Riverwood Estate State Significant Precinct Canopy Cover Assessment
Canopy Cover Summary Report

NSW Land and Housing Corporation

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Project Name	Riverwood Estate State Significant Precinct Canopy Cover Assessment
Project Number	17531
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Status	**Draft**
Version Number	**V3**
Last saved on	**8 April 2021**

This report should be cited as 'Eco Logical Australia. 2021 Riverwood Estate State Significant Precinct Canopy Cover Assessment. Prepared for NSW Land and Housing Corporation.'

ACKNOWLEDGEMENTS

This document has been prepared by Eco Logical Australia Pty Ltd with support from NSW Land and Housing Corporation

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Abbreviations

Abbreviation	Description
BDAR	Biodiversity Development Assessment Report
CHM	Canopy Height Model
DCP	Development Control Plan
DTM	Digital Terrain Model
DSM	Digital Surface Model
ELA	Eco Logical Australia
ICSM	Intergovernmental Committee on Surveying and Mapping
LAHC	Land and Housing Corporation
LGA	Local Government Area
LiDAR	Light Detection and Ranging
LPI	Land and Property Information
NSW	New South Wales
SEPP	State Environmental Planning Policy
SSP	State Significant Precinct

1. Introduction

1.1 Overview

Eco Logical Australia (ELA) was engaged by Land and Housing Corporation (LAHC) to undertake a canopy assessment of the Riverwood Estate State Significant Precinct (the Study Area). The Study Area covers an area of approximately 30 hectares within the Canterbury Bankstown Local Government Area (LGA).

1.2 Overview of Canopy Assessment

Within the Study Area, trees are located across a broad spectrum of public and private spaces including streets, parks, reserves and backyards. This assessment combines light detection and ranging (LiDAR) data with high-resolution imagery to identify and delineate canopy cover within the precinct and to calculate canopy density.

Evaluating the canopy cover and density will not only assist in identifying canopy impacts resulting from the proposed development, but also assist master planning in identifying planting opportunities and potential areas to increase canopy.

2. Methodology

2.1 Data Inputs

LiDAR data for the project was sourced from the Elevation and Depth Foundation spatial data portal (ELVIS). ELVIS point cloud LiDAR data was captured over the entire Sydney region by an ALS80 (Airborne Laser Scanner) sensor during May 2020. The point cloud dataset had been classified according to the Intergovernmental Committee on Surveying and Mapping (ICSM) Classification standards Level 3 in which the point clouds have been classified according to what likely feature each pulse is reflected off (such as ground, vegetation, buildings, water, and bridges).

Table 1 below summarises the possible ICSM classification levels and their associated land use type. Four Point Cloud tiles covering the Study Area were downloaded from the ELVIS spatial data portal for the Riverwood canopy assessment with a capture date of May 2020. The data had a vertical accuracy of 0.3m and a horizontal accuracy of 0.8m with a minimum point density of approximately 6 points per 1 metre square. The spatial extent of the LiDAR datasets used in the analysis are shown in Figure 1 below.

Existing vegetation within the Study Area, mapped as part of the accompanying Biodiversity Development Assessment Report (BDAR) (ELA, 2021) was used to mask the CHM and to provide statistics of canopy height based on vegetation community or whether the vegetation was proposed to be retained or removed.

Table 1: ICSM LiDAR Classification Levels (ICSM 2011)

Number	Point Class	Definition
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	Buildings, structures	Buildings, houses, sheds, silos etc.
7	Low/High points	Spurious high/low point returns (unusable)
8	Model key points	Reserved for 'model key points' only
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 to 31	Not used	Reserved for future definition

Figure 1: The spatial extent of the LiDAR dataset tiles is shown in yellow and the Study Area in red

2.2 LiDAR Canopy Height Model

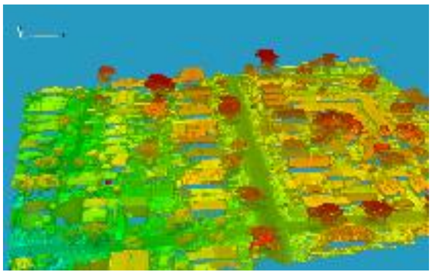
As multispectral imagery was not available for this project the CHM was created using the ELVIS point cloud LiDAR data and refined using existing vegetation mapping from the accompanying BDAR (ELA,2021). Proposed tree impacts identified in the BDAR were also taken into consideration.

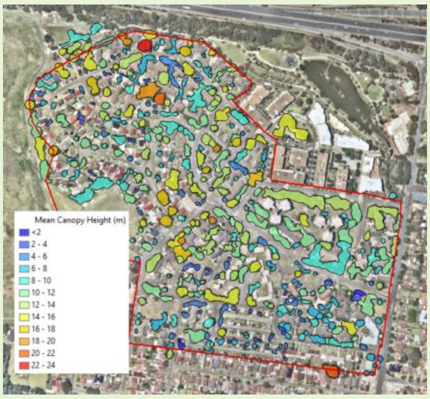
The resolution of the CHM output was 1m grid size which is sufficient resolution and exceeding the minimum requirements of 4 times the average spacing between the LiDAR points as per recognised methods (e.g Crawford 2009).

