

Virginia Lidar 2025 – Richmond

Lidar Mapping Report

October 2025

EXECUTIVE SUMMARY

[The Sanborn Map Company, Inc.](#) (Sanborn) was tasked to provide remote sensing services in the form of QL1 lidar. Utilizing a multi-return system, Light Detection and Ranging (Lidar) detects 3-dimensional positions and attributes to form a point cloud. The high accuracy airborne system is integrated with both Global Navigation Satellite System (GNSS) and an Inertial Measure Unit (IMU) for accurate position and orientation. Acquisition of the project area's ~ 117 mi² was completed on March 1st, 2025.

The Riegl VQ-1560 II was used to collect data for the aerial survey campaign. The sensor is attached to an aircraft's underside and emits rapid laser pulses that are used to calculate ranges between the aircraft and subsequent terrain below. The Airborne Lidar Systems (ALS) are boresighted by completing multiple passes over a known ground surface before the project acquisition. During data processing, the system calibration parameters are updated and used during post-processing of the lidar point cloud.

Differential GNSS unit in aircraft sampled positions at 2Hz or higher frequency. Lidar data was only acquired when GNSS PDOP is ≤ 4 and at least 6 satellites are in view. The atmosphere was free of clouds and fog between the aircraft and ground. The ground was free of snow and extensive flooding or any other type of inundation.

The contents of this report summarize the methods used to establish the base station coordinates, perform the lidar data acquisition and processing as well as the results of these methods.

CONTENTS

EXECUTIVE SUMMARY	1
CONTENTS	2
1.0 INTRODUCTION	3
1.1 CONTACT INFORMATION.....	3
1.2 PURPOSE OF LIDAR ACQUISITION	3
1.3 PROJECT LOCATION	3
2.0 ACQUISITION.....	4
2.1 INTRODUCTION	4
2.2 ACQUISITION PARAMETERS	4
2.3 FIELD WORK PROCEDURES.....	4
3.0 PROCESSING	6
3.1 INTRODUCTION	6
3.2 COORDINATE REFERENCE SYSTEM.....	7
3.3 LIDAR MATCHING.....	8
3.4 LIDAR CLASSIFICATION	10
4.0 PRODUCT GENERATION	11
CLASSIFIED POINT CLOUD	11
BARE-EARTH DIGITAL ELEVATION MODEL (DEM).....	12
BREAKLINES	13
MAXIMUM SURFACE HEIGHT RASTERS (MSHR).....	14
SWATH SEPARATION IMAGES	15
OTHER DELIVERABLES	15
APPENDIX A – ABGNSS/IMU PLOTS.....	16

1.0 INTRODUCTION

This document contains the technical write-up of the lidar campaign, including system calibration techniques, and the collection and processing of the lidar data.

1.1 Contact Information

Questions regarding the technical aspects of this report should be addressed to:

Tarika Hanawalt, PMP
Senior Program Manager
The Sanborn Map Company, Inc.
305 S. Rockrimmon Blvd , Suite 200
Colorado Springs, CO 80919
(503) 327-3046
thanawalt@sanborn.com

1.2 Purpose of Lidar Acquisition

The objective of this project is to collect accurate measurements of the bare-earth surface as well as above ground features to be provided as geometric inputs for surface and/or change modeling as it relates to survey assessments.

1.3 Project Location

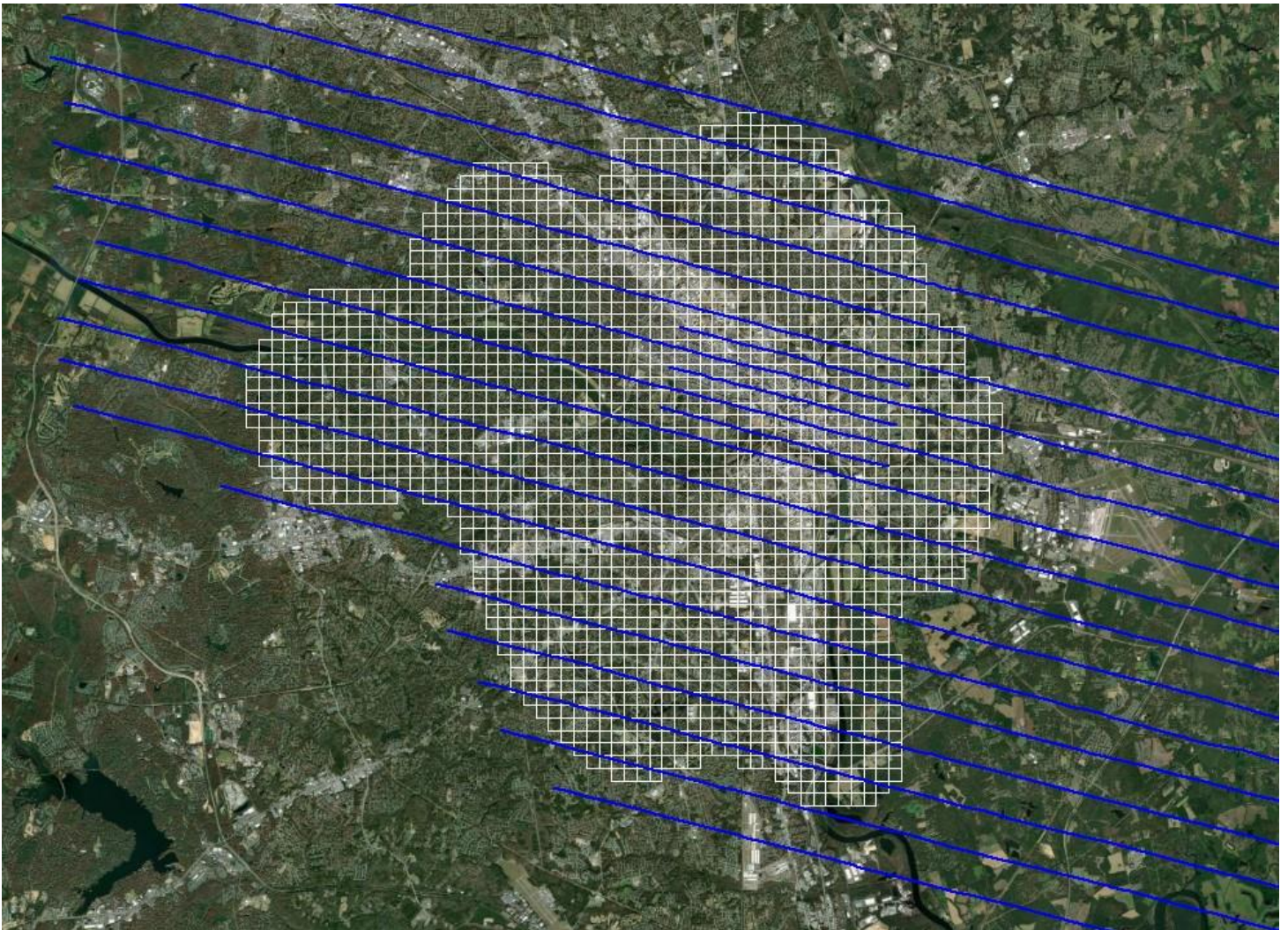


Figure 1: Index and Trajectories As-Flown

2.0 ACQUISITION

2.1 Introduction

This section outlines the lidar system, flight reporting, and data acquisition methodology used during the collection of the lidar campaign. Although Sanborn conducts all lidar missions with the same rigorous and strict procedures and processes, all lidar collections are unique.

