Geospatial Problem Solving

Web GIS

Image from NASA: https://commons.wikimedia.org/wiki/File:Earth_Western_Hemisphere_transparent_background.png#filelinks

In this module, we will introduce web GIS. Web mapping and web apps have become a powerful means to collect and share data. Note that we have an entire course available on the West Virginia View webpage associated with web GIS title *Client-Side Web GIS*. These slides were taken from that course. Here, we primarily focus on (1) how the web works, (2) ArcGIS Online, and (3) web data models.

Module Topics

1. How the web works
2. ArcGIS Online
3. ESRI web app creation tools
4. Geospatial data for the web

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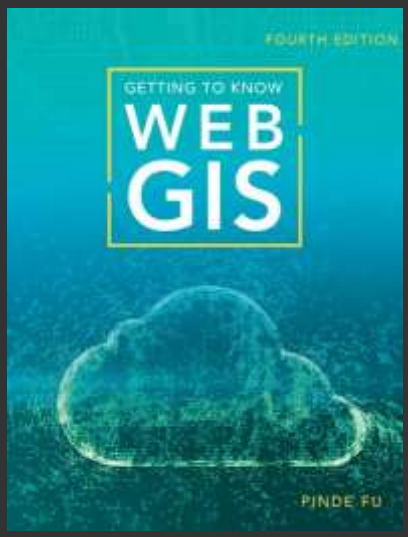
These are the topics covered in this module.

Book Recommendation

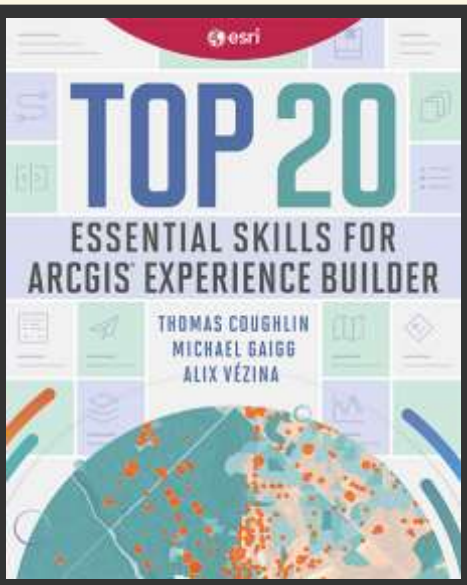


https://www.esri.com/en-us/esri-press/browse/getting-to-know-web-gis-fourth-edition

3

Before we get started, I wanted to provide some recommendations and links to additional resources. If you are interested in learning more about ArcGIS Online, I would recommend the “Getting to Know Web GIS” text by Fu.

Book Recommendation



Top 20 Essential Skills for ArcGIS Experience Builder

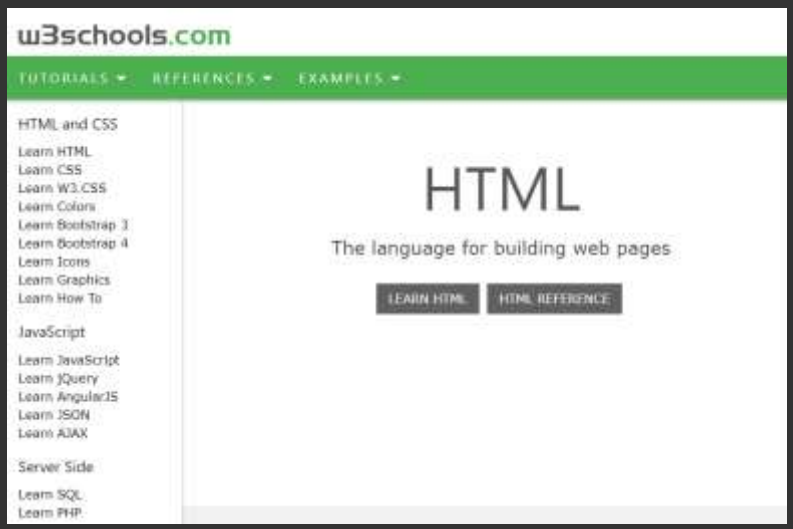
By Thomas Coughlin, Michael Gaigg, and Alix Vézina

- Design and create visually stunning and highly functional map apps with *Top 20 Essential Skills for ArcGIS Experience Builder*.

4

If you are interested in a book focused on Experience Builder, I recommend the text referenced on this slide and published by ESRI Press.

Learning to Code



https://www.w3schools.com/

5

If you are interested in learning languages for web development and web GIS, I would recommend w3schools.com.

Book Recommendation

https://www.oreilly.com/library/view/html-css/9781118206911/

https://www.oreilly.com/library/view/javascript-and-jquery/9781118531648/

https://www.wiley.com/en-us/PHP+%26+MySQL%3A+Server+side+Web+Development-p-9781119149217

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This book series is a great resource if you want to learn web development.

