COURSE WORKBOOK

Working with Lidar Data in ArcGIS®

Official Esri Training Courseware

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Working with Lidar Data in ArcGIS®

STUDENT EDITION

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Course introduction

Light detection and ranging (lidar) uses laser pulses to capture high-resolution elevation data, which has many applications in GIS. Lidar data can be used to accurately represent the height and even shape of buildings. It can help determine when stands of commercial timber are ready for harvest, and it can play a crucial role in delineating floodplains.

But before you can start using lidar data in analysis, you need to learn the basics of how it is captured, classified, stored, and managed. This course provides an overview of fundamental lidar concepts and an introduction to storing, managing, and using lidar data with ArcGIS Pro.

Course goals

After completing this course, you will be able to perform the following tasks:

- Validate the quality and accuracy of lidar data.
- Edit lidar data to correct errors.
- Organize, process, visualize, and share lidar data using ArcGIS LAS datasets, mosaic datasets, and point cloud scene layers.
- Derive useful information products from lidar data, including raster surfaces, building footprints, and vegetation estimates.

Installing the course data

Some exercises in this workbook require data. Depending on the course format, the data is available on a DVD in the back of a printed workbook or as a data download. To use the data, extract it to your C:\EsriTraining folder.

DISCLAIMER: Some courses use sample scripts or applications that are supplied either on the DVD or on the Internet. These samples are provided "AS IS," without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose, or noninfringement. Esri and its authorized distributors shall not be liable for any damages under any theory of law related to the licensee's use of these samples, even if Esri and its authorized distributors are advised of the possibility of such damage.

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Your instructor will provide a temporary account and group to use during class.

Record the information below:

User name: ______________________________

Password: ______________________________

Group name: ______________________________

Organization URL: ______________________________

After completing this course, you will need your own account to perform course exercises that require signing in to ArcGIS Online. The sign-in steps will vary based on your account type.

Icons used in this workbook

Estimated times provide guidance on approximately how many minutes an exercise will take to complete.

Notes indicate additional information, exceptions, or special circumstances about specific course topics.

Recommended practices improve efficiency and save time.

Esri Academy resources provide more in-depth training on related topics.

Additional resources provide additional information about related topics.

Warnings indicate potential problems or actions that should be avoided.

1 Exploring lidar data

The last decade has seen a huge expansion in the use of lidar data in GIS. The growth in the amount of available data and the increasing number of applications where it is captured and used have resulted in the need for GIS professionals to better understand lidar data and how it can be used in a GIS context. In this lesson, you will be introduced to the lidar format and build a foundation for working with lidar data throughout the rest of the course. Using a variety of activities, you will learn the components of lidar data, as well as how it is collected, stored, and commonly used.

Topics covered

- Lidar data collection
- Comparing lidar data formats
- Lidar classification standard
- Exploring common lidar applications

What is lidar?

Lidar (light detection and ranging) is an optical remote-sensing technique that uses laser light to densely sample the surface of the earth, producing highly accurate x,y,z measurements. In lidar data collection, laser pulses are transmitted toward a target while moving through a specific route. The reflection of the laser from the target is detected and analyzed by receivers in the lidar sensor to record the precise round-trip time of each laser pulse. These timings are combined with the positional information of the sensor and then transformed to measurements of actual three-dimensional points of the reflective target in object space.

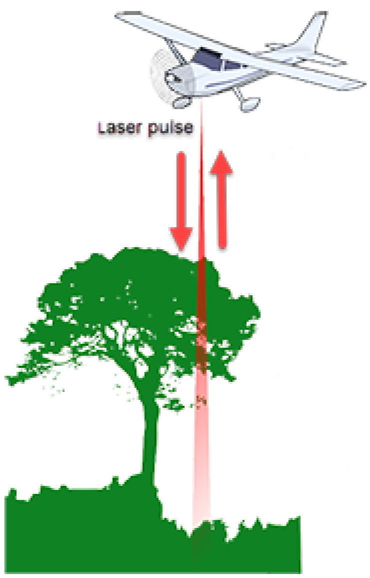


Figure 1.1. Airborne lidar data collection.

Lidar produces mass point cloud datasets that can be managed, visualized, analyzed, and shared using ArcGIS.

What is lidar? (continued)

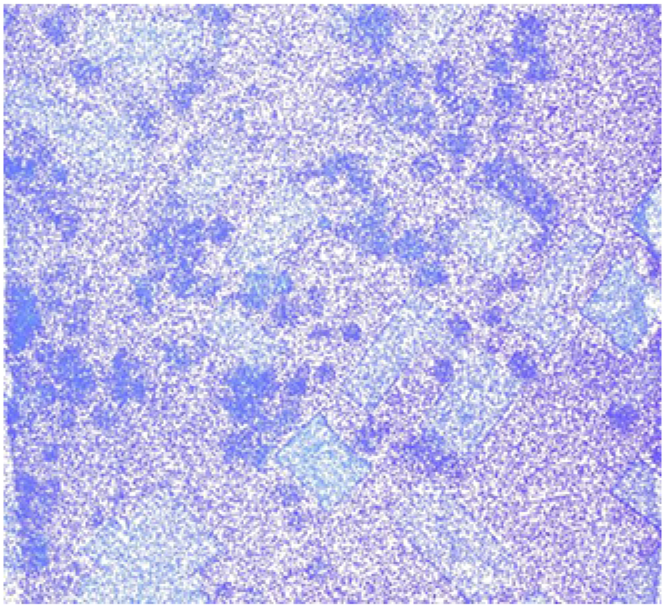


Figure 1.2. Example of a lidar point cloud.

The major hardware components of a lidar system include a collection vehicle (airplane, helicopter, automobile, and tripod), laser scanner system, GPS (Global Positioning System), and INS (inertial navigation system). An INS measures the orientation, such as roll, pitch, heading, and velocity, of the lidar system using gyroscopes and accelerometers.

Lidar returns

Laser pulses emitted from a lidar system reflect from objects both on and above the ground surface: vegetation, buildings, bridges, and so on. One emitted laser pulse can return to the lidar sensor as one or up to five returns. Any emitted laser pulse that encounters multiple reflection surfaces as it travels toward the ground is split into as many returns as there are reflective surfaces.

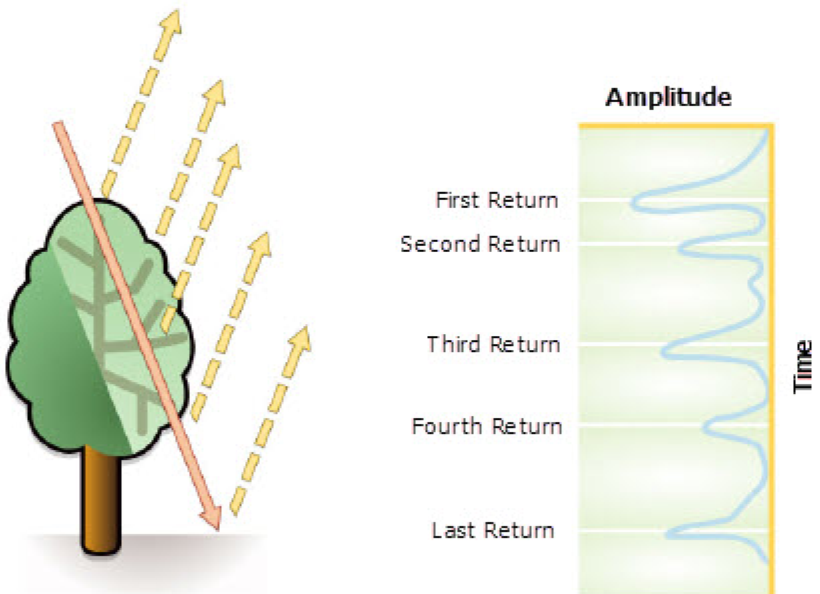


Figure 1.3. Laser pulse splitting into returns.

The first return of any given laser pulse is normally associated with the tops of features in the landscape, like a treetop or the top of a building. The first return can also represent the ground, in which case only one return will be detected by the lidar system. Multiple returns are capable of detecting the elevations of several objects within the laser footprint of an outgoing laser pulse. In general, the intermediate returns are used for vegetation structure, and the last return is used for bare-earth terrain models. However, the last return will not always be from a ground return. For example, consider a case where a pulse hits a thick branch on its way to the ground and does not actually reach the ground. In that case, the last return is not from the ground but from the branch that reflected the entire laser pulse.

Lidar quality

There are two major criteria that determine lidar quality levels (QL): The first criterion is point density, measured as points per square meter, and the second criterion is vertical accuracy. The U.S. Geological Survey (USGS) defines QL 1 as 8 points per square meter with a nominal point spacing of at least 0.35 meters and a vertical accuracy of at least 10 centimeters.

The following chart from the USGS describes additional lidar quality level specifications.

USGS lidar quality level requirements

Quality Level	Data Source	Vertical Accuracy RMSEz (cm)	Nominal Pulse Spacing (NPS) meters	Nominal Pulse Density (NPD) points per square meter	Digital Elevation Model (DEM) cell size (meters)
QL0	**Lidar**	**5 cm**	**≤ 0.35 m**	**≥ 8 pts/square meter**	**0.5 m**
QL1	**Lidar**	**10 cm**	**≤ 0.35 m**	**≥ 8 pts/square meter**	**0.5 m**
QL2	**Lidar**	**10 cm**	**≤ 0.71 m**	**≥ 2 pts/square meter**	**1 m**
QL3	Lidar	20 cm	≤ 1.41 m	≥0.5 pts/square meter	2 m
QL4	Imagery	139 cm	N/A	N/A	5 m
QL5	IfSAR	185 cm	N/A	N/A	5 m

Source (Public Domain): https://www.usgs.gov/3d-elevation-program/topographic-data-quality-levels-qls

Lidar quality (continued)

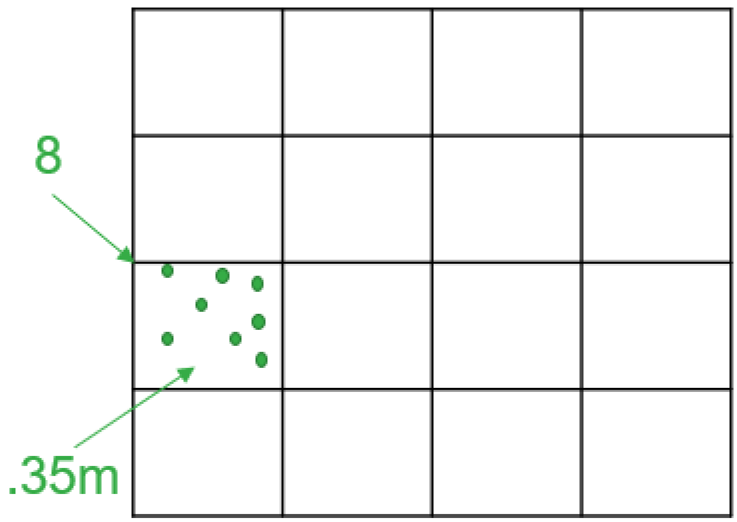


Figure 1.4. Example of Lidar Quality Level 1 in a 1-square-meter grid with an average point spacing of 0.35 m.

Examine lidar attributes

Along with the x, y, and z positional value, several valuable lidar point attributes are maintained for each laser pulse recorded. The following table describes the attributes that can be provided with each lidar point.

Lidar attribute	Description
Intensity	The return strength of the laser pulse that generated the lidar point.
Return number	An emitted laser pulse can have up to five returns, depending on the features that it is reflected from and the capabilities of the laser scanner used to collect the data. The first return will be flagged as return number one, the second as return number two, and so on.
Number of returns	The number of returns is the total number of returns for a given pulse. For example, a laser data point may return two (return number) within a total number of five returns.
Point classification	Every lidar point that is post-processed can have a classification that defines the type of object that has reflected the laser pulse. Lidar points can be classified into several categories, including bare earth or ground, top of canopy, and water. The different classes are defined using numeric integer codes in the LAS files.
Edge of flight line	The points will be symbolized based on a value of 0 or 1. Points flagged at the edge of the flight line will be given a value of 1, and all other points will be given a value of 0.
RGB	Lidar data can be attributed with RGB (red, green, and blue) values. This attribution often comes from imagery collected at the same time as the lidar survey.
GPS time	The GPS timestamp at which the laser point was emitted from the aircraft. The time is in GPS seconds of the week.

Examine lidar attributes (continued)

(Table continued from previous page)

Lidar attribute	Description
Scan angle	The scan angle is a value in degrees between -90 and +90. At 0 degrees, the laser pulse is directly below the aircraft at nadir. At -90 degrees, the laser pulse is to the left side of the aircraft, while at +90, the laser pulse is to the right side of the aircraft in the direction of flight. Most current/modern lidar systems collect data at a scan angle of ±30 degrees.
Scan direction	The scan direction is the direction the laser scanning mirror was traveling at the time of the output laser pulse. A value of 1 is a positive scan direction, and a value of 0 is a negative scan direction. A positive value indicates the scanner is moving from the left side to the right side of the in-track flight direction, and a negative value is the opposite.

Instructions

a Use the table to answer the following questions.

1. **Which attribute represents the total number of returns for a lidar pulse?**

2. **Which value represents points that are not at the edge of a flight line?**

3. **What is the scanning angle range for most currently used lidar systems?**

4. **Which attribute categorizes lidar points into classes like ground, water, and building?**

Lidar classification

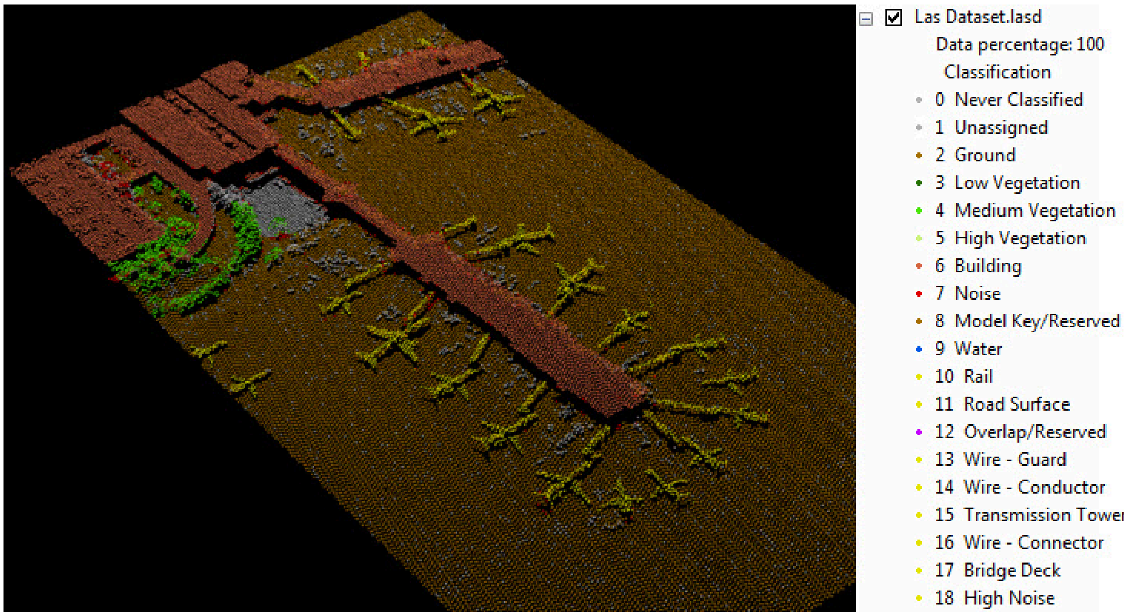


Figure 1.5. Lidar classification categories.

Lidar points can be classified into several categories, including bare earth or ground, vegetation (low, medium, and high), and water. The different classes are represented using integer codes defined by the American Society for Photogrammetry and Remote Sensing (ASPRS). The ASPRS lidar classification standard applies to the LAS data format (also defined by ASPRS), which is the industry-standard data format for lidar data. The ASPRS classification codes apply to LAS formats 1.1, 1.2, 1.3, and 1.4. ArcGIS supports all versions of LAS. LAS version 1.4 is the latest and includes additional point classification and information compared to earlier versions. The LAS 1.4 classification system is represented in the following table.

Classification value	Description
0	Never classified
1	Unclassified
2	Ground
3	Low Vegetation

Lidar classification (continued)

(Table continued from previous page)

Classification value	Description
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key/Reserved
9	Water
10	Rail
11	Road Surface
12	Overlap/Reserved
13	Wire - Guard (Shield)
14	Wire - Conductor (Phase)
15	Transmission Tower
16	Wire - Structure Connector (Insulator)
17	Bridge Deck
18	High Noise
19–63	Reserved
64–255	User Definable

Collecting lidar data

1. **Which lidar data collection method do you think is most commonly used by GIS professionals?**

2. **Which collection method would you use to create a detailed 3D model of the facade of a historical building?**

3. **Which collection method would you use to understand the size and number of trees on a forested area of land?**

Collecting lidar data video summary

These videos provide a brief explanation of terrestrial and airborne lidar data collection, respectively.

Storing lidar data

Whether lidar data is collected by airborne or terrestrial methods, it needs to be stored in a format supported by ArcGIS. Fortunately, most lidar data is delivered in one of two common formats, and both are supported by ArcGIS.

ASCII

Lidar data was originally delivered in ASCII text format. This format was easily supported by a variety of software programs, but the large amount of lidar data in a single collection frequently resulted in massive file sizes that were difficult to work with. The lidar ASCII format represents the lidar returns as a grid, with a header that stores information about the data collection and the bulk of the file that stores the actual elevation values.

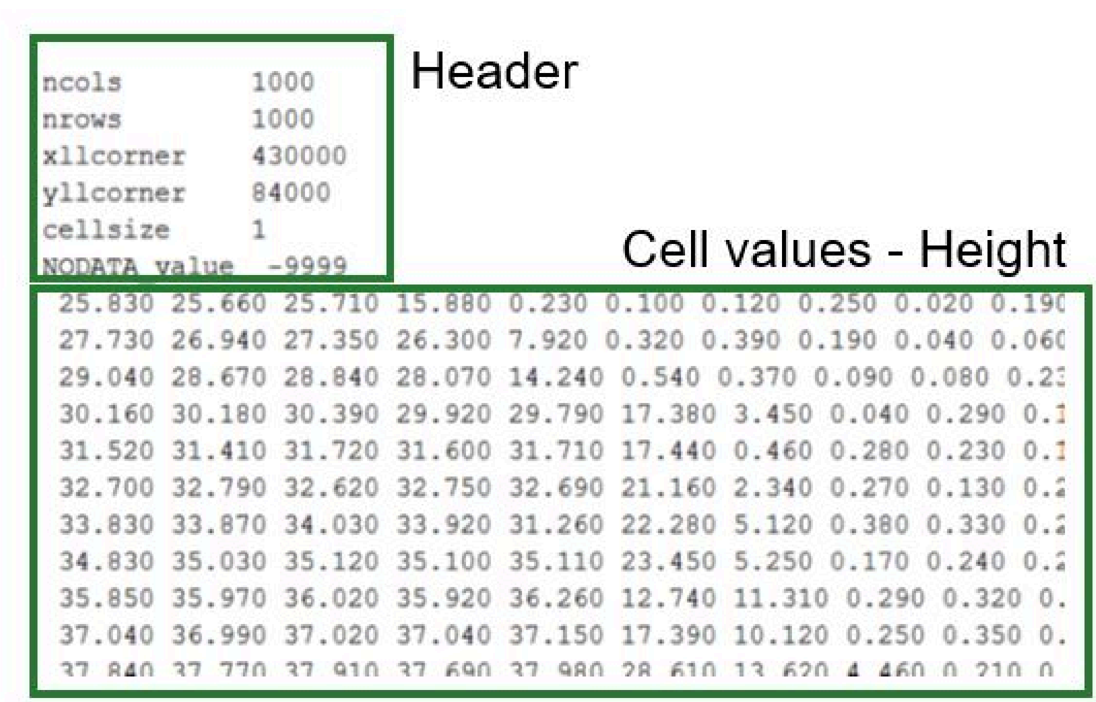


Figure 1.6. Example of lidar data in ASCII format.