2.2 Acquisition Parameters

Sanborn specifically defined the collection parameters to accomplish the desired QL1 project specifications. **Table 1** shows the planned acquisition parameters utilized for this aerial survey with the sensor(s) installed.

Planned Acquisition Parameters	
Aircraft	N59848 - PIPER PA-31-325
Sensor	Riegl VQ-1560 II
Max Number of Returns	15
Point Spacing (m)	0.34
Point Density (pls/m²)	8.79
Flying Height (AGL) (m)	1501
Air Speed (kts)	160
Field of View (degrees)	58.52
Scan Rate (Hz)	334
Pulse Rate (kHz)	2206
Laser Footprint (m)	0.279
Wavelength (nm)	1064
Multi-Pulse	Yes
Swath Width (m)	1682
Overlap (%)	20

Table 1: Lidar Acquisition Parameters

2.3 Field Work Procedures

Sanborn's standard procedure before every mission is to perform pre-flight checks to ensure correct operation of all systems. All cables were checked, and the sensor head glass was cleaned. A three-minute static session was conducted on the ground with the engines running prior to take-off to establish fine-alignment of the IMU and to resolve GNSS ambiguities.

The project acquisition consisted of five (5) missions. During the data collection, the operator recorded information on log sheets which includes weather conditions, lidar operation parameters, flight line statistics and PDOP.

Preliminary data processing was performed in the field immediately following the missions for quality control of GNSS data and to ensure sufficient coverage of the project AOI. Any problematic data could then be re-flown immediately as required. Final data processing was completed in the Colorado Springs, CO office. **Table 2** below shows the flight acquisition metrics for the entire collection. **Table 3** contains the base station names and locations in operation during acquisition. Base station coordinates are provided in NAD83 (2011), Geographic Coordinate System, Ellipsoid, Meters.

Date	Sensor	Serial #	Tail #	MissionID	PDOP	Start (UTC)	End (UTC)
2/14/2025	Riegl VQ-1560 ii	2222736	N59848	20250214A_N59848_2222736	1.7	16:48:52	18:59:28
2/14/2025	Riegl VQ-1560 ii	2222736	N59848	20250214B_N59848_2222736	1.5	21:39:35	23:57:46
2/17/2025	Riegl VQ-1560 ii	2222736	N59848	20250217A_N59848_2222736	1.7	19:25:07	21:52:47
2/17/2025	Riegl VQ-1560 ii	2222736	N59848	20250217B_N59848_2222736	1.5	23:01:34	2:17:07
3/1/2025	Riegl VQ-1560 ii	2222736	N59848	20250301A_N59848_2222736	1.9	14:58:14	18:04:09

Table 2: Collection Date Time by Mission

Designation	Type	PID	Latitude (N)	Longitude (W)	Elevation
LOYO	CORS	DL2310	38 03 00.65699	077 20 51.19703	41.861
LOYX	CORS	DL3186	37 16 35.06106	076 41 43.84130	0.845
LS02	CORS	DL2314	37 15 47.93026	077 24 39.93522	-7.670
UVFM	CORS	AJ4870	37 52 43.49504	078 41 37.27288	512.951

Table 3: GNSS Reference Station Coordinates



Figure 2: GNSS Reference Stations

3.0 PROCESSING

3.1 Introduction

The GNSS/IMU data was post-processed using POSPac software to create Smoothed Best Estimate Trajectory (SBET) file(s). The SBET was then combined with the laser range measurements in Riegl LMS software to produce the 3-dimensional coordinates resulting in an accurate set of Raw Point Cloud (RPC) mass points. These raw swath (*.las) files are output in WGS84, UTM, Ellipsoid, Meters and transformed to the project Coordinate Reference System (CRS) upon ingest into GeoCue before project wide-lidar matching.

