



# EXERCISE 3

## Bare Earth Surface Metrics: Creating and Using a DEM from a LAS Dataset

### Introduction

One of the most valuable and commonly used metrics that lidar data can provide is a bare earth surface. A bare earth surface is important for many lidar applications. To measure vegetation height, for example, you need to know where the ground surface is to know how high above it the canopy surface is. In this exercise, you'll be using the bare earth surface to create a stream layer, showing where water will flow in the study area.

### Objectives

- Filter LAS Dataset to ground points
- Create bare earth rasters
- Create a lidar hydrology model from the bare earth rasters

### Required Data

- GTAC\_lasd\_training.lasd (created in exercise 1)

### Prerequisites

- Completion of Exercises 1 and 2





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## Part 1: Opening ArcGIS and loading data

Before you begin creating bare earth rasters that you'll be using for your hydrology model, you need to make sure you have your LAS Dataset open in ArcGIS Pro, and that you have it filtered correctly. You learned how to do this in the previous exercise, but as a review these steps will walk you through how to do that.

### A. Open ArcGIS Pro and Load a Map

1. Launch ArcMap from the start menu by clicking **Start, All Programs, ArcGIS, ArcGIS Pro, ArcGIS Pro**.
2. In the window that opens, you can either create a new project or load the project you created in the last exercise. If you start a new project, click **Blank** in the **Create a new project** pane on the right.
3. In the Create a New Project pop-up, give the project a name. You can save the project location as the default.
4. Click **Ok**.
5. In the upper left corner click **New Map**. If you don't see the New Map button, make sure you're on the **Insert** tab on the toolbar at the top of the ArcGIS Pro window.

### B. Load and filter LAS Dataset

1. In the toolbar at the top, click the **Map** tab.
2. Click the **Add Data** button.
3. In the explorer window, navigate to the **GTAC\_lasd\_training** LAS Dataset that you created in the first exercise.
4. Click **OK** to open the dataset.
5. Because you're going to be creating bare earth products from the LAS Dataset, you'll need to filter out the non-ground points. Fortunately, you've already learned to do this in the previous exercise. Make sure you have the LAS Dataset selected in the table of contents in ArcGIS Pro. Then click the **Appearance** tab at the in the toolbar at the top of the ArcGIS Pro window.
6. In the **filters** section, click the **LAS Points** dropdown.
7. In the dropdown, select **Ground** to filter out all but the ground points. These will be the points you need to create the bare earth surface products later in the exercise.

## Part 2: Creating Bare Earth Surface Products

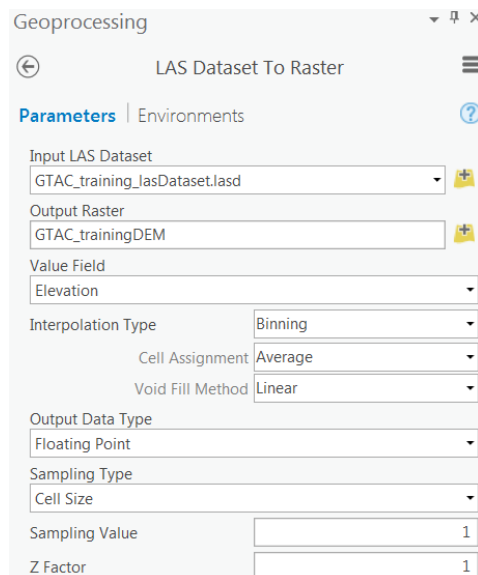
Any person using lidar data, for forestry, hydrology, or even disaster relief, will want to create bare earth surfaces. These surfaces are used in subsequent steps for many lidar processing tasks. Later in the exercise, you're going to use these products to create a hydrology model. This part of the exercise is going to walk you through how to create the bare earth surfaces from a LAS Dataset.

