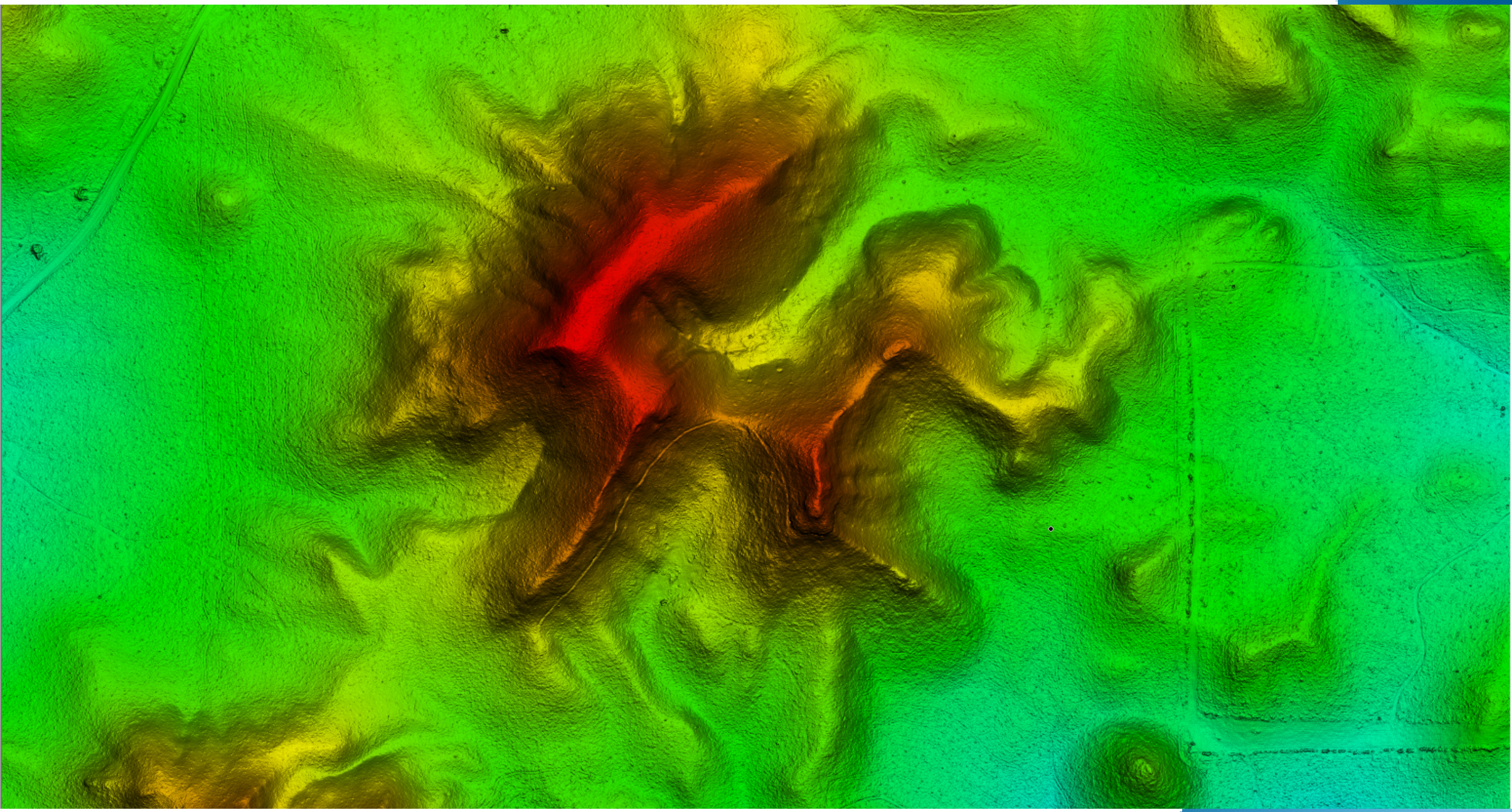
NV5 GEOSPATIAL



WI 12County B22 Burnett LIDAR PROCESSING REPORT

2023

Submitted: April 20, 2023

Project ID: 230110
Work Unit: 300214

Prepared for:

USGS
science for a changing world

Prepared by:

NV5 GEOSPATIAL

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1. Summary / Scope

1.1. Summary

This report contains a summary of the Wisconsin 12 County - Burnett, Work Unit 300214 lidar acquisition task order, issued by USGS under their Contract 140G0221D0012 on 3/25/2022. The task order yielded a work unit area covering 891 square miles over Wisconsin at Quality Level 1. The intent of this document is only to provide specific validation information for the data acquisition/collection, processing, and production of deliverables completed as specified in the task order.

1.2. Scope

Aerial topographic lidar was acquired using state of the art technology along with the necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems. The aerial data collection was designed with the following specifications listed in Table 1 below.

Table 1. Originally Planned Lidar Specifications

Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
8 pts / m2	2083 m	58.5°	20%	≤ 10 cm

1.3. Coverage

The work unit boundary covers 891 square miles over Burnett County, Wisconsin. Work unit extents are shown in Figure 1.

1.4. Duration

Lidar data was acquired from 5/06/2022 to 5/10/2022 in 4 total lifts. See “Section: 2.4. Time Period” for more details.

1.5. Issues

No issues were discovered.

<table>
<tr><th colspan="2">Wisconsin 12 County - Burnett Work Unit 300214
Projected Coordinate System: Wisconsin Coordinate Reference System - Burnett
Horizontal Datum: NAD83 (2011)
Vertical Datum: NAVD88 (GEOID 18)
Units: Survey Feet</th></tr>
<tr><td>Lidar Point Cloud</td><td>Classified Point Cloud in .LAS 1.4 format</td></tr>
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• 2-foot Maximum Surface Height Raster in GeoTIFF format
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• DEM
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</table>