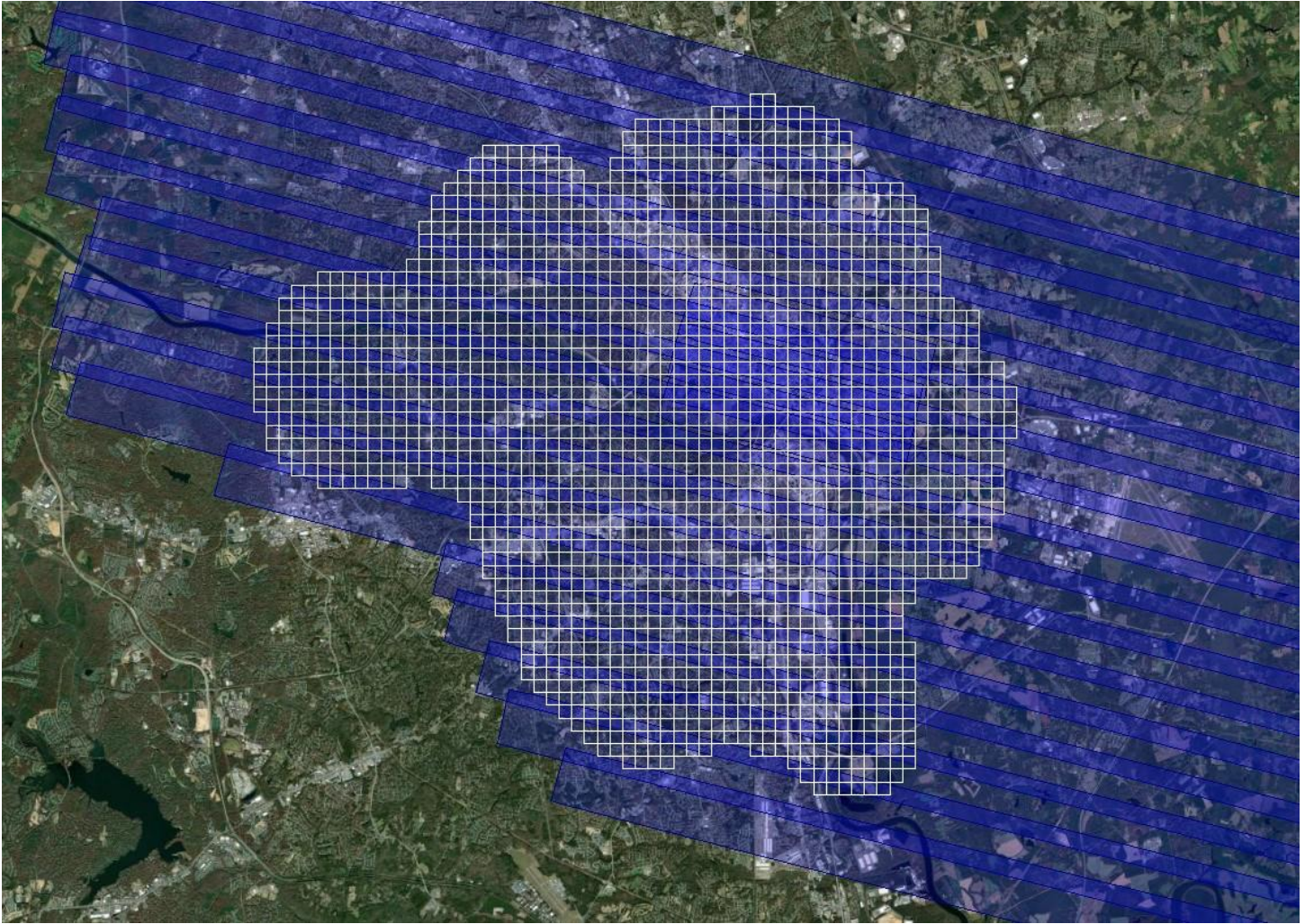
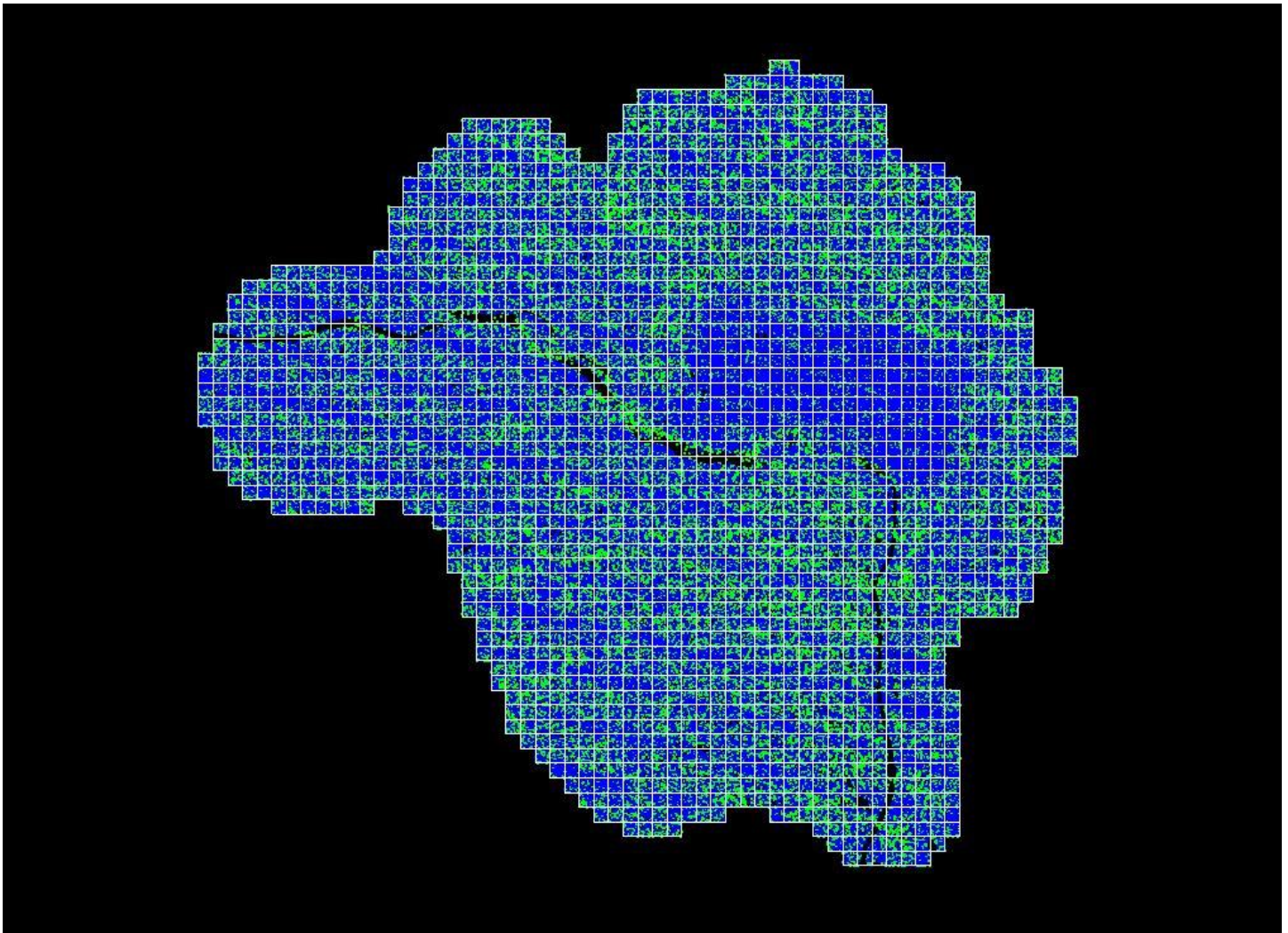


Figure 3: Raw Swath Coverage

The Riegl LMS pre-processing software created raw swath files with all return values. This multi-return information was processed and classified to obtain the required features for delivery. All lidar data is processed using the ASPRS binary LAS format version 1.4. **Table 4** illustrates the achieved point cloud statistics.

Category	Value
Aggregate Total Points	7,005,514,735
Aggregate Nominal Pulse Spacing (m)	0.25
Aggregate Nominal Pulse Density (pls/m ²)	15.5
Aggregate Nominal Pulse Spacing (ft)	0.83
Aggregate Nominal Pulse Density (pls/ft ²)	1.4

Table 4: Point Cloud Statistics



No Data	< 8pts/m ²	8 to 16pts/m ²	> 16pts/m ²

Figure 4: Point Cloud Density

3.2 Coordinate Reference System

Horizontal Datum: North American Datum of 1983 (HARN)
Projection: Virginia South
Vertical Datum: North American Vertical Datum of 1988
Geoid Model: Geoid18
Units: Feet

3.3 Lidar Matching

Sanborn uses pre-processing software and the latest boresight values to combine the processed SBET with the laser scan files to produce the lidar point cloud. The data is processed by mission and/or block and is output in ASPRS LASv1.4 Point Data Record Format (PDRF) 6 with 16bit linearly scaled intensities to the nearest 0.001 3D position. Each mission is produced in WGS84, UTM, Ellipsoid, Meters and transformed to the project CRS upon import into GeoCue.

