Introduction to LiDAR in GIS: Fundamentals and Applications

LiDAR point-cloud data contain high-resolution information about the earth's surface – terrain, hardscape, and vegetation. These data can be applied to virtually any field of study and are a useful addition to your GIS analysis. The purpose of this workshop is to gain basic skills in loading, viewing, manipulating, and processing LiDAR data in ArcGIS Desktop 10.5.

By the end of this workshop, you will be able to:

- Create an LAS Dataset
- Calculate and view data statistics
- Visualize the data in 2D and 3D in a variety of ways
- Construct high-resolution digital elevation models (DEM) and digital surface models (DSM)
- Become familiar with several applications of LiDAR data for problem solving

Getting Started

- Open ArcMap. If necessary, connect to the D:\IntroToLidar folder and open IntroToLidar_Initial.mxd.
- Go to Customize > Extensions and make sure 3D Analyst and Spatial Analyst are selected.

Activity 1

A LAS dataset stores reference to one or more LAS files on disk, as well as to additional surface features. An LAS file is an industry-standard binary format for storing airborne lidar data. The LAS dataset allows you to examine LAS files easily and quickly obtain detailed statistics and inspect the areal coverage of the lidar data contained in the LAS files. *Note: Statistics are important to calculate because point filters will not work properly without them!*

TOOLS USED

LAS Dataset Statistics (Data Management):

Calculates or updates statistics for a LAS dataset and generates an optional statistics report.

1.1 Creating an LAS Dataset

- 1. In the ArcCatalog window, right-click on the IntroToLidar folder and select New > LAS Dataset.
- 2. Name it ClemsonCampus.lasd. Right click on the name and open the Properties.
- 3. Click LAS Files tab, click Add Files button.
- 4. Navigate to D:\IntroToLidar\LAS_Files and add the following files:

    - 20110319_SC_PickensCo_2011_000034.las
    - 20110319_SC_PickensCo_2011_000035.las
    - 20110319_SC_PickensCo_2011_000040.las
    - 20110319_SC_PickensCo_2011_000041.las
    - 20110319_SC_PickensCo_2011_000065.las
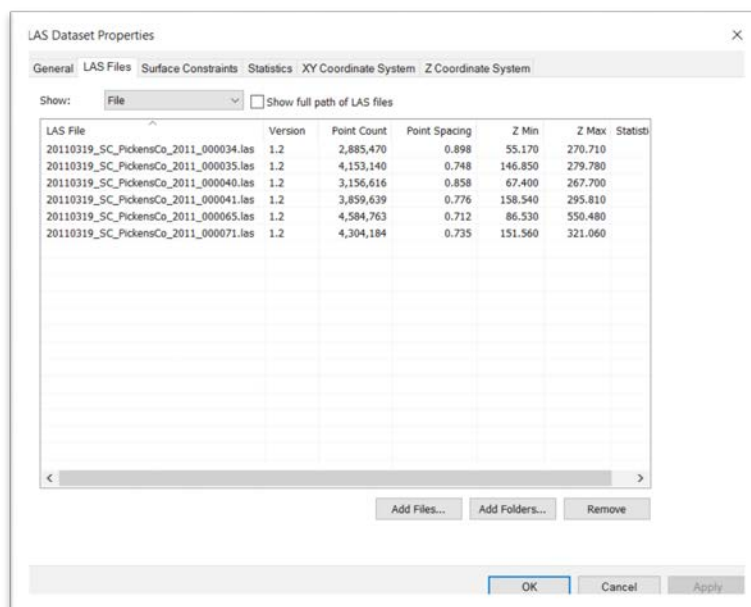   - 20110319_SC_PickensCo_2011_000071.las

Figure 1. LAS Dataset Properties showing the LAS files added to ClemsonCampus.lasd.

- 5. Go to the Statistics tab and click the Calculate button to generate statistics.
- 6. On the General tab, select the Store relative path names to data sources check box. Click Apply.
- 7. Go to the XY Coordinate System tab.

Q. What is the XY coordinate system of the LAS Dataset? What is the unit of distance?

You have now created an LAS Dataset file that points to six LAS files and calculated statistics about the point cloud data. The dataset is in a projected coordinate system. Let's add the dataset to our map and view the data.

- 8. Click OK to close the Properties window.
- 9. Drag ClemsonCampus.lasd from the ArcCatalog window into the map.

Figure 2. The boundaries of individual LAS files in ClemsonCampus.lasd

Notice the four red boxes showing the boundary of each individual .las file in the dataset. Look in the Table of Contents and notice that the Data percentage says 0. At this zoom level (around 1:14,500) there are too many points for the computer to render. We have to zoom in to show the points.

- 10. Go to the Zoomed 1:8000 bookmark.

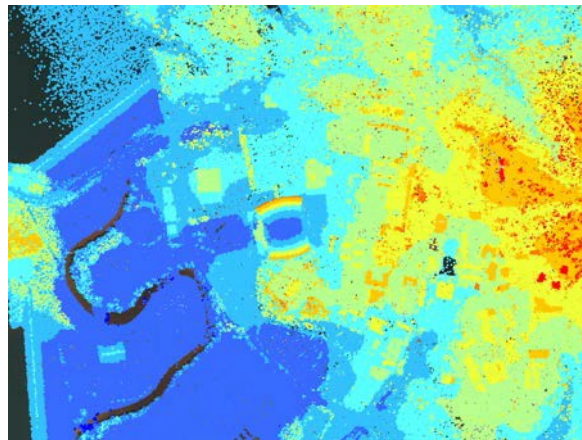At this scale, the computer will now draw the points.

Figure 3. Point cloud data show up at the 1:8000 scale.

Q: What are your observations about the point cloud data being shown?

- 11. Zoom in to 1:200 near the stadium and compare the locations of the points to the imagery layer. Then navigate back to the Zoomed 1:8000 bookmark.
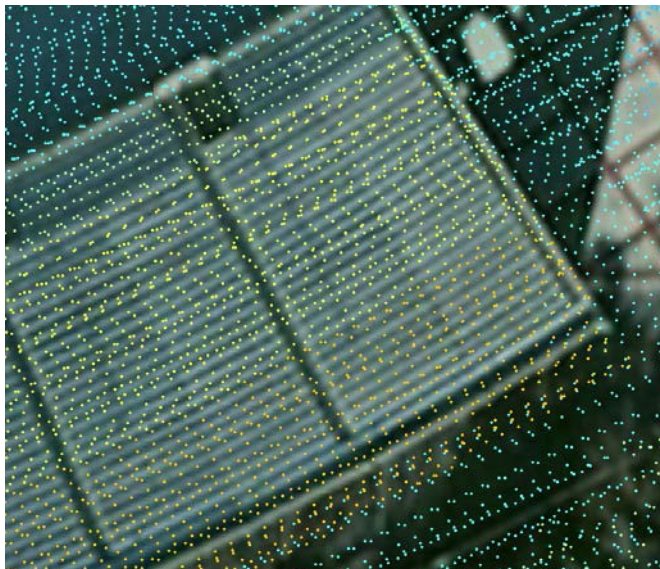

Figure 4. The LiDAR points nearly (but not perfectly) match locations in the aerial image basemap.

We can change the number of points being displayed in ArcMap by adjusting the Display properties. Let's alter the point density and number of points shown.

- 12. Open the ClemsonCampus.lasd properties in the Table of Contents and open the Display tab.
- 13. Change the point limit to 5000000 (5 million) and click Apply. Notice how the Data Percentage changes in the TOC.
- 14. Slide the Point Density slider to Coarse and click Apply. Then change it to Fine and click Apply.

Q: What did this do to the way in which the LiDAR points displayed?

- 15. Set the density to 4 points/cm and click apply.

Now let's visually inspect the point distribution and measure spacing between points. We will compare our measurements to the average spacing for the files.

- 16. Zoom in close enough to clearly see distinct points (about 1:200 scale).
- 17. Open the Measure tool. Measure the point spacing for a few points.

Q: What are the minimum/maximum you find?

Q: What do you estimate as the average point spacing?

Q: What might impact the spacing between points?

- 18. Close the Measure tool window. In the ArcCatalog window, right click on ClemsonCampus.lasd and open the Properties. Go to the LAS Files tab.

Q: What are the point spacings listed in the properties?

Q. How do these compare to what you measured?

1.2 LiDAR Attributes, Classification, Returns, and Data Statistics

When the LiDAR data are collected, the instrument may record multiple reflections, called returns, and labels each point with the return number. The first return from a specific location will be a reflection from the upper-most feature, such as the top of a tree. Successive returns (second, third, and fourth) will be from lower elevations than the first return. If there are no above-ground objects, then the first return will be a reflection from the ground surface. In some situations, such as very dense tree canopies, only the first return may be recorded and ground-return points will be sparse.

LiDAR data are commonly classified, a processing step that adds a classification code describing what type of surface caused the reflection. For instance, if the laser reflected off of the ground, the point may be classified as Ground, or classified as Vegetation if the energy reflected from a tree. Standardized classification formats are published by the American Society of Photogrammetry and Remote Sensing (ASPRS).

When we created the ClemsonCampus.lasd LAS Dataset, we calculated the Statistics, which give us detailed information about point spacing as well as the percentage of points falling into certain classification codes or return types. *Statistics are important to calculate because point filters will not work properly without them!* We will view these statistics and then output the statistics to a file.

- 1. Open the ClemsonCampus.lasd layer properties (if not open already) from the ArcCatalog window and select the Statistics tab.

Q. What percent of the data are 1st returns? 2nd returns?

Q. What are the supplied classification codes?

Q. How might the point spacing affect the usefulness of our LiDAR data?

- 2. Close the Las Dataset Properties window.
- 3. Search for and open the LAS Dataset Statistics (Data Management) tool.
- 4. Set the Input LAS Dataset to ClemsonCampus.lasd. Save the Output Statistics Report Text File as ClemsonStatistics.csv. Click OK to run the tool.

The output text file is in a CSV format which can be opened using a spreadsheet program, such as Microsoft Excel.

1.3 Using the LAS Dataset toolbar

ArcGIS can interpret the .las file classifications and return types and quickly visualize the LiDAR points based on return and classification using the LAS Dataset Toolbar. The data can also be drawn as a surface (a triangular irregular network, or TIN). The toolbar has functions which can be used to view the LiDAR as 2D profiles and in 3D.

- 1. Go to Customize > Toolbars and select LAS Dataset. Notice the ClemsonCampus.lasd file is selected in the dropdown menu.
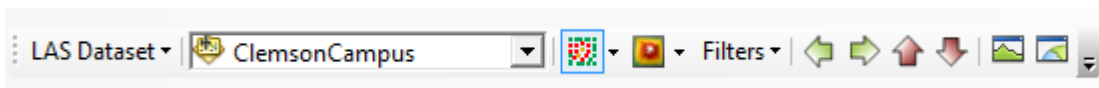

Figure 5. The LAS Dataset toolbar.

