Elevation data products specification and description

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Contents

1. Introduction

This document describes the specifications and deliverables for airborne Light Detection and Ranging (LiDAR) surveys undertaken by Land Property Information (LPI).

The LiDAR survey produces a spatially accurate point cloud as the primary product. It may be classified or unclassified and captured at varying point densities and accuracies as described by the Inter-Governmental Committee on Surveying and Mapping (ICSM) Guidelines for Digital Elevation Data (2008). The derived products include a bare earth Digital Elevation Model (DEM), Model Key Points (MKP) and Intensity Images.

2. Data specification and description

2.1 Point density

Point density specifications are based on the creation of bare earth DEMs at one, two, five and ten metre resolutions. The aim is to acquire enough elevation points to minimise interpolation in the creation of the DEM.

The flight planning documentation (contained in the Quality Assurance report) demonstrates the point spacing scenario will achieve an appropriate density for DEM products to avoid interpolation. Refer to section 2.6 for further information.

2.2 Accuracy

Vertical Accuracy is assessed by comparing LiDAR point returns against survey check points in bare open ground. It is calculated at the 95 per cent confidence level as a function of the vertical Root Mean Square Error (RMSE). This is undertaken after the standard relative adjustments of the point cloud have taken place. For example, flight line matching.

Horizontal accuracy is checked by comparing the LiDAR intensity data viewed as a Triangular Irregular Network (TIN) surface against existing imagery and known locations. The LiDAR data can be viewed as an intensity image to correctly identify common points. Refer to **Section 2.6** for further information.

2.3 Check points

Category 1 - Check points are surveyed by connection to the local Survey Control Information Management System (SCIMS) with ‘accurate’ height (class LD/B or better). Where possible, levelled marks are used to establish the local Australian Height Datum (AHD) in preference to Global Positioning System (GPS) derived heights. Check points are distributed throughout the geographic extent of the LiDAR capture area and are used to provide a best fit by way of a block shift adjustment, or where necessary, a transformation to account for geoid anomalies.

Category 2 and 3 – Check points will have a measured ellipsoidal height. Check points are distributed throughout the geographic extent of the LiDAR capture area, dependant on access.

2.4 Point classification

Point classification only applies to Category 1 LiDAR Survey products. The LiDAR product is the classified point cloud which contains all points measured during the flight. Initially, every point is allocated to the ‘default’ class. Automated algorithms and manual processes then attribute the points with a more meaningful classification, such as ground, vegetation, water, building or structures. Refer to **Appendix B** for the Standard Point Classifications.

2.5 Classification levels

Point cloud information created will have a classification ranking. Refer to **Appendix C** for LPI's Classification levels defining completeness and effort.

2.6 Data specifications

The table below identifies the positional requirements and accuracy associated with the three identified ICSM categories of LiDAR capture.

Feature	Category 1	Category 2	Category 3
General			
Horizontal Datum	GDA94		
Vertical Datum (Orthometric)	AHD71	AHD71 orthometric height derived by application of a Geoid model to ellipsoid heights of the source data	
Vertical Datum (Ellipsoidal)	GDA94		
Projection	MGA Zones 54-57		
Geoid	AUSGeoid09		
Metadata	ANZLIC Metadata Profile Version 1.1		
Point density			
Point density	Minimum 1 point per square metre at nadir	Minimum 1 point per 2 square metre at nadir	Minimum 1 point per 4 square metre at nadir
Accuracy			
Typical use	Modelling of inundation from floods or storm surges in areas of high value assets. Planning of large infrastructure projects	Modelling of inundation from floods or storm surges in areas with minimal infrastructure	Hydrological modelling of large catchment areas, preliminary route assessment and 3D modelling
ICSM Vertical Accuracy 95% confidence (1.96 x RMSE)	+/-0.30 metres on bare open ground		
ICSM Horizontal Accuracy 95% confidence (1.73 x RMSE)	+/-0.8 metres on bare open ground		
Recommended Contour Interval	0.5 metre	1 metre	2 metres
Minimum Grid Cell Size (DEM)	1 metre	2 metres	5 metres
Maximum Tile Size	2km x 2km		
Check Points			
Number of Check Points	Minimum 12 points equally distributed throughout the job extent.	Minimum 5 per 1000Km^2	
Check Point Vertical Accuracy	Direct connection to a local SCIMS mark with an accurate AHD height (Class LD/B or better)	Ellipsoidal Height accurate to 0.1m 95% confidence (1.96 x RMSE)	
Check Point Horizontal Accuracy	Positional uncertainty better than 0.9m	Positional uncertainty better than 1.5 metres	
Note	*The classified point cloud is retained in ellipsoid height format to allow for future improvements in the vertical datum and accurate nesting of adjacent elevation data*	*The unclassified point cloud is also retained in its primary ellipsoid height format so as to allow for future improvements in the vertical datum and to enable accurate nesting of adjacent elevation data*	

