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ID SouthernID 2018 D19-Final Accuracy Report

Report Produced for U.S. Geological Survey

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1. EXECUTIVE SUMMARY

The following report documents the comprehensive final project accuracy results for the ID SouthernID 2018 D19 lidar project. Preliminary accuracy testing was verified for each WUID to ensure project-wide accuracy would meet specification.

The ID SouthernID 2018 D19 lidar project survey report includes all information regarding the survey checkpoints, please refer to that report for details on the survey. However, there are fifteen checkpoints that were collected for this project that fell outside of the project boundary. These fifteen checkpoints were not used in final accuracy tested and are not reported out in the checkpoint geodatabases but have been delivered in the coordinate excel file to ensure all survey points are being delivered to USGS. These points are listed here: NVA-392, NVA-444, NVA-445, NVA-483, NVA-484, NVA-504, NVA-505, NVA-506, VVA-217, VVA-240, VVA-315, VVA-334, VVA-335, VVA-336, VVA-337.

For accuracy testing, Dewberry typically uses proprietary software (which utilizes both Esri and lastools software within its workflow) to test the swath lidar vertical accuracy and classified lidar vertical accuracy, Esri software to test the horizontal lidar accuracy, and Esri software to test the DEM vertical accuracy. Below is a description of the types of checkpoints utilized and the acceptable criteria for the ID SouthernID 2018 D19 lidar project accuracy requirements.

NVA (Non-vegetated Vertical Accuracy) reflects the calibration and performance of the lidar sensor. NVA was determined with checkpoints located only in non-vegetated terrain, including open terrain (grass, dirt, sand, and/or rocks) and urban areas. In these locations it is likely that the lidar sensor detected the bare-earth ground surface and random errors are expected to follow a normal error distribution. Assuming a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error ($RMSE_z$) of the checkpoints x 1.9600.

VVA (Vegetated Vertical Accuracy) was determined with all checkpoints in vegetated land cover categories, including tall grass, weeds, crops, brush and low trees, and fully forested areas. In these locations there is a possibility that the lidar sensor and post-processing may yield elevation errors that do not follow a normal error distribution. VVA at the 95% confidence level equals the 95^{th} percentile error for all checkpoints in all vegetated land cover categories combined. The VVA is accompanied by a listing of the 5% outliers that are larger than the 95^{th} percentile used to compute the VVA.

The relevant testing criteria are summarized in the table below.

Table 1. Vertical accuracy acceptance criteria

Land Cover Type	Quantitative Criteria	Measure of Acceptability
NVA	Accuracy in open terrain and urban land cover categories using RMSEz *1.9600	19.6 cm ($RMSE_z$ 10 cm)
VVA	Accuracy in vegetated land cover categories combined at the 95^{th} percentile	30 cm

1.1 Project Area

The ID SouthernID 2018 D19 lidar project encompasses approximately 42,120 square miles within the state of Idaho, covering two different UTM zones. The figure below shows the two UTM zones for the ID SouthernID 2018 D19 project and the checkpoints that were collected.

