Street Tree Planting Design Manual

NSW Department of Planning, Industry and Environment

September 2021

NSW GOVERNMENT

Acknowledgement of Country

NSW Department of Planning, Industry and Environment acknowledges the Traditional Custodians of the land and pays respect to all Elders past, present and future.

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Title: Street tree planting design manual

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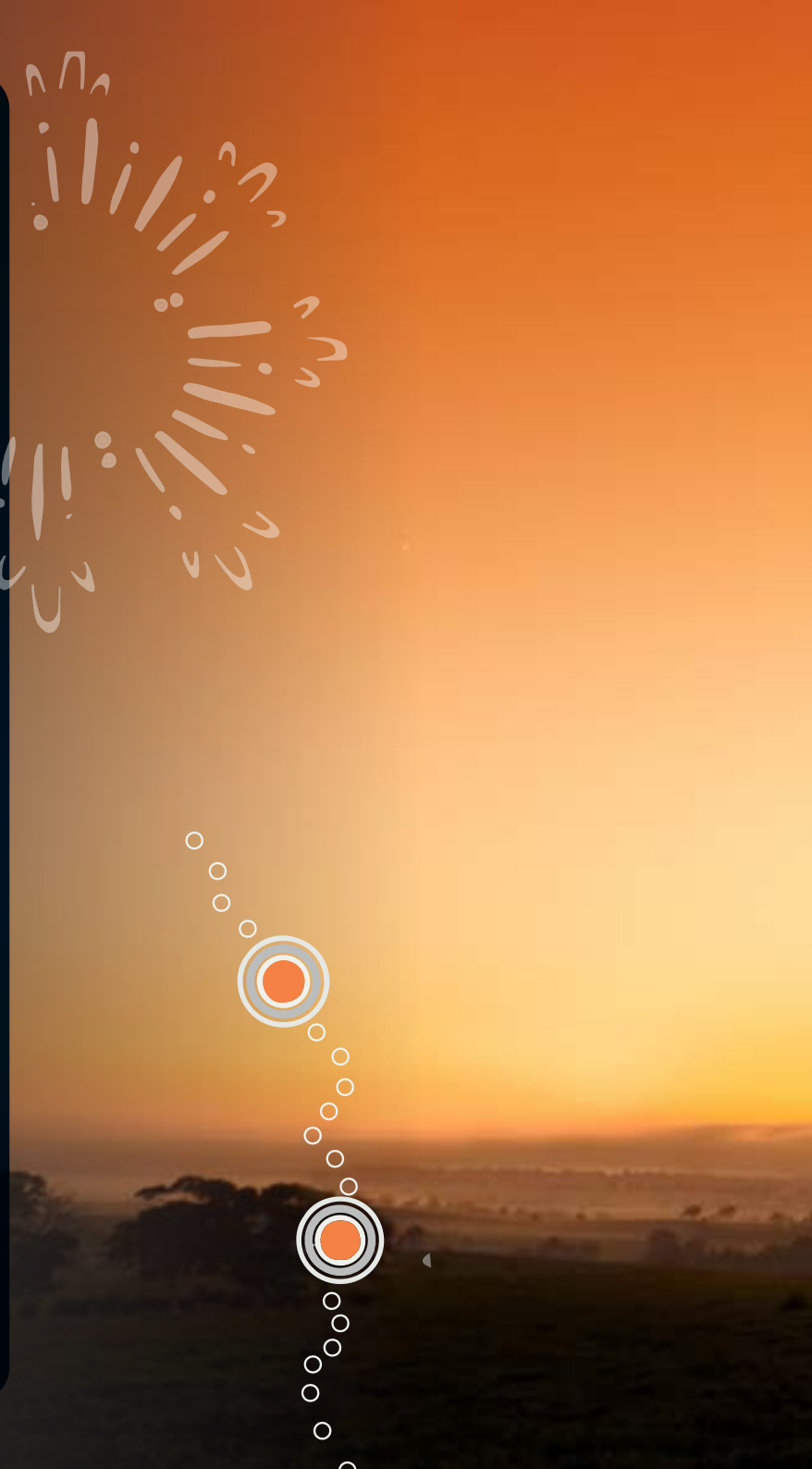
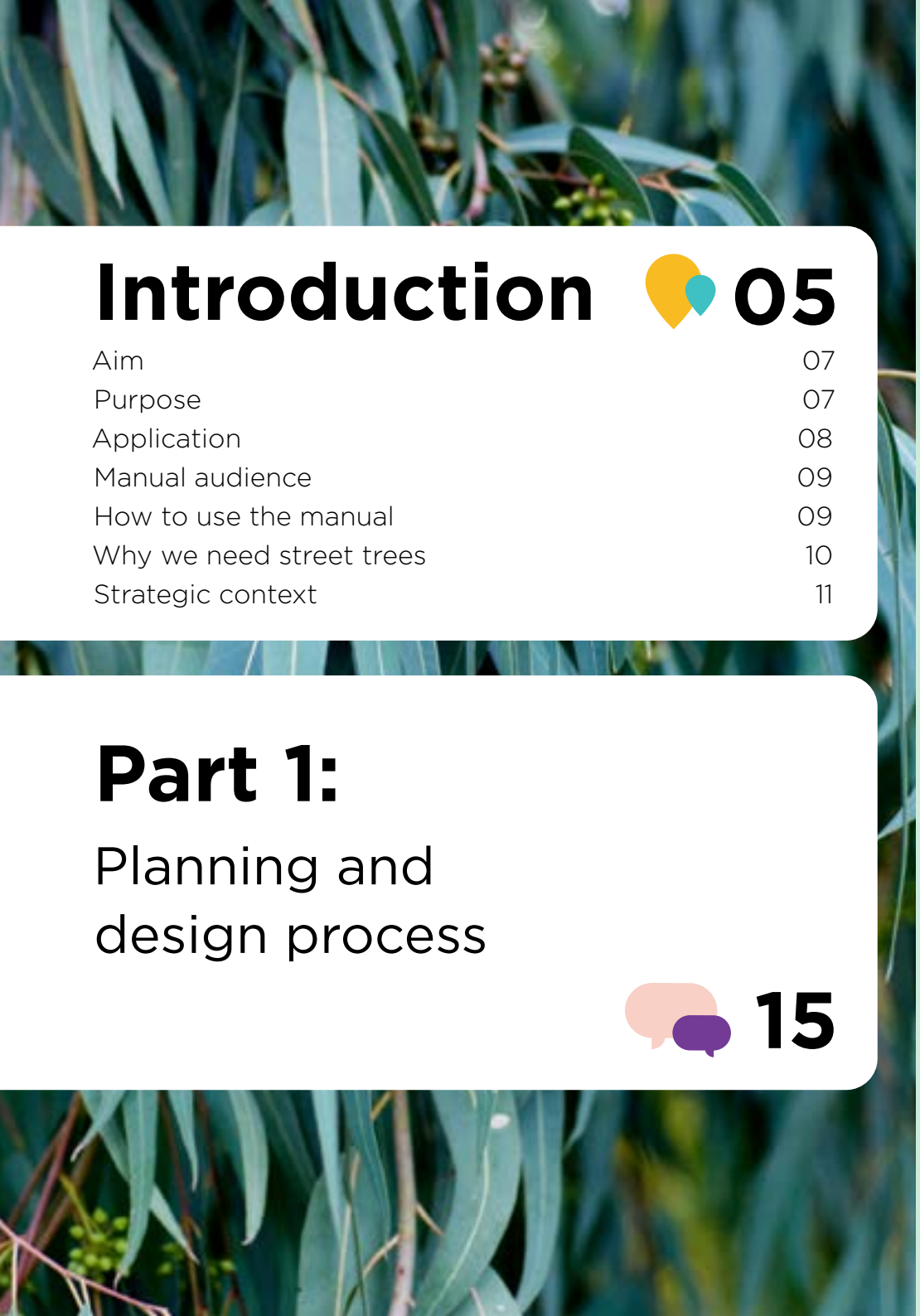
Illustration: Credit Nikita Ridgeway





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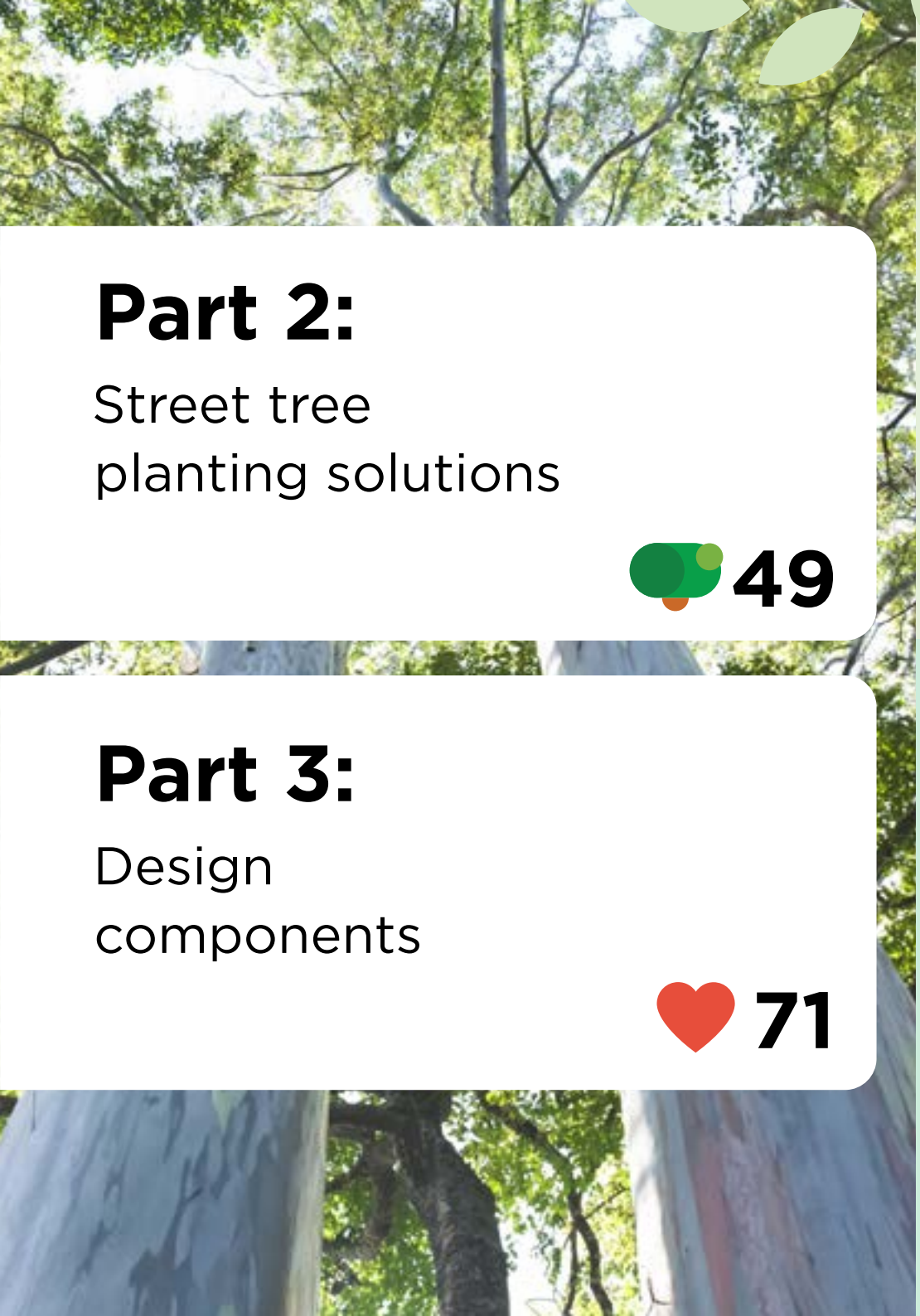

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Introduction

Introduction

Aim

This manual outlines the planning, placement and integration of healthier trees in residential streetscapes. This aims to help achieve the NSW Government's target of 40% canopy cover across Greater Sydney and supports the delivery of two NSW Premier Priorities:

Greening our city – Increase the tree canopy and green cover across Greater Sydney by planting 1 million trees by 2022.

Greener public spaces – Increase the proportion of homes in urban areas within 10 minutes' walk of quality green, open and public space by 10 per cent by 2023.

This manual provides a planning and design process of planting trees in residential streets and outlines how to:

- identify and prioritise streets that will benefit most from the presence of trees and increased tree canopy cover
- identify typical streetscapes and provide example tree planting solutions
- provide a best-practice catalogue of design innovations for reference in creating site-specific solutions.

Purpose

Trees have always been an important component of the streetscape; however, they are needed now more than ever. Increasing tree canopy cover is a major priority for climate change adaptation in urban areas as trees are an effective provider of shade and cooling and contribute to improved stormwater management and general amenity.

The purpose of this report is to assist in increasing tree canopy across the metropolitan region to cool Greater Sydney as it becomes hotter and drier.

Increasing the canopy cover towards 40% cannot be achieved in streets alone. Effort is required across a range of public and private land uses and is a shared responsibility across government and community stakeholders, requiring a collaborative response.

This manual provokes and challenges our current thinking on streetscapes to highlight trees as an integral part of all streets. Traditional street design has often not supported healthy tree growth. This makes it difficult to retrofit streets to integrate healthy trees that will deliver many benefits over a long life. A reprioritisation of space is required for trees, amongst what is often a crowded ground-level, underground, and overhead environment, with many competing elements.

This manual's purpose is to help overcome these challenges with comprehensive street tree solutions.

Application

This manual uses Rosemeadow as a focus area for the planning, placement and integration of street trees. This manual becomes a reference methodology and provides typical solutions that are applicable across other areas of Greater Sydney.

The manual addresses street typologies found in Rosemeadow, ranging from local to neighbourhood residential streets, which are typically managed by Campbelltown City Council.

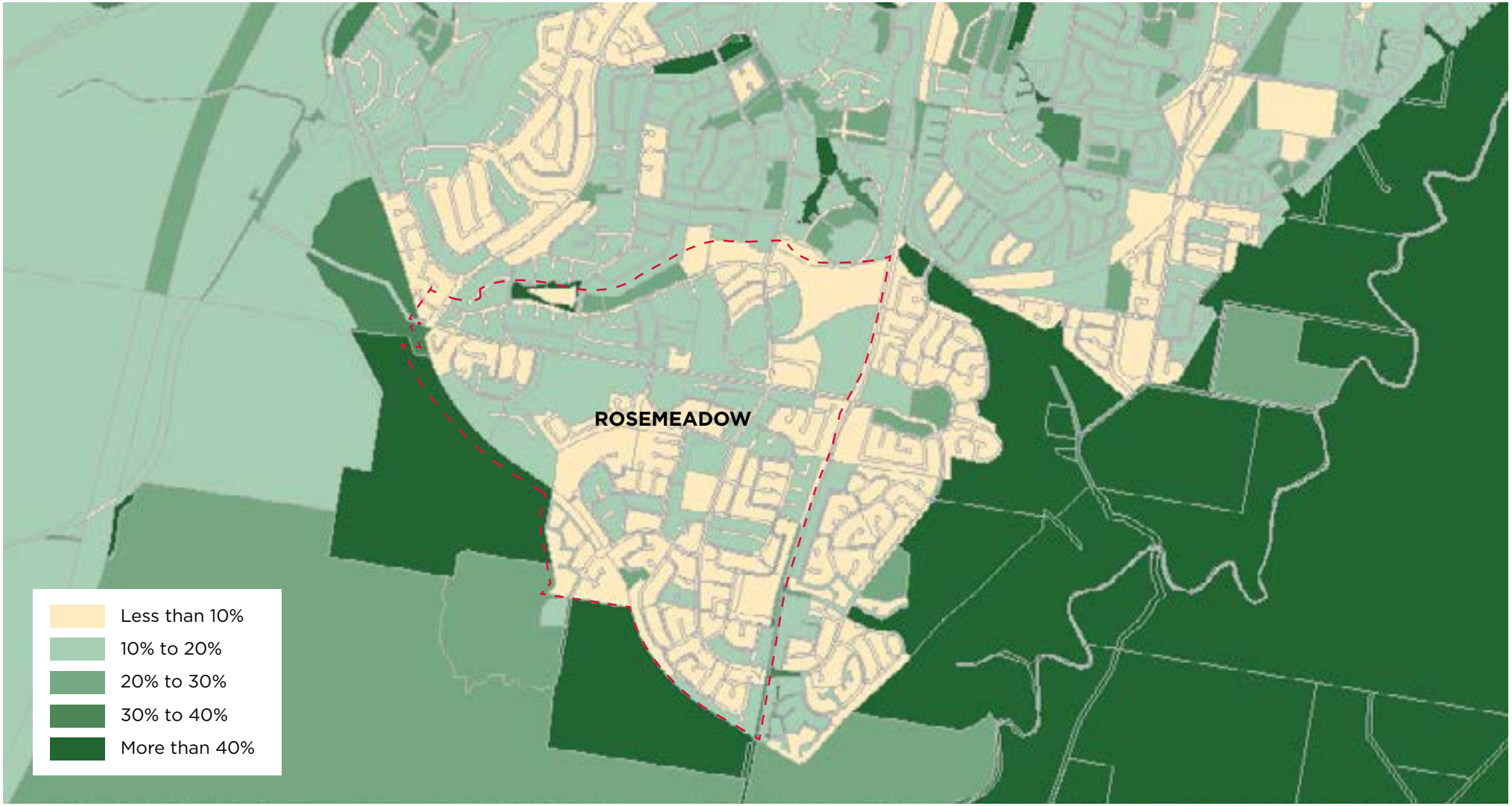


Figure 1: Tree canopy cover – The Greater Sydney Region Urban Vegetation Cover to Modified Mesh Block 2016. *Source: www.datasets.seed.nsw.gov.au/*

Manual audience

The successful integration of trees requires input from multiple professions and stakeholders, including:

- planners involved in green infrastructure, climate adaptation and development
- urban designers/landscape architects involved in the enhancement of public spaces
- civil and road engineers involved in road improvement works, including road and pavement renewals, traffic calming initiatives and kerb and channel upgrades
- drainage engineers involved in improving street drainage or stormwater management
- arborists involved in enhancing, replacing or introducing street trees
- maintenance and operations staff involved in identifying improvements of streets
- community members.

How to use the manual

This manual is structured to assist in the strategic planning and the implementation of street tree planting. A step-by-step guide is provided to assist through the varying stages:

Part 1: Planning and design process

Identifies and prioritises streets that require tree planting and outlines key design principles and site features to be considered when developing design solutions.

Part 2: Design solutions

Identifies typical street typologies and possible design solutions, illustrating the application of the key design principles and site considerations.

Part 3: Design elements

Recognising that solutions are often unique, a catalogue of design elements are proposed for designers to create bespoke design solutions that respond to localised site conditions.

Why we need street trees

Rosemeadow developed during the 20th century as land was subdivided to form residential housing estates. During this period, there was no consideration for tree planting in streets.

Streets are important public spaces that are used every day for people to gather, walk, cycle, access public transport or drive. Trees have always been an important part of streetscapes and are essential to sustainable and resilient urban street life, serving to:

- connect us with nature in built-up areas
- sustain cool urban temperatures for heat comfort
- develop healthier communities and environments
- support biodiversity and habitat for wildlife
- restore soil moisture levels to recharge and stabilise groundwater levels in catchments
- improve urban air and restore soil quality
- assist with vehicle calming
- provide amenity and place character.

Streets, however, are typically composed of hard surfaces with limited vegetation to facilitate the safe movement of people and vehicles. Hard, impermeable surfaces create issues for the health and well-being of urban areas including:

Heat island effect: hard surfaces store heat, increasing local temperatures and intensifying the effects of heat waves.

Stormwater runoff: impermeable surfaces prevent water from infiltrating into the ground, and shed water and pollution into waterways.

Absent ecologies: lack of trees and vegetation decreases human (physical and mental) and ecological health.

Retrofitting streets for trees

Trees are commonly absent in the existing streets of Rosemeadow as a result of no tree planting at the time of subdivision and no successful follow-up tree planting campaigns by council. The lack of consideration for tree planting has resulted in streets with limited volume of soil media or access to deeper and/or surrounding soils, with soils typically heavily compacted, and lacking nutrients and oxygen.

