Department of Planning and Environment

Technical guidance for achieving Wianamatta–South Creek stormwater management targets

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Role of this guide

The NSW Government has set construction and operational phase stormwater management targets to achieve waterway health objectives for protecting and restoring the blue grid in the Wianamatta–South Creek catchment. The blue grid is made up of waterways, riparian vegetation communities, wetlands, and other water dependent ecosystems.

The role of this guide is to support:

- approval and consent authorities in the assessment of state significant development (SSD), state significant infrastructure (SSI), development applications and modification applications
- the Minister in determining whether to approve Master Plans that are proposed to apply to specified land to which Chapter 4 of the State Environmental Planning Policy (Precincts – Western Parkland City) 2021 applies
- *any* practitioner, applicant or proponent involved in planning, design, approval, delivery and operation of water sensitive urban design (WSUD) strategies to achieve the stormwater management targets.

The guide provides specific direction on what modelling to undertake, assumptions to make and which data to use to demonstrate that the stormwater management targets are being achieved. It provides information on how to access a calibrated MUSIC[1] model file with source nodes suitable for use in the Wianamatta–South Creek catchment.

The guide outlines WSUD design considerations in the context of the vision for the Western Parkland City, landscape constraints such as salinity and sodicity hazards, and interactions with the floodplain. Example WSUD strategies that achieve the stormwater management targets are also provided in this guide for large format industrial (LFI), high density residential (HDR) and low density residential (LDR) typologies.

How to use this guide

This guide has 4 chapters, plus appendices and a glossary, as outlined in Table 1.

Table 1 Structure of this guide

Chapter	Description
Chapter 1 – Stormwater management targets	Outlines the construction and operational phase stormwater management targets required to achieve waterway health objectives
Chapter 2 – Achieving stormwater management targets	Guidance on what modelling to undertake, assumptions to make and which data to use to demonstrate that the targets are being achieved Information on a modelling toolkit that contains a calibrated MUSIC model and post-processing spreadsheet, which were developed to support proponents in demonstrating compliance with the targets A range of considerations to support existing lodgement requirements / submissions

[1] MUSIC (Model for Urban Stormwater Improvement Conceptualisation) is an industry standard and widely used tool for developing WSUD strategies.

Chapter	Description
Chapter 3 – WSUD design considerations	A range of design considerations for WSUD infrastructure in the Wianamatta–South Creek catchment with reference to other guidelines to ensure best contemporary practice
Chapter 4 – Example WSUD strategies	A range of example WSUD strategies that suit different typologies. These include strategies for different scales of development as well as an interim strategy, which demonstrates how partial development can achieve the targets until the site is fully developed and connected to a regional stormwater system
Appendix A – MUSIC model parameters	Sets out acceptable parameters to use for specific elements of a MUSIC model, including the appropriate climate data
Appendix B – Water demand data	A consistent set of water demand data for use in performance modelling to demonstrate compliance with the operational phase stormwater quality and quantity targets
Acknowledgements	Details about the preparation of this guide
Glossary	Explanations of specialised terms used in this guide
References	Documents cited in this guide
More information	Links to online resources

Relationship to other documents

Further guidance on the design of stormwater treatment systems and WSUD strategies for developments in the Wianamatta–South Creek catchment includes:

- *Managing Urban Stormwater: Soils and Construction* – Blue Book (NSW Government 2004)
- *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks: Stormwater harvesting and reuse* (NRMC, EPHC and NHMRC 2009)
- *Penrith City Council Water Sensitive Urban Design (WSUD) Policy* (PCC 2013)
- *Penrith City Council WSUD Technical Guidelines* (PCC 2015)
- *Blacktown City Council Developers Toolkit for Water Sensitive Urban Design (WSUD)* (BCC 2022)
- *Blacktown City Council WSUD developer handbook MUSIC modelling and design guide* 2020 (BCC 2020)
- *Blacktown City Council Water sensitive urban design (WSUD) standard drawings* (BCC 2017)
- *Liverpool City Council Water Sensitive Urban Design (WSUD) guideline* (LCC 2015).

Background and other supporting information for this guide is available from:

- *Mapping the natural blue grid elements of Wianamatta–South Creek: High ecological value waterways, riparian vegetation communities and other water dependent ecosystems* (DPE 2022b)
- *Performance criteria for protecting and improving the blue grid in Wianamatta–South Creek: Water quality and flow related objectives for use as environmental standards in land use planning* (DPE 2022c)
- *Wianamatta–South Creek stormwater management targets* (DPE 2022d)
- *Review of water sensitive urban design strategies for Wianamatta–South Creek* (DPE 2022e)
- *Urban salinity management in the Western Sydney Aerotropolis area* (DPIE 2021c)
- *Soil and land resource mapping for the Western Sydney Aerotropolis area* (DPIE 2021d).

Chapter 1 – Stormwater management targets

The Wianamatta–South Creek catchment is part of the Hawkesbury–Nepean River system and lies approximately 50 km west of Sydney. It is the central location for the Western Parkland City, and Sydney's second international airport. Strategic land-use planning for the area has been landscape led (DPE 2022a; DPIE 2021e), predominantly achieved through the creation of a Blue–Green Infrastructure Framework to provide a range of benefits related to liveability, building resilience to city hazards like urban heat and flooding, and protecting the iconic and/or endangered ecological communities and waterways that characterise the area (GSC 2018; DPIE 2021e; DPE 2022a).

This landscape led approach has changed almost all aspects of land-use planning for the airport and surrounding precincts that make up the Western Sydney Aerotropolis. This includes changes to planning controls for stormwater infrastructure delivery, which have shifted from long standing post development stormwater load reductions targets to the new outcomes-based targets outlined in this guide. The new targets are designed to achieve ambient water quality and flow related objectives (viz. waterway health objectives) for protecting and restoring the waterways and water-dependent ecosystems making up the blue grid.

The targets are provided to strengthen provisions for controlling sediment during the construction phase of development, and for compliance at the outlet of a development site during the operational phase (i.e. once the site has been developed).

Construction phase targets

Construction phase stormwater quality targets apply to development sites >2,500 m^2 (Table 2). The targets were designed to strengthen existing requirements in the Managing Urban Stormwater: Soils and Construction (the Blue Book), in particular with regard to treating a minimum volume of annual runoff from a construction site.

It is ideal for independent audits to be undertaken by a Certified Professional in Erosion and Sediment Control (CPESC) to certify that the management of the site complies with these targets, or where not in compliance, specific advice is provided to the proponent to achieve compliance.

Table 2 Construction phase stormwater quality targets

Parameter	Target (reduction in mean annual load from unmitigated development)
Total suspended solids (TSS) and pH	All exposed areas greater than 2,500 m^2 are to be provided with sediment controls that are designed, implemented and maintained to a standard that would achieve treatment of at least 80% of the average annual runoff volume of the contributing catchment (i.e. 80% hydrological effectiveness) to 50 mg/L TSS or less, and pH in the range (6.5–8.5) No release of coarse sediment is permitted for any construction or building site Sites less than 2,500 m^2 are required to comply with the requirements of the Blue Book

Parameter	Target (reduction in mean annual load from unmitigated development)
Oil, litter and waste contaminants	No release of oil, litter or waste contaminants
Stabilisation	Prior to completion of works for the development, and prior to removal of sediment controls, all site surfaces are to be effectively stabilised including all drainage systems An effectively stabilised surface is defined as one that does not or is not likely to result in visible evidence of soil loss caused by sheet, rill or gully erosion or lead to sedimentation and water contamination

Operational phase targets

For the operational phase targets there are 2 options available for stormwater quality and 2 for stormwater quantity (flow). The choice of 2 options is intended to provide flexibility in demonstrating compliance with the targets.

> One option each for stormwater quality and stormwater quantity must be achieved to demonstrate compliance.

For stormwater quality targets, most development will likely adopt Option 1, which is based on annual load reduction targets (Table 3). If a development incorporates significant areas of pervious space (e.g. by adopting green roofs), then a proponent may prefer to use Option 2, which is based on allowable loads (Table 4).

Differences between the 2 options for the stormwater quantity (flow) targets are mainly related to the extent of post-processing of results generated from the industry standard model MUSIC. Option 1 allows results to be directly extracted from MUSIC and compared with the targets (Table 5). Option 2 requires flow data to be extracted from MUSIC and a flow duration curve to be developed (Table 6). The proponent is free to select whichever option suits their WSUD strategy best, noting that:

- Option 1 stormwater quantity (flow) targets are based around limiting the mean annual runoff volume (MARV) from a development site as well as ensuring there is a suitable low flow regime in the streams.
- Option 2 stormwater quantity (flow) targets are based on preserving key percentiles of a flow duration curve.
- Compliance with the flow percentiles is demonstrated when the stormwater volume discharges at the outlet of a development site is between the upper and lower bands/ranges specified for the flow percentile

Table 3 Operational phase stormwater quality targets Option 1 – annual load reduction

Parameter	Target – reduction in mean annual load from unmitigated development
Gross pollutants (anthropogenic litter >5 mm and coarse sediment >1 mm)	90%
Total suspended solids (TSS)	90%
Total phosphorus (TP)	80%
Total nitrogen (TN)	65%

Table 4 Operational phase stormwater quality targets Option 2 – allowable loads

Parameter	Target – allowable mean annual load from development
Gross pollutants (anthropogenic litter >5 mm and coarse sediment >1 mm)	<16 kg/ha/y
Total suspended solids (TSS)	<80 kg/ha/y
Total phosphorus (TP)	<0.3 kg/ha/y
Total nitrogen (TN)	<3.5 kg/ha/y

Table 5 Operational phase stormwater quantity (flow) targets Option 1 – MARV

Parameter	Target
Mean annual runoff volume (MARV)	≤2 ML/ha/y at the point of discharge to the local waterway
90%ile flow	1,000–5,000 L/ha/day at the point of discharge to the local waterway
50%ile flow	5–100 L/ha/day at the point of discharge to the local waterway
10%ile flow	0 L/ha/day at the point of discharge to the local waterway

Table 6 Operational phase stormwater quantity (flow) targets Option 2 – flow percentiles

Parameter	Target
95%ile flow	3,000–15,000 L/ha/day at the point of discharge to the local waterway
90%ile flow	1,000–5,000 L/ha/day at the point of discharge to the local waterway
75%ile flow	100–1,000 L/ha/day at the point of discharge to the local waterway
50%ile flow	5–100 L/ha/day at the point of discharge to the local waterway
Cease to flow	Cease to flow to be between 10% and 30% of the time

Chapter 2 – Achieving stormwater management targets

This chapter provides guidance on technical modelling requirements to demonstrate that the operational phase stormwater targets (Table 3 to Table 6) are being achieved, including what assumptions to make and which data to use. The technical modelling requirements apply, irrespective of the scale of delivery of WSUD infrastructure; that is, lot, streetscape, precinct or regional scale. Examples of the application of the technical modelling requirements at varying scales of delivery are provided in Chapter 4 of this guide.

The general approach to demonstrating the targets are achieved is to:

a. establish which stormwater quality and quantity target options (1 or 2) will be used – refer to Table 3 to Table 6 in Chapter 1 of this guide
b. devise WSUD strategies that will meet the stormwater quality and quantity targets:
    i. follow technical modelling requirements and WSUD design considerations to demonstrate the performance of the WSUD strategies. These requirements and considerations are specified in this guide, in the section titled ‘Technical modelling (MUSIC) requirements’ and Chapter 3 ‘WSUD design considerations’, respectively
    ii. refer to examples of WSUD strategies in Chapter 4 of this guide
c. establish management arrangements for WSUD strategies to demonstrate long-term operation
d. compile lodgement requirements (see respective section in this chapter) for submission to relevant approval or consent authority.

The example WSUD strategies in Chapter 4 of this guide include an interim solution to allow development to commence while planning for a regional stormwater system is undertaken. The interim solution includes:

- *interim* WSUD strategies that can comply with the stormwater quality and quantity targets in the absence of the regional stormwater system – typically these include partial development of an area
- *ultimate*/*final* WSUD strategies that enable the interim solutions to transition to full development that incorporates the regional stormwater system, such as reticulated stormwater harvesting and regional treatment.

Technical modelling (MUSIC) requirements

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is required for developments to demonstrate how the targets are achieved. MUSIC modelling should follow the specifications provided in this guide, and for parameters outside the scope of this guide, follow the recommendations of the relevant documents of local council’s in Wianamatta (see the ‘Relationship to other documents’ section of this guide).

Appendix A provides ranges of acceptable parameters to use for specific elements of a MUSIC model, including the appropriate climate data. Further guidance on WSUD strategies and how to model them is presented in Chapter 4 of this guide. A MUSIC file that contains the climate data and source node parameters is part of a MUSIC modelling toolkit to support this guide. A spreadsheet for post-processing daily modelled flow data to generate and assess whether the flows from the site of development achieves the stormwater quantity (flow) targets is also available in the toolkit.

MUSIC modelling toolkit

The ‘MUSIC modelling toolkit for Wianamatta–South Creek’ is available from the NSW Government Sharing and Enabling Environmental Data (SEED) portal. Refer to the ‘More information’ section below for a link to the toolkit.

Presenting MUSIC results

The results of the MUSIC modelling should be compared to the operational phase stormwater management targets (Table 3 to Table 6) to demonstrate they have been achieved.

Stormwater quality targets (% load removed) can be directly extracted from the ‘treatment train effectiveness’ statistics in MUSIC models from the most downstream node, and expressed as either annual load reductions or allowable loads.

Accordance with stormwater quantity (flow) targets can be demonstrated in 2 ways depending on which targets are adopted (Table 5, Table 6).

For Option 1, (MARV; Table 5) mean annual runoff volumes and selected flow percentiles can be extracted directly from MUSIC (Statistics/Flow-weighted Daily Mean). Note that the results presented in MUSIC are in m^3/s and therefore need to be converted to ML/ha/day or L/ha/day to compare with the target values.

Option 2 (flow percentiles; Table 6) requires daily flow data to be extracted from MUSIC (Export/Flow-daily timestep) at the most downstream node. These data are then plotted in a flow duration curve to compare with the target values. The post-processing spreadsheet contained in the MUSIC modelling toolkit was developed to support this option. Accordance is shown with the stormwater quantity (flow) targets by presenting the flow rates for different flow duration percentages and comparing to the ranges of the targets, either in tables or plots. Examples of how to present this data are provided in Chapter 4.

Supporting information for applications

This section of the guide provides supporting information to assist applicants to demonstrate how they achieve the stormwater management targets.

Pre-lodgement

Prior to lodging SSD, SSI or development applications, it is recommended that an applicant or proponent meet with the relevant approval or consent authority to confirm the stormwater management targets and acceptable WSUD strategies and devices.

An optimal approach would be for the applicant or proponent to undertake a preliminary site assessment and provide a range of baseline information to inform pre-lodgement discussions and/or be included in scoping reports. These could include, but are not limited to:

- natural attributes such as existing environmental values of the site and its surrounding area including waterways or wetlands, native vegetation, native flora and fauna and its habitat, biodiversity corridors, waterway corridors/buffers and other natural features. Natural attributes proposed to be either retained, enhanced or removed should be clearly identified
- stormwater drainage characteristics such as the site’s existing topography, stormwater drainage within and downstream of the development site. Existing and proposed discharge points should be identified

- geology and soils to support evaluations in identifying soil types, erosivity, hydraulic conductivity, presence of sodic or saline soils, presence of rock and general groundwater details. If this is not available, the default assumption for the Wianamatta–South Creek catchment is that the soils are saline and sodic
- the proposed approach for achieving the stormwater targets should be provided along with a summary of the likely WSUD strategy for the site. Performance modelling is not required at this stage
- presence of lakes or dams to inform whether they will be retained or decommissioned. Note that if a new lake or dam is proposed, the design objectives should be described (i.e. amenity or stormwater harvesting) and the proposed ownership of the lake outlined.

Development applications (local and state government)

SSD, SSI or development applications should ensure the stormwater management targets are achieved as outlined in an Erosion and Sediment Control Plan (ESCP) for the construction phase, and in a Water and Stormwater Management Plan for the operational phase.

> Concept development applications should demonstrate that the concept plan, Stage 1 and subsequent stages of development can achieve the stormwater management targets set out in this guide (Table 3 to Table 6).

Erosion and Sediment Control Plan

An ESCP would generally include the following information to demonstrate the construction phase stormwater quality targets (Table 2) are achieved. A conceptual ESCP would be required for an area of disturbance less than 2,500 m^2. A more detailed plan is generally required to demonstrate compliance with targets for areas greater than 2,500 m^2.

The detailed plan would:

- be developed and certified by a Certified Professional in Erosion and Sediment Control (CPESC) or a qualified and experienced civil engineer with at least 5 years' experience in the development of site-specific soil and water management plans
- illustrate appropriate controls, that when implemented will achieve the construction phase stormwater quality targets in Table 2
- be prepared in accordance with the Blue Book (NSW Government 2004)
- be prepared in accordance with the WSUD design considerations set out in Chapter 3 of this guide (especially WSUD measures)
- provide conceptual designs that include the site, catchment and key features of the ESCP on scaled drawings.

The scope of each ESCP is dependent on the scale of disturbance and site characteristics with larger-scale construction requiring more detail.

Water and Stormwater Management Plan

A Water and Stormwater Management Plan should demonstrate how the operational phase stormwater quality and flow targets are achieved for the development site. To ensure the plan is implementable it would typically be prepared and certified by a suitably qualified engineer with at least 5 years' experience in modelling, design and supervision of WSUD systems, and describe the site, development, water use and WSUD strategy.

The plans are generally concise yet present all the information outlined in Table 7 to demonstrate how the targets can be achieved. The plan focuses on a particular site and its attributes and is not required to reproduce general information from other WSUD guidelines such as descriptions of treatment systems.

Table 7 Information to include in a Water and Stormwater Management Plan

Section / item	Contents
Site description	• Location of site • Plan of waterways and habitat (scaled) and summary of what is to be preserved • Receiving waterways and waterway buffers • Existing wetlands, native vegetation, native flora and fauna and its habitats, biodiversity corridors • Existing catchment and drainage plan (scaled) • Sub-catchments with areas • Contours • Drainage and discharge locations to waterways • Geology and soils (with plans as required)
Proposed development	Plan of development (scaled) with land use or land type split shown (roof, ground level impervious, pervious, road, open space, drainage and WSUD) Estimate of water demand and sources including the use of alternative water sources such as stormwater and recycled water
Stormwater targets	Summary of stormwater targets that apply
WSUD strategy	Details of the proposed WSUD strategy for the development including drawings, tables and relevant descriptions of the following: • catchment and drainage plan showing sub-catchment extents, areas of roof, ground level impervious/pervious and associated drainage systems (i.e. kerb, surface drainage pits, pipes, etc.), WSUD measure locations, stormwater quantity management systems and drainage connection or outlet locations for WSUD measures • details of connections to any relevant regional stormwater and recycled water systems • WSUD system details including type, purpose, location and size • conceptual design of each WSUD measure with sufficient detail to confirm its feasibility; typically including area, surface levels, inflow and outflow levels, batters and a conceptual earthworks plan in 3D form to show how it relates to the development • plan views and cross-sections showing levels and functional details for each WSUD system • staging plan to illustrate how each WSUD measure will be delivered with the development stages to ensure compliance with the operational phase stormwater targets • details of any interim WSUD strategy if the regional stormwater system cannot be implemented initially, to ensure the operational phase stormwater management targets are achieved at all times
Performance assessment	MUSIC modelling: • MUSIC assumptions (for any that are different from this guide) • catchment assumptions (land use or land type split and % impervious) • stormwater quality performance (% removal) • stormwater flow performance for all discharge locations • stormwater quantity modelling • pre and post development flows/levels
Maintenance and operations	Draft operation and maintenance manual for assets, submitted in support of development applications to outline maintenance requirements / commitments

Post development application (local and state government) approval

The documentation should include drawings and plans prepared by qualified professionals, specifically:

- **Erosion and Sediment Control Plan**

Detailed ESCPs and drawings should demonstrate the construction approach and timing so that the construction phase stormwater quality targets (Table 2) are met. Plans should be prepared in accordance with the Blue Book (NSW Government 2004), and with the WSUD design considerations set out in Chapter 3 of this guide (especially WSUD design on waterfront land). The ESCP should be prepared and certified by a CPESC or a qualified and experienced civil engineer with at least 5 years' experience in the development of site-specific soil and water management plans.

