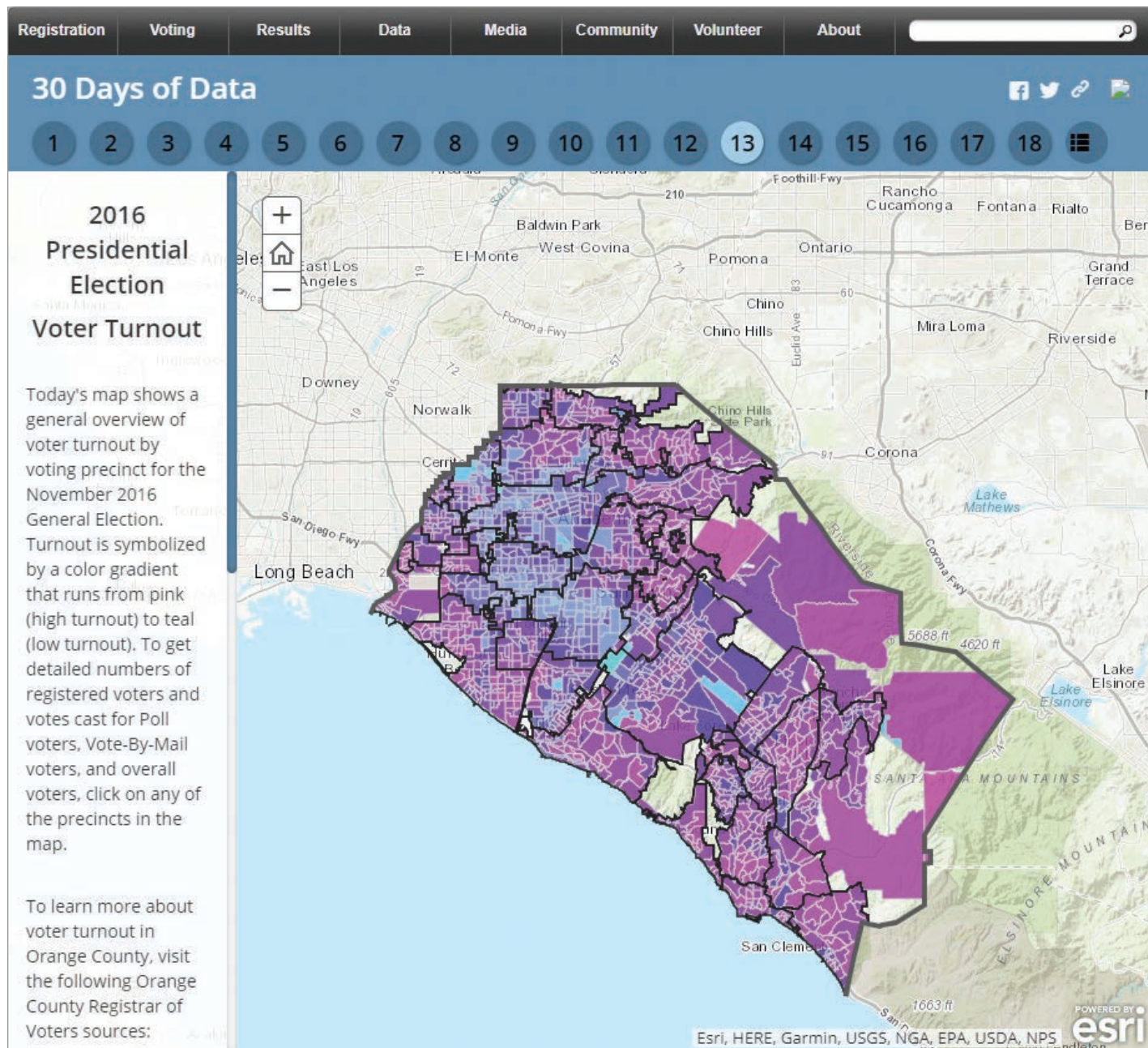
GIS has improved not only the preparation for elections but also the county's execution on election night. In pre-GIS days, OCROV verified that precincts had

reported via phone, which was a staff-intensive process that took a significant amount of time. Time is something that OCROV does not have on election night, since all ballots must be returned to OCROV on election night. The return of ballots following the closing of the polls on election night is mandated by law.

Now, instead of having every precinct

call in, Operations Dashboard for ArcGIS is used to verify the status of polling places and track the return of machines containing electronic ballots known as Judge's Booth Controller boxes (JBCs). JBCs are the control unit of the Hart InterCivic eSlate Voting System. A combination of Survey123 for ArcGIS, ArcGIS Pro, and some Python scripting is used to accomplish this.

↓ An Esri Story Maps app, "30 Days of Data for the 2018 Primary Election" (www.ocvote.com/data/30-days), maps a wealth of information about how elections are held and on voter characteristics and behavior.



Operations Dashboard lets Kelley see the status of all aspects of an election. GIS tracks the location of JBCs in real time, verifying that election night procedures are being followed. A series of milestones are recorded—polling place closure, JBC en route, and JBC received and processed—documenting that JBCs are being returned. Throughout this process, the locations of all vehicles simultaneously returning JBCs from polling places are tracked. During the 2018 General Election, 984 JBCs were tracked. The Orange County Sheriff's department works with OCROV to ensure the secure return of JBCs from the collection centers to OCROV.

OCROV uses GIS not only to better run elections but also to inform the public, encourage voter participation, and provide easier access to election results. Using spatial analysis, OCROV produces posters showing voting trends by neighborhood. An Esri Story Maps app, "30 Days of Data for the 2018 Primary Election" (www.ocvote.com/data/30-days), maps a wealth of information not only about how elections are held but also on voter characteristics and behavior.

The Your Voter Registration page on the OCROV websites uses GIS behind the scenes to provide voters with the correct polling place, information on the districts in which they reside, and information about their elected officials. Voters can also use the site to apply for a vote-by-mail ballot, download a sample ballot, or opt out of receiving a sample ballot. These outreach efforts have had a positive effect: the turnout for the 2018 midterm election hit a historic high of 71 percent.

MEETING NEW CHALLENGES

More challenges constantly arise for OCROV. In 2016, the county conducted an Early Vote Center pilot program and in 2018 increased the number of these centers with a mobile pop-up Early Vote Center. In the March 2020 Presidential Primary Election, absentee ballots will be mailed to all voters, the county will open full-service Vote Centers in many more locations throughout the county that will operate on weekends and extend the period to cast a



↑ Using spatial analysis, OCROV produces posters showing voting trends by neighborhood.

vote in person beyond the traditional one day of voting on election day.

OCROV is making extensive use of the spatial analysis capabilities of ArcGIS Pro to help OCROV meet these new requirements. Analysis of available structures means the county will not have to consider all possible locations when locating Vote Centers—just the ones that meet the 14 state-mandated criteria under Senate Bill 450, which is also known as the Voter's Choice Act (VCA). Since OCROV must give reasons why it picked each of the Vote Center locations, this analysis provides the rationale for OCROV's choices. Utilizing

GIS will continue to provide data-based analysis to inform the OCROV operations planning and assessments.

ABOUT THE AUTHOR

Monica Pratt is the founding and current editor of *ArcUser* magazine, the executive editor of *ArcNews* magazine, the editor of *Esri Globe*, and head of the Publications team at Esri. She has been writing on technology topics, specializing in GIS, for more than 25 years. Before joining Esri in 1997, she worked for newspapers and in the financial industry. Follow her on Twitter on @ArcUser.



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↓ Transport Canada oversees approximately 30 million shipments of dangerous goods transported across the country each year.



Modeling the Flow of Dangerous Goods *by Rail*

By Jim Baumann, Esri Writer

Gases, flammable liquids and solids, explosives, oxidizing agents, poisonous substances, radioactive materials, and corrosives are dangerous materials that are essential to industries such as manufacturing and agriculture, but their transport poses risks.

In Canada, approximately 30 million shipments of dangerous goods are transported across the country each year. Transport Canada, a federal institution responsible for all transportation policies and programs, oversees these shipments.

About 25 percent of those shipments are transported by rail. To analyze the movement of dangerous goods along 78,000 kilometers (48,500 miles) of railway track, Transport Canada creates commodity flow maps that identify the types and amounts of dangerous goods transported through specified geographic areas. These maps allow safety risks and trends to be evaluated and help forecast demand for the future movement of these goods. The maps can contribute to the identification of spots where there may be a greater risk in moving dangerous goods and provide the locations of emergency services along those routes.

Flow maps were originally developed by Charles Joseph Minard, a French civil engineer, who is recognized for his contribution to the field of information graphics. His first flow map, created in 1845, depicted the routing of a railway line between Dijon and Mulhouse, two cities located in eastern France. Most commonly, flow maps indicate the route used by goods or people in transportation

networks and represent the volume of goods or people by the thickness of the route line.

"The Safety Research and Analysis branch under the Transportation of Dangerous Goods Directorate at Transport Canada implemented its ArcGIS platform in 2014," said Elise Pietroniro, team lead for the branch's GIS team. The team created the commodity flow processes using rail data in Microsoft Excel spreadsheets that were interpreted with Python scripts to validate data and isolate the relevant information that was subsequently visualized and analyzed using the ArcGIS Network Analyst extension.

According to Pietroniro, the advantage of commodity flow maps is that they provide an easy-to-understand visual context for very complex data analyses. In rail transportation, they can be used to spatially analyze data across multiple variables for safety assessment including emergency response services, population density, sensitive infrastructure, and topography.

"The commodity flow process models segments of the railway network and provides connectivity between those segments to develop a least impedance routing solution. That is, it determines the best route for a particular cargo, based on various criteria," noted Pietroniro.

These criteria include data from a variety of sources. The distance traveled from origin to destination and the railway track ownership are examples of impedance factors. The origin and destination of the goods, rail carrier, and international border crossings in and out of Canada (if applicable) are used in the analysis as well

as the Standard Point Location Code (SPLC). An SPLC is a 9-digit geographic reference code used in the United States, Canada, and Mexico that specifies the location of railway stations within those countries. It is maintained by the American Association of Railways. Commodity type and volumes are used along with the routing analysis to generate a commodity flow map.

“The collected data used in our impedance analysis comprises our network datasets. From it, we run the script we created to extract that information needed for network routing analysis within Network Analyst, which creates our commodity flow model and the resulting flow maps,” said Pietroniro. “The script analyzes route segments using specific logic and validation checks to ensure verifiable results. Among a variety of checks, the methodology ignores invalid SPLC codes, detects apparent conflicts in rail carriers along a specified route, and reveals inconsistencies regarding border crossings.”

Because the network datasets used for the route analysis are extracted from thousands of records that contain millions of georeferenced vertices, a series of steps are used for the processing of this data to avoid memory errors. The outcome from the multi-step geoprocessing procedure is later aggregated into total railcar counts per railway route segment. The route analysis results are applied to map templates with standardized layouts and symbology. The resultant maps depict the volume and direction of dangerous

goods as they move along a specified rail line from origin to destination. Map templates are available for different regions and on a variety of scales. The entire data analysis and map production process takes between 15 and 45 minutes.

Previously, all this work was done by hand. “The spreadsheets were manually parsed to extract the routing data that was necessary for the analysis. From the analysis, a map was created to depict the commodity flow,” said Pietroniro. The manual process normally took about two weeks to create a single flow map, and because each was designed individually, there was no continuity between them.

Pietroniro has plans to extend the use of commodity flow maps. “In the future, we would like to animate the commodity flows for rail transport to provide a greater sense of how, when, and where the flow of dangerous goods increase and decrease.” This methodology may be applied to other transportation modes used for moving dangerous goods that also fall under the responsibility of the Transportation of Dangerous Goods Act (1992).

“Linking the commodity flow of dangerous goods by other modes with our existing commodity flow model for rail transport would provide us with a door-to-door visualization of the transportation of dangerous goods throughout the country. This could be used to implement greater safety measures and provide more efficient transportation services.”

↓ The commodity flow maps that Transport Canada creates identify the types, amounts, and routes of dangerous goods transported.



Improving Efficiencies in the Pipeline Industry with Location Intelligence

By Jim Baumann, Esri Writer

Oil and gas industry operations are divided into three stages: upstream (exploration and production), midstream (processing, storing, transporting, and marketing), and downstream (refining and distribution of by-products). As a midstream company, pipeline operator Crestwood Equity Partners LP (NYSE:CEQP) transports unprocessed petroleum from upstream oil and gas exploration and production facilities to downstream refineries, where it is processed into various products for distribution and commercial sale.

Crestwood makes broad use of the ArcGIS platform to manage and maintain the integrity of its extensive assets as it gathers, stores, and transports crude oil, natural gas, and natural gas liquids. These assets include not only physical infrastructure such as compressor and pump stations, pipelines, valves, and storage facilities but also real estate rights such as rights-of-way, easements, and surface leases.

In the United States, more than 70 percent of refined and unrefined petroleum products are shipped through the 2.4 million miles of pipeline that crisscross the country. These products include crude oil; fuel such as gasoline, diesel, and jet fuel; and natural gas, both liquefied and vaporized.

↓ Crestwood makes broad use of the ArcGIS platform to manage its extensive assets.

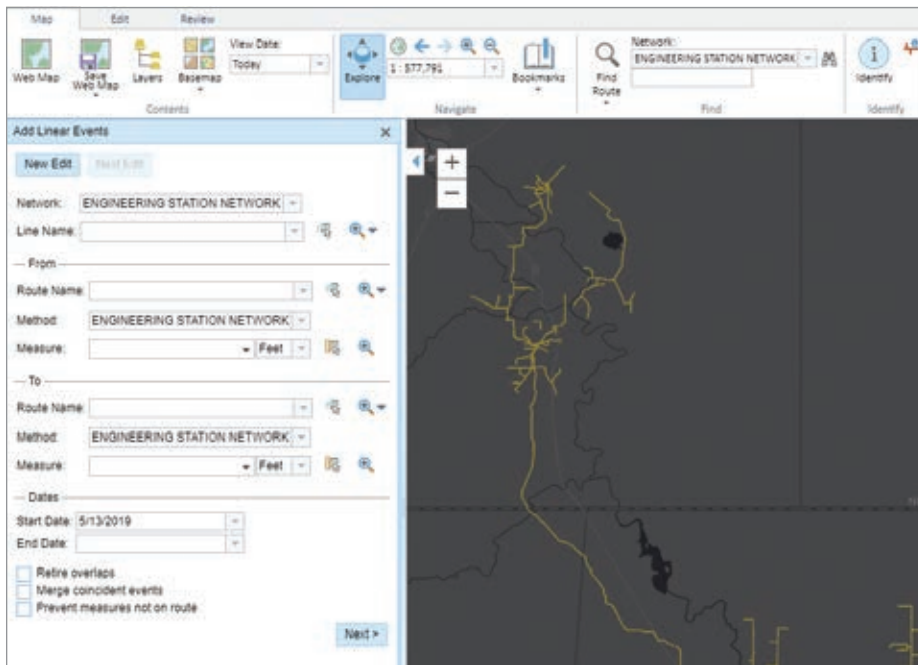


The midstream industry has implemented data models to store and analyze the information needed to monitor and maintain the millions of miles of petroleum pipeline networks throughout the US. Information about assets that is maintained in models includes construction details, inspection results, integrity management, regulatory compliance, and risk analysis, as well as operational data.

According to Craig Hawkins, a GISP and the manager of Asset Information and GIS at Crestwood, midstream companies store data in very similar ways. Many data models used by midstream companies are cooperatively developed by the pipeline industry with the support and direction of organizations like the Pipeline Open Data Standard (PODS) Association, which has been developing these models for more than 20 years. Members of the association contribute to the development of the data models and leverage the latest and greatest model available.

The models use a linear referencing system (LRS), which stores the geographic location of a pipeline asset by its relative position along a measured linear distance, rather than determining the x,y coordinates of each asset as other models do. LRS specifies features (or assets) along linear route sections between defined starting and ending points. It is commonly used by engineers because of its precision. To perform its linear measurements, LRS references the centerline axis of a pipe, which is a calculated line that runs longitudinally through the midpoint of the pipe's diameter.

In addition to being more precise, LRS is also more cost-effective for data



← The ArcGIS Pipeline Referencing tools provide GIS capabilities that are useful in performing linear referencing data management.

Hawkins noted that Crestwood is continually seeking ways to leverage new technology in the pipeline industry. In addition to streamlining data management best practices, the company is looking at better ways to leverage geospatial technology, reporting, systems integration, and big data infrastructure.

“Because we collect large volumes of data, we are considering making better use of ArcGIS Data Store, along with Elasticsearch, a distributed search and analytics engine,” said Hawkins. “This would allow us to expand our commercial efforts by allowing us to quickly tap into a variety of databases and run different analytics to help with business development and the decision-making process.”

Crestwood is also exploring the use of Insights for ArcGIS to do more spatial and statistical analyses of its operations for scheduled procedures, such as inspections, maintenance, risk assessment, environmental impact, regulatory requirements, and health and safety compliance. That information could be presented in dashboards for review by management.

“These are just a few of the areas that we will be exploring in the future to help us better maintain our assets and expand our business. I think that geospatial technology holds tremendous potential for our industry because it can help us improve our efficiencies through the use of location-based intelligence, which is already a strategic part of our information infrastructure,” said Hawkins.

maintenance procedures. When a change is made to a section of the pipeline, the affected section is recalculated by the software and stored in its related data model, maintaining the referential integrity of the pipeline. Many pipeline companies use ArcGIS in their operations. Models developed by PODS have provided links to the ArcGIS geodatabase for the past 10 years.

After Hawkins joined Crestwood in 2016, one of his first tasks was determining how to consolidate the company’s different data models into a single system. Crestwood had a PODS relational data model running on Microsoft SQL Server, an ArcGIS Pipeline Data Model (APDM) from a previous acquisition, and other legacy data stored in ArcSDE. It was clear to Hawkins that these disparate data sources should be migrated into a single “source-of-truth” database so the company could manage its data and perform analyses more effectively.

There were many options available, but Crestwood decided to implement the extended version of PODS Next Gen, which is supported by the ArcGIS Pipeline Referencing location model and provides GIS capabilities that are useful in performing linear referencing data management.

