HEALTHY WATERWAYS
Because we're all in the same boat

water by design
A Program of the South East Queensland Healthy Waterways Partnership

Concept Design Guidelines for Water Sensitive Urban Design

Acknowledgements

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The guidelines have been developed to assist in the conceptualisation and development of design solutions that integrate best practice sustainable urban water management with the urban form. They were written by a team of civil and environmental engineers, ecologists, town planners, urban designers and landscape architects within EDAW and SEQ HWP:

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Disclaimer

The material contained in this publication is produced for general information only. It is not intended as professional advice on specific applications. It is the responsibility of the user to determine the suitability and appropriateness of the material contained in this publication to specific applications. The guidelines are not designed to be prescriptive but rather to act as a general guide, as the optimal water sensitive urban design will differ between sites. The content of this guideline does not necessarily reflect the views of each of the Partners of the SEQ Healthy Waterways Partnership, its funders, or the review team. The SEQ HWP and EDAW assume no responsibility or liability in relation to anyone acting on the information provided in these guidelines.

water by design
Creating water sensitive cities

HEALTHY WATERWAYS
Because we're all in the same boat

Water by Design is a program of the South East Queensland Healthy Waterways Partnership

Water by Design

The Water by Design program was established in 2005 and is a program of the South East Queensland Healthy Waterways Partnership. Water by Design creates products and services for the water and urban development sectors to help build capacity for the successful implementation of sustainable urban water management in the region. Sustainable management of the urban water cycle supports sustainable development, including protection of the natural water cycle.

The South East Queensland Healthy Waterways Partnership

The South East Queensland Healthy Waterways Partnership (formerly the Moreton Bay Waterways and Catchments Partnership) is a collaboration between government, industry, researchers and the community. The Partnership was created in 2001. The Partners work together to improve catchment management and waterway health in Moreton Bay and the rivers of South East Queensland between Noosa and the Queensland–New South Wales border. The South East Queensland Healthy Waterways Partnership developed and implemented the South East Queensland Regional Water Quality Management Strategy (2001) and its successor, the South East Queensland Healthy Waterways Strategy 2007–2012 (2007). The Partnership also manages the Ecosystem Health Monitoring Program, which produces an annual report card on the health of the region's waterways, estuaries and bays.

Further information on the SEQ Healthy Waterways Partnership and the Water by Design program is available from:

www.healthywaterways.org
www.waterbydesign.com.au

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Context and audience

The purpose of these guidelines is to assist interdisciplinary teams conceptualise and develop design solutions that integrate best practice sustainable urban water management within the urban form.

Water Sensitive Urban Design (WSUD) for urban planning and design sets the context for, and content of, these guidelines.

Context

The *Concept Design Guidelines for Water Sensitive Urban Design* are written to be informative rather than instructional. Information is provided as layers to assist the conceptual design process of water planning from inception to completion. Case studies are included to demonstrate how the layers can be applied. The case studies are to inform and guide processes, rather than be followed as 'recipes'.

Audience

These guidelines can be used by all practitioners involved in the conceptual design phase of urban development—from initial site analysis, objective setting, through to conceptual site layout.

While not exhaustive, the target audience is broad and multi-disciplinary, covering most disciplines engaged in urban planning and design processes. The guidelines provide information relevant to each discipline taking into account typical roles and responsibilities throughout the conceptual design process.

Content

The content of these guidelines are tailored for specific application in South East Queensland, but they are also relevant and applicable for areas outside South East Queensland.

These guidelines are complemented by a number of other information resources about WSUD in South East Queensland. These resources are shown in Figure 1.

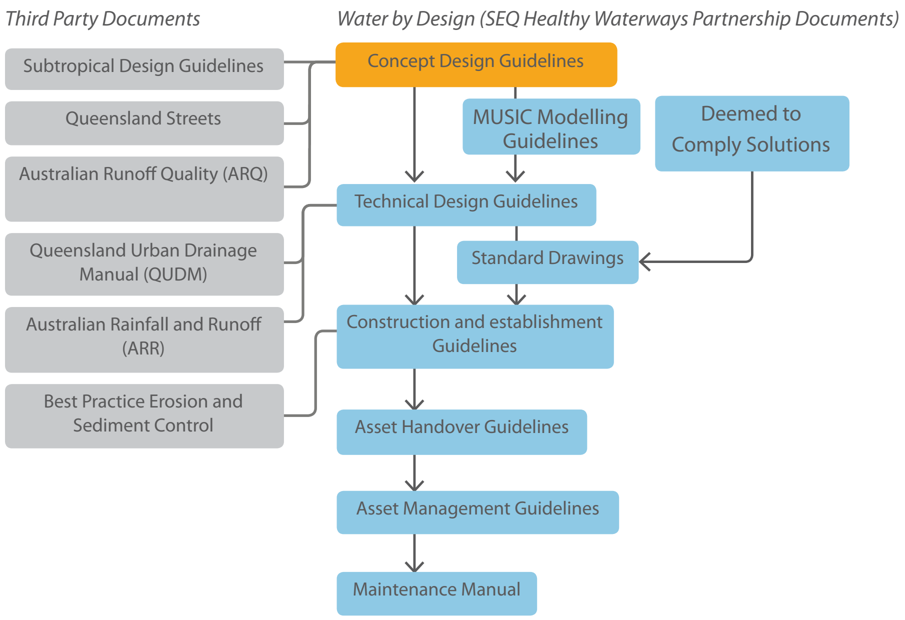

Figure 1 — Document map showing related guidelines and information resources

Audience Icons

- Town Planners
- Architects
- Urban Designers
- Landscape Architects
- Civil Engineers
- Environmental Engineers
- Ecologists
- Land Developers

Abbreviations

ARI	Average Recurrence Interval
ASR	Aquifer Storage and Recovery
ATC	Australia Trade Coast
BMP	Best Management Practices
BPP	Best Planning Practices
CBD	Central Business District
DIP	Department of Infrastructure and Planning
DRO	Desirable regional outcomes
EPA	Environmental Protection Agency
EPP Water	Environmental Protection (Water) Policy 1997
ESD	Ecologically Sustainable Development
GFA	Gross Floor Area
GPT	Gross Pollutant Trap
HACCP	Hazard Analysis and Critical Control Point
HEV	High Ecological Value
IDAS	Integrated Development Assessment System
IPA	Integrated Planning Act 1997
LED	Light Emitting Diodes
LAP	Local Area Plan
LGMS	Local Growth Management Strategies
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NLA	Net Lettable Area
NWI	National Water Initiative
PASS	Potential acid sulfate soils
PCWFMP	Pimpama Coomera Water Future Master Plan
PRW	Purified Recycled Water
QDC	Queensland Development Code
QDC MP	Queensland Development Code Mandatory Part
SEQ	South East Queensland
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WELS	Water Efficiency Labelling and Standards
WSUD	Water Sensitive Urban Design
YEA	Yatala Enterprise Area

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This section provides an overview of the guidelines and includes an introduction to WSUD, highlighting the importance of incorporating WSUD into developments.

Project Teams and WSUD Conceptual Design Process 02

This section outlines recommended project teams and a structured design process to deliver successful WSUD concept designs. This information is not prescriptive but identifies team attributes required at each stage of the conceptual design process.

WSUD Strategies 03

This section provides guidance on selecting best management practices (BMPs) and appropriate technology for successful WSUD design.

Best Planning Practices (BPPs) 04

This section presents best planning practices (BPPs) to give clear guidance on how to deliver WSUDs successfully given various urban design considerations. An overview of relevant strategic and statutory planning considerations is also provided.

Best Management Practices (BMPs) 05

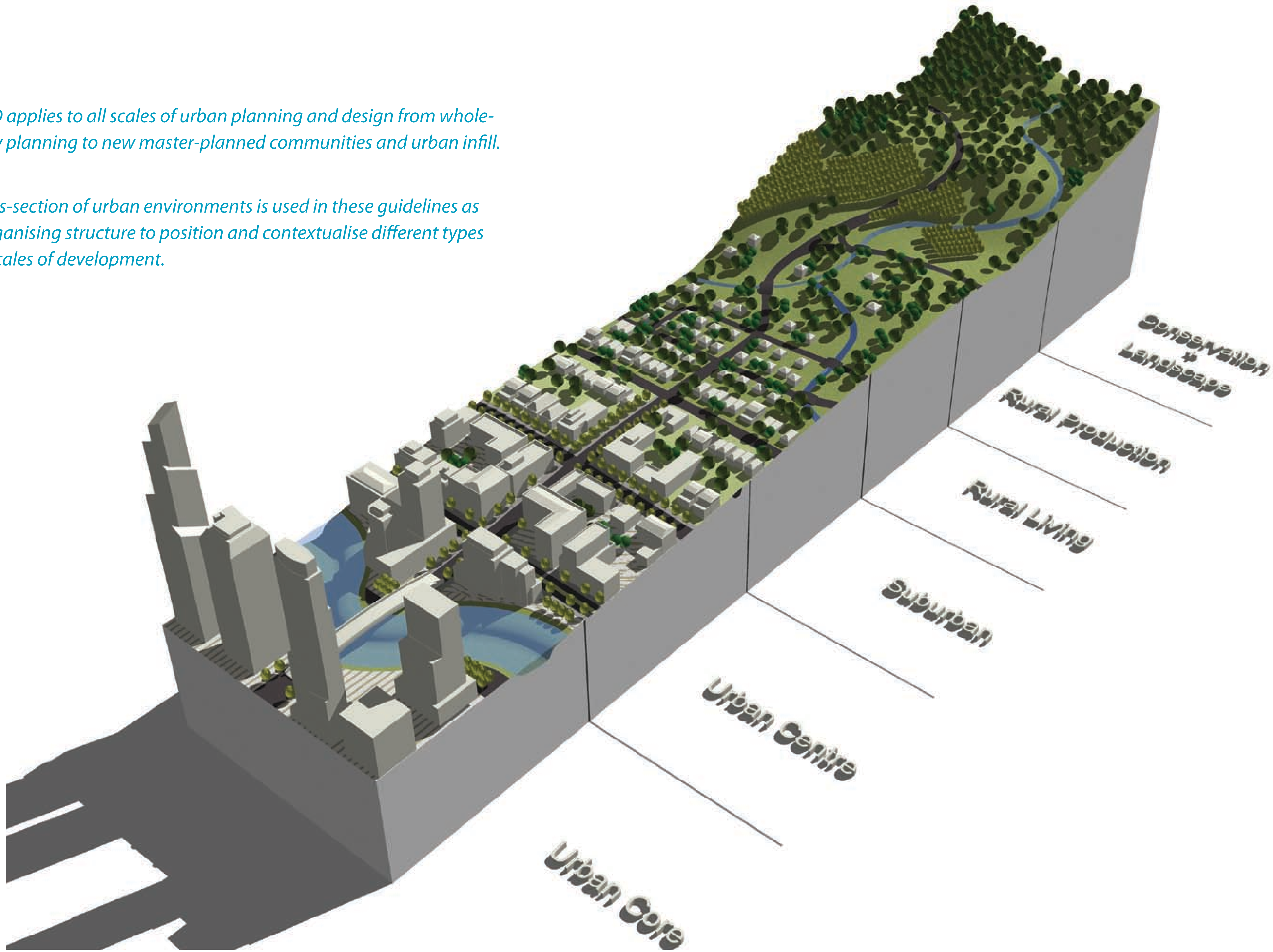
This section provides more detail about the best management practices (BMPs) summarised in the WSUD strategies section, with information about how to apply them.

Case Studies 06

This section presents case studies that provide good examples of how WSUD can be delivered at a range of scales in the urban environment. Details on the project characteristics and its WSUD solution are given for each case study. Project successes and lessons learnt are also summarised.

WSUD applies to all scales of urban planning and design from whole-of-city planning to new master-planned communities and urban infill.

A cross-section of urban environments is used in these guidelines as an organising structure to position and contextualise different types and scales of development.



Introduction to the Guidelines

Content:

01

Introduction

Traditional forms of urban development in Australia have dealt with water in a conservative way:

- drinkable 'potable' water is delivered to households and businesses from centrally-controlled supply networks where water is treated to the highest standards, irrespective of the quality required by the end use
- fresh water is supplied in unlimited quantities, except in drought conditions when restrictions are applied
- wastewater (greywater and blackwater) is collected and transported to centralised treatment facilities and discharged to vulnerable receiving aquatic environments. It is disregarded as a usable resource
- stormwater, polluted by urban land uses and activities, is collected and efficiently transported in sub-surface conduits to vulnerable receiving aquatic environments.

This traditional response to urban water management has contributed to a culture of misuse and waste of precious fresh water resources, as shown by:

- the water security issues facing many urban centres
- the disconnect between human behaviour and impacts on the natural environment
- the loss from public consciousness of basic concepts such as 'supply and demand' and 'cause and effect'
- the assumption there is an endless supply of natural resources to sustain urban lifestyles.

WSUD seeks to:

- recognise the resource value and life-sustaining qualities of water in the urban environment by overtly communicating these values and qualities through thoughtful building and landscape design
- re-connect individuals and local communities with the management of their own water supplies through using rainwater tanks and greywater recycling schemes at an allotment or cluster scale, reinforcing an understanding of supply and demand, and encouraging more diligent management and use of available water
- address the fundamental water-cycle transformations caused by traditional forms of urban development by employing principles and practices borrowed from the natural environment
- promote evapo-transpiration, infiltration of rainfall, and conveyance of stormwater runoff within surface systems enabling natural filtering and cleaning processes to be better incorporated within the urban environment
- re-connect people with the natural landscape, in particular to water, and connect the built landscape with locally-generated water resources, reducing reliance on imported water resources from outside the urban footprint to sustain urban landscapes.

Water Sensitive Cities

Water Sensitive Cities: a whole-of-government initiative

Water Sensitive Cities is a new policy initiative of the Australian, State, and Territory Governments under the National Water Initiative (NWI). The Water Sensitive Cities concept recognises the impact of urban planning and development on natural aquatic ecosystems and the inefficiency and vulnerability of ageing water services infrastructure and institutional arrangements.

While no formal definition has been established, a Water Sensitive City should, as a minimum, ensure:

- environmental repair and protection
- water supply security
- public health and economic sustainability through water-sensitive urban design
- enlightened social and institutional investment in water management
- diverse and sustainable technology choices.

Figure 2 illustrates the transition to a Water Sensitive City, highlighting socio-political drivers and the responses water infrastructure should make to each driver. Most Australian cities are transitioning to being 'Waterways Cities' with some major cities moving to 'Water Cycle Cities' in response to threats to future supply security. With heightened public awareness and political acceptance of climate change, the socio-political drivers for transitioning through the Water Cycle City to the Water Sensitive City are in place. The challenge for designers is to provide a new pattern and form of development that can better adapt to climate change and is more resilient to climatic uncertainty.

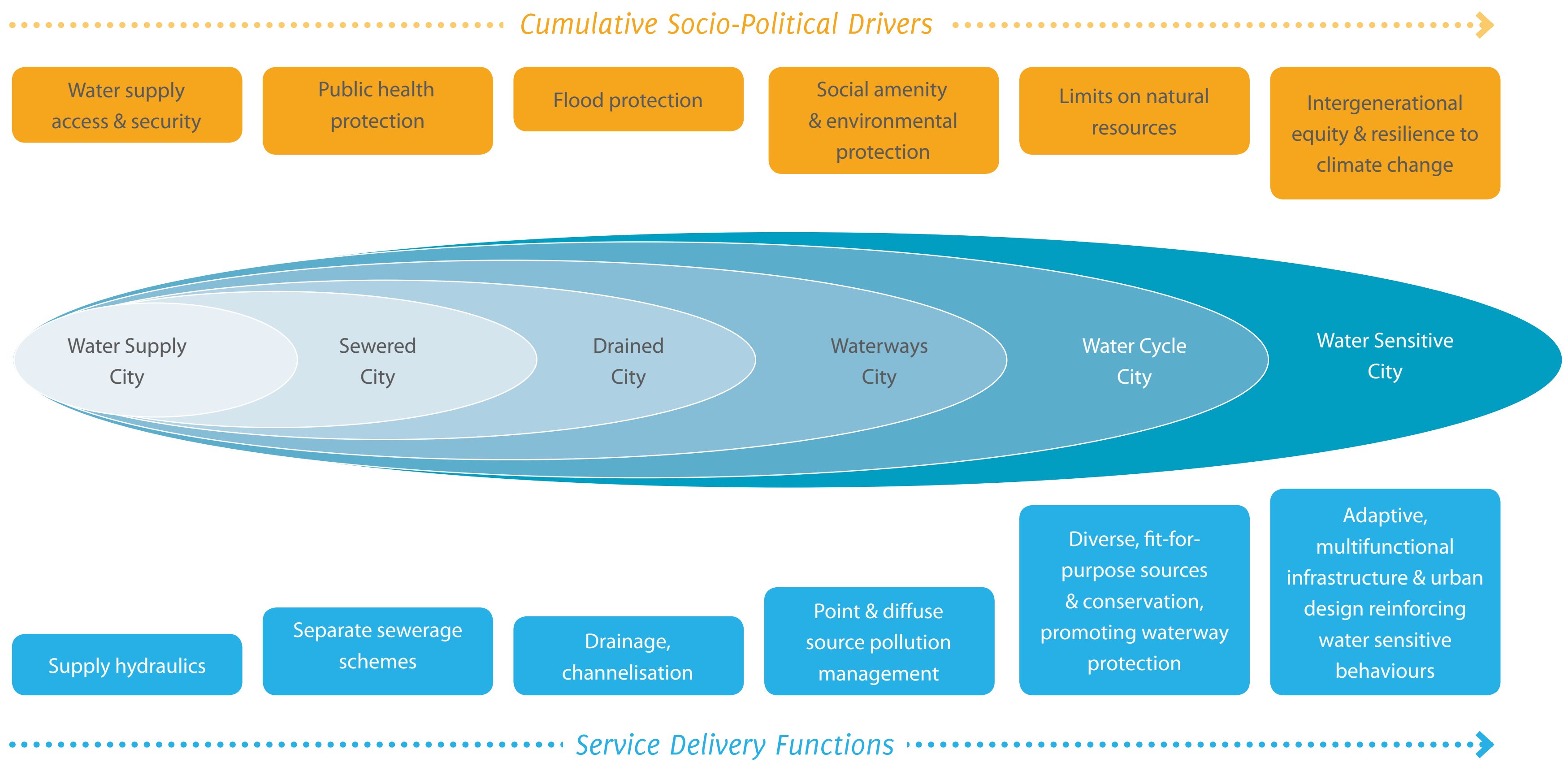


Figure 2 — Key transitional stages to a Water Sensitive City (Brown et al., 2008)

Water Sensitive Urban Design (WSUD)

Water Sensitive Urban Design: an urban planning and design approach

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates land and water planning and management into urban design. WSUD is based on the premise that urban development and redevelopment must address the sustainability of water (Engineers Australia, 2006).

WSUD integrates into the built form at the earliest stage of the decision-making process. WSUD opportunities include (Engineers Australia, 2006):

- detaining, rather than rapidly conveying, stormwater
- capturing and using rainwater and stormwater as alternative water sources to conserve potable water
- using vegetation to filter water
- water-efficient landscaping
- protecting water-related environmental, recreational, and cultural values
- harvesting localised water for various uses
- localising wastewater treatment systems.

Figure 3 positions WSUD as a layer in the delivery of Ecologically Sustainable Development (ESD) and as the framework to integrate water-cycle management with urban planning and design.

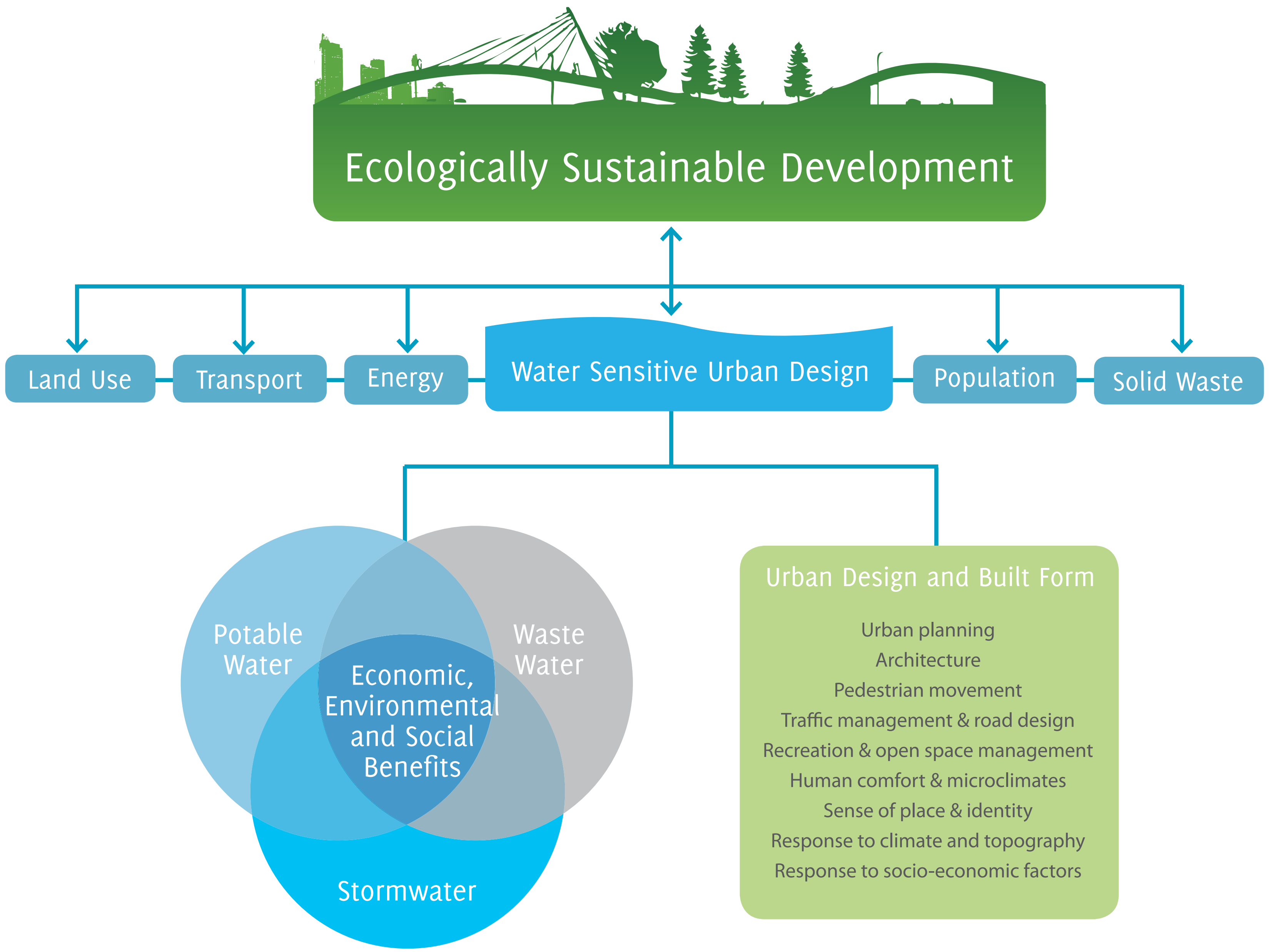


Figure 3 — Role of WSUD in achieving Ecologically Sustainable Development (Hoban and Wong, 2006)

What WSUD achieves

WSUD is a holistic approach to urban water-cycle management, where all parts of the water cycle are being managed in an integrated way (Engineers Australia, 2006).

Figure 4 shows an integrated approach to urban water-cycle management and the synergies that can be found by looking at the three streams of urban water—potable water, stormwater, and wastewater—as an inextricably linked system.

Figure 5 shows changes to the natural water cycle with traditional urban development and with WSUD. WSUD tries to preserve the natural water balance.

WSUD avoids or minimises urban development impacts on the natural water cycle and environmental values by (Qld DIP, 2008b):

- protecting and enhancing the intrinsic value of the natural water cycle by minimising disturbance to natural landforms, wetlands, watercourses, and riparian zones
- protecting the quality of surface water and groundwater to maintain and enhance aquatic ecosystems and enable re-use opportunities
- reducing downstream flooding and drainage impacts on aquatic ecosystems by managing stormwater runoff and peak flows
- promoting more efficient use of water by reducing potable water demand and encouraging alternative water supplies
- minimising wastewater generation and ensuring the treatment of wastewater is to a standard suitable for effluent re-use or release to receiving waters
- controlling soil erosion during construction and operational (post-construction) phases of land development
- using stormwater in the landscape to maximise visual and recreational amenity and promote an understanding of water in the urban environment.

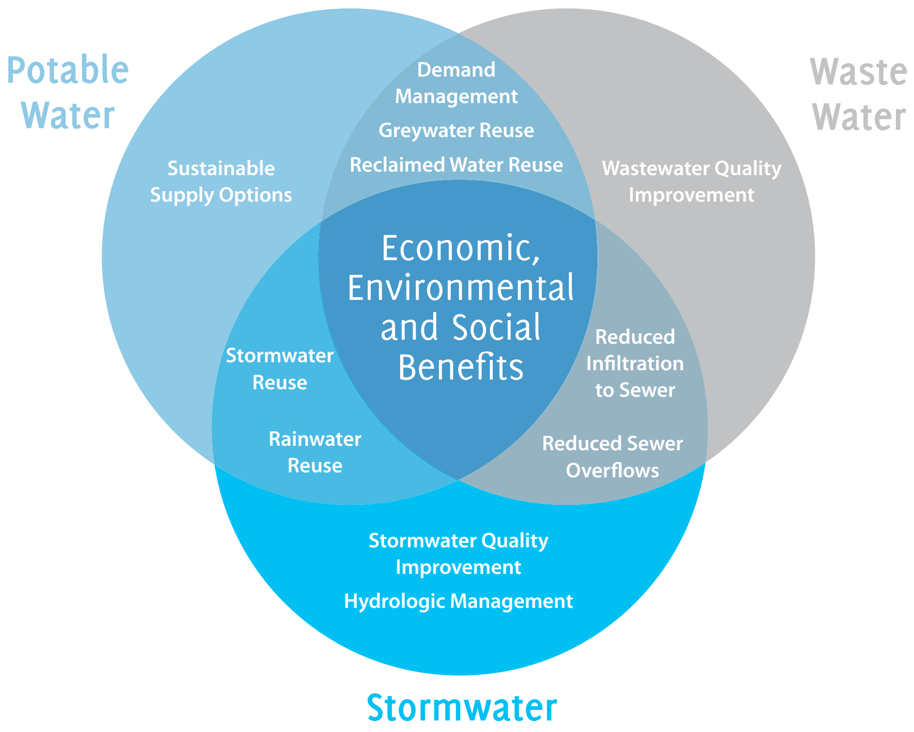


Figure 4 — Integrated Management of the Urban Water Cycle (Hoban and Wong, 2006)

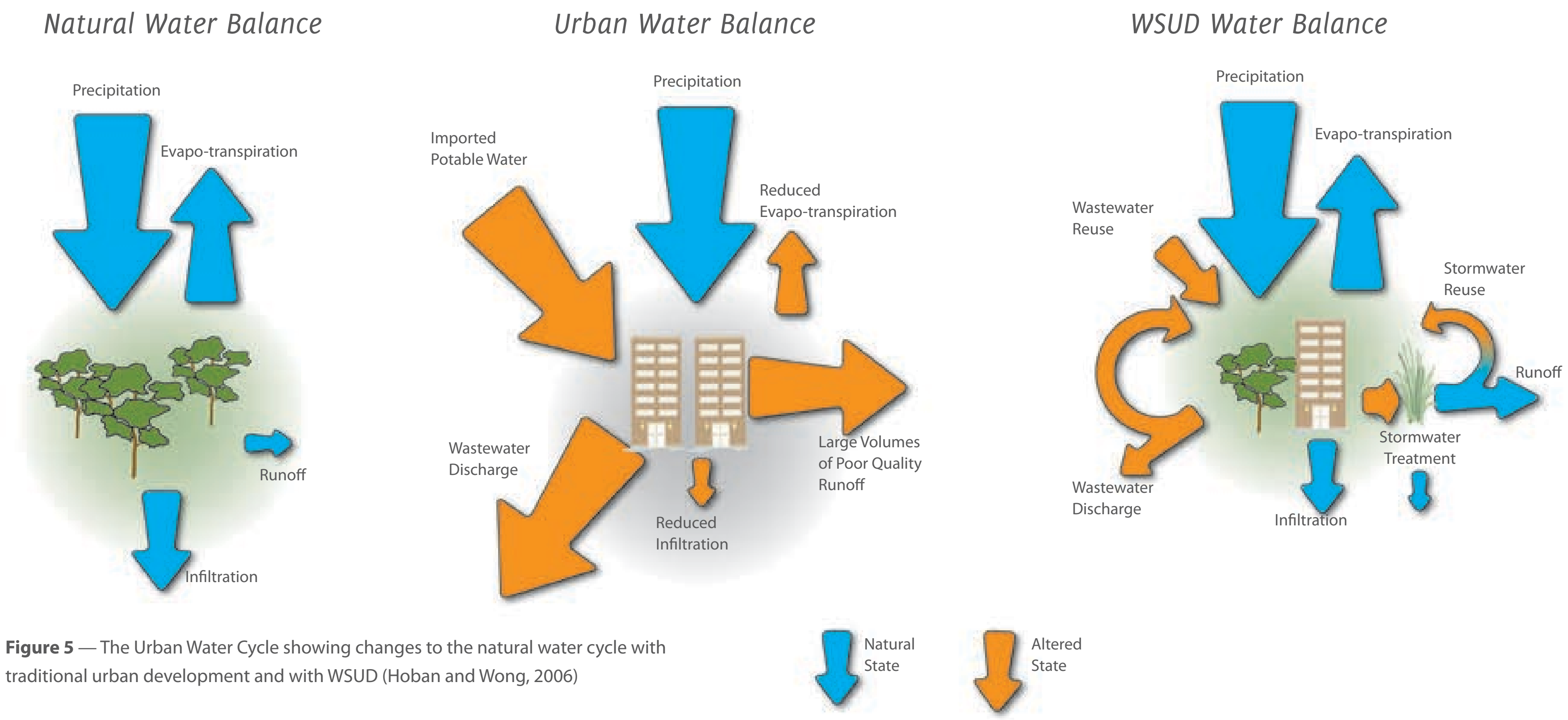


Figure 5 — The Urban Water Cycle showing changes to the natural water cycle with traditional urban development and with WSUD (Hoban and Wong, 2006)

Water Sensitive Urban Design (WSUD)

How WSUD achieves its aims

WSUD employs a range of best planning practices (BPPs) and best management practices (BMPs) to achieve its aims. Figure 6 outlines how BPPs and BMPs combine in the urban planning and design process to achieve WSUD.

BPPs relate to the 'site assessment, planning, and design components of WSUD' (Engineers Australia, 2006). BPPs can be implemented at strategic planning levels. For example, statutory land use planning instruments can be used to locate land use suitable for treating effluent adjacent to a municipal wastewater treatment facility. BPPs can also be implemented at the site design stage. For example, site layout can be developed to retain or restore natural flow paths, wetlands, and riparian vegetation.

BMPs refer to the structural and non-structural elements of urban design that prevent, collect, treat, convey, store, and re-use water within an integrated water management scheme (Engineers Australia, 2006).

Section 4 of these guidelines provides a more detailed discussion on WSUD BPPs.

The WSUD Strategies (Section 3) and Best Management Practices (Section 5) sections of these guidelines provide a more detailed discussion on WSUD BMPs.

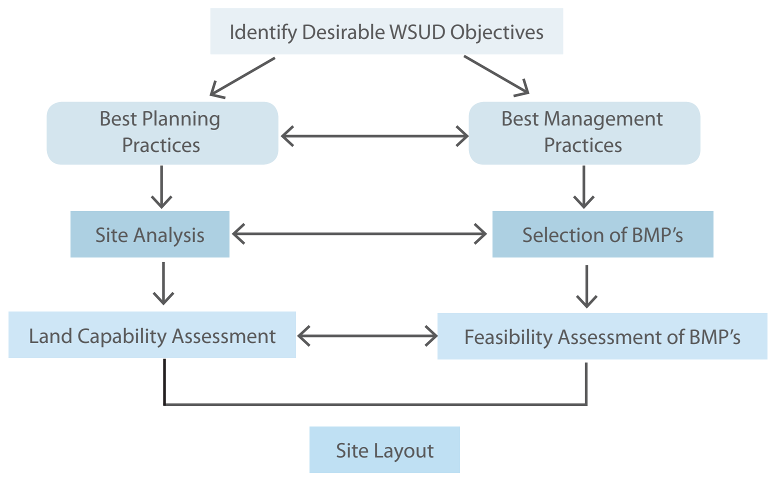


Figure 6 — WSUD planning and design process (Engineers Australia, 2006)

WSUD uses a best practice hierarchy:

- retention and restoration—retain or restore natural channels, wetlands, and riparian zones
- source controls (non-structural)—educational and enforcement measures to minimise water use and polluting activities
- source controls (structural)—structural techniques located as near to the source (or use) to minimise water use, minimise wastewater generation, minimise stormwater runoff quantity, maximise stormwater quality using infiltration and natural physical treatment processes, and maximise re-use of treated wastewater and stormwater
- in-system controls (structural)—structural techniques installed in precinct- or district-level water services infrastructure to augment source controls.

(Engineers Australia, 2006).

By integrating WSUD BPPs and BMPs at the earliest stages of the conceptual urban design process, and by adhering to the WSUD best practice hierarchy, the likelihood of delivering a successful water-sensitive development will be improved and progress towards a Water Sensitive City will be made.

Photo: Peter Breen/EDAW

South East Queensland's 2.7 million residents have a strong connection to the region's waterways, which are one of its most valuable natural assets.

In economic terms, commercial fisheries and aquaculture are worth about $45m a year, and the recreational fishing sector is worth about $195m a year. Tourism in the region is worth $3.6b, and the waterways, which are a substantial tourism drawcard, could be affected by increased algal blooms. Water supplies are also threatened by algal blooms in reservoirs, and by the misuse and mismanagement of water supplies. Poor quality discharges from wastewater treatment plants add to the challenge of sustainable urban water management.

In terms of total pollutant loads to receiving environments, point sources such as industry and wastewater treatment plants contribute 26% of nitrogen loads, 71% of phosphorus loads and 1% of sediment loads. Diffuse sources of pollution from urban areas, principally through stormwater runoff, contribute 28% of nitrogen loads, 13% of phosphorus loads and 26% of sediment loads (this is much higher when best practice erosion and sediment control practices are not followed on construction sites). The balance of pollution is generated from rural diffuse sources.

The South East Queensland Healthy Waterways Partnership was formed to address these issues in a collaborative manner, and has the vision:

'By 2026, our waterways and catchments will be healthy ecosystems supporting the livelihood and lifestyles of people in South East Queensland, and will be managed in collaboration between community, government and industry.'

The *Water Sensitive Urban Design Action Plan* to the *SEQ Healthy Waterways Strategy* has the target that, 'By 2026, all developed urban land in SEQ will meet consistent regional standards for Water Sensitive Urban Design.'

WSUD Design Objectives

WSUD design objectives currently exist in the following documents:

- *Queensland Development Code (QDC)* and *South East Queensland Water Strategy*
- *South East Queensland Regional Plan Implementation Guideline No. 7: Water Sensitive Urban Design* (Qld DIP, 2008b).

Water conservation design objectives

Water conservation design objectives are presented in the QDC, Mandatory Parts (MP) 4.1, 4.2, and 4.3. MPs 4.1 and 4.2 require that buildings are retrofitted and constructed to meet water-savings targets. These targets can be met through demand management (BMP 1), roofwater harvesting (BMP 2), stormwater harvesting (BMP 3), and wastewater treatment for re-use (BMP 4). MP 4.3 requires alternative water sources are sought for new Class 3 to Class 9 buildings and associated Class 10 buildings (see Section 3 WSUD Strategies: Water Conservation).

The *South East Queensland Water Strategy* (QWC, 2008) includes a requirement for all new dwellings to provide 70,000 L/year from alternative (non-grid) water sources.

Stormwater Management Design Objectives

Design objectives for best practice urban stormwater management are outlined in the *South East Queensland Regional Plan Implementation Guideline No. 7: Water Sensitive Urban Design* (Qld DIP, 2008b). The *Implementation Guideline No. 7* describes how these objectives should be adopted. The suite of design objectives are:

- Frequent-flow management design objective: This objective aims to protect in-stream ecosystems from the effects of increased runoff by capturing the initial portion of runoff from impervious areas. This approach ensures that the frequency of hydraulic disturbance to in-stream ecosystems in developed catchments is similar to pre-development conditions.
- Waterway stability management design objective: This objective aims to prevent in-stream erosion downstream of urban areas by controlling the magnitude and duration of sediment-transporting flows.
- Stormwater quality management design objective: This objective aims to protect receiving water quality by limiting the quantity of key pollutants discharged in stormwater from urban development. It is based on a percentage reduction in the loads of sediment, phosphorus, nitrogen, and litter in stormwater runoff generated by urban developments, compared to untreated runoff.

These design objectives are described in more detail in Tables 1–3.

Queensland Development Code, Mandatory Parts 4.1, 4.2, and 4.3

QDC MP 4.1 Sustainable buildings

Existing Class 1 buildings and sole occupancy units in existing Class 2 buildings require a mandatory retrofit of water-efficient devices and toilets as part of other renovations.

QDC MP 4.2 Water-savings targets

All building development applications for Class 1 buildings are required to meet water-savings targets. Water-savings targets can be met through a number of options including the installation of rainwater tanks, communal rainwater tanks, greywater re-use, dual reticulation, or stormwater re-use.

QDC MP 4.3 Alternative water sources—commercial buildings

All building development applications for the construction of new Class 3 to Class 9 buildings and associated Class 10 buildings are required to use alternative water sources. Acceptable water sources are rainwater, stormwater, greywater, and dual reticulation.

(Qld DIP, 2008a)

Table 1 — Frequent-Flow Management

Objective	Capture and manage the following design runoff capture depth from all impervious surfaces of the proposed development: • 0% to 40% impervious: capture first 10 mm of runoff from impervious surfaces • >40% impervious: capture first 15 mm of runoff from impervious surfaces. Runoff capture capacity needs to be replenished within 24 hours of the runoff event.
Background	Under pre-development conditions, small rainfall events are absorbed by catchment soils and vegetation and do not produce surface runoff in small urban creeks. In an urban catchment, impervious surfaces generate runoff during small storms that, if directly connected to a formal stormwater drainage system, is transported directly to receiving waterways. This increase in the number of surface runoff events results in frequent delivery of urban pollutants to streams and regular disturbance of in-stream ecosystems. Studies within Australia and overseas have shown a strong correlation between the impervious area directly connected to streams and aquatic ecosystem degradation. Using local hydrologic data from South East Queensland, it has been shown that capturing up to 15 mm of runoff from impervious areas within a development will ensure a similar frequency of flow in the receiving urban streams to that of pre-development conditions.
Recommended application	As this objective aims to protect in-stream ecology in ephemeral waterways, it should only be applied where runoff from or within the site passes through an unlined channel, creek, or non-tidal river that is not a degraded waterway. Where a receiving waterway is degraded, the local or regional authority may choose to waive this objective on the basis that the receiving waterway and its associated catchments have limited potential for future rehabilitation or WSUD retrofitting. Management of captured stormwater should include one or more of the following: • stormwater reuse (including roofwater collection and use) • infiltration to native soils, or otherwise, filtered through an appropriately designed soil and plant stormwater treatment system, such as bioretention • stormwater evapo-transpiration.
Demonstrating compliance	Compliance with this objective may be easily demonstrated by providing a total stormwater capture volume (m^3) calculated as follows: **capture volume (m^3) = impervious area (m^2) x target design runoff capture depth (m/day).** The spatial distribution of the required capture volume may be adapted to suit individual site conditions, provided that the required volume from all impervious areas is captured before leaving the site. Implementing the required capture volume may reduce pollutant load, providing a synergistic benefit for water quality. There may be an opportunity to incorporate the required capture volume within stormwater quality treatment measures, potentially eliminating the need for separate additional storage to meet the frequent-flow management design objective. Since the objective requires this capture volume is available every day, the management system (whether infiltration, evaporation, reuse, or bioretention) must be capable of draining the captured stormwater within 24 hours.

Source: Qld DIP, 2008b

Table 2 — Waterway Stability Management

Objective	Limit the post-development peak one-year Average Recurrence Interval (ARI) event discharge to the receiving waterway to the pre-development peak one-year ARI event discharge.
Background	Urbanisation typically increases the duration of sediment-transporting flow in urban streams, leading to increased rates of bed and bank erosion. The purpose of this design objective is to limit changes in downstream sediment transport potential by over-attenuating events of intermediate magnitude. These events are responsible for a large proportion of total sediment movement in streams.
Recommended application	Since this objective aims to control in-stream erosion, the objective should only be applied where runoff from, or within, the site passes through an unlined channel, creek or non-tidal river. Where a receiving waterway is degraded, the local or regional authority may choose to waive this objective, on the basis that the receiving waterway and its associated catchments have limited potential for future rehabilitation or WSUD retrofitting. The local authority may also substitute an alternative criteria where catchment-scale studies have been undertaken to develop a catchment-specific approach to the management of in-stream erosion impacts.
Demonstrating compliance	Compliance with this design objective can be demonstrated using a runoff routing model. At the discretion of the local authority, the adoption of simplified methods for demonstrating compliance for small developments is acceptable.

Source: Qld DIP, 2008b

Table 3 — Stormwater Management

Objective	Achieve the following minimum reductions in total pollutant load, compared to untreated stormwater runoff from the developed part of the site: • 80% reduction in total suspended solids • 60% reduction in total phosphorus • 45% reduction in total nitrogen • 90% reduction in gross pollutants.
Background	Receiving water quality objectives are typically specified in terms of desired pollutant concentrations. However, experience within Australia and overseas has identified difficulties with the application of concentration-based receiving water targets as discharge criteria for urban stormwater. These difficulties include the possibility that the median (or some other percentile) concentrations of pollutants in stormwater may be low, but pollutant concentrations and loads during infrequent storm events may be very high. In addition, the increase in runoff volumes that typically accompany urban development can significantly damage urban streams through increased disturbance and erosion, even if discharged pollutant concentrations are low. For these reasons the proposed design objectives for stormwater quality management adopt a load-based approach. The numerical values of the load-based targets are based on achievable load reductions from current best practice stormwater management infrastructure operating in South East Queensland. The infrastructure is best practice given climatic and pollutant export conditions and depends on if the infrastructure is operating near the limit of its economic performance. This means that higher load reductions could potentially be achieved, but substantial extra cost would be incurred to obtain a very small additional water quality benefit. Since the load-based reductions are relative to untreated runoff, a higher standard is imposed on low-pollutant-generating development, requiring pollutant removal to unachievable levels for developments having less than 25% total imperviousness.
Recommended application	It is recommended that this design objective is applied to all developments, except very low density development that: • comprises six or less dwellings with no internal road, or • is less than 25% total imperviousness (unless local government 'deemed to comply' solutions apply), and • captures and manages the first 10 mm of runoff per day from all impervious areas. Management of captured stormwater should include one or more of the following: • stormwater reuse (including roofwater collection and use) • infiltration to native soils, or otherwise, filtered through an appropriately designed soil and plant stormwater treatment system, such as bioretention • stormwater evapo-transpiration.
Demonstrating compliance	Some local governments may provide pre-determined infrastructure solutions that are 'deemed to comply' with the stormwater quality management design objective. This eliminates the need for detailed modelling. For high risk developments, large and complex developments and innovative approaches, numerical modelling of pollutant export and stormwater treatment performance will be required to demonstrate compliance. The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) model (CRCCH, 2005) is widely adopted for this purpose. Modelling should be undertaken based on a continuous simulation of catchment hydrology using models, parameters and methodologies in accordance with local government requirements.

Source: Qld DIP, 2008b

Project Teams and WSUD Conceptual Design Guide

Content:

Project Teams
WSUD Conceptual Design Process

02

Project Teams

Team composition

Selecting the right project design team to deliver urban development projects can have a significant impact on the success of the project and in particular on the capacity and cost efficiencies to deliver the WSUD elements.

The design team must embrace a collaborative and cooperative process and will typically have the following 'core' attributes:

- physical sciences including environmental engineering, civil engineering, geotechnics, terrestrial and freshwater ecology, and geomorphology
- architecture, urban design, and landscape architecture
- statutory (town) planning.

It should be noted that not all projects or development types will require all of the above attributes. However, it is important that all identified relevant disciplines are included in each project as deficiencies in any of these areas may result in failure to identify critical land capability issues and key development opportunities and constraints. This can lead to a sub-optimal pattern and form of development and infrastructure with higher than necessary development costs.

Team continuity

While the composition of the design team is critical, continuity of key design team members' input into the conceptual design process, the detailed design stage, and preferably through to construction and establishment is also important. A lack of continuity in key team members can often lead to misinterpretations or uninformed changes being made to critical design elements.

Development proponents may consider establishing a 'partnership' arrangement with the design team, guaranteeing continuity subject to performance targets, in return for a commitment of key personnel and resource capacity to the project. Ownership by the project team can deliver significant cost efficiencies across the life of the project through reduced overheads, enhanced service delivery formed through strong working relationships, and reduced design iterations.

Photo: EDAW

WSUD Conceptual Design Process

Integrating planning, urban design, landscape architecture, engineering, and ecology is critical for the successful inclusion of WSUD principles and measures in a development. A process that addresses the relevant tasks in a logical manner is required.

These guidelines present a conceptual design process in which key tasks, activities, and expertise are highlighted. A collaborative process can also help to manage project risks. The conceptual design process cannot be undertaken separately to other processes. Several iterations may be needed through the overall development of the project.

