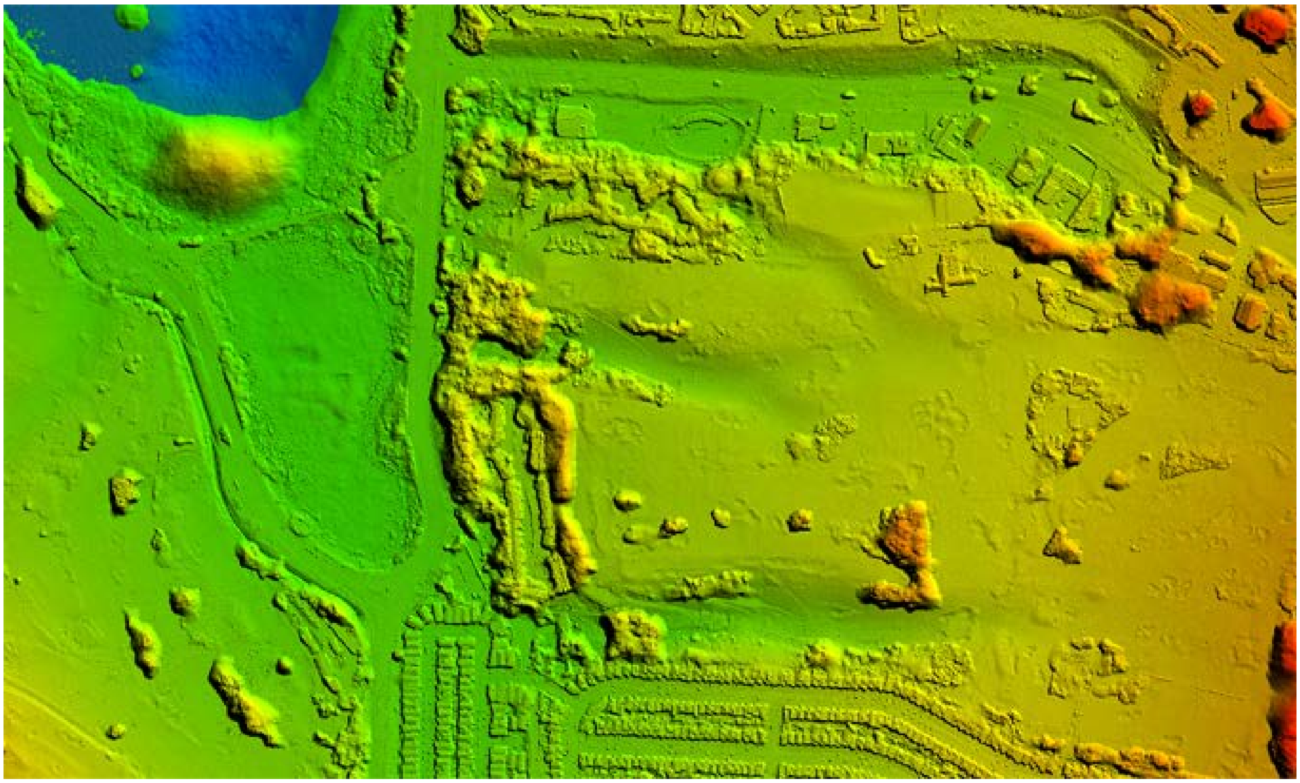
# Introduction to LiDAR using ArcGIS Pro: Part A



: ArcGIS Pro version 2.3

**A guided computer tutorial designed by**

**The New Mexico Forest**

**and Watershed Restoration Institute.**

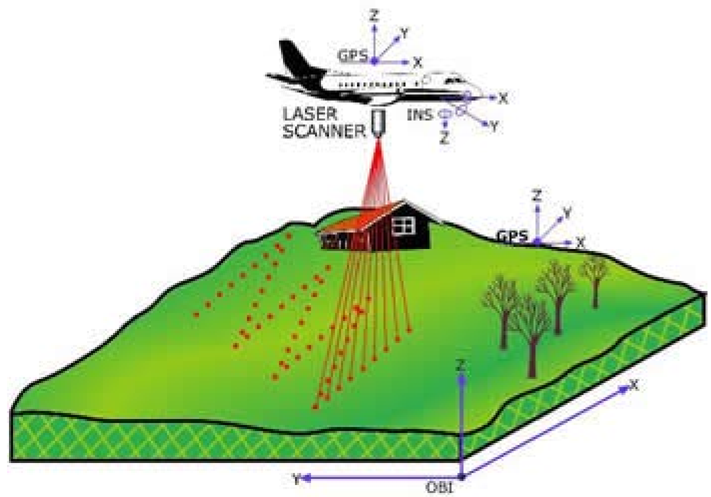
**http://nmfwri.org**

New Mexico
Forest and Watershed
Restoration Institute

*New Mexico Highlands University*

# Introduction to LiDAR using ArcGIS Pro: Part A

ARCGIS PRO VERSION 2.3




**Time to complete**
*Approximately 60 minutes*
**Requirements***: An Internet connection, ArcGIS Pro v. 2.3 with Spatial Analyst and 3D Analyst Extensions*

In this guided tour you will be using ArcGIS Pro to:

- Import LAS files into an ArcGIS LAS Dataset
- View the LiDAR Point Cloud and change the symbology
- Colorizing the LAS Dataset with Digital Orthophotography
- View in 2D and 3D

## Introduction

What is LiDAR? LiDAR stands for Light Detection and Ranging. LiDAR data provides high levels of detail and precision in describing elevation. Products derived from LiDAR include such things as very accurate elevation models as well as surface height information for such things as building and trees.

In this training tutorial will be using publicly available LiDAR data for an area in Arroyo Seco, New Mexico**. In Part A** you will be using ArcGIS Pro to introduce you to the LAS Dataset and view LiDAR point clouds in both 2D and 3D. **In Part B** you will further explore how to create a Digital Elevation Model (DEM), a Digital Surface Model (DSM), calculate absolute heights, and create a vegetation density model.

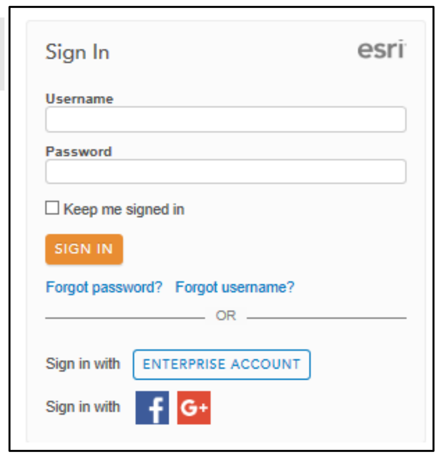
# Let’s Get Started

In this first section, we will introduce you to ArcGIS Pro and will explore 2016 LiDAR data collected in Taos County New Mexico near the town of Arroyo Seco. You will learn how to use ArcGIS Pro to create a LAS Dataset and view and display LiDAR data.

## Open ArcPro and Login using provided login information

To open ArcPro, go the Windows Start Menu. Go To ArcGIS and use the dropdown menu to see all of the programs. When you see ArcGIS Pro


double click to open the program.

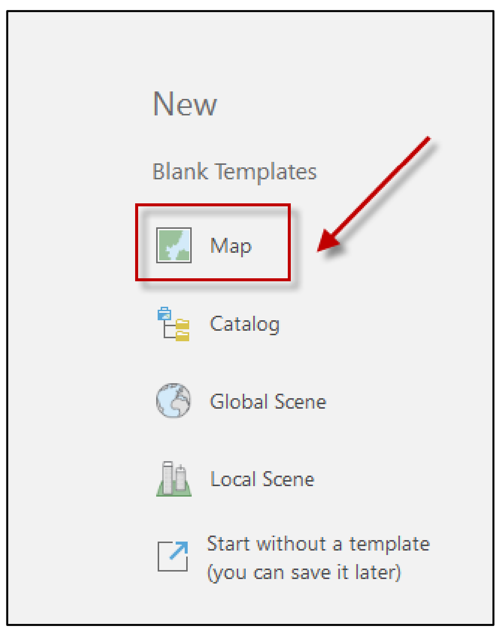



Once you open ArcGIS Pro you will need to sign into an ArcGIS Online account. **For this exercise you will be provided with a temporary Username and Password, enter this information provided by your instructor.** Your instructor will provide these details before this lab begins.

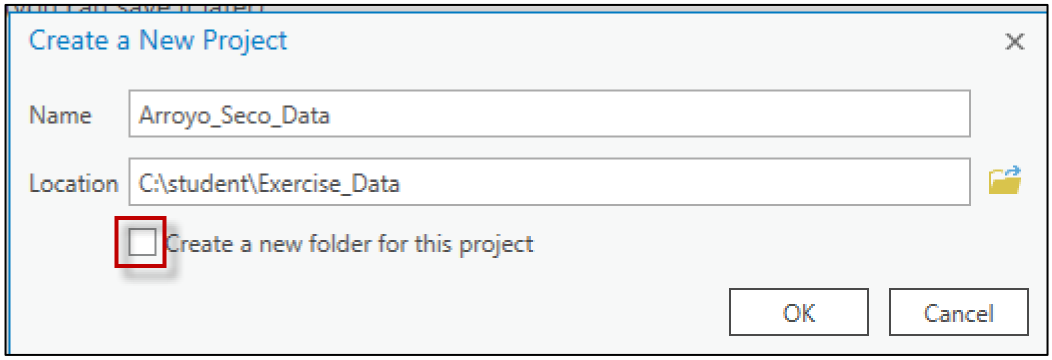
* This is a temporary account tied to Highlands. Back in your office you will need to create an ArcGIS Online account that is linked to your licensing account to fully access ArcGIS Pro at your work computer.

## Step I. Create a New Project and a LAS Dataset

Once you have signed in, ArcGIS Pro will prompt you to create a new project. Under NEW, Blank Templates **Click on MAP**

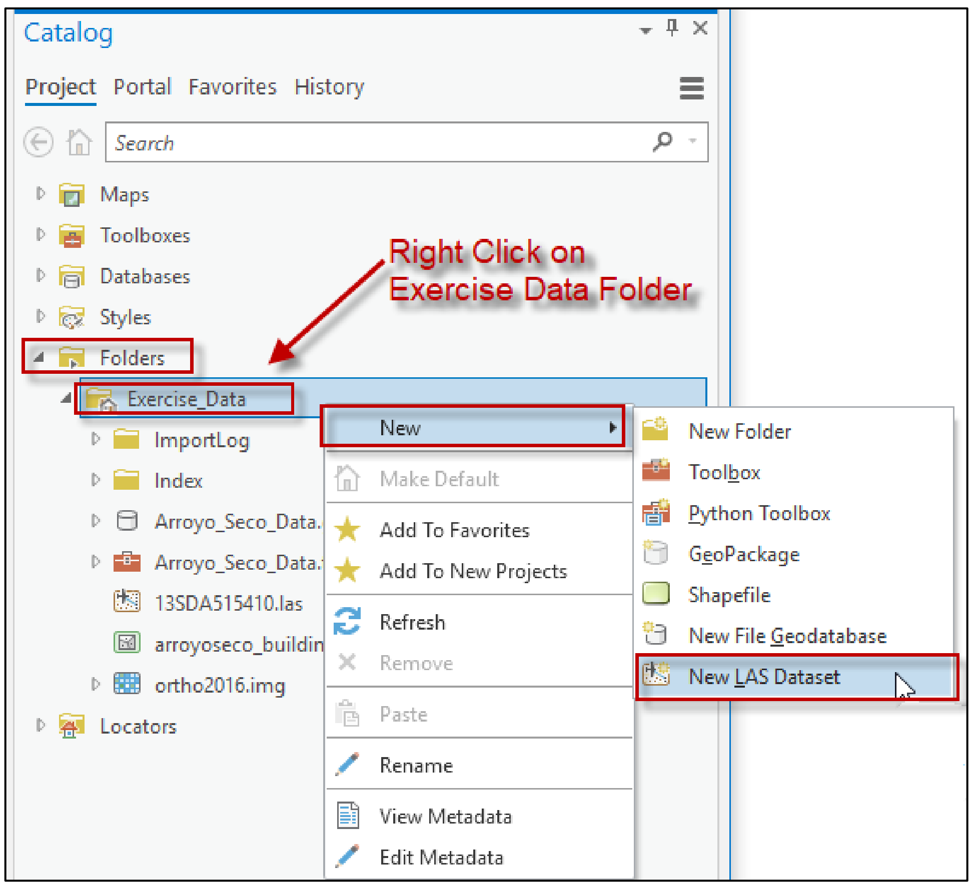


Another window will open where you will enter the name of the new project and its location on your computer.




1. Enter the **Name** as **ArroyoSeco_Data**
   For **Location,** click on the folder icon to **browse** to this location your computer **C:\students\Exercise_Data**
   Be sure to **UNCHECK the box** next to create a new folder for this project and the click **OK.**

ArcPro will then open to your project Catalog page.



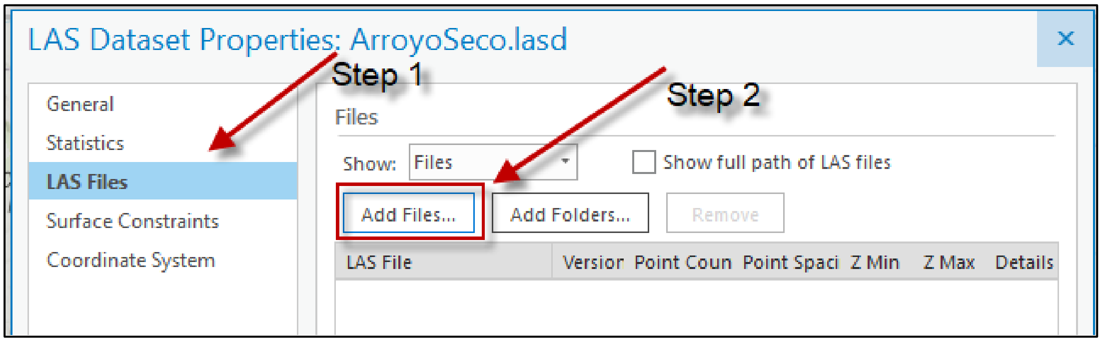

2. **Click on the 'Folders'** icon from the Project Catalog window. Next, **open the Exercise_Data** folder

3. With the Exercise_Data folder selected, **right click** and Select **New > New LAS Dataset**. This will create a LAS Dataset, which is a container to hold .las files so that we can use them in ArcGIS Pro.

4. Name the new LAS Dataset file **ArroyoSeco.lasd**

5. Next, Right click on the newly created ArroyoSeco.lasd and click on **Properties**.

6. This will open the LAS Dataset Properties. Click on the tab on the left **LAS File** and then click on the button to **Add Files.**




7. Now you can browse to where your .las files is located on your hard drive.
   Go to: /students/Exercise_Data/ and select 13SDA515410.lasd

8. Before clicking OK, continue looking at your LAS Dataset properties and you will now see your LAS File loaded. Click on the left hand **Statistics** Tab and click on the **Calculate** button. This will calculate the statistics for the LiDAR file so now you will see more information about your LiDAR data. Within that same Statistics window One at a time, click on the **Classification Codes, Attributes, Returns, and Classification Flags** to get more information about your data.

9. Answer these questions with while looking at the LAS Dataset properties:

   ***Question A: What is the point count of your 1$^{st}$ returns and what percentage does this make up of the total returns?***

   *1$^{st}$ Return Point Count* ____________________________________

   *Percent of Total* __________________________________________

   ***Question B: What is the Projection of your LAS Data?***

   *Current X,Y Coordinate System(2D)* ___________________________________________

   *Current Z Coordinate System(3D)* _____________________________________________

   *What are the coordinate units? Circle the correct answer: Meters Feet Inches*

   ***Question C: What is the Point Spacing of your LAS Data?***

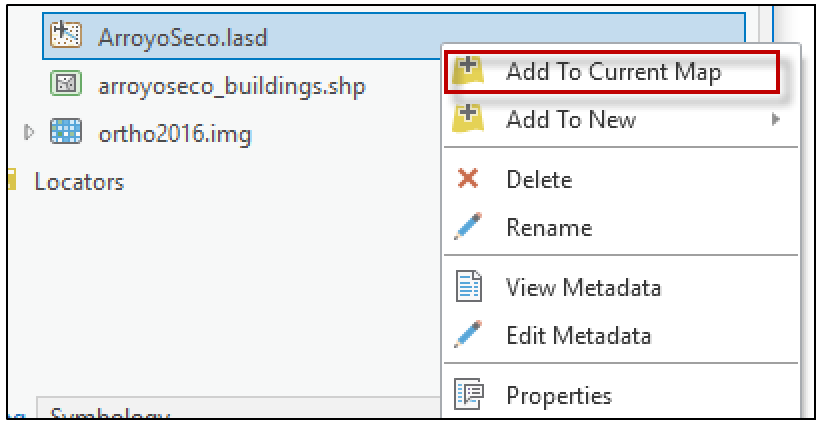
   *Point Spacing* ___________________________________________

10. Now click the **OK** button to close the LAS Properties window.

## Step 2. Add your LAS Dataset to a map and view your LiDAR data

1. Close the LAS Dataset Properties window by clicking **OK** at the bottom of the window.

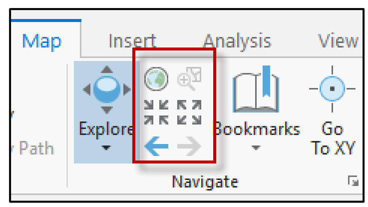
2. This will take you back to the Catalog window. Right Click on your ArroyoSeco.lasd file and then click on **Add to Current Map**




3. This will add your LiDAR data to your open Map. You will only see a red box identifying the extent of your LiDAR data.

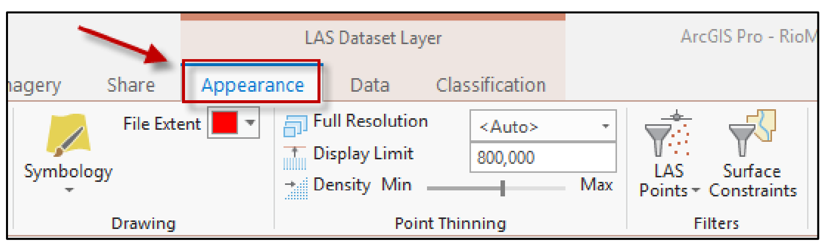
   Using the Roller Ball on your mouse roll it away from you to zoom in until you start to see you LiDAR Points.

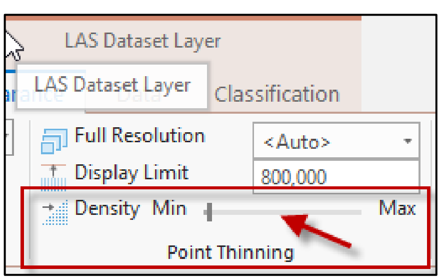
   Alternatively, you can use the navigational tools from the MAP menu bar to zoom in and zoom out (arrows pointing in and pointing out). To get to your last extent use the blue arrows. To see the full extent of your data click on the globe icon.




4. Now that you can see the LiDAR points, look at the top of your window and you should see **LAS Dataset Layer** highlighted. The LAS Dataset Layer provide commands and tools specific to LiDAR datasets. Three functions appear underneath; **Appearance, Data, Classification**.

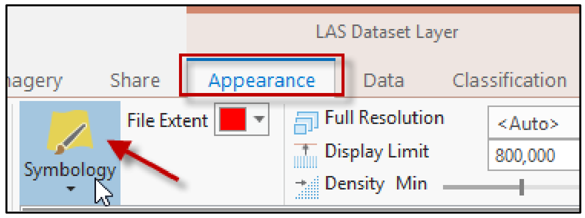
   Click on the **Appearance Tab.** You can now change the appearance of your LiDAR data.



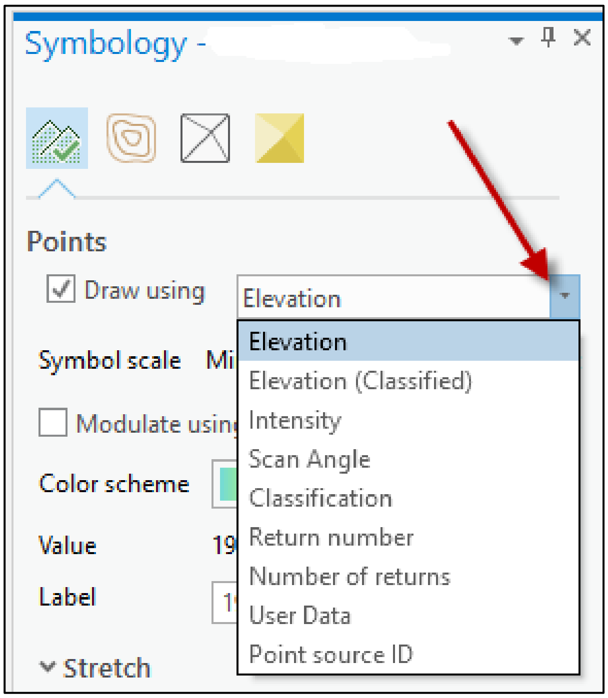




Under the Point Thinning click on the slider tool going from Density Min – Max. Notice the point cloud differences when you increase and decrease the point density.

