

Scottish National LiDAR Delivery Report

Block: NK00_NK05

Prepared for: Scottish Government

Prepared by: Bluesky International Ltd.

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Project Number: QT_112680_1



Location and Purpose of Survey

This project specifies the provision of aerial LiDAR across all of Scotland. This delivery refers to blocks NK00_NK05 and is highlighted in the figure below.

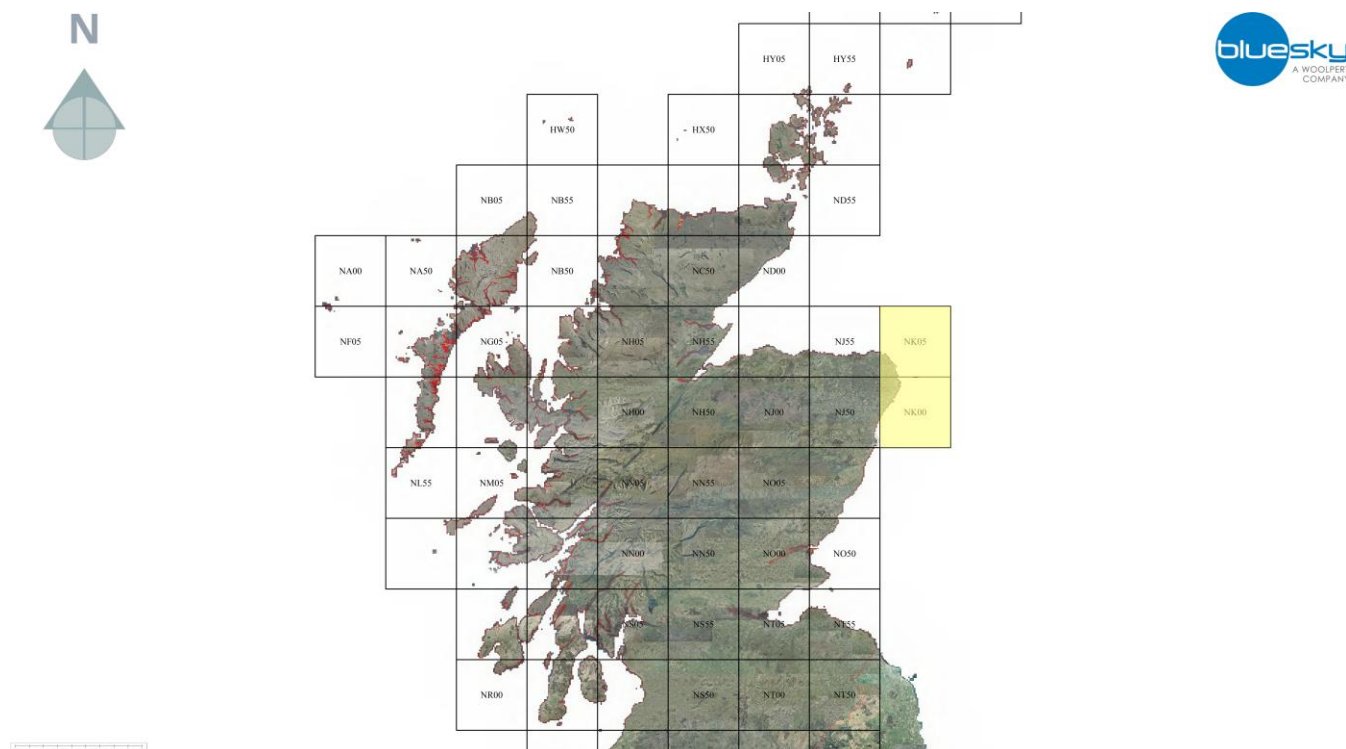


Figure 1: Overview of block areas for National LiDAR Survey Scotland.

Data Capture

LiDAR data was acquired using a Leica Terrain Mapper scanner with an integrated Hyperion 2+ LiDAR unit. Scanner settings and flying height were optimized to meet the required specification for a minimum of 10 laser measurements per meter and an absolute vertical accuracy of 15cm or better.

