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

Digital Cartography

Generalization and Scale

WV VIEW

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

All maps are a representation and generalization of reality. Since our world is infinitely complex, map design is an exercise in generalization and deciding what is most important for communicating information accurately and effectively. This module will explore how we deal with issues of scale and generalization. We will also relate this to issues of base map and reference map design.

Module Topics

1. Map scale
2. Defining map scale
3. Map orientation
4. Defining map orientation
5. Graticules and coordinate grids
6. Inset maps
7. Feature generalization methods
8. Base map considerations
9. Base map data sources

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These are the topics covered in this module.

Scale and Orientation

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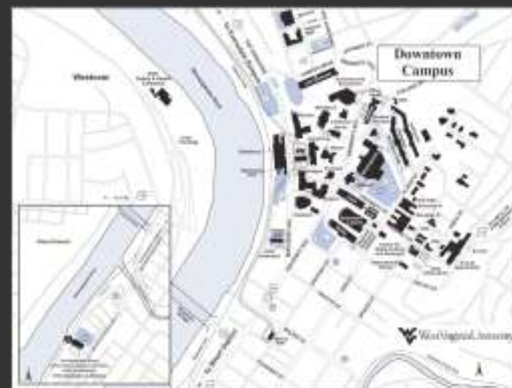
Map Scale

Small Scale = Zoomed Out, Less detail



Large Scale = Zoomed In, More detail

Assumes maps are printed at same size

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Small scale maps are more “zoomed out” or show less detail.

In contrast, large scale maps are more “zoomed in” or show more detail.

For example, if a map of the United States and a map of New York city are printed at the same size, the United States map would be a smaller scale map than the New York map.

Scale

Scale Bars

- Most useful

Representative Fraction

- 1:10,000
- 1:1,000,000

Verbal

- One inch to one mile

Neither Representative Fraction nor Verbal should be used if map is to be enlarged or reduced in size

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Scale can be represented using a scale bar, representative fraction, or verbal scale.

Scale bars provide a graphical representation of scale.

An example of a representative fraction would be 1:24,000. This indicates that one unit on the map is equivalent to 24,000 units on the ground.

An example of a verbal scale is "1 centimeter is equal to 5 kilometers".

If a map is going to be resized, representative fractions or verbal scales should not be used, as the defined relationship will not be true at different sizes.

A scale bar can be used if the map is going to be resized; however, it must be resized along with and proportional to the map.

Scale Bar Tips

1. Make sure your units make sense
2. Reference maps often require more involved/detailed scale bars then thematic maps
3. Is a scale bar always required?
4. Breaks should be clean numbers (such as multiples of five or ten)
5. You can control the number of divisions and subdivisions
6. You can include a representative fraction or verbal scale
7. It might be worth stating the projection on the map, as this makes your scale bar more meaningful
8. It should have the same font as the rest of the map
9. It should fit within the visual hierarchy of your map
10. The size and position should be consciously determined
11. You can change the labels and position of the labels
12. You can change the position of numbering
13. You can change the frequency and position of marks

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Here are some tips for designing and placing a scale bar.

Note that a scale bar can sometimes be misleading, especially on small scale or global maps. This is because some projections distort distance and size, so scale will actually vary across the map space.

For larger scale maps, graticules are sometimes used instead of a scale bar as a representation of scale.

I generally recommend using simple scale bars for thematic maps where users will not use the map for navigation purposes. In contrast, a reference map generally requires a more detailed scale bar to use for measurement.

Orientation

- North Arrow
- Graticules = latitude and longitude
- Coordinate Grids = grid of map coordinates (UTM grid)
- References Grids = grid of reference cells

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We will now discuss means to describe the map orientation.

North Arrow Tips

1. Make sure it fits within the visual hierarchy of your map
2. It should not be too big
3. The size and position should be consciously determined
4. You can use ArcGIS north arrows or create your own
5. North may not always be up
6. Is a north arrow always necessary?

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Here are some tips for designing a north arrow.

ArcGIS provides many north arrows to choose from.

Similar to scale bars, north arrows can also be misleading on small scale or global maps, as some projections distort directions.

In this case, you can use a graticule in place of a north arrow.

Generally, I prefer to use simple north arrows. Also, north arrows do not generally need to be large since they are ancillary map information.

Graticules

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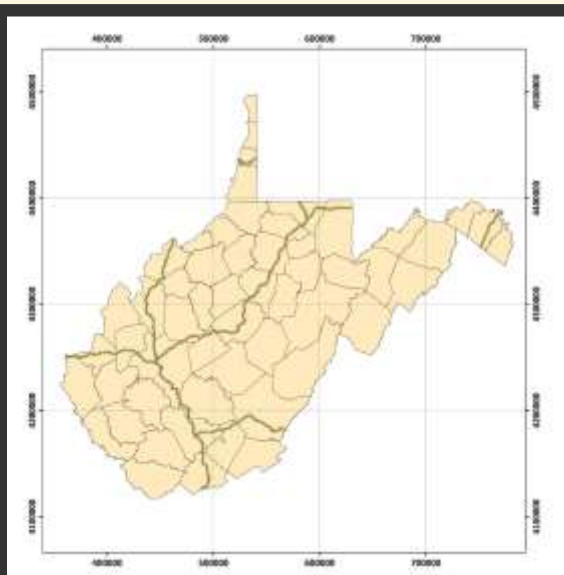
Graticules represent latitude and longitude or parallels and meridians, and they are often used on small scale maps.

They can be used to represent scale and orientation. Again, you may choose to use graticules in place of a scale bar and/or north arrow for small scale maps where orientation and scale are distorted and/or inconsistent across the map space.

Coordinate Grid



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Coordinate grids are similar to graticules except that a projected coordinate system is represented as opposed to latitude and longitude.

An example would be a UTM grid of easting and northing values.

Reference Grid

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Reference grids break the map space into labeled rows and columns.

In the example above, the map space is divided horizontally into columns A through E and vertically into rows 1 through 5.

Tips for Designing Grids

- Can change origin
- Can change interval
- Can change grid lines and tick mark symbology
- Can remove zero measurements
- Can round off
- Can change font characteristics
- Can make labels horizontal or vertical
- Can change label position
- Can change label frequency/interval
- Can add/remove gridlines
- Can add/remove neatlines
- Can convert to graphic for additional editing

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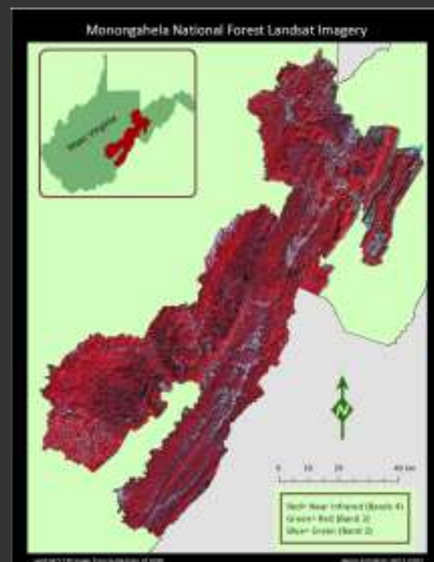
Here are some tips for designing grids.

I generally find that grids need substantial editing to improve upon default settings. For example, you may need to change the intervals at which lines, ticks, and/or labels are produced. You may need to change the ticks and lines to make them more or less noticeable. This can be accomplished by changing the color and/or width. You can also change the size of the text labels and edit the number of significant digits. For example, you may want to round off to the nearest minute or even degree for smaller scale maps.

Inset Maps

- Locator
- Enlarge important areas
- Show related topics
- Show different areas

Map by Adam Sharp



Map by Aaron Arrington

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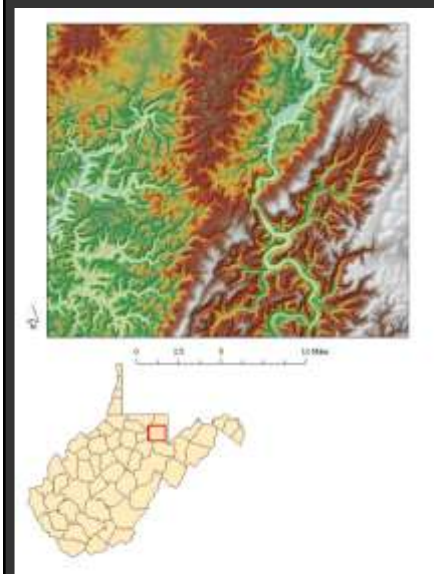
Inset maps can be used to provide a locator, or show where your main map occurs within a larger spatial extent, enlarge important areas, show related topics, or show different areas.

One common use of inset maps for the United States is to include Hawaii and Alaska in separate frames.

In ArcGIS Pro, inset maps can be created by adding additional map frames to a layout.

When using inset maps or multiple maps on the same layout, each map frame should be intentionally placed. Generally, the primary map is largest and most centered in the layout. If you have multiple maps of equal importance, such as a series of maps representing change over time, it is generally a good idea to make the frames the same size, scale, and extent with uniform placement in the layout space.

Extent Indicators



- Show the extent of one map on another map

Maps by Adam Sharp

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Relating to inset maps, extent indicators can be used to show the extent of one map on another, smaller scale map.