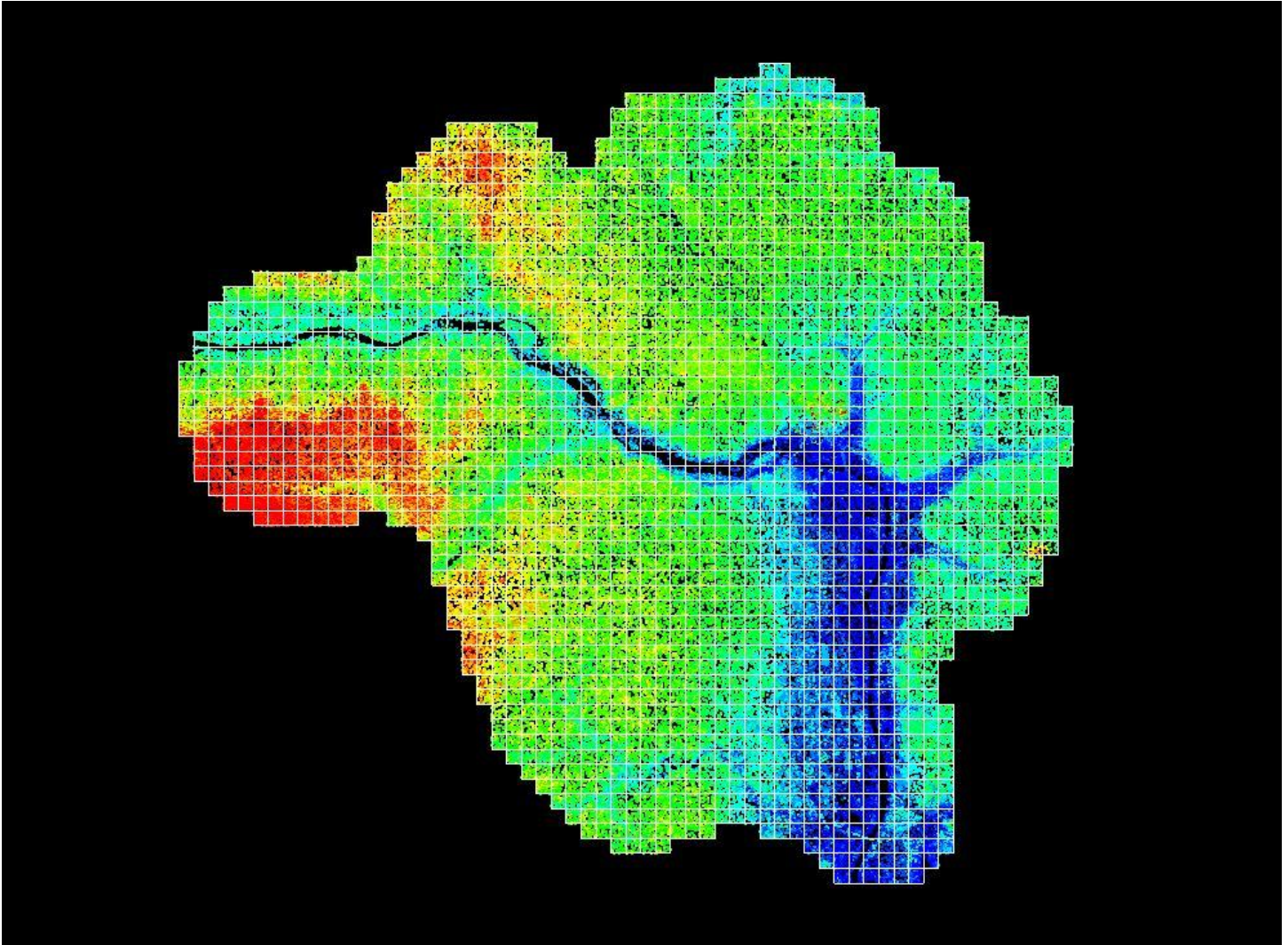


Figure 5: Point Cloud Elevation

Each mission is imported into GeoCue where each individual flight line is assigned a unique Source ID number. The SBET is cut per swath into TerraScan Trajectory files based on Source ID number and timestamp; these are utilized during the lidar matching process. The project area(s) is broken into logical blocks based on AOIs or predetermined delivery blocks and the individual flight lines are populated into lidar matching tile grids. These lidar matching tile grids are prepared for scanner, line, mission, block and eventual project wide lidar matching routines by first running point cloud filters to identify ground and building features to be used during any TerraMatch processes.

Sanborn takes advantage of visual validation methodology to review and ensure alignment of the lidar dataset. Swath Separation Images, modulated by Intensity, are representative of the interswath alignment and provide a holistic qualitative look at the positional quality of the point cloud. This review guarantees the relative accuracy of the lidar dataset. **Table 5** outlines the relative accuracy requirements of the project.

Category	Value (m)	Value (ft)
Smooth Surface Repeatability	≤ 0.060	≤ 0.197
Swath overlap difference, RMSDz	≤ 0.080	≤ 0.262

