# Exercise 20: Working with LiDAR

This exercise describes how to work with light detection and ranging (LiDAR) data in ArcGIS Pro. LiDAR data are commonly made available as point clouds in LAS format. You will learn to process these LiDAR data to create LAS Datasets, digital elevation models (DEMs), digital surface models (DSMs), normalized digital surface models (nDSMs), first return intensity images, and hillshades. You will also explore the statistics of the point cloud.

The LiDAR data used in this lab are large files, so it may take your computer some time to complete each task. The LiDAR data used in this exercise can be freely obtained from the West Virginia Department of Environmental Protection (WVDEP) (https://tagis.dep.wv.gov/lidar/) or West Virginia View (https://www.wvview.org/). These data will support the creation of 1 m spatial resolution raster grids; however, you will produce 5 m resolution products in this lab to reduce processing time and file size. The data used in this lab were collected near Parsons, West Virginia.

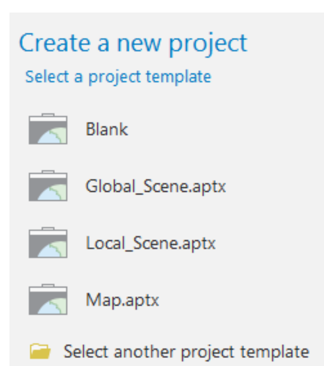
Topics covered in this exercise include:

1. Create LAS Datasets
2. Filter point clouds
3. Rasterize LiDAR point cloud data as DEMs, DSMs, nDSMs, and intensity images.
4. Analyze and interpret LiDAR derivatives
5. Extract raster values at points
6. Explore point cloud statistics

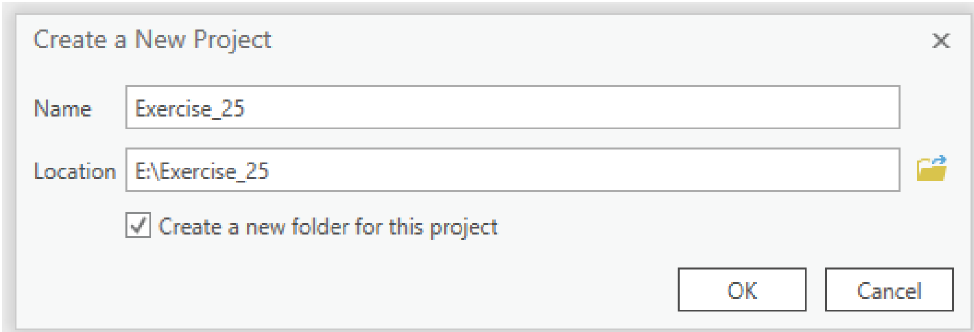
### Step 1. Create and Prepare a New Project

You will begin the analysis by creating a new project to work within.

- Open ArcGIS Pro. This can be done by navigating to All Apps followed by the ArcGIS Folder. Within the ArcGIS Folder, select ArcGIS Pro. Note that you can also use a Task Bar or Desktop shortcut if they are available on your machine.
- Once ArcGIS Pro launches, select **Map.aptx** under Create a new project on the right side of the page.



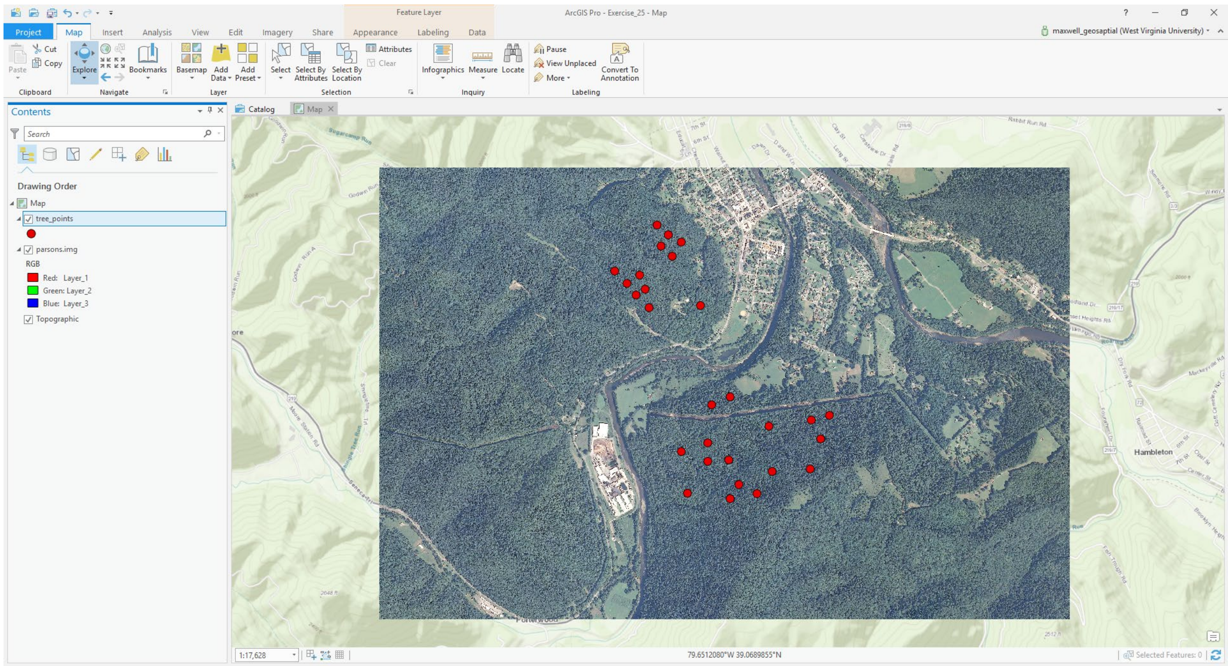
- In the Create a New Project Dialog Box, name your new project **Exercise_20** and save it to your personal folder. You can leave the "Create a new folder for this project" option selected.




You have now created a new project. Since you used the **Map.aptx** template, a map has already been added to the project. You will now need to add data to the map.

- Download the **Exercise_20** data from https://www.wvview.org/. All lab materials are available on the course webpage and linked to the exercise. You will need to extract the compressed files and save it to the location of your choosing.
- Click on the Add Data Button. Navigate to your copy of the lab data. Navigate to the downloaded **Data** folder. Add the **parsons.img** and **tree_points.shp** files.