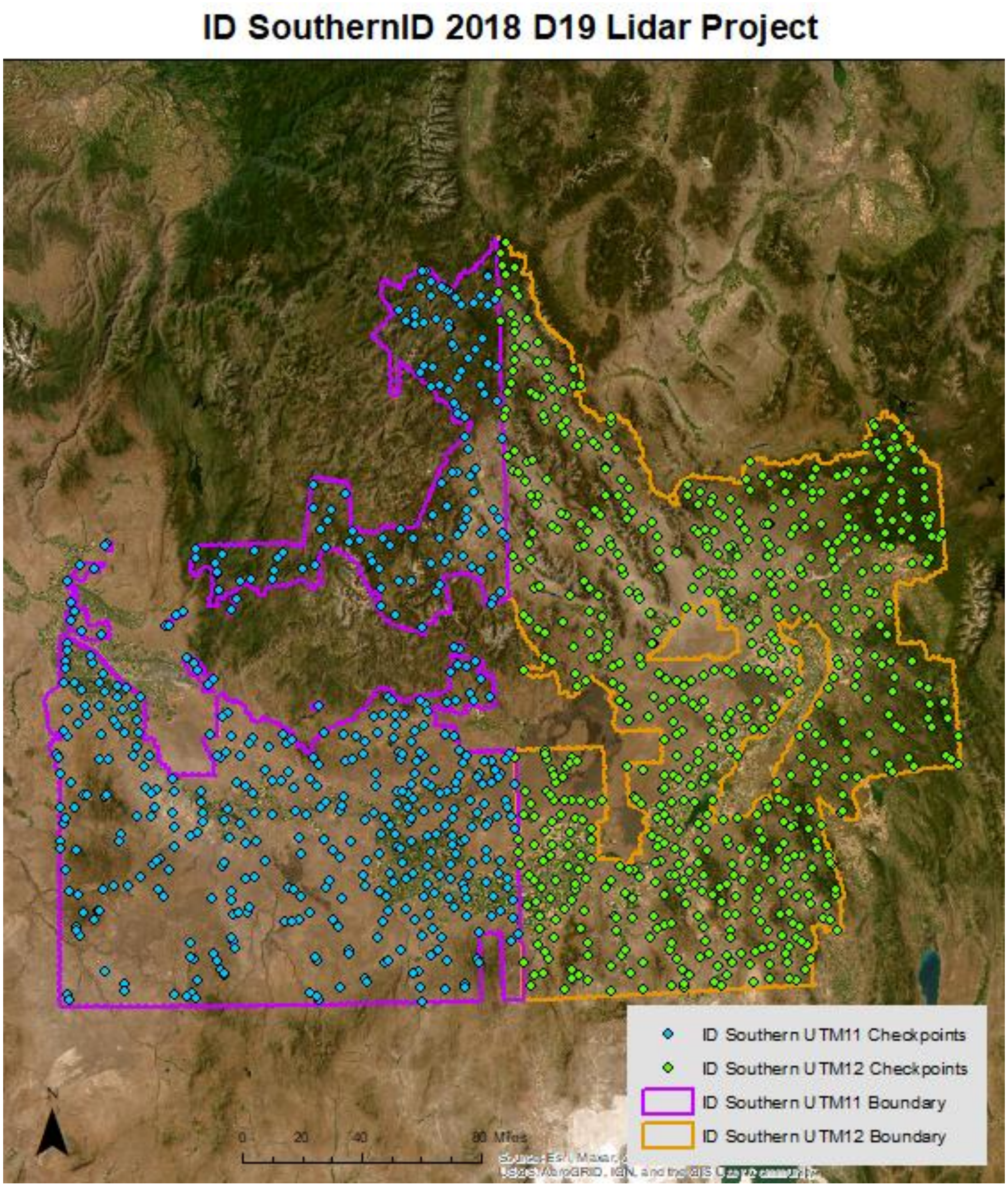

Figure 1. Project map with UTM zones outlined and checkpoints in each UTM zone displayed.

1.2 Coordinate Reference System

Data produced for the project are delivered in the following spatial reference system:

Horizontal Datum:	North American Datum of 1983 with the 2011 Adjustment (NAD 83 (2011))
Vertical Datum:	North American Vertical Datum of 1988 (NAVD88)
Geoid Model:	Geoid12B
Coordinate System:	Albers Equal Area, UTM Zone 11N, UTM Zone 12N
Horizontal Units:	Meters
Vertical Units:	Meters

2. LIDAR POSITIONAL ACCURACY

Dewberry quantitatively tested the dataset by testing the vertical accuracy of the lidar. The vertical accuracy is tested by comparing the discreet measurement of the survey checkpoints to that of the interpolated value within the three closest lidar points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the end result is that only a small sample of the lidar data is actually tested. However, there is an increased level of confidence with lidar data due to the relative accuracy. This relative accuracy in turn is based on how well one lidar point "fits" in comparison to the next contiguous lidar measurement and is verified as part of the initial processing. If the relative accuracy of a dataset is within specifications and the dataset passes vertical accuracy requirements at the location of survey checkpoints, the vertical accuracy results can be applied to the whole dataset with high confidence due to the passing relative accuracy.