The data are displayed initially as points and assigned a color according to elevation.

- 2. Go to the Zoomed 1:8000 bookmark to get a good view of the data.
- 3. Use the Point Symbology dropdown on the toolbar to change to Class. Pan around the map area.
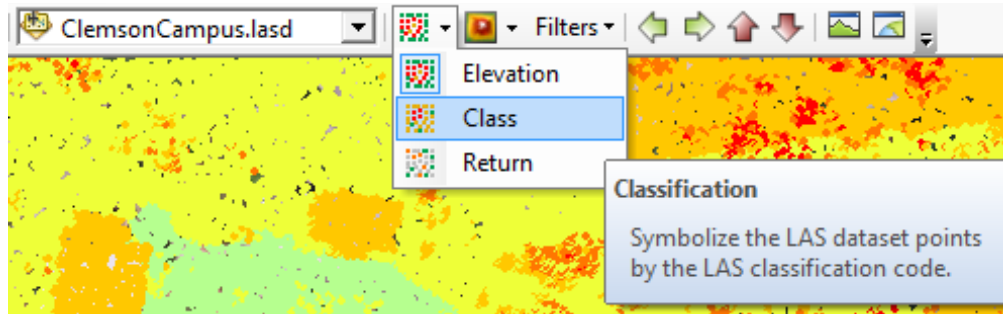

Figure 6. Changing the point symbology from Elevation to Class.

Q. What class codes do you see?

- 4. Change the visualization to Return and pan around the map area.

Q. Are there any locations with 4 returns? (Hint: change the color of the 4th return if needed).

Q. Why would they be in that location?

Surface display illustrates the points as a TIN surface.

- 5. Change the visualization to a surface display which shows the elevation.
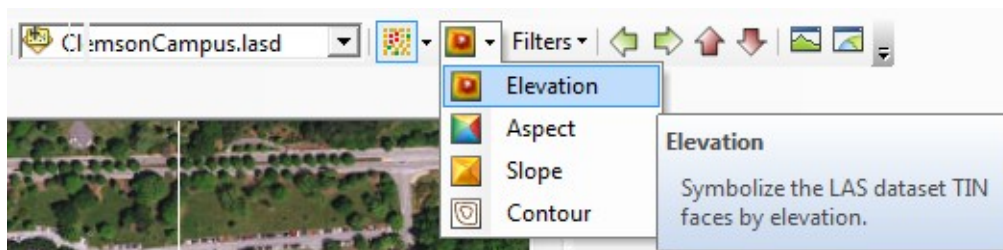

Figure 7. Changing the symbology to a surface based on elevation.

- 6. Experiment with changing the view to Slope, Aspect, and Contour.

Now, let's see how different filters which work on the classification affect the display.

- 7. Change back to a surface showing Elevation.
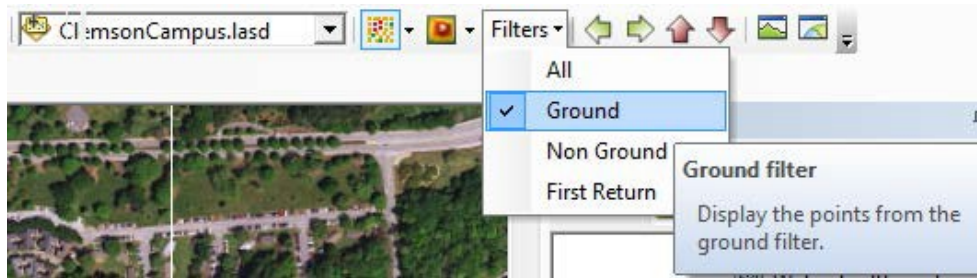- 8. Use the Filters dropdown and select Ground returns.

Figure 8. Filtering the display to show only ground returns.

- 9. Then try Non-Ground and First Returns.

Q. How does the display change based on the return?

1.4 The 2D Profile and 3D Views

The LAS Dataset toolbar has tools to view the LiDAR points/surfaces in 2D along a user-specified profile and in 3D. Any filters applied to the data will be preserved in the 2D and 3D views.

- 1. Change the display to show Elevation and All Returns.
- 2. Navigate to Death Valley Stadium using the Stadium bookmark.
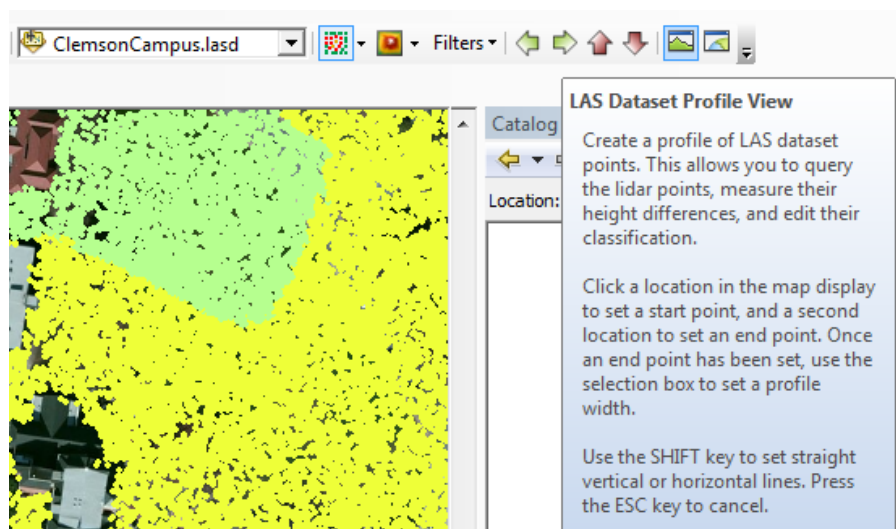- 3. Click on the LAS Dataset Profile View Tool on the LAS Dataset toolbar.

Figure 9. Selecting the LAS Dataset Profile View.

This tool will prompt the user to draw a line which will be profiled in 2D. Once the line is drawn, the user can adjust the width of the box to include the desired amount of points.

- • 4. Draw a roughly northwest-southeast line through Death Valley stadium. Adjust the box to the maximum width and click the mouse.
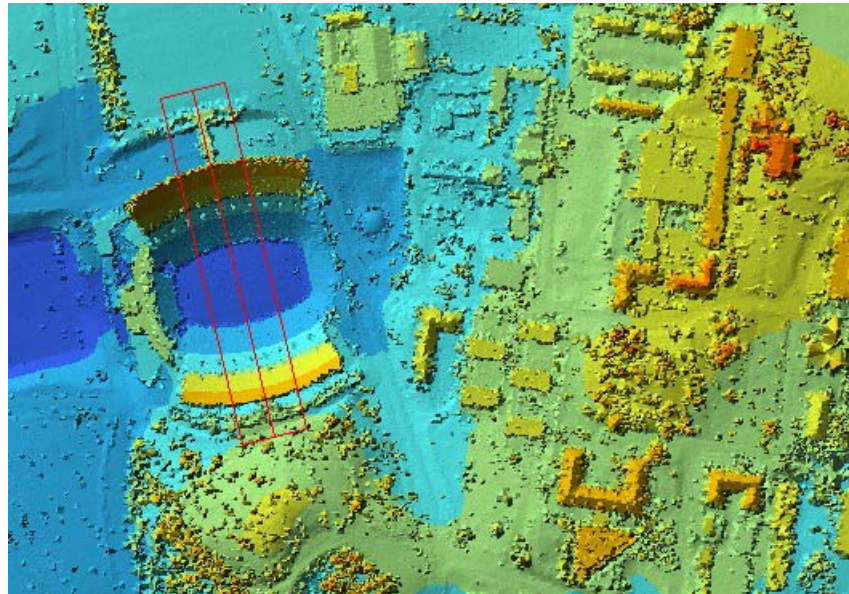

Figure 10. The red box for selecting points to include in the profile view.
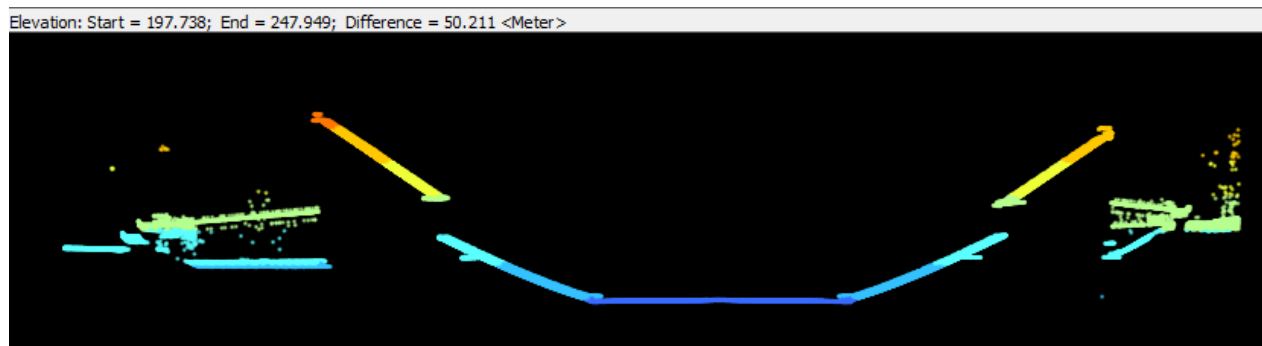
The Profile View window opens.

Figure 11. 2D profile view through Death Valley stadium.

From this view, you can use the zoom and pan tools, identify and select features, and measure distances.

- • 5. Using the Measure tool, determine the height difference from the field level to the top of Death Valley stadium.

Q. What is the height difference?

- 6. Close the Profile View window.

Try some other profiles through the dataset, and see how the width of the selection box affects the displayed profile.

Now let's use the LAS Dataset 3D View to look at the data in 3D. Note that the 3D View will display both points and surfaces, depending on what you have selected.