ASCII remains a supported ArcGIS format for lidar data, but it is primarily used for interchange between different software systems.

Storing lidar data (continued)

LAS

To overcome the limits of the ASCII format, a binary format called LAS was soon adopted to manage and standardize how lidar data was organized and disseminated. Now it is quite common to see lidar data represented in LAS. LAS is a more acceptable file format because LAS files contain more information. Because they are binary, they can also be read by ArcGIS more efficiently.

LAS is an industry format created and maintained by the American Society for Photogrammetry and Remote Sensing (ASPRS). It is a published standard file format for the interchange of lidar data that maintains specific information related to lidar data. It is a way for vendors and clients to interchange data and maintain all information specific to that data.

Each LAS file contains metadata of the lidar survey in a header block, followed by individual records for each laser pulse recorded. The header portion of each LAS file holds attribute information on the lidar survey itself: data extents, flight date, flight time, number of point records, number of points by return, any applied data offset, and any applied scale factor. The following lidar point attributes are maintained for each laser pulse of a LAS file: x,y,z location information, GPS timestamp, intensity, return number, number of returns, point classification values, scan angle, additional RGB values, scan direction, edge of flight line, user data, point source ID, and waveform information.

Checkpoint

1. **The lidar LAS format is maintained by the American Society for Photogrammetry and Remote Sensing.**
    a. **True**
    b. **False**
2. **LAS is the only lidar format supported by ArcGIS Pro.**
    a. **True**
    b. **False**

Exercise 1

Minutes: 20

Explore lidar data in ArcGIS Pro

Lidar data has many uses, and as it has become increasingly common, GIS professionals are employing it across a range of applications. In this exercise, you will begin learning about lidar by exploring a common format for storing the data: the LAS file. You will also be introduced to methods for visualizing this data in ArcGIS Pro.

In this exercise, you will perform the following tasks:

- Explore LAS file properties.
- Explore ArcGIS Pro lidar visualization options.

Step 1: Explore a LAS file

a. Start ArcGIS Pro.

b. Near Recent Projects, click Open Another Project.

c. On the left side of the Open Project dialog box, expand Computer, click This PC, and then browse to **C:\EsriTraining\LIDR**.

d. Open LIDR.aprx.

The project has one map named StateCollege currently open, which only contains a basemap.

e. In the Catalog pane, expand Folders, and then expand the LIDR folder.

This folder contains all the data that is required for this course.

f. Expand USGS_StateCollege, and then expand the LAS_Classified folder.

g. From the LAS_Classified folder, drag the PA000138 LAS file into the map.

You will notice that the LAS file is symbolized as a very dense point cloud.

h. Zoom out until the point cloud disappears, and then click inside the square that represents the LAS tile.

The red box represents the extent of the LAS tile at display scales where symbolizing the point cloud is impractical.

i. Use the information in the pop-up to answer the following questions.

1. **How many points are in the point count?**

___

2. **What is the point spacing?**

___

3. What is the highest z-range value? (The z-range indicates the lowest and highest elevations found in the point data.)

____

j. Close the pop-up.

k. Zoom in to the LAS tile until the point cloud begins to appear.

l. Continue zooming in until you can distinguish the individual points (1:1000 is generally enough), and then click a point.

The pop-up now shows the attributes of the lidar return, not the properties of the entire LAS file. One of the available attributes is the class code for the return.

m. Use the information in the following table to determine the description for the class code of the lidar point, and then click a few more points to identify their class codes.

Class code	Description
1	Unclassified
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Noise
8	Model Key/Reserved
9	Water
12	Overlap/Reserved
15	Transmission Tower

n. After you are finished exploring a few points, close the pop-up.

o In the Contents pane, right-click the PA000138 LAS file layer and choose Properties.

p In the Layer Properties dialog box, click the LAS Filter tab.

The LAS Filter properties allow you to manually filter the point cloud based on the Classification Codes, Return Values, and Classification Flags parameters. These filters are important because geoprocessing tools honor them. That filtering will be an important step when creating other derived products from the LAS data.

q For Classification Codes, uncheck the All box, and then check the 2 Ground box.

This setting filters the point cloud to include only ground-classified points.

r Leave the Return Values and Classification Flags parameters on their default settings, and then click OK.

s From the Map tab, click the Bookmarks down arrow and choose Campus Research Area.

You will notice how the buildings in the basemap are not obstructed by points because only ground returns are being displayed.

t In the Contents pane, right-click the PA000138 LAS file layer, point to LAS Filters, and choose All Points.

This setting will clear the filter and display all the points without having to open the layer properties.

The buildings are now obscured because the lidar points with a class code of Building are being displayed, along with all the other points.

Now that you have explored the LAS layer properties, you will examine the file properties.

u In the Catalog pane, right-click the PA000138 LAS file and choose Properties.

The LAS file properties are different from the layer properties. The layer properties contain information that will affect how the layer is rendered and managed in the map, whereas the file properties store details about the LAS file itself.

v In the LAS File Properties dialog box, click the Statistics tab.

The statistics may not be calculated for this file.

w Click Update, if necessary.

4. Which classification code accounts for more than half of the point returns in this file?

____

x Click OK to close the LAS file properties.

Now that you are familiar with some of the LAS file properties, you will explore a few ways that you can work with a LAS file in ArcGIS Pro.

Step 2: Work with a LAS file in ArcGIS Pro

a In the Contents pane, verify that the PA000138 LAS file is selected.

b On the ribbon, note that the LAS Dataset Layer, Data, and Classification tabs are now visible.

c Click the LAS Dataset Layer tab.

The LAS Dataset Layer tab contains commands to help you visualize your lidar data effectively. These commands include visibility scale ranges, symbology options, transparency and swipe controls, and LAS point filters.

d In the Drawing group, click the Symbology down arrow and, under Symbolize Your Layer Using Points, choose Class.

e In the Contents pane, expand the LAS layer to see its legend.

The points are now symbolized according to their classification code.

f From the LAS Dataset Layer tab, click the Symbology down arrow and, under Symbolize Your Layer Using A Surface, choose Elevation.

g Zoom in to see the features more clearly.

This choice symbolizes the lidar points as a triangulated irregular network (TIN) surface. TINs are often useful in visualization and analysis.

h Return to the full extent of the PA000138 LAS file.

Hint: Right-click the layer > Zoom To Layer

i. From the LAS Dataset Layer tab, in the Drawing group, click the Symbology down arrow and, under Symbolize Your Layer Using Points, choose Elevation.

j. Close the Symbology pane.

k. Click the Data tab.

This tab gives you data management commands for calculating statistics, exporting lidar to different formats, conducting some analyses, and extracting features. You will use several of these commands later in the class.

l. Click the Classification tab.

This tab allows you to reclassify lidar points interactively and with geoprocessing tools. You will explore these commands later in the class.

Now that you have explored this LAS file in 2D, you will view the same file in a 3D scene.

Step 3: Create a 3D local scene

a. From the View tab, in the View group, click the Convert down arrow and choose To Local Scene.

ArcGIS Pro automatically interprets the LAS layer as a 3D data source and includes it in the list of 3D layers in the Contents pane.

b. In the map, press your mouse wheel to activate the 3D rotation tool .

c. While the 3D rotation tool is activated, tilt the scene so that you have a better perspective of the relative elevation of the different lidar points.

> If you do not have a mouse wheel or a three-key mouse, you can press and hold the V key on your keyboard to activate the 3D rotation tool. If you are new to the ArcGIS Pro 3D navigation tools, refer to ArcGIS Pro Help: *Navigation in 3D*, as well as the useful keyboard shortcuts discussed in ArcGIS Pro Help: *Keyboard shortcuts for navigation*.

d. Continue to zoom, tumble, and pan around to explore your scene, and see whether you can identify features using the point cloud and information in the basemap.

e. After you are comfortable exploring the 3D scene, save your project and keep ArcGIS Pro open for the next exercise.

Lesson review

1. **What does the "L" in lidar stand for?**
    a. **Laser**
    b. **Laboratory**
    c. **Light**
    d. **Location**
2. **Airborne-collected lidar is more commonly used in GIS applications than terrestrial-collected lidar.**
    a. **True**
    b. **False**
3. **One laser pulse can have only one return.**
    a. **True**
    b. **False**

Answers to lesson 1 questions

Examine lidar attributes (page 1-7)

1. Which attribute represents the total number of returns for a lidar pulse?

   Number of returns

2. Which value represents points that are not at the edge of a flight line?

   0

3. What is the scanning angle range for most currently used lidar systems?

   Less than ±30 degrees

4. Which attribute categorizes lidar points into classes like ground, water, and building?

   Point classification

Collecting lidar data (page 1-11)

1. Which lidar data collection method do you think is most commonly used by GIS professionals?

   GIS professionals primarily use airborne-collected lidar.

2. Which collection method would you use to create a detailed 3D model of the facade of a historical building?

   Terrestrial

3. Which collection method would you use to understand the size and number of trees on a forested area of land?

   Airborne

Answers to lesson 1 questions (continued)

Checkpoint (page 1-15)

1. The lidar LAS format is maintained by the American Society for Photogrammetry and Remote Sensing.

   a.

   True

   b. False

2. LAS is the only lidar format supported by ArcGIS Pro.

   a. True

   b.

   False

   (ArcGIS Pro supports both ASCII and LAS as lidar data sources.)

Exercise 1: Explore lidar data in ArcGIS Pro (page 1-16)

1. How many points are in the point count?

   4,288,574

2. What is the point spacing?

   4.826 feet

3. What is the highest z-range value? (The z-range indicates the lowest and highest elevations found in the point data.)

   4782.480 feet

4. Which classification code accounts for more than half of the point returns in this file?

   Ground

2 Using lidar data in ArcGIS Pro

Lidar data has a wide range of exciting applications in GIS. To ensure that GIS professionals can take advantage of lidar data's potential, ArcGIS Pro supports working directly with individual LAS files, as well as managing LAS file collections as LAS datasets, mosaic datasets, and point cloud scene layers. These options mean that you have the flexibility to choose a workflow that best fits your needs, whatever they may be. In this lesson, you will learn to distinguish between LAS datasets, mosaic datasets, and point cloud scene layers. You will also create a LAS dataset and populate it with LAS files.

Topics covered

- Distinguishing between LAS datasets, mosaic datasets, and point cloud scene layers
- Working with LAS datasets

LAS files in ArcGIS

Many GIS applications that use lidar data require working with multiple lidar files as one collection, or dataset. However, it is often efficient to work with individual files for data exploration and editing. For these purposes, ArcGIS Pro supports the direct use of both LAS and ZLAS files. The ZLAS format is a compressed and optimized type of LAS file that drastically decreases LAS file sizes and makes display, sharing, publishing, and archiving more efficient. As a compressed format, however, ZLAS is read-only, and it must be uncompressed before you can edit the point classifications. LAZ is another commonly available compressed format, which cannot be read directly by ArcGIS but can easily be converted into a LAS or ZLAS format using the Convert To LAS tool.

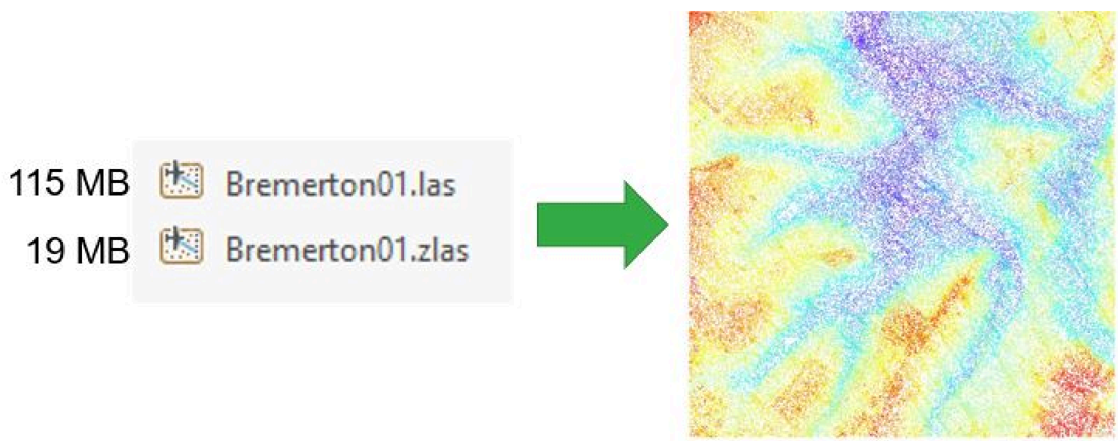


Figure 2.1. ZLAS files are compressed and optimized to perform better than raw LAS files.

ZLAS and LAZ files are created from LAS files with the Convert To LAS tool, available in ArcGIS Pro. This tool will also convert ZLAS and LAZ files into a LAS format.

Managing lidar data in ArcGIS

ArcGIS Pro supports lidar data provided as LAS or ZLAS files, but there is often a need to work with many files as one collection. To accomplish this task, there are different formats (datasets) that can be used to manage and work with your lidar data in ArcGIS Pro, depending on your needs. These formats include the LAS dataset, the mosaic dataset, and the point cloud scene layer.

The following table compares lidar support in ArcGIS using a LAS dataset (or LAS file), a mosaic dataset, and a point cloud scene layer.

	LAS dataset or LAS file	Mosaic dataset	Point cloud scene layer
Storage location	File system	Geodatabase	Scene layer package
Relationship to LAS source files	Points to	Points to	Builds a cache
Surface constraints	Supported	Not supported directly (supported if present in LAS dataset or terrain dataset)	Not supported
Lidar inputs	LAS files, ZLAS files	LAS files, terrain datasets, LAS datasets	LAS dataset
Types of lidar	Airborne and terrestrial	Airborne	Airborne and terrestrial
Rendering	Points, triangulated surface viewed in 2D and 3D	Raster	Points viewed in 3D

Managing lidar data in ArcGIS (continued)

(Table continued from previous page)

	LAS dataset or LAS file	Mosaic dataset	Point cloud scene layer
Analysis	Tools that can ingest point clouds or TINs. Use with 3D Analyst and LAS dataset tools.	Use with tools that can ingest raster data, such as Spatial Analyst and other raster dataset tools.	Not supported.
Display	Thinned points. Can change display by choosing different class types or data types. Display is modified by changing the symbology or point filters.	Uses cache for faster display. Can change display by choosing different class types or data types. Display is modified using the Layer Properties dialog box or the Image Analysis pane.	Thinned points. Uses cache for faster display. Display is modified by changing the symbology or point filters.
Editing points	Can edit the point classification residing in the LAS files	Cannot edit points	Cannot edit points
Combining with data	Supports LAS files, feature classes, and shapefiles	Supports LAS files, LAS datasets, terrain datasets, and other raster formats	Supports LAS datasets

Choosing a lidar data type

Three scenarios are presented. Following the previous instruction activity and with help from the table, you will choose the best lidar data type for each scenario.

Scenario 1: Editing point returns

You have several LAS files for one study area that you want to manage as one collection, but you might be required to edit your lidar data classification codes in the future.

1. **Which lidar data type provides you with the ability to edit the point returns?**

Scenario 2: Viewing 3D web scenes

You have a LAS dataset that you want to share as a fast-displaying visualization that members of your organization can view in a 3D web viewer.

2. **Which lidar data type allows you to share LAS datasets as 3D web scenes?**

Scenario 3: Performing raster processing

You want to use a collection of LAS files to perform slope calculations for a study area, as well as other raster processing.

3. **Which lidar data type can be used as input for most raster processing and analysis tools?**

What is a LAS dataset?

A LAS dataset stores references to one or more LAS or ZLAS files, as well as to additional surface features. The LAS dataset allows you to examine LAS files in their native format quickly and easily, providing detailed statistics and area coverage of the lidar data contained in the LAS files.

A LAS dataset can also store references to feature classes containing surface constraints. Surface constraints are breaklines, water polygons, area boundaries, or any other type of surface feature enforced in the LAS dataset when displaying it as a TIN. Surface constraints can be either geodatabase feature classes or shapefiles.

LAS datasets allow you to manage multiple LAS files as one unit while still providing access to the point returns in the source data. With a LAS dataset, you can quickly display lidar data as point clouds or a triangulated surface in 2D or 3D, conduct statistical analysis on the input LAS files and lidar points, conduct QA/QC by assessing data coverage and point sample density, and even edit the lidar point returns using ArcGIS Pro editing tools.

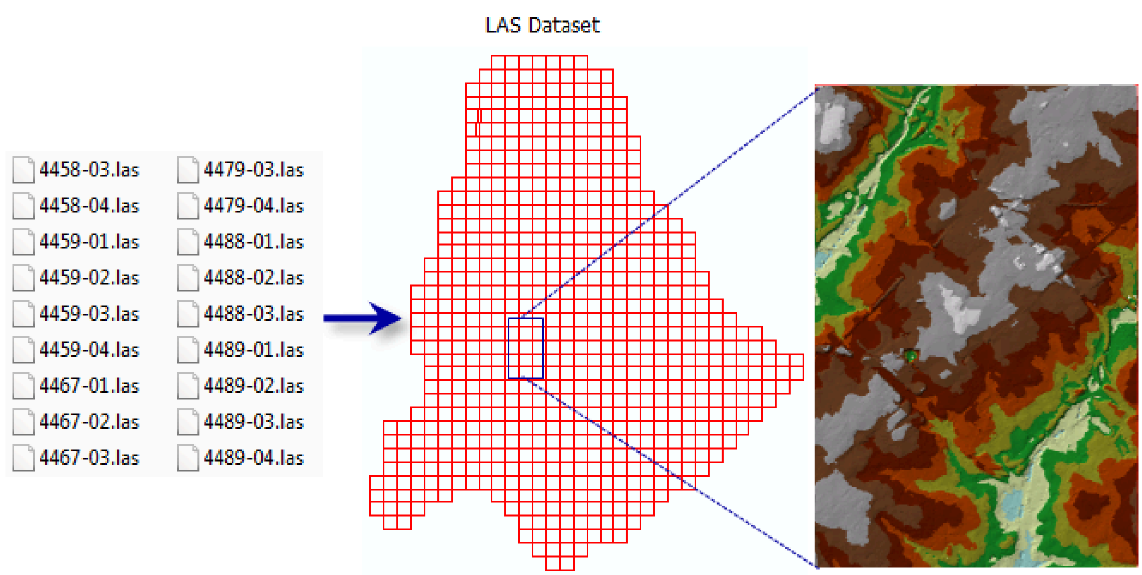


Figure 2.2. A LAS dataset can reference multiple LAS files.

Identify surface constraints

Surface constraints are features whose geometry captures or defines the characteristics of the surface when displaying it as a TIN. Breaklines, water polygons, and area boundaries are all examples of surface constraints. For instance, a lake polygon could be used to enforce an area of constant elevation by replacing the lidar point elevation values within it. There are several types of surface constraints, and the choice of which ones to use can have a dramatic impact on the TIN display of a LAS dataset.