### A. Creating Rasters From a LAS Dataset

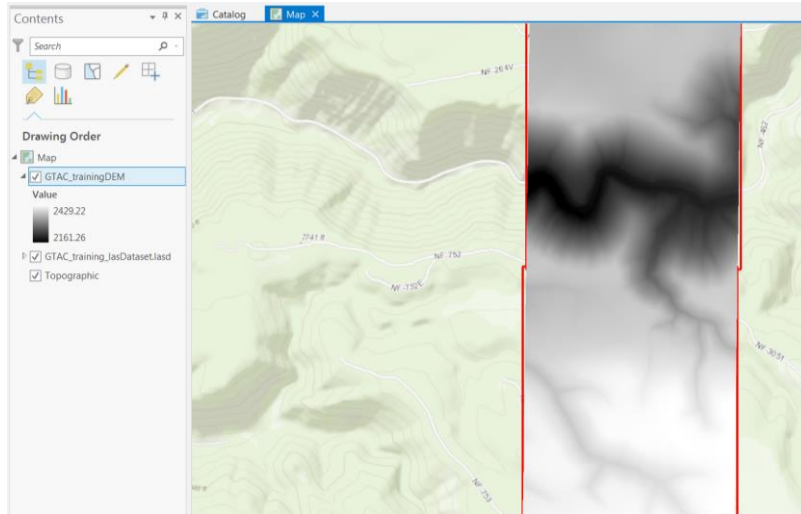
1. Make sure that you have the LAS Dataset loaded and filtered to ground points from the previous section.
2. In the toolbar at the top of your ArcGIS Pro window, click the **Analysis** tab.
3. In the Geoprocessing section, click **Tools**. This will open the geoprocessing pane.
4. In the "Find tools" search bar, type **LAS Dataset to Raster**.
5. Click the **LAS Dataset to Raster** tool in the search results. This will open the tool in the geoprocessing pane.
6. In the "Input LAS Dataset" section, click the dropdown button on the right, and select the LAS Dataset **GTAC\_lasd\_training**, which you have loaded and filtered to ground points.
7. The "Output Raster" field will automatically fill with a default name, and will be output to a default location. Click the yellow icon next to the Output Raster box. This will open an explorer window. You can choose the location to save the raster. Name it **GTAC\_trainingDEM**.

**Note:** If you're saving the raster outside of a geodatabase, you'll have to give it a shorter name. ESRI only allows you to have 13 characters in the output file name. If you run into this issue, you can give the output raster a shorter name (simply trainingDEM, for example). You'll just need to remember where you've saved it and what name you've given it

8. You can keep the "Sampling Type" as Cell Size. In the box below that, change the "Sampling Value" to **1**.



9. The rest of the options in the tool pane adjust how the DEM raster values are interpolated from the lidar points. These options will change the values in the DEM, so when you create a DEM for your own project you should determine what the best settings for you are. You can read about them here: <http://pro.arcgis.com/en/pro-app/tool-reference/conversion/las-dataset-to-raster.htm>
10. Click **Run**. The tool will take a few minutes to create the DEM.
11. When the tool is run it will look similar to the image below:



12. You've created a valid DEM, ready to be used for analysis.

## B. Creating a HillShade

Once you've created a DEM, making a Hillshade for visualization purposes is trivial. The steps below will teach you how to do this.

1. In the toolbar at the top of your ArcGIS Pro window, click the **Analysis** tab.
2. In the Geoprocessing section, click **Tools**. This will open the geoprocessing pane.
3. In the "Find tools" search bar, type **Hillshade**.
4. Click on **Hillshade (Spatial Analyst Tools)**. This will open the tool in the geoprocessing tools pane.
5. In the "Input Raster" section, click the dropdown on the right side of the input row and select **GTAC\_trainingDEM**, which you created in the previous section.
6. The "Output Raster" field will automatically fill with a default name, and will be output to a default location. Click the yellow icon next to the Output Raster box. This will open an explorer window. You can choose the location to save the raster. Name it **GTAC\_trainingHillshade**.



Hillshade rasters are useful for a number of purposes. First, they make visualizing the bare earth surface easier, so they're used frequently for viewing purposes. There are also some tasks, such as digitizing roads or identifying archeological features, which are usually done by hand and are made far easier by having a Hillshade layer.