How the Web Works

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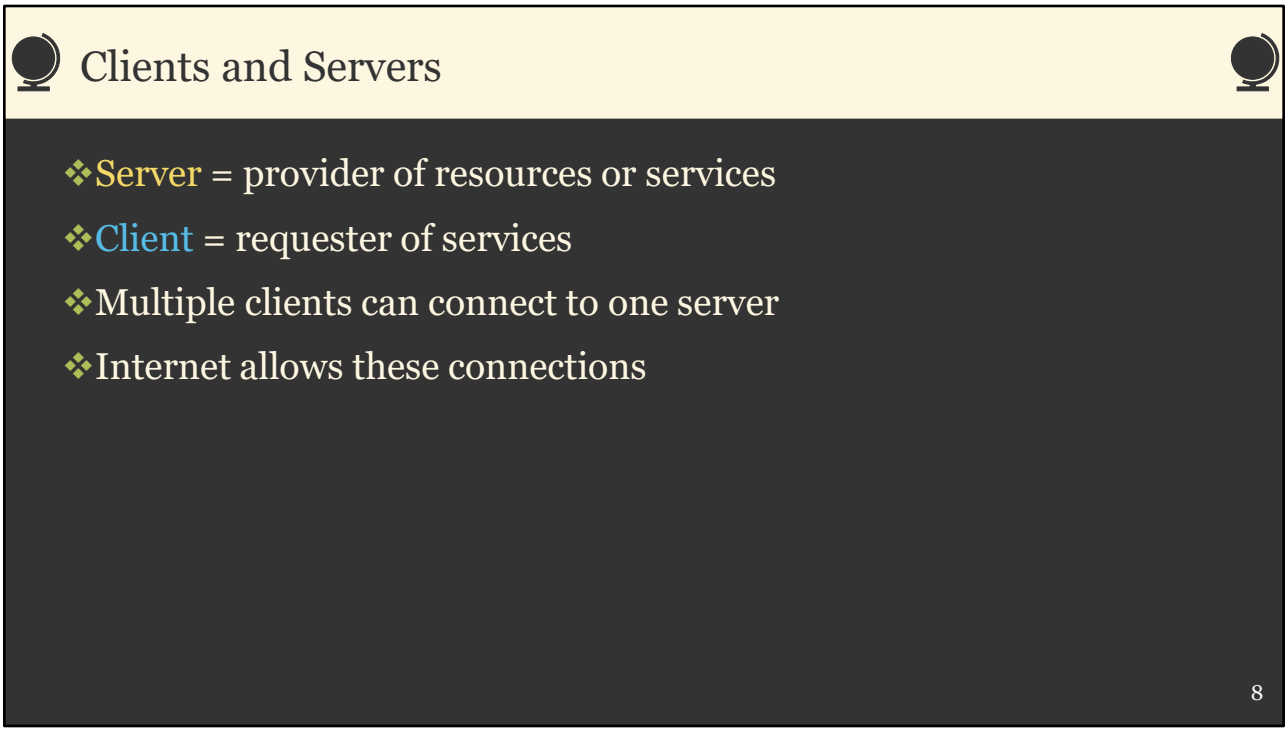
Let's get started by exploring how the web works.



The internet consists of computers and other devices that are connected remotely to form a network.

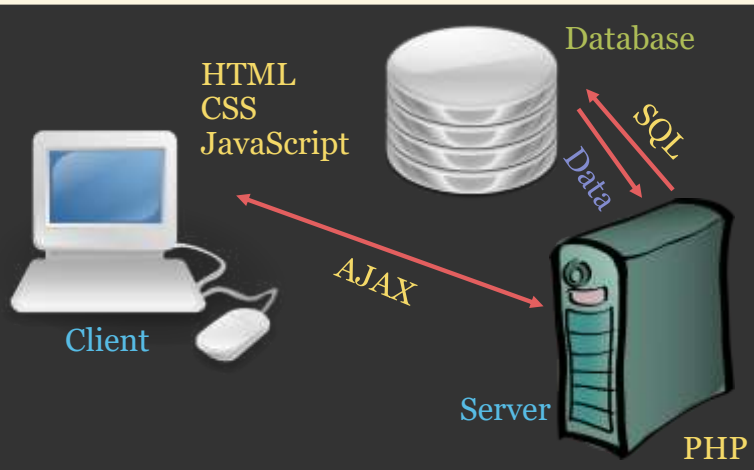
Within this network, servers provide resources and services while clients request these services.

It is possible for multiple clients to access or connect to one server using the internet.

In order to transfer information and perform tasks, protocols have been established for standardization.

Client-Server Architecture

- Client = computers, tablets, phones, etc.
- Multiple clients can interact with one server
- Client requests data from server
- Server processes request and returns result
- Client does something with result



https://commons.wikimedia.org/wiki/File:Oxygen480-places-server-database.svg

https://commons.wikimedia.org/wiki/File:Scribley_PC_clip_art.png

By OpenClipart - OpenClipart, CC0, https://commons.wikimedia.org/w/index.php?curid=721320

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Client devices are those that request information from a server and can then do something with this information, such as render a webpage or view data from a database. Client devices include personal computers, tablets, phones, etc. Multiple clients can request data from the same server simultaneously.

Servers process requests from clients and return information, such as the information needed to render a webpage or data from a database.

A variety of computer languages are used on the client device, generally termed client-side technologies. These include hypertext markup language (HTML), cascading style sheets (CSS), and JavaScript.

It is common for different technologies and languages to be used on the server-side. For example, structured query language (SQL) can be used to access data from a database.

Although we commonly think of clients and servers as computers, they are really software, as a traditional desktop computer can act as a server with the correct software installed.

Client-Side Web Languages

- HTML (Hypertext Markup Language) = used to create the basic structure and content of a webpage

https://www.w3schools.com/html/default.asp

- CSS (Cascading Style Sheets) = used to design the webpage (where everything is placed and how it looks)

https://www.w3schools.com/css/default.asp

- JavaScript = define the interactive elements of a webpage that helps to engage the users

https://www.w3schools.com/js/default.asp

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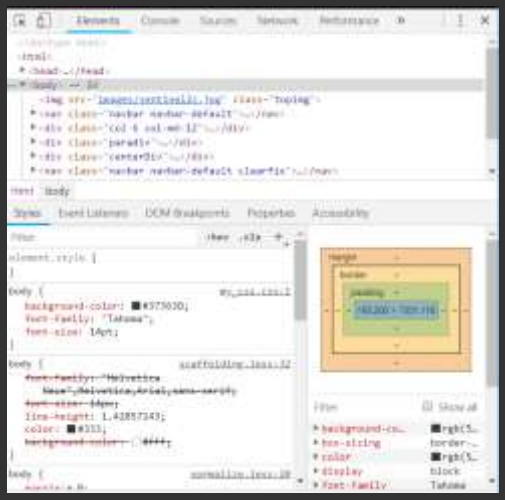
Hypertext Markup Language (HTML) is used to define or build the content of a webpage. For example, it is used to define text, images, lists, links, and additional content on a webpage. Currently, we are using HTML5, the most recent iteration of the language.