Surface constraint type	Description
Anchorpoints	Elevation points that never get thinned away. This option is only available for single-point feature geometry.
Hardline or softline	Breakline that uses a height value to enforce an elevation change.
Hardclip or softclip	Polygon dataset that defines the boundary of a LAS dataset.
Harderase or softerase	Polygon dataset that defines holes in the LAS dataset.
Hardreplace or softreplace	Polygon dataset that defines areas of constant height.

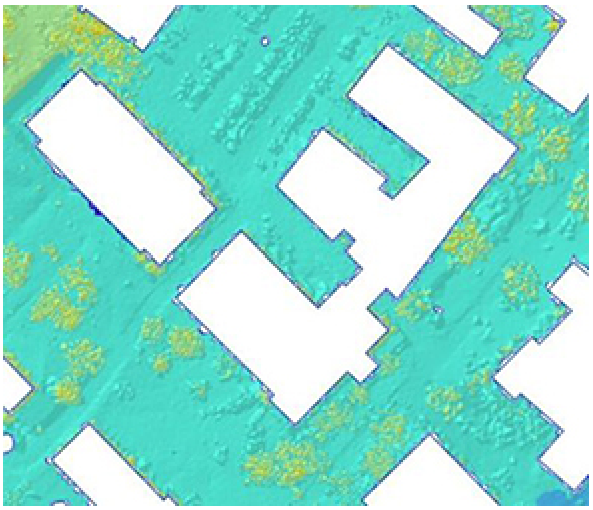
In the table, the hard and soft designations refer to whether the feature edges represent distinct breaks in slope or a gradual change.

Instructions

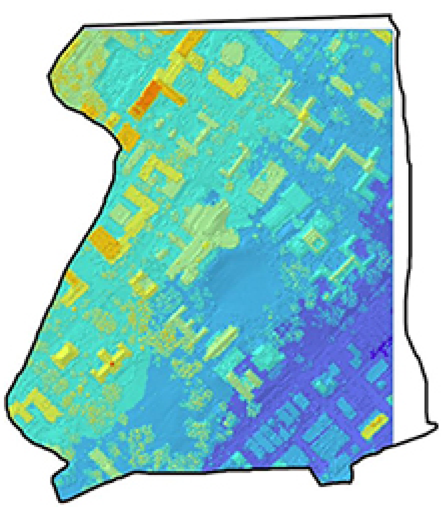
a Use the table to answer the following questions.

Identify surface constraints (continued)

1. **Which surface constraint is being enforced in this display?**



2. **Which surface constraint is being enforced in this display?**



Identify surface constraints (continued)

3. **Which surface constraint type will define lidar points that will always be used in the surface creation, regardless of thinning?**

Exploring a LAS dataset

LAS datasets provide a way to work with a collection of LAS files as one seamless dataset in ArcGIS Pro. Creating a LAS dataset allows you to filter the return points of all the input LAS files at one time and visualize them as a TIN using surface constraints.

Figure 2.5. LAS datasets help with filtering and visualization.

Exercise 2

Minutes: 15

Create and work with LAS datasets

You will combine multiple LAS files into a LAS dataset in ArcGIS Pro. You will also use the LAS dataset to find potentially erroneous returns.

In this exercise, you will perform the following tasks:

- Create a LAS dataset.
- Add files to a LAS dataset.
- Find lidar point outliers.

Step 1: Create a LAS dataset

a. Restore ArcGIS Pro and the LIDR project, if necessary.

b. Activate the StateCollege map.

> Make sure to activate the 2D StateCollege map, not the 3D local scene.

c. In the Catalog pane, from the LIDR folder, expand the LIDR.gdb file geodatabase.

d. Drag the StateCollege_Streams and StudyArea feature classes into the StateCollege map.

e. In the Contents pane, zoom to the extent of the StudyArea layer.

f. Below the layer name, click the StudyArea symbol, and then in the Symbology pane that opens, choose one of the black outline symbols for the polygons.

g. Using the same method, change the StateCollege_Streams symbol to something thicker and easier to see.

> In the Symbology pane, you can also click the Properties tab to access the color and line width properties.

h. After you have made these changes, close the Symbology pane.

i. From the Analysis tab, in the Geoprocessing group, click Tools to open the Geoprocessing pane.

j. In the Geoprocessing pane, search for and open the Create LAS Dataset tool.

k. For Input Files, click the Browse button and browse to the **C:\EsriTraining\LIDR\USGS_StateCollege\LAS_Classified** folder.

l. Select the PA000137, PA000138, and PA000139 LAS files, and then click OK.

Hint: To select multiple files, press the Ctrl key while clicking each file.

m. For Output LAS Dataset, browse to the **..\EsriTraining\LIDR\LAS_Datasets** folder.

n. For Name, type **SC_USGS.lasd**, and then click OK.

o Under Surface Constraints, for Input Features, choose StudyArea from the drop-down list.

p For Type, verify that Soft_Clip is selected.

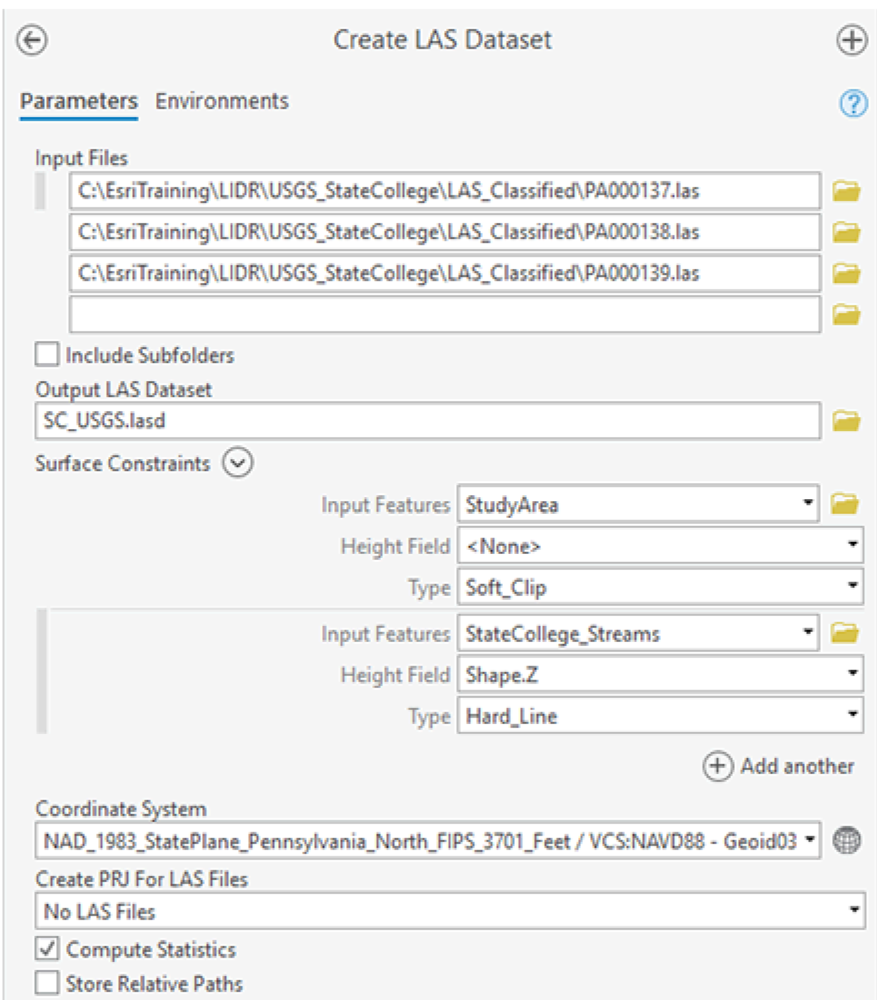
q Click Add Another to add another constraint with the following parameters:

- Input Features: StateCollege_Streams
- Height Field: Shape.Z
- Type: Hard_Line

r For Coordinate System, choose the PA000138 LAS file from the drop-down list.

s For Create PRJ For LAS Files, verify that No LAS Files is selected.

t Ensure that the Compute Statistics box is checked.

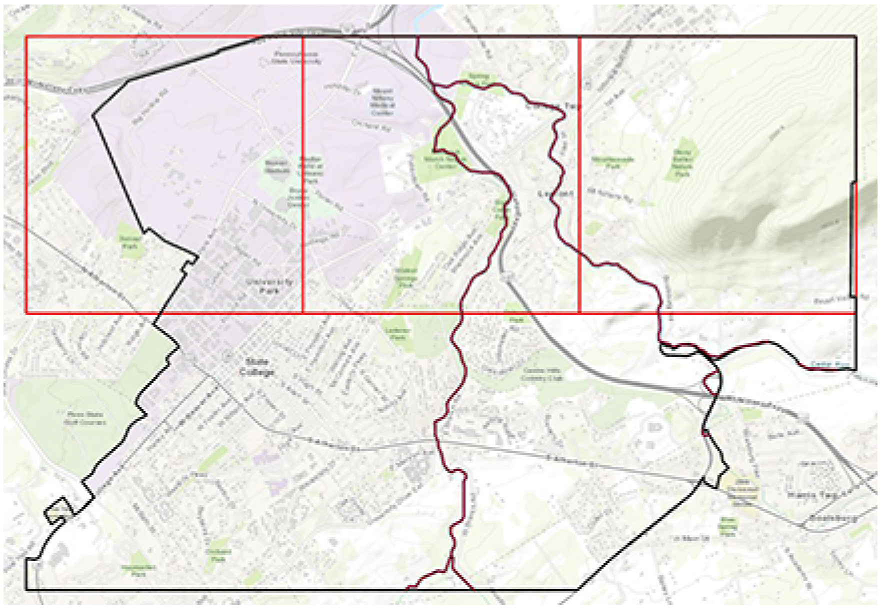


u. Click Run to execute the tool.

v. Notice that the SC_USGS LAS dataset is automatically added to the map.

w. In the Contents pane, remove the PA000138 LAS layer.

x. Zoom out, if necessary, to see the entire extent of the new LAS dataset.



Your symbology may differ from this graphic.

y. Zoom in so that you can see the point clouds.

The LAS files were not copied into the LAS dataset; they are just being referenced. The LAS dataset is providing a way to manage the three separate files as if they were one. Now that you have created a LAS dataset, you will learn how to add additional LAS files to it.

z. Close the Geoprocessing pane.

Step 2: Add files to a LAS dataset

a. In the Catalog pane, from Folders, expand the LAS_Datasets folder, right-click the SC_USGS LAS dataset, and choose Properties.

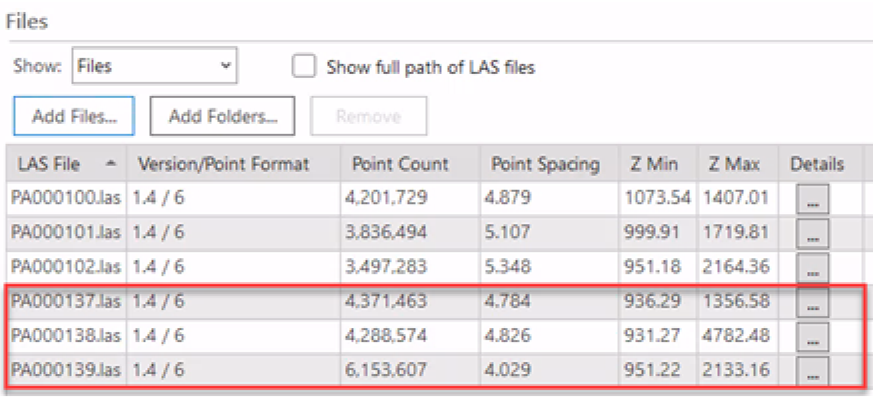
b. In the LAS File Properties dialog box, click the LAS Files tab.

The LAS Files option allows you to explore the properties of the individual LAS files referenced by the LAS dataset. You can also add additional LAS files to the dataset. There are several ways to accomplish this task in ArcGIS Pro, but you will use the LAS File Properties dialog box.

c Click Add Files, and then browse to the **..\EsriTraining\LIDR\USGS_StateCollege\LAS_Classified** folder.

d Select the PA000100, PA000101, and PA000102 files, and then click Open.

e Notice that these three files are now listed in the properties.


Files

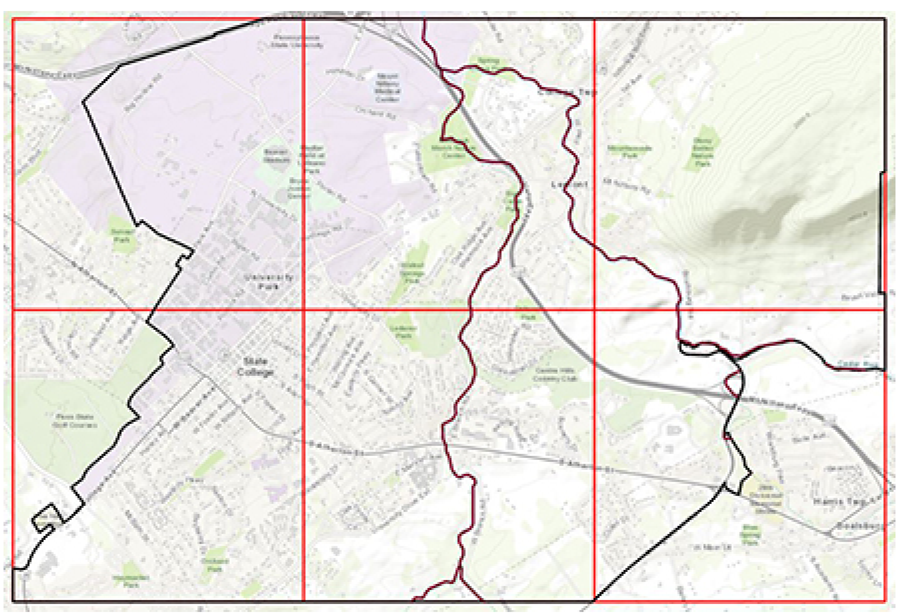
Show: Files ☐ Show full path of LAS files

Add Files... Add Folders... Remove

LAS File	Version/Point Format	Point Count	Point Spacing	Z Min	Z Max	Details
PA000100.las	1.4 / 6	4,201,729	4.879	1073.54	1407.01	...
PA000101.las	1.4 / 6	3,836,494	5.107	999.91	1719.81	...
PA000102.las	1.4 / 6	3,497,283	5.348	951.18	2164.36	...
PA000137.las	1.4 / 6	4,371,463	4.784	936.29	1356.58	...
PA000138.las	1.4 / 6	4,288,574	4.826	931.27	4782.48	...
PA000139.las	1.4 / 6	6,153,607	4.029	951.22	2133.16	...

f Click OK, and then click Yes if you are prompted to save changes.

g In the Contents pane, right-click the SC_USGS.lasd layer and choose Zoom To Layer.



Your map should now include a total of six LAS files.

If you do not see all six LAS files, in the lower-right corner of the map, click the Refresh Display button. If refreshing the display does not work, remove the SC_USGS.lasd layer from the Contents pane and add SC_USGS.lasd to the map again from the Catalog pane.

Now that the LAS dataset is complete, you will examine it for potential erroneous points. This type of informal quality control is a common task when you are working with lidar data.

h. Close the Geoprocessing pane.

Step 3: Find lidar point outliers

a. In the Catalog pane, expand Maps.

b. Right-click the StateCollege_QAQC scene and choose Open Local View.

c. From the LAS_Datasets folder, drag the SC_USGS.lasd LAS dataset into the scene.

If a Build LAS Dataset Pyramid dialog box appears, click No.

d. Zoom out until the point cloud appears as a series of transparent red cubes, and then tilt the scene so that the perspective is similar to the following graphic.

1. What do you notice about the red cubes?

e Click the taller red cube.

2. **Which LAS file is this cube associated with?**

___

3. **What is the z-range of this LAS file?**

___

A z-range that is this wide and different is a clue that some of the lidar returns in this file might be outliers.

f Close the pop-up.

g From the Map tab, click Bookmarks and choose Birdshots.

h Pan, tilt, and zoom the scene, if necessary, to view the birdshots.

> The outliers should appear as red points just above the horizon. If you do not see the points, they may be filtered out. Click the LAS Dataset Layer tab and, in the Point Thinning group, move the Density slider to the maximum.

These unusually high points are referred to as "birdshots," which may be caused by sensor errors, random noise, or the laser pulse bouncing off a bird or other object.

i Click the topmost point to view its attributes.

4. **What is the Elevation value?**

___

5. **What is the Class Code value?**

___

___

It is unlikely that these points are legitimate returns, and they should not be used in future visualization, surface creation, or analysis. In the next section, you will learn how to filter out these erroneous points when you create surfaces. You could also use the Locate Outliers tool to find erroneous points.

j. Close the pop-up.

k. Close the StateCollege_QAQC scene and the StateCollege_3D scene.

l. Save your project and keep ArcGIS Pro open for the next exercise.

Lesson review

1. Does a LAS file or a ZLAS file appear as a read-only file in ArcGIS Pro?

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2. Which data type manages lidar as raster output?
   a. LAS dataset
   b. Mosaic dataset
   c. Point cloud scene layer
   d. Geodatabase feature class

3. Which option could you use to limit the extent of a LAS dataset when displaying it as a TIN?
   a. Surface constraint
   b. Analysis mask
   c. Interpolation method
   d. Geographic transformation

Answers to lesson 2 questions

Choosing a lidar data type (page 2-5)

Scenario 1: Editing point returns

1. Which lidar data type provides you with the ability to edit the point returns?

   LAS dataset

Scenario 2: Viewing 3D web scenes

2. Which lidar data type allows you to share LAS datasets as 3D web scenes?

   Point cloud scene layer

Scenario 3: Performing raster processing

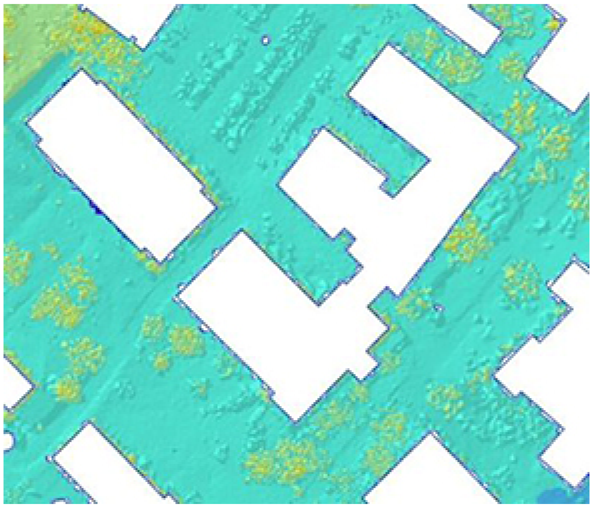
3. Which lidar data type can be used as input for most raster processing and analysis tools?