2.1 Final Swath Vertical Accuracy Assessment

Dewberry tested the vertical accuracy of the non-vegetated terrain swath data prior to additional processing. Dewberry tested the vertical accuracy of the swath data using the non-vegetated (open terrain and urban) independent survey checkpoints. The vertical accuracy is tested by comparing survey checkpoints in non-vegetated terrain to a triangulated irregular network (TIN) that is created from the raw swath points. Only checkpoints in non-vegetated terrain can be tested against raw swath data because the data has not undergone classification techniques to remove vegetation, buildings, and other artifacts from the ground surface. Checkpoints are always compared to interpolated surfaces from the lidar point cloud because it is unlikely that a survey checkpoint will be located at the location of a discrete lidar point. Dewberry typically use proprietary software to test the swath lidar vertical accuracy. The table below summarizes the swath project accuracy specification, the amount of NVA points tested, and the final tested swath accuracy results.

Table 2. NVA at 95% Confidence Level for Raw Swaths

100 % of Totals	# of Points	RMSEz (m) NVA	NVA (m) Spec=0.196	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	703	0.073	0.143	-0.004	0.000	1.376	0.073	20.984	-0.352	0.791

Three checkpoints (NVA-37, NVA-337, and NVA-369) were removed from the raw swath vertical accuracy testing due to various reasons. Only non-vegetated terrain checkpoints are used to test the unclassified swath data because the unclassified swath data has not been classified to remove vegetation, structures, and other above ground features from the ground classification. Two of these checkpoints (NVA-37, NVA-337) are unable to report accuracy values due to vegetation or above ground obstructions in the data that has not yet been properly classified. One checkpoint (NVA-369) is showing an erroneous high value due to an incorrect recording of the survey elevation. Due to the reasons above, these points were removed from the final swath accuracy calculations. Once the data underwent the classification process, the obstructions were excluded from the final ground classification and two of these points (NVA-37, NVA-337) could be used in the final vertical accuracy testing for the fully classified lidar data. One checkpoint (NVA-369) was also excluded from the final vertical accuracy testing. Table 3, below, provides the coordinates for these checkpoints and the vertical accuracy results from the unclassified swath data. Table 4, below, provides the usable vertical accuracy results of these checkpoints from the fully classified lidar. The differences in the tables show how above ground features can cause erroneous vertical accuracy results in the unclassified swath data. Figures 2 through 8, below, show 3D models of the lidar point cloud and the locations of the checkpoints.

Table 3. Checkpoints removed from unclassified swath vertical accuracy testing

Point ID	Albers Equal Area NAD83(2011), m		NAVD88 Geoid 12B, m		Delta Z (m)
	Easting X (m)	Northing Y (m)	Survey Z (m)	Lidar Z (m)	
NVA-37	-1541747.860	2328860.081	1155.364	1156.86	1.49138
NVA-337	-1309937.188	2265519.078	1452.346	1459.42	7.069
NVA-369	-1308247.283	2309443.446	2025.505	2027.790	2.285

Table 4. Final tested vertical accuracy of the post ground classification

Point ID	Albers Equal Area NAD83(2011), m		NAVD88 Geoid 12B, m		Delta Z (m)
	Easting X (m)	Northing Y (m)	Survey Z (m)	Lidar Z (m)	
NVA-37	-1541747.860	2328860.081	1155.364	1155.290	-0.074
NVA-337	-1309937.188	2265519.078	1452.346	1452.460	0.114
NVA-369	-1308247.283	2309443.446	2025.505	2027.790	2.285