Wisconsin 12 County - Burnett
Work Unit 300214 Boundary

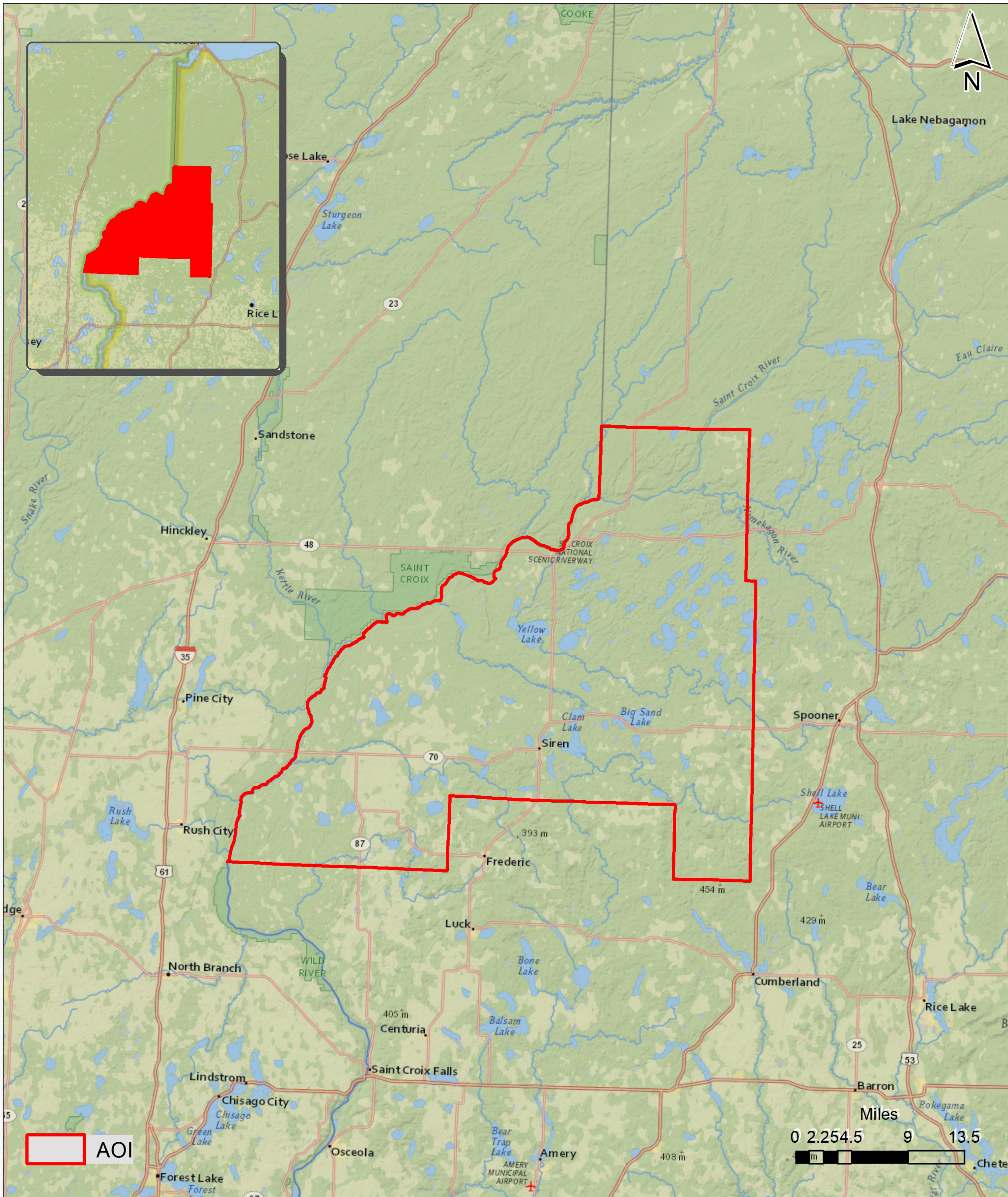


Figure 1. Work Unit Boundary

2. Planning / Equipment

2.1. Flight Planning

Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity.

Detailed project flight planning calculations were performed for the project using RiPARAMETER planning software.

2.2. Lidar Sensor

NV5 Geospatial utilized Riegl VQ-1560ii lidar sensors (Figure 2), serial number(s) 3543 and 3062, for data acquisition.

The Riegl 1560ii system is a dual channel waveform processing airborne scanning system. It has a laser pulse repetition rate of up to 4 MHz resulting in up to 2.66 million measurements per second. The system utilizes a Multi-Pulse in the Air option (MPIA) and an integrated IMU/GNSS unit.

A brief summary of the aerial acquisition parameters for the project are shown in the lidar System Specifications in Table 2.

Table 2. Lidar System Specifications

		Riegl VQ1560ii (SN3062)	Riegl VQ1560ii (SN3543)
Terrain and Aircraft Scanner	Flying Height	1767 m	1767 m
	Recommended Ground Speed	160 kts	160 kts
Scanner	Field of View	60°	60°
	Scan Rate Setting Used	177 Hz	191 Hz
Laser	Laser Pulse Rate Used	1100 kHz	1200 kHz
	Multi Pulse in Air Mode	YES	YES
Coverage	Full Swath Width	2040 m	2040 m
	Line Spacing	1632 m	1632 m
Point Spacing and Density	Average Point Spacing	0.35 m	0.35 m
	Average Point Density	8 pts / m^2	8 pts / m^2

Figure 2. Riegl VQ-1560ii Lidar Sensor

2.3. Aircraft

All flights for the project were accomplished through the use of customized aircraft. Plane type and tail numbers are listed below.

Lidar Collection Planes

- Piper PA-31, Tail Number(s): C-FFRY
- Piper PA-31, Tail Number(s): C-GAYY

These aircraft provided an ideal, stable aerial base for lidar acquisition. These aerial platforms have relatively fast cruise speeds, which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds, proving ideal for collection of high-density, consistent data posting using a state-of-the-art lidar system. NV5 Geospatial's operating aircraft can be seen in Figure 3 below.

Figure 3. NV5 Geospatial's Aircraft

2.4. Time Period

Project specific flights were conducted between 5/06/2022 and 5/10/2022. Four aircraft lifts were completed. Accomplished lifts are listed below.

Lift	Start UTC	End UTC
05062022A (SN3543, C-FFRY) 5/06/2022 UTC	5/06/2022 12:08:18 PM	5/06/2022 1:38:42 PM
05072022A (SN3543, C-FFRY) 5/07/2022 UTC	5/07/2022 4:30:32 PM	5/07/2022 4:42:04 PM
05102022A (SN3062, C-GAYY) 5/10/2022 UTC	5/10/2022 3:47:00 PM	5/10/2022 9:01:50 PM
05102022A (SN3543, C-FFRY) 5/10/2022 UTC	5/10/2022 2:47:22 PM	5/10/2022 7:30:43 PM

3. Processing Summary

3.1. Flight Logs

Flight logs were completed by Lidar sensor technicians for each mission during acquisition. These logs depict a variety of information, including:

- Job / Project #
- Flight Date / Lift Number
- FOV (Field of View)
- Scan Rate (HZ)
- Pulse Rate Frequency (Hz)
- Ground Speed
- Altitude
- Base Station
- PDOP avoidance times
- Flight Line #
- Flight Line Start and Stop Times
- Flight Line Altitude (AMSL)
- Heading
- Speed
- Returns
- Crab

Notes: (Visibility, winds, ride, weather, temperature, dew point, pressure, etc). Project specific flight logs for each sortie are available in Appendix A.

3.2. Lidar Processing

Applanix + POSPac software was used for post-processing of airborne GPS and inertial data (IMU), which is critical to the positioning and orientation of the lidar sensor during all flights. Applanix POSPac combines aircraft raw trajectory data with stationary GPS base station data yielding a "Smoothed Best Estimate Trajectory" (SBET) necessary for additional post processing software to develop the resulting geo-referenced point cloud from the lidar missions.

During the sensor trajectory processing (combining GPS & IMU datasets) certain statistical graphs and tables are generated within the Applanix POSPac processing environment which are commonly used as indicators of processing stability and accuracy. This data for analysis include: max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, base station baseline length, processing mode, number of satellite vehicles, and mission trajectory.

