*04 February 2013*

**2012 North Kaibab LiDAR, Second Installment**

**Quality Assurance Results**

The purpose of this acquisition was to provide LiDAR data for portions of the Kaibab NF and Grand Canyon NP on the Kaibab Plateau, in support of ongoing studies of Northern Goshawk demographics. 3Di West, through its subcontractor Watershed Sciences Incorporated (WSI), acquired LiDAR data for over 450,000 acres in the summer of 2012. The data were to be delivered in two installments. The first installment encompassed 108,745 acres (109,871 including buffer) and was acquired between 25 and 31 August 2012. The second installment, which is covered in this report, encompassed 336,582 acres (348,054 including buffer) and was acquired from 1-15 September 2012.

The deliverables for the second installment met the contract specifications. Output from the **Catalog** command in Fusion software showed that the average pulse density for the second delivery area was 13.32/m2, exceeding the target rate of 8/m2.

**Data Quality Assurance**

A thorough quality assurance assessment was conducted to determine if the lidar data deliverables met the specified Technical Specifications. The procedure for assessing the quality of the data is outlined below.

**1. Using FUSION software –**

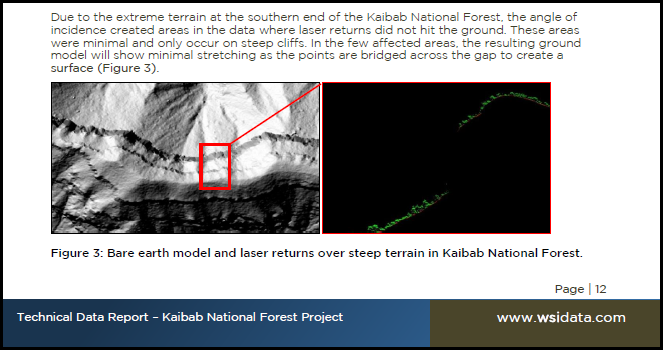
**a. Used the catalog DOS command to assess pulses per sq. meter to determine if the dataset meets the Technical Specifications, averaged over a 100m by 100m area.\***

|  |  |  |  |
| --- | --- | --- | --- |
| **Data acquisition** | **Survey Design** | **Minimum requirements** | **Specs met?** |
| Aggregate pulse density | 8 pulses/m2 | Baring non-reflective areas (e.g. open water):   * ≥85% design pulse density for entire project area * no 100m x 100m area with <50% design pulse density (4 pulses/m2) * in areas of large terrain relief, more closely space flightlines may be necessary to meet minimum point density and double coverage | Yes. More than 89% (100%-10.63%) of the entire North Kaibab study area met the design pulse density of 8 pulses / m2. 1.52% of the second delivery area had fewer than 4 pulses / m2, which is less than the 3% allowable.  See Appendix A |

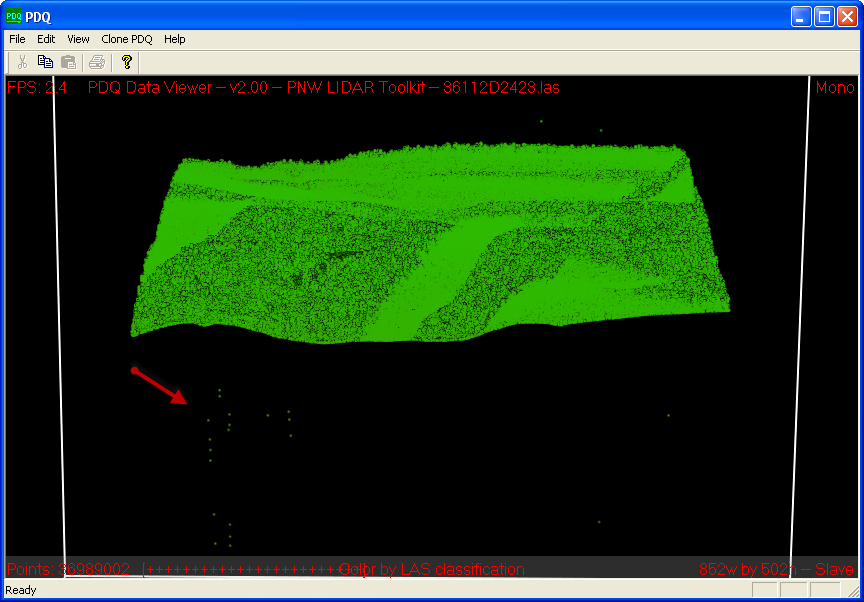
**b. Use the catalog DOS command to flag tiles with potential elevation outliers.**

