

PGF Version: New Zealand National Aerial LiDAR Base Specification

Land Information New Zealand

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Table of Content

Version History	3
Abbreviations	3
Foreword	5
Purpose and Summary	5
Background	5
Acknowledgements	5
References	6
1 Scope	7
1.1 Mandatory deliverables	7
1.2 Accuracy and pulse density	7
2 Intended use of standard	8
3 Copyright and Creative Commons	8
4 Exceptions to requirements	8
5 Collection	8
5.1 Collection area	8
5.2 Quality level	9
5.3 Multiple discrete returns	9
5.4 Intensity values	9
5.5 Data voids	9
5.6 Collection conditions	10
6 Data Processing and Handling	10
6.1 The ASPRS LAS file format	10
6.2 Time stamp of navigational data	10
6.3 Datums and coordinate reference system	12
6.4 Positional accuracy validation	12
6.4.1 Relative Vertical Accuracy	12
6.4.2 Check Sites	13
6.4.3 Local Accuracy	13
6.5 Use of the LAS withheld flag	14
6.6 Use of the LAS v1.4 Overlap Flag	14
6.7 Point Classification	14
6.8 Classification Accuracy	15
6.9 Classification Consistency	15
7 Hydro-Flattening	17
8 Deliverables	19
8.1 Reporting and metadata	19

8.1.1	Project reports	19
8.1.2	Extents	19
8.1.3	Flight lines	20
8.2	Classified point cloud tiles	20
8.3	Elevation models	21
8.3.1	Bare-Earth Digital Elevation Model (DEM)	21
8.3.2	Digital Surface Model (DSM)	22
8.4	Breaklines	22
8.5	GNSS data	22
8.6	Backed up project source data	22
9	Tiles	22
9.1	Tiling and delivery	22
9.2	File naming	23

Version History

Version and Date	Description
May 2019	Base specification modified for PGF project and presented to regional partners
July 2019	Specific vegetation thresholds and snow cover guidance added
December 2019	Further clarification added for Withheld Flag, Overlap Flag, and GNSS data

Abbreviations

For the purposes of this specification, the following abbreviations are used.

Abbreviation	Meaning
2D	two-dimensional
3D	three-dimensional
ANPD	aggregate nominal pulse density
ANPS	aggregate nominal pulse spacing
ASPRS	American Society for Photogrammetry and Remote Sensing
DEM	digital elevation model
DSM	digital surface model
DTM	digital terrain model
GIS	geographic information system
GNSS	global navigation satellite system
GPS	global positioning system
HA	horizontal accuracy
LAS	LAS file format (.las)

LiDAR	light detection and ranging
NVA	Non-vegetated vertical accuracy
RMSD	root mean square difference
RMSDz	root mean square difference in the z direction (elevation)
RMSE	root mean square error

Foreword

Purpose and Summary

This is a modified version of the New Zealand National Aerial LiDAR Base Specification v1.1 (Reference 12) and provides further clarity and specific requirements to support the PGF-LiDAR programme. Modified sections are highlighted yellow. All changes are in the interest of removing ambiguity, defining a standard product, and emphasising commonly missed details. The only additional requirement beyond Reference 12 is for the classification of vegetation and buildings.

This specification provides a foundation for New Zealand public sector airborne linear mode light detection and ranging (LiDAR) data procurement. It defines a consistent set of minimum products to ensure compatibility across projects and regions. Using this specification in procurement processes will ensure that high quality LiDAR point cloud data and digital elevation models (DEMs) are gathered when it is commissioned. It will also allow for the Land Information New Zealand (LINZ) led National Elevation Programme to facilitate easier discovery and access through central data management. Data captured under this specification will contribute to the National Elevation Model consisting of a bare earth DEM, a digital surface model (DSM), and the corresponding classified point cloud.

This specification is intended to be referenced in procurement contracts but is not a procurement template. Additional deliverables and higher standards may be required by the procuring agency (Contract Authority) which should be specified in the contract. The *New Zealand Aerial LiDAR Procurement Guide* (Reference 1) provides a template and information to help organisations to commission aerial LiDAR data work.

Background

Reference 12 is based on the US Geological Survey *LiDAR Base Specification* (Reference 2) and the Intergovernmental Committee on Surveying and Mapping (ICSM) *LiDAR Acquisition Specifications and Tender Template* (Reference 3). It was developed for use primarily by the New Zealand public sector in support of the National Elevation Programme by a Technical Working Group representing local government, central government, Crown Research Institutes, LiDAR data providers and industry.