Point clouds in flightline swath format were created using the RiPROCESS software. The generated point cloud is the mathematical three dimensional composite of all returns from all laser pulses as determined from the aerial mission. Each flightline swath point cloud was calibrated using Strip Align software that corrects systematic geometric errors and improves the relative and absolute accuracy of the flightline swath point cloud. The calibrated point cloud swaths were imported into GeoCue distributive processing software and the imported data was then tiled so further processing could take place in TerraScan software. Using TerraScan, the vertical accuracy of the surveyed ground control was tested and any vertical bias was removed from the data. TerraScan and TerraModeler software packages were then used for automated data classification and manual cleanup. The data were manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler.

DEMs and Intensity Images are then generated using proprietary software. In the bare earth surface model, above-ground features are excluded from the data set. Global Mapper is used as a final check of the bare earth dataset.

Finally, proprietary software is used to perform statistical analysis of the LAS files.

Software	Version
Applanix + POSPac	8.6
RiPROCESS	1.8.6
GeoCue	2020.1.22.1
Global Mapper	19.1;20.1
Microstation Connect	10.16.02.34
TerraModeler	21.008
TerraScan	21.016
StripAlign	2.21

3.3. LAS Classification Scheme

The classification classes are determined by Lidar Base Specifications 2021, Revision A and are an industry standard for the classification of lidar point clouds. All data starts the process as Class 1 (Unclassified), and then through automated classification routines, the classifications are determined using TerraScan macro processing.

The classes used in the dataset are as follows and have the following descriptions:

Table 3. LAS Classifications

	Classification Name	Description
1	Processed, but Unclassified	Laser returns that are not included in the bare earth class, or any other project classification
2	Bare earth	Laser returns that are determined to be bare earth using automated and manual cleaning algorithms
7	Low Noise	Laser returns that are often associated with scattering from reflective surfaces, or artificial points below the bare earth surface
9	Water	Laser returns that are found inside of hydro features
17	Bridge Deck	Laser returns falling on bridge decks
18	High Noise	Laser returns that are often associated with birds or artificial points above the bare earth surface
20	Ignored Ground	Bare earth points that fall within the given threshold of a collected hydro feature.
21	Snow	Bare earth points that fall on snow, where identifiable
22	Temporal Exclusion	Points that are excluded due to differences in collection dates

3.4. Classified LAS Processing

The bare earth surface is then manually reviewed to ensure correct classification on the Class 2 (Ground) points. After the bare-earth surface is finalized, it is then used to generate all hydro-breaklines through heads-up digitization.

All ground (ASPRS Class 2) lidar data inside of the Lake Pond and Double Line Drain hydro flattening breaklines were then classified to water (ASPRS Class 9) using proprietary tools. A buffer of 1.5 feet/0.5 meter was also used around each hydro flattened feature to classify these ground (ASPRS Class 2) points to Ignored ground (ASPRS Class 20). All Lake Pond Island and Double Line Drain Island features were checked to ensure that the ground (ASPRS Class 2) points were reclassified to the correct classification after the automated classification was completed.

Any noise that was identified either through manual review or automated routines was classified to the appropriate class (ASPRS Class 7 and/or ASPRS Class 18) followed by flagging with the withheld bit.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper is used as a final check of the bare earth dataset. NV5 Geospatial's proprietary software was then used to create the deliverable industry-standard LAS files for all point cloud data and to perform final statistical analysis of the classes in the LAS files, on a per tile level to verify final classification metrics and full LAS header information.

3.5. Hydro-Flattened Breakline Processing

Using heads-up digitization, all Lake-Ponds, Double Line Drains, and Islands are manually collected that are within the project size specification. This includes Lake-Ponds greater than 2 acres in size, Double Line Drains with greater than a 100 foot nominal width, and Islands greater than 1 acre in size within a collected hydro feature. Lidar intensity imagery and bare-earth surface models are used to ensure appropriate and complete collection of these features.

Elevation values are assigned to all collected hydro features via NV5 Geospatial's proprietary software. This software sets Lake-Ponds to an appropriate, single elevation to allow for the generation of hydro-flattened digital elevation models (DEM). Double Line Drain elevations are assigned based on lidar elevations and surrounding terrain feature to ensure all breaklines match the lidar within acceptable tolerances. Some deviation is expected between breakline and lidar elevations due to monotonicity, connectivity, and flattening rules that are enforced on the breaklines. Once complete, horizontal placement, and vertical variances are reviewed, all breaklines are evaluated for topological consistency and data integrity using a combination of proprietary tools and manual review of hydro-flattened DEMs.

Breaklines are combined into one seamless shapefile, clipped to the project boundary, and imported into an Esri file geodatabase for delivery.

3.6. Hydro-Flattened Raster DEM Processing

Hydro-Flattened DEMs (topographic) represent a lidar-derived product illustrating the grounded terrain and associated breaklines (as described above) in raster form. NV5 Geospatial's proprietary software was used to take all input sources (bare earth lidar points, bridge and hydro breaklines, etc.) and create a Triangulated Irregular Network (TIN) on a tile-by-tile basis. Data extending past the tile edge is incorporated in this process so that proper triangulation can occur. From the TIN, linear interpolation is used to calculate the cell values for the raster product. The raster product is then clipped back to the tile edge so that no overlapping cells remain across the project area. A 32-bit floating point GeoTIFF DEM was generated for each tile with a pixel size of 1-foot. NV5 Geospatial's proprietary software was used to write appropriate horizontal and vertical projection information as well as applicable header values into the file during product generation. Each DEM is reviewed in Global Mapper to check for any surface anomalies and to ensure a seamless dataset. NV5 Geospatial ensures there are no void or no-data values (-999999) in each derived DEM. This is achieved by using propriety software checking all cell values that fall within the project boundary. NV5 Geospatial uses a proprietary tool called FOCUS on Delivery to check all formatting requirements of the DEMs against what is required before final delivery.

3.7. Intensity Image Processing

Intensity images represent reflectivity values collected by the lidar sensor during acquisition. Proprietary software generates intensity images using first returns and excluding those flagged with a withheld bit. Intensity images are linearly scaled to a value range specific to the project area to standardize the images and reduce differences between individual tiles. Appropriate horizontal projection information as well as applicable header values are written during product generation.

3.8. Swath Separation Raster Processing

Swath Separation Images are rasters that represent the interswath alignment between flight lines and provide a qualitative evaluation of the positional quality of the point cloud. NV5 Geospatial proprietary software generated 2-foot cell size raster images in GeoTIFF format using last returns, excluding points flagged with the withheld bit, and using a point-in-cell algorithm. Images are generated with a 75% intensity opacity and (4) absolute 8-cm intervals, see below for interval coloring. Intensity images are linearly scaled to a value range specific to the project area to standardize the images and reduce differences between individual tiles. Appropriate horizontal projection information as well as applicable header values are written to the file during product generation. NV5 Geospatial uses a proprietary tool called FOCUS on Delivery to check all formatting requirements of the images against what is required before final delivery.

