EVALUATING OPTIONS FOR WATER SENSITIVE URBAN DESIGN - a national guide

Prepared by the Joint Steering Committee for Water Sensitive Cities
in delivering Clause 92(ii) of the National Water Initiative

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Evaluating Options for Water Sensitive Urban Design – A National Guide

Preface

This document – *Evaluating Options for Water Sensitive Urban Design (WSUD*) is a comprehensive national reference, providing guidance on how WSUD options can be evaluated for those assessing and designing water sensitive urban developments.

The guidelines have been developed in accordance with National Water Initiative Clause 92 (ii) by the Joint Steering Committee for Water Sensitive Cities and funded under the Raising National Water Standards program. The Guidelines are intended to assist in advancing WSUD within Australia and facilitate better and more efficient management of water in urban areas.

In addition to these Guidelines, the Joint Steering Committee has undertaken further work to review *icon WSUD* developments and incentives to stimulate WSUD developments. Outputs from this work is set out are provided in the ICON Water Sensitive Urban Developments report (CSIRO) and in the Incentives to Stimulate WSUD report (EDAW).

Acknowledgements

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Local Government and Planning Ministers' Council
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National Environmental Protection Council
NSW Department of Water and Energy
NT Environmental Protection Agency
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1 INTRODUCTION

1.1 Background

Australia is a nation where the majority of people live in cities or towns. The impact of these cities and towns spreads far beyond the actual extent of developed areas, specifically via:

- The requirement for large (upstream) land areas to supply, capture and store water for urban use;
- The discharge to (downstream) receiving waters (rivers, lakes, estuaries and coastal areas) of a cocktail of wastewater and stormwater discharges; and
- The significant modification to natural hydrological regimes and associated ecological processes in waterways upstream, within and downstream of the urban areas.

As well as the 'ecological footprint' analogy outlined above, factors compounding these effects include increasing populations, the progressive realisation that the supplying and receiving resources around our cities and towns are finite, and climate change. Climate change in particular is one of the greatest challenges facing Australia. The high dependency of Australian water supplies on surface water sources means that Australia is particularly vulnerable to climate change, with alterations in rainfall patterns and increases in evaporation rates reducing catchment yields. While pressure on water supply has always existed in Australia due to the arid nature of much of the continent and the highly variable rainfall, recent drought conditions have highlighted Australia's vulnerability to climate change. Major urban centres in Australia face increasing water shortages in the future.

In order to assist in addressing the above[1], the Australian, State and Territory Governments have put in place an inter-governmental agreement - the National Water Initiative (NWI), which is a comprehensive national strategy to improve water management across the country. The NWI encompasses a wide range of water management issues and encourages the adoption of best practice approaches to the management of water in Australia.

In the context of urban water management, the NWI is intended to facilitate better and more efficient management of water in urban areas. It is recognised that Water Sensitive Urban Design (WSUD), this being the integrated design of the urban water cycle, incorporating water supply, wastewater, stormwater and groundwater management, urban design and environmental protection, is a key way in which this objective can be achieved. These guidelines are intended to assist in advancing WSUD within Australia.

1.2 Purpose of these Guidelines

These guidelines have been developed in accordance with NWI Clause 92(ii), as follows, and focus on providing guidance on WSUD option ***evaluation***, rather than addressing in detail issues such as WSUD concept formulation, design, operation, etc:

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[1] It is important to note, independent of the NWI, that for local or regional imperatives many State/Territory/Local Governments within Australia have been advancing significant activities in this field, to varying degrees.

> *"Develop National Guidelines for evaluating options for water sensitive urban developments, both in new urban subdivisions and high-rise buildings"*

These Guidelines:

- Identify issues that should be considered in evaluating strategies to achieve WSUD;
- Provide a consistent framework which can be applied nationally for the facilitation and evaluation of WSUD proposals. The framework may be used by developers and development assessors and will maximise the success of WSUD proposals;
- Supplement (but not replace) existing WSUD regulations and detailed design and implementation guidelines. In areas where local guidelines don't exist, these Guidelines may assist with the assessment and evaluation of WSUD proposals;
- Direct readers to more detailed technical WSUD literature on specific issues and for location specific advice; and
- Could be used or considered in developing WSUD planning scheme provisions.

After considering and appraising these National Guidelines, the reader is encouraged to specifically address and, where appropriate, apply the following:

- State or Local Authority specific construction phase erosion and sediment control guidelines and requirements;
- Existing State or Local Authority specific comprehensive WSUD technical documentation;
- Regional initiatives or strategies for the implementation of WSUD; and
- Established State or local area specific targets to be applied when considering WSUD strategies.

In all instances, relevant State or Local Authority requirements override advice provided in these Guidelines.

These Guidelines focus primarily on the final or built form of a WSUD oriented development. It is important to note that stormwater management during the construction phase of such a development, as addressed by the need for careful erosion and sediment control planning and implementation, is also important. Without proper site management, construction stage sourced litter and sediment can cause irreparable damage to stormwater management devices and the environment. These guidelines do not address this issue in detail as such information is provided in other relevant State and National publications. It is important that such issues be considered during the planning of how a WSUD (or any other) project is implemented.

These Guidelines have a primary orientation of addressing the water quantity, water quality, planning, environmental and amenity elements of a WSUD project. Specific consideration is not given to the energy consumption and greenhouse gas implications of WSUD in any of the evaluation processes. Such considerations are still the subject of research and system scale investigations.

These guidelines do not imply nor promote an 'all or nothing' approach to WSUD. Rather, it would be preferable to see the ideals and objectives espoused in these guidelines being progressively or incrementally applied, thereby enabling improved knowledge of how these measures operate and how they should be designed to be collected, at the same time minimising the risks of implementation problems which could adversely affect subsequent WSUD take up.

In addition to these guidelines, further case study developments and "icons" are discussed in the ICON Water Sensitive Urban Developments report (CSIRO 2008).

1.3 What is WSUD?

In its broadest context, WSUD is the integrated design of the urban water cycle, incorporating water supply, wastewater, stormwater and groundwater management, urban design and environmental protection. It represents a fundamental shift in the way water and related environmental resources and water infrastructure are considered in the planning and design of cities and towns, at all scales and densities. WSUD aims to see all streams of water being managed as a resource, as they have quantitative and qualitative impacts on land, water and biodiversity, and the community's aesthetic and recreational enjoyment of waterways. This applies at all levels of urban water governance, i.e. community, institutional and government

WSUD is based on the premise that the process of urban development and (importantly) redevelopment needs to address adequately the sustainability of the water environment.

A planning and design approach is adopted in WSUD that integrates the following potential opportunities into the built form of cities and towns:

- The use of water efficient appliances and rainwater, stormwater, wastewater, groundwater and greywater reuse as alternative sources of water to conserve potable supplies;
- Detention, rather than rapid conveyance, of stormwater;
- Reuse, storage and infiltration of stormwater, instead of drainage system augmentation;
- Use of vegetation for stormwater filtering purposes;
- Water-efficient landscaping to reduce potable water consumption;
- Protection of water-related environmental, recreational and cultural values by minimising the ecological footprint of a project associated with providing supply, wastewater and stormwater services;
- Localised wastewater treatment and reuse systems to reduce potable water consumption and minimise environmentally harmful wastewater discharges;
- Provision of stormwater or other recycled urban waters (in all cases subject to appropriate controls) to provide environmental water requirements for modified watercourses[2];
- Flexible institutional arrangements to cope with increased uncertainty and variability in climate; (Brown et al (2007)).
- A focus on longer term planning;
- A 'diverse portfolio' of water sources, supported by both centralised and decentralised water infrastructure (refer to the PMSEIC (2007)); and
- Ongoing monitoring, evaluation and review.

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[2] The above material was edited from original text extracted from Australian Runoff Quality, Chapter 4 Water Sensitive Urban Design

The overall objectives of WSUD include:

- Reducing potable water demand through demand and supply side water management, incorporating the use of water efficient appliances and fittings as well as a fit-for-purpose approach to the use of potential alternative sources of water;
- Minimising wastewater generation and treatment of wastewater to a standard suitable for effluent reuse and/or release to receiving waters;
- Treating stormwater to meet water quality objectives for reuse and/or discharge;
- Restoring or preserving the natural hydrological regime of catchments;
- Improving waterway health by the management of the previous two objectives;
- Improving aesthetics and the connection with water for the residents of developments where it is applied; and
- Promoting a significant degree of water related self sufficiency within a development by optimizing the use of water sources from within the development to minimise potable water inflows and water outflows from a development, both stormwater and wastewater.

The most innovative WSUD approaches also incorporate the design of localised water storage, treatment and reuse technologies. Such approaches, often referred to as distributed systems, can involve the application of these alternative technologies at lot, neighbourhood or district residential scales or for commercial/industrial/high rise developments.

The move towards WSUD practices is part of an international trend towards integrated urban water management. The growing number of examples of these forms of development highlights this trend.[3]

When applied to the design and operation of urban developments, WSUD adopts an integrated approach of combining potable water, wastewater, stormwater quantity and stormwater quality management. The outcome is a site-responsive range of design solutions. Urban design and layout will be influenced by WSUD design objectives for a development and the adopted suite of urban water management measures will be similarly influenced by urban design considerations. These may include storage of stormwater at, or near, its origin, with subsequent reuse of collected stormwater to replace potable supplies, slow release to groundwater or downstream receiving bodies. Stormwater detention and/or retention and infiltration (which can help retain water in the environment, provide water to vegetation, counteract the ‘urban heat island effect’ and replenish groundwater) are the principal elements in this more storage-oriented system. Important construction stage erosion and sediment control issues should also be considered in regard to how appropriate management measures can interface with the ultimate built form of a project to ensure environmental protection during the construction phase, as well as protection of stormwater treatment measures (which can be otherwise smothered by sediment).

This *integrated* approach is gaining acceptance as being preferred to the more traditional (*separate*) potable, wastewater, stormwater systems, and a conveyance-oriented approach to stormwater management, because it can:

- Reduce the quantities of potable water required, and wastewater produced, by a development;

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[3] Edited from original text extracted from Australian Runoff Quality, Chapter 4 Water Sensitive Urban Design

- Minimise stormwater pollution and water balance problems by ensuring hydrological regimes change minimally from pre-development conditions; and
- Reduce development costs[3].

This integrated approach also has synergistic benefits between what were (formerly) separate urban water streams. For example, harvesting stormwater for open space irrigation has downstream river morphology/flood/water quality benefits, potable water supply security benefits and local open space and groundwater benefits.

Recent experience also suggests WSUD projects may retail for a premium, offsetting potentially higher initial costs for WSUD implementation[4].

1.4 Where did WSUD come from?

The term 'Water Sensitive Urban Design' was originally coined in Western Australia (Whelans et. al. 1994) to describe a new Australian approach to urban planning and design and was first referred to in various publications in the early 1990's (Lloyd 2001). A wider international movement towards the concept of integrated land and water planning and management has paralleled the emergence of WSUD in Australia. The underlying aim of this shift is the need to provide more economical, and less environmentally damaging, ways of providing urban water, wastewater and stormwater solutions.[5]

1.5 Where is WSUD being applied in Australia?

WSUD is being encouraged widely across Australia, with the transition of such to real, on the ground, works having been more readily accepted in some areas than others. These guidelines are intended to assist with the adoption of WSUD on a more widespread scale. In some States/Territories, WSUD is mandatory for certain scales and types of developments.

By way of example of where WSUD techniques have and are being successfully applied in Australia, the case studies in Table 1-1 are listed. More complete descriptions of these case studies are provided in Appendix A. The case studies have been categorised into the respective fields of greenfield, retrofit/brownfield and multi-storey (realising that these fields are not mutually exclusive) in order to demonstrate that WSUD is **not** only applicable to greenfield residential developments. In fact, it is both retrofit and redevelopment where WSUD can have the most benefit in improving existing degraded water quality (Weber 2008).

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[4] Walker et al 2002 suggested that WSUD may add 0.5% to the overall project budget mainly due to unfamiliariaty with construction techniques leading contractors to include a "safety margin" in project costs. There was also strong support for WSUD adoption within the development studied.

[5] Edited from original text extracted from Australian Runoff Quality, Chapter 4 Water Sensitive Urban Design

Table 1-1 Example WSUD Applications in Australia

State	Project	Field(s) of Development
QLD	Pimpama Coomera Water Futures Project	Greenfield
QLD	Springfield Development	Greenfield
QLD	Carindale Pines	Greenfield
QLD	The Healthy Home	Retrofit
NSW	Fig Tree Place	Redevelopment
NSW	Kogarah Town Square	Retrofit/Multi-Storey
VIC	Lynbrook Estate	Greenfield
VIC	Doncaster Park and Ride	Retrofit
SA	New Brompton Estate	Retrofit
SA	Salisbury City Council ASR scheme	Retrofit
WA	Ascot Waters	Retrofit

1.6 Relationship to State/Territory Legislation and Guidelines

This document provides guidance on evaluating WSUD projects in Australia, to promote the uptake of this approach to more sustainable urban water management. All Local Governments, States and Territory Agencies are encouraged to consider the adoption of the WSUD principles and techniques presented in this document. However, these guidelines are not mandatory and have no formal legal status. The adoption of national guidelines provides a shared national objective, while allowing flexibility of response to different circumstances at regional and local levels. Application of these guidelines may vary between States/Territories, depending on local water management and other arrangements.

Aspects of WSUD addressed in these Guidelines are regulated by States/Territories and are not controlled by the Australian Government. State or Local jurisdictions may use their own legislative and regulatory tools to refine these Guidelines into their own locally specific material. Relevant State/Territory regulations, standards or guidelines, where they exist, should be consulted to ensure that any local requirements are met. Where State/Territory guidelines differ from this document, the State/Territory guideline should be followed or the local planning or regulatory agency consulted to clarify appropriate requirements.

State/Territory regulatory frameworks which may be relevant to WSUD could include:

- Planning approvals;
- Water resource allocation;
- Natural resource management, including works in watercourses or riparian zones;
- Public health;
- Pollution control; and
- Dam safety.

1.7 Guidelines Structure

These Guidelines are structured as follows

- **Chapter 2** provides guidance in regard to WSUD objective setting;
- **Chapter 3** introduces the various techniques which can be used to configure a WSUD which will then achieve the objectives derived in accordance with Chapter 2;
- **Chapter 4** provides guidance on how to assess WSUD options;
- **Chapter 5** discusses some of the actual and perceived risks and issues associated with WSUD;
- **Chapter 6** provides guidance in regard to potential monitoring requirements of a WSUD project;
- **Chapter 7** directs the reader to more detailed State or Local Government specific WSUD guidance material;
- **Appendix A** provides several WSUD Case Study examples;
- **Appendix B** provides detailed descriptions of relevant WSUD Best Management Practices; and
- **Appendix C** provides a Glossary of Terms.

1.8 Target Audience

The target audience for these Guidelines comprises engineering consultants, land developers, architects, building and construction industry professionals, strategic urban planners, urban designers, landscape architects and development assessment staff involved in the formulation and evaluation of WSUD strategies.

It is assumed that the reader is familiar with the land development process, the planning framework for land rezoning and the development approval processes in their local area.

1.9 Guidelines Usage

These Guidelines are intended for use in the following ways:

- ***Developers, Strategic Urban Planners, Urban Designers*** – The Guidelines will assist with the identification and scoping of issues that affect the urban water cycle as well as be able to advise on the general principles and issues that need to be considered when formulating a WSUD. Issues will be identified that should be discussed with the local development assessment authority to minimise the time involved in the approval process through lack of information in the original application.
- ***Consultants, Landscape Architects*** – While formulating WSUD plans, the Guidelines will assist with improved understanding of the issues that need to be addressed to meet the requirements of the local development assessment authority, thereby expediting the approval process.
- ***Development Assessment Authorities*** – The Guidelines will assist authorities by identifying issues that need to be considered when evaluating a WSUD project. The issues may, in some cases, require the regulator to undertake separate evaluations to establish local criteria and benchmarks. Once these benchmarks are known, they will be available to the proponents of a

WSUD project and all relevant issues will be known to all parties so that the subsequent applications should be consistent and address all requirements of the regulators or drainage authorities.

