Spring 2025

ArcUser

The Magazine for Esri Software Users

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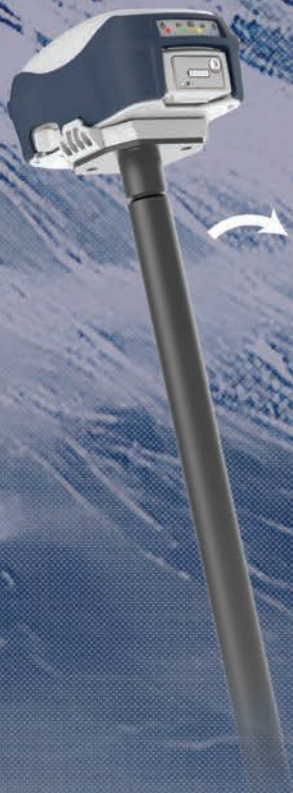

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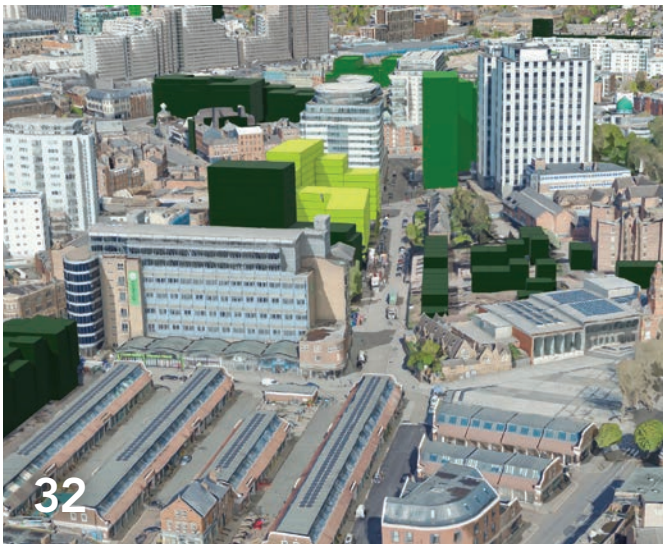
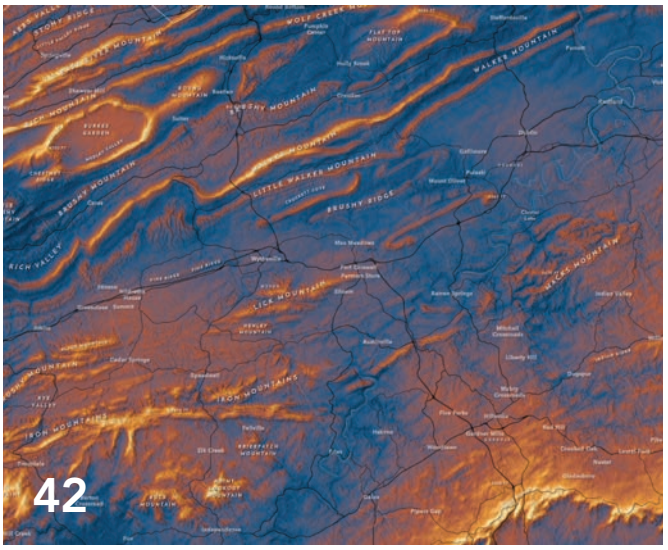


Focus



Special Section

End Notes

Expand Your Geospatial Horizons

It's almost impossible to cover all the things GIS can do. It is a crucial tool used to solve myriad problems and presents a unique way of looking at the world—through the lens of *where*.

For example, GIS can help people live more sustainably by investing in renewable power, as Pattern Energy is doing with its massive SunZia project in the Southwestern United States. When completed, SunZia is slated to be the largest wind energy project in the Western Hemisphere and will likely provide power to three million Americans. Geospatial technology is also instrumental in humanitarian work, even during or just after times of conflict. Tanzania-based organization Anti-Persoonsmijnen Ontmijnende Product Ontwikkeling (APOPO) demonstrates this by using GIS to track the health and locations of its mine-sniffing dogs. GIS can help plan urban renewal projects and make public utility work more effective and efficient. Some companies and organizations, like the environmental and engineering firm Dudek, are using GIS in a variety of innovative ways, from emergency response to mapping Kauai's aging dams and reservoirs.

Equally important as asking what GIS can do is asking what GIS can do for *you*. How can you use GIS to expand your geospatial horizons?

Maybe this is simply about bringing efficiency to your workflows, as many of the articles in this issue address. Streamline how you edit metadata for your ArcGIS Online items. Use web components rather than widgets to build code in ArcGIS Maps SDK for JavaScript. Automate the process of sharing computer-aided drafting (CAD) and building information modeling (BIM) data within and outside of your organization. Improve the readability of your maps for viewers who are color-blind. Whether you are an experienced GIS user or new to the industry, even small improvements to efficiency or quality of life can go a long way toward helping you do big things with GIS technology.

But taking your GIS work to another level can also be about pushing the boundaries of how you use GIS on a day-to-day basis. Incorporate reality capture into your indoor GIS. Explore whether drone imagery, suitability modeling, or geospatial digital twins can improve or expand the way GIS operates in your organization.

The stories in this issue are as much about how capabilities within ArcGIS can change your work as they are about how GIS can change the world. Because solving even the most monumental issues with a geospatial approach starts with exactly that—your work.

Ben Van Voorhis
ArcUser Editor

ArcUser

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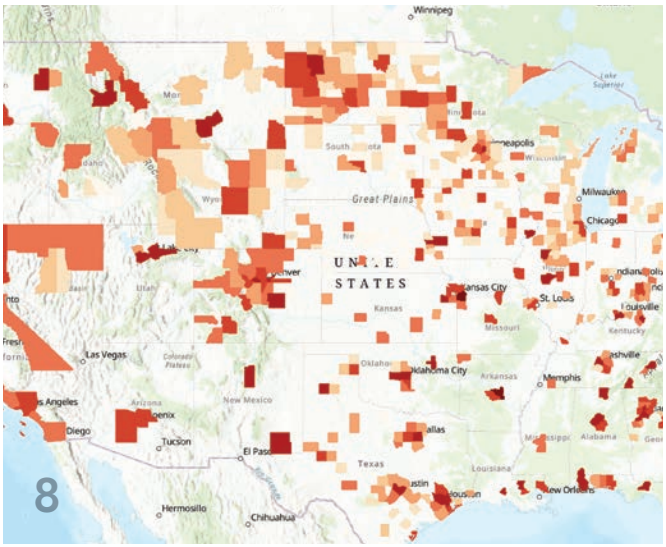
Departments



Briefly Noted

→ ArcGIS Desktop (ArcMap) Is Retiring

ArcGIS Desktop (ArcMap) retires in 2026, so now is the time for organizations to step into a modern geospatial platform by migrating to updated user types with access to ArcGIS Pro—the most secure, advanced version of ArcGIS. Esri has prepared resources to help users make the change, including the instructor-led courses Migrating from ArcMap to ArcGIS Pro (go.esri.com/migration-course) and ArcGIS Pro: Essential Workflows (go.esri.com/workflows-course), as well as the Migrate to ArcGIS Pro learning plan (links.esri.com/migrateLP).

For more information—and to talk to someone about your organization's unique needs—go to links.esri.com/migrate-arcmap.

→ Get System Health Notifications in the Esri Support App

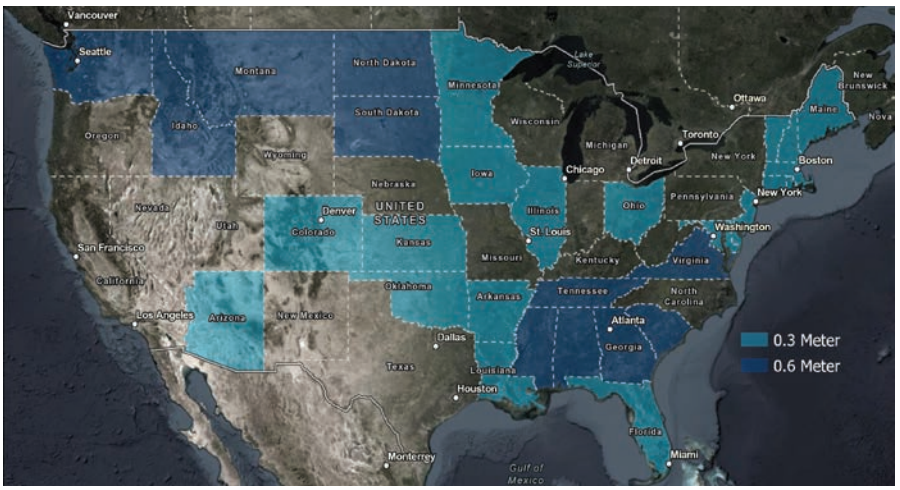
With the Esri Support app, ArcGIS Online administrators can get proactive insight into the status of their ArcGIS Online systems with health notifications. ArcGIS Online Health Dashboard notifications let administrators know when the status of their dashboard changes. Administrators can then ask the Esri Support AI chatbot for more information on their implementation's status and get immediate answers.

When you subscribe to a bug or open a case, you can expect notifications for status changes and messages from your support analysts. The app also sends notifications about new technical support articles, blogs, and videos. By combining real-time notifications, AI-powered chat support, and case management, the Esri Support app offers tools to help you resolve issues faster, stay informed about the status of your system, and make the most of your time and resources.

For more information, go to links.esri.com/notifications.

↓ Esri Support app updates will give you proactive insights into the ArcGIS Online system status.

→ New NAIP Imagery Available in ArcGIS Living Atlas



↑ You can discover and access NAIP imagery through ArcGIS Living Atlas of the World.

With this latest update, the time series dataset in ArcGIS Living Atlas includes all NAIP imagery from 2010 through 2023 and provides access to four spectral bands (RGB and Near Infrared). The imagery can be displayed in Natural Color, Color Infrared, or Normalized Difference Vegetation Index (NDVI). The time series allows you to access different vintages of imagery for each year and state where coverage is available.

→ Esri Collaborates with Google to Offer Photorealistic 3D Tiles in ArcGIS Online

Esri is partnering with Google to integrate their photorealistic 3D Tiles into the ArcGIS suite. Beginning in fall 2025, the tiles will be available as Google 3D Basemaps in the ArcGIS basemap gallery. This will enable ArcGIS Online users to access the Google 3D Basemap directly from ArcGIS basemap galleries and easily integrate it into their projects, so they can create a realistic and immersive foundation to any GIS.

Available in several ArcGIS 3D apps for web, desktop, and mobile, including Scene Viewer, ArcGIS Earth, ArcGIS Instant Apps, and ArcGIS Experience Builder, the Google 3D Basemap will be seamlessly integrated into the familiar ArcGIS workflow, available directly alongside other 2D and 3D basemaps when the user wants a photorealistic GIS foundation. This basemap will be optimized for ArcGIS and will require no preprocessing, coding, or technical integration, making it ready to use out of the box.

This entry into a 3D photorealistic experience will be an excellent option for users who want the benefits of 3D meshes without the work involved in obtaining the high-resolution imagery and technical expertise involved in creating them. The Google 3D Basemap provides an accessible introduction to the power of ArcGIS reality mapping technology, which is tailored for advanced users and more in-depth analysis.

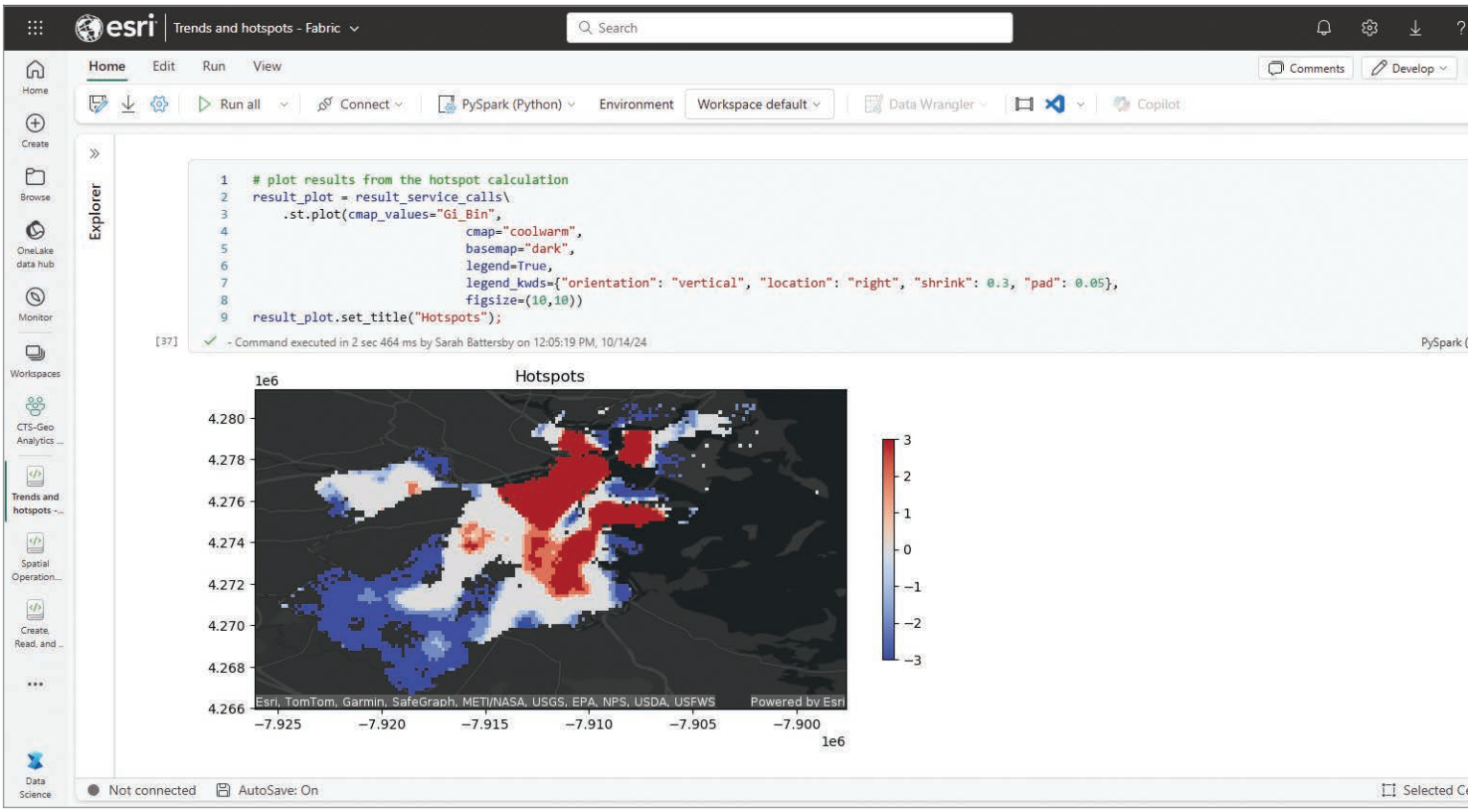
All this content will be available to users through their ArcGIS Online subscriptions in fall 2025. To learn more about Esri's work with Google, visit go.esri.com/3Dtiles.

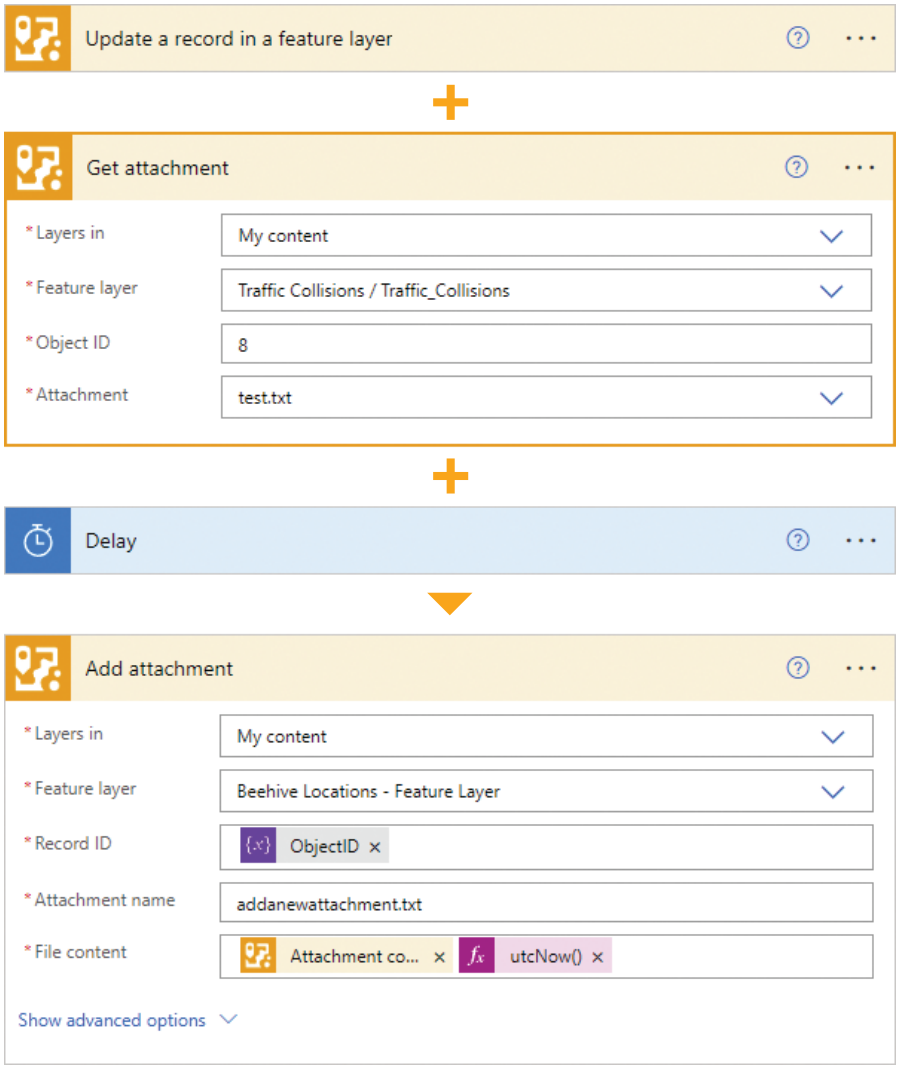
How Microsoft Users Can Seamlessly Unlock the *Where* in Data

For more than 20 years, Esri and Microsoft have partnered to deliver innovative technology that empowers customers with location-based insight. This long-standing relationship has enhanced product integrations via ArcGIS for Microsoft, which brings ArcGIS capabilities and data directly into the secure and familiar Microsoft environment.

New to the suite of integrations available for Microsoft users is **ArcGIS GeoAnalytics for Microsoft Fabric**. In public preview this spring, GeoAnalytics for Fabric allows data scientists and data engineers to conduct spatial data integration, transformation, enrichment, and analysis at scale using Apache Spark, a distributed computing framework for processing large amounts of data.

Users can seamlessly access Esri's advanced spatial analytics tools within Microsoft Fabric to detect patterns, perform predictive analytics, or produce business intelligence-ready data for exploration and strategy development. This integration results in powerful spatial insight that can easily be shared across organizational





→ ArcGIS Connectors for Power Automate helps users automate repetitive tasks directly in ArcGIS Connectors for Power Automate.

↙ With ArcGIS GeoAnalytics for Microsoft Fabric, data scientists and data engineers can conduct geospatial analysis using Apache Spark to uncover patterns and trends in their data.

tools such as Microsoft Fabric, Microsoft 365, Microsoft Power BI, and Esri's ArcGIS environment.

Together, Microsoft and Esri Offer Unmatched Value

ArcGIS for Microsoft seamlessly integrates ArcGIS capabilities and data with Microsoft productivity apps, intelligence services, and data platforms. It allows users to access and leverage geospatial information within Microsoft products such as Microsoft 365, Microsoft Fabric, and Microsoft Power Platform. This integration lets users across an organization—from data analysts performing complex spatial analyses to executives using spatial insight to make operational decisions—easily share location data and collaborate on important projects.

With ArcGIS for Microsoft, data analysts and data scientists can visualize and analyze data at scale to gain a deeper understanding of spatial relationships and underlying patterns. Users can uncover hidden trends and correlations that might not be apparent in traditional data analysis, leading to more informed and effective decision-making.

Because teams can work with ArcGIS geospatial data and apps directly in the Microsoft environment instead of switching between platforms, users are more productive and can collaborate more easily and efficiently. Additionally, sensitive information remains protected with Esri and Microsoft's robust identity and access management solutions, as well as role enforcement. These safeguards—which comply with data privacy regulations and organizational policies—ensure that only authorized users can access an organization's ArcGIS data.

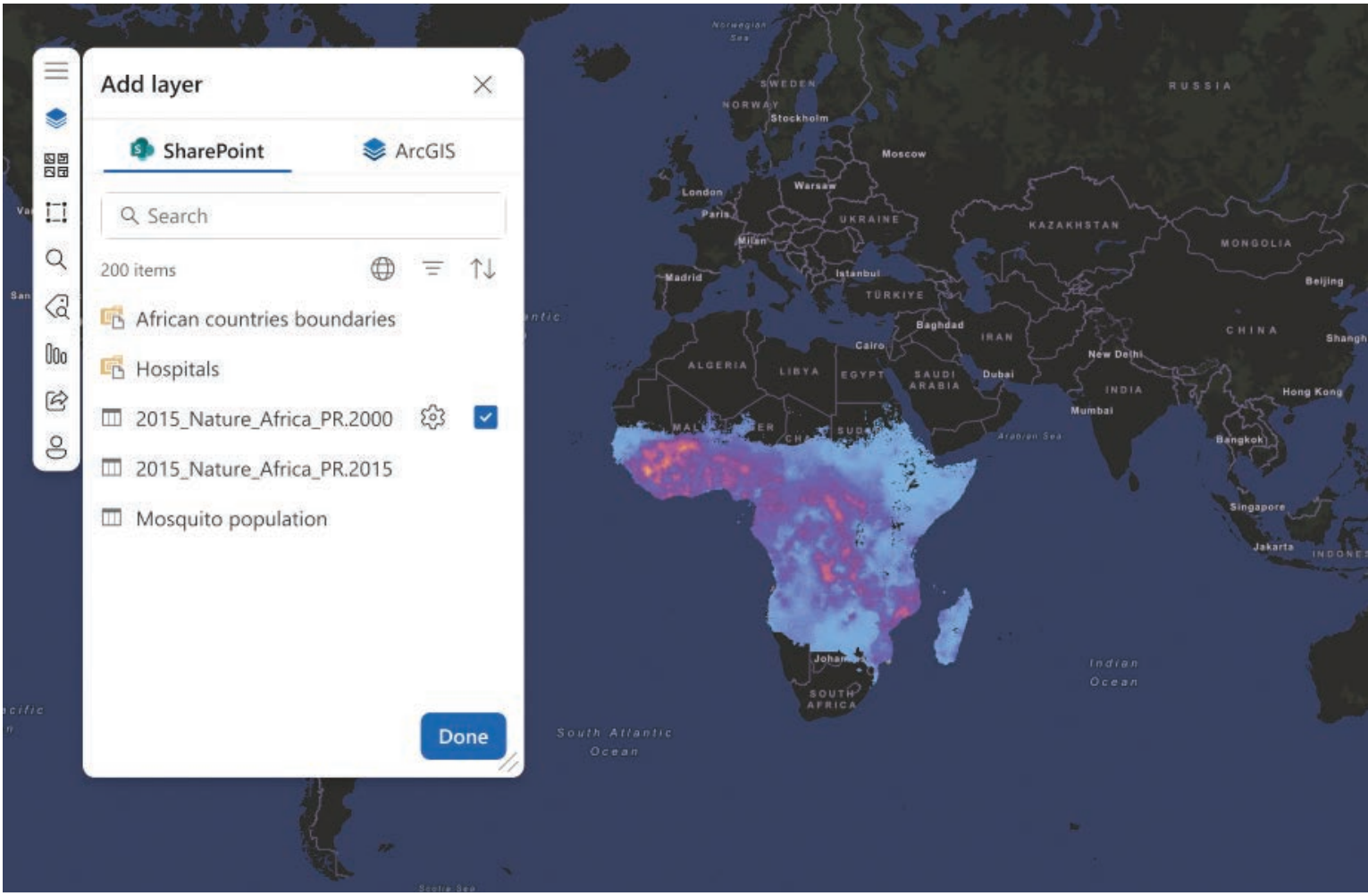
One notable integration is that ArcGIS capabilities work in Microsoft's Power Automate, an end-to-end cloud automation platform that helps users automate business processes through self-service configuration, without significant or costly involvement from IT. This integration can handle complex geospatial tasks, reducing manual effort and the potential for errors. And for developers, ArcGIS Maps SDK for .NET offers tools to build robust geospatial and location intelligence apps for both desktop and mobile platforms. This SDK enables developers to create custom apps that work seamlessly with existing Microsoft tools, enhancing the functionality and usability of geospatial data.

Add the Geospatial Perspective to Data Analysis

One of the most exciting new releases in the Microsoft-Esri ecosystem is ArcGIS GeoAnalytics for Microsoft Fabric. This new Spark-native library is packed with geospatial analytics tools to help users discover where things happen, how they relate, and which actions to pursue. It integrates directly into Fabric's data science and data engineering workloads, allowing users to work with geospatial data—from integration and transformation to enrichment and analysis—within Microsoft Fabric's Spark-based notebooks.

With GeoAnalytics for Fabric, users can do the following:

- **Automate spatial data engineering and transformation:** This allows users to streamline the process of managing and transforming geospatial data so they can increase efficiency and accuracy in their projects.
- **Enrich data with location context:** Users can enhance individual data points and big data analytic workflows by bringing in contextual datasets.


Add layer
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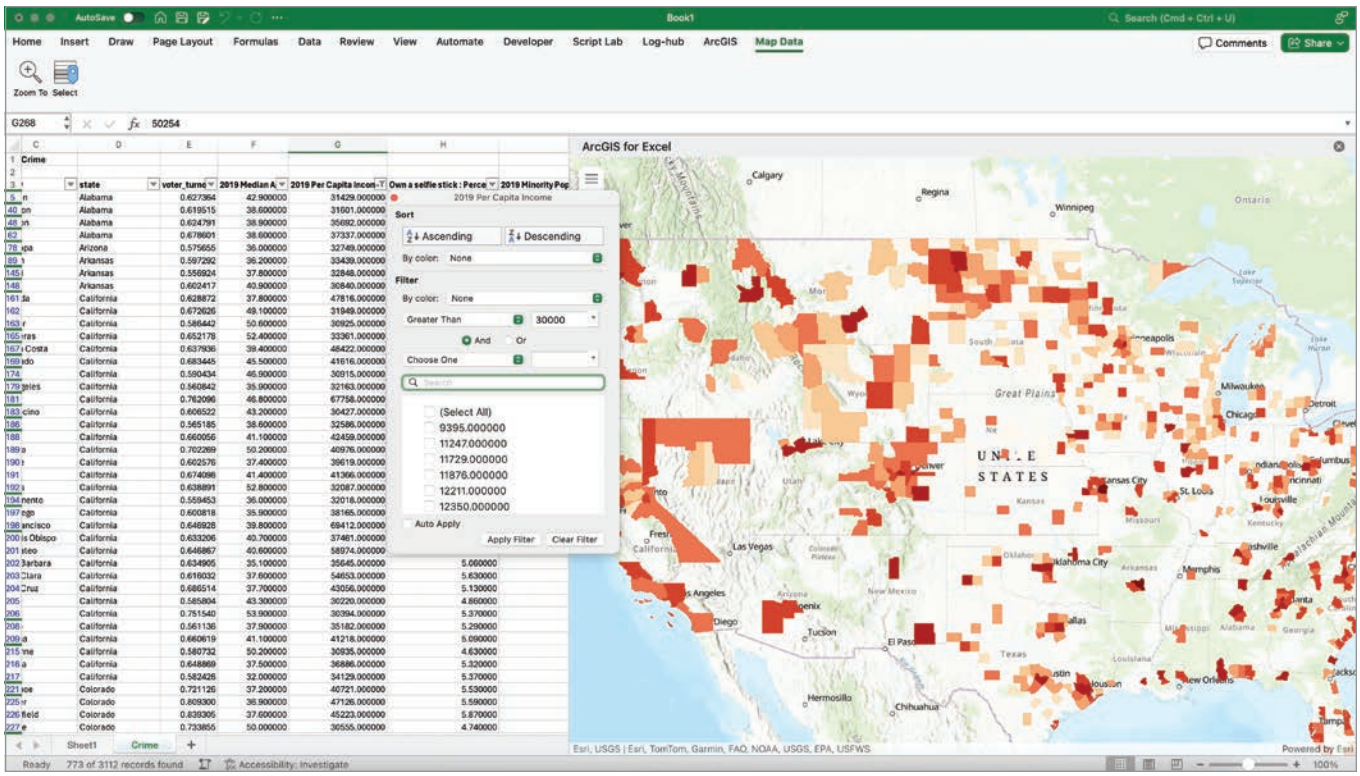

ArcGIS for Excel
Map Data
Sheet1
Crime

← Users can add interactive maps and location-enriched content to Microsoft SharePoint sites.

↙ ArcGIS for Excel enables everyone in an organization to create, edit, and visualize geographic information in Microsoft Excel.

- **Analyze events geographically:** By incorporating geospatial analytics into Microsoft Fabric, users can discern patterns and trends in their data to gain a better understanding of where—and why—events occur.
- **Visualize spatial relationships:** Users can explore how different locations influence and relate to each other.
- **Identify strategic locations:** Organizations can improve their operations by finding the most strategic locations with ideal situational characteristics.
- **Integrate with Microsoft Power BI:** Users can deliver the results of their analyses in Microsoft Power BI or take their exploration further by leveraging the powerful interactive mapping capabilities of ArcGIS Online and ArcGIS Enterprise.

A Continued Commitment to Innovation

The ArcGIS for Microsoft team continues to enhance integrations between the two platforms and develop new products to provide Microsoft users with the spatial capabilities of ArcGIS technology. This ongoing commitment to innovation and integration ensures that organizations can harness the full power of geospatial data to drive business outcomes.

To learn more about ArcGIS for Microsoft, visit go.esri.com/arcgis-microsoft. To submit feedback or ideas about other uses for ArcGIS GeoAnalytics for Microsoft Fabric, post in Esri Community at links.esri.com/fabric-community.

ArcGIS for Microsoft is designed for business leaders, data analysts, data engineers, data scientists, developers, and GIS professionals. The full capability suite provides users with the tools they need to perform advanced geospatial data processing, modeling, and spatial analysis, as well as automate spatial workflows. In turn, ArcGIS for Microsoft enables executives to make informed strategic decisions that leverage geospatial insight. Key integrations include the following:

ArcGIS for Microsoft Fabric

ArcGIS for Microsoft Fabric integrates mapping capabilities and geospatial analysis tools directly in the Microsoft Fabric environment. ArcGIS GeoAnalytics for Microsoft Fabric is an interface for Apache Spark that provides a collection of spatial SQL functions, track functions, and analysis tools to help data scientists and engineers detect patterns in their data. Users can also employ ArcGIS for Power BI to seamlessly incorporate the insights garnered in GeoAnalytics for Fabric into business reporting and further analysis, helping to uncover the "where" and "why" of the data.

ArcGIS for Microsoft 365

ArcGIS for Microsoft 365 integrates location analytics and provides access to spatially enabled apps and data in familiar Microsoft 365 apps. Everyone in an organization can create, edit, and analyze maps in Microsoft Excel; augment Microsoft SharePoint sites with interactive maps and location-enriched content; and collaborate on geographic content in real time during Microsoft Teams meetings.

ArcGIS for Power Platform

ArcGIS for Power Platform offers low- to no-code development tools that enable users to build geospatial apps and set up automated workflows. ArcGIS Connectors for Power Automate offer geospatial triggers and actions that can be set up with little to no coding, allowing users to automate repetitive geospatial and data management tasks directly within ArcGIS Connectors for Power Automate.