Table 5: Relative Accuracy Requirements

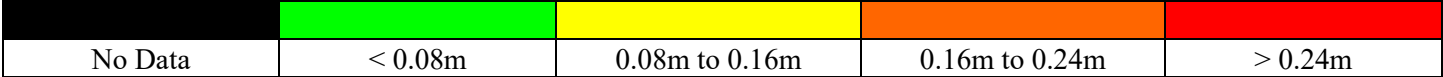
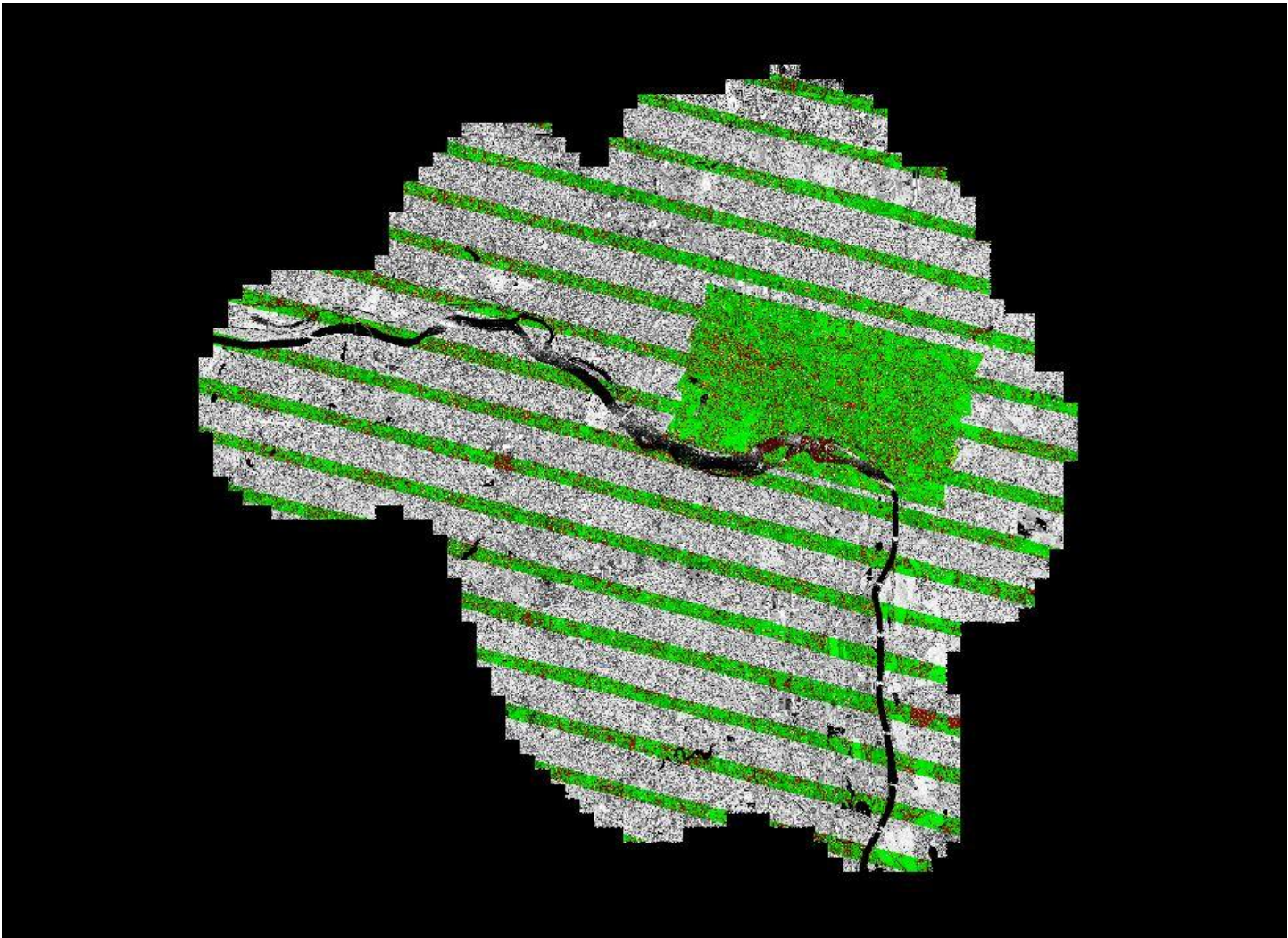


Figure 7: Swath Separation Images

3.4 Lidar Classification

Lidar filtering was accomplished using GeoCue with TerraSolid processing and modeling software. The filtering process reclassifies all the data into classes within the point cloud classification scheme. Once the data is classified, the entire dataset is reviewed and manually edited for anomalies that are outside the required guidelines of the product specification or contract requirements. This can include, but is not limited to, classifying bridges, structures, filling culverts, and manually analyzing the bare-earth surface by classifying features that belong in non-extraneous classification codes. **Table 6** outlines a statistical summary of the point classes leveraged in the lidar dataset.

Code	Class	Points
1	Unclassified	2,373,406,104
2	Ground	1,513,134,509
3	Low Vegetation	334,951,393
4	Medium Vegetation	653,828,697
5	High Vegetation	1,558,144,877
6	Buildings	543,039,786
7	Low Noise	3,432,670
9	Water	13,837,436
17	Bridge Decks	10,508,849
18	High Noise	1,186,247
20	Ignored Ground	44,167
Flag	Withheld	4,618,917

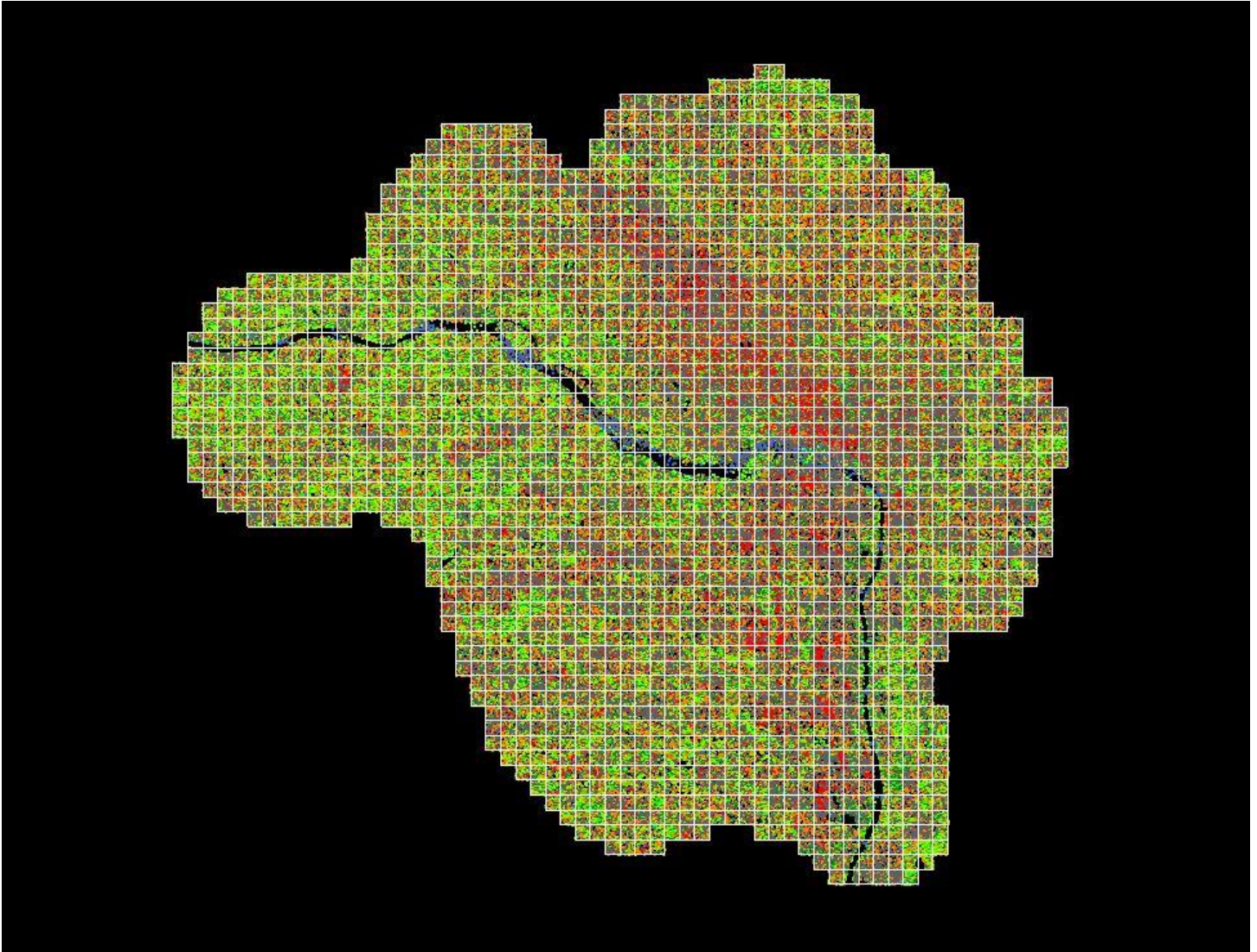
Table 6: Lidar Classification Statistics

