URBAN TREE CANOPY TARGETS & DEVELOPMENT CONTROLS REPORT

Prepared for

NSW DEPARTMENT OF PLANNING, INDUSTRY AND ENVIRONMENT

by

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1.0 INTRODUCTION

PROJECT OVERVIEW AND SCOPE

Gallagher Studio and Studio Zanardo were commissioned in January 2021 to develop urban tree canopy targets and planning controls to ensure the planning system is providing for enhanced urban canopy across NSW. The tree canopy targets, as described in the brief, are;

- To be evidence based and defensible.
- To consider a range of land uses, types, and contexts.
- Be applicable and transferable to NSW planning controls.

The tree canopy targets and controls will be used to inform current policy reforms including the new Design and Place State Environmental Planning Policy (SEPP), the final Greener Places Design Guide, the Secretary's Environmental Assessment Requirements (SEARs) and conditions of approval for State Significant Development/ Infrastructure projects. This work will also be used to inform the development of a potential tool for measuring the green infrastructure credentials of development.

The goal of the project is to establish achievable future tree canopy targets for inclusion across a range of policies and planning instruments. This project scope was not to assess existing tree canopy cover across NSW or wider Sydney. This is currently being delivered by DPIE spatial mapping and GIS Team.

This report is structured into 6 sections. Section 2 describes the relevant literature and includes a synthesis of relevant studies that informed the project method. Section 3 describes the method and Section 4 outlines the testing and results. Section 5 describes how the targets could be used in a case study example. Section 6 summaries the urban tree canopy targets and recommendations.

DEFINITIONS

The following definitions have been adopted in this study.

URBAN LAND: for the purpose of this project we have adopted the definition of urban land as defined in the Explanation of Intended Effect For the Design and Place SEPP. This states that the SEPP "..will exclude certain zones (such as Rural Zones as defined by the Standard Instrument Local Environmental Plans)." (D& P EIE p6)

URBAN TREE CANOPY (UTC) refers *to the layer of leaves, branches, and stems of trees that cover the ground when viewed from above* (Greener Places p56).

DEEP SOIL: Deep soil is a landscaped area connected horizontally to the soil system and local ground water system beyond and is unimpeded by any building or structure above or below ground with the exception of minor structures. Deep soil zones with a minimum dimension of 3m allows sufficient space for the planting and healthy growth of new trees that provide canopy cover and assist with urban cooling and infiltration of rainwater to the water table. Deep soil also allows for the retention of existing trees.

Minor structures is defined as (a) a path, access ramp or area of paving with a maximum width up to 1.2m (b) essential services infrastructure (such as stormwater pipes) with a maximum diameter up to 300mm. (c) landscape structures (such as lightweight fences, light poles or seating) requiring a footing with a maximum size of up to 300mm x 300mm in cross section.

TREE: Tree is defined in AS4970-2009 1.4.6 as a l*ong lived woody perennial plant greater than (or usually greater than) 3m in height with one or relatively few main stems or trunks (or as defined by the determining authority).*

REPLENISHMENT TREES: Replenishment trees are trees recommended for planting in deep soil areas. They are defined as woody or fibrous perennial plant with a self-supporting stem/trunk and a distinctly elevated crown and have been categorised as small, medium and large. Small trees are trees with a canopy spread of

6 metres or greater, medium trees are trees with a canopy spread of 8 metres or greater and large trees are defined as trees with a canopy spread of 12 metres or greater.

REPLENISHMENT TREES RATE: The minimum number of replenishment trees to be provided in deep soil zones. This study has nominated small trees in replenishment targets as a minimum of 6 metres in diameter for several reasons. A tree less than 6 metres in diameter would generally be not tall enough to shade the roofs of single storey buildings. The minimum tree height for the purposes of UTC should be able to shade roofs. Scientific literature indicates that larger trees provide substantially larger shade and cooling benefits that small trees. This is important given urban heat is a core threat in NSW (Adapt NSW, 2015). Additionally, this tree size is unlikely to create an obstruction to walking or access. Please note that smaller trees (5 metres in diameter) have been used within verges located under overhead power lines in existing street design testing. Small trees, which provide unobstructed access to their assets are commonly required by NSW Energy providers.

2.0 LITERATURE REVIEW

This literature review is divided into three parts. Part 1 describes the policy context. Part 2 covers the approach cited in the wider scientific literature to establishing tree canopy targets. Part 3 describes the way that canopy targets have been adopted and established by city authorities in urban plans and policies.

POLICY CONTEXT

URBAN TREE CANOPY IN EXISTING POLICIES

Several current state government policies provide high level targets and related objectives to protect and enhance canopy cover. These policies include the Government's Priorities, the Greater Sydney Region Plan by the Greater Sydney Commission, the Sydney Green Grid by GANSW, as well as its Greener Places framework and Draft Greener Places Design Guide. Priority 12 Greening our City seeks to increase the tree canopy and green cover across Greater Sydney by planting 1 million trees by 2022.

DRAFT GREENER PLACES DESIGN GUIDE 2020

The Government Architect NSW's Draft Greener Places Design Guide nominates an urban tree canopy target of 40% for Greater Sydney by 2056. This includes indicative targets based on context:

- CBD areas: > 15%
- Urban residential (medium to high density) and light commercial areas: > 25%
- Suburban areas: > 40%

The draft Guide notes that optimal tree canopy varies depending on the climatic and land-use patterns within a city and that targets are best developed based on site specific constraints such as density and land use.

GREATER SYDNEY COMMISSION - GREATER SYDNEY REGION PLAN – A METROPOLIS OF THREE CITIES (MARCH 2018)

This plan nominates a 40% urban tree canopy for the Greater Sydney Region. The plan establishes aspirations for the region over the next 40 years (to 2056). Under Objective 30, urban tree canopy is increased through:

- Prioritising expansion of urban canopy in the public realm in the planning and design of new neighbourhoods (including urban renewal)
- Establishment of neighbourhood benchmarks for tree canopy cover
- Amendments to planning controls to protect urban canopy
- The recognition and reporting by councils of urban canopy alongside other local infrastructure assets.

The Greater Sydney Commission District Plans (North, South, Eastern City, Central City and Western City) published in March 2018 include aims to 'increase tree canopy cover'. All of these district plans reference the NSW Government's target to increase tree canopy cover across Greater Sydney to 40%. They do not provide region specific targets.

STANDARD INSTRUMENT LEP'S AND DCPS

Generally, councils use Local Environmental Plans (LEP's)and Development Control Plans (DCP's) to prescribe the delivery of urban tree canopy. Many councils may align their controls with their Local Strategic Planning Statements to achieve urban tree canopy and urban greening objectives. A detailed assessment of planning controls adopted by a range of councils is included in chapter 4. It is noted that DCPs are not statutory controls and have lesser weight than LEPs. It is also noted that LEP provisions can often be overwritten by provisions in SEPPs.

The Standard Instrument LEP currently provides no development standards, controls or zone objectives (particularly for urban zones) for delivery of urban greening, or to increase tree canopy.

METHODS USED TO ESTABLISH TARGETS IN THE SCIENTIFIC LITERATURE

The benefits of urban tree canopy are well established in the literature. In the US there is 39.4% tree cover in urban areas, providing an annual benefit valued at US$18.3 billion in air pollution removal, reduced building energy use, carbon sequestration and avoided pollutant emissions (Nowak and Greenfield 2018 p.35). However, methods for developing appropriate city or regional canopy target are less evident.

The scientific literature has few studies that explore methods to develop urban tree canopy targets. The most prevalent research in this field is from North America. Researchers (Racciti et al 2006; Grove et al 2006) have developed a three-step process that combines spatial mapping with a decision-making framework. The mapping calculates existing canopy and predicts future canopy for various conditions (building footprints, land use, streets, lots, water and canopy). Once possible targets were established, a decision-making tool was used to refine the target based on each organization's goals and constraints. This method has been used to develop targets for New York and Chesapeake Bay.

Urban Forest Researcher, American Forests' Science Advisory Board member and academic Gregory McPherson, has stated that the city specific canopy target should be developed based on a range of factors including development densities, land use patterns, ordinances and climate. Likewise, US research (Nowak et al, 1996) indicates that a target of between 40 and 60% urban tree canopy is attainable under ideal conditions in forested states.

A recent Australian study has suggested an alternative strategy. Parker and Simpson 2020 used a text-based tool that uses 11 criteria to generate a weighed percentage output. Criteria includes physical characteristics (water resource availability, cost of water, soil characteristics, shade requirements, climate, extreme weather events, ecological demand) as well as social/economic factors (financial investment, community desire, political influence, zoning). While a useful aspect of this tool is the inclusion of climatic and soil characteristics, the limitation of this tool is the absence of spatial mapping to validate testing targets.

Some literature does identify the importance of recognising the impact of land use on tree canopy provision. Mincey Schmitt-Harsh and Thurau 2013 found in a study from the US that residential high-density zones are significantly different than all other residential zones and more akin to commercial zones in canopy metrics. This suggests that consideration of specific land use and built form characteristics are key factors that should be considered when establishing effective targets.

METHODS USED TO ESTABLISH TARGETS IN CITY PLANS & POLICIES

As part of the preparation of this study , we undertook a review of other urban tree canopy plans and policies to ascertain how their targets were specified. From this review, we found that while those policies contained some type of urban tree canopy target, few provided an explanation of the method used to establish the target. Only two international studies (Urban Tree Canopy Plans for New York and Chesapeake Bay) described their method in detail. Many targets appeared to be aspirational, based on examples set by other municipalities or cities or based on generalised benefits, without explanation of specific parameters or method.

Nationally, however, there are several recent urban tree canopy plans and policies that provide more detailed explanation of their methods for establishing the targets. They are listed below.

- The City of Sydney originally adopted tree canopy targets based on United States Department of Agriculture guidelines on canopy cover targets for general urban classifications (e.g., 15% for CBD and 50% for suburban areas). The City then undertook a major in-house project to review these canopy cover targets based on detailed analysis of land use and capacity to support urban tree canopy across the entire LGA. Subsequent work in 2020 by Studio Zanardo and Gallagher Studio tested the application of the targets for various development types to propose amendments to planning controls to achieve urban tree canopy.
- The City of Hobsons Bay has adopted an overall LGA target for private and public land using a process of GIS mapping and predictive modelling incorporating targets for a variety of zones. This work undertaken by Gallagher Studio developed specific canopy targets for each land use drawn from published precedents for canopy in similar land uses across western Melbourne.
- The City of Gold Coast have completed a strategy paper with suggested next steps to determine a canopy target. Existing canopy was mapped against movement networks and land zones to determine the distribution of canopy relative to these zones. Case studies of each land use were used to determine preliminary canopy capacity and prioritised according to impact. Draft canopy targets were developed for "liveable streets" (50%), "conservation corridors" (60%) and "liveable neighbourhoods" (30%). The authors note "the important next step would be to reality test some aspirational targets against actual capacity to achieve forecast levels of tree placement, planting and growth." (City of Gold Coast, p84).
- Additional smaller studies by Woollahra Municipal Council have used development application testing to analyse potential capacity for increased deep soil and tree canopy in R2 and R3 residential zones. This approach is similar to the approach adopted in the recent City of Sydney work.

The selected studies listed above have used methods that differentiate whether targets are to be applied to public or private land.

LITERATURE REVIEW SUMMARY

The key findings from this literature review are as follows:

- The importance of considering environmental factors – specifically soil moisture and rainfall when developing canopy targets.
- The value in considering the variations in both development and land use when developing tree canopy targets. Generalised assumptions based on broad categories such as inner urban, suburban have been replaced by more refined approaches that explore capacity based on specific built and spatial conditions relative to land use zoning.
- The role of capacity testing using spatial mapping, landscape and architectural design knowledge and analysing approved development application examples. This has been adopted in the most recent work by the City of Sydney and Woollahra Municipal Council and has helped to refine targets and demonstrate feasibility with a solid evidence base.
- The use of urban climate data in developing targets. Some urban tree canopy literature has derived targets based on the microclimatic benefits including improvements to urban heat. These studies however are more generalised in nature and often are cited as a general starting point rather than a fine-grained tool extrapolating cooling benefits relative to percentage tree canopy cover.

Table 1: Urban tree canopy plans, targets, and methods.

Name	Target	Method to Establish Target
City of Sydney Urban Forest Strategy	27.13% by 2050	Based on capacity testing relative to land use type. Additional modelling in 2019 to test land use capacity. Additional testing in 2020 to determine deep soil and canopy capacity using development applications for various development types (apartments, attached and detached dwellings, industrial, commercial).
City of Melbourne Urban Forest Strategy: Making a Great City Greater, 2012-2032,	40% by 2040	Based on modelling for tree-planting opportunities, but unclear how the models were devised.
City of Gold Coast Urban Tree Canopy Study 2020	51% native vegetation cover	Benchmarking and capacity testing.
Brisbane City Council Brisbane's Urban Forest	50% target in streets	No stated methodology.
City of Greater Geelong Urban Forest Strategy 2015 – 2025	25%: 30 years (p39)	Unclear why 40% target not adopted. Capacity testing for streets.
Hobsons Bay City Council Urban Forest Strategy	30%	Based on land use and development type and local precedents.
Moreland City Council Urban Forest Strategy 2017 – 2027	29% by 2050	Based on changing tree species to replace small trees with large trees in streets (but no additional trees); capacity testing in private open space; combination of larger and more trees in public open space.
City of Perth Urban Forest Plan	30%: 30 years	No stated methodology.
Woollahra Municipal Council, Greening our LGA, 2020	Min tree canopy area R2 and R3 zones: 40%- Attached/ detached dwellings, 30% Multi-dwellings.	Development application testing including deep soil provision and canopy provision based on R2 and R3 Land uses.

3.0 METHOD

We developed a method for establishing tree canopy targets that draws from the wider literature and from our previous experience delivering projects of a similar nature. Our method considers critical items affecting canopy including the spatial characteristics of common types of development based on specific land use zones. This method considers the proportion of building to lot area as well as specific environmental factors such as soil type.

ESTABLISHING THE RELATIONSHIP BETWEEN LAND USE ZONES AND DEVELOPMENT TYPES

The first step in the process was to determine the most prevalent types of development within urban areas in NSW. We reviewed the land use zones described by the Standard Instrument Local Environmental Plans (SILEP). The SILEP describes permissible development types within each land use zone. We then developed categories for the most common types of development on public and private land.

Three key categories were defined for public land and seven categories for private land. Table 2 lists the categories and their alignment with land uses as listed in the SILEP. Please note that Council LEPs are often amended to allow other permissibility of other development types in these zones.

Table 3 shows the proposed private categories and their alignment with land uses as listed in the SILEP. Some land categories have been excluded from this testing. Rural lands (RU1 – RU6) are excluded from the scope to align with urban land parameters anticipated to be defined in the new Design and Place SEPP. Environmental land uses (E1, E2, E3 and E4), Waterways (W1, W2, W3), Private recreation (RE2), Tourist (SP3), Working waterfront (IN4), and Infrastructure (SP2) have also been excluded from this study as they are highly specialized conditions, subject to certain constraints defined by other authorities. Canopy in these conditions can be highly varied and cannot be generalized, and therefore have been excluded from this testing.

Centres such as metropolitan, neighbourhood and local centres have been excluded from this testing. This is due to a number of factors. Firstly these enviornments are often mixed use, with retail tenancies lining streets with zero street setbacks. It is uncommon to have tree canopy and deep soil in private lots in these locations.

Secondly these spaces often have wider streets, and public squares or plazas that have capacity for public domain tree planting. In these environments public lands and facilities such as streets, parks and schools offer the primary space for deep soil tree canopy. Tree canopy in these locations may be primarily delivered in the public domain and targets designed through a place-based master plan.

The private land categories capture the most prevalent urban development types across NSW. The most common urban land use category in this scope is R2 Low Density Residential land which comprises 7% total land area in Greater Sydney and 0.18% across NSW (Table 4). The other prevalent land use categories to be examined in this scope include:

- RE1 Public Recreation Land – 2% (225 km2) in Greater Sydney and 0.09% (653 km2) in NSW
- R3 Medium Density Residential Land – 1.1% (119 km2) in Greater Sydney and 0.08% (201 km2) in NSW
- IN1 General Industrial Land - 1% (108 km2) in Greater Sydney and 0.05% (361km2) in NSW

Table 2: Categories for public and private land testing and their common occurrence in SILEP Zones.

Public types	SILEP ZONES	Private types	SILEP ZONES
1. Streets: Local, existing and new streets	RE1, R1, R2, R3, R4, IN1, IN2, IN3, B1, B2, B3, B4, B5. B6. B7. B8	1. Detached dwellings	R1, R2
2. Public Parks: Local 0.15 ha to 7 ha	RE1	2. Attached dwellings	R1, R3
		3. Apartments	R3, R4
		4. Multi dwelling	R1, R3
		5. Business parks	B6,B7, IN1
		6. Bulky goods	B5, B6, B7, IN1, IN2
		7. Industrial	B5, B6, B7, IN1, IN2, IN3

Table 3: Categories proposed for private land, and their alignment with land use zones in the SILEP zones.

SILEP ZONES	
Zone RU1 Primary Production	**Zone B7 Business Park**
Zone RU2 Rural Landscape	Zone B8 Metropolitan Centre
Zone RU3 Forestry	**Zone IN1 General Industrial**
Zone RU4 Primary Production Small Lots	**Zone IN2 Light Industrial**
Zone RU5 Village	**Zone IN3 Heavy Industrial**
Zone RU6 Transition	Zone IN4 Working Waterfront
Zone R1 General Residential	Zone SP1 Special Activities
Zone R2 Low Density Residential	Zone SP2 Infrastructure
Zone R3 Medium Density Residential	Zone SP3 Tourist
Zone R4 High Density Residential	***Zone RE1 Public Recreation****
Zone R5 Large Lot Residential	Zone RE2 Private Recreation
Zone B1 Neighbourhood Centre	Zone E1 National Parks & Nature Reserves
Zone B2 Local Centre	Zone E2 Environmental Conservation
Zone B3 Commercial Core	Zone E3 Environmental Management
Zone B4 Mixed Use	Zone E4 Environmental Living
Zone B5 Business Development	Zone W1 Natural Waterways
Zone B6 Enterprise Corridor	Zone W2 Recreational Waterways
	Zone W3 Working Waterways

Bold denotes LEP land use zone and alignment with proposed private land category and white are land uses excluded from this scope. * Denotes landuse explored in public land parks category.

Table 4: Proposed land uses for testing of canopy capacity: summary of area of urban land uses in Greater Sydney and in NSW.

Land use Class Greater Sydney	Area (km2) Greater Sydney	% of Total Area Greater Sydney	Land use Class NSW	Area (km2) NSW	% of Total Area NSW
R2	752	7.08	R2	1474	0.18397
RE1	225	2.12	R1	760	0.09485
R3	119	1.12	RE1	653	0.08143
IN1	108	1.01	IN1	361	0.04504
R1	47	0.44	R3	201	0.02512
R4	40	0.37	IN3	89	0.01111
IN2	26	0.24	IN2	85	0.01060
B4	25	0.23	B4	53	0.00663
B2	16	0.15	B2	43	0.00540
B7	11	0.11	R4	42	0.00520
B5	10	0.09	B5	29	0.00367
IN3	9	0.09	B6	26	0.00319
B6	7	0.07	B7	23	0.00285
B1	6	0.05	B3	21	0.00262
B3	5	0.05	B1	11	0.00131
B8	2	0.02	B8	2	0.00023

LAND USE CATEGORIES AND THE PLANNING INSTRUMENTS.

Tables 5, 6 and 7 describe the relationship between the private land categories, their definitions and typical provisions.

The light blue rows define the seven development categories we have developed. There are four residential categories comprised of common housing types organised in increasing density (Table 5 and 6). There are three non-residential categories comprised of types that are common outside of B1, B2, B3, B4 and B8 zones (excluded from study).

The first column briefly describes the distinguishing built form qualities exhibited by each category. The second column lists the SILEP land uses which would commonly fall under each of the development categories based on their distinguishing built form qualities. The third column provides an abridged version of the SILEP definition for each land use. The fourth column notes which provisions would typically control each land use.

Table 5A: Categories, land use and typical provisions for detached dwellings.