3. Deliverables

The range of standard products listed below is designed in consideration for user functionality, storage space, production capacity, minimising redundancy and control costs whilst maintaining the potential to create alternate or value-added products as required.

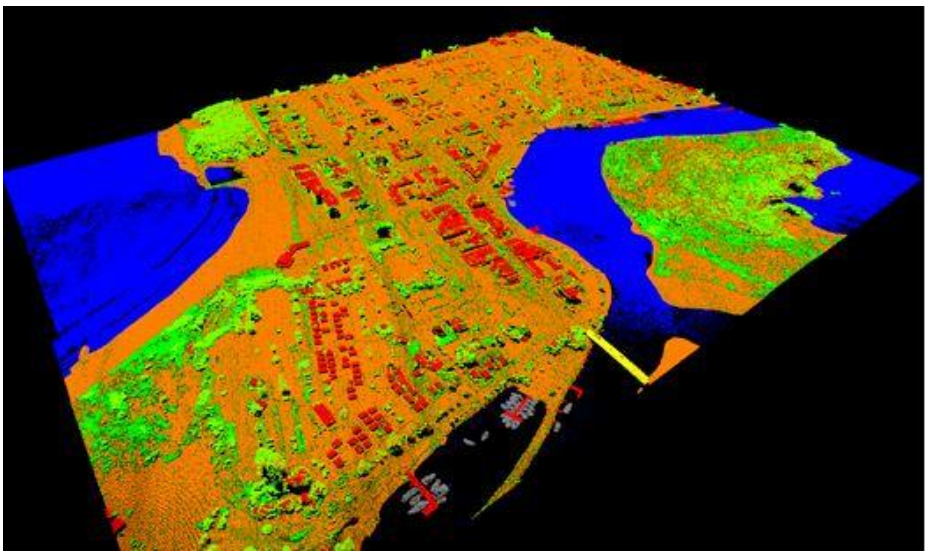
Product	File Format	Description	Category		
Primary Products			**1**	**2**	**3**
Classified Point Cloud	ASPRS LAS v1.2	Attributed in accordance with designated classification level; 2km x 2km tiles	✓		
Unclassified Point Cloud	ASPRS LAS v1.2	Created from LiDAR and includes the attributes of easting and northing coordinates; elevation values; Intensity values in 2km x 2km tiles		✓	✓
Derived Products: Digital Elevation Models (DEMs)					
DEM	ESRI ASCII Grid	1 metre resolution 'bare earth' (artefact free) DEM; 2km x 2km tiles	✓		
DEM	ESRI ASCII Grid	2 metres resolution 'bare earth' (artefact free) DEM; 2km x 2km tiles		✓	
DEM	ESRI ASCII Grid	5 metres resolution 'bare earth' (artefact free) DEM; 2km x 2km tiles	✓	✓	✓
DEM	ESRI ASCII Grid	10 metres resolution 'bare earth' (artefact free) DEM; 2km x 2km tiles	✓	✓	✓
Supporting Products					
Model Key Points	ASPRS LAS v1.2	'Thinned' ground points; 2km x 2km tiles	✓		
Intensity Image	Compressed ECW	0.5 metre resolution laser intensity image. (Single file mosaic - tiles combined)	✓	✓	✓
Tile Boundaries	ESRI Shapefile	Depicting tile layout and naming. Includes 'no data area' polygons	✓	✓	✓
Metadata	XML	ANZLIC Metadata profile version 1.1	✓	✓	✓
Project Report	PDF	As required, detailing methodology and quality assurance details	✓	✓	✓

Refer to **Section 4** on page 9 for visual product representations.