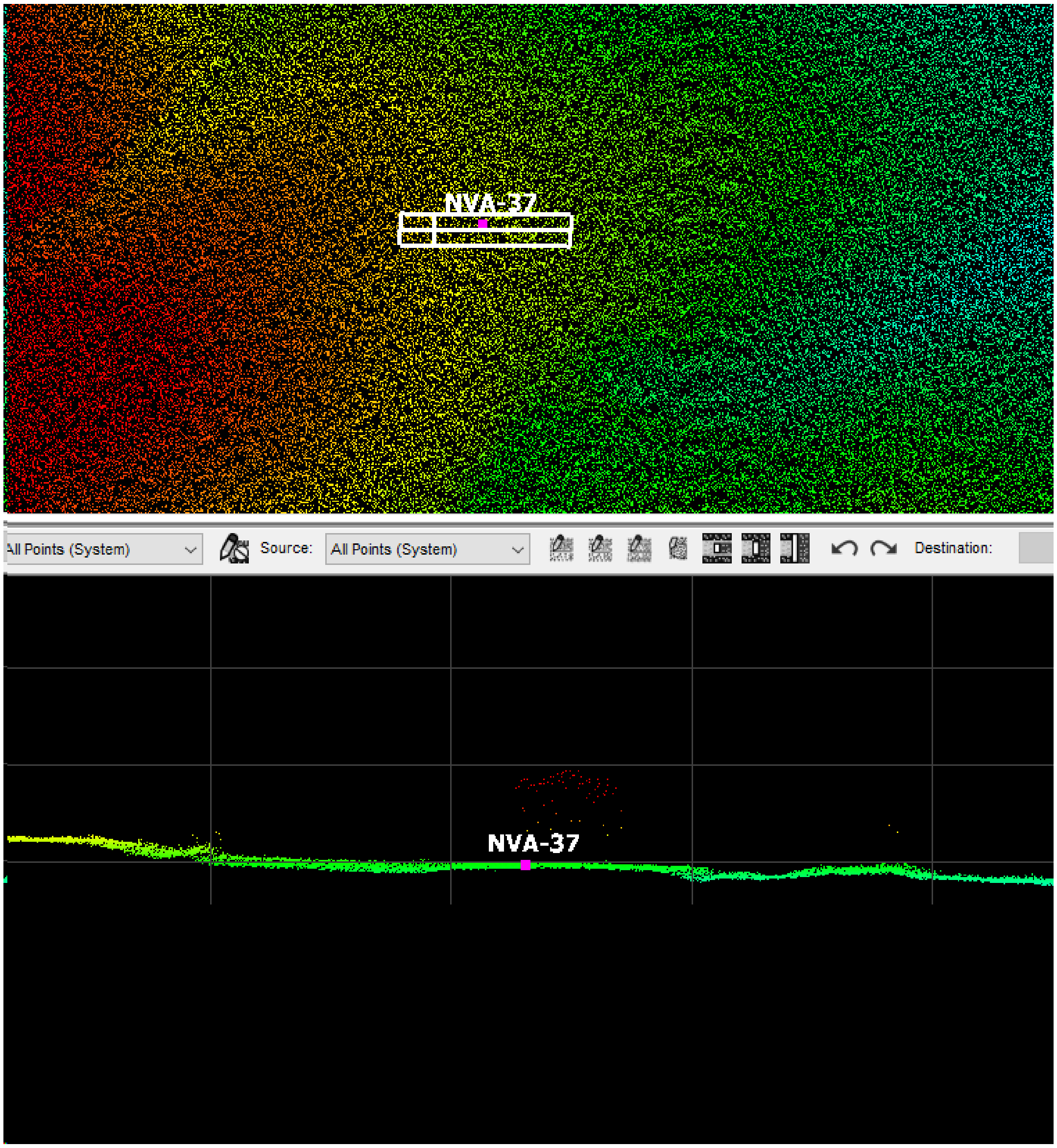

Figure 2. NVA-37, shown as the purple dot, is located underneath noise or another above ground feature. This point was removed from raw swath vertical accuracy testing because above ground features have not been separated from the ground classification yet.

