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

GIScience

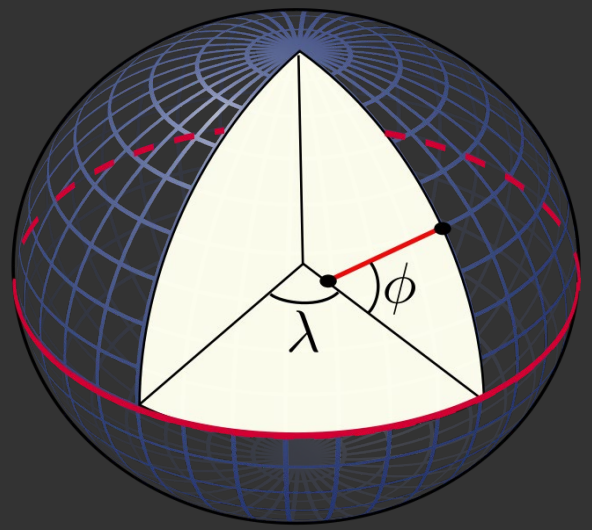
Geospatial Data

WV VIEW

AmericaView℠
Empowering Earth Observation Education
AmericaView.org - Est. 2003

Coordinates on a Sphere

- Latitude and Longitude
- Specified as angles or degrees



https://commons.wikimedia.org/wiki/File:Latitude_and_longitude_graticule_on_an_ellipsoid.svg

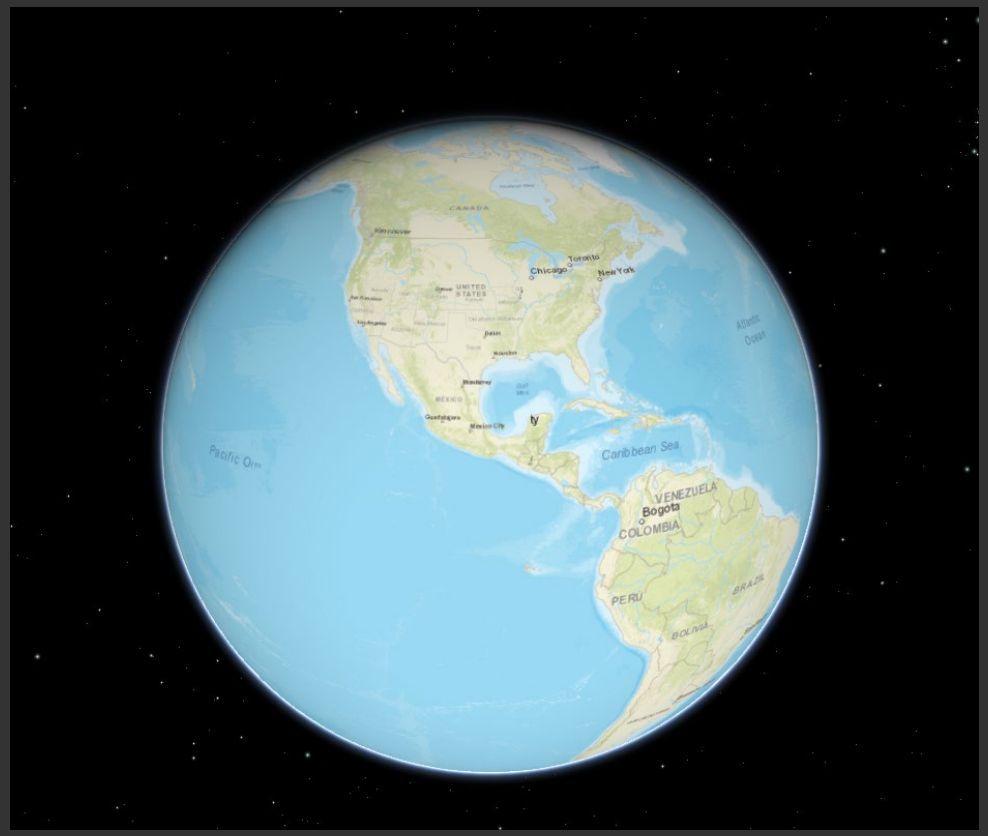
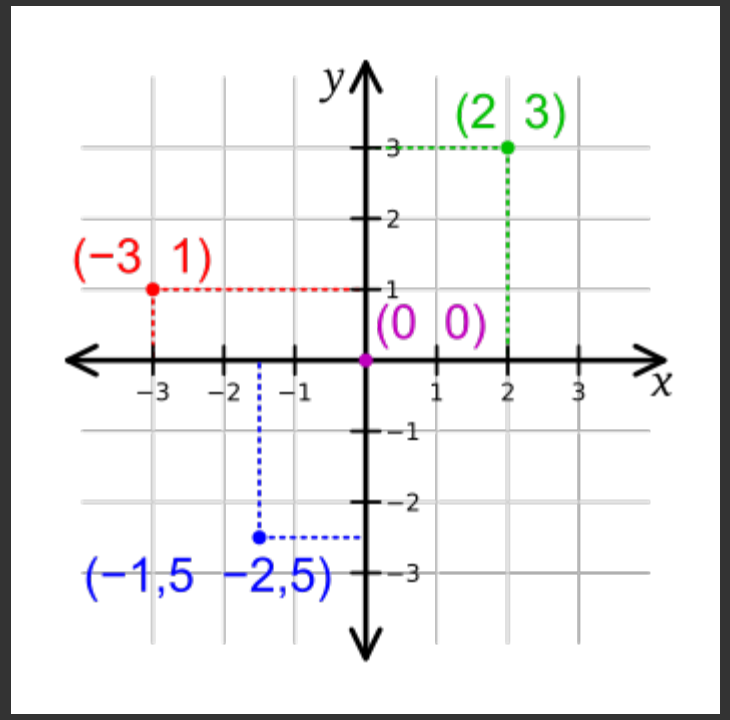


Image from ArcGIS API for JavaScript

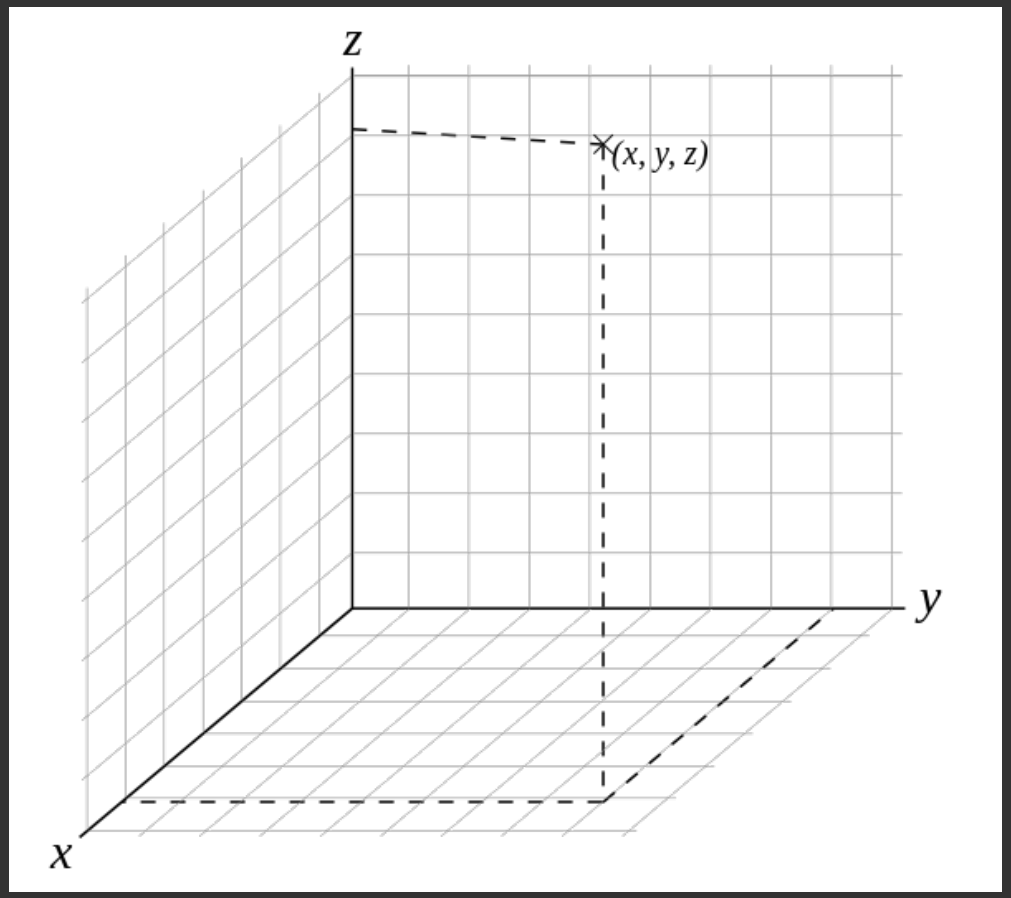
Coordinates on a Plane

- X, Y
- For projected coordinate systems
- Length or distance units relative to an origin



https://commons.wikimedia.org/wiki/File:Cartesian_coordinate_system_(comma).svg

Coordinates in 3-D Space



https://commons.wikimedia.org/wiki/File:Cartesian_with_grid.svg

- Can expand to 3D

Geographic Coordinates vs. Projected Coordinates

Image from ArcGIS API for JavaScript

Non-Spatial Data in GIS

Attributes = non-spatial characteristics associated with spatial data

Categorical
- Nominal = A unique identifier or unique types
- Ordinal = Ranked data

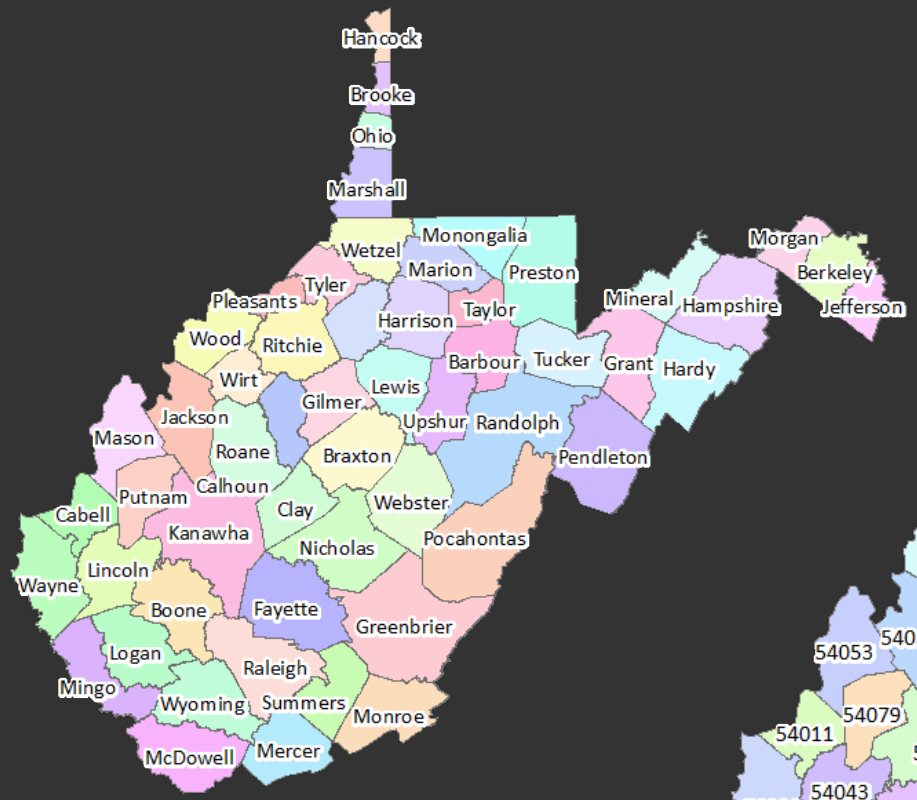
Numeric
- Interval = Difference between numbers is significant, but no fixed non-arbitrary zero point
- Ratio = Difference between numbers is significant, and there is a fixed non-arbitrary zero value

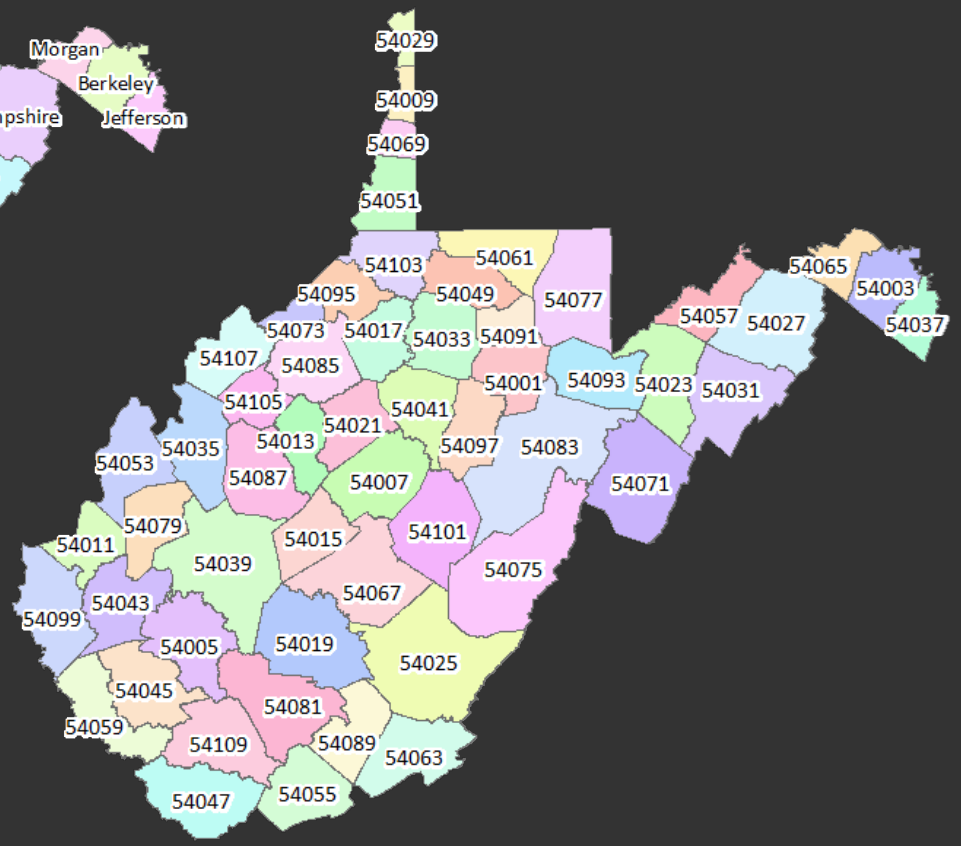
counties_detailed

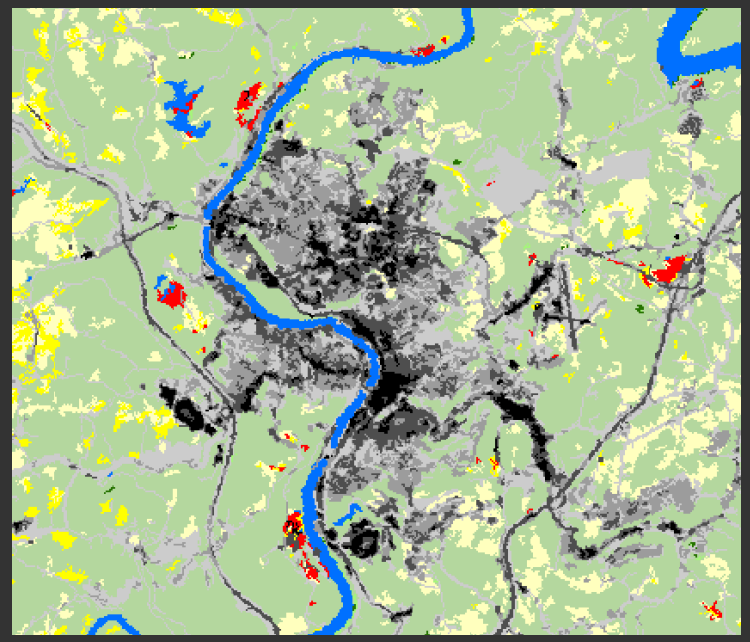
Field: Add Delete Calculate Selection: Zoom To Switch Clear Delete

FID	Shape	AREA	PERIMETER	NAME	STATE	FIPS	STATE_ABBR	SQUARE_MIL	POP2000	POP00SQMIL	MALE2000	FEMALE2000	MA
0	Polygon	281936384.193	69539.619328	Ohio	54	54069	WV	106.176	47427	446.7	22177	25250	
1	Polygon	807157354.71	125167.039523	Marshall	54	54051	WV	306.994	35519	115.7	17288	18231	
2	Polygon	1686168096.7	179373.536795	Preston	54	54077	WV	648.324	29334	45.2	14535	14799	

Nominal Data



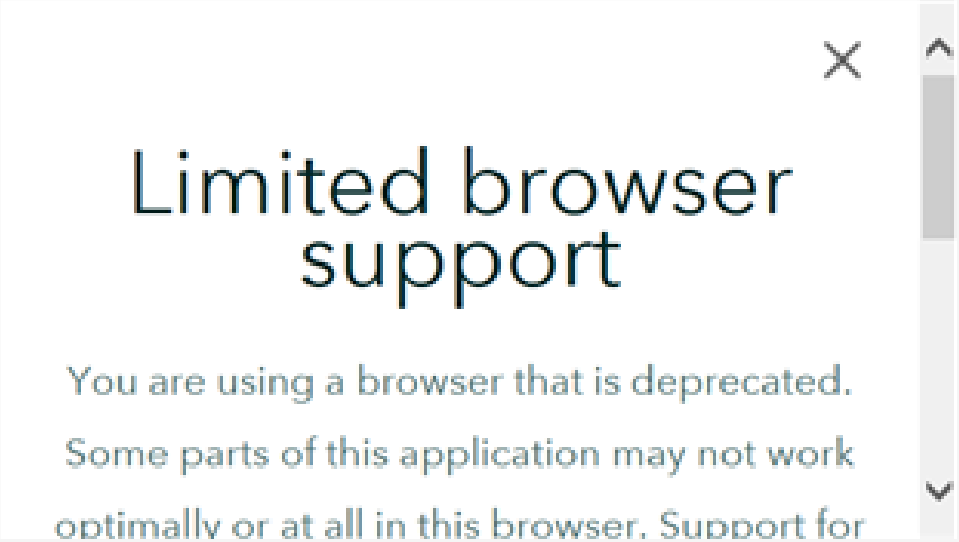




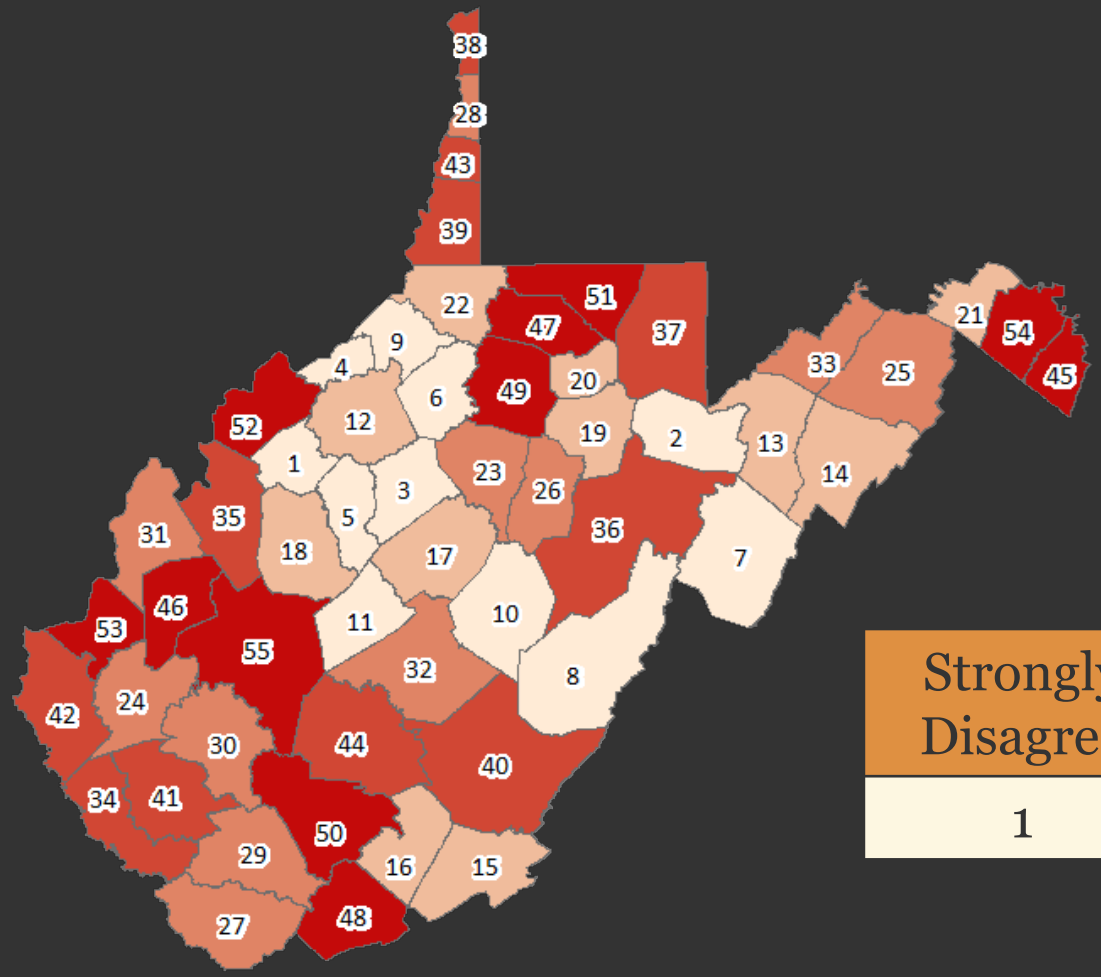
Nominal Data

Web Object

Select this object and click the **Web Object** button to edit



Ordinal Data



Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Interval Data

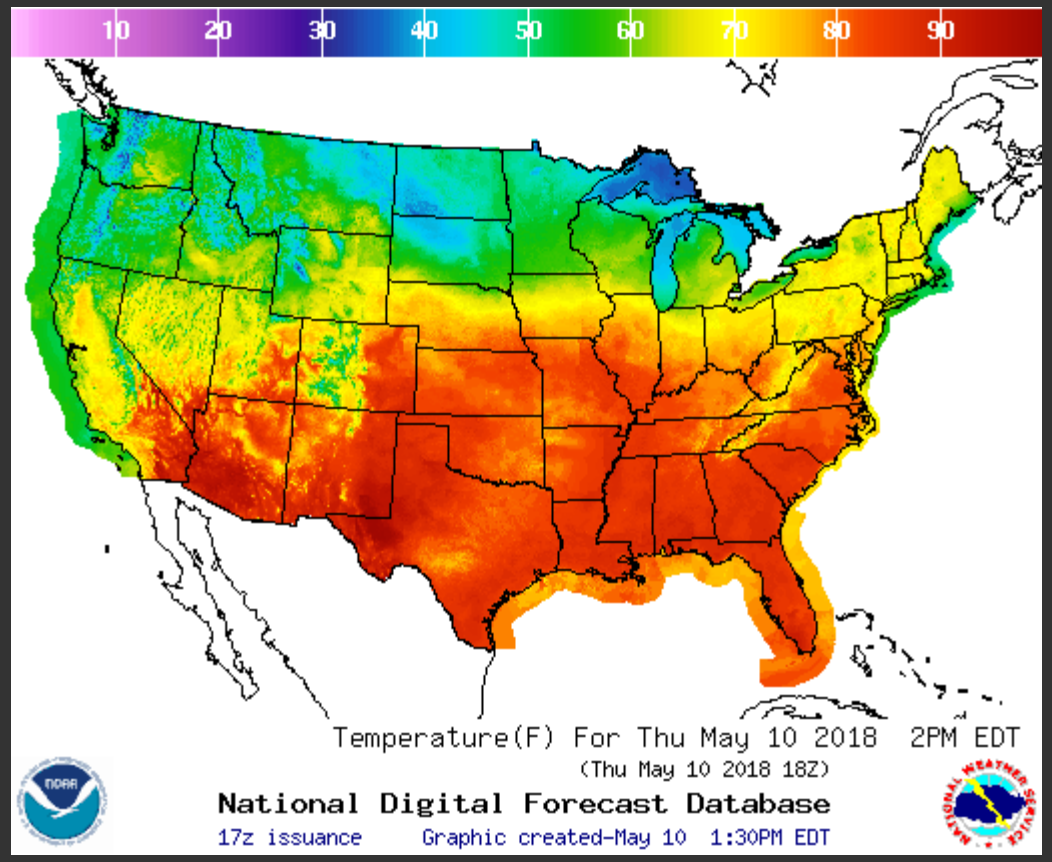
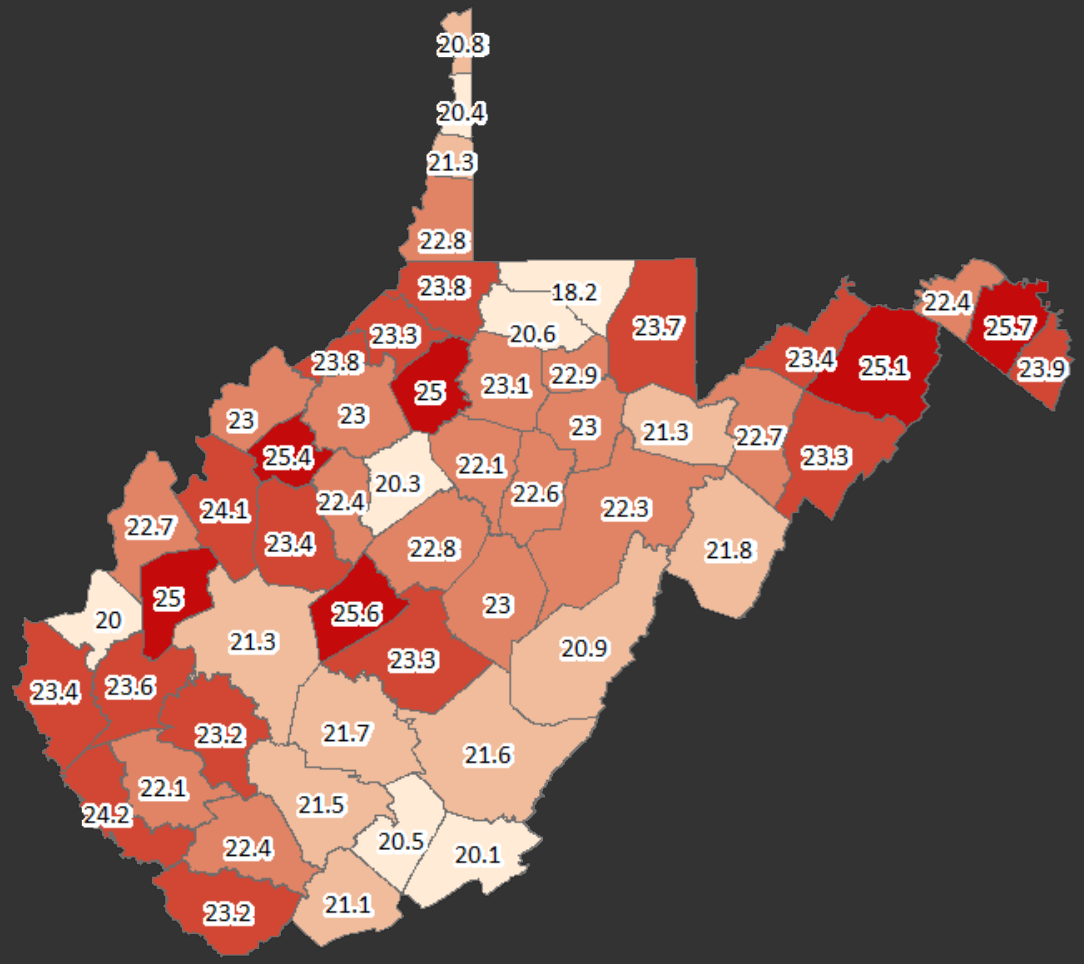
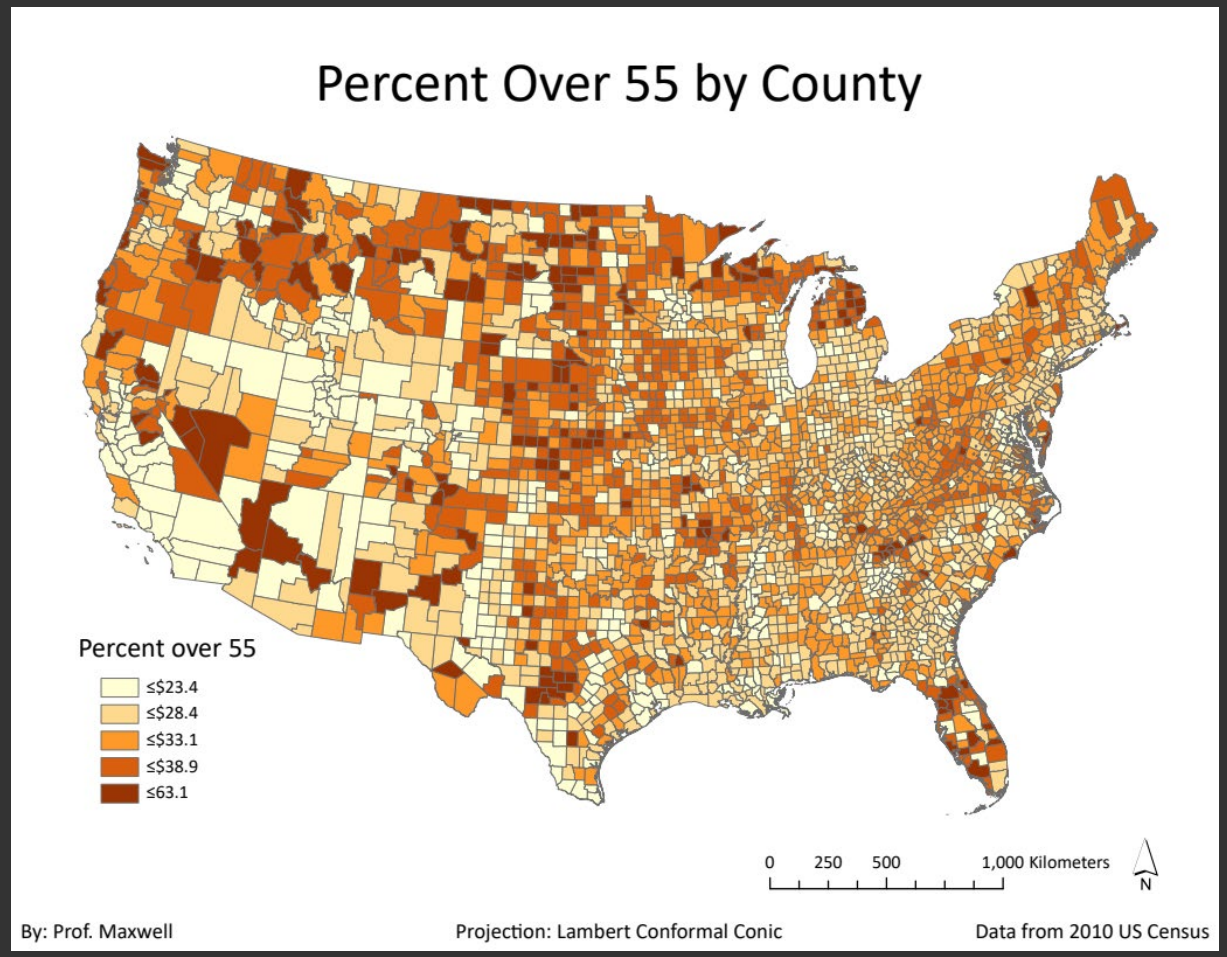
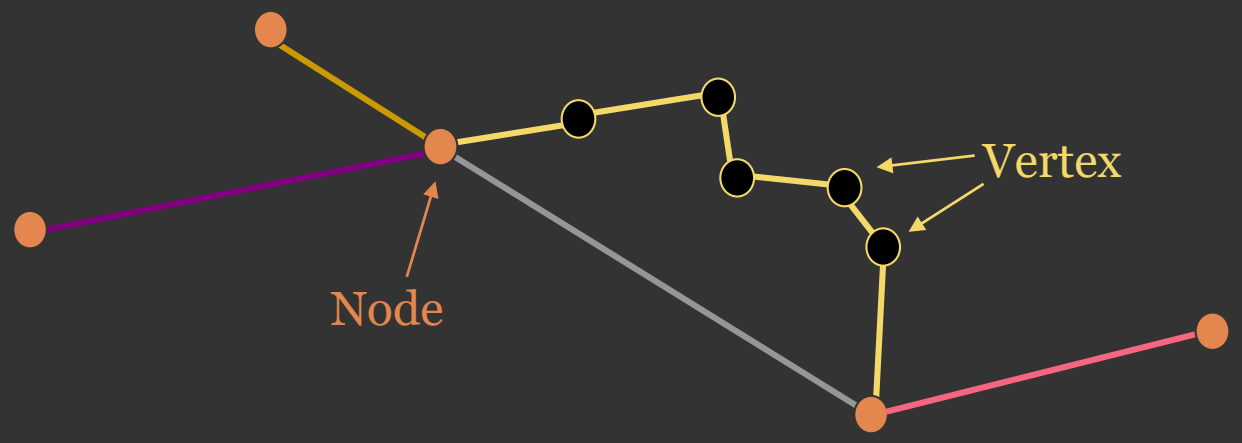


