A workflow for assessing tree canopy cover in the Greater Sydney Region (2019)

Version Nov 2022

Contents

A workflow for assessing tree canopy cover in the Greater Sydney Region (2019)

Version Nov 2022

A workflow for assessing tree canopy cover in the Greater Sydney Region (2019)

Version Nov 2022

A workflow for assessing tree canopy in the Greater Sydney Region (2019)

TECHNICAL REPORT:

Executive summary

This document offers a workflow (method) used for the 2019 assessment of tree canopy cover in the Greater Sydney Region. The assessment of current tree canopy is a key component of the NSW Greening our City Premier's Priority, the aim of which is to increase the tree canopy and green cover across Greater Sydney by planting one million trees by end of 2022. This is part of a broader commitment to plant five million trees by 2030.

This workflow provides a reliable and repeatable approach to creating spatial data for assessing tree canopy by Local Government Area or by land use. The outputs can be combined with other spatial data for more detailed analysis at a local scale. This workflow builds on the 2016 Urban Heat and Green Cover Baseline Assessment project (Hurley et al 2019) conducted by the Department of Planning and Environment, which provided tree canopy data that was instrumental to establishing indicators for the Pulse of Greater Sydney and a foundation for the Greening our City Premier's Priority.

The objectives of this workflow include simplifying the vegetation classification at the modified mesh block level (ABS 2019) and assignment of land-use and zoning categories to enable analysis at greater detail for planning purposes.

The revised workflow creates several intermediate datasets. It provides for a high level of data accuracy by using a rigorous and repeatable GIS processing method that takes account of known data errors. The modified mesh block (MMB) dataset combines the known spatial extents of land use with the Australian Bureau of Statistics (ABS) census mesh blocks (see: ABS Cat: 1270.0.55.001). Land use is based on the principal land use categories as defined by the ABS in the mesh blocks dataset. The NSW Cadastre and Land Zoning datasets are used as the input for the land use and zoning aggregation and to create boundary coincidence. By using these datasets, this method enables fine scale land use and demographic analysis in support of environmental and policy goals. An additional option to improve land use categorisation, not currently employed in this method, is to consider using the road corridors category of the NSW Cadastre. As with every method, future workflow implementation should review all datasets for currency and quality.

A workflow for assessing tree canopy cover in the Greater Sydney Region (2019)

Version Nov 2022

Introduction

The workflow described in this document contextualises the workflow used by Hurley et al (2019) with bottom-up aggregation of publicly available datasets. dataset. This workflow was designed to create a new tree canopy dataset using 2019 imagery that covers the Local Government Areas (LGA) of the Greater Sydney Region whereas the 2016 vegetation cover dataset covered the Greater Sydney metropolitan area, a designation of urban and peri-urban areas, regardless of LGA boundaries (Figure 1).

This workflow enables tree cover to be summarised by Land Use type, category, zoning and by LGA or ABS statistical area. In addition, the output tree canopy can be combined with urban heat island and demographic/socio-economic spatial data to assess heat vulnerability.

A workflow for assessing tree canopy cover in the Greater Sydney Region (2019)

Version Nov 2022

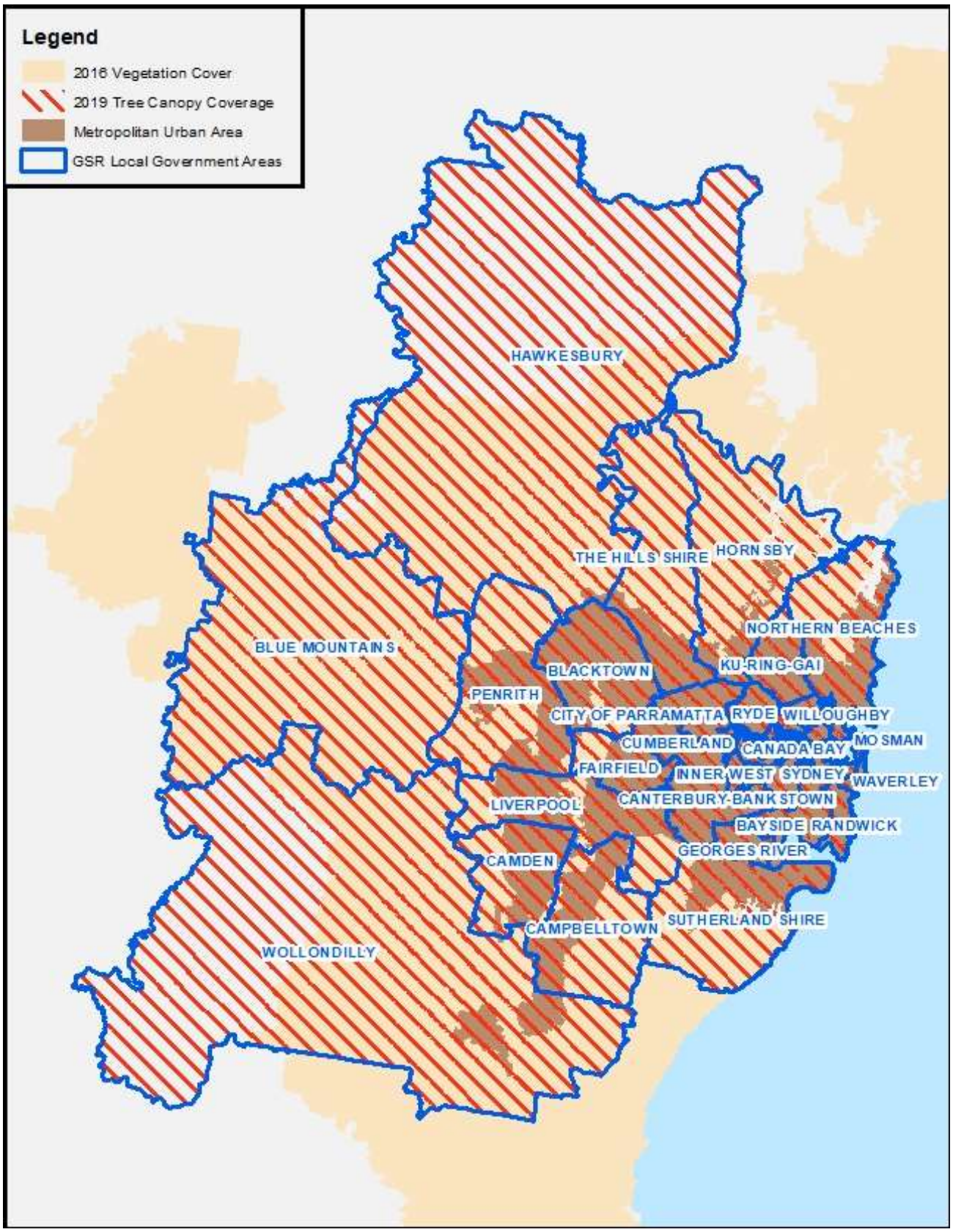


Figure 1 **2016 Vegetation Cover and 2019 Tree Canopy map coverage**

A workflow for assessing tree canopy cover in the Greater Sydney Region (2019)

Version Nov 2022

Audience

This document is primarily a guide for spatial analysts. It can be used to derive comparable modified mesh blocks (MMB) for tree canopy analysis in locations other than Sydney or be used to assess additional environmental or socio-economic variables using other ABS Mesh Blocks at various statistical area levels. This document has also been designed to assist planners and decision makers have confidence in the quality of tree canopy data generated by this method.

Background

Hurley et al (2019) documents the workflow for producing vegetation cover data outputs for the 2016 "*Urban Heat and Green Cover Baseline Assessment"* project. The project was conducted and funded by the Climate and Atmospheric Science Branch of the NSW Office of Environment and Heritage (now the NSW Department of Planning and Environment). Undertaken in collaboration with the Clean Air and Urban Landscapes (CAUL) Research Hub, the project included contributions from RMIT University, The University of Western Australia and CSIRO. The project sits within a broader research context of the *Clean Air and Urban Landscapes* (CAUL) Research Hub, under the "*Making greening happen in consolidating cities"* Project.

Several intermediatory datasets were created as part of the Hurley et al (2019) workflow. These included an urban heat / green cover assessment for the Greater Sydney metropolitan area for the years 2014 and 2016. Hurley et al (2019) key objective was the creation of spatial data for Sydney to support analysis of vegetation cover (all vegetation) against various land uses which would enable the analysis of the relationship between land use and canopy cover (trees over 3m) and detection of changes over time. The 2016 baseline vegetation cover was mapped using air photography acquired over all seasons between late February and the end of December of 2016 (Caccetta et al 2019).

This 2019 workflow supports a similar analysis using the 2m pixel Geoscape surface cover and tree themed products for urban centres based on imagery captured predominately between January and September 2019 (PSMA, 2019). This was supplemented with earlier (2018) imagery in the Geoscape surface cover and tree theme products range. Any gaps in spatial coverage were filled using the best available 30m pixel Geoscape surface cover classification product derived from Landsat imagery.

This workflow uses revised data processing and quality assurance standards. It is compatible with input datasets with both a finer and coarser resolution and can be used for repeatable assessment of canopy cover by NSW Government. Comparison with the 2016 baseline is possible at the LGA, suburb and Mesh Block levels.

Revised spatial method for modified mesh blocks

Where possible, datasets were aligned with the cadastral dataset. Mesh Block boundaries, as compiled by the ABS, aggregate a collection of cadastral lots which should spatially align to aggregated boundaries allowing capture of population statistics within each mesh block (i.e. people in buildings within a lot[s] within a mesh block). It should be noted that the minimum dwelling count of Mesh Blocks is designed to be small enough to aggregate accurately to a wide range of areas to enable a ready comparison of statistics between geographic regions. The Mesh Block target size helps the ABS protect against accidental disclosure of confidential information ABS (2021). The same 2016 mesh blocks dataset was used in both Hurley et al (2019) and this method. Comparison between 2019 and 2016 canopy cover results is therefore possible.

A workflow for assessing tree canopy cover in the Greater Sydney Region (2019)

Version Nov 2022

The spatial accuracy of data inputs and workflow, defined by the map projection, topology, XY resolution and tolerance are a critical feature of this workflow. For the cadastre data, the input datasets were kept in the native GDA94 geographics projection within a spatial geodatabase. Figure 2 summarises the workflow.

The Planning Institute of Australia (PIA) recommends that digital planning infrastructure be built with open technology. This would include the public sharing of these scripts to allow others to replicate the workflow (PIA (2021).