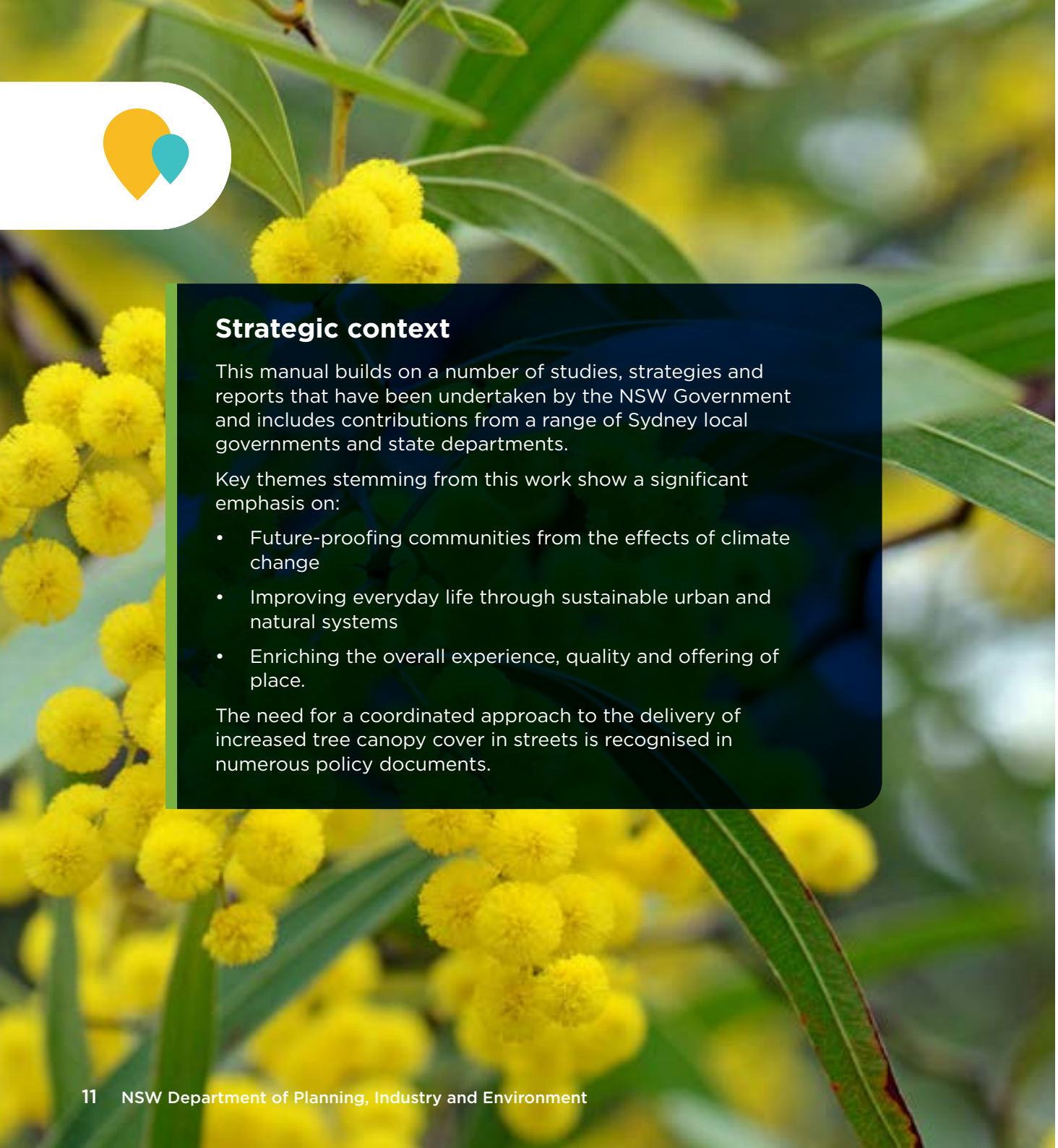
Where trees do exist, it is uncommon for them to be provided with sufficient access to water despite stormwater flowing along street drainage systems. Without access to adequate soil moisture, a tree's growth is limited, and its lifespan is compromised.

These prevailing conditions make it difficult for trees to thrive, placing trees under stress and leaving their root systems compromised and in search of adequate nutrients, oxygen and moisture. This stress can cause surface uplift and root damage to underground infrastructure, which are often cited as reasons not to include trees in streets.

Retrofitting the existing streets to provide adequate soil volume, soil condition and access to water is key to creating larger tree canopies and healthier trees in streets. If retrofitted appropriately, this can result in:

- double the growth rate (Grey, V. et.al 2018)
- canopy cover which is 8 to 10 times as large (Hitchmough, J. 1994)
- an increased lifespan of the tree from 13 to 50 years (Skiera, B. and G. Moll. 1992)

This manual focuses on retrofitting existing streets with healthy trees, while integrating with other street functions and infrastructure.



Strategic context

This manual builds on a number of studies, strategies and reports that have been undertaken by the NSW Government and includes contributions from a range of Sydney local governments and state departments.

Key themes stemming from this work show a significant emphasis on:

- Future-proofing communities from the effects of climate change
- Improving everyday life through sustainable urban and natural systems
- Enriching the overall experience, quality and offering of place.

The need for a coordinated approach to the delivery of increased tree canopy cover in streets is recognised in numerous policy documents.

NSW Government Premier's Priorities

The Hon Gladys Berejiklian, Premier of NSW, June 2019

The Premier has set priorities that aim to tackle tough community challenges, lift the quality of life for all citizens and put people at the heart of creating a better environment.

Greener public spaces – Increase the proportion of homes in urban areas within 10 minutes' walk of quality green, open and public space by 10 per cent by 2023.

Greening our city – Increase the tree canopy and green cover across Greater Sydney by planting 1 million trees by 2022.

Greater Sydney Region Plan

Greater Sydney Commission, 2018

The vision for A Metropolis of Three Cities sets out how residents will live within 30 minutes of jobs, education and health facilities, services and great places. The regional plan focuses on supporting a growing community through land use and transport to boost liveability, productivity and sustainability. Of relevance to this manual, the Greater Sydney Regional Plan sets out to achieve:

'Urban tree canopy is valued for its economic, social and environmental benefits.

- The waterways are protected and healthier
- Biodiversity is protected, urban bushland and remnant vegetation is enhanced
- Urban tree canopy cover is increased
- Public open space is accessible, protected and enhanced
- The Green Grid links parks, open spaces, bushland and walking and cycling paths
- Heatwaves and extreme heat are managed'

Western City District Plan

Greater Sydney Commission, 2018

The Western City District Plan sets out the 20-year vision for the Western Parkland City, which draws on the strength of the new Western Sydney Airport and the first stage of a North–South Rail Link. The Western Parkland City will capitalise on the established centres including Campbelltown. Of relevance to this manual, the following planning priorities have been considered:

'Planning Priority W15: Increasing urban tree canopy cover and delivering Green Grid connections

- Objective 30: Urban tree canopy cover is increased.
- Objective 32: The Green Grid links parks, open spaces, bushland and walking and cycling paths.
- Planning Priority W18: Delivering high quality open space
- Objective 31: Public open space is accessible, protected and enhanced.'

The Greater Sydney Green Grid

The NSW Government Architect's Office, 2018

An integrated approach to the green infrastructure of the district – waterways, bushland, urban tree canopy and open spaces – will improve sustainability.

The Greater Sydney Green Grid will provide cool, green links and a network of high-quality open spaces to support waking, cycling and community access to open space.

'A spatial framework to regional planning providing:

- Opportunity to put policy into action
- Adds value to urban development
- Increases access to open space
- Promotes healthy living
- Improves sustainable travel connections
- Conserves and enhances biodiversity and increase access to nature facilitates
- Adaptation to climate extremes and promotes urban greening
- Enhances distinctive destinations and boosts the visitor economy'

Greener Places: An urban green infrastructure design framework for New South Wales

The NSW Government Architect's Office, 2020

Green infrastructure is fundamental to creating a high quality of life and is important in creating a region that is climate-resilient and adaptable to future needs. Greener Places is a green infrastructure framework produced by the Government Architect NSW to guide the planning, design and delivery of green infrastructure. It identifies the need to plan streetscapes as integral components of green infrastructure.

The policy identifies the need to enhance streets by planting alongside all available footpath locations to create safer and more accessible tree-lined streets.

Five Million Trees for Greater Sydney

NSW Department of Planning, Industry and Environment, 2018

5 Million Trees for Greater Sydney Program (5MT) aims to expand urban tree canopy across all 33 local government areas (LGAs) within Greater Sydney. The objective of the program is to plant trees in public streets, open spaces and on private property with the goal to increase Sydney's urban tree canopy to 40%.

The overall objectives of 5MT are:

- Plant five million more trees in Greater Sydney by 2030.
- Increase Greater Sydney's existing urban tree canopy cover of 16% towards 40%.
- Assist in the amelioration of climate extremes by providing shade and cooling of urban areas through tree planting.
- Creating a healthier, more liveable and greener Greater Sydney.

Safe Active Streets

Transport for NSW, 2018

Transport for NSW is currently carrying out work to deliver 'Safe Active Streets' that promote active transport including cycling and walking across areas of Greater Sydney.

It aims to create an 'interconnected network of active pathways which connect residents to Metro, transport and retail hubs, schools, recreational facilities, and suburban points of interest. Provides a safe network for current users, and creates future users by focusing on developing confidence amongst younger residents.'

North West Integrated Services Plan 2018–2024

Integrating the principles developed in the strategy will help communities understand how tree planting can:

- promote healthier alternatives to driving
- facilitate safe streets for children that encourage independent trips over short distances and other street uses (playing on street)
- connect transport hubs and points of interest to create safe and efficient routes between destinations
- calm traffic and create a safe active environment for active travel modes
- incorporate branding so residents know when they are entering an Active Zone
- be developed in collaboration with street communities.

Campbelltown Bicycle Plan

Campbelltown City Council, 2018

The bicycle plan lays out a vision for cycling across Campbelltown that looks to increase the number of residents who ride for recreation, education, shopping, travel to work or any other purpose. The plan aims to:

- 'Improve cyclist safety, especially for vulnerable cyclists such as children;
- Increase the range of people who cycle in the area;
- Facilitate healthy communities through increased physical activity and fun;
- Improve the liveability of neighbourhoods and increase social connections;
- Increase opportunities for local cycling trips that support Campbelltown's economy (e.g. cycling to shops, reserves, schools etc.).'

Part 1:

Planning and design process

Overview

When integrating trees into streets, an understanding of their benefits is required from the outset of the process. It is important to consider trees as a key part of street infrastructure from planning, through to street design, to implementation.

Establishing mature tree canopy takes time. It is important to protect and enhance both new and existing trees to maintain and extend canopy coverage.

In Rosemeadow, there are multiple opportunities to integrate, protect or enhance trees in the streets. These opportunities need to be identified at key points of the street upgrade process, including:

Stage 1 - Planning: identify and prioritise locations of streets for tree planting.

Stage 2 - Design: apply principles that ensure healthy growing conditions for trees, selected to respond to the existing street settings.

Stage 1: Planning

The strategic planning of trees in Rosemeadow will help to prioritise street tree planting in areas where they can deliver maximum benefit.

The planning process should be informed by all stakeholders and a strong evidence base to identify priority projects with clear implementation time frames and budgets.

Planning priorities

Key planning priorities are considered to help identify priority streets for tree planting. These principles are derived from the benefits that trees bring (as outlined on page 10) and include:

Urban tree canopy

Identify streets with low percentage tree canopy cover (considering lifetime of existing trees) to prioritise tree planting that contributes to the overall 40% canopy cover target.

Cooler places

Identify streets that are affected by urban heat island intensity as a spatial indicator for tree planting prioritisation.

Resilient communities

Identify streets with communities that are vulnerable to heat extremes as a spatial indicator for tree planting prioritisation.

Social infrastructure

Prioritise tree planting in key civic and commercial activity areas, along key movement corridors and in areas that require improved character of place.

Hydrology

Identify streets where tree planting solutions can be connected to stormwater runoff to improve stormwater management outcomes, e.g. water quality or flood risk management

Access and movement

Identify walking, cycling and recreation routes/streets that would benefit from shade and greening and prioritise for tree planting.

Ecology

Identify existing habitat areas and the missing biodiversity links along streets for the prioritisation of tree planting to provide linked habitat and resources for birds and insects.

Strategic prioritisation

Rosemeadow has an existing tree canopy cover of 5.63%. This is one of the lowest in Greater Sydney and is significantly lower than the existing Greater Sydney canopy cover of 16% and the proposed 5MT 40% target.

The low tree canopy cover in Rosemeadow has contributed to extreme urban heat island effects. Much of the neighbourhood is 9 degrees warmer than non-urban areas on hot days.

Heat Vulnerability Index data can also help direct tree planting projects. The index identifies populations with high vulnerability to heat waves. It consists of three indicators: heat exposure, sensitivity to heat and adaptive capacity. It creates a vulnerability rating that is scaled from 1 (low vulnerability) to 5 (high vulnerability). The index takes into account the location of vulnerable groups such as the elderly, very young and those with lower adaptive capacity using socio-economic data as an adaptive indicator. Rosemeadow has a population that is extremely vulnerable to heat waves.

Seventy per cent of Rosemeadow's tree canopy cover is provided on private land and school grounds. The remaining 30% covers public parks and streets. Rosemeadow's streets lack municipal street tree planting and only 12.73% of the street's area is covered by tree canopy.

Growing a healthy tree canopy cover across Rosemeadow is particularly important in response to increasing temperatures as well as the numerous other benefits trees bring.

To guide tree planting for the people and places that need it most in Rosemeadow, strategic mapping provides a framework for where tree canopy is required and should be prioritised. Streets that contribute most to the planning priorities will be identified as a priority for tree planting.

Regardless of these priorities, trees will bring high-value opportunities across all local areas of Rosemeadow.

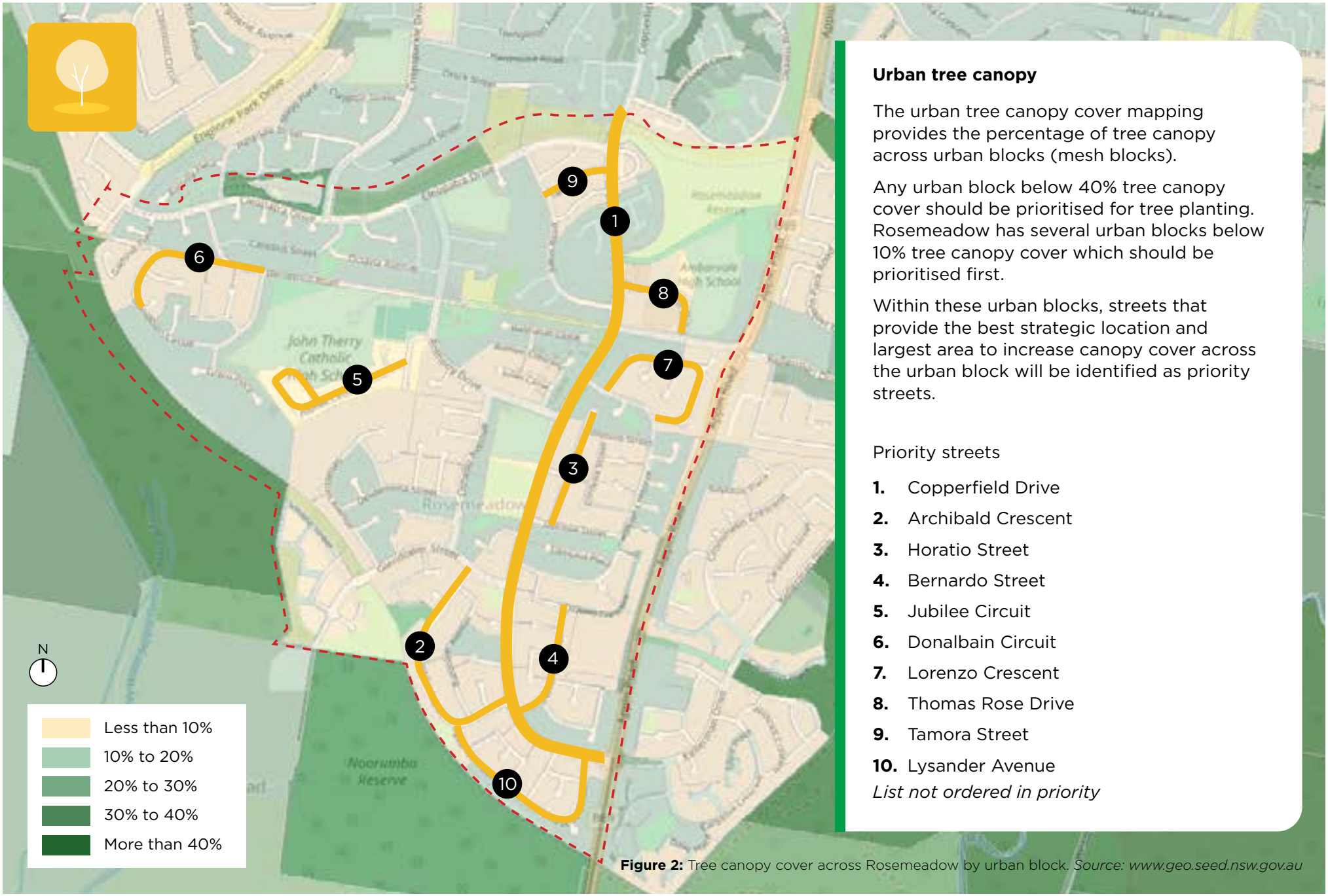


Figure 2: Tree canopy cover across Rosemeadow by urban block. *Source: www.geo.seed.nsw.gov.au*

Urban tree canopy

The urban tree canopy cover mapping provides the percentage of tree canopy across urban blocks (mesh blocks).

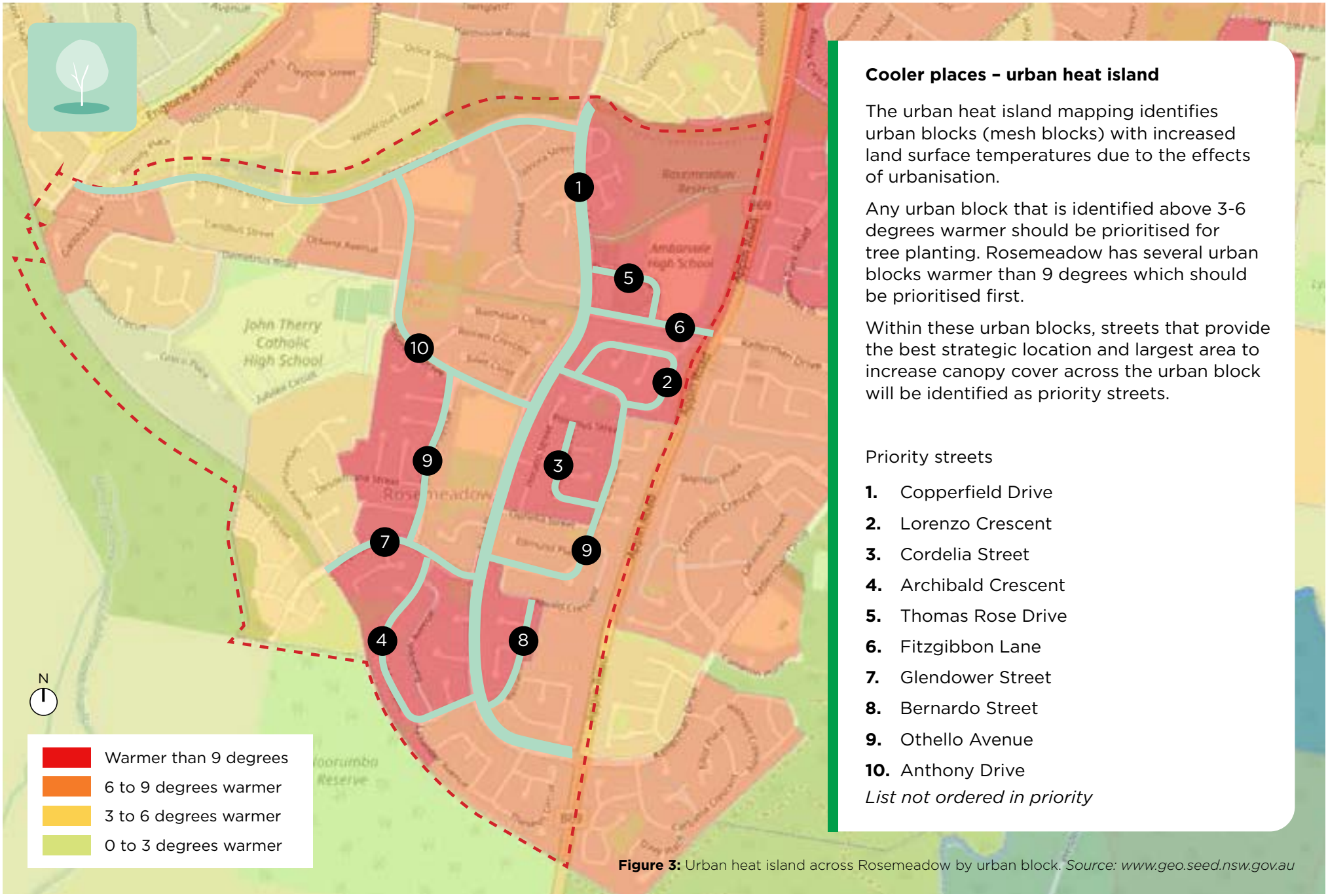
Any urban block below 40% tree canopy cover should be prioritised for tree planting. Rosemeadow has several urban blocks below 10% tree canopy cover which should be prioritised first.

Within these urban blocks, streets that provide the best strategic location and largest area to increase canopy cover across the urban block will be identified as priority streets.

Priority streets

1. Copperfield Drive
2. Archibald Crescent
3. Horatio Street
4. Bernardo Street
5. Jubilee Circuit
6. Donalbain Circuit
7. Lorenzo Crescent
8. Thomas Rose Drive
9. Tamora Street
10. Lysander Avenue

List not ordered in priority



Cooler places – urban heat island

The urban heat island mapping identifies urban blocks (mesh blocks) with increased land surface temperatures due to the effects of urbanisation.

Any urban block that is identified above 3-6 degrees warmer should be prioritised for tree planting. Rosemeadow has several urban blocks warmer than 9 degrees which should be prioritised first.

Within these urban blocks, streets that provide the best strategic location and largest area to increase canopy cover across the urban block will be identified as priority streets.