   Mosaic dataset

Answers to lesson 2 questions (continued)

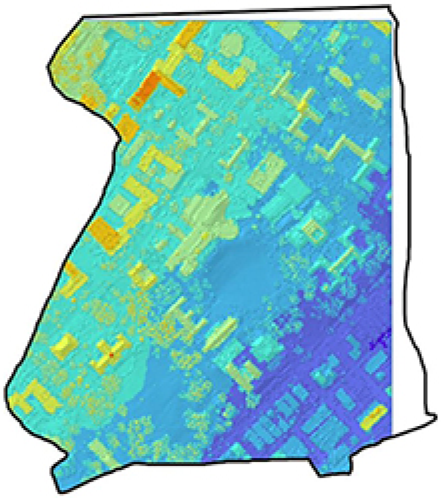
Identify surface constraints (page 2-7)

1. Which surface constraint is being enforced in this display?



Harderase

2. Which surface constraint is being enforced in this display?



Hardclip

3. Which surface constraint type will define lidar points that will always be used in the surface creation, regardless of thinning?

Anchorpoints

Answers to lesson 2 questions (continued)

Exercise 2: Create and work with LAS datasets (page 2-11)

1. What do you notice about the red cubes?

   One of the cubes is taller than the others.

2. Which LAS file is this cube associated with?

   PA000138

3. What is the z-range of this LAS file?

   931.270 to 4782.480 feet

4. What is the Elevation value?

   4782.48 feet

5. What is the Class Code value?

   The class code is 12. Knowing the class code will help you filter these erroneous returns from the LAS dataset.

3 Creating surfaces from lidar

One of the most common uses of lidar data in GIS is to derive elevation surfaces representing individual or groups of return value classes. These surfaces are raster outputs that can be further used in analysis and visualization to answer questions or provide better clarity about the study area. In this lesson, you will learn how to use a LAS dataset to create three types of surfaces: a digital terrain model (DTM), a digital surface model (DSM), and a digital height model (DHM).

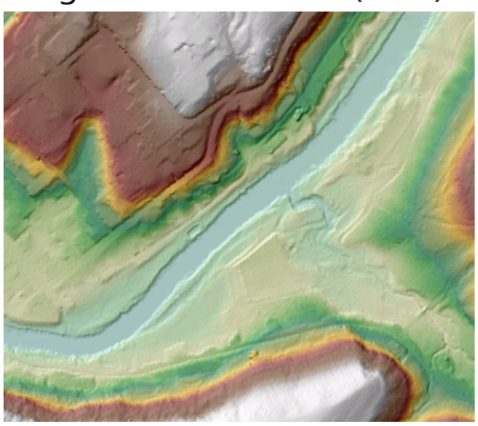
Topics covered

- Understanding different surface models
- Storing surfaces as raster datasets
- Managing surfaces in a mosaic dataset

Common surface models

An elevation surface is a raster dataset interpolated from sample points, like lidar. Because lidar data contains multiple returns for the same laser pulse, different types of surfaces can be created for the various return classes. One of the most common types of surfaces is a digital terrain model (DTM), which is interpolated using only the ground returns. A DTM represents the elevation of the bare earth surface without vegetation or structures. Another type of surface commonly created from lidar is created from the highest hit returns. This digital surface model (DSM) represents bare ground, trees, and structures.

Digital terrain model (DTM)



Bare earth surface made using only ground hits

Digital surface model (DSM)

- Highest hit returns
- Includes ground, trees, and buildings

Creating a raster surface from lidar

Surfaces like DTMs and DSMs can be created from lidar using the LAS Dataset To Raster tool. This tool will honor any class filters that you have set, so the first step to creating a DTM is filtering out all returns except those representing bare earth. The tool then uses only those bare earth points in the calculation of the output raster dataset. The LAS Dataset To Raster tool has several parameters that can influence the output raster surface. Although the parameters have default settings, understanding the parameters individually will enable you to produce a surface that best meets your particular needs.

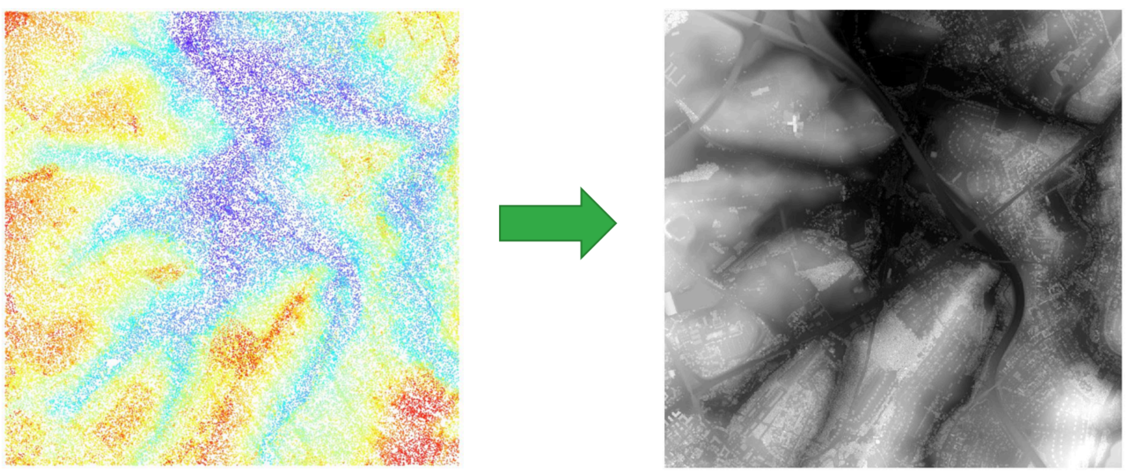


Figure 3.2. The LAS Dataset To Raster tool helps produce output rasters.

Output resolution

When creating surfaces with the LAS Dataset To Raster tool, one important consideration is the resolution of your output raster surface. The resolution can be determined by specifying a cell size or a number of cells for the LAS dataset's (input) longest side. Defining a resolution that is too high will result in cells with few or no sample points to define their output values. A resolution that is too large may not capture the amount of detail that your lidar data is capable of representing. A resolution that is too small could result in undersampling while not gaining, and possibly overstating, accuracy. A good rule of thumb is that your output resolution should be three times your lidar point spacing.

In the following graphic, the grid on the left represents a resolution of 1 meter, while the grid on the right represents 1.5-meter cells. If the average point spacing of the input lidar is 0.5 meters, the 1.5-meter resolution does a better job of avoiding undersampling.

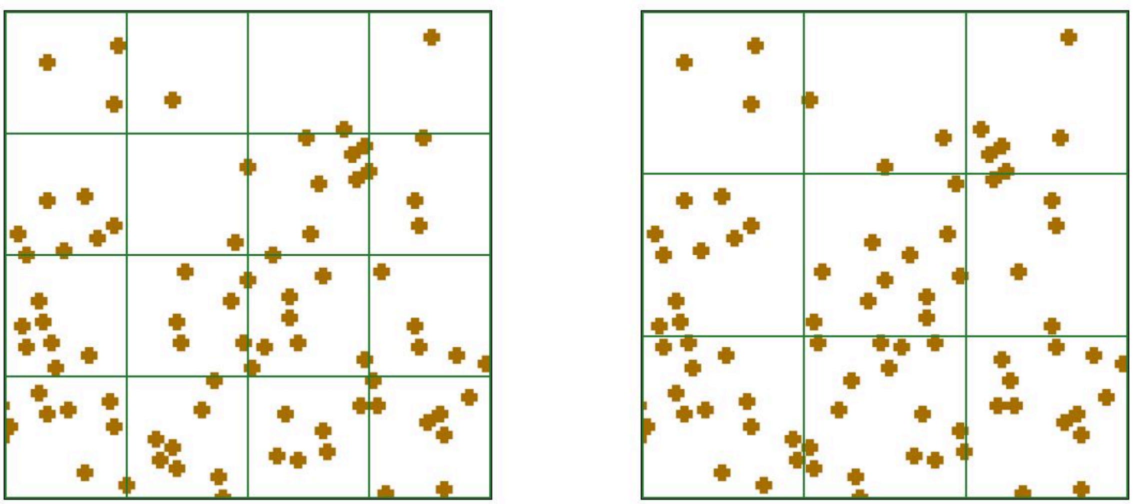


Figure 3.3. 1-meter resolution compared to 1.5-meter resolution.

Interpolating output cell values

The LAS Dataset To Raster tool includes two different methods for calculating the values of output raster cells: binning and triangulation. Although binning is usually faster, triangulation uses true interpolation and results in an output surface that is typically smoother than binning results. Triangulation will also always fill voids (cells with no lidar point samples), so if you prefer to leave voids unfilled, binning is a better solution than triangulation. The following graphic illustrates the differences in output between the two interpolation methods. The red cells in the binning example are voids.

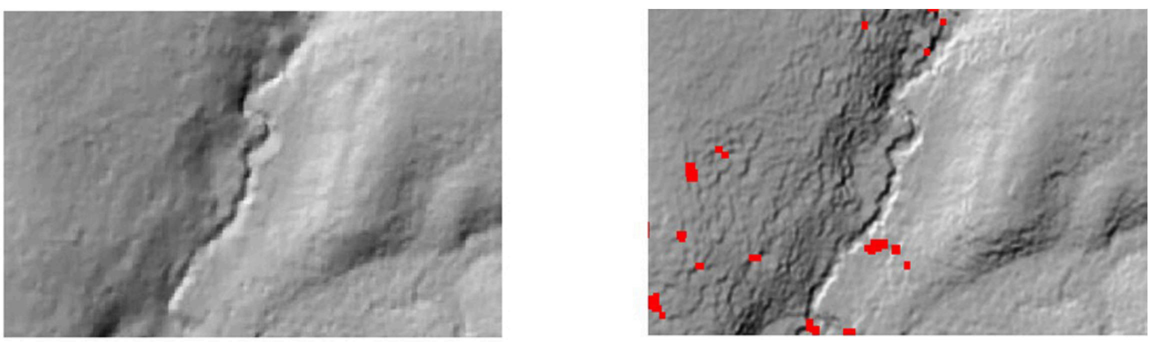


Figure 3.4. The two interpolation methods available in the LAS Dataset To Raster tool are triangulation (on the left) and binning (on the right).

The following table provides a comparison of these two interpolation methods.

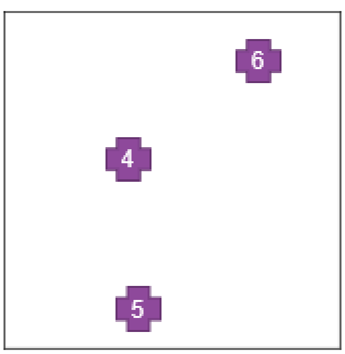
	Triangulation	Binning
Output cell value calculation	Derives cell values using a TIN-based approach and one of two interpolation methods	Assigns values based on points within the output cell using one of five assignment methods
Voids	Always filled	Allowed, but has filling options
Performance	Typically slower due to more robust calculations	Typically faster because calculations are easier
Output surface	Often more smooth compared to binning, with more gradual changes in neighboring cell values	Often more rough compared to triangulation, with more dramatic differences between neighboring cells

Checkpoint

1. **Which interpolation type has options for filling output cells without sample points or allowing them to remain unfilled?**
   a. Binning
   b. Triangulation
   c.
   d.

2. **Which interpolation type usually results in a smoother surface?**
   a. Binning
   b. Triangulation
   c.
   d.

3. **With the binning interpolation type, what would the output be for this cell (the black square) using the Average Assignment method?**



   a. 4
   b. 5
   c. 6
   d. 15

Creating surfaces from lidar

Creating DTMs and DSMs is one of the most common tasks that analysts perform with lidar data. A LAS dataset can be filtered so that only certain return points are considered when creating the respective surfaces. These resulting surfaces have many visualization and analytical applications.

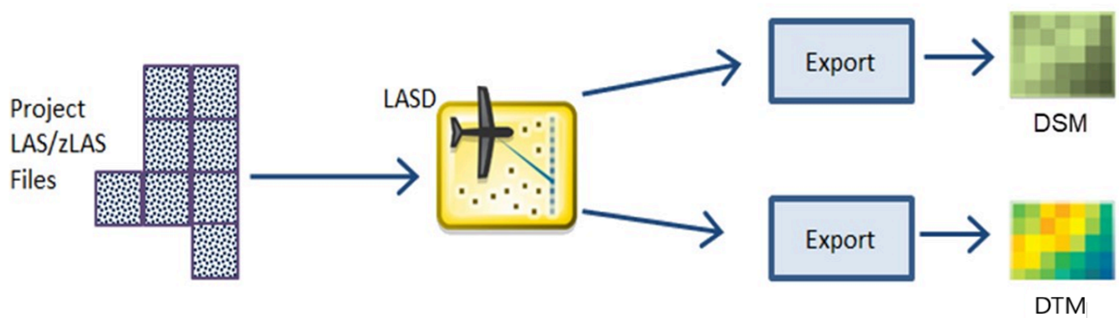


Figure 3.6. Filtering a dataset can aid with visualizing and analyzing.

Exercise 3

Minutes: 20

Create surfaces

One of the main reasons that organizations capture airborne lidar data is to derive accurate elevation models of their study area. The density of lidar sampling enables the creation of high-resolution outputs that are impractical to create any other way. In this exercise, you will learn how to use ArcGIS Pro tools to create three types of surfaces: a DTM, a DSM, and a DHM.

In this exercise, you will perform the following tasks:

- Create a digital terrain model (DTM).
- Create a digital surface model (DSM).
- Create a digital height model (DHM).

Step 1: Create a DTM

First, you will create the DTM, which is a surface representing only the ground readings from the lidar data.

a. Restore ArcGIS Pro and the LIDR project and activate the StateCollege map.

b. In the Contents pane, right-click the SC_USGS.lasd layer and choose Properties.

The following instructions are only necessary if you did not already complete the previous workflow to create the LAS dataset. If you are unsure, ask your instructor for assistance.

1. From the Catalog pane, expand the LIDR folder and the Results folder.
2. From the Results folder, add SC_USGS.lasd to the map.

c. Click the LAS Filter tab, if necessary.

d. For Classification Codes, uncheck the All box, and then check the 2 Ground box.

e. Click OK to close the layer properties.

f. In the Contents pane, verify that the SC_USGS layer is selected.

g. From the Data tab, in the Manage LAS Data group, click the Export down arrow and choose Export Raster to open the LAS Dataset To Raster tool in the Geoprocessing pane.

h. Specify or confirm the following parameters:

- Input LAS Dataset: SC_USGS.lasd
- Output Raster: **SC_DTM**
- Value Field: Elevation
- Interpolation Type: Triangulation
- Interpolation Method: Natural Neighbor
- Thinning Type: No Thinning
- Output Data Type: Floating Point
- Sampling Type: Cell Size

- Sampling Value: **15**
- Z Factor: 1

Your sampling value (output raster spatial resolution) choice is dependent on your point spacing. You can learn about the average point spacing in your LAS dataset by opening its properties from the Catalog pane, as you did earlier. In this case, the average point spacing is between 4 feet and 5 feet, so you will use the best practice of creating pixels that are about three times the point spacing.

i Click Run to execute the LAS Dataset To Raster tool.

The new raster is added to the map as a layer. The new raster dataset is stored in the LIDR geodatabase, which is set as the default output workspace in this project's environment settings.

In the new DTM, it is easy to see where the lower and higher elevations are. However, it is sometimes more effective to visualize an elevation surface as a hillshade. A hillshade is a grayscale raster where the cells are shaded based on their slope and aspect relative to the position of the sun.

j From the Analysis tab, in the Raster group, click Raster Functions.

k In the Raster Functions pane, scroll to the bottom, expand Surface, and then choose Hillshade.

l For Raster, choose SC_DTM from the drop-down list.

m Accept the default settings for the remaining parameters, and then click Create New Layer to execute the function.

A hillshade is created on the fly and added to the map. It provides a more intuitive way to visualize the DTM surface. Now that you have created a DTM, you will remove the filter on your LAS dataset and use it to create a DSM using all the lidar classes.

Step 2: Create a DSM

a In the Contents pane, right-click the SC_USGS layer and choose Properties.

b Click the LAS Filter tab, if necessary.

c For Classification Codes, check the All box, and then uncheck the 12 Overlap/Reserved box.

The 12 Overlap/Reserved setting represented an unusually high birdshot, so you do not want to include these points in your derived surfaces.

d. Click OK to close the layer properties.

e. From the Data tab, in the Manage LAS Data group, click the Export down arrow and choose Export Raster to open the LAS Dataset To Raster tool in the Geoprocessing pane.

f. In the Geoprocessing pane, specify or confirm the following parameters:

- Input LAS Dataset: SC_USGS
- Output Raster: **SC_DSM**
- Value Field: Elevation
- Interpolation Type: Triangulation
- Interpolation Method: Natural Neighbor
- Thinning Type: No Thinning
- Output Data Type: Floating Point
- Sampling Type: Cell Size
- Sampling Value: **15**
- Z Factor: 1

g. Click Run to execute the tool.

You might notice that this surface takes a little longer to create than the previous one. Remember that this surface is being created from all the lidar points (except those classified as 12), whereas the DTM only used the ground points.

When the new DSM is added to the map as a layer, it should be obvious that this surface includes buildings and trees, as well as ground readings. However, it might be easier to see that in a hillshade.

h. Using the same raster function that you used in the previous step, create a hillshade layer for the SC_DSM layer.

i. In the Contents pane, turn off the SC_DSM layer, and then confirm that the new Hillshade_SC_DSM layer is selected.

j From the Raster Layer tab, in the Compare group, click Swipe.

k Use the Swipe tool to compare the DSM and DTM hillshades, zooming in if necessary.

1. What kinds of features can you identify in the DSM that are not in the DTM?

____

l After you are finished comparing the two surfaces, from the Map tab, in the Navigate group, click Explore to turn off the Swipe tool.

So far, you have created two commonly used surfaces from lidar data. Now you will use these surfaces to create a final one: a DHM.

Step 3: Create a DHM

The DTM that you created represents the ground elevation of your study area, whereas the DSM represents the highest points, including things like the tops of trees and buildings. It is often helpful to also know the height of the objects themselves. These heights can be estimated by subtracting the DTM from the DSM, resulting in a representation of the heights of trees and structures in the study area known as a digital height model, or DHM. In some applications, such as forestry, it is known as a canopy height model.

In some literature, a DHM is referred to as a normalized digital surface model, or nDSM.

a On the right side of the project window, at the bottom of the Raster Functions pane, click the Geoprocessing tab to view the Geoprocessing pane.

b At the top of the Geoprocessing pane, click the Back button, and then search for and open the Minus (Spatial Analyst Tools) tool.

This tool will subtract one raster dataset from another and output the result. There are several ways to perform this operation, but the Minus tool is particularly easy and straightforward.

c In the Geoprocessing pane, specify the following parameters:

- Input Raster Or Constant Value 1: SC_DSM
- Input Raster Or Constant Value 2: SC_DTM

- Output Raster: **SC_DHM**

d. Click Run to execute the tool.

The SC_DHM layer is automatically added to the map.

e. In the Contents pane, if necessary, expand the three surface layers (SC_DTM, SC_DSM, and SC_DHM) so that their legends are visible.

f. Compare the elevation values in the legends of these three surfaces.

2. How are the elevation values in SC_DHM different from the other two surfaces?

____

g. From the Map tab, zoom to the Jordan Center bookmark, which represents the Bryce Jordan Center on the Penn State University campus.

h. In the Contents pane, turn off all the layers except SC_DHM.

Hint: Press Ctrl and uncheck one of the layer boxes to turn off all layers first.

i. With the Explore tool active, click the center of the Bryce Jordan Center.

3. What is the SC_DHM pixel value where you clicked?

____

The SC_DHM shows that the Jordan Center is about 100 feet tall, which seems reasonable for a midsize stadium with seating for about 15,000 people.

j. Explore a few other structures in the SC_DHM surface to see whether the measurements correspond to what you think they should be.

k. After you are finished, close the pop-up.

l. Save your project and leave ArcGIS Pro open for the next exercise.