4.0 PRODUCT GENERATION

The following products were generated using the final coordinate system as defined in the contract:

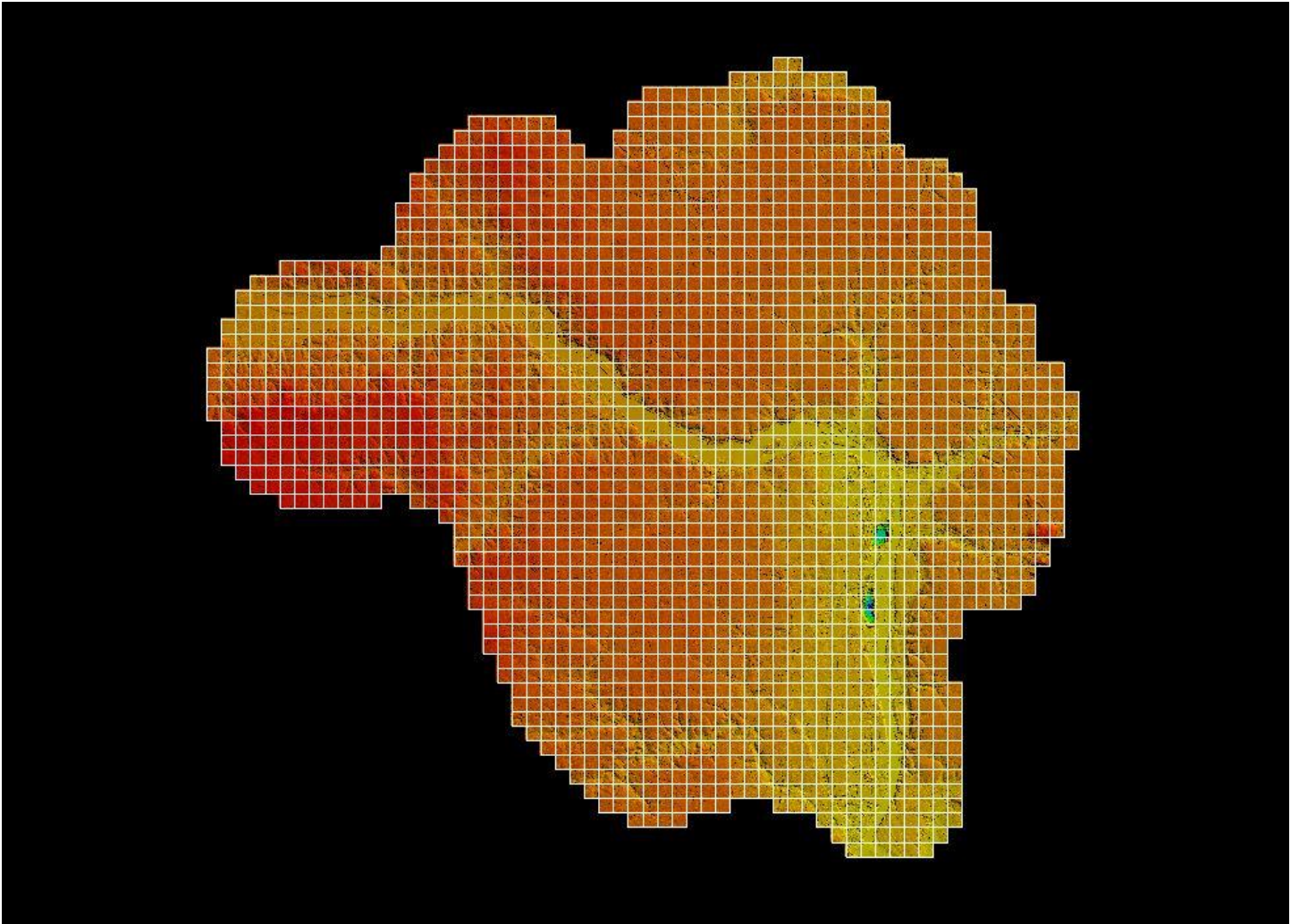
Classified Point Cloud

The Classified Point Cloud, containing all returns, is delivered in LASv1.4 (*.las) format and meets project specifications. The Classified Point Cloud contains file names referencing the tile index.