5. Next click
   on the Symbology tab




Your LiDAR point cloud default view is Elevation. You will also see a menu appear in the right side of your map which provides more detail on how your data are displayed. You can view your point cloud as Points, Lines or Rasters.




6. Take a few minutes to view your points by Elevation values. Notice that the Values range from 2453 to 2833.
   These values are listed in the same units as the LiDAR's coordinate system. Look back to Question B. Are the elevation values in Meters or Feet?

   You can change the symbol scale (Size of points), the color scheme, and the Stretch (How your data are grouped statistically).

7. Let's look at other ways to view your point cloud. **Under Points > Draw Using**

   Click alternatively on these options:
   **Elevation (classified), Intensity, Classification, Return Number, Number of Return.**

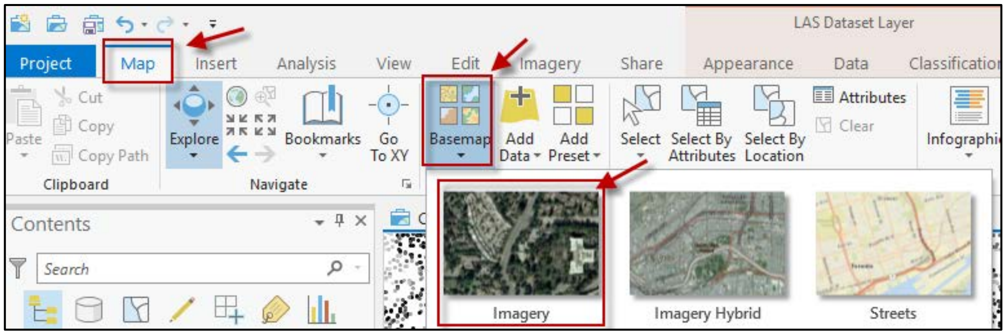
Take time to look at the results and change the settings for each to see how your LiDAR data can be displayed in different ways.

**A. Elevation** – shows elevation values high to low in the units of your data (in this case meters). **Elevation Classified** allows you to classify your elevation ranges. You can also set breakpoints to Classify areas higher or lower than a set elevation.
   **Change the number of classes and see the results.**

**B. Intensity** –Displays the intensity of the return signal. Buildings will have a different intensity values comparted to natural features such as grass and trees. Notice where intensity values are higher or lower. (Hint - areas with a lot of texture have lower intensity values as it scatters the laser pulse when it hits the ground).

**To view imagery for this area, go back to the <u>Map Tab</u> and <u>add Basemap</u> and select <u>Imagery.</u> To return to your LiDAR symbology click on <u>LAS Dataset Layer > Appearance</u>**

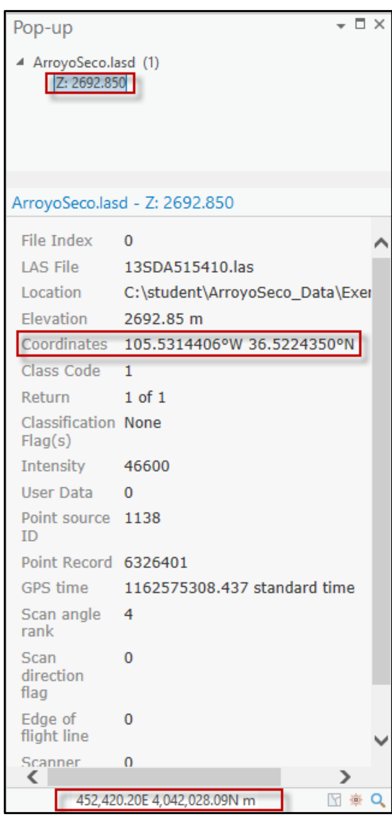
***Note uncheck (turn off) your World Imagery layer when not needing it as it will slow down your display refresh rate.**




**C.** **<u>Classification</u>** - reflects how the Lidar points are classified. With this dataset there are only two classes, Unassigned (1) and Ground class (2).

**D.** **<u>Return Number</u> –**Displays the return number of each LiDAR laser pulse. First Return represents the first location that the laser pulse hits. Second through Fourth returns are intermediate returns, (ie points hitting through the tree canopy) Last return is not always the ground, it is simply the last place the laser hits before return back to the sensor. This can be hard to see as multiple returns may be underneath.

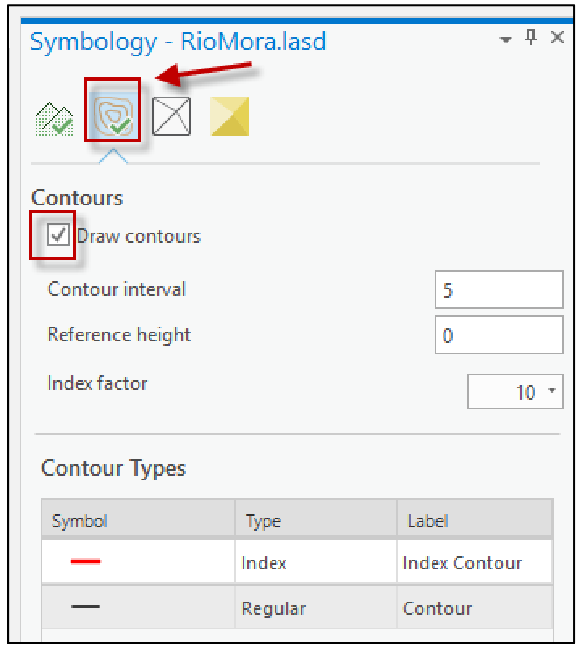
**E.** **<u>Number of Returns -</u>** This displays were the multiple returns are versus single returns.




7. You can also see more information about the point cloud by clicking on individual points. Zoom into an area with your LiDAR Data so you can see individual points.

Use your mouse cursor and click on a point of the point cloud.

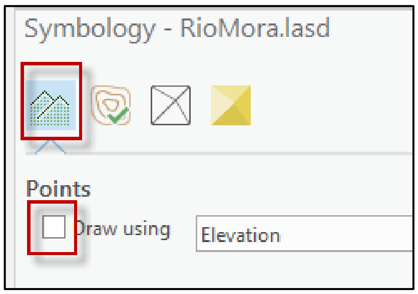
The pop-up window will provide the raw information associated with that point. The Z value is the elevation. Notice it gives Latitude and Longitude for the coordinate but then at the bottom you see the coordinates in Northing/Easting in UTM



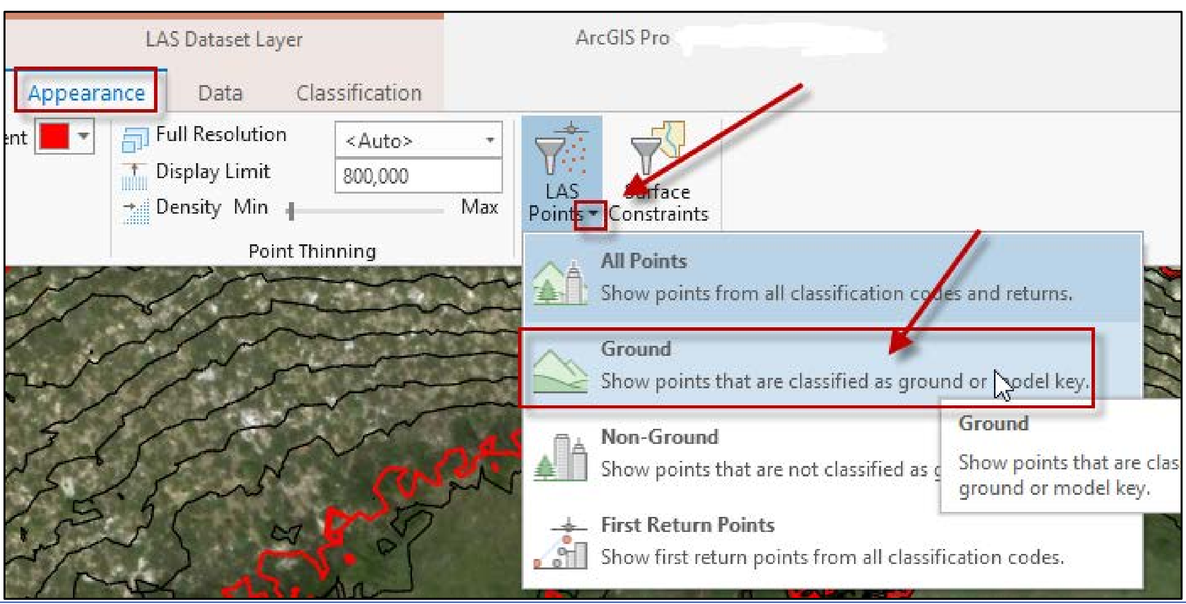

8 Now let's view the LiDAR data symbolized as Contour Lines.
Go Back to your Symbology menu.

**Click on the contour icon** and then check **Draw Contours**. The contour intervals are in the same units as the LiDAR data (meters). Now look at your map, the contours are drawn on top of your point cloud.

To see your contours better turn off your point cloud. Click on your **Points icon** and then **uncheck** the box next to 'Draw using'




9 Now look at your contours. Does anything seem strange? Do you see elevation contours around the trees and buildings? This is due to the fact that it is symbolizing all of your point cloud - even points on the surface such as trees and buildings. To get a better idea of what is only on the ground, let's only create contours from ground points.
Go to the top menu and select LAS Dataset Layer > Appearance. Then Click on the black arrow next to the LAS Points button and click on **Ground Points.** This filter tool will now only display points that are classified as Ground.



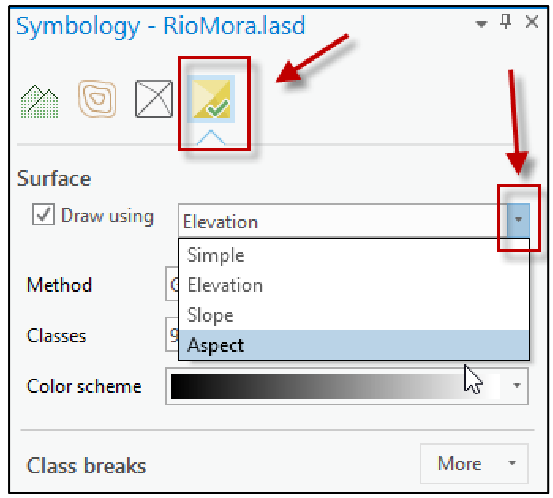
10 If you have your contours still turned on they will automatically update to only show contours using ground points (Notice the contours in the trees are no longer there). Change the contour interval from 5 to 2 and see what happens.

*NOTE – If your LAS Dataset Layer tools disappears from your top menu. Go to your table of contents and click on ArroyoSeco.lasd , now your LAS Dataset Layer menu will appear. ArcPro is selective in the tools it displays so your window is not full of so many commands.

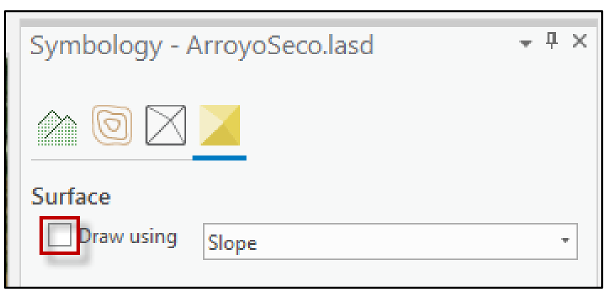
11 Finally you will symbolize your LiDAR data using an interpolated Raster Surface.

Go back to Symbology and with the Contours option open, uncheck Draw Contours so it is no longer displayed in your map. Now go back to the **Symbology** menu and click on **Surface**.

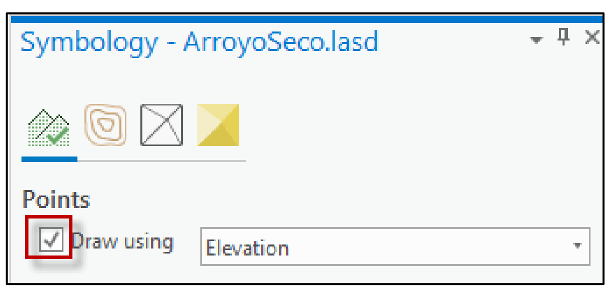
a. Go through each of the surface options: Elevation, Slope (Percent Slope), Aspect
b. You can change the number of classes and the color scheme as you would like.




12 Before we move on to our next section be sure uncheck the Raster display.

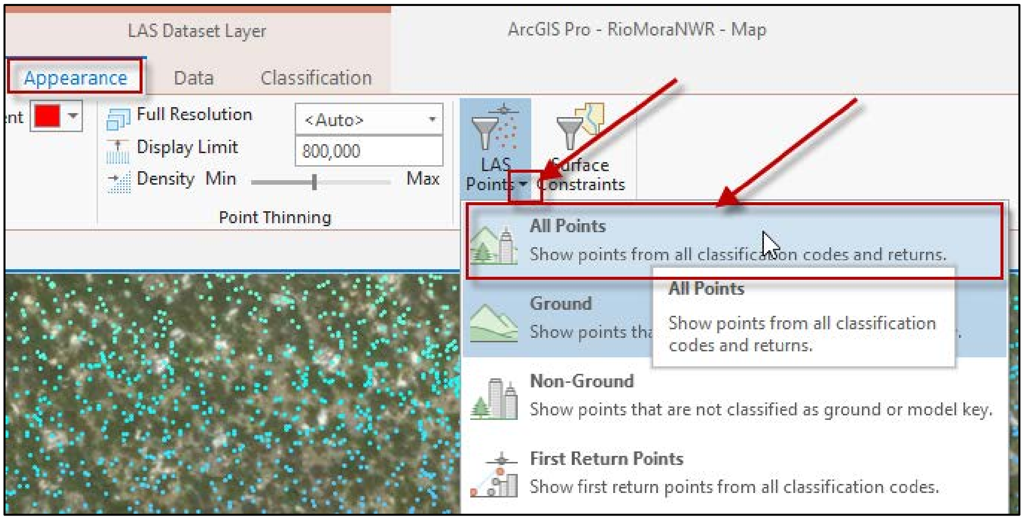



13 Now turn on the point cloud using Elevation



14 Remove the ground filter as you will want to be viewing all off the point cloud, not just the points classified as Ground.

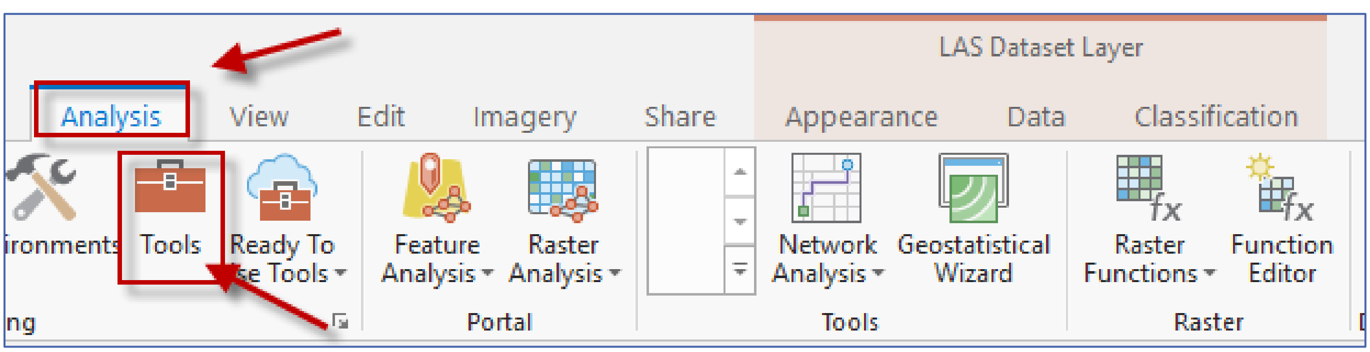
Go to **LAS Dataset Layer > Appearance > LAS Points >** and using the dropdown arrow click **on All Points**




## Step 3. Colorize your LiDAR point clouds using Aerial Imagery

So far you have changed the appearance of the LiDAR point cloud based its attributes such as elevation, return number, etc. Now you are going to add the RGB color values of a 2016 NAIP image to the Point Cloud. Using this information from Aerial Imagery, you can provide an immersive, photorealistic display with your LiDAR data.

1. To run this tool, you need to go to the top menu and click on **Analysis > Tools**

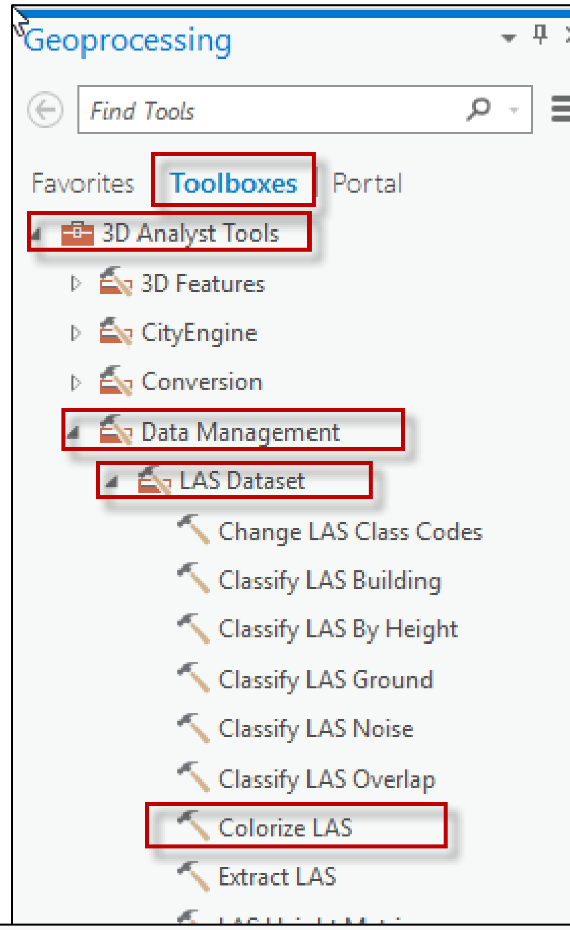


When you click on the Tools Icon it will open the Geoprocessing Pane, Be sure to click on the **Toolboxes Tab.**

Within Toolboxes, to open the tool you need, click in this order:
**3D Analyst Tools > Data Management >**
**LAS Dataset > Colorize LAS**

Be sure to **double click on Colorize LAS** to open the tool.

*Note you can also Type 'Coloraize LAS' in the box where is says *Find Tools*
to search for the command.




With the Colorize LAS tool open, enter the following information:

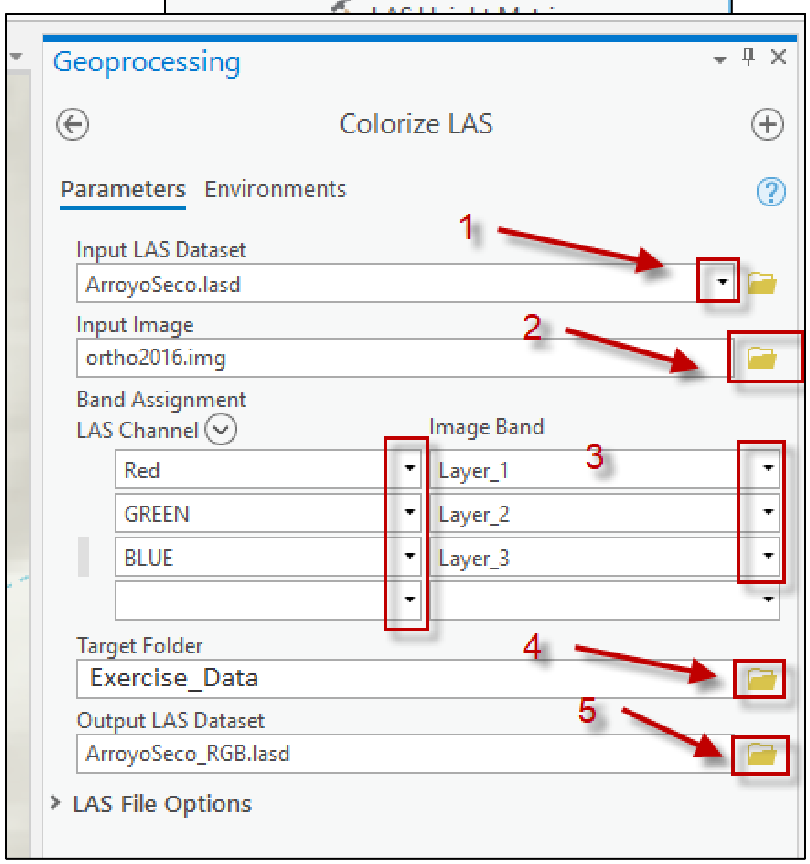
1. Use the drop down arrow to select your file ArroyoSeco.lasd

2. Click on the Folder icon to browse to C:\student\Exercise_Data
   and select the file: ortho2016.img

3. Use the drop down arrows to select LAS Channel as Red, Green, Blue and Image Band Layer_1, Layer_2, Layer3

4. Browse to your target folder: C:\student\Exercise_Data

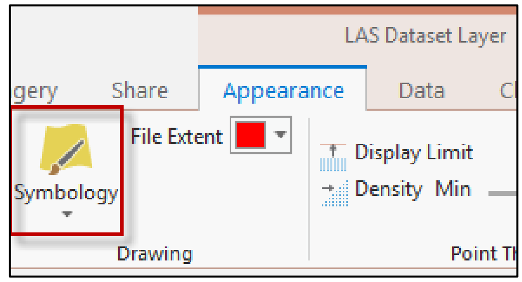
5. Type in your file name: ArroyoSeco_RGB.lasd
6. Click on RUN at the bottom to run the command.