A number of Uniform Resource Locator (URL) links to web sites have been included in these Guidelines. With time, some of these links may change for reasons beyond the control of the authors of these Guidelines, however the benefits of inclusion of the links are considered greater than the potential inconvenience which may be caused by gradual changes in web site locations and content.

2 WSUD OBJECTIVE SETTING

The implementation of WSUD requires the clear definition of design and performance objectives that are to be achieved through its application. These objectives ensure consistency within a region in the delivery and integration of WSUD and facilitate achievement of the desired overall water and environmental protection objectives of WSUD. It should be noted that current best practice may not achieve the necessary improvements necessary to achieve the environmental and/or water protection objectives and as such, targets that are set relative to the performance of current best practice should be regularly reviewed in order to narrow the gap between what is actually required to protect ecological systems and the performance of latest technologies with regards to WSUD.

For many areas within Australia, such objectives will already have been defined by the development of various forms of management plan (e.g. stormwater management plans, catchment management plans, water quality management plans, etc) that will have included specific input from community and government bodies. Where such material already exists, it should be used as the basis for WSUD objective setting.

Objectives can apply at varying scales, such as broad regional objectives that may identify overall goals for receiving environments such as oceans, rivers and estuaries, down to the local scale where specific objectives may apply to creek health, house lot configurations, and road design. Section 4 presents further guidance on applying and assessing objectives at the broad, local and fine scale.

Objectives can represent a variety of overall design intents and policy directions, and ideally there will be consistency between objectives across various agencies at Local, State and National levels. Figure 2-1 represents the groups of objective that are most commonly applied, though locally specific objectives (e.g. road design elements, maintenance pathways etc) may also be required.

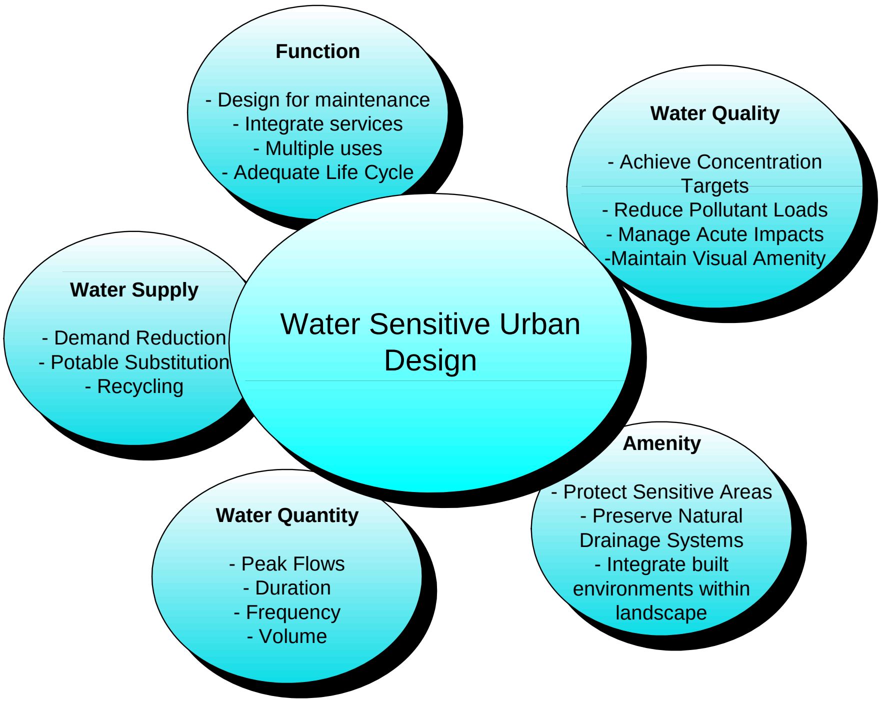

Figure 2-1 WSUD Objectives

A description of the key factors that should be considered in setting and applying specific groups of objectives is provided below.

2.1 Water Quality

The implementation of WSUD is a key technique to minimise the diffuse pollution load which may be derived from urban areas, to reduce point source/wastewater discharges and to preserve the hydrologic regime of natural drainage systems, all of which will contribute to improved ecological health outcomes of waterways. Without such intervention, the water quality, health and amenity of waterways upstream, within and downstream of an urban area can be seriously degraded.

Most areas of Australia will have relevant urban pollutant (both wastewater and stormwater) load reduction targets. Compliance of a WSUD project with such objectives can be assessed using commonly applied and accepted software tools such as MUSIC (Model for Urban Stormwater Improvement Conceptualisation) for stormwater quality - (http://www.toolkit.net.au/cgi-bin/WebObjects/toolkit.woa/1/wa/productDetails?productID=1000000&wosid) and Aquacycle for potable water and wastewater flow management assessments (http://www.toolkit.net.au/cgi-bin/WebObjects/toolkit.woa/1/wa/productDetails?productID=1000043&wosid=GwTxvc4k2nQrgDnRdOZBbw). Other tools such as UVQ, WaterCRESS and Hydroplanner may also provide benefit. Ongoing research in Australia by the eWater CRC (http://www.ewatercrc.com.au/) and other bodies will progressively provide new and improved tools in this regard.

Relevant performance objectives should be used as primary performance criteria against which a WSUD is assessed for its ability to ensure protection of receiving water quality. Typically, specific guideline values are available at Local, Regional and State levels, identifying both the performance objectives and where they are to be applied.

In regard to stormwater, in cases where greater than practical load reductions are required to ‘achieve’ environmental protection, it is usual to default to ‘best practice’ standards. Such standards may vary between regions, and local guidelines and manuals should be consulted.

Section 2.3 of these Guidelines introduces potential objectives which could be applied to the water supply and wastewater elements of the urban water cycle in association with WSUD. There are significant receiving water ecological health related benefits associated with complying with such water supply and wastewater performance standards, for example:

- Effluent reuse is both a water source and a pollution reduction/water quality improvement strategy; and
- Reducing sewage flows can reduce sewer overflows, which will have a direct water quality and ecosystem health benefit.

Example *stormwater quality* related conditions which a Local Authority could place on a development are shown below. It should be noted that these objectives are a surrogate for achieving improved ecosystem health of waterways, however this is not as easily assessed or measured, so water quality targets are specified that, if complied with, may assist in maintaining and/or improving ecosystem health. It should also be noted that these example conditions may not necessarily be transferable across all regions in Australia and as such, appropriate local targets should be derived. Section 2.3

of these Guidelines provides example water supply and wastewater objectives which, as stated above, can have a definitive water quality benefit:

- *During the construction phase, total suspended solids concentrations for all flows up to the 1 yr Average Recurrence Interval event to be less than 100 mg/L; and*
- *During the operational phase, achieve the following minimum reductions in total pollutant load, when compared to untreated stormwater run-off:*
    - *80% reduction in total suspended solids.*
    - *60% reduction in total phosphorus.*
    - *45% reduction in total nitrogen.*
    - *90% reduction in gross pollutants.*

2.2 Water Quantity – Hydrologic Management

One of the major benefits of implementing WSUD is that in enables the management of not only water quality, but of the hydrology of the catchment in which it is applied. When urban development occurs in an area that was previously dominated by vegetation, increases in both hard surfaces, and the efficiency of the drainage system are usually the result. This leads to not only increased flows, but also far more rapid delivery of those flows and the associated pollutants into the receiving environment. The introduction of WSUD measures can lead to a severing of the connection between the hard surfaces and the drainage system which can therefore lead to both a reduction in flow volumes through increased infiltration and/or retention, and also a slowing down of water travelling to the drainage system, resulting in reduction in flow velocities and opportunities for settlement and biological removal of pollutants.

WSUD can assist in managing the water quantity impacts of a development if design techniques focussing on water detention, harvesting/reuse and infiltration are included.

Specific water quantity objectives may relate to the following:

- Ensuring that peak runoff flows do not exceed those of the pre-existing condition of the site;
- Maintaining flow volumes equivalent to the undeveloped site;
- Managing flow durations and flow velocities, such that downstream waterway morphology is not affected[6];
- Providing infiltration to ensure maintenance of groundwater systems;
- Ensuring that the frequency of flows from the developed site (which can be significantly increased due to the greater proportion of effectively, or directly connected, impervious area) is similar or equivalent to that of the undeveloped case; and
- Providing stormwater or other recycled urban waters (in both cases, subject to appropriate control) to provide environmental water requirements for water courses that have been modified.

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[6] Greater than 10% effective impervious area (those hard surfaces which are most efficient at converting rainfall to runoff and delivering it to downstream waterways) has been shown to result in significant deterioration of downstream aquatic ecosystems (Fletcher and Walsh 2007)

It should be recognised that WSUD elements in isolation will be unable to address all flooding/hydraulic requirements, but that they may be integrated within the overall hydraulic design of a development.

There are obvious synergies between the various water conservation elements of WSUD (e.g., rainwater tanks, stormwater harvesting and reuse, aquifer storage and recovery) and stormwater quantity requirements which should be considered when conceptualising, designing and evaluating a WSUD project. One obvious example in this regard is using a portion of a rainwater tank for stormwater detention and the remainder for storage and reuse.

Example conditions which a Local Authority could place on a development are as follows (once again, locally specific targets should be derived wherever possible):

- *Capture and infiltrate or reuse the first 15 mm/day of run-off from all impervious surfaces; and*
- *Limit the post-development peak 1 yr Average Recurrence Interval event discharge to the receiving waterway to the pre-development condition.*

2.3 Water Supply and Wastewater

One of the major advantages of WSUD is the ability to incorporate measures that can benefit all components of the urban water cycle. WSUD elements such as demand management, rainwater tanks, aquifer storage and recovery and stormwater/greywater/wastewater reuse can all be useful elements in achieving potable water and wastewater flow reduction objectives.

Specific objectives are usually focused on the following:

- Substitution of potable water supply (e.g. irrigation of parks and gardens with harvested stormwater or recycled wastewater, provision of a third pipe recycled water system to industrial users, use of collected rainwater for domestic toilet flushing, external applications, hot water supply (with appropriate controls) and cold water supply to the laundry);
- Improvement in waste water quality through additional treatment to allow for more beneficial uses;
- Reduction in potable demand (e.g. 40% (or as appropriate to the local area) reduction in potable water usage); and
- Wastewater reuse (e.g. 40% (or as appropriate to the local area) reduction in wastewater discharge).

One important concept of water supply provision associated with WSUD is ‘fit for purpose’. Specifically, this implies that not all water used in a household or urban area (including industrial and commercial applications) needs necessarily to be potable quality. An example in this regard is toilet flushing, for which lower grade water can readily be used. Relevant State and Local guidelines which define acceptable qualities of water which embrace the ‘fit for purpose’ concept should be consulted and used to advance the water conservation and recycling aspirations of WSUD.

2.4 Natural Function and Amenity

One of the key features of WSUD is the ability to use vegetation as part of the overall landscape aesthetic, thus improving the amenity and overall function of a development. Usually objectives for preserving or enhancing amenity are not deterministic, i.e. there are no quantitative values that can be associated with them. What WSUD allows however is for the built environment to 'integrate' within the natural fabric. Objectives therefore tend to focus on aspects which promote this.

Some typical examples, or themes, of amenity objectives are as follows:

- Ensure the sustainability of landscape amenity through design which accounts for longevity of the system, considering maintenance and community use aspects (e.g. vandalism, litter protection);
- Provide 'green' elements and visual breaks in the urban landscape;
- Maximise the use of appropriate native vegetation to enhance the local environment, improve stormwater quality (due to generally reduced fertiliser requirements) and assist with water conservation;
- Identify the broad character area in which the site is located;
- Preserve valuable natural water environment features such as riparian corridors and wetlands; and
- Identify the landscape character elements that are important for the site.

Other more landscape orientated objectives can include:

- Consistency with the current character of the area;
- The qualities of the existing or built environment landscape are retained;
- Retention of existing landscape and heritage features;
- Social and recreational opportunities are provided; and
- Important view and vistas are retained.

Amenity may also include desired overall objectives for the preservation of existing natural features within the urban fabric, including:

- Protection and enhancement of waterways, wetlands and their buffers;
- Protection of aquifers and groundwaters beneath a WSUD site;
- Ensuring appropriate development setback from waterways and wetlands;
- Protection of remnant vegetation communities;
- Retention and reinstatement of native vegetation; and
- Natural channel design responses for natural gullies and waterways.

Finally, amenity should also consider the overall social aspects of implementation of WSUD, which also tend to be relatively intangible. It is important to recognize that these objectives may be set for the overall development, rather than specifically applying to WSUD.

Key objectives, focusing on the social aspects, may include:

- Public safety (e.g. improved lighting, safety benching in water features, visibility);

- Improving connections through WSUD assets (e.g. boardwalks through wetlands, grassed swales as walking trails etc);
- Community enhancement (e.g. urban renewal); and
- Recreational opportunities.

2.5 Functionality and Operational Issues

Issues relating to the maintenance and ongoing operation of WSUD elements, and their adoption in constrained or existing urban areas are critical, and need to be considered in the objective setting process. Objectives relating to this should therefore consider the following:

- Designing for maintenance (e.g., access pathways, consideration of machinery required, drying areas etc);
- Utility placement;
- Provision of maintenance plans with any WSUD asset;
- Providing dedicated service corridors within particular elements (e.g. grassed swales);
- Consideration of multiple use corridors, wherever possible (e.g., drainage paths aligning with service locations); and
- Designing for minimum life-cycle costs, with specific consideration of regular maintenance and asset renewal.

Local authorities should therefore consider these guidelines in terms of existing design guidance and evaluation processes to ensure that WSUD is delivered in an integrated manner consistent with existing guidelines and policies.

3 OPTIONS FOR ACHIEVING WSUD

WSUD incorporates water cycle management and environmentally oriented sustainability measures at all levels of the urban development process (i.e. strategic planning, concept planning to detailed design). Achieving WSUD objectives requires more than constructing a lake or wetland system. Fundamental to the philosophy of WSUD is the integrated adoption of appropriate Best Planning Practices (BPPs) and Best Management Practices (BMPs).

Figure 3-1 outlines how BPPs and BMPs combine in the design process to achieve WSUD objectives and highlights the role these Guidelines play in providing a means of assessing and evaluating a WSUD.

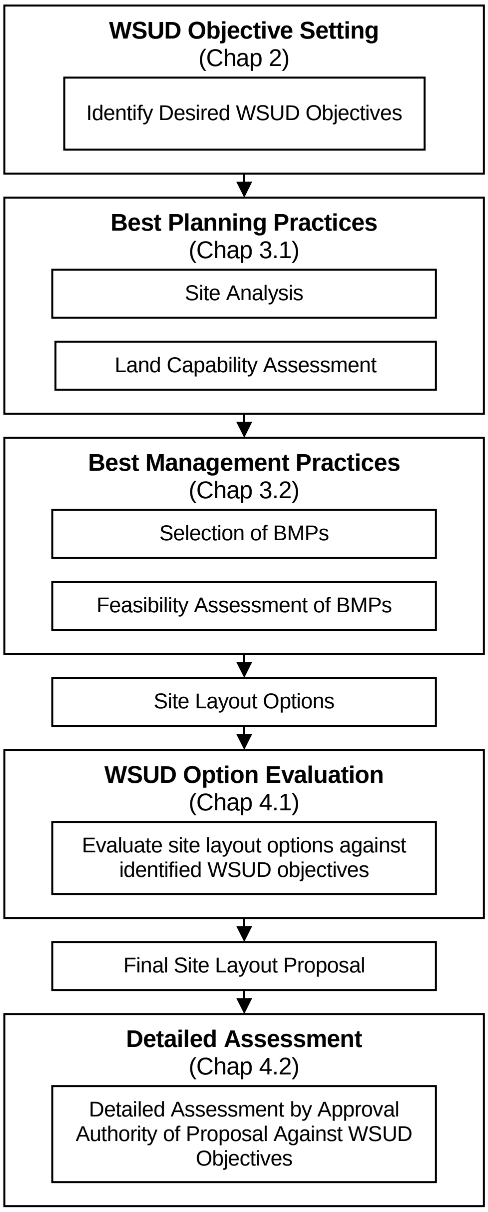

Figure 3-1 Overview of Steps Involved in Implementing WSUD

In regard to Figure 3-1, Chapter 2 of these Guidelines has provided advice in regard to the first step, that being the identification of WSUD objectives. Subsequent sections of this chapter introduce the ‘building blocks’ of WSUD, these being Best Planning Practices and Best Management Practices. Chapter 4 then provides guidance in regard to how to evaluate and assess a WSUD scheme for compliance with the defined objectives.