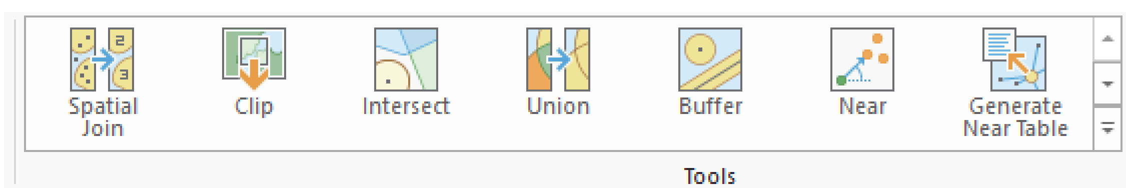
**Note:** The map will take on the datum and projection of the added layers: NAD 1983 UTM Zone 17 North.



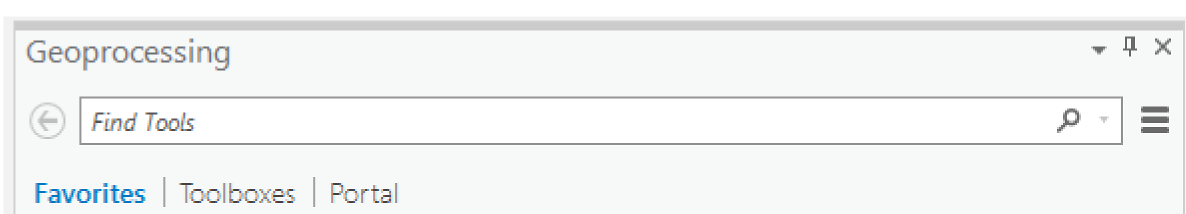

## Step 2. Create a LAS Dataset

In order to work with LiDAR data in ArcGIS Pro, you must create a LAS Dataset from the LAS files. This can be accomplished using the **Create LAS Dataset Tool**.

**Note:** In this lab, we will access tools from ArcToolbox. However, there are many ways to access tools in ArcGIS Pro. For example, some of the more common tools are provided in the Tools list in the Analysis Tab.

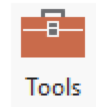



Once you open the Geoprocessing Pane, you can access favorite tools or search for Tools.

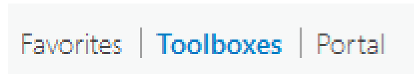



We have decided to demonstrate ArcToolbox here so that you get a sense of where the tools are located in the Toolbox directory.

- In the Analysis Tab, select Tools from the Geoprocessing Area. This should open the Geoprocessing Pane.

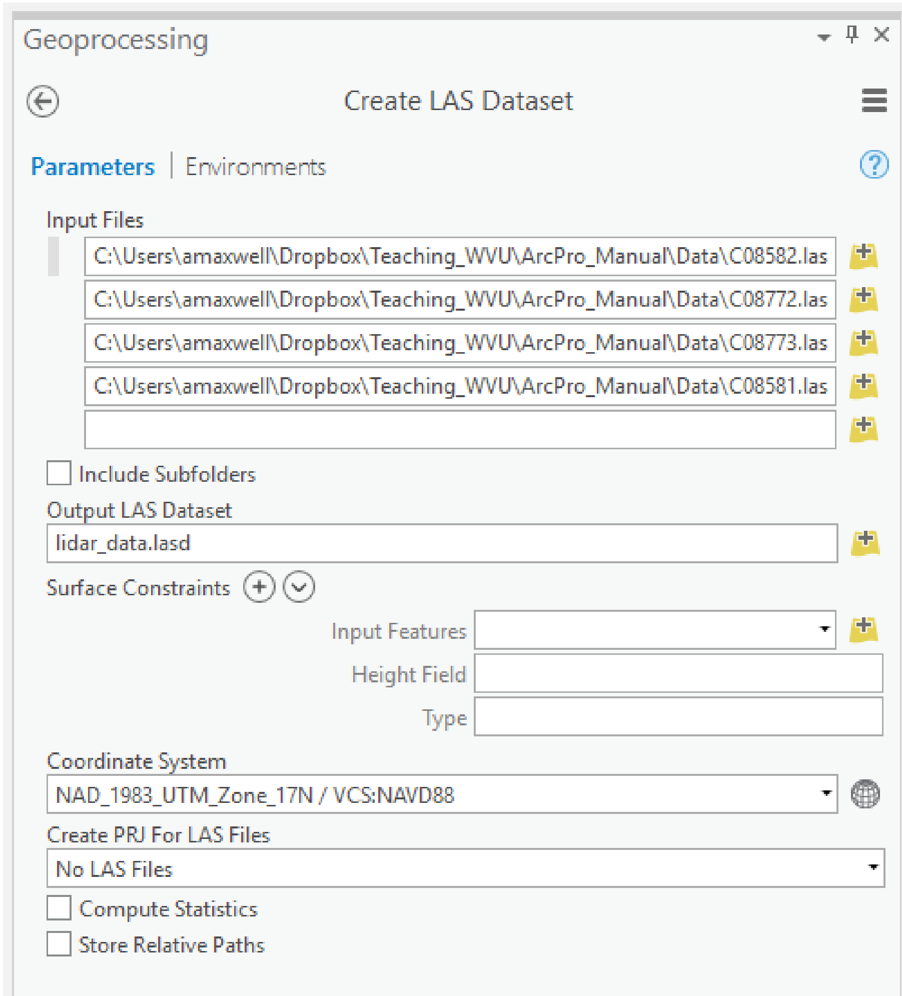



- In the Geoprocessing Pane, navigate to the Toolboxes.




**Note:** We will not provide these directions for accessing other tools. We will just tell you where to find them within ArcToolbox.