- 7. Go to the Zoomed 1:8000 bookmark.
- 8. Click on the LAS Dataset 3D View button on the LAS Dataset toolbar.
- 9. Rotate and pan the display. Try different returns or display types.
- 10. Click on the drop-down to change the vertical exaggeration from 1.0 another value and note how the display changes.
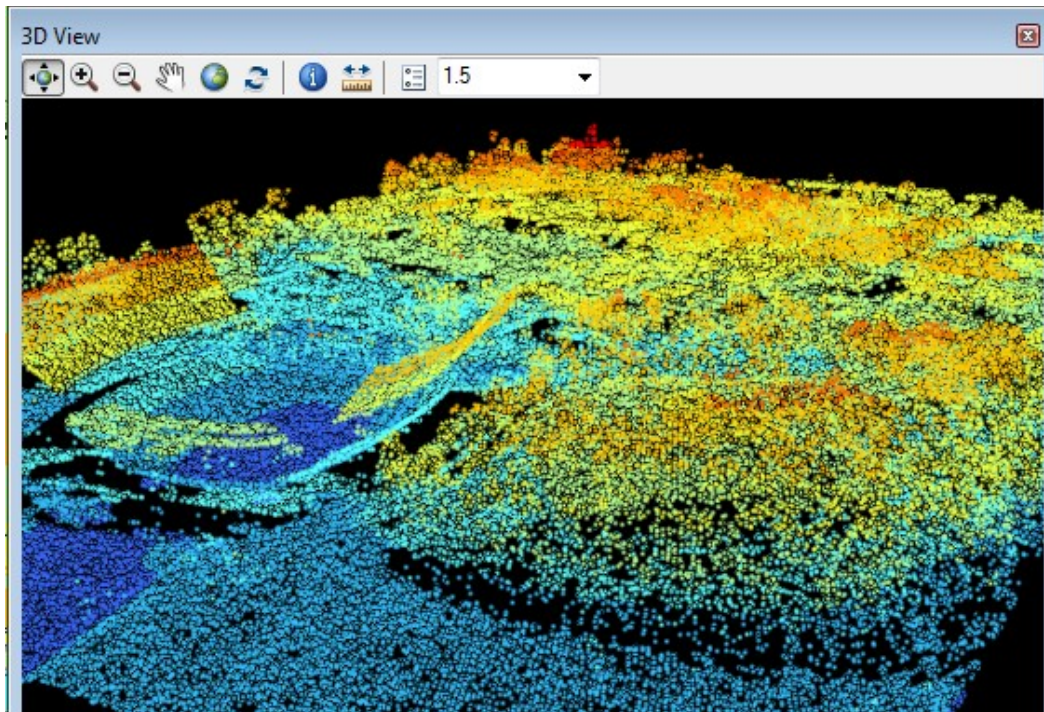

Figure 12. The 3D view of ClemsonCampus.lasd near Death Valley stadium.

Activity 2. Elevation and Surface Models

LiDAR data can have very small point spacings (sub-meter to cm scale!) and thus can represent topography, buildings, roads, forests, and other features with excellent detail. These high-resolution data can be used to create raster elevation models with very small grid spacing. Many of our spatial analysis tools do not work on point-cloud data (yet!) but will work on rasters derived from LiDAR.

Let's use our ClemsonCampus.lasd LiDAR dataset to create high-resolution elevation rasters. We will use only the ground-classified returns to construct a digital elevation model (DEM) and then the first returns to create a model of the highest elevations, called a digital surface model (DSM). We will also create a 3D visualization of our DSM and Clemson university buildings using ArcScene.

TOOLS USED

LAS Dataset to Raster (Conversion):

Creates a raster using elevation, intensity, or RGB values stored in the lidar files (*.las) referenced by the LAS dataset.

Feature to Point (Data Management):

Creates a feature class containing points generated from the representative locations of input features.

Add Surface Information (3D Analyst):

Attributes features with spatial information derived from a surface.

2.1 Construct a Digital Elevation Model (DEM)

We will first create the DEM from ClemsonCampus.lasd using the ground returns.

- 1. Activate the *Elevation_Models* data frame.
- 2. Add the ClemsonCampus.lasd to the data frame. Turn off the Clemson_University_Buildings_2011 layer.
- 3. In the LAS Dataset toolbar, use the Filters dropdown and select Ground.
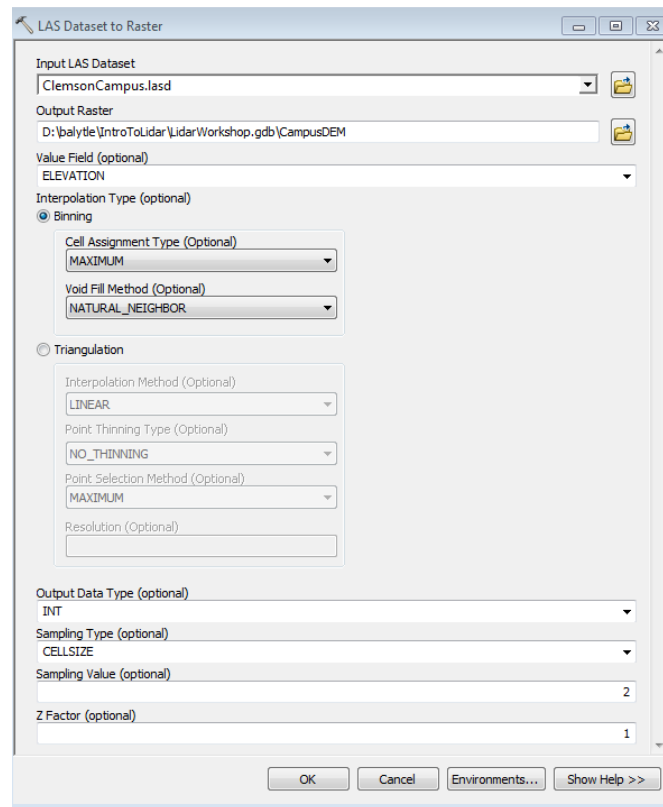- 4. Search for the LAS Dataset to Raster (Conversion) tool.

Figure 13. The LAS Dataset to Raster tool settings.

- 5. Set the input to ClemsonCampus.lasd
- 6. Set the output to LidarWorkshop.gdb and name it CampusDEM
- 7. Make sure the value field is ELEVATION
- 8. Set the binning parameters to MAXIMUM and NATURAL NEIGHBOR.
- 9. Set the output to INT and the sampling value to 2 m.
- 10. Click OK to run.
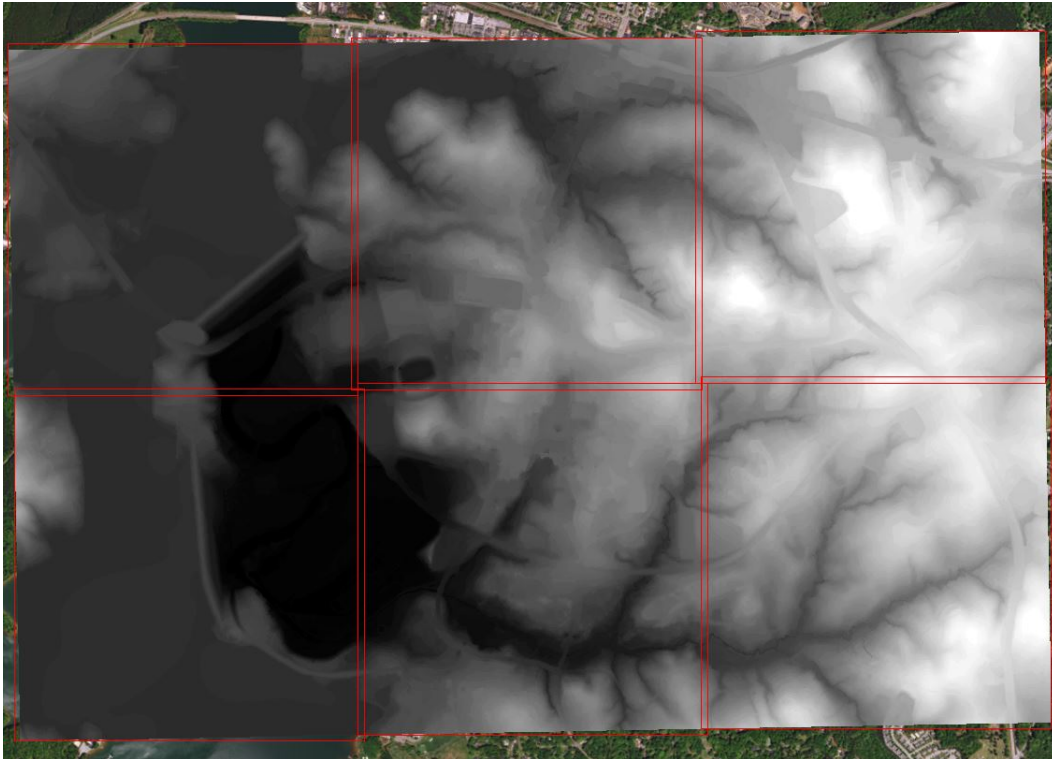
The CampusDEM raster is added to the map.

Figure 14. The CampusDEM raster created from ground returns.

Q: What are the minimum/maximum elevations?

Q. What do you notice about the western edge of campus right next to Lake Hartwell?

Q. What are your observations or remarks on the created DEM?

2.2 Construct a Digital Surface Model (DSM)

Now we will create the DSM using first returns.

- • 1. Change the filter on the LAS Dataset toolbar to First Return and repeat steps 5-10 from above, saving as CampusDSM.

Q. What are the minimum/maximum elevations?

Q. What are your observations on the DSM? How might it be used differently from the DEM?

2.3 Create a 3D Scene of Campus Buildings

We have building footprints for the Clemson University buildings. Using our DSM, we can get the height information for each building polygon and then create a 3D scene in ArcScene which will show these buildings as 3D objects.

- 1. Right click on the Clemson_University_Buildings_2011 layer and select Data>Export Data. Save the output in the IntrotoLidar geodatabase as CampusBuildings2.
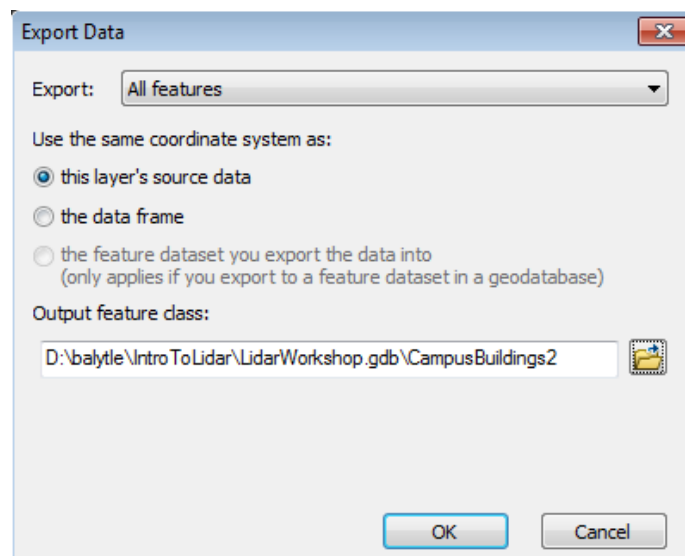

Figure 15. Export data window to create the CampusBuildings2 feature.