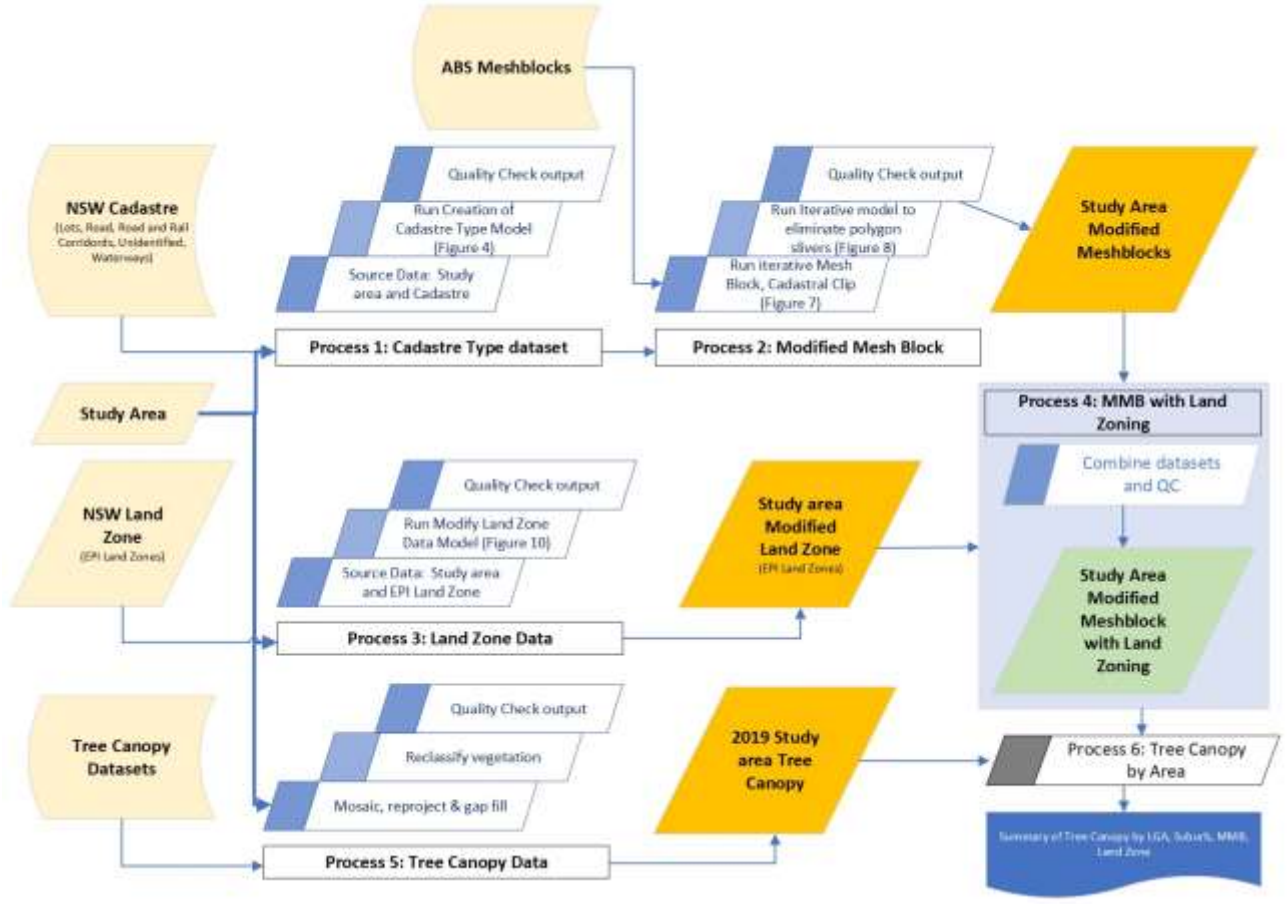


Figure 2 **Modified Mesh Block with land zoning workflow summary**

Spatial data configuration and structure

To enable the application of topological rules, analysis of spatial data was undertaken in an ESRI file geodatabase.

Topological consistency was set within a feature dataset with the resolution and tolerances duplicating the source datasets (Table 1); the NSW Cadastre (NSW Land Parcel and Property Theme). Figure 3 outlines the domain, resolution and tolerance of the data.

All data was processed in geographics (GDA94), the native projection for the majority of input datasets (Table 1).

The following dataset properties were also used in the processing of the models with the 'environment settings' for each of the described models using the same XY Tolerances as in Figure 3.

Figure 3 **Data Domain, Resolution and Tolerance**

A workflow for assessing tree canopy cover in the Greater Sydney Region (2019)

Version Nov 2022

Spatial processing workflows

Input datasets

The datasets listed in Table 1 are the inputs to the GIS processing of the revised workflow.

Table 1 Input datasets

Name	Description	Metadata URL link
NSW Cadastre - NSW Land Parcel and Property Theme		
Lot	A Lot is a parcel of land created on a survey plan. Each lot may be represented by standard lots, standard part lots, strata or stratum. Each lot has a lot number, section number, plan lot area, plan number, plan label, ITS title status and stratum label. It is part of the NSW Land Parcel and Property Theme.	https://portal.spatial.nsw.gov.au/portal/home/item.html?id=6a96afdba8d6407d8bde5a3bbacb0f02
Road	A road is part of the NSW Land Parcel and Property Theme: A road represents dedicated public roads which are open ways for the passage of vehicles, persons or animals on land. The road dataset includes public roads in use. Each road type has a section number, plan number, plan label, ITS title status, road type, road width or Crown/Council width, lot number and stratum label.	https://portal.spatial.nsw.gov.au/portal/home/item.html?id=43207b4665b548b7b264fedb63d74aa4
Road Corridor	Road Corridor is a polygon dataset that represents spatial extent of roads and maintenance boundaries.	https://portal.spatial.nsw.gov.au/portal/home/item.html?id=2a0c8e8a65a74f72a2dcfcbf7d6f9691
Unidentified	Unidentified is a polygon feature that represents a parcel of land that is unidentified.	https://portal.spatial.nsw.gov.au/portal/home/item.html?id=59659684299a4e109ac18e32c33399d6
Railway Corridor	Railway Corridor is a polygon dataset that represents the spatial extent of rail boundaries.	https://portal.spatial.nsw.gov.au/portal/home/item.html?id=1522ac11430a487d9b4561a77b96eaf3
Water Feature	Water Feature is a polygon feature that represents the cadastral boundary of tidal, non-tidal and ocean waters. Parcel polygons are defined by a series of boundary lines that store recorded dimensions as attributes in the lines. It visualises these boundaries of land parcels, often buildings on land, the parcel identifier and basic topographic features.	https://portal.spatial.nsw.gov.au/portal/home/item.html?id=7afa328966224875944992 7a03e88dfd

Name	Description	Metadata URL link
Local Government Areas	NSW Local Government Area is a dataset within the administrative boundaries theme (FSDF). It depicts polygons of gazetted boundaries defining the Local Government Area. It contains cadastral line data or topographic features which are used to define the boundaries between adjoining shires, municipalities, cities (Local Government Act) and the unincorporated areas of NSW. The dataset also contains Council Names, ABS Codes, Ito Codes, Vg Codes, and Wb Codes. Any changes that occur to the dataset should have a reference in the authority of reference feature class in the Land Parcel and Property.	https://portal.spatial.nsw.gov.au/portal/home/item.html?id=3e1edb6861524b5490c74db81e42433a
Suburb	NSW Suburb is a dataset that represents a gazetted boundary of a suburb or locality area.	https://portal.spatial.nsw.gov.au/portal/home/item.html?id=38bdaa10b7cc41a3a19be6eca91f5368
Australia Bureau of Statistics		
ABS Mesh Block	Mesh Blocks are the smallest geographic unit compiled by the ABS as part of the Australian Statistical Geography Standard (ASGS)	https://www.abs.gov.au/geography
Other NSW Government datasets		
Environmental planning instrument land zoning	Identifies land use zones and the type of land uses that are permitted (with or without consent) or prohibited in each zone on any given land as designated by the relevant NSW environmental planning instrument (EPI) under the Environmental Planning and Assessment Act 1979.	https://datasets.seed.nsw.gov.au/dataset/environment-planning-instrument-local-environmental-plan-land-zoning
Estuaries (including macrophyte detail)	The Estuaries datasets contain the water boundary of each estuary in NSW up to its tidal limits and includes areas vegetated with the macrophytes; seagrass, mangrove, and saltmarsh.	https://datasets.seed.nsw.gov.au/dataset/estuaries-including-macrophyte-detail5ebff

Name	Description	Metadata URL link
Surface cover (tree cover)		
Geoscape Surface Features - 2m June 2020 release -30m June 2020 release (Appendix A)	"Geoscape Trees is a national dataset representing tree cover and associated heights in Australia's urban areas. It's a raster dataset with a digital pixel representation of tree cover and heights at a two-metre resolution. The Trees spatial dataset is created by combining surface classification and elevation data, making it consistent with Urban Surface Cover. Tree heights enable the identification of risk across any location within urban Australia. By combining trees data with Geoscape Buildings, assessment can be made of tree overhang and the risk posed by a tree to a building considering its distance from the building and its height." Geoscape (Online 2022)	Commercial Dataset available under license. Contact vendor.

Output datasets

The datasets listed in Table 2 are the outputs of the revised workflow.

Table 2 Output datasets

Name	Description	Data type
2019 Tree Canopy GSR	This is a derived product with inputs sourced from Geoscape surface cover layers (Product Version 6.1 June 2020 release). Data set covers the Greater Sydney Region. Derived from a commercial product of Geoscape Australia which is the trading name of PSMA Australia Limited. (PSMA, 2019)	Derived product
Modified Mesh Block	Spatially defined unit of measurement initially designed by the Clean Air and Urban Landscapes (CAUL) Hub Linear infrastructure is incorporated into the ABS Mesh Block structure, in this case, the New South Wales cadastral boundaries. The CAUL Hub principles were maintained as part of the revised method	Derived intermediate dataset
Modified Land Zoning	Modification of the 'EPI land zoning' dataset to compensate for data errors.	Derived intermediate dataset

Name	Description	Data type
Modified Mesh Block with Land Zoning	Integration of both Modified Mesh Blocks and Modified Land Zoning	Derived intermediate dataset
Greater Sydney Urban Vegetation Cover to Modified Mesh Block 2019	The dataset provides area (sqm) of Tree Canopy for each modified mesh block	Final product

Process 1: Creation of intermediate cadastral type dataset

The intermediate dataset Cadastre Type merges the five NSW Cadastre feature classes into one dataset (feature class) and categorises them with a cadastre type field. The purpose of the dataset is to allow these categories to be merged with the ABS Mesh Block to create the modified mesh block dataset.

The cadastral datasets consist of the feature classes listed in Table 1. The cadastral (CAD) Type 6, 'Water Feature' is added (Table 3).

Each layer was given precedence over the other where they spatially overlapped as per the following order.

1. Road Corridor
2. Rail Corridor
3. Lot
4. Unidentified
5. Water Feature

Table 3 Cadastral (Cad) Type source NSW Cadastre feature classes

Attribute	Definition	
CAD Type (CADtype) field attributes	Cadastral Feature Class in this workflow	Hurley 2019
1	Lot	cadastral parcel
2	Road	road casement
2	Road Corridor	road casement
3	Not required	Cadastral void
4	Unidentified	Unidentified parcel
5	Railway Corridor	railway corridor
6	Water Feature	Not used

Attribute	Definition	
	Easement (assessed but not required)	Not used

Cadastre challenges

There are several points of note:

- Easements generally provide the right to access and use land while the legal title or ownership of the land remains with the owner of the land. An easement does not grant ownership of the land. (NSW Govt, 2021)
- Road and Rail Easements can overlap due to the presence of a bridge or a tunnel. Some road corridors may be underground such as the M5 and M8 motorways. There are numerous examples of where roads / rail crossing land parcels have not been subdivided or separated into the appropriate cadastral corridor or easement, largely due to ownership of the land. For example, the M7 / M5 are not easily separated from the lots (parcels) they cut through because ownership of the underlying lot is held by government.
- There are examples of where road / rail features exist, but no asset has been built.
- There is an administrative processing time between the subdivision of a parcel of land and it being changed in the NSW Cadastre.
- The quality of the output is dependent on the quality of the input data. The errors in the underlying cadastre features with the misclassification of parcels of land, in-particular road and rail, has flow-on implications for the modified mesh block product. These errors can only be fixed by the custodian of the input dataset or a method yet to be devised.

The revised method could be improved with more accurate land use inputs such as the actual impervious road surface area within current road corridors in the NSW Cadastre.

To validate the use of road and rail parcels, a future option would be to use the NSW Topographic datasets line features (road and rail) to select parcels of land that intersect those features. However, discrepancies will still arise due to differences in spatial accuracy and boundaries of the mapped features verse ‘as built’. Improvement in infrastructure features could also be gained by sourcing data from rail and road infrastructure owners or local government. If this were to occur, different business units within Transport NSW responsible for road and rail would have more accurate information on the as built location of these assets. Local Government would have more accurate information on the as built location of road assets under their jurisdiction. The collation and integration of datasets from Transport NSW and Local Government was beyond the scope of this project. This method assumed that the cadastre road, road & rail corridors was existing infrastructure.