ArcGIS Maps SDK for .NET

ArcGIS Maps SDK for .NET lets developers build 2D and 3D location-based mapping apps that work online and offline. Using .NET Multi-platform App UI (.NET MAUI), Windows UI Library (WinUI), and Windows Presentation Foundation (WPF), developers can create apps for Windows, iOS, and Android platforms that include capabilities such as geocoding, geofencing, routing, and navigation, as well as data collection and editing.

ArcGIS Enterprise on Microsoft Azure

ArcGIS Enterprise on Microsoft Azure leverages the full power of self-hosted infrastructure within a scalable, secure, and reliable cloud environment. Deploying ArcGIS Enterprise on Microsoft Azure enables organizations to improve their efficiency and scale resources to meet evolving needs.

ArcGIS Pro on Microsoft Azure Virtual Desktop (AVD)

ArcGIS Pro on Microsoft Azure Virtual Desktop (AVD) delivers a powerful, flexible GIS solution by leveraging Azure's scalable resources. With support for Windows 11 multisession virtual machines, it provides a seamless user experience and maximizes the value of cloud technology.

Edit Your Metadata WITH EASE

By Laura Busolo, Jordan Duft, and Vishwesh Sangarya

In ArcGIS, users can create, modify, save, and delete metadata. The metadata editor also provides the functionality to overwrite an item's existing metadata. When you need to update or correct information associated with an item in your ArcGIS portal, metadata editing should be painless. The enhanced metadata editor makes this process simpler than ever. Find out what happens when you overwrite metadata, explore the options available, and learn to overwrite your metadata in ArcGIS Online or ArcGIS Enterprise.

What Are Your Overwrite Options?

Before getting started, you will need to enable metadata for your organization. Only item owners and administrators can edit an item's metadata.

To launch the metadata editor, navigate to the item's page and click the Metadata button. Once you're in the metadata editor, click the ellipsis in the top right corner and select the Overwrite option.

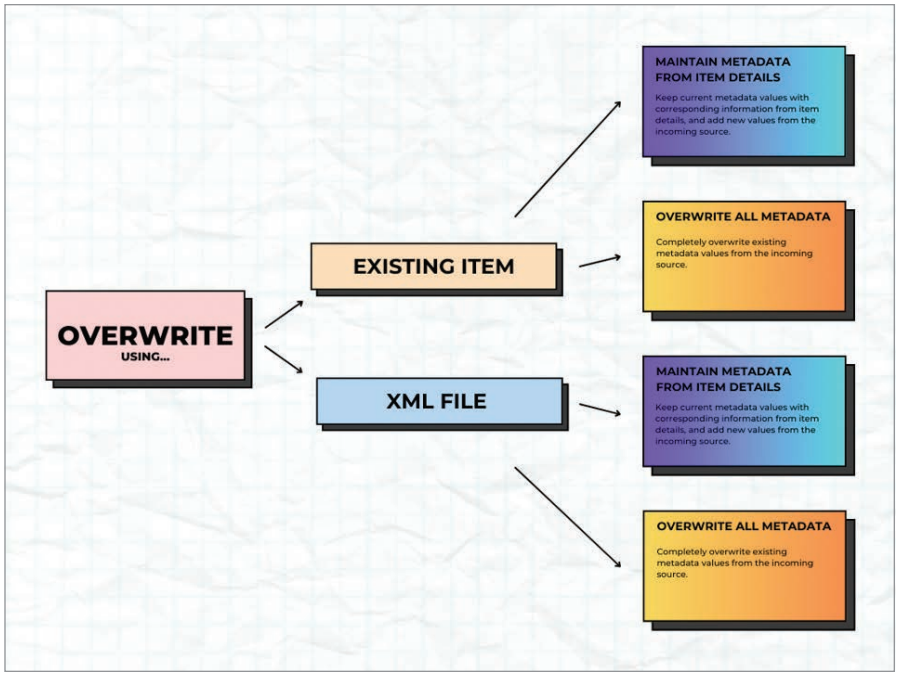
Now you'll need to decide which metadata source you want to use. You have two options for overwriting your metadata: using metadata from an item in your ArcGIS Online or ArcGIS Enterprise organization, or from an ArcGIS metadata XML file.

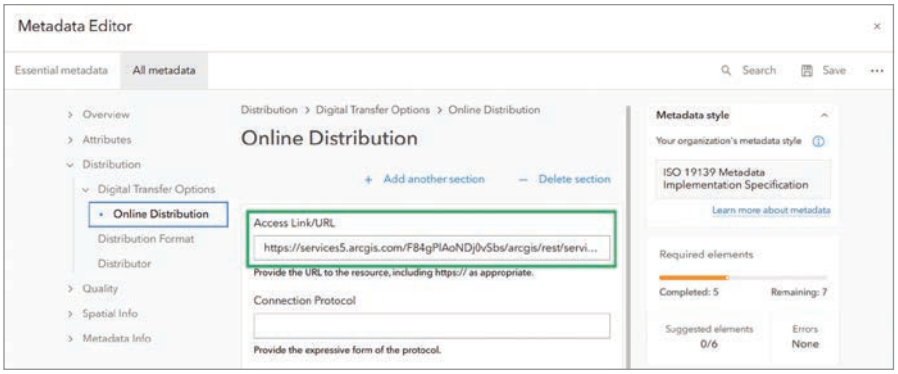
- **From item:** Use this option to overwrite your metadata using metadata from another item in your portal or a publicly shared item. Simply provide the URL or item ID of the source item.
- **Choose file:** This option allows you to overwrite metadata using a local ArcGIS metadata XML file. You can export metadata to this format from ArcGIS Pro or the metadata editor in your ArcGIS portal.

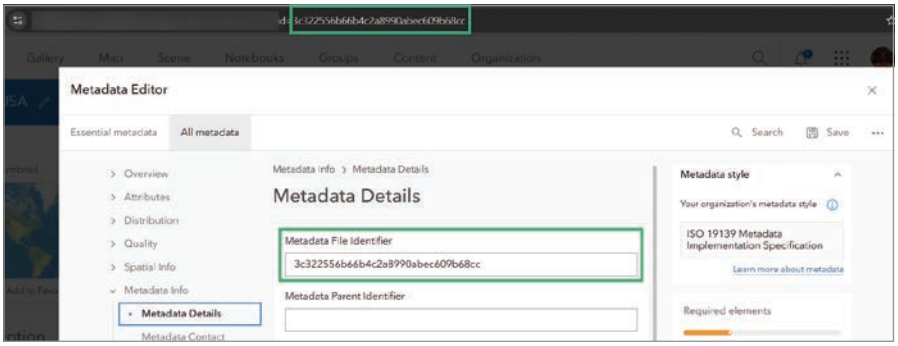
Next, decide whether to maintain the metadata from the item details page or to overwrite all metadata.

The option to maintain metadata from item details is selected by default. It allows you to avoid unintentionally losing any metadata. This option preserves the metadata already populated on your item page—such as Title, Summary, Description, and Terms of Use—and the ArcGIS metadata XML.

↓ Multiple options exist for overwriting metadata.







However, if the existing metadata contains null values (i.e., is not populated), those values will be replaced with the new metadata you are using to overwrite.

Let's say you have an existing item with a description but no summary. The item you are overwriting from has both the summary and description. Selecting Maintain metadata from item details on the Overwrite dialog will ensure the description of your existing item does not change, but the summary will be filled with the values from the new metadata you are applying.

The help documentation linked in the dialog box specifies the metadata elements that will be maintained when you overwrite metadata. This includes not only the item details, but also elements such as Extent, Access Link/URL, and Metadata File Identifier.

To locate the Access Link/URL element, navigate to All Metadata > Distribution > Digital Transfer Options > Online Distribution. When you create metadata for a layer, the web service URL for the item automatically populates in the Online Distribution section of the metadata editor interface. Generally, you should avoid overwriting this metadata element; it reflects the web service URL for the item's layer, as illustrated in the screenshot above. Altering or removing the Access Link/URL in the metadata will not affect the web service for the web layer, but it will only impact the information stored in your metadata.

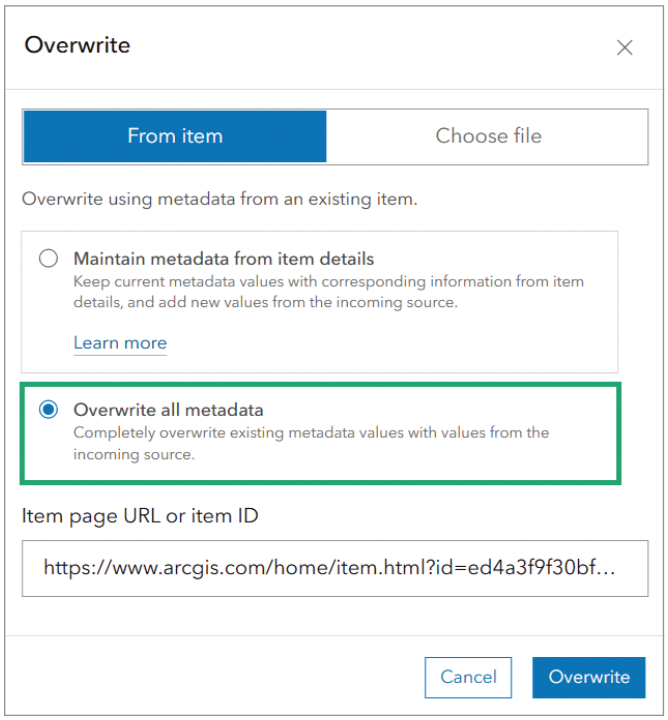
To locate the Metadata File Identifier, open the metadata editor and navigate to All metadata > Metadata Info > Metadata Details. The system automatically assigns the Metadata File Identifier when you create metadata for an item. This identifier corresponds directly to the item ID. Unless necessary, avoid overwriting this metadata element, as it represents the specific metadata file ID linked to the item's ID.

The Overwrite all metadata option completely replaces existing metadata with the values from the incoming metadata source, which can be either an item or a metadata file.

Let's take a look at the different options for overwriting your metadata.

↑↑ Altering or removing the Access Link/URL in the metadata will not affect the web service for the web layer; it will only impact the information stored in your metadata.

↑ The system automatically assigns the Metadata File Identifier when you create metadata for an item.



→ When overwriting metadata, review the results before saving your changes.

1 Leverage a Template

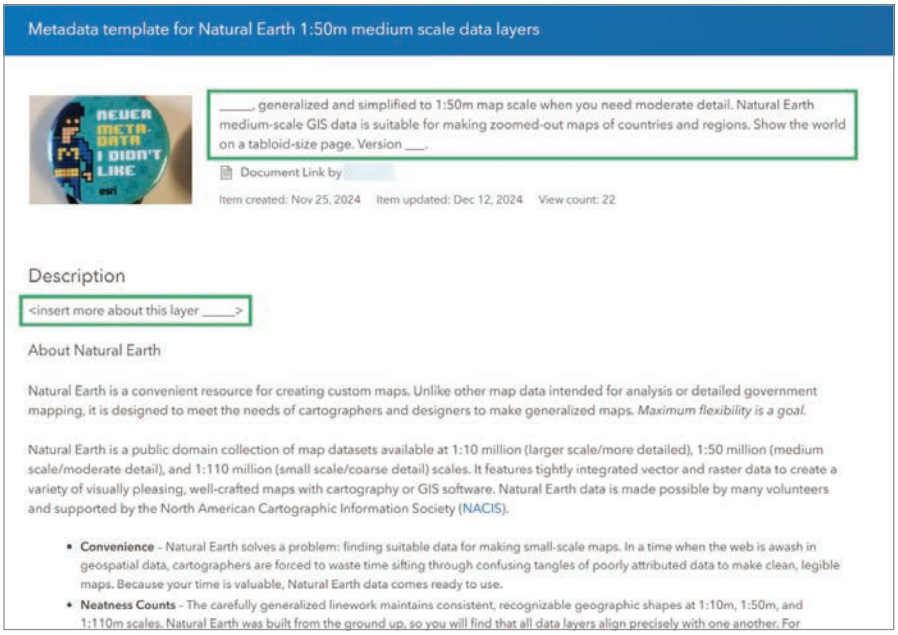
To quickly edit the metadata of web layers that currently lack it in your organization, apply a basic metadata template.

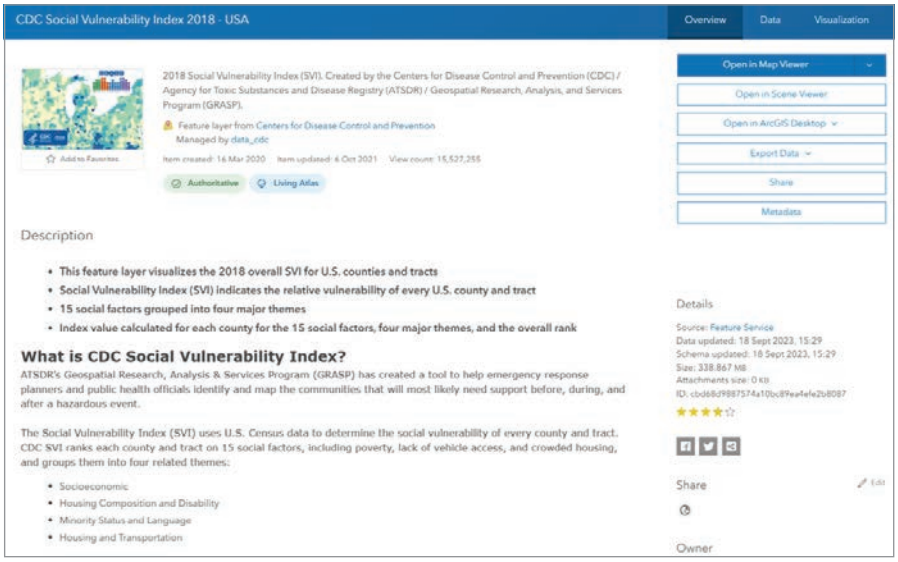
For instance, if you're tasked with creating a collection of layers, you can systematically fill in their metadata. You can create an item that acts as your metadata template for new items, as illustrated in the image to the right. When designing your template, thoughtfully choose the values to include, such as placeholder text and your organization's contact information, ensuring compliance with your organization's metadata standards. Additionally, consider adding helper text to assist users in populating metadata according to best practices.

You can use the metadata from an item's URL to overwrite existing metadata, as discussed in the options above. By copying the URL of the template item and navigating to the new item that lacks comprehensive metadata, you can use the overwrite feature to jump-start the process of filling out your metadata.

Selecting Maintain metadata from item details in the dialog will ensure that any populated metadata elements in the item details are retained in both the item details and the ArcGIS metadata XML.

Null values in the item page will be replaced with information from the template. You can always review your metadata before saving.





2 Edit Metadata on a Filtered Layer

For this option, create a filter from a layer and make updates to your newly created layer's metadata. Let's use the CDC Social Vulnerability Index 2018 - USA layer from ArcGIS Living Atlas of the World as an example. This layer has been recommended by the Centers for Disease Control and Prevention (CDC) as authoritative, which instills a level of confidence in its reliability for reuse. By leveraging the capabilities of web layers, you can dynamically filter and quickly share authoritative data with relevant metadata.

In this example, use the CDC layer to apply a filter for the state of Texas. Save the filter as a new layer, "Texas," that will appear in your content. However, the new Texas layer lacks metadata.

You can choose to duplicate the metadata from the CDC layer to your Texas layer. By following a workflow like the one demonstrated in the template metadata example, you can paste the source layer URL for the overwrite process. This action enables you to

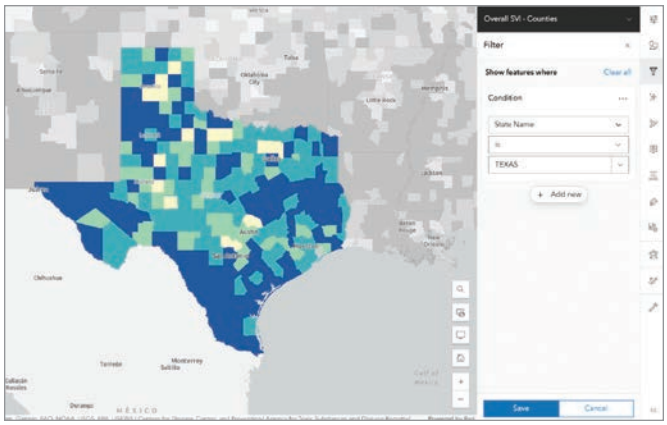
↑↑ Items can be used as templates for metadata.

↑ The CDC Social Vulnerability Index 2018 - USA layer can be used as a metadata source.

→ Overwrite metadata using the API while keeping the existing item details intact. By using the item_properties parameter, you can overwrite metadata (excluding the title) while preserving the existing item details.

seamlessly use essential source metadata, including descriptions and terms of use. Additionally, you improve the context by updating the geographic extent to accurately represent the filtered layer as well as other metadata elements.

In addition to overwriting the Texas layer's metadata, you can also make relevant changes in the editor. Editing the metadata helps to accurately reflect the filtered content in the metadata editor. Note that you cannot edit the sublayer metadata of your new copy of the layer, since it is still referencing the USA layer.



↑ The CDC Social Vulnerability Index - Texas layer still references the CDC Social Vulnerability Index layer's web service. Therefore, any changes the CDC makes to Social Vulnerability Index web service within the state of Texas will be reflected in this layer.

3 Overwrite Metadata Using ArcGIS API for Python

You can also automate your metadata editing and overwriting processes by using ArcPy or ArcGIS API for Python. If you aim to streamline your workflows, ArcGIS API for Python offers a programmatic approach to overwrite metadata efficiently. Through scripting, it is possible to entirely replace the metadata for an item by sourcing it from an ArcGIS portal or an ArcGIS metadata XML file. Additionally, the API enables you to overwrite all metadata while retaining the existing item details, such as summary. This ensures the descriptive properties on the item page remain intact, even as the rest of the metadata gets updated. For scenarios that necessitate a complete metadata overwrite, the API effectively facilitates these updates.

No matter how you edit or overwrite your metadata in ArcGIS, leveraging the capabilities of the metadata editor has never been easier.

```python
from arcgis.gis import GIS

def OverwriteMetadata(item, source, keepItemDetails=False):
    """
    Description:
        Overwrite current item's metadata with new metadata from metadata xml file or item on ArcGIS
Online or ArcGIS Enterprise
    Params:
        item: ArcGIS Online/Enterprise item to update
        source: Source item path (either a local metadata xml file or an ArcGIS Online or ArcGIS
Enterprise portal item's metadata)
        keepItemDetails: Overwrite all metadata but maintain current item details if true
    """

    # Obtain current item's item details
    item_properties = {
        "title" : item.title,
        "tags" : item.tags,
        "description" : item.description,
        "snippet" : item.snippet,
        "accessInformation" : item.accessInformation,
        "licenseInfo" : item.licenseInfo,
        "access" : item.access,
    }
    # Overwrite all metadata
    item.update(metadata = source)
    #Revert back item properties
    if keepItemDetails:
        item.update(item_properties = item_properties)
    print(f"Done overwriting metadata")

# ArcGIS Online or ArcGIS Enterprise URL
url = f"https:///"

# Create a GIS session with ArcGIS Online or ArcGIS Enterprise URL
gis = GIS(url=url, username= "", password="")

# Obtain an active token for the current session
token = gis.session.auth.token

# Item ID to overwrite the item's metadata
itemID = ""

# If using overwrite with source metadata from an ArcGIS Online or ArcGIS Enterprise Portal URL item
sourceItemID = ""
sourceItemUrl = f"{url}/sharing/rest/content/items/{sourceItemID}/info/metadata/metadata.xml"
metadataSource = f"{sourceItemUrl}?token={token}"

# If using overwrite with local metadata xml as the source
# metadataSource = ""

# GIS item object for the target item
item = gis.content.get(itemID)

# Call the overwrite method, overwrite all metadata while maintaining item details
keepItemDetails = True #Set it to False for a complete overwrite
OverwriteMetadata(item, metadataSource, keepItemDetails)
}
```

About the Authors

Laura Busolo is a native Kenyan based in California who loves exploring culture and most things art. With years of experience in the world of geospatial technology, she currently works as a product engineer at Esri, collaborating across teams to help users manage their content in ArcGIS Online.

Jordan Duft is a product manager at Esri, responsible for metadata, catalog, and search functionalities across the ArcGIS platform. She enjoys working with cross-functional teams to support users as they unlock the full potential of their geospatial data.

Vishwesh Sangarya is a product engineer at Esri, working on metadata functionality in ArcGIS Pro and across the ArcGIS platform.

Location Intelligence Guides Renewable Energy Construction

By Matt Piper and Geoff Wade

In 2023, construction kicked off in New Mexico and Arizona on the largest wind energy project in the Western Hemisphere. Pattern Energy's $11 billion SunZia will provide 3,000 megawatts of clean energy from 916 wind turbines, and its 550-mile transmission line will carry enough power for three million Americans when it comes online in 2026. Not only do the region's consistently high wind speeds make it a fantastic source of wind power, but the demand for this type of renewable energy is close by.

"The shape of power makes a good match between the source of power in New Mexico and the market across the Southwest," said David Janssen, project director of engineering and construction at Pattern Energy. "As the sun goes down in California and Arizona and the solar panels are going offline, the wind is picking up in New Mexico."

SunZia has been years in the making, and every step was meticulously planned. The size and complexity of the project required using GIS technology at an enterprise scale from the start. Along with volumes of data and drones equipped with Site Scan for ArcGIS, a shared mapping solution called Maps to Megawatts, developed by Esri partner Aegean Energy Group, has helped manage all phases of the project.

Maps to Megawatts is a software-as-a-service (SaaS) solution created with ArcGIS Online that is specifically designed for renewable energy development projects. It incorporates software such as ArcGIS Dashboards and ArcGIS Hub to more efficiently communicate geographic information. Pattern Energy uses the SunZia Maps to Megawatts ArcGIS Online instance to create web applications that support environmental impact assessments, site selection, transmission routing, and construction. The solution aggregates data using dashboards that track progress and helps coordinate the many project phases.

← Pattern Energy has been developing, constructing, and operating wind, solar, transmission, and energy storage projects at a large scale globally for over 15 years.

↓ A map of Pattern Energy's SunZia Wind and Transmission project shows its immensity, spanning two states.

"We have dashboards tracking construction progress, showing captured drone imagery in relation to the design, and dashboards we've shared with the Bureau of Land Management [BLM] that track environmental information," said Michelle Pruse, director of geospatial technologies at Pattern Energy. "We also have various applications that tracked our land acquisition progress and visualized specific constraints on individual parcels."

Mapping Out Sites and Paths

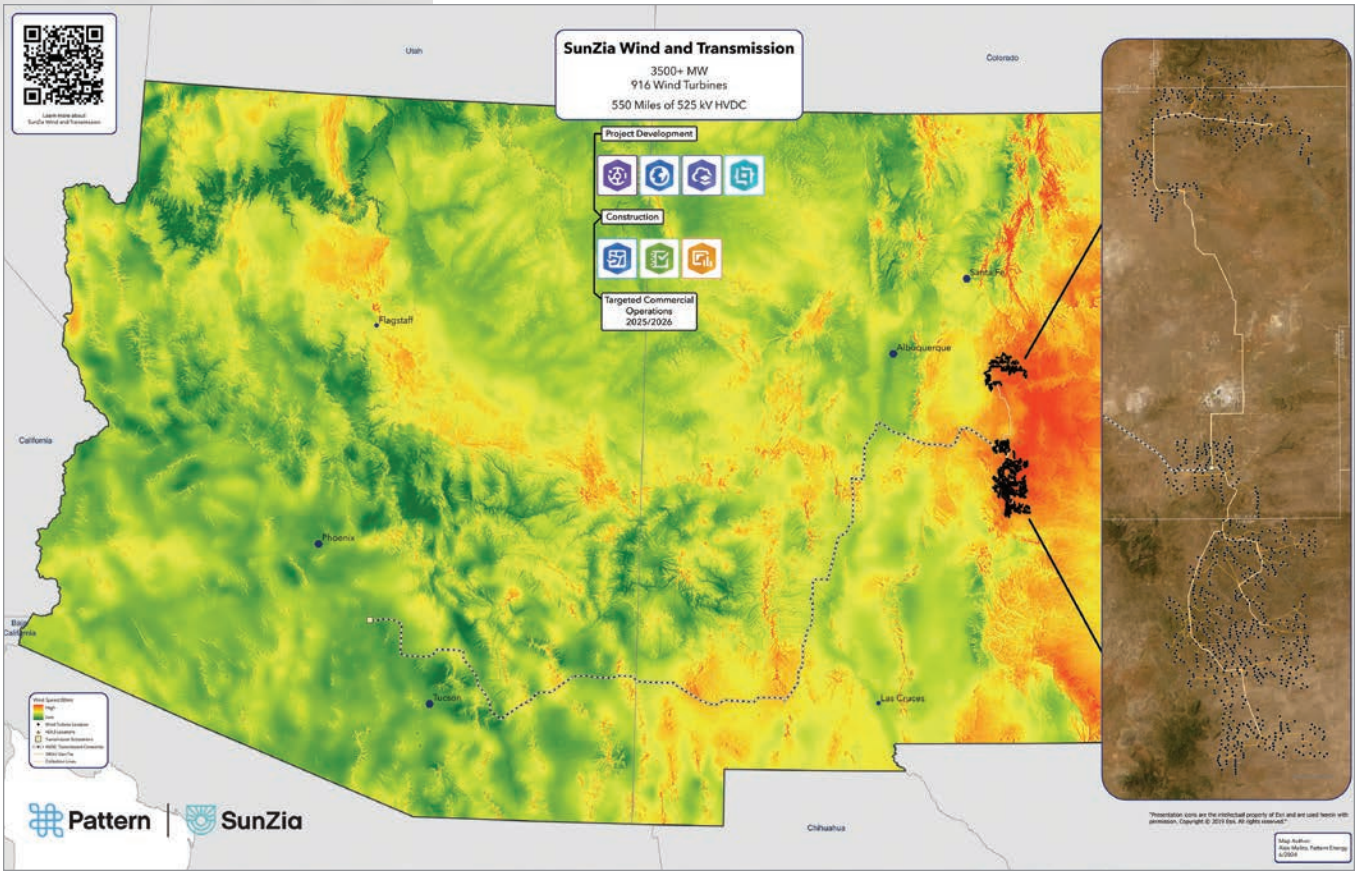
The SunZia Wind and Transmission project began over a decade ago with the mapping of land parcels. The real estate team recorded details about ownership, land use, water rights, utilities, geology, and more. Surveyors added precise locations.

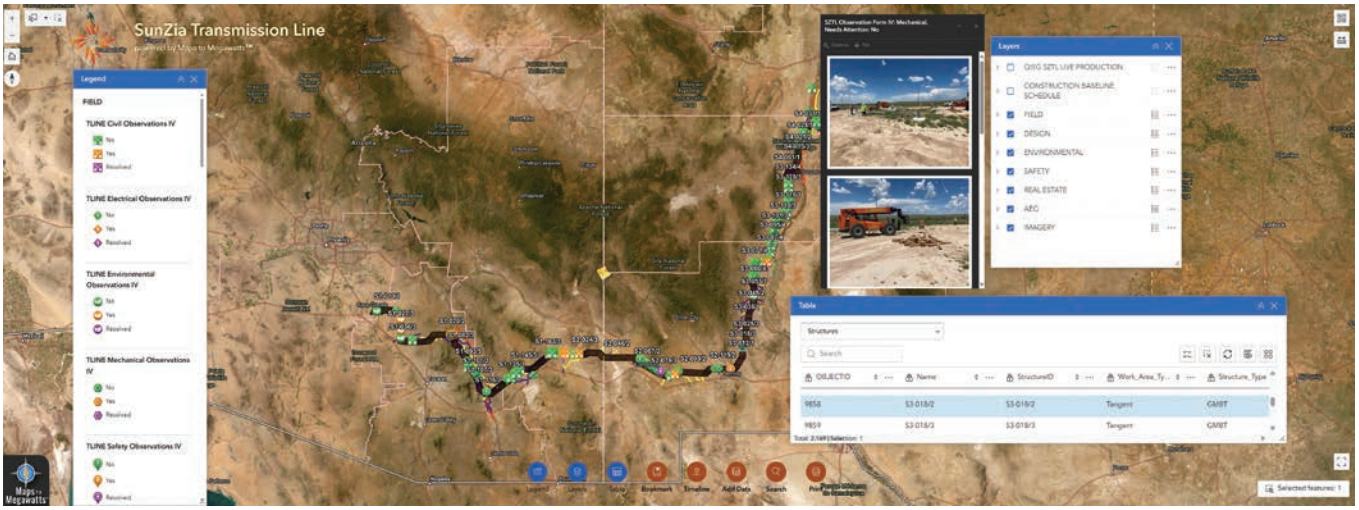
To find the best wind pad sites and transmission path, the land was analyzed for terrain, protected habitat, fragile environments, and proximity to homes. Mapping the cultural heritage sites of Indigenous tribes was also of paramount importance. Maps to Megawatts enabled planners to consider all these factors, as well as calculate costs to find optimal sites and corridors.

While the wind project stretches across counties, and the transmission corridor spans two states, the area under analysis was much larger.

"When you kick off a project, you think you have a ton of available land, but then you start overlaying all of your constraints," Pruse said. "It's a little eye-opening to go from a giant slice of the state down to what you can actually use."

The project's success depends heavily on cooperation and coordination with government agencies, Tribal Nations, and





private landowners. Detailed maps guided conversations and deliberations before Pattern Energy could obtain the necessary permits to proceed.

To achieve route approval, dashboards in Maps to Megawatts were used to help create environmental impact statements required by the National Environmental Policy Act.

"Our environmental teams worked closely with BLM to make sure that we have all of the information that we need in order to analyze those areas and make sure that we're not encroaching on anything we shouldn't," Pruse said.

Because the line goes through a national wildlife refuge, the US Fish and Wildlife Service is also a stakeholder.

"Having all of these different types of landowners isn't typical," Janssen said. "GIS helps us identify the specific needs of each landowner and have a common approach that crews in the field can navigate and understand."

Guided Construction

After the site locations were solidified, the design and permitting teams worked to match their plans with the constraints at each site. Engineers improved designs for both the wind and transmission towers. They recorded details for each tower's unique foundation and made plans for earthmoving to allow stormwater drainage or establish access roads.

The Maps to Megawatts solution captured details of all the 2,100 transmission tower structures along the line, each with a custom design. The transmission line project will employ more than 1,000 construction workers across three teams deployed to different sections of the route.

Now that the project has reached the construction phase, work crews have embraced GIS-powered apps to

↖ Workers pour concrete for a wind turbine foundation. Every wind turbine and transmission tower foundation is different, depending on soil conditions and other constraints at each site.

↙ The primary web app for the SunZia Transmission Line project features a detailed map, with clickable updates that include photos, drone-captured images, and notes on progress.

↓ A drone captured this view from above as a tower was being erected.

navigate and document the work. Each tower has specific access requirements. For instance, some can only be reached by helicopter.

"Being able to visualize work areas, and look at access routes and constraints, allows us to be more efficient," Janssen said. "It beats getting everyone in a truck to drive out to do a review, and then looking at pages and pages of drawings to sort it all out."

More than 50 inspectors review construction to ensure that all parts of the project align with environmental and operational standards. Drones and on-the-ground observations from crews capture every move to manage risks and ensure careful environmental compliance.

"GIS influences what everyone is doing in the field," Janssen said. "About a tenth of the crew are using a tablet, phone, or laptop to make observations, take photos, create production reports, or look up data. When someone finds something that's helpful for them, they can share that with the rest of the group."

Navigating Barriers to Construction Progress

With millions of dollars spent on construction each day, the cost of delays compounds quickly. Whenever something stands in the way, drones and the data in the GIS solution help the team plan around it.

Drone imagery, captured and processed using Site Scan for ArcGIS, helps the crews see whether fences and roads are in good condition or in need of repairs. The crews use this imagery to evaluate changing conditions, such as the effects of monsoon rains. It also helps track movements of material, including calculating the amount of earth moved to flatten the terrain.