The processing steps utilised to obtain surface height and canopy height models from LiDAR data are outlined in Table 2**.** LiDAR was downloaded from the ELVIS portal as 'Point Cloud' data files (.las files – see 'Process Step 1' in Table 2), which were batch processed within ENVI LiDAR (v5.6.0) to produce a 1m Digital Terrain Model (DTM) (step 2) and a Digital Surface Model (DSM) (step 3) of the Study Area. The DTM represents the elevation of the surface of the Earth but does not contain elevation of features such as buildings or trees is first created. The DSM represents the elevation of all features on the ground, including trees, buildings, and the ground surface. ESRI recommended settings for filtering were used for both DSM and DTM development. In order to produce a Canopy Height Model (CHM) the DTM must be subtracted from the DSM. This process was completed in ArcGIS (v10.7.1) by subtracting the DTM from DSM (step 4) to produce a 1m CHM of the Study Area. The CHM was then masked to the existing vegetation mapping extent (step 5) to remove non tree features such as buildings. Canopy statistics were calculated (step 6) by assigning each polygon within the vegetation mapping a unique ID and running the 'Zonal statistics to table' tool using the vegetation mapping polygons and CHM raster. The resulting table was then joined to back to the vegetation mapping based on the unique polygon ID.

The results of this analysis are provided in Table 4 and displayed in Figure 4 **to 6.**

Table 2: Process of creating a Canopy Height Model (CHM) using LiDAR Point Cloud data

Process Step	Product	Example Image	Processing and Parameters
1	LiDAR Point Cloud		Source data within ENVI LiDAR
2	Digital Terrain Model (DTM)		Batch import of point cloud tiles into ENVI LiDAR Pixel size = 1m Filter Lower Points = Rural Area Filtering

Process Step	Product	Example Image	Processing and Parameters
3	Digital Surface Model (DSM)		Batch import of point cloud tiles into ENVI LiDAR Pixel size = 1m
4	Canopy Height Model (CHM)		Import DTM and DSM into ArcGIS Raster subtraction: DSM - DTM
5	CHM masked to existing vegetation mapping		Extract CHM raster by mask (existing vegetation mapping)
6	Canopy Statistics		Zonal statistics to table for each unique polygon within the vector vegetation mapping layer using the CHM. Join table back to vector vegetation mapping dataset assign vegetation community or whether the vegetation is proposed to be retained or removed.

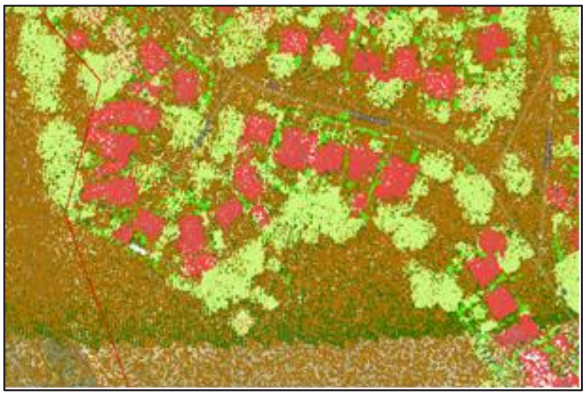
2.3 Canopy density using LiDAR data

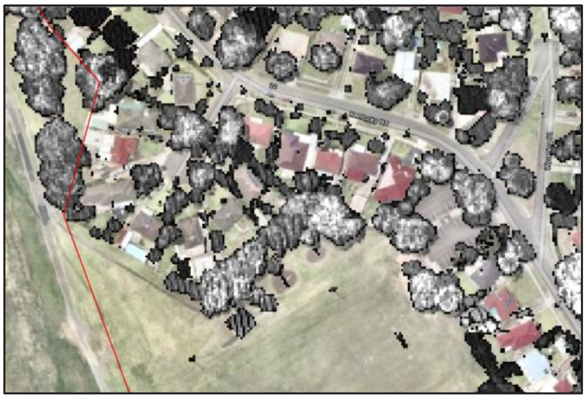
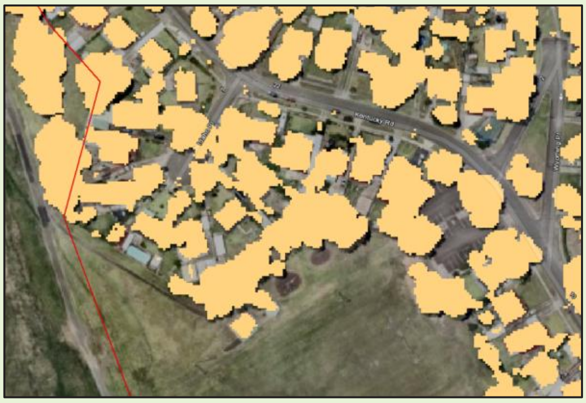
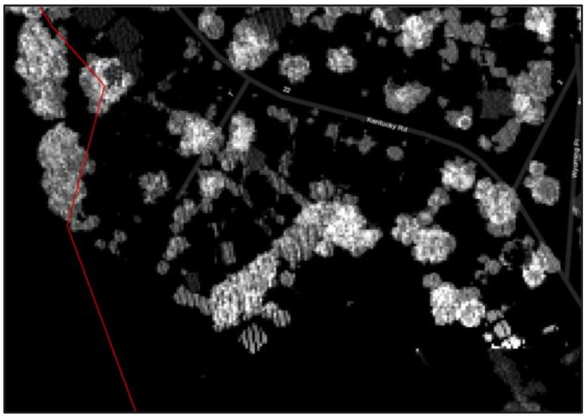
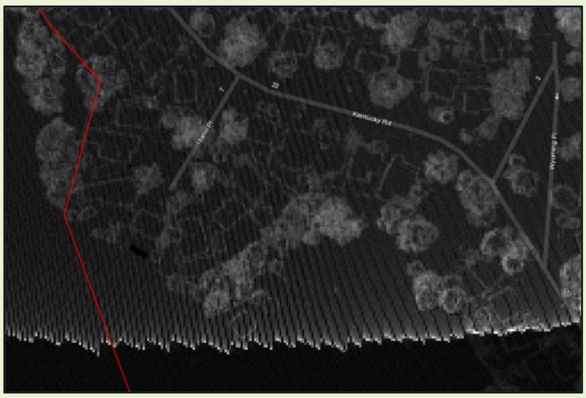
Canopy density was assessed utilising the ratio of LiDAR points classified as Class 5 (High Vegetation) and of heights greater than 3m to the total number of LiDAR points within each cell. Class 5 'High Vegetation' was determined to be the most appropriate classification for canopy trees following a rapid visual interrogation of the LiDAR points which revealed that points classified as either 'Low Vegetation' or 'Medium Vegetation' were more likely to be for areas of open space rather than tree canopy. The CHM was utilised to mask out areas canopy less than 3 metres in height.