Green	0-8cm
Yellow	8-16cm
Orange	16-24cm
Red	>24cm

3.9. Maximum Surface Height Raster Processing

Maximum Surface Height rasters (topographic) represent a lidar-derived product illustrating natural and built-up features. NV5 Geospatial's proprietary software was used to take all first-return classified lidar points, excluding those flagged with a withheld bit, and create a raster on a tile-by-tile basis. Data extending past the tile edge is incorporated in this process so that proper gridding can occur. The raster product is then clipped back to the tile edge so that no overlapping cells remain across the project area. A 32-bit floating point GeoTIFF was generated for each tile with a pixel size of 2-foot cell size. NV5 Geospatial's proprietary software was used to write appropriate horizontal and vertical projection information as well as applicable header values into the file during product generation. Each maximum surface height raster is reviewed in Global Mapper to check for any anomalies and to ensure a seamless dataset. NV5 Geospatial uses a proprietary tool called FOCUS on Delivery to check all formatting requirements of the DEMs against what is required before final delivery.

Wisconsin 12 County - Burnett
Work Unit 300214 Tile Layout

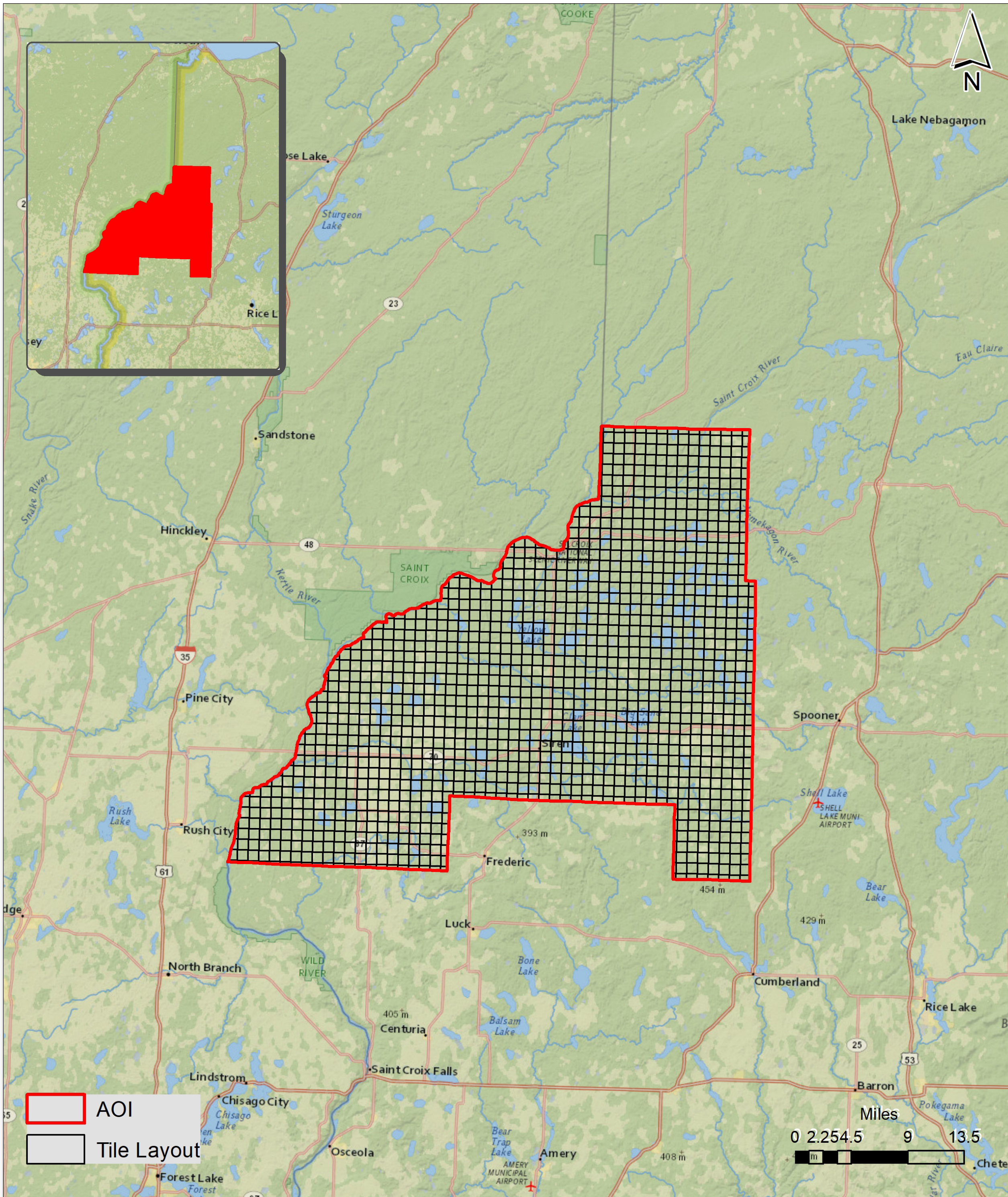


Figure 4. Lidar Tile Layout

4. Project Coverage Verification

A proprietary tool (FOCUS on Flight) produces grid-based polygons of each flightline, depicting exactly where lidar points exist. These swath polygons are reviewed against the project boundary to verify adequate project coverage. Please refer to Figure 5.