In the example provided, the extent of the terrain map is shown within West Virginia.

Extent indicators can be useful for making the spatial relationships between different map frames clear.

When you create an extent indicator, you can change the color and outline width. If the extent is very small, then you can replace it with a point symbol. If the intent is not obvious, you may want to add the indicator to the legend to provide needed explanation. I sometimes find that it is effective to use the same color for the indicator and the associated map frame border to highlight the relationship. This is especially useful if there are multiple inset maps, such as the example on the left.

Generalization

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Types of Generalization

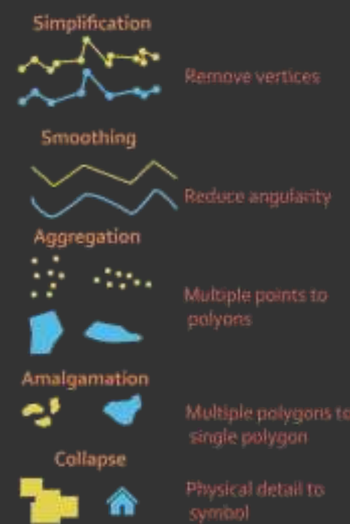
Simplification = Selectively reducing the number of points/vertices required to represent an object

Smoothing = Reducing angularity of segments between vertices

Aggregation = Grouping point features and representing them as areal objects

Amalgamation = Grouping of individual areal features into a larger extent

Collapse = Replacing an object's physical detail with a symbol representing the object



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There are a variety of techniques that are used to generalize map features. Simplification relates to reducing the number of vertices used to represent a feature. In the example, some of the vertices that define the line have been removed to simplify the feature. Smoothing attempts to reduce the angularity of features by smoothing or curving the line segments, which can result in a more cartographically pleasing representation. Aggregation is representing multiple point features as an areal feature; for example, points representing houses in a development could be aggregated to a polygon boundary representing the extent of the development. Amalgamation is similar to aggregation, except that smaller polygons are aggregated to a single areal unit. For example, small islands could be combined and represented as single island or multiple buildings that make up a complex could be shown as a single polygon encompassing the entire complex. Lastly, collapse means to represent an areal feature as a point, such as representing a building as a point symbol.

Note that the appropriate use of these different generalization methods will depend on map scale, map purpose, and the features being represented.

Types of Generalization

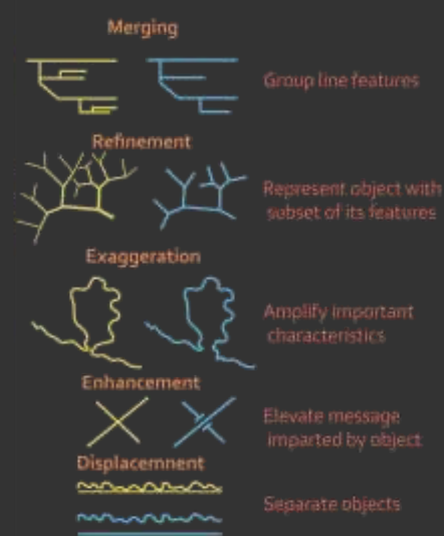
Merging = Grouping of line features

Refinement = Selecting specific portions of an object to represent the entire object

Exaggeration = To amplify a specific portion of an object

Enhancement = To elevate the message imparted by the object

Displacement = Separate objects



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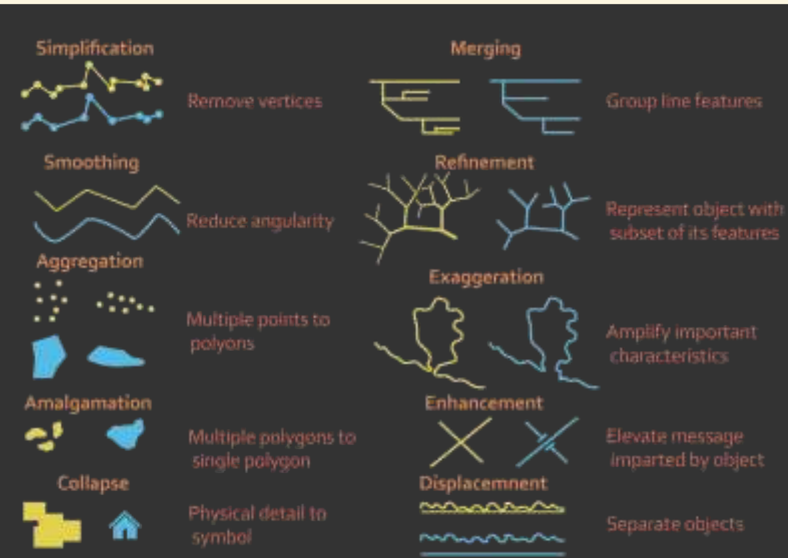
Merging relates to grouping line features to simplify the representation while refinement means to subset out only certain features without any grouping. For example, a stream network could be refined by removing the smallest tributary streams and only visualizing larger channels. Exaggeration means to enhance key information or important characteristics. For example, a mountain pass or inlet to a bay could be widened to denote its existence more clearly. Enhancement is used to elevate the message imparted by objects, such as the representation of the tunnel in the example, which is not obvious by the simple crossing of the lines. Lastly, displacement is used to provide separation between features so that they can be more easily distinguished. For example, a railroad could be separated from an adjacent road or stream so that the features are more easily differentiated.

Again, the appropriate use of these different generalization methods depend on map scale, map purpose, and the features being represented.

Types of Generalization



Slocum et al. Figure 6.4

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This slide provides a side-by-side comparison of all the methods discussed in the prior slides.

Generalization

Raster	Methods	Vector	Methods
Structural Generalization	Resampling/ Pixel Aggregation	Point generalization	Aggregation
Numerical Generalization	Low-pass filters, High-pass filters, image indices, principal component analysis	Line generalization	Simplification, Smoothing, Displacement, Merging, Enhancement, Refinement, Exaggeration
Numerical Categorization	Image classification	Areal Generalization	Amalgamation, Collapse, Displacement
Categorical Generalization	Reclassify, Majority filtering		

Slocum et al. Table 6.1

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A variety of techniques are available to generalize geospatial raster and vector data. For example, raster data can be structurally generalized by aggregating pixels into larger cells or resampling the cell size. They can be numerically generalized by applying convolutional filters, image indices, or variable reduction using principal component analysis. Image data can be converted into categories using unsupervised and supervised classification techniques. Lastly, categorical data can be generalized by reclassifying to aggregate to a smaller number of classes or applying a majority filter to remove local noise.

Vector data are generalized using the techniques discussed above. In later slides, we will explore specific tools for accomplishing these tasks.

Scale Considerations

- Are raster grids too coarse for mapping scale? Do you need to find a different data source?
- Are raster grids too detailed for mapping scale? Is generalization required? Does the raster need resampled?
- Are vector features too generalized? Do you need to find a different data source?
- Are vector features too detailed? Do they need to be generalized?

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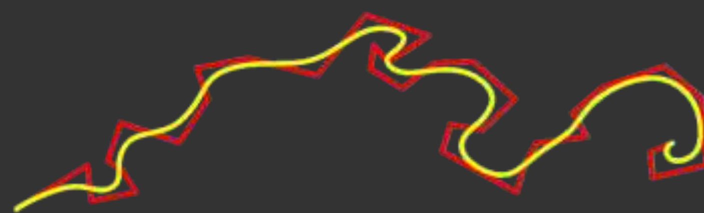
This slide describes some important considerations when trying to decide how best to generalize or represent data. Scale is an important consideration, as the appropriate representation may change with scale. For example, it might be preferable to use an areal extent to represent a city on a large scale map and a point symbol on a small scale map. Raster data can appear coarse when zoomed in to an inappropriate scale. If you need to generate a map at this scale, you may need to find another data source. Alternatively, you may find that raster data are too spatially detailed or too many categories are represented. Vector data may also look too generalized when zoomed in to an inappropriate scale. For example, county boundaries generated at 1:100,000 scale may look inaccurate on a 1:24,000 scale map. So, you may need to find a different data source. If the data are too detailed, they may need to be generalized to improve the cartographic presentation.

Line Generalization

- Remove unnecessary vertices
- Smooth curves
- For cartographic generalization
- Simplify Line Tool
- Smooth Line Tool



Available under Generalization Tools in the Cartography Toolbox

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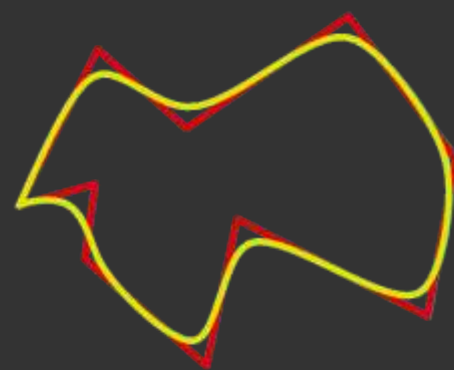
We will now explore some tools that are used to generalize vector and raster data.

For line features, simplify is used to remove vertices while smooth is used to smooth curves in the lines. In the provided example, the yellow line represents a smoothed version of the red line, which may be deemed more appropriate for cartographic visualization.

