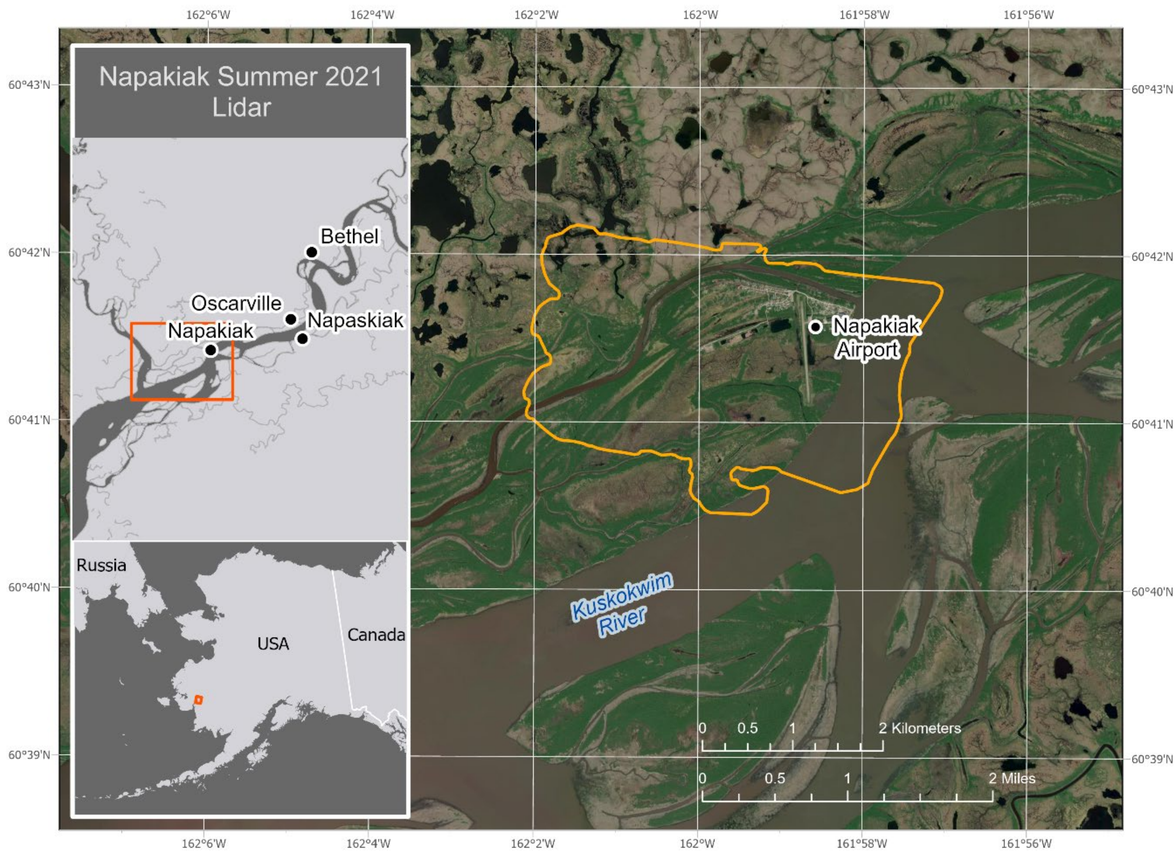
# LIDAR-DERIVED ELEVATION DATA FOR NAPAKIAK, SOUTHWEST ALASKA, COLLECTED AUGUST 20, 2021

Jenna M. Zechmann, Andrew M. Herbst, Richard M. Buzard, Katreen M. Wikstrom Jones, and Gabriel J. Wolken

Raw Data File 2024-12




Location map of survey area.

This report has not been reviewed for technical content or for conformity to the editorial standards of DGGS.