Wisconsin 12 County - Burnett
Work Unit 300214 Lidar Coverage

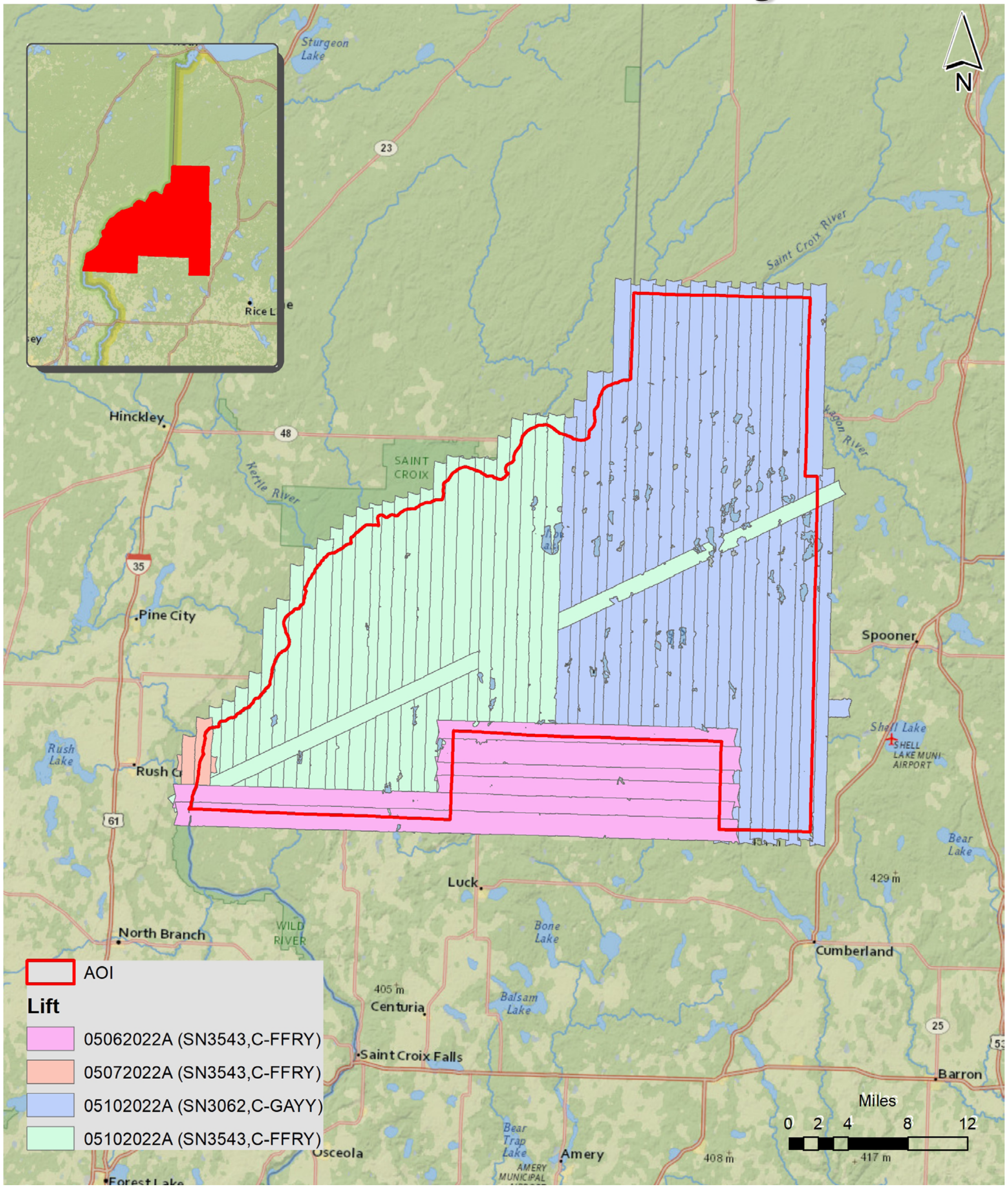


Figure 5. Lidar Coverage

5. Geometric Accuracy

5.1. Horizontal Accuracy

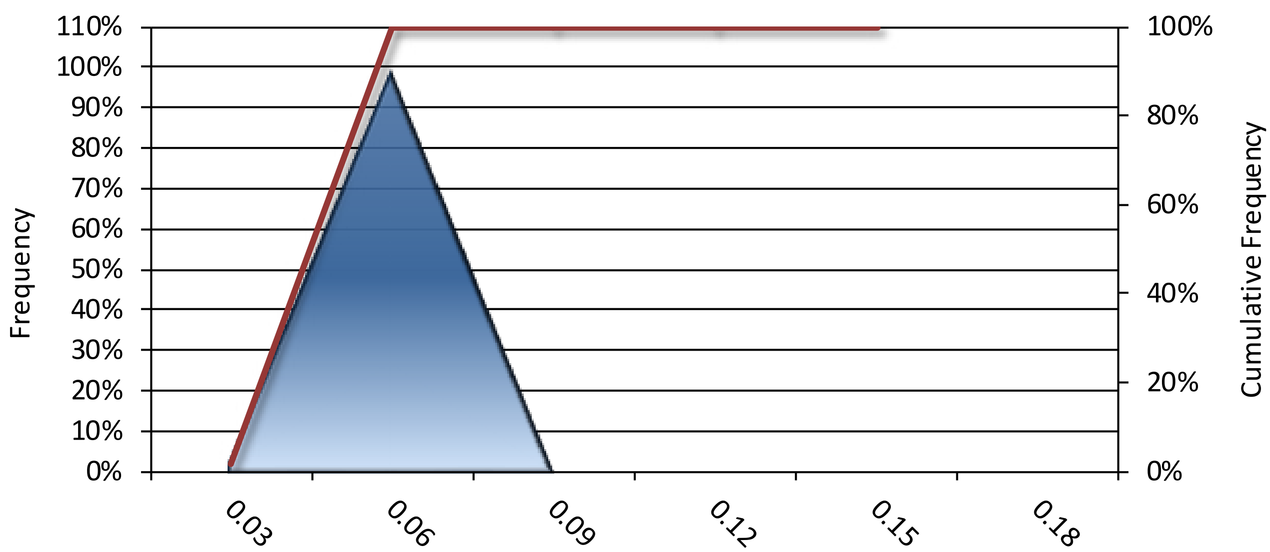
Lidar horizontal accuracy is a function of Global Navigation Satellite System (GNSS) derived positional error, flying altitude, and INS derived attitude error. The obtained $RMSE_r$ value is multiplied by a conversion factor of 1.7308 to yield the horizontal component of the National Standards for Spatial Data Accuracy (NSSDA) reporting standard where a theoretical point will fall within the obtained radius 95% of the time. Based on a flying altitude of 1767 meters, an IMU error of 0.002 decimal degrees, and a GNSS positional error of 0.015 meters, this project was compiled to meet 0.19 meter horizontal accuracy at the 95% confidence level. A summary is shown below.

Horizontal Accuracy	
$RMSE_r$	0.37 ft
	0.11 m
ACC_r	0.63 ft
	0.19 m

5.2. Relative Vertical Accuracy

Relative vertical accuracy refers to the internal consistency of the data set as a whole: the ability to place an object in the same location given multiple flight lines, GPS conditions, and aircraft attitudes. When the lidar system is well calibrated, the swath-to-swath vertical divergence is low (<0.10 meters). The relative vertical accuracy was computed by comparing the ground surface model of each individual flight line with its neighbors in overlapping regions. The average (mean) line to line relative vertical accuracy for the Wisconsin 12 County - Burnett project was 0.041 feet (0.013 meters). A summary is shown below.

Relative Vertical Accuracy	
Sample	52 flight line surfaces
Average	.047 ft
	.014 m
Median	.046 ft
	.014 m
RMSE	.046 ft
	.014 m
Standard Deviation (1σ)	.007 ft
	.002 m
1.96σ	.013 ft
	.004 m



Wisconsin 12 County - Burnett, Wisconsin Relative Vertical Accuracy (ft)
Total Compared Points (n = 9,705,001,569)

Project Report Appendices

The following section contains the appendices as listed in the Wisconsin 12 County - Burnett Lidar Project Report.

Appendix A

Flight Logs

Julian Day 126	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	May 06, 2022	**Aircraft**	C-FFRY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	Kane G
Location	Eau Claire WI	**Operator**	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T- 8 C
H- 71%
AMLS-278m
Hpa-1013

Time to next maintenance: ______ ⦿ 50 hr ○ 100 hr

Aircraft Block Time		
Engine On 11:28	**Takeoff** 11:46	
Engine Off 18:20	**Landing** 18:10	
Total 6.9 hrs	**Total** 6.4 hrs	

Mission Plan				
AGL Height	2300	**m**	**Pulse Rate**	500khz/ch
Target Speed	160	**kts**	**Scan Rate**	100hz/ch
Laser Current	100	**%**	**FOV**	60 degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	1134	1139
Post Mission	1813	1818

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp ______	
F8			1157	1202				
2032	432212601		1208	1220			120817	
2001	432212602		1227	1234			122753	
2002	432212603		1238	1245			123815	
2003	432212604		1248	1255			124859	
2004	432212605		1259	1306			125955	
2005	432212606		1309	1322			132517	
2006	432212607		1325	1338			132517	
2007	432212608		1342	1354			134214	
2008	432212609		1358	1411			131833	
2009	432212610		1418	1430			141833	
2010	432212611		1434	1447			143410	
2011	432212612		1450	1503			145054	
2012	432212613		1508	1519			150838	
2013	432212614		1522	1529	1530	6.3nm	152231	TCP Error media disconnected