Land Categories	Land Use	Definition	Typical Provisions
Detached Dwellings	(*not in SILEP)		
Single lots	Dwelling houses	1 on one lot [detached]	SEPP E&C/DCP
Free standing	Dual occupancy (attached)	2 on one lot/attached	SEPP E&C/DCP
	Dual occupancy (detached)	2 on one lot/detached	SEPP E&C/DCP
	Secondary dwelling	An conjunction with principle dwelling/on same lot/within/ attached/separate [detached]	SEPP ARH/DCP
	*Manor house	Residential flat building/3 or 4 dwellings/attached/above/2 storeys maximum	SEPP E&C & LRHDDG
	Rural worker's dwelling	Additional to dwelling house on one lot/employees for agricultural or rural industry	DCP

Table 5B: Categories, land use and typical provisions for attached dwellings.

Land Categories	Land Use	Definition	Typical Provisions
Attached Dwellings	(*not in SILEP)		
Separate lots (or appearance of)	Dwelling houses	1 on one lot [abutting]	SEPP E&C/DCP
Separate driveway/ parking	Dual occupancy (attached)	2 on one lot/attached [abutting]	SEPP E&C & LRHDDG/DCP
All dwellings face a public road	Dual occupancy (detached)	2 on one lot/detached [abutting]	SEPP E&C & LRHDDG/DCP
	Secondary dwelling	In conjunction with principle dwelling/on same lot/within/ attached/separate [abutting]	SEPP ARH/DCP
	Attached dwellings	3 or more/common wall/own lot of land	SEPP E&C & LRHDDG/DCP
	Semi-detached dwelling	Attached to only one dwelling/ own lot of land	DCP
	*Multi dwelling housing (terraces)	Multi dwelling houses where dwellings are attached and face to public road	SEPP E&C & LRHDDG/DCP

Table 5C: Categories, land use and typical provisions for multi dwelling housing.

Land Categories	Land Use	Definition	Typical Provisions
Multi Dwelling Housing			
Strata/community lots	Multi-dwelling housing	3 or more on one lot/access at ground level/not residential flat building	SEPP E&C & LRHDDG/DCP
Ground floor access	Seniors housing	Self-contained dwellings/seniors/ disability/staff/household	SEPP HSPD & SLPUDG/DCP
Shared driveway/ parking			
Not all dwellings face a public road			

SEPP E&C State Environmental Planning Policy (Exempt and Complying Development Codes) 2008
SLP UDG: Seniors Living Policy Urban Design Guidelines for Infill Development
SEPP HSPD State Environmental Planning Policy (Housing for Seniors or People with a Disability) 2004
SEPP 65 State Environmental Planning Policy No 65—Design Quality of Residential Apartment Development (2002 EPI 530)
ADG: Apartment Design Guide
LRHDDG: Low Rise Housing Diversity Design Guide
DCP: Development Control Plan

Table 6: Categories, land use and typical provisions for apartment buildings.

Apartment Buildings			
Dwellings arranged vertically	Residential apartment development	Residential flat building/shop top/mixed use/3 or more storeys/4 or more dwellings	SEPP 65 & ADG/DCP
Basement/reduced parking	Residential flat buildings	3 or more on one lot/not attached dwelling or multi dwelling housing [not manor house]	DCP
	Seniors housing	Self-contained dwellings/seniors/disability/ staff/household	SEPP HSPD & SLPUDG/ SEPP 65 & ADG/DCP
	Seniors housing	Residential care facility/seniors/disability/ staff/household/services	SEPP HSPD & SLPUDG/ DCP
	Seniors housing	Vertical villages	SEPP HSPD & SLPUDG SEPP 65 & ADG
	Boarding houses NCC class 3	Lodgings/more than 3 months/shared facilities	SEPP ARH/DCP
	Shop top housing	1 or more located above ground floor retail premises or business premises	SEPP 65 & ADG/DCP

Table 7A: Categories, land use and typical provisions for business parks.

Business Park			
Office	Light industry	Industrial activity that does not interfere with amenity	Zone B7 Business Park
Light industrial	Office premises	Administrative, clerical, technical, professional activities not dealing with public	SEPP E&C EIE (p33) indicative
	Warehouse and distribution centres	Storing or handling not dealing with public	

Table 7B: Categories, land use and typical provisions for bulky goods.

Bulky Goods			
Business	Garden centres	Retail/plants, landscaping and gardening	Zone B5 Business Development
Warehouse	Hardware and building supplies	Retail/construction and maintenance	SEPP E&C EIE (p33) indicative
Specialised retail premises	Landscaping material supplies	Retail/landscaping	
	Specialised retail premises	Retail/large are for handling, display or storage/ direct vehicular access by public	
	Warehouse and distribution centres	Storing or handling not dealing with public	

Table 7C: Categories, land use and typical provisions for industrial developments.

Industrial			
Industrial	Depots	Storing plant and machinery	Zone IN1 General Industrial
Warehouse	Freight transport facilities	Bulk handling of goods for transport/parking and service of transport vehicles	Zone IN2 Light Industrial
	Garden centres	Retail/plants, landscaping and gardening	
	Hardware and building supplies	Retail/construction and maintenance	
	Light industries	Industrial activity that does not interfere with amenity	
	Warehouse and distribution centres	Storing or handling not dealing with public	

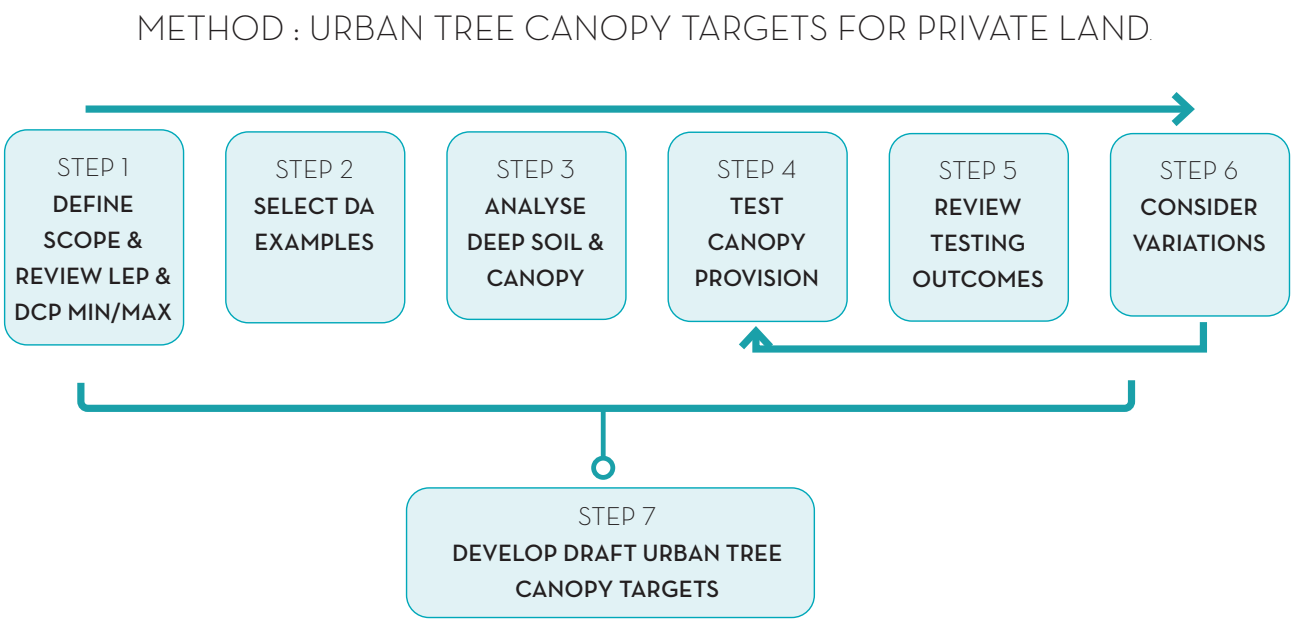


Figure 1: Method for developing urban tree canopy targets on private land.

PRIVATE LAND TESTING

STEP 1: PLANNING CONTROLS REVIEW

Step 1 involved analysing tree canopy controls and deep soil controls in SEPPs and DCPs across Metropolitan Sydney and NSW applicable to each private land category. This provided a picture of what is currently being delivered and to benchmark the minimum delivery. The data captured the minimum and maximum range of deep soil area provision (where directly controlled) as well as other factors influencing tree canopy provision. This included street, rear and side setbacks, site coverage, private open space and landscaped area (which can act as proxies for deep soil area).

STEP 2: SELECT DA EXAMPLES

Step 2 involved selecting a representative range of development examples to be used for analysis. Forty-one approved development applications across the 7 private development categories were selected. The development application data was sourced and provided by NSW Department of Planning, Industry and Environment. Drawings were imported into CAD format, scaled and measured to determine the area of deep soil and the area of tree canopy provided on proposed deep soil. Some applications did not include landscape plans therefore existing tree canopy provision could not be determined. However, as the priority of the testing was to determine capacity for tree planting through deep soil area, this was not viewed as a study limitation.

The number of samples were weighted to align to the most prevalent urban land uses across Sydney and NSW. For example, a higher number of DA's for detached dwelling were analysed as are prevalent in R2 Low Density Residential Land within Greater Sydney and NSW. Table 9 shows the testing numbers as a proportion of land across greater Sydney. Table 10 lists the location and category of each sample.

STEP 3: ANALYSE DEEP SOIL AND CANOPY

A core factor in this assessment was to determine how much capacity there is for tree canopy. Deep soil is fundamental to the delivery of effective urban canopy cover by providing capacity for a viable and healthy

urban forest. Deep soil provides capacity for growth of larger trees which provide the most urban cooling benefits. Deep soil provision is inextricably linked to healthy canopy cover and the area and dimension of deep soil is directly related to the number and size of trees and canopy cover that can be achieved.

Deep soil differs from tree planting on structure. Planting on structure is limited in soil volume which can affect the ability of trees to develop stable rooting systems and grow to full capacity. Additionally, trees in planting on structure are more susceptible to failure through moisture loss and limb and branch drop from wind exposure. Whilst providing some positive environmental benefits, planting on structure cannot be considered as comparable to deep soil in terms of supporting canopy provision. Therefore, we prioritised review of deep soil, in both our review of the controls and in design testing.

In Step 3 each of the approved development applications were analysed to determine the amount of deep soil and canopy cover being delivered in the proposal as a percentage of site area. Deep soil has been defined as a landscaped area with a minimum dimension of 3 metres that is unimpeded by any building or structure above or below ground except for minor structures. Existing tree canopy of 3 metres or greater was measured. Deep soil of less than 3 metres min dimension and planting less than 3 metres in diameter were excluded in the calculations. Areas of canopy overhanging site boundaries were also excluded.

STEPS 4 – 6: DESIGN TESTING

Steps 4 – 6 involved design testing using the approved plans to improve deep soil and tree canopy cover outcomes. The value of testing aspirational targets against actual capacity using spatial mapping and landscape and architectural design knowledge has been established in recent work by the City of Sydney and Woollahra Municipal Council. This method has helped to refine targets and demonstrate feasibility with a solid evidence base. Using actual development applications presents a range of advantages. It clearly demonstrates capacity and feasibility as well as identifying limitations and constraints.

Step 6 involved additional scenario modelling to test increased canopy cover. Two options were tested: Option 1 applied minimal design changes to the scheme. This included the redesign of landscape areas to reduce pavements and to relocate rainwater tanks clear of deep soil zones. Option 2 schemes were used to explore more substantial changes such as minor adjustments to the building layout, with the aim to retain the development potential of each site. Option 2 schemes were not developed in some instances, where the existing schemes already had a high provision of deep soil.

The deep soil for options 1 and 2 were then measured and results calculated as a percentage of site area for comparison. Design observations and comparisons were then made to determine the differences between the approved development application scheme and the alternative approaches. These findings provide the basis for recommendations in Chapter 6: Recommended Controls. Additional analysis was undertaken of built examples for business parks, bulky goods and industrial sites.

Table 8: Private and public land design testing category and numbers.

Public / Private	Category	Design Testing No.	Additional Precedent Analysis
Private	Detached dwellings	15	
Private	Attached dwellings	6	
Private	Apartments	10	
Private	Multi-housing	6	
Private	Business parks	3	10
Private	Bulky goods	4	7
Private	Industrial	4	27
Public	Streets: local	14	
Public	Public open space: local	10	

Table 9: Testing numbers as a proportion of land use – Greater Sydney Region (GSR).

Zone	UTC Development Category	% of Land	Land area in UTC scope %	Testing no based-UTC scope	UTC Design Testing	
					Public Types	Private Types
RE1: Public Recreation						
RE1	Public Parks : Local	2.12%	15.9%	8 (8)	10	N/A
R1: General Residential						
R1	Streets: Local, Detached dwellings, Attached dwellings, Apartments, Multi dwelling	0.44%	3.3%	1.66 (2)	14	33
R2: Low Density Residential						
R2	Streets: Local, Detached dwellings	7.08%	53.5	26.74 (27)	14	15
R3: Medium Density Residential						14
R3	Streets: Local, Attached dwellings ,Apartments	1.12%	8.47%	4.24 (4)	14	12
R4: High Density Residential						14
R4	Streets: Local, Apartments, Multi Dwelling	0.37%	2.82%	1.41 (1)	14	10
IN1: General Industrial						14
IN1	Streets: Local, Business Parks Bulky Goods, Industrial	1.01%	7.64%	3.82 (4)	14	11
IN2: Light Industrial						14
IN2	Streets: Local, Bulky Goods Industrial	0.24%	1.84%	0.92 (1)	14	8
IN3: Heavy Industrial						14
IN3	Streets: local, Industrial	0.09%	0.67%	0.34 (1)	14	4
B1: Neighbourhood Centre						14
B1	Streets: Local	0.05%	0.41%	0.21 (1)	10	4
B2: Local Centre						
B2	Public Land – Streets: Local	0.15%	1.11%	0.55 (1)	15	0
B3: Commercial Core						
B3	Public Land – Streets: Local	0.05%	0.37%	0.19 (0)	15	0
B4: Mixed Core						
B4	Streets: Local	0.23%	1.75%	0.88 (1)	15	0
B5: Business Development						
B5	Streets: Local, Bulky Goods, Industrial	0.09%	0.69%	0.35 (0)	14	8
B6: Enterprise Corridor						
B6	Streets: Local, Industrial Business Parks, Bulky Goods	0.07%	0.52%	0.26 (0)	14	11
B7: Business Park						
B7	Streets: Local, Industrial, Business Parks, Bulky Goods	0.11%	0.8%	0.4 (0)	14	11
B8: Metropolitan Centre						
B8	Streets: Local	0.02%	0.13%	0.7 (1)	15	4
	Total of Sydney's land use	**13.24%**	**100%**	**50.67 (50)**		

Table 10: Location of development applications used in design testing.

Category	Design Testing No		LGA
Detached Dwelling	15	1	Tweed Shire Council
		2	Campbelltown City Council
		3	Blacktown City Council
		4	Lake Macquarie City Council
		5	Ku-ring-gai Council
		6	Wollongong City Council
		7	Port Macquarie-Hastings Council
		8	Northern Beaches Council
		9	Albury City Council
		10	Mid coast Council
		11	City of Canterbury-Bankstown
		12	Sutherland Shire Council
		13	Maitland City Council
		14	The Hills Shire Council
		15	Woollahra Municipal Council
Attached Dwelling	6	1	Inner West Council
		2	Liverpool City Council
		3A	Lake Macquarie City Council
		3B	Lake Macquarie City Council
		4A	City of Canterbury-Bankstown
		4B	City of Canterbury-Bankstown
Multi-dwelling	6	1	Central coast Council
		2	Liverpool City Council
		3	Lake Macquarie City Council
		4	The Hills Shire Council
		5	Maitland City Council
		6	Sutherland Shire Council
Apartments	10	1	Waverley Council
		2	Tweed Shire Council
		3	City of Sydney
		4	City of Parramatta
		5	City of Parramatta
		6	Georges River Council
		7	Ku-ring-gai Council
		8	Ku-ring-gai Council
		9	Liverpool City Council
		10	Shoalhaven City Council
Business Parks	3	1	Lake Macquarie City Council
		2	Blacktown City Council
		3	The Hills Shire Council
Bulky Goods	4	1	Central Coast
		2	Blacktown City Council
		3	The Hills Shire Council
		4	Lake Macquarie City Council
Industrial	4	1	Blacktown City Council
		2	Central Coast
		3	City of Canterbury-Bankstown
		4	Wagga Wagga

STEP 7: DEVELOP DRAFT CANOPY TARGETS

The achievement of a percentage canopy cover requires the planting of a certain number of trees of a certain canopy size relative to site area. A certain area and dimension of deep soil is required to sustain these tree's health and growth.

A tree replenishment rate is the number of trees required to be planted in deep soil. A replenishment tree rate minimises confusion and allows applicants and assessors to check compliance. Canopy targets have been employed as a tool to determine the 'best fit' tree replenishment within each site area bracket but are not intended as a control. Tree canopy area targets are harder to estimate and there can be confusion in determining canopy extent, including overhang to adjacent sites. A canopy % target control can make it difficult for authorities and applicants to confirm compliance.

It is anticipated that this replenishment rate should occur in tandem with suitably revised deep soil percentage controls and the revised deep soil definition.

CALCULATING TREE REPLENISHMENT

Once the reasonable/achievable minimum deep soil area was established, suitable canopy cover targets were developed. Using standardised tree sizes (small, medium and large listed in table 11) we calculated the number of trees required to deliver the canopy cover target based on the deep soil area. This became the tree replenishment rate. It is expressed as a number of trees for every Xm2 of site area so that the control can be immediately understood and applied in design and assessment (for example a 1000m2 site requires X medium trees).

TREE REPLENISHMENT RATES AND SOIL TYPE

Clay soils have a finer texture and smaller pore size providing less rooting depth than sandy loam soils. As clay soils are common across large areas of NSW, it is important to ensure that tree replenishment rates provide adequate soil area for trees planted in clay.

Soil volumes have been calculated using Leake and Haege' (2014) research and interpolated for sandy loams and clay. This area calculation assumed the rooting depth for trees in sandy loams to be one metre, and in clay soils, to have a potential rooting depth of 600mm only. Using Leake and Haege's research, the formula to determine area of soil in sandy loam soils is: Area (m2) = Volume (m3). In clay soils that are typically impenetrable to roots beyond 600mm, the formula is: Area = Volume (m3) / 0.6. This value also assumed that no irrigation would be provided to trees, to capture varying rainfall patterns.

This soil area requirement is in Table 12. These tree replenishment rates were then checked to ensure that an appropriate allowance of soil had been provided to achieve the projected tree canopy targets. It is expected that in many cases the local soil type will be appropriate to support more than the minimum number of trees.

Table 11: Tree replenishment categories, size, and area.

Tree Replenishment Categories	Diameter Minimum (m)	Canopy Area (m2)
Small	6	28m2
Medium	8	50m2
Large	12	113m2

Table 12: A comparison of soil area requirements for trees.

Tree Replenishment Categories	Leake and Haege Sandy Loam (m2)	Leake and Haege Clay (m2)	Adopted UTC Soil Area (m2)
Small tree	14m2	23m2	23m2
Medium tree	18m2	30m2	30m2
Large tree	26m2	43m2	43m2

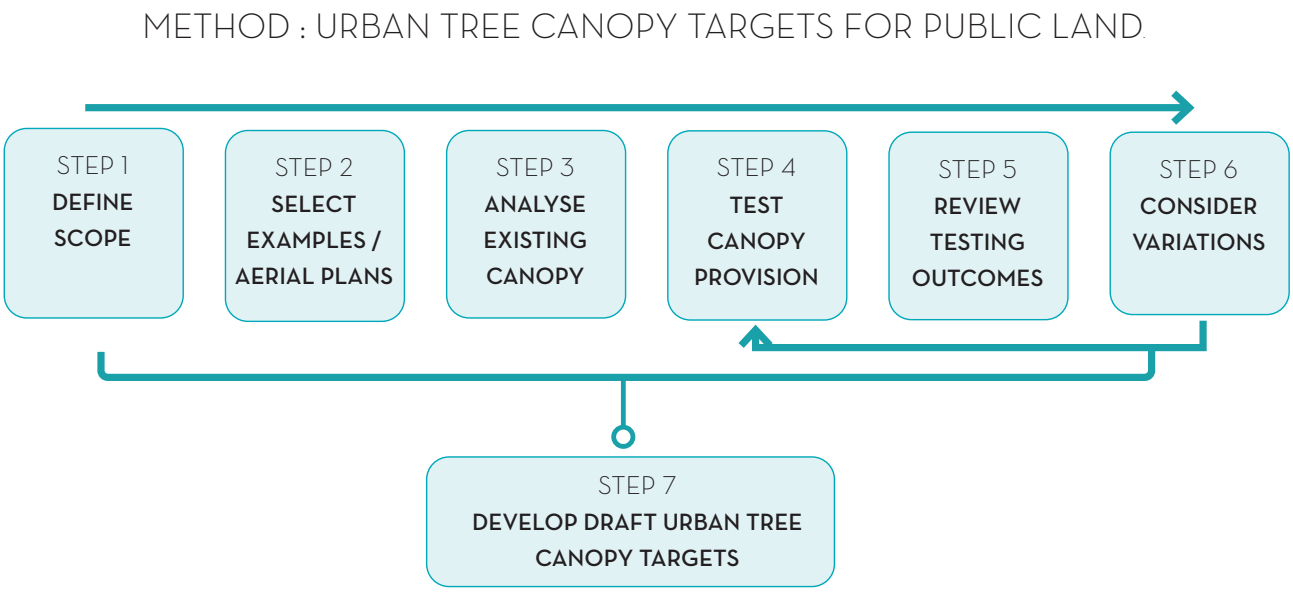


Figure 2: Method for developing urban tree canopy targets on public land.