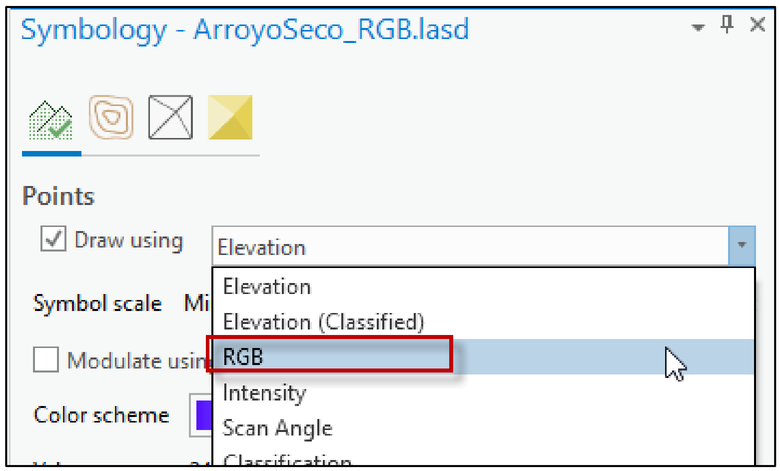
It will take a few minutes to run, once it is finished it will appear in your table of contents.

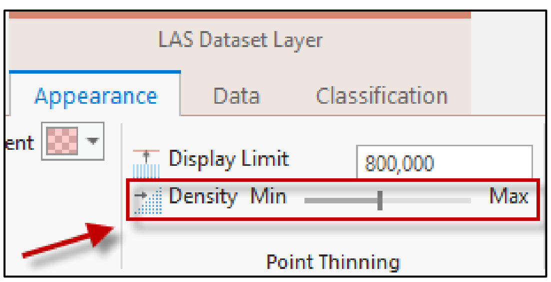
7. Turn off your Arroyo Seco.lasd so that the ArroyoSeco_RGB.lasd is the only point cloud.
8. Turn off your basemap if necessary to see the colorized point cloud.
9. Zoom out to see your point cloud as it will zoom you in too far

10. You will not see it displayed as the symbology defaults to Elevation
    so go back to **LAS Dataset Layer > Appearance > Symbology.**



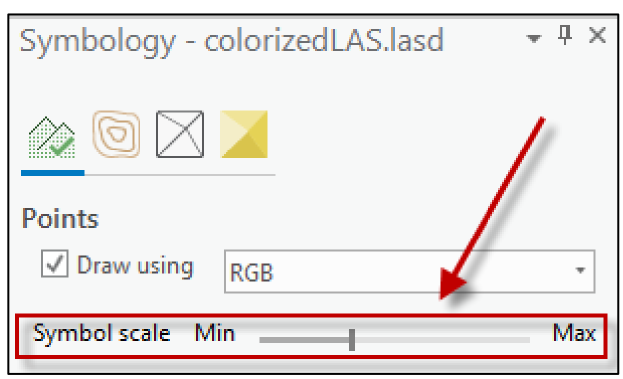

From the drop down menu select Draw Using **RGB**




To get the point density and point size the way you would like it,
if needed adjust the density slider.

Also adjust the Symbol Scale slider unit the point size is appropriate.

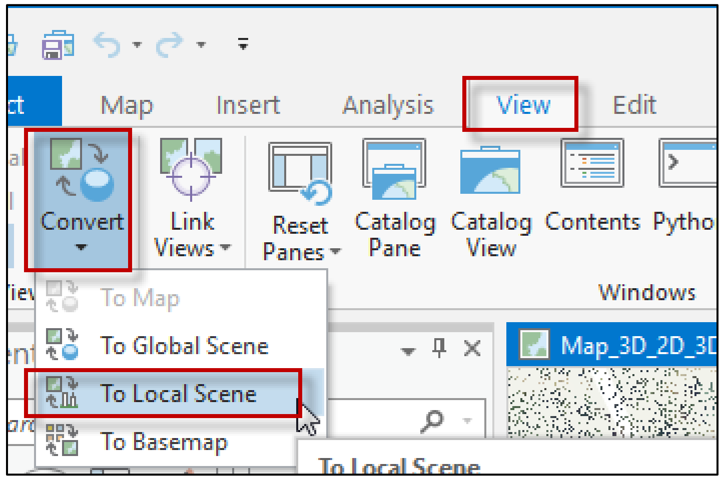


## Step 3. View your Colorized LiDAR data in 3D

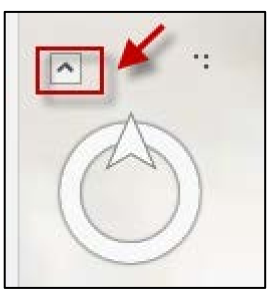
To get a better visualization of our LiDAR display we will now convert our map display from 2D to 3D.

1. From the top menu click on **View > Convert > To Local Scene**
   It will take a minute to convert your display to 3D.

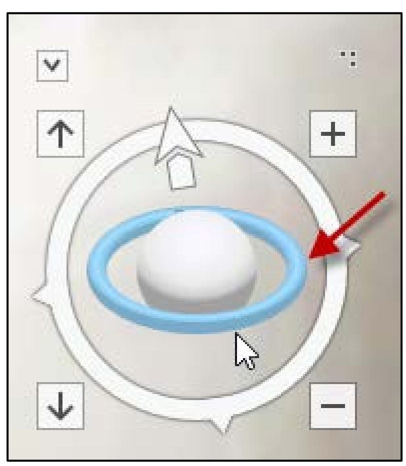
   Then zoom out to see your point cloud.




2. At the bottom left corner of your map you will see the Navigator Tool, click on the arrow to get the full use of the tool. By clicking on the blue circle you can change the vertical perspective.

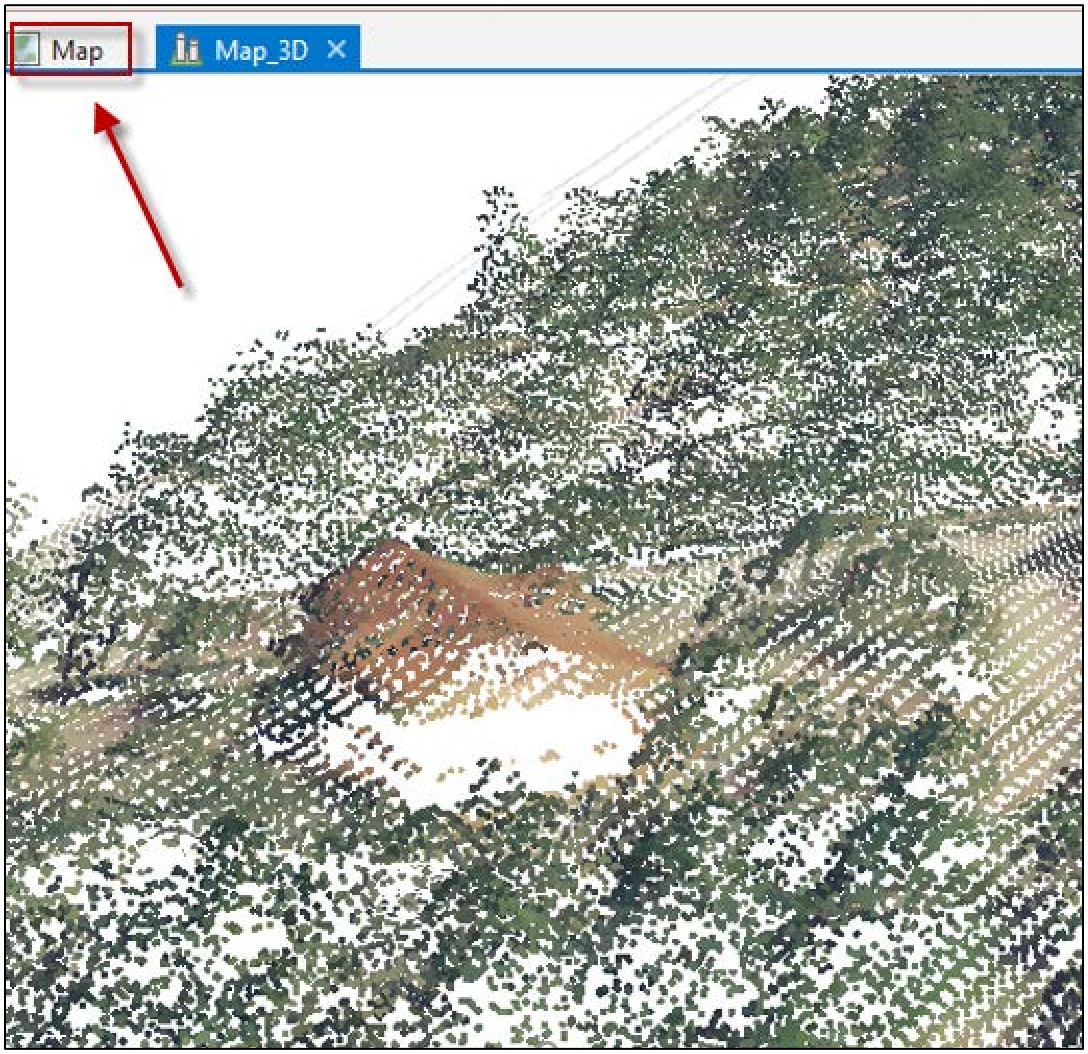


Spend some time zooming around your display. It takes some trial and error to get this to work.

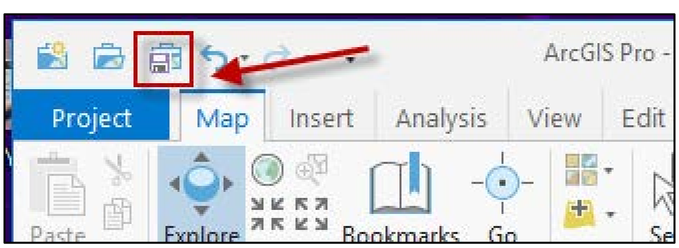


3. To go back to your 2D view, clicking on your **Map Tab**.

You can close your Map 3D tab by clicking on the X.

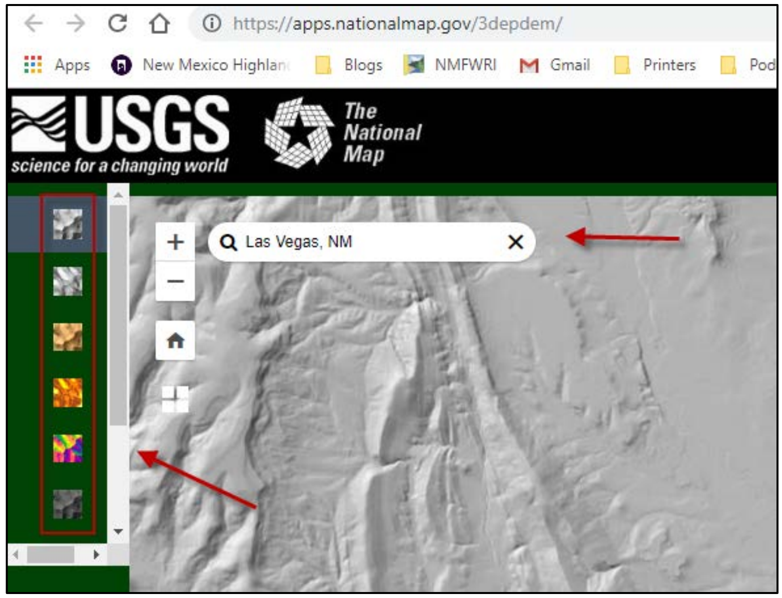



4. Your very last step is to save your project.



This is the end of Exercise Part A.

## Other LiDAR Links / Tools




If you have finished the exercise and there still time, look at these online tools to learn more about LiDAR

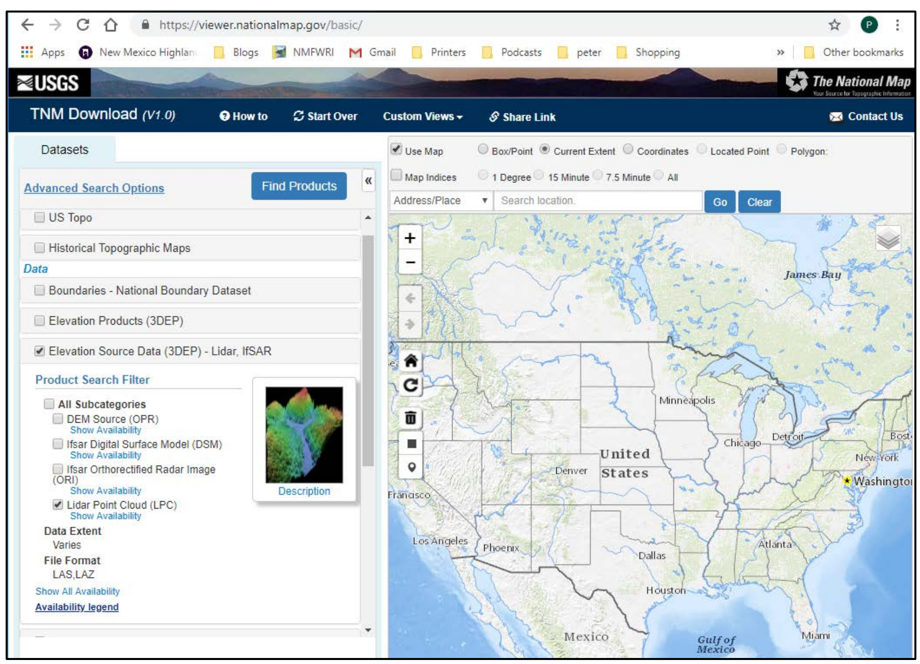
### USGS 3DEP Viewer

This viewer was developed to display USGS DEM derived products from LiDAR via the USGS 3D Elevation Program (3DEP).

To open the viewer go to:
https://apps.nationalmap.gov/3depdem/

Type in a few locations that you are familiar with to see these different LiDAR derived products.

The USGS 3D elevation program is an initiative to gather nationwide LiDAR data by 2023. This new elevation map service introduced by USGS allows users to create multi-resolution visualizations on demand, including automated contours, hillshade, aspect, slope, and tinted hillshade.
Users can generate DEMs at a mixture of scales, down to 1 meter. For more information on the USGS 3DEP program visit:
https://www.usgs.gov/core-science-systems/ngp/3dep




### The National Map : TNM Download for LiDAR Data

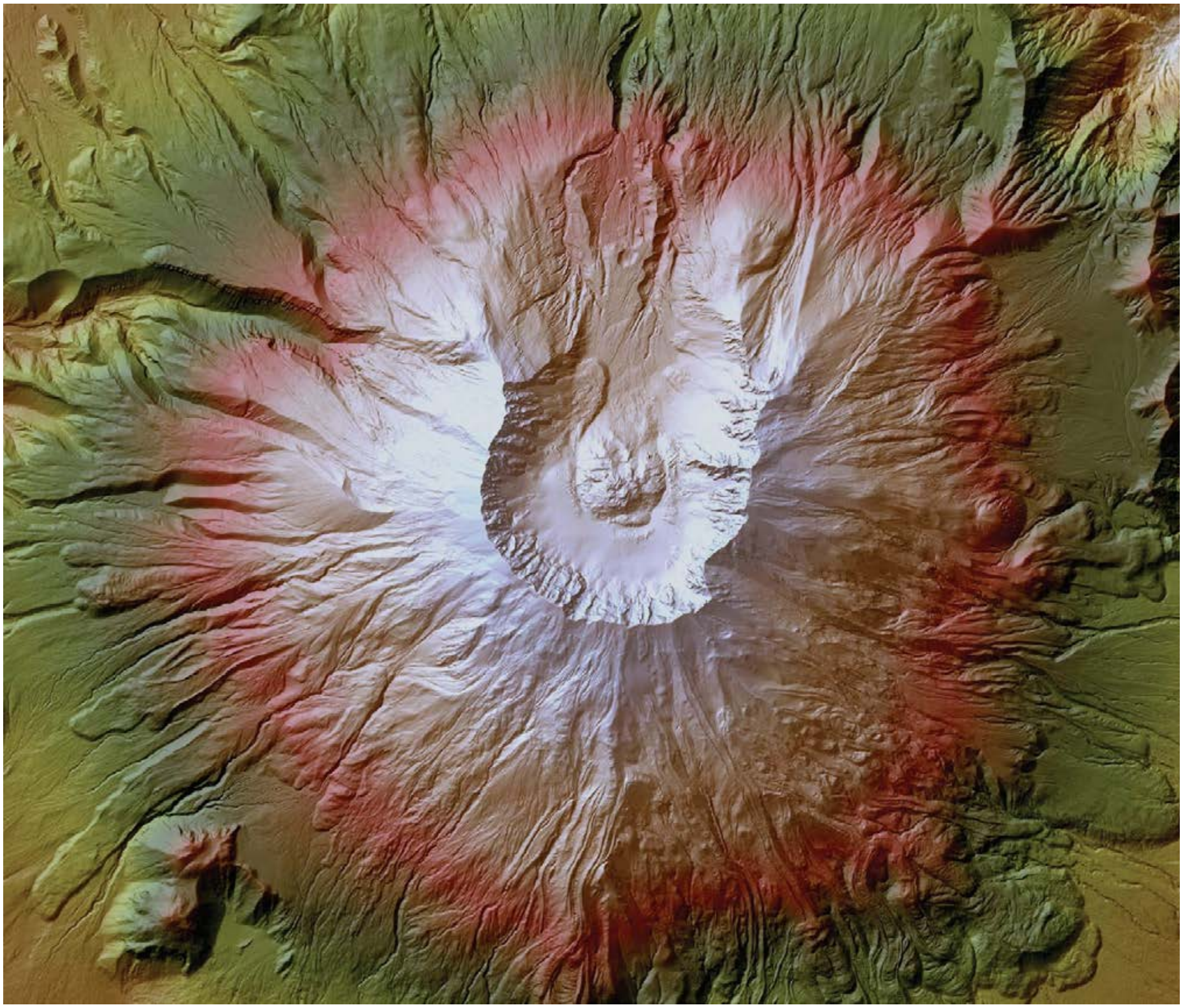
To download LiDAR data for areas across the Unites States go to:

https://viewer.nationalmap.gov/basic/

Select Elevation Source Data 3DEP

*Please don't download data on Lab Computers but just look at how the process works.

# LIDAR DERIVED PRODUCTS: PART B



: Using ArcGIS Pro version 2.3

**A guided computer tutorial designed by The New Mexico Forest and Watershed Restoration Institute**
www.nmfwri.org

New Mexico Forest and Watershed Restoration Institute
New Mexico Highlands University

# Lidar Derived Products: Part B

USING ARCGIS PRO VERSION 2.3

*Time to complete*

*Approximately 2.5 hours*

## Outcomes for the lab

In this lab, you will use LiDAR data in ArcGIS Pro to:

1. **Classify Buildings**
2. **Create LiDAR Products:**
    a) **Bare Earth Digital Earth Model (DEM)**
    b) **Digital Surface Model (DSM)**
    c) **Hillshade**
    d) **Slope**
    e) **Aspect**
    f) **Contour**
3. **Calculate Vegetation Height**
4. **Calculate Canopy Density**
5. **Design a Map**

# Introduction

## Let’s Get Started

Open ArcGIS Pro. Open the Project: ArroyoSeco_Data.aprx.

On the left side of the browser under Open → Recent Projects click ArroyoSeco_Data.


# Part 1. Classifying Buildings

Every lidar point can have a classification assigned to it that defines the type of object that has reflected the laser pulse. Lidar points can be classified into a number of categories, including bare earth or ground, top of canopy, and water. The different classes are defined using numeric integer codes in the LAS files.