- **Water and Stormwater Management Plan**

Detailed Water and Stormwater Management Plans and drawings should demonstrate the construction approach and timing so that the operational phase stormwater quality and quantity targets (Table 3 to Table 6) are met by:

- being completed and certified by a **suitably qualified engineer** with at least 5 years' experience in WSUD design
- **updating the Water and Stormwater Management Plan** – the Water and Stormwater Management Plan should be updated if the WSUD strategy has changed as part of detailed design (e.g. changes in catchments, treatment systems, sizes)
- providing **engineering drawings** that document the WSUD measures. WSUD drawings are clearly identified in a drawing set and are of sufficient detail and resolution to support a detailed appraisal and tender issue. They would include annotated drawings for all WSUD elements including plan views, cross-sections and long sections. The designs would occur in accordance with the WSUD design considerations set out in Chapter 3 of this guide and with the section titled 'Relationship to other documents'
- providing **landscape drawings** to document planting and hardscape details of the WSUD measures. These would include topsoil requirements, planting details of surface and all batters and embankments (species, zones and densities), planting schedule, mulching details, hardscape details including maintenance access, finishes and notes
- providing completed **checklists and certification** for the proposed WSUD measures based on those prepared by Local Government Authorities as listed in the section titled 'Relationship to other documents'. Other best practice checklists should also be consulted; for example, *Water Sensitive Urban Design Technical Design Guidelines* (Water by Design 2006), *Bioretention Technical Design Guidelines* (Water by Design 2019a) and *Wetland Technical Design Guidelines* (Water by Design 2019b). The checklists are typically accompanied by a letter of certification by the preparer of the WSUD strategy confirming that the detailed design is consistent with the approved strategy and the operational phase stormwater quality and quantity targets are achieved.

Chapter 3 – WSUD design considerations

Development will typically generate 3–5 times more runoff than existing or pre-development volumes, depending on the specific development scenario (e.g. greenfield). Infiltrating this excess volume is a common and best practice approach for frequent rain events to reduce impacts on waterways; however, one of the critical considerations for the Wianamatta–South Creek catchment is the highly saline and sodic soils (DPIE 2021c, d).

The soil and hydrogeological landscapes of the catchment are well documented by the NSW Government (DPIE 2021c, d), and include specific actions to manage the high risk of salinity hazard impacts on both the built form and the water dependent ecosystems. As shown in Figure 2, almost all the development area within the Aerotropolis is identified as having high to very high salinity hazard risk. The specific management actions outlined by the NSW Government were therefore key factors in developing the WSUD design considerations set out in this guide. These considerations should be applied with reference to other documents listed in this guide (see section titled 'Relationship to other documents') to ensure best contemporary practice, in the context of relevant legislation and policies.

Figure 1 *Juncus acutus* (tussock forming rush) indicates presence of saline subsoils in the Wianamatta–South Creek catchment

Photo: Rob Muller

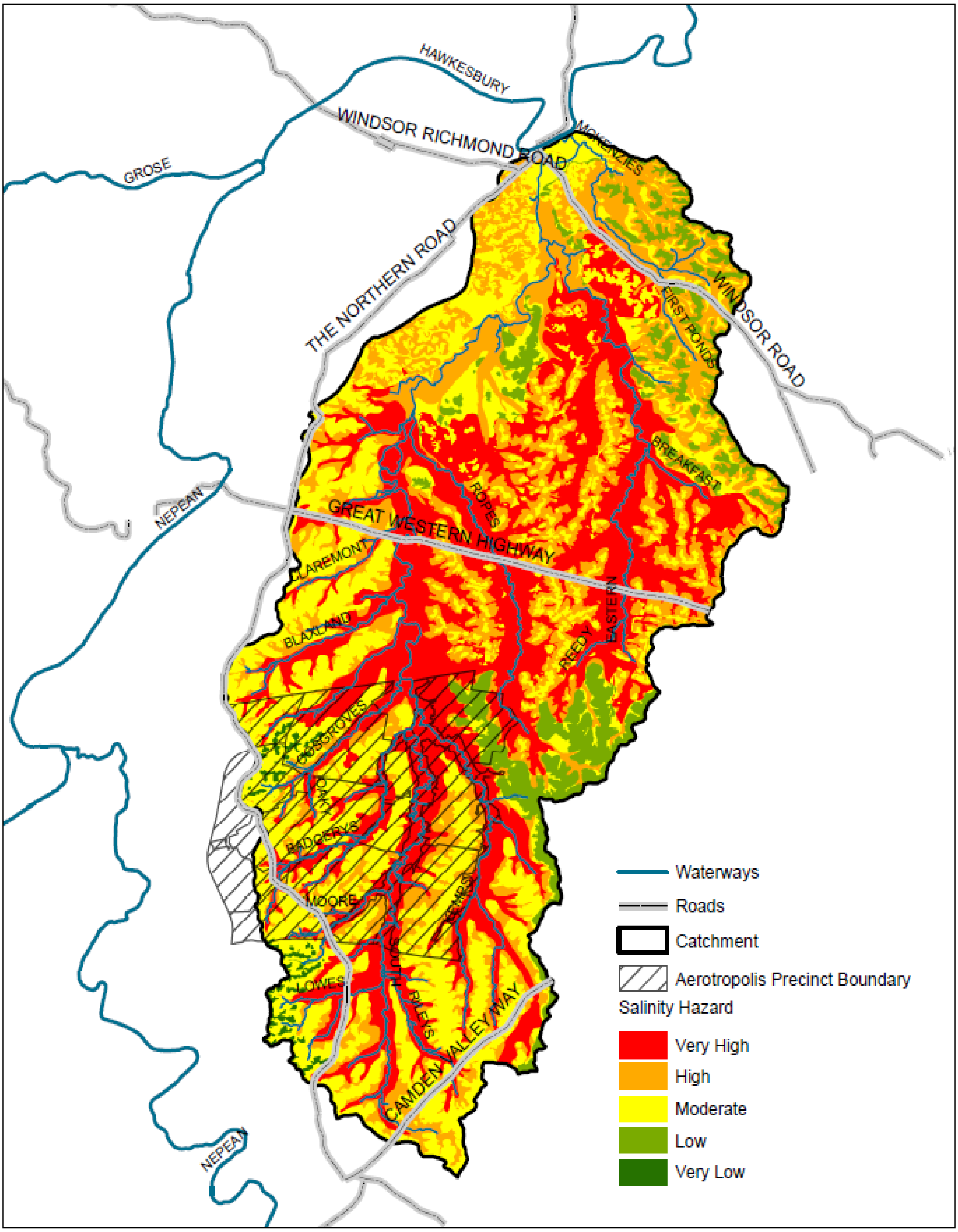

Figure 2 Landscape salinity hazard risk in Wianamatta–South Creek
Data source: South Creek Hydrogeological Landscapes: June 2020 (First Edition)

Erosion and sediment control design principles

The intent of an ESCP is to prevent water contaminants from being released from a construction or building site. Best practice measures to be undertaken would be consistent with the Blue Book (NSW Government 2004). These would typically include components that cover:

- minimising soil exposure and erosion
- drainage and stormwater control
- sediment capture and minimising contaminant releases
- work within waterways.

Best practice initiatives that strengthen the elements in the Blue Book include achieving the construction phase targets outlined in Table 2. For areas larger than 2,500 m^2, this involves designing and implementing sediment controls that treat at least 80% of the average annual runoff volume (i.e. 80% hydrological effectiveness) to 50 mg/L TSS or less, and pH in the range 6.5–8.5. To achieve these construction phase targets, the design of the basins generally needs to:

- be sized and operated in accordance with either a Type-A or Type-B sediment basin as documented in IECA (2008) Appendix B (June 2018)
- be provided with an automated system of flocculant dosing and a suitable supply of flocculant/coagulant, with the type of flocculant/coagulant determined based on the International Erosion Control Association (IECA) chemical coagulants and flocculants fact sheet (IECA 2018)
- have markers within each basin to show the maximum sediment storage level and any additional water storage capacity for water reuse
- limit discharge from the primary outlet system to 50 mg/L TSS, with a pH within the range of 6.5–8.5
- be operational before any disturbance occurs in the catchment upslope of the basin.

Figure 3 High efficiency basin
Photo: Design Flow Consulting

WSUD design principles

The main WSUD design principles that should be considered when selecting WSUD measures for a particular WSUD strategy are:

1. Preference for vegetated treatment systems as they provide hydrologic and green infrastructure benefits.
2. Infiltration measures (including unlined porous pavements) are unlikely to be feasible because of saline and sodic soils, unless detailed site analysis is done to confirm feasibility.
3. Stormwater treatment systems should be arranged in parallel as much as possible, to minimise double treating of stormwater.
4. Stormwater harvesting is likely to be a fundamental part of the WSUD strategy for protecting waterways. Preference is for a reticulated scheme that delivers harvested water to all lots and for all non-potable demands.
5. Irrigation rates are managed to avoid over irrigation and exacerbating saline and sodic soil issues.
6. Stormwater management systems should be lined to minimise infiltration (e.g. engineered clays or synthetic liners).
7. Stormwater treatment and harvesting systems can be located within the 1% AEP. However, they are to be avoided in flood conveyance areas (i.e. 1% AEP floodways and high floodways) and critical flood storage areas unless a flood impact and risk assessment for the development demonstrates that their impacts on flood behaviour and on the community can be managed. Refer to principles set out for the floodplain in this chapter of the guide (see section ‘Location on the floodplain and design principles’).
8. Stormwater treatments and harvesting storages can be located within the vegetated riparian zone (VRZ), provided the function of the VRZ is preserved and design principle 7 (above), and those set out for waterfront land in this chapter of the guide are satisfied (see section ‘WSUD design principles on waterfront land’).

Water demands

Non-potable water demands on lots and in public open spaces are a critical consideration in achieving the stormwater quantity (flow) targets (Table 5, Table 6). The higher the water demand, the easier it is to achieve the targets. Demands for water on industrial, retail or business lots vary a great deal depending on the tenant.

End use assessment by Sydney Water (2021) for industrial users in Sydney found the average total water demand to be 12.5 kL/ha/day with the non-potable portion of this to be approximately 50%. This average total water demand was determined after excluding the very high and very low demands from the analysis, with only properties having demands between the 5th and 95th percentiles included. From this perspective, the average total water demand of 12.5 kL/ha/day was considered to be conservatively low.

The demand for water on industrial land varies considerably from lot to lot as illustrated in Figure 4. It is therefore inappropriate to rely on these high demands when applying rainwater tanks that assume an even demand across lots. The only way of accessing these high average demands is with a reticulated recycled water system that delivers the recycled water to all allotments.

Non-potable water demand data for use in MUSIC modelling are provided in Appendix B of this guide. The data covers industrial, business/commercial and residential land uses including indoor and outdoor demands. Adopting consistent values for non-potable water demands is critical to ensure WSUD strategies can be compared between different areas. Hence, the water demand data in Appendix B are intended to provide a level of consistency in establishing WSUD strategies for a site (as input into MUSIC models). When designing a regional-scale strategy, the stormwater drainage manager should be referred to for the appropriate water demand in that catchment.

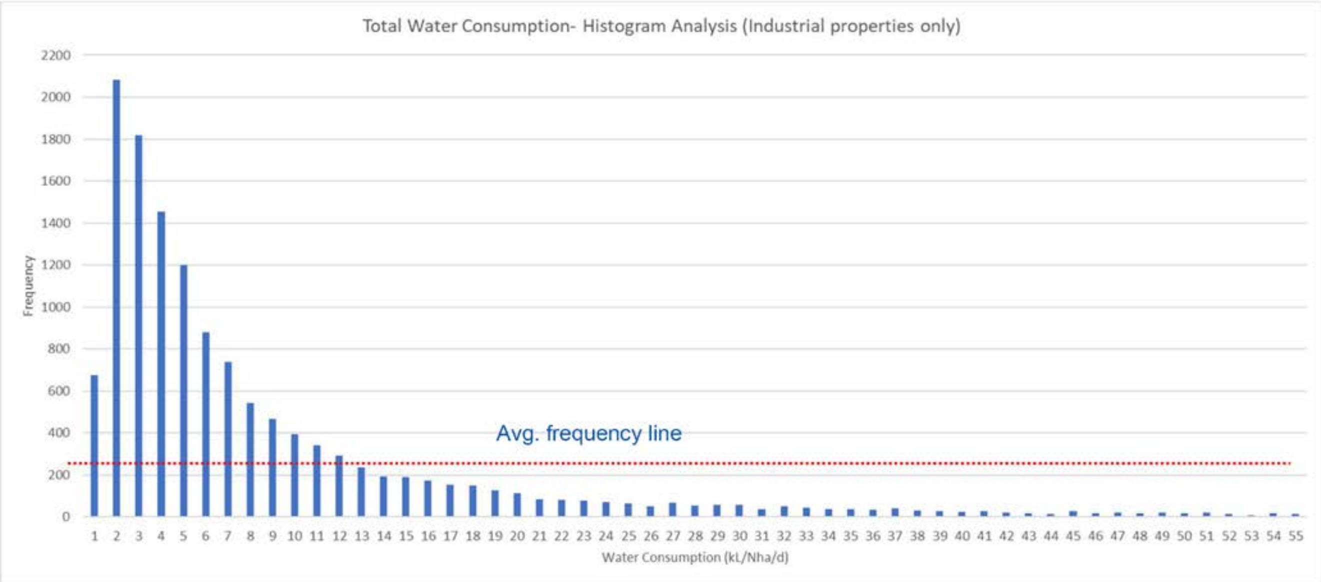

Figure 4 Water demands for industrial developments
Data source: Sydney Water 2021

Streetscape measures

Streetscape measures may form part of WSUD strategies to manage streetscape runoff and contribute to other objectives such as cooling and tree canopy targets. Typical streetscape measures include:

- irrigated street trees
- passively watered street trees
- bioretention street trees
- bioretention basins.

The design of a streetscape measure should consider existing documents relevant to the Wianamatta–South Creek catchment (see section 'Relationship to other documents'). Important considerations include:

- accounting for service corridor requirements in the road reserve
- carefully considering the interaction with pathways and driveway cross-overs
- complying with all the road safety standards
- the number of bioretention trees and raingardens should be optimised by careful design of the road survey and kerb/gutter drainage.

On lot or allotment measures

Typical on lot or allotment WSUD measures include, but are not limited to:

- rainwater tanks
- on-site stormwater detention
- gross pollutant traps (GPTs)
- bioretention basins
- swales
- wetlands, subject to relevant wildlife risk mitigation measures to manage bird strikes (note that wetlands are likely to be interim or temporary under a regional-scale WSUD strategy, see Chapter 4 of this guide)
- stormwater harvesting systems (likely to be interim or temporary under a regional-scale WSUD strategy, see Chapter 4 of this guide).

The design of on lot or allotment measures should consider the existing documents relevant to the Wianamatta–South Creek catchment (see section ‘Relationship to other documents’). Important considerations include:

- accessibility for inspections and maintenance
- protection from damage during construction and building phase and then finalised once the site is finished and landscaped
- careful integration with the landscape but avoiding large level drops and walls, and vegetated with trees.

Soils, infiltration and impermeable liners

Given the saline and sodic nature of the soils in the Wianamatta–South Creek catchment, the following principles are recommended when designing WSUD measures:

- infiltration of collected stormwater should generally be avoided unless detailed site analysis is done to confirm feasibility
- WSUD systems should incorporate an impervious liner (e.g. 1×10^{-9} m/s maximum) to avoid infiltration to local soils
- passively irrigated landscapes that are designed to accept and reduce stormwater runoff volume should be lined and appropriately vegetated (i.e. promoting high evapotranspiration and supporting root systems)
- vegetate pervious areas to promote evapotranspiration
- irrigate landscapes to meet the needs of vegetation and avoid any infiltration past the root zone. Higher profile landscapes requiring additional irrigation may require lining to avoid infiltration, careful control of irrigation rates and potential management of flows downstream (i.e. capture)
- where a core/priority groundwater dependent ecosystem is present and the soils and geology are suitable, infiltration should be considered but subject to a detailed soil and groundwater assessment and ongoing monitoring. A list of core/priority groundwater dependent ecosystems is available in the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*.

Landscape integration and interfaces

The design of WSUD measures should complement and integrate within the public and private realm, using natural processes to the greatest extent possible. Important considerations include:

- location and spatial requirements of WSUD should occur early in the site planning and design process
- locate to protect and complement retained vegetation and areas of environmental significance
- integrate within the development layout and landscape to increase visual amenity and biodiversity
- locate adjacent to public open space and waterway corridors to increase amenity and reduce maintenance
- achieve a naturalised shape and design for the stormwater infrastructure to complement the natural landform and retained trees
- ensure all overland flows entering and exiting stormwater management systems do not compromise the intent, function and safety of co-located uses (e.g. recreational parks)
- ensure stormwater management infrastructure is safe
- use endemic plants wherever possible
- minimise level differences between WSUD measures and surrounding landscapes
- minimise the use of walls, but where walls are required, designs should be sufficiently developed to show they do not negatively affect surrounding landscapes
- adopt suitable batters in accordance with documents relevant to the Wianamatta–South Creek catchment (see section ‘Relationship to other documents’).

WSUD levels and outlets

It is critical that WSUD measures can freely drain to a receiving waterway. Sufficient design investigations are required to demonstrate the functionality of the WSUD measures. These would typically consider inlet pipe levels, the level of the WSUD measure (normal water level or surface), the outflow inverts from the WSUD measure and the tailwater level in the receiving waterways. This may require survey to confirm invert levels and standing water levels, capacity to accept flows, and review of downstream waterway condition and stability.

Refer to the documents relevant to the Wianamatta–South Creek for further requirements, in particular refer to any WSUD technical guidelines (for bioretention basins and wetlands) when setting WSUD levels and designing stormwater outlets in and out of the WSUD measures.

Designing for maintenance

The design of WSUD measures needs to carefully consider future maintenance requirements. There are 2 key aspects to consider in designing for maintenance:

- providing adequate access so the intended maintenance activities can be safely carried out
- ensuring the design and materials specified do not result in unnecessarily intensive, costly, onerous or risky maintenance.

Access

Suitable access tracks are required from roads to the location of the WSUD measure. Access should be to the inflow level to allow access for bobcats or excavators, not to the top of headwall or other location away from the inlet zone.

Access tracks for GPTs (where not serviced directly from a roadway), sediment basins or forebays associated with bioretention basins or wetland inlet ponds should ideally have the following characteristics and be consistent with documents relevant to the Wianamatta–South Creek:

- minimum width of 3 m
- constructed of reinforced access track suitable to withstand loads of full trucks
- include provision for turning and stockpiling of material as required
- provide a lockable gate to restrict public access.

Location on the floodplain and design principles

When locating WSUD measures on the floodplain, 2 important factors need to be considered:

- WSUD measures should not adversely impact on flood behaviour and the community locally and at a strategic catchment scale.
- WSUD measures are not washed away or destroyed up to a defined flood event.