- Town Planners
- Architects
- Urban Designers
- Landscape Architects
- Civil Engineers
- Environmental Engineers
- Ecologists
- Land Developers

Step	Team Members	Task
Step 1: Preliminary Site Analysis	Town Planners, Civil Engineers, Environmental Engineers	Understand the most recent WSUD policy and regulations
	Environmental Engineers, Ecologists	Identify regionally and locally significant ecosystems and understand the site's context in relation to the protection and/or enhancement of these ecosystems, particularly riparian and wetland ecosystems associated with waterway corridors
	Civil Engineers, Environmental Engineers	Identify environmental values and water quality objectives for key receiving waters within, and downstream of, the development
	Ecologists	Establish ecological condition and management requirements for key receiving waters within, and downstream of, the site
	Civil Engineers, Ecologists	Establish the site's existing hydrologic cycle and its regional context
	Civil Engineers	Understand the regional and local integrated water cycle infrastructure context
	Civil Engineers	Understand the current and future flooding risk on, and downstream of, the site
	Civil Engineers, Environmental Engineers	Understand the site terrain and soils
	Civil Engineers, Environmental Engineers	Prepare a preliminary WSUD opportunities and constraints overlay
Step 2: Establish WSUD Objectives	Civil Engineers, Environmental Engineers	Determine water conservation objectives
	Civil Engineers, Environmental Engineers	Determine wastewater minimisation objectives
	Civil Engineers, Environmental Engineers, Ecologists	Determine stormwater management objectives
	Civil Engineers, Environmental Engineers, Ecologists	Confirm WSUD design objectives with local council
Step 3: Conceptual Site Layout	Town Planners, Architects, Urban Designers, Landscape Architects, Civil Engineers, Environmental Engineers, Ecologists, Land Developers	Integrate the conceptual design process
	Civil Engineers, Environmental Engineers, Ecologists	Undertake detailed site analysis
	Civil Engineers, Environmental Engineers, Ecologists	Undertake quantitative modelling
	Town Planners, Architects, Urban Designers, Landscape Architects, Civil Engineers, Environmental Engineers, Ecologists, Land Developers	Prepare final conceptual site layout and present to the local council at a pre-lodgement meeting

WSUD Conceptual Design Process

Step 1: Preliminary site analysis

	01	02	03	04	05
Task	**Understand the most recent WSUD policy and regulations**	**Identify regionally and locally significant ecosystems and understand the site's context in relation to the protection and/or enhancement of these ecosystems, particularly riparian and wetland ecosystems associated with waterway corridors**	**Identify environmental values and water quality objectives for key receiving waters within, and downstream of, the development**	**Establish ecological condition and management requirements for key receiving waters within, and downstream of, the site**	**Establish the site's existing hydrologic cycle and its regional context**
Key Activities	Review the most recent version of relevant state government policy and supporting guidelines, including: *EPP Water* (Qld EPA, 1997), *SPP Healthy Waters*, and the *Queensland Best Practice Environmental Management Guidelines—Urban Stormwater* (Qld EPA, 2009). Review the most recent version of the *South East Queensland Regional Plan* and its implementation guidelines, specifically *Implementation Guideline No. 7: Water Sensitive Urban Design* (Qld DIP, 2008b). Review the most recent regulations on issues relevant to WSUD to establish minimum acceptable requirements for the development. The QDC regulates WSUD issues that are assessed as part of a building approval. Policies and codes in local government planning schemes developed under the *Integrated Planning Act 1997* (IPA) deal with WSUD issues assessed as part of a development approval.	Review state government regional ecosystem mapping and local government vegetation mapping and vegetation protection overlays.	Review *Queensland Water Quality Guidelines* (Qld EPA, 2006)	Inspect waterways and wetlands on, and immediately downstream of, the development to establish current condition, key stressors, system vulnerability, resilience, and key management requirements such as protecting critical sustaining hydrology, water quality, stream stability, and ecological health.	Review regional surface water hydrology and groundwater hydrology mapping and statistical data to identify the site's regional hydrologic context, for example whether the site is a recharge area for a regional aquifer system or a key source of environmental flows to a local waterway. Obtain and review information on aquifers within the development site to determine the potential for sustainable groundwater abstraction as part of a portfolio of alternative water sources or for aquifer storage and recovery. Inspect waterways and wetlands on, and downstream of, the development site to confirm key hydrologic pathways and ecosystem dependencies on surface water and groundwater flows.
Project Team Members & Expertise	Civil / Environmental Engineer (WSUD specialist); Town Planner	Environmental Engineer / Ecologist (terrestrial and aquatic ecology specialist)	Civil / Environmental Engineer (WSUD specialist)	Ecologist (aquatic ecology and botany specialist)	Civil Engineer (hydrology and hydrogeology specialist); Ecologist (terrestrial and aquatic ecology specialist)
Project Risk Management Benefit	Ensures project will be consistent with key WSUD policy directions and compliant with minimum statutory requirements.	Ensures the project is compliant with state and local government regulations about regional ecosystem protection and enhancement.	Ensures the project is compliant with the intent of state government scheduled water quality objectives.	Ensures endangered or vulnerable ecosystems on, or downstream of, the site are protected.	Ensures key hydrologic pathways are protected together with hydrologic dependent ecosystems.

WSUD Conceptual Design Process

06

Understand the regional and local integrated water cycle infrastructure context

Identify locations of all existing and planned regional trunk water supplies, wastewater and stormwater infrastructure, including any recycled water supply pipelines or 'centralised' water treatment facilities that are needed to service the development. If the local council has prepared an integrated water-cycle strategy that includes the site, identify actions relevant to the site. In particular, identify all priority infrastructure subject to infrastructure charges levied on the development.

Establish if the capacity of existing or planned regional infrastructure is able to support the intended future impact and population of the proposed development. If not, consider costs and benefits of augmenting infrastructure versus on-site management to reduce demand on the integrated water-cycle infrastructure.

Establish if the development is located within a Purified Recycled Water (PRW) scheme area. Review the operating rules for any PRW schemes to establish if on-site or local wastewater treatment and re-use is an option for the development. Alternatively, an allocation of PRW may be available to the development. The South East Queensland Water Grid Manager is responsible for allocations.

Identify alternative water sources available to the development from centralised or regional schemes, such as reclaimed wastewater.

Civil Engineer (water services infrastructure specialist)

Ensures the project captures least-cost integrated water-cycle management infrastructure that is compliant with regional water-cycle operating rules.

07

Understand the current and future flooding risk on, and downstream of, the site

Review flood studies and historic flood mapping. Establish flood extents, depth, and velocities along major overland flow paths and watercourses.

Consider the impacts of climate change on future flooding around the site, particularly low-lying developments that are vulnerable to sea-level rise and increased storm surge.

Civil/Environmental Engineer (WSUD specialist); Town Planner

Ensures the project manages flood risk over the long term.

08

Understand the site terrain and soils

Review three-dimensional terrain data for the site to establish surface slopes across the development site and key topographical features such as ridge lines, gullies, and waterway corridors. If the site is small, obtain regional topographic mapping at an appropriate scale to understand the site's context within the regional terrain.

Prepare a slope analysis map for the site to delineate slopes >15% and < 5%. Slopes > 15% are difficult to manage using distributed at-source WSUD techniques. In most cases stormwater will need to be collected in conventional stormwater infrastructure and directed to stormwater infrastructure downslope on gentler sloping land. The availability of suitable downslope locations for stormwater management will determine the appropriateness of development on steep slopes. Similarly, slopes between 5% and 15% are also challenging. However, a range of possible urban design responses, including aligning streets parallel or tangential to contours to reduce longitudinal street grades, and strategically located public open space can create opportunities for a combination of distributed at-source as well as end-of-pipe WSUD infrastructure solutions. Low-grade or flat sites (<5%) require deliberate design and earthworks responses to ensure flood immunity and efficient drainage of the land surface. These sites are best managed using on-surface conveyance and treatment of stormwater runoff with distributed at-source WSUD infrastructure solutions.

Identify watershed sub-catchments within the site and key points of discharge to receiving waters or to existing stormwater infrastructure. There must be sufficient information on invert levels of receiving systems to enable a preliminary assessment of constraints to achieving a free draining outfall from WSUD infrastructure. Again, this is particularly important for flat sites. For flood-prone flat sites, consider the pattern of site filling to achieve flood immunity and on-surface conveyance and treatment of stormwater runoff.

Obtain soils mapping and bore log data for the development site to establish physical and chemical characteristics for each of the A, B, and C horizons. An assessment of the horticultural characteristics of the A horizon should also be undertaken to assess suitability for landscaping and to identify requirements for soil amendments to minimise water and fertiliser use. Soils should also be tested for their suitability for irrigation by treated wastewater.

Development sites located in areas of potential acid sulfate soils (PASS) must undertake additional soils testing to map areas of PASS and to establish clear management requirements for any areas of PASS likely to be oxidised as a result of development of the site.

Civil /Environmental Engineer (WSUD specialist); Geologist, Soil Scientist, Erosion and Sediment Control specialist or Acid Sulfate Soils specialist

Ensures the project is informed with sufficient information on terrain and geology to aid selection of appropriate WSUD planning and management practices suited to the conditions of the site.

09

Prepare a preliminary WSUD opportunities and constraints overlay

A WSUD opportunities and constraints overlay should be prepared based on the information gathered in the previous eight tasks. The WSUD overlay should then be used to inform an integrated conceptual urban design discussion with the other members of the project team.

Civil/Environmental Engineer (WSUD specialist)

Ensures the conceptual site design process is fully informed by information relevant to selecting the most appropriate WSUD planning and management practices to achieve the project's WSUD design objectives at least-life cycle cost.

WSUD Conceptual Design Process

Step 2: Establish WSUD objectives

	10	11	12	13
Task	**10. Determine water conservation objectives**	**Determine wastewater minimisation objectives**	**Determine stormwater management objectives**	**Confirm WSUD design objectives with local council**
Key Activities	Determine from the most recent state government regulations such as the QDC, the minimum statutory requirements for water savings and using alternative water sources given the building types proposed in the development. Determine if 'stretch' targets, that is targets beyond minimum regulations, for water conservation are necessary based on the capacity of existing bulk water supply infrastructure servicing the site and the availability of acceptable alternative water sources. If stretch targets are necessary, undertake relevant water balance analyses and triple bottom line assessments to establish the optimal water conservation targets for the site. This task must consider alternative water source priorities based on the other WSUD objectives of wastewater minimisation and stormwater management for environmental protection so that multiple objectives are achieved.	Based on the capacity of existing trunk sewers and wastewater treatment infrastructure servicing the development, determine if wastewater minimisation is required. If it is, consider options for increased wastewater recycling within the development such as employing greywater and blackwater splitting and land use clustering to maximise the benefits of treated greywater generated within the development. Also consider specifying 'smart sewer' technology to minimise infiltration into sewer lines.	Based on the development type and the nature and condition of the receiving waters (i.e. whether tidal or non-tidal or of high environmental value or degraded), determine the minimum stormwater quality and quantity management objectives from the local council's planning regulations. In South East Queensland, the Department of Infrastructure and Planning (DIP) is responsible for administering the South East Queensland Regional Plan. DIP has prepared the *Implementation Guideline # 7: WSUD Design Objectives for Urban Stormwater* (Qld DIP, 2008). This guides local councils in South East Queensland on the adoption of a standard set of WSUD design objectives in local planning schemes. If there are special ecological conditions on, or downstream of, the development site that require additional stormwater quantity or quality management to protect them, they should be clearly identified and specialist advice sought. This may include stormwater harvesting to preserve key sustaining hydrologic patterns and it may be necessary to prioritise stormwater harvesting within the range of alternative water sources used by the development.	The WSUD design objectives established for the development site should be confirmed with the local council. Where the intended design objectives differ from minimum statutory requirements, this should be clearly explained to the council with technical information and analyses for review and approval.
Project Team Members & Expertise	Civil / Environmental Engineer (WSUD specialist)	Civil / Environmental Engineer (WSUD specialist)	Civil / Environmental Engineer (WSUD specialist); Ecologist (aquatic ecology and botany)	Civil / Environmental Engineer (WSUD specialist) and, if required, Ecologist (aquatic ecology and botany specialist)
Project Risk Management Benefit	Ensures the project delivers minimum regulatory requirements and proceeds through the Integrated Development Assessment System (IDAS) process.	Ensures the project delivers minimum regulatory requirements and proceeds through the development approvals process.	Ensures the project delivers minimum regulatory requirements and proceeds through the development approvals process.	Ensures the project delivers minimum regulatory requirements and proceeds through the development approvals process.

WSUD Conceptual Design Process

Step 3: Conceptual site layout

	14	15	16	17
Task	**Integrate the conceptual design process**	**Undertake detailed site analysis**	**Undertake quantitative modelling**	**Prepare final conceptual site layout and present to the local council at a pre-lodgement meeting**
Key Activities	Integrate the WSUD opportunities and constraints from Step 1 with other site analysis information in an inter-disciplinary conceptual design process to formulate a preliminary structure plan, or site master plan. Informed by the site analysis and relevant design objectives from Steps 1 and 2, workshop BPPs and BMPs to attain the WSUD design objectives. Other equally important design objectives for the project must also be detailed. This is an iterative design process ensuring all objectives are considered within a holistic, inter-disciplinary design process. Competing design objectives must be resolved and cost synergies across objectives explored.	As the site planning process converges, more detailed site visits will be required to confirm, in greater detail, the conditions at locations for key WSUD infrastructure. For example, more detailed topographic and features surveys and soils and geotechnical information may be required to confirm the suitability of sites for intended WSUD infrastructure. Additional discussions may be required with local water service regulators and providers to confirm the intended integrated water-cycle strategy.	Quantitative modelling of land use and infrastructure layouts to measure performance against the WSUD design objectives is an important part of the site design optimisation process. Quantitative models allow various WSUD planning and infrastructure scenarios to be evaluated on a triple bottom line basis. Depending on the scale of the development, quantitative modelling will involve water balance modelling or end use modelling, water supply and wastewater network modelling, and stormwater quality and quantity modelling.	The conceptual site design plans, together with supporting reports, including the WSUD strategy report, should be submitted to the local council in support of a Material Change of Use or Reconfiguring of an Allotment application.
Project Team Members & Expertise	Town planner (statutory planning); Architect / Urban Designer (master planning); Landscape Architect (open space planning); Civil / Environmental Engineer (WSUD specialist); Ecologist (terrestrial and aquatic ecology specialist); Developer	Civil / Environmental Engineer (WSUD specialist) and, if required, Ecologist (aquatic ecology and botany specialist)	Civil / Environmental Engineer (WSUD specialist) and, if required, Ecologist (aquatic ecology and botany specialist)	Town Planner (statutory planning); Architect / Urban Designer (master planning); Landscape Architect (open space planning); Civil / Environmental Engineer (WSUD specialist); Ecologist (terrestrial and aquatic ecology specialist); Developer
Project Risk Management Benefit	The collaborative and inter-disciplinary conceptual site design process ensures a fully integrated design process where WSUD requirements, for compliance with WSUD Design Objectives, are seamlessly integrated into the conceptual site design with all cost delivery synergies and multiple benefits realised.	Ensures the WSUD planning and management practices adopted within the conceptual site design are 'tested' with sufficient rigour to confirm appropriateness and constructability. This helps to avoid unnecessary conceptual site design changes at sub-division design (i.e. operation works) stage and thus ensures a more expeditious pathway through the development approvals process.	Ensures the WSUD planning and management practices adopted within the conceptual site design are 'tested' with sufficient rigour to confirm appropriateness and constructability. This helps to avoid unnecessary conceptual site design changes at sub-division design (i.e. operation works) stage and thus ensures a more expeditious pathway through the development approvals process.	Ensures the WSUD planning and management practices adopted within the conceptual site design are 'tested' with sufficient rigour to confirm appropriateness and constructability. This helps to avoid unnecessary conceptual site design changes at sub-division design (i.e. operation works) stage and thus ensures a more expeditious pathway through the development approvals process.

Water Conservation Garden - Australian Garden

MDG Landscape Architects

Photo: Alan Hoban

WSUD Strategies

Content:

Introduction

Water Conservation

Wastewater Minimisation

Stormwater Management

03

Introduction

This section on WSUD strategies aims to provide additional information on how incorporating WSUD in conceptual designs can provide a means of managing the urban water cycle. Figure 7 provides an overview of how the three streams of urban water — potable water, wastewater and stormwater — are linked.

In this section, each urban-water stream is presented separately. Appropriate management strategies are provided for each of these streams. A successful WSUD concept design should incorporate management strategies for all of these urban water streams where appropriate.

To be able to fulfil these WSUD strategies, Best Planning Practices (BPPs) and Best Management Practices (BMPs) will be required. These are referred to throughout this section and are described in more detail in the later parts of the guidelines.

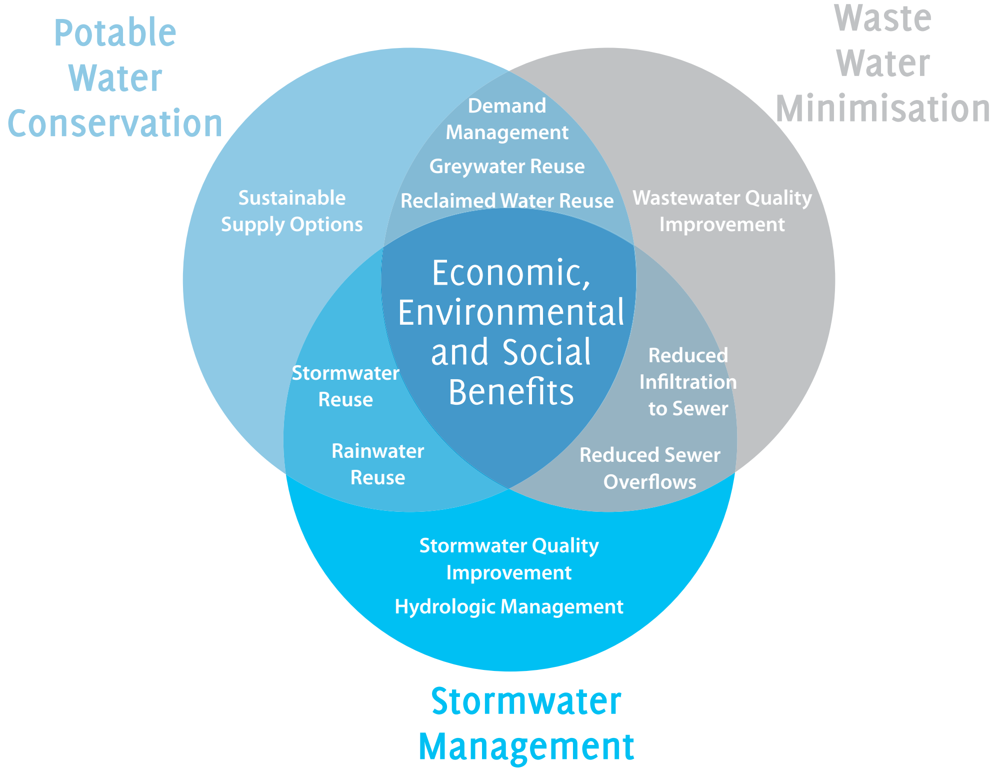


Figure 7 — Integrated Management of the Urban Water Cycle (Hoban and Wong, 2006)

Photo: Alan Hoban

Photo: Alan Hoban

Water Conservation

Conserving existing potable water supplies is a key objective of WSUD to reduce or delay the need to augment supplies. Water conservation reduces urban developments' reliance on imported water as shown in Figure 8. Conservation enables regional river systems and aquifers to be protected from further exploitation and may allow restoration of environmental flows, giving these systems greater resilience to future climate change impacts.

Water conservation includes demand management and using alternative sources to substitute for potable water where quality is not an issue for the end use.

Reducing the use of potable water contributes to building future urban water supplies that are more resilient to peturbations, including climate change. The Queensland Government has recently amended key pieces of state legislation and regulations mandating more efficient water use by residential, commercial, and industrial users. The new MP 4.1–4.3 of the QDC (Qld DIP, 2008a) strengthen regulation of water efficiency and use of alternative water sources in new buildings and renovations in Queensland (refer to Section 1: WSUD Design Objectives).

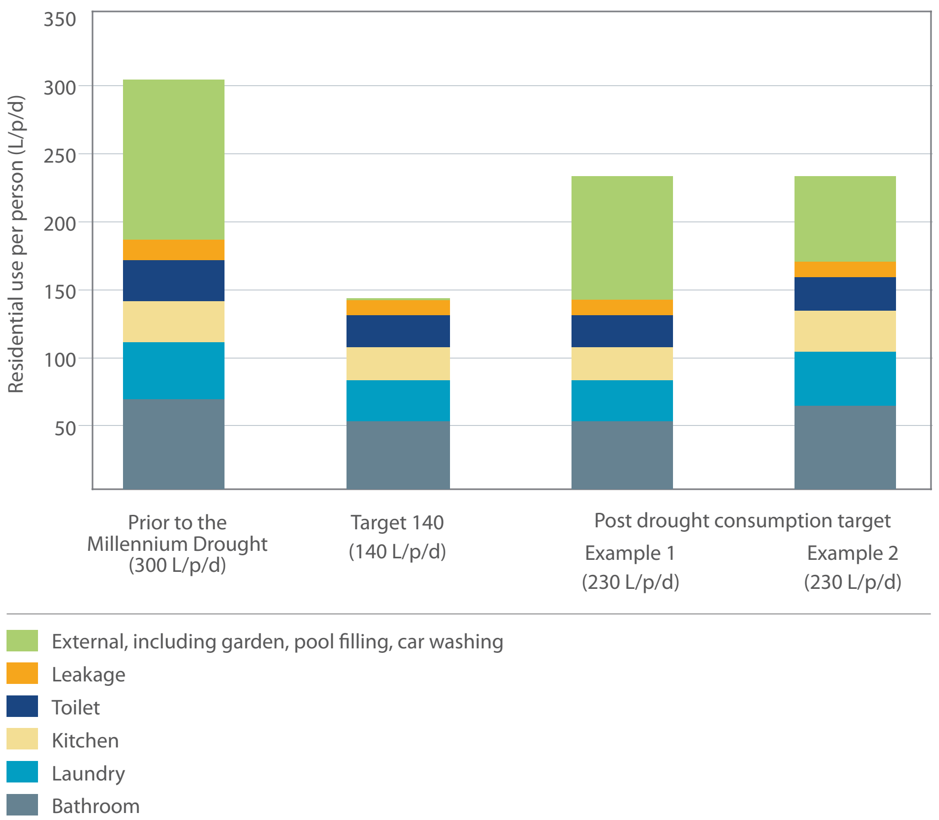


Figure 8 — Typical residential water use in SEQ showing water reductions achieved through water conservation strategies (QWC, 2008)

Demand management

Potable water demand management BMPs are not contentious and are reasonably easy to introduce (see BMP 1). Mechanisms such as education, incentives, and regulation can be used. Initiatives include (Landcom, 2004):

1. Education to achieve behavioural change with regard to:

- tap maintenance
- efficient garden watering practices
- no hosing of paths and driveways
- use of swimming pool blankets to reduce evaporation
- reduced domestic water use (shower times, etc.).

2. A mix of education, incentives and regulation to achieve:

- The use of Water Efficiency Labelling and Standards (WELS) rated water-efficient plumbing fittings
- The use of WELS-rated water-efficient appliances (e.g. dishwashers and washing machines)
- 6/3 or 4.5/3 dual flush cisterns
- Pressure regulation (depending on the type of household appliances)
- Garden design incorporating low water requirement vegetation and mulching (xeriscaping).

Potable water demand management BMPs can be implemented in most development types. Queensland Water Commission provides useful information on demand management initiatives at http://www.qwc.qld.gov.au/.

Alternative water sources

Decision process for selecting alternative water sources

1. Identify site characteristics and interactions with the built environment:

- development type and scale
- current centralised potable water supply capacity
- potential upgrades required to cater for development
- potential offsetting investment in infrastructure upgrades with reuse treatment opportunities.

2. Conduct a site water balance:

- fit-for-purpose alignment of water sources and water uses
- assess water demands with an end-use analysis
- calculate water balance
- align demand profile with supply profile .

3. Identify water reuse options:

- on-site
- localised treatment
- dual supply pipeline from centralised reclamation plant.

4. Consider social aspects and human health:

- adopt a risk-based approach to defining methods of delivery and corresponding water quality requirements, including developing a Hazard Analysis and Critical Control Point assessment (HACCP)
- define requirements for pre-commissioning monitoring and demonstration of compliance to current health standards for reused water
- identify community receptiveness to different applications of reused water.

5. Evaluate the impact on the natural environment:

- receiving water quality impacts
- greenhouse gas emissions
- land suitability.

6. Consider life cycle costing and economics:

- economies of scale
- capital, operational, replacement and decommissioning costs.

7. Select appropriate alternative water sources and associated water quality treatment BMPs based on steps 1–6.

Source: Landcom 2006.

Fit-for-purpose

Integrated water cycle management matches available water sources with their most appropriate uses. In most urban developments there are three major water sources: potable water, wastewater, and stormwater. The wastewater component can be further split into greywater (showers, bathroom and laundry sinks, and washing machines) and blackwater (kitchen and toilets). Stormwater can also be divided into roof runoff and ground level surface runoff (roads, paths, and pervious surfaces such as lawns) (Landcom, 2004).

'The major objective of water re-use initiatives is to replace potable water use with other water sources where the quality is fit-for-purpose (Landcom, 2004).'

Table 4 and Figure 9 show a suggested hierarchy of source-to-use matches for a typical household.

Table 4—Compatibility of water source, quality, and use

	Areas Of Water Use							
	Garden	Kitchen		Laundry		Toilet	Bathroom	
Source		Cold	Hot	Cold	Hot		Cold	Hot
POTABLE WATER	3	1	2	1	2	3	1	2
WASTEWATER								
• Purified Recycled Water (PRW)	3	1	2	1	2	3	1	2
• Class A+ Recycled Water	1	4	4	4	4	2	4	4
• Class A Recycled Water	2	4	4	4	4	4	4	4
• Treated Greywater	2	4	4	4	4	2	4	4
STORMWATER								
• Rainwater Runoff	2	2	1	1	1	2	2	1
• Stormwater Runoff	2	4	4	3	3	2	4	4

1 = optimal use of water source; **2** = compatible use; **3** = sub-optimal use; **4** = not compatible

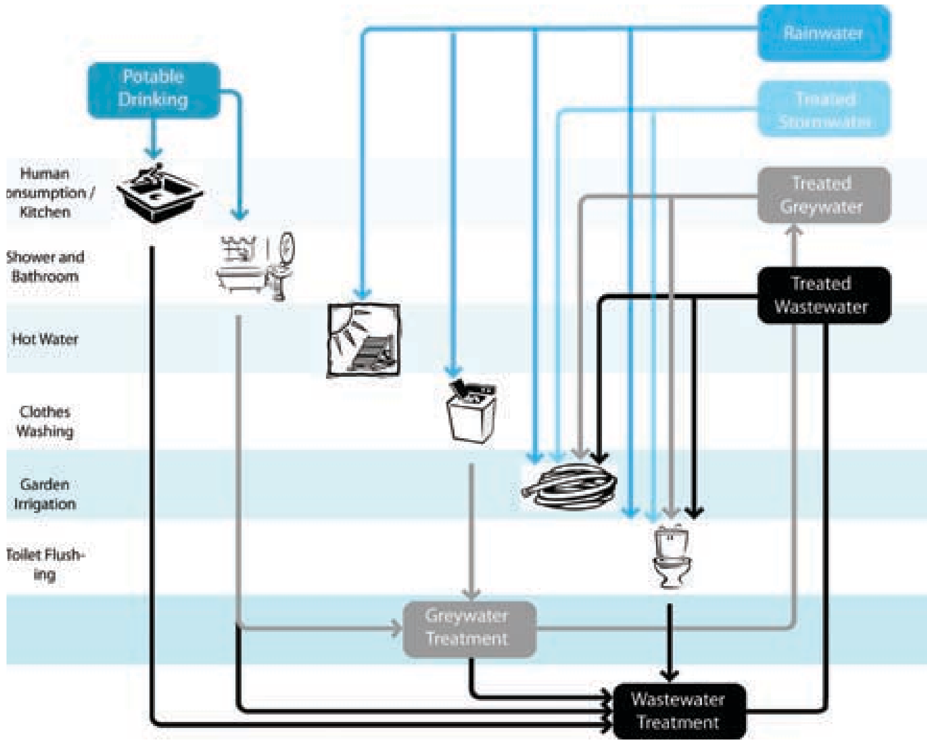


Figure 9 — Water harvesting, treatment and reuse options

Adapted from Landcom, 2004.

**The information in this table is indicative only. Technologies for water treatment, as well as regulations, change from time to time. Practitioners must consult relevant local authorities to obtain latest guidelines on acceptable use of various water sources. Relevant authorities include Queensland Health, Natural Resources and Water, and the National Health and Medical Research Council.*

A good understanding of the treatment required for each water source is important. This information is shown in Table 5 to help appropriate treatment BMPs to be selected. BMP technologies and their treatment efficiencies are outlined in more detail in Section 3: Stormwater Management and Section 5: Best Management Practices.

Table 5 — Summary of water quality and treatment requirements for urban water sources

Water	Source	Quality	Treatment Required
Potable drinking water	Reticulated water distribution	High quality	Minimal — chlorination and filtration
Rainwater runoff	Primarily roof runoff	Reasonable quality	Low level — sedimentation occurs within a rainwater tank
Stormwater runoff	Catchment runoff — predominantly urban impervious surfaces	Moderate quality	Treatment to remove litter and reduce sediment and nutrient loading. More information is provided in Section 5: Best Management Practices.

(Landcom, 2006).

Water Conservation

'Light' greywater	Shower, bath, bathroom basin	Cleanest wastewater — low pathogens and organic content	Moderate treatment to reduce pathogens and organic content. More information is provided in Section 5: Best Management Practices.
Greywater	Laundry (basin and washing machine)	Low quality — high organic loading and highly variable	High level due to high organic level and highly variable quality. More information is provided in Section 5: Best Management Practices.
Blackwater	Kitchen and toilet, industrial wastewater	Lowest quality — high levels of pathogens and organics	Advanced treatment and disinfection. More information is provided in Section 5: Best Management Practices.

Matching alternative water sources to typical development types

Alternative water sources suited to typical development types are described in this section. As at 2008, sewer mining and other forms of local blackwater treatment for internal re-use in toilets and cooling towers is not permitted within sewered areas of Queensland. Trials of on-site blackwater treatment and re-use are being conducted by state government agencies. This situation may be reviewed in the future.

Greenfield developments

Greenfield residential developments can cater for a wide range of alternative water sources. Centralised and localised stormwater harvesting and reuse schemes are suitable. Currently, reusing treated sewage effluent is an efficient way of supplying alternative water on a large scale. The proximity to, and scale of, the local sewage treatment plant determines the viability of dual-pipe reticulation (Landcom, 2006).

Residential urban development or redevelopment

The scale of development will determine the suitability of alternative water source options. Larger scale redevelopments enable localised schemes such as sewer mining (Landcom, 2006).

Initiatives in residential developments on a smaller scale, either an infill development (knock down and rebuild) or renovation of an existing building, create opportunities for rainwater harvesting and greywater re-use on individual lots (Landcom, 2006).

Mixed-use urban developments

Building height, density, landscape area and end use help to determine the integrated WSUD strategy for mixed-use urban developments. Alternative water sources on a localised scale are required for toilet flushing and garden irrigation (Landcom, 2006).

The ratio of roof area to number of residents will determine the feasibility of rainwater harvesting. The feasibility of greywater re-use depends on the mix of residential and commercial uses. Residential developments generate more greywater than can be re-used, while commercial developments have a high re-use demand with low greywater generating capacity. Co-locating high-rise residential land uses with high-density commercial land uses maximises opportunities for precinct-scale re-use of treated greywater (Landcom, 2006)

In a higher-density environment, reclaimed water from sewer mining may also be a feasible alternative water source (Landcom, 2006).

High-rise residential development

A high-rise urban development is typical of future residential growth within cities. Residential water demand is similar to a typical household, except for garden irrigation. Rainwater capture from the roof is often limited due to the relatively small surface area to water demand ratio. A combination of demand management, roofwater harvesting, and greywater re-use is the preferred approach (Landcom, 2006).

Commercial developments

The commercial sector includes offices, schools, business premises, and event venues such as sporting stadiums. In commercial buildings, water use is dominated by toilet flushing. Relatively little demand exists for drinking water and garden irrigation. Greywater generation is expected to be small as there is minimal showering in these buildings, so a combination of demand management, roofwater harvesting at the allotment scale, supplemented by a precinct-scale treated greywater source or sewer mining source is recommended (Landcom, 2006).

Photo: Alan Hoban

Wastewater Minimisation

Minimising wastewater flows can reduce conveyance and treatment requirements, sewer overflows, and discharge of nutrients to aquatic environments.
Wastewater minimisation is a key objective of WSUD.

Wastewater minimisation involves one or more of the following approaches to be undertaken:

1. Reduce wet weather flows:

- reduce stormwater infiltration into sewers during wet-weather
- eliminate illegal or accidental cross-connections between sewers and stormwater.

2. Reduce wastewater discharge from the development:

- reduce generation of wastewater by adopting potable water demand management BMPs (see BMP 1)
- maximise opportunities for wastewater reuse as a replacement for potable water (i.e. alternative water source BMP (see BMP 4)).

Wastewater minimisation within a Purified Recycled Water (PRW) Scheme area

In Brisbane and Ipswich, wastewater from centralised treatment plants is treated to PRW standard and re-used for industry, power stations, and recharge of the greater Brisbane potable water supply. The investment in advanced water treatment plants and infrastructure to supply PRW to end-uses in South East Queensland requires a minimum allocation of wastewater flows to the PRW scheme. Wastewater minimisation by on-site and local wastewater treatment and recycling witwehin a PRW scheme must be carefully considered so it does not impact the yield of the PRW scheme. However, it is possible to implement some treatment and recycling on projects located within PRW schemes. For example, if wastewater flows are in excess of the needs of the PRW scheme and it is cost effective and beneficial to implement on-site and local treatment and recycling, a case can be made. If alternative sources of water such as stormwater harvesting or local aquifer abstraction replace the development's wastewater flow contribution to the PRW scheme, on-site and local treatment and recycling may be agreed by the PRW scheme regulator.

Reducing wet weather inflows

Contemporary sewer technologies can minimise the inflow of stormwater into the sewer network. Water authorities in South East Queensland are promoting smart sewer technology (such as Brisbane City Council's NuSewer standards). Smart sewers use small-bore flexible pipes in lieu of conventional clay, resulting in fewer joins and manholes, decreasing the pathways for stormwater inflows into the pipe network and reducing wastewater flows. Cross connections of stormwater lines and sewer lines at the allotment scale require plumbers to be educated and local councils to police implementation.

Reducing wastewater discharge from the development

Addressing water conservation design can reduce wastewater generation. Objectives to reduce demand on potable water supplies through demand management and using alternative water sources should be developed.

Maximising the re-use of treated wastewater for end uses as outlined in Table 4 helps to reduce potable water demand and reduces discharge to aquatic ecosystems. Under current Queensland regulation, in sewered areas it is only acceptable to treat and re-use greywater for garden watering and select internal uses such as toilets and possibly cooling towers in high-rise residential and commercial office buildings. As on-site or local blackwater treatment and re-use is not permitted, it is necessary to consider splitting the collection and transport of wastewater within the building to separate greywater and blackwater. The relatively continuous supply of greywater means storage can be short term, avoiding the need for significant treatment or risk to water quality problems in storage (Landcom, 2004). Current regulations state that greywater can only be stored for 24 hours (Qld DIP, 2008a). After that the stored water must be purged to sewerage.

Separation of greywater into 'light greywater' (shower and hand basin only) can further reduce the risk of water quality issues in storage and re-use. Separation of light greywater reduces the amount of water available for re-use, but this reduced amount can be matched to an appropriate end use such as toilet flushing (Landcom, 2004).

Where wastewater splitting is undertaken on a large scale, the capacity of the existing sewerage system to process higher concentration, lower volume wastewater must be considered (Landcom, 2004).

The type of development influences the feasibility of wastewater splitting within a building. For example, commercial office towers generate a relatively small amount of greywater—the dominant generator of wastewater is toilet flushing. There is little benefit in splitting greywater and blackwater in this type of building. However, high-rise residential towers generate a lot of greywater relative to blackwater and have a greywater surplus assuming re-use for toilets, cooling towers, and landscape areas. This creates potential water-cycle benefits for mixed-use precincts where high-rise commercial buildings are located alongside high-rise residential buildings. Greywater surplus from the residential towers can be connected to end uses in commercial office towers. Even greater efficiency can be gained if individual high-rise towers are mixed use—residential on the upper floors and commercial and retail on the lower floors (reduced costs associated with pumping). Refer to BPP 5: Symbiotic Land Use Clustering.

Integrated water cycle management can have a significant impact on land use planning and, in particular, symbiotic clustering of water generating land uses with high-demand land uses.

Stormwater Management

Managing stormwater to protect aquatic ecosystems and the natural water cycle is a key objective of WSUD. Conventional management of urban stormwater runoff to prevent flooding is still an important objective. However, the traditional approach of rapidly collecting stormwater runoff within hydraulically efficient conduits in underground pipe networks cannot be the only means of stormwater management. This traditional approach impacts on aquatic ecosystem health and prevents urban landscapes from benefitting from stormwater.

Stormwater management BMPs operate instead of, or with, traditional stormwater management infrastructure. Flood management is concerned with extreme, infrequent flooding events that occur less than once every two to five years. Stormwater management focuses on more frequent, everyday stormwater runoff to protect aquatic ecosystems and the natural water cycle. Frequent runoffs are most affected by urbanisation and have the greatest impact on the health of aquatic ecosystems. Stormwater management BMPs do not conflict with traditional management methods but work with them to ensure the holistic management of stormwater runoff for multiple benefits.

To ensure regulation keeps pace with the scientific findings underpinning better management of frequent stormwater runoff, the Queensland State Government has amended key pieces of state environmental and planning policy. These policies introduce a consistent set of new design standards for urban stormwater management. The WSUD Design Objectives section in these guidelines describes the new design standard objectives for the protection of waterway health.

Photo: Alan Hoban / Ecological Engineering

Stormwater management BMPs can be used in a treatment train, or in a sequence of BMPs to achieve the design objectives for waterway health. Stormwater treated by a treatment train of BMPs can be discharged to receiving aquatic ecosystems or can be stored for re-use (see BMP 3: Stormwater Harvesting).

Overview of stormwater management BMPs

Stormwater management BMPs form a tool kit from which individual BMPs can be selected to create a treatment train to suit the characteristics of each development and to treat a range of likely pollutants generated in urban areas (Landcom, 2004). Treatment trains should typically consist of BMPs that provide different levels of treatment—primary, secondary, or tertiary, and be located in that general order.

The following is a brief summary of the range of stormwater management BMPs. More detailed descriptions of each BMP, relevant to the conceptual design phase of urban developments, can be found in Section 5: Best Management Practices. The *WSUD Technical Design Guidelines for South East Queensland* (SEQ HWP, 2006) also provides detailed technical design guidance for stormwater management BMPs.

Table 6 shows the different development scales and treatment efficiencies for each BMP. The quality of treatment relates to the BMPs' performance for its target pollutants only.

Primary treatment BMPs

Primary treatment devices usually target litter, other pollutants, and coarse sediment. Without primary treatment devices, there is a risk that secondary or tertiary treatment devices will be become smothered, affecting their treatment capacity.

Gross pollutant capture devices

Gross pollutant capture devices retain gross organic and man-made litter washed from urban surfaces. They rely on physical screening rather than flow retardation to remove litter. Studies have found increased nutrient concentrations downstream of some gross pollutant traps under dry weather flows. There are potential detrimental impacts on downstream water quality where gross pollutant capture devices are used in isolation (i.e. when not used in conjunction with a vegetated bioretention or wetland system). The maintenance costs associated with gross pollutant traps must also be taken into account. (see BMP 5).

Sediment basins

Sediment basins store stormwater and promote settling of sediments by reducing flow velocities and temporary detention. There are a number of types of sediment basin and they can be used as permanent systems integrated into urban design, or used as temporary measures to control sediment discharge during construction (see BMP 6).

Secondary treatment BMPs

Secondary treatment devices usually target sediments, partially removing heavy metals and bacteria. These devices manage both quality and quantity of stormwater flows, but they cannot provide adequate water quality treatment to meet the South East Queensland water quality objectives when used in isolation.

Grass or vegetated swales

Vegetated swales disconnect impervious areas from downstream waterways and help protect waterways from storm damage by reducing flow velocity. They remove coarse and medium sediments and are commonly combined with buffer strips and bioretention systems (see BMP 7).

Sand filters

Sand filters are similar to bioretention systems, except the stormwater passes through a filter (sand) that has no vegetation on the surface. This reduces treatment performance compared to bioretention systems. Vegetation is minimised due to the low water-holding capacity and organic matter levels in sandy soils and lack of light because the systems are often installed underground. Sand filters should only be considered where site conditions, such as space or drainage grades, limit the use of bioretention systems (see BMP 8).

Table 6 — Scale of Stormwater BMP Applications and Performance Effectiveness

WSUD Measure	Scale			Runoff Quality and Quantity Management Effectiveness		
	Allotment Scale	Street Scale	Precinct or Regional Scale	Quality Treatment*	Peak Flow Attenuation	Reduction in Runoff Volume
Gross pollutant capture devices		✓		L	L	L
Sediment basins			✓	M	M	L
Grass or vegetated swales		✓	✓	M	M	L
Sand filters	✓	✓		M	L	L
Infiltration measures	✓	✓		N/A	L	H
Bioretention systems	✓	✓	✓	H	M	L
Constructed wetlands		✓	✓	H	H	L
Rainwater tanks	✓			L	M	M (with reuse)
Porous pavements		✓		L	L	M/H

H = High; M = Medium; L = Low

* Quality treatment = effectiveness in removing key environmental pollutants (stressors) such as TSS, TP and TN

Tertiary treatment BMPs

Tertiary treatment devices remove nutrients, bacteria, fine sediments, and heavy metals from stormwater. Without the inclusion of tertiary systems in a treatment train, South East Queensland water quality objectives cannot be met.

Bioretention systems

Bioretention systems operate by filtering stormwater runoff through densely planted vegetation, which then percolates runoff through a filter media. During percolation, pollutants are retained through fine filtration, absorption, and some biological uptake. Bioretention systems have flexible designs and can be applied at many scales, taking different forms such as street tree systems, bioretention swales, and rain gardens (see BMP 9).

Constructed wetlands

Constructed wetlands are densely vegetated water bodies that use enhanced sedimentation, fine filtration and biological uptake processes to remove pollutants from stormwater (see BMP 10).

Source control BMPs

Source control devices minimise the amount of stormwater entering systems.

Rainwater tanks

Sealed tanks capable of collecting stormwater directly from roofs or other above ground surfaces allow re-use of the collected water and can be located either above or below ground. Temporary flood storage can reduce peak flows by up to two-year ARIs. Tanks also provide some treatment by the settlement of suspended solids (see BMP 2).

Porous pavements

Porous pavements are pavement types that promote infiltration, either to the soil below or to a dedicated water storage reservoir under them. They are more aesthetically pleasing than conventional asphalt or concrete pavements (see BMP 11).

Infiltration systems

Infiltration systems do not treat stormwater, but capture runoff and encourage infiltration into surrounding soils and underlying groundwater. This reduces runoff peak flows and volumes, reducing downstream flooding, managing the flow entering downstream aquatic ecosystems and improving groundwater recharge (see BMP 12).

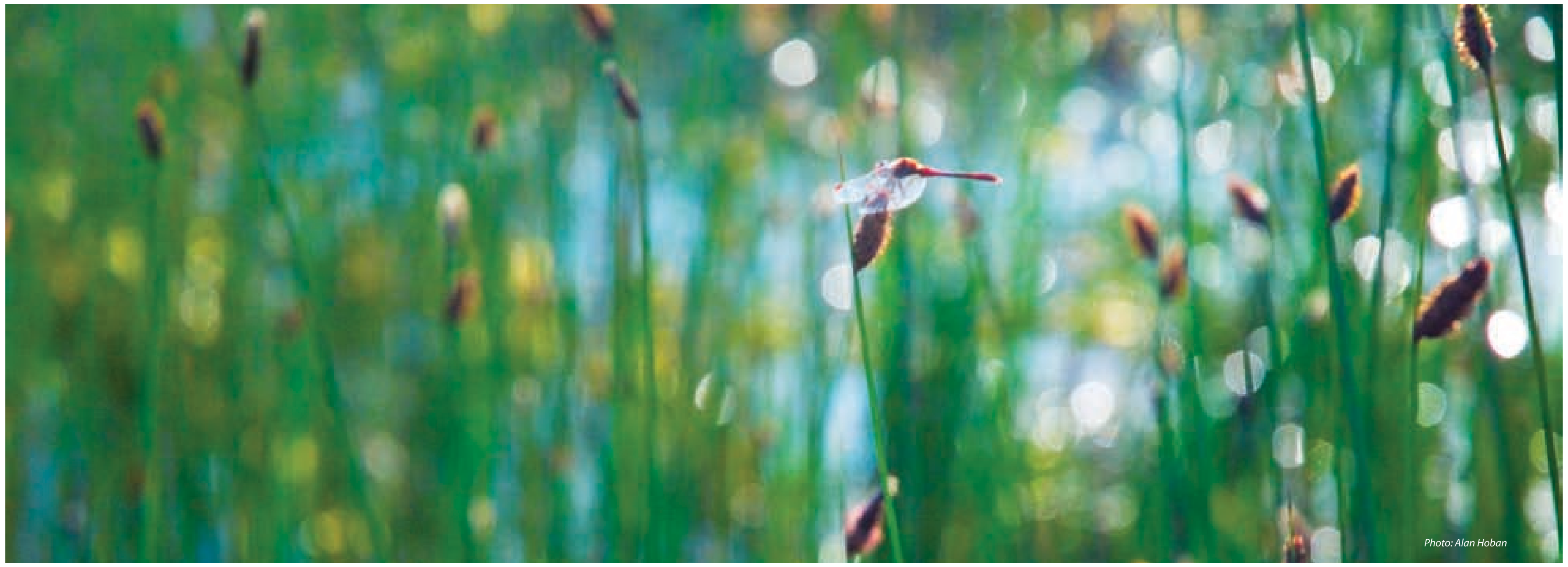


Photo: Alan Hoban

Stormwater Management

Bioretention systems vs constructed wetlands

Bioretention systems and constructed wetlands are both tertiary treatment BMPs. Without the inclusion of either of these devices in a stormwater treatment train, South East Queensland water quality objectives will not be met.

Site characteristics and the overall intention of the landscape help to determine which system to use. This is outlined in Table 7.

Table 7 — Comparison of Bioretention Systems and Constructed Wetlands for Different Design Considerations.

Design Consideration	Bioretention System	Constructed Wetland
Available area for treatment	Treatment area needs to be 1% to 2 % of the contributing catchment.	Treatment area needs to be at least 5% of the contributing catchment.
Flat site	Can be distributed throughout flat catchments to treat stormwater at-source. Design considerations on flat sites include the depth required to drain the systems (see Figure 10).	Flat sites are ideal as there are fewer constraints on the location of the system. They require less depth difference between inflows and outflows (see Figure 10).
Undulating site	Can be applied as a distributed system. Smaller bioretention 'pods' can be distributed throughout the site on small pockets of flatter land within the catchment, reducing risks associated with larger end-of-pipe solutions.	Large areas of flat land are required. This may result in large end-of-pipe systems being created in low-land public open spaces, which may impact on other beneficial uses.
High sediment loads	Are at a higher risk of failure in catchments with high sediment loads resulting in clogging and smothering of vegetation.	Treatment technologies provide an inbuilt resilience to sediment loading, making wetlands the preferred treatment choice in catchments with high sediment loads.
Landscape design	Do not retain water so can be incorporated into an overall landscape planting design for road reserves and public open space.	Can provide an interesting focal point in landscape design as they include open water.
Construction and establishment (see Table 9)	Can take longer to become fully established, depending on the establishment method adopted.	Can become fully established in a shorter timeframe than bioretention systems.
Public safety	Do not retain surface water so there is no requirement to restrict public access due to open water.	Public safety is a consideration when designing these systems due to permanent open water bodies.