Priority streets

1. Copperfield Drive
2. Lorenzo Crescent
3. Cordelia Street
4. Archibald Crescent
5. Thomas Rose Drive
6. Fitzgibbon Lane
7. Glendower Street
8. Bernardo Street
9. Othello Avenue
10. Anthony Drive

List not ordered in priority

Figure 3: Urban heat island across Rosemeadow by urban block. *Source: www.geo.seed.nsw.gov.au*

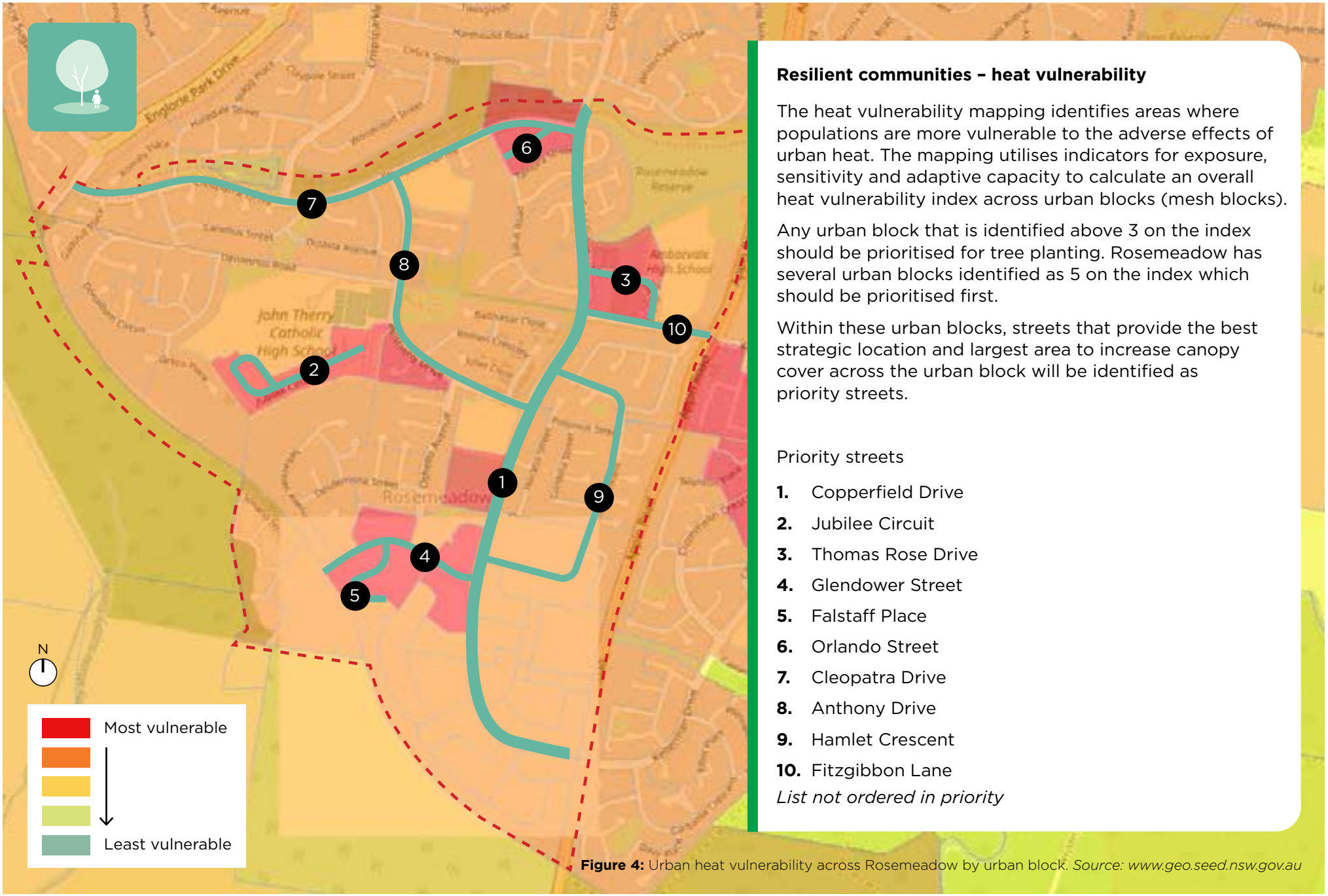


Figure 4: Urban heat vulnerability across Rosemeadow by urban block. *Source: www.geo.seed.nsw.gov.au*

Resilient communities – heat vulnerability

The heat vulnerability mapping identifies areas where populations are more vulnerable to the adverse effects of urban heat. The mapping utilises indicators for exposure, sensitivity and adaptive capacity to calculate an overall heat vulnerability index across urban blocks (mesh blocks).

Any urban block that is identified above 3 on the index should be prioritised for tree planting. Rosemeadow has several urban blocks identified as 5 on the index which should be prioritised first.

Within these urban blocks, streets that provide the best strategic location and largest area to increase canopy cover across the urban block will be identified as priority streets.

Priority streets

1. Copperfield Drive
2. Jubilee Circuit
3. Thomas Rose Drive
4. Glendower Street
5. Falstaff Place
6. Orlando Street
7. Cleopatra Drive
8. Anthony Drive
9. Hamlet Crescent
10. Fitzgibbon Lane

List not ordered in priority

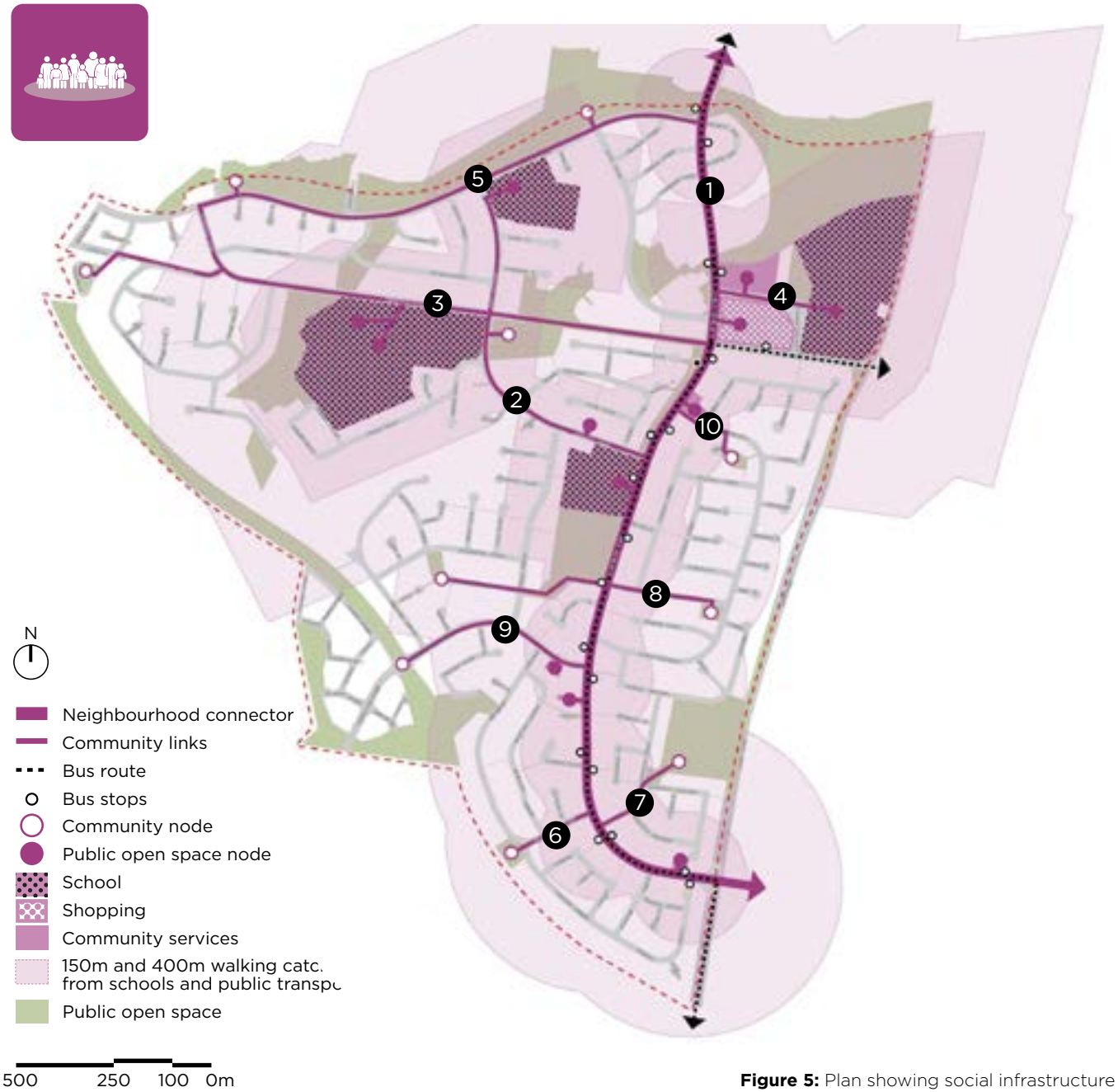


Figure 5: Plan showing social infrastructure and the associated walking catchments across Rosemeadow

Social infrastructure

To ensure heat comfort for the day-to-day activities of people, key community, business and civic activity areas and their walking distances are mapped.

Providing cool areas and cool routes to key social infrastructure will be prioritised. Streets that connect public transport to schools and shops should be prioritised first. Connections to public open space nodes and smaller community services should be prioritised second. Where possible, the number and frequency of people attending each piece of social infrastructure should be considered.

Priority streets

1. Copperfield Drive
2. Anthony Drive
3. Demetrius Road
4. Thomas Rose Drive
5. Cleopatra Drive
6. Archibald Crescent
7. Bernardo Street
8. Ophelia Street
9. Glendower Street
10. Hamlet Crescent

List not ordered in priority

Hydrology

Prioritising tree planting on streets in the upper catchment will relieve pressure on flood easements and detention zones whilst providing a resilient water source for healthy tree growth. Passive irrigation will provide trees with ongoing access to water and improve stormwater management outcomes. By intercepting stormwater runoff from hard surfaces and infiltrating it for the benefit of the trees, passive irrigation helps restore catchment permeability.

Passive irrigation best works with a catchment slope between 0.5% to 5%. Streets that have an appropriate slope, a significant catchment area, sufficiently wide road or verge and are strategically located for stormwater management will be prioritised first.

Priority streets

1. Copperfield Drive
2. Valentine Place
3. Hamlet Crescent
4. Canidius Street
5. Anthony Drive
6. Bernardo Street
7. Thomas Rose Drive
8. Julius Road
9. Lorenzo Crescent
10. Glendower Street

List not ordered in priority

Figure 6: Plan showing stormwater catchments and hydrological flows across Rosemeadow

Figure 7: Plan showing primary active and public transport routes across Rosemeadow

Access and movement

To provide safe and shaded routes for pedestrians, cyclists and scooters, trees will be prioritised in areas that require traffic calming measures and/or shade along active transport routes.

Streets with existing or proposed dedicated cycle routes and pedestrian footpaths will be prioritised first for tree planting. Streets that are popular pedestrian links will be prioritised next. These often link open space and social infrastructure and have footpaths on both sides of the street.

Priority streets

1. Copperfield Drive
2. Anthony Drive
3. Cleopatra Drive
4. Demetrius Road
5. Fitzgibbon Lane
6. Glendower Street
7. Thomas Rose Drive
8. Bernardo Street
9. Othello Avenue
10. Ophelia Street

List not ordered in priority

Figure 8: Plan showing habitat areas and biodiversity corridors across Rosemeadow

Ecology

To provide linked habitat and resources for fauna, trees will be prioritised to link habitat areas and green spaces.

Streets that link high biodiversity areas will be prioritised first with links between public open spaces secondary.

Priority streets

1. Demetrius Road
2. Copperfield Drive
3. Anthony Drive
4. Glendower Street
5. Archibald Crescent
6. Bernardo Street
7. Fitzgibbon Lane
8. Cleopatra Drive
9. Jubilee Circuit
10. Ophelia Street

List not ordered in priority

Community prioritisation

The planning process should be informed by a community engagement process, which aims to:

- Educate and inform the community about the value of street tree planting
- Consult and collaborate with the community about their local streets (what they have and what they need), and set priorities for street tree planting by identifying community values around trees and any barriers to achieving increased tree planting (e.g. cost, wrong location, leaf drop/mess).

In Rosemeadow, a consultation event was held with the community on Saturday 21 September, 2019, in Haydon Park. Between 100 and 150 residents attended the event.

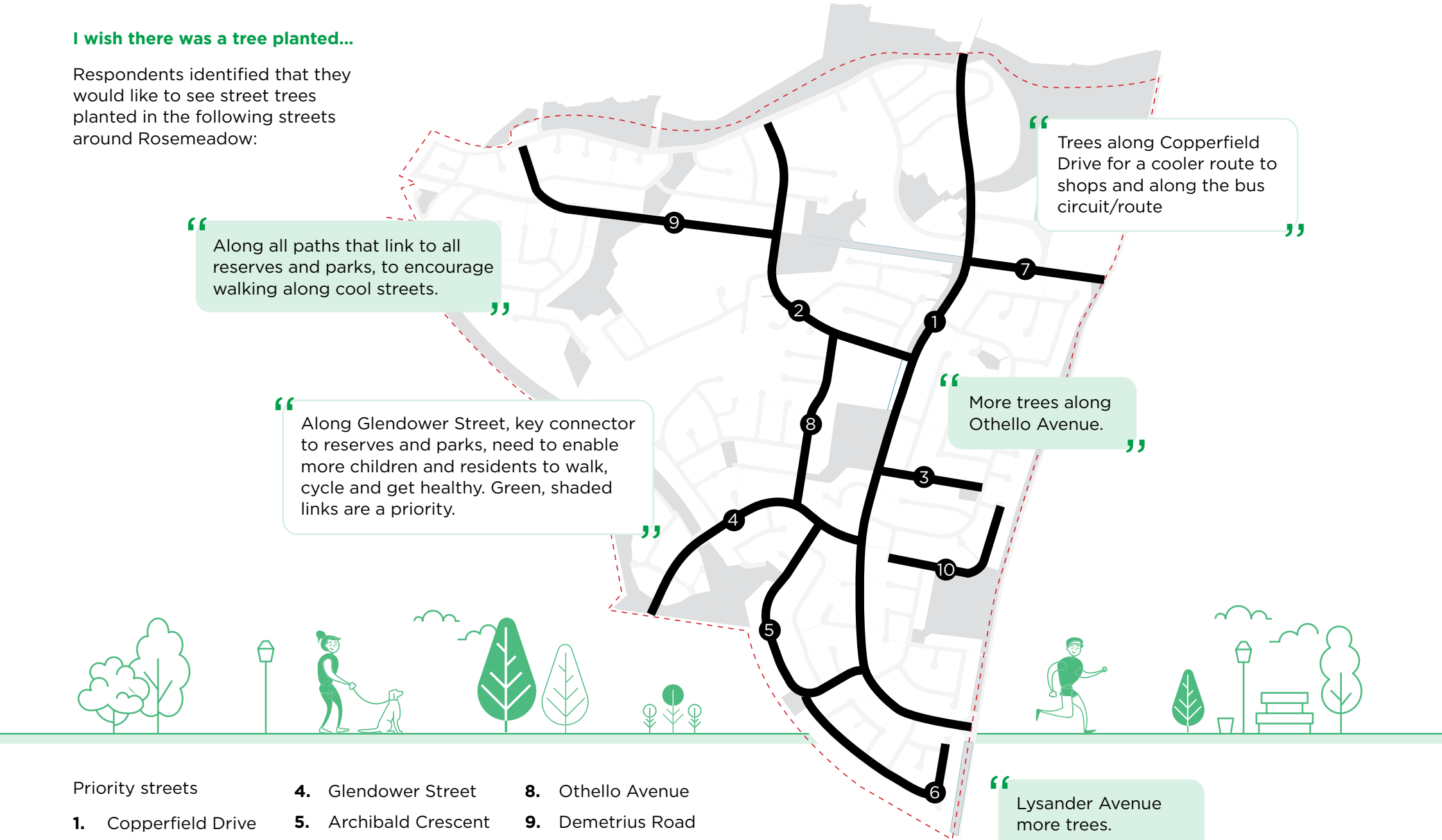
The purpose of the community event was for people to learn more about trees and help prioritise street tree planting across Rosemeadow.

The event also aimed to encourage the community to plant trees in their private yards.

Figure 9: Rosemeadow community consultation in late 2019.

I wish there was a tree planted...

Respondents identified that they would like to see street trees planted in the following streets around Rosemeadow:



> "Along all paths that link to all reserves and parks, to encourage walking along cool streets."

> "Trees along Copperfield Drive for a cooler route to shops and along the bus circuit/route"

> "Along Glendower Street, key connector to reserves and parks, need to enable more children and residents to walk, cycle and get healthy. Green, shaded links are a priority."

> "More trees along Othello Avenue."

> "Lysander Avenue more trees. Intermittent trees."

Priority streets

1. Copperfield Drive
2. Anthony Drive
3. Ophelia Street
4. Glendower Street
5. Archibald Crescent
6. Lysander Avenue
7. Fitzgibbon Lane
8. Othello Avenue
9. Demetrius Road
10. Oswald Crescent

List not ordered in priority

Identification of priority streets

Cross-referencing of community feedback and strategic high-priority streets have been collated into four tree planting projects as illustrated on the plan on the following page.

Priority streets	Community	Canopy cover	Cooler places	Resilient communities	Social infrastructure	Hydrology	Movement and access	Ecology	Total
Anthony Drive	●			●	●	●	●	●	6
Archibald Crescent	●	●			●			●	4
Bernardo Street		●			●			●	3
Canidius Street						●			1
Cleopatra Drive							●		1
Copperfield Drive	●	●	●	●	●	●	●	●	8
Cordelia Street				●					1
Demetrius Road	●				●		●	●	4
Falstaff Place			●						1
Fitzgibbon Lane	●						●		2
Glendower Street	●		●				●	●	4
Hamlet Crescent						●			1
Horatio Street		●							1
Jubilee Circuit		●	●						2
Lorenzo Crescent				●					1
Lysander Avenue	●								1
Malcolm Way				●					1
Ophelia Street	●								1
Orlando Street			●						1
Othello Avenue	●								1
Oswald Crescent	●								1
Tamora Street		●							1
Thomas Rose Drive			●	●	●	●			4
Valentine Place						●			1

Table 1: Cross-referencing matrix of top five priority streets of each strategic objective

Priority Project 1

8-7 objectives met

- Copperfield Drive

Priority Project 2

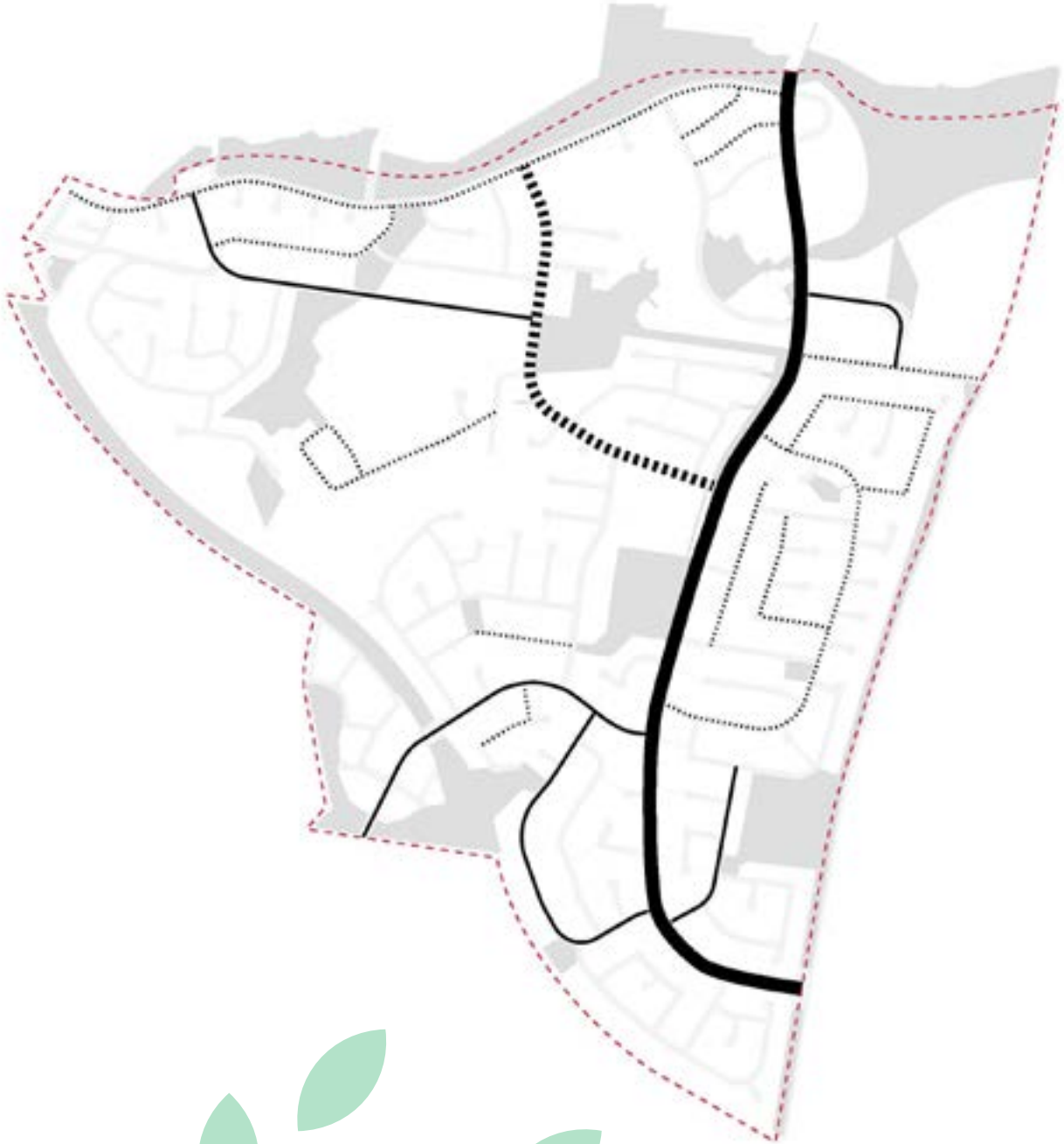
6-5 objectives met

- Anthony Drive

Priority Project 3

4-3 objectives met

- Archibald Crescent
- Bernardo Street
- Demetrius Road
- Glendower Street
- Thomas Rose Drive



Priority Project 4

2-0 objectives met

- Canidius Street
- Cleopatra Drive
- Cordelia Street
- Falstaff Place
- Fitzgibbon Lane
- Hamlet Crescent
- Horatio Street
- Jubilee Circuit
- Lorenzo Crescent
- Lysander Avenue
- Malcolm Way
- Ophelia Street
- Orlando Street
- Othello Avenue
- Oswald Crescent
- Tamora Street
- Valentine Place

Figure 10: Plan showing priority street tree planting projects categorised

Opportunistic alignment with street upgrade projects

In existing streets, a lot of opportunities to effectively integrate trees will come about during regular upgrade works as part of routine maintenance or renewal.

Integrating trees with other works such as footpath upgrades, traffic works, road renewals and redevelopment, will minimise costs and disturbance to communities.