In order to apply simplification or smoothing, an algorithm is used. You may have to experiment with the provided settings to obtain the desired result. This is often accomplished using trial-and-error.

Polygon Generalization

- Remove unnecessary vertices
- Smooth curves
- For cartographic generalization
- Simplify Polygon Tool
- Smooth Polygon Tool
- Aggregate Polygons Tool



Available under
Generalization Tools in the
Cartography Toolbox

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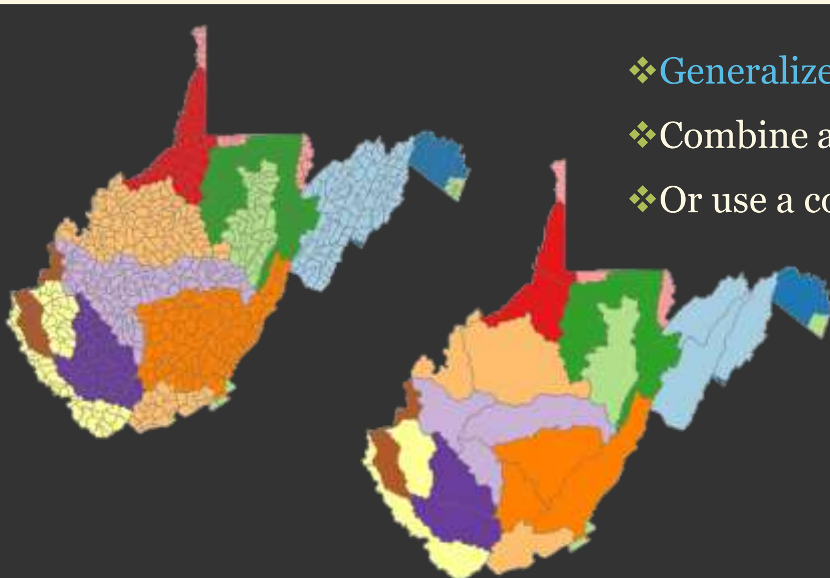
Polygons can also be simplified or smoothed to remove vertices or smooth curves, respectively.

It is also possible to aggregate smaller polygons into larger polygons for cartographic generalization. For example, polygons representing smaller neighborhoods could be aggregated into a larger polygon representing a generalization of the smaller neighborhood boundaries.

Generalization: Dissolve



- Generalize boundaries
- Combine all features to one feature
- Or use a common attribute

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Dissolve is specifically used for boundary generalization. Detailed boundaries can be combined to less detailed boundaries, similar to an amalgamation generalization.

Feature to Point

- **Multipoint feature** = the output point will be located at the average x and y coordinates of all the points in the multipoint feature
- **Input line feature** = the output point will be located at the weighted average x and y coordinates of the midpoints of all line segments in the line feature
- **Polygon feature** = the output point will be located at the center of gravity (centroid) of the polygon.
- Can force result to be inside of polygons

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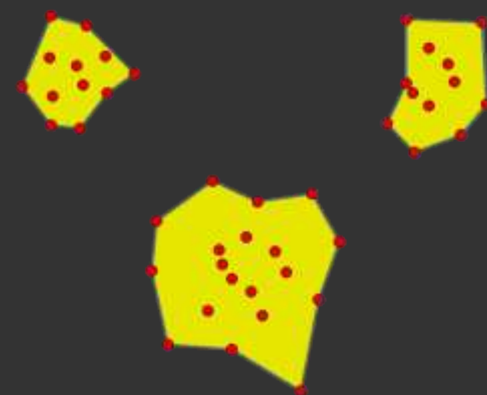
Feature to point will generate a point for each input feature and can thus be used to perform a collapse generalization.

The input can be multipoint, line, or polygon features. The output will always be points.

This slide provides explanations as to how points are generated for different input features or geometry types.

Point Aggregation

- Aggregate points to polygon
- Can be used for cartographic generalization
- Point Aggregation Tool



Available under Generalization Tools in the Cartography Toolbox

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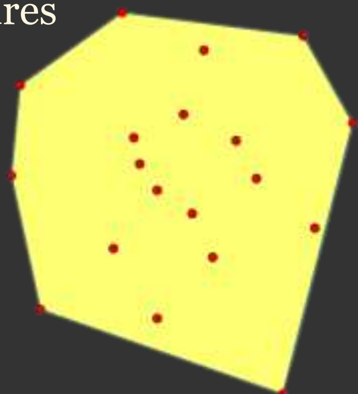
Points can be aggregated into polygons.

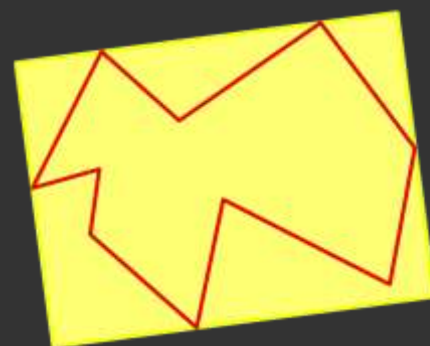
Based on an algorithm and specified settings, near points will be used to define a new polygon extent.

Minimum Bounding Polygon

- Creates a feature class containing polygons which represent a specified minimum bounding geometry enclosing each input feature or each group of input features



Convex Hull



Rectangle by Area or Width

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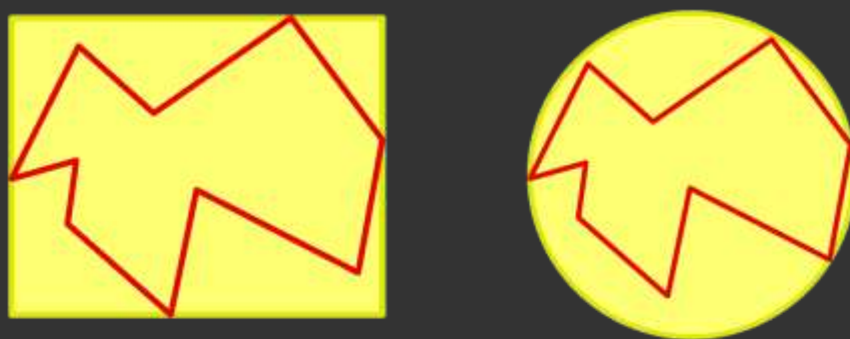
Minimal bounding polygons represent a specified minimal bounding geometry that encloses an input feature or group of input features.

A convex hull represents the area that encompasses a set of input features without any concave angles or sides. This can be conceptualized as stretching a rubber band between the outlying features or points.

A minimal bounding rectangle can be defined based on minimal area or minimal width. If area is used, then the rectangle with the smallest area that completely encompasses the input feature or features will be returned. Using width, the rectangle with the smallest width will be returned.

Minimum Bounding Polygon

- Creates a feature class containing polygons which represent a specified minimum bounding geometry enclosing each input feature or each group of input features



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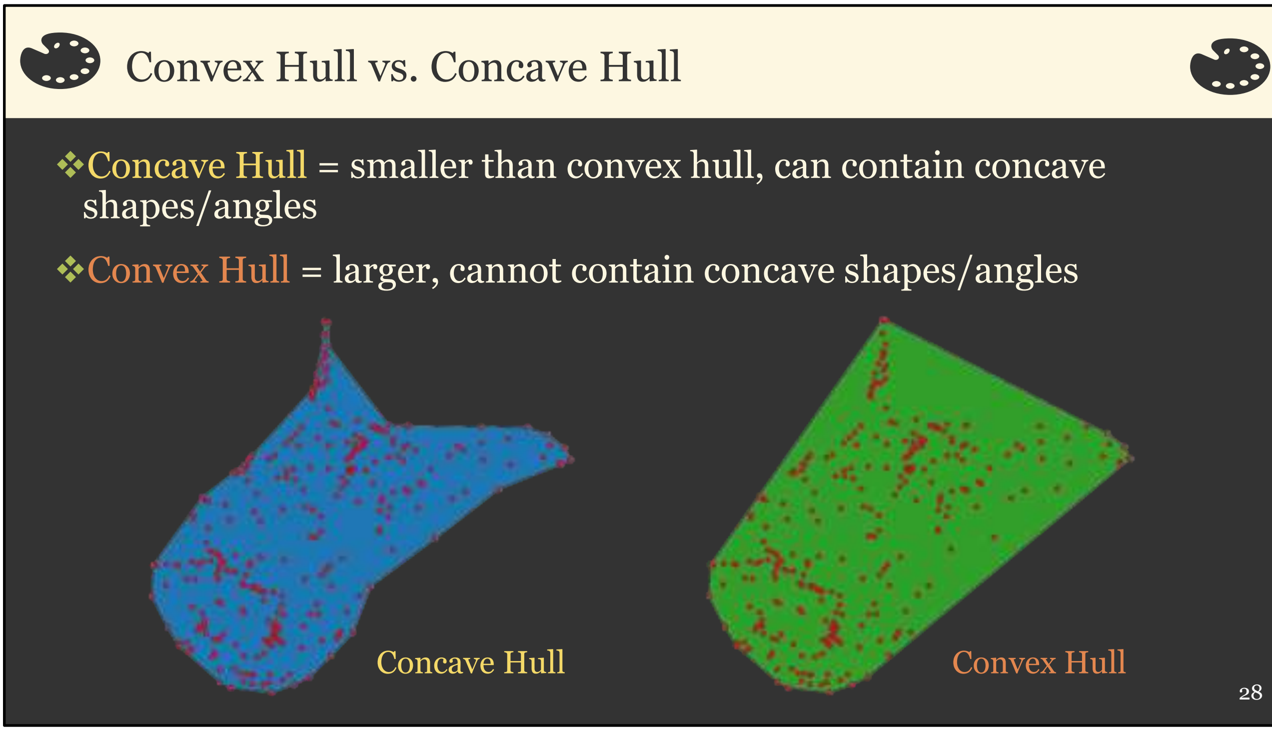
The minimal bounding envelope is often confused with the minimal bounding rectangle. The minimal bounding envelop is different from the minimal bounding rectangle because the sides of the rectangle must occur along the cardinal directions (north-south and east-west). It cannot be rotated relative to these directions.