What is a mosaic dataset?

As more and more raster surfaces are derived from your lidar data, you may need a method for managing the multiple surfaces collectively. Alternately, you might want a mechanism to manage your many LAS datasets that allows you to produce raster surfaces on the fly, without the need to store multiple outputs. The solution for both of these requirements is the mosaic dataset. A mosaic dataset is a data model within a geodatabase that is used to store, manage, view, and query large collections of raster data. It can be a heterogeneous collection of raster datasets with multiple formats, sources (including LAS datasets), data types, resolutions, number of bands, file sizes, and coordinate systems.

Raster datasets in mosaic datasets are not loaded into the geodatabase. Instead, they remain in their location and native format on disk. Applications access a mosaic dataset as an image or as a catalog of footprints and metadata.

A mosaic dataset includes multiple components:

- Footprints representing each item in the mosaic
- A boundary defining the extent of the data
- An image layer that controls the rendering of the data sources as a mosaicked image
- Overview-reduced resolution copies of the mosaic dataset that improve drawing performance when panning and zooming
- Statistics on the source data cell values

What is a mosaic dataset? (continued)

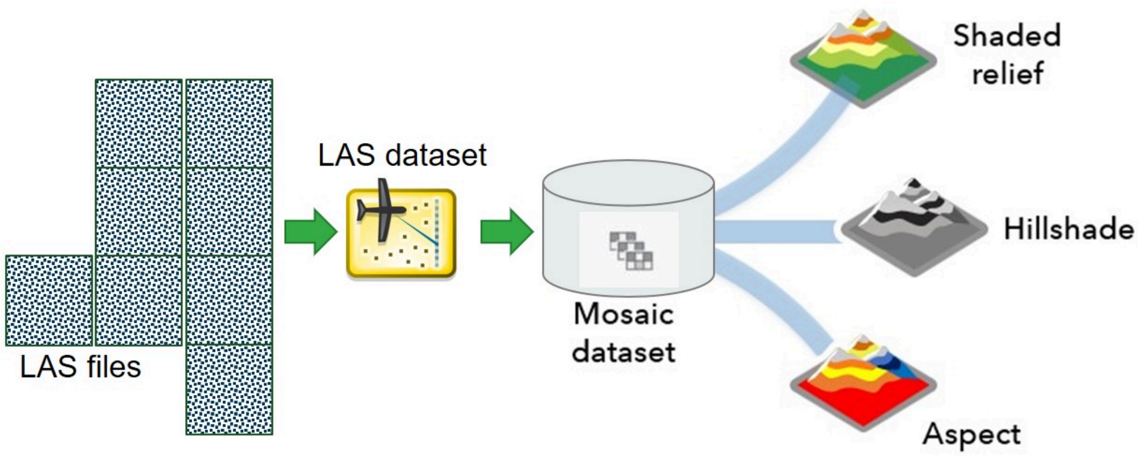


Figure 3.7. A mosaic dataset can be beneficial for management and storage considerations.

Pros and cons of managing lidar data with mosaic datasets

Managing lidar data as a mosaic dataset provides some unique advantages, as well as some disadvantages that you should be aware of before deciding to use this dataset.

What are some advantages and disadvantages of managing lidar data with a mosaic dataset?

Managing lidar data in a mosaic dataset

Creating a mosaic dataset with lidar data allows you to use lidar data as an input for raster tools and functions. The workflow begins with creating an empty mosaic dataset and then populating it with one or more LAS datasets. Keep in mind that the mosaic dataset is not storing the lidar data; it is merely referencing the source LAS files through the LAS dataset.

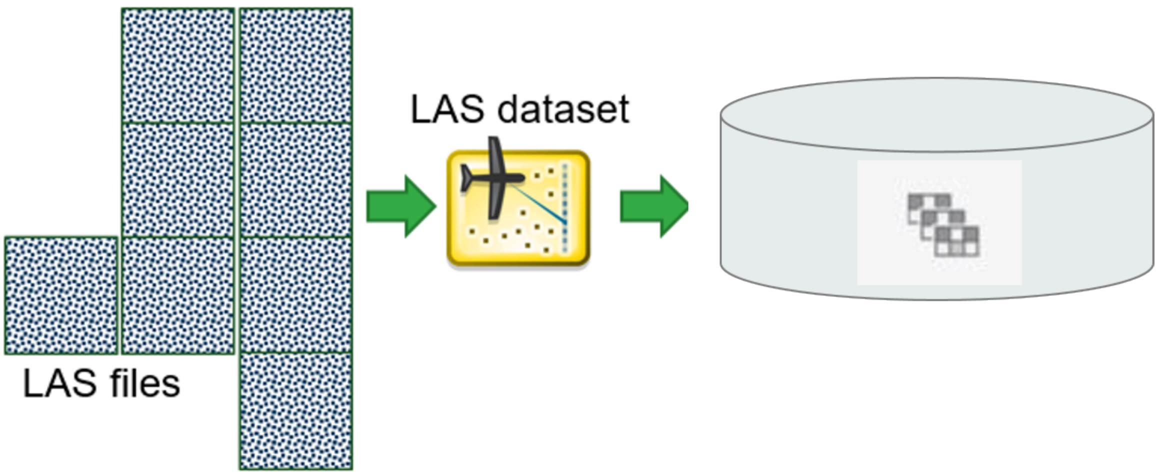


Figure 3.8. The mosaic dataset workflow.

Workflow review

Lidar data is often used to produce a DTM. The workflow for creating a DTM from a LAS dataset is straightforward, but disregarding a step can have significant impacts on your end result. Review the workflow to answer the following questions.

Figure 3.9. Creating a DEM from a LAS dataset workflow.

1. **Why is it necessary to filter out all returns except Ground before running the LAS Dataset To Raster tool?**

2. **What are the two interpolation types for the LAS Dataset To Raster tool?**

Answers to lesson 3 questions

Checkpoint (page 3-6)

1. Which interpolation type has options for filling output cells without sample points or allowing them to remain unfilled?

   a.

   Binning

   b. Triangulation

   c.

   d.

2. Which interpolation type usually results in a smoother surface?

   a. Binning

   b.

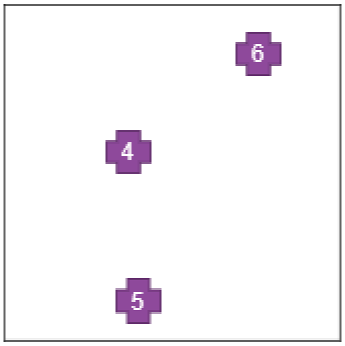
   Triangulation

   c.

   d.

Answers to lesson 3 questions (continued)

3. With the binning interpolation type, what would the output be for this cell (the black square) using the Average Assignment method?



a. 4

b.
5

c. 6

d. 15

Exercise 3: Create surfaces (page 3-8)

1. What kinds of features can you identify in the DSM that are not in the DTM?

   Answers can vary but may include houses, trees, and large buildings.

2. How are the elevation values in SC_DHM different from the other two surfaces?

   They are much smaller because they reflect the difference between the two surfaces.

3. What is the SC_DHM pixel value where you clicked?

   Results will vary, but the value should be around 100 feet.

Pros and cons of managing lidar data with mosaic datasets (page 3-16)

What are some advantages and disadvantages of managing lidar data with a mosaic dataset?

Possible advantages include the following:

- **A centralized way to manage multiple files**
- **Avoiding redundancy with on-the-fly output**

Answers to lesson 3 questions (continued)

- **The ability to use raster tools and functions**

Possible disadvantages include the following:

- **Must maintain access to LAS files**
- **Must use a geodatabase**

Workflow review (page 3-18)

1. Why is it necessary to filter out all returns except Ground before running the LAS Dataset To Raster tool?

   A DTM depicts ground elevation, so only the ground points should be used when creating a DTM.

2. What are the two interpolation types for the LAS Dataset To Raster tool?

   Binning and triangulation

4 Modifying lidar data

While it is common for vendors and other data providers to deliver lidar data with the ASPRS classification codes already assigned, it is also quite common that these classifications will need to be updated based on your own local knowledge. It is also possible that you may acquire lidar data that is unclassified. In these cases, it is helpful to know how you can assign initial classification codes or modify existing ones in ArcGIS Pro to derive a better representation of your study area.

Topics covered

- Understanding reasons to edit lidar data
- Differentiating between geoprocessing tools and interactive editing

Why edit?

Editing lidar data in ArcGIS Pro is not only possible—sometimes, it is necessary. However, the edits that are made to LAS files are limited to one attribute.

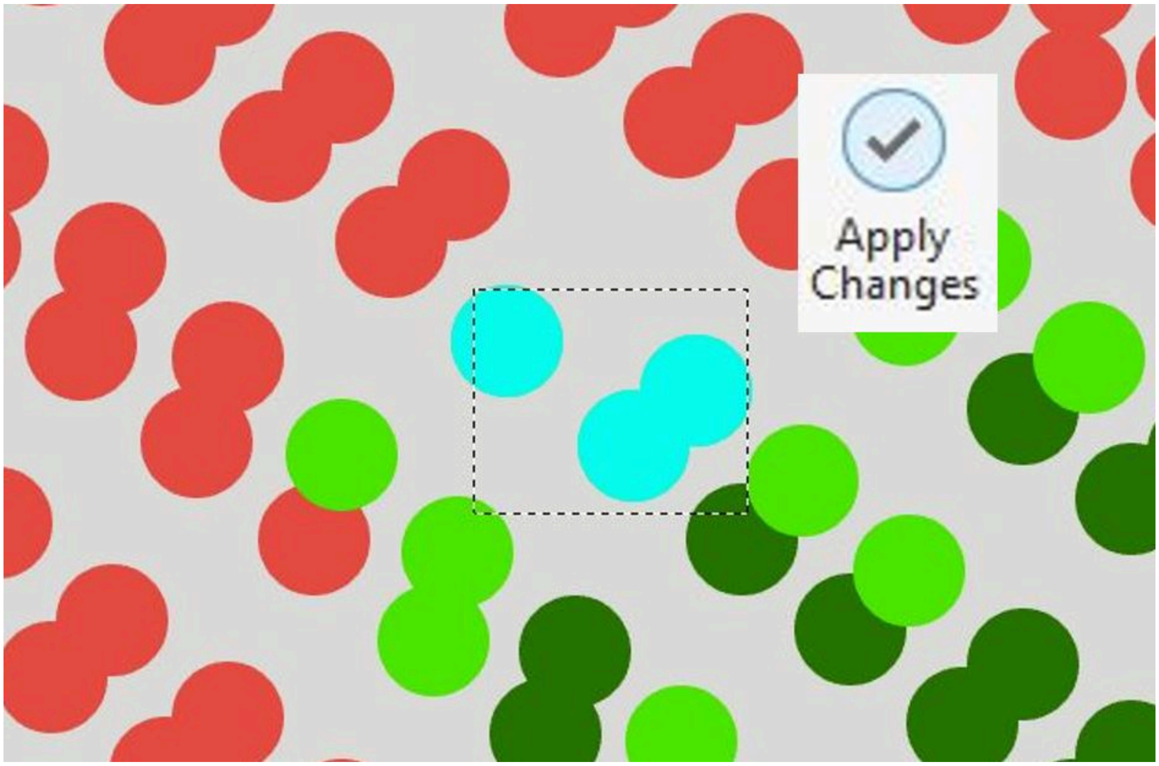


Figure 4.1. Editing points in ArcGIS Pro.

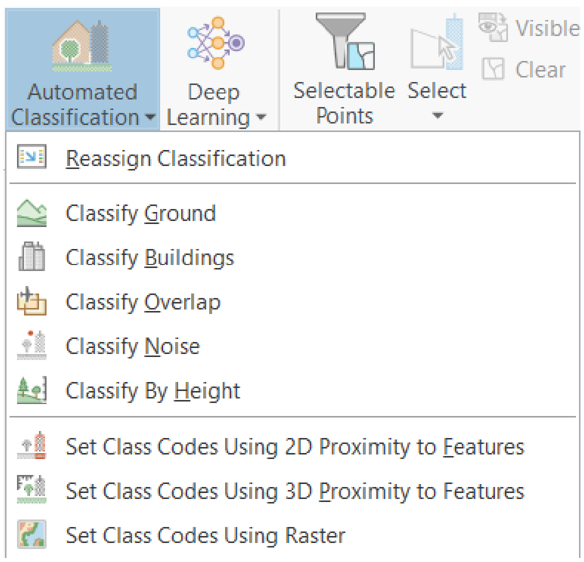
Which lidar attribute most likely requires editing?

Why might you need to modify this attribute?

Editing methods

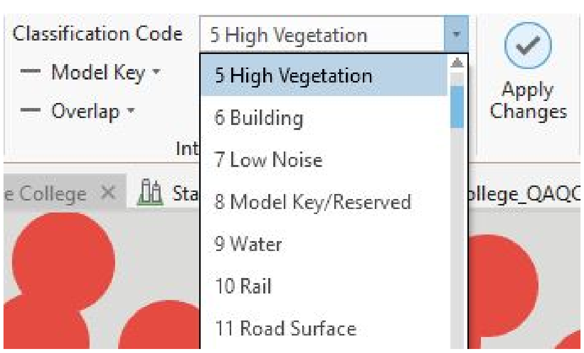
Whether correcting inaccurate classifications or working with unclassified lidar to determine the appropriate codes for the return points, you should be familiar with the tools and processes available to you in ArcGIS Pro for modifying LAS files.

Geoprocessing tools



For changing or assigning classification codes in bulk, ArcGIS Pro provides several automated classification tools that will determine which points represent features like ground or buildings and assign the appropriate code. Additionally, the Change LAS Class Codes tool allows you to manually control the reassignment of all codes in one operation.

Interactive editing tools



When you need to change the classification of an individual point or a small group of points, you can take advantage of the interactive editing tools on the Classification tab. In this method, you can manually select the points that you want to change and then choose an appropriate code from the Classification Code drop-down list.

Lidar editing considerations

Although the ability to directly edit LAS files in ArcGIS Pro is extremely helpful, there are certain considerations to keep in mind.

- LAS file editing is limited to changing the classification codes of the return points through the geoprocessing or interactive tools available for your LAS dataset layer. No spatial editing or other attribute edits are supported.
- All changes are made directly to the points, without the ability to undo or the need to save edits. For this reason, it is recommended that you perform your edits on a copy or extracted subset of your original data so that you always have an original to return to if necessary.

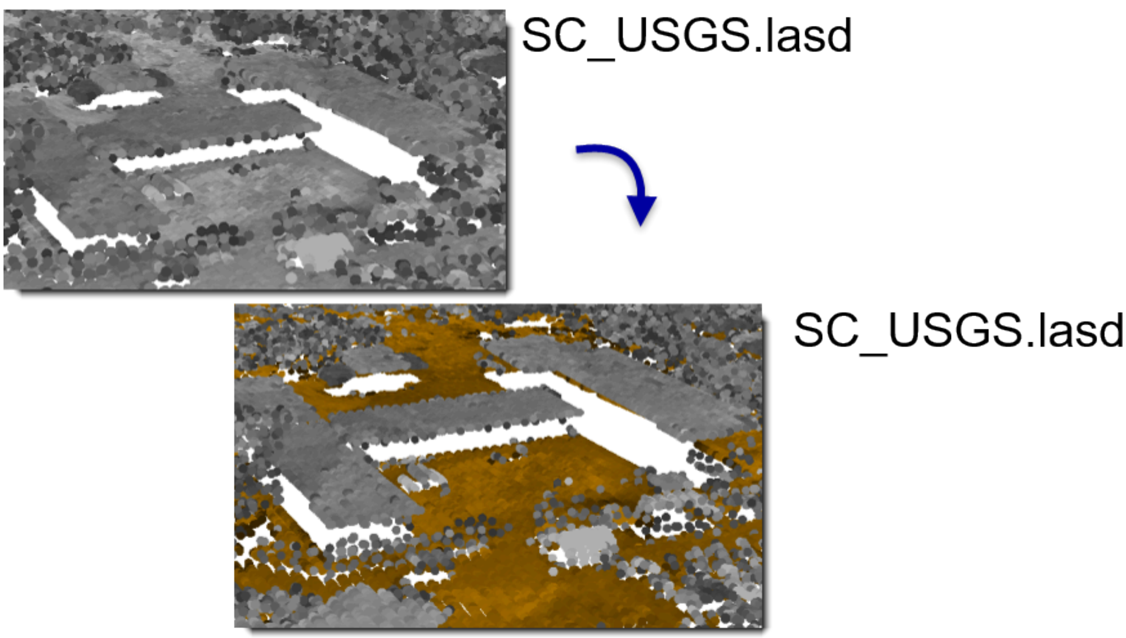


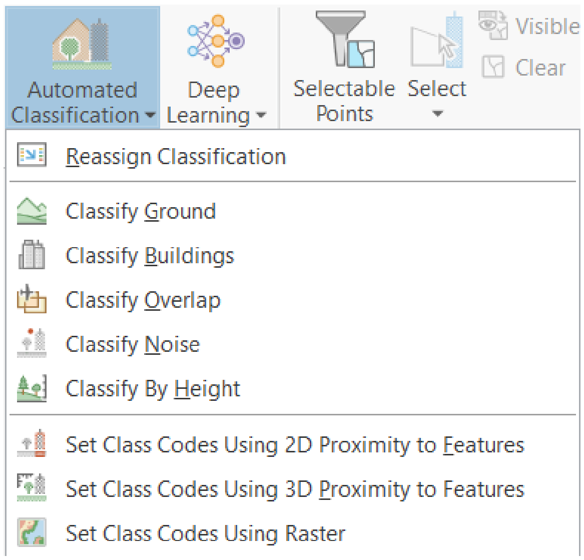
Figure 4.2. Edits to LAS datasets are made directly to the source files.

Choosing an editing method

Editing your lidar data classification codes can be made more efficient by knowing which editing method (geoprocessing tool or interactive) to use in a given situation. Based on what you have learned so far, choose an editing method for each scenario.

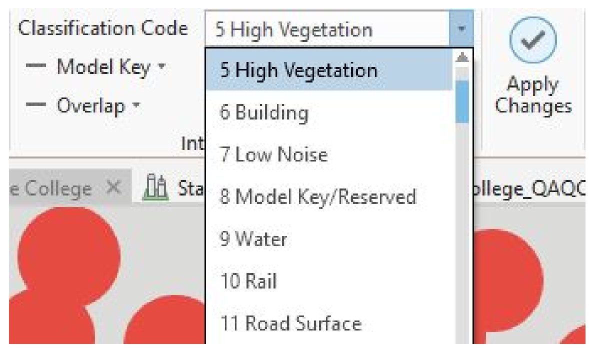
<table>
<tr><th>Geoprocessing tools</th><th>Interactive</th></tr>
<tr><td>

- Make changes in bulk



</td><td>

- Select points and change classification codes



</td></tr>
</table>

Scenario 1: Storage shed

Visual inspection of the LAS dataset along with satellite imagery reveals that a group of points classified as medium vegetation is actually a small campus storage shed, and you want to reclassify them as Building.

1. **Which editing method (geoprocessing tool or interactive) would you choose to perform the edits?**

___

___

Choosing an editing method (continued)

Scenario 2: Nonstandard classification

The LAS dataset points are classified according to a nonstandard scheme and need to conform to the ASPRS classification.