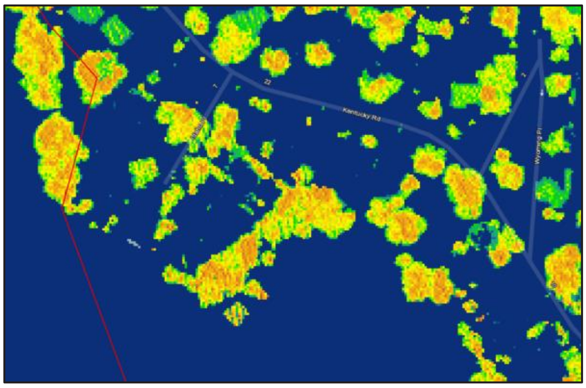
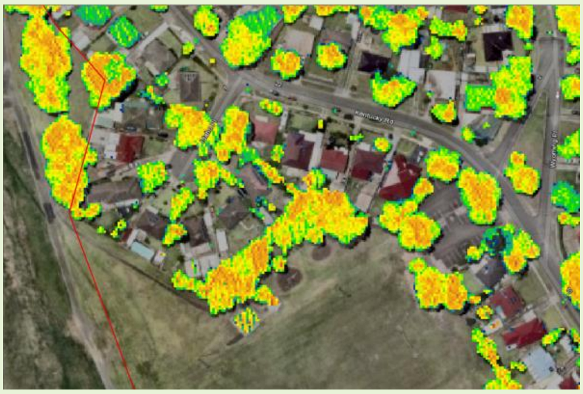
To assess the density of the canopy the data was assessed in raster format using a cell size of 1m, which exceeds the minimum required size in regard to LiDAR point spacing. The cell size of 1m was also selected to be consistent with the DTM, DSM, and CHM generated using the same LiDAR data. The density of tree canopy was determined by the ratio of identified tree canopy points to the total count of points for each cell, producing an output raster with cell values between 0.0 and 1.0. Values close to 1.0 being very dense canopy and values of 0.0 meaning very thin or no canopy is present.

Table 3 below outlines each step in the creation of the Canopy Density raster. The output of the tree density raster is shown in Figure 6.

Table 3: Process of creating a canopy density raster using LiDAR data

Process Step	Product	Example Image	Processing Parameters
1	Raw LAS dataset		Visualised based on point classification Classification 1 Unassigned 2 Ground 3 Low Vegetation 4 Medium Vegetation 5 High Vegetation 6 Building 7 Noise 9 Water 17 Bridge Deck 18 High Noise
2	Point Cloud to Multipoint (Class 5 Points shown in example)		Run 'LAS to Multipoint' in ArcMap for: - All ground points (all returns) - Class 5 points only (all returns)

Process Step	Product	Example Image	Processing Parameters
3	Point to Raster		Converted from multipoint to raster, 1m resolution, with the value of the cells being the count of the points within each cell: Point to Raster was performed on both: - All ground points - Class 5 points
4	Remove areas within the 'High Vegetation Raster' that are less than 3m in height		Using 'Raster Calculator' in ArcMap to create a new raster from the CHM for values greater than 3 (see example image for the resulting mask raster). Use this raster as the mask for 'Extract by Mask' tool to only include areas with heights greater than 3m as potential tree canopy
5	Add no data into rasters as value 0		The 'Is Null' and 'Con' tools in ArcMap was used to assign areas with No Data the value (which is equal to the count of LiDAR points within each cell of the raster) to zero (0). Process was performed on both the Masked Class 5 (High Vegetation) raster, and the All Ground Points rasters.
6	Add the above ground points (Class 5 points) to the All Ground Points raster		The 'Plus' tool in ArcMap was used to add the two outputs from Step 5 to form a raster with values of all of the LiDAR points (regardless of classification). This raster was put through the 'Float' tool to allow the value of the cell to be a floating-point variable.

Process Step	Product	Example Image	Processing Parameters
7	Divide Masked Class 5 raster (Step 4) with Floating-point raster (Step 6)		Use the 'Divide' tool in ArcMap to divide the Class 5 (High Vegetation) raster created in Step 4 by the Floating-point raster created in Step 6 $$\text{Canopy Density} = \frac{\text{Masked Class 5 raster}}{\text{Floating point all points raster}}$$
8	Canopy density raster		Background value (0) is shown as transparent/no data Finished canopy density raster with values between 1.0 and 0.0. Values close to 1.0 being very dense canopy and values of 0.0 meaning very thin or no canopy is present.

