Transport for NSW

Water sensitive urban design guideline

Applying water sensitive urban design principles to NSW transport projects

NSW GOVERNMENT

Urban Design Roads and Waterways

Acknowledgements

This document has been prepared by the Urban Design Roads and Waterways section of the Customer Strategy and Technology division and the Planning, Policy and Assessment section of the Safety, Environment and Regulation division. Significant input has been received from across the transport cluster.

Image — Quakers Hill Station Commuter Car Park
Cover image — Swale within public open space created as part of the Westconnex Stage 1b project

Contents

Foreword

Producing positive urban design outcomes, and minimising impacts from infrastructure on the natural environment, in a way which reduces the burden on asset maintenance and whole-of-life costs, are measurable result areas for the NSW transport cluster.

'Water sensitive urban design' is a term which recognises that when used correctly, drainage and stormwater systems which replicate those found in nature, have advantages in meeting the following two objectives when adopted on transport infrastructure projects.

- They can improve environmental performance by capturing pollutants and slowing flow rates before stormwater is discharged beyond corridor boundaries.
- Their situation in the landscape means that stormwater infrastructure contributes to the quality of the built environment.

This document explores the lessons from the application of these principles, including where the principles have been successfully incorporated over many years, gives practical advice to project managers, design engineers and landscape and urban designers about how to design projects which adopt water sensitive urban design principles, and describes the considerations which will lead to a successful design.

Several techniques available for adoption, selected for their suitability for use in projects undertaken by Transport for NSW where considerations of safety, maintenance, space, aesthetics, sustainability, value for money and amenity together influence the type of environment we create that surrounds our projects.

This guideline was developed through a research and development process to investigate techniques available in the industry (local, national and international) and identify those applicable to transport projects given the constraints that may apply in different situations. It was developed collaboratively by relevant staff from the Safety Environment & Regulation, Infrastructure & Place and Customer Strategy & Technology divisions.

1 Introduction

1.1 What is water sensitive urban design?

Water sensitive urban design (WSUD) is the industry term describing the integration of water cycle management into planning, design and construction of the built environment. It is the term given to the replication of natural processes into treatment of water in a constructed environment and is relevant to all built environments from highly urbanised to rural settings.

The main interaction with the water cycle in the development and operation of Transport projects is through the management of stormwater, where the amount of hard surface area created during construction increases the volume and decreases the quality of water entering downstream waterways.

This guideline describes the application of water sensitive urban design principles and techniques which are appropriate to the construction and operation of the NSW transport network. Adoption of this approach where feasible and cost-effective will assist in development of a network which:

- More closely matches the pre-development stormwater regime, in both quality and quantity.
- Fits sensitively into its context.
- Reduces the amount of water transported between catchments intersected by projects, in particular linear projects such as road or rail corridors.
- Provides a higher level of consideration to projects passing through more sensitive waterways and catchments, and projects which cause the greatest amount of change to effective imperviousness.
- Best uses water resources (e.g. rainwater, stormwater etc.) that enters a project area.
- Is durable, functional and sustainable.

The approach essentially promotes the use of soft landscape areas (i.e. areas of turf and planting) for the conveyance, retention and treatment of stormwater. Because this approach replicates natural processes, it results in drainage systems being considered as part of the built environment rather than being hidden from view. The negative impacts of activities on the water cycle, namely an increase in pollutants, velocity and volume of water, caused by a traditional piped system can be avoided by this approach.

The effectiveness of WSUD as an approach for managing surface runoff has been common practice for many decades. For example table drains have been frequently used in verges on roads in rural NSW to allow stormwater falling on the pavement surface to be more conveniently distributed into the adjacent verge areas and allowed to infiltrate there instead of being piped directly into receiving waterways.

This approach differs from end-of-pipe water quality treatment systems and comes from a recognition that there can be benefits to treating stormwater closer to the source. This evolution is described in figure 1 on the following page.

> The main interaction with the water cycle in the development and operation of Transport projects is through the management of stormwater.

Figure 1. Evolution of stormwater design

NO TREATMENT OF STORMWATER

Drain everything to waterway Further urban development will increase impervious surfaces = more frequent flooding downstream	Solution: more underground piping and detention basins

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END-OF-PIPE APPROACH TO TREATMENT

Water Quality – new issue = cleaner waterways	Solution: create large end of line treatments

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WATER SENSITIVE URBAN DESIGN APPROACH

WSUD – current approach = cleaner waterways, increasing absorption thus reduction of stormwater runoff volumes; improved visual and amenity outcomes for the community	Solution: multi objective design, treatment trains

1.2 Purpose of this guideline

The purpose of this document is to provide guidance to project managers, civil designers, urban designers, landscape architects, stormwater engineers and planners on how to best apply WSUD to Transport for NSW (Transport) projects. This guideline does not mandate the use of WSUD techniques, but provides a range of industry-standard elements which can be practically incorporated into our projects and describes what situations are appropriate for each. It also considers broader design issues including construction cost, safety and maintenance requirements.

This guideline also provides a process to ensure that broader infrastructure design aspects are considered in the adoption of WSUD including:

- opportunities based on site conditions, e.g. slope and available land
- cost, both capital as well as operational
- maintenance requirements
- user and community safety
- water quality and quantity design objectives that have been committed to in the environmental assessment
- urban design objectives and opportunities.

It is not intended to be a technical manual providing detailed design advice, formulae and standard details, which are held elsewhere or would be developed throughout the design of a particular project to suit a specific need.

This guideline also provides a process to ensure that broader infrastructure design aspects are considered in the adoption of WSUD.

1.3 Application of the guidelines

This guideline primarily focuses on the incorporation of water sensitive urban design into the transport project development process (planning, development and implementation) and the assessment of benefits and impacts for maintaining the asset.

It includes all projects across all modes but in particular road, rail, light rail, and transitway projects which are linear in nature and cross a number of catchment boundaries, as well as commuter car parks, depots and other area-based projects which are developed by Transport.

An initial feasibility assessment early in the design process will help direct the decision to adopt a WSUD approach on a project or not. Even if it has been already committed to through an environmental assessment, one should also be carried out building on and refining the information already included in the initial environmental assessment. The types of factors which would need consideration include:

- Sensitivity of the adjacent environment — for a pristine environment or drinking water catchment, there would be higher need to ensure that water leaving the project is of a high quality compared to a degraded area where any improvement from the project would be of marginal value to the greater environment.
- Effective imperviousness — an understanding of the amount of change to the imperviousness of a project area compared to what is currently present.
- Space — the amount of physical space available may be a limiting factor.
- Environmental constraints — whether there are other environmental issues, such as the presence of national parks or threatened species and ecological communities, which may be regarded as being of a higher level of importance for a project to resolve or influence the amount of available space.
- Landform — overall topography of the land through which the project passes.
- Geology — the type of geology and soil types of the site will help to ascertain which WSUD elements may be best suited for implementation.
- The nature and scale of the project — a project's inherent scope may determine the amount of benefit that could be achieved by incorporating WSUD.
- Safety — an understanding of the safety issues that may be present when incorporating WSUD should be made. This would include for both user and maintenance personnel.
- Maintainability — the ability and capacity of the asset owner to maintain the WSUD element.
- Cost — whether the whole-of-life cost (capital as well as operational cost) of incorporating WSUD into the project is regarded as being sufficiently worthy of inclusion.
- Legislative or policy obligation — any Local, State or Federal planning or legislative instruments, or any internal or external requirements such as the Transport Sustainable Design Guidelines or the Infrastructure Sustainability Council of Australia Rating Tool.

2 Integrating water sensitive urban design into projects

2.1 Relationship between WSUD and wider organisational objectives

The design of transport projects is driven by organisation wide principles across a number of disciplines. Most importantly, it is implicit that a project should be inherently safe for both users and those maintaining or operating it. Similarly, the whole-of-life cost and performance of the network should not be compromised.

Several of these principles are common with those of WSUD, so multiple outcomes can be achieved through integrating WSUD within projects. However, without proper consideration WSUD may also conflict with broader organisational objectives — a cross-disciplinary approach to its consideration will ensure its proper integration.

2.2 Relationship between WSUD and wider organisational processes

2.2.1 WSUD and the Project Delivery Life Cycle

A common approach to project delivery is taken across the transport cluster, where a project will be considered in an increasing amount of detail from scope definition and options selection through concept and detailed design to construction and handover.

WSUD is best considered as early in this process as possible to allow its feasibility to be adopted by a project or corridor to be properly assessed. Once a decision has been made to adopt a WSUD approach, its design should be considered throughout the development, construction and operational phases as shown in the flowchart which follows (Figure 2).

2.2.2 Early consideration is important

The inclusion of WSUD into any project will require early planning to ensure it can be successfully integrated with corridor- or project-specific objectives and organisation-wide obligations such as safety, and value for money. When the project's physical design commences, WSUD should be considered in parallel with, and help guide, other design elements, such as drainage and landscape works. The critical factor in the planning process is to determine the WSUD objectives for the project, and what opportunities will be available to meet those objectives in the project design. Early planning will also ensure that sufficient space is made available to accommodate WSUD infrastructure, by either allocating existing land or purchasing additional land. It is recommended that the development of these WSUD opportunities be undertaken at or before the environmental assessment stage.