- 2. Search for the Feature to Point (Data Management) tool. Set the input features to CampusBuildings2 and save the output as BldgsPts in the geodatabase. Click OK to run the tool.
- 3. Search for and open the Add Surface Information (3D Analyst) tool
- 4. Set the BldgsPts as the input feature class and CampusDSM as the input surface. Check the box to select the Z output property. Click OK to run the tool.
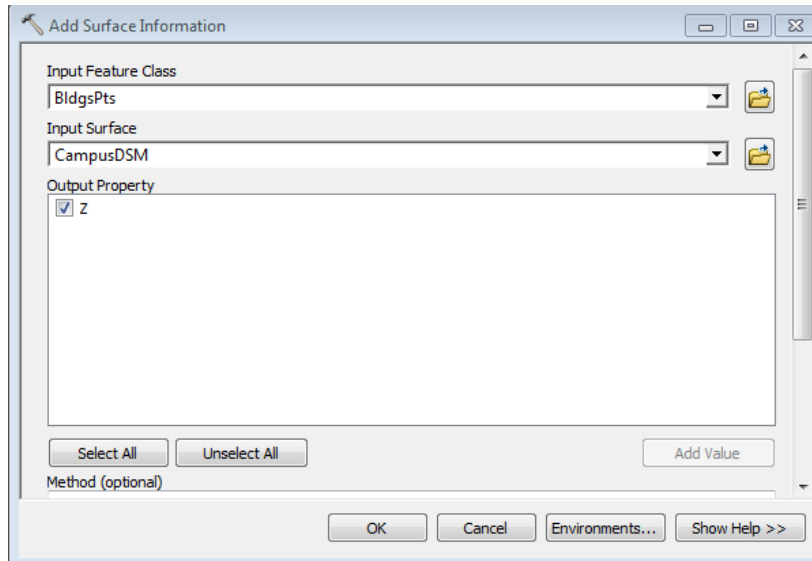
Figure 16. The Add Surface Information tool settings.

- 5. Right click CampusBuildings2, select Joins and Relates > Join...
- 6. Choose to join attributes from a table, using the OBJECTID field in step 1. Make sure BldgsPts is selected in step 2.
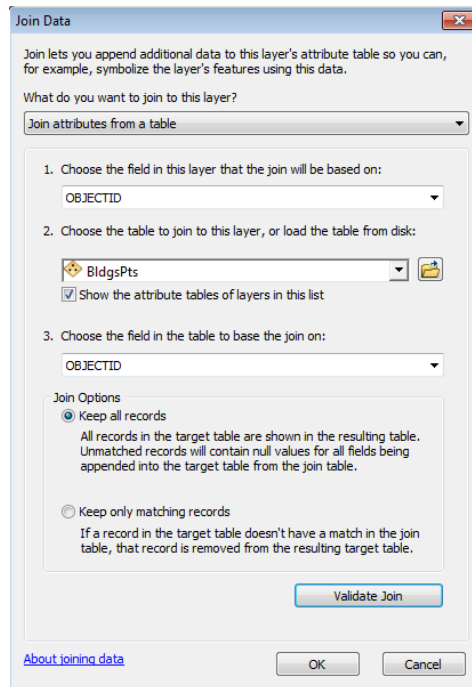

Figure 17. Join parameters to get the Z attribute data from BldgsPts.

- 7. Right click on CampusBuildings2 and select Data > Export Data. Save the output as CampusBuildings3.
- 8. Double click Clemson3D.sxd in the ArcCatalog window to open ArcScene.

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- 9. Add CampusDSM and CampusBuildings3 to the scene by dragging them from the ArcCatalog window.
- 10. Right click CampusDSM in the Table of Contents, select Properties, and go to the Base Heights tab.
- 11. Change the Elevation from surfaces option to Floating on a custom surface and select CampusDEM. Click OK.
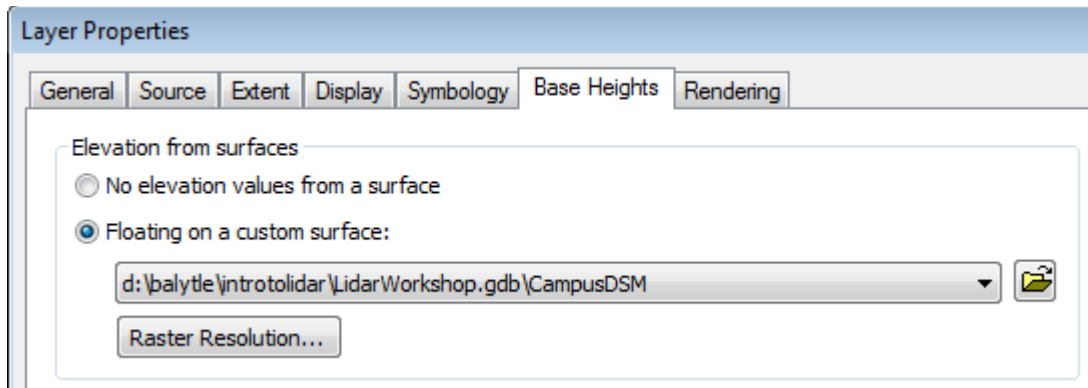

Figure 18. Changing the Campus DSM properties to displaying using height information contained in the raster.

- 12. Open the layer properties for CampusBuildings3. On the Base Heights tab, select Floating on a custom surface using the CampusDSM.
- 13. Go to the Extrusion tab. Click the check box to extrude features in the layer.
- 14. For the Extrusion value or expression, enter [Z]
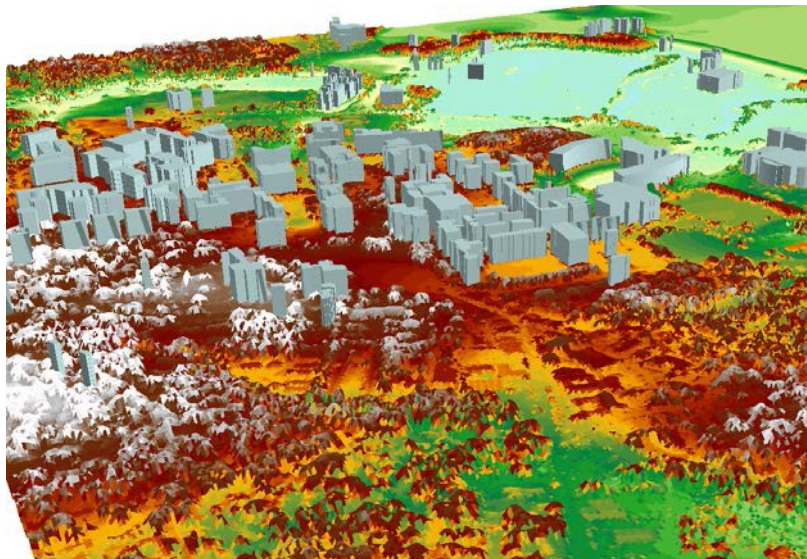- 15. Apply extrusion by adding it to each feature's base height. Click OK.

Figure 19. The 3D scene containing CampusDSM and CampusBuildings3 extruded using the Z attribute.

Applications

The following activities demonstrate applications of LiDAR data through scenarios in which you, a GIS consultant, are asked to solve a problem or give a recommendation. We will use what we have learned about LiDAR data to demonstrate why LiDAR data are so useful for geospatial analysis.

Activity 3. Locating a Solar Panel Array

The LiDAR data can provide the high-resolution information needed to calculate incoming solar radiation (insolation) for each individual rooftop. We will even be able to see how insolation varies for individual rooftops, enabling us to optimize the placement of solar panels.

Scenario: The University wants to build an array of solar panels on a building rooftop on campus and needs to know which buildings would be best suited for this purpose.

Solution: We can calculate the insolation which will land on the buildings using the DSM, which gives us the elevation as well as the aspect (direction) and slope of the buildings.

T00LS USED

Extract by Mask (Spatial Analyst):

Extracts the cells of a raster that correspond to the areas defined by a mask.

Area Solar Radiation (Spatial Analyst):

Estimates the insolation based on latitude, elevation, slope, aspect, shifts in sun angle, and account for shadows from topography.

Activity 3.A. Using the Tools Sequentially

- 1. Activate the *SolarPanels* data frame.

It contains a feature dataset of polygons representing buildings on campus.

- 2. Add ClemsonCampus.lasd and CampusDSM to the data frame.

Let's use the winter solstice, Dec. 21, as it is a low point for incoming radiation. We only calculate insolation received by the buildings to speed up calculations. We will trim our DSM to the boundaries defined by our campus buildings.

- 3. Search for the Extract by Mask (Spatial Analyst) tool.
- 4. Set the input raster to CampusDSM, the input data mask to the Clemson_University_Buildings_2011 feature, and the output as bldgs._raster. Click OK to run the tool.

Figure 20. Extract by Mask tool settings.

- 5. Search for and open the Area Solar Radiation (Spatial Analyst) tool.
- 6. Set the input raster to bldgs._raster.
- 7. Save the output raster as Dec21Rad.
- 8. Set the time configuration to within a day, and select day 355 (Dec 21).
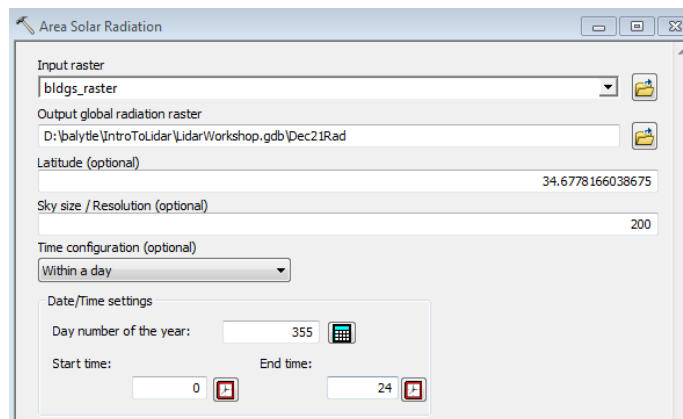- 9. Click OK to run the tool.

Figure 21. Area Solar Radiation tool settings.