Top left: Wetland as a feature in the landscape. **Top right:** Bioretention incorporated in street trees. **Middle right:** Bioretention as part of a streetscape landscape planting. **Bottom:** Bioretention as part of an end-of-pipe landscape planting.

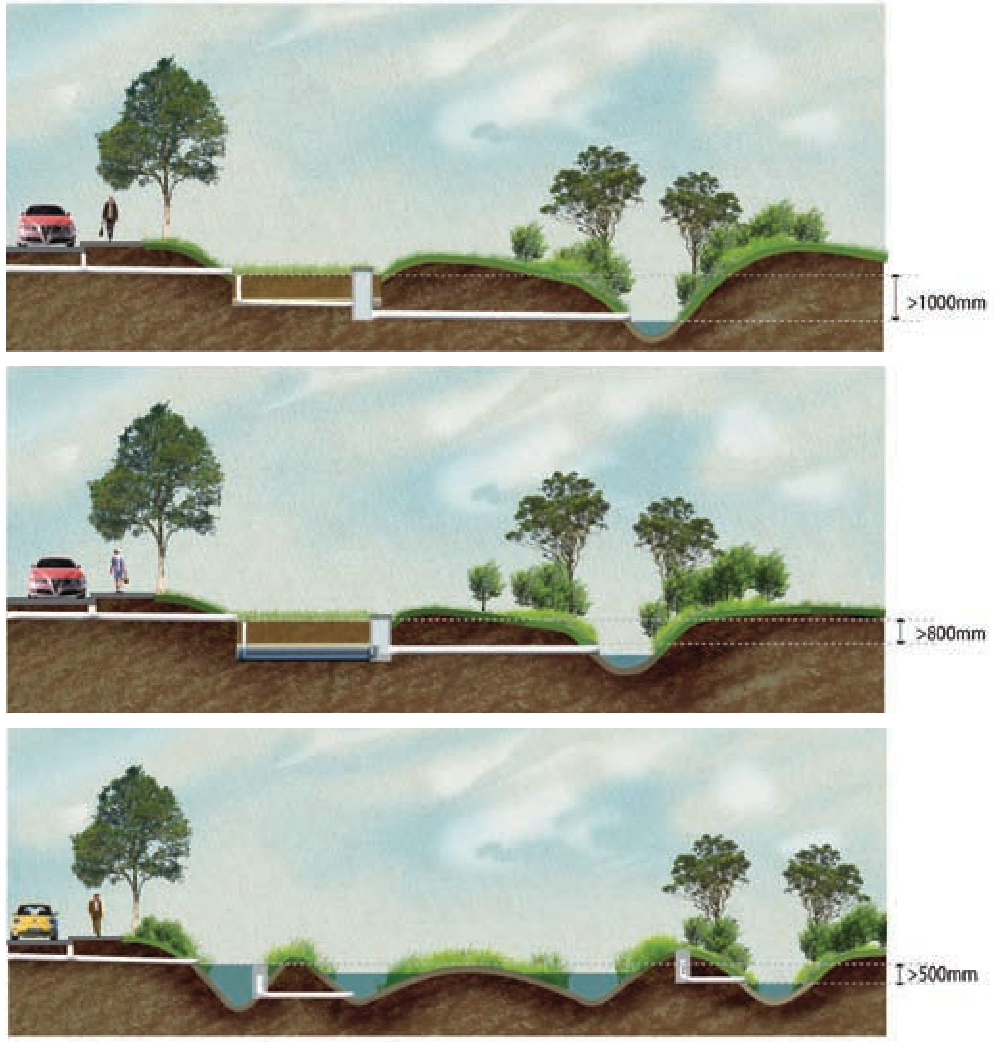


Figure 10 — Bioretention and constructed wetland systems differ in their requirements for minimum vertical fall from inflow pipes or channels to ensure unimpeded free draining outfall. The top image shows that a typical bioretention system requires at least 1000 mm to be able to drain into the receiving environment from the base of the system. Adding a submerged zone to a bioretention system decreases the required depth to at least 800 mm. Wetlands (bottom image) require the least vertical fall (>500 mm).

Developing stormwater ‘treatment trains’

Stormwater can carry a wide range of pollutant types and sizes. The range of potential pollutants means no single measure can effectively treat all pollutants carried by stormwater. Some stormwater BMPs are better able to remove certain pollutants than others. Therefore, a combination of stormwater BMPs is required to reduce the pollutants in stormwater (Landcom, 2004).

‘A series of treatment measures that collectively address all stormwater pollutants is called a “treatment train.” ’ (Landcom, 2004)

The selection and order of stormwater BMPs is a critical consideration in developing treatment trains. Coarse pollutants generally need to be removed first so that BMPs that target fine pollutants can operate effectively. Other considerations when determining a treatment train are the proximity of the treatment to its source, the distribution of stormwater BMPs throughout a catchment, constructability and maintenance (Landcom, 2004).

Site conditions and the characteristics of the target pollutants influence the type of stormwater BMP suitable for different locations and stormwater treatment trains. Table 8 and Figures 11 and 12 describe the site constraints and target pollutants for different stormwater BMPs. Different configurations of these BMPs in stormwater treatment trains depending on the site conditions and contributing landuses, are shown on pages 28-29.

Table 8 — Site Constraints for Stormwater BMPs

WSUD Measure	Steep Site	Shallow Bedrock	Acid Sulfate Soils	Low Permeability Soil (e.g. Clay)	High Permeability Soil (e.g. Sand)	High Water Table	High Sediment Input	Land Availability
Gross pollutant capture devices	✓	D	D	✓	✓	D	✓	✓
Sediment basins	D	D	✓	✓	D	D	✓	✓
Grass or vegetated swales	C	D	D	✓	D	C	D	✓
Sand filters	✓	D	D	✓	✓	C	D	✓
Bioretention systems	D	D	D	✓	D	C	D	✓
Constructed wetlands	C	D	D	✓	D	D	D	D
Rainwater tanks	✓	✓	✓	✓	✓	✓	✓	✓
Porous pavements	C	C	C	C	✓	C	C	✓
Infiltration measures	C	C	C	C	✓	C	C	✓

C = Constraint may preclude use
D = Constraint may be overcome through appropriate design
✓ = Generally not a constraint

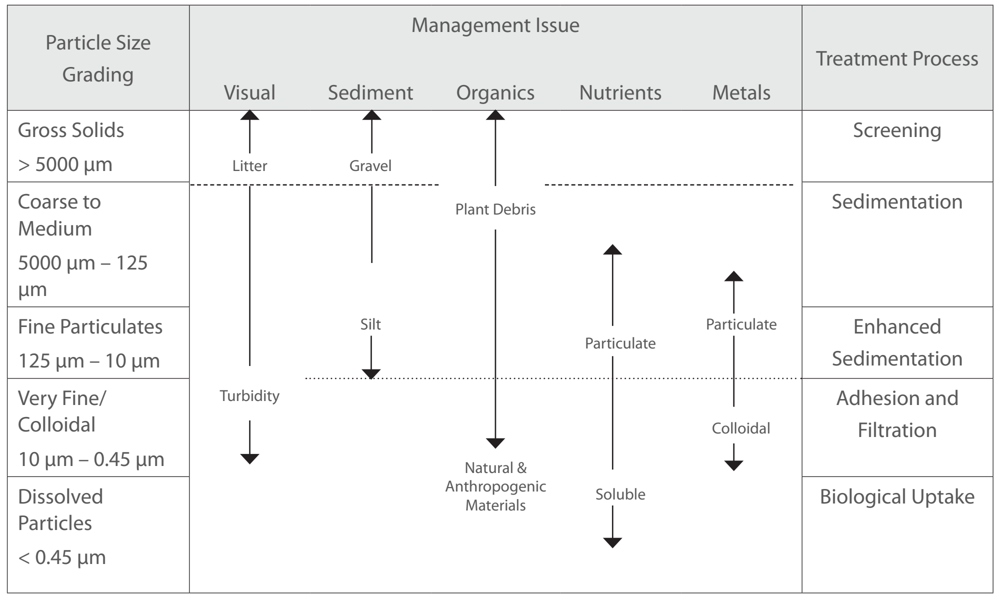


Figure 11 — Stormwater management issues, pollutants and treatment processes (Ecological Engineering, 2003)

A treatment train consists of a combination of BMPs that can address the range of pollutant particle sizes found in stormwater. A treatment train, therefore, employs a range of processes to achieve pollutant reduction targets (such as physical screening, filtration and enhanced sedimentation). (Landcom, 2004)

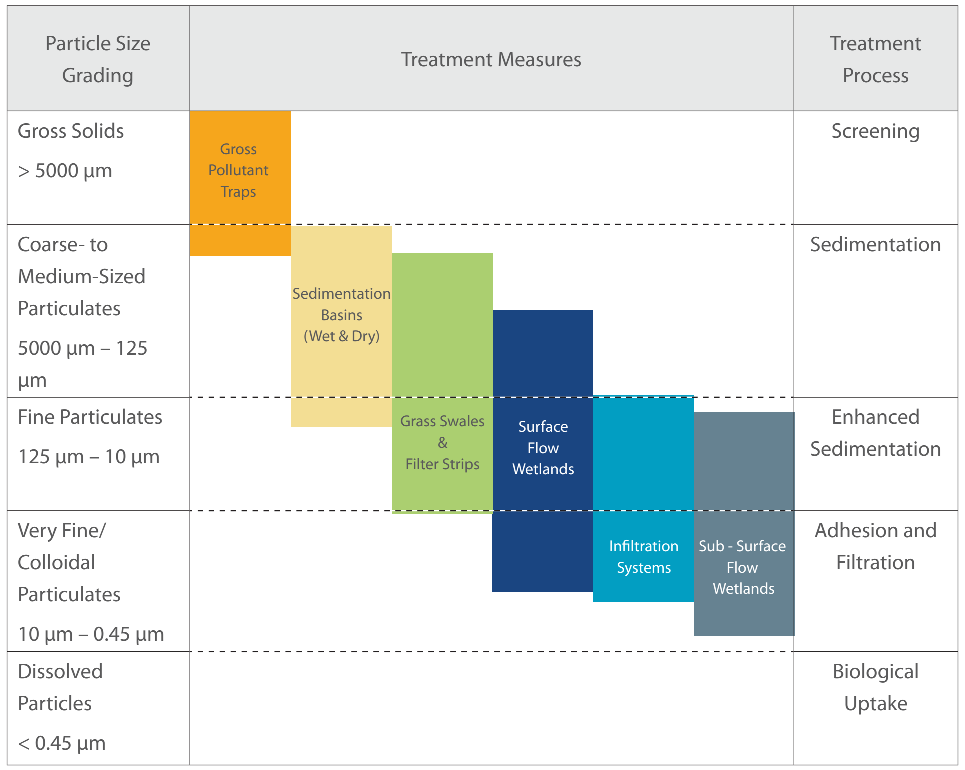
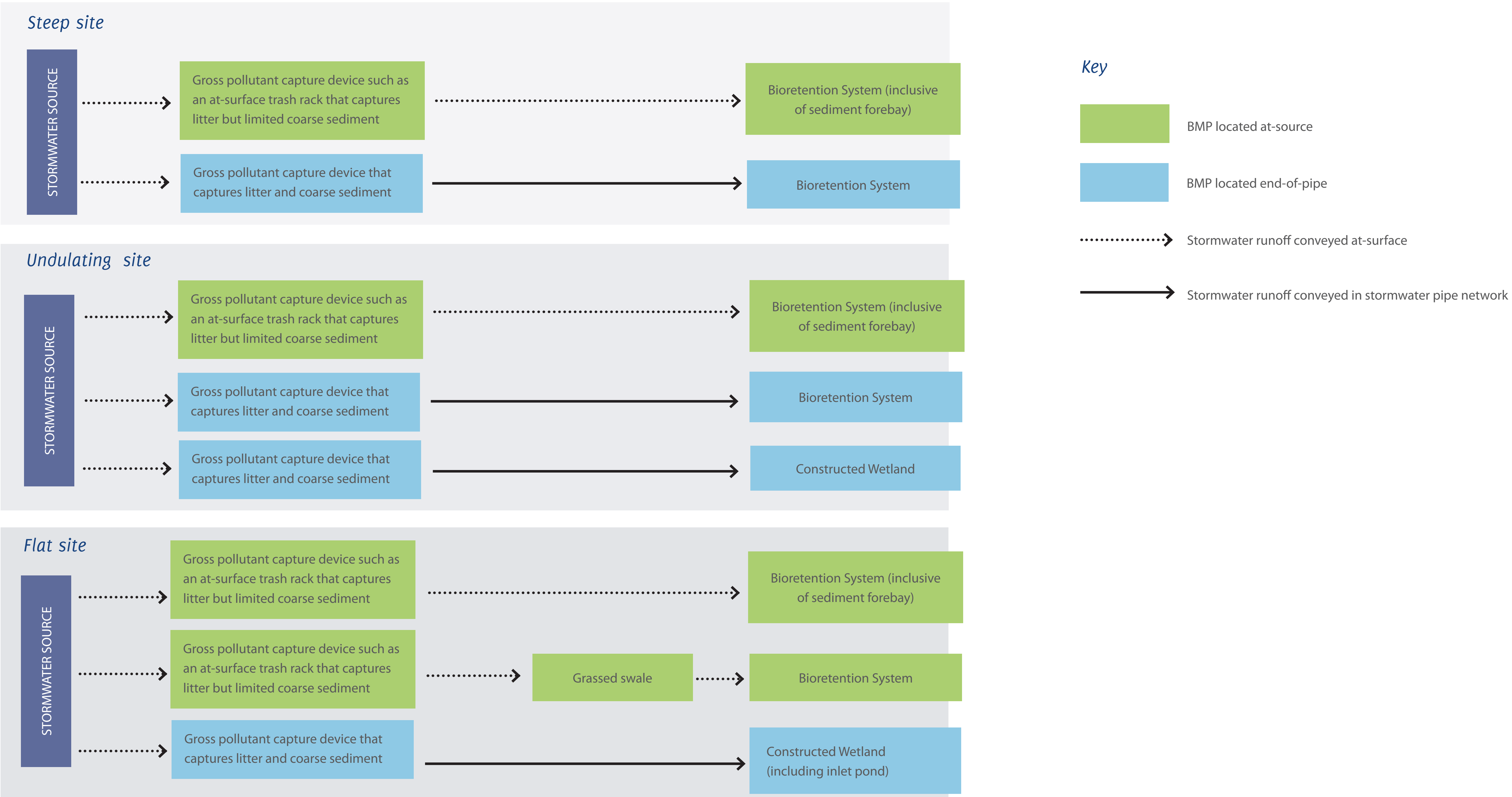


Figure 12— Pollutant ranges for stormwater BMP treatment measures (Ecological Engineering, 2003)

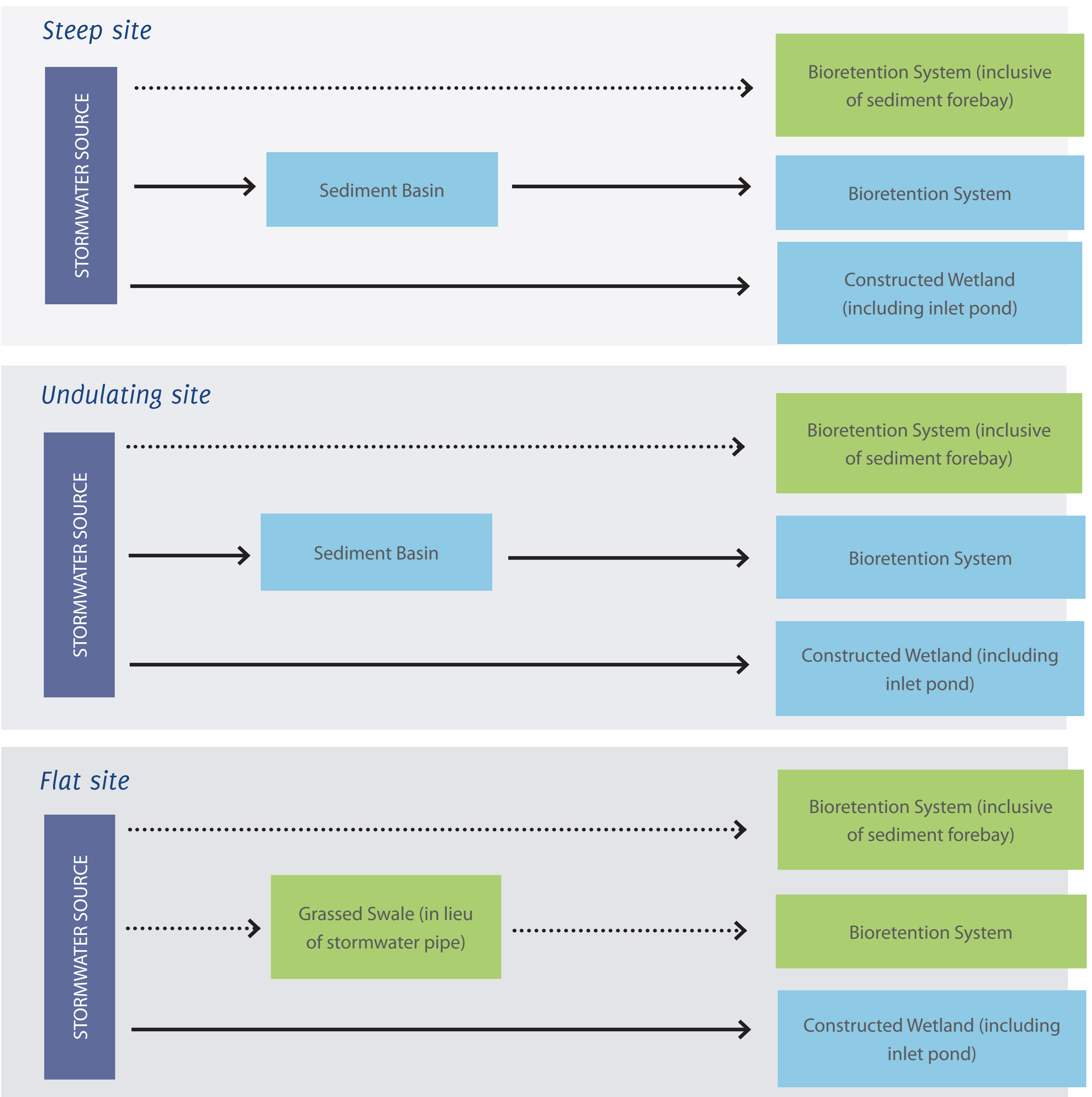
Stormwater Management

Typical stormwater treatment trains

Commercial / Industrial



Residential



More information on the configuration of treatment trains can be found in the Best Planning Practices (BPP) and the Best Management Practices (BMPs) sections of these guidelines.

Treatment train assessment methods

Performance assessment of treatment trains is often based on estimating mean annual pollutant loads from a site after it is developed. Using well-established computer models of urban stormwater management systems is a recognised method for determining long-term performance, such as the Model for Urban Stormwater Improvement Conceptualisation (MUSIC, 2005).

Using models to predict the performance of individual stormwater BMPs or treatment trains requires a level of modelling expertise. Most models are capable of providing reliable predictions of likely water quality performance when used correctly.

Stormwater Management

Constructing and establishing bioretention systems and constructed wetlands in a greenfield or infill development.

The following information on the typical construction sequencing for bioretention systems and constructed wetlands is provided to inform the conceptual urban design process of the different phases of system delivery including visual impacts and typical timeframes for each phase. This information allows the conceptual urban design process to optimise visual outcomes and delivery timeframes.

Construction and establishment should be staged to overcome the challenges associated with delivering bioretention systems or wetlands when developing greenfield or infill projects. *Construction and Establishment of Vegetated Stormwater Systems* (SEQ HWP, 2009a) gives further guidance on the construction of these treatment devices. Figure 13 shows a three-stage approach and the timings usually associated with subdivision construction and allotment building.

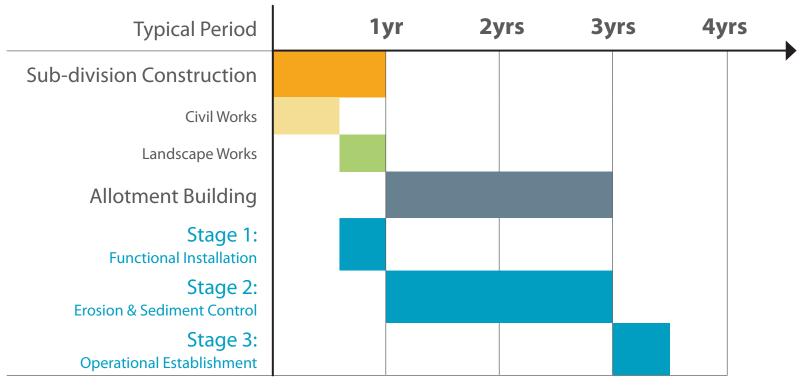


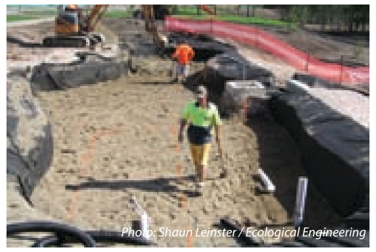
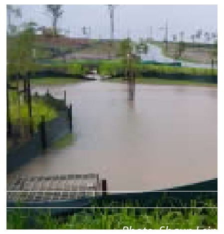
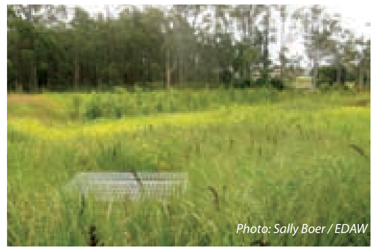
Figure 13 — Staged construction and establishment of a greenfield or infill project (Leinster, 2006)

The staged approach for constructing and establishing bioretention and constructed wetland systems is as follows:

- Stage 1: Functional stage. Construction of the functional elements of the systems at the end of the subdivision construction and installation of temporary protective measures.
- Stage 2: Erosion and sediment control. The temporary protective measures guard the systems from damage and provide temporary erosion and sediment control throughout the allotment building phase to protect downstream aquatic ecosystems.
- Stage 3: Operational establishment. At the completion of the building phase, the temporary measures can be removed along with all accumulated sediment.

The comparison of these phases for bioretention systems and constructed wetlands is shown in Table 9. Note the differing landscaping and final operational timeframes for both systems when life cycle considerations are included in the construction and operation of stormwater BMPs.

Table 9—Comparison of Construction and Establishment for Bioretention Systems and Constructed Wetlands

Stage	Constructed Wetland	Bioretention System
1	• Construction of functional elements: inlet zone, macrophyte zone, hydraulic control structures and high-flow bypass channel • Temporary protective measures: disconnect inlet zone from macrophyte zone, isolating the macrophyte zone from stormwater flows • Plant macrophyte zone and inlet and shore area with designed vegetation  	• Construction of functional elements: drainage layer, filter media, outlet structures • Temporary protective measure: filter cloth to cover filter media, which is then covered with topsoil and turfed  
2	• Inlet zone acts as a sediment control device 	• Protected turfed bioretention system acts as a temporary sediment control device 
3	• Inlet zone de-silted and reconnected to wetland with established (2 -year old) vegetation • System is now operational 	• Temporary filter cloth and turf are removed with all accumulated sediment • System re-profiled and planted with designed vegetation • System will be operational once vegetation is established (2 years)  

Operation and maintenance considerations

A well-designed and constructed treatment train will not necessarily require operation and maintenance costs above conventional stormwater infrastructure and public open space. However, poor construction or damage caused during the allotment building phase can result in escalated costs for stormwater BMPs targeting fine sediment and nutrient removal. Special design considerations are therefore required for stormwater BMPs with a staged approach to construction and establishment recommended. An example of a staged construction and establishment approach for bioretention systems and constructed wetlands is shown in Table 9. A number of alternative approaches have also been documented in *Construction and Establishment of Vegetated Stormwater Systems* (SEQ HWP, 2009a).

More detail on life cycle design considerations for stormwater management BMPs is provided in Section 5: Best Management Practices of these guidelines.

Photo: Alan Hoban

Storm Waters—Jennifer Turpin & Michaelie Crawford

Photo: Patrick Bingham Hall

Best Planning Practices (BPPs)

Content:

04

Integration of WSUD into Strategic and Statutory Planning

Government strategic and statutory planning manages the development of land to achieve multiple objectives. Under Queensland planning and environmental legislation, land use and infrastructure planning is a hierarchical process. Generally, the planning process starts at the regional level, progressing through to local governments or districts, to local area planning, subdivision level, and individual lots.

Regional planning

Regional land use and infrastructure planning provides direction to communities and land developers about sustainable regional growth management.

District planning

Local government is responsible for strategic land use and infrastructure planning at a municipal or district level, guided by regional land use and infrastructure planning instruments and relevant state legislation and policy. Local Growth Management Strategies (LGMS) are local government statutory planning instruments that outline how areas will deliver the desirable regional outcomes (DRO) established in over-arching regional land use and infrastructure plans.

Structure planning

Structure planning (sometimes called neighbourhood planning) and detailed master planning is then undertaken by local governments for major development areas to ensure developments:

- contain acceptable land uses
- achieve required targets for dwelling densities, land use and transport integration, and open space
- are designed in accordance with best practice sustainability principles.

Strategic and statutory planning prevents inappropriate development and maximises opportunities for a synergy between land use and infrastructure. For WSUD, this means:

- avoiding land development in catchments contributing to high ecological value (HEV) waterways
- establishing minimum setbacks from waterways to protect ecological and flood conveyance functions
- considering the pre-developed catchment hydrology and sensitivity of local water-dependent ecosystems to modifications in catchment hydrology and water quality
- establishing acceptable land-use criteria and stormwater management objectives to protect significant water-dependent ecosystems such as freshwater wetlands
- considering the existing and planned future capacity of local and regional water services infrastructure and establishing complementary design objectives for water conservation, wastewater minimisation, and stormwater management to achieve least-cost provision of water services while meeting all statutory standards of service
- considering the regional water cycle infrastructure context, such as the South East Queensland water grid, for synergy between land use planning and water infrastructure planning to protect investments made in regional infrastructure (see also BPP 5: Symbiotic Land Use Clustering)
- ensuring all mandatory requirements for water savings, water conservation, alternative water sources, and stormwater management are delivered in strategic land use and infrastructure plans and statutory planning instruments.

WSUD considerations are just one element in strategic and statutory land use and infrastructure planning. WSUD should always be planned in an overall sustainability context where all issues are considered collectively to ensure the best overall outcome is achieved (Engineers Australia, 2006).


Photo: Shannon McGrath

BPP 1: Steep and Undulating Sites

Topography is often one of the most important influencing factors when conceptualising urban design layouts. It is particularly important for water-sensitive developments. Topography defines watershed boundaries and the pre-existing pathways for water movement, and establishes ecological corridors that support regional biodiversity. Urban design that responds sympathetically to topography will generally deliver better environmental protection. In water-sensitive developments, topography informs spatial location, scale, and form of stormwater management measures and therefore influences the pattern of urban development.

Steep sites with a >15% slope are difficult to develop due to:

- land stability
- the extent of earthworks to create road corridors and developable allotments
- challenges associated with treating stormwater runoff to protect aquatic ecosystems.

Strategic and statutory land use planning instruments should help to avoid urban development on steep sites.

Undulating sites with a <15% slope generally support a range of possible WSUD layouts. Most contemporary stormwater treatment technologies (see Section 3: WSUD Strategies and Section 5: Best Management Practices) operate in flat to gently undulating conditions up to a 5% slope. The range of available treatments diminishes as slopes increase up to 15%. More complex and generally more costly forms of stormwater treatment are required for moderate to steep slopes. Efforts should be made to minimise the extent of public areas, such as road reserves and open public spaces, with slopes >5%. On terrain steeper than 5%, aligning road reserves tangentially to contour lines to achieve longitudinal road grades of less than 5% will help at-source stormwater management BMPs (also see BPP 4: Street Layout and Streetscapes).

Where it is not practical to achieve public space slopes of <5%, consider:

- managing stormwater runoff at-source with a higher capital cost
- using conventional pit and pipe infrastructure to convey flows to downstream low-land locations where slopes are gentler and better suited to more cost-effective treatment options.

The end-of-pipe treatment option is not the favoured approach of WSUD best practice hierarchy, but is acceptable if all at-source options are exhausted.

End-of-pipe application of stormwater treatment

If an end-of-pipe treatment is the only viable option, consideration must be given to the consequences of accommodating a treatment system with a larger footprint in low-land public open space. Low lands will often be linear open space corridors with natural waterway corridors. Other important management issues for these public open spaces may include retention or restoration of riparian vegetation, conveying flood flows, and accommodating other uses. These issues need to be considered within an appropriate decision-making process such as a triple bottom line assessment. This will ensure the optimal outcome, or 'best net benefit', for the open space is reached. In some instances, it may not be optimal to accommodate end-of-pipe treatment within the public open space and an at-source approach will be required. BPP 3: Multiple-Use Public Open Space also discusses integration of stormwater treatment within public open space.

End-of-pipe treatments on steep and undulating sites also:

- increase the risk of damage to the treatment facility from high sediment loads generated from the contributing catchment if the timeframe for the subdivision development and building phase is protracted
- increase the risk of a failure of the treatment facility if there is a toxic spill within the contributing catchment.

It may take several years for the completion and build-out phases of multiple-staged developments. During this time, sediment loads in stormwater runoff are likely be high and potentially damaging to the stormwater treatment facility. It is usual to incorporate a temporary or removable protective barrier to treatment facilities, beneath which the functional elements of the facilities are protected. However, if the protective barrier has to be in place while several subdivision stages are constructed, the full operation of the treatment facility is delayed for completed subdivision stages. This results in a poor level of protection for aquatic ecosystems. Therefore, it is preferred to have end-of-pipe systems in locations that avoid several subdivision stages within the contributing catchment area. If possible, end-of-pipe facilities should only contain one subdivision stage of about 40–60 allotments.

The distributed nature of at-source applications of stormwater treatment substantially remove the risks inherent in end-of-pipe systems.

Coomera Waters, Gold Coast

The Coomera Waters development is a good example of the incorporation of WSUD on an undulating site on the Gold Coast. WSUD principles were integrated at every level of the planning process. This was achieved by taking a multidisciplinary approach and incorporating extensive stakeholder consultation into the concept design stage of the project. WSUD is considered to be an integral factor in the urban planning process for Coomera Waters, which has resulted in creative and cost-effective stormwater management strategies that consider stormwater as a resource rather than a problem.

Through comprehensive early integration of WSUD, the master plan incorporates innovative solutions throughout the urban environment to achieve best practice quality objectives.

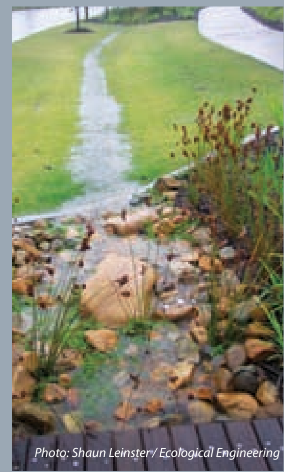


Photo: Shaun Leinster / Ecological Engineering

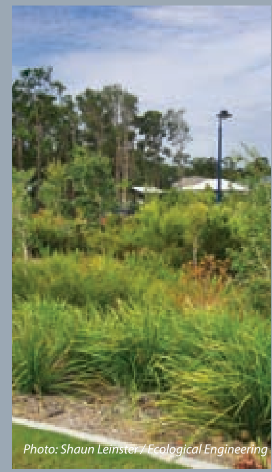


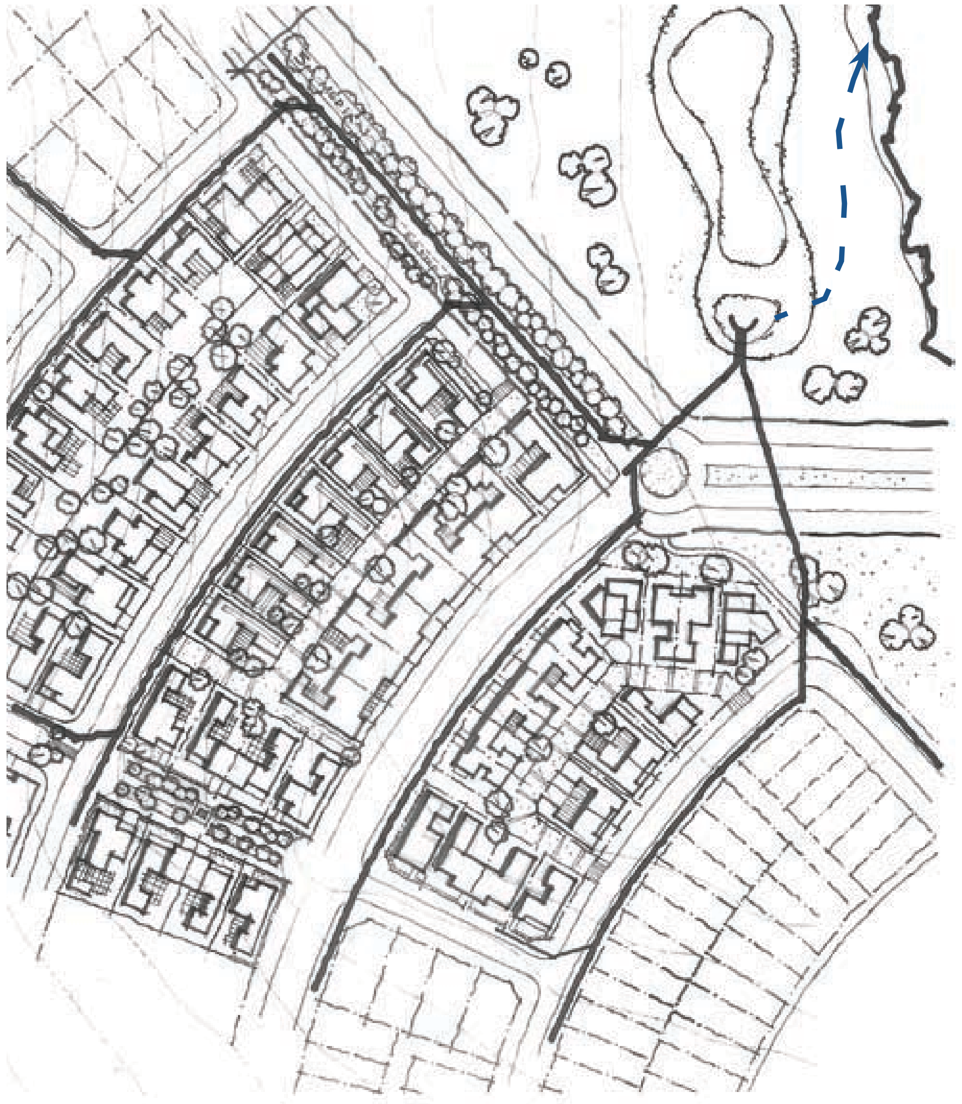
Photo: Shaun Leinster / Ecological Engineering

At-source and at-surface treatments such as vegetated and bioretention swales and road reserve bioretention raingardens have been adopted at Coomera Waters. On steeper topography, conventional collection and conveyance systems were installed with downstream wetlands and bioretention raingardens collecting and treating stormwater in public open space.


Photo: Kerry McWalter / EDAW

The Coomera Waters WSUD systems are widely recognised by authorities and designers as setting the industry standard in South East Queensland. Many of technical aspects of the design are being incorporated into regulations and documented in industry guidelines.

See Case Study 5 for more information on this project.



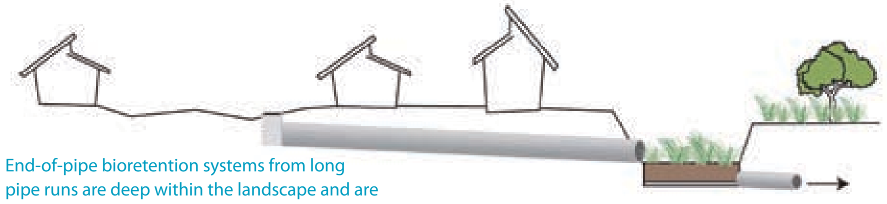
End-of-pipe wetlands can be an appropriate response if there is suitable open space available.

BPP 2: Flat Sites

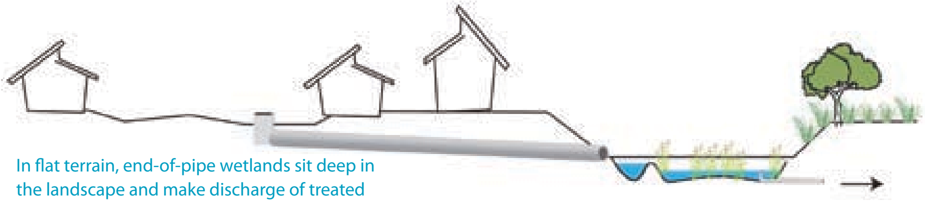
Flat sites can present a challenge for cost-efficient stormwater infrastructure, particularly if the urban design and site earthworks are developed without considering stormwater infrastructure requirements to protect aquatic ecosystems.

Traditional pit and pipe stormwater infrastructure can be expensive on flat sites due to the need for large pipe diameters to compensate for the minimum grades. If long runs of pipe are required, the pipes get progressively deeper, often ending up several metres below ground surface levels. This can result in expensive laying costs and difficulties in achieving free-draining outfall. Stormwater treatment is inherently difficult on flat sites once stormwater has entered the pipe network. The depth of the pipe network in relation to finished surface levels can result in treatment facilities set several metres below the surrounding landscape. This creates a visual disconnect from the otherwise flat natural terrain.

Figure 14 illustrates the difficulties treating stormwater runoff on flat sites after the stormwater has entered the underground pipe network.



End-of-pipe bioretention systems from long pipe runs are deep within the landscape and are difficult to drain into receiving environments.



In flat terrain, end-of-pipe wetlands sit deep in the landscape and make discharge of treated water difficult.

Figure 14 — Challenges treating stormwater on flat sites after it enters the pipe drainage network (Hoban, Eadie and Rowlands, 2007)

To overcome these challenges, the traditional response has been to incorporate a deep, centrally-located water feature (lake) into which the stormwater drainage pipe networks can discharge. The excavation for the water features can be a source of fill material to provide flood immunity. In the majority of cases, the lake becomes the principal stormwater treatment element with pre-treatment of inflows limited to the removal of gross pollutants. Many of the 'urban lakes' created by this response have poor water quality and ecological health with aquatic plant growth and algal bloom issues.

Adopting an at-surface approach to conveying and treating stormwater on flat sites can address most of the challenges and issues faced by the traditional approach. At-surface treatments also have the potential to significantly reduce the overall capital cost of stormwater infrastructure and improve visual integration of stormwater within the urban fabric. To achieve at-surface management on flat sites the urban design and site earthworks need to ensure street layouts and allotment orientations accommodate at-surface collection, transport, and treatment.

Figure 15 shows a model WSUD for a flat site where roads are the primary conveyance system. Street leg lengths from high points to sag points, longitudinal grades, and pavement cross-falls ensure stormwater is conveyed within the road carriageway to stormwater treatment sites located at sag points. The stormwater is treated before entering the pipe drainage network (or discharging directly to a receiving waterway). Figure 16 shows the model layout applied to an urban design for a flat site.

Figure 17 illustrates the benefits of treating stormwater while it is still 'at-surface' in terms of achieving a free discharge of treated water to the receiving waterway.

Photo: Alan Hoban / Ecological Engineering

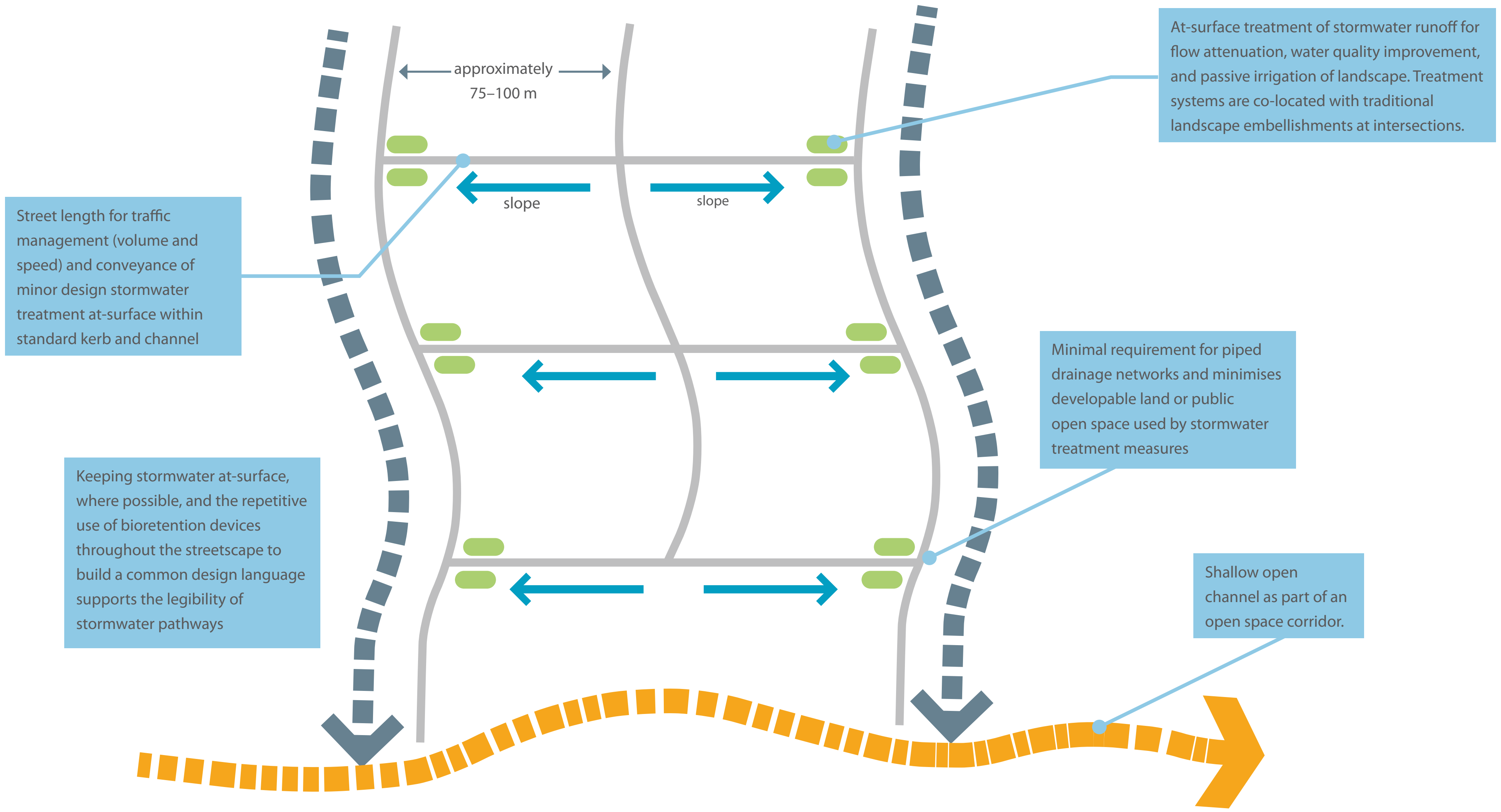


Figure 15 — Model water sensitive urban layout for flat sites

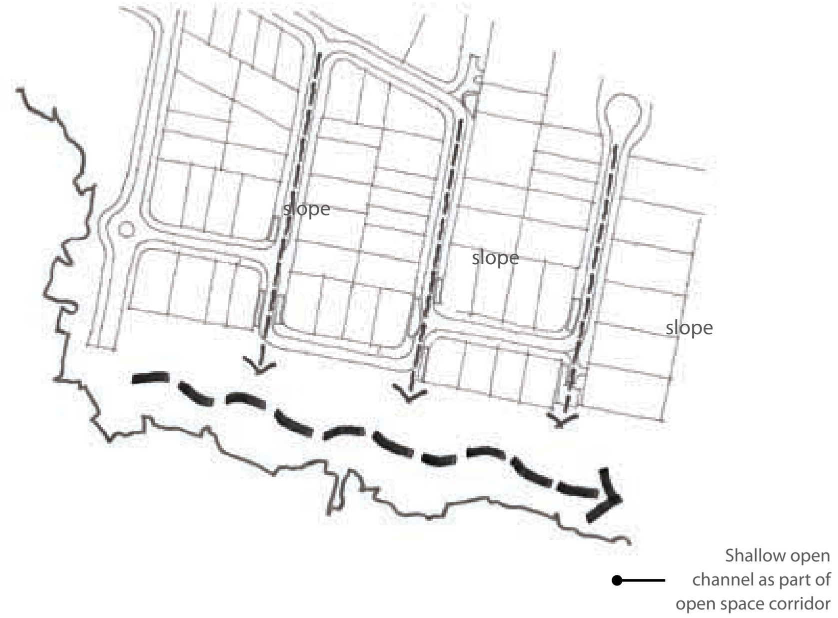


Figure 16 — Conceptual sketch applying model WSUD for flat sites

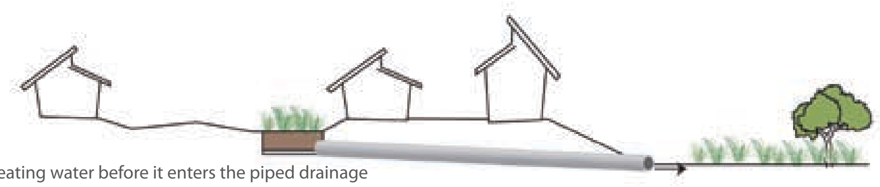


Figure 17 — Benefits of treating stormwater at-surface on flat sites (Hoban, Eadie and Rowlands, 2007)

BPP 2: Flat Sites

Figure 18 — Bioretention is clustered at the entry to the local access street. The figure also illustrates the preferred allotment orientation adjacent to entry points to local access streets on flat sites. A typical application of bioretention to the road verge for stormwater treatment is also shown.

Figure 18 illustrates the benefits of at-surface treatment in terms of integration of the treatment system with local streetscape landscapes.

The model urban layout results in stormwater treatment facilities that are typically clustered at entry points to local access streets. Contemporary landscape architecture uses themed mass plantings at the entry to local access streets to establish a sense of identity and place. Clustering stormwater treatment at entry points to local access streets allows treatments to be integrated within a broader mass planting, creating cost advantages and providing a visual relationship between stormwater runoff and the sustainability of local landscapes.