No limits on outliers were specified. However, numerous tiles were identified by the **catalog** command (using the switch */outlier:2*) as having outlier elevation values (Appenix A). Outliers were defined as values that were less or more than two standard deviations from the average minimum or average maximum elevation, respectively, for all tiles in the project area. These may represent valid data in areas with steep canyons and abrupt changes in elevation.

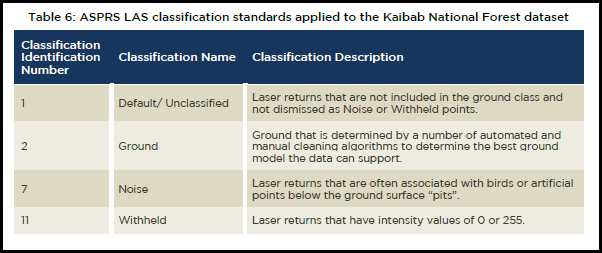
However, two issues should be noted in regard to outliers in the North Kaibab dataset. First, as explained in the contractor’s report, *Kaibab\_LiDAR\_Report\_Delivery2.pdf*, \*.las tiles that contain areas with steep cliffs sometimes contain erroneous elevation values:



Second, many of these \*.las tiles also included essentially “subterranean” points, even in areas without extreme relief. These may have been caused by laser pulses that reflected off multiple low surfaces, such as vegetation or objects on the forest floor, slowing their response time to the sensor and resulting in erroneous time/distance measures. An example is shown here:



According to the contractor’s report, such low points should be assigned to class 7, but these also included class 11 points:

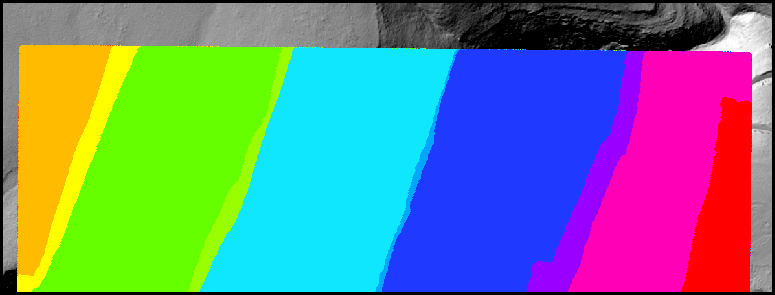


The individual \*.las tiles contain all points, including low elevation and high elevation (such as birds-in-flight, see Appendix A) errors. This should be considered when using the full point cloud for analyses. However, the low elevation outliers were removed by the contractor during the modeling process that was used to produce the 1m resolution “bare earth” layers. And the high elevation errors can be reduced by setting a threshold for the maximum allowable “height above ground” value. (Note: all 25m metrics produced from these data used a “height above ground” threshold of 100m.)

**c. Visual inspection – inspect 3D point cloud for all tiles for outliers, holes, gaps, etc.**

Visually inspected a sample of the \*.las tiles in Fusion. Also inspected the bare earth and highest hit models for the entire acquisition area (Step 2, a. and b., below).

**d. Use catalog DOS command graphical output to visually inspect flightline overlap (50% sidelap, 100% overlap) based on pulse density.**

Graphical output from the Catalog command of First Return (Pulse) Density indicated complete coverage (see Appendix A). Also displayed the GPSTime for three LAS files, using the *LidarGpsTime.esriAddIn* produced by RSAC, to visually inspect flightline overlap. See Appendix B. For example:

**2. Using ArcGIS software –**

**a. Visual inspection of Bare-earth surface model (DEM) – looking for tile boundary artifacts, gaps and holes.**

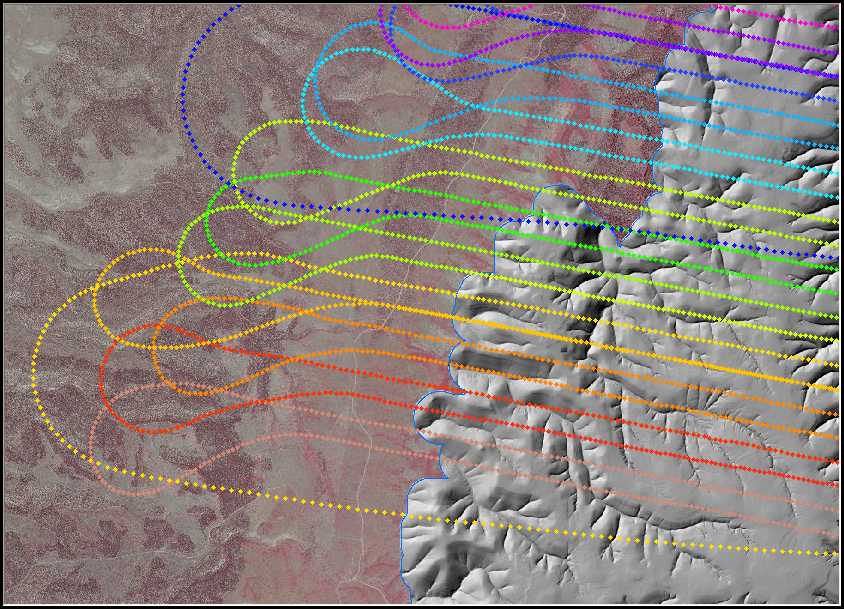
No artifacts or errors were observed during the visual inspection of the bare earth model, when displayed at a scale of 1:20,000. (See Appendix C.)

**b. Visual inspection of First-return (highest-hit) surface model (DSM) - looking for tile boundary artifacts, gaps and holes.**

No artifacts or errors were observed during the visual inspection of the highest hit model, when displayed at a resolution of 1:20,000. (See Appendix C.)

**c. Visual inspection of flightline shapefile for opposing flightline pattern.**

Visually inspected three of the Smoothed Best Estimated Trajectory (SBET) shapefiles, using a GPS\_Time field to color-code the points, to determine that adjacent flight lines were in opposing directions. (**Note** that for this delivery, as opposed to previous deliveries from 3DiWest/WSI, a GPSTime(s) field was provided as a *text* rather than a *numeric* field. A numeric GPSTime field needed to be created before its symbology could be changed using **Symbology > Quantities > Graduate colors > Value=GPS\_Time; Classes = 32**. The **Maximum Sample Size** was increased by clicking on **Classify > Sampling**.)



**d. Review shapefiles for coverage and completeness and ensure they include correct naming convention, metadata, and attributes.**

All shapefiles were displayed in ArcMap and visually inspected to confirm coverage and completeness. Metadata was included for all shapefiles.

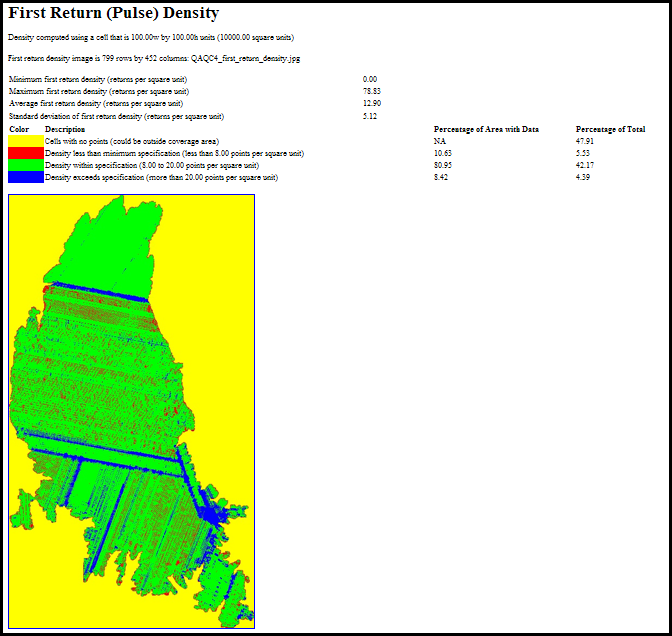
Note: The README files for both the All\_Returns and Ground\_Returns LAS files specified the UTM Zone as “11N”. These appears to be just a typo in both \*.txt files. All data appear to be in the correct Zone, 12N.

