URS

QUALITY CONTROL REPORT

SUBMITTED TO:

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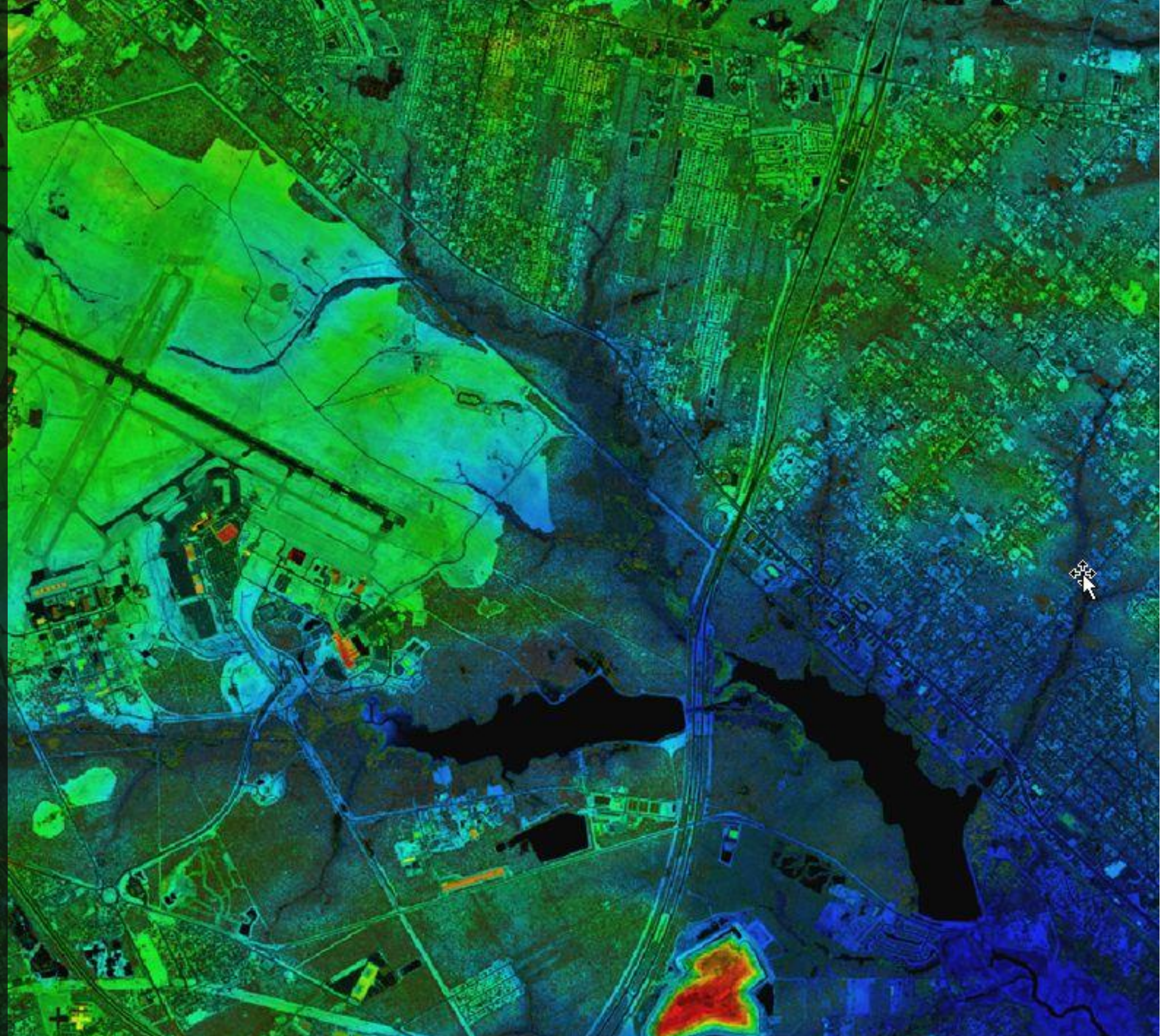
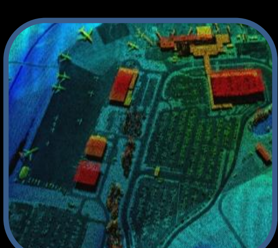


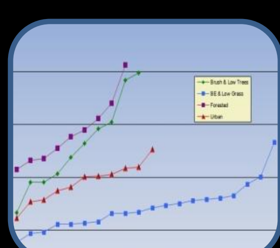
January 11, 2012

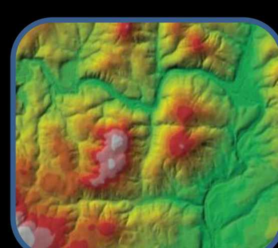
Independent LiDAR Quality Control Report

Calvert County Area of Interest

CATS II TORFP # 060B1400054
Digital High Resolution Aerial Photography (Orthophotography)







Calvert County Independent LiDAR Quality Control Report

1 Overview

The Independent LiDAR Quality Control review for LiDAR acquired under CATS II TORFP # 060B1400054 was performed by URS to validate LiDAR data quality for use in developing new flood hazard information that may be used in the update and creation of accurate flood zone maps in support of the National Flood Insurance Program. This document reports on the Calvert County Area of Interest (AOI) data deliveries received on July 8, 2011as well as 3 redeliveries of corrections applied by Surdex. URS conducted a 100% QA of the project deliverables.

Included in this report are the following items:

- Overview of independent quality control scope of work
- Pre-acquisition assessment
- Quality control checkpoint survey data
- Assessment practices and methodologies
- Post-acquisition assessment
- Data accuracy assessment
- Lessons learned
- Aerial acquisition assessment

For convenience, this report is organized by the major phases of project work as outlined in Section 1.1.

1.1 Independent Quality Control Scope of Work

For the Calvert County AOI, the following scope of work tasks were completed during the review:

URS – Independent Quality Control Tasks	
Phase	**Tasks**
Phase I: Pre-flight Planning	1. Review specifications and establish sign-off procedures 2. Review flight operations plan and procedures 3. Review field calibration and control procedures
Phase II: Data Acquisition	1. Establish ground survey control checkpoints 2. Review flight operations reports
Phase III: Data Processing	1. Data inspection 2. Produce accuracy report
Phase IV: Product Development	1. Review data product tiles 2. Review metadata 3. Produce QA report of quality practices and accuracy assessments

Table 1 Independent quality control tasks

1.2 Project Area and Deliverables Received

The project area for this task order consists of one, contiguous AOI denoted in the below figure as a white tile layout. Note that the LiDAR was clipped to the AOI boundary, resulting in partial tiles along the project boundary.

Figure 1 Project area of interest

For this AOI the deliverables were received in the following formats:

Deliverables Received	
Deliverable	**Number of units**
Raw Point Cloud Swaths in LAS 1.2 format	47
Classified Point Cloud Tiles in LAS 1.2 format	335
Hydro-lines in ESRI geodatabase 9.3.1 or higher	1
Low confidence polygons in ESRI geodatabase	1
Metadata (file level)	335
Checkpoint survey report	1
LiDAR Data Acquisition Report	1

Table 2 Deliverables received for this project

1.3 Applicable Specifications & Guidelines

The following guidelines, specifications, and standards are applicable to this report:

A. USGS LiDAR Guidelines and Base Specifications, V13 dated February 22, 2010
http://lidar.cr.usgs.gov/USGS-NGP%20Lidar%20Guidelines%20and%20Base%20Specification%20v13(ILMF).pdf

B. FEMA Procedure Memorandum No. 61 – Standards for LiDAR and Other High Quality Digital Topography
http://www.fema.gov/library/viewRecord.do?id=4345

C. American Society for Photogrammetry and Remote Sensing (ASPRS) Guidelines, Vertical Accuracy Reporting for LiDAR Data, May 24, 2004
http://www.asprs.org/society/committees/lidar/Downloads/Vertical_Accuracy_Reporting_for_Lidar_Data.pdf

D. FGDC-STD-001-1998: Content Standard for Digital Geospatial Metadata (version 2.0)
http://www.fgdc.gov/metadata/csdgm/

2 Phase I: Pre-flight Planning QA Tasks

Pre-flight planning QA was conducted to assist the planning process as well as to ensure that no significant issues were present prior to data acquisition. For the pre-flight planning phase, URS conducted a review of flight operations and plan files submitted by Surdex prior to the mobilization of data collection flights. These files included, but were not limited to:

- Planned flight lines
- Planned GPS base stations
- Planned airport locations
- Calibration plans
- Schedule
- Terrain consideration
- Quality procedures
- Planned scanset (sensor settings)
- Type of aircraft
- Procedure for reflights
- Land cover considerations

All files and planning documents generated for this phase were reviewed against the project specifications and guidelines provided. Planning documents further facilitated the QA process during the acquisition, survey and processing tasks of the project.