Image from the National Weather Service

Ratio Data

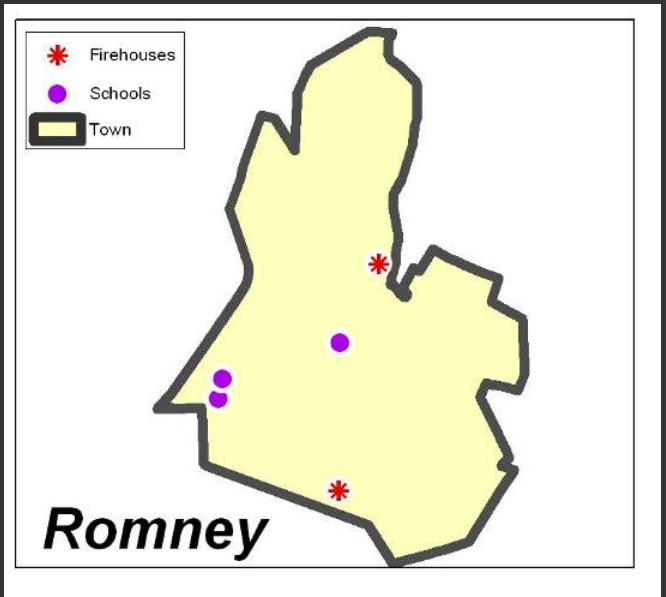

20.8
20.4
21.3
22.8
23.8
18.2
23.7
22.4
25.7
23.9
23.3
20.6
23.8
25
23.1
22.9
23.4
25.1
23
23
23
21.3
22.7
23.3
25.4
20.3
22.1
22.6
22.3
22.7
24.1
22.4
23.4
22.8
21.8
25
20
25.6
23
21.3
23.3
20.9
23.4
23.6
23.2
21.7
21.6
22.1
24.2
21.5
22.4
20.5
20.1
23.2
21.1


Percent Over 55 by County
Percent over 55
≤$23.4
≤$28.4
≤$33.1
≤$38.9
≤63.1
0 250 500 1,000 Kilometers
N
By: Prof. Maxwell
Projection: Lambert Conformal Conic
Data from 2010 US Census



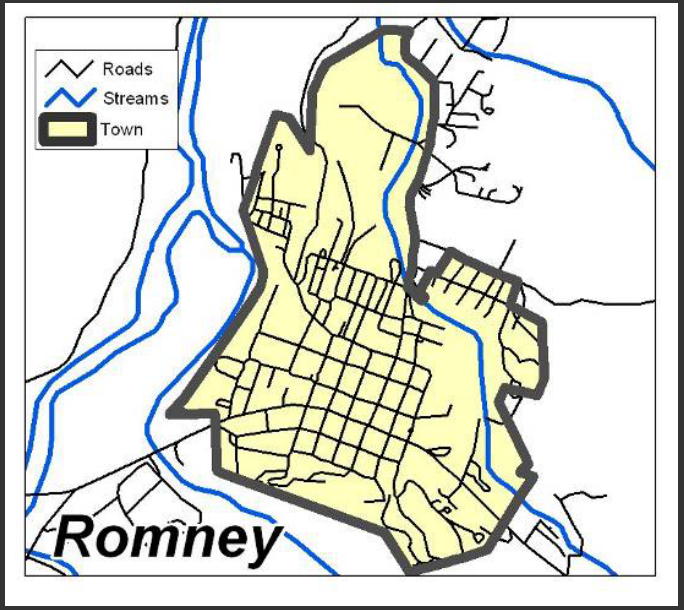
Vector Data

The Basics



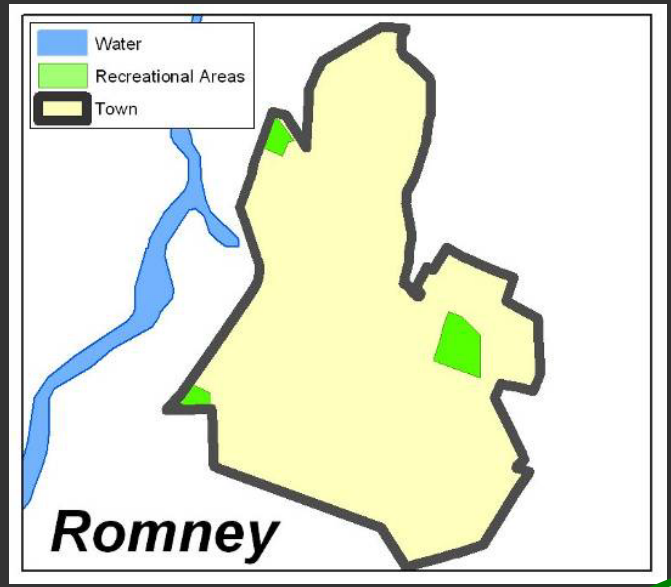
Points

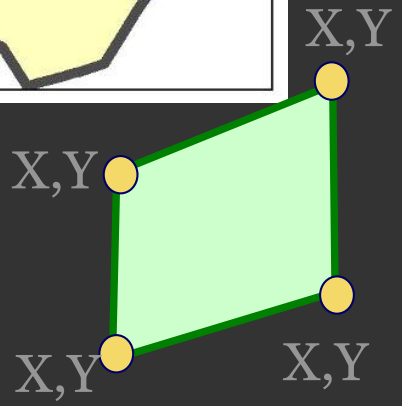
Coordinate locations,
Zero-dimensional



Lines

One-dimensional,
Length, No width





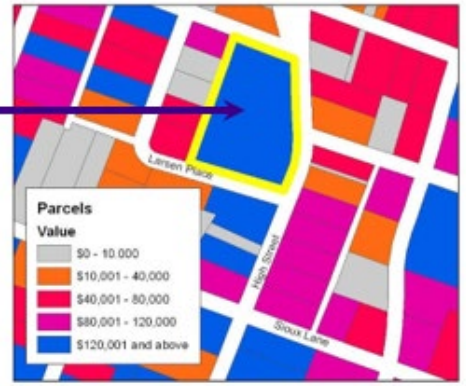
Polygons

Two-dimensional,
An area

Geometric considerations

- Points
  - Only a coordinate
  - No length
  - No area
- Lines
  - Multiple coordinates (vertices)
  - Linked as a linear feature
  - Length
  - No area
- Polygon
  - A closed feature (area)
  - Has length (perimeter)
  - Has area

All types can store attribute information



Parcel ID	Owner	Acres	Zoning	Building Value	Year Built
08-001	West, Peggy	0.45	R	$64,000	1954
08-002	School District	5.12	Ex	-	1972
08-003	North, Tim	1.33	R	$72,000	1956
08-004	7-Eleven	2.03	C	$92,000	1995

Examples by Mike and Jackie Strager

Need to Generalize

Polygon Inclusions

Need to Generalize

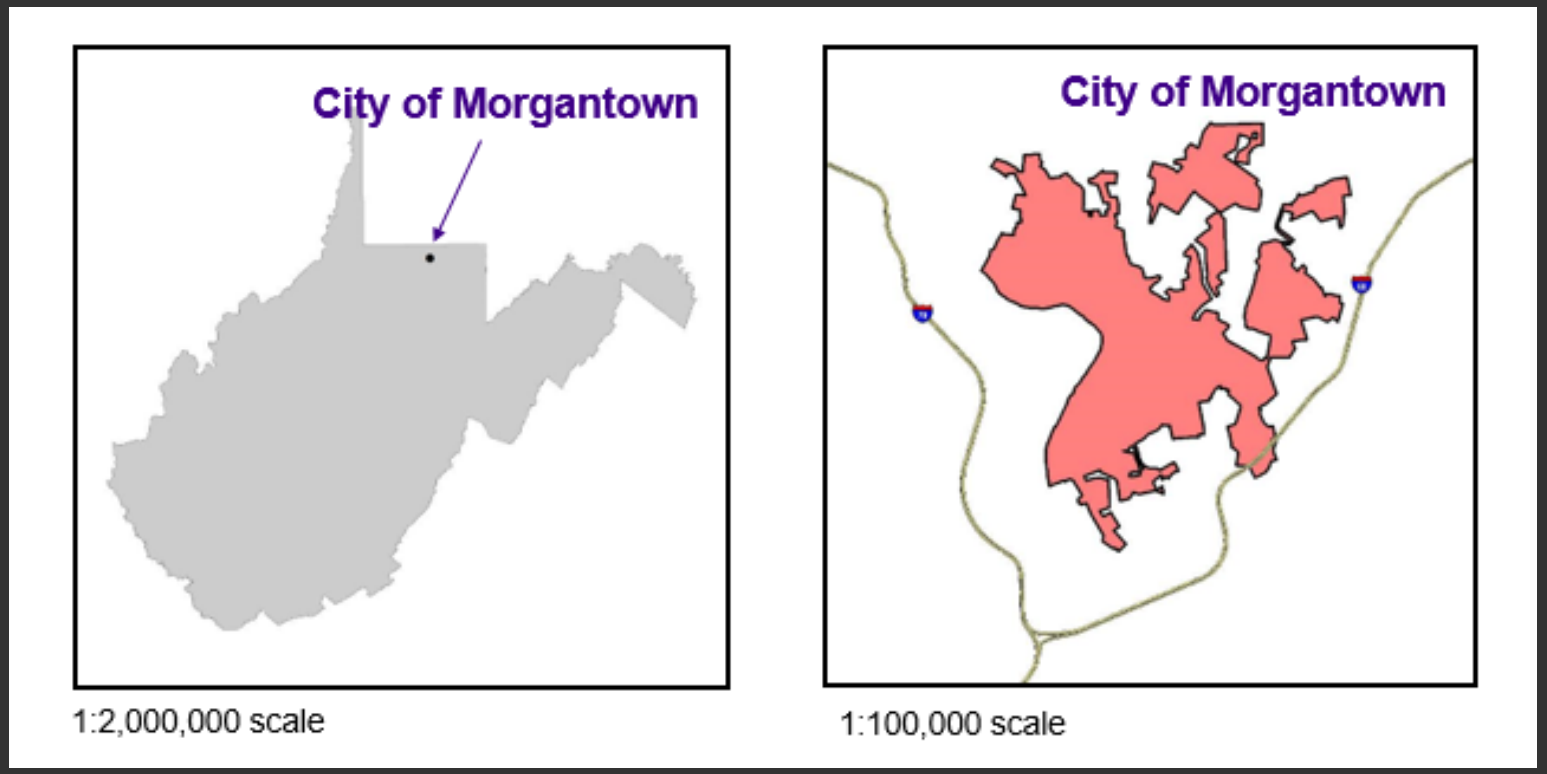
Boundary Generalization

Minimal Mapping Unit (MMU)

- Smallest area/feature to be mapped

Images from Google Earth

Point, Line, or polygon?



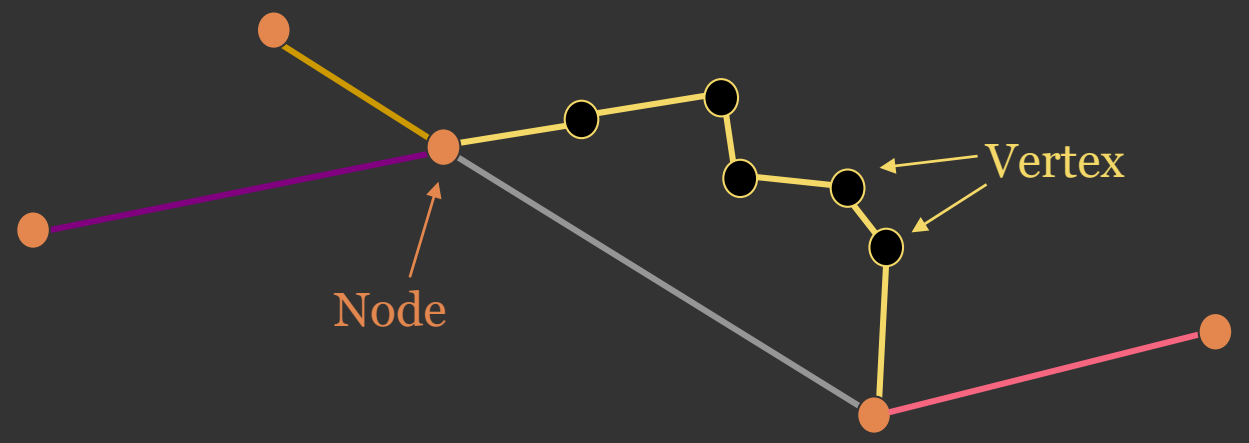
Example by Mike and Jackie Strager

Vector Data Structure

Vector data are made up of connected vertices.

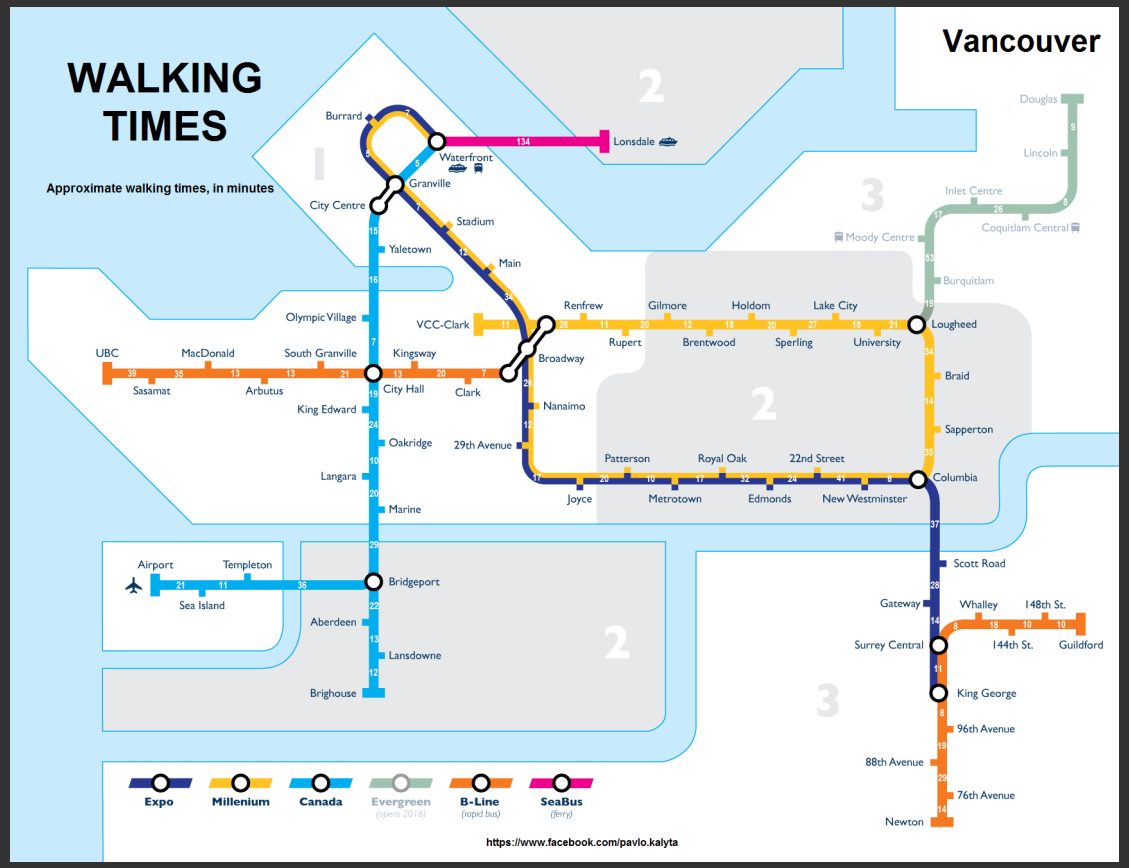
End vertices are called nodes.

Vertices can be connected as lines and polygons.



A computer uses relationships between features to build geometric features that are spatially referenced.

Topology



http://www.insidevancouver.ca/2016/04/04/vancouver-map-showing-walking-times-between-skytrain-stations-and-b-line-stops/

Study of properties of geometric objects that remain invariant under certain transformations such as bending or stretching (Massey, 1967)

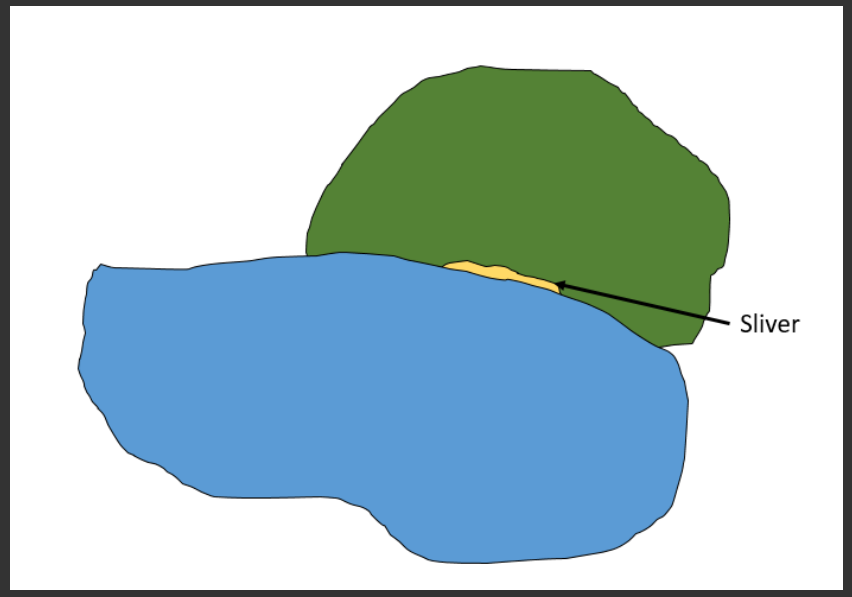
Examples:

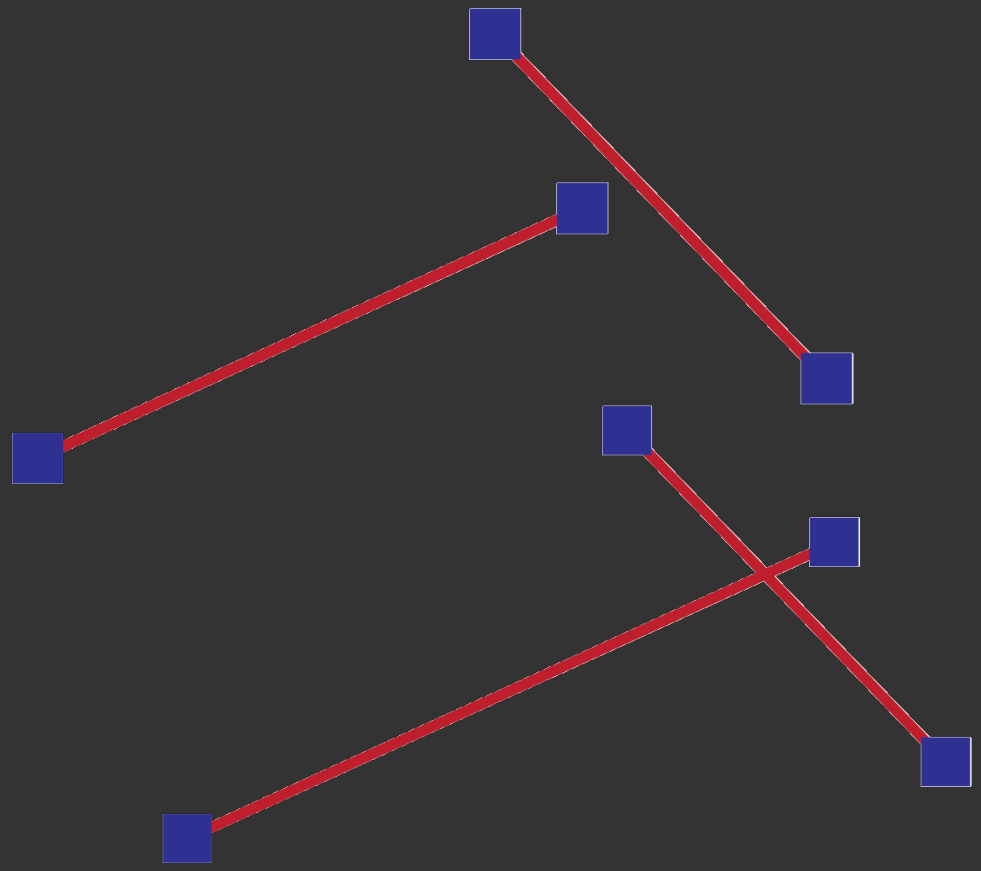
- Adjacent to
- Incident with

Topology and Topography are different!