“Migrating multiple databases at the same time can be complex, but ultimately, we were able to generate one LRS network to get a single, comprehensive view of our pipeline network,” said Hawkins. “The APR [ArcGIS Pipeline Referencing] tools allow us to manage the centerline geometry and data maintenance on a daily basis, which is key to our work.” If a pipeline is rerouted, the centerline and any associated data can be edited.

↓ Crestwood has implemented data models to store and analyze the information needed to monitor and maintain the millions of miles of petroleum pipeline networks throughout the United States.



The Best Time to Plant a Tree

By Brent Jones

According to a Chinese proverb, the best time to plant a tree was 20 years ago.

The second-best time is now.

Like planting a tree, the best time for your organization to expend the time and money to make a major change is sometime in the past. Now is the second-best time.

An article I wrote in the spring issue of *ArcUser*, “The High Cost of Low-Hanging Fruit,” observed that transformation is disruption that you do to yourself.

Although technology causes a lot of disruption in our daily lives, it’s not a single technology in isolation that enables large disruptions—it’s a combination of technologies, data, and other elements. Enabling technologies—such as a good street network, maps, GPS-enabled smartphones, cloud computing, and online payment—contributed to the disruption of taxis by Uber. However, the availability and capabilities of the Uber app was critical to Uber’s success. Average folks needed to be able to use the app and make payments through it.

This sounds simple, but do you remember when you were skittish about entering your credit card online? Although the iPhone was released in 2007 and an Android smartphone in 2008, it took several years for people to get used to downloading and using apps.

Now smartphones are owned by 62 percent of the global population and nearly 80 percent of Americans, and these percentages are growing rapidly.

Because new enabling technologies appear every day, defending against disruption is an ongoing process. You probably own technologies that enable

disruption and transformation, but you may not use them to their full extent or in a way that transforms your organization.

GIS is a disruptive technology. It continues to be a disruptive technology by leveraging other emerging and evolving disruptive technologies. A few of the key ones are associated with computing infrastructure, data, and GIS innovation.

The cloud, software-as-a-service (SaaS), mobile, and distributed computing are improvements to the computing infrastructure that deliver answers faster and in ways that are more accessible.

From weather, traffic, and real-time sensor data to imagery, demographics, and scientific measurements, the data available today enables new and better types of analysis that improve decision-making.

GIS is rapidly innovating with advanced analytics, smart mapping apps, and robust and readily available SDKs and APIs for developers that help deliver rapidly evolving capabilities that can be accessed and used by non-GIS professionals and GIS professionals alike.

The combination of these technologies delivers Web GIS, an emerging disruptive technology. ArcGIS has transformed (self-disrupted) into Web GIS, which is driving transformation in many organizations. Web GIS enables organizations to move from sequential to simultaneous workflows with integrated operations that share data and services and totally change how the organization works.

And there’s more technology coming, enabling more and larger disruptions more quickly.

This process won’t stop.

Just when you think you’re safe, more enabling technologies will combine to disrupt your work. You can’t afford to be complacent. Staying current with technology and beginning your own transformation

are your best defense against external disruption. Complacency is fatal in these times of rapid technological advances and disruption.

Now is the time to look more closely at your GIS and discover how you can use it to enable your transformation by asking some of the following questions:

- Are you using dashboards to have the information you need at your fingertips?
- Are you leveraging location analytics to see what your data is trying to tell you?
- Are you using external datasets to augment your operational data?
- Will artificial intelligence and machine learning improve your operations?
- Have you investigated how to standardize or automate some of your work?

Simply put, will using all the benefits of GIS improve your organization and aid in transformation? It’s difficult to imagine it won’t.

Now’s the time to get started. Sign up for a webinar. Attend a user meeting and learn from peers. Engage with your technology providers and ask the tough questions. Ask yourself, how can I do things better? Think transformation and disruption. Think, how do I leapfrog my organization and get maximum value from today’s GIS technology? Examine your GIS and your organization. Learn what Web GIS can mean to your organization’s mission and mandates.

The second-best time to plant a tree is now.

The second-best time to transform your organization is also now.



About the Author

Brent Jones oversees Esri's worldwide strategic planning, business development, and marketing activities for land records, cadastre, surveying, and land administration. As a recognized innovator, Jones specializes in modernizing existing land administration systems and designing new GIS-based cadastral management systems for small and large governments globally. He is a member of the URISA board of directors, past president of the Geospatial Information and Technology Association, and a current member of the United Nations Committee of Experts on Geospatial Information Management and its Expert Group on Land Administration and Management.

What It Takes to Be a GIS Leader

By James Pardue

What is a GIS leader?

A GIS leader is usually not associated with a specific job description, position, or title.

A GIS leader can be a manager, analyst, technician, administrator, developer, programmer, or specialist.

A GIS leader leads by example and serves as a partner and adviser who refines and enhances GIS business processes.

As a thought leader and change agent, a GIS leader approaches GIS with a business mind-set and understands how to integrate business intelligence. To lead an organization in developing and executing geospatial strategy, a GIS leader:

- Provides innovative/creative solutions that solve complex geospatial problems.
- Coaches and guides through geospatial mentorship.
- Possesses domain expertise.
- Develops abilities to establish a GIS vision, designs a road map to get there, and leads the organization on the journey.
- Challenges everyone's thinking.
- Encourages supervisors, managers, peers, and subordinates to embrace change.
- Inspires and motivates individuals.
- Cultivates and nurtures professional and personal growth.

- Fosters a teaching/learning environment within the organization that challenges members to apply critical thinking to geospatial problem solving.
- Evangelizes the use of GIS capabilities.
- Stimulates new ideas and concepts.
- Infuses GIS innovation into the organization's culture.
- Consistently focuses on effectiveness, efficiency, and improvement through constant self-assessment and organizational assessment.
- Masters the ability to see what no one else sees, knows where to go, and figures out how to get there.

If you are not sure who the GIS leaders are in your organization, find out who's doing the actions in the previous list. This will tell you who the GIS leaders are in your organization.

By now most of us know that managers and leaders are not the same thing. Managers tend to manage resources, projects, funds, and time, while leaders lead people, teams, and organizations. Over time, good leaders develop the ability to be change agents. While not all managers are leaders, based on my experience, the most effective leaders are great managers as well. During a time of crisis or chaos, you cannot manage your team out of the situation—you must lead them out of it.

I once heard another good way to explain this difference. A GIS

Sample list of a GIS manager's daily fires

- A customer who requested hard-copy products works in a remote location. How do we get them what they need?
- Our data is in the wrong projection for the type of analysis we need to do. How do we want to tackle re-projecting all the data?
- Due to a software upgrade, one of our automated workflows has broken. How do we proceed?
- A customer has new requirements in a business area we have not worked in yet. What do we do?
- Not everyone is trained in the new workflow process we've implemented. What's the plan to resolve this?

Sample list of a GIS leader's problem sets

- How do we ensure we are utilizing and integrating the full potential and capabilities of our GIS platform/enterprise? What is the plan to address the gaps and shortfalls?
- How do we provide for the sustained professional growth of our GIS workforce and ensure that growth is relevant, challenging, stimulating, and motivates the workforce?
- How do we ensure the entire organization has integrated GIS into their business practices?
- Are we getting at the biggest problems—the ones that keep department heads awake at night?
- Are we effectively transferring experience and knowledge within our organization/team? How do we tell if this is happening? How do we know we are being effective?

manager reactively puts out fires. A GIS leader proactively ignites fires. That proactive component equates to passion. GIS leaders typically are passionate about what they are doing and have also learned to evangelize GIS within their organizations. Compare the concerns of a GIS manager and a GIS leader.

Too often when we think of developing individual analysts, we think of the technical aspects of their development. Software skills, programming, database management, or analysis skills are areas we have become proficient at developing.

It is the soft skills we are missing. In "The largest skills gap managers see in IT workers isn't technical," the article's author Lila MacLellan mentions that LinkedIn CEO Jeff Weiner sees a need in the future for skills such as written communication, oral communication, team-building, and leadership skills—better known as soft skills.

"Next-Generation IT Talent Strategies," a recent report by CISCO on the state of IT hiring and training, surveyed over 600 companies that generated over \$1 billion in revenue annually. I feel that the report is significant because I see the GIS and IT worlds as tightly connected with many similarities. I'm confident trends in one are visible in the other. The CISCO report showed how business leaders addressed questions on gaps in business skills, and the survey responses were very heavy on soft skills. Their top six gaps can easily be addressed through mentoring and leader development.

To return to the original question, what is a GIS leader, a GIS leader is a GIS change agent within the organization who champions all GIS initiatives and who advises, mentors, and educates all on GIS capabilities and usage. As a practitioner of The Science of Where, a leader applies geography through GIS while navigating the expanding world of mapping and location intelligence. Through selfless leadership, a leader provides a GIS vision and the geospatial strategy to successfully achieve it.

How do you get GIS leaders?

You make them. You mentor them. You create your own. Paying it forward is something we all should be doing with those whom we come in contact with in our profession. Whether you use the term *GIS*, *geospatial*, or *GEOINT* [*geospatial intelligence*], it's all location intelligence and it's all about practicing The Science of Where.

Whatever your personal flavor of geospatial is, ask yourself who your leaders are. Are you are one of those leaders? What are you doing to develop leaders and create more of them? Together, we can work to fill the soft skill gaps within our profession and industries through junior leader development; managing our bosses; and effective up, down, and lateral mentoring.

About the Author

James Pardue has been working in the geospatial field for 32 years as a cartographer, terrain analyst, data specialist, imagery analyst, GEOINT analyst, and geospatial engineer. He has held positions as an instructor, career developer, production manager, database manager, tradecraft and training lead, and recently as a technical consultant. He has spent most of his career providing support to military conventional operations, the intelligence community, and special operations forces. As a GIS change agent, Pardue has designed, built, and led diverse geospatial teams throughout the US Department of Defense (DoD), in the US Army and the US Air Force, and in a joint environment, the federal civilian service, and in academia. He is currently focused on geospatial strategy implementation, and the development of GIS leaders and the GIS workforce.



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Create a Custom Web Editing Experience with the ArcGIS API for JavaScript

By Julie Powell

Do your users need to edit data using your web app? Web editing allows your organization, the public, or any group of users you deem appropriate to collaborate on data creation and updates from any device. As the developer, you can enable editing workflows within your custom web app that create any experience needed for your business.

As of version 4.11, ArcGIS API for JavaScript includes an out-of-the-box Editor widget. It enables the full workflow for creating and updating features with several configuration options that allow you to fine-tune the experience for your end users. The API also offers opportunities to fully customize editing workflows using the underlying business logic.

Engineering the Editor Widget

You might be familiar with the 3.x series of the ArcGIS API for JavaScript and its version of the Editor widget. Like all widgets in the 4.x API, the Editor widget was redesigned using lessons learned from the 3.x widget, along with an updated, modernized approach.

The design of the 4.x widget incorporates these principles:

- Have a mobile-first design, since web editing can take place from any device and screen size.
- Provide simple editing workflows that maximize the end user's productivity.
- Must be easily configurable (from an architectural perspective) to mold appropriately to the developer's requirements.
- Must also follow the API's widget development pattern, which separates the business logic from the user interface (UI).

Maintaining a clean separation between the underlying logic and the UI means developers don't have to rewrite the logic that takes care of the map interaction and underlying feature editing,

even if they want to fully customize the presentation of the widget or completely replace it using the JavaScript library of their choice.

Prepare Your Layers for Editing

To simplify the code and take advantage of the API's editing experience features, your services should be properly configured. The API will use the definition of each editable feature layer to create the default edit UI, and it will honor the aspects you configure directly in your app. You can override some of the settings via code. For example, you can hide some of the editable fields.

There are a variety of considerations when it comes to preparing your layers for web editing, as described in the following sections.

Feature Templates

Defined in the service, feature templates contain all the information required to create new features in each feature layer. This information can be the default attribute values with which a feature will be created and the default symbol for the feature. The Editor widget displays all feature templates for editable layers. The user can browse, filter, and search feature templates to find one suitable for the kind of feature they want to create.

Subtypes and Domains

When defining your feature templates, use attribute domains and subtypes whenever appropriate. Attribute domains are applied to a field to enforce data integrity during editing by restricting the input to a list or range of valid values and eliminating the entry of invalid data.



See These Online Resources to Learn More

Manage hosted feature layers

Manage hosted feature layers in ArcGIS Enterprise

Author, publish, and manage a feature service using ArcGIS Server

esriurl.com/AGOLayers

esriurl.com/entLayers

esriurl.com/createFS

Subtypes allow you to categorize a layer into a subset of features that share the same attributes. Domains and default values can be applied to the fields of each subtype.

Security

Designing the security strategy of your services is an important step when setting up services. You control what (if any) edits can be made to a layer, who can edit it, and if the layer will keep track of when edits are made and who made them for each feature in a layer. When using hosted feature layers, you can also take advantage of layer views, which allow you to put constraints on a subset of the data. For example, you can spatially limit editing so that only those features contained in the layer view can be edited, rather than making the entire layer editable.

When authoring a feature service using ArcGIS Pro and publishing it to ArcGIS Server, you have many of the same options as you do for hosted feature layers, as well as other capabilities at the database level.

Attribute Editing Bells and Whistles

Have you ever filled out a form on a website that didn't give you a tailored experience based on the input type? Perhaps there were just too many unnecessary fields to fill out. With the Editor widget, you

can give your end users an efficient attribute editing experience. The following configuration options enable a superior editing experience.

Configure the Layers to Be Edited

The Editor widget automatically detects editable feature layers in the map by examining the feature service that each layer points to, and it will create the appropriate UI to allow users to edit each of those layers. However, you might be building a focused application that should only expose editing of a subset of the editable layers. This is achieved by configuring the widget with only the layers that you want to be included.

Limit the Attributes Displayed

Often, end users only need to update a few attributes. To provide a streamlined experience, you can configure the widget to show the specific attributes that they need to edit so users aren't burdened with the nonrequired fields. It is important to note that this configuration simplifies the user experience. It does not secure your data. If you have attributes that should not be edited, set up your service so it will not allow editing of those attributes. This prevents someone from accessing your feature service's REST endpoint directly and editing fields that should not be edited.

↓ The Editor widget aggregates all available feature templates for all editable feature layers in the map and displays them in the widget.





↑ Using the Editor widget, you can create apps that let your users create or update feature geometry interactively on the map. They can edit individual vertices and scale or rotate features.

Ensure Valid Input

Preconfiguring acceptable values for a feature either by limiting the range or providing a list of possible values saves time and supports accurate data entry. If your feature service's attributes have attribute domains as described previously, they will be detected by the Editor widget and will be enforced. If you've defined a set of possible values, they will appear in a drop-down.

Determine When an Attribute Should Be Visible

Sometimes it only makes sense to edit an attribute based on a specific condition. For example, if your user is editing work orders, you should make the attribute describing the resolution of a work order visible once the work order has a completed status. Do this by writing a visibility expression for the field. After resolving to true, it will be displayed for editing.

Displaying Lots of Attributes

Sometimes you simply can't avoid displaying a lot of attributes. So that your users can easily find the one attribute they want to edit, you might want to visually group attributes. Even when the number of attributes is not large, configuring them into logical groups can help put attributes into context.

Go Beyond a Pretty Label

Field aliases are used to display a pretty label for field editing. However, it's often useful to provide more of a description for each field or group of fields so that end users can better understand

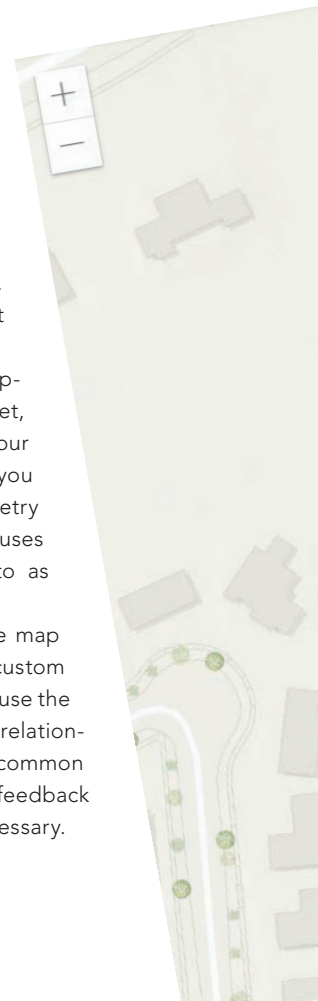
what the field is or see an example attribute of what kind of value is expected.

Geometry Editing: Basics and Beyond

The editing tools in 4.x that allow you to create and update geometries are similar to tools in the 3.x version. However, 4.x lets the user undo and redo updates while the edit is in progress. For example, they can undo (or redo) the last vertex added while drawing the new geometry.

The end-to-end experience for creating and updating geometries is handled by the Editor widget, but you might want to customize it based on your editing workflow requirements. For example, you might want to display statistics about the geometry of a polygon being drawn. The Editor widget uses the Sketch widget's business logic (referred to as SketchViewModel) to draw on the map.

You can use SketchViewModel to capture the map interaction events needed for executing your custom code during the drawing process. Your code can use the client-side geometry engine for testing spatial relationships, calculating measurements, or any other common spatial operation. The end user gets immediate feedback while drawing a polygon and can adjust it as necessary.



What If You Just Want to Draw on the Map?

If your app requirements only consist of redlining (i.e., sketching on the map without persisting the changes), you can use the Sketch widget. The Sketch widget provides the common tools for drawing graphics on the graphics layer that do not persist in a feature service. Since the graphics layer is unstructured, you can draw more than one type of geometry in the same layer with different symbology.

What If You Only Care about Editing Attributes?

If you are only interested in editing attributes, you can use the FeatureForm widget. It has all the same aspects as the Editor widget for attribute editing because the Editor widget actually incorporates the FeatureForm widget into its UI. If you use this widget, you will have to handle the applyEdits on the feature layer.