2.1 Aerial Acquisition Reporting Guidelines

During the planning phase, URS provided a set of aerial acquisition reporting guidelines to Surdex. The guidelines incorporated reporting guidelines from the project scope of work as well as additional report items to help facilitate quality control reviews, post-acquisition.

The following table outlines the reporting guidelines communicated to Surdex during the planning phase:

Minimum Aerial Acquisition Reporting Guideline for Vendors		
Item	**Content**	**Format**
	Pre-flight reporting guidance	
Flight operations plan	• Planned flight lines • Planned GPS stations • Planned control • Planned airport locations • Calibration plans • Quality procedures for flight crew • Planned scanset (sensor settings and altitude) • Type of aircraft • Schedule for flights • Procedure for tracking, executing, and checking reflights • Considerations for terrain, cover, and weather in AOI's	MS Word or PDF
	Flight progress reporting guidance	
Flight logs	• Job # / name • Lift # • Block or AOI designator • Date • Aircraft tail number, type • Flight lines: line #, direction, start/stop, altitude, scan angle/rate, speed, conditions, comments • Pilot name • Operator name • AGC switch setting • Laser pulse rate • Mirror rate • Field of view • Airport of operations • GPS base station names	Excel, MS Word, or PDF
Daily activity reports	Summary of flight activities for the day and map of area/s covered	Web-based, PDF, MS Word, or Excel
	Post-flight reporting guidance (Final Acquisition Report)	
GPS base station information	• Base station name • Latitude/longitude (ddd-mm-ss.sss) • Base height (ellipsoidal meters) • Maximum PDOP • Map of locations	Excel, TXT, MS Word, or PDF for data; ESRI shape file for map of locations (data and info may be in attribute table)
GPS/IMU processing summary	• Max horizontal GPS variance (cm)	MS Word or PDF with screenshots

Minimum Aerial Acquisition Reporting Guideline for Vendors		
Item	**Content**	**Format**
	• Max vertical GPS variance (cm) • Notes on GPS quality (high, good, etc.) • GPS separation plot • GPS altitude plot • PDOP plot • Plot of GPS distance from base station/s	
Coverage	Verification of project coverage	ESRI shape files and/or screenshots
Flights	• As-flown trajectories • Calibration lines	ESRI shape files or .trj
Flight logs	Incorporated as appendix	Excel or MS Word
Project survey control	Ground control and base station layouts	Excel or ESRI shape file
Internal data QA	• Description of data verification/QC process • Results of verification and QC steps	MS Word, Excel or PDF

Table 3 Aerial acquisition reporting guidelines

2.2 *Aerial Acquisition Pre-flight Planning Review*

A review was conducted by URS to validate aerial acquisition flight planning and reporting requirements in accordance with the LiDAR Technical Scope of Work. For the purpose of this review, Surdex provided URS with planned flight lines and GPS stations, sensor settings (scan set), control points, and field calibration plans.

The following table reports the results of the URS review for the planning phase of the aerial acquisition effort:

QA Checks and Results – Flight Operations Planning and Procedures		
Items Reviewed	**Pass/Fail**	**Comments**
Planned lines – sufficient coverage, spacing, and length	Pass	None
Planned GPS stations –in range of all missions	Pass	None
Planned ground control – sufficient to control and boresight	Pass	None
Planned airports – within reasonable distance of AOI	Pass	None
Calibration plans	Pass	None
Schedule	Pass	None
Quality procedures	Pass	None
LiDAR sensor scan set – planned for proper scan angle, sidelap, design pulse	Pass	None
Aircraft utilizes ABGPS	Pass	None
Sensor supports project design pulse density	Pass	None

QA Checks and Results – Flight Operations Planning and Procedures		
Items Reviewed	**Pass/Fail**	**Comments**
Type of aircraft – supports project design parameters	Pass	None
Re-flight procedure – tracking, documenting, processing	Pass	None
Project design supports accuracy requirements of project	Pass	None
Project design accounts for land cover and terrain types	Pass	None
Daily / weekly communications plan in place	Pass	None
Planned lines – sufficient coverage, spacing, and length	Pass	None

Table 4 QA checks and results for the flight operations phase

3 Phase II: Data Acquisition

The following quality control actions were taken during and immediately after the aerial acquisition of LiDAR data for this AOI.

3.1 Review of Aerial Acquisition Operations

URS conducted a review of acquisition progress and daily records kept by the flight crews. The following table outlines the checklist and results for the acquisition phase:

QA Checklist for Aerial Acquisition Phase		
Deliverable	**Included (Yes/No)**	**Comments**
Daily activity reports	No	Not done for this project
Flight logs – job #/name	Yes	Included with base stations
Flight logs – block or AOI	Yes	None
Flight logs – date	Yes	None
Flight logs – aircraft tail #	Yes	None
Flight logs – lines - #	Yes	None
Flight logs – lines - direction	Yes	None
Flight logs – lines – start/stop	Yes	None
Flight logs – lines – altitude	No	Not included
Flight logs – lines – scan angle	Yes	None
Flight logs – lines – speed	No	Included in acquisition rpt.
Flight logs – conditions	Yes	None
Flight logs – comments	Yes	None
Flight logs - pilot name	Yes	None
Flight logs - operator name	Yes	None
Flight logs - AGC switch	No	Not included on logs
Flight logs – GPS base stations	Yes	None

Table 5 QA checklist and results table for acquisition phase

3.2 Post-flight: Aerial Acquisition Report

For the post-flight QA review, URS conducted a review of the vendor's report titled: "*LiDAR Acquisition & Processing, Calvert County, MD LiDAR Project*" submitted by Surdex. The following table outlines the checklist and results for the post-flight review:

QA Checklist for the Aerial Post-acquisition Vendor Report		
Deliverable	**Included (Yes/No)**	**Comments**
GPS base station - name	Yes	Included with flight logs
GPS base station – lat/long	Yes	Included with flight logs
GPS base station – height	Yes	Included with flight logs
GPS base station – map	Yes	Included with flight logs
GPS quality - separation	Yes	None
GPS quality – PDOP	Yes	None
GPS quality - horizontal accuracy	Yes	None
GPS quality - vertical accuracy	Yes	None
Sensor calibration	Yes	None
Verification of AOI coverage	Yes	None
As-flown trajectories included	Yes	None
Ground control layout	Yes	None
Data verification	Yes	None

Table 6 QA checklist for post-acquisition report

URS verified the differential baseline lengths of the aerial vendor's base stations used for the project. To ensure that baseline lengths did not exceed the 25-mile specification of the project, URS plotted the base station coordinates provided in the aerial acquisition report from the vendor by generating 25-mile (radius) range rings around each point and comparing them against the AOI tile layout

In the following graphic, there is a small area noted within the project (highlighted in pink) that is not covered by the minimum 25 mile range requirement.

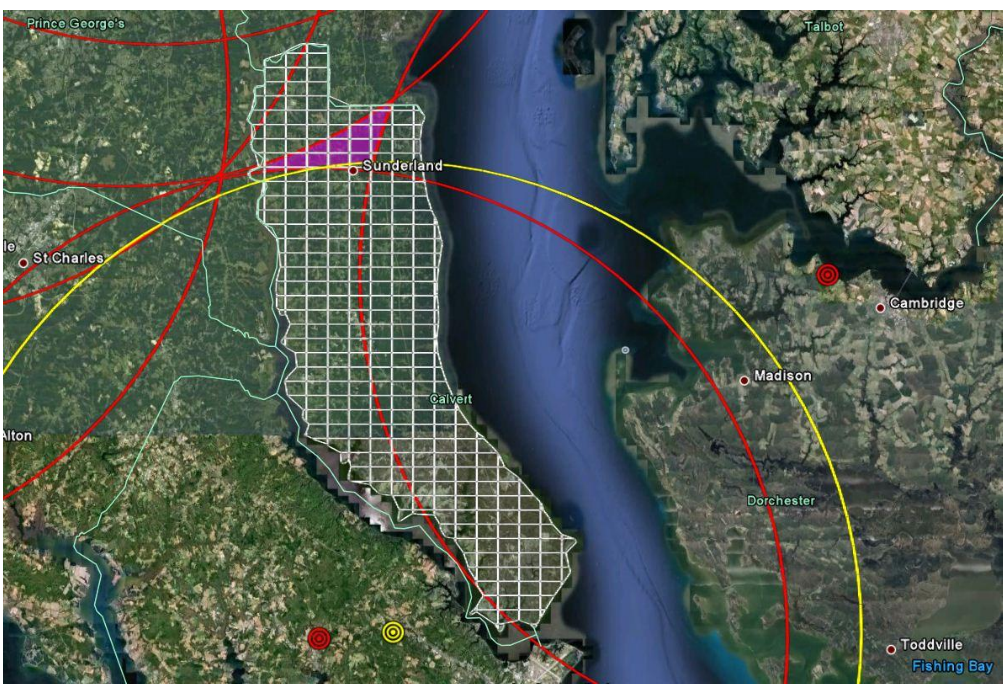


Figure 2 GPS base station baseline check. Area not within the 25-mile range of a base station is highlighted in pink

URS does not consider this to be an issue as the aerial acquisition report and supporting data for Calvert County confirms that no issues were encountered during flight.