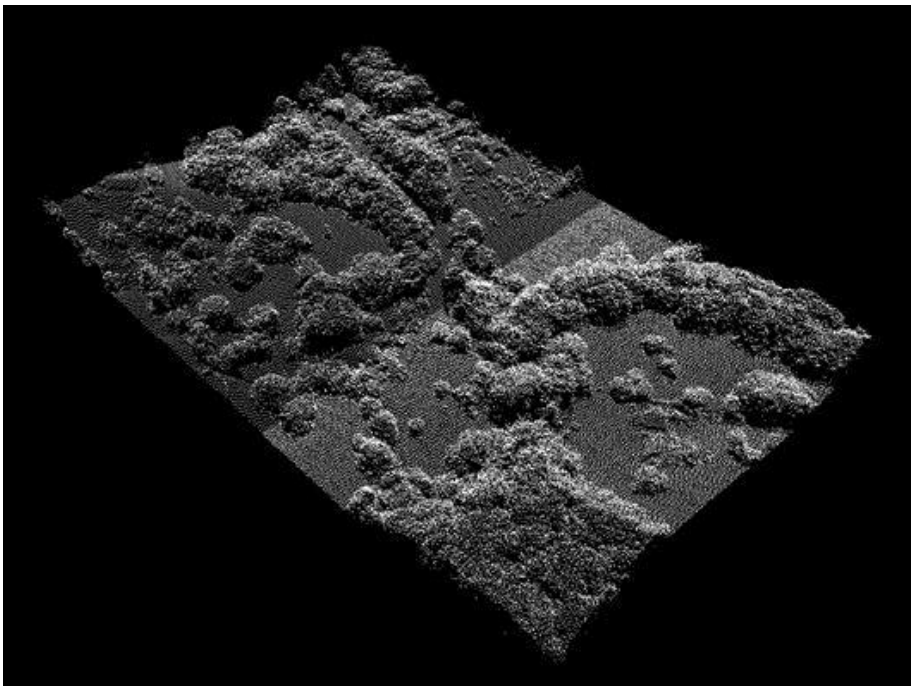
4. Product details

4.1 Point cloud

Point cloud data products apply to all categories of capture, however only Category one LiDAR data will be classified to level three. Category two and three point clouds will be supplied in an unclassified state. Every point captured is supplied within a 2 x 2 km tile LAS 1.2 format. Refer to **Appendix A** for point cloud known issues and anomalies.