Over the last several releases, the ArcGIS API 4.x for JavaScript has been iteratively growing its editing capabilities. With the Editor widget, you can implement a tailored editing experience

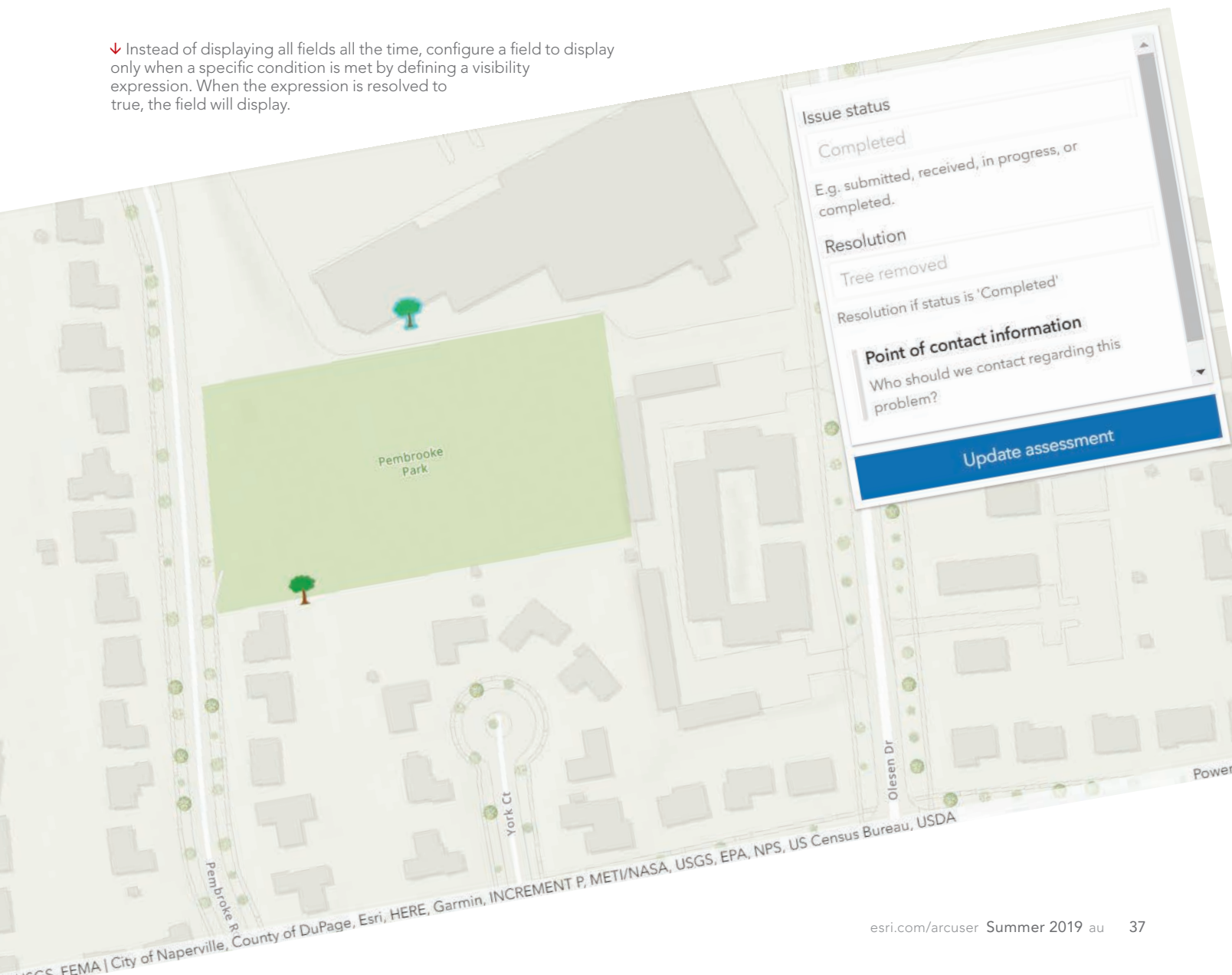
with little effort, configuring or customizing it to your heart's content. Check out the API samples to give it a test-drive at esriurl.com/editorwidget.

Happy editing!

About the Author

Julie Powell is a technical product manager at Esri. Her primary focus is the ArcGIS API for JavaScript. She has more than 18 years of experience working with software development, delivering solutions for both enterprise and consumer markets. She interfaces with a wide user community to maintain awareness and insight into GIS community needs, meanwhile contributing feedback to development teams to help ensure users can be successful in building state-of-the-art, purposeful solutions using ArcGIS software.

↓ Instead of displaying all fields all the time, configure a field to display only when a specific condition is met by defining a visibility expression. When the expression is resolved to true, the field will display.



ArcGIS API for Python Core Concepts: Python, APIs, and REST

By Rebecca Richman

Are you interested in using the ArcGIS API for Python to automate your ArcGIS Online or ArcGIS Enterprise workflow, but find the number of components and software options daunting?

The ArcGIS API for Python can seem overwhelming due to the complexity and number of installation options, as well as the different Python environments that are possible. The ArcGIS API for Python also integrates third-party products, such as Anaconda and Jupyter Notebook, which may be new to many.

However, the ArcGIS API for Python can be very useful and intuitive, especially when best practices are followed. It can also greatly simplify your scripts. For example, if you are writing a script for reassigning content from one user to another user and don't use the ArcGIS API for Python, you will have to create text strings for URL requests for every action you want to perform. This will be a very long script.

In contrast, to perform the same workflow using the ArcGIS API for Python, you will have a lovely short script because the ArcGIS API for Python constructs URL

requests for you. In this example, using the ArcGIS API for Python could reduce the number of lines of code from 117 to 19 to complete the same task.

Before you start using the ArcGIS API for Python, it is nice to have a good grasp on what the ArcGIS API for Python is and some best practices in using it. This article breaks down the components and how they relate to each other, explains the concepts behind the ArcGIS API for Python, and provides some best practices for using it.

The ArcGIS API for Python, Defined

The definition "A Python API developed by Esri to manage Web GIS via the ArcGIS REST API" may not be very useful because it assumes that you already know what Python, an API, the ArcGIS REST API, and Web GIS are.

Although I assume you already understand Web GIS, just to get everyone on the same page, let me note that Web GIS is a concept that contains any GIS data management system using the web to share, edit, or manage the data. Esri uses Web

GIS to refer to both ArcGIS Online and ArcGIS Enterprise (particularly Portal for ArcGIS). The rest of this article dives into the other concepts and how they allow you to manage your Web GIS.

Understanding Python Installation

Python is an open-source programming language that Esri, along with many other software companies, uses to create processing tools. A Python installation comes with core code (a python.exe and associated files) and a package of additional tools and functions. The user can add other packages to expand functionality.

Python Installation for ArcGIS Desktop

The Python installation that comes with ArcGIS Desktop has the ArcPy package, which contains all ArcGIS geoprocessing tools. Other common packages include numpy, urllib, and requests. Numpy, which has mathematical functions, is usually installed by default with Python, but the user must install urllib and requests, which allow

↓ The relationship between applications, the ArcGIS REST API, and the ArcGIS Server Site.



➤ Figure 1: The REST endpoint for Sample Server 6

➤ Figure 2: Opening the Geology/Feature Service, which is inside the Energy folder, will add /Energy/Geology/FeatureServer to the URL.

you to construct and send URL requests through your Python script.

ArcGIS Desktop comes with a Python installation, but not all ArcGIS Python installations are the same. Between the development of ArcMap and ArcGIS Pro, Python came out with several new versions. An ArcMap installation comes with Python 2.7 because the ArcPy package in ArcMap works with Python 2.7.

ArcGIS Pro was developed using Python 3.5, and the ArcGIS Pro ArcPy package requires a Python 3.5 installation. Similarly, the ArcGIS API for Python can only be installed on a client using Python 3.5, and the Python package for ArcGIS API for Python is called `arcgis`.

ArcGIS Pro Python 3.5 Installation

"But wait," you may be thinking, "I thought the ArcGIS API for Python was an API. Why are you referring to it as a Python package?"

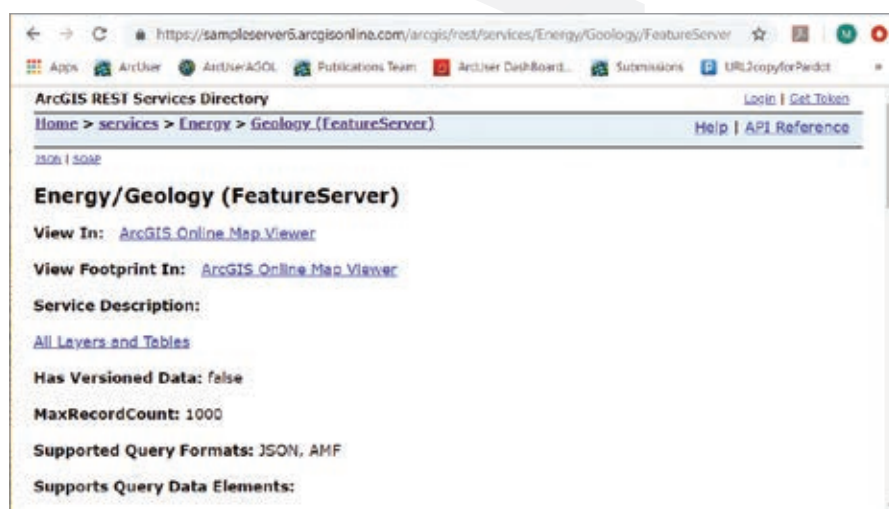
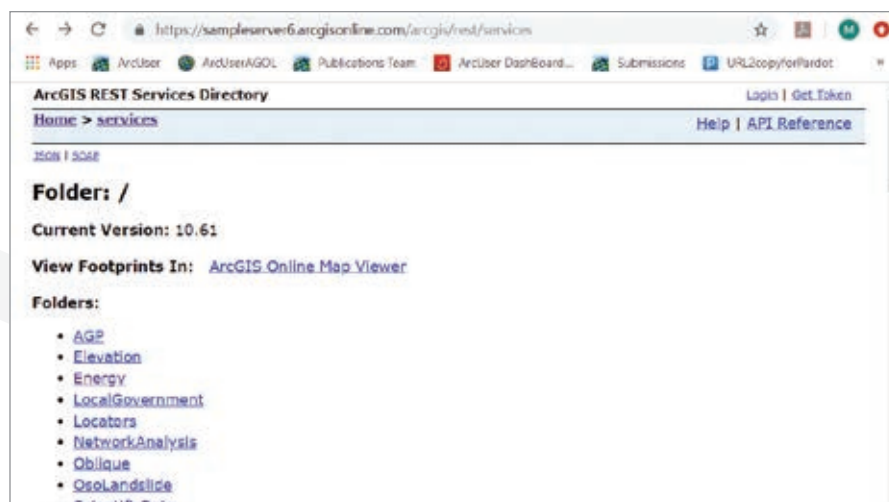
Good question!

The ArcGIS API for Python is both a Python package and an API. Python packages are packages of tools that can be installed in a Python environment, and that is exactly what the ArcGIS API for Python is. However, the ArcGIS API for Python is also an API. Which leads us to the next question: What is an API?

What Is an API?

API stands for application programming interface. It is a library of tools that allows two applications to interact with each other. Examples include the ArcGIS API for JavaScript and the ArcGIS REST API.

Imagine you have a colleague who wants a drink from a vending machine. You have an application (a thirsty colleague) that would like to make a request (buy a soda) from a server (the vending machine). To do this, there must be an interface that both the application and the server can understand and interact with. In this case, the keypad acts as the interface between the application and the server.



An Application Making a Request from a Server

A real-world example of an API is the ArcGIS REST API. It is a set of tools that allows applications to make requests of ArcGIS Server sites. As the name implies, the ArcGIS REST API contains the tools to allow applications to make REST requests of the RESTful ArcGIS Server sites. Since the ArcGIS API for Python interacts with the ArcGIS REST API, let's dig into what it means to say a server site is RESTful.

What Is REST?

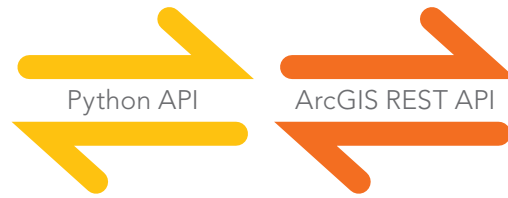
REST, or Representational State Transfer, is an architectural style that, among other functions, organizes a site in a way that allows people to read URLs. ArcGIS Server sites use the REST architectural style to create sites that can be navigated the same way you navigate through computer folders.

Look at an example of a RESTful site in figure 1, which shows `https://sampleserver6.arcgisonline.com/arcgis/rest/services`. If I open the Energy folder in the Service Directory, `/Energy` gets added to the URL just as it would in Windows Explorer. Inside the Energy folder, I can open Geology (FeatureServer), which will also get added to the URL as `Geology/FeatureServer`, as shown in figure 2. If I want to work with a specific service layer, such as the Fault layer, the number of the layer (0) will be added to the URL.

Once the URL is pointing to a specific service or service layer, operations you want to perform on that service or layer can be appended to the end of the URL. For example, if you want to query a specific feature by its ObjectID from the Fault (0) layer of the Geology service, you could add the `query?` operation from the ArcGIS REST



Python Script



ArcGIS Server Site (RESTful)

↑ The Python API is the interface between Python scripts and the REST API.

API and any parameters for the operation (for example, `objectIds=41568`). The URL request now looks like this:

`https://sampleserver6.arcgisonline.com/arcgis/rest/services/Energy/Geology/FeatureServer/0/query?objectIds=41568`

When you send the URL request, `SampleServer6` responds to the request with information on feature 41568 in the first layer of the Geology feature service.

The ArcGIS REST API is a list of all the operations you (or an application) can perform on services in ArcGIS Server sites. These operations are then applied to the services using the REST architecture in the URL request.

The ArcGIS API for Python versus the ArcGIS REST API

If an API is the interface between two applications, and the ArcGIS REST API is the interface between an application and

ArcGIS Server sites, what is the ArcGIS API for Python an interface between?

There are two ways to think about this. You can think of the ArcGIS API for Python as the interface between a Python script and the ArcGIS REST API. The ArcGIS REST API then interfaces between the ArcGIS API for Python and the ArcGIS Server site.

The Python API interfaces between Python scripts and the REST API. Alternatively, you can think of the ArcGIS API for Python as a Pythonic wrapper around the ArcGIS REST API, and both work together as the interface between the script and the ArcGIS Server site.

The ArcGIS API for Python wraps the construction of ArcGIS REST API URLs in Pythonic functions, so instead of having to construct a URL manually in a script, you can call on prebuilt functions that will construct the URLs in the back end.

What Is the ArcGIS API for Python?

Now that we have dissected Python, Python packages, APIs, and the ArcGIS REST API, we can come up with this final definition.

The ArcGIS API for Python is both an API and a Python package. It includes tools that help a Python script use the ArcGIS REST API, which in turn includes the tools to make requests of ArcGIS Server services. The ArcGIS API for Python helps you write Python scripts to manage your content and users in your Web GIS.

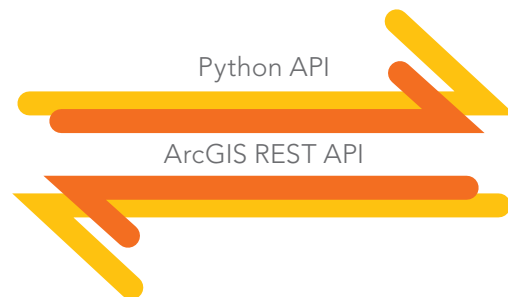
About the Author

Rebecca Richman is an Esri desktop support analyst with a background in geography, biology, anthropology, and archaeology. She has had training in cartography, remote sensing, and GIS management.

↓ The Python API as a Pythonic wrapper for the REST API.



Python Script



ArcGIS Server Site (RESTful)




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Do More with ArcGIS Runtime SDKs 100.5

By Nick Furness and Rex Hansen

The April 2019 release of version 100.5 of the ArcGIS Runtime SDKs enhanced 3D and KML functionality, augmented offline workflows, and introduced support for fundamental mapping requirements such as reference scale and group.

Working in 3D

You'll see lower memory usage and better all-around performance when working with scenes as Esri continues to optimize the experience. This release of ArcGIS Runtime SDKs adds some significant 3D functionality. ArcGIS Runtime SDKs squeeze great performance out of mobile devices, displaying large volumes of symbolized and filtered lidar data. With Point Cloud Scene layers, datasets of hundreds of millions of points can be interactively visualized. It's truly impressive.

Not to be confused with the Point Cloud Scene layer, Point Scene layers provide fast display of point features in a 3D view based on scale, distance, and threshold parameters associated with a viewpoint. Publish these from point feature layers as a service or as a scene layer package or as part of a mobile scene package.

You can now work with features that lie below ground level by adding transparency to the scene's surface or simply by navigating and positioning the camera below ground. Properties on a scene's surface allow you to enable or disable subsurface navigation and control the transparency of the ground.

Mobile Scene Packages

Version 100.5 adds support for Mobile Scene Packages (MSPKs). These files parallel Mobile Map Packages but (you guessed it) are for scenes and are generated in ArcGIS Pro to be side loaded onto your devices for an offline 3D experience.

Working Offline

Speaking of offline, Esri has been working on enhancements to the On Demand and Preplanned offline workflows that enable even greater control when working with data while disconnected.

Basemap by Reference

In both On Demand or Preplanned workflows, you can now opt to make use of a locally stored basemap. For example, perhaps you have a vector tile package or raster tile package already downloaded, which covers your entire service area. Not having to generate or download the basemap tiles can significantly reduce the time it takes to generate and download an offline map.

Next Gen Locators and Tile Packages

Esri's geocoding team has been hard at work on next generation locators. At 100.5, ArcGIS Runtime SDKs bring support for these LOC files to Runtime. These are smaller and faster. What more could you want?

Alongside that, Esri added support for the new Tile Package (TPKX) file format for local raster tiles. TPKX files use the Compact Cache V2 open spec. Generate a TPKX from ArcGIS Pro or ArcGIS Enterprise 10.7, or lean on the spec to create your own tile packages.

Reference Scale

Although utility customers have long clamored for reference scale functionality, you don't have to be a utility to make good use of a reference scale. Now a map authored in ArcGIS Pro can have reference scales set on the map or on individual layers, and these scales are honored in ArcGIS Runtime SDKs.

Annotation

Annotation—text that is pinned in place relative to a feature or to the map—is another feature that is of great use to utilities. It's not dynamically positioned like a label. It is statically positioned when the map is authored.

Although this is just the first release that includes reference scale and annotation, these are already very capable features. However, Esri will be enhancing these features and adding APIs to better control them over the next few releases of the ArcGIS Runtime SDKs.