Table 1: Typical flight-plan settings for aerial survey.

LiDAR Scanner	Leica Hyperion 2+ Terrain Mapper
Approximate Flying Altitude	2130m AMSL
Approximate Flying Speed	140 – 160 Knots
Pulse Repetition Frequency	1.92 GHz
Scan Rate	150Hz
Scan Pattern	Circle
Scanner Field of View	30.5 Degrees

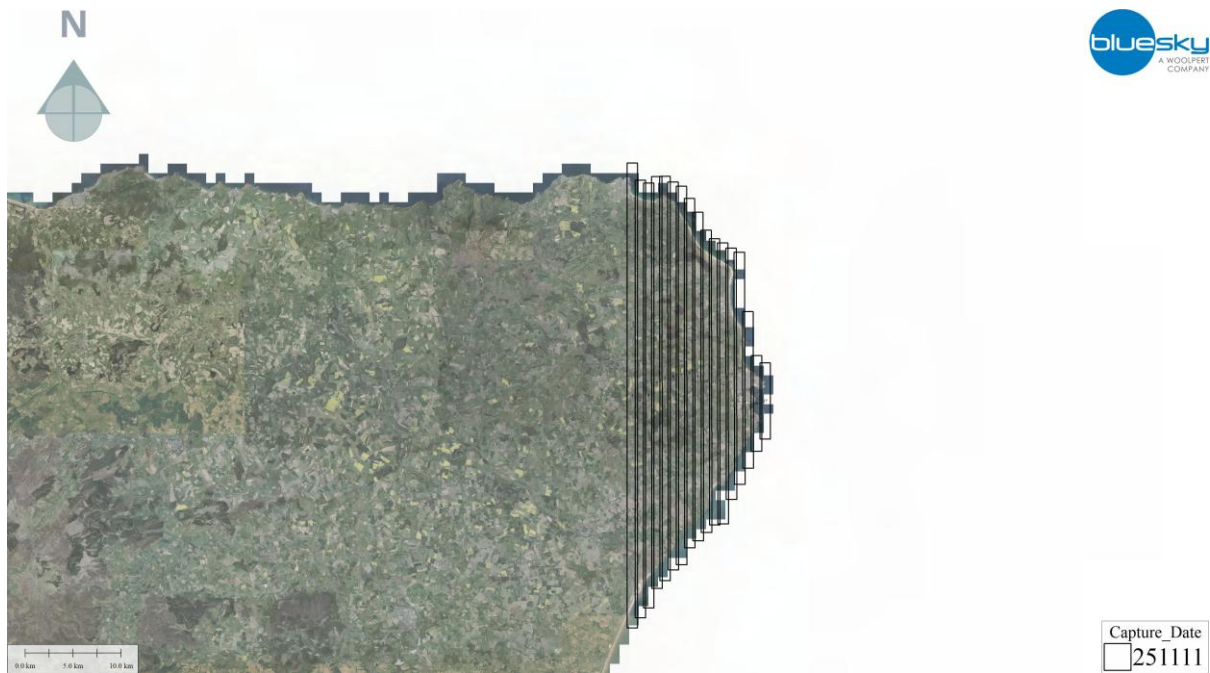


Figure 2: Date of capture YYMMDD and associated footprints

Data Processing

On completion of operations all data was transferred to the Bluesky Ashby office for data processing. Raw flight data was processed using the following methods. Data was output to coordinate system: **British National Grid (EPSG 27700) Ordnance Datum Newlyn (ODN)** using **OSTN15/OSGM15**. (note: OSGM15 incorporates local datums such as Stornoway, Lerwick and Newlyn, Orkney)

Initial Trajectory Processing

The initial flight trajectory was processed using **Waypoint Inertial Explorer 10.0**. This software processed GNSS recordings made in-flight against nearby ground measurement from continually operating reference stations. Processed GNSS values are coupled with inertial measurements recorded by the scanner IMU which in turn provides an accurate reported aircraft position and orientation at a rate of 500Hz.