If it is determined that the acquired lidar data is insufficient based on the Quality Assurance assessment, the Contractor may be required to reprocess and/or re-fly problem areas to receive full-payment or may be asked to re-negotiate a reduced price of the lidar deliverables. Each Quality Assessment cell (100m by 100m) that does not meet the minimum Technical Specifications will cause a reduction in payment to the Contractor equivalent to the cells percentage of the total area surveyed. If 3 percent or more of the Quality Assessment cells do not meet the minimum Technical Specifications, then the Authorized Purchaser has the right to re-negotiate a reduced price of the lidar deliverables.

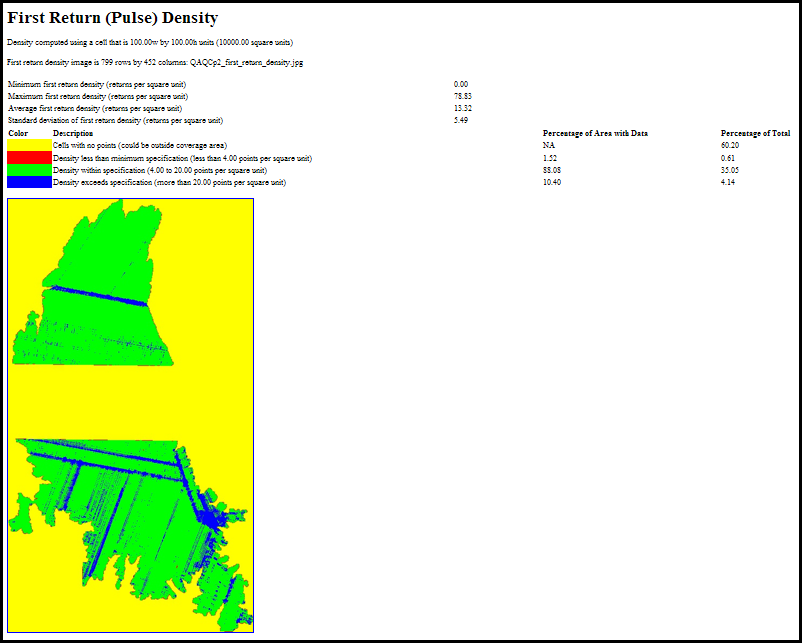
**Appendix A:**

**Aggregate Pulse Density**

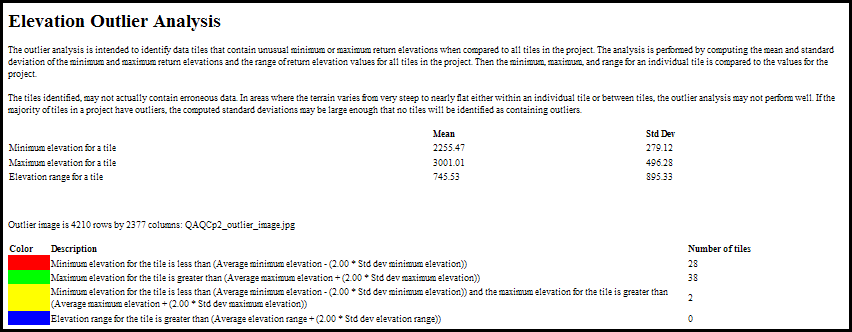
With minimum set to **8** pulses/m2 and entire North Kaibab study area included:

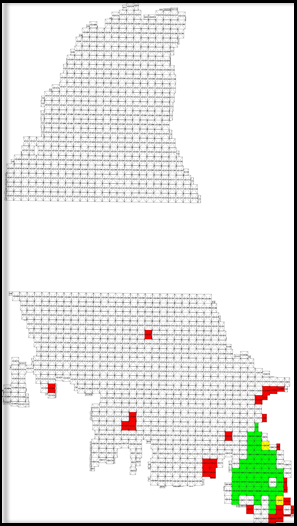


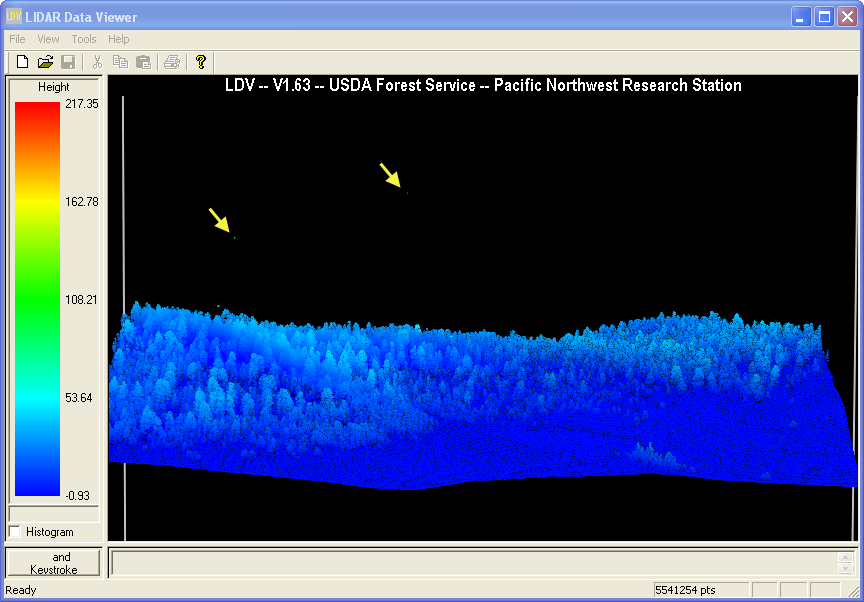
With minimum set to **4** pulses/m2 and only the second delivery area considered:



**Elevation Outliers**





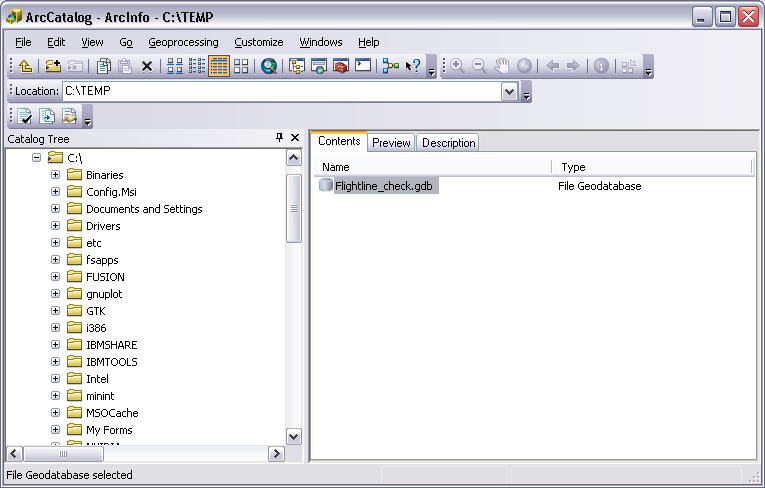
Examples of elevation outliers (possibly birds in flight) that were not detected by the catalog command when using the switch */outlier:2*. 