The minimal bounding circle represents the smallest circle, based or radius, that encompasses the input feature or features.

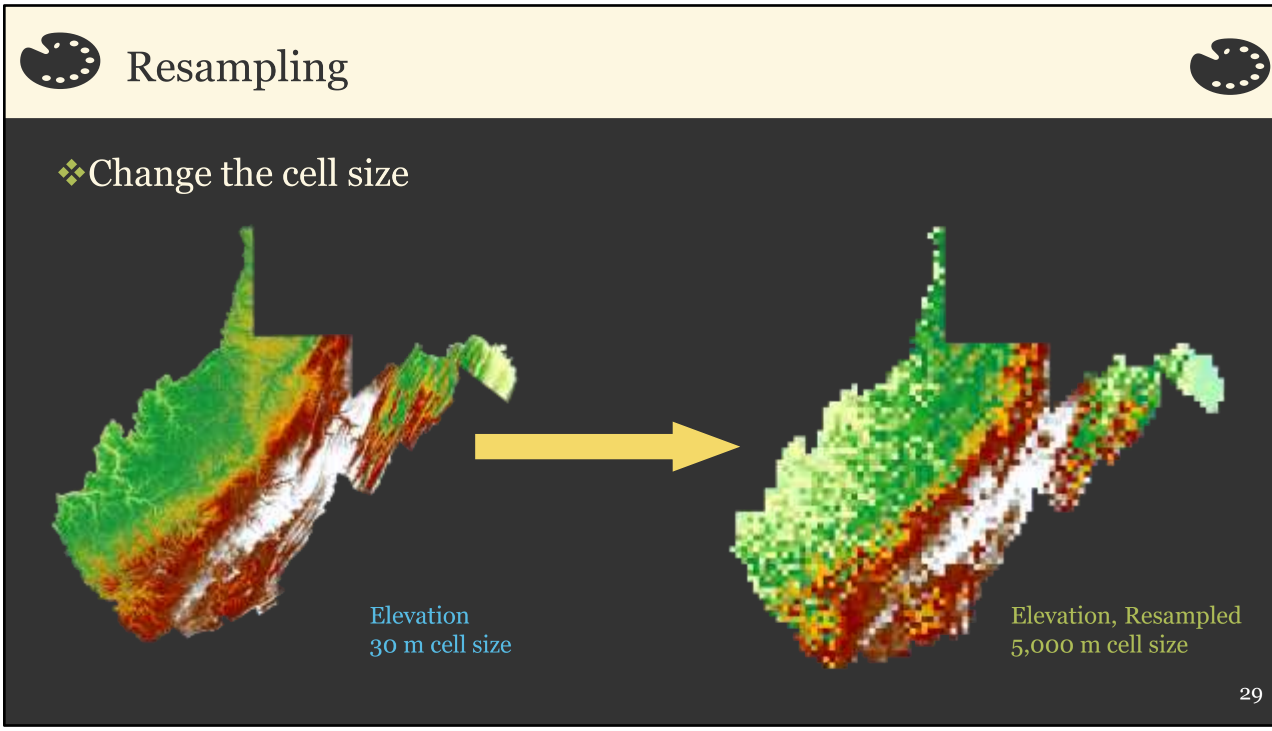


It is also possible to calculate concave hulls, as opposed to convex hulls.

Concave hulls can contain concave edges or shapes.

For a set of input features, the concave hull will have the same or a smaller area than the convex hull.

In the example provided, a concave and convex hull have been generated for a set of points in West Virginia. Note that the convex hull has no concave edges or shapes and that it contains a larger area than the concave hull.



Resampling is used to change the cell size of raster data. Generally, cells are made larger, or the data are coarsened, since making the cells smaller will not really add information but will just duplicate existing values. You can't increase the detail by simply resampling a coarser dataset to a finer spatial resolution.

You may resample raster data to make it easier to process over large extents or to change the cell size to match other inputs in an analysis.

We will now talk about methods used to resample raster data.

Resampling Methods

- Majority Resampling
- Resample using the most common cell value
- Good for categorical data

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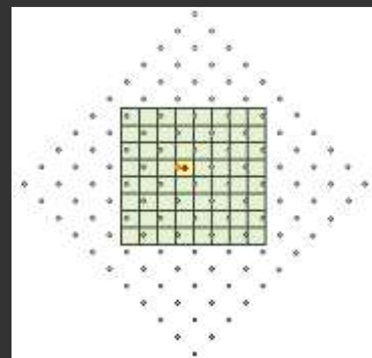
Majority resampling will assign the most common cell value of the original cells that fall within the new cell to the new cell.

This method is not generally used for continuous data. It is more commonly used for categorical data.

For example, if a land cover categorical raster grid was resampled using this method, each new cell would be assigned the majority land cover class from the smaller original cells that fall inside of it.

Resampling Methods

- Nearest Neighbor
- New value will be the value of the original cell closest to the center of the new (larger) cell
- Good for categorical data



http://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/performing-analysis/cell-size-and-resampling-in-analysis.htm

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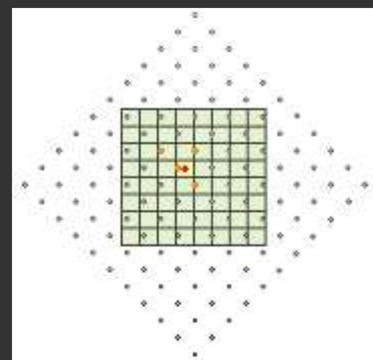
Nearest neighbor resampling assigns the closest cell value from the original raster grid to the new cell.

No averaging is performed, so this method can be used to resample both categorical and continuous data.

Resampling Methods

- Bilinear Interpolation
- Uses the inverse distance-weighted average of the four nearest pixel values to estimate a new pixel value
- The four cell centers from the input raster that are closest to the cell center for the output processing cell will be weighted based on inverse distance and then averaged
- Good for continuous data
- Creates a smoothed image



http://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/performing-analysis/cell-size-and-resampling-in-analysis.htm

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Bilinear interpolation uses the inverse distance-weighted average of the four nearest pixel values in the original grid to estimate the new cell value.

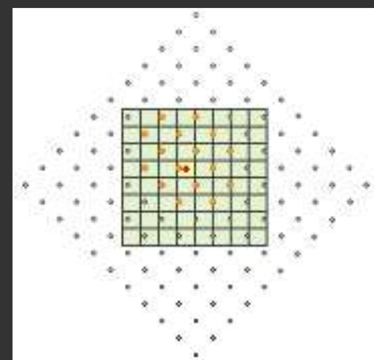
The four cell centers from the input raster that are closest to the cell center for the output processing cell will be weighted based on inverse distance and then averaged. So, nearer cells will have a larger weight in the calculation than cells that are further away.

Since averaging is performed, this method is not appropriate for categorical data. However, it can be used for continuous data.

This method tends to smooth the image or raster data.

Resampling Methods

- Cubic Convolution
- Similar to bilinear interpolation, except the 16 nearest input cell centers and their values are used
- Tends to sharpen images
- Good for continuous data



http://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/performing-analysis/cell-size-and-resampling-in-analysis.htm

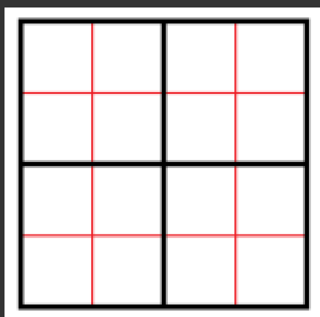
33

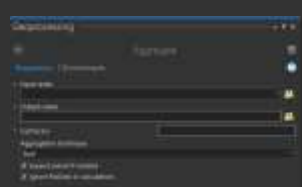
Cubic convolution is similar to bilinear interpolation except that the nearest 16 cells are used as opposed to the nearest 4. Since it makes use of averaging, it is also not appropriate for categorical data but can be used for continuous data.

This method tends to sharpen images more than bilinear interpolation.

Bilinear interpolation and cubic convolution are both commonly used to resample image data.

Another Option: Pixel Aggregation





- Generates a reduced-resolution version of a raster grid
- Each output cell contains the Sum, Minimum, Maximum, Mean, or Median of the input cells that are encompassed by the extent of that cell

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Another option to change the cell size is to use pixel aggregation. This is also sometimes referred to as image degradation.