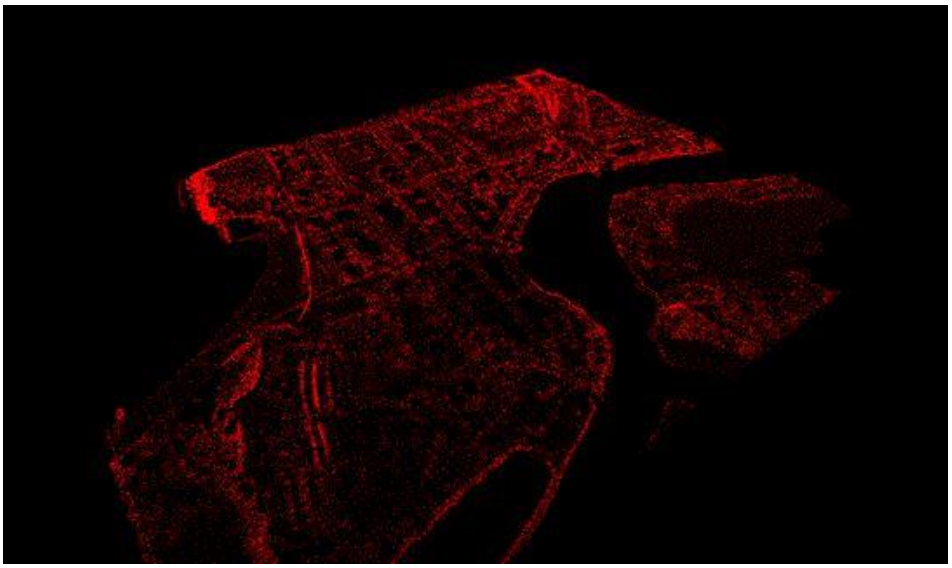
Level 3 classified point cloud



Level 0 unclassified point cloud

4.2 Model key points

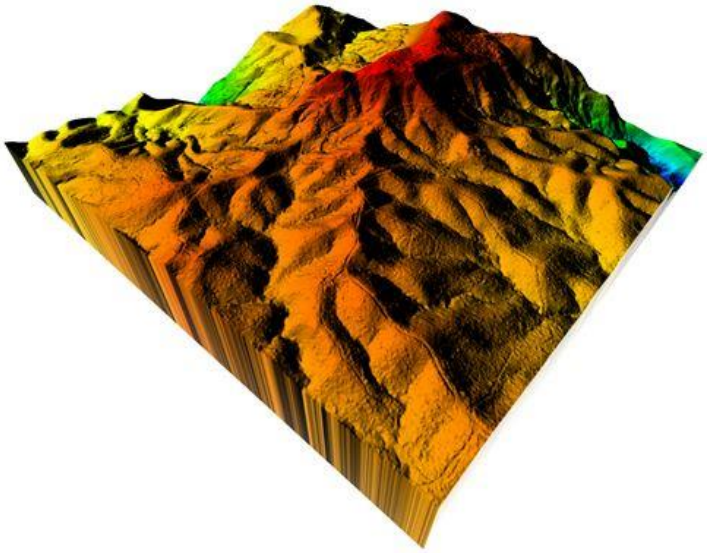
MKP only apply to Category one LiDAR Survey products. MKP are a generalised subset of the original mass points and represent the minimum number of points required to determine the shape of the ground only.



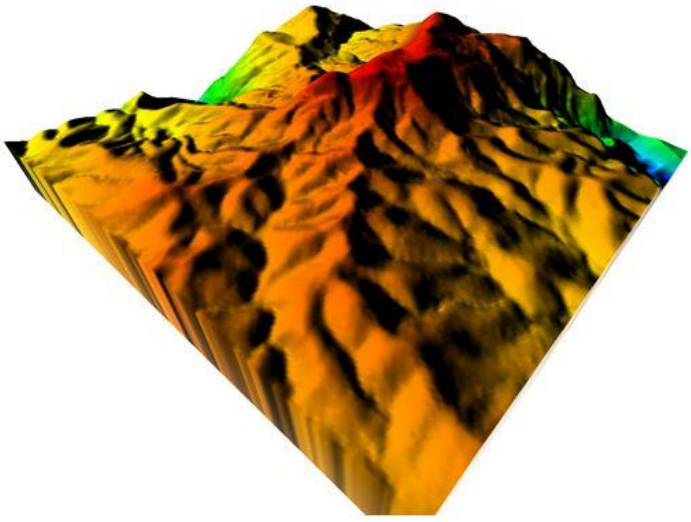
Model Key Points

4.3 Digital elevation model

The resolution bare earth DEM is derived from point cloud data. The data is not hydrologically enforced (break lines) or hydrologically conditioned (identification and analysis of sinks). It is anticipated stakeholders will become involved in value-adding activities to produce other applications and specific products such as hydrologically sound data.



One metre bare earth digital elevation model



Ten metre bare earth digital elevation model

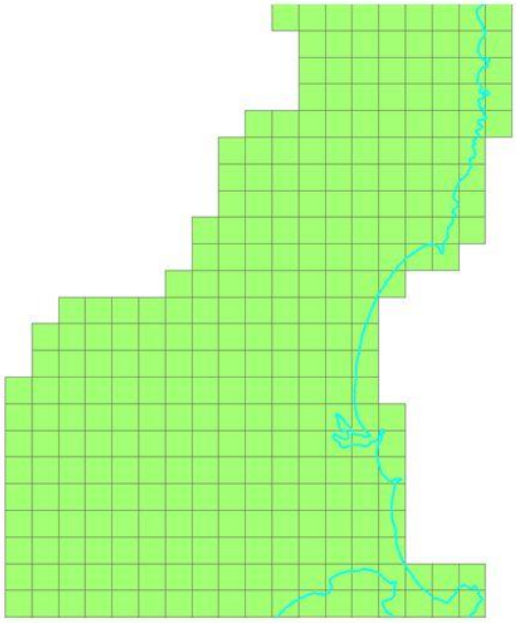
4.4 Intensity image

A 0.5 metre resolution image generated using average laser intensity from all point returns. This image will generally cover the entire extent of the survey.