Campbelltown City Council needs to coordinate street upgrade works across disciplines and delivery teams to identify possible alignments with tree planting.

Mapping street upgrade works spatially and in time will help to understand alignments for coordinated tree planting and capital expenditure.

Stage 2: Design

Creating design solutions and healthy growing conditions for varying street contexts

To deliver the benefits trees bring across Rosemeadow, it is important to deliver larger tree canopies and healthier trees. Ensuring trees reach maturity is vital to delivering the long-term benefits they bring.

To achieve this, design principles have been developed that focus on the character, condition and function of the existing streets.

A significant challenge is to ensure adequate above and below ground space is provided for healthy tree growth. This requires close work with multiple disciplines and authorities to resolve conflicted space.

Cross-organisational governance is required to successfully deliver tree planting. Governance authorities should consider tree planting as part of their projects and objectives i.e. allowance for tree planting in the designated budget for realigning utilities.

Street safety

Providing a safe street environment is crucial. Tree planting must not impede pedestrian, cyclist or vehicle safety. Tree solutions can be used as traffic calming, but must preserve lines of sight.

Considerations:

- Ensure the long-term safety of road-users and maintenance staff. For example, should mechanisms be included to protect road users from trees, and can maintenance staff safely access areas for routine works to trees and the street?
- Risks associated with vehicles and more vulnerable road users
- Risks associated with pedestrian tripping hazards

Reference the Beyond the Pavement, NSW Roads and Maritime Services, 2014 for further detail.

Figure 11: Raised kerb and understory planting along the street – provides good separation of vehicles and pedestrians

Checklist

- Is the site adjacent to high-speed traffic with limited access?
- Will trees compromise sight lines?
- Does the site have high pedestrian or bike traffic?
- How will the site be accessed for maintenance?

Place making

Tree planting should respond to the local context, contribute to the character of the street, and enhance the street's function and liveability.

Considerations:

- Is tree planting compatible with ongoing and future community activities – playing, socialising, growing?
- Prioritise shade and cooling, amenity and character and air quality improvements in strategic locations.
- Understand how tree planting will integrate with the surrounding context to create a safe and functional place, that builds on the character of the street and adds value for the community.
- Engage with residents and community groups to understand their needs and aspirations at a local street level.
- Consider the inclusion of street furniture and traffic calming methods to further enhance the street function and liveability.

Figure 12: Trees complementing activity outside building – providing shade and celebrating local character

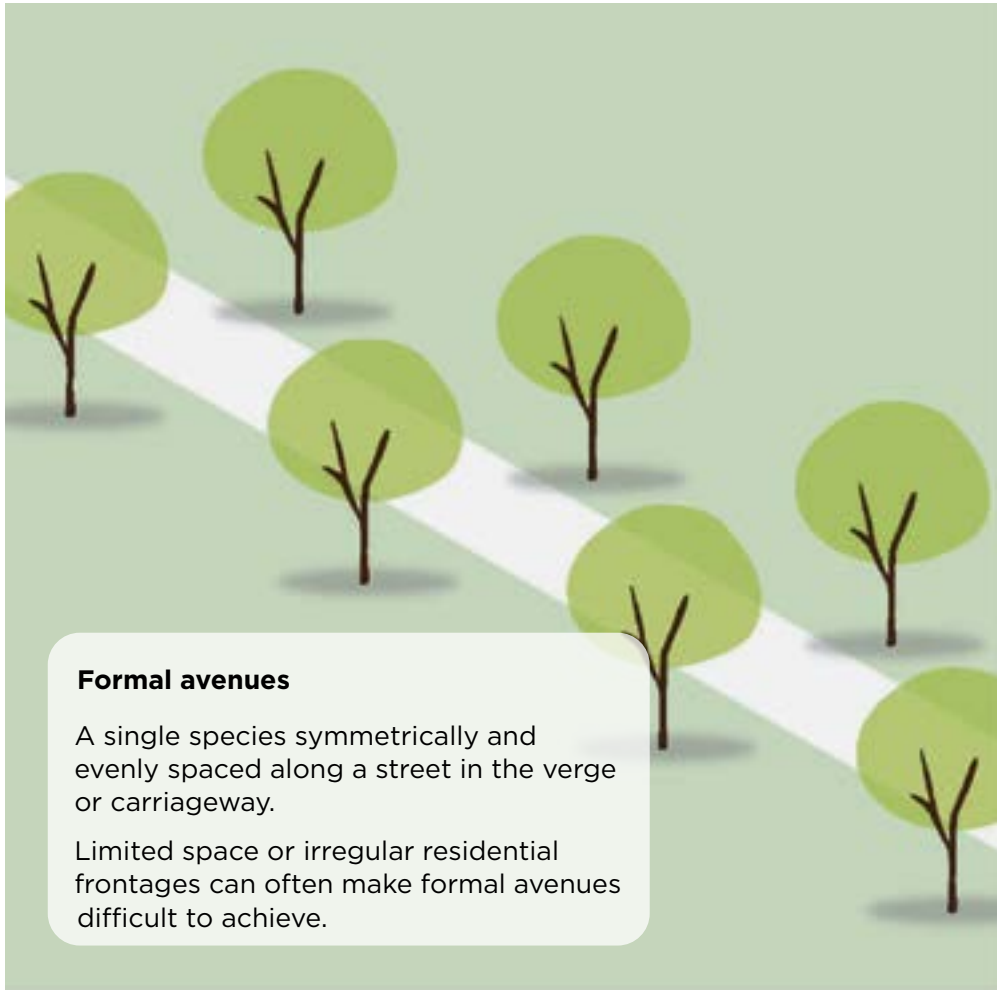
Planting configuration

Trees can add beauty and a human scale to streets. The configuration in which trees are planted plays an important part in place making. A beautiful tree-lined street can create a strong sense of community and civic pride. Trees also visually signal the change of seasons, further adding to the memories we have of a place.

When developing the planting configuration, each street should be considered individually, based on the site constraints and the desires of the local community. The following configurations offer a preliminary guide to many possible arrangements.

Checklist

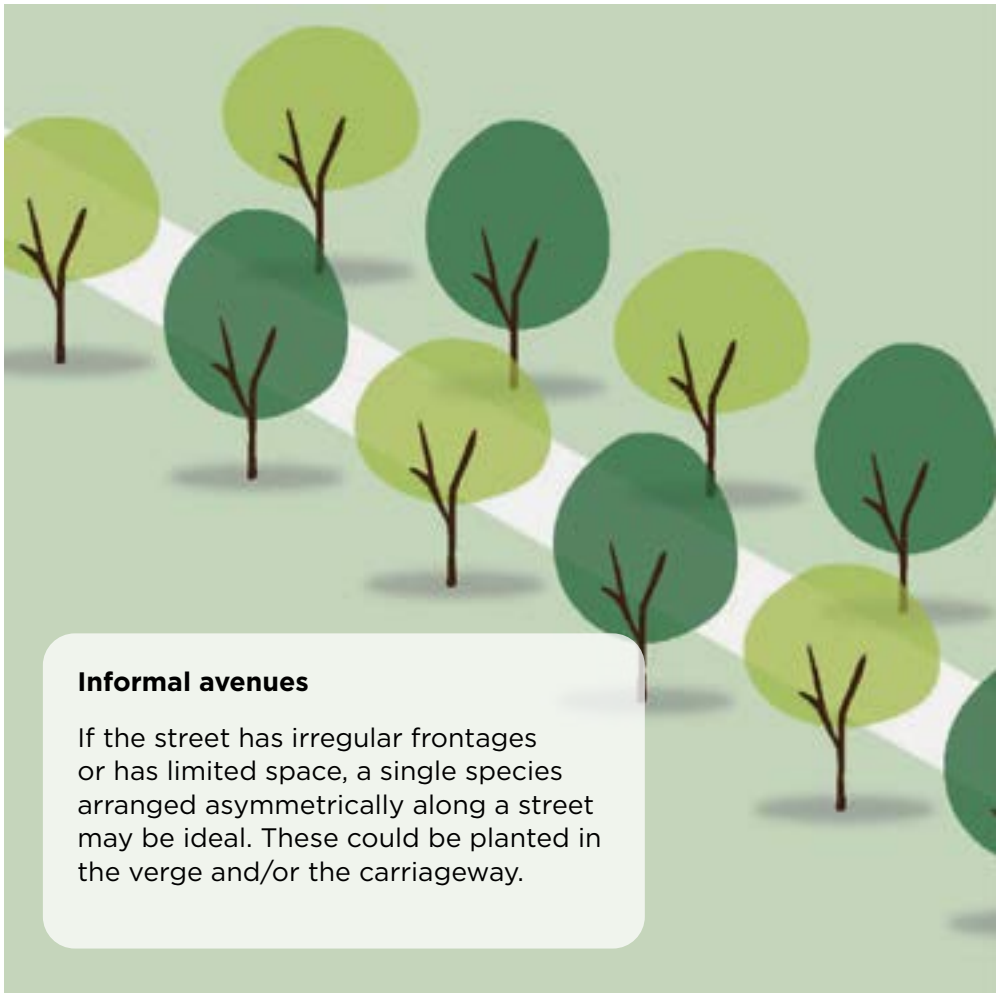
- What are the local community's needs and aspirations?
- Which trees are found in the surrounding context and how are they configured?
- Can trees highlight key routes, rest points, gathering spaces or other community focus?
- Can trees provide a visual and/or noise buffer?



Formal avenues

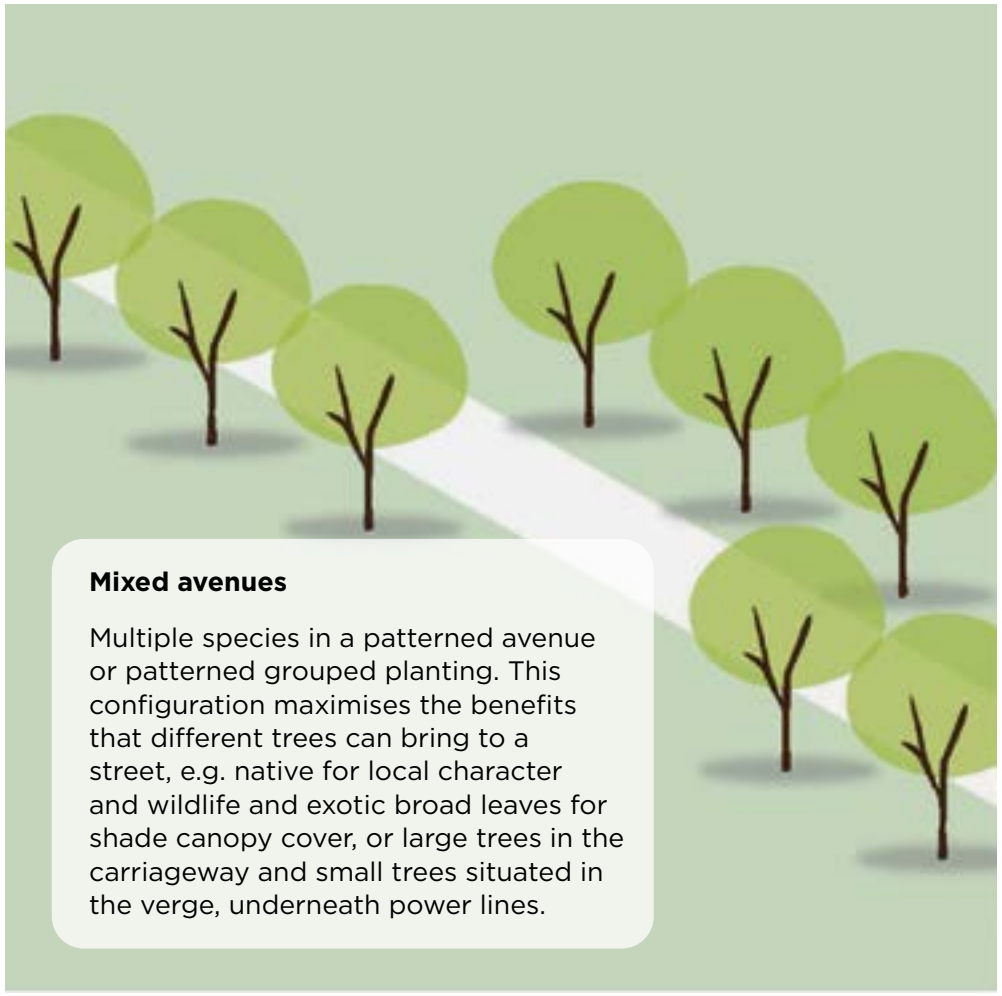
A single species symmetrically and evenly spaced along a street in the verge or carriageway.

Limited space or irregular residential frontages can often make formal avenues difficult to achieve.



Informal avenues

If the street has irregular frontages or has limited space, a single species arranged asymmetrically along a street may be ideal. These could be planted in the verge and/or the carriageway.

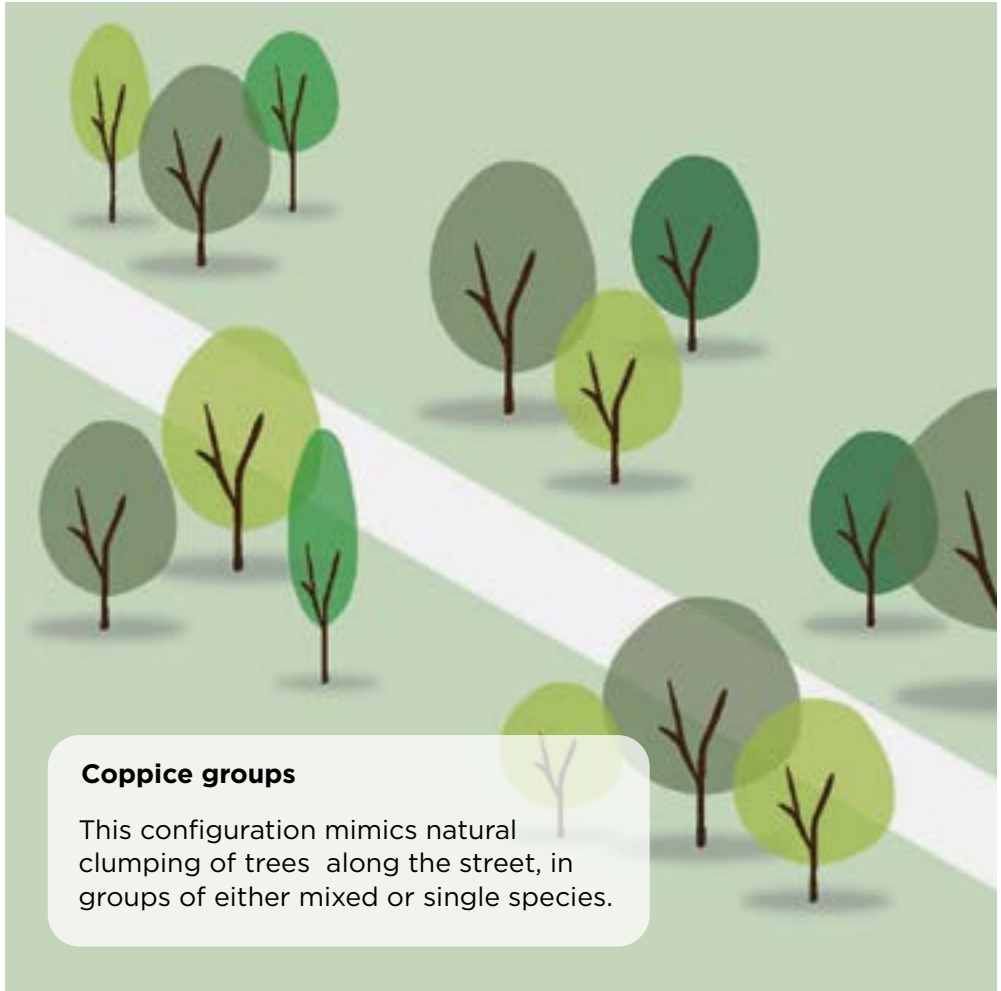


Mixed avenues

Multiple species in a patterned avenue or patterned grouped planting. This configuration maximises the benefits that different trees can bring to a street, e.g. native for local character and wildlife and exotic broad leaves for shade canopy cover, or large trees in the carriageway and small trees situated in the verge, underneath power lines.

Feature trees

In focal points along the street, a visually contrasting feature tree can be used to highlight junctions, entries, the end of vista or community focus points.



Coppice groups

This configuration mimics natural clumping of trees along the street, in groups of either mixed or single species.

Engaging the community in place making

Street tree planting should be informed by a community-led place making process. This will allow the local community the opportunity to play a key role in giving their street an enhanced identity. Involving the community in the planting projects is crucial in achieving community ownership and the sustained success and stewardship of street trees.

Identifying issues and opportunities

The community that regularly uses the street will have strong insights into how their street functions. Understanding this will identify issues and opportunities in the street and around trees. Potential questions to ask the community may include:

- Are there any trees in your street?
- Do you have any concerns about the planting of trees in your street – if yes, why?
- Would you like to see fewer, the same number, or more trees in your street?
- What do you currently use your street for?
- In the future, what would you like to use your street for?

What do you value most about trees?

- Make a home for nature
- Fight climate change
- Cool our neighbourhood
- Clean the air we breathe
- Prevent UV exposure
- Make us happier and healthier
- Healthy snacks
- Reduce energy bills
- Reduce flash flooding
- Clean the soil and water
- Increase home value
- Connects us to Country
- Reduce crime
- Calm traffic
- Make our streets more social

Where could we plant more trees to make your street better?

Community street tree vision

Developing a community street tree vision will form the basis of the design and implementation of planting projects. This requires the community to consider the existing street character, activities and uses and the design potential of trees. Potential questions to ask the community may include:

What quality do you most like about trees?

- Colourful flowers
- Seasonal leaf colour
- Feature flowers
- Year-round leaves
- Deciduous
- Weeping
- Horizontal branching
- Conical
- Attractive bark
- Neat canopy
- Multi-stem
- Feature foliage

How should trees be planted in your street?

- Formal avenue: single species symmetrically spaced
- Informal avenue: asymmetrically arranged single species
- Multi-species avenue: multiple tree species in a patterned avenue
- Feature: trees used to highlight entry, focus or use
- Coppice: multiple species in group planting

Community support

A lack of funds is a common reason for not carrying out street improvements. Tree planting however is a lighter, quicker and cheaper street transformation tool and the local community can be utilised as a potential delivery partner. Consultation should aim to combine the willingness of the local community to help enhance the street through community planting projects.

Integrating infrastructure

Tree planting around existing infrastructure should provide sufficient space for healthy growth, to enhance the benefits that trees bring.

Common infrastructure in Rosemeadow that may be encountered includes:

- Underground services (water, sewer, gas, electricity, telecommunications)
- Overhead power
- Light columns
- Street signs and furniture
- Car parking, footpaths, bike lanes and driveways

Considerations

- Choose locations that avoid infrastructure clashes. If clashes are unavoidable, investigate whether infrastructure can be removed, relocated or reconfigured to create sufficient space for trees.
- Ensure services adjacent to the tree can be accessed without damaging the tree or its roots.

Figure 13: Trees well integrated with street infrastructure

Figure 14: Tree pruned around overhead powerline.

Overhead conditions

Large trees may contribute greater to cooling and canopy, but are not always suitable when overhead power lines or lighting are present.

Considerations:

- Understand power line easements that may limit tree locations and species
- Investigate if bundling and/or relocation of electrical services is possible
- Select species of appropriate scale and for ease of maintenance

Checklist

- Are there overhead power lines?
- Can utilities be bundled or relocated?
- What species are appropriate?
- Procure survey and services proving

Figure 15: Underground services.

Underground conditions

Trees require deep soil for healthy root growth. Underground services and trees roots are often conflicting, which may lead to less soil volume available for trees.

Considerations:

- Identify services and easements that may limit tree locations and species
- Investigate whether services can be co-located or re-located
- Ensure there is adequate below ground room assigned for trees

Checklist

- Undertake Dial Before You Dig
- Check council and utility records (stormwater, water, sewer)
- Map services on layout plans
- Select suitable options for tree layout or rearranging services
- Procure survey and services proving

Growing conditions

Soil volumes are essential to support healthy tree growth. To support tree planting, soil volumes should be a third of projected canopy, with a minimum depth of one metre.

Considerations

- Understand any requirements for imported soils. Commonly, this requires importing a high-quality sandy clay loam soil.
- In constrained environments, soil volume can be provided underneath load-bearing surfaces with permeable surfaces and structural soils.
- If working with existing soils, do rooting volumes need to be increased? Urban soils are often disturbed, compacted, and soil chemistry is commonly less than ideal – so it is often not much use to trees. If existing soils are not suitable, rooting volumes may need to be increased by 40% to 50%.

Figure 16: Good planting technique

Soil medium and volume

The ultimate size of a tree is influenced by the quality and quantity of growing media available for root growth.

Root growth is defined by:

- available soil oxygen
- available moisture
- available soil volume and profile
- degree of soil compaction.

Figure 17: Typical clay loom soil

Soil conditions in Greater Sydney vary from shallow sandy impoverished soils derived from Hawkesbury Sandstone to fertile soils derived from shales or alluviums.

The selection of tree species must take into account the soil type, both in locality and the geo-region. Some species are adaptable to a range of soil conditions, where others are more particular.

In clay loam soils, mature tree roots may extend up to two or three times the spread of the canopy, but usually extend no deeper than one metre from surface level. Tree roots are opportunistic and will flourish in favourable soil conditions. This is important as roots are critical for encouraging trees.

Street trees rely on infiltration of natural rainfall to the root zone and growth is limited by the volume and moisture-holding capacity of the soil.

As a rule of thumb, street trees should be provided the following minimum unobstructed soil volumes:

- Between 5 and 15 cubic metres for a small tree
- Between 20 and 40 cubic metres for a medium-sized tree
- Between 50 and 80 cubic metres for a large tree.

