Office of Environment & Heritage

URBAN GREEN COVER IN NSW

TECHNICAL GUIDELINES

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Main image, front cover: Darling Park (Photograph: Courtesy City of Sydney)

Small images (left to right):
Urban Native Garden (Photograph: N. Kapos)
Planting the Thornley Street raingarden (Photograph: Courtesy Marrickville Council)
De-channelisation at Fairfield (Photograph: L. Hobbs)
360 M-Central green roof (Photograph: Courtesy City of Sydney)
Bligh Street Green Wall (Photograph: Courtesy City of Sydney)

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(Photograph: Western Sydney Parklands Trust)

MINISTER'S FOREWORD

The NSW Government is taking action to minimise and accommodate the impacts of climate change on our local communities. This includes understanding how climate change will not only affect local environments, but how changes to the environment and the climate will impact on everything from health services to local infrastructure.

In NSW almost 90 per cent of our population lives in towns or cities, so it is essential we adapt our urban environment to withstand projected increases in extreme events such as heatwaves, intense storms and localised flooding.

The information in the following pages provides practical guidance on how to adapt the urban environment through urban green cover projects. Urban green cover includes a range of strategies such as vegetated and reflective roofs, green walls, street plantings, permeable and reflective road surfaces, and cool open spaces and parks.

These relatively low-cost approaches can cool our cities and towns while providing benefits such as reduced energy costs for cooling, stormwater management, cleaner air and biodiversity habitat.

Best of all they make our neighbourhoods more pleasant places to live.

The Urban Green Cover Guidelines will assist NSW built environment professionals increase resilience to future extreme events and natural hazards and help communities prepare for a changing climate. I trust you will find them a useful resource for planning and achieving more liveable and resilient neighbourhoods and communities in NSW.

Rob Stokes MP
Minister for the Environment
Minister for Heritage
Minister for the Central Coast
Assistant Minister for Planning

CONTENTS

GLOSSARY

Australian Standard

Australian Standards are 'published documents setting out specifications and procedures designed to ensure products, services and systems are safe, reliable and consistently perform the way they were intended to. They establish a common language which defines quality and safety criteria.' (Standards Australia, 2013)

Bioswale

Bioswales are bioretention systems that are located within the base of a swale. The bioretention system involves some treatment by vegetation prior to the filtration of runoff through a prescribed media. Following treatment water may be infiltrated to the subsoil or collected in a subsoil pipe for retention or disposal (South Australian Department of Planning and Local Government 2009).

Building Code Of Australia

'The Building Code of Australia (BCA) is Volumes One and Two of the National Construction Code (NCC). The BCA is produced and maintained by the Australian Building Codes Board (ABCB) on behalf of the Australian Government and State and Territory Governments. The BCA has been given the status of building regulation by all States and Territories.' (Australian Building Codes Board, 2011)

Climate Change

'A change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.' (Intergovernmental Panel on Climate Change 2012, p.167)

Cool Carpark

Cool carparks include strategies of increased canopy tree planting, median and bioswale planting and the use of permeable pavements to help reduce the surface and ambient temperature and to modify the micro climate.

Cool Roof

Cool roofs are designed to increase reflection of sunlight while maintaining the aesthetic of more traditional non-white roofs.

Cool Pavement

Cool pavements include reduction in the surface area of hard paving with an increase of soft landscaping with planted areas or grass, to help reduce the surface and ambient temperature and to modify the micro climate.

Cool Street

Cool streets can be achieved with an increase in canopy trees within the verge or carriageway, increased understory planting, bioswales/rain gardens and verge and median planting, to help reduce the ambient temperature and to modify the micro climate.

Ecologically Sustainable Design (ESD)

Ecologically sustainable development is: 'using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased'. (Australian Government, 1992)

Green Roofs

Green roofs are roof surfaces that are partially or fully vegetated.

Green Walls

Green walls are vegetated systems grown on the vertical facade of a building envelope.

Green Facade

A green facade is a system that mimics self-clinging plants but uses an engineered, trellis system to support the climbing plants off the building surface.

Park Cool Island (PCI) Effect

The modifying effect of green spaces on the urban micro climate is known as the Park Cool Island (PCI) effect.

Permeable or Porous Pavements

Permeable or porous pavements include gravels or unit paving systems with either cut outs allowing water to permeate through or porous pavers that allow water to filter through across the surface area of the paver.

Rain Garden

'Rain gardens are shallow planted depressions designed to take the excess rainwater runoff from a house roof or other building, assisting runoff to infiltrate the underlying soil, recharge the ground water, and reduce peak flows from the site' (South Australian Department of Planning and Local Government, 2009). Runoff from paved surfaces can also be directed into rain gardens.

Reflective Pavement

Reflective pavements are pavements with higher surface solar reflectivity, or high albedo. Reflective pavements have a cooling effect on surface and ambient air temperatures and over-night cooling of urban areas.

Resilience

'The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.' (Intergovernmental Panel on Climate Change, 2012)

Urban Heat Island (UHI) Effect

The Urban Heat Island Effect is 'localised warming due to the increase in the large amounts of paved and dark coloured surfaces like roads, roofs and car parks as a result of urban development. The sun's heat is absorbed, not reflected, and causes the surface and ambient temperatures to rise. Anthropogenic heat production, such as the heat produced through car engines and air conditioners also contribute to the Urban Heat Island Effect'. (Greening Australia, undated)

Water Sensitive Urban Design (WSUD)

'Water Sensitive Urban Design is about working with communities to ensure the planning, design, construction and retrofitting of urbanised landscapes are more sensitive to the natural water cycle.' (Sydney Metropolitan Catchment Authority, 2012).

White Roofs

White roofs are roofs made from white, reflective materials and are typically used when the roof surface is not visible from street level. These materials have high albedo that reflects and emits solar energy.

1 INTRODUCTION

Forest Lodge Eco House *(Photograph: Courtesy City of Sydney)*

(Photograph: Courtesy Marrickville Council)

1.1 UNDERSTANDING THE URBAN ENVIRONMENT

Australia is one of the most urbanised societies in the world, with approximately 89% of residents living in cities or towns (DIT 2013).

Urban centres bring services, transport and economic and social opportunities closer together. However urbanisation also results in the loss of natural landscape areas to man-made, engineered structures.

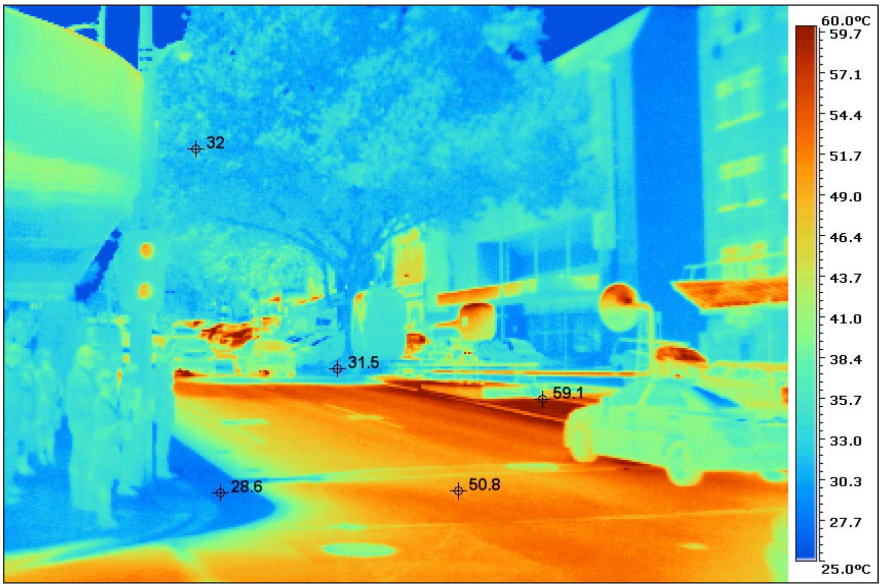
These dark, impervious surfaces and buildings absorb solar energy which causes the surface temperature of our cities and towns to rise as much as 10-20°Celsius higher than surrounding air temperatures (Taha, Akbari & Sailor 1992).

As the surface temperatures increase, overall ambient air temperature also increases. This temperature difference is larger at night as rural areas cool while dense urban environments remain relatively warm. This is commonly known as the 'urban heat island' (UHI) effect.

The higher temperature caused by the urban heat island increases demand for cooling energy in commercial and residential buildings, in order to maintain comfort levels. In addition, summer heat islands can have negative impacts on air quality, when nitrous oxides and volatile organic compounds combine to produce ground level ozone (SOS 1995).

The UHI effect is also compounded by the urban geometry, where the layout of urban streets can trap hot air and pollutants, and where lack of shade and green space can increase thermal loading in dense urban environments.

In short, urbanisation affects the urban climate by increasing temperature and impacting evaporation and wind.



A thermal image at the corner of Russell and Bourke Streets, when the day's top temperature was 32.4. Numbers on this photo indicate degrees Celsius.
(Photograph: Jason Dowling, courtesy City of Melbourne)

MINIMISING LOCAL TEMPERATURE IMPACTS IN CITIES AND TOWNS

Research demonstrates that increasing the vegetation on and around our urban environments produces a cooling effect for neighbourhoods and nearby buildings. This is because, unlike hard surfaces, trees and vegetation reflect heat and actively cool and clean the air by evapotranspiration.

The NSW Office of Environment and Heritage has modelled the influence of vegetation cover on land surface temperature in the Sydney Basin (Adams, M. A. and Smith, P. L. 2014). The research found that in Sydney during summer mornings, urban structures increase land surface temperature by 1.5°C. However, every 10% increase in tree cover can reduce land surface temperatures by more than 1°C. This means that a 14% increase in tree cover would completely offset the thermal loading effect of urban structures in the Sydney basin.

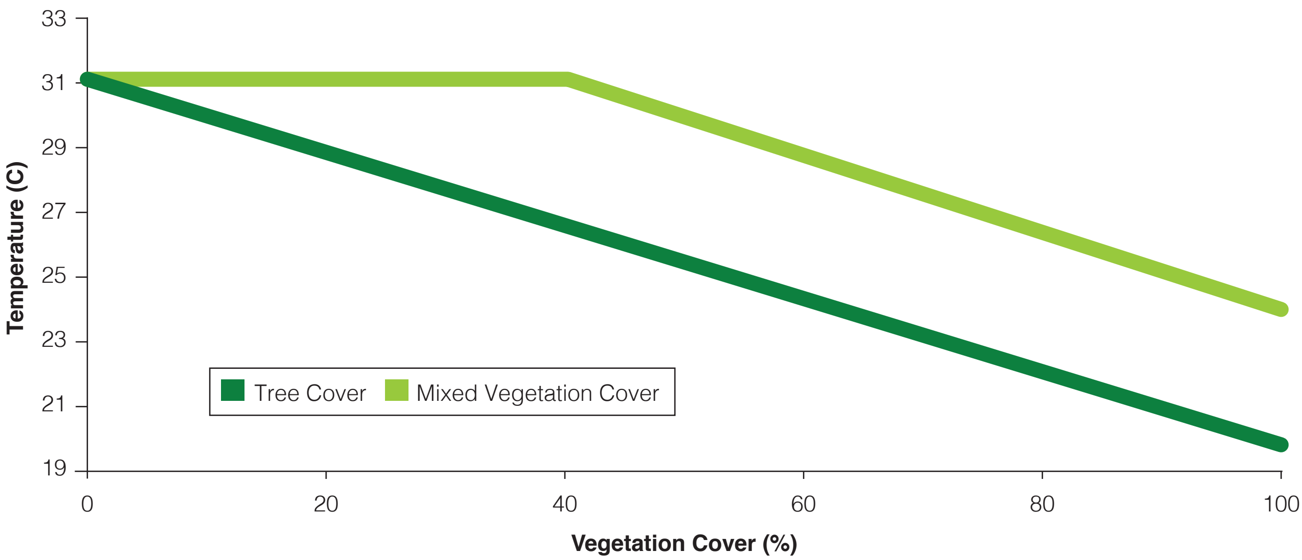


Figure 1: The modelled relationship between vegetation cover and land surface temperature

It was also found that when vegetation cover is greater than 40% of a total area, a 10% increase in vegetation leads to a reduction in land surface temperature of more than 1°C. However, when mixed vegetation cover is less than 40%, there is no reduction in land surface temperature.

It is likely that increasing global temperatures will exacerbate the urban heat impacts we already experience. Heat waves will inflict major human and economic costs on communities and are expected to be more frequent, hotter, longer and affect greater areas, under the influence of climate change (QUT 2010).

Building the resilience of NSW settlements and communities to natural hazards and future extreme events requires a long term view to minimise potential risks and protect our health, economy and community.

URBAN GREEN COVER

Urban green cover is a broad range of relatively low cost strategies to integrate green, permeable and reflective surfaces into cities and towns.

- **Green Roofs and Cool Roofs** are vegetated roofs and light coloured and reflective roof surfaces.

- **Green Walls** are vegetated walls and shaded walls.

- **Green Streets** means opportunistic street tree planting with shade providing canopy, mass planting understorey, bio-swales and median planting, as well as permeable and/or light coloured, highly reflective surfaces on roads, pavements and car parks.

- **Green open space** means canopy trees and shade provision to parks, cycleways, footpaths, amenities and forecourts, as well as green infrastructure such as bio-swales, raingardens, soft-landscaped detention basins, de-channelisation of hard engineering (concrete culverts).

By integrating vegetation, green spaces and permeable surfaces into our cities and towns, communities can adapt urban environments to minimise local temperatures, now and into the future. Increasing urban green cover provides effective and relatively low cost resilience to heat impacts while improving community amenity and providing multiple benefits.

1.2 WHAT IS URBAN GREEN COVER?

Urban green cover is the integration of vegetation with permeable and reflective surfaces to minimise local temperatures and encourage evaporation from soil and plants into the urban environment.

Urban green cover may include bushland, private and community gardens, parks, greenways, habitat corridors, street trees, green roofs and green walls, as well as reflective and permeable pavements and surfaces.

Increasing green cover in urban environments can be achieved in a number of ways, from protecting local green spaces and designing eco-friendly buildings, through to creating a green space network.

Urban green cover delivers a high performance landscape. Current global best practice integrates multiple environmental benefits, which can include:

- Stormwater management
- Thermal insulation
- Air quality improvement
- UHI effect reduction
- UV radiation protection for buildings
- Open space increase
- Evapotranspiration and increased vegetation
- Wildlife habitat and biodiversity increases
- Food production and urban agriculture
- Pollination of crops and other important plants
- Visual amenity and urban design
- Noise reduction
- Maintaining atmosphere composition: CO_2/O_2 balance
- Creating micro climates for buildings and urban canyons.

1.3 PROTECTING HEALTH, SAFETY, AND AMENITY THROUGH URBAN GREEN COVER

Living and working in urban areas can expose communities to heat impacts and heat related illnesses such as heat stroke. Major heat waves are Australia's deadliest natural hazard, particularly for cities (DIT 2013). Those at high risk from heat waves include the elderly (Hansen et al. 2011), people who live alone (Zhang et al. 2013), the socially disadvantaged such as those on lower incomes or the homeless (CSIRO 2011) and those with underlying medical conditions (Nitschke et al. 2011 and DIT 2013). Increasing the amount of green cover in urban areas can help manage the risks associated with exposure to urban heat (McPherson et al. 1994) and protect public health.

Green spaces are also shown to improve community cohesion and well being. Kuo et al. (1998) observed that the more trees and greenery that form part of inner-city public spaces, the more these spaces are used by residents. The study also found that, compared with residents living near barren spaces, those closer to greenery enjoy more social activities, have more visitors, know more of their neighbours, and have stronger feelings of belonging.

Wells and Evans (2003) found that children who live in close proximity to green space are more resistant to stress; have lower incidence of behavioural disorders, anxiety, and depression; and have a higher measure of self-worth (Grahn et al. 1997; Fjortoft and Sageie 2000).

Recent research has found direct links between urban green spaces and enhanced sense of wellbeing, improved mental well being, improved attention span and a reduction in stress and anxiety. This is a result of a number of factors including an increase in physical activity, an increase in social contact and the restorative qualities of green spaces that provide opportunities for relaxation and respite from the often demanding urban lifestyle (Ward Thompson et al., 2012).

More generally, parks, protected green space, gardens, street trees and landscaping in urban areas can provide vital ecosystem services, acting as green lungs absorbing and filtering air pollution, and filtering waste water (TEEB 2010). For example, in Chicago, urban trees provided a service for air cleansing that is equivalent to US$ 9.2 million dollars and their long-term benefits are estimated to be more than twice their costs (McPherson et al. 1994).

Urban green cover can decrease rainwater runoff through interception, storage and infiltration, and thereby replenish groundwater and lower the risk of flooding during peak flows.

A changing climate will have implications for the costs of, and approaches to, maintaining urban green space such as increased watering requirements during droughts, greater pressure on spaces as they are used more intensively and an effect on the health of some species of vegetation. Lawns in urban areas need to be well maintained to be effective because if grass becomes dry and bare it will have less of a cooling effect (Gill et al. 2007).

Millennium Park, Chicago
(Photograph: H. Lochhead)

1.4 PURPOSE OF NSW URBAN GREEN COVER TECHNICAL GUIDELINES

These guidelines offer built environment professionals working in state and local government and the private sector practical information and typical details to encourage best practice applications of green cover, so as to minimise urban heat impacts across NSW.

The guidelines include practical information for planning and implementing green cover, in consultation with urban design and engineering professionals, utilities and relevant stakeholders.

This information can also be used by local government for integration into strategic plans, development controls, public domain guidelines or urban design studies, so as to influence development outcomes in a local government area.