**Appendix B:**

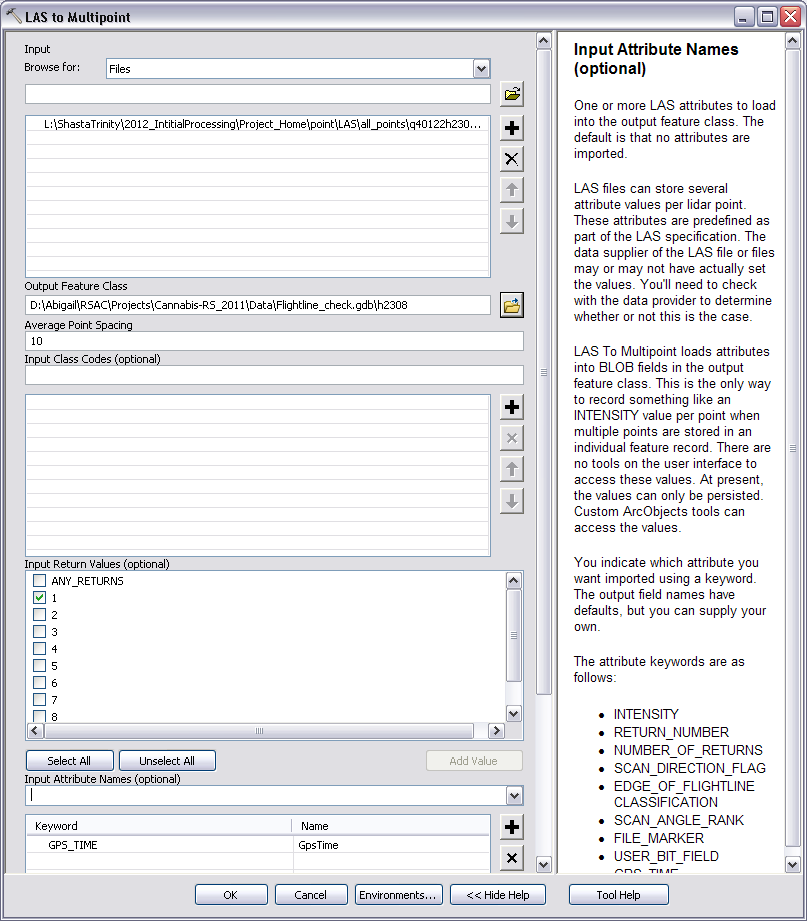
Adapted from the report *RSAC\_QA-Report\_forShastaTrinity\_Jan30\_2012.docx*.

Checking Flightline Sidelap

**Step 1:** Create **File Geodatabase**



**Step 2:** In **ArcToolbox > 3DAnalyst > Conversion > From File > LAS to Multipoint**, convert a LAS tile to multipoint (as a **Feature Class** in the newly created **File Geodatabase**). Be sure to include the **GPS\_time** attribute in the output **Feature Class**.

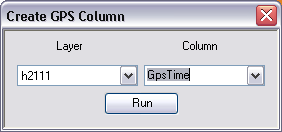
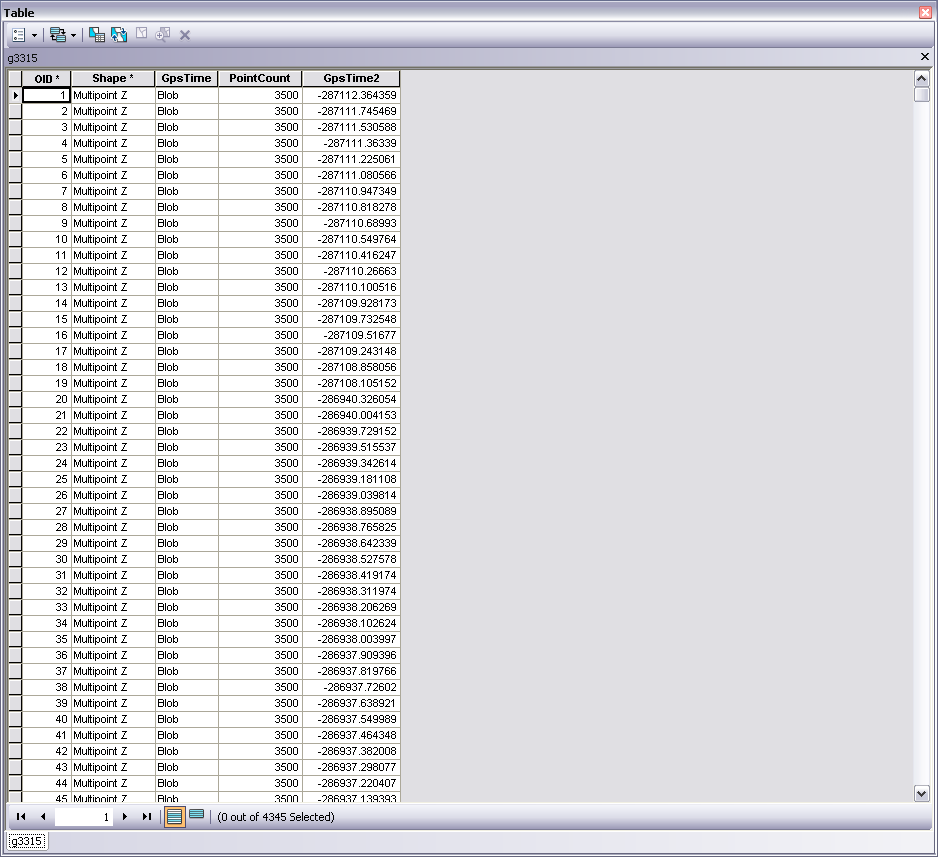