Another design consideration to support at-surface management of runoff on flat sites is the orientation of allotments, particularly adjacent to entry points of local access roads. By aligning allotments on either side of entry points to local access streets, the long access of the allotment runs parallel to the street. The allotment frontage and driveway ensures a relatively unencumbered length (30–40 m) of street verge adjacent the sag points at the entry to the street. These verges can then support stormwater treatment as part of the verge landscaping without driveway crossovers. Some widening of road reserves and offsetting of carriageways may be required to accommodate stormwater treatment to both verges.

Figure 18 illustrates the preferred allotment orientation adjacent to entry points of streets on flat sites. It also shows the typical application of bioretention treatment to the road verge.

The model water sensitive design layout for flat sites allows stormwater runoff to be carried on the road using the hydraulically efficient kerb and channel to deliver flows via the kerb cutout directly onto the surface of the treatment system. Stormwater is managed at-surface before discharging to the pipe drainage network.

An alternative to kerb and channelling for at-surface runoff on flat sites is roadside swales located within the road verge (Figure 19). Flush kerbs deliver stormwater runoff as sheet flow from the carriageway to the swale where the stormwater is pre-treated before discharging to a tertiary-level treatment device such as bioretention or a constructed wetland. However, using roadside swales on flat terrain can be difficult due to the low longitudinal grade of the swale, which is often <0.5%. This can create poor drainage along the swale invert. A further, and more significant risk, of roadside swales is the requirement for adjoining allotment owners to maintain the conveyance capacity of the swale. If one resident changes the hydraulic characteristics of the swale, either by filling within the swale or increasing the swale's hydraulic roughness with additional planting, it will impact the drainage from the road.

Using road side swales on flat (and undulating) terrain is not a preferred solution, except where the urban design can achieve separation of the swale from allotment frontages. This can be done through shared driveways to create an 'island' between the road carriageway and the shared driveway (Figure 20). Refer to BMP 7: Grass or Vegetated Swales for more information on the use of swales.

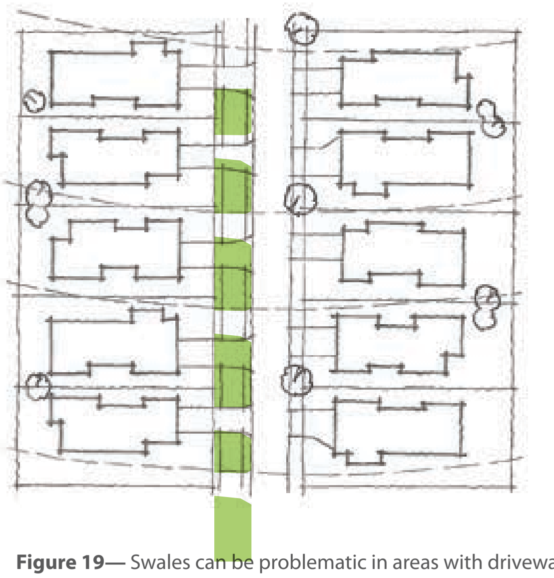


Figure 19— Swales can be problematic in areas with driveway crossovers and adjoining allotment owners

Figure 20— Shared driveways can achieve separation between allotments and swales

Bellvista, Sunshine Coast

Bellvista Estate is located on the flat coastal plan of the Sunshine Coast. The low relief of the site and the surrounding environment required urban drainage solutions to avoid creating expensive, low gradient, large diameter pipe drainage networks. These networks could not free-drain into the shallow drainage channels that run through the site.

The only way to drain deep-piped drainage systems is to construct deep open-water bodies at the pipe outfalls. Using deep pipe outfalls usually precludes the use of best practice stormwater treatment measures such as constructed wetlands and bioretention systems to deliver water quality objectives for the site.

After considering several approaches, an at-source and at-surface approach was adopted using bioretention pods in residential streets. This strategy is the best outcome for the site given the constraints of low-lying, flat topography and sensitive receiving waters. By using an approach that finds the synergies between stormwater quality, road drainage, traffic calming, and landscape design, Bellvista Estate delivers innovative streetscapes that provide at-source treatment of stormwater integrated into the urban landscape.

The solution represents current best practice in urban stormwater management by protecting natural systems, integrating stormwater treatment into the landscape, protecting water quality, reducing runoff and peak flows, and adding value while minimising development costs. Stormwater sustains the landscape at Bellvista Estate, and the landscape provides an important ecological function by protecting the local waterways.

See Case Study 4 for more details.

BPP 3: Multiple Use Public Open Spaces

Open space corridors serve multiple functions. Therefore, they must be carefully planned and designed to generate the best net benefit to the local community and to the natural environment. Contemporary design principles for public open space include (Landcom 2008a):

- being meaningful to place and community
- being multi-functional and adaptable
- providing diversity
- encouraging social interaction
- promoting health and well-being
- providing equity and accessibility
- embodying environmental sustainability
- ensuring financial stability.

The integration of WSUD within public open space networks must be considered within this context and deliver the best outcome across all these design principles. At-source stormwater treatments should always be given first consideration so that local parks and open space corridors can maximise public amenity and extend and enhance remnant natural ecosystems.

Figure 21 — Multiple use open space corridor incorporating WSUD BMPs, a constructed wetland and bioretention systems to treat stormwater runoff from adjoining development areas.

Stormwater quality systems in retarding basins

Stormwater quality systems such as bioretention systems can normally be located within flood-retarding basins provided appropriate design considerations are followed.

Further discussion is provided in BMP 9.

Figure 21 shows an example of a multiple-use public open space corridor incorporating water sensitive urban design BMPs including constructed wetlands and bioretention systems.

Where at-source stormwater treatment is not practical, integrating stormwater treatment within public open space networks should be guided by a number of general principles:

- The footprint of the stormwater treatment facility should not take up more than 50% of the available public open space. It should be located to maximise the amenity and use of the balance of the area and next to active public open space where possible. In open space areas that contain a stormwater treatment facility as part of a larger, continuous corridor of open space, a larger footprint may be required. The local council should be consulted about using dedicated public open space for stormwater management.
- The stormwater treatment facility should fit seamlessly within the surrounding landscape setting considering form, public safety, community education, terrestrial landscape plantings, and controlled public access using viewing platforms and boardwalks.
- The form of the treatment facility should maximise visual interest and amenity while adhering to guiding principles for optimal stormwater treatment for each treatment type. Refer to Section 5: Best Management Practices.
- Stormwater treatment facilities located along waterway corridors should be located away from flood flows capable of impacting treatment performance. Flood flows that can impact the performance of treatment are flow velocities in excess of 2 m/s for constructed wetlands, bioretention systems, and vegetated swales. Where flow velocities permit, and inundation durations are short (hours not days), the stormwater treatment facility can be wholly, or partly, within the flood extent used by the local council to designate public open space. For example, if the developed catchment 20-year ARI flood extent is used to delineate public open space, locating the stormwater treatment facility within the 20-year ARI flood extent will minimise the impact of the facility, provided flow velocities permit. The facility should not impinge on the riparian zone where it would result in loss of existing vegetation and discontinuity of riparian canopy cover.
- Remnant vegetation should not be removed to accommodate stormwater treatment except where it can be regenerated to the same extent within a reasonable timeframe. The needs of local fauna and issues of land and waterway stability must be taken into account.
- Opportunities should be sought to collect treated stormwater to re-use for irrigation or for public water features such as art installations.

South Australian Museum Forecourt, Adelaide

The South Australian Museum Forecourt is a large rectangular space in the centre of a busy precinct of North Terrace in the Adelaide CBD. The space is used for both informal activities such as sitting and picnicking, as well as more structured events such as performances, fairs, and exhibition openings.

A key objective of the forecourt redevelopment was to showcase the museum's commitment to a sustainable environment. At an early stage in the project it was decided that urban water management is an important component of environmental sustainability in South Australia, and tahat this aspect of the forecourt should be explored for opportunities to capture water and re-use it in the space.

A fully integrated bioretention re-use system was constructed that captures diverted water from North Terrace as well as from surrounding roofs. It is designed as a 'living display' for the museum and incorporates seating and rest areas and supplies sufficient irrigation for the forecourt and the adjoining North Terrace landscape.

Early collaboration between engineers and urban designers was an essential element in the project's success. Critical parameters of the water system, such as the bioretention area and storage tank volume, were estimated early in the project, confirming the spatial requirements and viability of the scheme. These areas were then implemented by the urban designers.

(Allison and Taylor, 2004)

Photo: Simon Brown / TCL

Photo: Robin Allison / Ecological Engineering

Photo: Robin Allison / Ecological Engineering

BPP 4: Street Layout and Streetscapes

WSUD preferences the management of stormwater runoff at-source and at-surface. This means streets play an integral role in accommodating stormwater BMPs. Streets are a primary generator of stormwater runoff and pollutants. In most urban situations, except sandy sites, streets also receive stormwater runoff from adjoining allotments via drainage outfalls to the kerb and channel system. Streets also convey stormwater runoff to underground pipe drainage networks and provide overland flow pathways for stormwater runoff to trunk drainage systems such as open channels or natural receiving waterways.

Urban streets perform multiple other functions including: acting as movement corridors for vehicles, pedestrians, and bicycles; providing space for utility services; acting as public area connectors; and providing place-making and community amenity through visual containment and continuity. As dwelling densities increase to reduce the urban footprint, streets take on an even greater importance as movement corridors and public area connectors. The incorporation of WSUD within streetscapes requires careful consideration by an inter-disciplinary team with experience in the various aspects of street design and function.

Street layout is most often influenced by the shape of the development area, site topography, street hierarchy, the presence of significant natural features, and the need to provide connection to existing surrounding streets.

WSUD influences the horizontal and vertical alignment of streets and their cross-sectional composition to ensure:

- the safe passage of stormwater runoff while trying to maximise the travel time for stormwater runoff by aligning streets parallel or tangential to contours for steep sites of >5%
- stormwater runoff volumes and pollutant loads are reduced by encouraging vegetation and soil-based filtration and infiltration and harvesting of treated stormwater for re-use
- utility services can be accommodated within verges, together with stormwater treatment facilities and pedestrian and bicycle movement.

The WSUD imperatives, aimed at minimising the impact of urban development on the natural water cycle and aquatic ecosystem health, may be at odds with other equally important design principles for urban streets, such as:

- aligning streets perpendicular to contours for steeper sites (>5%) to avoid the creation of 'high-side' and 'low-side' allotments (Landcom, 2008b)
- maximising the length of streets with east–west orientation to create north–south allotments for optimal solar orientation
- minimising stormwater infiltration within the verge adjacent to the street carriageway to prevent swelling and shrinkage of pavement sub-base.

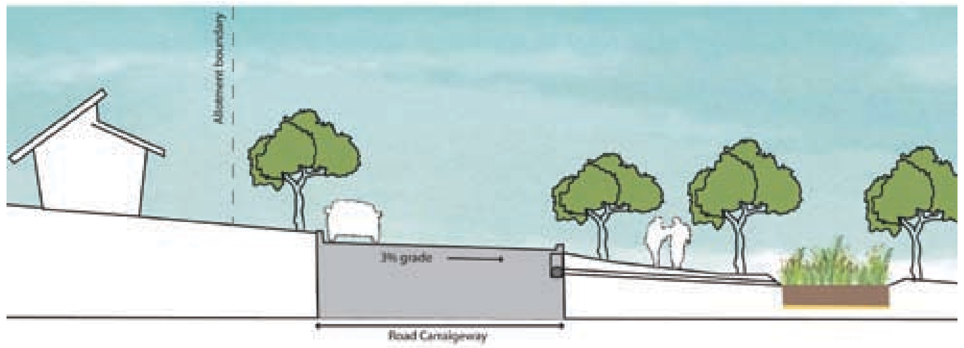


Figure 22 — WSUD street layout 1: Streets aligned parallel (or tangential) to contour and with open space corridor on 'low side' of the street

Figure 23 — WSUD street layout 2: Streets aligned parallel (or tangential) to the contour with allotments on both sides of street

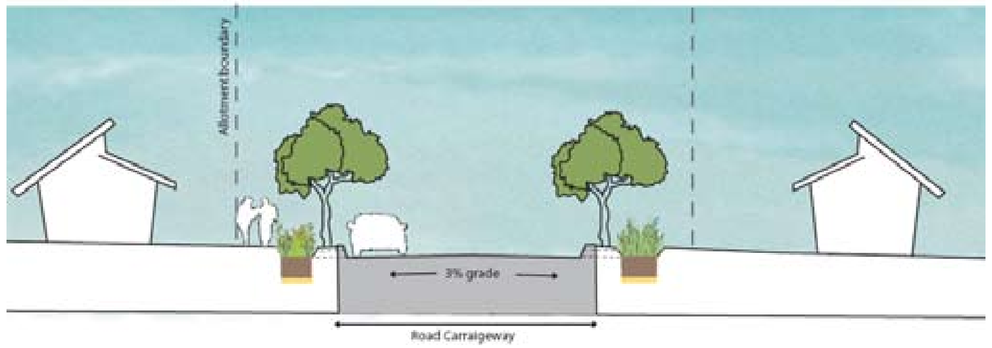


Figure 24 — WSUD street layout 3: Street on flat topography (< 1%) aligned to maximise east–west street orientation and with allotments on both sides of the street

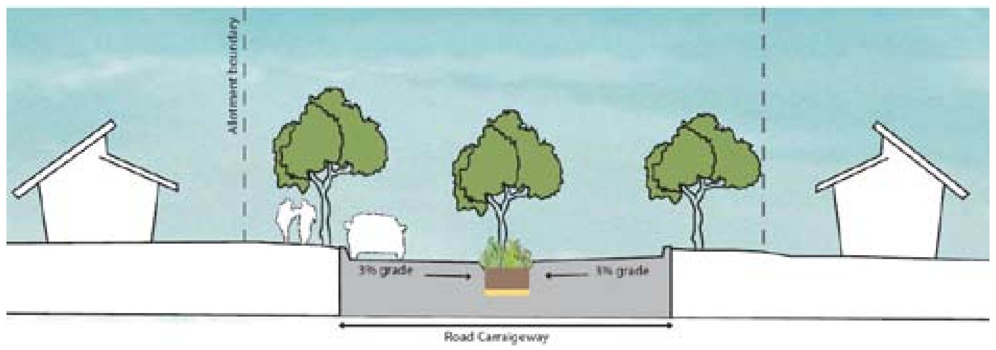


Figure 25 — WSUD street layout 4: Streets with centre medians on flat to gently undulating topography (< 5%) with allotments on both sides

Integration of WSUD within streets will normally involve using bioretention technology (refer to Section 5: Best Management Practices) operating with a complementary conveyance system to deliver runoff to the surface of the bioretention system. Stormwater flows treated by bioretention treatment are usually discharged to a conventional pipe drainage network together with excess stormwater flows. The pipe drainage network and major overland flow network continue to provide important flood flow conveyance.

With careful planning of street networks at the earliest stage of the concept design process, it is possible to maximise the use of kerb and channel conveyance and minimise underground pipe drainage networks, reducing the overall cost of stormwater drainage infrastructure (as discussed in BPP #1 and BPP #2,). This is particularly relevant for flat sites (see BPP 2: Flat Sites).

When considering using bioretention treatment within streetscapes, there are a number of key design considerations to ensure the amenity and functionality of the street is protected. These include ensuring:

- safe and un-encumbered access from streets to allotments for pedestrians, cyclists and vehicles
- safe and easy access from the street to the verge for pedestrians and cyclists if suddenly confronted by a vehicle
- safe egress to the verge from cars parked along streets
- pedestrian safety is not compromised
- ease of access to utility services for maintenance
- streetscape landscapes incorporating stormwater treatment protect a sense of place with legibility and continuity.

Figures 22–25 model WSUD street layouts illustrate the application of bioretention treatment within streetscapes for a range of typical situations. These street layouts are by no means exhaustive and are provided to inform early consideration of street layout and function as part of conceptual design of urban layout.

Example of WSUD street layout 1: Bioretention system in local park on the low side of street

Example of WSUD street layout 2: Bioretention swale located on the high side of street (note the minimal number of driveway crossovers)

Example of WSUD street layout 3: Bioretention 'pod' located within street verge

Example of WSUD street layout 3: Bioretention in the form of street tree planters located within the street verge with the same system on opposite verge

Example of WSUD street layout 4: Bioretention swale in centre median

BPP 5: Symbiotic Land Use Clustering

Symbiotic land-use clustering enhances the potential for water recycling by co-locating land uses that can benefit from using recycled water with suitable sources of recycled water.

Water recycling is a key objective of WSUD, maximising the resource value of urban water streams (potable water, wastewater, and stormwater) by capturing all available opportunities to recycle and re-use water as it moves throughout the urban environment. This objective delivers multiple benefits including:

- delayed, or avoided, augmentation of existing potable water supplies
- protection, or restoration, of environmental flows in river systems supporting existing potable water supplies
- reduced wastewater flows
- improved resilience of water supplies and aquatic ecosystems to potential future climate change.

Strategic land use planning can, and must, play a significant role in maximising the benefits of water recycling.

Sources of recycled can be:

- regional-scale supplies such as reclaimed wastewater supplied via dual reticulation from centralised wastewater treatment plants, either as PRW or as various classes of tertiary-treated wastewater
- precinct- and allotment-scale supplies such as reclaimed wastewater (treated greywater and blackwater) from local-scale wastewater treatment plants (including sewer mining); roofwater and stormwater harvesting (including aquifer storage and recovery); and groundwater.

Beneficial use of recycled water is any end use that does not require potable water quality. This includes most end uses that carry limited risk of human ingestion, typically:

- internal uses such as toilet flushing; laundry (cold taps); cooling towers (for multi-unit dwellings); and industrial process water
- external uses such as landscape irrigation, vehicle washing, and swimming pool top-ups.

Using recycled water for hot water is possible if the quality of the recycled water carries a low risk of pathogens. Recycled water sources such as PRW and roofwater may be suitable sources for hot water systems. Section 3: WSUD Strategies provides a more detailed discussion on alternative water sources and fit-for-purpose matching of water sources to end uses.

Distance from the source to the end use and the fit-for-purpose quality of the recycled water are the major determinants of the economic feasibility of water recycling schemes. Strategic land use planning can capture economic efficiencies by:

- locating land uses with beneficial end uses close to the available recycled water sources, matched on a fit-for-purpose basis to the quality of the available recycled water
- identifying land uses that generate recycled water and land uses that demand recycled water to co-locate compatible generating and demanding land uses within mixed-use precincts.

Examples of symbiotic land use clustering

Major industrial water users clustered around a centralised wastewater treatment and reclamation plant

Major industrial land uses such as refineries, food and beer manufacturers, and concrete batching plants are a significant consumers of urban potable water supplies. If located within close proximity to a large centralised wastewater treatment and reclamation plant, water intensive industries can significantly reduce their use of potable water by using recycled water to meet part, or all, of their processing water needs.

In South East Queensland, the Australia Trade Coast (ATC), which includes the Brisbane Airport, the Port of Brisbane, and a significant area of greenfield and brownfield land, is located adjacent to Brisbane's two largest wastewater treatment plants—Luggage Point and Gibson Island. These two wastewater treatment plants produce tertiary treated effluent, the majority of which is further treated to PRW standard in advanced water treatment plants. This water is supplied to the Western Corridor Recycled Water Pipeline for delivery to end users, including the Brisbane potable water supply. The ATC will also receive recycled water from the Luggage Point and Gibson Island treatment plants and is an example of symbiotic land use planning.

Large 'shed' bulk storage warehouses co-located with recycled water demanding land uses

Large, portal frame warehouses generate significant roofwater runoff, but usually have minimal on-site demand for the recycled water. These types of land uses can cause significant increases in stormwater runoff volumes and peak flows, which impact on aquatic ecosystem health. A precinct master plan that co-locates warehouse buildings with land uses with a high demand for recycled water would enable the excess roofwater resource to be used by adjoining land uses. Storage of the roofwater could be on the warehouse site, if the site area permits, or within a dedicated precinct storage area with inputs and off-takes metered to enable water supply and demand to be monitored. Figure 26 illustrates a few of the possible water cycles that could be employed at the individual building or precinct scale to maximise water recycling opportunities.

High-rise residential tower co-located with commercial office tower in a mixed use precinct

Residential towers generate a large amount of greywater. Under current Queensland building regulations, the QDC, treated greywater is an accepted alternative water source for certain non-potable water uses. Therefore, separating greywater from blackwater with separate plumbing enables greywater to be collected, treated, and re-used within the residential tower. However, end uses for treated greywater are typically limited to toilet flushing, landscape irrigation, and for cooling tower water provided salt and ammonia concentrations are low. Also, treated greywater can only be stored for a maximum period of 24 hours, after which the stored water must be purged to the sewer (Qld DIP, 2008a).

The typical generation of greywater from a residential tower will significantly exceed the re-use demand, resulting in an excess of treated greywater being purged each day to the sewer. However, if a commercial office tower is located adjacent the residential tower, the excess treated greywater from the residential tower can be used for toilet flushing, landscape irrigation, and cooling tower water needs within the commercial site.

Commercial office towers generate very little greywater. The majority of the wastewater they generate is blackwater from toilet flushing. Due to regulations restricting use of on-site treated blackwater, commercial towers are limited to roofwater collection and re-use, which falls well short of meeting daily re-use demand. Large precincts of commercial office towers without any co-located high-rise residential towers, or other sources of recycled water, will deliver poor water re-use outcomes and poor potable water conservation outcomes. However, mixed-use precincts containing both commercial and residential towers produce the best potable water conservation outcome.

Figure 27 shows a schematic representation of the water recycling opportunities within and between a residential high-rise tower and a commercial office tower located along side each another.

Mixed use commercial and residential tower

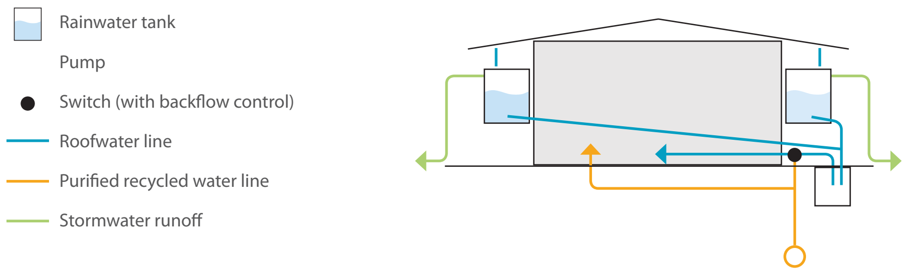
An extension of the previous example is to have both residential and commercial uses in the same building with the residential floors located on top of the commercial floors. This is also shown schematically in Figure 27.

These examples are by no means exhaustive, but they are provided to illustrate the role of strategic land use planning in the optimisation of water recycling opportunities.

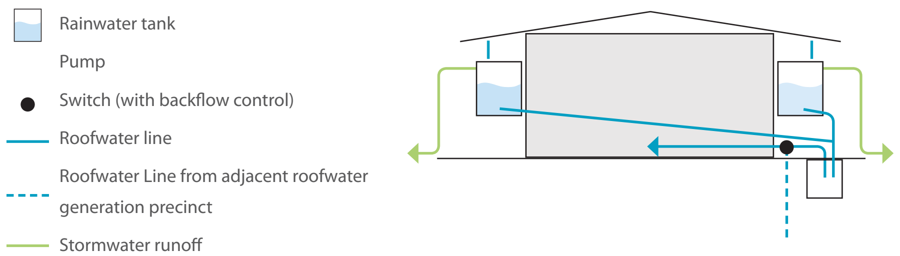
Strategic land-use planning processes informed by expertise in WSUD and, in particular, expertise in water recycling opportunities at regional, precinct, and allotment scales, should deliver:

- significant savings of potable water
- a reduction in wastewater and stormwater discharges to aquatic ecosystems
- improved resilience of urban systems to the threat of climate change.

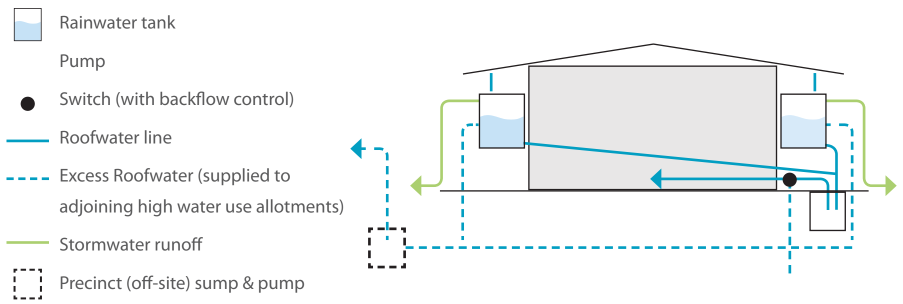
Conversely, a poorly informed strategic land use planning process is likely to limit future water recycling opportunities or, at least, make water recycling more costly than it needs to be.



Model land use 1 — High water-demanding industries requiring high quality PRW for process water and roofwater for all other non-potable uses. These land uses can be clustered in close proximity to distribution pipelines carrying PRW from water reclamation plants.



Model land use 2 — High water demanding industry NOT requiring high quality PRW for any on-site water demands. These land uses use roofwater as the primary alternative water source and can be clustered to form a precinct of similar high water-demand land uses and located adjacent to precincts of roofwater generating land uses (i.e. model land use 3).



Model land use 3 — Low water demanding industry NOT requiring high quality PRW for any on-site water demands. These land uses (typically large storage warehouses) use roofwater as the primary alternative water source. As the on-site water demand is low, these land uses become potential roofwater generating land uses for use by adjoining high water-demand land uses (i.e. model land use 2).

Figure 26 — Water recycling opportunities for industrial and warehouse landuses

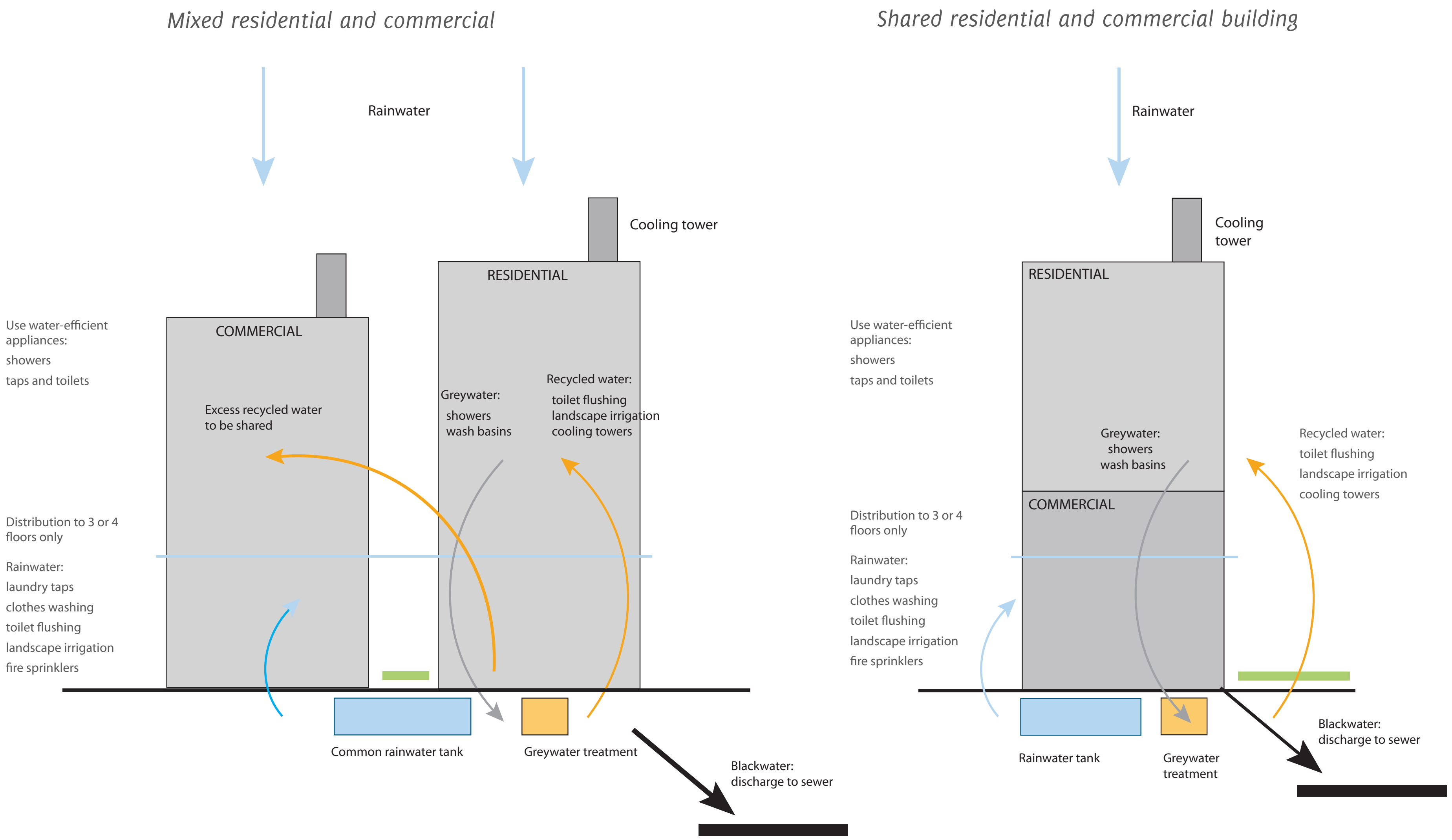


Figure 27 — Water recycling opportunities within buildings based on current building regulations

Note: once blackwater re-use within sewered areas is permissible, this image will be outdated as other design conditions will apply.

BPP 6: Industrial Sites

The impacts of industrial development

Industrial development is typically characterised by:

- large impervious areas
- the presence of a wide range of industrial chemicals and other potential pollutants.

Therefore, industrial areas often discharge large volumes of stormwater containing a wider, more toxic, and a more variable range of pollutants than stormwater from residential or commercial areas.

Water consumption and sewage generation on industrial sites is highly variable depending on the nature of the industrial activity. Warehouses typically consume small volumes of water and produce low amounts of sewage compared to sites where large volumes of processed water are used and discharged to the sewer, usually under licence.

Applying WSUD to industrial development

Effective application of WSUD to industrial sites may be achieved by:

- structurally separating work areas from roofs and car parks to prevent industrial pollutants from contaminating stormwater so standard urban stormwater treatment devices can be applied
- maximising stormwater harvesting and reuse opportunities.

These principles can be applied to new and existing industrial developments ranging from greenfield subdivisions to small individual lots.

Structural separation

WSUD can be used to achieve best practice stormwater management standards if pollution from work areas is structurally separated from stormwater runoff pathways. Work areas include areas where industrial pollutants may be stored, used, transferred, or manufactured. For most industrial sites, work areas include all parts of the site other than car parks and landscape areas.

Structural separation can be achieved by roofing work areas, directing wash-down water to storage tanks subsequently pumped out as industrial waste or to the sewer, and controlling activities undertaken in areas connected to stormwater drains.

If work areas are not separated, WSUD measures designed to treat the typical range of pollutants in urban stormwater may be overloaded by industrial pollutants.

Alternative stormwater management strategies, based on treating known pollution from a particular industrial activity, may be ineffective in the longer term because of unforeseen pollution from a current or future tenant. Businesses change premises regularly and therefore so do the key pollutants and the likelihood of their release. Devices tailored to the needs of one business are unlikely to suit subsequent businesses. Devices aimed at treating a wide range of pollutants may have limited ability to accommodate storm events or may require combinations of treatment devices and specialised management.

As an alternative to roofing work areas, structural separation may also be achieved by containing runoff from work areas and disposing of it in an acceptable way. Acceptable disposal may include, for example, reusing the water in industrial processes or treating the water and then infiltrating it to groundwater. However, the size of storage required to contain the runoff from high intensity summer rainfall in South East Queensland reduces the feasibility of this option for most sites.

Stormwater harvesting

The viability of stormwater harvesting is site-specific and depends on the potential to capture, store, and re-use stormwater at each site. Roofwater is typically of suitable quality for many re-use purposes; however, high nitrogen levels may need treatment before storage in open water bodies. Water usage can vary greatly across industrial sites depending on whether the site is used for warehousing or manufacturing.

Raising awareness for tenants

Education programs to promote good environmental practice by tenants in industrial precincts are also important to help sites to meet water quality objectives. Education programs should promote operational practices that minimise opportunities for industrial pollutants to enter the stormwater system, as well as raising the environmental awareness of individuals working in industrial precincts.

Water sensitive industrial site design also applies to industrial precincts. However, designers of industrial precincts have an opportunity to consider solutions that extend beyond individual lot boundaries.

Designing water sensitive industrial sites or precincts

Defining design objectives

Design objectives for stormwater management are usually set by the local government. For industrial locations, achieving design objectives involves:

- isolating industrial pollutants from stormwater catchments
- treating stormwater to ensure compliance with design objectives.

Some sites will also need to meet specific water-cycle management objectives set by the local government, for example:

- reuse of stormwater or wastewater
- environmental flows in a local creek
- recharge of local groundwater reserves
- attenuation of peak discharges during heavy rainfall events
- minimal use of potable water or minimal discharge of sewage.

Site appraisal

The proposed development site should be assessed for opportunities and constraints, including:

- identifying natural drainage lines and possible pathways and discharge locations for runoff from minor and major storm events
- identifying any external catchments draining through the site and assess flood conveyance requirements
- assessing the site topography to determine feasible WSUD strategies.

Table 10 provides a guide to the feasibility of stormwater treatment approaches for degrees of steepness. Only steep sites will have sufficient relief to enable end-of-pipe stormwater treatment, where underground pipes can be 'daylighted' to deliver water to a vegetated treatment system. Most other sites will require stormwater to be treated before it enters the underground drainage system. This will typically require an iterative approach to drainage and site design.

Where the elevation difference between the lowest impermeable surface of the site and the legal point of discharge is less than 1m, it will be difficult to drain bioretention systems. To meet treatment requirements, combinations of the following options may be required:

- filling the site
- using stormwater treatment wetlands
- contributing to a local offset scheme, where available.

When the opportunities and constraints of the site are assessed, a preliminary drainage strategy or lot layout can be developed.

Structural separation of work areas

Structural separation of work areas includes designing the layout of structures within lots to:

- ensure all potential work areas are covered with a roof, or that runoff from work areas can be contained and re-used
- avoid small spaces behind, or beside, buildings that could potentially be used for informal storage or disposal of materials.

Achieving structural separation enables the site to support a range of future industrial activities without significant site redesign. Where the risk associated with a particular activity is compatible with a simple and generic means of treating stormwater to best practice pollution targets, structural separation may not be necessary. This exemption from structural separation would need to be reassessed if the nature of the work activity changed. Figure 28 illustrates structural separation.

Establishing a WSUD strategy for stormwater runoff

Local government requirements for stormwater treatment can generally be achieved using a combination of rainwater tanks and bioretention systems. Other available technologies include wetlands and gross pollutant traps. Site design will need to ensure that runoff can be delivered to these systems.

During concept design, provisional allocation of space for stormwater treatment areas should be made at 1.5–2% for bioretention systems (BMP 9) and 5–7% for wetlands (BMP 10). Guidance on the detailed design of WSUD systems is available from *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland* (SEQ HWP, 2006).

Table 10—Feasible stormwater treatment measures

Elevation difference between lowest point of site and legal point of discharge	Likely feasible stormwater treatment measure	Treatment area required (as % of catchment area)
2 m (steep)	End-of-pipe bioretention	2%
1 m (relatively flat)	At-surface bioretention	2%
Less than 1 m (flat)	Constructed wetland	5%

Consideration must be given to water cycle objectives such as harvesting and re-use of roofwater for end uses such as toilet flushing, landscape irrigation, vehicle wash down, and processing water. Check with local government agencies about locally specific requirements.

Many industrial areas have minimum landscape requirements. With a considered approach to site design, WSUD systems can generally be accommodated within these minimal designated landscape areas without impacting on developable site area.

Stormwater management in industrial precincts

Developers of industrial precincts are required to provide treatment for stormwater runoff from road reserves and public areas, as well as for any untreated stormwater runoff from allotments. The pollutant profile of these areas is generally compatible with simple, conventional WSUD treatment measures. Transport of materials within industrial estates presents an inherent risk of industrial pollutants entering WSUD systems, potentially resulting in significant and costly damage. Distributed stormwater treatment systems are more robust than centralised treatment systems where a chemical spill could disable a precinct's entire stormwater treatment system.

For industrial precincts, developers have the flexibility of assessing the relative life-cycle costs of providing treatment for stormwater runoff from allotments and in public areas. Developers can enlarge the size of treatment systems that would otherwise be required to treat road reserve runoff rather than treating all allotment runoff within allotment boundaries.

Factors to consider in assessing the balance between allotment-based treatment and precinct-based treatment include:

- site topography
- proposed future ownership structures and maintenance responsibilities
- construction staging
- potential impacts of on-site WSUD requirements on future tenants
- the risks to centralised WSUD.

Features of site layouts that prevent industrial pollution entering stormwater systems can be incorporated into greenfield and redevelopment sites at an acceptable cost if they are considered during the planning and design phase.

Structural separation

Roof over all work areas — then drainage on floors is not directed to stormwater

If unattainable, then

Contain runoff from, open work area and do not dispose to stormwater: e.g. reuse, evaporation

If unattainable, then

Stormwater runoff from work areas treated. Proof must be provided that the risk associated with a particular work activity is compatible with simple and generic means of treating stormwater to meet design objectives.

Exemption from structural separation

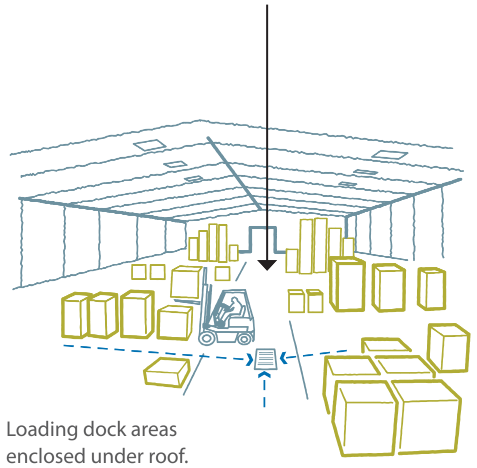
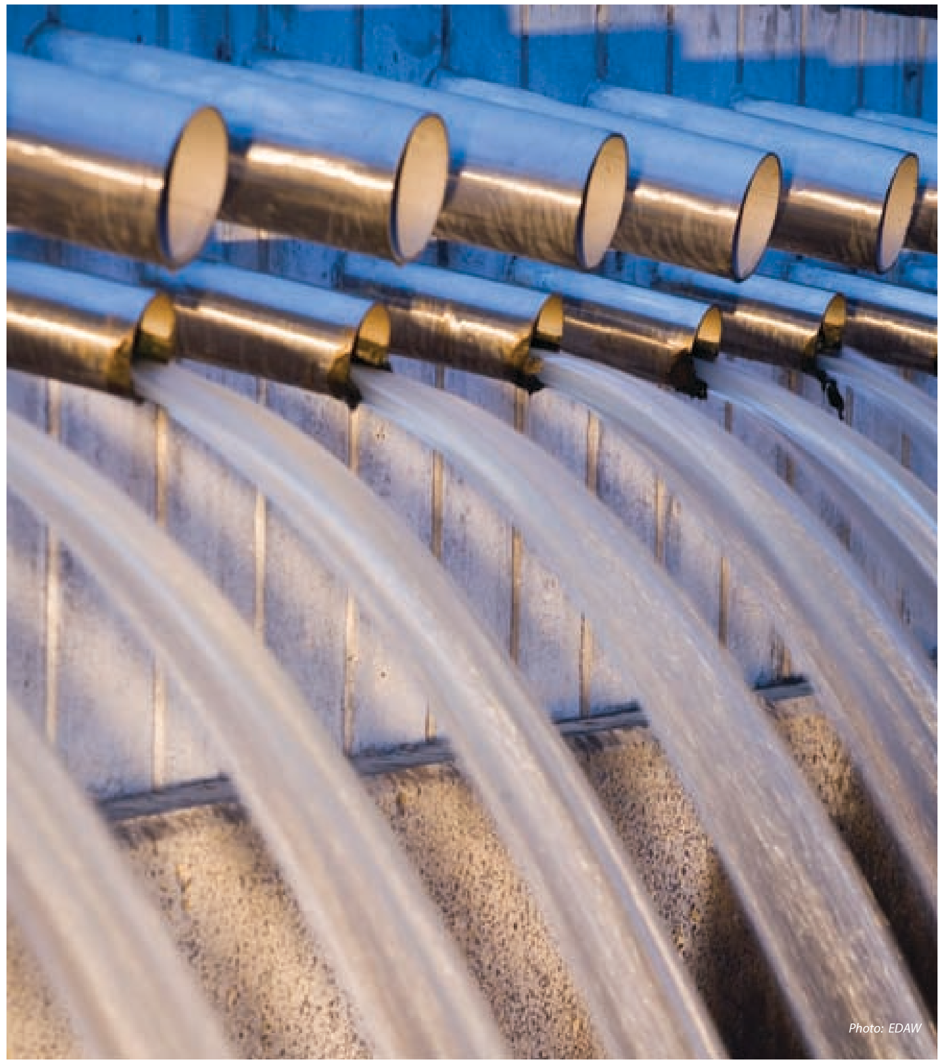


Figure 28 — Example of structural separation (source: SEQ HWP, 2007)

Key messages

- Developing industrial areas using conventional approaches can have a substantial negative impact on the natural water cycle and on waterway health.
- WSUD can be effectively applied in industrial areas to minimise the impacts of industrial development on the natural water cycle.
- Structural separation of work areas from roofs and car parks is a key aspect of stormwater management in industrial areas. This prevents industrial pollutants from contaminating stormwater so that standard approaches to treating urban stormwater can be applied.
- Roofed areas within industrial sites can generate large volumes of water suitable for a number of uses. To minimise potable water requirements, opportunities for local re-use of this resource should be investigated.

BPP 7: Waterscapes as Public Art



WSUD reconsiders traditional approaches to urban water management. In particular, stormwater management, which has employed an 'out of sight, out of mind' approach, is represented in new ways.

WSUD celebrates water in the urban landscape and re-engages people with water and the natural environment by predominantly using at-surface conveyance and treatment systems integrated within public areas. Integrating waterscape public art installations within WSUD stormwater systems can provide an effective means of enhancing the community's response to these systems and assist in communicating the aesthetic and resource value of urban stormwater.

A number of leading WSUD projects in Australia have incorporated waterscape public art to enhance the overall project aesthetics and legibility of WSUD systems. The Dockland's redevelopment in Melbourne and the Victoria Park re-development in Sydney are two well-known examples where public artists created waterscape installations incorporating the use of treated stormwater runoff.

Waterscapes can be incorporated within WSUD systems as purely aesthetic installations such as ornamental fountains or as more interactive installations encouraging human contact with the water such as water play areas. In cases such as water play areas, care is required to ensure the quality of water is suitable for the level of human contact. Where treated stormwater is used, UV irradiation treatment is recommended.

'Take thought, when you are speaking of water, that you first recount your experiences, and only afterwards your reflections.'

Leonardo Da Vinci

Melbourne Docklands

'The Memory Line', Clear Paddock Creek, Sydney

07

Storm Waters—Jennifer Turpin © Michaelie Crawford

Photo: Patrick Bingham Hall

Australian Garden, Royal Botanic Gardens Cranbourne
Design: Taylor Cullity Lethlean
Photo: Alan Hoban

Best Management Practices

Content:

05

Introduction

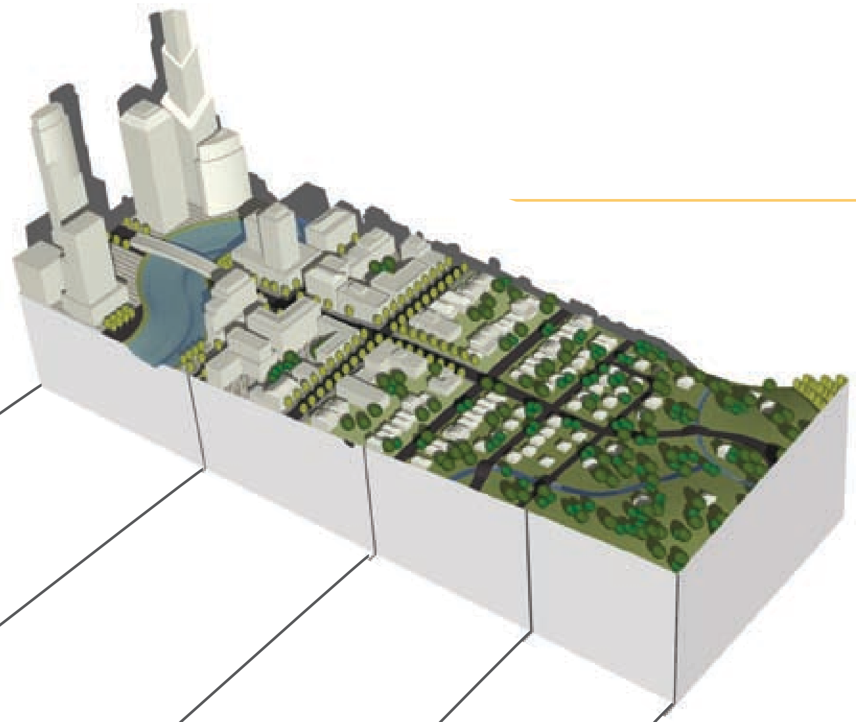
This section on Best Management Practices (BMPs) aims to provide information relevant to the conceptual design phase of a water sensitive development. Commentary of a more technical nature can be found in other resources including:

- *Australian Runoff Quality* (Engineers Australia 2006)
- *WSUD Technical Design Guidelines for South East Queensland* (SEQ HWP 2006) and other local equivalents.

In this section, each BMP is presented separately. Each BMP is introduced in the context of its role and contribution to the three WSUD strategies: water conservation, wastewater minimisation, and stormwater management. More specific commentary is provided on considerations relevant to decisions made at the conceptual design phase of an urban development including, where applicable:

- statutory compliance requirements
- typical spatial (land take) requirement and associated landscape "integration" considerations
- whole-of-lifecycle considerations including: expected effective service life; visual and aesthetic transformations over service life; decommissioning or re-installation requirements; typical maintenance requirements including by whom, how frequently and requirements for access
- BMP performance risk considerations including: potential constraining physical site characteristics, poor design, and operational risks.

By way of summary, Figure 29 aligns each BMPs with its potential contribution to the three WSUD strategies and to its application within the urban setting (i.e. within developments located in the urban core, urban centre, suburban and peri-urban settings). There will of course be opportunistic cases where individual BMPs can be implemented in areas where they would otherwise typically be un-suited. Figure 29 is therefore provided as a guide only and should not be used as reason to rule out a specific BMP based on a development's location.