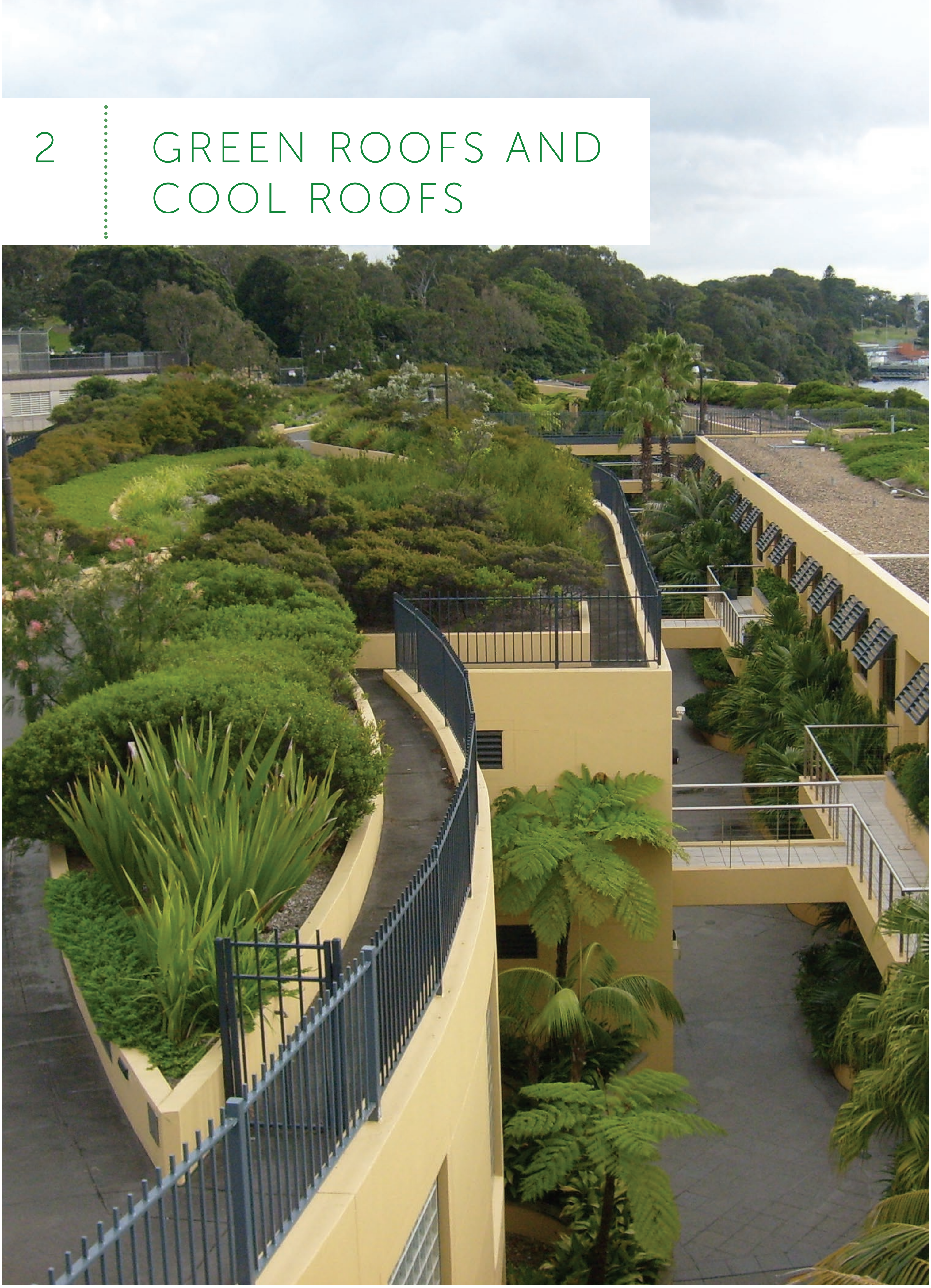
These guidelines complement the Department of Planning and Infrastructure's draft centres design guidelines, which encourage green cover in new centres, by promoting the protection of existing natural features and green links and increased green cover through street trees, green roofs and walls.

FAST FACTS

By increasingly integrating Green Cover, green spaces and permeable surfaces in our cities and towns, we can adapt our urban environments to climate changes and provide multiple benefits such as:

- **Heat mitigation:** Urban green cover reflects sunlight and can reduce air temperatures through transpiration, providing shade and passive cooling. This not only makes the urban environment more comfortable, but can provide health benefits reducing the incidence of heat related illnesses and deaths.
- **Energy efficiency:** The heat mitigating features of increased green cover can reduce the need for air conditioning in offices and homes.
- **Improved air quality:** Foliage can trap and remove carbon dioxide and pollutants from the urban atmosphere, especially air-borne particulates, keeping urban spaces cleaner and healthier.
- **Water absorption and improved water quality:** urban green cover and the soil or substrate in which it grows can capture storm water, reduce peak flows and improve water quality in urban streams and catchment health. Improved water absorption can also moderate localised flooding.
- **Noise reduction:** Urban green cover can insulate against urban noise pollution.
- **Biodiversity protection:** Urban green cover can provide important habitat and corridors for birds and animals. Biodiversity is vital for a healthy urban environment.

2 GREEN ROOFS AND COOL ROOFS



Wharf Terrace Woolloomooloo (Photograph: Courtesy City of Sydney)

POTENTIAL BENEFITS

- Reduced building heat absorption and radiation provides insulation and a cooling effect in warmer months and insulation during winter
- Reduced heating and cooling/energy consumption and costs and reduced strain on electrical grid during peak periods and temperatures, decreasing the risk of power outages
- Evapotranspiration creates a cooling effect, reducing temperatures and increasing humidity
- Reduced stormwater run-off, rainwater harvesting of roof water and reuse
- Air purification. Plants filter airborne particulates and absorb gaseous pollutants through photosynthesis
- Sound insulation
- Reduced greenhouse gas emissions
- Roof membrane protection and extended life span with reduced solar impacts, constant heating and cooling
- Increased usable square metres of a building with outdoor amenity and recreation spaces (intensive)
- Improved efficiency of photo voltaic cells (solar panels) when used in combination with green roofs
- Visual amenity/enhancement of urban texture
- Habitat and increased biodiversity

2.1 GREEN ROOFS

Roofs are one of the major elements that currently make up the impervious, hard surfaces of the urban area and therefore one of the contributing factors of the Urban Heat Island (UHI) effect. Green roofs and cool roofs can have a strong regulating effect on the temperature of roofs and building interiors, reducing the energy needed for cooling and the impact of the UHI effect.

Green roofs are roof surfaces that are partially or fully vegetated. Green roofs can be applied at a domestic or commercial scale.

Green roofs can decrease heat absorption and radiant heat from building rooftops, reduce ambient air temperatures and mitigate the urban heat island effect.

Where green roofs are not possible due to structural loads, white or cool coloured roofs are recommended to reduce the building's absorption of solar radiation and increase re-radiation of urban heat. Examples include light coloured roofing products or heat reflective roof coatings and paints. Blue roofs, which are roofs covered with water, such as a shallow, reflective pool, can also reduce and reflect heat.

The green roof has added advantages over a cool roof, including evapotranspiration, stormwater detention and storage, and providing habitat for urban ecology.

Green roofs can be extensive (low maintenance, minimal access) or intensive (accessible and usable rooftop garden or courtyard).

EXTENSIVE GREEN ROOFS

An extensive green roof has a growing medium depth of approximately 150mm, is lighter in weight and in many cases can have the ability to be retrofitted to existing buildings. Plant species suitable for extensive green roofs are low growing ground covers or grasses requiring minimal maintenance. Extensive green roofs are typically more cost effective and are usually non-accessible or have limited maintenance access.

INTENSIVE GREEN ROOFS

An intensive green roof has a growing medium of typically more than 150mm deep, is heavier, requires a stronger roof structure and is capable of sustaining plant species from shrubs to trees.

In addition to the environmental and economic and physical benefits, intensive green roofs provide amenity and recreational areas providing health and well-being benefits to the public and/or building occupants.

ELEVATED LANDSCAPES

An elevated landscape has a deeper profile again, with greater than 600mm depth creating a new ground plane and greater opportunities for biodiversity and varied topography (Hopkins & Goodwin 2011).

2.2 GREEN ROOF COMPONENTS

ROOF STRUCTURE

Green roofs are constructed on the concrete slab, plywood sheet or lightweight metal roof deck (extensive green roofs only). Green roofs are typically flat; however they can be sloped up to about 35°C, providing soil erosion control techniques are followed. If retrofitting a green roof to an existing building, the structural capacity of the roof must be assessed by a structural engineer, who will take into account the added saturated weight of the green roof profile, any live loads from people accessing the roof for maintenance or recreation, wind loads and any additional structures required.

THERMAL INSULATING LAYER

Insulation is required by the Building Code of Australia (BCA) for roof construction. The BCA does not identify a green roof as a roof construction system, and therefore does not include the insulation value of a green roof. Insulation is applied either above or under the building roof structure.

A green roof provides its own insulation value. Research in Adelaide shows that a 300mm profile reduces roof surface temperature by 41% in summer (Hopkins & Goodwin 2012).

Additional thermal insulation can be installed either above or below the waterproof membrane, but is not common or best practice in Australia.

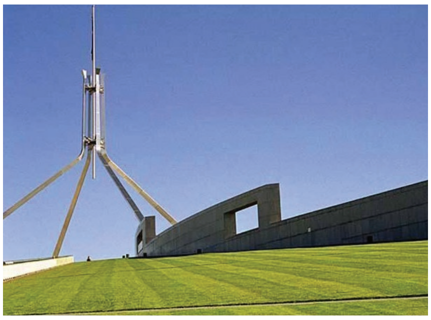
WATERPROOFING MEMBRANE

Waterproofing is critical in all green roof design and construction to prevent water damage of the roof structure, especially when retrofitting an existing roof with a green roof installation. Any existing waterproofing on buildings should be assessed by a qualified professional to determine if it meets the requirements of the addition of a green roof or requires repair or replacement.

Waterproofing is always required on new buildings and should be designed in consultation with a qualified professional to meet the requirements of a green roof. Following installation the waterproofing layer should be tested by flooding to identify any leaks.

Forest Lodge Eco House
(Photograph: Courtesy City of Sydney)

Conservatorium of Music, Sydney
(Photograph: Courtesy WSUD.org)



Iconic green roof – Parliament House, Canberra
(Photograph: Green Roofs Australasia)

Waterproofing membranes used on green roofs are typically:

- Bitumen/asphalt roofing felt or bituminised fabrics
- Bituminous membrane sheets set in a polymer modified bitumen and coal/tar polyester built-up system
- Liquid applied membranes
- Single ply roof membranes designed for green roofs
- Concrete admixture water-proofing (Urbis Limited, 2007).

LEAK DETECTION LAYER

Flood testing has been the traditional method to ensure that the membrane is watertight. Flood testing has limitations as there is no accurate way to locate any breaches, or the number of breaches, and this method cannot be used on sloped surfaces.

A leak detection layer is laid over the waterproofing membrane and substrate. This is a low voltage test method that creates an electrical potential difference between a non-conductive membrane surface and conductive structural deck or substrate, which is earthed or grounded. An electric field is created and a breach in the membrane creates a ground fault connection (Vector) which can be measured with pin-point accuracy.

ROOT BARRIER

The root barrier is usually located above the drainage layer to prevent the root systems from choking up the drainage voids. This may be incorporated into the filter membrane layer.

Root barrier protection in green roofs can be part of the waterproofing layer, except when this layer contains bitumen, asphalt or any organic material. Root penetration can cause micro-organisms to deteriorate the organic oil based materials (Urbis Limited, 2007).

DRAINAGE LAYER

The primary purpose of the drainage layer is to drain excess water from the saturated growing medium or substrate. In some systems a secondary role is water storage within the drainage layer structure. The substrate should have a minimum slope of 1:100, but preferably 1:40, sloping towards roof drain points or gutters. All drainage fittings such as sumps and outlet points should have aggregate surrounds for ease of maintenance and to reduce any root infiltration.

The drainage layer can be composed of either a synthetic drainage cell system or granular aggregates. The drainage layer can be composed of:

- Mineral aggregates: expanded slate and clay, lava and pumice, gravel and crushed stone
- Recycled aggregates: crushed brick, slag, crushed or foamed glass or crushed tiles
- Porous mats: of polystyrene, plastic or organic material

- Lightweight plastic drainage cells: high strength, interlocking modules with some designs creating a water store/reserve
- Drainage boards: foam pellet boards, studded rubber boards, shaped rigid plastic boards, shaped rigid foam boards
- Subsoil drainage such as perforated PVC agricultural pipes (intensive and elevated landscapes) (Environa Studio, City of Sydney and Urbis Limited, 2007).

Rooftop drainage also includes the roof drains, gutters and eaves and down pipes. Drainage systems need to be accessible for maintenance and include inspection access points that enable the system to be cleaned out if required.

360 MCentral
(Photograph: Courtesy City of Sydney)

GEOTEXTILE FABRIC/FILTER LAYER

This layer is installed on top of and parallel to the drainage layer. It prevents the fine material and particles of the growing medium from being washed into the drainage layer and subsequently causing blockages in the drainage system. The filter layer can be either a woven or non woven material. A non woven material is preferable as this is more resistant to root penetration and can sometimes be used as a root barrier system. A filter layer can be installed independent of the drainage layer or as part of the drainage layer.

GROWING MEDIUM OR SUBSTRATE

The growing medium for green roofs is specific and should be a lightweight engineered soil that can be either organic or inorganic.

The growing medium must have the following properties:

- Efficient moisture retention
- Well aerated
- Well drained
- Ability to absorb and supply nutrients
- Retain its volume over time
- Provide anchorage for plants
- Lightweight
- Permeable
- Fire resistant.

The growing medium can be a standard pre-mixed mixture, or a customised soil mixture that can be developed in conjunction with a soil expert.

The growing medium needs to be carefully selected or designed for the particular green roof type. An extensive roof may require a well drained, open mix with more inorganic than organic material, whereas an intensive roof may be a mixture of organic and inorganic material such as an engineered, lightweight soil.

Note that the use of clay, especially with fine clay particles, is not recommended as the fine particles can seal over the filter fabric and cause drainage issues. Sloping green roofs should not contain

ABC Rooftop Garden
(Photograph: Courtesy City of Sydney)

Intensive Green Roof on the Readers Digest Building
(Photograph: Courtesy City of Sydney)

any clay material as this can create a slippage plane. On steep sloping green roofs erosion control methods need to be installed to stabilise the growing medium.

PLANTS

Plant selection depends on a number of factors including the orientation, overshadowing, type of green roof and wind exposure.

Plants used on extensive green roofs are typically shallow and fibrous rooted, low-growing and hardy plants, such as ground cover, grasses, and plants that are adapted to high light intensities, high temperatures and dryness. For example, native grasses, succulents and cacti which have evolved to retain water to meet the harsh conditions of semi-arid Australia. Plants with similar soil, irrigation and drainage requirements should be selected and planted together in zones.

Intensive green roofs typically have a greater variety of plant species given the deeper soil profile, and sometimes even relatively large trees can be placed over the building's structural grid, such as columns, where the extra load can be carried safely.

IRRIGATION SYSTEM

A green roof may or may not require irrigation, depending on the water requirements of the plant species, the efficiency of the drainage layer in storing water, and the maintenance budget. Consideration should be given to ensuring sufficient irrigation during the establishment phase (the first 4-6 weeks) and during periods of high plant stress. There are a number of ways of irrigating a green roof including:

- Manual hose irrigation: requiring connection to water points
- Automatic irrigation system: programmed to irrigate at set times
- Semi automatic system: programmed system with manual overrides
- Drip-irrigation system
- Grey water irrigation
- Soil substrate moisture holders.

ADDITIONAL ELEMENTS

Additional elements are commonly used on intensive green roofs and elevated landscapes. These roofs are designed for daily use by the building inhabitants and are generally referred to as recreation green roofs.

These additional elements may include:

- shade structures
- furniture
- planter beds and seating walls
- balustrades

- paved areas and paths
- garden bed edging
- solar panels.

2.3 COOL ROOFS

Cool roofs use reflective material to reflect and emit more solar energy than traditional dark roofs. Cool roofs use two processes to cool the building:

- Solar reflectance: solar energy is reflected by the surface of the roof
- Emittance: also called thermal emittance, this is the amount of absorbed heat that is radiated from a roof.

Cool roofs can be white roofs, cool coloured roofs and blue roofs.

2.4 COOL ROOF COMPONENTS

2.4.1 WHITE ROOF COMPONENTS

White roofs are typically used on a lightweight roof where the roof surface is not visible from street level. Roofing products for white roofs include:

- Single-ply membrane: one layer membrane that is rolled onto the roof and attached with mechanical fasteners and adhesives or held in place with ballast.
- Elastomeric coating: liquid surfacing material (acrylic, elastomeric or asphaltic)
- Painted metal
- Tile
- Ballast: a heavier roofing material of gravel, stones or pavers, used to weigh down waterproof layers and increase thermal mass of the surface to decrease heat absorption through the building.

(US Department of Energy Berkeley Lab, 2013)

2.4.2 COOL COLOURED ROOF COMPONENTS

Cool coloured roofs can be used as an alternative to a green roof where the structural capacity of the building does not allow the addition of the load of a green roof.

Cool coloured roofs are designed to increase reflection of sunlight while maintaining the aesthetic of more traditional non-white roofs.

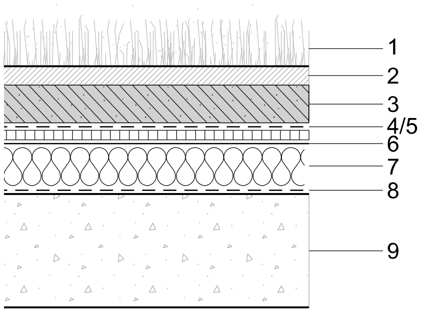
Cool coloured roofs include:

- Asphalt shingle
- Metal
- Tile
- Ballast.