2.2.3 Stakeholder inclusion

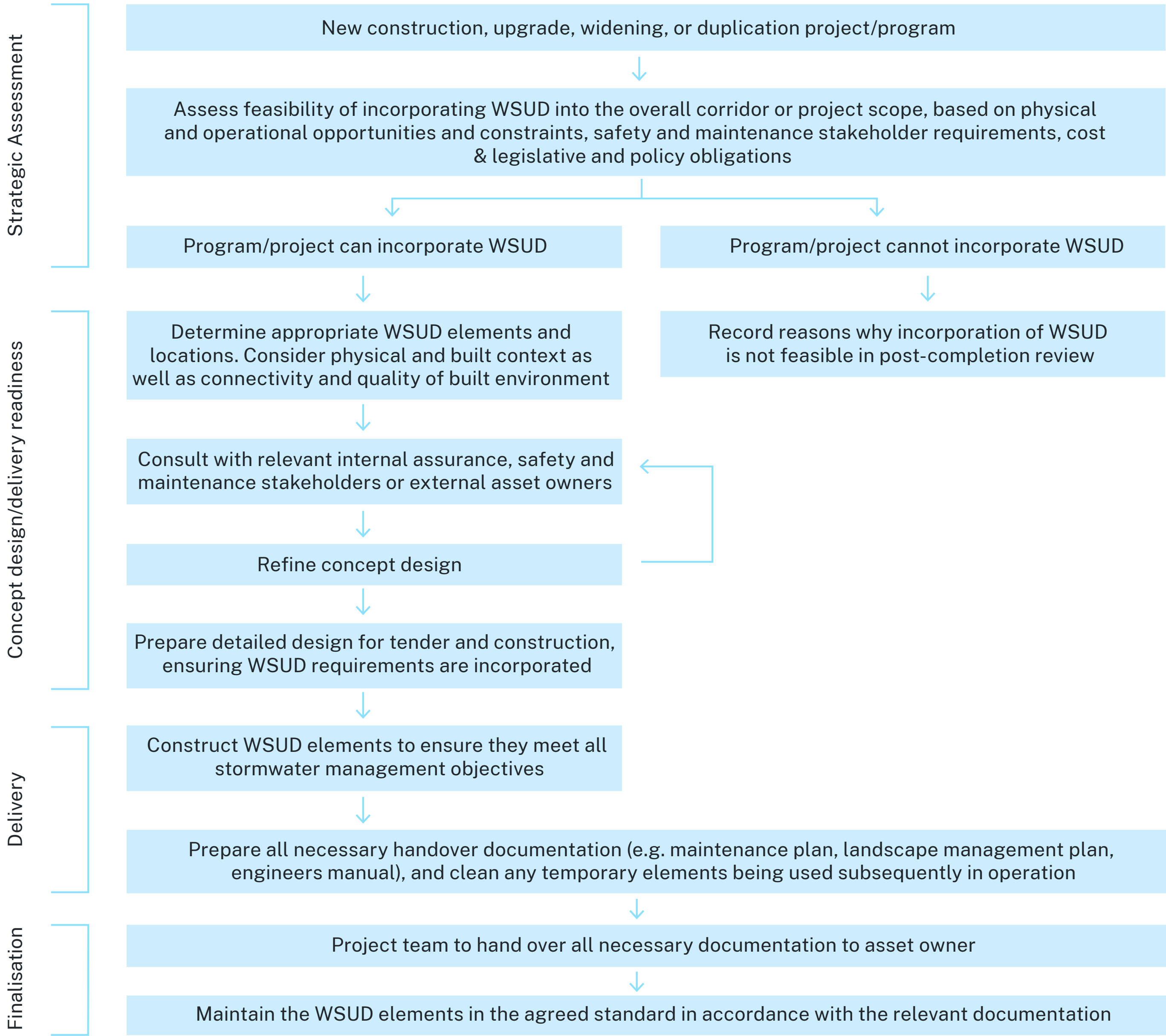
Project-specific WSUD objectives may be determined by consultation and negotiation with stakeholders, both internal and external. Further, most WSUD infrastructure will require some ongoing maintenance to remain effective, so inclusion and concurrence with the post-construction asset owner is fundamental to the success of the project. Relevant stakeholders might include:

- other internal sections within an organisation or agencies within the transport cluster (e.g. asset managers, Sydney Trains) who will take ownership of the asset post-construction
- external organisations (e.g. local councils and stewardship maintenance contractors) who will take responsibility of the asset post-construction
- NSW Department of Planning and Environment, including the Environment, Energy and Science Group
- Department of Primary Industries — Fisheries
- Infrastructure NSW
- local water authorities.

2.3 Relationship between WSUD and broader urban design and environmental policy

This guideline is intended to describe the benefits and desirable physical design outcomes of adopting a WSUD approach. It is supported by other technical guidance, policy and legislation available from subject matter experts within agencies which would be used by project teams to best incorporate WSUD to achieve the outcomes on projects described here.

Figure 2. WSUD Activities in the project development life cycle



3 Designing of WSUD systems

3.1 Design principles for WSUD

As stated previously, the physical design outcome of using WSUD systems is for drainage infrastructure to be considered as an integral part of the project landscape. Principles to meet the desired physical outcome of WSUD systems are:

- Stormwater management elements should be considered as part of a unified design of the project and contribute to a positive urban design outcome. They should visually and physically integrate with the adjacent built and natural context.
- Stormwater management should consist of a treatment train approach rather than an 'end of pipe' solution using multiple elements in combination rather than a single one in isolation to achieve water quality and quantity objectives. Elements should be located as close as possible to the point where adjacent hard surfaces discharge.
- The approach should aim to improve the quality of water discharged to waterways, with an amount of treatment being provided relative to the amount of change to the effective imperviousness of the catchment and the sensitivity of the receiving environment.
- The approach should minimise the intensity of stormwater events by managing the quantity of water as it passes through a project site.

3.1.1 Physical context

There is no 'one element fits all' approach to good WSUD. Good WSUD should be project specific — it should consider the project objectives, individual site, its landform, natural patterns/environments, heritage and cultural contexts and other site constraints and be innovative — there are no standard details and there should be no standard design approach. However in saying this, there are some basic design approaches that are relevant to all WSUD elements. Existing drainage systems may be disconnected from waterways in rural areas and have a very low effective imperviousness, with pollutants absorbed in open swales and vegetated buffer strips adjacent to roads. When infrastructure is upgraded, it is important to understand the existing hydrological and pollutant flows, and where possible, avoid making new drainage connections to waterways where none exist. Assessing proposed changes in effective imperviousness will provide the existing versus new drainage context, informing drainage and WSUD objectives. Drinking water catchments for example, may have significant size catchments, careful placement of water quality treatments at source to prevent drainage into waterways should be a priority to enable the effective protection of the water supply.

Figure 3. Pond near Windsor Road at Baulkham Hills

3.2 Incremental treatment approach

The concept of a water sensitive urban design approach is that it treats water incrementally and manages flow along the conveyance system (a 'treatment train'). This means that the requirement for an end-of-pipe device is minimised or eliminated. This fits well with transport projects which usually have space limitations.

A treatment train may be designed to address both water quantity (where the system is used to detain high volume flows and slow down their velocity) and water quality (where a range of sediments, pollutants and nutrients are removed from stormwater before it is discharged into receiving catchments). Treatment elements are arranged where they can have the most effect, and are classified as primary, secondary or tertiary depending on the size of contaminant they filter as shown in the following table.

Table 1. Treatment levels

Level of treatment	Description	Typical retained pollutants	Example
Primary	Screening of gross pollutants Sedimentation of coarse particles	Litter Coarse sediment	GPT
Secondary	Sedimentation of finer particles Filtration	Fine particles Attached pollutants	Grass swale
Tertiary	Enhanced sedimentation and filtration Biological uptake Adsorption on to sediments	Nutrients Heavy metals Free oils and greases	Bioretention Basin Wetland

Figure 4. Five Islands Road, Lake Macquarie

3.3 The whole

This section deals with the selection of WSUD elements at the planning and project-wide scale of design, while 'The Parts' section describes the WSUD elements themselves. The 'Detailed Design Considerations' section describes some considerations when selecting elements. These sections are interrelated, and should not be read in isolation.

Water sensitive urban design is implemented broadly to achieve a range of objectives. In order for these objectives to be met, it must be incorporated at the scoping and design stages of a project, when opportunities and constraints are considered. The approach to water management should consider stormwater as an asset with diverse purposes, not a liability.

In order for WSUD to be fully effective, designers should be looking to integrate stormwater with recreational and ecological landscape functions in a way that conventional piped stormwater infrastructure cannot. This multi-disciplinary approach sets WSUD apart from the singular function of conventional stormwater systems.

Water sensitive urban design systems can range from localised treatments to larger precinct based systems, and do not need to comprise only typical and well-defined elements. Intermediate designs which combine the benefits of more than one element and are appropriate for a specific site should be considered. This allows for an evolution of WSUD design limited only by the creativity of the designer.

Figure 5. Bioretention swale at Lawson

Figure 6. Rock lined swale which leads to a basin at Bullaburra West

3.3.1 'Soft' vs 'hard' engineering or hybrid solution

Whilst WSUD elements will be most effective when vegetation is used in its design to reduce runoff, improve aesthetics and capture nutrients, factors such as the need for water to be transported across paved areas, land availability and topography may require piped (i.e. hard) components to be incorporated into a broader WSUD system. Permeable hard surfaces such as rock rip-rap or paving may also be included in the design to reduce runoff intensity whilst providing a level of durability. Further, more rectangular and hard-edged built structures may be more appropriate in some locations, particularly in urban environments. There is no standard approach that should be applied to all situations.

3.3.2 Identifying site-wide opportunities and constraints

Water sensitive urban design elements should be considered as part of the overall site landscape and integrated with the adjacent context. Some sites will provide opportunities for various WSUD options to be considered. However, in some situations a more extensive WSUD construction footprint may have a greater environmental impact than a piped solution.

Variables such as scale, region, topography, climate and rainfall will influence the way in which WSUD is implemented at each site. There are also many site-specific variables which cannot be captured within this guideline. As an example, a constructed wetland for containment and water quality may not be appropriate on a highly constricted ridgetop alignment, but could be the ideal solution in a rural floodplain environment.

The key to implementing appropriate WSUD systems is to firstly identify the site-wide design opportunities and constraints. This will require investigation beyond the site boundaries, and sometimes at a catchment scale.

As well as responding to performance criteria, the main issues to consider are:

Design

The drainage designer, landscape architect and civil designer need to consider opportunities and constraints for WSUD in the concept design phase. Methods of design which can facilitate the implementation of WSUD are:

- design main alignments to run parallel to contours to facilitate placement of treatment elements across the catchment
- design cross falls to direct run-off to localised treatment elements
- reduce the area of impervious surfaces through minimising hard surfaces
- allow drainage to discharge directly to planted areas
- use the areas created by remnant acquired land, site compound areas, and parking areas for locating WSUD elements
- incorporate swales to carry minor flows, with major storm events bypassed to larger basins.

Safety

Safety must be considered in all aspects of WSUD.

Fencing or balustrading may be required where there are dangers from falling or drowning. Ideally deep water or high walls should be avoided so fences and balustrades are not required. Where it is unavoidable, fencing or balustrading should be integrated into the surrounding landscape, with appropriate materials and vegetation used to disguise its presence.

Visibility and lines of sight may need to be considered in some transport environments.

Capital and Maintenance Budget

A major advantage of adopting a treatment train over a piped stormwater treatment system is that it combines two separate components of the project into one. With soft landscape works and stormwater infrastructure constructed as one integrated element, a correctly designed system should be cheaper to construct in comparison.

Combining elements should similarly reduce project whole-of-life cost. As with any project, the relevant asset managers should be consulted during the design process to provide feedback on the maintenance implications of a proposal's compatibility with maintenance activities across the rest of the asset.

Water Quality and Quantity

The water quality and quantity of both the catchment and the receiving environment need to be understood to help input into the design process. Setting objectives in relation to these two parameters will help, among other design criteria in both sizing and the type of WSUD element that would be best suited to achieve those set objectives. Further information is provided in Appendix B.