Julian Day 126	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	May 06, 2022	**Aircraft**	C-FFRY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	Kane G
Location	Eau Claire WI	**Operator**	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T- 8 C
H- 71%
AMLS-278m
Hpa-1013

Time to next maintenance: ______ ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On 11:28	**Takeoff** 11:46	
Engine Off 18:20	**Landing** 18:10	
Total 6.9 hrs	**Total** 6.4 hrs	

Mission Plan					
AGL Height	2300	m	**Pulse Rate**	500khz/ch	
Target Speed	160	kts	**Scan Rate**	100hz/ch	
Laser Current	100	%	**FOV**	60	degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	1134	1139
Post Mission	1813	1818

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp	
Test Strip			1533	1533			153328	
2013	432212615		1536	1541			153601	Refly 6.3nm from the W EOL
2014	432212616		1549	1559			154906	
2015	432212617		1602	1611			160216	
2016	432212618		1615	1624			161520	
2017	432212619		1628	1637			162810	
2018	432212620		1641	1649			164102	
2019	432212621		1700	1709			170014	
2020	432212622		1712	1721			171209	
2021	432212623		1724	1733			172408	
2022	432212624		1736	1745			173620	
F8			1746	1751				

Julian Day	127	Flight	A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	May 07, 2022	**Aircraft**	C-FFRY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	Kake G
Location	Eau Claire WI	**Operator**	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T- 7 C W-34Knt gusting from the S
H- 75%
AMLS-278m
Hpa-1015

Time to next maintenance: ________ ⦿ 50 hr ○ 100 hr

Aircraft Block Time					
Engine On	11:16	**Takeoff**	11:32		
Engine Off	17:28	**Landing**	17:16		
Total	6.2 hrs	**Total**	5.7 hrs		

Mission Plan					
AGL Height	2300	m	**Pulse Rate**	500 khz/ch	
Target Speed	160	kts	**Scan Rate**	100 hz/ch	
Laser Current	100	%	**FOV**	60	degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	1122	1127
Post Mission	1719	1724

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp ____	
F8			1345	1359				
2023	432212711		1404	1413			140436	
2024	432212712		1417	1426			141711	
2025	432212713		1429	1439			142934	
2026	432212714		1443	1443			144315	
2027	432212715		1456	1507			145635	
2028	432212716		1510	1520			151039	
2029	432212717		1523	1534			152359	
2030	432212718		1537	1547			153740	
2031	432212719		1550	1601			155043	
Xtie	432212721		1606	1611			160652	
F8			1619	1624				
3122	432212723		1630	1632			163031	
3123	432212724		1635	1638			163541	
Xtie	432212725		1641	1642			164111	

Julian Day 127 | **Flight** A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	May 07, 2022	**Aircraft**	C-FFRY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	Kake G
Location	Eau Claire WI	**Operator**	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T- 7 C W-34Knt gusting from the S
H- 75%
AMLS-278m
Hpa-1015

Time to next maintenance: ________ ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On 11:16	**Takeoff** 11:32			
Engine Off 17:28	**Landing** 17:16			
Total 6.2 hrs	**Total** 5.7 hrs			

Mission Plan					
AGL Height	2300	m	**Pulse Rate**	500 khz/ch	
Target Speed	160	kts	**Scan Rate**	100 hz/ch	
Laser Current	100	%	**FOV**	60	degs

Static Alignment	**GPS Time**	
	Start	**End**
Pre Mission	1122	1127
Post Mission	1719	1724

Flight Line	**LiDAR File Name**	**Flight Direction**	**GPS Time**		**Line Aborted**		**Mission ID**	**Comments**
			Start	**End**	**Time**	**nmi to End**	Time Stamp ________	
F8			1642	1647				

Julian Day 130 | Flight A

LIDAR Flight Log

AIRBORNE IMAGING — A Clean Harbors Company

Date	May 10, 2022	Aircraft	C-FFRY
Project	3238_NV5_WI3DEP_V3	Pilot	Kane G
Location	Eau Claire WI	Operator	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T- 16C
H- 82%
AMLS-278m
Hpa-1015

Time to next maintenance: ________ ◉ 50 hr ○ 100 hr

Aircraft Block Time			
Engine On 13:57		Takeoff 14:12	
Engine Off 20:23		Landing 20:11	
Total 6.4 hrs		Total 6.0 hrs	

Mission Plan				
AGL Height	1584	m	Pulse Rate	1200 khz/ch
Target Speed	160	kts	Scan Rate	186 hz/ch
Laser Current	100	%	FOV	60 degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	1403	1408
Post Mission	1914	1919

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp ________	
F8			1437	1442				
3173	432213001		1447	1504			144722	
3124	432213002		1508	1510			150814	
3125	432213003		1513	1516			151349	
3126	432213004		1519	1522			151942	
3127	432213005		1526	1529			152613	
3128	432213006		1532	1537			153246	
3129	432213007		1541	1546			154101	
3130	432213008		1549	1555			154914	
3131	432213009		1558	1604			155805	
3132	432213010		1607	1614			160729	
3133	432213011		1619	1626			161958	
3134	432213012		1629	1636			162943	
3135	432213013		1644	1651			164433	
3136	432213014		1654	1701			165445	

Julian Day	130	Flight	A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	May 10, 2022	Aircraft	C-FFRY
Project	3238_NV5_WI3DEP_V3	Pilot	Kane G
Location	Eau Claire WI	Operator	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T- 16C
H- 82%
AMLS-278m
Hpa-1015

Time to next maintenance: ________ ⦿ 50 hr ○ 100 hr

Aircraft Block Time					
Engine On	13:57	Takeoff	14:12		
Engine Off	20:23	Landing	20:11		
Total	6.4 hrs	Total	6.0 hrs		

Mission Plan					
AGL Height	1584	m	Pulse Rate	1200 khz/ch	
Target Speed	160	kts	Scan Rate	186 hz/ch	
Laser Current	100	%	FOV	60	degs

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	1403	1408
Post Mission	1914	1919

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID Time Stamp	Comments
3137	432213014		1705	1712			170512	
3138	432213015		1715	1722			171530	
3139	432213017		1726	1733			172604	
3140	432213018		1736	1744			173645	
3141	432213019		1748	1756			174831	
3142	432213020		1759	1807			175942	
3143	432213021		1811	1819			181108	
3144	432213022		1822	1829			182259	
3145	432213023		1832	1838			183234	
3146	432213024		1841	1848			18157	
3147	432213025		1851	1858			185151	
3148	432213026		1902	1909			190204	
3149	432213027		1912	1919			191248	
3150	432213028		1923	1930			192315	
F8			1932	1937				

Julian Day 134	Flight A

LIDAR Flight Log

Date	May 14, 2022	**Aircraft**	C-FFRY
Project	3238_NV5_WI3DEP_QL1	**Pilot**	Kane G
Location	Duluth MI	**Operator**	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T-11C 30Kt Wind/ Moderate to Severe
H- 71% Turbulence
AMLS-278m
Hpa-1012