2024
STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

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**Suggested citation:**
Zechmann, J.M., Herbst, A.M., Buzard, R.M., Wikstrom Jones, K.M., and Wolken, G.J., 2024, Lidar-derived elevation data for Napakiak, Southwest Alaska, collected August 20, 2021: Alaska Division of Geological & Geophysical Surveys Raw Data File 2024-12, 9 p. https://doi.org/10.14509/31258

# LIDAR-DERIVED ELEVATION DATA FOR NAPAKIAK, SOUTHWEST ALASKA, COLLECTED AUGUST 20, 2021

Jenna M. Zechmann[1], Andrew M. Herbst[1], Richard M. Buzard[2], Katreen M. Wikstrom Jones[1], Gabriel J. Wolken[1]

## INTRODUCTION

The Alaska Division of Geological & Geophysical Surveys (DGGS) used aerial lidar to produce a classified point cloud, digital surface model (DSM), digital terrain model (DTM), and an intensity model of Napakiak, Southwest Alaska, during leaf-on conditions (cover figure). The survey provides snow-free surface elevations for flooding hazard assessment and coastal erosion studies. Ground control data were collected October 8, 2020, and aerial lidar data were collected August 20, 2021, and subsequently merged and processed using a suite of geospatial processing software. This data collection is released as a Raw Data File with an open end-user license. All files are available to download on the DGGS website at doi.org/10.14509/31258.

## LIST OF DELIVERABLES

Classified Points
DSM and DTM
Intensity Image
Metadata

## MISSION PLAN

### Aerial Lidar Survey Details

DGGS used a Riegl VUX1-LR laser scanner integrated with a global navigation satellite system (GNSS) and Northrop Grumman LN-200C inertial measurement unit (IMU) designed by Phoenix LiDAR Systems. The sensor can collect a maximum of 820,000 points per second at a range of 215 m, or a minimum of 50,000 points per second at a range of 820 m (ranges assume ≥ 20% natural reflectance). The scanner operated with a pulse refresh rate of 400,000 pulses per second, with a scan rate of 200 revolutions per second. We used a Cessna 180 Skywagon fixed-wing platform to survey from an elevation of approximately 180–230 m above ground level, at a ground speed of approximately 40 m/s, and with a scan angle set from 80 to 280 degrees. The total survey area covers approximately 9.9 km$^2$.

### Weather Conditions and Flight Times

The survey area was accessed by air (fig. 1) from Bethel Airport. Data collection occurred between 10:40 am and 11:00 am (AST), and the weather throughout the survey was partly cloudy.

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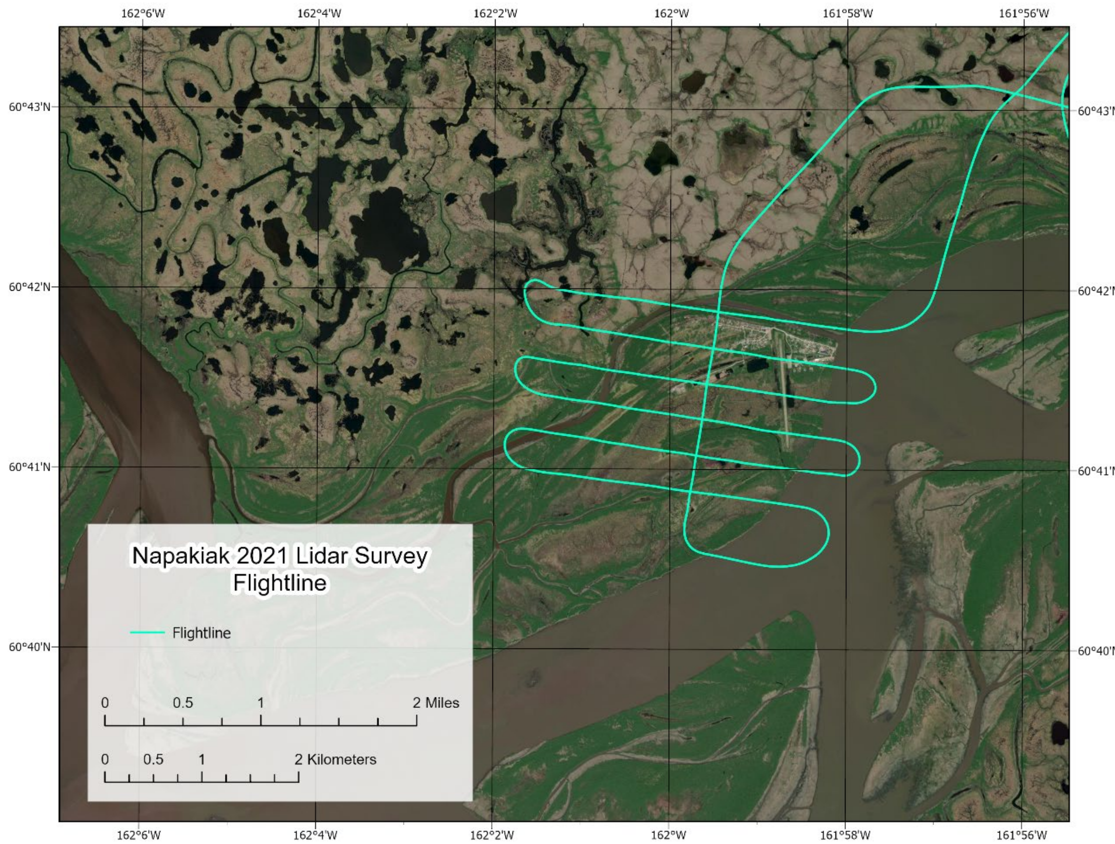