Some tower sites are still under review, causing concern about construction delays. "GIS has allowed us to analyze those areas and come up with workarounds and resequencing to keep our crews engaged and not just sitting at a locked gate waiting for someone to open it," Janssen said.

Drone imagery also enables real-time collaboration between the field and the office, especially when potential delays arise. One BLM permit requirement, for instance, called for the relocation of all cactus and endangered plants, and drone imagery eased the effort.

"If we've got a problem that comes up, we can all look at the drone data to talk about it intelligently," Janssen said. "We've got people on the ground tagging and identifying saguaro and other cacti, then crews go pick them up and move them out of our right-of-way. By looking at the imagery before and after, we can see which cacti make it through the move and which might need some help."

Creating a System of Record to Guide Operations

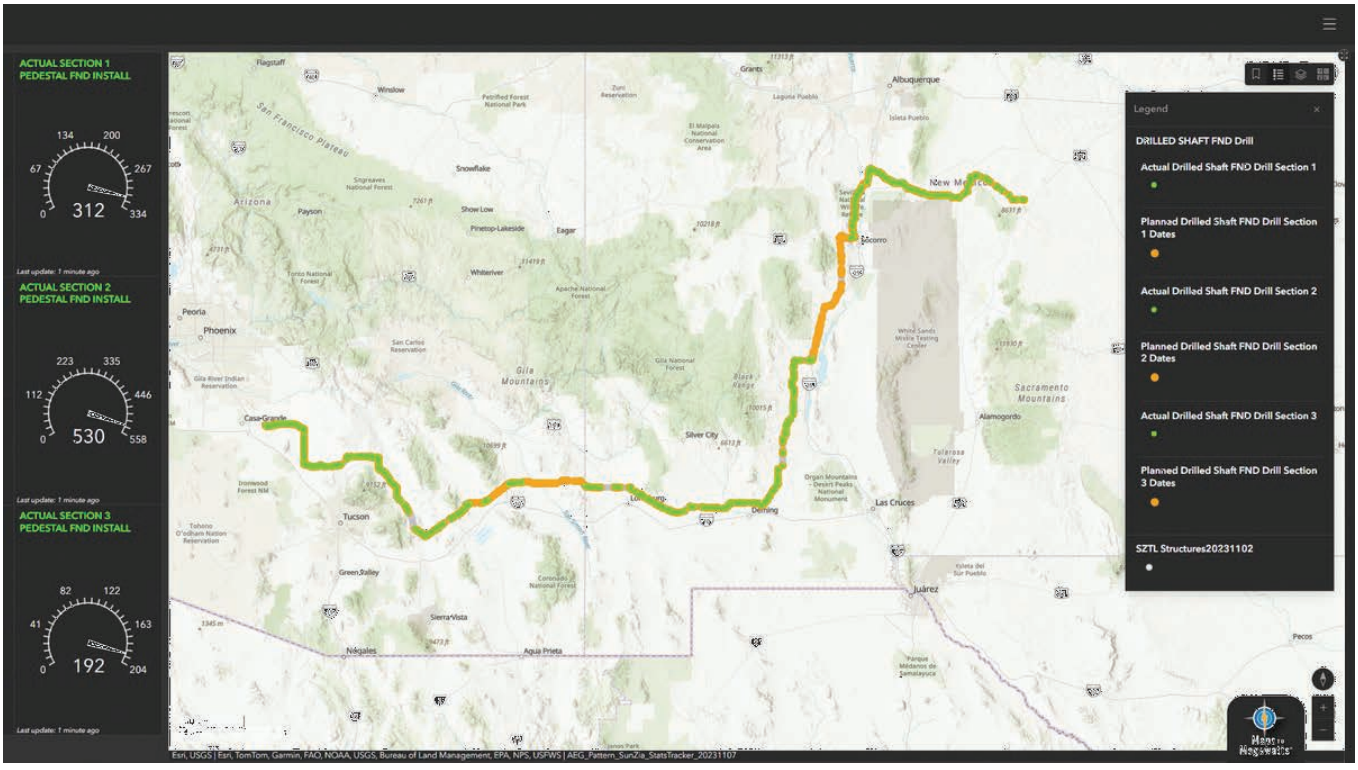
The careful collection of construction data and an accurate record of what was on the land before construction started will also support the ownership and operation of SunZia.

"We've taken a photo of every single crack that looked like it was susceptible to any kind of damage during construction," Janssen said. "That crack may come back to be a big deal 10 years down the road."

GIS records of project construction will be useful for at least the next 20 years. These records will guide the operations team in its upkeep of wind turbines and transmission lines and stations when the project is officially handed off to that team.

"Having the common GIS platform makes that job so much easier for us," said Janssen. "We have the data already assembled, and the construction observations packaged up. This helps the operations team digest it and get up to speed on the project."

↑ After the blades are installed, the wind tower is complete.



↑ The SZTL Schedule StatsTracker contains a map and dials that track progress on key deliverables.

Well before construction started, Pattern Energy's SunZia project was praised for its many potential benefits. These included creating good-paying jobs, lowering energy costs, stopping power outages in the face of extreme weather, and accelerating the transition to clean energy. However, it took 15 years for the utility-scale energy project to finalize all the necessary approvals.

"What gets the most attention in the industry seems to be the length of time it's taken to bring this to market," Janssen said.

The many agencies involved in the project in different jurisdictions had a lot to do with the long delay. But other clean energy projects have also faced long development timelines, leading to calls for bipartisan legislation to reform the permit process.

From Pattern Energy's perspective, the documentation of end-to-end workflows could speed future permitting and construction. If regulators embraced technology and used GIS-powered digital twins for approvals and oversight, inspections could happen remotely with online approvals. This level of modernization would be in-line with a growing local government trend to electronically process permits and enforce requirements via online tools.

"We are hoping some of the lessons we've learned during permitting and construction—collaborating with GIS—can help us streamline the environmental review process so we can be more efficient," Janssen said.

About the Authors

Matt Piper is Esri's Global Industry Solutions Infrastructure Director. He focuses on technology for sectors, including telecommunications, utilities, water, and architecture, engineering, and construction (AEC). Piper joined Esri in 2018 as a global industry manager and director of electric and gas. With 20 years of experience working in the utilities industry, Piper is recognized for his expertise in digital transformation, asset management, and thought leadership on GIS as an enterprise-wide solution for operational awareness, efficiency, and digital twins. Prior to Esri, he worked for Ergon Energy.

Geoff Wade has more than 25 years of experience in applying technology to the business and operational challenges of natural resources companies. He began his career as a geologist and has held marketing management roles at Esri for more than two decades. Wade takes an active role in the petroleum and mining sectors, and helps coordinate Esri's activities across the wider natural resources sector.

Evansville Cuts Turnaround Time with GIS Transition

By Christa Campbell and Emma Hardy

Located in Indiana alongside the Ohio River, the city of Evansville is home to roughly 115,000 people. Evansville Water and Sewer Utility (EWSU) is dedicated to providing this community with high-quality, safe, and reliable water and sewer services.

With the retirement of ArcMap and the geometric network, EWSU decided to migrate to ArcGIS Pro and ArcGIS Utility Network. During the transition, staff saw an opportunity to resolve widespread inaccuracies in their existing asset locations.

"As we were thinking about moving to and taking advantage of [ArcGIS] Utility Network, we knew our source data had to be squeaky clean," said Ryan Key, GIS manager at EWSU.

Taking six months to recapture data with high accuracy became a priority. Inaccurately mapped clusters of infrastructure, such as multiple water meters at one site, had made it difficult to locate individual assets during maintenance, annual inspections, and capital refresh projects.

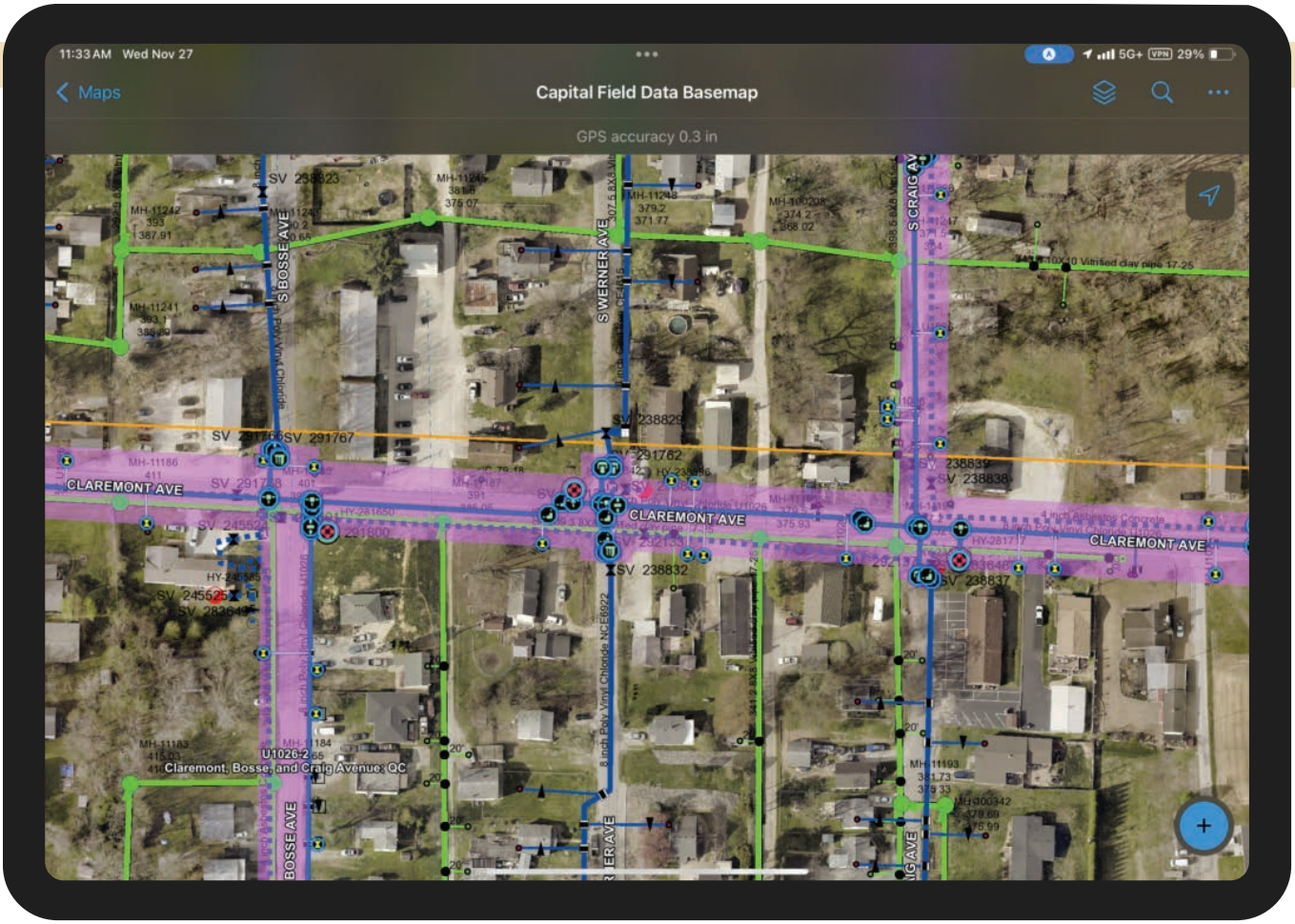
Additionally, responding to service requests with inaccurate locations often wasted time, with customer service representatives unable to access real-time customer data geospatially.

Meanwhile, capital refresh projects—which target the replacement of aging infrastructure and include design, construction, installation, and final as-built drawings—sometimes experienced project-design delays due to location inaccuracies. As a result, updating EWSU's GIS environment could often take anywhere from months to a year. The utility's staff realized that, in addition to preparing EWSU for the migration to Utility Network, remapping and rectifying their asset data could provide a host of additional immediate benefits.

Implementing GNSS Receivers with ArcGIS

As a first step in updating their system, EWSU decided to integrate real-time Global Navigation Satellite System (GNSS) technology. Key had heard about the effectiveness of Arrow Series GNSS receivers from Eos Positioning Systems through a GIS specialist and industry peer. As a firm believer in trying technology before buying it, Key decided to put the receivers to the test.

"I actually went out with our field crew and tested an Arrow receiver alongside



↑ By pairing ArcGIS Field Maps with Arrow Gold GNSS receivers, Evansville Water and Sewer Utility (EWSU) captures asset locations in the field with centimeter-level accuracy.

← The EWSU operations team—(left to right) instrumentation and electrical technician Larry Smith, lead valve operator Shawn Williams, and instrumentation and electrical technicians Randy Norman and Kyle Murray—poses with the Arrow Gold receivers.

some other receivers," Key said. "We did side-by-side comparisons of the location data, and in the end, Arrow won. Our decision really came down to the accuracy of the Arrow receiver and its quick integration with ArcGIS Field Maps."

Since EWSU was already using ArcGIS software, integrating the Arrow receivers with ArcGIS Field Maps was a huge advantage. Asset locations in the field can be captured with centimeter-level accuracy, and these positions are instantly synced to ArcGIS Online, making real-time updates accessible from the office. Additionally, the receivers were device agnostic, meaning they could pair with the iOS devices field crews were already using.

"If we're going to collect data, why not have it as accurate as it could possibly be?" Key said. "When you get tight clusters of things like system valves, that accuracy is important."

EWSU's in-house surveyor set up two real-time kinematic (RTK) base stations, which provide the differential corrections needed for centimeter-level accuracy. By connecting the rover receivers to a base station, crews could achieve real-time, high-accuracy results.

"We can cover most of the county with one base station," Key said. "The second acts as more of a redundancy if one becomes inoperant."

The EWSU GIS team trains employees new to the technology on the hardware, software configuration, and actual data collection, all of which takes only about an hour. After training, field crews receive a basic user guide for reference. Key noted that crews rarely need follow-up support.

"The cool thing about this [GNSS] technology and the integration with [ArcGIS] Field Maps is that it is super user-friendly," Key said. "It's essentially plug and play. A lot of these guys had no GIS experience, and they transitioned to collecting data like ducks to water."

In the Office

Next, using dashboards created with ArcGIS Dashboards, staff in the office visualize and analyze data collected in the field. Back at his desk, GIS technician Aaron Krohn monitors these dashboards to see data collection as it occurs.

"I can look at everything our crews have collected and see those numbers update in real time," Krohn said. "They record the type of asset [and] its status as well as the fix type."

Using ArcGIS Dashboards, Krohn can also respond to edit requests in real time. He can also use the new, accurate locations from

the GNSS receivers to correct outdated infrastructure from previous plans.

EWSU also built a custom ArcGIS Utility Network web application, U-Net, by using ArcGIS Maps SDKs. U-Net is a launching point for other teams to access information from GIS-related systems—such as an asset management system, a CCTV application, a customer service portal, as well as historical and as-built drawings—all on a map. Non-GIS teams now use U-Net to view their information geospatially without having to open and navigate desktop GIS software. This expands the reach of GIS to teams that are not GIS professionals.

"We're truly harnessing the service-driven architecture of Utility Network," Key said. "It's easier to send our colleagues a web URL than have everyone in our organization use a desktop GIS, which has too many bells and whistles for someone who wants to dive in and review, for instance, only customer service information on a map."

To enable this widespread information access, Key and Krohn have been diligently upgrading other systems and data and migrating them onto the cloud.

"Our thought process was, if we're going to go ahead and do this Utility Network migration, why not go ahead and move other applications to the cloud too?" Key said.

EWSU's new mobile mapping workflow has resulted in better accuracy in the utility's asset maps. This, in turn, has streamlined inspections and set a new standard for the utility's capital-refresh project timelines. EWSU now completes the as-built process in near real time, rather than up to one year later, thanks to field crews being able to map installations during on-site inspections.

"We've collected about 9,000 assets in as little as two years," Key said. "And we can see those on the map in real time—including maintenance holes, system valves, service connections, and other infrastructure assets."

Access to Utility Network, along with its increased accuracy, has even enabled EWSU staff to expand use of their GIS to contractors, especially those performing 8-1-1 underground-asset location requests for new development.

Looking Ahead

In the future, EWSU plans to leverage tracing tools in Utility Network. Key envisions how this will simplify customer notifications in impact areas. During boil-water advisories, for instance, truck valve operators will no longer have to manually draw a polygon around the impact area. Instead, operators can change the operation mode of a valve at two ends and immediately generate an impact-area polygon directly from their mobile devices. This will be powered by the squeaky-clean data and meticulous cloud environments that EWSU has already created.

"Our field crews who collected this data understand that what they did will ultimately end up making their lives easier in the future," Key said.

The same workflow can be expanded to engineers to create impact areas for water main replacements, part of the utility's capital refresh projects.

Key emphasized that all this was made possible thanks to the support of EWSU's executive leadership. Throughout the utility, there is an understanding that technology enables EWSU to deliver a higher quality of service. That forward-thinking mindset allows the utility to push the boundaries of what is capable in terms of how and why staff serve customers.

"It's all about customer service," Key said. "Having this type of accuracy in our system allows for greater response, reaction, and repair—which translates to greater customer experience."

↗ EWSU's Field Data Dashboard displays the total number of water and sewer assets collected, their locations, fix types, and other details.

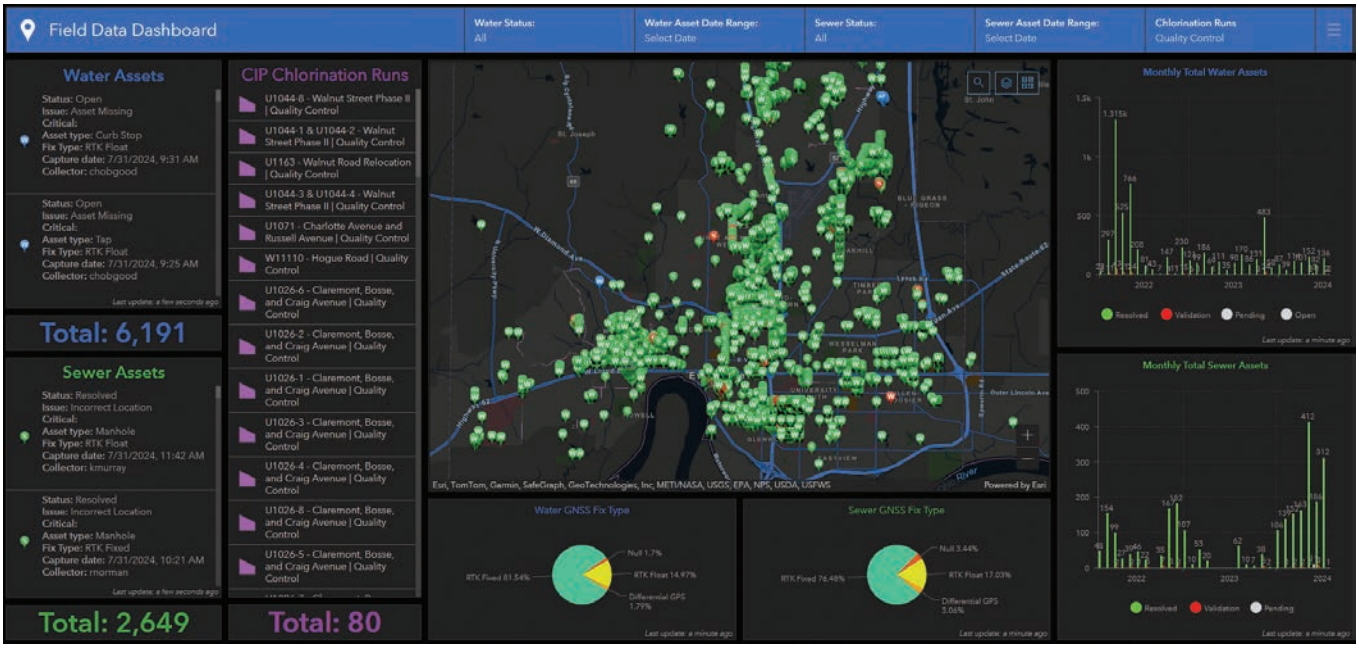
↘ EWSU's Field Data map displays the locations of water assets collected with ArcGIS Field Maps and Arrow Gold GNSS receivers.

About the Authors

Christa Campbell is a water industry professional with over 20 years of success using and promoting technology. She is a passionate GIS advocate, lifelong learner, and collaborator. As the director of Esri's water industry team, she provides strategic direction, builds awareness of water industry challenges and trends, and inspires organizations to work smarter using GIS-based solutions.

Emma Hardy is the multimedia producer at Eos Positioning Systems. Using her experience in journalism, video production, and photography, she is dedicated to amplifying stories throughout the geospatial community.

← Evansville Water and Sewer Utility field crews can now submit data in real time from the field by connecting to ArcGIS Field Maps on an iPad via Bluetooth.



GIS AND DRONES BRING A NEW DIMENSION TO LAND SURVEYING

By Rae Johnson

→ Dudek's field team completed an 8,000-acre orthophoto in a remote area of Upcountry Maui. The imagery is used to track the progress of invasive species management efforts.

WHEN heavy rainfall caused mud and trees to slide down the Pali Highway on Oahu in December 2023, access to roads in and out of town was blocked. A scenic 10-mile main thoroughfare also known as Hawai'i Route 61, the Pali Highway connects downtown Honolulu to Kailua and fields thousands of drivers' worth of traffic during the morning commute alone.

Dudek, an environmental and engineering consulting firm, was able to jump into action, using drones and GIS technology to quickly collect and share road conditions with government agencies, helping them unblock this critical route. Department of Transportation crews removed over 30 truckloads of mud and debris off the highway, careful not to destabilize the slope of the hill.

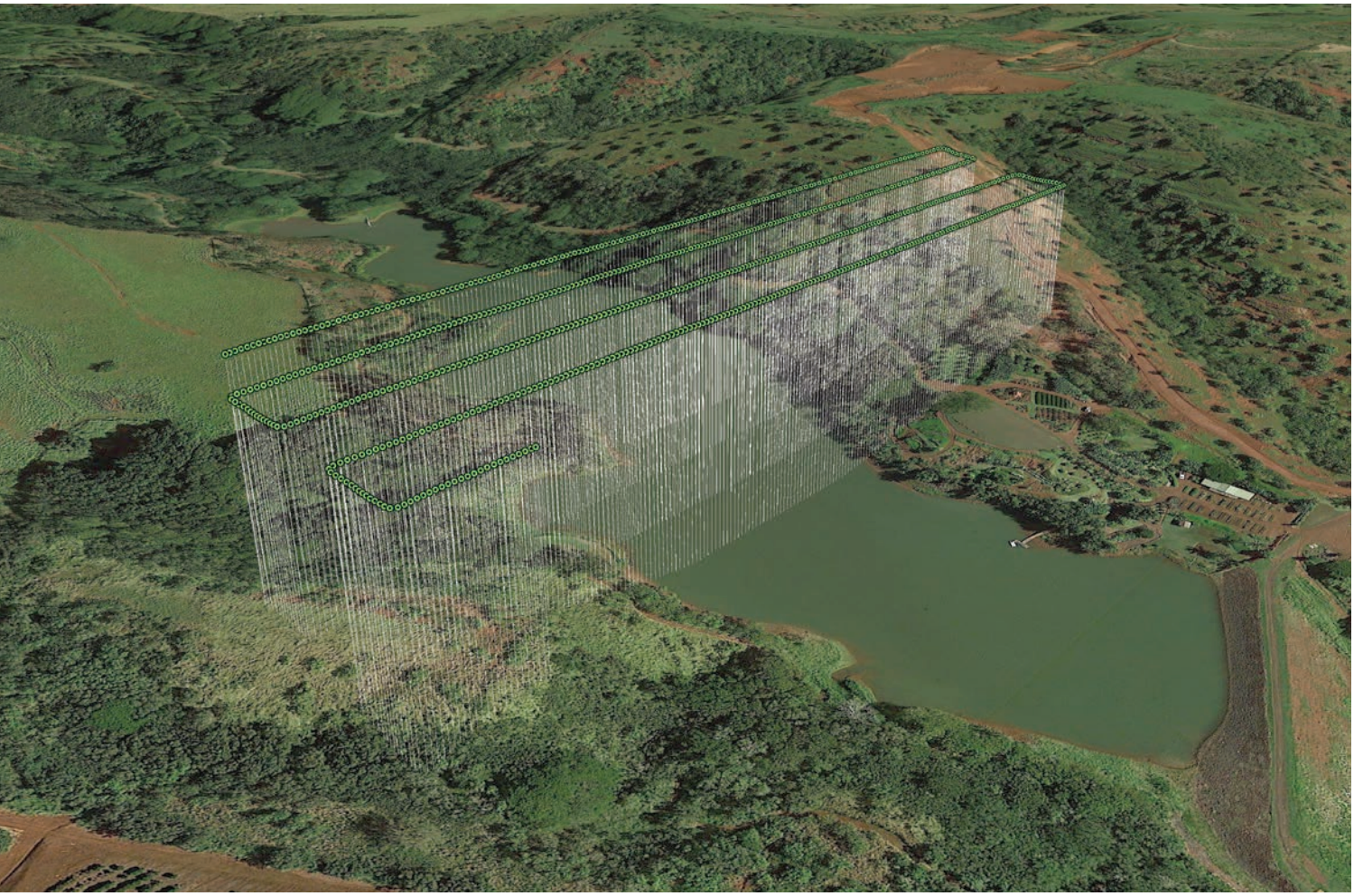
One reason Dudek was prepared to tackle this emergency was that the company had recently introduced Site Scan for ArcGIS into its land surveying workflow, modernizing the way the company collected and processed drone imagery.

In addition to emergency management operations, Dudek helps clients with scheduling, designing, and permitting for their construction projects, using GIS technology to complete projects on time and within budget. These clients work in a variety of industries throughout North America, including water utilities, energy, retail, conservation, education, and health care. Combining drones with GIS was a new approach for Dudek, and the main clients that staff initially identified as ideal for this integration were those working on renewable energy projects.

"We did site planning, engineering, and evaluations to determine if a site was viable for solar development," said Steven Hochart, practice director at Dudek. "The faster those clients could get data, the faster they could submit their application to the local utilities to get their project in the queue. For them, it was all about speed. If we collected drone data for a small site in the morning, the client could see the data by the afternoon."

Dudek collected aerial imagery data with drones and analyzed it using GIS, then presented the results to clients as a dynamic visualization. From easements being plotted to topographic

↓ Drones captured an aerial view of a landslide blocking the road on the Pali Highway; construction crews are on-site clearing debris.



↑ Dudek's drone imaging supports local engineers on the island of Kauai by mapping aging dams and reservoirs to determine their current condition. This is a representation of the flight path flown by the drone to complete the project.

data, everything is accessible on a near real-time map of the project schedule.

FROM DISCONNECTED SYSTEMS TO A CENTRALIZED DATABASE

In the past, Dudek had used multiple systems to plan drone flights and collect imagery data in the field. Initially, they used UgCS, unpiloted aerial vehicle (UAV) software for geophysical surveys. Data from UAVs was stored on laptops and transferred to Dropbox, a file storage software with cloud storage. Eventually, the data was moved onto servers. Imagery processing was handled by Agisoft Metashape, a tool for photogrammetry, adding more complexities to Dudek's workflow.

BY TRANSITIONING FROM PREVIOUSLY OUTDATED, DISCONNECTED SYSTEMS TO SITE SCAN TO GATHER, ORGANIZE, AND ANALYZE DRONE DATA, DUDEK SAVED OVER $80,000 IN ONE YEAR.

This disjointed process was inefficient due to the lack of integration, and expensive because each system had its own costs associated with it. Additionally, traditional methods like helicopters and airplanes used to survey land and collect imagery data were slow and costly.

"We had to mobilize a plane if there weren't any in the area," said Hochart. "We had projects all over the country, so drone technology was critical to our business."

Staff at Dudek recognized the need to streamline their operations to eliminate unnecessary steps and costs to get data to their customers faster. Dudek saw Site Scan for ArcGIS as an opportunity to fix the company's fragmented workflow and modernize its drone imagery collection, processing, and analysis with end-to-end, cloud-based drone mapping software. Staff at Dudek were already well acquainted with ArcGIS software, so incorporating the tool into their existing GIS infrastructure was easy.

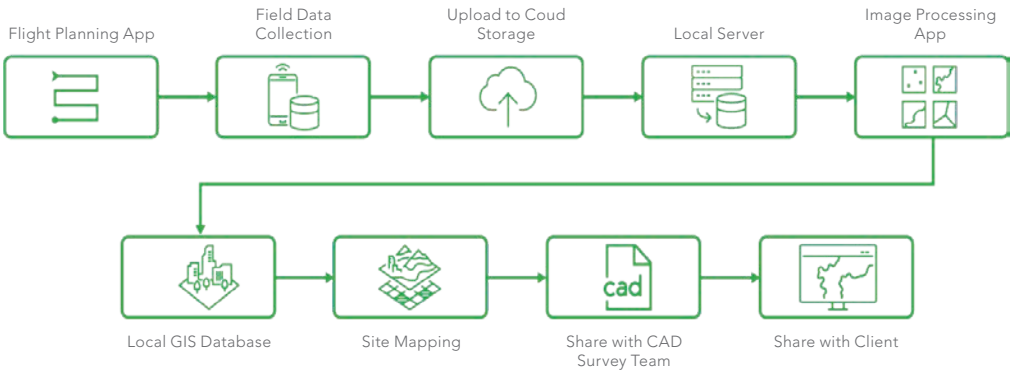
"For us, Site Scan is a very simple solution," continued Hochart. "We have mobile teams using ArcGIS Field Maps, mappers using ArcGIS

Pro, and our surveyors are using [ArcGIS for AutoCAD] to create a database for us."

With Site Scan fully integrated into their workflow, the staff uses it for flight planning, data collection, and processing. The GIS team also uses Site Scan for mapping and integrating GIS and computer-aided design (CAD) data to share in real time with other staff and customers into a custom-built site called the Dudek Land Development Portal. The portal combines GIS and CAD data for faster, more informed decision-making.

By transitioning from previously outdated, disconnected systems to Site Scan to gather, organize, and analyze drone data, Dudek saved over $80,000 in one year. The new portal was what provided staff with the opportunity to put this innovation to work right away on landslide mitigation and emergency response in Hawai'i.

This newfound efficiency was particularly evident on smaller projects. Personnel could capture, process, and share imagery in a single day, impressing clients with quick turnaround times.



← A flowchart illustrates the slow and costly workflow for aerial surveying and data processing before ArcGIS was introduced.

↓ A drone captures aerial data while surveyors ensure optimal positioning for comprehensive site analysis.

"We do a lot of work with rockfall hazards," said Hochart. "Captured with Site Scan, the clients love it because they get a dynamic 3D view where they can pan around, zoom in, and get an understanding of [the site]."