2.4 Limitations

It is not uncommon for some discrepancies in the classification of LiDAR data to occur given the nature of the data capture process. For example, errors may result if the electromagnetic wave is disrupted during the capture of point cloud data, or during classification if an object displays similar reflectance properties to vegetation cover. As shown in Figure 2, some discrepancies in the LiDAR data were observed in this study, such as where buildings were classified as Class 5 or 'High Vegetation' within the LiDAR dataset.

Future analysis incorporating multispectral satellite imagery, which was not available for this study, could assist in the classification of vegetation through use of vegetation indices, such as the Normalized difference vegetation index (NDVI). NDVI is a ratio of the red and near-infrared bands on multispectral imagery and is sensitive to vegetation growth. Higher values of the index correspond to vigorous growth while bare soil, built structures and water exhibit low values. Utilising a vegetation index would not only assist to minimise classification discrepancies, but also assist in the identification of vegetation that was not assigned through the LiDAR data classification. Figure 3 below is an example of classification of land cover types using multispectral imagery and NDVI.

An example of how NDVI can be utilised to refine a canopy assessment is evident in Figure 3**. Tile A** in Figure 3 is a raw multispectral satellite imagery tile. **Tile B** is the raw outputs of NDVI assessment of the red and near-infra red bands of the tile. **Tile C** is the reclassified NDVI tile depending on the NDVI values and heights derived from a canopy height model: dark green is tree canopy, yellow is open green space, and dark grey is cleared or impervious structures (such as buildings, roads).

Access to multi spectral imagery across a temporal timeframe would also enable seasonal NDVI analysis. This would facilitate a more detailed assessment of canopy cover and density, including temporal changes in canopy related to seasonal variation in tree foliage.

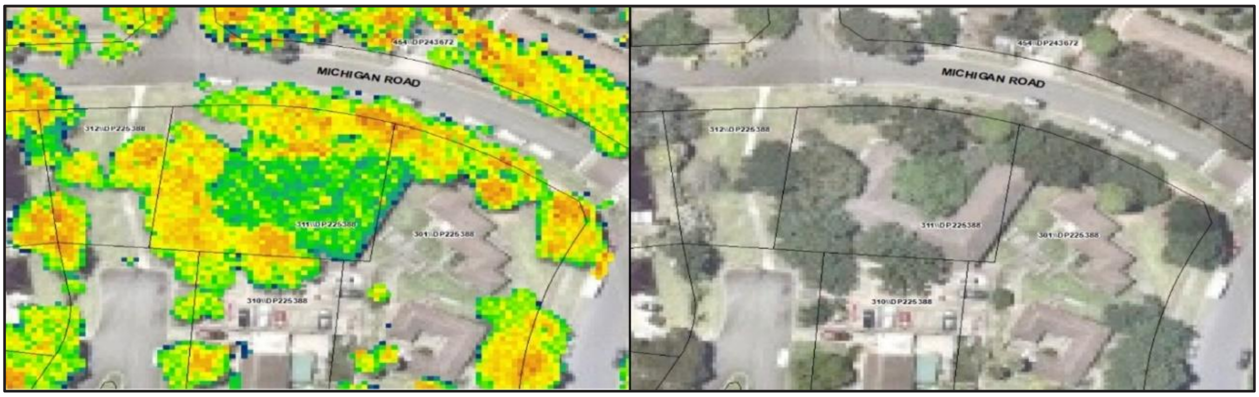


Figure 2: An example of building roofs incorrectly classified as 'High Vegetation' (Lot 311 DP225388)

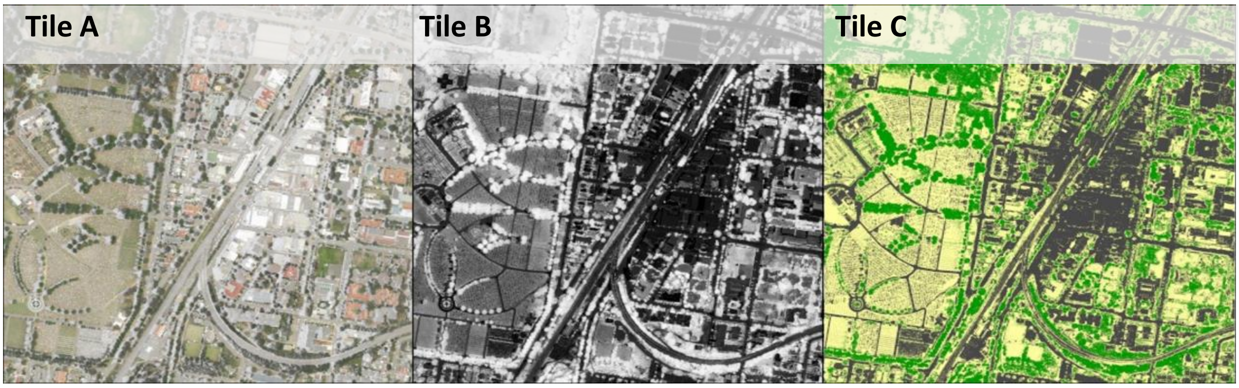


Figure 3: Example combining NDVI assessment with multi-spectral imagery and LiDAR to delineate land cover (ELA 2018)

3. Data Outputs

Outputs of the canopy analysis are presented below as a series of tables and maps below. Figure 4 **to 6** visualise the outputs related to the canopy height model (CHM). Figure 7 **to 9** in **Appendix A** visualise the intermediate processes in calculating the canopy statistics. Table 4 summarises canopy area and height in relation to the current extent of mapped vegetation used within the BDAR report.