Cascading Style Sheets (CSS) are used to define the styling of the webpage, such as fonts, font size, colors, and layout. It is also used for responsive web design, which entails the layout of the page changing based on the screen size. This is how a website can function on screens of variable sizes. Given the wide variety of devices we currently use to access web content, this is extremely important.

JavaScript is a programming language that allows for interactive content. For example, clicking a button on a webpage causes something to happen, such as data from a form being uploaded or the page content changing. JavaScript is also used to generate interactive web maps (for example, the ArcGIS Maps SDK for JavaScript and the Leaflet JavaScript API). APIs will be explained in a later slide.

The DOM

- DOM = Document Object Model
- HTML is parsed by the browser to create the DOM
- Attempt to convert the structure and content of the HTML document into an object model represented as a node tree
- Browser uses this model to render the webpage



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A web browser (Chrome, Firefox, Edge, Internet Explorer, Safari, etc.) is able to receive information from a server (for example, HTML, CSS, and JavaScript) to render a webpage.

To complete this task, the browser will need to generate a Document Object Model (DOM) from the data. I like to think of this as diagramming a sentence. The HTML is converted into a node tree to represent the components of the page and their interrelationships. This model is then rendered to generate the page.

You can think of this as the process of creating a conceptual model from the code that is used to render the actual page. If there is an error in the code, then the DOM may not be generated as intended, which can result in problems with the webpage.

Later in this course, we will use JavaScript to manipulate the DOM and change the page content or styling.

What is an API?

- API = Application Programming Interface
- Allow software to interact with each other
- Provide code, functions, and classes that can be used to complete a task on the web

```
<link rel="stylesheet"
href="https://unpkg.com/leaflet@1.9.4/dist/leaflet.css"
integrity="sha256-p4NxAoJBhIIN+hmNHrzRCf9tD/miZyoHS5obTRR9BMY="
crossorigin="" />

<script src="https://unpkg.com/leaflet@1.9.4/dist/leaflet.js"
integrity="sha256-20nQCchB9co0qIjJZRGuk2/Z9VM+kNiyxNV1lvTlZBo="
crossorigin=""></script>
```

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An Application Programming Interface (API) is a set of rules, functions, and tools that allows one piece of software to interact with another.

APIs provide predefined code and procedures that developers can use to perform specific tasks without needing to write the underlying functionality from scratch.

For example, the Leaflet JavaScript API provides functions and classes that allow developers to create interactive web maps.

APIs have many uses and can be thought of as libraries of code and tools that allow programs to access data, process information, or generate content.

Web 2.0

Websites that emphasize:

- User-generated content
- Usability (ease of use, even by non-experts)
- Interoperability (this means that a website can work well with other products, systems, and devices) for end users

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Web 2.0 is the concept of making the web user-friendly for compatibility and the production of user-generated content.

As GIS professionals, we have embraced this concept to create interactive web maps and make our data and maps more accessible.

Volunteered Geographic Information (VGI)

- Allows users to edit geospatial data using a mobile or web interface
- Users will edit the data made available by the feature service

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Volunteered geographic information (VGI) relates to collecting geospatial data and information from volunteers or the general public. Examples include the Waze app for collecting traffic data and OpenStreetMap for digitizing geospatial data.

Web GIS technologies have greatly improved our ability to collect VGI data using web pages, web maps and apps, and mobile apps.

Location-Based Services (LBS)

- Use real-time geospatial data from a mobile device or smartphone to provide information, entertainment, or security
- Since smartphones are GPS enabled, your location information can be integrated into the apps

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Location-based services relate to using your location information to locate yourself and your device and collect spatial location information. This is how a phone app knows your location: it has access to your GPS data if enabled.

Location-based services have been well integrated into mobile apps and can enhance and simplify the user experience.

ArcGIS Online

ArcGIS Online

- Allows you to create maps and apps and host content for use on the Web

https://www.arcgis.com/home/index.html

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I will now introduce the ArcGIS Online platform, which provides web mapping capabilities and is produced by ESRI.

ArcGIS Online

- Created by ESRI
- Integrated with ArcGIS Pro
- Can obtain a free account with limited access
- Can pay for an account and use more advanced functionality
  - Organization accounts
  - Allotted credits

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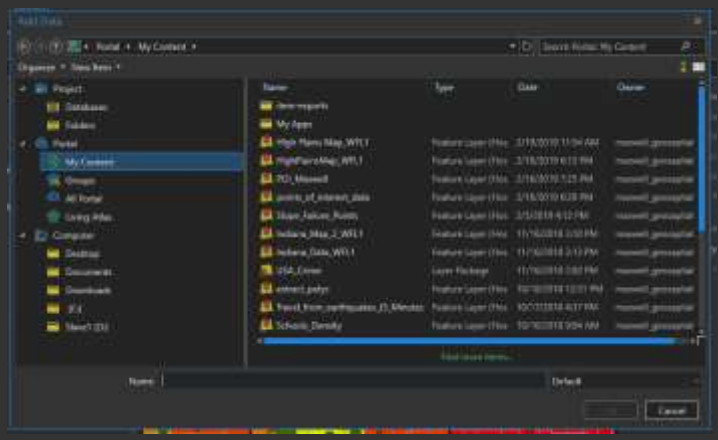
ArcGIS Online is an ESRI product that is well integrated with ArcGIS Pro.