ADVANCING THE INDUSTRY

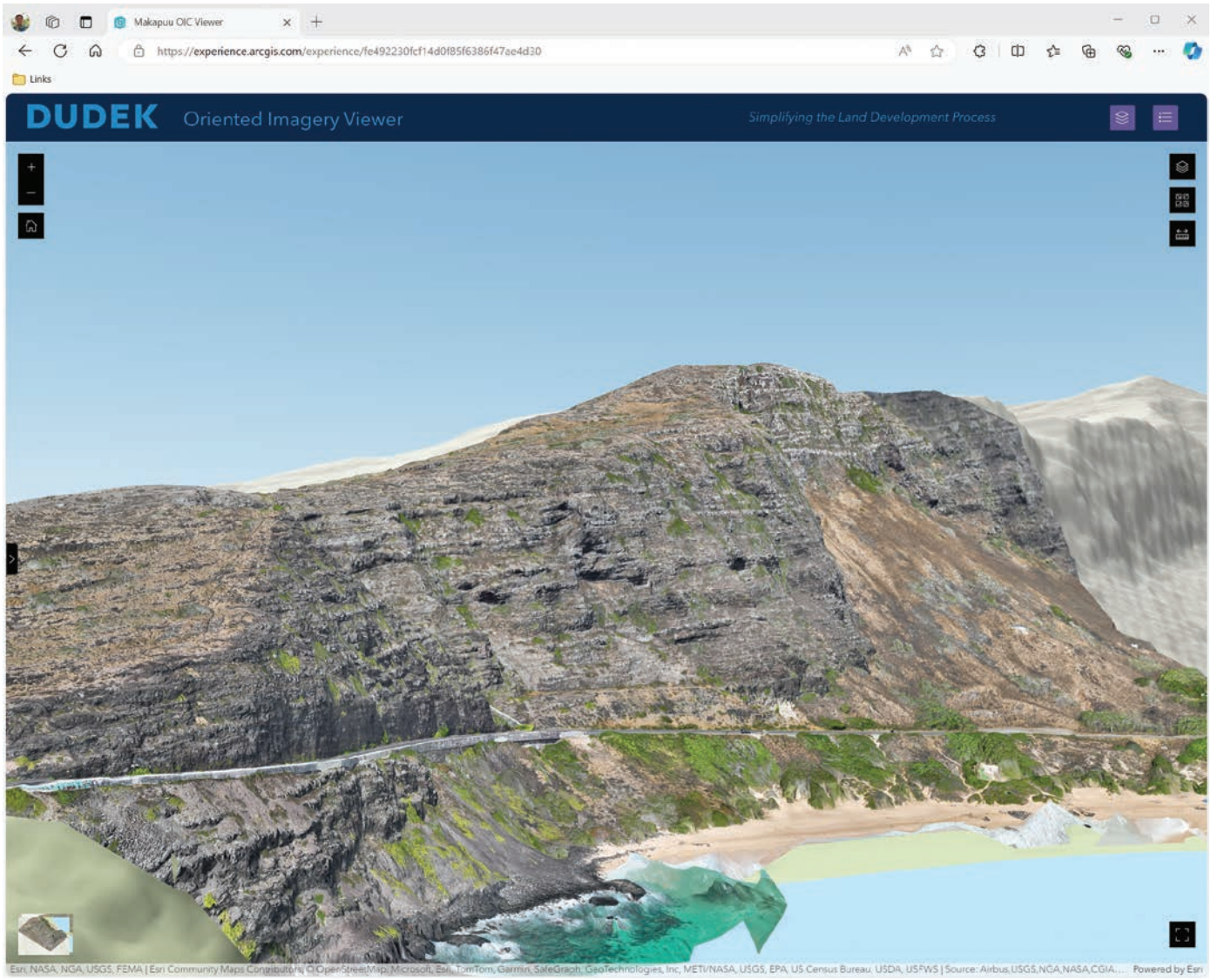
Now that staff at Dudek are comfortable integrating GIS software and drones, leadership is looking to explore more ways to serve clients and transform the land surveying industry. Dudek is actively reaching out to similar firms in sectors like the civil engineering field to demonstrate how they implement GIS and drone technology in a cloud-based system.

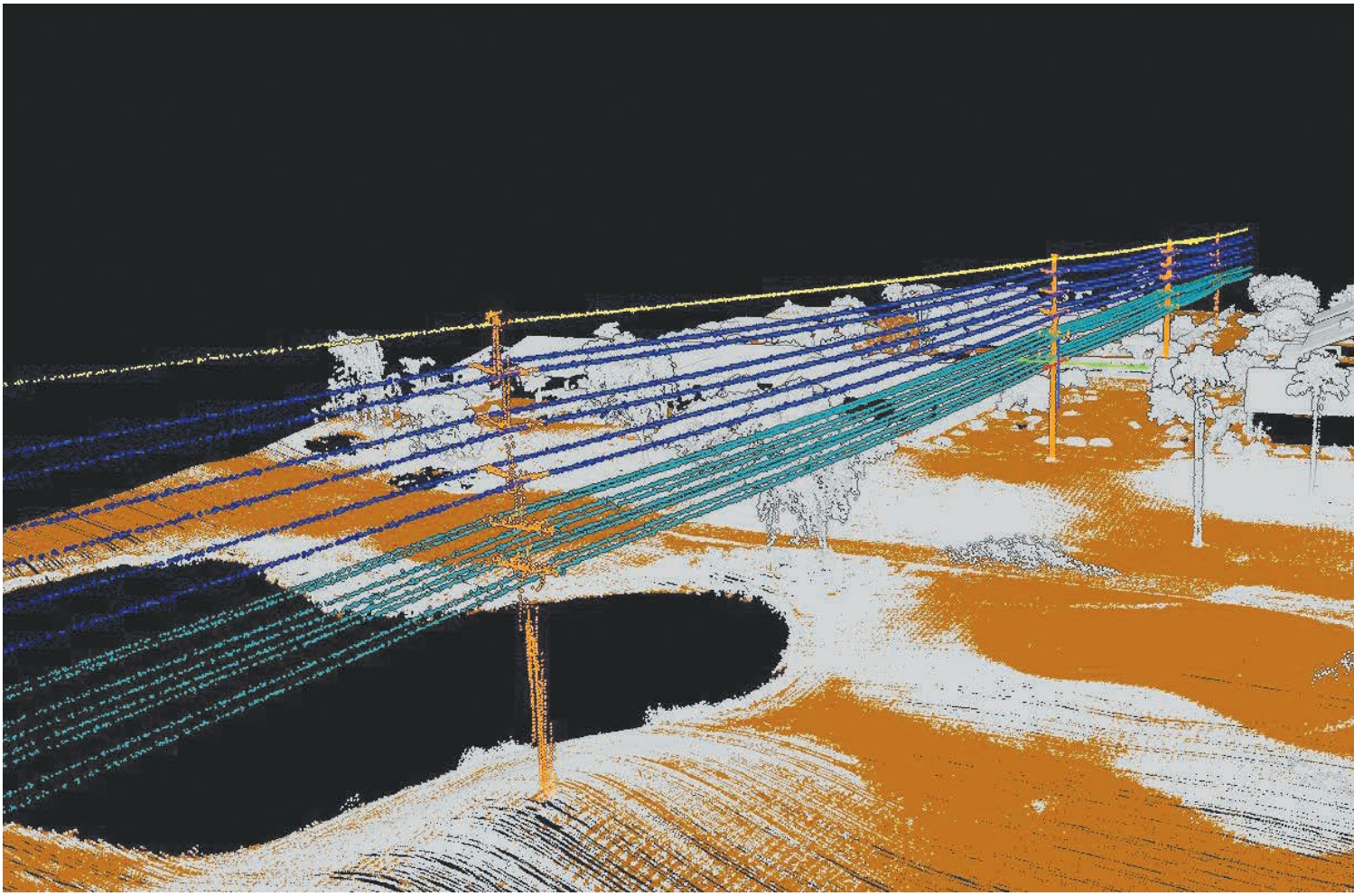
"We weren't shipping hard drives around [the US], waiting for things to upload or sitting in a hotel dealing with VPN issues," continued Hochart. "For the land surveying industry, this is a big deal."

Additionally, Dudek hopes to advance the land surveying industry by including more geospatial artificial intelligence (GeoAI) into their workflows. GeoAI combines AI with GIS, giving maps and other spatial tools capabilities like automated

→ The diagram shows the end-to-end process of transforming raw data into actionable insights with ArcGIS Flight and Site Scan for ArcGIS.

↓ Dudek's oriented imagery viewer shows a 3D model of a coastal cliffside.





↑ Dudek staff use lidar to classify and model power lines with GeoAI.

data processing and even predictive analysis. For land surveyors, GeoAI can be leveraged to extract key information from documents and drone imagery, supporting the land surveying process.

"We fly a site anywhere from five to 2,000 acres, creating planimetric data for those sites," said Hochart. Planimetric data provides crucial information about the measurement and mapping of the locations and shapes of roads, buildings, rivers, and other landmarks as they appear from an aerial view. "Having the ability to use GeoAI within the GIS system helps us streamline the creation of our planimetric and basic image segmentation to integrate with CAD and BIM systems later on."

Once Dudek's surveyors gather all the data needed with Site Scan, they can create and share a digital twin in a single view with ArcGIS GeoBIM. Combining the spatial analysis capabilities of GIS with detailed 3D design and construction data, these digital twins are dynamic virtual representations of reality that provide contextual understanding of built environments.

For instance, Dudek collected imagery data for wastewater utilities by using a UAV to fly street corridors. In the past, the company would send mobile surveyors to collect GPS data from sewer lines and water meters. This approach was inherently risky because staff had to walk along roadsides to access the water system. Now, with GeoAI and digital twins, drone data and GIS workflows are easily integrated within the utility network schema.

Hochart noted that this approach streamlines operations for civil engineers, GIS users, and site designers from the very beginning by prioritizing the collection and processing of data-rich imagery with drones using GIS technology throughout the life cycle of a project. "That first aerial image of a site sets the foundation for any future planning," he said.

ABOUT THE AUTHOR

Rae Johnson is a marketing content writer at Esri, crafting customer success stories to highlight equity and inclusion through GIS technology. Previously, Johnson led communications in local government and wrote for various publications in her hometown of Milwaukee, Wisconsin.

Nottingham's Digital Twin Drives Urban Renewal

By Brooks Patrick

Like most urban centers, the city of Nottingham, England, has a rich history and strong cultural heritage, but remnants of past retail and industrial patterns have posed challenges to its development. For years, the city's Broadmarsh Centre shopping mall stood mostly vacant. Several former manufacturing sites needed to be cleaned up and repurposed. Train and bus transport hubs looked drab and required costly maintenance.

Nottingham City Council met these challenges with an ambitious revitalization plan that included new parks, office space, and housing. Using a 3D digital twin built with ArcGIS Urban and other GIS technology, Nottingham planners created and shared their vision for what the city center could become. The digital twin combines a 3D object model, real-world scans of buildings, and location-specific data to guide planning decisions. It also helped the city secure £4 billion worth of investments and redevelopment bonds for Nottingham's transformation.

The city has already undergone numerous changes, including a renovated train station and the addition of a new bus station and parking garage that now connect pedestrians and cyclists with trains, trams, buses, and taxis. The city has a new central library and other public spaces. The Green Heart park now provides access to nature downtown with a pond, wetland plants, and a flowering meadow. The Island Quarter development includes 300 homes as well as housing for University of Nottingham students. The Queens Road development will add 380 homes near the train station.

"When other developers see that investment, they want a piece of it," said Mick Dunn, business development specialist in geographical information services, Nottingham City Council. "That's the beauty of pushing out the information in 3D. It's a selling piece."

With all this development and an influx of new residents in the center of the city, Nottingham already feels more vibrant. And with the help of its investment in digital twin technology, the city still plans to add more than 7,000 new homes, 15,000 new jobs, and two million square feet of office and commercial floor space.

← For Nottingham, the benefits of 3D modeling include a more engaged public, improved communication with developers, and data-driven decision-making.

Digging Beneath the Surface

Nottingham began using 3D modeling for city planning 20 years ago. The planning team also explored 3D technology to map the vast network of 850 underground caverns carved out of the sandstone beneath the city. These caves played a pivotal role in the city's past, including helping Edward III sneak into Nottingham Castle in 1330 during a coup against his mother. Later, they provided shelter from bombing during World War II. They now serve as a tourist attraction; an interactive map created by Nottingham City Council guides exploration.

This map of the past helped planners build their skills to map the future. By mapping the caves, the planning team gained proficiency in 3D modeling and earned a reputation for app development. When the team received central government funding for city revitalization, they wanted to showcase how 3D technology could support advanced analysis.

"It's gone from just a visualization tool to more of an analytical tool for design and metrics," Dunn said.

Nottingham's digital twin now covers more than 73 square kilometers and depicts thousands of historic and modern buildings, open spaces, and infrastructure. It includes data about conservation areas, floodplains, and parks, as well as live feeds for traffic and street-level video from CCTV cameras. Planners rely on the digital twin to assess site context, see how traffic behaves, and safeguard natural areas across the city.

Part of the Planning Process

Now, 3D modeling has become embedded in Nottingham's workflows to assess the impact of development proposals. Planners drop a model of each proposed building into the digital twin to check visual impact, calculate site capacity, and negotiate height and floor space with the developer.

Paul Seddon, director of planning and transport at Nottingham City Council, noted in a press release that the digital twin has helped staff negotiate better design. "It gives confidence to both planning officers and applicants about the appropriateness of development and therefore the likelihood of planning approval being granted," he said.

> "It's gone from just a visualization tool to more of an analytical tool for design and metrics."
>
> **Mick Dunn**
> Nottingham City Council

With the successful adoption of a 3D digital twin workflow, Nottingham City Council has achieved three key objectives: greater ease for people to engage in the planning process, increased transparency of decision-making, and a decrease in the amount of time it takes to move from application to formal decision.

This tech-driven, collaborative approach is making Nottingham more livable and resilient. The digital twin helps reenvision the city with input from residents, focusing on architecture and design. It prioritizes quality spaces that promote health, safety, and nature while welcoming people of all ages.

→ Nottingham City Council's digital twin helps everyone see planned developments, approved projects, and completed work.

← The ArcGIS Urban viewing app of major developments in Nottingham gives context about the density of redevelopment in the city center.

The city that once thrived on manufacturing has been fostering connections to high-growth industries, such as clean energy and life science research. The digital twin enables city leaders to better promote the city's advantages to potential employers.

Sharing the Value of 3D Across the UK

Nottingham City Council has been sharing its expertise about the value of 3D technology with other local authorities. The city has forged strong connections with the University of Nottingham and other partners to test and understand the benefits of digital twin technology, and to discuss effective implementation.

Recently, the 3D digital twin of Nottingham City won a Geography in Government 2024 award for innovation. The Nottingham planning team hopes that the recognition and the demonstrated value of digital twins will help make 3D planning the standard across the UK.

"The move to 3D geospatial technology is inevitable," said Laura Pullen, GIS manager at Nottingham City Council. "We are creating a blueprint to support rapid deployment of similar capabilities across other local planning authorities."

This blueprint comes at an opportune time in the UK. An ongoing national

→ Nottingham's digital twin enables interactive discussions about development plans.

housing shortage has created a strong interest in speeding up the building approval process to address a deficit of 1.5 million homes across the country.

In March 2023, Nottingham secured a £375,000 government grant to further improve 3D technology and modernize the planning application process. Funds from the Ministry of Housing, Communities, and Local Government have enhanced the city's 3D modeling process.

As part of the project, Nottingham planners helped the nearby city of Bradford adopt 3D planning workflows using technology like ArcGIS Urban. A cost-benefit analysis assessed the value of this digital transformation and found that for every pound invested in digital twin technology, a local planning authority can expect to get back £2 in efficiency and money saved over a 10-year period.

"The interest this has sparked across other local planning authorities has been amazing," Dunn said. "Now we have a growing number of central government departments very interested in our approach and how this can be expanded to support operational and policy decisions relating to energy, transport, and other urban considerations."

← A bird's-eye view of Nottingham's Wollaton district shows a mix of green space and homes at the city's edges.

Balancing Nature and Development

Nottingham's 3D digital twin, packed with environmental data, also aids planners in reaching biodiversity net-gain goals, and will provide regulatory metrics. This is especially significant as the UK now requires planners to measure nature's value as part of the approval process, in accordance with a 2024 law. They must detail habitat improvements that will show at least a 10 percent gain in biodiversity over a 30-year period. By linking development to natural-area improvements, the country is encouraging more creative, nature-based solutions.

To that end, Nottingham's sustainable urban drainage systems are being engineered to mimic natural wetlands. This will provide habitat for aquatic species and reduce the threat from flooding. The city also has added natural ponds and rain gardens to absorb stormwater and calm turbulent waters that could otherwise cause flooding.

Additionally, city planners have woven habitat enhancement into Nottingham's long-term plan. The city has taken steps to protect and enhance natural areas as part of its revitalization efforts, including planting diverse species of trees and pollinator-friendly flowering plants. Residents are being encouraged to allow the growth of native plants and to give wildlife a chance to move in.

On top of this, Nottingham aims to become the first carbon-neutral city in the United Kingdom by 2028. Thanks to improved transit options, new energy-efficient buildings, and the transition to renewable energy across the city, this goal is becoming more achievable. New housing in the city center will maximize connectivity to the city's district heating network, and enhanced green spaces will provide a cooling effect in hot weather.

The digital twin has become essential to calculating the carbon sequestration value of natural areas and comparing that value with carbon emissions to monitor the Carbon Neutral Nottingham 2028 goal. It is equally essential in transforming Nottingham into a more vibrant, sustainable city.

About the Author

Brooks Patrick is a global business development manager for smart cities at Esri. He helps customers and partners across local government and private sectors to understand and implement Esri software and solutions.

7 Essential Skills Every GIS Manager Needs

By Matthew Lewin

Recently, I was asked which specific skills are essential for a GIS manager to excel. Not just general management capabilities, but skills that are uniquely critical to the job of GIS manager. Leadership? Political influence? Strategic thinking? All are essential skills for a manager. But are they unique to the GIS profession?

GIS managers have responsibilities that extend well beyond merely overseeing technology; they are essential in influencing how organizations leverage geospatial data to enhance decision-making and foster innovation. The most accomplished GIS managers navigate intricate team dynamics and align GIS initiatives with overarching business objectives. Their skill set goes far beyond the technical ins and outs of software.

With that in mind, here are seven distinct skills that every GIS manager needs to thrive in this challenging role.

1 Understanding the Capabilities of Modern GIS

Today's GIS platforms are incredibly versatile. They build upon legacy mapping as well as spatial data management software, and incorporate modern capabilities such as live data feeds, workflow automation, and artificial intelligence for predictive analysis. They also provide spatially infused insights on all manner of mobile and web-based devices. If you don't understand these capabilities, you risk missing out on opportunities to help your organization solve problems and meet its objectives.

Imagine this: You're a GIS manager at a mid-sized city's planning department. A team member approaches you with an idea to use GIS to track real-time traffic patterns and predict congestion during rush hour. But what if you're still thinking of GIS as a tool for making zoning maps, not as a dynamic system capable of integrating live data streams? You dismiss the idea, assuming it's too complicated or expensive.

A month later, you find out that a neighboring city implemented this very solution, and is being celebrated for reducing commute times. Meanwhile, your city is stuck fielding complaints about traffic bottlenecks.

By understanding what's possible with modern GIS, you can lead your team to innovate and proactively tackle challenges rather than playing catch-up. Plus, staying informed keeps you ready to respond when decision-makers ask, "Can GIS help with this?" Instead of scrambling for answers, you'll confidently say, "Yes—and here's how."

2 Articulating the GIS Value Proposition

To secure buy-in and build support for GIS initiatives, a GIS manager must be able to articulate its value clearly. That means explaining, *specifically*, how GIS contributes to the goals of your organization. As a GIS manager, you know GIS is valuable, but if you can't explain its impact in terms that resonate with decision-makers, your message gets lost. Leaders don't care about geospatial lingo—they care about results.

Let's say you're a GIS manager at a utility company, and your team just developed a tool which uses GIS to predict equipment failures. It's cutting-edge stuff that could save the company hundreds of thousands of dollars in repairs and downtime. You're excited to share it with leadership, so you walk into a meeting, fire up your presentation, and start talking about spatial modeling, predictive algorithms, and data layers.

Fifteen minutes in, you notice your audience members checking their phones or looking confused. Then someone interrupts: "This sounds interesting, but how does it help us hit our bottom line?"

As a GIS manager, you have to bridge the gap between technical capability and business value. Executives don't want to know how the magic happens—they want to know why it matters. Instead of focusing on technical details, you could say, "Using GIS, we can predict which assets are at risk of failure, allowing us to plan

maintenance proactively. This reduces emergency repair costs by 30 percent and minimizes service disruptions for customers. It's a win for the budget and our reputation."

Now you've got their attention. You've articulated the GIS value proposition.

3 Managing the All-In Cost of GIS Systems

The cost of GIS systems extends beyond the software itself, encompassing hardware, licensing, data acquisition, staff training, and ongoing maintenance.

Of course, this is not unique to GIS. All information systems have multiple components comprising their all-in cost (or total cost ownership). But as GIS manager, you're expected to be the most familiar with the costs pertaining to GIS systems and related geospatial services. It's not a small task, considering the breadth of capabilities and integration points of modern GIS systems.

Consider the following key questions to ask yourself:

- Have you accurately estimated how many users will need access and at what level to avoid unexpected licensing costs?
- Do you have sufficient infrastructure to support CPU-intensive workloads? What about training for staff?
- Are your people sufficiently trained to leverage and support our portfolio of geosolutions?

If you're not on top of these factors, you risk blowing your budget and losing credibility with leadership. But if you do your homework—by asking tough questions, planning for future needs, and mapping out total costs over the system's life cycle—you'll not only avoid unpleasant surprises, but also make a solid case for GIS investments.

Understanding and managing costs isn't just about keeping the budget in check—it's about showing you're a strategic thinker who knows how to make GIS work and make it worth the money.

4 Understanding How GIS Integrates with Other Systems

In most organizations, GIS tools and systems fit into a broader ecosystem of enterprise systems, such as enterprise resource planning (ERP), customer relationship management (CRM), and asset management platforms. GIS also straddles the world of data analytics and interoperability systems. These systems collectively support workflows that span multiple departments or lines of business. It's critical that a GIS manager be conversant in these systems and the key GIS integration points that support end-to-end processes. This can avoid the inefficiencies resulting from siloed systems and data.

Imagine developing a GIS app for a municipality's emergency response program that isn't integrated with its dispatch system. Your app might do a great job of mapping out road closures, evacuation zones, and shelter locations—everything first responders need during a disaster. But when a storm hits, and first responders try to use the system, you could inadvertently create chaos as dispatchers are forced to spend a lot of time manually copying updates back and forth between systems. When time is of the essence, these inefficiencies can be costly.

As a GIS manager, it's not enough to just know GIS—you need to understand how it connects with the tools your organization already relies on. This ensures GIS isn't just another standalone tool but a core part of your organization's success.

5 Building a GIS Team

A successful GIS program depends on having the right team in place. A GIS manager needs to understand the various roles involved and pathways to developing the necessary, unique skills.

Imagine a company that decides to leave GIS team building to a general manager with no GIS experience. The company approaches this like any other department: hire a few tech-savvy people, give them some software, and expect results. But soon, the cracks start to show.

The general manager hires an IT specialist to manage the GIS database. However, that person doesn't understand spatial data structures or projections. Critical analysis workflows break down. Then, the manager hires a graphic designer to create "maps that look good." However, the designer doesn't understand geospatial analysis or how to derive meaningful insights from data. Finally, they assign a data analyst to the team who's great with numbers but struggles to integrate nonspatial data into GIS workflows.

The result? A fragmented team with mismatched skills, inefficient workflows, and frustrated employees.

GIS is a unique field that blends spatial thinking, technical expertise, and domain-specific knowledge. A GIS manager needs to understand this complexity and build a team capable of handling it. In short, a GIS manager knows that GIS isn't just another IT function or analytical discipline—it's a specialized field with its own challenges and opportunities.

6 Managing and Governing Geospatial Data

GIS systems rely on high-quality data, making data governance a critical responsibility for GIS managers. This includes establishing policies for data accuracy, security, access, and compliance with legal and ethical standards. Effective data governance ensures that GIS data remains a reliable and trustworthy resource for decision-making.

Because geospatial data is tied to coordinate systems and projections, and often comes from multiple sources with varying formats and accuracies—public records, satellite imagery, IoT sensors, and more—integration can be a more complex task.

Geospatial data is also highly dynamic. Land use changes, infrastructure evolves, and real-time data streams provide updates every second. Governance for geospatial data must address temporal accuracy, ensuring that datasets are up-to-date and historical versions are archived for comparison. Ordinary data governance often focuses on static records, with far less emphasis on managing temporal elements.

Managing this data means more than just filing it away. You need processes for version control, metadata documentation, quality assurance, and access permissions. Geospatial data governance is about ensuring that GIS data is accurate, consistent, secure, and properly managed. As a GIS manager, you're the gatekeeper of your organization's most valuable spatial asset—its data.

7 Tracking the Direction of the GIS Industry

The GIS industry is continuously evolving, influenced by emerging technologies like artificial intelligence, augmented reality, and real-time data integration. A GIS manager must stay informed about these trends to anticipate future needs and guide the organization in adopting innovations that enhance GIS capabilities.

Failure to track these trends can lead to decisions that lock your organization into outdated technologies or workflows. Worse, you may miss opportunities to solve problems in innovative ways that stakeholders now expect. On the flip side, staying informed about the industry allows you to proactively introduce solutions that can make your organization a leader.

Let's say you manage a team that supports the tools and workflows you've been using for years. Then, one day, another department asks if they can start using GIS for something like real-time tracking of mobile crews or predictive analytics for infrastructure maintenance. Your chief information officer (CIO) comes to you asking about porting your on-premise systems to a cloud-based platform to take advantage of elastic, utility-based scaling. Is your GIS cloud-ready? You might not be sure how to make them happen or if they're even feasible.

That's the risk of not staying tuned in to where the GIS industry is heading. If you don't keep up with these trends, you could be caught flat-footed when someone expects you to deliver. Decision-makers might look outside your team for solutions, leaving GIS out of critical projects.

Staying informed keeps you ahead of the game. When someone asks about cutting-edge technology, you can tell them you're already on it. In this way, you're not just managing GIS—you're shaping how your organization uses it to solve problems and drive innovation.

Wrapping Up

Being a GIS manager is about much more than maps—it's about strategy, leadership, and making GIS a critical part of your organization's success. From understanding the latest GIS capabilities and communicating their value to managing costs, building the right team, and staying ahead of industry trends, the role requires a unique mix of technical know-how and big-picture thinking.

Becoming an expert in these skills isn't just good for the organization—it's good for you, too! When you guide a GIS program that solves real problems, saves money, and drives innovation, you're not just a manager—you're a leader. In a field that's evolving as quickly as GIS, that's what every organization needs.

About the Author

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

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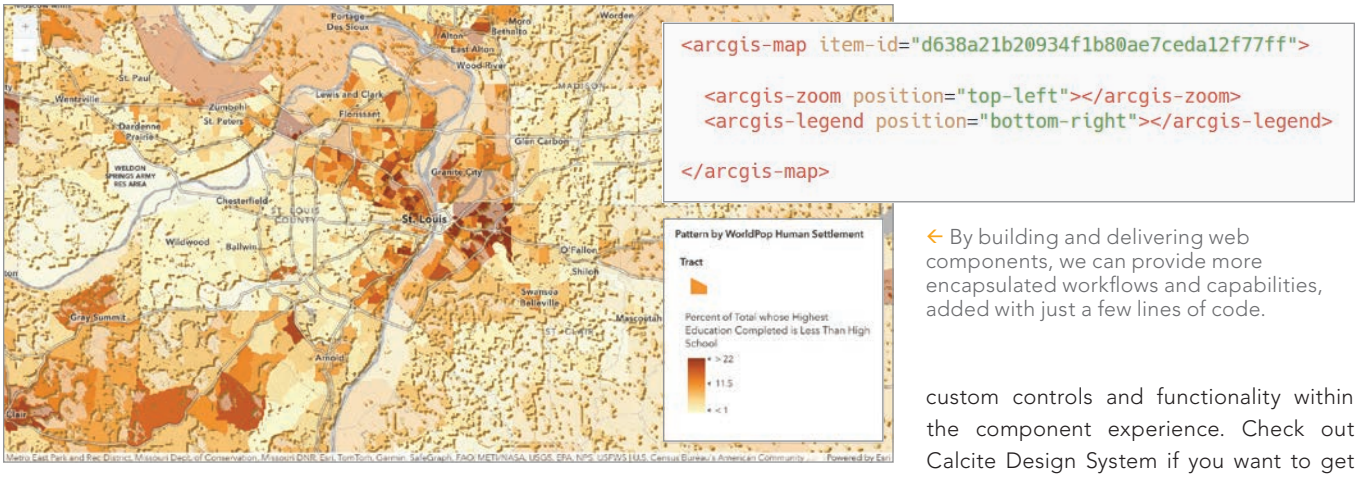
JavaScript Maps SDK Transitions to Web Components

By Julie Powell



← By building and delivering web components, we can provide more encapsulated workflows and capabilities, added with just a few lines of code.

When ArcGIS Maps SDK for JavaScript was first created, standards for web components were still maturing and didn't have broad browser adoption. At that time, Esri didn't commit to a specific JavaScript framework, as the landscape is a constant moving target. For that reason, JavaScript Maps SDK was developed with a widget architecture, which over time included more than 60 widgets for developers to use in their web apps. However, now that web components standards are supported across all major browsers, the technology can evolve alongside the browser. Therefore, JavaScript Maps SDK is undergoing a full transition from a widget-based architecture to one based on web components.

The recommended approach for building web apps using ArcGIS Maps SDK for JavaScript is to use web components, which allow you to create reusable custom HTML elements that you can use in your web apps, such as <arcgis-map></arcgis-map>. Esri is fully committed to building standards-based web components that extend the core API of JavaScript Maps SDK. This applies to both internal development of ArcGIS products, as well as the pre-built UI components offered as part of JavaScript Maps SDK. In fact, all core widget functionality is already available in the form of components.

This shift in architecture maximizes the productivity of front-end web development. Custom elements provide a familiar programming experience (HTML, CSS, JavaScript) and enable seamless integration with application frameworks. Internally, components are constructed using Calcite Design System's components, so they can be styled using Calcite's design tokens (via CSS). In addition, since Esri is encapsulating ArcGIS experiences as web components in Esri products, we can deliver proven workflows as configurable components in the SDK (such as the already released Arcade editor and Charts components). The SDK's collection of higher-level components will continue to grow over time.

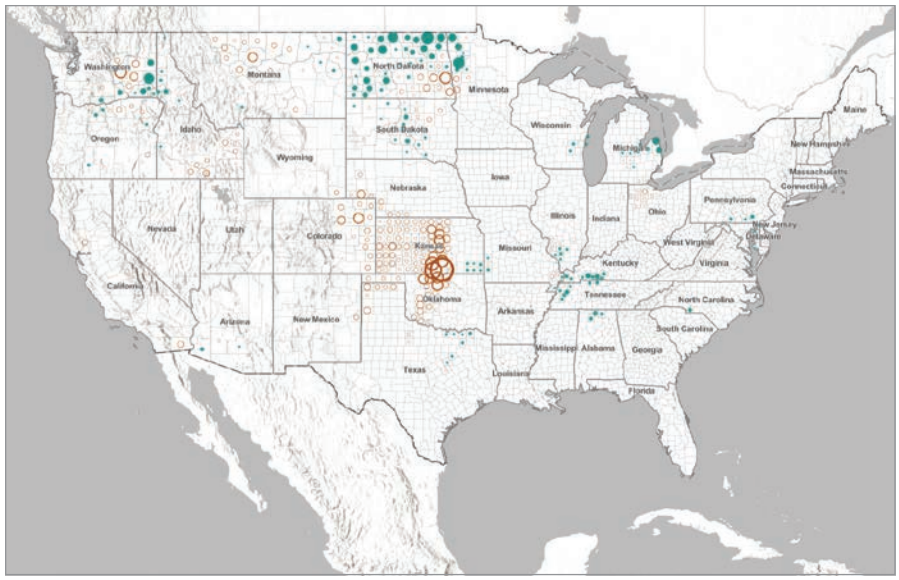
From Widgets to Map Components

Initially, widgets are wrapped as web components, and over time, component internals are being reimplemented with an optimized structure, including the removal of the legacy widget architecture. To see a list of components that have completed this transition, refer to the release notes for the most recent version of JavaScript Maps SDK. Once the component reimplementation is done, support for slots will be added, which will enable you to integrate custom controls and functionality within the component experience. Check out Calcite Design System if you want to get familiar with how slots will eventually work in the SDK's components, as most Calcite components contain slots.

