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Creating Flood Depth Rasters for Flood Impact Analysis

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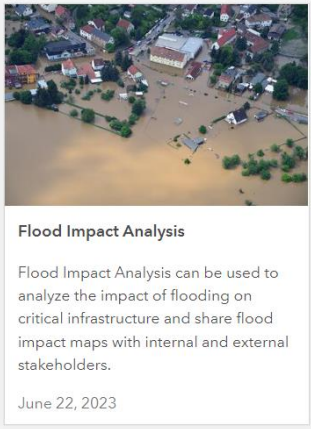
1.0 Background

The Flood Impact Analysis Solution (FIAS) is a guided workflow that allows users to visualize flooding (in both 2D and 3D) at various intensities. User can also determine which populations may be vulnerable to the flood event and quantify the infrastructure impacted. Flood impact analysis is practical for any entities that want to mitigate for the disruption caused by high peak flow events. As sea level rise and natural hazards such as flooding become more persistent with climate change it is crucial to execute workflows such as FIAS and account for the ramifications. A more detailed explanation of the solution can be found here https://doc.arcgis.com/en/arcgis-solutions/latest/reference/introduction-to-flood-impact-analysis.htm. The solution can be deployed through the ArcGIS Solutions app. Once the solution is downloaded into an appropriate folder on your computer, it contains a project package that can be opened in ArcGIS Pro.

It is important to note that an assumption of FIAS is that flood depth rasters for your area of interest have already been derived. This document serves to provide guidance in how you may create flood depth rasters for your area of interest if they are not already available.



2.0 System and Data Requirements

2.1 System Requirements

User will need ArcGIS Pro and a compatible version of Arc Hydro. The Arc Hydro toolset is available for all versions of Pro and can be downloaded here https://www.esri.com/en-us/industries/water-resources/arc-hydro/downloads#arc-hydro-for-arcgis-pro.

2.2 Input Data and Sources

The only input data required for creating flood depth rasters will be an elevation raster (i.e. DEM, DTM, …) for your area of interest. It is important to note that input data within this document only pertains to the creation of flood depth rasters. While the flood depth rasters generated will serve as an input in the FIAS, the solution has additional data inputs that are not listed in this document as they are irrelevant to the creation of the flood depth rasters. Numerous agencies have publicly available elevation datasets for download including the following:

- NOAA's Elevation Inventory
- NASA's EarthData
- USGS's Earth Explorer
- ESRI's Living Atlas Portal

This document will detail how to create flood depth rasters based on the FIAS sample data found here https://www.arcgis.com/home/item.html?id=e1efdb09a93c4943baf458941512dbec.

NOTE: All of the input and output data should be under the same local projected coordinate reference system (CRS).

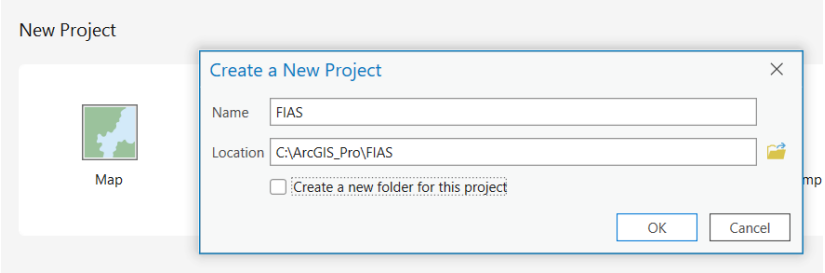
2.3 Data Structure

If not already familiar with how to properly set up an Arc Hydro based project one can refer to the following documents:

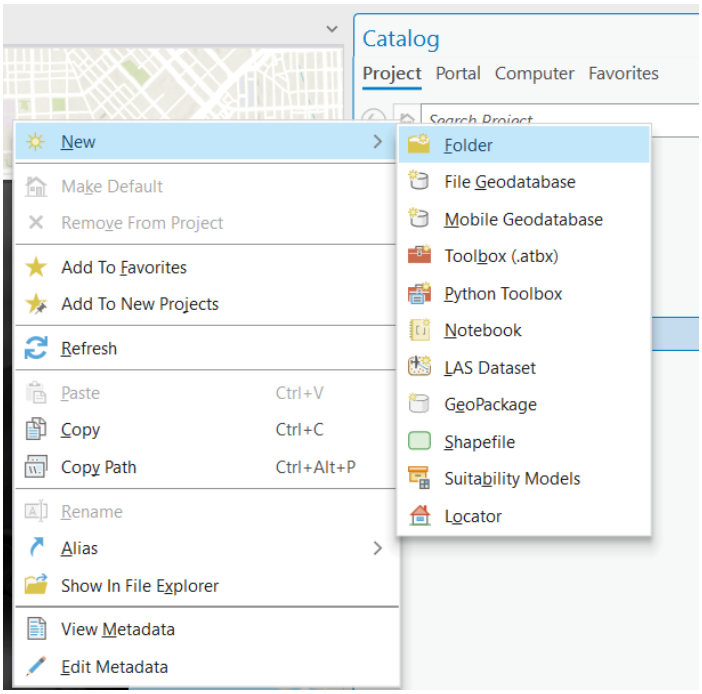
- https://community.esri.com/t5/water-resources-documents/arc-hydro-arcgis-pro-project-startup-best/ta-p/920366
- https://community.esri.com/t5/water-resources-documents/arc-hydro-project-development-best-practices-pdf/ta-p/920431

In summary, vector data should be stored in the project geodatabase whereas raster data should exist outside the geodatabase in a folder labeled "Layers". All the data should have the same local projected coordinate reference system and data that is unprojected is not suitable for analysis. Data should be stored into a single "parent" folder. Naming of data should describe the output in a consistent and concise manner. Spaces and special characters must be avoided in nomenclature.

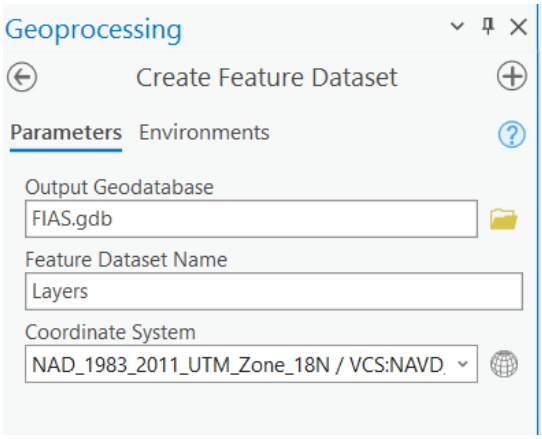
1. Create a folder in your computer file manager called "FIAS".
2. Open Arc GIS Pro and select the map icon. Select the FIAS folder as the location and uncheck the box to create a new folder for the project.



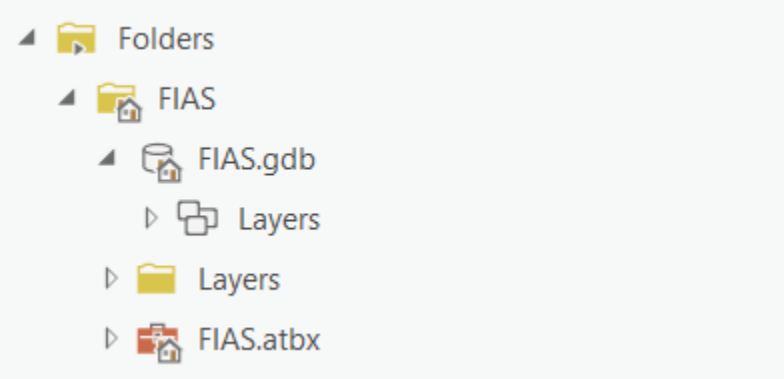
3. Navigate to the catalog pane and right click on the FIAS parent folder to create a new folder labeled “Layers”. This will be used to store raster data.