Intensity image of coastal area

4.5 Tile boundaries – key diagram

Depicts all tiles (some partial) for the full extent of the survey.



Depiction of tile boundaries

4.6 Metadata

A single (xml) metadata statement is provided for each product group. A parent-child relationship is established using the ANZMET Lite and National Elevation Data Framework (NEDF) Portal metadata tools. A readable text version is also included.

4.7 National elevation data framework filename convention

The table below is the NEDF filename convention used.

Description	Job Name	YYYY	SG#	PT	CL	DAT	eee	nnnn	zz	wwww	hhhh	res
	Placepoint for LiDAR	Year of capture	Sensor generated from LiDAR (LiD) + ICSM cat 1,2, 3	Product type	Classification level	Datum (ELL:AHD)	Easting value south-west corner of tile	Northing value south-west corner of data tile	Map Grid Zone	Tile width in whole kilometres	Tile height in whole kilometres	Resolution or posting in metres
Product Type												
Point Cloud	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	
Example	**Kempsey2009-LID1-C3-AHD_3106640_56_0002_0002.las**											
Model Key Points	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
Example	**Kempsey2009-LID1-MKP-AHD_3106640_56_0002_0002.las**											
DEM	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓
Example	**Kempsey2009-LID1-AHD_3106640_56_0002_0002_1m.asc**											
Intensity Image	✓	✓		✓								✓
Example	**Kempsey2009_50cm_INT.ecw**											
Tile Boundaries	✓	✓	✓									
Example	**Kempsey2009_LID1.shp**											
Metadata	✓	✓	✓	✓								
Example	**Kempsey2009-LID1_ClassifiedLAS_Metadata.xml**											

5. Appendix A

5.1 Point cloud known issues and anomalies

5.1.1 Anomaly: Hydro area triangulation interpolation

Interpolation lines can be seen across the waterway in areas where the DEM is created using a triangulation process. The classification observed is C3

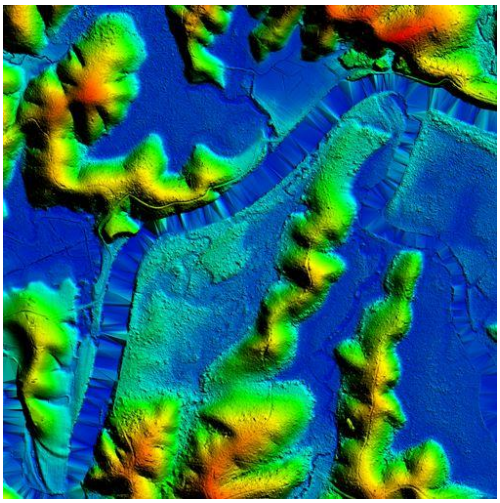
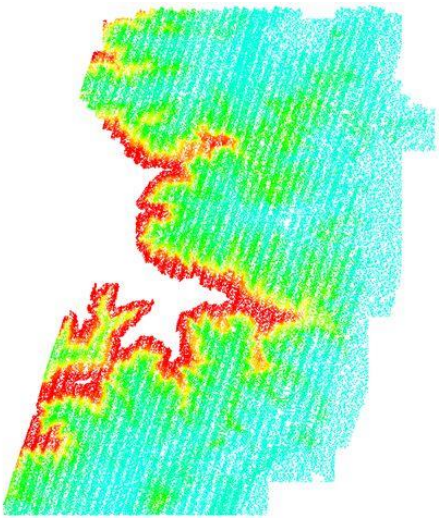


Image of triangulation issue in waterway

5.1.2 Anomaly: Drop out

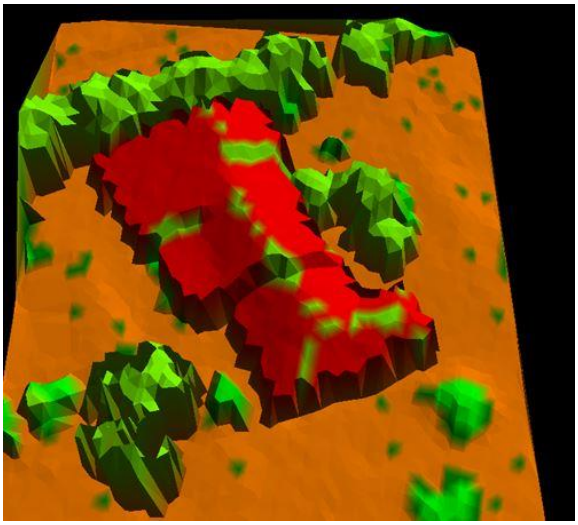
Dropout from the sensor when the terrain breaches the minimum allowable distance between the ground and sensor. The classification observed is all point clouds.