**Figure 1.** Lidar data collection flightline.

## PROCESSING REPORT

### Lidar Dataset Processing

We processed point data in Spatial Explorer for initial filtering and multiple-time-around (MTA) disambiguation. MTA errors, corrected in this process, result from ambiguous interpretations of received pulse time intervals and occur more frequently with higher pulse refresh rates. IMU and GNSS data were processed in Inertial Explorer, and flightline information was integrated with the point cloud in Spatial Explorer. We calibrated the point data at an incrementally precise scale of sensor movement and behavior, incorporating sensor velocity, roll, pitch, and yaw fluctuations throughout the survey. For the lidar data collection, the average pulse density is 8.95 pulses/m$^2$, and the average pulse spacing is 33.4 cm.

We created macros in Terrasolid software and classified points in accordance with the American Society for Photogrammetry & Remote Sensing (ASPRS) 2019 guidelines (ASPRS, 2019). Once classified, we applied a geometric transformation and converted the points from ellipsoidal heights to GEOID12B (Alaska) orthometric heights.

Raster products were derived from the point cloud in ArcGIS Pro. A 50-cm DSM was interpolated from maximum return values from ground, vegetation, bridge deck, and building classes using a binning method. A 50-cm DTM was interpolated from all ground class returns using a binning method and minimum values. We also produced a 50-cm intensity image for the entire area using average binning in ArcGIS Pro, with no normalization or corrections applied.

### Classified Point Cloud

Classified point cloud data are provided in LAZ format. Data are classified following ASPRS 2019 guidelines (table 2) and contain return and intensity information. For classified ground points, the average point density (fig. 2) is 1.83 pts/m$^2$, and the average spacing is 74.0 cm.

**Table 2.** Point cloud class code definitions.

| Class Code | Description |
|---|---|
| 1 | Unclassified |
| 2 | Ground |
| 3 | Low Vegetation, ≥0.0m, <0.5m |
| 4 | Medium Vegetation, ≥0.5m, <3m |
| 5 | High Vegetation, ≥3m, ≤60m |
| 6 | Building |
| 14 | Wire (conductor) |
| 7 | Low Noise |
| 17 | Bridge Deck |
| 18 | High Noise |
| 30 | Noise (manually classified) |

### Digital Surface Model

The DSM represents surface elevations, including heights of vegetation, buildings, powerlines, bridge decks, etc. The DSM is a single-band, 32-bit GeoTIFF file of 50-cm resolution. No Data value is set to -3.40282306074e+38 (32-bit, floating-point minimum).

### Digital Terrain Model

The DTM represents bare earth elevations, excluding vegetation, bridge decks, buildings, etc. The DTM is a single-band, 32-bit GeoTIFF file of 50-cm resolution. No Data value is set to -3.40282306074e+38.

### Lidar Intensity Image

The lidar intensity image describes the relative amplitude of reflected signals contributing to the point cloud. Lidar intensity is (1) primarily a function of scanned object reflectance in relation to the signal frequency, (2) dependent on ambient conditions, and (3) not necessarily consistent between separate scans. The intensity image is a single-band, 32-bit GeoTIFF file of 50-cm resolution. No Data value is set to -3.40282306074e+38.