This aim of developing Reference 12 was to ensure that when public sector organisations commission LiDAR, the data gathered will meet minimum requirements which will allow LINZ to host consistent data and provide on-line access.

Reference 12 provides some flexibility in the expectation for compliant data. This can result in rework required by LINZ prior to making the data accessible. This specification removes some of this flexibility by explicitly stating requirements where Reference 12 provides options.

Acknowledgements

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LINZ:

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References

1. New Zealand Aerial LiDAR Procurement Guide, Land information New Zealand, 2016
2. LiDAR Base Specification version 1.2, United States Geological Survey, November 2014
3. LiDAR Acquisition Specifications and Tender Template New Zealand Version 1.0, Intergovernmental Committee on Surveying and Mapping, September 2011
4. Standard for the Geospatial Accuracy Framework – LINZS25005, Land Information New Zealand, September 2009
5. LAS Specification version 1.4, American Society for Photogrammetry and Remote Sensing, November 2011
6. LAS Specification version 1.2, American Society for Photogrammetry and Remote Sensing, September 2008
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8. Standard for New Zealand Geodetic Datum 2000 - LINZS25000, Land Information New Zealand, September 2009
9. LINZS25009: Standard for New Zealand Vertical Datum 2016 - LINZS25009, Land Information New Zealand, June 2016
10. Standard for New Zealand Geodetic Datum 2000 Projections: Version 2 - LINZS25002, Land Information New Zealand, July 2008
11. Positional Accuracy Standards for Digital Geospatial Data, American Society for Photogrammetry and Remote Sensing, 2014
12. New Zealand Aerial LiDAR Base Specification v1.1, Land information New Zealand, 2018

1 Scope

1.1 Mandatory deliverables

The following deliverables are required for the National Elevation Programme in standard specified formats as detailed in Section 8 - Deliverables:

- (a) 1m gridded bare earth digital elevation model (DEM) and digital surface model (DSM) elevation models (New Zealand Transverse Mercator 2000 (NZTM2000), New Zealand Vertical Datum 2016 (NZVD2016))
- (b) Classified point cloud (.las file format (LAS), NZTM2000, NZVD2016)
- (c) Breaklines for hydroflattened features (NZTM2000)
- (d) Project reports.

1.2 Accuracy and pulse density

The minimum accuracy and pulse density required for the National Elevation Programme are as follows:

- (a) Vertical Accuracy (95%) ≤ 20 cm
- (b) Horizontal Accuracy (95%) ≤ 100 cm
- (c) Pulse density ≥ 2 pls/m².

A Contract Authority may specify more stringent criteria than identified in this section.

Accuracy

Accuracy, as used in this document, refers to local accuracy and is the uncertainty of the bare-earth point cloud and DEM relative to 4th order or better control. See the Standard for Geospatial Accuracy Framework (Reference 4) for accuracy related definitions.

95% confidence interval

The 95% confidence interval is used for stating positional accuracy requirements in this document and means that 95% of the population distribution is contained in the confidence interval. LiDAR specifications and procurement requirements often refer to one-sigma (σ) positional accuracy meaning that 68.27% of the population distribution is contained in the confidence interval. The 95% confidence requirements stated in this document are 1.96 times the one sigma requirement; that is +/-20cm (95%) is equal to +/-10cm (σ or root mean square error (RMSE)).

2 Intended use of standard

This specification is applicable to LiDAR data and deliverables to be used by the National Elevation Programme. It is a requirement for data collection supported with financial or in-kind contributions for the National Elevation Programme.

The National Elevation Programme is a New Zealand partnership programme managed by LINZ which seeks to maximise the amount of LiDAR data available for re-use. LiDAR may be commissioned by LINZ or other Contract Authorities including other central government agencies, local councils, and private sector businesses.

This specification applies to traditional linear mode airborne LiDAR data capture, and it is not directly applicable to newer technologies such as single photon or Geiger mode LiDAR.

3 Copyright and Creative Commons

The Contract Authority requires unrestricted copyright to all delivered data and reports, allowing it to release data for widespread re-use with a Creative Commons license (CC BY) with attribution to the Contract Authority in line with the New Zealand Government Open Access Licensing framework (NZGOAL). This specification places no restrictions on the rights of the data provider to resell data or derivative products.