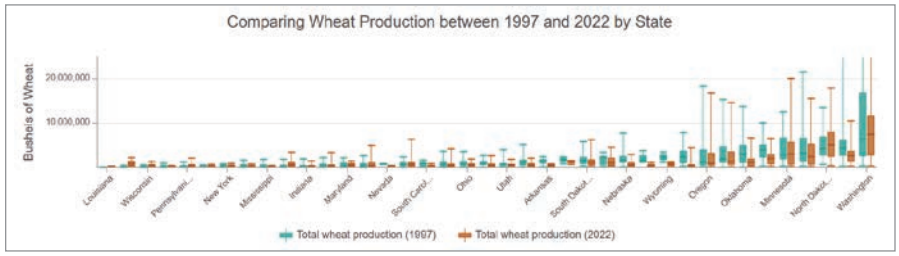
Many resources in JavaScript Maps SDK are already component-based. These include new and updated resources such as the getting started guides, programming patterns and best practices, tutorials, a collection of samples, integration of the component playground and API reference, and more. However, as the JavaScript Maps SDK website includes resources that Esri has been working on for eight years, a full transition will take multiple releases. While JavaScript Maps SDK is in transition, you will see samples and code snippets throughout the website that do not yet reflect the recommended coding patterns (i.e., they aren't component-based). Every release will bring notable progress.

Widget and Component Road Map

Eventually, all widgets will be deprecated and removed. Therefore, developers are strongly encouraged to migrate their UI code to use components in place of widgets and MapView or SceneView. The level of effort required to perform the migration to a component-based UI will vary between applications. In some cases, the process will be quick. In other cases, it can involve a reasonable amount of effort,



← When used alongside maps, chart components provide a complete data visualization story of your data.



planning, and prioritization. Many Esri product teams will be undergoing the same migration work. The widget road map factors into this required effort, as well as the component development road map.

As part of the full transition to web components, Esri is targeting a few milestones. Once a component in the @arcgis/map-components package has been updated to no longer wrap widget code, the equivalent widget will be deprecated. Deprecations will be signified in the API reference, sample code, and console messages. Additionally, all widgets are planned to be deprecated as early as 2026, and all widgets are planned to be removed from the SDK as early as 2027.

While the *presentation* of UI elements is transitioning from widgets to components, the underlying business logic (currently available via view models) isn't going anywhere. That means you can build custom experiences and workflows using the SDK's business logic going forward. However, as Esri works to modernize and continuously improve JavaScript Maps SDK, we want to know how you use the business logic. This helps inform Esri's longer-term road map.

For example, some developers might use view models for UI simplification, such as removing buttons or options. To achieve this goal, a configuration option can be added to the component which indicates whether a certain element is visible.

Other developers use view models to integrate a custom workflow. However, slots can be added which enable you to embed a component of your choice within the UI. For example, a button could be integrated to launch a custom workflow. Additional events can also be added which allow you to react to user interaction or other conditions.

Sometimes, view models are used to implement fully custom workflows. A common example is SketchViewModel, which is used to handle interactive drawing on the map, a requirement for one aspect of a workflow. In this case, the pattern going forward would continue to depend on the SDK's business logic for the custom workflow.

If you are using view models today, please fill out a survey at arcg.is/005zS9 so that Esri can use your input to inform the SDK's road map. We want to continue to offer an SDK that provides maximum productivity when building your apps, and at the same time, offers the flexibility you need to meet your organization's specific requirements.

Learn more about building apps with components at links.esri.com/components.

About the Author

Julie Powell is a principal product manager at Esri focusing on web development technologies. She works to ensure developers can be successful in building state-of-the-art, purposeful solutions using ArcGIS software. Powell brings 20 years of experience working with global leaders such as Hewlett-Packard and Esri, delivering a variety of software solutions for both the enterprise and consumer markets. Powell has worked on a wide range of projects and consulting endeavors, including serving as technical lead for web mapping solutions for strategic customers.

Harnessing the Power of the Wind with ArcGIS Living Atlas

By Craig McCabe and Emily Meriam

The Global Wind Atlas is a collection of layers in ArcGIS Living Atlas of the World that can be used not only to visualize factors like wind speed and density around the world, but also to assess wind energy resources for policy and planning.

Humankind has harnessed the wind's power for millennia—first to propel sailboats across oceans and against river currents, then by windmills for grinding grain, cutting wood, or pumping water. By the late 1800s, small wind turbines were generating electricity. It took almost 100 more years before wind turbines would be deployed on an industrial scale to capture this free and renewable resource.

The first wind farm in the world was built in 1980, on Crotched Mountain in New Hampshire. It was mostly a test of whether this network of electricity-generating turbines would disrupt the existing power grid. The site wasn't able to generate any meaningful power, and in 1981, it was relocated to a windy corridor northeast of Livermore, California, known as the Altamont Pass.

Since then, the economics of wind energy production have improved, as has wind turbine technology. With a growing need for renewable energy and energy independence, wind farm capacity has more than doubled in the last 10 years. This new interest comes with a need to make more informed decisions about where to invest in new wind farms and their supporting infrastructure, while minimizing any negative impacts to the local environment or its residents.

Tracking the Wind

The Global Wind Atlas puts wind potential on the map for the world to use. This project is the result of a partnership between the Department of Wind and Energy Systems at the Technical University of Denmark and the World Bank Group. The goal is to help policymakers, planners, and investors identify high-wind areas for wind power generation virtually anywhere in the world.

Wind power estimates are made using a downscaling process, starting with the ERA5 climate data from 2008–2017, provided by the European Centre for Medium-Range Weather Forecasts (ECMWF). ERA5 provides hourly estimates of multiple climate variables and includes climate data stretching back to 1940.

The result of this process is a collection of 250m resolution local wind estimates across the globe, at five elevations above the ground (or ocean) surface: 10m, 50m, 100m, 150m, and 200m. These different elevations account for the local "roughness" of the terrain below, and its influence on wind strength and turbulence.

← A near-shore wind farm sits just off the coast of Copenhagen, Denmark.

↗ Higher mean wind speeds normally indicate better wind resources.

→ Wind power density is a measure of the amount of wind power available per unit area.

↘ Higher capacity factors indicate higher annual energy yield for wind turbines.

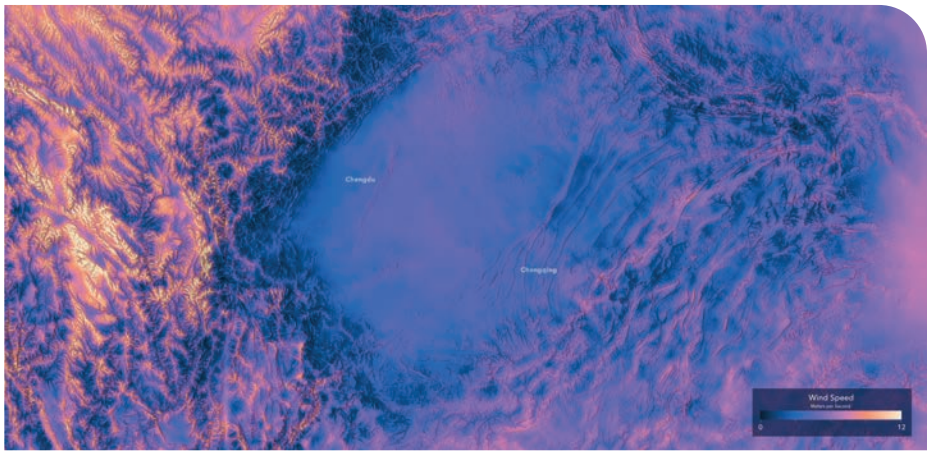
You can use the following multidimensional Global Wind Atlas layers for analysis, planning, and visualization in ArcGIS Pro, ArcGIS Online, ArcGIS Enterprise, or in custom applications:

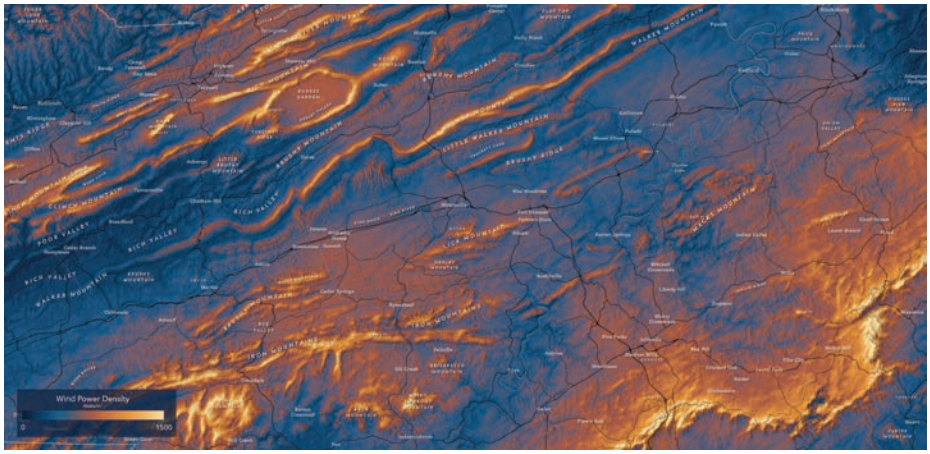
- **Global Wind Atlas - Wind Speed**
- **Global Wind Atlas - Power Density**
- **Global Wind Atlas - Capacity Factor**

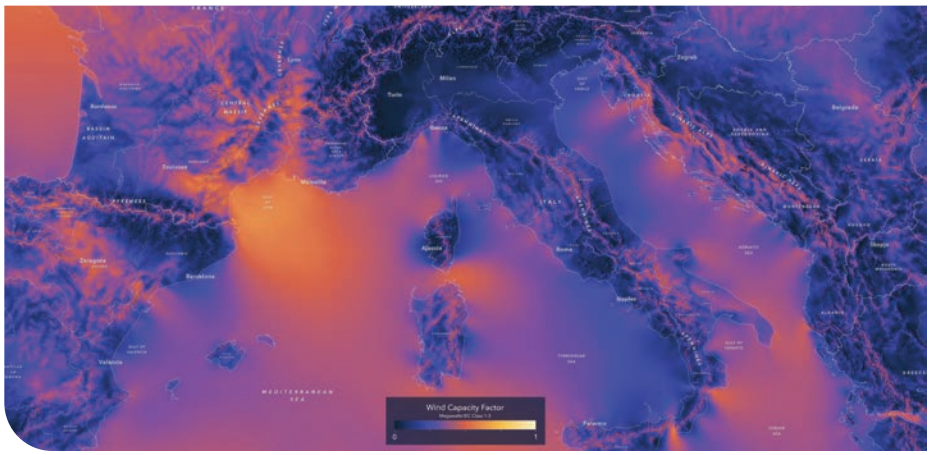
Wind speed is a measure of the wind resource and is expressed as a velocity in meters per second (m/s). Higher mean wind speeds normally indicate better wind resources. This 250-meter resolution layer displays the mean wind speed over the 10-year period (2008–2017) for five wind turbine hub heights: 10, 50, 100, 150, and 200 meters.

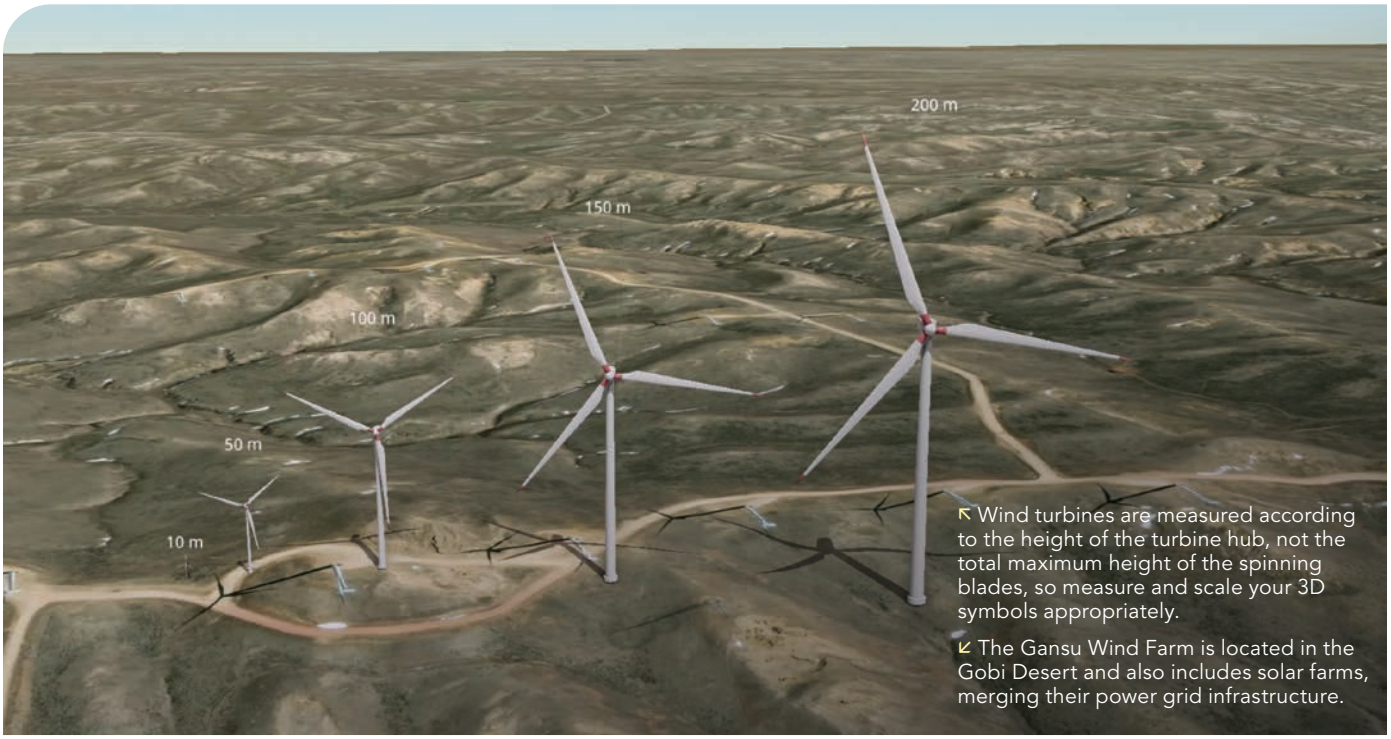
Wind power density is a measure of the total wind resource—in other words, the amount of wind power available per unit area. This is calculated using factors such as wind speed and elevation and reported in watts per square meter (watts/m^2). Wind density also takes into account geographical variations in terrain roughness, high values of which will reduce wind power at a given height. Compared to wind speed, wind power density generally gives a more accurate indication of the availability of wind resources and their ability to move a turbine. This 250-meter resolution layer displays the power density over the 10-year period (2008–2017) for five wind turbine hub heights: 10, 50, 100, 150, and 200 meters.

The capacity factor is a measure of the annual energy yield of a wind turbine and is reported in megawatts (MW). Higher capacity factors indicate higher annual energy yield. The maps show estimated capacity factors, and wind turbine site suitability should be considered separately. The capacity factor layers were calculated for three distinct wind turbines, with 100-meter hub height and rotor diameters of 112, 126, and 136 meters, which fall into three International Electrotechnical Commission (IEC) Classes—IEC1, IEC2, and IEC3. Capacity factors can be used to calculate a preliminary estimate of the energy yield of a wind turbine (in the MW range), when placed at a location. This can be done by multiplying the rated power of the wind



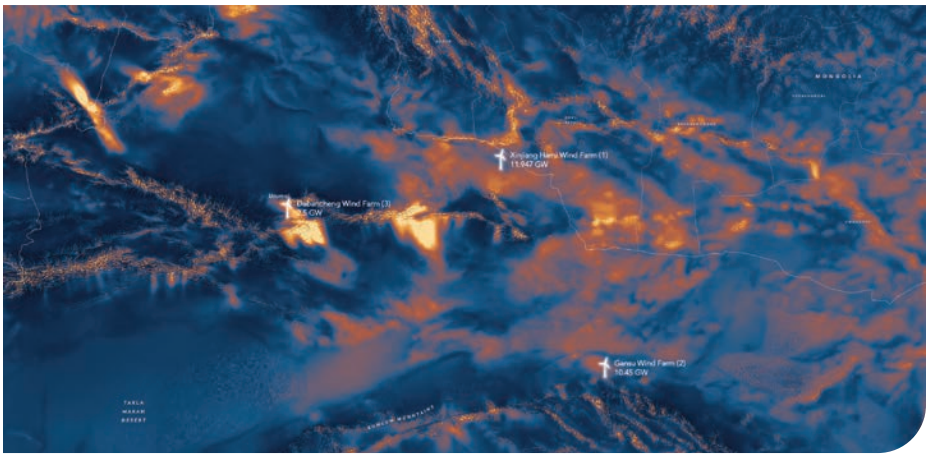






↖ Wind turbines are measured according to the height of the turbine hub, not the total maximum height of the spinning blades, so measure and scale your 3D symbols appropriately.

↙ The Gansu Wind Farm is located in the Gobi Desert and also includes solar farms, merging their power grid infrastructure.



turbine by the capacity factor for the location (and the number of hours in a year).

The height of a wind turbine—and the size of its blades—also has a lot to do with the amount of power it can produce in a given location. The height values of 10 meters to 200 meters used by the Global Wind Atlas correspond directly to common wind turbine hub heights. These range from a 10-meter small turbine, which might generate 200W–400W, all the way up to a 200-meter offshore wind turbine with a 200-meter rotor diameter, which can output 11MW, or 27,500 times more than a 10-meter turbine. While many of the onshore turbines being installed are commonly in the 80m–100m hub height range, offshore turbines have migrated to 200 meters, with plans to go higher.

Exploring the Global Wind Atlas

The Global Wind Atlas offers a tremendous amount of information about wind power generation around the world. For instance, where are the largest wind projects being built? What are the new frontiers of wind energy on land and sea? You may notice some striking differences in onshore as opposed to offshore wind resources.

China has dominated in onshore wind energy. In 2023, it had 404,605 MW of installed electricity capacity, according to the International Renewable Energy Agency (IRENA). By comparison, the United States had less than a third of that, at 147,979 MW. In fact, the three largest onshore wind farms in the world can all be found in China, which plans to greatly expand capacity in the coming decade.

Some of the most powerful offshore wind farms can be found off the coast of the United Kingdom, in the North Sea. Offshore farms, free of surface obstacles to wind currents, can produce much more electricity than those onshore.

A simple comparison of the wind power density at any of these locations and turbine heights is easy to do using the multidimensional analysis tools in ArcGIS Pro, including Sample or Zonal Statistics.

Wind Suitability Modeling in Practice

Of course, these ArcGIS Living Atlas wind layers are more than just objects of curiosity. Their primary purpose is to help make better-informed decisions on where to invest in future wind farm infrastructure.

For a deeper dive, we'll analyze a particularly wind-rich state: Wyoming.

Wyoming's bounty of wind potential is a byproduct of the state's geography. As prevailing westerly winds from the Pacific Ocean pass over the Rocky Mountains, they funnel through mountain passes and gust over the plains to the east. This makes Wyoming a great case study to determine some ideal candidate sites for future wind farms.

Suitability modeling starts with a goal in mind—in this case, finding a suitable location for a wind farm. This is an iterative process where subject matter expertise meets experimentation, evaluation, and

repetition. It involves determining relevant base criteria to make an informed decision, then analyzing, transforming, weighing and combining these layers to arrive at the most suitable locations.

Finding locations for potential wind farms is a perfect use case for the Suitability Modeler tools in ArcGIS Pro. For this exercise, we'll use the Wind Power Density layer to determine which site in Wyoming would be a suitable place for a new wind farm, using several ArcGIS Living Atlas layers to aid in our site evaluation and selection.

First, consider that different criteria are considered when selecting onshore and offshore wind farms. Since Wyoming is landlocked, our terrain, transportation, and other infrastructure layers will apply only to locating onshore wind farms.

The first step in the modeling process is to compile and prepare the layers that will participate in the suitability model. In this case, some are related to the availability of wind resources, which include Power Density and the types of landforms where the wind is highest. Other criteria might include how difficult it is to access and construct the wind farm or connect it to the power grid. This can be done using suitability submodels in ArcGIS Pro.

Once you have a list of criteria assembled, you need to prepare the layers, which may include creating derivatives of the source data or projecting to a common coordinate system among all criteria (geographic coordinate systems using decimal degrees are not allowed). For our example, we'll use the following criteria layers in Web Mercator Auxiliary Sphere for simplicity:

- **Global Wind Atlas - Power Density**
  The 100m turbine height approximates the ~80m–94m wind turbine sizes that are common in Wyoming, as seen in the ArcGIS Living Atlas US Wind Turbine database.
- **US Electric Power Transmission Lines**
  The Distance Accumulation tool creates a raster surface whose cell values represent the distance to the nearest power transmission line.
- **USGS Wyoming Roads**
  Road segments with road classes of 1, 2, and 3 represent major roads in the state, which can support the enormous blades and towers on their journey to assembly on the wind farm site. The Distance Accumulation tool creates a raster surface whose cell values represent the distance to the nearest road.
- **Elevation: Landforms**
  The Geomorphon Landforms tool converts a statewide Wyoming digital elevation model (DEM) to a classified landforms raster, delineating slopes, valleys, peaks, ridges, and other landform types. You will often see wind farms on ridges and flatlands, but never in hollows or pits.
- **Elevation: Slope**
  A slope raster was created from a statewide Wyoming DEM. Construction on steep slopes is dangerous and expensive, so we are going to prefer low values (up to ~10–15 percent) and not build if it's much steeper than that.

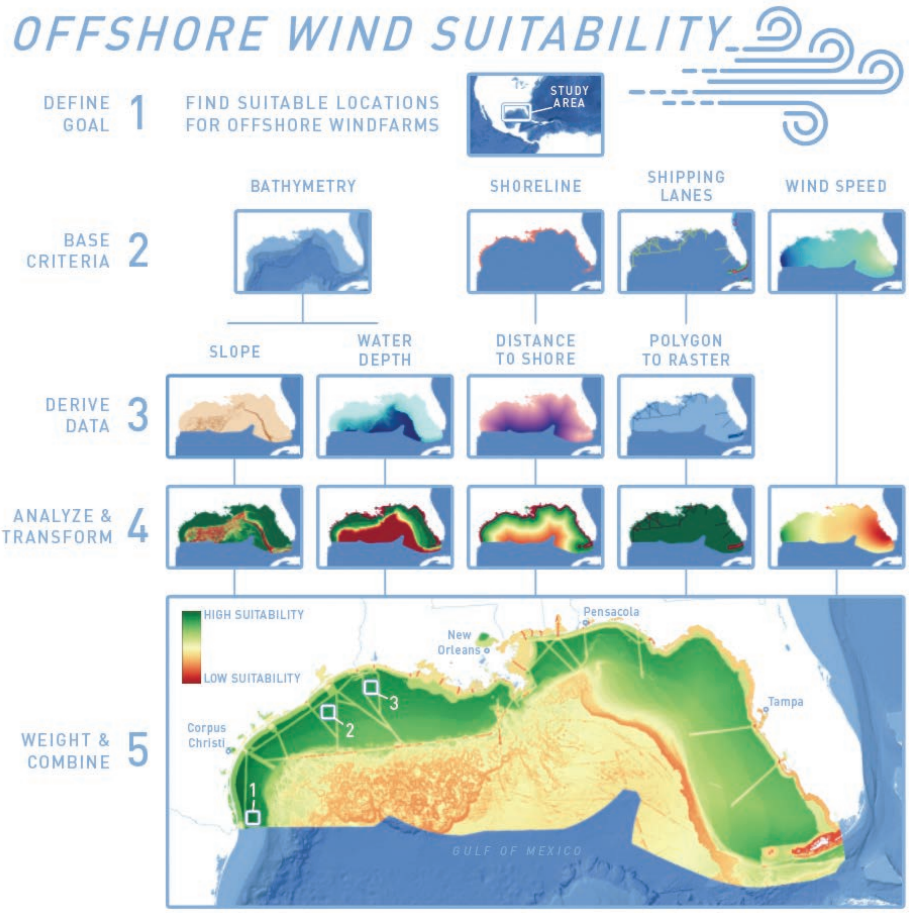
Knowing where you *can't* place a wind farm is just as important as where you can, which is where restricted areas come in. Whether the construction restriction is due to land ownership, line of sight or viewshed analysis, or areas where plant and animal habitats are endangered or imperiled, these locations are taken into account early in the suitability modeling process—effectively masking and removing them from contention. You will find all of these in ArcGIS Living Atlas:

- USA National Park Service Lands
- Areas of Unprotected Biodiversity Importance of Imperiled Species in the United States
- US Wind Turbine Database

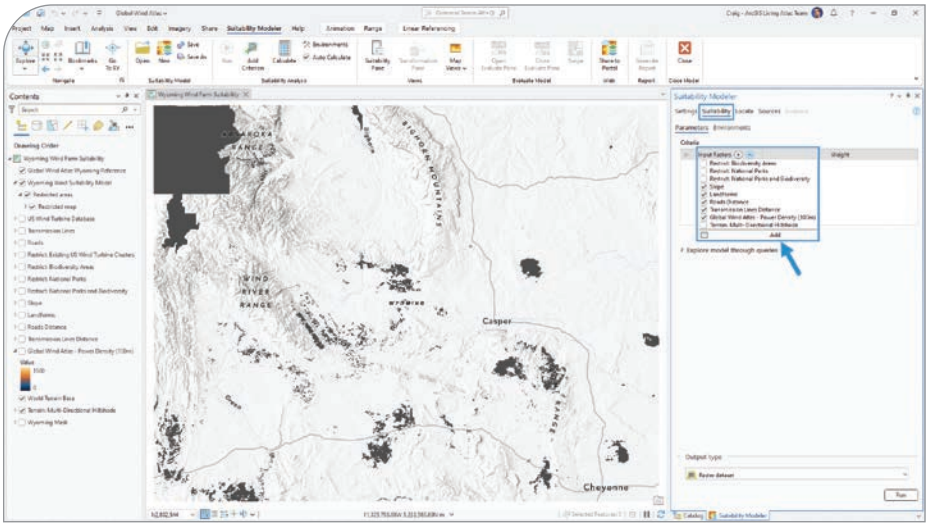
Configuring the Suitability Model

A power company constructing a real wind farm would likely have a much more exhaustive list of suitability criteria and restrictions, but this exercise will illustrate the overall process with a simplified set of inputs and configuration steps.

To start a new suitability model, add all the prepared criteria and restriction layers to a new map in ArcGIS Pro.



→ Suitability criteria used for offshore wind farms differ from those used onshore.



↑ Click on the Suitability tab in the Suitability Modeler pane and use the drop-down menu to select your criteria.

In the Analysis tab of the top ribbon, select Suitability Modeler.

In the Suitability Modeler pane, specify a new model name and configure the input type, scale, and weight options. (We're using default values.)

Next, add the Restricted Locations. We've preprocessed and merged the national parks and biodiversity areas into a single restriction raster, but you can also use the Add Clause button to create an "OR" expression and combine multiple restriction layers.

Click Apply and a new Restricted areas group layer will be added to the Contents pane on the left.

Click on the Suitability tab in the Suitability Modeler pane and use the drop-down menu to select multiple inputs. In our case, these are the criteria:

1. **Global Wind Atlas - Power Density (100m)**
2. **Transmission Lines Distance**
3. **Road Distance**
4. **Landforms**
5. **Slope**

Once selected, click the Add button to add them to the model.

The new criteria layers will be added to the Suitability Model group in the Contents pane on the left. Now, you can start to configure each input.

Click the radio button next to the Global Wind Atlas layer in the Suitability Modeler pane to open the Transformation pane.

This process will transform the min-max range of the data in the raster to output values between 1 and 10, representing least- to most-suitable regions.

Configure Wind Power Transformation

With the Global Wind Atlas layer selected, the Transformation pane will open below the map.

Because our data is continuous, we will use a function to transform the value range to a suitability range. Use the drop-down to select a function that is appropriate to the preferred distribution of the values in your raster, using the graph on the right.

We've selected the MSLarge function, which prefers the highest values. Feel free to experiment with the Mean multiplier and other options to find a curve shape that best ranks the suitability of the wind power. As you change the settings, the Suitability_map layer in the Contents will update, giving you immediate feedback on your choices. The most suitable areas are green, while the least suitable are red.

It can be helpful here to compare the Power Density values to the Suitability map to make sure high wind areas correspond to the green high suitability areas.

Configure Transmission Lines Transformation

Next, select the Transmission Lines Distance layer in the modeler window to configure its transformation.

We are using a Continuous Function again, preferring small values, with a Mid point of 20 km and a maximum Upper threshold of 50 km. This limits the distance we are willing to build new power lines to connect to the existing electrical network.

As you move through the modeling process, it can also be helpful as a check to add the existing wind turbine points to the map to make sure we are capturing the existing wind farms (which were presumably constructed under similar constraints) in the green areas of the Suitability_map.

Configure Road Distance Transformation

Treat this function the same as transmission lines, as they're both infrastructure and have similar building/distance constraints to keep costs down.

Only the larger, multilane classes of road segments were used in this analysis, due to the challenge of transporting large wind farm equipment on single-lane roads.

Transporting large wind turbine blades requires advanced planning to traverse the road network.

Configure Landforms Transformation

Next, configure the Landforms layer. We are dealing with a categorical raster with 10 landform types, so select the Unique Categories tab in the Transformation pane.

The drop-down allows you to change from numeric values to text Landform names. Once populated, the Suitability values in the right column can be ranked from most suitable (10) to least suitable (1).

If you are unsure of how to rank landforms, one option is to determine the landform type for each of the existing 1,560 wind turbines in Wyoming. Using the existing distribution of wind turbines to set landscape type ranks falls back on the expertise of those who have already constructed these farms in Wyoming. We can mimic their distribution in our suitability model.

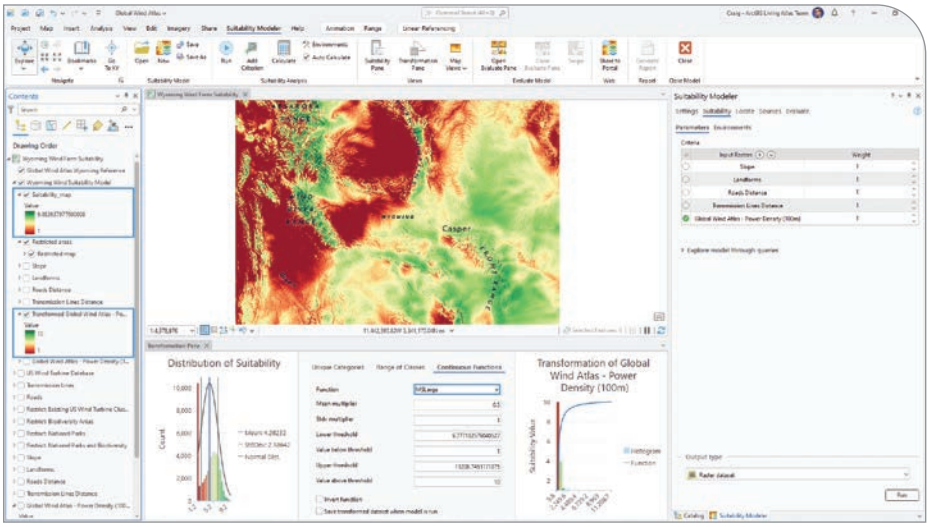
Flat, Shoulder, and Ridge are the most popular landform types for installing wind turbines in Wyoming.

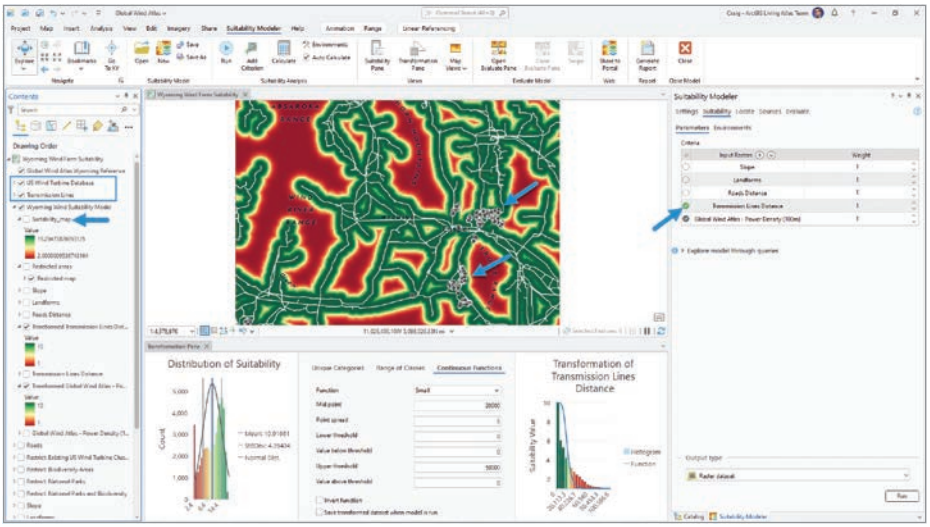
Flats were given the top ranking of 10, followed by Shoulder at 8, down to the least desirable Hollow and Valley at 1.