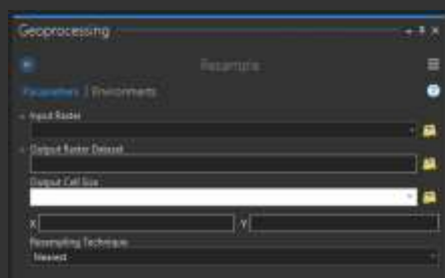
When using this method, a statistic from the cells that fall within the new larger cell is calculated and returned to the new cell.

Examples include sum, minimum, maximum, mean, or median.

The raster data can only be reduced in resolution in such a manner that a whole number of input cells will fall perfectly within a new cell. For example, a 2-by-2 meter raster grid could be converted to a 4-by-4 meter grid but not a 3-by-3 meter output.

This method can be used for both categorical and continuous data depending on the statistic returned.

Resampling in ArcGIS Pro



❖A good resource:

http://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/performing-analysis/cell-size-and-resampling-in-analysis.htm

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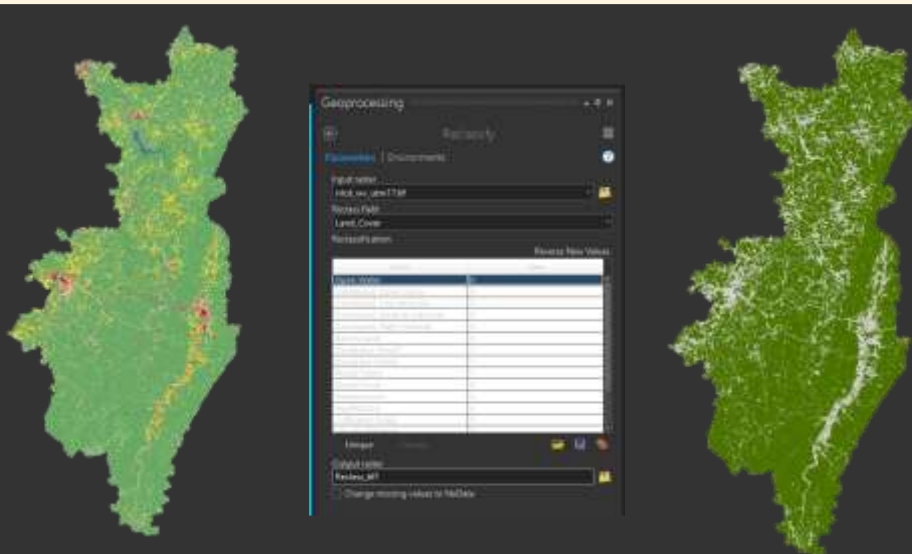
If you would like to read more about resampling, check out this ESRI link.

Note that resampling is made available in a variety of GIS and remote sensing software packages.

Reclassify Categorical Raster



Change cell values

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Reclassification allows you to change the cell values in a raster grid. The example in this slide demonstrates changing the cell values for a categorical raster grid, in this case a land cover grid from the National Land Cover Database. Here, all values corresponding to forest types were recoded to 1 and all other types were coded to 0. So, many categories were generalized to forest vs. not forest.

Majority Filter

- Replace center cell with majority value in 3 x 3 cell window
- FOUR vs. EIGHT = use just orthogonal cells or orthogonal and diagonal cells
- MAJORITY vs. HALF = must have a majority or only half to change value
- This is used to generalize categorical raster data

30	20	30
30	20	20
40	30	30

Majority filtering can be used to replace a cell value with a different value based on neighboring cells. Generally, this is performed using a 3-by-3 moving window. Specifically, this method is used to replace a cell value with the majority cell value of the neighboring cells.

If the FOUR method is used, then only orthogonal cells will be considered. These are the cells that share a side with the center cell. If the EIGHT method is used, then all eight neighboring cells will be considered, or the four orthogonal and four diagonal cells. If the Majority setting is applied, then the cell value will only be changed if a majority, or more than half, of the neighbors contain the new cell value. If the Half setting is used, then at least half of the neighboring cells must contain the cell value.

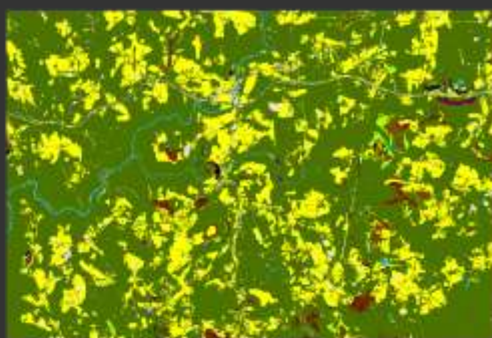
In the example provided here, if EIGHT and Majority were used then the cell value would be changed to 30. This is because 30 is the majority value in the eight neighboring cells, as five of the eight cells contain this value. If the FOUR and majority method were used, then the center cell value would be maintained as 20, since there are two 30 and two 20 cells in regards to the orthogonal neighbors, so there is no majority.

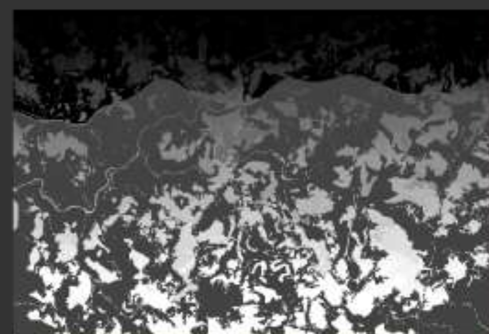
Regardless of the settings used, the 3-by-3 moving window will move through the grid to perform this calculation using each cell as the center cell.

A common application of majority filtering is to reduce the salt-and-pepper effect that commonly results from image classification. Pixels that are different from their neighbors can be recoded to the majority value of their neighbors, thus reducing the salt-and-pepper issue.

Region Group

- Group cells with the same code in a categorical raster and code them with a unique identifier



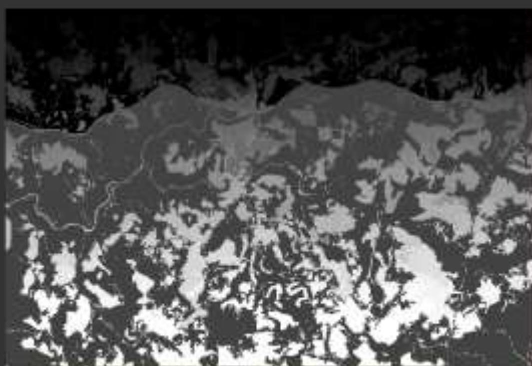


38

Region group is used to code all regions in a categorical raster to a unique code. So, any contiguous set of pixels that have the same code will be grouped, and each of these unique regions will be assigned a unique code.

The goal here is to identify contiguous regions of the same category.

Region Group



- Must decide between the FOUR or EIGHT method
- Can convert to polygons after regions are grouped
- Will need to decide if you want to simply the polygons

39

When performing region grouping, similar to majority filtering, the FOUR or EIGHT method can be applied. If the EIGHT method is applied, an area of the same code will be considered contiguous even if the pixels only touch diagonally. In contrast, when using the FOUR method an area will only be considered contiguous if the cells share a side, or are orthogonal. Generally, the FOUR method will yield more unique regions than the EIGHT method.

Once regions have been assigned unique codes, they can be converted to polygons with or without simplification. If no simplification is applied, then the polygons will follow the boundaries of the cells.

Expand

- Expand out a specific category in a categorical raster by a specified number of cells

Green expanded by 5 30 m pixels

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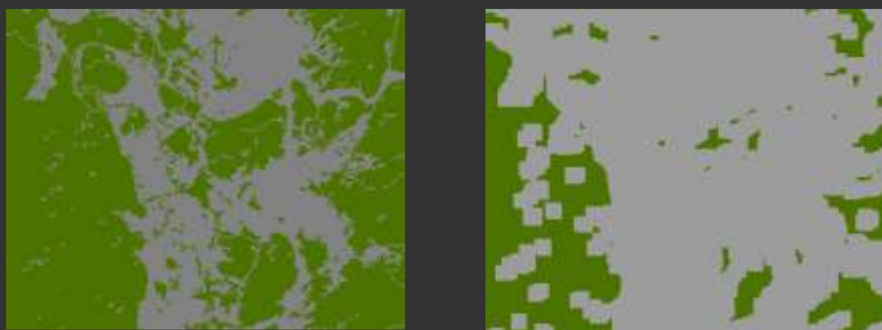
Expand is used to extend a certain code or category out by a defined number of cells.

In the example provided, the green cells represent forest, and the gray cells represent all other categories.

Using Expand, the forest areas have been expanded by 5 cells or 150 meters, reducing the area of not forest.

