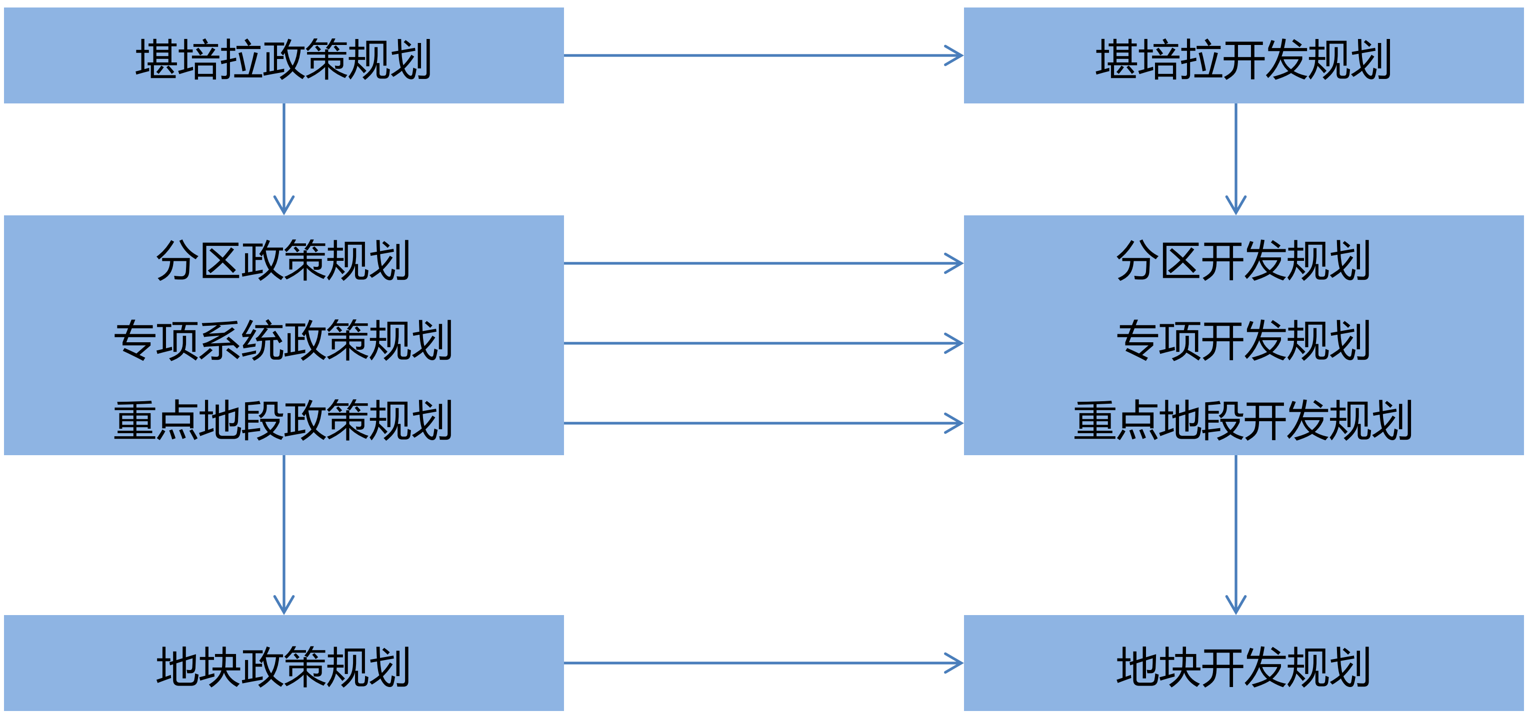
WSUD STUDY

澳大利亚行政区划

澳大利亚联邦
湖鹰 2009.2.15
达尔文
Darwin
凯恩斯
汤斯维尔
芒特艾萨
北部地方
Northern
Territory
黑德兰港
爱丽斯斯普林斯
昆士兰
Queensland
罗克汉普顿
西澳大利亚
Western Austrilia
布里斯班
Brisbane
黄金海岸
南澳大利亚
South Austrilia
卡尔古利
珀斯
Perth
弗里曼特尔
新南威尔士
New South Wales
纽卡斯尔
Canberra
堪培拉
悉尼Sydney
伍伦贡
阿德莱德
Adelaide
奥尔巴尼
Victoria
维多利亚
首都直辖区
Austrilian
Capital
Territory
吉朗
墨尔本
Melbourne
图 例
首都
州首府
重要城市
注：澳大利亚行政区划
全国共分为6个州和2个地方。
塔斯马尼亚
Tasmania
霍巴特 Hobart