It is noted that most of the amenity, open space and general ‘planning’ elements of a WSUD are introduced via BPPs, while the structural elements of WSUD are achieved via BMPs.

3.1 Best Planning Practices

A **BPP** refers to a site assessment, planning and design component of WSUD. A BPP is defined as the best practical planning approach for achieving or contributing to defined management objectives in an urban situation. This includes site assessment of physical and natural attributes of the site and capability assessment. Using this as a basis, the next step is integrating water and related environmental management objectives into site planning and design.

BPPs may be implemented at the strategic level or at the design level. At the strategic level, BPPs can include the decision to create a foreshore reserve, make provision for arterial infrastructure or to include water sensitive policy provisions or design guidelines in town planning schemes. At the design level, BPPs refer to specific design approaches.

BPPs can be applied at a wide range of scales within a WSUD project. Some examples of BPPs include:

- The identification and protection of land to allow for an integrated stormwater system, incorporating storage locations, drainage and overflow lines and discharge points;
- The identification of developable and non-developable areas;
- The identification and protection of public open space networks including remnant vegetation, natural drainage lines, recreational, cultural and environmental features; and
- The identification of options for the use of water-conserving measures at the design level for:
  - ➢ Road layout;
  - ➢ Building Design (e.g. encouragement of green roofs);
  - ➢ Internal services;
  - ➢ Housing layout; and
  - ➢ Streetscape (including regulated self-supply options)

A number of planning and design tools based on BPP principles have been developed which relate to the following[7]:

- Public open space networks;
- Housing layout;
- Road layout; and
- Streetscape.

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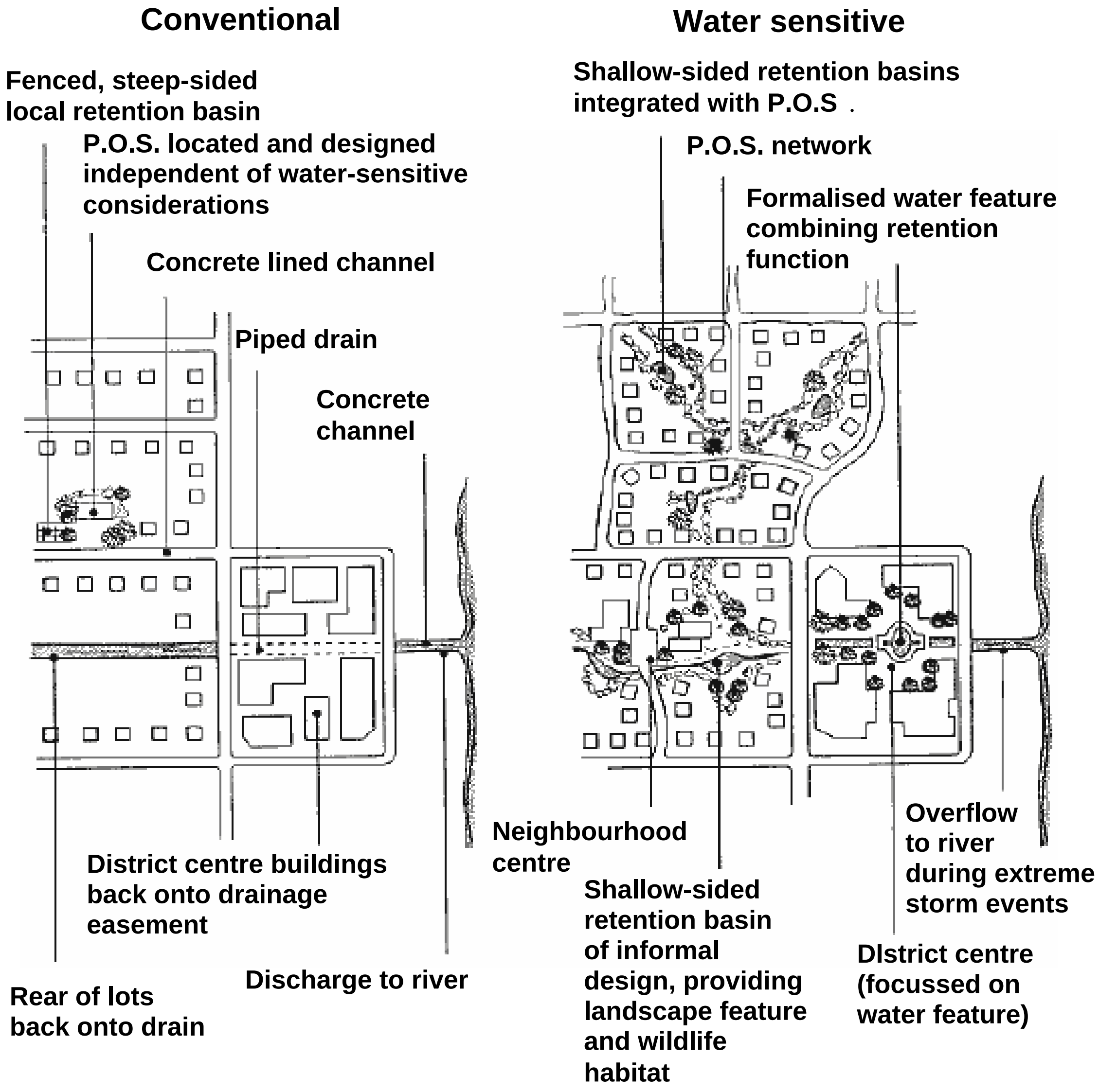
[7] This entire section has been edited from original text extracted from Australian Runoff Quality, Chapter 4 Water Sensitive Urban Design

3.1.1 Public Open Space Networks

WSUD often incorporates multi-purpose drainage corridors in residential developments. These integrate public open space with conservation corridors, stormwater management systems and recreation facilities, with commensurate social and economic benefits. Open space becomes more useable because of the opportunity to link and share space for multiple activities. Vegetated drainage corridors can also provide buffer strip protection for natural water features in the development. The development of active recreation areas next to drainage facilities can introduce some elements of public safety and health risk. This requires consideration during the design phase and can often be addressed using techniques such as safety signs and barriers. Figure 3-2 compares a 'conventional' design with a 'water-sensitive' design of a neighbourhood, incorporating public open space (P.O.S.).



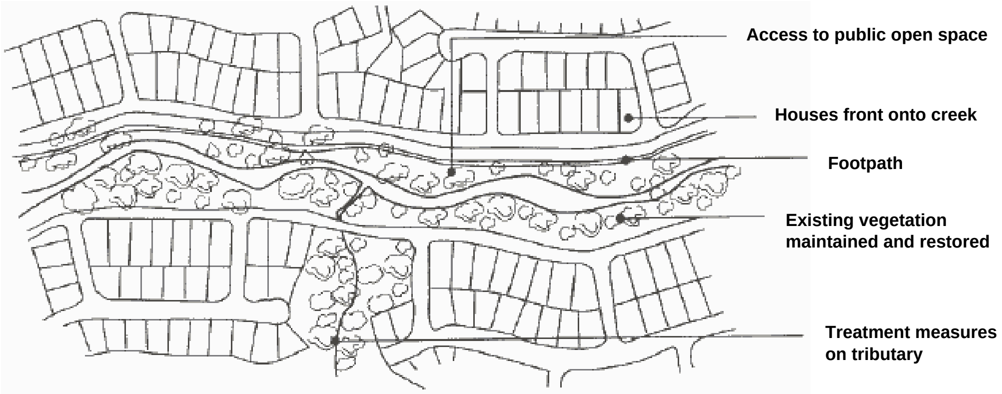
Source: Whelans et al in Engineers Australia (2006)

Figure 3-2 Networked Public Open Space Incorporated in Development

3.1.2 Housing Layout

A water sensitive housing layout integrates residential blocks with drainage function and public open space. Such housing layouts often include a more compact form of development, which reduces impervious surfaces and helps protect the water quality and health of urban waterways.

Figure 3-3 illustrates how housing layout can be adjusted to incorporate and highlight natural open space, waterway and drainage corridors.



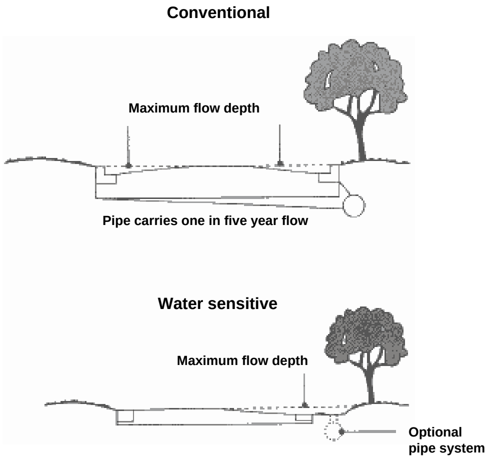
Source: Whelans et al in Engineers Australia (2006)

Figure 3-3 Integration of Housing with Waterway Corridor

3.1.3 Road Layout

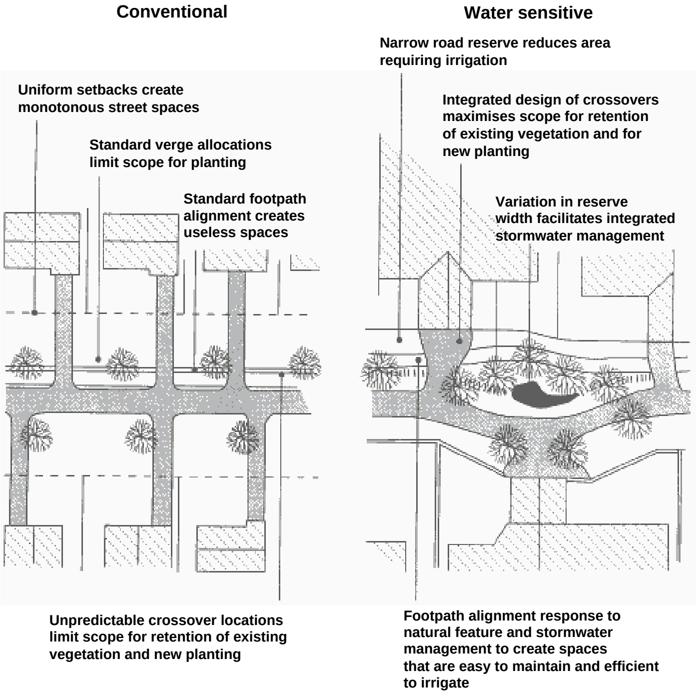
A water sensitive road layout incorporates the natural features and topography of a site. It implements the practice of locating roads beside public open spaces wherever possible. This enhances visual and recreational amenity, temporary storage, infiltration at or close to source and water quality. It also aims to minimise the extent of impervious road surfaces. As with all road design, road safety should not be compromised. Limitations also exist according to the site's topography, and in this case, road alignments that allow for shallower grades by following contours may be one possible method of facilitating WSUD implementation.

Figure 3-4, Figure 3-5 and Figure 3-6 illustrate the application of WSUD in road layout.



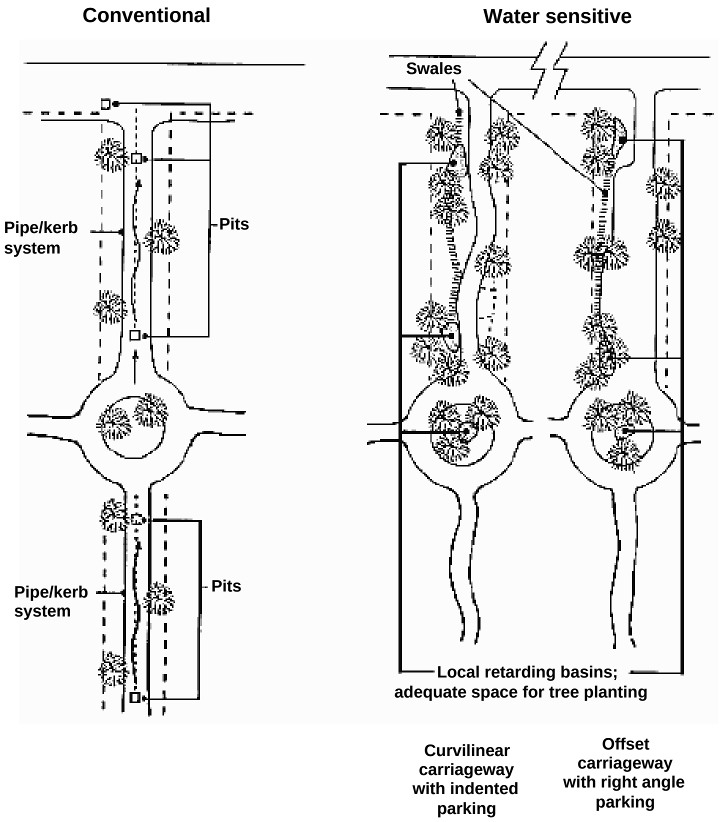
Source: Victorian Stormwater Committee (1999)

Figure 3-4 Conventional Versus Water-Sensitive Road Cross Section



Source: Victorian Stormwater Committee (1999)

Figure 3-5 Conventional Versus Water-Sensitive Road Layout



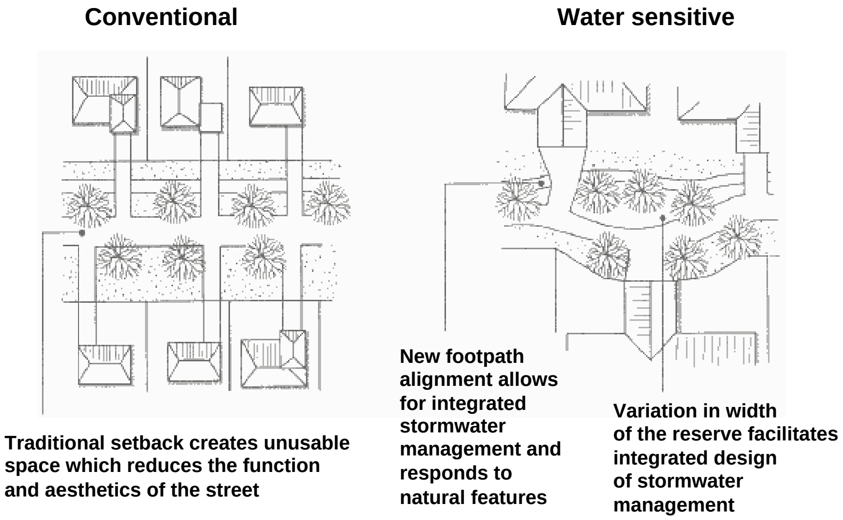
Source: Victorian Stormwater Committee (1999)

Figure 3-6 Verge Design and Management

3.1.4 Streetscape

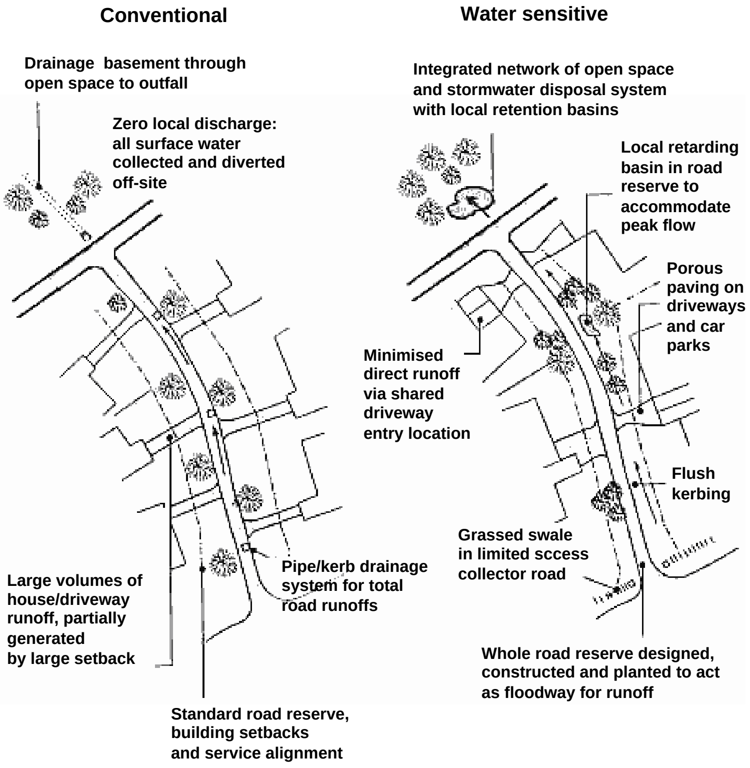
A water sensitive streetscape integrates the road layout and vehicular and pedestrian requirements with stormwater management needs. It uses design measures such as reduced frontages, zero lot-lines, local detention of stormwater in road reserves and managed landscaping.