Land Use

Urban and rural land uses often require different WSUD responses. In rural areas it is often possible to disperse stormwater directly to the surrounding landscape. In urbanised areas, often water can only travel on the surface for short distances before being connected with surrounding infrastructure. It is important to look for opportunities with surrounding land managers (e.g. local councils) to see if there may be mutual benefit from addressing water management issues holistically.

Space Restrictions

A major constraint for the implementation of WSUD in many projects is space. Detailed engineering calculations (using such modelling tools as Model for Urban Stormwater Improvement Conceptualisation (MUSIC) or DRAINS) are required to adequately size the hydraulic components of a system and help determine whether it is feasible to incorporate WSUD elements.

However, there may be opportunities to use WSUD where space is limited by incorporating individual elements into designs such as incorporating bioretention tree pits or permeable pavers.

Effective Imperviousness of Catchment

There is little benefit in providing additional treatment where a high level inherently exists such as along a rural highway with grass buffers and table drains disconnected from waterways. Designers should assess the existing impervious surface area and connections to waterways, versus proposed impervious surface area that will have a drainage connection to waterways and sensitive receiving environments.

At-source treatment disconnected from waterways, within or adjacent to the project alignment with vegetated buffers, table drains and biofiltration swales can form part of the design response to treat new impervious surface run-off, and where possible, eliminate the need for new drainage connections to waterways if none are existing. Assessing the effective imperviousness may reduce costs by eliminating the need for hard drainage infrastructure such as kerb, gutter, pipes and pits, and may prevent over-specification of treatment by being more targeted to waterway disconnection and protecting sensitive receiving environments.

Sensitivity of Catchment/Receiving Environment

The level of stormwater treatment to be provided should be identified as early as possible during design, and should be appropriate for the sensitivity of the receiving environment so that the design is well resolved when scrutinised during environmental assessment. Higher levels of treatment will be required for environmentally sensitive areas such as national parks, marine parks, drinking water catchments, key fish habitat, SEPP14 wetlands, aquaculture, recreational fishing and primary water contact, and recreational water activities.

Region and Climate

Climate and rainfall vary significantly between regions, and WSUD elements should be designed accordingly.

In low rainfall areas the focus is usually the direct irrigation of ephemeral vegetated depressions and treating the potential erosion caused by peak rainfall events. In high rainfall areas the focus is usually the detention and treatment of peak flows, using permanent water bodies.

Climate and season also significantly affect the vegetative component of WSUD, both during establishment and long term operation.

Geology and Soils

Underlying geology and soils play a critical role in the selection of treatment elements. They determine rates of exfiltration and infiltration and also whether any built structure is required to support the weight of water when the geology is unstable.

The type of soil and underlying geology determines the rate of percolation as well as the amount of water that can be absorbed and stored. Fine particles (e.g. clay and silts) do not allow rapid percolation while course particles (e.g. sands and gravels) do. The underlying rock formations can be fractured or impervious, increasing or limiting percolation respectively.

If Acid Sulfate Soil is present this will need special consideration and possible treatment or removal.

Soil salinity and sodicity should be considered when designing WSUD. In particular, basins and swales should be designed so that water quality is not adversely affected by soil salinity. This may require hydraulic separation from natural soils in certain soil landscapes.

Topography/Slope

Topography and slope dictate the movement of water on land. The steeper the terrain, the faster draining it will be, and the more difficult it will be for water to infiltrate into the ground. Drainage can be provided on the top and bottom of slopes, and can be supplemented with terraces and batter chutes, to slow the path of water. In some cases, highly engineered water quality and quantity control structures may be required.

Flatter areas can be designed so that WSUD elements drain to localised low points, containing depressed landscape garden beds. Depending on the local geology, some WSUD elements can also be designed with permeable bases such that treated stormwater infiltrates into the ground to recharge the local groundwater aquifer.

Existing Landscape/Retention of Habitat

It may be possible to integrate existing vegetation into a new WSUD project, as long as the changed hydrologic regime will not adversely affect the vegetation. Landscape terracing and contouring can be incorporated around existing and planted vegetation to provide a buffer strip and water treatment between the site and the receiving environment.

Cross programming

Certain projects may require vegetation offsets due to the initial removal of exiting native vegetation for construction purposes. If area permits, a combined WSUD/vegetation offset site may be developed where appropriate vegetation is planted within the WSUD element that will both provide water quality and quantity services and achieves the objective as an offset for the project.

Other dual examples of benefits with WSUD are in providing general planting to the project or creating visual barriers where required.

Spill Containment

Spill containment may be a design requirement where sensitive receiving environments may be damaged by pollutant spills from transport operations. In many situations, existing WSUD elements such as basins, ponds and wetlands can be configured to contain spills to avoid the need for a dedicated spill containment structure.

Community Benefit

There are numerous benefits that WSUD implementation into a project provides the community which are dependent on the type of WSUD elements included but could provide — landscaping both in itself and also as a landscape feature, fauna habitat, fit for use water for irrigation purposes, heat island reduction, water quality and quantity reduction, bush regeneration site, and interactive and educational elements.

3.4 The parts

The following pages include a range of potential water quality treatment elements that may be incorporated by project managers/designers into a ‘treatment train’ for the treatment of project runoff. The matrix below provides a summary of the following elements in terms of application, water quality and quantity treatment and cost.

Figure 7. Pond near Bonville on the Pacific Highway

Table 2. Attributes of various treatment elements

			Runoff Quality and Quantity Effectiveness							Cost	
Stormwater Treatment Element	Location in Treatment Train	Application	Litter/Organic Matter	Coarse Sediment	Fine Sediment	Total Phosphorus/ Nitrogen Removed	Oli & Grease	Heavy Metals	Reduction in Runoff Volume	Construction	Maintenance
Vegetated Swales	Primary/Secondary	Linear land area, grades maximum 5%	H	H	H	L	L	L	L	L	L
Bioretention Swales	Primary/Secondary/ Tertiary (may need sediment and litter pre-filtering)	Linear land area, grades maximum 5%	H	H	H	M	L	M	L	M	M
Bioretention basins/ raingardens	Primary/Secondary/ Tertiary (may need sediment and litter pre-filtering)	Sensitive receiving waters. Can include detention and/or exfiltration.	H	H	H	M	L	M	L	M	M
Sediment Basins	Primary, often combined with detention	Upstream of a secondary treatment device	M	H	M	L	L	L	L	L	M
Ponds/Wet Basins	Primary/Secondary/ Tertiary	Drainage to watercourses. Non-linear land area. Also act as detention and spill containment.	H	H	M	L	L	L	L	L	M
Constructed Wetlands	Secondary/Tertiary	Sensitive receiving waters. Polishes water by removing nutrients and fine sediment	–	–	H	H	L	M	L	H	M
Exfiltration Systems	Secondary (needs sediment and litter pre-filtering)	Maintain natural water balance. Sensitive receiving waters. Can be contained within wet basins or detention basins	–	–	H	M	L	M	H	M	M
Gross Pollutant Trap	Primary	Limited space, high litter/ organic matter loads	H	M	L	L	L	L	L	L/M	H
Porous & Permeable Pavements	Primary	Road verges, footpaths, car parks	L	L	M	L	L	L	M/H	M	M

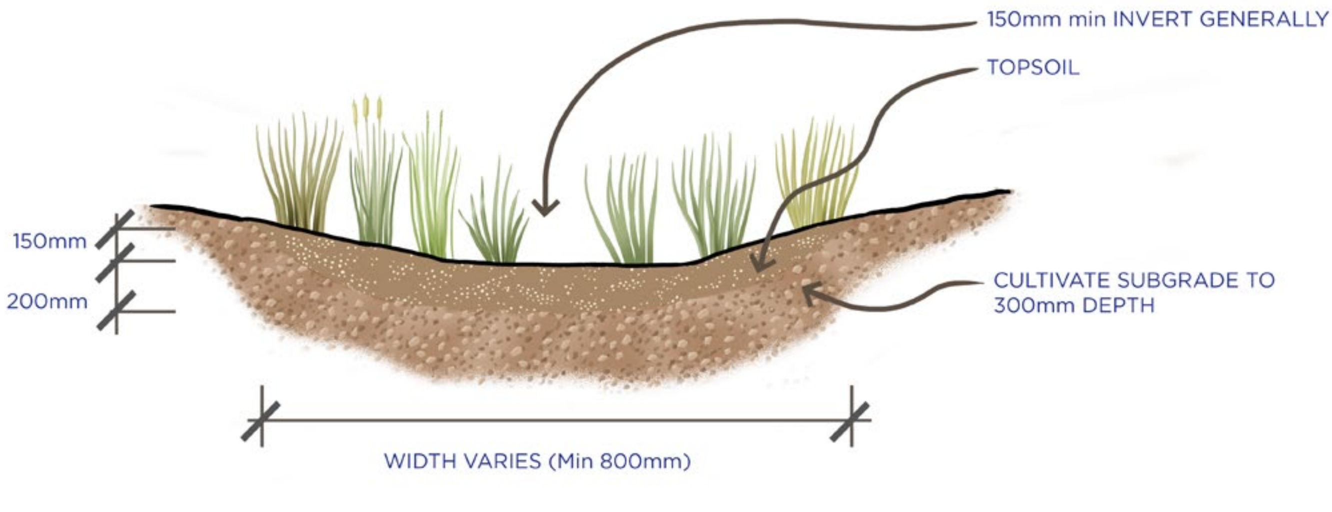
3.4.1 Vegetated swales (table drains)

Vegetated swales are linear features that convey stormwater along the surface within a wide, shallow channel, typically at gentle longitudinal grades (<5%). The linear form of swales makes them ideally suited to a linear environment in both rural and urban areas, as well as locations without defined drainage systems. Vegetated swales are generally used as a primary treatment device at the upper end of the treatment train, however can be used as the sole treatment element. Vegetation is used to promote uniform flow and also the slowing of water velocity to encourage the settlement of course sediments and also capture significant amount of litter and organic matter.

Vegetated Swales are generally compatible with adjacent project corridors, however vehicle traversability, maintenance safety and water conveyance objectives must be considered during design. Some protection may be required from vehicle damage if deemed to be a risk. Whilst swales require additional land in comparison to piped drainage systems, they may also be used as a boundary defining feature, and be part of the landscape design.

Vegetated Swales have limited effectiveness removing fine sediment, nutrient and heavy metal removal due to their generally short detention times during large storm events.

Whilst vegetated swales can have a low construction cost in comparison to piped drainage systems, high initial maintenance will be required during establishment of the vegetation, with ongoing periodic monitoring for vegetation cover, and infrequent mowing and litter removal. Vegetation should be selected based on local climate and rainfall regime, sufficient density, and be maintained at a height above the treatment flow level to maximise filtration. Vegetated swales work most efficiently with distribution of flow along the swale from the catchment edge. Concentrated flows at a single entry point can lead to overwhelming of the vegetation and erosion.