(US Department of Energy Berkeley Lab, 2013)

2.5 TYPICAL CONSTRUCTION

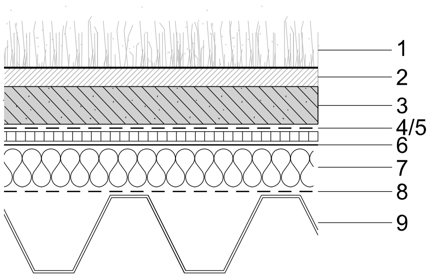
2.5.1 EXTENSIVE GREEN ROOF SYSTEM (CONCRETE SLAB ROOF)



1 LOW PLANTING
2 MULCH 50mm
3 SOIL TYPE 1
4 GEOFABRIC FILTER LAYER
5 DRAINAGE CELL
6 WATER PROOFING SHEET MEMBRANE
7 ADDITIONAL INSULATION (OPTIONAL)
8 VAPOR SEAL
9 EXISTING REINFORCED CONCRETE ROOF

Section Scale 1:20

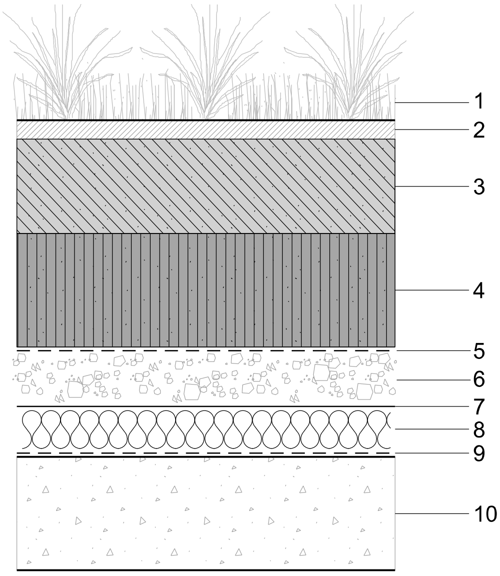
2.5.2 EXTENSIVE GREEN ROOF SYSTEM (SHEET METAL ROOF)



1 LOW PLANTING
2 MULCH 50mm
3 SOIL TYPE 1
4 GEOFABRIC FILTER LAYER
5 DRAINAGE CELL
6 WATER PROOFING SHEET MEMBRANE
7 ADDITIONAL INSULATION (OPTIONAL)
8 VAPOR SEAL
9 EXISTING SHEET METAL ROOF

Section Scale 1:20

2.5.3 INTENSIVE GREEN ROOF SYSTEM



1 PLANTING
2 MULCH (50mm)
3 SOIL TYPE 1 (250 - 400mm)
4 SOIL TYPE 2 (300 - 600mm)
5 GEOFABRIC FILTER LAYER
6 20mm GRAVEL (NO FINES) LAYER
7 WATER PROOFING SHEET MEMBRANE
8 ADDITIONAL INSULATION (OPTIONAL)
9 VAPOR SEAL
10 EXISTING REINFORCED CONCRETE ROOF

Section Scale 1:20

NOTE:

- Investigation is required to determine the construction and load bearing capacity of the roof;
- Insulation shown above the roof structure can alternatively be a part of the roof construction;
- Integrated irrigation systems can be installed if required.

Solar panels have improved efficiency when used in combination with green roofs

2.6 ESSENTIAL CONSIDERATIONS

2.6.1 DESIGN

The design of a green roof will depend first and foremost on the primary function of the space. It is critical that the roof designer is fully briefed on the objectives of the project from the outset, so the roof can be conceived to deliver the benefits that are sought. All green roofs need to deliver more than just one function.

Key factors that will influence the design process include the building size and roof surface area, age and structural capacity, height of the roof, exposure to wind, solar access, microclimate, the budget, views to and from the roof, and the ongoing maintenance budget.

2.6.2 LOCAL PLANNING REQUIREMENTS

Relevant local council planning requirements need to be reviewed for applicable requirements and approval processes for green roofs on commercial and private buildings. This may include Development Control Plans (DCP) and Local Environment Plans (LEP). The heritage status of the building should also be considered if applicable. If green cover is not listed in the Council's development controls, the designer should call the Council to determine relevant considerations and requirements.

2.6.3 BUILDING PERMIT PROCESS

A building permit may be needed to construct a green roof. Some of the issues that a building surveyor would consider prior to issuing a permit include:

- Site considerations – is a planning permit required, or does this location need to be assessed against the building regulations?
- A report from a structural engineer if additional loads are proposed, people, planted areas, retained water, additional structures
- Applicable fire ratings for new structures
- Access for people occupying the area
- Waterproofing and drainage of the existing structure and new green roof area to ensure health and amenity of occupants below the roof is not compromised
- Safe movement for users in and around the area, including ramps, stairs and balustrades
- Any necessary alterations to "essential safety measures" within the building, for example additional emergency and exit lighting
- Adequate and legal weatherproofing and drainage.

2.6.4 PROFESSIONAL CONSULTANT ADVICE AND INPUT

The engagement of a green roof professional consultant, who may be an architect or landscape architect specialising in this area, is essential to all green roof projects. This green roof professional will coordinate and direct the other disciplines that may be needed, depending on the function, size and location of the project.

Vancouver Convention Centre
(Photograph: Bruce Hemstock)

The green roof professional may require the services of some or all of the following professionals to be involved in the development of the green roof:

- Landscape architect: design and document the layout and planting design and species selection
- Architect: if the green roof is part of a new building an architect will be involved in integrating the design of the green roof with the overall building
- Structural engineer: determine load capacity of existing roof or design of new roof, design of any new structures to tolerate wind exposure specific to the site
- Mechanical engineer: calculate heating and cooling implications with the addition of a green roof and its integration with existing and new rooftop mechanical equipment
- Hydraulic engineer: design of irrigation system and drainage needs and integration into existing roof drainage system
- Horticulturist: plant species selection and advice
- Growing media manufacturers: for selection of appropriate growing media.

2.6.5 BUILDING STANDARDS

Although they are not specifically mentioned in the National Construction Code, green roof systems are considered an extension of the roof system, and therefore must comply with requirements for structural loading and moisture protection. Information on relevant standards are in Chapter 6 of this guideline.

If the green roof is accessible for more than routine maintenance – in other words, if tenants or the public use the roof as an accessible outdoor green space – then the design must also comply with requirements for occupancy, exiting, lighting, guardrails, and barrier free access.

2.6.6 MAINTENANCE

As with any project, a maintenance plan and budget must be determined at the design stage. This is especially true for green roof projects, as the health and longevity of the growing media and the roof membrane are critical to the ongoing integrity of the green roof and its function.

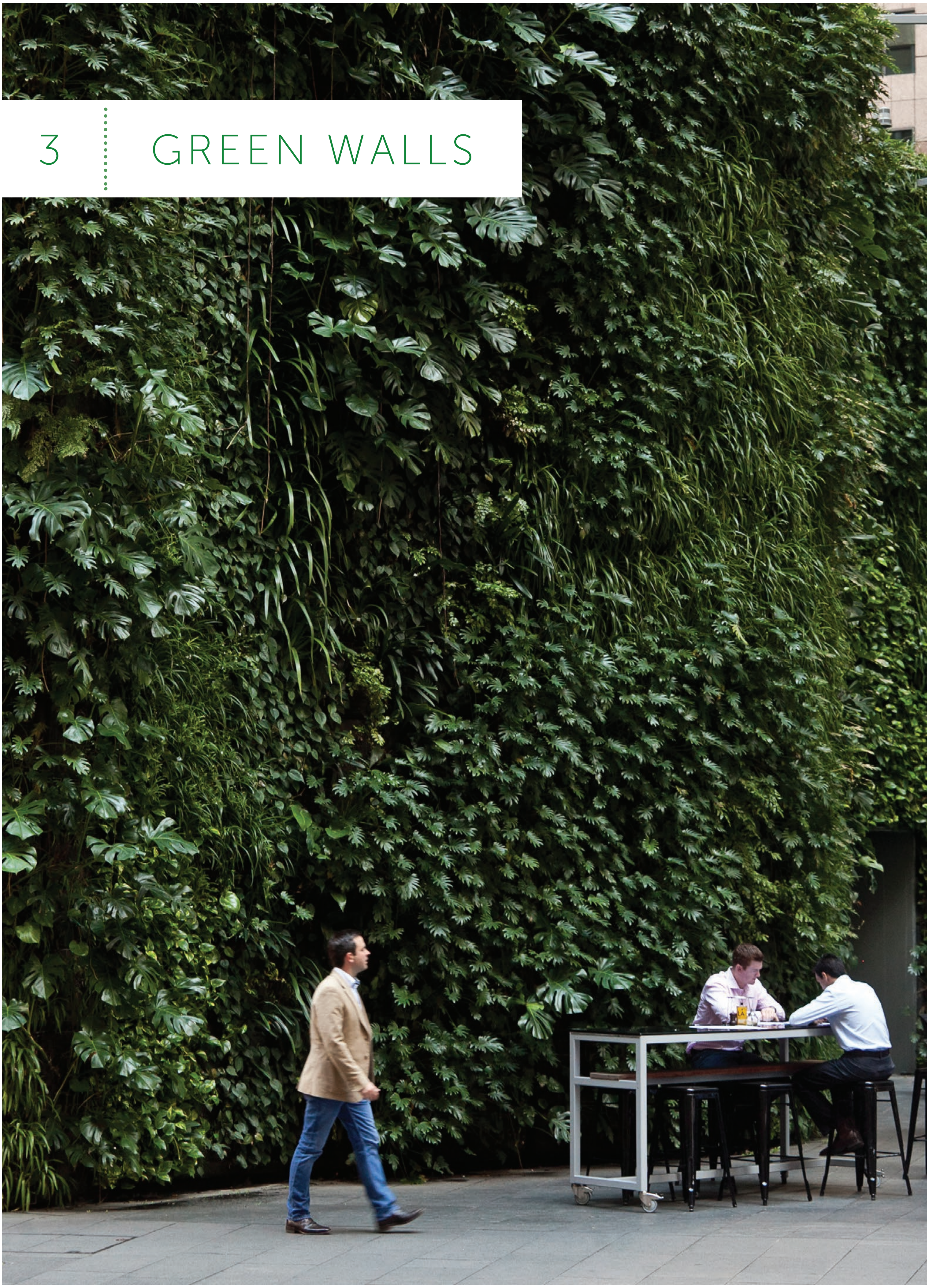
Depending on whether the green roof is extensive or intensive, required plant maintenance will range from two to three annual inspections to check for weeds or damage, to more regular visits for pest control, pruning, and replanting. Regular inspections of the waterproofing membrane to ensure leaks are not occurring will also be required.

Many installers can include maintenance services for the first years of the roof in the contract, to ensure the continuity of the component warranties and effective establishment of the roof system. This can also provide an opportunity to transfer maintenance skills into an in-house asset protection or maintenance program, over time.

The issues of access and safety for maintenance staff must be accommodated in the design and comply with all the relevant WorkSafe and National Construction Code requirements.

Prince Alfred Park and swimming pool
(Photograph: Brett Boardman, Neeson Murcutt Architects, Sue Barnsley Design and The City of Sydney)

3 GREEN WALLS



Bligh Street Green Wall (*Photograph: Courtesy City of Sydney*)

POTENTIAL BENEFITS

- Reduced building heat absorption and radiation and reduced UHI effect
- Evapotranspiration produces water vapour that creates a cooling effect by reducing temperatures and increasing humidity
- Air purification via plants filtering airborne particulates and absorbing gaseous pollutants
- Carbon dioxide absorption through photosynthesis
- Sound insulation
- Reduced heating and cooling requirements and costs for the building and reducing GHG emissions
- Visual amenity/enhancement of urban texture
- Habitat and increased biodiversity

3.1 GREEN WALLS

Green walls are vegetated systems that are grown on the vertical facade of the building envelope. These vegetated systems can be grouped into two main categories: green facade and green wall; each having several minor categories. Both these systems can range from low technology to highly engineered, technically sophisticated systems.

These green wall systems can be of varying scales. The balcony scale consists of small, modular proprietary systems that are fixed to the wall, containing a number of small planting pockets or pots. The domestic scale is a system that covers between one to four floors in height and is usually modular, fixed to the wall or on a supporting framework. Commercial scale systems cover the building facade between four to around thirty floors high and are fixed to the facade by a support framework integrated into the building facade.

Self-clinging plants have been used to create green walls for centuries, but often their sucker root system damages the wall and its structural integrity.

Research has shown green walls can reduce adjacent pavement temperatures by 5°C through reduced building surface temperature and surrounding ambient air temperature (Hopkins et al. 2012 (b)).

GREEN FACADES

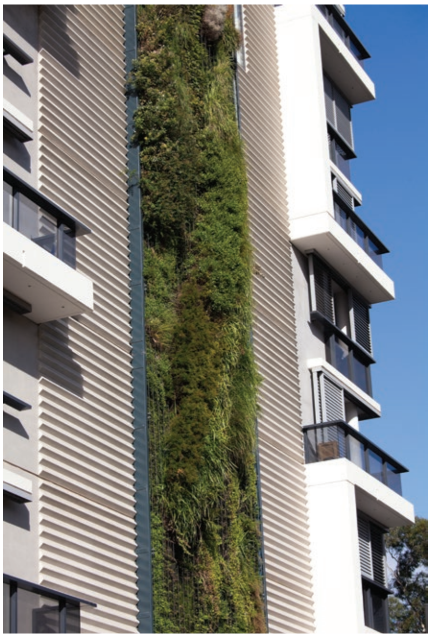
A green facade is a system that mimics the self-clinging plant, but uses a trellis system of either cables or mesh to support the climbing plant off the building surface. Modular systems can be secured to, or integrated into, the design of the building facade. Green facades can cool the skin surface by 8°C (Hopkins et al. 2012 (b)).

GREEN WALLS

These systems can be constructed from pre-vegetated panels that hold growing media to support the plant material, or planted blankets with planting pockets filled with plants and growing media. These systems are fixed to a structural framework or to a wall. Research has shown a green wall can reduce the skin surface temperature by 9°C and air temperature by 4-5°C (Hopkins & Goodwin 2011).

The hybrid living wall, a system for multi-storey buildings developed by Fifth Creek Studio and Woods Bagot, Adelaide uses both green facade and green wall technology. This living wall system is a cost effective system that could be applied to new buildings or retrofitted to existing buildings. This system integrates the maintenance access into the supporting framework, allowing the system to be built on multi-storey buildings.

Monitoring of this hybrid living wall system found that the building surface temperature was reduced by 8°C and that heat penetrating into the building was reduced by 2.4 W/m^2 or 35% in summer and heat escaping from the building in winter was reduced by 3.6 W/m^2. Solar radiation was reduced by 95% and daylight to the window surface reduced between 43 and 63% depending on the cable or mesh aperture. It intercepted 20% of the rainfall before it reached the ground, reducing reliance on mains water supply and ultimately reducing energy consumption and costs for the building occupier or owner and lowering greenhouse gas emissions (Hopkins et al., 2012 (b)).



Trio Apartments
(Photograph: Courtesy City of Sydney)

Green walls can be either outside or within a building. Both indoor and outdoor green walls can humidify and provide oxygen, absorb carbon dioxide, filter air particles and absorb pollutants on the plant surfaces. Outdoor green walls provide thermal mass to a building that insulate and moderate indoor temperatures. Evaporation from leaf surfaces provides a cooling effect on air temperature. As shown in the research findings above, a green wall can subsequently reduce heating and air-conditioning requirements, expenditure and greenhouse gas emissions. Additional benefits of green walls are sound insulation, visual amenity and increased biodiversity particularly with the use of native plant species. Indoor green walls can even form part of a building's air circulation system, such as the bio wall system with fans directing air through the green wall where the plants filter pollutants and increase oxygen in the air before being circulated throughout the building.

3.2 GREEN WALL COMPONENTS

Green walls are also referred to as living walls, green facades, bio walls or vertical gardens and can refer to specific designs, construction techniques and scales of implementation applied to both commercial and residential projects, located on the building's exterior or interior.

GREEN WALLS

Green walls are either pre-grown modular panels, vertical modules or vegetated mat walls. These systems can either be fixed to a structural framework or to a wall. Green walls are typically:

- Felt or vegetated mat system or
- Modular panels: these are typically pre-planted with the plant growth established off site prior to installation.

GREEN FACADES

Green facades are green wall systems where the plants are trained to specifically-designed supporting structures. Plants can either be grown in-ground or in planters at intermediate levels.

Gazebo wine bar, Sydney
(Photograph: Edward Warburton)

Green facades can be either attached to existing walls or designed as independent structures (Green Roofs for Healthy Cities). Green facades can be:

- Trellis and container system
- Modular trellis panels
- Cable and wire net systems: made up of high tensile steel cables and anchors. Cable systems are designed to support fast growing climbing plant species, while net systems are appropriate for slower growing species that will require additional support at closer intervals. A wire net system has greater flexibility than cables (Green Roofs for Healthy Cities).

INTERIOR GREEN WALLS

Interior green walls can be designed and constructed using either the panel, felt or trellis system. Lighting requirements are a major design consideration, especially where natural light is low and artificial light may be required. This can be determined by producing a light plan.

LUX is the measure of light similar to how the human eye perceives brightness in the middle range of the light spectrum. Plants react to light differently, with photosynthesis being driven by "Photosynthetically Active Radiation" or PAR light.

The light frequency range for PAR is either side of the LUX frequency, therefore the region of the light spectrum that is brightest to human eyes is the area with the least effect on plants. If the reading is below 6000 LUX, artificial supplementary lighting will be required for an interior green wall.