4. Use the geoprocessing tool Create Feature Dataset to create a feature dataset called “Layers” under the project geodatabase. This will be used to store any vector data.



This should be the resulting organization.



3.0 Processing Elevation Raster

3.1 Add Elevation Data

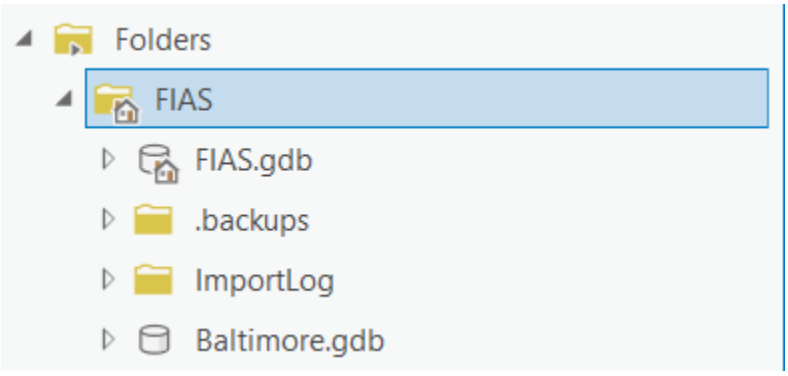
1. If you have elevation data in your area of interest, you can follow the steps **1a** to bring it into your map project workspace. If you are working with the elevation from the sample dataset follow set **1b** instead.

   a. Download elevation data for your area of interest into the FIAS folder you created.

   b. Download the solution's sample data from this link https://www.arcgis.com/home/item.html?id=e1efdb09a93c4943baf458941512dbec. Proceed to extract the files into the FIAS folder you created.

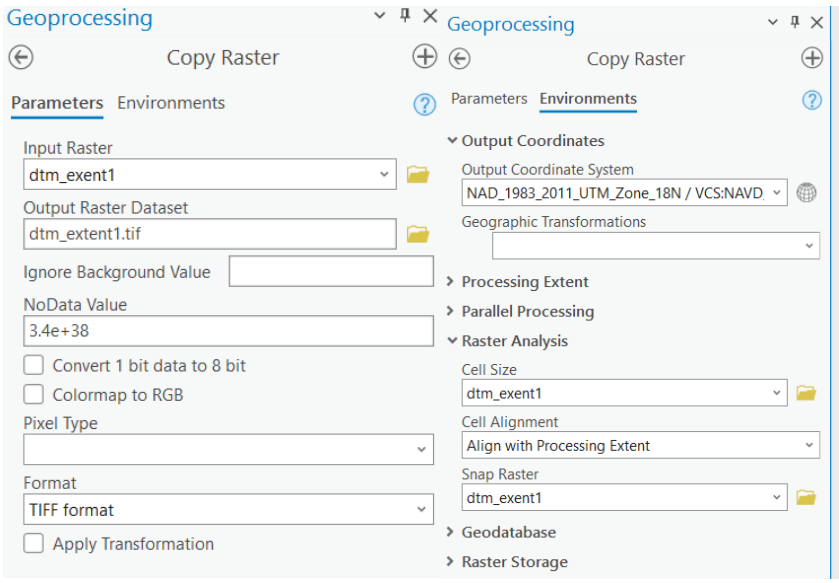
2. Open the FIAS map project you created.

3. Refresh the FIAS parent folder in your map project and the geodatabase labeled Baltimore.gdb will appear or the elevation data you downloaded will appear based on whether you chose to follow step **1a** or **1b**.



4. Use the geoprocessing tool Copy Raster to copy the elevation raster into the Layers folder you created.

- Using the environments tab, ensure the snap raster and cell size input is the original elevation raster.
- It is also crucial that the coordinate reference system remains consistent for all the data.
- The raster copy should also be a Tiff file.

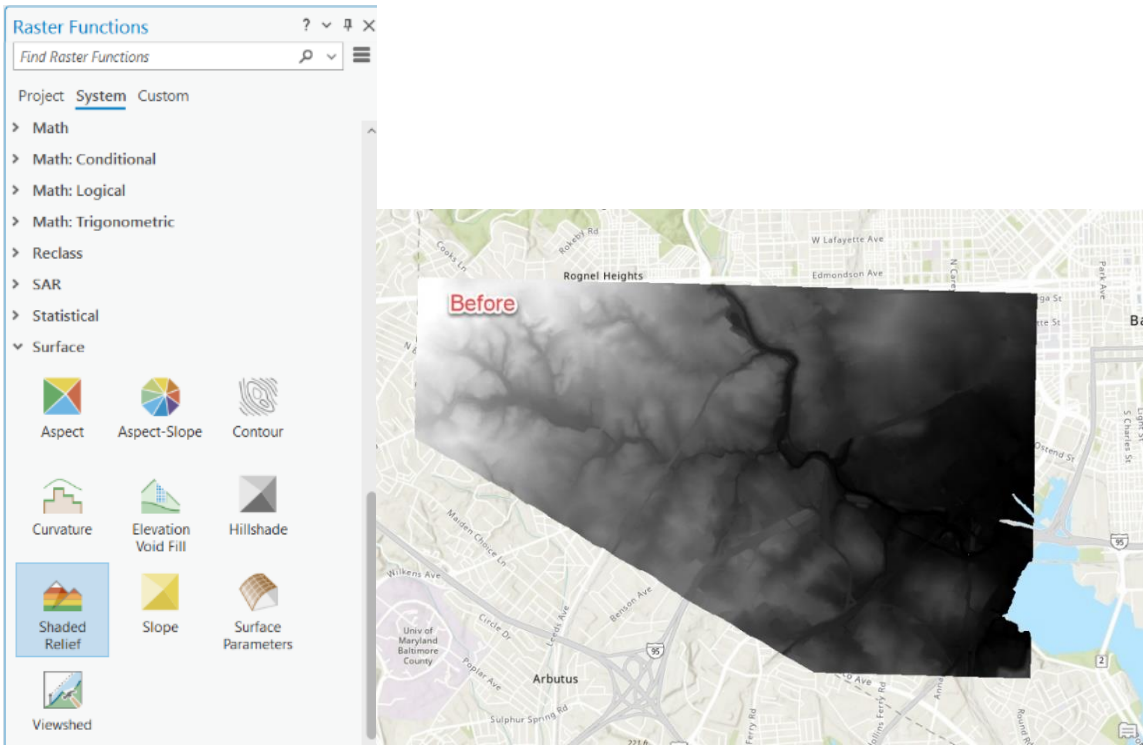


3.1.1 Visualization of Elevation Data

NOTE: This is an optional step and is purely for visualization. The generated shaded relief elevation raster should not be used as an input for any geoprocessing tools.

For a better visualization of the elevation raster and map features, select the elevation raster in your contents pane and then click on the Imagery tab.