Table 4: Summary of the canopy analysis for the present mapped vegetation

Vegetation Community	Total Canopy Area	Max Canopy Height	Average Canopy Height
PCT 849 - *Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain*	0.14 ha	25.49 m	13.87 m
Planted natives	4.63 ha	30.30 m	11.13 m
Exotic vegetation	3.18 ha	28.90 m	8.12 m

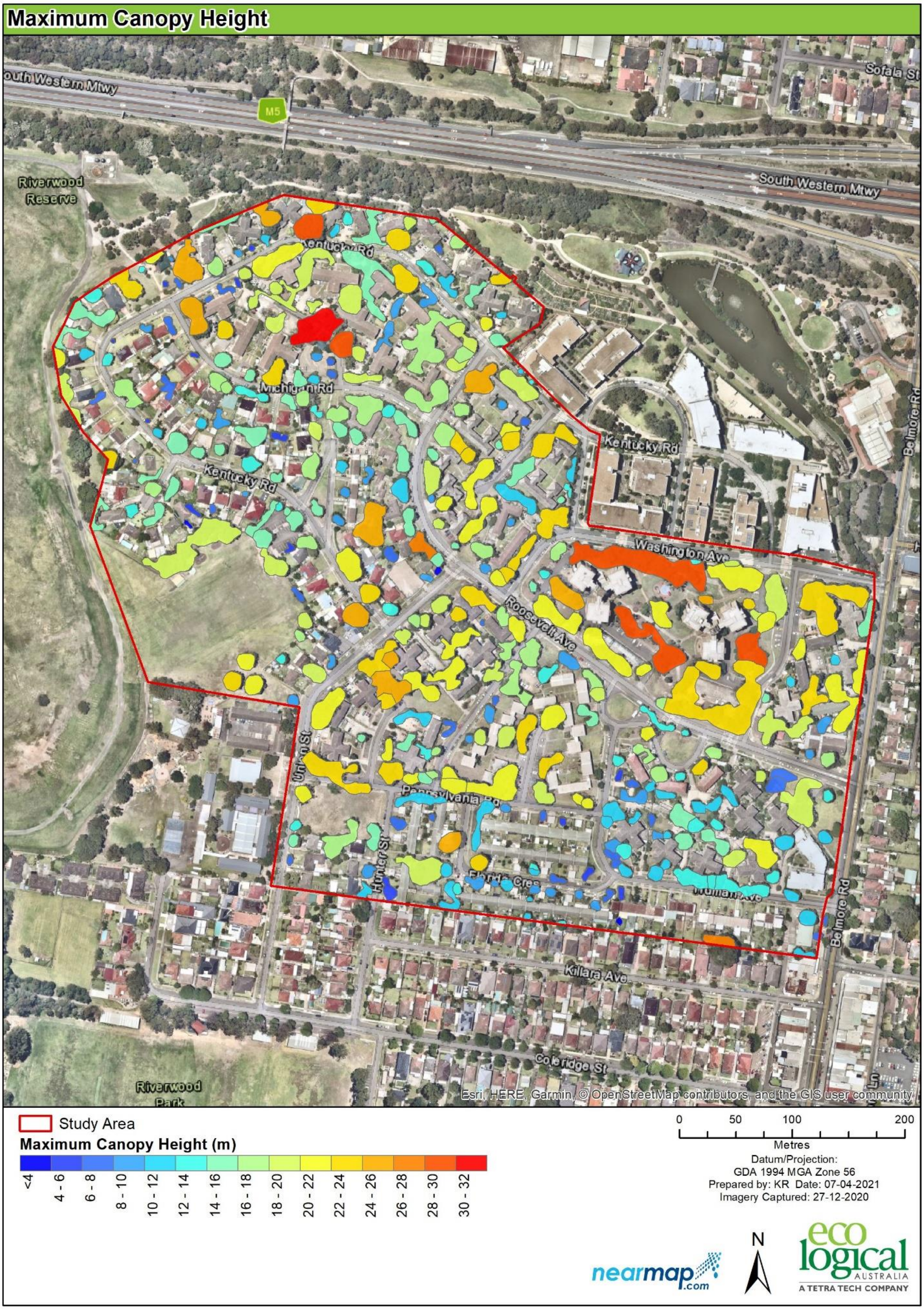


Figure 4: Maximum canopy height assigned to vegetation mapping from CHM

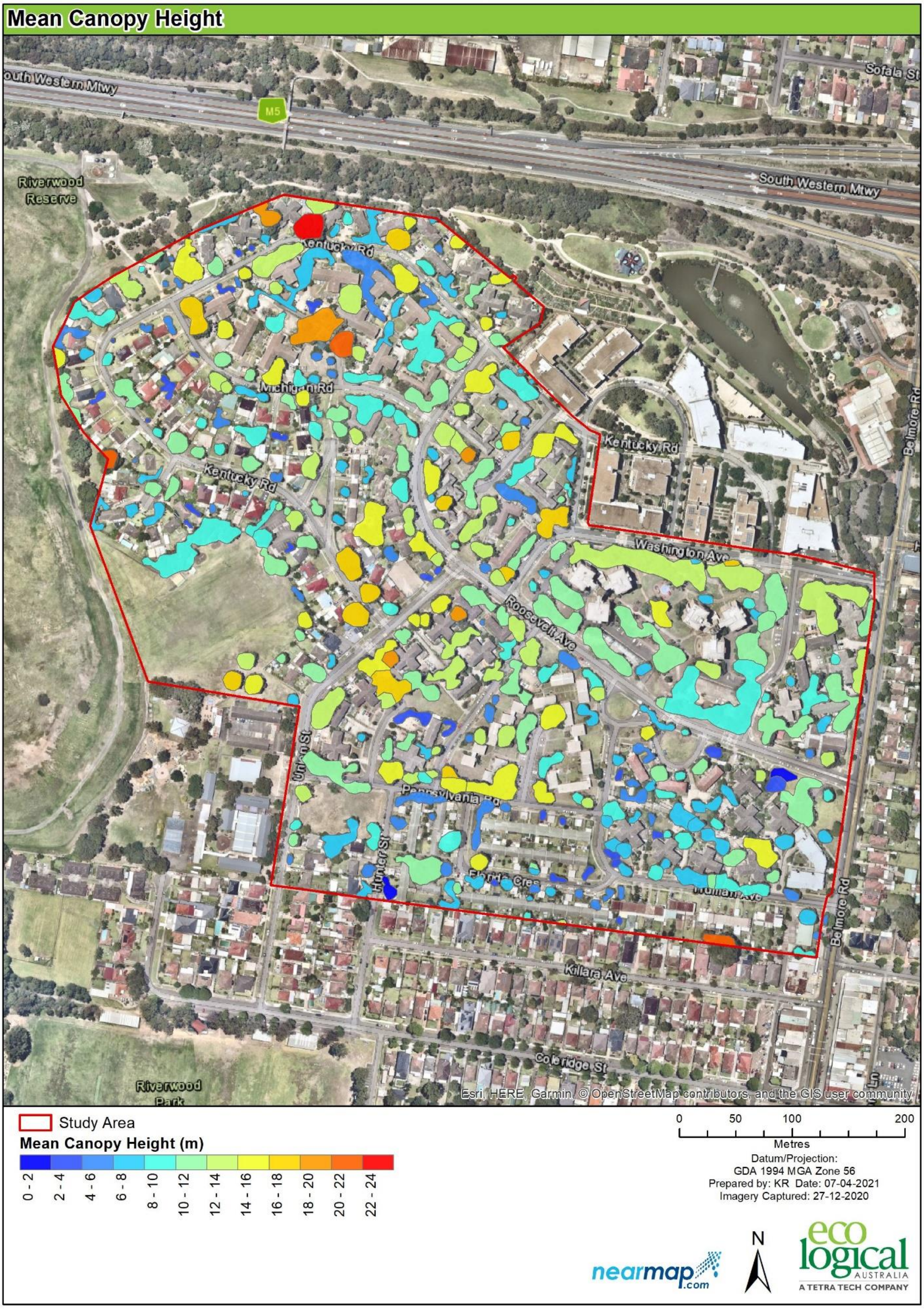


Figure 5**: Average canopy height assigned to vegetation mapping from CHM**

Figure 6: Canopy Density derived from LiDAR data for the Study Area

4. References

Crawford, C., 2009. Lidar Solutions in ArcGIS_part4: Estimating Forest Density and Height. [Blog] ArcGIS Blog: 3D Visualization & Analytics, Available at: <https://www.esri.com/arcgis-blog/products/arcgis-desktop/3d-gis/lidar-solutions-in-arcgis_part4-estimating-forest-density-and-height/> [Accessed 21 January 2021].

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Eco Logical Australia (ELA), 2018. *Sutherland Shire Vegetation Analysis Benchmark Assessment, Technical Specifications*. Prepared for Sutherland Shire Council.

Intergovernmental Committee for Surveying and Mapping (ICSM), 2011. *ICSM LiDAR Acquisition Specifications and Tender Template*. 1st ed. [PDF] ICSM, p.9. Available at: <https://www.icsm.gov.au/sites/default/files/2017-03/NZ-LiDAR_Specifications_and_Tender_Template.pdf> [Accessed 15 February 2021].