The Dec21Rad raster is added to the map showing the insolation received by building rooftops.
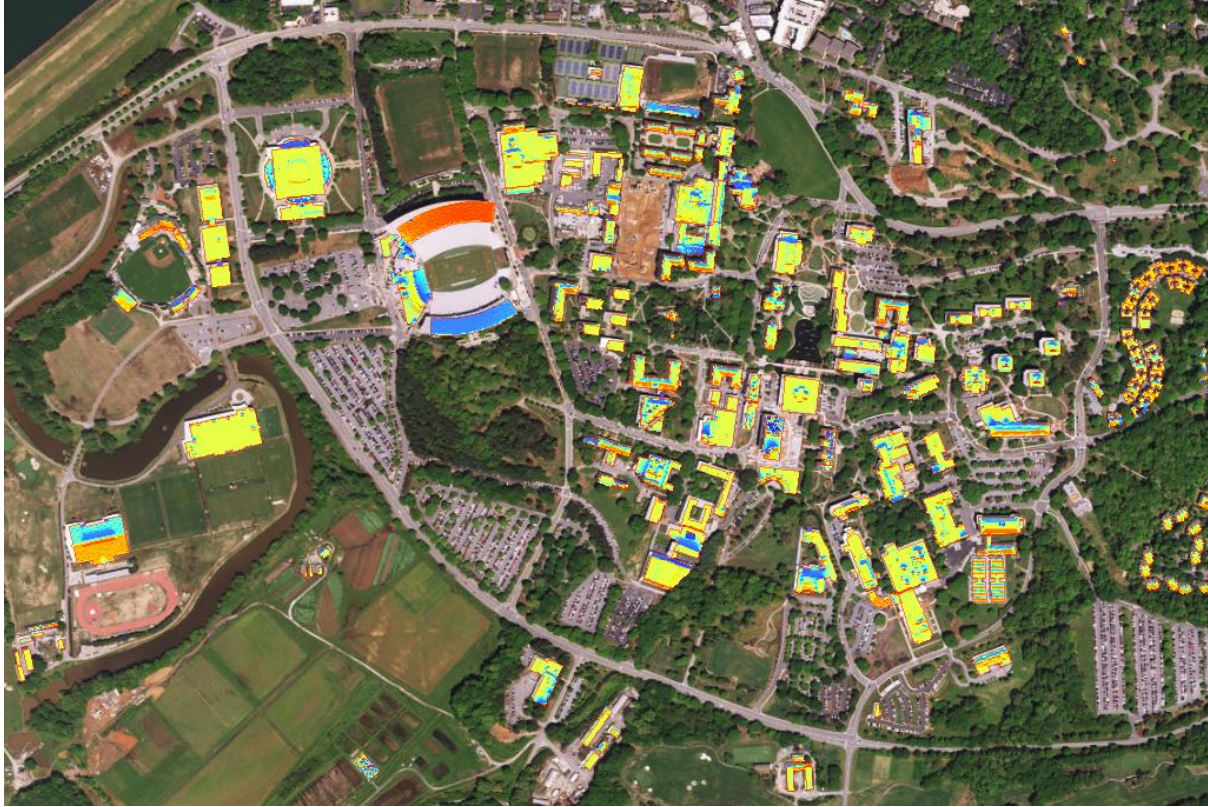
Figure 22. Insolation received at building rooftops on Dec. 21.

Q. What are your thoughts on where the best locations for solar panels would be? What are the limitations or other considerations?

Activity 3B. Automating Your Workflow Using Model Builder

As your GIS activities incorporate more geoprocessing, you will probably want to find ways to save time, such as automating your processing workflow. ArcGIS has the Model Builder for just this purpose. This is a visual environment where you can link sequences of tools and processing steps to create, modify, and save as a model. The model not only saves time by automating the processing, but it can be easily modified to change input and output and enables you to verify the workflow and check for potential errors. Finally, the Model Builder is a convenient tool for documenting your work.

Tools Used

Model Builder
ModelBuilder is an application you use to create, edit, and manage models. Models are workflows that string together sequences of geoprocessing tools, feeding the output of one tool into another tool as input. ModelBuilder can also be thought of as a visual programming language for building workflows. Models are saved within a Toolbox, just like the collection of Toolboxes in ArcToolbox, and you can create a Toolbox similarly to creating data in ArcCatalog.
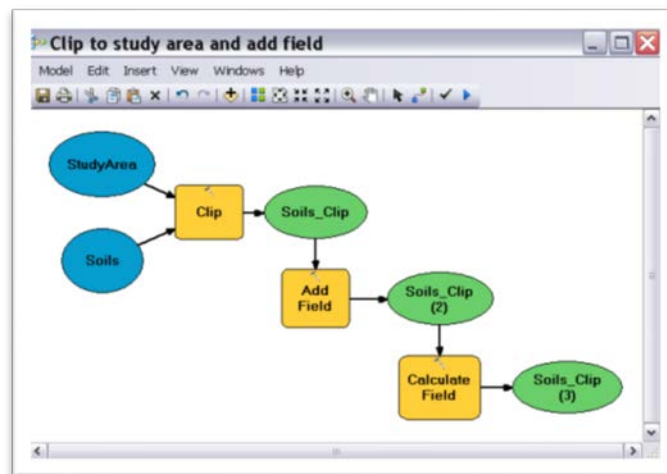
For this part of the activity, we will compare the output of our prior workflow to demonstrate that the Model Builder functions the same as a sequence of tools. First, let's clean up the map document a bit:

1. Turn off the bldgs._raster and Dec21Rad layers in the map document.

We need to create a Toolbox to store our Models. We'll save it in our working directory. Then we will create the blank Model.
2. In the ArcCatalog panel, right click on the IntroToLidar folder, select New > Toolbox.
3. Rename the Toolbox Lidar_Workflows.
4. Right click on the Lidar_Workflows toolbox and select New > Model. The Model Builder window will open.

To create a Model, you can click and drag tools from ArcToolbox as well as from the Search

window. We will add our tools from Activity 3.A to build our Model.

5. Search for Extract by Mask (Spatial Analyst).
6. Click on the name in the Search window and hold the mouse button. Drag your mouse into the Model window and release the mouse button.
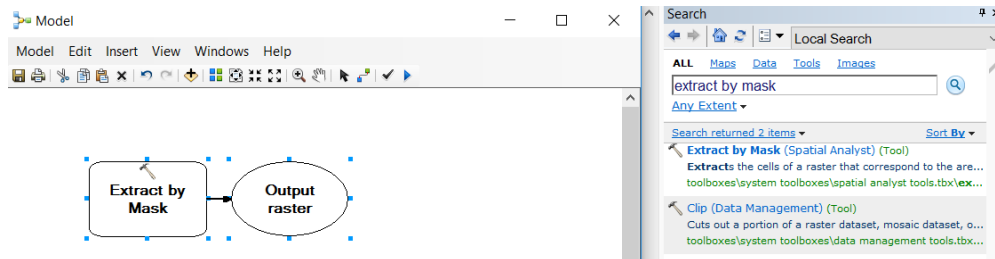

Figure 23. Tools show up as rectangular boxes with a hammer icon in the Model Builder, and datasets show up as ovals. Notice the arrow between the icons, indicating that this tool will create an output.

7. Repeat these steps, instead searching for Area Solar Radiation, and add it to the space to the right of the Extract by Mask icons.

We have the pieces for our analysis Model. Let's specify the input, output, and parameters for each tool.

8. Right click on the Extract by Mask box and click Open.
9. Set the input raster to CampusDSM, the input data mask to the Clemson_University_Buildings_2011 feature, and the output as bldgs._raster_MB. Click OK.

Notice that the icons have changed color to indicate that their parameters have been specified. Two blue ovals are now pointing to the Tool, one for each input, and the green oval is the output.

10. Double click on the Area Solar Radiation tool to open the dialog. Set the input raster to bldgs._raster. Notice the different icon next to its name, indicating it is a dataset in the model. Save the output raster as Dec21Rad_MB. Set the time configuration to within a day, and select day 355 (Dec 21). Click OK.

The tool and output icons have changed color and updated with the name. An arrow is linking the output from our first tool to be input to the second tool. Notice the optional output that the tool can provide (but we do not need) in the white ovals.
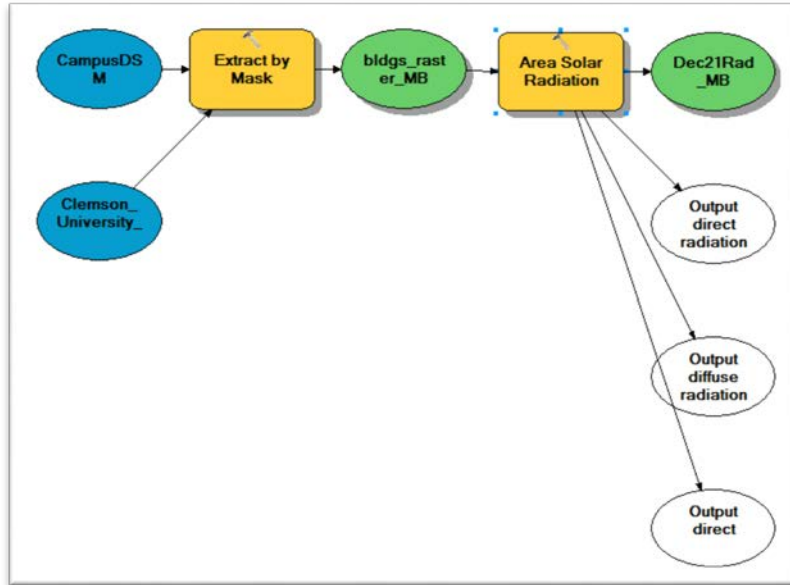
Figure 24. The completed Model for this analysis.

11. Right click on the icon for bldgs_raster_MB and click on Add to Display. Repeat for the Dec21Rad_MB dataset. This will make sure the output are added to the map document.
12. Click on the Verify icon (the checkmark) to see if there are any errors.
13. Click the Model menu, click Save As, and save the model with the name Clemson_Bldgs_Solar_Rad.
14. Click the Model menu and click Run.

Q. How do the results compare to the previous analysis?

Activity 4. Cell Tower Viewshed Analysis

A viewshed is the geographic area visible from a specific location, either a point or a line. Finding which areas are visible, or not visible, is important when you are locating a feature which needs lots of visibility, such as a fire tower, or in placing unattractive features out of sight, such as a parking lot.

Scenario: There are currently several cell phone towers around Clemson, but a new cell phone tower is proposed at the location of Manning Hall to increase coverage on campus. The client wants to see which parts of campus will receive additional coverage to assess the proposed tower placement.

Solution: Performing a viewshed analysis using our DSM of Clemson and the locations of cell phone towers will show us what is visible from a particular area and what is not. The visibility will be determined from the cell towers to random points on campus. Comparing the viewshed from the original towers to the viewshed including the new tower will show which areas receive additional coverage.

TOOLS USED

Viewshed (Spatial Analyst):

Determines the raster surface locations visible to a set of observer features.