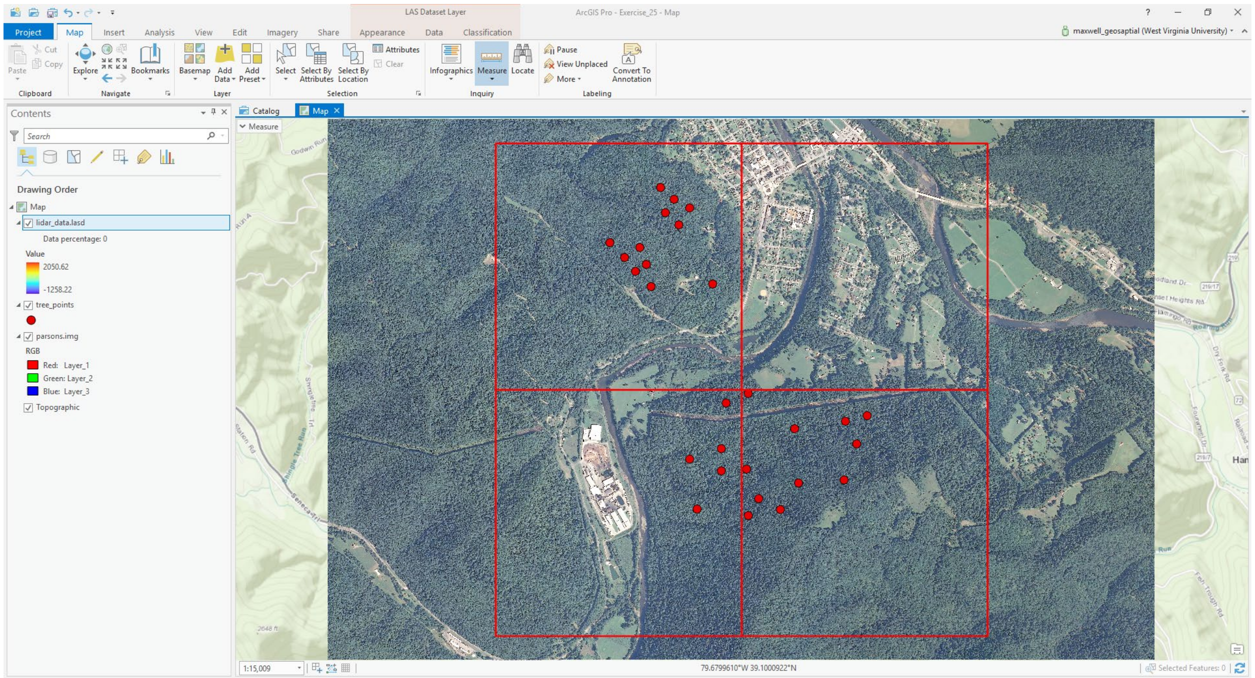
- Navigate to Data Management Tools followed by the LAS Dataset subtoolbox. Click on the **Create LAS Dataset Tool**.
- Add the four LAS files from the **Data** folder to the Input Files list (**C08582.las**, **C08772.las**, **C08773.las**, and **C08581.las**).
- Name the Output LAS Dataset **lidar_data.lasd** and save it to a location of your choosing.
- Make sure the Coordinate System is set to NAD_1983_Zone_17N/VCS: NAVD88.
- You do not need to change any of the other settings.
- Click Run to execute the tool.




- In order to view the LiDAR points, you will need to move the **lidar_data.lasd** layer to the top of the list in the Contents Pane.

When you are zoomed out, the extent of the LiDAR tiles are drawn as red boxes. If you want to see individual points, you will need to zoom in.

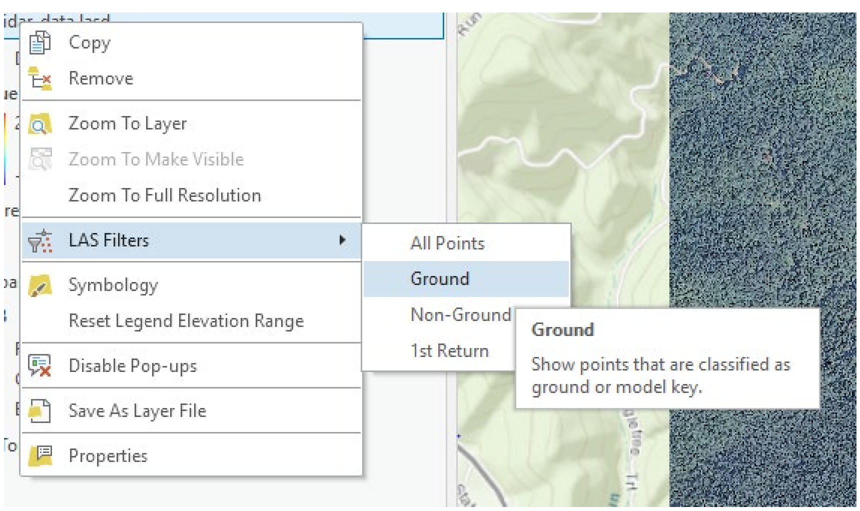
**Question 1.** What are the dimensions of each of the four LiDAR tiles in kilometers? (2 Points)




## Step 3. Create a DEM

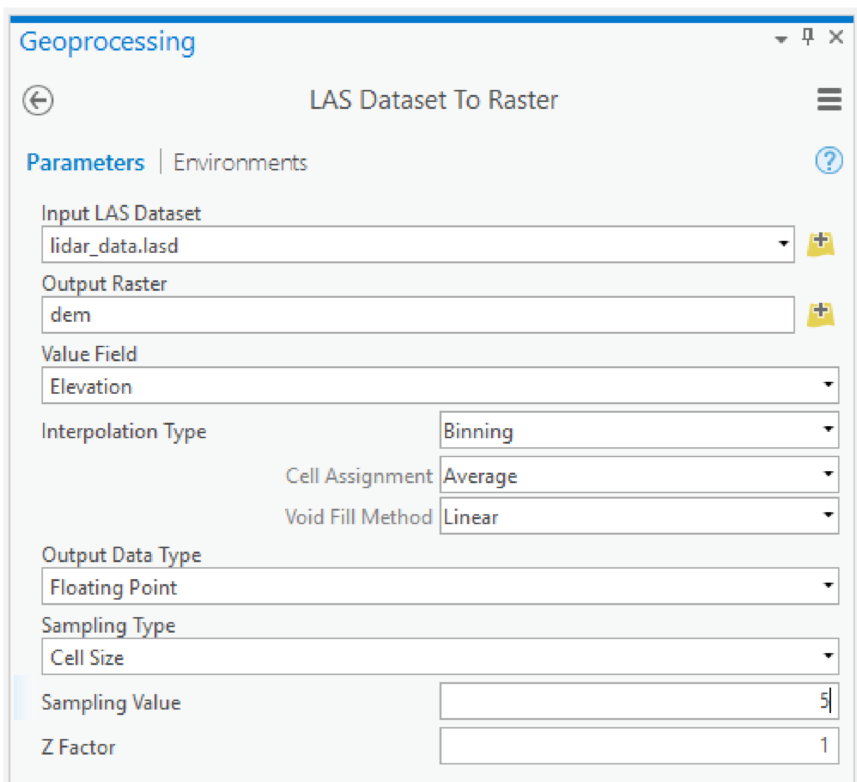
You will now convert the point cloud data to a digital elevation model or DEM. To create this surface, you only want to use ground returns. So, you will first need to adjust the filter.

- Right-click on the **lidar_data.lasd** layer in the Contents Pane then select LAS Filter followed by Ground.