2. **Which editing method (geoprocessing tool or interactive) would you choose to perform the edits?**

Exercise 4

Minutes: 25

Edit a LAS dataset

When working with lidar data, it is sometimes necessary to change the classification codes of the point returns. This need is often driven by the fact that no classification is 100 percent accurate. Analysts consistently want to improve how well the lidar data represents actual real-world conditions. ArcGIS Pro provides several tools to automatically identify and classify certain codes, as well as reclassify entire datasets. It is also possible to select points interactively and change their codes manually.

In this exercise, you will perform the following tasks:

- Classify points as Ground, Building, and Noise with automated classification tools.
- Interactively classify lidar points.

Step 1: Classify ground points

In this course so far, you have been working on lidar data that represents one part of the Penn State University campus. In this exercise, you will work with different LAS files representing another part of the campus.

a. Restore ArcGIS Pro and the LIDR project, if necessary.

b. Close all open map and scene views.

c. In the Catalog pane, expand Maps.

d. Right-click the PennState map and choose Open.

   Ignore any Transformation Warnings that may appear.

The PennState map contains a LAS dataset called PSU_Working that includes points that have not been classified. All the points have a classification code of Unassigned. You will use geoprocessing tools to classify some of the points in the PSU_Working LAS dataset.

e. In the Contents pane, ensure that the PSU_Working layer is selected.

f. From the Classification tab, in the Geoprocessing group, click the Automated Classification down arrow and choose Classify Ground.

g. In the Classify LAS Ground tool, specify or confirm the following parameters:

   - Input LAS Dataset: PSU_Working.lasd
   - Ground Detection Method: Standard Classification
   - DEM Resolution: **3** US Survey Feet
   - Ensure that the Compute Statistics box is checked.

h. Point to Ground Detection Method, and then point to the Input Information link .

i. Read through the information about the various methods of detecting ground lidar returns.

Based on this information, the Standard Classification method is probably the most suitable choice.

j Click Run.

k From the LAS Dataset Layer tab, click the Symbology down arrow and choose Class.

l Zoom in, if necessary, until you can see the lidar points.

Most of the points are still classified as Unassigned, but some points have now been reclassified to Ground. Using these ground returns, you will create a new DTM LAS layer.

m In the Geoprocessing pane, search for and open the Make LAS Dataset Layer tool.

A LAS dataset layer is an easy way to apply a filter and surface constraints to a LAS dataset. This layer in the map can then be used as an input for geoprocessing tools.

n In the Make LAS Dataset Layer tool, specify the following parameters:

- Input LAS Dataset: PSU_Working.lasd
- Output Layer: **GroundReturns**
- Class Codes: Check box 2
- Return Values: Click Select All

o Click Run.

The Make LAS Dataset Layer tool applies a filter to the LAS dataset and uses only the filtered values as inputs to geoprocessing tools. In this case, you will use this filtered layer to create a DTM.

p From the Data tab, click the Export down arrow and choose Export Raster.

q In the LAS Dataset To Raster tool, specify or confirm the following parameters:

- Input LAS Dataset: GroundReturns
- Output Raster: **PSU_DTM**
- Value Field: Elevation
- Interpolation Type: Triangulation
- Interpolation Method: Natural Neighbor
- Thinning Type: No Thinning
- Output Data Type: Floating Point

- Sampling Type: Cell Size
- Sampling Value: **3**
- Z Factor: 1

r Click Run.

Disregard the clip constraint warning.

s In the Contents pane, right-click the PSU_DTM layer and choose Zoom To Layer.

This DTM is based solely on the points included in the GroundReturns layer, which resulted from the Classify LAS Ground tool. In the next step, you will use some additional tools to classify returns as Noise or Buildings.

Step 2: Classify noise and building points

In any lidar workflow, it is important to know whether your LAS dataset contains noise points. Noise points may contain erroneous elevation measurements that can drastically exaggerate the z-range of your data. Noise points can be caused by atmospheric conditions, collection system errors, or even something like a high-flying bird. Reclassifying these erroneous points as "noise" can help improve the accuracy of your derivative products.

a In the Contents pane, select the PSU_Working.lasd layer.

b From the Classification tab, click the Automated Classification down arrow and choose Classify Noise.

c In the Classify LAS Noise tool, specify or confirm the following parameters:

- Input LAS Dataset: PSU_Working.lasd
- Method: Isolation
- Verify that the Edit Classification and Compute Statistics boxes are checked.
- Height Detection:
    - Ground: PSU_DTM
    - Minimum Height: **-2** US Survey Feet
    - Maximum Height: **1400** US Survey Feet

d Click Run.

In this tool, all lidar points above 1,400 feet are being reclassified as noise. This reclassification will allow you to filter these points to exclude them from further analysis and processing.

e In the Contents pane, turn off all the layers except PSU_Working.lasd.

f Right-click the PSU_Working layer and choose Properties.

g From the LAS Filter tab, notice that the classification code of 7 Noise is now present, along with Ground and Unassigned.

Even though the Noise class code is present, the symbology does not automatically show it. When symbolizing lidar points by classification, ArcGIS Pro defaults to filtering out noise returns on the assumption that you typically do not want to see them. You could symbolize them by manually adding them in the Symbology pane, but it is not necessary in this case.

h Uncheck the 7 Noise box so that the PSU_Working.lasd layer is filtered to include only 1 Unassigned and 2 Ground classified points.

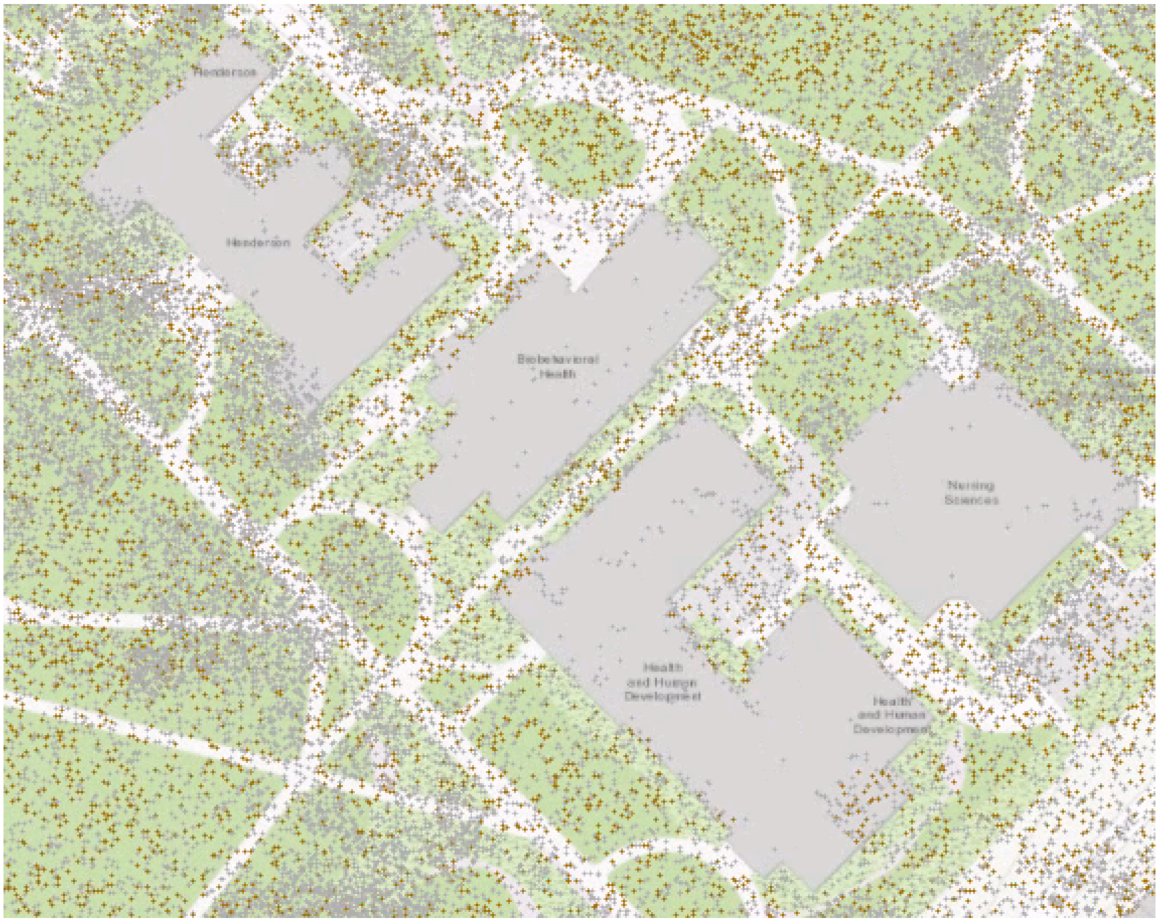
i Click OK to close the layer properties.

j From the Classification tab, click the Automated Classification down arrow and choose Classify Buildings to open the Classify LAS Building tool.

k Confirm that Input LAS Dataset is set to PSU_Working.lasd and that the Compute Statistics box is checked.

l Accept the remaining default settings and click Run.

When the tool completes, you should notice a change in the symbology, with blank areas where the buildings are. These blank areas display because those points are no longer being symbolized as Ground or Unassigned.



m In the Contents pane, open the properties of the PSU_Working layer and view the LAS Filter tab.

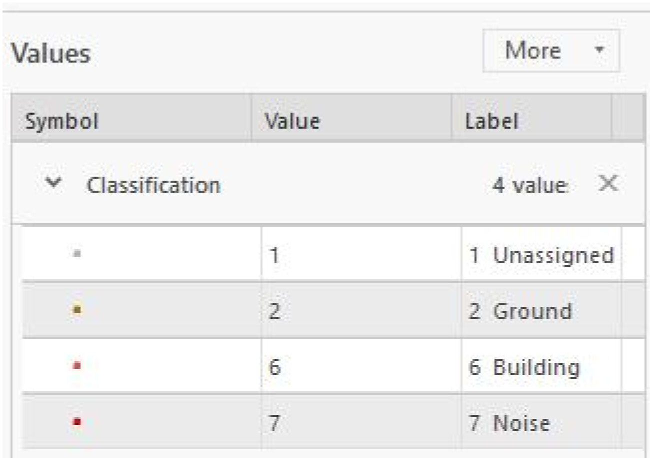
You will notice that 6 Building is now listed as a classification code.

n Uncheck the currently selected classification codes and check 6 Building, and then close the layer properties.

> If the Building classification code is not available in your layer properties, you may need to recalculate statistics on the PSU_Working.lasd layer. From the Data tab, click Statistics and choose Calculate Statistics, and then return to the layer properties to filter all the points except Building.

o From the LAS Dataset Layer tab, click the Symbology down arrow and choose Class.

p For Values, click the More down arrow and choose Add All Values, if necessary.



- **q** Close the Symbology pane.
- **r** From the Map tab, change the basemap to Imagery, and then zoom to the Old Main bookmark.

Old Main is one of the most prominent and recognizable buildings on the Penn State University campus, which makes it an excellent choice for validating the building classification that you just performed.

1. **Do the Building points in the LAS dataset conform to the shape of the Old Main building?**

   ____

2. **What do you notice about the points in the center of the Old Main building?**

   ____

The missing points, in this case, represent the bell tower of the building, and they were not captured by the automatic classification.

In the next step, you will learn how to interactively correct misclassified points.

- **s** Save your project.

Step 3: Classify lidar points interactively

- **a** From the Catalog pane, open the Interactive Editing map.

This map contains only the 937228 LAS file and the World Street Map basemap.

The points along the street named E. Calder Way (near the center of the map) are classified as High Vegetation. You suspect that the points are misclassified because high vegetation does not normally grow within streets. To further investigate, you will filter the points so that only those with a High Vegetation classification code are displayed.

Next, you will change the symbology of the LAS layer in order to visualize the lidar point's class code.

b In the Contents pane, select the LAS layer.

c From the LAS Dataset Layer tab, change the symbology to Class.

d Close the Symbology pane.

e Open the layer properties for the 937228.las layer and click the LAS Filter tab, if necessary.

f Uncheck all classification codes except for 5 High Vegetation.

g Click OK to close the layer properties.

3. What do you think the lidar points along the street E. Calder Way represent?

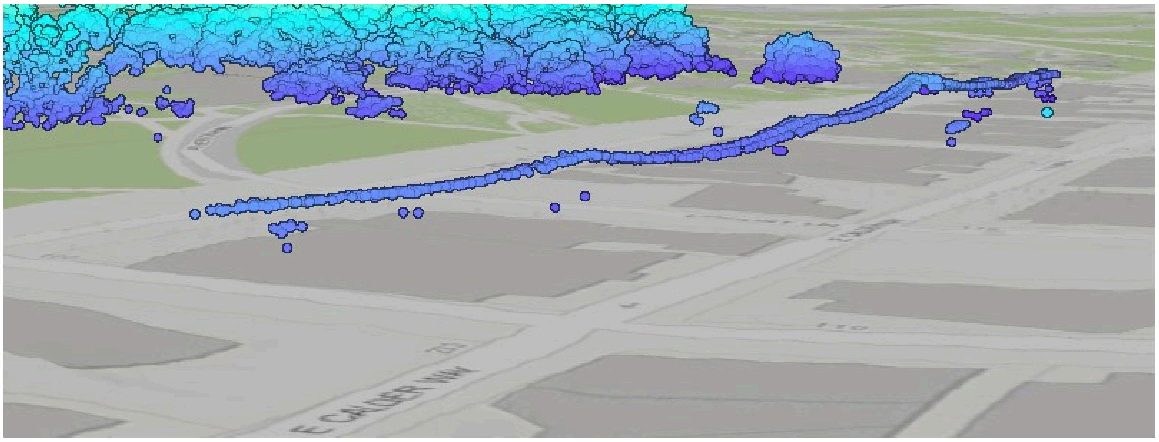
____

You will convert the 2D map to a 3D scene to better visualize the points.

h From the View tab, click the Convert down arrow and choose To Local Scene.

i Tilt the view to see the points along E. Calder Way from a somewhat side view, as shown in the following graphic.

You may have to zoom out to see the points.



4. After viewing the points in 3D, what kind of features do you think the points represent?

Through additional research, using 3D scenes and aerial photography, you have determined that the points represent electrical power lines.

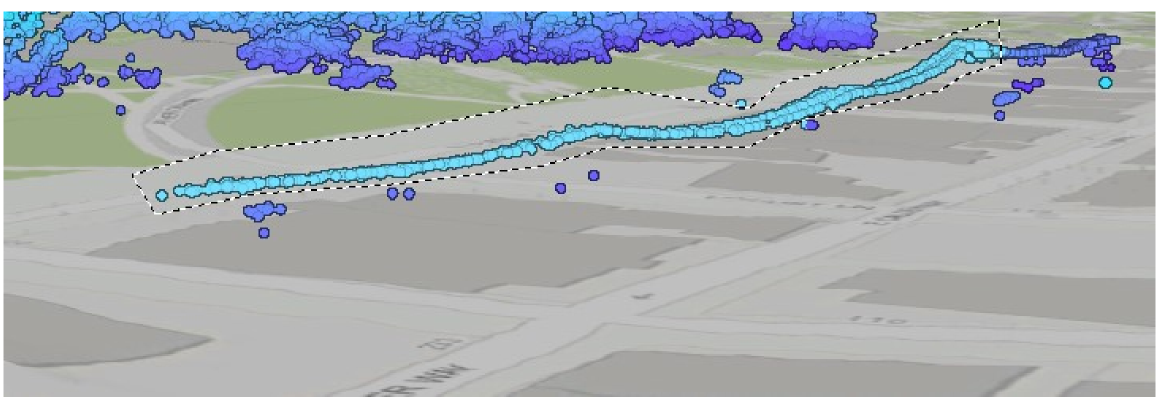
Next, you will interactively edit the points to correct their classification by drawing a polygon around the power line points.

j Make the 937228.las layer active.

k From the Classification tab, in the Selection group, click the Select down arrow and choose Polygon.

> If the Select tool in the Selection Group is grayed out and is not active, incrementally zoom in until it becomes active.

l Draw a polygon around the power line points along E. Calder Way within your current scene extents and double-click when finished, similar to the following graphic.



Your extents, perspective, symbology, and selected points may differ from this graphic.

m. In the Interactive Editing group, for Classification Code, click the down arrow and choose 14 Wire – Conductor.

n. Click Apply Changes.

Because you are filtering out most of the points, your map will update to include points on the power line that were not included in the first interactive selection. You can perform the same steps to reclassify the remaining points that are misclassified. You may need to tilt and pan the view. For this exercise, it is not necessary to select every misclassified point.

o. Continue selecting and changing the 5 High Vegetation points to 14 Wire – Conductor until most have been selected.

Now that you have classified the power lines, you will set the LAS filter back to include all points and symbolize the points based on their classification value.

p. For the 937228.las layer, open the layer properties and click LAS Filter, if necessary.

q. Make all the classification codes active and click OK.

r. In the Contents pane, expand the 937228.las layer to show all the classes.

You have interactively classified (edited) lidar points and symbolized the layer by classification. Classification codes can also be edited in 2D maps.

s. Close all maps and 3D scene views.

t. Save your project and leave ArcGIS Pro open for the next exercise.

Lesson review

1. **Spatial edits on lidar points are supported in ArcGIS Pro.**
    a. **True**
    b. **False**
2. **If you acquired a LAS file where 90 percent of the points had a classification code of Unassigned, would you use an interactive editing method or a geoprocessing tool?**

Answers to lesson 4 questions

Choosing an editing method (page 4-5)

Scenario 1: Storage shed

1. Which editing method (geoprocessing tool or interactive) would you choose to perform the edits?

   This type of tactical edit to a limited number of points would be best done with interactive editing.

Scenario 2: Nonstandard classification

2. Which editing method (geoprocessing tool or interactive) would you choose to perform the edits?

   This type of bulk edit would be best done with a geoprocessing tool, particularly the Change LAS Class Codes tool.

Exercise 4: Edit a LAS dataset (page 4-7)

1. Do the Building points in the LAS dataset conform to the shape of the Old Main building?

   Yes.

2. What do you notice about the points in the center of the Old Main building?

   There is a gap with many points missing.

3. What do you think the lidar points along the street E. Calder Way represent?

   It is not clear what the points represent.

4. After viewing the points in 3D, what kind of features do you think the points represent?

   Power lines

5 Creating and sharing 3D layers with lidar

3D visualization is a powerful tool for understanding and communicating spatial phenomena. In the past, creating these detailed 3D displays was an expensive and technically difficult process. Today, using lidar as a data source, it is easier and faster to create realistic 3D displays than ever before. This lesson will provide a comprehensive overview on how to use lidar to create 3D visualizations (of building features specifically) and share them as a web layer.

Topics covered

- Comparing 3D feature types
- Creating 3D building features
- Publishing a 3D point cloud scene layer

The power of 3D

The world is not a 2D map. While most spatial questions lend themselves naturally to a 2D map environment, people are instinctively drawn to visualizations in 3D, which more realistically represent the environment they interact with all the time. Lidar data is perfectly suited as a data source for creating a variety of 3D visualization types, from topographic surfaces to the point clouds themselves.

