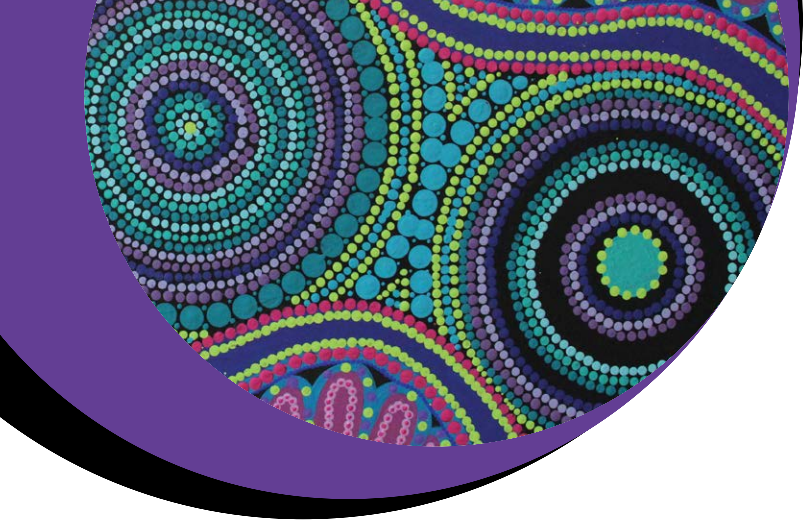
ACT Practice Guidelines for Water Sensitive Urban Design

June 2026



Acknowledgement of Country

Yuma

Dhawura Nguna Dhawura Ngunnawal Yanggu ngalwiri dhunimanyin Ngunnawalwari dhawurawari

Nginggada Dindi yindumaralidjinyin

Dhawura Ngunnawal yindumaralidjinyin

Hello

This is Ngunnawal Country

Today we are meeting on Ngunnawal country

We always respect Elders, male and female

We always respect Ngunnawal Country

The ACT Government acknowledges the Ngunnawal people as traditional custodians of the ACT and recognises any other people or families with connection to the lands of the ACT and region. We acknowledge and respect their continuing culture and the contribution they make to the life of this city and this region.

Director-General, City and Environment Directorate, ACT Government, GPO Box 158, Canberra ACT 2601.

Telephone 02 6207 1923
Website www.planning.act.gov.au

Produced by the City and Environment Directorate

Artwork on this page: *Reconciliation through Caring for Country*. Artist: Leilani Keen Church, 2018. The inner circles represent the environment and country. The outer symbols represent people and community standing side by side in reconciliation and taking care of country. The pathways represent the journey.

Cover image: Ponds and subsurface wetland near Belconnen Town Centre, ACT

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Restored creekline,
Tattersall Crescent,
Florey, ACT

1. Introduction

Purpose of the WSUD Guidelines

Water sensitive urban design (WSUD) is an approach to urban planning and design that aims to integrate the management of the urban water cycle into the urban development process. This includes using mains water and rainwater efficiently, re-using water where feasible and managing stormwater quantity and quality to minimise flood risk, erosion and pollution.

Effective WSUD also contributes significantly to maintaining biodiversity, reducing urban heat and increasing the recreational and scenic values of the urban landscape.

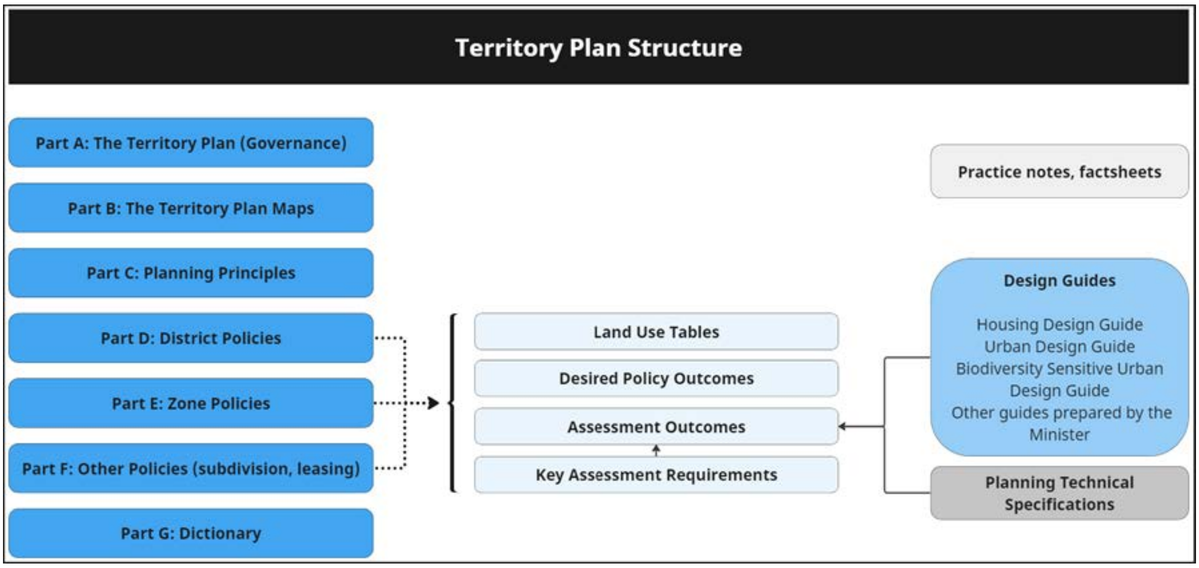
The purpose of the ACT Practice Guidelines for Water Sensitive Urban Design (the WSUD Guidelines) is to guide developers, designers, builders and assessors to meet water-related outcomes that are specified in the ACT planning framework. The WSUD Guidelines provide practical guidance for the delivery of WSUD across the ACT, including recommendations for the planning, design, establishment, operation, maintenance and decommissioning of WSUD assets.

This 2026 edition replaces the 2018 WSUD Guidelines. The introduction outlines the new ACT planning framework and WSUD provisions, which superseded the previous WSUD General Code. Throughout these guidelines, references to the WSUD General Code have been replaced with references to the Technical Specifications under the Territory Plan 2023.

WSUD in the ACT planning framework

Planning in the ACT is primarily guided by the Territory Plan 2023 (the Territory Plan), in force under the Planning Act 2023 (the Planning Act). The Territory Plan structure is shown in Figure 1.

Figure 1 Territory Plan structure



The Territory Plan contains ten district policies and seven zone policies that shape places and communities in the ACT. It implements strategic planning objectives, protects and minimises the impacts on our environment, and establishes future urban form and development patterns across the ACT.

The policies outline desired policy outcomes that are important to each district and zone and include assessment outcomes and key assessment requirements. Developments must meet all the relevant assessment outcomes and assessment requirements in order to receive development approval.

Each district and zone policy includes several assessment outcomes that require development proposals to adopt Water Sensitive Urban Design to deliver those outcomes.

District and zone policies specify that "in demonstrating compliance with the assessment outcomes, consideration is to be given to the relevant design guides and may be given to planning technical specifications which may serve as a benchmark".

Technical Specifications are in force under the Planning Act and apply to each district and zone. Technical specifications are used as a possible solution or to provide guidance for identified aspects of a development proposal. The specifications may be used as a reference or benchmark in the preparation and assessment of development proposals to demonstrate compliance with the assessment outcomes in the Territory Plan.

The Technical Specifications for each of the seven zones refer to the WSUD Guidelines. Following the WSUD Guidelines can assist proponents to demonstrate a proposed development's consistency with assessment outcomes for the relevant district and zone of the proposed development.

Proponents must ensure that development proposals meet all statutory requirements under the Planning Act and the applicable outcomes in the Territory Plan.

In summary the WSUD Guidelines fit within the ACT's planning hierarchy as outlined below.

- *Planning Act 2023* (ACT) – authorising law
- Territory Plan 2023 – statutory instrument under the Planning Act; includes district, zone and other policies which set assessment outcomes and assessment requirements
- Technical Specifications – notifiable instruments under the Planning Act that outline how to meet the assessment outcomes in the Territory Plan and specify targets for:
  - Mains water reduction
  - Flood risk
  - Stormwater retention and detention
  - Stormwater management
  - Stormwater quality
  - Site permeability
- WSUD Guidelines – practical guidance to assist developments to meet the assessment outcomes in the Territory Plan and to comply with the Technical Specifications
- Design Guides – notifiable instruments under the Planning Act providing qualitative guidance that identify design possibilities and encourage innovation.

Relationship with Municipal Infrastructure Standards

The Municipal Infrastructure Standards (MIS) are the approved standards for all municipal infrastructure in the ACT, providing a clear and consistent source of information to inform urban development. They are available online at www.cityservices.act.gov.au. The MIS (in particular MIS08 Stormwater) set the standards for industry to design stormwater assets that are acceptable by the ACT Government.

MIS08 refers to the WSUD Guidelines for further information on several topics. When designing WSUD assets that are to be maintained by the ACT Government, industry should use the WSUD Guidelines for information only and should primarily refer to the current edition of MIS08 to identify the standards required for WSUD assets to be accepted by the ACT Government.

This 2026 edition of the WSUD Guidelines refers to the December 2024 edition of MIS08.

Use of the WSUD Guidelines

The WSUD Guidelines are relevant to those involved in the planning, design and delivery of WSUD projects, and to those involved in the assessment and approval of developments. This includes government agencies, utilities, developers and their planning and design teams:

→ **Land and commercial developers**, including urban developers in both the public and private sectors, can use the WSUD Guidelines in the planning and design of all new urban developments and redevelopments to integrate the WSUD requirements and achieve the specified planning outcomes.

→ **Planners and design consultants** can use the WSUD Guidelines to understand the concepts behind current best management practices and for specific technical information to inform the planning, design and delivery of WSUD measures for new projects. This information is relevant for planners, urban designers, civil engineers, landscape architects, cultural heritage professionals and ecologists, as successful WSUD delivery requires the collaboration of all of these disciplines.

→ **Builders of new urban** dwellings and extensions and alterations that increase the floor area by more than 50% that are not classified as single dwellings can use this guideline will help builders identify suitable WSUD solutions for this scale of development.

→ **Government agencies and utilities** with responsibilities for various aspects of water management can use the WSUD Guidelines to achieve assessment outcomes in their own projects and in the assessment of developments. Government agencies and utilities that use these guidelines include the Suburban Land Agency, Infrastructure Canberra, City and Environment Directorate and Icon Water.

Floating wetlands,
Lake Tuggeranong, ACT

2. Overview of the WSUD planning, design and delivery process

Key steps are required to successfully plan, design and deliver WSUD assets. These steps are summarised in Figures 2 and 3 and described in more detail throughout this document.

Figure 2 presents a summary of a typical WSUD design and delivery process for estate development. The process starts with the development of suitable WSUD strategies that reflect an understanding of the site and the required objectives, followed by the design of the appropriate treatment systems. It is critical that the planning and design of WSUD assets is undertaken with the collaboration of planners, civil engineers and landscape architects to ensure these systems are well integrated within the development and meet the treatment requirements as well as the amenity and landscape values for the site. It is also critical that the planning and design steps consider the staging, establishment and maintenance of the WSUD assets and their lifecycle costing.

The construction and establishment phase of WSUD assets is critical to ensure the ongoing function of the systems and to reduce the burden of ongoing maintenance requirements. Staging of this in the process can help protect WSUD assets from construction phase erosion and sediment impacts. Once WSUD assets are successfully established (which can take up to two years for vegetated systems), the ongoing maintenance requirements for these systems is minimised. However they do require ongoing inspections and monitoring to ensure they continue to operate as designed.

Castellated kerb and tree pit, Childers Street, Canberra, ACT

Figure 2 Summary of a typical WSUD design and delivery process for estate developments. The blue boxes show where this process information is described in more detail in this document

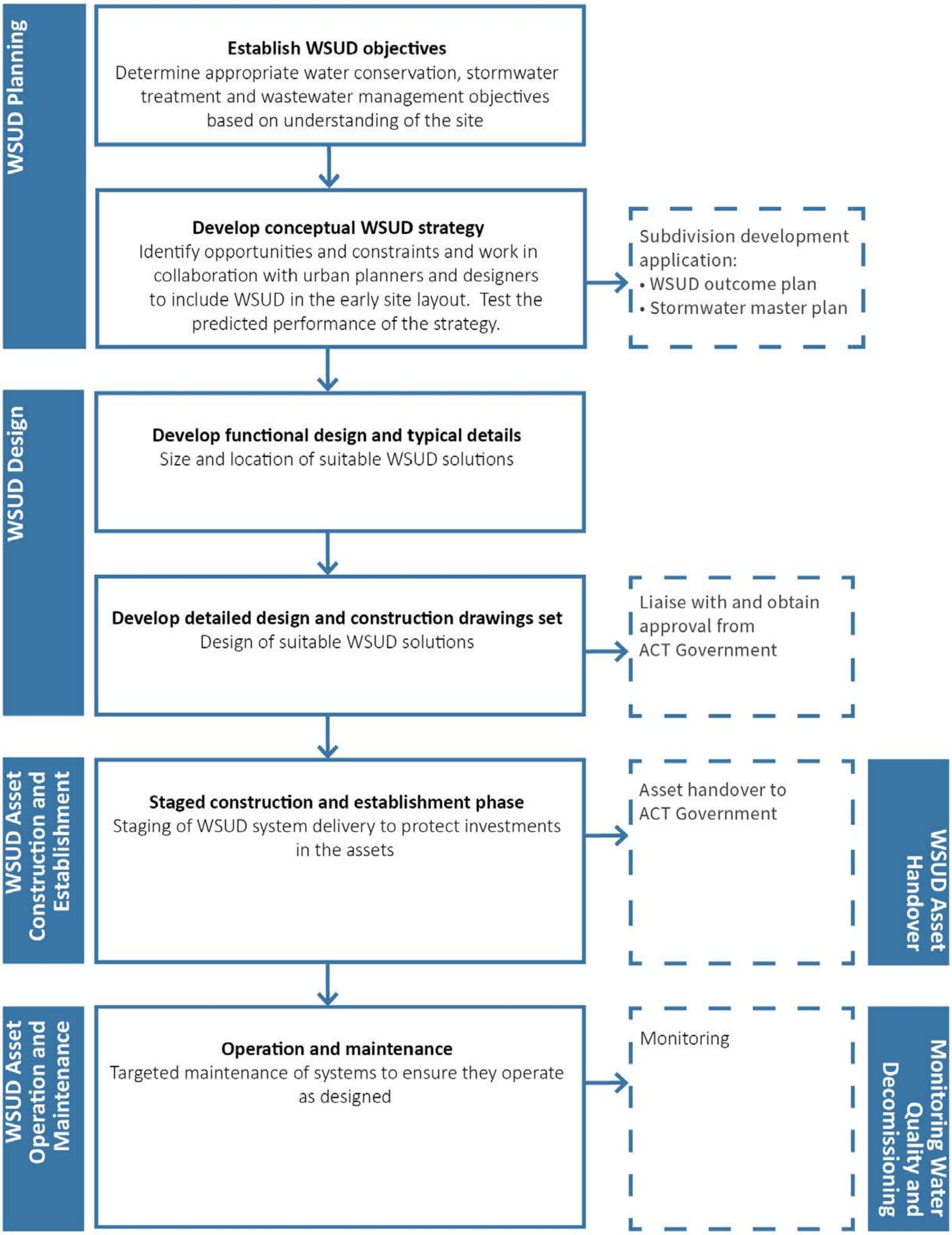
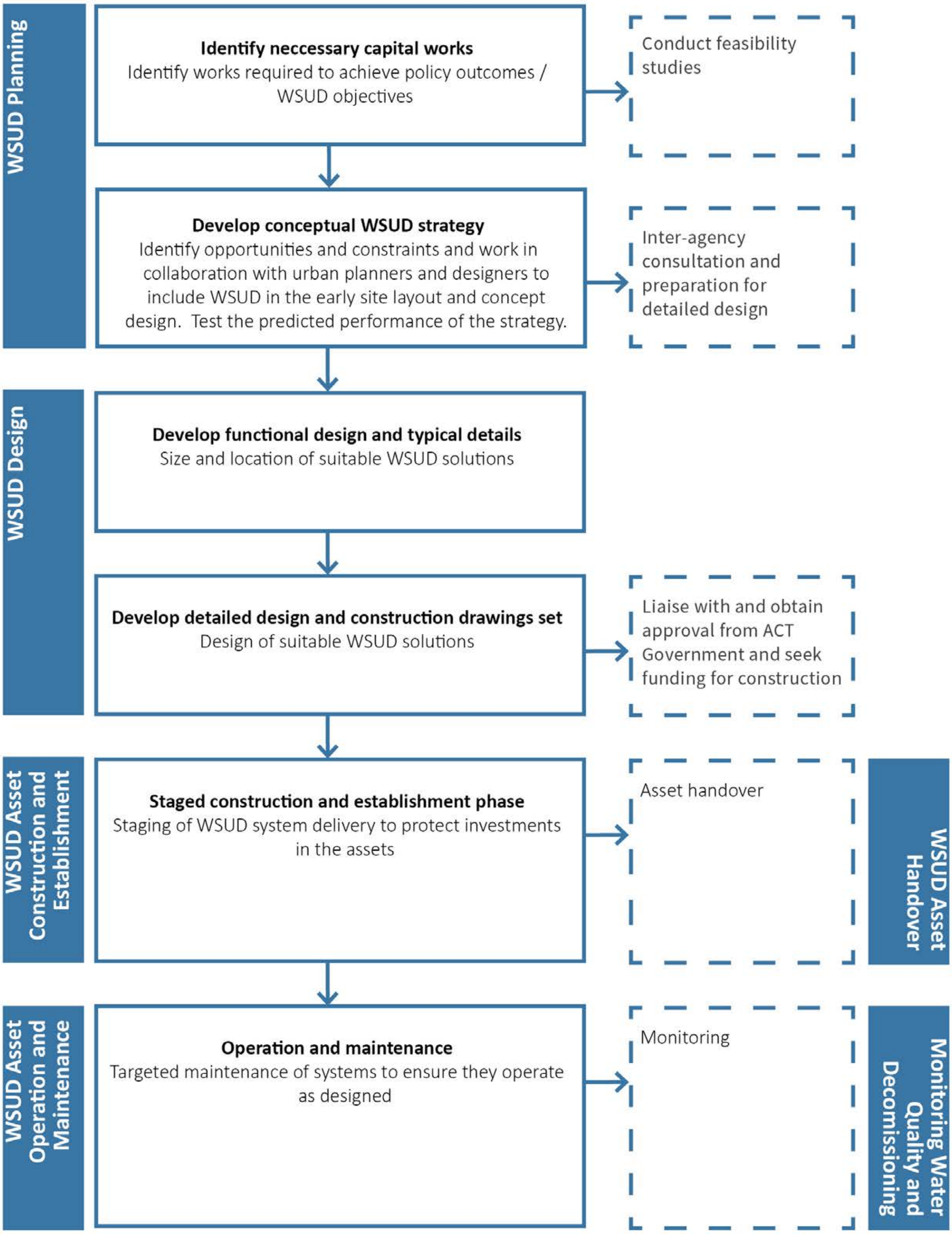


Figure 3 A summary of a typical WSUD design and delivery process for capital works projects. The blue boxes show where this process information is described in more detail in this document



Bioretention swale,
Franklin, ACT

3. Critical steps to WSUD planning

The initial stage for the design and delivery of any WSUD asset is to develop a conceptual plan for the solution.

The planning process will be the same for any scale (catchment vs plot), but the outcomes will be different (different objectives will apply and different solutions will be suitable for different scales and types of development). While outside the scope of this Guideline, it is important to note the elements of WSUD planning need to start at the catchment planning and land use planning stage. WSUD considerations at these early stages can play a large role in reducing stormwater run-off and pollutants.

The key steps required for WSUD planning are:

Step 1

Identify the WSUD targets applicable to the development type and scale.

Step 2

Identify the suitable WSUD strategy for the site to meet the relevant assessment outcomes under the Territory Plan 2023, supported by relevant Technical Specifications. This may include a fully integrated solution, on-block measures or neighbourhood solutions.

Step 3

Assess the ability and effectiveness of this strategy to meet the required targets.

The following sections guide each of these steps.

Step 1: Identify the WSUD targets applicable to the development type and scale

This initial step in the planning process identifies the targets the WSUD strategy needs to achieve. These targets will differ for different scales and types of development so it is important to have an understanding of the site characteristics to enable to identification of the required targets.

Use the Technical Specifications for the relevant zone under the Territory Plan 2023 and these WSUD Guidelines to help identify the suitable WSUD targets for the site based on the site and proposed development characteristics. The following table provides a summary of the types of targets applicable for different development types and scales.

Table 1 The type of WSUD targets required for different development types / site areas. More details on the specific target requirements can be found in the Technical Specifications for the relevant zone under the Territory Plan 2023

Development type / site area	WSUD targets				
	Potable use reduction	Stormwater quantity		Stormwater quality	
		On-site stormwater retention	On-site stormwater detention	Development or redevelopment sites	Regional or catchment wide targets[1]
All assessable development and major alterations and/or extensions to existing buildings (if the work affects more than 50% of the floor area of the whole of an existing building)	★				
Sites > 2000 m^2 (developer responsibility)	★	★	★	★	
Estates / capital works (government responsibility)					★
Transport infrastructure		★	★	★	

1 refer to Appendix A

Step 2: Identify the suitable WSUD strategy

Once the WSUD targets are known (step 1), use the site characteristics to identify the suitable strategy to achieve these targets (this step).

To gain an understanding of the site and to develop an appropriate WSUD strategy to meet the WSUD targets, the following tasks will be required.

Task 1: Identify site constraints and opportunities

Different catchments and types of development have differing site constraints and opportunities for WSUD strategies. For example, flat sites can be problematic for getting stormwater pipes to discharge at the surface of treatment systems or to get free draining WSUD assets so potential strategies could look to keep water at the surface before treatment (using swales or streetscape treatments), thereby reducing the depths and lengths of stormwater pipes.

This first task in the development of a WSUD strategy involves preliminary research of the site including a desktop analysis and site visit to the development location. Consider the site constraints and opportunities in Table 2 in this analysis.

Table 2 Possible constraints and opportunities for different site characteristics and sources of information

Site characteristic	Possible constraints and opportunities	Potential source of information
Topography	*Flat sites (<1%)* - can be difficult for stormwater treatment and conveyance *Moderate slopes (2-5%)* - offer the most flexibility in WSUD solutions *Steep sites (>10%)* - can be risky or expensive to develop	Topography map with contours, GIS system such as ACTMAPi
Receiving environments	*Waterways* – need to protect waterway stability, water quality and in-stream environments *Lakes and ponds* – need to ensure good water quality by reducing pollutant loads *Water levels* – the water level in the receiving environments will set the levels of the stormwater treatment systems within the development to ensure they are free-draining	Waterway and catchment mapping, site visit outcomes
Vegetation and habitat	*Existing protected and significant species* – protection requirements *Native vegetation* – protect where possible and use as a local planting palette where appropriate	Threatened species register
Soil	*Impermeable soils* – reduced opportunities for infiltration to occur[1]	Soil landscapes map
Existing infrastructure	*Capacity* – the capacity of existing infrastructure may not be able to accommodate additional inflows and therefore may require expensive upgrades or on-site solutions are required to reduce discharge volumes *Levels* – the level of existing infrastructure will set the levels of the stormwater treatment systems within the development to ensure they are free-draining	Water (potable, stormwater and wastewater) network mapping and planning

Site characteristic	Possible constraints and opportunities	Potential source of information
Pollution type and load	*Pollutant types* – understanding this will help to identify the preferred stormwater treatment train for the site	MUSIC modelling tool / guidelines

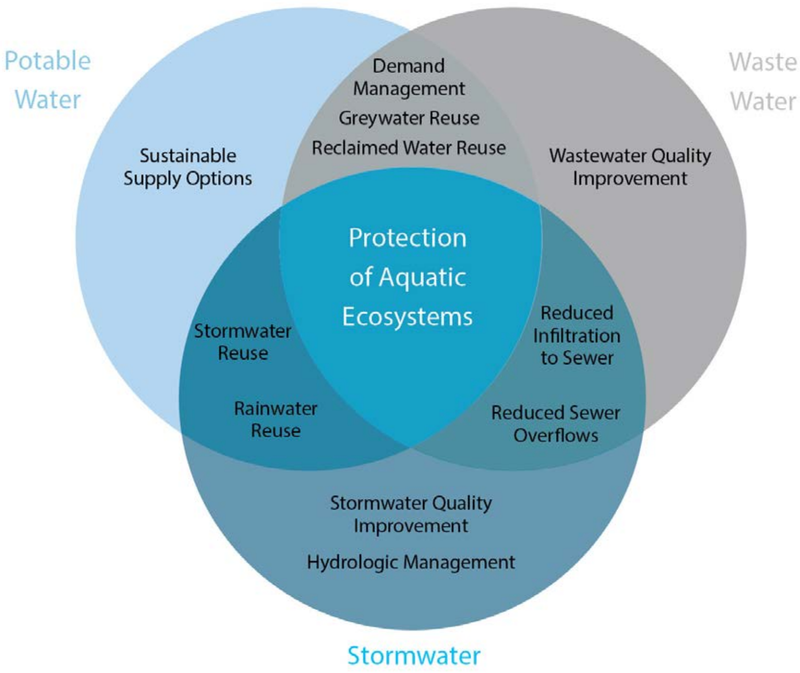
1 Canberra soils are generally clay-based and therefore do not absorb water quickly. They also have fine particle sizes, so can be easily eroded. This does not preclude the use of WSUD in the ACT, but it does mean that WSUD strategies for all types and scales of development are recommended to achieve the following:

- soil stability and management of flow velocities to prevent erosion and sedimentation;
- use of porous underdrainage to support infiltration type assets (e.g. porous pavements); and
- encourage enhanced water penetration through soil improvement and retention of upper soil moisture.

Task 2: Identify Total Water Cycle Management (TWCM) Strategy

WSUD considers all elements of the urban water cycle including potable water, stormwater, wastewater and groundwater. This holistic consideration of the urban water cycle is described as Total Water Cycle Management (TWCM).

Figure 4 The concept of Total Water Cycle Management (TWCM) considers all elements of the urban water cycle and their interactions. TWCM is an important component of WSUD (Hoban & Wong 2006)



Understanding the WSUD targets and the characteristics of the site will help build the requirements of the TWCM strategy for the site. For example:

→ Sites with limited capacity in downstream wastewater infrastructure may need to consider on-site treatment and re-use of wastewater as a primary driver for the TWCM strategy.

→ Sites with sensitive receiving waterways may need to consider on-site treatment and re-use of stormwater for the management of (excess) flows as a primary driver for the TWCM strategy.

→ Sites with requirements for potable water conservation may need to consider the use of alternative water supplies on site as a primary driver for the TWCM strategy.