You can obtain a free ArcGIS Online account with limited capabilities. Paying for an account will provide more robust functionality.

It is also possible to set up organizational accounts to allow for collaboration, licensing, and the sharing of content. For example, at West Virginia University we have an organizational account that can be used by our faculty, staff, and students if they are provided with a user account and invited to join.

Seeing your ArcGIS Online Content in ArcGIS Pro

- Must be logged in
- Available under Add Data → Portal → My Content



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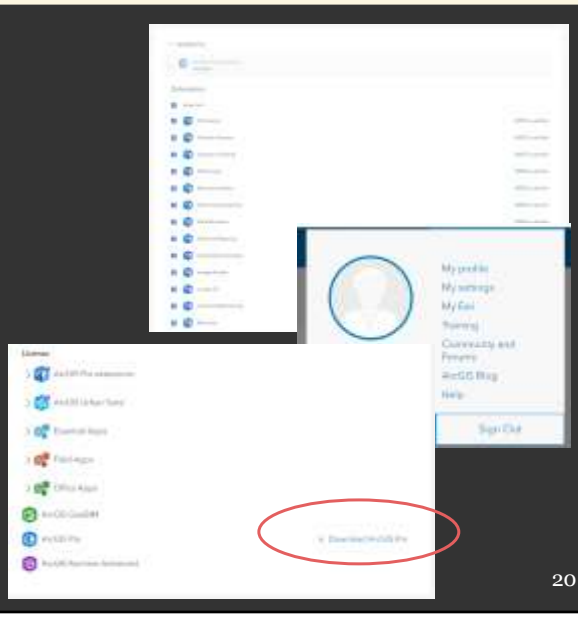
If you are logged into ArcGIS Online within ArcGIS Pro, you will be able to access your online content within the desktop application.

Your online content will be available under Portal followed by My Content. You may also have access to data shared with you via your organizational account and/or the Living Atlas.

Licensing ArcGIS Pro with ArcGIS Online Account

- Administrator can allow access to ArcGIS Pro for specific user accounts (GIS Professional user type)
- Can also provide access to extensions and other ESRI apps
- Can download ArcGIS Pro from ArcGIS Online once logged in
  - Click on your username
  - Select My settings
  - Navigate to Licenses



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ArcGIS Online can also be used to provide licensing for the ArcGIS Pro desktop software. If your account is tied to an organization, the administrators of the organization account can grant access to ArcGIS Pro to specific users. The GIS Professional user type will have access to ArcGIS Pro by default.

Administrators can also provide access to ArcGIS Pro extensions such as Spatial Analyst, Network Analyst, 3D Analyst, and Image Analyst.

Note that licensing agreements with ESRI generally limit the number of users that can have access to ArcGIS Pro and specific apps, so administrators may have to limit access to those that need the software or extensions.

If you have been granted access to ArcGIS Pro via your ArcGIS Online organizational account, you can download the installation file on the ArcGIS Online page once logged in by clicking on your username, selecting My settings, and navigating to License. The download file should be available to the right of the ArcGIS Pro logo.

User Types

- Viewer = allows member to view items that have been shared with them by other ArcGIS Online users.
- Editor = allows member to view and edit items that have been shared with them by other ArcGIS Online users.
- Mobile Worker = allows member to view and edit items that have been shared with them by other ArcGIS Online users with a primary focus on field apps.
- Creator = allows member to view, edit, create, and share content.
- GIS Professional = allows member to view, edit, create, and share content. Member also has access to the ArcGIS Pro desktop application.

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Your rights and capabilities on ArcGIS Online are governed by your User Type. For example, a Creator is able to view, edit, create, and share content within the organization and to the general public. Your User Type will be defined by your organization administrators. Read through the examples on this slide to understand the differences between user types. Note that ESRI often updates the available user types or their associated names.

Roles

- Viewer = allows member to view items that have been shared with them by other ArcGIS Online users. The member will also be able to join groups within the organization.
- Data Editor = allows the member to view and edit data. The member will also be able to join groups within the organization.
- User = allows member to view items that have been shared with them by other ArcGIS Online users. Users can also create maps and apps, edit features, add items, share content, and create groups.
- Publisher = allows member to have all the privileges of users plus the ability to publish features and map tiles as hosted web layers.
- Facilitator = publisher privileges plus the ability to invite partnered collaboration members to groups. This includes the privilege to create and manage partnered collaboration groups, invite members from another organization into groups, and create shared update groups.
- Administrator = allows member the same privileges as publishers plus the ability to manage the organizational account and other users.

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You can also be assigned a role within your organization. Different roles are described on this slide.

General Steps for Making a Web App using ArcGIS Online

1. Find, prepare, publish, and/or create required layers/data
2. Configure layer(s) for editing if necessary
3. Create a web map or scene
4. Configure web map or scene
5. Add layers to map or scene
6. Edit layer symbology and/or visibility
7. Configure or disable pop-ups
8. Choose an app generation method
9. Configure and save app
10. Test app
11. Edit/update as needed

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This slide outlines the common steps used to generate a web map and associated web apps using ArcGIS Online and associated technologies.