Lidar points stored in LAS files are typically classified into different categories using specialized classification tools outside of ArcGIS. This classification is usually completed by setting parameters based on the terrain, and then running algorithms on the point cloud to determine the feature type associated with each point. The classification code assigned to each point is written to the LAS file and, in most cases, adheres to the ASPRS standard.

**TABLE 1: ASPRS LAS CLASSIFICATION CODES**

| Classification Value | Meaning | Classification Value | Meaning |
|---|---|---|---|
| 0 | Never Classified | 11 | Road Surface |
| 1 | Unassigned | 12 | Reserved * |
| 2 | Ground | 13 | Wire – Guard (Shield) |
| 3 | Low Vegetation | 14 | Wire – Conductor (Phase) |
| 4 | Medium Vegetation | 15 | Transmission Tower |
| 5 | High Vegetation | 16 | Wire-Structure Connector (Insulator) |
| 6 | Building | 17 | Bridge Deck |
| 7 | Low Point | 18 | High Noise |
| 8 | Reserved * | 19-63 | Reserved |
| 9 | Water | 64-255 | User Definable |
| 10 | Rail | | |

When a classification is carried out on LiDAR data, points may fall into more than one category of the classification. Classification flags are used to provide a secondary description or classification for lidar points. In later versions (LAS 1.1 and later), class flags were used to solve this problem. Classification flags were added to the LAS standard to mark points with information additional to the traditional classification. Synthetic, key-point, withheld, and overlap flags can be set for each LiDAR point. These flags can be set along with the classification codes. For example, a water record could be given a classification code for water (9), as well as a withheld flag. The point will remain in the dataset but will be withheld from any additional analysis on the LAS files.

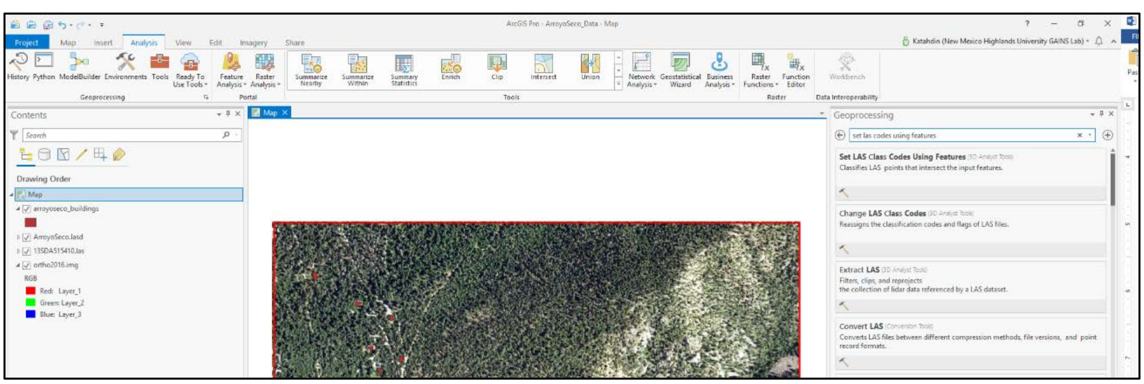
In many cases, LAS files may not be fully or correctly classified when introduced to the GIS tools in ArcGIS. ArcGIS provides the LAS dataset and associated tools to enable classification or data cleanup of classification codes and classification flags residing in the LAS files.

Interactive and geoprocessing tools provide the ability to edit classification codes present in the LAS file. The Classification tab for a LAS dataset provides interactive editing capabilities as well as automated editing by opening the appropriate geoprocessing tool associated with the analysis.

The ArroyoSeco LAS Dataset is classified into just two codes: Unassigned and Ground. In this part of the exercise, you will add one more classification: Buildings.

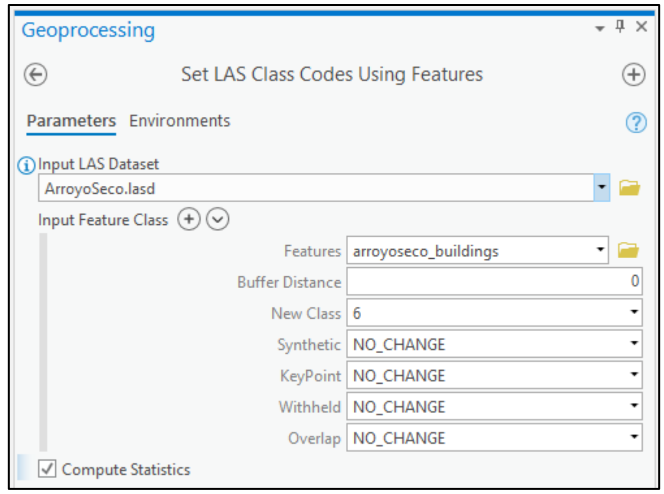
Classifying the buildings will allow you to easily pull out the non-natural features from the landscape and withhold them from vegetation analysis. With this exercise you will use a shapefile of the buildings in Arroyo Seco to classify the LAS Dataset. ***The shapefile is a subset of a much larger dataset that was developed by Microsoft Bing which includes building footprints for the entire United States.***

1) In the catalog pane on the right, browse to the exercise data folder and right click 'arroyoseco_buildings.shp'. Select "Add to Current Map". You will now see a polygon feature class of the footprints of all the buildings within the LiDAR tile. Add an air photo to see the actual locations of the buildings (in the Catalog pane, right click on ortho2016.img, select "add to current map"). Within the Contents pane, toggle on and off the buildings shapefile to compare the shapefile footprints to the aerial imagery of the buildings.

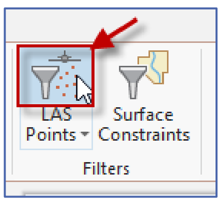


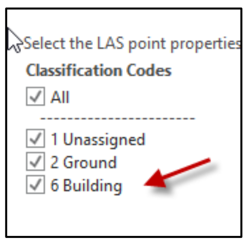
2) Next, go to the Analysis tab. Click Tools. In the right pane, type "Set LAS Codes Using Features" into the search bar at the top of the geoprocessing pane.

3) Click the first result that appears – “Set LAS Class Codes Using Features”
4) Under Input LAS Dataset choose ArroyoSeco.lasd from the dropdown menu
5) Under Features choose arroyoseco_buildings.shp from the dropdown menu
6) Under the New Class field select 6 from the dropdown menu. If you recall from Table 1: ASPRS classification codes, 6 is the code used for buildings.
7) Check the box to Compute Statistics.
8) Click Run at the bottom of the pane.




Now click on the top of the LAS Points button in the Filters section of the Appearance Tab.

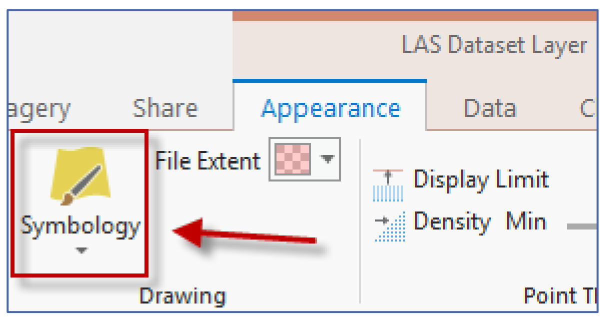


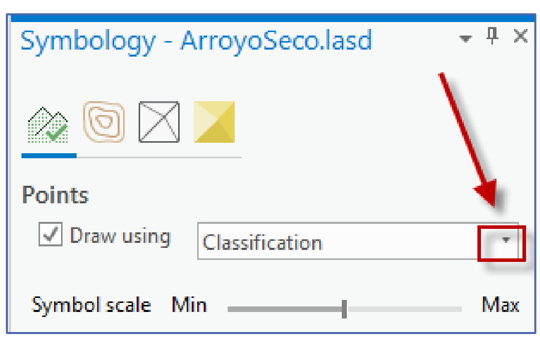

You will now see that the building classification code has been added to the ArroyoSeco LAS Dataset.

To view the data you just classified:

9) Go to the Symbology pane.

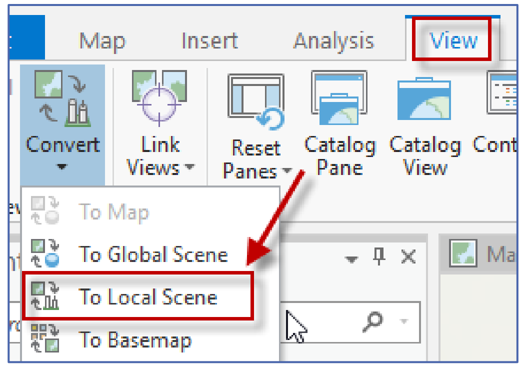



10) From the drop down menu change Draw Using to Classification.

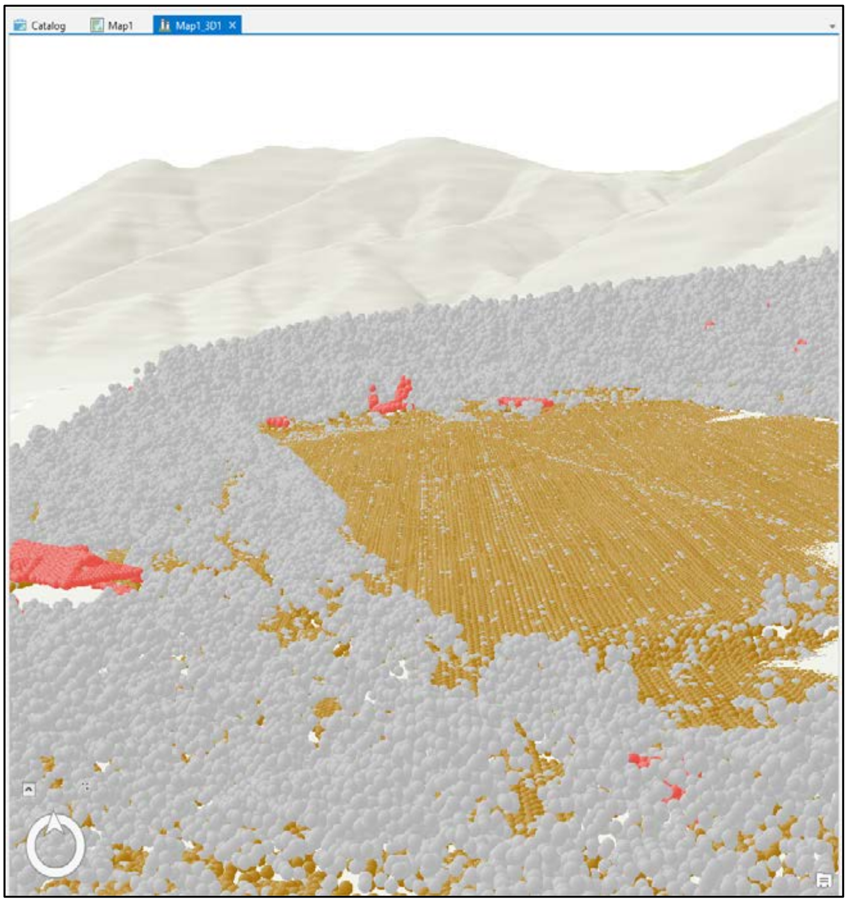



11) If you have any aerial imagery in your map, toggle it off in the Contents pane. Toggle off any other layers, such as the buildings shapefile. The LAS Dataset should be the only viewable layer.

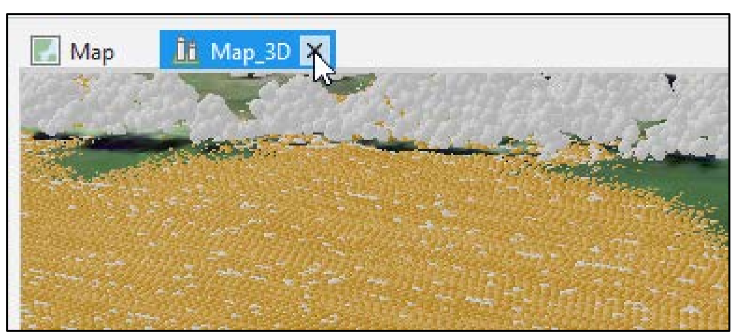
12) On the View Tab, click Convert, to Local Scene




A new 3D Scene tab will be created so that you can view the classified LAS Dataset in 3D. Zoom out and around. Note the Building points in pink. Feel free to change toggle on the Ortho2016 aerial imagery in the Contents pane order to see the buildings on the air photo. Change the symbol scale and density if you would like.



13) When you are done viewing the map in 3D, close the 3D map and return to the 2D map (by clicking the X)



# Part 2. Create LiDAR Products

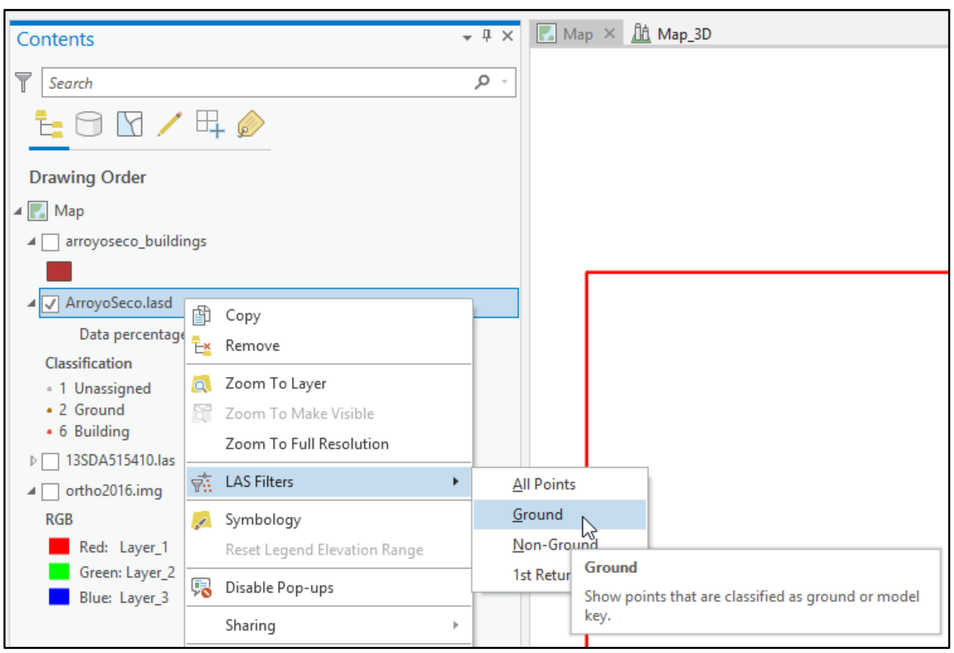
In this section you will produce derivative data from the LAS Dataset. Using geoprocessing tools in ArcGIS Pro, you will create a bare earth model, digital surface model, hillshades, and slope, aspect, and contour maps. LiDAR provides you with the opportunity to make high-quality elevation models of two distinct types: first return and ground. A first return surface includes tree canopy and buildings and is often referred to as a digital surface model (DSM). The ground, or bare earth, contains only the topography and is frequently called a digital elevation model (DEM). Once you have created these two data sets, you can use them to develop other products, such as 3D hillshades, aspect and slope datasets, and contour lines.

## A) Bare Earth Model or Digital Elevation Model (DEM)

To create the DEM or Bare Earth Model:

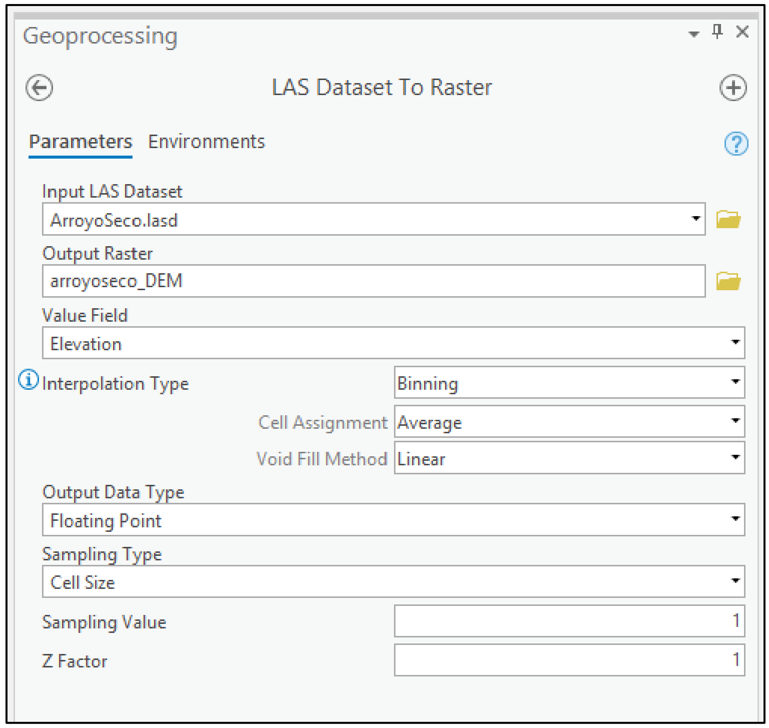
1) In the Contents pane on the left, right click on ArroyoSeco.lasd.

2) Scroll down to LAS Filters. Select "Ground". This will filter the LAS Dataset input so that only ground points are included in the digital elevation model.

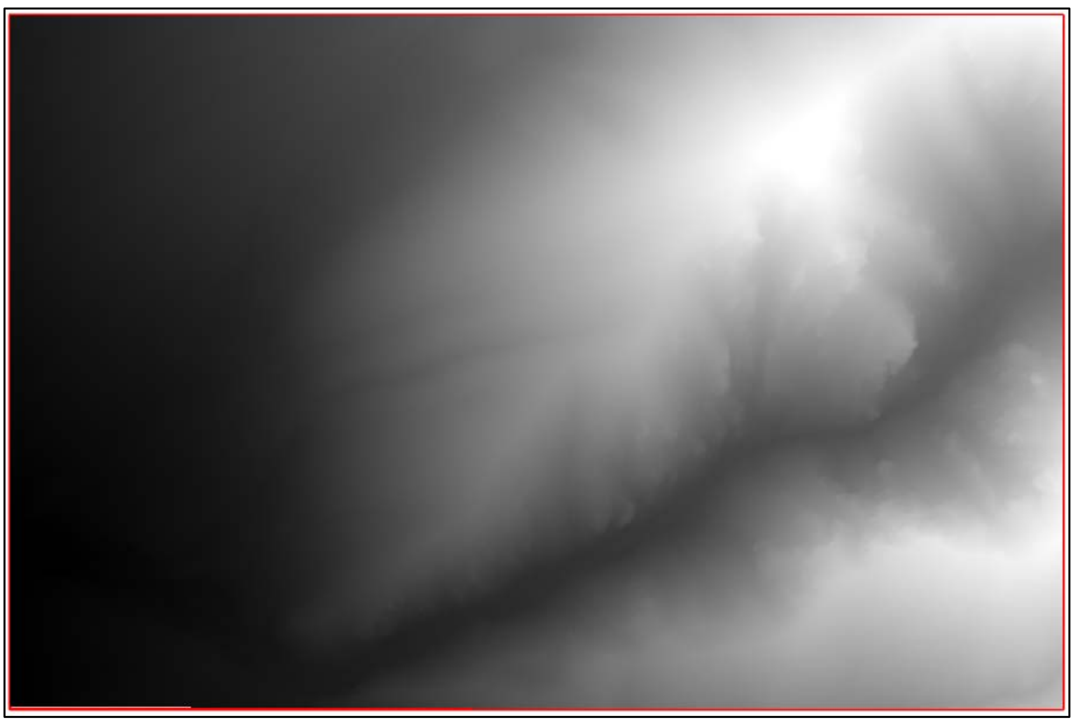



3) In the geoprocessing pane, on the right side of your browser, click the back arrow button to return to the search bar. Type "LAS Dataset to Raster" in the Find Tools search bar.

4) Click LAS Dataset to Raster to open the tool
5) Under Input LAS Dataset choose ArroyoSeco.lasd from the drop down menu
6) Change the name of the output file to ArroyoSeco_DEM. Keep the Output location the same (inside the ArroyoSeco_data geodatabase)
7) Change the Sampling Type cell size to 1
8) Click Run at the bottom of the pane.