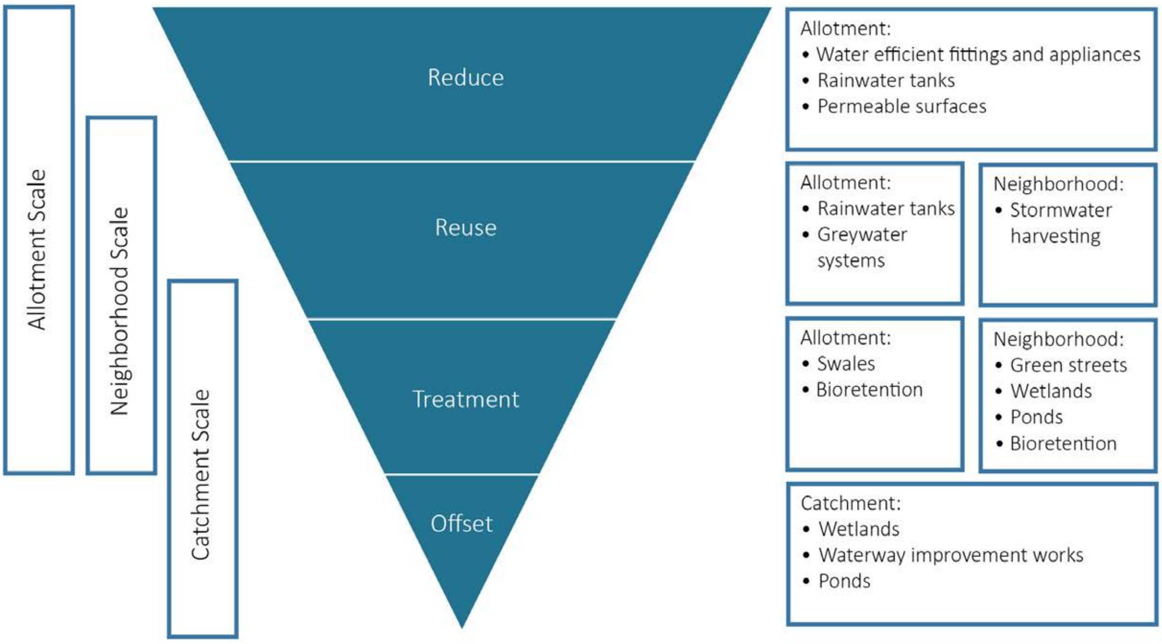
→ Sites with regional initiatives located downstream of the site but within the catchment (e.g. regional stormwater treatment measures) may influence the TWCM strategy for the site.

Once the objectives and strategic direction for the TWCM strategy have been determined, suitable solutions can be identified.

Task 3: Identify lot-scale solutions

Once the TWCM strategy has been identified, the specific WSUD solutions can be investigated. It is always best to try and follow the WSUD hierarchy when selecting solutions that focus on 'reduce and reuse' before treatment, disposal or offsetting is undertaken (refer Figure 5). Figure 5 shows that the allotment scale presents opportunities for the reduction, reuse and treatment of urban water.

Figure 5 The WSUD hierarchy promotes the adoption of solutions that reduce or re-use water before treatment, disposal or offsetting is undertaken.



The incorporation of lot-scale WSUD solutions has a range of benefits and can help achieve the TWCM strategy requirements by reducing:

- → the potable water consumption at the source by using water-efficient fittings and appliances and alternative water sources (e.g. rainwater)
- → the generation of wastewater at the source (using water conservation techniques, fittings and appliances)
- → the generation of stormwater at the source (reducing impervious areas and harvesting roofwater)
- → the export of sediment and nutrients at the source (using water quality treatment systems to treat stormwater before it is discharged to the stormwater pipe network).

Task 4: Configuration of urban layout

Allotment-scale solutions can help reduce the volume of stormwater and wastewater discharging from a development, but they may not always be able to meet the overall performance targets for the development or catchment. This is because there will still be other areas (roads, common areas, etc.) that will produce stormwater run-off in excess of pre-development conditions that may require treatment. As such, a holistic and integrated approach to planning is required. Task 4 requires the collaboration and input from urban planners, civil engineers and landscape architects to design and configure the site and drainage layout to maximise the opportunities for the inclusion of WSUD solutions across the site by considering some of the following:

- Slope: Having roads designed along the contours reduces the grade and allows for at-source streetscape WSUD solutions to be integrated.
- Road layouts: The width of verges, location of pathways and underground services and any traffic calming devices can either prohibit or allow for the integration of at-source streetscape WSUD solutions.
- Parklands: Successful end-of-line solutions integrated within parklands require stormwater network levels to be designed to allow for at-surface discharge of stormwater flows. It also requires sufficient flat land for the treatment system; otherwise the batter widths and slopes can be problematic. There is also opportunity to maximise the potential for stormwater harvesting for irrigation of large parklands by having sufficient catchment area draining to the site.
- Receiving waters: While it may appear to the community that stormwater from developments discharges to pipes and concrete channels in many cases, and therefore have limited impact on natural waterways, this is not the case; all urban stormwater will eventually discharge to a natural environment (creek, river or lake). Therefore it is important that the receiving waterway condition is considered in the planning of the urban layout and selection of WSUD solutions. For example, lakes are not as susceptible to erosion as waterways, but they can have issues when large volumes of sediments and nutrients are discharged into them. Conversely, waterways can be eroded easily if the volume and velocity of stormwater discharge is not managed.
- Catchment: The scale of the development and the planning of the broader catchment will also influence the WSUD solutions. It is therefore important to understand what is planned for the broader catchment so the development and the WSUD strategy complement this broader planning.

Castellated kerbs and native grasses in median strip, ACT

Task 5: Treatment train selection

Once the layout of the development has been progressed, the WSUD treatment trains can be identified across the site. The treatment trains will differ based on development type, scale and context, but the process for identifying treatment trains remains the same.

The configuration of a successful treatment train will incorporate a range of treatment types in a logical sequence, removing large pollutants first and fine particulates and nutrients last. There will also be no double-up of treatment process, which adds unnecessary costs and assets to a development project. Note: bioretention and wetland systems have inbuilt treatment trains (i.e. a constructed stormwater treatment wetland consists of an inlet pond for coarse sediment removal and a macrophyte zone for nutrient removal; and bioretention systems often include sediment forebays). Bioretention systems (both bioretention swales and bioretention basins) are vegetated systems which rely on the filter materials for treatment of stormwater flows. Additional treatment systems may be required in the treatment train to remove gross pollutants (e.g. a GPT as the first element in the treatment train for a commercial catchment).

The configuration of the treatment train will depend on the site characteristics, including the scale, development type, slope, and expected pollutant characteristics. For example, a suitable treatment train for a large and undulating residential development may include rainwater tanks (on lots connected to suitable end uses), a sediment inlet pond and macrophyte wetland (located within a neighbourhood parkland). A commercial development with limited space may include rainwater tanks (to toilets), permeable paving, water smart landscaping and at-source bioretention tree pits.

Task 6: Test and refine with broader design team

Throughout the development of the conceptual WSUD strategy, input should be sought from the urban planners, civil engineers and landscape architects to ensure the proposed strategy integrates with and is reflected in the site layout and civil and landscape plans, which will also be developed at this stage.

Tools to assist in Step 2: Development of a suitable WSUD Strategy

The following tables can be used throughout Step 2 to identify which WSUD solutions are most suitable for different site characteristics. More details on the function, design and constraints for these WSUD solutions are provided in Section 3: Critical steps to WSUD design.

Table 3 can be used in the early stages of the planning process to identify the types of WSUD solutions that can help achieve the WSUD targets for the site. This information is based on an industry accepted understanding of the general performance level of WSUD solutions to meet water reduction, re-use, treatment and flow/flood management targets.

Appendix B provides a checklist that can be used to help guide and document outcomes in the development of a WSUD strategy.

Table 3 The effectiveness of WSUD solutions to achieve WSUD targets. Solutions are identified as generally suitable ✓, generally not suitable ✗, or possibly suitable with design modifications ? (based on Joint Steering Committee for Water Sensitive Cities, 2009).

	Objectives											
	Potable water reduction		Stormwater quality			Stormwater quantity		SW harvesting	Wastewater		Climate change adaption	
WSUD solution	Provides alternative water source	Reduce potable demand	Gross pollutant removal	Coarse -medium particle removal	Fine particles & dissolved nutrients removal	Reduce urban excess (e.g. infiltration or storage)	Provide detention to ensure pipe capacity is not exceeded	Allow stormwater /roof water harvesting	Allows wastewater re-use	Reduce wastewater flows	Encourages evapotranspiration	Helps address nuisance flooding
Reduce												
Water Efficient Fittings and Appliances		✓								✓		
Porous Pavements	✓	✗	✗	✓	✗	✓	?	?			✓	✓
Infiltration Systems	✗	✗	✗	✓	✗	✓	?	?			✓	✓
Re-use												
Rainwater Tanks	✓	✓	?	?	?	✓	✓	✓		✓		✓
Stormwater Harvesting/Reuse	✓	✓	?	?	?	✓	✓	✓				✓
Reticulated Recycled Water	✓	✓							✓	✓		
Greywater Treatment/Reuse	✓	✓							✓	✓		
Treatment												
GPTs	✗	✗	✓	✗	✗	✗	✗	✗			✗	✗
Buffer Strips	✗	✗	✓	✓	?	✓	✗	✗			✓	✓
Swales	✗	✗	✓	✓	?	✓	?	✗			✓	✓
Bioretention Swales	✗	✗	✗	✓	✓	✓	?	✗			✓	✓
Bioretention Basins	?	?	✗	✓	✓	✓	✓	✗			✓	✓
Ponds	?	?	✗	✓	?	✓	✓	✓			✓	✓
Sediment Basins	?	✗	✓	?	✗	?	✓	?			✓	✓
Constructed Wetlands	?	?	✗	✓	✓	✓	✓	✓			✓	✓
Flood management												
Retarding basin	✗	✗	?	?	?	?	✓	?			?	✓

Table 4 will assist in identifying treatment trains based on development type and scale. This information is based on an industry accepted understanding of what WSUD solutions can be generally applied successfully for sites with different scale and pollutant characteristics (for example, GPTs are typically most suited to commercial developments with large volumes of anthropogenic litter compared to residential sites, which generate more leaf litter, which can become problematic in GPTs[1]).

Table 4 The suitability of WSUD solutions for various development types and scales. Solutions are identified as generally suitable ✔, generally not suitable ✘, or possibly suitable with design modifications ? (based on Joint Steering Committee for Water Sensitive Cities, 2009).

WSUD solution	Household	Medium density	High rise	Commercial and industrial	Subdivision	Urban retrofit
Reduce						
Water Efficient Fittings and Appliances	✔	✔	✔	✔	✔	✔
Porous Pavements	✔	✔	?	✔	✘	✔
Infiltration Systems	?	?	✘	✔	✔	✔
Re-use						
Rainwater Tanks	✔	✔	✔	✔	✔	✔
Stormwater Harvesting/Reuse	✘	✘	?	✔	✔	✔
Reticulated Recycled Water	✘	✘	✔	✔	✔	✘
Greywater Treatment/Reuse	✔	✔	✔	?	✔	✔
Treatment						
GPTs	✘	?	✘	✔	?	?
Buffer Strips	✔	✔	✘	✔	✔	?
Swales	✔	✔	✘	✔	✔	?
Bioretention Swales	?	✔	✘	✔	✔	?
Bioretention Basins	✔	✔	?	✔	✔	✔
Ponds	✘	✘	✘	?	✔	?
Sediment Basins	✘	✘	✘	✘	✔	✘
Constructed Wetlands	✘	✘	✘	?	✔	?
Flood management						
Retarding basin	✘	?	✘	?	✔	?

Table 5 is similar to Table 4 and can be used to identify the types of WSUD solutions appropriate for a development. It provides the next level of detail to enable WSUD solutions to be shortlisted based on the specific site characteristics. For example, use Table 4 to identify potentially suitable WSUD solutions for a commercial site and Table 5 to shortlist those solutions based on site characteristics.

1 In wet sump GPTs, organic matter such as leaf litter, can break down under anaerobic conditions (i.e. lack of oxygen) resulting in the release of nutrients. Under these circumstances, the GPTs produce pollutants that can be washed down to the receiving waterway rather than removing pollutants.

This information is based on an industry accepted understanding of what WSUD solutions can be generally applied successfully for sites with different characteristics (for example, wetlands are not ideally suited to steep sites as they are typically larger and will therefore require steep batters to fit into the undulating topography, compared to bioretention systems, which are smaller and can be designed as tiered systems to accommodate grade changes).

Table 5 The suitability of WSUD solutions for different site characteristics. Solutions are identified as generally suitable ✓, generally not suitable ✗, or possibly suitable with design modifications ? (based on Water by Design, 2009)

WSUD solution	Steep site	Flat site	Shallow bedrock	Acid sulphate soils	Low permeability (e.g clay)	High permeability (e.g. sand)	High water table	High sediment input	Land availability
Reduce									
Water Efficient Fittings and Appliances	✓	✓	✓	✓	✓	✓	✓	✓	✓
Porous Pavements	✗	✓	?	✗	✗	✓	✗	✗	✓
Infiltration Systems	✗	✓	?	✗	✗	✓	✗	✗	✓
Re-Use									
Rainwater Tanks	✓	✓	✓	✓	✓	✓	✓	✓	✓
Stormwater Harvesting/Reuse	?	?	?	?	✓	?	?	?	?
Reticulated Recycled Water	✓	?							
Greywater Treatment/Reuse	✓	✓							
Treatment									
GPTs	✓	?	?	?	✓	?	?	✓	✓
Buffer Strips	✗	✓	✓	?	✓	✓	✓	?	✓
Swales	?	?	?	?	✓	✓	✗	?	✓
Bioretention Swales	✗	?	?	?	✓	?	✗	?	✓
Bioretention Basins	?	✓	?	?	✓	?	✗	?	✓
Ponds	?	✓	?	?	✓	?	?	✗	?
Sediment Basins	?	✓	?	?	✓	?	?	✓	✓
Constructed Wetlands	✗	?	?	?	✓	?	?	?	?
Flood management									
Retarding basin	?	✓	✓	?	✓	✓	✓	?	?

Step 3: Documenting and testing the WSUD strategy

Once the WSUD Strategy has been developed, assess its performance. This process will identify if the strategy is achieving the targets identified in Step 1 or if further changes are required. This testing should be done using numerical modelling and reported against the Territory Plan 2023 assessment outcomes and Technical Specifications that were relevant for the site.

Table 6 presents a summary of the recommended tools to help develop and test the WSUD strategy performance. Modelling files should be submitted for auditing by the City and Environment Directorate.

Castellated kerbs and grassy swale along Alec Hope Crescent, Franklin, ACT

Table 6 A summary of the recommended tools that can assist in the WSUD planning process

Assessment tool	Type of analysis undertaken	Recommended use
MUSIC (Model for Urban Stormwater Improvement Conceptualisation)	Stormwater quality and quantity (on site retention)	→ Required **(Default parameters in MIS08)** → Current primary tool to assess stormwater quality performance → Industry accepted tool which is adequate and suitable for purpose
SWMM (Storm Water Management Model)	Stormwater quality and quantity (on site retention)	→ Optional → Current secondary tool to assess stormwater quality performance → Note this tool requires specialist training, but allows complex hydrologic and hydraulic processed to be analysed, and can help deliver integrated stormwater designs.
Blue Factor (Victoria)	Stormwater quality and quantity (on site retention)	→ Recommended for simple designs as it is user friendly → Requires local adaptation and configuration
MUSIC-link	Model assessment	→ Strongly recommended → Supports and checks MUSIC assessment
ACT Waterways Calculators	Mains water reduction	→ Recommended → Current primary tool to assess potable water reduction performance
BASIX (NSW)	Mains water reduction	→ Recommended → Part of a broader sustainability assessment which can be used to complement the ACT Waterways Calculators
Green Star rating	Mains water reduction	→ Optional → Part of a broader sustainability assessment which can be used to complement current ACT Water Reduction Calculators
DRAINS	Stormwater quantity (detention)	→ Stormwater drainage system design and analysis program typically used to model peak stormwater flows. **(Default parameters in MIS08)**

Planting areas at street level improve rainwater absorption

The outcomes of the planning process should be documented for assessment. This documentation of the WSUD strategy and its expected performance could include:

- description of the proposed development/works and existing site conditions including the receiving environments
- summary of the relevant site objectives (water quality, quantity etc.)
- description of the opportunities and constraints for the application of WSUD solutions on the site (e.g. steep slopes preventing use of swales etc.)
- description of the WSUD assets selected for the site and design approach
- site plans showing the key features for the site (e.g. drainage pathways) and location of the proposed WSUD assets (also known as a WSUD Concept Plan)
- MUSIC modelling approach and results demonstrating compliance with site objectives.

The above items can act as a typical table of contents for a WSUD strategy/stormwater master plan for a site in the ACT.

Floating wetlands,
Lake Tuggeranong, ACT

4. Critical steps to WSUD design

Once the WSUD strategy has been developed for the site, the WSUD systems need to be designed. It is important for this design process to be undertaken correctly by suitably qualified persons to ensure the systems can be effectively constructed and established, are integrated into the landscape and can be maintained to ensure ongoing function.

The key steps required for WSUD design are:

Step 1

Undertake the sizing and design for each WSUD measure.
This design needs to ensure that future maintenance is considered.

Step 2

Select the appropriate plants for the WSUD system.

Step 3

Document the WSUD measures and confirm the WSUD targets are met.

Step 4

Undertake lifecycle costing/cost-benefit analysis

The following sections provide guidance for each of these steps.

Step 1: Functional and detailed design of WSUD assets

The first step after the WSUD Strategy is the development of the concept into a functional design—a detailed design which documents all of the elements and levels that will make the system function correctly. This may include confirming levels and batter slopes, sizing of pits and pipes, design of outlet controls and planting and soil specifications.

This section outlines the important considerations that will assist practitioners to design WSUD assets to ensure they will operate effectively in the ACT. The type of information provided for each asset includes:

- function, describing the asset and how it works
- key design considerations, outlining the key components of the asset
- design constraints and key risk factors, providing a description of the types of site conditions that may make this asset unsuitable and identifies key potential risks that may impact on asset function and which need to be considered and addressed during design
- sizing guidance, providing guidance on the typical sizing required for the asset
- WSUD performance summary, an assessment of the WSUD asset and how well it achieves the ACT WSUD assessment outcomes and Technical Specifications
- detailed design considerations, providing guidance on best practice design parameters for the WSUD asset.

Note: All municipal infrastructure will need to comply with the Municipal Infrastructure Standards (MIS). The MIS (in particular MIS08 Stormwater) sets the default values for practitioners and engineers to design stormwater assets that are currently acceptable by the ACT Government.

The ACT Government Municipal Infrastructure Technical Specifications detail requirements from planning stages through to construction processes. They can be found at https://www.cityservices.act.gov.au/plan-and-build/standards-codes-and-guidelines/municipal-infrastructure-technical-specifications-mits

Documentation to support these stages must be submitted and may include considerations such as materials to be used and how they will be tested before they can be utilised. The MITS provides standardised hold points and witness points making it clear for applicants to understand contractual agreements between them and the authority.

This document provides guidance in relation to best practice design to help the ACT Government assess and approve innovative approaches outside of the MIS. Innovative approaches should align with the best practice design approaches documented in this guideline and be justified in writing and discussed with and approved by the City and Environment Directorate and a certified engineer.

Rubble filter drain, Forde, ACT

The following table identifies the WSUD assets described in this guideline compared to the assets included in MIS08 (December 2024 edition).

Table 7 Comparison of the WSUD assets described in this guideline and MIS08

WSUD assets in this guideline	WSUD asset in MIS08	Comments
Water efficient fittings and fixtures	Not included in the MIS08	
Porous pavement	Not included in the MIS08	
Infiltration systems	Infiltration (Chapter 12)	In the MIS, infiltration standards include vegetated landscapes, sub-surface drainage and buffer strips. In these guidelines, infiltration systems are a separate asset specifically designed to promote the infiltration of stormwater.
Rainwater tanks	Harvested stormwater tanks (Chapter 17)	
Stormwater harvesting and re-use	Stormwater harvesting and re-use (Chapter 17)	
Greywater harvesting and reticulated recycled water	Not included in the MIS08	
Gross Pollutant Trap (GPT)	Gross Pollutant Trap (Chapter 16)	
Buffer strips	Buffer strips (Chapter 12)	
Not included as a separate asset in the Guideline	Tree pits (Chapter 15)	This guideline provides a section on bioretention systems which can be designed as tree pits.
Swales (for stormwater treatment and conveyance)	Swales (Chapter 4)	
Bioretention swales	Bioretention basins (Chapter 15)	
Bioretention basins	Bioretention basins (Chapter 15)	
Ponds	Ponds (Chapter 14)	
Wetlands	Wetlands (Chapter 13)	
Sediment basins	Sediment forebay zone of wetlands (Chapter 13)	
Retarding basins	Retarding basins (Chapter 10)	
Not included in the Guideline	Waterways (Chapter 4)	In best practice WSUD, waterways are considered as receiving environments and thus all treatment and flow management should occur upstream. In the MIS, waterways are overland flow conveyance systems. Examples include: constructed and natural channels, floodways, swales and cut off drains.

WSUD solutions to reduce watercycle impacts

Water efficient fittings and fixtures

Function

Water efficient fittings and fixtures refer to appliances and plumbing fittings designed to reduce the amount of water required within the building. They help reduce use of potable water and the generation of wastewater. Some typical examples of water efficient fittings and fixtures include low use water taps and shower roses, dual flush toilets and front-loading washing machines.

Key design guidance

The Water Efficient Labelling and Standards (WELS) scheme is an Australian scheme that requires certain products to be registered and labelled with their water efficiency in accordance with the standard set under the *National Water Efficiency Labelling and Standards Act 2005*. It is recommended that water efficient fittings and fixtures are chosen with regard to their WELS rating.

Design constraints and key risk factors

Typically, water efficient fittings and fixtures are easily installed in new builds or retrofit scenarios. However, if there is an existing problem with transporting solids within the sewer network (possibly due to low pipe grades and low dry weather flows), water efficient fittings and fixtures may not be suitable to retrofit as they will reduce the dry weather flows and may further impact the sewer network flows.

Sizing guidance

The design and the type of water efficient fitting and fixture will depend on the design and requirements of the building and the water demands.

Table 8 Water efficient fittings and fixtures WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	Water efficient fittings and fixtures are designed to reduce the volume of water used.	Water efficient fittings and fixtures can significantly reduce the amount of potable water being used.
Stormwater quantity	N/A	N/A
Stormwater quality	N/A	N/A
Climate change adaptation	N/A	N/A

Detailed design considerations

Refer to the WELS website (www.waterrating.gov.au) to find out more about registered products, regulations and standards for water efficient fittings and fixtures.

The Water and Sewerage Regulation 2001 (ACT) reflects the National Construction Code by mandating that domestic showerheads and taps must have a maximum flow of 9L per minute (3-star WELS rated). Toilet cisterns must be dual-flush with volumes no greater than 6L and 3L for full and half flush.

Porous paving

Function

Permeable pavements are an alternative to typical impermeable surfaces. They come in many different forms, from brick paving where water infiltrates between the cracks to paving material designed so water can move through the blocks. The intent is to create a paved surface where water can infiltrate into the underlying soil. In the ACT, soils are predominately clay, so porous paving usually requires a drainage sub-layer of material to transport excess water laterally to the drainage system. Stormwater retention, such as infiltration through porous paving, helps to facilitate dissipation of run-off. This function can also be achieved by incorporating green infrastructure including vegetated green spaces and sustainable water systems such as stormwater harvesting.

Pavements fall into two categories:

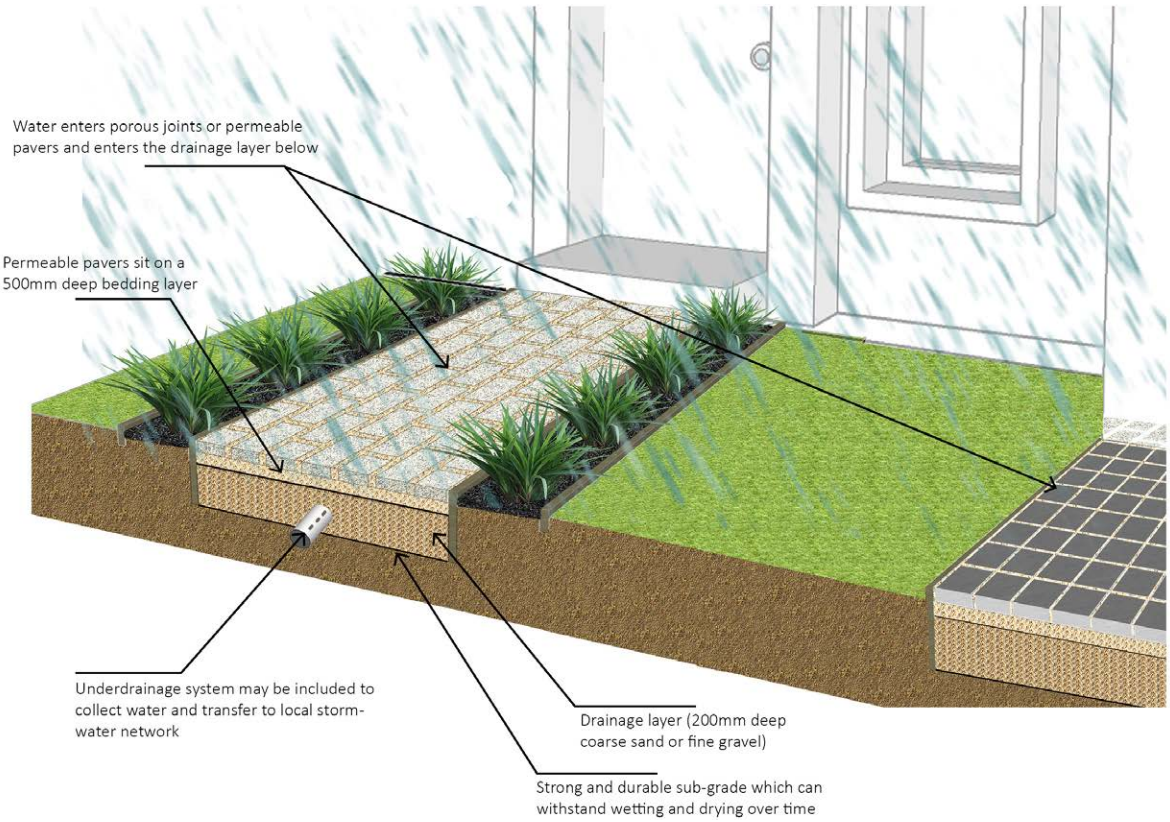
1. Porous pavements, which comprise a layer of highly porous material
2. Permeable pavements, which comprise a layer of paving blocks, typically impervious, specially shaped to allow the ingress of water by way of vertical 'slots' or gravel-filled 'tubes'.