Topological Issues

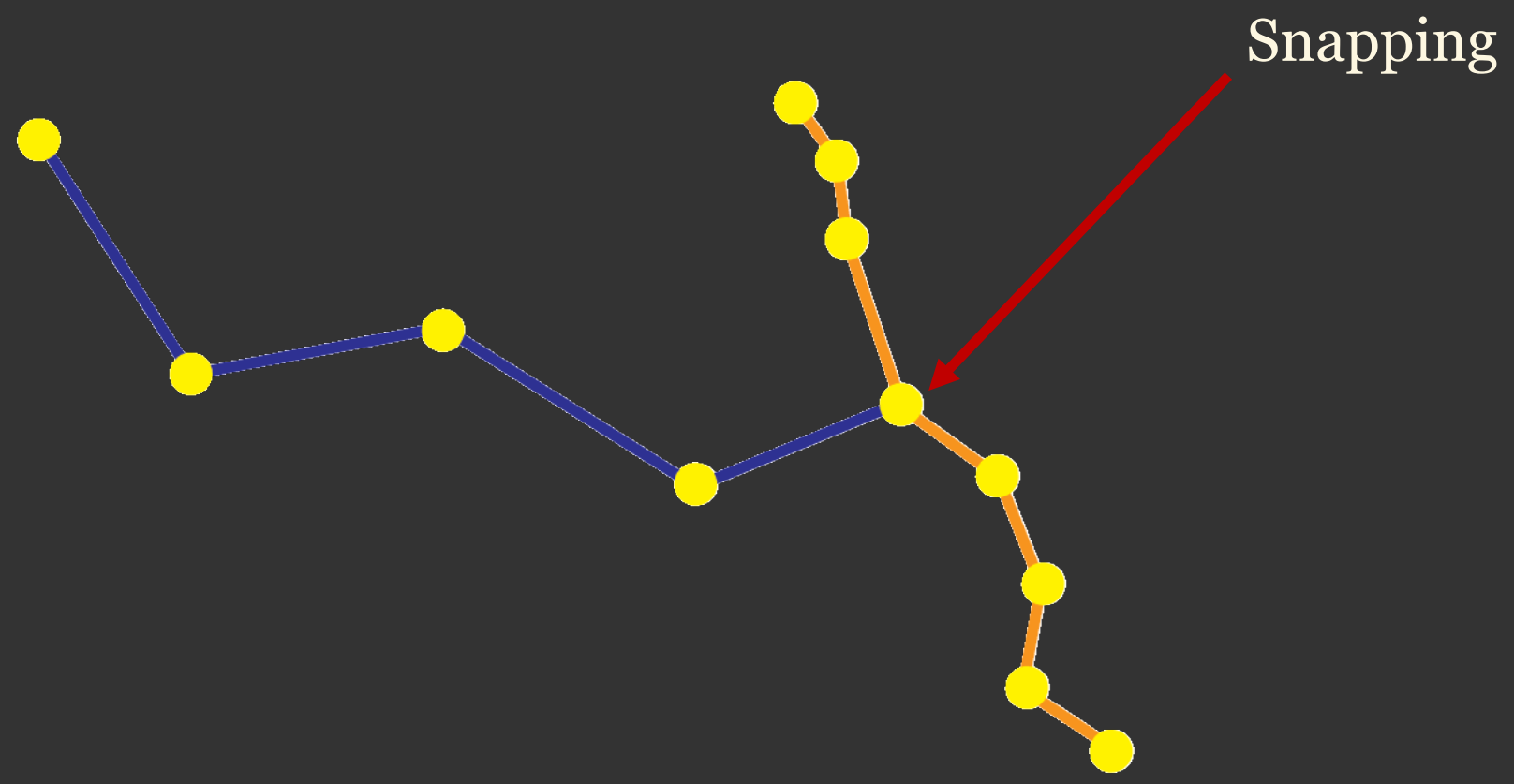
1. Dangles
2. Overshoots
3. Slivers





Snapping

- Causes/forces vertices to match up



Types of Topology

- Spaghetti Model = Early model for lines that did not model topology
- Planar Topology = All features exist on a plane. If features cross, they must share the same space or intersect
- Non-Planar Topology = Allow for overlap. It is not assumed that features that cross share the same space

Topology for Points, Lines, and Polygons

- Points

  Simple, independent features

- Lines

  Substantial structure, start node, end node, direction

- Polygons

  Nodes and vertices that make up the line, connected lines, start and end nodes connect

Vector Data Models

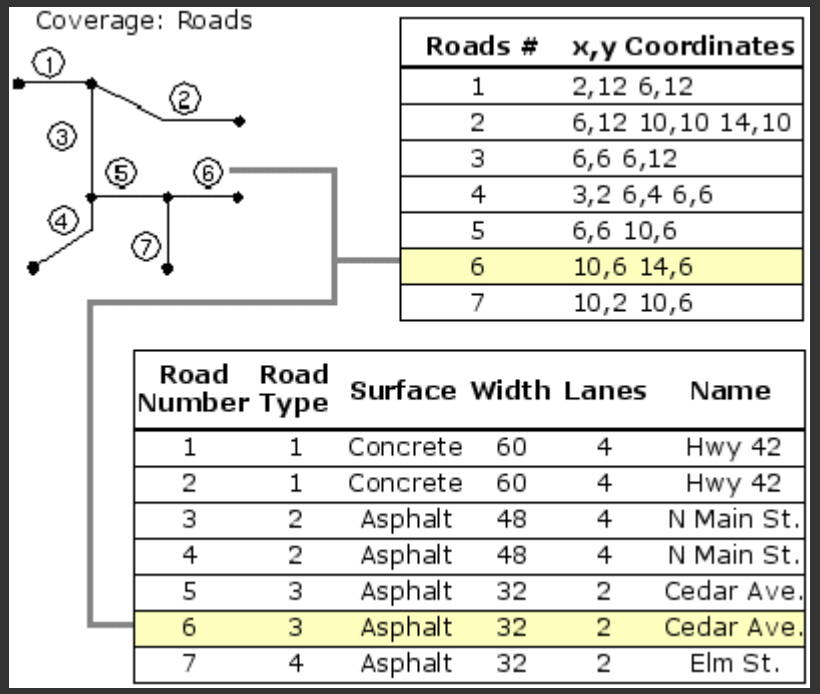
- Georelational = stores geometries and attributes separately
  - Coverage
  - Shapefile
- Object-Based Data Model = treats geospatial data as objects
  - Geodatabase

gid integer	postgis_fi bigint	lat_y_dd numeric	long_x_dd numeric	status character varying (254)	nest_id bigint	geom geometry
1	1	2999999999	546999999995	ACTIVE NEST	1	0101000020E6100000DAACFA5C6D335AC02E39EE940E224440
2	35	3000000001	141000000001	INACTIVE LOCATION	35	0101000020E61000001EE1B4E045235AC04E62105839144440
3	36	0999999999	619999999997	ACTIVE NEST	36	0101000020E6100000FC3559A31E3E5AC03BC780ECF5F64340
4	37	8000000001	663000000007	ACTIVE NEST	37	0101000020E61000000A2E56D4603E5AC017BCE82B48474440
5	46	9000000000	635999999996	ACTIVE NEST	46	0101000020E6100000A94D9CDCEF405AC0B3075A8121074440
6	47	4999999999	231000000001	ACTIVE NEST	47	0101000020E6100000E92B4833162B5AC039622D3E052C4440

ESRI Vector File Formats

Coverage Files

- Early vector data model by ESRI (1980s)
- Can model topology
- Connectivity = Arcs connect at nodes
- Area Definition = Area is defined by a series of connected arcs
- Contiguity = Arcs have directions and left and right polygons



Roads #	x,y Coordinates
1	2,12 6,12
2	6,12 10,10 14,10
3	6,6 6,12
4	3,2 6,4 6,6
5	6,6 10,6
6	10,6 14,6
7	10,2 10,6

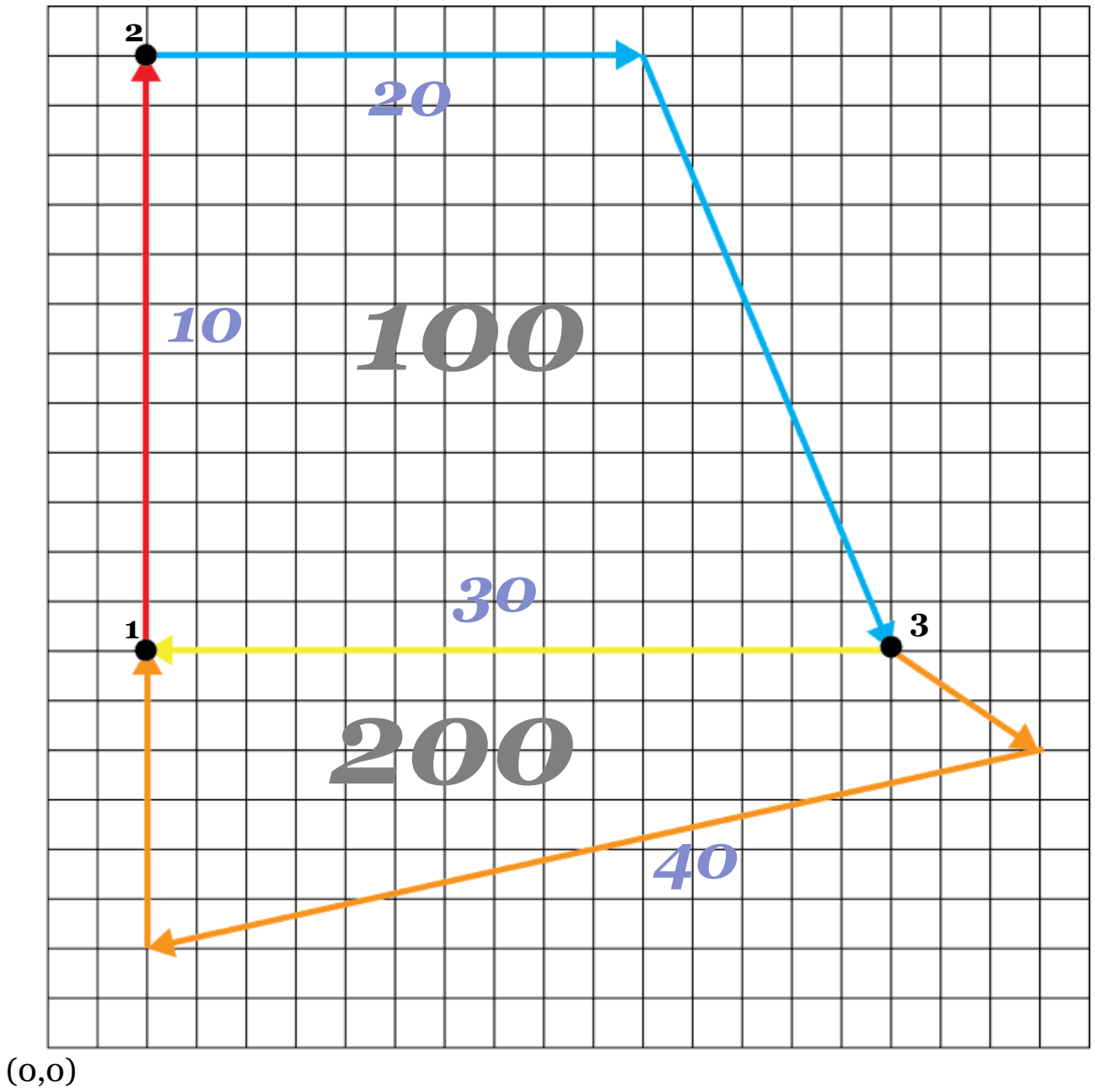
Road Number	Road Type	Surface	Width	Lanes	Name
1	1	Concrete	60	4	Hwy 42
2	1	Concrete	60	4	Hwy 42
3	2	Asphalt	48	4	N Main St.
4	2	Asphalt	48	4	N Main St.
5	3	Asphalt	32	2	Cedar Ave.
6	3	Asphalt	32	2	Cedar Ave.
7	4	Asphalt	32	2	Elm St.

http://desktop.arcgis.com/en/arcmap/10.3/manage-data/coverages/what-is-a-coverage.htm

Arc #	F-Node	T-Node
10	1	2
20	2	3
30	3	1
40	3	1

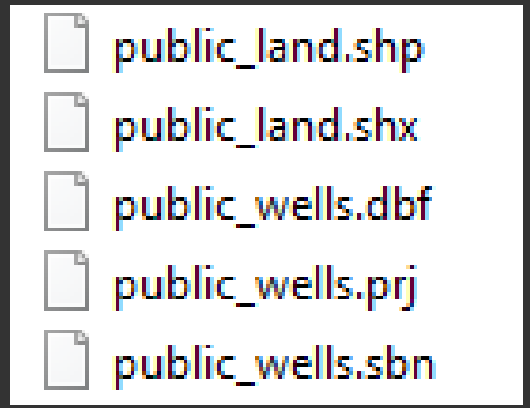
Arc #	X, Y Coordinates
10	(2, 8) (2, 20)
20	(2, 20) (12, 20) (17, 8)
30	(17, 8) (2,8)
40	(17, 8) (20, 6) (2, 2) (2, 8)

Polygon #	Arc #
100	10, 20, 30
200	30, 40



The Shapefile

- Nontopological
- No files describe the spatial relationships among geographic objects



.shp = geometry data

.prj = spatial reference/projection information

.dbf = attribute table/aspatial data

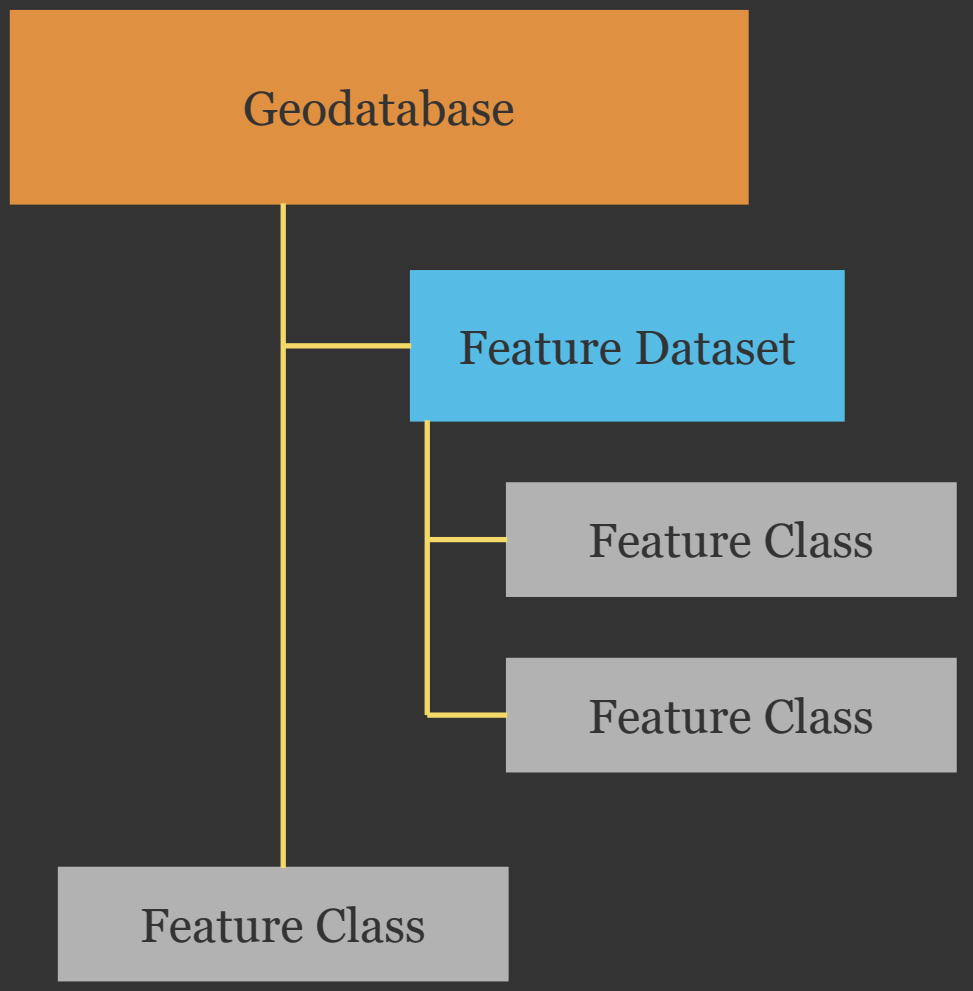
.shx = index file for geometry (helps with speed)

.sbn and .sbx = index file for features

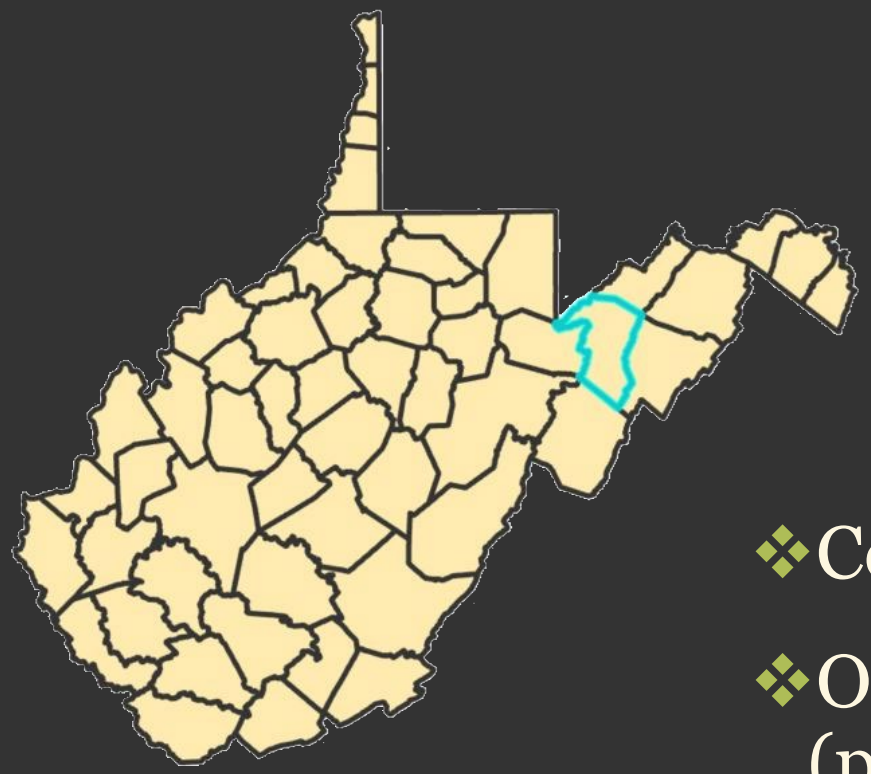
.xml = metadata

The Geodatabase

- Stores data in a relational database structure
- Object-based vector model
- Stores geometries and attributes in a single system
- Geometry is stored in a BLOB (binary large object) field
- Vector data are stored in a geodatabase as a feature class
- Can model topological rules on-the-fly
- Allows for topological relationships between feature classes in a feature dataset



Attribute Tables



counties_detailed

Field: Add Delete Calculate Selection: Zoom To Switch Clear Delete

FID	Shape	AREA	PERIMETER	NAME	STATE	FIPS	STATE_ABBR	SQUARE_MIL	POP2000	POP00SQMIL	MALE2000	FEMALE
17	Polygon	1174558903.03	190866.47067	Ritchie	54	54085	WV	453.512	10343	22.8	5070	
18	Polygon	1243179000.53	205207.603298	Grant	54	54023	WV	477.209	11299	23.7	5585	
19	Polygon	887178857.707	146810.022398	Barbour	54	54001	WV	340.788	15557	45.6	7646	
20	Polygon	1090401465.58	162556.831726	Tucker	54	54093	WV	418.871	7321	17.5	3570	

- Commonly one-to-one
- One row entry for each geometric feature (point, line, or polygon)
- Stored in .dbf component of the shapefile

Attribute Tables

counties_detailed

Field: Add Delete Calculate Selection: Zoom To Switch Clear Delete

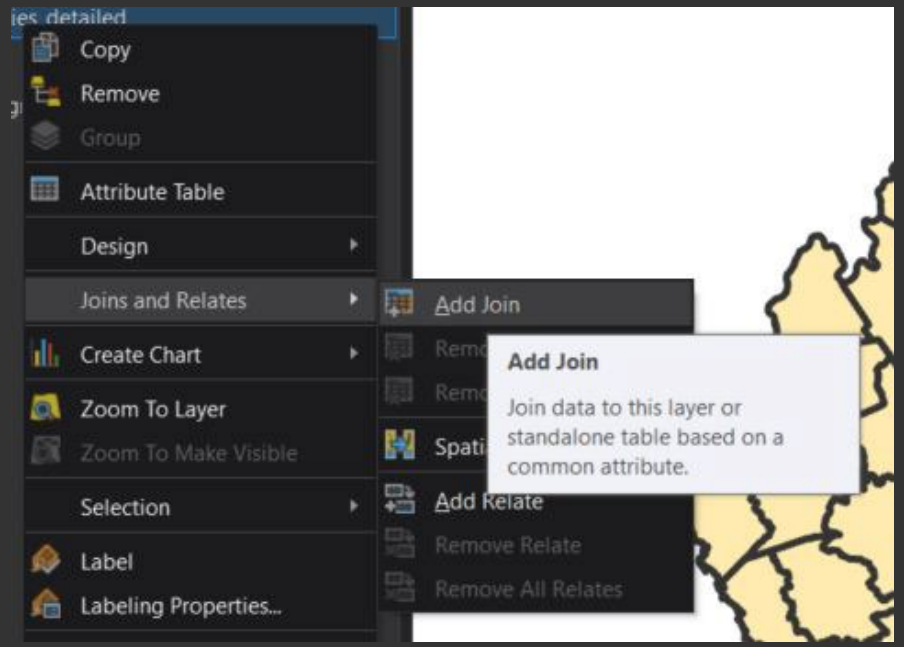
FID	Shape	AREA	PERIMETER	NAME	STATE	FIPS	STATE_ABBR	SQUARE_MIL	POP2000	POP00SQMIL	MALE2000	FEMALE
17	Polygon	1174558903.03	190866.47067	Ritchie	54	54085	WV	453.512	10343	22.8	5070	[illegible]
18	Polygon	1243179000.53	205207.603298	Grant	54	54023	WV	477.209	11299	23.7	5585	[illegible]
19	Polygon	887178857.707	146810.022398	Barbour	54	54001	WV	340.788	15557	45.6	7646	[illegible]
20	Polygon	1090401465.58	162556.831726	Tucker	54	54093	WV	418.871	7321	17.5	3570	[illegible]
21	Polygon	1513690918.56	207396.438169	Hardy	54	54031	WV	583.393	12669	21.7	6255	[illegible]
22	Polygon	608205867.85	133536.114018	Wirt	54	54105	WV	232.987	5873	25.2	2939	[illegible]
23	Polygon	1008177060.8	168255.380867	Lewis	54	54041	WV	382.142	16919	44.3	8206	[illegible]
24	Polygon	2691753634.8	324281.73498	Randolph	54	54083	WV	1039.725	28262	27.2	14222	[illegible]
25	Polygon	918241922.761	148989.496649	Upshur	54	54097	WV	354.758	23404	66	11354	[illegible]
26	Polygon	878938845.427	157414.412621	Gilmer	54	54021	WV	340.045	7160	21.1	3600	[illegible]
27	Polygon	1220556327.97	178691.609587	Jackson	54	54035	WV	465.792	28000	60.1	13623	[illegible]
28	Polygon	725902912.067	164688.558169	Calhoun	54	54013	WV	280.623	7582	27	3786	[illegible]
29	Polygon	1152234212.77	181232.373499	Mason	54	54053	WV	431.852	25957	60.1	12724	[illegible]
30	Polygon	1807519120.32	197019.787819	Pendleton	54	54071	WV	697.871	8196	11.7	4125	[illegible]
31	Polygon	1252066309.44	171703.11633	Roane	54	54087	WV	483.572	15446	31.9	7645	[illegible]
32	Polygon	1337033182.79	172607.315752	Braxton	54	54007	WV	513.48	14702	28.6	7444	[illegible]
33	Polygon	2437515275.93	269650.535179	Pocahontas	54	54075	WV	940.288	9131	9.7	4703	[illegible]
34	Polygon	1439510921	167601.512884	Webster	54	54101	WV	555.968	9719	17.5	4783	[illegible]
35	Polygon	906777879.744	142760.149326	Putnam	54	54079	WV	346.232	51589	149	25363	[illegible]
36	Polygon	889922110.089	133636.623724	Clay	54	54015	WV	342.399	10330	30.2	5109	[illegible]

- Columns = fields or attributes
- Info stored for each record
- Rows = Records
-
- One record for each vector feature

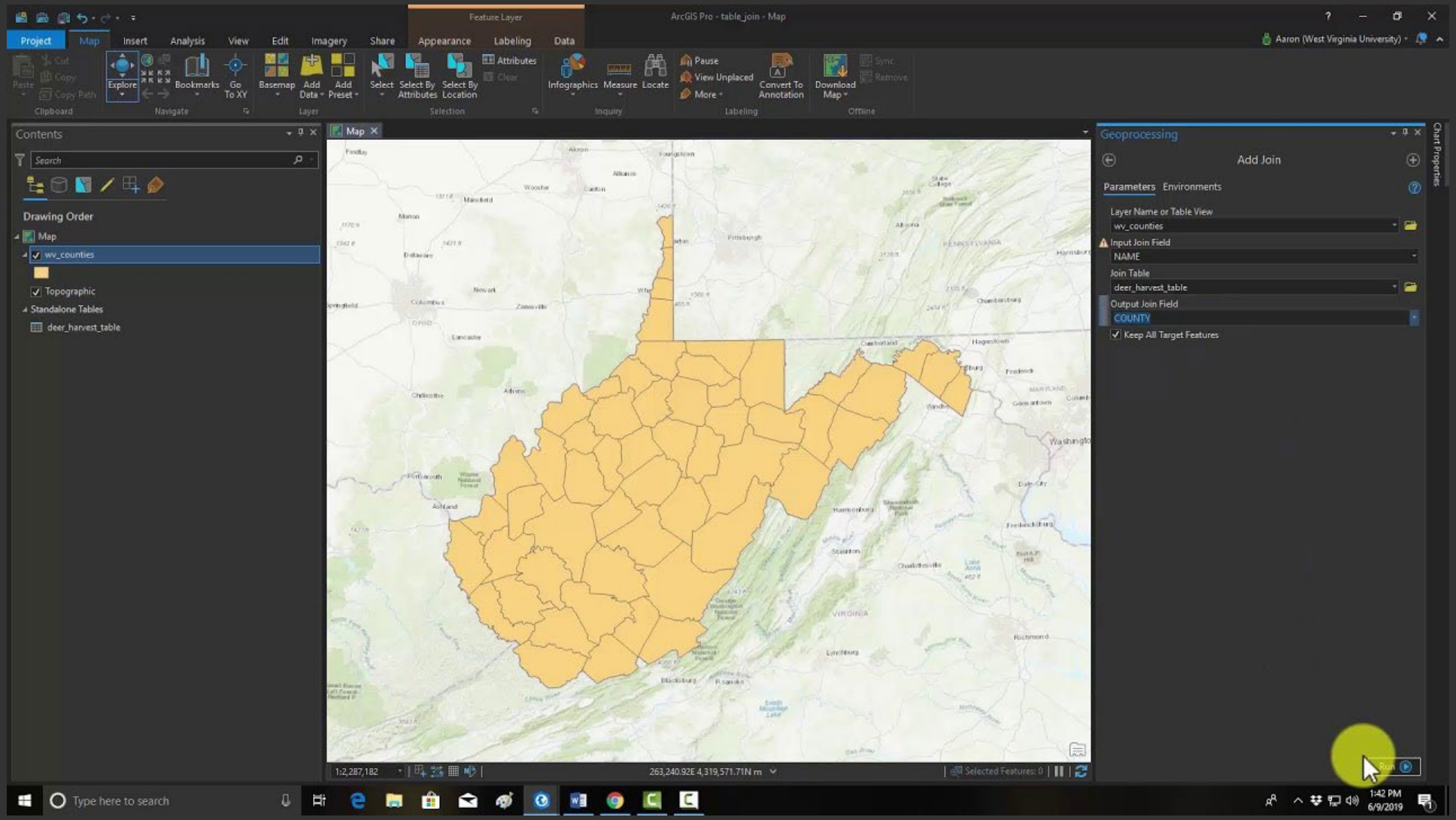
- All shapefiles and feature classes have an attribute table
- Some categorical raster data can also have attribute tables

Joining Aspatial Data and Spatial Data

- Join
- Non-spatial data can be joined to spatial data as long as there is a common field between the data.
- Later, the joined fields can be used for analysis or to symbolize the features.
- Relate
- New fields are not added to table. However, a relationship is established.