(Refer to illustrated detail on following page)

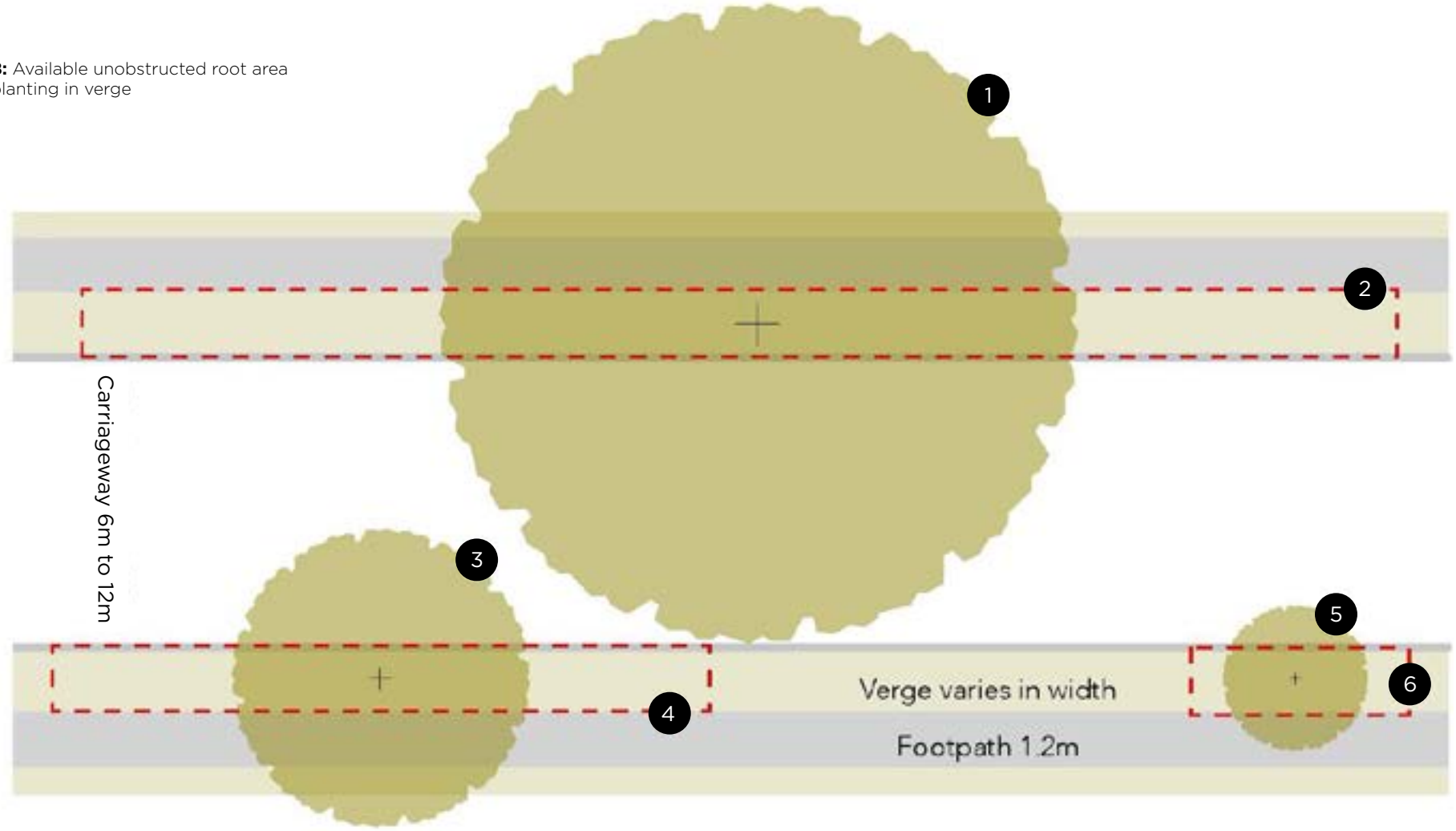
Root growth is dependant on available soil oxygen, which depletes with depth. Therefore, soil volume should not extend deeper than one metre with increased lateral soil volume relating to the tree's mature size.

Checklist

- What is the existing soil profile and condition?
- What is the available or potential soil volume/depth?
- What are the existing soil moisture levels?

1. Large tree 12m canopy
2. Unobstructed root area – soil volume 50m² to 80m². Typical 1.65m x 36.50m x 1m deep
3. Medium tree 8m canopy
4. Unobstructed root area – soil volume 20m² to 40m². Typical 1.65m x 18.2m x 1m deep
5. Small tree 6m canopy
6. Unobstructed root area – soil volume 5m² to 15m². Typical 1.65m x 6m x 1m deep

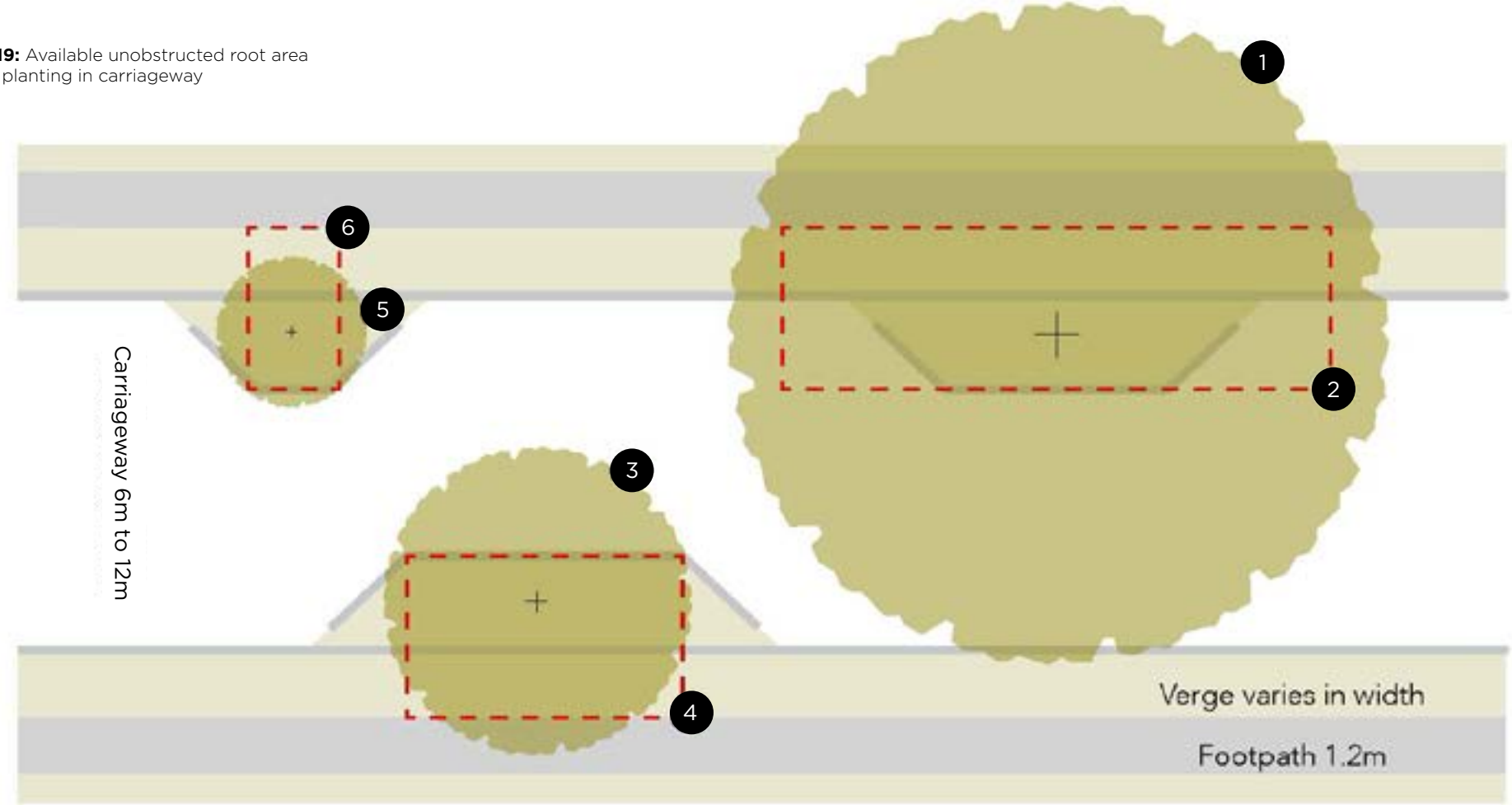
Figure 18: Available unobstructed root area for tree planting in verge



NOTE: Trees can share unobstructed root zone with average volume applying per tree

1. Large tree 12m canopy
2. Unobstructed root area – soil volume 50m² to 80m². Typical 1.65m x 36.50m x 1m deep
3. Medium tree 8m canopy
4. Unobstructed root area – soil volume 20m² to 40m². Typical 1.65m x 18.2m x 1m deep
5. Small tree 6m canopy
6. Unobstructed root area – soil volume 5m² to 15m². Typical 1.65m x 6m x 1m deep

Figure 19: Available unobstructed root area for tree planting in carriageway



NOTE: Trees can share unobstructed root zone with average volume applying per tree

Where unobstructed root zone is located under carriageway, structural soil should be provided

Soil moisture

Optimal soil moisture is required for healthy tree growth and urban cooling and can improve stormwater management outcomes.

Considerations:

- Provide sufficient soil volumes for root growth
- Understand the frequency and volume of water provided for irrigation
- Understand potential for tree roots causing moisture differentials and damage to pavements, especially in areas with expansive soils
- Provide free-draining soils to ensure appropriate soil moisture levels
- Passively irrigate trees with stormwater where possible, so that trees can grow faster, bigger and live longer overall
- Too dry: connect tree planting with surrounding soils to allow roots access to other moisture sources as it grows
- Too wet: provide aerobic soils for the tree, ensuring the top 400m to 500 mm of soil is free-draining with subsurface drainage if required.

Figure 20: Reticulated irrigation system

Figure 21: Passive irrigation from stormwater runoff

Figure 22: Manual irrigation

Achieving good soil moisture:

Understand the frequency and volume of water provided for irrigation. Most trees planted in urban streets need about 120L to 150L of water every few days to thrive.

- Provide free-draining soils to avoid water logging trees
- Avoid risk of soil becoming too dry: connect tree planting with surrounding soils to allow roots access to underground moisture sources as it grows
- Avoid risk of soil becoming too wet: always provide aerobic soils for the tree, ensuring the top 400mm to 500mm of soil is free-draining with subsurface drainage if needed.

Irrigation can be provided to trees via:

- Passive irrigation using storm water runoff from adjacent surfaces (figure 21)
- Reticulation system (figure 20)
- Manual irrigation (figure 22)

NSW has been in drought since mid-2017. Water conservation is crucial during times of drought and consideration should be given to rainwater harvesting (e.g. roof water harvesting) to water trees where practical.

Passive irrigation

Passive irrigation is best practice for streets and should be considered first as it provides sustainable access to water and can also improve stormwater management outcomes. To achieve optimal soil moisture using passive irrigation, designers need to understand and plan for the soil volume, connected catchment and drainage arrangement. The catchment area (square metres) should ideally be 30 times larger than the soil volume (cubic metres).

The connected catchment may comprise roads, footpaths, adjacent properties and/or roof draining to the kerb. If the catchment is too large, the tree can become waterlogged. If the catchment is too small, trees may provide little stormwater benefit and soils may become too dry (without other irrigation sources). Design elements such as dedicated overflows, subsoil drainage and submerged water zones all help control soil moisture levels.

Passive irrigation works best with a catchment slope of between 0.5% to 5%.

Pavement design

When planning trees alongside roads, designers should consider soil moisture interactions between the trees and roads.

Risks to roads, footpaths and tree growth are often related to soil moisture levels:

- Saturation, which can reduce the strength and life of the pavement
- Localised variations in soil moisture, which in reactive soils, lead to variation in surface levels and accelerated pavement damage.

Tree roots can commonly cause damage to footpaths and roadways, especially if the trees do not have adequate access to high quality soils and water. If the soils underlying the road base are sensitive to changes in moisture levels, then roots extracting moisture can cause the soils to expand and contract, damaging the surface above.

Passive irrigation aims to increase soil moisture levels for healthy tree growth while avoiding saturation, resulting in relatively stable moisture levels for both the tree and surrounding pavements. Subsurface drainage should also be included in most designs to drain both the tree's soils and the pavement sub-base. As a further precaution to the road pavements the design arrangement of the subsurface drainage should isolate moisture levels between the tree growth zone and the road base.

Checklist

- What is council's existing irrigation schedule and capacity?
- What is the street catchment grade, area and width?
- What are the existing soil moisture levels – are they expansive?
- What frequency and volume of water is available?

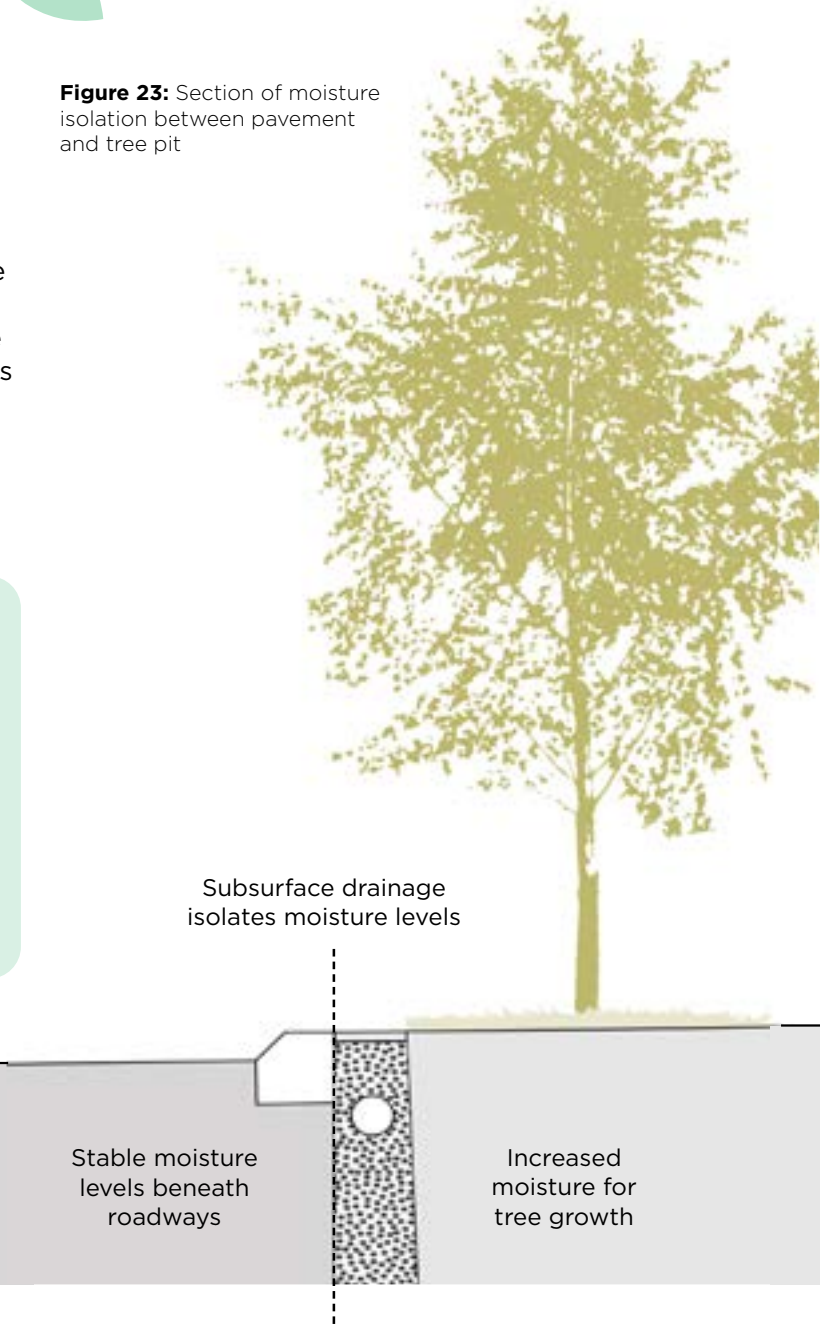


Figure 23: Section of moisture isolation between pavement and tree pit

Figure 24: Mix of tree species providing shade and sunlight

Figure 25: Leaf debris – Johnston Street, Sydney

Sunlight and shade

Specific tree species require varying amounts of sunlight to thrive. Inappropriate species selection can result in sun damage, stunted or unusual growth and premature death.

Considerations:

- A mix of tree species with different canopy habit and form to optimise cooling outcomes
- Clustered trees with overlapping canopies to maximise shade
- Minimise heat trapping underneath canopies by planting in clusters with breaks to provide ventilation
- Street orientation – trees on the south side of east-west streets and the east side on north-south streets will provide the greatest shade benefit.

Checklist

- Will the site get adequate sunlight?
- What is the street orientation?

Debris and maintenance

The surface surrounding trees is important in the long-term maintenance requirements.

Considerations:

- Passive irrigation – street debris such as litter, sediment, and organics can wash into tree pits during rainfall events. An accumulation of debris can reduce their effectiveness. To reduce the likelihood of these outcomes, regular street cleaning and maintenance is required
- Conventional tree planting – collecting leaves and organic matter in larger beds can be used as valuable compost mulch. This can be collected using understorey to contain mulch and reduce maintenance.

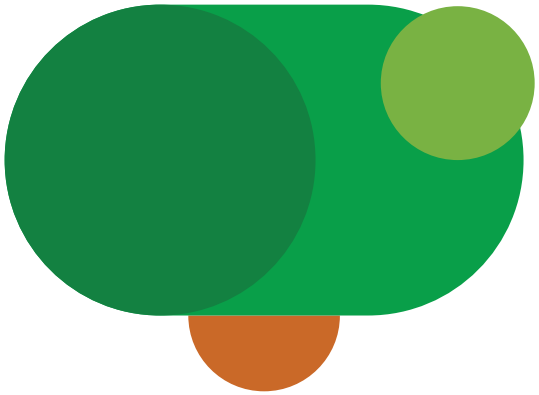
Checklist

Passive irrigation:

- Will runoff carry leaf drop or high sediment loads?
- Is the street cleaned regularly?

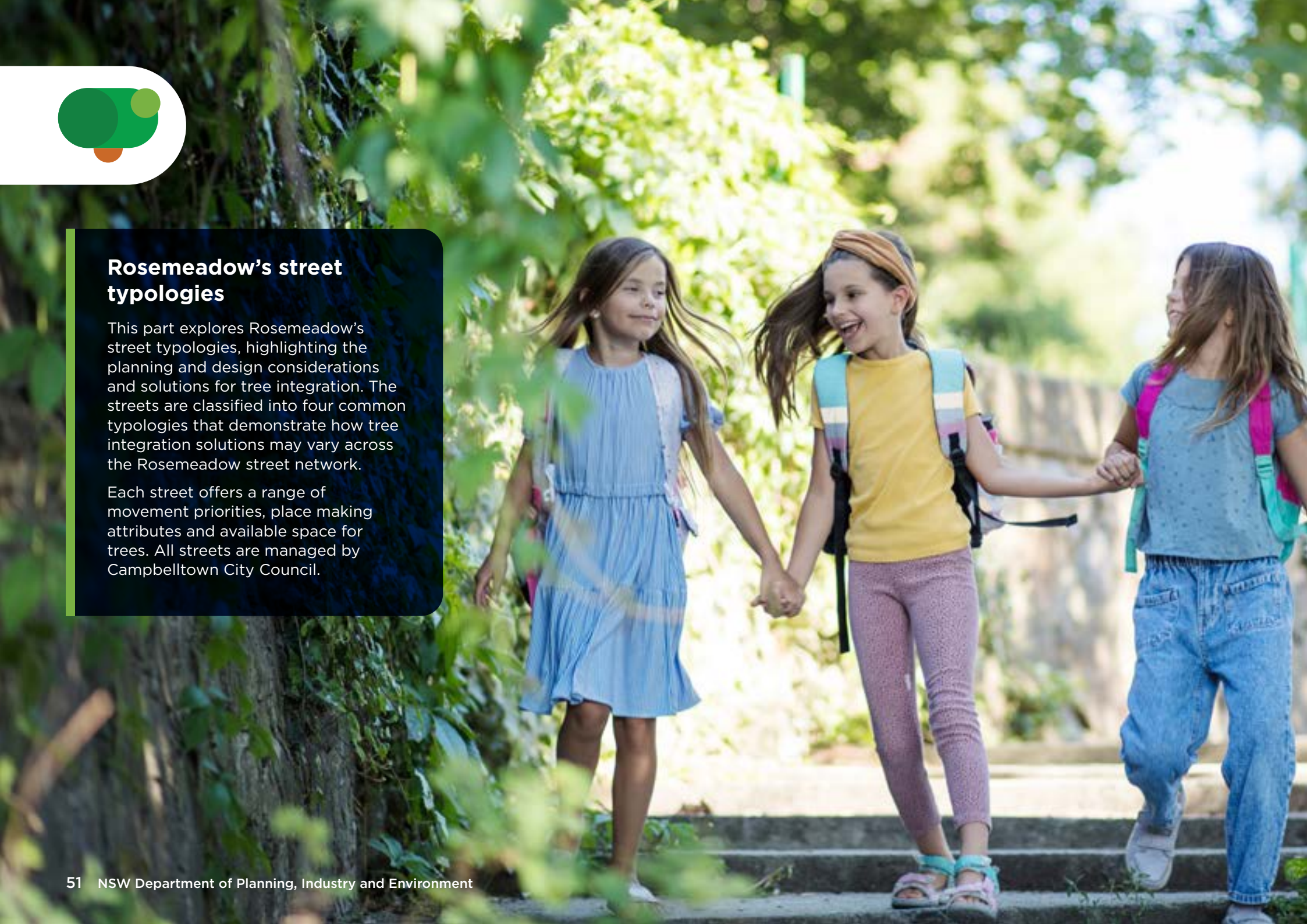
Conventional:

- Can leaf fall be captured?



Part 2:

Street tree planting solutions



Rosemeadow's street typologies

This part explores Rosemeadow's street typologies, highlighting the planning and design considerations and solutions for tree integration. The streets are classified into four common typologies that demonstrate how tree integration solutions may vary across the Rosemeadow street network.