VEGETATED SWALE

Figure 8. Vegetated table drain on the Princes Highway near Merimbula

Figure 9. Bioretention swale in commuter car park at Quakers Hill

3.4.2 Bioretention swales

Bioretention swales (or Bioretention trenches) are linear systems that include a vegetated swale and subsurface filter. These swales provide a surface conveyance function as well as efficient treatment of stormwater through fine filtration, extended detention and some biological uptake.

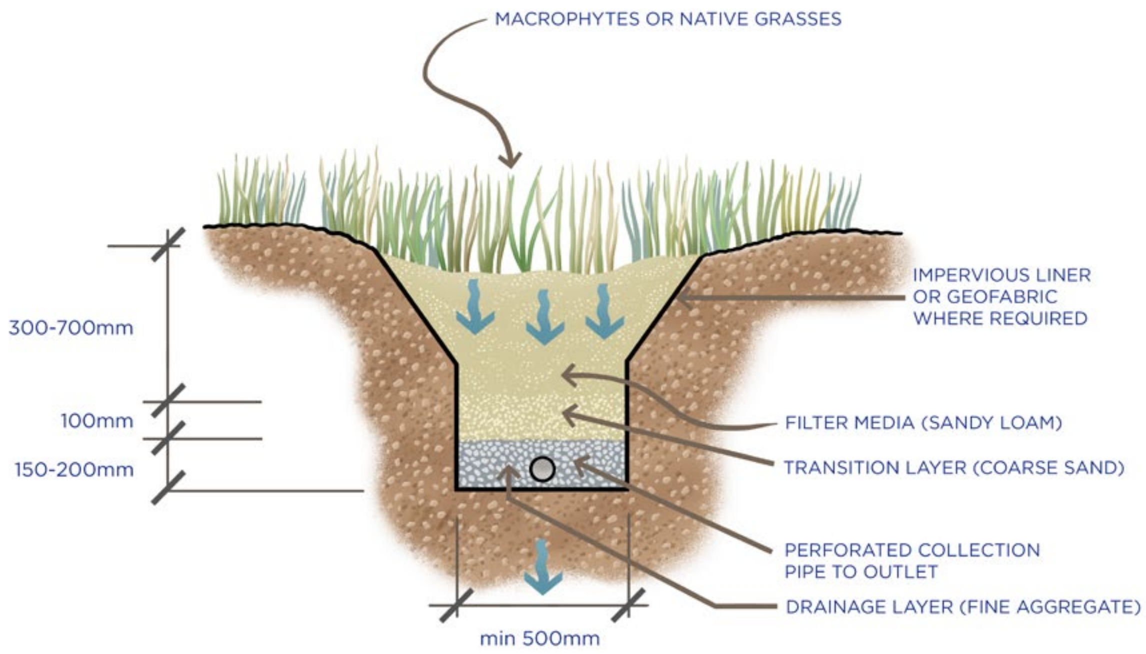
Bioretention swales provide primary and secondary treatment of stormwater. The filter media and vegetation that grows in it absorbs pollutants, improving the element's effectiveness. Vegetation that grows in the filter media improves the function of the system in a number of ways. Erosion and clogging of the surface and filter media is avoided by continuous plant growth. Plant roots and filter media also allow biofilms to form which pollutants will adsorb to.

The safety considerations for bioretention swales are quite similar to those of vegetated swales with particular attention to the trafficable nature of the swale when constructed in such areas where this may be a risk. They are suited to highly urbanised areas within metropolitan and rural centres incorporated as a boundary defining feature, landscape element or if relevant located within medians of roads, depots or car parks.

Bioretention swales have a comparable construction cost to piped systems, usually requiring very little maintenance. It is important in that they are properly sized and vegetated. In the event that the filter material becomes compacted or blocked, replacement of both the vegetation and filter material will be required. Removal of litter and organic matter may be required if they are placed in high litter load areas.

Design of bioretention swales must consider the potential for infiltrated stormwater to impact on surrounding infrastructure which can be avoided by using such techniques as installing an impervious membrane across the shared boundary with the element and/or having them installed with a slotted pipe at the base to convey any excess water.

Bioretention swales are sometimes designed with drain inlets at the lowest point in the structure, to promote more efficient drainage. This approach is discouraged, as it has the potential to compromise efficient operation of the treatment structure. In particular, such designs generally result in insufficient water residence time, ineffective water treatment and poor vegetation growth.



BIORETENTION SWALE

3.4.3 Bioretention basins/raingardens

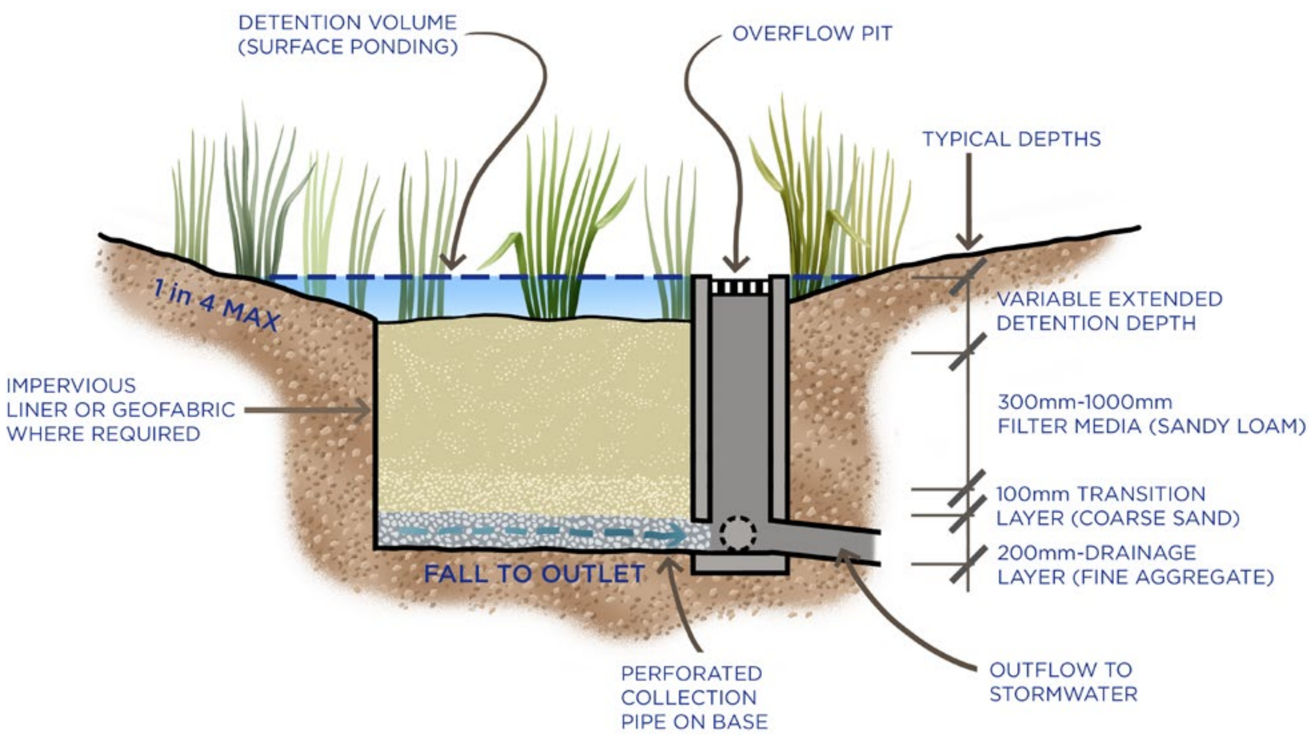
Bioretention basins operate with the same treatment process as bioretention swales with the exception that they are non-linear and do not convey stormwater but they may be designed to provide a detention function. The basins can be a range of scales and shapes and therefore flexible in their design and location. The location and size of the basins should consider such safety aspects as errant vehicles and pedestrian interactions.

Bioretention basins are highly effective at treating pollutants associated with impervious surface runoff such as roads, car parks and roof areas prior to entering sensitive receiving waters. They have the advantage of being able to be distributed along a project at regular intervals and treat runoff close to source, or can be located at outfalls of a drainage system to provide treatment for larger areas. Bioretention basins are susceptible to any materials that may clog the filter media, therefore appropriate upstream protection by a sediment basin or other primary treatment (i.e. gross pollutant trap) should be considered. A wide range of vegetation can be used allowing them to be integrated into the surrounding landscape and within features such as medians, traffic calming elements, parking bays, and planting beds.

It has become common for shallow bio-retention basins ('raingardens') to be installed as a default WSUD option on large non-linear projects such as at-grade car parks. The use of raingardens may be appropriate for these settings, however the designer should evaluate all options to ensure they identify the most suitable treatment option. Use of raingardens in publicly accessible areas should consider the safety risks associated with uneven and unstable ground, the potential for vegetation to be damaged by pedestrians and litter accumulation.

Bioretention basins should be designed with the adjacent infrastructure in mind, considering the impacts on the water table level, water ingress into surrounding pavement and possible inclusion of impermeable membranes to ensure flows pass to an outlet pipe. Bioretention basins should require minimal maintenance if sized and designed appropriately. Removal of litter and organic matter may be required if upstream protection is not provided. After initial establishment of the vegetation, minimal weeding should be required. If clogging or contamination occurs there may be a need to replace both the vegetation and filter media layer.

Considerations around drainage inlet depth are similar for bioretention basins as they are for bioretention swales.