As a final check and assurance of this, URS inspected the delivered LiDAR LAS files in this area to ensure that a GPS time-stamp was present.

3.3 Post-flight: Notes

URS noted the following during the post-flight review:

- **Map of GPS base stations** – a graphic of the location of the GPS base stations used during the acquisition was not included in the aerial acquisition report. However, the lat/long coordinates of the base stations were included and URS was able to verify coverage by plotting the base station coordinates.

4 Phase III: Data Processing

The following quality control reviews were conducted during the data processing phase for the Calvert County AOI.

4.1 Qualitative Assessment

This section describes the specifications checked, the methods and tools used and the results of the quality assessment of the Calvert County AOI delivery.

4.1.1 Specifications Checked: Aerial Acquisition

The following list outlines the checks against the project specifications and indicates whether or not the check was conducted for this particular delivery.

QA Checklist for Aerial Acquisition Phase			
Deliverable	**Specification/Description**	**Checked for this delivery? Yes/No**	**Comments**
Pulse returns	Sensor capable of a minimum of 3 multiple discrete returns containing range and intensity values for first, intermediate and last returns for each emitted pulse.	Yes	None
Scan angle	$\leq \pm$ 20 degrees	Yes	None
Swath overlap	Overlap between adjacent flight lines 20% or greater	Yes	None
Design pulse density	1.4 meters	Yes	None
GPS procedures	Documented	Yes	None
Survey conditions	Leaf-off, free of snow/fog/clouds, and no unusual flooding or inundation	Yes	None

QA Checklist for Aerial Acquisition Phase			
Deliverable	**Specification/Description**	**Checked for this delivery? Yes/No**	**Comments**
Coverage	No voids greater than $(4*NPS)^2$	Yes	None

Table 7 QA checklist for aerial acquisition phase

4.1.2 Specifications Checked: Processing

4.1.2.1 Raw Point Cloud

The following checklist outlines the standard checks for the raw point cloud product and indicates whether or not the check was conducted for this particular delivery.

QA Checklist for Processing phase: Raw Point Cloud			
Deliverable	**Specification/Description**	**Checked for this delivery? Yes/No**	**Comments**
Vertical datum	NAVD88, most recent geoid	Yes	None
Horizontal datum	NAD83 (NSRS2007)	Yes	None
Projection	State Plane	Yes	None
Vertical units	Feet	Yes	None
Horizontal units	Feet	Yes	None
Attributes	Returns contain – GPS week and second, easting/northing, elevation, intensity, return # and classification	Yes	None
Attributes	No duplicate entries	Yes	None
Attributes	GPS second reported to nearest microsecond	Yes	None
Attributes	Easting, northing, and elevation reported to nearest 0.01 m or 0.01 ft	Yes	None
Attributes	Compliant with LAS 1.2 format	Yes	None
Attributes	Tiled delivery, no overlap	Yes	None

Table 8 QA checklist for raw point cloud

4.1.2.2 Classified Point Cloud

The following list outlines the standard checks for the classified point cloud product and indicates whether or not the check was conducted for this particular delivery.

QA Checklist for Processing phase: Classified Point Cloud			
Deliverable	**Specification/Description**	**Checked for this delivery? Yes/No**	**Comments**
Vertical datum	NAVD88, most recent geoid	Yes	None
Horizontal datum	NAD83 (NSRS2007)	Yes	None

QA Checklist for Processing phase: Classified Point Cloud			
Deliverable	**Specification/Description**	**Checked for this delivery? Yes/No**	**Comments**
Projection	State Plane	Yes	None
Vertical units	Feet	Yes	None
Horizontal units	Feet	Yes	None
Attributes	Returns contain – GPS week and second, easting/northing, elevation, intensity, return # and classification	Yes	None
Attributes	No duplicate entries	Yes	None
Attributes	GPS second reported to nearest microsecond	Yes	None
Attributes	Easting, northing, and elevation reported to nearest 0.01 m or 0.01 ft	Yes	None
Attributes	Correct classes – 1. Unclassified; 2. Ground; 7. Noise; and 9. Water; 10.Ignored breakline 11. Withheld 12. Overlap	Yes	None
Attributes	Compliant with LAS 1.2 format	Yes	None
Attributes	Tiled delivery, no overlap	Yes	None

Table 9 QA checklist for classified point cloud

4.1.2.3 Low-confidence Polygons

The following list outlines the standard checks for the low-confidence polygons and indicates whether or not the check was conducted for this particular delivery.

QA Checklist for Processing phase: Low-Confidence Polygons			
Deliverable	**Specification/Description**	**Checked for this delivery? Yes/No**	**Comments**
File Format	Delivered as ESRI geodatabase	Yes	None

Table 10 QA checklist for low confidence polygons

4.1.2.4 3d Hydro-lines

The following list outlines the standard checks for the 3d hydro-lines and indicates whether or not the check was conducted for this particular delivery.

QA Checklist for Processing phase: 3d Hydro-lines			
Deliverable	**Specification/Description**	**Checked for this delivery? Yes/No**	**Comments**
Inland Ponds, Lakes, and Boundary Waters	Features greater than ½ acre in surface at time of collection are collected	Yes	None

QA Checklist for Processing phase: 3d Hydro-lines			
Deliverable	**Specification/Description**	**Checked for this delivery? Yes/No**	**Comments**
Single line streams and rivers	Features with a 4' minimum nominal width and a 20' maximum nominal width and atleast ½ mile in visible length are collected	Yes	None
Dual line streams and rivers	Features greater than a 20' nominal width and atleast ½ mile in visible length are collected	Yes	None
File Format	Delivered as ESRI geodatabase (9.3.1 or greater)	Yes	None
Georeference Information	Feature classes must include a projection and use the same coordinate system (horizontal and vertical) as the LiDAR point delivery	Yes	None
File Format	Delivered as continuous layer or in tiles	Yes	None

Table 11 QA checklist for 3d hydro-lines

4.1.3 Software Used

The main software programs used by URS in performing the qualitative assessment are as follows:

- *GeoCue:* a geospatial data/process management system especially suited to managing large LiDAR data sets
- *TerraModeler:* used for analysis and visualization
- *TerraScan:* runs inside of Bentley Microstation; used for point classification checks and points file generation
- *Proprietary tool:* developed in-house to conduct a statistical analysis of .LAS files
- *QT Modeler:* data density checks

4.1.4 Qualitative Assessment Process

The following systematic approach was used for performing the qualitative assessment of this delivery.

- Delivery was reviewed for completeness of content
- Delivery was uploaded to the GeoCue data warehouse
    - Projection of data was verified
    - Best-available imagery was referenced to facilitate data review
- Performed coverage/gap check to ensure proper coverage of the tiles submitted
    - Created a density grid to check that delivery meets data density requirements
    - Conducted a statistical analysis of delivery to check point classifications, variable-length record values, and maximum/minimum x,y,z ranges
- Performed tile-by-tile analysis (100% of the project area)
    - Verified that tile naming conventions were followed
    - Verified that deliverable formats were correct
    - Using TerraScan, checked for errors in profile mode (noise, high and low points)

- Conducted measurements to determine if delivery met applicable specifications outlined in aerial acquisition specifications (overlap, gaps, etc.)
- Reviewed hydo-breakline data for accuracy and completeness
- Reviewed each tile for anomalies; if problems were found, the areas were identified using polygons in ESRI shape file format and accompanied by comments and relevant screenshots. Note: best-available imagery was used when necessary to aid in making final determinations with regards to:
    - Buildings left in the bare-earth points
    - Vegetation left in the bare-earth points
    - Water points left in the bare-earth points *(not reviewed in this delivery)*
    - Proper definition of roads and drainage patterns
    - Bridges and large box culverts removed from bare-earth points
    - Areas that have been “shaved off’ or “over-smoothed” during filtering

4.1.5 Qualitative Assessment Results

The following sections outline the results of the quality assessment conducted during the data processing phase of this project.

4.1.5.1 Against LiDAR Aerial Acquisition Specifications

QA Checklist for Aerial Acquisition Phase			
Deliverable	**Specification/Description**	**PASS/FAIL**	**Comments**
Pulse returns	Sensor capable of a minimum of 3 multiple discrete returns containing range and intensity values for first, intermediate and last returns for each emitted pulse.	Pass	None
Scan angle	$\leq \pm$ 20 degrees	Pass	None
Swath overlap	Overlap between adjacent flight lines 20% or greater	Pass	None
Design pulse density	1.4 meters	Pass	None
GPS procedures	Documented	Pass	None
Survey conditions	Leaf-off, free of snow/fog/clouds, and no unusual flooding or inundation	Pass	None
Coverage	No voids greater than $(4*NPS)^2$	Pass	None

Table 12 QA results - aerial acquisition

A check of the swath overlap criteria was made by colorizing the LiDAR tiles by source identification (flight line) and making direct measurements in multiple locations of the tile. The following figure is an example from the AOI.