Maps vs. Scenes

- Map = 2D projected map (generally uses Web Mercator)
- Scene = 3D scene of a 3D globe

Image from ArcGIS API for JavaScript

Image from ArcGIS API for JavaScript

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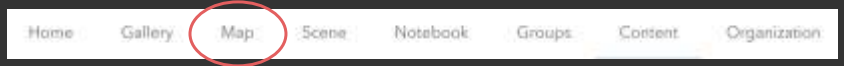
Web maps are designed to represent your data in a 2D projected map space, generally Web Mercator.

In contrast, scenes allow for data to be displayed on a digital globe using 2D or 3D symbology.

Create a Map

- Log into ArcGIS Online (https://www.arcgis.com/index.html)
- Click on Map
- Click Save and Open Icon
- Save as
- Provide title, save location, tags, and summary
- Click Save



*I highly recommend using subfolders to organize your content.

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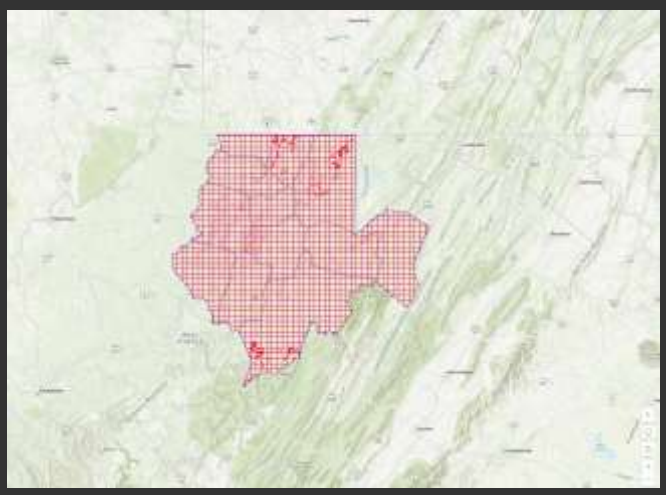
Before generating a web app, you will need to create a web map. This can be accomplished in ArcGIS Online by selecting Create within the Content section. Alternatively, you can create a map using the Map tab, which opens the Map Viewer, then save the product to your Content.

When you generate a map, you will need to provide a unique title and some tags to make it searchable.

You can also provide a summary and save the map to a subfolder in your Content.

Create a Map



- Map designed to be viewed in web browser
- WGS84 Web Mercator projection used

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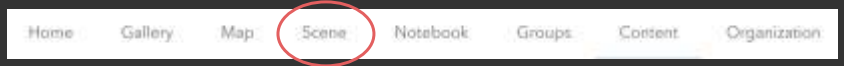
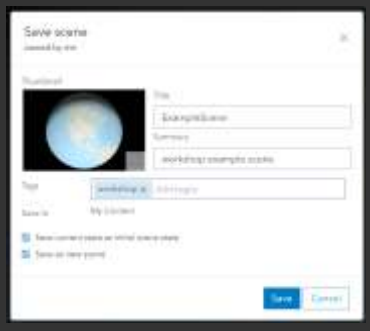
Web maps make use of the WGS84 Web Mercator projection.

Create a Scene

- Log into ArcGIS Online (https://www.arcgis.com/index.html)
- Click on Scene
- Click Save and Open Icon
- Save as
- Provide title, save location, tags, and summary
- Click Save





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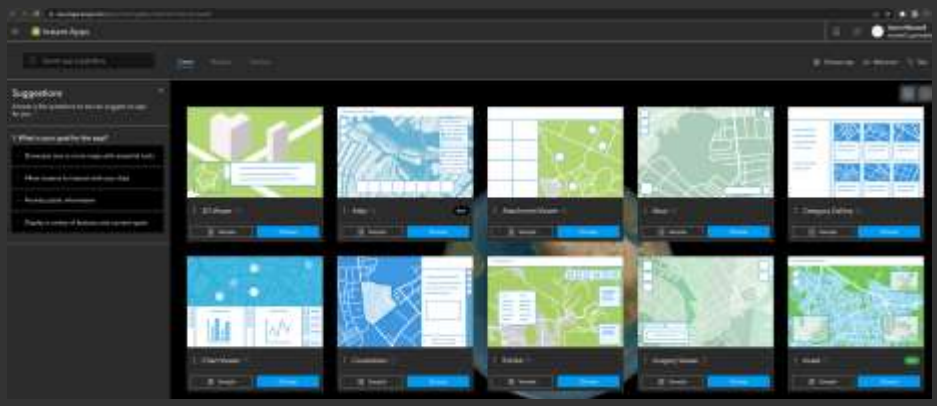
You can also generate web scenes using ArcGIS Online. Scenes are viewed and created under the Scene tab. Similar to maps, they are saved as items to your ArcGIS Online content.

Presenting Your Data

- Instant Apps = pre-made applications that you can load your layers into

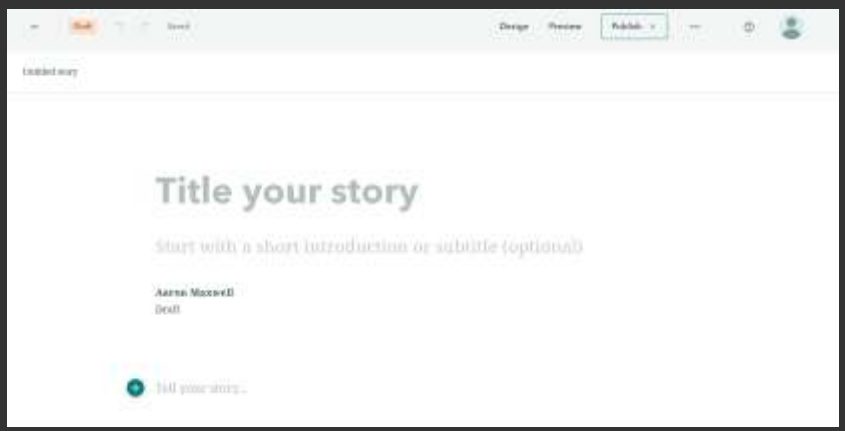


28

ArcGIS Online provides many options for generating web apps. For example, Instant Apps allow you to configure a template. These are generally easy to set up and deploy; however, customization is limited.