Figure 3-7 and Figure 3-8 illustrate the application of WSUD to streetscape layout and design.



Source: Victorian Stormwater Committee (1999)

Figure 3-7 Lot/Street Interface



Source: Victorian Stormwater Committee (1999)

Figure 3-8 Streetscape Layout

3.2 Best Management Practices

A BMP refers to the structural and non-structural elements of a design that perform the prevention, collection, treatment, conveyance, storage and reuse functions of WSUD.[8]

Existing technical literature provides detailed descriptions of BMP techniques. This section of the Guidelines provides a brief overview of selected strategies and their relative key features. The reader

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[8] Edited from original text extracted from Australian Runoff Quality, Chapter 4 Water Sensitive Urban Design

is directed to the more detailed manuals listed in Section 7 of this report for greater design and performance detail on individual techniques.

There are physical constraints on the use of many of the BMPs presented below, particularly the effluent reuse, greywater and stormwater BMPs (e.g. catchment area, soils, slopes, depth to groundwater etc). The reader is referred to the relevant detailed design guidelines presented in Section 7 for more information in this regard. This is an important issue for option selection and evaluation. Also important is the ongoing maintenance obligations with the implementation of WSUD and this should be considered as part of the overall evaluation process.

For convenience, BMPs have been grouped into two generic assemblages, these being 'potable water demand reduction techniques' and 'stormwater management techniques'. In many cases there are overlaps or synergies between BMPs within these groupings (e.g. rainwater tanks and stormwater harvesting and reuse will also assist in managing stormwater quantity and quality). These groupings do not imply singularity of purpose.

Appendix B provides a more detailed description of selected practical issues associated with these techniques.

3.2.1 Potable Water Demand Reduction Techniques

3.2.1.1 Water Efficient Appliances

Use of water efficient appliances can significantly reduce household water consumption and subsequently reduce demand on potable water supplies. They also reduce wastewater generation, which in turn reduces the quantity of wastewater to be treated at treatment plants and subsequently disposed of/discharged t o the environment.

The use of water efficient appliances is encouraged and in some instances mandated in both new and existing single story, low rise and multi storey buildings and developments within Australia.

Some jurisdictions in Australia have introduced rebate schemes to promote such measures, with legislative minimum requirements for new construction often also being specified.

Relevant guidance material in regard to water efficient appliances can be found as follows:

- Water Efficiency Labelling and Standards (WELS) scheme - http://www.waterrating.gov.au/; and
- Smart Approved Water Mark scheme - http://www.smartwatermark.info.

3.2.1.2 Water Efficient Fittings

Indoor and outdoor water efficient fittings such as showerheads, taps, sprinklers and water timers all contribute to reduced water consumption while the indoor measures also reduce wastewater flows.

Recent research has found that the adoption of water efficient showerheads and dual flush toilets can reduce indoor water use and wastewater generation rates by some 15%-20% (11%-15% of total internal and external water use).

Water efficient fittings can readily be used on both new and existing single storey and multi storey buildings.

Some jurisdictions in Australia have introduced rebate schemes to promote such measures, with legislative minimum requirements for new construction often also being specified.

3.2.1.3 Rainwater Tanks

The core WSUD roles of using rainwater tanks are to conserve water through substituting potable water supply, protect urban streams by reduce stormwater runoff volumes (particularly for small, frequent storms) and reducing the loads of some stormwater pollutants entering waterways by loss of water through consumption, which in turn can lead to loads of nitrogen and other constituents present in rainwater in urban environments being reduced, and also by reducing the hydraulic load on downstream stormwater treatment devices, potentially making them more efficient. Maximum benefits are gained from rainwater tanks in this regard when the collected water is regularly used, that is if tanks are plumbed into the house and used for applications such as toilet flushing and washing machine supply. For the majority of applications, some potable top up is usually required when the rainwater tank has insufficient water. This can be either through an in-tank top up system, or may also be through an external switching valve which is triggered automatically when tank volumes fall below a certain level.

Another important benefit of rainwater tanks is the interest that is engendered in water consumption through residents becoming interested in the fluctuations in tank volume due to both water use and rainwater inflows. This can be an important mechanism to improving overall water consumption behaviour, especially where the tank is used for internal supply.

Water quality is an important consideration for all rainwater systems, especially in urban areas. Rainwater poses little health risk when adopted for non-potable uses such as garden watering, toilets, appropriate hot water supply systems and washing machines. Additional treatment may be desirable when rainwater is to be used as a potable supply. Further guidance in this regard is provided in the enHealth Council publication 'Guidance on use of rainwater tanks' which can be found at the following web site:

http://enhealth.nphp.gov.au/council/pubs/ecpub.htm

When utilised in conjunction with water efficient appliances and fittings, rainwater tanks can greatly reduce the mains water supply requirements of a WSUD configured dwelling.

Some jurisdictions in Australia have introduced rebate schemes to promote such measures, with legislative minimum requirements for new construction often also being specified.

3.2.1.4 Reticulated Recycled Water

Providing a reticulated recycled water supply (a 'third pipe' system – supplied from one or more sources such as sewer mining, stormwater harvesting, aquifer storage and recovery or advanced wastewater treatment and reticulation systems) will normally be a regional scale decision, though cluster/suburb scale systems have been proposed. Where such a supply is available, a development would normally utilise the recycled supply as a non-potable water source, targeting external usage and toilet flushing.

Both single storey and multi storey buildings can readily be connected to a reticulated recycled water supply.

There is also considerable scope for the collection, treatment and recycling of water inside high-rise office and apartment buildings (e.g. greywater being recycled for toilet flushing purposes). With the progressive trend towards apartment style living in the community, such uses are expected to increase.

3.2.1.5 Stormwater Harvesting and Reuse

The collection and reuse of stormwater for potable water substitution purposes can be undertaken on individual lots, or at the cluster or suburb scale. One of the greatest challenges facing stormwater harvesting and reuse schemes is the storage of water (when it is raining) for subsequent use (when it is dry). Urban lakes, wetlands and aquifers can provide this storage function.

3.2.1.6 Greywater Treatment and Reuse

The collection and reuse of greywater for potable water substitution purposes can also be undertaken on individual lots, or at the cluster or suburb scale. Greywater reuse can result in cost savings (to both the consumer and state water authority), reduced sewage flows and substantial savings in potable water use, especially when combined with sensible garden design. Greywater reuse needs to be applied in a manner which does not cause environmental contamination or present a public health hazard.

3.2.1.7 Changing Landscape Form

A significant proportion of water use around residential dwellings is usually in landscape and garden watering. The choice of garden plants, garden design and alternative landscaping techniques are therefore important to reduce overall water consumption. Efforts such as retaining native vegetation, converting landscape plantings in gardens and public spaces to more water efficient planting varieties, or using gardens with xeriscape forms, will reduce demands on the potable water system.

In many areas of Australia, the importance of improving landscape water consumption has been a major focus due to reducing potable water supplies and increased overall demand due to population growth. This has led to education campaigns targeting nurseries and hardware stores where garden supplies are purchased to assist in changing gardening behaviour. Many guidelines are therefore available on water efficient gardening approaches and forms.

3.2.1.8 Water Use Education Programs

Community education programs have been demonstrated to contribute to reductions in potable water consumption (e.g. Queensland Water Commission Target 140 campaign – a program which has both educative and enforcement elements - http://www.target140.com.au).

Source: Sydney Water Commission

Successful education programs have been conducted by many of Australia's larger water supply utilities.

Education campaigns alone are unlikely to be successful in achieving a site's WSUD objectives. However, they are an important component of the suite of structural (BMPs) and non-structural elements of a WSUD solution which, when applied appropriately, will achieve these objectives. It is also necessary to ensure that there is on-going 'maintenance' of the campaign so that its effectiveness is established over a long time period, rather than as a 'one-off' measure.

3.2.1.9 Aquifer Storage and Recovery

This technique, discussed in more detail in Section 3.2.2.9, is an applicable way of reducing potable water demands by storing stormwater or wastewater in appropriate aquifers and reusing it in place of otherwise potable applications.

3.2.2 Stormwater Management Techniques

3.2.2.1 Sediment Basins

Sediment basins provide a flow control and water quality treatment role, usually in the form of an inlet pond to a constructed wetland or bioretention basin.

Sediment basins are generally most effective at removing coarser sediments larger than 125μm. The amount of sediment removed is dependent upon the basin area and the design discharge, however sediment basins are typically designed to remove 70 to 90 % of sediments larger than 125μm.

The design discharge for a sedimentation basin is typically the maximum flow rate for a 1 or 2 year Average Recurrence Interval event. In a flow event greater than this design discharge, a secondary spillway directs water to a bypass channel or conveyance system, preventing the resuspension of sediments previously trapped in the basin.

Sediment basins should be designed with sufficient sediment storage capacity to ensure acceptable frequencies of desilting.

3.2.2.2 Swales and Buffer Strips

These facilities provide both a flow conveyance function, along the swale, and water quality treatment role through sedimentation and contact of flowing water with swale vegetation. The water quality treatment component provides a maximum effect for small to modest flow rates. A limited flow detention capacity can also be provided if the cross section of the swale is large relative to the flow rate.

Typical swales are created with longitudinal slopes between 1% and 4% in order to maintain flow capacity without creating high velocities, potential erosion of the bioretention or swale surface and safety hazard. Check dams can be used in steeper areas to flatten the longitudinal hydraulic grade.

The amount of pollutant removal in a swale and buffer strip system is dependent on the longitudinal slope, the vegetation height and the area/length of the swale. Swales are generally most effective at removing sediment particles larger than 125μm. Swales in isolation provide limited treatment of fine pollutants, but can provide an important pre-treatment role for other, downstream, measures.

3.2.2.3 Bioretention Swales

Bioretention swales provide both flow conveyance and storage in the swale and water quality treatment through the bioretention area in the base of the swale. The bioretention area provides maximum water quality treatment efficiencies for small to modest flow rates. Limited flow detention capacity may also be provided if the cross section of the swale is large, relative to the flow rate.

Typical bioretention swales are created with longitudinal slopes between 1% and 4% in order to maintain flow capacity without creating high velocities, potential erosion of the bioretention or swale surface and safety hazard. Check dams can be used in steeper areas to flatten the longitudinal hydraulic grade.

The amount of pollutant removal in a bioretention swale is dependent on the filter media, landscape planting species and the hydraulic detention time of the system. Pollutant removal is achieved through sedimentation, filtration of water through the filtration media and through biological processes.

3.2.2.4 Bioretention Basins

Bioretention basins provide flow control and water quality treatment functions. The annual pollutant removal efficiency for a basin can be maximised, concurrently with flow control functionality, through the use of the extended detention component of the basin for small to medium runoff events. The terms biofilter and raingarden are also used to describe bioretention systems, however raingardens are usually considered smaller, individual lot scale bioretention basins.

Bioretention basins can be used on lots where there are several buildings and the lot is under single ownership. Alternately, larger basins are frequently used as part of a development-wide WSUD strategy.

The amount of pollutant removal is dependent upon the selection of the filtration media in the bioretention, depth below underflow drains, amount of infiltration to surrounding soils and relative magnitude of the extended detention component of the basin.

Pollutant removal is achieved through sedimentation, filtration of water through the filter media and through biological processes. In the majority of cases, bioretention systems can offer a smaller footprint than other similar measures (e.g. constructed wetlands), however their use on a larger scale can be complex and hence other devices more appropriate to this scale may be more beneficial.

3.2.2.5 Sand Filters

Source: www.wsud.org

Sand filters operate in a manner similar to bioretention systems, with the exception that they do not usually support vegetation owing to the filtration media having a hydraulic conductivity (the speed at which water travels through the filter media) which is usually too high to support vegetation. The use of sand filters in stormwater management is suited to confined spaces where vegetation cannot be sustained (e.g. underground).

Sand filters typically comprise three separate chambers, respectively with sedimentation, sand filtration and overflow roles. The sedimentation chamber removes gross pollutants and medium to coarse sediments. The sand filter chamber then removes much of the medium to coarse sediment as well as some of the finer particulate and dissolved pollutants.

Regular maintenance of a sand filter is required to prevent a crust forming on the surface which decreases the infiltration capacity

3.2.2.6 Constructed Wetlands

Constructed wetland systems are shallow, extensively vegetated water bodies that use extended detention, fine filtration and biological pollutant uptake processes to remove pollutants from stormwater.

Wetlands generally consist of an inlet zone (sedimentation basin), a macrophyte zone, and a high flow bypass channel. The macrophyte zone generally has an extended detention depth of 0.25m to 0.5m, specialist plant species (depending on the desired operation and target pollutant) and a notional detention time of between 48 and 72 hours.

Wetlands can also provide a flow control function by rising during rainfall events and slowly releasing stored flows after the event has finished. To increase flow control benefits, wetlands can be constructed with extra retention or detention capacity.

When flows exceed the ‘design operational flow’ of a wetland, excess water is directed around the wetland (macrophyte zone) via a bypass channel to protect wetland vegetation and to ensure trapped pollutants are not resuspended.

Careful consideration needs to be given to potential conflicts between mosquito/midge management and optimum wetland designs to improve water quality, together with the effect of groundwater on wetland operations. As per all elements of these guidelines, Local/State specific BMP construction and operation manuals should always be consulted in this regard.

3.2.2.7 Ponds and Lakes

Ponds and lakes are artificial bodies of open water usually formed by a simple dam wall with a weir outlet structure, or created by excavating below the natural surface level. Ponds and lakes can provide water storage for stormwater reuse schemes and often form part of a flood detention system. They also serve to remove pollutants by promoting sedimentation, adsorption of nutrients and ultraviolet disinfection.

Ponds should not be used as 'stand-alone' stormwater treatment measures and require pre-treatment via constructed wetlands or other measures. In the majority of cases, ponds and lakes are usually designed as aesthetic features and therefore should be considered as receiving waters than as part of a treatment train, unless it can be demonstrated that the water quality within the pond or lake will be maintained at a suitable quality to minimise nuisance issues such as algal blooms.

Outlets for ponds and lakes can be designed to mimic historical runoff and/or predevelopment flows for a range of flood events. To prevent water quality problems in a pond or lake, they should be designed with locally appropriate minimum average turnovers as defined in local/State specific BMP construction and design manuals.

3.2.2.8 Infiltration Systems

Stormwater infiltration systems encourage stormwater to infiltrate into surrounding soils. Their performance is dependent on local soil characteristics and they are generally best suited to sandy-loam soils with deep groundwater, though systems have been built within Australia in areas of low permeability soils by ensuring sufficient detention within the design.

Stormwater infiltration systems can reduce the volume and magnitude of peak discharges from impervious areas, particularly for small storms.

Source: www.wsud.org

Pre-treatment to remove sediments is a vital component to prevent the deterioration of infiltration effectiveness over time due to clogging. For this reason, infiltration systems are generally positioned as the final element in a WSUD system, with their primary function being the discharge of treated stormwater into surrounding soil and groundwater systems.

3.2.2.9 Aquifer Storage and Recovery

Source: City of Salisbury

Aquifer storage and recovery, also referred to in some areas as Managed Aquifer Recharge, is a means of enhancing water recharge to underground aquifers though either natural means, pumping or gravity feed. Water stored in the aquifer can then be pumped from below ground during dry periods for subsequent reuse, thereby providing a low cost alternative to large surface water storages.

The overriding consideration for introducing treated stormwater or recycled water to aquifers is to ensure that there is no subsequent deterioration of groundwater quality or aquifer properties. For this reason, aquifer storage and recovery systems typically incorporate a constructed wetland, detention pond, dam or tank, part or all of which act to remove pollutants and provide a temporary storage role. The level of treatment of recycled water prior to injection or infiltration to an aquifer is dependent on the quality of the groundwater and its current use.