Shrink

- Shrink a specific category in a categorical raster by a specified number of cells by replacing them with the values of the cell that is most frequent in its neighborhood



Green shrank by 5 30 m pixels and replaced with gray

41

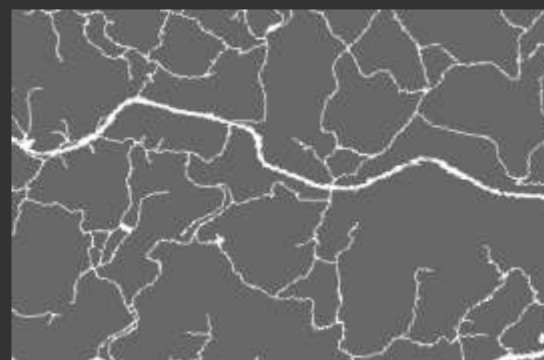
Shrink is the opposite of expand. Instead of expanding areas with a certain code or value, that extent of the code or value is reduced.

The areas that are reduced for this class are replaced with the most frequent value or code from its neighborhood.

In the example above, the forest class has been reduced by 5 cells or 150 meters. Cells in these areas have been recoded as not forest.

Nibble

❖Replace cells of a raster corresponding to a mask with the values of the nearest neighbor



42

Nibble is used to replace cell values with the nearest cell value that is not masked out.

In the example above, the red areas indicate some level of development. We would like to remove these areas and replace them with the nearest non-developed category. To accomplish this task, a mask is produced. This mask is used to mask out all developed areas. Using this mask, areas that are developed will be recoded as the nearest code that is not developed, since all developed areas were masked out.

Progress to the next slide to see the result.

Nibble

- Replace cells of a raster corresponding to a mask with the values of the nearest neighbor

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As you can see, the developed cells have now been replaced by the nearest non-developed category, effectively removing this class from the dataset.

Sieving

- ❖Replace regions smaller than a certain size in a categorical raster with the surrounding class
- ❖Can be used to approximate a minimal mapping unit (MMU)

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As a last example of raster generalization methods, sieving can be used to remove contiguous areas of the same category that are smaller than a certain size.

The user must define a minimal size area to maintain as a land area or number of cells. The tool will then find all contiguous regions that are smaller than this defined size. Once these areas are found they will be removed and assigned to the surrounding class.

As an example, this tool could be used to remove small areas in a land cover classification that are smaller than a defined size. For example, small barren areas within a forested extent could be removed and coded as forest.

This method can be used to remove the salt-and-pepper effect common in land cover classifications.

Additionally, this method can be used to approximate a minimal mapping unit. Areas smaller than the minimal mapping unit can be recoded and assigned to the surrounding class.

Scale and Generalization for Base Maps

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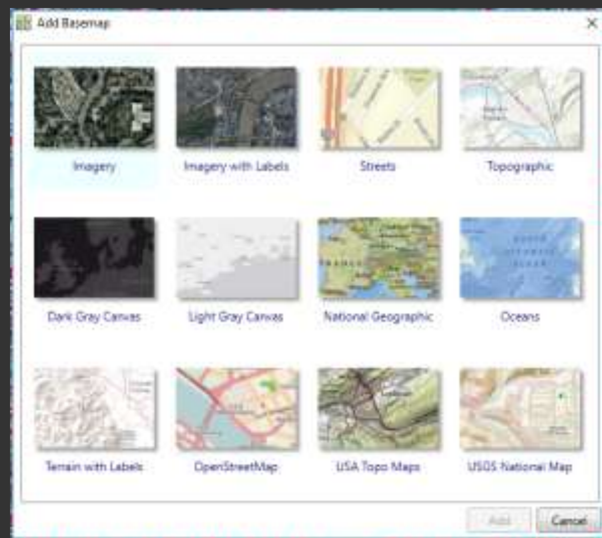
ArcGIS Basemaps



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ArcGIS Pro provides base maps that can be used in your projects and map layouts. However, these provided base maps will need to be appropriately cited.

Base Maps

- Open Street Map
- Stadia
- Stamen
- CartoDB
- NASA
- USGS

https://leaflet-extras.github.io/leaflet-providers/preview/

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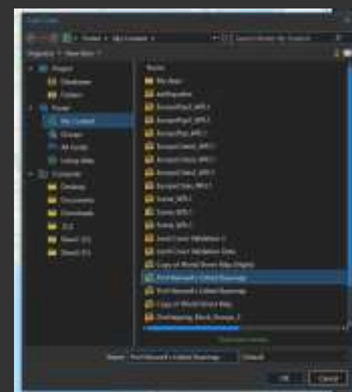
There are other sources of base maps that are provided as web services for use in desktop software, web maps, and web apps. The link on this page provides some examples of base maps from multiple providers. Different maps will have different allowed uses and citation requirements.

Vector Tiles

- ❖Can edit like vector graphics
- ❖Allows you to customize ESRI Basemaps
- ❖Must have ArcGIS Online Publisher account
- ❖Can save to your ArcGIS Online content
- ❖Can use online or in ArcGIS Pro



https://developers.arcgis.com/dashboard

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Another option for base maps that have 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 TIFF 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).

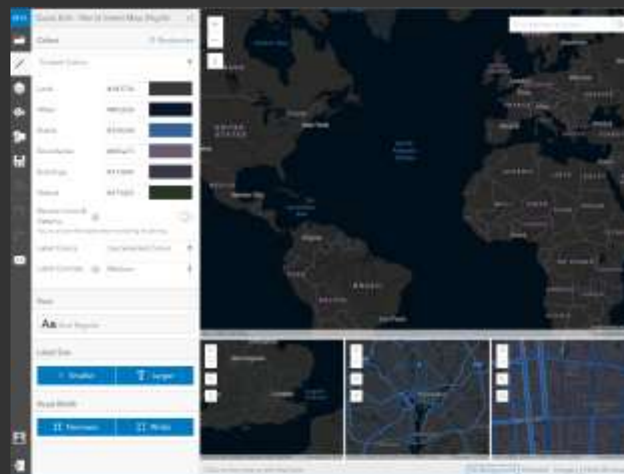
Vector graphics store the font, vector, and color information and generally allow for more symbol editing than raster files.

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. These layers can also be accessed in ArcGIS Pro.

Vector Tile Basemaps

- ❖Can edit ESRI basemaps as vector tile graphics
- ❖Use ArcGIS for Developers: https://developers.arcgis.com



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ESRI now allows users to edit the provided ESRI basemaps as vector tile basemaps to generate customized base maps.

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 your ArcGIS Online account to access your ArcGIS Online content.

Citation

- You should generally include a citation or reference for the base map used
- Sometimes watermarks or citations will automatically be added

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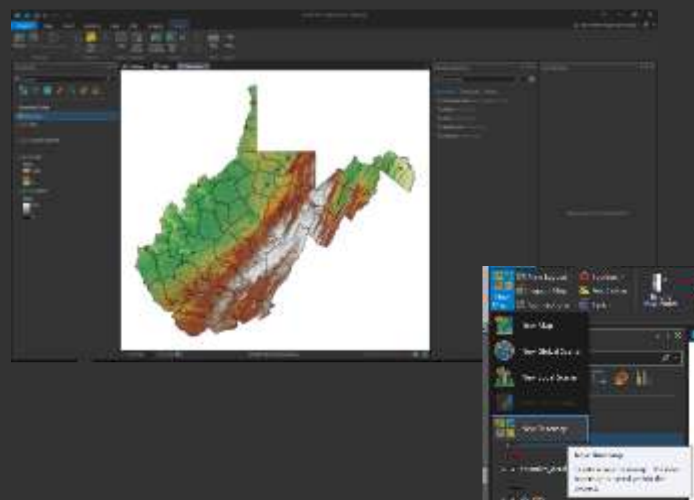
Again, the use of provided base maps may have some use or licensing restrictions and will likely require a citation or credit.

Make your own Base Map in ArcGIS Pro

- ❖Add a new basemap
- ❖Add layers to base map
- ❖Apply symbology
- ❖Edit viewing scales
- ❖Define layers as reference or background
- ❖Can save as Map file
- ❖Can add to online content



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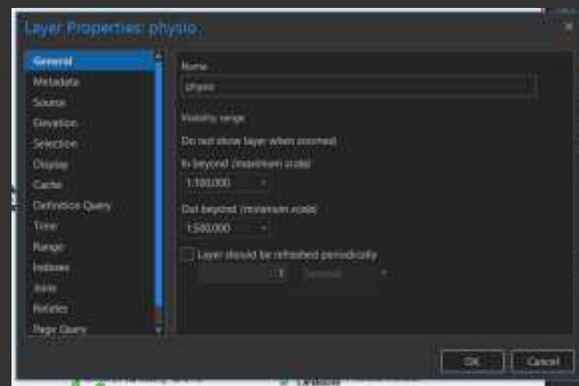
ArcGIS Pro allows for the generation of custom base maps that can then be used in multiple maps and/or scenes within a project. Designing a base map will require adding and symbolizing layers and editing viewing scales and symbology. Generated base maps can also be saved to your ArcGIS Online content for use in other projects, web maps, and web apps.

Incorporating Scale in ArcGIS Pro

- Visibility scales can be set for all layers in the map
- Can use this to control generalization and displayed data as you change the scale of your map



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When designing a base map, you should consider which data layers are most appropriate to show at different scales and whether or not layer symbology should change with scale. ArcGIS allows you to define the scales at which data will be displayed using visibility ranges. When you are zoomed in or out outside of this range, the layer will no longer draw. For example, you could have state boundaries draw until a certain scale is reached. Then, the state boundaries could disappear and be replaced by county boundaries. You could also include multiple copies of the same layer with different symbology and visibility ranges applied so that the layer symbology updates as you zoom in and out. In short, this allows for the generation of custom base maps that change with scale to support a variety of needs.