Air movement is important to prevent insect and fungal attack and supplementary fans may need to be installed to maintain the best atmospheric conditions.

Green wall, Kings Cross (Photograph: Courtesy City of Sydney)

Interior green walls can be integrated into the building's wall and can even form part of a building's mechanical air circulation system, such as the bio wall. Fans can direct recycled or fresh air through the green wall where the plants filter pollutants and increase oxygen and humidity in the air before being circulated throughout the building.

PLANTS AND ORIENTATION

The design of a green wall and plant species selection should consider the orientation, climate and microclimate of the site. Plant species may need to vary from the bottom of the wall to the top with varying levels of light, air circulation and humidity.

The plants of modular panels can be pre-grown off site prior to installation, providing instant greening when installed.

Forest Lodge Eco House
(Photograph: Courtesy City of Sydney)

GROWING MEDIUM

The growing medium of green facades or container systems is either in natural ground or planter boxes using engineered, lightweight soil. In both in ground and modular systems the growing medium or lightweight topsoil layer where the plants roots are found is typically a minimum of 150-250mm deep (Hopkins et al 2010). The growing medium must be kept moist and be free draining to avoid drying out or becoming waterlogged.

Walls should be lightweight and ideally not deteriorate through decomposition. The growing medium can be a soil-less synthetic product where the green wall essentially functions as a hydroponic system. Synthetic products are foam-like substances that should have an optimum air/water ratio, be light weight, pH neutral, sterile, inert and biodegradable.

IRRIGATION

Appropriate levels of water and nutrients are essential for the success of green walls, and techniques of irrigation will vary between in-ground and container systems.

In-ground green facade systems use irrigation just as common garden beds do such as drip irrigation or sub soil drip systems (Hopkins et al 2010).

Green wall container or module systems are irrigated using drip lines at various heights, approximately 3 metres apart (Hopkins et al 2010). Some modular green walls have irrigation lines integrated into the system. Water, nutrients and fertilisers can travel downwards through the modules. Excess water may be collected for reuse at the base in a drip tray and fed back into the system.

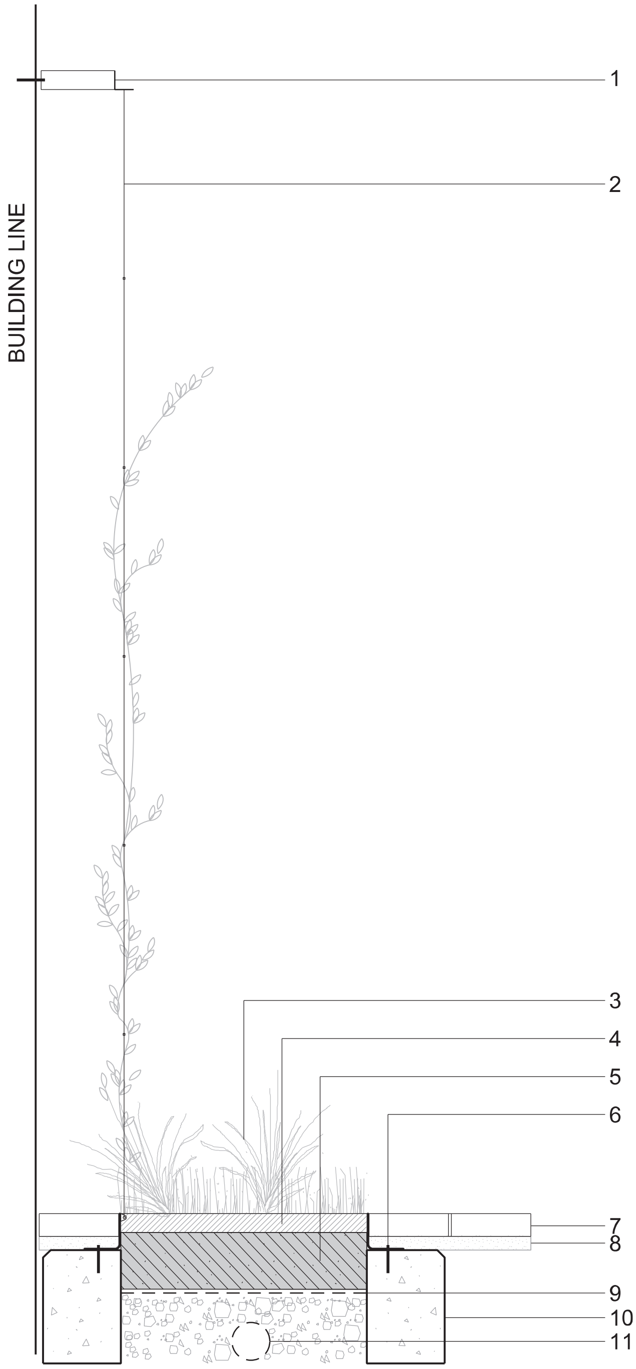
Water sensors can also be used in green walls to monitor water levels and provide automatic irrigation.

3.3 TYPICAL CONSTRUCTION

3.3.1 CABLE AND WIRE NET SYSTEM

NOTE:

- Planting can be integrated into footpath or building apron or in an above ground planter box.



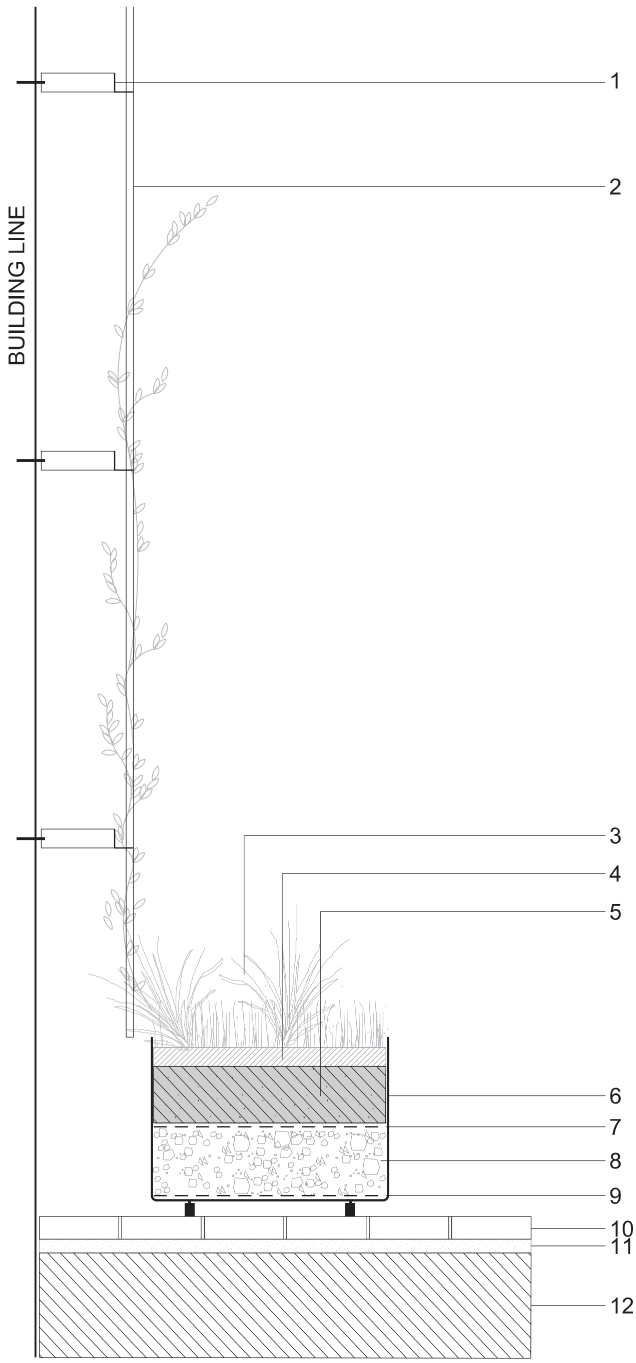
Section Scale 1:20

1 BUILDING ANCHOR AND BRACKET SYSTEM
2 STAINLESS STEEL CABLE OR WIRE NET
3 PLANTING
4 MULCH (50mm)
5 SOIL TYPE 1
6 GALVANISED STEEL ANGLE
7 PAVING
8 BEDDING COURSE
9 GEOFABRIC FILTER LAYER
10 CONCRETE HAUNCH
11 SUBSOIL DRAINAGE PIPE WITHIN 20mm GRAVEL (NO FINES)

3.3.2 TRELLIS AND CONTAINER SYSTEM

NOTE:

- Planting can be integrated into footpath or building apron or in an above ground planter box.



1	BUILDING ANCHOR AND BRACKET SYSTEM
2	TRELLIS SYSTEM FIXED TO BUILDING ANCHORS
3	PLANTING
4	MULCH (50mm)
5	SOIL TYPE 1
6	GALVANISED STEEL PLANTER
7	GEOFABRIC FILTER LAYER
8	20mm GRAVEL (NO FINES) LAYER
9	GEOFABRIC FILTER LAYER
10	PAVING
11	BEDDING COURSE
12	EXISTING PAVING SUBSTRATE

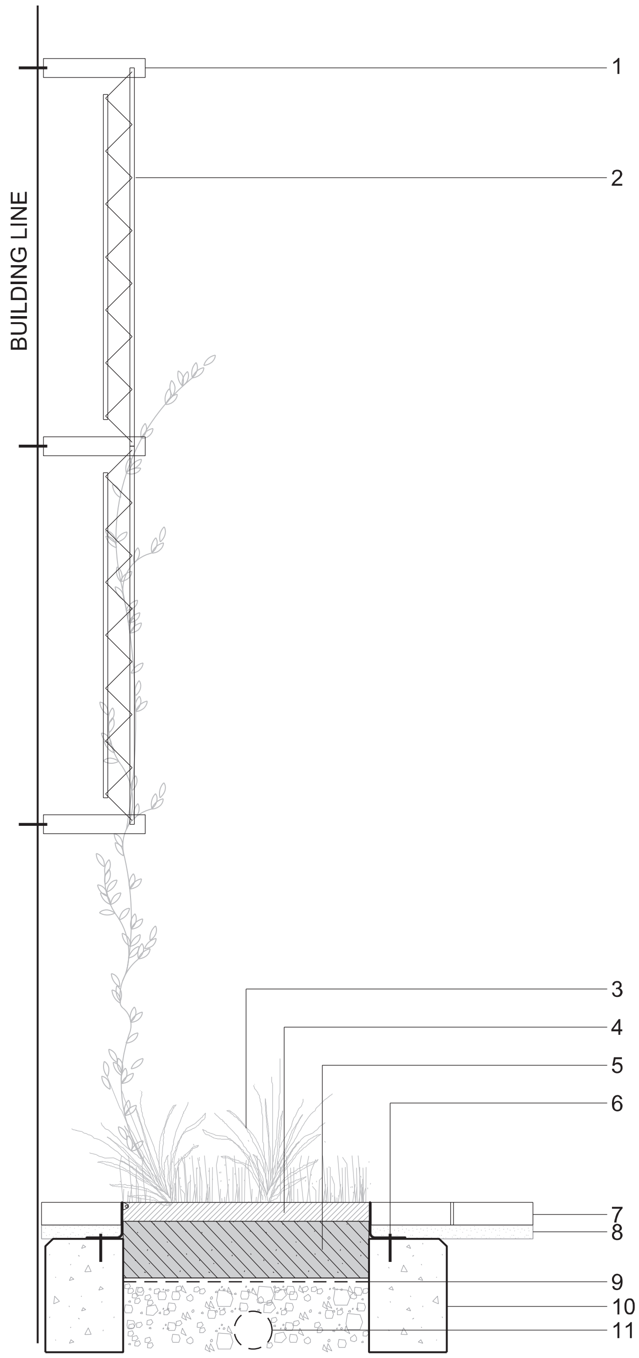
Section Scale 1:20

3.3.3 MODULAR TRELLIS PANELS

NOTE:

- Planting can be integrated into footpath or building apron or in an above ground planter box.

1 BUILDING ANCHOR AND BRACKET SYSTEM
2 STAINLESS STEEL CABLE OR WIRE NET
3 PLANTING
4 MULCH (50mm)
5 SOIL TYPE 1
6 GALVANISED STEEL ANGLE
7 PAVING
8 BEDDING COURSE
9 GEOFABRIC FILTER LAYER
10 CONCRETE HAUNCH
11 SUBSOIL DRAINAGE PIPE WITHIN 20mm GRAVEL (NO FINES)



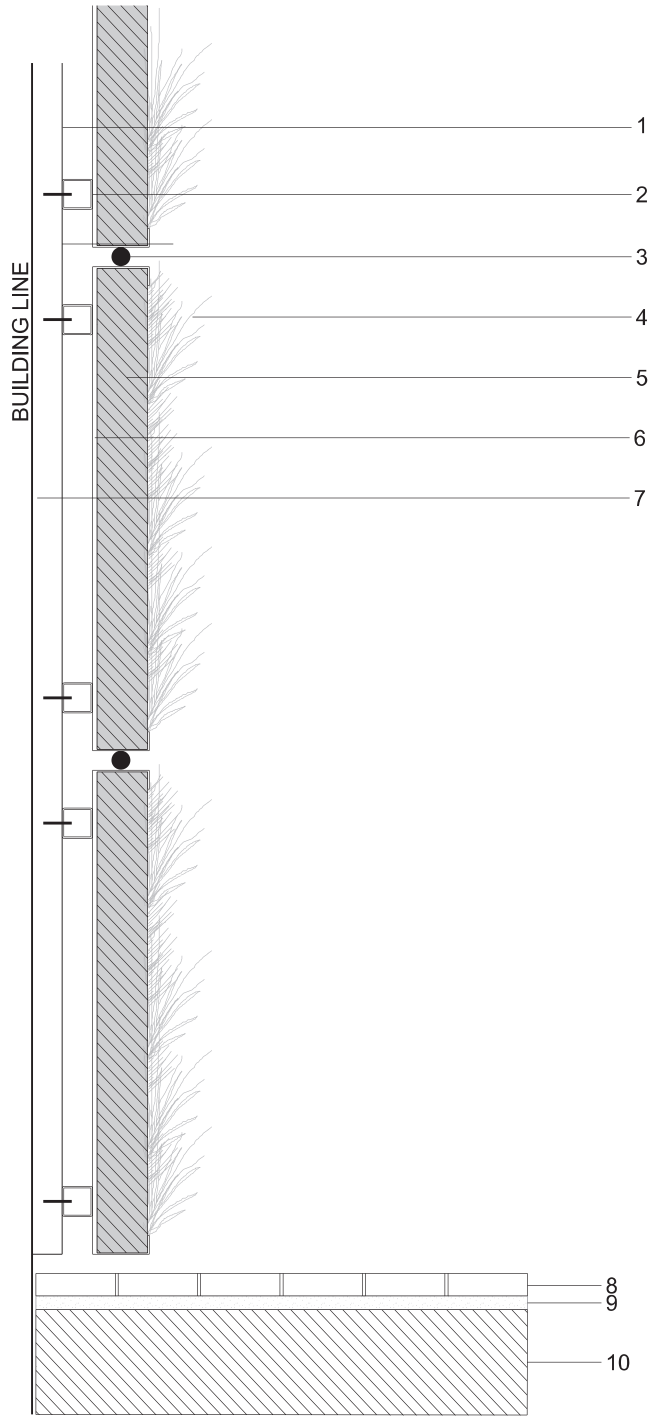
Section Scale 1:20

3.3.4 MODULAR PANEL SYSTEM

NOTE:

- Planting can be integrated into footpath or building apron or in an above ground planter box.

1 STAINLESS STEEL WALL CHANNEL
2 STAINLESS STEEL PURLIN FIXED TO WALL CHANNEL
3 IRRIGATION LINE
4 PLANTS
5 GROWING MEDIUM
6 WALL PANEL
7 WATERPROOF MEMBRANE
8 PAVING
9 BEDDING COURSE
10 EXISTING PAVING SUBSTRATE

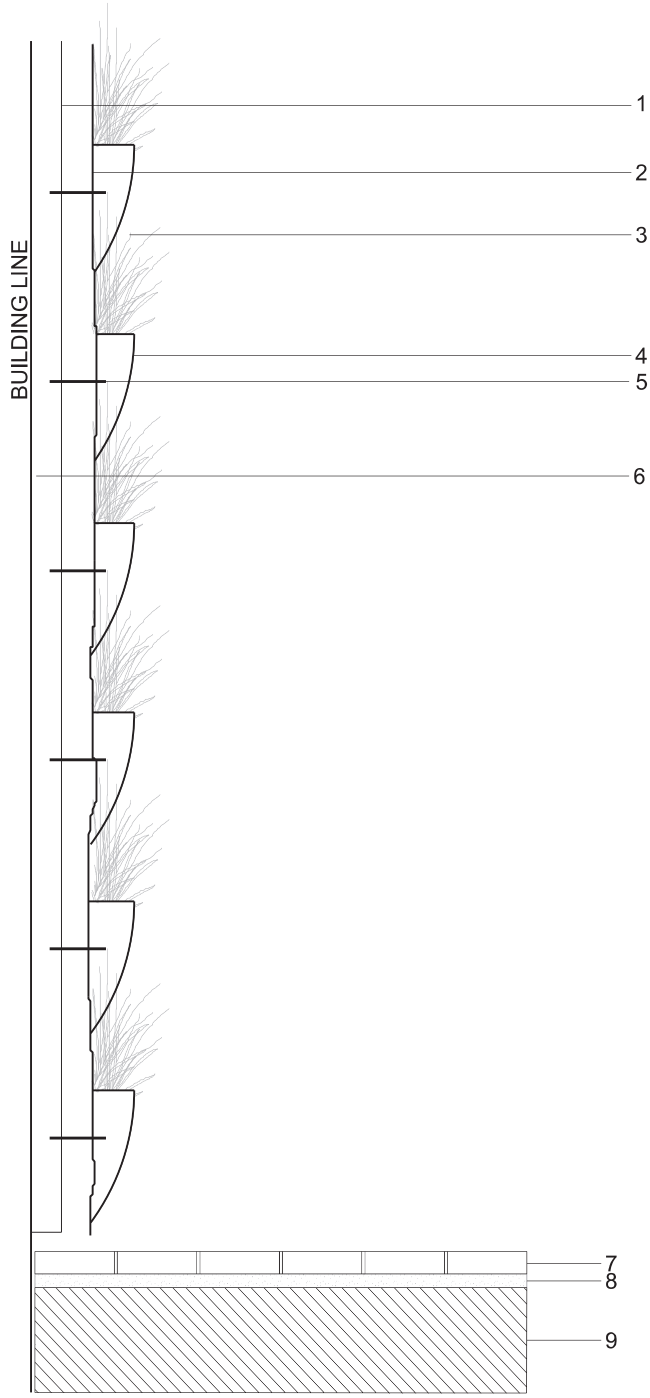


Section Scale 1:20

3.3.5 FELT/MAT SYSTEM

NOTE:

- Planting can be integrated into footpath or building apron or in an above ground planter box.