LiDAR Processing

Leica HxMap Workflow Manager 4.5 was used to combine the processed trajectory created in the previous step with raw laser range data recorded from the scanner. This created an accurate geo-referenced three-dimensional point cloud that was output in LiDAR Data Exchange Format (LAS). Raw data was refined using the LiDAR matching tool within the software. Quality control of LiDAR point cloud data was carried out using **Bentley Microstation Connect** with **TerraSolid v25**. LiDAR data was checked for coverage, point density and relative/absolute accuracy.

Ground Control

Ground control sites for LiDAR verification were chosen roughly every 20 square kilometres. Repeat measurements within a 5m x 5m grid from a hard surface was used to determine vertical alignment to LiDAR point cloud data. Clear surface features such as road markings were used to determine values of horizontal alignment from easily identifiable intensity values in LiDAR and RGB imagery.

The suitability of sites was determined on the following factors:

Accessibility – Only publicly accessible areas were chosen.

Safety – Sites were away from areas of high traffic.

Hard consistent surfaces – Sealed minor roads away from dense vegetation.

Feature Markings – Where available distinguishable features such as road markings were chosen.

The average residual vertical error at each control site was applied to the LiDAR point cloud. If an adjacent finalised processing block was present, hard surface vertical offsets were calculated from block boundaries and applied to the data to ensure seamless matching.

LiDAR Classification

TerraSolid v25 was used to classify the point cloud. Spurious data points that appeared at anomalous elevations above and below the model were classified out of the dataset. An automated ground classification macro was then run to delineate the difference between ground and non-ground features. The iteration angle of the macro was adjusted accordingly to better identify features such as drainage ditches and local embankments. The classified ground model was then manually checked for any errors.

The LiDAR point cloud was manually classified into the following classes.

Table 2: LiDAR data has been classified to the following feature codes.

Class	Description
1	Default (Unclassified)
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
9	Water

DTM/DSM Generation

The LAS files were converted to raster DEMS using the following methods:

All terrain classes were converted to a TIN model and then sampled at a regular interval to produce the digital terrain models. The highest elevation value from all classes (except noise and water) were sampled at a fixed interval and used to produce the digital surface models.

Hydro-breaklines were digitized around large water bodies in **Bentley Microstation Connect** and used to remove large bodies of water in the DEM where irregular interpolation from sparse LiDAR hits occurs. For large inland water bodies, these were replaced by flattened points to provide a smooth water surface in the DEMs. As seawater heights vary, these areas were replaced with no-data.

Quality Checks – Point Density

Point Density

A point density raster map for the survey area is displayed below. The colours in the legend refer to the average number of measurements per meter recorded in the raw LiDAR data. The map was generated by rasterizing the average points per meter within a 5m x 5m cell outputting an ASCII grid of point density values. These values were then verified to check data exceeded 10 points per meter. As per client specification, only first returns were used for this analysis and excess points in areas of flightline overlap removed. Areas of low returns reflect water bodies where the laser is typically absorbed.