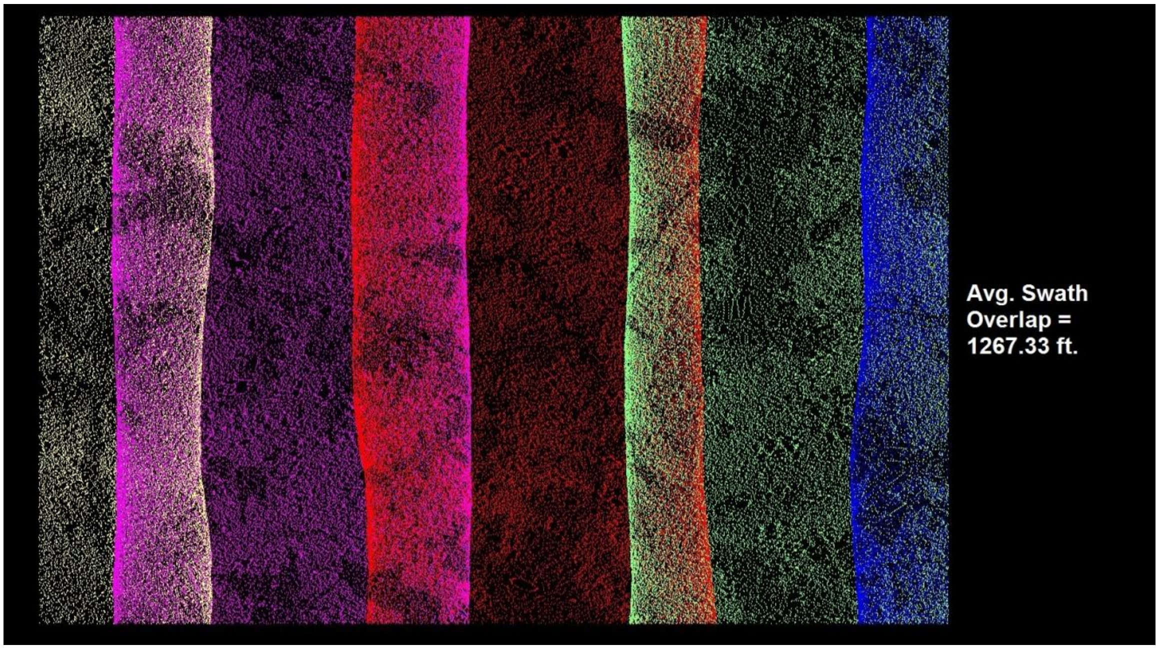


Figure 3 - Example of LiDAR points in a Calvert tile colorized by source identification

4.1.5.2 QA Results - Raw Point Clouds

QA Results for Processing phase: Raw Point Cloud			
Deliverable	**Specification/Description**	**Pass/Fail**	**Comments**
Vertical datum	NAVD88, most recent geoid	Pass	None
Horizontal datum	NAD83 (NSRS2007)	Pass	None
Projection	State Plane	Pass	None
Vertical units	Feet	Pass	None
Horizontal units	Feet	Pass	None
Attributes	Returns contain – GPS week and second, easting/northing, elevation, intensity, return # and classification	Fail	Header records contained error. Two redeliveries corrected the issue
Attributes	No duplicate entries	Pass	None
Attributes	GPS second reported to nearest microsecond	Pass	None
Attributes	Easting, northing, and elevation reported to nearest 0.01 m or 0.01 ft	Pass	None
Attributes	Compliant with LAS 1.2 format	Pass	None
Attributes	Tiled delivery, no overlap	Pass	None

Table 13 QA results - all-return point cloud files

The following figure depicts a void/gap check conducted on Calvert County AOI (all return) using LiDAR orthophotos generated in GeoCue. The imported .LAS files were used to create the LiDAR "orthos." The LiDAR orthos were one of the tools used to verify data coverage and point density, to check for gross data voids or gaps, and to use as reference data during checks for data anomalies and artifacts. These LiDAR orthos are not intended to be a project deliverable. The orthos were derived from the full point cloud elevations and LiDAR pulse return intensity values. The intensity values were used as delivered, with no normalization applied. Due to the point density of the original collection, the LiDAR orthos were produced at a 1m pixel for the entire area of interest. Acceptable voids are those found over water features and some areas of dense vegetation.

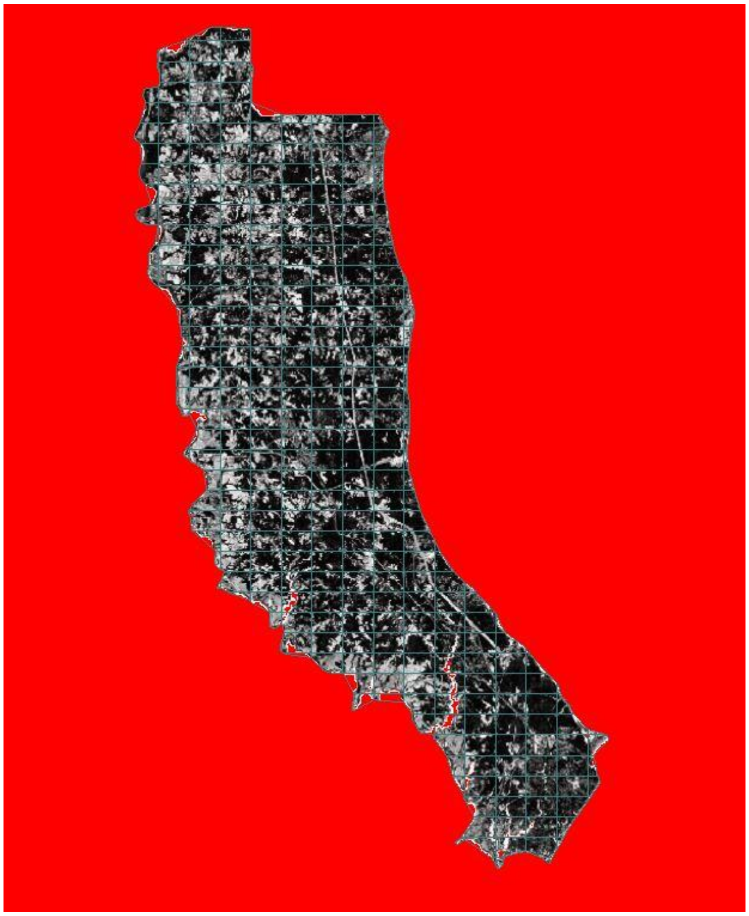


Figure 4 – Void/gap check on the AOI. Intensity image is overlaid onto a colored background (in this case red) to allow thorough identification of gross gaps and voids

4.1.5.3 QA Results - Classified Point Clouds

QA Results for Processing phase: Classified Point Cloud			
Deliverable	**Specification/Description**	**Pass/Fail**	**Comments**
Vertical datum	NAVD88, most recent geoid	Pass	None
Horizontal datum	NAD83 (NSRS2007)	Pass	None
Projection	State Plane	Pass	None
Vertical units	Feet	Pass	None
Horizontal units	Feet	Pass	None
Attributes	Returns contain – GPS week and second, easting/northing, elevation, intensity, return # and classification	Pass	None
Attributes	No duplicate entries	Pass	None

QA Results for Processing phase: Classified Point Cloud			
Deliverable	**Specification/Description**	**Pass/Fail**	**Comments**
Attributes	GPS second reported to nearest microsecond	Pass	None
Attributes	Easting, northing, and elevation reported to nearest 0.01 m or 0.01 ft	Pass	None
Attributes	Correct classes – 1. Unclassified; 2. Ground; 7. Noise; and 9. Water; 10.Ignored breakline 11. Withheld 12. Overlap	Fail	Two tiles contained above ground artifacts in the ground class. Three tiles had misclassified ground/water points. Vendor did not classify any points as Class 10.
Attributes	Compliant with LAS 1.2 format	Pass	None
Attributes	Tiled delivery, no overlap	Pass	None

Table 14 QA results for classified point cloud review

The Figure 8 demonstrates the quality of the filtering to bare ground. Profiles like this were taken across the project area to check the quality of the filtering.