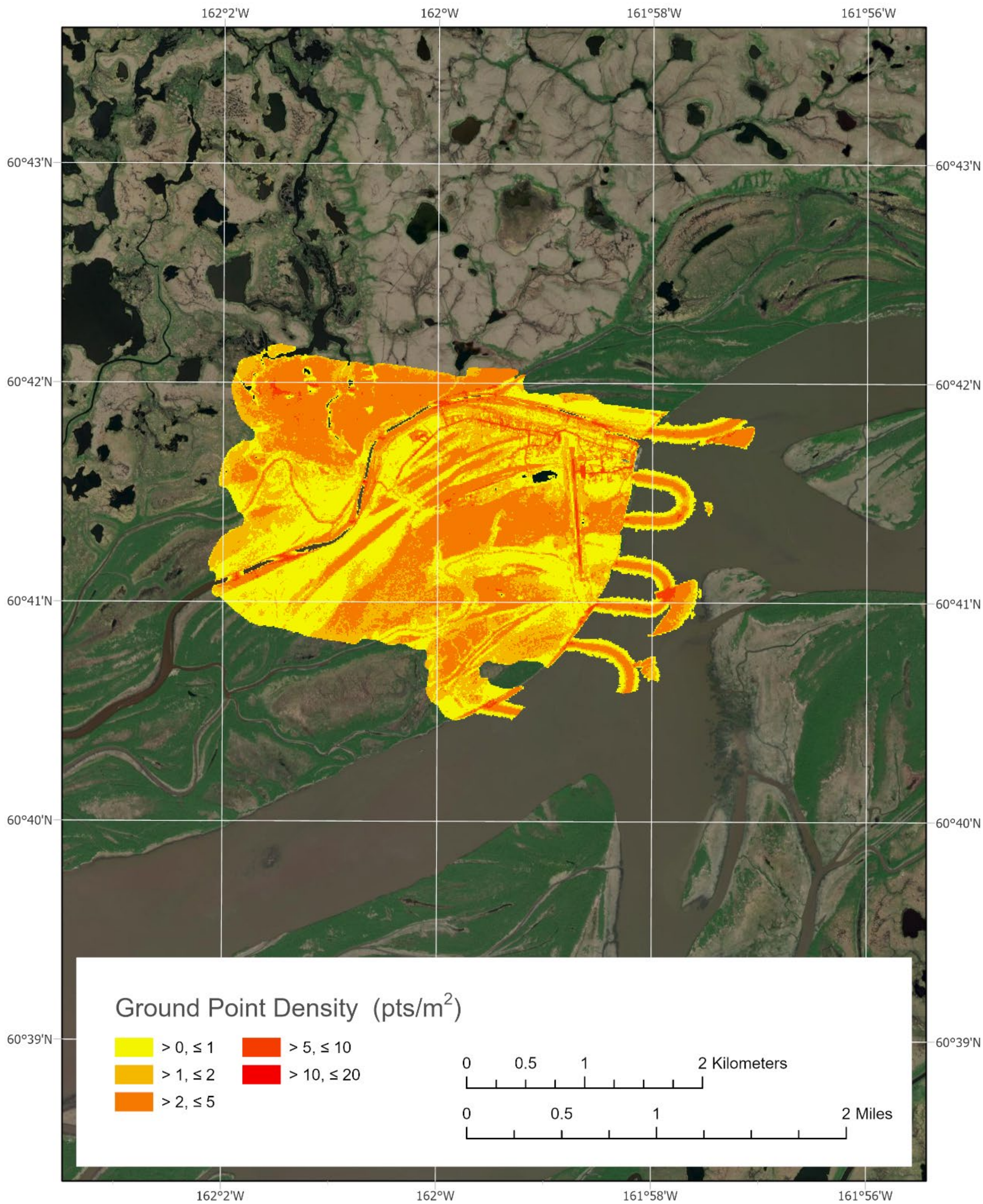


**Figure 2.** Ground point density for the survey displayed as a raster.

## SURVEY REPORT

### Ground Survey Details

Ground control points were collected on October 8, 2020. We deployed a base Trimble R10 GNSS receiver to provide a base station occupation and real-time kinematic (RTK) corrections to points we surveyed with a rover Trimble R10 GNSS receiver/Mesa3 controller. Napakiak Airport served as the base station location (cover figure). We collected 92 ground control points and checkpoints to use for calibration and to assess the vertical accuracy of the point cloud. Checkpoints were collected on bare earth and in vegetation.