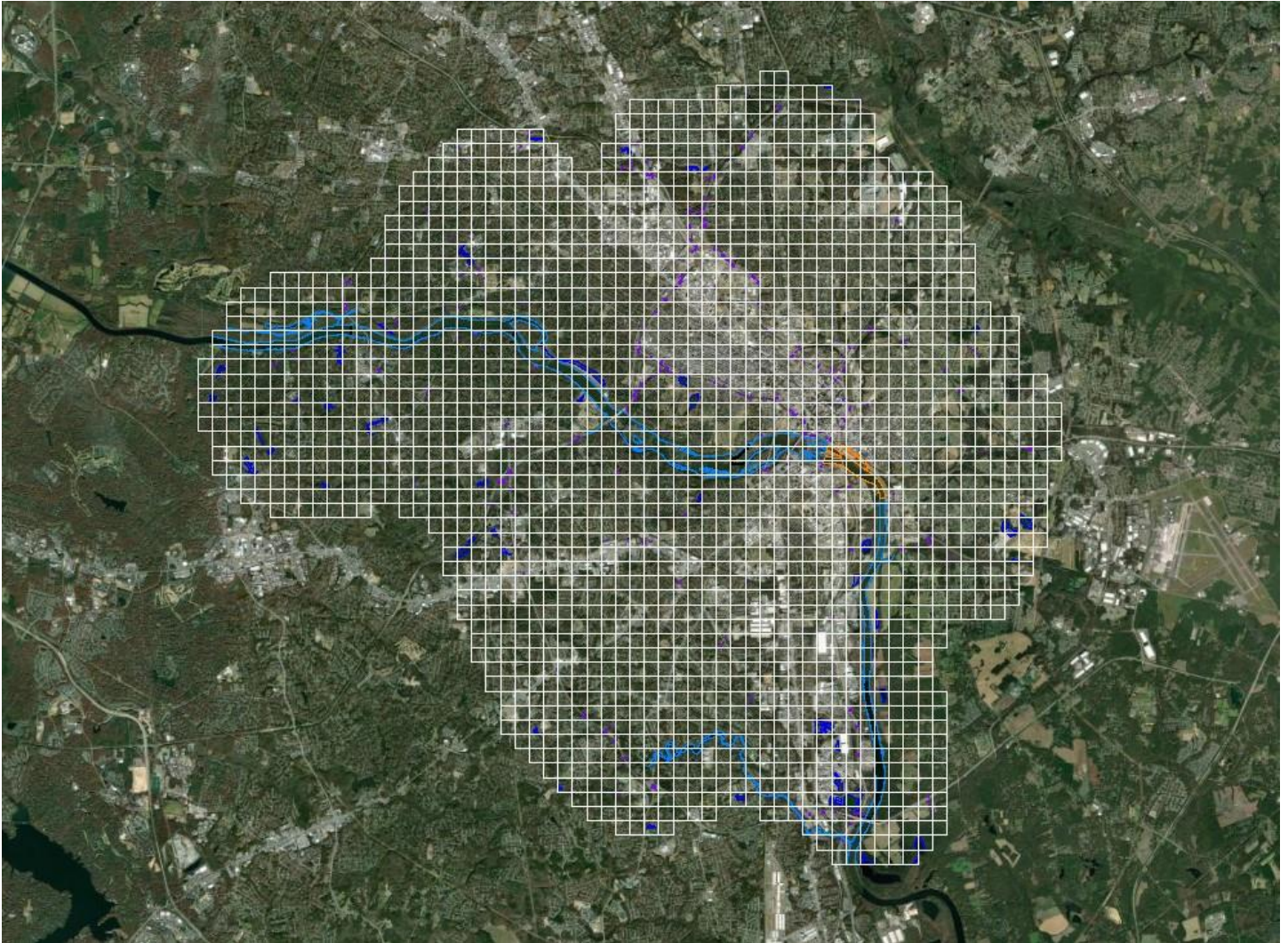
Bare-earth Digital Elevation Model (DEM)

32-bit GeoTIFF (*.tif) elevation rasters were created from the bare-earth points in the processed lidar dataset and hydro-flattened breaklines. Bare-earth rasters were produced with the bilinear interpolation methodology and GDAL v2.4.0 was used to define the CRS. Each pixel contains an elevation.



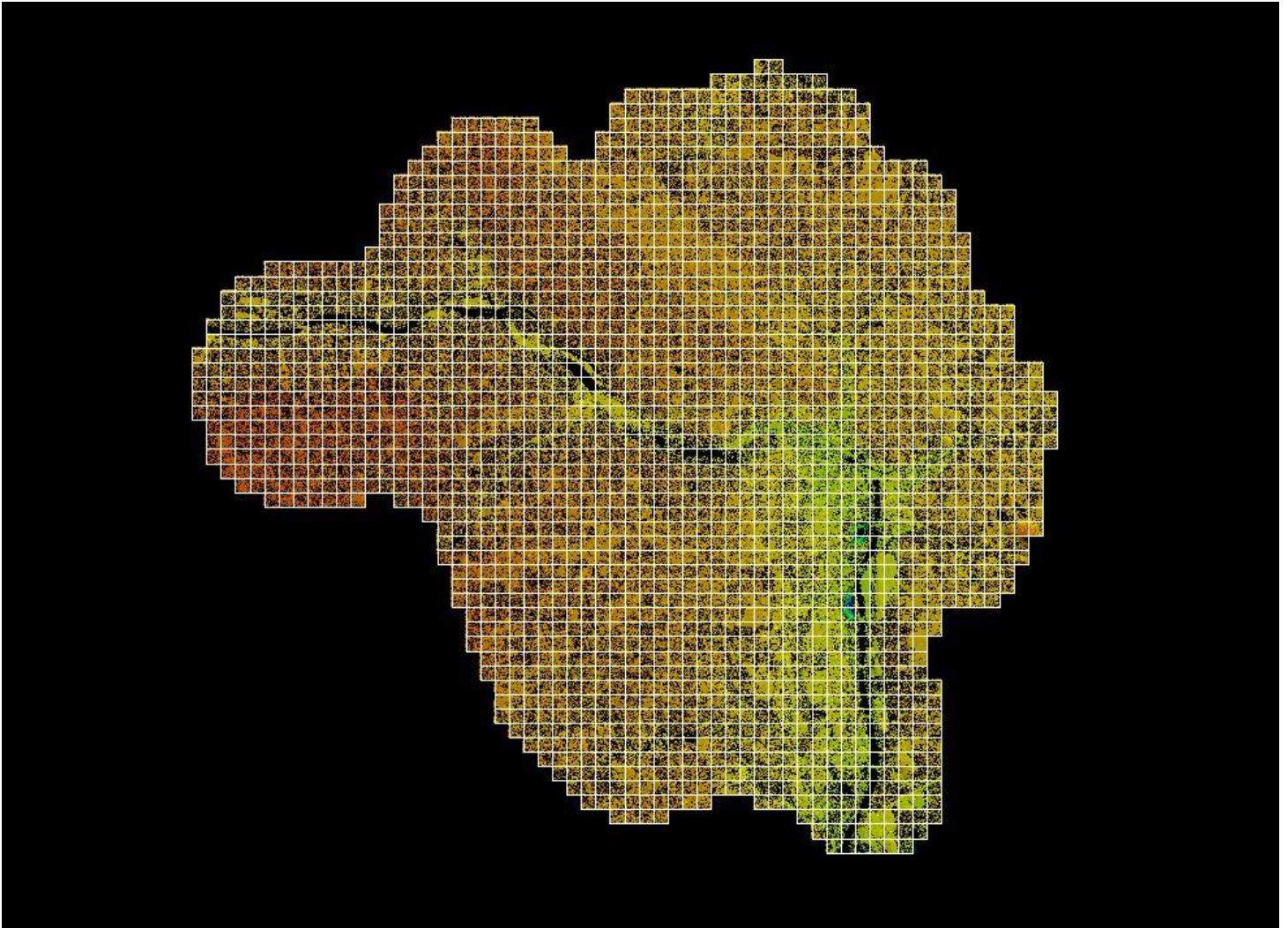
Breaklines

Hydro-flattened breaklines were generated from digitized water features conflated to the elevations derived from the bare-earth points in the processed lidar dataset. Delivered in Esri (*.gdb) format.