4 Exceptions to requirements

Any exceptions to these requirements are understood to be by the Contract Authority with agreement of those contributing funding or in-kind support to the applicable dataset. This includes LINZ if it is hosting the data.

Vendors and Contract Authorities are encouraged to contact LINZ to discuss any proposed exceptions in the applicable Request For Proposal (RFP) or project contract. In the event of conflict, the relevant procurement contract takes precedence over this specification.

This specification sets the minimum requirements for the National Elevation Programme. Additional deliverables and more stringent criteria may be added by the Contract Authority in procurement documents.

Technical alternatives, for any given collection, that enhance the data or associated products are encouraged and may be submitted with any tender response. Alternatives will be considered by the Contract Authority and LINZ.

5 Collection

5.1 Collection area

The project extent is specified as tiles. These are expected to be delivered as complete tiles over land – no missing data. The project must be adequately buffered to avoid edge effects and safeguard against missing data, including to ensure the complete capture of shorelines and all land exposed during the tidal data collection window. Data does not need to be collected over water, but specific requirements apply to the delivery of the raster products (DEM and DSM).

- Where these tiles are over land, they must be delivered as complete tiles, ie real data in every 1m x 1m cell.

- Where the tiles cross water bodies, the water surface does not need to be captured with lidar, and the relevant cells may be filled with the “no data” value or hydroflattened. If the AOI tile index includes tiles that are entirely over water, they do not need to be provided.

5.2 Quality level

The minimum acceptable point cloud quality level is per Table 1. Individual procurements may require better accuracy and greater pulse density, and the required accuracy and point density will be specified by the Contract Authority. The Contract Authority may also specify additional requirements such as scan angles and swath overlap depending on end user applications.

Table 1 – Minimum Point Cloud Quality Level

Non-vegetated Vertical Accuracy (95%)	≤20 cm
Horizontal Accuracy (95%)	≤100 cm
Aggregate Nominal Pulse Density (ANPD)	≥ 2pls/m ²

Pulse

A pulse of laser light emitted from the LiDAR instrument.

Point/return

A discrete point measured from the returning pulse to the LiDAR instrument. In vegetated areas there are often multiple points/returns per pulse.

Aggregate nominal pulse density (ANPD)

The total density of pulses (not points) recorded by the LiDAR instrument per specified unit area resulting from the aggregate of all collections such as overlap or multiple passes.

5.3 Multiple discrete returns

Collecting and delivering discrete returns (points) from the ground and surface features such as shrubs, buildings, and trees is required. The LiDAR system must be capable of recording at least three returns per pulse.

5.4 Intensity values

Intensity or reflectance values are required for each discrete return. **Note the requirement for normalised intensity values in section 8.2.**

5.5 Data voids

Data voids are gaps in the point cloud first return coverage, caused by problems including instrumentation failure, processing anomalies, surface non-reflectance and improper survey planning.

Data voids greater than or equal to 16/ANPD measured using first returns only are not acceptable (example: if ANPD is 2pls/m², then the maximum allowable data void is 8 m²), except in the following circumstances:

- (a) Where the data void is caused by water bodies.
- (b) Where the data void is caused by areas of low near infrared (NIR) reflectivity, such as asphalt or composition roofing.
- (c) Where the line of sight from the sensor to the ground is in the shadow of buildings, structures, vegetation and terrain features (as expected after accounting for the Contract Authority's requirements and the survey planning that formed the basis for flying altitudes, scan angles, overlap and other factors).

The Contract Authority may allow lower passing thresholds for this requirement in areas where larger data voids are deemed acceptable and do not compromise the quality of the dataset.

5.6 Collection conditions

LiDAR data must be collected when the following conditions are met:

- (a) Atmospheric conditions must be free of cloud, fog, heavy smoke and haze between the aircraft and ground during all collection operations.
- (b) Ground conditions must be free of snow (except for permanent snowfield/glaciers). For reference, these areas are mapped as 'Permanent Snow and Ice' in the Landcare Research Land Cover Database – Version 4.1.
- (c) Ground conditions must be free of extensive flooding or any other type of inundation. Floodplain/wetland data must be captured during times of base flow.
- (d) Surveys of the Coastal Marine Area must be flown within three hours either side of low tide to minimise the effect of standing water or wave action, unless other bounds are provided by the Contract Authority.

The Contract Authority may waive these requirements on a case by case basis. This must be in writing, and in advance of data collection.