Section Scale 1:20

1. STAINLESS STEEL WALL CHANNEL
2. FELT LAYER
3. PLANTS
4. POCKET
5. TIE
6. WATERPROOF MEMBRANE
7. PAVING
8. BEDDING COURSE
9. EXISTING PAVING SUBSTRATE

3.4 ESSENTIAL CONSIDERATIONS

3.4.1 DESIGN

The design of a green wall or facade will depend upon the building size, age (if retrofitting) and structural capacity, exposure to wind, solar access, microclimate and the budget. The factors that may limit or inform the design need to be established prior to design and implementation.

3.4.2 LOCAL PLANNING REQUIREMENTS

Relevant local council planning requirements need to be reviewed for applicable requirements and approval processes for green walls on commercial and private buildings. This may include Development Control Plans (DCP) and Local Environment Plans (LEP). The heritage status of the building should also be considered if retrofitting. If green cover is not listed in the council's development controls, the designer should call the council to determine relevant considerations and requirements.

Central Park
(Photograph: Courtesy City of Sydney)

3.4.3 BUILDING PERMIT

A building permit may be needed to construct a green wall. Some of the issues that a building surveyor would consider prior to issuing a permit include:

- Site considerations – is a planning permit required, or does this location need to be assessed against the building regulations?
- A report from a structural engineer if additional loads are proposed, people, planted areas, retained water, additional structures
- Applicable fire ratings for new structures
- Adequate and legal weatherproofing and drainage.

3.4.4 PROFESSIONAL CONSULTANT ADVICE AND INPUT

The engagement of a green wall professional consultant, who may be an architect or landscape architect specialising in this area, is essential to all green wall projects. This green wall professional will coordinate and direct the other disciplines that may be needed, depending on the function, size and location of the project.

The green wall professional may require the services of some or all of the following professionals to be involved in the development of the green wall:

- Landscape architect: design and document the layout and planting design and species selection
- Architect: may be involved in integrating the design of the green wall or facade within the technical and aesthetic components of the building
- Structural engineer: determine load capacity of existing wall or design of new wall to integrate a green wall or façade system

- Mechanical engineer: calculate heating and cooling implications with the addition of a green wall and its integration with existing and new mechanical systems within the building
- Hydraulic engineer: design of irrigation system and drainage needs and integration into existing drainage systems or rainwater harvesting systems
- Horticulturist: plant species selection and advice
- Growing media manufacturers: for selection of appropriate growing media

3.4.5 BUILDING STANDARDS

All design, construction and maintenance of green walls should be in accordance with all relevant Australian standards and the National Construction Code.

3.4.6 MAINTENANCE

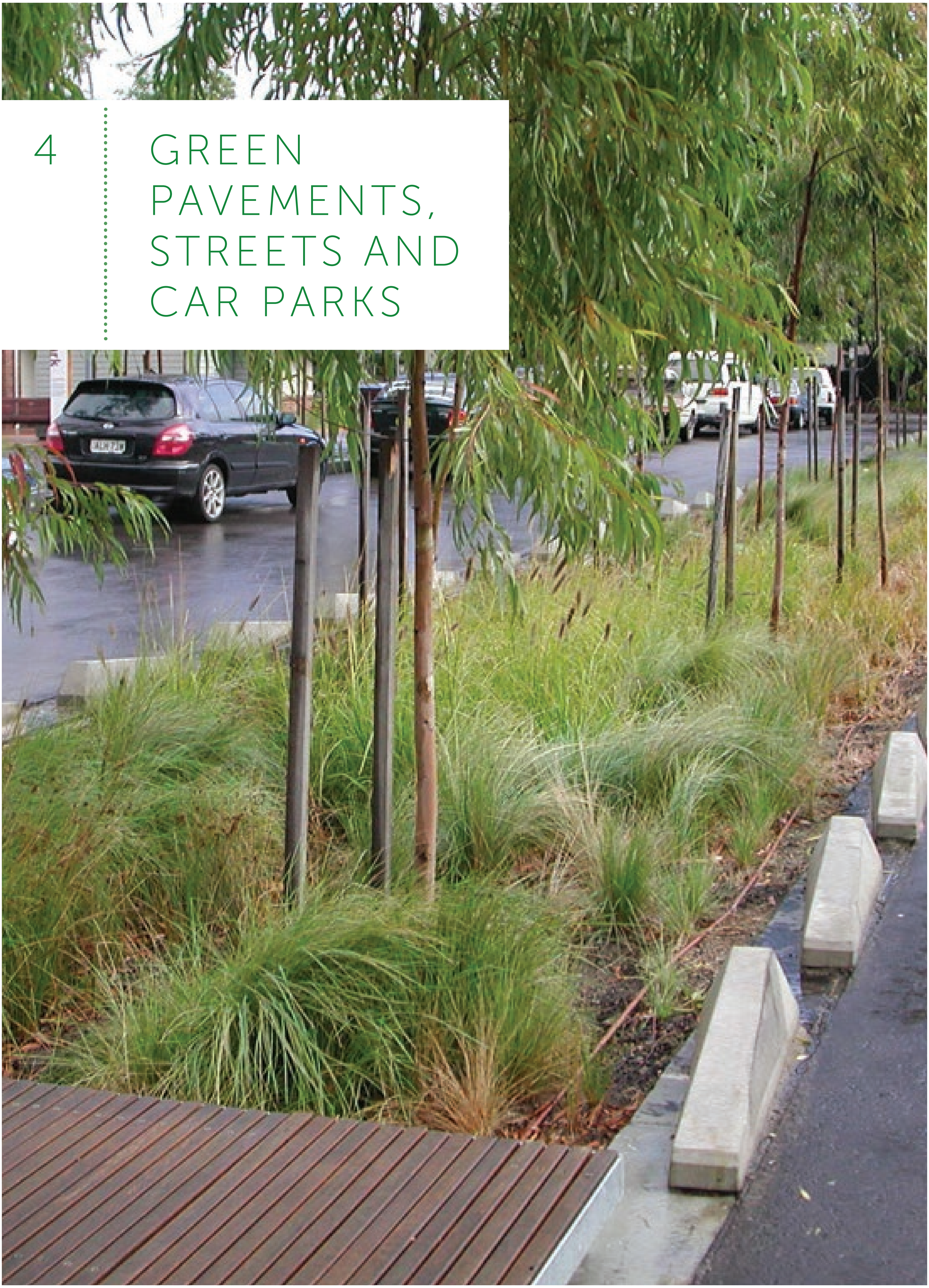
As with all projects, a maintenance plan and budget must be determined as part of the green wall design process. This is especially true of green walls as the method of maintenance may require additional structures, such as built-in fixings and attachment points.

Maintenance of green walls and green facades should include watering (more frequent during establishment period), pruning and replacement of individual plants and inspections of the irrigation system.

Maintenance access of green walls may require additional equipment such as forklifts, elevated platforms or an industrial abseiling system.

Easy green wall (Photograph: N. Kapos)

4 GREEN PAVEMENTS, STREETS AND CAR PARKS



Victoria Park, Zetland, NSW (Photograph: Government Architect's Office)

POTENTIAL BENEFITS
Reduced heat absorption and radiation
Increased reflection of solar radiation with high albedo, light coloured pavements
Evapotranspiration creates a cooling effect, reducing temperatures and increasing humidity
Greater night-time cooling
Surface permeability reduces pavement temperature
Reduces stormwater run-off
Improves water quality with filtering of pollutants and particles
Reduced stormwater mitigates flood risk
Lower temperature of run-off results in reduced thermal shock to aquatic life in waterways and drains
Permeable pavements improve safety by reducing water spray from moving vehicles and improved traction
Reflective pavements can enhance night time visibility
Permeable pavements can reduce tyre noise

4.1 GREEN PAVEMENTS

Scientific research and assessment indicates the urban heat island (UHI) effect results from an increase in temperatures of urban centres due to development, hard paved and dark coloured surfaces, car engines, air conditioners, reduced green cover and global and local climate change.

Expanses of hard pavements, particularly unshaded pavements including roads, carparks and footpaths significantly contribute to the heat island effect.

The heat island effect can be mitigated by reducing the absorption and radiation of heat from pavement. This can be achieved through the reduction of hard paved areas, increased areas of mass planting, the use of more reflective (high albedo) light coloured pavements and permeable pavements.

Both reflective or light coloured pavements and permeable pavements have a cooling effect on surface and ambient air temperatures and over-night cooling of urban areas.

Permeable pavements can be designed with a number of objectives. In addition to being used for their cooling effect, permeable pavements can be used for:

- Flood control
- Pollution control
- Stormwater harvesting.

Where permeable pavements form part of a stormwater harvesting system, stormwater is collected and temporarily stored before reuse as non-potable water.

Permeable or porous pavements include gravels or unit paving systems with either cut outs allowing water to permeate through or porous pavers that allow water to filter across the surface area of the paver.

Permeable paving also includes resin bonded gravel surfaces, pavements with reflective coatings, turf paving/reinforced turf.

Cool pavements are either pavements with higher surface solar reflectivity or permeable pavements that reduce runoff by infiltrating rainwater and have evaporative cooling qualities.

Cool paving can be used in place of conventional concrete and asphalt pavements.

Air, water and water vapour permeates into the voids of permeable pavements and subsequently reduce the temperature of the pavement. Surface temperatures are cooled through evapotranspiration, with the heat drawn out as the moisture is evaporated.

Rock aquifer cool paving is paving cooled by the storage of water in the base course and sub-base. The water replaces the air space between the crushed rock, while maintaining the structural capacity of the base course. The base course and sub-base is contained by a waterproof membrane, creating an underground storage vessel.

4.2 GREEN PAVEMENT COMPONENTS

REFLECTIVE PAVEMENTS

- Modified asphalt pavements
- Concrete
- Concrete (white cement)
- Resin bound aggregates
- Coloured asphalt
- Coloured concrete

PERMEABLE PAVEMENTS

- Porous asphalt
- Pervious concrete
- Permeable interlocking concrete pavers
- Unit pavers with slots or widened joints
- Resin bound aggregates

SURFACE INFILTRATION

The surface of permeable pavements needs to allow for the rapid infiltration of stormwater to minimise or eliminate runoff from the high intensity rainfalls experienced in Australia. In order to have a high infiltration rate, the entire pavement system and depths of sub-structures must be designed to have high permeability and designed for specific storm events relevant to the local climate (CMAA 2010).

SUBGRADE INFILTRATION

Full infiltration

Where the existing subgrade has a gravelly or sandy and permeable quality, permeable pavements can be designed to allow for full infiltration of rainfall into the subgrade and then water table (CMAA 2010). In this instance no additional drainage pipes are used. It must be established prior to the design whether the relevant local council permits water infiltration into the subgrade.

Partial infiltration

This system is used where the subgrade is clay and only a small amount of runoff will infiltrate. The pavement acts as temporary water storage, with additional sub-surface drainage pipes to gradually drain to the stormwater system (CMAA 2010).

No infiltration

A system of no infiltration can be used when the soil is contaminated or infiltration is not permitted. In this case, an impermeable membrane is laid between the base course and

Laying permeable paving
(Photograph: HydroCon Australasia hydroston.com.au)

Tom Foster Community Centre
(Photograph: Courtesy Marrickville Council)

the subgrade. This system temporarily stores stormwater before being gradually released via drainage pipes to the stormwater system (CMAA 2010). This system can also be used for stormwater harvesting in a sump and recycling of non-potable water (CMAA 2010).

DRAINAGE

When designing permeable pavements for particular storm events, additional drainage may be required at the perimeter to manage overflows. This drainage can be traditional gully inlets to stormwater pipes or planted swales or bio-retention areas adjacent to the permeable pavement (CMAA 2010).

JOINTS (UNIT PAVERS ONLY)

Some permeable pavings use widened joints filled with aggregate to act as drainage voids. Joints can be filled with uniform 1-3mm crushed no fines aggregate.

BEDDING COURSE

The bedding course is a crushed no fines aggregate (2-5mm) course typically 20-40mm thick. Sand is not suitable as a bedding course for permeable pavements in Australia as it does not allow water to infiltrate rapidly enough (CMAA 2010).

GEOTEXTILE/GEOFABRIC

The geotextile layer acts as a separating layer between the bedding and the base course and as a filter, by enabling the development of microbes and bacteria that breakdown hydrocarbons and pollutants (CMAA 2010).

BASE COURSE

The base course is typically a 5-20mm crushed no fines aggregate. The base course is the main load-bearing layer and must be designed to meet the traffic loads of the intended function and also to provide adequate water storage. Although some of the permeability is reduced with compaction, permeable pavements designed for vehicular traffic must have a compacted base course and sub-base to minimise rutting deformation (CMAA 2010).

SUB-BASE

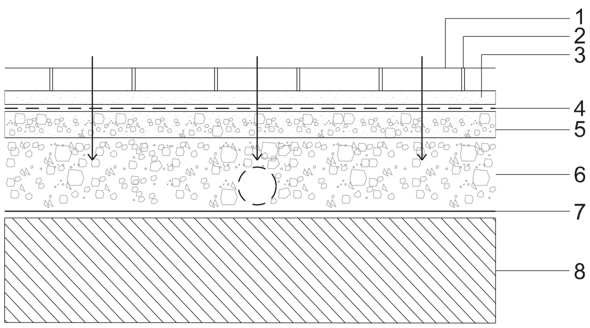
The sub-base is an optional layer and usually 20-40mm crushed no fines aggregate.

EDGE RESTRAINT

Concrete unit pavements require an edge restraint at the perimeter to resist horizontal movement of the pavement. Edge restraints include precast concrete kerbs, kerb and gutters and edge strips (CMAA 2013).

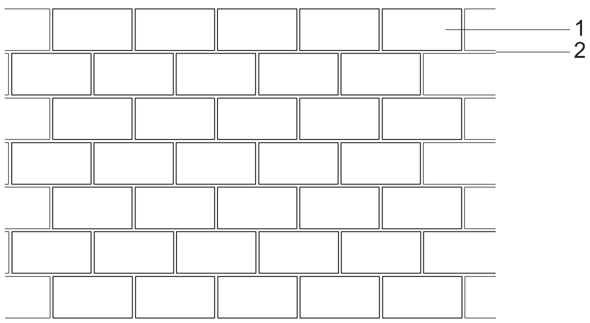
4.3 TYPICAL CONSTRUCTION

4.3.1 PERMEABLE/POROUS PAVERS



Section Scale 1:20

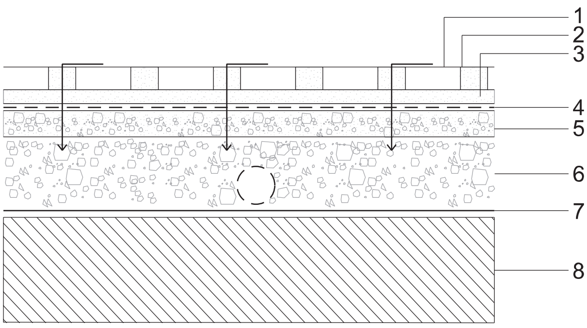
1. PERMEABLE PAVER
2. 1-3mm CRUSHED AGGREGATE (NO FINES)
3. 2-5mm CRUSHED AGGREGATE (NO FINES)
4. GEOFABRIC FILTER LAYER
5. 5-20mm AGGREGATE (NO FINES)
6. COMPACTED SUBGRADE
7. WATERPROOF SHEET MEMBRANE



Section Scale 1:20

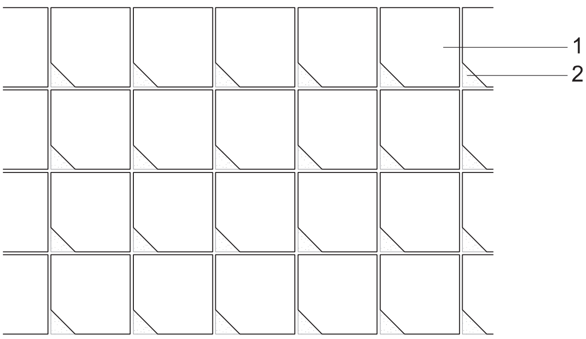
Water infiltration through permeable paving units – Hydroston permeable paver
(HydroCon Australasia hydroston.com.au*)*

4.3.2 PERMEABLE PAVERS – INTERLOCKING SYSTEM



Section Scale 1:20

1 UNIT PAVER
2 1-3mm CRUSHED AGGREGATE (NO FINES)
3 2-5mm CRUSHED AGGREGATE (NO FINES)
4 GEOFABRIC FILTER LAYER
5 5-20mm AGGREGATE (NO FINES)
6 COMPACTED SUBGRADE
7 WATERPROOF SHEET MEMBRANE



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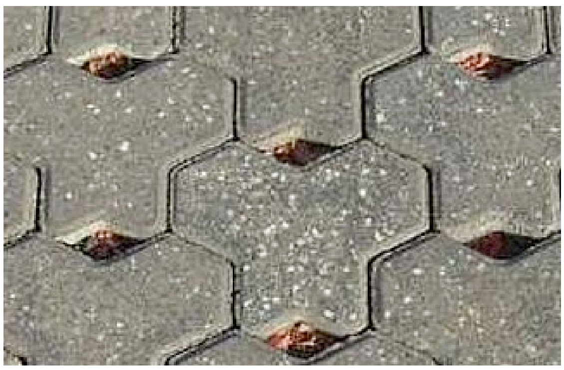


Interlocking unit pavers with gravel filled drainage gap

4.4 ESSENTIAL CONSIDERATIONS

4.4.1 LOCAL PLANNING REQUIREMENTS

Relevant local council planning requirements need to be reviewed for applicable requirements and approval processes. This may include Development Control Plans (DCP) and Local Environment Plans (LEP).