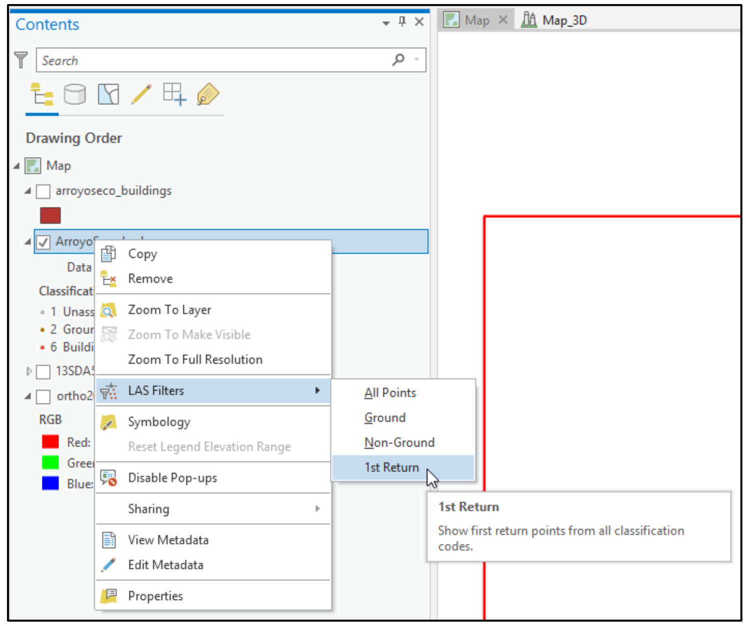



The DEM raster will appear in the Map window once the file is processed.

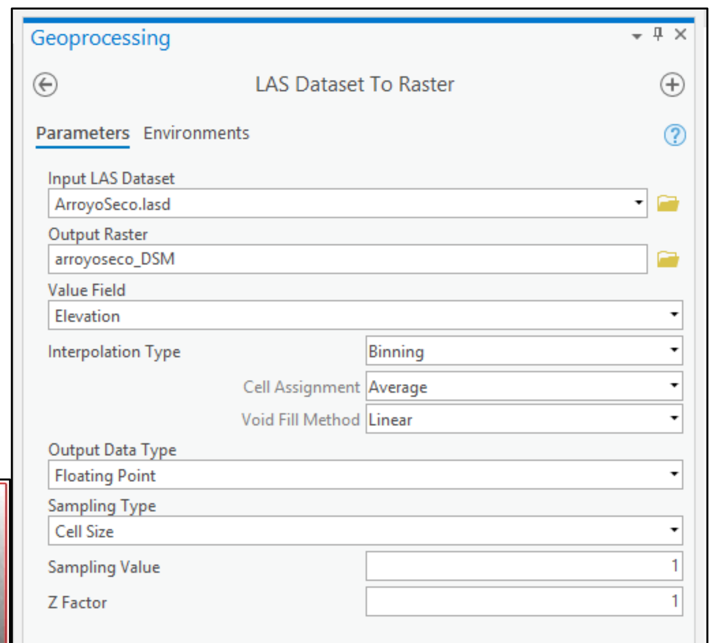


## B) Digital Surface Model (DSM)

To create the DSM:

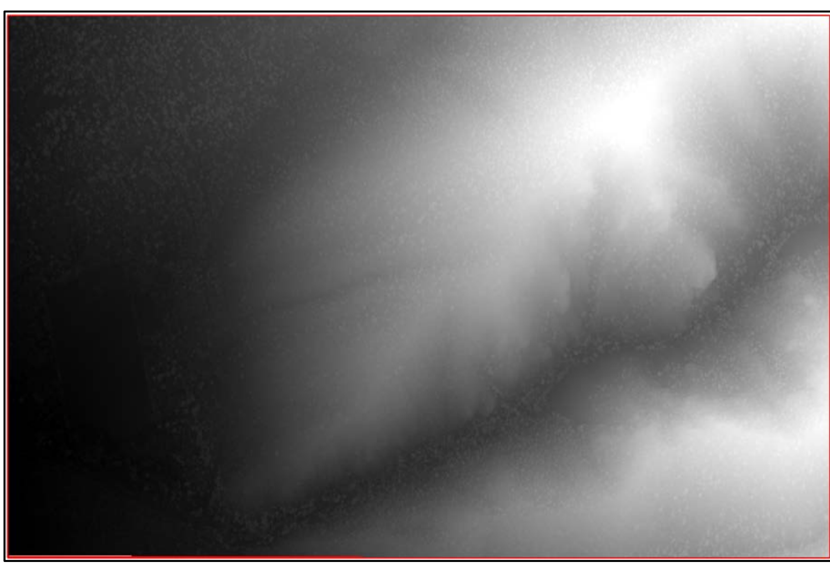



1) In the Contents pane on the left, right click on ArroyoSeco.lasd.
2) Scroll down to LAS Filters. Select “1$^{st}$ Return”. This will filter the LAS Dataset so that only 1$^{st}$ return points are included in the digital surface model.
3) In the geoprocessing pane, on the right side of your browser, click the back arrow to return to the search bar page. Type “LAS Dataset to Raster” in the Find Tools search bar.
4) Click LAS Dataset to Raster to open the tool
5) Under Input LAS Dataset choose ArroyoSeco.lasd from the drop down menu
6) Change the name of the output file to ArroyoSeco_DSM. Keep the Output location the same (inside the ArroyoSeco_data geodatabase)
7) Change the Sampling Type cell size to 1
8) Click Run at the bottom of the pane.




The DSM raster will appear in the Map window once the file is processed.

In the Contents pane on the left, toggle the ArroyoSeco_DSM file on and off so that you can compare it to the ArroyoSeco_DEM image.

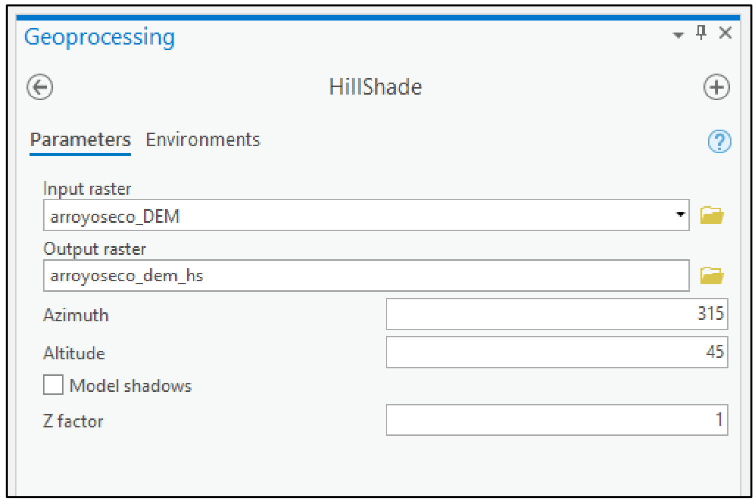


## C) Hillshades

To create 3D hillshades of the DEM and DSM raster files you just created:

1) In the geoprocessing pane, click the back arrow to return to the search bar page. Type "Hillshade" into the Find Tools search bar.
2) Click the Hillshade (3D Analyst) tool to open it
3) Under Input Raster select ArroyoSeco_DEM
4) Rename the output raster to "ArroyoSeco_DEM_hs"
5) Click Run
6) Repeat the above steps to make a hillshade out of the DSM. Name the DSM hillshade "ArroyoSeco_DSM_hs"

In the Contents pane on the left, toggle the DSM hillshade on and off to compare it to the DEM hillshade.



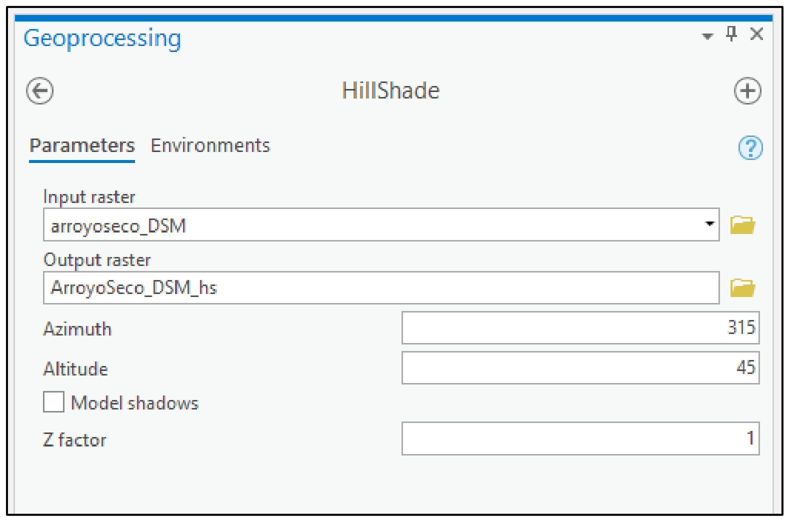




**FIGURE 1- DEM HILLSHADE**

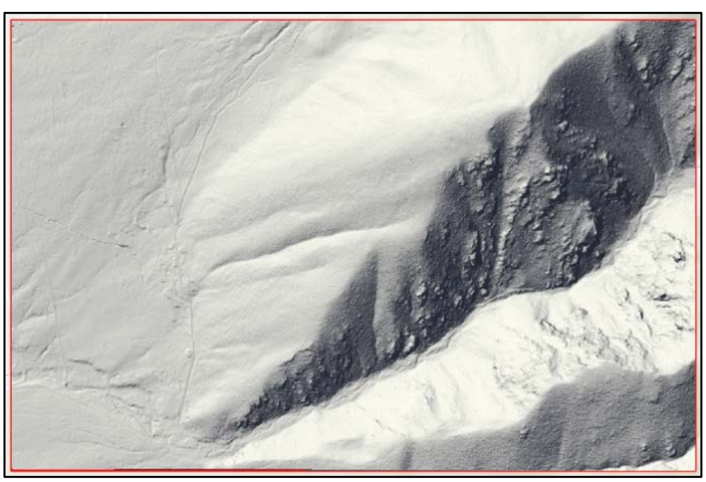
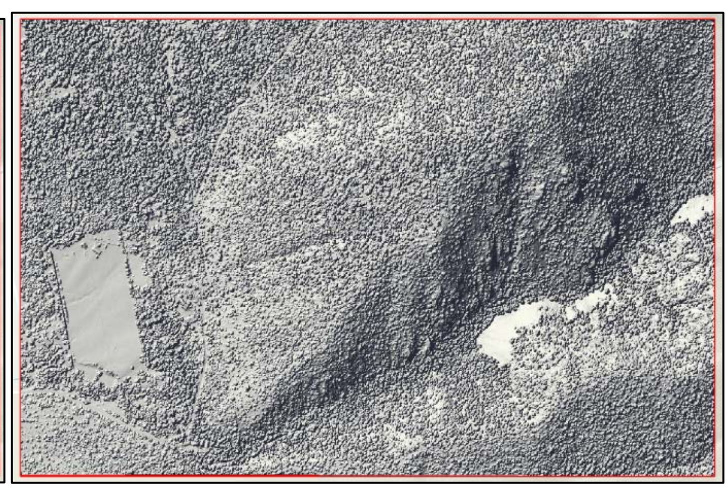


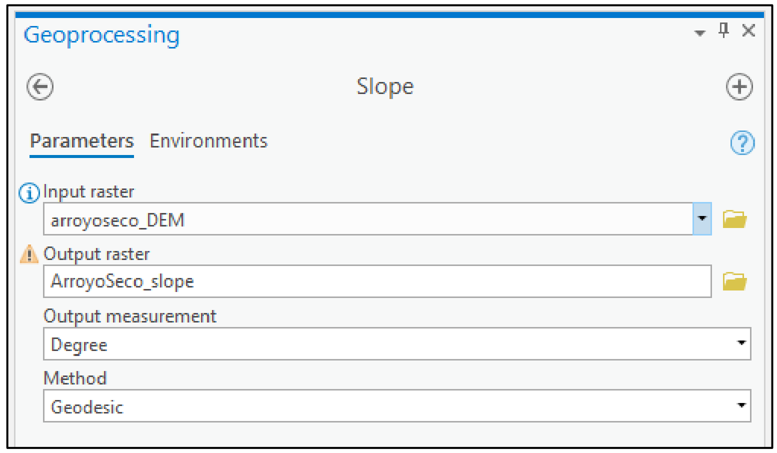
**FIGURE 2- DSM HILLSHADE**



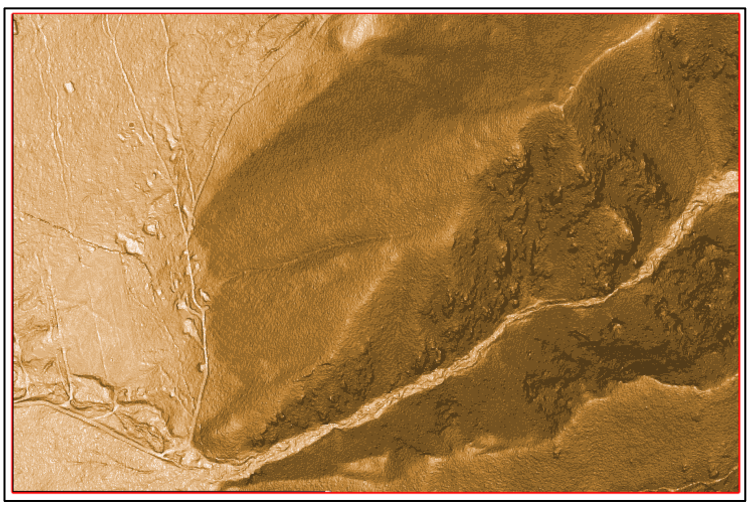
## D) Slope

To create a slope map:

1) In the geoprocessing pane, click the back arrow to return to the search bar. Type “Slope” into the Find Tools search bar.
2) Click the Slope (3D Analyst) tool to open it
3) Under Input Raster select ArroyoSeco_DEM
4) Rename the output raster to “ArroyoSeco_slope”
5) Leave the Output Measurement as Degree
6) Change the Method to Geodesic.
7) Click Run



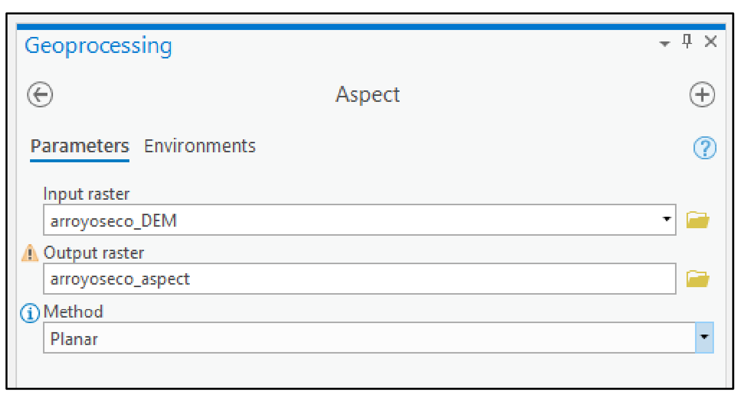

The Slope raster will appear in the Map window once the file is processed.



## E) Aspect

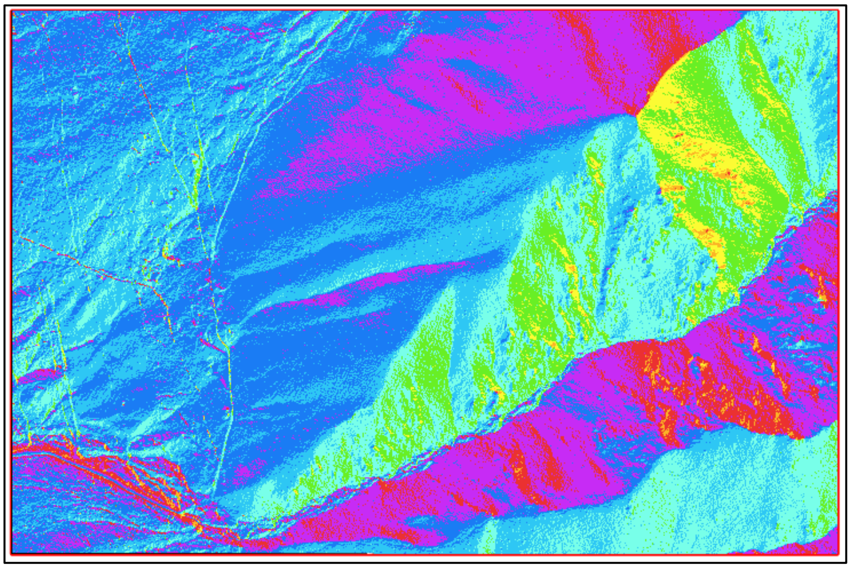
To create an aspect map:

1) In the geoprocessing pane, click the back arrow to return to the search bar. Type “Aspect” into the Find Tools search bar.
2) Click the Aspect (3D Analyst) tool to open it



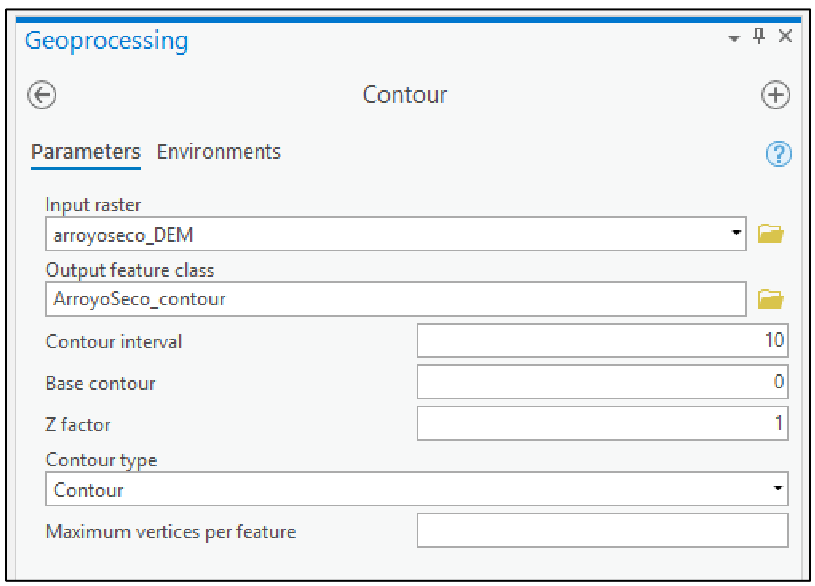
3) Under Input Raster select ArroyoSeco_DEM
4) Rename the output raster to “ArroyoSeco_aspect”
5) Click Run

The Aspect raster will appear in the Map window once the file is processed.



## F) Contour

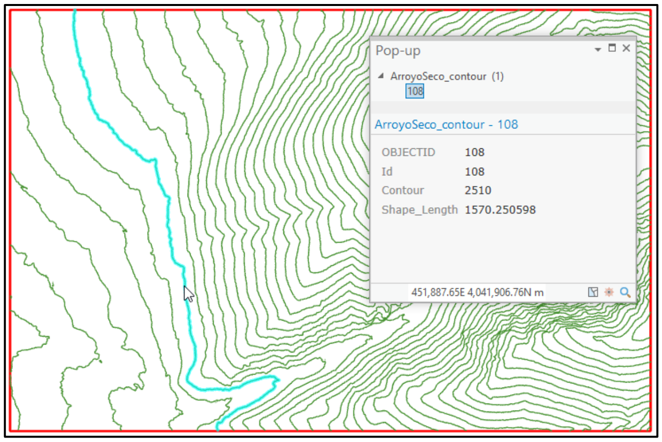
To create a feature class with elevation contour lines, like those that appear on topographic maps:



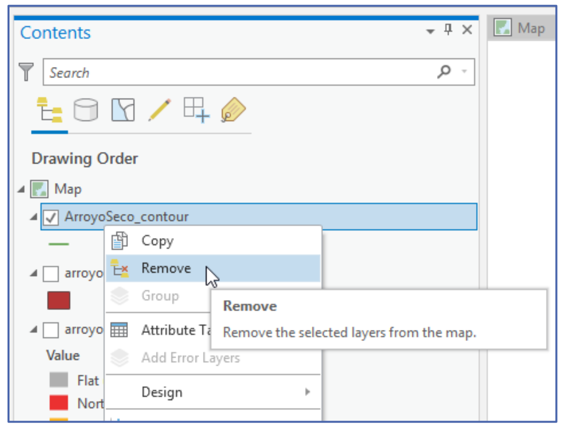

1) In the geoprocessing pane, click the back arrow to return to the search bar, type “Contour” into the Find Tools search bar.
2) Click the Contour (3D Analyst) tool to open it
3) Under Input Raster select ArroyoSeco_DEM
4) Rename the output feature class to “ArroyoSeco_contour”
5) Enter ‘10’ for the contour interval
6) Click Run

The contour line feature class will appear in the Map window once the file is processed.

7) Turn off the other layers by unchecking the boxes next to the layers in the Contents pane




8) Click on a contour line – a pop up will appear with the attributes for the line including the elevation (in meters).