1. Under the Analysis heading click on Raster Functions.
2. Scroll to the heading called Surface and expand the results.
3. Choose shaded relief and select your elevation raster as the input.


Raster Functions
Find Raster Functions
Project System Custom
Math
Math: Conditional
Math: Logical
Math: Trigonometric
Reclass
SAR
Statistical
Surface
Aspect
Aspect-Slope
Contour
Curvature
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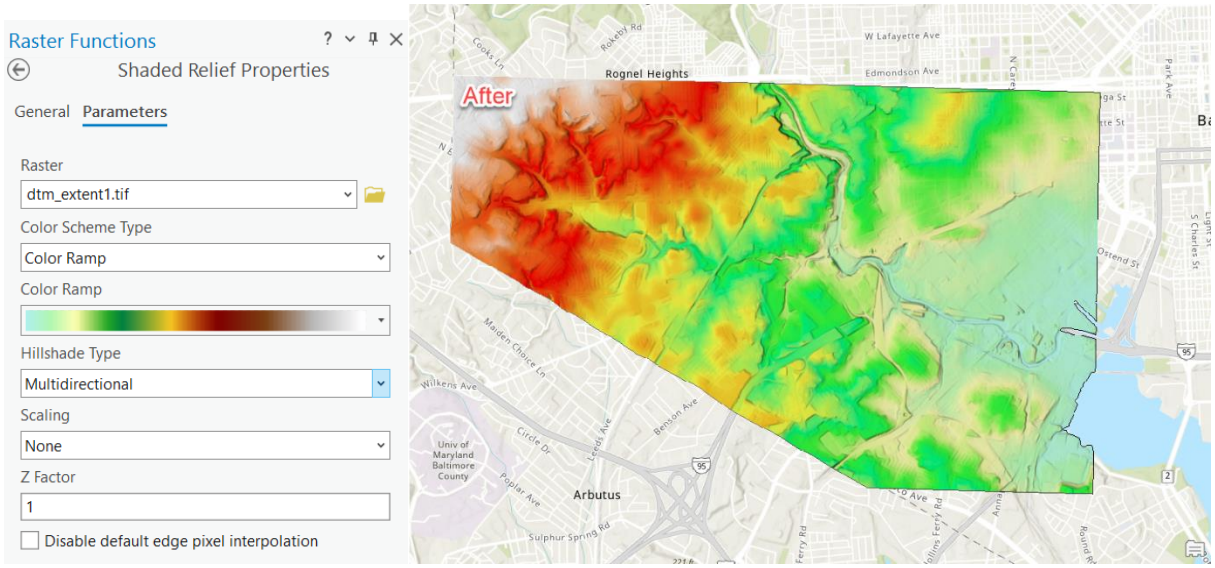
Hillshade
Shaded Relief
Slope
Surface Parameters
Viewshed
Before
Rognel Heights
Arbutus


Raster Functions
Shaded Relief Properties
General Parameters
Raster
dtm_extent1.tif
Color Scheme Type
Color Ramp
Color Ramp
Hillshade Type
Multidirectional
Scaling
None
Z Factor
1
Disable default edge pixel interpolation
After
Rognel Heights
Arbutus

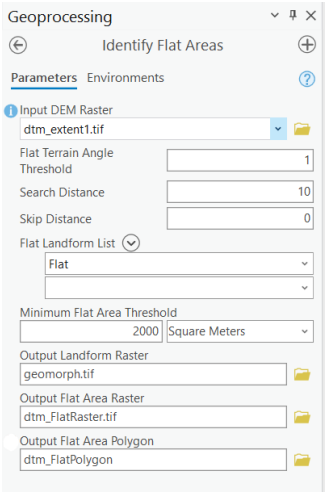
3.2 Addressing Flat Areas

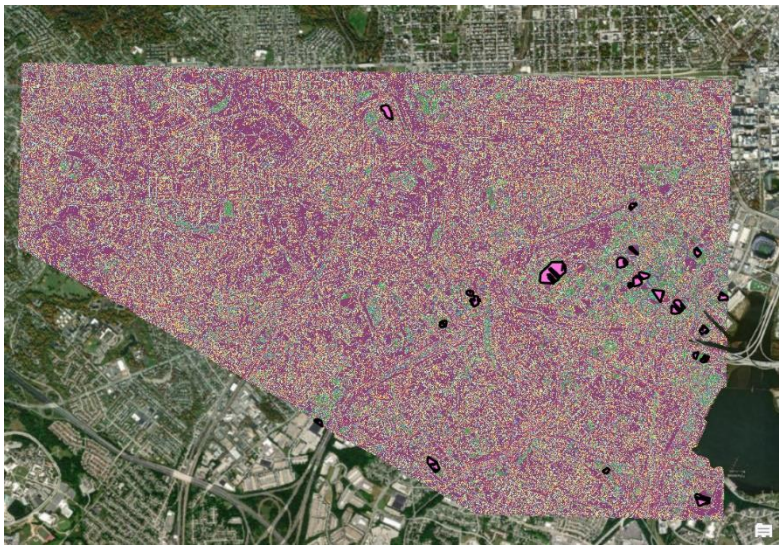
Elevation data can be comprised of flat areas. Thus, running flow accumulation without accounting for flat areas may generate jagged streams that zig zag within stream channel bed. Flat areas need to be addressed and incorporated into DEM to avoid inaccuracies and created smoother, central streamlines. **NOTE:** This step is only for versions of Pro 3.1 and more recent because filling sinks will resolve this issue.

1. Search for the Identify Flat Areas tool in the geoprocessing pane.

   - Input DEM raster is the elevation raster

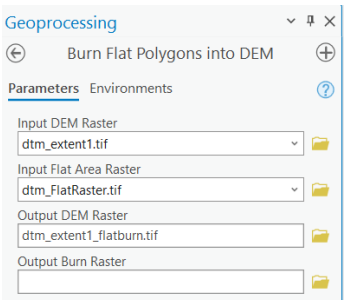
   - The rest of the parameters were kept on default values for the sample data. One should alter the parameters as they see fit for their own data.





2. If the generated flat areas from the previous step affect the anticipated river channels, then follow step **2a**. Otherwise, if flat areas do NOT affect the anticipated river channels, proceed to section **3.3**. For the Baltimore sample data, the flat area polygons are negligible to the stream because they do not intersect with anticipated stream channel, so this step was deemed unnecessary and skipped.

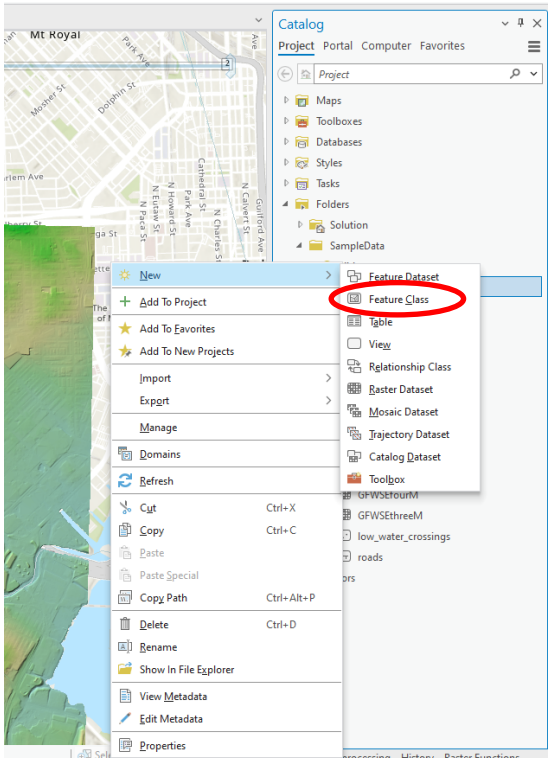
   a. Burn the flat polygons into the elevation raster using the tool Burn Flat Polygons into DEM.