TYPICAL BIORETENTION BASIN

3.4.4 Sediment basins

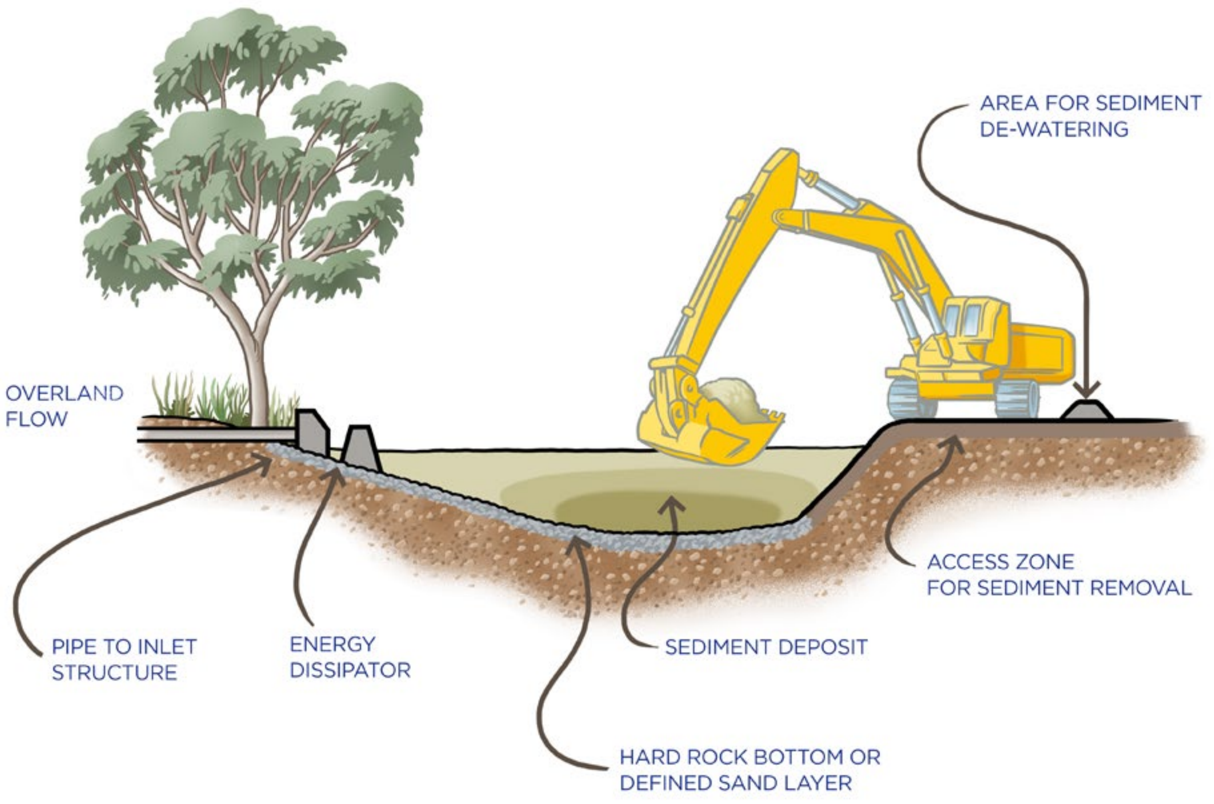
Sediment basins are primary treatment elements used mainly to trap course sediment however, they may also be designed to function as a detention and/or retention component of the stormwater system. The basins function by providing reduced flow velocities therefore encouraging the settlement of coarse sediments. Sediment basins, like other non-linear elements are limited to areas where sufficient land is available for construction.

Due to sediment basins limited water quality function, they are frequently located upstream of secondary treatment elements such as wetlands or bioretention basins to protect them from being overloaded with sediments, or can be used as an end of line treatment element for sediment-sensitive receiving environments. Typically the basin will be designed with a permanent pool to maximise settling, however they can be designed to fully drain during dry periods.

Sediment basins can be used to temporarily detain water after rainfall events. As such, they can play an important role in managing flooding, where appropriately designed and positioned.

Construction of sediment basins is relatively low cost providing land is available and are typically installed during the construction phase of projects. Generally they are difficult to successfully incorporate into narrow project reserves. Maintenance of sediment basins is relatively simple if the basins has been designed with suitable access, and requires the dewatering and dredging of accumulated sediments generally using an excavator or similar. The maintenance period varies depending on the upstream catchment, and consideration to analysis of removed sediments for contamination and appropriate disposal may be required.

Sediment basins require consideration for protection against accidental pedestrian and vehicle access if relevant and attraction of wildlife to the water source if that wildlife will be endangered by activities surrounding it (i.e. traffic). Sediment basins may need to be protected by appropriate barriers and fencing depending on their location.



SEDIMENT BASIN CONCEPTUAL LAYOUT

Figure 10. Basin on the Great Western Highway near Bullaburra

Figure 11. Bioretention basin in commuter car park at Edmondson Park

3.4.5 Ponds/wet basins

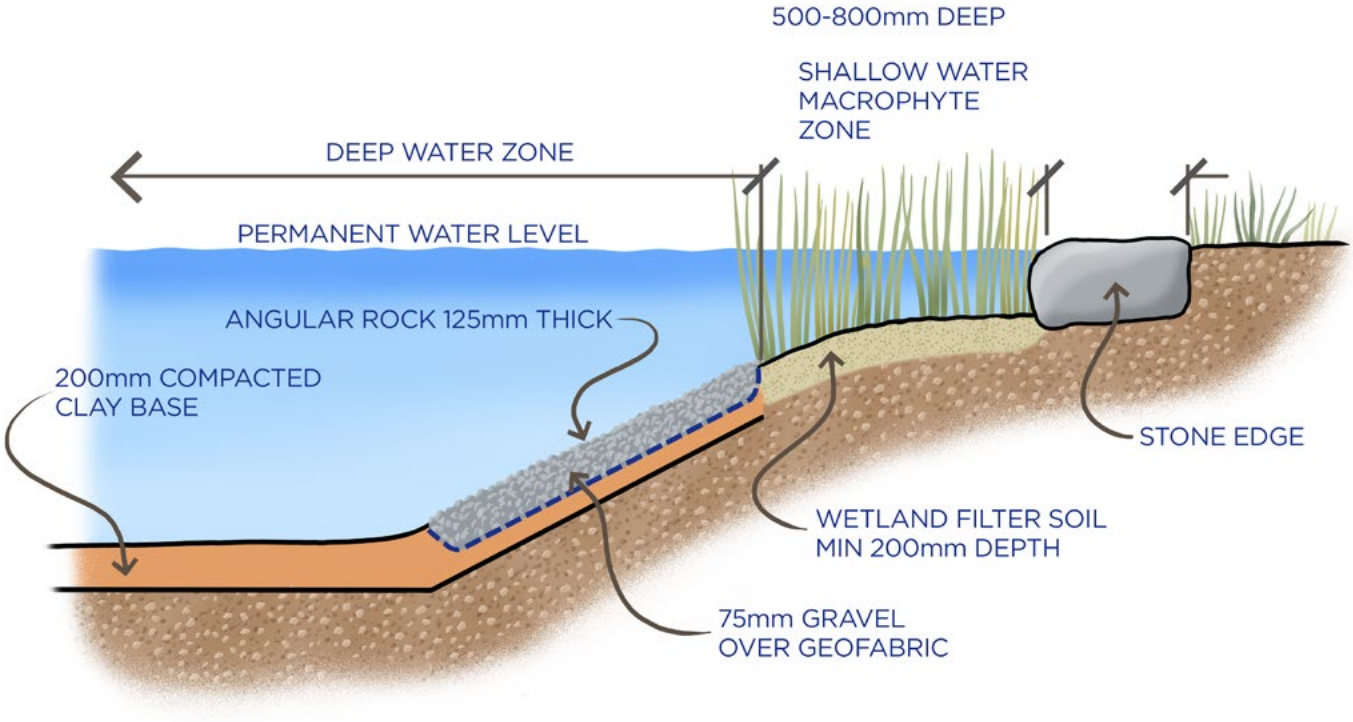
Ponds target the removal of coarse and fine sediments through sedimentation, as well as some adsorption of nutrients from fringe plants (although less than wetlands). The use of ponds for stormwater treatment is an accepted practice, however they are unlikely to be the best solution for many projects due to safety risk limiting their application close to transport corridors. The primary safety risk associated with ponds is their attraction of wildlife, which is generally undesirable near transport projects. Consideration must also be given to pedestrian and potentially traffic safety due to the risk of drowning. Appropriate barriers may be required depending on the location and features.

Ponds can be used to temporarily detain water after rainfall events. As such, they can play an important role in managing flooding, where appropriately designed and positioned.

Ponds can be constructed in various locations including in steep terrain, in areas where sufficient land is available or can be acquired. Ponds can be used for detention basins where storage above the permanent pond level is provided. Depending on upstream protection, ponds will generally require similar maintenance to sediment basins.

Ideally the majority of sediment loads would be trapped near to the inlet point, which can be designed to allow easy access for removal of deposited sediment.

Special care is required in the detailed design of ponds, taking into account their management and operation. Issues such as algae blooms, accumulation of oil and scum, and mosquito infestation can be minimised through good engineering design. Plant species selection and placement should create a barrier to restrict public access to open water bodies.



WATER QUALITY POND

3.4.6 Constructed wetlands

Constructed wetlands are extensively vegetated water bodies that provide enhanced sedimentation, fine filtration and biological processes to remove stormwater pollutants. They range from large end-of-pipe treatment elements of many hectares down to 'micro' wetlands filling a small available pocket of land. They can take various sizes and shapes to suit the topography and can be designed with a natural look or be more engineered and manicured. Positioning of wetlands should consider their potential interaction with the water table and surrounding infrastructure.

Wetlands are typically designed to release storm flows over a period of about 3 days, allowing the treatment processes, particularly the uptake of soluble pollutants to be optimised. They provide efficient treatment and removal of nutrients and other soluble or fine particulate pollutants including heavy metals. They will have variation in depth throughout the wetland to allow for a variety of vegetation and pollutant removal processes and quite frequently are protected upstream by a sediment basin and/or GPT.

Larger wetlands provide recreational opportunities such as walking paths and resting areas and may provide habitat for wildlife and fish. The primary safety risk associated with wetlands is their attraction of wildlife, which is generally undesirable near transport projects such as roads and rail. If access is provided, consideration must also be given to pedestrian and traffic safety and the inclusion of suitable barriers and fencing.

Wetlands are usually planted with aquatic and semi-aquatic vegetation that require continuous water input. Depending on the size and location of a wetland, they will require sufficient runoff to sustain the required water levels for the plant species and initial maintenance and weeding. They are also compatible with edge tree planting providing an appropriate distance is maintained to prevent shading of macrophytes and edge zone plants. Following an initial establishment period, provision of upstream protection and appropriate vegetation species, limited ongoing maintenance of wetlands is required.