Now, only ground returns should be displayed or used in an analysis. You are now ready to create the DEM.

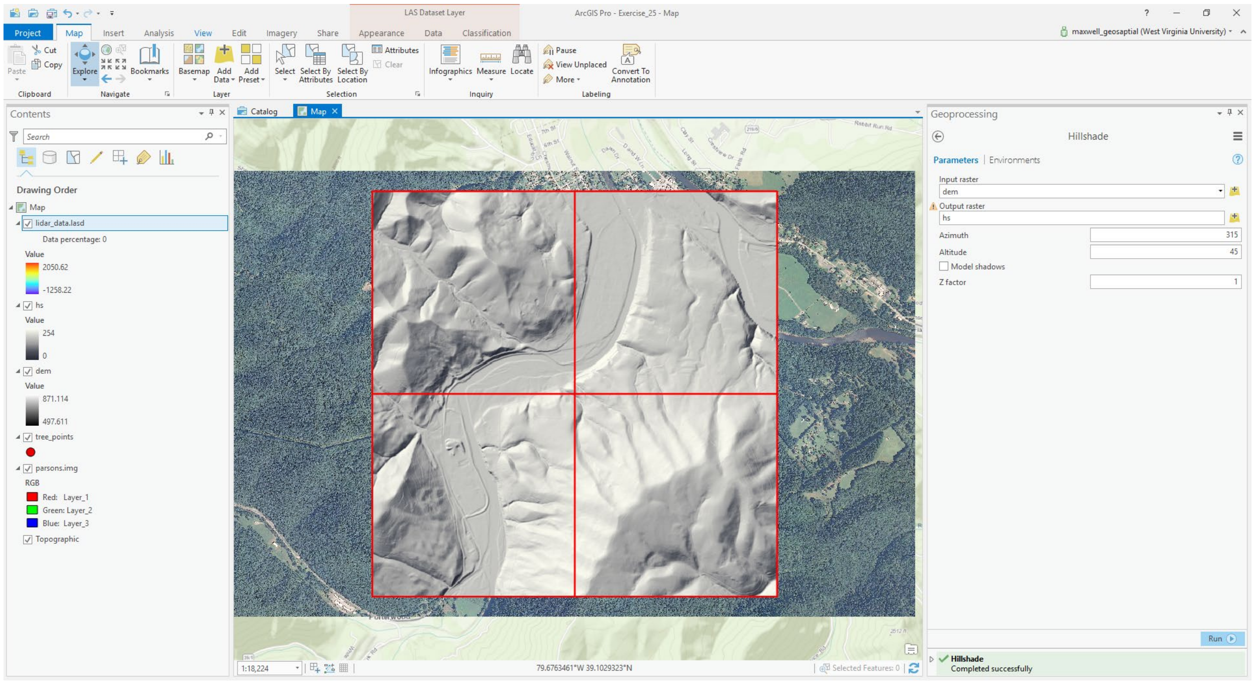
- Navigate to Conversion Tools followed by the To Raster subtoolbox. Click on the **LAS Dataset to Raster Tool**.
- Set the Input LAS Dataset to the **lidar_data.lasd** layer.
- Name the Output Raster **dem** and save it to a location of your choosing.
- Make sure the Value Field is set to Elevation.
- Make sure the Interpolation Type is set to Binning, the Cell Assignment is Average, and the Void Fill Method is Linear.
- Make sure the Output Data Type is set to Floating Point.
- Make sure the Sampling Type is set to Cell Size.
- Set the Sampling Value to 5.
- Click Run to execute the tool.




## Step 4. Create a Hillshade

To visualize the terrain, you will now create a hillshade from the DEM.

- Navigate to Spatial Analyst Tools followed by the Surface subtoolbox. Click on the **Hillshade Tool**.
- Set the Input Raster to the **dem** layer.
- Name the Output Raster **hs** and save it to a location of your choosing.
- You do not need to change any of the other settings.
- Click Run to execute the tool.



**Question 2.** Using the available help, how is the cell value assigned using the Binning Method and the Average Cell Assignment? (4 Points)

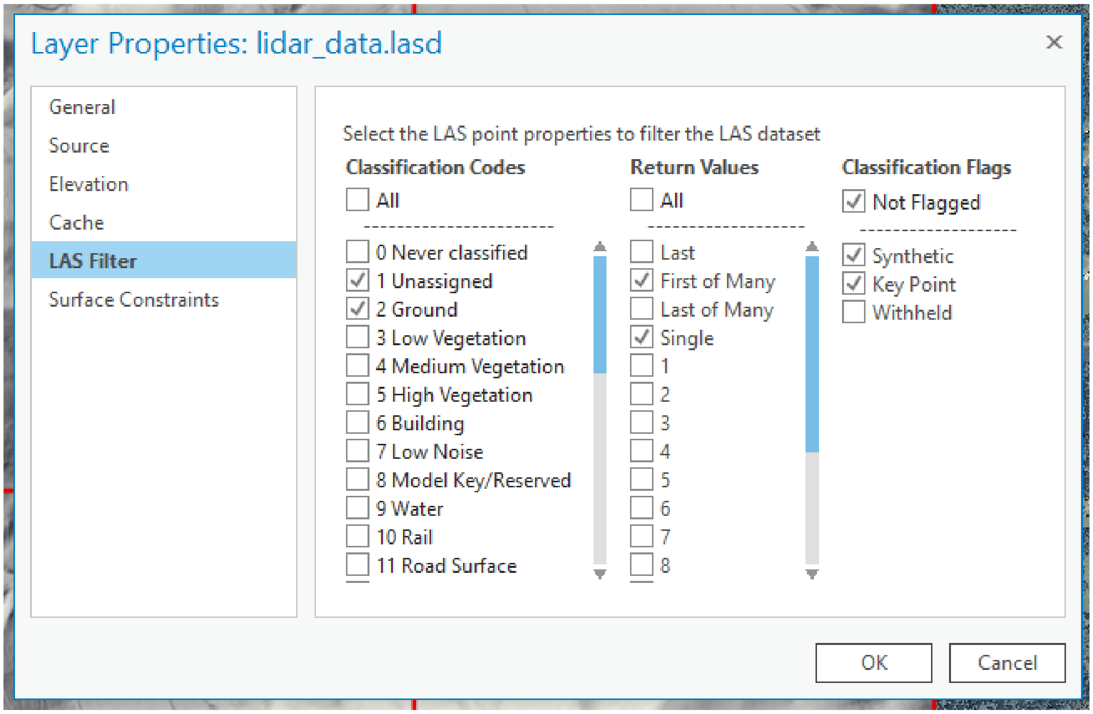
**Question 3.** Using the available help, explain the purpose of the Linear Void Fill when using the Binning Method. (4 Points)