The cadastral and infrastructure boundaries used to derive the modified mesh block should be as close as possible to the imagery date which is used to define the vegetation cover / tree canopy. This means that the intersection calculation of vegetation area and land use match in time. For example, if the imagery used to calculate tree canopy cover was taken 18 October 2018 and the cadastral version used for the modified mesh block was 1 November 2019, commission / omission errors in the calculation of tree canopy cover area by land use could occur. A road or other infrastructure for example could have been built in the preceding 12 months after the image was taken and be reflected in the cadastral data but not the imagery. This could lead to a false positive

(commission error). It is common for both Hurley et al (2019) and the revised workflow to use canopy cover and cadastre from different dates (months/years). This is because the cadastre is regarded as stable, changing rarely. This may be the case in established suburbs of Sydney but not so in growth areas or around infrastructure projects.

Cadastre Type Creation: Arc Model

The model to create Cadastre Type considers precedence of features and the fact that corridors and easements cross land parcels. The base cadastre is therefore a combination of Lot, Road, Rail & Road Corridors, Unidentified and Water feature classes. From this combined dataset of the 'study area cadastre type' (CombCadGSR1_populated in the below model), it is possible to erase and append rail and road corridors in the order of road then rail. The model used was titled Create Greater Sydney Region (GSR) Cadastre Type (CreateGSRcadastre2) and is displayed in Figure 4.

On completion of the model (Figure 4), quality checking was undertaken by building topology, checking and fixing gaps and overlaps in the dataset.

The product of the model is a single cadastre dataset (feature class) with the new field 'CADtype', consistent with Hurley et al (2019). The area of features, calculated in hectares, was also included in the dataset by reprojecting the data "*on the fly*" to calculate area in MGA56 projection.

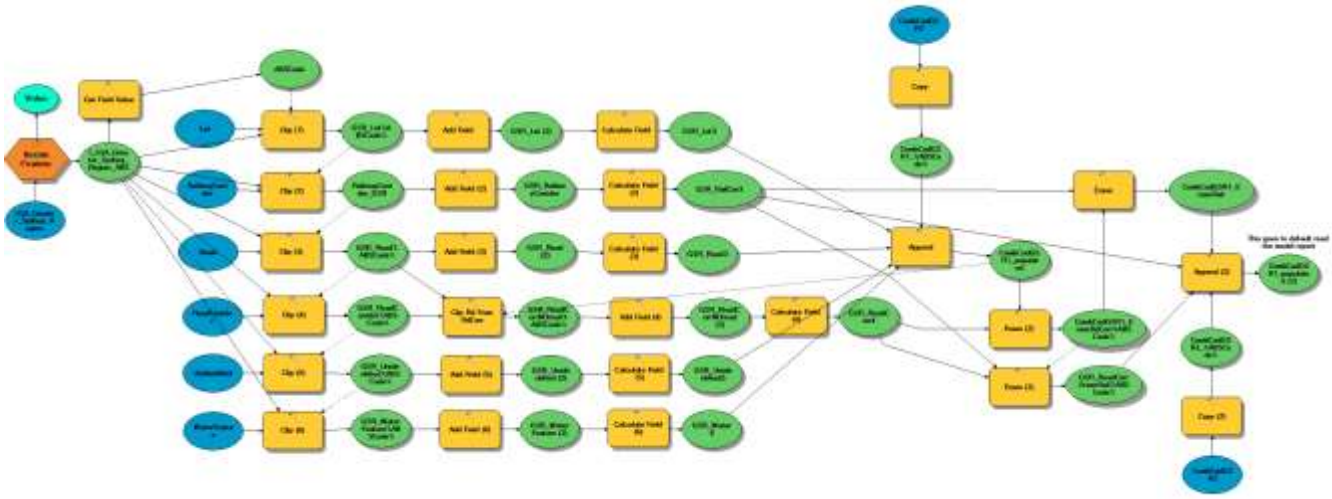


Figure 4 Model to create Cadastral Type

Process 2: Creation of intermediate modified mesh blocks dataset

Modified Mesh Blocks are a combination of ABS Mesh Blocks and the 'cadastral type' dataset (described above). The purpose of modified mesh block is to provide areas of known cadastral type for statistical analysis. A process model was developed in ArcGIS to create the modified mesh blocks (Figure 5). This allows the base layer to maintain cadastral boundary integrity within the integrated mesh block and cadastral type dataset.

Data set size and the number of cadastral blocks in the Greater Sydney Region meant that it was not feasible to combine the ABS Mesh Blocks with 'the cadastral type' dataset through a single GIS intersect tool. Instead, an iterative process was undertaken. Cadastral lots were clipped by individual mesh blocks, attributing and appending the 'CADtype' output to a completed dataset.

The iterative process was computationally slow. This resulted in the breaking up of the Greater Sydney Region into batches by LGA or MB numbers. The batches were then merged (append GIS tool) back together to complete this process. Polygons were also split into 'single part' polygons before and after processing.

Portions of the mesh block boundaries should follow lot boundaries, although mesh block boundaries do go down the centre of a road, splitting the road features (Figure 6). It is common for the ABS Mesh Block and cadastre boundaries to not align, creating errors in any product produced from their intersection. The misalignment of mesh blocks and cadastre results in 'slivers' (very small areas of land split from their parent polygon) which were corrected later in the process (Figure 7). Misalignment of boundaries can also be due to changes in lot boundaries over time (e.g., subdivision). It should be noted that the mesh blocks were derived from a cadastre prior to 2016 whereas the modified mesh blocks in the revised method were derived from the most current cadastre at the time of processing (Figure 4).

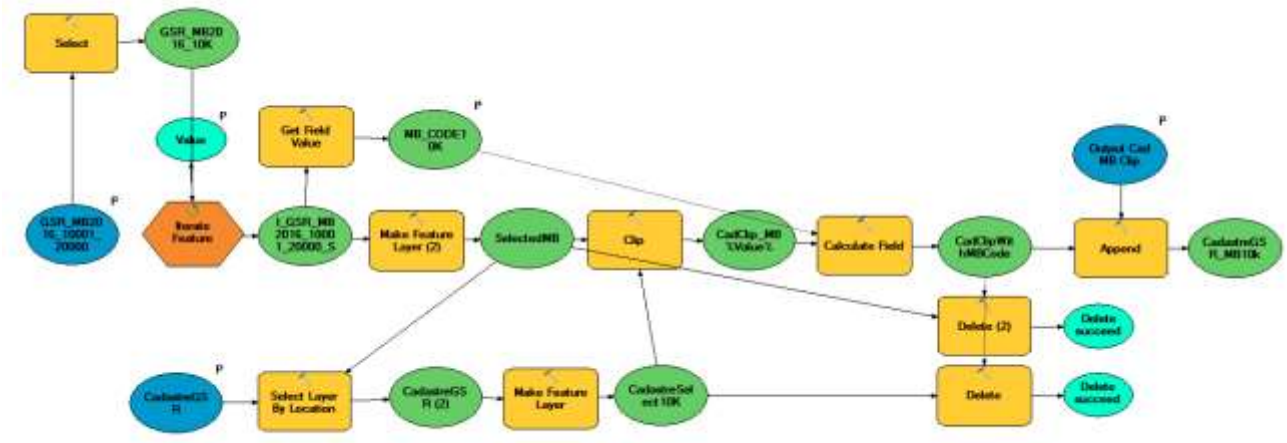


Figure 5 Process to create Modified Mesh Blocks

.