Representation of point cloud dropout due to excessive elevation

5.1.3 Anomaly: Vegetation in buildings

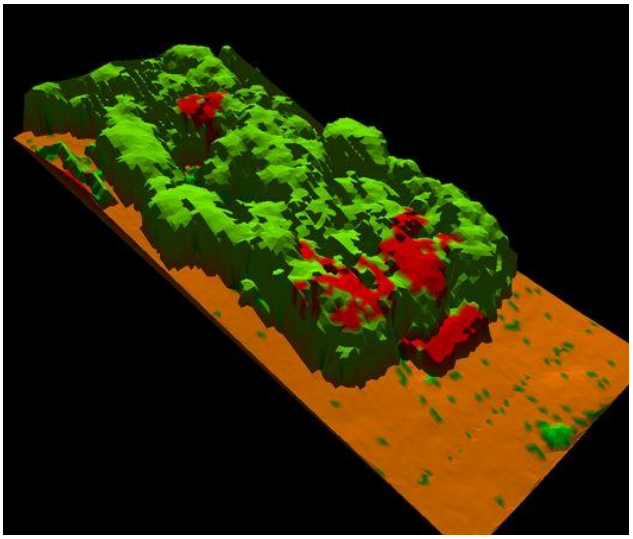
Edges of the buildings remain in the vegetation class. The classification observed is C3



Misclassified vegetation and buildings parts

5.1.4 Anomaly: Buildings in trees

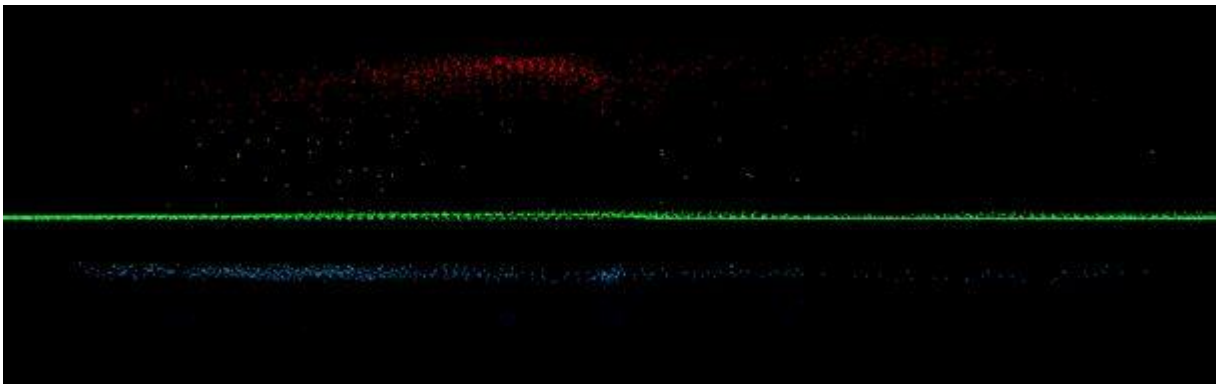
Linear surfaces in tree canopy that meet the requirements for a building tolerance. The classification observed is C3.



Misclassified vegetation and buildings parts

5.1.5 Anomaly: Spurious points

Spurious points that may be present over water caused from the intense reflection of the laser along with excessive solar glare. The classification observed is all point clouds at nadir over water.