In accordance with these factors, WSUD measures may be located within the 1% AEP flood extent provided the following criteria are met:

- no adverse impact on regional flood behaviour or the community, in accordance with a Flood Impact and Risk Assessment (FIRA) undertaken by a qualified professional engineer
- considering the following areas as identified in *Wianamatta South Creek Catchment Flood Study – Existing Conditions* (Advisian 2022):
  - WSUD measures are allowed within the 1% AEP flood fringe areas provided the first bullet point above is demonstrated
  - WSUD measures are allowed within the 1% AEP non-critical flood storage areas provided the first bullet point above is demonstrated
  - WSUD measures are avoided in flood conveyance areas (i.e. 1% AEP floodway and high floodway) and 1% AEP critical flood storage areas, other than waterway rehabilitation, waterway diversion works, dam rehabilitation works or works to support significant stormwater harvesting infrastructure. Any works must demonstrate the first bullet point above
  - WSUD measures are to achieve the levels of protection suggested in Table 8
- generally, WSUD measures should be located offline from external waterways for drainage areas greater than 25 ha to provide a level of protection from stormwater related damage
- appropriate hydraulic modelling should confirm the relevant flood levels, velocities and inundation periods. Where a WSUD measure is potentially prone to high velocity, a geomorphic assessment may be required to confirm the WSUD measure and associated embankments will be stable and will not cause erosion in an adjacent waterway.

Table 8 Protection of WSUD measures on a floodplain

Treatment type	Regional flooding	Local stormwater flooding	Flow velocities in adjacent floodplain
Bioretention	Top of embankment >50% AEP flow level (with 200 mm freeboard) Inundation period <24 hours for events up to 50% AEP Velocity over surface <1 m/s in 1% AEP	Top of embankment >50% AEP flow level (with 200 mm freeboard) Inundation period <12 hours for events up to 50% AEP Velocity over surface <1 m/s in 1% AEP	Embankments (external and internal) designed to withstand flood velocities for all events up the 1% AEP. Allowance to be made for appropriately sized rock armour for flows above 1 m/s
Wetland	Top of embankment >63% AEP level (with 200 mm freeboard) Inundation period <5 days for events up to 63% AEP Velocity over surface <0.5 m/s in 20% AEP and <1 m/s in 1% AEP	Top of embankment >63% AEP flood level (with 200 mm freeboard) Inundation period <3 days for events up to 63% AEP Velocity over surface <0.5 m/s in 20% AEP and <1 m/s in 1% AEP	Embankments (external and internal) designed to withstand flood velocities for all events up the 1% AEP. Allowance to be made for appropriately sized rock armour for flows above 1 m/s
Sediment basin	Top of embankment >63% AEP level (with 200 mm freeboard)	Top of embankment >63% AEP flood level (with 200 mm freeboard)	Embankments designed to withstand flood velocities for all events up the 1% AEP. Allowance to be made for appropriately sized rock armour for flows above 1 m/s
Stormwater harvesting storage	Top of embankment >63% AEP level (with 200 mm freeboard)	Top of embankment >50% AEP flood level (with 200 mm freeboard)	Embankments designed to withstand flood velocities for all events up the 1% AEP. Allowance to be made for appropriately sized rock armour for flows above 1 m/s

Integration with on-site stormwater detention

A WSUD measure and on-site stormwater detention can be co-located where the area of stormwater treatment for a development site is coincident with the area for the local stormwater quantity detention (on-site stormwater detention), or there is only a small external catchment (<25 ha). This co-location effectively reduces the overall land required to manage stormwater.

In these situations, WSUD measures will infrequently become inundated to greater depths than the extended detention depth. The inundation duration is relatively short (hours) and is unlikely to affect the vegetation in the treatment system provided that water can drain following frequent storm events (i.e. 50% AEP, 63% AEP) without scouring the surface or batters.

The following design principles should be addressed when combining WSUD measures and on-site stormwater detention:

- on-site stormwater detention is designed in accordance with the relevant approval or consent authority requirements
- extended detention volume for the treatment system is not included in on-site detention volume (i.e. is assumed to be full, prior to the storm event)
- on-site detention volume is not part of the extended detention of the WSUD measure (i.e. on-site detention volume is not considered in the MUSIC modelling for the WSUD measure)
- for the following situations, an inlet pond and high flow bypass system will be required to ensure higher flow rates than a peak 63% AEP bypass are contained in the detention facility. The hydraulic controls provided at the on-site detention outlet will control flows greater than 63% AEP ensuring higher flows backwater over the top of the WSUD treatment system(s):
    - stormwater detention drainage area is larger than the stormwater treatment drainage area
    - bioretention system size is greater than 800 m^2
    - all wetland systems
- address public safety risks in accordance with the relevant approval or consent authority requirements, noting that these design principles apply to frequent storm events
- avoid vertical drops that will be hidden when the flood storage is engaged
- densely vegetate the on-site detention surface that will be inundated by the peak 63% AEP water level with appropriate native plant species.

WSUD design principles on waterfront land

The following design principles are relevant to WSUD measures proposed to be located on waterfront land, especially where a buffer area is degraded to such an extent that the construction of the WSUD measure would result in an enhancement of the condition and ecological function of the buffer area. The design principles are intended to support existing requirements in the *Guidelines for controlled activities on waterfront land: Riparian corridors* (DPI–NRAR 2018).

- Waterfront land is generally part of the 1% AEP flood function area, and therefore the design principles should be read in conjunction with the design principles for the floodplain set out this guide. As such any works in the 1% AEP flood function area should demonstrate no adverse impact on flood behaviour or on the community in accordance with an FIRA.
- Only vegetated stormwater management systems (earth and vegetation) that provide stormwater management and ecological function should be used.

- Avoid construction of WSUD measures in areas of existing native vegetation.
- Vegetation in the WSUD measures should complement riparian vegetation and provide fauna friendly movement.
- The toe of batters should be set back in accordance with the *Guidelines for controlled activities on waterfront land – Riparian corridors*, which is 50% of the required setback required by the category of stream order in accordance with the Strahler system, and be certified by a geomorphologist that works will not impact on the stream stability. Stormwater infrastructure must include a VRZ or an offset in accordance with the guidelines.
- Ensure there is minimal impact as a result of earthworks when narrowing a flood prone area to prevent adverse hydrologic and hydraulic impacts to vegetation and stream stability. Where there is no formed channel or bank features, the channel width is to be determined by measuring open channel width reaches up or downstream of the site. Top of bank is to be measured from the edge of the assumed channel width.
- If a waterway has a wider buffer on one side of a waterway, WSUD measures could be placed in the wider buffer provided it only takes up half of the overall waterway buffer width (i.e. on both sides of the waterway).
- Any encroachment into the buffer should be offset along the same watercourse alignment (within 300 m).
- Areas requiring scheduled maintenance such as inlet ponds should remain at the outer edge of a buffer to avoid maintenance access encroachment.
- Detailed assessment of the geomorphology of the waterway and stabilisation of both the waterway and stormwater system are required where:
    - it has been identified as an erosion prone area by consent authorities
    - there is instability, erosion, steep banks or waterway movement has occurred or is a risk of occurring in the future
    - there is a risk of hydrologic change in the waterway due to changes in the catchment that may increase stream instability
    - placement of the WSUD measure will increase risk of stream instability or risk of the WSUD measure being eroded.

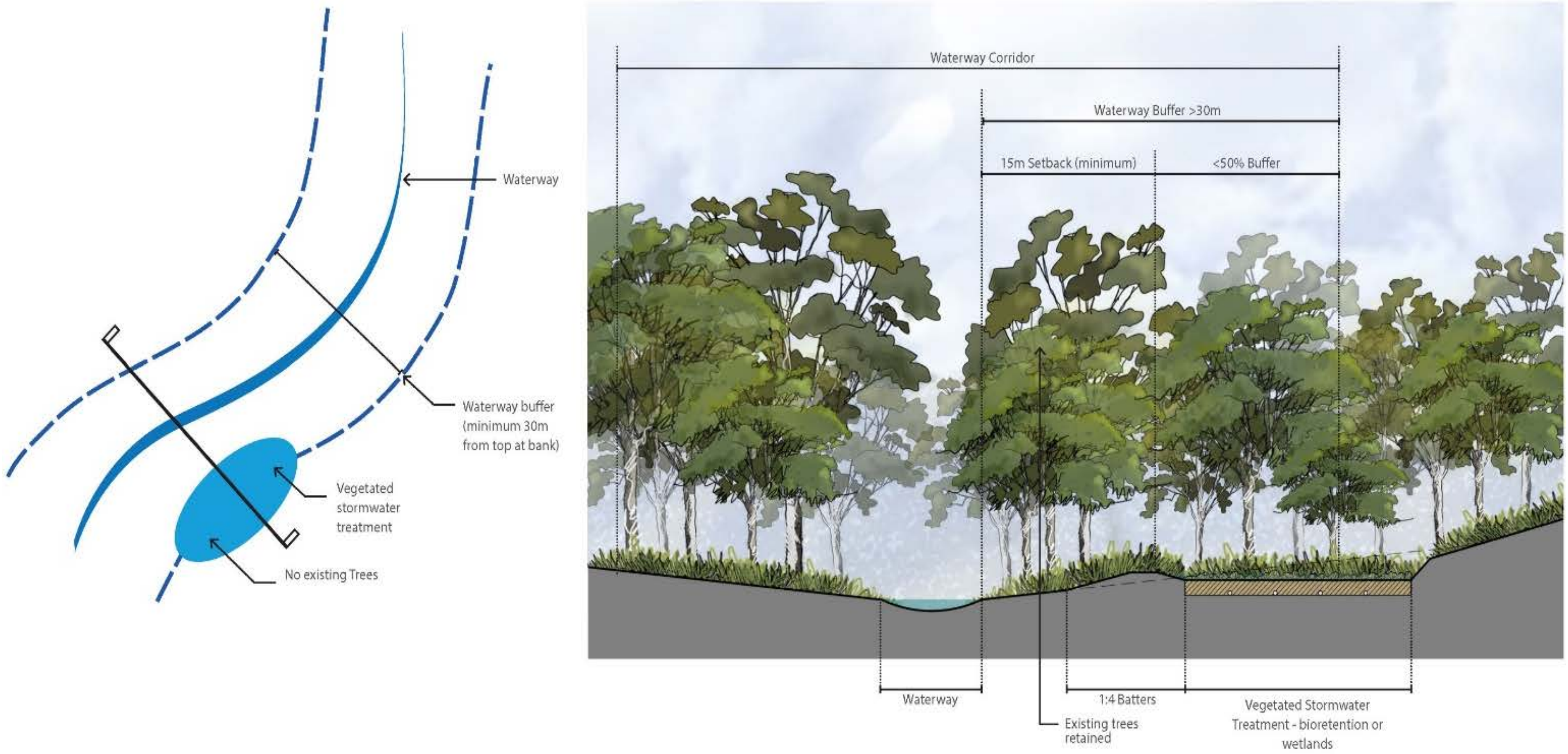

Figure 5 Example layout of WSUD within waterway buffer (waterfront land)

WSUD measures

The following WSUD measures are recognised as practical and reliable measures for performance assessment (MUSIC) modelling, and form the basis of the example WSUD strategies described in Chapter 4 of this guide. The concise descriptions below outline specific design principles for the Wianamatta–South Creek catchment context. More comprehensive guidance on the function and design of these systems is available in a range of existing guidelines (see section 'Relationship to other documents').

Rainwater tanks

Rainwater tanks will likely be required to achieve the stormwater quantity (flow) targets (Table 5 and Table 6), particularly when a reticulated stormwater harvesting system is not available.

Allotment tanks (collecting roof water) should be designed to:

- meet BASIX and/or council requirements for residential land uses
- supply 80% of industrial, commercial and business non-potable water demands.

Supplying 80% of non-potable demands may not be possible where demands on industrial, commercial and business are high. Under this case, tank sizes could be optimised by considering the diminishing rate of return of cost and performance as well as achieving the stormwater quantity (flow) targets.

Street trees

Creating the Western Parkland City requires an increase in tree canopy cover to 40% (see the Premier's Priority 'Greening Our City'). Part of this strategy is the placement of trees along streets and providing suitable water to support these trees. The following types of measures for watering street trees should be considered, in addition to the documents relevant to Wianamatta–South Creek catchment (see section 'Relationship to other documents'):

- **Irrigated street trees** – These are street trees that are delivered in accordance with normal standards but are provided with irrigation from a reticulated stormwater harvesting (and/or recycled water) system. These measures represent the simplest implementation of street trees with a non-potable source of irrigation.
- **Passively irrigated street trees** – These measures operate by diverting small proportions of stormwater via kerb inlet connections to the soil surrounding the trees to increase soil moisture around the tree. Their purpose is to maintain tree health, rather than providing any significant management of stormwater quality or flows. There are various types of passive irrigation techniques for street trees, including open kerb inlets (that deliver stormwater flow on the surface around trunks) and kerb diverters that filter flows and transfer stormwater from a kerb to soakaway pits and/or perforated pipes around a tree. There are industry guidelines and designs available for passively irrigated trees. It is important to note that the standard requirements for healthy street trees still apply (i.e. root zones, topsoil depths, setback to pavement/paths/services) with the only addition being a connection from a kerb to a watering system in the tree root zone that delivers stormwater into the soil around the tree when it is raining.
- **Bioretention street trees** – These street trees provide a stormwater treatment function. They require an open connection from the kerb/gutter that delivers stormwater onto the (depressed) surface of bioretention filter media into which the trees are planted. The system functions as a bioretention system with excess stormwater collected in the base of the system and discharged out to the street pit and pipe drainage. Filter media depth,

excluding drainage and transition layers, should be a minimum 700 mm to support the tree. A saturated zone can be created below the bioretention street tree to hold water for dry periods. Bioretention tree pits are generally expensive stormwater management systems and therefore, are only recommended where road reserve runoff cannot be managed at a precinct or regional scale.

Bioretention basins

Bioretention basins are a fundamental part of WSUD strategies in the Wianamatta–South Creek catchment, and are typically delivered at lot, street, precinct and regional scale. The following design principles are intended to support existing requirements in relevant documents for Wianamatta–South Creek (see section 'Relationship to other documents'):

- extended detention depth to be a maximum of 300 mm for basins, with streetscape systems having a maximum of 150 mm
- have a mixture of groundcovers, shrubs and trees to get shading onto the surface of the basin; therefore, filter media depth is to be >600 mm excluding drainage and transition layers
- bioretention systems with groundcovers should only be considered for small systems (<100 m^2) in highly visual locations or that are co-planted with trees on the batters and surrounds, and filter media depths need to be >400 mm
- a saturated zone to be adopted for all bioretention systems
- an impermeable liner or equivalent (e.g. compacted clays) to the base and sides is required to create the saturated zone and avoid infiltration to in-situ saline and sodic soils
- a sediment forebay is acceptable for catchments up to 10 ha; above 10 ha a sediment basin (or wetland) is to be adopted to pre-treat flows entering the bioretention system
- the surface of the bioretention system to be planted at high diversity and density (e.g. 4–6 groundcover plants per m^2).

Sediment basins

Sediment basins commonly form part of WSUD strategies. The following design principles should be considered, in addition to existing principles in relevant documents for Wianamatta–South Creek (see section 'Relationship to other documents'):

- minimum 1.5 m depth (2 m maximum)
- include 1 in 8, 1.5 m wide minimum safety bench around the perimeter (refer to relevant documents)
- reinforced access to base of sediment basin of thickness and reinforcing suitable for heavy vehicles (e.g. concrete or cement stabilised rubble)
- reinforced base and sides up to within 300 mm of normal water levels
- include an impermeable liner that can operate under both wet and dry conditions (i.e. not crack)
- edges and batters to be fully vegetated with suitable species
- consider public safety requirements
- where a sediment basin is combined with a bioretention basin and the levels of both measures is the same or similar, they can share the extended detention (i.e. the extended detention of the sediment basin and bioretention are the same).

Wetlands

Wetland measures (including sediment basins) are a fundamental part of WSUD strategies in the Wianamatta–South Creek catchment, and will apply at lot (only large lots), precinct and regional scales. The following design principles should be considered, in addition to existing principles in relevant documents for Wianamatta–South Creek (see section 'Relationship to other documents'):

- extended detention depth to be a maximum of 350 mm
- notional detention times of between 48 and 72 hours are to be achieved when extended detention depth is above 100 mm
- in some cases, small extended detention depths (<100 mm) may be used with longer extended detention times to help achieve stormwater quantity (flow) targets
- include an impermeable liner that is protected so it can operate under both wet and dry conditions (i.e. not crack)
- harvesting stormwater directly from a wetland can occur but only from the top 100 mm (to ensure water plant health). Typically treated water from a wetland will be directed to a dedicated storage system as part of a reuse scheme
- consider public safety requirements such as 1 in 8 safety bench or fencing around the perimeter
- wetland to consist of a mixture of marsh depths and species and generally use at least 12 different wetland species
- where the wetland is combined with a bioretention system and the levels of both systems are the same or similar, they can share extended detention (i.e. the extended detention of the wetland and bioretention are the same). In this case, the MUSIC modelling method changes such that the wetland extended detention depth is reduced to <50 mm and the bioretention extended detention surface area is increased to include the wetland area
- minimise the risk of large populations of flying waterbirds by addressing requirements set out in relevant in Development Control Plans (e.g. DPIE 2021a, b), and ensure the wetland is supported by a Wildlife Hazard Assessment and Management Plan if located within 13 km of the Western Sydney Airport (WSPP 2020). This will involve but is not limited to avoiding islands and perching/roosting areas, avoiding rock/turf edges that are easily accessed by birds, minimising trees that overhang water, disrupting bird flight paths and adopting wetland vegetation to dissuade birds.

Proprietary devices

Proprietary devices are WSUD measures that are manufactured by a corporate entity, and that have proprietary components specific to the manufacturer.

Gross pollutant traps

GPTs are proprietary devices that target litter, debris and coarse sediment and can be accepted as both private and public infrastructure in appropriate situations. There are 2 broad classes of devices:

- GPTs / in-line devices
- gully pit baskets.

Proprietary nutrient removal devices

Proprietary devices for nutrient and fine sediment removal may be considered for private infrastructure under the following situations:

- the device is approved and certified through the *Stormwater Quality Improvement Device Evaluation Protocol* (Stormwater Australia 2018)
- use is limited to HDR (>60 dwellings/ha), commercial, or industrial developments only
- the site is constrained such that the application of vegetated WSUD measures on the private allotments is not practicable
- performance (MUSIC) modelling of such devices is to be consistent with claims verified through the *Stormwater Quality Improvement Device Evaluation Protocol* (Stormwater Australia 2018).

Stormwater harvesting and reuse systems

Stormwater harvesting and reuse represents the most effective measure for reducing stormwater flow volumes from frequent flow events to achieve the stormwater quantity (flow) targets (Table 5 and Table 6). Common options for stormwater harvesting most relevant to Wianamatta–South Creek catchment include:

- **Private allotment stormwater harvesting** (privately owned) – This may involve capturing roof runoff, overflows from tanks and ground level runoff and then treatment, storage and reuse for irrigation of landscape and undeveloped zones. Likely to be an interim or temporary measure only as a way to reduce stormwater export until a regional stormwater system is implemented.
- **Stormwater harvesting and open space irrigation** (publicly owned) – Capture, treatment, storage, disinfection and reuse of stormwater to irrigate public open space and reduce stormwater flow reaching waterways.
- **Reticulated stormwater harvesting** (managed by a stormwater drainage manager) – Capture, treatment, diversion and storage of stormwater that is then directed to a regional reuse system. Stored flows are disinfected and then fed into a reticulated recycled water pipe that is connected to all lots to provide non-potable water for a variety of uses (including to irrigate street trees and parks).

Under the *Water Management Act 2000*, water is only permitted to be taken under a water access licence, a basic landholder right or an access licence exemption. The Natural Resources Access Regulator should be consulted regarding the regulatory settings that apply to the take of water.