澳大利亚规划体系

以堪培拉为例

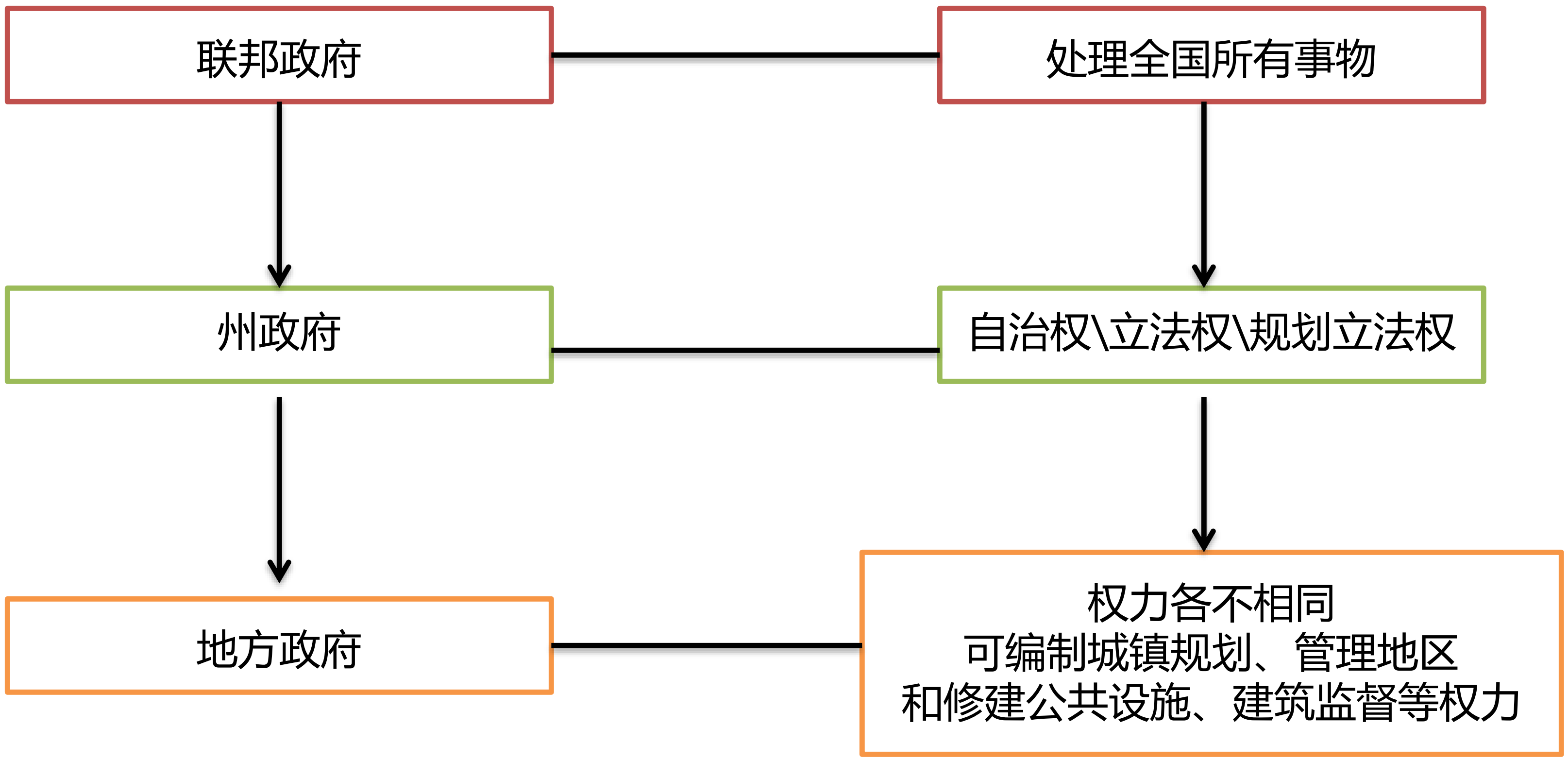


澳大利亚规划体系

以墨尔本为例

政策	国家级	州级
环境政策	国家生态可持续发展战略 Department of the Environment and Heritage	我们的环境，我们的未来，可持续行动申明（2006）
水政策	全国水动议 Council of Australia Governments, 2004 国家水安全计划 Prime Minister of Australia, 2007	共同保护我们未来的水（2004） 可持续水战略中心区域行动（2055）
城市规划政策	可持续城市计划2003	墨尔本2030规划
立法	联邦环境及生物多样性保护法（1999） 水法（2007）	环境保护法（1970） 水法（1989） 集水及土地及保护法（1994） 规划与环境法（1987） 环境影响法（1978）