The viability of an aquifer storage and recovery scheme is dependent on local hydrology, the underlying geology of an area and the presence and nature of aquifers. If the salinity of an aquifer is greater than the injection/infiltration water, then this may influence the viability of recovering water from the aquifer.

3.2.2.10 Porous Pavements

Porous (or pervious) pavements are an alternative to conventional impermeable pavements with many stormwater management benefits. These surfaces allow stormwater to be filtered by a coarse sub-base, and may allow infiltration to the underlying soil. Porous pavements can also be provided with an underground tank in appropriate locations to collect filtered stormwater, which can then be used for other purposes.

A number of porous (or pervious) pavement products are, usually consists of monolithic material (i.e. a single continuous porous medium), or individual paving blocks. These are available as commercial products including:

- Pavements made from special asphalts or concrete containing minimal fine materials
- Concrete grid pavements
- Concrete, ceramic or plastic modular pavements

Porous (or pervious) pavement can be utilised to promote a variety of water management objectives, including:

- Reduced (or even zero) peak stormwater discharges from paved areas;
- Increased groundwater recharge;
- Ability to store stormwater;
- Improved stormwater quality; and
- Reduced area of land dedicated solely for stormwater management.

3.2.2.11 *Retarding Basins*

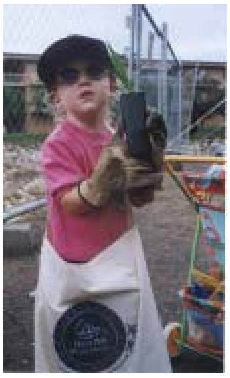
Under urban conditions, floods are made more frequent and severe because runoff is increased in both volume and rate, as a result of increased impervious areas. This increase in flood frequency adversely affects stream health because of hydraulic forces and increased sediment transport. If the hydrology can be made more natural, i.e. more like it was before urbanisation; stream health is improved. Retarding basins are designed to reduce flood frequency. Research suggests that smaller flood events (around the six months to two years average recurrence interval) cause the flow stress that affects stream health. Including a retarding basin as part of a WSUD scheme can improve the attenuation of these regular floods and improve stream health.

3.2.2.12 *Green Roofs/Roof Gardens*

A green roof system is an extension of an existing roof which involves a high quality water proofing and root repellant system, a drainage system, filter cloth, a lightweight growing medium and plants which can also be used as a rooftop food production system that meshes the technologies of aquaponics, vermiculture, rooftop water harvesting, and solar-powered air moisture harvesting. Green roofs can provide a wide range of public and private benefits, including significantly reduced fossil fuel use, reduced peak runoff rates of roof water, aesthetically pleasing cityscapes, longer roof life, and reduced ‘heat island effects’ of cities.

The use of green roofs has been prevalent in Europe, the United Kingdom and in the United States. In Australia, the need to capture roof runoff in a rain garden competes with the need to harvest the roof runoff as a secondary water source. In dryer areas of the country, green roofs may also require irrigation during prolonged dry periods to ensure that the vegetation is kept in a suitable condition. As such, the use of green roofs in Australian applications should be considered through the examination of all elements of the water cycle rather than simply as a means to reduce runoff from roof areas.

3.2.2.13 Stream and Riparian Vegetation Rehabilitation



Streams and waterways in urban areas are often heavily degraded due to the changed hydrology associated with catchment development and also may be affected by vegetation clearing and pest/weed invasion. As part of the amenity elements of WSUD and to assist in improving stream heath and stormwater quality, stream and riparian vegetation rehabilitation can be a very effective measure, supplementing the more structural BMPs presented above.

3.2.2.14 Water Quality Education Programs

Community education programs can also contribute to improvements in stormwater quality. Successful education programs have been conducted by many of Australia's larger local governments, state agencies and regional planning bodies.

3.2.3 Cost Implications

The application of WSUD measures in urban developments in Australia has been quantified by several researchers examining both applications in greenfield and retrofit applications. Further studies have been conducted into maintenance implications and the resultant cost burdens of WSUD measures for local governments. In greenfield WSUD applications in Melbourne, it was found that initial construction costs were higher for WSUD measures when compared to equivalent conventional measures (e.g. grassed swales used for conveyance compared to underground pipe work), however these costs became equivalent and in some cases, less than conventional measures when construction staff became more familiar with the methods required for WSUD implementation (Lloyd et al 2002).

For retrofit costs, a range of elements can influence the ultimate cost of the WSUD measures being constructed. These can include relocation of existing services, construction difficulties due to constrained areas for application, specific site issues such as acid sulfate soils and contaminated land and the requirement to provide other services in conjunction with the WSUD measure (e.g. flood storage, park amenities, increased conveyance capacity etc). Any or all of these elements can therefore impact on the overall cost of delivering a retrofit strategy and need to be carefully examined in the evaluation process.

Recurrent cost implications can be a challenge to quantify as most funding mechanisms are satisfactory at identifying and providing for construction costs (e.g. infrastructure charging plans and development contribution schemes), though maintenance and rehabilitation costs are less well defined and often fall directly onto local government to fund. Recent evaluation of maintenance conducted in local government showed that minimal efforts were being expended on maintaining WSUD features for a range of reasons, including lack of sufficient funding (BMT WBM 2006). There are also few processes in place with most local governments to allow expansion of funding mechanisms for WSUD maintenance that take into account the increased numbers of WSUD measures being contributed by the requirement for development to achieve water quality targets. While this may seem difficult, recent efforts by a local government in Queensland have identified a process for ensuring that the amount of funding required for maintenance over an extended period is identified and included in future budget processes (McGarry 2007). In addition to this funding, the process also identifies what future resources (plant, equipment and staff) may be required.

During the planning and evaluation process for applying WSUD, a thorough analysis of the costing implications is therefore warranted. This process has to account for both the cost of construction and ongoing operation (maintenance and occasional refurbishment), and also the costs of replacing the measure at the end of its operational life. Further guidance on this can be found in Taylor (2005).

3.2.4 Summary

Table 3-1 outlines the potential applicability of the previously discussed potable water demand reduction and stormwater BMPs for different development types.

Table 3-1 Potential WSUD Options for Various Development Types and Scales

Option		Household	Medium Density	High Rise	Commercial and Industrial	Subdivision	Urban Retrofit
Potable water demand production techniques	Water efficient appliances	Y	Y	Y	Y	Y	?
	Water efficient fittings	Y	Y	Y	Y	Y	Y
	Rainwater tanks	Y	Y	Y	Y	Y	Y
	Reticulated recycled water	N	N	Y	Y	Y	N
	Stormwater harvesting and reuse	N	N	?	Y	Y	Y
	Greywater treatment and reuse	Y	Y	Y	?	Y	Y
	Changing landscape form	N	?	N	N	Y	N
	Water use education programs	Y	Y	Y	Y	Y	Y
Stormwater management techniques	Sediment basins	N	N	N	N	Y	N
	Bioretention swales	?	Y	N	Y	Y	N
	Bioretention basins	Y	Y	N	Y	Y	Y
	Sand filters	N	?	N	Y	Y	Y
	Swales and buffer strips	Y	Y	N	Y	Y	?
	Constructed wetlands	N	N	N	?	Y	?
	Ponds and lakes	N	N	N	?	Y	?
	Infiltration systems	?	?	N	Y	Y	Y
	Aquifer storage and recovery	?	?	N	?	Y	?
	Porous pavements	Y	Y	?	Y	Y	?
	Retarding basins	N	N	N	?	Y	N
	Green roofs/roof gardens	Y	Y	Y	Y	N	Y
	Stream and riparian vegetation rehabilitation	N	N	N	?	Y	Y
	Water quality education programs	Y	Y	Y	Y	Y	Y

Y Potentially suitable ? – Possibly suitable N – Generally Not Suitable

4 EVALUATION OF WSUD OPTIONS

A WSUD project can be assessed at two quite distinct levels, one being at the (broadscale) ***option evaluation*** stage when a wide range of potential site layouts, configurations and BMPs will be screened to develop a preferred WSUD option, and the second at the (finescale) ***option assessment*** stage when the preferred WSUD option and associated range of BPPs/BMPs has been selected, and there is a desire to determine if this option is acceptable. In this context:

- WSUD ***option evaluation*** involves providing guidance to WSUD designers on how to evaluate a range of potential WSUD options; and
- WSUD ***option assessment*** involves providing guidance to a consent authority (e.g. Local Government) on how to evaluate a specific WSUD proposal submitted by a developer.

There are obvious links between WSUD ***option evaluation*** and WSUD ***option assessment***, however the target audiences are generally different. WSUD ***option assessment*** can often be a simpler process than the evaluation of a range of possible WSUD options. As such, this section has been divided into two parts – the WSUD ***option evaluation*** process (Section 4.1) and the WSUD ***option assessment*** process (Section 4.2).

In the overall evaluation process, it cannot be stressed enough of the importance of a multidisciplinary approach. WSUD implementation is not just an engineering process, but one that has to take account of planning, landscape design, architecture, open space management and asset management at the minimum. When examining a WSUD strategy, care therefore needs to be taken that as many disciplines as possible provide input into the evaluation process to ensure that a balanced outcome is achieved. The strategy should also be considered as one element in an overall risk based evaluation of the proposed project, where the likely risks from all aspects of the project are considered and the most beneficial options chosen. In this regard, the assessment of environmental and health based risks should make reference to the National Water Recycling Guidelines (EPHC/NHMRC/NRMMC) 2008.

4.1 WSUD Option Evaluation

Taylor (2005) suggests methods for evaluating projects using a triple bottom line (TBL) framework. Within this framework, a 12 step process is proposed. While this may be appropriate for larger strategies, for specific WSUD projects (e.g. evaluating the WSUD measures proposed for a single subdivision, it is suggested that these steps involve:

1. Definition of the project's or strategy's objectives and evaluation criteria (e.g. financial targets, water quality objectives, amenity outcomes);
2. Clear definition of the issues to be addressed (improvement in water quality by a certain amount, restoration of habitat, improvement in pedestrian access, cost-benefit ratios identified);
3. Identification, description and screening of potential options; and
4. Evaluating options against objectives (the evaluation process).

Objectives: The objectives can include water management and other objectives, which can be usefully considered in a triple bottom line (TBL) framework.

Table 4-1 outlines broad TBL criteria/objectives that could be considered in this regard.

Options: Section 3 of these Guidelines outlines a range of potential structural (BMP) and planning (BPP) WSUD options which could be considered. Table 4-7 provides information on potential options, which can be used with Section 3 and Table 3-1 to identify potential options for different development types and scales to meet the water management objectives.

Evaluation: An initial screening assessment should be undertaken, whereby options that are likely to be clearly unfeasible or inappropriate are not considered further (e.g. options requiring maintenance equipment or expertise not held by the local council).

For almost all developments, more than one action will be required to meet the water management objectives. Development of a WSUD strategy will usually involve an initial screening assessment of potential options, combination of various potentially feasible options into different strategies and subsequent evaluation. The focus should initially be on a source control approach that seeks to adopt best planning practices which aim to reduce the overall impact of the project on the water cycle, rather than simply focus on best management practices (usually structural). This is likely to be an iterative process, often completed with stakeholder input. This is also likely to involve an assessment of site constraints and opportunities which may support or hinder specific options. Further guidance on the detailed process is provided in Taylor (2005).

Table 4-1 Potential Triple Bottom Line Objectives for Urban Stormwater Projects (from Taylor 2005)

Category	Possible TBL Assessment Criteria to Assess the Project's Performance Against Objectives (*Note: these criteria can be assessed in a qualitative or quantitative*)
Financial (i.e. project costs and values that are relatively easy to express in financial terms)	The life cycle cost of the project over a given life cycle/ span (note that to properly compare alternative stormwater projects, the time period over which the life cycle costing analysis is undertaken needs to be the same). For details on how to calculate a life cycle cost for stormwater projects, see Taylor (2003).
	The equivalent annual payment cost (i.e. the life cycle cost divided by the life cycle/ span).
	The total acquisition cost (i.e. the initial capital cost including all costs associated with feasibility studies, design and construction).
	The typical annual maintenance cost (this may include an energy cost component for stormwater reuse projects).
	The cost of land occupied by the stormwater management measure (may include the cost of the land and the cost of not being able to use the land for another purpose).
	Savings associated with a reduced need for reticulated potable water (may include the avoided cost of using mains water as well as avoided costs associated with water supply infrastructure).
	Changes to the value of nearby properties as a result of the project.
	The ability to fund/ resource the asset's costs over the whole life cycle.
	Savings associated with a reduced need for maintenance of downstream stormwater infrastructure and waterways (e.g. due to reduced downstream erosion associated with small, frequent storm events).
	Hidden costs (e.g. costs associated with taxes, delays in gaining a development approval, environmental permits, environmental monitoring, environmental management during construction, insurance, etc).
	Contingent costs (e.g. possible additional costs relating to construction, environmental fines, property damage, legal expenses, etc).
	Changes to annual property rates of nearby properties due to changes in their value.
	The impact on the rate of sales for lots' houses on new estates.
	The organisation's exposure to financial risk.
Social (i.e. 'use values' that relate to people's quality of life)	The impact on the area's general amenity/ liveability (a broad social criterion that reflects many of the more specific criteria in this table).
	The impact on the safety of people using the area (e.g. the risk of drowning).
	The impact on the health and well-being of nearby residents who may be affected by disease vectors (e.g. mosquitoes), pests and odours.
	The impact on the area's aesthetic values.
	The intra-generational equity associated with the project. That is, ensuring the benefits and costs of the project to the community are equally shared rather than one part of the community experiencing substantial costs/ benefits compared to the broader community (e.g. substantially elevated property values in the immediate vicinity of a public project or disadvantaged disabled citizens as a result of a new design).
	The inter-generational equity associated with the project. That is, ensuring the project produces costs and benefits that are equally shared by current and future generations. For example, ensuring an option does not degrade ecosystems services within n a local estuary, so that future generations are unable to enjoy these services.
	The impact on passive and active recreation around the stormwater asset (e.g. walking, jogging, cycling, bird-watching, etc).
	The impact on individual and community well-being and welfare (e.g. social cohesion and economic prosperity).
	The impact on research and/or educational opportunities (e.g. in association with a constructed wetland).
	The maintenance burden for local residents (e.g. maintaining grassed swales in the road reserve).
	The inconvenience associated with nuisance flooding (e.g. temporarily ponding in swales

Category	Possible TBL Assessment Criteria to Assess the Project's Performance Against Objectives (*Note: these criteria can be assessed in a qualitative or quantitative*)
	outside of residential premises).
	The inconvenience to people using the road reserve (e.g. car parking may be restricted due to the presence of stormwater treatment measures).
	The impact on transport opportunities along and/or through the water/ drainage corridor (e.g. walkways, cycle paths and bridges).
	The acceptability to stakeholders of the project.
	The impact on the area's cultural and spiritual values (indigenous or otherwise).
	Likelihood of associated behavioural change and/or participation by local stakeholders.
	Flexibility of the project to accommodate changing social expectations over its life cycle.
	The impact on commercial fishing, aquaculture and/or recreational fishing in affected receiving waters.
	The impact swimming and/or boating in affected receiving waters.
	The impact on tourism and/or water-based transport in affected receiving waters.
	The risk of vandalism and/or theft in association with the stormwater infrastructure (e.g. theft of release nets).
	Impact on the availability of shallow groundwater for local reuse.
	Shading/ cooling, air quality improvement and carbon sequestration benefits from the use of *vegetated* stormwater treatment measures (e.g. wetlands, street trees that filter road runoff, etc).
	The magnitude of greenhouse gas emissions associated with the project's power use (potentially relevant to stormwater reuse projects with electric pumps).
Ecological (i.e. 'intrinsic values' that do not relate to the current use of ecosystem services by people)	The impact on the ecological health of affected local and/or regional ecosystems (i.e. the impact on the 'existence value' of these ecosystems). Several *secondary* criteria and indicators may be developed to assess the likely impact on ecological health. For example, the loads of nutrients entering downstream wetlands could be used as a secondary criterion. In this case the indicator could be kilograms of nitrogen and/or phosphorus per hectare per year, as estimated by modelling. For examples of typical ecosystem health indicators of fresh water, estuarine and marine system, see the 'Ecological Health Monitoring Program for South East Queensland'. (EHMP, 2004).
	The impact on the value of having healthy aquatic and riparian ecosystems for potential use in the future (i.e. the impact on the 'option value' of these ecosystems).
	The impact on the value of providing future generations with healthy aquatic and riparian ecosystems (i.e. the impact on the 'bequest value' of these ecosystems).
	Ecological impacts associated with the project's materials, wastes and/or energy use during construction, operation, maintenance and/or decommissioning.