6 Data Processing and Handling

6.1 The ASPRS LAS file format

Processing will be carried out with the understanding that all point deliverables are required to be fully compliant with **LAS Specification Version 1.4, using Point Data Record Format (PDF) 6, 7, 8, 9 or 10 (referred to as LAS v1.4)**.

6.2 Time stamp of navigational data

Each Global Navigation Satellite System (GNSS) aircraft positional measurement **must be time stamped using Adjusted Global Positioning System (GPS) Time**, at a precision sufficient to allow unique timestamps for each LiDAR pulse.

Adjusted GPS time is the satellite GPS time minus 1×10^9 .

6.3 Datums and coordinate reference system

The required datum for latitude, longitude, and ellipsoid heights is the New Zealand Geodetic Datum 2000 (NZGD2000) (Reference 8).

The required vertical datum for normal-orthometric heights is NZVD2016 (Reference 9). If a local vertical datum is requested by the Contract Authority then the relevant deliverables in this specification shall be supplied in both the local datum and NZVD2016.

Projected data products are to be delivered in NZTM2000 projection (Reference 10) with NZVD2016 normal-orthometric heights.

6.4 Positional accuracy validation

The Vendor is expected to apply best practice in assessing the project accuracy and achieving compliance with this specification.

Before classifying and developing derivative products from the point cloud, the relative vertical, local vertical and horizontal accuracies of the point cloud must be verified.

The Vendor must deliver a detailed report of the validation processes used.

6.4.1 Relative Vertical Accuracy

The relative vertical accuracy refers to the internal geometric quality of a LiDAR dataset, without regard to surveyed ground control. The minimum acceptable relative vertical accuracy needed to support the national minimum point cloud requirements (in Table 1 above) is included in Table 2.

Individual procurement contracts may require greater local vertical accuracy. In these cases, the Vendor is expected to ensure the relative vertical accuracy is sufficient.

Table 2 – Swath relative vertical accuracy requirements

	Variation
Smooth surface repeatability (intraswath, maximum)	≤6 cm
Swath overlap consistency (interswath, root mean square difference in the z direction (RMSDz))	≤8 cm
Swath overlap consistency (interswath, maximum)	≤16 cm

Smooth surface repeatability

A measure of variations documented on a surface that would be expected to be flat and without variation.

Overlap consistency

A measure of geometric alignment of two overlapping swaths. The principles used with swaths can be applied to overlapping flights and projects. Overlap consistency is the fundamental measure of the quality of the calibration or boresight adjustment of the data from each flight. This is of particular importance as the match between the swaths of a single flight is a strong indicator of the overall geometric quality of the data and establishes the quality and accuracy limits of all downstream data and products.

6.4.2 Check Sites

A check site is a surveyed array of points used to estimate the positional accuracy of a LiDAR dataset against an independent source of greater accuracy. Control points used in the calibration process for data acquisition must not be used as check sites.

Check sites must be an independent set of points used for the sole purpose of assessing the vertical and horizontal accuracy of the project. **Check sites may not be used for the calibration of data without approval from LINZ and the Contract Authority.**

Check sites must be:

- (a) uniformly distributed across the project area; and
- (b) surveyed to better than +/-5cm (95%) vertical and horizontal local accuracy relative to 4th Order or better control.

Where feasible, approximately half of the check sites should include features that can be used for horizontal accuracy assessment.

Table 3 provides the required number of check sites for vertical accuracy assessment as a function of the areal extent of the project, based on the recommendation in the ASPRS *Positional Accuracy Standards for Digital Geospatial Data* (Reference 11).

Table 3 – Required number of check sites based on area

Project area	Number of static 3D check sites in non-vegetated vertical accuracy (NVA) assessment
<100 km ²	As agreed by Contract Authority and Vendor
100 to 750 km ²	4 + 1 per additional 40 km ² over 100 km ²
750 to 2500 km ²	20+5 per additional 250 km ² over 750 km ²
> 2500 km ²	55+3 per additional 500 km ² over 2500 km ²

The Vendor is expected to apply best practice selecting and surveying check sites.

The Vendor must agree check site details including locations, array sizes and surface type with the Contract Authority.

6.4.3 Local Accuracy

The vendor is expected to apply best practice in assessing the project accuracy. Two local accuracy (Reference 4) values must be assessed and reported:

- (a) Non-vegetated Vertical Accuracy (NVA); and
- (b) Horizontal Accuracy (HA) for the point cloud.