### Coordinate System and Datum

We processed and delivered all data in NAD83 (2011) UTM4N and vertical datum NAVD88 GEOID12B.

### Horizontal Accuracy

Horizontal accuracy was not measured for this collection.

### Vertical Accuracy

We measured a mean offset of -1.45 m between 62 control points and the point cloud (app. 1). This offset was reduced to -0.7 cm in non-vegetated areas (app. 2) and +18.4 cm in vegetated areas (app. 3) by applying a constant vertical correction to the lidar point data. We used 17 checkpoints to determine the non-vegetated vertical accuracy of the point cloud ground class using a Triangulated Irregular Network (TIN) approach. The project's non-vegetated vertical accuracy has a root mean square error (RMSE) of 7.1 cm (app. 2). Thirteen additional checkpoints were used to calculate the vegetated vertical accuracy, which has an RMSE of 22.2 cm (app. 3). We evaluated the relative accuracy for this dataset as the interswath overlap consistency and measured it at 5.8 cm RMSE.

### Data Consistency and Completeness

This is a full-release dataset. There was no over-collect. Data quality is consistent throughout the survey.

## ACKNOWLEDGMENTS

This survey area is on the traditional homelands of the Yup'ik people. This work was funded by the National Coastal Resilience Fund and collected and processed by DGGS. We thank Clearwater Air for their aviation expertise and contribution to these data products. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

## REFERENCES

The American Society for Photogrammetry & Remote Sensing (ASPRS), 2019, LAS Specification 1.4 - R15. https://www.asprs.org/wp-content/uploads/2019/07/LAS_1_4_r15.pdf

## APPENDIX 1: GROUND CONTROL POINTS

| GCP | Easting (m) | Northing (m) | GCP Z (m) | Pointcloud Z (m) | Elevation Difference (Pointcloud Z – GCP Z) (m) |
|---|---|---|---|---|---|
| 1 | 337457.151 | 6732336.492 | 4.751 | 3.318 | -1.433 |
| 2 | 337461.836 | 6732343.462 | 4.635 | 3.200 | -1.435 |
| 3 | 337463.708 | 6732351.032 | 4.529 | 3.100 | -1.429 |
| 4 | 337472.225 | 6732394.118 | 4.290 | 2.864 | -1.426 |
| 5 | 337475.464 | 6732439.412 | 3.987 | 2.589 | -1.398 |
| 6 | 337459.808 | 6732478.306 | 3.849 | 2.398 | -1.451 |
| 7 | 337427.162 | 6732540.571 | 4.312 | 2.801 | -1.511 |
| 8 | 337371.462 | 6732641.711 | 3.652 | 2.213 | -1.439 |
| 9 | 337261.336 | 6732648.501 | 3.860 | 2.352 | -1.508 |
| 10 | 337208.847 | 6732594.881 | 4.299 | 2.796 | -1.503 |
| 11 | 337191.591 | 6732576.410 | 4.428 | 2.897 | -1.531 |
| 12 | 337070.821 | 6732546.438 | 4.762 | 3.309 | -1.453 |
| 13 | 337028.978 | 6732548.396 | 4.727 | 3.274 | -1.453 |
| 14 | 336968.044 | 6732535.408 | 4.557 | 3.106 | -1.451 |
| 15 | 336905.612 | 6732509.893 | 4.403 | 3.005 | -1.398 |
| 16 | 337002.490 | 6732620.282 | 4.517 | 3.021 | -1.496 |
| 17 | 337006.063 | 6732680.424 | 4.463 | 3.020 | -1.443 |
| 18 | 336941.986 | 6732689.039 | 4.565 | 3.140 | -1.425 |
| 19 | 336895.795 | 6732699.286 | 4.675 | 3.259 | -1.416 |
| 20 | 336649.960 | 6732768.326 | 4.393 | 2.936 | -1.457 |
| 21 | 336548.171 | 6732797.576 | 4.529 | 3.098 | -1.431 |
| 22 | 336388.829 | 6732770.170 | 4.326 | 2.889 | -1.437 |
| 23 | 336314.221 | 6732743.774 | 4.166 | 2.718 | -1.448 |
| 24 | 336269.999 | 6732908.793 | 1.685 | 0.284 | -1.401 |
| 25 | 336265.294 | 6732848.007 | 3.341 | 1.933 | -1.408 |
| 26 | 336242.012 | 6732717.502 | 4.175 | 2.749 | -1.426 |
| 27 | 336161.398 | 6732643.628 | 4.093 | 2.676 | -1.417 |
| 28 | 336095.478 | 6732672.480 | 4.290 | 2.859 | -1.431 |
| 29 | 336098.109 | 6732629.333 | 4.126 | 2.717 | -1.409 |
| 30 | 336126.030 | 6732610.863 | 4.157 | 2.705 | -1.452 |
| 31 | 335959.463 | 6732459.436 | 4.202 | 2.866 | -1.336 |
| 32 | 337073.893 | 6732669.944 | 4.265 | 2.778 | -1.487 |
| 33 | 337155.793 | 6732645.687 | 4.187 | 2.711 | -1.476 |
| 34 | 337231.609 | 6732650.186 | 3.937 | 2.493 | -1.444 |

