Lab 5: Rasters Part 1 (Georeferencing Mitigation Plans and Topographic Siting)
Introduction

Raster data structures represent geographic phenomena as a continuous grid of cells (pixels). While vector datasets are optimal for defining discrete boundaries, rasters are required for continuous surfaces such as elevation, precipitation, and imagery. In general, “rasters are faster, vectors are correct-er”.

In this lab, you will do a basic evaluation of the topographic controls on the 2018 Ellicott City flood and assess the county's proposed engineering solutions. First, you will georeference a non-spatial engineering plan for preventing future floods to extract the alignment of proposed conveyance tunnels and the locations of upstream dry flood mitigation ponds. Second, you will process a high-resolution topographic map (Digital Elevation Model; DEM). By classifying the continuous elevation surface into discrete topographic zones, you will analyze the physical reasoning behind placing retention ponds high in the watershed to protect the vulnerable historic district.

Learning Goals
By the end of this lab you will be able to:

- Georeference an unreferenced static image (e.g., PDF map or engineering plan) using defensible ground control points.
- Evaluate transformation models and quantify positional error using the Root Mean Square Error (RMSE).
- Digitize proposed vector features from a georeferenced raster baseline.
- Process a Digital Elevation Model (DEM) using clipping and reclassification to isolate vulnerable topographic thresholds and upstream catchments.

Datasets Provided (in /raw/)

- Maryland_Six_Inch_Imagery (Raster service): High-resolution modern basemap.
- EC_SafeAndSound_3G7_Plan.jpg (Raster): A static, non-spatial graphic showing the master plan for flood mitigation, including completed and proposed retention ponds (H-7, Quaker Mill, H-4, NC-3, T-1) and the Extended North Tunnel.
- Lab06_NED_10m_Ellicott.tif (Raster): A bare-earth digital elevation model representing the physical topography.
- Lab05_EllicottCity_HistoricDistrict_Core.shp (Polygon): The boundary of the vulnerable downtown corridor.

Part A: Raster Setup and Inspection

1. Initialize Project

- Create your lab05_lastname directory.
- Open a new ArcGIS Pro project and map. Set the CRS to NAD 1983 StatePlane Maryland Meters.
- Add the basemap imagery, the historic district polygon, the DEM, and the .jpg mitigation plan.

2. Raster Inspection

- Open the Properties for both the DEM and the Mitigation Plan. Navigate to the Raster Information and Spatial Reference tabs.
- Note the CRS, the Cell Size, and the Extent values. The Mitigation Plan will display an "Unknown Coordinate System" and arbitrary extent values (e.g., 0 to 1000) because it is a raw image file, not a spatial dataset.

Part B: Georeferencing the Mitigation Plan

You can translate the arbitrary pixel coordinates of the Mitigation Plan into the Maryland State Plane coordinate system by linking them to the known coordinates of the basemap. This is called georeferencing, and is a pretty common workflow in GIS, since many datasets lack any sort of spatial data.

3. Establish Ground Control Points (GCPs)

- Select the Mitigation Plan in the Contents pane. Click the Imagery tab → Georeference.
- Use the Add Control Points tool.
- The strategy is to mark things that you can identify in both the Mitigation Plan and the basemap image. Good examples are building edges, road intersections, etc. – objects that are fixed in place.
- Click a distinct, stable feature on the Mitigation Plan (Source), then click the exact corresponding location on the Six-Inch Imagery (Target).
- Selection Strategy: Use major highway interchanges (e.g., the US 40 and US 29 intersection), major arterial road intersections, and the edges of large buildings.
- The previous extent button (located on the left of the Map tab) will be helpful
- Distribute 6 to 8 points evenly across the image extent. Avoid collinearity (e.g., placing all points along a single highway).
- Note that there is an Auto Georeference tool, but it typically takes a while to run and rarely works.

4. Evaluate Transformations and Error

- Open the Control Point Table.
- The default mathematical transformation is a 1st Order Polynomial (Affine), which shifts, scales, and rotates the image. Switch the transformation to a 2nd Order Polynomial and observe how the image warps to account for the map's localized distortions. There are other transformations that you can explore as well, though some require more control points.
- Review the Residual column. This represents the spatial error (in meters) between where your point was placed and where the mathematical model calculated it should be.
- Delete or replace any points with severe outliers. Record your final RMSE.

5. Save the Spatial Image

- In the Georeference tab, click Save as New to export the rectified image. Name it Mitigation_Plan_Georeferenced.tif. Close the Georeferencing session and remove the original .jpg from the map.

Part C: Digitizing Engineering Interventions

With the plan spatially anchored, you can extract the proposed county interventions into your geodatabase.

6. Digitize Mitigation Features

- In your default geodatabase, create a new Polygon feature class named Mitigation_Ponds. Add a text field named Project_Name and a text field named Status.
- Create a new Line feature class named Conveyance_Tunnels.
- Using the georeferenced plan as your guide, digitize the footprints of the five labeled retention ponds (H-7, Quaker Mill, H-4, NC-3, T-1). Fill in their names and status (e.g., Complete, In Design) based on the map's legend.
- Digitize the centerline of the "Extended North Tunnel" and the "MD Ave. Culvert".

Part D: Topographic Extraction (DEM Processing)

You can now isolate the physical topography of the Tiber Branch watershed to analyze why the county placed the retention ponds in these specific locations.

7. Classify Topographic Zones

Group the continuous elevation values into discrete zones representing the valley floor, the valley walls, and the uplands.

- Execute the Reclassify tool on the DEM.
- Click Classify. Set the method to Natural Breaks (Jenks) and the number of classes to 4.
- Output: Elevation_Zones.tif.
- Note that this algorithm minimizes variance within classes and maximizes variance between classes, effectively separating the flat valley bottom (Class 1) from the steep valley walls (Classes 2 and 3) and the high ridges (Class 4).

Part E: Topographic Siting Assessment (Do It Yourself)

You now have the discrete topographic zones, the location of the highly vulnerable Historic District, and the footprints of the upstream retention ponds. You can quantify the topographic relationship between the hazard zone and the mitigation infrastructure.

8. Extract Elevation to Ponds and Town

- Task: Convert your newly digitized mitigation ponds polygons into centroid points using the Feature to Point tool.
- Task: Create a centroid point from the core historic district polygon.
- Task: Use the Extract Values to Points tool to pull the underlying bare-earth elevation value from the DEM and append it to the pond centroids and the historic district centroid.

9. Compare Topographic Positioning

- Task: Open the attribute tables. Calculate the Mean elevation of the five mitigation ponds.
- Task: Identify the exact elevation of the Historic District centroid.

10. Final Documentation

Address the following:

- Report your final transformation method (e.g., 2nd Order Polynomial) and the total RMSE. Explain why a low RMSE does *not* guarantee that the image is perfectly accurate in the spaces between your control points.
- Report the mean elevation of the mitigation ponds versus the elevation of the Historic District.
- Based on your elevation zone map and the elevations you extracted, explain the physical strategy of the Safe and Sound plan. Why are the ponds geographically scattered and placed at significantly higher elevations than the town, rather than building flood walls directly inside the Historic District? (Consider watershed accumulation and gravity-fed conveyance in your answer).