Each street offers a range of movement priorities, place making attributes and available space for trees. All streets are managed by Campbelltown City Council.

Figure 26: Plan showing street tree typologies across Rosemeadow

Neighbourhood streets

Neighbourhood streets are any streets with a road carriageway wider than 8 metres. These are then further defined by their role:

Connector: provide links to surrounding neighbourhoods

Street: provide primary access throughout Rosemeadow.

Neighbourhood Connector - Copperfield Drive:

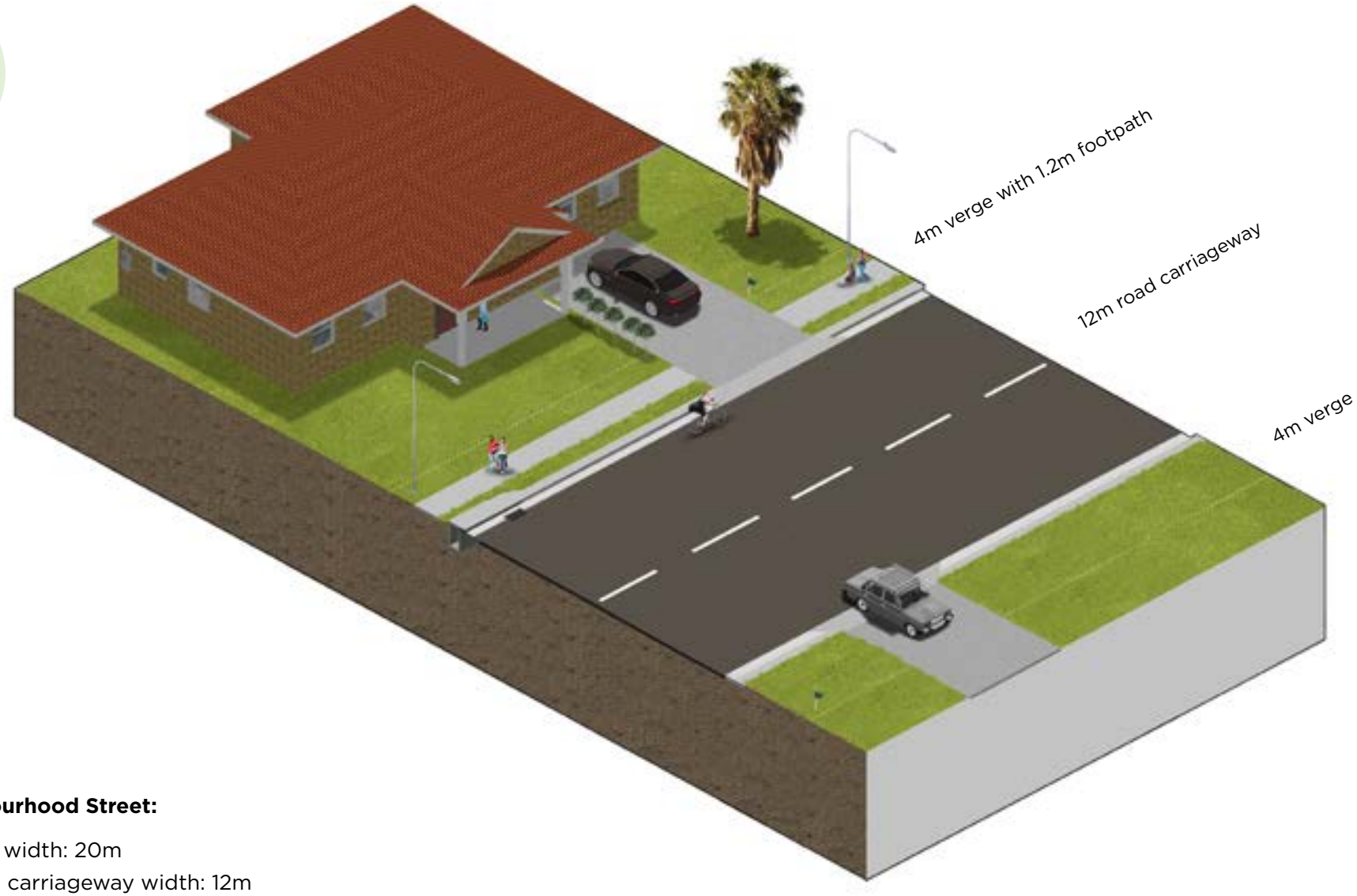
- Total width: 23m
- Road carriageway width: 12m
- Footpath: 1.2m on one or both sides
- Other: on-road bike lane, parking and bus route
- Function: residential and access to public amenity

Figure 27: Axon-metric section of existing neighbourhood connector

Potential Neighbourhood Connector tree planting arrangement:

1. Place trees on-road as 2.5m wide blisters for traffic calming and framing parking spaces.
2. Capture road runoff using a modified kerb and channel that directs water to the trees for irrigation.
3. Provide infiltration trench or drop-down kerb for passive irrigation of grass verge tree planting.
4. Potential option to integrate 3m wide shared path for cyclists and pedestrians.
5. Traffic calming by reducing the lane width to 3.5 m wide.
6. Where passive irrigation is not achieved dry tree species will be planted.

Figure 28: Axon-metric section of potential neighbourhood connector



Neighbourhood Street:

- Total width: 20m
- Road carriageway width: 12m
- Footpath: 1.2m
- Other: parking
- Function: residential

Example: Glendower Street

Figure 29: Axon-metric section of existing neighbourhood street

Potential Neighbourhood Street arrangement:

1. Place trees on-road as 2.4m wide blisters for traffic calming and framing parking spaces.
2. Capture road runoff using a modified kerb and channel that directs water to the trees for irrigation.
3. Provide infiltration trench or drop-down kerb for passive irrigation of grass verge tree planting.
4. Where passive irrigation is not achieved dry tree species will be planted.
5. Integrate on-road 1.8m wide cycle path in both directions
6. Reduce lane widths to 3m wide

Figure 30: Axon-metric section of potential neighbourhood street

Local streets

Local streets are any street with a road carriageway of 8 metres or less. These are then further defined by their role:

Connector: provide links to local streets

Street: are defined for local use only – these are often cul-de-sacs.

Local Connector:

- Total width: 16m
- Road carriageway width: 8m
- Footpath: 1.2m
- Other: informal parking possible
- Function: residential

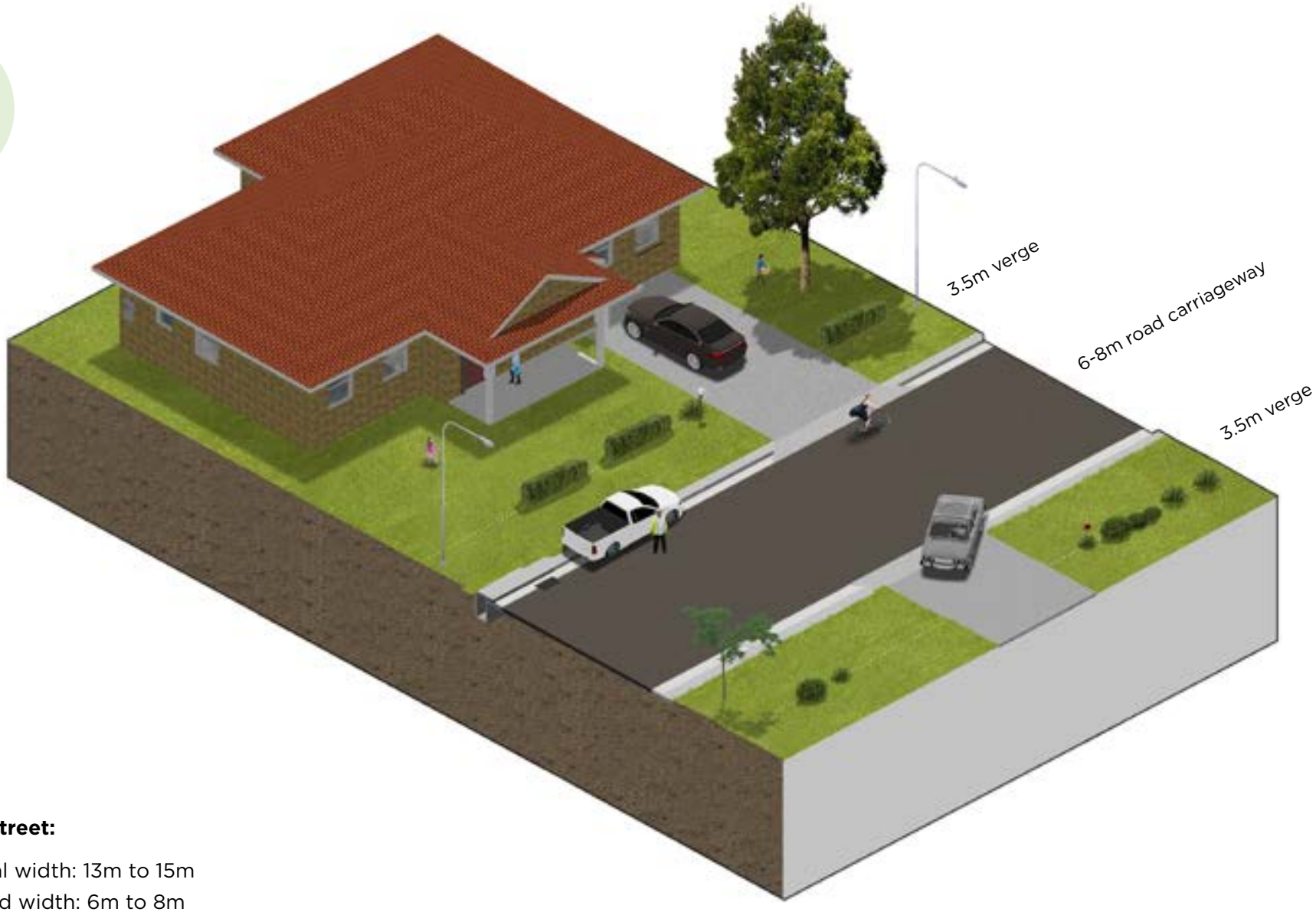
Example: Hamlet Crescent

Figure 31: Axon-metric section of existing local connector

Potential Local Connector arrangement:

1. Place trees on-road 2.5m wide blisters for traffic calming.
2. Capture road runoff using a modified kerb and channel that directs water to the trees for irrigation.
3. Provide infiltration trench or drop-down kerb for passive irrigation of grass verge tree planting.

Figure 32: Axon-metric section of potential local connector



Local Street:

- Total width: 13m to 15m
- Road width: 6m to 8m
- Footpath: none
- Other: informal parking possible
- Function: residential

Example: Valentine Place

Figure 33: Axon-metric section of existing local street

Potential Local Street arrangement:

1. Place trees on-road as 3m wide blisters for traffic calming and defining a shared zone.
2. Capture road runoff using a modified kerb and channel that directs water to the trees for irrigation.
3. Provide infiltration trench or drop-down kerb for passive irrigation of grass verge tree planting.

Figure 34: Axon-metric section of potential local street

Street orientation

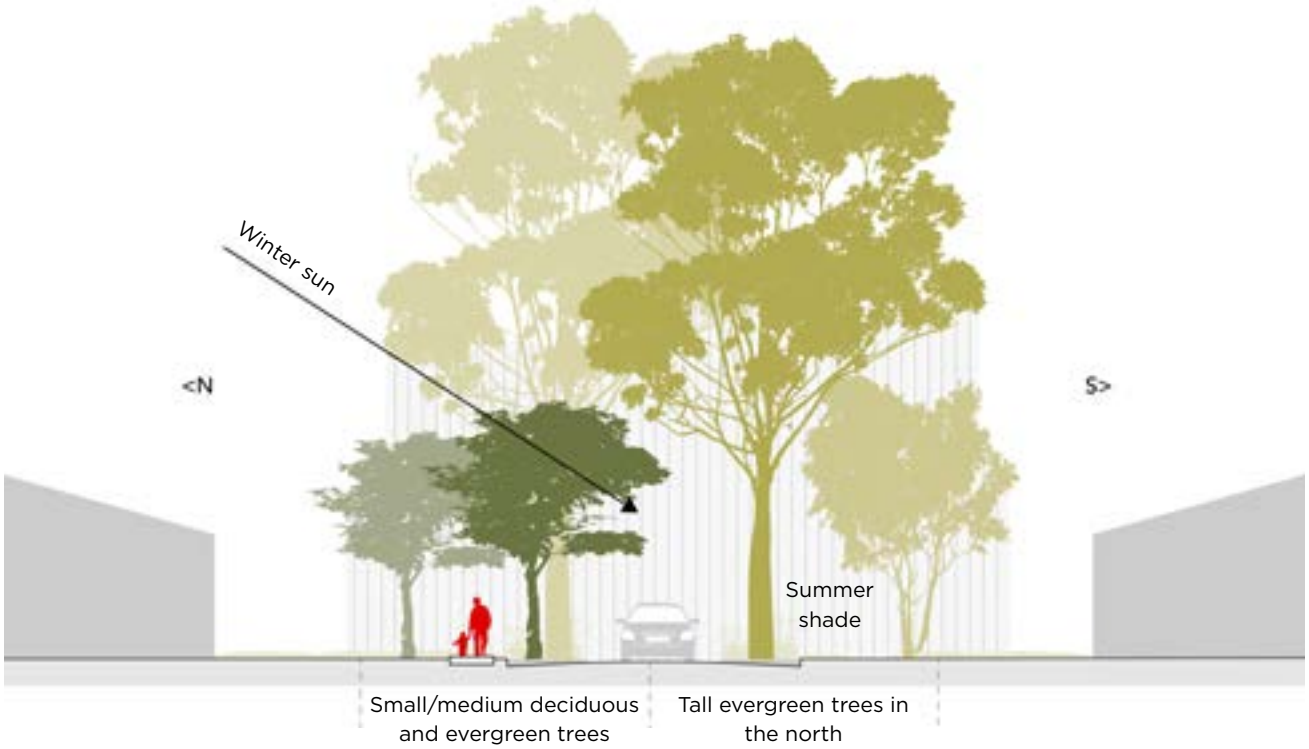
Maintaining human thermal comfort is essential for pedestrians and cyclists. Modification of street microclimates using tree canopy cover can provide important cooling and warming benefits through the day and seasons.

In streets with high-percentage canopy cover, air temperature, relative humidity, solar radiation, and mean radiant temperatures, will be significantly lower than in streets with low-percentage canopy cover.

The reductions in air temperature under high-percentage canopy cover are greater for east–west streets than for north–south streets.

On the following page, street sections show the best arrangment and selection of trees to create ideal microclimates throughout the day and seasons. These can then be applied to the relevant street orietations in Rosemeadow as indicated in the below plan..

Figure 35: Plan showing street orientation in relation to tree planting in Rosemeadow.

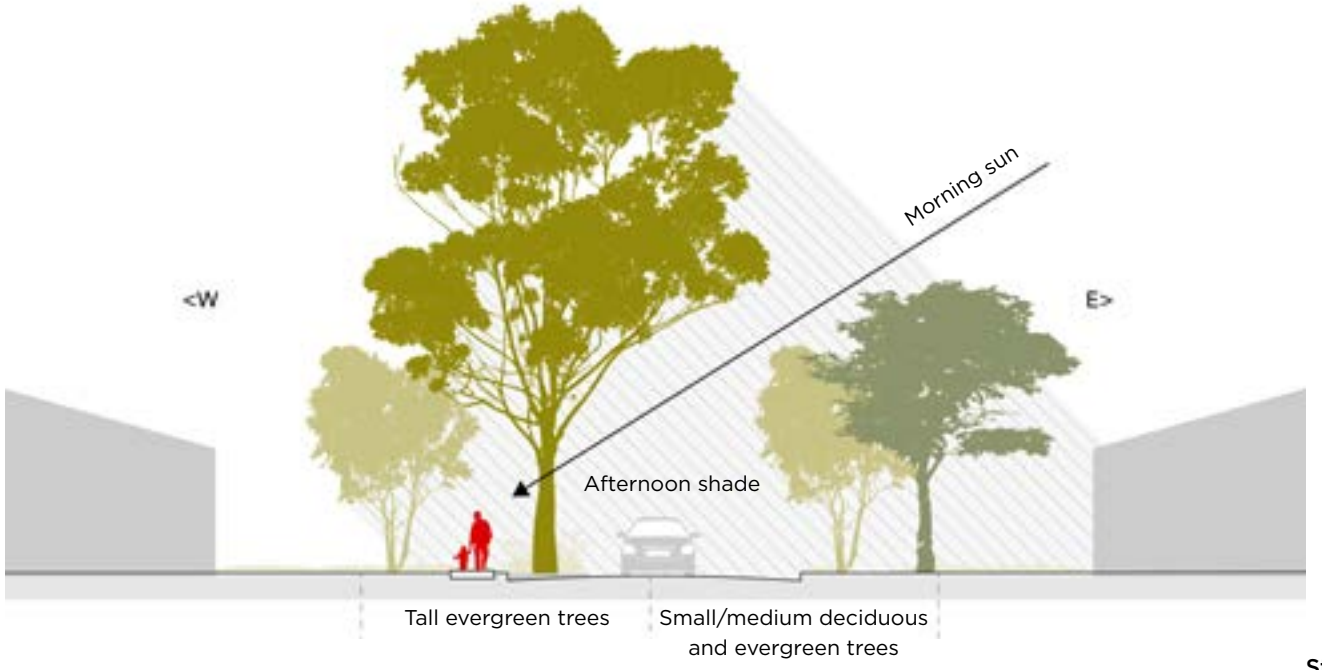


East–west orientated streets

The midday thermal benefits are restricted on E–W streets which are oriented in the same direction as the summer sun's zenith. Therefore, it is important to create a fully closed tree canopy to maximise shade and thermal benefits.

Using a mix of deciduous and evergreen trees on the north side of the street will provide thermal warming in winter. Planting evergreen trees on the south side of the street will maximise shade and thermal benefits all year round.

Figure 36: Section showing a typical east-west orientated local connector street



North–south orientated streets

For N–S streets air temperature, mean radiant temperature and solar radiation are greater on the east side in the early morning and greatest on the west side in the mid-afternoon. Planting small to medium deciduous trees on the east side of the street will take advantage of the thermal warming of winter morning sun. Planting large and small evergreen trees on the west side of the street will block the undesirable afternoon sun all year round.

Figure 37: Section showing a typical north-south orientated local connector street

Engineered solutions

There are four tree planting solutions that have been selected for the streets of Rosemeadow:

Solution 01 - Open tree pit

Tree planted within garden area created in a 'bump-out' into the roadway, which can be also be used for traffic calming, pedestrian crossing points or parking delineation. Kerb and channel provides opportunity for passive irrigation.

1. Broken kerb inlet on road-side
2. Tilted kerb inlet
3. Dense understorey planting
4. Sandy loam soil media, typically 600mm to 1000mm depth.
5. Structural zone of influence
6. Back-of-kerb ag-drain can also service tree pit. Place within gravel trench, full depth of tree pit. The invert should be min. 500mm below the surface of the soil, and ideally elevated ≥100mm above base for water retention and infiltration.
7. Road base