**Question 4.** Why was the output type defined as float instead of integer? (4 Points)

### Step 5. Create a DSM

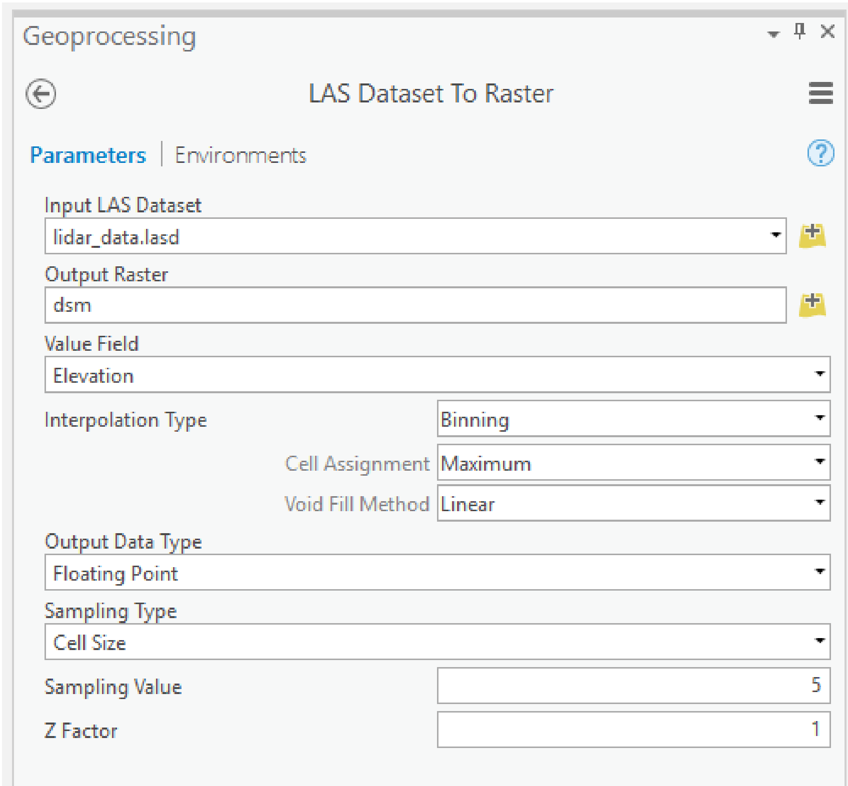
You will now need to create a surface that includes not just ground elevations but also incorporates aboveground features, such as buildings and trees. This is called a digital surface model or DSM. You will create this surface from the first laser pulse returned, so you will need to change the filter.

- ☐ Right-click on the **lidar_data.lasd** layer in the Contents Pane then select Properties. Navigate to LAS Filter.
- ☐ Under Classification Codes, make sure only Unassigned and Ground are selected. Under Return Values make sure only First of Many and Single are selected. Click OK to change the filter.




You are now ready to create the DSM using the **LAS Dataset to Raster Tool**.

- Navigate to Conversion Tools followed by the To Raster subtoolbox. Click on the **LAS Dataset to Raster Tool**.
- Set the Input LAS Dataset to the **lidar_data.lasd** layer.
- Name the Output Raster **dsm** and save it to a location of your choosing.
- Make sure the Value Field is set to Elevation.
- Make sure the Interpolation Type is set to Binning, the Cell Assignment is Maximum, and the Void Fill Method is Linear.
- Make sure the Output Data Type is set to Floating Point.
- Make sure the Sampling Type is set to Cell Size.
- Set the Sampling Value to 5.
- Under Environments, set the Snap Raster to the **dem** layer. This will make the two layers align correctly.
- Click Run to execute the tool.