Video: Joins


ArcGIS Pro - table_join - Map
Contents
Drawing Order
Map
wv_counties
Topographic
Standalone Tables
deer_harvest_table
Geoprocessing
Add Join
Parameters
Environments
Layer Name or Table View
wv_counties
Input Join Field
NAME
Join Table
deer_harvest_table
Output Join Field
COUNTY
Keep All Target Features

Adding Fields

- Make sure to define the correct type

Visible	Read Only	Field Name	Alias	Data Type	Allow NULL	Highlight	Number Format	Default	Precision	Scale	Length
✓	✓	FID	FID	Object ID			Numeric		0	0	
✓		Shape	Shape	Geometry					0	0	
✓		Id	Id	Long			Numeric		6	0	
✓		name		Text							255

Attributes | Geometry

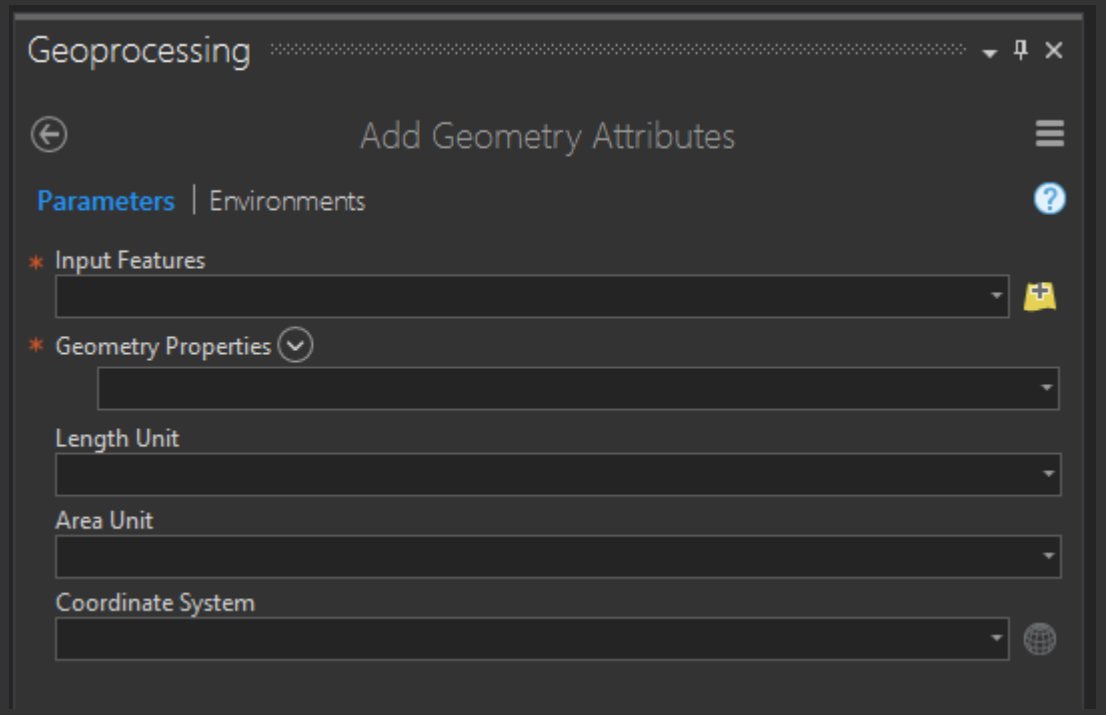
FID	0
Id	0
Name	Brooks Hall

Data Type	Description
Short Integer	Integer values between -32,768 and 32,767
Long Integer	Integer values between -2,147,483,648 and 2,147,483,647
Float	Decimal values with 1-6 decimal places
Double	Decimal values with more the 6 decimal places
Text	Text strings
Date	Data info (mm/dd/yyyy)

Add Geometric Fields

❖ Use Add Geometry Attributes Tool

Points	Lines	Polygons
X-coordinate	Start-X	Area
Y-coordinate	Start-Y	Perimeter
Z-coordinate (if z-enabled)	End-X	Centroid-X
M-coordinate (if m-enabled)	End-Y	Centroid-Y
	Mid-X	
	Mid-Y	
	Length	
	Bearing	

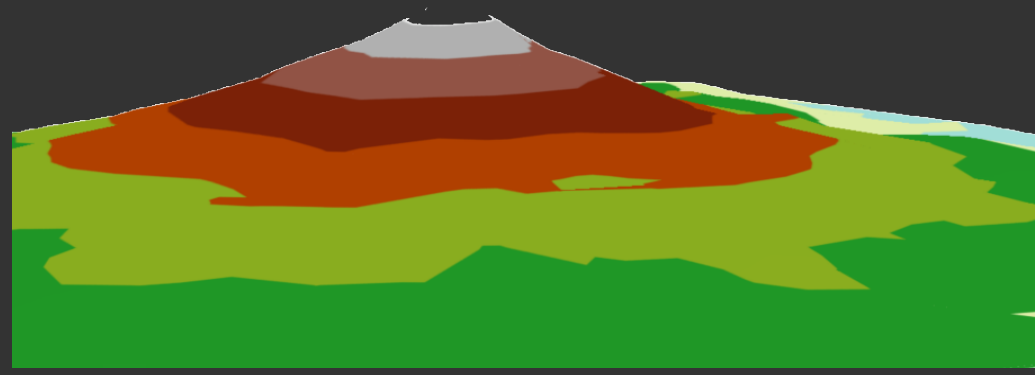


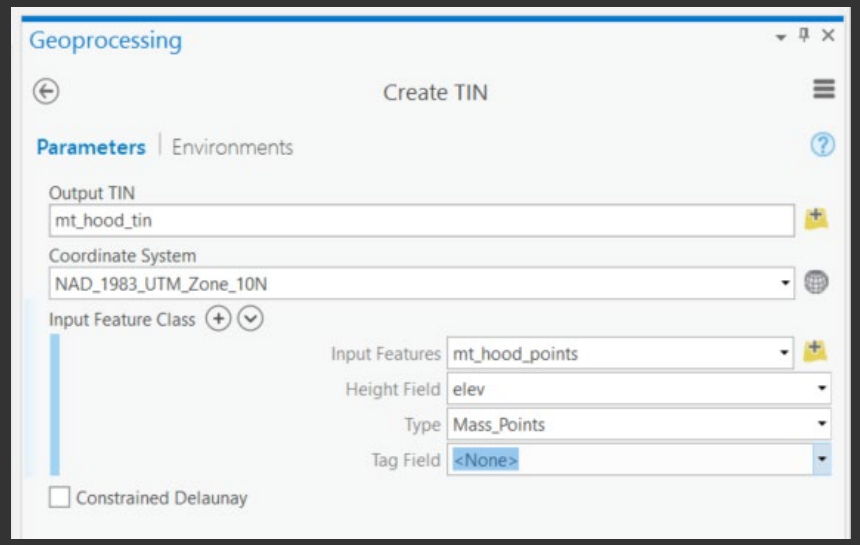
Calculating Area of a Polygon

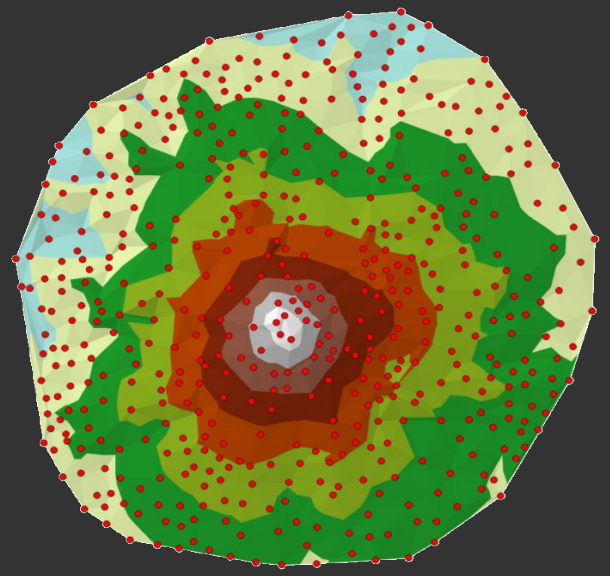
- Area is generally calculated in 2-D space
- This does not take into account topography and the 3D lay of the land.
- This can be misleading in complex terrains
- However, it is computationally much simpler and requires less data

Vector Data, Not for Discrete Features

- TINs (Triangulated Irregular Network)
- Good for representing terrain data
- A space filling model







TINs

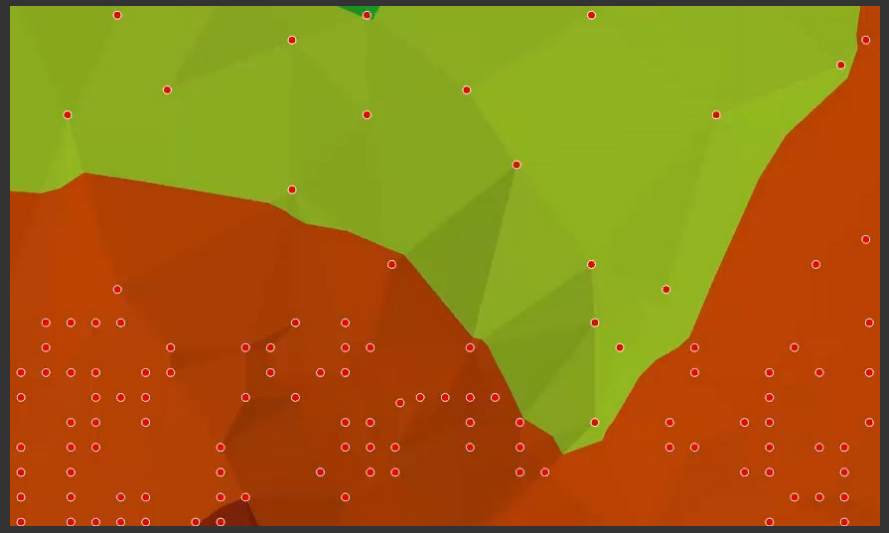
Connect measurement points to form a triangle (face)

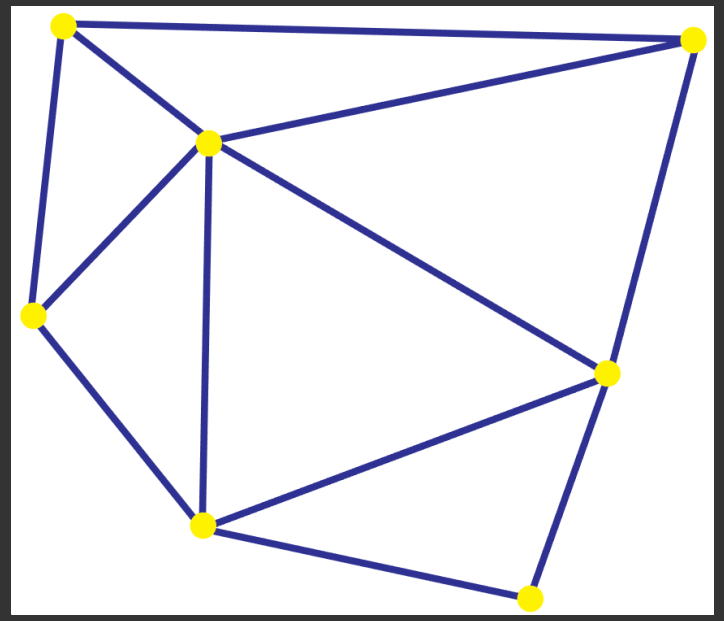
Can also include contours and/or breaklines

Lines connecting points = edges

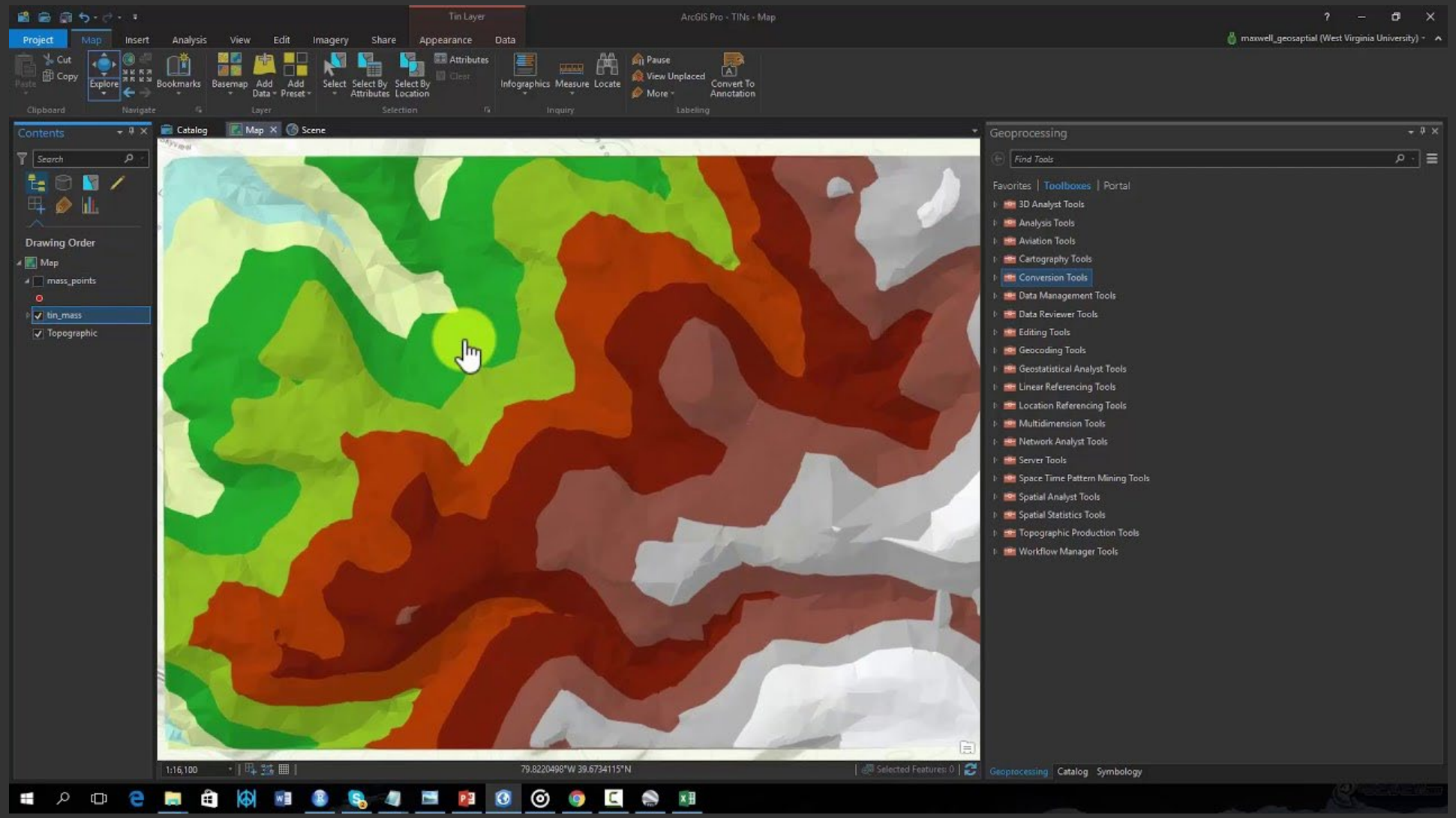
Can be used to represent a terrain (or other continuous surfaces)

Pros and cons compared to raster data



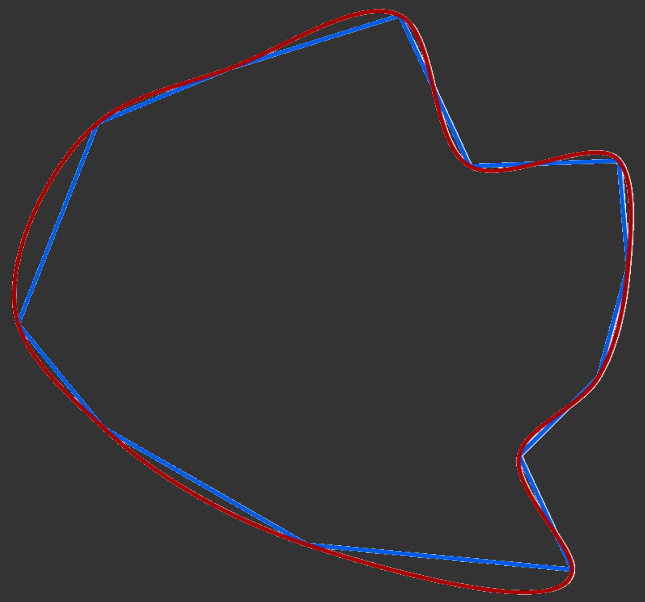


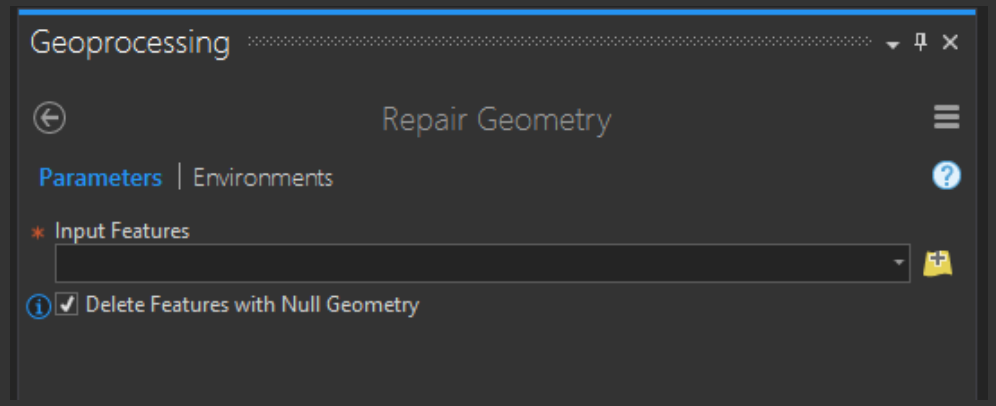
Video: TINs

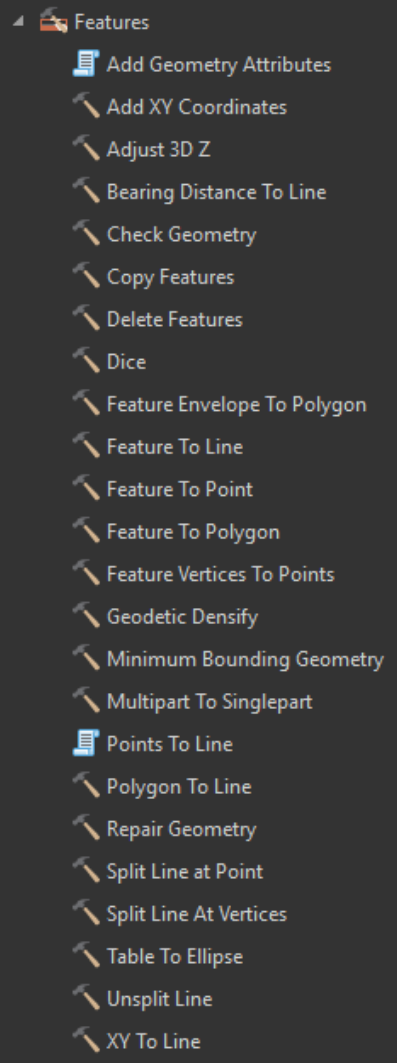

Tin Layer
ArcGIS Pro - TINs - Map
Project
Map
Insert
Analysis
View
Edit
Imagery
Share
Appearance
Data
Contents
Drawing Order
Map
mass_points
tin_mass
Topographic
Catalog
Map
Scene
Geoprocessing
Favorites
Toolboxes
Portal
3D Analyst Tools
Analysis Tools
Aviation Tools
Cartography Tools
Conversion Tools
Data Management Tools
Data Reviewer Tools
Editing Tools
Geocoding Tools
Geostatistical Analyst Tools
Linear Referencing Tools
Location Referencing Tools
Multidimension Tools
Network Analyst Tools
Server Tools
Space Time Pattern Mining Tools
Spatial Analyst Tools
Spatial Statistics Tools
Topographic Production Tools
Workflow Manager Tools

Important geometric operations for vector data

1. Repairing geometry
2. Smoothing/generalization
3. Merging/splitting
4. Etc.

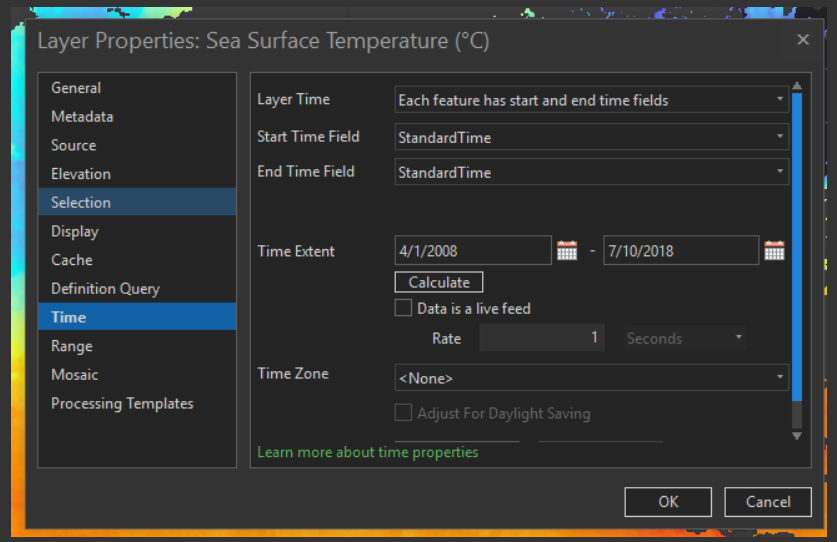


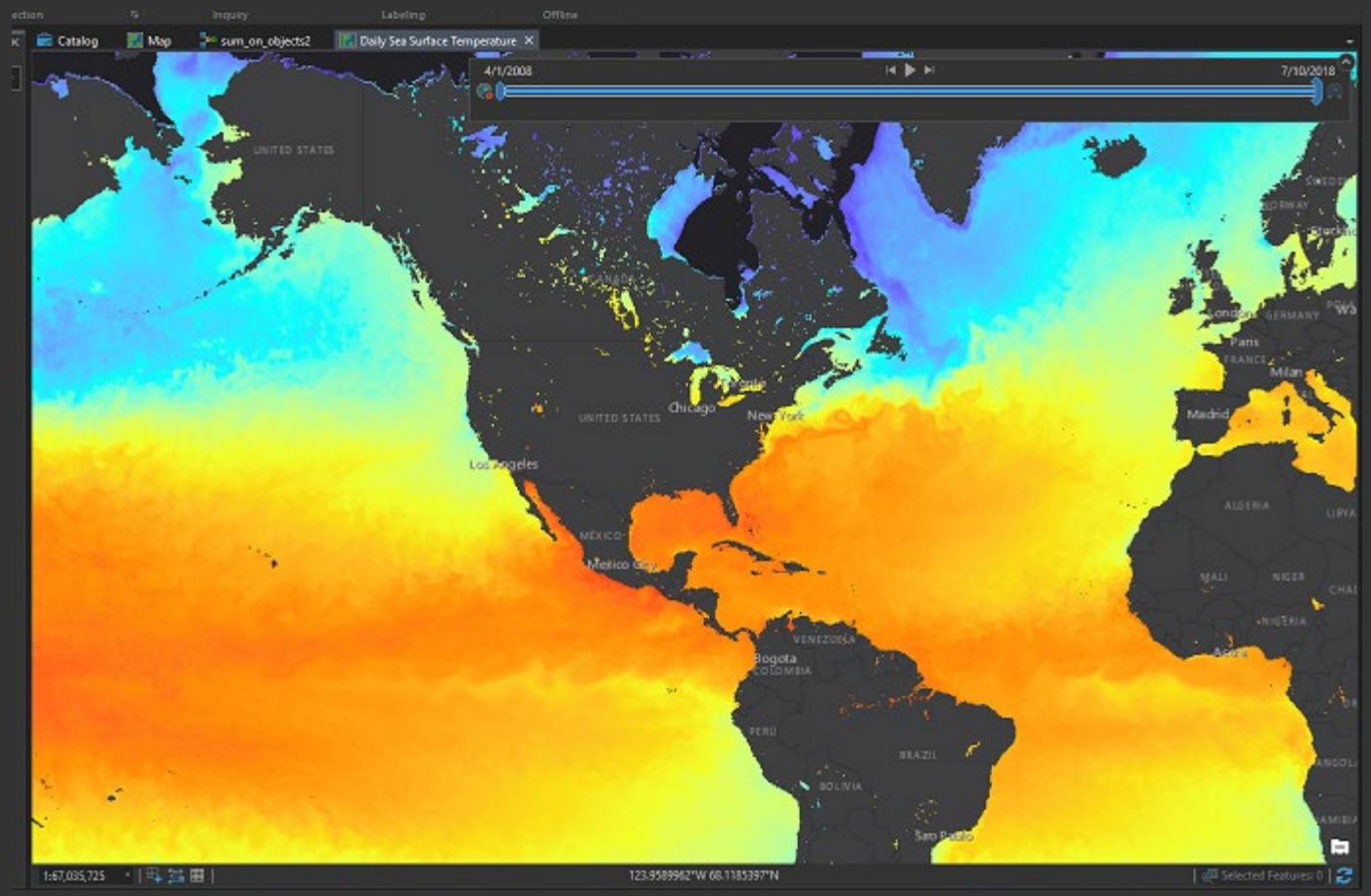




Time Enabled Data

- If data are time enabled, you can use time information to analyze, display, and query the data





Data from Naval Oceanographic Office and made available in the ESRI Living Atlas

Other Vector Data Models

GeoJSON

- JSON = JavaScript Object Notion
- Used to store and exchange data
- Text written with JavaScript object notation
- GeoJSON = allows you to encode geographic structures
- Used in web applications
- One file can store multiple geometry types

GEOJSON

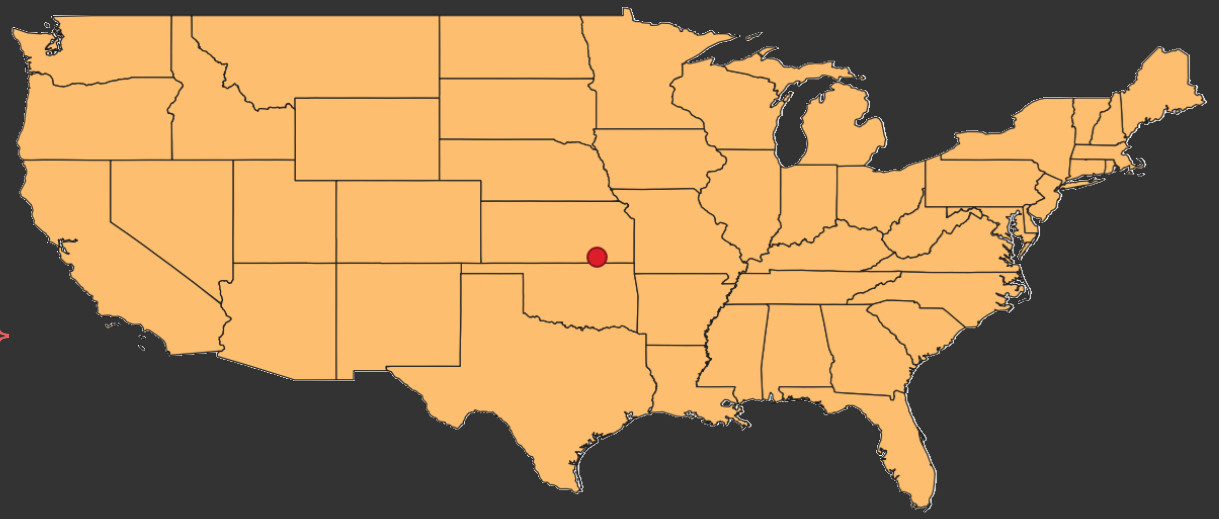
GeoJSON is a format for encoding a variety of geographic data structures.

```
{
  "type": "Feature",
  "geometry": {
    "type": "Point",
    "coordinates": [125.6, 10.1]
  },
  "properties": {
    "name": "Dinagat Islands"
  }
}
```

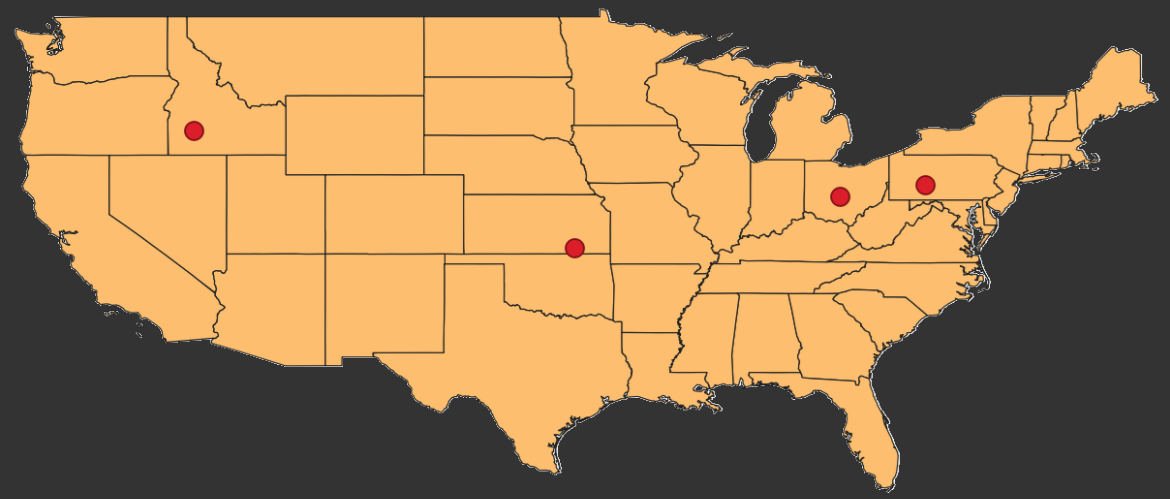
http://geojson.org/

GeoJSON: Point


```
{
"type": "FeatureCollection",
"name": "json_point2",
"crs": { "type": "name", "properties": {
"name": "urn:ogc:def:crs:OGC:1.3:CRS84" }
},
"features": [
{ "type": "Feature", "properties": { "id": 1,
"attribute1": 1, "attribute2": "point1",
"attribute3": 0.1111 }, "geometry": { "type":
"Point", "coordinates": [ -96.437, 37.283 ] } }
]
}
```