Key design guidance

The porous pavement solutions will typically have the following elements:

- An area of permeable surface (whether it is the porous pavement itself, or the permeable areas between pavers)
- Underlying bedding and drainage layer (typically coarse sand or gravel)
- Subgrade material and underdrainage system (optional)

Figure 6 Typical porous pavement features



Design constraints and key risk factors

- → Attention is to be given to the risk of clogging in porous pavements and the materials that are used. They are not suitable in locations with high sediment loads and heavy traffic.
- → Pretreatment may be required to minimise the potential for clogging and to protect groundwater quality. Pretreatment measures may include providing leaf and roof litter guards along roof gutters, vegetated swales, sediment forebays or buffer strips.
- → Infiltration will be impacted if the in-situ soils are impermeable. Performance can be improved by creating below ground storage (e.g. deeper gravel drainage layer for storage and slow infiltration).
- → The materials used should satisfy filter criteria which prevent movement of fine sediment between the bedding layer and drainage layer. This will avoid clogging and pavement subsidence.
- → Where there are contaminated flows or issues of soil salinity, an impermeable liner needs to be placed between the subgrade and in-situ soils to protect the quality of groundwater. Drainage pipes will be required to covey flows in excess of the retention capacity, preferably to downstream treatment measures.
- → Overflows or surface flows (i.e. flows in excess of the storage capacity, underdrainage capacity and/or infiltration capacity) should be diverted towards the stormwater system. The design will need to demonstrate that overflows will not be directed towards or cause damage to buildings, structures and services.
- → The surface level of the porous pavement should be flat or as close to this as possible to ensure uniform distribution of flow and to prevent hydraulic overloading on a small portion of the surface. Generally, porous pavement should be on a slope of less than 3% and should not generally be considered for slopes greater than 5%. If used on slopes >5% extreme care and consideration needs to be given to the likely infiltration rate and the structural integrity of any areas used by vehicles.
- → The design will have to consider the expected vehicle load and demonstrate structural integrity of the pavement to a standard consistent with the MIS.

Sizing guidance

Porous pavements are used in lieu of typical impermeable surfaces, so the size will depend on the use of the pavement and suitable area available. They are well suited to sites with light vehicle weights and low-traffic streets in residential and commercial areas; footpaths; driveways and parking bays.

Table 9 Porous pavements WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	N/A	N/A
Stormwater quantity	Porous pavements are designed to infiltrate stormwater into the underlying soils.	The infiltration minimises the volume of stormwater entering downstream systems.
Stormwater quality	They provide treatment through the removal of particulate pollutants.	There is some stormwater quality benefit attributed to the infiltration of flows and removal of particulates, however porous pavements are unable to provide best practice stormwater treatment.
Climate change adaptation	Porous pavements infiltrate and retain water in the soil.	Local microclimate benefits are provided by keeping water in the soil and infiltration reduces the peak volumes entering stormwater networks which also helps to address nuisance flooding.

Detailed design considerations

The detailed design of permeable pavements may involve the following:

- Confirmation of concept design and treatment performance
- Pretreatment design, if required
- Determination of design flows
- Size of the porous pavement system
- Specify the underdrainage design
- Check the emptying time of detention volume following the cessation of rainfall
- Check the requirement for impermeable lining
- Specify porous pavement layers
- Size of the overflow pit/ pipe
- Specify the bedding structures and expected vertical and tractive loads

Further information on the design of permeable pavements is provided in Australian Run-off Quality (Engineers Australia 2006) and Planning Scheme Policy 11, Section 13.11 Porous and Permeable Paving (Gold Coast City Council, Amended 2007) and the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region (Department of Planning and Local Government, Government of South Australia, 2010).

Infiltration systems

Function

Infiltration systems capture and detain flows to encourage infiltration, which can help minimise the volume of stormwater run-off from a development and recharge groundwater. While other permeable WSUD assets such as swales and porous pavements provide opportunity for stormwater to infiltrate into the ground, the infiltration systems described below are assets designed specifically for enhanced infiltration. They will not be widespread in the ACT due to the predominance of heavy soils with lower potential for infiltration, but may be considered on sites with less clay/higher infiltration rates. In general, infiltration systems should have high catchment area ratios (>25%) and principally be designed to manage and treat their own catchment area.

Key design guidance

Infiltration systems typically consist of:

- detention volume – can be located above or below ground and is designed to detain a volume of stormwater for infiltration
- infiltration area – this is the surface between the detention volume and the in-situ soils which the stormwater will infiltrate into.

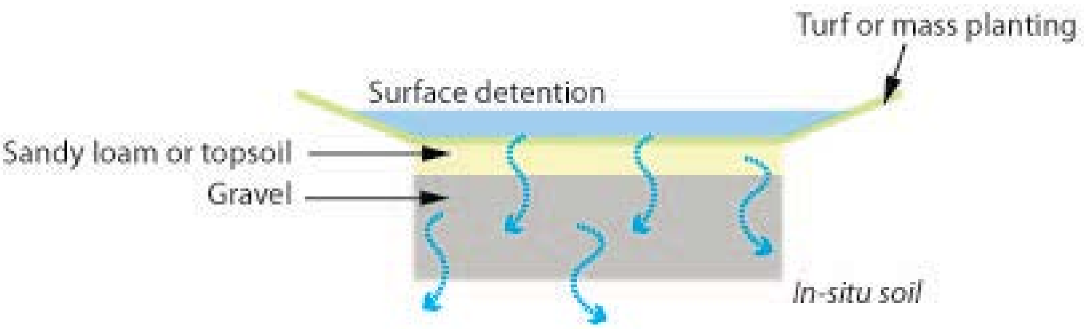
These are designed to detain flows at-source and contain suitable porous materials (e.g. coarse sand or gravel) to allow rapid infiltration or sized with sufficient area to allow infiltration in heavier soils. Overflow systems can be connected to the local stormwater network.

In low catchment area ratio systems (<25%), pretreatment to remove coarse and medium sediments and litter is required to avoid blockage of the infiltration system. If the infiltration systems do not have a densely vegetated surface, additional pretreatment to remove fine particulates, nutrients and metals will be required to protect groundwater quality. Pretreatment measures may include the provision of upstream vegetated swales, bioretention systems or even constructed wetlands.

Infiltration systems can range in their designs and may include the following types:

- Leaky well: Water enters the top of a well which consists of a vertical perforated pipe with an open base. These openings are covered with geotextile and the well is surrounded by clean gravel. When the volume of the well is exceeded, an overflow pipe discharges flows to the local stormwater network.
- Infiltration trench: Consists of a trench which is filled with gravel and lined with geotextile and sits under topsoil, which can be planted. Stormwater is directed into the trench via a pipe.
- Infiltration basin: This is a depression which is designed to capture and stormwater run-off on the surface prior to infiltration into the in-situ soils.

Figure 7 Typical infiltration basin features



Design constraints and key risk factors

- Infiltration systems are not ideally suited to sites with very low permeability soils (i.e. medium or heavy clays with saturated hydraulic conductivities of < 3.6 mm/hr). This does not preclude the use of infiltration systems however the required storage may become prohibitively large.
- Infiltration systems should be avoided in locations where there are sodic/saline soils, dispersive soils, shallow groundwater or shallow rock or shale.
- Shallow groundwater may result in localised mounding of the groundwater level. Investigations need to be carried out to ensure mounding/raising groundwater levels will not cause problems to nearby structures.
- The base of the infiltration system should always be above the seasonal high groundwater level.
- It is not ideal to locate these systems beside a building or other structural footings that may be affected by saturated soils. Ensure the required minimum building setback distances are achieved.
- Infiltration into steep terrain (>5-10%) can result in stormwater re-emerging onto the surface at some point downslope. This is most likely to occur on sites with duplex soils and shallow soil over rock.
- On steep terrain there is a risk of slope instability. A detailed engineering assessment will need to be undertaken in such cases.
- The surface of the infiltration system should be as flat as possible to ensure uniform distribution of flows to avoid hydraulic overload on part of the infiltration surface.
- To avoid overloading and clogging of the infiltration system, ideally 'above design' flows should be bypassed.

Sizing guidance

The size of the infiltration system will depend on the infiltration rates and the storage volume. When modelling a system's performance in the ACT, it is recommended that heavy clay infiltration rates be used unless testing shows the site's soils have a different infiltration rate.

Table 10 Infiltration system WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	N/A	N/A
Stormwater quantity	Infiltration systems are designed to infiltrate stormwater into the underlying soils.	Infiltration minimises the volume of stormwater entering downstream systems.
Stormwater quality	Infiltration systems will remove some pollutants as they are filtered through infiltration materials and in-situ soils.	Infiltration systems are not designed to provide stormwater treatment, rather to facilitate groundwater recharge and therefore are most appropriate to be used at the end of a treatment train.
Climate change adaptation	These systems infiltrate and retain water in the soil.	Local microclimate benefits are provided by keeping water in the soil and infiltration reduces the peak volumes entering stormwater networks which also helps to address nuisance flooding.

Detailed design considerations

The detailed design of infiltration systems may involve the following:

- → Confirm site conditions with site and soil evaluation
- → Confirm design objectives and concept design
- → Select infiltration type
- → Determine pretreatment requirements and design
- → Determine design flows
- → Size infiltration system
- → Locate infiltration system
- → Set infiltration depths (sub-surface systems only)
- → Specify detention volume media/materials
- → Design flow management components (e.g. inflow pipes, overflow pipes and pits)

Further information on the design of infiltration systems is provided in WSUD Technical Design Guidelines for South East Queensland (Healthy Waterways, 2006).

Re-use WSUD solutions

Rainwater tanks

Function

Rainwater tanks capture and store rainwater from a roof catchment. Rainwater tanks can make an important contribution towards minimising potable water demand and decreasing stormwater peak flows and volumes, which can improve hydrology downstream.

Water captured from the roof catchment is stored and then used in place of mains water for commercial, industrial or domestic uses that do not require a potable standard of water. On a residential block, stored rainwater can be used for garden watering, toilet flushing and laundry use. Using rainwater for hot water systems is a possibility that is currently under review in many jurisdictions.

Recommended end uses (by order of priority) are:

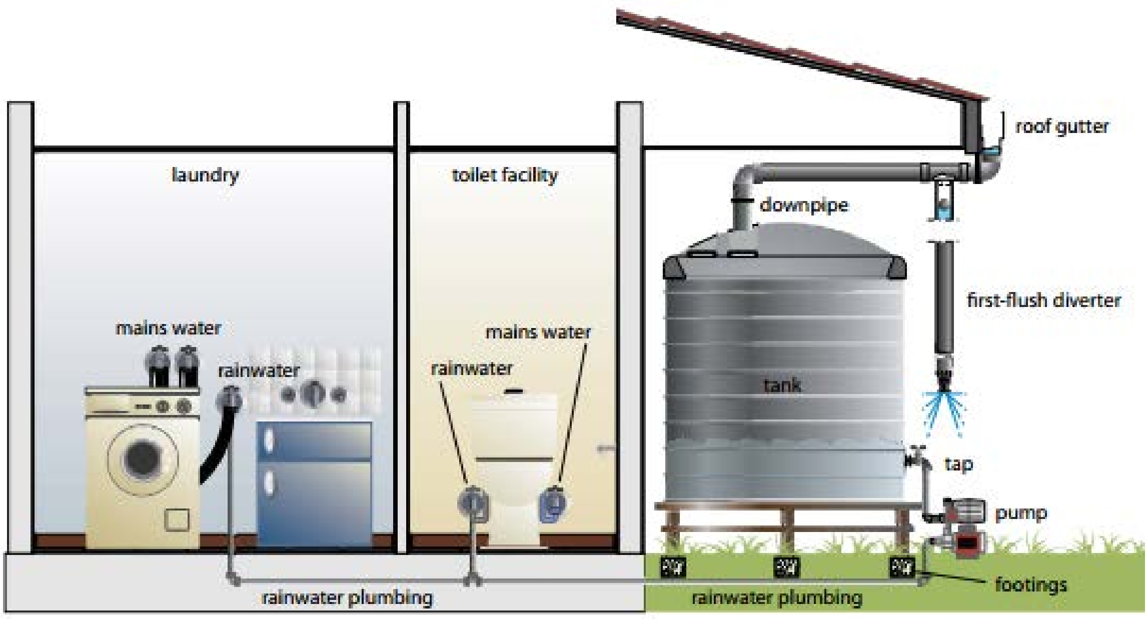
- toilet flushing
- garden watering
- laundry.

Rainwater tanks are among the options listed in the Technical Specifications for single dwellings to achieve the mains water use reduction target. Rainwater tanks are also often used in other developments to meet assessment outcomes under the Territory Plan 2023.

Key design guidance

Rainwater tanks will typically have a first flush diverter and protection mesh screen to reduce the risk of contaminants and mosquitoes entering the tank via the down-pipe. Modern tanks have an enclosed roof to restrict pest access (birds and mosquitoes). The outlet can either be an external connection only, or can be connected to internal uses as well. A pump is typically required and potable water back-up will be required if it is used for internal uses. The rainwater tank will also have an overflow system which will discharge water to the local stormwater network when it is full.

Figure 8 Basic and internal configuration for rainwater tank features (from Rainwater tanks – Guidelines for residential properties in Canberra [ACT Government, 2010])



Design constraints and key risk factors

- Underground systems can be problematic where there is shallow bedrock or high groundwater.
- Aboveground tanks require suitable areas; however, due to the large range of product sizes and shapes available, this should be achievable for most sites.
- The use of rainwater for drinking purposes is not recommended where a reticulated supply is available. In urban areas, airborne contaminants and other pollutants may find their way into rainwater tanks.
- To minimise any water quality associated risks, replace or coat any lead flashings on the roof, screen all openings to prevent leaves, insects or other foreign material from entering the tank and use a first flush device to divert dirty roof water away.
- Ensure contaminated groundwater does not infiltrate underground rainwater tanks.
- Ensure tank overflows or discharge from purposely designed 'leaky tanks' does not enter adjacent properties or pond under floors or flood around building foundations.
- Closed (rooved) tanks limit mosquito access to tanks. Inflow litter screening and a dark environment limit food sources for mosquitoes in closed screened tanks.

Sizing guidance

Maximising the roof area connected to the tank and the demand of suitable regular end-uses will yield the greatest benefits from rainwater tanks. To determine the most appropriate size of the tank, assessments can be undertaken of roof area, rainfall volume collected and demand. This data can be used to generate sizing curves and identify volumetric reliability. A reasonable reliability for a rainwater tank is 65–75%. While the required connected roof area in the ACT is 50% (under the Territory Plan 2023 Technical Specifications), it should be noted that connecting 100% roof area to the tank typically delivers improved use and reliability of the tank.

Table 11 Rainwater tank WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	Rainwater tanks provide a source of low risk alternative water which can be used for a number of uses that typically use potable water.	If sized correctly and plumbed to suitable end-uses, rainwater tanks can reduce potable water use significantly.
Stormwater quantity	Rainwater tanks capture and store rainwater which can be re-used, reducing the volume.	Rainwater tanks detain the initial volume of rainfall, reducing peak flows entering waterways. If the water is re-used with good demands, the volume of stormwater entering the waterways is also significantly reduced.
Stormwater quality	Water captured in rainwater tanks can be re-used for many end-uses.	The re-use of rainwater reduces the volume and associated pollutants entering waterways.
Climate change adaptation	Rainwater tanks capture and reduce the volume of water flows entering the stormwater network.	Reducing the volume of rainwater entering the stormwater pipe network which also helps to address nuisance flooding.

Detailed design considerations

Refer to Rainwater Tanks, Guidelines for Residential Properties in Canberra, ACT (2010) for detail on the design of small (<20 KL) rainwater tanks.

Leaky Rainwater Tanks

Objectives: Harvesting and attenuation

Benefit: Improved reduction in volume of stormwater conveyed to receiving waters with limited impact on supply

Sizing: To achieve 25-30% 'leaky volume'

Status: Voluntary only

Connection:

→ Supply to toilets, etc.

→ Slow drainage to network or kerb

Set-up: The passive irrigation tank can take a variety of forms such as:

→ a completely separate tank that takes the overflow from a tank that is already used to supply the indoor uses (such as the toilet)

→ the top portion of a larger tank, where the water only leaks out from the top part leaving the water in the base of the tank for reuse

Figure 9 Example of a typical tank system

Stormwater harvesting

Function

Stormwater harvesting schemes are designed to store and supply an alternative to potable water that can be used for fit-for-purpose demands. This reduces the volume of discharge of urban stormwater excess to waterways.

Key design guidance

Stormwater can be stored in a number of different systems, including tanks and open water storages.

Stormwater harvesting tanks at sportsgrounds, Dickson, ACT

When deciding on the appropriate design of the stormwater harvesting system the following should be considered:

→ Demand volume
→ Required storage for buffering
→ Diversion requirements (is pumping required?)
→ Water quality of stormwater and risk of end use (is additional treatment required?)
→ Operational, maintenance costs of infrastructure including pumps
→ Licensing and operational requirements

Design constraints and key risk factors

Open water storage design will need to consider the following possible site constraints:

→ Space required for the storage and batters
→ Ensuring draw down of water does not impact plant health on batters

Underground storages may not be suitable for sites with:

→ shallow bedrock
→ high groundwater.

Sizing guidance

Sizing of the storage will depend on the rainfall, catchment and demand. Optimal sizing is site specific. With the exception of single household systems, optimal storages for precinct reuse schemes will typically be sized to deliver between 70–80% reliability. To reduce pumping and infrastructure costs, the demands are likely to be located within 2 km of the point of supply.

To size the storage, use a water balance assessment including the main supply and demand requirements.

Table 12 Stormwater harvesting WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	Stormwater harvesting schemes are designed to capture and store stormwater for re-use.	Harvested stormwater can be used for a range of fit-for-purpose demands which will reduce potable water use.
Stormwater quantity	These systems capture and store stormwater from rainfall events.	The storage and re-use of stormwater removes this water from the volume entering downstream waterways. They have the greatest impact on reducing flow volumes associated with frequent flow events.
Stormwater quality	Stormwater harvesting schemes are typically located at the end of a treatment train	Stormwater harvesting schemes benefit downstream environments by ensuring a large portion of stormwater and its associated pollutant loads are do not enter the receiving waters.
Climate change adaptation	Stormwater harvesting schemes can involve a range of solutions such as open water storages or tanks.	Open water storages provide local microclimate benefits by keeping water in landscape. The storage and re-use of water in all solutions helps to address downstream flooding. Outdoor re-use of water can be very effective as a source of irrigation for green spaces, providing local microclimate benefits by keeping water in the soil and the process of evapotranspiration.

Detailed design considerations

The design of stormwater harvesting and re-use assets will vary significantly as they can range from tanks through to open water bodies. Chapter 17 of the Municipal Infrastructure Standards MIS 08 Stormwater details design considerations of stormwater harvesting systems in the ACT. Two key considerations are:

- End-use requirements for water quality and quantity
- The reliability of supply including the design frequency of instances without supply and the average duration of instances without supply
- If designing for irrigation, this should be designed to MIS21

It is important to design stormwater harvesting and re-use assets to minimise their public health risks and environmental risks by:

- providing appropriate stormwater quality treatment
- minimising mosquito habitat
- minimising contaminant inputs downstream of the final treatment facilities
- minimising public exposure to untreated stormwater
- minimising cross-contamination with mains water distribution networks or confusion with mains water supplies
- extracting sufficient water to meet the end use requirements without compromising downstream aquatic ecosystems
- potentially stopping collection in the event that stormwater is contaminated by an incident within the catchment
- minimising the risk and/or impact of upstream flooding.

Wastewater re-use

Greywater systems and reticulated recycled water

Function

Wastewater is the 'liquid wastes normally collected in a sewer system and processed in a treatment plant'. It comprises two components—blackwater (e.g. from toilets) and greywater (e.g. from shower and washing machines).

The re-use of greywater (typically at a building scale) and recycled wastewater (typically at a precinct scale) reduces the potable water requirements and the volume of treated wastewater entering receiving environments.

A greywater system enables re-use of greywater from buildings[2] The average Australian household can re-use around 1500 litres of greywater each week. There are simple and complex systems, but all involve reusing water that would otherwise enter the sewer network. Some systems involve storing the water and treating it to remove impurities.

A reticulated recycled water system typically involves a third pipe (purple pipe) being connected to buildings to allow recycled water to be distributed to customers from a central treatment location.

Refer to the Australian Guidelines for Water Recycling (2006) for more details on the safe use of recycled water.

2 Greywater from the kitchen is not recommended for use due to it typically being heavily polluted with food particles, oils, fats and other wastes, which can cause blockage and promote the growth of micro-organisms. It is also often chemically pollutant with detergents and cleaning agents, particularly those from dishwashers, which are very alkaline and over time may damage the soil.

Key design guidance

Fit-for-purpose re-use of wastewater requires recycled water to be treated to a quality which is suitable for the intended use. Therefore the type of treatment required will depend on the type of recycled water and its intended end use. The following table provides examples of reuse.

Table 13 End uses for recycled water

Type of Re-use
Uncontrolled public access – e.g. irrigation, ornamental water bodies
Residential uses – e.g. garden watering, toilet flushing, car washing
Controlled public access – e.g. irrigation, dust suppression
Ornamental water bodies with restricted public access
Pasture, fodder and horticulture
Turf farms and non-food crops
Food crops in direct contact with water – e.g. sprays
Food crops not in direct contact with water or processed or cooked before sold

Design constraints and key risk factors

It is essential that public health and the environment are protected when recycled water is used. It is also important to consider public and industry knowledge and confidence to ensure the scheme is well understood, supported and managed.

The following site characteristics may preclude the use of recycled water for irrigation:

- **Steep sites:** Slopes above 10% are not suitable for pasture spray irrigation, but trickle irrigation can be used for plants such as trees and vines on these steeper slopes. Note: Retention banks may be required to prevent run-off from the site on steep slopes.
- **Water bodies and receiving environments:** Need to protect surface water systems used as a domestic supply from contamination. Buffer distances are very site specific but typically a 500 m distance between the irrigation area and surface water system is required.
- **Groundwater:** Need to protect groundwater from contamination by recycled water. Typically a 3 m depth to groundwater is required.
- **Soil types:** Clay soils can be difficult due to low infiltration and low hydraulic conductivity. Sandy and gravel soils can also be difficult as their infiltration capacity and permeability are so high the recycled water is not retained long enough for effective plant use and results in rapid movement to the receiving environments.

Sizing guidance

The size of the treatment and reticulation system will depend on the scale of the network (e.g. ranging from an on-site greywater treatment system to a development-wide recycled water network). The design of the system will also depend on the volume of wastewater the system is able to collect, treat and distribute. On average, a two to three person Canberra household generates:

- 185 litres of greywater per day from the hand basin, shower and bath
- 121 litres of greywater from the laundry per day.

Table 14 Greywater systems and reticulated recycled water WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	These systems are designed to provide fit-for-purpose water for uses which don't require potable water.	Greywater and reticulated recycled water systems are very successful at reducing the potable water used in developments as there are many demands which can be met with this recycled water (e.g. toilet flushing and irrigation).
Stormwater quantity	N/A	N/A
Stormwater quality	N/A	N/A
Climate change adaptation	Recycled water can be used throughout the year as a suitable irrigation source.	The constant supply of recycled water in our urban environments means that recycled water can be very effective as a source of irrigation for green spaces, providing local microclimate benefits by keeping water in the soil and the process of evapotranspiration.

Detailed design considerations

A recycled water system will need to consider how water is managed from the source through to the application site or receiving environment. Typically, recycled water systems will include the following:

- Recycled water source and characteristics: Consider where the water is coming from and its characteristics e.g. flows, pollutant constituents, variability, etc.
- Treatment system: This will include a range of different equipment designed to provide varying levels of treatment (primary, secondary, tertiary, etc.).
- Storages: Consider size, public accessibility, etc.
- Distribution systems, application and receiving environments: Consider how the treated recycled water will be used and the water quality requirements for that use.

Treatment WSUD solutions

Gross Pollutant Traps (GPTs)

Function

GPTs were first developed in Australia in the ACT in the late 1970s and 1980s. A GPT treats catchment run-off prior to its discharge to a downstream stormwater treatment system or waterway by removing litter, debris and coarse sediment. There are numerous proprietary devices developed for trapping gross pollutants that may be suitable for use in Canberra.

Key design guidance

The most common types of GPT in Canberra to date have been the 'Minor DUS GPT' and the 'Major DUS GPT', as defined in the Municipal Infrastructure Standards MIS08 Stormwater. These GPTs consist of a concrete sediment basin with a fixed trash rack at the downstream end of the basin.

Figure 10 Example of a GPT

Design constraints and key risk factors

GPTs can be placed in many locations throughout a catchment to capture gross pollutants in a screening process. These systems will not operate effectively if the site has the following characteristics:

→ Backwatering: Materials captured in the GPT can be resuspended.

→ High leaf litter loads: Collecting and storing organic litter in saturated devices can be problematic as it can result in the leaching of nutrients. GPTs that retain water may not be appropriate in catchments with deciduous trees.

→ Limited maintenance access: Without regular maintenance, GPTs build up litter which affects their capacity to filter flows and can create amenity issues.

Sizing guidance

Appropriate catchments exceeding 5 ha should be equipped with a DUS GPT. Proprietary GPTs may be considered for smaller catchments with predominantly commercial land use. The land take requirement of the GPT system will depend on the type of system used; however, they typically require less area than other stormwater treatment devices.