Add the new multipoint feature class to an ArcMap session. Open its attribute table, left-click on its **Table Options** and select **Turn All Fields On**. This will make the **GPSTime** field visible.

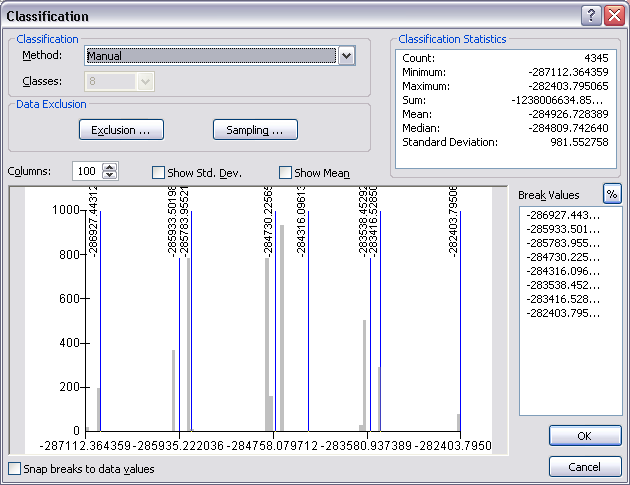
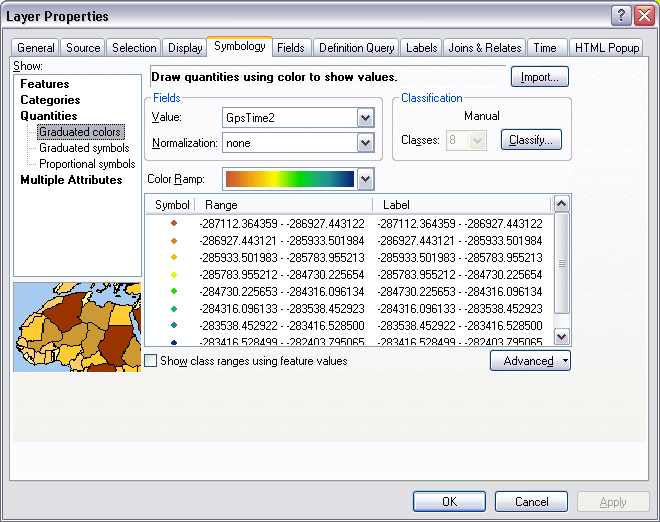
**Step 3:** Add the Lidar GPS tool AddIn (*LidarGpsTime.esriAddIn*) from the following location: [\\166.2.126.25\lidar\LAS\_AttributeConversionTool\lidarGpsTime.esriAddIn](file:///\\166.2.126.25\lidar\LAS_AttributeConversionTool\lidarGpsTime.esriAddIn)

**(NOTE:** Contact Abigail Schaaf at RSAC if you encounter problems downloading or running the tool.)

Use this tool to convert the GpsTime field to a readable field in the Attribute table (renames as GpsTime2). This GpsTime2 field is used to symbolize the lidar points and represent flightline paths.

**Step 4:** From the Symbology tab, choose Quantities and Graduated colors. Choose GpsTime2 from the Value Field and then click the Classify button to set the breaks and number of classes based on the histogram (see below). You can see where the natural breaks are for the different time chunks – each one likely corresponds to a different flight line. Make sure you have a class that captures each time chunk.