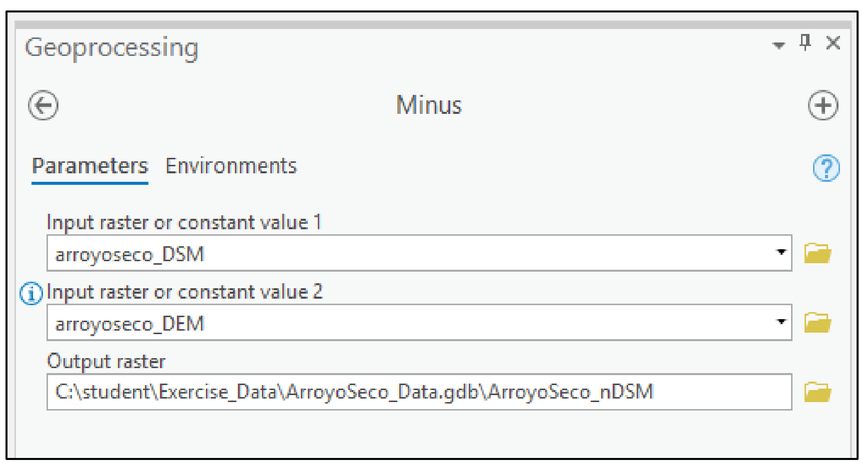



9) Before beginning the next section remove the contour, aspect, slope, arroyoseco_buildings and hillshade layers from your map.
   In the **Contents pane, right click on the layer and select Remove.** When you are done removing layers, you should just have the DSM, DEM and LAS Dataset remaining in your map.

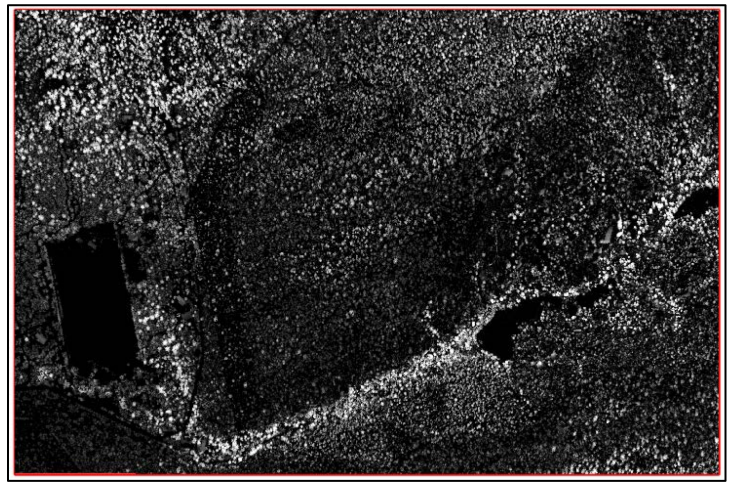
# Part 3. Calculating Vegetation Height

To calculate vegetation height, you will create a raster file called a normalized Digital Surface Model or nDSM that shows the height of features above the ground. Previously, you created two raster files -- the DEM which shows the ground elevation, and the DSM which shows the elevation of features on top of the ground. You will subtract the values in the DEM from the values in the DSM to create a nDSM.

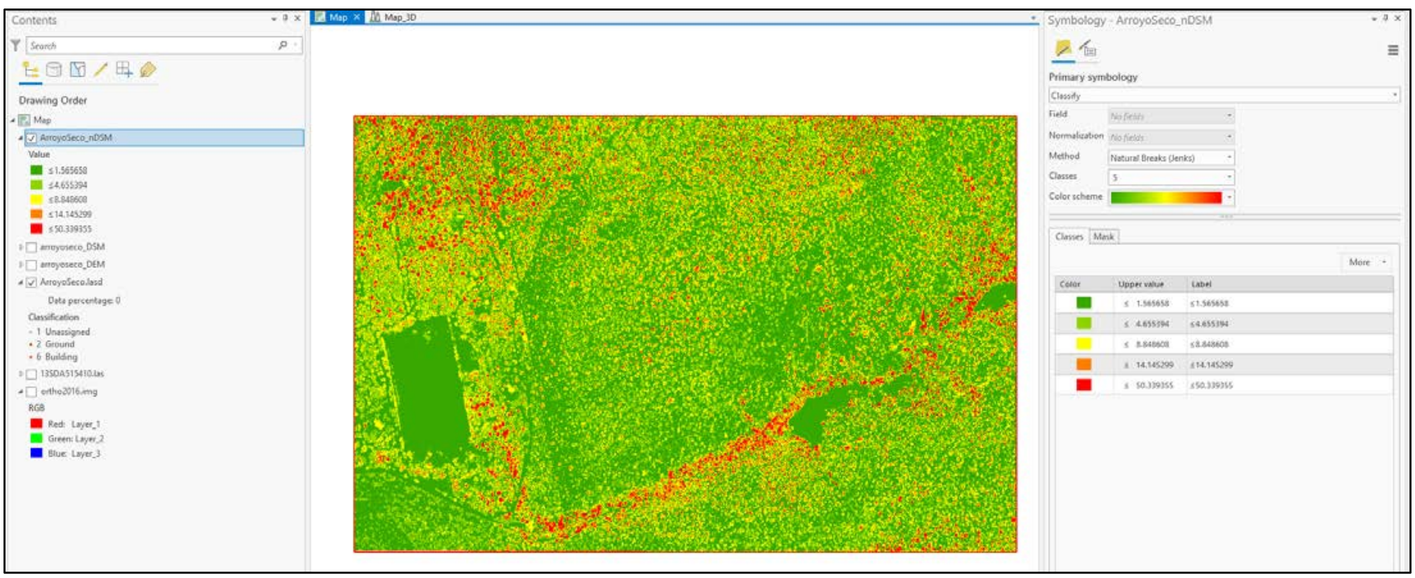
1) In the geoprocessing pane, click the back arrow to return to the search bar.
   Type the word “Minus” into the Find Tools search bar.
2) Click the Minus (3D Analyst) tool to open it
3) Under Input Raster or constant value 1 select ArroyoSeco_DSM
4) Under Input Raster or constant value 2 select ArroyoSeco_DEM
5) Name your output raster: ArroyoSeco_nDSM
6) Click Run



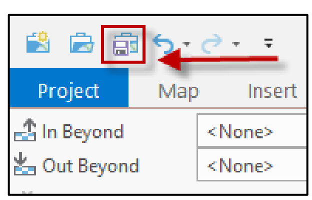
7) Go to the Symbology pane on the right side of your ArcGIS Pro window, by toggling to the tab at the bottom of the Geoprocessing pane.
8) Under Primary Symbology change the type to "Classify"
9) Keep the default (Natural Breaks, 5 Classes)
10) From the drop down menu choose this color ramp:

The following image represents vegetation height. The dark green areas are the shortest features, including areas with bare ground. The bright red areas indicate the tallest trees. Zoom into the image and click different trees to find out their heights. All heights are in meters.



11. Be sure to save your Project
 Look at the top menu and click on Save



# Part 5. Calculating Canopy Density

Forest canopy density is used as a variable in a number of environmental applications, such as biomass estimation, vegetation coverage, and biodiversity determination. Canopy density, or canopy cover, is the ratio of vegetation to ground as seen from the air.

The following are steps to calculate canopy density from LiDAR points. First, you need LiDAR that has been classified into ground returns (bare earth) versus non-ground returns. This type of point classification is usually performed by your data provider. Secondly, you need to consider when the LiDAR was collected and the type of vegetation in the study area. If there are a lot of deciduous trees and the collection was performed during winter (leaf off), the density calculation is not going to work.

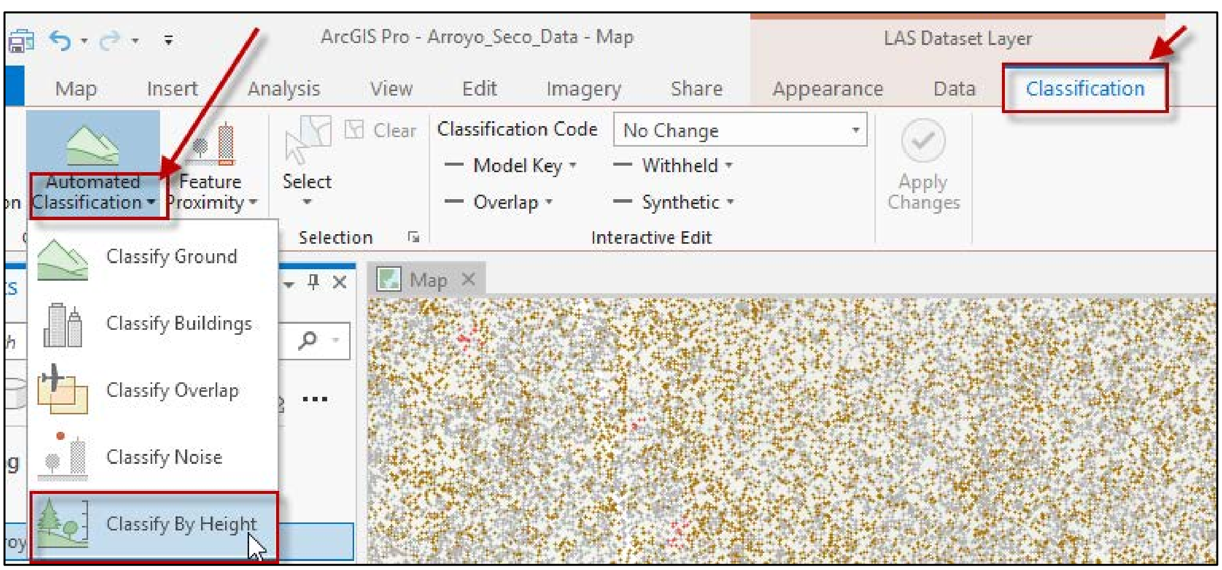
The most effective way to determine the canopy density is to divide the study area into many small equal-sized units through rasterization. In each raster cell, you compare the number of above ground points to the total number of points.

The important technique to remember here is to determine an appropriate **cellsize** for this analysis. It needs to be at least four times the average point spacing. You can go larger but not smaller with the cell size.

### Part A) Classify LAS by Height

You have already classified buildings in our point cloud, our next goal is to classify our point cloud by height above ground.

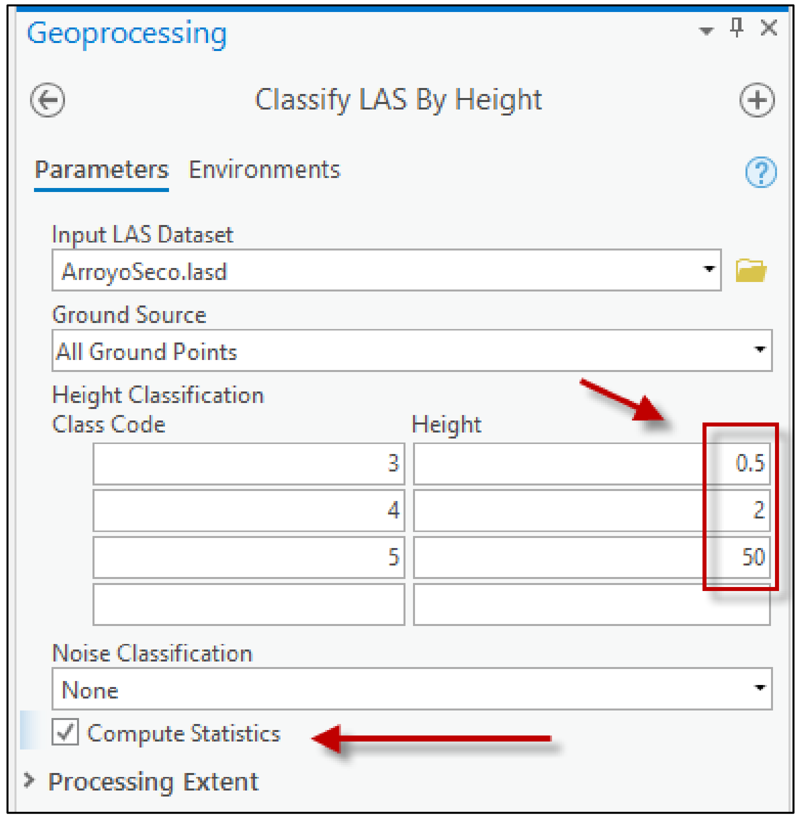
1) Click once on your **ArroyoSeco.lasd** file in the contents pane to enable the **LAS Dataset Layers** at the top Menu.
2) Click on **Classification Tab** and then click on the drop down arrow for **Automated Classification** and select **Classify by Height**.



3) Under Input LAS Dataset choose **ArroyoSeco.lasd** from the drop down menu
   Change the Height values to **0.5, 2 , 50** (these values are in meters), leave the height classification codes as they are.

   *These settings will classify the lidar; Code 3 – Low vegetation points from 0 - 0.5 meters, Code- 4, Medium Vegetation points from 0.5 to 2 meters, Code 5 High vegetation from 2 to 50 meters. See Classification Table below.*

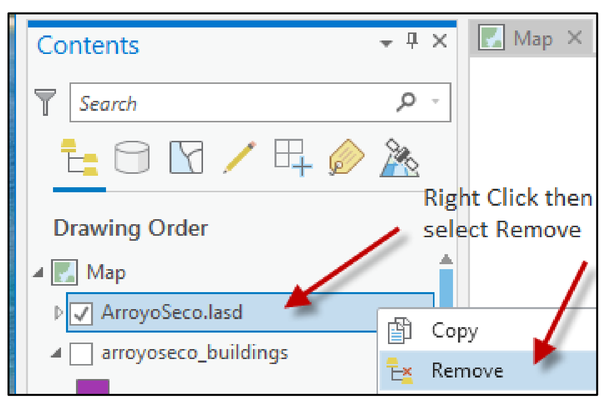
4) Check Compute Statistics
5) Then check RUN.
6) Note - This process only classifies unassigned points (Classification Code 1) so the buildings class (Code 6) will not be changed.




For more information the Classifications Codes 1-6 are:

| Classification Value | Meaning |
|---|---|
| 0 | Never Classified |
| 1 | Unassigned |
| 2 | Ground |
| 3 | Low Vegetation |
| 4 | Medium Vegetation |
| 5 | High Vegetation |
| 6 | Building |

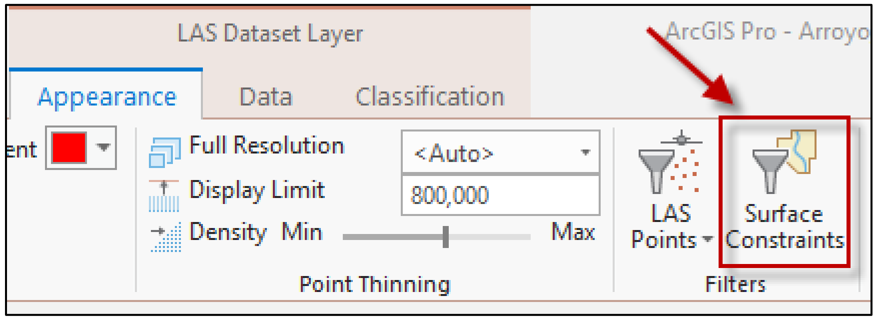
Since we have changed the classification we need to refresh our data values before we display them. The best way to do this is to remove our ArroyoSeco.lasd and then re-add it to our Contents Pane.



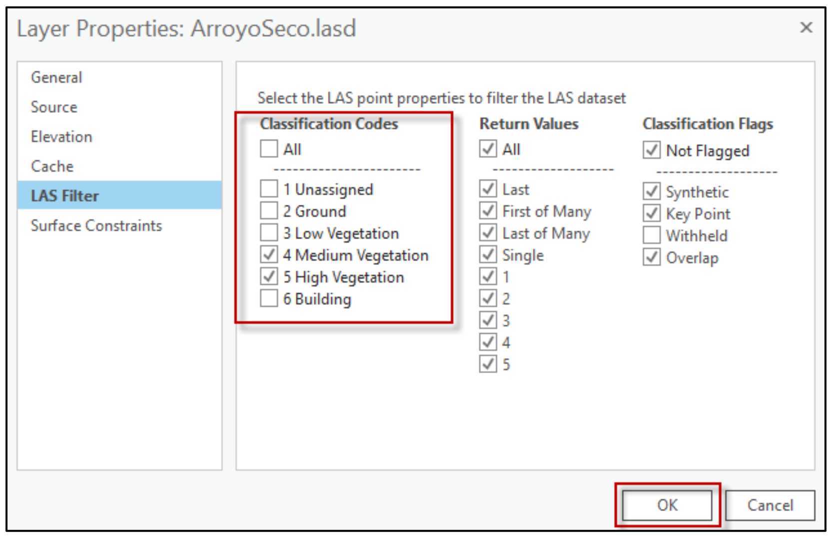

7) From the Contents Pane, **Right Click** on the ArroyoSeco.lasd file and then select **Remove.**
8) Now go back to the Catalog Pane and add that same ArroyoSeco.lasd file to your map. If you cannot find it be sure to look in your C:\Student\Exercise_Data\Arroyo_Seco_Data folder.

Now you will look to see how the points were classified. Since you are only interested in tree canopy you let's display only Classification Code Values 4 and 5: Medium and High Vegetation

9) From the LAS Dataset Layer menu click on Appearance and under filters select **Surface Constraints**




10) Then select LAS Filter: And only check **Medium and High Vegetation** to be displayed. Then click OK.



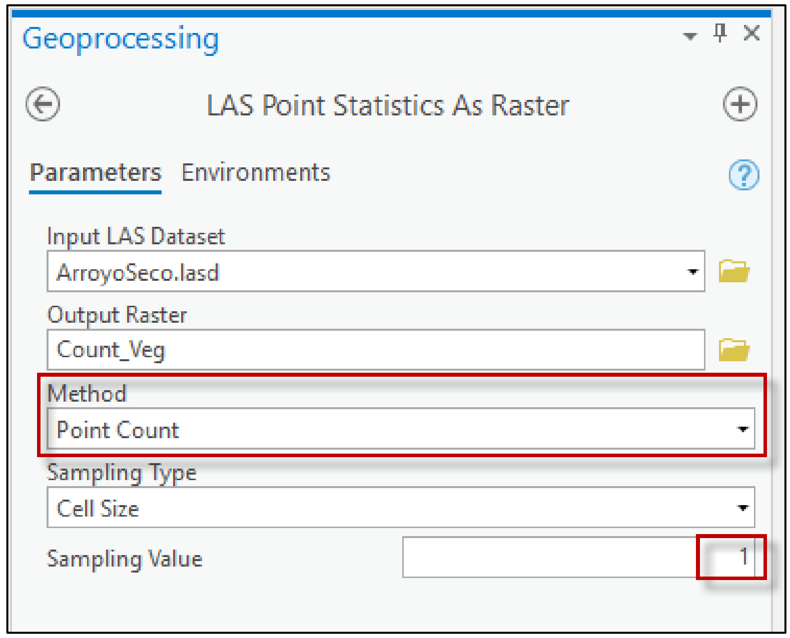

11) To view the difference between the two classes, open the Symbology Pane and select Draw points using Classification.


12) Turn on the Ortho2016.img and compare the imagery with the point cloud. Zoom in and you will notice more detail with the LiDAR points.
For the classification, only unassigned points were classified by height, buildings were not reclassified and so they were left out. NOTE: There may be some buildings missed by our buildings footprints shapefile and those would be mistakenly classified as high vegetation.

### Part B) Convert Medium and High Vegetation LiDAR points to a Raster

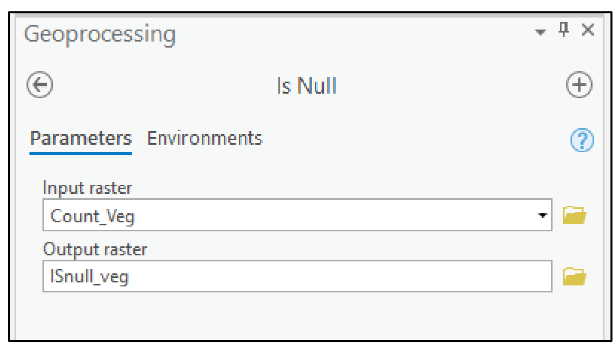
At the end of Part A you filtered our LAS points to only view classification codes 4 and 5, (Medium and High Vegetation). You will now convert only those points to raster.