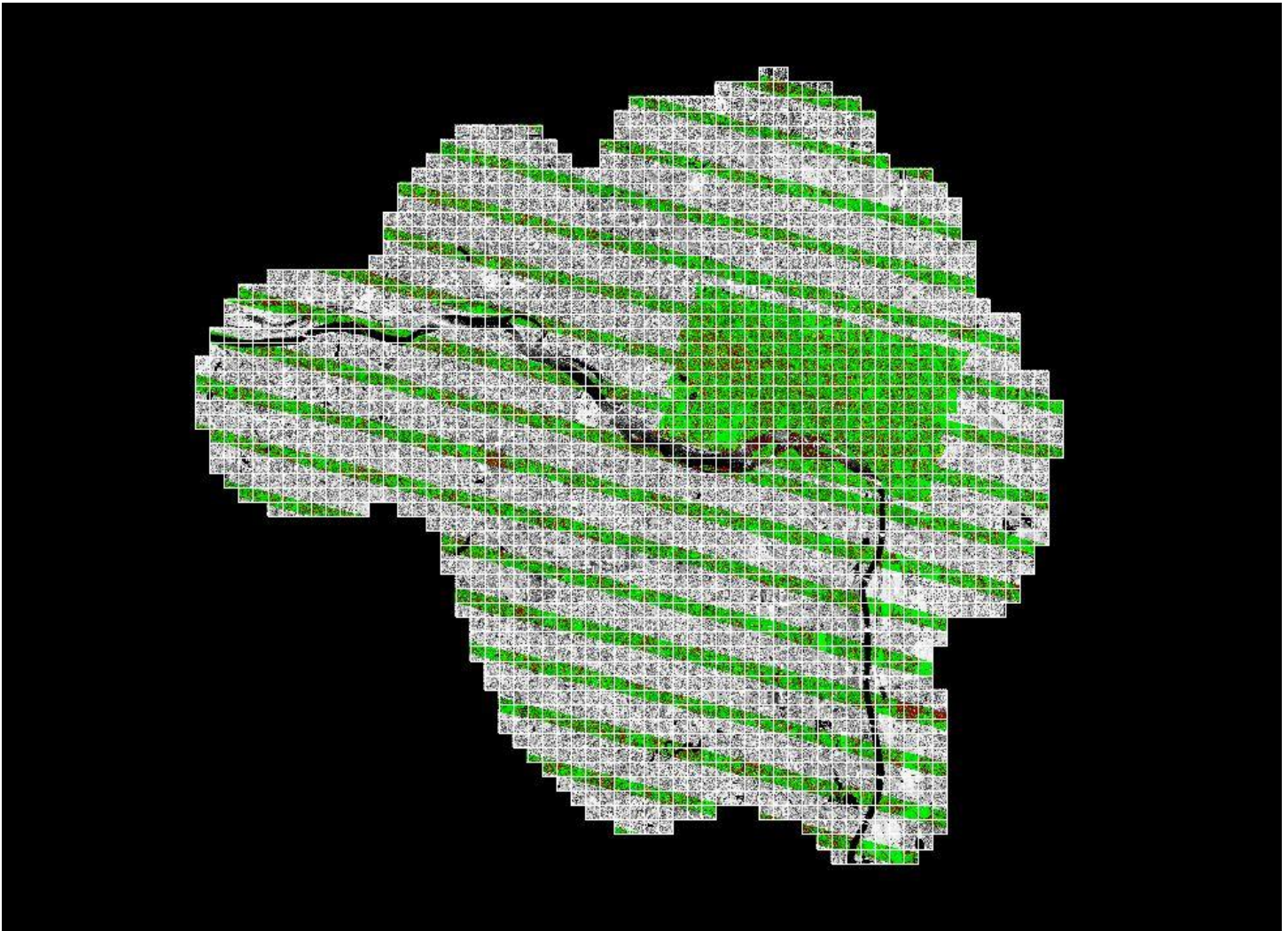
Maximum Surface Height Rasters (MSHR)

32-bit GeoTIFF (*.tif) elevation rasters were created from all return points in the processed lidar dataset. The rasters were produced with the point insertion methodology and GDAL v2.4.0 was used to define the CRS. Each pixel contains an elevation.



Swath Separation Images

24-bit GeoTIFF (*.tif) swath separation images modulated by intensity were created from the last-return points in the processed lidar dataset. GDAL v2.4.0 was used to define the CRS.



Other Deliverables

Metadata

Vertical Accuracy

A final quality assurance process was undertaken to validate all deliverables for the project. Prior to release of data for delivery, Sanborn's Quality Control/Quality Assurance department reviews the data and then releases it for delivery.

APPENDIX A – ABGNSS/IMU PLOTS

Coverage Map	Plots the Aircraft GNSS-IMU Trajectory in reference to localized GNSS Reference Stations.
Estimated Position Accuracy	Plots the standard deviations of the east, north, and up directions versus time for the solution. The total standard deviation with a distance dependent component is also plotted.
Number of Satellites	Plots the number of satellites used in the solution as a function of time. The number of GPS, GLONASS, and the total number of satellites are distinguished with separate color-coded lines.
Combined Separation	Plots the north, east, and height position difference between any two solutions loaded into the project. These are most often the forward and reverse processing results unless other solutions have been loaded from the Combine Solutions dialog. Plotting the difference between forward and reverse solutions can be very helpful in quality checking. When processing both directions, no information is shared between forward and reverse processing. Thus, both directions are processed independently of each other. When forward and reverse solutions agree closely, it helps provide confidence in the solution. To a lesser extent, this plot can also help gauge solution accuracy.
PDOP	PDOP is a unitless number which indicates how favorable the satellite geometry is to 3D positioning accuracy. A strong satellite geometry, where the PDOP is low, occurs when satellites are well distributed in each direction (north, south, east, and west) as well as directly overhead. Values in the range of 1-2 indicate very good satellite geometry; 2-3 are adequate in the sense that they do not generally, by themselves, limit positioning accuracy. Values between 3 and 4 are considered marginal, and values approaching or exceeding 5 can be considered poor. PDOP spikes can occur on aircraft turns where the antenna angle is unfavorable; these spikes while aesthetically unfavorable do not generally reduce the accuracy of the acquired data.