## Part 3: Using DEM to Create Stream Networks

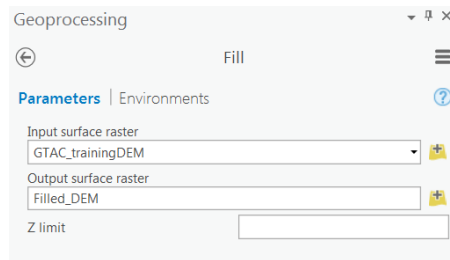
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ArcGIS Pro has a suite of hydrology tools built in to the spatial analyst toolbox. In this part of the exercise you'll learn to use several of these tools to create a stream layer in the study area.

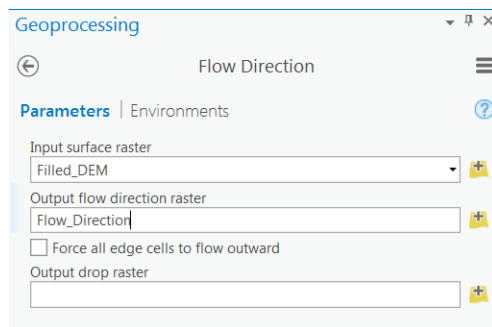
### A. Filling the DEM and Measuring Flow Direction

When a DEM is created, there are small imperfections in the surface. Sinks that may not actually appear on the surface may be present in the DEM. When you're creating hydrologic models these imperfections can distort the simulated water flow. Below you're going to remove these imperfections from the DEM and use the new DEM to calculate flow direction.

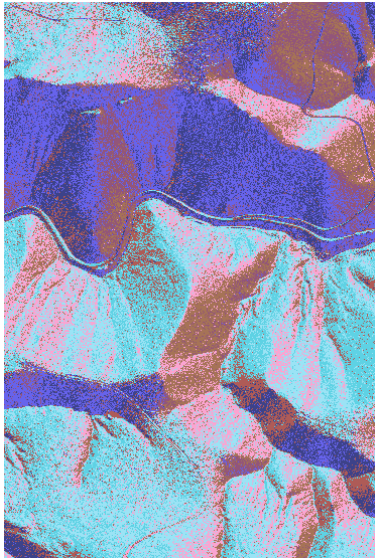
1. To fill the imperfections in the DEM, use the fill tool. In the toolbar at the top of your ArcGIS Pro window, click the **Analysis** tab.
2. In the Geoprocessing section, click **Tools**. This will open the geoprocessing pane.
3. In the "Find tools" search bar, type **Fill**.
4. Click on **Fill (Spatial Analyst Tools)**. This will open the tool in the geoprocessing tools pane.
5. In the Input surface raster section, click the arrow on the right side to open the dropdown menu, and select **GTAC\_trainingDEM.tif**.
6. Name the Output surface raster **Filled\_DEM**.
7. You can leave the Z limit field blank.



8. Click **Run**. The output DEM will look nearly identical to the DEM you created earlier. The changes in the raster won't be perceptible. All you've done is "filled" the small interpolation artifacts so that the water in your hydrology model will "flow" more smoothly over the surface.
9. Now you need to use the filled DEM to create a flow direction raster. Flow direction uses the pixel values to indicate which direction water will flow on the surface. Open the geoprocessing pane again and type **flow direction** in the "Find tools" search bar.
10. Click on **Flow Direction (Spatial Analyst Tools)**. This will open the tool in the geoprocessing tools pane.
11. In the Input surface raster section, click the arrow on the right side to open the dropdown menu, and select **Filled\_DEM**.
12. In the Output flow direction raster section, name the output **Flow\_Direction**.