4.2 WSUD Option Assessment

4.2.1 Overview

The implementation of a preferred WSUD option derived from the process described in Section 4.1, either in a greenfield or retrofit context, requires careful consideration of the broad principles of WSUD and the required objectives that may be specific to a site. To accomplish this, a formalised assessment process is beneficial to determine whether a proposed strategy is suitable and/or appropriate in terms of the defined principles and objectives. Though numerous guidelines exist for detailed technical assessment of particular measures applied 'within' a WSUD, there has been little guidance provided in terms of a more broad scale assessment of the overall 'suitability' of a WSUD option.

Several authorities across Australia have developed specific tools (e.g. NSW BASIX, Melbourne Water's STORM tool) to assist in assessing various specific elements of WSUD. This section of the Guidelines is intended to provide guidance on the more detailed assessment of a WSUD option, and provides checklists that can be used to supplement other, more formal, tools. It is not intended to be used in preference to other tools, simply to highlight those matters which should be considered when assessing a WSUD option. The checklists are also presented individually in **Error! Reference source not found.**, for ease of copying.

4.2.2 Assessment Aims

As outlined earlier in these Guidelines, the application of WSUD requires addressing a range of broad principles and, often site specific, objectives. These can be grouped into the following generic 'outcomes':

- Integration of the whole water cycle;
- Management and minimisation of hydrologic impacts;
- Protection and enhancement of the ecological function of local and regional receiving environments;
- Provision of alternative sources of water/reduction of potable water use/reduction of waste water generation and discharge;
- Maintenance and/or enhancement of visual and social amenity values; and
- Minimisation of whole of life asset costs

Any assessment of the suitability of a WSUD option needs to consider how well the proposed design addresses these outcomes. Given that every site has different characteristics, the aim should be to optimise the design such that the majority of the outcomes are met, realising that some may be more adequately addressed than others. The result of an assessment should not be a ***rejection*** of WSUD if one of the outcomes cannot be efficiently delivered, but a consideration of how the majority of them can be maximised through the use of WSUD.

4.2.3 Assessment Process

Assessment of a WSUD requires consideration of the above outcomes at several levels. A ***broad scale*** assessment of compliance with the outcomes may initially be appropriate to ensure that a proposal complies with the overall intent of WSUD and identifies key objectives. Further, detailed, ***local scale*** assessments may then be needed to identify if site specific water quality, hydrologic and potable water use/wastewater generation reduction objectives are satisfied. Finally, examination of the ***fine scale*** design elements of each measure may be needed to ensure they are adequate to treat the required stormwater flows and loads being discharged to them and achieve the required potable water/wastewater reduction targets. This hierarchy of assessment is illustrated below and discussed further in Section 4.2.4 to Section 4.2.6.

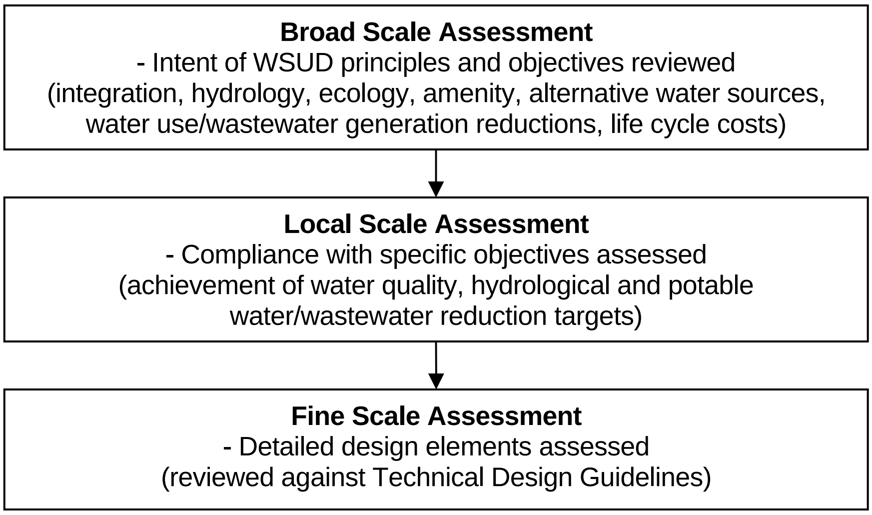


Figure 4-1 Assessment Hierarchy

4.2.4 Broad Scale Assessment

Initial ***broad scale*** assessment of a WSUD should review the overall level of compliance of a project against the previously defined principles and objectives. To assist in this process,

Table 4-2 presents a checklist of items against which a WSUD can be reviewed.

Where a strategy has been checked against

Table 4-2 and the majority of outcomes are expected to be achieved, it indicates that the development is likely to be consistent with WSUD principles. In addition, there may be Local, State or National outcomes which need to be considered, (for example Local Environmental Plans, State Planning Policies (e.g. coastal management, water reuse, plumbing codes, building codes etc) and National Guidelines and Standards for specific WSUD elements (e.g. Australian Standards). These policies and guidelines may have mandatory requirements, so the practitioner should be familiar with these where they are applicable.

In regard to these broad scale assessments, there are numerous examples within Australia of large-scale water efficiency programs (e.g. BASIX in New South Wales, Queensland Development Code Part 25: Water Savings Targets), which have had major benefits in regard to reducing potable water demands and wastewater discharges, both key objectives of WSUD. Publications such as the previously referenced enHealth rainwater tank guidelines and various State specific guidelines are also available to assist in this regard.

Table 4-2 Broad Scale Assessment Checklist

Outcome	Intent Achieved	
	Y	*N*
Integration of the whole water cycle		
- Single WSUD measures deliver multiple water related benefits		
Management and minimisation of hydrologic impacts		
- Hydrologic Objectives have been identified (design events, conveyance requirements, peak flows, environmental flows etc)		
- High flows have been catered for (bypass structures etc)		
- Impacts upon the receiving environment have been determined and minimised where appropriate (erosion protection, minimisation of velocities etc)		
Protection and enhancement of the ecological function of receiving environments		
- Water Quality Management Objectives are identified		
- A treatment train approach has been developed		
- Source controls are used where practicable		
Provision of alternative sources of water		
- Use of rainwater harvesting considered		
- Alternative water sources identified and used appropriately		
Maintenance and/or enhancement of visual and social amenity		
- WSUD measures have been integrated into landscape form		
- Multiple use assets and/or corridors are proposed		
- Public Health and Safety issues considered and addressed		
Minimisation of whole of life asset costs		
- Maintenance requirements are considered (plans, access etc)		
- Asset life cycle costs determined		
- Asset ownership and responsibility defined and agreed		
- Cost-effectiveness of strategy evaluated and maximised		
Potable water/wastewater generation		
- Potable water use reduction targets achieved		
- Wastewater generation reduction targets achieved		

4.2.5 Local Scale Assessment

4.2.5.1 Overview

Broad scale assessment of a development may indicate whether it can effectively be ‘considered’ as a WSUD, however this may not provide the necessary confidence that the WSUD practices proposed can be delivered successfully ‘on-the-ground’. Considerable effort has been directed in recent years toward increasing awareness of the need for WSUD implementation, and this has led to a significantly improved understanding of the importance of WSUD. As such, there is currently considerable scope for the adoption of WSUD in developments and urban renewal projects Australia wide.

A common barrier raised in this regard is the lack of guidance at the conceptual design level as to what is needed to demonstrate that a WSUD proposal can be effectively and successfully implemented. Practitioners and agencies responsible for assessing WSUD strategies are required to understand the implications of specific WSUD practices and measures, and how these may achieve WSUD outcomes. This section of the Guidelines outlines processes to provide confidence that a WSUD application will be successful, and provides tools which can assist in understanding whether the proposed measures or group of measures (sometimes called a treatment train) which will 'constitute' a WSUD are appropriate.

As such, this document sets out two broad sets of local scale assessment or checking tools, one which qualifies the overall applicability/suitability/risk profile of WSUD to a particular site (Section 4.2.5.2), and a second which assists in evaluating whether an appropriate configuration of management measures has been adopted within a WSUD (Section 4.2.5.3). As these assessments focus on the stormwater elements of WSUD, Section 4.2.5.4 subsequently provides guidance in regard to local scale assessments of the potable water and wastewater elements of WSUD.

4.2.5.2 Site Stormwater Treatment Suitability Assessment

Without a proper understanding of a site, it is unlikely that any application of WSUD will be successful. This understanding of a site is best conducted by field assessments – there is simply no substitute for 'kicking the dirt' if the opportunities and constraints of a site are to be properly understood. During this review, it usually becomes apparent where specific practices may be placed, and also how an overall strategy may best be implemented.

It follows that there are several key characteristics of a site which can influence the overall delivery of WSUD and which equally may increase the risk of failure. These characteristics can dictate the level of detail necessary to give confidence that WSUD can be successfully delivered. To assist in determining the level of information necessary, Table 4-3 provides a scoring system to determine the potential risk of WSUD implementation. If the risk is identified as being high, the level of detail necessary to demonstrate that the WSUD strategy can be successfully implemented will also need to be high.

In particular, terrain and topography can be critical to the selection of stormwater treatment devices as such influences can totally preclude some BMP options for consideration. The basic design and layout of a development needs to carefully consider this issue.

Table 4-3 Site Suitability Review

Characteristic	Potential Implementation Constraint			Score
	Low	Moderate	High	
% Imperviousness (post implementation)	1 = 0-10%	2 = 10-50%	3 = 50-100%	
Average Slope	1 = 2-5%	2 = 0-1%	3 = >5%	
Developed Area	1 = <1ha	2 = 1-10ha	3 = >10ha	
Mean Annual Rainfall	1 = <600mm/yr	2 = 600-1200mm/yr	3 = >1200mm/yr	
Soil permeability	1 = 3.6-3600mm/hr	2 = >3600mm/hr	3 = <3.6mm/hr	
Groundwater Elevation	1 = >2m below surface	2 = 1-2m below surface	3 = <1m below surface	
Salinity or Acid Sulfate Hazard	1 = Not in defined hazard area	2 = low to moderate hazard	3 = high hazard area	
			Total Score	

The 'score' derived using Table 4-3 can then provide a guide as to the level of information required. A suggested set of information requirements related to the risk profile is provided in Table 4-4. It is highly likely that other, site specific, issues may require further information to demonstrate that a proposed WSUD strategy can be implemented successfully, for example acid sulfate soil impacts, soil structure, environmental flow assessments, groundwater etc.

Table 4-4 indicates the level of detail necessary for most common site issues. The risk level noted is associated with the degree of complexity of WSUD implementation, in that those that score highly in the site suitability review are likely to have issues which may present challenges to construction and/or application of WSUD technologies on-site.

Table 4-4 Information Requirements

Total Score	Implementation Risk	Local Scale Assessment Level	Information requirements
7 - 9	Low	Demonstrate implementation of best practice techniques	(i) Site Plan showing location, size and dimensions of measures (ii) Detailed design calculations (compliant with relevant guidelines) (iii) Public Health and Safety Issues considered and addressed
10 - 16	Medium	Demonstrate how relevant WSUD objectives are achieved (e.g. load based reduction targets achieved, peak flows compliant with hydraulic objectives)	Overall Water Management Plan provided, including: (i) Site Plan showing location, size and dimensions of measures (ii) Detailed design calculations (compliant with relevant guidelines) (iii) Estimates provided to show how WSUD targets are achieved (e.g. MUSIC modelling, Hydraulic assessments, compliance with planning codes for landscape elements etc, % of potable water demand satisfied by alternative sources) (iv) Public Health and Safety Issues considered and addressed
17 -21	High	Demonstrate how relevant WSUD objectives are achieved (e.g. load based reduction targets achieved, peak flows compliant with hydraulic objectives) Demonstrate how high risk factors addressed	Overall Water Management Plan provided, including: (i) Site Plan showing location, size and dimensions of measures (ii) Detailed design calculations (compliant with relevant guidelines) (iii) Estimates provided to show how WSUD targets are achieved (e.g. MUSIC modelling, Hydraulic assessments, compliance with planning codes for landscape elements etc, % of potable water demand satisfied by alternative sources) (iv) Detailed assessment of risk factors and proposed mitigation (v) Public Health and Safety Issues considered and addressed

4.2.5.3 Stormwater Treatment Train Assessment

Overview

In managing stormwater quality and, to a lesser extent, quantity, WSUD practices are best utilised via a series of measures, each focussing on one or more objective(s) or target pollutant(s). This ‘treatment train’ approach is utilised to ensure that the measures selected operate most effectively in terms of their specific hydraulic and treatment capabilities.

It is therefore important to understand the locations where treatment measures may be utilised within a WSUD so that the quantities of pollutants and flow likely to be received at each location are appropriate.

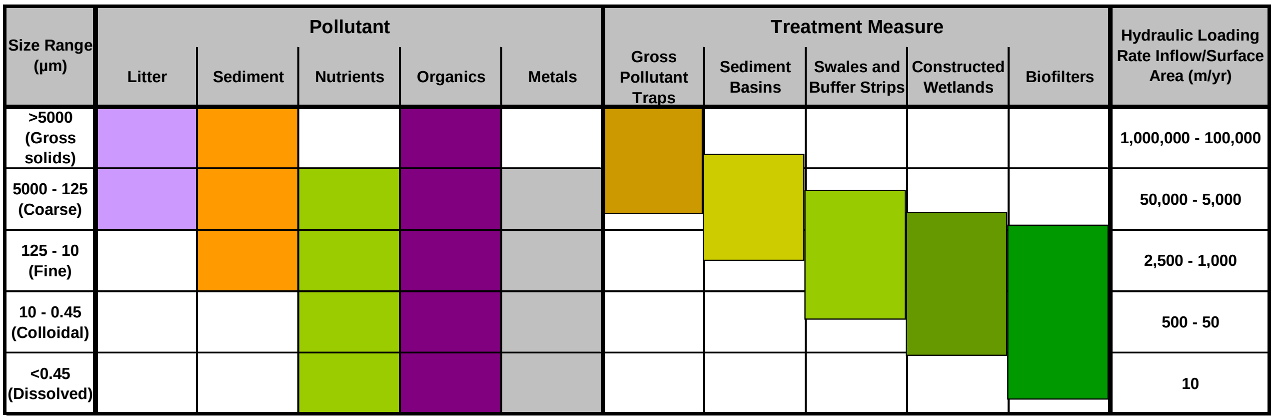
A sequence of stormwater treatment measures should be formulated which aims to manage specific size ranges of pollutants at appropriate timescales, based on the areas available for siting treatment measures. For example, coarse sediment will settle out of stormwater in a matter of minutes once stilling of the flow occurs, whereas removal of nutrients can take hours to days. As such, a treatment measure that is effective at removing coarse sediment may not necessarily be suitable to remove nutrients. It may also mean that a stormwater treatment measure designed to remove nutrients may require more frequent maintenance if it also has to remove coarse sediment.

Treatment Processes

As discussed above, each stormwater treatment measure operates over particular hydraulic loading rates and pollutant size ranges, however the pollutants typically targeted for removal by the stormwater elements of a WSUD (e.g. sediment, nutrients, litter etc) can have very large size ranges. This is shown in Table 4-5 below.

From Table 4-5, it can be seen that to treat a certain suite of pollutants, one treatment measure will not be suitable. For example, while a vegetated swale may be able to remove some nutrients, it will not be effective in removing colloidal and dissolved material, and a wetland or bioretention system may provide more efficient treatment. The swale may then become the pre-treatment measure for the wetland, and hence a 'treatment train' is created.