General

The following apply to the design of stormwater harvesting systems:

- only treated water from stormwater treatment systems is to be directed to reuse storages (i.e. overflows or bypasses should bypass)
- *Managing Urban Stormwater: Harvesting and reuse* guidance (DEC 2006) and *Stormwater Harvesting Guidelines* (Water by Design 2009)
- *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks: Stormwater harvesting and reuse* (NRMC, EPHC and NHMRC (2009).

Storage

Storage systems will vary depending on context, scale and ownership:

- small-scale systems may use above or below ground tanks
- moderate and large systems may use tanks or open storages with an active storage that will be dewatered. In most situations the active storage depth will be at least 2 m to reduce the footprint of the system. These systems will have a variable water level and dry out at times, which can result in poor amenity during those times. Hence, the location and design of the storage needs to consider local amenity and safety
- very large stormwater harvesting systems may divert or pump treated stormwater flows from WSUD measures to large, centralised storages. The storage will be open and could have a large active storage depth thus have limited amenity at times, or could have a small active storage depth (e.g. <0.3 m) that preserves a permanent waterbody for amenity reasons. In this case, the sustainability of the lake system needs to be carefully considered
- where an open water storage is adopted it should:
    - include an impermeable liner that can operate under both wet and dry conditions (i.e. not crack)
    - consider public safety requirements
    - minimise the risk of large populations of flying waterbirds by addressing requirements set out in relevant Development Control Plans (e.g. DPIE 2021a, b), and be supported by a Wildlife Hazard Assessment and Management Plan if located within 13 km of the Western Sydney Airport (WSPP 2020). This will involve but is not limited to avoiding islands and perching/roosting areas, avoiding rock/turf edges that are easily accessed by birds, minimising trees that overhang water, disrupting bird flight paths and adopting wetland vegetation to dissuade birds.

Disinfection

The stormwater harvesting and reuse system should meet requirements set out in the national stormwater reuse guidelines: *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks: Stormwater harvesting and reuse* (NRMC, EPHC and NHMRC 2009).

These national guidelines include requirements for pathogen log reduction values to adequately manage public health risks during public open space irrigation. The log reductions can be achieved by either limiting exposure (e.g. limiting access during times of irrigation or using subsurface irrigation) or through treatment processes. For public parks it is likely that treatment will be used to achieve the required log reductions.

If full restriction can be achieved (e.g. on private property), such as restricted access during irrigation and 25–30 m buffers to public access, then the national guidelines suggest no additional treatment is required.

The national guidelines specify likely reductions for a range of treatment types for the different criterion (Table A3.5 in Appendix 3 of NRMC, EPHC and NHMRC 2009). It is likely that an ultraviolet (UV) treatment system would be most economically effective, and these are quoted as being able to reduce pathogens by >1.0, >3.0 and 2–4 for viruses, protozoa and bacteria, respectively.

The national guidelines also suggest that ‘for most small-to-medium sized schemes, UV disinfection is the most practical and commonly used disinfection technique for achieving the required log reductions’.

Another important criterion in selecting a UV system is to ensure there is adequate dosing (i.e. light bulb strength for a given turbidity). Typically, for treated stormwater a transmissivity of 50% is assumed and a dosing rate of at least 40 mJ/cm^2. The selection of the UV system should be co-designed with the supplier.

Lakes and existing dams

The design principles below are applicable to constructed lakes or retained dams dominated by open water, noting wetlands have 80% vegetation coverage and are considered separately. The approval of the lake or dam is at the discretion of the relevant approval or consent authority, and the design principles below are intended to support existing requirements:

- the lake or existing dam does not form part of the stormwater quality treatment train. Stormwater must be treated prior to entering the lake. Lakes can contribute towards achieving the stormwater quantity (flow) target
- the lake system incorporates suitable turnover and treatment to minimise the risk of algal blooms and aquatic weeds. Residence time in the lake of <15 days is achieved through natural or mechanical flushing
- the lake system is designed to support landscape, passive recreation and ecological values, and should not pose a health, safety or aesthetic risk
- the lake is designed such that it can be dewatered for maintenance, and if required, dewatered and converted to a waterway or ephemeral wetland
- the system is designed and managed to protect downstream receiving waterways, maximise resource use efficiency and minimise life cycle costs and risks
- a detailed maintenance and monitoring program is developed to show how a constructed lake will be adaptively managed to ensure the water quality of the lake meets the performance criteria (water quality objectives) for Wianamatta–South Creek (DPE 2022c).

Key factors that should be considered when designing lakes or retaining existing dams include, but are not limited to, the following:

- Dam Safety NSW requirements
- impacts on flood behaviour and on the community as per design principles set out in this chapter of the guide
- weeds, in particular floating weeds
- nutrients, light, temperature and turbidity
- algae growth
- organic carbon loads
- lake detention time (<15 days) and flushing rates
- salinity
- water level and depth (maximum 3 m)
- shape, mixing and stagnant zones
- hydraulic control (lowering water level for maintenance)
- maintenance access (for desilting, access for weed harvesting, litter removal, outlet hydraulic structures, perimeter for riparian weeds)
- pest and bird management (i.e. consider recommendations in the Wildlife Management Assessment Report for the Aerotropolis – see WSPP 2020)
- erosion, particularly during large events and from wave action

- inflow and outflow locations
- public safety
- whether the lake/dam is a Prescribed Dam under the *Dam Safety Act 2015* and requires referral to the NSW Dam Safety Committee
- whether a licence is required from Water NSW to capture more water than the Maximum Harvestable Right Dam Capacity (MHRDC)
- wall/embankment stability, seepage and scour protection.

Chapter 4 – Example WSUD strategies

This chapter provides examples of WSUD strategies for select typologies to demonstrate the type and scale of WSUD measures required to meet the operational phase stormwater quality and quantity targets (Table 3 to Table 6). The examples should not be viewed as solutions that are ‘deemed to comply’.

Three typologies were selected to represent a range of impervious area impacts of development and different potentials for allotment non-potable water demands. Examples of WSUD strategies for varying scales of development are presented for LFI, HDR and LDR typologies. The varying scales include:

- **Lot and streetscape** – The WSUD strategy for the development is limited to allotments and streets only.
- **Lot and precinct** – The WSUD strategy for the development includes allotments, streets and area of public open space.
- **Regional treatment** – The WSUD strategy for the development is planned for larger scales than one development parcel (or owner), and is planned and coordinated by a separate entity from the developer (e.g. planning for a reticulated stormwater harvesting and reuse scheme).

WSUD measures used in WSUD strategies

The WSUD measures used in the examples of WSUD strategies are outlined in Table 9, together with brief descriptions of the assumed configuration of each measure.

Table 9 Description of WSUD measures used in WSUD strategies

Measure	Description
Green roofs	Roof areas that are covered with soil and vegetation. They act to capture rainwater, promote evaporation, reduce runoff volumes and cool the buildings
Gross pollutant traps	GPTs filter litter and debris from stormwater and act to contain oil spills
Roof water tanks	Tanks that collect roof water that is then pumped to supply indoor uses (e.g. toilets, laundries and sometimes hot water) and/or outdoor uses (irrigation)
On-site stormwater detention	Sunken landscaped areas that provide stormwater storage during infrequent local stormwater flooding events
Lot bioretention	Bioretention basins that collect and filter stormwater within a lot, typically targeting roads, carparks and hardstand areas
Lot wetlands	Constructed wetlands for the purpose of stormwater treatment. Once treated, the water is commonly pumped to storages for reuse
Lot storages	Lot storage can either be in tanks (e.g. above ground) or open storages (e.g. dam) and is used to supply pumps for reuse systems (e.g. irrigation)
Street bioretention	Bioretention basins located in road verges that collect and filter stormwater from the road (assumed earth batters and no grate covers)
Passively irrigated street trees	Stormwater diverters installed in kerbs to direct small amounts of stormwater into soils around street trees for irrigation (not bioretention)

Measure	Description
Precinct wetland	Constructed wetlands for the purpose of stormwater treatment, habitat and recreation in public open spaces. Treated water is commonly directed to storages for reuse. Can be located above or below the 1% AEP level, in accordance with the floodplain and waterfront land principles set out in Chapter 3 of this guide
Precinct bioretention	Bioretention basins that collect and filter stormwater located in public open space above or below the 1% AEP level, in accordance with the floodplain and waterfront principles set out in Chapter 3 of this guide
Combined wetland/ bioretention	Wetlands in combination with bioretention, where wetlands treat baseflows and then overflow into bioretention basins during storm events – both share extended detention volumes
Public open space storage tank and reuse	Treated water storage in public open space can either be in tanks (in smaller parks) or open water storage (e.g. dams/ lakes) and is then used for irrigation
Regional reuse storage	Treated water storage in open water dams or lakes, can be located above or below the 1% AEP level (in accordance with the floodplain and waterfront land principles set out in Chapter 3 of this guide), and is then transferred to a regional reuse scheme
Reticulated reuse pipe	A dedicated reticulated water pipe to supply recycled stormwater to allotment and open space. Can be combined with recycled wastewater

Large format industrial

The LFI typology represents the largest land-use zone in the initial precincts for the Western Sydney Aerotropolis and Mamre Road. It was considered to be the most challenging typology in terms of achieving the stormwater quality and quantity targets (DPE 2022d, e). This is because LFI typologies are typically characterised by large expanses of roof space, hardstand and limited landscape. So while the vision for the Western Parkland City is for relatively more green space, there will still be large areas within an LFI typology that are impervious. It was assumed that if a compliant WSUD strategy can be developed for an LFI typology, then it can also be replicated for other typologies.

The following range of example WSUD strategies were devised for delivery at the lot/ allotment, precinct or regional scale. Some of the latter examples include regional treatment, stormwater harvesting and reticulated reuse, as part of or making up a regional stormwater system. An interim approach is provided for the example lot/allotment WSUD strategies to show how partial development can achieve the targets until the site is fully developed and connected to a regional stormwater system.

All example WSUD strategies below account for the WSUD design considerations in Chapter 3 of this guide, and are especially subject to the principles under the section titled ‘Soils, infiltration and impermeable liners’. Infiltrating stormwater is generally inappropriate because of the saline and sodic soils, making it additionally challenging to capture and find methods for losing or using the excess stormwater.

Example WSUD strategies for LFI

Example WSUD strategies for LFI are shown in Table 10, and described more generally below. These WSUD strategies cover a mix of allotment measures, streetscape measures, local public open space and regional stormwater systems. Table 11 shows the types and sizes of WSUD measures required to achieve the operational phase stormwater quality and quantity (flow) targets under each WSUD strategy.

In general, WSUD strategies that include measures on allotments, in streetscapes and local parks also rely on a reduction in the impervious coverage of allotments compared to the maximum allowable (i.e. 85%, see the *Mamre Road Precinct Development Control Plan 2021* (DPIE 2021b)). When a reticulated stormwater reuse system is adopted, WSUD strategies can adopt a variety of stormwater measures along with maximum site imperviousness to achieve the operational phase stormwater quality and quantity (flow) targets.

The WSUD strategies are specifically discussed in more detail, including cost estimates, in a companion study (DPE 2022d). There are 5 types of WSUD strategies for LFI provided as examples in this guide:

- **LFI A option** – 50% of roof areas drain to tanks for toilet use and irrigate 50% of lot garden beds. Each lot includes a GPT and bioretention system and there is also a precinct bioretention to meet post development load reduction stormwater quality targets (TSS 85%, TP 65%, TN 45%). *This option does not comply with the stormwater quality and quantity (flow) targets outlined in Table 3 to Table 6 of this guide, and is provided for comparison only*.
- **LFI B options** – Lot yields are reduced to an equivalent of 40–50% of lot area being pervious. The remaining undeveloped areas are used for treatment (wetland or bioretention) and storage ponds before irrigating the pervious areas. Tanks are used for toilet flushing and bioretention is used for allotment carparks and along streetscapes.
- **LFI C1 to C3 options** – Lot yields are reduced to an equivalent of 20–30% of lot area being pervious. Allotment bioretention is used for hardstand areas, streetscape bioretention is implemented and local public open space is used for treatment (wetland) and evaporation (and sometimes reuse to irrigate the local parks).
- **LFI C4 option** – This option adopts full development yields and requires considerable stormwater harvesting and reuse. It requires large tanks within the allotment for toilets and to irrigate 100% of allotment gardens in addition to allotment and streetscape bioretention for treatment. A precinct wetland then treats and evaporates stormwater to contribute to a reuse scheme that irrigates 100% of public open space areas.
- **LFI D options** – Lots are fully developed with regional treatment and the treated water is directed to regional storage ponds as part of a broader reuse scheme. Reticulated treated stormwater is used for all non-potable uses as well as irrigating public open spaces. Tanks and allotment / streetscape bioretention may or may not be required depending on the particular option.

Interim solution

LFI B options and LFI C1 to C3 options could be considered an interim solution (by fully developing some allotments and leaving others pervious) until a regional stormwater system is implemented and the lot can be fully developed to maximum imperviousness (as outlined in the relevant Development Control Plan).

More detailed descriptions and example layouts for different WSUD strategy types are shown in the following sections for:

- lot and streetscape strategies (LFI B2)
- lot and precinct strategies (LFI C4)
- regional treatment and reticulated reuse strategies (LFI D2-b)

Table 10 Example WSUD strategies for LFI typologies

WSUD strategy – LFI		Delivery approach – dependent on scale of development and options for regional harvesting and reuse								
		Reduced site coverage	Tanks	Lot WSUD	Streetscape WSUD	Precinct WSUD (above 1% AEP)	Regional WSUD (maximise below 1% AEP)	Stormwater quantity detention	Public open space stormwater harvesting	Reticulated regional stormwater harvesting
A	Post development load reduction targets (85% TSS, 65% TP, 45% TN)		✓	✓		✓		✓		
B1	Lot and streetscape	✓	✓	✓	✓			✓		
B2	Lot, streetscape and local irrigation	✓	✓	✓	✓			✓		
C1-a	Lot, local public open space and regional treatment (above 1% AEP)	✓	✓	✓	✓	✓		✓		
C1-b	Lot, local public open space and regional treatment (above 1% AEP)	✓	✓	✓	✓	✓		✓		
C2-a	Lot, local public open space and regional treatment (below 1% AEP)	✓	✓	✓	✓		✓	✓		
C2-b	Lot, local public open space and regional treatment (below 1% AEP)	✓	✓	✓	✓		✓	✓		
C3-a	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	✓	✓	✓	✓		✓	✓	✓	
C3-b	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	✓	✓	✓	✓		✓	✓	✓	
C4	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)		✓	✓	✓		✓	✓	✓	
D1-a	Lots, regional treatment and reticulated stormwater reuse		✓	✓			✓	✓		✓
D1-b	Lots, regional treatment and reticulated stormwater reuse		✓				✓	✓		✓
D2-a	Regional treatment and reticulated stormwater reuse (no tanks)						✓	✓		✓
D2-b	Regional treatment and reticulated stormwater reuse (no tanks)						✓	✓		✓
D3-a	Lots and streetscape with regional treatment and reticulated stormwater reuse		✓	✓	✓		✓	✓		✓
D3-b	Lots and streetscape with regional treatment and reticulated stormwater reuse		✓	✓	✓		✓	✓		✓

*Differences between the ‘a’ and ‘b’ options are different mixes of wetlands and bioretention systems for treatment. Option A does not achieve the stormwater quality and quantity targets.

Table 11 Sizes of WSUD measures and impervious cover of example WSUD strategies for LFI typologies

WSUD strategy – LFI		WSUD measures												% Open space proportion		% Impervious	
		Tanks (kL/ha)	Lot bioretention (m^2/ha)	Street bioretention (m^2/ha)	Lot / precinct wetland (m^2/ha)	Regional wetland (m^2/ha)	Regional bioretention (m^2/ha)	Stormwater harvesting on lot storage (m^3/ha)	Stormwater harvesting on lot to irrigation (ML/y/ha)	Stormwater harvesting to public open space storage (m^3/ha)	Stormwater harvesting (local) to POS irrigation (ML/y/ha)	Regional stormwater harvesting storage (m^3/ha)	Reticulated regional stormwater harvesting (ML/y/ha)	Local	Regional	Lot imperviousness	Total imperviousness
A	Post development load reduction targets (85% TSS, 65% TP, 45% TN)	31	42				40							7.4	7.0	85	72
B1	Lot and streetscape	140	10	35	550									0	0	50	48
B2	Lot, streetscape and local irrigation	14	10	35	550			300	0.7					0	0	60	53
C1-a	Lot, local public open space and regional treatment (above 1% AEP)	104	69	25	500									7.4	7.0	70	62
C1-b	Lot, local public open space and regional treatment (above 1% AEP)	47	56	20	600									5.6	30	85	54
C2-a	Lot, local public open space and regional treatment (below 1% AEP)	104	69	25		500								7.4	7.0	70	62
C2-b	Lot, local public open space and regional treatment (below 1% AEP)	47	56	20		600								5.6	30	85	54
C3-a	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	75	69	24		500				200	0.3			7.4	7.0	75	65
C3-b	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	47	60	14		350				200	0.6			6	20	85	62
C4	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	60	69	24		350				200	0.8			7.4	7.0	85	72
D1-a	Lots, regional treatment and reticulated stormwater reuse	55	24			500						300	1.3	7.4	7.0	85	72
D1-b	Lots, regional treatment and reticulated stormwater reuse	14				200	60					300	1.9	7.4	7.0	85	72
D2-a	Regional treatment and reticulated stormwater reuse (no tanks)					375	60					380	1.6	7.4	7.0	85	72
D2-b	Regional treatment and reticulated stormwater reuse (no tanks)					200	60					380	2.0	7.4	7.0	85	72
D3-a	Lots and streetscape with regional treatment and reticulated stormwater reuse	55	69			300						300	1.4	7.4	7.0	85	72
D3-b	Lots and streetscape with regional treatment and reticulated stormwater reuse	55	69	24		150	40					300	1.6	7.4	7.0	85	72

Note that Option A does not achieve the stormwater quality and quantity targets, and Option B has a 0% open space proportion because it considers a development of only allotments and streets (not public open space)

LFI lot and streetscape strategy

Summary

This strategy (B2 in Table 10 and Table 11) focuses on delivering the operational phase stormwater quality and quantity (flow) targets on allotments and in adjacent streets. It is not possible to achieve the stormwater targets using a standard development footprint (i.e. the maximum allowable impervious area, such as 85% for the Mamre Road Precinct) and adopting only lot and streetscape measures, because too much stormwater is generated and there are insufficient reliable demands to use the stormwater before discharge.

The approach taken for this strategy is to reduce the impervious proportion of the development and use a part of that (pervious) area for irrigation. Runoff from the lots is collected, treated, stored and then used for this irrigation.

This approach is in addition to collecting and reusing roof water for toilets, and incorporating bioretention for allotment hard paved areas of the lot and installing streetscape bioretention. Monitoring of the lot/allotment storage and irrigation system is likely to be required along with independent audits on a regular basis of all allotment WSUD measures, to ensure they are meeting the design intent.

It may be possible that this approach is adopted as an interim solution until a regional treatment and reticulated reuse scheme is implemented. The example layout shown in Figure 6 shows one potential configuration that would enable development of the full site should a regional treatment and reticulated reuse scheme be delivered at a later date.

Strategy components

A summary of the size of the WSUD measures required in this example is presented in Table 12.

Table 12 LFI B2 option – lot and streetscape strategy components

LFI B2 option	Tank for toilet use	Lot bioretention	Allotment wetland	Storage for allotment irrigation	Maximum lot imperviousness	Amount of pervious lot irrigated	Street bioretention	On-site stormwater detention
	kL/ha	m^2/ha	m^2/ha	kL/ha	%	%	m^2/ha	m^3/ha
Requirements	14	10	550	300	60	50	35	390

Indicative layout

An indicative layout for this LFI (B2) option, which only proposes WSUD measures on the allotment (i.e. private land) and adjacent streets is shown in Figure 6. As indicated by the yellow dashed lines, LFI development could expand to cover the full site if a regional treatment and reticulated stormwater harvesting scheme is implemented (e.g. any of the Option D strategies in Table 10 and Table 11). In the example shown, the lot/allotment wetland, storage and irrigated area could be decommissioned, and the area developed into industrial lots with all drainage contributing to a regional treatment and harvesting scheme.