The minimum NVA and HA for the point cloud are the Vertical and Horizontal Accuracies in Table 1 unless a higher level of accuracy is specified by the Contract Authority.

The NVA for the point cloud is assessed by comparing NZVD2016 elevations for check sites surveyed in clear, open, non-vegetated areas (which produce only single LiDAR returns) to the corresponding single return LiDAR point cloud.

The method for assessing HA must be documented in the project reporting.

If the unclassified point cloud does not comply with the required NVA or HA at any check site, it must be investigated, reported and discussed with the Contract Authority and LINZ before further classification and processing is carried out.

If the data is still not compliant with the required NVA or HA, options to consider include a re-survey of the check site if it is suspect, verification of the control points used for the check site and LiDAR survey, or a repeat LIDAR survey for the local area if this is determined to be the cause of significant non-compliance.

6.5 Use of the LAS withheld flag

Withheld flag - All data collected must be delivered in the classified point cloud. The use of the withheld flag ensures that the client receives all data collected (rather than the vendor simply deleting the points they consider "unusable"), while allowing the vendor to apply their best judgement in what to use for further classification. Withheld points are still included in the classified point cloud delivery. Any deletion of data prior to delivery requires council approval.

Outliers, noise points, geometrically unreliable points near the extreme edge of the swath, and other points the Vendor deems unusable must be identified using the Withheld Flag, as defined in the LAS Specification.

6.6 Use of the LAS v1.4 Overlap Flag

Overlap flag - If overlap/overage points are explicitly identified, this must be done using the overlap flag, not a classification number. Points flagged as overlap must still be delivered in the classified point cloud, and they must still be classified per the project classification requirements. This ensures classification of all points not withheld, including those treated as overlap or overage.

Identifying overage points is not required unless requested by the Contract Authority. However, if overage points are explicitly identified using LAS v1.4, they must be identified using the overlap flag.

(Note the term 'overlap' is incorrectly used in LAS v1.4 to describe the flag intended to identify overage points. In LAS v1.2/3, classification code '12' is used for overage.)

Overlap

Any part of a swath that also is covered by any part of any other swath.

Overage

A subset of overlap, meaning those parts of a swath that are not necessary to form a complete single, non-overlapped, gap-free coverage with respect to the adjacent swaths. In collections designed using multiple coverage, overage are the parts of the swath that are not necessary to form a complete non-overlapped coverage at the planned depth of coverage.

6.7 Point Classification

The minimum classification scheme required for LiDAR point clouds is listed in Table 4. Additional classes may be required for specific projects.

A point classification scheme must meet the following requirements:

- (a) All points not identified as Withheld must be processed for classification.
- (b) No points in the classified LAS point cloud deliverable can remain assigned to Class 0 (created but not processed for classification).
- (c) Overage points must only be identified using the Overlap Flag, as defined in the LAS v1.4.

Table 4 Minimum LAS point cloud classification scheme

Code	Description
1	Processed, but unclassified
2	Ground
3	Low vegetation <2m
4	Medium vegetation
5	High vegetation >8m
6	Building
7	Low noise
9	Water
18	High noise

6.8 Classification Accuracy

It is expected that automated classification will be used with further manual ground surface improvement to incorporate hydro-flattening and clean up poor automated classification results. Classification of returns shall be as complete as is feasible and without avoidable return misclassification.

Following classification processing:

- (a) no non-withheld points can remain in Class '0'; and
- (b) Within any 1km x 1km area, no more than two percent of non-withheld points can have demonstrable errors in the classification value (Classification Level 2 Reference 3).

In most circumstances, detailed visual inspections of individual classified scan line profiles and use of high quality reference imagery will be sufficient to independently demonstrate if classification standards have been achieved for the specified classes.

The Vendor must report on how classification accuracy is checked and assured.

The Contract Authority may relax these requirements to accommodate collections in areas where classification is particularly difficult.

6.9 Classification Consistency

Point classification must be consistent across the entire project. Noticeable variations in the character, texture, or quality of the classification between tiles, swaths, flights, or other unnatural divisions are grounds for rejection of the entire deliverable.

7 Hydro-Flattening

Hydro-flattening

The process of creating a LiDAR-derived DEM in which water surfaces appear as they would in traditional topographic DEMs created from photogrammetric digital terrain models (DTMs).