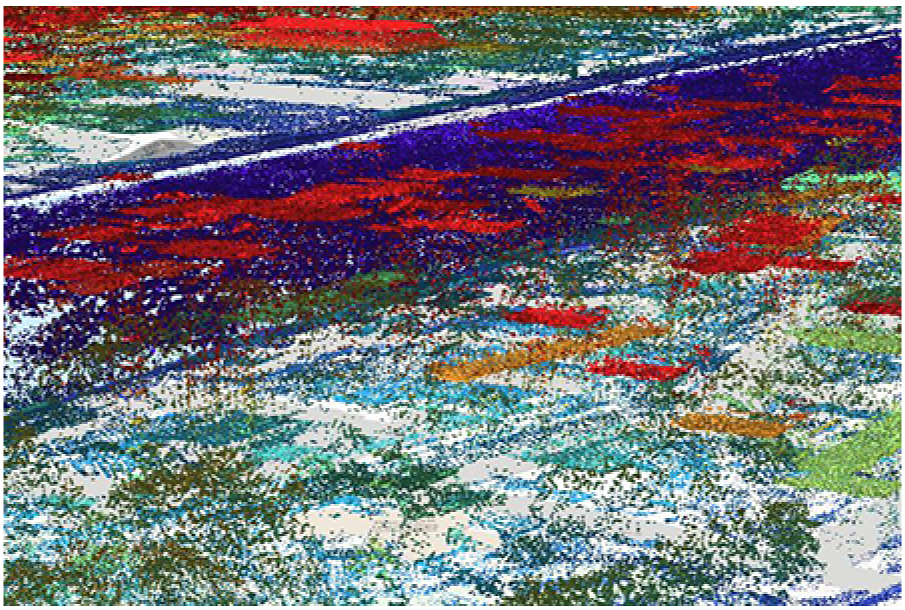


Figure 5.1. Point cloud of New York City viewed as a 3D scene.

In some cases, the most exciting way to bring lidar into 3D visualization and analysis is to use the point cloud to create actual 3D features. These features (typically buildings) can be used to effectively model real-world conditions. They are particularly helpful in planning and communicating the potential impacts of development projects on the surrounding environment.

The power of 3D (continued)

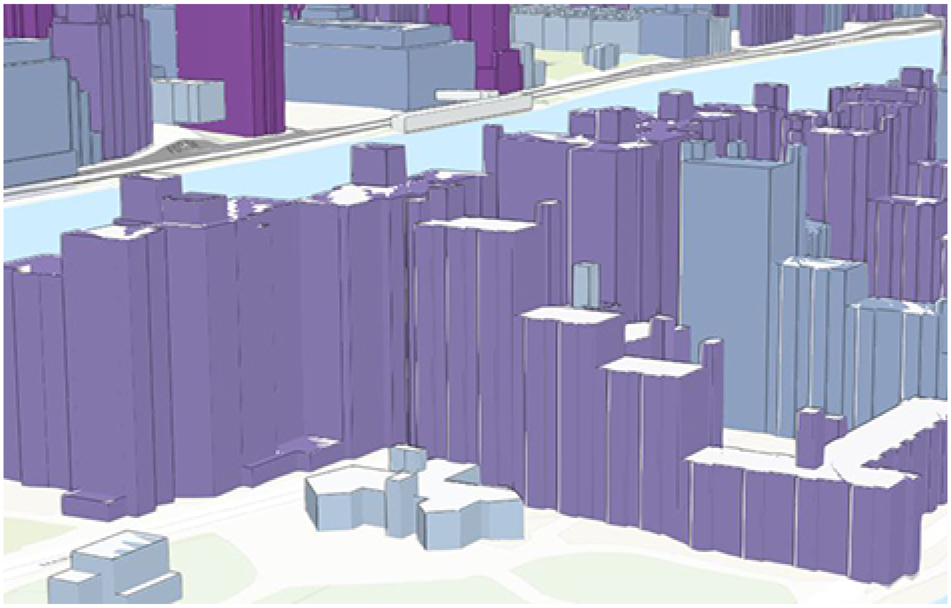


Figure 5.2. Extruded buildings derived from the New York City lidar point cloud.

Using 3D features

3D visualizations can be stunning, but in GIS, they are much more than just visually interesting; they actually have many practical applications.

What are some ways that 3D features can be used to better understand and answer spatial questions?

3D geometries

ArcGIS provides two ways to store elevation (for example, building height) with feature geometry: 3D features and multipatch geometry.

3D features

3D features store z-coordinates embedded inside their feature geometry, or Shape field, of their feature class. Z-values are automatically included with every new vertex created for a 3D polygon, allowing its perimeter to connect any two points—regardless of whether they are on, above, or below the ground. For polygons, in particular, 3D features are most effective at representing the exterior perimeter of the shape. If the feature (a building, for example) has multiple parts with irregular heights, then this type of 3D geometry would be inappropriate. 3D features are best suited to simple shapes with consistent elevation values.

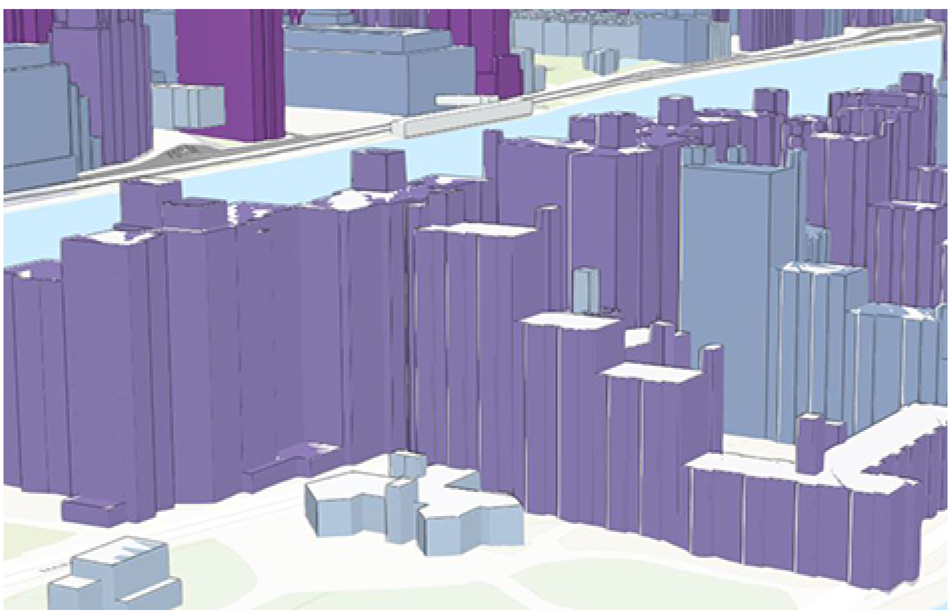


Figure 5.3. 3D features include simple geometry with x,y,z values for each vertex. This geometry type is good for noncomplex shapes.

Multipatch features

A multipatch feature is a GIS object that stores a collection of patches to represent the boundary of a 3D object as a single row in a database. Patches store z-values, as well as texture, color,

3D geometries (continued)

transparency, and geometric information representing parts of a feature. Because of the numerous patches and their variety, multipatches can represent more complex and textured polygonal shapes than 3D polygons and are a common choice when producing 3D buildings from lidar data.

Figure 5.4. Multipatch features are enclosed volumes defined with three-dimensional rings and triangular patches. They are used to model the outer surface or shell of natural and as-built 3D features.

ArcGIS Desktop Help: *About 3D features*

ArcGIS Pro: *3D GIS terminology*

Creating 3D buildings

Using lidar data to create 3D and multipatch features creates more possibilities for visualization and analysis. Buildings are one of the most common types of features to extract from lidar data. Buildings can be represented as polygons, as 3D features (extruded polygons), or, with greater detail, as multipatch features. The following workflow shows the primary geoprocessing tools necessary to create building polygons and multipatch features from a LAS dataset.

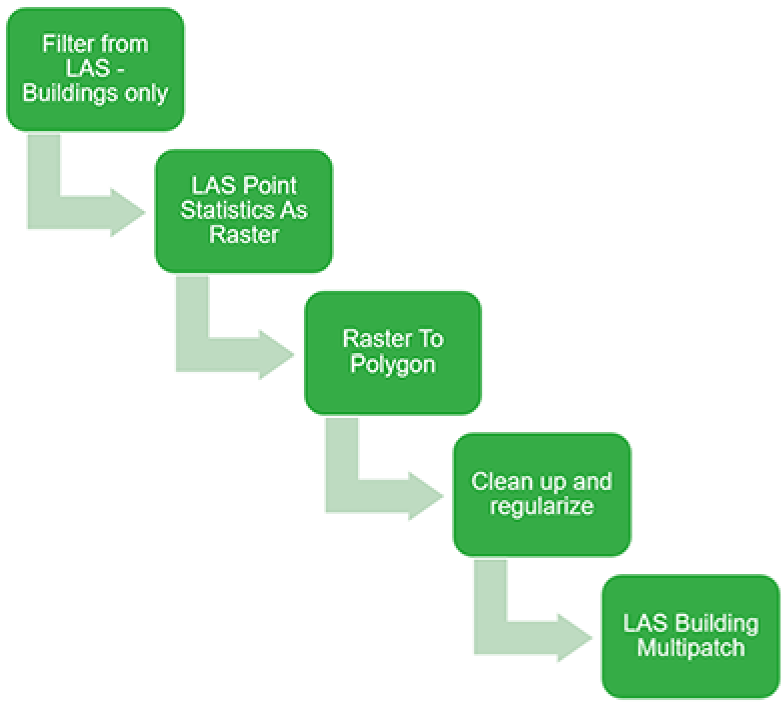


Figure 5.5. Workflow for creating polygons and multipatch features from LAS points.

Exercise 5A

Minutes: 25

Create 3D buildings from lidar

Using lidar data to create 3D representations of buildings is a common need for lidar users. The resulting building features can have important visualization and analytical uses. In this exercise, you will implement a workflow for creating 3D buildings from the Penn State University lidar data.

In this exercise, you will perform the following tasks:

- Filter a LAS dataset.
- Create a statistics raster.
- Convert raster buildings to polygons.
- Convert polygons to multipatch buildings.

Step 1: Create a building footprint layer

The first step to creating 3D features from lidar usually involves creating a raster dataset from the lidar points that represent the intended features. In this step, you will use the LAS Point Statistics As Raster tool to create the initial raster.

a. Restore ArcGIS Pro and the LIDR project, if necessary.

b. From the Insert tab, add a new map titled **PennState_Buildings**.

c. Change the basemap to Imagery.

d. From the Catalog pane, expand the LIDR folder and the LAS_Datasets folder.

e. From the LAS_Datasets folder, add PSU_Working.lasd to the map.

> If you did not complete the previous workflow to classify lidar points, perform the following steps to add a correctly classified LAS dataset to the map:
>
> 1. From the Catalog pane, expand the LIDR folder and the Results folder.
> 2. From the Results folder, add PSU_Working.lasd to the map.

f. In the Contents pane, open the properties of the PSU_Working.lasd layer and click the LAS Filter tab.

g. Uncheck all class codes except for 6 Building and click OK.

h. Zoom in until the LAS dataset renders.

i. From the Data tab, in the Analyze group, click the Statistics down arrow and choose Summarize Point Statistics As Raster.

j. In the LAS Point Statistics As Raster pane, specify or confirm the following parameters:

- Input LAS Dataset: PSU_Working.lasd
- Output Raster: **PSU_BldgRas**
- Method: Most Frequent Class Code
- Sampling Value: **3**

k Click Run.

This tool creates a raster based on the predominant lidar class code. In this case, the only class code showing is Building, so it is by default the most frequent one.

l In the Contents pane, turn off the PSU_Working layer.

m Zoom to one of the raster buildings.

1. **Is the raster building a good representation of the building footprint? What potential problems do you see?**

   ____

The output from the LAS Point Statistics As Raster tool is a good start for creating the building footprints. However, before converting the raster buildings to polygons, some cleanup will be necessary to close the holes present in a lot of the buildings.

n In the Contents pane, ensure that the PSU_BldgRas layer is selected.

o From the Analysis tab, in the Raster group, click Raster Functions.

p In the Raster Functions pane, search for and open the Elevation Void Fill function, and then specify the following parameters:

- DEM: PSU_BldgRas
- Short Range IDW Radius: **1**
- Max Void Width: **1**

q Click Create New Layer to execute the function.

Often, your raster data may contain voids (No Data grid cells). The Elevation Void Fill raster function is designed to create pixels where you have voids in your raster. It estimates grid cell values by using the surrounding cells' values.

r Inspect some of the buildings in the new layer and compare them to the buildings in PSU_BldgRas.

You will notice that many of the holes have been filled in.

Now that you have created a raster dataset of the buildings and performed some initial cleanup, you will continue the process by converting the raster data to polygon features.

Step 2: Create building footprint polygons

a In the Geoprocessing pane, search for and open the Raster To Polygon tool.

Hint: If you closed the Geoprocessing pane: Analysis tab > Tools.

b Specify or confirm the following parameters:

- Input Raster: Elevation Void Fill_PSU_BldgRas
- Field: Value
- Output Polygon Features: **PSU_Bldgs_Raw**
- Uncheck the Simplify Polygons box.

Unchecking the Simplify Polygons box ensures that all details and vertices are considered.

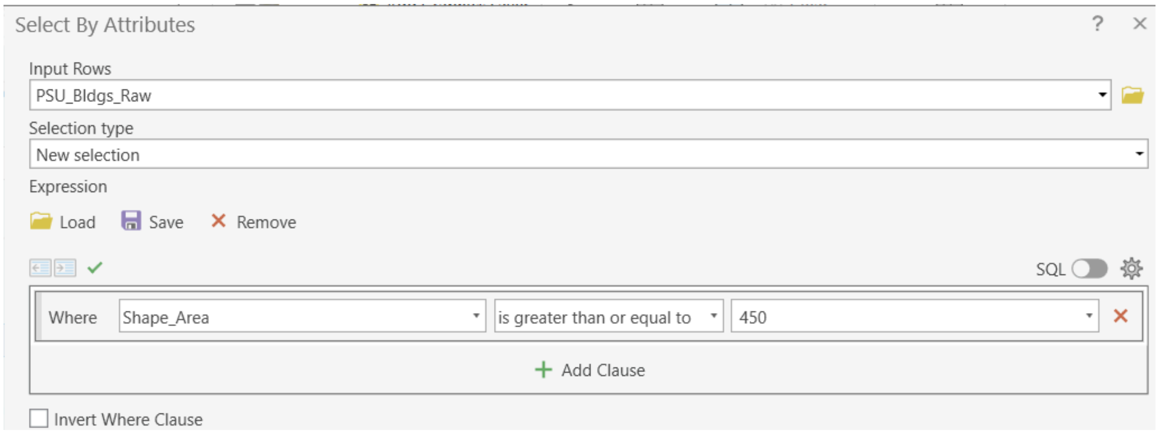
c Leave the remaining parameters blank and click Run.

This tool creates polygons from the raster input. As you can see from examining the PSU_Bldgs_Raw layer, there are several very small polygons in the output. In some cases, these polygons represent small buildings or parts of buildings. In other cases, they are just misclassified points and are not building-related at all. You will filter out these small polygons so that they are not included in your final output.

d From the Map tab, in the Selection group, click Select By Attributes.

e In the Select By Attributes dialog box, confirm that Input Rows is set to PSU_Bldgs_Raw and that Selection Type is set to New Selection.

f Under the Expression group, look for the word Where and construct the following query: `Where Shape_Area Is Greater Than Or Equal To 450`.



g Click OK.

If you explore the PSU_Bldgs_Raw layer, you will notice that only the larger building polygons are selected. The query filtered out the small non-building polygons. You will now fill in some of the holes that remain from the previous step.

h In the Geoprocessing pane, search for and open the Eliminate Polygon Part tool, and then specify or confirm the following parameters:

- Input Features: PSU_Bldgs_Raw
- Output Feature Class: **PSU_Bldgs_Clean**
- Condition: Area
- Area: **1000** Square US Survey Feet

i Confirm that the Eliminate Contained Parts Only box is checked, and then click Run.

This tool fills holes in polygons according to a user-specified size criteria (1,000 square feet in this case).

j In the Contents pane, make the PSU_Bldgs_Clean and PSU_Bldgs_Raw the only visible layers.

k Turn the top visible layer on and off so that you can see the difference between these layers.

Now that the building polygons are filled in and the small erroneous polygons are filtered out, you will convert the polygons into more regularly shaped building footprints.

l In the Geoprocessing pane, search for and open the Regularize Building Footprint tool, and then specify or confirm the following parameters:

- Input Features: PSU_Bldgs_Clean
- Output Feature Class: **PSU_Bldgs_Reg**
- Method: Right Angles
- Tolerance: **7**
- Precision: **0.15**

m Leave the remaining parameter blank and click Run.

n In the Contents pane, remove all layers except for PSU_Bldgs_Reg, PSU_Working.lasd, and the World Imagery basemap.

You have used lidar data to create regularized building footprints. In the next step, you will use the lidar data to add the building height as an attribute to the 2D polygons and then create multipatch 3D features.

Step 3: Add height attributes to building polygons

a In the Catalog pane, expand the LIDR geodatabase, and then add SC_DHM to the map.

b If prompted to build pyramids, click Yes.

This file is the digital height model that you created earlier. You will use the values of this raster to extract height values for the building footprints.

c In the Geoprocessing pane, search for and open the Zonal Statistics As Table tool, and then specify the following parameters:

- Input Raster Or Feature Zone Data: PSU_Bldgs_Reg
- Zone Field: ORIG_OID
- Input Value Raster: SC_DHM
- Output Table: **PSU_Bldgs_Stats**
- Statistics Type: Minimum, Maximum And Mean

d Click Run.

This tool produces a table where each row represents one of the building footprints in the study area. The MAX column represents the maximum height extracted into the building footprint. You will use this field to add the building heights to the building footprints attribute table, which then could be used for further analysis or to extrude the building polygons. First, you must join the table back to the original building footprints.

e In the Contents pane, right-click the PSU_Bldgs_Reg layer, point to Joins And Relates, and choose Add Join.

f In the Add Join dialog box, specify or confirm the following parameters:

- Input Table: PSU_Bldgs_Reg
- Input Join Field: ORIG_OID
- Join Table: PSU_Bldgs_Stats
- Join Table Field: ORIG_OID

g Click OK.

h In the Contents pane, right-click the PSU_Bldgs_Reg layer and choose Attribute Table.

You can see that the statistics fields have been joined to the table. You will now export the result as a new feature class.

i Close the attribute table.

j In the Contents pane, right-click the PSU_Bldgs_Reg layer, point to Data, and choose Export Features.

k Export the joined data as a new feature class named **PSU_BuildingHeights**.

l Click OK.

Exporting the PSU_Bldgs_Reg layer creates a new feature class with the building statistics permanently added to the feature class.

m From the View tab, convert your map to a local scene.

In the next step, you will turn these buildings into 3D multipatches.

Step 4: Create detailed 3D buildings

a In the Catalog pane, from the LIDR geodatabase, add PSU_DTM to the scene.

The DTM will provide the ground elevation for your new 3D multipatch buildings.

b In the Geoprocessing pane, search for and open the LAS Building Multipatch tool, and then specify or confirm the following parameters:

- Input LAS Dataset: PSU_Working.lasd
- Input Features: PSU_BuildingHeights
- LAS Rooftop Point Selection: Building Classified Points
- Ground Height:
    - Raster Layer
    - PSU_DTM
- Output Multipatch Feature Class: **PSU_Bldgs_3D**

c Leave the remaining parameters blank and click Run.

d In the Contents pane, remove all of the operational layers except for PSU_Bldgs_3D, PSU_DTM, and PSU_Working.lasd.

e Explore the 3D multipatch buildings by tilting and rotating the scene.