澳大利亚规划体系



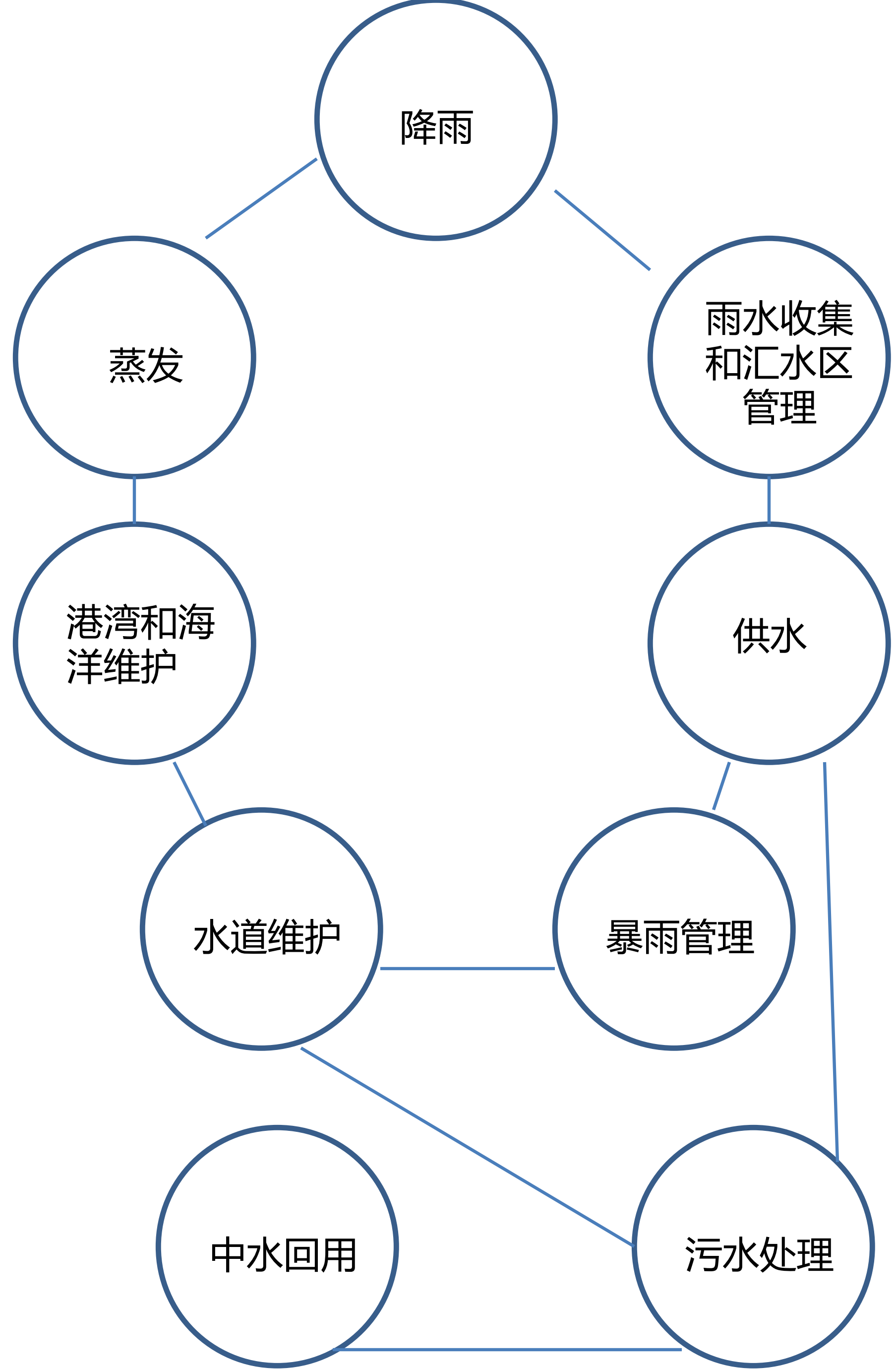
通过联邦政府和州政府制定战略性规划并将规划目标层层分解，为地方规划设计做出宏观指导。