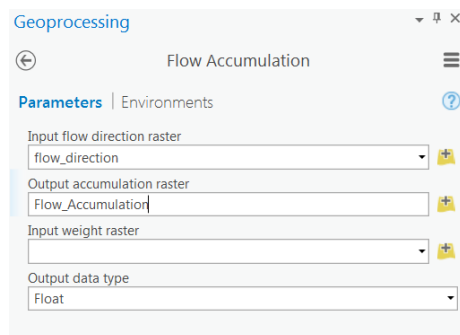
13. You can leave the other options at their default. Click **Run**. The output raster will look similar to the image below.



## B. Create and Filter a Flow Accumulation Raster

You can use the flow direction raster to determine how many cells (pixels) are flowing into a given pixel. Larger streams and hydrology logic features will have more water flowing into them and therefore have a higher accumulation. This image is called a flow accumulation raster.

1. In the toolbar at the top of your ArcGIS Pro window, click the **Analysis** tab.
2. In the Geoprocessing section, click **Tools**. This will open the geoprocessing pane.
3. In the "Find tools" search bar, type **Flow Accumulation**.
4. Click on **Flow Accumulation (Spatial Analyst Tools)**. This will open the tool in the geoprocessing tools pane.
5. In the Input flow direction raster section, click the arrow on the right side to open the dropdown menu, and select **Flow\_Direction**, which you created in the previous section.
6. In the Output flow direction raster section, name the output **Flow\_Accumulation**.



7. You can leave the other options at their default. For this example, we will not create a weight raster. Click **Run**. The output raster will look similar to the image below.





It's important to realize that the white lines that you see are the highest values because they have the most accumulated flow into them. The lowest value in the raster is 0, because some pixels don't accumulate any water. These pixels would be high points. But the low points can have very high values, tens or hundreds of thousands depending on the size of your area. To define the largest streams, you're going to filter the accumulation raster.

8. In the toolbar at the top of your ArcGIS Pro window, click the **Analysis** tab.
9. In the Geoprocessing section, click **Tools**. This will open the geoprocessing pane.
10. In the "Find tools" search bar, type **Con**.
11. Click on **Con (Spatial Analyst Tools)**. This will open the tool in the geoprocessing tools pane.
12. In the Input conditional raster section, click the dropdown arrow on the right side and select the **Flow\_Accumulation** raster you just created.
13. In the Expression section, click the **SQL** icon.



This will allow you to enter an SQL expression for the Con tool.

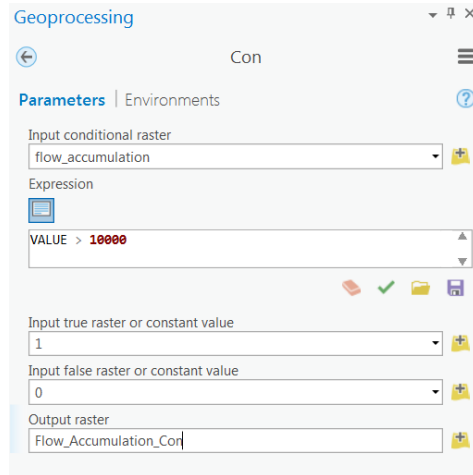
14. In the expression window, type **VALUE > 10000**. When you execute the Con tool, this expression will mean that the tool applies to all pixels where the accumulation value is greater than 10,000. Remember that the accumulation value is how many cells are flowing into that cell. So using a lower value in the con tool will include smaller, more ephemeral streams, while a higher value will include only large, primary streams. When you do this on your own data, you'll need to use your best judgement for the value to use.

**Note:** When entering the expression, if you start typing an SQL expression, possible options will appear. So in the expression window, if you type "v", the **VALUE** option will appear, and you can click on it to add to the expression.

15. In the Input true raster or constant value section, enter **1**.

16. In the Input false raster or constant value section, enter **0**. This means that where values in the flow accumulation raster are greater than 10,000 become 1, and values less than 10,000 become 0.