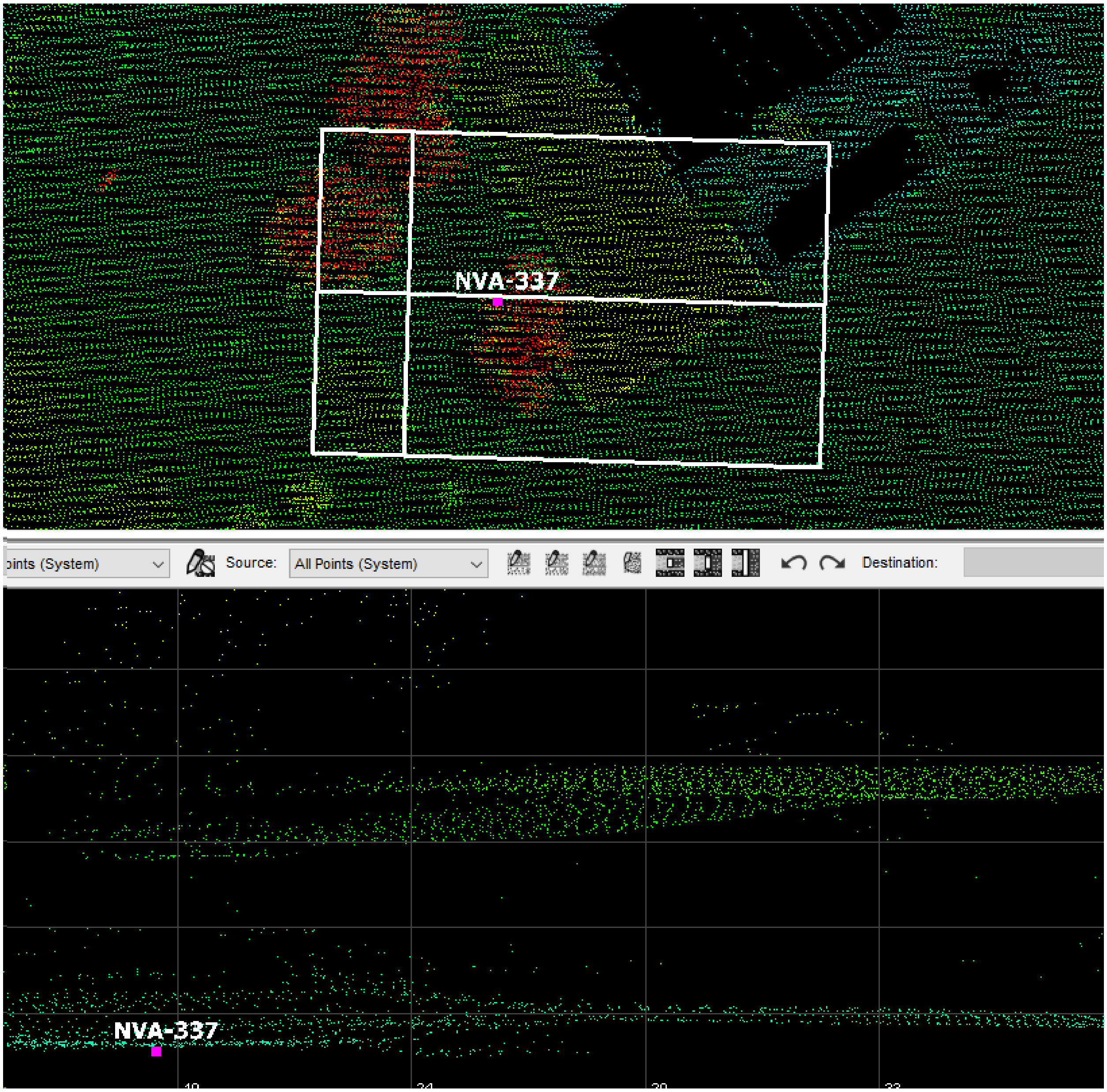

Figure 3. NVA-337, shown as the purple dot, is located underneath vegetation. This point was removed from raw swath vertical accuracy testing because above ground features have not been separated from the ground classification yet.