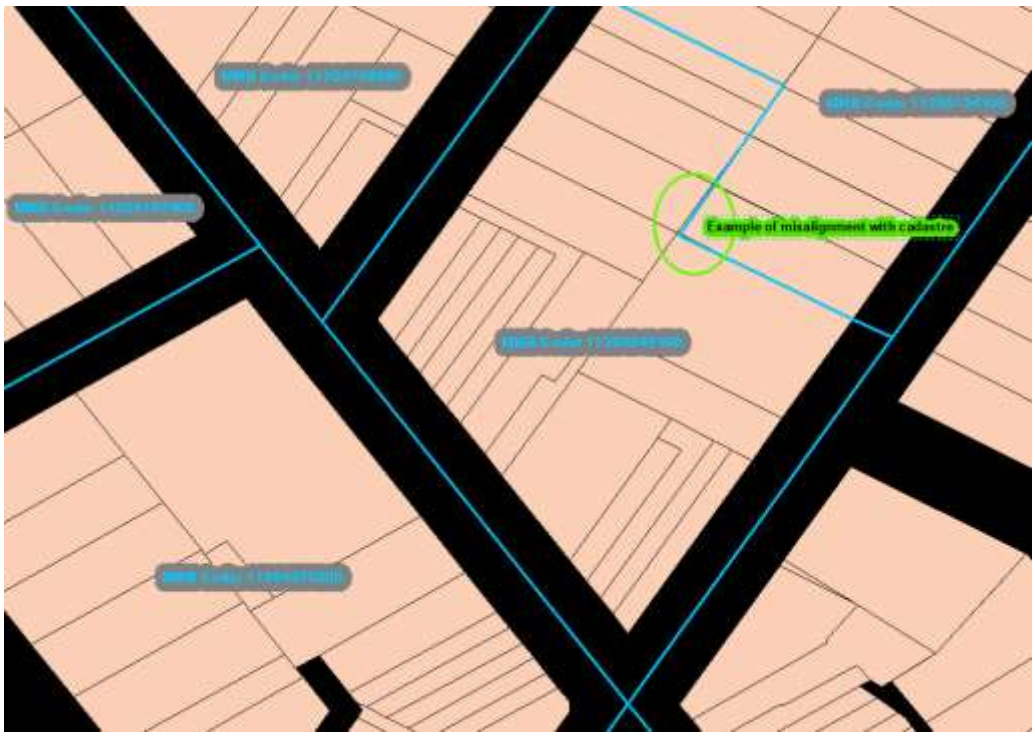


Figure 6 **Example of Mesh Block boundaries**

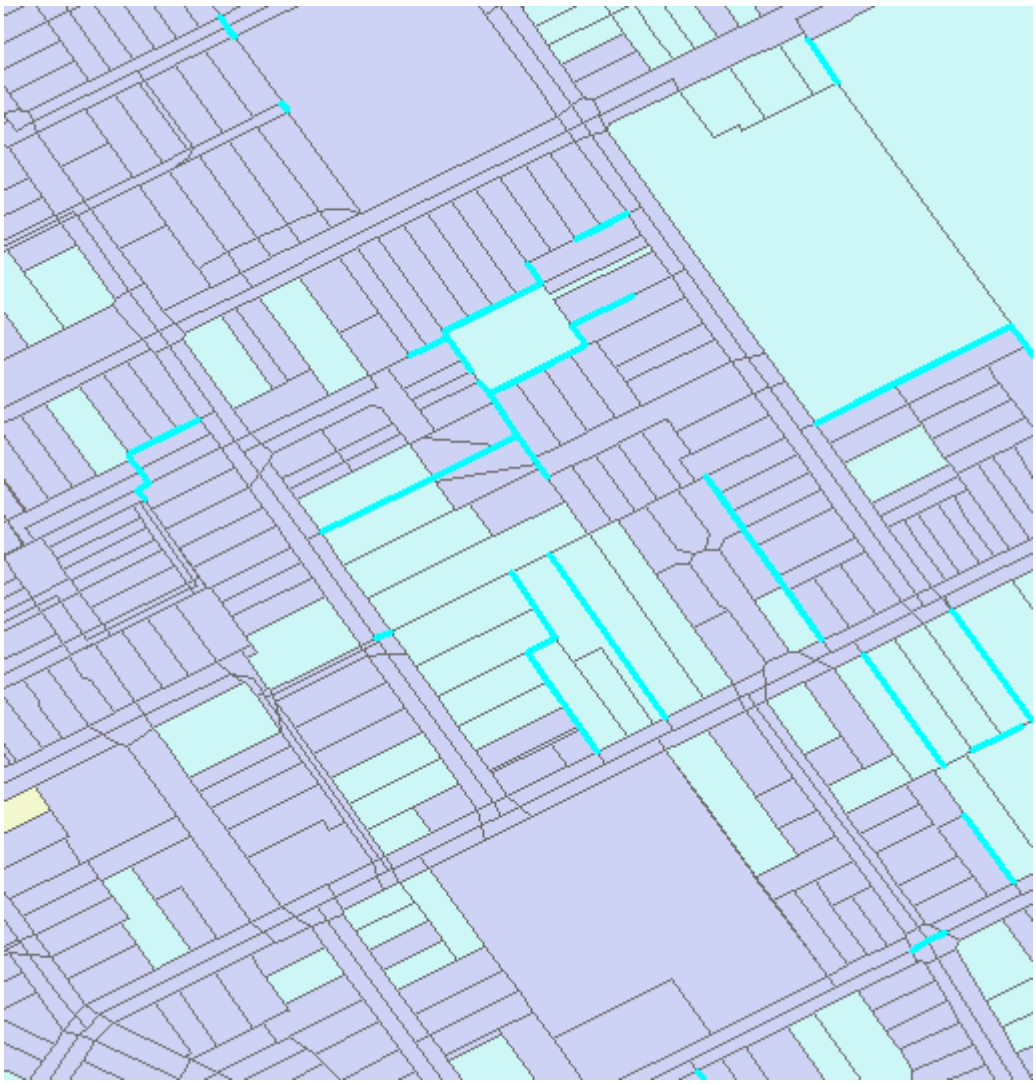


Figure 7 Examples of polygon slivers between features (light blue features)

Quality checks on the dataset were undertaken to find as many sliver errors as possible (Figure 7), with the slivers being merged back into their parent cadastral feature based on CADID (unique ID for each cadastral parcel), shape and size/area. Sliver polygons were found using the ESRI software topology tools where size was less than the cluster tolerance requirement of the dataset. The list of topology errors was then an input into the model below to remove or “eliminate” (ESRI toolbox function) the slivers. This process eliminated the errors of misalignment of mesh blocks with cadastral features and slivers from processing (Figure 8). Appendix B also lists other error checking methods used throughout the quality checking steps of this methodology.

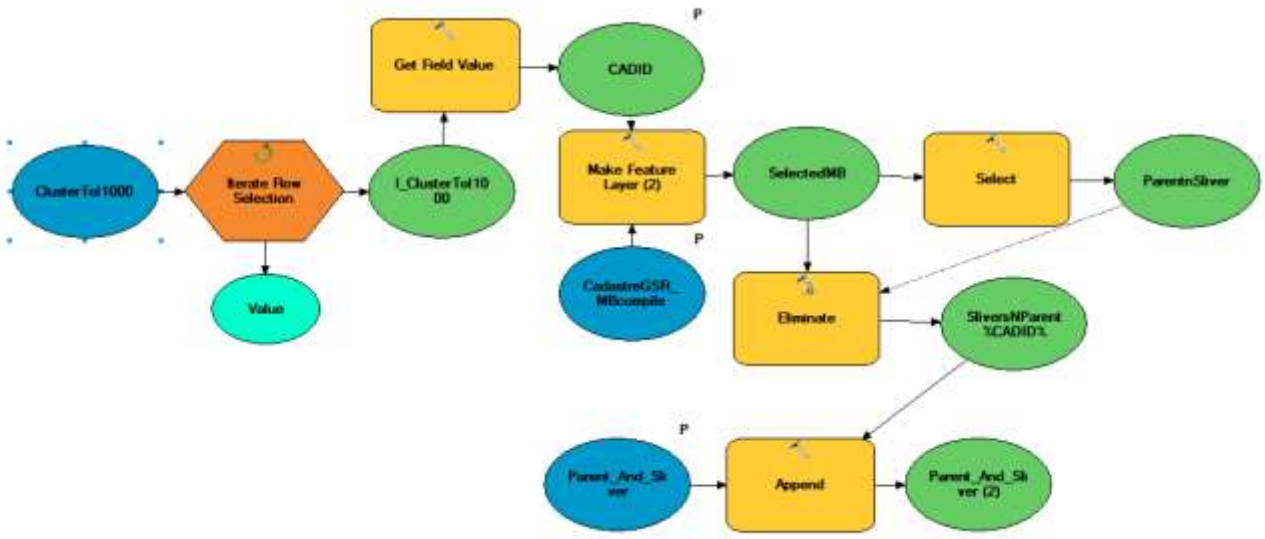


Figure 7 Modified Mesh Block quality control: Iterative process to 'eliminate' polygon slivers

Process 3: Process intermediate land zoning dataset

Process 3 and 4 enabled tree cover by Land Zone to be estimated. This required the integration of the NSW Land Zoning (EPI_Land Zoning,Table 1). Appending land zoning to the modified mesh block dataset allowed statistical analysis to be undertaken. The product of process three is titled the 'Study Area modified land zoning' dataset (Figure 2), which was then combined with the modified mesh block in process four.

Land zone data challenges

Hurley et al (2019) identifies several issues associated with the process of intersecting land zoning with cadastral mesh block features. The revised method resolves some of these issues which include:

- the overlap between local government LEPs;
- the overlap between State and Local government planning zones;
- gaps between local government LEPs resulting in unzoned land areas; and
- multiple land zonings over some areas.

The results of Hurley et al (2019) workflow which could not be altered were incorporated in the development of the modified land use zoning dataset. These included:

- Miss-alignment of boundaries with cadastral parcels where the intention was for a zone to align with the cadastre or landscape feature such as a river.
- Cluster Tolerance of 'EPILandZoning' dataset is set to 0.000000000000005 degree and XY Resolution is set to: 0.000000000000003 degree. An example of the impact of this setting is shown in Table 4 where the on-ground distance as it relates to the NSW Cadastre is given. Tolerance sets "*the distance range in which all vertices and boundaries in a shapefile or feature dataset are considered identical or coincident*" (ArcGIS Help). This means that nodes which make up a line or polygon are beyond the necessary accuracy of the dataset by multiples of 1000 (Table 4) which results in spatial errors of the datasets boundaries. This results in overlaps and unmapped areas (holes) in the dataset leading to

difficulty in processing the data. The complexity and number of nodes that make up each shape boundary will add to the computational effort of processing GIS functions. If the dataset has the same cluster tolerance as the NSW Cadastre (example Lot datasets), this allows the zones dataset to match the cadastre where coincident. Table 4 and Figure 9 describe the cluster tolerance differences and on ground distance. Conversion of degrees to metre comes from known mathematical functions (Geosciences Australia, 2021) and survey accuracy measurement is often graded (LINZ, 2021; NSW 2021). The use of cluster tolerance impacts on geoprocessing is discussed in ESRI (2010).

Table 4 Degree precision verse length at 45°N/S of datasets

Dataset	Tolerance in Degrees	On ground distance at
EPI Land Zoning		Microscopic
- XY Resolution	0.000000000000003	
- Cluster Tolerance	0.000000000000005	
Lot		Approx. 1mm (0.787 mm)
- XY Resolution	0.000000001120497	
- Cluster Tolerance	0.00000001792796	

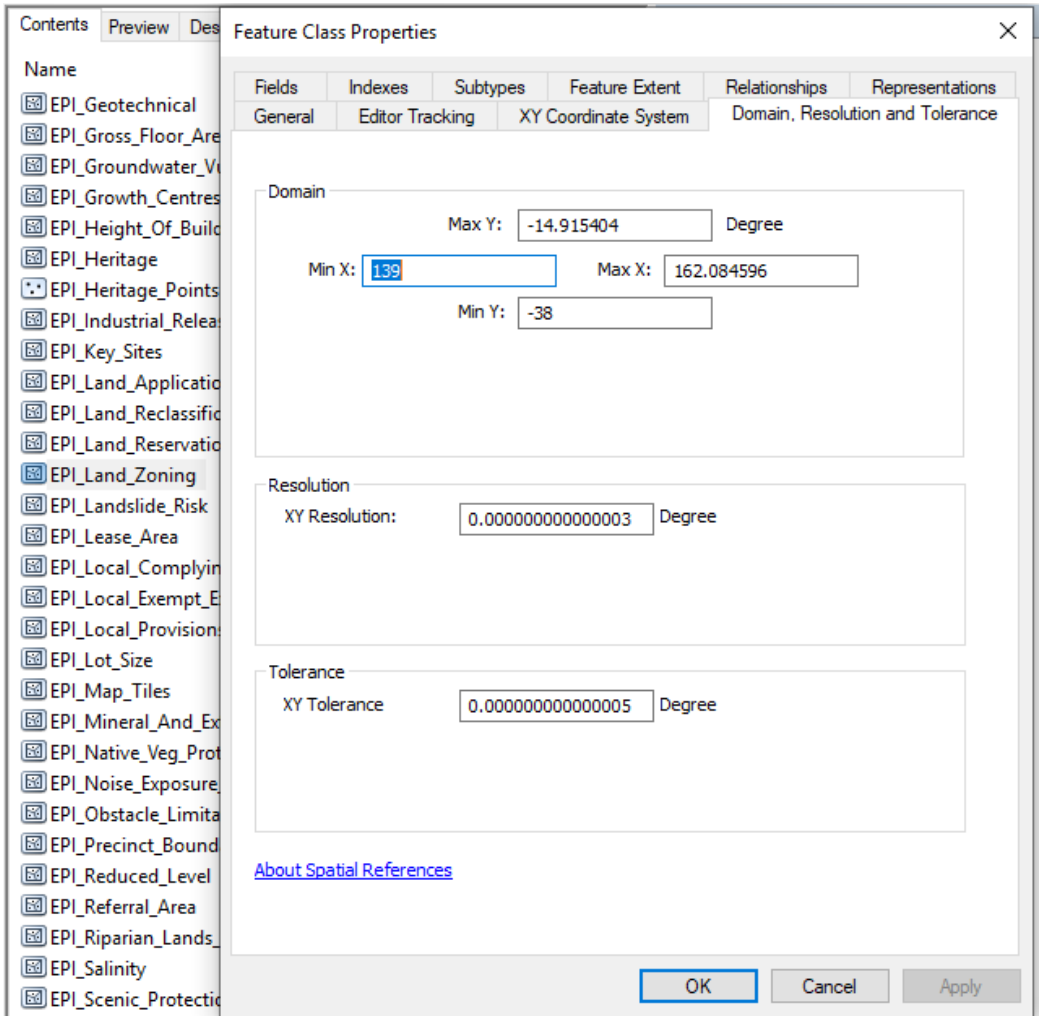


Figure 8 Cluster tolerances of EPI land zoning dataset

The Land zone map used was 'EPI_LandZoning' which can be found in the NSW Planning Portal. A method to remove overlaps based on LGA was developed. Authoritative LGA boundaries were provided by NSW Spatial Services. Any area gaps between a LGA boundary in the zoning data were filled with polygons attributed as 'unknown'. To deal with overlaps in the zoning data, a precedence list was developed.