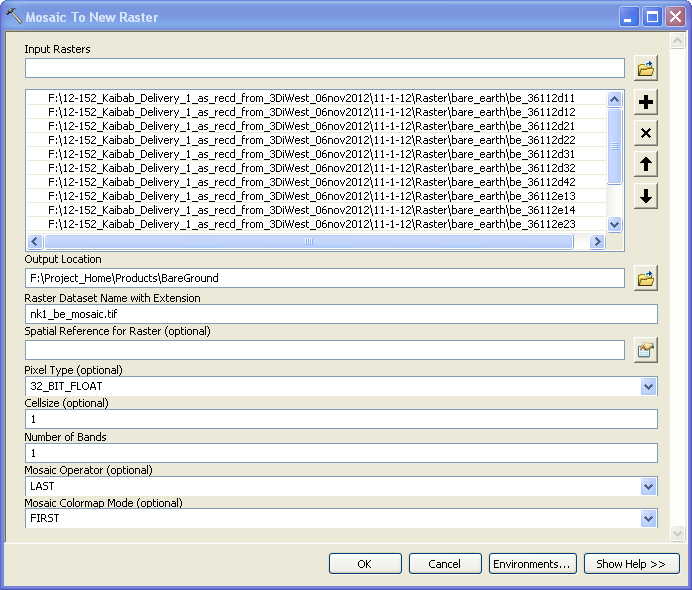
 

**Step 5:** Let the multipoint tile draw with the symbology you have given it. The flightlines should be apparent if you have symbolized it with the right number of classes and with the proper break locations. It is obvious from this rendering that there is ~50% sidelap between flightlines.

**Appendix C:**

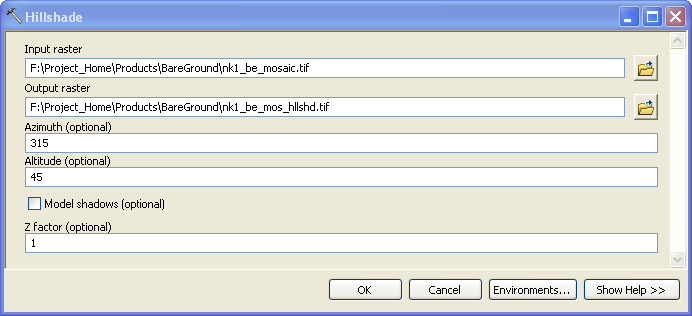
Produce mosaic of the bare earth tiles (example is from the first delivery):

**ArcToolbox > Data Management Tools > Raster > Raster Dataset > Mosaic to New Raster**



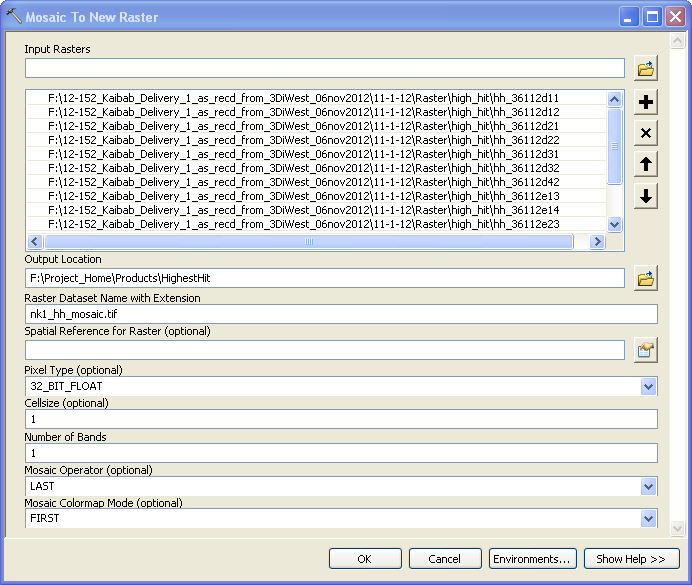
And then convert the mosaic to a hillshade version for easier visual analysis:

**ArcToolbox > Spatial Analyst Tools > Surface > Hillshade**



Produce mosaic of the highest hit tiles:

**ArcToolbox > Data Management Tools > Raster > Raster Dataset > Mosaic to New Raster**



And then convert the mosaic to a hillshade version for easier visual analysis:

**ArcToolbox > Spatial Analyst Tools > Surface > Hillshade**