PUBLIC LAND TESTING

A slightly different approach was used to test tree canopy in the public domain, illustrated in Figure 2. This uses built examples of public projects to determine what canopy can be delivered across a range of conditions. This approach provides a better understanding of typical canopy provision in these environments.

STEP 1 AND 2: SCOPE AND SELECTION OF EXAMPLES

We selected a cross section of examples from a range of locations for parks, and streets. The parks captured a variety of local parks from urban, suburban and regional environments and included parks that were used for passive recreation and parks with sports fields and courts. Nearmap imagery and GIS mapping was used to determine the current tree canopy provision and for design testing.

Streets required a further categorisation to capture existing and new streets of varying reserve dimensions. Additionally, streets were classified into those with underground services and those with overhead power lines. Variation in reserve width was important to capture as this can impact on space for trees. This scope excluded analysis of underground services. A summary of the testing samples is listed below in Table 13.

STEPS 4 – 6: DESIGN TESTING

Steps 4 - 6 involved developing options for increased canopy. We undertook an additional assessment of soil areas, within existing streets verges drawing from Leake and Haege' research (Table 12). This is an important factor in existing streets, where soil areas are constrained by pavements and kerbs. This is less of a concern for local parks or for school playgrounds where there is often more open space for healthy tree growth.

Table 13: Public land design testing locations.

Category	Type Testing No		Location
Existing streets	14	1	Curlew St, Newington
		2	Corben St, Surry Hills
		3	Jennings Cr, Spring Farm
		4	Glebe St, Glebe
		5	Tropic Bird Cr, Hinchinbrook
		6	Waratah St, Port Macquarie
		7	Dalmeny Ave, Russell Lea
		8	Cormorant Cr, Dubbo
		9	Oleander Cr, Riverstone
		10	Bucello St, Griffith
		11	Young St, Annandale
		12	Ridgeline Dr, The Ponds
		13	Salisbury Rd, Castle Hill
		14	Gibbens Rd, West Gosford
Parks	10	1	Shannon Reserve, Surry Hills
		2	Macquarie Place Park, Sydney
		3	Gollan Park, Doonside
		4	Sutherland Shire Centenary Park, Miranda
		5	Collins Park, Wagga Wagga
		6	Chaffey Park, Tamworth
		7	Bigge Park, Liverpool
		8	Camperdown Park, Camperdown
		9	Nagle Park, Maroubra
		10	Beauchamp Park, Chatswood

4.0 RESULTS & RECOMMENDATIONS

A full summary of the detailed analysis and recommendations for public and private land types has been provided in this chapter. Appendix B: Private land testing and Appendix C: Public land testing contain accompanying diagrams showing existing sites and design options. Chapter 5 explores application of these targets, using a case study example.

PRIVATE LAND TESTING

OVERVIEW

Development applications from seven development categories were selected for testing. These development categories were detached dwellings, attached dwellings, apartment buildings, multi dwelling housing, business parks, bulky goods and industrial. Table 13 lists the category and location of each development analysed. The following overview is to be read in conjunction with Appendix A and B: Private land controls and testing.

DETACHED DWELLINGS

REVIEW OF DETACHED DWELLINGS: CURRENT CONTROLS.

An analysis was undertaken of current landscape and deep soil controls for detached dwellings in 24 Local Government Areas across NSW (Table A1 in Appendix A). The assessment also identified other factors influencing deep soil provision including minimum street, side and rear setback controls, and maximum site coverage controls. The SEPP Exempt and Complying Development and the SEPP Affordable Rental Housing were also reviewed to establish controls that influence tree canopy.

Most DCPs did not include specific tree canopy controls. Only 2 LGA's assessed had adopted targets – minimum 15% canopy cover for detached dwellings (City of Sydney SDCP2012) and minimum 40% canopy cover (Ashfield CIWDCP2016). However, many DCPs included either deep soil or landscape area requirements. Seven DCPs required deep soil ranging from 12.5% site area to 35% site area and 9 included Landscaped area (10% to 50%). Landscaped area is defined under the SILEP as 'part of a site used for growing plants, grasses and trees, and does not include any building, structure or hard paved area'.

Additionally, built form controls that influence tree canopy including minimum setback dimensions and maximum site coverage controls were prevalent. Site coverage controls were evident in 12 DCPs, ranging from 50% site area (Lake Macquarie LMDCP2014) to 65% site area (Ashfield CIWDCP2016). Site coverage is directly related to the amount of available landscaped area and potential space for trees. Tree canopy targets/ replenishments requirements could work with these existing built form controls.

DETACHED DWELLINGS: DEVELOPMENT APPLICATION TESTING

Fifteen detached development applications were reviewed. These applications were in urban, suburban, and rural areas. The lots varied from 287m2 to 1000m2. Appendix 1 includes detailed information including testing diagrams and design options listed in Table 14.

Design options were developed for sites that provide less than 40% existing deep soil area. This parameter was used at it aligns with outline targets listed in the Draft Greener Places Design Guide. Design Options 1 applied minimal design changes to the scheme, such as redesign of landscape areas to reduce/replace paving zones. Design Options 2 tested more substantial changes such as minor modifications to building layout or garages. These options had minimal impact on living internal spaces.

The results of the testing were gathered and compared (Table 14). Just under half of the schemes (6) already provided 40% or more deep soil of a minimum 3m dimension. The lowest deep soil within the existing schemes analysed was 16% site area and the highest was 64% site area. On lots greater than 600m2 all achieved 34% or

Table 14: Testing results for detached dwellings.

No.	Address	Lot size (m2)	Building coverage (%)	Deep Soil (%)	Option 1 Deep Soil (%)	Option 2 Deep Soil (%)
1	20 Calotis Crescent, Denham Court	287	60%	16%	22%	32%
2	Valiant St, Nirimba Fields	300	64%	20%	26%	30%
3	7 Leura Road, Double Bay	315	55%	25%	34%	42%
4	48A Cylinders Drive Kingscliff	394	70%	12%	29%	31%
5	21 Courin Drive, Cooranbong	437	58%	30%	37%	N/A
6	67 Saddleback Crescent, Kembla Grange	450	57%	29%	39%	N/A
7	7 Pountney Avenue, Thrumster	510	42%	51%	N/A	N/A
8	9 Boronia Street, Cronulla	527	45%	35%	39%	N/A
9	56 Rogers Street Roselands	594	56%	20%	27%	39%
10	47 Burgess Road, Forster	616	45%	47%	N/A	N/A
11	53 Cardiff Drive, Thurgoona	636	55%	34%	44%	N/A
12	3 Langdon Road, Baulkham Hills	702	47%	51%	N/A	N/A
13	33 Quirk Street, Dee Why	703	42%	41%	N/A	N/A
14	38 Ardennes Circuit, Gillieston Heights	723	48%	47%	N/A	N/A
15	153 Bobbin Head Road, Turramurra	1000	34%	64%	N/A	N/A

more deep soil in the existing schemes. Larger lots generally had more capacity to deliver deep soil than smaller lots, however the proportion of building footprint to site area (site coverage) was the most important influencing factor.

With Option 1 designs, 11 out of 15 sites achieved 30% or deep soil. Additionally, 3 out of 15 sites provided greater than 25% deep soil. This outcome was achieved through minor design modifications, primarily to the landscape schemes to reduce pavements, and to relocate rainwater tanks and shade structures clear of deep soil zones. Option 2 designs resulted in all sites comfortably achieving 30% or more deep soil.

DETACHED DWELLINGS: RECOMMENDATIONS

From the testing, it was evident that canopy targets needed to reflect variations in lot area. For detached dwellings, three categories were developed: sites less than 300m2, sites 300m2 - 600m2 and sites greater than 600m2. Canopy targets are conservative, based on what is already currently provided in existing development applications, or with minor modifications to layout (as shown in Option 1 designs). Table 15 lists the recommended allowances canopy, deep soil, and tree replenishment to achieve the canopy targets by lot size.

These targets align with the minimum 50% to maximum 65% site coverage controls evident in the current DCP planning controls (Table A1 in Appendix A). They are in the mid-range (10% to 50%) of Landscaped Area assessed in planning controls.

Table 15: Recommended tree canopy controls for detached dwellings.

Recommended Guidance Detached dwellings	Tree Canopy Target (%) site area	Deep Soil min (%) site area	Tree Replenishment Requirements
Less than 300m2	20%	20% Minimum 3m dimension.	For every 200m2 of site area or part thereof, at least one tree of small size is to be planted in the deep soil area.
300m2 - 600m2	25%	25% Minimum 3m dimension.	For every 250m2 of site area or part thereof, at least one medium tree is to be planted in the deep soil area.
Greater than 600m2	30%	30% Minimum 3m dimension.	For every 350m2 of site area or part thereof, at least two medium trees are to be planted in the deep soil area.

ATTACHED DWELLINGS

REVIEW OF ATTACHED DWELLINGS: CURRENT CONTROLS

An analysis was undertaken of current landscape and deep soil controls for attached dwellings in 12 Local Government Areas across NSW (Table A2 in Appendix A). The analysis was the same as that described for detached dwellings controls. Four of the DCPs included a deep soil control, ranging from a minimum 15% site area to a maximum of 30% site area. Landscaped area ranged from 10% to 40%. Like detached dwellings, only 2 LGA's assessed had adopted canopy targets for attached dwellings (City of Sydney SDCP2012, Ashfield CIWDCP2016).

Additionally, built form controls that influence tree canopy including minimum setback dimensions and maximum site coverage controls were prevalent. The site coverage controls ranged from minimum of 60% site area to a maximum of 75% site area. Of note is the SEPP Exempt and Complying Development Part 3B - Low Rise Housing Diversity Code (terraces) and Low-Rise Housing Diversity Code (dual occupancy) which require 20% and 25% Landscaped Area respectively.

ATTACHED DWELLINGS: DEVELOPMENT APPLICATION TESTING

Six applications from inner urban, suburban, and regional areas were reviewed. The sites ranged from 145m2 to 300m2 site area. Some samples were drawn from the same development application, to capture and compare site level variations. The building footprint coverage ranged from 43% to 64% site area (Table 16).

Initial analysis of deep soil found that existing development applications were highly variable ranging from a minimum of 16% deep soil site area and up to 49% deep soil site area. It is notable that the smallest site analysed (145m2 at Busby) was providing 20% deep soil in the current scheme. Option 1 designs made minor design changes such as relocating water tanks, replacing paving with permeable surfaces such as decks . These designs increased deep soil to a minimum of 21% site area up to a maximum of 52% site area. Two sites that included swimming pools in this testing (Tempe and Yagoona) could retain swimming pools whilst also providing improved deep soil (23% and 27% respectively).

Option 2 designs included similar landscape modifications, alongside more substantial changes such as removing swimming pools, with no impact on the gross floor area of the buildings. All Option 2 designs achieved 30% or more deep soil.

Table 16: Sample DA testing for attached dwellings.

No.	Address	Lot size (m2)	Building coverage (%)	Existing Deep Soil (%)	Option 1 Deep Soil (%)	Option 2 Deep Soil (%)
1	78 Terry Street, Tempe	159	51%	16%	23%	39%
2	40 Lyndley Street Busby	145	64%	20%	34%	N/A
3	Unit 1 76 Cantrell Street Yagoona	300	43%	38%	38%	N/A
4	Unit 2 76 Cantrell Street Yagoona	300	43%	20%	27%	42%
5	19 Nott Street Warners Bay	173	64%	18%	21%	30%
6	19 Nott Street Warners Bay	246	50%	49%	52%	N/A

Table 17: Recommended tree canopy controls for attached dwellings.

Recommended Guidance Attached dwellings	Tree Canopy Target (%) site area	Deep Soil min. (%) site area	Tree Replenishment Requirements
Less than 150m2	15%	15% Minimum 3m dimension.	One small tree is to be planted in the deep soil area.
150m2 - 300m2	20%	20% Minimum 3m dimension.	For every 200m2 of site area or part thereof, at least one small tree is to be planted in the deep soil area.
Greater than 300m2	25%	25% Minimum 3m dimension.	For every 225m2 of site area or part thereof, at least one medium tree is to be planted in the deep soil area.

ATTACHED DWELLINGS: RECOMMENDATIONS.

The recommended canopy targets (Table 17) recognise that attached dwellings were generally more efficient in delivering consolidated deep soil due to their compact building footprints. This is because they have removed narrow strips of landscape area to side boundaries and consolidated deep soil landscape areas in the front and rear of the lots.

The categories reflect the variations in capacity for tree canopy and deep soil across a range of lot sizes. Three categories were developed: sites less than 150m2, sites 150 - 300m2 and sites greater than 300m2. Targets for deep soil on sites greater than 300m2 are the same as targets for detached dwellings.

This guidance aligns with six of the DCPs reviewed which had deep soil controls, ranging from a 15% to 25% site area. This deep soil and canopy controls would not conflict with the DCP site coverage controls (60% - 75% site area).

MULTI DWELLING HOUSING

REVIEW OF MULTI DWELLING HOUSING: CURRENT CONTROLS

We analysed current landscape and deep soil controls for multi dwelling housing in 20 Local Government Areas across NSW (Table A3 in Appendix A). Six of the DCPs included a deep soil control, of minimum 12.5 % site area to minimum 40% site area. Landscaped area ranged from 10% to 50% site area.

Built form controls that influence tree canopy including minimum setback dimensions and maximum site coverage controls were common. The site coverage controls ranged from minimum of 40% site area to a maximum of 70% site area. The SEPP ARH and HSPD requires 30% landscape area and 15% deep soil. Only one DCP included a canopy target (25%) for multi dwelling housing (Ashfield CIWDCP2016).

MULTI DWELLING HOUSING: DEVELOPMENT APPLICATION TESTING

Six schemes were reviewed (Table 18). These sites varied from 822m2 to 3722m2. The schemes included on grade and basement carparking. The smallest provision of deep soil (16%) was on the second largest site at Aberglasslyn, a 3683m2 site which had on grade parking. The highest provision (30%) of deep soil was evident at the site at Castle Hill (2269m2) and at Caringbah (3193m2). Basement carparks were evident in 3 of the 6 applications reviewed, and substantially improved tree canopy capacity and deep soil provision.

Option 1 designs included minor changes such as relocating rainwater tanks, reducing roof overhangs and excess paved zones. This increased deep soil to between 24% and 30% in all schemes. Option 2 designs included more extensive changes such as minor modifications to the building footprint. Deep soil provision was substantially improved in Option 2 designs, particularly on multi dwelling schemes with on grade car parking (at Aberglasslyn and Charlestown). Deep soil was doubled (from 16% to 33%) on the second largest site at Aberglasslyn, providing capacity for more shade to buildings and on grade car parks.

Table 18: Sample DA testing for multi dwelling housing.

No.	Address	Lot size (m2)	Building coverage (%)	Existing Deep Soil (%)	Option 1 Deep Soil (%)	Option 2 Deep Soil (%)
1	184B Newbridge Road, Moorebank*	822	57%	22%	26%	34%
2	84 - 86 Dudley Road, Charlestown	1585	47%	23%	24%	28%
3	9-11 Actinotus Av. Caringbah*	2269	41%	30%	N/A	N/A
4	21 Church Street, Castle Hill*	3193	40%	30%	N/A	N/A
5	13 Ruby Road, Aberglasslyn	3683	47%	16%	27%	33%
6	170-176 Blackwall Road, 8 Farnell Road, Woy Woy	3722	57%	29%	30%	N/A

*: Development proposals with basement car parking

MULTI DWELLING HOUSING: RECOMMENDATIONS

Multi dwelling developments are often larger sites, with above ground and underground basement parking. These developments are becoming increasingly common in western Sydney and regional locations, places that are often vulnerable to increased urban heat. Schemes that include on grade car parking are especially prone to increase temperatures due to the high proportion of impermeable surfaces. Tree planting is a priority in these developments to shade high albedo pavements and improve indoor thermal comfort.

The multi dwelling canopy and deep soil recommendations align with the existing and Option 1 design testing scenarios and would not require substantial change to buildings. Three categories are nominated: sites less than 1000m2, 1000 – 3000m2 sites and sites greater than 3000m2. Deep soil canopy targets have been developed to reflect variations in capacity between sites of different scales. Medium trees are recommended in these large sites, to maximise tree shade benefits on these large sites.

Table 19: Recommended tree canopy controls for multi dwelling housing.

Recommended Guidance Multi dwelling housing	Tree Canopy Target (%) site area	Deep Soil min (%) site area	Tree Replenishment Requirements
Less than 1000m2	20%	20%. Minimum 3m dimension.	For every 300m2 of site area or part thereof, at least one medium tree is to be planted in the deep soil area.
1000 – 3000m2	25%	25%. Minimum 3m dimension.	For every 200m2 of site area or part thereof, at least one medium tree is to be planted in the deep soil area.
Greater than 3000m2	30%	30% Minimum 3m dimension.	For every 350m2 of site area or part thereof, at least two medium trees or one large tree are to be planted in the deep soil area.

APARTMENTS

REVIEW OF APARTMENTS: CURRENT CONTROLS

We reviewed the Development Control Plan apartment minimum provisions across 21 Local Government Areas in a range of NSW locations (Table A4 in Appendix A). The maximum site coverage controls ranged from 30% (Marrickville MDCP2011, Ku-ring-gai KDCP2015) to 70% site area (Maitland MDCP2011). Landscaped area ranged from 20% (Lake Macquarie LMDCP2015) to 50% (The Hills HDCP 2012).

Deep soil is a well-established control used for apartments. While the Apartment Design Guide (ADG) requires 7% deep soil, many councils including Parramatta (30%) and Ku-ring-gai (50%) require substantially more. Two state government instruments - SEPP ARH (clause 14) and the SEPP HSPD (clause 50) require 15% deep soil to be provided. Many councils, who do not have deep soil controls for apartment buildings will reference the deep soil guidance in the ADG.

Deep soil provision can be established through common building controls, such as site coverage, basement controls and building separation. For example, the ADG requires minimum dimensions to achieve adequate building separation (ADG 2F and 3F). These are commonly located on side and rear boundaries and between buildings on site. These areas can range in size from minimum 3 to 12 metres wide. These spaces are often delivered as contiguous deep soil zones, between adjacent property boundaries. These spaces can provide space for healthy tree growth and contribute to neighbourhood wide canopy cover (Figure 3).

APARTMENTS: DEVELOPMENT APPLICATION TESTING

Ten projects were reviewed, on sites from 430m2 to 4820m2 (Table 20). The sites were in inner urban, suburban, and regional locations and included schemes with single buildings and schemes with multiple buildings. The lowest provision of existing deep soil was 0% site area and highest was 48% of site area.

Larger sites over 1500m2 could comfortably achieve 30% deep soil with minor design changes (Option 1). These changes included changes to the landscape design, to reduce paving, increase permeable materials, and to expand communal garden zones.