To compensate for challenges described in relation to the integration of land zoning and overlaps with the original data, the following process was developed:

1. SEPP data was separated from 'EPI LandZoning.'
2. The Greater Sydney Region study area was used to clip 'EPI LandZoning' GSR land zones.
3. The iterative Arc model in Figure 10 was run on GSR to remove LEP features which overlapped into adjoining council areas. The overlaps between LGA areas were extracted into separate datasets for each LGA in the same process (Figure 10) 'zoneError%ABSCODE% and stored by LGA ABS code. A total of 34 error outputs were produced. The main output used was 'GSR_EPI_LandZoneModified'.

4. The areas overlapping 'EPI Landzoning SEPPs were then erased from the 'GSR_EPI_LandZoneModified'. This allowed the removal of any overlaps, with SEPP taking precedence over LEP features in the dataset. SEPP data was then appended back to fill the holes resulting from the erase function.
5. Overlaps and holes that still existed along LGA boundaries were filled using ESRI topology rules and allocated to the appropriate LGA as 'unknown' zone.

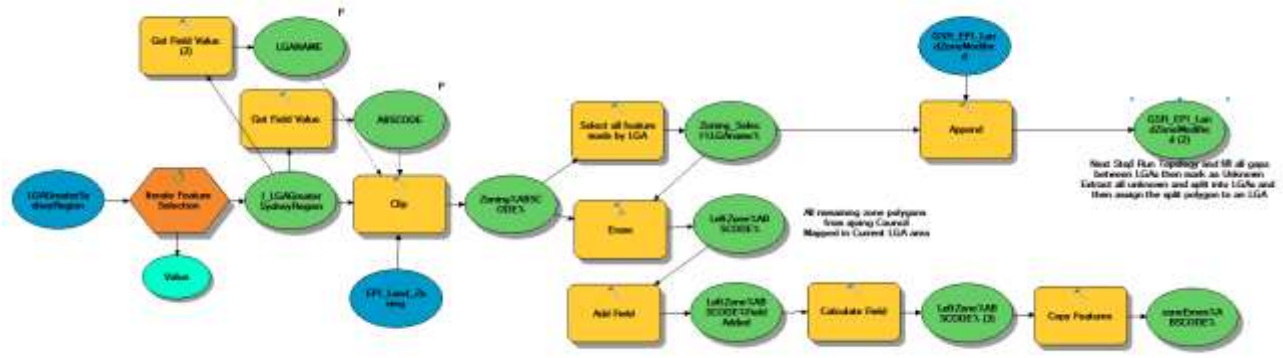


Figure 9 Arc Model to modify land zone data

The process described above produced a Study Area Modified Land Zone dataset where:

- Overlaps were minimised
- SEPP polygons were prioritised over LEP polygons, and
- Gaps along LGA boundaries were filled.

Process 4: Modified mesh blocks with land zoning

Process 4 combines the 'Study Area Modified Land Zone' with the 'Study Area Modified Mesh block. This was achieved through a GIS union process. Incorporating relevant land zoning information with modified mesh blocks enables the output dataset to be analysed for planning purposes. The output of the union was clipped to the boundaries of the Greater Sydney region to exclude irrelevant features. All polygons with an area less than 10 sq m (sliver) were merged with the adjacent parcel they shared the largest border with, provided that the adjacent parcel was bigger than the sliver. Every modified mesh block was then classified based on its land use into the appropriate type, category and subcategory. Contiguous modified mesh blocks with the same classification and which shared the same zoning information and parent mesh block were aggregated. The areas of the final modified mesh blocks were calculated and presented in the MMB_AREA field.

Classification of modified mesh blocks

Each modified mesh block was assigned a land use classification in accordance with a three-tiered hierarchical classification scheme that defines the type (MMB_TYPE), category (MMB_CAT) and subcategory (MMB_SUBCAT) of land use (Table 5 The hierarchical relationships between MMB_TYPE, MMB_CAT and MMB_SUBCAT. It is a revision and extension of the original classification scheme described in Hurley *et al* (2019) and provides additional level of detail and flexibility that will enable analyses by land use (type, category and sub- category) to support different planning and/or policy objectives.

Table 5 The hierarchical relationships between MMB_TYPE, MMB_CAT and MMB_SUBCAT

MMB_TYPE	MMB_CAT	MMB_SUBCAT
Infrastructure	Road	Road
		Planned Road
	Railway	Railway
	Airport	Airport
Parkland	Environmental	National Park/Nature Reserve
		Conservation
	Recreational	Public Recreation
		Private Recreation
		Parkland/Open Space
Property	Commercial	Commercial
	Education	Education
	Industrial	Industrial
	Hospital/Medical	Hospital/Medical
	Residential	Residential
		Environmental Living
		Environmental Management
	Primary Production	Primary Production
	Other	Defence
		Tourism
		Other
Water	Water	Water

The four types of modified mesh block (Infrastructure, Parkland, Property, and Water) described in Table 6 depict the four functional grouping of land parcels based on the broad-scale typology of land use with planning and policy implications.

Table 6 Modified mesh block types

MMB_TYPE	Description
Infrastructure	Any cadastral parcel that is dedicated for linear transport infrastructure or air transport facilities
Parkland	Any cadastral parcel that is dedicated for the purpose of conservation, open space or recreation
Property	Any cadastral parcel not classified as infrastructure, parkland or water is functionally considered as property
Water	Cadastral parcel that has been classified as part of the waterway

The modified mesh block categories (Table 7) and subcategories (Table 8) adopted in the revised classification scheme were based on the generic land use categories of the original ABS Mesh Blocks. Two of the original categories were further subdivided to provide greater resolution to the types and nature of land use. The previous ‘Transport’ category was integrated with the ‘Infrastructure’ category which was split into the three main forms of transport infrastructure: road, railway and airport. Parkland was further classified based on whether the intended primary purpose was environmental or recreational.

Table 7 Modified mesh block categories

MMB_CAT	Description
Road	Land that is part of existing or future road network or road transport related infrastructure
Railway	Land that is part of existing railway lines or rail related infrastructure
Airport	Land that is part of existing airports or air transport facilities
Environmental	Land containing area dedicated for the purpose of conservation and/or environmental protection
Recreational	Land containing area dedicated for recreational activities
Commercial	Land primarily used to support a range of business or commercial functions
Education	Land primarily used to support a range of functions relating to education or religion
Industrial	Land primarily used to support a variety of industrial activities and facilities
Hospital/Medical	Land primarily used for hospitals or medical facilities
Residential	Land used for housing/accommodation of varying densities
Primary Production	Land used primarily for primary production or other agricultural purposes
Other	Land with use(s) that could not be easily placed in one of the other categories due to the nature of the land use, and/or due to evidence of high mixed use
Water	Bodies of water

Table 8 Modified mesh block subcategories

MMB_SUBCAT	Description
Road	Land used for existing streets/roads
Planned Road	Land reserved for planned streets/roads that do not current exist
Railway	Land used for railway line and rail related infrastructure
Airport	Land used for airport and air transport related infrastructure
National Park/ Nature Reserve	Land reserved and managed as national parks or nature reserves
Conservation	Land managed to protect identified high ecological, scientific, cultural or aesthetic values
Public Recreation	Land zoned as public open space areas and land used for recreational activities
Private Recreation	Privately owned land used for recreational activities and recreational facilities compatible with enhancing and protecting the natural environment
Parkland/Open Space	Public land and open space used for recreational activities but not specifically zoned for Public Recreation
Commercial	Commercial lots / private commercial land
Education	Land used for educational, research or religious purposes
Industrial	Industrial lots / private industrial land
Hospital/Medical	Land used for hospital/medical purposes
Residential	Residential Lots / private residential land
Environmental Living	Land with special environmental or scenic values where residential development can be accommodated
Environmental Management	Land with special ecological, scientific, cultural or aesthetic attributes or environmental hazards/processes suitable for limited range of development
Primary Production	Agricultural lots / private agricultural land
Other	Land used for any purposes that are not covered by all the other subcategories
Defence	Land used for defence purposes
Tourism	Land used for tourism related purposes
Water	Waterways

The land use classification applied to the modified mesh blocks (presented in the MB_Reclass field) was a reclassification (based on cadastral information) of the generic land use categories assigned to the parent ABS Mesh Blocks. The parent ABS mesh blocks were considered no longer appropriate once partitioned and modified. The revised method and data processing considered available zoning and cadastral information. The revised reclassification reflected more accurately the actual, intended or permissible land use for any given modified mesh block (Table 9). For modified mesh blocks in zones with non-specific purposes (for example, Unzoned Land and Deferred Matter), the classification of the surrounding or adjacent land use was considered and/or adopted. The land use classification of the original ABS Mesh Block was used by default only if no other information was available or suitable.

The complete suite of rules and criteria used in this revised method to classify the modified mesh block into land use categories is provided in Appendix C.

Some modification and additions were made to the original data structure and tabular attributes as outlined in the Hurley et al (2019).

All relevant information, if available, relating to the environmental planning instrument and the planning zone is retained for each modified mesh block. This allows the identification and more focused analysis of canopy information for one of more land use type, category or subcategories that occur in one or more zones of interest (Table 9 and 10). For example, canopy cover for roads in residential zones in general, or in R1 zones only.

It should be noted that the areas that share the same MMB_Code in the 2016 and 2019 datasets are not necessarily the same. This is because the modified mesh blocks used in the 2019 dataset were subject to further partitioning and different inputs creating a varying number and size of modified mesh blocks. As such, more modified mesh blocks were derived from the same parent mesh block. The unique identification code of the original ABS Mesh Block remains unchanged. Information relating to the MB_CAT16 and MB_Reclass (relabelled here as MB_CLASS16) attributes from the 2016 dataset were retained purely as a frame of reference to allow cross-referencing and comparison with the 2019 dataset.

Table 9 Key attributes relating to environmental planning instrument and planning zones

Attribute	Description
EPI_NAME	Name of the environmental planning instrument applicable to the modified mesh block
LZN_CODE	The zone code of the used to further partition the ABS Mesh Block and subsequent designate the land use classification of the derived modified mesh block
ZN_PURPOSE	The purpose, if specified, of the planning zone

Table 10 Key attributes in dataset relating to the modified mesh blocks

Attribute	Description
MB_CODE16	The unique numeric identification code assigned to each individual ABS Mesh Block
MB_CAT16	The land use category assigned to each individual mesh block from which the modified mesh blocks are partitioned.
MB_CLASS16	The designated ABS land use classification used in the 2016 dataset. This is provided for the purpose of comparison
MMB_CODE	The unique numeric identification code assigned to each individual modified mesh block

Quality Control of MMB classification

Post classification quality control involved a combination of (a) audit of random modified mesh blocks to assess the validity of the classification, and (b) visual inspection of the continuity of correctly classified modified mesh blocks along known linear transport infrastructure, in particular railway lines and major arterial roads. The accuracy of classification is dependent on the quality, accuracy and currency of the input data. The land use classification assigned to the modified mesh blocks should be taken as broad scale and indicative rather than absolute. Further consideration of local circumstances is advised if the different levels of modified mesh block classification are to be used as the basis for analysis and comparison at a focused and localised scale.

Process 5: Creation of 2019 Tree Canopy from Geoscape

The 2019 Tree canopy dataset was derived from the Geoscape surface cover datasets with some reclassification for trees under 3 metres, mangroves and unspecified vegetation. The steps are briefly summarised below. Geoscape is a commercial product which is purchased under license.

1: Mosaic and reproject

A) Reproject (to GDA 1994 MGA zone 56) and mosaic all Geoscape 2m resolution Surface Cover tiles that are applicable to the Greater Sydney Region (GSR). Geoscape 2m Surface Cover tiles are only available for urban centres.

B) Reproject and mosaic all Geoscape 30m resolution Surface Cover tiles that are applicable to the Greater Sydney Region. Resample raster to 2m grids.