| | | | | | |
|---|---|---|---|---|---|
| 35 | 337558.554 | 6732550.148 | 4.492 | 3.003 | -1.489 |
| 36 | 337598.159 | 6732532.176 | 4.415 | 2.916 | -1.499 |
| 37 | 337661.816 | 6732511.547 | 3.946 | 2.463 | -1.483 |
| 38 | 337782.324 | 6732482.495 | 4.102 | 2.626 | -1.476 |
| 39 | 337468.852 | 6732308.424 | 4.556 | 3.151 | -1.405 |
| 40 | 337498.021 | 6732298.416 | 4.061 | 2.639 | -1.422 |
| 41 | 337537.211 | 6732298.447 | 3.988 | 2.549 | -1.439 |
| 42 | 337570.264 | 6732298.548 | 3.986 | 2.560 | -1.426 |
| 43 | 337643.605 | 6732297.796 | 3.701 | 2.267 | -1.434 |
| 44 | 337671.391 | 6732300.528 | 3.538 | 2.111 | -1.427 |
| 45 | 337698.027 | 6732299.226 | 3.624 | 2.206 | -1.418 |
| 46 | 337736.711 | 6732308.168 | 3.643 | 2.200 | -1.443 |
| 47 | 337819.662 | 6732332.999 | 3.720 | 2.277 | -1.443 |
| 48 | 337865.144 | 6732339.159 | 3.738 | 1.949 | -1.789 |
| 49 | 337790.105 | 6732456.544 | 4.204 | 2.764 | -1.440 |
| 50 | 337621.407 | 6732441.592 | 3.863 | 2.391 | -1.472 |
| 51 | 337613.341 | 6732389.971 | 4.149 | 2.669 | -1.480 |
| 52 | 337620.823 | 6732328.529 | 4.093 | 2.639 | -1.454 |
| 53 | 337462.301 | 6732277.848 | 4.685 | 3.245 | -1.440 |
| 54 | 337406.965 | 6732308.149 | 4.481 | 3.051 | -1.430 |
| 55 | 337380.506 | 6732264.169 | 4.901 | 3.480 | -1.421 |
| 56 | 337381.081 | 6732198.682 | 4.901 | 3.540 | -1.361 |
| 57 | 337384.382 | 6732081.999 | 4.740 | 3.345 | -1.395 |
| 58 | 337387.915 | 6731893.606 | 4.415 | 2.866 | -1.549 |
| 59 | 337387.171 | 6731818.552 | 4.633 | 3.130 | -1.503 |
| 60 | 337390.548 | 6731734.238 | 4.693 | 3.224 | -1.469 |
| 61 | 337394.447 | 6731618.294 | 4.817 | 3.356 | -1.461 |
| 62 | 337400.680 | 6731402.538 | 3.074 | 1.715 | -1.359 |
| | | | | | |
| **Average elevation difference (dZ) (m)** | -1.450 | | | | |
| **Minimum dZ (m)** | -1.789 | | | | |
| **Maximum dZ (m)** | -1.336 | | | | |
| **Average magnitude error (m)** | 1.450 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Root mean square error (m)** | 1.451 | | | | |
| **Standard deviation (m)** | 0.059 | | | | |