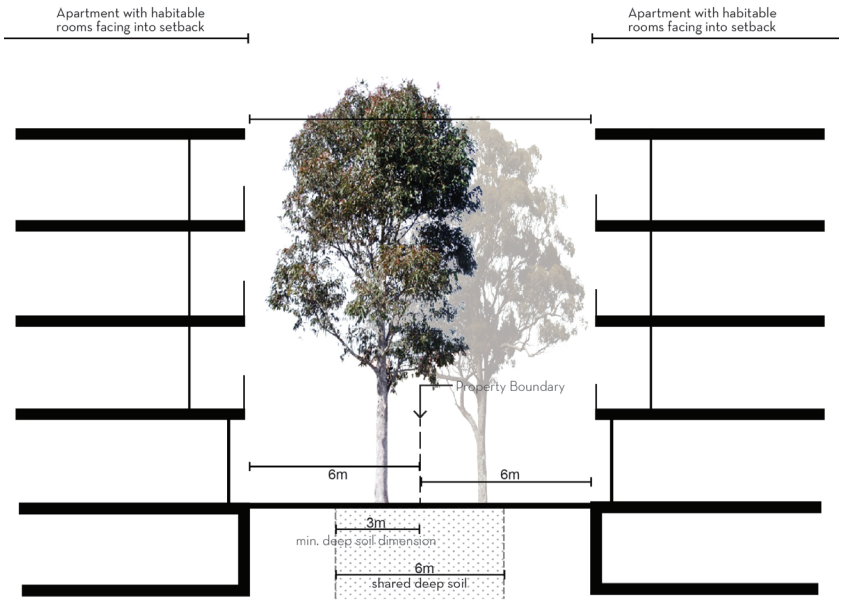


Figure 3: Contiguous deep soil zone within building setbacks.

Table 20: Sample DA testing for apartments.

No.	Address	Lot size (m2)	Building coverage (%)	Existing Deep Soil (%)	Option 1 Deep Soil (%)	Option 2 Deep Soil (%)
1	Pacific Rd , Bronte	430	63%	0%	6%	16%
2	44 Sutherland Street, Kingscliff	688	57%	6%	13%	16%
3	19 Ralph Street, Alexandria	976	56%	2%	7%	21%
4	Collett Parade North Parramatta	1014	34%	15%	36%	44%
5	75-77 Kissing Point Road, Dundas	1416	57%	22%	31%	N/A
6	Nielsen Ave Carlton	2054	46%	30%	N/A	N/A
7	Newhaven Street, St Ives	2326	36%	50%	N/A	N/A
8	19-21 Turramurra Ave, Turramurra	2931	35%	48%	N/A	N/A
9	37 - 40 Croatia Avenue, Edmondson Park	3599	36%	13%	31%	34%
10	Anson Street, St George Basin	4820	46%	33%	N/A	N/A

Option 2 designs were undertaken for 5 sites with the lowest existing deep soil. These design changes included minor modifications such as relocating basement stairs (Edmondson park) and bin stores (North Parramatta) reducing paving (Bronte) and modifying a basement tank (Kingscliff). These changes had dramatic impacts on schemes, increasing deep soil by 23% (Edmondson Park), 29% (North Parramatta), 16% (Bronte) and 9% (Kingscliff).

The Alexandria development (976m2) required the most design changes to increase deep soil. This scheme would require a reduction in ground level parking. This site is in an inner urban area and has no minimum requirement to deliver parking. If parking had been reduced, the project could provide 21% deep soil.

APARTMENTS: RECOMMENDATIONS

Often new apartment developments remove large established trees and replace these large trees with smaller trees or shrubs. This loss of larger trees has multiple negative consequences, from increased urban heat and energy use to reductions in habitat and loss of interconnected neighbourhood canopy. For urban dwellers, this loss of greenery can impact on physical and mental wellbeing.

Apartments are higher density living environments. Tree canopy provides important amenity, environmental and social benefits in these environments. Larger trees shade facades and improve building thermal comfort. Tree shade can reduce energy costs. In NSW there is projected to be an increase in air conditioning by 90% by 2050 (Saman et al 2014). Direct tree shade has been shown to reduce household cooling KWH by 30%. Trees provide an alternative, non-mechanical mechanism for cooling, particularly when heat related electricity outages occur.

The recommendations for deep soil have adopted targets based on variations in site scale. The scale includes sites less that 650m2, sites 650 - 1500m2, sites 1500m2 - 3000m2, and sites greater than 3000m2. These categories for site area align with current categories in the ADG. The deep soil targets nominated range for 10% on the smallest sites to 30% on sites greater than 3000m2. Five of the 10 existing development applications reviewed would comply with these recommended controls and 9 schemes would comply with very minor design changes. The only scheme that would not is an inner urban site with ground level parking. This parking was not a requirement for development approval; the scheme could with redesign comfortably achieve these deep soil targets.

These deep soil targets generally align with the research undertaken by DPIE Greener City Branch, in October 2020. This research recommended that the deep soil target in the ADG be updated to adopt higher deep soil percentages of 14% for sites less than 3,000 sqm and 21% for sites greater than 3,000 sqm. The proposed mid-range targets of 650 to <1500m2 (15%) and 1500 to <3000m2 (20%) align with the D & P EIE range. On extra-large sites greater than 3000m2 a target of 30% is nominated. Testing demonstrated that these sites could comfortably provide 30% deep soil with very minor landscape design changes (Option 1). We propose a 10% target on sites less than 650m2 as these sites were found to be the most constrained in delivering deep soil.

The recommended tree canopy and replenishment target for apartments is slightly higher than the deep soil provision. This is in recognition of the importance of maximising urban greening and trees in high density environments, where many people are living. These tree replenishment rates have been checked to ensure that an appropriate allowance of soil had been provided to achieve the projected tree canopy targets. It is expected that in many cases the local soil type will be appropriate to support more than the minimum number of trees.

Table 21: Recommended tree canopy controls for apartments.

Recommended Guidance Detached dwellings	Tree Canopy Target (%) site area	Deep Soil min (%) site area	Tree Replenishment Requirements
Less than 650m2	15%	10%. Minimum 3m dimension.	For every 350m2 of site area or part thereof, at least one small tree is to be planted in the deep soil area.
650 – 1500m2	20%	15%. Minimum 3m dimension.	For every 275m2 of site area or part thereof, at least one medium tree is to be planted in the deep soil area.
1500m2 – 3000m2	25%	20%. Minimum 3m dimension with a wider contiguous portion that is a minimum 6m wide and at least 25% of the minimum deep soil area.	For every 450m2 of site area or part thereof, at least two medium trees or one large tree is to be planted in the deep soil area.
Greater than 3000m2	35%	30%. Minimum 3m dimension, with a wider contiguous portion that is a minimum 6m wide and at least 25% of the minimum deep soil area.	For every 300 m2 of site area or part thereof, at least two medium trees or one large tree are to be planted in the deep soil area.

NON-RESIDENTIAL DEVELOPMENTS

This section reviews business parks, bulky goods, and industrial developments. As on grade car parking is often provided in developments of this type, we have reviewed and tested parking requirements as part of this scope.

On grade carparks are commonly provided on a range of business and industrial sites. These carparks require large expanses of pavement and are often configured with limited tree canopy. Research has found that dense tree shade can substantially reduce temperatures in high albedo areas such as asphalt car parks (Rahman et al, Rosenfield 2014). Shade can also improve pavement longevity and reduce pavement fatigue cracking, and rutting (McPherson & Muchnick 2005).

ON GRADE CAR PARKS: CURRENT CONTROLS

We reviewed 17 LGAS's to understand the current landscape requirements for carparks (Table 22). This is a common control used in a range of inner urban, suburban and regional LGA's. Controls are developed using a proportion of landscape for every x number of car parking bays. They ranged from 4 to 10 car spaces per landscape bay. Widths of landscape bay ranged from 1 to 2.5 metres.

Table 22: Sample of car park landscape controls.

Authority	Policy/Plan	Reference	Carpark landscape rate (bay/no. cars)	Carpark bay min dimension (m)
Local Government				
Albury	ADCP2010	Part:12.3 Industrial Developments	3	-
Ashfield	CIWDCP2016	Chapter A5 Landscaping/Chapter A8 Parking	6	1
Bankstown	BDCP2015	Part B3 Industrial	5	2
Blacktown	BDCP2015	Part E4 - Industrial Areas	4	-
Blacktown	BDCP2015	Part E6 - Business Park Zone	9	2
Campbelltown	C(SC)DCP2015	Part 5 - Commercial Development	-	2
City of Sydney	SDCP2012	Part 3.5 - Urban Ecology	4	2
Greater Taree	GTDCP2010	Part N - Landscaping Requirements	-	1.8
The Hills	HDCP 2012	Part C3 Landscape	10	2
Ku-Ring-Gai	KDCP2015	Part 9 - Non-Residential and Office Buildings	5	2
Lake Macquarie	LMDCP2015	Part 5 - Industrial and Business Park	6	2
Liverpool	LDCP2008	Part 1.20 - Car Parking and Access	10	2
Liverpool	LDCP2008	Part 7 - Industrial Areas	8	2.5
Maitland	MDCP2011	Part C.11 - Vehicular Access & Car Parking	10	-
Marrickville	MDCP2011	Part 2.18 - Landscaping and Open Spaces	5	1.5
Mid Coast	GLDCP2013	Part 7 - Industrial Development	-	2.5
Sutherland	SSDCP2015	Chapter 25 -B5 Business Development	6	2.5
Wollongong	WDCP2009	Chapter B5 - Industrial Development	10	1.5
Wyong	WDCP2013	Part 2.11 - Parking and Access	6	-
State Government				
State	ADG	Part 3J	4-5	-
Range Low			3	1
Range High			10	2.5

ON GRADE CAR PARKS: TREE CANOPY TESTING

We tested two large scale bulky goods sites in Orange (4.4 hectares) and in Boolaroo (6.8 hectares). The site in Boolaroo had some perimeter landscaping providing 6% tree canopy. It was difficult to determine the tree canopy on the site in Orange however from aerial imagery, it appeared to be very limited.

We tested inclusion of 1 x medium tree (8m wide canopy or greater) for every 4 car parking spaces. This spacing was used, as it assumed that the medium tree's spread would provide shade to adjacent parking bays (4 spaces up to 10m wide). This would maximise shade over pavement areas and reduce heat gain, across the most exposed and hot areas.

Applying this target would substantially improve tree canopy providing an increase of 11% and 17% tree canopy area (Table 23). Incorporating these trees into the existing car park layout on the 2 sites tested would reduce car spaces by 8% and 10% respectively. However, it is noted that this testing did not substantially adjust the current design. If the scheme were redesigned using this proposed target, there could be capacity to maintain current parking numbers, through improved efficiencies in the carpark layout.

ON GRADE CAR PARKS: RECOMMENDATIONS

Business parks, bulky goods, and industrial categories all typically have large areas of on grade car parking. Tree planting in on grade car parks would provide shade, improving comfort for visitors and customers. It is recommended that tree planting rate be adopted as listed in table 24. This target for car parks would considerably improve local microclimates and contribute to tree canopy on these large sites.

Table 23: Sample DA testing for bulky goods car parks.

No.	Address	Lot size (m2)	Additional trees in car park (%) site area	Car space reduction (%) parking area
1	2A Main Street, Boolaroo	68512	17%	10%
2	236-237 Leeds Parade, Orange	44902	11%	8%

Table 24: Recommended tree canopy controls for on grade car parks.

Recommended Guidance On Grade Car Parks	Tree Replenishment
All sites where on grade car parking is proposed	1 x medium tree should be planted in every fifth car parking space provided. The tree is to be located in a deep soil planted zone of 13m2, the equivalent of a parking bay. Trees should be evenly distributed, ideally in a checkerboard fashion, to increase shading. Car park trees are to be provided in addition to the site tree canopy target.

Figure 4: Example of car parking layout demonstrating the checkerboard layout.

BUSINESS PARKS

Business parks includes office premises with administrative, clerical, technical, professional activities not dealing with public. These sites can include warehouse and distribution centres for storing or handling goods. These developments often have on grade car parking.

BUSINESS PARKS: CURRENT CONTROLS

Controls for 11 Local Government Areas were reviewed (Table A5 in Appendix A). From this review it was evident that there were limited controls for deep soil or landscape for this development type. Only one LGA (City of Sydney SDCP2012) had a canopy control of 15%. Two LGAs had deep soil controls (City of Sydney 10% SDCP2012) and (Ryde RDCP2014 20%) and two had landscape area controls-(Albury 15% and Ryde 20%). Street setback controls however are nominated in 10 of the 11 DCP's reviewed. These ranged from 5 metres to up to 30 metres width. These landscape spaces could easily provide consolidated deep soil and tree planting.

Due to the absence of tree canopy or deep soil controls, we undertook an additional review of sample precedents to better understand the amount of deep soil currently being delivered.

BUSINESS PARKS– ADDITIONAL ANALYSIS

To obtain a broader understanding of what has been delivered in business park sites, we undertook a wider review of 10 samples across Greater Sydney and NSW. We used Nearmap to analyse sites and measure deep soil zones (Table 25). Lot sizes ranged from 0.2 to 5.4 hectares. Of the sample selection, the average percentage of deep soil was 21%. The highest deep soil provision was 42% and the lowest was 11%.

BUSINESS PARKS: DEVELOPMENT APPLICATION TESTING

Three development applications were reviewed in detail. The lots ranged from 2953m2 to 16850m2 (Table 26). The existing deep soil in the development applications was between 19% and 35% site area. With minor landscape design modifications to reduce paved areas (as illustrated in Option 1 designs), there was capacity to increase deep soil to a minimum 25% deep soil. These schemes could be delivered with no impact on building layout or reductions in on grade parking.

BUSINESS PARKS: RECOMMENDATIONS

Business parks are often interpreted as Buildings set in a 'park'. They generally have a landscaped frontage, to provide an attractive entrance to the facility. The recommendations are for 25% deep soil and 35% tree canopy be provided across all sites. This target was able to be easily achieved through minor landscape design changes to the development application schemes. Please note that this target only applies to office premises in the relevant zones, and not B1-B4 which are typically more urban.

The recommended tree canopy and replenishment target for business parks is slightly higher than the deep soil provision. Increasing urban greening and trees in environments where many people are working, will improve local microclimates and improve workers health and wellbeing. Trees will also provide shade to office buildings, reducing air conditioning use.

Table 25: Supplementary analysis of business parks.

No.	Address	Lot size (m2)	Building footprint (%)	Deep Soil (%)
1	15-17 Chaplin Drive Lane Cove	2776	1441	24%
2	10 Solent Circuit, Norwest	10961	4492	42%
3	8 Solent Circuit, Norwest	11852	4384	32%
4	90 Euston Road, Alexandria	13936	10071	11%
5	Lot 8 Brookhollow Avenue , Baulkham Hills	16850	10447	35%
6	12 Blueridge Drive, Dubbo	2953	1240	19%
7	1 Eden Park Drive, Macquarie Park	7953	3420	20%
8	5-7 Inglewood Place, Norwest	18203	5899	23%
9	5 Hudson Avenue, Castle Hill	18330	7782	23%
10	2 Solent Circuit, Norwest	53907	18914	19%

Table 26: Sample DA testing for business parks.

No.	Address	Lot size (m2)	Building coverage (%)	Existing Deep Soil (%)	Option 1 Deep Soil (%)
1	Lot 8 Brookhollow Avenue The Hills	16850	62%	35%	N/A
2	12 Blueridge Drive Dubbo	2953	42%	19%	25%
3	1 Eden Park Drive, Macquarie Park	7953	43%	20%	25%

Table 27: Recommended tree canopy controls for business parks.

Recommended Guidance Business parks	Tree Canopy Target (%) site area	Deep Soil min % site area	Tree Replenishment Requirements
All lots	35%	25%. Minimum 3m dimension.	For every 300m2 of site area or part thereof, at least one tree of large size or two trees of medium size are to be planted in the deep soil area.
On grade car parking where there are 4 spaces or more.	1 x medium tree should be planted in every fifth car parking space provided. The tree is to be located in a deep soil planted zone of 13m2, the equivalent of a parking bay. Trees should be evenly distributed, ideally in a checkerboard fashion, to increase shading. Car park trees are to be provided in addition to the site tree canopy target.		

INDUSTRIAL

Industrial buildings can be any shape or size depending on their function. Industrial sites can accommodate warehouses, freight transport, garden centres, hardware and building suppliers and depots storing plant and machinery. Industrial facilities often require large areas for truck access and maneuvering. Generally, as industrial buildings increase in size and height, they require larger setbacks. Smaller buildings can be configured in many ways (abutting, attached or freestanding), whereas larger buildings are more likely to be freestanding with setbacks to allow fire egress. Larger buildings require fire truck access on all sides.

INDUSTRIAL: CURRENT CONTROLS

Controls for 17 Local Government Areas were reviewed (Table A6 in Appendix A). Four LGAs have landscape area of 10% controls (Liverpool, Canterbury, Parramatta and Wollongong). Three LGAs have site coverage controls ranging from 50 – 70%. Only one LGA (City of Sydney SDCP2012) had a canopy control of 15% and deep soil control of 10% for their industrial lands.

Like the business park controls, many of the industrial controls nominated generous street setbacks. These are likely to improve visual amenity and screen the development from the street. These landscape spaces are likely to already provide deep soil zones and could easily provide canopy plantings.

INDUSTRIAL: ADDITIONAL ANALYSIS

To obtain a broader understanding of what has been delivered in industrial sites, we undertook a wider review of 27 samples across Greater Sydney and NSW (Table 28). We used Near Map to analyse sites and measure deep soil zones. Lots ranged from 0.13 hectares to 13.3 hectares. Of the 27 industrial sites analysed, we found that the sample average percentage of deep soil was 21%. The highest deep soil provision was 50% and the lowest was 4%.

INDUSTRIAL: DEVELOPMENT APPLICATION TESTING

Four development applications were reviewed in detail. These ranged from 4064m2 to 51418m2 site area and were in regional and suburban areas (Table 29). Three of the sites had 5 – 6% deep soil and one site had 21% deep soil. These deep soil provisions are low compared to the previous samples analysed (as listed in Table 28). Option 1 designs applied landscape design modifications to reduce hardstand areas, with no impact on truck maneuvering areas. The Wagga Wagga site could comfortably achieve 15% deep soil on side and rear boundaries with no impact on building or operational areas. The Casula and Greenacre sites could provide over 14% deep soil by providing landscape setbacks on boundaries and by reducing on grade parking. Option 2 designs further reduced hardstand areas and one scenario (Casula) shifted the building footprints to maximize deep soil on the boundary.

Table 28: Supplementary analysis on sample industrial sites.

No.	Address	Lot size (m2)	Building footprint (%)	Deep Soil (%)
1	94-98 Euston Road, Alexandria	1340	1032	4%
2	Horsley Park	3041	1060	50%
3	41-43 Anzac Street, Greenacre	4046	2398	6%
4	34 Jones Street, East Wagga Wagga	4504	810	5%
5	100-104 Euston Road, Alexandria	4649	3224	9%
6	Apollo St Warriewood	5669	2934	25%
7	7-9 Yulong Close, Moorebank	6504	3290	30%
8	Lot 21 Manns Road, West Gosford	7167	3010	21%
9	122-130 Euston Road, Alexandria	7246	5419	4%
10	Victoria Avenue Castle Hill	8701	1540	30%
11	Victoria Avenue Castle Hill	9315	2529	32%
12	1 Broadcast Way Artarmon	10668	6970	28%
13	Warriewood	11355	4948	18%
14	90 Euston Road, Alexandria	13936	10071	11%
15	2 Campbell Street Artarmon	18519	2283	22%
16	Horsley Park	19894	6454	24%
17	Ingleburn Industrial Park	20163	8051	26%
18	Victoria Avenue Castle Hill	20202	9540	18%
19	Ingleburn Industrial Park	22049	7002	20%
20	Horsley Park	22057	9172	10%
21	Victoria Avenue Castle Hill	22168	10184	19%
22	Ingleburn Industrial Park	23174	8271	37%
23	Horsley Park	39293	15396	25%
24	Ingleburn Industrial Park	40632	17947	12%
25	Lot 21 Beech Road, Casula	51418	29308	5%
26	Ingleburn Industrial Park	78615	25914	23%
27	Ingleburn Industrial Park	133192	51115	21%

INDUSTRIAL: RECOMMENDATIONS

Although industrial sites vary significantly in scale and layout, it was evident from the analysis that many of these sites already provide substantial deep soil. This was on average 21% site area of the sample sites reviewed. Detailed design testing found that with moderate design changes all four sites were able to achieve a minimum of 15% or greater deep soil. Industrial sites can provide 25% tree canopy cover in 15% deep soil site area (Table 30).