Presenting Your Data

- ArcGIS Storymaps = configurable apps designed for developing narratives using maps, text, and media



29

ArcGIS Storymaps are a type of Instant App that allow you to build webpages with a variety of content including text, maps, media, and links. These are generally easy to use, edit, and configure. You can even use them to build webpages without any maps.

Presenting Your Data

- Dashboards = focused on data visualization and data insights

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Dashboards are used as a means to monitor data. These apps are more focused on data as opposed to maps.

Presenting Your Data

- ArcGIS Experience Builder = web-based tool for generating multi-page websites that do not need to be centered around a map

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ArcGIS Experience Builder offers more customization than the Configurable Apps. It is a tool to generate multipage websites with a variety of content. You don't even need to include geospatial data or maps; you could design an entire webpage without any maps or geospatial data or design pages with lots of maps. All this can be done without any coding.

Presenting Your Data

- ArcGIS Maps SDK for JavaScript = offers fully customizable web maps and apps (requires coding)

https://developers.arcgis.com/javascript/

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The ArcGIS Maps Software Development Kit (SDK) for JavaScript allows for the generation of interactive web maps using JavaScript. It allows for a high level of customization; however, the user must have an understanding of the JavaScript coding language.

At the time of this writing, the ArcGIS Maps SDK for JavaScript is in version 5.0.

ArcGIS Enterprise

- Not hosted by ESRI
- Hosted by user on a physical or virtual server

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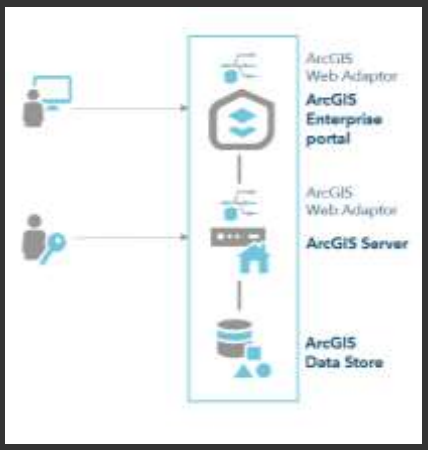
A key difference between ArcGIS Enterprise and ArcGIS Online is that the user hosts an ArcGIS Enterprise instance on their own physical or virtual server as opposed to using ESRI's hardware.

ArcGIS Enterprise Components

- Portal for ArcGIS = front-end web GIS interface (like AGOL but runs on users' infrastructure)
- ArcGIS Server = GIS engine that processes and publishes services
- ArcGIS Data Store = managed databases
- ArcGIS Web Adaptor = Connects ArcGIS Enterprise to user web server



https://enterprise.arcgis.com/en/get-started/11.4/windows/what-is-arcgis-enterprise-.htm

There are several components to ArcGIS Enterprise, which are briefly described on this slide.

Leaflet

- JavaScript library for interactive web maps
- Client-Side

Leaflet

https://leafletjs.com/

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The Leaflet JavaScript library is a free and open-source alternative to ESRI products and the ArcGIS Maps SDK for JavaScript specifically.

Server-Side

- GeoNode (~Portal)
  - User authentication
  - Data catalog
  - Map sharing
  - Metadata management
  - Group permissions
- GeoServer (~ArcGIS Server)
  - Serve WMS, WFS, WCS, and WMTS
- Spatial Database (~Data Store)
  - PostgreSQL/PostGIS
- Nginx/Apache HTTP Server (~Web Adapter)
- Leaflet (~ArcGIS web apps)
- OpenLayers (~ArcGIS web apps)
- MapLibre GL JS (~ArcGIS web apps)

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There are a variety of free and open-source tools used to implement web GIS. This slide provides descriptions of some key components.

Data

Layers

- Base Maps
  - Raster-based background layer
  - Provides context
  - Not generally used for analysis
  - Tiled layer
  - Not interacting with raw data
- Operational Layers
  - Thematic layers
  - Main information being presented on map
  - Can be tiled layers or feature layers

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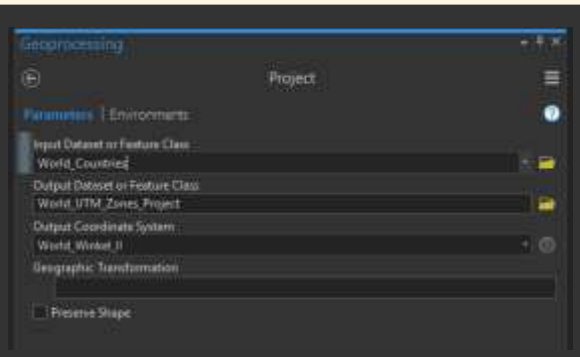
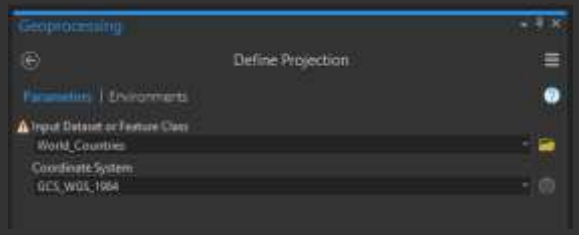
Layers included in a map or scene can be grouped into two broad categories: base maps/layers and operational layers. Base maps are used for context and are generally provided as raster-based or vector-based tile layers. The user does not have access to the raw or original spatial data and attributes. In contrast, operational layers generally represent the central or highlighted map information and may require that the user have access to data attributes.