Blending Modes

- Controls how colors are combined for overlapping layers
- Commonly applied on raster graphic editing software (Adobe Photoshop)
- Can be applied to map layers in ArcGIS Pro
- More control over blending than simply using transparency

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ArcGIS Pro has recently integrated blending modes that allow you to control how colors are combined when layers overlap to create the final visualization of the data. These types of technique are commonly applied in raster graphics editing software (e.g., Adobe Photoshop), but can now be applied in ArcGIS Pro. Blending modes offer more control over how layers are graphically combined as opposed to just using transparency.

I encourage experimenting with blending modes as you build map layouts.

Base Map Data

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Common Base Map data

1. Terrain data
   - DEMs
   - Hillshades
   - Contours
   - Curvature
2. Land cover/Land use
3. Imagery
4. Parcels/zoning
5. Surface water features
6. Political boundaries
7. Transportation
8. Geographic names

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In this last section, I provide a brief overview of sources of common data used in base maps. Again, you should make sure that any data you obtain can be used for your intended purpose and what citation, licensing, or use restrictions may apply. You may have to seek special permission to use some data.

Data Sources in West Virginia

- West Virginia GIS Technical Center
- http://wvgis.wvu.edu/

The West Virginia GIS Technical Center provides statewide GIS services to advance the State's Spatial Data Infrastructure

A few of these services include the State Data Clearinghouse, a GIS People Directory, and the MapWV.gov web mapping portal

WV GIS Technical Center
WVU Department of Geology & Geography
330 Brooks Hall
P.O. Box 6300
Morgantown, WV 26506
Phone: (304) 293-0557
Fax: (304) 293-6522

http://wvgis.wvu.edu/data/data.php

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The West Virginia GIS Technical Center provides access to a wide variety of spatial datasets.

If am looking for data for areas within the state, I generally start here.

One of the goals of the GIS Tech Center is to provide statewide GIS services to advance the state's spatial data infrastructure.

Most datasets can be downloaded from the website, unless they are very large.

National Elevation Dataset (NED) and 3DEP

- ❖Available at multiple scales (30 m, 10 m, 3 m)
- ❖Products vary by location
- ❖Currently working toward high spatial resolution products from LiDAR (3DEP program)

https://nationalmap.gov/3DEP/

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The National Elevation Dataset, or NED, provides digital elevation data at a variety of scales depending on the location.

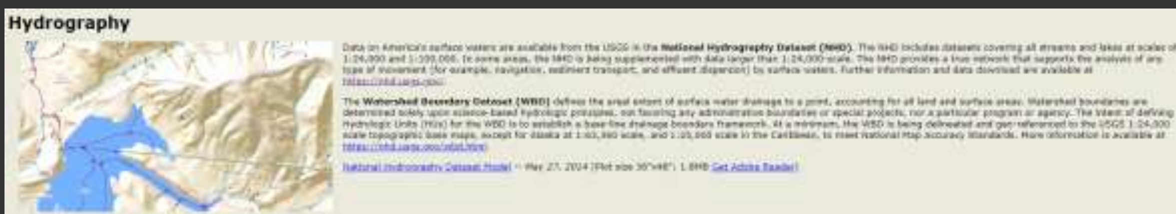
Products include 30 meter, 10 meter, and 3 meter elevation raster grids.

This program has now been superseded by the 3DEP program. This newer program is predominantly funding LiDAR-derived, high spatial resolution elevation data across the United States. Interferometric Synthetic Aperture RaDAR, or IfSAR, data will be collected over Alaska.

This project is ongoing. However, once it is complete, the data will have a variety of uses, such as floodplain mapping.

Hydrography

- National Hydrography Dataset
- Watersheds Boundaries Dataset



https://nhd.usgs.gov/

Hydrography in the United States is made available through the National Hydrography Dataset. This dataset models the surface water features at different spatial scales across the country. The data are topologically integrated so that network analysis can be performed through the drainage system.

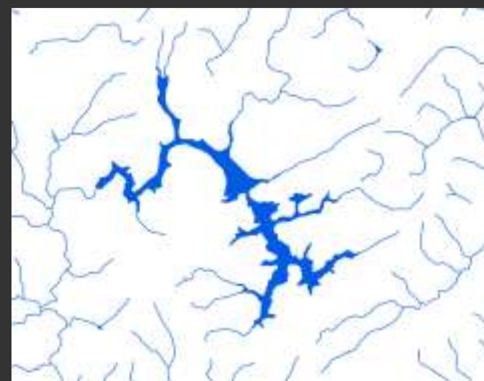
The NHD data include lakes, ponds, streams, rivers, canals, dams, and stream gages.

The Watershed Boundary Dataset defines the areal extent of drainage basins or watersheds at different scales.

The scales are defined relative to the Hydrologic Unit Code, or HUC, system.

Water

- Can use NHD 100K for small scale maps
- Can use NHD 24K for large scale maps
- Can change thickness based on flow or drainage area
- May need to edit data to remove connectors, artificial paths, and other unwanted features



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When displaying water bodies using the NHD data, it is generally preferred to use the 1:24,000 scale data for larger scale maps and only use the 1:100,000 scale data for smaller scale maps. In order to take into account the size of streams, the thickness can be changed based on the average flow or drainage area. Note that the NHD incorporates features that you may not want to include, such as artificial paths, so you may need to subset the data before display. These data are very well documented, so the metadata can be useful for making these display decisions.

National Land Cover Database (NLCD)

- 1992, 2001, 2004, 2006, 2008, 2011, 2013, and 2016, 2019
- Created at Landsat scale (30 m)
- Land cover
- Percent forest canopy
- Rangeland
- Percent impervious surface

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High spatial resolution land cover is not currently available for the entirety of the United States.

However, some high spatial resolution datasets have been produced for certain regions of the country. One example is the Chesapeake Bay Land Cover Project that mapped land cover for all counties that at least partially intersect the drainage basin of the Chesapeake Bay.

The only consistent product for the entire country is the moderate spatial resolution National Land Cover Database (NLCD).

Different version of this dataset has been produced including data from 1992, 2001, 2006, 2011, and 2016.

A variety of broad land cover types are differentiated using consistent methodologies that rely predominantly on Landsat imagery.

Since these data are produced using the Landsat sensor, the spatial resolution is 30-by-30 meters.

Other than just land cover, percent impervious surface and canopy cover products are also generated.

Census Data

- Decennial census
- Data collected:
  - Population counts
  - Demographic data
  - TIGER/Line vector data (roads, other)
- Geographic units for Census
  - State > County > Tract > Block Group > Block
  - Populated places (Census designated places)
  - Urban areas/MSAs

Tracts

Block Groups

Blocks

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A variety of data layers are made available by the US Census, which is conducted every ten years.

Examples include population counts, demographic data, and vector data representing roads.

Census results are aggregated to different units, including states, counties, tracts, block groups, and blocks.

They also map populated places and urban areas.

National Agriculture Imagery Program (NAIP)

http://usdaonline.maps.arcgis.com/apps/MapTour/index.html?appid=445e3dfd16c4401f95f78ad5905a4cce&webmap=6d117f2ede424ace93917e2bc88202b3

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The National Agriculture Imagery Program (NAIP) is a good source of predominantly leaf-on orthophotography in the United States.

ESRI Open Data

http://www.esri.com/software/open/open-data

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ESRI provides access to a wide variety of free and open data layers through its Open Data website.

ArcGIS Living Atlas of the World

https://livingatlas.arcgis.com/en/

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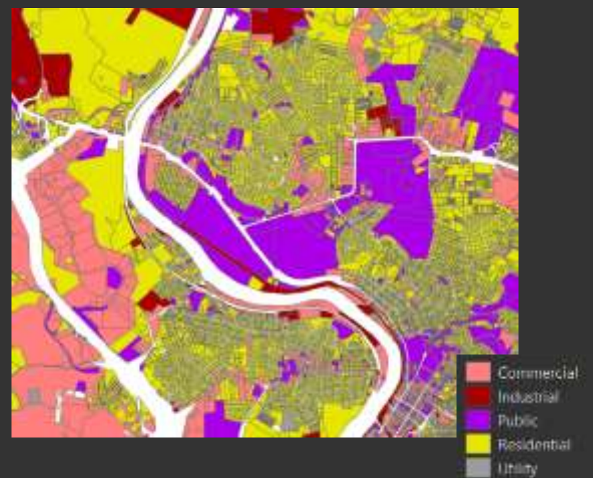
With a valid ArcGIS Online account, you can also access data via the ArcGIS Living Atlas of the World.

These data layers can be used in both ArcGIS Pro and ArcGIS Online.

Analyses can even be performed on some of the layers.

Parcels or Cadastral Maps

- Useful for large-scale maps
- Provides information on land use
- Provides information on zoning
- Provides information on road locations
- General characteristics of a town
- American Planning Association (APA) recommends particular color schemes



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Parcels or cadastral data are sometimes used when producing large-scale maps. These data provide information about land use, zoning, the location of roads, and the general characteristics of a town. In the example, I have displayed parcel data for Morgantown, WV and differentiated different zoning types: commercial, industrial, public, residential, and utility. Parcel data may not be readily available for all locations in a digital format, and not all municipalities make these data readily available. The American Planning Association (APA) provides recommended color schemes for displaying parcel data.