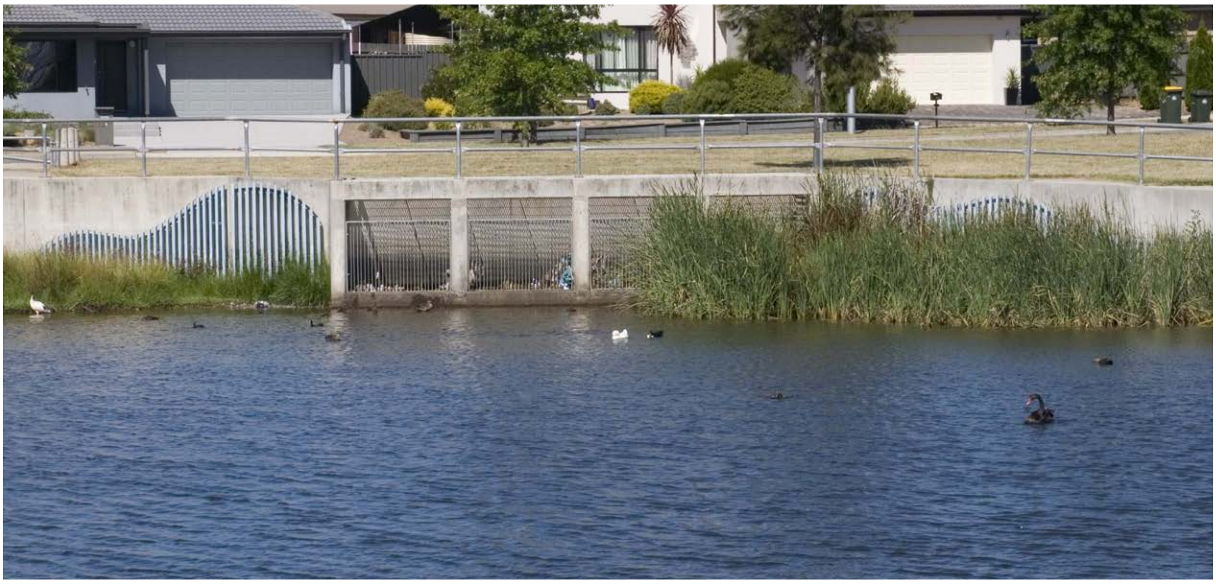
Table 15 GPT WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	N/A	N/A
Stormwater quantity	N/A	N/A
Stormwater quality	GPTs target the removal of gross pollutants from stormwater, such as litter.	GPTs are effective primary treatment devices in treatment trains that target the removal of large pollutants. They are effective at removing litter from stormwater but unable to achieve the best practice pollutant load reductions for other pollutants.
Climate change adaptation	N/A	N/A

Detailed design considerations

The Municipal Infrastructure Standards and ACT Standard Drawings for MIS08 Stormwater drainage contain details on the design requirements of GPTs in Canberra. These highlight the importance of designing GPTs with the following as considerations:

- Lifecycle costing
- Footprint and depth of the unit
- Hydraulic impedance and requirements
- Occupational health and safety
- Ease of maintenance (e.g. special equipment required)
- Maintenance requirements: Design the GPT for maintainability and operability including the following considerations:
  - Ease of maintenance and operation
  - Allowance for dewatering
  - Access to the treatment site
  - Frequency of maintenance
  - Special equipment requirements
  - Disposal



Gross pollutant trap, West Belconnen, ACT

Buffer strips

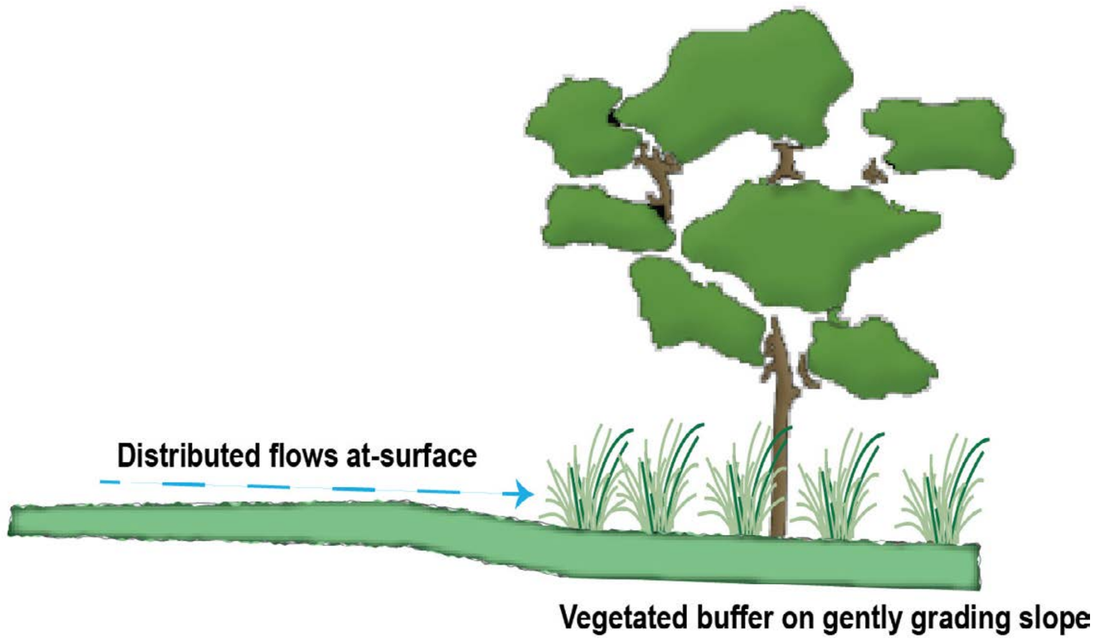
Function

Buffer strips are zones of vegetation designed to intercept and treat surface stormwater flows. Stormwater treatment occurs as shallow stormwater passes through the dense vegetation, which slows velocities causing sediments to deposit.

Key design guidance

Vegetated buffers require uniformly distributed sheet flow and are therefore most often combined with riparian edges that accept surface flows or in conjunction with swales when they are used along roads that have a flush kerb.

Figure 11 Typical buffer features



Design constraints and key risk factors

Buffer strips are not ideally suited to sites:

- **in the lower reaches of catchments** (beyond first order drainage reaches)
- **with steep topography (>4%):** Flow velocities are likely to move quickly through the buffer area, reducing treatment performance.
- **with a large catchment (>1–2ha):** Flow volume and velocities will be too large to achieve optimal treatment performance.
- **with channelised flows:** Buffers require distributed surface flow and are unable to provide optimal treatment for channelised flows.

Sizing guidance

Typically, buffer strips are applicable for smaller scale contributing catchments up to 1–2 ha. Run-off from larger catchments is likely to be already within drains and the larger flows will be difficult to manage and disperse.

The width and slope of the buffers will influence treatment performance. Wider buffers provide more treatment surfaces while steep slopes increase flow velocities and decrease treatment potential.

Table 16 Buffer WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	These systems are passively irrigated from impermeable surfaces.	Passively irrigated landscape feature which does not require potable water for on-going performance.
Stormwater quantity	N/A If systematically applied from the top of the catchment buffers could reduce the time of concentration of a catchment.	N/A Site specific applications would need to be clearly documented to contribute to meeting overall stormwater management objectives.
Stormwater quality	Buffers target sediments and particulates but provide limited dissolved nutrient removal.	Buffers are unable to meet best practice requirements by themselves. Treatment performance will depend on the width, vegetation cover and slope.
Climate change adaptation	Buffers retain water in the soil and provide evapotranspiration through the vegetation.	Local microclimate benefits are provided by keeping water in the soil and the process of evapotranspiration. If systematically applied from the top of the catchment buffers could reduce the time of concentration of a catchment.

Table 17 Detailed design considerations

Design consideration	Design rationale
Sizing	
Buffer area	User defined based on length and width.
Inlet properties	
Inlet types	Buffers required distributed flows and therefore are not ideally suited to piped inflows unless a flows can be spread using flow spreaders before they enter the buffer area. The buffer should accept distributed overland flows.
Vegetation set down from inlet area	Vegetation is recommended to be below the inlet invert to ensure flows pass through the vegetation.
Buffer properties	
Slope	The maximum design of slopes needs to be selected to reduce risk of erosion (slower velocities) and provide stability and allows for mowing.
Velocity	Riparian zone vegetation can withstand maximum velocity as outlined in the MIS depending on the vegetation community. The lateral flow velocity of water flowing through the riparian and entering the waterway should be considered. Vegetation communities have different properties for example riparian species is acceptable for slower velocities and turf is acceptable for faster velocities.
Flow distribution	Even flow distribution across the buffer strip is important as it is required to ensure there is no short circuiting of flows and minimises the risk of erosion. Dense and even vegetation is effective to ensure no short circuiting of flows and rilling of surface. Flow spreaders help to distribute flows. Spreading flows evenly through the vegetated buffers allow sedimentation to occur .

Vegetated swales

Function

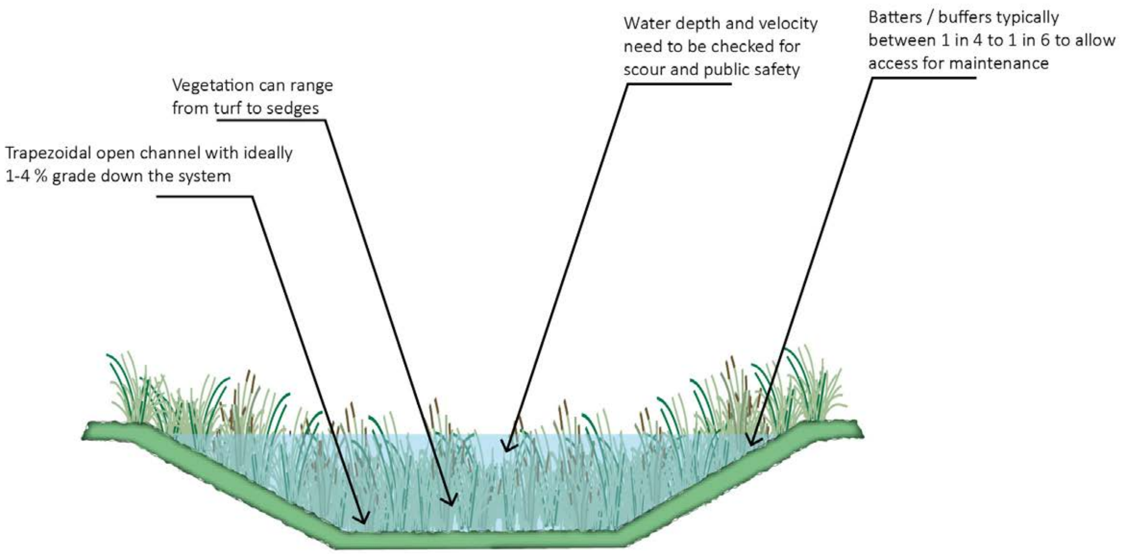
Swales are stormwater conveyance and treatment measures that primarily treat run-off through filtering and deposition of sediments. To facilitate stormwater treatment, swales are typically vegetated with turf, native grasses or sedges. Note: The MIS considers swales as waterways (conveyance systems).

In the context of this WSUD Guideline, vegetated swales are considered as vegetated treatment and conveyance systems that would be located upstream of natural waterways to help protect the water quality and hydrology of the receiving waterway. Treatment and conveyance swales do not permanently retain water and may incorporate subsurface drainage on flat/low grade sites.

Key design guidance

Vegetated swales are typically shallow channels/drainage lines with a trapezoidal cross section. The vegetation in the vegetated swale enhances treatment by filtering the stormwater. The vegetation can vary from mown turf to sedges; however, treatment performance is best in systems with dense vertical plantings. The species, height and density of plants specified will influence the roughness of the swale (Mannings 'n') and hence the conveyance capacity and treatment performance. Mown turf will provide a relatively high conveyance capacity compared with sedges, but sedges will provide a greater level of stormwater treatment through increased contact with stormwater flows. Careful consideration needs to be given to the longitudinal grade of the swale and flow velocities. Steep grades can result in high velocities and scour. Relatively flat longitudinal grades can result in wet and boggy swale inverts unless subsurface drainage is provided.

Figure 12 Typical swale features



Design constraints and key risk factors

Vegetated swales are not ideally suited to sites with:

- **steep topography (>4%):** Check whether dams may be required for these slopes to protect the swale from scour. Higher maintenance costs are also likely due to more difficult machinery operation requirements.
- **Flat topography (<1.0%):** Vegetated swales can become waterlogged or boggy if they are unable to drain effectively. Consider using underdrainage within the invert of the swale and planting with taller grasses and sedges rather than turf.

→ **Large catchment (>2 ha):** There is an optimal size for all systems. Vegetated swales can be designed and built at any scale. However, catchments <2 ha are generally better suited to the application of swale technology unless adequate space is available.

→ **Driveway crossovers:** Vegetated swales may be inappropriate where they result in the need for driveway crossovers due to high cost, difficulties with maintenance and inconsistency in maintenance.

Sizing guidance

Where vegetated swales are employed they would typically form the start of the minor drainage system and be sized to convey the five exceedances per year (EY) flow. Water quality improvement and treatment performance would occur within this context.

Vegetated swales should typically be trapezoidal in section and for maintenance purposes, larger swales in public open space that need to be mown, need to be at least 3 m wide at the base.

Table 18 Vegetated swale WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	These systems are passively irrigated from impermeable surfaces.	Passively irrigated landscape feature which does not require potable water for on-going performance.
Stormwater quantity	Vegetated swales slow stormwater flows. Depending on the underlying soils, they can also enhance infiltration.	Vegetated swales can help to reduce the volume of water entering downstream systems. If combined with an underlying infiltration trench losses can be enhanced.
Stormwater quality	Vegetated swales target sediments and particulates but provide limited dissolved nutrient removal.	Vegetated swales are typically unable to meet best practice requirements by themselves. Treatment performance will depend on the vegetation and infiltration. Determining an appropriate infiltration rate is critical to assessing swale treatment performance.
Climate change adaptation	Vegetated swales retain water in the soil and provide evapotranspiration through the vegetation	Local microclimate benefits are provided by keeping water in the soil and the process of evapotranspiration. The slowing of flows also helps to address nuisance flooding.

Grassy swale

Water sensitive urban design reduces stormwater flow volume and speed

Table 19 Detailed design considerations

Design Consideration	Design rationale
Sizing	
Swale area	User defined based on swale length, base width and top width.
Inlet properties	
Low flow bypass	No low flow bypass.
Inlet types	Flush kerbs or designated inlet zone means swales wales can receive distributed lateral inflow along its length or accept point source discharge .
Vegetation set down from kerb inlet	Vegetation is recommended to be below the kerb inlet to ensure flows pass through the vegetation.
Swale properties	
Bed slopes	Longitudinal slopes will determine the use of subsoil drains beneath the invert and designed avoid waterlogging; steeper slopes require check dams to distribute flows, reduce velocities and potential for scour.
Batter slopes	For stability and access for mowing (if turf).
Vegetation height / Manning's N	Lower vegetation (e.g. turf) has less roughness (lower Manning's n) and provides less stormwater treatment. Higher vegetation (e.g. sedges) have higher roughness (higher Manning's n) and provide more stormwater treatment.
Velocities	Vegetation will influence the minor flood and major flood flows therefore needs to be considered. It should be noted that turf will provide less stormwater treatment than longer grasses.
Depth / velocity	The maximum ponding depth and velocity (v x d) will be determined by the City and Environment Directorate and is aimed at ensuring public safety will not be impacted. Maximum velocities are set out in MIS08
Exfiltration rate	Only use heavy clay infiltration rates unless there is testing to demonstrate soil has higher infiltration rates.
Outlet properties	
Overflow pit	Overflow pits to be provided for when flow capacity of swale is exceeded. This ensures higher flows enter the drainage network and don't result in local flooding.
Maintenance access	
Swale and structures	For turf swales, ensure batter grades and base widths are suitable for ride on mowers. Ensure access to overflow pits or other structures is provided for inspection and general maintenance. Dedicated access tracks or ramps are typically not required for swales. Maintenance is usually by foot access or ride on mowing (for turf). MIS08 specifies that the preferred maximum for swale side slopes is 1(V):6(H), however 1(V):4(H) may be permitted in locations where space is limited such as in narrow street verges.

Bioretention swales

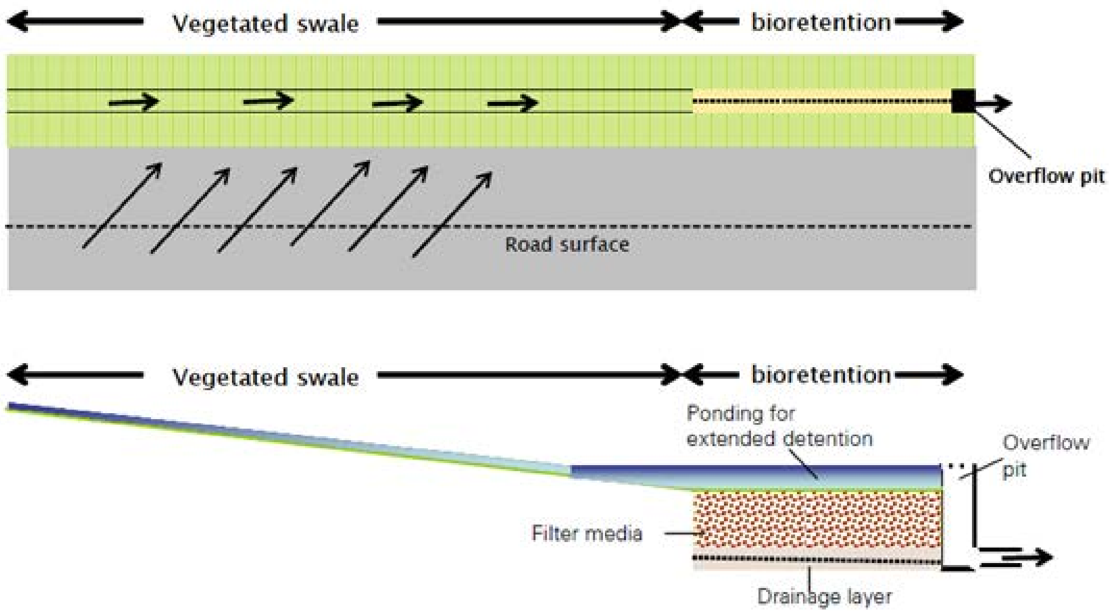
Function

Bioretention swales are swales with the addition of a biofiltration trench with filter media and an underlying pervious (slotted) collector pipe. The intent of bioretention swale is to both convey and treat stormwater flows by infiltrating frequent low flow events through the filter material, providing both physical and biological treatment, while higher flows are carried within the swale.

Key design guidance

The swale is a graded vegetated channel which conveys flows. It also provides pre-treatment (removal of sediments) of stormwater before it enters the bioretention component of the system. There are two possible design configurations for bioretention swales. The bioretention component can be located at the downstream end of the swale or provided as a continuous 'trench' along the full length of a swale. The choice of bioretention location within the overlying swale will depend on a number of factors, including area available for the bioretention filter media and the maximum batter slopes for the overlying swale. Typically, when used as a continuous trench along the full length of a swale, the desirable maximum longitudinal grade of the swale is not greater than 4%. For other applications, the desirable grade of the bioretention zone is either horizontal or as flat as possible to encourage uniform distribution of stormwater flows over the full surface area of bioretention filter media and allowing temporary storage of flows (extended detention) for treatment before bypass occurs.

Figure 13 Typical bioretention swale features with bioretention component located at the downstream end of the swale (from SEQ HWP 2006)



Filter media specifications and sourcing
Bioretention systems require special filter media as specified in the ACT Municipal Infrastructure Technical Specification 16A - Bioretention Systems. Early consideration of where these materials can be sourced will be required; they should be locally sourced if possible.

Design constraints and key risk factors

Bioretention swales are not ideally suited to sites with:

- steep slopes: Bioretention swales require a relatively low surface grade (between 1% and 4%) to allow for effective treatment.
- large catchments: Flow depths, velocities and large loads of sediment from larger catchments (>1ha) can impact vegetation and can clog or scour the filter media. Therefore, they are not ideally suited at the end of large catchments.

Sizing guidance

Bioretention swales can be sized to meet best practice treatment objectives. This treatment performance is influenced by rainfall characteristics, swale vs bioretention area, catchment size, land use and filter media saturated hydraulic conductivity and depth. The Model for Urban Stormwater Conceptualisation (MUSIC) is used to test and refine bioretention size to meet the site's objectives.

Table 20 Bioretention swale WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	Bioretention swales are passively irrigated from impermeable surfaces.	Passively irrigated landscape feature which does not require potable water for on-going performance.
Stormwater quantity	Bioretention swales capture and attenuate frequent flow events as water is filtered through the system.	The attenuation of flows reduces the peak volume entering waterways and stormwater networks.
Stormwater quality	Bioretention swales provide treatment of stormwater, targeting fine sediments, metals, particulate and dissolved nutrients	Bioretention swales can achieve the best practice pollutant load reductions when sized correctly.
Climate change adaptation	Bioretention swales retain water in the soil and provide evapotranspiration through the vegetation. They also infiltrate flows reducing the peak volume of flows entering the stormwater network.	Local microclimate benefits are provided by keeping water in the soil and the process of evapotranspiration. The reduction of peak volumes entering the stormwater network also helps to address nuisance flooding.

Bioretention swale at playing fields, Kambah, ACT

Table 21 Bioretention swale detailed design considerations

Design Consideration	Design rationale
Sizing	
Swale area	User defined based on swale length, base width and top width.
Filter area	If systematically applied from the top of the catchment swales could reduce the time of concentration of a catchment. Dependent on swale area, catchment land use, imperviousness, extended detention depth and filter media saturated hydraulic conductivity and therefore is user defined.
Inlet properties	
Low flow bypass	No low flow bypass
High flow bypass	No high flow bypass
Swale properties	
Bed slopes	Longitudinal slopes will determine whether the swales require check dams to distribute flows, reduce velocities and potential for scour. The greater the grade on the swale the less effective the bioretention treatment component will be.
Batter slopes	For stability and access for mowing (if turf).
Vegetation height / Manning's N	Lower vegetation (e.g. turf) has less roughness (lower Manning's n) and provides less stormwater treatment. Higher vegetation (e.g. sedges) have higher roughness (higher Manning's n) and provide more stormwater treatment.
Velocities	Vegetation will influence the minor flood and major flood flows therefore needs to be considered. It should be noted that turf will provide less stormwater treatment than longer grasses.
Depth / velocity	The maximum ponding depth and velocity (v x d) will be determined by the City and Environment Directorate and is aimed at ensuring public safety will not be impacted.
Exfiltration rate	For modelling purposes set exfiltration rate to zero.
Bioretention properties	
Extended detention	Designed to provide additional water quality and infiltration. Depths over the maximum may impact on plant health and pose public health and safety risks.
Filter media area	Filter media surface areas will be dependent on catchment land use, imperviousness, extended detention depth and filter media saturated hydraulic conductivity. Additional area will be required for batters. Considerations for master planning may be 0.5-2% of the catchment (filter media surface area).
Filter depth	Shallower depths are at risks of drying out and may not be able to support vegetation.
Filter media properties	
Saturated hydraulic conductivity	Avoid higher hydraulic conductivities as the media will have low water holding capacity and result in drought-stressed plants. For performance modelling purposes long term hydraulic conductivity is unlikely to be consistently greater than 200mm/h.
Nutrient Content	Prevents leaching of nutrients from the media.
Organic matter content	Some organic matter helps retain water for vegetation and can benefit pollutant removal, however higher levels may lead to nutrient leaching.
Grading of particles	Smooth grading provides a stable media, avoiding structural collapse from downward migration of fines.
pH	AS 4419-2003 Natural Soils and soil blends helps with soil pH and plant growth.
Electrical conductivity	AS 4419-2003 Natural Soils and soil blends helps with plant growth.

Design Consideration	Design rationale
Horticultural suitability	Media must be capable of supporting healthy vegetation (assessment by horticulturalist). To support healthy vegetation over the long term. Trees and shrubs are generally not supported to be planted in the filter media. Clarification will need to be sought from the City and Environment Directorate for municipal infrastructure. Trees and shrubs can be provided outside of the filter media for shade. Deciduous trees should be avoided at all times.
Transition layer properties	
Material	Clean well-graded sand prevents filter media washing down into the saturated zone.
Depth	Depths avoid migration of fines from the filter media and to avoid inundation of the filter media by the saturated zone.
Hydraulic conductivity (Ksat)	
Fine particle content	Prevents the bioretention system leaching nutrients.
Particle size distribution	Bridging criteria- the smallest of sand particles must bridge with the largest of filter media particles to avoid migration of the filter media downwards into the transition layer.
Saturated zone properties (only on bioretention systems with flat surface)	
Material	The pore space between the sand//fine aggregate grains retains the water. If sand is used, sand has a greater capillary rise and will be most beneficial during extended dry periods.
Saturated zone depth	Provides storage of water to maintain soil moisture and enhance nutrient removal.
Outlet properties	
Overflow pit	Overflow pits to be provided for when flow / extended detention capacity of bioretention swale is exceeded to ensures higher flows enter the drainage network and don't result in local flooding.
Underdrainage pipes	Standing water in the filter media section of bioretention results in leaching of nutrients. Having regular underdrainage pipes ensures the system drains effectively and the water level within the saturated zone does not rise to inundate the filter media. Inspection access allows pipes to be inspected and flushed. The drainage aggregate avoids material falling into the slots of the drainage pipes.
Maintenance access	
Vegetation and outlet	Most maintenance for bioretention systems is undertaken by hand. However, batter grades should allow access and if the swale components are turf, it is recommended these are flat enough to be suitable for ride on mowers. Ensure access to overflow pits or other structures is also provided for inspection and general maintenance. Dedicated access tracks or ramps are typically not required for bioretention swales. Maintenance is usually by foot access or ride on mowing (for turf).

Raingardens / bioretention systems

Function

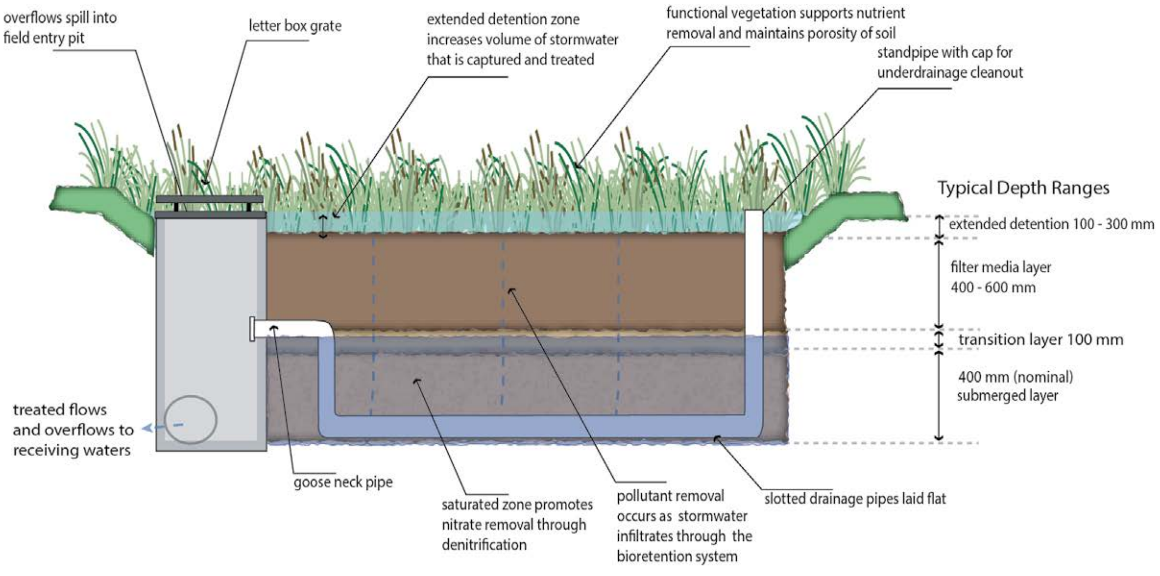
Bioretention systems are depressed garden beds that detain flows within a defined extended detention area. These flows then percolate down through a prescribed filter media and a saturated zone. This saturated zone provides plants with access to water (soil moisture) during extended periods of dry weather. It also enhances nitrogen removal through denitrification processes. Treatment is provided by filtering and nutrient processing on the densely vegetated surface as well as within the filter media. Swales can be used upstream of bioretention systems in a treatment train. Rain gardens are also bioretention systems that are situated in streetscapes and urban environments.

Key design guidance

Bioretention systems typically contain the following elements:

→ Inlet area, which may incorporate a coarse sediment forebay
→ Filter media, transition layer and saturated zones
→ Densely vegetated surface and batters
→ Extended detention set by outlet structure, which diverts high flows to local stormwater network
→ Pipework for the collection and discharge of treated flows to the local stormwater network and to allow for underdrainage cleanout (standpipe)

Figure 14 Typical bioretention features



Filter media specifications and sourcing
Bioretention systems require special filter media as specified in the ACT Municipal Infrastructure Technical Specification 16A - Bioretention Systems. Early consideration of where these materials can be sourced will be required; they should be locally sourced if possible.