17. Name the Output raster **Flow\_Accumulation\_Con**.



18. Click **Run**. Your result will look similar to the result below.



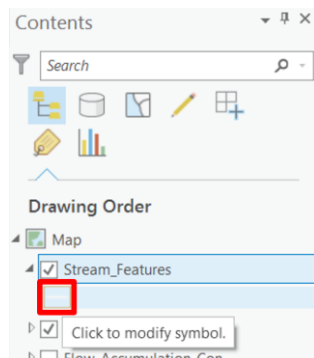
## C. Create Stream Order Raster

1. In the toolbar at the top of your ArcGIS Pro window, click the **Analysis** tab.
2. In the Geoprocessing section, click **Tools**. This will open the geoprocessing pane.
3. In the "Find tools" search bar, type **Stream Order**.
4. Click on **Stream Order (Spatial Analyst Tools)**. This will open the tool in the geoprocessing tools pane.
5. In the Input stream raster, click the dropdown arrow on the right side and select the **Flow\_Accumulation\_Con** raster you created in the previous step.

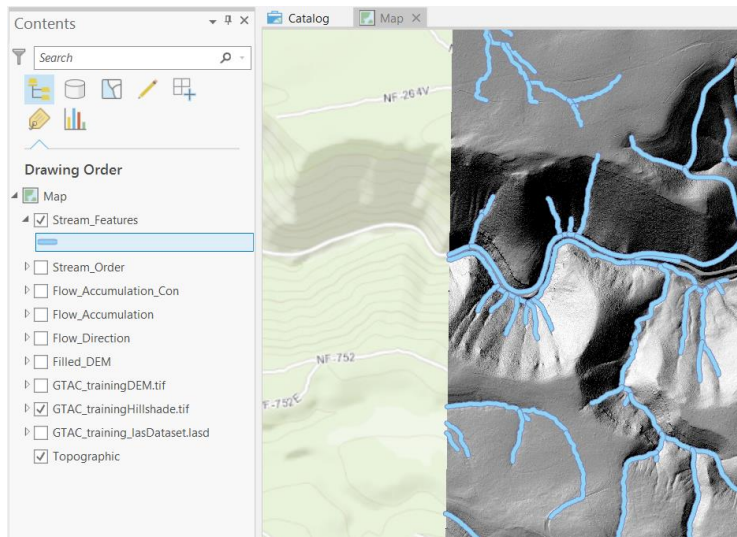
6. In the Input flow direction raster section, click the dropdown arrow on the right side and select the **Flow\_Direction** raster.
7. In the Output raster section, name the raster **Stream\_Order**.
8. You can leave the Method of stream ordering as Strahler. Strahler and Shreve are methods of ordering linear networks that operate slightly differently. You can read more about these methods here: [http://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/how-stream-order-works.htm#ESRI\\_SECTION1\\_332E8909620C461B9B991A7FC1A5E843](http://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/how-stream-order-works.htm#ESRI_SECTION1_332E8909620C461B9B991A7FC1A5E843)

## D. Create Stream Features

1. You'll use the Stream to Feature tool. In the geoprocessing pane, use the "Find tools" search bar again to search for **Stream to Feature**.
2. In the stream to feature tool, in the Input stream raster section, click the dropdown arrow on the right side and select **Stream\_Order** that you created in the previous section.
3. In the Input flow direction raster section, click the dropdown on the right side and select **Flow\_Direction**.
4. Name the Output polyline features **Stream\_Features**.
5. You can leave Simplify Polylines checked. Click **Run**.
6. When the tool runs, it's possible that the symbology of the stream layer is very difficult to see. Clicking the symbol below the Stream\_Features layer will open the symbology tab. There you can change the color of the stream layer.



7. Below is an example of the streams generated, colored in blue. They are shown on the hillshade that was created earlier in the exercise.



The steps above show a "generic" setup for finding stream features. The workflow could be modified to find smaller stream features, or could be changed to find only the largest streams in the image. On your own data it's important to understand the steps above and adjust them to best suit your needs.

**Congratulations!** In this exercise you have learned to filter the LAS Dataset to the ground points and created bare earth rasters from the LAS Dataset. You've also learned to use some basic hydrology tools to create stream lines from the bare earth rasters.