3.3 Addressing Culverts

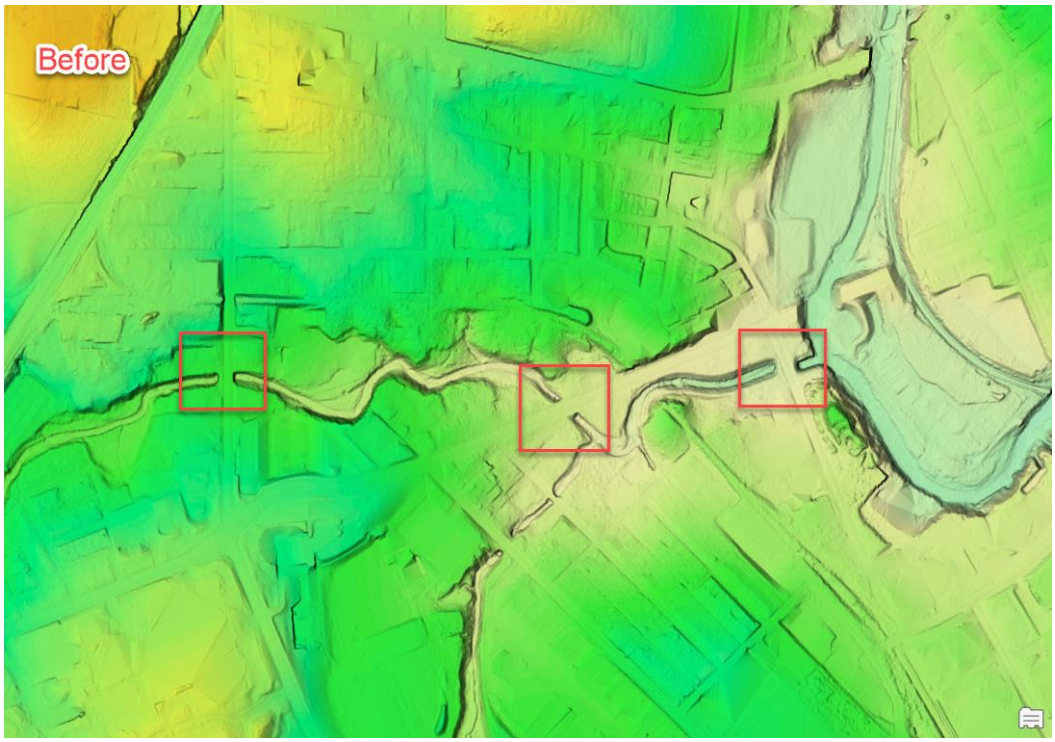
Flow direction and accumulation will follow the least cost path downstream meaning it will go around culvert as opposed to through it since the initial elevation data does not account for its presence. Thus, culverts need to be burned into the elevation raster for stream analysis.

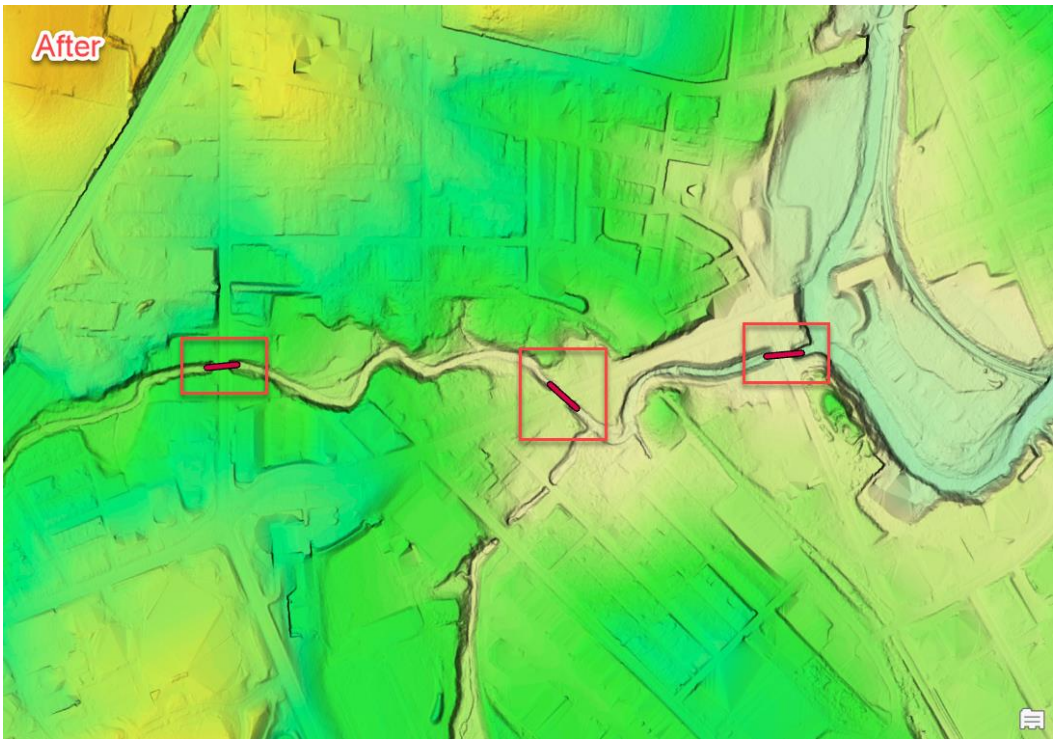
1. Create a new feature class in the project geodatabase.



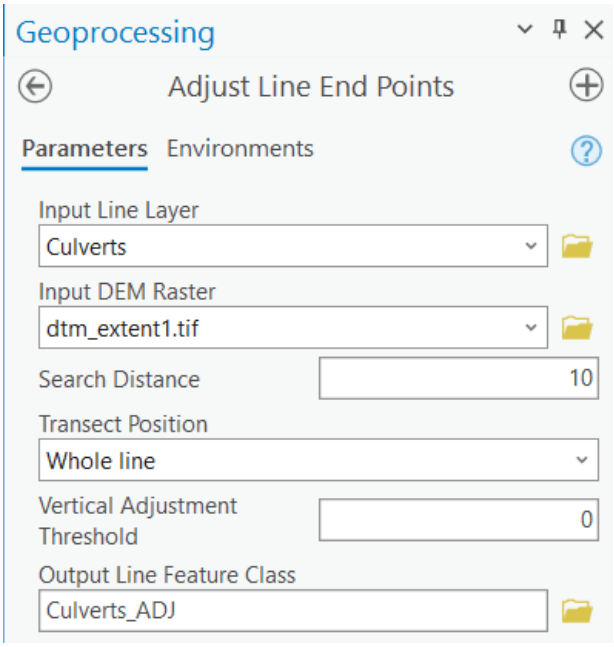
2. Name the feature class “Culverts” and select line as the type of feature class.