You should notice that the multipatch features created from the lidar points provide a detailed 3D view of the buildings. In the final exercise, you will learn how to share these types of features.

f Save your project and leave ArcGIS Pro open for the next exercise.

Challenge (optional): Challenge step

Minutes: 5

In Exercise 4, you classified points that represented power lines. In this challenge step, you will extract lines from the power line points you classified earlier using the Extract Power Lines From Point Cloud tool. This tool contains several parameters, specific to power lines, that can be adjusted to control the extraction process.

a Activate or open the Interactive Editing map.

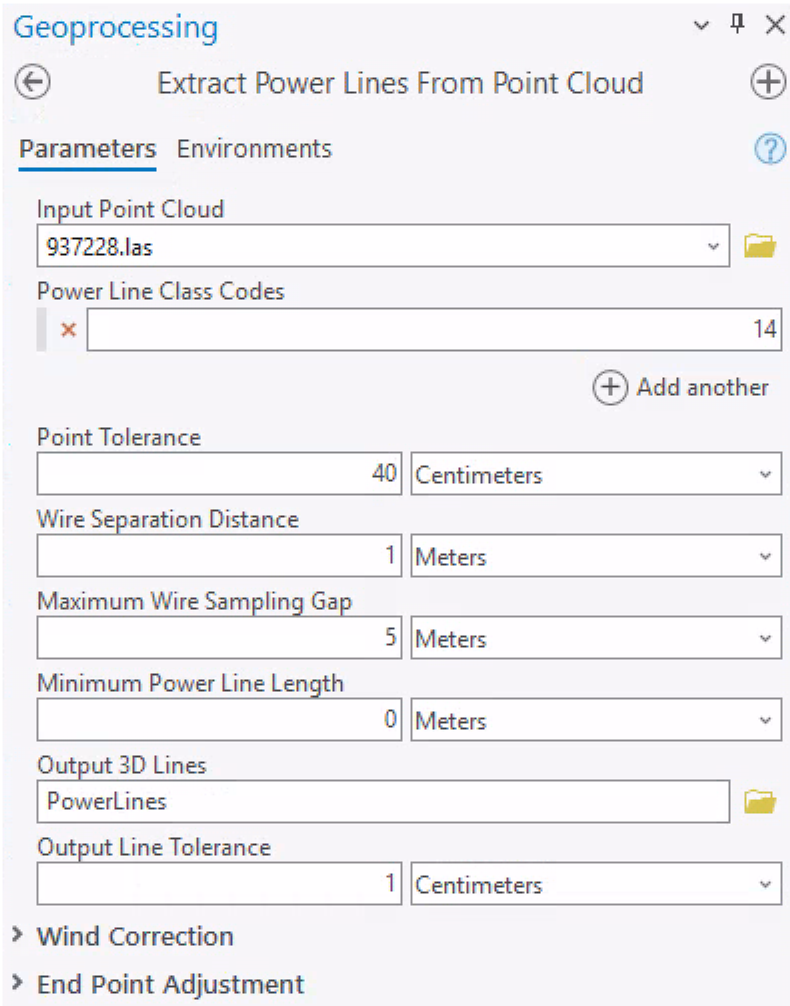
If you closed the Interactive Editing map, you can reopen it from the Catalog pane under Maps.

b Open the layer properties for the 937228.las layer and choose LAS Filter.

c Uncheck all class codes except for 14 Wire – Conductor and click OK.

d From the Data tab, in the Extract Features group, choose Power Lines, and then specify or confirm the following parameters:

- Input Point Cloud: 937228.las
- Power Line Class Codes: 14
- Point Tolerance: **40** Centimeters
- Wire Separation Distance: **1** Meters
- Maximum Wire Sampling Gap: **5** Meters
- Output 3D Lines: **PowerLines**
- Output Line Tolerance: **1** Centimeters



e Accept the default for the other parameters and click Run.

f Examine the resulting PowerLines layer.

Do you see any issues with the power lines? Can you explain why the anomalies exist?

You have now created lines from a lidar point cloud, another example of extracting features from lidar data. In practice, it may take several iterations to discover the best parameter settings for the Extract Power Lines From Point Cloud tool.

g Close the Interactive Editing map.

h Save your project and leave ArcGIS Pro open for the next exercise.

Challenges with sharing lidar

As useful as lidar data and the 3D visualizations that it can create are, sharing point clouds can present challenges.

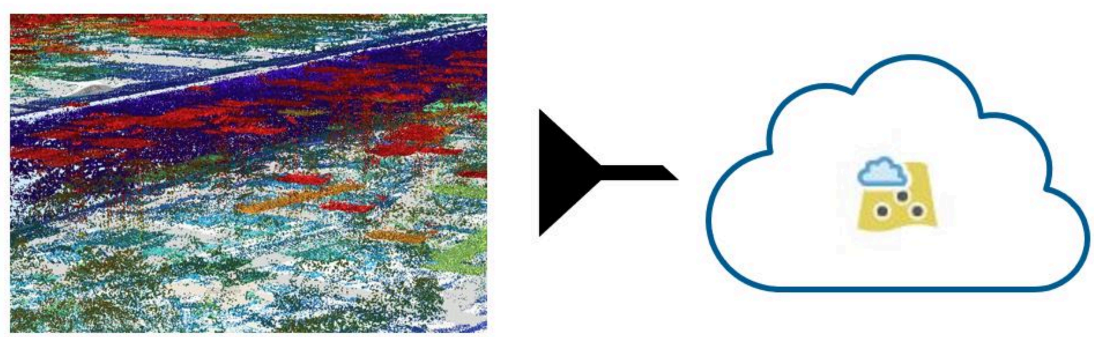


Figure 5.6. Sharing point clouds can be difficult.

What is the primary challenge of sharing a lidar point cloud as a web layer?

Sharing 3D layers

Point cloud scene layers provide fast display of large volumes of symbolized and filtered point cloud data. They are optimized for the display and sharing of many kinds of sensor data, including lidar. Point cloud scene layers can be built directly from a LAS dataset layer and help support sharing 3D point cloud content across the platform. LAS, ZLAS, and LAZ files are supported by a point cloud scene layer. You create point cloud scene layers by generating a scene layer package (.slpk) file on disk and publishing it as a scene service on ArcGIS Enterprise or ArcGIS Online. Optionally, you can preview the scene layer package as a layer directly in ArcGIS Pro.

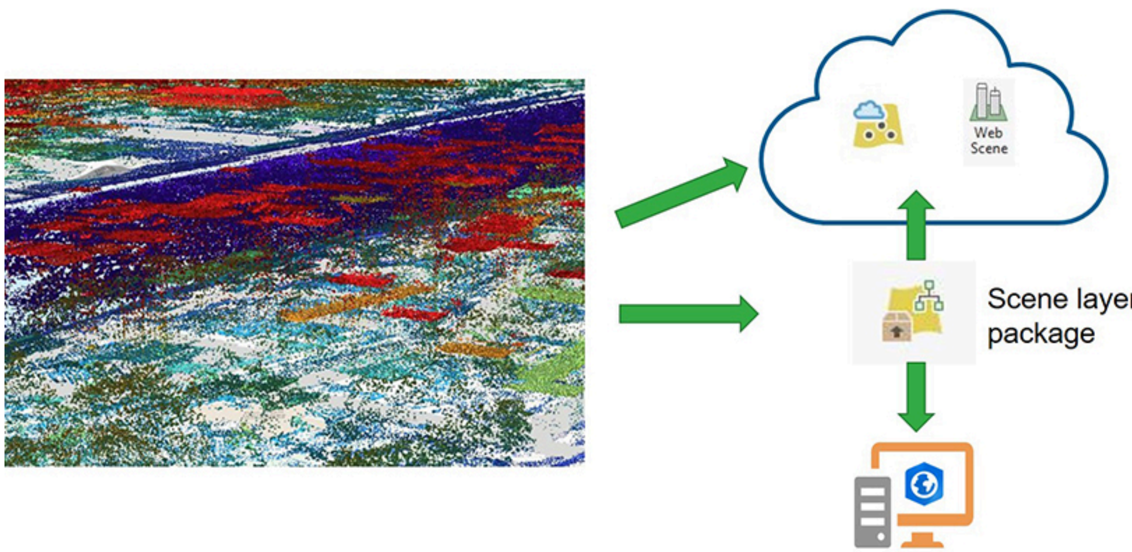


Figure 5.7. An illustration of the sharing process.

A point cloud scene layer can be created by using the Create Point Cloud Scene Layer Content geoprocessing tool. A point cloud scene layer supports point cloud data in LAS format and Optimized LAS (.ZLAS) format, which is referenced by a LAS dataset. Individual and folders of LAS, ZLAS, and LAZ files can also be used as input to the Create Point Cloud Scene Layer Content tool. Symbology and point filtering that has been applied to the points of a LAS dataset layer will be used to create the point cloud scene layer. The default elevation symbology and no point filtering will be used to create a point cloud scene layer when individual files or a folder of files is used as input to the tool.

Exercise 5B

Minutes: 35

Share lidar data to a portal

Due to the immense number of points in a typical LAS dataset, sharing lidar as a web layer can be challenging. Even in an ArcGIS Pro environment, rendering very large point sets can be slow, partially due to hardware limitations. Point cloud scene layers are efficient because the areas that you need to visualize are rendered at an optimized point resolution. In this exercise, you will create and upload a scene layer package to ArcGIS Online. You will then use that package to create a point cloud scene layer. You will also see how you can create a 3D object scene layer to visualize the multipatch buildings that you created in the previous exercise.

In this exercise, you will perform the following tasks:

- Create a scene layer package.
- Upload a scene layer package to a portal.
- Publish a 3D object scene layer.

Step 1: Create a scene layer package

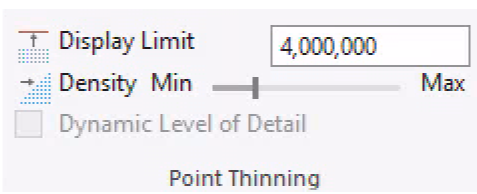
Sharing lidar point clouds or derivative products is essential for many organizations, and there are several ways to accomplish your sharing goals. In this step, you will create a scene layer package that can be shared with other ArcGIS Pro users.

a. Restore ArcGIS Pro and the LIDR project, if necessary, and activate the PennState_Buildings_3D scene.

b. Turn off all layers except for PSU_Working.lasd.

c. Right-click the PSU_Working layer, point to LAS Filters, and choose All Points to ensure that all classification codes are visible.

d. From the LAS Dataset Layer tab, in the Point Thinning group, use the Density slider to set the point thinning density to about 25 percent.



e. Click the Symbology down arrow and, under Symbolize Your Layer Using Points, choose Elevation, if necessary.

f. In the Geoprocessing pane, search for and open the Create Point Cloud Scene Layer Content tool, and then specify the following parameters:

- Input Dataset: PSU_Working.lasd
- Output Scene Layer Package: C:\EsriTraining\LIDR\SceneLayer_Packages\
  PSU_SceneLayer_<your initials>.slpk
- Attributes To Cache:
  - RGB
  - CLASS_CODE
  - RETURNS

g. Leave the remaining defaults and click Run.

The packaging process may take a few minutes.

h. In the Catalog pane, from the LIDR folder, expand the SceneLayer_Packages folder and notice that your new package is there.

You can now share this file with anyone who has ArcGIS Pro, because they will be able to open the file and view the 3D scene with your lidar point cloud. This sharing method is fine for ArcGIS Pro users, but in the next step, you will learn how to upload the package into an online portal and create a web layer for even easier distribution.

Step 2: Upload a scene package to a portal

If you are working in a disconnected environment, you will not be able to perform the final two steps.

a. In a web browser, go to ArcGIS Online (www.arcgis.com).

b. Click Sign In.

c. In the ArcGIS Sign In dialog box, expand ArcGIS Login, if necessary.

d. Type the username and password provided by your instructor, and then click Sign In.

e. You are now signed in to the Esri Training Services ArcGIS Online organizational portal.

f. Click the Content tab.

g. Click New Item and click Your Device.

h. For File Name, browse to your scene layer package, select it, and then click Open.

i. In the New Item window, accept the default option of Add PSU_SceneLayer.slpk And Create A Hosted Scene Layer and click Next.

j. For Tags, type **PSU, Lidar**, and then click Save.

It may take several minutes to publish the service.

After the point cloud scene layer package finishes uploading, the item page for a new point cloud scene layer will automatically open.

k On the right side of the item page, review the details.

1. How was the new scene layer created?

____

l Click the Content tab.

PSU_SceneLayer_	Scene layer (hosted)
PSU_SceneLayer_	Scene Layer Package

You have two new items in your My Content folder: the scene layer package that you uploaded and the scene layer that was created from the package. The package can be downloaded and opened in ArcGIS Pro. The scene layer can also be added to a web scene in your portal or to a scene in ArcGIS Pro.

m Next to the scene layer (hosted) file, click the More Options button ••• and choose Open In Scene Viewer.

n Use the scene navigation tools to explore the lidar point cloud.

> You can also use your mouse wheel to zoom in and out of the scene, the right mouse button to tilt the scene, and the left mouse button to pan the scene.

Because you included all the points in the scene layer package, the birdshot returns are visible again.

o On the left toolbar, click the Save button.

p For Title, type **PSU_Scene_<your initials>**.

q For Tags, type **PSU, LIDR** and press Enter.

r Click Save, and then minimize your web browser.

Now that you have uploaded a scene layer package to an ArcGIS Online portal and explored the resulting scene layer, you will publish a scene layer directly from ArcGIS Pro.

Step 3: Publish a 3D object scene layer

You created a scene layer package to share your LAS dataset. You will now publish a scene layer directly from ArcGIS Pro to ArcGIS Online. However, to publish, you must be signed in to ArcGIS Pro with your ArcGIS Online user account provided to you by your instructor.

a. In the upper-right corner of ArcGIS Pro, click Not Signed In, and then click Sign In.

b. In the ArcGIS Sign In dialog box, expand ArcGIS Login, if necessary.

c. Type the username and password provided by your instructor, and then click Sign In.

d. You are now signed in to ArcGIS Pro.

e. Activate the PennState_Buildings_3D scene, if necessary.

This scene includes the detailed multipatch features that you created in the previous exercise.

f. In the Contents pane, right-click the PennState_Buildings_3D scene and choose Properties.

g. In the Map Properties dialog box, click the Coordinate Systems tab.

h. Change Current XY to WGS 1984 Web Mercator (Auxiliary Sphere).

   Hint: Projected Coordinate System > World

i. Change Current Z to <None>, if necessary, and then click OK to close the map properties.

j. Right-click the PSU_Bldgs_3D layer and choose Properties.

k. In the Layer Properties dialog box, click the Elevation tab and verify that Features Are is set to At An Absolute Height.

l. Click OK to close the layer properties.

m. Right-click the PSU_Bldgs_3D layer, point to Sharing, and choose Share As Web Layer.

n. In the Share As Web Layer pane, specify the following parameters:

   - Name: **PSU_Buildings_3DScene_<your initials>**

- Summary: **Multipatch buildings derived from PSU lidar**
- Tags: **PSU, LIDR**

o Leave the remaining defaults and click Publish.

Publishing may take several minutes. Upon completion, you will see a message confirming that the web layer was successfully published and is being cached.

p After the layer has successfully published, from the Share tab, in the Status group, click Jobs.

Part of the publishing process is to create a cache, which can take several minutes (up to 10 minutes). The Job Status pane allows you to monitor the progress of the caching process. You will see a green check mark when the process is complete.

q Monitor the status of the PSU_Buildings_3DScene publishing/cache.

After you see the green check mark, indicating that caching is complete, you will view the scene that you just published in your browser.

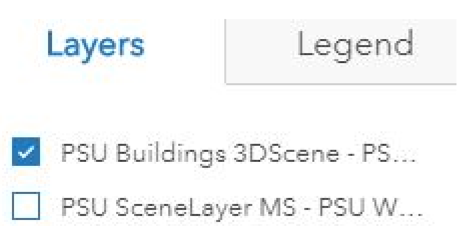
r Restore the web browser with Scene Viewer.

s On the left, click the Add button and choose Browse Layers.

t Under My Content, search for PSU_Buildings_3DScene and click the Add button to add it to the scene.

u In the upper-right corner of the scene, click the Layers button to open the Layers list, if necessary.

v In the Layers list, turn off the point cloud layer so that only the buildings are visible.



w Use the scene navigation tools to explore the buildings layer.

x After you are finished exploring, save the scene, and then close the web browser.

y. Save your project and exit ArcGIS Pro.

Lesson review

1. **Multipatch geometry would be better suited than 3D polygons to represent the dome of the United States Capitol.**
   a. **True**
   b. **False**
2. **Which benefit is not an advantage of a point cloud scene layer?**
   a. **Optimized for fast display**
   b. **Able to be packaged as a scene layer for easy sharing**
   c. **Usable in ArcGIS Pro and in a portal**
   d. **Editable**

Answers to lesson 5 questions

Using 3D features (page 5-4)

What are some ways that 3D features can be used to better understand and answer spatial questions?

Possible responses include the following answers:

- **Visualizing projects in different scenarios to better understand their impact**
- **Designing buildings to better fit their surrounding environment**
- **Planning projects to minimize negative impacts like sunlight glare**
- **Indoor routing**
- **Viewshed protection and visibility analysis**

Exercise 5A: Create 3D buildings from lidar (page 5-8)

1. Is the raster building a good representation of the building footprint? What potential problems do you see?

   The basic shapes are there, but there are many holes and missing building parts.

Exercise 5B: Share lidar data to a portal (page 5-20)

1. How was the new scene layer created?

   This web layer was generated from the package that you uploaded.

Exercise 5A challenge solution

Solution: Challenge step

The points that represent power lines may contain points that are not actually power lines. For example, a point could be part of the power pole or transmission tower or be another component, such as a guy wire that has been misclassified.

Exercise 5B challenge solution

Appendix A

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Appendix B

Answers to lesson review questions

Answers to lesson 1 review questions

1. What does the "L" in lidar stand for?

   c. **Light**

2. Airborne-collected lidar is more commonly used in GIS applications than terrestrial-collected lidar.

   a. **True**

3. One laser pulse can have only one return.

   b. **False**

   (One laser pulse can reflect off of several objects, resulting in up to five returns.)

Answers to lesson 2 review questions

1. Does a LAS file or a ZLAS file appear as a read-only file in ArcGIS Pro?

   ZLAS file

2. Which data type manages lidar as raster output?

   b. **Mosaic dataset**

3. Which option could you use to limit the extent of a LAS dataset when displaying it as a TIN?

   a. **Surface constraint**

Answers to lesson 4 review questions

1. Spatial edits on lidar points are supported in ArcGIS Pro.

   b. **False**

   (Lidar editing is limited to modifying the classification code.)

Answers to lesson review questions (continued)

2. If you acquired a LAS file where 90 percent of the points had a classification code of Unassigned, would you use an interactive editing method or a geoprocessing tool?

   Geoprocessing tool

Answers to lesson 5 review questions

1. Multipatch geometry would be better suited than 3D polygons to represent the dome of the United States Capitol.
   - a. **True**

2. Which benefit is **not** an advantage of a point cloud scene layer?
   - d. **Editable**

Appendix C

Additional resources

Lesson 5	Resources
3D geometries	• ArcGIS Desktop Help: *About 3D features* • ArcGIS Pro: *3D GIS terminology*

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