Minus (Spatial Analyst):

Subtracts the value of the second input raster from the value of the first input raster on a cell-by-cell basis.

- 1. Activate the *CellTowers* data frame. Add the CampusDSM to the data frame.
- 2. Open the Attribute Table for the CellTowers layer.

There are five records. The first 4 are pre-existing towers around Clemson, and the fifth is the proposed Manning Hall tower. Let's first determine the viewshed for the original cell towers.

- 3. Use Select by Attributes to select the first 4 towers. (Hint: select CLASS = 'Existing'). Close the attribute table.

CellTowers

	OBJECTID *	SHAPE *	OFFSETA	StrucType	HeightB
▶	1	Point	60	1	250
	2	Point	60	1	250
	4	Point	60	1	250
	5	Point	60	1	250
	7	Point	8	2	250

Figure 25. Original cell towers selected in the attribute table.

- 4. Search for the Viewshed (Spatial Analyst) tool. Set the input raster as CampusDSM, the input points as CellTowers, and save the output as Viewshed_Init. Click OK to run the tool.
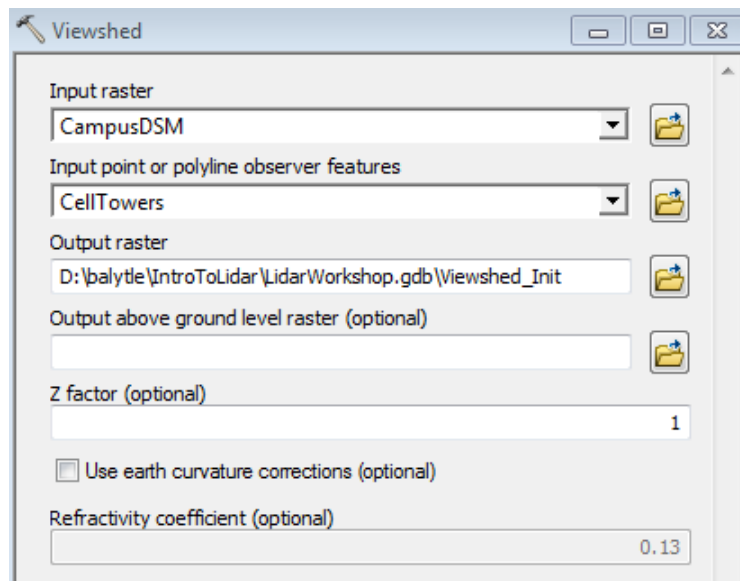
Figure 26. Viewshed tool settings to create the initial viewshed.

The default symbology shows that green-colored cells are visible and red-colored cells are not visible from the current cell towers around campus.

Figure 27. The original viewshed. Green areas are visible from the current cell towers and red areas are not visible.

Q. Which areas of campus have no visibility from the current cell phone towers?

Now repeat the process to determine the new viewshed with an additional tower.

- 5. Clear the selected CellTowers to include all the towers in the Viewshed calculation.
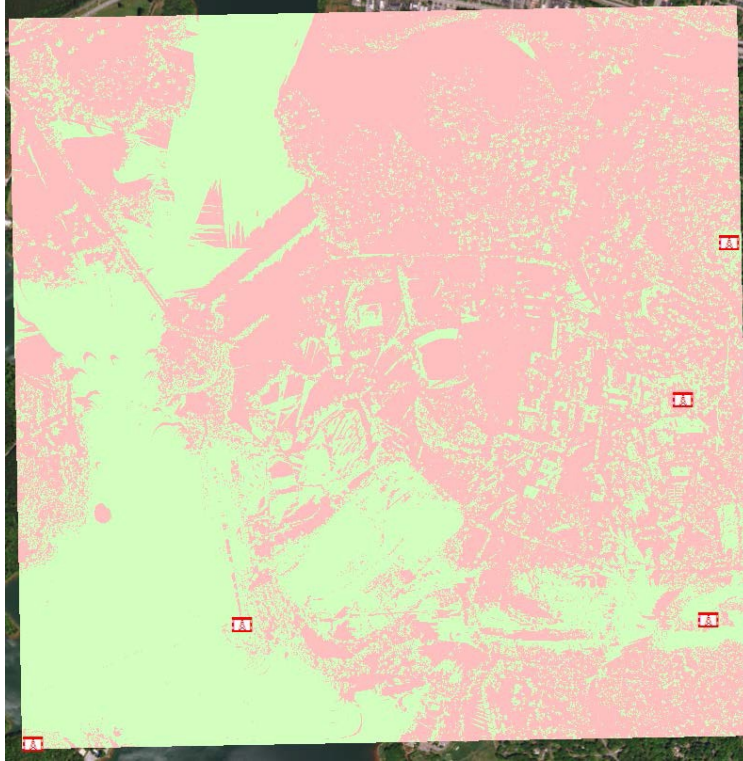- 6. Search for and open the Viewshed tool. Repeat the steps as before but save the output as Viewshed_New.

Figure 28. The viewshed with increased coverage from the new tower.

The differences between the viewsheds are subtle. To highlight the areas of increased coverage, we can use the Minus tool to find areas now visible by adding a tower.

- 7. Search for and open the Minus (Spatial Analyst) tool.
- 8. Select Viewshed_New as constant value 1 and Viewshed_Init as constant value 2.
- 9. Save the output as Increased_Vis. Click OK to run the tool.

Figure 29. The Minus tool settings (above) and the areas of increased cell visibility from the new tower (below).

Q. What locations on campus have received the most improvement in cell coverage? (Hint: Changing the symbology of the Increased_Vis layer will highlight changes).

Activity 5. Determining Forest Canopy Height

The height of the tallest vegetation above ground level is termed the canopy height. Characterization of the canopy height in a forest is useful for studying forest succession, understanding the history of a forested site, monitoring logging and recovery, and in evaluating certain types of forest habitat. The canopy height can be determined by subtracting a ground-return DEM from a first-return DSM of the forest.

Scenario: The Clemson Tiger-bird, a very rare and elusive creature, has been spotted south of the university in a forest tract adjacent to Lake Hartwell. We have an LAS Dataset for this forest tract named ClemsonForest.lasd. The animal only nests in smaller second-growth trees of 5-10 m height, and land managers want to identify areas of potential habitat for this unique animal in their tract as well as a percentage of the area which may constitute habitat.

Solution: Using the ClemsonForest.lasd dataset, create a DEM and DSM. Subtract the DEM from the DSM using a raster calculator to determine the canopy height. Then, reclassify the LiDAR points based on their height to find areas of potential habitat.

TOOLS USED

LAS Dataset to Raster (Conversion):

Creates a raster using elevation, intensity, or RGB values stored in the lidar files (*.las) referenced by the LAS dataset.

Minus (Spatial Analyst):

Subtracts the value of the second input raster from the value of the first input raster on a cell-by-cell basis

Raster Calculator (Spatial Analyst):

Builds and executes a single Map Algebra expression using Python syntax in a calculator-like interface.

Classify LAS By Height (3D Analyst):

Reclassifies lidar points based on their height from the ground surface.

5.1 Create DEM's and DSM's

- 1. Activate the *Canopy_Height* Data Frame.
- 2. Use what you have learned to create a DEM and DSM from the ClemsonForest.lasd file. Make the rasters with 1 m resolution. Save the DEM as ForestDEM and the DSM as ForestDSM.
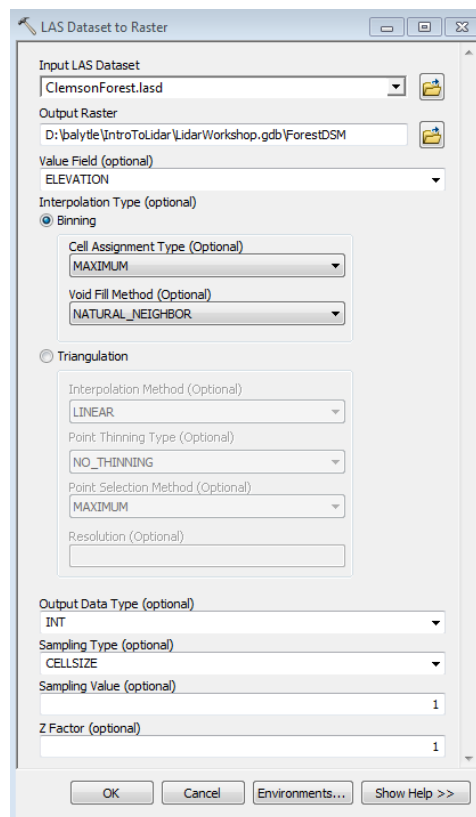
Figure 30. LAS Dataset to Raster settings, in case you forgot!

Q. What are your observations about the DEM? Are there any remarkable features?

Q. What are your observations about the DSM?

5.2 Determine Canopy Heights

To get the height of the canopy, we are going to subtract the ground elevations (DEM) from our canopy surface (DSM).

- 1. Search for the Minus (Spatial Analyst) tool. Enter the ForestDSM as constant value 1, ForestDEM as constant value 2, and save as canopyheight raster.
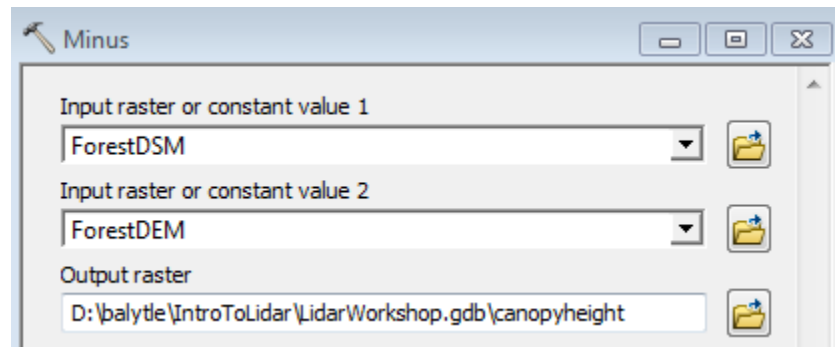

Figure 31. Minus tool settings to find the canopy height.

What are the minimum and maximum heights?

Now we will determine what portion of the forest canopy would be suitable as nesting ground for the bird by changing the raster symbology.

- 2. Open the canopyheight attribute table and inspect the values.

Notice that there are few cells above 43 m in height. We will use 43 m as an upper bound for our classification, as trees in this region are unlikely taller. (43 m is over 140 ft tall!)