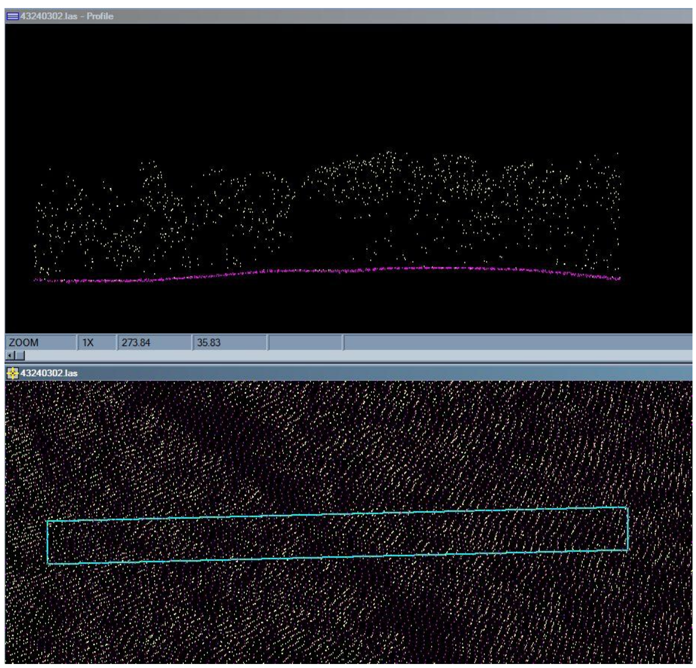


Figure 5 - Profile drawn in Calvert tile to check filtering quality. Pink denotes ground points; all other colors are above ground points or overlap.

4.1.5.4 QA Results – Low-confidence Polygons

QA Results for Processing phase: Low-Confidence Polygons			
Deliverable	**Specification/Description**	**Pass/Fail**	**Comments**

QA Results for Processing phase: Low-Confidence Polygons			
Deliverable	**Specification/Description**	**Pass/Fail**	**Comments**
File Format	Delivered as ESRI geodatabase	Pass	None

Table 15 QA results for low confidence polygons

4.1.5.5 QA Results – 3d Hydro-lines

QA Results for Processing phase: 3d Hydro-lines			
Deliverable	**Specification/Description**	**Pass/Fail**	**Comments**
Inland Ponds, Lakes, and Boundary Waters	Features greater than ½ acre in surface at time of collection are collected	Pass	None
Single line streams and rivers	Features with a 4' minimum nominal width and a 20' maximum nominal width and atleast ½ mile in visible length are collected	Pass	None
Dual line streams and rivers	Features greater than a 20' nominal width and atleast ½ mile in visible length are collected	Pass	None
File Format	Delivered as ESRI geodatabase (9.3.1 or greater)	Pass	None
Georeference Information	Feature classes must include a projection and use the same coordinate system (horizontal and vertical) as the LiDAR point delivery	Pass	None
File Format	Delivered as continuous layer or in tiles	Pass	Delivered as continuous layer

Table 16 QA results for 3d hydro-lines

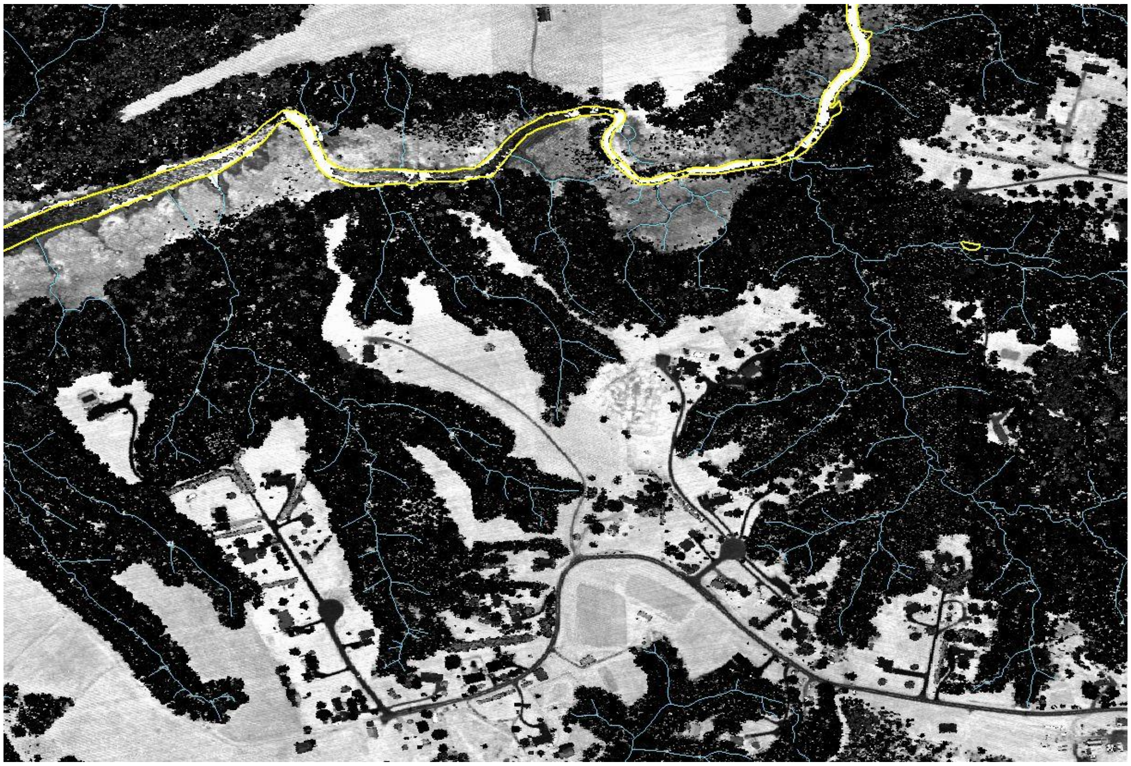


Figure 6 - Hydro-line check for Calvert County. Yellow lines are collected dual line features, light blue lines are collected single line features.

4.1.5.6 Failed Items for This Delivery

As summarized by the QA tables in the previous sections of this report, the following items failed initial QA inspections and were subsequently corrected and redelivered to URS:

- Raw swath header records: the following issues were identified with the header records in the raw swaths delivered by Surdex –
    - A portion of the swaths delivered were produced using libLAS 1.2, which appeared to be the source of a header error where the headers displayed the incorrect number of points and the incorrect number of returns by point
    - The swaths with the above issue would not display correctly nor load into GeoCue
- 2 tiles in the AOI contained above-ground artifacts, which were found to be structures.

Figure 7 - TIN of tile containing building artifact in the ground points

Figure 8 - The above image in the same location clearly showing a road salt storage facility

- 3 tiles in the AOI contained points misclassified as either ground or water. These were either an island within a hydropolygon misclassified as water or ground points within hydropolygons not classified as water. See Figure 9 for an example.

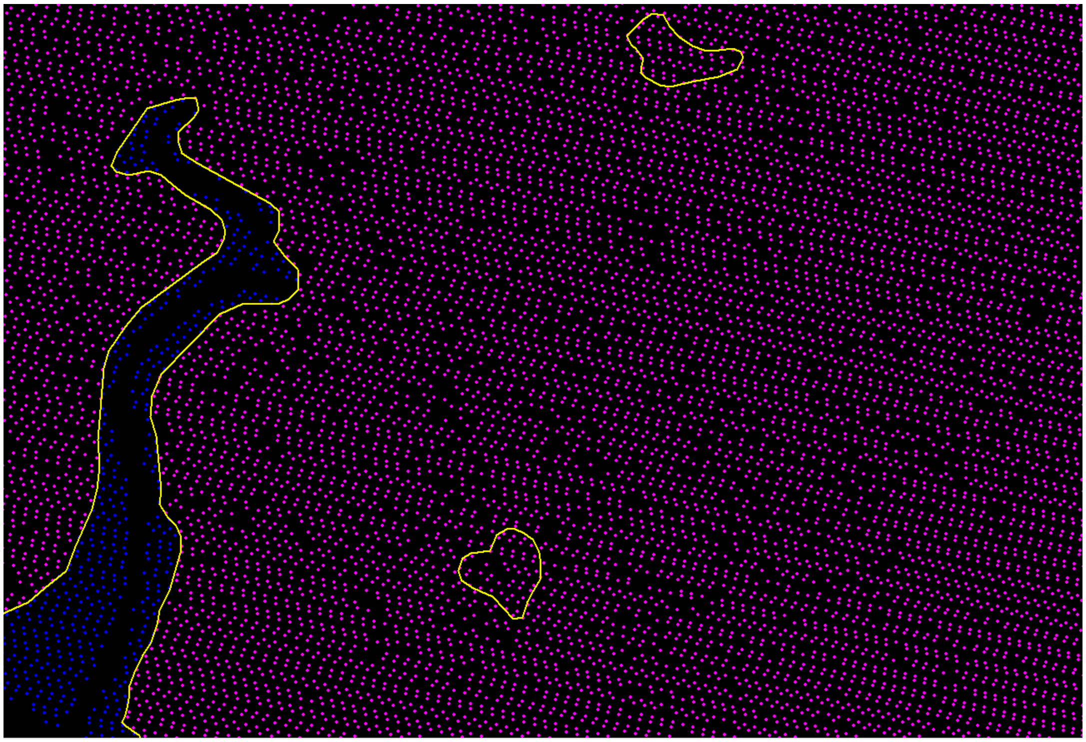


Figure 9 - Ground point misclassification. Ground points (pink) with yellow polygons should have been misclassified as water points (blue).