澳大利亚WSUD规划体系

WSUD是在保持城市人类发展的基础上，恢复自然的水循环过程。

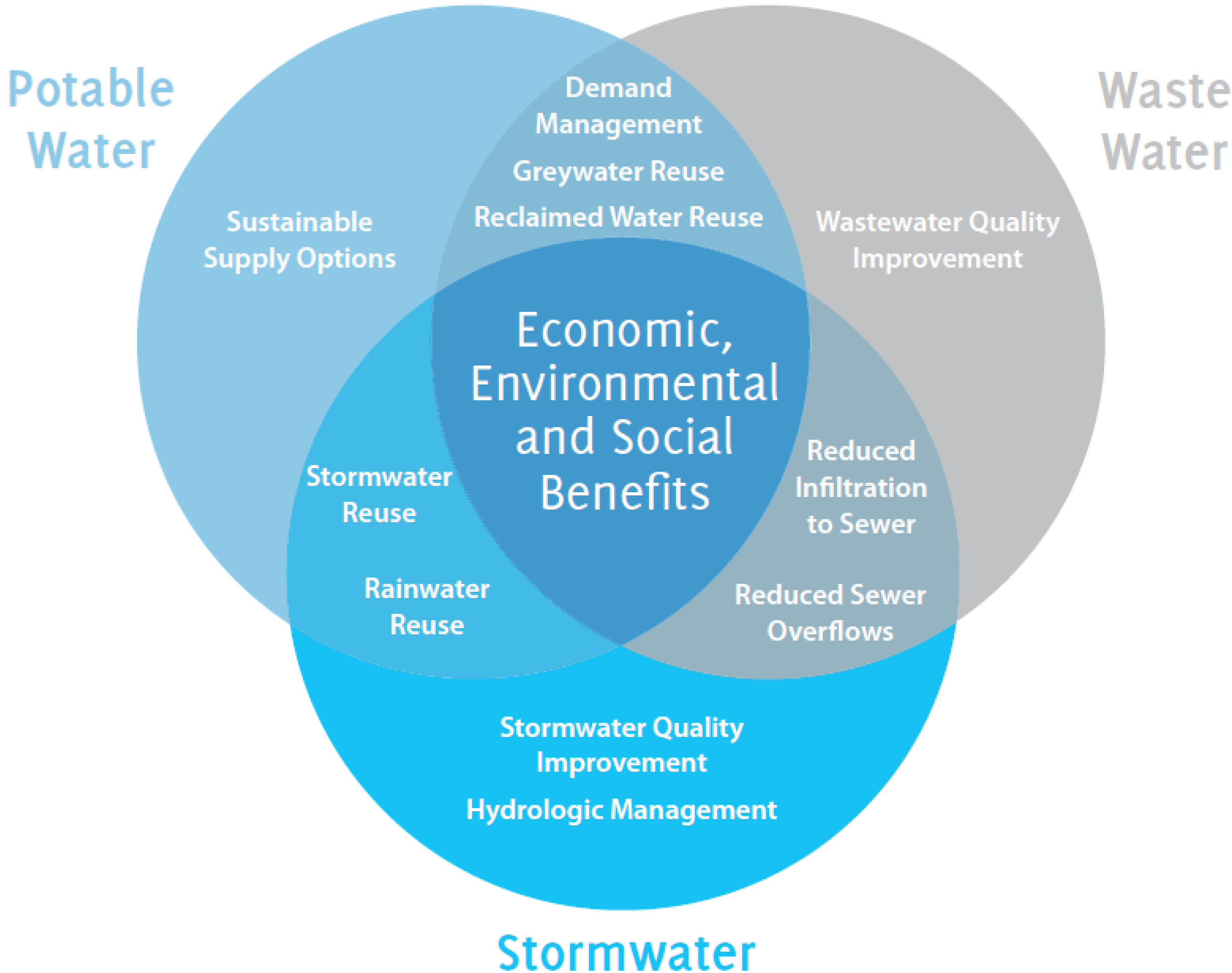
强调通过城市规划和设计的整体分析方法来减少对自然水循环的负面影响和保护水生生态系统的健康。

将雨洪管理、供水、污水管理一体化，兼顾景观和生态系统。



From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

What WSUD achieves



From Concept Design Guidelines for Water Sensitive Urban Design (South East Queensland Healthy Waterways Partnership)