GeoJSON: Point



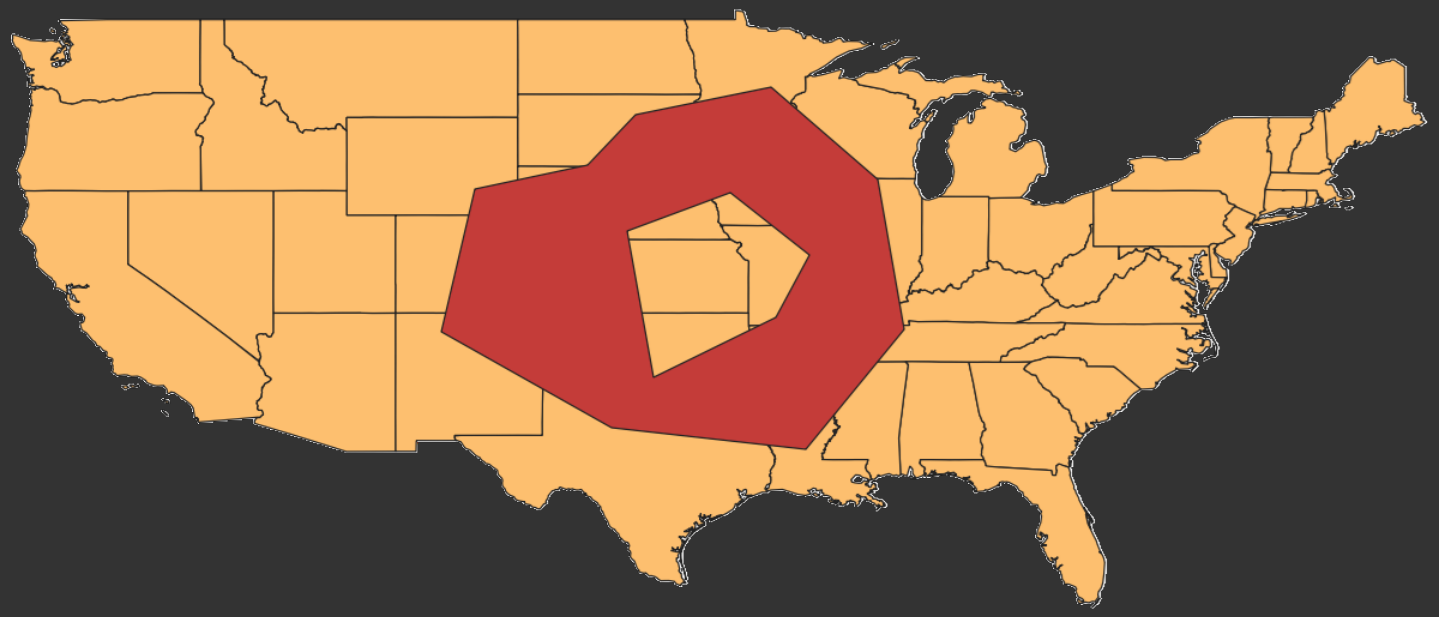

```
{
"type": "FeatureCollection",
"name": "example_point",
"crs": { "type": "name", "properties": { "name":
"urn:ogc:def:crs:OGC:1.3:CRS84" } },
"features": [
{ "type": "Feature", "properties": { "id": 1, "attribute1": 1,
"attribute2": "point1", "attribute3": 0.1111 }, "geometry": { "type":
"Point", "coordinates": [ -96.437, 37.283 ] } },
{ "type": "Feature", "properties": { "id": 2, "attribute1": 2,
"attribute2": "point2", "attribute3": 0.22222 }, "geometry": {
"type": "Point", "coordinates": [ -83.006, 39.913 ] } },
{ "type": "Feature", "properties": { "id": 3, "attribute1": 3,
"attribute2": "point3", "attribute3": 0.33333 }, "geometry": {
"type": "Point", "coordinates": [ -115.666, 43.247 ] } },
{ "type": "Feature", "properties": { "id": null, "attribute1": null,
"attribute2": null, "attribute3": null }, "geometry": { "type":
"Point", "coordinates": [ -78.691, 40.501 ] } }
]
}
```

GeoJSON: Line

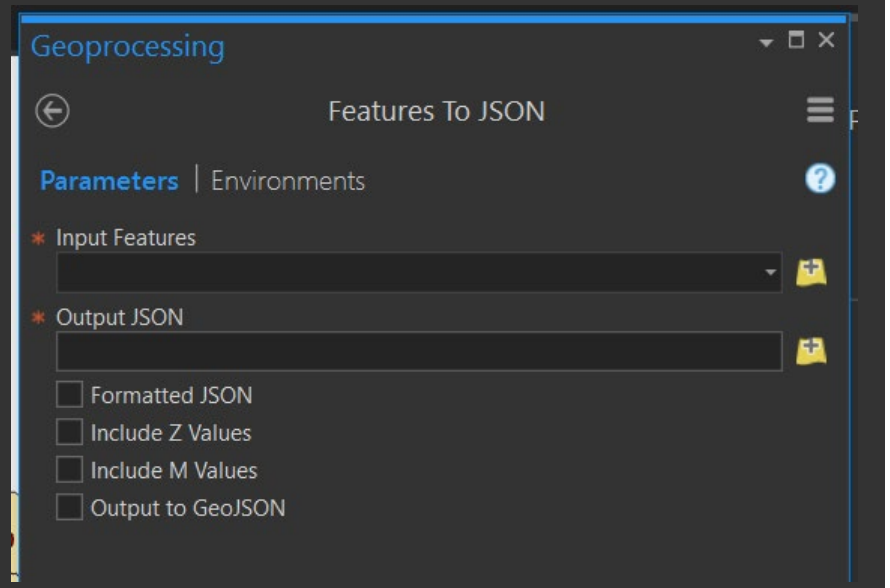

```
{
"type": "FeatureCollection",
"name": "line_example",
"crs": { "type": "name", "properties": { "name": "urn:ogc:def:crs:OGC:1.3:CRS84" } },
"features": [
{ "type": "Feature", "properties": { "id": 1, "attribute1": 1, "attribute2": 1111, "attribute3": "line" }, "geometry": {
"type": "MultiLineString", "coordinates": [ [ [ -118.903, 39.471 ], [ -112.086, 41.188 ], [ -105.957, 42.315 ], [ -
97.718, 41.237], [ -90.313, 39.030], [ -85.458, 36.234], [ -78.544, 38.883 ] ] ] } }
]
}
```

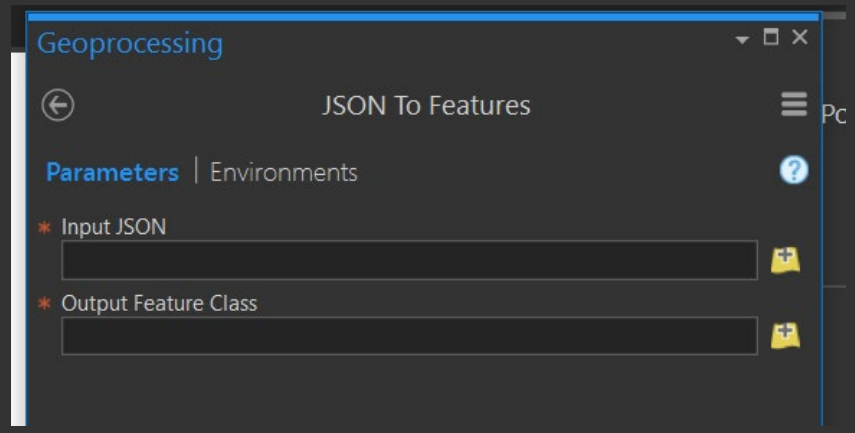
GeoJSON: Polygon

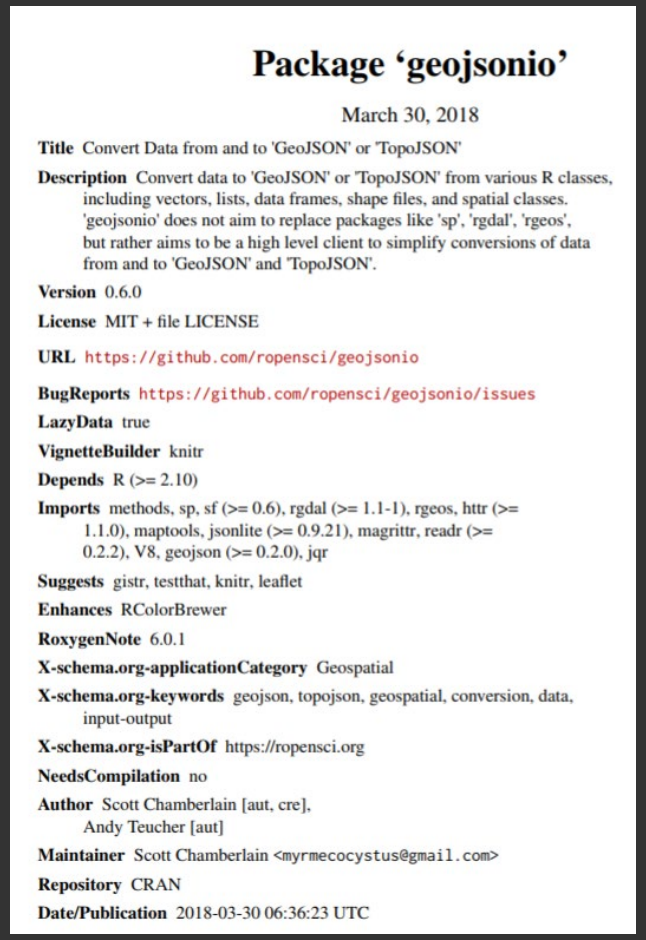

```
{
"type": "FeatureCollection",
"name": "polygon_example3",
"crs": { "type": "name", "properties": { "name":
"urn:ogc:def:crs:OGC:1.3:CRS84" } },
"features": [
{ "type": "Feature", "properties": { "id": 1 },
"geometry": { "type": "MultiPolygon",
"coordinates": [ [ [ [ -101.2, 43.051 ], [ -99.238,
45.111 ], [ -99.238, 45.111 ], [ -93.697, 46.239 ],
[ -89.332, 42.463 ], [ -88.254, 36.333 ], [ -
92.275, 31.429 ], [ -100.219, 32.312 ], [ -
107.183, 36.235 ], [ -105.809, 42.07 ], [ -101.2,
43.051 ] ], [ [ -99.581, 40.354 ], [ -98.503,
34.371 ], [ -93.501, 36.823 ], [ -92.128, 39.373
], [ -95.364, 41.923 ], [ -99.581, 40.354 ] ] ] ] }
}
]
}
```

GeoJSON Conversion







Package 'geojsonio'

March 30, 2018

Title Convert Data from and to 'GeoJSON' or 'TopoJSON'

Description Convert data to 'GeoJSON' or 'TopoJSON' from various R classes, including vectors, lists, data frames, shape files, and spatial classes. 'geojsonio' does not aim to replace packages like 'sp', 'rgdal', 'rgeos', but rather aims to be a high level client to simplify conversions of data from and to 'GeoJSON' and 'TopoJSON'.

Version 0.6.0

License MIT + file LICENSE

URL https://github.com/ropensci/geojsonio

BugReports https://github.com/ropensci/geojsonio/issues

LazyData true

VignetteBuilder knitr

Depends R (>= 2.10)

Imports methods, sp, sf (>= 0.6), rgdal (>= 1.1-1), rgeos, httr (>= 1.1.0), maptools, jsonlite (>= 0.9.21), magrittr, readr (>= 0.2.2), V8, geojson (>= 0.2.0), jqr

Suggests gistr, testthat, knitr, leaflet

Enhances RColorBrewer

RoxygenNote 6.0.1

X-schema.org-applicationCategory Geospatial

X-schema.org-keywords geojson, topojson, geospatial, conversion, data, input-output

X-schema.org-isPartOf https://ropensci.org

NeedsCompilation no

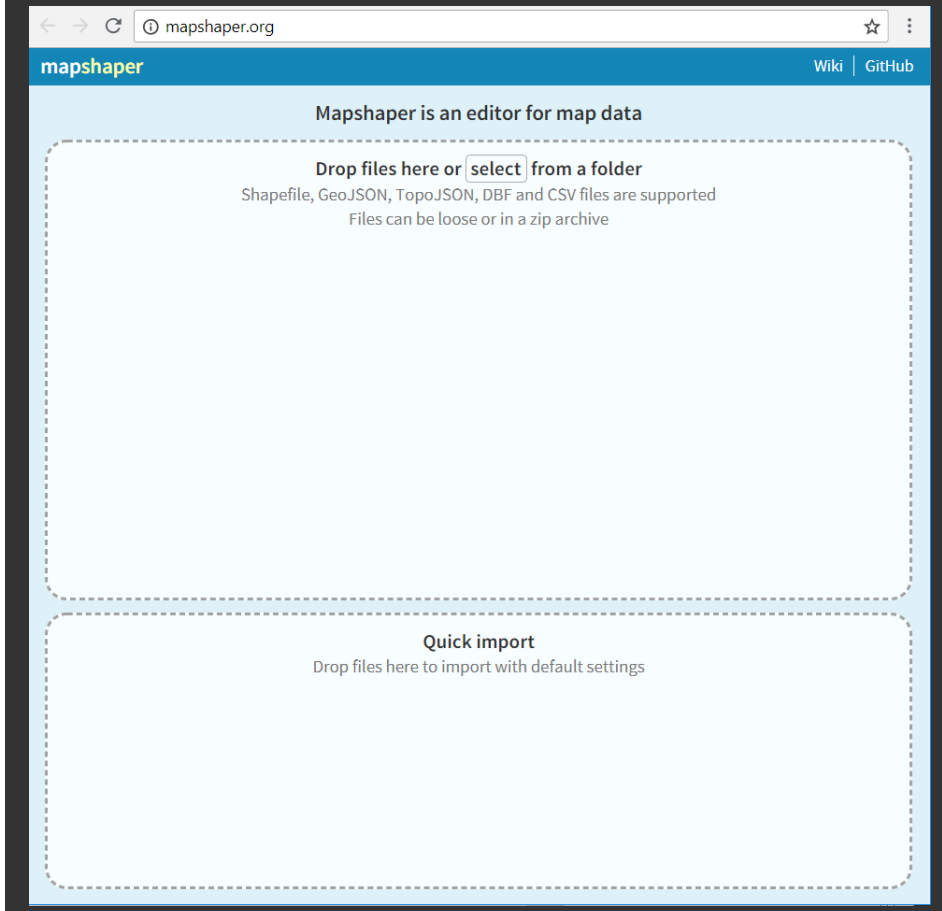
Author Scott Chamberlain [aut, cre], Andy Teucher [aut]

Maintainer Scott Chamberlain <myrmecocystus@gmail.com>

Repository CRAN

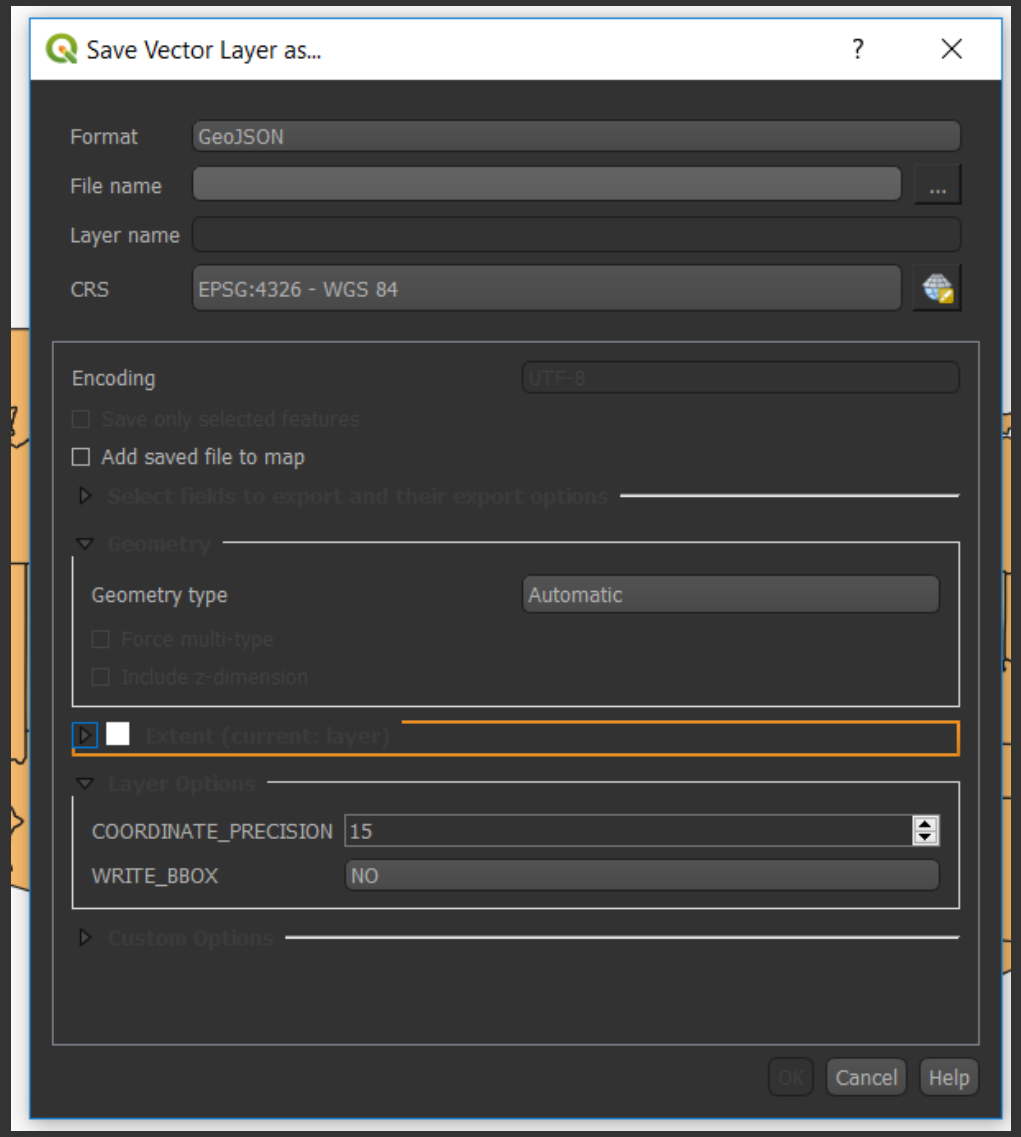
Date/Publication 2018-03-30 06:36:23 UTC

https://cran.r-project.org/web/packages/geojsonio/geojsonio.pdf



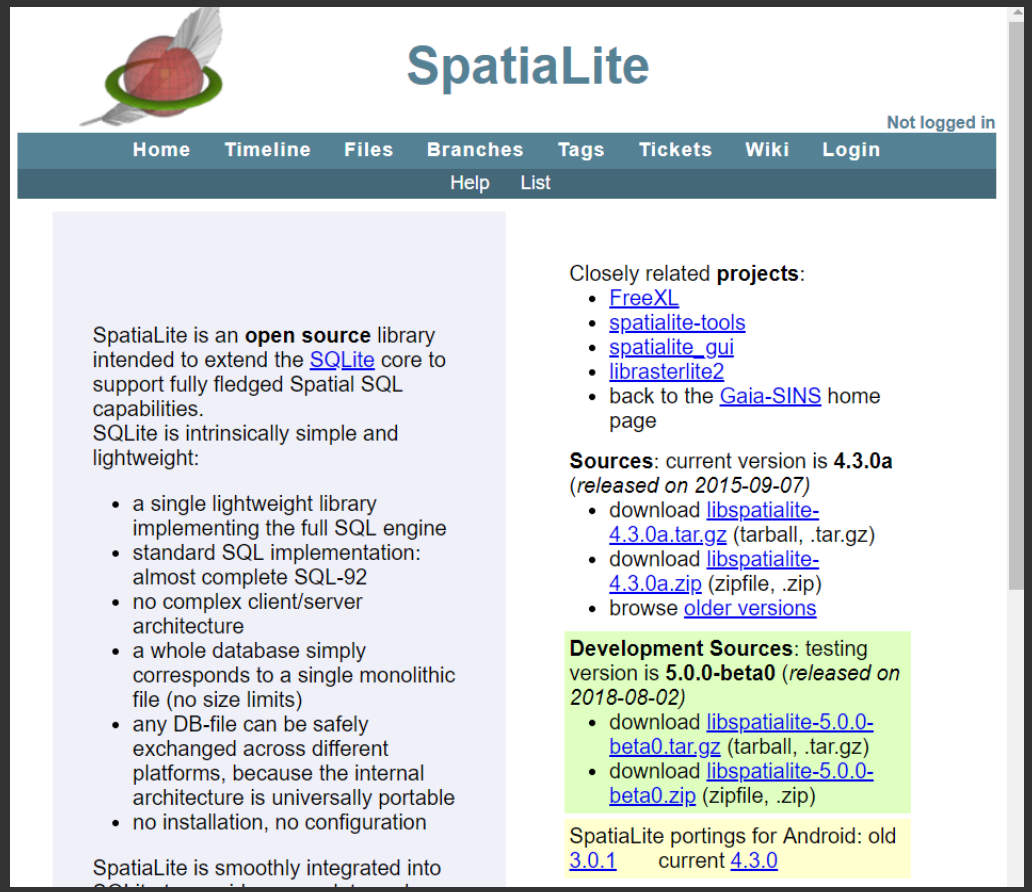
http://mapshaper.org/

GeoJSON in QGIS



- Can export files to GeoJSON format
- Can create bounding box
- Can set coordinate precision
- QGIS can read an write many file types

SpatiaLite

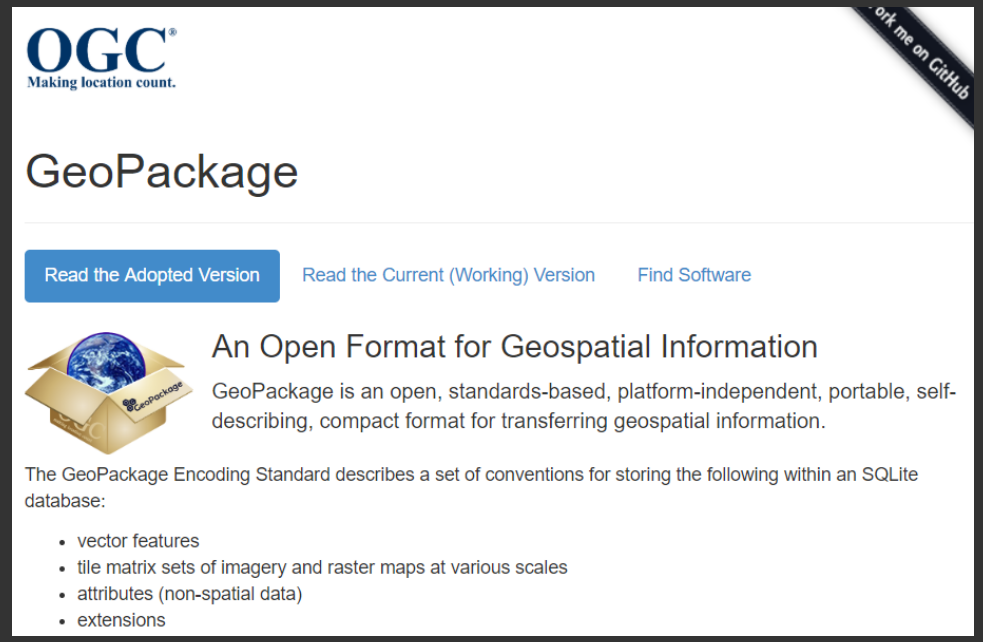


https://www.gaia-gis.it/fossil/libspatialite/index

- Extension for SQLite
- Stores data in a file-based database
- Not a true client-server database
- Alternative to ESRI file geodatabase
- Only for vector data

GeoPackage

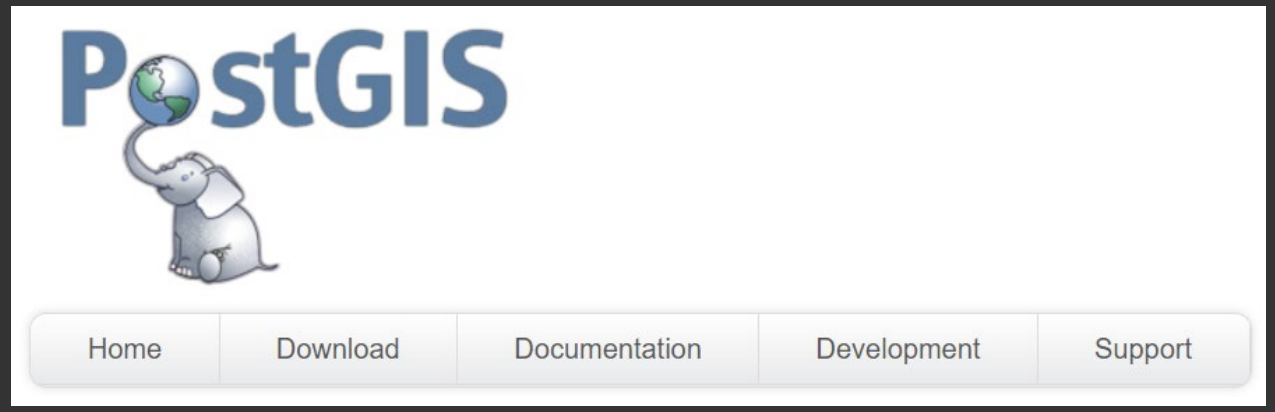
- Developed by the Open Geospatial Consortium
- Store data in an SQLite database
- File-based database structure
- May see more support in the future
- Supports vector and raster storage
- Store tiled raster layers
- Lightweight



https://www.geopackage.org/

PostGIS

- Allows spatial data to be stored in a PostgreSQL database
- True client-server infrastructure
- Spatial data are stored as tables
- Geometry is stored in a column in the table
- Open and free to use
- Can be ran as a local host



https://postgis.net/

GPX

- GPS Exchange Format
- Uses Extensible Markup Language (XML)
- Open data format
- Store waypoints, tracks, and routes


```
<?xml version="1.0"?>
<gpx version="1.1" creator="GDAL 2.2.4" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:ogr="http://osgeo.org/gdal"
xmlns="http://www.topografix.com/GPX/1/1" xsi:schemaLocation="http://www.topografix.com/GPX/1/1
http://www.topografix.com/GPX/1/1/gpx.xsd">
<metadata><bounds minlat="37.283000000000001" minlon="-115.665999999999997" maxlat="43.247000000000000" maxlon="-
78.691000000000003"/></metadata>
<wpt lat="37.283" lon="-96.437">
  <extensions>
    <ogr:id>1</ogr:id>
    <ogr:attribute1>1</ogr:attribute1>
    <ogr:attribute2>point1</ogr:attribute2>
    <ogr:attribute3>0.1111</ogr:attribute3>
  </extensions>
</wpt>
<wpt lat="39.913" lon="-83.006">
  <extensions>
    <ogr:id>2</ogr:id>
    <ogr:attribute1>2</ogr:attribute1>
    <ogr:attribute2>point2</ogr:attribute2>
    <ogr:attribute3>0.22222</ogr:attribute3>
  </extensions>
</wpt>
<wpt lat="43.247" lon="-115.666">
  <extensions>
    <ogr:id>3</ogr:id>
    <ogr:attribute1>3</ogr:attribute1>
    <ogr:attribute2>point3</ogr:attribute2>
    <ogr:attribute3>0.33333</ogr:attribute3>
  </extensions>
</wpt>
<wpt lat="40.501" lon="-78.691">
  <extensions>
  </extensions>
</wpt>
</gpx>
```

Keyhole Markup Language (KML)

- Used in Google Earth
- KMZ is a compressed versions of a KML
- Uses XML


```
<?xml version="1.0" encoding="utf-8" ?>
<kml xmlns="http://www.opengis.net/kml/2.2">
<Document id="root_doc">
<Schema name="kml_example" id="kml_example">
                <SimpleField name="id" type="int"></SimpleField>
                <SimpleField name="attribute1" type="int"></SimpleField>
                <SimpleField name="attribute2" type="string"></SimpleField>
                <SimpleField name="attribute3" type="float"></SimpleField>
</Schema>
<Folder><name>kml_example</name>
 <Placemark>
                <ExtendedData><SchemaData schemaUrl="#kml_example">
                        <SimpleData name="id">1</SimpleData>
                        <SimpleData name="attribute1">1</SimpleData>
                        <SimpleData name="attribute2">point1</SimpleData>
                        <SimpleData name="attribute3">0.1111</SimpleData>
                </SchemaData></ExtendedData>
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 </Placemark>
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                        <SimpleData name="attribute1">2</SimpleData>
                        <SimpleData name="attribute2">point2</SimpleData>
                        <SimpleData name="attribute3">0.22222</SimpleData>
                </SchemaData></ExtendedData>
   <Point><coordinates>-83.0063918894116,39.9125142095311</coordinates></Point>
 </Placemark>
 <Placemark>
                <ExtendedData><SchemaData schemaUrl="#kml_example">
                        <SimpleData name="id">3</SimpleData>
                        <SimpleData name="attribute1">3</SimpleData>
                        <SimpleData name="attribute2">point3</SimpleData>
                        <SimpleData name="attribute3">0.33333</SimpleData>
                </SchemaData></ExtendedData>
   <Point><coordinates>-115.666206923678,43.2471499787955</coordinates></Point>
 </Placemark>
 <Placemark>
   <Point><coordinates>-78.690980893893,40.5009793452837</coordinates></Point>
 </Placemark>
</Folder>
</Document></kml>
```