4.2 Quantitative Assessment (Accuracy Report)

URS performed the LiDAR vertical accuracy assessment for the Calvert County AOI in accordance with ASPRS /NDEP specifications and guidelines. Only the Fundamental Vertical Accuracy (FVA) was checked for this delivery.

The LiDAR data produced for this project adheres to the ASPRS/NDEP accuracy standards for FVA, as demonstrated by this accuracy check.

4.2.1 Specifications Checked

The following specifications were checked for the Calvert County AOI for this review:

Vertical Accuracy Specification – Urban		
Standard	**Description**	**Accuracy Threshold**
ASPRS/NDEP – FVA ONLY	ACCz	0.41ft
ASPRS/NDEP – FVA ONLY	RMSEz	0.8ft

Table 17 Vertical accuracy thresholds for this AOI

4.2.2 Software Used

- *GeoCue:* a geospatial data/process management system especially suited to managing large LiDAR data sets
- *Z-probe:* A program within GeoCue used for direct comparison of the QC checkpoints against the LiDAR Class 2 or ground points
- *Microsoft Excel:* used to calculate accuracy values and statistics from the measurements

4.2.3 Quantitative Assessment Process

The primary quantitative assessment steps were as follows:

1. Surdex acquired new raw LiDAR data between March 27 and March 28 of 2011 and performed post-processing to derive the bare-earth digital terrain model.
2. URS created a table of horizontal coordinates and orthometric heights for all surveyed checkpoints provided by J.A. Rice, the County of Calvert, and control from the orthophotography project that were deemed to be useable in the LiDAR accuracy check.
3. URS created a triangulated irregular network (TIN) from the bare-earth LiDAR points, and interpolated a z-value at each of the survey point locations.
4. URS compared the LiDAR-derived elevations of the check points to the surveyed check point orthometric heights and computed the vertical accuracy assessment according to ASPRS/NDEP specifications.

4.2.4 QA Checkpoint Survey

During the planning phase URS provided a set of guidelines to J.A. Rice outlining the reporting and placement requirements for the QC checkpoints. These guidelines incorporated items from the project scope of work, as well as guidelines derived from URS experience on similar projects.

The ground survey layout for the quality control checkpoints was developed by URS by selecting control point locations on a project layout and by reviewing and adjusting the locations using aerial imagery as a reference. The aerial imagery was referenced to confirm that control point locations were accessible, in the relevant land cover categories, and to ensure that the locations chosen conformed to project specifications and guidelines.

Due to a communication error, the checkpoints specifically surveyed for the purpose of LiDAR QA were erroneously supplied to the LiDAR vendor, Surdex, and used for their boresight process. Because of this error, URS calculated the FVA using all available points. It should be noted that an additional set of independent QA survey checkpoints are currently being collected in the field to complete a more thorough accuracy assessment per ASPRS/NDEP guidelines.

The following table and figure outline the FVA checkpoints used in the calculations and indicate which checkpoints were used by Surdex and which were truly independent.

QA Survey Checkpoints Legend	
Checkpoint color	**Land cover category**
Red	County survey points not used by Surdex
Orange	Surveyed by J.A. Rice
Yellow	County survey points used by Surdex

Table 18 QA checkpoint legend

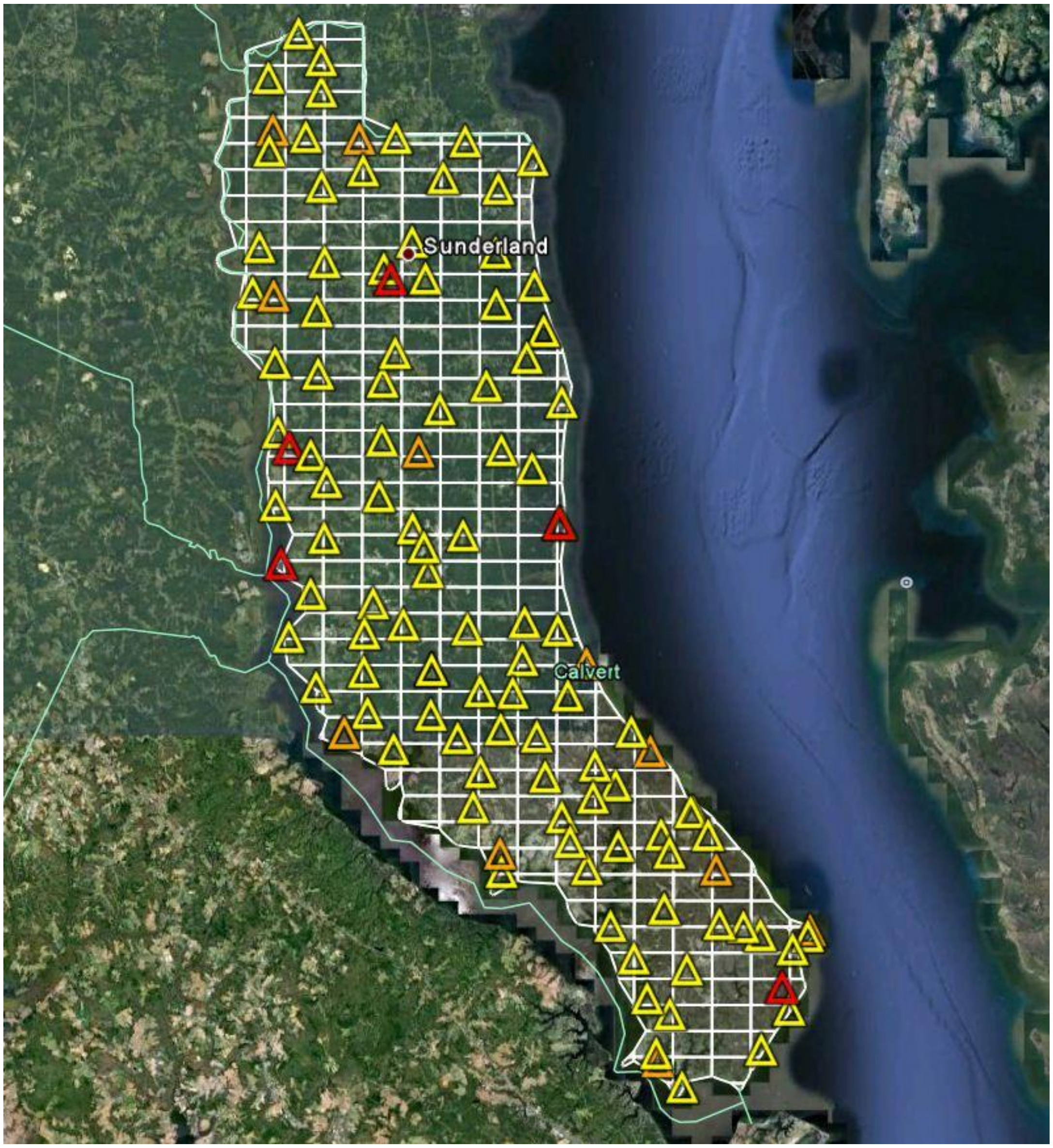


Figure 10 Checkpoints used in the FVA calculation

4.2.5 Detailed Statistics

Detailed statistics and survey checkpoint comparisons are outlined in the following tables by the land cover categories present in this AOI:

Detailed Comparison Against Survey Checkpoints – Bare Ground Category								
Point No	Land Cover Class	Survey X Coord.	Survey Y Coord.	DTM Height	Survey - Z	ΔZ	ΔZ*2	ABS ΔZ
34	Bare Ground	1448302.284	285979.1853	132.620	133.45	-0.83	0.691	0.831
41	Bare Ground	1434824.555	291878.0055	134.086	134.91	-0.83	0.681	0.825
3	Bare Ground	1486469.192	259602.2925	6.117	6.85	-0.73	0.538	0.733
141_87	Bare Ground	1441376.06	274187.45	4.873	5.57	-0.70	0.486	0.697