What WSUD achieves

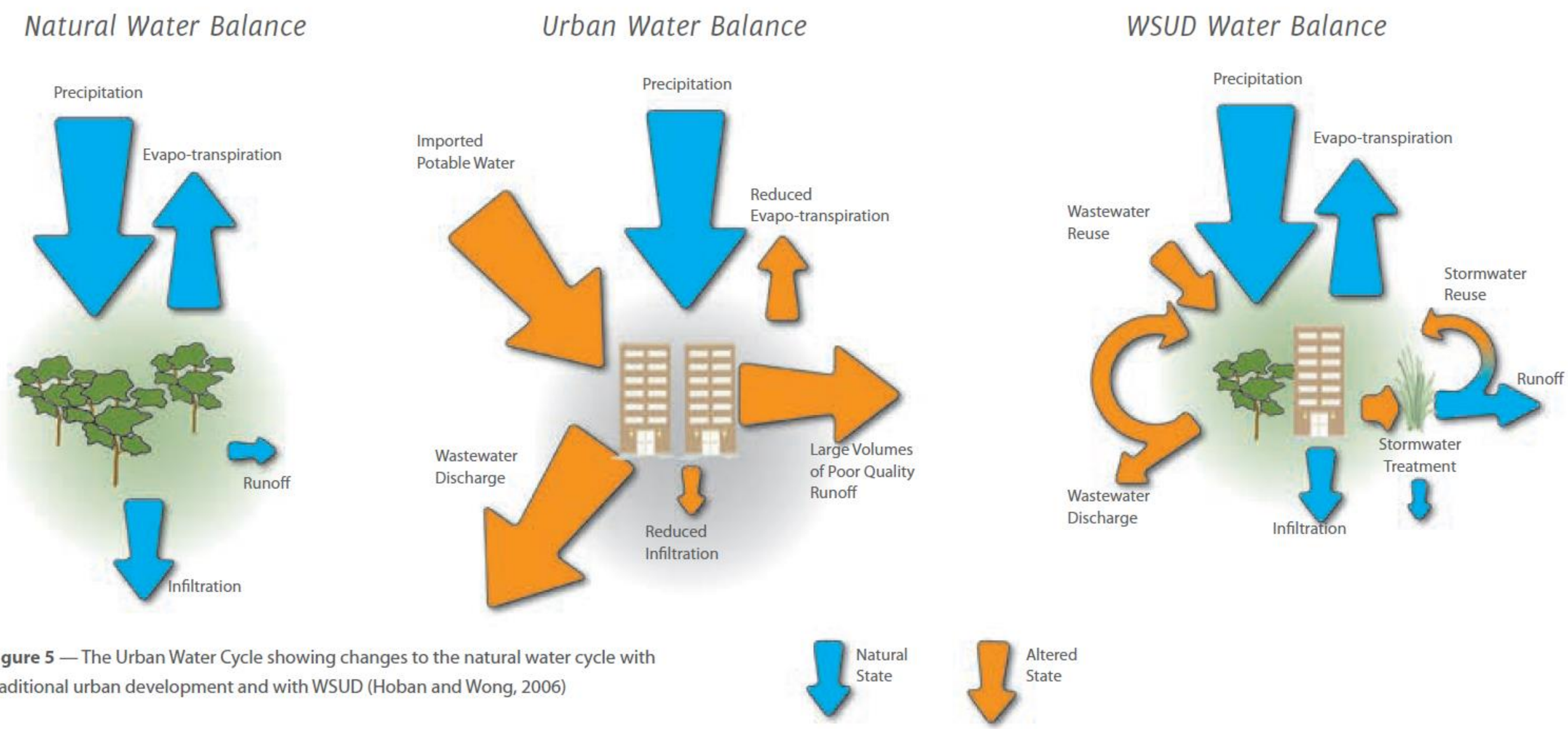
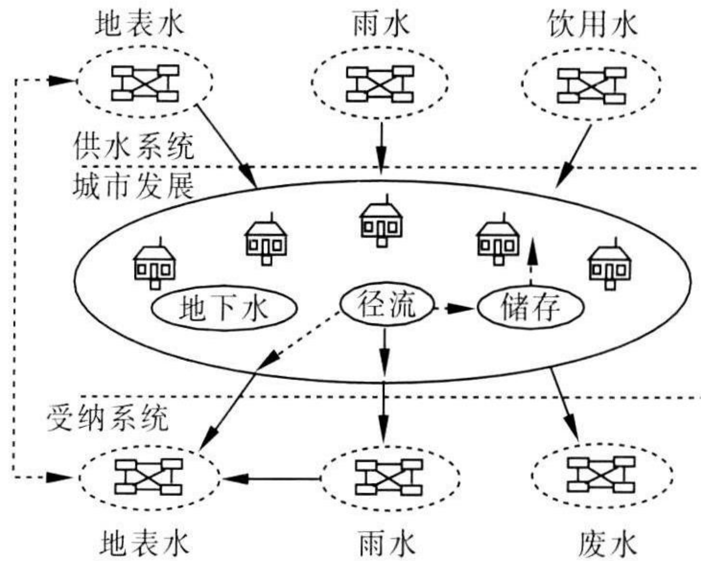
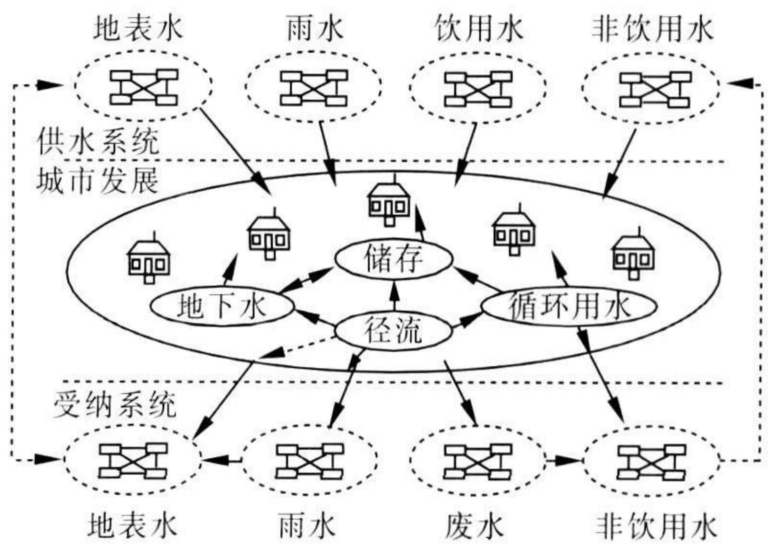


Figure 5 — The Urban Water Cycle showing changes to the natural water cycle with traditional urban development and with WSUD (Hoban and Wong, 2006)