C) Reproject and mosaic all Geoscape 2m resolution Tree tiles that are applicable to the Greater Sydney Region. Geoscape Tree tiles are only available for urban centres.

D) Clip and retain only the parts of the 2m and the 30m rasters for surface cover that are within GSR boundaries using the appropriate GSR boundary shapefile/feature class.

2: Gap filling

Supplement the missing areas in GSR not covered by the 2m Surface cover raster using the resampled 30m surface cover raster. This will create a new surface cover raster that contains the best available surface cover classification for the entire GSR, hereafter referred to as the GSR Surface Cover raster.

3: Reclassify trees <=3m as Unspecified Vegetation (Classification code = 6)

Use the Geoscape Tree raster (which contains tree height information) to reclassify pixels originally classified as “Trees” (i.e. pixel value = 5) to “Unspecified Vegetation” (i.e. pixel value = 6) if tree height is 3 metres or less. For the purposes of this dataset, >3m is the cut-off threshold for vegetation to be defined as a tree

4: Reclassify Unspecified Vegetation as Mangrove (classification code = 20)

Use the Mangrove information from the ‘Estuary (including Macrophyte detail)’ vector layer to identify areas of known mangrove occurrence. This was used to reclassify pixels originally classified as “Unspecified Vegetation” (i.e. pixel value = 6) that coincide with areas of known mangrove occurrence to “Reclassified Vegetation: Mangrove” (i.e. pixel value = 20)

5: Reclassify Unspecified Vegetation as Tree (Classification code = 23)

The 2016 OEH 0.2m resolution vegetation height raster tiles (i.e. tiles stored with the aa9m6 stage code) was used to identify pixels with tree height value >3m. This was used to reclassify pixels originally classified as “Unspecified Vegetation” (i.e. pixel value = 6) that coincide with areas of known mangrove occurrence to “Reclassified Vegetation: Trees” (i.e. pixel value = 23). This was done to capture any trees that may have been misinterpreted as shrubs and classified as “Unspecified Vegetation” in the original surface cover classification. The rationale for the reclassification was that if a pixel had been classified as non-grass or non-herbaceous vegetation, and the same pixel was previously classified as tree and >3m in height based on the 0.2m resolution imagery used for the 2016 baseline dataset, then it was reasonable to assume that the same tree has persisted. This has been visually scrutinised and validated. However, it must be acknowledged that in some instances it is possible that the original tree has in fact been lost and subsequently replaced by shrub/scrub or other non-grass vegetation. In future use of this process, this dataset must be replaced with a height raster of trees in the same time period as the sourced tree canopy data.

Process 6: Tree canopy by area

The following is a list of the data inputs (Table 11) and output (Table 12) from the calculation of tree canopy by area (LGA, Suburb).

Data inputs

Table 11 Data inputs to summarise tree canopy by LGA and suburb

Dataset	Comments
2019_treecanopy_rc.tif	tree canopy raster. Grid value of 1 = presence of tree
Study area Modified Mesh Block with Land Zoning	ABS Mesh Blocks processed with Cadastre and EPI Land Zoning datasets to create statistical area based on land use categories.
NSW Suburbs	
NSW Local Government Areas	

Data Outputs

Table 12 Data outputs for tree canopy calculation

Dataset	Comments
GSR_MMB_revised_footprint_intersect_LGAs.shp	Intermediary data products: LGA and Suburb boundaries were adjusted to match the whole area of the intersecting modified mesh block boundary. The matching of boundary is based on the percentage of area within the associated LGA suburb. Some LGAs/Suburbs with major waterways will be smaller than the administrative boundaries of the LGA/Suburb.
GSR_MMB_revised_footprint_intersect_Suburbs.shp	

The area of tree canopy (AREA_TREE) within each modified mesh blocks was calculated using the ESRI ArcMap 'Tabulate Area' tool function on the 2x2m tree canopy raster file. The percentage tree canopy cover for individual modified mesh blocks was calculated by dividing the area of tree canopy (AREA_TREE) by the area of the modified mesh block (MMB_AREA) then multiplied by 100. The attributes are summarised in Table 13.

Table 13 Key attributes relating to the calculation of MMB-level tree canopy cover

Attribute	Description
MMB_AREA	Area of the modified mesh block in square metres
AREA_TREE	Area of tree canopy in square metres
PCT_TREE	Percentage tree canopy cover

Calculation of tree canopy by area (LGA, suburb and modified mesh block)

Process

1. Run 'Tabulate Area (Spatial Analyst)' toolbox in ArcGIS.
   Found in ArcToolbox under 'Spatial Analyst Tools' then 'Zonal' to run 'Tabulate Area'.
   a. Use GSR_MMB_revised_footprint_intersect_LGAs.shp as input zone data, and LGA Name as zone field.
   b. Use 2019_treecanopy_rc.tif as input class data, and cell value as class field.
   c. Set processing cell size to 2 (because the raster is 2mx2m).
2. Join the output table to the shapefile by using the LGA name as the matching field.
3. Once area of canopy is in sq m, add a new field for calculating the % canopy for each LGA.
4. Save the data as a new dataset and remove any irrelevant fields.

Repeat the same steps for suburbs using GSR_MMB_revised_footprint_intersect_Suburbs.shp. The same process is used to calculate Tree Canopy by modified mesh block.

Temporal comparison

Previous studies and statistical results from 2014 and 2016 datasets can only be compared to 2019 by geographic areas and boundaries of LGA, suburb and Mesh Block (map scale). A number of considerations must be taken into account when doing a comparison of tree canopy over time. These are discussed below.

LGA and suburb administrative boundaries and Mesh Blocks can change over time. Any comparison study must therefore check for changes in for the geographic boundaries before proceeding. These changes are announced in the NSW Government gazette by the Geographic Names Board and reflected in the spatial data supplied by NSW Spatial Services. This is especially relevant when undertaking studies in growth precincts in Western Sydney. For example, the 29th June 2018 gazettal of the change of suburbs of Kellyville, Baulkham Hills, and Bella Vista with the new suburbs of North Kellyville and Norwest (The Hills, 2018).

The method for the development of the ABS Mesh Block should be referred to before proceeding with comparison of individual mesh blocks as areas change between Census years.

Tree Canopy, in land use comparison, can only be done at the mesh block scale using the generalised ABS land use classification from 2016 census ('MBCat16' field). In this report, ABS land use is defined as the 'MB_CLASS16' field. Tree canopy is the only changing variable at mesh the block scale largely because this study used the 2016 Census mesh block boundaries.

Other land use categories and modified mesh blocks cannot be compared as the method to derive these differed between workflows. It is not recommended to use temporal comparisons of modified mesh blocks because the revised method uses a more spatially accurate definition of these categories, being derived from different input datasets for land use, including NSW Land Zoning. This corrects some of the errors noted in Hurley et al (2019) such as omission and commission errors in built infrastructure (roads / rail) that were found in the cadastral datasets. Differences in land use category cannot be compared and only gives an indication of change over time due to differences in deriving the modified mesh block.

The tree canopy data is commonly derived from air-photography. Caccetta et al (2019) notes that photography for monitoring should ideally be drawn from the same season within the year, and specifications to minimize the effect of solar angle and shadowing on the images be included. Past canopy cover analysis is derived from the following imagery:

- 2014: "data comprised 11845 image frames of data, acquired within January and early October of 2014 (Caccetta et al 2019)
- 2016: data comprised 18184 image frames of data, acquired over all seasons between Late February and the end of December of 2016 (Caccetta et al 2019). No photography was flow between 15th May up to 1st October. Ideally, imagery should be acquired in a single season and if flown in winter as deciduous trees would be bare of leaves and automapping techniques would not capture canopy due to a lack of leaf reflectance.
- 2019: tree canopy information is derived from multiple sources described in this method. These include Geoscape Surface Cover 2M and Trees which was updated in Geoscape Buildings, Surface Cover and Trees v1.3.0, in particular, the Geoscape 2m Surface Cover (June 2020 release) layer, Geoscape 30m Surface Cover (June 2020 release) layer, Geoscape Trees (June 2020 release) layer. These Geoscape products are derived from various imagery, over time (see Appendix D). They were combined with Estuary Macrophytes vector layer, and the OEH 2016 vegetation height raster layer to derive the 2019 canopy cover, compensating for differences in spatial resolution (scale) between time periods.

The difference in the methodology and source imagery to develop tree canopy data will impact temporal comparison. The source tree canopy data and methods came from different data providers. A method use of different imagery can result in 'errors of scale' in temporal comparison because of the use of different resolution imagery between the years will result in different areas of

tree canopy. Some of this may be dealt with through aggregation or splitting of raster grids, though the underlying difference of source resolution may remain.

The 2016 and 2019 Tree Canopy cover data do not cover the same extent several LGA's e.g. Blue Mountains, Hawkesbury and Wollondilly (see Figure 1). Therefore, statistical comparison of tree cover in these LGA's is not possible.

It should be noted that drought and seasonal changes will impact tree canopy cover. The Bureau of Meteorology reported drought over most of NSW between 2017 to 2019 (BoM, Online 2021) with the Greater Sydney Region likely to have been impacted. Weather changes and influencers such as El-Nino and La Nina drive rainfall and the subsequent impact on vegetation growth. Factors like seasonal weather patterns (drought), bushfire, infrastructure and urban development are just some of the influences that must be also considered when reviewing the causes of tree canopy cover change over time.

The role of this report is not to derive conclusions on the cause of change only report the method used to measure change and influences in comparing that change over time. The key is that the resolution imagery and method to derive tree canopy should be the same and the units of geographic comparison (LGA, Suburb, mesh block) should also have same geographic extent (no change in boundary). Method and data changes should be accounted for with the environmental / urban development changes to understand temporal changes in tree canopy.

Future improvements

Given that some of the source inputs into this process were not fit for purpose without modification, future assessments should consider the use of more reliable 'as built' infrastructure datasets. Working with data custodians could improve these data inputs to meet the needs of this style of assessment as well as its spatial and quality specifications.

The imagery from which the tree canopy cover is derived should follow the recommendations of Caccetta et al (2019) that photography for monitoring be drawn from the same season within the year, and specifications to minimize the effect of solar angle and, in particular, shadowing on the images be considered. It is recommended that imagery be flown in the summer season or between late spring to early autumn which would allow for a common seasonal change in vegetation and sun azimuth for imagery capture. The imagery should also be of the same resolution (scale) or within tolerance limits of +/- 10%. Without imagery created from consistent standards over time it is difficult to do true comparisons of changes in tree canopy.

Any comparison of canopy change should also consider and report on potential factors that cause tree cover loss which could include construction of infrastructure, land development and fire. Separate reporting on growth (change) within known funded tree planting areas is also recommended.

Change over time statistical comparisons need to use the same geographic boundaries e.g. LGA or suburbs as at 1st July 2016 to compare with the changing vegetation / canopy cover.

The revised method uses several ArcGIS models to help automate the processing of data. These models (Figure 4, 5, 8 and 10) could be converted to scripts (e.g. python language) to improve the speed of processing. Further development of the scripts into an automated spatial server application which accepts inputs from an end user is recommended. The development of web based spatial application would provide a service to the Local Government and other agencies who need to do analysis on tree canopy and vegetation data. This would also then support the Planning Institute Australia's technology principles of open-source code who note that where public

funding is used in the development of new digital tools, they should be provided as open source to enable reuse across different agencies and authorities (PIA, 2021).

A public web service could be possible using spatial servers and an application programming interface (API). The revised method is recommended to reduce processing time and provide standardised reporting of vegetation / tree canopy change over time. A regular production of canopy cover derived from air photography would provide the source vegetation information to this web service.

Please refer to Appendix E for the metadata description.

APPENDIX A: Geoscape surface cover data

The following datasets are commercial products available from PSMA.