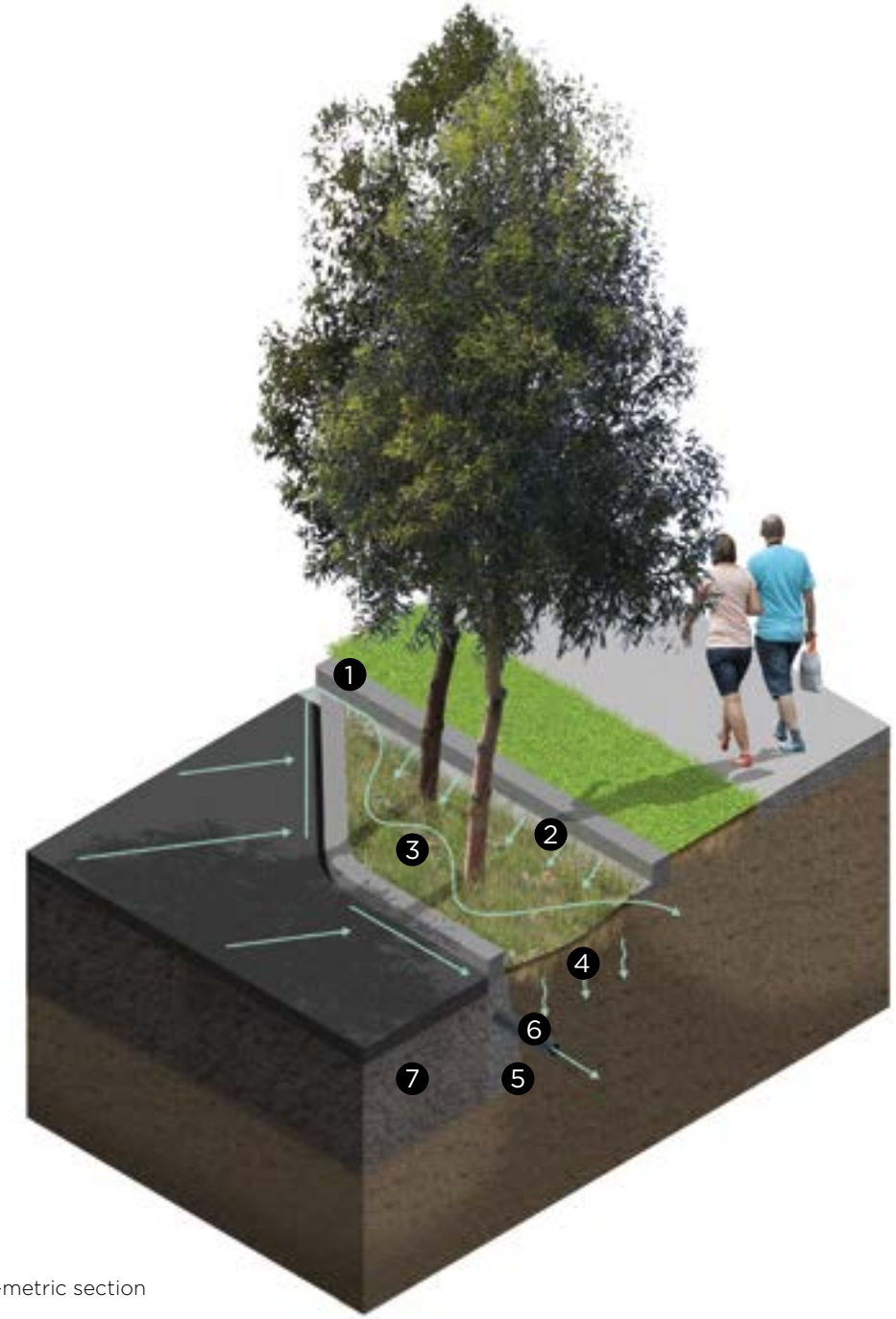


Figure 38: Open tree pit – axon-metric section

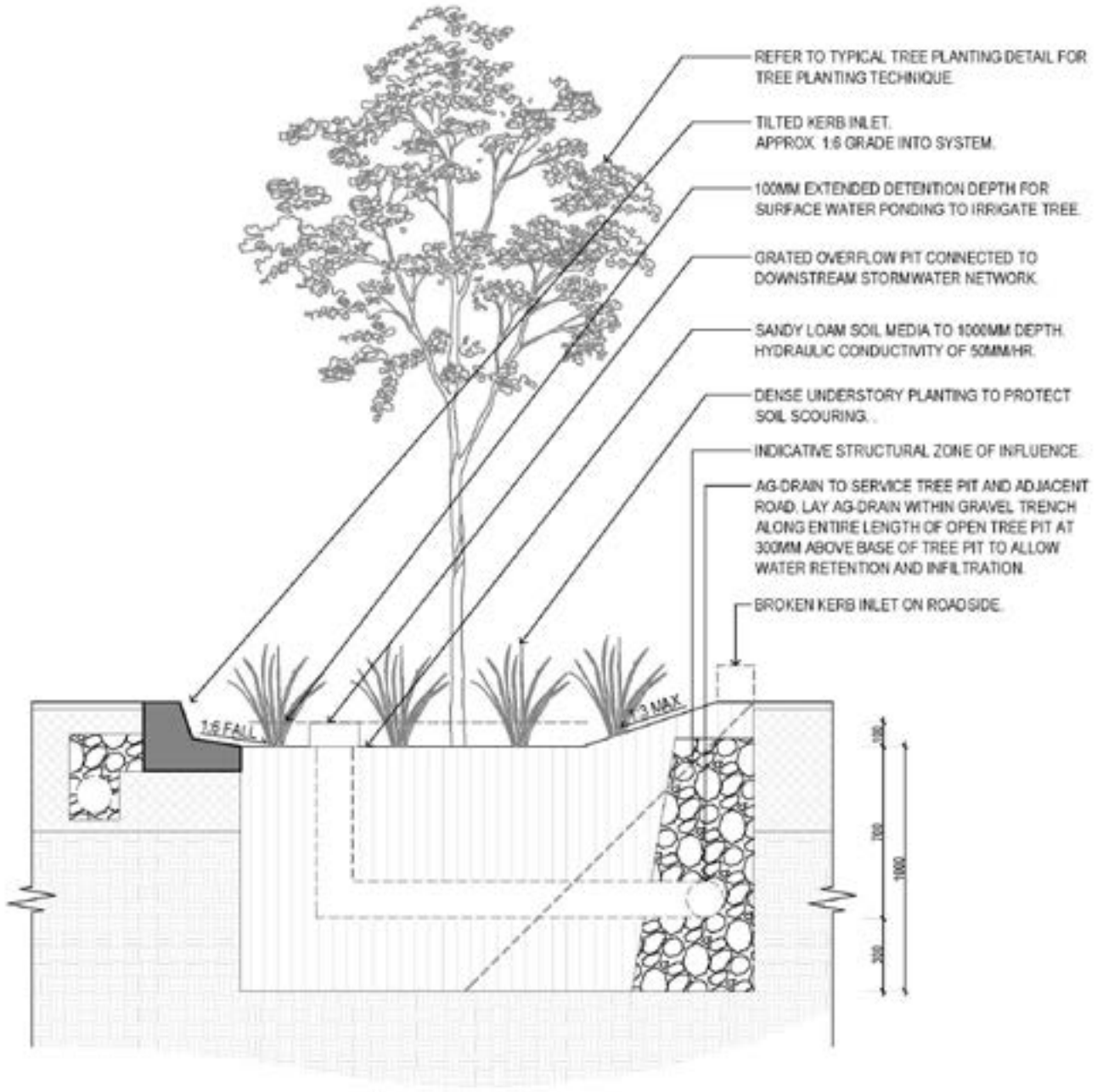


Figure 39: Open tree pit – detailed section (n.t.s.)

Solution 02 - Trees in grass verges

Create rain garden or 'moat' around tree which allows tree to be fed by road runoff via a kerb cut or side entry.

1. Drop in kerb to allow flows from road to enter
2. Batters at max. 1:4
3. Sandy loam soil media, typically 600mm to 1000mm depth. Min. 12m^3 soil volume preferred
4. Structural zone of influence
5. Back-of-kerb ag-drain can also service tree pit. Place within gravel trench, full depth of tree pit. The invert should be min. 500mm below the surface of the soil, and ideally elevated ≥100mm above base for water retention and infiltration.
6. Road base

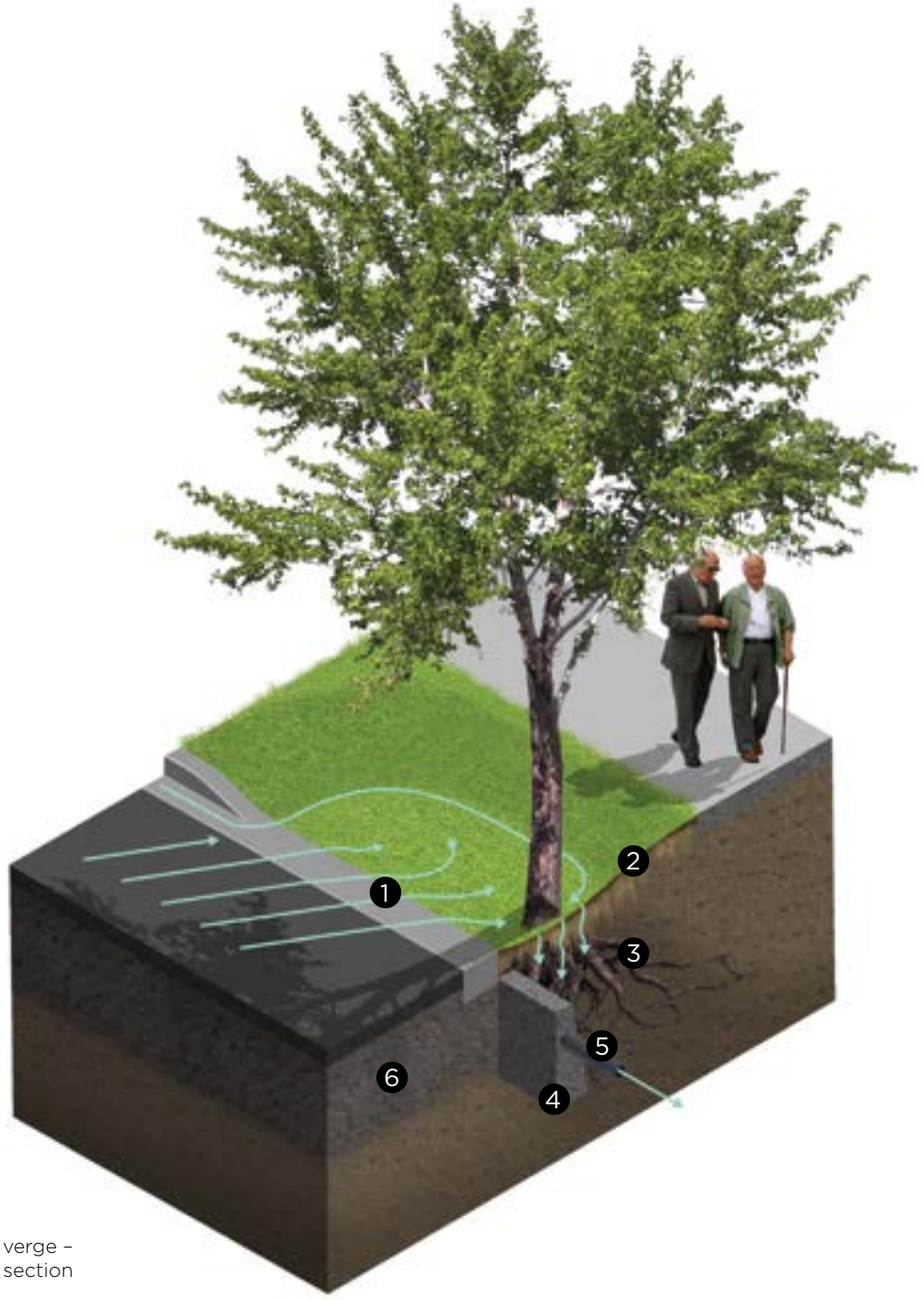


Figure 40: Trees in grass verge – axon-metric section

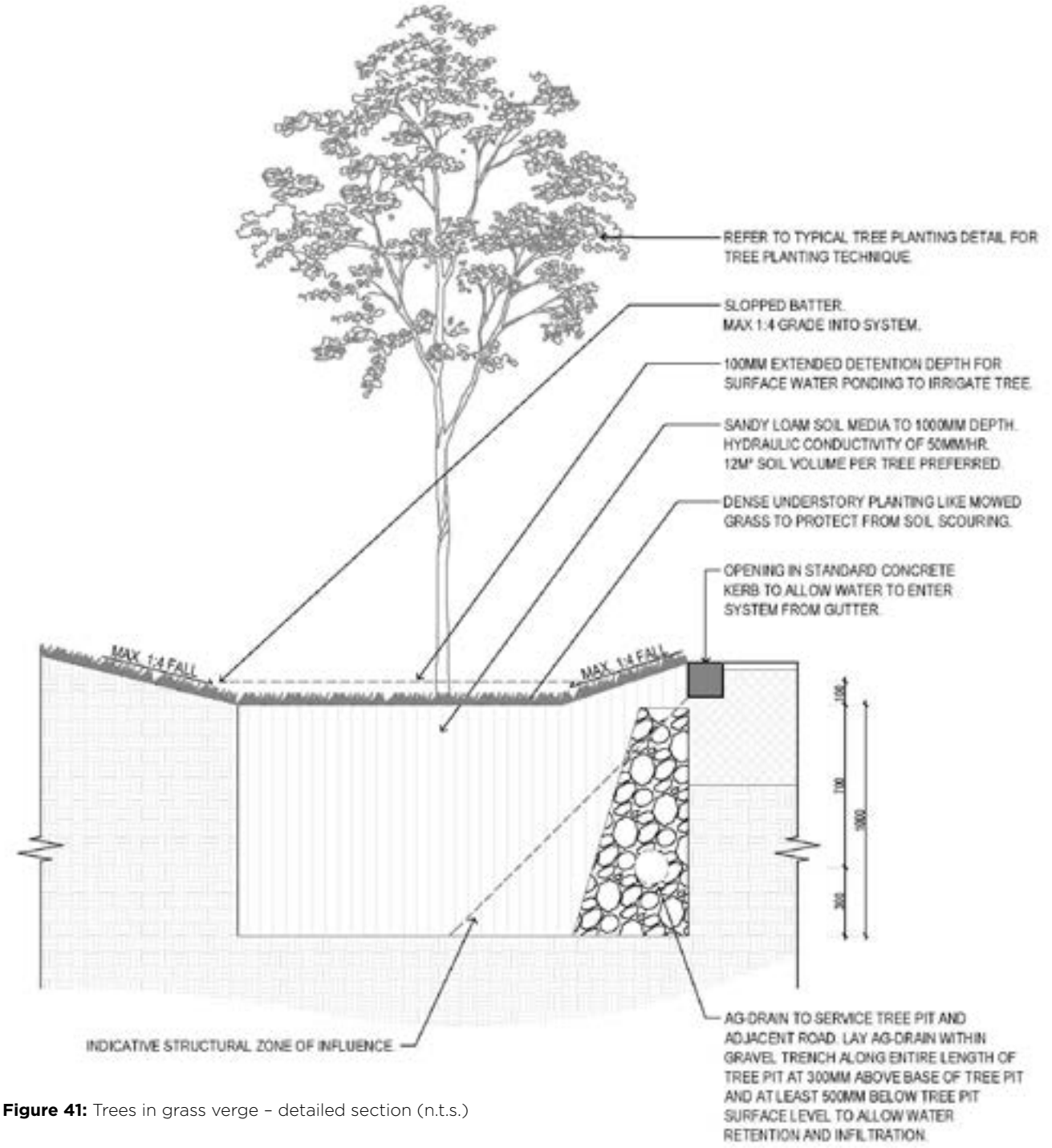


Figure 41: Trees in grass verge – detailed section (n.t.s.)

Solution 03 - Infiltration trenches

Infiltration trenches adjacent to trees are a low-cost option to provide passive irrigation without under drainage.

1. Ag-pipe lowered from kerb to allow water to enter. Inlet should be angled towards soils to prevent build up of sediments within the inlet (behind the kerb)

Figure 42: Nature strip infiltration trench – axon-metric section

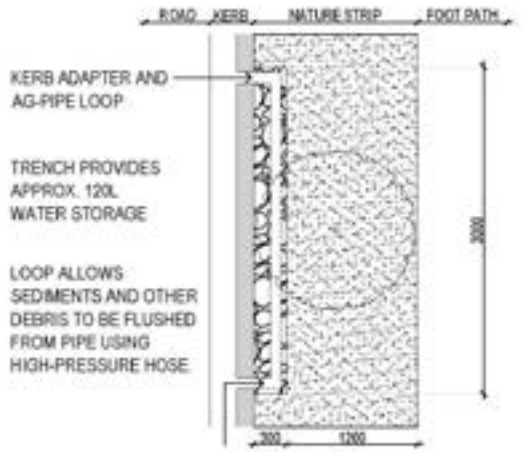


Figure 43: Nature strip infiltration trench – detailed plan (n.t.s.)

Figure 44: Nature strip infiltration trench – detailed section (n.t.s.)

Solution 04 – Drought-tolerant species

Careful species selection, site preparation and maintenance can generate good results without the need for passive irrigation in particular soil types and locations.

1. Tree growing area is maintained with bowl-shaped 50mm to 100mm layer of woody mulch.
2. Soil inoculation with beneficial fungi, bacteria and other micro-flora.

Figure 45: Drought-tolerant species – axon-metric section

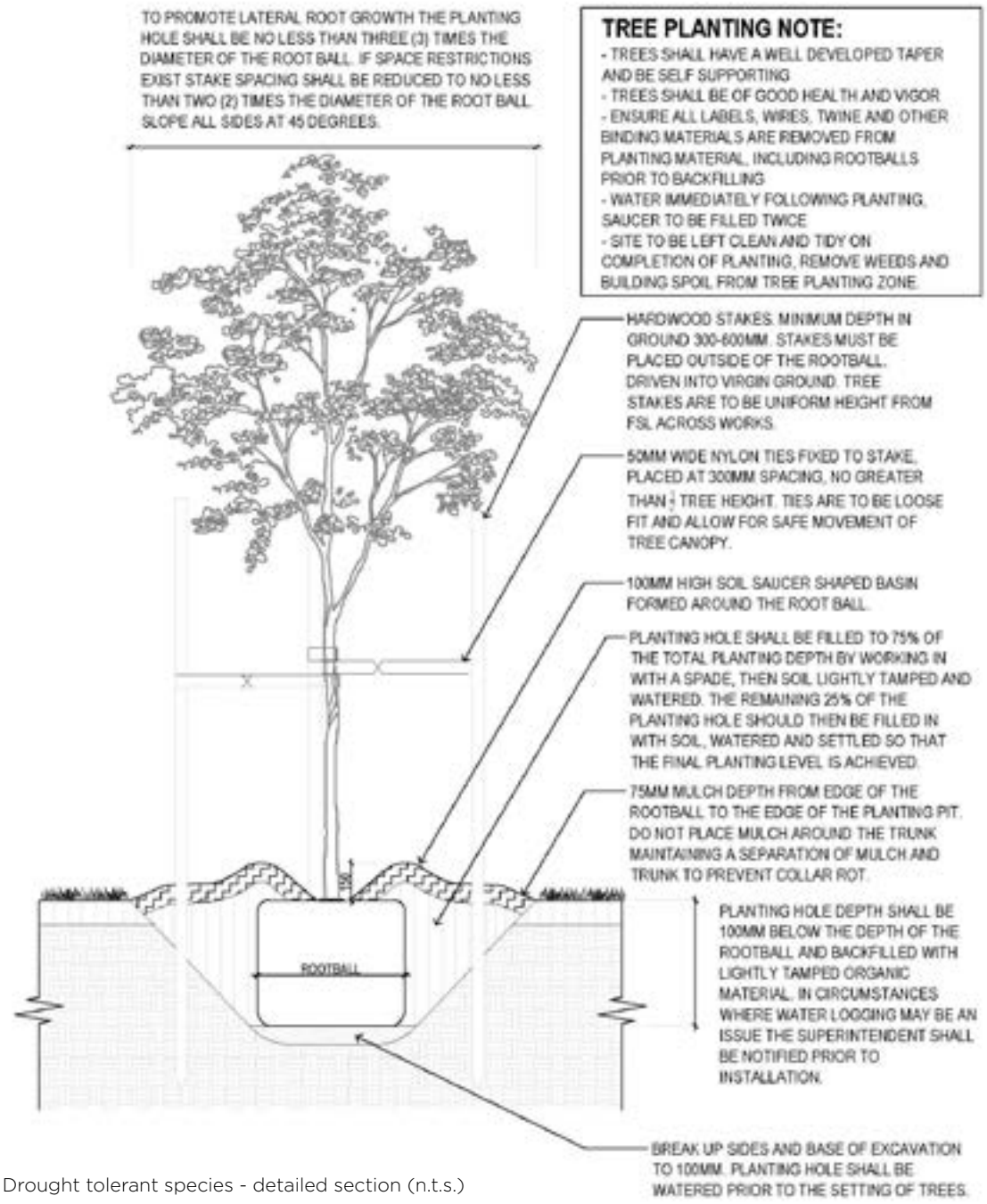


Figure 46: Drought tolerant species - detailed section (n.t.s.)

Part 3:

Design components

Designs need to be tailored to the street context; however, a common range of design components can be organised to create a bespoke design for most street contexts in Rosemeadow.

Stormwater inlets

Figure 47: Kerb side opening allows stormwater to enter soil

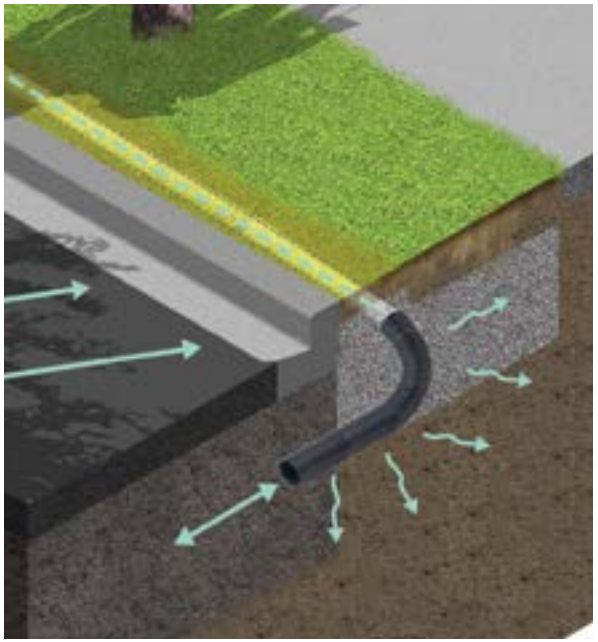


Figure 48: Graphic representation of subsurface infiltration

Side kerb opening inlets

- Kerb openings are formed through the creation of 'gaps' in the kerb to allow stormwater to freely pass horizontally to the soil media.
- Simple to construct.
- Collects small and large debris.
- Can allow high inflow velocities. Rock at opening can be used to dissipate energy upon entry. Multiple kerb openings promote distributed inflows to occur.

Subsurface infiltration

- Allows water to infiltrate into the soil surrounding the tree roots while maintaining flush soft finish levels at the surface.
- Configurations vary (see storage reservoirs), including:
  - Kerb adapter ag-pipe within a gravel trench located adjacent to the tree or around the tree trunk
  - Infiltration well connected to underground inlet.

Stormwater outlets

Figure 49: Kerb overflow. *Source: E2 Design Lab*

Figure 50: Excess water exits via overflow outlet

Figure 51: Inlet controlled outlet

Kerb overflows

- Outlets at downstream of the system can be designed to allow excess stormwater to pass out of the system and continue downstream. This may occur for designs with kerb edges where an opening is provided on the downstream edge.
- The surface level should be lower than the surroundings to ensure regular stormwater inflows pond within the system and do not quickly pass through and exit.

Overflow pits

- High flow capture efficiency.
- Should be raised above the surface level of the tree to create extended detention for ponding.
- Connects to underground stormwater drainage.

Inlet controlled outlet

- In systems with extended detention, inlets may also act as a stormwater outlet whereby flows backwater into the kerb and channel once extended detention is reached.