- 3. Close the attribute table.
- 4. Open the canopyheight layer properties and go to the symbology tab.
- 5. Classify height raster as Unique Values. Remove any negative values, group 1-4 m as LowVegetation, 5-10 as MediumVegetation, 11-43 as HighVegetation, and remove values over 43. Use light green for LowVegetation, contrasting color (e.g. red) for MediumVegetation, and dark green for HighVegetation. Click OK.
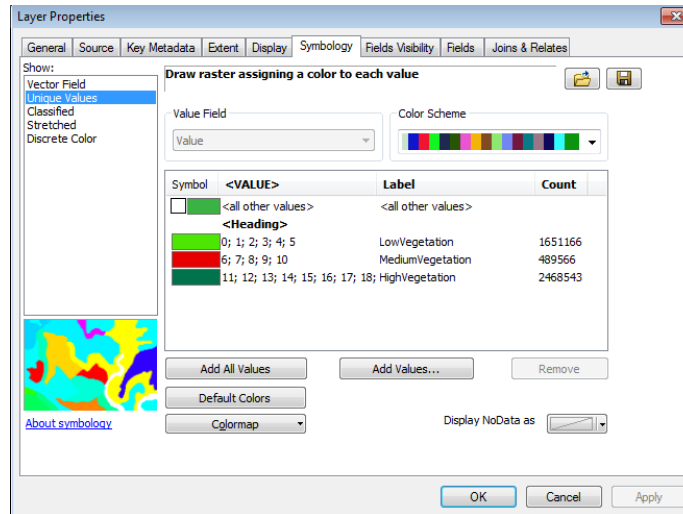
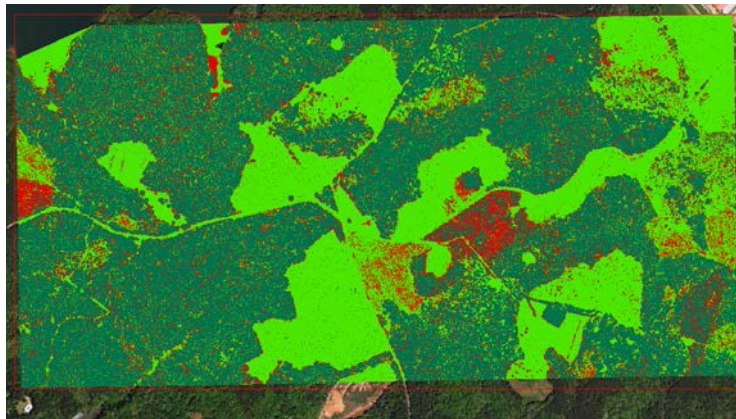Figure 32. Symbology settings to view as Low, Medium, and High vegetation.

Figure 33. The canopyheight raster visualized according to canopy height. Areas in red show potential habitat.

Q. What areas look most suitable for habitat of the tiger bird?

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5.3 Reclassify the LAS Data

Now let's try a different approach. Perhaps we want to go beyond changing the visualization of our data and to find the locations of appropriate habitat and <u>permanently </u>reclassify the points within the LAS file based on their height. In this way, the points themselves can be quickly visualized using the tools in ArcGIS as well as processed a bit differently.

- 1. Open the ClemsonForestReclass.lasd layer properties in the ArcCatalog window.

Inspect the source file, the statistics, and note the current classes: (1) Unassigned, (2) Ground, (7) Noise, (8) Reserved, (9) Water, and (10) Rail. We are going to add three new classes: (3) Low vegetation, (4) Medium Vegetation, and (5) High Vegetation. Class 4 will represent our ideal tiger-bird habitat.

Figure 34. The original ClemsonForestReclass.lasd classifications.

Remember our ideal habitat is for small trees 5-10 m in height, and anything taller than 43 m was suspect, so we use these as guidelines for our classification.

- 2. Search for and open the Classify LAS By Height (3D Analyst) tool. Set the Input LAS Dataset to ClemsonForestReclass.lasd.
- 3. Change the Height From Ground values to be 5, 10, and 43 for class 3, 4, and 5, respectively.
- 4. Check the Compute Statistics box to update the information. Click OK to run the tool.
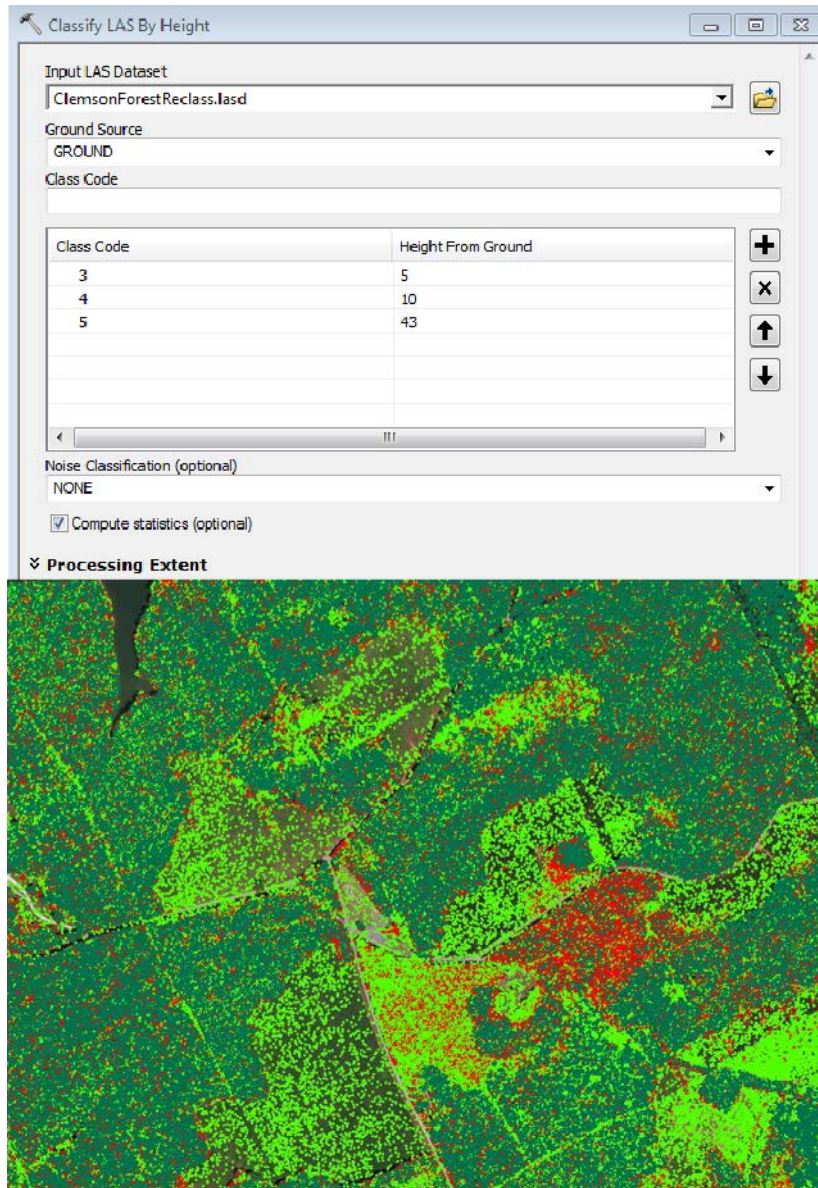
Figure 35. The Classify LAS by Height tool settings (above) and the data visualized by class (below) with colors matching the canopyheight raster (below).

- 5. Remove ClemsonForestReclass.lasd from the map and then add it back to the map. Change the visualization on the LAS Dataset toolbar to Class.

The points now include vegetation classification codes as well as ground.

Q. What percentage of the ClemsonForestReclass.lasd dataset is classified as Medium Vegetation?

Q. What advantages or drawbacks would this method have over the raster method?

Activity 6. Watershed Delineation

A watershed (also called a catchment or drainage basin) is the area surrounding a stream or river which contributes runoff to that stream, and watersheds are separated by drainage divides, often topographic ridges or high points. Delineation of the watershed boundary can be done by connecting topographic highs surrounding a stream. Understanding the watershed boundary is important for proper land management as it shows which areas drain to a particular stream and the impacts to the water quality can be assessed.
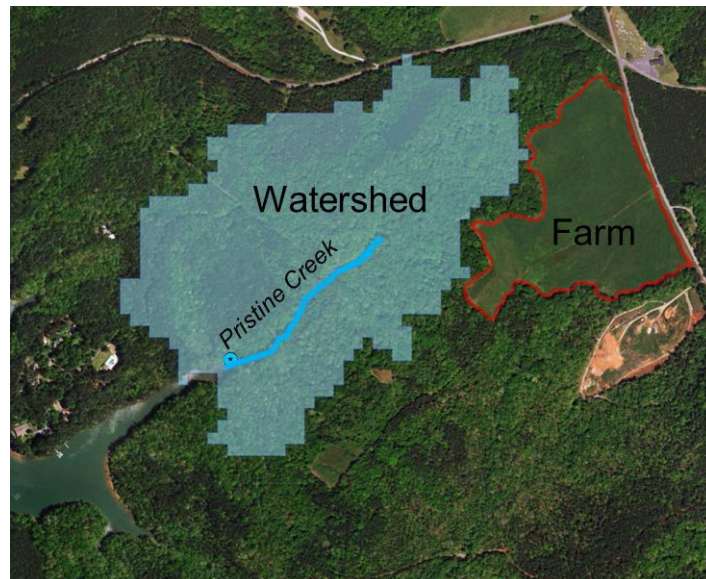
Scenario: Land managers have detected fertilizer pollution in Pristine Creek, which is south of Clemson and drains into Lake Hartwell. The watershed boundary determined by the previous contractor, Universal Stream Corporation (USC) was derived from a 30 m DEM and

shows that the nearby farm field is entirely outside of the watershed. The land managers have obtained LiDAR data to help their investigation into the pollution source and have hired you as an analyst.

Solution: We will use a high-resolution DEM obtained from Watershed.lasd to determine the drainage catchment for Pristine Creek and compare the results to the USC watershed to determine whether the farm is contributing runoff to the creek.

<u>TOOLS USED</u>

Clip (Data Management):

Cuts out a portion of a raster dataset.

Fill (Spatial Analyst):

This tool outputs a raster with sinks (closed depressions) in our elevation model "filled". Sinks create problems in flow direction calculations (the drainage direction from a sink is undefined).

Flow Direction (Spatial Analyst):

Creates a raster of flow direction from each cell to its steepest downslope neighbor.

Basin (Spatial Analyst):

Creates a raster automatically delineating all drainage basins based on the topography.

Raster to Polygon (Conversion):

Converts a raster dataset to polygon features.

6.1 Getting Started

- Activate the *Watershed* data frame.