Keyhole Markup Language

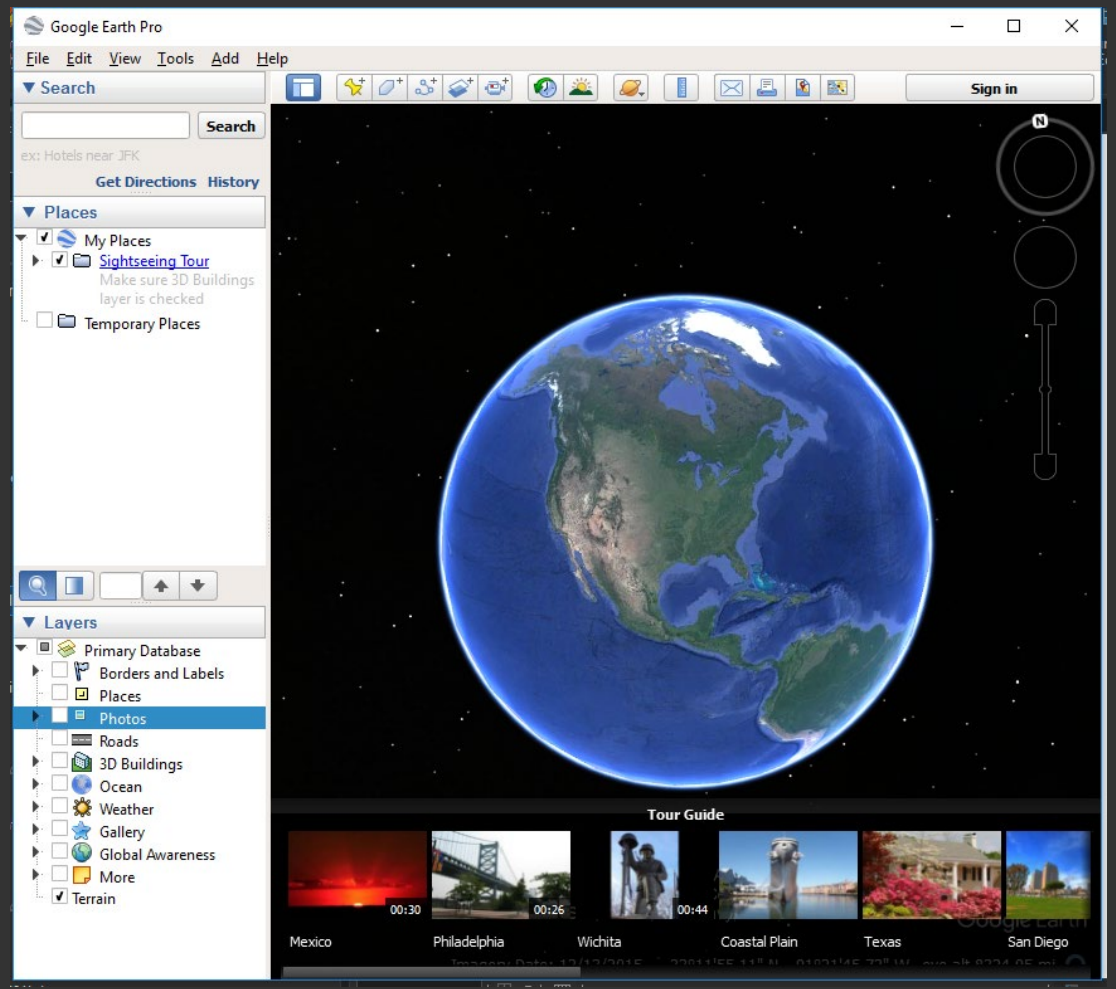
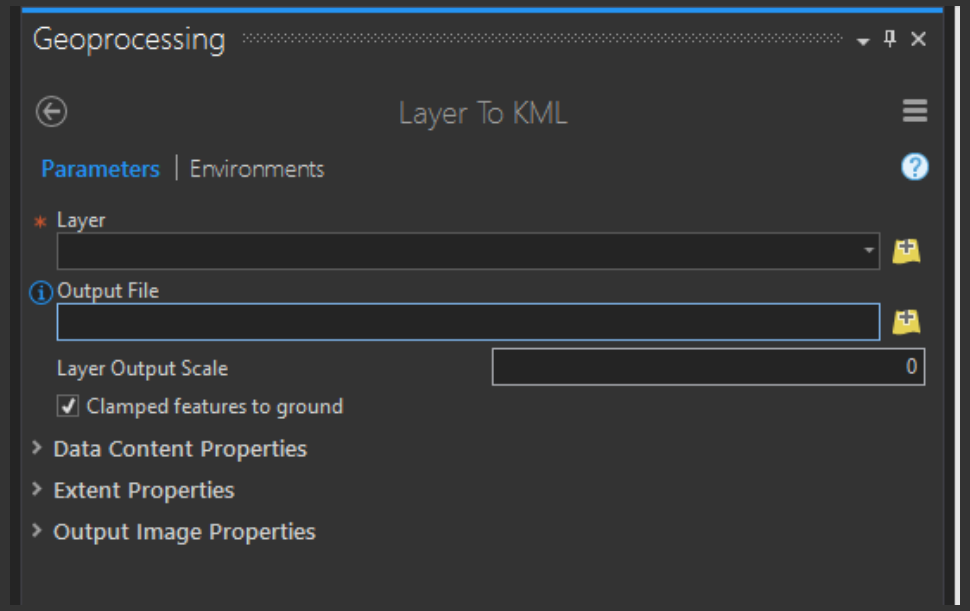
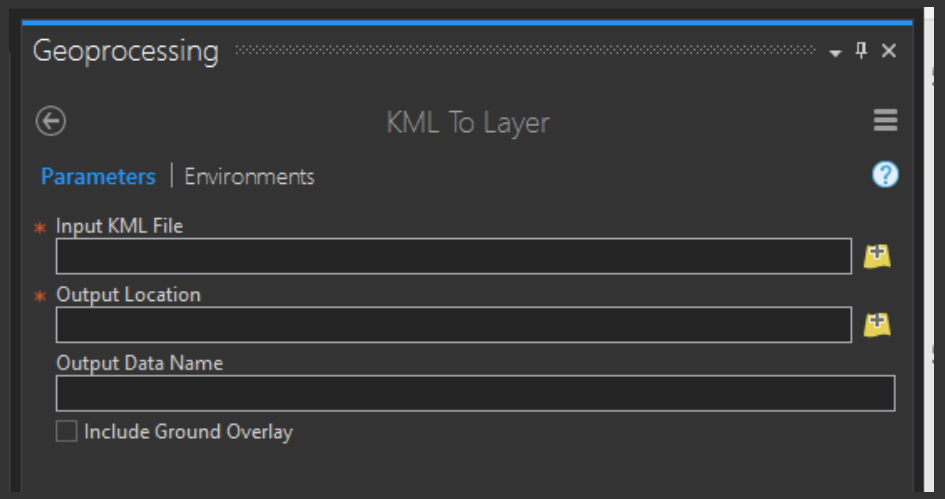
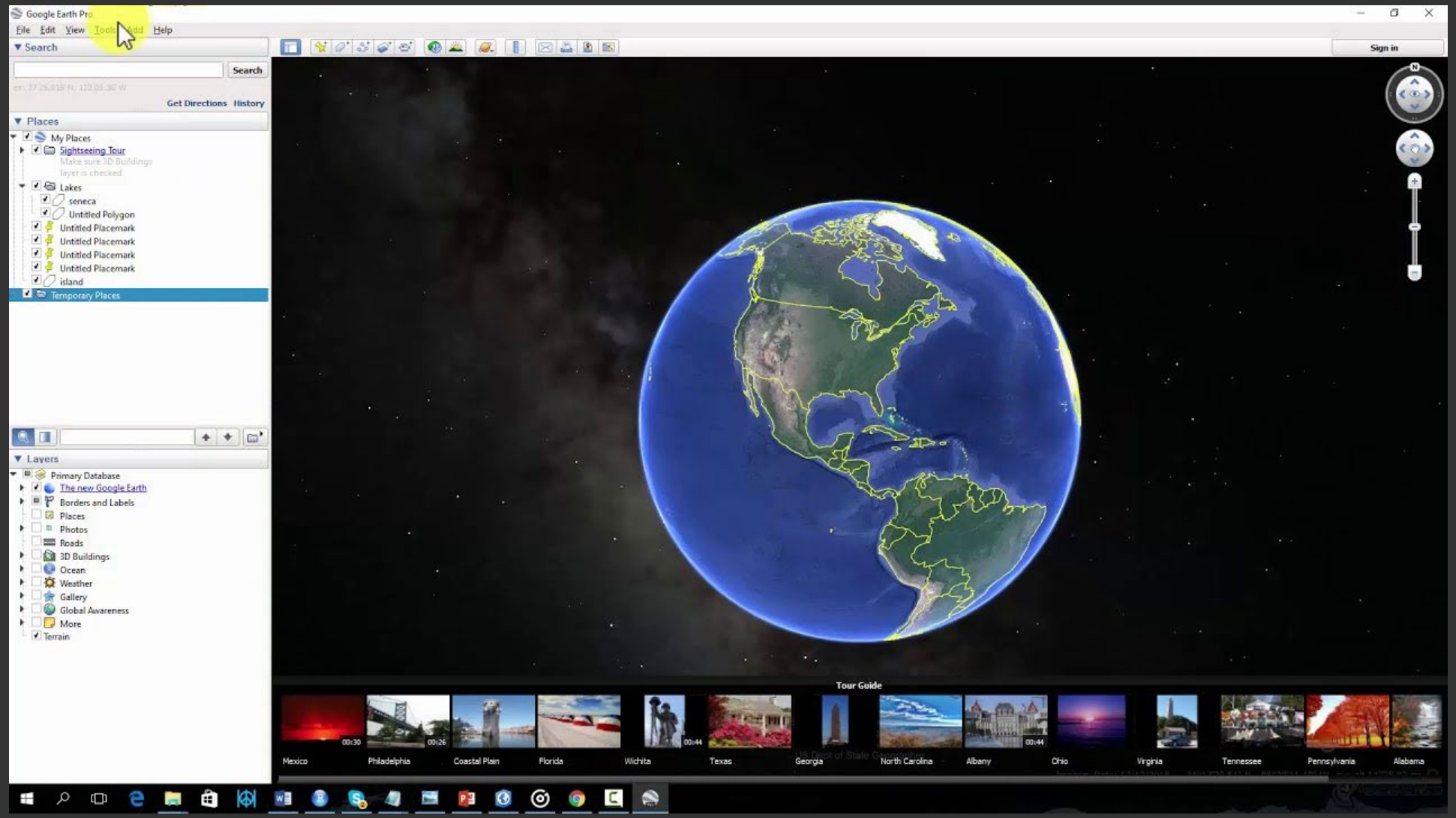


Image from Google Earth

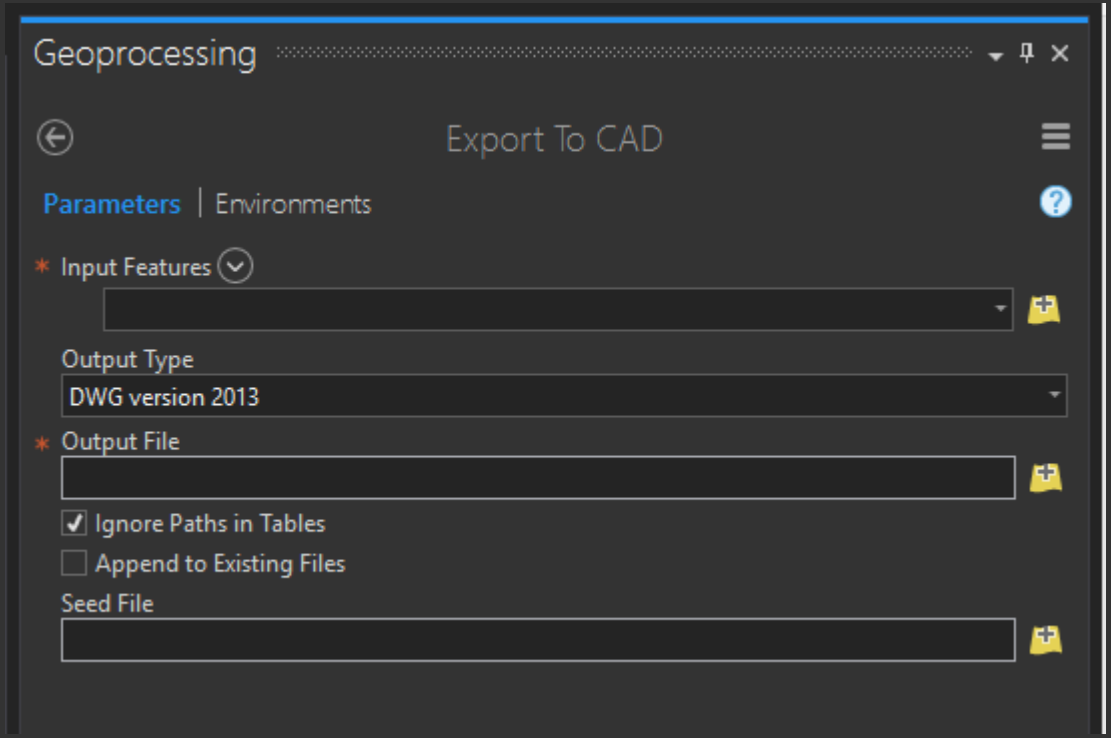


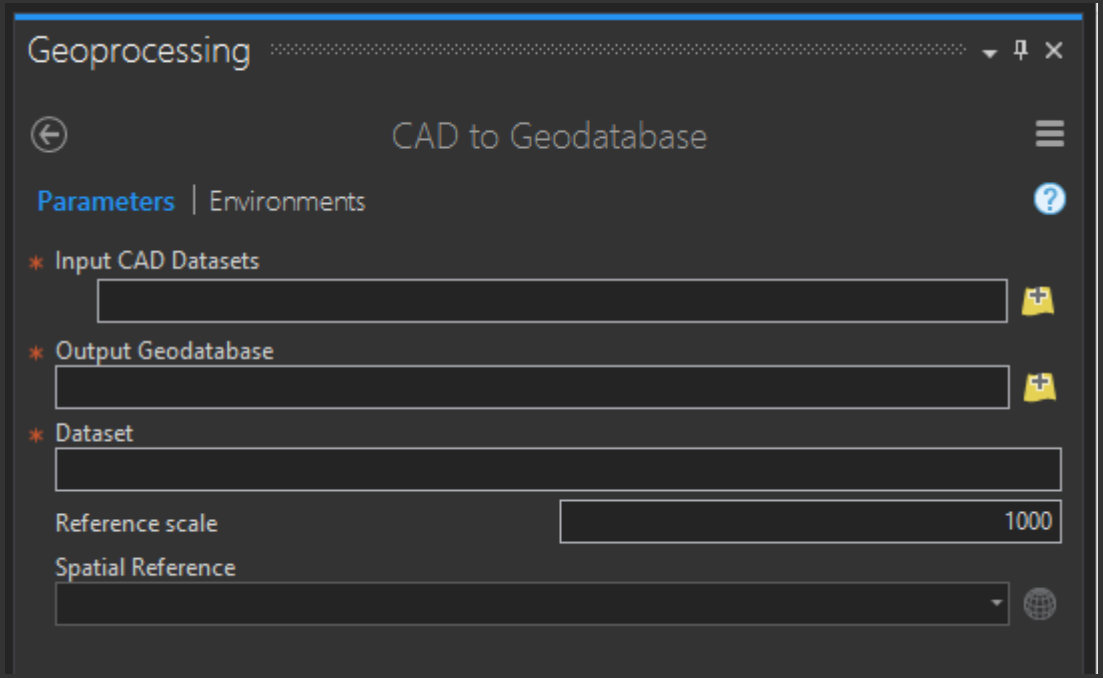


Video: KML Files



A Note on CAD Files

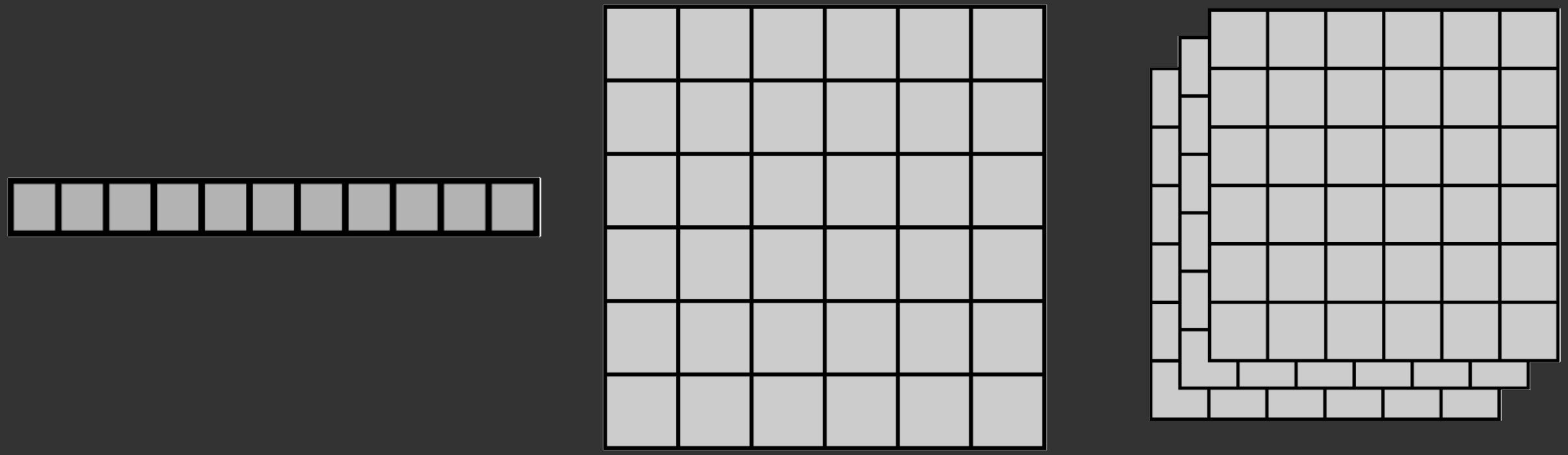




pixels

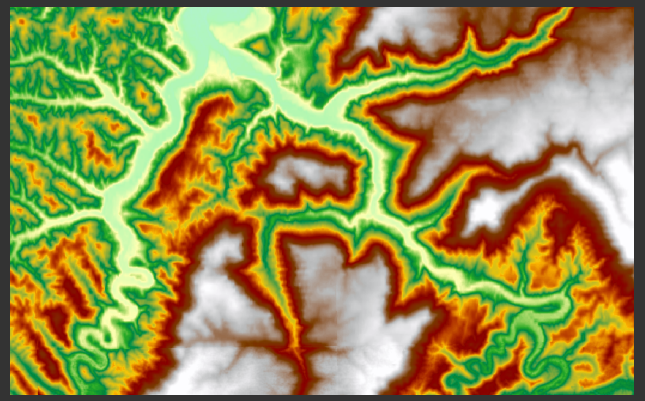
Raster Data

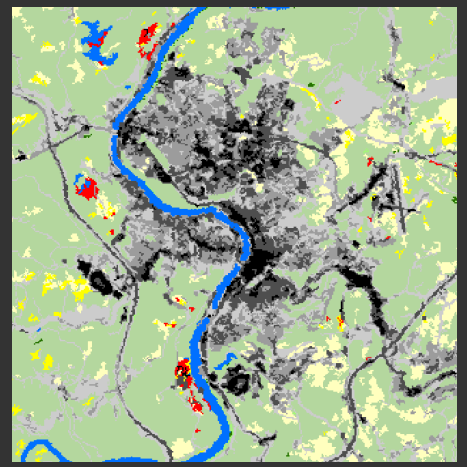
Arrays

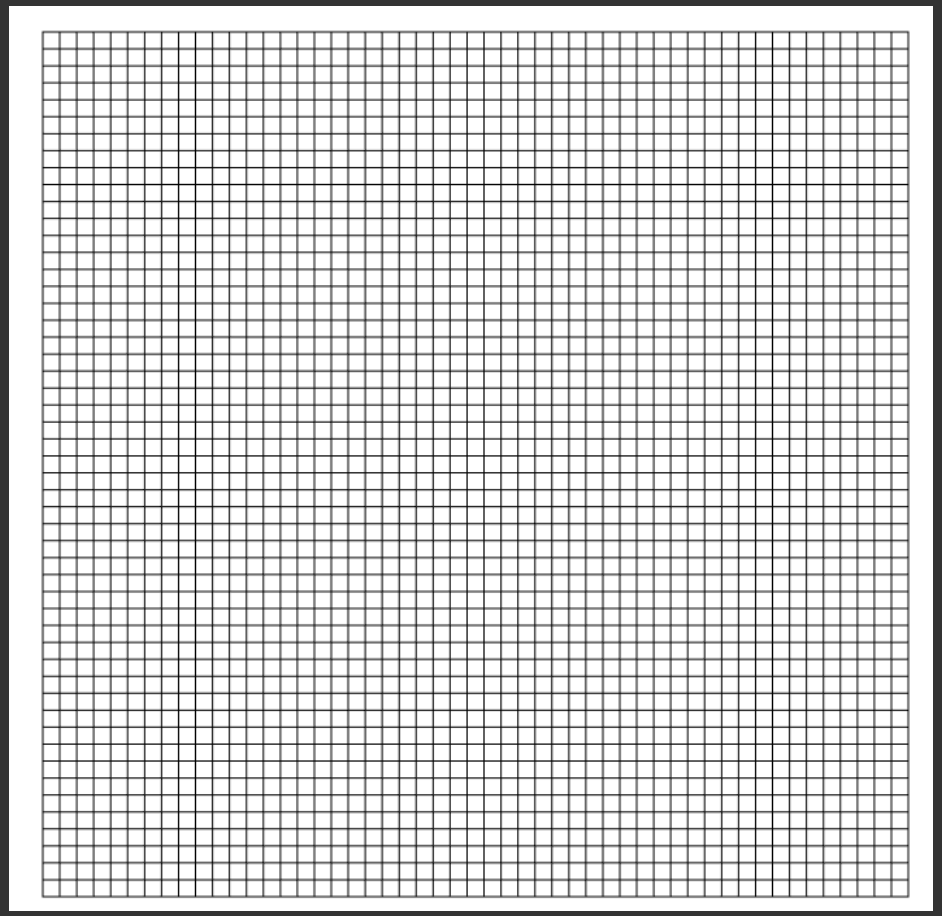


Raster Data

- Like a matrix or array of data
- Origin generally defined as coordinates of upper-left corner
- Cells have defined height and width relative to the coordinate system/projection







Raster Data: Categorical

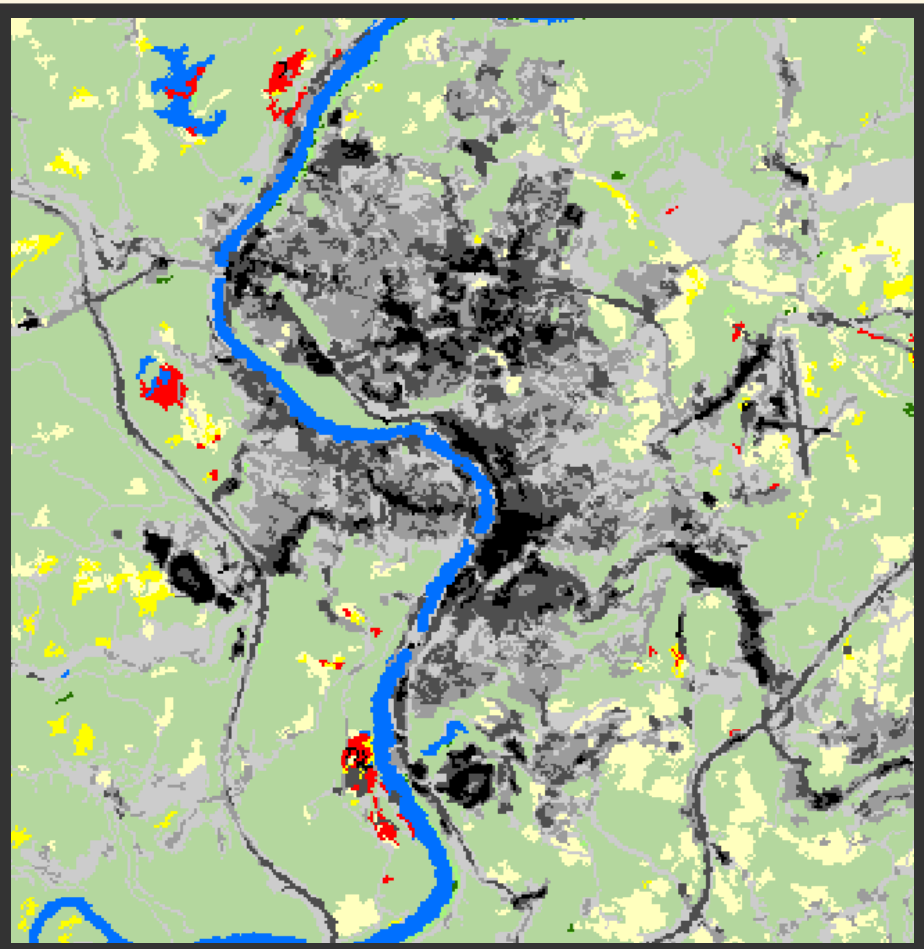
- Cells hold a value
- Value is a place holder for a category (nominal data)
- Commonly has attribute table

wv_nlcd01lulc

VALUE

- Open Water
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren Land (Rock/Sand/Clay)
- Deciduous Forest
- Coniferous Forest
- Mixed Forest
- Shrub/Scrub
- Grassland/Herbaceous
- Pasture/Hay
- Cultivated Crops
- Woody Wetlands
- Emergent Herbaceous Wetlands

Rowid	VALUE	COUNT
0	11	692997
1	21	3564751
2	22	989578
3	23	398502
4	24	92139
5	31	410192
6	41	54708767
7	42	1822591
8	43	1291515
9	52	15218
10	71	1018245
11	81	5761593
12	82	966030
13	90	53301
14	95	40661



Attribute tables for categorical raster grids

Table

wv_nlcd01lulc

Rowid	VALUE *	COUNT
0	11	692997
1	21	3564751
2	22	989578
3	23	398502
4	24	92139
5	31	410192
6	41	5470876
7	42	1822591
8	43	1291515
9	52	15218
10	71	1018245
11	81	5761593
12	82	966030
13	90	53301
14	95	40661

1 (0 out of 15 Selected)

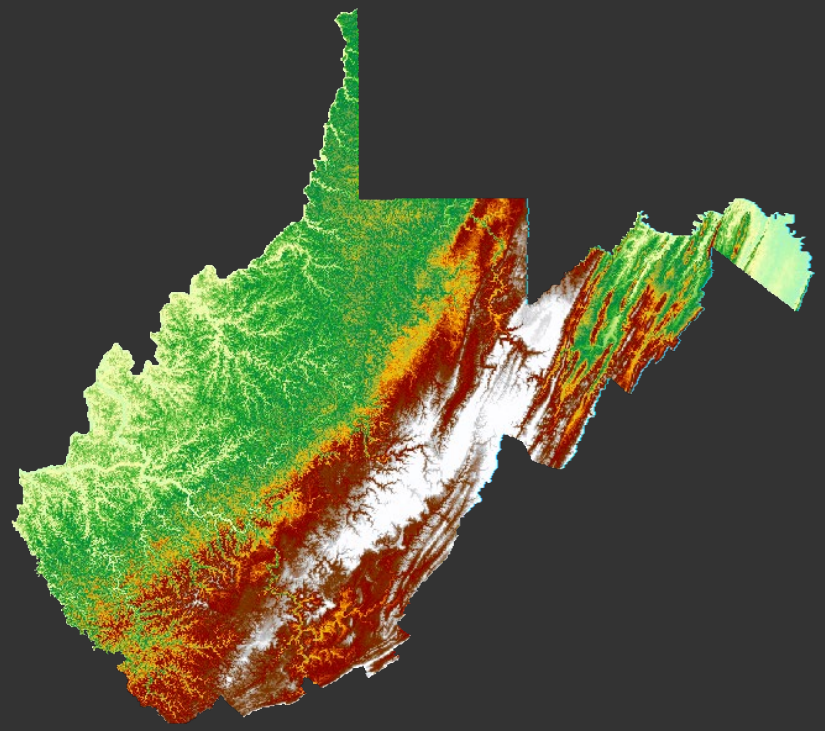
wv_nlcd01lulc

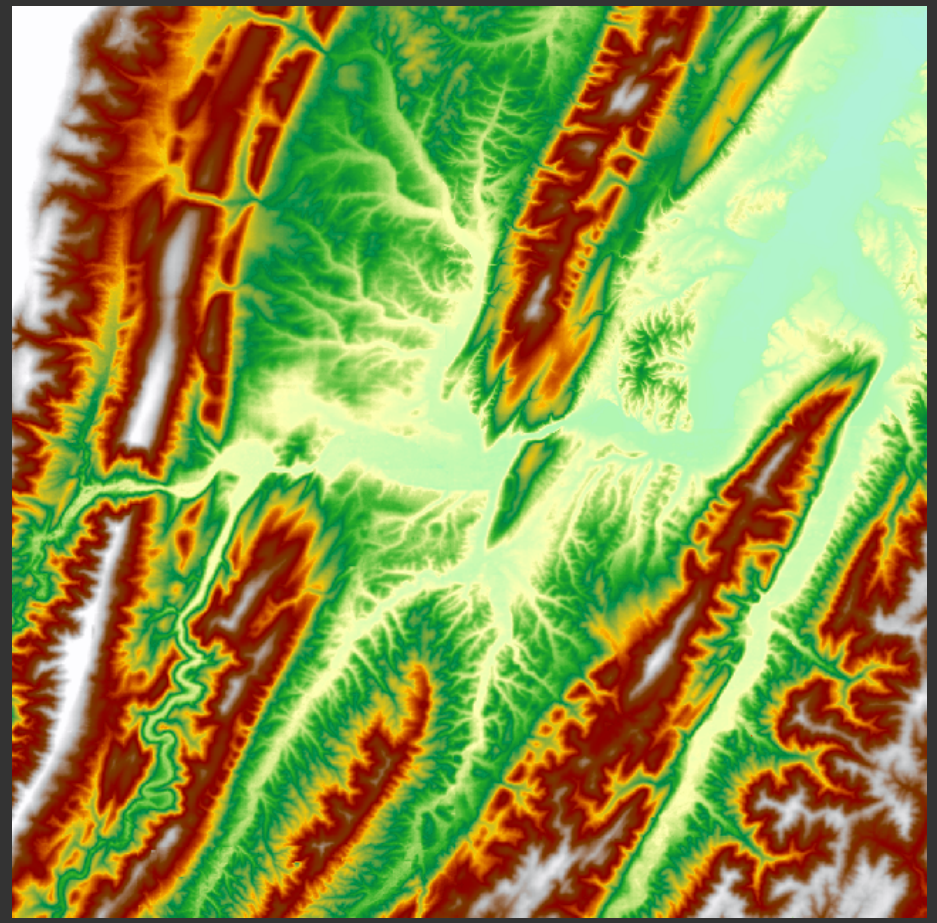
Rowid	VALUE	COUNT
0	11	692997
1	21	3564751
2	22	989578
3	23	398502
4	24	92139
5	31	410192
6	41	54708767
7	42	1822591
8	43	1291515
9	52	15218
10	71	1018245
11	81	5761593
12	82	966030
13	90	53301
14	95	40661

- How do you convert from a count to an actual area?