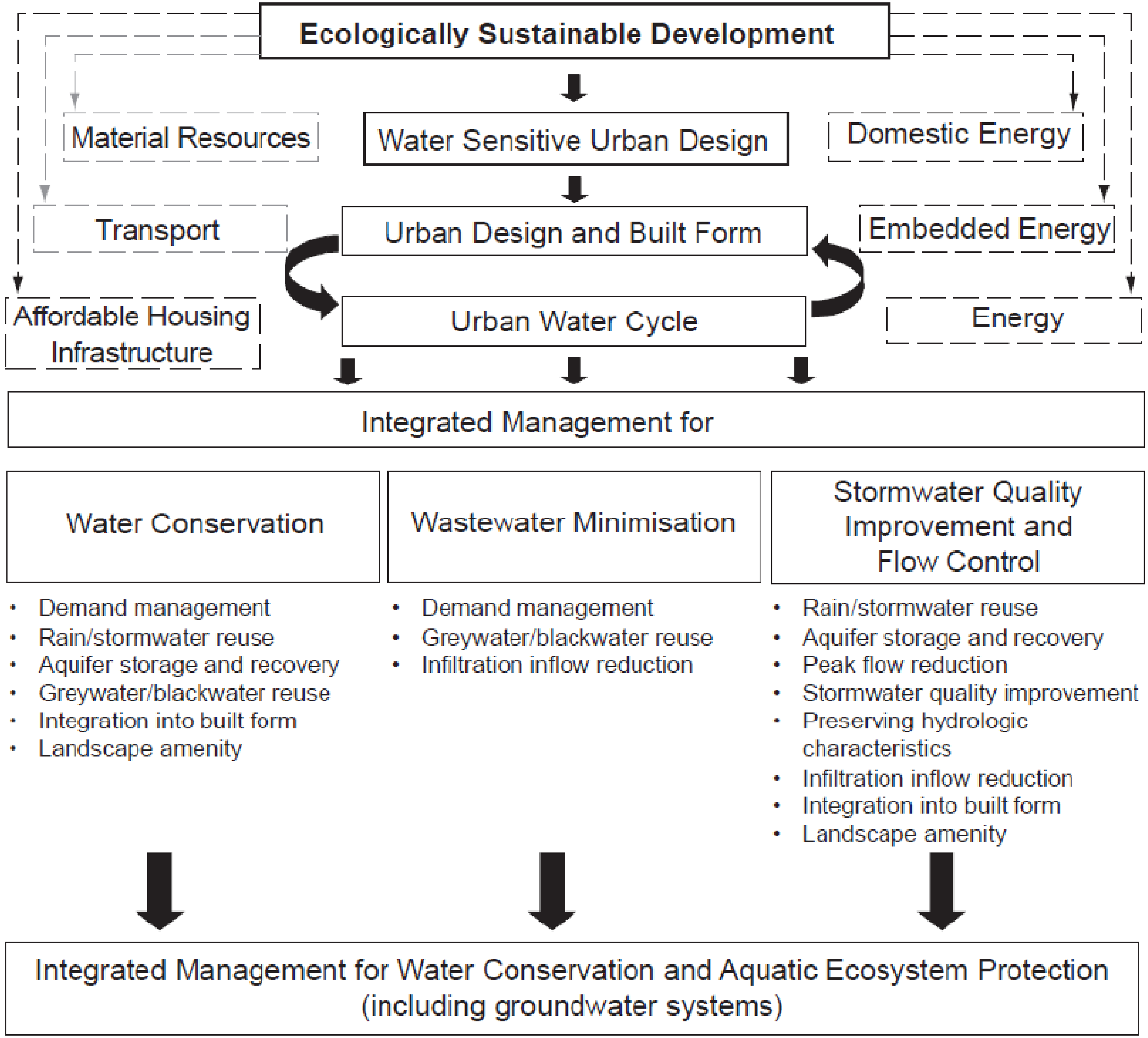
What WSUD achieves



a. “传统”城市发展



b. 与 WSUD 结合的城市发展



The Status of Water Sensitive Urban Design Schemes in South Australia
Goyder Institute for Water Research Technical Report Series
No.13/11,Adelaide, South Australia

Figure 1 - The water sensitive urban design framework (Source: Wong, 2006, pg. 1-3).

BMP LID SUDS WSUD主要差异比较

名称	特点
最佳管理作业措施BMP	针对面源污染问题，关注水质，技术性强
低影响开发LID	从源头上对小区域或保护天然的水文进行控制，技术性强
可持续排水系统SUDS	通过分级排放思想来控制雨水径流量、减少径流污染以及增加环境舒适性
水敏性城市设计WSUD	从城市开发尺度上，通过整合城市空间设计和综合水资源管理的手段实现雨水的综合利用

BMP LID SUDS WSUD主要差异比较

表 1　典型雨洪管理体系的特征

Tab. 1　Characteristics of typical stormwater management systems

项　目	中小降雨控制（水质/水量）	暴雨控制	采用源头措施	早期评估及介入	顶层设计	跨学科	多尺度	多目标	恢复良性水文循环	水系统综合管理
传统排水（自 19 世纪初）		*								
BMPs（20 世纪 70 年代至今）	*	*	*				*	*	*	
LID（20 世纪 90 年代至今）	*		*	*		*		*	*	
GI/GSI（自 USEPA2007 年引入至今）	*	*	*	*	*	*	*	*	*	
SUDS（20 世纪 90 年代至今）	*	*	*	*			*	*	*	
WSUD（20 世纪 90 年代至今）	*	*	*	*	*	*	*	*	*	*
LIUDD（21 世纪初至今）	*	*	*	*	*	*	*	*	*	
雨水（洪）控制利用（21 世纪初至今）	*	*	*	*	*	*	*	*	*	*
注：　* 表示密切关联或突出作用。										