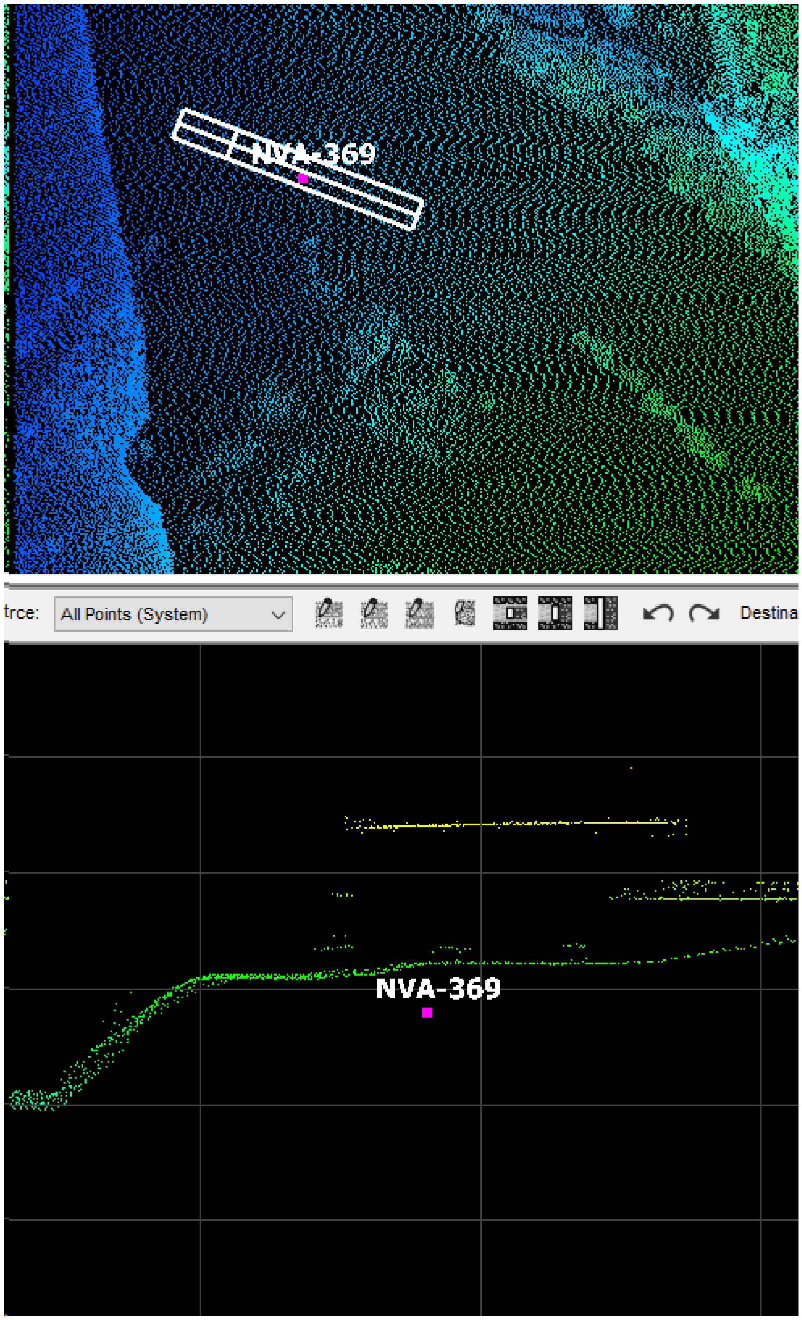

Figure 8. NVA-369, shown as the purple, is located underneath the ground surface. This point was removed from raw swath and final classified lidar vertical accuracy testing because the point elevation was incorrectly recorded.

2.2 Classified Lidar Vertical Accuracy Results

The table below summarizes the tested vertical accuracy resulting from a comparison of the surveyed checkpoints to the elevation values present within the fully classified lidar LAS files.

Table 5. Tested NVA and VVA for the classified lidar

Land Cover Type	# of Points	NVA (m)	VVA (m)
Project Specification	**1,170**	**0.196**	**0.300**
NVA	705	0.145	-
VVA	478	-	0.176

This lidar dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =7.4 cm, equating to +/- 14.5 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 17.6 cm at the 95th percentile.

Table 6 lists the 5% outliers that are larger than the VVA 95th percentile.

Table 6. VVA 5% Outliers

Point ID	Albers Equal Area NAD83(2011), m		NAVD88 Geoid 12B, m		Delta Z (m)
	Easting X (m)	Northing Y (m)	Survey Z (m)	Lidar Z (m)	
VVA-103	-1436010.188	2251723.398	1565.432	1565.660	0.228
VVA-108	-1431209.881	2271293.515	1567.082	1567.280	0.198
VVA-159	-1449148.692	2348054.921	1286.278	1286.490	0.212
VVA-196	-1508697.355	2403684.992	1540.891	1541.120	0.229
VVA-202	-1461906.909	2414341.565	1564.954	1565.150	0.196
VVA-205	-1465542.967	2445325.688	1813.258	1813.450	0.192
VVA-209	-1360912.124	2406050.636	1518.773	1519.000	0.227
VVA-210	-1338015.194	2399657.442	1612.305	1612.550	0.245
VVA-211	-1324603.831	2400114.931	1623.279	1623.490	0.211
VVA-221	-1280099.608	2369845.624	1639.844	1639.630	-0.214
VVA-246	-1291557.604	2328892.917	1674.533	1674.320	-0.213
VVA-26	-1647640.662	2451737.510	818.752	818.940	0.188
VVA-27	-1641850.511	2437233.291	784.883	785.080	0.197
VVA-287	-1301369.237	2254097.534	1505.457	1505.650	0.193
VVA-328	-1302919.872	2422303.334	1461.180	1461.360	0.180
VVA-354	-1498716.783	2500237.281	2001.372	2001.140	-0.232
VVA-359	-1413079.655	2467290.550	1874.999	1875.190	0.191
VVA-408	-1271969.809	2487256.835	2028.001	2028.200	0.199
VVA-429	-1253115.599	2495480.830	2122.572	2122.860	0.288
VVA-432	-1213317.837	2486907.024	1956.926	1957.240	0.314
VVA-438	-1216864.060	2510782.550	2026.783	2026.990	0.207
VVA-44	-1572972.429	2394352.719	977.500	977.790	0.290
VVA-462	-1431196.797	2587726.476	1647.125	1646.680	-0.445
VVA-468	-1429202.822	2606307.937	1223.995	1223.760	-0.235