Web Feature Service

Rounding out Esri's Open Geospatial Consortium (OGC), Inc. format support, Web Feature Service (WFS) has been added. Now WFS, Web Map Service (WMS), and Web Map Tile Service (WMTS) layers can directly display OGC services in your map.

KML Tours

The addition of KML tours completes the functional coverage for KML in the ArcGIS Runtime SDKs. Open a KML tour in the runtime and control its playback using an API.

Group Layers

Group layers are another frequently requested feature. Esri introduced an API to support combining operational layers into group

layers in both maps and scenes. In addition, group layers defined in a web scene or mobile scene package will be honored.

Local Server

Local server has been updated at 100.5 to add compatibility with ArcGIS Pro 2.3 and ArcMap 10.7.

Updated SDKs

At each release, Esri updates its world-class SDKs to cover the new capabilities added. In addition to updated guide topics and API reference docs, new sample apps and updated toolkits and open-source apps have been added. Additional specific information is available in the release notes for .NET, Java, Qt, Android, iOS, and macOS SDKs. This is the last release with a dedicated macOS SDK, but you can still use Java and Qt SDKs to build macOS apps.

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About the Authors

Nick Furness is a technical product manager for ArcGIS Runtime SDKs for iOS and macOS. He has spent more than 20 years working in GIS, building projects that have ranged from small mom-and-pop solutions to enterprise utility and national government deployments. He presents at the Esri Developer Summit, the Esri User Conference, and many other events, mostly on ArcGIS Runtime SDKs with the odd bit of JavaScript thrown in.

Rex Hansen is a product manager for ArcGIS Runtime. He has more than 25 years of experience in GIS, spatial analytics, and computer mapping. Recently, he has helped guide the development of native solutions and technologies in the GIS industry that use authoritative geospatial data in immersive, extended reality experiences.

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SEEING THE POWER OF GIS

By Citabria Stevens and Carla Wheeler

The more than 18,000 people attending the 2019 Esri User Conference (Esri UC) in San Diego, California, saw the phrase *SEE WHAT OTHERS CAN'T* everywhere. It was emblazoned on a banner wrapping around several floors of the Hilton San Diego Bayfront, on the signs and banners blanketing the San Diego Convention Center, and on T-shirts and water bottles handed out to those at the 39th annual conference, held July 8–12.

More than a slogan, this phrase describes the power of GIS. The stories told by Esri software users from government agencies, nonprofits, private companies, and schools on the plenary stage and in presentations throughout the week demonstrated how GIS lets them see relationships, dependencies, and connections that have enabled them to understand the *how* and *why*, as well as the *where*, to make better decisions and respond effectively.

The conference theme, GIS: The Intelligent Nervous System, is built on the metaphor of the human nervous system. As Esri president Jack Dangermond observed, “Our world resembles a living organism in that it is complex, interconnected, self-healing, resilient, and constantly changing. GIS integrates data from many sources and couples it with values and emotions and carries out coordinated response.”

➤ Everywhere they looked, Esri User Conference attendees could *SEE WHAT OTHERS CAN'T*.



An Intelligent Nervous System for Conservation

During its presentation, NatureServe unveiled its Map of Biodiversity Importance for the United States, providing a high-resolution view of the most imperiled species for the first time.

NatureServe is a nonprofit group that helps guide conservation efforts by providing species-related data, tools, and services. It uses GIS to better see and understand where to find at-risk species in the United States, Canada, and Latin America.

"Using Microsoft cloud computing and Esri's modern [GIS] tools, we are able to generate, analyze, and share biodiversity data at a pace and scale never before possible," said Healy Hamilton, NatureServe's chief scientist. "We've stacked these maps to see what we've never seen before: We can identify the places that matter for sustaining our nation's biodiversity," said Hamilton.

The data for this map was collected over decades by NatureServe's network of botanists and zoologists. For areas where little or no data has been collected, data science can fill in the gaps through the use of predictive information models for thousands of species.

"With Esri technology and support from Microsoft's AI for Earth program, we've built a spatial modeling infrastructure in the cloud that allows our scientists from New York to Arizona to work together to fill in these blank places on the map," said Regan Smyth, director of spatial analysis for NatureServe.

understanding of the human and ecological landscapes," explained Naftali Honig, the organization's director of research and development at Garamba National Park in the Democratic Republic of the Congo.

A problem in Garamba is poaching. By monitoring collared animals, the team can see—in real time—when a herd is acting erratically, which could indicate it is evading poachers. They also map other indicators such as fires or illegal camps. By always knowing where its rangers are, African Parks can quickly dispatch them directly to areas where poachers might be. This has helped reduce elephant poaching in Garamba by more than 90 percent.

African Parks also uses GIS for supporting

Naftali Honig, Evan Trotsuk, and Geoff Clinning of African Parks described how they use a vast network of sensors and ArcGIS to combine traditional conservation measures with context-based strategies.

NatureServe unveiled its Map of Biodiversity Importance for the United States, providing a high-resolution view of the most imperiled species for the first time.

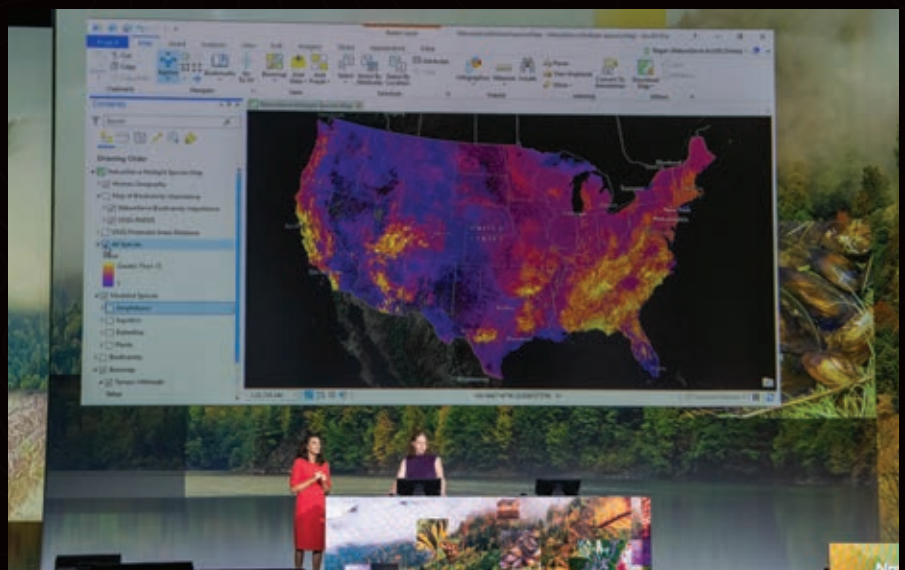


Traditional Conservation Goes Holistic

Another presentation described how GIS is preserving species on the other side of the world. To restore and manage protected areas across Africa, the nonprofit African Parks partners with governments and local communities. But it's a big job that spans 15 parks in nine countries.

"Working at this scale across Africa's diverse landscape requires holistic and adaptable management," said Geoff Clinning, African Parks' technology development manager.

Using a vast network of sensors along with ArcGIS technology, African Parks combines traditional conservation measures with context-based strategies. It fuses "our





✦ Marcel Broekhaar, an adviser for the City of Zwolle's Smart Zwolle initiative, told how residents of Zwolle are contributing to efforts to make the city more resilient.

✦ Scientists Jane Goodall and E. O. Wilson discussed their shared concerns over threats to biodiversity.

the young people involved in her Roots and Shoots program, who take on projects such as studying invasive species, biodiversity loss, climate change, and habitat destruction.

"We've just got this one blue and green planet. We do have the intellect. If we get together now, we can find ways to deal with the terrible crises that we are in," she said.

Residents Join Together to Supply and Use Open Data

Applying GIS to local as well as global survival was the focus of a presentation about Zwolle, a city in the Netherlands that is prone to flooding. It's a problem that is only getting worse.

"We need to be resilient to climate change, and GIS is helping us do that," said Marcel Broekhaar, an adviser for the City of Zwolle's Smart Zwolle initiative.

The city wanted to involve residents of the Stadshagen neighborhood in flood monitoring, so Broekhaar and his team created an ArcGIS Hub initiative called SensHagen. They built and dispatched weather and air quality sensors and then held an informational meeting for residents to show them how the sensors work and where to access data on the hub.

"[Residents] appreciated that we involved them," said Broekhaar. "They wanted to participate."

And they did. Local university students made more sensors. Residents learned how to use SensHagen Hub to make maps and analyze data. People downloaded a Survey123 for ArcGIS app to report standing water. A group of engineers even built wet feet sensors that report flooding directly to the hub.

"What started as a project became an initiative—and is now a movement," said Broekhaar.

Getting a Census Ready—and Right

Obtaining citizen participation is also important to the United States Census



surrounding communities. For example, outside Rwanda's Akagera National Park, African Parks started a fishing operation that generates revenue for the community while promoting sustainable fishing.

Treating these unique landscapes as a nervous system—complete with sensory inputs, related analyses, and intelligent actions—is a good start. However, there is still much to do to ensure that Africa's protected areas thrive for generations.

Chimpanzees, Insects, and Biodiversity

Dangermond moderated an hour of conversation between Jane Goodall, DBE, and founder of the Jane Goodall Institute, and

Edward O. Wilson, honorary curator in entomology and university research professor emeritus at Harvard University. The two scientists have worked in very different fields—chimpanzees and ants, respectively—but they share a concern about preserving the Earth's biodiversity.

Wilson, through his E.O. Wilson Biodiversity Foundation, supports the Half-Earth Project, which has as its goal conserving half the Earth's lands and seas to protect 85 percent or more of the planet's biodiversity. Mapping all these species is necessary to better understand every plant and animal.

Goodall said she's optimistic about biodiversity conservation. Much of her optimism centers around youth, including

➤ The United States Census Bureau is using GIS “to count everyone once, only once, and in the right place.”

➤ Musician and GIS fan Kevin Eubanks performs a piece he wrote for the plenary session.

Bureau. It is a pressing concern, because the 2020 Census is just months away.

“Our goal is to count everyone once, only once, and in the right place,” said Deirdre Dalpiaz Bishop, chief of the US Census Bureau’s geography division. Which is why the bureau has incorporated GIS heavily.

To verify that every state, county, city, tract, block, and address is accounted for, the Census Bureau uses imagery. Census takers, who follow up with nonresponding households, will use an enumeration app, built with ArcGIS Runtime, on iPhones.

“Our route optimizer leverages data from industry leaders, combined with census-specific criteria such as work availability, and calculates [an] optimized case assignment,” said IT specialist Anika Adams-Reefer.

All completed cases will automatically sync to the Census Bureau’s servers, saving time, money, and paper. To help tribal, state, and local governments prioritize census outreach efforts, the bureau is using a configured web app—the Response Outreach Area Mapper, or ROAM. The app lets local leaders identify areas with high predicted nonresponse rates and plan appropriate actions.

“We’re able to make quick, well-informed, and responsible data-driven decisions to help motivate people to respond,” concluded computer mapping specialist Suzanne McArdle.

Call to Action

Dangermond emphasized that conference attendees should continue applying and developing GIS, saying, “Your work is essential. The geospatial revolution is just beginning. It is going to profoundly transform our world.”

He exhorted them to be more than technologists. “Building an intelligent nervous system is more than just technology. It will take leadership to envision what’s possible through learning, sharing, and collaborating just like you do now, and strategic thinking by engaging communities,



getting it together, and also—above all—a passion for creating a better world. It will take leveraging The Science of Where to SEE WHAT OTHERS CAN’T.”

Although this article provided only highlights from the daylong plenary session, recordings of these and other presentations are available at bit.ly/2JEh1wK. To learn even more about some of the organizations that presented on the plenary stage, see ArcNews articles on the City of Pasadena (p.ctx.ly/r/9i6t) and the Geneva International Centre for Humanitarian Demining (p.ctx.ly/r/9i6s).

About the Authors

Carla Wheeler is a technology editor and writer at Esri and a former journalist. She currently edits *ArcWatch*. Follow her at @gisjourno.

Citabria Stevens is the senior editor of Esri’s *ArcNews* magazine. She helps users tell compelling stories about how they employ Esri technology in innovative ways and ensures that readers stay well-informed about ArcGIS solutions. She began her career as a journalist at CNN before moving into the fields of international development and geopolitics. Follow her at @ArcNewsMagazine.

Arcade-a-Cadabra

This expression language can magically transform your maps

By Jennifer Bell

“Arcade is magic!”

That was the reaction of Sari Ladin-Sienne, the chief data officer for the City of Los Angeles after viewing a demonstration of ArcGIS Arcade by Esri staff at a cross-departmental meeting last May.

ArcGIS Arcade is an expression language that transforms data on the fly to create meaningful labels, symbology, and pop-ups. This is especially useful when working with live feed data and layers that are owned by someone else. Arcade can save hours that would otherwise be spent updating or processing data.

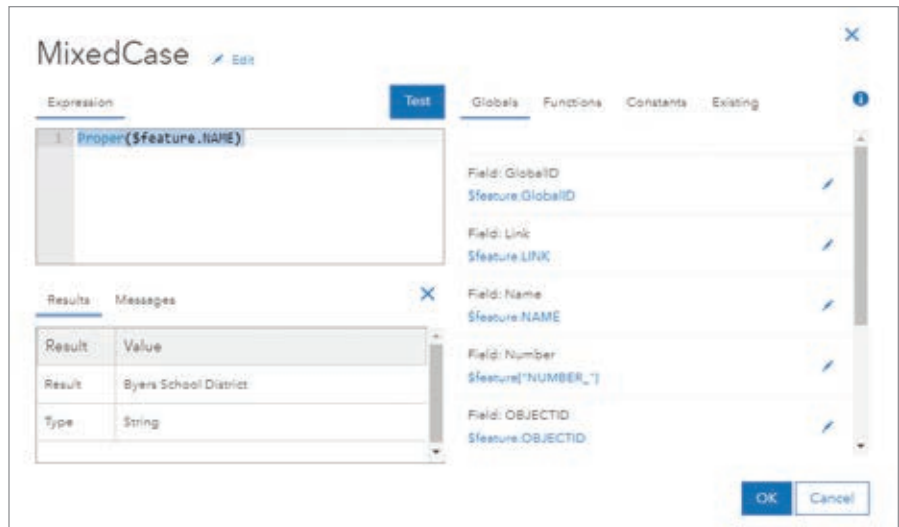
Like the functions in Microsoft Excel, Arcade can take existing data and create new information on the fly, performing operations that range from simple calculations, such as addition or multiplication, to complex If-Else statements or For loops.

Traditionally, to change data, you must own the layer or make a copy of it, rather than modify the data in the source layer. If you owned the data or a copy and you wanted to symbolize the data based on a new attribute, you would add a field, calculate it, and verify the results. Although sharing layers that are centrally maintained by an organization reduces duplication of work, members of that organization can be stymied when they want to modify data in a layer that they do not own.

Ladin-Sienne and the other 30 data leaders in that meeting have been instrumental in optimizing the city’s data, which is maintained in and shared from the Los Angeles GeoHub. Arcade meets the city’s data transformation needs and is a data processing time saver.

Whether you are part of a large organization, like the City of Los Angeles, or you are a one-person shop, you can use Arcade in ArcGIS Online and ArcGIS Pro to modify layers to best serve the needs of your project. The Arcade expression builder looks the same whether you are creating expressions for your pop-ups, labels, or symbology.

The following scenarios highlight how Arcade can enhance ArcGIS Online maps. The first scenario is a beginner level example of labeling; followed by an intermediate example about symbolology; and finally, an advanced scenario with pop-ups.



↑ Generate an expression in the Arcade builder by choosing fields in the layer and applying the Proper function so the school district labels display as mixed case format rather than the uppercase format of the source data layer.

Create the Perfect Label

A county GIS analyst in Colorado (let’s call her Monica) needs to quickly create a map of school districts for a meeting that will be held in a couple of hours. Her county’s ArcGIS Online organization content contains a school districts layer, but the names of the school districts are all capitalized so the labels display as BYERS SCHOOL DISTRICT instead of Byers School District. She prefers mixed case to uppercase because it makes the labels easier to read. However, she won’t have time to ask the person who made the layer to change the field, let alone have the time to download the data, edit the field, and rehost the layer.

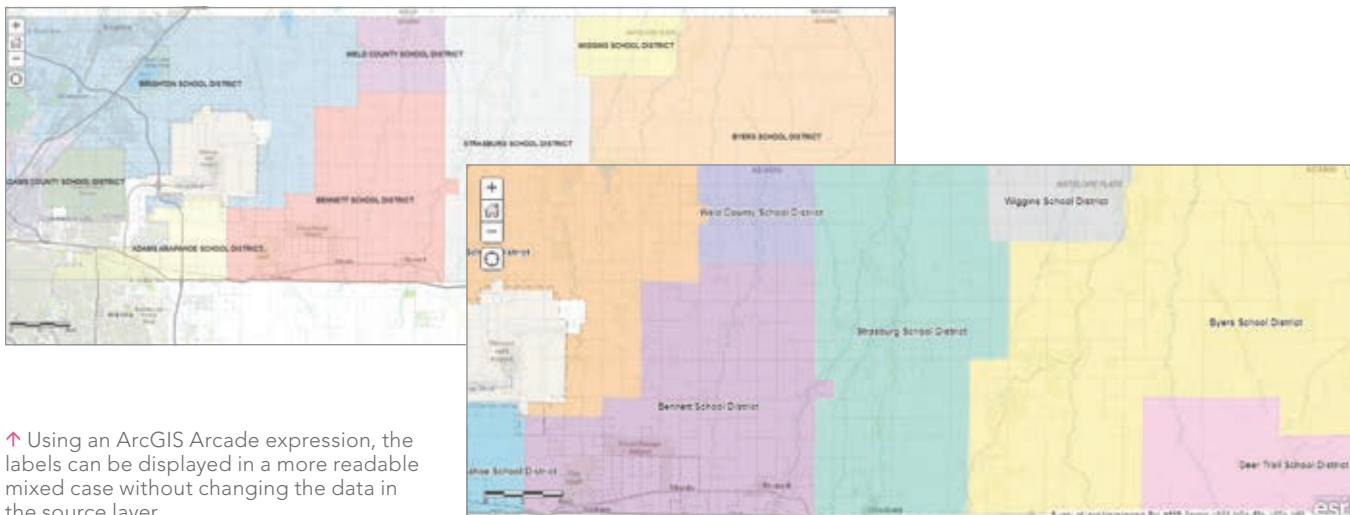
Monica just learned about the power of Arcade to edit labels on the fly and tries it out on the school districts layer. She opens the Arcade editor by choosing Label Features and choosing Custom Expression, located at the bottom of the drop-down list. She uses the Proper function, which sets the first letter of each word to uppercase and the rest to lowercase, to create this expression,

```
Proper($feature.NAME)
```

which transforms BYERS SCHOOL DISTRICT to Byers School District.