Many industrial sites are already required to provide wide street setbacks in current DCP controls. The deep soil recommendation nominated in this report would complement these existing controls. The 6-metre deep soil dimension could be in the provided in the street setbacks. This would provide an efficiency in site layout and site access, as deeper street setbacks could provide longer driveways for manoeuvring articulated trucks. This layout would also facilitate more tree planting adjacent to industrial streets which would improve neighbourhood amenity.

The recommended tree canopy and replenishment target for industrial sites is slightly higher than the deep soil provision. This target is especially important to achieve on these sites, as they are often located in areas vulnerable to increased heat and have large expanses of hardstand areas and pavements.

Table 29: Sample DA testing for industrial sites.

No.	Address	Lot size (m2)	Building coverage (%)	Existing Deep Soil (%)	Option 1 Deep Soil (%)	Option 2 Deep Soil (%)
1	34 Jones Street, East Wagga Wagga	4504	18%	5%	16%	23%
2	Lot 21 Beech Road, Casula	51418	57%	5%	15%	20%
3	Lot 21 Manns Road, West Gosford	7167	42%	21%	22%	25%
4	41-43 Anzac Street, Greenacre	4046	59%	6%	15%	18%

Table 30: Recommended tree canopy controls for industrial sites.

Recommended Guidance Industrial sites	Tree Canopy Target % site area	Deep Soil % site area	Tree Replenishment Requirements
All lots	25% site area	15% site area. Minimum 3m dimension, with a wider contiguous portion that is a minimum 6m wide and at least 50% of the minimum deep soil area.	For every 400m2 of site area or part thereof, at least one tree of large size or two trees of medium size is to be planted in the deep soil area.
On grade car parking – requirement for < 4 on grade car parking spaces.	1 x medium tree should be planted in every fifth car parking space provided. The tree is to be located in a deep soil planted zone of 13m2, the equivalent of a parking bay. Trees should be evenly distributed, ideally in a checkerboard fashion, to increase shading. Car park trees are to be provided in addition to the site tree canopy target.		

BULKY GOODS

Bulky goods are like industrial sites in that they can include warehouses. These sites often have specialised retail premises for handling, display or storage as well as direct vehicular access by the public. Bulky goods can be used as garden centres, and for landscaping material supplies. They can include large expanses of on grade car parking.

BULKY GOODS: CURRENT CONTROLS

Controls for 8 Local Government Areas were reviewed (Table A7 in Appendix A). Landscape and tree canopy controls are very limited for this development type. Only one LGA, the City of Sydney, had a canopy control and deep soil control (15% and 10% SDCP 2012). Only one LGA, Albury, had a landscape area control of 10% site area (ADCP2010). Albury also had a 60% site coverage control. However, setback controls in all locations (other than the City of Sydney) were generous, ranging from 4 metres to 30 metres wide. This objective is usually to achieve visual amenity and screening of the building from the street. These street setbacks provide capacity for deep soil tree canopy.

BULKY GOODS: ADDITIONAL ANALYSIS

We undertook and a wider review of 7 sample bulky goods sites across Greater Sydney and NSW (Table 31). Lot sizes ranged from 3325 m2 to 68 512m2. Of the sample selection, the average percentage of deep soil was 20%. The highest deep soil provision was 34% and the lowest was 1%.

BULKY GOODS: DEVELOPMENT APPLICATION TESTING

Table 31: Supplementary analysis bulky goods sites.

No.	Address	Lot size (m2)	Building footprint (m2)	Deep Soil (%)
1	Northern Distributor Orange	44895	13866	21%
2	21-23 Victoria Avenue, Castle Hill	21049	14102	16%
3	2A Main Street, Boolaroo	68512	15073	13%
4	357-373 Warringah Road Frenchs Forest	21750	8918	34%
5	3 Pat O'Leary Drive, Kelso	52032	17793	24%
6	347-351 Albert Street Deniliquin	3325	890	1%
7	16-20 Ray McCarthy Drive Coffs Harbour	8933	1008	33%

Four sites were reviewed in detail (Table 32). The sites were between 2 hectares and 6.9 hectares. The sites included warehouses and hardstand zones as well as large areas of on grade car parking. The sites provided deep soil of between 13% and 34% site area. This was primarily in the street setbacks. Option 1 designs included minor changes to two schemes such as relocating tanks and reducing excess paved areas. These changes increased deep soil to 18% and 22% site area. The design modifications did not impact on building footprints. No design change was tested for the Frenchs Forest site as this was already providing 34% deep soil.

BULKY GOODS: RECOMMENDATIONS

A target of 25% canopy with a minimum 15% deep soil site area is recommended for bulky goods sites (Table 33). This is less than the sample selection which had on average 20% deep soil. It also represents a minor increase to only one of the existing schemes and would require no change to the other sites as they already meet this target. The recommended tree canopy and replenishment target is slightly higher than the deep soil provision to maximise shade on these sites, often located in areas vulnerable to increased heat.

On bulky goods sites, on grade car parking takes up a large amount of lot area. In these sites it is crucial to provide increased tree canopy to provide shade, to reduce local temperatures and provide sun protection for visitors and customers. It is recommended that tree planting be designated for on grade parking bays. The rate of 1 medium tree (8m or greater) in every fifth car parking spaces provides distributed shade to car parking areas from a connected tree canopy.

Table 32: Sample DA testing for bulky goods

No.	Address	Lot size (m2)	Building footprint %	Existing Deep Soil %	Option 1 Deep Soil %
1	21-23 Victoria Avenue, Castle Hill	21049	67%	17%	18%
2	2A Main Street, Boolaroo	68512	22%	13%	20%
3	357-373 Warringah Road Frenchs Forest	21750	41%	34%	N/A
4	236 - 237 Leeds Pde Orange	44900	34%	22%	22%

Table 33: Recommended tree canopy controls for bulky goods sites

Recommended Guidance bulky goods	Tree Canopy Target (%) site area	Deep Soil (%) site area	Tree Replenishment Requirements
All lots	25% site area	15% site area. Minimum 3m dimension, with a wider contiguous portion that is a minimum 6m wide and at least 50% of the minimum deep soil area.	For every 400m2 of site area or part thereof, at least one tree of large size or two trees of medium size are to be planted in the deep soil area.
On grade car parking - requirement for greater than 4 on grade car parking spaces.	1 x medium tree should be planted in every fifth car parking space provided. The tree is to be located in a deep soil planted zone of 13m2, the equivalent of a parking bay. Trees should be evenly distributed, ideally in a checkerboard fashion, to increase shading. Car park trees are to be provided in addition to the site tree canopy target.		

PUBLIC LAND

OVERVIEW

Testing of urban tree canopy on public land was developed using a range of built examples. The major categories reviewed were streets, and local parks. A cross section of samples were drawn from a range of locations in urban, suburban, and regional environments. Public land testing, (as described in Chapter 3: Method) has focused on the most common types of urban public land in NSW.

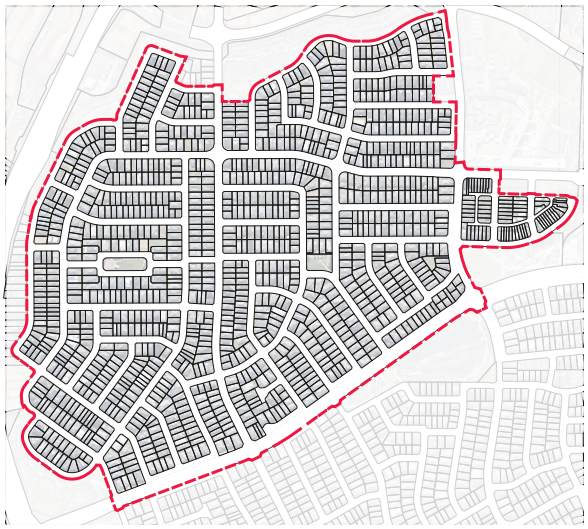
Local parks are generally zoned as RE1 Public recreation. RE1 land is the second largest urban land use, covering 760 square kilometres of land in NSW. Local streets comprise an equally large portion of public land. It is difficult to determine the amount of area that streets comprise in LEP land use zoning maps, as they are not identified as a separate item. However, in our analysis of three new residential neighbourhoods (Figures 5 - 7) we found that streets comprised between 30 and 34% of the land use area. It is likely that this proportion would be higher in inner urban areas, which commonly have a finer grain street network.

STREETS: CANOPY TESTING OVERVIEW

The first phase of the work was to capture a range of street conditions that influence tree canopy. The aim was to understand how much street tree canopy was already evident in theses streets and to explore what street tree canopy could be delivered. The categories were:

- Existing residential streets
  - Streets with underground power
  - Streets with overhead power lines
- Existing industrial streets
- New residential streets

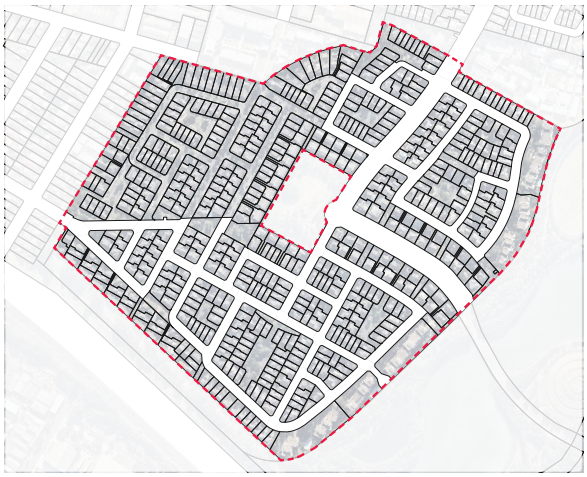
Five reserve dimensions (12m, 14m, 15m, 16m, 18m, 20m) for existing streets were analysed. On new streets, three reserve widths (16m, 18m, 20m) were analysed. As noted previously, arterial roads have been excluded from this scope as they are subject to street specific design controls and are not able to be generalized. Likewise mixed-use high streets are influenced by highly varied local conditions. They often include shops and retail premises and are designed to address specific parking, servicing, and outdoor dining requirements. Councils should establish street specific canopy targets for these conditions.



ORAN PARK, Camden Council

Land zoning:	R1
Scope area:	889546m²
Road area:	294814m² / 33%
Lot area:	597747m² / 67%

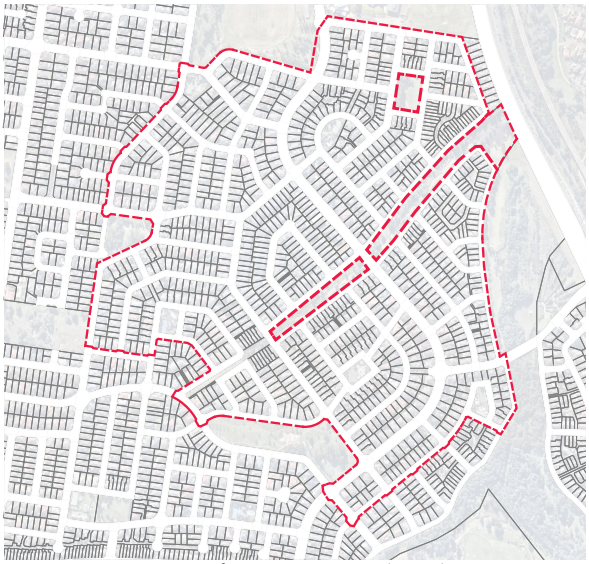
Figure 5: Proportion of streets in a residential precinct in Oran Park



NEWINGTON, City of Parramatta

Land zoning:	R3 / R4
Scope area:	308105m²
Road area:	104854m² / 34%
Lot area:	202985m² / 66%

Figure 6: Proportion of streets in a residential precinct in Newington



STANHOPE GARDENS, Blacktown City Council

Land zoning:	R2, R3, RE1, SP2
Scope area:	731559m²
Road area:	222571m² / 30%
Lot area:	508988m² / 70%

Figure 7: Proportion of streets in a residential precinct in Stanhope Gardens

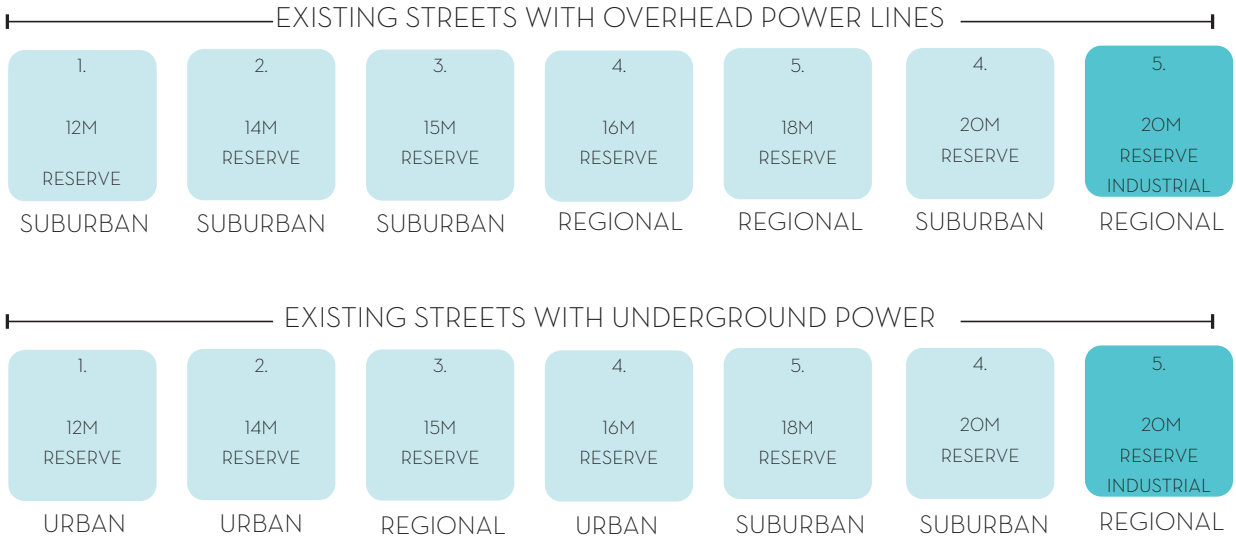


Figure 8: Selected streets.

EXISTING STREETS: CANOPY TESTING OVERVIEW

We selected 14 existing streets within inner urban, suburban, and regional locations (Figure 8). Twelve streets were in residential neighbourhoods, and two streets were in industrial areas. Aerial images were exported from Nearmap into CAD and measured, to determine the reserve and verge width. Plans used a 70 metre length of street and excluded intersections. Street view images were used to examine locations of overhead power lines and power poles which were subsequently mapped in CAD. Street trees with a diameter 3m or greater were measured to estimate the existing proportion of existing tree canopy in the street. Overhangs from street trees on adjacent lots were excluded. This determined the amount of canopy cover as a percentage of the total street reserve.

Design Options 1 and 2 were then developed. Option 1 were infill designs which planted trees in available verge space on streets. Option 2 designs marginally modified the infill schemes, to replace existing small street trees with larger trees (8m or greater). In locations where there were no overhead power lines, medium sized trees (8m diameter) were spaced at 10 metre centres. In locations under power lines small trees (5m diameter) were spaced at 7 metre centres. The designs did not include trees where service pits were evident. It is noted that this scope did not include detailed analysis of underground services. New trees were located clear of power lines and light poles and at a 2 metre offset from driveways on residential streets and a 4 metre offset from industrial streets. These designs were then measured, and a canopy cover percentage was calculated for the total street reserve.

Intersections were excluded for several reasons. The number and layout of intersections can vary significantly depending on the block layout, street grid and land use type. In some neighbourhoods, street intersections may occur at large distances due to the configuration of deeper, wider lots, or natural conditions such as creeks or landform. Likewise, there may be a higher number of intersections configured closer together locations where there are smaller lots, such as close to town centres. Therefore, the canopy target has been established for a street length only. Public land targets can be developed for a new precinct or an existing area based on its specific block pattern. Refer to Chapter 5: Case Study for an example of how to apply tree canopy targets to streets in a new precinct.

STREETS WITH OVERHEAD POWER LINES: CANOPY TESTING

Six residential streets on 12 to 20 metre reserves were tested (Table 34). Most had overhead power lines located on one side of the street, and some had cables connecting to houses on the other side of the street. The lowest existing canopy was 0% (on Waratah St, Port Macquarie) with the highest was 43% (on Oleander St, Riverstone). On average the existing canopy cover for the 6 selected streets was 28%. Option 1 designs increased canopy cover to an average of 44% tree canopy. Option 2 designs increased tree canopy to an average of 48%.

STREETS WITH UNDERGROUND POWER: CANOPY TESTING

Six residential streets with underground power on 12 to 20 metre reserves were tested (Table 35). It is noted that many of these streets were newly established, therefore tree canopy was either yet to be planted or still juvenile. Existing canopy on these streets ranged from between 0% (on Bucello Street, Griffith) to 63% (on Curlew Avenue, Newington). On average there was 19% existing canopy evident on these selected streets. Option 1 and Option 2 designs increased the average to 48% and 53% canopy cover respectively. It is notable that the street with the highest existing tree canopy (63%) was also in narrowest street reserve (Curlew Avenue, Newington). This was due to the larger tree species used on this street.

Table 34: Sample testing for residential streets with above ground power lines.

No.	Reserve width (m)	Address	Region	Existing Canopy (%)	Option 1 infill canopy (%)	Option 2 infill/ replacement canopy (%)
1	12m	Corben St, Surry Hills	Inner urban	40%	49%	N/A
2	14m	Glebe St, Glebe	Inner urban	33%	44%	49%
3	15m	Waratah St, Port Macquarie	Regional	0%	43%	N/A
4	16m	Dalmeny St, Russell Lea	Inner urban	5%	30%	35%
5	18m	Oleander St,Riverstone	Suburban- West	43%	61%	N/A
6	20m	Young St, Annandale	Inner urban	33%	38%	48%

Table 35: Sample testing for residential streets with underground power lines.

No.	Reserve width (m)	Address	Region	Existing Canopy (%)	Option 1 infill canopy (%)	Option 2 infill/ replacement canopy (%)
1	12m	Curlew Avenue, Newington	Inner urban	63%	72%	N/A
2	14m	Jennings Cr, Spring Farm	Suburban- South	18%	29%	48%
3	15m	Tropic Bird Cr,Hinchinbrook	Suburban- South	13%	38%	39%
4	16m	Cormorant Cr Dubbo	Inner urban	3%	53%	58%
5	18m	Bucello Street Griffith	Suburban- West	0%	49%	N/A
6	20m	Ridgeline Drive The Ponds	Inner urban	16%	52%	N/A

INDUSTRIAL STREETS: CANOPY TESTING

We reviewed two existing examples of industrial streets, in Castle Hill and West Gosford (Table 36). These streets have overhead power lines, and wide carriageways (13m and above). These was no existing tree canopy on these streets. Option one located medium sized trees (8m diameter) at 10m centres in the verge with small trees (5m diameter) spaced at 7 metre centres on the verge under power lines. Option 2 modified tree sizes to include 10 wide canopies on verges without power lines. Option 1 designs achieved 29% and 33% canopy. Option 2 designs achieved 36% and 45% canopy.

Table 36: Sample testing for industrial streets with above ground power lines.

No.	Reserve width (m)	Address	Region	Existing Canopy (%)	Option 1 infill canopy (%)	Option 2 infill large trees canopy (%)
1	20m	Salisbury Rd, Castle Hill	Suburban	0%	29%	36%
2	20m	Gibbens Rd, West Gosford	Regional	0%	33%	45%

EXISTING STREETS: RECOMMENDATIONS

Streets are important areas for tree canopy provision. Street trees provide capacity to improve microclimates by shading roads and shading buildings. This in turn reduces air-conditioning, lowers local temperatures, and improves community health. Minor changes can be made to existing streets to provide more tree canopy.

Two categories of recommendations have been developed for streets. A target of 40% canopy cover is proposed for existing streets with overhead power lines. A target of 50% canopy cover is proposed for existing streets with underground power (Table 37). This first target reflects the Option 1 design results, which found that with targeted infill, streets with overhead power could achieve on average 44% tree canopy. The second target reflects that findings that streets with underground power lines could achieve a considerably higher canopy target of on average 53%. While it is recognised that there can be high variability in existing streets, the target has been developed based on conservative estimates for tree spacings. This ensures that there can be degree of design flexibility in achieving these targets. Refer to Chapter 5: Case Study for a description of how to apply these targets to existing and new neighbourhoods.