The use of breaklines is the predominant method used for hydro-flattening. The National Elevation Programme does not require that breaklines be used for flattening but does require the delivery of breaklines for all flattened water bodies and any other breaklines developed for each project.

Hydro-flattening will be performed in the local vertical datum specified by the Contract Authority. If no datum is identified, hydro-flattening must be performed in NZVD2016.

Converting data between local vertical datums and NZVD2016 is not simply achieved by applying a fixed offset value. As a result 'tilting' of hydro-flattened features may be present in data represented in a vertical datum that has not been used for the hydro-flattening. This is acceptable.

Vendors are expected to use professional judgement in how to best display the hydro-flattened features in other datums. The aim is to provide good cartographic appearance and not introduce errors that are propagated into derivative products such as contours.

Specific requirements that must be met for hydro-flattening are (including the minimum features for which breaklines must be collected and delivered):

- (a) Permanent islands 5,000 m² or larger must be delineated.
- (b) Inland ponds and lakes - water bodies of 10,000 m² (1 hectare) or greater surface area at the time of collection must be flattened.
 - (i) Flattened water bodies must present a flat and level water surface (a single elevation for every bank vertex defining the water body's perimeter, in the vertical datum used for hydro-flattening).
 - (ii) The entire water-surface edge must be at or below the immediately surrounding terrain (bottom of bank level or just above water strike).
 - (iii) Long impoundments such as reservoirs, inlets, and fjords, whose water-surface elevations decrease with downstream travel must be treated as streams or rivers.
- (c) Inland streams and rivers of ≥ 30 m nominal width (width of water flow in a single channel at time of capture) must be flattened. In most cases braided rivers will not be flattened and shingle beds treated as ground:
 - (i) Streams or rivers whose width varies above and below 30 m must not be broken into multiple segments; data producers will use their professional cartographic judgment to determine when a stream or river has attained a nominal 30m width.
 - (ii) Flattened streams and rivers must present a flat and level water surface bank-to-bank (perpendicular to the apparent flow centreline).
 - (iii) Flattened streams and rivers must present a gradient downhill water surface, following the immediately surrounding terrain.

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- (iv) In cases of sharp turns of rapidly moving water, where the natural water surface is notably not level bank-to-bank, the water surface must be represented as it exists while maintaining an aesthetic cartographic appearance.
 - (v) The entire water-surface edge must be at or below the immediately surrounding terrain.
 - (vi) Stream channels must break at culvert locations leaving the roadway over the culvert intact.
 - (vii) Streams must be continuous at bridge locations.
 - (viii) When the identification of a structure as a bridge or culvert cannot be made definitively, the feature must be regarded as a culvert.
- (d) Non-tidal boundary waters:
- (i) Boundary waters, regardless of size, must be represented only as an edge or edges within the project; collection does not include the opposite shore.
 - (ii) The entire water-surface edge must be at or below the immediately surrounding terrain.
 - (iii) The water-surface elevation must be consistent throughout the project.
 - (iv) The water surface must be flat and level, as appropriate for the type of water body (level for lakes, a gradient for streams and rivers).
 - (v) Any unusual changes in the water-surface elevation during the course of the collection (such as changes in upstream dam discharge) must be documented in the project metadata.
 - (vi) In the event of an unusual change in water-surface elevation, the water body shall be handled as described in 'Tidal Waters' below.
- (e) Tidal waters:

Tidal water bodies are defined as any water body that is affected by tidal or other variations in water level, including oceans, seas, gulfs, bays, inlets, estuaries, creeks, salt marshes, lower reaches of rivers/streams, and large lakes.

Water level variations during data collection or between different data collections can result in lateral and vertical discontinuities along shorelines.

LiDAR ground points must not be removed for the sake of adjusting a shoreline inland to match another shoreline. Likewise, adjusting a shoreline outland can create an equally unacceptable area of unmeasured land in the DEM.

In addition to meeting the requirements for inland water bodies listed in (b) Inland ponds and lakes and (c) Inland streams and rivers above, the treatment of tidal water bodies must also meet the following requirements:

- (a) Within each water body, the water surface must be flat and level for each different water-surface elevation.
- (b) Vertical discontinuities within a water body resulting from tidal or other variations in water level during the collection are considered normal and must be retained in the final DEM.