Time to next maintenance: ________ ⦿ 50 hr ○ 100 hr

Aircraft Block Time			
Engine On 11:58	**Takeoff** 12:15		
Engine Off 17:58	**Landing** 17:47		
Total 6.0 hrs	**Total** 5.5 hrs		

Mission Plan					
AGL Height	1584	m	**Pulse Rate**	1200 khz/ch	
Target Speed	160	kts	**Scan Rate**	188 hz/ch	
Laser Current	100	%	**FOV**	60	degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	1203	1208
Post Mission	1752	1757

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp ________	
F8			1245	1250				
3007	432213401		1258	1315			125801	
3008	432213402		1319	1337			131909	
3009	432213403		1340	1358			134041	
3010	432213404		1404	1421			140416	
3011	432213405		1425	1443			142544	
3012	432213406		1446	1504			144656	
3013	432213407		1507	1526			150759	
3014	432213408		1529	1546			152948	
3019	432213409		1549	1607			154920	
3020	432213410		1610	1626			161028	
Xtie	432213411		1630	1635			163007	
F8			1635	1640				
F8			1716	1721				
1001			1730	1732	1732		173024	Aborted Rain 3237_NV5_QL1

Julian Day	134	Flight	A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	May 14, 2022	**Aircraft**	C-FFRY
Project	3238_NV5_WI3DEP_QL1	**Pilot**	Kane G
Location	Duluth MI	**Operator**	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T-11C 30Kt Wind/ Moderate to Severe
H- 71% Turbulence
AMLS-278m
Hpa-1012

Time to next maintenance: ______ ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On 11:58		**Takeoff** 12:15		
Engine Off 17:58		**Landing** 17:47		
Total 6.0	hrs	**Total** 5.5	hrs	

Mission Plan				
AGL Height	1584	m	**Pulse Rate**	1200 khz/ch
Target Speed	160	kts	**Scan Rate**	188 hz/ch
Laser Current	100	%	**FOV**	60 degs

Static Alignment	GPS Time	
	Start	**End**
Pre Mission	1203	1208
Post Mission	1752	1757

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID (Time Stamp ______)	Comments

Julian Day 134	Flight A

LIDAR Flight Log

Date	May 14, 2022	Aircraft	C-FFRY
Project	3238_NV5_WI3DEP_QL1	Pilot	Kane G
Location	Duluth MI	Operator	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T-11C 30Kt Wind/ Moderate to Severe
H- 71% Turbulence
AMLS-278m
Hpa-1012

Time to next maintenance: ________ ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On 11:58	Takeoff 12:15			
Engine Off 17:58	Landing 17:47			
Total 6.0 hrs	Total 5.5 hrs			

Mission Plan				
AGL Height	1584	m	Pulse Rate	1200 khz/ch
Target Speed	160	kts	Scan Rate	188 hz/ch
Laser Current	100	%	FOV	60 degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	1203	1208
Post Mission	1752	1757

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp ________	

Julian Day	134	Flight	A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	May 14, 2022	Aircraft	C-FFRY
Project	3238_NV5_WI3DEP_QL1	Pilot	Kane G
Location	Duluth MI	Operator	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T-11C 30Kt Wind/ Moderate to Severe
H- 71% Turbulence
AMLS-278m
Hpa-1012

Time to next maintenance: ________ ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On 11:58		Takeoff 12:15		
Engine Off 17:58		Landing 17:47		
Total 6.0	hrs	Total 5.5	hrs	

Mission Plan					
AGL Height	1584	m	Pulse Rate	1200 khz/ch	
Target Speed	160	kts	Scan Rate	188 hz/ch	
Laser Current	100	%	FOV	60	degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	1203	1208
Post Mission	1752	1757

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp ________	

Julian Day 134	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	May 14, 2022	**Aircraft**	C-FFRY
Project	3238_NV5_WI3DEP_QL1	**Pilot**	Kane G
Location	Duluth MI	**Operator**	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T-11C 30Kt Wind/ Moderate to Severe
H- 71% Turbulence
AMLS-278m
Hpa-1012

Time to next maintenance: ________ ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On	11:58	**Takeoff**	12:15	
Engine Off	17:58	**Landing**	17:47	
Total	6.0 hrs	**Total**	5.5 hrs	

Mission Plan					
AGL Height	1584	**m**	**Pulse Rate**	1200 khz/ch	
Target Speed	160	**kts**	**Scan Rate**	188 hz/ch	
Laser Current	100	**%**	**FOV**	60	degs

Static Alignment	GPS Time	
	Start	**End**
Pre Mission	1203	1208
Post Mission	1752	1757

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp ________	

v 20200520

Julian Day 135	Flight A

LIDAR Flight Log

A I R B O R N E I M A G I N G — A Clean Harbors Company

Date May 15, 2022		**Aircraft**	C-FFRY
Project 3238_NV5_WI3DEP_2022		**Pilot**	Kane G
Location Duluth MI		**Operator**	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T- 8C Moderate to Severe Turbulence
H- 76%
AMLS-435m
Hpa-1012

Time to next maintenance: ________ ○ 50 hr ◉ 100 hr

Aircraft Block Time		
Engine On 11:55	**Takeoff** 12:12	
Engine Off 17:56	**Landing** 17:44	
Total 6.0 hrs	**Total** 5.5 hrs	

Mission Plan					
AGL Height	1584	m	**Pulse Rate**	1200 khz/ch	
Target Speed	160	kts	**Scan Rate**	186hz/ch	
Laser Current	100	%	**FOV**	60	degs

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	1200	1205
Post Mission	1747	1752

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID Time Stamp ________	Comments
F8			1245	1250				
3021	432213501		1255	1311			125511	
3022	432213502		1314	1332			131459	
3023	432213503		1335	1351			135443	
3024	432213504		1355	1412			135541	
3025	432213505		1416	1432			141621	Laser did not stop after fiish the line
3026	432213506		1439	1456			143958	
3027	432213507		1503	1519			150329	
3028	432213508		1523	1539			152311	
Xtie	432213509		1542	1545			154212	
F8			1550	1555				
F8			1630	1631				
1001	432213510		1644	1656			164415	3237_NV5_QL1_2022
1002	432213511		1659	1611			165916	
1003	432213512		1714	1726			171414	

Julian Day 135	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	May 15, 2022	**Aircraft**	C-FFRY
Project	3238_NV5_WI3DEP_2022	**Pilot**	Kane G
Location	Duluth MI	**Operator**	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T- 8C Moderate to Severe Turbulence
H- 76%
AMLS-435m
Hpa-1012

Time to next maintenance: ________ ◉ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On	11:55	**Takeoff**	12:12	
Engine Off	17:56	**Landing**	17:44	
Total	6.0 hrs	**Total**	5.5 hrs	

Mission Plan				
AGL Height	1584	m	**Pulse Rate**	1200 khz/ch
Target Speed	160	kts	**Scan Rate**	186hz/ch
Laser Current	100	%	**FOV**	60 degs

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	1200	1205
Post Mission	1747	1752