Table 4-5 Relationship of Particle Size and Hydraulic Loading (adapted from CRCCH 2004)



Size Range (µm)	Pollutant					Treatment Measure					Hydraulic Loading Rate Inflow/Surface Area (m/yr)
	Litter	Sediment	Nutrients	Organics	Metals	Gross Pollutant Traps	Sediment Basins	Swales and Buffer Strips	Constructed Wetlands	Biofilters	
>5000 (Gross solids)	🟪	🟧		🟪		🟫	🟨				1,000,000 - 100,000
5000 - 125 (Coarse)	🟪	🟧	🟩	🟪	▨	🟫	🟨	🟩	🟩	🟩	50,000 - 5,000
125 - 10 (Fine)		🟧	🟩	🟪	▨		🟨	🟩	🟩	🟩	2,500 - 1,000
10 - 0.45 (Colloidal)			🟩	🟪	▨			🟩	🟩	🟩	500 - 50
<0.45 (Dissolved)			🟩	🟪	▨					🟩	10

Table 4-5 also shows that to treat gross pollutants and coarse sediment in stormwater, the hydraulic loading rate (i.e. the quantity of water able to pass through a given surface area of a treatment measure) can be very high, whereas to treat nutrients or metals a much smaller hydraulic loading rate is required. This means that either less water can be treated, or the treatment measure needs to be much larger to treat an equivalent amount of water. The space requirements for a device are then inversely proportional to the hydraulic loading rate; the lower the loading rate, the larger the measure.

For this reason, treatment trains should be focussed on treating gross particulates (litter, larger organic matter etc) first, then coarse particulates (sediment) and finally fine, colloidal and dissolved material.

One treatment measure cannot treat all of the particle size ranges and a combination of measures will be most effective.

4.2.5.4 Potable Water/Wastewater Assessments

The key issues to consider in the context of local scale assessments of the potable water and wastewater elements of WSUD essentially relate to the suite of techniques which have been applied and whether these techniques are suitable to the particular area under investigation. Key considerations in this regard are summarised in Table 4-7, and are also discussed below:

- Generic considerations relating to techniques applied
    - Have a range of techniques been applied; and
    - Has consideration being given to both demand reduction and water reuse/recycling techniques.
- Specific considerations relating to the local site on which the techniques are being applied
    - Are local soils a potential constraint (e.g. recycled greywater/wastewater cannot be applied to certain soil types);
    - Is the local vegetation suitable for receiving recycled waters;
    - Are there local groundwater issues that would constrain certain recycled water applications; and
    - Are there any specific public-health issues which would constrain or preclude certain recycled water applications.

4.2.5.5 Combined Stormwater, Water and Wastewater Assessments

To assess whether a WSUD system is appropriate requires an understanding of the requirements of WSUD outcome, and the suitability of particular measures to assist in achieving those outcomes. In developing a proposed WSUD strategy, it is often necessary to review this on an iterative basis, so that the characteristics of different elements can be appropriately integrated.

The information provided in Table 4-6 is intended to assist in the strategy development and review process. To 'demonstrate' compliance may require further, more detailed assessments, either through a fine scale assessment (see Section 4.2.5.4), or via predictive modelling of the performance of a WSUD. Such modelling may be used to assist in the decision-making process.

Within Table 4-6, if a particular goal is determined as being an essential component, a score of 1 for that objective suggests that the measure or treatment train needs to be re-examined. Once again, this is simply a guide to assist the practitioner where other, more detailed, guidelines are not available, but can also provide an overview of how measures can be optimised to achieve objectives.

In certain local area specific applications of the material presented in Table 4-6, there may be a desire or need to rank or weight the suite of objectives presented to ensure that good performance on less critical issues does not mask poor performance on important issues.

It should be apparent from Table 4-6 that particular measures may not achieve all objectives and some may be completely unsuitable. As such, guidance is also required on which types of measure or practices are most appropriate to specific objectives. This is provided in Table 4-7.

4.2.6 Fine Scale Assessment

The fine scale assessment process is usually conducted in accordance with detailed design guidelines, (e.g. Melbourne Water's WSUD Engineering Procedures – Stormwater) and also in conjunction with applicable standards such as those provided by the Water Services Association of Australia and Standards Australia. For National Guidelines such as these, it is not considered appropriate to provide additional guidance beyond those documents. WSUD practitioners are therefore advised to consult Chapter 7 for detailed guidance material available for specific measures, or appropriate to the area of application.

Table 4-6 WSUD Design Suitability Assessment

Objective	Suitability			Score	Essential Component (y/n)
Water Quality					
Treatment Train elements					
- Primary Treatment (Screening / Sedimentation)	1 = None (no specific measure)	2 = Incidental (measure may treat though not designed to)	3 = Dedicated (e.g. GPT, Sediment Basin)		Y
- Secondary Treatment (Enhanced sedimentation / Vegetative filtering)	1 = None (no specific measure)	2 = <50% Vegetation coverage (e.g. pond)	3 = >50% Vegetation coverage (e.g. wetland, swale)		
- Tertiary Treatment (Biological uptake)	1 = None (no specific measure)	2 = Filtration Only (e.g. sand filter, porous pavement)	3 = Filtration + Vegetation (e.g. bioretention system, raingarden)		
Load Based Reductions Achieved	1 = No compliance for any parameter	2 = Partial Compliance	3 = Full Compliance / Not Applicable		Y*
Water Quantity					
Disconnection of Impervious areas	1 = no disconnection	2 = Conveyance provides disconnection, but >10% directly connected impervious area	3 = Disconnection achieves <10% directly connected impervious area		
Maintenance of hydrologic regimes	1 = significant increases in flow volumes, frequencies and runoff peaks	2 = minor increases in volumes, frequencies and/or runoff peaks	3 = maintenance or improvement of pre-development regime		
Detention	1 = no detention capacity	2 = detention component provided for minor flows	3 = detention for major flows integrated into measure		
Water Supply					
Measure can provide alternative water source	1 = None possible	2 = One potable water source can be substituted	3 = Two or more water sources can be substituted		
Reduces Potable Water Demand	1 = No demand reduction possible	2 = 0-20% reduction expected	3 = >20% reduction expected		Y*
Wastewater					
Reduce Wastewater discharge	1 = No reduction possible	2 = 0-20% reduction expected	3 = >20% reduction expected		Y*
Amenity					
Multiple uses provided by the measure	1 = only has one function	2 = has an amenity function in addition to primary function	3 = has multiple functions		
Form is integrated into landscape	1 = discontinuous from other landscape elements	2 = has one or more consistent features with overall landscape character	3 = completely integrated within landscape		
Existing natural features retained	1 = <25% natural features retained	2 = 25-75% features retained or enhanced	3 = >75% of natural features retained		
Public safety elements addressed	1 = likely to pose public safety hazard	2 = public safety elements incorporated into design	3 = No public safety issue		
Linkages (pedestrian, bicycle, vehicular) maintained or enhanced	1 = links severed by measure	2 = existing links retained through measure	3 = existing links maintained and additional linkages provided		
Functionality					
Maintenance elements incorporated within measure	1 = no dedicated maintenance elements incorporated	2 = maintenance access provided	3 = maintenance access provided, working areas highlighted and provision for waste handling included		
Maintenance plans provided	1 = no maintenance plans given	2 = generic maintenance plan provided	3 = maintenance plan specific to measure provided, including costings		Y
Service corridors allowed for	1 = no services allowed for	2 = services can be included, but constrained	3 = service corridors dedicated and sufficient		

* indicates this may not be required in all applications

Total Score:
19 – 29 – Strategy, measure or treatment train may need considerable refinement
30 – 42 – Strategy, measure or treatment train may achieve WSUD objectives, however further refinement would be beneficial
43 – 57 – Strategy, measure or treatment train has a high likelihood of successful implementation

Table 4-7 WSUD BMP Functionality Assessment

Measure	Objective																		
	Water Quality					Water Quantity			Water Supply		Wastewater	Amenity					Functionality		
	Primary Treatment	Secondary Treatment	Tertiary Treatment	Achieve WQOs	Reduce Pollutant Loads	Disconnect Impervious areas	Provide detention	Allow Stormwater Harvesting	Can provide alternative water source	Reduce potable demand	Reduce wastewater flows	Measure allows multiple uses	Form can be integrated into landscape	Retain natural features and enhance or restore riparian corridor	Minimal public safety issues	Linkages (pedestrian, bicycle, vehicular) maintained or enhanced	Maintenance elements can be incorporated within measure	Maintenance plans can be provided	Allows integration with service corridors
Potable Water Demand/Wastewater Generation Reduction Techniques																			
Water Efficient Appliances										🟩	🟩								
Water Efficient Fittings										🟩	🟩								
Rainwater Tanks	🟧	🟧	🟧	🟧	🟧	🟩	🟩	🟧	🟩	🟩	🟩		🟧		🟧			🟩	▒
Reticulated Recycled Water									🟩	🟩	🟩		🟧		🟧			🟩	🟧
Greywater Treatment/Reuse									🟩	🟩	🟩		🟧		🟧			🟩	🟧
Stormwater Harvesting/Reuse	🟧	🟧	🟧	🟧	🟧	🟧	🟩	🟩	🟩	🟩		🟧	🟧	🟧	🟧		🟧	🟩	🟧
Changing Landscape Form	🟧			🟧	🟧	🟧		🟧	🟥	🟩		🟧	🟩	🟧	🟩	🟩	🟧	🟩	🟧
Water Use Education Programs	🟧	🟧	🟧	🟧	🟧					🟩	🟩				🟩			🟩	
Stormwater Management Techniques																			
Sediment Basins	🟩	🟧	🟥	🟧	🟩	🟧	🟩	🟧	🟧			🟩	🟩	🟧	🟧	🟧	🟩	🟩	🟥
Bioretention Swales	🟥	🟩	🟩	🟩	🟩	🟩	🟧		🟥	🟥		🟩	🟩	🟧	🟧	🟧	🟩	🟩	🟩
Bioretention Basins	🟥	🟩	🟩	🟩	🟩	🟩	🟩		🟧	🟧		🟩	🟩	🟩	🟧	🟧	🟩	🟩	🟧
Sand Filters	🟥	🟩	🟩	🟩	🟩	🟧	🟧		🟧			🟧	🟧	🟧	🟧	🟧	🟩	🟩	🟧
Swales	🟩	🟩	🟧	🟧	🟩	🟩	🟧		🟥	🟥		🟩	🟩	🟧	🟧	🟧	🟩	🟩	🟩
Buffer Strips	🟩	🟩	🟧	🟧	🟩	🟩	🟧		🟥	🟥		🟩	🟩	🟩	🟧	🟧	🟩	🟩	🟩
Constructed Wetlands	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟧	🟧		🟩	🟩	🟩	🟧	🟧	🟩	🟩	🟥
Ponds and Lakes	🟥	🟩	🟧	🟧	🟩	🟩	🟩	🟩	🟧	🟧		🟩	🟩	🟧	🟧	🟧	🟩	🟩	🟥
Infiltration Systems	🟥	🟩	🟩	🟩	🟩	🟩	🟧	🟧	🟧	🟧		🟩	🟩	🟧	🟧	🟧	🟩	🟩	🟧
Porous Pavements	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟧	🟧	🟧		🟩	🟩	🟧	🟩	🟩	🟩	🟩	🟩
Aquifer Storage and Recovery	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		🟩	🟩	🟧	🟧	🟧	🟩	🟩	🟧
Water Quality Education Programs	🟧	🟧	🟥	🟧	🟧									🟧	🟩	🟧		🟩	

Practice/Measure ideally suited 🟩
Practice/Measure may assist 🟧
Measure generally unsuitable 🟥
Not applicable ☐

5 WSUD RISKS AND ISSUES

Although WSUD can provide significant benefits (e.g. improved waterway health, reduced rates of water usage and wastewater discharge), there are risks and issues associated with its implementation that, if not addressed adequately, can reduce its success in achieving desired objectives. These risks are summarised below.

5.1 Rainwater Capture and Reuse

Rainwater capture and reuse is typically seen as being a ***low*** risk activity, provided appropriate measures are put in place.

In regard to rainwater capture and reuse, the key risks and issues relate to the quality of water stored in the tank and the uses to which this water is put (together with what treatment measures are applied). Rigorous studies in Australia and internationally have been conducted which show conclusively that stored rainwater has acceptable 'fit for purpose' quality for uses such as toilet flushing, external usage and clothes washing (i.e. all non-potable uses), provided:

- Tanks are appropriately sealed to prevent the ingress of external waters;
- Inflowing water is screened to remove leaf litter and debris; and
- First flush runoff is diverted from entering the tank.

Key references in regard to these studies include CRC for Water Quality and Treatment (2004), the previously referenced enHealth guidelines and Coombes (2000).

One other risk potentially associated with rainwater tanks is that they may provide a site for mosquito breeding. In this regard, all tanks should be sealed and screened to ensure this potential risk is minimised.

5.2 Wastewater, Stormwater and Greywater Reuse

Wastewater, stormwater and greywater reuse is typically seen as being a ***moderate to high*** risk activity, depending on the degree of management measures put in place.

Similarly to rainwater capture and reuse, recycled wastewater, harvested stormwater and greywater are regularly considered as a source of non-potable replacement/substitution for water otherwise used for purposes such as toilet flushing and outdoor usages.

In regard to the risks which may be associated with such reuse activities, a particularly comprehensive compendium of relevant advice and support material is provided in the National Water Quality Management Strategy publication, 'Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)'. This publication can be obtained at the following web address.

http://www.ephc.gov.au/pdf/water/WaterRecyclingGuidelines-02_Nov06_.pdf

This document is supported by the 'Australian Guidelines for Water Recycling Phase 2 - Stormwater Harvesting and Reuse and Managed Aquifer Recharge'. This publication can be obtained at the following web address.

http://www.ephc.gov.au/ephc/water_recycling.html

These documents analyse the issue of wastewater, stormwater and greywater reuse and present the following:

- A framework for the management of recycled water quality and use, including consideration of:
    - System assessments;
    - Preventative measures for recycled water management;
    - Operational procedures and process controls;
    - Verification requirements;
    - Incident and emergency management;
    - Operator and end-user awareness and training;
    - Community involvement and awareness;
    - Documentation and reporting;
    - Evaluation and audit; and
    - Review and continuous improvement requirements.
- Guidance on managing health risks associated with recycled water, including consideration of:
    - Risk assessments;
    - Performance targets;
    - Preventative measures; and
    - Monitoring.
- Guidance on managing the environmental risks associated with recycled water, including consideration of:
    - Risk assessments;
    - Preventative measures; and
    - Monitoring.
- Guidance on monitoring, including consideration of:
    - Types of monitoring;
    - Monitoring for management of health risks;
    - Monitoring for management of environmental risks;
    - Quality assurance/quality control;
    - Laboratory analyses;
    - Data analysis and interpretation; and
    - Reporting.
- Guidance on consultation and communication, including consideration of:
    - Factors that influence community attitudes to water recycling;
    - Essential features of successful communication strategies;

- Establishing partnerships and engaging stakeholders; and
- Public crisis communication.

This is a complete and rigorous presentation and analysis of all cogent risks associated with wastewater, stormwater and grey water reuse.

5.3 Stormwater Treatment

Stormwater treatment is typically seen as being a ***low*** risk activity, provided appropriate design and operation and maintenance measures are put in place.

The main risks and issues typically associated with the stormwater Best Management Practices (BMPs) applied in WSUD can be summarised into the following five categories:

- Services;
- Construction & Establishment;
- Erosion/ Scour;
- Public Safety; and
- Maintenance.

These risks and issues are summarised in the following sub-sections.

Appendix B also describes the main operational risks associated with individual types of BMPs.

5.3.1 Services

BMPs located within road verges or footpaths (e.g. swales, bioretention swales, bioretention basins) must consider the location of services and utilities within the verges and ensure access for maintenance of these services without regular disruption or damage to the BMP. Many Local Governments in Australia are in the process of developing ‘standard drawings’ for many BMP’s to enable the accommodation of services within such a WSUD context.

5.3.2 Construction and Establishment

Two key issues are related to the construction and establishment of WSUD measures. Firstly, the management of the construction site for minimising erosion and sediment export is critical in the overall implementation. Failure to manage the site appropriately can lead to far more sediment export during the construction phase than may occur over the next several decades of an urban development. It is therefore meaningless to install WSUD measures if failure to manage erosion and control sediment occurs as not only will the sediment exported from a poorly managed site lead to compromise of the WSUD measure, but may actually significantly impair or even totally destroy downstream waterway health that the WSUD measure was designed to protect.