Storage reservoirs

Figure 52: Side kerb opening outlet

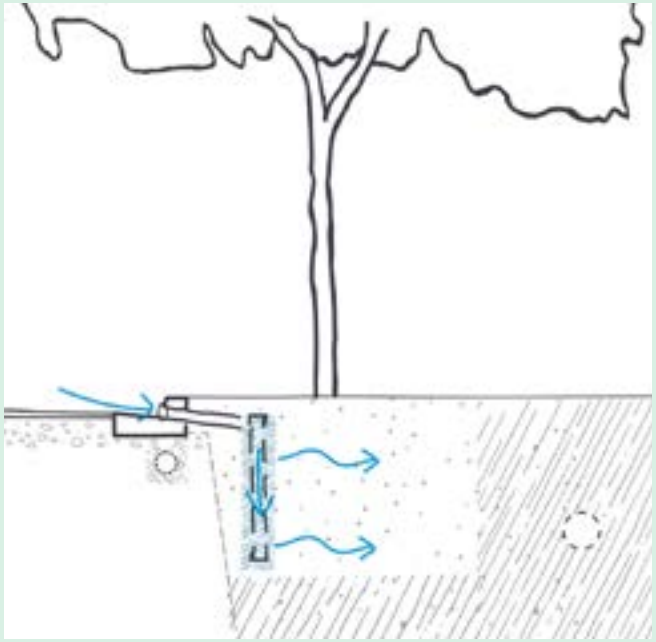


Figure 53: Graphic representation of an infiltration trench

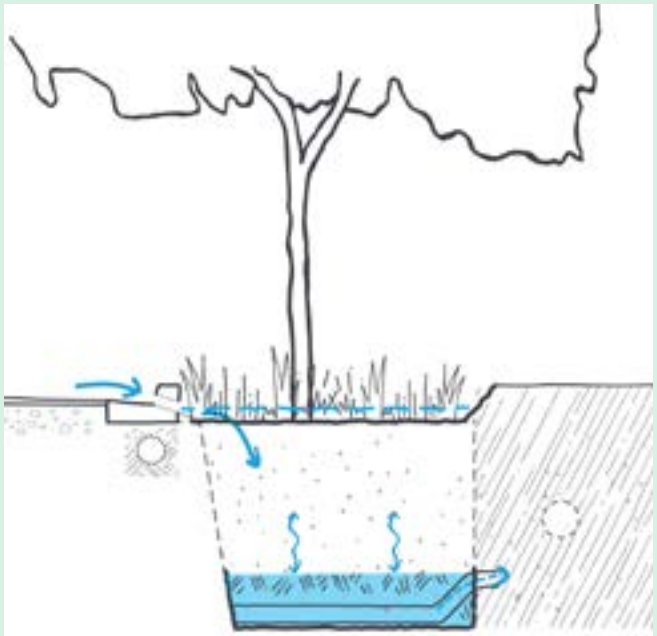


Figure 54: Graphic representation of wicking zone

Extended detention

- Most common form of capture storage where the surface levels are lowered from the inlet to allow water to pond and soak into the tree's soils.
- Storage reservoir volume is dictated by the depth and area of the extended detention.
- Extended detention can also be provided under paved areas using structural soil systems with gravel in the top layer to create void space for water storage.

Infiltration trenches and wells

- Infiltration trench: gravel trench and slotted ag-pipe. Cheap and simple ways to achieve infiltration.
- Infiltration well: dedicated storage or soakage well. Typically filled with gravel encased in a permeable geotextile. Can be used to connect nearby underground stormwater network to tree.
- Means that soil surface levels can be flush with surrounds, instead of lowered for ponding.
- Storage reservoir volume is dictated by the void space and total volume of gravel.

Wicking zones

- There are two types of wicking zones: a sealed dedicated wicking zone with porous wicking bed material, or less structured approach using a saturated deep soil zone (created using an elevated underdrain) over low permeability subsoils.
- Supports healthy tree growth (trees will uptake the water as they need it).
- Means that surface levels can be flush with surrounds, instead of lowered for ponding.

Tree hardware

Figure 55: Tree guards

Figure 56: 'Root Barrier on Brown Road: Petaluma, California 2013' by DeepRoot Green Infrastructure

Figure 57: Timber stakes and fabric ties

Tree guards

- Protect trees from accidental damage or vandalism.
- Design should allow for easy removal once the tree is of sufficient size. Segmented types that can be disassembled from around the tree are preferable to single-piece structures.
- Minimum intrusion into the ground should also be considered as footing for tree guards can form an obstruction to root growth and displace valuable root volume.

Root barriers

- Adequate soil volume and quality should be considered first. If not achievable, root barrier will be required.
- Root barriers may be required adjacent to kerbs, to deflect roots away from structures and avoid damage.
- Root barrier cannot guarantee protection of infrastructure and requires specialist knowledge in design, installation and maintenance.

Source: www.flickr.com/photos/deeproot/17977570881.
License at creativecommons.org/licenses/by-nc-nd/2.0/

Plant stakes & ties

- Best practice is for tree stock not to require staking for support.
- Trees that become reliant on stakes for support develop weak stems that do not strengthen naturally.
- Where stakes are necessary, there should be sufficient flexibility in the ties to allow some movement of the stem, which will promote increase in stem calliper and strengthening of the trunk.

Surface treatments

Figure 58: Tree planted in surrounding vegetation

Figure 59: Tree planted in bare soil with mulch

Figure 60: Tree planted in gravel (decomposed granite)

Vegetation

- Groundcovers, sedges and grasses are preferable to grass for ecological and aesthetic reasons as well as maintenance cost.
- They can remove nutrient and pollutants from stormwater.
- Vegetation also provides natural mulch and surface stabilisation.

Bare soil pits

- Low-cost soil surface finish.
- Design may be susceptible to erosion and weeds.
- Best suited to flat sites.

Stabilised sand/gravel

- Advantages – cheap and easy to install and replace.
- Disadvantage – can be damaged by street sweepers, and the sand can deposit in drains.
- Not ideal adjacent to permeable pavement, as the sand can clog the pavement requiring increased maintenance regimes.

Edge treatments

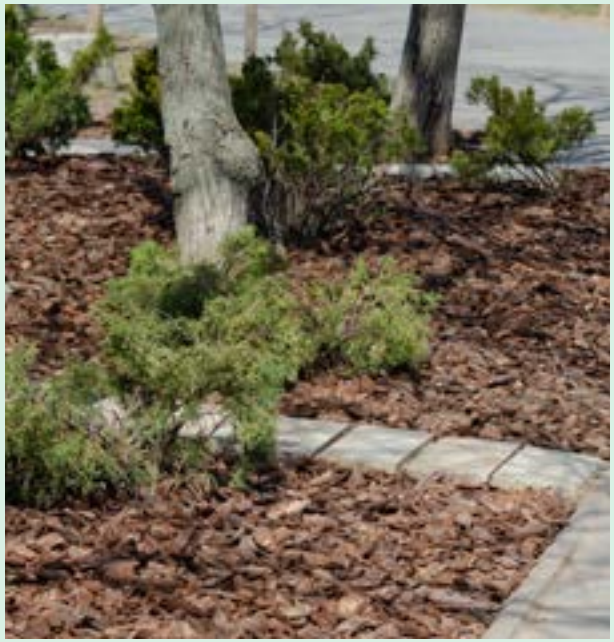


Figure 61: Mulched tree pit

Mulch

- Light mulches with high organic content can wash into stormwater networks and damage waterways.
- Dense planting or non-floating mineral mulch alternatives are preferred over mulch to manage weeds and moisture loss.
- Keep mulch layers to a minimum, less than 30m.

Figure 62: Tree planting dropped below kerb

Drop kerb and vegetation

- Can be used to create flush visual effect when garden bed is sunken below the adjacent land.
- Surface level beneath vegetation should typically be sloped on the edges (e.g. 1 in 3 batters), to avoid a tripping hazard in case someone should step into the garden bed.
- Allow water to sheet into system.
- Vegetation buffers and slows flows entering system.

Figure 63: Concrete upstand kerb provides separation of road from pedestrians

Kerb upstand

- Effective in separating pedestrians, cyclists and vehicles from system.
- Cut-outs can be included in edge to allow surface flows to enter system.

Tree diversity

The greater the diversification of tree species within a given area, the lower the risk of losing the entire population in one disaster event such as a pest or disease attack or an extreme heat event. Diversification relates to:

- species and genus
- age
- growth rates.

Ensuring that these types of diversity are considered reduces the overall vulnerability of the tree population. As a general guide, no more than 30% of trees should belong to any one family, no more than 20% of trees should belong to a single genus, and no species should account for more than 10% of the tree population.

Diversification of origin should also be considered. Broad leaf exotics often provide greater shade and benefit to daily thermal comfort, however native trees provide greater ecological benefits, supporting a higher richness of biodiversity.

Figure 64: Diverse tree species providing good canopy

Tree species selection

Tree species selection is influenced by a range of factors including available overhead space, leaf fall, infrastructure risk, native/exotics and aesthetic considerations.

Available overhead space for tree canopy must be considered to avoid issues with powerlines. Full mature canopy and future infrastructure works must be considered when assessing appropriate tree species for a site. Tree species with small canopies are recommended for sites with overhead constraints.

Native species tend to be non-deciduous and therefore lend themselves to more successful implementation within open tree pits. Native species are also generally better suited to Australian conditions and can be hardier through dry periods.

Deciduous trees can have a large impact on the performance of other infiltration systems. Autumn leaf litter can block inlets and the high concentration of organic material can hamper the ability of water to soak into the system. Where possible, avoid planting deciduous species in or around open tree pits. When deciduous species must be near these systems, ensure that maintenance schedules are increased throughout autumn to intercept leaf fall.

Certain species have aggressive root systems that actively seek out underground water, and can cause problems for nearby underground infrastructure. Care must be taken when planning near underground services. Arborists should be consulted before the specification of plantings to ensure they suit the context and conditions.

Environmental selection criteria

- Climate: Consider that in addition to the prevailing climate there are micro-climatic conditions that exist such as wind, reduced solar amenity, radiated heat from surrounding buildings and pavements.
- Soils: Consider that the soils may be highly modified or disturbed and in poor condition. Compacted soils and paved areas will also reduce the amount of oxygen that is available to the roots.
- Contribution towards micro-climate: Choose species that can improve the micro-climate of the street, for example by providing shade and reducing glare and ultra-violet light in summer, and/or winter deciduous trees that will allow sun through in the colder months.
- Minimal water requirements: In order to reduce reliance on potable water use, species selected must be able to survive without further watering beyond early establishment.
- Tolerance of pests and diseases: Consider use of a diversity of tree species to reduce the impact of a particular pest or disease on any single species.
- Wildlife habitat: Preference the use of locally native and indigenous tree and plant species adjacent to waterways.
- Low risk of becoming an environmental weed: Species that pose a risk of becoming an environmental weed are generally not considered suitable. This is particularly important given proximity to the Georges River environs.

Management selection criteria

- High-performing species: Preference trees that establish quickly and those that have consistently performed well in local conditions.
- Litter (leaf, fruit) at acceptable levels: Preference species (or cultivars of species) with low levels of leaf and fruit drop where this is likely to be an issue.
- Minimal disturbance by roots to pavements, kerbs and roads: Plant appropriately sized trees to ensure there is sufficient space above and below ground to allow the tree to grow undisturbed to prevent damage of surrounding hardscape by vigorous tree roots.
- Low maintenance requirements: Choose appropriate species that once established, should not require additional watering, fertilising and pruning beyond that of routine maintenance

Street aesthetic selection criteria

- Unity: Establish strong planting theme.
- Scale: Create the desired scale within the streetscape through use of the largest possible tree in each planting location, whilst ensuring that the tree height and width are appropriate for the street width and urban form of the street.
- Obstructions: Ensure there is sufficient space for the above and below ground parts of each tree to grow undisturbed and to contribute the character of the streetscape

Tree schedule

The following tree list has been developed specifically for Rosemeadow; however, it aims to assist other councils in developing their own methodology for tree selection, particularly for the balance of species mix, growth rate, seasonality and origin.

Table 2: Tree species list

Suggested species			Growth rate			Seasonality		Origin	
Botanical name	**Common name**	**Family**	**Slow**	**Medium**	**Fast**	**Evergreen**	**Deciduous**	**Native**	**Exotic**
Small trees (Mature height 6m to 9m x spread 6m)									
Angophora hispida	Dwarf Apple Gum	Myrtaceae	●			●		●	
Backhousia citriodora	Lemon-scented Verbena	Myrtaceae	●			●		●	
Callistemon viminalis	Weeping Bottlebrush	Myrtaceae		●		●		●	
Callitris rhomboidea	Port Jackson Pine	Cupressaceae			●	●		●	
Cercis siliquastrum	Judas Tree	Fabaceae	●				●		●
Lagerstroemia indica x L. fauriei	Crepe Myrtle	Lythraceae		●			●		●
Melaleuca linariifolia	Narrow-leaved Paperbark	Myrtaceae		●		●		●	
Polyscias sambucifolia	Elderberry Panax	Araliaceae			●	●		●	
Prunus campanulata	Taiwan Cherry	Rosaceae		●			●		●
Syzygium leuhmannii	Small-leaf Lillypilly	Myrtaceae		●		●		●	
Medium trees (Mature height 10m to 15m x spread 8m)									
Acacia parramattensis	Parramatta Wattle	Fabaceae			●	●		●	
Acer buergeranum	Trident Maple	Sapindaceae		●			●		●
Allocasuarina luehmannii	Buloke	Casuarinaceae	●			●		●	
Angophora bakeri	Narrow-leaved Apple	Myrtaceae	●			●		●	
Brachychiton acerifolius	Illawarra Flame Tree	Malvaceae	●				●	●	
Brachychiton populneus	Kurrajong	Malvaceae		●		●		●	
Calodendron capense	Cape Chestnut	Rutaceae		●			●		●
Corymbia eximia	Yellow Bloodwood	Myrtaceae		●		●		●	
Eucalyptus sclerophylla	Scribbly Gum	Myrtaceae		●		●		●	
Exocarpos cupressiformis	Cherry Ballart	Santalaceae		●		●			
Malus floribunda	Japanese Crabapple	Rosaceae		●			●		●
Melaleuca decora	White Feather Honeymyrtle	Myrtaceae		●		●		●	
Nyssa sylvatica	Tupelo	Nyssaceae		●			●		●
Pistacia chinensis	Chinese Pistachio	Anacardiaceae		●			●		●
Large trees (Mature height 16m< x spread 12m)									
Angophora costata	Smooth Barked Apple	Myrtaceae		●		●		●	
Angophora floribunda	Rough Barked Apple	Myrtaceae		●		●		●	
Angophora subvelutina	Broad-leaved Apple	Myrtaceae		●		●		●	
Casuarina glauca	Swamp She-oak	Casuarinaceae			●	●		●	
Eucalyptus amplifolia	Cabbage Gum	Myrtaceae	●			●		●	
Eucalyptus crebra	Narrow-leaved Ironbark	Myrtaceae		●		●		●	
Eucalyptus fibrosa	Red Ironbark	Myrtaceae		●		●		●	
Eucalyptus melanophloia	Silver-leafed Ironbark	Myrtaceae		●		●		●	
Eucalyptus moluccana	Grey Box	Myrtaceae			●	●		●	
Eucalyptus robusta	Swamp Mahogany	Myrtaceae		●		●		●	
Eucalyptus sideroxylon	Mugga Ironbark	Myrtaceae		●		●		●	
Melia azedarach	Chinaberry	Meliaceae		●			●	●	
Pyrus calleryana	Callery Pear	Rosaceae			●		●		●
Ulmus parvifolia	Chinese Elm	Ulmaceae		●			●		●

Figure 65: Quality nursery grown tree stock

Figure 66: High quality installation to trees

Sourcing and procurement

Beyond the selection of an appropriate species for planting, consideration needs to be given to the availability of plant stock in terms of pot size, quantities and quality.

Availability

Tree stock is often grown in containers and sourced from commercial nurseries. Some tree stock is grown in-ground and transplanted to containers prior to delivery. To ensure trees are a suitable size for street conditions, pot sizes should range from 45L to 200L.

Limited quantities of trees are grown by nurseries, depending on their popularity and commercial viability. Unusual tree species or large quantities will need to be pre-ordered several years in advance.

Some local tree species may be required to preserve genetic integrity. Where local tree species are required, procurement should be undertaken several years in advance so that seeds can be collected and grown on.

Quality

The quality of tree stock can be variable. To ensure consistent high-quality tree stock, Natspec guideline *Specifying Trees – a Guide to Assessment of Tree Quality* and Australian Standard 2303:2018 *Tree stock for landscape use* should be used. The guidelines outline how to specify and assess tree stock quality to industry best practice.

Tree stock branch and root structure is especially critical for their long-term success. If not supplied to industry best practice, tree stock may result in future structural defects or weaknesses that lead to safety hazards such as falling limbs or uprooting by wind.

Establishment and maintenance

To ensure the best possible establishment and future tree canopy outcomes, a high level of maintenance is required for the first two growing seasons. This will include:

- regular watering
- monitoring for pests and diseases
- potential formative pruning.

Figure 67: Maintenance of trees

Due to the increasingly high temperatures experienced in Greater Sydney, it is recommended that a dedicated team is engaged to manually water trees that are less than 3 years post-planting. These trees will require supplementary watering a few days prior to extreme temperature days (e.g. days > 35 degrees).

Larger scale plantings should have a dedicated team to carry out watering, fertilizing and inspections for the establishment period.

Watering

Passive irrigation should not be relied upon for watering new tree plantings. Supportive watering is critical to tree survival.

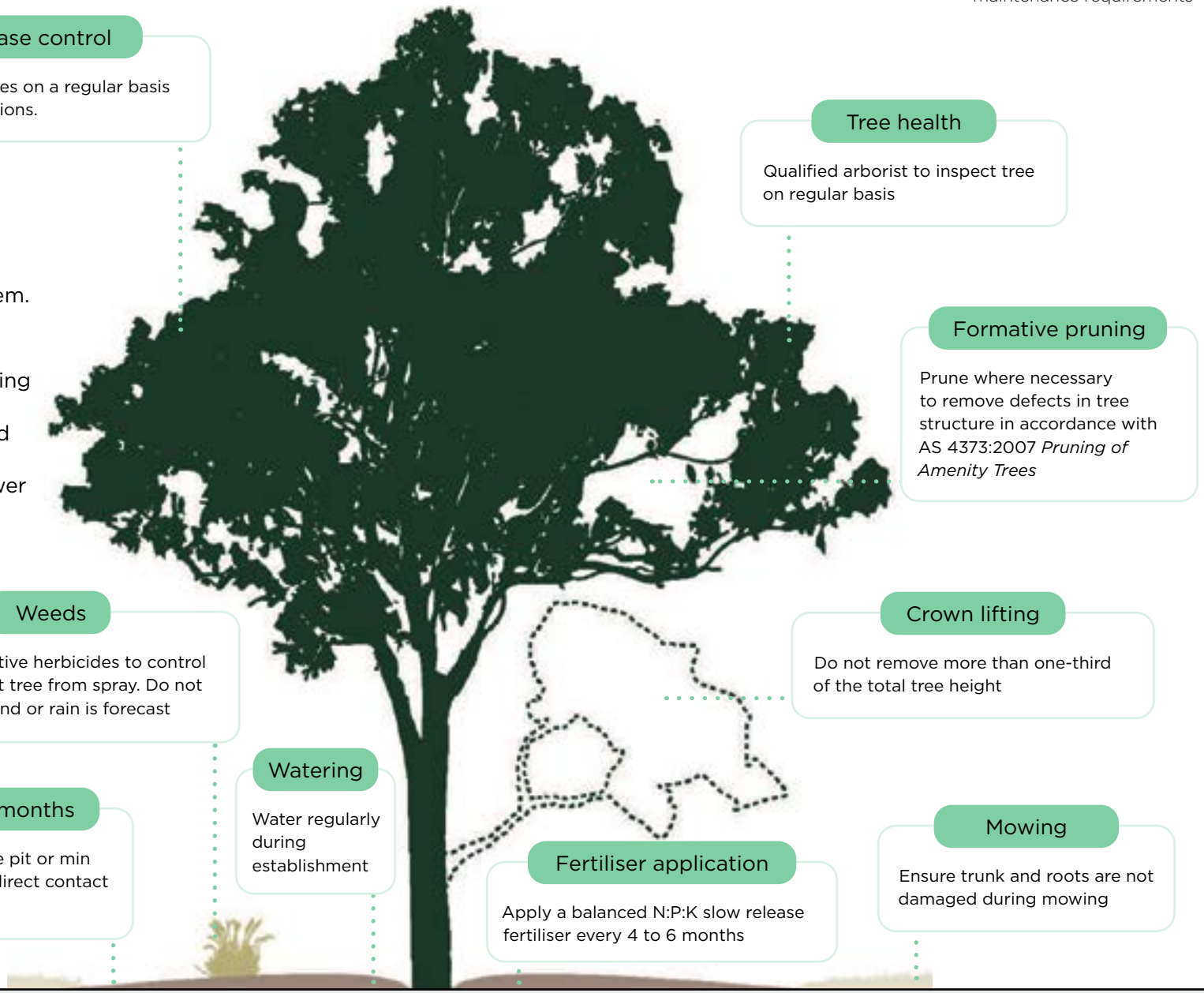
- Trees need to be watered 50% of the root ball volume immediately upon arrival on site and again after planting, e.g. 100L for 200L trees.
- Trees need to be watered daily in the first weeks.
- Trees need more water in summer, less in spring/autumn, and less again in winter as shown in the table.

Time of year	Watering frequency		
	1st month	2nd and 3rd month	Establishment period
Sep-Feb	4 x per week*	3 x per week*	2 x per week*
Mar-May	3 x per week*	2 x per week*	1 x per week*
Jun-Aug	2 x per week*	1 x per week*	1 x per fortnight*

* Generally, the larger the tree container size, the longer its watering needs will need to be to achieve establishment.

Container size	Free draining	Heavy/clay
45L	10L	5L
100L	20L	15L
150L	30L	20L
200L	40L	30L
250L	50L	35L
300L	60L	45L
400L	80L	60L
500L	100L	75L

Figure 68: Graphic section illustrating maintenance requirements



Fertilising

- Established trees (e.g. >2 years post-planting) may only need one application of fertiliser to assist them.
- In the landscape nutrients are provided by decomposing organic matter such as fallen leaves, decaying mulch, and minerals in the soil. Long-term Fertilising of established trees is probably unnecessary (except perhaps where fruit or flower production is the aim).

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