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID Time Stamp	Comments
Xtie	432213513		1728	1730			172855	
Test Strip			1730	1731			173039	do not process
F8			1731	1736				

v 20200520

Julian Day	136	Flight	A

LIDAR Flight Log

A I R B O R N E I M A G I N G
A Clean Harbors Company

Date	May 16, 2022	**Aircraft**	C-FFRY
Project	3237_NV5_QL1_2022	**Pilot**	Kane G
Location	Duluth MN	**Operator**	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T- 8C
H- 71%
AMLS-435m
Hpa-1010

Time to next maintenance: ________ ⦿ 50 hr ○ 100 hr

Aircraft Block Time

Engine On 11:35	**Takeoff** 11:54	
Engine Off 14:15	**Landing** 14:06	
Total 2.7 hrs	**Total** 2.2 hrs	

Mission Plan

AGL Height	1600	m	**Pulse Rate**	1000 khz/ch
Target Speed	160	kts	**Scan Rate**	295 hz/ch
Laser Current	100	%	**FOV**	60 degs

Static Alignment	GPS Time	
	Start	**End**
Pre Mission	1141	1146
Post Mission	1408	1413

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp ________	
F8			1205	1210				
1004	432213601		1213	1225			121332	
1005	432213602		1229	1243			122902	
1006	432213603		1248	1301			124822	
1007	432213604		1305	1320			130505	Possible cloud
Xtie	432213605		1332	1333			133216	

Julian Day 137	Flight A

LIDAR Flight Log

Date	May 17, 2022	Aircraft	C-FFRY
Project	3237_NV5_QL1_2022	Pilot	Kane G
Location	Duluth MN	Operator	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T- 5C
H- 75%
AMLS-435m
Hpa-1017

Time to next maintenance: ______ ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On	10:46	Takeoff	11:07	
Engine Off	16:28	Landing	16:16	
Total	5.7 hrs	Total	5.2 hrs	

Mission Plan					
AGL Height	1600	m	Pulse Rate	1100 khz/ch	
Target Speed	160	kts	Scan Rate	177hz/ch	
Laser Current	100	%	FOV	60	degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	1052	1057
Post Mission	1622	1627

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp ______	
F8			1110	1115				
1008	432213701		1117	1131			111745	
1009	432213702		1134	1148			113424	
1010	432213703		1151	1205			115155	
1011	432213704		1209	1223			120903	
1012	432213705		1226	1241			122658	
1013	432213706		1244	1259			124424	
1014	432213707		1302	1316			130223	
1015	432213708		1320	1334			132006	
1016	432213709		1338	1351			133804	
1017	432213710		1355	1409			135512	
1018	432213711		1412	1426			141251	
1019	432213712		1429	1443			142934	
1020	432213713		1446	1459			144626	
1021	432213714		1502	1516			150247	

Julian Day 137 | Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	May 17, 2022	**Aircraft**	C-FFRY
Project	3237_NV5_QL1_2022	**Pilot**	Kane G
Location	Duluth MN	**Operator**	Daniel. A
Mission Objective			

System	Riegl VQ-1560ii
Unit	43
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

T- 5C
H- 75%
AMLS-435m
Hpa-1017

Time to next maintenance: ______ ○ 50 hr ◉ 100 hr

Aircraft Block Time				
Engine On 10:46	**Takeoff** 11:07	
Engine Off 16:28	**Landing** 16:16	
Total 5.7 hrs	**Total** 5.2 hrs	

Mission Plan				
AGL Height	1600	m	**Pulse Rate**	1100 khz/ch
Target Speed	160	kts	**Scan Rate**	177hz/ch
Laser Current	100	%	**FOV**	60 degs

Static Alignment	GPS Time	
	Start	**End**
Pre Mission	1052	1057
Post Mission	1622	1627

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp	
1022	432213715		1519	1532			151934	
1023	432213716		1535	1548			153555	
Xtie	432213717		1553	1557			155317	
F8			1600	1605				

Julian Day 130 | Flight A

LIDAR Flight Log

A I R B O R N E I M A G I N G
A Clean Harbors Company

Date	April 10, 2022	**Aircraft**	C-GAYY
Project	3238_NV5_QL1	**Pilot**	A. Hering
Location	Eau Claire, Wisconsin	**Operator**	B.Eisenbart
Mission Objective			

System	VQ-1560II
Unit	S2223062
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

Time to next maintenance: ________ ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On	15:05	**Takeoff**	15:18	
Engine Off	21:38	**Landing**	21:29	
Total	6.6 hrs	**Total**	6.2 hrs	

Mission Plan				
AGL Height	1584	m	**Pulse Rate**	1200 khz/ch
Target Speed	160	kts	**Scan Rate**	191 lps/ch
Laser Current	100	%	**FOV**	60 degs

Static Alignment	GPS Time	
	Start	**End**
Pre Mission	15:08	15:13
Post Mission	21:31	21:36

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp 220510	
figure 8		-	15:38	15:42			-	
X-TIE	622213030	273°	15:46	15:53			154659	
3151	622213031	001°	15:58	16:05			155811	
3152	622213032	181°	16:09	16:17			160913	
3153	622213033	001°	16:19	16:28			161959	
3154	622213034	181°	16:31	16:40			163152	
3155	622213035	001°	16:43	16:54			164309	
3156	622213036	181°	16:57	17:07			165707	
3157	622213037	001°	17:10	17:21			171031	
3158	622213038	181°	17:23	17:34			172354	
3159	622213039	001°	17:37	17:47			173704	
3160	622213040	181°	17:50	18:01			175037	
3161	622213041	001°	18:03	18:14			180353	
3162	622213042	181°	18:16	18:27			181659	
3163	622213043	001°	18:32	18:44			183217	

Julian Day	130	Flight	A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	April 10, 2022	**Aircraft**	C-GAYY
Project	3238_NV5_QL1	**Pilot**	A. Hering
Location	Eau Claire, Wisconsin	**Operator**	B.Eisenbart
Mission Objective			

System	VQ-1560II
Unit	S2223062
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	
Scanner 2 Drive	

Additional Notes

Time to next maintenance: ________ ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On 15:05		**Takeoff** 15:18		
Engine Off 21:38		**Landing** 21:29		
Total 6.6	hrs	**Total** 6.2	hrs	

Mission Plan					
AGL Height	1584	m	**Pulse Rate**	1200 khz/ch	
Target Speed	160	kts	**Scan Rate**	191 lps/ch	
Laser Current	100	%	**FOV**	60	degs

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	15:08	15:13
Post Mission	21:31	21:36

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID Time Stamp 220510	Comments
3164	622213044	181°	18:47	18:59			184733	
3165	622213045	001°	19:03	19:15			190306	
3166	622213046	181°	19:18	19:30			191816	
3167	622213047	001°	19:33	19:45			193332	
3168	622213048	181°	19:48	20:01			194852	
3169	622213049	001°	20:04	20:16			200409	
3170	622213050	181°	20:19	20:31			201930	
3171	622213051	001°	20:34	20:47			203456	
3172	622213052	181°	20:53	21:01			205306	
figure 8		-	21:02	21:06			-	