Raster Data: Continuous

- Cells hold a value
- Value is a true quantity (numeric data), not a place holder



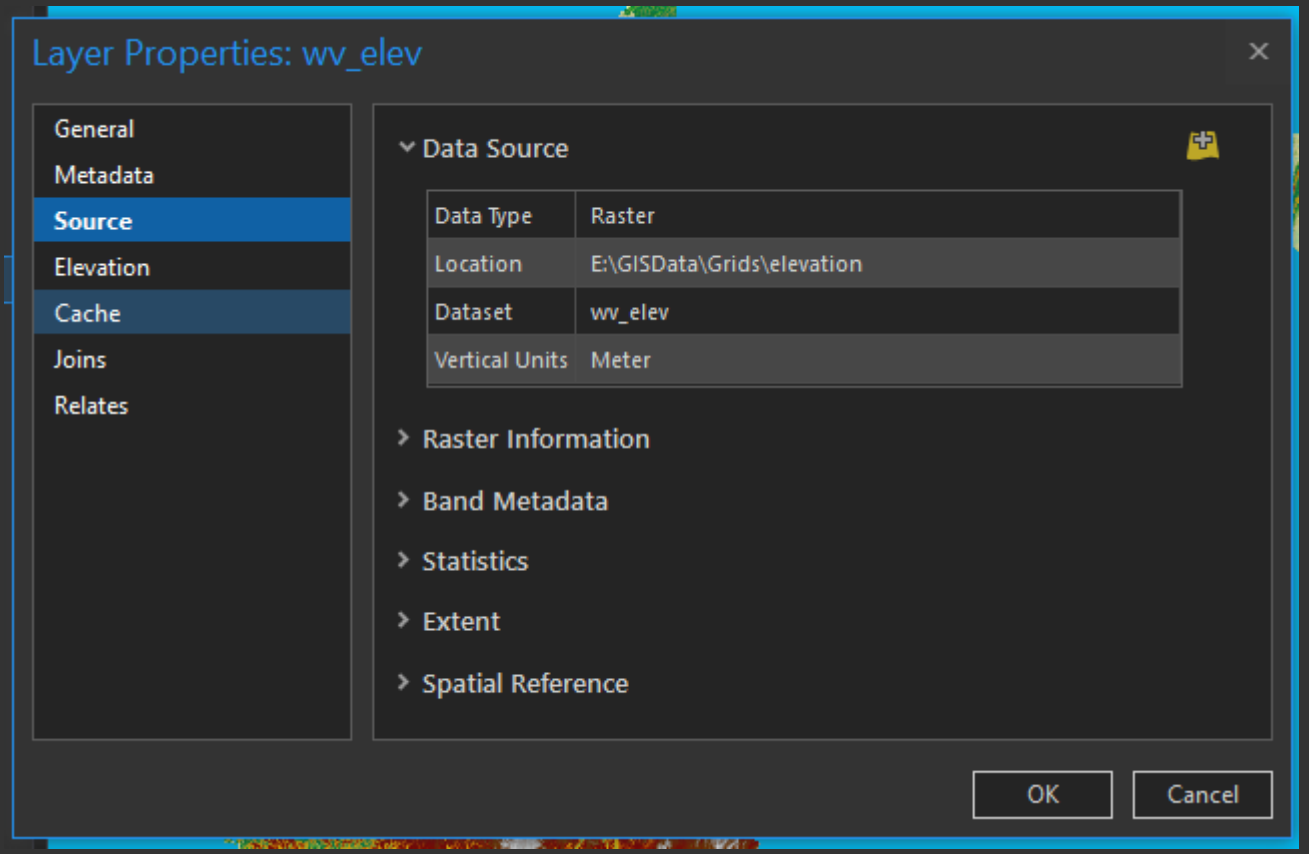


Radiometric Resolution

- Integer = Only holds whole numbers
- Float = Can hold decimals
- Signed = can hold negative values
- Unsigned = cannot hold negative values
- Pixel Type/Pixel Depth
  - 4-bit = 2^4 (16) unique values
  - 8-bit = 2^8 (256) unique values
  - 16-bit = 2^{16} (65,536) unique values
  - 32-bit = 2^{32} (4,294,967,296) unique values
  - 1-bit, 2-bit, 11-bit, 12-bit, etc.

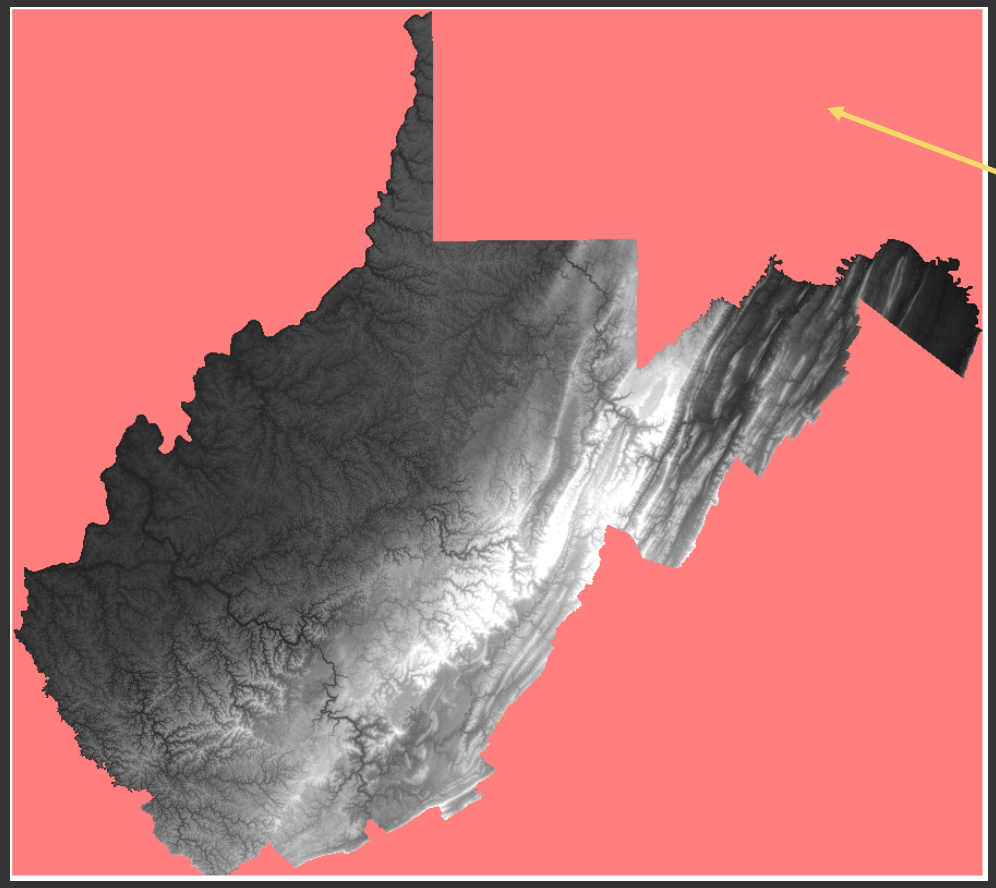
Can think of this as the degree of brightness difference that can be quantified

Info about your raster data



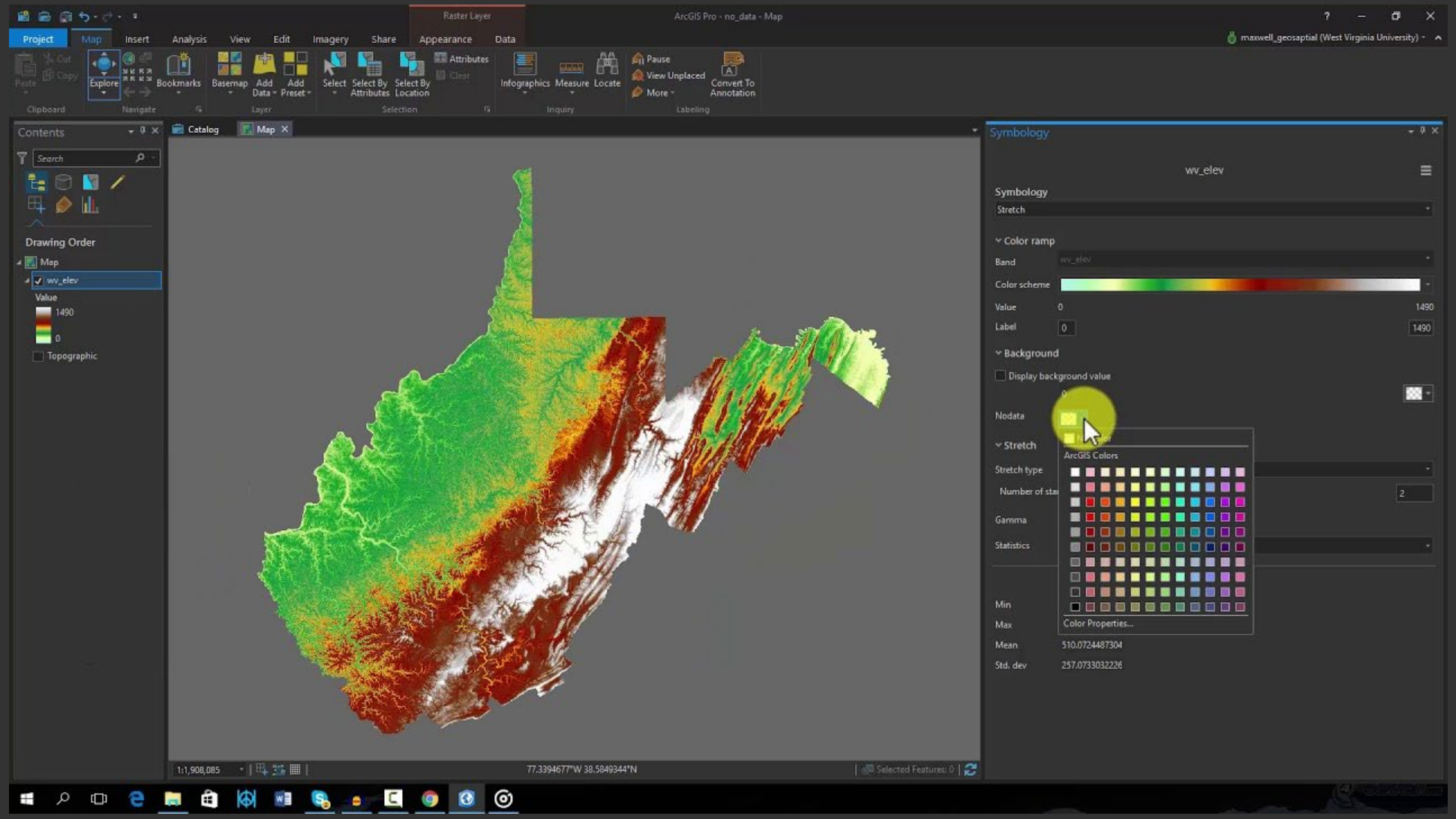
- Number of columns
- Number of rows
- Number of bands
- Cell size
- File size
- Pixel type/Pixel depth
- NoData value
- Spatial reference

Raster data are always rectangular

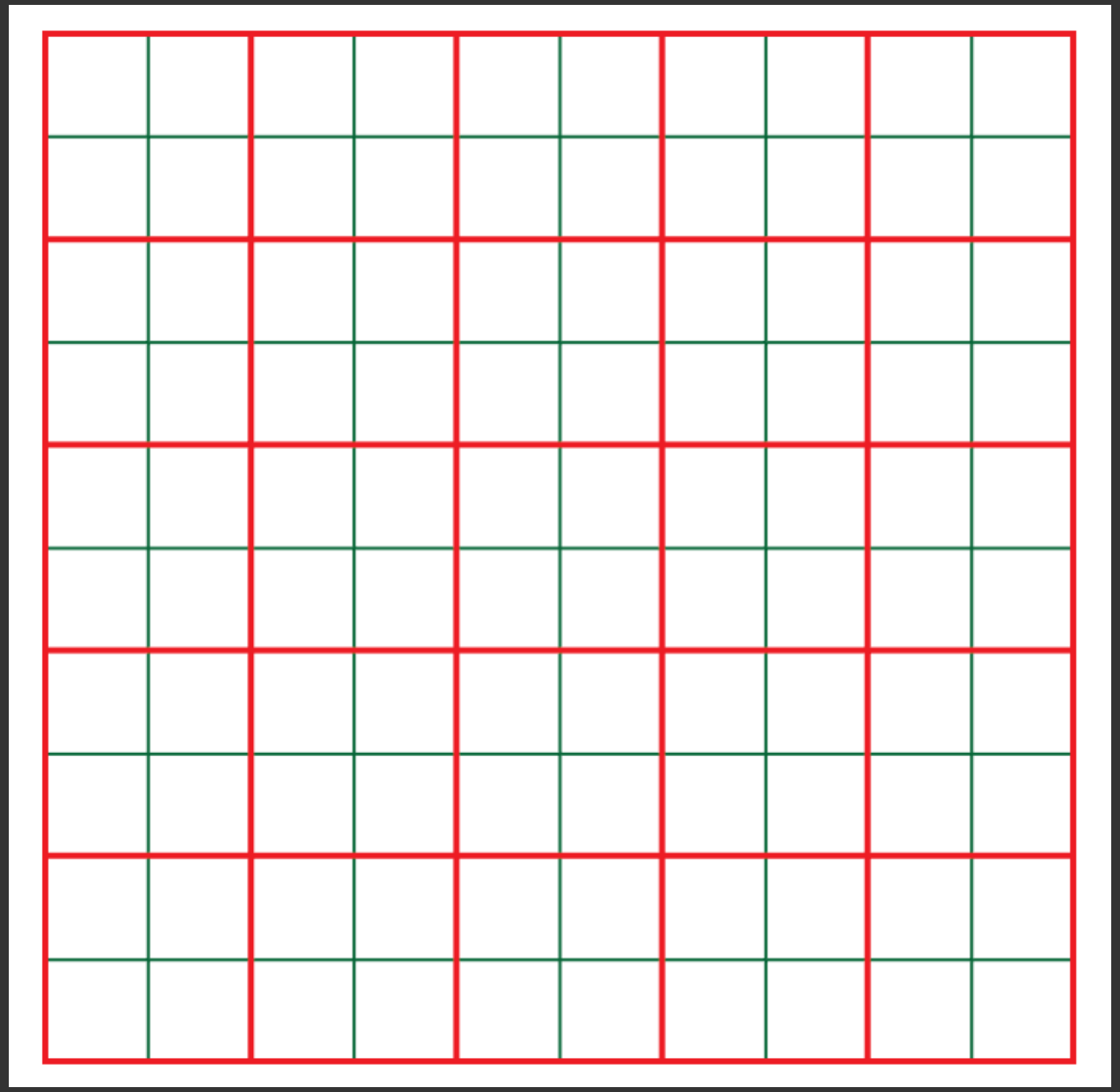


No data cells still exist

Video: Raster Data

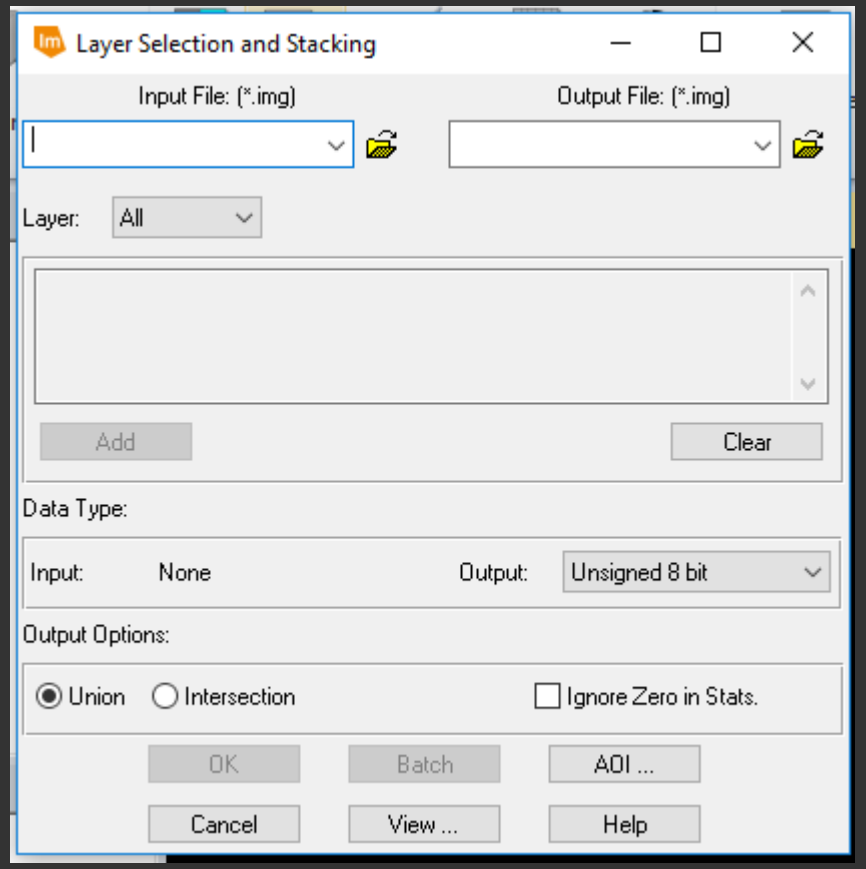


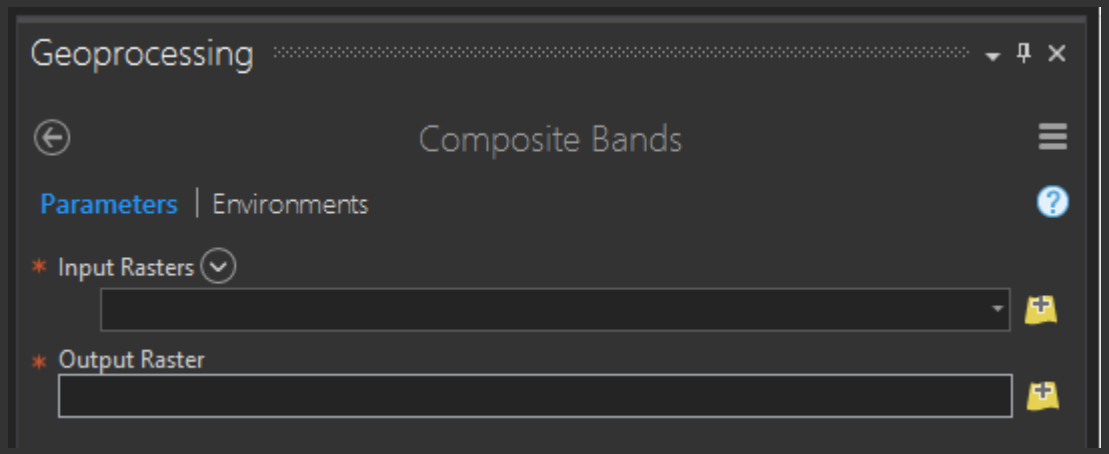
Cell Size



Raster Grids with Multiple Bands/Layers

- Can have multiband raster that acts as a singe file but is actually composed of multiple raster grids
- Common for multiband imagery
- However, can be use for other types of raster data





Raster Grids with Multiple Bands/Layers

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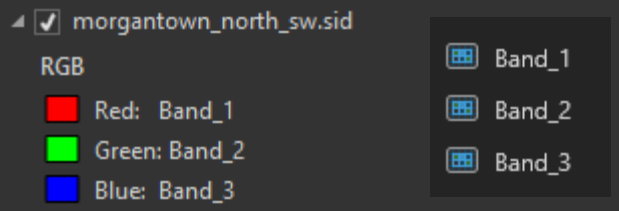
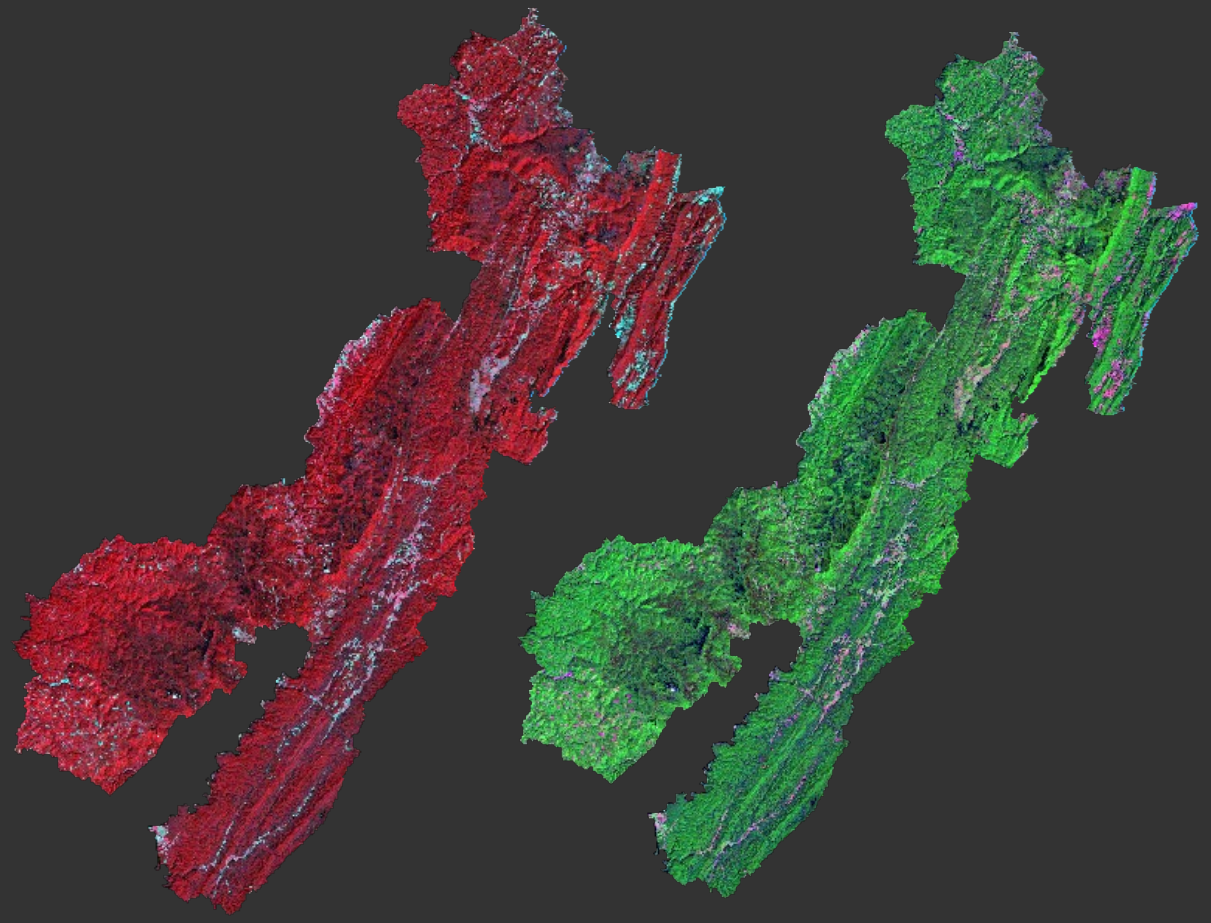
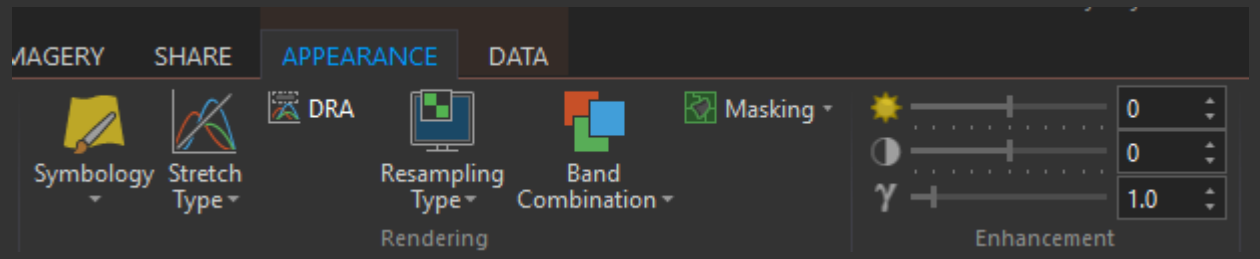


Raster Grids with Multiple Bands/Layers

- Can display single band as a grayscale image
- Can display multiple bands as a false color composite
- Common technique in remote sensing



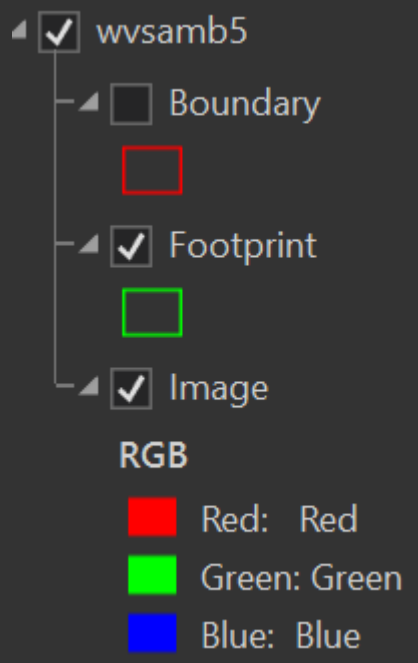


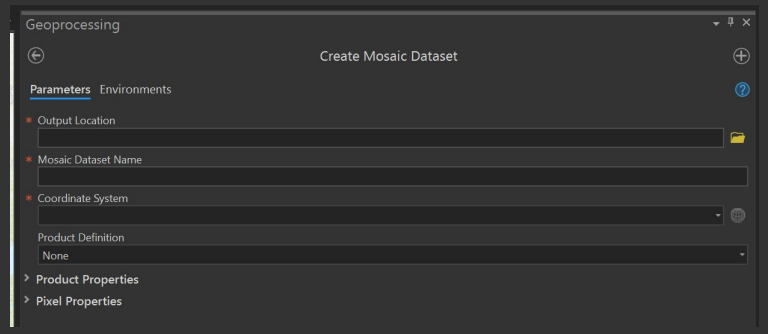
Raster File Formats

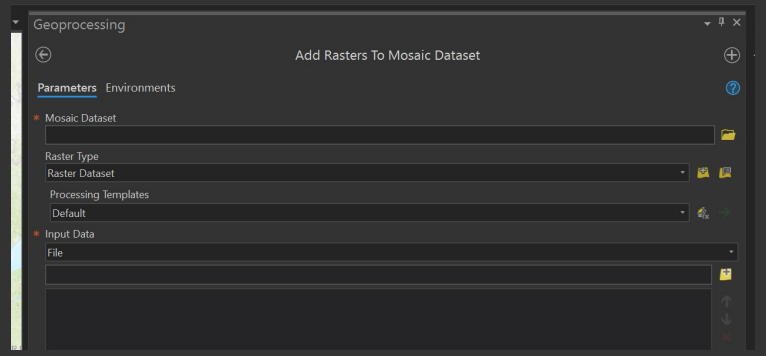
1. ESRI Grid
2. Erdas Imagine (.img)
3. GeoTIFF (.tif)