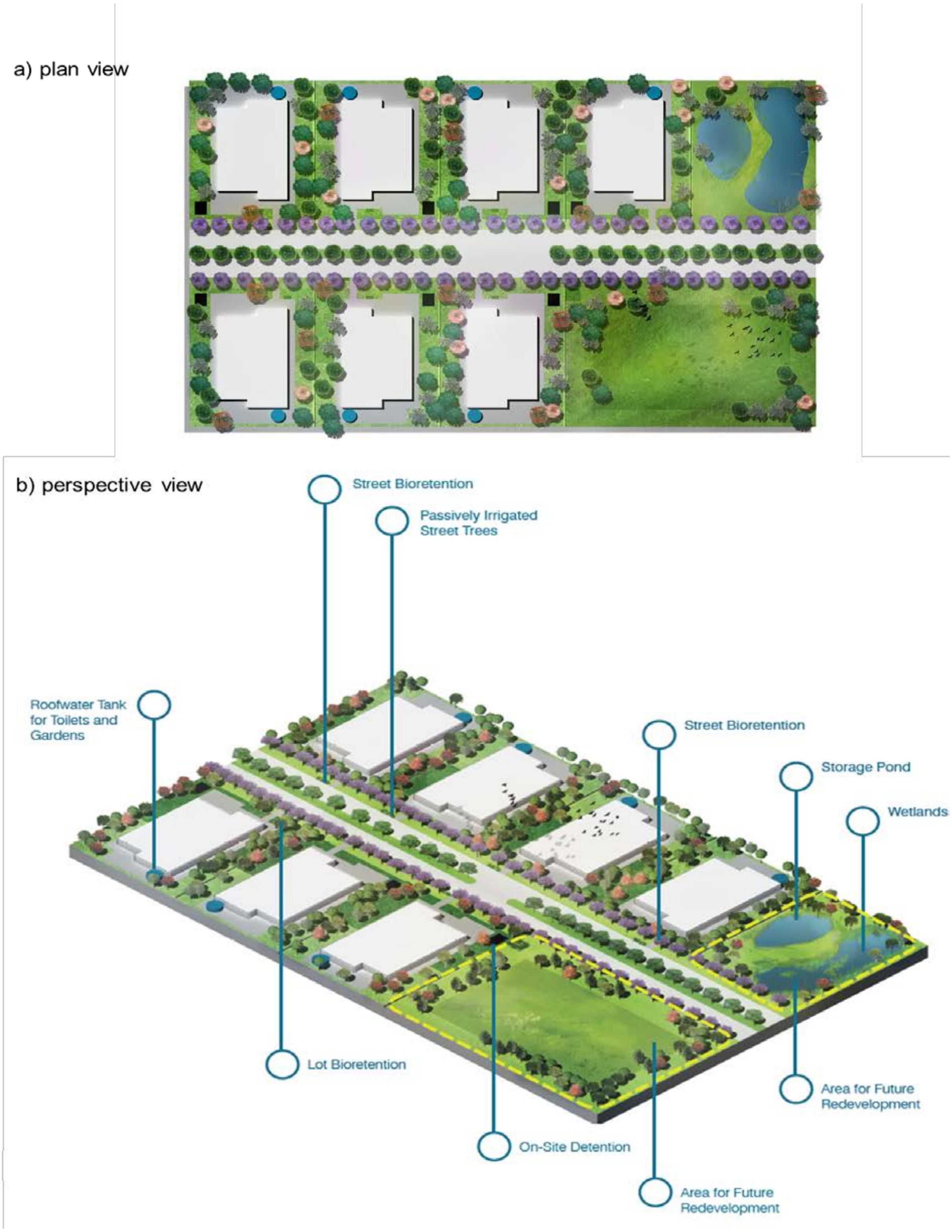

Figure 6 Indicative layout for LFI lot and streetscape measures

Note the yellow dotted boundaries indicating opportunities for future development if a regional stormwater system is established.

Stormwater targets achieved

An example MUSIC model is shown in Figure 7 to demonstrate how the treatment nodes relate to the source catchments/drainage areas for all works to be contained within the lots or streets. Table 13 and Table 14 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

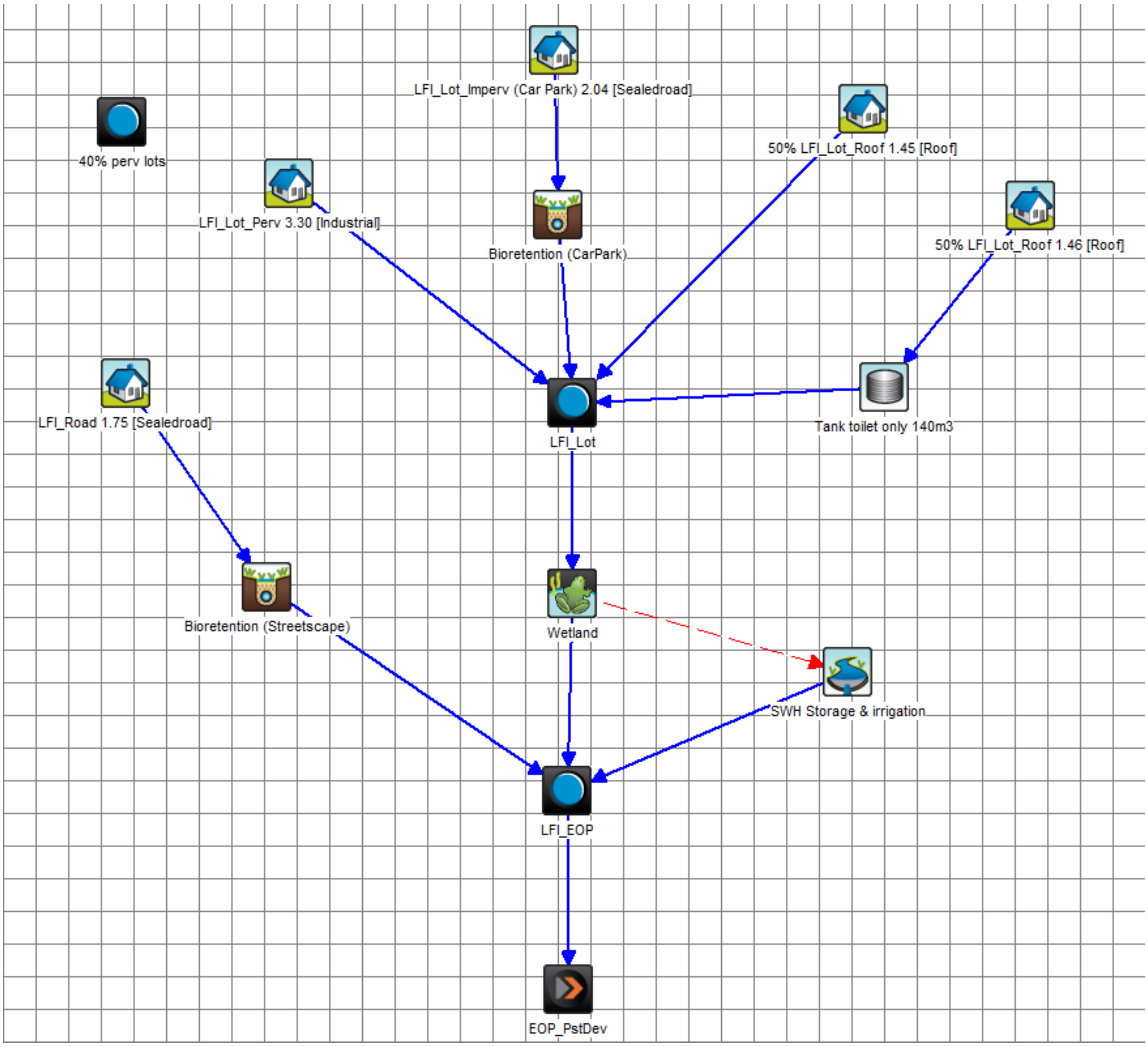

Figure 7 Example MUSIC model structure for LFI lot and streetscape measures

Perv denotes pervious, Imper denotes impervious, EPO denotes end of pipe, PstDev denotes post development, and SWH denotes stormwater harvesting.

Table 13 Compliance of WSUD strategy LFI B2 option with operational phase stormwater quantity (flow) targets

Flow targets based on flow percentiles			
Parameter	**Target**	**Result**	**Compliance**
95%ile flow	3,000–15,000 L/ha/day	13,608	Yes
90%ile flow	1,000–5,000 L/ha/day	4,826	Yes
75%ile flow	100–1,000 L/ha/day	486	Yes
50%ile flow	5–100 L/ha/day	8	Yes
Cease to flow	10–30%	31	Yes

Table 14 Compliance of WSUD strategy LFI B2 option with operational phase stormwater quality targets

Quality targets based on post development load reductions			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	91	Yes
Total phosphorus (TP)	80%	81	Yes
Total nitrogen (TN)	65%	68	Yes

LFI lot and precinct strategy

Summary

This strategy (C4 in Table 10 and Table 11) adopts a suite of WSUD measures on lots, in streets and in public open space to enable full development of each lot (i.e. up to 85% impervious, see the *Mamre Road Precinct Development Control Plan 2021*) and still comply with the operational phase stormwater quality and quantity (flow) targets (Table 3 to Table 6).

The strategy includes collecting roof water in tanks and using this to supply toilets within the building as well as irrigating 100% of the pervious area of allotments with a dedicated irrigation system. This irrigation coverage is more than the recommended areas for irrigation (see Appendix B of this guide), and should therefore be confirmed with the consent/approval authority and/or stormwater drainage manager. Adopting this example strategy would be subject to detailed salinity and sodicity assessments and/or delivery of suitable WSUD measures (e.g. lining; see also DPIE 2021c, d). Adopting this example strategy will also likely require certification of the design to ensure 100% irrigation coverage and monitoring/ reporting of the system, and independent auditing to ensure the system is achieving the design intent.

Bioretention is implemented for driveways and carparks in the lots, as well as along the streets. A wetland is to be integrated into local parks and this will treat stormwater that is then used to irrigate the park area, as well as losing some water to evaporation. Treated water could be stored in a tank (either above or below ground) or in an open storage pond that could be integrated within the park setting (as long as water level variations can be managed for amenity and safety).

Agreement is required with the consent authority and/or stormwater drainage manager for the ownership and operation of the precinct wetland, storage and reuse scheme.

Any Positive Covenant for ongoing operation and maintenance of WSUD and on-site stormwater detention measures should be registered on title. Monitoring of tanks and allotment irrigation systems is also likely to be required along with independent audits on a regular basis of all allotment WSUD measures, to ensure they are meeting the design intent.

Strategy components

A summary of the size of the WSUD measures required in this example is presented in Table 15.

Table 15 LFI C4 option – lot and precinct strategy components

LFI C4 option	Tank for indoor use and lot irrigation	Number of gardens irrigated	On-site stormwater detention	Lot bioretention	Streetscape raingarden	Precinct wetland	Reuse storage for public open space	Amount of public open space irrigated
	kL/ha	%	m^3/ha	m^2/ha	m^2/ha	m^2/ha	kL/ha	%
Requirements	60	100	390	69	25	450	300	50

Indicative layout

An indicative layout for this LFI (C4) option, which proposes WSUD measures on the allotment (i.e. private land), adjacent streets and local parks is shown in Figure 8. The layout shows how allotment and streetscape measures complement WSUD measures that have been integrated into a local park, and how captured stormwater is used to irrigate the park. In addition, a waterway is incorporated into the open space that increases the blue grid components in the developed area.

Stormwater targets achieved

Table 16 and Table 17 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 16 Compliance of WSUD strategy LFI C4 option with operational phase stormwater quantity (flow) targets

Flow targets based on flow percentiles			
Parameter	**Target**	**Result**	**Compliance**
95%ile flow	3,000–15,000 L/ha/day	9,485	Yes
90%ile flow	1,000–5,000 L/ha/day	3,968	Yes
75%ile flow	100–1,000 L/ha/day	921	Yes
50%ile flow	5–100 L/ha/day	42	Yes
Cease to flow	10% to 30%	14	Yes

Table 17 Compliance of WSUD strategy LFI C4 option with operational phase stormwater quality targets

Quality targets based on post development load reductions			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	94	Yes
Total phosphorus (TP)	80%	82	Yes
Total nitrogen (TN)	65%	73	Yes

Figure 8 Indicative layout for LFI lot and precinct-scale measures

LFI regional treatment and reticulated stormwater reuse strategy

Summary

LFI areas that have reticulated stormwater reuse (D2-b in Table 10 and Table 11) will provide stormwater treatment and storage at precinct or regional scales that is managed by a stormwater drainage manager. The WSUD systems would deliver treated stormwater to a regional stormwater reuse scheme that is then reticulated through the development for all non-potable uses (e.g. toilets, irrigation, as well as any industrial applications).

On-site stormwater detention is included in the landscape of each lot with the potential for some detention to also occur over the regional stormwater system. On-site stormwater detention requirements should be determined with reference to relevant legislation and policies, including those listed in the section of this guide titled ‘Relationship to other documents’.

Street trees throughout the area would incorporate passive irrigation techniques to increase soil moisture retention in street verges to increase canopy cover. Under this example strategy the street trees do not play a role in achieving the stormwater targets. These passive irrigation techniques transfer a very small proportion of stormwater into the soil, and play an insignificant role in stormwater treatment, but are valuable for soil moisture and much less expensive than bioretention street trees.

Treatment in this example WSUD strategy is via a wetland and adjacent bioretention combination where the extended detention is shared. Low flows are maintained in downstream waterways by configuring the wetland with a small extended detention and wetland riser flows directed to the waterway. When the extended detention of the wetland is exceeded, flow is transferred to adjacent bioretention basins that treat flows and direct treated water to the stormwater harvesting storage with overflows/bypasses discharged to the creek. The stormwater treatment and stormwater harvesting storage components are integrated into the regional open space and located below the 1% AEP level, in accordance with the floodplain and waterfront land principles set out in Chapter 3 of this guide.

Agreement is required with the stormwater drainage manager for the ownership and operation of the precinct/regional wetland, bioretention, storage and reuse scheme.

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 18 and an indicative layout is shown in Figure 9.

Table 18 LFI D2-b option – regional treatment and reuse strategy components

LFI D2-b option	On-site stormwater detention	Precinct / regional wetland	Precinct / regional bioretention	Reuse storage for public open space (tank or pond)
	m^3/ha	m^2/ha	m^2/ha	kL/ha
Requirements	390	200	60	380

Figure 9 Indicative layout for an LFI regional treatment and reticulated reuse strategy

Stormwater targets achieved

Table 19 and Table 20 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Figure 10 is a plot of a flow duration curve as an alternative to the tabular format for demonstrating compliance with the operational phase stormwater quantity (flow) targets. The flow duration curve can be obtained directly from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 19 Compliance of WSUD strategy LFI D2-b option with operational phase stormwater quantity (flow) targets

Flow targets based on flow percentiles			
Parameter	**Target**	**Result**	**Compliance**
95%ile flow	3,000–15,000 L/ha/day	10,174	Yes
90%ile flow	1,000–5,000 L/ha/day	1,660	Yes
75%ile flow	100–1,000 L/ha/day	917	Yes
50%ile flow	5–100 L/ha/day	29	Yes
Cease to flow	10% to 30%	22	Yes

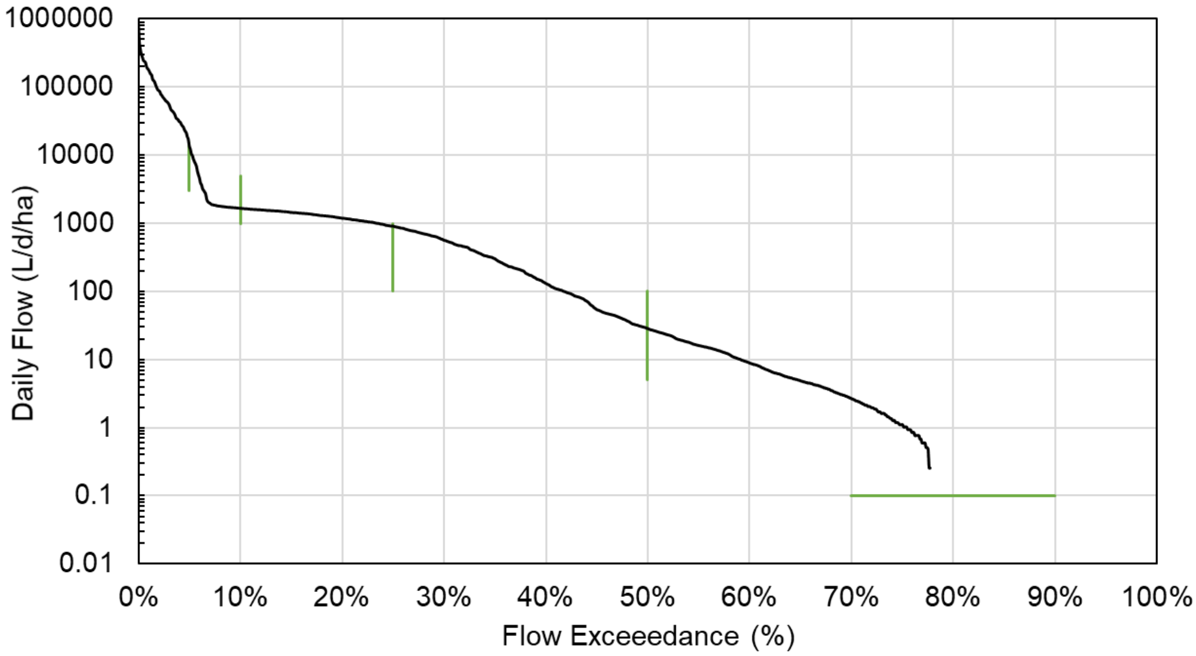

Figure 10 Flow duration curve for an LFI regional treatment and reticulated reuse strategy (D2-b in Table 10 and Table 11)

Green bands represent ranges of stormwater quantity (flow) targets.

Table 20 Compliance of WSUD strategy LFI D2-b option with operational phase stormwater quality targets

Quality targets based on post development load reductions			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	94	Yes
Total phosphorus (TP)	80%	86	Yes
Total nitrogen (TN)	65%	74	Yes

High density residential

HDR developments are characterised by relatively large populations (e.g. 125 people per hectare) with multi-storey dwellings set amongst landscaped areas. The non-potable water demands of these typologies provide an opportunity to supply harvested stormwater, and the landscaped surrounds offer a potential to integrate WSUD measures with multiple functions including treatment, harvesting, cooling and amenity improvements. Local parks in HDR areas also provide opportunities to integrate water into the urban fabric and increase the blue–green network that is central to the vision for the Western Parkland City.

Careful management of stormwater quality and quantity (flow) is still required to ensure the performance criteria (water quality and flow objectives; DPE 2022c) for protecting and restoring the blue grid are met. Similar to the LFI typology, a challenge for HDR typologies is intercepting and using sufficient stormwater to limit the quantity of discharges to meet the stormwater quantity (flow) targets.

A range of example WSUD strategies are provided in the following sections, which apply depending on the scale of development and whether there is a regional stormwater treatment, harvesting and reticulation system, as well as the proponent’s preference.

Three example WSUD strategies are presented in more detail for street and allotment measures, using local parks and public open space, and one that incorporates a reticulated stormwater harvesting scheme.