3. Under the Edit tab, select create from the features heading, and begin digitizing culverts with the “Culverts” feature class. **NOTE:** when creating a culvert feature class start with upstream vertex and then move downstream.

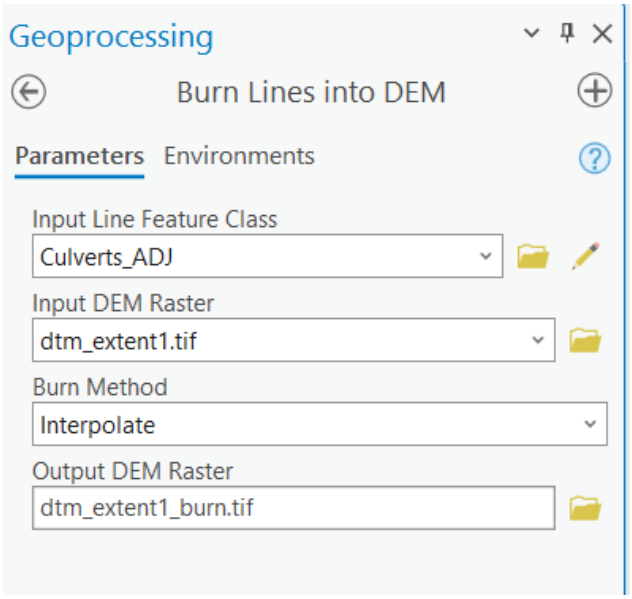

Before

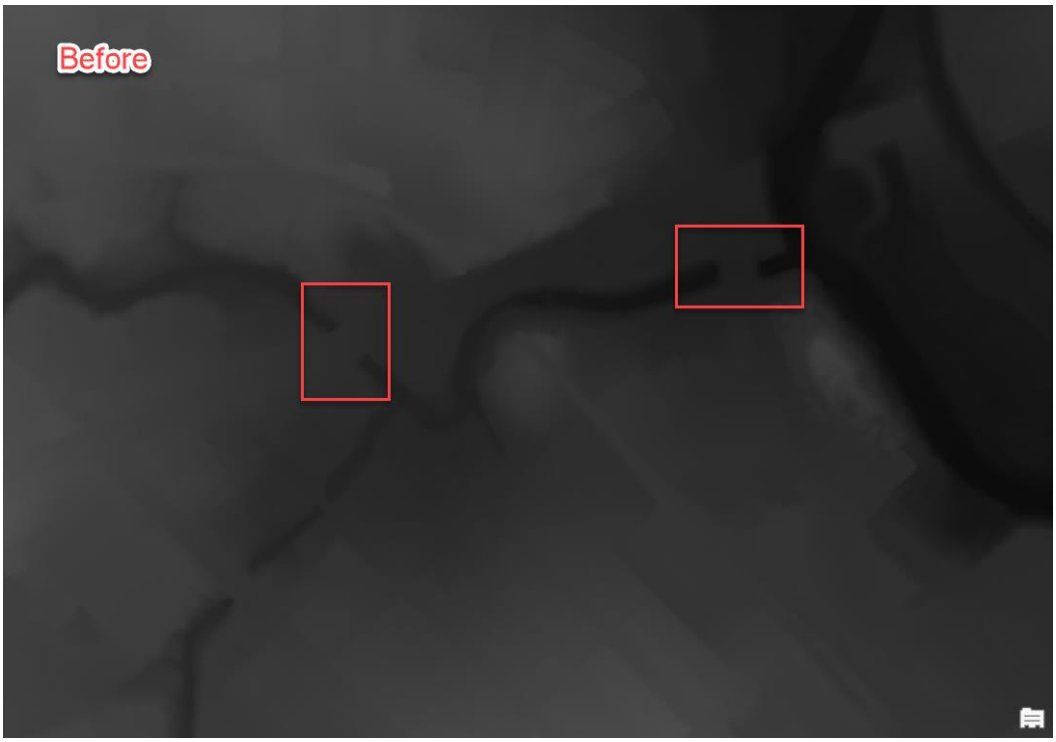

After

4. Adjust the end vertices of the culverts to be at the local DEM minima using the tool Adjust Line End Points.



5. Use the Burn Lines into DEM tool to incorporate the culverts into the elevation raster.

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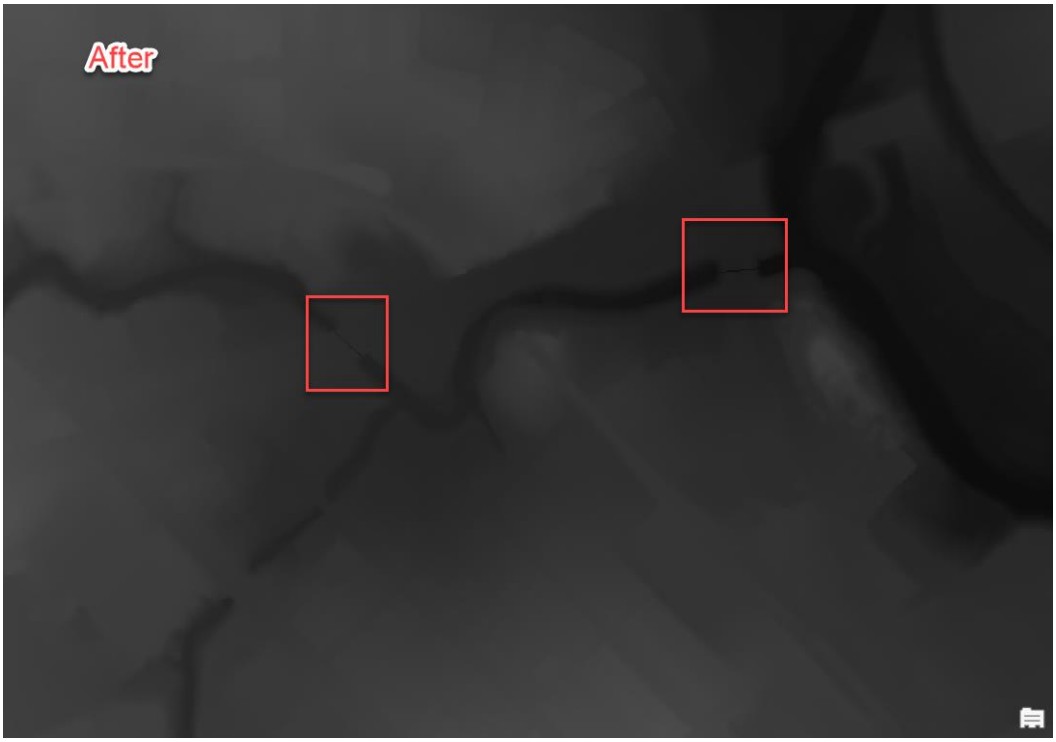

After

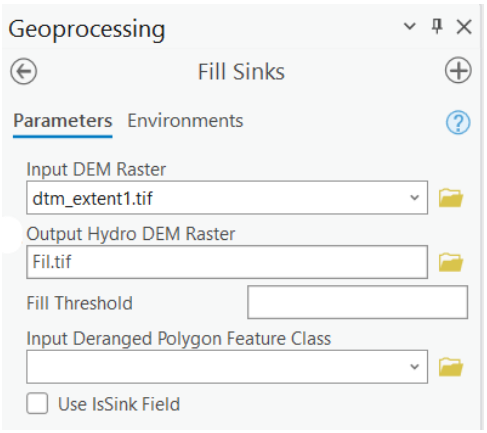
4.0 Stream Characterization and Identification