BMP	*WSUD Strategy*			*Urban Core*	*Urban Centre*	*Suburban*	*Peri-Urban (Rural)*
	Water Conservation	*Wastewater Minimisation*	*Stormwater Management*				
Demand Management							
• Internal	✓	✓		✓	✓	✓	✓
• External	✓					✓	✓
Roofwater Harvesting	✓		✓	✓	✓	✓	✓
Stormwater Harvesting	✓		✓		✓	✓	✓
Wastewater Treatment and Re-Use	✓	✓		✓	✓	✓	✓
Gross Pollutant Capture Devices			✓	✓	✓		
Sedimentation Basins			✓			✓	✓
Grass or Vegetated Swales	✓		✓			✓	✓
Sand Filters			✓	✓	✓		
Bioretention Systems	✓		✓	✓	✓	✓	✓
Constructed Wetlands			✓		✓	✓	✓
Porous Pavements			✓	✓	✓	✓	
Infiltration Measures	✓		✓			✓	✓

Figure 29 — BMP potential contribution to WSUD strategies and application within the urban setting.

Passively irrigated bioretention street trees

Photo: Alan Hoban

BMP 1: Demand Management

Description

Demand management refers to both behavioural change measures and structural measures to reduce water use in the urban environment. Behavioural change measures include community education and the creation of new water sensitive urban environments. Behavioural change measures seek to enhance social awareness of issues such as regional water security and water resource depletion and to shift personal and business water use patterns to reduce overall water demand. Structural measures include the deployment of more water-efficient appliances and fittings within buildings and the use of lower water-demanding urban landscapes (commonly referred to as xeriscapes). Amending sandy soils to improve water- and nutrient-holding capacity can also significantly reduce irrigation water demand for urban landscapes. Some typical examples of water-efficient fittings and fixtures include: low water use taps and shower roses, 4.5L/3L dual flush toilets, front loading washing machines, waterless urinals for commercial and industrial applications, and composting toilets.

Community education helps to reduce the demand for water by making people aware of the implications of their water consumption.

Contribution of demand management to WSUD strategies

Demand management measures (both behavioural and structural) serve to extend the safe service capacity of existing water supply systems and reduce the drain on regional water resources to 'carry' the future needs of urban water users. Demand management measures can deliver significant benefits for water conservation by reducing overall urban water demand, and wastewater minimisation by reducing the quantity of water used in wastewater generating urban uses such as toilets, showers, washing machines. While less explicit, demand management also indirectly benefits stormwater management because it reduces the pressure on regional water resource systems such as rivers, streams and groundwater aquifers.

Who needs to know about demand management?

Demand management measures need to be well understood by all involved in the conceptual design of urban developments as the creation of more water sensitive urban environments is as fundamental to the behaviour change journey as targeted education. State regulations governing water savings to be achieved in new buildings requires knowledge of the minimum requirements and associated targets. Knowledge is also required about the range of available structural demand management measures to demonstrate compliance with state regulations. Behavioural change measures are the domain of both public and private sector practitioners with education the responsibility of both civic leaders and design leaders. Structural measures tend to fall more squarely onto the private sector designers who must design for and specify the most appropriate water efficient fittings and fixtures in order to satisfy the new statutory requirements. The national Water Efficient Labelling Scheme (WELS) provides design practitioners with considerable information on the water efficiency of water-using appliances. The WELS uses a star rating system to rank the water-use efficiency of appliances and enables designers to make informed choices. A minimum three star rating is required under current state regulation QDC MP 4.1 (Qld DIP, 2008a).

Considerations when incorporating demand management measures in a concept design

Statutory compliance requirements

The QDC MP 4.2 establishes minimum water-saving targets to be achieved in all new type 1 buildings in Queensland. For all non type 1 buildings, the Queensland Government must be consulted to establish the current statutory water savings requirements.

Spatial (land take) requirements

Structural demand management measures work within conventional building infrastructure and typically do not require allocation of additional floor space within a building.

Low water-demanding landscapes are an alternate form of landscape to traditional urban landscapes and tend to use more native and indigenous plantings. Therefore, a low water-demanding landscape need not take any more land.

Whole-of-lifecycle considerations

Capital and operating costs

Capital and operating costs for structural demand management measures are consistent with other less water-efficient equivalents.

Low water-demanding landscapes may have a slightly higher capital cost than traditional urban landscapes if soil amendment is required to increase water- and nutrient-holding capacity. However, ongoing costs can be expected to be considerably lower due to lower rates of active irrigation.

Expected effective service life

Most structural demand management measures would have an effective service life consistent with other less water-efficient equivalents.

Low water-demanding landscapes could be expected to have a longer lifecycle and lower plant mortality rates than more traditional urban landscapes.

Visual and aesthetic transformations over service life

Not applicable.

Decommissioning and/or re-installation requirements

There is no difference to traditional, high water-use appliances and fittings.

Typical maintenance requirements

There is no difference to traditional high water-use appliances and fittings.

Low water-demanding landscapes will require less active irrigation than traditional urban landscapes, but may require specific knowledge of the responsible maintenance party to maintain them properly. If that knowledge does not currently exist, it may be necessary to provide explicit documentation on appropriate maintenance actions in support of a low water-demanding landscape design proposal.

Demand management can occur both internally and externally to effectively reduce water demand.

BMP performance risk considerations

Potentially constraining physical site characteristics

If there is an existing problem with transporting solids within the sewer network due to a combination of low pipe grades and low dry weather flows., it may preclude retrofitting water-efficient appliances and fittings. While not common, this situation requires care to avoid reducing dry weather flows. If flows are too low, solids in the wastewater may block the sewer network resulting in uncontrolled sewer overflows.

Low water-demanding landscapes should be implementable in all site conditions, although it may be necessary to amend soils to achieve appropriate water- and nutrient-holding capacity.

Poor design

Poor design can reduce the effective service life of demand management measures. For water-efficient fittings and fixtures, WELS should be relied on to make informed decisions about new appliances and fittings.

Best practice design for low water demand landscapes is well documented. Queensland's Department of Natural Resources and Water provides design advice for low water-demanding landscapes (www.nrw.qld.gov.au/waterwise) .

Operational risks

Most water-efficient appliances will deliver measurable water savings independent of operator behaviour and, due to their capital cost, are not likely to be readily replaced with higher water--use equivalents. Low water-use fittings on the other hand, such as low-pressure shower roses, can be more easily replaced with high water-use equivalents and the individuals behavioural preferences, such as shower time can potentially negate any planned water savings from low water-use fittings. Ongoing education will probably be needed to maintain low-water use behaviour patterns to realise the full benefits of low water-use fittings.

Photo: Alan Hoban

BMP 2: Roofwater (Rainwater) Harvesting

Description

Roofwater harvesting involves the collection of rainwater from roofs and podiums within above- or below-ground storage systems for re-use. Roofwater harvesting will often require a pump to deliver the collected rainwater to its intended end uses. Where the storage system can be elevated above the intended end uses, then the need for a pump may be removed, or reduced. Another method that may be used to reduce the energy required to re-use harvested rainwater involves a small solar pump (or low-duty electric pump) to lift the stored rainwater to a header tank elevated above the intended end uses.

Rainwater contains substances such as nitrogen that are harmless in most urban non-potable uses (and even beneficial if used for irrigation) but that can be harmful to water environments such as bays and inlets. Most of the nitrogen in rainwater is absorbed from the air as the rain falls. Rainwater can be used directly (without treatment) for most non-potable household applications. It can also be used in hot water systems with a storage temperature of 60°C. This temperature will effectively destroy most pathogens. If pathogens are a particular concern, then chemical or UV disinfection can be used. Recent innovations using Light Emitting Diodes (LED) for water disinfection offer a low energy alternative to UV disinfection. A greater level of treatment may be required for certain industrial uses.

Due to the episodic nature of rainfall and the variable patterns of end use demand, it is typical for roofwater harvesting systems to be 'backed up' by a secure water source, such as the local potable mains water supply to ensure full reliability of supply. The reliability of supply of a roofwater harvesting system operating without back-up is determined by a combination of variables including: local rainfall patterns, connected roof area, storage system size (capacity) and the magnitude and pattern of connected end uses. In general, a skillion roof arrangement will be the most efficient for rainwater collection. For other roof types, it is possible to maximise the roof area connected to a rainwater storage system by sealing the downpipes and providing underground connections between the downpipes and the storage system (i.e. using the hydraulic head between the roof gutters and the storage system to drive water into the storage). This type of roofwater harvesting system is often referred to as a 'wet' system.

Water demand will vary depending on the internal appliances and fittings to which the rainwater storage is connected and the type and area of landscaping irrigated. For any given rainwater storage size, constant demands such as indoor uses will be met with greater reliability than variable outdoor uses such as irrigation. If rainwater storages are being used within a stormwater treatment train as a means to attain 'best practice' stormwater pollutant removal targets and hydrology management targets, then the selection of a constant demand may enable a smaller storage system to be used.

Contribution of roofwater (rainwater) harvesting to WSUD strategies

Roofwater harvesting contributes to both water conservation and stormwater management outcomes. While rainfall dependent, the performance of roofwater harvesting systems for water conservation is much less sensitive to drought conditions than traditional reservoirs or diversions that are supplied from rural or natural catchments. This is because roofwater runoff, like stormwater, is from hard surfaces that are not affected by dry soil conditions that absorb large amounts of rainfall before a runoff threshold is exceeded. Under climate change uncertainty, roofwater harvesting systems are a useful water supply alternative to traditional dams, reservoirs and weirs.

Roofwater harvesting systems can be part of a stormwater treatment train providing water quality and quantity management benefits. Re-use of harvested roofwater reduces the volume of stormwater runoff entering urban streams and associated stormwater pollutant loads.

If used for non-potable purposes, rainwater does not require treatment and is simple to manage; however, reliability of supply is affected by the irregular nature of rainfall.

Who needs to know about roofwater (rainwater) harvesting?

Roofwater harvesting systems is most effective when considered as early as possible in the conceptual design of a building. Maximising connected roof areas and connecting to a regular daily demand will yield greatest return on investment. Architects and building services engineers will need to know how to configure a building to optimise its roofwater harvesting potential and to provide the most aesthetically pleasing solution.

Considerations when incorporating roofwater (rainwater) harvesting in a concept design

Statutory compliance requirements

Roofwater harvesting is an acceptable solution to achieve mandatory water savings targets for new type 1 building in Queensland (QDC MP 4.2) and is an acceptable alternative water source for non-potable uses in new commercial and industrial buildings in Queensland (QDC MP 4.3).

The *Queensland Plumbing and Drainage Act*, 2002 and its related regulations control the plumbing requirements for rainwater harvesting systems to prevent cross connection with potable mains water supplies and to minimise the risk of mosquito breeding within storage systems. Designs for rainwater harvesting systems must therefore comply with the relevant state and local government regulations.

Spatial (land take) requirements

The land take required for a roofwater harvesting system is dependent of the scale of the system, which is driven by site specific characteristics such as: roof area; end use demand; storage size (optimised to demand); and whether above- or below-ground storage is used. For multi-storey buildings, it is common for the storage to be located within basement carparks while detached residential housing commonly use above-ground tank storage systems. Recent innovations in above-ground tanks provide a broad range of tank shapes and forms allowing for increased storage capacity with reduced land take (e.g. slim line tanks).

Consideration could also be given to 'internal' locating of roofwater storage systems, taking advantage of the high thermal mass qualities of stored water.

Whole-of-lifecycle considerations

Capital and operating costs

Roofwater harvesting systems have a relatively high capital cost and a high lifecycle cost but have the benefit of being a self-contained water source not impacted by use restrictions that may be imposed on centralised water supplies. Capital and operating costs can be optimised by correctly sizing the roofwater harvesting system (i.e. not over-sizing storage systems in pursuit of an unrealistic reliability of supply) and by seeking ways to reduce energy requirements.

Expected effective service life

The effective service life of a roofwater harvesting system depends on the type of storage system used (i.e. above ground or below ground and materials such as plastic versus steel). Typically, a well-maintained roofwater harvesting system should have an effective service life of 20 to 30 years for the storage element, with pumps potentially requiring more frequent replacement (typically every 10 years) depending on the intensity of their use.

Visual and aesthetic transformations over service life

There is considerable choice of roofwater harvesting storage systems with a range of shapes, configurations, materials and colours available. Early consideration of the roofwater harvesting system in building design can further enhance the aesthetics of roofwater harvesting systems by more seamlessly integrating them within the building architecture.

Decommissioning or re-installation requirements

Roofwater harvesting systems will require individual elements to be replaced over time and, therefore, provision must be made in site and building design for access to each element to decommission or remove expired elements and to install new or replacement elements.

Typical maintenance requirements

Regular maintenance of roofwater harvesting systems is important to manage water quality (i.e. avoid excessive ingress of organic matter and other non-desirable elements into storage systems from roofs and gutter systems) and to mitigate mosquito risk. Guidance on proper maintenance of roofwater harvesting systems can be found in the Queensland Department of Natural Resources and Water's 'Waterwise' advice at: http://www.nrw.qld.gov.au/water/waterwise/pdf/rainwater_tanks.pdf.

Rainwater harvesting is a low complexity WSUD element appropriate for conserving potable water and preventing some pollutants from entering waterways.

BMP performance risk considerations

Potentially constraining physical site characteristics

Shallow rock or high groundwater may preclude the use of below-ground storage systems.

The variety of above-ground storage systems means there should be a suitable storage system for all site conditions.

Some roof material types may be unsuitable for roofwater harvesting if there is potential for human ingestion of the collected roofwater. For example, roofs painted with lead-based paints, coated in bitumen or treated timber roofs are typically not suitable for roofwater harvesting. Similarly, roof areas subject to discharges from wood burner flues or air conditioning units should also be avoided.

Mosquito risk is a major concern with roofwater harvesting systems. Regulations require effective screening of open access points into storage systems and regular inspection of these screens. Failure to do this can create conditions conducive to mosquito breeding and potential exposure to mosquito-borne viruses.

Poor design

A poorly designed roofwater harvesting system may result in poor return on investment in terms of cost per unit of water generated and may increase public health risk. Correct sizing of roofwater harvesting systems using appropriate water balance methods and adherence to design requirements in relevant state and local regulations should ensure good overall performance from roofwater harvesting systems.

Operational risks

The expected water savings and stormwater management benefits from roofwater harvesting systems is largely dependent on how the system will be used by its owner. Connecting the system to regular internal uses such as toilet flushing removes a certain amount of user influence on system performance, whereas more discretionary uses such as outdoor watering, which can be highly variable based on the user's watering habits, can significantly influence system performance.


Photo: Alan Hoban

BMP 3: Stormwater Harvesting

Description

Stormwater harvesting captures stormwater flows from ground surfaces such as roads, car parks, and pedestrian areas. Depending on the land use mix, urban stormwater can contain gross pollutants, sediments, nutrients, heavy metals, hydrocarbons, and faecal contamination. Catchments that may generate potentially toxic contaminants within stormwater runoff (e.g. industrial spills) should generally be avoided. Stormwater can be harvested from pipes, culverts, or open channels.

All stormwater must be treated before it can be re-used. Pre-treatment of harvested stormwater for environmental pollutants such as organic litter, nutrients and heavy metals may also be necessary before it can be safely stored. Treatment is particularly necessary if stormwater is being stored within an above-ground open surfaced storage system such as an urban pond or lake which may develop eutrophic conditions if excessively loaded by environmental pollutants. After treatment, and depending on the level of treatment provided, harvested stormwater can potentially be used for a range of indoor non-potable uses, irrigation, and for industrial and commercial uses.

Stormwater harvesting, like roofwater harvesting, requires a storage system to balance the timing of supply with the timing of demand. The size of the storage varies depending on:

- the reliability of the supply required (if no supplementary supply is available)
- the desired cost or benefit of the system, if a supplementary supply is available.

Storage of pre-treated stormwater runoff may be in large centralised storage systems (typically urban ponds or lakes) or within smaller distributed storages such as allotment- or precinct-scale tanks. A further storage option is the use of natural or constructed aquifers. Aquifer storage and recovery (ASR) is widely used in other parts of Australia, particularly Adelaide, to store pre-treated urban stormwater runoff for subsequent urban re-uses. An ASR scheme has also been implemented in the Coomera–Pimpama region on the Gold Coast.

Because of the cost of providing treatment for even the smallest stormwater harvesting projects, the economics of stormwater harvesting tend to improve as the scale of the project increases. However, allocating sufficient land area for an optimally-sized stormwater harvesting storage system can be difficult and expensive in large-scale projects or if retrofitting into an existing urban area. In areas where ASRs can be used for stormwater storage, the land take constraint is removed.

Because of the economies of scale and management complexities, stormwater harvesting systems are typically less well-suited to individual properties and are more appropriately located at the downstream end of a stormwater catchment, preferably close to where the stormwater will be re-used, to reduce distribution costs.

If considering a stormwater harvesting system, care is required to ensure the proposed system does not impinge on the environmental flow requirements of the local receiving waterways. In most urban settings, it is unlikely that a stormwater harvesting system would cause adverse impacts on environmental flows due to the considerable increase in stormwater runoff volumes accompanying urban development. If designed specifically with environmental flow protection as an objective, stormwater harvesting can contribute to the protection or restoration of environmental flows in urban waterways.

Aquifer Storage and Recovery

The viability of an aquifer storage and recovery (ASR) scheme is dependant on local hydrology, the underlying geology of an area and the presence and nature of aquifers. There are a range of aquifer types that can accommodate an ASR scheme, including fractured un-confined rock and confined sand, and gravel aquifers. In addition, it may be possible to construct an aquifer if costs allow. Detailed geological investigations are required to establish the feasibility of any ASR scheme.

The broad requirements of ASR systems include:

- protecting or improving groundwater quality where ASR is practised
- ensuring that the quality of recovered water is fit for its intended use
- protecting aquifers and aquitards (fractured rock) from being damaged by depletion or excessive pressure (from over-injection)
- avoiding problems such as clogging or excessive extraction of aquifer sediments
- ensuring reduced volumes of surface water downstream of the harvesting point are acceptable and consistent with a catchment management strategy and environmental flow requirements.

Factors to consider when choosing a suitable aquifer include:

- the environmental values of an aquifer (e.g. high quality groundwater may exclude the use of an aquifer for ASR)
- the benefits an aquifer may already be providing to others and maintaining the quality and flow requirements of these users
- the permeability of a receiving aquifer
- the salinity of aquifer water because if it is greater than injection water, then the salinity concentration will influence the viability of recovering water from the aquifer
- the possible damage to confining layers due to pressure increases
- the adverse effects of reduced pressure on other groundwater users
- the aquifer mineral dissolution, if any, and potential for well aquitard collapse.

Further information on the technical design of ASR schemes is in Chapter 9 of the *WSUD Technical Design Guidelines for South East Queensland* (SEQ HWP, 2006).

Contribution of stormwater harvesting to WSUD strategies

Stormwater harvesting contributes to both water conservation and stormwater management outcomes. While rainfall dependent, the performance of stormwater harvesting systems for water conservation is much less sensitive to drought conditions than traditional reservoirs or diversions that are supplied from rural or natural catchments. This is because stormwater runoff, like roofwater, is from hard surfaces that are not affected by dry soil conditions that absorb large amounts of rainfall before a runoff threshold is exceeded. Under climate change uncertainty stormwater harvesting systems are a useful water supply alternative to traditional dams, reservoirs and weirs.

Stormwater harvesting systems can be part of a stormwater treatment train providing water quality and quantity management benefits. Re-use of harvested stormwater reduces the volume of stormwater runoff entering urban streams and associated stormwater pollutant loads. Capturing and re-using up to the first 15 to 20 mm of runoff from impervious surfaces can assist in protecting or restoring the pre-developed natural hydrologic conditions of an urban waterway.

Who needs to know about stormwater harvesting?

Stormwater harvesting systems require an adequate allocation of land for the main storage element and any pre-treatment systems (such as swales or bioretention systems). Therefore, designers responsible for allocating land use need to be familiar with the land take requirements of the stormwater harvesting system. Sizing of the elements is typically undertaken by a civil engineer with experience in water balance modelling and the design of stormwater treatment facilities. If the storage element is intended to be an urban pond or lake, these elements require considerable knowledge of urban lake ecology to ensure the storage system itself does not become an environmental or public health risk. Experienced aquatic ecologists and hydrologic engineers are needed to ensure the appropriate sizing and design of pond or lake systems.

Considerations when incorporating stormwater harvesting in a concept design

Statutory compliance requirements

Regulations relating to stormwater harvesting change from time to time. For the latest requirements, refer to the relevant local government's policy and regulations on stormwater harvesting. The most recent version of the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2) — Stormwater Harvesting and Reuse (*Environment Protection and Heritage Council, the Natural Resource Management Ministerial Council and the Australian Health Ministers' Conference, 2008) for acceptable treated stormwater requirements for managing public health risk.

Spatial (land take) requirements

The spatial requirements for stormwater harvesting systems are site-specific and depend largely on the level and type of pre-treatment required and the type of storage system used. Pre-treatment of stormwater to remove environmental pollutants is typically provided by WSUD BMPs configured in treatment trains and sized to comply with local regulations. As a guide, BMPs to remove particulate and soluble nutrients and fine sediments generally require the greatest land take (e.g. bioretention systems will typically require a land area equivalent to 3% of the contributing catchment and constructed wetlands may require up to 7% to 10% of contributing catchment).

The storage element of a stormwater harvesting scheme can also consume significant land area, particularly if above-ground storage systems are used and particularly in larger stormwater harvesting schemes. Water balance modelling is required to establish the final land take requirement for the storage element.

Treatment to disinfect the stored water prior to re-use involves either UV radiation or chlorine dosing. Both of these processes require only a minimal land take.

Whole-of-lifecycle considerations

Capital and operating costs

Capital costs for stormwater harvesting systems are typically higher than most other non-potable water sources. However, the cost of the pre-treatment infrastructure (i.e. the same pre-treatment infrastructure is typically required under regulation to protect waterway health) is a cost to development irrespective of whether or not stormwater harvesting is to be implemented. Therefore, the true capital cost of stormwater harvesting is the cost of the storage element, final disinfection treatment system and the reticulation infrastructure.

By over-sizing the storage element to achieve an unrealistically high reliability of supply or over-treating the stormwater are two issues that can significantly increase the capital cost of stormwater harvesting. Engaging the right expertise to undertake the water-balance modelling and water quality treatment system sizing is central to optimising the capital cost of stormwater harvesting.

While capital costs may be high for stormwater harvesting systems, it is important to also consider the energy costs of stormwater harvesting to other non-potable water sources. Typically, stormwater harvesting has a low energy footprint because the treatment options use low-energy processes and the reticulation distances from source to end use are typically much shorter than other non-potable water sources.

Operating costs should be relatively low and relate to maintaining the pre-treatment system performance. Again, this cost is independent of whether or not stormwater harvesting is implemented in a development). There are also operating costs associated with maintaining the water quality in the storage element and maintaining the disinfection infrastructure.

Expected effective service life

Stormwater harvesting systems should have a long effective service life with pre-treatment systems typically having 20 year life, storage elements a 50+year life and disinfection treatment systems 10+years.

Visual and aesthetic transformations over service life

The visual appearance of the pre-treatment and storage (above ground only) elements of stormwater harvesting systems will transition over time as these elements mature as functioning systems. Consideration should be given in the conceptual design to both short-term and long-term visual impacts and, where necessary, provide landscape elements for visual screening.

The potential requirement for future re-set of elements of stormwater harvesting systems should also be considered in the conceptual design with compensating landscape elements provided to off-set the visual impact of the decommissioning and rebuilding of these elements.

Decommissioning or re-installation requirements

The pre-treatment elements of a stormwater harvesting system are the only elements likely to need periodic (20+years) decommissioning and re-installation. Specific decommissioning and re-installation requirements for these pre-treatment elements can be found in this same section of the other BMPs covered in this guideline.

Photo: Alan Hoban

Photo: Alan Hoban

BMP 3: Stormwater Harvesting

Typical maintenance requirements

Maintenance of stormwater harvesting systems includes maintaining:

- the pre-treatment system performance
- the water quality in the storage element
- the disinfection infrastructure.

Conceptual design should make appropriate allowance for maintenance vehicle access to all elements of stormwater harvesting systems.

BMP performance risk considerations

Potentially constraining physical site characteristics

Shallow rock may preclude the use of below-ground storage systems.

Poor groundwater quality, particularly highly soluble nutrients, may impact on the quality of water stored in open-water storage systems such as ponds and lakes where these intercept the groundwater table. Lining the pond or lake may be required if groundwater quality is poor. Care is needed to ensure the draw down of the pond or lake does not create conditions where a high groundwater table results in buoyancy conditions lifting or cracking the lining. Poor groundwater quality may also preclude ASR.

The variety of above-ground storage systems means there should be a suitable storage system for all site conditions.

Poor design

As mentioned earlier, poor design resulting in over-sizing treatment and storage elements can significantly reduce the economic return on investment of a stormwater harvesting system.

Poor design of pre-treatment systems can compromise the suitability of harvested stormwater for its intended end uses and, if using open water storage systems such as ponds and lakes, can impact on the health and aesthetic amenity of the storage system. Guidance on best practice design for pre-treatment systems can be found in *WSUD Technical Design Guidelines for South East Queensland (*SEQ HWP, 2006).

Poor design of the storage elements, particularly if using open water storage or aquifer storage, can impact on the quality of the harvested stormwater and compromise its suitability for the intended end uses. Detailed guidance on the design of urban ponds and lakes can be found in various references; however, when used as part of a stormwater harvesting system, it is highly recommended that an experienced freshwater ecologist with specific expertise in urban lake ecology is engaged to advise on the design of the storage element.

Similarly, detailed guidance on ASR can be found in various references, but given the highly specialist nature of this method of stormwater storage and recovery, it is recommended that specialist advice is engaged.

The SEQ HWP have prepared detailed technical design guidance for stormwater harvesting systems in the document *Stormwater Harvesting Techincal Guidelines* (SEQ HWP, 2009b). This should be referred to avoid poor design.

Operational risks

The expected water savings and stormwater management benefits of stormwater harvesting systems are largely dependent on how the system is used. Connecting the system to regular internal uses such as toilet flushing removes a certain amount of user behaviour influence on system performance, whereas more discretionary uses such as domestic outdoor watering and public realm landscape watering can significantly influence system performance. As a rule, the more rapidly the stormwater storage is drawn-down by connected end uses, the more effective the system yield.

Stormwater harvesting provides great potential for mitigating the impacts of urbanisation on waterways and is much less energy intensive than wastewater harvesting.

Opposite Page:
Construction of Stormwater Harvesting System
South Australian Museum (North Terrace Redevelopment)

Photos: Taylor Culity Lethlean

03

BMP 4: Wastewater Treatment for Re-Use

Description

Wastewater includes blackwater and greywater. Blackwater is wastewater from toilets and kitchen sinks. Greywater is wastewater from non-toilet plumbing fixtures such as showers, basins, washing machines, and taps.

Wastewater can be treated to 'fit-for-purpose' standards at centralised or decentralised (small) sewage treatment plants for a range of re-use applications including: industrial uses, agricultural uses, non-potable domestic uses, urban open space irrigation, and for indirect potable re-use if treated to PRW standards. National guidelines for recycled water use provide minimum water quality requirements for recycled water uses (Environment Protection and Heritage Council, the Natural Resource Management Ministerial Council and the Australian Health Ministers' Conference, 2006).

Table 11 lists the main wastewater treatment processes and their effectiveness in treating target environmental and public health pollutants. Table 12 lists more specific treatment process, their typical operating bounds, spatial requirements and typical application.

The different treatment processes each have limitations and it is usually necessary to combine either physical (i.e. membrane) or biological treatment processes with chemical disinfection (or other means of disinfection such as UV irradiation) to deliver 'fit-for-purpose' recycled water as shown in Table 11. Biological treatment processes should generally be avoided if there is a high risk of toxic spills entering the wastewater stream. Toxic substances may adversely impact on biological processes and diminish the treatment performance and potentially lower the effective service life of biological wastewater treatment systems.

Wastewater treatment for re-use reduces water demand as well as protecting urban streams and rivers by capturing some of the water and nutrients that would otherwise be discharged from sewage treatment plants.

Current regulations in Queensland prohibit decentralised wastewater treatment and re-use in sewered areas. Decentralised greywater treatment and re-use is, however, accepted usually at the discretion of the local government and is listed as an acceptable alternative water source for new industrial and commercial buildings in Queensland (QDC MP 4.3). The Queensland Government is currently trialling decentralised blackwater treatment and re-use on a number of pilot sites to test the performance of treatment processes and operational requirements. The outcome of these trials may be a future amendment to current legislation and regulations to enable decentralised blackwater treatment and re-use in sewered areas.

Depending on the intended end use, greywater may require less treatment than blackwater, although it is generally agreed that the treatment process can be just as onerous as for blackwater given the highly variable quality of greywater.

Sewer mining (or water mining) is another means of sourcing wastewater for treatment and re-use. Sewer mining involves 'mining' water from the town sewer using pumps to extract a portion of the wastewater flows for treatment and re-use. Typically, not more than 50% of the dry weather flow in the sewer can be extracted to avoid solids build-up. Sewer mining has the advantage that the treatment facility can be located close to the end use demand, reducing distribution costs.

Table 11 — Wastewater Treatment Processes and their Removal Effectiveness in Removing Pollutants

Treatment Process	TSS	Biodegradable Organics	Nitrogen	Phosphorus	Salts	Pathogens
Physical filtration	Yes	Function of size	Limited	Limited	No	Limited
Chemical disinfection	No	No	No	No	No	Yes
Biological processes	Yes	Yes	Yes	Limited	No	Limited

Dual reticulation is the provision of a non-potable water supply to communities in a second supply pipe network. This secondary supply of water can be used for toilet flushing, irrigation and other outdoor uses.

Implementing wastewater treatment for re-use within a conceptual design will often be driven by a regional strategy or policy driver such as minimising wastewater flows from a new development into an already overloaded trunk sewer or avoiding a costly augmentation of downstream trunk sewer networks and wastewater treatment plants. Other drivers may be localised and may include securing a reliable locally-generated recycled water source to sustain private and public realm landscapes or to supply fit-for-purpose recycled water to a specific industrial process. The drivers will dictate the scale and nature of the wastewater recycling scheme and the requirement for the conceptual design process to make appropriate urban design and infrastructure provision to accommodate the specific land take and infrastructure requirements of the scheme.

Other equally important considerations when deciding on a wastewater treatment and re-use scheme include:

- community acceptance of the use of recycled water for intended end uses
- public and environmental health risk management requirements
- suitability of soils and terrain for irrigation by treated wastewater
- sensitivity of local ecosystems to potential surface and groundwater runoff from areas under irrigation by treated wastewater.

Contribution of wastewater treatment for re-use to WSUD strategies

Wastewater treatment for re-use reduces the demand on potable water supplies and reduces the discharge of wastewater and its associated environmental pollutants (organics, particulate and soluble nutrients, pathogens) to receiving aquatic environments. Wastewater treatment for re-use contributes to the WSUD strategies of water conservation and wastewater minimisation.

Wastewater treatment for re-use does not contribute to stormwater management, in some circumstances if adopted as an alternative to stormwater harvesting, may potentially result in an adverse impact on the health of local waterways receiving stormwater runoff if it is not managed to best practice standards.

Who needs to know about wastewater treatment for re-use?

An experienced civil engineer with a strong knowledge of the local and regional wastewater infrastructure context and its overarching strategy and policy drivers is essential to ensure the most appropriate wastewater treatment and re-use scheme is selected for the development. Architects and building services engineers will need to understand the spatial requirements and internal infrastructure requirements for wastewater treatment and re-use schemes.

Considerations when incorporating wastewater treatment for re-use in a concept design

Statutory compliance requirements

Relevant national, state and local government policy, guidelines and regulations must be reviewed before embarking on a wastewater treatment and re-use scheme. Current regulatory restrictions on blackwater treatment for re-use in sewered areas may change in the near future and it is recommended that relevant government departments are contacted to confirm the current regulatory position.

Spatial (land take) requirements

Spatial requirements will vary depending on operating requirements (i.e. daily throughflow) and treatment processes. It is important to have selected the most suitable treatment process for the particular development and intended end uses as part of the conceptual design process. This will ensure adequate allowance is made for both floor space, land take and infrastructure provision to ensure seamless implementation of the scheme in detailed design. Table 12 describes the range of different treatment processes typically employed within proprietary wastewater treatment systems and their associated operating bounds and spatial requirements.

Table 12 — Summary of Wastewater Treatment Processes

Treatment Process	Operating Range	Water Quality Generally Suitable For:	Footprint (m²)	Application
Natural — humus filter situated at each household	0.5 – 10 kL/d	Subsurface irrigation	2 – 1	Single household, clustered development
Biological filtration + membrane filtration	0.5 – 100 kL/d	Toilet flushing, irrigation, cold washing machine tap	3 – 60	Single household, localised development
Subsurface wetland	0.5 – 360 kL/d	Toilet flushing, irrigation (disinfection required)	2 – 800	Single household, clustered development
Membrane bioreactor	0.5 – 500 kL/d	Toilet flushing, irrigation, cold washing machine tap (disinfection required)	1 – 200	Single household, localised residential development (e.g. multi-unit dwellings)
Biological — fixed film bioreactor	1 – 150 kL/d	Restricted irrigation (additional treatment required)	2	Single household, clustered development
Biological system — primary settling + recirculating media filtration	2 – 10 kL/d	Restricted irrigation	20 – 200	Clustered development
Membrane filtration	40 – >3000 kL/d	Toilet flushing, irrigation, cold washing machine tap	7 – 30	Localised residential development (e.g. multi-unit dwellings), large residential development
Filtration	9000 – 38000 kL/d	Additional treatment required to attain non-potable urban water uses	4 – 9	Large residential development

BMP 4: Wastewater Treatment for Re-Use

Whole-of-lifecycle considerations

Capital and operating costs

The capital cost of decentralised wastewater treatment systems are highly dependent on the selected treatment processes and the type of device (i.e. most decentralised wastewater treatment systems are proprietary systems). Typically there is more than one proprietary system available to meet the requirements of the project and, therefore, it is prudent to assess all options.

Operating costs also are highly dependent on the selected treatment process and type of device. Biological treatment systems may require more regular maintenance to protect treatment efficiency whereas physical filtration (i.e. membrane) systems require periodic replacement of membranes due to fouling over time.

Expected effective service life

The effective service life of decentralised wastewater treatment systems is dependent on the selected treatment process, the type of device and importantly, the effective operation and maintenance of the scheme. Typically there is more than one proprietary system available to meet the requirements of the project and, therefore, it is prudent to assess all options to establish the scheme with the lowest lifecycle cost, while meeting the operational requirements of the scheme.

Visual and aesthetic transformations over service life

Most decentralised wastewater treatment processes are contained within a surrounding encasement or structure or are located underground. The visual impact will therefore be minimal provided due consideration is given in building design or urban design to locate the systems appropriately and, where necessary, to screen or buffer the systems.

Decommissioning or re-installation requirements

It is likely that decentralised wastewater treatment systems will need to be decommissioned and re-installed within the operating life of the building or urban development. Conceptual design must make adequate provision for future access for routine maintenance and for ultimate decommissioning and replacement.

Typical maintenance requirements

Maintenance depends on the selected treatment processes and type of device. Operation and maintenance of decentralised wastewater treatment and re-use systems is typically be carried out by a contractor with demonstrated experienced in the operation and maintenance of wastewater treatment systems and is often the same contractor that supplied the treatment device.

BMP performance risk considerations

Potentially constraining physical site characteristics

The variety of available decentralised wastewater treatment processes and their associated operating bounds means there is a suitable treatment system for most projects.

Where treated wastewater is intended to be used for landscape irrigation, the following physical site conditions may preclude this:

- steep terrain that may result in treated wastewater re-expressing itself as a surface flow down slope from the irrigation site
- heavy clay soils that may accumulate salts and nutrients
- free draining soils that may leach salts and nutrients to groundwater, which may then impact on receiving aquatic ecosystems or other beneficial users of the groundwater resource
- shallow groundwater table, which may restrict infiltration and cause surface runoff of treated wastewater.

Poor design

Selecting the most appropriate treatment processes and type of device for the project based on expected quality of raw wastewater flows and intended end uses for the treated wastewater will be critical to the success of the scheme.

As a guide fore selecting treatment processes and proprietary devices, refer to *Water Re-use in the Urban Environment: Selection of Technologies* (Landcom, 2006).

Operational risks

Inappropriate operation of wastewater treatment and re-use schemes results in a high risk to the performance of the system. The scheme may not deliver on the water conservation and wastewater minimisation expectations and it may also cause an unacceptable public and environmental health risk. All decentralised wastewater treatment and re-use schemes must be accompanied by a detailed operation and maintenance plan and implementation should be by qualified, experienced professionals.

Photo: Ross Pottinger

04

Photo: Alan Hoban

BMP 5: Gross Pollutant Capture Devices

Description

There are many types of gross pollutant capture devices with varying levels of performance efficiency (Table 13). These devices may be located at the point of entry into the drainage system or 'on-line' within the drainage system. Devices located on-line within the drainage system may be 'dry' traps such as simple nets placed over the end of pipes, or 'wet well' traps that can potentially trap much smaller particles.

The choice of device should be based on the expected gross pollutant loads being generated in the contributing catchment. Gross pollutant capture devices are ideally suited to catchments in shopping centres and commercial precincts that have high man-made litter loads (such as plastic bottles, bags and styrofoam) and low organic loads.

Residential catchments are likely to have high organic loads (such as grass clippings and leaves) and only relatively small anthropogenic (human-generated) litter loads. The capture of organic loads in wet well traps can be problematic due increased decomposition rates and the release
of nutrients and toxins into downstream environments. This nutrient release will negatively impact on receiving environments unless the wet well system is located at the start of a treatment train in which flows from the system will discharge into a secondary or tertiary treatment device that can remove the nutrients prior to discharge into the receiving environment. If the device is to be used in isolation, it is preferred to have a dry trap to capture the high organic loads to reduce the risk of nutrient and toxin release. These dry trap systems are typically located above-ground and can therefore be difficult to integrate into the landscape and can present a potential public health risk if collecting dangerous litter such as syringes.

Gross pollutant capture devices serve as primary (first) stormwater treatment devices in a stormwater treatment train as they target litter, coarse sediments and other large particles (larger than 5 mm) (See Figure 30). This pre-treatment of stormwater flows can help to reduce the risk of secondary or tertiary treatment devices, located downstream, from being smothered, affecting their treatment performance and effective service life. These secondary and tertiary stormwater treatment devices are required in addition to gross pollutant capture devices to manage fine sediments and nutrients such as TN and TP to meet best practice load reductions.

Gross pollutant capture devices may often be the only retrofit treatment option in highly constrained sites such as in the urban core and urban centre. In this situation, the preferred treatment train may consist of a side-entry basket to remove litter followed by a cartridge media filter type device that can then remove sediments and some heavy metals and nutrients. This solution will not meet best practice load reductions, but may be the only practical solution for inner-city locations.

Contribution of gross pollutant capture devices to WSUD strategies

Gross pollutant capture devices contribute to stormwater quality management outcomes, in particular the removal of visually obtrusive litter. These devices do not contribute to water conservation or wastewater minimisation outcomes, or to stormwater quantity management.

Who needs to know about gross pollutant capture devices?

Typically civil engineers select the most appropriate range of devices to match the hydraulics of the drainage system and the specific stormwater treatment train configuration. Urban designers and landscape architects refine the selection to match device aesthetics to the available site location.

Considerations when incorporating gross pollutant capture devices in a concept design

Statutory compliance requirements

The *South East Queensland Regional Plan Implementation Guideline No 7: Water Sensitive Urban Design* (Qld DIP, 2008b) establishes the minimum reduction of gross pollutants at 90%.

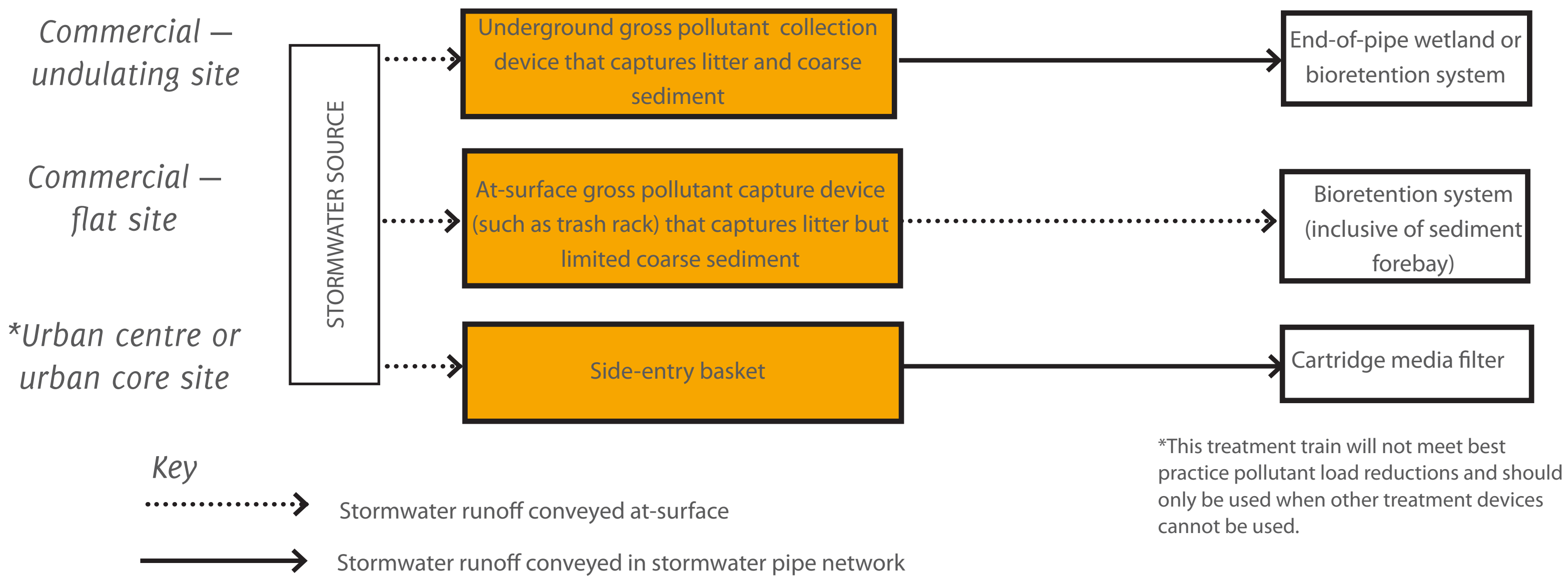


Figure 30 —Gross pollutant capture devices as part of stormwater treatment trains

Table 13: Gross pollutant capture devices management of stormwater runoff water quality and hydrology

	WATER QUALITY								HYDROLOGY	
Treatment Type	Coarse Sediment	TSS	TP	TN	Anthro Litter	Organic Litter	Hydro-Carbons	Heavy Metals	Disconnect Impervious Areas	Provide Detention
'Point-of-entry' litter basket or side-entry pit	NS	NS	NS	NS	H	M	NS	NS	NS	NS
'Within-drain' trash rack or net	L	NS	NS	NS	H	M	NS	NS	NS	NS
Device with sediment trapping function	M	L	L	L	H	L	NS	NS	L	NS
Cartridge media filter	M	M	M	L	H	H	M	M	NS	NS

L - Low; M - Medium; H - High; NS - Not Suitable (requires pre-treatment);
Shaded cells indicate where removal of this pollutant would be problematic to the long-term performance of the treatment measure and would significantly increase the maintenance frequency. Pre-treatment of this pollutant is therefore required.

Spatial (land take) requirements

The spatial requirements of gross pollutant capture devices differ depending on the type of device used. Underground systems will impose minimal impact on how a site is developed or used. Dry traps are typically located above ground and may require visual screening for successful integration with the landscape, especially in residential areas.

Typically, gross pollutant capture devices require minimal space compared to other stormwater treatment BMPs, due their ability to operate under high hydraulic loading rates.

Whole-of-lifecycle considerations

Capital and operating costs

The capital costs of gross pollutant capture devices can be high, so their use should be carefully considered and matched to catchments considered most likely to generate high anthropogenic litter loads (e.g. commercial and industrial precincts).

The ongoing operational costs associated with the maintenance of gross pollutant capture devices is higher than other stormwater treatment BMPs due to the high mass or volume of gross pollutants compared to other stormwater pollutants. Some devices require purpose built machinery or plant to maintain the devices. These devices should only be considered if there is a local operator with easy access to the required machinery or plant.

Expected effective service life

Most gross pollutant capture devices have an effective service life consistent with other structural stormwater infrastructure (e.g. 50+ years).

Visual and aesthetic transformations over service life

The visible accumulation of high litter loads within gross pollutant capture devices should be considered when determining the location and type of device. Smaller distributed systems are usually visually unobtrusive as they can be constructed underground or within gully pits. Larger above-ground systems can be visually obtrusive with a hard engineering structure and a highly visible accumulation of litter. Visual screening of above-ground systems using landscape plantings should be considered while ensuring provision for maintenance access.


Photo: Peter Breen / EDAW


Photo: Robin Allison

Regular maintenance is important to ensure that gross pollutant accumulation in above-ground devices does not become an visual or aesthetic issue.

Decommissioning or re-installation requirements

Due to their long service life, gross pollutant capture devices do not require regular decommissioning or re-installation. Provision must be made for access when it is required.

Typical maintenance requirements

Frequent maintenance by a nominated system operator is essential for gross pollutant capture devices to work successfully. This maintenance responsibility depends on the type of device and the resources available to the owner or operator of the system. Many systems are simple to maintain, but larger, more complex devices may require ongoing maintenance to be undertaken by a private company with purpose built machinery.

BMP performance risk considerations

Potentially constraining physical site characteristics

Gross pollutant capture devices are able to be located at many locations and scales. Sites with shallow rock and high groundwater tables may restrict the use of sunken wet well systems. Gross pollutant capture devices can also be problematic in areas influenced by backwatering, such as in tidally influenced areas. Backwatering can dislodge and resuspend litter and organic loads back into the catchment.

Poor design

As most gross pollutant capture devices are proprietary devices, their design and construction is well controlled and therefore poor design or construction should not be a risk to the performance of the device.

Operational risks

For gross pollutant capture devices to operate as designed, they require regular clean-outs. If regular clean-outs are not undertaken, flows and their gross pollutant loads will bypass the device and be deposited in downstream receiving environments. If the gross pollutant capture device is located in a treatment train before a wetland or bioretention system, the failure of the capture device to retain gross sediments and litter will potentially impact on the treatment performance and maintenance requirements of the downstream treatment system.

Care should be taken when maintenance is undertaken on devices located downstream of areas that may contain harmful gross pollutants such as syringes etc.