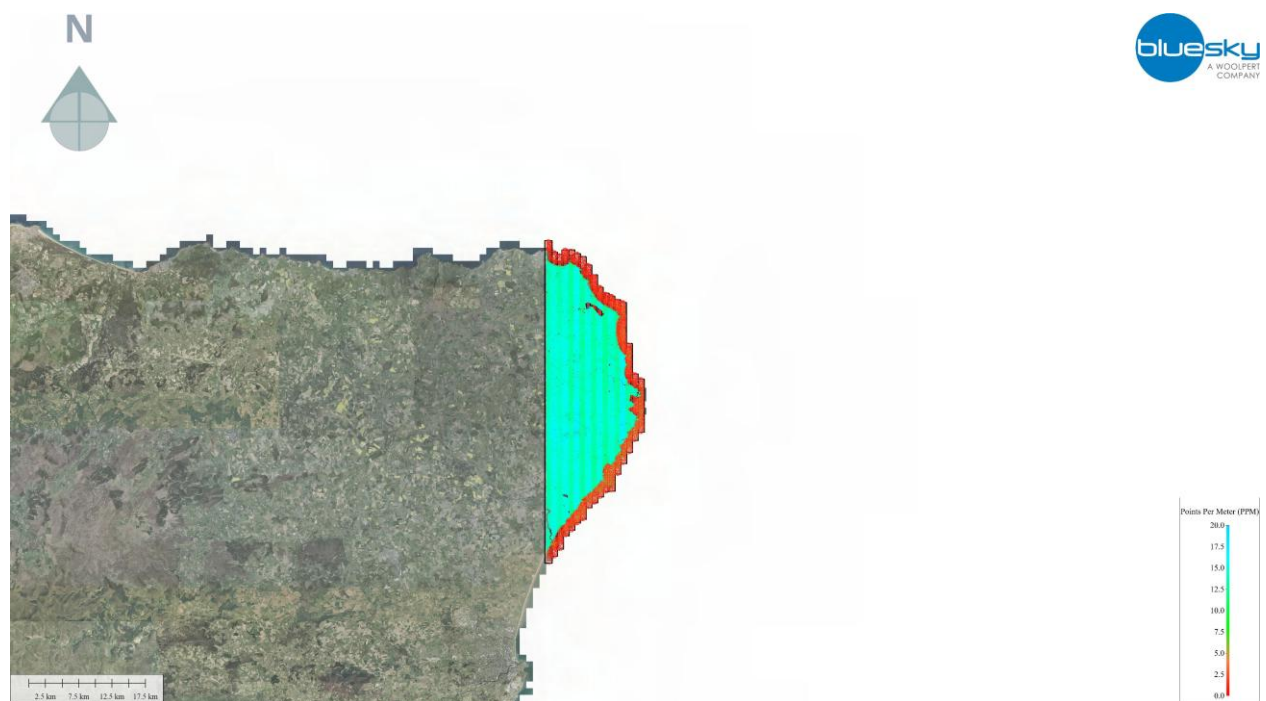


Figure 3: LiDAR point density map of survey area. The colours in the legend refer to the average number of measurements per meter recorded in the raw LiDAR data. The average point density exceeds 10 points per meter.

Quality Checks – Accuracy

Relative accuracy

A map showing relative alignment within the survey area is displayed below. The colours in the legend refer to the relative alignment between individual flight-strips. The tool lasoverlap within the LAsTools software suite was used to output a PNG grid of average flight-line overlap, a cell size of 5m x 5m was used. All records from hard surfaces are reporting misalignment values lower than 0.05m.