1) In the geoprocessing pane, enter "**LAS Point Statistics as Raster**" in the Find Tools search bar."
2) Click LAS Point Statistics as Raster to open the tool.
3) Under Input LAS Dataset choose **ArroyoSeco.lasd** from the drop down menu
4) Change the name of the output file to **Count_Veg**.
5) Change the Method to **Point Count**
6) Change the Sampling Value to **1**.
7) Click **Run**



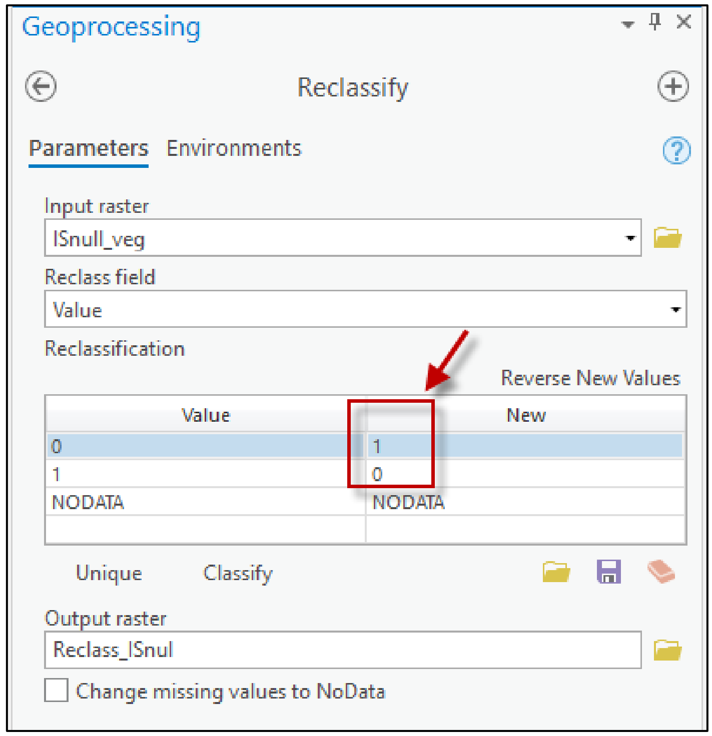

If you look at the results of Count_Veg, you will notice no data values. You need to fix this raster so that no data has a value in order to determine percentage of canopy.

8) In the geoprocessing pane, click on the back button to get to Find Tools, enter "**Is Null**" in the Find Tools search bar."
9) Set the **Input Raster as Count_Veg** and the Output Raster as **ISnull_Veg**
10) Click **Run**.




Look at the results of ISnull_veg. The values are opposite what we need to run our analysis. Canopy is 0 and no canopy is 1, so to fix this we will use the reclassify tool.

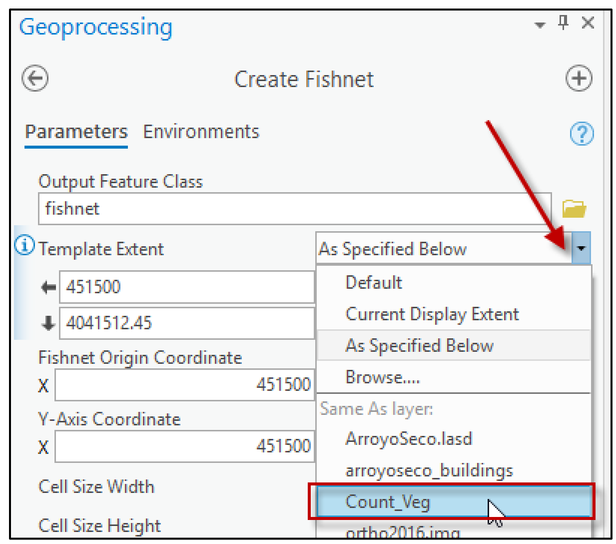
11) In the geoprocessing pane, click on the back button to get to Find Tools, enter “**Reclassify**” in the Find Tools search bar.”
12) For input raster **ISnull_veg**
13) Reclass field is **Value**
14) Then under New type **1, 0**
15) Output raster : **Reclass_ISnull**
16) Then click **RUN**.



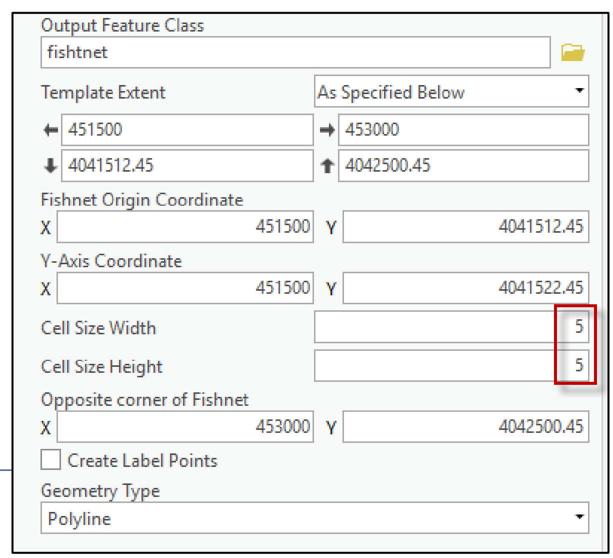

Now when you view Reclass_ISnul you will see that canopy now has a value of 1 and no canopy has a value of 0. (you can look at Ortho2016.img to compare where there is canopy).

### Part C) Calculate Percent Canopy Density

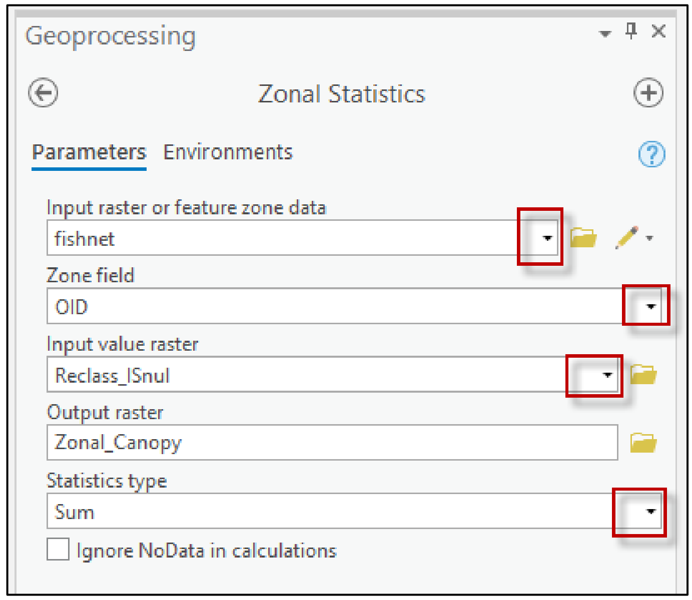
One way to determine canopy density is to divide the study area into many equal-sized units and then compare the number of canopy pixels with non-canopy pixels. In this next step, you will do this by creating a regular sized 5x5 meter vector lattice and then running a command using Zonal Statistics.



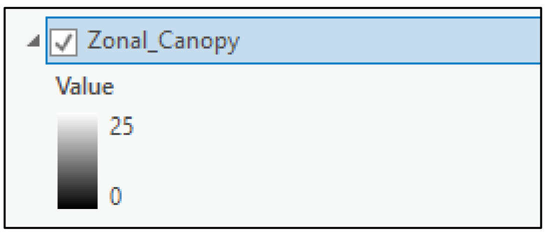

1) To create a lattice from which you will summarize our canopy cover use the Fishnet command.
2) In the geoprocessing pane, click on the back button to get to Find Tools, enter “**Create Fishnet**” in the Find Tools search bar.”
3) For in output feature class enter ‘fishnet’
4) For **Template Extent** click on **As Specified Below** and choose Same as Layer **Count_Veg**. This will populate the extent settings.
5) For Cell Size Width enter 5
6) For Cell Size Height enter 5
7) For Geometry Type select **Polygon**
8) Then click **RUN**.



In your map you will now see the 5x5 meter grid. Our next step is to summarize the number of canopy pixels within each 5x5 meter area.



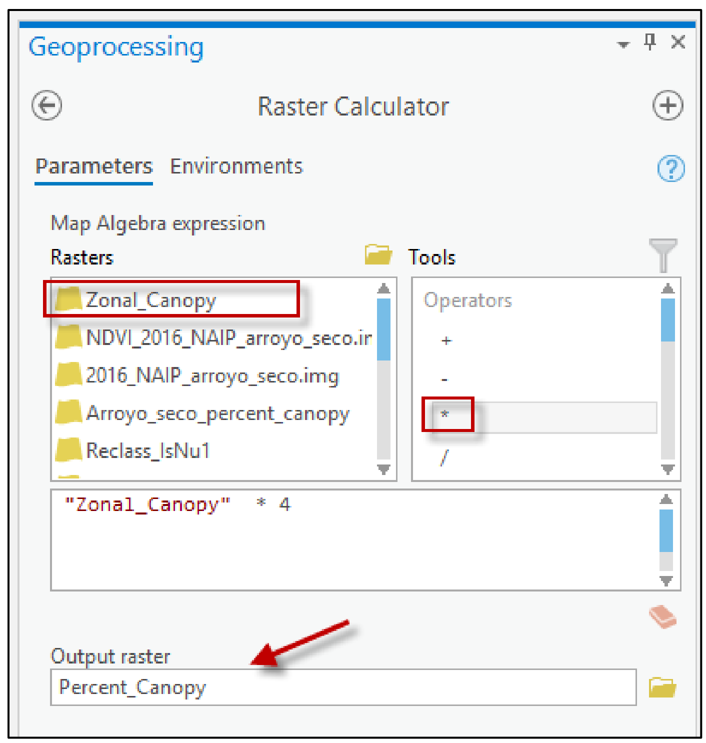

9) In the geoprocessing pane, click on the back button to get to Find Tools, enter "**Zonal Statistics"** in the Find Tools search bar."
10) Input feature zone data select your **fishnet** layer
11) Choose the zone field **OID**
12) Input value raster: **Reclass_ISnull**
13) Name your output raster **Zonal_Canopy**
14) Statistics Type: **SUM**
15) Then click **RUN**.



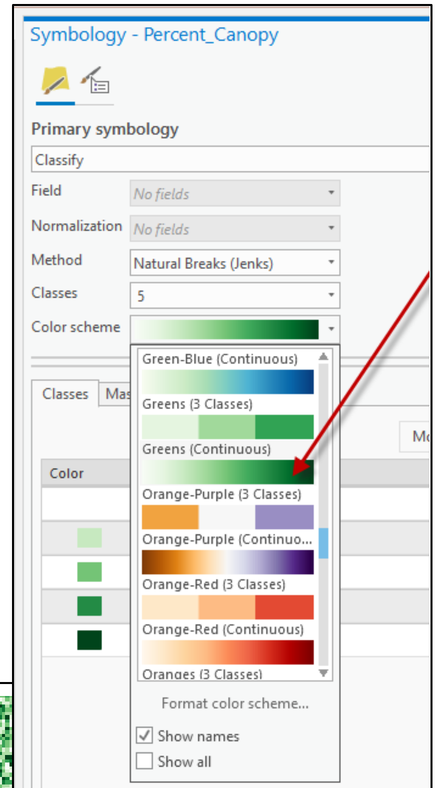

The Zonal Canopy Results will appear in your map. Notice that the highest value is 25. Since we were counting the number of 1 meter pixels in a 5x5 meter grid the highest total or 100% canopy is 25. To scale this to range from 0-100% we need to multiply these values by 4.

16) In the geoprocessing pane, click on the back button to get to Find Tools, enter "**Raster Calculator"** in the Find Tools search bar."
17) Once Raster calculator is open, double click on the Raster **Zonal_Canopy** so that it appears in the box below. Then double click on the **multiplication symbol** and then type in **4**.
18) Name the output raster **Percent_Canopy**
19) Then click **RUN**.

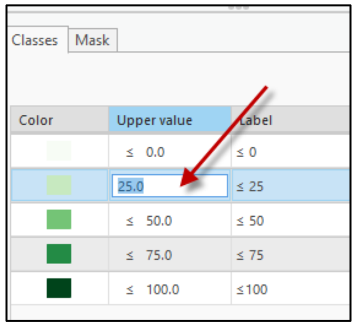
You now should have your Percent Canopy Raster that totals 100.



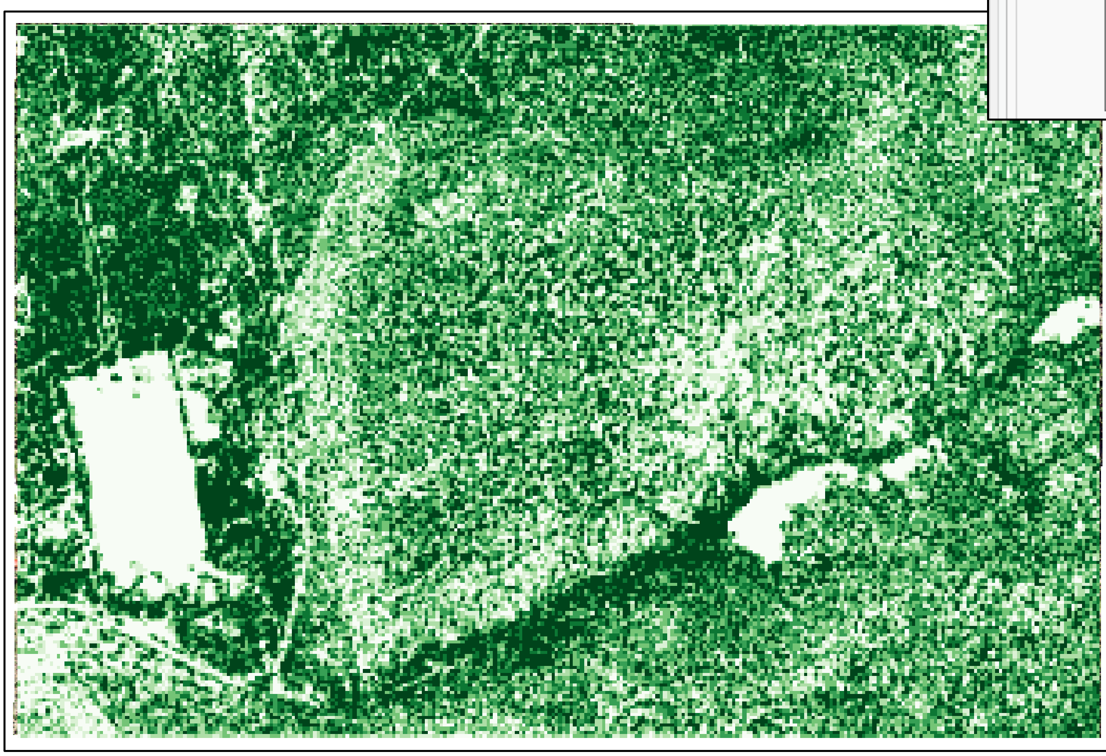
20) Now Change the Symbology so your Percent Canopy is classified using **5** classes and use a green (Continuous) color ramp




21) Type in the Class Breaks **Upper Values** to
0 , 25, 50, 75, 100
You can type directly on the number to change the values

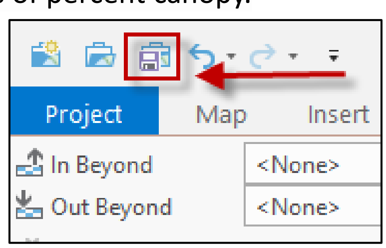



Your image should look similar to the image below.



22) Click the image in different areas to view the percent canopy.
Just use your mouse and click on the image to see values of percent canopy.

23) Be sure to save your project before going on to the next section.

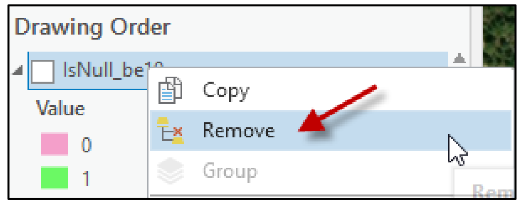


# Part 6. Design a Map Layout

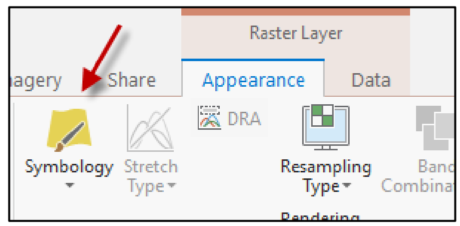
Now that you have created multiple LiDAR products, let's design a map that can provide useful information in a traditional map layout format. You will design a map showing vegetation height.

1. Before you create our map remove all layers from your table of contents **EXCEPT** for
   a. DEM : ArroyoSeco_DEM
   b. DEM Hillshade: ArroyoSeco_DEM_hs
   c. Vegetation Height: ArroyoSeco_nDSM

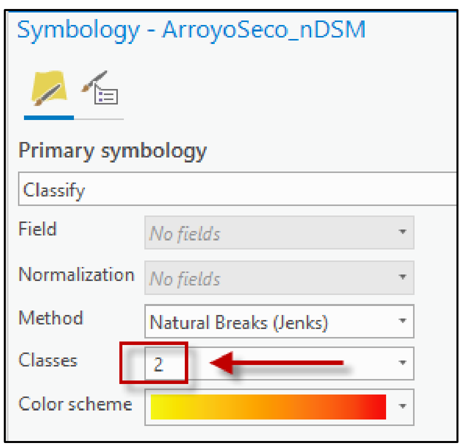
   To remove layers from your view, right click on your data layer and select '**Remove**'



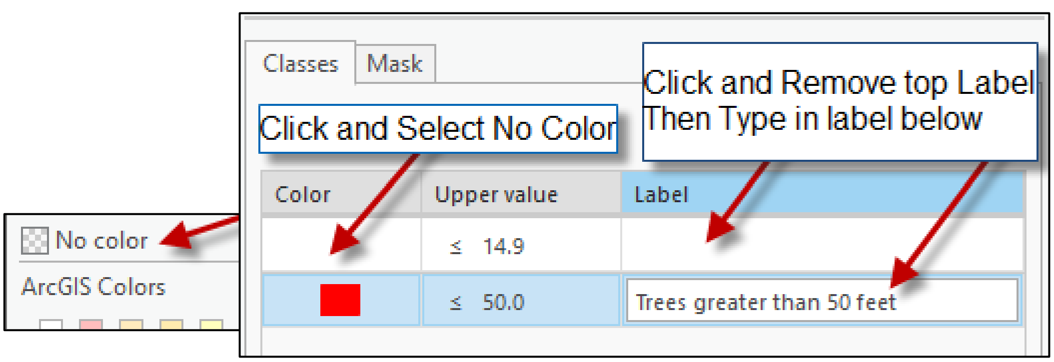

2. Turn on ArroyoSeco_nDSM to see your map to view above ground height values. These values are in meters and you are interested in only looking at the tall trees. Click on Symbology and select Classify




3. Change the number of classes to two.

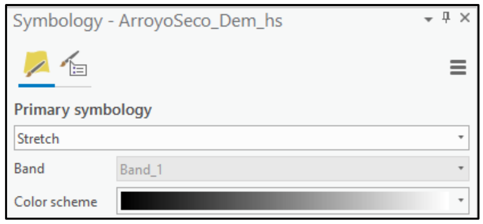


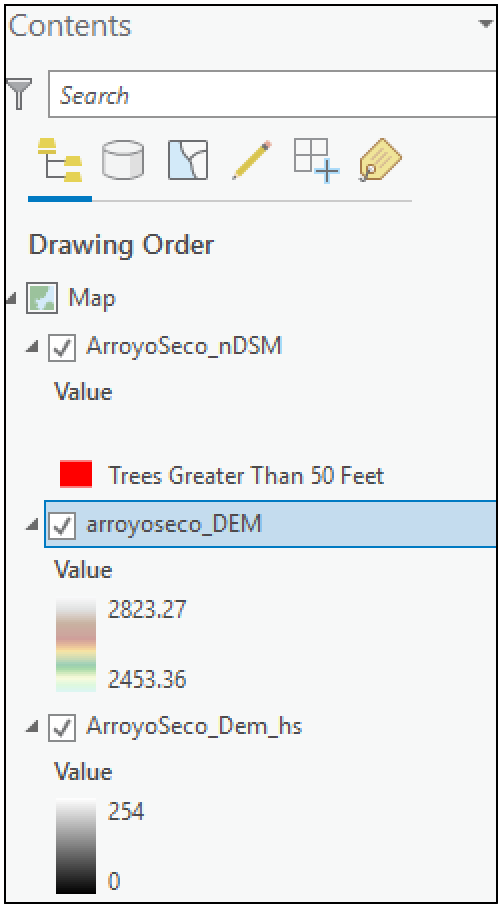

4. Manually enter the Upper Values and Label as shown below. For the first class type 14.9 and the second class type 50 in the Upper Value box. The first class represents areas between 0-14.9 meters, the second class represents areas between 15-50 meters. Click on the color box and select No Color. On the second class leave the color as red and then type in the label 'Trees Greater than 50 Feet' (as 15 meters = approximately 50 feet). Make sure this class is red.



5. Now you should see in your map only Trees Greater than 50 feet as red with your other vegetation heights less than 50 feet will be transparent.