Photo: Ross Pottinger

Gross pollutant capture devices should be used if anthropogenic (man-made) litter is a problem for the downstream system. 'Dry' storage systems should be considered in preference to 'wet well' systems.


Photo: Stormwater360

BMP 6: Sedimentation Basins

Description

Sedimentation basins are typically located as part of a stormwater treatment train and sized to achieve approximately 80% reduction in coarse sediment loads (> 125 microns) from the contributing catchment.

It is important that sedimentation basins are sized correctly. If they are undersized, larger sediments will be deposited into downstream treatment devices, which can be problematic to the performance of downstream treatment elements. Conversely, an oversized system is also problematic as it will capture fine sediments that have heavy metals and nutrients attached to them. These pollutants cannot be effectively managed in sedimentation basins due to the absence of dense wetland vegetation. For this reason, sedimentation basins are typically located upstream of tertiary treatment devices such as bioretention of constructed wetlands
(see Figure 31).

Note: Sedimentation basins described in this section are only for the operation phase of urban development i.e. after all subdivisional works and allotment construction is completed. Sediment basins for sediment and erosion control during the earlier phases of urban development are described in other documents.

Contribution of sedimentation basins to WSUD strategies

Gross pollutant capture devices contribute to stormwater quality management outcomes, in particular the removal of coarse sediments. These devices do not contribute to water conservation or wastewater minimisation outcomes.

Who needs to know about sedimentation basins?

Typically, civil engineers size and design sedimentation basins to match the required sediment removal for a catchment and the specific stormwater treatment train configuration e.g. upstream of a constructed wetland. Urban designers and landscape architects then design the sedimentation basin to match its aesthetics to the available site location e.g. hard edges structure versus a natural form with edge vegetation.

Considerations when incorporating sedimentation basins in a concept design

Statutory compliance requirements

The *South East Queensland Regional Plan Implementation Guideline No 7: Water Sensitive Urban Design* (Qld DIP, 2008b) establishes the minimum reduction of pollutant loads from stormwater runoff to be:

- 80% reduction in total suspended solids
- 60% reduction in total phosphorus
- 45% reduction in total nitrogen.

These targets should be met by using sedimentation basins as part of stormwater treatment trains as these load reductions will not be possible by using sedimentation basins in isolation.

Spatial (land take) requirements

The land area required for a sedimentation basin is generally less than 1% of the contributing catchment area with the basin's water surface area typically being sized at 0.5% of the contributing catchment area.

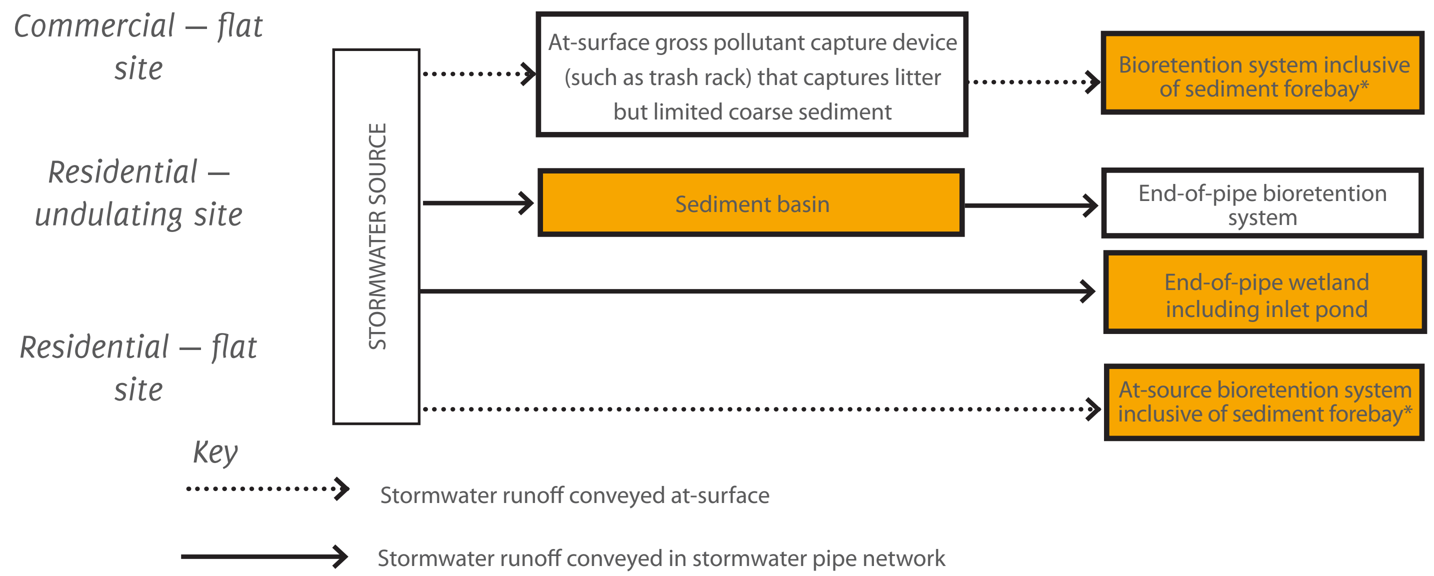


Figure 31 —Sediment basins (and sediment forebays) as part of stormwater treatment trains

*Bioretention systems may use a coarse sediment forebay located within the bioretention system instead of an up-stream sediment basin.

As the catchment size becomes larger, reliance on a single bioretention system involves greater risk and the capital cost of a formal sediment basin may then be preferred over a simple sediment forebay. Such a decision is also influenced by the superior aesthetic outcome that a wet sediment basin might provide.

Whole-of-lifecycle considerations

Capital and operating costs

Most sedimentation basins are simple, excavated pools with basic hydraulic control structures such as riser pipes and overflow weirs. As such, they are relatively low capital cost structures. The low frequency of clean-out (typically every five years) means annual operating costs are also low.

Expected effective service life

Most sedimentation basins would have an effective service life of more than 50 years. Clean-outs once every five years are required to ensure that the accumulation of sediments does not impact on the treatment capacity of the systems.

Visual and aesthetic transformations over service life

Sedimentation basins are typically located as the first or second element of a treatment train and are therefore likely to have relatively turbid water, especially after high rainfall events.

Floating plants can establish in poorly designed sedimentation basins (i.e. if no dense littoral emergent macrophyte vegetation is present) and can lead to the deterioration of the aesthetics of the basin. Dense-edge vegetation not only improves the aesthetics of the system and reduces the risk of floating plant growth, but it also restricts public access to open water zones and helps to maintain aerobic conditions.

In sedimentation basins where regular maintenance is not upheld, sediment may accumulate to a point where the sedimentation basin no longer has a permanent pool. This can lead to the growth of weed species throughout the system.

Decommissioning or re-installation requirements

Sedimentation basins should not need to be decommissioned or re-installed unless unexpected damage to the system occurs. As re-installation typically requires heavy earthworks machinery, an appropriate provision for future access should be made in the conceptual design. The periodic removal of accumulated sediments from the sedimentation basins will require maintenance access for an excavator or equivalent machinery. This maintenance access should be adequate for re-installation.

Typical maintenance requirements

When sedimentation basins are cleaned out (approximately once every five years) disturbance to the edge vegetation is likely to occur. An allowance for the replacement of these plants is required, together with careful consideration during the concept design process of plant species selection and provision for maintenance access.

BMP performance risk considerations

Potential constraining physical site characteristics

The area required for sedimentation basins typically precludes their use in highly constrained urban settings such as those in the urban core and urban centre.

Poor design

Sizing sedimentation basins to target the capture of coarse sediments (>125 microns) is the most important design requirement. As discussed earlier, if the basins are too small, excessive sediment loads will be released to downstream systems. If the system is too large, nutrients can be transformed in the basin and released to downstream systems in a highly bio-available form.

Best practice design for sedimentation basins is well documented in the *WSUD Technical Guidelines for South East Queensland* (SEQ HWP, 2006).

Operational risks

Routine removal of accumulated sediments from the sedimentation basins is critical to the system's performance. This is a simple task and should be well within the capacity of most local government or community-based asset management teams.


Photo: Shaun Leinster / Ecological Engineering


Photo: Peter Breen / EDAW

'Wet' sediment basins with edge vegetation can create an attractive design element.

BMP 7: Grass or Vegetated Swales

Description

Swales are shallow, open, vegetated channels that serve as secondary stormwater treatment devices in stormwater treatment trains (see Figure 32). They also provide a means of conveyance instead of, or in concert with, underground pipe drainage systems. The vegetation in the swales can range from mown turf to sedges and rushes.

Grass and vegetated swales can be included into urban design along streets in median strips or verges, in parklands, and between allotments where maintenance access can be preserved. They are ideally located 'near to source' where stormwater flows are relatively small and can be easily arranged as low velocity, shallow flows across the base of the swale's cross section.

Contribution of grass or vegetated swales to WSUD strategies

Grass or vegetated swales contribute to stormwater quality management outcomes by removing coarse sediments and some nutrients and heavy metals. Grass or vegetated swales also contribute to water conservation through passive irrigation of these landscape elements from stormwater, thus reducing demand on alternative water sources for irrigation.

Grass or vegetated swales do not contribute to wastewater minimisation outcomes.

Who needs to know about grass or vegetated swales?

Typically, civil and environmental engineers work together to size and design the grass or vegetated swales to match the conveyance requirements for the site. Urban designers and landscape architects integrate the swale systems into the landscape and urban design for the site. Collaboration between the engineers and landscape architects is important to ensure the planting palette is consistent with the swale design parameters, in particular finding a balance between maintaining the swale conveyance function and the desired landscape aesthetic.

Considerations when incorporating grass or vegetated swales in a concept design

Statutory compliance requirements

The *South East Queensland Regional Plan Implementation Guideline No 7: Water Sensitive Urban Design* (Qld DIP, 2008b) establishes the minimum reduction of pollutant loads to be:

- 80% reduction in total suspended solids
- 60% reduction in total phosphorus
- 45% reduction in total nitrogen.

These load reductions will not be possible by using swales in isolation. A stormwater treatment train that incorporates swales should be designed to meet these targets.

Spatial (land take) requirements

Grass or vegetated swales typically require a land area of less than 1% of the contributing catchment areas, depending on site grades and the required extent of bunds and batters. Conceptual designers should confirm with the local council if swales can be credited as forming part of the development's open space contribution.

Whole-of-lifecycle considerations

Capital and operating costs

Swales provide stormwater conveyance and therefore reduce the requirement for underground pipe drainage. This can result in capital cost savings to the overall stormwater infrastructure costs of a development. The relatively simple construction requirement for swales also results in the capital costs for swales being lower than other stormwater treatment BMPs. Driveway crossovers increase the capital cost of swale systems.

The operational costs depend on the type of swales. Vegetated swales, once established, typically have a lower ongoing maintenance cost than grassed swales, which require regular mowing to maintain their hydraulic capacity.

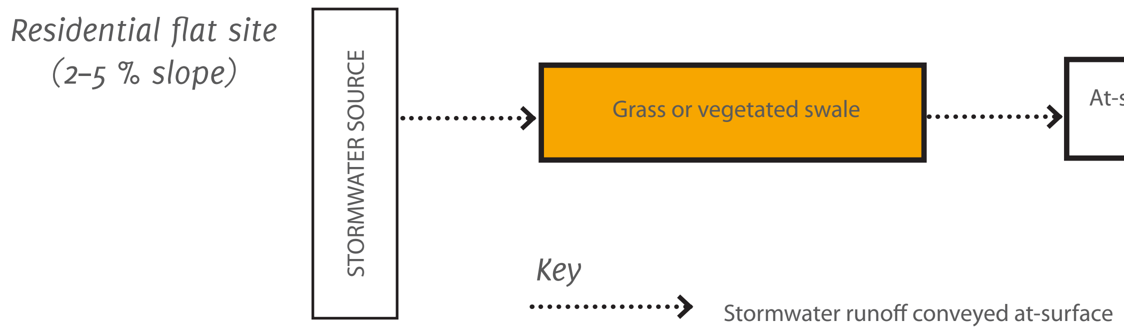


Figure 32 —Grass / vegetated swale as part of a stormwater treatment train

Swales are typically applied to catchments of < 2ha where there are gentle grades between 2% and 5%.

Expected effective service life

The effective service life of grass or vegetated swales is dependent on the ability to maintain the design conveyance capacity of the swale and an acceptable landscape aesthetic. The service life can be maximised with regular maintenance to maintain the design vegetation height and remove accumulated sediment.

Visual and aesthetic transformations over service life

The potential accumulation of litter and sediments in the swale diminishes the visual and aesthetic values of the system. This should be considered when determining the suitability of swales in areas with known high anthropogenic litter loads. Regular maintenance is important to ensure that litter and sediment accumulation in the swale systems does not become an visual or aesthetic issue.

Decommissioning or re-installation requirements

Grass or vegetated swales should not need to be decommissioned or re-installed unless the conveyance capacity is substantially reduced requiring the swale to be reprofiled and revegetated or turfed.

Typical maintenance requirements

It is critical that the designed hydraulic capacity of the swales is maintained. This requires maintaining the design vegetation heights and removing accumulated sediments, introduced weeds and litter or debris. For this reason, it is preferred to have swales located in public open spaces rather than at the front of private property where residents may not maintain the swale as required.

BMP performance risk considerations

Potentially constraining physical site characteristics

Swales are not ideally suited to flat sites (<2%) or steep sites (>5%) with large contributing catchments (> 2ha). As discussed earlier, swales can be problematic in areas with driveway crossovers as they can increase design and capital costs and introduce risk of damage associated with ongoing operation.

Poor design

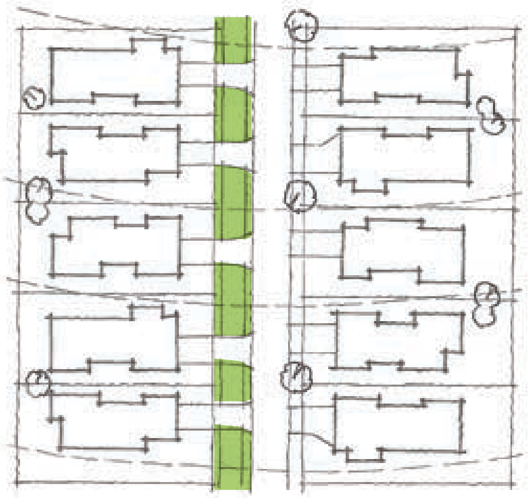
The size, longitudinal grade and location of swales must be carefully considered during conceptual design. Systems that are not sized correctly may result in localised flooding. Swales designed with low grades (< 2%) may retain water and experience boggy inverts, while swales designed with steep grades (> 5%) may experience scour and erosion. Swales can be problematic in areas with driveway crossings as they can increase the costs and risk associated with the implementation of swales. One way to accommodate these issues into the swale design is to have shared driveways, reducing the amount of driveway crossovers. It may be preferred to place swales in locations with no driveway crossings, such as open space areas and median strips. If street width allows, swales can be placed into central median strips, avoiding driveways altogether.

Best practice design for swales is well documented in the *WSUD Technical Guidelines for South East Queensland* (SEQ HWP, 2006).

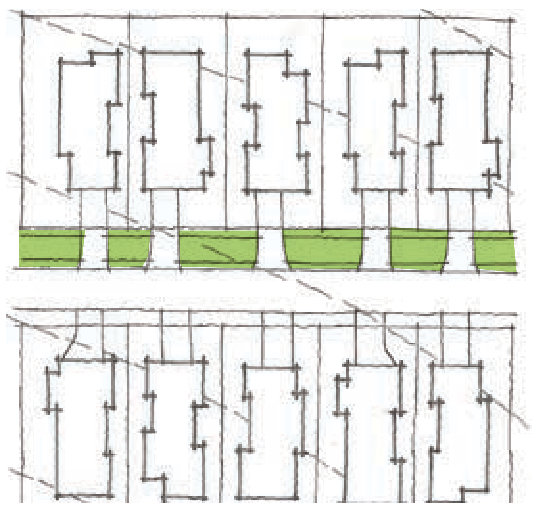
Operational risks

Routine removal of accumulated sediments, litter and weeds from the grass or vegetated swales is critical to the system's conveyance and treatment performance. This is a simple task and should be well within the capacity of most local governments or community-based asset management teams.

An operational risk of roadside swales is the requirement for adjoining allotment owners to maintain the conveyance capacity of the swale. If one resident changes the hydraulic characteristics of the swale, either by filling within the swale or increasing the swale hydraulic roughness with additional planting, it will impact the drainage from the road and increase the risk of flooding.



It is not preferred to have swales located on steep slopes (>5%).



On steep and undulating sites, roads should be aligned to reduce the grade. The suitability of swales on moderate slopes (2% to 5%) is increased, but the presence of driveway crossovers can be problematic.

The preferred solution is to have swales on grades between 2% and 5% with local access to allotments via shared driveways.

Photo: Shaun Leinster / Ecological Engineering

BMP 8: Sand Filters

Description

Sand filters serve as secondary stormwater treatment devices and also delay runoff peaks by providing retention capacity and reduced flow velocities. They consist of two layers of filter media—a drainage layer consisting of gravel-sized material to encase perforated underdrains and a sand filtration layer. They operate in a similar way to bioretention systems; however, sand filters do not have vegetation growing on their surface. This increases their likelihood of blocking and reduces their stormwater treatment performance. This reduced performance is due to the absence of a biologically active soil layer created around the root zone of vegetation planted in bioretention systems, which help to maintain porosity and infiltration capacity.

Sand filters should only be used when bioretention (BMP 9) or constructed wetlands (BMP 10) cannot be used due to limited available land area or in situations where the treatment needs to be provided below the surface (e.g. under a carpark pavement).

Contribution of sand filters to WSUD strategies

Sand filters contribute to stormwater quantity and quality management outcomes. They slow stormwater flows and target the removal sediments and some nutrients and heavy metals.

Sand filters do not contribute to water conservation or wastewater minimisation strategies.

Who needs to know about sand filters?

Typically civil and environmental engineers work together to size and design sand filter systems to match the catchment hydrology and the specific treatment train configuration requirements. Urban designers and landscape architects then integrate the swale systems into the landscape and urban design for the site.

Considerations when incorporating sand filters in a concept design

Statutory compliance requirements

The *South East Queensland Regional Plan Implementation Guideline No 7: Water Sensitive Urban Design* (Qld DIP, 2008b) establishes the minimum reduction of pollutant loads to be:

- 80% reduction in total suspended solids
- 60% reduction in total phosphorus
- 45% reduction in total nitrogen.

These load reductions are not possible using a sand filter in isolation.

Spatial (land take) requirements

Sand filters typically require an area of less than 1% of the contributing catchment areas and can be located underground or as part of the urban design.

Whole-of-lifecycle considerations

Capital and operating costs

Sand filters will typically be implemented beneath hard surfaces such as car parks and industrial hard stand areas and, therefore, will likely be contained within a load bearing structural surround, typically reinforced concrete. This makes sand filters high capital cost stormwater treatment systems. The absence of vegetation is likely to result in higher operational costs than bioretention systems due to the requirement for regular maintenance to manage clogging.

Expected effective service life

Due to the absence of vegetation in these systems, the expected service life of sand filters is likely to be less than vegetated stormwater treatment devices such as bioretention or constructed wetlands. As sand filters have no ability to convert or dispose of nutrients, fine particulates and accompanying pollutants such as heavy metals, there is a limited life-span for the filter media. The absorptive capacity of the sand filter can quickly be exhausted as there is no inbuilt mechanism to translocate nutrients into biomass through uptake by plant roots.

This life-span is highly variable depending on the catchment, but is potentially as little as 2–5 years before the sand should be replaced.

Sand filters may be enclosed in underground chambers and are best near-source in areas where bioretention devices are not suitable due to space limitations.

Visual and aesthetic transformations over service life

Large, at-surface sand filters can be unattractive due to the absence of vegetation. Without appropriate pre-treatment and maintenance, the surface of the system may also become loaded with sediments and other gross pollutants. Most sand filters will, however, be located below ground and are therefore unlikely to be visually obtrusive.

Decommissioning or re-installation requirements

Due to the shorter life-span of sand filters compared to other stormwater treatment BMPs, sand filter media requires removal and replacement on a regular basis. The timeframe for this may be as little as 2–5 years.

Typical maintenance requirements

The ability of a sand filter to operate as designed depends heavily on reliable maintenance by the owner or operator. Proposals for sand filters should therefore be supported by formal arrangements for scheduled maintenance.

Maintenance access must be provided in the design of these systems to allow for regular maintenance and for periodic removal and replacement of the sand filter media.

Photo: Stormwater360

BMP performance risk considerations

Potentially constraining physical site characteristics

Sand filters are not ideally suited for locations with high sediment loads. Due to their limited treatment efficiency, they should only be used when site conditions restrict the use of bioretention systems or constructed wetlands.

Poor design

The location of a sand filter is critical to its design. The incorporation of a sand filter in a stormwater treatment train without pre-treatment to remove gross pollutants and sediments may result in system failure due to clogging.

Best practice design for sand filters is well documented in the *WSUD Technical Guidelines for South East Queensland* (SEQ HWP, 2006).

Operational risks

If sand filters are not maintained adequately, there is a risk that the systems will not be able to filter and treat stormwater runoff as designed. This can cause ponding, which can lead to bad odours and mosquito issues as well as reducing the treatment of stormwater, impacting on downstream environments. For above ground systems, the visual and aesthetic value of the systems will also be compromised if maintenance is not carried out when required.

Proprietary Media Filters

A range of proprietary media-filled filter systems are available which are more closely related to sand filters than gross pollutant traps . These often use engineered filter media to enhance the pollutant removal performance. When considering proprietary products it is important to obtain independent, peer reviewed performance results and to understand the ongoing maintenance costs and requirements. Such systems can be useful in underground installations and highly constrained sites.

Sand filters do not have vegetation planted in them because their filter media does not retain sufficient moisture to support plant growth. Some sand filters are installed in low light areas or underground.

Photo: Alan Hoban

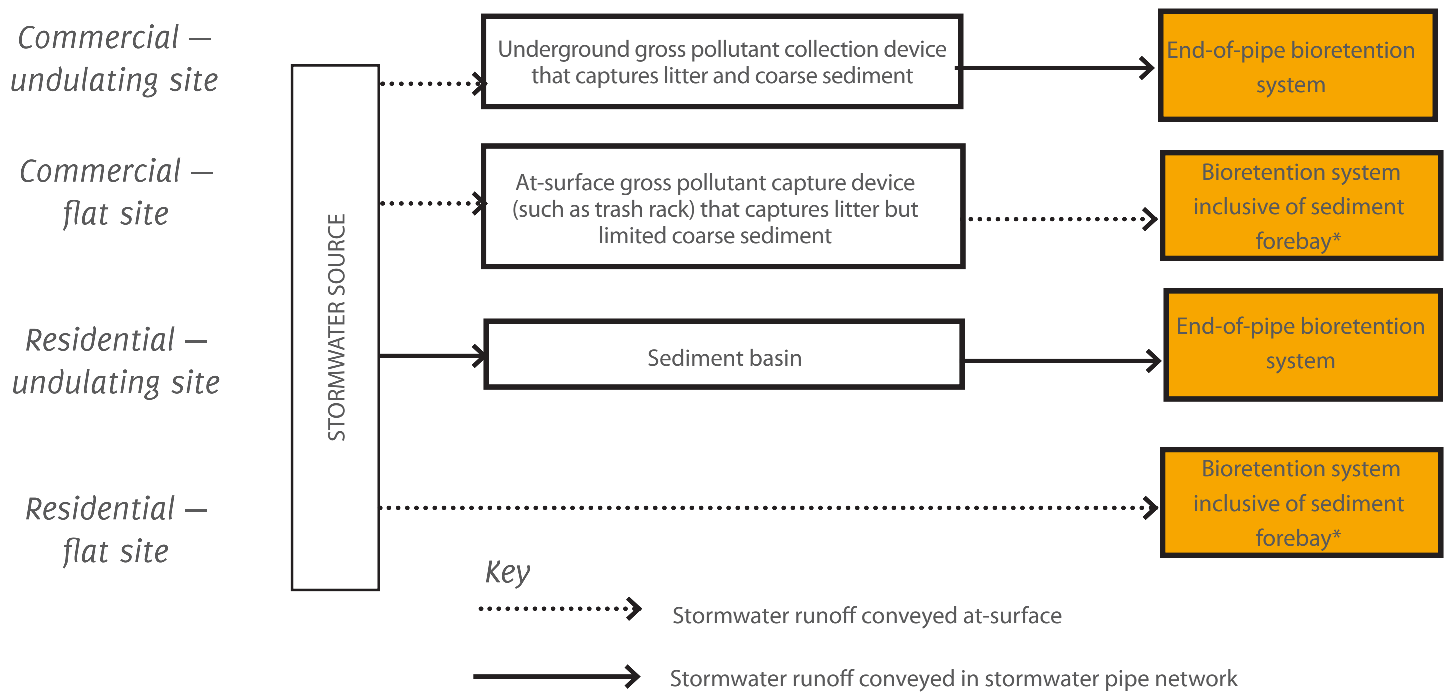
BMP 9: Bioretention Systems

Description

Bioretention systems operate by filtering stormwater runoff through densely planted surface vegetation and then percolating runoff through a prescribed filter media. During percolation, pollutants are retained through fine filtration, adsorption and some biological uptake. These systems are quite flexible in their design and can be applied at different scales, taking many different forms including street tree systems, bioretention swales, and raingardens.

Bioretention systems serve as tertiary (last) stormwater treatment devices in a stormwater treatment train (see Figure 33). They target fine sediments, metals, particulates and dissolved nutrients. Particulates including organic matter are captured on the surface of these systems while dissolved pollutants are removed as the stormwater percolates into the filter media. Bioretention systems provide the highest level of stormwater treatment per unit of treatment area and, in the absence of constructed wetlands, are required to meet current best practice stormwater pollutant load reduction targets. The tertiary level treatment of stormwater helps to protect the receiving environment (waterways, oceans) from the impacts of increased stormwater runoff and pollutants associated with development.

Bioretention filter areas are typically sized at 2% of the contributing catchment area. The system's total footprint increases depending on batter design.



*Bioretention systems may use a coarse sediment forebay located within the bioretention system instead of an up-stream sediment basin.

As the catchment size becomes larger, reliance on a single bioretention system involves greater risk and the capital cost of a formal sediment basin may then be preferred over a simple sediment forebay. Such a decision is also influenced by the superior aesthetic outcome that a wet sediment basin might provide.

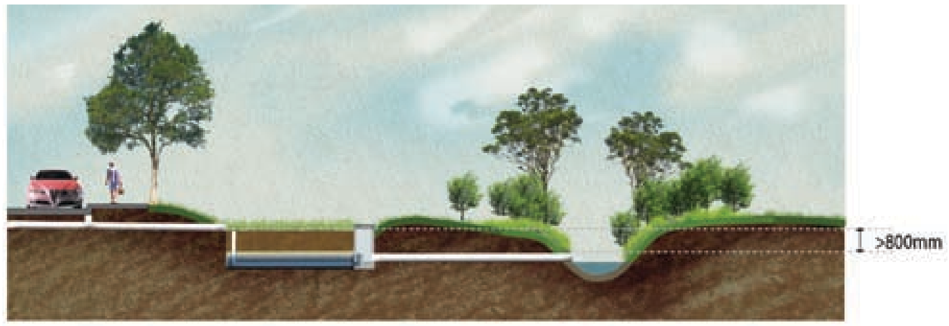
Figure 33 —Bioretention systems as part of stormwater treatment trains

Contribution of bioretention systems to WSUD strategies

Bioretention systems deliver significant stormwater quality management outcomes through the reduction in pollutant concentrations and loads. They also contribute to hydrology management by slowing the rate of discharge of stormwater to the receiving environment and reduce volume through evapo-transpiration. Water conservation outcomes are achieved through the passive irrigation of these landscape elements by stormwater, reducing the demand on alternative water sources for irrigation. Bioretention systems do not contribute to wastewater minimisation outcomes.

Who needs to know about bioretention systems?

The bioretention systems form an integral part of the landscape and stormwater drainage network. Therefore, urban designers, landscape architects and civil engineers must work collaboratively to ensure optimal design outcomes are achieved for stormwater management and landscape aesthetics.



Bioretention systems require enough vertical fall to allow for free drainage from the system. Including a submerged zone in the design not only increases nitrogen removal, but also reduces the vertical fall required between the inflow and the receiving environment required.

Considerations when incorporating bioretention systems in a concept design

Statutory compliance requirements

The *South East Queensland Regional Plan Implementation Guideline No 7: Water Sensitive Urban Design* (Qld DIP, 2008b) establishes the minimum reduction of pollutant loads to be:

- 80% reduction in total suspended solids
- 60% reduction in total phosphorus
- 45% reduction in total nitrogen.

These load reductions can be met by bioretention systems designed to meet best practice design standards.

Spatial (land take) requirements

The area required for a correctly designed bioretention system is generally 2% to 3% of the contributing catchment area depending on site grades and the required extent of bunds and batters. The actual bioretention treatment area (i.e. the surface area of the bioretention filter media) is typically 1.5% to 2% of the contributing catchment area. Bioretention systems, being vegetated systems, are essentially an alternate, passively watered, form of landscape to traditional urban landscapes.

Conceptual designers should confirm with the local council if bioretention systems can be credited as forming part of the development's open space contribution.

Bioretention systems are one of the most adaptable stormwater treatment system as their design can range from small, raised garden beds, long narrow bioretention systems, to large raingardens within public open space areas.

Whole-of-lifecycle considerations

Capital and operating costs

Capital costs for bioretention systems are comparable, on a capital cost to expected benefit basis, with other stormwater treatment systems targeting fine sediment and nutrient removal, namely constructed wetlands. Land take is, however, less than wetlands and therefore total capital cost, when accounting for land take, will typically be less for bioretention systems than for constructed wetlands.

Ongoing costs can be expected to be similar to traditional landscapes on the basis that active irrigation is not required, however, some sediment and debris removal will be required to maintain aesthetics. The frequency of maintenance will depend on the contributing catchment area, land use and the treatment train adopted.

Expected effective service life

Bioretention systems are expected to have a service life of 20 to 30 years. After this time it may be necessary to replace some or all of the filter media to reactivate effective pollutant removal. The type of filter media installed and its ability to adsorb pollutants (i.e. the number of adsorption sites) is one determinant to the effective service life. Sustaining dense and healthy vegetation will ensure the maximum service life of these systems. The movement of foliage and growth of roots maintains a high infiltration capacity (saturated hydraulic conductivity).

Photo: Alan Hoban / Ecological Engineering

Visual and aesthetic transformations over service life

The visual aesthetics of bioretention systems is largely dependent on the vegetation selection and maintenance regime. Visually, bioretention systems will transform commensurate to the growth and maturity of the vegetation used. The life span of the plants selected is an important design consideration as to is the height, form and colour of foliage. Where trees are planted within bioretention systems, the effective service life of the system must be acknowledged to avoid community refute when the system requires resetting. Plant species that require high levels of maintenance such as pruning or slashing should only be considered in locations where this intensity of maintenance can be appropriately maintained by the local council or by a body corporate.

A suitable stormwater treatment train, guided by the catchment size and land use, will influence the rate of accumulation of sediment and litter within the bioretention system. Monitoring and maintenance is important to ensure that accumulated sediment or litter does not become a visual or aesthetics issue.

Decommissioning or re-installation requirements

Reinstallation of new filter media will be required at the end of the system's service life to maintain its stormwater treatment function. At this time the vegetation will also require replacement. The effective service life is commensurate to the typical renewal period of most landscaped gardens. At this time, the function and capacity of the under-drains and drainage media, pits and pipes should also be checked and replaced if damaged.

BMP 9: Bioretention Systems

Typical maintenance requirements

The most intensive period of maintenance is during the first two years of plant establishment. In new developments, this maintenance is usually the responsibility of the developer (via a landscape contractor). Maintenance focuses on establishing healthy, dense vegetation and ensuring high sediment loads associated with catchment development do not impact on the permeability of the filter media.

Once vegetation is established in bioretention systems and the system is 'on-line', active irrigation is typically not required because the system is passively irrigated by stormwater. Proper maintenance of bioretention systems requires specific knowledge. If the responsible party for maintenance does not have that knowledge, it may be necessary to provide explicit documentation on appropriate maintenance actions in the design proposal.

Conceptual design must therefore make provision for maintenance access. The type of access required depends on the scale of the bioretention system. For example, streetscape bioretention systems will not require a maintenance access track as the adjoining road provides access. Large bioretention systems located at the end-of-pipe in parkland areas require provision of a maintenance access track for de-silting sediment forebays (if included in the design) and for ongoing vegetation management and ultimate decommissioning and re-installation. The frequency of required maintenance is likely to be low; attempts should be made to provide a maintenance track that is visually integrated into the surrounding landscape.

BMP performance risk considerations

Potentially constraining physical site characteristics

Sites with steep topography, high water tables and shallow bedrock require additional design considerations.

Poor design

Poor design can reduce the effective service life of bioretention systems.

Best practice design for bioretention systems is well documented in the *WSUD Technical Guidelines for South East Queensland* (SEQ HWP, 2006).

Operational risks

In the context of a large development site and associated construction and building works, delivering bioretention systems and establishing vegetation can be a challenging task due to the inherent large sediment load and movement of contractors and machinery. Therefore, bioretention systems require a carefully staged construction and establishment to ensure the basin establishes in accordance with its design intent.

Suitable filter media selection and careful installation (without compaction) together with successful vegetation establishment is the key to maintaining the treatment performance of bioretention systems. Failure of the filter media to maintain an appropriately high infiltration capacity is the most significant operational risk for bioretention systems.

Bioretention systems located within large, regional-scale flood retardation basins or along major overland flow paths and floodways

The use of bioretention systems in developments is increasing due to their adaptability. Many bioretention systems are located within large, regional-scale flood retardation basins or within major overland flow paths or floodways to reduce land-take impacts on developable land. There are a number of key risks associated with locating bioretention systems in these areas including:

- plant mortality due to smothering by sediments, particularly in regional flood retarding basins with little, to no, sediment export management in the contributing catchment
- plant and filter media damage due to erosive flows with velocities exceeding 2 m/s, especially in bioretention systems located along major overland flow paths and floodways
- filter media 'blinding' due to excessive fine sediment loading if the bioretention systems are subjected to fine sediment loading from stormwater runoff generated from a large, external catchment
- filter media blinding due to organic biofilm growth under continuously wet conditions if systems are not located offline from any watercourse or overland flow path that has a persistent or seasonal baseflow.

These risks can be overcome by ensuring the following considerations are included in the bioretention designs:

- sediments must be captured within an appropriately-sized sedimentation basin, pond, or other suitable sediment-trapping device located immediately upstream of the bioretention system
- the surface of the bioretention system's filter media should be set above the peak one-year ARI flood level
- the bioretention system can be designed with a high-flow bypass with sufficient conveyance capacity (> peak one year ARI flow) to ensure the retardation basin outlet causes flows to backwater over the bioretention system before any breakout flows from the bypass move onto the surface of the bioretention system.

09

Streetscape Biopod, Bellvista Estate
Photo: Alan Hoban / Ecological Engineering

BMP 10: Constructed Wetlands

Description

Constructed wetlands are densely vegetated water bodies that use enhanced sedimentation, fine filtration, adhesion and biological uptake, and transformation processes to remove pollutants from stormwater. They generally consist of an inlet zone (sediment basin); a macrophyte zone, which is a shallow, densely vegetated area; and a high flow bypass channel, which is typically a wide vegetated swale from the inlet pond around one side of the wetland.

Constructed wetlands serve as tertiary (last) stormwater treatment devices in a stormwater treatment train (see Figure 34). They target fine sediments, metals and particulates, and dissolved nutrients. This tertiary level treatment of stormwater helps to protect the receiving environment (waterways, oceans) from the impacts of increased stormwater runoff and pollutants associated with development. Constructed wetlands can achieve current best practice stormwater pollutant load reduction targets and are, therefore, important elements to consider in the concept design of new developments.

Wetlands can be constructed on many scales, from lot scale to large regional systems. In highly urban areas, wetlands can have a hard edge and be part of a streetscape or forecourt. In regional settings, they can be more natural looking, with some systems over 10 ha in size, providing significant wildlife habitat. They must be sized appropriately for the catchment to ensure hydraulic loading is not too large or too small to hinder the wetland's stormwater treatment performance.

Contribution of constructed wetlands to WSUD strategies

Constructed wetlands deliver significant stormwater quality management outcomes through a reduction in pollutant concentrations and loads. They also contribute to hydrology management by slowing the rate of discharge of stormwater to the receiving environment and volume reduction through evapo-transpiration. These landscape elements consist of a permanent pool of water and, therefore, do not require irrigation, with the exception of the landscaped surrounds. Constructed wetlands therefore indirectly result in water conservation outcomes. Constructed wetlands do not contribute to wastewater minimisation outcomes.

Who needs to know about constructed wetlands?

Constructed wetlands form an integral part of the landscape and stormwater drainage network and therefore landscape architects and civil engineers must work collaboratively to ensure optimal design outcomes are achieved for stormwater management and landscape aesthetics.

Considerations when incorporating constructed wetlands in a concept design

Statutory compliance requirements

The *South East Queensland Regional Plan Implementation Guideline No 7: Water Sensitive Urban Design* (Qld DIP, 2008b) establishes the minimum reduction of pollutant loads to be:

- 80% reduction in total suspended solids
- 60% reduction in total phosphorus
- 45% reduction in total nitrogen.

These load reductions can be met by constructed wetlands designed to meet best practice design standards.

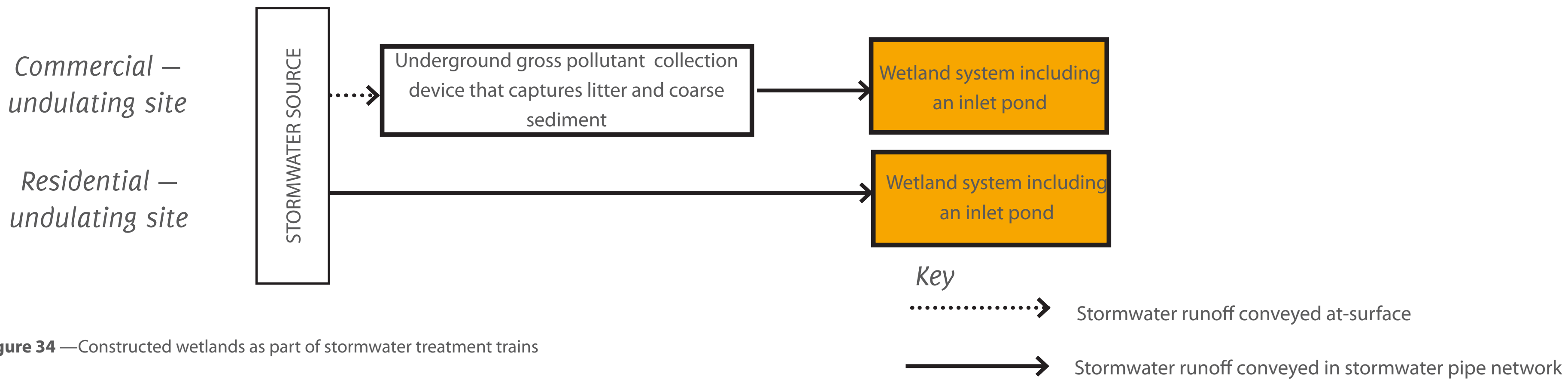


Figure 34 —Constructed wetlands as part of stormwater treatment trains

Spatial (land take) requirements:

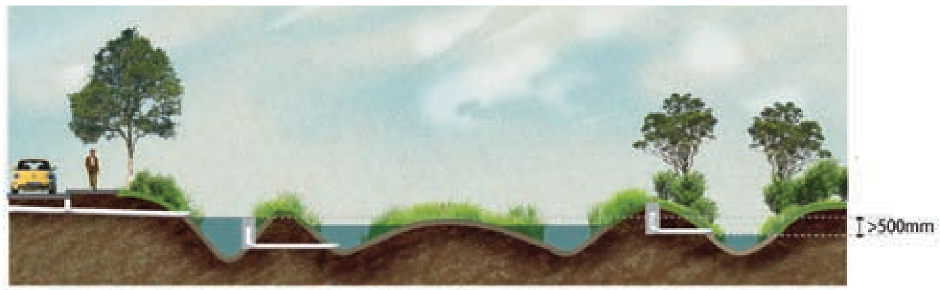
The area required for a correctly designed constructed wetland is generally 7% to 10% of the contributing catchment area, depending on site grades and the required extent of bunds and batters. The actual treatment area (i.e. the surface area of the macrophyte zone) is typically 5% to 7% of the contributing catchment area. While they offer significant landscape aesthetics, passive recreation and education benefits, under current land development guidelines, constructed wetlands do not constitute creditable public open space.

Whole-of-lifecycle considerations

Capital and operating costs

Capital costs for constructed wetlands are comparable with other stormwater treatment systems that target fine sediment and nutrient removal, such as bioretention systems, on a cost-benefit basis. Land take is, however, more than that required for bioretention systems and therefore total capital cost, when accounting for land take, will typically be more for constructed wetlands than for bioretention systems.

Ongoing costs can be expected to be similar to traditional landscapes on the basis that active irrigation is not required, however, sediment removal from the inlet pond and debris removal will be required to maintain aesthetics and inlet pond capture efficiency. The frequency of maintenance is typically low as the inlet pond is usually designed with a clean out frequency of once every five years.



Wetland treatment areas are typically sized at 5%–7% of the contributing catchment area. The system's total footprint will increase depending on batter design.

Expected effective service life

Constructed wetlands are expected to have a service life of 20 to 30 years. After this time it may be necessary to remove accumulated sediment and reset the bathymetry of the wetland. Sustaining dense and healthy macrophyte vegetation in the wetland ensures the maximum service life is achieved by maintaining a high surface area for biofilm growth, even flow dispersion and effective water filtering.

Visual and aesthetic transformations over service life

Wetland macrophytes tend to establish relatively quickly and maintain their visual aesthetics when the wetland is designed with appropriate hydrology and water depths. Seasonal floating plants such as Azolla sp. may colonise and cover the open water pools during warmer months, but typically die off reasonably quickly. Similarly, filamentous green algae can proliferate over summer and float to the surface where it can be visually unappealing for a short period of time. The inlet pond of constructed wetlands is generally turbid, particularly after rain events. While inlet ponds should appear as open water pools with vegetated edges, if they are not maintained, sediment can accumulate and result in more extensive plant growth.

A suitable stormwater treatment train, guided by the catchment size and land use, will influence the rate of sediment and gross pollutant accumulation in the wetland inlet pond. Monitoring and maintenance is important to ensure that accumulated sediment or gross pollutants do not become a visual or aesthetics issue.

Photo: Shannon McGrath

Decommissioning or re-installation requirements

Removal of wetland sediments, reprofiling (including provision of new topsoil) and replanting is required at the end of the system's service life to maintain stormwater treatment function. This should only be undertaken if it is identified through monitoring that the constructed wetland is no longer performing as designed.

Typical maintenance requirements

The most intensive period of maintenance is during the first two years of plant establishment. During this period, water level management is critical to ensure the wetland plants do not drown and that the ephemeral marsh and littoral plants do not dry out. Weed management may also be required. In new developments, maintenance is typically the responsibility of the developer (via a landscape contractor). Maintenance focuses on establishing healthy, dense, emergent wetland plants to achieve 80% coverage in the macrophyte zone.

Once wetland vegetation is established and the system is 'on-line', infrequent sediment and debris removal from the inlet pond is the key maintenance task required (generally once every five years). Constructed wetlands require specific knowledge to maintain properly. It may be necessary to provide explicit documentation on appropriate maintenance actions in the design proposal.

Conceptual design must therefore make provision for maintenance access, especially for the wetland inlet pond, which will typically require earthworks machinery to remove sediment and debris, generally once every five years. Access to the other sections of the wetland, such as the macrophyte zone, will typically be required for routine vegetation management with heavy machinery access only required when the system is to be decommissioned or re-built.

BMP performance risk considerations

Potentially constraining physical site characteristics

Sites with undulating and steep topography (> 2%), high water tables and shallow bedrock require additional design consideration and, in some instances, may preclude the use of a constructed wetland.

Poor design

Poor design can reduce the effective service life of constructed wetland systems.

Best practice design for constructed wetlands is well documented in the *WSUD Technical Guidelines for South East Queensland* (SEQ HWP, 2006).

Operational risks

Constructed wetlands can be highly efficient at removing organic and anthropogenic litter, however, it is not recommended to use them to target these pollutant as they can be problematic to the long-term performance of the system. It is also likely to significantly increase the maintenance frequency. Pre-treatment using primary treatment measures such as GPTs to target these pollutants in a treatment train approach should be provided in cases where the pollutant load from the contributing catchment is high (e.g. commercial catchments).

Photo: Shaun Leinster / Ecological Engineering

BMP 11: Porous Pavements

Description

Porous pavements are an alternative to typical, impermeable pavements and are available in several commercially-available forms. They consist of modular block pavements or permeable pavements overlaying a shallow storage layer of aggregate material.

Porous pavements provide some removal of sediments and attached pollutants by infiltration though an underlying sand or gravel media layer. However, their main purpose is to reduce runoff volume by infiltration into the sub-soils and delaying runoff peaks by providing retention storage capacity and reducing flow velocities. They should be designed to function parallel to stormwater treatment trains.

Porous pavements can be successfully retrofitted into small residential streets, pathways, and car parks.

Contribution of porous pavements to WSUD strategies

Porous pavements serve as source-control stormwater treatment devices as they minimise the volume of stormwater entering downstream systems and provide primary level treatment through the removal of particulate pollutants. They do not provide tertiary level stormwater treatment or contribute to water conservation or wastewater minimisation strategies.

Who needs to know about porous pavements?

Typically, civil engineers determine the required infiltration rate and sub-surface design and collaborate with urban designers and landscape architects to select a suitable porous pavement product to integrate with the landscape and urban design for the site.

Photo: Damien McGarry / Sunshine Coast Regional Council

Considerations when incorporating porous pavements in a concept design

Statutory compliance requirements

Statutory compliance requirements do not apply to porous pavements.

Spatial (land take) requirements

Porous pavements are only intended to be used to replace existing or planned paved areas so the landtake depends on the planned paved area that is suitable for porous pavements within a development.

Whole-of-lifecycle considerations

Capital and operating costs

Capital and operating costs for porous pavements are higher than traditional, impervious paved areas. This increased cost is due to the process involved in the manufacturing of these pavers, the subsurface storage requirements, as well as the continued maintenance required to ensure they operate as designed.

Expected effective service life

The service life of porous pavements depends on the sediment and pollutant loads from the catchment and the frequency of maintenance. An allowance for a 50% reduction in design capacity over a 20-year life-span should be made during design.