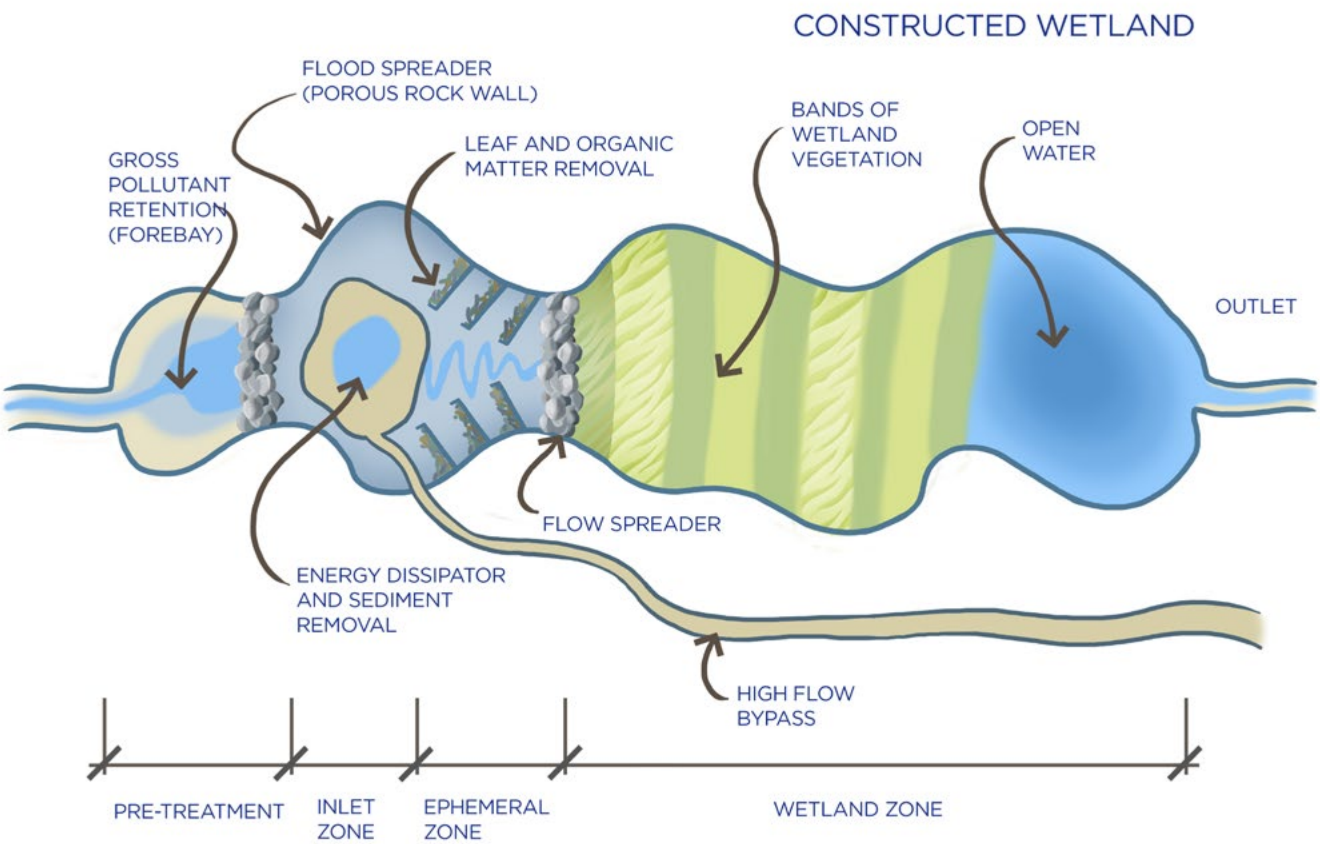


Figure 12. Constructed wetland on the Pacific Highway, Banora Point

Figure 13. Pond on the Great Western Highway, Bullaburra

3.4.7 Exfiltration/aquifer recharge

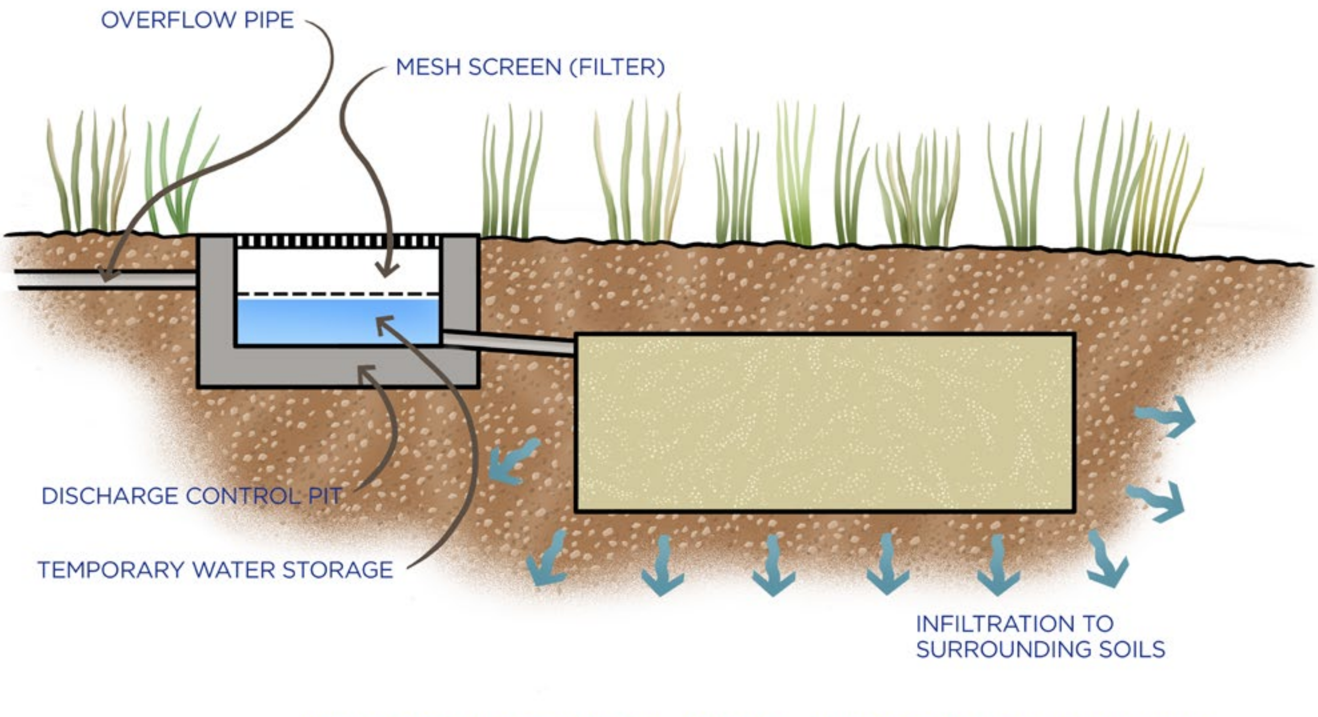
Exfiltration systems encourage the infiltration of stormwater into the surrounding soils or aquifers (layers of rock or sand which can hold and store water underground). Using exfiltration to recharge aquifers would need to be part of a broader regional program in which project management elects to participate with other stakeholders such as councils and catchment management authorities.

This technique is dependant on the ability of the local soils to accept stormwater and are best suited to areas where the surrounding soils are sandy and have high infiltration rates. They should be considered when groundwater recharge is beneficial and the total runoff volume needs to be limited. Similar to bioretention basins consideration should be given to their compatibility and impact on adjacent infrastructure.

Typically, exfiltration provides secondary treatment and commonly require the use of a combination of swales, sediment basins and/or GPTs upstream of the system to limit sediment loads, and be effective in removing fine sediments and medium quantities of heavy metals and nutrients. Most commonly they will be applied as bioretention systems where infiltration is allowed at the base of the filter media, rather than implementing a subsurface collection system. Exfiltration systems can also be vegetated and landscaped to provide character and amenity. This also provides improved nutrient removal through plant uptake and also helps to reduce clogging as the plant root systems assist in maintaining the permeability of the surface and subsurface.

The systems are flexible in their shape, size and structure and can be installed underground allowing for their use in areas of limited space, however they are not suited to steep slopes or areas with stability issues. If appropriately protected upstream from sediment and pollutants, limited maintenance will be required.

In coarse soils, exfiltration may lead to groundwater contamination where dissolved pollutant removal is not achieved. They are susceptible to clogging by pollutants and sediments on the surface as well as the subsoil media.



INFILTRATION MEASURES- GRAVEL FILLED TRENCH (SOAK AWAY)

3.4.8 Porous and permeable pavements

Porous and permeable pavements are generally only suitable under light traffic loads due to them usually being laid on a sand or fine gravel base. They can be utilised for a variety of projects where traffic volumes are suitably low (and light) and can be included in many locations such as roadside rest areas, car parks, depots, pedestrian thoroughfares, train stations etc.

Porous and permeable pavements promote infiltration through the pavement surface itself to a subsurface collection system or to the subsoil. Porous pavements allow for infiltration through the internal structure of the material itself. Examples would include such materials as porous asphalt, porous concrete, porous pavers, and plastic grid systems. In comparison, permeable pavements are generally made of individually impermeable pavers, but designed in such a way that there are vertical gaps between the pavers, often filled with coarse sand or other highly permeable material which allows for high infiltration rates.

Porous and permeable pavements are a primary treatment method typically designed to provide infiltration and detention of smaller catchments of surface water to an underlying sand or aggregate and collection system. They provide filtration as well as some nutrient uptake through biofilms on particle surfaces. In some instances the collected water can be stored and reused or infiltrated to the surrounding subsoil, however the risk of groundwater contamination is possible. As mentioned, these pavements are only effective on limited catchment areas and can have some ability to attenuate flood peaks for small, frequent flood events. They are only suitable for mild slopes (<5%). The pavements can be aesthetically more pleasant than conventional drainage channels and create edge treatment delineation through a change in hard surface material, colour and texture.

Porous and permeable pavements are susceptible to clogging during and immediately following construction, or through long term use. Given these pavements are susceptible to clogging, regular maintenance is required but will depend on the type and frequency of usage. Maintenance can be in the form of deep pore suction cleaning and vacuum sweeping.