Industrial streets are more constrained. This was due to their functional requirements for truck access which require wide carriageways and driveways for vehicle maneuvering. Therefore, the recommended target for industrial streets is slightly lower to reflect these constraints (Table 37). A 35% canopy cover target is recommended on existing industrial streets with overhead power lines. A 45% canopy cover is recommended on industrial streets with underground power.

Table 37: Recommended tree canopy targets for existing streets.

Existing Residential Streets	Overhead power lines	Underground power
12-20 metre reserve*	Minimum 40% canopy cover	Minimum 50% canopy cover
Existing Industrial Streets	**Overhead power lines**	**Underground power**
20-25 metre reserve*	Minimum 35% canopy cover	Minimum 45% canopy cover

* Excludes intersections

STREETS: ADDITIONAL TESTING OF SOIL PROVISIONS AND CONDITIONS

As existing streets are constrained environments, we undertook an additional analysis of soil conditions to ascertain that these street verges could provide capacity for targets nominated above.

Soil areas differ in their capacity to support trees. More area is required in locations with clay soils as tree roots are likely to occupy only 400-600mm depth of soil whereas in sandy loam soils tree roots can grow deeper. Soils for Landscape Development by Leake and Haege 2014 has been referenced to understand the variations in soil volume for different soil conditions and to establish minimum soil area required. Table 38 lists soil area requirements for trees on clay and trees on loam. Refer to Chapter 3: Method for further detail on soils calculations. These volumes assumed no irrigation, which is common for street trees. All street design options were tested (Table 39) and found to achieve the minimum soil area requirements, and most options achieve the maximum range of soil area based on soil conditions.

Table 38: Average soil volume area requirement for trees (Leake and Haege 2014).

Tree size Canopy Dia.(m)	Leake and Haege Sandy Loam	Leake and Haege Clay
5m (under power lines)	12m2	20m2
8m	18m2	30m2
12m	26m2	43m2

NEW STREETS

OVERVIEW

A range of new street layouts were developed to explore potential canopy targets. A typical street layout was designed with a central carriageway and verges of equal dimension. This structure was developed as a symmetrical structure as this is widely adopted in street engineering guidelines. Three reserve widths were tested: 16 metres, 18 metres and 20 metres. The layouts also tested three variations in lot configurations adjacent to streets (10m, 15m and 24m wide lots). This was to capture the impact of driveways on street tree canopy. It was assumed that verges would need to include footpaths and underground services.

Two sizes of tree planting were tested. Option 1 used medium sized trees (8m diameter) at 10 metre spacings and Option 2 used larger trees (10m diameter) at spacings of 10 metres. Driveways on verges were 3 metres wide. It was also assumed that all new streets would be designed with underground power.

NEW STREETS: CANOPY TESTING

Option 1 designs (Table 40) could achieve 49% or more tree canopy cover with 8m wide trees. The narrower the street, the more the canopy cover increased. The lowest target was 49% on the 20 metre wide street reserve and the highest canopy was 58% on the 16 metre street reserve.

Option 2 designs incorporating 10-metre-wide trees provided a minimum of 70% tree canopy and up to 83% tree canopy cover. This option would create an interconnected tree canopy and maximise shade to road pavements. These results could be further increased if tree planting were to be incorporated into street parking bays or wider street verges.

Table 39: Review of streets samples and soil area.

Reserve width	Street	Soil Type	Verge area (m2)	Minimum soil area (m2)	Maximum soil area (m2)	Exceeds Minimum Soil Area	Exceeds Maximum Soil Area
12m	Curlew Avenue						
	Option 1	Clay	490	218	244	Yes	Yes
12m	Corben Street						
	Option 1	Loam	350	176	204	Yes	Yes
14m	Jennings Crescent						
	Option 1	Clay	455	238	266	Yes	Yes
	Option 2	Clay	455	238	266	Yes	Yes
14m	Glebe Street						
	Option 1	Loam	350	226	253	Yes	Yes
	Option 2	Loam	350	238	266	Yes	Yes
15m	Tropic-Bird Crescent						
	Option 1	Clay	490	218	244	Yes	Yes
	Option 2	Clay	490	238	266	Yes	Yes
	Option 3	Clay	490	432	624	Yes	No
15m	Waratah Street						
	Option 1	Loam	490	167	186	Yes	Yes
	Option 2	Loam	490	265	366	Yes	No
16m	Dalmeny Avenue						
	Option 1	Clay	560	257	289	Yes	Yes
	Option 2	Clay	560	277	311	Yes	Yes
	Option 3	Clay	560	374	490	Yes	No- Uneven Verges
16m	Cormorant Crescent						
	Option 1	Clay	560	257	289	Yes	Yes
	Option 2	Clay	560	317	355	Yes	Yes
18m	Oleander Street						
	Option 1	Clay	630	338	438	Yes	Yes
18m	Bucello Street						
	Option 1	Clay	700	277	311	Yes	Yes
	Option 2	Clay	700	432	624	Yes	No - Uneven Verges
20m	Young Street						
	Option 1	Loam	490	206	226	Yes	Yes
	Option 2	Loam	490	206	226	Yes	Yes
20m	Ridgeline Drive						
	Option 1	Clay	630	436	488	Yes	Yes
	Option 2	Clay	630	337	377	Yes	Yes
20m	Gibbens Road						
	Option 1	Loam	532	179	200	Yes	Yes
	Option 2	Loam	532	228	290	Yes	Yes
20m	Salisbury Road						

NEW STREETS: OTHER PRECEDENTS

The Western Sydney Street Design Guidelines developed by the Western Sydney Planning Partnership provides recommendations for streetscape design. These guidelines include street designs that provide a target of 75% canopy cover for local streets and 60% canopy cover for industrial streets.

NEW STREETS: RECOMMENDATIONS

New streets have the potential to dramatically increase tree canopy in new neighbourhoods. The recommendation is that new residential streets be designed to provide 70% tree canopy, and that new industrial streets provide 60% tree canopy (as listed in Table 41). Refer to Chapter 5: Case Study for a description of how to apply these targets to new neighbourhoods.

Streetscape designs can be configured in various ways to achieve these targets. This would require careful selection of an appropriate street tree species, located in layouts that create an interconnected canopy. For example, our testing found that simply incorporating 10m wide trees at 10 metre centres on verges within a 20 metre street reserve would achieve this target. The principle underpinning this is that the scale and layout of new street trees should be designed based on the proportion of canopy to open street reserve.

There may be multiple design scenarios that could achieve the tree canopy target. This may include incorporating a mix of large and medium tree species, asymmetrical verge dimensions or plantings between on street parking bays. Additionally, street layouts vary to reflect specific site conditions including servicing, built form, driveway configurations. Therefore, rather than prescribing fixed street tree layouts, it is recommended that local authorities adopt a target for canopy, then adopt flexible design solutions that reflect a variety of conditions. Street reserves need to be of an adequate dimension, such as 20 metres to provide verge space for trees.

Table 40: New street canopy design testing.

No.	Reserve width (m)	Layout	Lot Width (m)	Driveways Total area (m2)	Option 1 8m trees (%)	Option 2 10m trees (%)
1	20m	12m carriageway, 4m verges	15	8%	49%	70%
2	20m	12m carriageway, 4m verge	10	13%	N/A	70%
3	20m	12m carriageway, 4m verges	24	8%	N/A	70%
4	16m	9m carriageway, 3.5m verges	15	8%	58%	83%
5	18m	9m carriageway, 4.5m verges	15	10%	56%	82%

Table 41: Recommended tree canopy targets for new streets

Residential Streets	Underground power
12-20 metre reserve*	Minimum 70% canopy cover
Industrial Streets	**Underground power**
20-25 metre reserve*	Minimum 60% canopy cover

* Excludes intersections

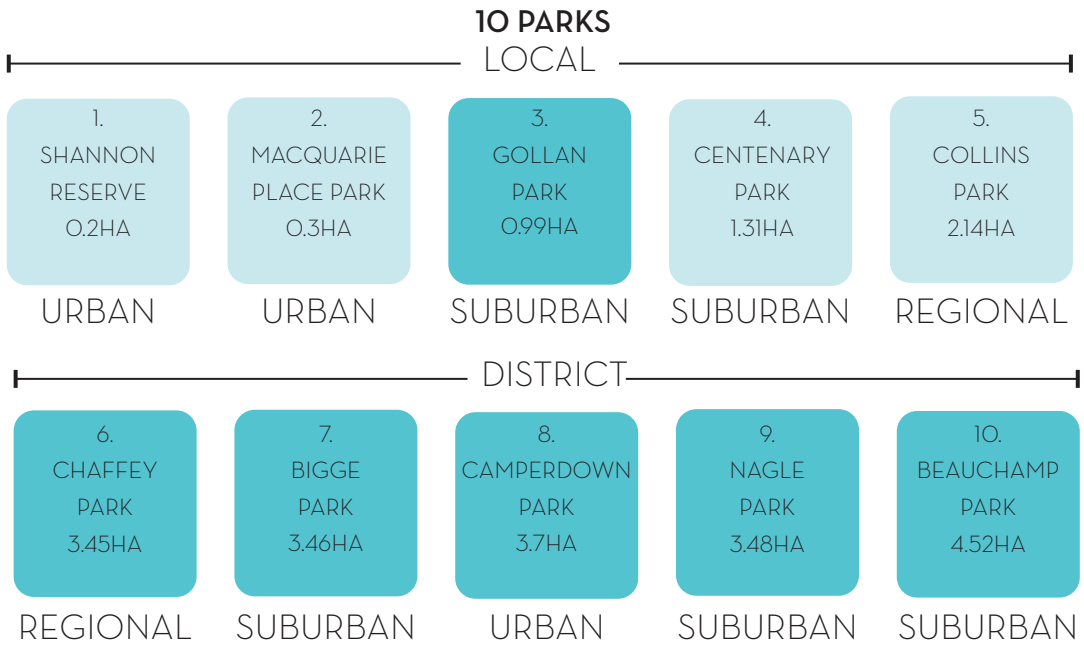


Figure 9: Selected parks

The light colour tone denotes parks without sports fields or courts. The dark colour tone denotes parks with sports fields or courts.

PARKS

PARKS: OVERVIEW

We selected a cross section of existing parks from urban, suburban, and regional environments. These were categorised into local and district parks as defined in the Government Architect NSW's Draft Greener Places Design Guide. This defines local public open space as between 0.3 and 2 hectares and district public open space as between 2 to 5 hectares (GAO NSW 2020 p17).

Our analysis has excluded regional parks. This is because regional parks are highly variable in character and form. They often have a range of facilities (such as multipurpose buildings, sports, and aquatic centres) and large on grade car parking. They can also be of heritage or ecological significance. It is recommended that site specific targets be developed for each regional park to address their specific physical characteristics.

Parks were then further grouped into parks used for passive recreation and parks with sports courts and fields. This can include tennis courts, hockey pitches, basketball courts, netball courts, futsal courts, volleyball courts, badminton courts, cricket, football and athletics fields. These need to be open to the sky and cannot be covered by trees. Canopy can cover some facilities such as cricket practice nets, half courts, indoor recreational courts and buildings. We ensured the sample included parks with sports fields and courts, and parks used for passive recreation.

Aerial images were exported from Nearmap into CAD, rescaled and measured, to determine the lot area and existing canopy (of trees greater than 3 metres in diameter). Where sports fields or courts were evident their areas were measured. In the initial phase of design testing a blanket target of 45% tree canopy was applied to all parks. These designs were then assessed for flexibility and recreational benefits. Refer to Appendix C for all parks analysis and design testing drawings.

PARKS: CANOPY TESTING

The results are collated in Table 42. The testing found that parks without sports fields could comfortably achieve 45% or more tree canopy. Although some parks with sports fields can have a good canopy provision such as Camperdown Park (33%) and Beauchamp Park (45%), applying park wide target on parks with sports fields and courts impacted on park amenity.

It was evident that different targets were required for parks with sports fields and courts. This was to ensure an appropriate proportion of tree canopy is provided in these parks while also retaining design flexibility and comfort.

An alternate approach was used for parks with sports fields and courts. A sliding scale was developed based on the amount of court/field area in a park. A target would then be applied to the remaining park area. The sliding scale adopted the following parameters:

- In parks where fields and courts comprise 10 to less than 20% of the park space, the remaining park area should accommodate 45% tree canopy.
- In parks where fields and courts comprise 20 to less than 30% of the park space, the remaining park area should accommodate 50% tree canopy.
- In parks where fields and courts comprise over 30% of the park space, the remaining park area should accommodate 55% tree canopy .

These targets were tested on three parks - Camperdown Park, Chaffey Park and Nagle Park. The schemes developed demonstrate that good design outcomes could be achieved when using this approach. The targets provided good canopy, as well as a mix of open and shaded park areas.

Table 42: Parks canopy design testing.

No.	Park Name	Size (m2)	Sports fields/ courts (m2)	Sports fields/ courts (%)	Existing tree canopy (%)	Option 1: Tree canopy (%)	Option 2: Tree canopy (%)
1	Sutherland Shire Centenary Park, Miranda	13160	0	0	43%	45%	N/A
2	Collins Park, Wagga Wagga	21403	0	0	42%	45%	50%
3	Shannon Reserve, Surry Hills	2664	0	0	32%	40%	45%
4	Gollan Park, Doonside	9994	4013	40%	16%	40%	45%
5	Macquarie Place Park, Sydney	0.33	0	0	69%	N/A	N/A
6	Camperdown Park, Camperdown	37077	14259	38%	33%	40%	45%
7	Bigge Park, Liverpool	34655	2246	6%	21%	40%	45%
8	Beauchamp Park, Chatswood	45229	13199	29%	46%	50%	N/A
9	Chaffey Park, Tamworth	34487	15462	45%	8%	40%	45%
10	Nagle Park, Maroubra	34801	15657	45%	18%	40%	45%

PARK RECOMMENDATIONS

Parks can contribute to neighbourhood amenity through tree planting. It is recommended that a minimum tree canopy of 45% be adopted for parks without sports courts and fields. A sliding scale should be adopted for parks with sports fields that provides flexibility in design and good amenity outcomes (table 43).

Table 43: Recommended tree canopy targets for local parks.

Local Parks	Target Park wide
All local parks up to 5 hectares where playing fields and courts comprise less than 10% of total site area.	Minimum 45% Canopy Cover

Local parks with playing fields or courts	Target for park areas excluding courts/playing fields
All local parks up to 5 hectares where playing fields and courts comprise between 10% and up to 20% total site area.	Minimum 45% Canopy
All local parks up to 5 hectares where playing fields and courts comprise between 20% and up to 30% total site area.	Minimum 50% Canopy
All local parks up to 5 hectares where playing fields and courts comprise over 30% total site area.	Minimum 55% Canopy

5.0 CASE STUDY

Following detailed testing of the public and private land types, a case study was selected to demonstrate how these detailed canopy targets could be applied in the master planning process. The case study selected was a recently developed precinct master plan in North Western Sydney.

CASE STUDY: OVERVIEW

The West Schofields Precinct forms part of the housing release within the NSW Government's North West Growth Area. The Precinct is approximately 576 hectares and is located within the Blacktown City Council LGA. An Indicative Layout Plan (ILP) (Figure 10) was developed in 2018 for exhibition. According to the West Schofields Exhibition Discussion Paper the precinct aims to provide housing, open space, green links, a local centre, a potential school, and biodiversity and heritage protection (NSW DPIE 2018 p6).

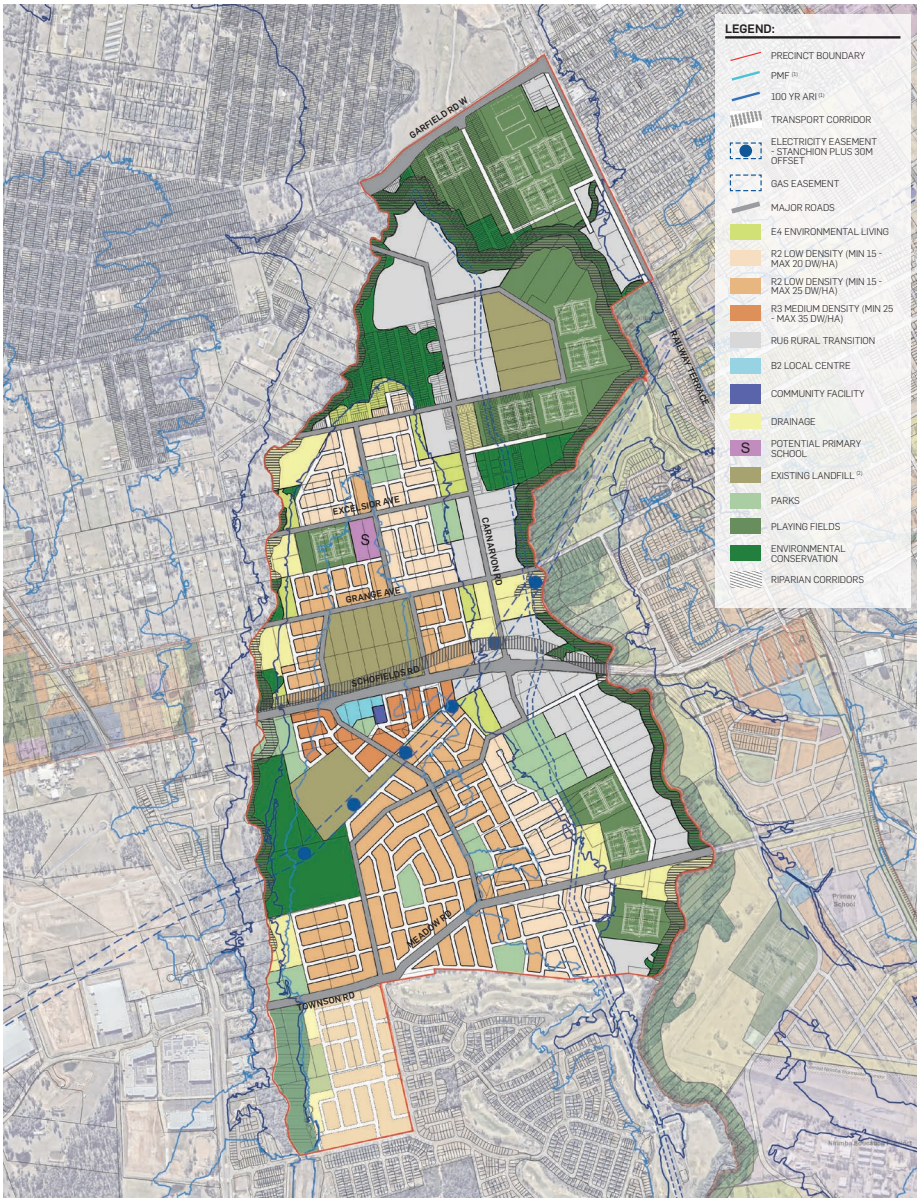


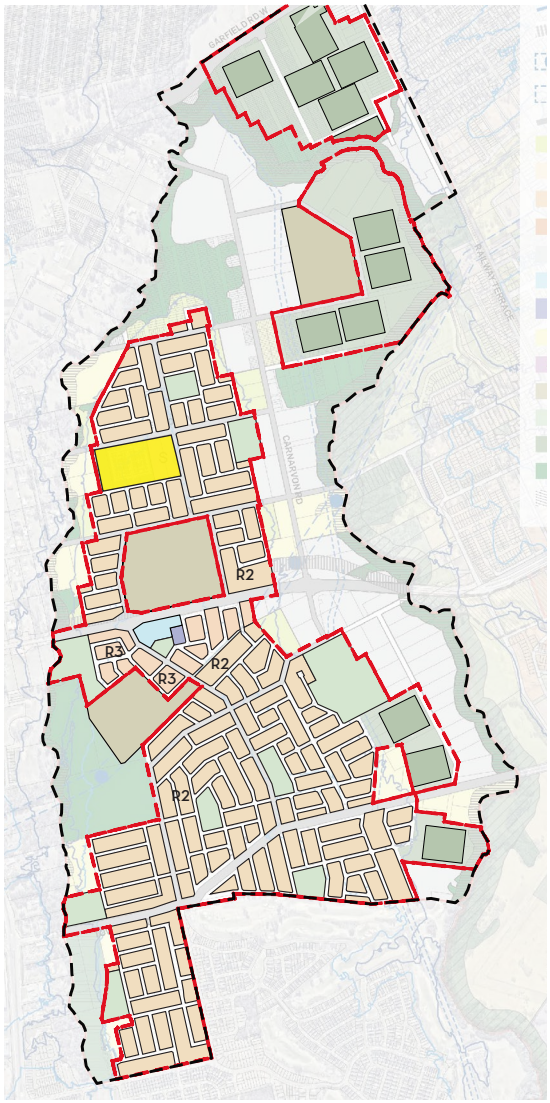
Figure 10: Indicative layout plan West Schofield Precinct.