Visual and aesthetic transformations over service life

Porous pavements can provide a more aesthetically pleasing surface compared to conventional asphalt or concrete pavements. The build-up of debris and sediment will impact on the visual and aesthetic values of the pavers over time if regular maintenance is not undertaken.

Decommissioning or re-installation requirements

Porous pavements and underlying aggregate need to be replaced once vacuuming and high-pressure hosing is not able to de-clog the system. This replacement may need to occur about every 20 years.

Typical maintenance requirements

Debris and sediment should be removed every three to six months. For lattice pavements incorporating vegetation, weeding or mowing may also be needed, depending on the design. Regular vacuuming, sweeping, or high pressure hosing can be used to clear blocked pores in the top layer of the pavement to avoid permanent clogging.

BMP performance risk considerations

Potentially constraining physical site characteristics

Porous pavements should not be located in areas with high sediment loads or with impermeable in-situ soils. They are ideally suited to sites with light vehicle weights such as small car parks and low-traffic streets (cul-de-sacs) within residential and commercial developments.

Poor design

The performance and lifecycle of porous pavements is reduced if they are not designed or installed in accordance with the manufacturer's recommendations and not maintained on a regular basis. They should only be included in designs as a hydrology management technology and on sites with favourable in-situ soil conditions and landuses.

Operational risks

If porous pavements are not maintained adequately, there is risk that they will not operate as designed, potentially leading to ponding of water and localised flooding. The visual and aesthetic value of the pavement will also be compromised if maintenance is not carried out when required because sediment and debris will accumulate.

Porous pavements are only intended to be used to replace existing or planned paved areas and are not intended to treat stormwater runoff from adjoining impervious and pervious areas. They should be designed to function parallel to treatment trains by reducing runoff volumes.

Photo: Damien McGarry / Sunshine Coast Regional Council

Photo: Damien McGarry / Sunshine Coast Regional Council

BMP 12: Infiltration Measures

Description

Infiltration measures consist of a 'detention volume' located either above or below ground, designed to capture runoff and an 'infiltration area' or 'surface' through which the captured stormwater is subsequently infiltrated into the surrounding soils and underlying groundwater.

Infiltration systems can operate at a variety of scales ranging from small, lot scale systems receiving inflows from rainwater tanks, to larger regional systems receiving treated stormwater runoff from whole urban catchments. There are four basic types of infiltration systems: leaky wells, infiltration trenches, infiltration soak-aways, and infiltration basins. The choice and size of the system depends on the size of the contributing catchment.

Infiltration measures are not intended to act as a stormwater treatment system and should only form the final element of a treatment train (i.e. after a tertiary level stormwater treatment element) to facilitate groundwater recharge.

Infiltration systems are best suited to sites with moderate to highly permeable soils.

Contribution of infiltration measures to WSUD strategies

Infiltration measures contribute to stormwater quantity management as they minimise the volume of stormwater entering downstream environments. They can also contribute to water conservation when they are designed as part of an aquifer storage and recovery strategy. They do not contribute to stormwater quality management or wastewater minimisation outcomes.

Who needs to know about infiltration measures?

Typically, civil engineers determine the required infiltration rates when sizing and designing an infiltration measure as part of a stormwater treatment train. Urban designers and landscape architects then integrate any surface infiltration systems into the landscape and urban design for the site.

Considerations when incorporating infiltration measures in a concept design

Statutory compliance requirements

Statutory compliance requirements do not apply to infiltration measures.

Spatial (land take) requirements

The size of infiltration systems is based on the rate of infiltration and storage volume. The infiltration system can also exist in the same footprint as the pre-treatment device. For example, a bioretention system may be configured with an infiltration system below it rather than a drainage layer connected to the downstream drainage system.

Whole-of-lifecycle considerations

Capital and operating costs

The capital costs of infiltration measures depend on the size and type of system chosen, the infiltration rate of in-situ soils, and the size of the storage required. Operating costs are dependent on the maintenance regime to maintain the infiltration rate. Typically, maintenance requirements are minimal due to the tertiary level treatment of stormwater prior to entering the infiltration measures. However, over time, the accumulation of fine sediments may require the removal of the surface layer to maintain an adequate infiltration rate.

In large catchments with permanent baseflows, maintenance costs will increase to maintain infiltration by removing surface biofilm growth. However, careful design should aim to avoid permanent flow through infiltration systems.

Infiltration systems are typically located to receive treated stormwater that is then infiltrated to soils and underlying groundwater.

Expected effective service life

Infiltration system life-cycles can be affected if they are clogged with sediments or biofilms, which will in turn impact on the infiltration rate. The service life of infiltration measures is dependent on loads from the catchment, catchment size (permanent baseflows) and pre-treatment efficiencies (especially the removal of sediments) and maintenance.

Visual and aesthetic transformations over service life

Infiltration measures can be located below ground reducing the risk of a decrease in visual and aesthetic transformations over their service life. The absence of vegetation on above-ground systems (due to difficulty in establishing vegetation) and the build-up of debris and sediment will impact the visual and aesthetic values.

Decommissioning or re-installation requirements

Re-installation of the infiltration media is required when the measure is compromised by clogging. This may only require the removal of the surface layers of media.

Typical maintenance requirements

Regular maintenance of upstream treatment devices, as well as the infiltration system, will be required to ensure there is no clogging of the infiltration surface.

Infiltration can be an important part of a WSUD strategy. It helps to address the hydrological impact that urbanisation has on stream ecology. However, it must be recognised that infiltration measures are not treatment systems and they need to be located at the end of a treatment train to achieve best practice reduction of pollutants.

BMP performance risk considerations

Potentially constraining physical site characteristics

Infiltration measures should not be located without pretreatment of flows, or in areas with impermeable in-situ soils. It is generally recommended that the base of infiltration systems is designed to be a minimum of 1m above the seasonal high groundwater table.

Infiltration systems should not be located near building footings to avoid the influence of continually wet sub-surfaces or varying soil moisture content on structural integrity.

Poor design

The performance and lifecycle of infiltration measures is reduced if they are not designed as part of a best practice stormwater management strategy. This will typically rely on infiltration measures only being included in designs as a hydrology management technology (receiving tertiary treated flows only) and on sites with favourable conditions such as permeable soils.

Operational risks

If infiltration measures are not maintained adequately, there is risk that they will not operate as designed. This can lead to ponding of water and potential mosquito issues. The visual and aesthetic value of surface infiltration measures will also be compromised if maintenance is not carried out when required.

Photo: Peter Breen / EDAW

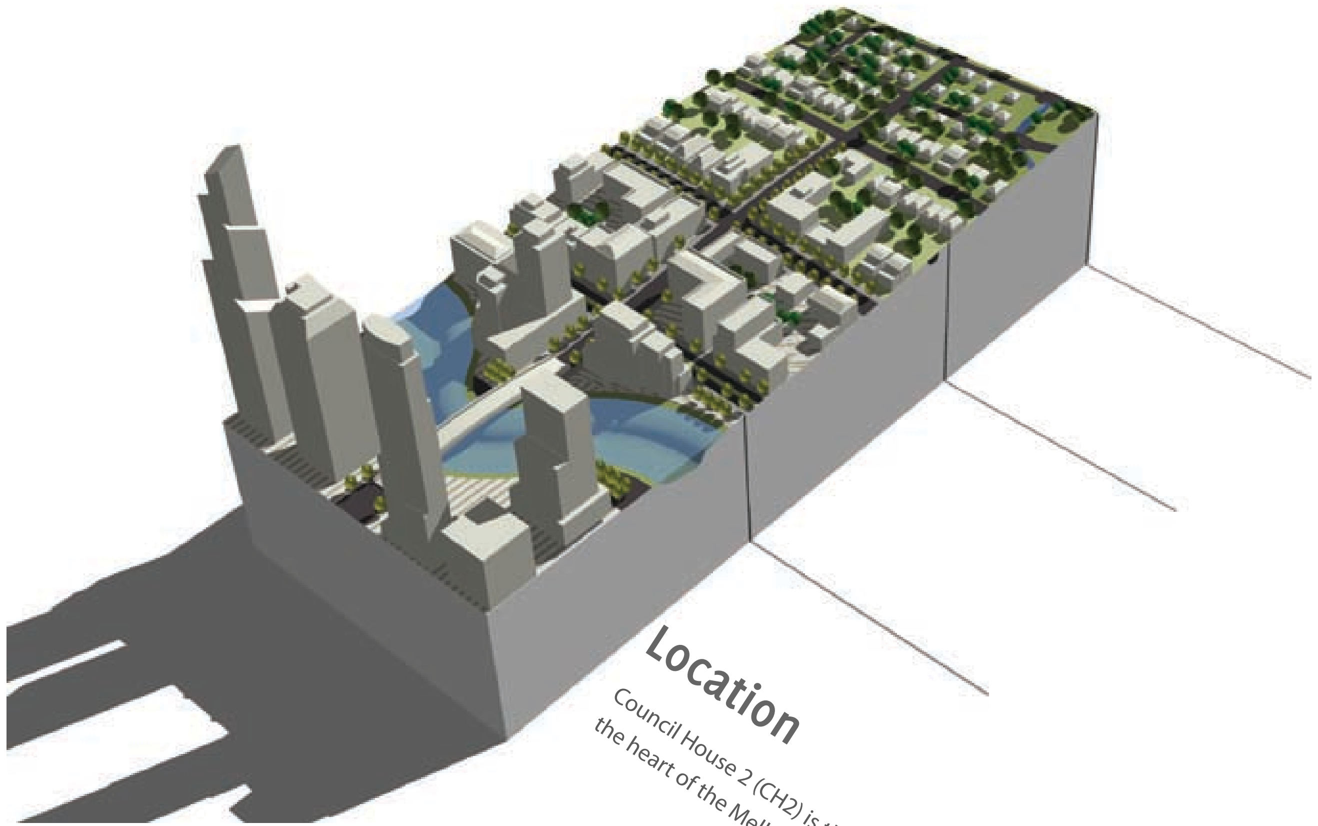

Photo: Shannon McGrath

Case Studies

Content:

06

Case Study 1: Council House 2, Melbourne



Location

Council House 2 (CH2) is the first certified six-star green-rated building located in the heart of the Melbourne CBD.

Project characteristics

Project type:

Commercial redevelopment

Landuse:

High density commercial office building with basement car parking and ground level retail

Site area:

Gross floor area (GFA): 12,536 m comprising:

- 1995 m^2 GFA basement areas
- 500 m^2 net lettable area (NLA) — ground floor retail
- 9373 m^2 total NLA
- 1064 m^2 GFA — typical floor

Building and dwelling densities:

10-storey commercial office building housing approximately 540 staff

Project team composition

Architect

Landscape Architect

Civil Engineer

Ecological Engineer

Others: Accommodations Consultant / Geotechnical Consultant / Acoustics Consultant / Public Artists

Project overview

In 2004, local government authority the City of Melbourne was faced with an accommodation dilemma. Staff were housed in dated office buildings that, although located close to the Town Hall, were nearing the end of their life. Rather than relocate staff to alternative offices, Council embarked on an ambitious plan to construct a new office building, Council House 2 (CH2), which would meet its spatial requirements and lead the way in the development of a holistic green environment (City of Melbourne, 2008a).

CH2 has been designed to not only conserve energy and water, but the quality of the internal environment has been designed to improve the wellbeing of its occupants. CH2 demonstrates a new approach to workplace design, creating a model for others to learn from and follow (City of Melbourne, 2008a).

CH2 emerged from a genuine commitment to explore how sustainable technologies could be integrated in every conceivable way, delivering tangible rewards to the property owner and its occupants (City of Melbourne, 2008a).

CH2's collaborative design process explored and challenged every aspect of a contemporary office design (City of Melbourne, 2008b).

CH2 began by assembling an expert team of consultants from around Australia and internationally. Firms were selected for their credentials and potential to work as part of a team. Working collaboratively with Council's own designers and project managers, the CH2 project team began by attending a two-week workshop, followed by a series of weekly design meetings across an eight-month period (City of Melbourne, 2008b).

This focus on collaboration was critical to achieving an integrated design concept for CH2. The CH2 design and development process was documented to enable others to learn from the experiences (City of Melbourne, 2008b).

WSUD objectives

Water is a major issue for the Greater Melbourne area, with shortages occurring over the last few years. The City of Melbourne's Total Watermark Strategy aims towards sustainable water management by 2020. This includes :

- reduced water consumption
- improved water quality
- improved use of wastewater and reclaimed water.

The City of Melbourne is committed to reducing its own, and the community's, potable water use by 40% per capita by 2020 and it was therefore important to incorporate water strategies and pioneer new technologies that reflected this commitment to integrated urban water management (City of Melbourne, 2008c).

These objectives are also supported by State building regulations effective from July 2005, requiring the installation of fittings and taps with a minimum of AAA level rating, and a water tank or solar hot water system. This is supported by WELS, which introduced mandatory labels on most appliances from 1 July 2006 and provides guidelines on the purchase of water efficient appliances. (City of Melbourne, 2008c)

Site characteristics

CH2 is located on a relatively flat inner city block in Melbourne.

WSUD solution

The approach to create a WSUD solution for CH2 was to first reduce the consumption of water by using efficient fixtures, followed by initiatives to collect rainwater, and then to look at water treatment. CH2 aims to reduce consumption of water from the public water mains by more than half compared to a standard, equivalent building. This is achieved by:

- blackwater and greywater treatment on-site via a multi-water treatment plant providing 72% of non-potable water demand
- on-site rainwater collection
- 25% of the building's potable water requirements are provided through rainwater and by reusing the water used to regularly test the building's fire sprinkler system, which, by law, must be sourced from the mains
- use of AAA-rated water-saving fittings
- cooling towers supplied with Grade A recycled wastewater and rainwater.

(City of Melbourne, 2008c)

Best Planning Practices employed

The WSUD BPPs employed in the project include:

- *BPP 5: Symbiotic Land Use Planning* – Even though CH2 does not provide any residential units, 100% of CH2's non-potable water is supplied by recycled water. This is due to a unique sewer mining system that treats up to 100,000 litres of wastewater per day, and provides Class-A water for toilet flushing, cooling, and irrigation. Any surplus water is transported off-site for use in other buildings, fountains, for street cleaning, and irrigation (City of Melbourne, 2008d).
- *BPP 7: Waterscapes as Public Art* – Public art is integrated into the fabric of CH2, complementing and extending the building beyond its engineering and architectural aspirations. The art aims to express a vision that reflects, complements, and questions the design team's commitment to sustainable design. One piece in particular named 'Waterveil', which forms the glass wall behind the concierge desk, creates a transparent atmospheric membrane that expresses and reveals hydrology processes, in particular the blackwater recycling treatment used in CH2 (City of Melbourne, 2008e).

Case Study 1: Council House 2, Melbourne

Best Management Practices employed

The WSUD Best Management Practices (BMPs) employed in the project include:

- *BMP 1: Demand Management* — AAA rated fittings and fixtures are used for the showers, taps, toilets and urinals. Where water-efficient systems were not yet available, the specifications allowed for their later addition. Vertical gardens that run the full height of the northern façade grow plants from special planter boxes that are filled with Fytogen Flakes, a soil additive that looks like polystyrene flakes but acts like large water crystals, storing an enormous amount of water and air until the soil needs it. When the crystals dry out and the water is used up, a float triggers a sub-irrigation device to re-fill with water, which is stored in the planter box until required (City of Melbourne, 2008c).
- *BMP #2: Roofwater (Rainwater) Harvesting* — 20,000L rainwater tanks store rainwater collected from the roof of the building. This rainwater supplements and enriches the treated water from the mining plant. This water is used for the irrigation of the plants (City of Melbourne, 2008c).
- *BMP #4: Wastewater Treatment for Re-Use* — The Blackwater Treatment Plant located in Basement 3 treats both the blackwater (toilet) and greywater (showers and basins) waste produced by the building, as well as treating sewerage 'mined' from the sewer in Little Collins Street, adjacent to CH2. Sewer mining allows water to be taken out of the sewer, treated to 'class-A' standard, which includes dosing it with chlorine. This water can then be safely used for non-drinking purposes such as toilet flushing and garden watering. The entire system will have the capacity to provide 100,000L per day, 45,000 of which is used in CH2 and 55 000L for other Council purposes such as CH1, street cleaning and garden irrigation. CH2 also collects wastewater from the sprinkler systems and uses it as intended potable water by storing it in 20,000L tanks and drawing on it for water needed at sinks and showers (City of Melbourne, 2008d).

Successes

The inter-disciplinary depth of the project team and the innovative technologies incorporated into the design throughout the design process has undoubtedly been a key success of this project.

Lessons learnt

Water use assumptions and projections for CH2, together with anticipated costs, benefits and savings, indicate the need for integration of considerations of water conservation throughout design and operation. Currently, there is no viable payback for installing water recycling technologies due to the relatively low cost of water in Australia. But a major driver of these technologies is from a future proofing stance, anticipating water becoming a valuable resource in the future, and the need for the City of Melbourne to be a good corporate citizen, leading the community on sustainable water management (City of Melbourne, 2008c).

Photo: Alan Hoban

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Photo: Alan Hoban

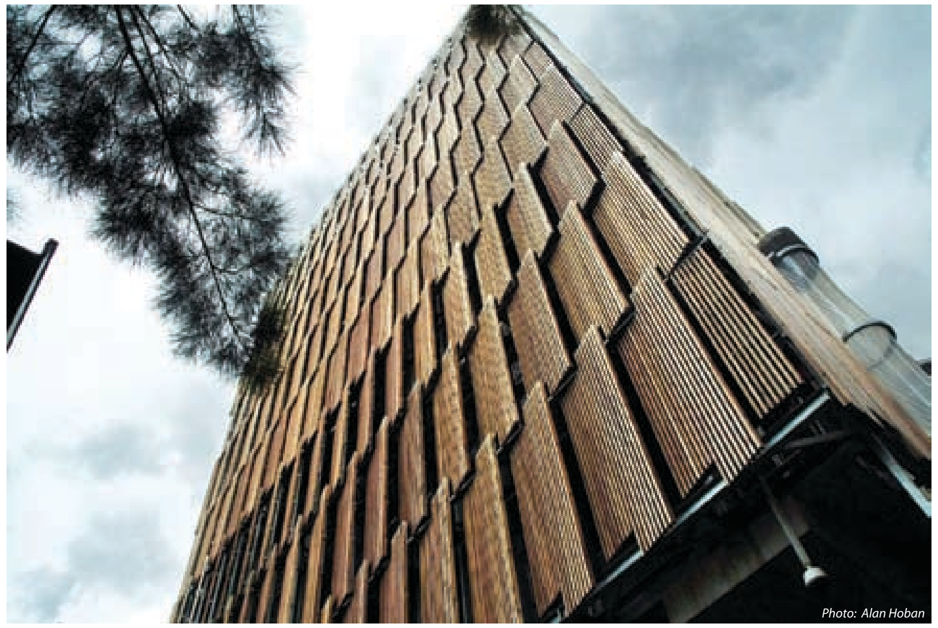
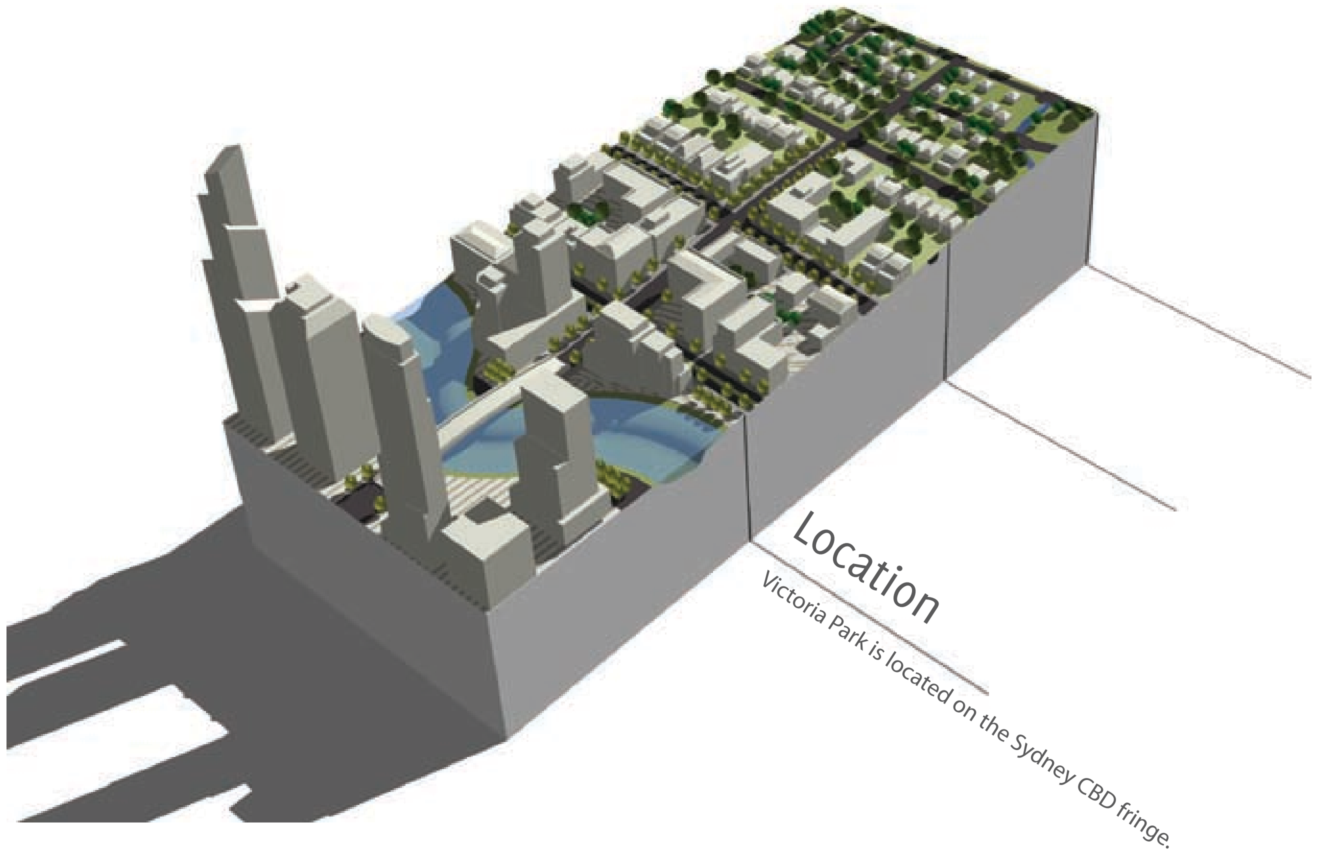


Photo: Alan Hoban


Photo: Alan Hoban

Case Study 2: Victoria Park, Sydney



Project characteristics

Project type:
Brownfield

Landuse:
Mixed use development — medium to high density residential living with commercial, retail and community spaces/

Site area:
24 ha

Building/dwelling densities:
2,500 dwellings and a mixed-use development consisting of 150,000 m^2 residential use, 25,000 m^2 of commercial use, 10,000 m^2 of retail use and 8,000 m^2 of commercial community use (Landcom, 2008c).

Project Team Composition

- Architect — Lead
- Urban Designer
- Landscape Architect
- Civil Engineer
- Ecologist

Others: Site Remediation Specialist / Public Artist

Project overview

Victoria Park is a 24-hectare mixed-use development that incorporates medium- and high-density housing, commercial, and retail facilities for a population of 5,000.

Prior to European development the site was part of the Botany Swamp — a large wetland and lagoon ecological system that extended from Centennial Park to Botany Bay. Watkins Tench described it in 1789 as 'the finest meadows in the world'. The site has been developed since the late 1800s, firstly as a racecourse and then for heavy industry.

The developer set a clear agenda for excellence and innovation on this difficult and degraded brownfield site. The brief for the renewal of the site included a requirement for a high quality landscape within a benchmark development for inner city urban redevelopment. To date, the project has exceeded these expectations by virtue of its innovative water management system and the integration of the system into a high quality, external living environment. In this respect, the project has become a benchmark for water sensitive urban design in an inner city urban redevelopment context.

The concept for the design of the public domain embodies four key principles that relate to its place. These include:

- environmental strategy—incorporating a site-wide approach to ecological systems, particularly water management
- interpretation of the natural heritage—show casing wetland systems similar to those that once dominated the site
- site connectivity—providing a simple legible typology of streets, with a small palette of strong landscape materials and urban elements that unify the site's complex built form
- community development—creating a variety of settings in the public domain to meet the needs of the new residential and working community.

The consistency of the design approach is evident throughout the public domain. East–west streets feature median bioretention swales or wetlands that are a focus of the water management system. North–south streets mimic more traditional avenues. The parks have a deliberate richness in spatial form and materials, unified by the common thread of indigenous planting of wetland species, structural form of buildings, and a landform that is moulded to accommodate water detention requirements. Public artworks express and celebrate improved water quality achievements, and plant selection and habitat creation consistently support the local ecosystem and promote biodiversity (Australian Institute of Landscape Architecture, 2004).

WSUD objectives

The vision for managing the water cycle at Victoria Park was to return the site to its natural state as a wetland/lagoon system that filters and infiltrates runoff from the upland catchment en-route to Botany Bay.

To achieve this vision, the following WSUD objectives were adopted:

- treatment of stormwater runoff to a standard suitable for recharge of local un-confined alluvial aquifers
- detention of stormwater runoff within on-site surface detention basins to avoid augmentation of downstream existing stormwater conveyance infrastructure
- stormwater volume reduction by promoting evapo-transpiration and infiltration to local aquifers
- conveyance of stormwater flows up to the 100-year ARI as surface flow using roads as primary overland flow path
- strong visual integration of stormwater management within the public realm and use of waterscapes as public art to celebrate the resource and amenity value of urban stormwater.

Site characteristics

The site is essentially flat and located toward the downstream end of a large urban watershed, where, historically, flood flows from the upper catchment have, by design, surcharged from the existing constructed stormwater drainage network onto the site for temporary storage to relieve downstream flooding. Shallow alluvial sands underlie the site over a sandstone bedrock. The sands form a contiguous un-confined alluvial aquifer flowing beneath the site.

The previous land uses on the site removed all remnant vegetation.

WSUD Solution

The WSUD solution for Victoria Park was informed by the site's natural heritage, flat topography, existing drainage function (as flood surcharge storage to relieve flooding of downstream areas) and the highly urbanised pattern of the proposed re-development.

The WSUD solution for Victoria Park, shown diagrammatically on page 95, was enabled by the collaborative process employed by the project team and supported by the developer. An in-depth investigation of the site's natural heritage by experienced ecologists and water engineers at the start of the conceptual design process enabled important watershed-scale and on-site-scale water-cycle management issues to be identified. This information was used to inform the project vision setting and initial urban layout considerations. Expertise available within the project team on WSUD BPPs and BMPs allowed key, early urban design decisions to be fully informed by the spatial and functional requirements of the WSUD infrastructure (BMPs) needed to deliver the project's WSUD objectives. A public artist was commissioned to design a waterscape feature for the project's central public park incorporating the use of treated stormwater generated from the development. The outcome is an urban design that has achieved a highly successful integration of stormwater management function within public realm landscapes. There is a strong legibility in the urban design, particularly in relation to the role of streetscape vegetation for stormwater management, local microclimate management and landscape amenity. The fact that almost every element of the project's public realm fulfils a water cycle management function makes Victoria Park an exemplar water sensitive development.

Case Study 2: Victoria Park, Sydney

Best Planning Practices employed

The WSUD BPPs employed in the project include:

- *BPP 2: WSUD on Flat Sites* — An at-source and at-surface approach to management of stormwater runoff using bioretention swales within centre medians of streets streetscapes has been adopted as a response to the flat terrain.
- *BPP 3: Integration of WSUD in Multiple Use Public Open Spaces* — The amenity of the public open space network is maximised by adopting an at-source and at-surface approach to management of stormwater runoff within streetscapes, thereby not encumbering the carrying capacity of the principle public park spaces with landscapes providing a stormwater management function.
- *BPP 4: Street Layout and Streetscapes* — Streets are designed with sufficient width to accommodate stormwater management within centre medians, parallel parking in both directions, one lane vehicle movement in both directions and pedestrian movement within the verges. Streets are graded to deliver stormwater runoff to the centre medians as sheet flow through specially designed kerb elements known as 'dolphins'. Longitudinal grades of streets are designed to convey flood flows through the site as a combination of bioretention swale, pipe and surface flow.
- *BPP 7: Waterscapes as Public Art* — A public art installation in the project's central park using treated stormwater celebrates the amenity value of urban stormwater in the urban environment.

Best Management Practices employed

The WSUD BMPs employed in the project include:

- *BMP 1: Demand Management*—The planting palette for landscapes was selected to be resilient to local free-draining soils and endemic to the local area, while being aesthetic and enhancing a sense of place.
- *BMP 3: Stormwater Harvesting* — Treated stormwater is collected from bioretention swales within a holding tank for use in the public art installation (additional treatment is provided by non-chemical electromagnetic filtration). Back-up water supply is provided by groundwater drawn from local un-confined alluvial (sand) aquifer. Treated stormwater is used to recharge the local un-confined alluvial (sand) aquifer and is recovered for irrigating public realm landscapes.
- *BMP 9: Bioretention Systems* — Bioretention swales are incorporated within the centre median of all east–west oriented streets.

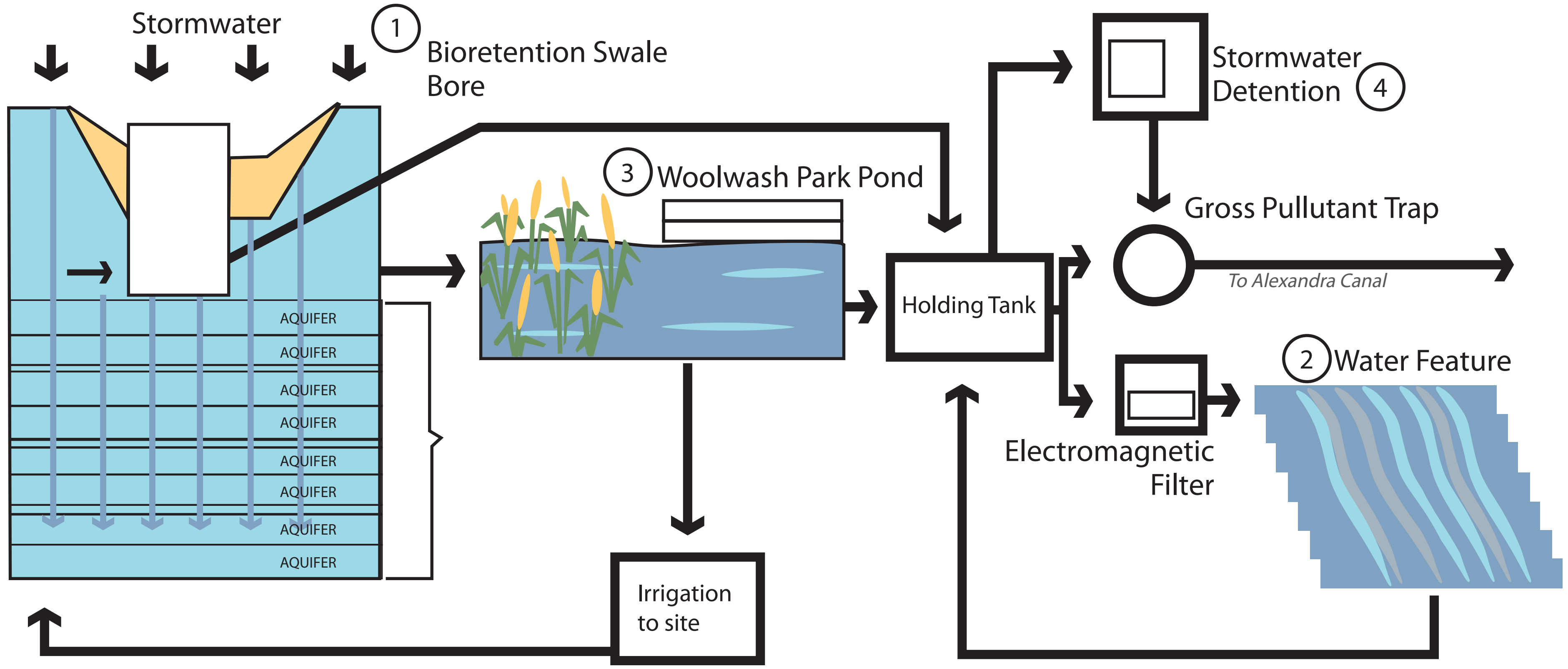
Successes

The inter-disciplinary depth of the project team and the collaborative spirit in which the master planning of the development was undertaken has been a key success of this project, evident by the industry accolade the project received for its water sensitive design.

Lessons learnt

A number of the centre median bioretention systems in the first few stages of the development were significantly damaged during the allotment build-out and required a complete re-build. The damaged bioretention systems were constructed to completion (i.e. final landscape planting installed) as part of the subdivision construction and prior to the build-out of the adjoining allotments. The medium-density nature of the allotment buildings meant that much of the building activity, including materials delivery and concrete preparation, occurred within the street verges. This resulted in significant wash-off of sediments and cement fines from the street verge into the centre median bioretention systems, causing clogging of the surface of the bioretention filter media. Rectification required complete removal of the bioretention plants and filter media and re-construction following completion of the adjoining allotment build-out.

To avoid this situation, the preferred approach is to build the sub-surface elements of the bioretention systems during subdivision construction but NOT to undertake the final landscape planting until build out of adjoining allotments is complete and sediment loading on the adjoining street carriageways from construction traffic is minimised. The surface of the bioretention should be protected during this period of allotment build-out by providing a protective covering capable of holding any sediments and other building materials washed into the centre median on the surface. A non-woven filtercloth overlaid with a thin layer of topsoil and turfed is generally adequate to protect the underlying bioretention filter media and will have reasonable presentation.



Graphic adapted from Landcom image

Photo: Peter Breen / EDAW

Photo: Peter Breen / EDAW

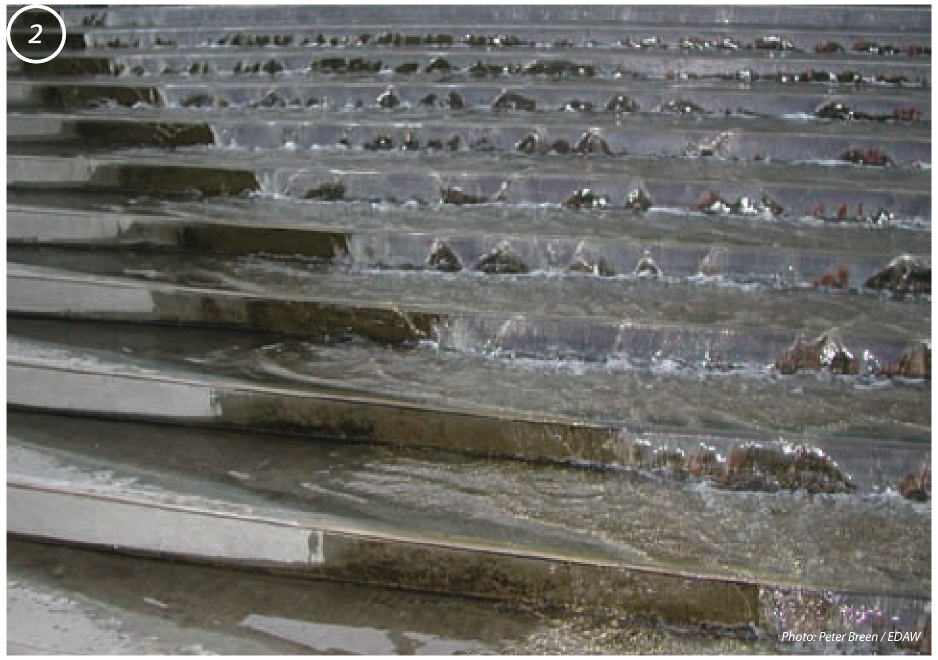
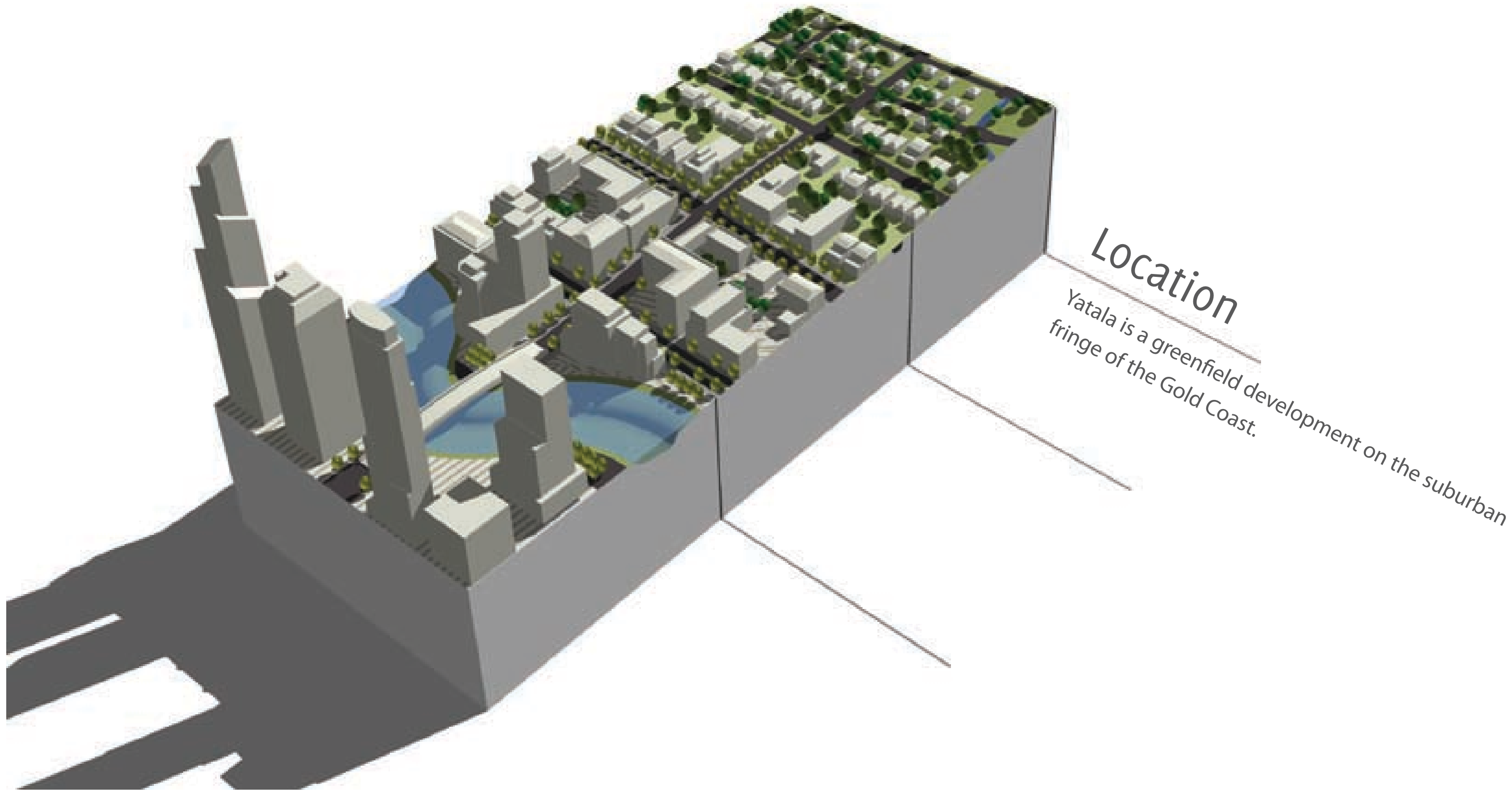


Photo: Peter Breen / EDAW

Photo: Peter Breen / EDAW

Case Study 3: Yatala, Gold Coast



Project characteristics

Project type:
Greenfield

Landuse:
Industrial area development

Site area:
61.5 ha

Project team composition

- Town Planner — Lead
- Urban Designer
- Ecological Engineer
- Civil Engineer
- Ecologist

Project overview

The Yatala Enterprise Area (YEA) is situated midway between Gold Coast City and Brisbane. The 3,000 hectare area of the YEA covers an extensive part of the northern tip of Gold Coast City and includes the localities of Yatala and Staplyton. Within the YEA, there are around 900 hectares of developed and greenfield industrial and commercial land, connected by integrated road, rail, air, and sea services. This area is covered by the YEA Local Area Plan (LAP), which has been incorporated into the Council's planning scheme. The LAP includes land on both sides of the Pacific Motorway (M1) and provides planning controls to ensure the orderly development of the locality.

The M1, which runs through the middle of the YEA, has been upgraded in recent years at a cost of $850 million, providing fast, free-flowing travel to Brisbane and Gold Coast City. Brisbane International Airport is 45 minutes away by road, while it takes just 40 minutes to reach the Port of Brisbane.

Lot 281 comprises 61.5 hectares within the YEA and forms part of *Precinct 2—Low Impact Business and Industry Precinct* within the LAP. Preferred activities for this precinct are production, manufacture, construction, maintenance, repair, or distribution of goods. Development in this precinct is required to recognise the relative proximity to existing or planned residential areas, so a high level of visual presentation, landscaping, and screening is required, as well as rigorous amenity impact mitigation measures in the areas of noise, odour, dust, and visual presentation.

Estate layouts are required to demonstrate robustness in design, connectivity in road layout, and sensitivity to the key physical features of the area.

The outcome of this project was a preferred conceptual design layout of the site, based on site opportunities and constraints (EDAW, 2006).

WSUD objectives

The Gold Coast City Council's Stormwater Management Guidelines recommend that the following reductions in the developed catchment mean annual pollutant loads must be achieved:

- 80% reduction in TSS
- 60% reduction in TP
- 45% reduction in TN
- 75% reduction in gross litter.

These guidelines also present some specific 'deemed to comply' requirements for code and impact assessable industrial developments including:

- no impervious area runoff to discharge from the site without appropriate treatment
- rainwater tanks are to be incorporated on the development site
- all of the site's impervious areas, including the overflow from rainwater storage devices, are to discharge to bioretention devices that are not less than 2.5% of the total contributing catchment.

Site characteristics

The site is bounded by Halfway Creek to the east and Peachey Road to the south and it is intended to be connected between Pearson Road and Peachey Roads by a future arterial road linkage.

Slope analysis determined that approximately 25 ha of the site (41%) has a slope of greater than 10% and 14 ha of the site (23%) has a slope of greater than 15%. The remaining 36 ha is relatively flat.

WSUD solution

The focus of investigations into WSUD solutions for this development was on the stormwater aspect of the water cycle. Typically, the local drainage system consisted of:

- allotment-scale drainage and water quality management within the private allotments typically include on-site detention or localised gross pollutant traps, oil-grease separators, or bioretention style infiltration landscape measures
- street-scale drainage and water quality management such as vegetated swales or bioretention swales within the street design of the development site
- trunk conveyance systems such as natural channel drainage lines preserving, enhancing, and rehabilitating natural drainage systems in the drainage design
- regional-scale measures such as wetlands and detention basins.

Certain aspects of the development needed contemporary minor and major drainage systems.

Best Planning Practices employed

The WSUD BPPs recommended for this project included:

- *BPP 1: Steep and Undulating Sites* — For conceptual planning purposes, all areas of the site with a slope of greater than 15% were considered unsuitable for development due to the likely costs of development and potential visual impact as a result of large cuts, batters, and retaining walls.

- *BPP 2: WSUD on Flat Sites* — Combinations of at-source and end-of-pipe applications of bioretention were used as the best stormwater treatment outcome. The conceptual design recognised the advantages of a distributed at-source system of bioretention treatment devices are that the number of allotments connected to each device can be minimised. This is a benefit for the establishment timeframe, commissioning, and hand-over to council.

- *BPP 4: Street Layout and Streetscapes* — Topography was recognised as a constraint on any proposed road networks within the site. The preliminary concept design studies identified a potential road network that would support either at-source or end-of-pipe bioretention, depending on grade.