2019_treecanopy_rc.tif

This raster is a simplified tree canopy data layer reclassed from the Geoscape_June2020_aa9m6_enhanced.tif raster

CODE	NAME	DESCRIPTION
1	Trees	All vegetation classified as trees and >3m in height. Aggregation of classes 5, 20 and 23 from Geoscape_June2020_aa9m6_enhanced.tif and reclassified.

Geoscape_June2020_aa9m6_enhanced.tif

This raster is an enhanced surface cover data layer derived using the Geoscape 2m Surface Cover (June 2020 release) layer, Geoscape 30m Surface Cover (June 2020 release) layer, Geoscape Trees (June 2020 release) layer, EstuaryMacrophytes vector layer, and the OEH 2016 vegetation height raster layer. This raster only contains classifications of surface vegetation that are highlighted in blue.

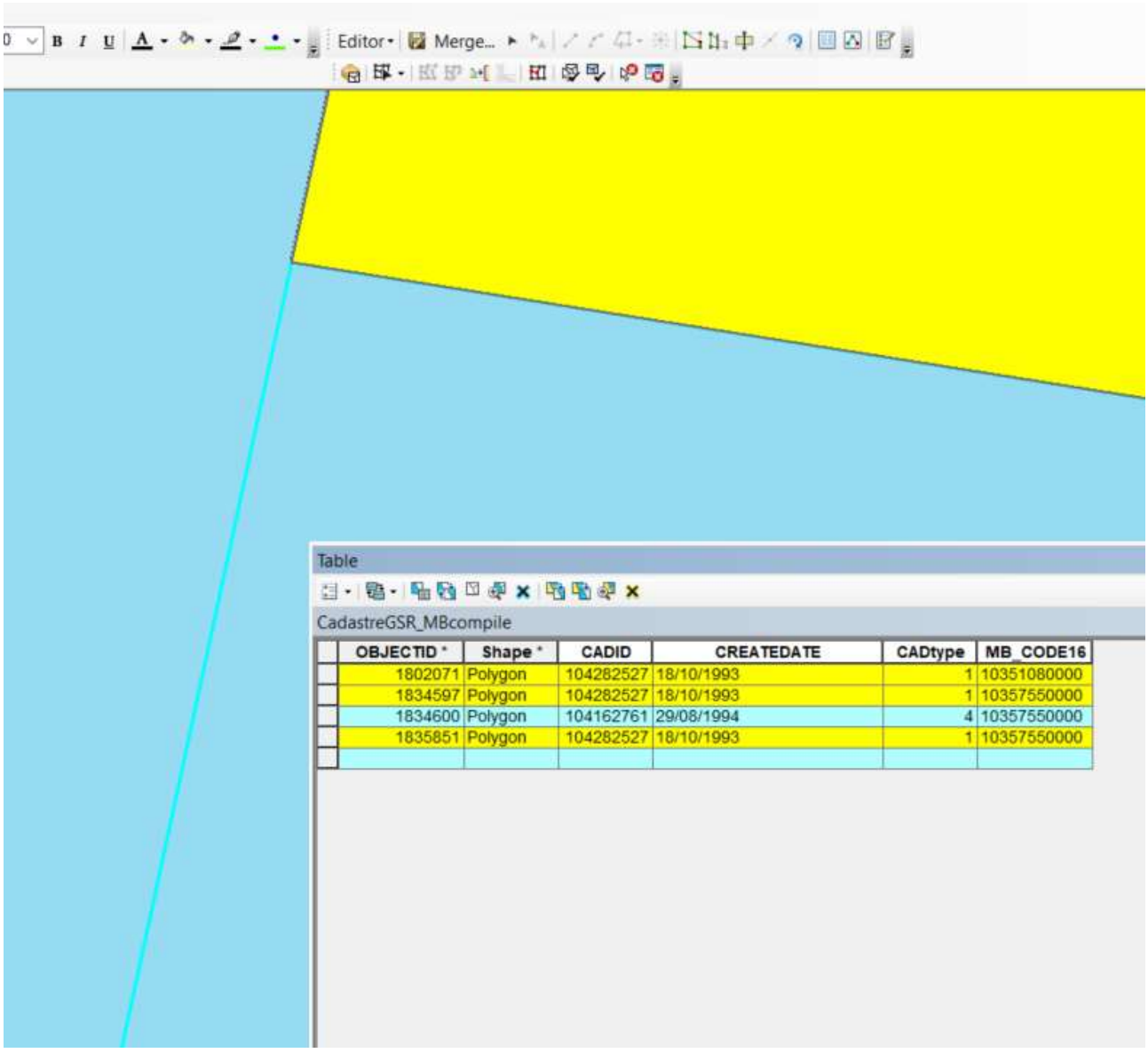
CODE	NAME	DESCRIPTION
2	Bare Earth	Includes sand dunes, desert, rock outcrops, bare soil other than bare agricultural land, and sparsely vegetated areas of grass and shrub. Non-vegetated strip mines and quarries except where covered by development or water.
3	Road & Path	Roads and parking lots covered in a man-made material excluding hard packed dirt trails.
4	Grass	Grass and herbaceous areas. The category may include herbaceous wetlands if images are collected during dry season or periods of drought.
5	Trees	Vegetation greater than 3 metres in height that was classified as Trees in the original Geoscape 2m surface cover dataset.
6	Unspecified Vegetation	Any other vegetative material not included within the Grass or Tree class. This may include, but is not limited to, shrub, scrub, agriculture, and aquatic plants. Also includes vegetation 3 metres or under in height that was classified as Trees in the original Geoscape 2m surface cover dataset.
7	Built-up Areas	Any areas of man-made environments and infrastructure excluding road and paths and buildings
8	Waterbody	Depending on the resolution quality of the imagery used, natural water will include streams, canals, ponds, lakes, reservoirs, estuaries and bays.
9	Buildings	Where the majority of a pixel intersects a Building, vector building polygon representation.
10	Cloud	The area covered with cloud on Date of collection.
11	Shadow	The area covered with shadow on Date/time of collection.
12	Swimming Pool	An area identified as a swimming pool.
20	Reclassified Vegetation: Mangrove	Vegetation that was originally classified as Unspecified Vegetation but reclassified as mangrove based on known occurrences of mangrove outlined in the macrophyte spatial data layer.

23	Reclassified Vegetation: Trees	Vegetation that was originally classified as Unspecified Vegetation but reclassified as Trees based on the known presence of trees (>3m in height) in the 2016 baseline tree canopy dataset.

APPENDIX B: Topological quality control

Common topological errors

1. Overlapping polygons: Found using the GIS topology rule ‘Must not overlap’.
2. Sliver polygons: Found when running GIS functions such as ‘intersect’ and ‘cut’, occurring when polygons are slivered to boundaries and not aligned because mesh block nodes did match the current Cadastre. Slivers were merged into the original CAD lot (by CADID).



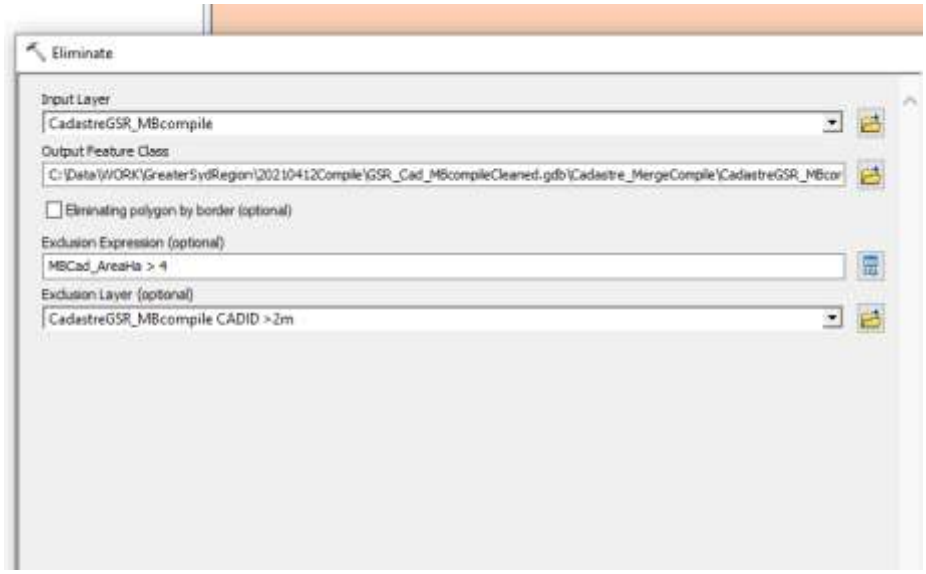
OBJECTID *	Shape *	CADID	CREATEDATE	CADtype	MB_CODE16
1802071	Polygon	104282527	18/10/1993	1	10351080000
1834597	Polygon	104282527	18/10/1993	1	10357550000
1834600	Polygon	104162761	29/08/1994	4	10357550000
1835851	Polygon	104282527	18/10/1993	1	10357550000

To remove slivers:

The following steps were used to merge slivers back into their parent cadastre parcel (e.g. Lot), after 'intersect' or union with other datasets.

- Select all the cluster tolerance error polygons.
- Extract to a table
- Create selection into layer
- Select features in MMBCompile that "touch the boundary of source' of layer
- Open the table in excel and create a column the formats CADID to put the numbers into a SQL selection: Create column cells formula =B2&"," copy that column and put into the next feature select
- Select features by attributes from current selection in MMBCompile that CADID IN *(paste column of* CADIDs)
- Run eliminate command

Care in the development of the eliminate command exclusion is required so the process does not result in some polygons losing their original CADID. For example, a road could end up with different CADID to the original.



Additional fields

The following fields were added to the dataset.

MMB_Code

MB_Reclass (Type text, 30 length)

Which was created by the following field calculations after joining the GS_MB2016 table by MB_CODE.

1. MB_ReClass = MB_CAT16
2. MB_Relcass
    a. CODE:
    def reclass (
    if (=2) or (=3) or (=5)
    return ‘Infrastructure’
    b. EXPRESSION:
    reclass(!
3. LandType

OR Just do:

CODE:

```
def reclass( [CadastreGSR_MBcompile.CADtype], [GSR_MB2016.MB_CAT16] )
  if ( [CadastreGSR_MBcompile.CADtype] =2 or [CadastreGSR_MBcompile.CADtype] =3 or [CadastreGSR_MBcompile.CADtype] =5)
  return 'Infrastructure'
  else
  return [GSR_MB2016.MB_CAT16]
```

EXPRESSION:

```
reclass(![CadastreGSR_MBcompile.CADtype]!,![GSR_MB2016.MB_CAT16]! )
```

APPENDIX C: Modified mesh block classification criteria

Rules and criteria used to designate the land use classification of individual modified mesh blocks. The specified purpose of the zone, if nominated, is provided in parentheses.