With just one Arcade expression, Monica saved hours of work and is now ready to go to the meeting with a more polished map in hand.

For extra credit, if Monica wanted to provide more information,



↑ Using an ArcGIS Arcade expression, the labels can be displayed in a more readable mixed case without changing the data in the source layer.

she could use Arcade to concatenate (string together) multiple fields into one label. For example, if she wanted to include the enrollment numbers for each school, she could create a label like “Byers School District – 2,570 students.” The following Arcade expression would accomplish this:

```
Proper($feature.NAME) + “ – ” + $feature.STUDENTS + “students”
```

Style the Map Your Way

A city worker in North Carolina (let’s call him Steven) is tasked with ensuring that all electric scooters that the city rents maintain a charge of at least 50 percent. Steven sees a layer in his city’s ArcGIS Online organization website that shows the current locations and battery levels of scooters throughout the city. Right now, it’s simply

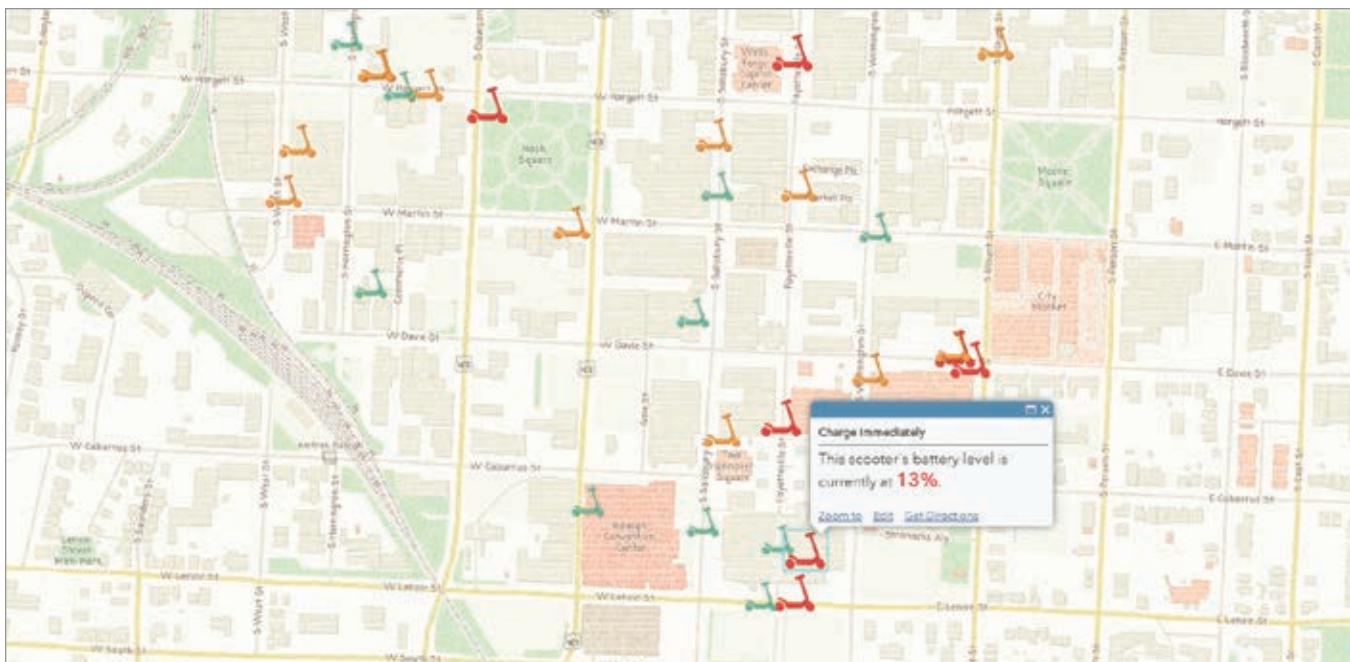
a map with lots of dots, but he’d like the map to highlight which scooters need an immediate charge, so he is going to use Arcade to style the map to highlight which scooters need immediate attention.

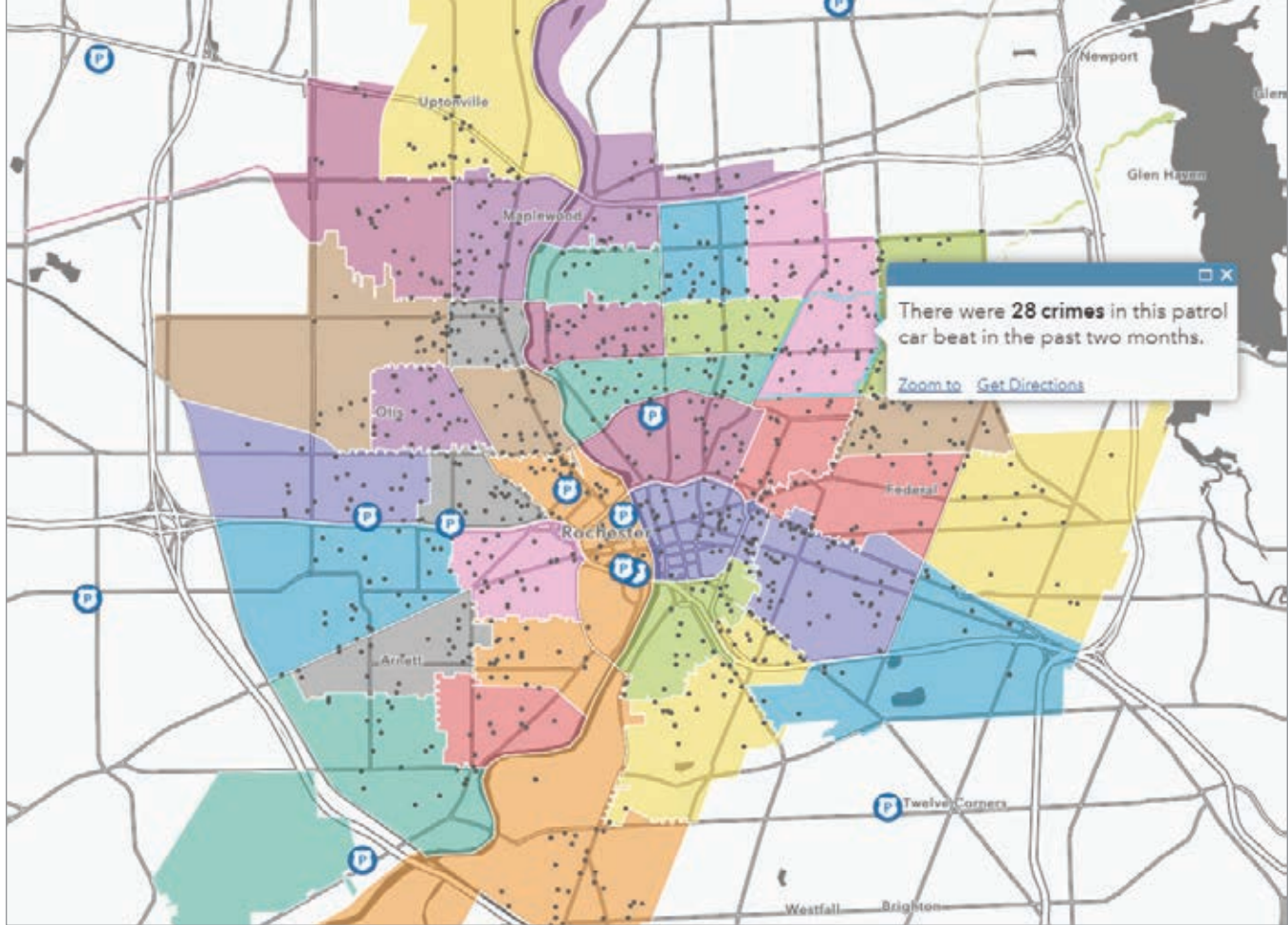
Unfortunately, the layer’s battery level field (battery_level) is stored as a string, or text, in the layer. Steven could ask the data’s owner to fix this in an upcoming update, but he knows that will take weeks. To do anything meaningful in the map, he must first convert the string field to a number field using the Number function in Arcade.

```
Number($feature[“battery_level”])
```

This is where things get interesting. He has been asked to make things very clear on the map, so Steven creates three categories—Charge

↓ Arcade expressions transformed the layer to show not only the location of each scooter but also its battery status so this map can be used to prioritize scooters charging.





↑ Arcade expressions can be used to calculate the number of points in a polygon as in this example, which shows the number of crimes in each patrol car beat in the past two months.

Immediately, Charge When Possible, or Fully Charged—that are based on a numeric field that indicates the battery level.

```
var battery = Number($feature["battery_level"])
```

```
When (battery < 50, "Charge immediately",
battery >= 50 && battery < 90, "Charge When Possible",
"Fully Charged")
```

↑ Listing 1

The code in Listing 1 is read as “When the battery level is less than 50, return Charge Immediately, when the battery level is between 50 and 90, return Charge When Possible, and for all other values return Fully Charged.”

These categories did not originally exist in the data, but with just a few lines of Arcade, Steven now has a map that is useful and will help him become more efficient with his time.

As a bonus, when the dataset updates with new scooter locations and battery levels, the Arcade expression incorporates the new information on the fly, so Steven does not need to manually recalculate values. For this reason, Arcade is especially useful with live feed data and datasets that update frequently.

Make Your Layers Talk to Each Other

A crime analyst at a police department in New York State (let’s call her Connie) calculates the number of crimes that occur in

each patrol car beat zone. Every time the data updates—which is every week—she must repeat her analysis and hardcode the total number of crimes within each zone.

The new FeatureSets option in Arcade lets two layers reference each other. Connie would like to use FeatureSets to make the police boundaries layer “talk” with the crime points layer to calculate the number of crimes in each beat.

To do this, she adds an Arcade expression to the pop-up that counts the number of points in each polygon, which is shown in Listing 2.

```
//This is where the polygon layer (police beats) makes a
"call" to the point layer (crimes)
```

```
var crimes = FeatureSetByName($map,"RPD - Part I Crime
60 Days - RPD Part I Crime - Last 60 Days")
```

```
//Counts the number of crimes that intersect with the
police beats layer
```

```
var countCrimes = Count(Intersects($feature, crimes))
```

```
//Return the result of the variable created in the line
above
```

```
return countCrimes
```

↑ Listing 2

The first line makes a “call” to the crime point layer in the web map. The second line counts all the crimes that fall within, or intersect, the patrol car beat. The last line returns the variable created in the second line. To make her pop-up even more meaningful, Connie can determine the distribution of the various types of crime using another Arcade expression that is shown in Listing 3.

```
//This is where the polygon layer (police beats) makes a
call to the point layer (crimes)
var crimes = FeatureSetByName($map,"RPD - Part I Crime
60 Days - RPD Part I Crime - Last 60 Days")
//Filters the field Statute_Text to a specific type of
crime and calculates the sum
var larceny =Count(Intersects(Filter(crimes,"Statute_Text
LIKE %larceny%"),$feature))
var aggravatedAssault = Count(Intersects(Filter(crimes,"St
atute_Text LIKE %assault%"),$feature))
var burglary = Count(Intersects(Filter(crimes,"Statu
te_Text LIKE %burglary%"),$feature))
var motorVehicleTheft = Count(Intersects(Filter(crimes,"St
atute_Text LIKE %vehicle%"),$feature))
var robbery = Count(Intersects(Filter(crimes,"Statute_Text
LIKE %robbery%"),$feature))
var murder = Count(Intersects(Filter(crimes,"Statute_Text
LIKE %murder%"),$feature))
//Returns a breakdown of crime types in each police beat
return "Larceny: " + larceny + TextFormatting.NewLine +
"Aggravated Assault: " + aggravatedAssault +
TextFormatting.NewLine +
"Burglary: " + burglary + TextFormatting.NewLine +
"Motor Vehicle Theft: " + motorVehicleTheft +
TextFormatting.NewLine +
"Robbery: " + robbery + TextFormatting.NewLine +
"Murder: " + murder
```

↑ Listing 3

Now, when the crime data updates, Connie’s meaningful pop-up will automatically update with the new aggregation. Arcade has saved Connie hours of work and has freed her time for additional analysis work.

Try Your Hand at Some Arcade Magic

Arcade is a powerful tool that is used especially when you do not own the data or when the layers are updated frequently. You can use Arcade to edit labels, symbology, and pop-ups. For more information on Arcade, visit esriurl.com/LearnArcade.



↑ By getting layers to “talk” to each other, the pop-ups in this map can not only provide the number of crimes but also give a breakdown of different types of crimes for each patrol car beat.

About the Author

Jennifer Bell is a data wizard, storyteller, and lover of all things maps. Her time living in Thailand, Saudi Arabia, and the United States cultivated her interests in human rights, social equity, and movement, which appear throughout her work. She works for Esri as a geographer on the ArcGIS Living Atlas team and is an advocate for better maps that provide understanding and cause action.

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Turn Raw Data into a Feature Layer

By Diana Lavery

Most demographic, economic, health, and education maps start with tabular data of some kind. This article will describe several ways you can turn a flat file of raw data into a feature layer. Feature layers allow you to do spatial analysis and create web maps that can be shared in apps and story maps.

Add a Spreadsheet with Location Data, Geocode, and Create Points

Often, data analysts and GIS specialists need to turn a spreadsheet on a local computer into a feature layer. In this example, I have a local spreadsheet containing information about Medicare spending per patient for various hospitals. The fields that contain location data for each hospital are called Address, City, State, and Zip_Code.

I am signed in to my ArcGIS Online organization account and have a User Type that allows me to publish hosted feature layers (Creator, GIS Professional, or Insights Analyst User Types). I have some analysis credits as these methods will consume credits, based on how many records are contained in my data.

In My Content in ArcGIS Online, I choose Add Item > From my computer and navigate to the CSV file. ArcGIS Online will prompt me to publish this file as a hosted feature layer, will pick up on the fact that the data has address fields in it, and will offer to use those as the location fields.

I check to make sure that Address, City,

State, and Zip are matched as desired. In this case, I manually set my field named ZIP_Code as ZIP.

I make sure the title and search tags are what I want, and then click Add Item. Depending on the number of records, it can take a few minutes to publish. Once published, a dialog box appears that tells me how many of my locations matched, and I have a chance to review any unmatched cases.

Once the item has been created, ArcGIS Online automatically brings me to the Item Details page for a new points feature layer. (Note: If your spreadsheet has latitude-longitude coordinate data instead of address fields, the process is very similar.)

When to Join to an Existing Feature Layer

I can also simply bring my data in as a table, then join to an existing feature layer. When would it be better to bring a spreadsheet in as a table instead of geocoding it immediately?

If I have a spreadsheet without addresses or latitude-longitude coordinates but still need to bring this data into a GIS workflow, maybe I can use hospital IDs, campus names, or other specific attribute data that will not be picked up by the geocoder but can be joined by attributes to an existing points layer in My Content on ArcGIS Online.

If I want to work with lines or polygons instead of points, I can find layers to use by

looking at the Boundaries category of the ArcGIS Living Atlas of the World for polygon feature layers of countries, states and provinces, telephone area codes, congressional districts, world time zones, counties, watersheds, and more.

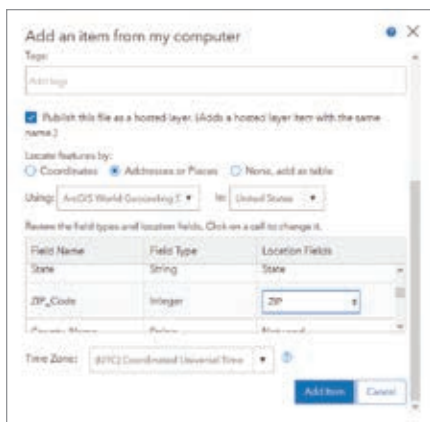
I downloaded a spreadsheet from the County Health Rankings Data and Documentation site that was named analytic_data2019_0.csv during the download. The first row in the CSV holds the descriptive name (such as Premature death raw value) that I will use for aliases. The second row is the short variable name used for coding purposes in statistical packages that corresponds to the data dictionary (such as "v001_rawvalue") that is recognized by others who use this dataset. If you plan to calculate any new fields or transform the data in any way, it will be much easier to work with these field names in formulas and macros, since they often follow a standard naming convention. I remove the top row of descriptive aliases for now but save them elsewhere.

This table contains records for the United States as a whole, records for each state, and records for each county. This is common for government datasets. Since I am just bringing this in as a basic rectangular dataset (or flat file) as a table into ArcGIS Online, this is okay. Once I'm working with it, I can apply filters.

I'll click My Content > From Computer, but this time I select None, add as table.

↓ This spreadsheet contains data on Medicare spending per patient for various hospitals. The Address, City, State, and Zip_Code fields will be used to geocode each record.