澳大利亚WSUD规划体系发展与演变

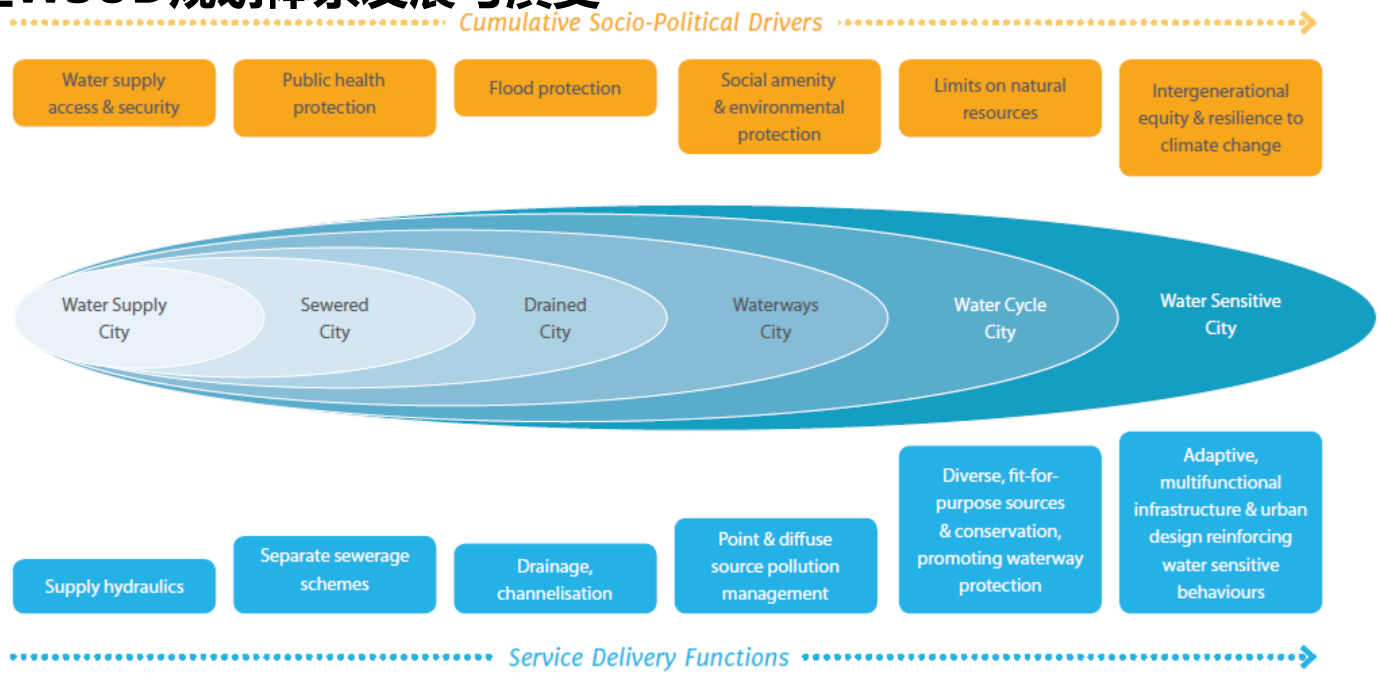


Figure 2 — Key transitional stages to a Water Sensitive City (Brown et al., 2008)

发展阶段	确保城市水供应（Water Supply City）	城市管网建设阶段（Sewered City）	城市水资源保护（Waterways City）	城市水资源保护阶段（Waterways）	水循环综合利用阶段（Water-Cycle City）	水敏感友好型城市（Water Sensitive City）
管理目标	保证城市充足的水源供应，大概时间十九世纪初	基于公共健康保护的城市排水建设	保证城市高效排除污水，保护城市不受洪水破坏	注重城市环境保护和舒适性	实现生物多样性，保护包括水在内的自然资源	保护自然资源，适应气候变化，建设更舒适、多功能有活力的水生态城市
主要实现手段	堤坝和管道等硬件设施	十九世纪九十年代前，词啊用合流制排污系统，其后发展出了分流制排污系统	快速排除雨水的各种措施，如管道建设、河道渠化	水变成了城市重要的视觉和休闲要素，建设污水处理设施，力求减少水体污染。结合非点源污染问题的研究，运用湿地和生物过滤方式减少水污染	采用水综合利用途径，包括水资源保护，多种水供应方式（净水、雨水、海水、污水等不同水质用于饮用水、灌溉、工业、日常等多种用途）同时多利益相关者、多专业多途径共同寻找解决办法	结合绿色基础设施（Green Infrastructure）建设，结合城市形态、生态技术、自然要素等多元化的手段