Case Study 3: Yatala, Gold Coast

Best Management Practices employed

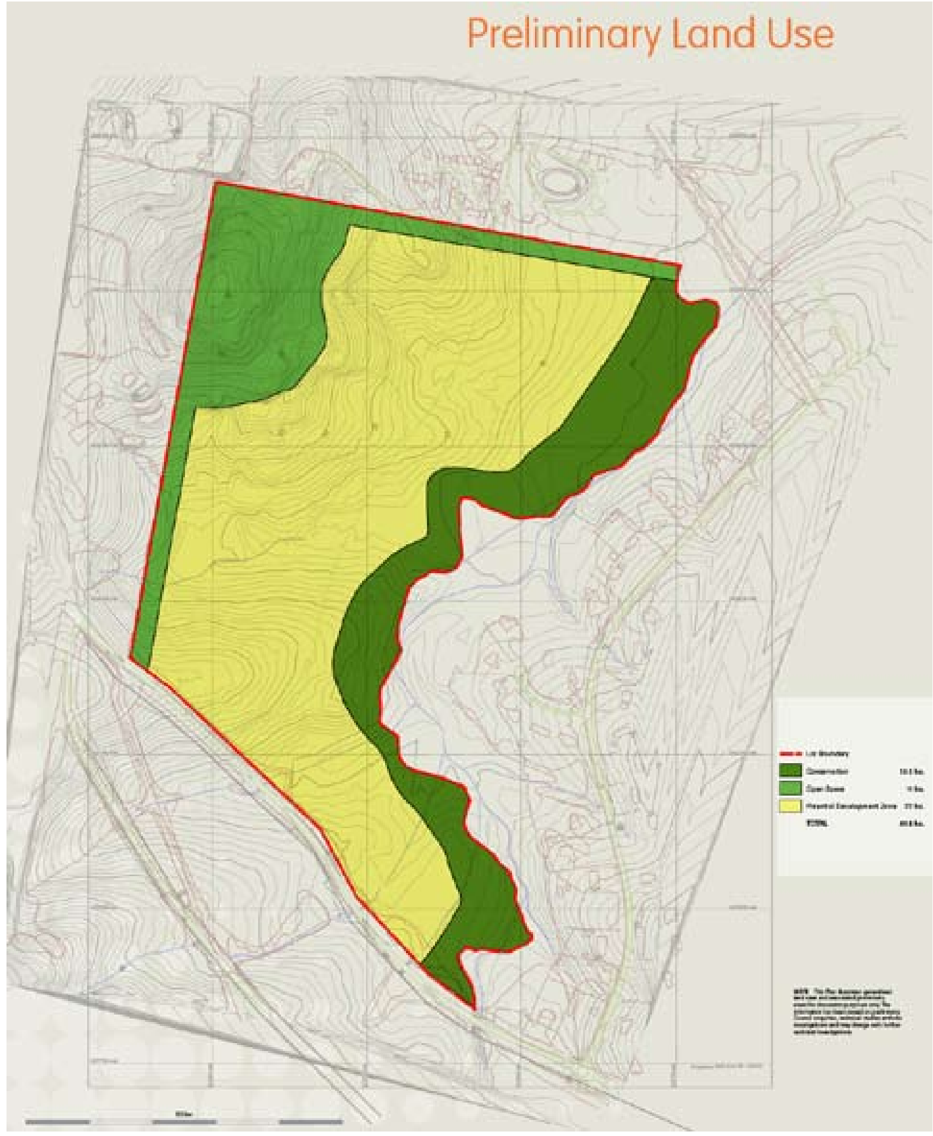
The WSUD BMPs employed in this project include:

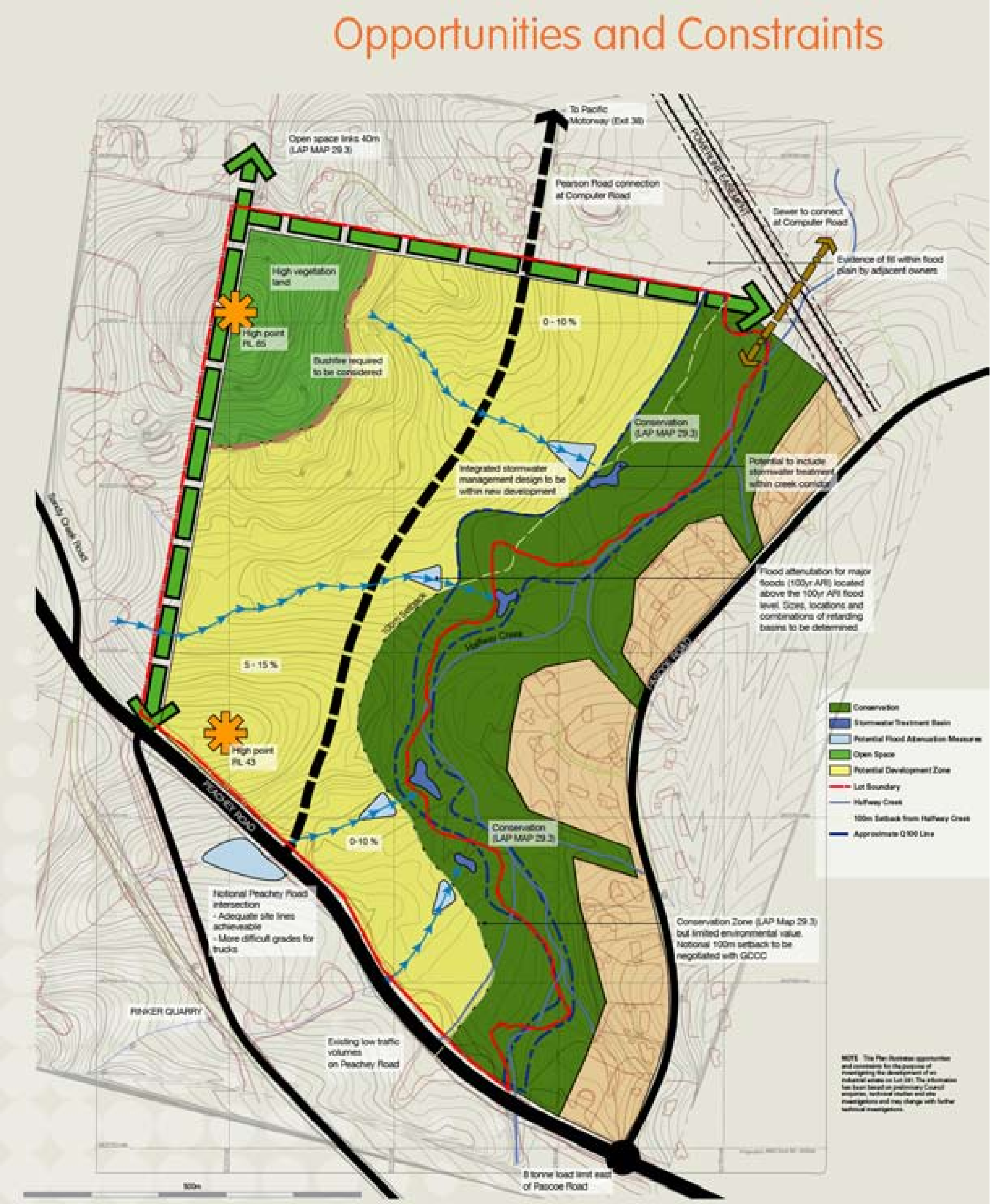
- *BMPs 1–4: Demand Management, Roofwater (Rainwater) Harvesting, Stormwater Harvesting, and Wastewater Treatment for Re-Use*—The conceptual design report recommended that some analysis of the overall water-cycle management on the site should be undertaken. This analysis assessed the likely magnitude of water consumption and wastewater generation, and the costs of establishing connections to trunk infrastructure compared with on-site treatment of wastewater and subsequent re-use. Stormwater harvesting was also considered in the analysis. Benefits of recycled water include availability of process water for future tenants and irrigation of the landscape. Rainwater tanks are incorporated on the development site, sized via water-balance modelling.

- *BMP 9: Bioretention Systems*—All of the site's impervious areas, including the overflow from rainwater storage devices, discharge to bioretention devices that are not less than 2.5% of the total contributing catchment.

Successes

The conceptual design process included a range of disciplines resulting in a well-researched and successful conceptual design for this industrial site.

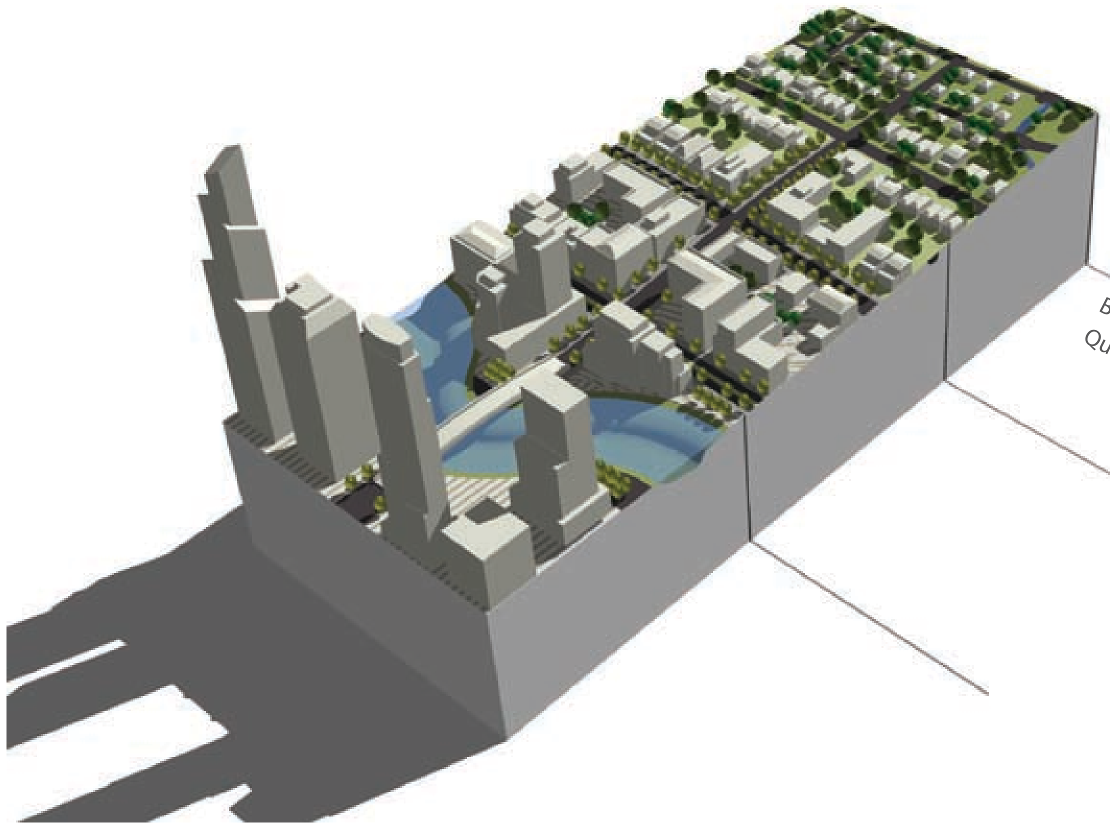




Opportunities and Constraints
To Pacific Motorway (Exit 38)
Open space links 40m (LAP MAP 29.3)
Pearson Road connection at Computer Road
Sewer to connect at Computer Road
Evidence of fill within flood plain by adjacent owners
High vegetation land
High point RL 85
Bushfire required to be considered
0 - 10 %
Conservation (LAP MAP 29.3)
Integrated stormwater management design to be within new development
Potential to include stormwater treatment within creek corridor
Flood attenuation for major floods (100yr ARI) located above the 100yr ARI flood level. Sizes, locations and combinations of retarding basins to be determined
Sandy Creek Road
Halfway Creek
5 - 15 %
High point RL 43
Peachey Road
0-10 %
Conservation (LAP MAP 29.3)
Notional Peachey Road intersection
- Adequate site lines achieveable
- More difficult grades for trucks
Conservation Zone (LAP Map 29.3) but limited environmental value. Notional 100m setback to be negotiated with GCCC
RINKER QUARRY
Existing low traffic volumes on Peachey Road
8 tonne load limit east of Pascoe Road
500m
Conservation
Stormwater Treatment Basin
Potential Flood Attenuation Measures
Open Space
Potential Development Zone
Lot Boundary
Halfway Creek
100m Setback from Halfway Creek
Approximate Q100 Line

Sandy Creek Road
Pearson Road
Open space and vegetatain retention on elevated, steep ground
Bushfire protection zone to be included
Drainage corridor integrated into streetscape
Potential link to Sandy Creek Road
Lot 17
Open space link (40m)
Extent of Q100 subject to further detailed survey
Possible stormwater treatment and flood attentuation measures.
Notional 100m Setback.
Bushfire protection zone to be included
RINKER QUARRY
Peachey Road
Preliminary Q100.

Case Study 4: Bellvista, Sunshine Coast



Location

Bellvista is located in the suburban area of Caloundra on Queensland's Sunshine Coast

Project characteristics

Project type:
Greenfield

Landuse:
Urban residential development

Site area:
Stages 3 and 4 of this development cover about 33 ha

Building and dwelling densities:
405 residential lots with allotment sizes ranging from 300–700 m^2. The development density is approximately 15 lots/ha.

Project team composition

- Urban Designer
- Landscape Architect
- Civil Engineer
- Ecologist
- Ecological Engineer

Project overview

The Bellvista Estate is located on the flat coastal plain of the Sunshine Coast. It is a residential neighbourhood designed with nature-inspired streetscapes, a large central lake, extensive parkland, linked walk and bike trails and substantial street landscaping. Underpinning Bellvista Estate is a network of open drains, wetlands, and a central lake accommodating the broader catchment area of Little Mountain.

During Bellvista's history there has been a fundamental change in the engineering practices between the traditional approach in stages of 1, 2, and 5 and the innovative WSUD engineering approach in stages 3 and 4.

The stage 3 and 4 streetscapes consist of approximately 500 lots ranging in size and, in some instances, located adjacent to conservation zones of natural heath land. The low relief of the site, and that of the surrounding environment, required careful consideration of urban drainage solutions to avoid the creation of expensive, low gradient, large diameter pipe drainage networks that would not be able to free-drain into the shallow drainage channels that run through the site.

After considering several approaches to the design of this site, the solution was to use small streetscape bioretention systems, or 'biopods', to treat stormwater at-surface before it enters piped drainage systems. By using an approach that harnesses the synergies between the objectives of stormwater quality, road drainage, traffic calming, and landscape design, Bellvista Estate delivers innovative streetscape stormwater quality improvement devices that provide at-source treatment of stormwater and are integrated into the urban landscape.

The solution incorporates sustainable land management into the urban footprint, down to the local street scale. Local residents directly engage with small streetscape raingardens, and are prompted by visual cues that the health of their raingarden depends directly on their actions. The receiving environment is no longer a remote waterway but immediately in front of their homes. This approach not only reflects ecological stewardship on the behalf of developer and council, but also promotes ongoing stewardship by local residents.

WSUD objectives

The development of stages 3 and 4 set the following land management objectives:

- protection of natural systems—protect and enhance natural water systems within urban developments
- integration of stormwater treatment into the landscape—use stormwater in the landscape by incorporating multiple-use corridors that maximise the visual and recreational amenity of developments
- protection of water quality—improve the quality of water draining from urban developments into receiving environments
- reduction in runoff volume and peak flows—reduce peak flows from the urban development by local retention and detention measures and minimising impervious areas
- adding value while minimising development costs—minimise the drainage infrastructure cost of the development.

Site characteristics

The site is located on coastal, low-lying land, which drains towards the locally sensitive waterways of Lamerough Creek, Pumicestone Passage, and Moreton Bay Marine Park. Much of the development occurs on fill pads above the 100-year ARI flood level. The site is generally flat with two major drainage channels—one through the centre of the development and one along the western boundary.

WSUD solution

The solution represents current best practice in urban stormwater management and protects natural systems, integrates stormwater treatment into the landscape, protects water quality, reduces runoff and peak flows, and adds value while minimising development costs. The WSUD stormwater solution for Bellvista stages 3 and 4 consists of the following initiatives:

- rainwater tanks included on each allotment to collect roof runoff for re-use
- bioretention pods within linear open space located along the eastern constructed open channel
- constructed wetland to capture runoff from a relatively small catchment (approximately 2.6 ha) via a sufficiently shallow pipe drainage system
- bioretention pods located within the streetscapes to accept and treat runoff from the road reserve and adjacent allotments.

There is an additional potable water conservation benefit of the streetscape bioretention systems since stormwater is used as passive irrigation for these landscape features. The landscape is the first priority for the re-use of stormwater. This results in potable water savings, or, during times of water restrictions when irrigation of public open space is restricted, will enable a higher quality streetscape to be maintained.

Best Planning Practices employed

The WSUD BPPs employed in the project include:

- *BPP 2: WSUD on Flat Sites* — An at-source and at-surface approach to management of stormwater runoff using bioretention pods within residential streets has been adopted as a response to the flat terrain.

- *BPP 3: Integration of WSUD in Multiple Use Public Open Spaces* — The amenity of the public open space network is maximised by an at-source and at-surface approach to management of stormwater runoff within streetscapes reducing the area of treatment required within public open spaces.

- *BPP 4: Street Layout and Streetscapes* — Streets have been designed with close collaboration between urban planners and WSUD designers to ensure that at-source and at-surface stormwater treatment is incorporated into the residential layout while minimising the level of encumbrance to lot frontage, accommodating pedestrian access and services, ensuring pedestrian safety, and that there are appropriate setbacks from lots and roadways.

- *BPP 7: Waterscapes as Public Art* — Locating bioretention pods within streetscapes helps foster an appreciation of urban stormwater management within the local community. The presence of litter within bioretention pods or the wetland provides important visual feedback to residents that they live in a catchment. This is starkly different compared with the 'out of sight, out of mind' mindset fostered by conventional stormwater drainage systems. Ownership and community pride in relation to the pods is encouraged through educating residents about the role and function of the bioretention pods. As a key feature of the streetscapes, the pods are profiled in marketing material and sales representatives were briefed to discuss the pods with prospective buyers.

Case Study 4, Bellvista, Sunshine Coast

Best Management Practices employed

The WSUD BMPs employed in the project include:

- *BMP 1: Demand Management* —An education program focused on the bioretention pods should also create awareness of broader catchment issues, including water conservation.
- *BMP 2: Roofwater (Rainwater) Harvesting*—Roofwater is harvested in rainwater tanks for individual houses. This is used for garden irrigation and toilet flushing.
- *BMP 9: Bioretention Systems*—Bioretention pods have been incorporated within residential streets and linear public spaces throughout the development.
- *BMP 10: Constructed Wetlands*—A constructed wetland has been integrated into the recreational reserve precinct.

Successes

Bellvista Estate is a highly successful development—it has been one of Australia's fastest selling developments. The greater consideration of stormwater at an early stage meant that the detailed design process was supported by having a highly considered urban layout that was conducive to at-surface stormwater treatment. The success of this project can be attributed to the inter-disciplinary depth of the project team and the collaborative spirit in which the master planning of the development was undertaken.

Photo: Alan Hoban / Ecological Engineering

Lessons learnt

- Desirable road lengths were determined to be 75–100 m on flat sites. These could be drained safely within road standards. This required adjustments to the urban road design with regard to driveway crossovers and verge widths to accommodate bioretention systems.
- Construction phase protection provided for early establishment of the bioretention systems.
- Bioretention species selection needs to consider visibility at road intersections.

Photo: Alan Hoban / Ecological Engineering

04

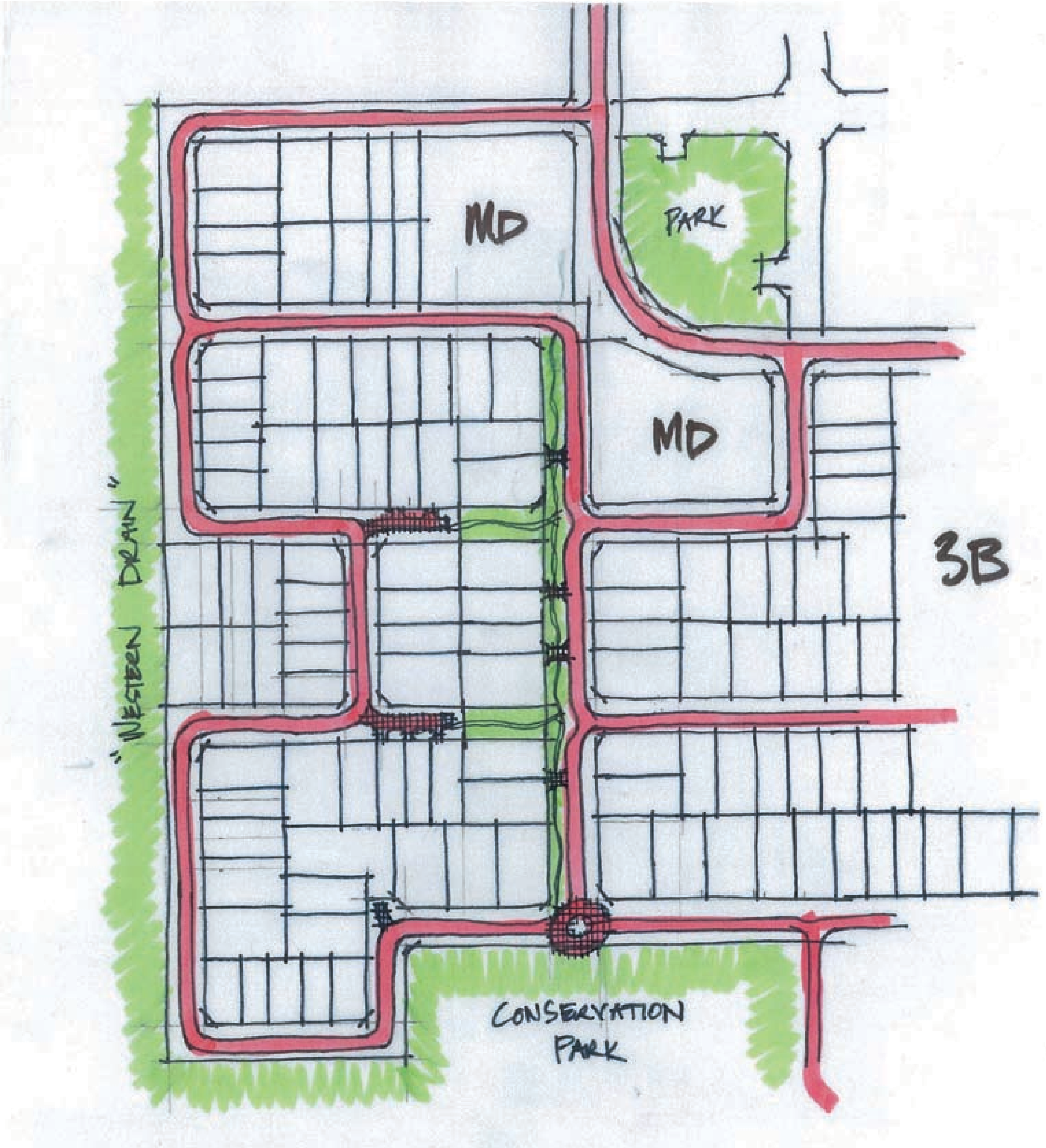
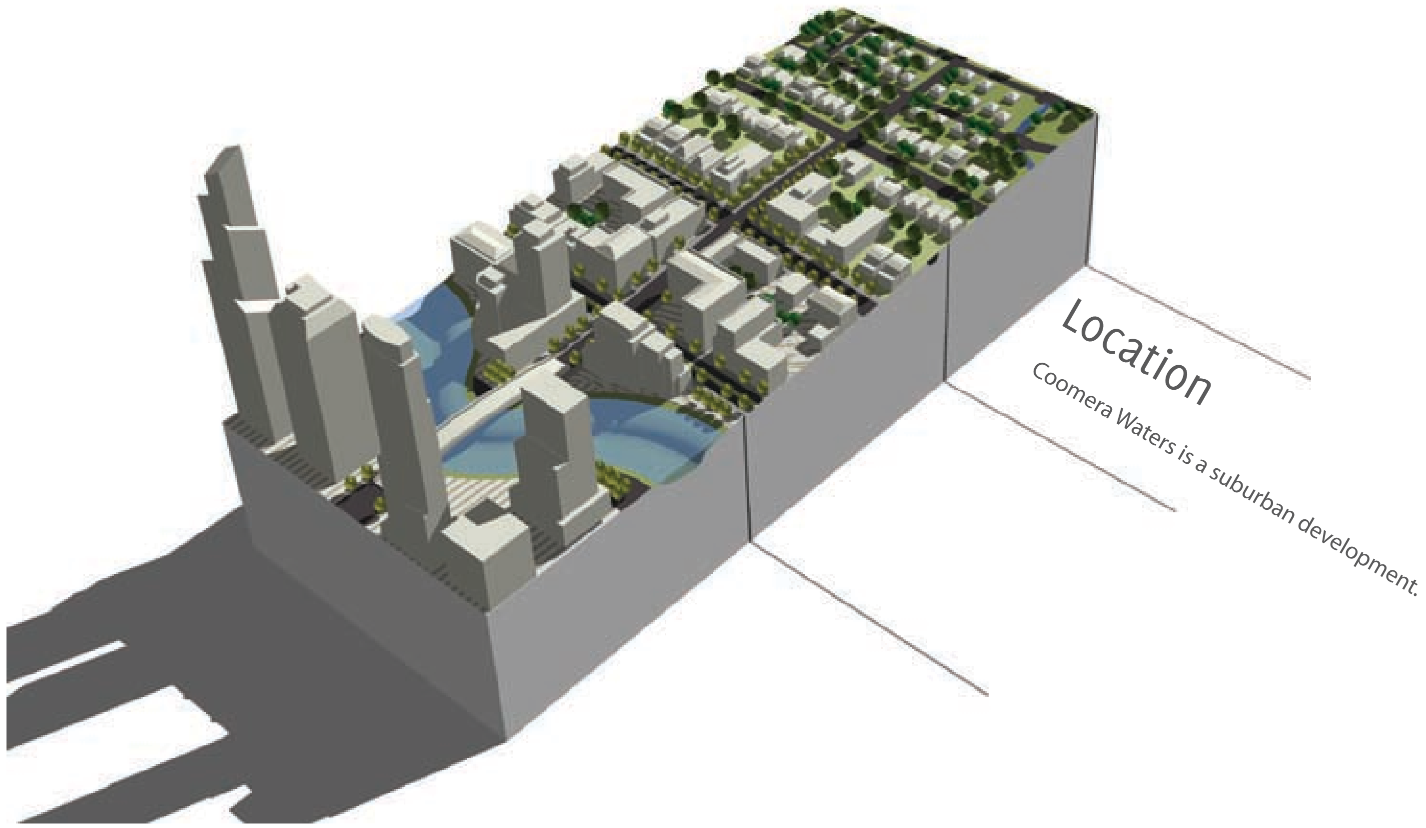


Photo: Alan Hoban / Ecological Engineering

Photo: Alan Hoban / Ecological Engineering

Case Study 5: Coomera Waters, Gold Coast



Project characteristics

Project type:
Greenfield

Landuse:
Residential development

Site area:
476 ha

Building and dwelling densities:
Almost 1,600 titles with land sizes ranging from under 350–4500 m2. Allotments are classified as waterfront lots, dry flat lots, gentle slopping lots, premium elevated land, or villas (Austcorp, 2009).

Project team composition

- Urban Designer
- Landscape Architect
- Civil Engineer
- Ecologist
- Ecological Engineer

Project overview

Coomera Waters is a large-scale residential development located at the northern end of the Gold Coast that is bounded by a series of regionally significant aquatic ecosystems including Moreton Bay Marine Park and McCoys Creek. Early planning for the development identified the protection of these ecosystems through the principles of WSUD as a key 'design vision'. To meet these expectations, the developer engaged WSUD specialists to develop and implement a WSUD strategy for Coomera Waters to ensure the development zone promotes sustainable and integrated management of land and water resources, and incorporates best practice stormwater management and WSUD solutions throughout the urban template.

The planning and design of Coomera Waters involved over six years of research to develop and implement the vision for the project, integrating urban forms with the surrounding ecosystems. The WSUD-related infrastructure established at Coomera Waters to achieve this vision includes:

- swale bioretention systems, bioretention raingardens, and constructed wetlands integrated within streetscapes and precinct parks to deliver best practice management of stormwater runoff
- a sustainable freshwater lake and wetland system within a significant regional parkland to create a focal point for the community
- dual reticulation and smart sewer systems to deliver the potable water conservation and wastewater minimisation targets established by Gold Coast Water's Pimpama Coomera Water Future Masterplan.

The outcome is a residential development that promotes sustainable and integrated management of land and water resources, and incorporates interesting streetscape and public realm WSUD solutions throughout the urban template.

The successful integration of WSUD at Coomera Waters is proof that environmentally and socially responsible solutions can enhance, rather than restrict, economic viability.

WSUD objectives

The vision for the Coomera Waters WSUD strategy was to protect regionally significant aquatic ecosystems. The objectives of WSUD are centred on the principles of water conservation and environmental protection and are delivered within the broader framework of ecologically sustainable urban development.

The specific WSUD stormwater drainage objectives adopted to achieve the vision of this project are:

1. Preserving the pre-developed hydrologic and hydro-geological regime by recharging groundwater and minimising the hydrological change induced by the increased impervious surfaces created by the development.

2. Providing appropriate collection and conveyance systems to prevent nuisance flooding and flood damages to property.

3.Treating stormwater runoff to a standard that is suitable for discharge to receiving waters, based on known or perceived environmental, social, and economic values associated with the receiving waters and re-use of treated stormwater on the site for:

- domestic uses using roofwater runoff
- irrigation of public open space areas using ground level treated stormwater runoff.

4. Incorporating the pathways for movement of stormwater into the urban design and landscape of the development as a means of promoting the resource and amenity value of urban stormwater.

Site characteristics

The development site is predominately undulating with slopes ranging from 3% to 30%. In general, the central portion of the site is the highest and the ground slopes downwards in all directions toward the site perimeter. Therefore, the site tends to drain via sheet flow from the centre towards the edges. Water that drains off the site ultimately flows into the McCoy's Creek floodplain, which is a regionally significant receiving environment containing Ramsar Convention on Wetlands-listed estuarine wetlands. The 100-year ARI flood level in the vicinity of the site is dominated by tidal storm surge conditions rather than local catchment runoff.

The development supported re-growth vegetation with some partially cleared areas. A number of substantial trees currently exist in the key corridors, which provide important natural features within the development. The urban form has been designed to retain these trees and the stormwater systems are designed to complement these trees.

Soil conditions on the site are likely to be a mixture of silty clays with lenses of heavy clays. There was potential for acid sulfate soils on the site and also a relatively high water table.

WSUD solution

The WSUD solution seamlessly incorporates innovative stormwater management solutions throughout the urban environment to achieve best practice water quality objectives and to manage the way stormwater flow enters the receiving ecosystems. WSUD initiatives that have been constructed include:

- bioretention swale systems integrated into road reserves to capture and manage road runoff while creating interesting public spaces
- raingarden bioretention systems planted out with rush and reed ground cover and trees endemic to the region encouraging the natural template up into the developed zone
- constructed wetlands integrated into precinct and regional parks to provide not only water quality and flow retardation but also to act as a focal point, which residents are actively encouraged to experience
- ephemeral melaleuca wetland systems that enhance the translocation of nutrients, in particular nitrogen, in runoff through the highly organic ground cover
- all current and future housing within Coomera Waters incorporates rainwater tanks with collected water used to supply hot water and laundry demands.

Coomera Waters also represents the first development to fully embrace and implement the outcomes of the Pimpama Coomera Water Future Master Plan (PCWFMP), which establishes a new and sustainable water cycle solution for future growth in the region. The key objective of the PCWFMP is to reduce current household potable water use by 80+%, through a combination of initiatives:

- demand management through community education and water-efficient fittings and appliances
- recycled treated wastewater delivered to households via a dual reticulation system to supply toilets and garden irrigation
- rainwater tanks on dwellings plumbed to relevant indoor uses.

Best Planning Practices employed

The WSUD BPPs employed in the project include:

- *BPP 1: WSUD on Steep and Undulating Sites* — At-source and at-surface treatment in the form of vegetated and bioretention swales as well as road reserve bioretention rain

Case Study 5: Coomera Waters, Gold Coast

gardens have been adopted at Coomera Waters. Where the adoption of these treatment solutions was not possible due to steeper topography, conventional collection and conveyance systems were installed with downstream wetlands and bioretention rain gardens collecting and treating the stormwater in public open space areas.

- *BPP 3: Integration of WSUD in Multiple Use Public Open Spaces* — The public amenity of the public open space network has been maximised by adopting an at-source and at-surface approach to the management of stormwater runoff within streetscapes, where possible. This approach minimises the treatment area required for downstream treatment in public open spaces and minimises the treatment area required for downstream treatment in the principle public park spaces.

- *BPP 4: Street Layout and Streetscapes* — Street reserves have been designed with sufficient width to accommodate stormwater management within the verge, vehicle movement, and parking allowances in both directions. Where grade allowed, roadside swales and bioretention systems were located on the high-side road verge with the road pavement cross-falling toward the system. This allows for major storm flows such as 100-year ARI to use the full road reserve without spilling over into low-side lots. Longitudinal grades of streets are designed to convey flood flows through the site as a combination of bioretention swale, pipe, and surface flow.

- *BPP 7: Waterscapes as Public Art* — Incorporating the pathways for movement of stormwater into the urban design and landscape amenity of the development promotes the resource and amenity value of urban stormwater.

Best Management Practices employed

The WSUD BMPs employed in the project include:

- *BMP 1: Demand Management* — Demand management is being achieved by water-efficient fittings and appliances and community education on water conservation.

- *BMP 2: Roofwater (Rainwater) Harvesting* — Roofwater is harvested in rainwater tanks, which are plumbed to relevant indoor uses.

- *BMP 4: Wastewater Treatment for Re-Use* — Recycled treated wastewater is delivered to households via a dual reticulation system to supply toilets and for garden irrigation.

- *BMP 7: Grass or Vegetated Swales* — Grassed swales are used as conveyance systems in the development. Because of the high number of driveway crossovers along local streets, shallow swale profiles were used (1 in 9 batters and maximum depth 0.22 m) allowing each driveway crossover to have the same profile as the swale. This avoided culverts under each driveway crossover.

- *BMP 9: Bioretention Systems* — Bioretention swales and bioretention raingardens are incorporated within the development in the road reserve, as well as in public open spaces.

- *BMP 10: Constructed Wetlands* — Constructed wetlands are integrated into precinct-level and regional-level parks as both stormwater management systems and as landscaped focal points, which residents are actively encouraged to experience.

Successes

A multidisciplinary approach and extensive stakeholder consultation at the concept design phase of the project accessed leading-edge WSUD expertise and integrated WSUD principles at every level of the planning process. Following conceptual design, an integrated design approach was adopted to ensure the WSUD objectives and intent conceived as part of the urban conceptual design phases were delivered through the design, documentation, and construction.

One of the important outcomes of the planning and design of Coomera Waters was the inclusion and successful collaboration with Gold Coast City Council throughout. This inclusive approach is certain to be replicated in other projects throughout Queensland by building on the experience and knowledge gained through this project, which has already attracted attention from the industry.

Lessons learnt

- Filter media protection using filtercloth and turf was used at Coomera Waters and has been a successful approach for protecting the filter media during construction.
- Bioretention swales can be successfully incorporated with driveways by providing local access shared driveways. This also reduced the risk of residents filling or changing the conveyance property of the swales.

Ross Pottinger/Winkphoto

Photo: Shaun Leinster / Ecological Engineering

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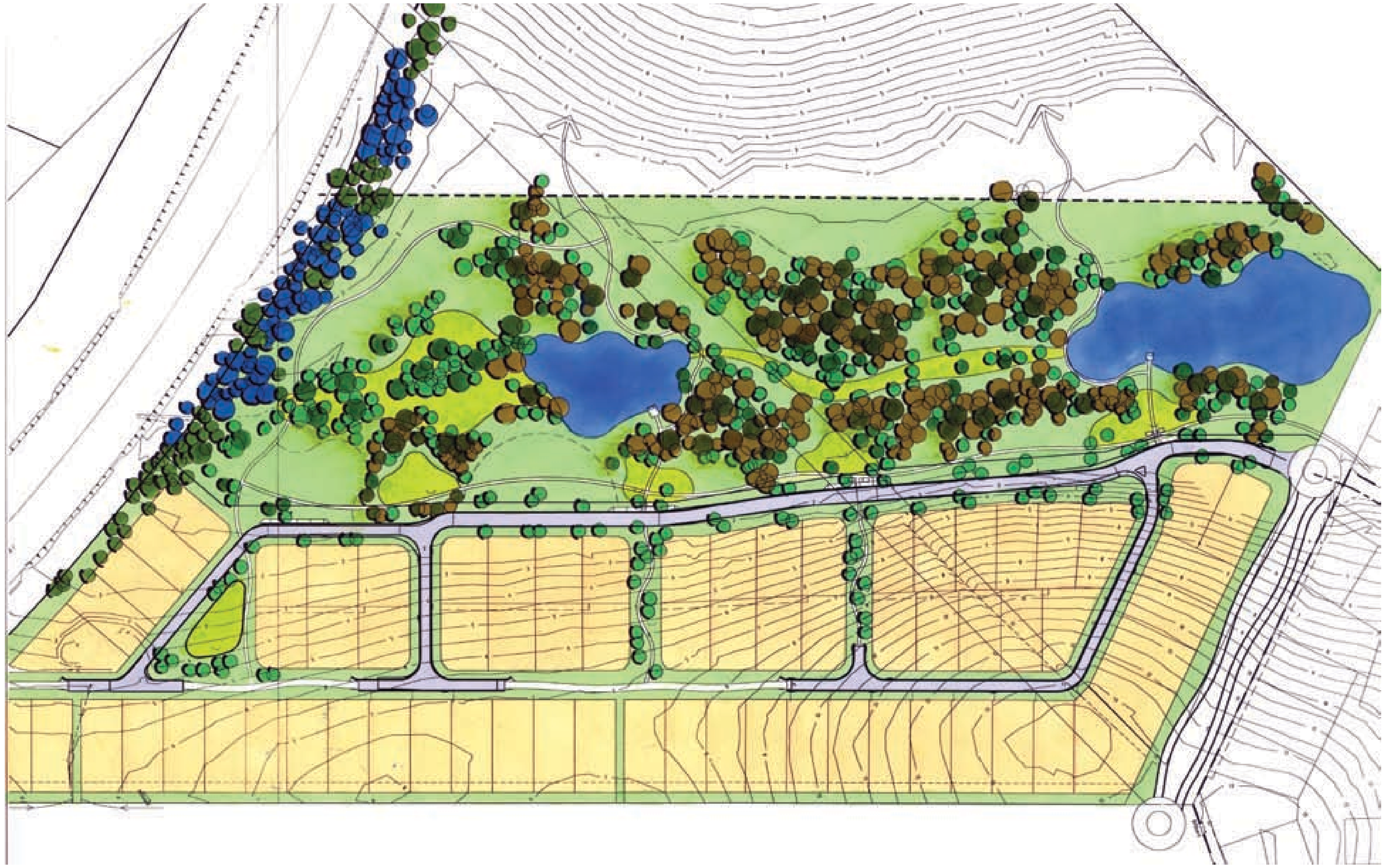

Graphic courtesy of DBI Design

River Quiver—Jennifer Turpin Studio
+ students from the Hunter Region
Photo: Ian Hobbs

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Glossary

Aquatic	Related to water.
Aquifer Storage and Recovery	Injection of recycled water into aquifers for storage, which may be recovered later to meet water demands.
Biodiversity	The number and variety of living organisms including genetic diversity, species diversity, and ecological diversity (same as biological diversity).
Biopods	Small bioretention systems that are commonly integrated into streetscapes.
Bioretention System	Vegetated depressions engineered to collect, store, and treat stormwater runoff at downstream locations within the catchment. Bioretention systems can vary in shape and size. They treat stormwater runoff via filtration through densely planted surface vegetation and infiltration into a prescribed filter media. Pollutants are primarily removed by adsorption and biological transformation within the filter media. Treated stormwater is then collected in a perforated under-drain system and discharged.
Bioretention Swale	Provide both stormwater treatment and conveyance functions, combining a bioretention system installed in the base of a swale that is designed to convey stormwater as part of a minor or major drainage system. Bioretention swales filter stormwater runoff through densely planted surface vegetation and through a prescribed filter media, which commonly flows to a perforated under-drain system. Commonly employed along roadways.
Blackwater	Wastewater from toilets and kitchen basins that is low in quality containing significant contamination including harmful micro-organisms
Brownfield	Abandoned, idle or under-used, already developed urban, industrial and commercial areas.
Buffer Strip	An area of vegetation through which stormwater runoff passes while travelling to a downstream receiving water or discharge point. In association with vegetated swales, buffer strips can slow runoff and provide water quality benefits. They reduce sediment loads by passing a shallow depth of flow through vegetation and rely on well-distributed sheet flow. Vegetation tends to slow velocities and coarse sediments are retained.
Catchment	An area of land bounded by topographic features such as hills, from which drainage flows to a common point, usually ending in a river or creek and eventually the sea.
Constructed Wetland	An aquatic environment that supports a range of aquatic vegetation across the majority of the waterbody area. Constructed wetland systems remove pollutants from stormwater runoff through enhanced sedimentation, fine filtration and biological uptake.
Ecologically Sustainable Development	Developments that are designed with consideration of the local environment, social and economic conditions to ensure the development will be successful in the long-term.
Ecology	The scientific study of the distribution and abundance of living organisms and the interactions among organisms and between organisms and their environment.
Ecosystem	A system formed by the interaction among organisms and between organisms and their environment.
Effluent	The outflow from a sewage treatment facility or the wastewater discharge from industrial facilities.
Environment	Surrounding conditions that can include physical conditions as well as social and cultural conditions that affect and influence individuals and communities.
Ephemeral	A short-lived, transitory event or occurrence often used to describe the life-cycle of plants and animals. When used to describe wetlands, ephemeral refers to habitats that are intermittently inundated, and go through periods of wetting and drying conditions.
Erosion	The mechanical process of wearing down the Earth's surface by processes such as weathering, abrasion and transportation.
Evaporation	The process by which molecules in a liquid state (e.g. water) spontaneously become gaseous (e.g. water vapour). Generally, evaporation can be seen by the gradual disappearance of a liquid, when exposed to a significant volume of gas.
Evapo-transpiration	The combined process of evaporation and plant transpiration which transforms water molecules in a liquid state from the Earth's surface into water vapour (gaseous form), which is returned into the air.
Flow Attenuation	The reduction in peak flow resulting from temporary water storage.
Geomorphology	The scientific study of the Earth's landforms and the processes that form them.
Greenfield	A piece of undeveloped land, either currently used for agriculture or in a natural state.
Greywater	Wastewater from non-toilet plumbing fixtures such as showers, basins, washing machines and taps that varies in quality from relatively clean to containing significant contamination including harmful micro-organisms.
Gross Pollutant Trap (GPT)	A trap designed to intercept coarse particulate material (by sedimentation) and trash and debris (by screens or booms). GPTs may be incorporated into inlet pits, collector drains or main drains.
Groundwater	Water in the saturated zone beneath the land surface.
Hydrology	The science of the natural occurrence, distribution and movement of water.
Hydrogeology	The scientific study of the geology of groundwater, its chemistry and movement.
Impervious Area	A hard surface area (e.g. parking lot or rooftop) that prevents or retards the entry of water into the soil, causing water to run off the surface in greater quantities and at an increased rate of flow.
Infiltration	The downward movement of water from the land surface into the soil.
Integrated Water-Cycle Management	Recognises the finite limits to a region's water resources and assumes greater importance as the level of demand approaches those limits. It is a holistic approach to balancing the competing demands placed on water resources, so as to meet defined water quantity and quality objectives, including those relating to the role of water in the environment. The key principles of integrate water-cycle management include: recognising all potential sources of water, including wastewater and stormwater; using all water sources sustainably; allocating and using water equitably; and integrating water use and natural water processes, including maintaining environmental flows and water quality.
Macrophyte	A plant adapted to living in water or periodically inundated habitats.
Natural Water Cycle	The cycle of water movement through the environment including rain, overland and groundwater flow, evaporation, and evapo-transpiration of water back into the atmosphere.
Nutrients	Substances such as nitrogen and phosphorus, which promote the growth of plants and algae. Excessive nutrients in waterways contribute to algal blooms and degrade our waterways.
Pervious Area	A permeable surface area (e.g. landscaped parkland) that allows the entry of water into the soil, reducing the quantity and rate of stormwater runoff when compared to impervious surfaces.
Pre-Developed Conditions	Catchment characteristics, such as water cycle and landscapes, as they would have been prior to development occurring.

Glossary

Pollutants	Substances that may naturally occur but are present at harmful levels (e.g. sediment or nutrients in a water body) or which may be unnatural in the environment and capable of producing environmental harm (e.g. chlorinated pesticides).
Potable water	Water that is treated to meet the *Australian Drinking Water Quality Guideline* (2004), and is safe for supply directly to households, commercial premises and industry for drinking and other purposes.
Raingarden	A term used to describe larger, end-of-pipe bioretention systems.
Rainwater	Rain is a type of precipitation, a product of the condensation of atmospheric water vapour that is deposited on the Earth's surface. It forms when separate drops of water fall to the Earth from clouds.
Receiving Water	A water body that may receive runoff from the catchment, and generally has some environmental value or beneficial use. Natural wetlands are included in the definition of receiving waters, but constructed wetlands that have been built primarily for the purpose of stormwater treatment, are not.
Retrofit	The addition of new technology or features to older, established, urban systems.
Riparian	The interface between land and a flowing surface water body. Plant communities along the river margins are called riparian vegetation, characterised by hydrophilic plants. Riparian zones are significant in ecology, environmental management, and civil engineering due to their role in soil conservation, their biodiversity, and the influence they have on aquatic ecosystems. Riparian zones occur in many forms including grassland, woodland, wetland or even non-vegetative forms. In some regions, the terms 'riparian woodland', 'riparian forest', 'riparian buffer zone' or 'riparian strip' are used to characterise a riparian zone.
Run-off	Rainwater that runs off surfaces such as roads and parking lots and is collected in stormwater infrastructure or flows directly into natural channels.
Terrestrial	Related to the land, as opposed to air or water.
Treatment Train	A series of stormwater treatment devices that collectively address all stormwater pollutants.
Sand Filter	Stormwater passes through and is treated by a filter media (typically sand) absent of vegetation. Sand filters do not incorporate vegetation because the filter media does not retain enough moisture to support plant growth and they are often installed underground. Sand filters require pre-treatment to remove litter, debris and coarse sediments.
Sediment	Particulate matter, such as sand or mud, that is generally derived from the land and can be suspended and transported by fluid flow.
Sedimentation Basin	A small pond or basin created to retain runoff long enough to allow coarse sediment and debris to settle out.
Sewage	see Wastewater.
Scouring	Severe erosion caused by water.
Stormwater	Surface water runoff following a rain event (including piped flows) from urban surfaces (roads, pavements, rooftops, car parks and vegetated open space).
Stormwater Harvesting	The capture of stormwater run-off for reuse.
Swales	Shallow, open, vegetated channels used to convey stormwater and to provide removal of coarse and medium sediments. The vegetation in swales can range from mown turf to sedges and rushes. They are commonly combined with buffer strips and bioretention systems.
Total Nitrogen (TN)	A measure of all forms of nitrogen (for example, nitrate, nitrite, ammonia-N, and organic forms) that are found in the water column.
Total Phosphorus (TP)	A measure of all phosphorus components (for example, soluble and particulate forms) that are found in the water column.
Total Suspended Solids (TSS)	A measure of the mass of solid material (organic and inorganic) suspended in water (commonly mg/L).
Urban Development	Non-rural forms of development including rural residential, suburban and dense urban (including residential, commercial, and non-rural industrial). Urban development forms could comprise greenfield, redevelopment, infill and retrofit of urban built infrastructure.
Urban Water Cycle	The cycle of water through the urban environment including potable water, wastewater and stormwater.
Wastewater	Any water that has been used at least once and cannot be used again without being treated. Treated wastewater can often be used for recycling purposes depending on the level of treatment undertaken.
Water Conservation	An approach to reducing the overall demand for water. It is also called demand management. Water conservation measures include educating people about how to save water and promoting the use of household and industrial appliances that use water more economically, such as dual-flush toilets.
Water Cycle	The cycle of water through the environment including rain, flow over and under the land and transpiration back into the atmosphere.
Water Quality	Physical, chemical and biological characteristics of the water column, including nutrients and sediment.
Water Quality Objectives	Measurable goals for the quality of receiving waters to ensure environmental values are protected.
Water Recycling	The multiple use of water, usually sourced from sewerage or stormwater systems, that is treated to a standard appropriate for its intended use.
Water Sensitive Urban Design	A holistic approach to the planning, design, construction and retrofitting of urban development that aims to minimise negative impacts on the natural water cycle and protect the health of aquatic ecosystems. It promotes the integration of stormwater, water supply and sewage management within a development precinct.
Water Sensitive Cities	A new policy initiative of the Australian, State and Territory Governments that aims to ensure environmental protection and repair, water supply and economic stability, enlightened social and institutional capital and diverse and sustainable technological choices.
Xeriscaping	A new term used for water-conserving gardens, landscaping to minimise water use by featuring plant species adapted to the local environment that require little or no irrigation. Plantings are also replacing planting with non-vegetative landscaping elements.

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