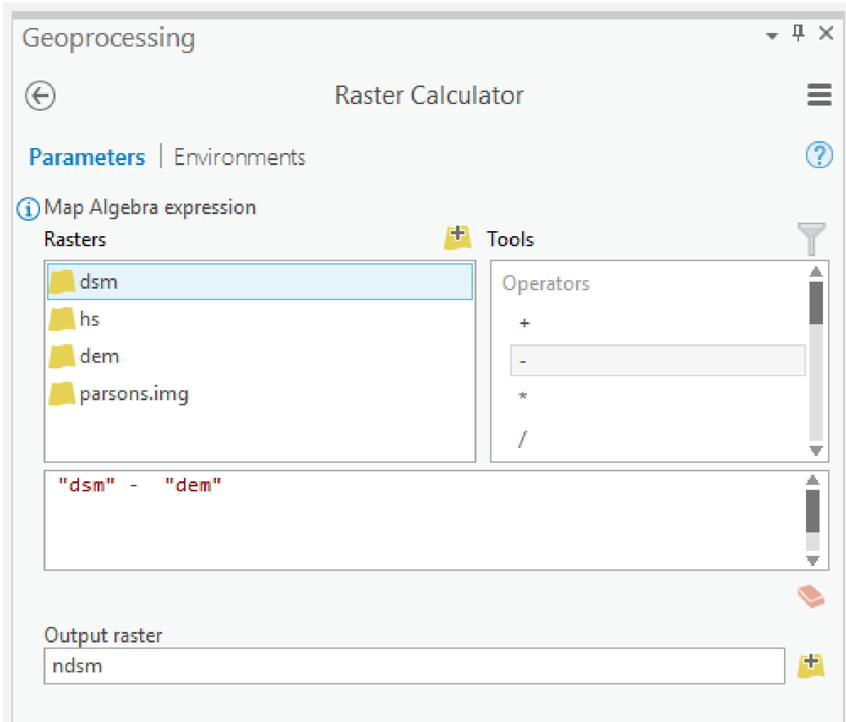



**Question 5.** Why did you use Maximum in this case as the Cell Assignment instead of Average? (4 Points)

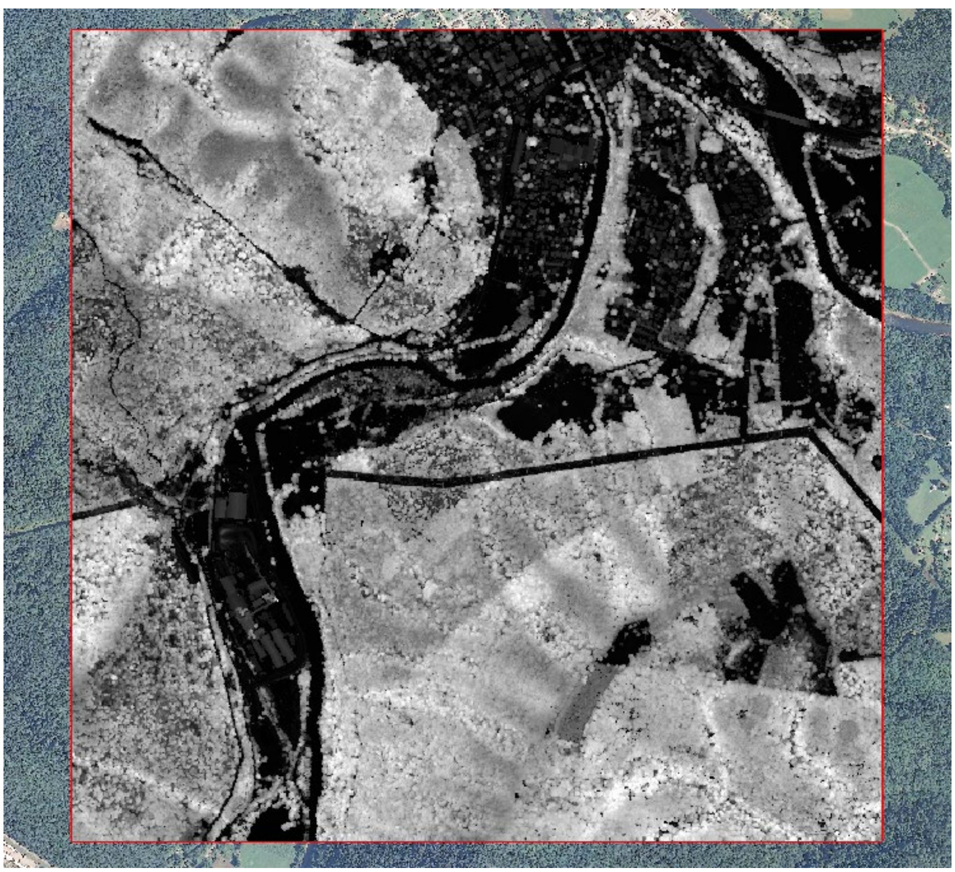
### Step 6. Create an nDSM from the DEM and DSM

A normalized digital surface model (nDSM) is a DSM that has had the ground elevations subtracted out. So, it can be created by subtracting the DEM from the DSM. This surface represents the height of above ground features, such as trees and buildings. You will now create this surface using the **Raster Calculator Tool**.

- Navigate to Spatial Analyst Tools followed by the Map Algebra subtoolbox. Click on the **Raster Calculator Tool**.
- Use the following syntax: "dsm" - "dem".
- Name the Output Raster **ndsm** and save it to a location of your choosing.
- Under Environments, set the Snap Raster to the **dem** layer. This will make the two layers align correctly.
- Click Run to execute the tool.



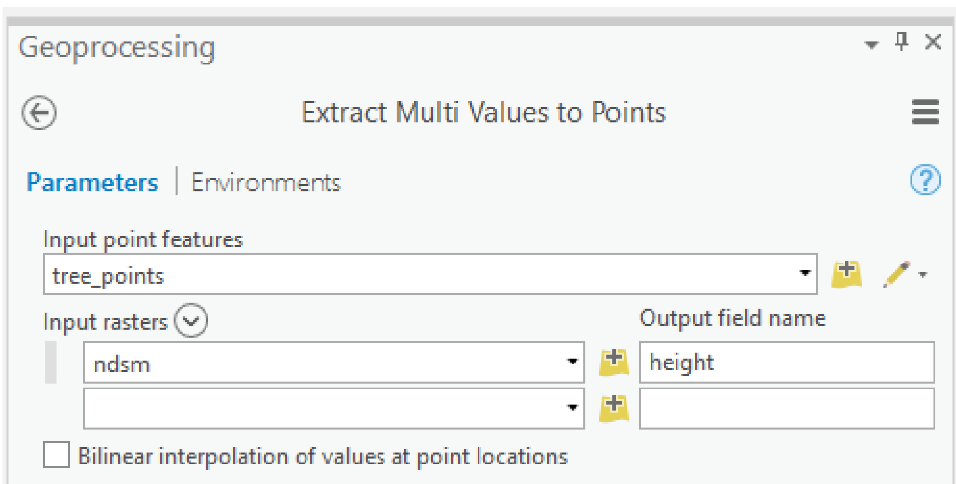

**Question 6.** Using the aerial image and the nDSM, what features on the landscape in this area are producing above ground heights? (4 Points)



## Step 7. Determine Heights of Trees using the nDSM

The **tree_points** layer represents the location of some trees. You will now use the nDSM to predict the height of these trees. To do this, you will need to extract the raster value at each point location. This can be accomplished using the **Extract Multi Values to Points Tool**. This could also be accomplished using the **Extract Values to Points Tool**; however, that will not be demonstrated here.

- Navigate to Spatial Analyst Tools followed by the Extraction subtoolbox. Click on the **Extract Multi Values to Points Tool**.
- Set the Input Point Features to the **tree_points** layer.
- Add the **ndsm** layer to the Input Rasters list and define the Output Field Name as "height." Do not include the quotes.
- Do not select "Bilinear interpolation of values at point locations."
- Click Run to execute the tool.




Use the attribute table of the **tree_points** layer to answer the following questions. The "height" field should have been added.