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- (c) Horizontal discontinuities along the shoreline of a water body resulting from tidal variations during the collection are considered normal and must be retained in the final DEM.
 - (d) Long tidal water bodies that also exhibit down-gradient flow (such as a sound or fjord) can present unusual challenges. Data Producers must exercise professional judgment in determining the appropriate approach solution to meet the overall goal of hydro-flattening as described in this section.

8 Deliverables

8.1 Reporting and metadata

8.1.1 Project reports

Project report(s) must be provided in pdf format and include the following:

- (a) A collection report detailing mission planning and flight logs, including dates of collection.
- (b) A survey report detailing the collection of all ground control, including the following:
 - (i) Control points used to calibrate and process the LiDAR and derivative data.
 - (ii) Check sites used to validate the LiDAR point data or any derivative product.

A processing report detailing calibration, classification, and product generation procedures including methodology used for breakline collection, insertion of contiguous breaklines (for example, crest elevation of stopbanks, seawalls, dams), hydro-flattening, DEM creation, and the process for calculating NZTM coordinates.

- (c) A QA/QC report, detailing analysis, accuracy assessment and validation of the following:
 - (i) Point cloud data, including a summary of relative (smooth surface repeatability and overlap consistency) and non-vegetated vertical and horizontal local accuracy.
 - (ii) QA/QC analysis materials for the vertical and horizontal local accuracy assessment, including a table of the product data compared to each check site.
 - (iii) Other optional deliverables as appropriate.

8.1.2 Extents

A geo-referenced, digital spatial representation of the detailed extents of each delivered dataset must be provided that meets the following requirements:

- (a) The extents must be those of the actual LiDAR source or derived product data, exclusive of TIN artefacts or raster void areas.
- (b) A union of tile boundaries or minimum bounding rectangles is not acceptable, unless these are identical to the dataset extents.
- (c) For the point clouds, the boundary line segment can be within four metres of the nearest LiDAR point.
- (d) Esri polygon shapefile is required.

8.1.3 Flight lines

Flightline shapefiles as Esri polylines are required. Each flightline must be assigned a unique File Source ID that is equal to the Point Source ID assigned to each point collected during that flightline.

8.2 Classified point cloud tiles

Point cloud data: A single classified point cloud is required, in LAS v1.4 PDRF 6-10 format, containing all classified data.

Delivery of a classified point cloud is required. Classified point cloud deliverables must include or conform to the following:

- (a) Data from all project swaths, returns, and collected points, fully calibrated, adjusted to ground, and classified, by tiles. Project swaths exclude calibration swaths, crossties, and other swaths not used in product generation.
- (b) Data is provided in the NZTM2000 coordinate system and the NZVD2016 vertical datum.
- (c) **Fully compliant LAS v1.4, Point Data Record Format (PDRF) 6-10. All files must have the same PDRF.**
- (d) Each point includes a Point Source ID linking it to the flightline File Source ID.
- (e) **Correct and properly formatted georeference information (EPSG: 2193 + 7839) as Open Geospatial Consortium (OGC) Well Known Text (WKT) included in all LAS file headers.**
- (f) File Source ID set to 0 for tiled LAS files.
- (g) GPS times recorded as Adjusted GPS Time at a precision sufficient to allow unique timestamps for each pulse.
- (h) Points are provided in the order in which they were collected.
- (i) Height values reported to three decimal places (nearest mm). (While not significant for accuracy, this supports numerical processing and reduces the number of identical values caused by rounding.)
- (j) **Intensity values, normalised to 16-bit by multiplying the value by 65,536/(intensity range of the sensor) per LAS v1.4. This will result in an intensity range of 0-65,536.**
- (k) Classification as required by the Contract Authority (Table 4 at a minimum).
- (l) Tiled delivery, without overlap, per the project tiling scheme in Section 9 – Tiles.
- (m) Files named per Section 9 – Tiles.

8.3 Elevation models

Digital Elevation Model (DEM)

A uniformly spaced bare-earth elevation model, devoid of vegetation and man-made structures.

Digital Surface Model (DSM)

A uniformly spaced elevation model that depicts the highest surface, including buildings, trees, towers, and other features.