Example WSUD strategies for HDR

Six WSUD strategies that achieve the operational phase stormwater quality and quantity (flow) targets are presented in Table 21. Two are for allotment and streetscape measures only, 2 use local parks in addition to lots and streetscape measures, and 2 have a reticulated stormwater reuse system. Table 22 provides the sizes of the WSUD measures used in the WSUD strategies.

The WSUD strategies (B1, B2 in Table 21) that are delivered on the allotment and streetscape rely on green roofs being implemented for at least 70% of the roof area. Such a strategy would improve amenity and contribute to connecting the green grid and other benefits such as cooling and increased biodiversity.

The strategies are described in general below, and further detail is provided in a companion study (DPE 2022d):

- **HDR A option** – bioretention in local public open space. *This option does not comply with the stormwater quality and quantity (flow) targets outlined in Table 3 to Table 6 of this guide, and is provided for comparison only.*
- **HDR B options** – these options rely on 70% of the roof area being a green roof and the remaining 30% of the roof draining to a tank for indoor uses. An allotment treatment system (either wetland or bioretention) then treats water to store in a pond or tank for irrigation of the gardens. Streetscape bioretention is also implemented.

- **HDR C options** – roof water tanks are used for indoor and allotment irrigation and bioretention treats hardstand areas of the allotments. Local parks have treatment systems (either wetland or wetland/ bioretention combinations) with treated water collected to irrigate the parks. Streetscape raingardens are also adopted for Option C1.
- **HDR D options** – lots are fully developed with regional treatment and treated water directed to regional storage ponds as part of a broader reuse scheme. Reticulated treated stormwater is used for all non-potable uses as well as irrigating public open spaces. Bioretention is implemented in allotment carparks and streets for Option D1.

More detailed descriptions and example layouts for different WSUD strategy types are shown in the following sections for:

- lot and streetscape (HDR B1)
- lot, streetscape and public open space bioretention and reuse (HDR C2)
- regional treatment (bioretention) and reticulated stormwater reuse (HDR D2).

Table 21 Example WSUD strategies for HDR typologies

WSUD strategy – HDR		Delivery approach – dependent on scale of development and options for regional harvesting and reuse								
		Reduced site coverage (green roof)	Tanks	Lot WSUD	Streetscape WSUD	Precinct WSUD (above 1% AEP)	Stormwater harvesting (local)	Stormwater quantity detention	Regional WSUD (maximise below 1% AEP)	Reticulated regional stormwater harvesting
A	Post development load reduction targets (85% TSS, 65% TP, 45% TN)					✓		✓		
B1	Lot (wetlands) and streetscape	✓	✓	✓	✓			✓		
B2	Lot (bioretention) and streetscape	✓	✓	✓	✓			✓		
C1	Lot, streetscape and public open space wetland and reuse		✓	✓	✓	✓	✓	✓		
C2	Lot, streetscape and public open space bioretention and reuse		✓	✓	✓	✓	✓	✓		
D1	Lot, street and regional treatment and reticulated stormwater reuse			✓	✓			✓	✓	✓
D2	Regional treatment (bioretention) and reticulated stormwater reuse							✓	✓	✓

Note that Option A does not achieve the stormwater quality and quantity targets

Table 22 Sizes of WSUD measures and impervious (imperv.) cover of example WSUD strategies for LFI typologies

WSUD strategy – HDR		WSUD measures													% open space		% imperv.	
		Green roof (m^2/ha)	Tanks (kL/ha)	Lot bioretention (m^2/ha)	Street bioretention (m^2/ha)	Lot / precinct wetland (m^2/ha)	Regional wetland (m^2/ha)	Regional bioretention (m^2/ha)	Stormwater harvesting on lot (m^3/ha)	Stormwater harvesting on lot to irrigation (ML/yr/ha)	Stormwater harvesting to public open space (m^3/ha)	Stormwater harvesting (local) to public open space irrigation	Reticulated regional stormwater harvesting (m^3/ha)	Reticulated regional stormwater harvesting (ML/yr/ha)	Local	Regional	Lot	Total
A	Post development load reduction targets (85% TSS, 65% TP, 45% TN)							80							10	5	70	62
B1	Lot (wetlands) and streetscape	2,600	94		41	100			52	0.2					0	0	32	41
B2	Lot (bioretention) and streetscape	2,200	94	200	55				52	0.3					0	0	32	41
C1	Lot, streetscape and public open space wetland and reuse		125	5	9	400					60	0.2			10	5	70	62
C2	Lot, streetscape and public open space bioretention and reuse		125	5		150		30			60	0.3			10	5	70	62
D1	Lot, street and regional treatment and reticulated stormwater reuse			5	13		500						200	1.2	10	5	70	62
D2	Regional treatment (bioretention) and reticulated stormwater reuse						150	30					200	1.6	10	5	70	62

Note that Option A does not achieve the stormwater quality and quantity targets, and Option B has a 0% open space proportion because it considers a development of only allotments and streets (not public open space).

HDR lot and streetscape strategy

Summary

This strategy (B1 in Table 21) focuses on delivering the operational phase stormwater quality and quantity (flow) targets on allotments and in the adjacent streets. A major component of the strategy is the use of green roofs for at least 70% of roof areas, with the remaining area of roof draining to tanks that supply indoor toilets and laundry facilities. In addition, all surface stormwater from the allotment is collected and treated in a wetland located on the allotment. The wetland also incorporates the on-site stormwater detention components. Treated water from the wetland is stored in a tank that then supplies irrigation to 50% of the allotment garden areas.

The adjacent street includes streetscape bioretention to treat runoff from the hard paved areas as well as passively irrigated street trees along the full length of the roads.

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 23, and an indicative layout is shown in Figure 11.

Table 23 HDR B1 option – lot and streetscape strategy components

HDR B1 option	Green roof area	Tank for indoor use	Allotment wetland	Tank for garden irrigation	Amount of lot gardens irrigated	On-site stormwater detention	Street bioretention
	m^2/ha	kL/ha	m^2/ha	kL/ha	%	m^3/ha	m^2/ha
Requirements	260	94	100	52	50	390	41

Stormwater targets achieved

Table 24 and Table 25 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 24 Compliance of WSUD strategy HDR B1 option with operational phase stormwater quantity (flow) targets

Flow targets based on MARV			
Parameter	**Target**	**Result**	**Compliance**
Mean annual runoff volume (MARV)	≤2 ML/ha/y	1.51	Yes
90%ile flow	1,000–5,000 L/ha/day	4,769	Yes
50%ile flow	5–100 L/ha/day	31	Yes
10%ile flow	0 L/ha/day	0	Yes

Table 25 Compliance of WSUD strategy HDR B1 option with operational phase stormwater quality targets

Quality targets based on allowable mean annual load			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	<80 kg/ha/y	64	Yes
Total phosphorus (TP)	<0.3 kg/ha/y	0.2	Yes
Total nitrogen (TN)	<3.5 kg/ha/y	2.1	Yes

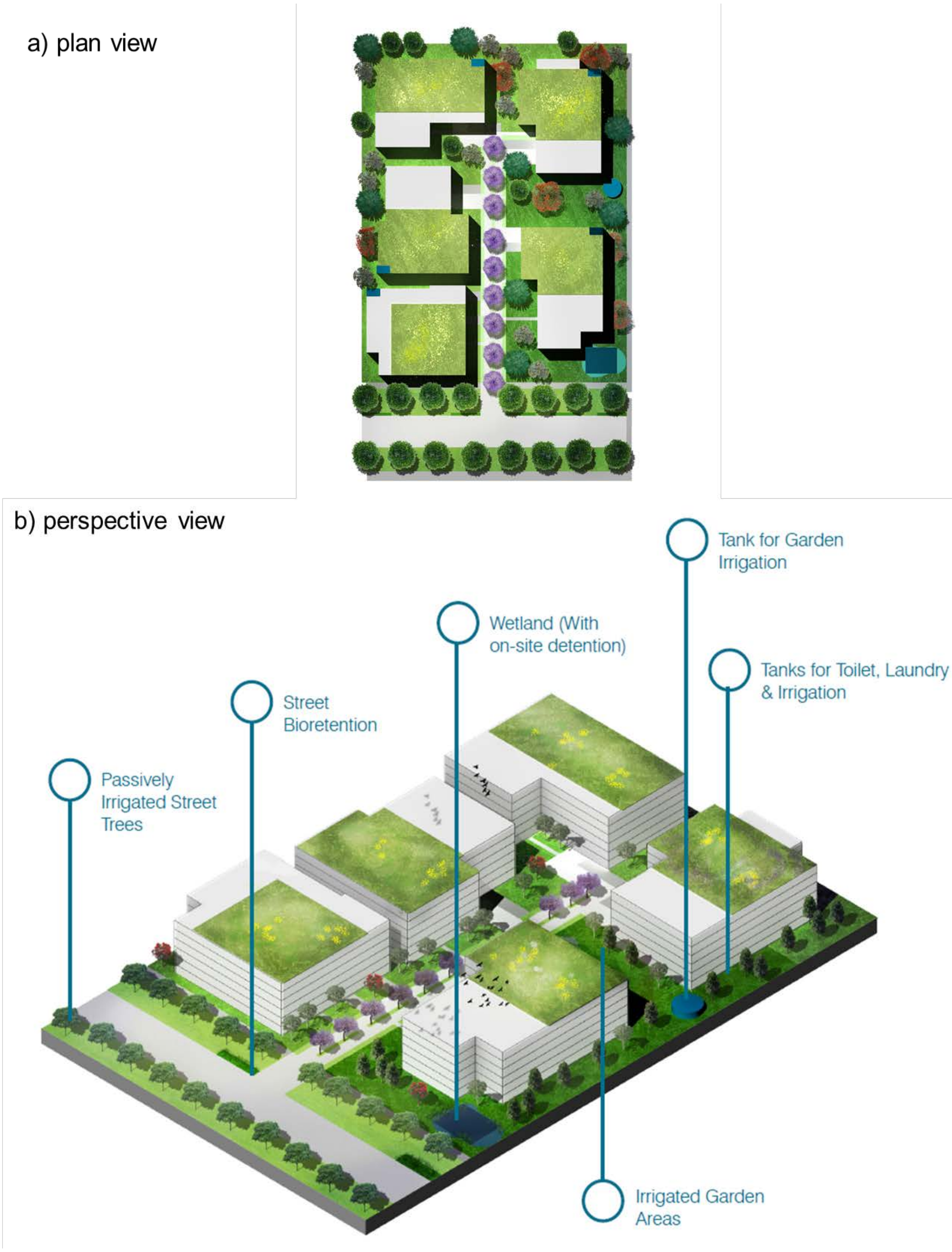

Figure 11 Indicative layout for HDR lot and streetscape measures

HDR lot and precinct strategy

Summary

This WSUD strategy (C2 in Table 21) for HDR focuses less on allotment measures and more on measures integrated into public open spaces (parks) within the precinct. This will introduce water into local parks, will add to the blue–green grid and provide multiple co-benefits such as urban cooling and amenity. This strategy will require agreement with an owner and/or stormwater drainage manager to operate the treatment and reuse system in the local parks.

Green roofs are not required to deliver the operational phase stormwater quality and quantity (flow) targets for this strategy. All of the roof areas drain into tanks that are used for toilets and laundries inside, and also to supply irrigation water for the allotment gardens (50%). On-site stormwater detention requirements will be included in the landscape of each lot.

Street trees throughout the area incorporate passive irrigation techniques to increase soil moisture retention throughout the streetscapes.

Runoff from the allotment and roads is conveyed into wetlands that are integrated into local parks. The wetland treatment system works in conjunction with an adjacent bioretention basin (which shares extended detention) to treat the majority of runoff from the area.

The wetlands are configured with small extended detention so that water from the wetland riser can be directed to the creek to maintain low flows (e.g. 50%ile). Higher extended detention depths transfer into the bioretention that treats the majority of the flow and directs treated water into a holding storage (either tank or pond) and this is used to irrigate the local park (50%).

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 26, and an indicative layout is shown in Figure 12.

Table 26 HDR C2 option – lot and precinct strategy components

HDR C2 option	Reuse storage for public open space (tank or pond)	Tank for indoor use and lot irrigation	Precinct wetland	Amount of public open space irrigated	Amount of lot gardens irrigated	On-site stormwater detention	Precinct bioretention
	kL/ha	kL/ha	m^2/ha	%	%	m^3/ha	m^2/ha
Requirements	60	125	150	50	50	390	30

Stormwater targets achieved

Table 27 and Table 28 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 27 Compliance of WSUD strategy HDR C2 option with operational phase stormwater quantity (flow) targets

Flow targets based on MARV			
Parameter	**Target**	**Result**	**Compliance**
Mean annual runoff volume (MARV)	≤2 ML/ha/y	1.97	Yes
90%ile flow	1,000–5,000 L/ha/day	2,576	Yes
50%ile flow	5–100 L/ha/day	8	Yes
10%ile flow	0 L/ha/day	0	Yes

Table 28 Compliance of WSUD strategy HDR C2 option with operational phase stormwater quality targets

Quality targets based on post development load reductions			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	94	Yes
Total phosphorus (TP)	80%	82	Yes
Total nitrogen (TN)	65%	72	Yes

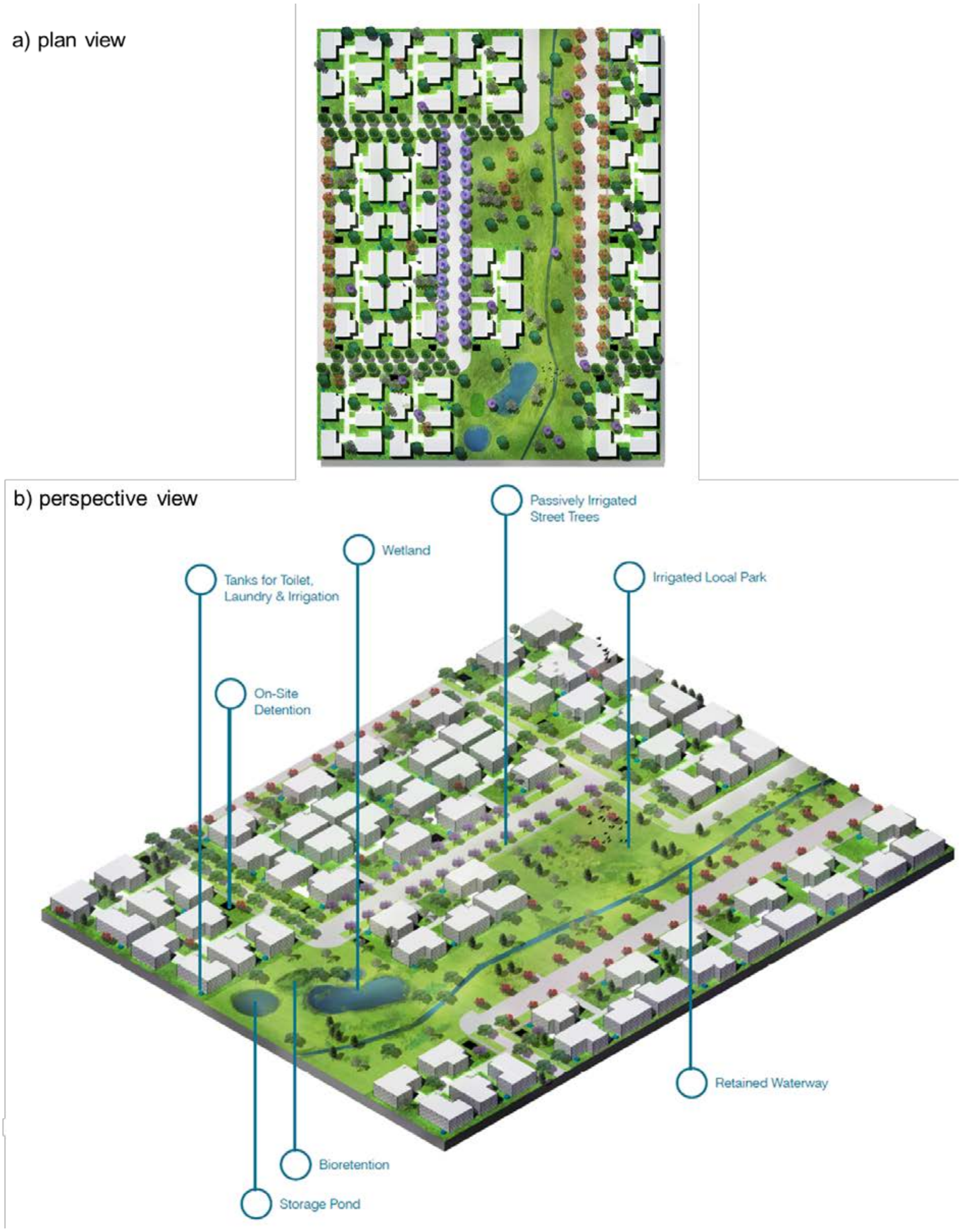

Figure 12 Indicative layout for HDR lot and precinct-scale measures

HDR regional treatment and reticulated reuse strategy

Summary

HDR typologies that have reticulated stormwater reuse will need to provide stormwater treatment and storage on a precinct or regional scale in order to contribute to the reticulated reuse scheme. Allotments are typically supplied with the reticulated harvested stormwater for all non-potable uses on site (e.g. toilets, laundries and outdoor irrigation) and on-site stormwater detention requirements are included in the landscape of each lot. Street trees through the area incorporate passive irrigation techniques to increase soil moisture retention throughout the streetscape, subject to a salinity and sodicity assessment (see Chapter 3 of this guide).

Treatment in this example WSUD strategy (D2 in Table 21) is with a wetland and adjacent bioretention combination, where the extended detention is shared between both. Low flows are maintained in downstream waterways by configuring the wetland with a small extended detention and for flows from the wetland riser to be directed to the waterway. When the extended detention of the riser is exceeded, flow is transferred into the bioretention basin that treats flows and directs treated water to the reuse storages.

The treatment measure will then deliver treated water to an open storage that will be connected to the regional stormwater harvesting and reticulation system. The treatment and storage components are integrated into the regional open space and located below the 1% AEP flood level, in accordance with the floodplain and waterfront land principles set out in Chapter 3 of this guide.

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 29, and an indicative layout is shown in Figure 13.