Detailed Comparison Against Survey Checkpoints – Bare Ground Category								
Point No	**Land Cover Class**	**Survey X Coord.**	**Survey Y Coord.**	**DTM Height**	**Survey - Z**	**ΔZ**	**ΔZ*2**	**ABS ΔZ**
95	Bare Ground	1420063.633	378897.5624	141.954	142.55	-0.60	0.354	0.595
97	Bare Ground	1435764.655	383405.8178	132.596	133.19	-0.59	0.352	0.593
EC116	Bare Ground	1408812.42	336315.36	27.667	28.25	-0.58	0.340	0.583
98	Bare Ground	1425098.328	383907.1882	75.650	76.19	-0.54	0.293	0.541
61	Bare Ground	1414552.023	331082.0708	54.160	54.67	-0.51	0.259	0.509
88	Bare Ground	1440613.894	358404.1027	138.239	138.72	-0.48	0.232	0.481
58	Bare Ground	1423290.001	363807.002	142.168	142.64	-0.47	0.224	0.473
135_126	Bare Ground	1406322.99	359681.77	57.728	58.18	-0.45	0.204	0.452
90	Bare Ground	1404104.328	367124.9875	34.098	34.54	-0.44	0.196	0.443
91	Bare Ground	1427646.059	367954.0246	159.757	160.17	-0.41	0.171	0.414
100	Bare Ground	1411216.292	384055.0062	113.361	113.77	-0.41	0.167	0.409
103	Bare Ground	1413545.49	395810.0253	101.403	101.81	-0.41	0.166	0.408
82	Bare Ground	1431941.132	342295.9525	114.924	115.33	-0.41	0.166	0.407
80	Bare Ground	1423148.404	346457.6043	155.423	155.78	-0.36	0.128	0.358
56	Bare Ground	1432406.627	377781.6952	148.108	148.46	-0.35	0.125	0.353
8	Bare Ground	1481678.887	244177.261	2.822	3.17	-0.35	0.121	0.347
84	Bare Ground	1450723.08	343428.3748	26.521	26.82	-0.30	0.090	0.300
35	Bare Ground	1438351.182	286683.2587	116.385	116.68	-0.29	0.087	0.295
101	Bare Ground	1413580.506	391021.672	129.478	129.77	-0.29	0.085	0.292
150_85	Bare Ground	1465715.78	242356.85	12.760	13.05	-0.29	0.084	0.290
79	Bare Ground	1413209.644	347680.535	105.952	106.21	-0.26	0.067	0.259
75	Bare Ground	1406724.936	327530.631	17.878	18.13	-0.25	0.063	0.252
1	Bare Ground	1403092.089	360124.949	28.719	28.97	-0.25	0.063	0.251
139_123	Bare Ground	1428707.55	335784.51	47.855	48.10	-0.24	0.060	0.245
137_87	Bare Ground	1417371.34	292644.24	39.292	39.50	-0.21	0.043	0.208
EC256	Bare Ground	1450360.91	324839.58	21.190	21.39	-0.20	0.040	0.200
49	Bare Ground	1430801.889	302336.9609	102.886	103.08	-0.19	0.038	0.195
57	Bare Ground	1414156.588	364805.3367	124.176	124.37	-0.19	0.038	0.194
102	Bare Ground	1405415.385	393070.8805	93.660	93.85	-0.19	0.037	0.192
157_112	Bare Ground	1474671.5	271824.83	105.040	105.23	-0.19	0.036	0.190
96	Bare Ground	1413659.469	376394.4637	63.711	63.89	-0.18	0.032	0.180
138_152	Bare Ground	1419438.68	383789.55	123.612	123.79	-0.18	0.032	0.178
72	Bare Ground	1450594.773	324796.0794	15.013	15.19	-0.18	0.031	0.177
134_135	Bare Ground	1406139.61	385095.38	96.433	96.61	-0.18	0.031	0.177
12	Bare Ground	1467572.416	249612.9686	64.438	64.61	-0.17	0.029	0.172
94	Bare Ground	1440877.584	376146.5673	88.417	88.58	-0.16	0.026	0.162
EC115	Bare Ground	1407548.44	318575.480	19.381	19.53	-0.15	0.022	0.149
27	Bare Ground	1452158.057	275986.282	118.034	118.18	-0.15	0.021	0.145
7	Bare Ground	1469498.587	238416.3801	6.008	6.15	-0.14	0.021	0.144
63	Bare Ground	1445079.324	309688.3964	159.047	159.19	-0.14	0.020	0.143
42	Bare Ground	1430679.173	295430.7149	78.122	78.26	-0.14	0.019	0.139
45	Bare Ground	1417269.16	292547.5153	38.463	38.60	-0.14	0.019	0.136
43	Bare Ground	1424959.601	290181.4702	82.178	82.30	-0.12	0.015	0.122
22	Bare Ground	1467450.576	274367.591	47.005	47.11	-0.10	0.011	0.105
55	Bare Ground	1408771.415	307339.1655	10.843	10.94	-0.10	0.010	0.099

Detailed Comparison Against Survey Checkpoints – Bare Ground Category								
Point No	Land Cover Class	Survey X Coord.	Survey Y Coord.	DTM Height	Survey - Z	ΔZ	ΔZ*2	ABS ΔZ
EC248	Bare Ground	1424388.22	362252.17	167.375	167.47	-0.09	0.009	0.095
74	Bare Ground	1423053.975	337510.8276	86.077	86.17	-0.09	0.009	0.094
148_123	Bare Ground	1454626.8	303367.12	7.426	7.52	-0.09	0.009	0.094
76	Bare Ground	1412105.978	335230.1235	114.419	114.51	-0.09	0.008	0.092
33	Bare Ground	1437213.733	281294.841	104.533	104.61	-0.08	0.006	0.077
87	Bare Ground	1446458.928	361308.1422	111.297	111.37	-0.07	0.006	0.074
EC257	Bare Ground	1484860.93	253771.63	110.996	111.07	-0.07	0.005	0.074
85	Bare Ground	1445331.939	350228.5351	161.058	161.13	-0.07	0.005	0.074
62	Bare Ground	1450202.378	308427.536	124.497	124.57	-0.07	0.005	0.073
67	Bare Ground	1421760.201	312500.1132	150.839	150.91	-0.07	0.005	0.070
50	Bare Ground	1420368.527	301981.5811	147.283	147.34	-0.06	0.003	0.056
77	Bare Ground	1407036.845	338710.6448	21.222	21.26	-0.04	0.001	0.038
65	Bare Ground	1412137.642	313935.901	15.743	15.78	-0.04	0.001	0.038
86	Bare Ground	1447897.016	354336.7257	119.274	119.30	-0.03	0.001	0.027
40	Bare Ground	1441443.626	293246.3656	156.093	156.09	0.00	0.000	0.004
59	Bare Ground	1429708.496	362331.5719	165.956	165.95	0.00	0.000	0.005
66	Bare Ground	1414199.275	322525.9724	34.443	34.43	0.01	0.000	0.014
81	Bare Ground	1425072.015	350903.583	151.515	151.50	0.02	0.000	0.016
44	Bare Ground	1420935.738	295703.49	144.163	144.14	0.02	0.001	0.023
73	Bare Ground	1422643.864	328939.1092	104.105	104.08	0.02	0.001	0.024
104	Bare Ground	1410045.546	399987.6449	21.681	21.64	0.04	0.002	0.041
13	Bare Ground	1464072.505	252031.2545	23.026	22.97	0.06	0.003	0.057
4	Bare Ground	1478875.179	263025.4123	106.225	106.17	0.06	0.003	0.057
78	Bare Ground	1406567.423	349400.4331	53.839	53.78	0.06	0.004	0.059
14	Bare Ground	1470189.392	256469.6577	108.444	108.38	0.06	0.004	0.065
5	Bare Ground	1429557.6	321144.3413	132.420	132.35	0.07	0.005	0.071
24	Bare Ground	1471094.742	280645.003	107.147	107.07	0.08	0.006	0.077
23	Bare Ground	1454769.935	271843.3933	80.698	80.62	0.08	0.006	0.078
30	Bare Ground	1459146.727	284663.3644	65.698	65.62	0.08	0.006	0.078
46	Bare Ground	1451754.482	298444.6885	116.900	116.82	0.08	0.006	0.079
71	Bare Ground	1446164.345	333274.8649	133.819	133.73	0.09	0.008	0.089
163_108	Bare Ground	1489142.1	262498.22	2.409	2.31	0.10	0.010	0.099
31	Bare Ground	1455682.876	282782.5447	113.367	113.26	0.11	0.011	0.106
51	Bare Ground	1413010.878	299645.9985	2.525	2.41	0.11	0.013	0.114
10	Bare Ground	1485990.67	250321.2612	8.257	8.14	0.12	0.014	0.117
145_154	Bare Ground	1447916.69	354404.19	116.348	116.23	0.12	0.014	0.118
39	Bare Ground	1447002.798	292148.0968	126.858	126.73	0.13	0.017	0.129
18	Bare Ground	1475173.319	263491.097	122.543	122.41	0.13	0.017	0.132
32	Bare Ground	1450885.655	279762.2029	110.028	109.88	0.15	0.022	0.149
17	Bare Ground	1481498.589	261741.9306	127.055	126.90	0.16	0.024	0.155
69	Bare Ground	1427819.277	324025.5199	136.085	135.91	0.18	0.031	0.176
53	Bare Ground	1426432.403	309247.4655	150.169	149.99	0.18	0.032	0.179
68	Bare Ground	1430178.921	317331.5865	160.164	159.95	0.21	0.045	0.213
52	Bare Ground	1444755.303	303868.6869	148.471	148.25	0.22	0.048	0.220
89	Bare Ground	1412976.305	357319.6889	104.423	104.20	0.22	0.050	0.224