Political Boundaries

- Countries, states, counties, Census tracts, Census block groups, Census blocks, zip codes, school districts, voting districts, wards, neighborhoods, incorporated places, etc.

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A wide variety of political boundaries and Census boundaries are available at a variety of scales. The choice of which boundaries to show will depend on scale and the purpose of the map.

Public Lands

- National parks, national monuments, national forests, national grasslands, national wildlife refuges, state parks, wildlife management areas, state forests, city parks, etc.

Data Set	Category	Summary Data	Date Created	Download
Public Lands - County/City Parks	Boundaries		2017	Download
Public Lands - National Forest Boundaries	Boundaries		2018	Download
Public Lands - National Park Boundaries	Boundaries		2017	Download
Public Lands - National Wildlife Refuges	Boundaries		2017	Download
Public Lands - State Forests	Boundaries		2018	Download
Public Lands - State Parks	Boundaries		2018	Download
Public Lands - Wildlife Management Areas	Boundaries		2017	Download

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It is generally easy to find boundaries of federal and state lands.

Physical Boundaries

- Physiography, ecological regions, biomes, watersheds, wetlands, estuaries, mountain ranges, basins, etc.

https://water.usgs.gov/GIS/metadata/usgswrd/XML/huc250k.xml#stdorder

https://water.usgs.gov/GIS/metadata/usgswrd/XML/physio.xml#stdorder

68

Geomorphologists, ecologists, and other physical Earth scientists are sometimes interested in displaying boundaries defined by the landscape characteristics, as opposed to politically. Different datasets are available for representing physiography, ecological regions, biomes, watersheds, wetlands, estuaries, and mountain ranges and basins. Such data are generally made available by state or federal agencies, such as the USDA Forest Service, EPA, or NASA.

Considerations when mapping boundaries

- Often hierarchical, which causes overlaying lines and clutter
- Can show different boundaries at different scales
- Different sources may not overlay perfectly (slivers)
- Can use dashed lines to help with overlay
- Use combination of dashed and solid lines
- Make use of color and width differences
- Use GIS operations to clean or generalize data

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When working with boundaries, it is generally a good idea to change the boundaries displayed based on scale to alleviate issues of clutter. Also, data from different sources may not overlap perfectly, resulting in slivers that may be noticeable when zoomed into different scales. To minimize these issues, you can generate less detailed boundaries from more detailed boundaries by dissolving. For example, state boundaries could be derived from county boundaries to maintain the same state extents. If you are experiencing issues of overlap and crowding, you can use dashed lines to aid in separability. You may also need to experiment with colors, transparency, and outline width. Lastly, generalization may be necessary.

Transportation

- Roads, trails, railroads, sidewalks, etc.
- May need to generalize
- May need to remove some categories
- US Census TIGER Data
  - Can use RTTYP codes
  - Can use MTFCC codes: https://www.census.gov/geo/reference/mtfcc.html

COUNTYFP	LINEARID	FULLNAME	RTTYP	MTFCC	Shape_Leng	Label
017	1101746350767	Co Rte 25/11	C	S1400	563.238221	25/11
017	1101746351215	Main Camp Rd	M	S1400	1378.068003	Main Camp Rd
017	1103890922857	Morgans Run Rd	M	S1400	3915.919593	Morgans Run Rd
017	1103660922064	Wolf Pen	M	S1400	3915.919593	Wolf Pen
017	1101746350347	Co Rte 5	C	S1400	4941.742063	5
017	1101746350420	US Hwy 50	U	S1200	10268.508196	50
017	1101746351170	Big Flint Rd	M	S1400	11412.518111	Big Flint Rd
017	1101746351240	Smithbury St	M	S1400	1003.740477	Smithbury St
017	1101746351443	Snake Run Branch	M	S1400	480.90118	Snake Run Branch

Route Type Code	Route Type Code Description
C	County
I	Interstate
M	Common Name
O	Other
S	State recognized
U	U.S.

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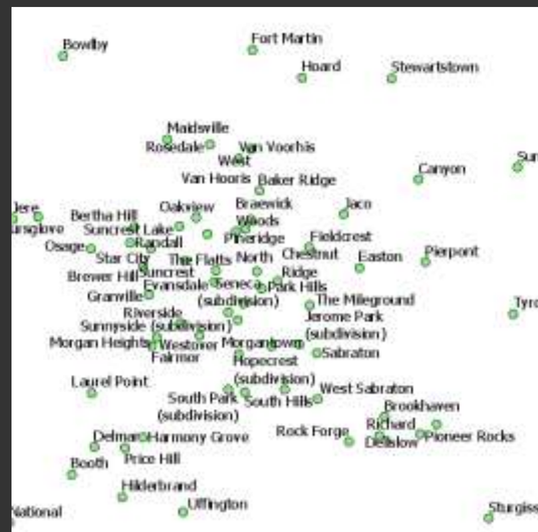
Transportation layers often use standard symbologies. For example, different symbols can be defined for different types of roads (e.g., interstate, state, and local). ESRI has some pre-defined symbology for roads and railroads. However, you can define your own. Included attribute data should allow you to differentiate features by type.

Point Data

- Towns, places of interest, structures, energy facilities, medical centers, cemeteries, places of worship, attractions, police stations, historic sites, etc.
- Can use points or just use them as labels
- Can make use of Geographic Names Information System (GNIS)
- Can be challenging due to variety



71

The US government provides point features that were originally developed from topographic map data. These data can be used to represent point features. Alternatively, they can be used to define labels only by making the symbol blank. These data can be difficult to work with since they are not well differentiated by type.

Natural Earth

- Provides open-source data for small scale maps (1:10M, 1:50M, 1:110M)

https://www.naturalearthdata.com/

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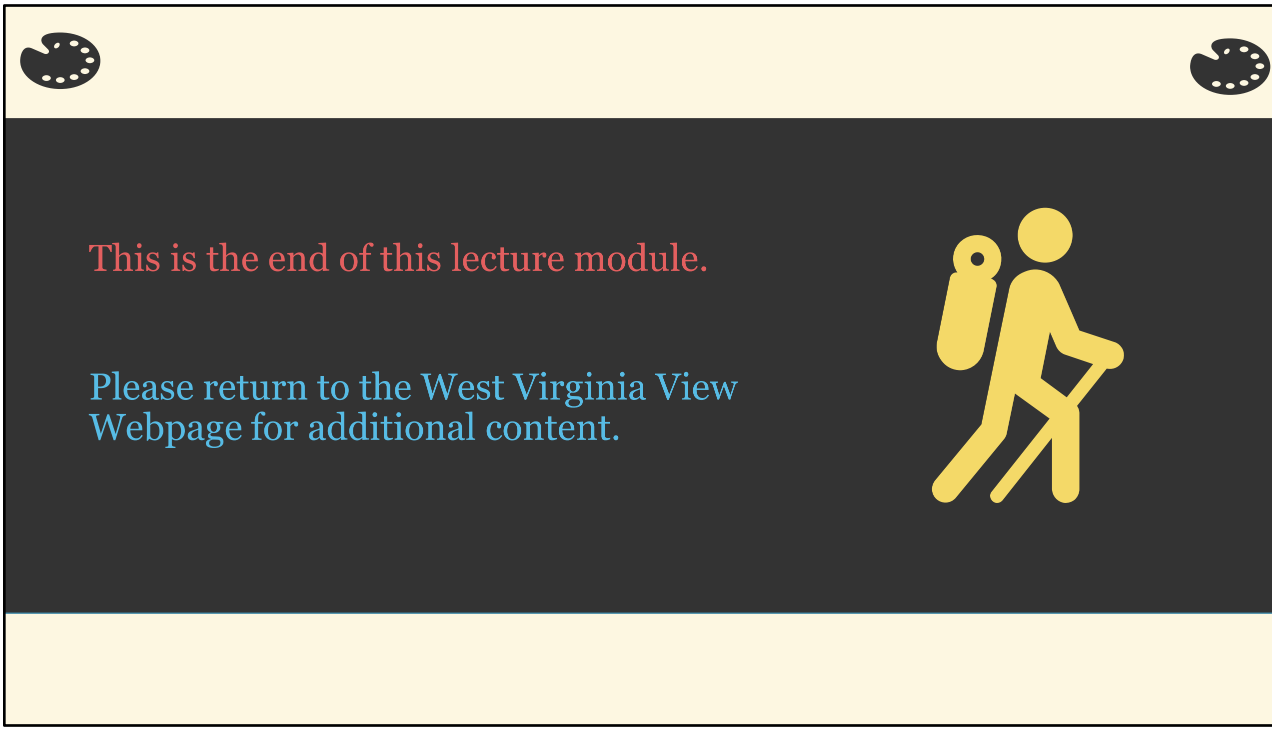
One good source of general base map data for smaller scale maps are the data provided by Natural Earth, which are free and open-source. However, Natural Earth should still be cited when these data are used.



Thanks! Hope you found this useful.