Depiction of excessive reflection error

6. Appendix B

6.1 Standard point classification

Standard Point Classes (derived from the LAS specifications and ASPRS guidelines) are:

Number	Point class	Description
0	Unclassified	Created, never classified
1	Default	Unclassified
2	Ground	Bare ground
3	Low vegetation	0 – 0.3m (essentially sensor ‘noise’)
4	Medium vegetation	0.3 – 2m
5	High vegetation	2m >
6	Building	Houses, sheds, etc.
7	Low high points	Spurious high/low point returns (not useable)
8	Model key points	Reserved for ‘Model Key Points’
9	Water	Any point in water
10	Bridge	Any bridge or overpass
11	NOT USED	Reserved for future definition
12	Overlap points	Flight line overlap points
13-31	NOT USED	Reserved for future definition

7. Appendix C

7.1 LPI Classification levels

Level	Description
0	**Undefined** All points allocated classes 0 (unclassified) or 1 (default) by LiDAR processing software with no classification algorithms applied.
1	**Automated Classification** Data is subjected to automated algorithms which, as a minimum, will classify the points into classes 2 (ground), 3-5 (vegetation), 6 (building/structures), 7 (low/highpoints and noise) and where required 12 (overlap).
2	**Ground Anomaly Removal** Level 1 classified data is further enhanced by the removal of significant anomalies which remain in the ground class (2). Typically, this editing will re-classify points into class 7 (low/high points and noise). The overall intent here is to create a ground surface suitable for orthorectification of imagery, with a minimum of effort.
3	**Manual Ground Correction** Significant (usually manual) effort is required here to ensure that only actual ground points are assigned class 2. Typically, this editing will both remove and add points to the ground class derived using the automated algorithms. Any points observed in water are to be re-classified into class 9, and other features which may require special attention include dense or low vegetation, rocky outcrops/boulders, contour/levee banks, wood/rubbish piles and islands. Ideally, to assist with the creation of hydrologically sound data, 'bridge-like' structures will be identified at this level and classified accordingly. This manual task is best undertaken with reference to associated imagery.
4	**Full Classification** All data are classified according the specified classes in Appendix B. Development of a hydrologically conditioned DEM will generally require this level of classification to properly identify buildings and other man-made structures which are likely to have an impact on water flow.

8. Appendix D

8.1 Specifications and accuracy of categories one, two and three of digital elevation models

The below table has been derived from ICSM Guidelines for Digital Elevation Data Version 1.0, 12 August 2008.

Category	Special	1	2	3
Typical Use	Surveys required for engineering and infrastructure design.	Modelling of inundation from floods or storm surges in areas of high value assets.	Modelling of inundation from floods or storm surges in areas with minimal infrastructure.	Modelling of large areas for preliminary route assessment.
Vertical Accuracy (RMSE, 1 sigma or 68%)	<0.1m	+/-0.15m	+/-0.3m	+/-0.5m
Horizontal Accuracy (RMSE, 1 sigma or 68%)	<0.3m (typically 2 or 3 times the vertical accuracy)	+/-0.45m	+/-0.9m (+/-2m ALB)	+/-1.5m (+/-5m ALB)
Recommended Contour Interval	<0.3m	0.5m	1m	2m
Minimum Grid Cell Size (DEM)	<1m	1m	2m (5m ALB)	5m (10m ALB)
Maximum Tile Size	1km x 1km	2km x 2km	2km x 2km	4km x 4km

Accuracy is specified in terms of RMSE and refers to points and/or measurements on clear ground or seabed in the case of Airborne Laser Bathymetry (ALB).

9. Appendix E

9.1 Glossary of terms

Definitions are taken from ICSM National Elevation Guidelines where possible. Asterisk (*) indicates that the definition is derived from alternate sources.

Accuracy	The closeness of an estimated (for example, measured or computed) value to a standard or accepted [true] value of a particular quantity. Note: Because the true value is not known, but only estimated, the accuracy of the measured quantity is also unknown. Therefore, accuracy of coordinate information can only be estimated
Artefacts	Buildings, trees, towers, telephone poles or other elevated features that should be removed when depicting a Digital Elevation Model (DEM) of the bare-earth terrain. Artefacts are not just limited to real features that need to be removed. They also include unintentional by-products of the production process, such as stripes in manually profiled DEM's. Any feature, whether man-made or system-made, that unintentionally exists in a digital elevation model
Australian Height Datum (AHD71)	Established in 1971 as a National datum for elevations based on observed mean sea level around the Australian coast line. Determined on the Australian mainland by an adjustment of a national levelling network constrained to mean sea level from continuous tidal observations over a period of 3 years at 30 tide gauges. AHD (Tasmania) was re-established in 1983 by adjusting the Tasmanian levelling network to mean sea level determined from one year of tidal observations at 2 tide gauges
Breakline	Linear features that describe a change in the smoothness or continuity of the surface
Calibration	Procedures used to identify systematic errors in hardware, software, and procedures so that these errors can be corrected in preparing the data derived there from
Checkpoint	A point in the sample used to estimate the positional accuracy of the dataset against an independent source of higher accuracy
Classification*	Refers to the class membership of a LiDAR point return. All points begin as 'default', i.e. have no classification and are then allocated a meaningful value (i.e. ground, vegetation, building, etc.) by either automated or manual methods or a mix of both