Table 7 provides overall descriptive statistics.

Table 7. Classified lidar vertical accuracy descriptive Statistics

100 % of Totals	# of Points	RMSEz (m) NVA	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	705	0.074	-0.010	-0.008	1.321	0.073	19.460	-0.352	0.771
VVA	478	N/A	0.020	0.021	-0.228	0.085	2.201	-0.445	0.314

2.3 Final Horizontal Accuracy Results

Dewberry tested the horizontal accuracy of lidar datasets when checkpoints were photo-identifiable in the intensity imagery. Photo-identifiable checkpoints included checkpoints located at the ends of paint stripes on concrete or asphalt surfaces or checkpoints located at 90 degree corners of different reflectivity, e.g. a sidewalk corner adjoining a grass surface. The XY coordinates of checkpoints as viewed in the intensity imagery were compared to surveyed XY coordinates for each photo-identifiable checkpoint. The horizontal differences were used to compute the tested horizontal accuracy of the lidar.

2.3.1 Horizontal Accuracy Test Procedures

Horizontal accuracy testing requires well-defined checkpoints that can be identified in the dataset. Elevation datasets, including lidar datasets, do not always contain well-defined checkpoints suitable for horizontal accuracy assessment. However, the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) recommends at least half of the NVA vertical checkpoints should be located at the ends of paint stripes or other point features visible on the lidar intensity image, allowing them to double as horizontal checkpoints.

Dewberry reviews all NVA checkpoints to determine which, if any, of these checkpoints are located on photo-identifiable features in the intensity imagery. This subset of checkpoints are then used for horizontal accuracy testing.

The primary QA/QC horizontal accuracy testing steps used by Dewberry are summarized as follows:

1. Dewberry's team surveyed QA/QC vertical checkpoints in accordance with the project's specifications and tried to locate half of the NVA checkpoints on features photo-identifiable in the intensity imagery.
2. Next, Dewberry identified the well-defined features in the intensity imagery.
3. Dewberry then computed the associated xy-value differences between the coordinates of the well-defined feature in the lidar intensity imagery and the ground truth survey checkpoints.
4. The data were analyzed by Dewberry to assess the accuracy of the data. Horizontal accuracy was assessed using NSSDA methodology where horizontal accuracy is calculated at the 95% confidence level. This report provides the results of the horizontal accuracy testing.

2.3.2 Horizontal Accuracy Results

Thirty-three checkpoints were determined to be photo-identifiable in the intensity imagery and were used to test the horizontal accuracy of the lidar dataset. As only thirty-three (33) checkpoints were photo-identifiable, the results are not statistically significant enough to report as a final tested value, but the results of the testing are still shown in the table below.

Using NSSDA methodology (endorsed by the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014)), horizontal accuracy at the 95% confidence level (called ACCURACYr) is computed by the formula RMSEr * 1.7308 or RMSExy * 2.448.

This dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 41 cm $RMSE_x$/$RMSE_y$ horizontal accuracy class which equates to a positional horizontal accuracy of ± 1 meter at the 95% confidence level. Using 33 photo-identifiable checkpoints, positional horizontal accuracy of this dataset was found to be $RMSE_x$ = 19.9 cm and $RMSE_y$ = 18.4 cm, which equates to ± 46.9 cm at the 95% confidence level.