Detailed Comparison Against Survey Checkpoints – Bare Ground Category								
Point No	**Land Cover Class**	**Survey X Coord.**	**Survey Y Coord.**	**DTM Height**	**Survey - Z**	**ΔZ**	**ΔZ*2**	**ABS ΔZ**
93	Bare Ground	1446166.891	380566.1418	3.430	3.20	0.23	0.053	0.231
140_103	Bare Ground	1430797.18	302337.72	102.791	102.55	0.24	0.058	0.241
54	Bare Ground	1420449.485	307902.6683	145.865	145.62	0.24	0.060	0.245
48	Bare Ground	1438250.857	299084.7627	145.889	145.64	0.25	0.062	0.249
28	Bare Ground	1441611.684	271356.1863	2.008	1.75	0.26	0.067	0.259
15	Bare Ground	1462027.04	258138.7947	28.653	28.39	0.26	0.070	0.264
60	Bare Ground	1441453.111	336033.5537	130.267	129.99	0.28	0.077	0.277
99	Bare Ground	1405582.56	381906.6738	102.062	101.76	0.30	0.090	0.300
70	Bare Ground	1435580.098	322960.1251	138.980	138.66	0.32	0.101	0.319
152_119	Bare Ground	1464483.3	289936.59	7.140	6.81	0.33	0.109	0.330
83	Bare Ground	1439100.678	345893.2091	127.060	126.73	0.33	0.110	0.331
64	Bare Ground	1436290.133	308541.2235	138.372	138.01	0.36	0.130	0.360
92	Bare Ground	1440507.08	366347.079	94.717	94.33	0.39	0.149	0.386
21	Bare Ground	1473392.864	277093.9996	114.218	113.81	0.41	0.167	0.409
25	Bare Ground	1466162.911	277148.5599	117.580	117.14	0.44	0.194	0.441
9	Bare Ground	1465494.231	243584.5653	17.564	17.11	0.45	0.206	0.454
20	Bare Ground	1458405.321	263126.7014	34.828	34.35	0.48	0.228	0.478
37	Bare Ground	1461550.883	292924.8505	4.880	4.33	0.55	0.302	0.549
19	Bare Ground	1466670.16	265780.7676	115.530	114.98	0.55	0.302	0.550
47	Bare Ground	1443280.568	298830.4588	156.194	155.63	0.56	0.318	0.564
26	Bare Ground	1459566.677	275395.7287	38.546	37.87	0.68	0.456	0.675
16	Bare Ground	1488812.915	261618.4761	4.943	4.12	0.82	0.676	0.822
38	Bare Ground	1455950.943	287715.2415	70.605	69.74	0.86	0.747	0.864
2	Bare Ground	1470696.501	280586.1449	117.115	116.18	0.93	0.872	0.934

Table 19 Detailed comparison of QA checkpoints against the LiDAR bare ground classification

Detailed Statistics for this AOI – Bare Ground Category

Geo-referencing

Horizontal	MD SPCS NAD83 NSRS07
Vertical	NAVD88 (Geoid09),
Units	US Survey Feet

RMSE Calculation

Square Root of ∑(Zn-Z'n)²/N

Zn = LiDAR DEM heights

Z'n = Checkpoint heights

N = The number of check points

Statistics	
Sum of dz² (ft)	13.148
Count	118
Sum dz2/count (ft)	0.111
RMSE (ft)	0.334
1.96 * RMSE (ft)	0.654
Mean (ft)	-0.030
Median (ft)	-0.063
Skew (ft)	0.216
Std. dev. (ft)	0.334
95th percentile (cm)	**0.702**

Accuracy Targets and Results

Land Cover	RMSEz (ft) <	ACCURACYz (ft) <	Actual RMSEz (ft)	95% Acc Z (ft)	Dz Min (ft)	Dz Max (ft)
Bare Ground	0.41	0.80	0.33	0.65	-0.831	0.934

Table 20 Detailed statistics for bare ground land cover category

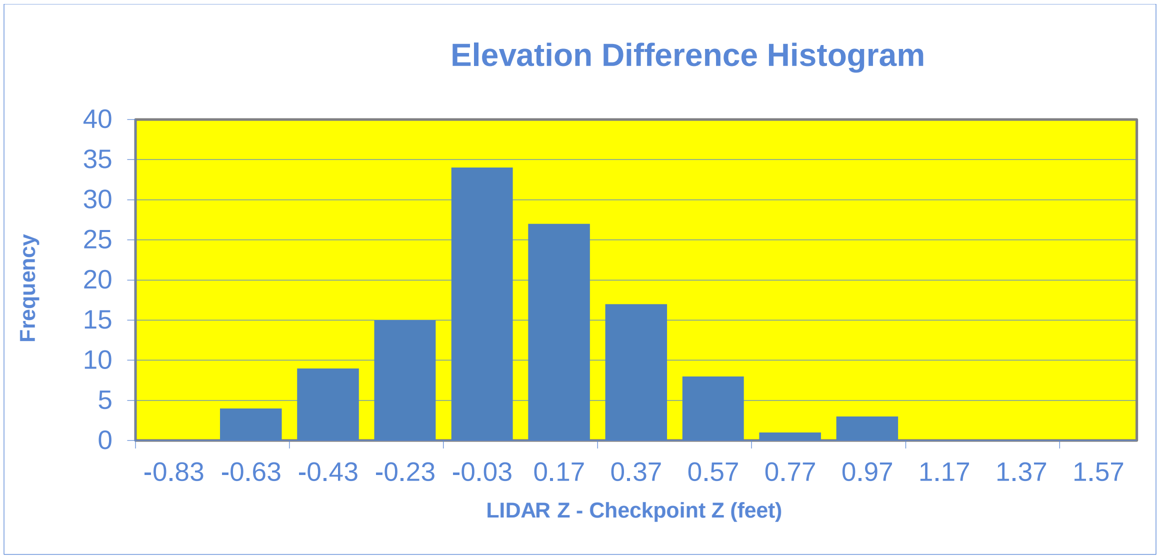


Figure 11 Elevation difference histogram

4.2.6 Accuracy Statements

The LiDAR data for the Calvert County AOI meets the project specifications for FVA, as demonstrated by the following, accuracy statement:

1. Tested 0.654ft at 95 percent confidence level in open terrain using RMSE * 1.96 and tested 0.702ft at the 95th percentile method.

4.2.7 Credits

Organizations involved in the procurement, acquisition, processing, and quality control of the Calvert County AOI LiDAR dataset are identified below.

Credits	
Project Function	**Responsible Organization**
LiDAR procurement	Maryland Information Technology
LiDAR acquisition and processing	Surdex
QA checkpoint ground surveys	J.A. Rice
3d hydro-lines and low confidence areas	AXIS Geospatial
Accuracy assessment and QA review and reporting	URS Corporation

Table 21 Credits

4.2.8 References

American Society for Photogrammetry and Remote Sensing (May 2004), *ASPRS Guidelines: Vertical Accuracy Reporting for LiDAR Data*, Version 1.0, http://www.asprs.org/society/committees/lidar/Downloads/Vertical_Accuracy_Reporting_for_Lidar_Data.pdf

Federal Geographic Data Committee, Sub Committee for Base Cartographic Data, Geospatial Positioning Accuracy Standards, PART3: National Standard for Spatial Data Accuracy (NSSDA),

FGDC-STD-007-1998, http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3

National Digital Elevation Program (May 2004), *Guidelines for Digital Elevation Data*, Version 1.0, http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf

5 Phase IV: Product Development

URS conducted all delivery and redelivery quality checks during Phase III of this project. The remaining tasks for URS during Phase IV involved a check of the project metadata provided by Surdex and the completion and submission of this report.

5.1 Metadata

The project metadata was reviewed and checked using the following methods:

- Structure of the metadata file was compared against FGDC standards by using the USGS Geospatial Metadata Validation Service: http://geo-nsdi.er.usgs.gov/validation/
- Metadata content was reviewed by using a visual check

The following errors were noted in the metadata:

- Tile names were not included in the metadata
- Place names were not included in the metadata
- Contact information not included in the metadata
- Source time period not included

6 Conclusions

A systematic problem related to incorrect header information was identified in a portion of the raw point cloud swaths. The systematic problem, consisting incorrect point information in the headers, is described in **Section 4.1.5.6** of this report. Surdex submitted a total of 2 redeliveries of corrected files. URS conducted a review and check to ensure that the headers were corrected.

A non-systematic problem was found during the detailed check of the LAS classified point cloud files The check found a handful of LAS files that contained above-ground artifacts. Surdex redelivered the corrected tiles the same week when notified of the problem. URS subsequently checked the tiles to ensure that the corrections were made.

A non-systematic problem was found during the detailed check of the 3d hydro-lines. The check found a handful of tiles that had ground or water point misclassifications. These misclassifications were small in scope and only required minor edits. URS corrected the .las tiles using TerraScan.

Based on the qualitative and quantitative assessment conducted by URS on the initial data delivered as well as all redeliveries, the Calvert County AOI delivery meets the applicable project specifications as set forth by LiDAR Technical Scope of Work.

Quantitative Assessment Conducted by:

Robert A. Ryan, CP, PLS
Project Manager

Qualitative Assessment Conducted by:

Jesse Pinchot,
Lead LiDAR Technician