Table 29 HDR D2 option – regional treatment and reticulated reuse strategy components

HDR D2 option	On-site stormwater detention	Precinct/regional wetland	Precinct/regional bioretention	Reuse storage for public open space (tank or pond)
	m^3/ha	m^2/ha	m^2/ha	kL/ha
Requirements	390	150	30	200

Stormwater targets achieved

Table 30 and Table 31 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 30 Compliance of WSUD strategy HDR D2 option with operational phase stormwater quantity (flow) targets

Flow targets based on MARV			
Parameter	**Target**	**Result**	**Compliance**
Mean annual runoff volume (MARV)	≤2 ML/ha/y	1.99	Yes
90%ile flow	1,000–5,000 L/ha/day	2,702	Yes
50%ile flow	5–100 L/ha/day	45	Yes
10%ile flow	0 L/ha/day	0	Yes

Table 31 Compliance of WSUD strategy HDR D2 option with operational phase stormwater quality targets

Quality targets based on allowable mean annual load			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	<80 kg/ha/y	55	Yes
Total phosphorus (TP)	<0.3 kg/ha/y	0.3	Yes
Total nitrogen (TN)	<3.5 kg/ha/y	3.1	Yes

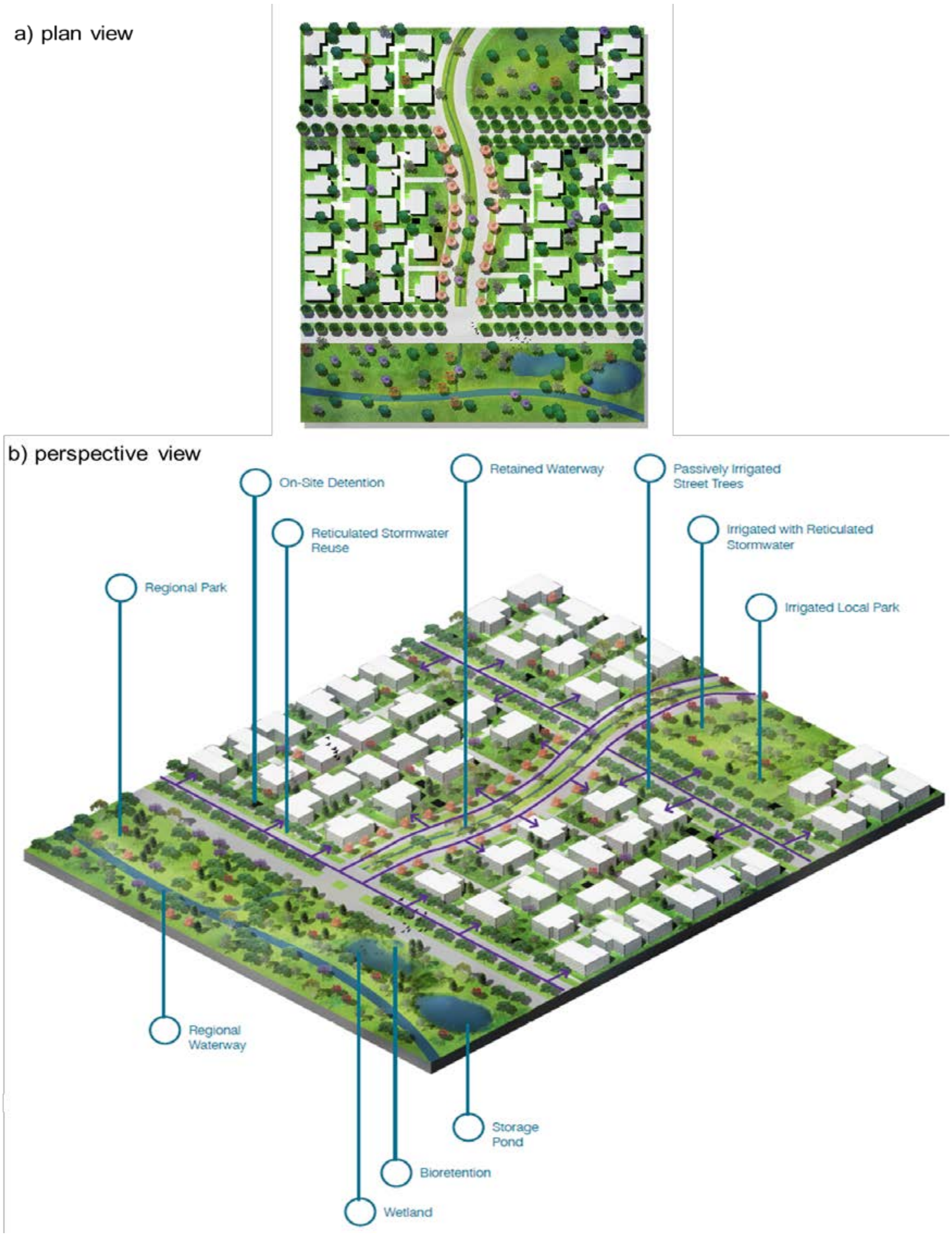

Figure 13 Indicative layout for an HDR regional treatment and reticulated reuse strategy

Low density residential

LDR typologies are characterised by approximately 15–20 allotments per hectare, with single or double storey dwellings. This typology was selected as a representative example of residential development that could occur in the Wianamatta–South Creek catchment.

From a stormwater management perspective, non-potable water demands generated in residential areas provide relatively uniform demands that could be met with harvesting (i.e. tanks) on the lot/allotment. In addition, residential areas are characterised by local parks and vegetated streetscapes, which offer potential to integrate WSUD measures that provide multiple functions of treatment, harvesting, cooling, biodiversity and amenity improvements.

Careful management of stormwater quality and quantity (flow) is still required to ensure the performance criteria (water quality and flow objectives; DPE 2022c) for protecting and restoring the blue grid are met. Similar to LFI and HDR typologies, a challenge for LDR typologies is intercepting and using sufficient stormwater to limit the quantity of discharges to meet the operational phase stormwater quantity (flow) targets.

A basic assumption of 15% pervious allotment is made for this typology. It is recognised that this provides less allotment garden space than development control specifications to achieve the vision for the Western Parklands City. However, this assumption serves to demonstrate how the operational phase stormwater quality and quantity (flow) targets can be met even with limited allotment pervious space.

A general approach adopted here is to avoid using WSUD measures (other than tanks) on individual allotments. The ongoing compliance requirements to ensure long-term operation is considered to be problematic for small-scale WSUD measures on private land. A preference, therefore, is for WSUD measures to be placed in the public domain where they are generally better managed. The approach for stormwater detention requirements is also to locate them in public land with an intent to combine with precinct WSUD measures.

A range of example WSUD strategies are provided in the following sections, which apply depending on the scale of development and whether there is a regional stormwater treatment, harvesting and reticulation system, as well as the proponent’s preference.

Three example strategies are presented in more detail for street and allotment measures, using local parks and public open space, and one that incorporates a reticulated stormwater harvesting scheme.

Example WSUD strategies for LDR

Eight WSUD strategies that achieve the operational phase stormwater quality and quantity (flow) targets are presented in Table 32. Three are for allotment and streetscape measures, 2 use local parks in addition to lots and street measures, and 3 have a reticulated stormwater reuse system. Table 33 presents the size of the WSUD measures needed to support each WSUD strategy. Note that on-site stormwater detention requirements are not listed as these should be determined with reference to relevant legislation and policies, including those listed in the section of this guide titled ‘Relationship to other documents’.

The WSUD strategies are described in general below:

- **LDR A option** – adopting 2.4 kL tanks and using bioretention in local public open space areas. *This option does not comply with the stormwater quality and quantity (flow) targets outlined in Table 3 to Table 6 of this guide, and is provided for comparison only.*
- **LDR B1 option** – 30% of lot area is set aside and used for bioretention and a storage pond to irrigate 50% of the area. The remaining lots are 15% pervious and have 50% of roof areas drain to 5 kL tanks that supply toilets, laundries and 50% of lot gardens.

- **LDR B2 option** – 30% of lot area is set aside and used for a wetland and storage pond to irrigate 50% of the area. The remaining lots are 15% pervious and have 50% of roof areas drain to 5 kL tanks that supply toilets, laundries and 50% of lot gardens.
- **LDR B3 option** – lots are 30% pervious (gardens) and all lots are developed. 100% of roof areas drain to 20 kL tanks that are used for hot water, toilets, laundries and to irrigate 75% of the lot garden areas. The lots drain to street gutters and street bioretention systems treat flows and direct treated water to storages that are used to irrigate (50%) street verges.
- **LDR C1 option** – lots are 15% pervious (gardens) and all lots are developed. 50% of roof areas drain to 6 kL tanks that are used for toilets, laundries and to irrigate 50% of the lot garden areas. Street bioretention systems treat road runoff. A wetland in public open space treats flows and directs treated water to a storage pond that is used to irrigate the local public open space area.
- **LDR C2 option** – lots are 25% pervious (gardens) and all lots are developed. 50% of roof areas drain to 5 kL tanks that are used for toilets, laundries and to irrigate 50% of the lot garden areas. Street bioretention systems treat road runoff. A combined wetland–bioretention system in public open space treats flows and directs treated water to a storage tank that is used to irrigate the local public open space area and street verges.
- **LDR D1 option** – lots are 15% pervious (gardens) and all lots are developed. 50% of roof areas drain to 2.4 kL tanks that are used for toilets and laundries. Stormwater flows to a regional wetland–bioretention combination that stores treated water in a pond as part of a regional stormwater harvesting scheme. Reticulated treated stormwater is used for all outdoor uses as well as irrigating public open spaces.
- **LDR D2 option** – lots are 15% pervious (gardens) and all lots are developed. 50% of roof areas drain to 2.4 kL tanks that are used for toilets and laundries. Street bioretention basins treat road runoff. Stormwater flows to a regional wetland that directs treated water to a storage pond as part of a regional stormwater harvesting scheme. Reticulated treated stormwater is used for all outdoor uses as well as irrigating public open spaces.
- **LDR D3 option** – lots are 15% pervious (gardens) and all lots are developed. No tanks or street bioretention is adopted. Stormwater flows to a regional wetland–bioretention combination that directs treated water to a storage pond as part of a regional stormwater harvesting scheme. Reticulated treated stormwater is used for all non-potable uses as well as irrigating public open spaces.

Interim solution

LDR B1 and B2 options could be considered an interim solution (by fully developing some allotments and leaving others pervious) until a regional stormwater system is implemented and the lot can be fully developed to maximum imperviousness (as outlined in the relevant Development Control Plan).

More detailed descriptions and example layouts for different WSUD strategy types are shown in the following sections for:

- lot and streetscape strategies (LDR B3)
- lot and precinct strategies (LDR C1)
- regional treatment and reticulated reuse strategies (LDR D1).

Table 32 Example WSUD strategies for LDR typologies

WSUD strategy – LDR		Delivery approach – dependent on scale of development and options for regional harvesting and reuse								
		Reduced site coverage	Tanks	Lot WSUD	Streetscape WSUD	Precinct WSUD	Stormwater harvesting (local)	Stormwater quantity detention	Regional WSUD	Reticulated regional stormwater harvesting
A	Post development load reduction targets (85% TSS, 65% TP, 45% TN)		✓			✓		✓		
B1	Lot (bioretention) and streetscape (interim)	✓	✓	✓	✓			✓		
B2	Lot (wetland) and streetscape (interim)	✓	✓	✓	✓			✓		
B3	Lot (30% pervious) and streetscape		✓		✓			✓		
C1	Lot, streetscape and public open space wetland and reuse		✓		✓	✓	✓	✓		
C2	Lot (25% pervious), streetscape and public open space WSUD and reuse		✓		✓	✓	✓	✓		
D1	Regional treatment and reticulated stormwater reuse		✓					✓	✓	✓
D2	Regional treatment (wetland) and reticulated stormwater reuse		✓		✓			✓	✓	✓
D3	Regional treatment and reticulated stormwater reuse (no tanks)							✓	✓	✓

Note that Option A does not achieve the stormwater quality and quantity targets.

Table 33 Sizes of WSUD measures and impervious (imperv.) cover of example WSUD strategies for LDR typologies

WSUD strategy - LFI		WSUD measures									% Open space		% imperv.	
		Tanks (kL/ha)	Street bioretention (m2/ha)	Precinct bioretention (m^2/ha)	Precinct wetland (m^2/ha)	Regional wetland (m^2/ha)	Regional bioretention (m^2/ha)	Stormwater harvesting on lot storage (m^3/ha)	Public open space harvesting to storage (m^3/ha)	Regional stormwater harvesting storage (m^3/ha)	Local	Regional	Lot imperviousness (%)	Total imperviousness (%)
A	Post development load reduction targets (85% TSS, 65% TP, 45% TN)	39		100							10	5	85	69
B1	Lot (bioretention) and streetscape (interim)	67		130				90			0	0	53	55
B2	Lot (wetland) and streetscape (interim)	67			550			90			0	0	53	55
B3	Lot (30% pervious) and streetscape	380	85						30		0	0	70	69
C1	Lot, streetscape and public open space wetland and reuse	97	33		750				75		10	5	85	69
C2	Lot (25% pervious), streetscape and public open space WSUD and reuse	81	40	40	300				125		10	5	75	63
D1	Regional treatment and reticulated stormwater reuse	39				200	60			300	10	5	85	69
D2	Regional treatment (wetland) and reticulated stormwater reuse	39	33			500				300	10	5	85	69
D3	Regional treatment and reticulated stormwater reuse (no tanks)					200	60			340	10	5	85	69

Note that Option A does not achieve the stormwater quality and quantity targets, and Option B has a 0% open space proportion because it considers a development of only allotments and streets (not public open space).

LDR lot and streetscape strategy

Summary

The Option B WSUD strategies in Table 32 focus on delivering the operational phase stormwater quality targets on allotments and in the adjacent streets (i.e. without local parks). Generally, to achieve the targets a lower site coverage is required compared to conventional development. This can either be delivered by increasing the pervious coverage of allotments or as an interim solution by developing less lots until a regional reticulated reuse system is implemented.

The WSUD strategy identified as B3 in Table 32, achieves the targets by allowing development of all allotments but increasing the pervious coverage of each lot to 30%. Other examples WSUD strategies include having 100% of roof areas draining to 20 kL tanks that are used for hot water, toilets, laundries and to irrigate 75% of the lot garden areas. The lots drain into street gutters and street bioretention basins treat flows from the lots and streets. Treated water from the bioretention basins is directed to storage tanks located along the streets that are used to irrigate (50%) street verges. There is also a very small proportion of bioretention systems that bypass the tanks and provide low flows to the waterways.

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 34, and an indicative layout is shown in Figure 14.

Table 34 LDR B3 option – lot and streetscape strategy components

LDR B3 option	Lot perviousness	Roof area to tank	Water from roofs for reuse	Street bioretention	Tank for verge irrigation	Amount of lot gardens irrigated	Amount of verges irrigated
	%	%	kL/ha	m^2/ha	kL/ha	%	%
Requirements	30	100	380	85	30	75	50

Stormwater targets achieved

Table 35 and Table 36 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 35 Compliance of WSUD strategy LDR B3 option with operational phase stormwater quantity (flow) targets

Flow targets based on MARV			
Parameter	**Target**	**Result**	**Compliance**
Mean annual runoff volume (MARV)	≤2 ML/ha/y	1.96	Yes
90%ile flow	1,000–5,000 L/ha/day	2,362	Yes
50%ile flow	5–100 L/ha/day	6	Yes
10%ile flow	0 L/ha/day	0	Yes

Table 36 Compliance of WSUD strategy LDR B3 option with operational phase stormwater quality targets

Quality targets based on post development load reduction			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	91	Yes
Total phosphorus (TP)	80%	81	Yes
Total nitrogen (TN)	65%	74	Yes

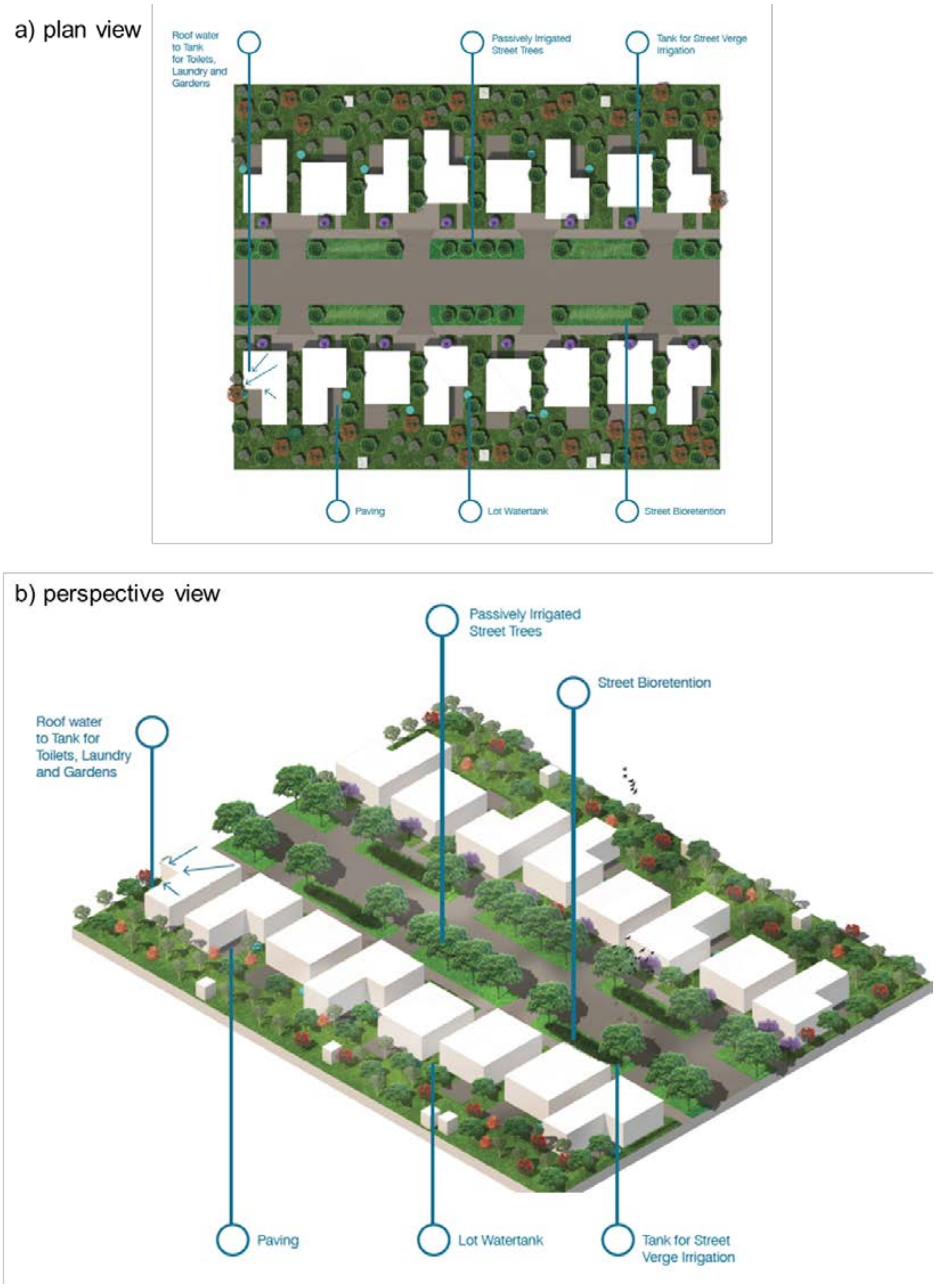

Figure 14 Indicative layout for LDR lot and streetscape measures

LDR lot and precinct strategy

Summary

This WSUD strategy for LDR focuses on providing conventional allotment pervious cover and full development, based on Option C1 in Table 32. To achieve this WSUD strategy and comply with the operational phase stormwater quality and quantity (flow) targets, the local public open space is used for a large wetland system that treats stormwater (for reuse), 'loses' water through evaporation and is a feature of the local park.

In addition, 50% of roof areas drain to 6 kL tanks that are used for toilets, laundries and to irrigate 50% of the lot garden areas. Street bioretention basins treat road runoff to ensure stormwater quality targets are met, and street trees not in bioretention adopt passive irrigation techniques.

A large wetland in public open space (e.g. occupies half of the public open space area) is used to treat flows to be suitable for irrigation. The wetland is configured using conventional design practices; for example, 350 mm of extended detention and 48–72 hours detention time (see Chapter 3 of this guide). Treated water is directed into a storage pond that is used to irrigate all of the local public open space area, subject to a salinity and sodicity assessment.

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 37, and an indicative layout is shown in Figure 15.

Table 37 LDR C1 option – lot and precinct strategy components

LDR C1 option	Lot perviousness	Roof area to tank	Water from roofs for reuse	Street bioretention	Precinct wetland	Storage for public open space	Amount of local public open space irrigated
	%	%	kL/ha	m^2/ha	m^2/ha	kL/ha	%
Requirements	15	50	97	33	750	75	100

Stormwater targets achieved

Table 38 and Table 39 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 38 Compliance of WSUD strategy LDR C1 option with operational phase stormwater quantity (flow) targets

Flow targets based on MARV			
Parameter	**Target**	**Result**	**Compliance**
Mean annual runoff volume (MARV)	≤2 ML/ha/y	2.00	Yes
90%ile flow	1,000–5,000 L/ha/day	4,545	Yes
50%ile flow	5–100 L/ha/day	11	Yes
10%ile flow	0 L/ha/day	0	Yes

Table 39 Compliance of WSUD strategy LDR C1 Option with operational phase stormwater quality targets

Quality targets based on post development load reduction			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	95	Yes
Total phosphorus (TP)	80%	86	Yes
Total nitrogen (TN)	65%	78	Yes

Figure 15 Indicative layout for LDR lot and precinct-scale measures

LDR regional treatment and reticulated reuse strategy

Summary

LDR typologies that have reticulated stormwater reuse will need to provide stormwater treatment and storage on a precinct or regional scale, to contribute to the reticulated reuse scheme. Allotments are typically supplied with the reticulated harvested stormwater for all non-potable uses on site (e.g. toilets, laundries and outdoor irrigation). Reticulated treated stormwater would also be used as a supply for irrigation of parks and streetscapes (where applicable, i.e. subject to a salinity and sodicity assessment).