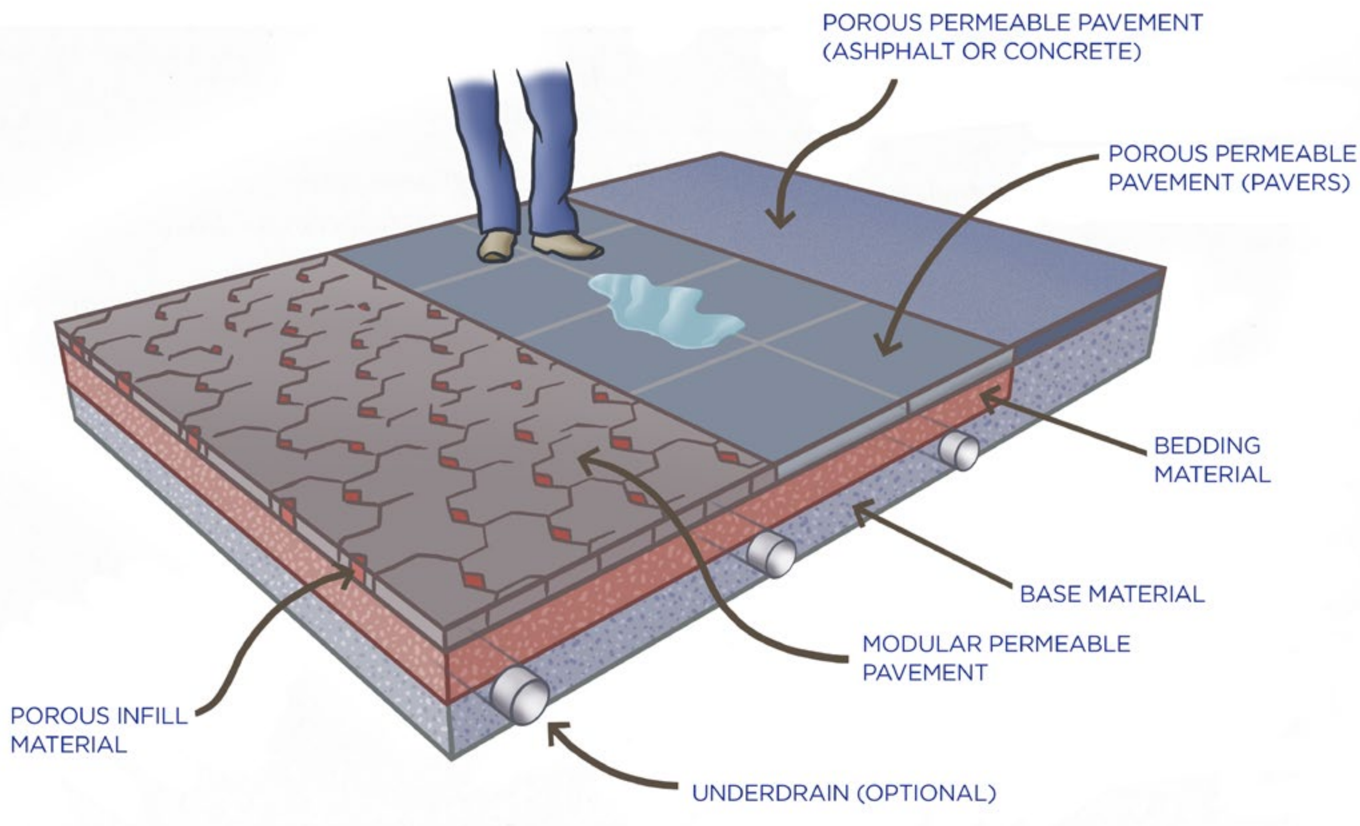


Figure 14. Permeable pavement in car park constructed as part of the Lane Cove Tunnel project

3.4.9 Water storage, irrigation or other reuse opportunities

Particular land uses within or adjacent to the project such as rest areas, compounds, recreational open space and other areas needing irrigation may mean it is beneficial to consider using land for stormwater harvesting and reuse.

Stormwater storage devices could include underground tanks as well as surface pond and wetlands. Opportunities may be investigated with neighbouring councils and land management agencies to provide water to their land when it is mutually beneficial.

3.5 Detailed design considerations

At the detail design stage of transport projects the design and selection of the various components of the WSUD elements need to be carefully considered. The main issues to consider are described in the following sections.

3.5.1 Maintenance and access

In order to keep WSUD systems in proper working order, maintenance is crucial. Whilst maintenance is usually carried out during establishment and operation, planning for maintenance should be considered during design.

The design of elements works best for maintenance when the maintenance activity is considered, and integrated with the wider landscape. Such considerations may include:

- Reduce maintenance scope: This may include the provision of forebays, trash racks and sediment basins prior to ponds, wetland and bioretention basins to minimise the maintenance frequency and extent.
- Ensuring a 'clean' system is provided at handover: Elements which may have been used to trap sediments during construction will clog up if not cleaned and flushed prior to handover at a point when construction sediment loads have diminished.
- Provide safe access to machinery and personnel: This may also include the placement of appropriate distances and isolated from any transport thoroughfare so maintenance may be carried out without the restriction and need for traffic management.
- Access: Is required for all maintenance activities. Provision of suitable access would include adequate load bearing surfaces and reasonable offset distances.
- Edge conditions: Maintenance can be made easier by reducing the width of boggy ground, impediments to personnel and machinery, and delineation between terrestrial and aquatic conditions

In order to keep WSUD systems in proper working order, maintenance is crucial.

Figure 15. Bioretention basin with sediment entrapment zone on the Central Coast Highway, Wamberal

3.5.2 Plant selection

Plants associated with WSUD elements are often required to tolerate specific conditions such as long dry spells followed by periodic flooding or extended wet periods.

In general plants for swales, bioretention swales and bioretention basins must be adapted to ephemeral wet/dry conditions and be able to tolerate the free-draining conditions of the growing media. It is crucial to establish a continuous uniform groundcover for the operation of swales and bioretention systems. Designers must account for the inundation time and the depth of water, and (for swales) the roughness of the channel. Low growing groundcovers and grass species are suitable for swales that require a low hydraulic roughness. Bioretention structures need plants with root systems extensive enough to prevent the filter media from clogging and tall enough to withstand extended inundation.

Macrophytes should be used in wetlands, sedimentation basins and other permanent or semi permanent water bodies. The macrophytes will be selected for their ability to tolerate the various water depths encountered at the edges of the water body and ability to assist the removal of nutrients.

Plants with spreading roots that rapidly fill the soil media, and those that have a symbiotic relationship with soil fungi, are best for nutrient removal. Plants such as *Carex appressa*, *Melaleuca ericifolia*, *Goodenia ovata*, *Ficinia nodosa*, *Juncus amabilis* and *Juncus flavidus* have proven to be species with exceptional nutrient stripping ability.

Whilst plants that are nitrogen fixing (such as Acacia spp.), shallow rooted and suited to dry conditions are unsuitable for general use in regularly inundated areas, they may be appropriate for the embankments of basins and at the top of berms for purposes including batter stabilisation, aesthetics and to restrict public access.

Plant selection should be from indigenous species if downstream ecosystems are susceptible to weed invasion.

Shrubs and trees play an important role adjacent to WSUD elements in providing screening, shade, and integrating the work within the surrounding landscape character. Shrubs and trees are not a functional requirement within WSUD elements, but can be integrated if required providing the filter media has a minimum depth of 800mm to avoid root interference with the subsurface drainage.

Shrubs and trees can be used to help control the algal growth in water bodies by shading, and conversely should be placed at a distance far enough so as not to shade a WSUD element where macrophytes or other active groundcover species are planted or they must be accompanied by shade tolerant groundcover species.

3.5.3 Soil media

Selection and use of appropriate soils and filter material is essential for the successful establishment and operation of all elements. Soils should be suitable as a growth media to support vegetation (retain sufficient moisture and provide nutrients) as well as sufficiently permeable to prevent ponding and then becoming waterlogged, whilst filter materials should be permeable and resistant to clogging.

Lower levels of permeability are required for vegetated swales, ponds, wetland and wet sediment basins. Higher permeability is needed for elements such as biofiltration swales and basins, exfiltration systems and porous/permeable pavements.

The effect of long periods of inundation is a consideration, as acidity levels, erodability and siltation levels may impact on the success of plant growth.

Further information can be found in the 'Guidelines for Filter Material in Stormwater Biofiltration Systems (v4.01)' July 2015 developed by the CRC for Water Sensitive Cities.

Lower levels of permeability are required for vegetated swales, ponds, wetland and wet sediment basins.

Lower levels of permeability are required for vegetated swales, ponds, wetland and wet sediment basins.

3.5.4 Fencing and edging

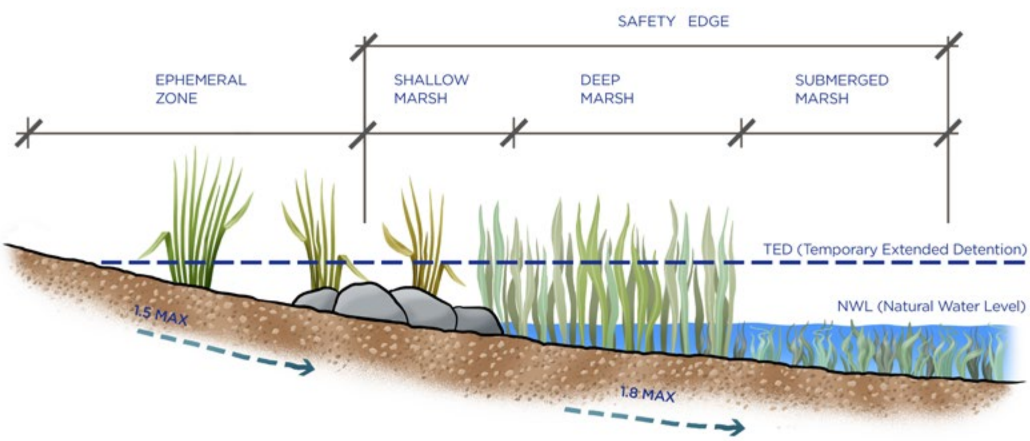
A risk-management approach should be undertaken to the provision of fencing of WSUD systems. Following are some items which will influence whether a fence is considered necessary:

- depth and time of inundation
- use of the area of land for other purposes (such as a basin being used as a recreation area during dry periods)
- levels and gradients at edges
- proximity to publicly accessible areas, including consideration of whether that includes children of an age where they aren't yet able to perceive danger adequately
- access requirements for maintenance
- location within clear zones if relevant.

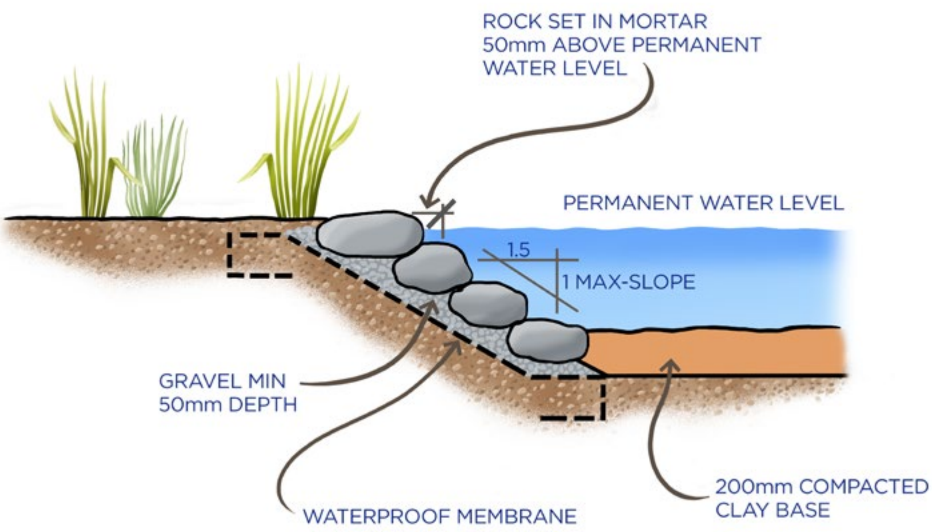
Depending on these factors, other methods of mitigation of identified risks may be more effective, including:

- terracing or grading edges so to allow easy egress and to allow actual depth of water to be perceived
- provision of dense planting
- temporary or permanent signage
- temporary patrols during times where usually dry elements are inundated.