Transforming Datums/Projections in ArcGIS





*Should use WGS84 or Web Mercator

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Data that will be use in a web map should be in the WGS84 geographic coordinate system or the Web Mercator projection. I prefer to use the Web Mercator projection. If you need to transform data to a new projection, this can be accomplished in ArcGIS Pro using the Project tool available in the Data Management Toolbox.

Hosted Feature Layer/Feature Layer

- Stores vector data (points, lines, or polygons)
- Used for operational layers
- Properties can be set (style, transparency, visibility range, refresh interval, and labels)
- View, edit, analyze, and execute queries
- Access to features and attributes
- Can sometimes be downloaded
- Can have multiple layers grouped as single object

https://doc.arcgis.com/en/arcgis-online/reference/layers.htm

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Feature layers allow you to store vector geospatial data for use in web maps and apps. A feature layer stored on ArcGIS Online is called a hosted feature layer. Feature layers allow for spatial data to be transferred between clients and a server. The user can also access attribute information, perform queries, and execute some analyses on the layer.

Symbology can be changed, pop-ups can be configured, and labels can be added or edited.

In short, feature layers provides web-based access to raw, vector geospatial data and are commonly used for operational layers.

Raster Tile Layer

- Pre-rendered tiles on server
- In compressed raster image format (JPEG or PNG)
- Cannot interact with raw data
- For basemaps and static operational layers
- Fast transfer
- Works well across a wide range of applications and devices

https://doc.arcgis.com/en/arcgis-online/reference/layers.htm

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Raster tile layers are not raw geospatial data. Instead, pre-rendered tiles are uploaded to a server, and the server sends these tiles or "pictures" of the data to the client for viewing when requested.

Data are commonly transferred between the client and server in a compressed raster graphic format, such as JPEG or PNG.

Since raster tile layers are just "pictures" of the data, the user does not have access to the raw data or attributes. They are also not able to change the symbology.

If the data need to be presented with different symbology or layers need to be updated, then the tiles need to be re-rendered to the server.

Although this is more limiting than feature layers, it allow for faster data transfer.

This method is generally adequate for base maps or static operational layers where the user does not need to access attributes or change the data symbology.

Understanding Tiling

- Individual image layers (JPEG or PNG)
- Set of pre-rendered images (256-by-256 pixels)
- Stored on server
- Spatially indexed
- Multiple zoom levels
- One zoom level active at a time
- Use tile layers produced by others
- Create your own tile layers

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For raster tile layers, different tiles will be delivered to the client based on the viewing extent and map scale. For example, if the user is more zoomed out then less detailed, coarser tiles can be delivered. Detailed data will not be delivered until the user zooms in.

Tiles are commonly stored in a compressed raster graphic format, such as JPEG or PNG. Pre-rendered images measuring 256-by-256 pixels are stored on the server for different scales and extents.

The tiles are spatially index so that the server knows what tiles to send to the client based on the extent and scale. Data for a single scale or zoom level will be loaded until the scale and/or extent is changed and new tiles need to be sent. The goal is to provide the necessary data but limit the amount of information that must be transferred to the client.

Note that raster tile layers can be generated from your data using ArcGIS Pro and published to ArcGIS Online or a server for use in maps and applications.

Zoom Levels

- Different set of tiles displayed at different zoom levels
- Lower zoom level = more zoomed out, less detailed
- Higher zoom level = more zoomed in, more detailed

Example on following slide is for Open Street Map (OSM):
https://wiki.openstreetmap.org/wiki/Zoom_levels

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A variety of tile sets are generated at different zoom levels.

Smaller numbers indicate more zoomed out, less detailed tiles.

Larger numbers indicate more zoomed in, more detailed tiles.

Level	# Tiles	Tile width (° of longitudes)	m / pixel (on Equator)	~ Scale (on screen)	Examples of areas to represent
0	1	360	156 412	1:500 million	whole world
1	4	180	78 206	1:250 million	
2	16	90	39 103	1:150 million	subcontinental area
3	64	45	19 551	1:70 million	largest country
4	256	22.5	9 776	1:35 million	
5	1 024	11.25	4 888	1:15 million	large African country
6	4 096	5.625	2 444	1:10 million	large European country
7	16 384	2.813	1 222	1:4 million	small country, US state
8	65 536	1.406	610.984	1:2 million	
9	262 144	0.703	305.492	1:1 million	wide area, large metropolitan area
10	1 048 576	0.352	152.746	1:500 thousand	metropolitan area
11	4 194 304	0.176	76.373	1:250 thousand	city
12	16 777 216	0.088	38.187	1:150 thousand	town, or city district
13	67 108 864	0.044	19.093	1:70 thousand	village, or suburb
14	268 435 456	0.022	9.547	1:35 thousand	
15	1 073 741 824	0.011	4.773	1:15 thousand	small road
16	4 294 967 296	0.005	2.387	1:8 thousand	street
17	17 179 869 184	0.003	1.193	1:4 thousand	block, park, addresses
18	68 719 476 736	0.001	0.596	1:2 thousand	some buildings, trees
19	274 877 906 944	0.0005	0.298	1:1 thousand	local highway and crossing details

This table provides an example of the tiling system used for OpenStreetMap.

A zoom level of 0 indicates a global scale while a zoom level of 12 would be appropriate for a city-level map.

The number of tiles, extent of each tile, and size of each pixel varies by zoom level.

Larger zoom levels will have more tiles, a smaller extent for each tile, and a smaller cell size; however, this is offset by the need to only send data for a smaller geographic extent to the client.