Provider ID	Hospital Name	Address	City	State	ZIP Code	County Name	Phone Number	Measure Name	Measure 1 Score
10005	MARSHALL MEDICAL CENTER SOUTH	2505 U S HIGHWAY 431 NORTH	BOAZ	AL	35957	MARSHALL	2565938310	Medicare hospital spending per pt MSPB-1	
10012	DEKALB REGIONAL MEDICAL CENTER	200 MED CENTER DRIVE	FORT PAYNE	AL	35968	DE KALB	2568453150	Medicare hospital spending per pt MSPB-1	
10131	CRESTWOOD MEDICAL CENTER	ONE HOSPITAL DR SE	HUNTSVILLE	AL	35801	MADISON	2568823100	Medicare hospital spending per pt MSPB-1	
11304	CHOCTAW GENERAL HOSPITAL	401 VANITY FAIR LANE, PO BOX 618	BUTLER	AL	36904	CHOCTAW	2054599100	Medicare hospital spending per pt MSPB-1	No
20018	YUKON KUSKOKWIM DELTA REG HOSPITAL	PO BOX 287	BETHEL	AK	99559	BETHEL	9075436300	Medicare hospital spending per pt MSPB-1	No
21301	PROVIDENCE VALDEZ MEDICAL CENTER	PO BOX 550	VALDEZ	AK	99686		9078352249	Medicare hospital spending per pt MSPB-1	No
21304	PETERSBURG MEDICAL CENTER	PO BOX 589	PETERSBURG	AK	99833		907724291	Medicare hospital spending per pt MSPB-1	No
21307	CORDOVA COMMUNITY MEDICAL CENTER	PO BOX 160 - 602 CHASE AVENUE	CORDOVA	AK	99574		9074248000	Medicare hospital spending per pt MSPB-1	No
21308	NORTON SOUND REGIONAL HOSPITAL	1000 GREG KRUSCHEK AVENUE (P O BOX 966)	NOME	AK	99762	NOME	9074433311	Medicare hospital spending per pt MSPB-1	No
21309	KANAKANAK HOSPITAL	P O BOX 130	DILLINGHAM	AK	99576	DILLINGHAM	9078425201	Medicare hospital spending per pt MSPB-1	No



↑ The Zip_Code field is manually mapped to ZIP.

Once the item is generated, ArcGIS Online brings me to the Item Details page, where I select Open in Map Viewer > Add to New Map.

Now I can filter out the records that I'm not interested in. With my table added to the Map Viewer, I can verify this table has 3,194 records. Remember, the table has records for the entire country and for each state and each county. Records for the US and the states have a value of 0 in the field called countycode. I can add the filter countycode is not 0 to remove any noncounty records, and this gets me down to 3,142 records.

Subset to an Area of Interest

Many health and education policies are set at the state level. Data analysts working in these fields don't need to work with all the counties in the nation, just the ones in their own state. For example, if I was working at the Ohio Department of Health, I would be interested in the County Health Rankings for all Ohio counties. Having to work with the entire national dataset would be distracting at best. It would likely be overwhelming, slow down processing time, and create file sizes larger than necessary. The best approach would be to apply a filter to only work with the Ohio data.

Back on the Filter tab, I click Add another expression to subset even further and leave the top drop-down option as Display features in the layer that match all the following expressions. The two expressions are countycode is not value and state is OH. This gets my table down to 88 records, which is the number of counties in Ohio.

From there, I'll click Add > Browse Living

Atlas Layers and add the USA Counties (Generalized) layer of county polygons to my map. I apply a filter to the counties layer so that it only shows counties in Ohio, not all counties in the US. This will decrease the running time for the Join and also consume fewer analysis credits.

My next step is to join my table to the county boundaries by clicking Analysis > Summarize Data > Join Features. I select the target layer, USA Counties (Generalize), and the table, analytic_data2019_0, to join to the target layer.

I'll join by FIPS, which stands for Federal Information Processing Standard. FIPS codes are widely recognized codes for states, counties, tracts, congressional districts, school districts, and many other administrative geography levels. I will do an attribute join, so I select Choose the fields to match and match FIPS as the target field to fipscode as the join field.

Next, I choose a name for my new layer, Health Rankings for Ohio Counties 2019. Note: If I were joining all counties in the US, I would have to uncheck Use Current Map Extent so that counties in Alaska, Hawaii, and Puerto Rico would also be included even though they're not displayed in the map's current extent.

Joining Tips

Here are some best practices when joining tables to feature layers.

When Joining by a Match ID Such as FIPS

Watch leading zeros for states with single-digit FIPS codes such as Alabama (01), Alaska (02), Arizona (04), Arkansas (05), California (06), Colorado (08), and Connecticut (09). Often these leading zeros get dropped because computers are quick to recognize this field as a numeric rather than string field.

↓ A CSV file of county health rankings data (analytic_data2019_0.csv) contains records for the entire United States.

1	State	FIPS	County	FIPS	5-digit	FIPS	State / Name	Release	Year	Count	Premature	Death	Raw	Premature	Death	Numerator	Premature	Death	Denominator
2	statecode	countycode	fipscode	state	county	year	coun	v001	rawvalue	v001	numerator	v001	denominator						
3	0	0	0	US	United States	2019		6900.630354			3745538		908266078						
4	1	0	1000	AL	Alabama	2019		9917.232898			80440		13636816						
5	1	1	1001	AL	Autauga County	2019	1	8824.057123			815		156132						
6	1	3	1003	AL	Baldwin County	2019	1	7224.63216			2827		576496						
7	1	5	1005	AL	Barbour County	2019	1	9586.165037			451		72222						
8	1	7	1007	AL	Bibb County	2019	1	11783.54368			445		63653						
9	1	9	1009	AL	Blount County	2019	1	10908.10182			1050		161107						
10	1	11	1011	AL	Bullock County	2019	1	12066.91026			205		29266						

When Joining by Name

When joining on County Name, join by both county and state. Unlike FIPS codes, county names are not unique across states. For example, there are 26 states that have a Franklin County. Also, make sure you're consistently using state abbreviations or state names in both the target layer and the table.

Beware of Country Names

Some sources list the official country name rather than the commonly understood name ("Russian Federation" vs. "Russia"). Watch for abbreviations such as St. Martin versus. Saint Martin. There are constant changes to country names. Two recent changes were Cape Verde to Cabo Verde and Macedonia to North Macedonia. New countries form all the time. I can remember a time before South Sudan existed.

Running the Join

Next, I click Run Analysis, and wait patiently. A join can take a few minutes depending on how many fields and records are in a table; whether the table is be joined to polygons (most complex), lines, or points (least complex); and where the two datasets being joined are stored. If you're running a join on a layer that you don't own, such as a Living Atlas layer, you might see the warning "Performing analysis using Living Atlas layers can result in greater execution times," since you're performing a join from multiple data sources.

I now have a new layer in my map that has the tabular data joined to the polygon layer. I can symbolize it and use it to configure pop-ups and create labels. I make sure I fill out the Item Details for my new layer. [Read how and why it is important to fill out the Item Details page in my article "Make Your Work Easy to Find, Understand, and Use by Others" in the Spring 2019 issue



← The uploaded table contains 3,194 records, but after adding it to ArcGIS Online, filters can be used to make it more manageable.

↓ Filters applied limit both layers to just 88 records relating to Ohio. This will save time and credits when joining layers.

to year look believable?

- Do all the parts add up to the whole?
To learn more about this topic, see the *ArcGIS Blog* post, "Evaluate and Prep Your Tabular Data in ArcGIS Online."

Add Aliases

Remember those nice display names I saved earlier? I can now add them as field aliases. There are two major benefits to adding aliases. Aliases make any auto-generated and pop-up legends instantly more meaningful, since the alias is used in legends and pop-ups first; the field name is used only if there are no aliases. Also, aliases help anyone working with the layer (including you) when you are viewing the attribute table, trying to figure out what this data is about, and making decisions for symbolizing the map. Aliases turn spreadsheet data into a shareable dataset.

I have two ways to add aliases. From within the web map, I can go to Configure

of ArcUser.] Part of documenting layers is managing settings such as sharing, enabling delete protection, setting the default extent, marking something as authoritative on behalf of your organization, or allowing others to edit.

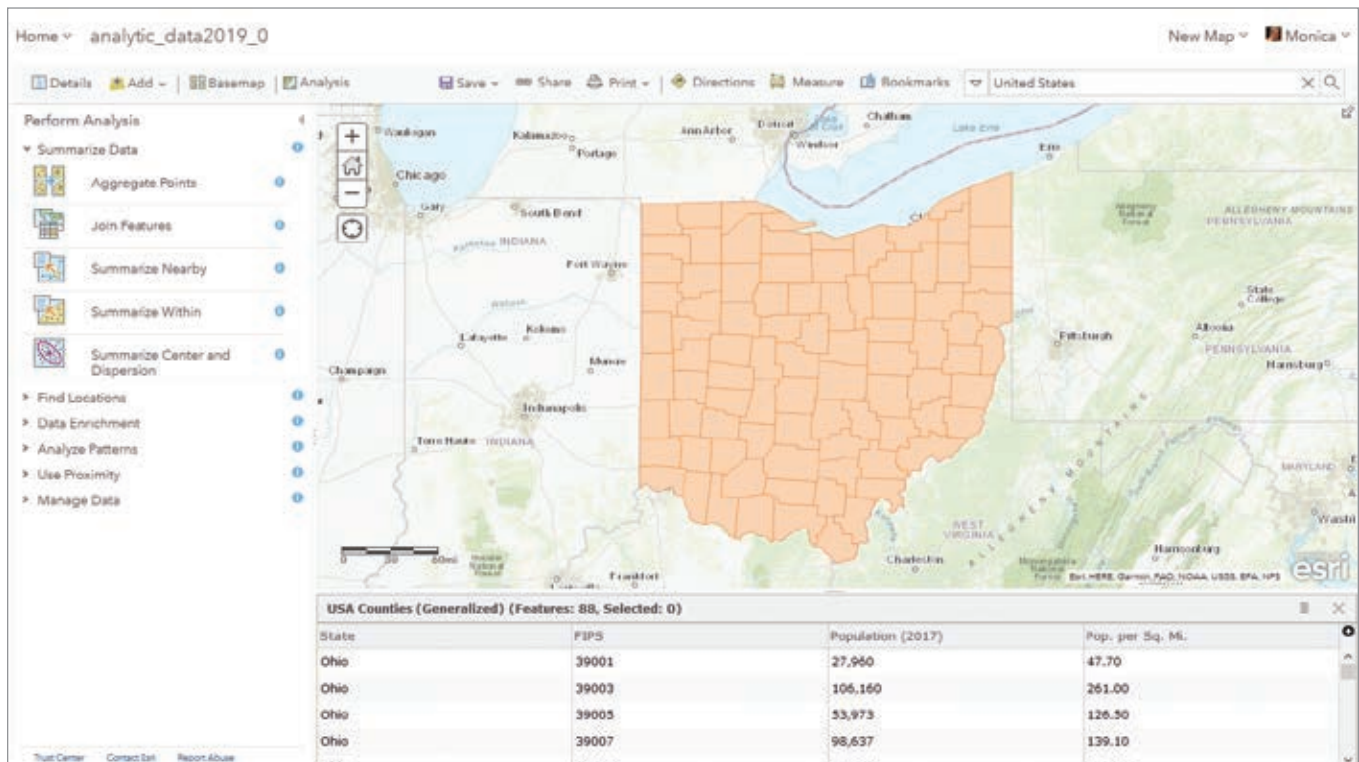
Basic Quality Assurance

Once you bring in your data to ArcGIS Online, either by geocoding it to create a point feature layer or by joining a table to

an existing feature layer, evaluate your data.

Here is a sample checklist you can use for quickly evaluating the data:

- Are the number of records what you expected?
- Are the data types what you want?
- Is the data sorted as you expected?
- Do the minimum and maximum values look right?
- Is anything out of range?
- If applicable, does the change from year



Pop-up > Configure Attributes and type in the aliases for my fields of interest. I can also go to the Item Details page, choose the Data tab then Fields, and click on the field I want to change. I will be taken to that field's properties, where I can click on the pencil icon to edit the alias and type in my alias for that field.

You can even batch assign all aliases at once by using this nice AliasAssigner.py tool (<https://bit.ly/2lvFFAk>) written by my colleague Lisa Berry.

Take it one step further and add field descriptions in addition to aliases to provide even more details about specific attribute fields such as detailed definitions, sources, and year(s) of data in a given field.

Create Information Products with Your Data

Now it's time to have fun performing analysis or creating a web map. Smart mapping capabilities and Arcade expressions can help you make a clear and polished web map with purposeful symbology, pop-ups, and labels. [To learn how to use Arcade

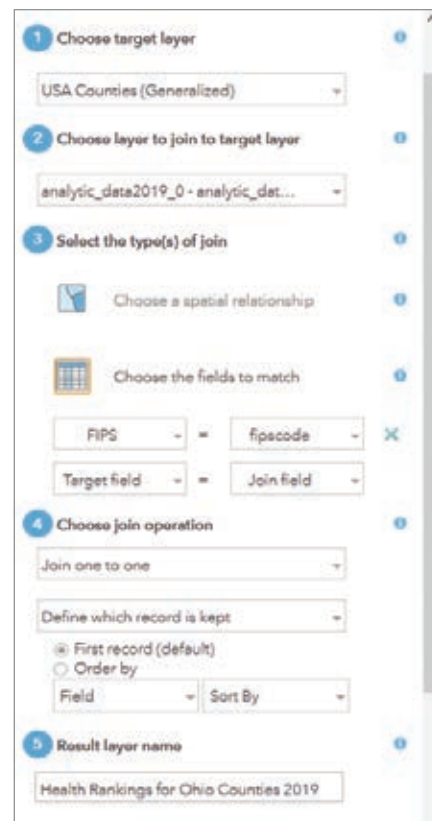
→ Join the layers by attribute using the FIPS code field from both.

expressions to be more productive, see the accompanying article, "Arcade-a-Cadabra," in this issue.]

For more information on getting started with data, see the ArcGIS Online documentation. If you have any questions when turning your raw data into a feature layer, feel free to post them to the ArcGIS Online community on GeoNet.

About the Author

Diana Lavery loves working with data. She has more than a decade of experience as a practitioner of demography, sociology, economics, policy analysis, and GIS—making her a true social science quantoid. Diana holds a bachelor's degree in quantitative economics and a master's vdegree in applied demography. She has been a product engineer on Esri's Living Atlas and Policy Maps teams since 2017. Diana enjoys strong coffee and clean datasets, usually simultaneously.



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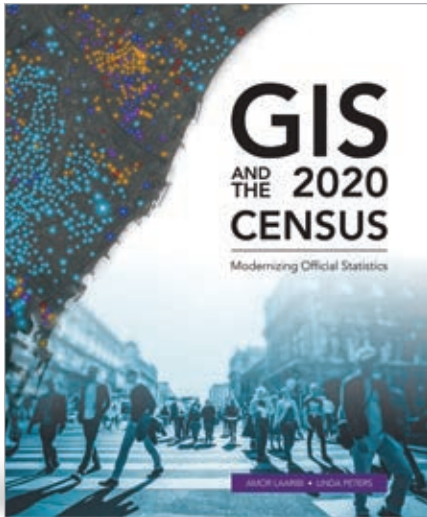
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Learn How Geospatial Technology Supports Critical Census Tasks

GIS and the 2020 Census: Modernizing Official Statistics provides statistical organizations with information on how the most recent geospatial methodologies can support all stages of a census.

The application of geography for optimizing census work has steadily increased worldwide. Mapping provides the geographic basis for the enumeration process, and geospatial technologies have made the process of planning and carrying out census work more efficient as well as improved the analysis and dissemination of census data.

Geography is acknowledged as the key to all national statistics systems. Esri's experience with many census mapping projects has proven this. The United Nations (UN) confirms the value of geospatial technologies for these activities. GIS-based census programs cover the pre-enumeration, enumeration, and postenumeration phases. Advances in the use of imagery and lowering of its cost have substantially enhanced census work in terms of speed, accuracy, and cost reduction.

GIS and the 2020 Census covers converting existing data, field operations, data processing and dissemination, developing geographic products, and many other aspects of the census workflow. Case studies from Albania, Portugal, Republic of the Philippines, Jordan, Arab Republic of Egypt, Ireland, and Canada demonstrate the successful application of geospatial technology.

Although this book is designed with fieldwork in mind, its techniques can be applied to register-based census work. Ancillary materials are available online and include the updated census data model, the Global Statistical Geospatial Framework and the UN *Handbook on the Management of Population and Housing Censuses*.

Authors Amor Laaribi and Linda Peters have extensive experience using geospatial data and statistics to support improved decision-making. Laaribi, who joined the United Nations Statistics Division (UNSD) in 2000, has a PhD in geomatics sciences. He contributed to the foundation of the UN Committee of Experts on Global Geospatial Information Management (UN-GGIM) and acted as secretary of the UN Expert Group on the Integration of Statistical and Geospatial Information (UN-EGISGI) since its inception.

Peters has a bachelor's degree in geography and more than 20 years of experience in the geospatial industry. During her 14 years at Esri, she has consulted with companies in many industries, helping them achieve greater efficiencies through spatial and location analyses. She helps National Statistical Offices (NSOs) across the globe understand how to apply geographic methods and analysis to census and statistical activities. Peters authored Esri's massive open online course (MOOC) *The Location Advantage*, which teaches how to apply geospatial technology to business. Esri Press, 2019, 264 pp., ISBN: 9781589485044.





“There is no better tool to understand our place in the world than GIS, and this book puts its power on beautiful display. It’s a book for scientists and all of Earth’s stewards.”

Jessica Hellmann
Director of the Institute on the Environment
University of Minnesota

Enabling Scientists to See a Better Future

GIS for Science: Applying Mapping and Spatial Analytics is about science and the scientists who use GIS. Its audience is made up of professional scientists, citizen scientists, and citizens who are interested in science and geography and how GIS can meet the challenges the world faces.

This is a collection of contributed articles that describe how the Earth works, how the Earth looks, and how we look at the Earth along with a section on how the up-and-coming generation is using GIS. The last section of the book features applications of GIS technology, such as the Sentinel Explorer application for viewing imagery over time and the National Water Model for simulating and forecasting water movement in the rivers and streams of the United States, that enable scientists to more deeply understand the Earth.

This book highlights the use of GIS for projects as diverse as mapping global ecosystems, analyzing natural hazards, studying climate change, mapping ancient settlements, and studying the surface of Mars.

As noted in the introduction by Esri president Jack Dangermond and Esri chief scientist Dawn Wright, “This book is full of examples that show how GIS advances rigorous scientific research.” Whether studying glacial retreat, super volcanoes, seagrass habitats, or the response of birds to the changing climate, more scientists today are turning to GIS, drones, remote sensing, machine learning, and other technologies to better understand how the planet works.

One example of how GIS advances scientific research is in “Mapping Ancient Landscapes,” written by Jason Ur, professor of anthropology and the director of the Center for Geographic Analysis at Harvard University, and Jeffrey Blossom, the center’s GIS service manager. It documents how a team of archaeologists from around the world used GIS, historical satellite imagery, geo-referenced drone imagery, and archaeological fieldwork to study the ancient settlements of the Assyrian Empire in what’s now the Kurdish-controlled region of Iraq. Because some sites are located near growing communities, archaeologists must work quickly to stay ahead of new housing.