Digital Elevation Model (DEM)*	Specifies elevations of the terrain (bare earth z-values) void of vegetation and manmade features. May incorporate a range of data models such as mass point, Triangular Irregular Network, grid or contours and may also include breaklines to better represent discontinuous features thereby improving the overall quality of the DEM
Derivative Data	Derivative data sets are interpolated from the primary data sets. These can include Triangular Irregular Network, contours and regular grid (or DEM) files interpolated from the primary (mass point) data
Digital Surface Model (DSM)*	Similar to DEMs except that they include various combinations of above ground data such as buildings, trees and other elevated features
Digital Terrain Model (DTM)*	A legacy term that refers to a sub-type of DEM
Elevation	Height above a specific vertical reference datum
Flight line overlap*	Refers to the common coverage between two overlapping flight runs in an aerial LiDAR survey. Overlapping points are removed (re-classified) during processing as points measured towards the extreme of the laser swath (in the case of an oscillating scanner) contain a large amount of data noise
Geocentric Datum of Australia 1994 (GDA94)	Australia's standard horizontal datum. GDA94 is defined by the International Terrestrial Reference Frame (ITRF) at epoch 1st January 1994
Hydrological/drainage enforcement	The removal of elevations from the tops of selected drainage structures (bridges and culverts) in a DEM, Triangular Irregular Network or topographic dataset to depict the terrain under those structures
ICSM	Inter-Governmental Committee on Surveying and Mapping
Intensity*	The intensity of the laser pulse return from the LiDAR instrument. This relates to the brightness of the object struck by the infrared laser pulse. It can generate an image which averages the intensity of all laser returns into a regular grid
Interpolation	The estimation of z-values at a point with x, y coordinates based on the known z-values of surrounding points

LAS	A standard LiDAR file format, defined by the American Society of Photogrammetry and Remote Sensing (ASPRS). LAS defines, amongst other things, mandatory data fields and point categories. This includes mandatory metadata documentation. See full description at www/lasformat.org/
Light Detection and Ranging (LiDAR)	Light Detection and Ranging (LiDAR). A technology that determines distance to a surface using laser pulses. Distance is computed by measuring the time delay between transmission and detection of the reflected signal. Also referred to Airborne Laser Scanning (ALS) and Airborne Laser Bathymetry (ALB)
Model Key Points (MKP)*	MKP also referred to as 'thinned ground points'. A sample of the full (classified) point cloud representing bare earth elevations. File size is smaller than the full set of ground points at the cost of reduced accuracy. The point thinning factor is set during processing, with the accuracy of the derived dataset within ±15cm of the full point cloud
National Elevation Data Framework (NEDF)*	A collaborative framework that can be used to increase the quality of elevation data and derived products such as digital elevation models (DEMs) describing Australia's landform and seabed. The specification in this document aims to conform to the framework as a minimum
Point Cloud*	Set of irregularly spaced points derived from LiDAR survey, each with an X, Y, Z value. Depending on the level of processing, points may also have a classification value, i.e. ground, vegetation, etc.
Point Density*	The number of points contained within a grid square of given size. Usually expressed as points per square metre, i.e. the number of points contained in a 1m x 1m grid
Primary Data	Elevation data that has been corrected using Global Positioning System and Inertial Measurement Unit data is calibrated against test points on the ground. Includes LiDAR returns in LAS format
RMSE	The square root of the mean of squared errors for a sample
Survey Control Information Management System (SCIMS)	All datasets related to the Survey Control Network
Triangular Irregular Network (TIN)	A set of adjacent, non-overlapping triangles computed from irregularly spaced points with xyz coordinates. The data structure may be based on point, line and polygon data interpreted as mass points and breaklines. The TIN stores the topological relationship between triangles and their adjacent neighbours