4.1 Determine Flow Direction and Flow Accumulation

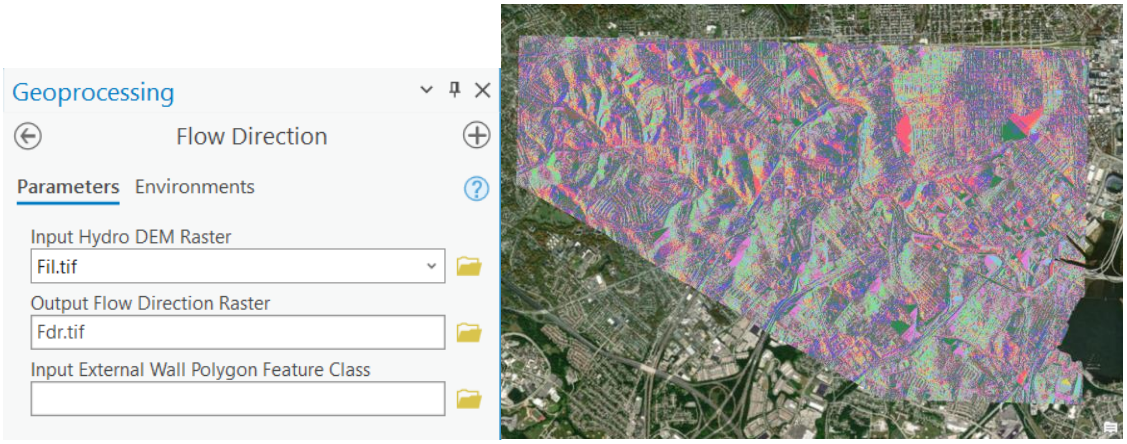
4.1.1 Versions of Pro older than 3.0

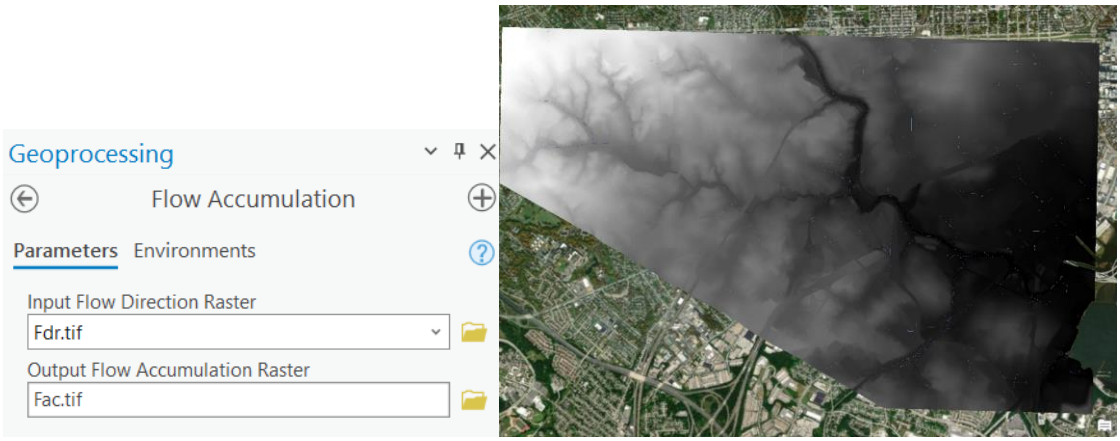
1. Find the Fill Sinks tool in the geoprocessing pane

   - Input surface raster is the elevation raster



2. Proceed to find the flow direction and accumulation using the Flow Direction and Flow Accumulation tools respectively with the filled elevation raster as the input Hydro DEM Raster



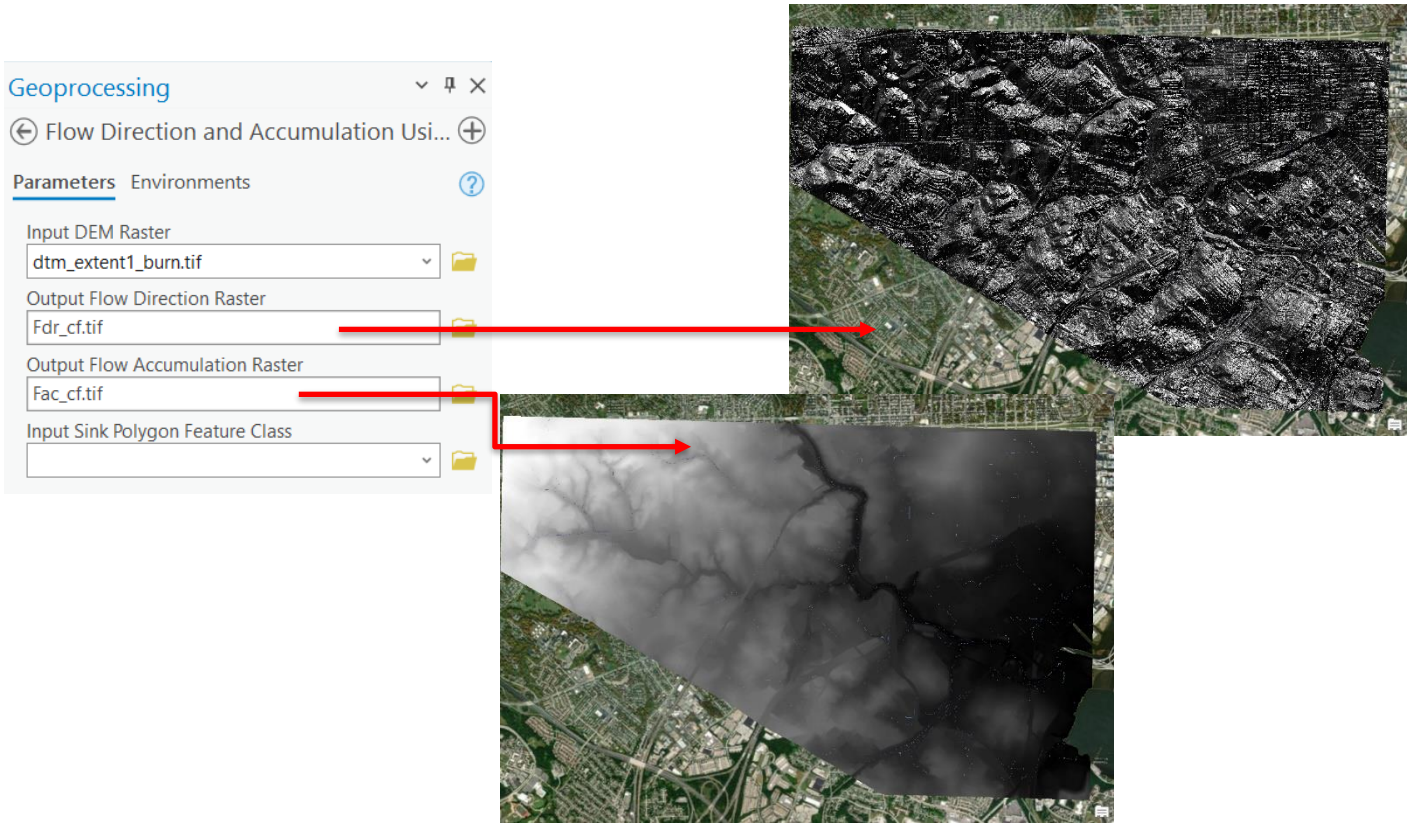


4.1.2 Versions of Pro 3.0 and more recent

1. Use the tool Flow Direction and Accumulation using CF from the Arc Hydro toolset.

   - The input DEM raster is the elevation raster with burned culvert features.