## APPENDIX 2: NON-VEGETATED CHECK POINTS

| Check Point | Easting (m) | Northing (m) | Checkpoint Z (m) | Corrected Pointcloud Z (m) | Elevation Difference (Corrected Pointcloud Z -–Checkpoint Z) (m) |
|---|---|---|---|---|---|
| 1 | 337470.693 | 6732333.177 | 4.634 | 4.520 | -0.114 |
| 2 | 337465.210 | 6732367.219 | 4.426 | 4.405 | -0.021 |
| 3 | 337430.709 | 6732591.868 | 3.737 | 3.852 | 0.115 |
| 4 | 337153.142 | 6732552.922 | 4.687 | 4.664 | -0.023 |
| 5 | 337006.545 | 6732555.496 | 4.476 | 4.274 | -0.202 |
| 6 | 336775.943 | 6732732.654 | 4.549 | 4.530 | -0.019 |
| 7 | 336294.608 | 6732813.809 | 4.167 | 4.179 | 0.012 |
| 8 | 336120.920 | 6732674.424 | 4.194 | 4.209 | 0.015 |
| 9 | 336045.235 | 6732538.084 | 4.137 | 4.210 | 0.073 |
| 10 | 337459.582 | 6732588.901 | 3.961 | 3.952 | -0.009 |
| 11 | 337872.686 | 6732446.831 | 4.077 | 4.052 | -0.025 |
| 12 | 337622.586 | 6732298.733 | 3.999 | 3.998 | -0.001 |
| 13 | 337781.728 | 6732322.000 | 3.571 | 3.566 | -0.005 |
| 14 | 337652.678 | 6732474.247 | 3.784 | 3.730 | -0.054 |
| 15 | 337437.837 | 6732281.675 | 4.658 | 4.726 | 0.068 |
| 16 | 337386.112 | 6731979.942 | 4.604 | 4.619 | 0.015 |
| 17 | 337394.174 | 6731474.577 | 4.657 | 4.708 | 0.051 |
| | | | | | |
| **Average elevation difference (dZ) (m)** | -0.007 | | | | |
| **Minimum dZ (m)** | -0.202 | | | | |
| **Maximum dZ (m)** | 0.115 | | | | |
| **Average magnitude error (m)** | 0.048 | | | | |
| **Root mean square error (m)** | 0.071 | | | | |
| **Standard deviation (m)** | 0.073 | | | | |

## APPENDIX 3: VEGETATED CHECK POINTS

| Check Point | Easting (m) | Northing (m) | Checkpoint Z (m) | Corrected Pointcloud Z (m) | Elevation Difference (Corrected Pointcloud Z -–Checkpoint Z) (m) |
|---|---|---|---|---|---|
| 1 | 337451.405 | 6731383.446 | 2.928 | 3.119 | 0.191 |
| 2 | 337459.470 | 6731358.161 | 2.924 | 3.418 | 0.494 |
| 3 | 337474.513 | 6731334.907 | 2.841 | 3.098 | 0.257 |
| 4 | 337471.822 | 6731255.128 | 2.796 | 3.098 | 0.302 |
| 5 | 337507.380 | 6731225.621 | 2.639 | 2.806 | 0.167 |
| 6 | 337521.924 | 6731212.086 | 2.785 | 2.875 | 0.090 |
| 7 | 337464.715 | 6731286.744 | 2.915 | 3.025 | 0.110 |
| 8 | 337466.654 | 6731329.597 | 3.056 | 3.111 | 0.055 |
| 9 | 337444.772 | 6731464.351 | 2.955 | 2.962 | 0.007 |
| 10 | 337454.503 | 6731537.831 | 2.912 | 2.978 | 0.066 |
| 11 | 337449.351 | 6731567.251 | 3.087 | 3.330 | 0.243 |
| 12 | 337446.712 | 6731631.632 | 3.315 | 3.546 | 0.231 |
| 13 | 337433.780 | 6731782.038 | 2.794 | 2.975 | 0.181 |
| | | | | | |
| **Average elevation difference (dZ) (m)** | 0.184 | | | | |
| **Minimum dZ (m)** | 0.007 | | | | |
| **Maximum dZ (m)** | 0.494 | | | | |
| **Average magnitude error (m)** | 0.184 | | | | |
| **Root mean square error (m)** | 0.222 | | | | |
| **Standard deviation (m)** | 0.128 | | | | |