Map Image Layer

- Collection of map cartography based on vector data
- Map image layers are dynamically rendered image tiles
- Pictures or tiles of the data are sent to the client
- However, the vector data from which the tiles originate are still available so that data can be visualized and queried

https://doc.arcgis.com/en/arcgis-online/reference/layers.htm

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Map image layers are a collection of map features and cartography based on vector data.

The raw vector data can be stored on a server; however, tiles are dynamically rendered to be sent to the client as opposed to sending the raw feature data.

Since the vector data from which the tiles originate are still available, data symbology can be changed and data can be queried; however, map image layers do not support editing of features from the client machine.

This is a “middle ground” between feature layers and raster tile layers.

Vector Tile Layer

- Map data delivered as vector tiles as opposed to raster tiles (PBF format)
- Layers are rendered on client machine based on a style delivered with the layer from the server
- Can adapt to the resolution of their display device and be restyled for multiple users
- Generally smaller file size than raster tiles
- Faster transfer and display
- More ability to edit style in comparison to raster tiles

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Another option that has become available more recently is vector tile layers.

Note that vector tile layers are not raw, geospatial vector data. Instead, they are representations of the geospatial data stored in a vector graphic format as opposed to a raster graphic format.

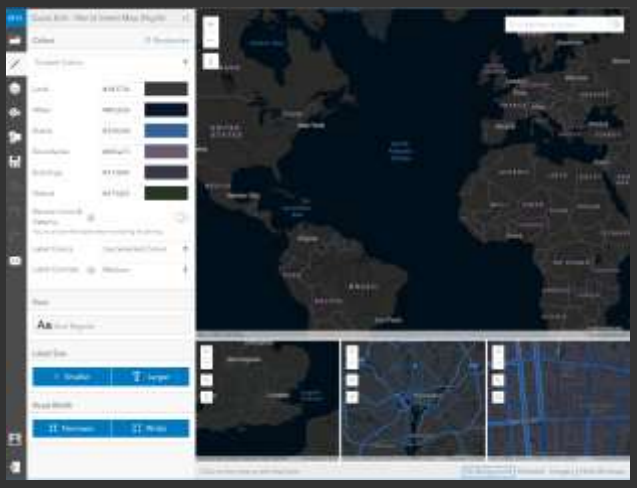
If you are a user of graphics editing software, this is analogous to storing a photograph as a JPEG or PNG file for editing as a raster graphic (for example, using Adobe Photoshop) vs. storing a graphic file as a vector graphic as a SVG or AI file for editing in a vector graphic software package (for example, Adobe Illustrator or InkScape).

Vector graphics store the font, vector, and color information and generally allow for more symbol editing than raster files.

Vector tile layers offer many benefits. Since they are vector graphics, they support the manipulation of data symbology without the need to store the raw geospatial data on the server and transfer the raw vector data to the client. File sizes are also generally smaller than raster tiles, and they support fast transfer and display. It is also easier to edit the style whereas raster tiles are pre-rendered images that do not allow for symbols and colors to be adjusted.

ArcGIS Pro currently supports the publication of vector tile layers to ArcGIS Online.

Vector Tile Basemaps



- Can edit ESRI basemaps as vector tile graphics
- Use ArcGIS for Developers: https://www.arcgis.com/apps/vtseditor/en/#/

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ESRI allows users to edit the provided ESRI basemaps as vector tile basemaps to generate customized base maps. Essentially, the user is specifying new styles to apply to the layers associated with the base map data. This requires that the data be stored as vector graphic data.

An edited base map can be saved to your ArcGIS Online account for use in your web apps and maps.

It can also be used in ArcGIS Pro if you are logged into you ArcGIS Online account to access your ArcGIS Online content.

Other Layer Types

- Imagery Layer = allows clients to access raw raster data
- Scene Layer = Collection of 3D feature objects and z-values for use in web scenes (points, 3D objects, integrated mesh, point cloud, and buildings)
- Table = collection of rows and columns (generally used to store aspatial or tabulated data)
- Elevation Layer = Special type for storing raster-based elevation data

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There are some additional web layers that we will not discuss in detail here. For example, Image Layers allow for the transfer of raw raster data from the server to the client. Scene Layers allow for the storage of 3D features and include point clouds, 3D objects, integrated meshes, and 3D buildings. Tables allow aspatial or tabulated data to be transferred to the client. Elevation layers store raster-based elevation data.

Open Web Services

- WMS = Web Map Service
  - Client receives georeferenced map images
  - JPEG, PNG, or GIF
- WMTS = Web Map Tile Service
  - Client receives georeferenced, pre-rendered, multiscale images
- WFS = Web Feature Service
  - Client receives the vector spatial data
  - Access to vector geospatial data and attributes
  - GML or GeoJSON
- WCS = Web Coverage Service
  - Client receives raw raster data
  - GeoTIFF, NetCDF, or HDF
- MVT = Mapbox Vector Tiles
  - Client Receives vector graphic tiles
  - PBF

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Open data standards have been established for web-based geospatial data. A Web Map Service (WMS) is similar to a Map Image Layer in that raw data are stored on the server and images of these data, as tiles, are rendered and sent to the server. A Web Map Tile Service (WMTS) is similar to a Raster Tile Layer in which image tiles are pre-rendered and cached to the server. A Web Feature Service (WFS) is similar to a Feature Layer or Hosted Feature Layer in which raw geospatial data are stored on the server and provided to the client.

Web Coverage Services (WCG) allow for accessing raw raster data while Mapbox Vector Tiles (MVT) are used for vector-based graphic files, similar to Vector Tile Layers.

This is the end of this lecture module.

Please return to the West Virginia View Webpage for additional content.

Thanks! Hope you found this useful.