Appendix A Figures of intermediate steps

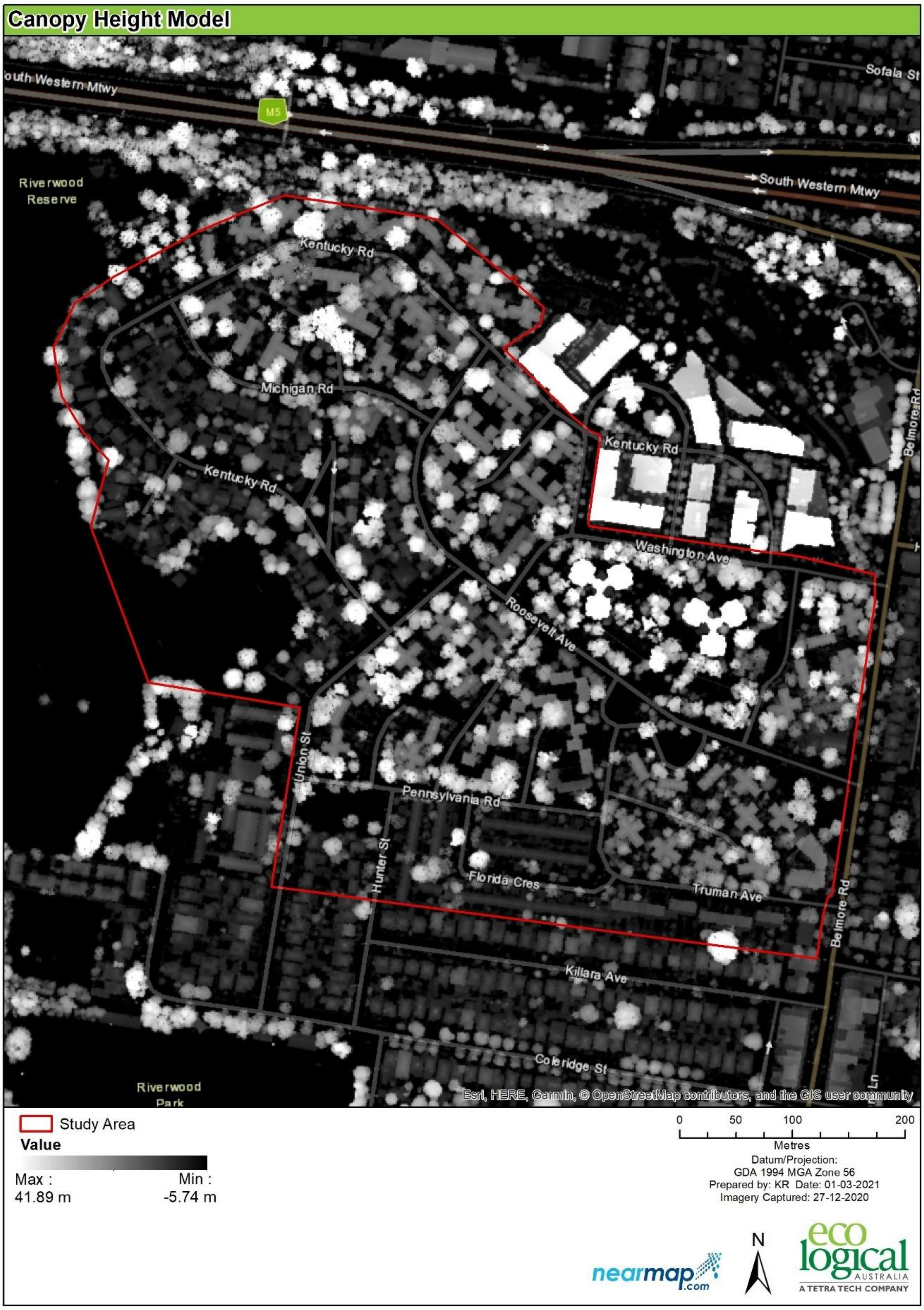

Figure 7: The Canopy Height Model (CHM) raster prior to applying the vegetation mask