MMB_SUBCAT	Classification criteria
Road	(a) Any land parcel labelled as 'road' according to the cadastre (b) Any land parcels not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones listed below, and overlaps with the occurrence of a named road in current road network layer: R2 (Classified Road), SP2 (Classified Road Acquisition), SP2 (Classified Road), SP2 (Future Classified Road Tunnel), SP2 (Future Classified Road), SP2 (Future Road), SP2 (Future Transport Corridor), SP2 (Local Road Widening), SP2 (Local Road), SP2 (Motorway), SP2 (Northern Road), SP2 (Public Purposes Corridor), SP2 (Public Transport Corridor), SP2 (Road and Traffic Facility), SP2 (Road Infrastructure Facility), SP2 (Road Widening), SP2 (Road), SP2 (Strategic Bus Corridor)
Planned Road	Any land parcels not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones listed below, but does not overlap with the occurrence of any named road in the current road network layer: SP2 (Bus Only Link), SP2 (Classified Road), SP2 (Future Classified Road Tunnel), SP2 (Future Classified Road), SP2 (Future Road), SP2 (Future Transport Corridor), SP2 (Local Road Widening), SP2 (Local Road), SP2 (Regional Road), SP2 (Road)

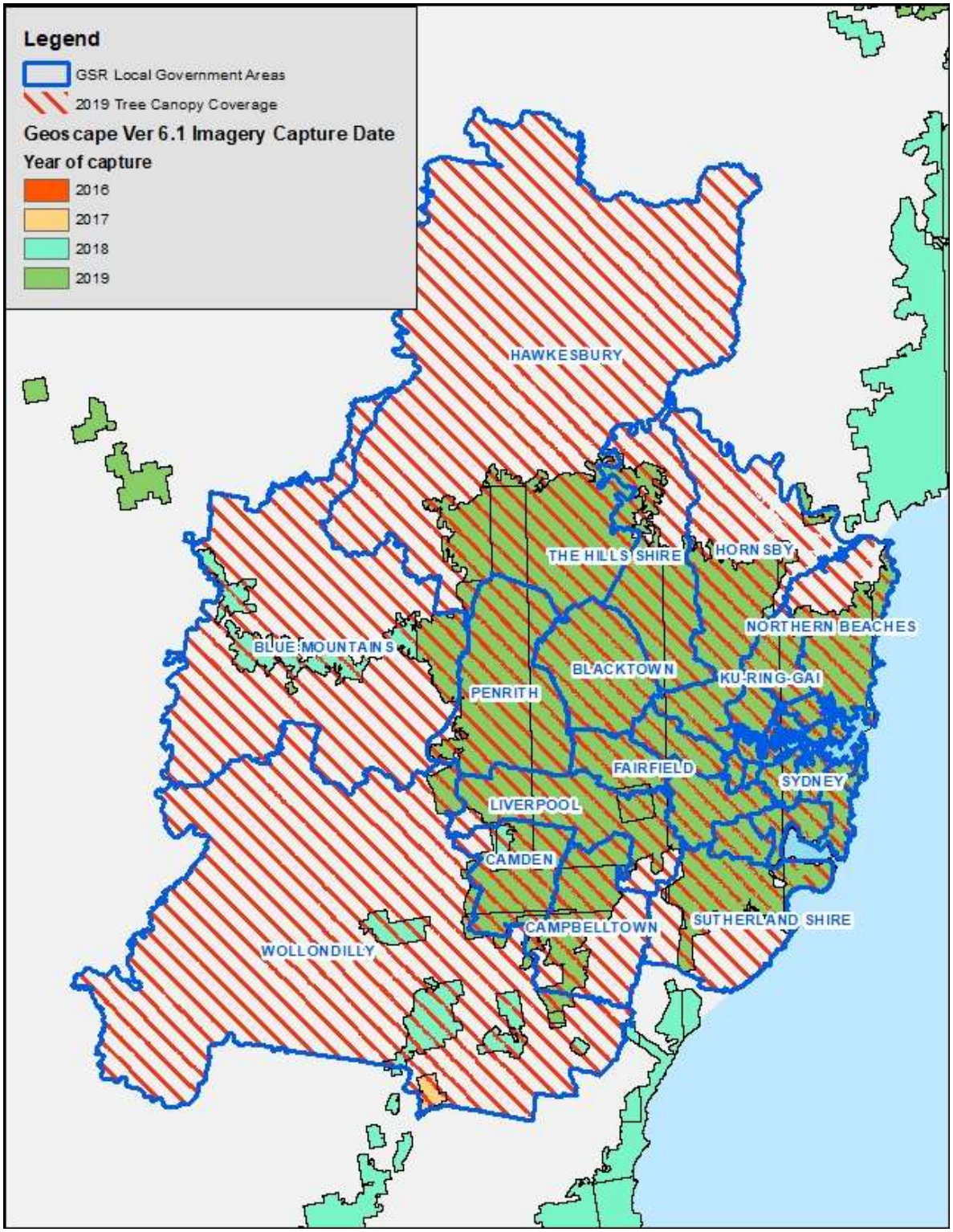
Railway	(a) Any land parcels labelled as 'railway corridor' according to the cadastre (b) For cadastral parcels not labelled as 'road', 'railway corridor' or water, the modified mesh blocks were classified as railway if within any of the following zones and overlap with the current railway network layer: SP2 (Classified Railway), SP2 (Rail), SP2 (Rail Corridor), SP2 (Rail Infrastructure Facilities), SP2 (Rail Infrastructure Facility), SP2 (Rail Infrastructure), SP2 (Railway Corridor), SP2 (Railway), SP2 (Railways)
Airport	Any land parcels not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones listed below, and/or overlaps with the known occurrence of airport, runways or air transport facilities: SP1 (Aerodrome), SP2 (Air Transport Facilities), SP2 (Air Transport Facility), SP2 (Airport)
National Park/Nature Reserve	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: E1
Conservation	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: E2, ENZ
Public Recreation	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: RE1, H, RO, RP
Private Recreation	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: RE2, I
Parkland/Open Space	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block overlaps with the occurrence of an existing green asset that is not within any of the following zones: E1, E2, RE1, RE2
Commercial	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: B1, B2, B3, B4, B5, B6, B7, B8, C, D, E, EM, ENT SP1 (Market), SP1 (Registered Club), SP1 (Sydney Wholesale and Retail Markets),

	SP1 (Wholesale and Retail Markets), SP1 (Zoological Gardens)
Education	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: SP1 (Education Agriculture) SP1 (Educational and POPW) SP1 (Educational Establishment & Place of Worship) SP1 (Educational Establishment) SP1 (Place of Public Worship) SP2 (Church & Community Purpose) SP2 (Church & Educational Est.) SP2 (Church and community purpose) SP2 (Educational Establishment & Place of Worship) SP2 (Educational Establishment) SP2 (Information and Education Facilities) SP2 (Place of Public Worship & Educational Establishmnt), SP2 (Place Of Public Worship And Cemetery), SP2 (Place of Public Worship and Community Facilities) SP2 (Place of Public Worship), SP2 (Place of Worship and Education Facility) SP2 (Place of Worship) SP2 (Research Facility) SP2 (Research Station) SP2 (School) SP2 (School, Church) SP2 (School, Place of Public Worship)
Industrial	IN1, IN2, IN3, IN4, SP1 (Quarry)
Hospital/Medical	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: SP1 (Health Services Facilities), SP1 (Hospital), SP2 (Aged Care Facility), SP2 (Convent and Hospital), SP2 (Health Services & Educational Facilities), SP2 (Health Services Facilities), SP2 (Health Services Facility SP2 (Health Services Facility and Seniors Housing), SP2 (Hospital), SP2 (Remand Centre & Hospital)
Residential	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: R1, R2, R3, R4, R5, RU5, UR, A
Environmental Living	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: E4

Environmental Management	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: E3
Primary Production	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: RU1, RU2, RU3, RU4, RU6
Water	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, does not also satisfy the criteria for road or railway or airport, and the modified mesh block is within any of the following zones: W1, W2
Defence	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: SP1 (Defence), SP2 (Defence), SP2 (Defence Land)
Tourism	Any land parcel not labelled as 'road', 'railway corridor' or 'water' according to the cadastre, and the modified mesh block is within any of the following zones: SP1 (Caravan Park, Camping Ground, Eco-Tourism, Functn), SP1 (Ecotourism, Camping Ground & Function Centre), SP3
Other	Any remaining modified mesh block not assigned to any of the other subcategories

APPENDIX D: Geoscape source imagery dates

Imagery on which the Geoscape tree cover product is derived covers multiple years and seasons.



A workflow for assessing tree canopy cover in the Greater Sydney Region (2019)

Version Nov 2022

APPENDIX E: Metadata

Description

The Greater Sydney Urban Vegetation Cover to Modified Mesh Block 2019 provides both an area and percentage of vegetation for city blocks and infrastructure corridors in the Sydney Greater Metropolitan Area as of 2019. With this dataset, users can estimate tree canopy and vegetation cover in urban areas at multiple scales that includes mesh block, precinct, or local government area. Having current and accurate estimates of tree canopy and vegetation supports citizens and governments to reliably identify areas of tree canopy and confidently develop urban greening and heat island mitigation strategies and action. This dataset provides the user with information of high spatial accuracy. The dataset uses vegetation information derived from high resolution aerial photography combined with boundary and land use information from the Australian Bureau of Statistics (ABS) Mesh Block polygon dataset augmented with road and railroad data from the NSW Digital Cadastral Database. The content was co-designed with state and local governments and developed using a scientifically rigorous method. The extent of the dataset covers urban, major urban, peri-urban and other urban areas within the Sydney Greater Metropolitan Area. While the dataset provides wall to wall coverage of many councils, it does not include far outlying rural areas in local government areas with a largely rural component

References

ABS (2021) Australian Statistical Geography Standard (ASGS) Edition 3. Sourced online 26th Oct 2021. https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026/main-structure-and-greater-capital-city-statistical-areas/mesh-blocks#mesh-block-design-criteria

BoM (2021) Drought Archive. Sourced online 30th Oct 2021 http://www.bom.gov.au/climate/drought/archive.shtml

Caccetta, P.A., Chia, J., Collings, S., Devereux, D., Traylen, A., Wu, X. (2019). Greater Sydney Canopy and Thermal Assessment 2014 and 2016, CSIRO Australia: Creation of UrbanMonitor® landcover and surface baselines.

ESRI (2010) Understanding geometric processing in ArcGIS. http://downloads.esri.com/support/documentation/ao_/J9880_ArcGIS_CoordMgmt_Geometric_Processing.pdf Sourced online 21/11/21, Redlands, CA.

Geoscape (2022 – online) Geoscape Surface Features Product description, https://geoscape.com.au/data/surface-features/

Geosciences Australia (2021 – online) AGRS Tools, Models and Resources; https://www.ga.gov.au/scientific-topics/positioning-navigation/australian-geospatial-reference-system/agrstoolsandmodels sourced online 22/11/21. Geosciences Australia, Canberra

Hurley, J., Saunders, A., Both, A., Sun, C., Boruff, B., Duncan, J., Amati, M. and Caccetta, P. (2019 - unpub) Metropolitan Sydney Vegetation Cover and Land-use Workflow, Department of Planning, Industry and Environment, Sydney, Australia.

LINZ (2021 - online) Summary of LINZ Teirs, Classes and Orders. Land Information New Zealand, https://www.linz.govt.nz/data/geodetic-system/datums-projections-heights/coordinate-height-/accuracy/accuracy-terms Sourced online 22/11/21.

NSW (2021 – online) Accuracy of marks; https://www.spatial.nsw.gov.au/surveying/scims_online/accuracy_of_marks Sourced online 21/11/21 NSW Spatial Services, Bathurst.

NSW Government (2021) Easements sourced https://www.industry.nsw.gov.au/lands/use/easements on 13/05/2021

PIA (2021 -online) PIA PlanTech Principles, https://www.planning.org.au/policy/plantech-national-working-groups/pia-plantech-principles, Planning Institute Australia

PSMA (2019) Geoscape Buildings, Surface Cover and Trees Product Description Version 1.4, PSMA Australia Limited, Canberra

The Hills (2018) Fact Sheet: Finalisation of Suburb Changes. Sourced online 23/12/2021 https://www.thehills.nsw.gov.au/files/sharedassets/public/ecm-website-documents/page-documents/fact-sheets-guides/fact_sheet_-_finalisation_of_suburb_changes_faq_-_north_kellyville_norwest__bella_vista_extension.pdf, The Hills Shire Council, Sydney

A workflow for assessing tree canopy cover in the Greater Sydney Region (2019)

Version Nov 2022