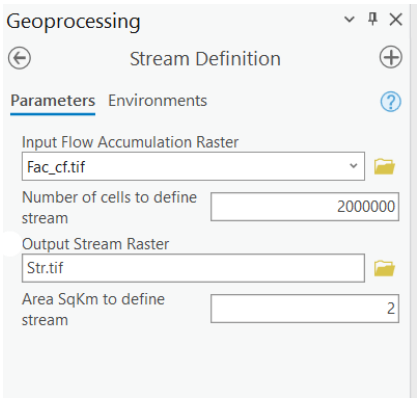
   - This terrain processing tool does not require any filling and generates the flow direction and accumulation rasters simultaneously.

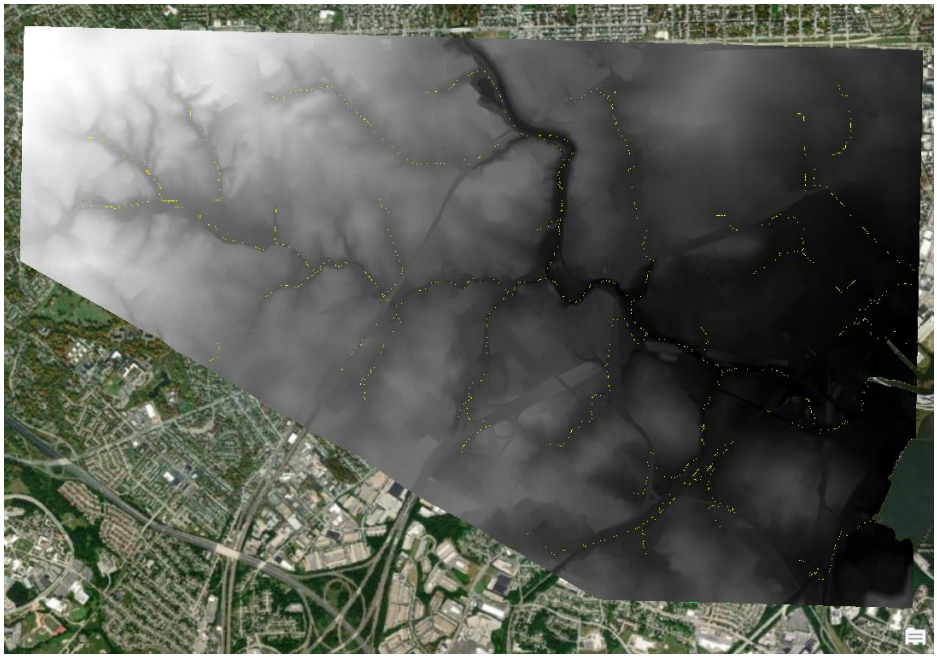


4.2 Stream Definition and Segmentation

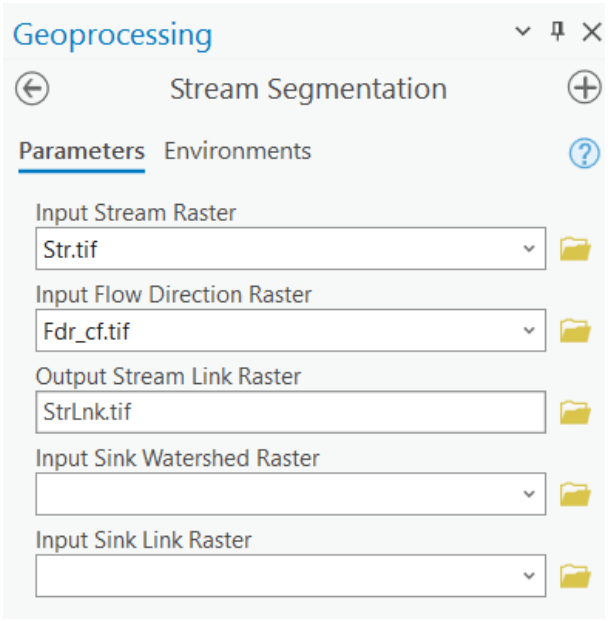
1. Use the Stream Definition tool to identify the stream network based on the flow accumulation raster.

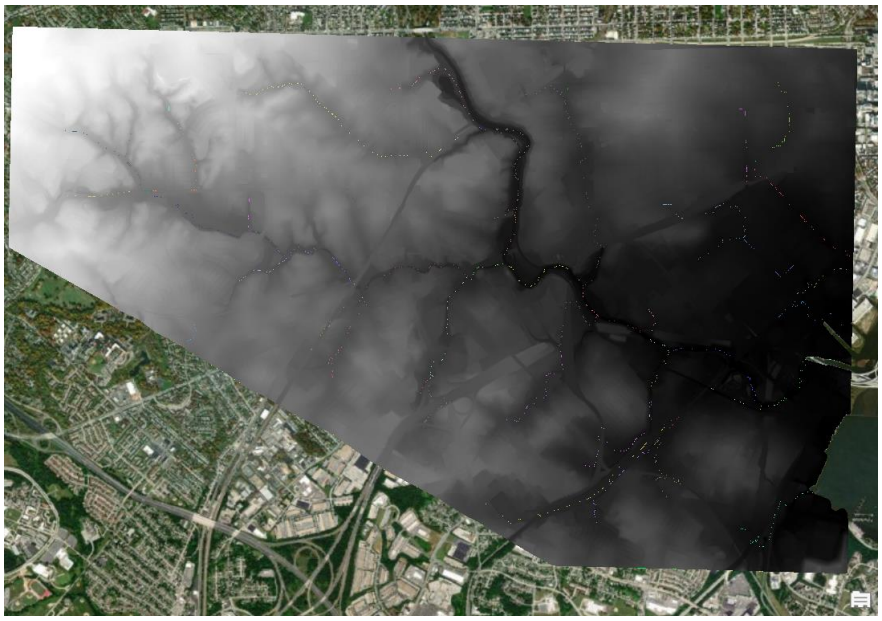
    - The number of cells to define is based on user preference. For sample data, a threshold of 2000000 was used. **NOTE:** The National Water Model (Hourly Forecast), The National Water Model (Hourly Forecast) which can be imported from the Living Atlas portal, can serve as guidance when selecting this numeric value.