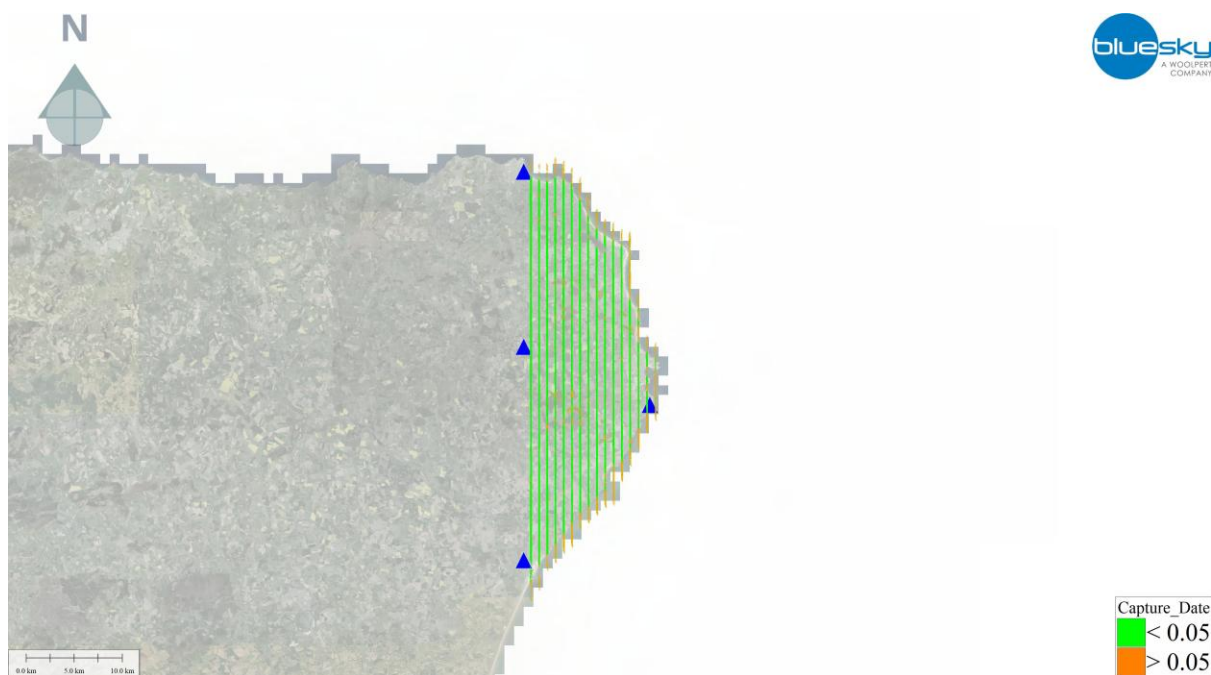


Figure 4: LiDAR Flightline Dz Map of survey area The colors in the legend refer to the relative alignment between individual flight-strips. All records from hard surfaces are reporting misalignment values lower than 0.05m. Blue triangles refer to location of ground control sites.

Absolute accuracy

The ground control sites for this block are represented by the blue triangles in the above figure. Control height was compared against elevation values in the LiDAR point cloud. XY positions were determined from GCPs surveyed on bright objects such as road markings. These can be verified against high intensity values in the LiDAR point cloud. Due to the point spacing of the dataset the positional accuracy cannot be determined to a high precision however visual checks indicated strong positional correlation between the control. Location analysis results of the GCPs against the LiDAR point cloud data are shown below:

Table 3: Dz RMS results from ground control against LiDAR elevation values from road surface. 392 control points were used in this analysis.

Measurement (Laser to Ground Control)	Value (m)
Average dz	-0.003
Minimum dz	-0.052
Maximum dz	0.115
Average Magnitude	0.014
Std Deviation	0.019
Root Mean Square	0.020

Final Deliverables

Final deliverables for this project are listed in the table below. All data has been provided in **British National Grid (EPSG 27700) Ordnance Datum Newlyn (ODN)** using **OSTN15/OSGM15**. (note: OSGM15 incorporates local datums such as Stornoway, Lerwick and Newlyn, Orkney). A tile index, quality control rasters and LASTools metadata output was provided for all the deliverables.

Table 4: Final Deliverables with associated file type. All deliverables have been transformed from ETRS89 to British National Grid using OSTN15 / OSGM15. If a product has an associated projection/world file it will be grouped as one file. As seawater is removed from the DTM/DSM but not LAZ, total file sizes may not match between the two.

Product	File Type	Area	Files
Classified LAZ	LAZ 1.4	Tiled 1km ²	508
Digital Terrain Model	Cloud Optimized Geotiff	Tiled 1km ²	425
Digital Surface Model	Cloud Optimized Geotiff	Tiled 1km ²	429
Tile Index	Shapefile	AOI	1
QC Files - Meta Report/ LASInfo	txt	Tiled 1km ²	508
QC Files Ground only - Meta Report/ LASInfo	txt	Tiled 1km ²	425
QC Files - Point_Density_Rasters	ASCII Grid	Tiled 1km ²	508
QC Files - Flightline Dz Files	PNG	Tiled 1km ²	508

The total file size for the delivery is below:

Delivery NK00_NK05 – 30/04/2026: 54,109,892,614 bytes