Secondly, one of the highest failure risks of WSUD measures occurs due to poor construction and/or establishment. Vegetated BMPs (e.g. swales, wetlands, bioretention swales/basins) are living systems and can require two years or more before vegetation matures and the BMP reaches a fully functional form. The construction and establishment phase of vegetated BMPs is a critical period. If appropriate management measures are not taken during this phase, the performance of the BMP is likely to be suboptimal. In particular, vegetated BMPs constructed as part of a greenfield (i.e.

undeveloped) or infill (i.e. redeveloped) site can be at a high risk of damage due to sediment-laden runoff from under construction upstream areas and vehicle damage during subdivision and allotment-scale construction activities.

One other key issue at this stage of a project is to ensure that WSUD elements are actually constructed to specification (e.g. that the correct filter media have been used in a bioretention system).

Figure 5-1 Example of Building Phase Destruction of a Bioretention Swale

Therefore, the construction and establishment of vegetated BMPs must be carefully managed and requires a staged approach, which involves (Leinster, 2006; GCCC WSUD Guidelines, 2006) the following:

- *Stage 1: Functional Installation* – Construction of the functional elements of the BMP at the end of subdivision construction (i.e. during landscape works) and the installation of temporary protective measures (e.g. geofabric covered with shallow topsoil and instant turf to protect the filter media).
- *Stage 2: Erosion and Sediment Control* – During the Building Phase, the temporary protective measures preserve the functional infrastructure of the BMP against damage, whilst also providing a temporary erosion and sediment control facility.
- *Stage 3: Operational Establishment* – At the completion of the Building Phase, the temporary measures protecting the functional elements of the BMP can be removed, along with accumulated sediment, and the BMP can be planted in accordance with its design planting schedule.

5.3.3 Erosion and Scour

During large rainfall events, BMPs are often subject to high stormwater flows that have the potential to cause erosion/scour within the BMP. In particular, BMPs located at the downstream end of large (i.e. greater than 5ha) catchments can frequently receive potentially erosive flows.

If not managed appropriately, high stormwater flows can cause erosion within BMPs, wash out 'biofilms' (attached to the surface of vegetation) and resuspend/remobilise accumulated pollutants (e.g. sediment and attached pollutants), subsequently reducing the treatment performance of the BMPs and potentially requiring ongoing rehabilitation works.

Figure 5-2 Examples of Erosion within Constructed Wetlands

Therefore, appropriate measures are often required to reduce the potential damage to BMPs caused by high stormwater flows. Some examples of appropriate measures to reduce such damage include high flow diversions, flow detention, appropriate erosion protection and less reliance on 'end-of-pipe' treatment (instead applying a more integrated stormwater 'treatment train' throughout the given catchment).

5.3.4 Public Safety

As outlined in Section 2.4 of these Guidelines, one of the objectives of WSUD is to integrate stormwater treatment into the landscape. However, BMPs integrated into urban environments may introduce risks to public safety due to standing water and flow conveyance.

BMPs with temporary or permanent standing water (e.g. sedimentation basins, wetlands, bioretention basins) introduce a potential risk of drowning. Appropriate measures are subsequently required to mitigate this risk, including gradual (i.e. less than 1 vertical: 3 to 5 horizontal) batter slopes, dense littoral planting and, in some cases, permanent fencing.

BMPs that involve the conveyance of stormwater flows (e.g. swales) can also pose a risk to public safety through the combination of elevated flow velocities and water depths that can cause persons (e.g. standing in a swale during high flows) to fall and potentially incur injuries. Therefore, BMPs that involve the conveyance of flow should be designed appropriately (e.g. appropriate 'flow x depth' factor) to satisfy local design requirements for public safety.

5.3.5 Maintenance

BMPs often rely on 'natural' treatment mechanisms (e.g. filtration, sedimentation, biological uptake) to improve the quality of stormwater. Like any asset, BMPs require regular maintenance to ensure they are performing in accordance with their desired design objectives. The costs associated with such maintenance can be higher than those associated with conventional stormwater systems, particularly in the first years when WSUD BMPs are establishing, and provisions need to be made to ensure that sufficient ongoing funds are available to enable the required works to proceed. Guidance on the likely costs are available via recent studies (Taylor et al 2005), and contained within life cycle costing module in the MUSIC (Model for Urban Stormwater Improvement Conceptualisation) software.

If BMPs are not inspected and maintained appropriately, their treatment performance may be reduced and the BMP can introduce several problems (e.g. public safety risks, odours, attract undesirable species). In particular, BMPs that are intended to capture highly degradable gross pollutants (i.e. gross pollutant traps) and (to a lesser degree) coarse sediment (e.g. sedimentation basins) require accumulated pollutants to be removed at regular intervals.

In regard to GPT's, the costs associated with maintenance can be considerable. Appropriate consideration needs to be given by Local Governments as to how such costs will be addressed when such assets are handed over following the completion of development works, which may include such measures as part of the stormwater treatment train. Unless GPT's are regularly and appropriately maintained, material present within the GPT can decay and undesirable pollutants can be liberated.

Figure 5-3 Accumulated Debris in a Gully Basket Gross Pollutant Trap

Therefore, it is necessary that appropriate maintenance plans be developed for BMPs addressing the following:

- Inspection frequency
- Maintenance frequency
- Data Collection/ storage requirements (i.e. during inspections)

- Detailed clean-out procedures (main element of the plans), including:
    - Equipment needs
    - Maintenance techniques
    - Occupational health and safety
    - Public safety
    - Environmental management considerations
    - Disposal requirements (of material removed)
    - Access issues
    - Stakeholder identification requirements
    - Data collection requirements (if any)
- Design details

5.4 Institutional Risks

The implementation of WSUD requires the sound understanding and commitment to the overall principles discussed in Section 1.3. This commitment therefore requires a degree of institutional capacity and leadership in order to ensure WSUD is adopted in an integrated fashion with existing regulatory frameworks. The risks associated with the adoption of WSUD in the institutional arena are therefore complex and highly dependent on human factors. Issues such as leadership and championing of WSUD principles, capacity building and development, staff turnover, loss of corporate knowledge, and institutional inertia are some of the key areas where risks lie. Further guidance on institutional risks and barriers to WSUD adoption are available through Monash University's National Urban Water Governance Program at http://www.urbanwatergovernance.com/.

6 WSUD MONITORING CONSIDERATIONS

6.1 Background

Monitoring WSUD measures is a complex undertaking and should not be simply considered as a way of ensuring that compliance is being achieved. In a large number of monitoring programs, data collected has been of little value in improving the understanding of the measures that were evaluated. Therefore, the development of a monitoring program to assess the effectiveness of a WSUD measure or treatment train should carefully quantify the outcomes to be sought by such a program, and whether these are best delivered through other mechanisms (e.g. through examination and comparison with other studies). It may be better to facilitate monitoring of devices through collaboration with other agencies (e.g. local and state governments) or in partnership with research groups in academia or Cooperative Research Centres. Monitoring needs to have a useful output such as helping to inform future management decisions at the site, inform future design at other sites etc. Monitoring is expensive and needs to have a specific purpose.

There are two levels of monitoring that could provide useful outputs:

- To assess achievement of overall WSUD objectives; and
- To assess the performance of individual WSUD measures.

6.2 Monitoring Objectives

To develop a monitoring program which will provide useful information, it is imperative that the objectives of the program are clearly identified. These objectives should not simply be “to see whether it works”, but focus on key characteristics of the WSUD measure (e.g. the quantity of sediment removed per year). The objectives should also be focussed on providing information for adaptive management, such that the results of the monitoring can be used to inform the changes to the management regime that may be required to ensure the treatment measure can operate at optimal efficiency. Typical objectives can be:

- Hydraulic performance - % of total flow treated, % of flow bypassed, water levels etc;
- Water quality performance – Inflow concentrations, outflow concentrations, loads captured;
- Economic – Capital cost of treatment measures, maintenance cost, potential savings through deferment of large infrastructure, land costs, lost opportunity costs;
- Maintenance – Inspection records, maintenance frequencies, maintenance activities, plant establishment performance;
- Ecological – Fauna and/or flora assessments, ecosystem health monitoring (e.g. primary production);
- Public health – Pathogen levels and other potential hazardous compounds which may be associated with recycled stormwater or wastewater; and
- Social/Aesthetic - Photographic records, resident surveys.

The above list is not exhaustive and the monitoring program objectives should be closely aligned with the objectives that were intended to be satisfied through the implementation of the WSUD measure or treatment train as outlined in Section 2 of these guidelines.

6.3 Monitoring Protocols

The former Cooperative Research Centre for Catchment Hydrology (now eWater CRC) previously commenced development of a Stormwater Monitoring Protocol (CRCCH 2000) which outlined three levels of assessment for the monitoring of stormwater treatment facilities. These levels of assessment were to provide guidance for the minimum set of parameters that should be collected, enabling additional parameters to be selected as monitoring budgets may allow:

- ***Level 1*** was considered to be the minimum set that must be collected to ensure that some useful information may be obtained. This included the assessment of physical performance, such as hydraulics (treatable flows, bypass flows etc), material captured, some basic physico-chemical and inorganic parameters (Total Suspended Solids, Total Nitrogen, Total Phosphorus, particle size distribution) and finally the results of maintenance activities and life cycle costs.
- ***Level 2*** parameters included speciated nutrient parameters (ammonia, organic nitrogen, oxides of nitrogen etc) contained in inflow and outflow, characteristics of trapped material (e.g. sediment characteristics).
- ***Level 3*** parameters addressed issues such as vegetation establishment and mapping, mapping of trapped material (e.g. location of sediment deposits), social assessments (e.g. adjacent resident surveys) and ecosystem assessments.

Further assessment levels were to be considered depending on available budget and at least after a suitable number (i.e. statistically relevant) of level 1 parameters had been completed. It should also be realised that considerable resources have already been expended (and are continuing) on the assessment of the efficacy of WSUD practices. Practitioners should consult available literature to gain further understanding on these activities.

6.4 Assessment, Accreditation and Asset Handover

Monitoring programs may also be related to providing the information necessary to give confidence to the final asset owner (in the majority of cases this will be local governments) that the asset is in a suitable condition and is operating satisfactorily prior to handover. This may simply be visual monitoring and inspection during an “on-maintenance” period for the asset. However, some regulatory agencies may also require monitoring results (e.g. water quality results, volumes of potable water substituted etc) to be provided to show that the asset is operating as intended. It should be noted that vegetated systems take at least one to two growing seasons to mature and therefore monitoring of devices during the establishment phase is not likely to indicate the operational performance of the treatment measure.

In the majority of cases, a simple asset transfer checklist may be beneficial and an example of one is provided in Table 6-1. This has been developed in response to the typical asset transfer issues identified by local government officers in a number of authorities.

6.5 Summary

The need for monitoring a WSUD element or treatment train should be determined by the degree of confidence in the performance of the element. Obviously, those measures which have been studied in depth by research agencies are not likely to require further monitoring to ensure that they are going to be successful. If any monitoring is to be conducted, it should focus on the consistency of the delivered WSUD implementation to that proposed in the conceptual and detailed design phases, as this is an area where there is the highest likelihood of non-compliance.

If a particular measure is an application of existing, well understood WSUD practice in a different environment, or is a new technique or element, then monitoring is likely to be beneficial. In all other cases, it is suggested that only where a monitoring program can considerably expand existing knowledge should a monitoring program be considered. In simplest terms, “monitoring for monitorings sake” is not likely to be successful.

Table 6-1 Example Asset Transfer Checklist

CHECKLIST		
Asset I.D.		
Asset Location:		
Construction by:		
'On-maintenance' Period:		
TREATMENT	**Y**	**N**
System appears to be working as designed visually?		
No obvious signs of under-performance?		
MAINTENANCE	**Y**	**N**
Maintenance plans and indicative maintenance costs provided for each asset?		
Vegetation establishment period completed?		
Inspection and maintenance undertaken as per maintenance plan?		
Inspection and maintenance forms provided?		
ASSET INSPECTED FOR DEFECTS AND/OR MAINTENANCE ISSUES AT TIME OF ASSET TRANSFER	**Y**	**N**
Sediment accumulation at inflow points?		
Litter within measure?		
Erosion at inlet or other key structures?		
Traffic damage present?		
Evidence of dumping (e.g. building waste)?		
Vegetation condition satisfactory (density, weeds etc)?		
Watering of vegetation required?		
Replanting required?		
Mowing/slashing required?		
Clogging of drainage points (sediment or debris)?		
Evidence of ponding?		
Damage/vandalism to structures present?		
Drainage system inspected?		
COMMENTS/ACTIONS REQUIRED FOR ASSET TRANSFER		
ASSET INFORMATION	**Y**	**N**
Design Assessment Checklist provided?		
As constructed plans provided?		
Copies of all required permits (both construction and operational) submitted?		
Proprietary information provided (if applicable)?		
Digital files (e.g. drawings, survey, models) provided?		
Asset listed on asset register or database?		

7 DETAILED WSUD GUIDANCE MATERIAL

7.1 National

Engineers Australia (2006). *Australian Runoff Quality: A Guide to Water Sensitive Urban Design*. Engineers Australia, ACT.

enHealth Council *Guidance on use of rainwater tanks'* – located via the following web site http://enhealth.nphp.gov.au/council/pubs/ecpub.htm

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NRMMC, EPHC and AHMC (Natural Resource Management Ministerial Council and Environmental Protection and Heritage Council, Australian Health Ministers Conference (2008) *National Water Quality Management Strategy - Australian Guidelines for Water Recycling Phase 2 - Stormwater Harvesting and Reuse and Managed Aquifer Recharge.* Australian Government.

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Proceedings of Rainwater and Urban Design 2007 Conference, Sydney, Australia, August and previous National WSUD Conferences.

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“Public Health Aspects Of Rainwater Tanks In Urban Australia”, Occasional Paper No. 10 , CRC for Water Quality and Treatment, Adelaide, 2005

“Water Quality and Health Risks from Urban Rainwater Tanks”, Research Report 42, CRC for Water Quality and Treatment, Adelaide, 2008.

Australian Standard 3500:2003, “Plumbing and Drainage”, Standards Australia, 2003.

“ICON Water Sensitive Urban Developments”, report prepared for National Water Commission, CSIRO, August 2008.

7.2 Australian Capital Territory

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ACT Government (2004). *Rainwater Tanks Guidelines for residential properties in Canberra*. ActewAGL, Environment ACT and ACT Planning and Land Authority.

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ACT Department of Urban Services *Design Standards for Urban Infrastructure, Section 1 Stormwater.*

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ACT Planning and Land Authority. (2007) *WaterWays – Water Sensitive Urban Design General Code*.

www.actpla.act.gov.au/__data/assets/pdf_file/0013/5440/Waterways.pdf

Think Water Act Water Program

http://www.thinkwater.act.gov.au/

7.3 New South Wales

Stormwater Trust and Upper Parramatta River Catchment Trust (2004) *Water Sensitive Urban Design – Technical Guidelines for Western Sydney*

http://www.wsud.org/tech.htm

NSW Government, Department of Water and Energy. (2007*) Interim NSW Guidelines for Management of Private Recycled Water Schemes*. NSW Government.

www.waterforlife.nsw.gov.au/__data/assets/pdf_file/0005/9923/Management_of_Private_Recycled_Water_Schemes.pdf

(for greywater and blackwater in more than one dwelling)

NSW Government, Department of Energy, Utilities and Sustainability. (2007). *NSW Guidelines for Greywater Reuse in Sewered Single Household Residential Premises*. NSW Government.

http://www.deus.nsw.gov.au/water/Greywater/Greywater.asp

NSW Government, Department of Environment and Conservation (2006). *Managing Urban Stormwater: Harvesting and Reuse*. NSW Government.

www.environment.nsw.gov.au/resources/managestormwatera06137.pdf

Water Sensitive Urban Design (WSUD) in the Sydney Region Capacity Building Program

http://www.wsud.org/index.htm

Hunter Central Coast Regional Environmental Strategy WSUD Capacity Building Program

http://www.urbanwater.info/index.cfm

7.4 Queensland

Moreton Bay Waterways and Catchments Partnership 2006, *Water Sensitive Urban Design: Technical Design Guidelines for South East Queensland*, Moreton Bay Waterways and Catchments Partnership and Brisbane City Council, Brisbane.

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http://www.dip.qld.gov.au/docs/temp/mp4_2_water_savings_targets.pdf

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