ESTABLISHING THE CANOPY SCOPE

A draft ILP for West Schofields was provided by DPIE to test the process to set targets for new precincts (Figure 10). The precinct is predominately residential with a small local centre (B2) and a primary school. The precinct did not include industrial or other business zones. The ILP includes riparian areas, drainage areas, landfill zones and environmental conservation zones, a local street network, proposed parks and playing fields.

Zones within the ILP, that aligned with the UTC private and public land types were identified. This included Residential zones (R2, R3), Parks, Playing Fields and a Primary School. Land types excluded from this analysis were Rural Transition (RU6), Environmental Living (E4) and Local Centre (B6), Drainage, Existing Landfill and Environmental Conservation Land types. As previously noted, these land types were excluded from the UTC study as their conditions can be highly variable and canopy provision needs to be determined on a site-by-site basis.

From this analysis, an UTC boundary was established. This included all land types that UTC canopy targets could be applied to. An amended UTC boundary was established as illustrated in Figure 11.



WEST SCHOFIELDS:

West Schofields Boundary:	4932143m²
R2 low density area:	1014256m² / 21%
R3 medium density area:	70627m² / 1.4%
School area:	16776m² / 0.3%
Parks - local:	213456m² / 4%
Parks - sports field:	440299m² / 9%
Street area:	615274m² / 12%

West Schofields Boundary
Urban Tree Canopy Targets Boundary
Lot boundary

Figure 11: Urban Tree Canopy Targets boundary West Schofield Precinct.

CASE STUDY: METHOD

The draft ILP was provided as a pdf with a scale bar. This was exported to an image file and imported into AutoCAD as a JPEG. The scale bar was used to scale the drawing to 1:1. Key items were then verified in the file to confirm the scale was accurate. Areas were then determined for each land use zone. Specifically, these were:

- R2
- R3
- School
- Local parks, and
- Sports fields.

The measurements calculated for this case study do not align exactly with the areas as nominated in the West Schofields Discussion Paper 2018. For the purposes of this work, we have adopted our own measurements. This case study is a demonstration only, to illustrate how targets could be applied to a precinct plan and should not be used for the West Schofields site.

CALCULATING TREE CANOPY ON PUBLIC LAND

The primary public land categories – local parks, and parks with sports fields were measured to determine their site area. A 45% canopy target was applied to local parks without playing fields. A 30% canopy target was applied to public schools with sports fields.

To determine the area of parks with sports fields, we first measured park area and then the proportion of fields within the park area. We then calculated for each site the amount of park area excluding sports fields and courts. The sports area was then calculated as a percentage of total park area. Once this is determined, the appropriate target could then be applied to each park. These targets are described below as follows:

- Where playing fields/ courts comprise between 10% and up to 20% total site area, apply 45% canopy to remaining park area.
- Where playing fields/ courts comprise between 20% and up to 30% total site area, apply 50% canopy to remaining park area.
- Where playing fields/ courts comprise between 30% and up to 40% total site area, apply 55% canopy to remaining park area.

Street reserves were measured to determine the proportion of residential street area. Street areas suitable for canopy excluded intersections and were located at a 10 metre offset from each intersection. Refer to Figure 12 which illustrates the approach used for measuring street area for the precinct.

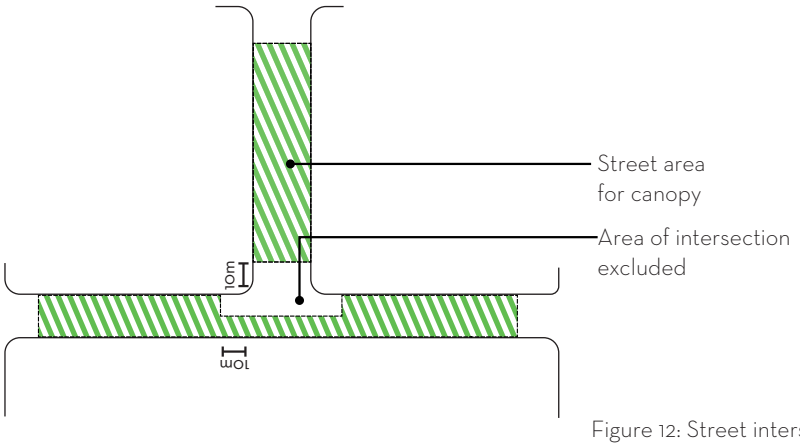


Figure 12: Street intersection exclusion area.

CALCULATING TREE CANOPY ON PRIVATE LAND

We then measured the area of developable land. This included the nominated R2 and R3 lands. R2 was proposed as land with a dwelling density of 15-20 dw/ha and 15-25 dw/ha. R3 land was proposed with a dwelling density of 25-35 dw/ha. The proposed residential zonings and their housing types was nominated in the West Schofields Exhibition Discussion Paper (p20) as follows;

R2 Low Density Residential – boarding houses, dual occupancies (attached or detached), dwelling houses (single), group homes, secondary dwellings, semi-detached dwellings, senior housing, shop-top housing and studio dwellings.

R3 Medium Density Residential – attached dwellings (contains three or more dwellings, eg townhouses), boarding houses, dual occupancies (attached or detached), dwelling houses (single), group homes, multi-dwelling housing (contains three or more dwellings attached or not attached), residential flat buildings (eg apartments), semi-detached dwellings (dwelling on its own lot of land and attached to one other dwelling), seniors housing, shop-top housing and studio dwellings.

As noted above there can be a range of private land types in each residential zone. For instance, R2 may have a combination of attached and detached dwellings of various lot sizes. Likewise, in R3 Land, the zoning allows for a range of residential building types including apartments, multi dwelling housing, and attached dwellings. Lots sizes can also vary substantially. Given this, a series of assumptions need to be made to estimate the development mix. For this example, we tested two alternate scenarios to estimate the dwelling types/lot dimensions (Table 44). It is worth noting the discussion paper included a height limitation plan and we were able to infer that in the R2 land, apartments would not be permissible.

Two scenarios were developed to explore possible built form outcomes (Table 44). Scenario 1 assumes that R2 land nominates a mix of 70% Detached dwellings on 300 – 600m2 lots) and 30% Attached Dwellings (on 150m2 – 300m2 lots). Scenario 1 assumed that R3 land would contain 70% apartments (on lots 1500 and 3000m2) and 30% Attached dwellings (on 150m2 – 300m2 lots). The assumption for apartments aligned with the West Schofields draft height map which had 12m for R3 Land. Scenario 2 assumed all R2 land would be detached dwellings (on 300 – 600m2 lots). R3 land 40% was assumed to be smaller apartments (650 – 1500m2), 20% multi dwelling (1000 – 3000m2) and 40% attached dwellings (less than 300m2).

Table 44: Two alternate scenarios to estimate the dwelling types for R2 and R3 land.

Landuse Zone	Proportion of UTC type within landuse zone % site area	UTC type area (m2)	UTC Lot category	Tree Canopy Target % site target	Area of projected canopy (m2)
Option 1					
R2 Low Density Residential	70% Detached dwellings	709979	300-600m2	25%	177495
	30% Attached dwellings	304279	150-300m2	20%	60855
R3 Medium Density Residential	70% Apartments	49439	1500m2-3000m2	25%	12360
	30% Attached dwellings	21188	150m2-300m2	20%	4238
Option 1: Estimated Canopy					254,948
Option 2					
R2 Low Density Residential	100% Detached dwellings	1014256	300m2-600m2	25%	253564
R3 Medium Density Residential	40% Apartments	28251	650-1500m2	20%	5650
	20% Multi dwellings	14125	1000m2-3000m2	25%	3531
	40% Attached dwellings	28251	>300m2	25%	7063
Option 2: Estimated Canopy					269,808

These assumptions were cross checked against the minimum lot sizes listed in the Blacktown City Council Growth Centres DCP which has a 300sqm minimum lot size for detached dwellings. However, there are design pathways that provide for a reduction in the minimum lot size to 250sqm. The minimum lot sizes for R3 land controlled by the Blacktown City Council Growth Centres DCP are between 1000sqm (for 35 dw/ha) and 2000 sqm (for 25 dw/ha).

CASE STUDY: RESULTS

We then applied the two scenarios to the overall calculations (Tables 45 and 46). The two scenarios indicated that a 33-34% canopy target was achievable within the UTC target boundary.

RESULTS AND DISCUSSION

This case study demonstrated an approach to using targets in a new precinct. The selected precinct had a relatively developed structure, with a layout for streets, public parks and sports fields. The land use zoning included a dwelling density and height controls had been nominated. This gave some indication of the type of development that could occur in this location.

The most substantial variable was the dwelling type and lot size. As demonstrated some assumptions had to be made to determine a realistic development mix. It is notable that this case study was a low-density residential precinct, with large areas dedicated to public parks, drainage zones and creek corridors. It is likely that applying targets for Rural Transition (RU6), Environmental Living (E4) Drainage, Existing Landfill and Environmental Conservation Land types would alter this target.

Table 45. Scenario 1 case study canopy targets.

Land use	Area (m2)	Canopy target	Area of canopy (m2)
School	16776	35%	5,872
Local Parks	213456	45%	96,055
Parks with Sports Fields	440,299	Sliding scale	206,164
Sporting Fields	285,999	0%	0
R2	1,014,256	Scenario 1	238,350
R3	70,267	Scenario 1	16,597
Streets	536060	70%	375,242
Precinct Area Totals	2,776,726	33.7%	938,280

Table 46: Scenario 2 case study canopy targets.

Land use	Area (m2)	Canopy target	Area of canopy (m2)
School	16776	35%	5,872
Local Parks	213456	45%	96,055
Parks with Sporting Fields	440,299	Sliding scale	206,164
Sporting Fields	285,999	0%	0
R2	1,014,256	Scenario 2	253,564
R3	70,267	Scenario 2	16,244
Streets	536060	70%	375,242
Precinct Area Totals	2,776,726	34.3%	953,141

Canopy targets for precincts can be set as an aspirational longer-term canopy target. For example, an aspirational target of 45% canopy may be adopted for the West Schofields precinct. The baseline target (33%-34%) assumes a minimum conservative and realistic target, comparable to business-as-usual. To achieve the aspirational target, alternative strategies could be adopted to increase tree canopy. This may for example provide minimum canopy targets for other lands in the precinct (such as Rural Transition, Environmental Living and Drainage lands). Alternatively, a higher target may be incorporated for new streets based on a wider street verge. The stage 4 testing found that 75% canopy was viable with slight modification to the street tree layout.

It is noted that this case study did not include an in-depth analysis of retention of existing trees. This should be a guiding principle for precinct planning and the UTC indicative targets should build upon and protect existing tree canopy.

OUTLINE CANOPY TARGETS

Part of the scope of this study was to provide outline urban tree canopy targets that could be applied to precincts at the very early stage of planning. This outline target could be used at a stage in the planning of a precinct where there are broad locations for land-uses but no detailed resolution on street layout, block layout, development densities or building configurations.

The intent is that these targets be used to set a baseline minimum urban tree canopy target that can be achieved for a particular land use. This baseline minimum can be achieved in all circumstances and should be increased according to the opportunities and characteristics of each. These targets could then be refined during the development of the master plan based on existing site characteristics (such as existing tree canopy, soils and climate) and desired future character.

Outline Canopy Targets have been developed for three land types that are often defined at precinct planning phase. These are;

1. residential
2. industrial
3. business development.

This assumes that land is dedicated to public streets as well as private land for development. This proportion varies depending on the land type. The following text describes how we have addressed this assumption for each land type.

We have assumed that these nominated land areas would not include recreational lands such as parks and environmental lands including nature reserves or creek corridors. Parks have been excluded as their size and number can be highly variable, based on the projected population. Outline targets have not been developed for mixed use zones or town centres. Mixed use development types have also not been analysed as part of this project. As these conditions are highly variable, detailed design is required to develop site specific tree canopy targets.

OUTLINE TARGET FOR RESIDENTIAL LANDS

Residential refers to areas designated for residential development zones. This includes residential private land and residential public land (streets). Residential private land refers to all residential development types including detached, attached, multi-dwelling and apartments.

Firstly, we nominated the proportion of public residential land (streets) and private residential land (for housing). We assumed a 30% allowance for public residential land (streets) and 70% for private residential land. This was based on analysis of 3 residential precincts described in Chapter 4: Results and Recommendations (Figures 5 - 7) which found that residential streets comprised 30% - 34% of total residential land area.

To establish the target canopy for residential streets we then reviewed our previous testing (described in Chapter 4). This testing found that new streets could provide between 70% and 83% tree canopy target. We then adopted an outline target of 75% canopy for streets.

To determine the target for residential private land, we collated detailed tree canopy targets for specific residential types - detached dwellings, attached dwellings, multi dwelling housing and apartments (15% - 35% as described in Chapter 4). We then identified development lots that would be are rare and less likely to comprise large proportions of residential land in new precincts. These were identified as lots less that 150m2 for attached dwellings (15% canopy) and lots less than 650m2 (15% canopy) or greater than 3000m2 (35% canopy) for apartments. This provided a canopy target range of between 20 – 30%. We then adopted the midpoint of 25% tree canopy for residential private land.

Once private residential land target (25%) and public land target for streets (75%) were nominated, and their proportion assumed (70% private/30% public), this established the outline precinct target of 40% tree canopy for residential land (Figure 13).

OUTLINE TARGET FOR INDUSTRIAL LANDS

Industrial land refers to industrial private land and public industrial land for streets. For industrial public land, we adopted a proportion of 80% private land to 20% public land for streets. This proportion was based on our analysis of existing precincts and additional design research for industrial precincts we undertook for Infrastructure NSW in 2020. This design research found that wider street verges and additional streets could provide efficiency in traffic circulation and servicing and improve canopy provision for cooling.

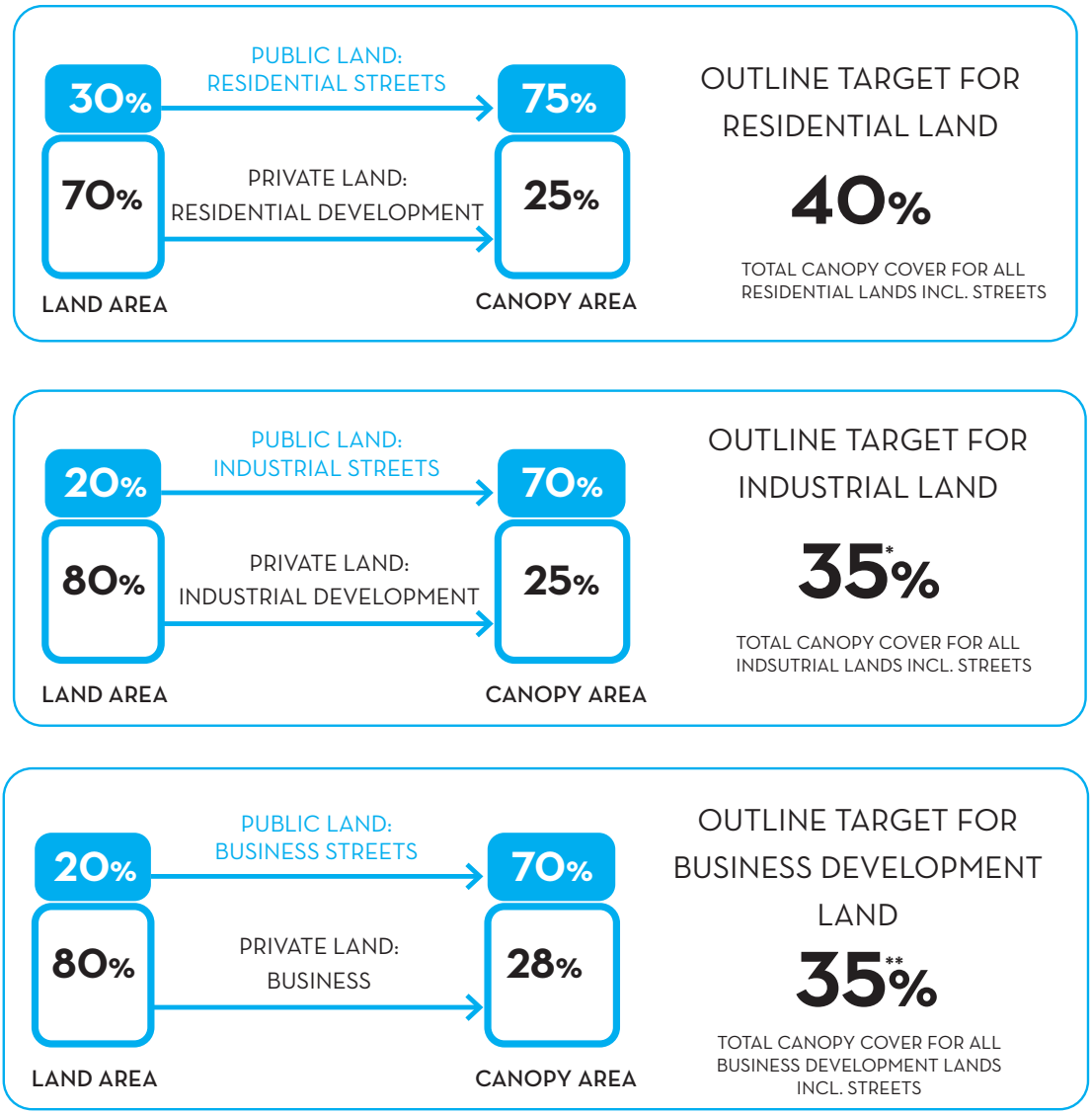
A target of 70% canopy has been adopted for industrial streets. This target would require designs to incorporate larger street trees (12m at maturity) planted more closely together in wider verges. A target of 25% canopy was adopted for private industrial land. This aligns with detailed testing for industrial lands as described in Chapter 4.

Once the private industrial land canopy target (25%) and public land target for streets (70%) were nominated, and their proportion assumed (80% private/20% public), this provided an indicative 34% numeric target. An outline precinct target of for industrial land which has been rounded up to 35% for clarity (Figure 13).

OUTLINE TARGET FOR BUSINESS DEVELOPMENT LANDS

Business development refers to areas with business parks, light industrial, and bulky goods developments. This excludes mixed use zones, town and commercial centres. This mix generally aligns with land uses found in SILEP B5 Business development, B6 Enterprise corridor, B7 Business park.

Business development lands are like industrial lands in that they provide fewer streets and large private lots. A proportion of 20% land area for new business streets and 80% land area for private business development land was assumed, based on testing and design review as described above. A target of 70% canopy is nominated for future business streets.



* This numeric target of 34% for industrial land has been rounded up for clarity.
** This numeric target of 36% for business development has been rounded down for clarity.

Figure 13: Outline canopy targets for residential, industrial and business development.

For private business land we included an equal portion for each type - business parks, industrial and bulky goods. Detailed tree canopy targets were then applied for each type in accordance with recommendations in Chapter 4 (25% for industrial, 25%for bulky goods and 35% for business parks). This provided an overall canopy target of 28%.

Once the private business development canopy target (28%) and public land target for streets (70%) were nominated, and their proportion assumed (80% private/20% public), this provided an outline precinct target of 36%, which has been simplified to 35% tree canopy for business development land (Figure 13).

ON GRADE CAR PARKS

It is noted that this business development target does not include targets for on grade car parking. Our testing found that bulky goods sites and business parks can often contain large areas dedicated to on grade car parking. Our testing found that adopting tree provision rates as recommended (one medium tree in every 5th parking space) could increase tree canopy by 10% or more for bulky goods sites / business parks (refer to Chapter 4: Private Land Testing: bulky goods car parks). It is recommended that outline precinct planning targets acknowledge that car park tree canopy would increase the outline canopy target for business development lands.