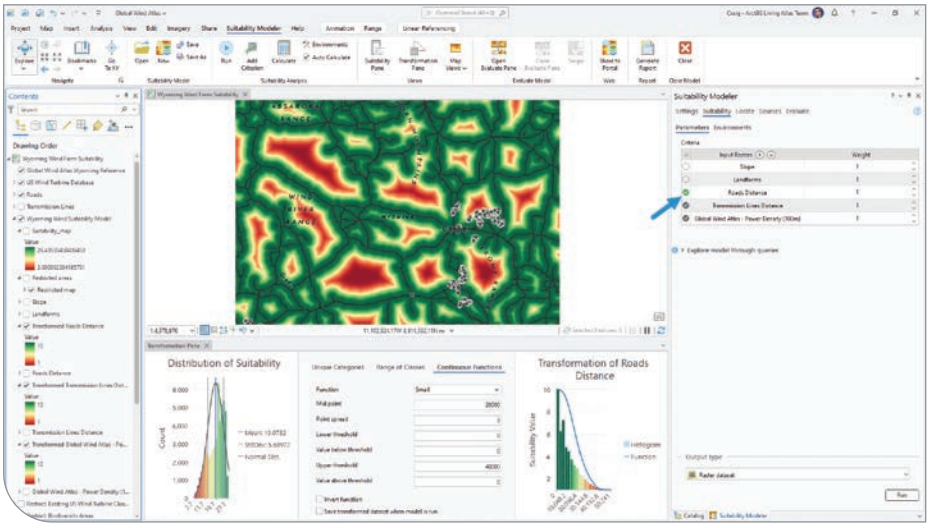
Configure Slope Transformation

Click on the Slope layer in the modeler to configure the final layer transformation.

We are back to a continuous function, MSSmall. This prefers small values (lower slope percent = flatter) as it is expensive and dangerous to construct wind turbines on steep slopes. Use the Mean







↖ It can be helpful to compare the Power Density values to the Suitability map to make sure high wind areas correspond to the green high suitability areas.

← Select the Transmission Lines Distance layer in the modeler window to configure its transformation.

↙ Treat the Road Distance Transformation function the same as transmission lines, as they're both infrastructure and have similar building/distance constraints to keep costs down.

multiplier and Threshold values to make the function curve drop to one before we exceed 30-percent slope. The bulk of our preference appears in the tall 0–4.4 percent green bar in the graph to the right.

As always, it is useful to turn off the Suitability_map in the Contents pane to check the Transformed Slope surface against the existing wind turbines. If these existing sites are mostly in the green areas, we're probably making reasonable decisions based on previous construction restraints.

Add Criteria Weights

Once all the criteria are transformed, each one is then weighed against the others. These weights then multiply each individual input's contribution to the final suitability model.

If one criteria has a weight of one and another has a weight of 2.5, the second is 2.5 times more important.

In our case, the most important criteria is Wind Power Density, so it received the highest weight value: if there is no wind, there is no wind farm. Landforms were given the lowest weight, with the other criteria falling in between. (These weight values are for demonstration purposes only.)

With weights assigned to all criteria, click the Run button to calculate the suitability raster.

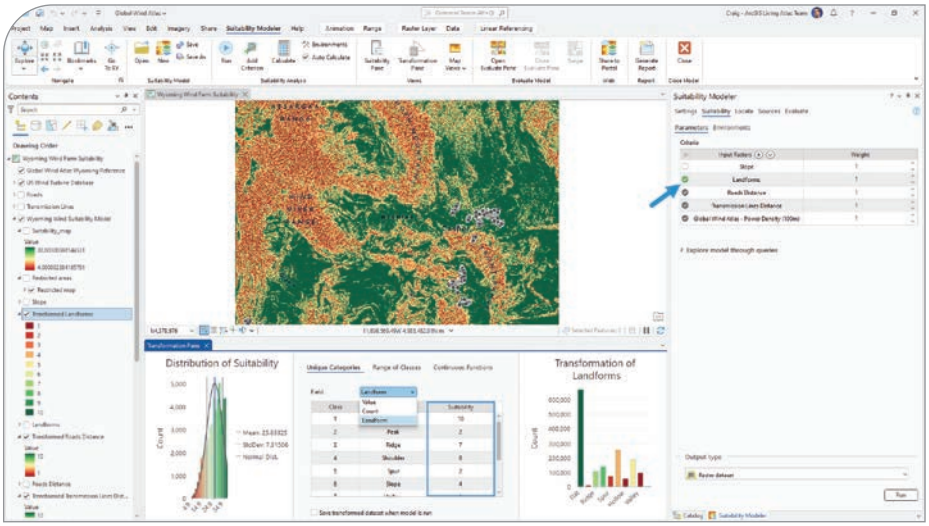
Locate Suitable Regions

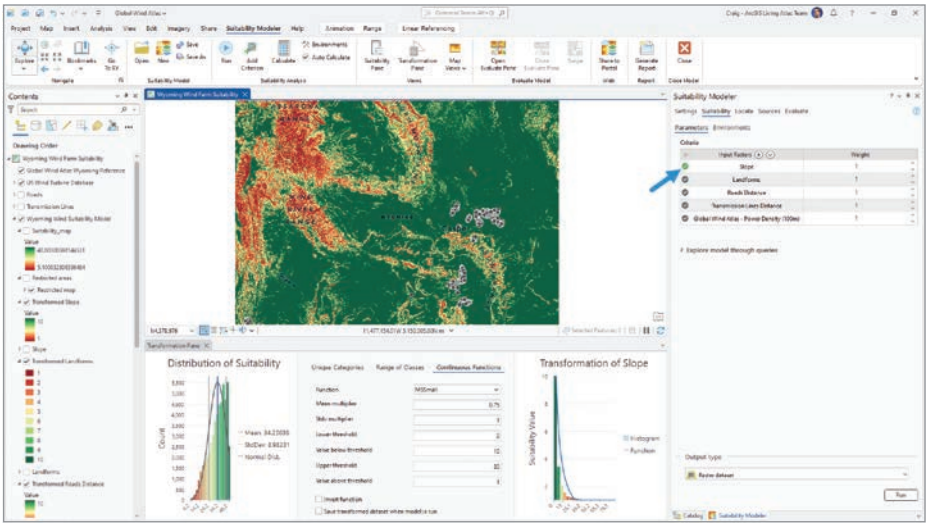
The final step is to combine the suitability layers, transformations, and weights to determine where a new wind farm can be placed. Click on the Locate tab of the modeler pane to enter the tool parameters.

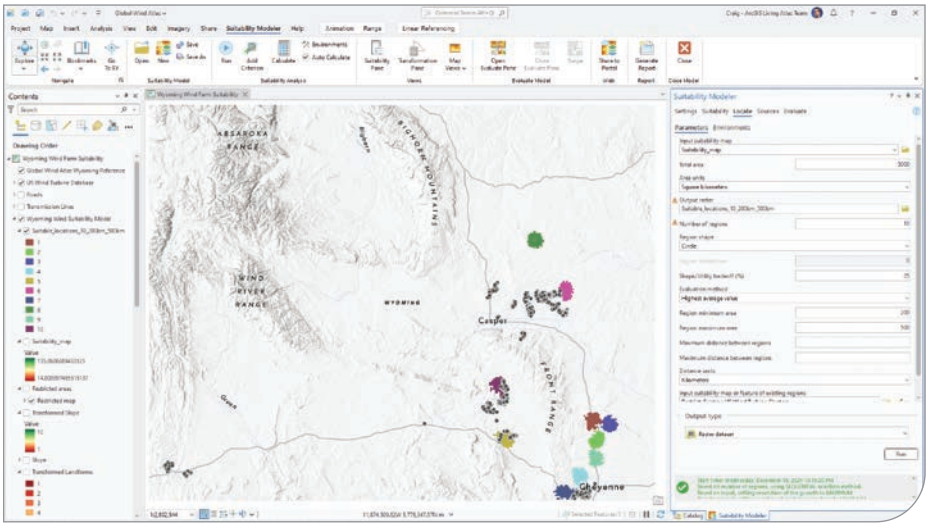
For this example, we'll look for 10 suitable wind farm sites, each about twice as big as the largest cluster of wind turbines in the US Wind Turbine Database—about 500 square kilometers. That gives us a total area of 5,000 square kilometers, which goes in the first box.

We'll use the default Circle region shape, and specify a Shape/Utility trade-off of 25 percent, which will prefer higher suitability over maintaining our target shape.

This is also where we can add an existing regions feature to our model, which are our existing wind farm points that we don't want to build on. The Find Point Clusters tool makes this easy. It uses the Self-Adjusting (HDBSCAN) option, with 10 features per cluster. Then, you can calculate







↖ When configuring the Landforms layer, we are dealing with a categorical raster with 10 landform types.

← Click on the Slope layer in the modeler to configure the final layer transformation.

↙ The final step is to combine the suitability layers, transformations, and weights to determine where we can place a new wind farm.

the Minimum Bounding Geometry, using the Cluster ID, to create individual wind farm polygons.

Once the inputs are specified, click on the Run button to create the suitability raster dataset.

Exploring the Results

When the calculation is complete, the 10 suitability regions are added to the map. Notice that the suitable regions are near existing wind turbine locations. To reduce that encroachment, rerun the model, this time providing a minimum distance between regions value. You can also buffer your wind turbine cluster polygons, try a slightly larger region maximum area to place a larger wind farm, or add new criteria. It's an iterative process!

To summarize your work, use the Generate Report button for a PDF summary of the model. Or, to access a suite of analytical maps and tools, use the Evaluate tab in the Suitability Modeler pane.

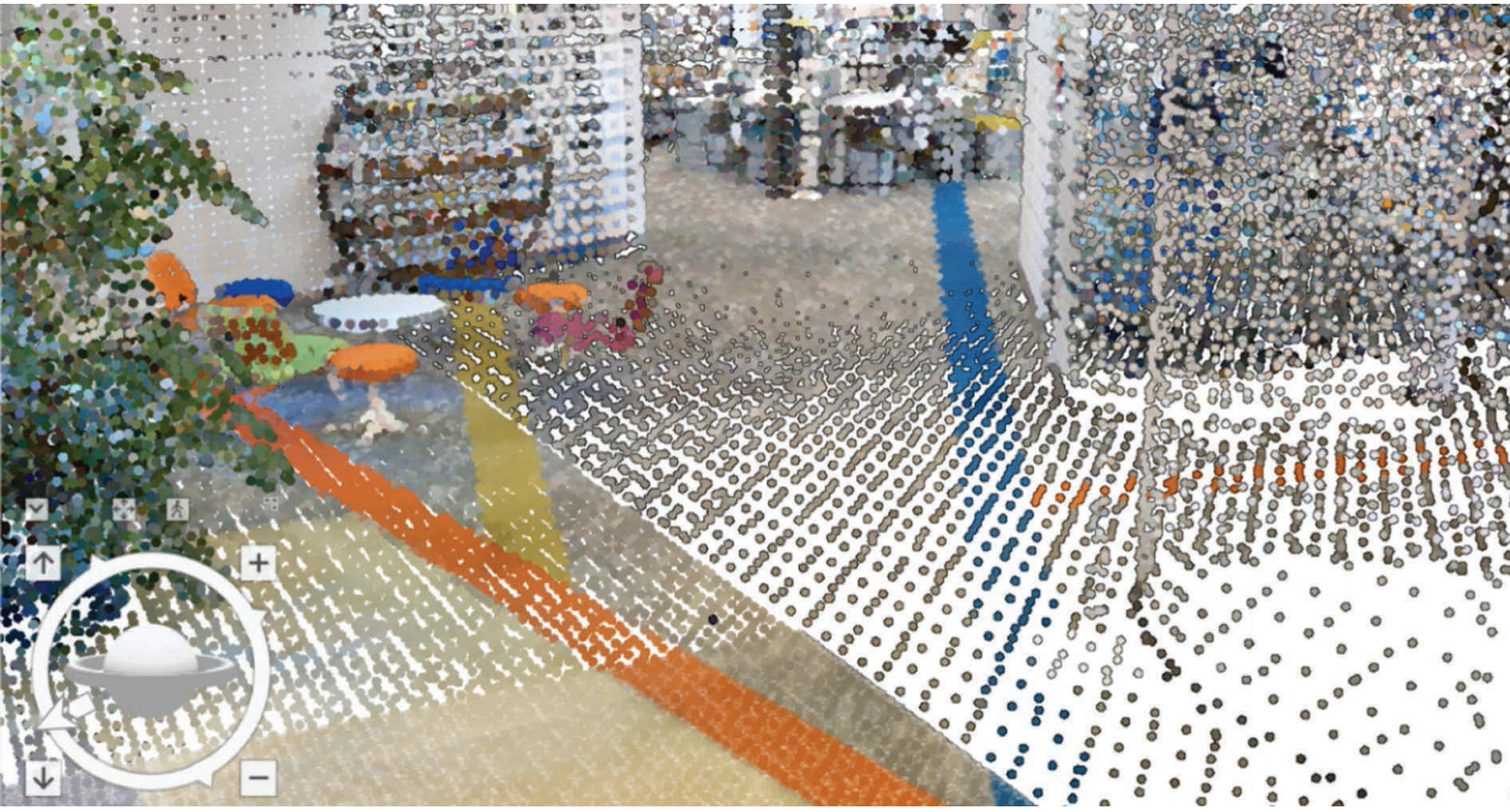
With a suitability model completed, use the map to investigate the optimal wind farm sites that were generated. Existing wind farm points have additional attributes about the year they were installed and the height of the wind turbine hub, which are useful for creating compelling 3D visuals using animated symbols in ArcGIS Pro.

ArcGIS Living Atlas of the World was created to share authoritative geographic data with people who can make a difference through its application towards a better and more sustainable world. Coupled with powerful visualization and analytic tools in ArcGIS, the Global Wind Atlas is a valuable resource to help achieve this goal.

About the Authors

Craig McCabe is a GIS engineer, geologist, and geographer on the ArcGIS Living Atlas team at Esri, with a passion for 3D visualization, analysis, and telling stories with spatial data.

With over two decades of GIS experience, **Emily Meriam** has mapped elephants in Thailand, wildlife poachers in the Republic of Palau, land-use-related issues around Yosemite National Park, and active wildfire incidents for the State of California. Presently, she is a senior product engineer and cartographer with Esri's ArcGIS Living Atlas team, where she styles and designs layers, maps, and apps. When not making maps, she loves traveling with her family.



Building Indoor GIS with Reality Capture

By Sophie Frank and Jason Hine

In recent years, the advent of reality capture technologies has revolutionized the way we collect and manage spatial data, particularly in indoor environments. An increasing number of scanning devices use light detection and ranging (lidar) and 360-degree cameras to capture highly accurate 3D representations of indoor spaces. But how exactly can reality capture data be used to support indoor GIS applications? What are the challenges of using reality capture data and the workflows that can help address them?

There are numerous situations in which reality capture data can enhance the creation and management of an indoor GIS. When computer-aided design (CAD) or building information modeling (BIM) floor plans are unavailable or outdated, reality capture can quickly generate accurate 3D representations of indoor spaces. The same goes for remodeled architecture, where capturing "as-built" conditions can provide essential data for future planning and design.

Additionally, 360-degree imagery can allow you to visualize equipment and amenities in spaces like conference rooms before booking. Accurate indoor data also assists facility managers in tracking assets, planning maintenance, and optimizing space utilization. Detailed, up-to-date indoor maps can aid in emergency response planning, and provide first responders with critical information about building layouts.

A growing number of companies offer portable reality capture devices that can achieve these goals. Once data has been collected using reality capture systems, the next step is to process this data for use in an indoor GIS. To effectively convert raw point cloud data into usable indoor GIS data, consider the following steps.

1 Register Scans

In many cases, a single indoor space may require multiple scans to capture all relevant areas. The first step is to register these scans together to create point clouds.

Registration involves aligning the scans based on overlapping features. In large datasets, consider registering scans on a floor-by-floor basis, rather than merging all scans into a single large point cloud.

If control points were captured during the data collection process, you can use them to autoregister the scans. If no control points are available, you can use the vendor's software to manually align scans by matching features in overlapping areas.

2 Georeference the Point Cloud

Georeferencing ensures that point cloud data is aligned with a real-world coordinate system.

Most vendors provide tools within their software to georeference the point cloud to a suitable projected coordinate system. You can use GPS control points if they were collected during the scanning process. If no control points are available, check if the vendor's software allows positioning by using a satellite imagery basemap.

3 Export the Processed Data

After processing, the next step is to export the point cloud data into a format that is compatible for use in ArcGIS Pro. This includes exporting point cloud data as LAS or LAZ file formats. If 360-degree images were captured alongside the point cloud, export these to an E57 format (which supports embedded images) as equirectangular images. You can then import the images from the E57 file using the Import Indoor Images tool.

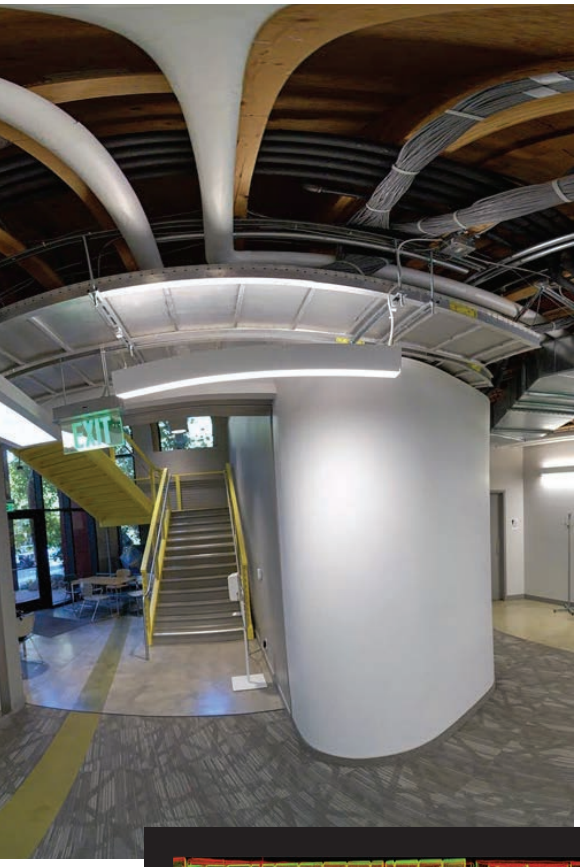
4 Generate Floor Plans from Point Cloud Data

Once the LAS or LAZ file is ready, you can use the Generate Floor Plan From Point Cloud tool in the Indoors toolbox in ArcGIS Pro to create polyline floor plan features in the GIS.

Learn more about best practices when scanning building data and creating an indoor GIS from the point cloud at links.esri.com/point-cloud.

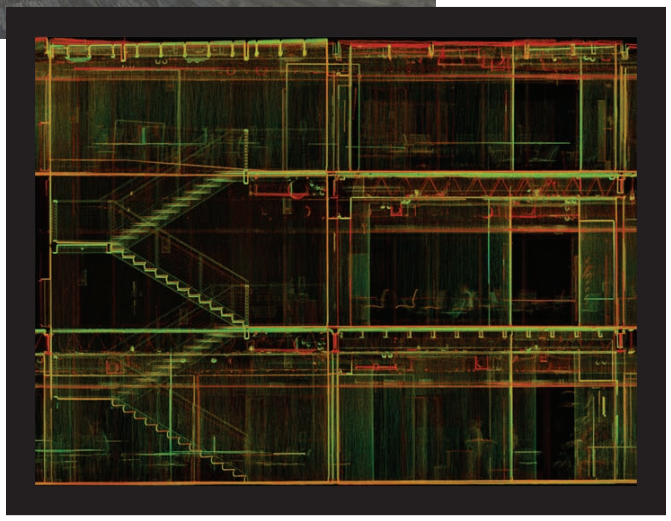
Quality Assurance and Editing

After generating your floor plans from point cloud data, it is essential to perform quality assurance and editing. This ensures that the output meets the required standards for accuracy and usability in indoor GIS applications.



← An equirectangular 360-degree image captured during a Lidar scan.

↓ Three scans can be registered together using a stairway as a common reference.



Once the Generate Floor Plan From Point Cloud tool has been run, the output will consist of polylines that represent walls, doors, and other vertical surfaces. Conduct a visual assessment of the linework in ArcGIS Pro to look for gaps, overlaps, and inaccuracies in the polylines. You can use the point cloud as a visual reference to differentiate between walls and furniture as well as to identify any missing features.

Once the review is complete, depending on the quality of the linework, you may need to perform various cleanup tasks:

- Close gaps in walls using the Create Features or Edit Vertices tools. Gaps may occur due to factors like large windows, open doors, or incomplete scanning.
- Delete unwanted features. For example, polylines may have been created where furniture or light fixtures were scanned, but these should not be included in the floor plan.
- Reshape polylines using the Modify Features tools to adjust polylines where necessary. This includes extending, trimming, or merging lines to ensure continuity, or using the Align Features tool to preserve parallel walls at a consistent thickness.

When modifying your data, it can be helpful to enable snapping to ensure that polylines connect at vertices. You can also use a reference grid to assist in aligning walls.

Once editing is complete, validate the accuracy of the edited floor plans by checking key dimensions against known measurements from the point cloud and cross-referencing with any other data you may have available, such as CAD or BIM. The final polylines should represent closed space boundaries and will be used to create polygons representing building footprints (building extent), floors, and rooms in the indoor GIS.

Import Polylines to an Indoors Workspace

After completing quality assurance and editing workflows, the final step is to import the refined polylines into an ArcGIS Indoors workspace. This allows you to create a comprehensive indoor GIS for facility management, emergency planning, and more.

To import into an Indoors workspace, run the Import Features To Indoor Dataset tool to create polygons representing building footprints, floors, and rooms based on input polylines.

After the tool runs, review the output to ensure the resulting floor plan features meet your needs. If you find errors or discrepancies, use the Create Features and Modify Features panes to make necessary adjustments. This may involve adding new features, deleting unnecessary ones, or reshaping existing features for accuracy.

After creating the floor plan geometry, you can add relevant attributes to the imported features, such as room names, space use types, and other metadata.

Import Images to an Indoors Workspace

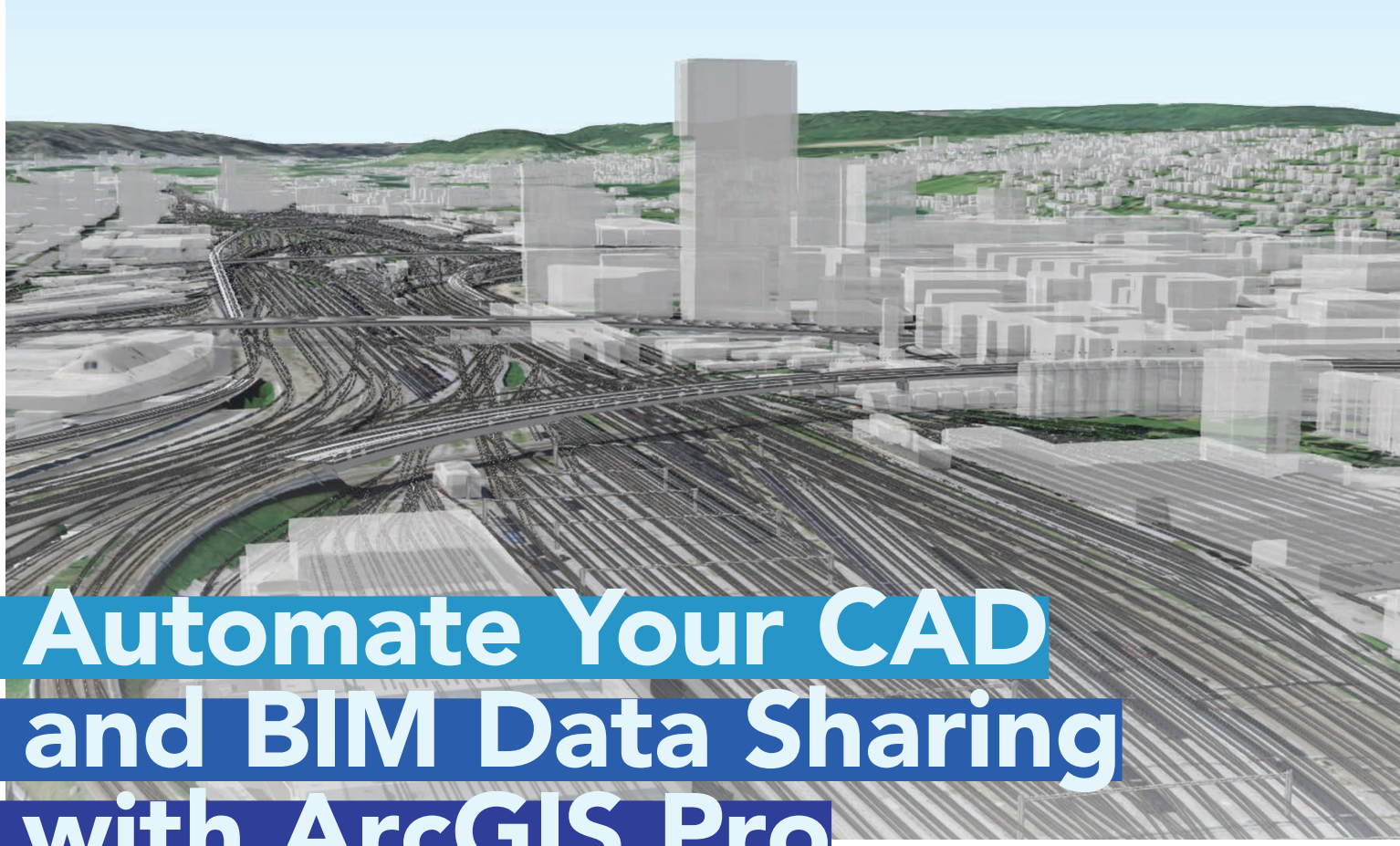
Once you have floor plan features in an indoor GIS, you can import any panoramic images captured during the scanning process. Run the Import Indoor Images tool to import 360-degree photos from an E57 file into an Oriented Imagery layer. This layer can be used in floor-aware maps within ArcGIS Indoors apps and across the Esri ecosystem.

Reality capture technologies, combined with effective processing and editing workflows, empower organizations to create accurate and detailed foundational data for an indoor GIS. By using tools like ArcGIS Pro and its Indoors capabilities, professionals can significantly improve facility management, emergency planning, and overall spatial data management workflows.

About the Authors

Sophie Frank is an Esri senior product engineer on the ArcGIS Indoors product team and the product owner for ArcGIS Indoors Pro.

Jason Hine is a principal product engineer at Esri for ArcGIS Indoors and product owner of ArcGIS Indoors for AutoCAD. He lives, works, and spends time outdoors with his family near Denver, Colorado.



Automate Your CAD and BIM Data Sharing with ArcGIS Pro

By Michael Davidson, Geoff Cook, and Cici Xiao

Computer-aided design (CAD) and building information modeling (BIM) data often undergo frequent changes by civil engineers, architects, and CAD technicians during the course of any project. These changes mean other project team members need to be kept in the loop for downstream decision-making. Sharing this data manually can be a pain—which is why parts of the process can be automated in ArcGIS Pro.

Project and asset managers invariably need timely and centralized access to up-to-date data for tracking progress and resolving issues. By reducing the time spent integrating 3D CAD and BIM content into 3D web scenes, GIS teams can mitigate all kinds of project risks for stakeholders.

Various workflows can benefit from tips and tricks to speed up the process, such as creating spatial representations of CAD and BIM data, preparing content, and publishing a scene to the web. In ArcGIS Pro, some of these steps can be automated with scripting, enabling faster sharing of CAD and BIM data.

Import and Add CAD and BIM Data

Let's say you're a GIS analyst working for a transportation department. With a project underway to replace a railway track segment, you're responsible for keeping infrastructure data centralized in a web scene for project coordination.

In this scenario, railway corridor models are stored in Autodesk Civil 3D drawings. Highway and pedestrian bridge components, which add context for maintaining the railway, are represented in Autodesk Revit models and Industry Foundation Classes (IFC) data. This design data contains real-world coordinates and a projected coordinate system, eliminating the need to manually georeference them in ArcGIS Pro. This CAD and BIM data is stored in Autodesk Construction Cloud.

To start, connect and import content stored in Autodesk Construction Cloud into ArcGIS Pro. From the Insert tab, click Connections, and select New BIM Cloud Connection. Provide a connection name and Autodesk account credentials.

In the Catalog pane, expand the BIM Cloud Connections entry. Then, expand the named connection folder to browse engineering files. Download files of interest, such as Civil 3D files containing corridors for the rail lines.

Use Check Status to detect changes to CAD and BIM files, including the Civil 3D drawing for the replacement track segment. Update the accompanying files in the ArcGIS Pro project home folder using Refresh From Source. After refreshing, the scene will reflect the current data, such as the latest design for the segment.

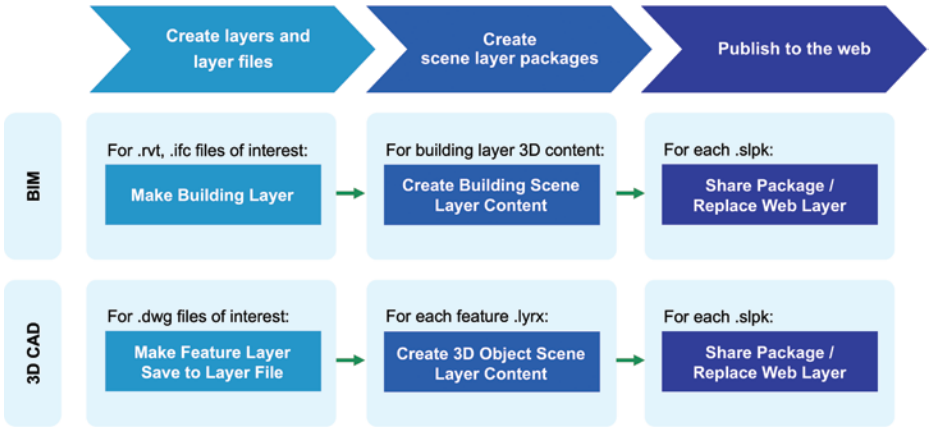
Multiple approaches are available for integrating CAD and BIM data into ArcGIS Pro scenes. The following approach, which involves running sequences of geoprocessing tools, is optimized for working with 3D content:

1. Represent CAD and BIM data as spatial features. For example, run Make Feature Layer and Save To Layer File for the

← Replacing a railway track segment in a multimodal transportation network requires collaboration across project teams.

→ This workflow illustrates how to create scene layer packages from 3D CAD and BIM content, and then publish it as a scene layer (hosted).

↓ You can use ArcGIS Pro to visualize, analyze, and share the transportation network scene.



rail corridor objects stored in the Civil 3D files. For BIM files, run Make Building Layer to create building layers.

2. Whether created from one or several engineering files, package the data into scene layer packages (.slpk files). For BIM datasets, this creates composite layers that organize design and engineering data as spatial features by discipline. Package 3D CAD content into 3D object scene layer packages.
3. After creating scene layer packages, publish them for efficient web streaming.

Automate Your Data Sharing

Instead of manually running these geoprocessing tools, you can automate these steps using ArcPy. With ArcPy, you can customize functions to process specific files in bulk. You can also add methods to automate more complex workflows that delete unwanted elements, update attributes, or copy elements between categories before creating scene layer packages.