Standards for tree pits, bioretention swales and bioretention basins (raingardens) are set out in chapter 15 of MIS08 Stormwater.

Design constraints and key risk factors

Bioretention systems are highly flexible in their design and size, although the following site conditions provide some design constraints:

- **Steep slopes (slopes greater than 4–5%)** – bioretention systems require a flat surface and, therefore, on steeper slopes, smaller bioretention systems are preferred or larger systems engineered as stepped systems to reduce batter widths and slopes.
- **Large catchments (> 2.5 ha)** – large loads of sediment can smother plants and clog the filter media. In addition, high velocity flows can result in scour of the bioretention surface. Therefore, they are not ideally suited at the end of large catchments and require additional infrastructure including sediment capture devices and energy dissipation.
- **Single large systems (< 500 m^2)** – Single cell systems over 500 m^2 can be difficult to construct and also have a high risk of ongoing issues associated with difficulty establishing and maintaining vegetation, scour from high velocity flows, clogging, soil moisture gradients, uneven flow distribution and poor amenity. They are unacceptable to the ACT Government.
- **Large systems (> 500 m^2)** – Systems over 500 m^2 requires the systems to be broken into cells, with cells being no greater than 500 m^2. It should be noted that cells towards this size have a number of design and operational risks therefore should be broken into much smaller cells, however the use of large systems needs to be carefully evaluated.
- **Within retarding basins** – bioretention systems within retarding basins are highly susceptible to clogging due to sediment loading. If systems are located in flood retarding basins they should be located to be protected from retarding basin inundation for all events less than the 1 in 20 (5%) annual exceedance probability (AEP).

Sizing guidance

The required size of a bioretention system is influenced by rainfall characteristics, catchment size, land use, presence or absence of rainwater tanks, extended detention depth, filter media, saturated hydraulic conductivity and depth. In the ACT, bioretention systems are typically sized between 0.5% and 2% of the contributing catchment area. MUSIC modelling is used to test and refine bioretention size to meet the site's objectives.

Table 22 Bioretention WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	These systems are passively irrigated from impermeable surfaces.	Passively irrigated landscape feature which does not require potable water for on-going performance.
Stormwater quantity	Bioretention systems capture and detain frequent flow events as water is filtered through the system.	The temporary detention of flows reduces the peak volume entering waterways and stormwater networks.
Stormwater quality	Bioretention systems provide treatment of stormwater, targeting fine sediments, metals, particulate and dissolved nutrients.	Bioretention systems can achieve the best practice pollutant load reductions when sized correctly.
Climate change adaptation	Bioretention systems retain water in the soil and provide evapotranspiration through the vegetation. They also infiltrate flows reducing the peak volume of flows entering the stormwater network.	Local microclimate benefits are provided by keeping water in the soil and the process of evapotranspiration. The reduction of peak volumes entering the stormwater network also helps to address nuisance flooding.

Table 23 Bioretention design considerations

Design Consideration	Design rationale
Sizing	
Filter area	Dependent on catchment land use, imperviousness, extended detention depth and filter media saturated hydraulic conductivity. Additional area will be required for batters. Considerations for master planning may be 0.5-2% of the catchment (filter media surface area). Note: that the filter media of the contributing catchment is encouraged not to be broken up into multiple systems across a catchment (e.g. 50 small rain gardens)
Total bioretention area	Total footprint area will depend on slope and required batter extent. Considerations for master planning may be 0.7-4% of the catchment (filter media surface area). Vertical retaining walls may be used but will increase cost and may impact visual amenity and public safety (typically only suitable for small systems).
Inlet properties	
Low flow bypass	No low flow bypass.
High flow bypass	Large bioretention systems can have an upstream sediment pond with a bypass weir to divert high flows around the bioretention system. Streetscape bioretention systems can backwater to the street to divert excess flows to a side entry pit. This avoids excess flows , scour and sediment loading.
Sediment capture area	Sediment forebays can be provided at the pipe outlet into bioretention systems to maintain inlet conditions. Depending on the catchment context, a sediment pond may be provided upstream of large bioretention systems. Where sediment ponds are employed up-stream of bioretention systems care is required in the sizing of the basin to ensure the basin does not prevent frequent flows from entering the bioretention system.
Bioretention properties	
Extended detention	Site characteristics will influence depth. Streetscape bioretention systems are typically suited to 100mm extended detention to reduce level difference with road and pavement surfaces and to reduce overall foot print in these constrained spaces. Depths over 300 mm may impact on plant health and pose public health and safety risks.
Filter media area	Dependent on catchment land use, imperviousness, extended detention depth and filter media saturated hydraulic conductivity. Additional area will be required for batters. Considerations for master planning may be 0.5-2% of the catchment (filter media surface area).
Filter depth	Shallower depths are at risks of drying out and may not be able to support vegetation.
Filter media properties	
Saturated hydraulic conductivity	Avoid higher hydraulic conductivities as the media will have low water holding capacity and result in drought-stressed plants.
Nutrient Content	Prevents leaching of nutrients from the media.
Organic matter content	Organic matter helps retain water for vegetation and can benefit pollutant removal, however higher levels may lead to nutrient leaching.
Grading of particles	Provides a stable media, avoiding structural collapse from downward migration of fines.
pH	AS 4419-2003 Natural Soils and soil blends helps with soil pH and plant growth.
Electrical conductivity	AS 4419-2003 Natural Soils and soil blends helps with plant growth.

Design Consideration	Design rationale
Horticultural suitability	Media must be capable of supporting healthy vegetation (assessment by horticulturalist). To support healthy vegetation over the long term.
Transition layer properties	
Material	Clean well-graded sand will prevents filter media washing down into the saturated zone.
Depth	To avoid migration of fines from the filter media and to avoid inundation of the filter media by the saturated zone.
Hydraulic conductivity (Ksat)	
Fine particle content	Appropriate sizing of fine particle content prevents the bioretention system leaching nutrients.
Particle size distribution	Bridging criteria- the smallest of sand particles must bridge with the largest of filter media particles to avoid migration of the filter media downwards into the transition layer.
Saturated zone properties	
Material	Clean sand or fine aggregate means the pore space between the sand/aggregate grains retains the water. Sand has a greater capillary rise and will be most beneficial during extended dry periods.
Saturated zone depth	Provides storage of water to maintain soil moisture and enhance nutrient removal.
Outlet properties	
Overflow pit / weir	Over flow pit with letter box grate or overflow weir to receiving waterway or swale takes flows in excessive of the extended detention capacity
Underdrainage pipes	Standing water in the filter media section of bioretention results in leaching of nutrients. Having regular underdrainage pipes ensures the system drains effectively and the water level within the saturated zone does not rise to inundate the filter media. Inspection access allows pipes to be inspected and flushed. The drainage aggregate avoids material falling into the slots of the drainage pipes.
Maintenance access	
Inlet zone Outlet	Inlet zones are required for large bioretention systems with dedicated sediment forebays. Most maintenance of bioretention systems is typically manual/ by hand. Consider access for a maintenance vehicle and where it can conveniently park for general inspection and maintenance activities.

Wetlands

Function

Stormwater treatment wetlands are specifically designed to accept and treat stormwater. They are densely vegetated water bodies that use enhanced sedimentation, fine filtration, adhesion and biological uptake and transformation processes to remove pollutants from stormwater. Water levels in the wetland rise during a rainfall event and are detained and slowly released over two to three days.

In the ACT, wetlands are generally constructed offline. There are a number of considerations required from the ACT Government if wetlands are to be online and it will be treated on a case-by-case basis. Contact the City and Environment Directorate for further information. Offline wetlands are located adjacent to a drainage line or waterway. A proportion of flow is diverted from the waterway into the sediment basin of the wetland system for water quality treatment. Wetlands may also be within a drainage path but may feature a bypass system to divert stormwater events of a given zone around the wetland to protect the integrity of the system. An online wetland is located within the waterway or drainage line with base flow and high flows pass through the system.

Key design guidance

Wetlands will typically have the following elements:

→ A sedimentation zone to treat sediments of greater than >125 µm in the stormwater prior to discharge to the vegetated wetland zone. This zone will typically incorporate a high flow bypass system to avoid damage to vegetated areas and resuspension of trapped sediments in storm events larger than the wetland design storm

→ A vegetated wetland (macrophyte) zone to provide treatment via uptake the uptake, decomposition and transformation of stormwater pollutants and plant litter. The wetland zone should also include an inlet pool to enable even flow distribution through the vegetated areas, intermediate pools between areas of dense plantings to mitigate short circuiting of flows, and an outlet pool to minimise the risk of blockage of the outlet

→ Balance pipes to ensure open water zones have a consistent water level and to enable the wetland to be drawn down for maintenance

→ An outlet system that acts as a hydraulic control to ensure the wetland operates as per the design hydrological regime

A typical wetland layout is shown in Figure 15 and Figure 16.

Figure 15 Typical wetland schematic plan view

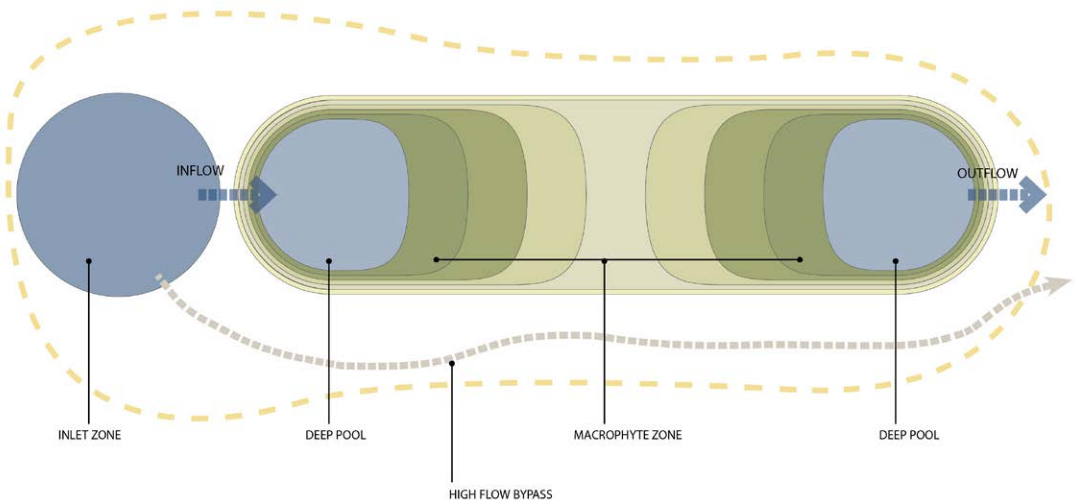
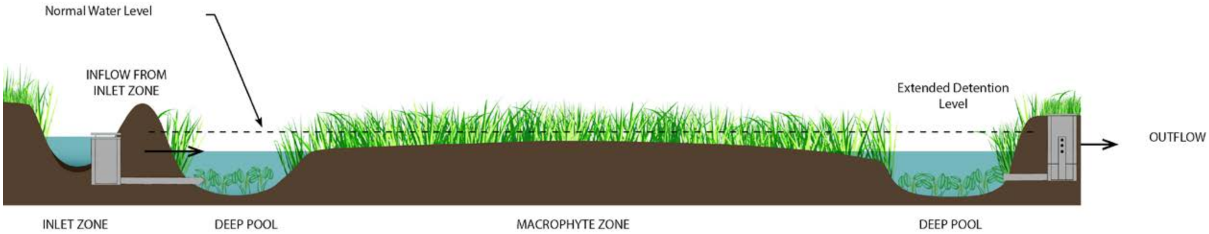


Figure 16 Typical wetland longitudinal section



Design constraints and key risk factors

Wetlands are not ideally suited to sites with:

- undulating and steep topography (>5%): A cross fall >2 m can be problematic for the depth of embankments required for the large, flat wetlands.
- limited space:
  - If there is less than 100 m^2 available, the combination of width, depth and edge profile will prevent the flow being uniformly distributed in the wetland and instead be dominated by edge effects. Smaller systems may require hard edges and heightened safety considerations.
  - If the macrophyte area available is less than 4% of the upstream catchment, performance might be compromised through, for example, insufficient detention time, high velocities causing scour or vegetation damage.
- shallow bedrock, high water tables and sandy soils: These wetlands may be difficult to construct.
- high water levels: Vegetation can be difficult to establish and maintain if water levels are too deep. It is recommended that extended detention depths not exceed 0.35 m and wetlands with a small area compared to catchment ratio need to have inundation frequency analysis undertaken to inform appropriate planting designs as these systems will experience flows more frequently.
- large flow volumes and velocities: Systems which are online or within floodplains need to be carefully designed to control how infrequent flows enter and flow through the wetland to maintain velocities less than 0.5 m/sec.

Although these site characteristics do not preclude the use of wetlands, they trigger the requirement for additional design considerations with potential cost implications.

The loss or lack of emergent wetland vegetation poses a key risk to the overall treatment function and resilience of the wetland. Some constructed wetlands do not establish or sustain adequate plant coverage. Some potential causes of this include:

- the normal water level is too deep for healthy plant growth
- damage to plants from waterfowl
- prolonged inundation during rainfall events, due to the wetland being poorly sized for its catchment, outlet not having sufficient capacity, or outlet being prone to blockage.

Narrabundah wetlands, ACT

Sizing guidance

Wetlands can be constructed on many scales, from lot scale to regional scales. They can be designed with hard edges and be part of a streetscape or forecourt or they can designed to be more natural looking.

They will typically be sized between 7–10% of the catchment (including sediment basin, batters and macrophyte zone).

It is important to use the following sizing guidance to inform the design of the system:

- → Sediment basin is typically around 5% of the macrophyte zone area.
- → Inlet and outlet ponds are typically 10% of the macrophyte zone.
- → Macrophyte zone covers 80% of the wetland area and bathymetry needs to accommodate a range of planting depths.
- → Intermediate zone: Inbetweenthe inlet and outlet zone/pond maybe required for large wetland systems.
- → High flow bypass is typically sized to convey the 1% AEP event.

Table 24 Wetland WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	Stormwater treatment wetlands are a landscape feature which are designed to have permanent pools within them, reducing the requirement for irrigation which can have potable water savings.	Passively irrigated landscape feature which does not require potable water for on-going performance.
Stormwater quantity	Wetlands capture and detain the frequent flows (typically the 4EY) for 48-72 hours within the extended detention volume to allow treatment processes to occur. Additional storage of larger flows can be provided above this which is released within a couple of hours (typically), providing an opportunity for some coarse sediment to be deposited, whilst not impacting on (drowning) the wetland plants.	Wetlands can be designed into the floor of flood detention basins with temporary short term flood storage above the extended detention storage when designed with a flood detention spillway which controls outflow and avoids scour of the wetland and banks.
Stormwater quality	Wetlands provide treatment targeting fine sediments, metals and particulates and dissolved nutrients.	Wetlands meet pollutant load objectives when designed to meet best practice requirements.
Climate change adaptation	Wetlands retain water in the landscape, provide evapotranspiration and slow and temporality store stormwater flows.	Local microclimate benefits are provided by keeping water in landscape and evapotranspiration.

Detailed design considerations

It is important that the wetland is sized appropriately for the catchment size to ensure hydraulic loading is not too large or too small to hinder the wetlands stormwater treatment performance and success for the wetland plants. The following table provides design parameters for stormwater wetlands designed in accordance with current best practice.

When designing atypical stormwater treatment wetlands, for example a wetland undersized for its catchment (i.e. with low hydrologic effectiveness), careful consideration needs to be given to outlet design, extended detention depth, time and normal water levels to ensure the wetland plants will be sustained and not drowned out by over inundation. Inundation frequency curves are recommended.

Table 25 Wetland design considerations

Design Considerations	Design rationale
Sizing	
Macrophyte zone	Macrophyte zones of this area will be able to achieve best practice stormwater treatment and will receive inflows often enough to support good plant health. Considerations for master planning is sizing of a minimum of 4% of contributing catchment.
Total wetland area	Total wetland is greater than the macrophyte zone area due to the inclusion of sediment pond, batters, etc. Considerations for master planning is sizing of a minimum of 4% of contributing catchment.
Inlet properties	
Low flow bypass	No low flow bypass.
Scour protection at inlet pipe	Required scour protection is dependent on pipe size and velocities rock apron, structural soil (rock mixed with soil) and/or flow resistant plant species.
High flow bypass	Bypass weir incorporated into inlet pond with sufficient length to convey above design flows. The bypass channel should have enough capacity to convey above design flows with sufficient scour protection. High flow bypass ensures protection of the macrophyte zone.
Inlet pond volume	Sediment ponds sized smaller than this will result in large particles entering the wetland, potentially smothering the vegetation. Sediment ponds sized larger than this will capture fine sediments and pollutants and will be at risk of poor water quality and algal blooms.
Inlet pond level	Inlet pond permanent pool levels to sit above the macrophyte zone permanent pool level.
Macrophyte zone properties	
Extended detention	Extended detention depths above the approved standard can result in plants drowning.
Permanent deep pools area and depth	Area – It is recommended that the total surface area of the pools be 20% of the total macrophyte zone area. Depth – deep pools should ensure permanent deep pool habitats. The deep pools ensure they provide a permanent refuge for mosquito predators during extended dry periods.
Vegetated macrophyte zone area and depth	Consideration for masterplanning means macrophyte zones need to cover 80% of the wetland to achieve best practice stormwater treatment as this is where the majority of the stormwater treatment occurs. The vegetated zone is designed to have complete vegetation cover, be gently grading and have water depths. Having a range of depths allows areas of the base soil profile to experience wetting and drying, which aids in the removal of phosphorus from the stormwater. Planting density is influenced by plant species.
Slope	Shallow slopes allow plants to grow and adapt to the wetland conditions. Steeper grades into deep water reduces the encroachment of planting into the deep pools which are designed to be open water zones. It is important all surface grading is smooth to ensure there are no isolated pools where mosquitoes can breed.

Design Considerations	Design rationale
Velocities	Velocities above the standard can result in the removal of biofilms from the vegetation surface. These biofilms remove the majority of nitrogen from the stormwater. High velocity flows can also damage vegetation.
Intermediate zone properties	
Depth	Provide the transition between the inlet and outlet zones for large wetland systems. Deep zones in the wetland help to break short-circuits when placed as intermediate pools and provide some degree of treatment via sedimentation, microbial processing in the substrate and via algal oxygenation and nutrient uptake in the water column.
Outlet zone properties	
Equivalent pipe diameter (riser outlet)	Typically sized to achieve the desired notional detention time (see below).
Overflow weir width	Typically caters for bypass of flows up to the capacity of the inlet structure. Where a wetland is fully on-line to its catchment it is recommended that high flow velocities through the wetland not exceed 0.5m/sec for the 1% AEP.
Notional detention time	Preferred time allows contact time for nutrient processing to occur whilst supporting plant health (not inundated for long durations) and drains to provide detention capacity for the next storm event.
Maintenance access	
Inlet zone	Provide access for maintenance machinery to measure and remove sediment. Access ramp and sediment dewatering area is required to allow sediment clean out when the basin is half full (sizing of sediment basin should result in clean-out every 5 years).
Dewatering area or drying pad	Area located next to the sediment pond for the placement of excavated sediments to allow dewatering. Water draining from the sediments is encourage to flow back into the sediment pond. This will reduce the cost of transporting sediment offsite. Sediments may also be spread to negate taking it offsite (if classified as low hazardous waste). These areas will be infrequently used and so can be grassed and part of the general landscaping. Some re-instatement may be required after a clean-out depending on the landscape design.

Dickson wetlands, ACT

Ponds and lakes

Function

Lakes with the primary function of providing landscape amenity and recreation opportunities should be considered as receiving environments and have stormwater treatment systems located upstream to protect the water quality.

Ponds are typically constructed open water bodies with fringing vegetation and submerged macrophytes. They retard storm flows and provide some stormwater treatment, predominantly through the capture and settling of sediments (down to coarse to medium silts).

Constructed wetlands are more effective at treating stormwater than ponds, particularly in relation to the removal of fine suspended particles and dissolved pollutants. However, where space or topographic constraints preclude the use of constructed wetlands (e.g. steep terrain), ponds may be appropriate as they have a smaller surface area to volume ratio. The use of stormwater treatment ponds should be limited to constrained sites with catchment geology predominantly yielding coarse to medium sized silt particles (Australian Run-off Quality (Engineers Australia 2006) Chapter 12 Constructed Wetlands and Ponds—Peter Breen, Tony Wong and Ian Lawrence).

When designing ponds for stormwater treatment there are key design considerations as outlined below.

IIn the ACT, ponds are generally constructed offline. Similar to offline wetlands, offline ponds are situated adjacent to a waterway while an online pond is located within the waterway or drainage line. There are several considerations if the pond is to be online, for example, the use of flumes to route water from the pond to a desired location. Proposals will be treated on a case-by-case basis. Contact the City and Environment Directorate for further information.

Key design guidance

Key design elements for ponds ensure they are sustainable systems with reduced risk and maintenance requirements. These include:

- simple shape and inlet and outlet placement to promote uniform distribution of flow velocity and to eliminate short-circuit flow paths and stagnant zones
- design of outlet control compatible with the hydrology and size of contributing catchment. Typically a riser outlet for control of extended detention and a bypass channel for high flows
- consideration of inundation depth and frequency of inundation at various depth ranges to inform and support fringing vegetation
- wedge shaped (deepest end towards the outlet) or a flat bottom with depths between 1–4 metres to encourage good vertical water column mixing and avoidance of persistent stratification
- size compatible with the hydrology and size of the catchment to promote flushing of the system and avoid problems associated with stagnant water and algal blooms
- good quality inflows or pretreatment to reduce the accumulation of organics, nutrients and fine sediments which impact water quality
- densely vegetated batters to reduce weed growth and provide a barrier for improved public safety
- factoring the draining and dredging of ponds into the design process for future operation and maintenance. Silted ponds can become a water quality and stormwater quantity issue (e.g. flooding).

Design constraints and key risk factors

- → Ponds are not ideally suited to sites with shallow groundwater, bedrock or highly permeable soils as they can be difficult to construct.
- → Poor water quality inflows (e.g. high proportion of fine particulates and/or organics) can lead to the accumulation of nutrients in the system which can lead to algal blooms and water quality issues.
- → In high profile/highly visible locations (e.g. regional or district parklands) competing primary objectives are likely (i.e. landscape amenity versus stormwater treatment/pollutant retention).
- → Erosion of inlets, outlets or batters occurs if hydraulics and hydrology are not appropriately considered in the design.

Sizing guidance

The size of a pond should depend on the catchment size (volume of inflows) to ensure that the residence time (turn-over of water) is less than 50 days.

Table 26 Pond WSUD performance summary

WSUD Elements	Function	Performance
Mains water use reduction	Ponds can be used to store water to be used for alternative water demands such as irrigation.	The reliability and volume of water that the pond can store for alternative uses depends on the catchment size and associated volume of stormwater, the demand and also the size of the system (it is important that water draw-down does not impact the batter vegetation health).
Stormwater quantity	Ponds can be designed as part of the flow quantity management for a site, detaining storm flows. This volume of detention can also be increased if water is stored for alternative uses.	The retention of flows in ponds reduces the volumes of water entering downstream waterways.
Stormwater quality	Ponds provide some level of treatment, targeting sediments and attached nutrients. However storing untreated stormwater in these open water bodies for prolonged periods of time lead to water quality issues and associated issues such as algal blooms.	Ponds are unable to treat stormwater to meet best practice load reductions. They can contribute however if they are integrated into a treatment train as a stormwater harvesting storage which results in less stormwater (and pollutants) entering downstream environments.
Climate change adaptation	These retain water in the landscape and store stormwater flows	Local microclimate benefits are provided by keeping water in landscape. The reduction of peak volumes entering the stormwater network also helps to address nuisance flooding.

Figure 17 Typical cross sections of a lake (from Melbourne Water, 2005)

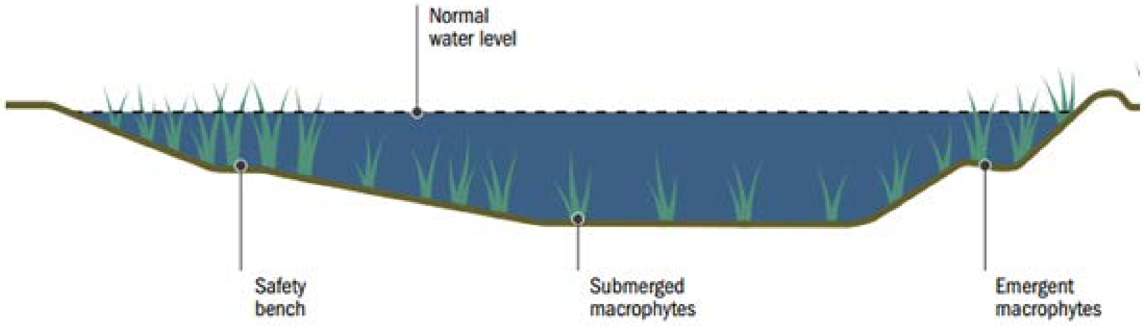


Table 27 Pond design considerations

Design Considerations	Design rationale
Sizing	
Pond area	Considerations for master planning may be 2-4% of the urban catchment. This is a rule of thumb to be used with caution. Sizing should be informed by residence time analysis and water quality objectives to be achieved (MUSIC modelling).
Residence time	Residence time help to reduce risk of algal blooms.
Inlet properties	
Inlet	The placement of inlets shall eliminate short-circuit flow paths and stagnant pools and reduce scour during periods of high inflow rates.
Low flow bypass	No low flow bypass.
High flow bypass	No high flow bypass required.
Batter properties	
Vegetation	Perimeter vegetation protects banks and improves public safety. Submerged plants provide oxygen to the sediments which helps to maintain good water quality. Floating plants can limit the availability of dissolved oxygen, block sunlight and contribute to organic matter and nutrient loading (due to rapid breakdown of soft leaf tissues).
Slope	The appropriate batter slope should be gentle enough to provide a safety bench for the public (i.e. should they venture into the water they can sense the water getting deeper and can easily retreat). City and Environment Directorate may consider steeper batter slopes (e.g. 1:4) if required and if adequately protected with specially chosen plants and increased planting density. Handrails are required for certain batters.
Open water zone properties	
Depth	Maximum depth is 3 m to reduce stratification of the water column. Minimum depth is 2.4 m to maintain open water zones and permanent pool.
Shape	Simple shape designs (not convoluted) with a minimum length to promote good mixing and eliminate stagnant zones. Ponds should be long relative to their width to provide better distribution of flows across the pond.
Extended detention	Maximising detention allows fine particles to settle and sunlight to kill bacteria, improving water quality outcomes.

Design Considerations	Design rationale
Outlet properties	
Overflow pit / weir	A primary outlet system helps to convey a proportion of the design flow to the outlet without compromising the other elements of the asset. A secondary outlet or spillway helps to prevent overtopping of embankments up to the design flood event.
Maintenance access	
Inlet	Access ramp and sediment dewatering area may be required to allow sediment clean out when the pond is half full.
Outlet	Access for maintenance shall be provided to all outlets.
Dewatering area	Area located next to the sediment pond for the placement of excavated sediments to allow dewatering. Water draining from the sediments is encourage to flow back into the pond. This will reduce the cost of transporting sediment offsite. Sediments may also be spread to negate taking it offsite (if classified as low hazardous waste). These areas will be infrequently used and so can be grassed and part of the general landscaping. Some re-instatement may be required after a clean-out depending on the landscape design.