4.4.2 PROFESSIONAL CONSULTANT ADVICE AND INPUT

The design of permeable or reflective pavements needs to meet the structural demands of the intended use. For example the pavement may be intended for pedestrian traffic, vehicular or industrial vehicle grade use, or a combination. Manufacturers of proprietary pavements can advise on suitable pavements and thicknesses. In the case of custom pavements, civil engineering input will be required.

Pavements that are to accommodate vehicular traffic must also have compacted base course and sub-base material. Compaction must be to Australian Standards which should be advised by a civil engineer.

A hydraulic engineer may also need to be consulted to calculate the permeable pavements capacity to manage rainfall and stormwater infiltration and mitigate flood risk according to local storm events. Hydraulic engineers will also provide advice on rainwater harvesting.

The design of carparks will need to consider the classification of the carpark. The Australian Standards (AS 2890.1) classifies off-street parking facilities based upon the user, required door openings, aisle widths and type of carpark (e.g. commuter parking, long term parking, short term with high turnover). These standards should be used to inform the design of the carpark.

The design of pavements for new or retrofitting of existing carparks will require consultation with both civil and hydraulic engineers.

4.4.3 SITE WORKS

When installing areas of permeable pavements it is critical to prevent sediment from entering the pavement surface or any of the permeable base layers. To ensure the permeable pavement infiltrates properly, silt traps, temporary drainage to divert run-off and staging of the construction until general works are complete are measures that should be taken (Adbri Masonry 2011).

Permeable paving in carpark reduces and filters surface stormwater run off
(Photograph: HydroCon Australasia hydroston.com.au)

POTENTIAL BENEFITS
Increased shade cover
Decreased surface heat absorption and radiation
Evapotranspiration creates a cooling effect, reducing temperatures and increasing humidity and greater night-time cooling
Permeable pavements reduce surface run-off, reduces surface temperatures, improve traction, decreases flood risk and improves water quality
Planted bioswales manage stormwater run-off and decreases flooding risk
Air purification via plants filtering airborne particulates and absorbing gaseous pollutants
Extended use of outdoor carparks with tree plantings in warmer months
Social, community, health and well-being benefits with green streets and greening of the public domain
Visual amenity/enhancement of urban texture
Habitat and increased biodiversity

4.4.4 MAINTENANCE

Permeable pavements do not require frequent maintenance. Over long periods of time (10 years) the infiltration of the pavement can be reduced as pollutants build up within the upper 20-40mm of the joints or porous paver surface (CMAA 2010). This can be rectified by periodic maintenance by sweeping, street vacuuming or machine blowing depending on the size of the pavement area. The top 30mm of aggregate/joint filler can also be removed and replaced to restore infiltration (CMAA 2010).

4.5 GREEN STREETS AND CAR PARKS

Cool streets can be achieved with an increase in canopy trees within the verge or carriageway, increased understory planting, bioswales/rain gardens and verge and median planting. Street tree planting can be done opportunistically where underground and overhead services, vehicle entries and pedestrian crossings permit.

Cooler carparks include strategies of increased canopy tree planting, median and bioswale planting and the use of permeable pavements. Increased planted areas can be achieved through use of minimum car space and aisle dimensions, planting to the 600mm car overhang beyond the wheelstop and small reductions in car space numbers if required.

The canopy shading of street trees and planting in carparks can reduce the pavement/ground surface temperature by up to 8°C (Moore 2012). This will reduce the UHI effect in dense urban environments, resulting in a reduction of air conditioner use by 12-15% in nearby buildings (Moore 2012).

The temperature reduction role of street trees in shading asphalt and concrete pavement roads and carparks is significant, but perhaps even more important is that this extends the life of street pavement by 2-3 times. Less frequent resurfacing of roads brings a major cost saving to the maintenance budget for road infrastructure (McPherson & Muchnick 2005).

Reducing surface temperatures can also be achieved by reducing the amount of paved surface areas. For example narrower streets, replacing paved areas with planted areas where possible and consolidating areas such as carparks, transport hubs, retail, schools etc.

4.6 COMPONENTS

TREE PIT

Street trees are typically planted within a tree or planting pit, confined by concrete or root barriers. This deep, confined planting area does not allow for the natural wider and shallower pattern of root growth (Leake 2007 (a)). To compensate for this reduced growing volume and deeper profile, a gravel layer and aeration pipes can be used (Leake 2007 (a)).

With variables such as the environmental conditions and species requirements aside, suggested minimum soil volumes for trees within street environments are:

- 5 to 15 cubic metres for a small tree
- 20 to 40 cubic metres for a medium tree
- 50 and 80 cubic metres for a large tree (Landcom 2008 (a)).

Green Street
(Photograph: Sydney Olympic Park Authority)

SOIL MEDIUM

The soil medium used for street tree planting and planting in urbanised environments should be designed for optimal supply of oxygen and gaseous exchange, moisture availability, nutrient supply, ease of extension of root system and stable anchorage (Leak 2008 (b)). The soil mix and type can also be specific to the tree species and nutrient and growth requirements.

STRUCTURAL SOIL

Structural soils have large no fines coarse rock aggregate and a horticultural filler soil that occupies the pores between the rocks. Structural soils maximise the soil volume for tree root growth while also providing a stable base for roads and pavements to be laid. Structural soils also increase the longevity and structural stability of the tree. This growing medium encourages growth of tree roots down the entire depth of the soil profile, reducing surface root growth that can create surface bulging in the pavement (Leake 2010 (c)).

Permeable paving, Sutherland (Photograph: Courtesy WSUD.org)

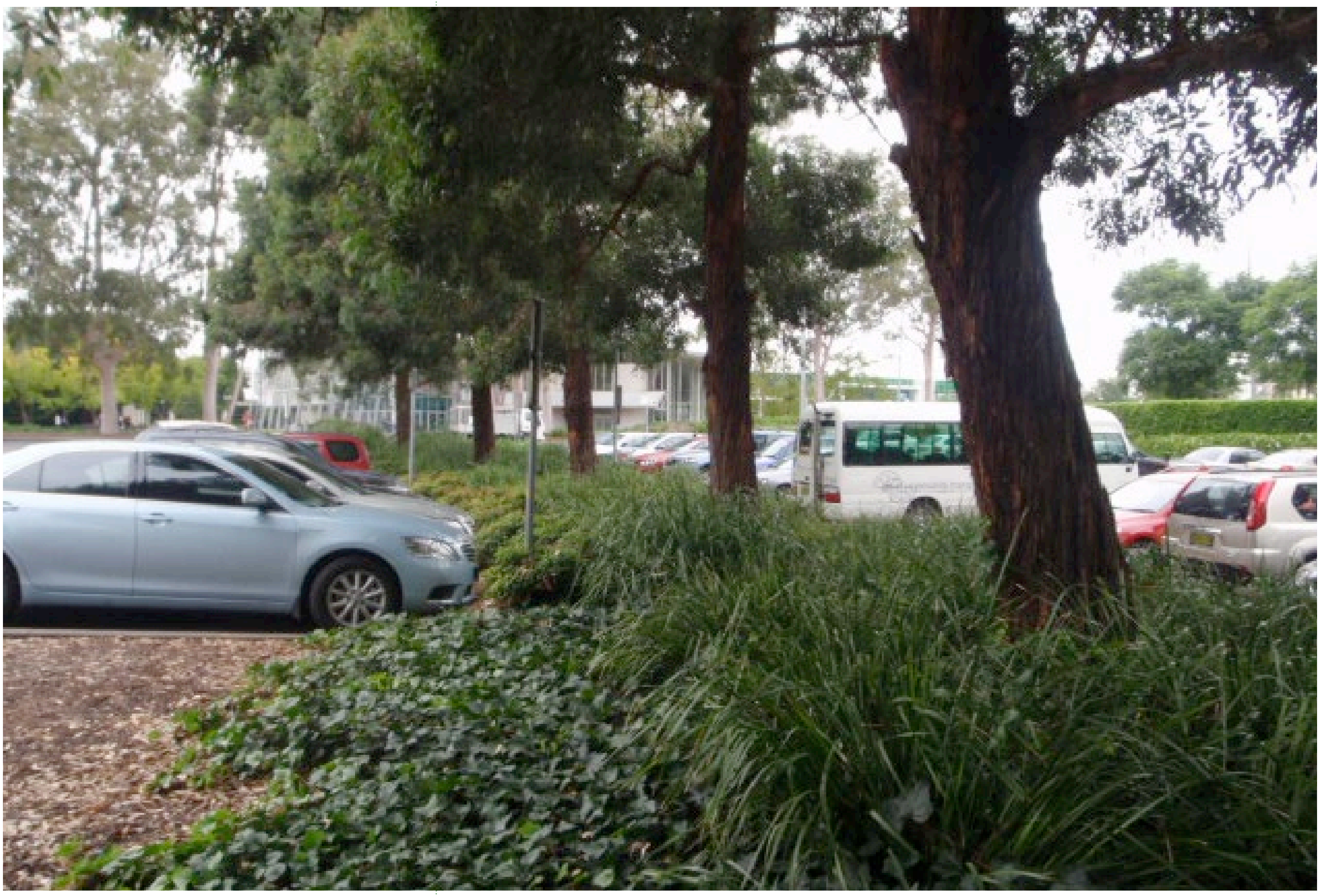
There are proprietary modular units available that assemble to form a skeletal matrix that supports relevant pavement loads while providing large volumes of soil within the structure for root growth. These systems have an advantage over the usual rock mix structural soil with its 80% of rock to total volume. The proprietary engineered modular systems are only 6% of total volume, leaving 94% volume for uncompacted soil.

In road verges with other infrastructure this structural soil system can be developed into linear trenches incorporating the street tree pits in one continuous trench which allows the tree roots to expand along the linear trench. This offers the potential for water harvesting and filtration to support the tree in areas of high pavement loadings.

DRAINAGE AND WATERING

Adequate water supply and drainage is critical for street tree and planting health within the urban environment.

Trees located within the road carriage way, within a kerb blister or rain garden can be irrigated passively, redirecting surface stormwater runoff from the road to the street tree pit. Water can be collected within a gravel drainage layer at the base of the tree pit with any overflow directed to the road stormwater system via subsoil drainage pipes (Landcom 2008 (a)). This has the additional benefit of reducing the demand on potable town water supply.



Median planting and shade trees in between rows of car parking provides shade, reduces hard paved areas, heat absorption and radiation and reduces stormwater run off (Photograph: Penrith City Council)

Bioswales adjacent to roads and carparks collect stormwater runoff and filter silt and pollution as the water infiltrates through the soil profile prior to any excess water being directed to the stormwater system or water table.

Tree grate
(Photograph: Courtesy of Street Furniture Australia)

PLANT STOCK

The selection of plant material and tree species for planting should be based upon its tolerance of harsh conditions of the urban environment. These include reduced soil volumes, poorer soil aeration, air and water pollution, drought tolerance or tolerance of waterlogging and microclimatic conditions such as wind tunnelling, overshadowing and reduced sunlight. The pot size of plant stock and trees may be specified by the local council, depend upon availability and project budget.

The specification, selection and approval of trees should use the NATSPEC *"Specifying Trees – a Guide to Assessment of Tree Quality'* (Clark, R. 2003) as a guideline to ensure stock conforms to current best practice in the nursery industry (Landcom 2008 (a)).

ROOT CONTROL BARRIER

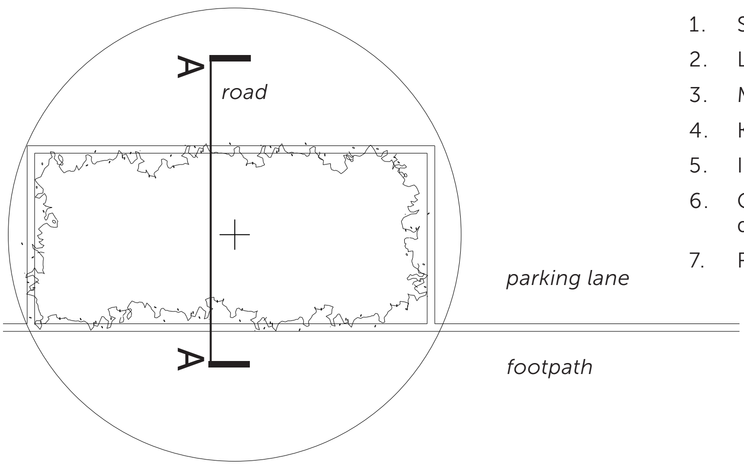
A root control barrier is a flexible ultra-violet stabilised polyethylene plastic that acts as a protective barrier to prevent tree root damage and uplift of roads, building foundations, walls, footpaths and underground pipes and services. Root barriers can also help preserve the water content of the soil medium. They are typically laid to the back of the kerb in tree pits or trenches, extending approximately 600mm deep to guide tree root growth downwards and laterally away from the protected infrastructure. Root control barriers are not a guarantee of protection of adjacent infrastructures and requires specialist knowledge in design, installation and maintenance (Landcom 2008 (a)).

TREE GRATES

Tree grates are an alternative to understorey planting surrounding the base of street trees. Tree grates can be used where a more durable solution, pedestrian access and urban aesthetic of the street environment is required. Tree grates allow water run off into the tree pit, however they do not have the benefits of mitigating the heat island effect that planted areas to the base of trees contribute. The opening or collar surrounding the tree trunk should be designed to accommodate growth of the trunk diameter. Tree grates also need to allow for maintenance and removal of trapped rubbish within drainage slots and openings that has built up over time.

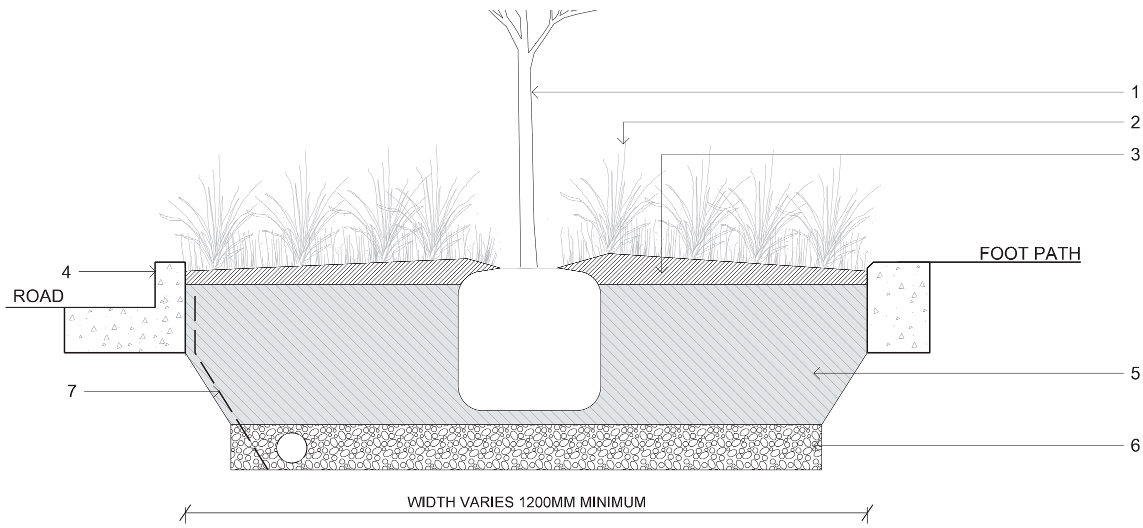
4.7 TYPICAL CONSTRUCTION

4.7.1 STREET TREE IN KERB BLISTER



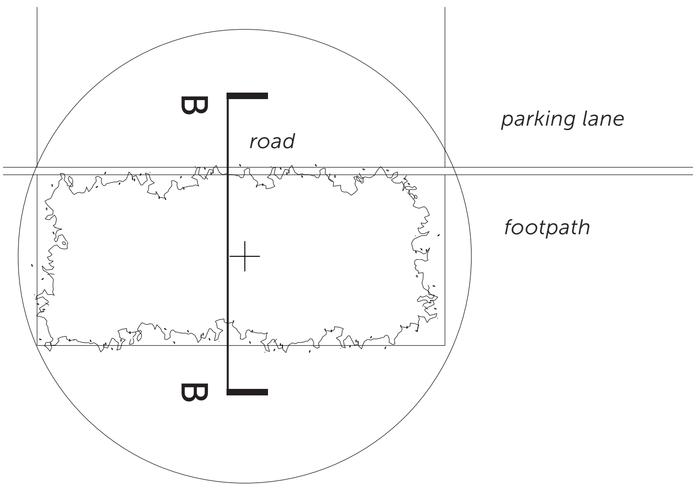
Plan Scale 1:100

1. Street tree planting
2. Low planting
3. Mulch layer 50-75mm depth
4. Kerb and gutter
5. Imported soil mix
6. Gravel drainage layer with perforated subsoil drainage pipes connected to drainage system
7. Root control barrier