Street trees through the area incorporate passive irrigation techniques to increase soil moisture retention throughout the streetscape, noting that no streetscape bioretention is required to meet the operational phase stormwater quality and quantity targets.

Treatment in this example WSUD strategy (D1 in Table 32) is with a wetland and adjacent bioretention combination where the extended detention is shared between both. Low flows are maintained in downstream waterways by configuring the wetland with a small extended detention and for flows from the wetland riser to be directed to the waterway. When the extended detention of the riser is exceeded, flow is transferred into the bioretention basin that treats flows and directs treated water to the reuse storage ponds.

The storage ponds are connected to the regional stormwater harvesting and reticulation system. The treatment and storage components are integrated into the regional open space.

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 40, and an indicative layout is shown in Figure 16.

Table 40 LDR D1 option – regional treatment and reticulated reuse strategy components

LDR D1 option	Lot perviousness	Roof area to tank	Water from roofs for reuse	Regional bioretention	Regional wetland	Storage for regional reuse
	%	%	kL/ha	m^2/ha	m^2/ha	kL/ha
Requirements	15	50	39	60	200	30

Stormwater targets achieved

Table 41 and Table 42 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 41 Compliance of WSUD strategy LDR D1 option with operational phase stormwater quantity (flow) targets

Flow targets based on MARV			
Parameter	**Target**	**Result**	**Compliance**
95%ile flow	3,000–15,000 L/ha/day	3,945	Yes
90%ile flow	1,000–5,000 L/ha/day	1,655	Yes
75%ile flow	100–1,000 L/ha/day	759	Yes
50%ile flow	5–100 L/ha/day	29	Yes
Cease to flow	10% to 30%	15	Yes

Table 42 Compliance of WSUD strategy LDR D1 option with operational phase stormwater quality targets

Quality targets based on post development load reduction			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	94	Yes
Total phosphorus (TP)	80%	86	Yes
Total nitrogen (TN)	65%	76	Yes

Figure 16 Indicative layout for an LDR regional treatment and reticulated reuse strategy

Appendix A: MUSIC model parameters

This appendix sets out the MUSIC model parameters to use when undertaking performance modelling to demonstrate compliance with the operational phase stormwater quality and quantity (flow) targets. These include the climate details, source node assumptions as well as acceptable ranges for parameters to use for species treatment nodes. If not listed below, the requirements of the relevant documents of local councils in Wianamatta should be followed (see 'Relationship to other documents' section of this guide).

A MUSIC file that contains climate data and source nodes is available for use, as is a spreadsheet to post process the modelled flow data to enable comparisons with the stormwater quality and quantity (flow) targets (see Chapter 2 of this guide).

MUSIC modelling climate

Table 43 Rainfall and potential evaporation data

Parameter	Timestep	Value (mm)
Rainfall (Penrith)	6 min. timestep between 01/01/1999 and 31/12/2008	691 (average annual)
Potential evapotranspiration (PET)	January	183
	February	144
	March	127
	April	88
	May	60
	June	41
	July	48
	August	73
	September	107
	October	138
	November	150
	December	177
	Total	**1,336**

MUSIC source node assumptions

Impervious areas should be measured from the layout plans for the development. The effective impervious area should be assumed to be the same as total impervious areas for new development.

Pollutant export parameters should adopt those recommended in relevant documents of local councils in Wianamatta (see 'Relationship to other documents' section of this guide).

Rainfall–runoff parameters in the Wianamatta–South Creek catchment should be adopted, as set out in Table 44.

Table 44 Rainfall–runoff parameters

Impervious area parameters	
Rainfall threshold (mm)	1.0
Pervious area parameters	
Soil storage capacity (mm)	150
Initial storage (% of capacity)	30
Field capacity (mm)	130
Infiltration capacity coefficient – a	175
Infiltration capacity exponent – b	2.5
Groundwater properties	
Initial depth (mm)	10
Daily recharge rate (%)	25
Daily baseflow rate (%)	1.4
Daily deep seepage rate (%)	0.0

MUSIC treatment node parameters

Table 45 to Table 50 set out the parameter ranges for sedimentation basins, wetlands, bioretention (raingardens), swales, tanks and storage ponds (dams).

Table 45 Parameter ranges for sedimentation basins

Sedimentation basin	Acceptable parameter ranges
Surface area	User defined
Extended detention depth	Maximum extended detention depth of 350 mm when part of a wetland system and up to 1.0 m when acting in isolation
Permanent pool volume	Calculate with depth up to a maximum of 2.0 m
Initial volume	Same as permanent pool volume
Exfiltration rate	Maximum of 0.01 mm/hour
Evaporative loss	Maximum of 100% of PET

Table 46 Parameter ranges for wetlands

Wetlands	Acceptable parameter ranges
Inlet pond volume	Set to zero if upstream sediment basin is modelled separately or sized to target 95% removal of 125 µm particles for 4EY[1] flow events
Extended detention depth	Maximum of 350 mm
Permanent pool volume	0.3–0.4 m x wetland surface area
Exfiltration	Maximum of 0.01 mm/hour
Evaporative loss	Maximum of 125% of PET
Outlet pipe	Adjust to ensure notional detention time is within ranges
Notional detention time	48–72 hours for detention depths of 100–350 mm No less than 48 hours for detention depths <100 mm
k & C* values (MUSIC)	Use default values

[1] 4EY = 4 exceedances per year

Table 47 Parameter ranges for bioretention (raingardens)

Bioretention	Acceptable parameter ranges
Extended detention depth	Maximum of 300 mm Maximum of 150 mm in streetscape bioretention
Unlined filter media perimeter	0.01 m (i.e. the systems are lined)
Saturate hydraulic conductivity	Maximum of 100 mm/hour
Filter media depth	0.4–0.7 m
TN content	800 mg/kg
Orthophosphate content	40 mg/kg
Exfiltration rate	zero
Lining	Yes – base is lined
Underdrain present	Yes
k & C* values (MUSIC)	Use default values

Table 48 Parameter ranges for swales

Swales	Acceptable parameter ranges
Bed slope	0.5–4%
Vegetation height	Mown turf swales: 50–100 mm Native grasses and sedges: 100–400 mm
Exfiltration	Zero

Table 49 Parameter ranges for tanks

Tanks	Acceptable parameter ranges
Water source	Only roof water or treated water into reuse tanks
Volume below overflow	User defined
Surface area	Calculate with maximum depth = 1.0–2.5 m
Initial volume	Same as volume below overflow
Reuse demands	Irrigation to be modelled as an annual demand Distribution* to be defined with a monthly pattern which is (Jan–Dec): 13%, 6%, 6%, 4%, 2%, 0%, 4%, 7%, 12%, 14%, 13%, 19% Indoor reuse to be modelled as a daily demand

* Irrigation distribution takes into account PET, rainfall and crop types

Table 50 Parameter ranges for storage ponds (dams)

Storage ponds	Acceptable parameter ranges
Water source	Only roof water or treated water into reuse storage ponds
Surface area	User defined
Permanent pool volume	Calculate with depth up to a maximum of 3.0 m
Initial volume	Same as permanent pool volume
Exfiltration rate	Maximum of 0.01 mm/hour
Evaporative loss	Maximum of 100% of PET
Reuse demands	Irrigation to be modelled as an annual demand Distribution* to be defined with a monthly pattern which is (Jan–Dec): 13%, 6%, 6%, 4%, 2%, 0%, 4%, 7%, 12%, 14%, 13%, 19% Indoor reuse to be modelled as a daily demand

* Irrigation distribution takes into account PET, rainfall and crop types

Green roofs

Green roofs can be modelled in MUSIC by setting the soil and vegetation proportion of the roof as pervious in the source node. The urban source nodes with associated soil parameters that are supplied with the MUSIC modelling toolkit can be used (see Chapter 3 of this guide).

Gross pollutant traps

GPTs are primarily designed for removal of litter and debris and some coarse sediment. Generally, GPTs have little impact on nutrient removal because of high through flow rates. GPTs should only be modelled for removal of gross pollutants, with the exception of GPTs that have approved removal rates for sediments and/or nutrients as outlined in the *Stormwater Quality Improvement Device Evaluation Protocol* (Stormwater Australia 2018). High flow bypasses should be included in the model.

Proprietary nutrient removal devices

Removal rates of particular pollutants for proprietary devices should be consistent with the assessment in the *Stormwater Quality Improvement Device Evaluation Protocol* (Stormwater Australia 2018).

Infiltration/ porous pavements

These are not permitted without site-specific soil capability assessment to demonstrate no adverse impacts of infiltration, and/or WSUD design considerations are demonstrated (Chapter 3 of this guide).

Passively watered street trees

Irrigation of street trees is encouraged for all street trees that are not bioretention street trees or bioretention systems (raingardens). Irrigation can occur in the form of either irrigation from the recycled water reticulation or passive watering. Passively watered street trees operate by diverting small proportions of stormwater via kerb inlet filters to the soil surrounding the trees to increase soil moisture around the tree. Passive irrigation systems divert only small proportions of the total stormwater runoff to the trees, and as such, typically should not be included in the performance (MUSIC) modelling. This is based on the assumption that each tree would only divert 0.1–0.5 L/s, with total diversion of stormwater to be 30–50 L per tree and therefore representing a small volume even with trees spaced every 10 m. The volumes are small and likely to be within the error bands of the modelling, and as such, conservatively excluded.

Appendix B: Water demand data

This appendix provides a consistent set of water demand data to use when undertaking performance modelling to demonstrate compliance with the operational phase stormwater quality and quantity (flow) targets. Water demand data are provided for industrial, residential and business/commercial developments.

Industrial developments

The non-potable water demands presented in Table 51 and Table 52 are applicable to industrial developments.

Table 51 Industrial non-potable water demands

Water use	Demand based on moderate uptake of water saving devices
Rainwater tank demand (toilets)	15 L/persons/ha/day persons/ha = refer to planning document or development plan (e.g. 15 L/persons/ha/day x 25 persons/ha = 375 L/ha/day)
Regional reticulation demand*	6.25 kL/ha (excluding regional open space, undeveloped areas) (This demand includes the lot outdoor demands, so when regional reticulation is applied, use this demand without any further outdoor demand on the lots)

* This demand figure was derived as 50% of the total water demands and is adopted for the purpose of assessing a regional-scale WSUD strategy. Future demand figures need to be confirmed by the relevant stormwater drainage manager.

Table 52 Industrial non-potable water demands for outdoor and open space

Water use	Demand	
Irrigation	Area = 50% of landscape areas (and public open space) Irrigation rate = 600 mm/y	
	Monthly distribution	
	January	13%
	February	6%
	March	6%
	April	4%
	May	2%
	June	0%
	July	4%
	August	7%
	September	12%
	October	14%
	November	13%
	December	19%

The irrigation rates and distribution were estimated from Penrith rainfall, evaporation data from the calibrated MUSIC file, and adopting a crop factor of 0.5.

Residential developments

The non-potable water demands presented in Table 53 and Table 55 are applicable to residential developments. The population rates (equivalent persons/ha) should be determined from the specific details of the development, along with the occupancy rates (equivalent persons/dwelling) provided in the following 2 modelling guidelines:

- *NSW MUSIC Modelling Guidelines* (BMT WBM 2015), which contains data provided by Sydney Water
- *MUSIC Modelling Guidelines* (Healthy Land and Water 2018).

Table 53 Residential non-potable water demands for indoor use

Water use	Demand (litres per person per day)	
	Moderate uptake of water saving devices	Full uptake of water saving devices
Toilet	27	26
Laundry	31	21
Total	**58**	**47**

Table 54 Residential occupancy and equivalent persons (EP)

Development type	Size*	Occupancy (EP per dwelling)
Detached dwelling	1 bedroom	1.6
	2 bedroom	1.9
	3 bedroom	2.5
	>3 bedroom	3.5
	Overall mixed	**3.1****
Townhouse	1 bedroom	1.2
	2 bedroom	1.6
	3 bedroom	2.3
	>3 bedroom	3.3
	Overall mixed	**2**
Unit/Apartment	1 bedroom	1.2
	2 bedroom	1.2
	3 bedroom	2.2
	Overall mixed	**1.7**

* The ‘overall mixed’ values should be adopted for land-use planning purposes or when the number of bedrooms is not known.

** Average Western Sydney household population from Western Sydney District Data Profile – Western Sydney and Blue Mountains (Communities and Justice 2021).

Table 55 Residential non-potable water demands for outdoor and open space

Water use	Demand	
Irrigation	Area = maximum of 50% of ground level area Irrigation rate = 600 mm/y	
	Monthly distribution	
	January	13%
	February	6%
	March	6%
	April	4%
	May	2%
	June	0%
	July	4%
	August	7%
	September	12%
	October	14%
	November	13%
	December	19%

The irrigation rates and distribution were estimated from Penrith rainfall, evaporation data from the calibrated MUSIC file, and adopting a crop factor of 0.5.

Business/commercial developments

The non-potable water demands presented in Table 56 and Table 57 are applicable to business/commercial developments.

Table 56 Commercial/business non-potable water demands

Water use	Demand based on moderate uptake of water saving devices
Rainwater tank demand	15 L/persons/ha/day persons/ha = refer to planning document or development plan (e.g. 15 L/persons/ha/day x 25 persons/ha = 375 L/ha/day)

Table 57 Commercial/business non-potable water demands for outdoor and open space

Water use	Demand	
Irrigation	Area = 50% of landscape areas (and public open space) Irrigation rate = 600 mm/y	
	Monthly distribution	
	January	13%
	February	6%
	March	6%
	April	4%
	May	2%
	June	0%
	July	4%
	August	7%
	September	12%
	October	14%
	November	13%
	December	19%

The irrigation rates and distribution were estimated from Penrith rainfall, evaporation data from the calibrated MUSIC file, and adopting a crop factor of 0.5.

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Glossary

Term	Definition
1% AEP	A flood that has a 1% chance of occurring in any given year within a 100-year cycle
Bioretention system	Vegetated sunken garden bed areas that collect and treat stormwater as it percolates through a sandy loam soil medium. They can be a range of sizes and located in a private allotment or local parks and support a wide range of vegetation types
Bioretention street tree	A bioretention system associated with a single street tree located in a road verge that collects and treats stormwater from the road kerb. These systems come in a number of different engineering and landscape forms
Blue grid (natural)	A network of waterways, waterbodies, wetlands, groundwater ecosystems, and vegetation that are water dependent. This includes the riparian vegetation in the Wianamatta–South Creek catchment
Blue–green grid	A network of high-quality green areas and waterways, from regional natural assets to local natural assets, that connect to centres, public transport and public spaces
Blue–Green Infrastructure Framework	An interconnected network of natural and semi-natural landscape elements; for example, blue includes waterbodies, creeks and dams (see definition for blue grid), green includes trees, parks and native vegetation
Coarse sediment	Particles larger than 0.125 mm transported in stormwater
Construction phase	The period during a development until at least 80% of the allotment buildings are deemed complete with occupation certification
Certified Professional in Erosion and Sediment Control (CPESC)	Individuals who demonstrate an established minimum level of competence through the application review process, and an examination process, will be certified in erosion and sediment control
Green roofs	Roof areas that are covered with soil and vegetation. They act to capture rainwater, promote evaporation, reduce runoff volumes and cool the building
Irrigated street trees	Street trees that are irrigated from a reticulated supply, such as from harvested stormwater and/or recycled water
Lot scale (or allotment scale)	WSUD infrastructure/measures that are located entirely within the boundaries of a lot Note: This does not include streetscape or precinct measures.
Operational phase	The period when development is deemed complete with occupation certification
Passively irrigated street trees	Stormwater diverters installed in kerbs to direct small amounts of stormwater into soils around street trees for irrigation (not bioretention)
Precinct scale	WSUD infrastructure/measures that are located in a mix of allotment, street and public open space locations within a precinct
Practitioners	An individual actively engaged in a profession; in this context, individuals such as stormwater engineers, flood engineers or landscape architects

Term	Definition
Regional scale	In this guide, regional scale specifically refers to WSUD infrastructure/measures that include a reticulated stormwater reuse system to provide stormwater treatment and storage at precinct, sub-catchment or catchment scales. A regional WSUD strategy (or otherwise termed regional stormwater system) is planned over multiple land holdings and typically requires a stormwater drainage manager
Storages	Storage for water reuse systems to collect treated stormwater and store it until it is required. They can be open water storages (dams or lakes) or in enclosed tanks that are either above or below ground
Streetscape scale	WSUD infrastructure/measures that are located along streets
Water and Stormwater Management Plan	A document that addresses urban stormwater from a management perspective to ensure the stormwater management targets and other related controls are achieved. These documents are also referred to as Stormwater Management Plans, Water Management Plans, or similar
Waterway	The whole or any part of a watercourse, wetland, waterbody (artificial) or waterbody (natural)
Waterway health objectives	The community environmental values and long-term goals for managing waterways. The objectives consist of 3 components: i) values and uses of waterways, ii) indicators, and iii) numerical criteria needed to protect the values and uses. They reflect NSW Government policy and are accordingly used as environmental standards for delivering healthy waterways, riparian corridors and other water dependent ecosystems
Wetlands (for stormwater management)	Shallow vegetated waterbodies that are intended for stormwater treatment. They can be a variety of scales and are generally configured to capture an initial volume of stormwater and slowly release it over 2–3 days
WSUD	Water Sensitive Urban Design (WSUD) is an approach to planning and designing urban areas to make use of stormwater and reduce the harm it causes to waterways, and provide a range of co-benefits such as urban cooling, public amenity and biodiversity
WSUD measure	A built (infra) structure or landscape feature that is designed to slow and disperse runoff from storm events by promoting retention, infiltration or evapotranspiration while cleaning the runoff of pollutants including litter and harmful chemicals
WSUD strategy/strategies	Method (strategy) of delivering WSUD measures at various scales, including allotment, streetscape, precinct or regional

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More information

- Australian Guidelines for Water Recycling: Managing Health and Environmental Risks: Stormwater harvesting and reuse
- Bioretention Technical Design Guidelines
- Blacktown City Council 2020 WSUD developer handbook – MUSIC modelling and design guide (PDF 3MB)
- Blacktown City Council Developers Toolkit for Water Sensitive Urban Design (WSUD)
- Blacktown City Council Water sensitive urban design (WSUD) standard drawings
- Guidelines for controlled activities on waterfront land: Riparian corridors [496KB]
- Mamre Road Precinct Development Control Plan 2021 [PDF 5.9MB]
- Managing Urban Stormwater: Soils and Construction Blue Book (PDF 21MB)
- MUSIC (Model for Urban Stormwater Improvement Conceptualisation)
- MUSIC modelling toolkit for Wianamatta–South Creek
- NSW Government Sharing and Enabling Environmental Data (SEED) portal
- Penrith City Council Water Sensitive Urban Design (WSUD) Policy [PDF 336KB]
- Penrith City Council WSUD Technical Guidelines [PDF 1.3MB]
- Premier's Priority – Greening Our City
- South Creek Hydrogeological Landscapes: June 2020 (First Edition)
- Water Sensitive Urban Design Technical Design Guidelines
- Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011
- Wetland Technical Design Guidelines