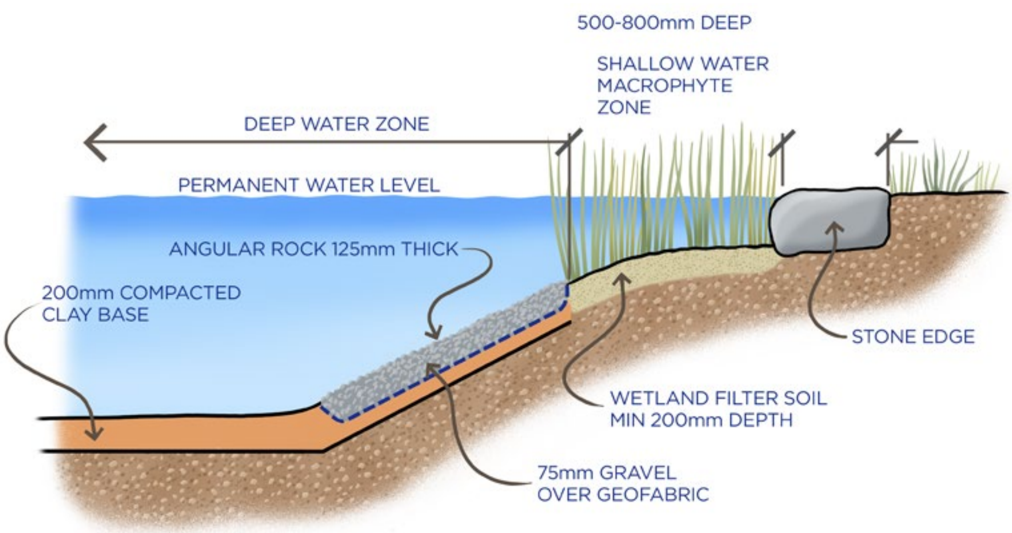
If fencing is required, its design should be considered as part of the design of the project in general. Screening it with planting may be appropriate in many circumstances, and multiple layers of fencing performing different purposes should be combined into a single fence.



EDGE DESIGN OF CONSTRUCTED WETLAND



POND-ROCK EDGE



WATER QUALITY POND

3.5.5 Mosquito control

Mosquitoes can present a problem in poorly constructed and maintained artificial wetlands, ponds and other WSUD elements that detain water for extended periods, particularly where there is an imbalance of available food, habitat and predators. Mosquitoes require still, ponded water and some level of shelter and attachment sites to carry out their life cycle. Wetlands and ponds generally provide some level of these habitats, however, after an establishment period they also provide significant habitats for mosquito predators.

There are a number of design and management techniques that can be used to manage the risk of mosquito borne disease and mosquitoes as nuisance. These include:

- Design open water and steep bank slopes where the water intersects the bank to reduce habitat sites.
- Vary water levels during the breeding cycle to kill off populations.
- Designing to allow wind wave disturbance.
- Consider location of planting areas and species to reduce breeding areas and to encourage predatory species.
- Creating water surface disturbance. A jet or cascade operated by a simple submersible pump will suffice in most instances.

Monitoring may be useful if there is a problem post construction, or, if it is considered a major risk, then monitoring of the existing conditions may also be helpful.

4 Appendix

Appendix A — Relevant associated Legislation, Environmental Planning Instruments and other policy documents

Documents

Legislation and Environmental Planning Instruments covering WSUD in NSW includes:

- NSW Protection of the Environment Operations Act (1997)
- National Parks and Wildlife Act (1974)
- Fisheries Management Act (1994)
- Water Act (1912)
- Water Management Act (2000)
- NSW State Environmental Planning Policy: The BASIX Scheme
- Other NSW State Environmental Planning Policies
- NSW Regional Environmental Planning Policies.

Various water management & Urban Design documents may be assessed in developing project water quality commitments. These may include:

- ANZECC Guidelines for Fresh and Marine Water Quality (NHMRC & ARMCANZ, 2018) but care should be taken as this does not relate to stormwater rather catchment wide objectives.
- Managing Urban Stormwater: Council Handbook (EPA, 1997)
- Australian Runoff Quality (Engineers Australia)
- NSW Water Quality and River Flow Objectives for various catchments
- Local Council Local Environment Plans
- Local Council Development Control Plans
- Urban Green Cover in NSW: Technical Guidelines (Environment and Heritage Group, DPE).

Table 3. Relevant policy documents of transport cluster agencies

Document	Content
Transport Environment and Sustainability Policy 2020	The Policy guides Transport to be accountable for addressing and minimising the environmental impacts of our activities to satisfy the expectations and legislative requirements of the NSW Government and the community.
Beyond the Pavement 2020 Urban design approach and procedures for road and maritime infrastructure planning, design and construction	Current RMS Urban Design Policy is contained in the publication. This requires projects to fit sensitively with the built, natural and community environments through which they pass. It endorses a collaborative approach to design where all disciplines engage in dialogue at all stages of the design process. This ensures safe, sustainable and cost effective solutions and to provide better visual and amenity outcomes for the community. This implicitly includes stormwater management as an integral part of the road design and therefore an important design consideration.
Code of Practice for Water Management	The Code of Practice provides details of the principles that the RMS is committed to in terms of meeting water quantity and quality objectives from planning through to post-construction, ultimately committing to best management practises.
Procedure for selecting treatment strategies to control road runoff	The procedure provides guidelines to assist in the selection of appropriate types of stormwater treatment measures for specific road and/or bridge projects.
Biodiversity Guidelines	The Guidelines aim to provide assistance and guidance to staff and contractors in the management of biodiversity throughout a project and during maintenance works. These Guidelines aim to improve biodiversity outcomes by minimising potential impacts on flora, fauna and habitats and assisting the organisation to meet statutory obligations under NSW and Commonwealth environmental legislation and policies.
Austroads Guide to Road Design, Part 5	This document provides practitioners with guidance on the design of drainage systems

Appendix B — Setting water quality objectives

Successful projects will set objectives early in the design process, rather than let the design process dictate the objectives. It is desirable that WSUD objectives are developed during or prior to the environmental assessment phase of the project. This will then effectively communicate the objectives to all relevant and interested stakeholders and importantly form part of the approval by any regulatory authorities (e.g. Department of Planning & Environment approval for Part 5.1 environmental impacts statements or internal approval for Part 5 review of environmental factors).

Objectives should be developed with consideration to the sensitivity of the receiving environment and the potential pollution impacts of the proposal.

Each NSW transport agency may choose to set its own organisational water quality objectives, or may opt to set objectives on a project-specific basis. In the absence of any organisational or project-specific objectives, current best practice industry targets may be considered for some aspects of WSUD design, but will depend on the scale and complexity of the project.

Recommended water quality and quantity objectives for urban development in NSW are provided in the publication 'Transport Sustainable Design Guidlines v4'. These objectives are reproduced in the table below.

Table 4. Water quality and quantity objectives

Objective	Parameter
Suspended solids	85% retention of the average annual load
Total phosphorus	65% retention of the average annual load
Total nitrogen	45% retention of the average annual load
Flow management	Maintain the 1.5year ARI (average recurrence interval) peak discharge to pre-development magnitude.

Appendix C — Glossary

Term	Definition
Acid Sulfate Soils	Soil which becomes acidic when exposed to air or is otherwise disturbed because of its chemical composition
Adsorption	Bonding of metals and nutrients onto the surface of sediment particles in a WSUD system, preventing them being transported downstream to receiving environments
Aquifer	An underground geologic formation which traps water and is considered a potential water source
Biofilm	A group of microorganisms in which cells stick to each other on the surface of plant roots or on soil particles, which will trap nutrients and pollutants
Bioretention	The control of stormwater by means of vegetation and soil that slow and filter the run-off, absorbing the pollutants
Built environment	The human-made surroundings that provide the setting for human activity, ranging in scale from buildings and parks or green space to neighbourhoods and cities and includes their supporting infrastructure
Catchment	An area of land where surface water runoff converges to a single point at a lower elevation
Detention	The act of temporarily storing water after a storm, but allowing it to eventually discharge at a controlled rate to a downstream water body
Effective imperviousness	Impervious area in catchment that is directly connected to waterways (i.e., precipitation falling on that area is effectively transported to the stream), thought to be a better predictor of ecosystem alteration to urban waterways when compared to total imperviousness
Element	An individual WSUD technology which provides storwmater treatment
End-of-pipe	An approach to the management of stormwater which pipes runoff to a single large treatment device at the lowest point of a catchment just prior to its discharge into a receiving environment
Ephemeral	Describes an element which does not store water permanently but only retains it for short period of time. Can also describe vegetation which is suited to growing in such an environmental
Exfiltration	The act of directing stormwater into the ground using a dedicated below-ground structure at the end of a treatment train.
Gross Pollutant	Debris items larger than around five millimetres. Typically includes litter (such as paper and plastics) and vegetation (such as leaves and twigs), which are transported by stormwater runoff
High-Flow	Part of a system designed to cater for heavy rainfall events which generate a large amount of runoff. The nature of runoff from these events is that they have a lower pollutant load, therefore their primary aim is to manage a large volume of water quickly
Hydraulic	Relating to the conveyance of water through a natural or artificial structure (e.g. wetland, pipe, channel)

Term	Definition
Hydraulic roughness	Surface roughness of any medium that influences the velocity of flow
Infiltration	The act of directing stormwater into the ground through permeable soils along a treatment train
Inundation	Flooding of an area, particularly in the context of controlling water depth in an individual element for detention and pollutant control
Nutrient	An element dissolved in water which has a negative impact on the health of waterways, commonly nitrogen or phosphorus
Percolation	The act of stormwater passing though a porous material such as soil
Permeability	The ability of a material or structure for water to easily pass through it
Receiving environment	The area downstream of a catchment where into which runoff from that catchment discharges
Retention	The act of managing stormwater runoff by retaining it in a permanent pool of water and preventing it from discharging downstream
Runoff	Stormwater that does not soak into the ground and therefore travels across land into downstream water bodies and drains
Stormwater	Water that originates during precipitation events (and in alpine areas with snowmelt)
Suspended solids	Small solid particles which remain in suspension in water which have a negative impact on the health of waterways,, used as one indicator of water quality
Swale	A continuous linear depressed area in a broader tract of land, designed to capture and convey runoff
Symbiotic	The living together of two species of organisms in which the union of the two is advantageous or necessary to both
Treatment train	A number of elements and structures arranged in serial throughout a catchment which manage quantity and quantity of runoff cumulatively
Water Sensitive Urban Design	The integration of water cycle management (including stormwater, groundwater and wastewater management and water supply) into planning, design and construction of the built environment
Wetland	A land area that is saturated with water, either permanently or temporarily, such that it takes on the characteristics of a distinct ecosystem, primarily via characteristic vegetation that is adapted to its unique soil conditions

Kiss and ride

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