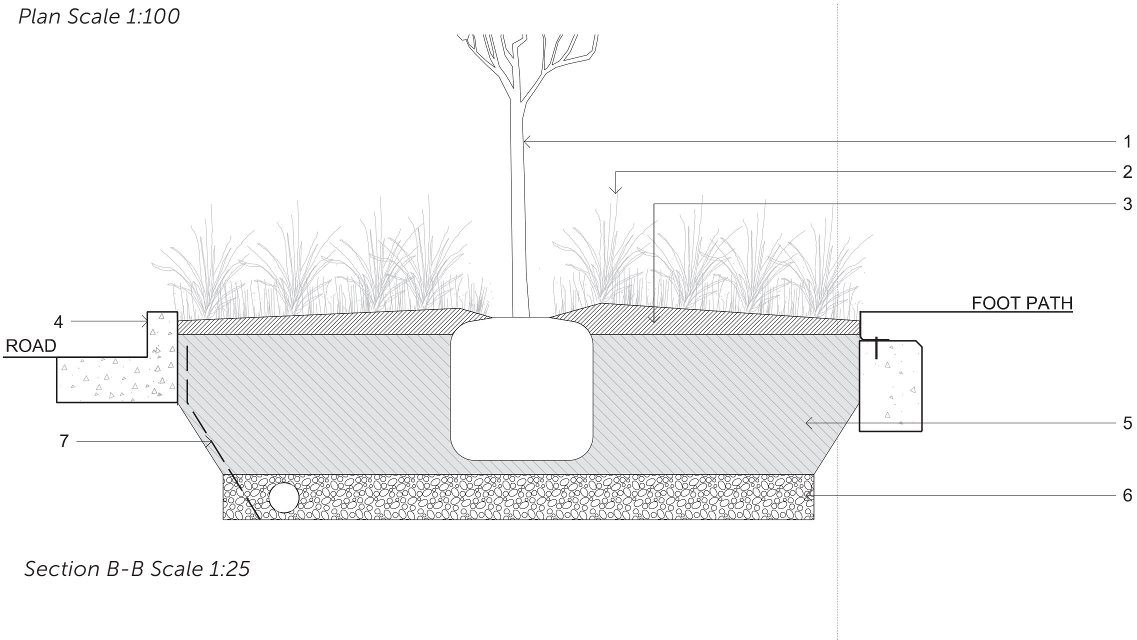
Section A-A 1:25

4.7.2 STREET TREE IN FOOTPATH/VERGE



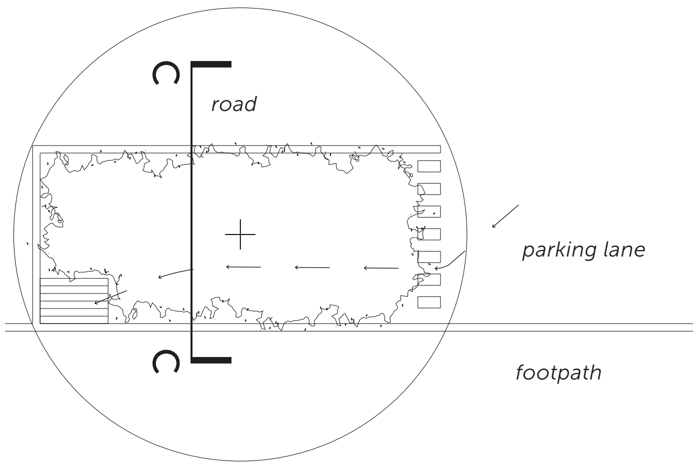
Plan Scale 1:100

1. Street tree planting
2. Low planting
3. Mulch layer 50-75mm depth
4. Kerb and gutter
5. Imported soil mix
6. Gravel drainage layer with perforated subsoil drainage pipes connected to drainage system
7. Root control barrier



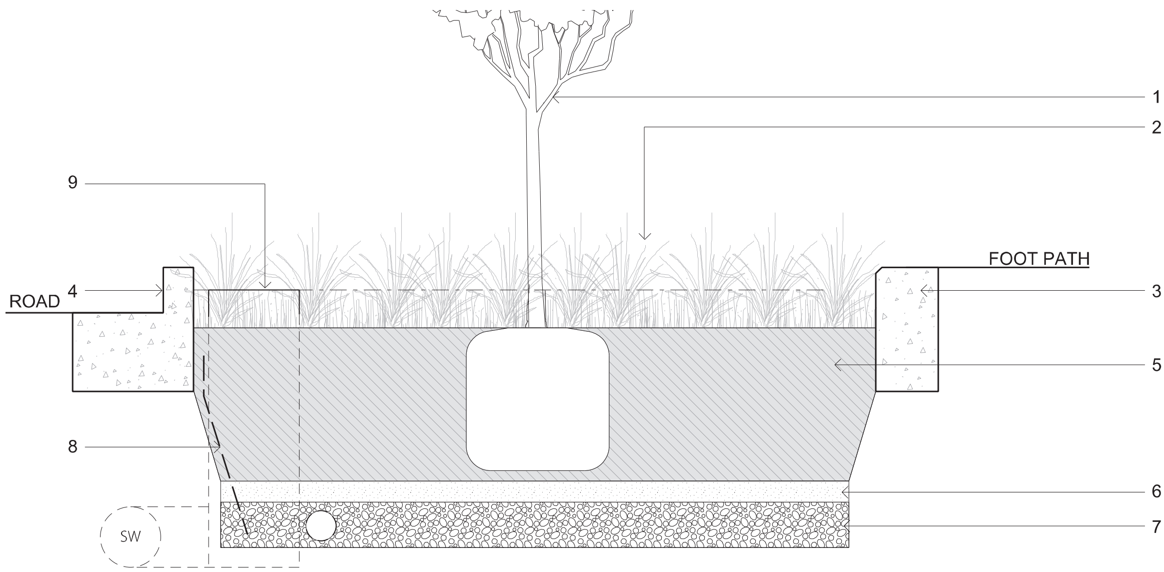
Section B-B Scale 1:25

4.7.3 KERB BLISTER RAIN GARDEN



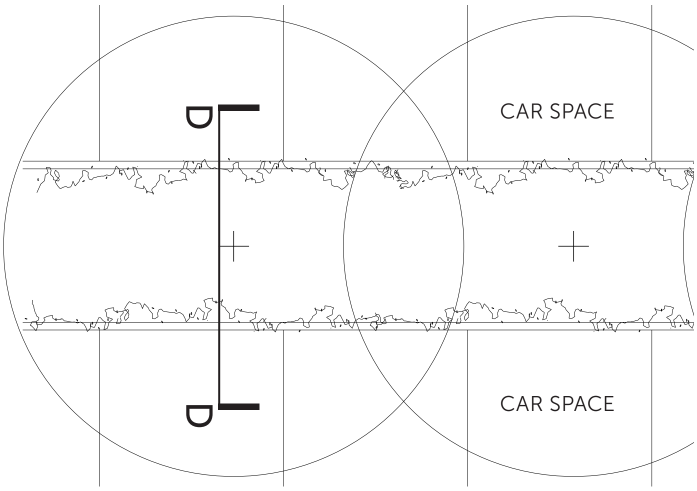
Plan Scale 1:100

1. Street tree planting (inundation tolerant)
2. Low planting (inundation tolerant)
3. Kerb
4. Kerb and gutter
5. Imported soil mix
6. Sandy transition layer
7. Gravel drainage layer with perforated subsoil drainage pipes connected to drainage system
8. Root control barrier
9. Overflow inlet pit



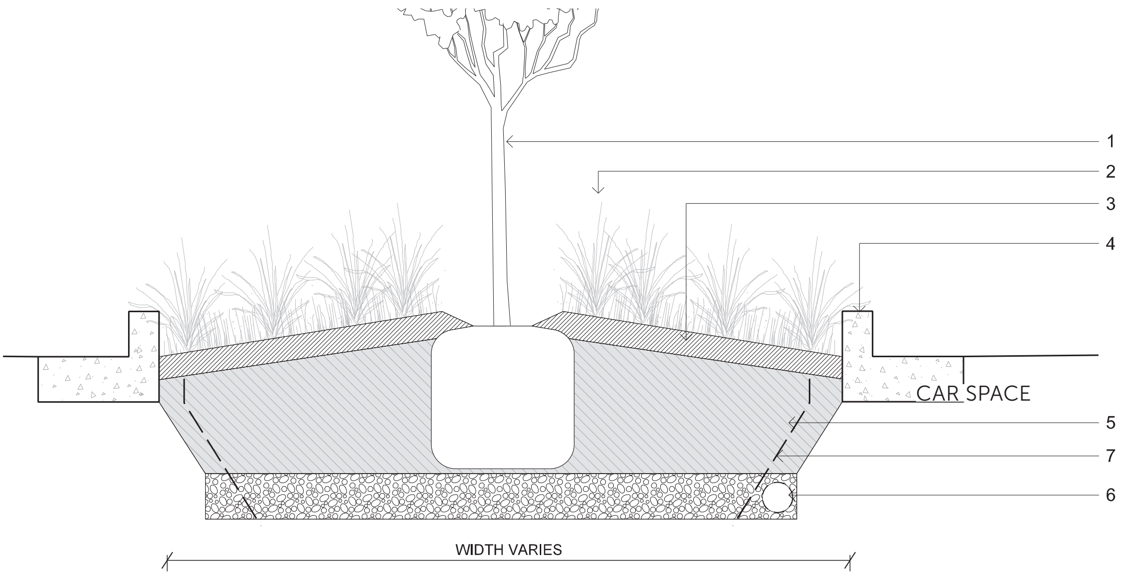
Section C-C 1:25

4.7.4 CARPARK MEDIAN PLANTING



Plan Scale 1:100

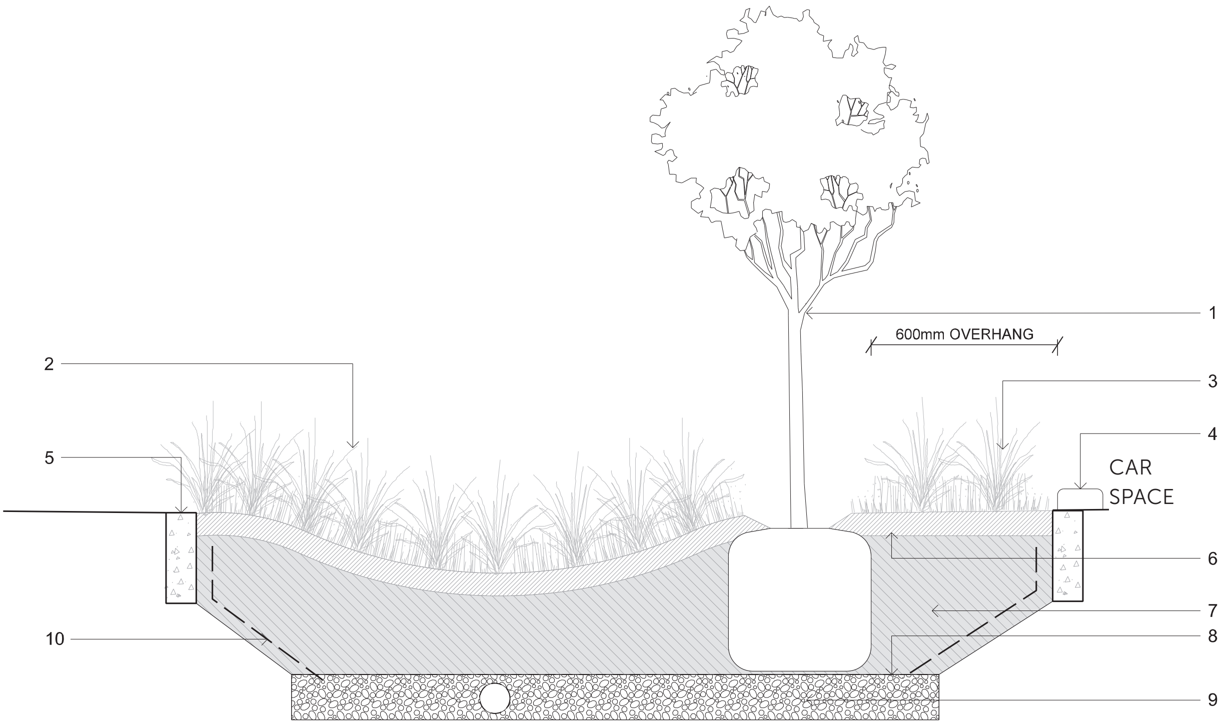
1. Tree planting
2. Low planting
3. Mulch layer 50-75mm depth
4. Kerb
5. Imported soil mix
6. Gravel drainage layer with perforated subsoil drainage pipes connected to drainage system
7. Root control barrier



Section D-D (median) Scale 1:25

4.7.5 CARPARK PLANTING IN BIOSWALE

1. Tree planting
2. Low planting in swale
3. Low planting in car space 600mm overhang
4. Wheel stop
5. Flush kerb
6. Mulch layer (50-75mm)
7. Imported soil mix
8. Geofabric
9. Gravel drainage layer with perforated subsoil drainage pipes connected to drainage system
10. Root control barrier



Section D-D (bioswale) 1:25

4.8 ESSENTIAL CONSIDERATIONS

4.8.1 DESIGN

The design of street tree planting will depend upon the location of underground and overhead services, location of vehicle and pedestrian crossings, intersections and presence of awnings along the footpath. These parameters will also determine whether in-road or verge plantings are appropriate or possible. The spacing of street trees will also need to be appropriate for the tree size at maturity, allowing adequate room for growth between trees.

Where space is limited by underground and overhead infrastructure, street trees can be replaced by green walls. It has been calculated that 40m^2 of green wall has the same environmental benefits as a 5m diameter canopy street tree (Hopkins et al. 2012 (c)).

The selection of tree species will depend upon the local area and microclimate, the scale of the street and mature size of the tree and the local council's preference of species as shown in the local street tree master plan.

Many local councils also have typical details or Public Domain Plans that should be referred to that will include street tree planting details that specify their preferred construction method and adjacent surface finishes.

Green Street, Portland Oregon

4.8.2 LOCAL PLANNING REQUIREMENTS

Relevant local council planning requirements need to be reviewed for applicable requirements for street tree planting requirements. This may include Street Tree Master Plans, Development Control Plans (DCP) and Local Environment Plans (LEP). If green cover is not listed in the council's development controls, the designer should call the council to determine relevant considerations and requirements.

4.8.3 PROFESSIONAL CONSULTANT ADVICE AND INPUT

Specialist consultants may be required when designing and implementing street tree planting. This may include civil engineering input on the impact of the street tree planting on adjacent road surfaces over time and the strength and durability of edges and pavements. Local utility services should also be consulted.

A hydraulic engineer may also need to be consulted to advise on water sensitive urban design (WSUD), calculate a rain garden or bioswales capacity to manage rainfall and stormwater infiltration and mitigate flood risk according to local storm events. Hydraulic engineers will also provide advice on rainwater harvesting.

Depending on the specific requirements of the local council or context of the design, a consulting arborist may be required to advise on planting techniques or species selection.

4.8.4 MAINTENANCE

The level of maintenance of street tree plantings, bioswales and planting areas will largely be determined by local council resources and maintenance programs.

Street trees are a significant investment for councils and should be selected to have a life span of at least 20 years. Maintenance during the establishment period is critical to ensure longevity and to establish the tree form. Establishment maintenance includes regular watering, formative pruning and inspections for pests and diseases.

The establishment maintenance period should continue for the first two growing seasons (Landcom 2008 (a)). Tree species should require minimal maintenance beyond the establishment period (Landcom 2008 (a)).

Well designed systems and durable pavements, the appropriate selection of tree and plant species will minimise the maintenance required.

Specific maintenance requirements in addition to general maintenance may be set out within a maintenance manual or program within the construction specification.

Bioswales/rain gardens will require intermittent removal of any rubbish collected within the swale and cleaning of any overflow inlet pits to avoid blockage.

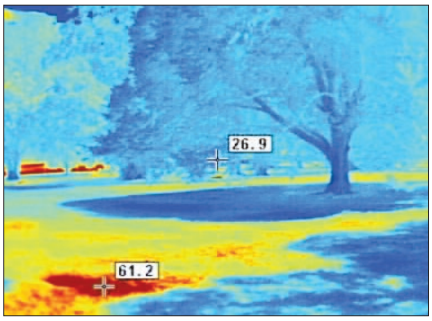
Permeable paving in nature strip – provides water infiltration to street tree root systems and reduces surface runoff (Photograph: HydroCon Australasia hydroston.com.au*)*

5 GREEN OPEN SPACES

(Photograph: Western Sydney Parklands Trust)

POTENTIAL BENEFITS

- Increased shade cover
- Reduced surface heat absorption and radiation
- Trees provide shade, cooling and increased humidity through evapotranspiration
- Air purification via plants filtering airborne particulates and absorb gaseous pollutants
- Social, community and health benefits with extended use of parks during warmer months due to shade and cooling effect of trees
- Greater night-time cooling
- Social, community, health and well-being benefits
- Stormwater management and reduced flood risk
- Reduced run-off and improved water quality
- Reduced maintenance (reduced lawn mowing with native grasses along channels)
- Visual amenity/enhancement of urban texture
- Habitat and increased biodiversity



Thermal Imaging (City of Melbourne)

5.1 GREEN OPEN SPACES

Green open spaces can contribute to the urban heat island (UHI) effect with expanses of open unshaded lawn areas, unshaded footpaths and cycle ways, exposed hard paved sports courts and concrete drainage channels. Increasing the number of canopy trees to provide shade to grass areas, cycle ways/footpaths, parklands and amenities can reduce the amount of heat absorbed and radiated.