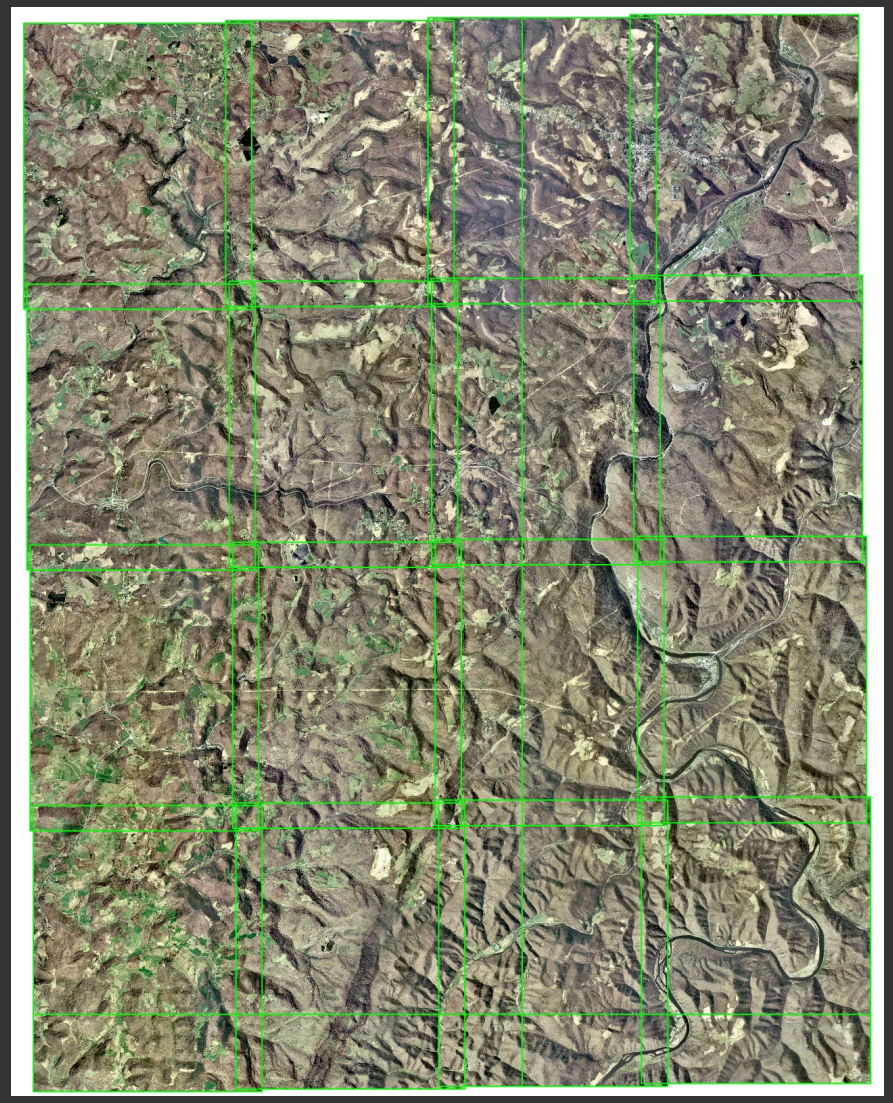
Mosaic Datasets

- Reference to raster layers
- Does not require data to be copied into a new file

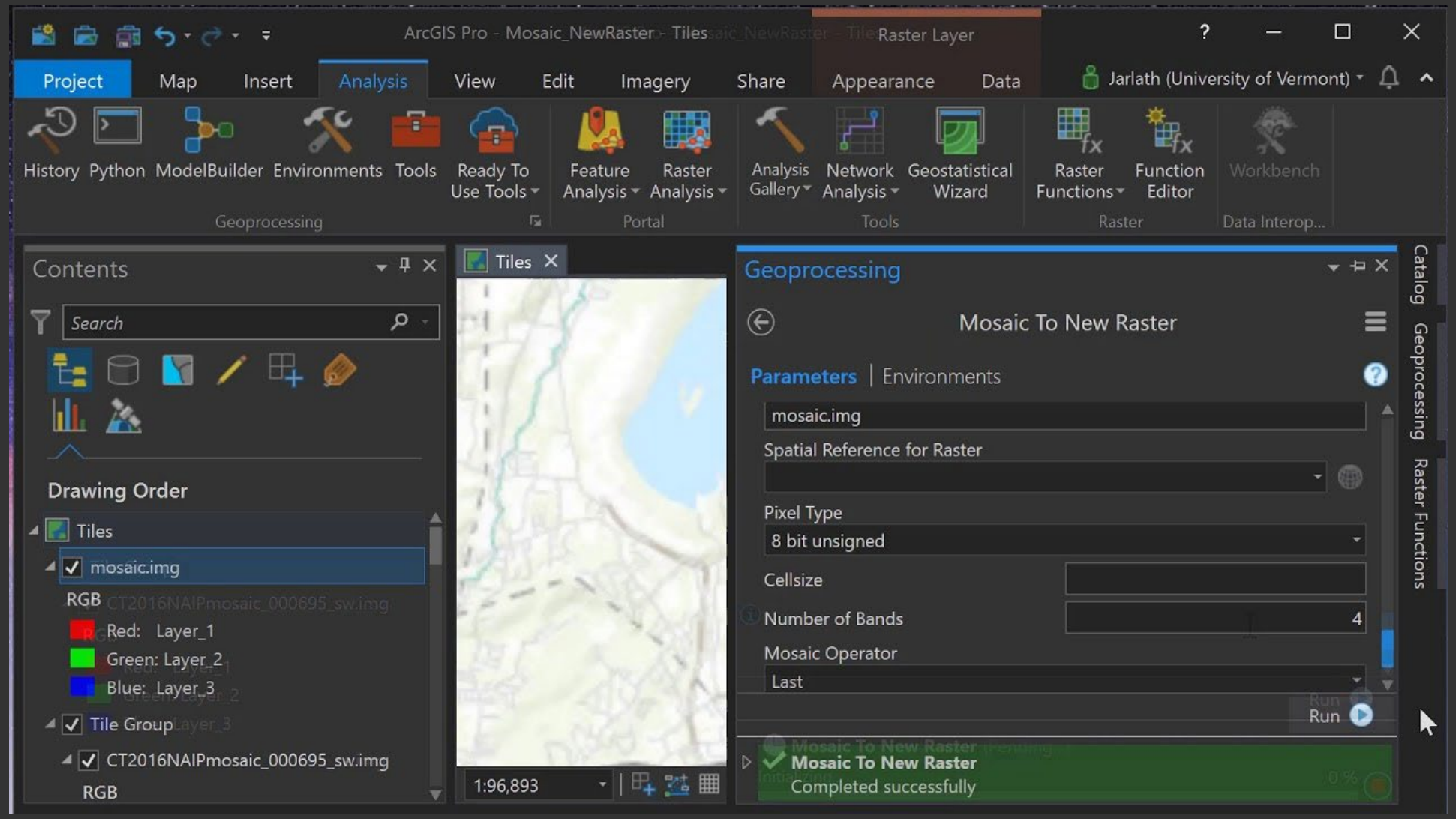








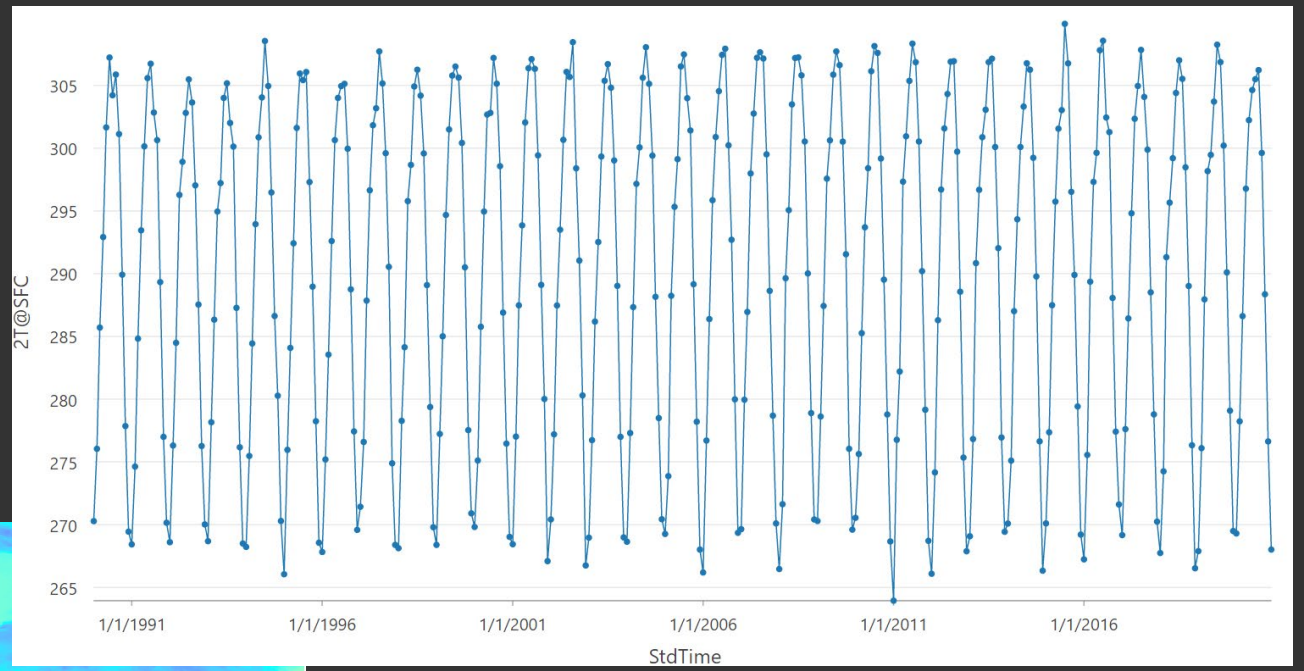
Video: Mosaic Dataset in ArcGIS Pro

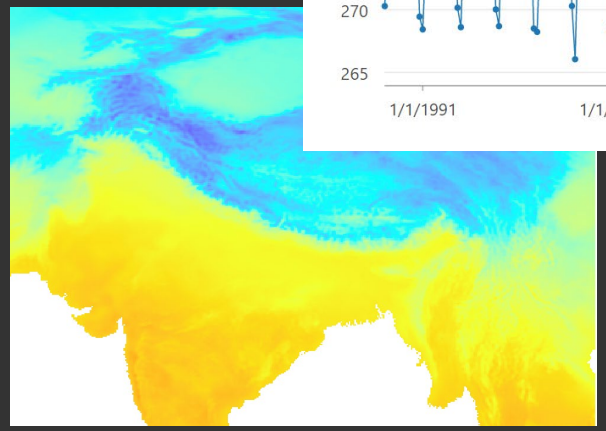


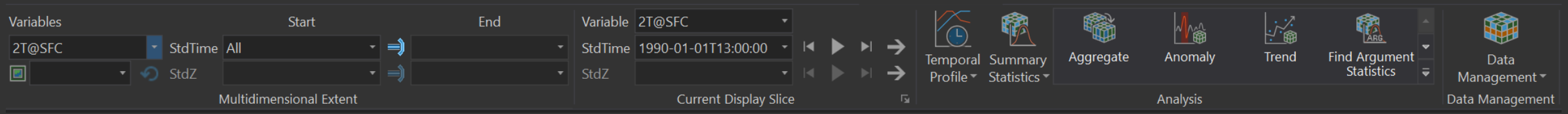
Video by Jarlath O'Neil-Dunne

Multidimensional Raster Grids

- Store more than three dimensions
- Commonly used in climate science
- Time
- Depth
- Multiple Variables
- Common Formats
  - GRIP, HDF, NetCDF, CRF

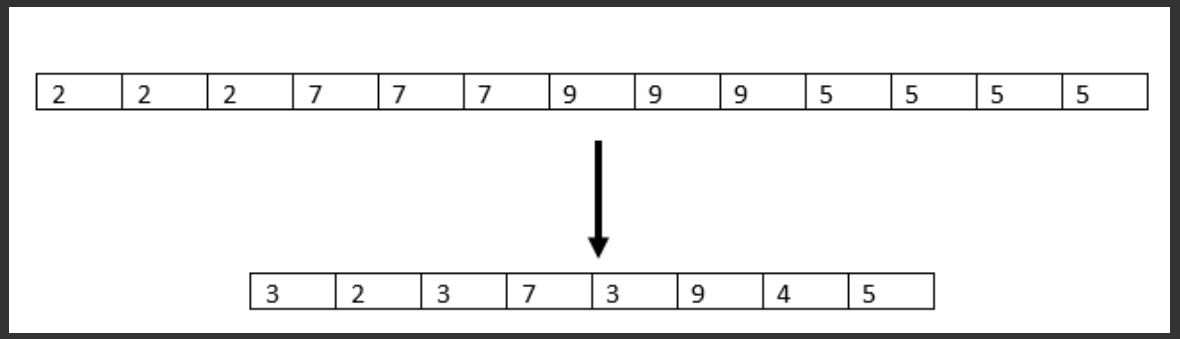


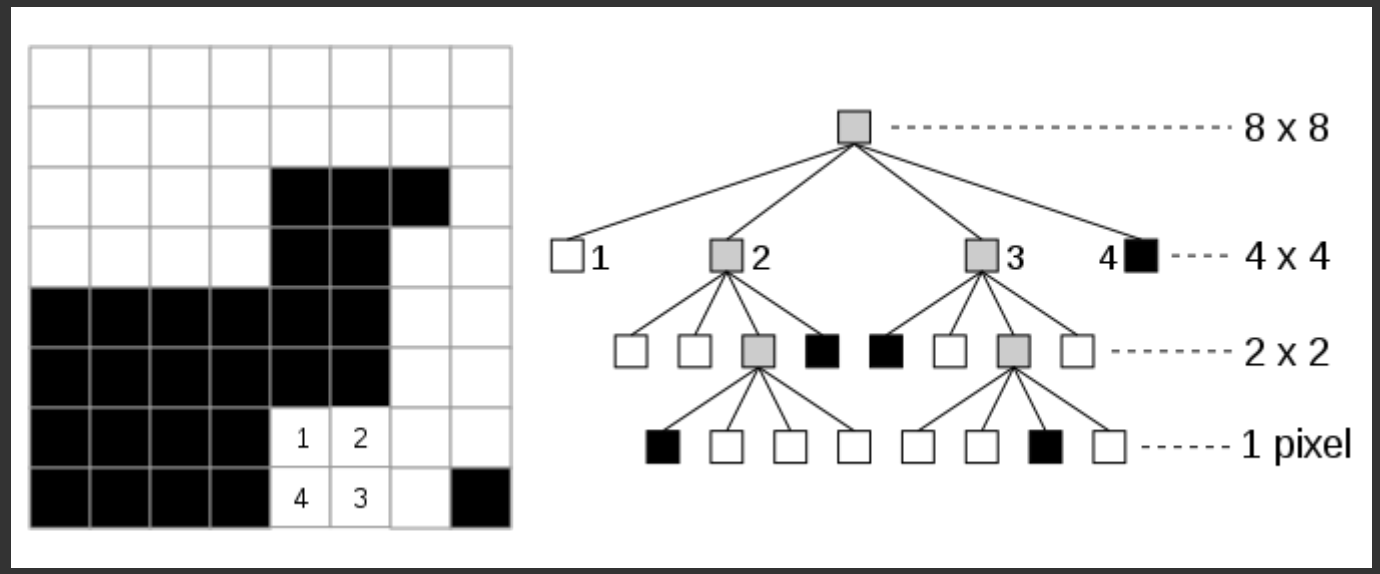




Data Compression

- Reduce file size
- Lossless = all information is maintained
- Lossy = some information is lost
- Limits redundancies in homogenous areas
- Types
  - Run-length encoding
  - Quad tree





https://commons.wikimedia.org/wiki/File:Quad_tree_bitmap.svg

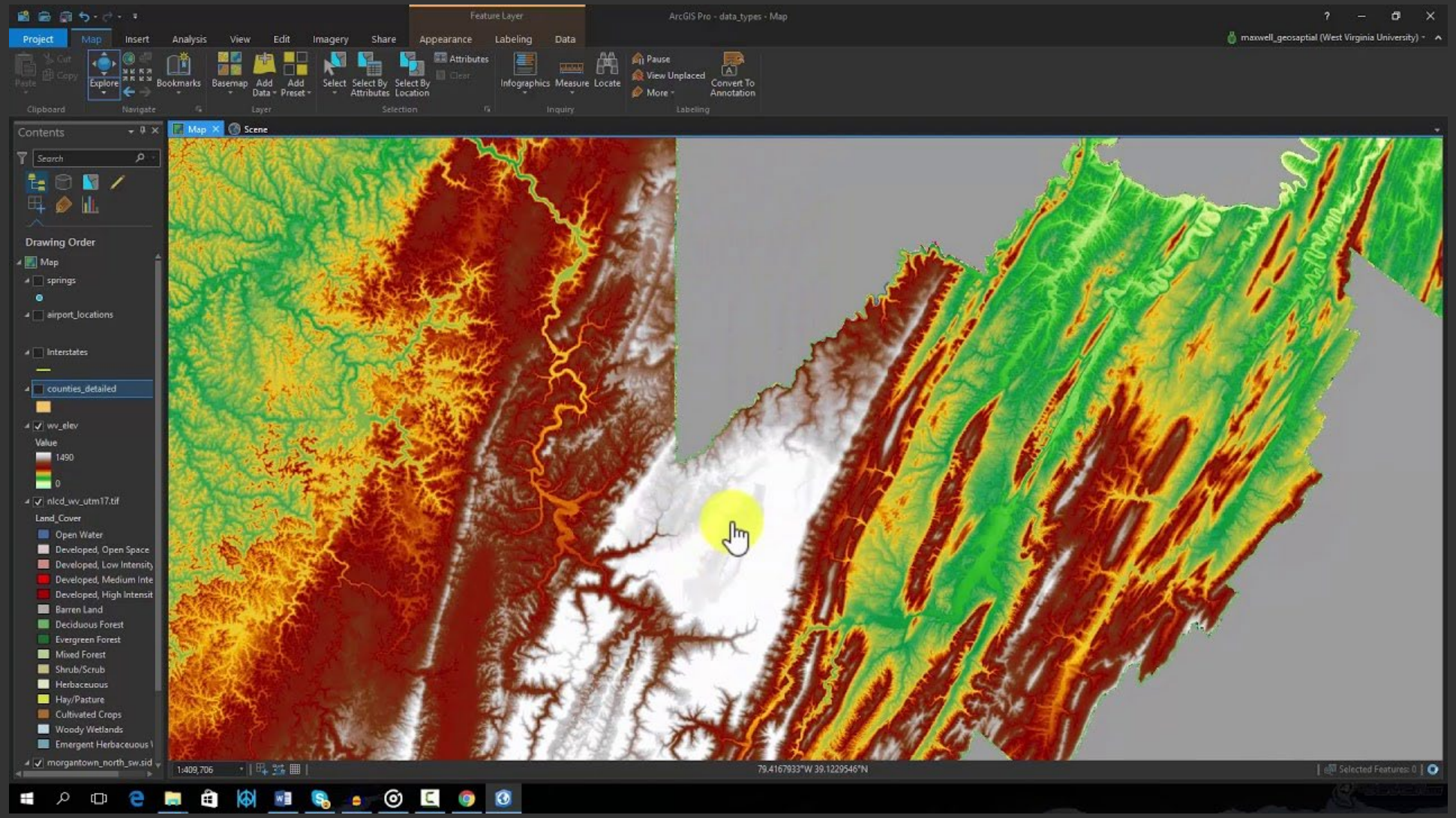
Comparisons

Comparing Raster vs. Vector

Comparison	Vector	Raster
Data structure	Complex, can also include complex attributes	Simpler
Storage requirements	Small for most datasets	Can be quite large (file size)
Precision/level of detail	Unlimited	Set by cell size
Ease of use in modeling	Best for network models, may be more difficult to do overlay computations	Good for quick layer overlays
Display/output	Map-like output (smoother edges)	Can be blocky

From *GIS Fundaments* by Bolstad

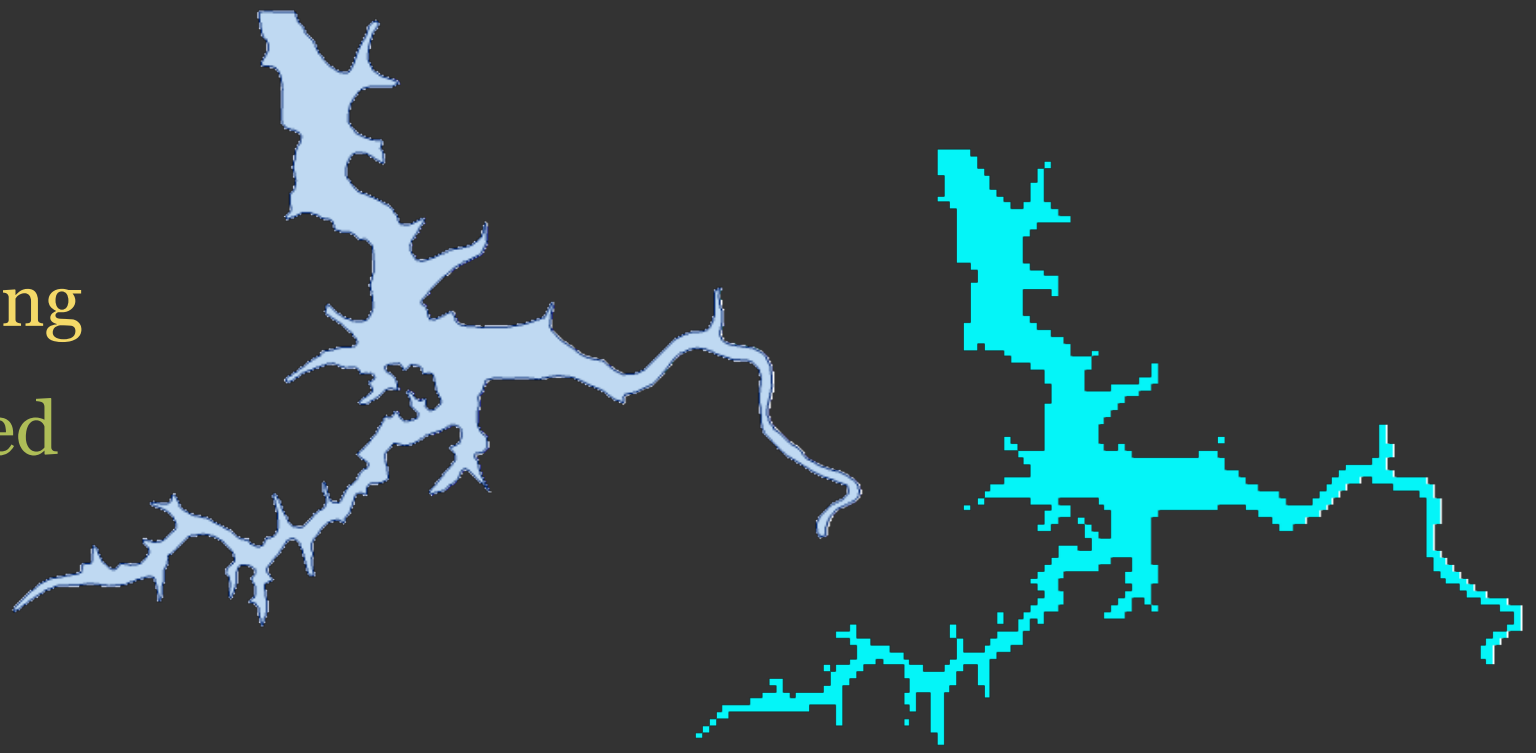
Video: Conversions



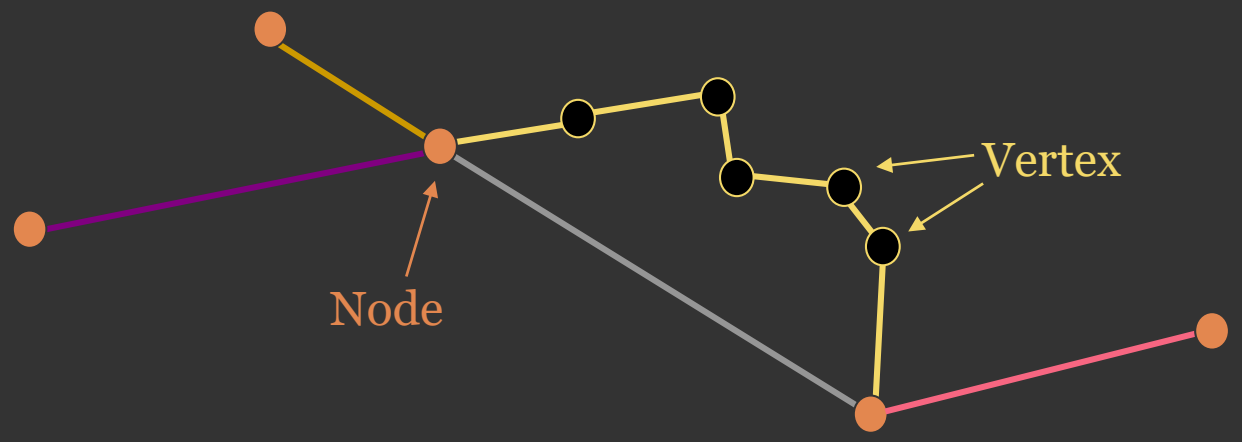
Conversions

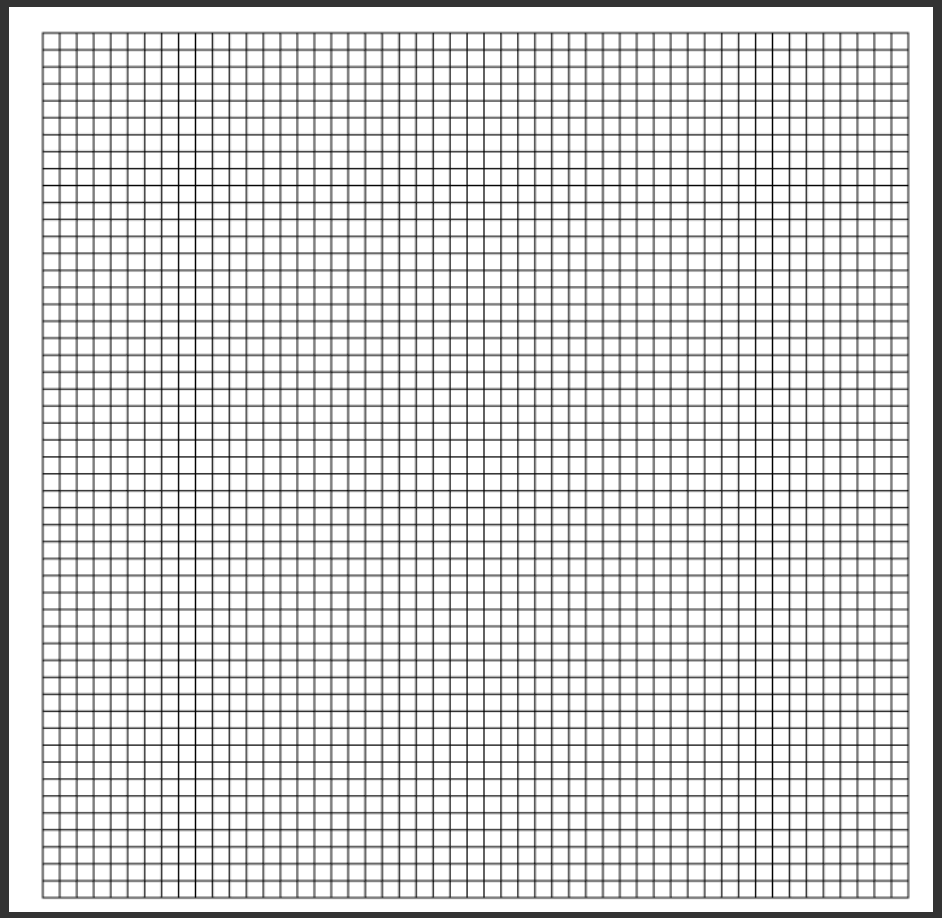
Things to consider

1. Cell size
2. Generalization/smoothing
3. How the data will be used



Vector or raster?





This is the end of this lecture module.

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