Delivery of a DEM (bare-earth) and DSM (surface) DSM is required. Deliverables must include or conform to the following:

- (a) Grid spacing: 1m cell size.
- (b) Generated to the limits of the project area.
- (c) Raster format: Geotiff (.tif)
- (d) Geo-reference information (EPSG 2193) in each raster file.
- (e) Tiled delivery without overlap.
- (f) NOT clipped using polylines for land-water boundaries from national databases (for example coastlines, river or lake boundaries) as these can be inaccurate and subject to continual geomorphic change.
- (g) Tiles with no edge artefacts or mismatch. A quilted appearance in the overall surface can be grounds for rejection of the entire deliverable - whether the rejection is caused by differences in processing quality or character among tiles, swaths, flights, or other unnatural divisions.
- (h) Void areas (for example, areas outside the project area but within the project tiling scheme such as off-shore water) coded using **"NODATA" value equal to -9999**. This value must be identified in the appropriate location within the raster file header.
- (i) Constrained with any additional breaklines required by the Contract Authority, such as stopbanks, streams, and narrower rivers.
- (j) Provided in the NZTM2000 coordinate system and the NZVD2016 vertical datum. Additional vertical datums may be specified by the Contract Authority.

8.3.1 Bare-Earth Digital Elevation Model (DEM)

The Bare-Earth DEM is the bare earth devoid of vegetation and man-made structures. It must also include or conform to the following:

- (a) Based on Classification level 2 or better ground return points.

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- (b) Hydro-flattening as outlined in Section 7 - Hydro-Flattening.
 - (c) Bridges removed from the surface, while culverts are treated as ground.
 - (d) Method for removal of buildings, structures or other ground cover/vegetation and interpolation techniques documented.

8.3.2 Digital Surface Model (DSM)

The DSM is the heights of the top of the highest feature at each gridpoint, including ground, vegetation, and man-made structures. The DSM is based on first return points after removal of noise.

8.4 Breaklines

Delivery of breaklines representing all hydro-flattened features in a project is required. Additional breaklines may also be required by the Contract Authority. These are to be delivered as ESRI Shape files (.shp) using the NZTM2000 projection.

8.5 GNSS data

Delivery of base station GNSS data is not required for delivery unless specifically requested by the Contract Authority.

GNSS data for all base station occupations of existing or new benchmarks in excess of six hours must be provided in current RINEX format (Receiver Independent Exchange Format) along with observation log sheets which include the following details:

- (a) Survey mark id
- (b) Occupation time and date
- (c) Antenna height measurements
- (d) Instrument /antenna types and serial numbers.

The GNSS observation log sheets must be provided in pdf format or Excel spreadsheet.

8.6 Backed up project source data

Raw project source data, such as native format LiDAR files and point cloud swaths, are NOT required for delivery. However the Vendor must hold a copy of all relevant raw project data, for a minimum of five years beyond the final delivery of the project deliverables. The vendor must provide this data, with unrestricted copyright, to the Contract Authority on request. The vendor may charge a reasonable access and distribution charge in such instances.

9 Tiles

9.1 Tiling and delivery

- (a) NZTopo50 subtiles based on NZTM2000 coordinates. The 1-m gridded raster products and point clouds must be delivered at 1:1000 nominal scale (2500 720m high x 480m wide subtiles per full NZTopo50 sheet).
- (b) The origin of the raster tiles must be placed on a whole metre coordinate value of the south west corner of each tile (for example, 5429500 mN_17490300mE).
- (c) The tiled deliverables must edge-match seamlessly and without gaps.
- (d) The tiled deliverables must conform to the project tiling scheme without overlap.
- (e) File naming must conform with the naming convention described in section 9.2.

A Tile Index must be provided in ESRI shape file format. The file name must be included as an attribute in the Tile Index file.

9.2 File naming

Naming Convention for point clouds, DEMs, and other tiled products <i>[product]_[sheet]_[year]_[scale]_[tile].[ext]</i>		
Product	<i>DEM</i>	CL2-Point Cloud Classification Level 2 DEM-Bare Earth Digital Elevation Model DSM-Digital Surface Model DTM-Digital Terrain Model UNC-Unclassified Point Cloud INT-Intensity image CHM – Canopy Height Model IMG-Aerial photography etc
Sheet	<i>BK34</i>	LINZ Topo50 identifier (4 characters)
Year	<i>2016</i>	Year of survey commencement
Scale	<i>1000</i>	Nominal scale of NZTopo50 subtiles
Tile	<i>4118</i>	Row number (41), Column number (18) of tile with respect to an upper left origin
ext	<i>tif</i>	File extension according to format conventions las tif shp etc
<i>For example: DEM_BK34_2016_1000_4118.tif</i>		