You can further increase efficiency by automating the publishing steps. Using your authentication scheme, create a script to access your online organization, whether ArcGIS Online or ArcGIS Enterprise. Boost automation by scheduling script calls, such as on evenings before recurring stakeholder meetings.

Automating this part of the workflow reduces time spent manually updating the scene layer content. It also ensures that stakeholders using the web scene for project coordination can make decisions based on current design information for the railway track segment.

You can also take these web scenes even further for cross-team coordination by creating and configuring project-specific web apps using ArcGIS GeoBIM and ArcGIS Experience Builder.

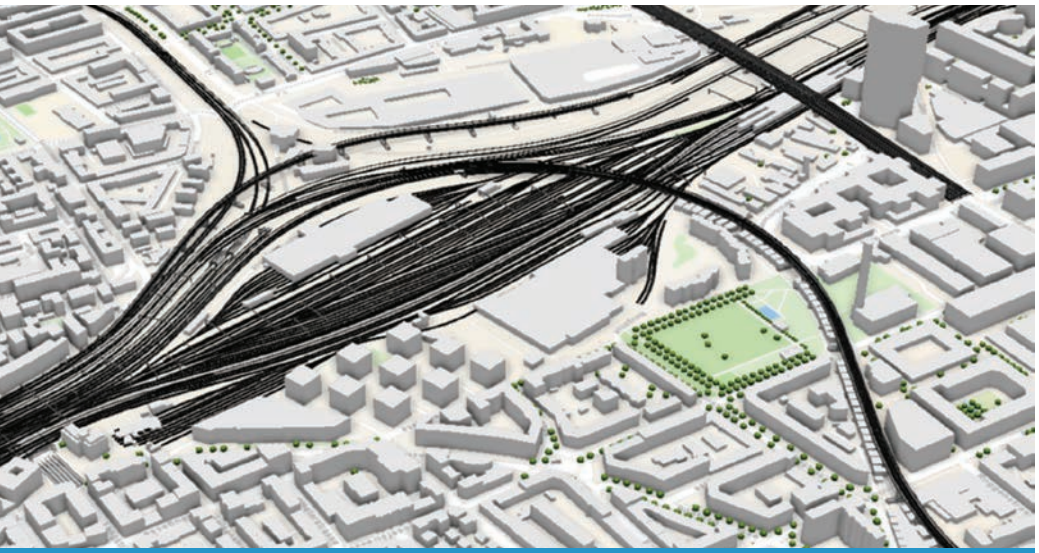
Reducing manual efforts when integrating CAD and BIM data in ArcGIS Pro and publishing web scenes for use by other stakeholders saves valuable time for focusing on other spatial analysis and visualization tasks. Other teams can greatly benefit from these automations, such as project and asset managers needing timely access to centralized subsets of evolving project data.

About the Authors

As an Esri product manager, **Michael Davidson** pushes the boundaries of interoperability across GIS, CAD, and BIM, as well as ArcGIS for AutoCAD. Davidson has more than 10 years of experience in civil engineering software development, including BIM for bridges and geostatistics. He has a PhD in civil engineering from the University of Florida and is a licensed PE in Florida.

Geoff Cook is senior product marketing manager for ArcGIS GeoBIM, ArcGIS for AutoCAD, and GIS/BIM interoperability at Esri. With over 10 years of working in the technology and sustainability sectors, he has supported the go-to-market and growth efforts of several enterprise cloud solutions. After first encountering GIS during his environmental management studies, Cook has always had a passion for design, innovation, and sustainable practices.

Cici Xiao is a product engineer on the CAD/BIM team. She joined Esri in 2020 with a background in environmental management and computer science. Her focus areas are CAD/BIM and GIS integration, quality assurance, and automation. She is a certified scrum master and agile tester.



Design Your Maps *for* Color-Blind Readability

By Stephanie Oliver

An estimated 350 million people in the world have some form of color vision deficiency (CVD). That's roughly one in 12 men and one in 200 women. Statistically speaking, the average person knows at least 25 people who are color-blind. Map designers who consider factors like these can more effectively ensure their maps are not only accessible to all, but also easier to read and interpret. A good place to start is with the following question:

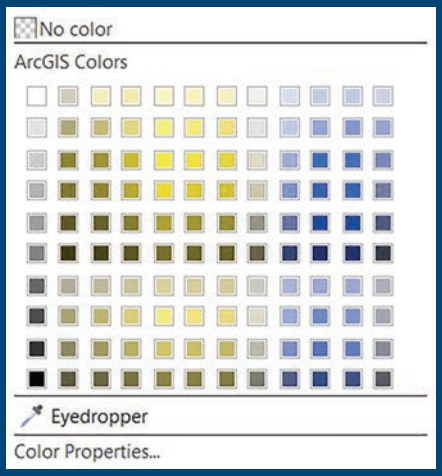
How can we make our maps readable for those who have some form of color blindness?

When recognizing the impact that color can have in your maps, especially those created in ArcGIS Pro, it's vital to first understand the different types of color blindness.

People with deuteranopia are unable to perceive green light. Deuteranomaly is a reduced sensitivity to green light. Deuteranopia and deuteranomaly are the most common forms of color blindness.

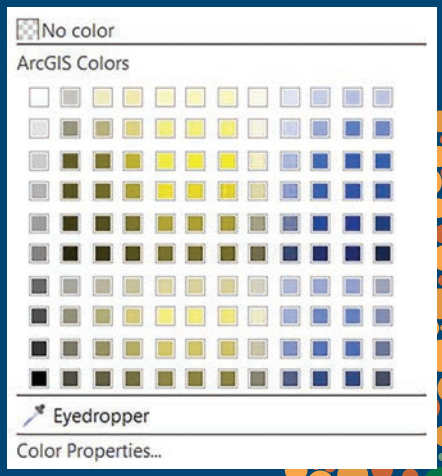
↓ The ArcGIS Pro color swatch selector with the two most common types of color vision readability.

Deuteranopia



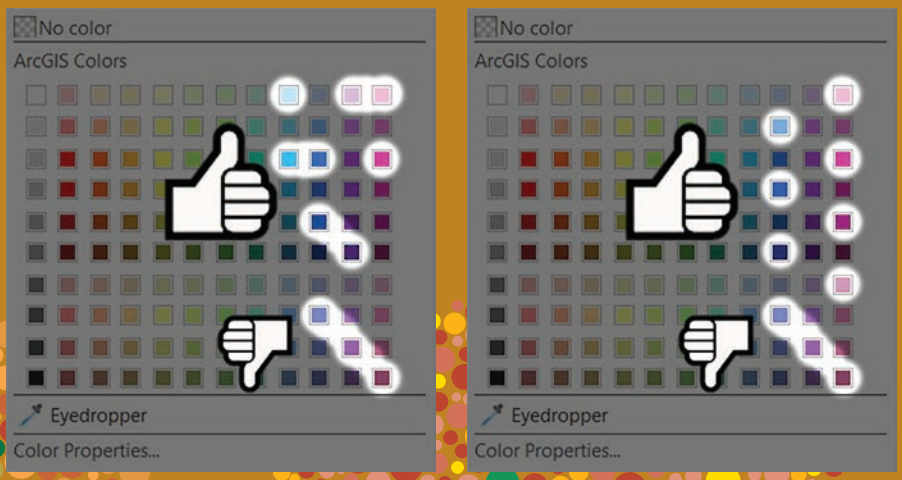
Common Vision

Protanopia



↑ How to pick multiple reds and oranges.

↑ How to pick multiple yellows and greens.



People with deuteranopia are more likely to confuse:

- Mid-reds with mid-greens
- Blue-greens with grays and mid-pinks
- Bright greens with yellows
- Pale pinks with light grays
- Mid-reds with mid-browns
- Light blues with lilac

Less common types of color blindness include protanopia and protanomaly, the inability to perceive red light and a reduced sensitivity to red light, respectively.

People with protanopia are more likely to confuse:

- Black with many shades of red
- Dark brown with dark green, dark orange, and dark red
- Some blues with some reds, purples, and dark pinks
- Mid-greens with some oranges

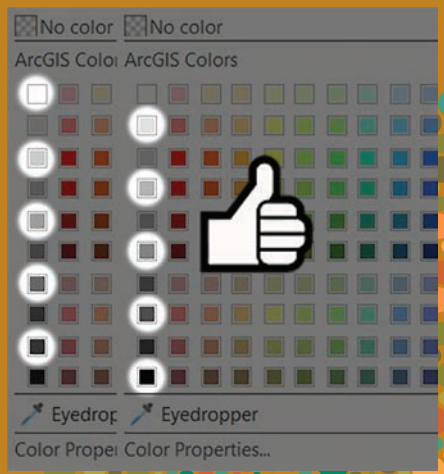
Rarer still are tritanopia and tritanomaly, an inability to perceive blue light and a reduced sensitivity to blue light.

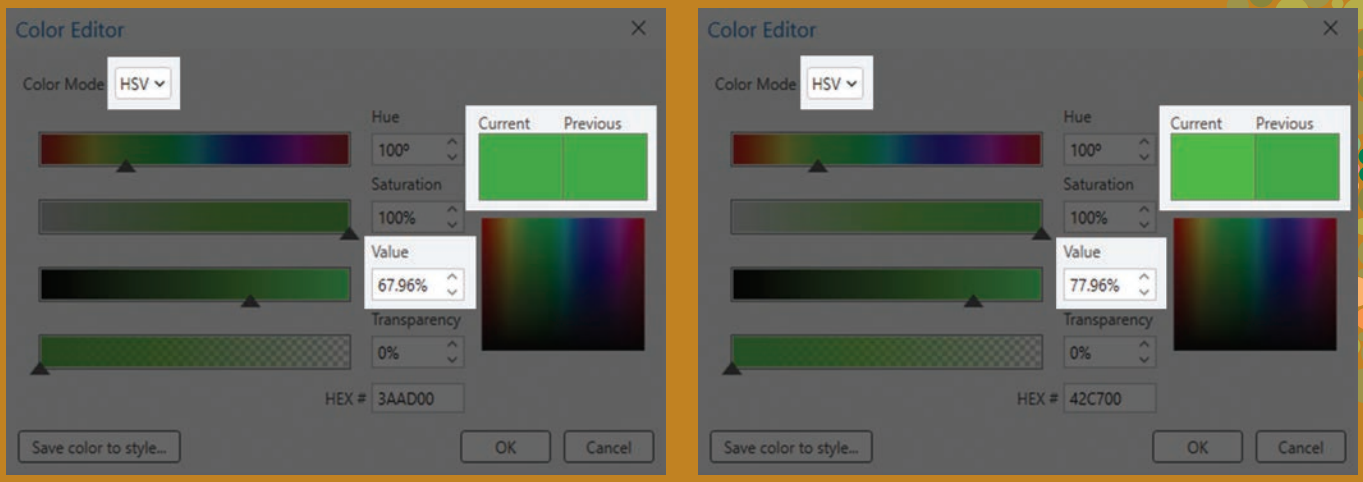
People with tritanopia are more likely to confuse:

- Light blues with grays
- Dark purples with black
- Mid-greens with blues
- Oranges with reds

← How to pick multiple blues and purples.

↓ How to pick multiple grays.





↑ Changing the value of a color can help make it more visually distinct.

Achromatopsia is one other rare type of color blindness and refers to the inability to perceive color at all. People with achromatopsia see only shades of gray.

Although it is important to take into account all forms of CVD when designing a map, we will focus primarily on readability for the most common types of color blindness—deuteranopia and protanopia.

Before we start talking about color-blind readability, it's also worth taking a step back to cover some color basics.

Hue refers to the wavelength our eye perceives. This term is often used interchangeably with color.

Value refers to the shade of a color. A lower value represents a darker color, and a value of zero is black. Value increases in the lightness or whiteness of the color.

Saturation refers to the intensity or purity of the color. An intense color is more saturated, and a dull color is less saturated and looks grayer.

Getting Colorful in ArcGIS Pro

Let's look at the color swatches available in ArcGIS Pro (see page 54). When you view the same colors through a filter that replicates how the swatches look to someone with deuteranopia or protanopia, you can see how the colors differ.

To choose the colors that work best for readability, first divide this color swatch into three main categories:

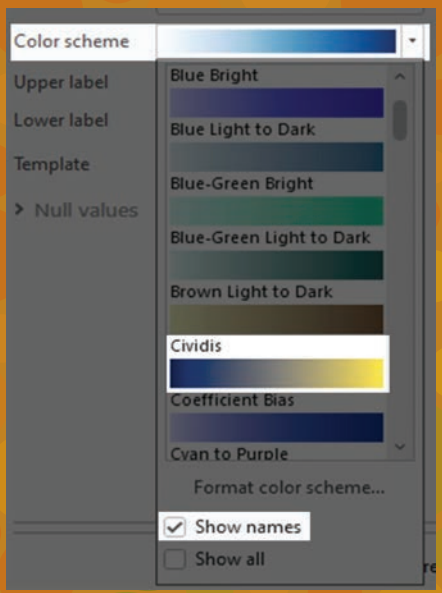
- reds/oranges
- yellows/greens
- blues/purples

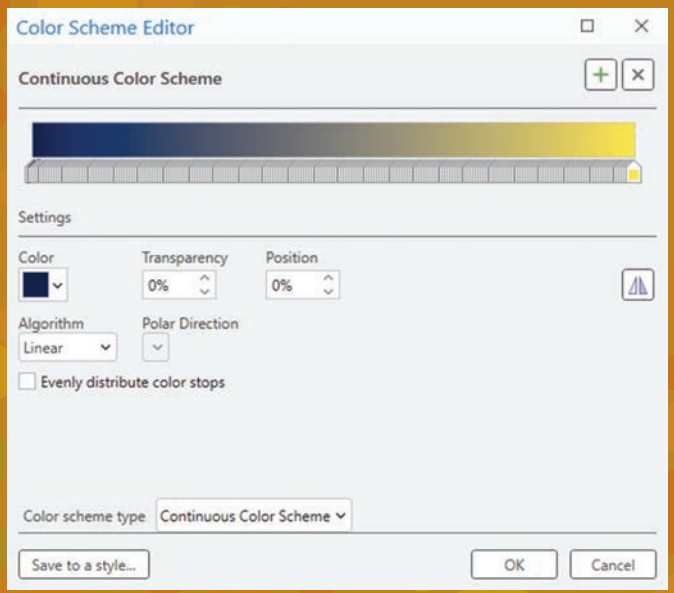
This is a good starting point, but I recommend that you check your final colors with an emulator. Emulators allow you to use a lens to see how your map will look to others.

To pick colors in the columns of red hues, go down the column (vertically) when choosing colors that are next to each other. Don't choose colors that are side-by-side in the same row (horizontally), as they are more difficult to distinguish.

In the orange column, choose one orange and one red in the same row. Be cautious when choosing colors diagonally in the reds and oranges. Some of these may appear to be the same color to someone with color-blind readability issues.

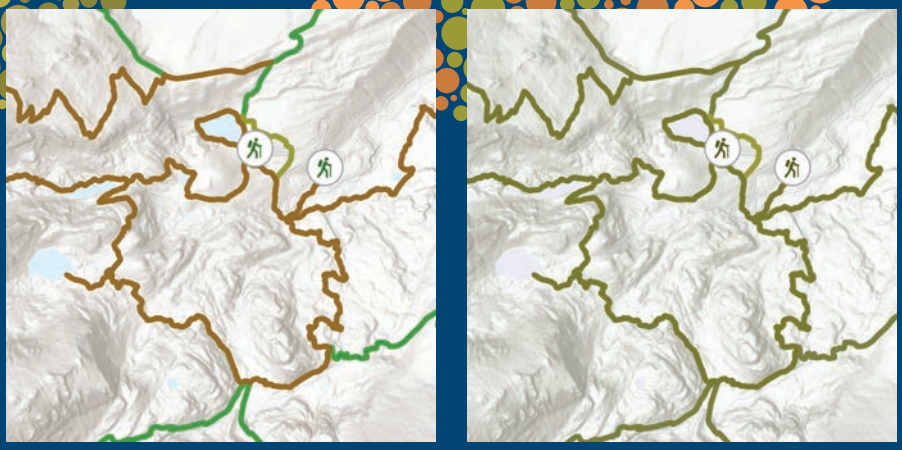
When it comes to yellows and greens, it's best to stick to a similar pattern. Don't choose colors that are side-by-side in the



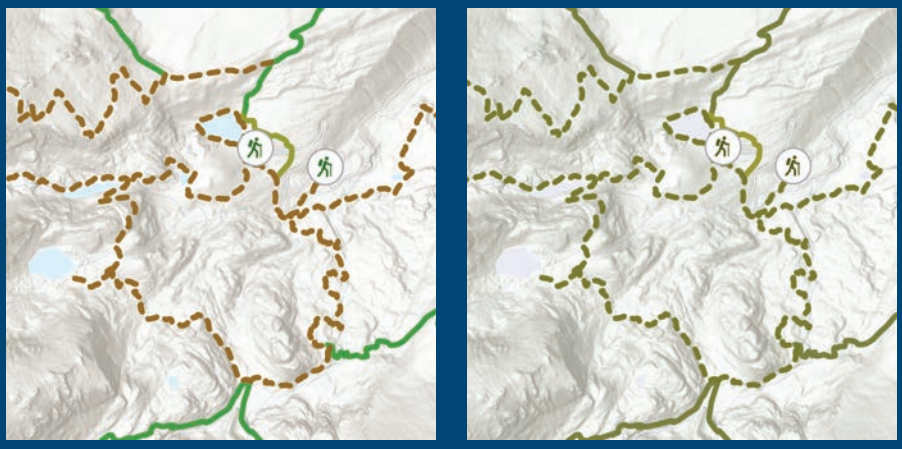


←← Use Show names to find the Cividis color scheme in the Color Ramp Selector.

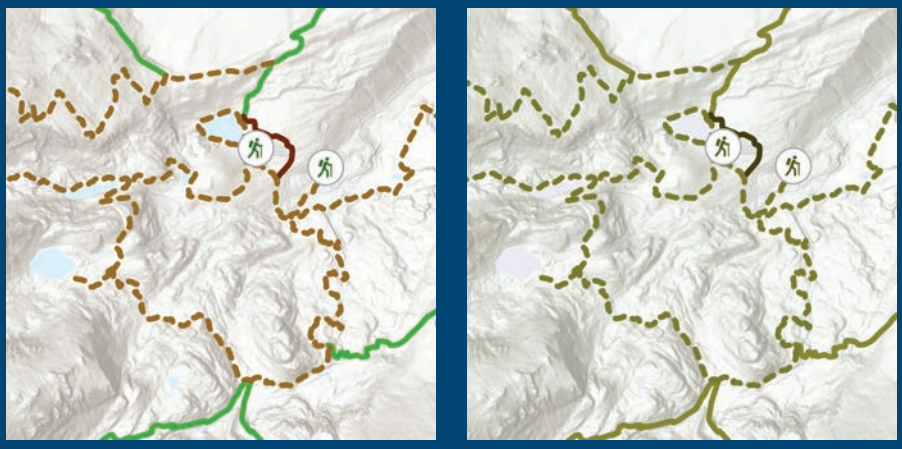
← You can use the Color Scheme Editor to change the color ramp or pull individual colors.



↑ On the left is a trail map seen with color vision. On the right is the same map with deuteranopia simulated.



↑ Dashed lines add an extra distinct element to the trail map.



↑ Dashed lines plus a difference in value improve the readability of the map further.

same row. If you choose colors in the same column, skip every other value, or choose two to three colors that are diagonal.

With blues and purples, choose three of the four colors in one row, typically skipping one hue in the two center columns. Choose two to three colors that are diagonal to each other. If you choose all four that are diagonal, you may find two colors that are too similar. If you choose colors in a column, skip every other value.

When working with the gray scale, skip every other value, no matter who is viewing the map. Even those who have no issues seeing color will have issues distinguishing between a 10-percent gray and a 20-percent gray.

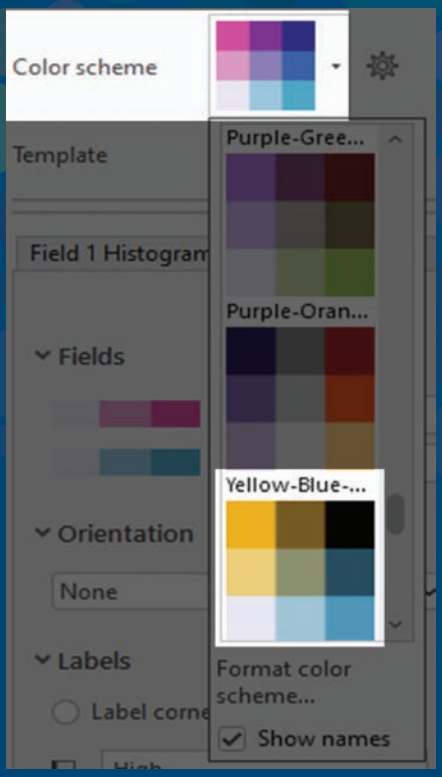
This can also be applied to custom colors. You can create custom colors in the Color Properties menu. If a color almost works, you can distinguish the color more by increasing or decreasing the value by 10 percent from another color that looks similar. Working with the saturation is another way to distinguish between similar colors.

In the Color Properties, switch from the RGB (red, green, blue) color model to the HSV (hue, saturation, value) color model to access the ability to change the value of a color, which can help make it more visually distinct.

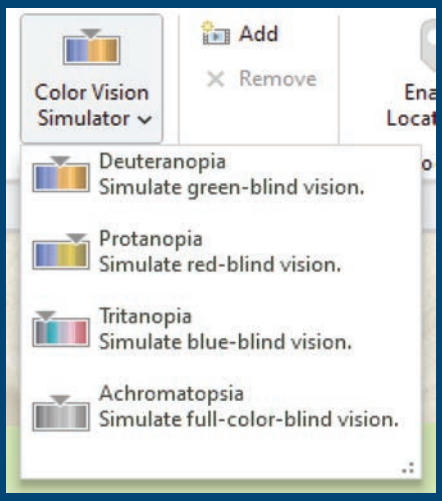
More than Just Color

Fills, point symbols, line weights, and other styles can help make your maps more understandable as well.

On this hiking trail map, you can see that hue might not be the most helpful variable to distinguish between features. Although



← The Yellow-Blue-Black 3x3 color scheme is available when working with the bivariate or trivariate color schemes.



↑ The Color Vision Simulator is an invaluable feature in ArcGIS Pro 3.0.

two of the lines might appear nearly the same color, you can use a dashed effect on the line to distinguish them, as seen in the second map.

When you use the color tips outlined earlier to choose different hues or vary the values, you can use both hue and shape to help make the distinction between features even clearer.

If this seems like a lot of work, there's an easier way to achieve the same effect.

In ArcGIS Pro 2.3 and beyond, a color ramp called Cividis allows you to use colors that were predesigned to be readable for those with some form of color blindness.

To choose a color ramp, click on Show Names and find the Cividis color ramp.

Additionally, you can choose colors from this ramp by selecting Format Color Scheme; this is where you can reverse the color ramp. You can also select any color in this scheme and save it as a Style to save and share your symbols, colors, color schemes, label placements, and layout items.

You can use the Color Scheme Editor to change the color ramp or pull individual colors.

If working with bivariate or trivariate symbology, a color-blind readability symbology option, called the Yellow-Blue-Black 3×3 color scheme, is also an option. Bivariate colors symbology shows the quantitative relationship between two variables in a feature layer. This type of symbology uses bivariate color schemes to visually compare, emphasize, or delineate values. Similar to graduated colors symbology, each variable is classified, and each class is assigned a color.

The ColorBrewer 2.0 website is another invaluable resource you can use to choose colors for color-blind readability. From here, input RGB or Hex color codes (values that tell the display how much color to show) directly in the Color Properties in ArcGIS Pro.

The Final Test

In order to test that these concepts and changes work, the final step is to use an emulator. In ArcGIS Pro 3.0 and beyond, this is called the Color Vision Simulator.

This will show what your map looks like to those who have deuteranopia, protanopia, tritanopia, or achromatopsia. You can access it in the View tab and check your map through three filters. Adjust your colors on the fly and see the changes.

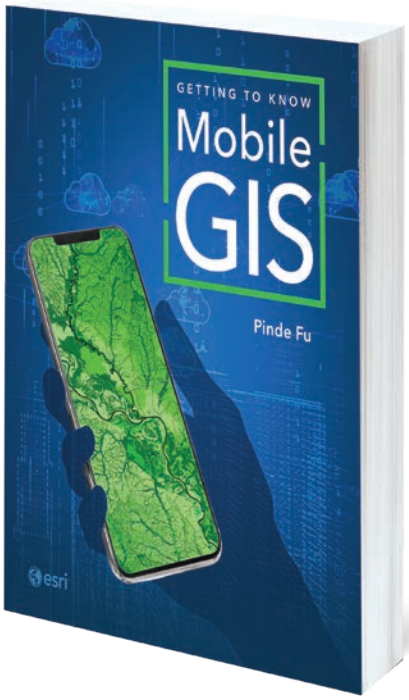
About the Author

Stephanie Oliver is a senior instructor at Esri who has worked in the GIS industry for over 15 years, much of that in the public sector. She has extensive experience with cartography, transportation, and emergency management. She teaches both ArcGIS Desktop and ArcGIS Enterprise classes.

Bookshelf

Getting to Know Mobile GIS

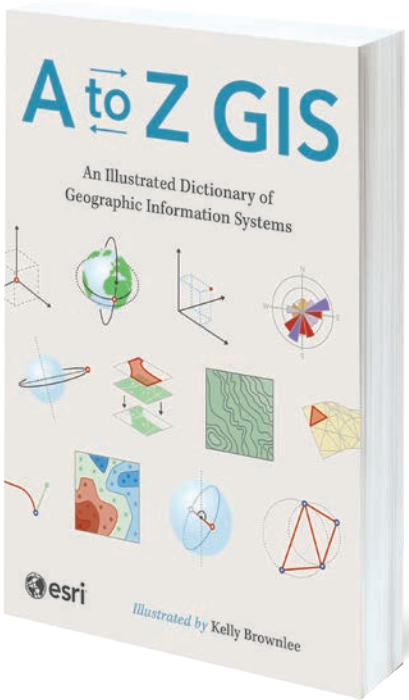
By Dr. Pinde Fu



"Mobile first" and the "post-PC era" aren't just buzzwords; they represent today's reality. Within the GIS industry, the mobile internet has profoundly transformed how people acquire, visualize, analyze, and disseminate geospatial information. *Getting to Know Mobile GIS* helps GIS professionals and students grasp the opportunities presented by mobile GIS across business operations in a variety of organizations. Using a low- to no-code approach, the book includes detailed tutorials that make the principles of mobile GIS fun and easy to learn. It helps readers become immediately productive in creating enterprise GIS solutions for online and offline spatial data visualizations, data collection, location sharing, and workforce coordination. February 2025, 286 pp. Ebook ISBN: 9781589488083 and print ISBN: 9781589488076.

A to Z GIS: An Illustrated Dictionary of Geographic Information Systems

By Esri



As GIS has evolved and grown, so has the language of this powerful technology. With more than 1,400 new terms and nearly 400 high-quality illustrations, the third edition of *A to Z GIS: An Illustrated Dictionary of Geographic Information Systems* helps readers elevate their understanding of GIS. Written, developed, and reviewed by more than 200 subject-matter experts, this comprehensive, fully cross-referenced dictionary—with nearly 3,000 terms in total—is essential for managers, programmers, users, writers, editors, and students discovering the interdisciplinary nature of GIS. March 2025, 354 pp. Ebook ISBN: 9781589488120 and print ISBN: 9781589488113.

For more information on all Esri Press publications, go to esri.com/esripress.

Maintaining Cell Towers with a Community Mindset

By Jesse Cloutier

Cell towers have a way of announcing themselves against the natural landscape. Whether surging upward in an open field or a stand of trees, they're hard to miss on a clear day. At night, flashing beacons warn low-flying aircraft of their presence. The average cell phone tower stands between 50 and 200 feet (roughly 15 to 60 meters), with some soaring hundreds of feet higher. Maintaining them is a demanding job that requires not only attention to detail, but also the guts to harness up and climb these huge structures.

Matt Edrich knows this all too well. He's the product manager for FieldSync, a data acquisition and analytics technology company, who climbs cell towers as part of his job. But while the wind-whipping experience of inspecting towers from bottom to top is a cherished part of the work, most of what Edrich does revolves around developing the next generation of geospatial tools and workflows for others to use while gathering streams of field data.

"At FieldSync, we're doing a lot of maintenance and conditioning reporting on telecom assets, mapping out cell phone towers for engineering purposes, and then sourcing parts to maintain all that infrastructure," Edrich said.

Given the size of cell tower sites plus the amount of information that needs gathering, traditional maintenance and conditioning reporting can easily take a team four to six hours of climbing, scribbling notes, and taking photos. That process, combined with sometimes hours of travel time between towers, can mean completing more than one site a day is often not in the cards.

With the help of geospatial technology used to collect and process this data—such as ArcGIS Survey123—that's changing. But just as integral to Edrich's process has been his involvement in Esri Community, which enables him to bounce ideas off other GIS professionals and develop more efficient workflows for cell tower maintenance.

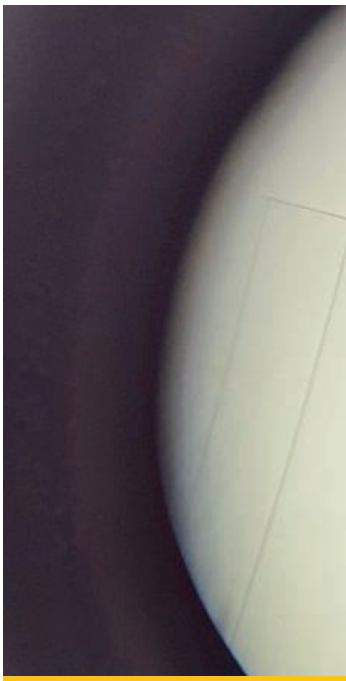
Transforming Telecom Data

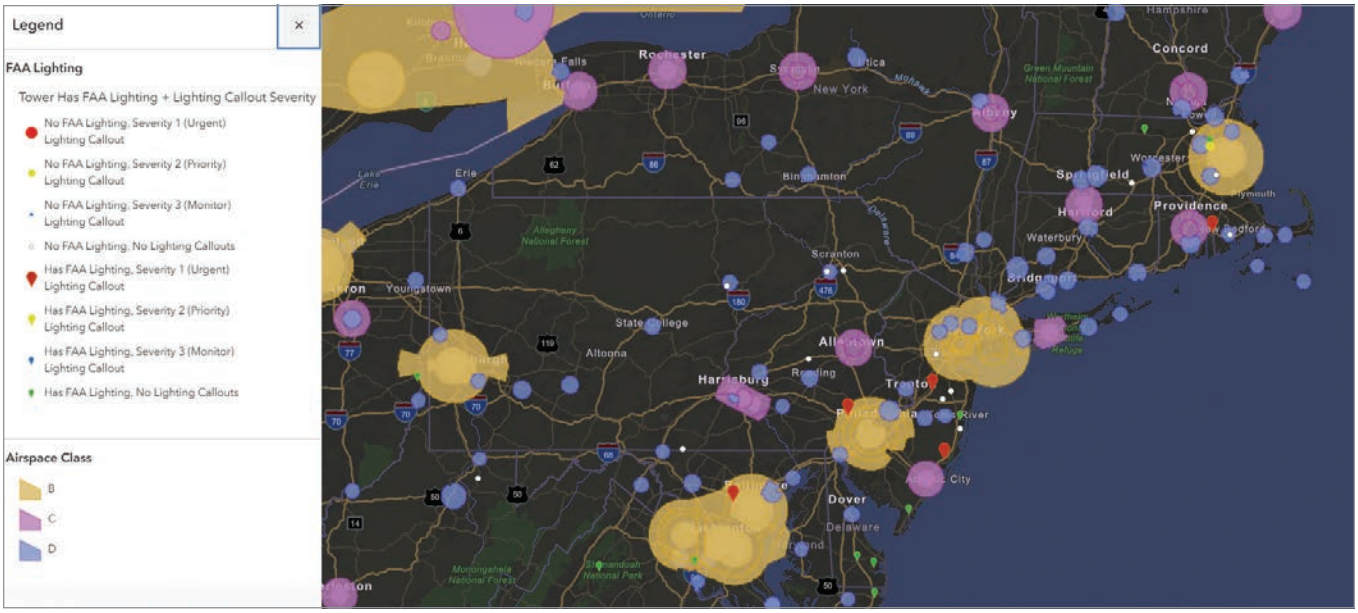
Edrich is constantly working to use GIS technology—including drones and devices that run ArcGIS Survey123 in the field—to change the way the company understands and maintains its structural assets. His goal has been to create a single workflow that starts with drone imagery, rather than data solely captured by climbers. This data is collected in ArcGIS Survey123 reports.