APPROACH TO DETERMINING CANOPY TARGETS FOR NEW PRECINCTS

The following provides some guidance on developing a canopy target for new precincts. This is not a detailed exploration but is intended as an outline only.

Developing a precinct target is intertwined with the master planning process. This master planning process considers a multitude of factors, including bushland, drainage, topography and climate as well as development factors including transport infrastructure and access. Tree canopy is an important existing feature but is also a component that can be conceived of and designed into a future master plan. Precinct canopy targets may also be incorporated to address a long-term issue. For example, it may be desirable to set a high canopy target across a precinct due to its local climate and vulnerability to increased urban heat. This canopy target may in turn shape the urban design and land use strategies.

STEP ONE: ESTABLISH THE UTC PRECINCT BOUNDARY

Establishing an appropriate boundary is the first step in developing a target. The boundary should define developable urban land. The boundary should exclude environmental land uses such as environmental conservation zones, ecological or bushland corridors. Any infrastructure corridors including electricity transmission corridors, arterial and collector roads and drainage easements should be plotted and excluded. The boundary should also exclude large reserves of public lands such as district parks greater than 5 hectares. The scope should be clearly defined on maps and quantifiable.

STEP 2: IDENTIFY EXISTING TREE CANOPY

Once the boundary has been established, the existing tree canopy should be calculated within the UTC zone. Existing canopy can be measured using recent detailed site surveys or from tree canopy data sets developed by DPIE. This existing canopy should establish a baseline, and any development approach should retain or improve on the existing tree canopy on the site. Retention of existing trees should be a guiding principle for precinct planning and the UTC indicative targets should build upon this existing tree canopy.

This canopy analysis may also inform the master plan. For example, existing tree canopy could inform the location for new parks or reserves. It is preferable to design the public domain to retain and protect existing canopy. Where private development is proposed, a process of detailed mapping of trees can inform master plan schemes and specific controls.

STEP 3: LAND USE ANALYSIS/ MAPPING

If a master plan with land uses has already been developed, the next step would involve identifying the land use categories and measuring the proportion of this land use within the UTC boundary. Once this has been measured, the zoning should be reviewed to determine the development types that could occur in each zone. Using a similar method to the case study, a range of predicted scenarios could be tested using a mix of various development types (i.e. detached dwellings, attached dwelling, multi dwelling, industrial, business parks, bulky goods). On residential land uses, lot areas should also be estimated. Once a range of scenarios have been tested this could then be averaged to develop a minimum canopy target.

If the precinct is still in the early stages of master planning, an iterative approach could be taken to developing tree canopy targets. This may employ an approach of canopy analysis, developing master plan layouts with a development mix, then testing a canopy target based on each land use mix. Outline targets could be adopted as previously described (residential lands: 40%, industrial lands and business development lands: 35%) as a starting point and refined during master planning process.

The work detailed in the previous chapters provides the baseline targets that assumes a minimum conservative and realistic target. These targets are comparable to existing development types. It is clear from this analysis that some land uses have higher capacity for canopy than others. Industrial types for example generally have lower capacity than business parks. Larger lots for detached dwellings are generally more flexible in providing tree canopy than smaller lots. Alternatively, lots with attached dwellings provide more consolidated landscape space for tree canopy.

It is important to recognise these baseline targets can be increased through the master planning process. For example, on proposed industrial lands, designing more streets with wider reserves can increase canopy on public land. Likewise in town centres or dense neighbourhoods, more public parks will also increase neighbourhood tree canopy.

STEP 4: CALCULATE THE PROPORTION OF STREETS WITHIN EACH LAND USE

Streets are critical public spaces for delivering tree canopy. Where street layouts have been designed the street reserve area (excluding intersections) should be measured. Once all street reserve areas have been measured the canopy target should be applied.

If no street layout has been determined, then the assumed proportion of streets should be estimated. This process is described in previous text on outline targets. Generally, masterplans that dedicate more area to public streets can achieve higher tree canopy targets. Streetscape designs should ensure that designs incorporate wide verges and consolidated underground services to maximise space for street trees.

STEP 5: CALCULATE THE AREA OF LOCAL PARKS

In an established plan, parks and sports fields will already be nominated. Parks without sports fields or courts can be estimated using the blanket target of 45% canopy. Parks with sports fields should be estimated by first measuring the park area, then measuring the proportion of sports fields and courts. Once this is established the appropriate target should be adopted. If the parks are yet to be incorporated into the master plan, areas required for parks are often defined by projected precinct population and a site specific open space strategy.

STEP 6: SITE SPECIFIC TARGETS FOR LOCAL/TOWN CENTRES

Town centres are highly walkable with mixed uses, zero limited setbacks and wide streets. They can have plazas or squares in or near to the centre. Town centres often have transport infrastructure such as train stations or light rail stops. They also may have a finer grain street network and a high proportion of public open space that can provide space for trees. A ‘rule of thumb' for these contexts is hard to determine as they can be so variable. It is recommended that an aspirational canopy target be established for these areas. This may be higher (greater than 40% canopy) to enhance urban cooling in a high pedestrian area. This could then be tested and refined within a place-based master plan.

STEP 7: CALCULATE AN OVERALL TREE CANOPY TARGET

Once these components have been established, an overall canopy target can be determined. This combines all estimated canopy area for public and private land uses as a percentage of the overall UTC precinct boundary.

6.0 RECOMMENDED CONTROLS

Tree canopy provision is a priority for in NSW. Tree canopy in deep soil is critical to delivering positive environmental and social outcomes. The goal of the NSW Government is to increase in urban tree canopy cover to 40% by 2056. In order to achieve this, all development sites need to contribute to urban tree canopy.

The following describes recommendations for urban tree canopy targets. Tables 47 - 49 provide a summary of all targets, deep soil controls and tree replenishment controls for private land.

LEP STANDARDS AND DCP CONTROLS

DEEP SOIL

Deep soil is critical to deliver effective urban tree canopy. Deep soil provides capacity for healthy tree growth for larger trees, one of the most valuable urban environmental assets. Larger trees provide greater environmental benefits through shading and microclimatic benefits than small trees.

Healthy tree canopy is inextricably linked to deep soil provision and without viable deep soil, tree canopy targets cannot be delivered. It is recommended that a definition for deep soil be included as a subset of the SILEP. 'Deep soil' is not currently defined by SILEP and it can be included as as a subset of 'landscaped area' . Deep soil will reflect the same aspects of 'landscaped area' does, however it will require some critical factors including a minimum dimension for tree planting and be unimpeded above and below ground. This definition should explicitly describe what is allowed in these zones. The following definition is proposed.

Deep Soil Definition: Deep soil is a landscaped area connected horizontally to the soil system and local ground water system beyond and is unimpeded by any building or structure above or below ground with the exception of minor structures. Deep soil zones with a minimum dimension of 3m allow sufficient space for the planting and healthy growth of new trees that provide canopy cover and assist with urban cooling and infiltration of rainwater to the water table. Deep soil also allows for the retention of existing trees.

Minor structures: For the purpose of calculating deep soil, the following may be included in the deep soil area where they have at least 1.2m clear width of deep soil to either side:

(a) a path, access ramp or area of paving with a maximum width up to 1.2m.

(b) essential services infrastructure (such as stormwater pipes) with a maximum diameter up to 300mm.

(c) landscape structures (such as lightweight fences, light poles or seating) requiring a footing with a maximum size of up to 300mm x 300mm in cross section.

The recommended deep soil percentage targets establish a minimum deep soil control able to be applied in almost all circumstances. They should not override higher local controls. Local deep soil controls reflect variations in character and local context. In some localities deep soil targets have been established for specific reasons, such as addressing urban heat and reflecting the local ecological characteristics. The exhibited EIE for the Design and Place SEPP (pA28) currently identifies deep soil zones as a proposed Clause 30 non-discretionary standard. This should be removed. Deep soil is not currently a SEPP 65 Clause 6A matter or Clause 30 standard. Making it a Design and Place SEPP Clause 30 standard will effectively 'overwrite' local DCP deep soil provisions. This would have negative consequences for local environmental character and should not occur.

PRIVATE LAND

Table 47: Recommendations: tree canopy controls for residential types.

Recommended Guidance	Tree Canopy Target % site area	Deep Soil % site area	Tree Replenishment Requirements
Detached dwellings			
less than 300m2	20% site area	20% site area. Minimum 3m dimension.	For every 200m2 of site area, or part thereof at least one tree of small size is to be planted in the deep soil area.
300m2 - 600m2	25% site area	25% site area. Minimum 3m dimension.	For every 250m2 of site area, or part thereof at least one medium tree is to be planted in the deep soil area.
Greater than 600m2	30% Site area	30% site area. Minimum 3m dimension.	For every 350m2 of site area, or part thereof at least two medium trees or one large tree is to be planted in the deep soil area.
Attached dwellings			
Less than 150m2	15% site area	15% site area. Minimum 3m dimension.	At least one tree of small size is to be planted in the deep soil area.
150m2 - 300m2	20% site area	20% site area. Minimum 3m dimension.	For every 200m2 of site area, or part thereof at least one small tree is to be planted in the deep soil area.
> 300m2	25% Site area	25% site area. Minimum 3m dimension.	For every 225m2 of site area, or part thereof at least one medium tree is to be planted in the deep soil area.
Multi dwelling housing			
Less than 1000m2	20% site area	20% site area. Minimum 3m dimension.	For every 300m2 of site area, or part thereof at least one medium tree is to be planted in the deep soil area.
1000 - 3000m2	25% site area	25% site area. Minimum 3m dimension.	For every 200m2 of site area, or part thereof at least one medium tree is to be planted in the deep soil area.
> 3000m2	30% Site area	30% site area. Minimum 3m dimension.	For every 350 m2 of site area, or part thereof at least two medium trees or one large tree is to be planted in the deep soil area.
Apartments			
Less than 650m2	15% site area	10% site area. Minimum 3m dimension.	For every 350m2 of site area, or part thereof at least one small tree is to be planted in the deep soil area.
650 - 1500m2	20% site area	15% site area. Minimum 3m dimension.	For every 275m2 of site area, or part thereof at least one medium tree is to be planted in the deep soil area.
1500m2-3000m2	25% site area	20% site area. Minimum 3m dimension with a wider contiguous portion that is a minimum 6m wide and at least 25% of the minimum deep soil area.	For every 450m2 of site area, or part thereof at least two medium tree or one large tree is to be planted in the deep soil area.
> 3000m2	35% Site area	30% site area. Minimum 3m dimension with a wider contiguous portion that is a minimum 6m wide and at least 25% of the minimum deep soil area.	For every 300 m2 of site area, or part thereof at least two medium trees or one large tree is to be planted in the deep soil area.

Table 48: Recommendations: tree canopy controls for business parks, industrial and bulky goods.

Recommended Guidance	Tree Canopy Target % site area	Deep Soil % site area	Tree Replenishment Requirements
Business parks			
All lots	35% site area	25% site area. Minimum 3m dimension.	For every 300m2 of site area, at least two medium trees or one large tree is to be planted in the deep soil area.
On grade car parking – requirement for more than 4 on grade car parking spaces	1 x medium tree should be planted in every fifth car parking space provided. Tree to be located in a deep soil planted zone of 13m2, the equivalent of parking bay area. Trees should be evenly distributed, ideally in a checkerboard fashion, to increase shading. Car park trees are to be provided in addition to the site tree canopy target.		
Industrial sites			
All lots	25% site area	15% site area. Minimum 3m dimension. A wider contiguous portion that is a minimum 6m wide and at least 50% of the minimum deep soil area.	For every 400m2 of site area or part thereof, at least two medium trees or one large tree is to be planted in the deep soil area.
On grade car parking – requirement for more than 4 on grade car parking spaces	1 x medium tree should be planted in every fifth car parking space provided. Tree to be located in a deep soil planted zone of 13m2, the equivalent of parking bay area. Trees should be evenly distributed, ideally in a checkerboard fashion, to increase shading. Car park trees are to be provided in addition to the site tree canopy target.		
Bulky goods			
All lots	25% site area	15% site area. Minimum 3m dimension. A wider contiguous portion that is a minimum 6m wide and at least 50% of the minimum deep soil area.	For every 400m2 of site area or part thereof, at least two medium trees or one large tree is to be planted in the deep soil area.
On grade car parking – requirement for more than 4 on grade car parking spaces	1 x medium tree should be planted in every fifth car parking space provided. Tree to be located in a deep soil planted zone of 13m2, the equivalent of parking bay area. Trees should be evenly distributed, ideally in a checkerboard fashion, to increase shading. Car park trees are to be provided in addition to the site tree canopy target.		

Table 49: Tree Replenishment Categories and Minimum Size.

Tree Replenishment Categories	Diameter (m)
Small tree	min. 6
Medium tree	min. 8
Large tree	min. 12

TREE REPLENISHMENT

The achievement of a percentage canopy cover requires the planting of a certain number of trees of a certain canopy size relative to site area. A certain area and dimension of deep soil is required to sustain these tree's health and growth.

A tree replenishment rate is the number of trees required to be planted in deep soil. A replenishment tree rate minimises confusion and allows applicants and assessors to check compliance. Canopy targets have been employed as a tool to determine the 'best fit' tree replenishment within each site area bracket but are not intended as a control. Tree canopy area targets are harder to estimate and make it difficult for authorities and applicants to confirm compliance. It is anticipated that this replenishment rate should occur in tandem with suitably revised deep soil percentage controls and the revised deep soil definition.

Tables 47 and 48 list the recommend controls for tree canopy across a range of development types. To achieve this canopy cover target, the following deep soil and tree replenishment control is proposed. This could be adapted into council DCP and LEP controls. The standard structure of the control needs to allow for a range of site areas. The control is structured as follows;

For sites greater than XXm2, the minimum area of deep soil is to be XX%. For every XX m2 of site area (or part thereof), at least X tree of X size (or larger) is to be planted and maintained in the deep soil area.

This structure links the site area, deep soil and tree replenishment in a single control. This ensures that trees will be provided alongside the space and capacity to deliver these trees. This example and the inclusion of part thereof ensures that all conditions are covered and avoids confusion regarding delivery on sites that are outside or less than the range of area brackets. The control also stipulates the size of the tree to be planted. Tree sizes are prescribed in Table 49.

In some instances, the guidance also includes flexibility in the delivery of medium or large trees on larger lots. This can include guidance that states for example that "at least two medium trees or one large tree is to be planted in the deep soil area". This ensures that there is some design adaptability in the planting layout, as well as encouraging the planting of large trees, which have substantial ecological and micro climatic benefits.

CAR PARKING

On site car parking is a common feature of many types of development across NSW. Large expanses of car park are frequently provided in business parks, bulky goods and industrial sites . Tree canopy is crucial in these landscapes to address the critical issue of urban heat, which is projected to increase in the coming decades. Established tree canopy on site car parks will be fundamental to maintaining the function of these businesses, by providing direct shade, improving local microclimates and protecting human health.

It is recommended that tree planting rate be adopted for onsite parking for non residential land uses as follows:

1 x medium tree should be planted in every fifth car parking space provided. Tree to be located in a deep soil planted zone of 13m2, the equivalent of parking bay area. Trees should be evenly distributed, ideally in a checkerboard fashion, to increase shading. Car park trees are to be provided in addition to the site tree canopy target.

This adjustment recognises that if there is space for car parking on site there should also be space for tree planting. This control will apply to all industrial, bulky goods and business parks, where on grade car parking is desirable.

PUBLIC LAND

Establishing healthy and viable tree canopy in the public domain is crucial to the development of healthy urban areas. The testing demonstrated the capacity for public land to deliver increased tree canopy. This guidance can help to inform ongoing design and management of local parks and streets. This guidance is collated in Tables 50 and 51. Public tree canopy cannot be relied on as the primary mechanism to deliver urban tree canopy. Public domain tree canopy targets should be adopted alongside minimum requirements for tree canopy on private land.

PUBLIC LAND

Table 50: Recommendations for tree canopy targets: existing and new streets.

Existing Residential Streets	Overhead power lines	Underground power
12-20 metre reserve*	40% canopy cover	50% Canopy cover
Existing Industrial Streets	**Overhead power lines**	**Underground power**
20-25 metre reserve*	35% Canopy cover	45% Canopy cover
New Residential Streets		
12-20 metre reserve* Underground Power	70% Canopy cover	
New Industrial Streets		
20-25 metre reserve* Underground Power	60% Canopy cover * Excludes intersections	

Table 51: Recommendations for tree canopy targets: local parks.

Local Parks	Target Park wide
All local parks up to 5 hectares where playing fields and courts comprise less than 10% of total site area.	Minimum 45% canopy cover
Local Parks with playing fields or courts	**Target for park area excluding courts/playing fields**
All local parks up to 5 hectares where playing fields and courts comprise between 10% and up to 20% total site area.	Minimum 45% Tree Canopy Cover
All local parks up to 5 hectares where playing fields and courts comprise between 20% and up to 30% total site area.	Minimum 50% Tree Canopy Cover
All local parks up to 5 hectares where playing fields and courts comprise over 30% total site area.	Minimum 55% Tree Canopy Cover

ADDITIONAL RECOMMENDATIONS TO IMPROVE TREE CANOPY OUTCOMES

The following provides additional recommendations to maximise tree canopy delivery on public and private land.

TREES ON PUBLIC LAND

- The standard LEP should represent streets as a standalone item, separate from land use zoning to assist in canopy estimation and delivery. The legal public status of streets is compromised by LEP drawings where the graphic representation of the zoning extends over streets.
- New streets offer a mechanism for increased tree canopy. It is critical that new streets are designed with an appropriate reserve width, preferably 20 metres wide to provide capacity for street tree planting, services and footpaths. This would also be designed for garbage truck access with minimal impacts on streetscape design. Ideally the verge proportion should be approximately 40% to 60% carriageway area. New street designs should exclude the use of rollback kerbs to protect tree plantings.
- All new streets should be delivered with new development incorporate street trees of minimum tree size of 8 metres diameter or greater. These should preferably be in spacings that achieve interconnected canopy and maximise shade (i.e. no further than 8 metre centres).
- For new streets an approach should be adopted that prioritises and values the delivery of effective tree canopy. Infrastructure and utilities policies should prioritise above ground and underground space for establishment and protection of effective urban tree canopy. All new streets should be designed to maximise soil volume. Services should be consolidated into a shared services trench and all new streets should be designed with underground power lines.
- Review of the impact on street trees by Energy providers. This should be investigated to avoid over pruning and minimise impact on new tree planting. An approach that allows local councils to manage their street trees under power lines, as adopted inVictoria, can improve street tree canopy and maintain and protect these assets.

TREES ON PRIVATE LAND

- Encourage local councils to develop LGA wide Tree Guidance that categories species by minimum canopy width as defined in this guidance (Small, Medium and Large). This schedule can be provided as guidance to assist in delivery of compliant tree replenishment.
- Ensure that controls promote deep soil being located where there is most capacity for viable connected soil networks – specifically on front, rear and side setbacks, which connect between the public and private domain. This extended collocated deep soil, in front and rear setbacks adjacent to street reserves and rear landscapes on adjacent sites facilitates neighbourhood wide canopy and soil networks.
- Encourage councils to amend their local planning controls to include strengthened requirements to reduce tree removal, particularly for juvenile trees. This should enshrine protection of all new tree planting and minimise tree removal of juvenile tree stock.
- Investigate planning controls that allow for tree removal on private land without approval. It is preferable that all proposals for tree removal are assessed through a DA application process. Tree removal only through development application still allows for tree removal where reasonable and required (due to building damage etc.) but provides a proper level of scrutiny in assessment commensurate with 'recognising' the tree as an essential element of the building development application.
- DPIE should provide further advice on priority tree planting locations on non-residential sites. This should prioritise tree planting to maximise shade to buildings and pavements to reduce urban heat.

A guide with precedents and examples could be developed to assist in delivering optimum tree canopy outcomes in these locations and assist councils in developing appropriate controls in these land uses.

- In locations where there is concern about bush fire, provide guidance on tree management in urban areas to reduce risk. This can be removal of leaf litter at ground level.
- Provide fact sheets/guidance on locating trees near houses with solar panels.
- Provide fact sheets on managing trees during heatwaves/drought periods.
- A requirement for all trees removed and planted during development to be registered on the NSW Planning Portal with spatial data, for future monitoring.

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