Table 8. Horizontal accuracy of the classified lidar data at the 95% confidence level

Land Cover Type	# of Points	$RMSE_x$ (m)	$RMSE_y$ (m)	$RMSE_r$ (m)	$Accuracy_r$ (m)
Project Specification	**-**	**0.410**	**0.410**	**0.580**	**1.000**
Non-Vegetated Terrain	33	0.199	0.184	0.271	0.469

3. DEM POSITIONAL ACCURACY

The same 1,183 checkpoints that were used to test the vertical accuracy of the lidar were used to validate the vertical accuracy of the final DEM products. Accuracy results may vary between the source lidar and final DEM deliverable. DEMs are created by averaging several lidar points within each pixel, which may result in slightly different elevation values at each survey checkpoint when compared to the linearly interpolated TIN created from the source LAS. The vertical accuracy of the DEM was tested by comparing the elevation of a given surveyed checkpoint with the elevation of the horizontally coincident pixel in the DEM.

The table below summarizes the tested vertical accuracy results from the final DEM dataset.

Table 9. DEM vertical accuracy results

Land Cover Category	# of Points	NVA (m)	VVA (m)
Project Specification	**1,170**	**0.196**	**0.300**
NVA	705	0.144	-
VVA	478	-	0.187

This DEM dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =7.4 cm, equating to +/- 14.4 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 18.7 cm at the 95th percentile.

Table 10 lists the 5% outliers that are larger than the VVA 95^{th} percentile.

Table 10. DEM VVA 5% outliers

Point ID	Albers Equal Area NAD83(2011), m		NAVD88 Geoid 12B, m		Delta Z, m
	Easting (X)	Northing (Y)	Survey Z	Lidar Z	
VVA-103	-1436010.188	2251723.398	1565.432	1565.661	0.229
VVA-108	-1431209.881	2271293.515	1567.082	1567.276	0.194
VVA-159	-1449148.692	2348054.921	1286.278	1286.502	0.224
VVA-196	-1508697.355	2403684.992	1540.891	1541.124	0.233
VVA-202	-1461906.909	2414341.565	1564.954	1565.167	0.213
VVA-205	-1465542.967	2445325.688	1813.258	1813.475	0.217
VVA-209	-1360912.124	2406050.636	1518.773	1518.999	0.226
VVA-210	-1338015.194	2399657.442	1612.305	1612.563	0.258
VVA-211	-1324603.831	2400114.931	1623.279	1623.519	0.240
VVA-221	-1280099.608	2369845.624	1639.844	1639.620	-0.224
VVA-234	-1214318.622	2347453.258	1734.443	1734.630	0.187
VVA-246	-1291557.604	2328892.917	1674.533	1674.327	-0.206
VVA-26	-1647640.662	2451737.510	818.752	818.954	0.202
VVA-27	-1641850.511	2437233.291	784.883	785.078	0.195
VVA-3	-1661420.488	2509685.124	700.088	700.281	0.193
VVA-328	-1302919.872	2422303.334	1461.180	1461.371	0.191
VVA-354	-1498716.783	2500237.281	2001.372	2001.161	-0.211
VVA-408	-1271969.809	2487256.835	2028.001	2028.202	0.201
VVA-429	-1253115.599	2495480.830	2122.572	2122.856	0.284
VVA-432	-1213317.837	2486907.024	1956.926	1957.231	0.305
VVA-438	-1216864.060	2510782.550	2026.783	2026.994	0.211
VVA-44	-1572972.429	2394352.719	977.500	977.789	0.289
VVA-462	-1431196.797	2587726.476	1647.125	1646.692	-0.433
VVA-468	-1429202.822	2606307.937	1223.995	1223.789	-0.206

Table 11 provides overall descriptive statistics.

Table 11. Overall Descriptive Statistics

Land Cover Type	# of Points	RMSE$_z$ (m)	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
NVA	705	0.074	-0.011	-0.009	1.532	0.073	-0.351	0.796	22.085
VVA	478	-	0.025	0.027	-0.241	0.085	-0.433	0.305	2.061

4. FINAL ACCURACY SUMMARY

Based on the accuracy testing conducted by Dewberry, the lidar and DEM dataset for the ID SouthernID 2018 D19 lidar project satisfies the project's pre-defined accuracy criteria as described throughout this report.