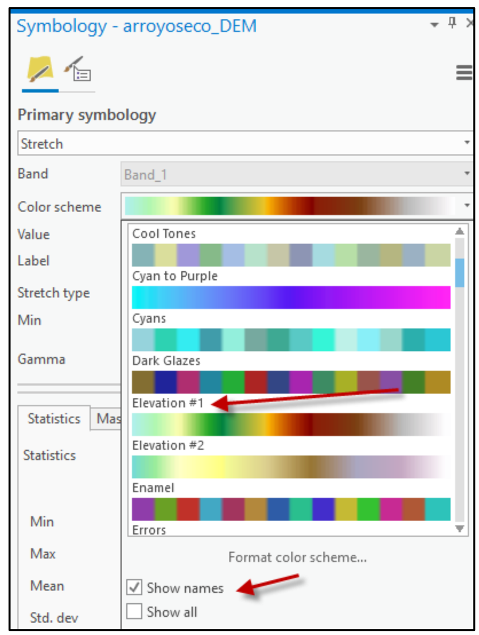
6. Turn on your DEM Hillshade: **ArroyoSeco_DEM_hs** and leave the symbology stretched and grey scale.



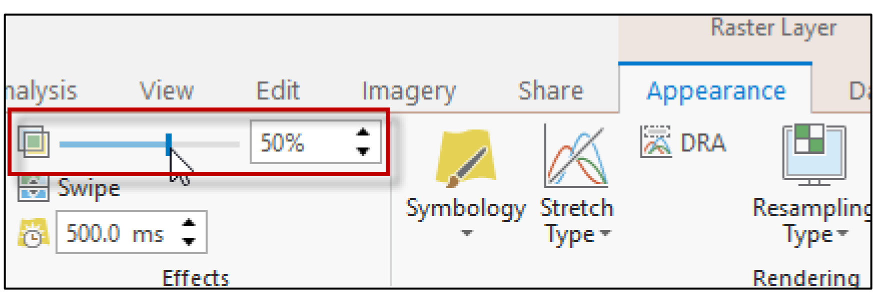




7. Within your Contents Pane make sure your Layers are arranged in the following order as shown on the left.

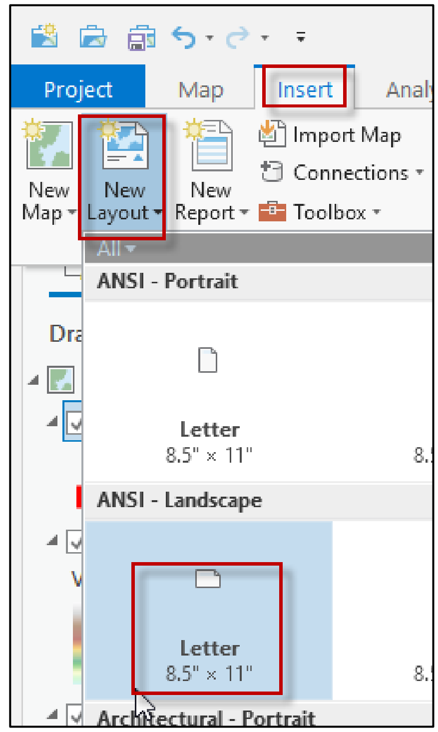
8. Now for your DEM: **arroyoseco_DEM** make sure your layer is turned on and choose the following Color Scheme **Elevation #1**. At the bottom of the menu you can click 'Show Names' to see the names for the Color Schemes.



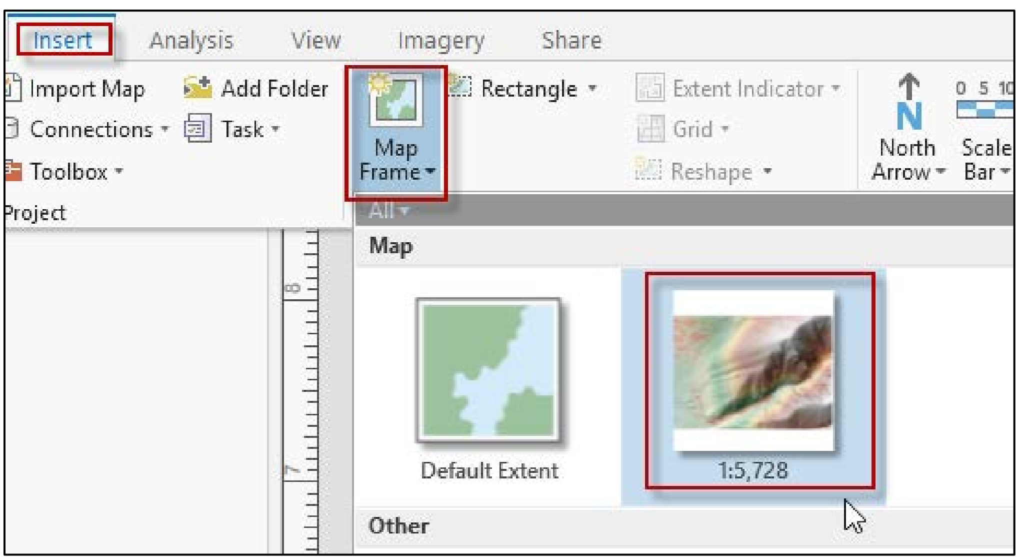

9. Next, Click on Arroyoseco_DEM once to select it and then from the top menu, **Raster Layer / Appearance** menu click on the transparency Slider and go to 50%



10. Now that our layers look that way we want them, it is now time to put them into a map layout.
    From the top menu click on **Insert / New Layout** and then select **ANSI Letter – Landscape 8.5x11**

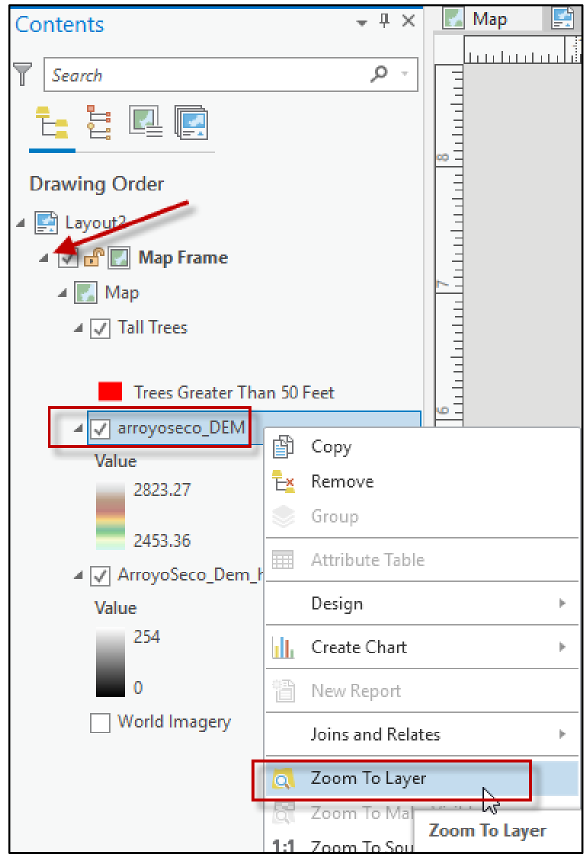



11. This will open a blank layout and then you need to insert the map frame with our data. From the top menu select **Insert / Map Frame** and select your map.




12. Now your cursor will show a rectangle shape, **click and hold to draw a box on the page where you want your map to be placed**. Now you should see the map in your view.

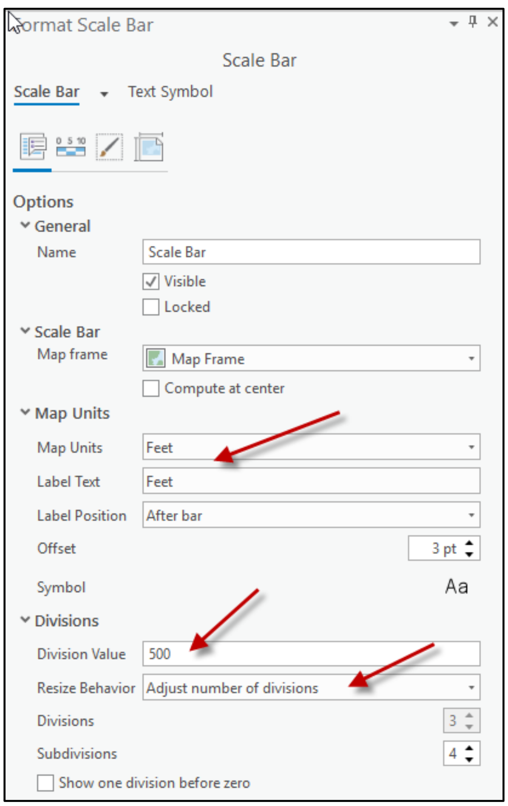
13. It may not look centered in your frame so go back to your Contents pane and click to Expand the Map Frame contents to see all the layers. **Right click on arroyoseco_Dem and select Zoom To Layer.**





14. With The Insert Menu still open you should see other features you can add to your map. Find North Arrow tool and click on the drop down arrow. Pick the style you would like and click on the map and it will paste the north arrow in that location.

15. Now add a Scale Bar. Click on the Scale Bar tool just next to the North Arrow tool. Once you have the scale bar on your map **right click** on the scale bar and then click on properties. This will bring up a window so you can format your scale bar.

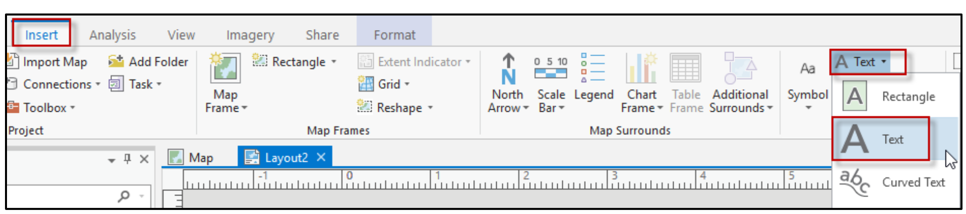



-Change the map units and Label Text to Feet.

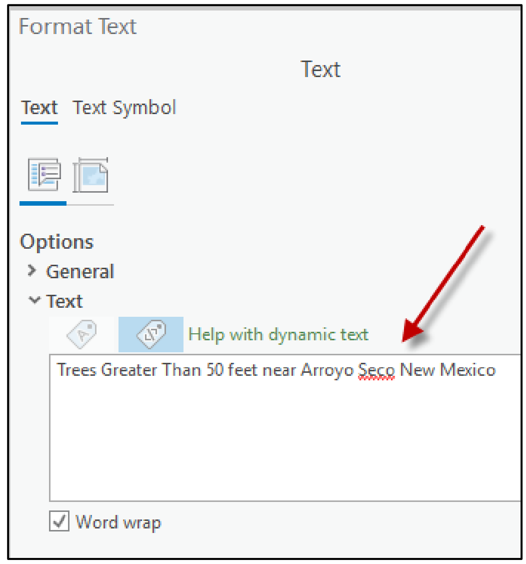
-Change the Resize Behavior under Divisions to “Adjust number of Divisions”

- Change the division value to 500

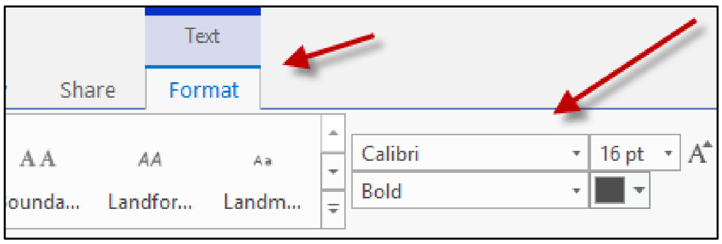
16. Next let’s add a title to our map. Click on Text and then select the simple text as shown below. Click at the top center of your map to place the text.



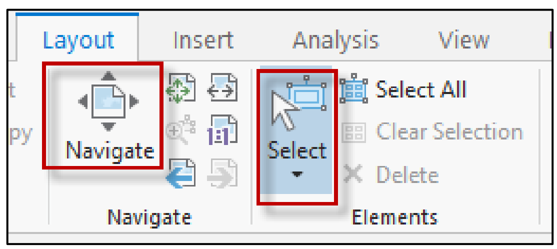
17. This will create a text box on your map and should also bring up the Format Text window where you can enter your text. Enter something similar as to what is here:




18. To increase the size of the text and to change the font. Click on the text box and go to the top menu **Text** and then **Format**

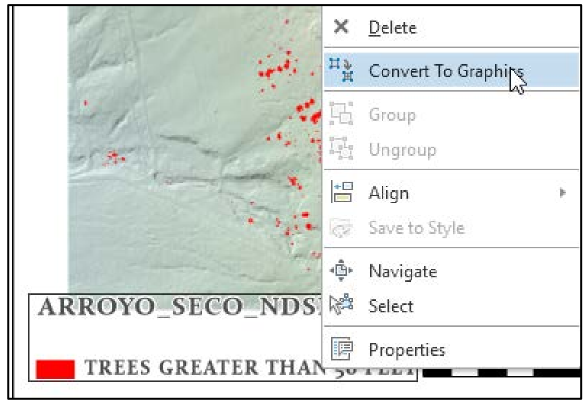



19. To navigate around your layout from to top click on **Layout / Navigate** to pan around To select features click on Select.



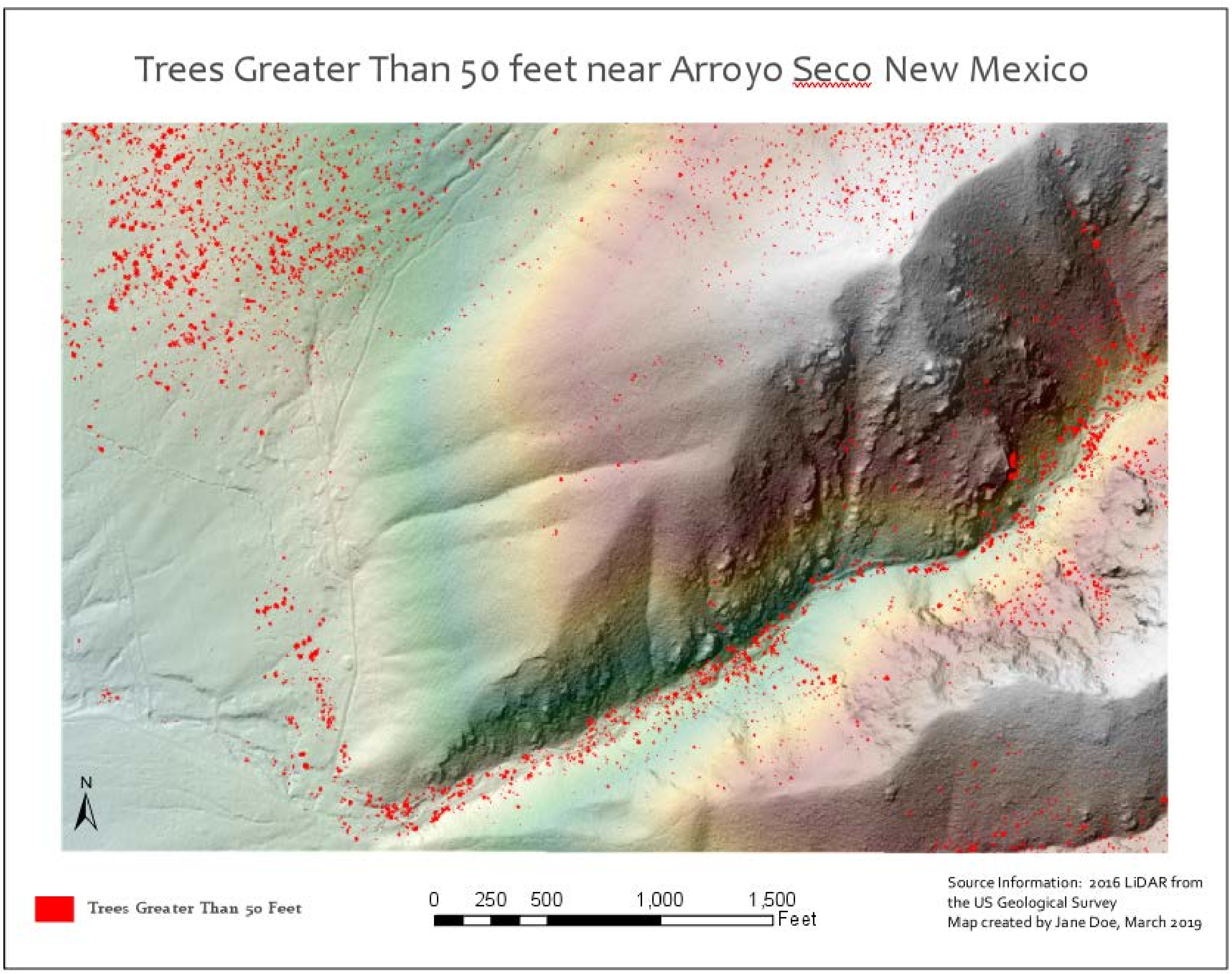

**20.** Next you will insert a legend. You will add the trees greater than 50 feet to a legend. Click once to highlight Arroyo_Seco_nDSM in your Contents Pane. Then from the top menu select **Insert / Legend** then click on your map where you would like to up your legend. It will then create a legend for the item you highlighted in the Contents Pane.

**21.** Since you don't need all of the information in the legend, such as layer name, you will convert it to a graphic and edit. **Right Click** on the legend and then select **Convert to Graphic**.

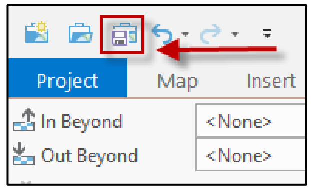



**22.** Then right click on the legend and select **Ungroup**. Now you can remove everything but the red color box and 'Trees Greater than 50 feet'. Select the item you want to delete and then hit the delete key.

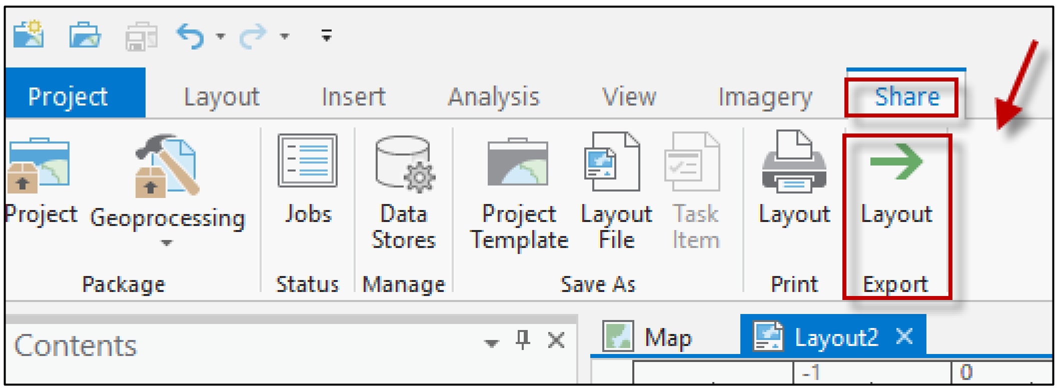
23. Finally you will add source information to our map. Insert another text box and add the following information: Source Information: 2016 LiDAR from the US Geological Survey. Choose a smaller font and put in either the lower right or lower left corner. Also add your name and date in the bottom corner.



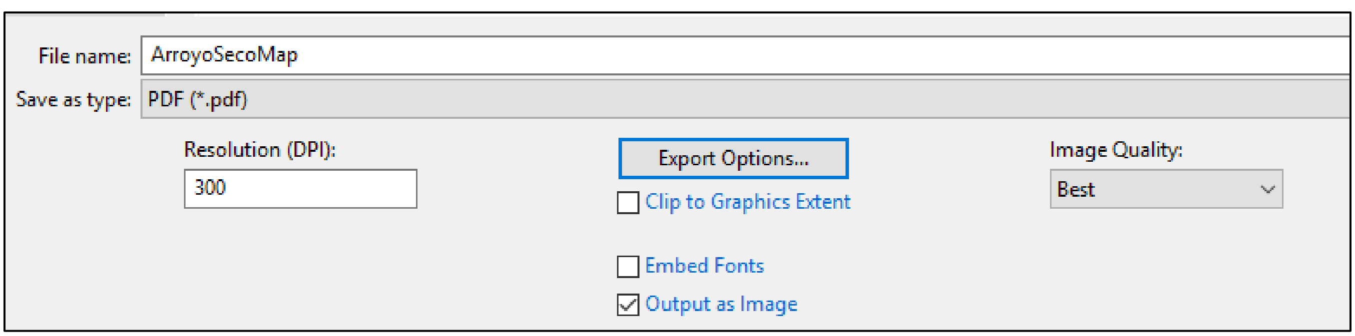
24. Now save your project one more time.




25. Lastly you will convert our map to a PDF. From the top menu select **Share/Layout/ Export**.




26. Give your file a name and save as PDF with 300 dpi resolution. Output as Image. Save this in your student folder. Open the file to look at your final product.




This is the end of Exercise Part B and
you are finished with the LiDAR workshop.