Edited by Wright and Christian Harder, a writer, editor, and map-maker at Esri, *GIS for Science* is beautifully illustrated. A companion website at GISforScience.com provides readers with data and other resources such as maps, apps, story maps, and videos. Esri Press, 2019, 258 pp., ISBN: 9781589485303.

HOT TOPIC AT SCIENCE SYMPOSIUM

By Monica Pratt, ArcUser Editor

The subject of the Keynote Address by Olga Wilhelmi and Jennifer Boehnert to the 2019 Esri Science Symposium was especially topical, as some of the highest temperatures ever recorded occurred during the previous month. In their July 9 speech, the pair discussed their work on heat waves just weeks after Europe experienced its hottest June on record and India had been scorched by blistering temperatures.

In temperate San Diego, California, nearly 700 people attended the fourth annual Science Symposium, held in conjunction with the Esri User Conference (Esri UC) and the Esri Education Summit. The event brings together scientists from domains beyond geography and GIScience and promotes networking and cross-disciplinary work. The symposium also highlights Esri's dual commitment to science: in supporting scientists who are expanding fundamental understanding in many fields of scientific study by developing geospatial tools and in doing good science itself because science underpins the company's work.

Each attendee of this year's event was presented with a copy of a new Esri Press book, *GIS for Science: Applying Mapping and Spatial Analytics*, a collection of articles contributed by scientists who use GIS. The book, edited by Dawn Wright, Esri's chief scientist, and Christian Harder, Esri writer and editor, highlights how scientists use GIS to understand how the Earth works, how the Earth's appearance and function have been changed by humans, and how measurement and analysis of the Earth and its processes are used to gain understanding. A companion website, Gisforscience.com, makes resources available for each chapter in the book that include links to presentations,



↑ Olga Wilhelmi, who heads the GIS program at NCAR and has been leading projects since 1999, researches the interactions of weather, climate, and society. She was one of the two keynote speakers.

blog posts, tutorials, story maps, Learn ArcGIS lessons, articles, and data.

Keynote speakers Wilhelmi and Boehnert, authors of a chapter in *GIS for Science* entitled "Extreme Heat Event in a Changing Climate," work at the National Center for Atmospheric Research (NCAR). NCAR's GIS program promotes the use of GIS for both analysis and the creation of an infrastructure that facilitates atmospheric research and interdisciplinary scientific work. To this end, the NCAR GIS program has formed strategic partnerships with Esri and the Open Geospatial Consortium (OGC), Inc.

Although both Wilhelmi and Boehnert are geographers and both use GIS, they bring diverse perspectives to their work on heat waves. Wilhelmi, who heads the GIS

program and has been leading projects at NCAR since 1999, researches the interactions of weather, climate, and society to understand the risks extreme weather events and climate change pose to society, particularly vulnerable populations, and explores potential adaptive strategies to these conditions.

Boehnert, the GIS coordinator at NCAR, supports the work of scientists and engineers and uses GIS to integrate atmospheric data with socioeconomic and geographic data. When she started working at NCAR 16 years ago, using GIS in atmospheric science research was relatively new. In the intervening years, she has been involved in research on integrating atmospheric data and science with the tools, data, and

analysis methods of GIS.

An important part of this integrative work has been developing the capability of ArcGIS to directly read Network Common Data Form (netCDF) data. The netCDF file format is widely used in the scientific community for storing multidimensional scientific data, such as temperature, humidity, and pressure, and is typically used in atmospheric and ocean research. Because it is self-describing, a netCDF file includes information about the data it contains such as when data was captured and what measurement units were used. Nawajish Noman, who leads software development teams at Esri, worked on developing the netCDF direct read capabilities in ArcGIS. He noted that Wilhelmi and Boehnert were critical to the successful implementation of this functionality because they provided data and use cases and were a direct link to the broader scientific community.

In introducing their keynote, Wilhelmi and Boehnert surveyed the effects of climate change, including an increase of extreme weather conditions that have led to disasters ranging from coastal flooding caused by storm surge to crop-killing droughts that create ideal conditions for deadly fires. However, excessive heat events are the focus of their research.

The deadly nature of extreme heat is unappreciated. The Centers for Disease Control and Prevention attributes 600 deaths annually to excessive heat. GIS has been valuable in Wilhelmi and Boehnert's study of excessive heat events or heat waves. Heat waves are defined as being prolonged periods of temperatures higher than normal for a place.

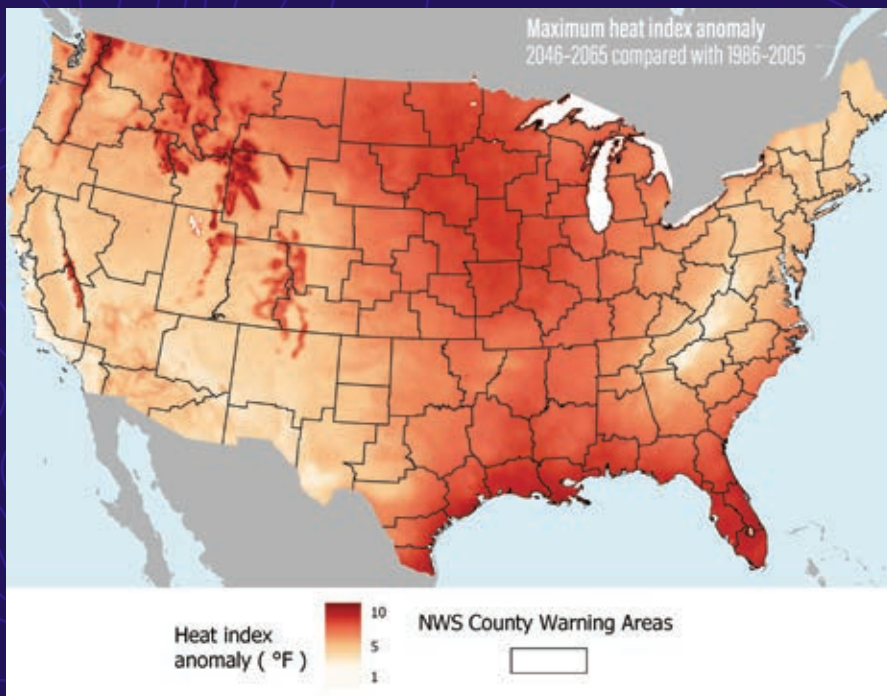
In an analysis of future climate scenarios, they used NCAR's Community Land Model Urban (CLMU), which simulates the climate of urban environments. They averaged hourly data in netCDF format for 20-year periods for the United States to smooth out single-year extreme events and uncover longtime climate trends. The period 1986–2005 was designated as present day, and model simulation projections for 2046–2065 designated as mid-century.

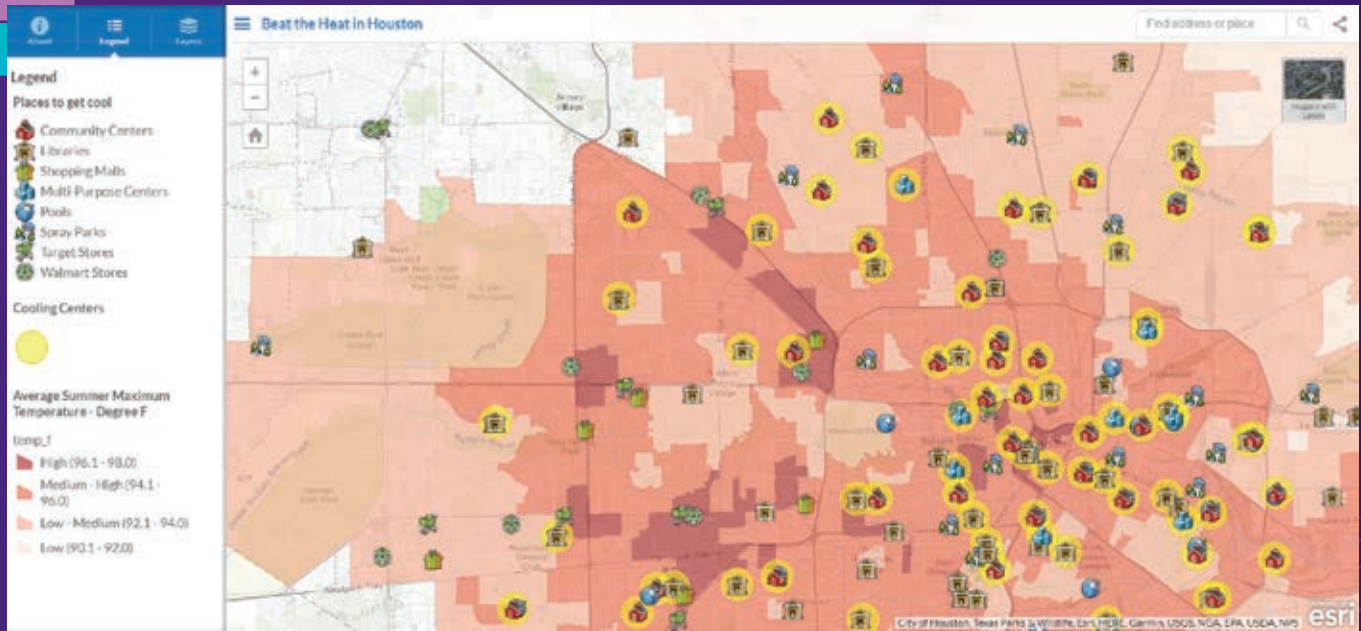
By using the ArcGIS raster calculator to

subtract averages from the current period (used as the norm) from the averages projected by model simulation for the future period, they determined an anomaly (i.e., deviation of a meteorological variable from the mean value). This anomaly—when mapped—was most pronounced in the southern and southeastern portions of the country. Mountainous areas of the West and some portions of the Midwest also have projected higher temperatures.

The increase in world population, with a greater percentage of that population dwelling in cities has an adverse affect on local conditions. Greater population density, more human activities causing more emissions from cars, factories, buildings, and the surface characteristics of the built environment in cities, (use of concrete and other impervious surfaces), geographic location, and regional climate can all amplify heat conditions. They can cause urban heat island (UHI) effects, which are characterized by temperature differences between cities and the surrounding nonurban area.

↓ This map visualizes research on differences in average summer heat in present and future climates visualized through mapping the average maximum heat index anomaly in the continental United States, based on simulations by an NCAR numerical model. (Image from *GIS for Science*.)





↑ This web map created by Boehnert shows the locations of cooling centers, such as libraries, pools, and community centers, set against a model simulation of average summer high temperatures for Houston.

Beyond assessing trends on a national scale, Wilhelmi and Boehnert developed a methodology for analyzing climate data on conditions that could influence actions locally. They modeled data for the Houston-Galveston area of Texas to understand the variability of heat events from year to year and the potential effects on area residents.

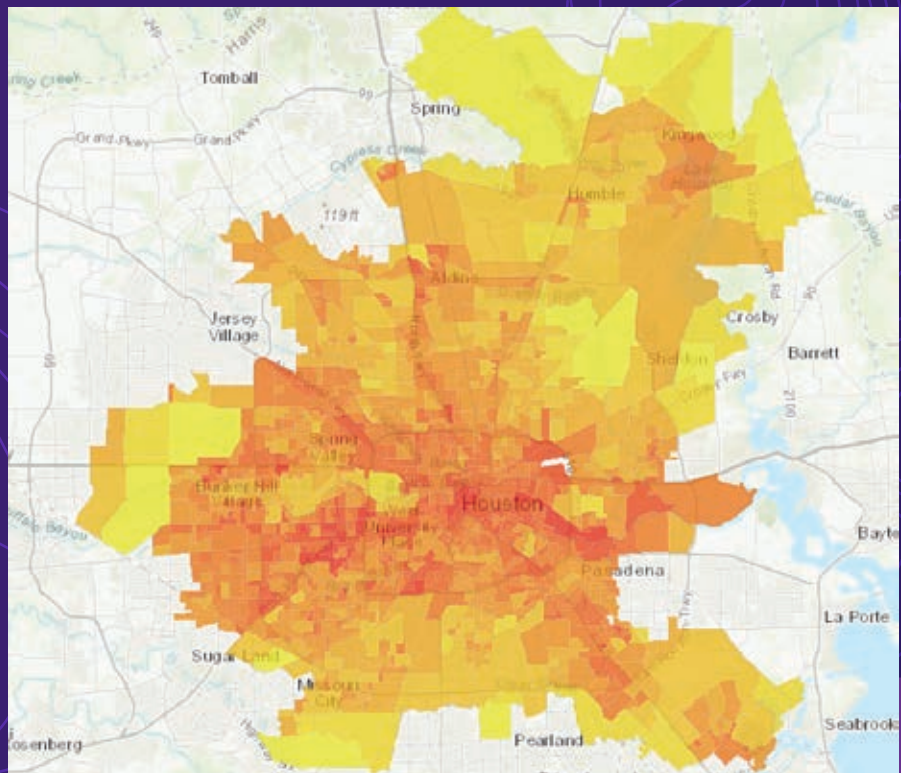
They performed spatiotemporal analysis of multidimensional data in netCDF format using ArcGIS Pro and ModelBuilder. They found the data clock chart, available in ArcGIS Pro, to be a most effective method for portraying changes in average daily maximum heat index (HI) findings. They used data clock charts to compare current and future periods as to the number of days, intensity, and season.

From a policy standpoint, an example of how to deal with an increase in extreme heat events could be providing access to cooling centers (air-conditioned public buildings) to mitigate the potentially lethal effect to at-risk populations, such as seniors or the disabled, as well as modifying regulations regarding utility shutoffs, evictions, and outside work. As a practical output of this work, Boehnert created a map on ArcGIS Online that identified the cooling centers in Houston.

The work by Wilhelmi and Boehnert highlights a new reality for planning, public health, and other organizations given

trends in both climate change and land use that amplify UHI effects. Projections show that just a change of one degree leads to drastic changes in the effects of heat waves on populations.

↓ Mapping the percentage of impervious surface, a contributor to urban heat island effect, in Houston.





← Jennifer Boehnert, the GIS coordinator at NCAR who supports scientists and engineers and uses GIS to integrate atmospheric data with traditional GIS data, was one of the two keynote speakers.

revising warning systems, implementing policies to mitigate adverse effects, and making efforts to identify and protect vulnerable populations. They urged taking an integrative approach to dealing with these conditions that incorporates society, science, and technology.

In the question and answer period following the address, members of the audience suggested ways to broaden the impact of this work by using citizen science groups to capture more types of data; making high-resolution, gridded climate data more widely available; and enlisting other segments of the scientific community.

As Wilhelm and Boehnert's work demonstrated, GIS supports the analysis and visualization that advances understanding of the Earth and how it is affected by human activities and helps communicate that knowledge.

About the Author

Monica Pratt is the founding and current editor of *ArcUser* magazine, the executive editor of *ArcNews* magazine, the editor of *Esri Globe*, and head of the Publications team at Esri. She has been writing on technology topics, specializing in GIS, for more than 25 years. Before joining Esri in 1997, she worked for newspapers and in the financial industry. Follow her on Twitter on @ArcUser.



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Assess Readiness First to Make the Most of Your Class

A new, free online tool can make sure you will get the most out of your instructor-led training, whether it is taken online or in person.



The Esri instructor-led class readiness tool will assess whether the class you are contemplating will be a good match for your existing knowledge and skills, so you can gain the maximum benefit from that course. If you are already registered for a class, you can use the readiness tool to make sure you are well prepared for the class.

The tool asks a series of multiple-choice questions that measure prerequisite knowledge and skills that were defined by the course designers. The result is qualitative, not quantitative. It doesn't return a score. Instead, if it detects any areas that might need some additional work, it suggests relevant e-Learning resources. The list of resources can be added directly to an Esri Academy learning plan.

Using the tool or taking any of the suggested courses is not required before attending an instructor-led class. The tool can help you prepare by strengthening or refreshing knowledge related to the course. It is designed to ensure that the time you spend in an instructor-led class is engaging, insightful, and yields knowledge and skills you can apply to get your work done more quickly, easily, and with better results.

Currently, the readiness tool is available for two popular instructor-led courses, ArcGIS Pro: Essential Workflows and ArcGIS Enterprise: Configuring a Base Deployment, but will be added for other courses.

↓ If the assessment tool detects areas that could be strengthened, it suggests learning resources and lets you add them to a learning plan.

Sharing GIS Content Using ArcGIS

For the best class experience, review the resources below before attending.

Knowledge and Skills Required	Learning Resources
Create selection sets.	Querying Data Using ArcGIS Pro ⓘ
Discover key elements and core functionality of the ArcGIS Pro interface.	Getting Started with ArcGIS Pro ⓘ
Apply and customize labels for map features.	Labeling Features Using ArcGIS Pro ⓘ
Manage feature visibility with scale ranges and definition queries.	Managing Add to Learning Plan ⓘ

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(Luigino Bruni)

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↓ The winning team, GEBCO-NF Alumni, used an uncrewed surface vehicle (USV), shown here, which acted as the mother ship and operational control hub for the autonomous underwater vehicle (AUV).

The Race to Make a High-Resolution Map of the World's Oceans

By Jim Baumann

While 71 percent of the Earth is covered by the ocean, less than 15 percent of the ocean floor has been mapped at greater than a 5-kilometer (3.1-mile) resolution.

"We have higher-resolution maps of the entire surface of the Moon, Venus, and Mars than we do of our own planet," said Esri chief scientist Dawn Wright. Other earth scientists have also noted this deficiency.

The Seabed 2030 project, sponsored by The Nippon Foundation and General Bathymetric Chart of the Oceans (GEBCO), plans to improve that situation by mapping the entire ocean floor by 2030. [See the accompanying article in this issue, "Joining Together to Map the World's Seafloor," to learn more about GEBCO.]

Announced in 2018, the project's goal is to build the technical, scientific, and management framework necessary to develop and compile high-resolution bathymetric information of the entire ocean floor into a seamless digital map.