**Question 7.** Which tree is the tallest? Use the name provided in the "Tree" field. (2 Points)

**Question 8.** What is the average height of these trees? (2 Points)

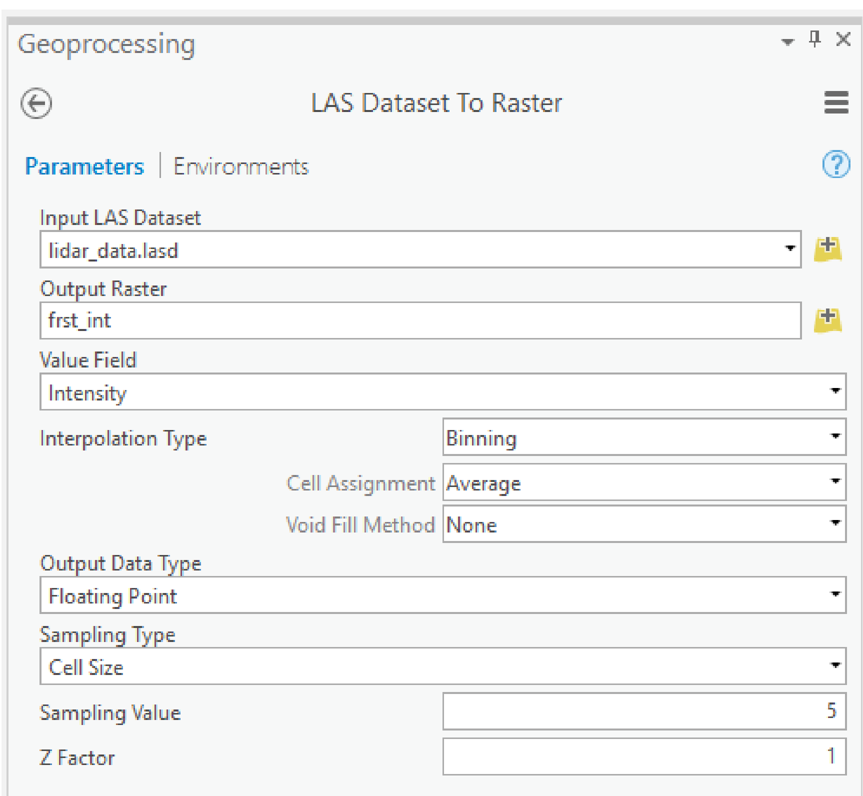
Hint: You will need to use the **Summary Statistics Tool**.

**Step 8. First Return Intensity Image**

Other than producing DEMs and DSMs, it is also possible to create return intensity images from the point cloud data. Different surfaces will absorb more or less of the infrared laser energy. Thus, these images are correlated with land cover.

**Note:** The DSM was created from first of many returns and single returns. This is the same filter that is required to create the first return intensity image. So, you will not need to filter the data again.

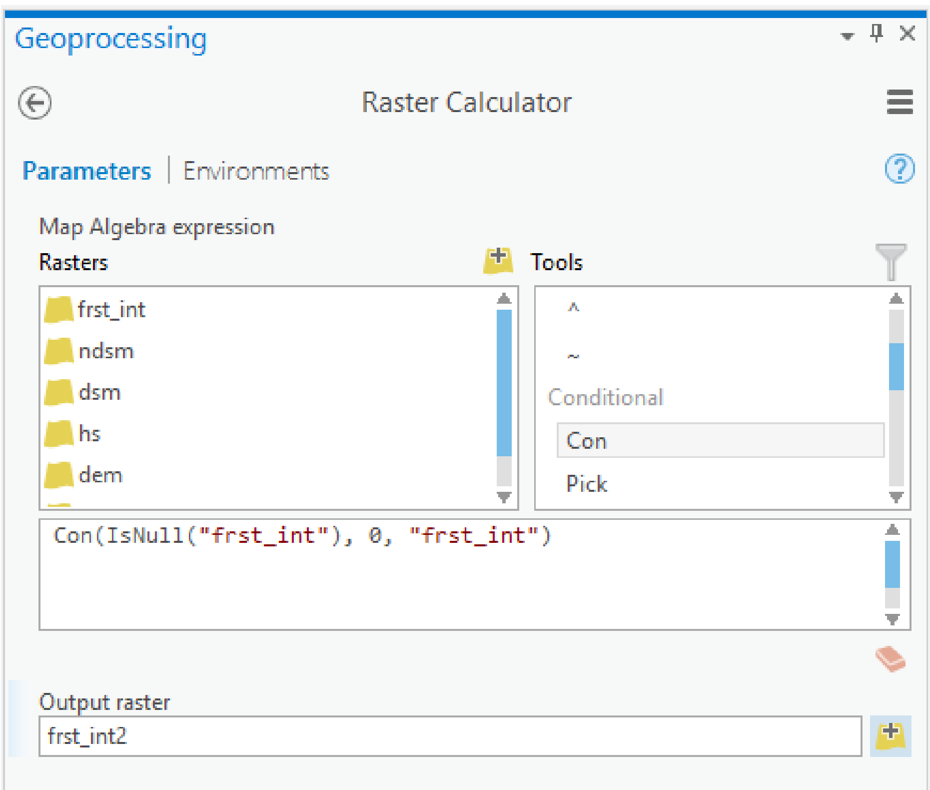
- Navigate to Conversion Tools followed by the To Raster subtoolbox. Click on the **LAS Dataset to Raster Tool**.
- Set the Input LAS Dataset to the **lidar_data.lasd** layer.
- Name the Output Raster **frst_int** and save it to a location of your choosing.
- Make sure the Value Field is set to Intensity.
- Make sure the Interpolation Type is set to Binning, the Cell Assignment is Average, and change the Void Fill Method to None.
- Make sure the Output Data Type is set to Floating Point.
- Make sure the Sampling Type is set to Cell Size.
- Set the Sampling Value to 5.
- Click Run to execute the tool.



We did not have you fill the voids because we assumed that cells that did not contain a return may have absorbed all of the infrared energy. We would now like you to code these cells as 0. This can be accomplished using a conditional statement and the **Raster Calculator Tool**.

- Navigate to Spatial Analyst Tools followed by the Map Algebra subtoolbox. Click on the **Raster Calculator Tool**.
- Use the following syntax: Con(IsNull("frst_int"), 0, "frst_int").
- Name the Output Raster **frst_int2** and save it to a location of your choosing.
- Click Run to execute the tool.

**Note:** Here is an interpretation of the syntax. If the cell holds the null assignment, change the value to 0. If it does not hold the null assignment, or hold any other value, return the original value. So, this syntax replaces null or NoData values with 0 and does not impact any other cells.



Use the intensity image and aerial image to answer the following questions.