Streamlining this workflow has enabled Edrich to cut down on the time it takes to complete site reporting by about 75 percent.

"Using this process, I was able to complete a 500-foot-tall tower in 90 minutes, which is unheard of," said Edrich. "That kind of efficiency gain is not at all [common] in the industry."

The vastly reduced site-reporting time frame has allowed Edrich, along with other FieldSync staff, to use their time more efficiently and productively. Clients opting for climber-powered reporting over drone-enhanced services are still coming around to these kinds of efficiencies, as well as a degree of informed decision-making that was previously out of reach.



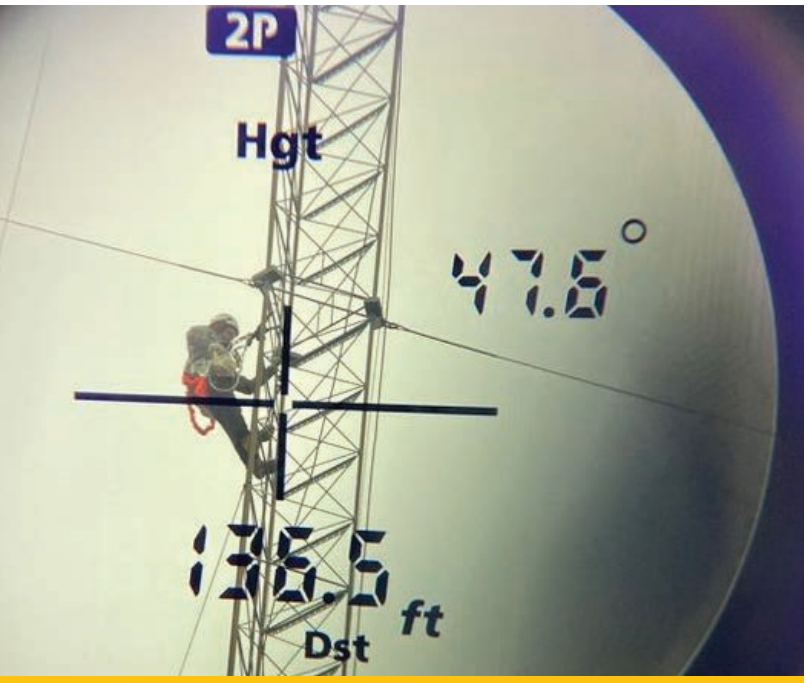


"You can have your data talk to itself and inform what your field technicians are doing and what they should do in the next five minutes because of what was done last month, which is not a thing in this little sector of telecom right now," said Edrich. "We consistently hear from our customers that we're changing what their expectations are for data on their towers, which is entirely possible because of ArcGIS Survey123. And the things you can do with ArcGIS Survey123, at least for us, were unlocked by Esri Community."

Finding Support and Camaraderie in Community

During the years Edrich has been involved with Esri Community, he has relied on the group-powered resource for a variety of needs.

"Almost everything I do right now is in ArcGIS Survey123," he said. "I'm looking in Esri Community to see if I'm doing things the best or the most controllable way."



Edrich relishes discovering he's not the only user trying to solve a particular challenge or track down a piece of information in Esri's expansive product documentation. Often, another user has already located some needed information or solved a tricky issue and shared their findings in Esri Community, saving him significant time and effort.

"You kind of realize you're at the edge of a sandbox," Edrich noted. "We can refine what we have now and consider other Esri products that can support this capacity or find workarounds that are not in this particular ArcGIS Survey123 software."

Edrich's experience collaborating with other ArcGIS users on Esri Community has led him to advocate for new capabilities through the ArcGIS Ideas Exchange. It's also led him to encourage others who might not be taking advantage of this resource to get involved.

"Just do it. As simple as that is to say, you learn the most by engaging with your peers and being honest about what you've tried and where your shortcomings are. I feel like a lot of people have this idea that they're going to get roasted because they don't know the answer to some question. That's never been the case," said Edrich. "It can help you expand your critical thinking process for how to solve problems."

About the Author

Jesse Cloutier is an Esri Community manager focused on engagement and content. His guiding ethos is that community—people coming together around shared purpose, demonstrating collective support, and collaborating in mutually beneficial ways—is the most powerful source of progress in the world.

↑ An ArcGIS Online map of New England created by Edrich displays colored polygons that indicate airspace classes. The smaller points indicate telecom tower lighting presence and condition.

← Matt Edrich climbing a cell tower, as seen through a rangefinder.

From "Street Economist" to GIS Professional

By Emmanuel Narteh Aklie

As an undergraduate majoring in economics and geography, I initially leaned toward economics as a future career path. Even before stepping into the world of GIS, I was passionate about managing resources to analyze and solve socioeconomic challenges in real time. I have always thought of myself as a "street economist," since I began to teach myself these skills before tackling them in a formal educational environment. But GIS has amplified my ability to analyze, visualize, and solve socioeconomic challenges in a spatial context, with location-based problem-solving. Finding my passion for spatial problem-solving has led me directly to where I am now in my geospatial career—a PhD candidate at Texas State University studying GIScience who has found success as a GIS professional.

After graduating from Ghana's University of Cape Coast in 2018, I began my compulsory one-year national service at the Ghana Lands Commission. There, I was introduced to property appraisal software while assisting as a land valuation apprentice and on-the-side land surveyor using AutoCAD.

After the onset of COVID-19, I asked myself what I could do to survive and support my family amid the ongoing effects of the pandemic. GIS provided a way to do both. Working with GIS is a skill that allows one to work remotely, solve spatial challenges, and connect other applications with spatial analysis. GIS became my calling, offering me both a purpose and a practical path forward.

Later, in 2022, I served as an assistant GIS utility officer at Ghana Water Company, where I was exposed to the ArcGIS technology that I now use regularly to solve spatial problems. This was the turning point—I was overwhelmed by how GIS tools could map solutions to real-world issues, and I felt a deep joy seeing the tangible results of my work.

Conferences and Connections

In my previous roles as a field officer, I enjoyed meeting clients face-to-face and solving their issues in real time. My ongoing GIS studies have been no different. Since moving to the USA, I have attended academic conferences hosted by several organizations. These include the Southeastern Division of the American Association of Geographers (SEDAAG), the American Association of Geographers (AAG) Annual Meeting, American Geophysical Union (AGU), the Esri User Conference, NASA's DEVELOP Day, and the Southwest American Association of Geographers (SWAAG). I have traveled to more than 12 states in the span of two years.

These conferences provided me with valuable opportunities to expand my GIS knowledge and connect with professionals in the industry. However, the experience that truly transformed my perception of GIS was being selected as a student assistant for the 2024 Esri User Conference in San Diego, California. This event opened my eyes to the immense possibilities of GIS. I met incredible professionals who suggested innovative ways to improve my work, which I approached with a revitalized mindset.

Another defining moment was attending AGU 2024 (AGU's Annual Meeting) in Washington, DC, an impactful showcase of science and geography. As someone passionate about spatial analysis, this was another reminder that GIS offers endless opportunities to make a meaningful impact. Whether it's understanding urban development, solving environmental issues, or improving access to resources, there is a niche for everyone in GIS—even a "street economist" from a place of limited resources like Ghana.

Practical Advice for Students and Young Professionals

One major factor that led to my quick progress in the field of GIS was looking for opportunities to attend conferences and seminars. In attending these valuable events and connecting with students, mentors, and industry experts, I have compiled some advice that will hopefully help someone else navigate their own GIS journey.

1 Build Your Network

Don't be shy. Attend conferences, workshops, and webinars. Speak to professionals and share your ideas. Opportunities often come through relationships and are frequently the conduit for opportunity.

2 Develop Transferable Abilities

GIS abilities, paired with skill sets in subjects such as economics, public health, or environmental science, are extremely important. I concentrate on learning technical skills, like geographic analysis, mapping, and programming (via Python for Everybody) through Esri massive open online courses (MOOCs), LinkedIn Learning, and YouTube, among others.

3 Be Adaptable

Careers are not necessarily linear. I began as an economist and discovered my interest in GIS via real-world experience. Be open to new directions.

4 Never Stop Learning

Make time to learn tools such as ArcGIS Pro, Python, and other geospatial technologies. Self-learning through books, online courses, and tutorials can help you stay ahead of the competition.

My journey has taught me that success is not just about where you start, but how you adapt, connect, and keep pushing forward. If you're looking to blend your passion with technology, GIS is the tool that can make it possible.

About the Author

Emmanuel Narteh Aklie is a PhD candidate at Texas State University studying GIScience, and has also worked at the Ghana Lands Commission and Ghana Water Company.

Building Digital Twins with the Help of Video Game Engines

By Brian Tomaszewski

Geospatial digital twins (GDTs) are a cutting-edge area of technological innovation at the intersection of 3D modeling and visualization, geospatial analytics, and real-time interaction. GDTs have all kinds of practical applications, including real-time monitoring of climate or weather, city planning, disaster response, and many others. Additionally, the emergence of generative AI is rapidly creating demand for computer programming skills often required to incorporate real-time data streams into GDTs—all of which makes it crucial to incorporate GDTs into GIS education.

At the Rochester Institute of Technology (RIT), the School of Interactive Games and Media (IGM) is one of the first Game Design and Development programs to fundamentally incorporate ArcGIS technology to teach students how to create geospatial digital twins.

"RIT's School of Interactive Games and Media is at the forefront of advancing practical knowledge in the creation and impact of living geospatial digital twins," said Rex Hansen, Esri's principal product manager for ArcGIS Maps SDKs for Native Apps and Game Engines. "By integrating Esri's industrial-grade GIS with game engines in its curriculum, RIT empowers students to develop immersive simulations grounded in real-world data and analytics."

Combining geospatial technology and data with video game engines is not a new idea, but it is becoming easier and more useful over time. The ability to visualize geospatial data in game engines can improve engagement, understanding, and decision-making in almost any industry by incorporating real-time data into virtual geospatial worlds.

"We quickly realized the potential that incorporating spatial reasoning and geospatial technology perspectives into game development had for broadening the possibilities of what is possible with game design," said David Schwartz, IGM's director. "It also is helping align our school's focus to contribute to the growing field of digital twins."

IGM wanted to reimagine how geospatial technology education could better prepare students for the rapidly changing landscape of GIS technology. Students would learn to create GDTs by integrating ArcGIS, computer programming languages such as Python, and generative AI. To that end, IGM redesigned a course that had been taught for several years called Spatial Algorithms and Problem Solving to use GDTs as an overarching learning outcome.

Although students in the class were from science, technology, engineering, and mathematics (STEM) backgrounds, many were unfamiliar with GIS technology or had only seen certain software products, such as ArcGIS Pro. Some students had extensive knowledge of computer programming but not necessarily in Python. Some students had no programming background at all. None of the students had ever taken a class that tackled such a wide range of technologies. Ultimately, they emerged with a better understanding not only of GDTs and other ArcGIS software, but also of how these technologies can affect outcomes beyond the classroom.

Technology Integration to Teach Geospatial Digital Twins

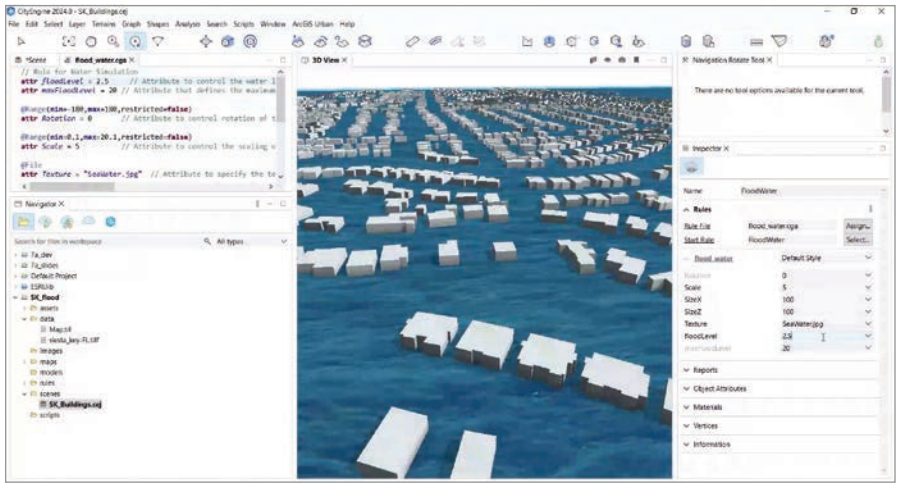
The technologies students were exposed to in the Spatial Algorithms and Problem Solving course ran the gamut from ArcGIS Pro to generative AI programs.

The students used ArcGIS Pro for spatial analytics and data management for a GDT as well as a general introduction to GIS. They were also instructed on the fundamentals of geospatial 3D data, and revisited ArcGIS Pro throughout the course to practice analytical techniques such as reclassifying rasters in the context of flood zones and spatial statistics like hot spot analysis.

ArcGIS Online, however, was primarily used to publish and host geospatial content that could eventually be brought into the ArcGIS Maps SDK for Unity plugin. Early in the class, students were taught about some of the very specific types of online data layers that are used in the ArcGIS Maps SDK for Unity plugin, such as image tile layers and 3D objects scene layers, which were unfamiliar to many of the students.

Students also used ArcGIS CityEngine for rapid procedural modeling and generation of city environments to form 3D models for a geospatial digital twin. ArcGIS CityEngine is a particularly complicated software without a background in 3D modeling and procedural generation. Therefore, the class took full advantage of free ArcGIS CityEngine tutorials available through the software and online. During the semester the course was taught, Hurricane Helene struck Florida. This provided an opportunity for the class to use ArcGIS CityEngine to simulate floodwater rising in Florida. They also implemented some introductory Computer Generated Architecture (CGA) scripts to see how this technology could work to create a GDT that could be used during a hurricane.

The class used ArcGIS Maps SDK for Unity to take advantage of video game engine interaction and modeling capacities. The course has used this plugin for years, and it becomes more accessible and easier to use each year, especially with students who do not have a background in game development. However, it is still a robust game development and game engine software that



↑ Students used Hurricane Helene as a case study for procedural generation and CGA rule modeling of floodwater to learn about geospatial digital twins.

can be challenging to learn. For this aspect of the course, students used existing Esri tutorials to help document the basic process for getting geospatial content into a game engine environment using the map Creator UI component.

Finally, students were instructed on the basics of Python and ArcPy for large data processing. They were also introduced to ChatGPT and prompt engineering to develop scripts supporting the creation of a GDT. While a GDT can theoretically be created without programming, incorporating real-time data feeds and advanced functionalities necessitates diverse coding approaches, including CGA scripting in ArcGIS CityEngine for procedural generation, Python scripting in ArcGIS Pro for data analytics, and C# scripting for creating Unity game environments.

Lessons Learned

For the most part, students were able to incorporate all these technologies into one workflow to create a GDT for both a midterm assignment and a final project. For the midterm, they were instructed to procedurally generate a 3D model from an area of interest in Florida after Hurricane Helene, publish the CityEngine 3D model to ArcGIS Online as a 3D scene layer, run a storm surge analysis and visualization of the area of interest in ArcGIS Pro, and incorporate the 3D model as 3D scene layers into Unity using the ArcGIS Maps SDK for Unity plugin.

Students also practiced using ChatGPT to extract subsets of extensive traffic volume data from New York City, generate hotspots using Python and ArcPy, and implement their work in the Visual Studio (VS) Code environment. Some students became frustrated when the AI would return results that were not working exactly as expected, and they could not troubleshoot erroneous Python code produced by the AI. Some students even reported getting in "fights" with the AI when it would not yield the desired results.

However, others were successfully able to generate ArcPy Python code that enabled them to complete the workflow. Many students attempted to create CGA scripts using generative AI and were often left frustrated that they could not get ChatGPT's CGA code to work in CityEngine.

The final project was a testament to the power of integrating these technologies, and of the work GDTs can do outside the classroom. Students were free to develop a GDT project that would incorporate several of the technologies.

Game Design and Development students Luke Lepkowski and Isaac Settle developed a GDT to visualize real-time and historical weather and cloud conditions, making radar and cloud maps more accessible and intuitive. The system updates hourly using Python workflows to process .grib2 radar and cloud data, along with an archive resource for historical data going back to December 2021. The ArcGIS Maps SDK for Unity plugin with capacities of the High Definition Render Pipeline (HDRP) of Unity integrated the processed data, creating an interactive, real-time weather visualization tool.

"By combining Esri's ArcGIS Maps SDK for Unity's user-friendly mapping and coordinate tools with Unity's volumetrics system and VFX Graph for clouds and rain, we could integrate numerous datasets into a more cohesive and immersive digital twin than we ever imagined," said Lepkowski.

GDTs offer an exciting opportunity to leverage various geospatial technologies to create engaging and transformative educational experiences. As this field evolves, its integration with generative AI and video game engines will play a pivotal role in addressing critical societal challenges, such as disaster response. By combining geospatial technology with game design and development education, we can foster interdisciplinary collaborations that inspire innovation and shape impactful solutions for the future.

About the Author

Brian Tomaszewski, Ph.D, is a professor at the Rochester Institute of Technology and a geographer specializing in GIS, with a strong focus on international research. His work, supported by the US National Science Foundation, Fulbright, and other funding sources, explores GIS applications in humanitarian crises, disaster response, and spatial data science, advancing global understanding of geospatial technologies.

Canines Clear Minefields with GIS

By Jim Baumann

Land mines and other explosive ordnances (EOs) are notoriously easy to manufacture and conceal. In addition, they are difficult to detect and remove, even when conflicts involving their use have died down. They not only hamper economic recovery and development in war-affected areas, but can also cut communities off from basic necessities, such as water and food supplies.

↑ Readying dogs for land-mine detection is an arduous process that takes months of extensive training.

→ The APOPO Technical Survey Dog Dashboard features detected explosive ordnance locations and daily progress. This dashboard supports strategic decision-making and reporting, facilitating the return of safe areas to mine-affected communities after clearance.

The Mine Ban Treaty, an international agreement prohibiting the use of antipersonnel land mines, was enacted in 1997, but according to Morgan Kline, roughly 60 million people in 70 countries still live with a daily risk of landmine detonation.

Kline is the global information systems manager at Anti-Persoonsmijnen Ontmijnende Product Ontwikkeling (APOPO), a Tanzania-based organization that trains animals—primarily rats and dogs—to assist in tuberculosis outbreaks, initiatives to thwart illegal wildlife tracking, search and rescue operations, and, of course, land-mine detection.

"Our GIS-centric management for this lifesaving work has helped return more than 100 million square meters of previously contaminated land to local communities," she said.

This work relies heavily on software such as ArcGIS Field Maps and ArcGIS Pro to track dogs' movements and range of scent detection in a minefield. While APOPO has employed Esri technology since 2019, the organization has been expanding its capabilities to include tracking of the dogs' physical condition and the impact of minefields on agricultural development using ArcGIS Dashboards.

Training and Implementation

APOPO began operations as an R&D facility in 1997, after obtaining grants from the Belgian government. Initially, the organization trained Gambian pouched rats as scent detectors for land mines. Later, they added both Belgian and Dutch Shepherd dogs to their detection resources.

"Training a dog for land-mine detection is a fairly complicated process," said Kline. "It takes between nine and twelve months and includes search path training—continuous search in a 25-meter lane through obstacles—and indication training—the exposure to explosive targets."

The use of mine-detection dogs began during World War II. The training of both the dogs and their handlers was an extensive process that lasted several years. Those responsible for removing EOs had to

first learn how to best develop a canine's skills for detecting a buried item with very little scent that reached the surface. A dog's natural keen sense of smell and the capability to quickly examine large swaths of uneven terrain are a good start, but need to be honed over time.

As part of APOPO's training process, the dogs are also exposed to nontargeted items, known as discrimination training, and taught to work in changing environments.

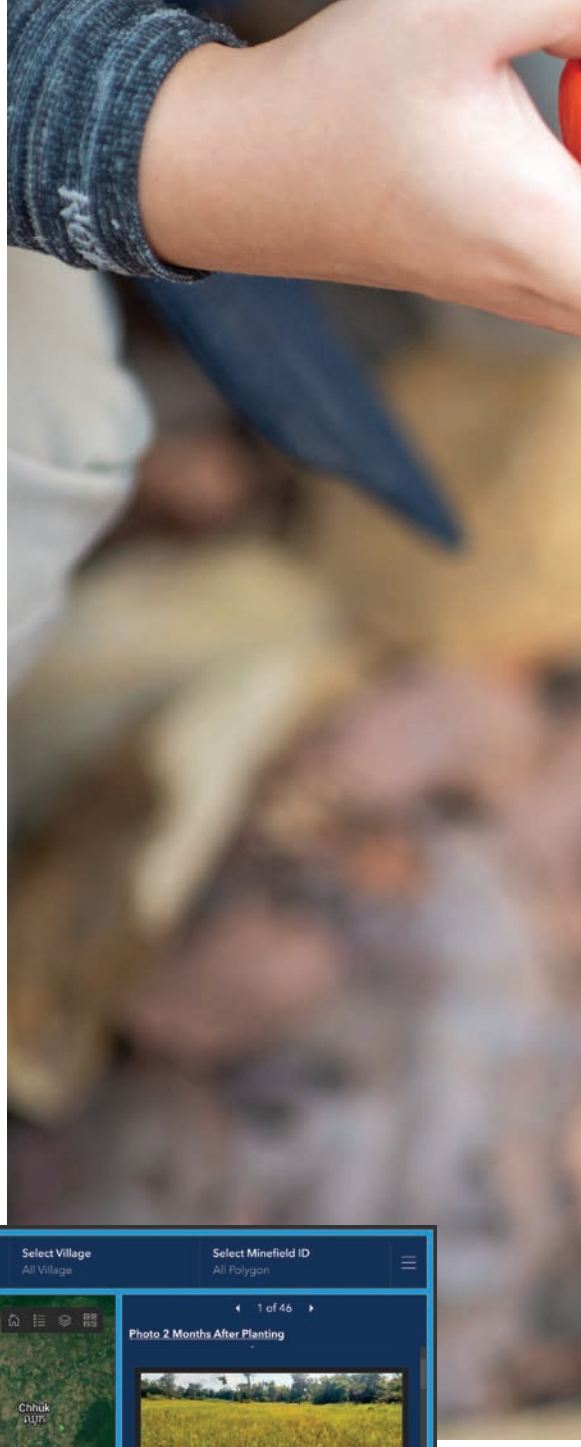
Today, APOPO uses both rats and dogs in their operations, although dogs are primarily used for mine detection. The animals complement each other in their detection efforts because of their relative size and capabilities. Canine breeds, for example, function better in dense foliage and are less susceptible to extreme temperatures than their rat counterparts. The trained animals and their handlers are in high demand and currently work in Ukraine, Cambodia, Angola, Azerbaijan, Turkey, South Sudan, Senegal, Argentina, and Zimbabwe.

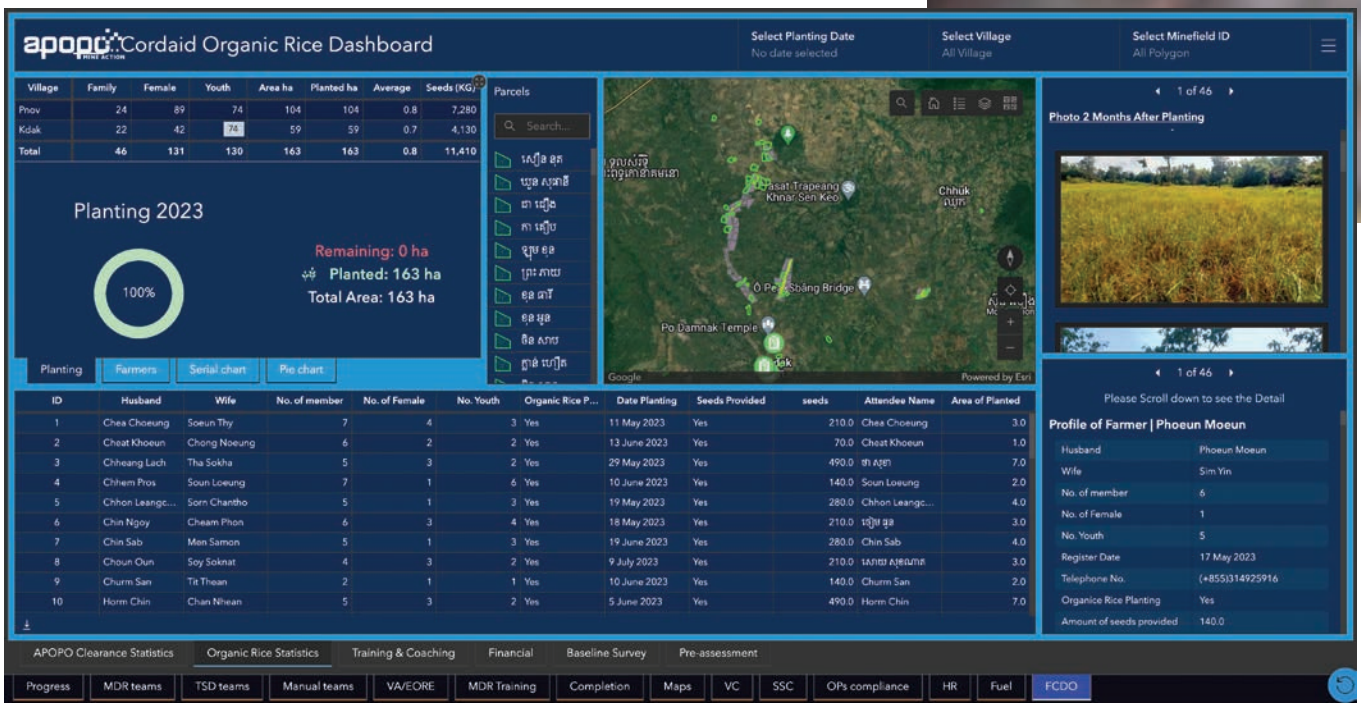
APOPO uses its canines mainly for technical survey, a key phase in confirming the presence or absence of land mines, and eventually determining the extent of the contaminated areas.

For track and trace operations, dogs are fitted with Garmin T5 collars, which collect GPS Exchange Format (GPX) files. These files are then converted to a polyline in ArcGIS Pro. A buffer is created around the line, indicating both the animal's movements through the minefield and its range of scent detection. An analysis of the polyline's characteristics determines whether there are EOs on the land, or if it can be used by local residents.

Information about a dog's exploration of a designated area is presented in a dashboard created with ArcGIS Dashboards for analysis. This includes data from an ArcGIS Survey123 form, which records the animal's daily progress, as well as EOs and other items it discovers. In addition, search obstructions and additional geographic features are recorded in ArcGIS Field Maps to complete the collection of data.

The ArcGIS environment allows APOPO to track the dog's metrics, such as how long it works, when it signals a find, what explosive items it detects, and how many meters it covers. These working attributes for each dog are displayed via widgets in ArcGIS Dashboards. Mobile workers verify the results before EO clearance begins.





↑ APOPO relies heavily on ArcGIS technology to track dogs' movements and range of scent detection.

← APOPO's Minefields to Rice Fields Dashboard showcases key data on areas impacted by land mines, the progress of mine detection rat operations, and farms made safe again for agriculture.

An Ongoing Process

APOPO continuously introduces new uses for ArcGIS technology. Recently, the organization added a health and welfare component to its GIS, allowing APOPO to track the location and well-being of each dog.

"With more than 300 working animals in the organization, ensuring the wellbeing of the animals is our primary concern," said Kline. "Using Esri's geospatial environment helps us monitor key components of our work and ensure compliance with the Government Accountability Office Working Dog Health and Welfare Act."

Also top of mind is a project multiple years in the making called Minefields to Rice Fields. Created with ArcGIS Dashboards, this dashboard tracks agricultural development alongside land-mine clearance activities with map overlays used to correlate the farmland cleared for selected planting.

APOPO has employed a rigorous registration system for those farmers participating in the program. Farmers are assigned QR codes used to validate their attendance at training and coaching sessions. APOPO also records the income earned by each

farmer through participation in the project, allowing direct tracking of the program's return on investment.

The work of the organization, its animals, and their handlers directly contributes to the safety and economic security of war-affected areas around the world, whether it is in the act of clearing mines or ensuring that the land is still viable after the fact.

"APOPO's management team collectively represents more than 100 years of experience in humanitarian mine action," said Kline. "We know what we want to see in our operational dashboards, what we want to highlight externally, and what we want to record and report. Our Esri-based reporting system allows for all of this and more."

About the Author

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

↑ For track and trace operations, dogs are fitted with Garmin T5 collars which collect GPS Exchange Format (GPX) files that are then processed in ArcGIS Pro.

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As a student in the School of Business & Society Master of Science in Business Analytics (MSBA) program, Owen Giron built lasting connections with his Redlands Professors —James Pick and Avijit Sarkar—who have become "incredible mentors." Now the trio are working together on a research project using GIS (geographic information systems) to study the global digital divide and artificial intelligence (AI) readiness in 137 countries.

Through this research, Owen has gathered global perspectives to discern how other countries view AI, how the technology impacts company ethics, and if leaders are ready to align the innovative software with the mission, vision, and values of an organization. The research goal is to illustrate how AI is shaping the future of education and the workplace.

"Professors like Avijit Sarkar and James Pick are the reasons why I am excited to learn and why I strive to help others in my journey both academically and professionally. Prospective students can expect mentorship while at the University of Redlands."

— Owen Giron '23 MSBA

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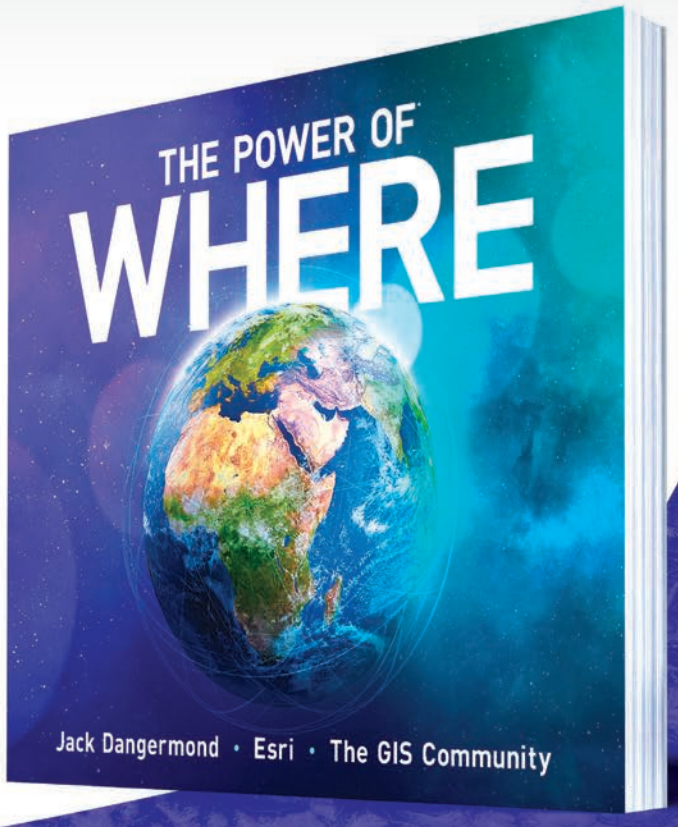

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