The traditional methods for terrestrial and extraterrestrial mapping use electromagnetic waves, such as radar and light, which are not effective in ocean water that is more than a few meters deep. While the ocean surface height measured by satellites provides a very general view of the ocean floor, it does not always provide measurements that are sufficiently accurate to be of significant value for scientific research of the ocean or other types of deep ocean activities. However, the Seabed 2030 project will use modern acoustic mapping technologies deployed on various platforms and bring together all available bathymetric data to produce the definitive map of the world ocean floor by 2030. This map will be made available to all.

Mapping the shape of the seafloor will

help in better understanding ocean circulation patterns in relation to the complex links in the ocean atmosphere system, which is responsible for the weather and climate on Earth. Bathymetric measurements from the deep ocean are valuable in both marine geology and geophysics to help scientists better understand the dynamic processes that are continually reshaping the seabed. In addition, bathymetric measurements are used for applications that include cable routing, fisheries management, and natural resource exploration and exploitation, as well as providing a critical dataset for dealing with the challenges of climate change.

Although ultimately the goal is to record 100-meter (328-foot)-resolution data throughout the entire 362 million square kilometers (140 million square miles) of

ocean floor, measurements will be made at varying resolutions, depending on the water depth. The threshold for deep ocean is 200 meters (645 feet). While the average depth of the ocean is 3,688 meters (12,100 feet), depth at any point can vary greatly. A depth of 11,033 meters (36,198 feet) has been recorded in the Mariana Trench located in the western Pacific Ocean.

Due to the limited time frame and scope of the project, innovative data-gathering strategies will be enlisted for bathymetric data collection. The International Hydrographic Organization (IHO) created the IHO Crowdsourced Bathymetry Initiative, which encourages the collection of worldwide bathymetry data by commercial fishing and cargo vessels, cruise ships, and recreational boats equipped with standard echo sounders. Depending on the precision of the equipment used and the amount of accumulated data, it can be quite accurate. However, even though some crowdsourced data may not entirely meet the accuracy requirements of the Seabed 2030 initiative, the data can be used to help identify uncharted features and verify the accuracy of previously charted areas.

For example, the Olex company in Norway has been collecting commercial fishing data using single-beam technology for more than 30 years. A study has determined that there was a water depth difference of less than 1 percent between the measurements made by Olex and those collected using multibeam technology.

It's also hoped that national governments, oil companies, survey companies, oceanography institutions, nongovernmental organizations (NGOs), mining, and other industries that maintain bathymetric data can be induced to contribute lower-resolution versions of their datasets to the project. Providing lower-resolution data would allow them to protect their vested interests while contributing to the common good and the universal value of the project.

The Seabed 2030 project also may benefit from an international contest to accelerate innovation in the development of the means for conducting unmanned exploration of the deep sea.

Global Competition Drives Undersea Exploration

The Shell Ocean Discovery XPRIZE competition has the potential to reduce the time and cost of ocean floor mapping, which would assist in data collection for Seabed 2030.

The XPRIZE Foundation was created 25 years ago. Its sponsors have awarded more than \$140,000,000 to advance technological solutions that benefit humanity in areas such as space, oceans, learning, health, energy, environment, transportation, safety, and robotics.

The Shell Ocean Discovery XPRIZE competition began in 2015. Competing teams launch—by either air or sea—an autonomous underwater vehicle that they use to explore the ocean depths. The prize money offered to the winning teams: \$7 million.

The semifinal challenge, held in 2017, tested the remaining 19 teams on 11 criteria to demonstrate that their technical solutions could meet the operational requirements necessary for rapid, unmanned, and high-resolution ocean mapping in 2,000 meters (6,561.7 feet) of water.

The final round, pared down to eight teams, was held in late 2018 off Kalamata, Greece, near the Hellenic Trench in the deepest part of the Mediterranean Sea. The specified area was less than 4,000 meters (13,123.4 feet) in depth and measured 500 square kilometers (193.1 square miles). Teams were required to map at least 250 square kilometers (96.5 square miles) of this area during a 24-hour period.

And the Winner Is...

As part of their support for the Seabed 2030 project, a group of alumni from the GEBCO Postgraduate Certificate in Ocean Bathymetry (PCOB) program formed the GEBCO-Nippon Foundation Alumni team (GEBCO-NF Alumni) to compete for the Shell Ocean Discovery XPRIZE. The team, consisting of 78 people from 22 countries, includes Dr. Rochelle Wigley, project director for Nippon Foundation GEBCO projects; Dr. Evgenia Bazhenova, data manager at the National Institute of Water and Atmospheric Research (NIWA); Wetherbee Dorshow, president of Earth Analytic, Inc.;

and Tim Kearns, chief technology officer for Numurus LLC.

"We are an international group of PCOB alumni and advisers from diverse backgrounds and disciplines including engineers, oceanographers, geomorphologists, geologists, and GIS specialists," said Wigley. "This synergy allowed us to approach the project from a unique perspective, which has led to our success and the top prize."

To design and develop its autonomous deep ocean exploration and mapping system, the team worked closely with its partners, which included the Sasakawa Peace Foundation, Hushcraft Ltd, Ocean Floor Geophysics Inc., Earth Analytic, Inc., Teledyne CARIS, Raitt Orr and Associates Limited, Shipowner's Club, and OmniAccess S.L., as well as equipment supplier Kongsberg Maritime.

"From the beginning, the team's goal was to integrate—as much as possible—existing technology (equipment and software) because a lot of the technology needed to map the ocean floor exists but not as an integrated solution in the way we needed it to work," said Wigley. "There were a couple of significant gaps to make the necessary

↓ Dr. Rochelle Wigley



solution—one was the uncrewed surface vehicle, and the other was the creation of an automated data workflow.”

Because of recent advances in robotics and sonar technology, the team developed its entry based on a deep-diving, autonomous underwater vehicle (AUV) equipped with bathymetric sonar systems to acquire high-resolution seabed data.

“At this time, only about 8 percent of the seafloor has been mapped with modern multibeam technology, and as a result, we know very, very little about it,” said Bazhenova. “Because of the size of the ocean, we needed to implement a system that included as much autonomous data-gathering technology with limited human interaction as possible. If equipment can be strategically dropped off in the ocean and perform the surveying work—data transfer and its own maintenance with minimal interaction—the high cost of deep ocean surveying can be significantly reduced. This will increase the potential to successfully map the entire ocean floor at a scale that will allow us to better understand the dynamics of our planet so that we may become better custodians of it.”

The team employed SEA-KIT, an uncrewed surface vehicle (USV) built by British company Hushcraft Ltd, which acted as the mother ship and operational control hub for the Norwegian Kongsberg Maritime company’s HUGIN AUV. Under the direction of the bathymetric scientists and technicians at the team’s land-based operations center, the USV is guided either autonomously or by remote control to its mapping location, carrying the torpedo-shaped AUV. Upon reaching the area to be mapped, the AUV is deployed and retrieved by an automated conveyor system on the USV. The USV also tracks the movements of the AUV during its autonomous operations. The AUV can operate to a depth of 4,500 meters (19,685 feet) at 4 knots (4.6 mph) for 2–36 hours, depending on the sensing equipment being used.

While the requirements for the competition were to map the ocean floor at a 5-meter (16.4-foot) resolution, the multi-beam echo sounder mapped at 1-meter (3.3-foot) resolution. Bathymetric side-scan

sonar systems create a photo of the seafloor that can be used to determine height. Together, the two systems create highly accurate 3D imagery of the ocean floor.

“Some of the side-scan data was post-processed down to two centimeters (0.8 inches),” said Kearns, but he noted that level of detail does impact battery life. The

USV can be deployed at sea for approximately seven months, while the batteries on the AUV must be recharged daily.

During the tests, the batteries were recharged when the vessels returned to land from their mission. However, in the future, the USV may recharge the AUV at sea when the AUV resurfaces to download the data

↓ The Kongsberg HUGIN AUV in the foreground with SEA-KIT USV Maxlimer during retrieval and deployment trials in Horten, Norway. (Photo courtesy of Alex DeCiccio/Inner Space Center.)





↑ The winning GEBCO-Nippon Foundation Alumni team and its partners at the International Hydrographic Organization (IHO) headquarters in Monaco. The team met with IHO Secretary General Mathias Jonas (front, fifth from right). (Photo courtesy of Rebecca Marshall.)

it has collected. To fully utilize the equipment, while one AUV is surveying the ocean floor, the other AUV could be charging its batteries at the USV.

Although the equipment used by the GEBCO-NF Alumni team can analyze the water column in which the AUV is passing for chemical signatures, temperature, salinity, and oxygen, the team did not focus on these capabilities because they were outside the scope of the XPRIZE concept and the amount of data collected would be huge.

"The datasets the team was working with was quite large," said Dorshow. It took

the team about two hours to download approximately 80 gigabytes of data and another four hours to preprocess it using customized software the team developed for the workflow.

The sensors onboard the AUV collect a variety of datasets in different formats that were then processed over 36 hours using in-house Kongsberg software as well as proprietary software developed by Teledyne CARIS and Qimera. ArcGIS was used to ingest the data and then ArcGIS Enterprise was used for on-the-fly processing and mosaicking. After creating image services

from the mosaic datasets, the team could make data available through ArcGIS Online as bathymetric maps and images.

"Our Esri stack of software is used as the middleware to get this deep scientific data into a web browser so that decision-makers can start using it without any knowledge of how to process bathymetric data," said Dorshow. "One of the advantages of getting the data into the GIS is that often the raw data is much, much larger than the derived products created from it. So we don't have that 80 gigabytes of data stored on the server because we processed it into optimized GeoTIFFs."

"By integrating and augmenting existing technologies and services with our own development work and that of our partners, we have created an autonomous, deep sea mapping system that is faster, less expensive, and safer than using traditional vessels with crews for operational procedures, while acquiring higher-resolution data," concluded Wigley. "And, none of this would have happened without the XPRIZE. It brought us together in a cutting-edge competition and allowed us to push the boundaries of the technology."

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President, Earth Analytic, Inc.



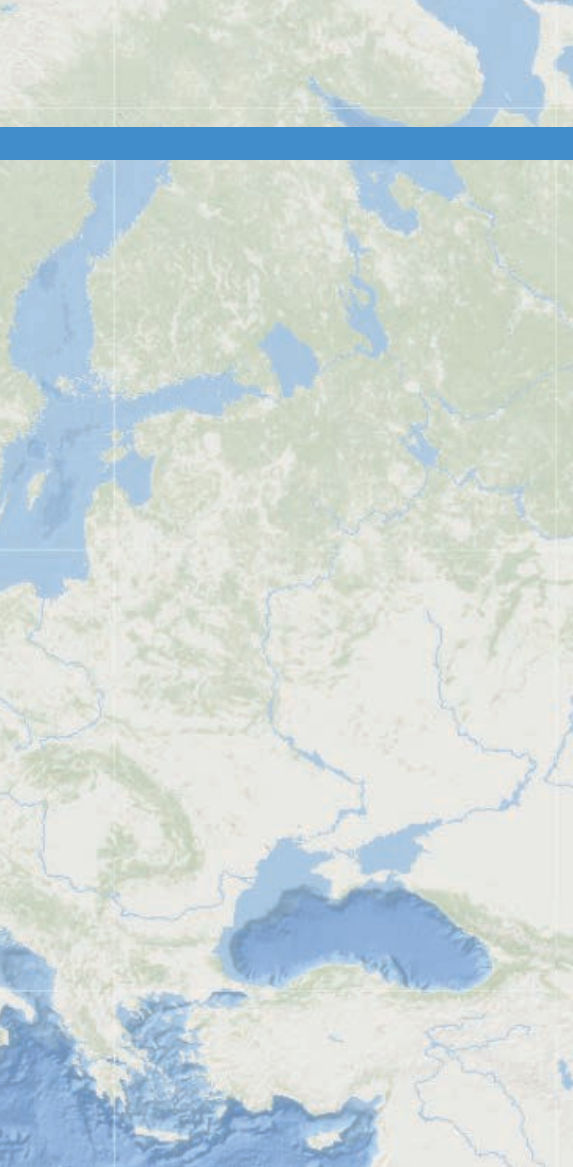
Joining Together to Map the World's Seafloor

The General Bathymetric Chart of the Oceans (GEBCO) commission is a non-profit-making organization of volunteer geoscientists and hydrographers who are dedicated to creating the most authoritative, publicly available bathymetry of the world's oceans. GEBCO's current world bathymetry map, released in 2019, depicts the ocean floor in shaded relief, but the organization's cutting-edge work has a long history that dates to 1899.

That year, the 7th International Geographic Congress met in Berlin to discuss what was needed to develop comprehensive hydrographic charts and nominate a commission. The commission was tasked with developing standards for the terminology used in these charts and the creation of a series of bathymetric charts of the world's oceans. Led by Prince Albert I of Monaco, it held an inaugural meeting in 1903 to plan the publication of general bathymetric charts.

The first edition of the GEBCO charts, published in 1905, was based on information from British and French hydrographic offices that came from the lead line soundings made by ships laying communications cable. Reports from various oceanographic expeditions during that time were also included. A second series of charts contained greater detail due to the introduction of the echo sounder in 1913, as well as other sonic and ultrasonic devices. This work was halted by World War I but later resumed, and the series was finally completed and published in 1931.

Today, GEBCO operates under the auspices of the International Hydrographic Organization (IHO) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) Intergovernmental Oceanographic Commission. It provides seamless digital



bathymetric charts of the world's oceans and has developed a global series of bathymetric grids for 3D ocean modeling and other mapping applications.

GEBCO's 2019 world bathymetry map is based on the latest GEBCO grid that includes bathymetric data at 15-arc-second (0.004-degree) increments; this map was primarily developed from a database of ship-track soundings. The interpolation between the soundings was determined from gravity data models derived from satellite altimetry. The points on the seafloor created by the model are approximately 0.5 kilometers (0.3 miles) apart.

GEBCO also promotes the future of ocean mapping. Through funding provided by the Nippon Foundation, a philanthropic organization headquartered in Japan, GEBCO also sponsors the Postgraduate Certificate in Ocean Bathymetry (PCOB). This yearlong program to help train the next generation of bathymetric scientists is held at the Center for Coastal and Ocean Mapping, University of New Hampshire (UNH), in the United States.

↑ Less than 15 percent of the ocean floor has been mapped at greater than a 5-kilometer (3.1-mile) resolution.

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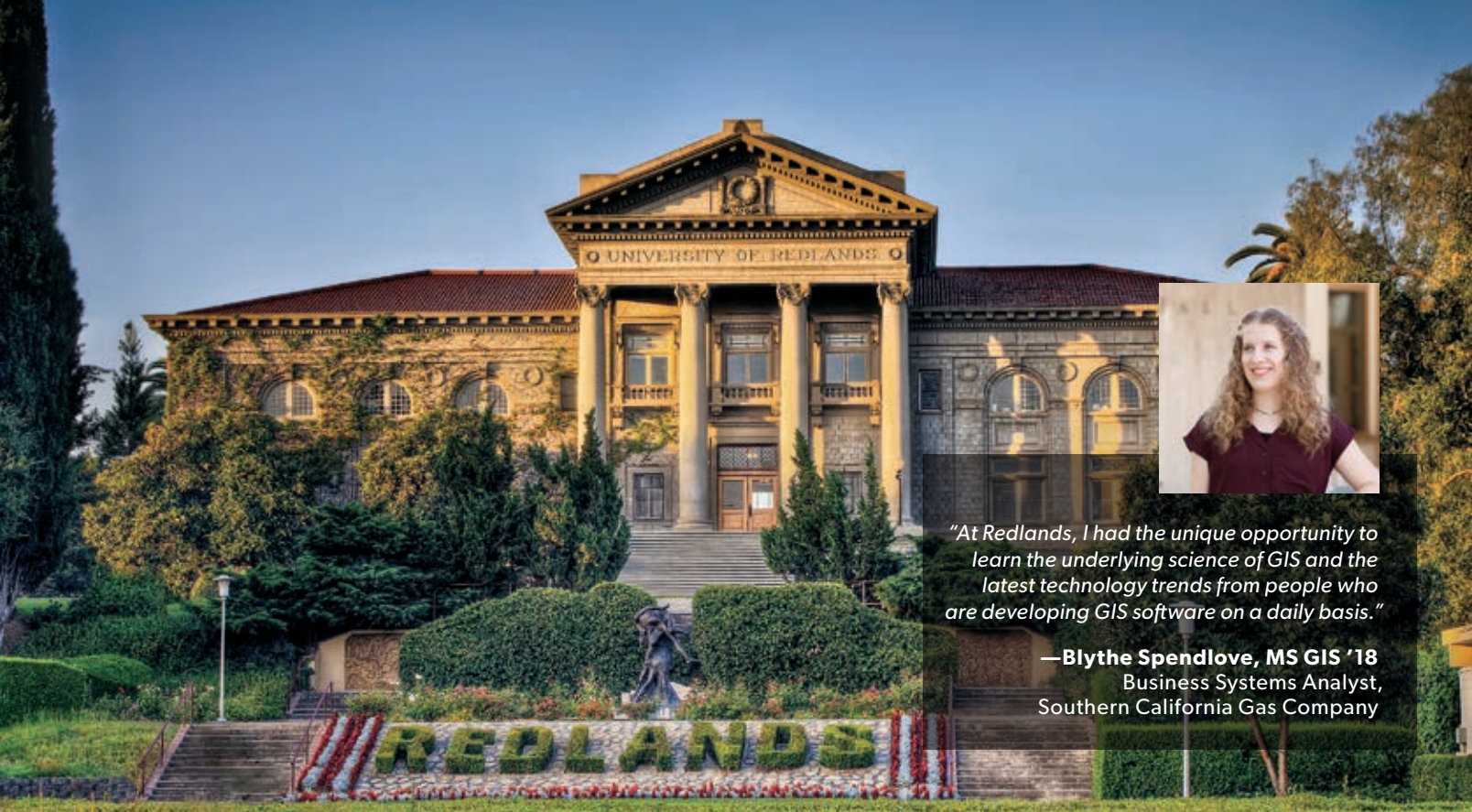
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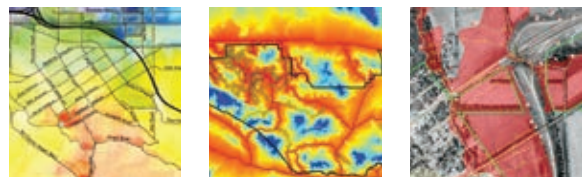
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