**Question 9.** Do forests generally show low or high first return intensity? (2 Points)

**Question 10.** Explain why forests tend to show different return intensity values than grass or pastureland. (4 Points)

**Question 11.** Does water generally show high or low return intensity? (2 Points)

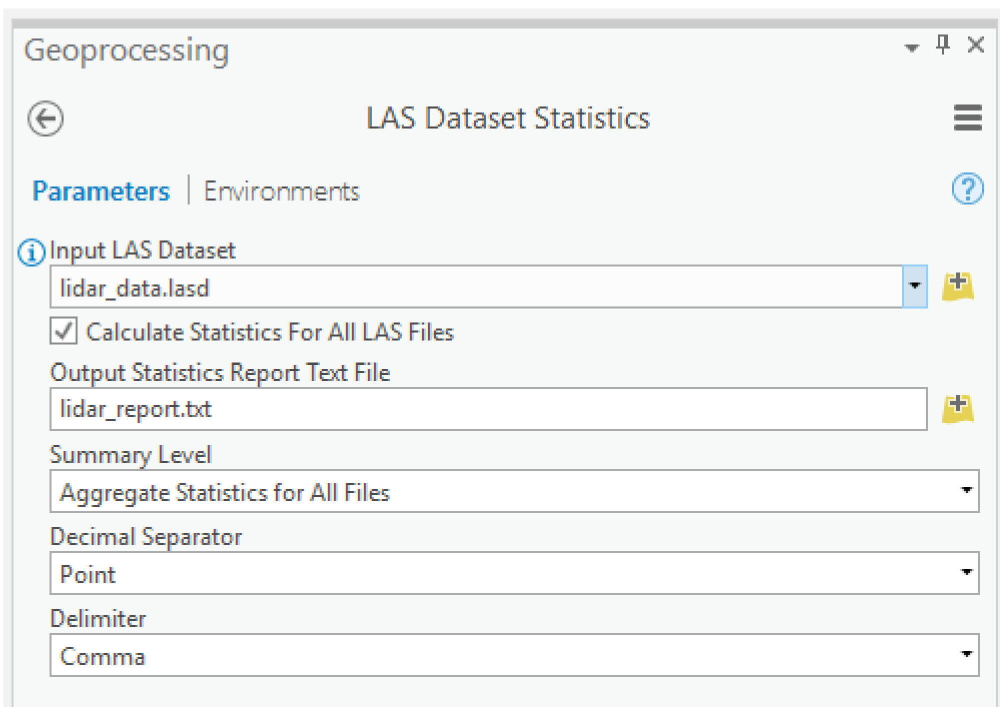
**Question 12.** Does pavement generally show low or high return intensity? (2 Points)

**Question 13.** Do you think that a first return intensity image provides additional information than what is provided by a true color image for differentiating land cover types? Why or why not? (4 Points)

**Step 9. Obtaining Point Statistics**

It is possible to calculate statistics for the LiDAR point cloud using the **LAS Dataset Statistics Tool**. You will now run this tool on your dataset.

- Navigate to Data Management Tools followed by the LAS Dataset subtoolbox. Click on the **LAS Dataset Statistics Tool**.
- Set the Input LAS Dataset to the **lidar_data.lasd** layer.
- Make sure "Calculate Statistics For All LAS Files" is selected.
- Name the Output Statistics Report Text File **lidar_report.txt** and save it to a location of your choosing. Make sure to include the file extension.
- Make sure the Summary Level is set to Aggregate Statistics for All Files.
- Make sure the Decimal Separator is set to Point.
- Make sure the Delimiter is set to Comma.
- Click Run to execute the tool.




The tool will generate a text file that is added to the Contents Pane. Open this file and use it to answer the following questions.

**Question 14.** What percentage of the returns were first returns? (2 Points)

**Question 15.** What percentage of the returns were classified as ground returns? (2 Points)

**Question 16.** What percentage of the returns were single returns? (2 Points)

**Question 17.** What percentage of the returns were the last of many returns? (2 Points)

**Question 18.** Were any of the returns flagged as low points or noise? (2 Points)

### Step 10. Obtaining LAS Point Statistics as a Raster Grid

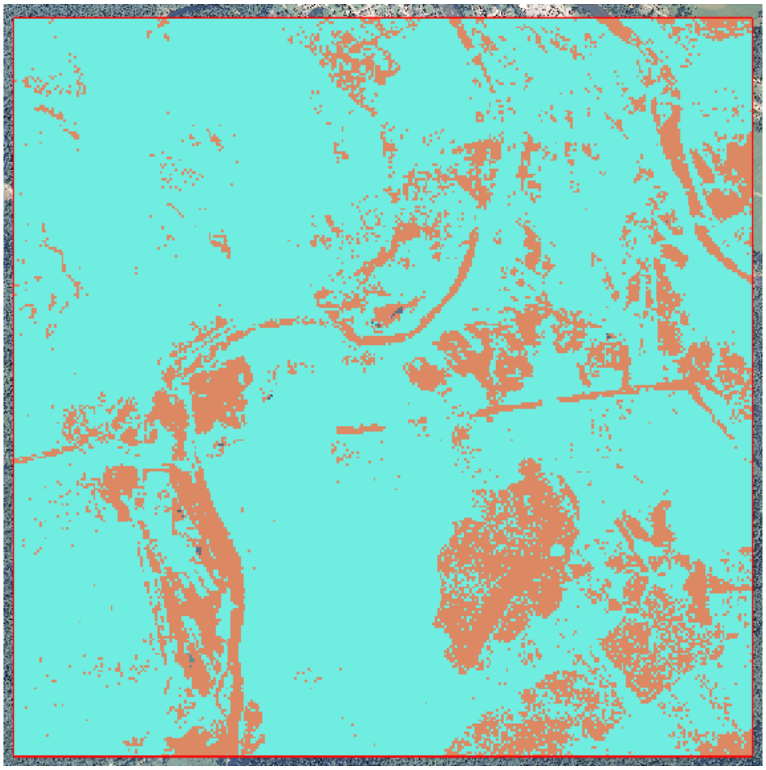
It is also possible to obtain statistics relating to the laser scanning data within a grid cell using the **LAS Point Statistics As Raster Tool**. Here, you will calculate the most frequent class code within 10 by 10 meters cells.

Before you do this, you will need to change the filter again.

- Right-click on the **lidar_data.lasd** layer in the Contents Pane then select filter followed by all points. This means that all points will be displayed and used in analyses.

You are now ready to perform the analysis.

- Navigate to Data Management Tools followed by the LAS Dataset subtoolbox. Click on the **LAS Point Statistics As Raster Tool**.
- Set the Input LAS Dataset to the **lidar_data.lasd** layer.
- Name the Output Raster **common_class** and save it to a location of your choosing.
- Set the Method to Most Frequent Class Code.
- Set the Sampling Type to Cell Size and the Sampling Value to 10. This will produce a grid with a 10 by 10 meter cell size.
- Click Run to execute the tool.



**Note:** If the output displays as a stretch instead of unique values, you will need to manually change the symbology of the layer.

A code of 1 indicates unassigned whereas a code of 2 indicates ground. Points coded as 7 indicate noise or outliers. Use this information and the result to answer the following questions.

**Question 19.** Does there appear to be a correlation between land cover and the most common class in each cell? Explain your reasoning. (4 Points)

**Question 20.** Explain what would be produced if the "Most Frequent Last Return" method was used. (4 Points)

**END OF EXERCISE**