The nearby farm is represented by the Farm polygon. There is already a 30 m DEM (1 degree x 1 degree) called ASTGTM2_N34W083_dem.tif and a portion of that DEM clipped to the extent of the LAS dataset and to exclude water called WatShed30m created by the previous consultant. There is a polygon feature called LandBound which we will use to clip the DEM we create. We want to delineate the watershed for Pristine Creek which meets Lake Hartwell at the point defined by the CreekPourPoint layer. A polygon called WatershedPoly30m was created by the previous consultant from the 30 m DEM, and we will repeat the process using our DEM and compare the two watersheds.

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- Add the Watershed.lasd to the map.

6.2 Create the DEM

- 1. Use what you have learned to create a 1 m resolution DEM using the ground returns from Watershed.lasd. Save the DEM as WatershedDEM.

Q. Compare the new WatershedDEM to the WatShed30m DEM. What are your observations?

6.3 Pre-processing for Watershed Delineation

For proper flow direction calculations, we need to exclude Lake Hartwell from our DEM.

- 2. Search for and open the Clip (Data Management) tool.
- 3. Select the Input Raster to WatershedDEM.
- 4. Set the Output Extent to the LandBound layer.
- 5. Check the box which says Use Input Features for Clipping Geometry
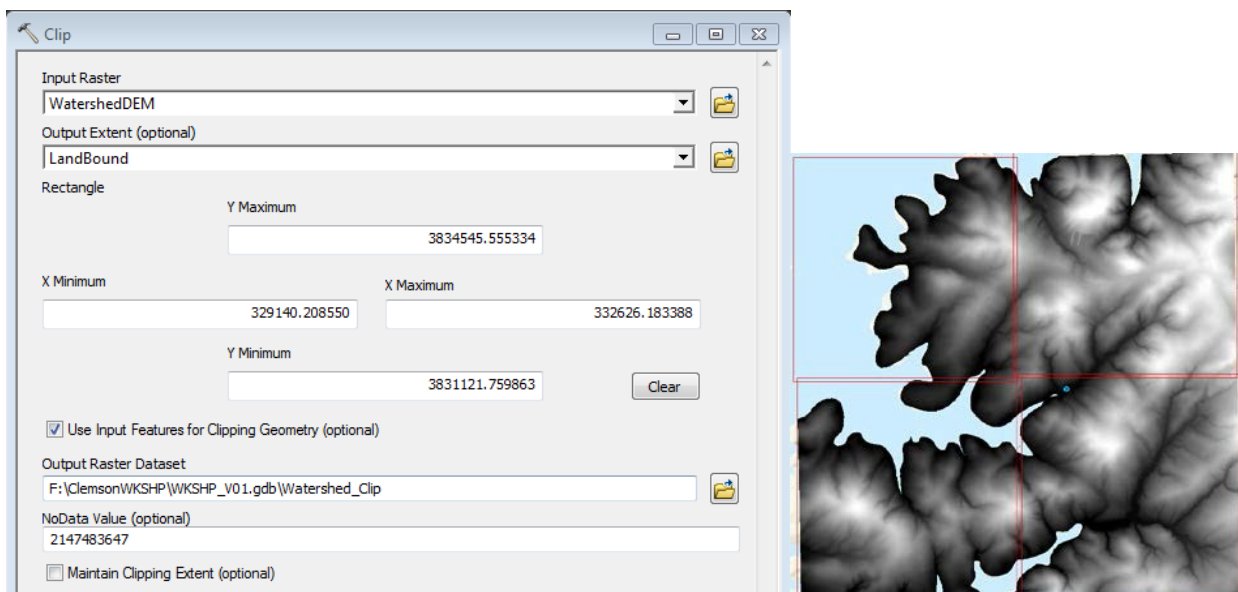- 6. Save the output as Watershed_Clip. Click OK to run the tool.

Figure 36. The Clip tool settings (left) and the 1 m WatershedClip 1 m DEM clipped to the land boundaries (right).

- 7. Search for and open the Fill (Spatial Analyst) tool. Set the input surface raster to Watershed_Clip, the output surface raster to Fill_1m. Click OK to run the tool.
- 8. Search for and open the Flow Direction (Spatial Analyst) tool. Set the Input surface raster to Fill_1m and the Output flow direction raster to FlowDir_1m. Click OK to run the tool.
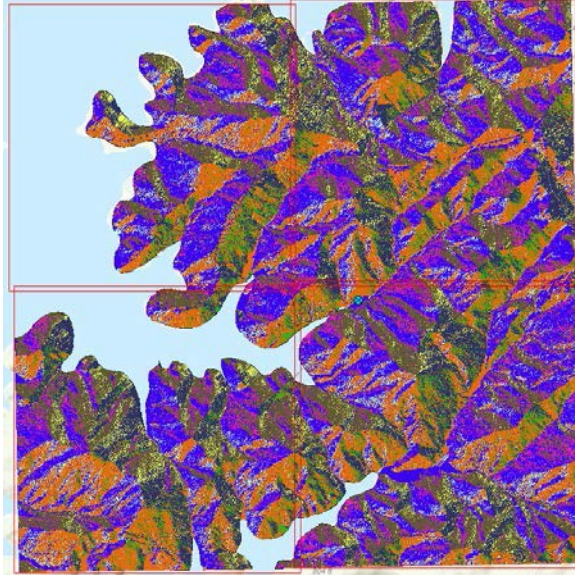
Figure 37. The FlowDir_1m raster showing directions in which water would flow across the DEM surface.

6.4 Automatically Create Watershed

The Basin tool will automatically delineate all watershed divides in our DEM area using the Flow Direction calculations from the previous step.

- 1. Search for and open the Basin (Spatial Analyst) tool. Set the Input flow direction raster to FlowDir_1m. Save the output as Basins_1m. Click OK to run the tool.

We now have all of the drainage basins within our DEM area. We can identify and select our watershed of interest and convert it to a polygon to determine the watershed area.

- 2. Use the Identify tool to click on the large basin adjacent to the CreekPourPoint to find the OBJECTID. Close the Identify window.
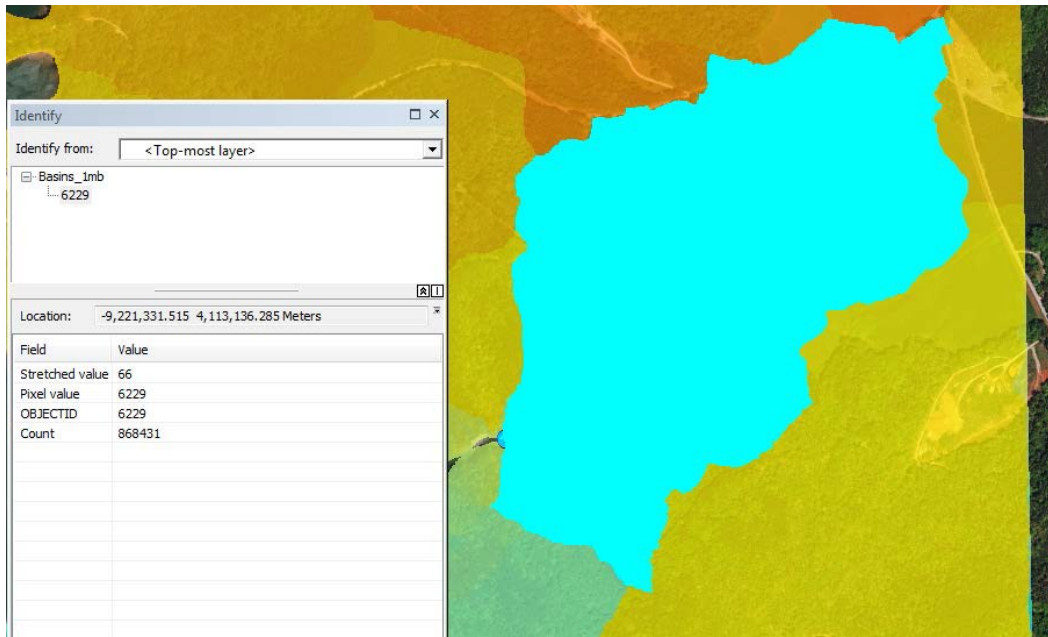
Figure 38. The automatically created watershed boundary identified by selecting from the Basins_1m raster.

- 3. Open the attribute table for Basins_1m. Select features using the OBJECTID you identified. Close the attribute table.
- 4. Search for and open the Raster to Polygon (Conversion) tool. Set the Input raster to Basins_1m and save the output as WatershedPoly. Click OK to run the tool.
- 5. Turn off every layer except, Farm, WatershedPoly and WatershedPoly30m. Adjust the transparency of WatershedPoly so both features are visible.

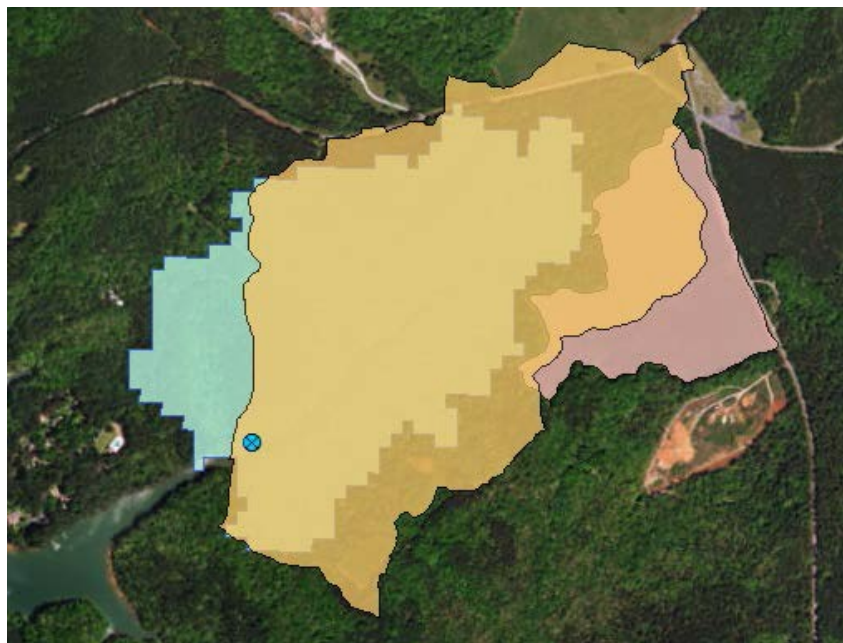Figure 39. Our watershed calculated from the 1 m DEM clearly shows the farm within the watershed boundaries.

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Q. What important differences do you notice between the two watersheds?

Q. What can you tell the land managers about the source of the pollution?

- 6. Use the Measure tool to find the area of WatershedPoly and compare it to WatershedPoly30m.

Q. What are the areas of the two different watersheds?