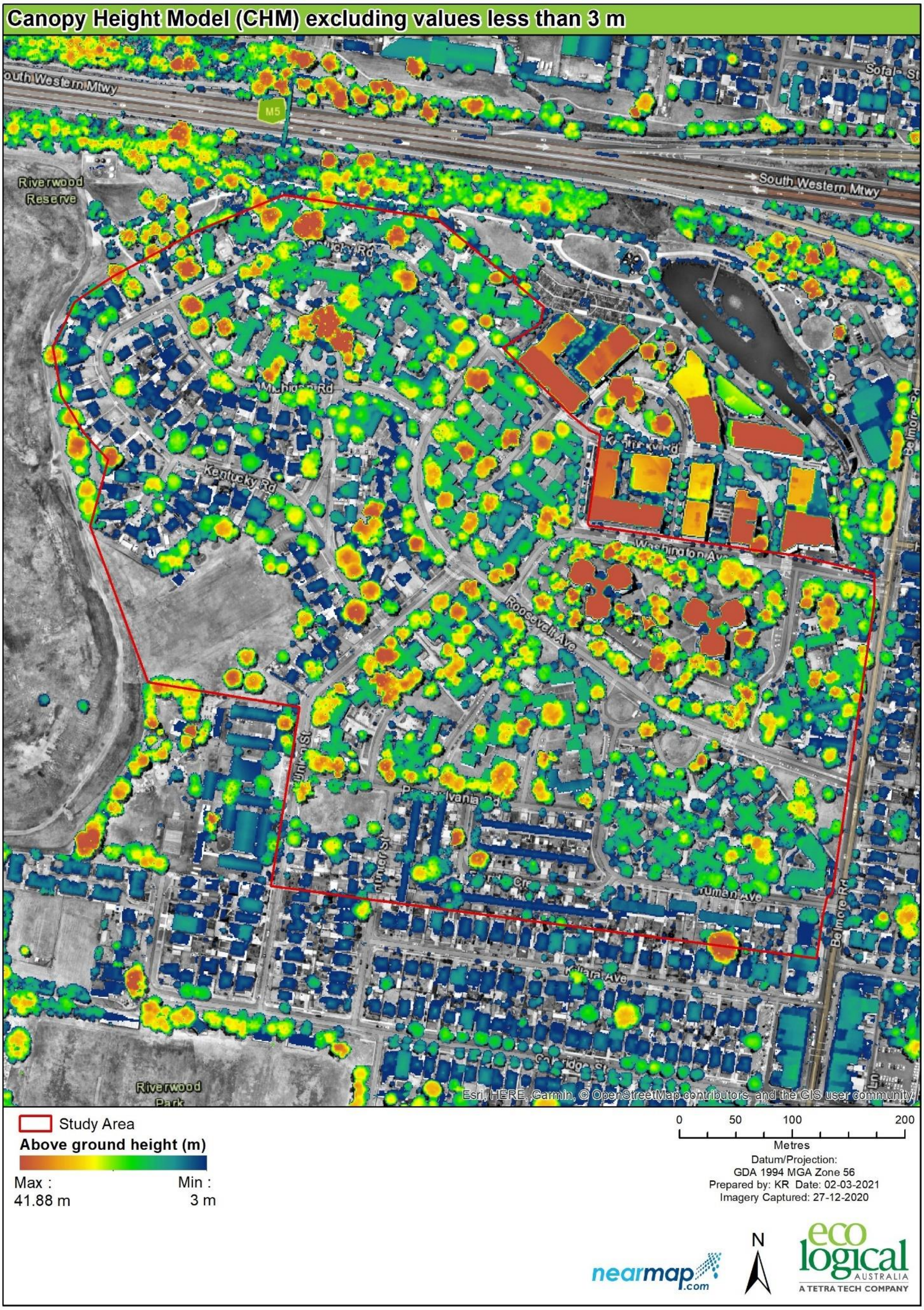

Figure 8: The Canopy Height model with values less than 3m shown as null

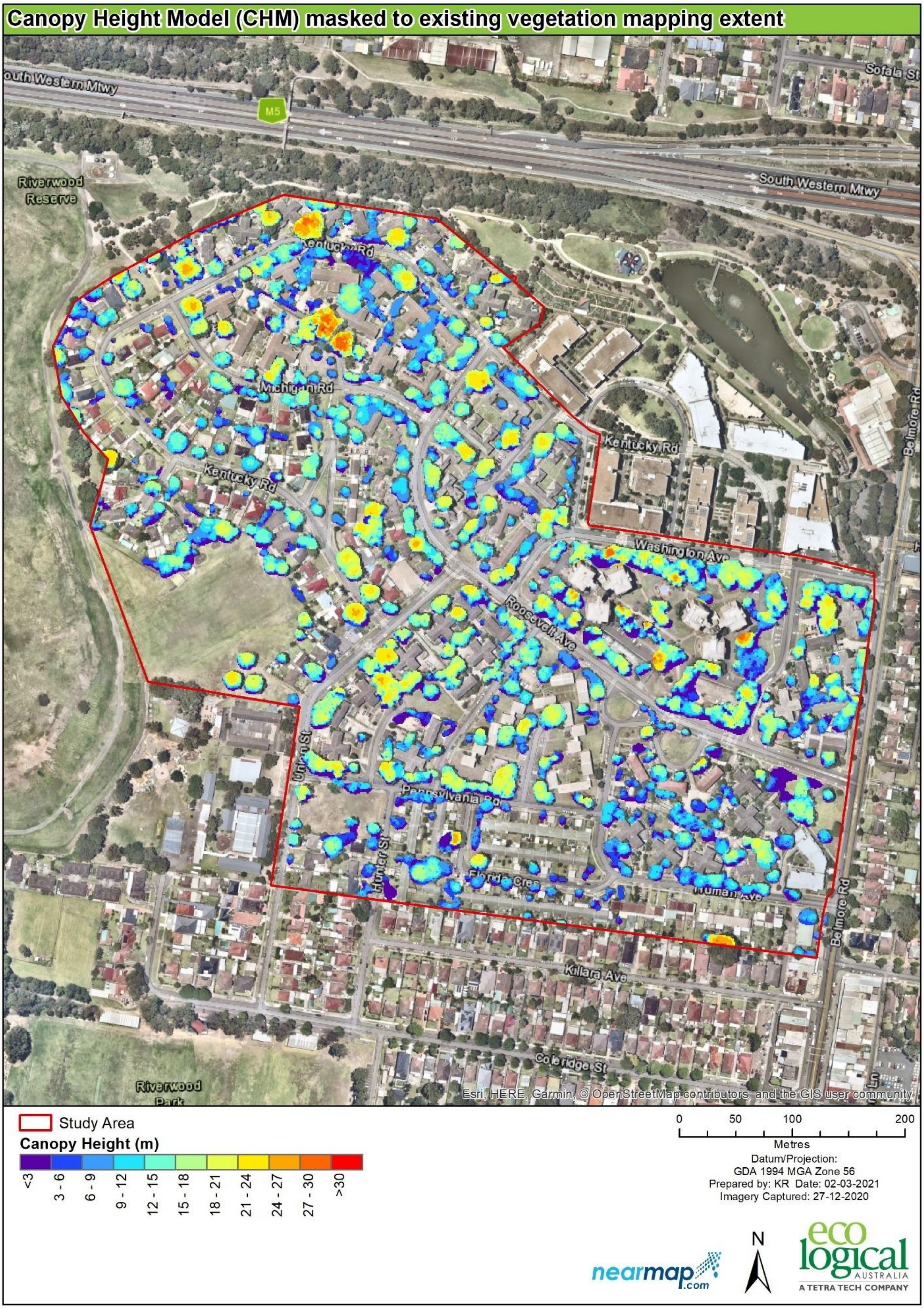

Figure 9: The Canopy Height model masked to existing vegetation mapping extent

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