The beneficial effect of green spaces in urban areas is known as Park Cool Island (PCI) effect. Studies have shown that individual green spaces can have a cooling effect on the microclimate up to 200m from the park, especially on the leeward side of the park assisted by wind (Hopkins 2011 (b)). The greener the park, the larger the cooling effect, and if the park is irrigated this corresponds to a greater level of cooling through evapotranspiration.

Shade trees planted at close centres so that their canopies meet to form one continuous canopy can reduce the surface temperature and UHI effect. This form of localised urban forest can replace the need for shade structures to the public realm. This lowers the ambient air temperature to a level accessible within the human comfort zone and also allows air movement to reduce humidity (Hopkins 2012).

Shade structures (for example pergolas with climbing plants) can also provide shade to surfaces and mitigate the UHI effect.

Water sensitive urban design in open spaces can also increase urban green cover and mitigate the heat island effect. This includes bioswales, rain gardens, soft landscaped detention basins and dechannelisation of hard engineering (concrete channels) to swales with mass planting and trees.

Urban wetlands are also an important component in reducing the UHI effect by evaporation and evapotranspiration through wetland plants. These urban wetlands can be part of the hard landscaping of the public realm or can be on top of building roofs or incorporated into a green wall system.

Natural ventilation using large water bodies is important to allow the cooling air to penetrate the urban environment. This needs to allow direct free air movements from the water body to the hot, built-up environment. To allow such free natural ventilation, the urban geometry of street canyons needs to be understood and designed in a manner that allows the natural removal of hot, polluted air from these street canyons.

5.2 COMPONENTS

Green open space consists of many elements that can contribute to lowering the UHI effect as well as providing spaces that are inviting and attractive for human comfort. This may be a localised urban forest, or a well-ventilated urban street or space with water sensitive urban design (WSUD) elements that clean and store stormwater within the landscape. These WSUD elements include rain gardens, bioswales, urban wetlands and dechannelisation of concrete channels.

BIOSWALE/DRAINAGE CHANNEL

Bioswales filter pollution and silt from surface water and drainage channels through their profile of vegetation, gravel and sand layers. A bioswale is typically a shallow depression with gently sloped sides. This design maximises the time water is in the swale and allows the removal of pollutants and particles before the water is released to the stormwater system or water table. Bioswales can be lined with plants or grasses. Plant species selected for bioswales will need to be tolerant of extended dry periods and shorter periods of wet. Bioswales increase the amount of stormwater returned to the water table, while subsoil drainage returns overflow water to the stormwater system.

RAIN GARDENS

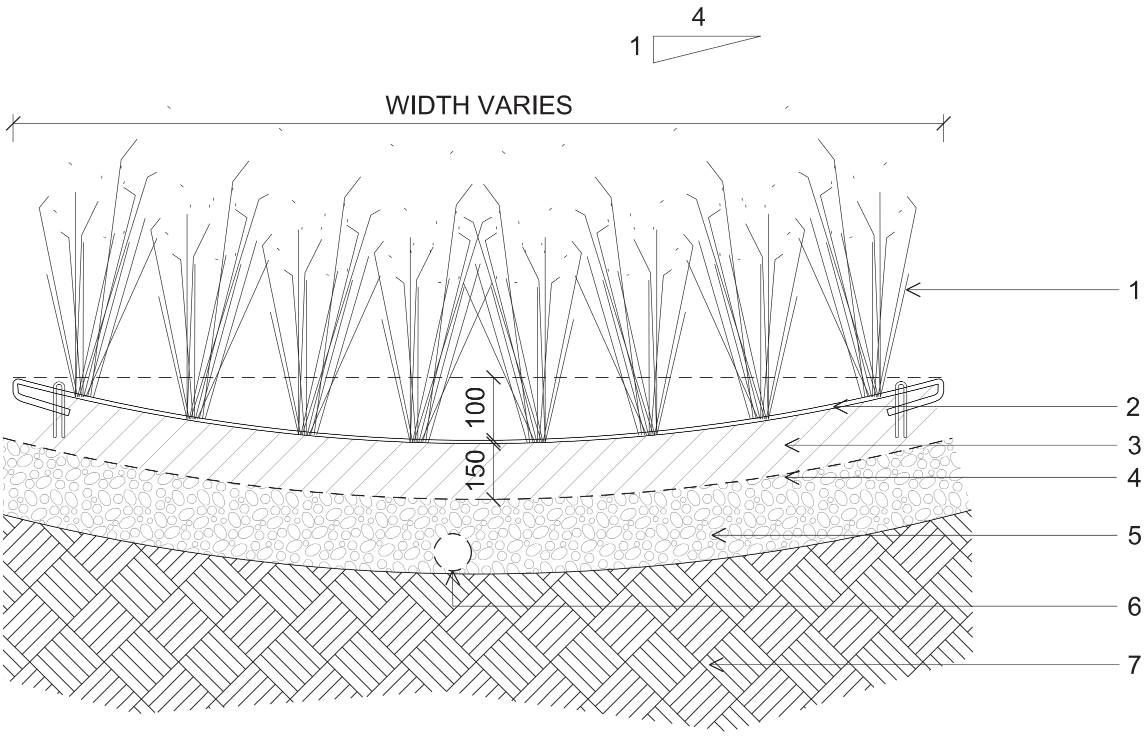
Rain gardens are garden beds that are specifically designed to capture stormwater runoff from hard surfaces or roofs. Rain gardens function as bioswales by slowing the rate of stormwater released back to the stormwater system and entering waterways and filtering pollutants and particles through layers of vegetation, gravel and sand.

Plant species selected for rain gardens will need to be tolerant of extended dry periods and shorter periods of wet. A rain garden can be sunken below adjacent surfaces or have a batter to the

Bioswale, Sydney Olympic Park Authority (Photograph: Courtesy WSUD.org)

5.3 TYPICAL CONSTRUCTION

5.3.1 BIOSWALE/DRAINAGE CHANNEL



Section 1:20

1 PLANTING
2 JUTE MAT FOR HIGH FLOW CONDITIONS OR MULCH LAYER FOR LOW FLOW CONDITIONS
3 IMPORTED TOPSOIL
4 GEOFABRIC
5 DRAINAGE LAYERS. GRAVEL AND/ OR SAND VARIES DEPENDING ON SITE CONDITIONS
6 SUBSOIL DRAINAGE IF REQUIRED
7 SUB-BASE WITH SITE SPECIFIC CROSS FALLS AND SUBSOIL TREATMENTS ACCORDING TO HYDRALUIC AND CIVIL ENGINEERS

NOTE:

- Hydraulic and civil engineering consultation required
- Swale can be planted with grass, reeds or groundcover species or turf.

sides of the trench. Like bioswales, rain gardens increase the amount of stormwater returned to the water table, while subsoil drainage returns overflow water to the stormwater system.

5.4 ESSENTIAL CONSIDERATIONS

5.4.1 DESIGN

Open space planning needs to address the orientation, local vegetation, usage/function, connectivity, urban ecology/habitat and potential urban micro climate contribution.

Water Sensitive Urban Design elements such as bioswales, rain gardens and detention basins need to be designed to manage the amount of stormwater it will receive based on the storm events specific for the local area.

5.4.2 LOCAL PLANNING REQUIREMENTS

Relevant local council planning requirements need to be reviewed for applicable requirements for green open space requirements. This may include Development Control Plans (DCP), Local Environment Plans (LEP), Recreation Plans and Plans of Management etc. Local councils may also have other authority design requirements such as Environmentally Sustainable Design (ESD) strategies, riparian corridors, bushfire management and heritage items. If green open space cover is not listed in the council's development controls, the designer should call the council to determine relevant considerations and requirements.

5.4.3 PROFESSIONAL CONSULTANT ADVICE AND INPUT

The engagement of professional consultants in creating new open spaces or enhancing existing green cover within open spaces may depend upon the project size, complexity and budget.

Thornley Street Raingarden (Photograph: Courtesy Marrickville Council)

De-channelisation, Fairfield NSW (Photograph: I. Hobbs)

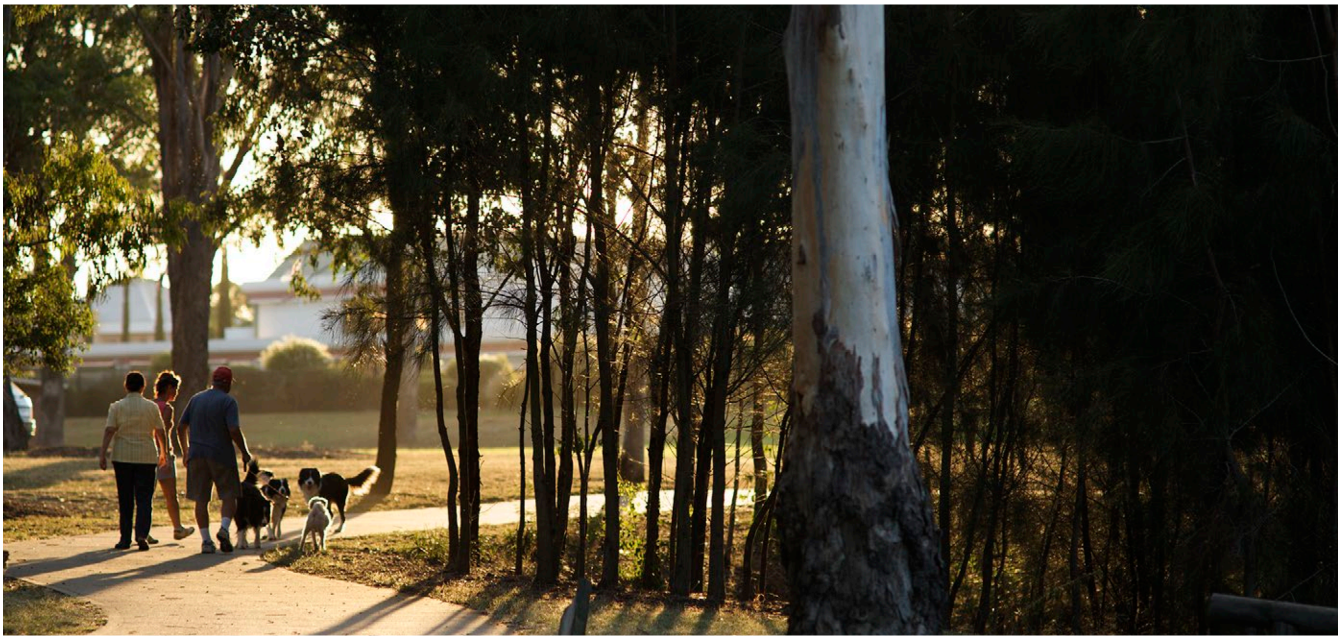
Consultants could include:

- Landscape architect: master planning, design and documentation of the open space, planting design and species selection
- Arborist: tree assessment and arboricultural advice
- Horticulturist: may be required for plant selection and soil advice
- Ecologist: can provide specialist advice on designing and planning for the flora and fauna specific to the local ecological systems, for example wetland management
- Structural engineer: required where any structures such as shade structures are proposed
- Hydraulic engineer: will be required to advise on stormwater infiltration and mitigation of flood risk according to local storm events. Hydraulic engineers will also provide advice on rainwater harvesting
- Civil engineer: will be required to advise on earthworks and any new pavements, slabs and appropriate loadings.

5.4.4 MAINTENANCE

In addition to the standard parks and open space maintenance programs, local councils may be involved in biodiversity, bush regeneration or environmental education programs to protect, enhance, manage and maintain open spaces. These programs may utilise the community for voluntary maintenance and planting programs.

Urban green cover designs and proposals need to consider the local council maintenance capacity, expertise and annual maintenance budget. An assessment of projected climate changes is also advisable so that changing climate trends and social responses can be accounted for in species selection, landscape design and asset and operations planning.



Tree planting in a park provides shade, reduces heat absorption and radiation (Photograph: I. Hobbs)

6 RELEVANT COMPLEMENTARY STANDARDS AND DOCUMENTATION

6.1 BUILDING STANDARDS

General Sustainability Guidelines

- AS 5334: Principle Based Climate Change Adaptation – Requirements for Settlements and Infrastructure
- 'Your home technical manual', 2011, 4th edition, Australian Government Dep. Of Climate Change and Energy Efficiency

Building Regulations

- Australian Standards
- Building Code of Australia (BCA) BCA Volume 1 Section J: Energy Efficiency Provision Changes, BCA Volume 2 Part 3.12 Energy Efficiency Provisions Changes
- BASIX (Building Sustainability Index) NSW Department of Planning and Infrastructure

Building and Structural Design

- AS/NZS: 1668 (Set) – 2005: The use of ventilation and air conditioning in buildings
- AS/NZS 1170.2:2011/Amdt 1-2012: Structural Design Actions – wind action
- AS/NZS 1170.0:2002: Structural Design Actions – General Principles
- AS/NZS 1170.0:2002/Amdt 2:2009: Structural Design Actions – Permanent, imposed and other actions
- AS/NZS 1170.3:2003: Structural Design Actions – Snow and ice actions
- AS 4055 – 2006/Amdt 1-2008: Wind Loads for Housing
- AS ISO 13822-2005: Basis for design of structures – Assessment of existing structures
- AS/NZS 1554:2011: Structural steel welding
- AS 4100-1998: Steel structures
- AS 1720.1-2010: Timber structures – Design methods
- HB 49-1999: Steel structures design handbook
- AS 1562.1-1992: Design and installation of sheet roof and wall cladding – Metal
- AS/NZS 1562.2:1999: Design and installation of sheet roof and wall cladding – Corrugated fibre-reinforced cement
- AS 1562.3-2006: Design and installation of sheet roof and wall cladding – Plastic
- AS 4256.1-2006: Plastic roof and wall cladding materials – General requirements
- AS 4040.0-1992: Methods of testing sheet roof and wall cladding

Maintenance

- AS 2698.2-2000: Plastics pipes and fittings for irrigation and rural applications – Polyethylene rural pipe

Health And Safety Workmanship

- Work Health and Safety Act 2011
- Code of Practice: Managing the risk of falls at the workplace, December 2011, Workcover
- Code of Practice: Preventing Falls in Housing Construction, July 2012, Safe Work Australia
- Code of Practice: Safe Design of Structures, July 2012, Safe Work Australia
- Code of Practice: Managing Risks of hazardous chemicals in the workplace, July 2012, Safe Work Australia
- Code of Practice: Managing the work environment and facilities, July 2012, Safe Work Australia
- Code of Practice: Construction Work, July 2012, Safe Work Australia

Waterproofing Specifications

- AS 4654.1-2012: Waterproofing membranes for external above-ground use-Materials
- AS 4654.2-2012: Waterproofing membranes for external above-ground use-Design and installation

Timber Specifications

- AS CA65-1972: Use of timber in structures (known as the SAA Timber Engineering Code)

Insulation Specifications

- AS 1366.1-1992: Rigid cellular plastics sheets for thermal insulation – Rigid cellular polyurethane (RC/PUR)
- AS 1824.1-1995: Insulation co-ordination – Definitions, principles and rules
- AS 3999-1992: Thermal insulation of dwellings – Bulk insulation – Installation requirements
- AS/NZS 4859.1:2002: Materials for the thermal insulation of buildings – General criteria and technical provisions
- AS/NZS 4200.1 1994.1: 'Pliable building membranes and underlay's – Material'

Drainage

- AS/NZS 3500 Set:2003: Plumbing and drainage Set
- AS 2439.1-2007: Perforated plastics drainage and effluent pipe and fittings
- AS/NZS 3500.1:2003: Plumbing and drainage – Water services
- AS/NZS 3500.3:2003: Plumbing and drainage – Stormwater drainage
- AS/NZS 3500.5:2012: Plumbing and drainage – Housing installations
- ATS 5200 Series: Technical Specification for plumbing and drainage products

Geotextile/Filter Layer

- AS 3705-2012: Geotextiles – Identification, marking and general data
- AS 3706.1-2012: Geotextiles – Methods of test-General requirements, sampling, conditioning, basic physical properties and statistical analysis

Growing Medium

- AS 1289.0-2000: Methods of testing soils for engineering purposes – General requirements and list of methods
- AS 4419-2003: Soils for landscaping and garden use
- AS 4454-2012: Composts, soil conditioners and mulches
- AS3743: Potting Mix
- Handbook (HB) 160-2006 Soils testing

Plant Stock

- NATSPEC 'Specifying Trees – a Guide to Assessment of Tree Quality' (Clark, R 2003)

Car Parking

- AS 2890.1 Parking Facilities Off-Street Car Parking: Pavement to accommodate vehicular traffic

6.2 CRIME PREVENTION THROUGH ENVIRONMENTAL DESIGN

- Crime Prevention Legislative Guidelines: Section 79C of the Environmental Planning and Assessment Act 1979
- NSW Police Force Safer by Design resources

6.3 DISABILITY ACCESS

- AS 1428: Design for Access and Mobility
- Disability (Access to Premises-Buildings) Standards 2010
- Disability Discrimination Act 1992 (DDA)

6.4 FIRE SAFETY

- Planning for Bushfire Protection (NSW Rural Bushfire Service, 1996)
- AS 3959: Construction of buildings in bushfire prone areas
- AS 1530.2: Methods for fire test on building materials, components and structures – test for flammability of materials
- AS1530.2: Surface fire performance for facings and foils
- AS/NZS: 1530.3: 1999: Methods for Fire Tests on Buildings, Materials, components and structures
- AS:1530.4: 2005: Methods for fire tests on building materials, components and structures – fire resistance test of element of construction
- AS 1530.1-1994: Methods for fire tests on building materials, components and structures – Combustibility test for materials
- HB 330-2009: Living in Bushfire Prone Areas
- Building amendment (private bushfire shelter construction) regulations 2011
- AS 1720.4-2006: Timber structures – Fire resistance for structural adequacy of timber members

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