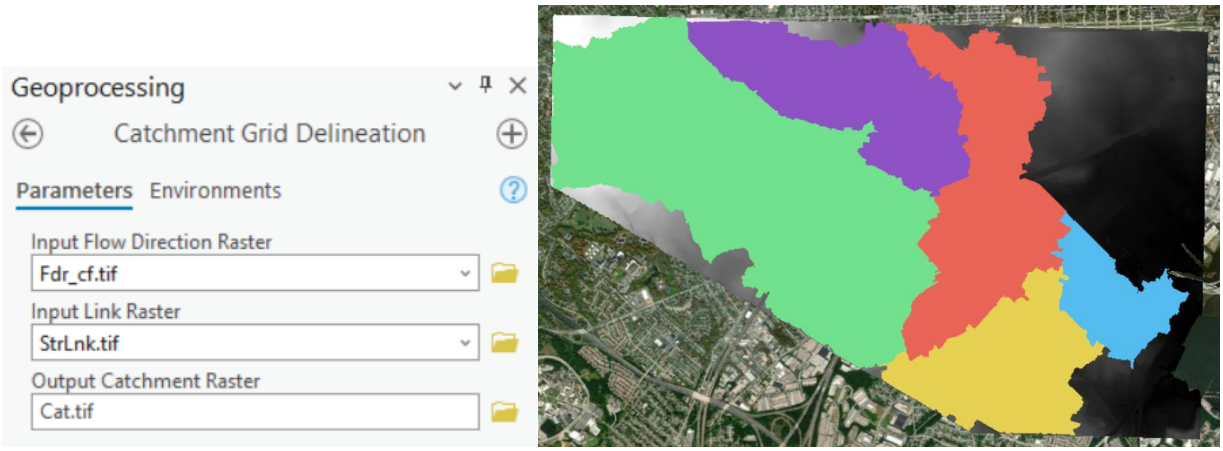
2. Use the Stream Segmentation tool to generate a stream link raster.



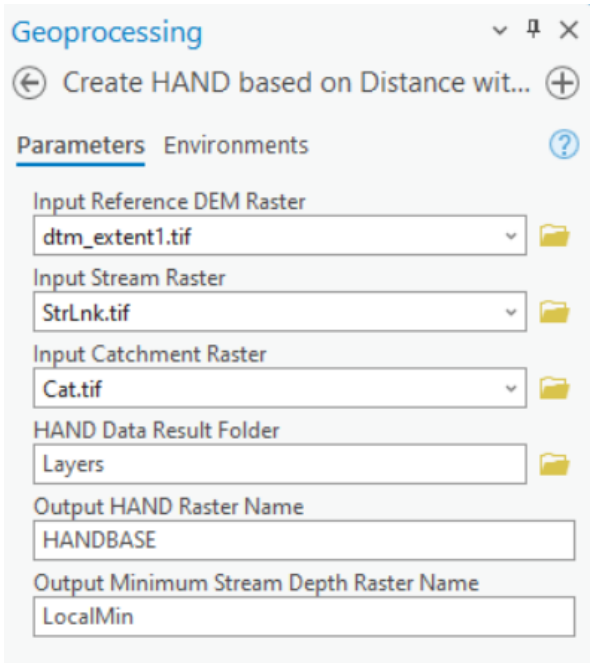


4.3 HAND Raster Creation

1. Use the Catchment Grid Delineation tool



2. Use the tool Create HAND based on Distance with Catchment Raster



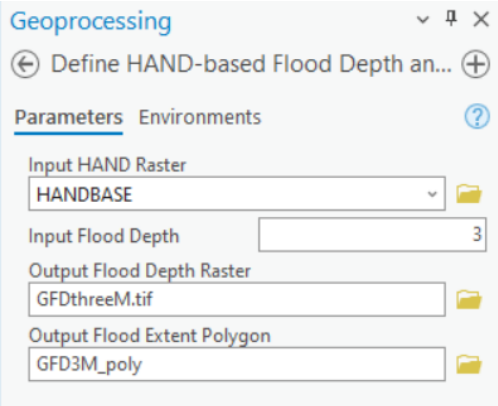
NOTE: Alternatively, you can build a HAND raster using the flow direction approach with Create Hand Based on Flow Direction tool, which would be equivalent to using the Flow Distance tool in the Spatial Analyst toolbox.

5.0 Create Flood Depth Rasters

1. Select the Define HAND-based Flood Depth and Extent tool from the Arc Hydro toolset

   - Input HAND raster is the flow distance output which was labeled HANDraster in steps above

   - Input flood depth is decided by user. For sample data this tool was run three times for the following depth intervals: 5 meter, 4 meter, and 3 meter



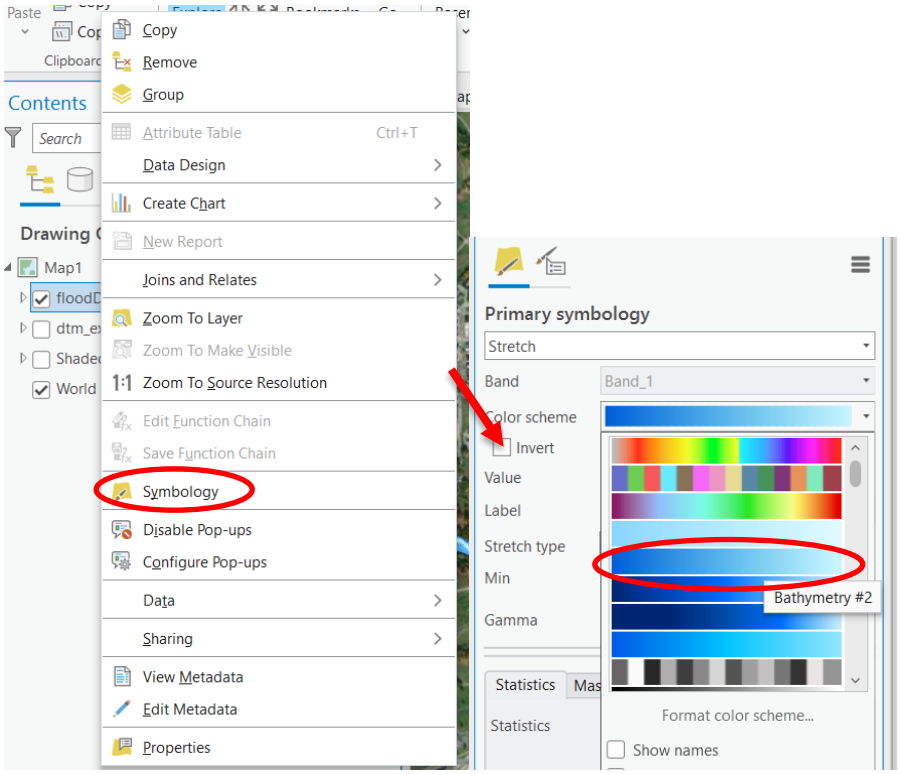
2. Label each output appropriately (i.e. GFDthreeM, GFDfourM, and GFDfiveM)

3. Right click on the generated depth raster in the contents pane and select symbology.

   - Change color scheme to Bathymetry #2 for better visualization and invert the color scheme so the darkest color correlates to a higher numeric value.

   - Repeat this for all the depth rasters generated

NOTE: If you have variable depth of flooding per reach, you can use the function Define Hand-based Flood Depth and Extent from Table to generate the output.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New Report
Joins and Relates
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Zoom To Make Visible
Zoom To Source Resolution
Edit Function Chain
Save Function Chain
Symbology
Disable Pop-ups
Configure Pop-ups
Data
Sharing
View Metadata
Edit Metadata
Properties
Primary symbology
Stretch
Band
Band_1
Color scheme
Invert
Value
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Min
Gamma
Bathymetry #2
Statistics
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Format color scheme...
Show names