Retarding basin sign, Lyneham, ACT

Flood management solutions

Retarding basins

Flood retarding basins are not considered a WSUD solution. They are a flood mitigation measure. They temporarily store stormwater from a drainage catchment for flood events and allow the downstream flow rates to be kept within the design capacity of the drainage system. The control of peak flow rates provides environmental protection to the downstream waterway. These basins are usually designed to reduce downstream flooding impacts (for the protection of human life and infrastructure/assets) associated with events up to a 1% AEP flood level.

Retarding basins are increasingly being recognised for their opportunity to be designed or retrofitted as a multifunctional asset combining flood mitigation function during flood events and incorporating a WSUD treatment element (such as a wetland) in the floor of the basin for water quality improvements during more frequent rainfall events.

The hydraulic performance of a retarding basin should be in accordance with the Municipal Infrastructure Standards MIS08 Stormwater (Chapter 10). The standards require performance to be tested using a range of 'design' storms or a long-term record of rainfall to determine the maximum storage requirements and the size of primary and secondary outlets for the basin. The maximum inundation period during the critical duration 1% AEP design storm must be 72 hours, to prevent long-term damage to grassed surfaces. The primary outlet must be sized to discharge all flows up to and including 1% AEP. The secondary outlet must be sized to discharge the full Acceptable Flood Capacity (AFC) AEP flow assuming that all primary outlets are 100% blocked.

In a new development area, flood retarding basins can be readily delivered by the developer. Managing and minimising the extent of impervious area and preserving floodplains will also contribute to flood management outcomes. Designs should allow space for water and ensure overland flow paths are not restricted. Responsible floodplain management and planning needs to be considered not only within the bounds of a development site but beyond the site to ensure no worsening of flood conditions/levels upstream and downstream of the site. There should be no net loss of floodplain storage.

Step 2: Plant selection

Vegetation is an important component of many of the WSUD systems described in the previous sections. It is important to ensure suitable vegetation is used for the different systems so they establish successfully and survive.

While the identification of appropriate vegetation would actually be undertaken during the design process (step 1), it has been separated out as a step in these guidelines for ease of use.

Planting selection will depend on:

→ inundation tolerances

→ tolerance to exposure (e.g. hot dry conditions as well as cold and frosty conditions).

The following table provides a list of suitable plants for WSUD systems in Canberra. These species are either recommended for their known treatment performance and/or are known to occur in the ACT area and therefore should be adapted to the extreme climate conditions. Other species can be used to supplement these core species in treatment systems to ensure there is design diversity for WSUD across the ACT. These additional plants should be chosen carefully from local palettes to ensure they can tolerate the inundation conditions in the WSUD system.

Table 28 Recommended WSUD planting species for ACT

Vegetation species	Plant type	Suitable planting zone
Bioretention / swales / batters		
Imperata cylindrica	Grass	Bioretention
Carex appressa*	Sedge	Bioretention
Lepidosperma laterale	Sedge	Bioretention
Juncus amabilis*	Rush	Bioretention
Juncus flavidus*	Rush	Bioretention
Juncus fockei	Rush	Bioretention
Juncus usitatis	Rush	Bioretention
Lomandra multiflora	Rush	Bioretention
Lomandra longifolia	Rush (decorative flowers)	Bioretention
Leptospermum continentale*	Shrub (decorative flowers)	Bioretention
Kunzea muelleri	Shrub (decorative flowers)	Bioretention
Kunzea parvifoia	Shrub (decorative flowers)	Bioretention
Kunzea ericoides	Shrub / tree (decorative flowers)	Bioretention
Leptospermum granifolium	Shrub / tree (decorative flowers)	Bioretention
Leptospermum lanigerum	Shrub / tree (decorative flowers)	Bioretention
Leptospermum micromyrtus	Shrub / tree (decorative flowers)	Bioretention
Melaleuca pallida	Shrub / tree (decorative flowers)	Bioretention
Melaleuca paludicola	Shrub / tree (decorative flowers)	Bioretention
Wetland / ponds		
Baloskion australe	Rush	Littoral (edge) zone
Juncus usitatis	Rush	Littoral (edge) zone
Schoenoplectus pungens	Sedge	Littoral (edge) zone
Lepidosperma laterale	Sedge	Littoral (edge) zone
Carex appressa	Sedge	Littoral (edge) zone
Carex fascicularis	Sedge (decorative flowers)	Littoral (edge) zone
Gratiola peruviana	Herbaceous / flowering plant	Littoral (edge) zone
Lycopus australis	Herbaceous (decorative flowers)	Littoral (edge) zone
Lythrum salicaria	Herbaceous (decorative flowers)	Littoral (edge) zone
Persicaria decipiens	Herbaceous (decorative flowers)	Littoral (edge) zone
Veronica derwentiana	Herbaceous (decorative flowers)	Littoral (edge) zone
Baumea rubiginosa	Sedge	Littoral/shallow (0.0-0.2m deep)
Carex tereticaulis	Sedge	Littoral/shallow (0.0-0.2m deep)
Cyperus lucidus	Sedge	Littoral/shallow (0.0-0.2m deep)
Eleocharis acuta	Sedge	Littoral/shallow (0.0-0.2m deep)
Eleocharis equisetina	Sedge	Littoral/shallow (0.0-0.2m deep)
Gahnia subaequiglumis	Sedge	Littoral/shallow (0.0-0.2m deep)
Schoenoplectus mucronatus	Sedge	Littoral/shallow (0.0-0.2m deep)
Triglochin multifructa	Herbaceous (decorative flowers)	Littoral/shallow (0.0-0.2m deep)
Alisma plantago-aquaticum	Herbaceous (decorative flowers)	Littoral/shallow (0.0-0.2m deep)
Phragmites australis	Grass	Shallow (0.2m deep)

Vegetation species	Plant type	Suitable planting zone
Bolboschoenus caldwellii	Sedge	Shallow (0.2m deep)
Bolboschoenus medianus	Sedge	Shallow (0.2m deep)
Schoenoplectus validus	Sedge	Deep (0.35m)
Eleocharis sphacelata	Sedge	Deep (0.35m)
Bolboschoenus fluviatilis	Sedge	Deep (0.35m)
* As recommended in Adoption Guidelines for Stormwater Biofiltration Systems, CRC for Water Sensitive Cities		

Note: MIS 25 Plant Species for Urban Landscape Projects can be used in conjunction with the above list as a guide for the terrestrial planting around the WSUD assets.

Typically it is preferred that more than one species is used for each planting zone. This provides diversity and resilience in the design of the system (i.e. if one plant species does not establish successfully, the others will hopefully survive and replace it through natural recruitment). To support plant growth and reduce the risk of weeds, it is recommended that planting densities are 6–10 plants/m^2.

Deciduous trees should be avoided due to the sudden nutrient deposition in autumn and winter.

Wetlands, ACT

Step 3: Documenting WSUD designs and their expected performance

Once the design of the WSUD systems has been undertaken, the detailed designs need to be documented for consideration and approval. Following this approval, the systems can then be constructed.

For details of current processes for development application, design and approval, see https://www.cityservices.act.gov.au/plan-and-build.

It is recommended that at an early stage of the design and approval process, the staging of the WSUD asset construction and establishment is identified and a clear lifecycle cost analysis undertaken to provide City and Environment Directorate with confidence that the proposed WSUD asset can be delivered successfully and is the most appropriate solution for the site.

Table 27 presents a summary of the recommended tools to help inform and test the WSUD asset designs.

Appendix B provides a checklist which can be used to help guide and document the design of WSUD assets.

Patrick White Pond, Franklin, ACT

Table 29 A summary of the recommended tools which can be used to assist in the WSUD design process

Assessment tool	Type of analysis	Recommended use
MUSIC	Stormwater quality and quantity continuous simulation	→ Required → Current primary tool to assess stormwater quality treatment performance → Industry accepted and it is adequate and suitable for the purpose
MUSIC-link	Model assessment	→ Strongly recommended → Supports and checks MUSIC assessment
SWMM	Stormwater quality and quantity continuous simulation	→ Optional → Current secondary tool for stormwater quality assessment that is difficult to set up and not typically used
ACT Waterways Calculators	Water balance	→ Recommended → Current primary tool to assessment potable water reduction
BASIX (NSW)	Water balance	→ Recommended → Part of a broader sustainability assessment that can be used to complement the ACT Water Reduction Calculators
Green Star rating	Water balance	→ Optional → Part of a broader sustainability assessment that can be used to complement the ACT Water Reduction Calculators
ACT Rainwater tank guidelines	Estimate	→ Optional
MUSIC	Hydrology only	→ Recommended for estimating benefit of WSUD on small and frequent events
TUFLOW, MIKE, SWMM or similar	Hydraulics and hydrology	→ Recommended for understanding impact of WSUD on flow routing and flood extents
DRAINS	Hydraulics primarily	→ Optional

Step 4: Lifecycle costing and cost–benefit analysis

An important part of a WSUD strategy is presenting the business case for investment.

A lifecycle costing includes consideration of both upfront and ongoing costs to provide a full picture of the investment requirements. Where all WSUD options provide similar benefits (or are designed to meet a performance target), lifecycle costing can assist in the direct comparison and selection of a preferred option.

Where it is important to demonstrate the benefits achieved by the proposal relative to the cost, or to compare several options that offer various benefits, a cost-benefit analysis can be undertaken whereby the immediate and long-term benefits are also estimated and compared with the lifecycle cost. WSUD projects often provide a range of benefits such as amenity, water quality improvement, flood mitigation and mains water use reduction—these can be estimated and used to compare options to determine overall value for money.

The following sections describe how to estimate the lifecycle cost, and how to estimate benefits to develop a cost-benefit analysis.

Lifecycle cost

Lifecycle costing is a process to determine the sum of all expenses associated with a project or product. In carrying out a lifecycle assessment, it is recommended that the evaluation consider:

→ capital expenditure
→ operation
→ maintenance (scheduled and corrective)
→ replacement costs (i.e. vegetation replacement, desilting/sediment removal)
→ lifespan
→ renewal or decommissioning costs.

The following table provides details of what the assessment may consider in further detail.

Raingarden, ACT

Table 30 Key considerations for a lifecycle assessment

Lifecycle Staging	What to consider?
Capital expenditure	The value to be incurred by the purchaser who will buy or construct the WSUD asset or add value to an existing asset (i.e. retrofitting). Capital expenditure will include all costs of products, materials and labour required for installation and establishment. It is important to consider specific landscaping costs for integration of WSUD features into surrounding environments. Any design, management and approval fees required for construction should also be included.
Operation	WSUD devices are usually passive devices without moving parts or ongoing energy or water needs. Some systems may include a pump which will have an ongoing energy cost.
Maintenance	It is recommended an ongoing maintenance plan be developed which will help to estimate the expected ongoing costs of maintenance. In estimating the cost of maintenance, consider: → What maintenance activities are required? Certain activities may require the skills of different work crews (e.g. landscaping, litter removal, pipe and pit maintenance). → How regularly does the asset needs to be maintained? → Will a higher level of maintenance be required in the establishment period? The labour and material costs related to maintenance can be estimated through review of the maintenance plan, or an overall estimate may be obtainable from reference projects. Generally, there are two broad categories of maintenance: → Frequent scheduled maintenance, which is predicted by a maintenance plan. → Unscheduled corrective maintenance, due to unexpected extreme events or due to breakage or fault. A contingency could be allowed for corrective maintenance. Time for regular inspections should be accounted for as part of the maintenance plan. During these inspections scheduled maintenance may be able to be completed, and required corrective maintenance can be identified and scheduled.
Replacement costs	Some WSUD assets may have staged replacement scenarios rather than require being completely replaced. For example a raingarden may need to have certain sections of filter media replaced at certain times or after certain events rather than require being replaced completely. These replacement costs need to be factored into the lifecycle costings. Replacement scenarios should be itemised. It is recommended that the timing for significant expenditure also be considered so there are no surprises on the expenditure.
Lifespan	A number of assets such as GPTs will have a product calculation of its lifespan. However the lifespan will be calculated in optimal conditions such as being maintained as per the schedule of maintenance. Many asset managers face the reality of being unable to maintain the asset to the maintenance schedule and will apply a blanket rule in scheduling maintenance. Considering the likely maintenance frequency, it is recommended a realistic lifespan be factored into the lifecycle assessment.
Decommissioning or renewal costs	Some assets will require decommissioning once they have reached the end of their product life, while some assets will require decommission from asset failure. Decommissioning costs will need to consider the cost to remove the asset (including labour and equipment hire); disposal cost and a replacement cost if required. Other assets may be renewed or reset. Costs will need to consider which components can be retained and reused and which components need to be replaced.

When summing or annualising the various components of a lifecycle cost, a discount rate should be applied to future costs to calculate totals to a present day value.

In completing a lifecycle cost estimate, it is also important to identify cost-bearers. WSUD is often delivered and managed by different parties. For example a land developer may contribute the upfront capital cost, while the ACT Government, a site manager or local community groups may be responsible for ongoing maintenance. Costs to different parties should be clearly delineated in the lifecycle cost assessment.

Cost–benefit analysis

The costs of an asset can be estimated with relative ease. However, the benefits that are directly accrued to the development and indirectly attributed to the works within the development are typically more difficult to monetise.

Multi-functional WSUD landscapes have many advantages such as maximising water reuse and promoting amenity or helping developers meet requirements to achieve development approvals. Other positive social outcomes from WSUD landscapes could include better health and wellbeing, improved safety, enhanced liveability and amenity values, improved resilience, higher environmental values and and improved cultural linkages to the environment. Reducing the impact on receiving waterways and integration of WSUD treatment elements into adjoining natural areas is a positive environmental outcome.

The current application of WSUD in the Territory has many social, environmental and economic benefits. The following table provides a brief overview of the current and future social, environmental and economic benefits of WSUD and the importance to improve on WSUD in the Territory which could be considered in cost–benefit analyses.

Table 31 Social, environmental and economic benefits of WSUD

Social	Economic	Environmental
→ Improved liveability for the Canberra community through recreational wellbeing, enhanced amenity to waterways. → Water supply security. → Opportunities to create and enhance green spaces and introduce water into the urban landscape, benefiting the appeal of neighbourhoods. → Having water in our urban environment through evapotranspiration of trees and vegetation helps to alleviate the effects of heatwaves in built up urban areas, particularly for vulnerable communities.	→ Improved water quality has positive economic impacts including enhancing community use and tourism activities. → WSUD ensures that future assets are not compromised by flooding, excessive stormwater retention and detention and poor water quality. → Reducing mains water usage can have positive economic impacts for consumers.	→ Implementation of WSUD provides environmental benefits including improved water quality and greater biodiversity. → The future benefits of WSUD include alleviating climate change impacts, such as less predictable rainfall and increased flash flooding, and reduced impacts of the urban heat island effect and heat waves. → Continuing to reduce mains water usage has environmental benefits on water resources.

The estimation of the scale of these effects can broadly be done in three ways:

- → Qualitative assessment
- → Quantitative assessment
- → Monetised assessment

A qualitative assessment is undertaken by judging the likely relative scale of benefit expected and making a comparison between the performance of options. It may be suitable to agree a rating or score for the benefits achieved between a group of stakeholders. The lifecycle cost and a summary of the qualitative assessment (e.g. a score or set of traffic light indicators) can be compared together to assess options or present the overall recommendation.

A quantitative assessment involves the measurement of benefits through modelling or other means. Some quantifiable benefits which can commonly be estimated for WSUD include the following:

- → Reductions in pollutants (TN, TSS, TP)
- → Supplied amount of non-potable water for reuse
- → New vegetated area
- → Reduction in flood risk / flood storage provided

A mixed qualitative–quantitative assessment could be used to appraise all relevant benefits by allocating thresholds and scores for each value.

Raingarden during rain event, Isabella Plains, ACT

Thirdly, a monetised assessment can be developed, where benefits are estimated in equivalent dollar terms. To 'monetise' a benefit, evidence is needed to relate the scale of the benefit to a dollar value. Ideally, evidence should be drawn from studies or documentation from a relevant context and which has been conducted recently. Some examples of benefits that have been monetised for WSUD projects include:

- uplift in surrounding property values due to improved amenity offered by enhanced waterways, WSUD or green infrastructure
- value of nitrogen and phosphorous removal from sensitive waterbodies (estimated as the equivalent cost/tonne of removal measures elsewhere in the city to provide protection
- value of substitution of mains potable water supply (taking into account long term marginal costs of supply and transfer)
- value of increased land productivity and tree canopy cover.

Monetising of benefits may require specialist economics advice to ensure it is fair and representative. Once dollar values have been allocated these can be directly compared with the lifetime cost to create a benefit/cost ratio.

Further guidance on cost-benefit assessment can be found at:

- VISES 2015, Green Infrastructure Economic Framework, Victoria University, Melbourne
- Jones, R.N., Symons, J. and Young, C.K. 2015, Assessing the Economic Value of Green Infrastructure: Green Paper, Climate Change Working Paper No. 24, VISES, Victoria University, Melbourne.

Raingarden and Upper Stranger Pond, Isabella Plains, ACT

Step-by-step process to develop a cost–benefit analysis

Step 1: Select the options you would like to compare.

You may select several different WSUD designs. As a minimum, select the preferred WSUD design and an alternative but well understood option to compare it to. This may be a 'conventional' or 'business-as-usual' drainage solution which is typically defined as an urban development with water quantity control but not quality control

Step 2: Set the lifecycle period for analysis.

A life cycle cost includes all costs incurred throughout the 'lifecycle' of the project. A suitable lifecycle period should be selected for analysis, typically 20–50 years. The lifecycle period must be the same for all options so they are compared on a fair basis.

Step 3: Estimate the costs of each option over the lifecycle.

Refer to the discussion in the section above regarding life cycle costs. A lifecycle cost includes all costs throughout the lifecycle period, including capital construction costs, operation and maintenance costs and replacement and decommissioning costs. All costs should be estimated, noting the year in which the cost is anticipated to occur. Costs estimates can be estimated from similar built projects, based on advice from quantity surveyors or using published rates.

Step 4: Estimate the net present cost for each option.

A net present value (NPV) can be calculated to combine the present values of all costs into a single figure. A suitable discount rate should be selected in order to calculate present values. Discount rates of 3–7% are common for infrastructure.

Step 5: Estimate the non-monetised benefits of each option over the lifecycle.

As discussed in the section above, benefits could be estimated using qualitative and quantitative assessment. Select a suitable assessment method based on information and time available. The assessment should allow all options to be assessed for the same benefits, and for a comparison to be drawn for each. As a simple comparison, benefits can be assessed as 'low', 'medium' or 'high' or given a score out of 10.

Step 6: Estimate the net present benefit for each option.

If benefits have been monetised (equated to a dollar value), they need to be treated the same way as costs, whereby a discount rate is used to calculate a net present value from benefits that occur at different points in time. If using qualitative or quantitative assessment of benefits, benefits that occur in the future should be suitably discounted to represent a fair 'present value'.

Step 7: Compare the cost–benefit of each option.

Compare the net present cost of each option with net present benefit. If benefits have been monetised, a cost–benefit ratio can be created for each option by dividing the net present cost by the net present benefits. This should be supported by a score or traffic light assessment used to assess other non-monetised benefits to allow options to be comprehensively compared.

Harvesting vegetation
on floating wetlands,
Lake Tuggeranong, ACT

5. WSUD treatment assets construction and establishment

It is critical that WSUD assets are constructed and established correctly to ensure they will function as designed and have low ongoing maintenance requirements.

The inflow of sediment-laden stormwater run-off can impact the establishment and long-term function of WSUD assets. It is therefore critical to protect these systems while the contributing catchment is being built-out. This protection can come from:

- effective erosion and sediment controls in the catchment
- protection measures around the WSUD asset
- staged construction and establishment methods.

Typically this protection is required through construction phase and until the building phase is 90% complete.

Figure 18 Construction and building phases of urban development (figure from Water By Design Construction and Establishment Guidelines, 2010)

The Environment Protection Guidelines for Land Development and Construction in the ACT provide guidance on the preferred methods for pollution control design, construction, operation and maintenance). This includes sediment and erosion control, noise pollution, air quality and spoil management. These guidelines should be followed for all development and construction projects in the ACT.

This section of the guidelines provides additional recommendations specifically on how WSUD assets can be constructed and established successfully using current best practice approaches to protect them during the construction and building phases. The following table summarises the WSUD assets included in this section of the guidelines and the reasons that others are not.

Table 32 WSUD assets described in this section of the guideline and the reasons that others are not

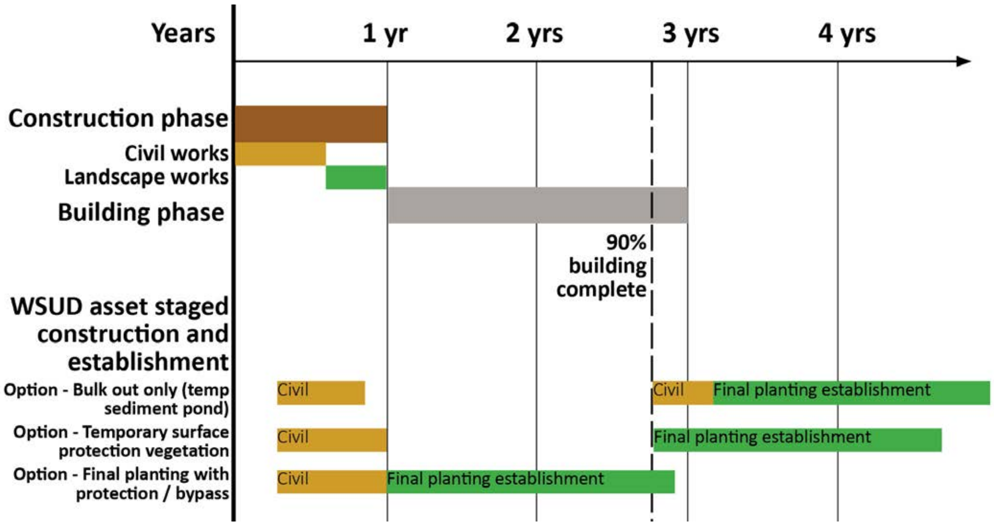
WSUD assets in this guideline	Construction and establishment advice	Reasons
Water efficient fittings and fittings	No	These can be installed at any stage of the building.
Porous pavement	Yes	
Infiltration systems	Yes	
Rainwater tanks	No	These can be installed at any stage and construction advice is provided in the Rainwater Tank Guidelines.
Stormwater harvesting and re-use	No	These systems will vary greatly, ranging from tanks through to open water bodies. The construction will depend on the type of system used.
Greywater harvesting and reticulated recycled water	No	The timing of this will depend on the civil infrastructure components of the development.
GPT	No	These systems are robust and can be constructed at any time during the development.
Buffer strips	Yes	
Swales	Yes	
Bioretention swales	Yes	
Bioretention basins	Yes	
Ponds	Yes	
Sediment basins	Yes	
Wetlands	Yes	

Patrick White Pond, Franklin, ACT

Staged construction and establishment approaches

Even with erosion and sediment control measures in place, some WSUD assets are at high risk during the building phase. To reduce this risk, staged construction and establishment methods can be adopted which aim to isolate the WSUD asset from the sediment-laden run-off. This staged approach has benefits and constraints. For example, early establishment of vegetation can provide high amenity outcomes, but the risk of failure is also higher.

Figure 19 Overview of typical construction and building phases of urban development with recommended staging options for WSUD assets



Porous pavements and infiltration systems

The primary function of porous pavements and infiltration systems is infiltration and therefore they are at high risk during the construction and building of the catchment as sediment laden run-off can clog the systems. It is recommended that these systems are staged so they are protected until the catchment is built out. Table 33 provides a summary of this recommended option, including the benefits and disadvantages.

Table 33 Recommended staged construction and establishment approach for porous pavements and infiltration systems

	Install system with surface protection and bypass
Building phase	
Actions	Construct functional elements of the system
	Install protective measures to bypass stormwater and ensure suitable erosion and sediment control is in place
90% building complete	
Actions	Remove protection devices
Benefits	
Water quality treatment during building phase	Low
Landscape amenity during building phase	Low
Disadvantages	
Delayed timing of final asset	No
Risk of sedimentation and asset failure	Moderate

Buffer strips and swales

Buffer strips and swales are vegetated systems which typically don't have any infiltration materials underlying the vegetation. Therefore there is little risk that sediment laden flows will clog the system, but they can impact the growth of vegetation. There is also little opportunity for these systems to act as sediment basins in the initial build out phase as they are designed to allow flows to pass through them at surface. The two proposed staging options are to either plant with sacrificial plants, which can be removed and replaced once building is almost complete, or to plant out with the final vegetation at the start. Table 34 provides a summary of these options, including the benefits and disadvantages.

Table 34 Recommended staged construction and establishment approaches for buffers and swales comparing benefits and disadvantages of options

	Staging option	
	Option 1: Temporary vegetation to provide surface protection	**Option 2: Final planting to provide surface protection**
Building phase		
Actions	Construct civil infrastructure	Construct civil infrastructure
	Topsoil shaped and turf or sterile rye used to protect surface	Topsoil and final planting
90% building complete		
Actions	Remove sediment build-up and replace temporary grass with final plantings	
Benefits		
Water quality treatment during building phase	Moderate	Moderate
Landscape amenity during building phase	Low	High
Disadvantages		
Delayed timing of final asset	Yes	No
Risk of sedimentation and asset failure	Low	Moderate

Bioretention systems

Bioretention systems (both bioretention swales and bioretention basins) are vegetated systems which rely on the filter materials for treatment of stormwater flows. Therefore it is very important to protect this filter media from clogging due to sediment laden flows through the construction and building phases in the upstream catchment. If this staging is not undertaken correctly, there is a risk that the bioretention filter media will clog and the system will need to be re-set completely. There are three proposed staging options for bioretention systems. The first is to build out the system and leave as a sediment basin; this option is not suitable for bioretention swales). The other options have the filter media installed at the start but either protected by covering with sacrificial protective layers (e.g. filter cloth, topsoil and turf) or bypassing flows around the system; this last option may also be difficult for bioretention swales. Table 35 provides a summary of these options, including the benefits and disadvantages.

Table 35 Recommended staged construction and establishment approaches for bioretention swales and bioretention basins comparing benefits and disadvantages of options

	Staging option		
	Option 1: Build out only (leave as sediment basin) – suitable to bioretention basins only	**Option 2: Temporary surface protection vegetation**	**Option 3: Final planting with protection / bypass**
Building phase			
Actions	Build out system and install hydraulic structures (do not plant)	Construct civil infrastructure	Construct civil infrastructure
	Allow to operate as sediment basin	Install filter media materials	Install filter media materials and plant out with final planting
		Install protection measures on top of filter media(e.g. filter cloth + topsoil + turf)	Bypass stormwater around system
90% building complete			
Actions	Clean out sediment, install underdrainage, filter media and final vegetation	Remove protective layers and establish final vegetation	Remove bypass
Benefits			
Water quality treatment during building phase	High	Moderate	Low
Landscape amenity during building phase	Low	Moderate to high	High
Disadvantages			
Delayed timing of final asset	Yes	Yes	No
Risk of sedimentation and asset failure	Low	Low	Moderate

Wetlands and ponds

The water and sediment quality within wetlands and ponds can be impacted by the accumulation of sediment laden run-off during the construction and building phases. The vegetation in the macrophyte zones in the wetlands can also be smothered by the sediments, impacting their growth and survival. Therefore it is recommended that if these systems are constructed and established early and accept sediment laden flows, they are treated as a sediment basin and de-silted once the building phase is almost complete. If wetland vegetation is to be established early to provide a high amenity landscape, it is recommended that the stormwater flows bypass the system until the building phase is almost complete. Table 36 provides a summary of these options, including the benefits and disadvantages.

Table 36 Recommended staged construction and establishment approaches for wetlands and ponds comparing benefits and disadvantages of options

	Staging option	
	Option 1: Bulk out only (leave as sediment basin)	**Option 2: Final planting with protection / bypass**
Building phase		
Actions	Build out system and install hydraulic structures	Construct civil infrastructure
	Allow to act as sediment basin	Install topsoil and plant final vegetation
		For wetlands - disconnect inlet pond from macrophyte zone
90% building complete		
Actions	Clean out pond and macrophyte zone (for wetland), install topsoil and final planting	Clean out pond and for wetlands - remove disconnection from macrophyte zone
Benefits		
Water quality treatment during building phase	High	Moderate
Landscape amenity during building phase	Low	High
Disadvantages		
Delayed timing of final asset	Yes	No
Risk of sedimentation and asset failure	Low	Moderate

Sediment basins

Sediment basins can be appropriate systems to use as part of an erosion and sediment control plan during the construction and building phases of a development. Therefore these systems can be built at the start of the development. However, they will need to be de-silted at the end of the building phase so they can operate as designed for the built catchment.

Dickson wetlands, ACT

Construction and establishment considerations

Once the construction and establishment approach has been determined, early consideration of the following is required to ensure the successful construction and establishment of WSUD assets. The following sections provide some advice on the key steps that may be required through this construction and establishment phase.

Understanding the construction requirements

Existing specifications for the construction and establishment of assets in the ACT may need to be considered for the construction of WSUD assets. They include the following Municipal Infrastructure Technical Specifications:

- MITS 02 Earthworks
- MITS 03 Underground services (includes stormwater)
- MITS 09 Landscape

These specifications are located online at https://www.cityservices.act.gov.au/plan-and-build/standards-codes-and-guidelines

The following sections provide some additional general guidance which may assist in the planning and construction and establishment of WSUD assets.

General guidance for WSUD asset construction and establishment

Ordering materials

To ensure the works are efficient, it is recommended that materials are ordered and supplied to site before construction starts. Typical materials include:

- pits
- pipes
- liners
- underdrainage
- topsoil
- filter media, transition layers, drainage layers
- plants
- sediment fences.

Construction tolerances

Achieving the correct tolerances is critical for the ongoing function of the WSUD assets. It is therefore recommended that 'as constructed' surveys be undertaken to ensure these tolerances have been met. Typical elements with tolerances that must be checked include:

- hydraulic structures (overflow pit, pipes, etc.) –/+25mm
- underdrains –/+25mm
- earthworks (base of systems) –/ +50 mm
- drainage and transition layers –/+25 mm
- surface levels –/+25 mm
- embankments and bunds –/+50 mm

Bioretention media specification and certification

The filter media is critical to the function of bioretention systems and must therefore be demonstrated that it meets the specifications set out in the Adoption Guidelines for Stormwater Biofiltration Systems (CRC Water Sensitive Cities, 2015). It is recommended that testing is undertaken on all bioretention media to ensure they meet these specifications.

The following table is taken from the Adoption Guidelines and presents the essential filter media requirements. More detail on the specifications for the other media components (e.g. transition layers and drainage layers) are provided in Appendix C of the guideline.

Saturated zones need to include a carbon source mixed throughout the submerged layers to drive denitrification. The carbon source should ideally:

- decompose in the first one to two years of operation while plant roots develop (which provide carbon over the longer term)
- be low in nutrients (appropriate materials include sugar cane mulch, pine chips (without bark) and pine flour ('sawdust').

It is recommended that the carbon source comprise approximately 5% (v/v) and include a mixture of mulch and hardwood chips (approximately 6 mm grading) by volume.

Topsoil specification and installation

MITS 09 Landscape details the type of soil which is suitable for different applications. The table of soil types is provided below. Performance criteria for each soil type are detailed in MITS 09.

Table 37 This table is from MITS 09 Landscape and provides the class of topsoil to be supplied for landscape works in the ACT

Soil Type	Applications
Type 1	Topsoil for irrigated grass or passive amenity turf
Type 2	Topsoil for non-irrigated dryland grass in open space and road verges
Type 3	Topsoil for garden bed planting – exotic and native species
Type 4	Topsoil backfill for advanced tree planting– native and exotic species
Type 5	Tree planting in paved areas – Structural support soil
Type 6	Subsoil backfill for advanced tree planting – exotic and native species.
https://www.cityservices.act.gov.au/__data/assets/pdf_file/0008/1387142/MITS-09A-Topsoil-1-0.pdf	

Quality of the topsoil is recommended to be tested to ensure it is suitable for supporting the vegetation and is free from weed banks. These tests will identify any amendments that are required before the topsoil can be used. If suitable, the existing site can be stripped and stockpiled for use, otherwise topsoils may need to be imported.

The installation of the topsoil will require the following:

- → Stripping and stockpiling of existing topsoil
- → Earthworks to ensure subsoil levels allow for required topsoil depth (see table)
- → Deep ripping of subsoils using a non-inversion plough
- → Re-application of stockpiled topsoils with remedial treatments if required
- → Adding imports topsoils where required

If the topsoil is being used within a wetland, it is recommended it is treated with gypsum or lime which facilitates flocculation, reducing the turbidity of the water column and allowing light to reach the plants. The gypsum should be applied at a rate of 0.4 kg/m^2. The application of lime may be required where the soil tests identify potential soil pH problems (pH <5).

Planting

It is critical that the correct planting considerations are undertaken to ensure successful establishment of vegetation in the WSUD assets. Establishment will typically take two growing seasons (two years) and will be considered successful if:

- → greater than 90% of plants survive and provide at least 80% coverage
- → at least 5 plants/m^2 but preferably 6–10 plants/m^2.
- → preferably more than one species
- → plant height increases at least 50% during the establishment phase
- → propagation is occurring, with more than 2–3 stems and through seeding
- → no weeds.

Types and densities

Correct plant species and densities need to be used to ensure successful establishment of vegetation in the WSUD assets. Ensuring the plants are suitable for the substrate and water level conditions and that there are high densities (6–10 plants/m^2) and diversity (at least two species per system) increases the likelihood of quick establishment of a dense and mature planting which will provide a high amenity landscape and good water quality treatment, and will also shade out weeds.

It is recommended the plant stock be mature when planted (300–500 mm high), sun-hardened and contain a fully established root ball. Key things to look for in plant stock that would impact their growth include:

- signs of pest and disease
- signs of nutrient deficiency (yellow wilting leaves)
- root-bound plants
- weeds.

The following tube stock sizes are recommended:

Table 38 Recommended tube stock sizes for WSUD vegetation

Tube type	Tube dimensions	Minimum height
Viro tubes	50 x 90 mm	300 mm
50 mm tubes	50 x 75-90 mm	300 mm
Native tubes	50 x 125 mm	300 mm

Mulch

Organic mulch cannot be used in zones where the systems are permanently or frequently inundated (e.g. base of wetlands). In bioretention systems, mulch that can break down quickly (e.g. sugarcane mulch) can be used during the establishment phase to maintain soil moisture; however, this will need to be pinned down with biodegradable netting (e.g. open weave jute mesh). Gravel mulch is not recommended as it can increase surface temperatures and kill the underlying root zones.

Watering

Regular watering is essential for successful plant establishment, especially in the ACT climate. The frequency of watering will depend on rainfall, maturity of planting stock and the water-holding capacity of the soil. Table 39 provides a summary of recommended watering regimes for to support vegetation during establishment.

Table 39 Recommended watering for WSUD asset vegetation establishment

Establishment period	Irrigation frequency
Week 1–6	5 times per week
Week 7–10	3 times per week
Week 11–16	2 times per week

After this initial four month period, additional watering may still be required, especially during dry periods. Watering requirements can be determined during inspections.

Water level manipulation

To maximise the success of vegetation establishment in wetlands and ponds, it is recommended that the water levels are manipulated during the early stages of growth. This is especially important for the establishment of deep marsh zone vegetation which are too small for the designed water depth when first planted. Water levels therefore need to be lowered to ensure the deep marsh plants have half of their stem above the water level.

This water level manipulation can be done by closing off the connection into the wetland or pond from the catchment and using the maintenance drain to set the desired establishment water level. When it is evident the vegetation is growing well and at the desired height (typically after 6–8 weeks planting), the connection can be temporarily opened to allow slow filling of the wetland or pond to the desired water depth. It is critical for the ongoing success of the vegetation growth that half of the vegetation stem is above the designed water level at this time.

Newly constructed stormwater retention ponds near Abena Avenue, Crace, ACT

Floodway Franklin, ACT

6. WSUD treatment asset operation and maintenance

Best practice WSUD asset management

Stormwater treatment assets require ongoing maintenance to ensure they function effectively and meet the desired performance indicators (such as treatment performance, amenity, public health and safety). WSUD infrastructure that is unable to perform to its original design has detrimental impacts. It places a strain on City Services in the maintenance process, which in turn has a social and amenity impact on the community, an environmental impact and an economic impact. Concerns over maintenance are commonly raised during public consultation for new proposals by concerned community members. However, if these assets have been established successfully (see Section 5), their operation and maintenance should be no different to any other landscaped area.

Operation vs Maintenance
Operation: The use of the asset to perform the designed function.
Maintenance: Actions undertaken to ensure the asset functions as designed.

The Municipal Infrastructure Standards MIS08 Stormwater outline some requirements for maintenance of stormwater assets, including maintenance access requirements. This section of the guidelines provides additional recommendations on how WSUD treatment assets could be effectively and efficiently maintained, including frequency of maintenance and the types of maintenance which may be required. The following table summarises the WSUD assets which are included in this section of the guidelines and the reasons that others are not.

Floodway and Christina Stead Pond, Franklin, ACT

Table 40 WSUD assets desribed in this section of the guideline and the reasons that others are not

WSUD assets in this guideline	Maintenance advice provided	Reasons
Water efficient fittings and fittings	No	This section focuses on public stormwater management assets, not plumbing fittings and fixtures within a building which will be maintained as part of building maintenance.
Porous pavement	Yes	
Infiltration systems	Yes	
Rainwater tanks	No	Maintenance advice is provided in the Rainwater Tank Guidelines.
Stormwater harvesting and re-use	No	These systems will vary greatly, ranging from tanks through to open water bodies. Maintenance requirements will depend on the system type.
Greywater harvesting and reticulated recycled water	No	This section focuses on public stormwater management assets, not on-site greywater systems or broader recycled water networks which will be maintained either by the building manager or water utility.
GPT	Yes	
Buffer strips	Yes	
Swales	Yes	
Bioretention swales	Yes	
Bioretention basins	Yes	
Ponds	Yes	
Sediment basins	Yes	
Wetlands	Yes	
Retarding basins	No	This section focuses on public stormwater management assets, not flood mitigation assets.

Gross pollutant traps require regular maintenance

Reasonable WSUD asset maintenance regime

Inspection frequency

It is recommended that routine inspections and regular operational actions are undertaken to ensure WSUD systems function as designed. Early detection of operational issues allow actions to be taken quickly, which can be more cost effective than leaving the issue unmanaged and later requiring costly maintenance (for example, the removal of weeds as they first appear is more cost effective than letting them establish throughout the system ,which will then require mass re-planting; prolonged high water levels in a wetland will drown out the vegetation, which is significantly more expensive to replace than changing the wetland outlet early before plant failure has occurred).

It is recommended that the following inspection frequencies are adopted for the different WSUD systems. This includes inspections after significant rainfall events.

Table 41 Recommended inspection frequency for WSUD assets

	Porous pavements and infiltration systems	Gross pollutant traps	Swales and buffers*	Bioretention swales and basins	Wetlands	Ponds	Sediment basins
Inspection frequency	3 months	Varies	4 months	3 months	3 months	3 months	3 months

* turf swales require more frequent inspections and regular operational works for mowing

If a system is consistently not meeting the performance indicators, the frequency of inspections may need to increase. If this increased frequency of operational inspections is not resolving the problem, maintenance actions to rectify the situation may be required.

Inspection activities

Frequent inspections and regular operation works undertaken on vegetated WSUD assets will typically include:

- → cleaning out litter and debris from inlets and outlets and from the surface or batters
- → desilting / removal of accumulated sediments
- → weeding (terrestrial and aquatic weeds)
- → mowing (e.g. turf swales)
- → revegetation.

Additional activities which may also be required include:

- → repairing inlets and outlets
- → addressing erosion and uneven surface levels
- → hydraulic testings (bioretention systems)
- → removal of surface crusts (bioretention systems)
- → cleaning of underdrains (bioretention systems)
- → adjusting water levels (wetlands and ponds)
- → water quality monitoring (ponds)
- → nuisance fauna
- → mosquitoes.

Table 42 provides more detail on these inspection items, including the recommended performance target and the part of the asset to be inspected for each inspection item.

Table 42 Recommended inspection items for WSUD assets, including the suggested performance target the element of the WSUD asset to be inspected

Inspection item	WSUD asset element to be inspected	Suggested performance indicator	Porous pavements	Infiltration systems	Gross pollutant traps	Swales and buffers	Bioretention swales and basins	Wetlands	Ponds	Sediment basins	Retarding basins
Litter / debris	→ Inlet /outlet → Surface → Batters	Minor litter or debris present	★	★	★	★	★	★	★	★	★
Sediment accumulation	→ Inlet/outlet → Surface → Batters → Open water zones	Minor amount of coarse sediment accumulation	★	★	★	★	★	★	★	★	★
Weeds	→ Surface → Batters → Open water zones	Maximum 10% cover of weeds No declared weeds	★	★		★	★	★	★	★	★
Mowing[7]	→ Surface → Batters	No overgrown turf				★					★
Vegetation health	→ Surface → Batters → Open water zones	Minimal bare patches Healthy plants				★	★	★	★	★	★
Structures	→ Inlet/outlet	No damage posing public safety or structural integrity risk		★		★	★	★	★	★	★
Erosion	→ Inlet/outlet → Surface → Batters	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended		★		★	★	★	★	★	★
Permeability / hydraulic testing	→ Surface	System is draining freely as designed	★	★			★				
Surface crusting	→ Surface	No surface crusting (fine sediments)		★			★				
Underdrain / clean out points	→ Under drainage	Clean out points not damaged and end caps in place	★				★				
Water levels	→ Open water zones	System is retaining water as designed (no more than 0.3m below NWL						★	★	★	

Inspection item	WSUD asset element to be inspected	Suggested performance indicator	Porous pavements	Infiltration systems	Gross pollutant traps	Swales and buffers	Bioretention swales and basins	Wetlands	Ponds	Sediment basins	Retarding basins
Surface levels	→ Surface → Batters	No surface mounding > 100 mm (can impact system drainage and treatment performance) No depressions > 100 mm (can result in isolated ponding and mosquito breeding)		★		★	★	★	★	★	★
Water quality	→ Open water zones	No odours or oil/grease Maximum 10% surface cover of algae/moss						★	★	★	
Nuisance fauna	→ Surface → Batters → Open water zones	No nuisance fauna causing issues to the function of the asset				★	★	★	★	★	
Mosquitoes	→ Open water zones	No problematic mosquito populations Permanent open water that can support mosquito predators						★	★	★	
Maintenance access provided	→ All	Adequate maintenance access is provided to the asset	★	★	★	★	★	★	★	★	★
Public health and safety issues	→ All	No features that will be cause potential public health and safety issues (e.g. tripping, drowning, structural integrity)	★	★	★	★	★	★	★	★	★

Operational and maintenance activities

The regular inspections may identify items that are not meeting the performance target and will therefore require actions to address this non-conformance. Depending on the scale of the non-conformance, remedial works required may be:

- simple, regular maintenance works that can be done during the inspection
- additional maintenance that may require some specialist skills or machinery and needs to be undertaken following the inspection
- extensive retrofit or rectification works if the issue is severe.

Actions are predominantly manual and can be undertaken using basic tools such as rakes, spades, shovels and hoes. The use of machinery and boats may be required depending on the type and scale of actions required.

The works will either be for landscape or civil components. Depending on the organisation structure, the inspections and actions may be undertaken by separate groups for these different items or they may be coordinated by one department.

The following table provides some guidance on how to undertake maintenance activities. Common, simple maintenance tasks are provided as well as additional maintenance works including uncommon or major rectification works.

Table 43 Guidance on how to undertake typical maintenance activities, identifying those which are simple to undertake as well as other and major rectification works

Action	Scale of works required		Civil or landscape components
	Simple maintenance	Major works / rectification maintenance	
Litter/debris removal	Litter and debris can be removed by hand during inspections. Boats or waders may be required to remove litter and debris from sediment basins, wetlands and ponds.	If litter is a continual issue, additional measures may need to be retrofitted – e.g. installation of GPT.	Civil
Sediment removal / desilting	Removal of minor sediment accumulation can be undertaken by hand. This also reduces risk of damage to vegetation.	Large scale removal will require larger machinery and need full replanting. If sediment removal is required from sediment basins, ponds, lakes or wetlands, dewatering will also be required. Vegetation will also need to be replaced if damaged during sediment removal. If sediment cleanout is required at an unacceptable or sustainable frequency, addition measures may be required (e.g. sediment basins).	Civil

Action	Scale of works required		Civil or landscape components
	Simple maintenance	Major works / rectification maintenance	
Weed removal	Weeds should ideally be removed as part of regular works. This is mandatory for declared weeds. A low level of undeclared weeds may be ok if it does not affect the function of the asset. Terrestrial weeds can be removed by hand or spot spraying. Aquatic floating weeds can be removed using floating booms or nets.	Persistent weed growth or excessive weed growth may require more regular inspections to be undertaken. If mass removal of weeds is required, this will need replanting of design species at high densities to provide cover and shade to inhibit the growth of weeds. Persistent weed growth may not be able to be managed through regular operational activities and may require investigation to identify the cause, for example uncontrolled weeds in the catchment which may require a broader weed management program.	Landscape
Mowing	Mowing can be undertaken as part of a regular mowing regime for assets which are designed with turf (e.g. swales).	If mowing is not possible due to consistent boggy conditions, the WSUD asset may need to be modified (e.g. underdrainage installed).	Landscape
Revegetation	Replanting small areas can be done using stock transplanted from elsewhere within the assets (e.g. for wetlands). Mature plants from a similar water depth can be divided by splitting at the base and directly planting into the new area. Use plant species which are growing well in other parts of the assets. Plant at density of between 6-10 plants / m2 and use a minimum of 2 species.	Major plant failure may be due to: → Poor planting substrate. → Selection of the wrong vegetation. → Poor establishment methods. → Disease or insect damage. → Damage by fauna (e.g. carp, birds). The cause should be identified and addressed to ensure plant failure does not occur again following revegetation.	Landscape

Table 44 Guidance on how to undertake additional maintenance activities, identifying those which are simple to undertake as well as other and major rectification works

Action	Scale of works required	
	Simple maintenance	**Major works / rectification maintenance**
Repairing structures	If the damage is not causing any issues, monitor the condition.	If the damage is causing issues to the structural integrity or public health and safety, repair or replace structure. Identify cause of damage and identify opportunities to reduce re-occurrence.
Repairing erosion	Minor erosion can be re-profiled using hand tools during inspections.	Large washouts may require large machinery and new fill materials and plantings. If erosion continues to occur, additional measures may need to be retrofitted – e.g. flow disposal or velocity dissipation options.
Uneven surface levels	Uneven surfaces can affect how water flows through a system and can also create isolated ponds. Minor depressions and mounds can be re-profiled by hand.	Major profile issues may require survey to identify how the surface needs to be reprofiled by machinery to achieve the design levels.
Hydraulic testing	Hydraulic testing can be undertaken on bioretention systems to test infiltration rates.	If infiltration is poor, it could be due to clogging due to fine sediments. Addressing this may require the removal and replacement of the top 100mm of filter material and replanting, or it may require a full re-set of the system.
Removing surface crust	Ponding in WSUD systems can be due to crusting of the surface (e.g. in bioretention systems). If this crusting is minor, it can be scrapped back using hand tools without impacting the vegetation.	If the crusting is severe and there is major clogging of the filter material, a full re-set of the system may be required.
Cleaning underdrains		Clogged underdrainage can be cleared out using high pressure water jetting. If there are blockages in PCV pipes, a drain cleaning machine can also be used.
Adjusting water levels	If it has not rained for 3 days and the water levels are still high, the outlet should be checked for blockages (which may be removed by hand). If the water level is low, check the inlet for blockages.	If the levels are high and there are no blockages, the outlet structure need to be modified or replaced. If the water level is much lower, the system may be leaking, too large for the catchment, the bathymetry may be too low or the inlet and outlet structures may not have been designed appropriately. These would all need investigation and would require replacement or re-profiling.
Mosquitos	Remove the breeding habitat (e.g. fill isolated depressions or remove dead or rafting vegetation around deep pools which can create isolated pockets of water that are protected from predators). Check water levels are able to maintain permanent water for mosquito predators.	If isolated pools or boggy conditions are continually occurring in a system which is not designed to hold water permanently (e.g. swales, bioretention systems, infiltration systems) then investigations are required to find out why they are not draining after rain and this needs to be addressed (e.g. underdrainage or outlet works might be required). If there are excessive mosquitos in the system, consult a mosquito specialist.

Action	Scale of works required	
	Simple maintenance	**Major works / rectification maintenance**
Water quality	Minor slicks can be left if they are not impacting the vegetation or function of a WSUD asset (e.g. wetlands are good at processing low to moderate concentrations of hydrocarbons). Floating filamentous algal mats are often seasonal and do not require action. Removal may be undertaken by hand using rakes, etc. to improve visual amenity.	*Oil spills* - The impact of moderate or major oil slicks should be minimised immediately through the use of barriers such as floating booms. The outlet of the asset should also be closed to avoid the risk of the oil spill entering downstream environments. For major spills it will be necessary to remove the bulk of the spill with an adductor truck. Medium to small spills in stormwater treatment systems could be manage in-situ by the application surfactants to break up the oil. *Algae* - If there is presence of blue-green algae or if there are other public health and safety concerns, signage should be placed around the WSUD asset and public access should be restricted through temporary fencing etc. Specialist advice should be sought before actions are undertaken. Excessive biomass of filamentous algae can impact asset function by blocking inlets and outlets and smothering vegetation. If the algae are impacting aesthetics of function of the wetland system, it can be removed by hand using rakes or with specialist machinery. If significant algae growth is observed on consecutive inspections, investigations should be undertaken to identify cause of algal growth. *Odour* - Odours are typically caused by decomposing organic matter, blue green algae, anoxic sediments or poor water quality. Investigations should be undertaken to identify cause of odour and appropriate management actions identified, such as removal or floating plants, blue green algae management, removal of sediment, management of oil slicks / spills and nuisance bird management. See Section 8 for recommendations for water quality monitoring.
Nuisance fauna	If large bird populations are causing issues to the bank stabilisation or water quality (such as ducks) signage can be installed to encourage the public not to feed the birds.	If Carp (common pest fish species) is present and causing damage to banks, vegetation and water quality, electrofishing can be used to remove the fish, however this is only practical in predominantly open water bodies. In heavily vegetated systems where electrofishing is not as effective, water level draw-down can be used to create a drying period which can control and eliminate carp. However this draw down period needs to be managed so it will dry the system long enough to kill the fish, but not to kill the vegetation. A fish poison such as rotenone could also be used but would require approvals. If bird populations are causing ongoing issues, look to remove their preferred habitat (e.g. islands and roosts).

Action	Scale of works required	
	Simple maintenance	Major works / rectification maintenance
Lack of maintenance access		To ensure actions can be undertaken on the treatment systems, maintenance access is required to structures and treatment areas. If this has not been provided, this will need to be retrofitted.
Unacceptable public safety		Permanent water (ponds and wetlands) can pose a potential safety hazard if there are steep matters, uncontrolled access and lack or perimeter planting. A risk assessment should be undertaken to identify the risk and to identify actions which would be required to address this (such as fencing, vegetation or batter re-profiling).

Considerations for undertaking maintenance

The following sections provide guidance on the types of considerations that are recommended when planning and undertaking maintenance.

Receiving environment protection

Care needs to be taken to ensure activities do not negatively impact on receiving environments.
For example, de-silting operations have the potential to release sediments to the receiving environment. Maintenance staff must be aware of these considerations when carrying out excavation of accumulated sediments. This would normally be done in dry periods when the risk of overflow to receiving environments is low.

Weeds also need to be managed and disposed of carefully to reduce risk of weed propagation throughout the downstream environment.

Safety and access

Occupational health and safety

Working near water and roads can potentially be a dangerous activity. It is therefore recommended that personnel be appropriately trained before undertaking maintenance work. Weather forecasts should be reviewed before undertaking maintenance activities and maintenance staff should be wearing Personal Protective Equipment (PPE) appropriate to their task or activity and consistent with relevant guidelines.

Up-to-date 'Dial Before You Dig' records are recommended so maintenance staff are aware of the location of existing services (i.e. sewer mains, power, communications). These services need to be appropriately protected before maintenance commences.

Public safety

If an activity is likely to pose a risk to public safety, it is recommended that access to the work area be appropriately screened to restrict public access.

Use of earthmoving equipment for de-silting operations will require a Traffic Management Plan to ensure pedestrian and traffic safety.

Note: Thick edge vegetation can be an important component to restricting general public access to a sediment basin, wetland or pond. Therefore it is recommended that vegetation be kept well maintained and in good condition, with dead plants replaced as soon as practical.

Maintenance access

Maintenance access should be considered and provided for all WSUD systems to allow for periodic works, including sediment and gross pollutant removal. The location of this maintenance access should be identified prior to undertaking maintenance. Note: It is also recommended that all activities close to water or roads be conducted according to pre-defined safety procedures.

WSUD asset operation documentation requirements

It is recommended that outcomes from the inspections and operation activities be recorded, identifying clearly ongoing maintenance activities required. This information should be kept in an appropriate operation and maintenance record file for future reference.

Using documentation to inform management decisions

Once the condition and maintenance requirements for WSUD assets are understood, the planning and funding of future maintenance works can be undertaken. Due to limited resources, WSUD asset maintenance typically requires prioritisation to ensure money is best spent.

Non-conformances should be recorded in a log and a corrective action plan logged and undertaken. Repetitive non-conformances need to be thoroughly reviewed to understand the root causes and take appropriate maintenance actions.

It is recommended that the following are used to prioritise maintenance works:

- Public health and safety: Higher priority is given to works which will address key public health and safety issues (for example flooding issues or embankment instabilities).
- Water quality treatment: Higher priority is required for systems where maintenance is required to rectify issues that impact the water quality performance of the system, especially if this system is upstream from a sensitive receiving environment.
- Simplicity of works: Higher priority should be given to works that can be easily undertaken or cheaply completed.
- Visibility and amenity: Higher priority is given to WSUD assets that are highly visible to address works that are impacting amenity (e.g. priority would be given to a streetscape system on a main street compared to a WSUD asset hidden behind fences at the back of a development).

Developing a fully costed maintenance schedule

To assist the long-term planning and budgeting of WSUD maintenance activities, it is recommended that the asset operation documentation is used to develop a fully costed maintenance schedule. This costed maintenance schedule would reflect the maintenance requirements required during the asset establishment period, the frequency of these actions and the cost to undertake these actions. This information can then be documented and provided to TCCS at the time of asset handover so there is a clear understanding of the ongoing maintenance requirements and costs for the WSUD asset.

Maintenance checklists

To assist in the inspection and maintenance process, template checklists have been developed as part of this guideline. These checklists, which can be used to guide and to record outcomes from inspections and maintenance activities, are at Appendix C.

Bioretention at
Ginninderra Creek,
Palmerston, ACT

7. Handover of WSUD treatment assets to the ACT Government

Typically, operational and maintenance activities are undertaken by the constructing party for the period until the asset is established and on-maintenance period is completed and the asset is handed over to the long-term asset owner.

Municipal infrastructure is handed over to City Services and requires a handover process. City Services requires a clear and accountable asset handover that outlines an operational procedure with maintenance requirements in order for maintenance to be carried out effectively.

Constructed municipal infrastructure assets are handed over to City Services after the following timeframes:

- 'Hard' civil infrastructure is handed over after a 12 months civil defects period has expired.
- 'Soft' landscape assets are handed over after a 13 week defects period (minimum)*.

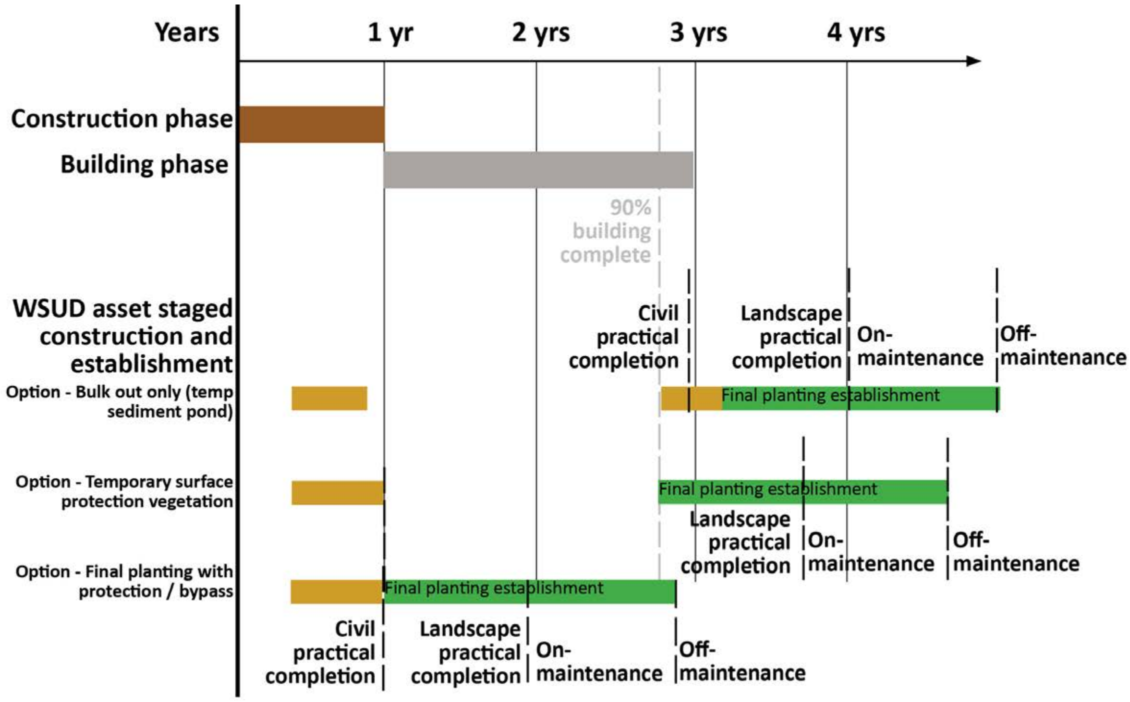
The handover requirements for assets to City Services is outlined on the ACT Government website: https://www.cityservices.act.gov.au/plan-and-build. This provides information about the lodgement process and provides the required forms.

*Due to the importance of the successful establishment of the vegetation in the majority of the WSUD treatment assets, it is recommended that the establishment and ultimate handover of vegetated WSUD assets differs from typical civil and landscape assets. This is because it requires two growing seasons (two years) before the asset is fully established and can be handed over. At this point the vegetation has a well-established root zone, ensuring the WSUD system is resilient (e.g. natural recruitment of vegetation to fill small gaps and porosity naturally maintained in bioretention systems). The timing of handover will therefore depend on when vegetation is planted and established in the WSUD system.

It is in the interest of the asset owner that the WSUD systems are fully established and operating to the desired performance targets at the time of handover as this will ensure the system is likely to continue to function as designed with minimal maintenance. If an asset is handed over to the asset owner before it is established or with design and construction issues which impact operational performance, the asset is likely to cost more in terms of long term maintenance and possible rectification.

Having clear guidance on the expected condition of the assets at the time of handover reduces the risk to both the constructing party and the eventual asset owner. The following provides a recommended multi-step handover process aimed to reduce risk throughout the handover process.

Figure 20 Recommended handover processes for WSUD assets associated with different construction and establishment options



Evatt wetlands, ACT

Recommended multi-step handover process aimed to reduce risk throughout the handover process

Pre-start

- This inspection takes place before any work has been undertaken on the WSUD asset.
- Purpose of this meeting is to ensure that the developer, contractor and compliance officer ae clear on the approval conditions, desired construction outcomes and the handover process.

Practical completion

- This inspection takes place once the WSUD asset has been constructed and planted before it is accepted for on-maintenance.
- This is the stage to identify if the asset has been constructed and planted as per the designs. If the asset is non-compliant, a request can be made to undertake major changes to the asset before pratical completion is signed-off.

On-maintenance

- Inspections can be undertaken throughout the on-maintenance period to ensure maintenance is being regularly undertaken by the developer / contractor as per the conditions of approval.

Off-maintenance

- This inspection takes place at the completion of the on-maintenance period before it is accepted by the ultimate owner as thier asset.
- The purpose of the inspection is to ensure the asset is free from defects, is fully established and is functioning as designed so the asset that is inherited is healthy, functional and stable, requiring only typical ongoing maintenance (i.e. no major works required).

The following tables can be used at each of these inspections to assist in the process.

Table 45 provides a summary of the inspection items which could be considered at the practical completion stage, before the stormwater asset is accepted onto on-maintenance. At this stage of the handover process, it is important that the asset has been constructed and planted as designed.

Table 45 Typical practical completion inspection requirements

Inspection item / requirements	Porous pavements	Infiltration systems	Gross pollutant traps	Swales and buffers	Bioretention swales and basins	Wetlands	Ponds	Sediment basins	Retarding basins
Civil components									
Certification requirements									
As constructed documentation	★	★	★	★	★	★	★	★	★
Designers certification of functional elements	★	★	★	★	★	★	★	★	★
Civil engineers certification of structural elements	★	★	★	★	★	★	★	★	★
Soil suppliers certification of topsoil				★		★	★	★	
Soil suppliers certification of filter media, transition layers and drainage layers with lab testing results					★				
Asset performance									
As constructed survey showing surface levels and structures (e.g. inlets, outlets, underdrains, connector pipes) are within acceptable limits of design levels	★	★	★	★	★	★	★	★	★
Minimum topsoil depths for planting provided				★		★	★	★	
Outlets and underdrains are free draining (no backwatering) and clear of debris		★	★	★	★	★	★	★	★
Outlets are controlling water levels to the required height to allow establishment of vegetation						★	★	★	
Extended detention depths not exceeding design levels					★	★		★	
Filter media, transition media and drainage media meet specifications					★				
Test results show hydraulic conductivity meets design requirements					★				
Temporary protection measures in place as per agreed construction and establishment approach				★	★				
Inlet sediment capture devices is installed as per design (e.g. sediment forebay in bioretention or sediment basin in wetlands)					★	★			
Landscape components									
Certification requirements									
As constructed drawings				★	★	★	★	★	

Inspection item / requirements	Porous pavements	Infiltration systems	Gross pollutant traps	Swales and buffers	Bioretention swales and basins	Wetlands	Ponds	Sediment basins	Retarding basins
Designers certification of plant species				★	★	★	★	★	
Asset performance									
Surface levels are consistent with design levels	★	★	★	★	★	★	★	★	★
Design species and planting densities achieved				★	★	★	★	★	
Plants healthy and free from disease				★	★	★	★	★	
No weeds or litter	★	★		★	★	★	★	★	★
No erosion	★	★		★	★	★	★	★	★
No sediment accumulation	★	★	★	★	★	★	★	★	★
Test results show hydraulic conductivity meets design requirements					★				
Inlet sediment capture device is operating correctly					★	★			
No leaking of water from permanent pools						★	★	★	
No permanent ponding water on surface	★	★		★	★				★

Table 46 provides a summary of the inspection items that could be considered at the end of the on-maintenance period, before it is accepted as an asset by City Services. This is an important inspection to ensure the asset is operating as it should and that the vegetation has been successfully established to ensure on-going maintenance should be minimal.

Large ponds and raingarden, Coombs, ACT

Table 46 Typical off-maintenance inspection requirements

Inspection item / requirements	Porous pavements	Infiltration systems	Gross pollutant traps	Swales and buffers	Bioretention swales and basins	Wetlands	Ponds	Sediment basins	Retarding basins
Certification requirements									
Evidence of any rectification works required	★	★	★	★	★	★	★	★	★
Completed maintenance forms from the on-maintenance period	★	★	★	★	★	★	★	★	★
Asset performance									
Design species and planting densities achieved				★	★	★	★	★	
Plants healthy and free from disease				★	★	★	★	★	
No weeds or litter	★	★		★	★	★	★	★	★
No erosion visible or surface depressions	★	★		★	★	★	★	★	★
No accumulated sediment	★	★	★	★	★	★	★	★	★
Inlet sediment capture device is operating correctly and is clear of sediment					★	★			
In-situ hydraulic conductivity >50mm/hr (100mm/hr preferred)					★				
Underdrainage clean out pipes have secured caps					★				
Extended detention depths not exceeding design levels					★	★			
No leaking of water from permanent pools						★	★	★	
No permanent ponding water on surface	★	★		★	★				★
Outlets are clear and free draining (no backwatering)	★	★	★	★	★	★	★	★	★

Monitoring water quality

Monitoring the water quality performance of WSUD assets is no easy task; it can be expensive and may not be necessary. It is important that the objectives of the monitoring program are clearly identified. If seeking to understand if a system is performing optimally, visual inspections to assess the condition of the asset to determine the appropriate course of action (as outlined in the maintenance section) should be undertaken. Visual assessment may include:

→ flow pattern (most relevant to wetlands and ponds) to identify the presences of short-circuiting that may inhibit the uniform distribution of inflow and optimal treatment performance

→ duration of inundation (most relevant to swales, wetlands, infiltration systems, bioretention swales and bioretention basins) to assess the operating detention time of these systems and to highlight potential clogging of soil media (bioretention systems) or blockages at the inlet/outlet structures that would have a direct impact on its performance in water treatment

→ sediment accumulation

→ vegetation density and health.

Water quality monitoring

Occasional sampling (grab samples) of permanent pool water quality in ponds and wetlands can be useful to determine the operation and health of the system. Sampling of the ambient water quality (sample taken at least five days after a flow event) can identify if the system is operating as expected and the quality of the water being flushed from the system for the next flow event is understood.

The ambient samples taken from ponds can also include an assessment for algal growth to identify a potential or existing human and ecological health concern with the water. If chlorophyll a values are recorded over 10 ug/L it is recommended that an algal cell count and species identification test is undertaken. Once this has been undertaken, the risk to the public and ecological health can be determined and appropriate management actions undertaken.

Floating wetlands aerial view, Lake Tuggeranong, ACT

If seeking to quantify hydraulic performance (% of total flow treated, % of flow bypassed, water levels, etc.) or water quality performance (pollutant loads captured) then long term datasets are required. Performance monitoring of WSUD assets can be undertaken through detailed water sampling and laboratory analyses for contaminant concentrations. It will be necessary to set up field monitoring sites to undertake the water quality sampling at inlet and outlet of systems. The water quality parameters which are typically monitored include:

- TSS
- TP
- FRP
- TN
- NOx
- NH3

The following points should be considered when undertaking a performance monitoring program:

- Auto-sampling with partial or full composite samples is most cost effective.
- Monitoring should be accompanied by continuous flow and depth observations.
- Design of monitoring set up and sampling intervals is site dependent.
- Water quality parameters should be analysed in registered laboratories.
- Erroneous performance assessment may occur when:
  - the volume of an inflow event is less than the permanent pool volume of system (most relevant to wetlands and ponds).
  - inaccurately accounting for the volumetric balance of inflow, outflow, or soil moisture replenishment.

Harvesting vegetation on floating wetlands, Lake Tuggeranong, ACT

Asset renewal and decommissioning

It is anticipated that WSUD assets will need to be renewed once they reach the end of their useful life. The useful life for each WSUD asset will be different and related to:

- whether the system has been designed, constructed and maintained according to best practice.
- catchment characteristics (influences the quality of the stormwater).
- general health of the system – the type of plants that have been used in the system.

Most WSUD assets will be renewed and never decommissioned as they are constructed to comply with environmental regulations, either as part of a development or as part of a responsible authority's relevant plan. However, it is recognised that well established assets such as wetlands and ponds may continue to function effectively well beyond this time and not require renewal as long as they are maintained effectively. Conversely, some assets may have failed due to poor design, construction or establishment issues leading to premature failure. These assets may need to be renewed or decommissioned before their expected useful life.

The decision to renew or decommission an asset may be influenced by the following considerations:

- Is the asset impacting (rather than protecting) the downstream receiving environment?
- Is the WSUD asset an ongoing liability to the asset owner and/or manager?
- Is an improved treatment system required to better protect the downstream receiving environment?
- Is it more cost effective to replace it with an alternative treatment system?
- Is there new technology available that will provide a better cost-benefit outcome?

Trash rack to sediment
bay, Kaleen, ACT

8. References

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Water by Design (2010) *Construction and Establishment Guidelines: Swales, Bioretention Systems and Wetlands. Appe*

Reference documents

A number of detailed guidelines are available nationwide and can provide additional information.

Concept design

Water by Design (2009) *Concept Design Guidelines for Water Sensitive Urban Design*. South East Queensland Healthy Waterways Partnership, Brisbane.

Detailed

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Water by Design (2012) *Transferring Ownership of Vegetated Stormwater Assets*

Dickson wetlands, ACT

9. Appendices

Appendix A: Pollutant reduction targets

The targets shown in in Table A1 are total values to be achieved from a development or redevelopment site or from a regional catchment outlet. They may be achieved by a single treatment measure or by a number of measures in a treatment train.

Table A1 Developer and regional pollutant reduction targets

Pollutant	Development or redevelopment sites[1]	Regional or catchment-wide[2]
Reduction in gross pollutant export load	90%	90%
Reduction in average annual TSS export load	60%	85%
Reduction in average annual TP export load	45%	70%
Reduction in average annual TN export load	40%	60%

1 See Zone Technical Specifications under the Territory Plan 2023

2 See Municipal Infrastructure Standards MIS08 Stormwater, Table 8-32

Many developments are located within catchments with varying amounts of urbanisation and the developments themselves can have varying amounts of imperviousness. For these circumstances, Table A2 outlines suggested targets at the outlet from the whole catchment (downstream of both urban and non-urban areas). In catchments with 50% or less urbanisation, offline treatment above the outlet from the urban area should be investigated as an alternative to treatment at the outlet of the whole catchment.

Table A2 Catchment-wide TSS / TP / TN Reduction Targets (%) Adjusted for Urbanisation and Urban Imperviousness

	Urban Imperviousness							
Urbanisation[1]	20%	30%	40%	50%	60%	70%	80%	90%
0% - 10%	23 / 15 / 15	27 / 18 / 18	31 / 21 / 21	35 / 23 / 23	38 / 26 / 26	41 / 28 / 27	43 / 30 / 29	45 / 31 / 30
11% - 20%	39 / 26 / 26	44 / 31 / 30	48 / 34 / 33	52 / 37 / 35	55 / 40 / 37	57 / 42 / 39	59 / 44 / 40	61 / 45 / 42
21% - 30%	50 / 36 / 34	55 / 40 / 38	59 / 43 / 40	62 / 46 / 42	64 / 49 / 44	66 / 50 / 46	68 / 52 / 47	69 / 53 / 48
31% - 40%	59 / 43 / 40	63 / 47 / 43	66 / 50 / 46	68 / 52 / 47	70 / 54 / 49	72 / 56 / 50	73 / 57 / 51	74 / 58 / 51
41% - 50%	65 / 49 / 45	69 / 53 / 48	71 / 55 / 49	73 / 57 / 51	75 / 59 / 52	76 / 60 / 53	76 / 61 / 53	77 / 61 / 54
51% - 60%	71 / 55 / 49	73 / 57 / 51	75 / 59 / 52	77 / 61 / 53	78 / 62 / 54	78 / 63 / 55	79 / 63 / 55	79 / 64 / 56
61% - 70%	75 / 59 / 52	77 / 61 / 54	78 / 63 / 55	79 / 64 / 55	80 / 64 / 56	80 / 65 / 56	81 / 65 / 57	81 / 66 / 57
71% - 80%	79 / 63 / 55	80 / 64 / 56	81 / 65 / 57	81 / 66 / 57	82 / 66 / 57	82 / 67 / 58	82 / 67 / 58	83 / 67 / 58
81% - 90%	82 / 66 / 57	82 / 67 / 58	83 / 68 / 58	83 / 68 / 58	83 / 68 / 59	83 / 68 / 59	84 / 68 / 59	84 / 68 / 59
91% - 100%	85 / 70 / 60	85 / 70 / 60	85 / 70 / 60	85 / 70 / 60	85 / 70 / 60	85 / 70 / 60	85 / 70 / 60	85 / 70 / 60

1 Urbanisation means the percentage of a catchment zoned urban, i.e. residential, industrial, commercial and urban open space

Example: 100 ha of land is zoned for urban development and is located in a 180 ha catchment. Expected overall imperviousness of the development is 50%. What are the targets for treatment at the outlet of the catchment?

Urbanisation = 100/180 = 0.555 = 55.5%

Urban Imperviousness = 50%

Catchment-wide Reduction Targets: TSS = 77%, TP = 61%, TN = 53%

Appendix B: Planning and design checklist

Step	Requirement	Outcome[1]	
WSUD Planning	Establish WSUD objectives	Potable water use reduction requirements	
		Stormwater quantity requirements	
		Stormwater quality requirements	
	Understand site characteristics	Site area	
		Topography	
		Receiving environments type and condition	
		Existing vegetation and habitat	
		Soil type	
		Existing infrastructure present	
		Expected pollutant type and loads	
	Identify Total Water Cycle Management (TWCM) key drivers and requirements	Wastewater capacity	
		Sensitive receiving environments	
		Potable water conservation	
	Develop WSUD Strategy	Lot scale solutions	
		Neighbourhood solutions	
		Treatment trains	
	Assess performance of strategy	Potable water use reduction performance	
		Stormwater quantity performance	
		Stormwater quality performance	
	Document strategy	Reporting meets requirements of assessment agency	

Step	Requirement	Outcome[1]	
WSUD Design	Develop design of treatment train elements	Treatment type	
		Treatment area	
		Design flows	
		Maintenance access provided	
		Civil structure design	
		Planting design	
		Landscape integration	
	Verification of designs	Treatment performance	
		Velocities	
	Documentation of designs	Documentation detail meets requirements of assessment agency	
		Lifecycle costing and cost benefit analysis undertaken	
		Staged construction, establishment and maintenance plans developed	

1 Insert details of how these have been considered and/or addressed.

Appendix C: WSUD inspection checklists

WSUD inspection checklist - Sediment basins

WSUD Asset:		**Inspected by:**	
Weather:		**Date of last rainfall:**	

Task Item	Performance target	WSUD element inspected	Observed condition	Maintenance required	Maintenance undertaken
Litter/debris	Minor litter or debris present	→ Inlet / outlet			
		→ Open water zones			
		→ Batters			
Sediment accumulation	Minor amount of coarse sediment accumulation	→ Inlet / outlet			
		→ Batters			
		→ Open water zones			
Weeds	"Maximum 10% cover of weeds No declared weeds"	→ Batters			
		→ Open water zones			
Vegetation health	"Minimal bare patches Healthy plants"	→ Batters			
		→ Open water zones			
Structures	No damage posing public safety or structural integrity risk	→ Inlet / outlet			
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	→ Inlet / outlet			
		→ Batters			
Surface levels	"No surface mounding > 100 mm (can impact system drainage and treatment performance) No depressions > 100 mm (can result in isolated ponding and mosquito breeding)"	→ Batters			

Task Item	Performance target	WSUD element inspected	Observed condition	Maintenance required	Maintenance undertaken
Water levels	System is retaining water as designed (no more than 0.3m below NWL	→ Open water zones			
Water quality	"No odours or oil/ grease Maximum 10% surface cover of algae/moss"	→ Open water zones			
Nuisance fauna	No nuisance fauna causing issues to the function of the asset	→ Batters			
		→ Open water zones			
Mosquitoes	"No problematic mosquito populations Permanent open water that can support mosquito predators"	→ Open water zones			
Maintenance access provided	Adequate maintenance access is provided to the asset	→ All			
Public health and safety issues	No features that will cause potential public health and safety issues (e.g. tripping, drowning, structural integrity)	→ All			

WSUD inspection checklist - Wetlands

WSUD inspection checklist:		**Inspected by:**	
Weather:		**Date of last rainfall:**	

Task Item	Performance target	WSUD element inspected	Observed condition	Maintenance required	Maintenance undertaken
Litter/debris	Minor litter or debris present	→ Inlet/outlet			
		→ Surface			
		→ Batters			
Sediment accumulation	Minor amount of coarse sediment accumulation	→ Inlet/outlet			
		→ Surface			
		→ Batters			
		→ Open water zones			
Weeds	"Maximum 10% cover of weeds No declared weeds"	→ Surface			
		→ Batters			
		→ Open water zones			
Vegetation health	"Minimal bare patches Healthy plants"	→ Surface			
		→ Batters			
		→ Open water zones			
Structures	No damage posing public safety or structural integrity risk	→ Inlet/outlet			
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	→ Inlet/outlet			
		→ Surface			
		→ Batters			
Surface levels	"No surface mounding > 100 mm (can impact system drainage and treatment performance) No depressions > 100 mm (can result in isolated ponding and mosquito breeding)"	→ Surface			
		→ Batters			

Task Item	Performance target	WSUD element inspected	Observed condition	Maintenance required	Maintenance undertaken
Water levels	System is retaining water as designed (no more than 0.3m below NWL	→ Open water zones			
Water quality	"No odours or oil/ grease Maximum 10% surface cover of algae/moss"	→ Open water zones			
Nuisance fauna	No nuisance fauna causing issues to the function of the asset	→ Surface			
		→ Batters			
		→ Open water zones			
Mosquitoes	"No problematic mosquito populations Permanent open water that can support mosquito predators"	→ Open water zones			
Maintenance access provided	Adequate maintenance access is provided to the asset	→ All			
Public health and safety issues	No features that will cause potential public health and safety issues (e.g. tripping, drowning, structural integrity)	→ All			

WSUD inspection checklist - Ponds and lakes

WSUD Asset:		**Inspected by:**	
Weather:		**Date of last rainfall:**	

Task Item	Performance target	WSUD element inspected	Observed condition	Maintenance required	Maintenance undertaken
Litter/debris	Minor litter or debris present	→ Inlet/outlet			
		→ Open water zones			
		→ Batters			
Sediment accumulation	Minor amount of coarse sediment accumulation	→ Inlet/outlet			
		→ Batters			
		→ Open water zones			
Weeds	"Maximum 10% cover of weeds No declared weeds"	→ Batters			
		→ Open water zones			
Vegetation health	"Minimal bare patches Healthy plants"	→ Batters			
		→ Open water zones			
Structures	No damage posing public safety or structural integrity risk	→ Inlet/outlet			
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	→ Inlet/outlet			
		→ Batters			
Surface levels	"No surface mounding > 100 mm (can impact system drainage and treatment performance) No depressions > 100 mm (can result in isolated ponding and mosquito breeding)"	→ Batters			
Water levels	System is retaining water as designed (no more than 0.3m below NWL	→ Open water zones			

Task Item	Performance target	WSUD element inspected	Observed condition	Maintenance required	Maintenance undertaken
Water quality	"No odours or oil/ grease Maximum 10% surface cover of algae/moss"	→ Open water zones			
Nuisance fauna	No nuisance fauna causing issues to the function of the asset	→ Batters			
		→ Open water zones			
Mosquitoes	"No problematic mosquito populations Permanent open water that can support mosquito predators"	→ Open water zones			
Maintenance access provided	Adequate maintenance access is provided to the asset	→ All			
Public health and safety issues	No features that will cause potential public health and safety issues (e.g. tripping, drowning, structural integrity)	→ All			

WSUD inspection checklist - Retarding basins

WSUD Asset:		**Inspected by:**	
Weather:		**Date of last rainfall:**	

Task Item	Performance target	WSUD element inspected	Observed condition	Maintenance required	Maintenance undertaken
Litter/debris	Minor litter or debris present	→ Inlet/outlet			
		→ Surface			
		→ Batters			
Sediment accumulation	Minor amount of coarse sediment accumulation	→ Inlet/outlet			
		→ Surface			
		→ Batters			
Weeds	"Maximum 10% cover of weeds No declared weeds"	→ Surface			
		→ Batters			
Mowing	No overgrown turf	→ Surface			
		→ Batters			
Vegetation health	"Minimal bare patches Healthy plants"	→ Surface			
		→ Batters			
Structures	No damage posing public safety or structural integrity risk	→ Inlet/outlet			
Erosion	Minor erosion that doesn't pose public safety risk and would not worsen if left unattended	→ Inlet/outlet			
		→ Surface			
		→ Batters			
Surface levels	"No surface mounding > 100 mm (can impact system drainage and treatment performance) No depressions > 100 mm (can result in isolated ponding and mosquito breeding)"	→ Surface			
		→ Batters			
Maintenance access provided	Adequate maintenance access is provided to the asset	→ All			
Public health and safety issues	No features that will cause potential public health and safety issues (e.g. tripping, drowning, structural integrity)	→ All			

ACT Practice Guidelines for Water Sensitive Urban Design

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