澳大利亚WSUD规划体系发展与演变

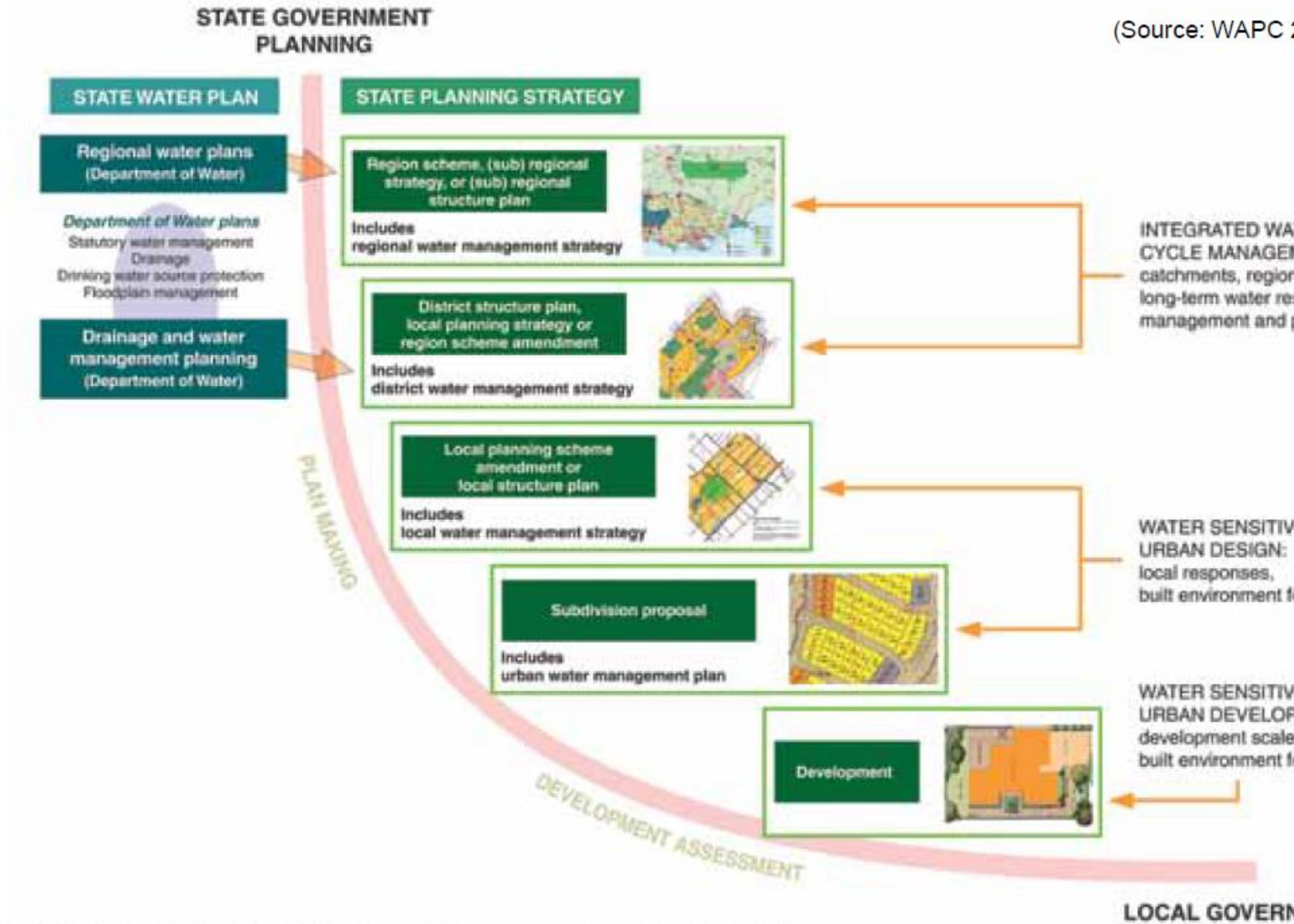
发展前期		起步阶段	加速发展阶段		稳定阶段前期
1960s-1989	1990-1995	1996-1999	2000-2003	2004-2010	2011-
大背景出现	技术革新小环境出现&议题明确关系开始建立	小环境形成&对议题形成共识	小环境扩散&知识传播	政策&实践拓展&议题深入（新的创新小环境出现）	雨水质量控制实践&创新小环境形成——雨水收集

阶段	参与者	机构之间的联结（以及战略目标）	联系
制度压力 （2011—） 雨水质量控制实践 创新小环境形成—雨水收集	**小环境参与者：** 研究者 当代政府部门 开发商及顾问 **制度参与者：** 政客 水务局 环保机构 水利用机构	（科研）水敏感城市水研究中心 （新成立的）研究城市水管理的社会—技术解决方案、教育培训计划等等（政策）内阁咨询委员会，为如何实现政策目标提供独立咨询 （新职业构建）清洁水计划 （重点项目）实验项目进行中，“水敏感城市”新研究课题，政策沟通渠道	建立起科研与生产实践、政策、提供就业机会、重点项目之间的联系

澳大利亚WSUD规划体系层级

规划阶段规模	规划内容	水管理内容	案例	使用面积大小
1.国家层面 Regional	区域策划 区域结构规划	确定水资源的环境需求，提出战略排水规划等关键性的策略	2006年国家政府颁布的《国家水质量管理策略》等	＞300ha
2.州层面 District	地方规划策略 地区计划 修正案 地区结构计划	提出满足可持续水循环的地区和区域管理目标，进行地表水和地下水分析，分析规划钱的土地利用性质确定潜在的污染可能性，确定关键性的蓝色基础设施	2004年新南威尔士州政府颁布的《西悉尼WSUD技术指引》等	＞300ha
3.地方层面 Local	局部规划方案 局部结构的计划 大纲发展计划	确定地区的水目标、场地的综合分析（主要分析内容包括：现存的和人工的水廊道，地区的自然条件分析，水资源的社会、文化价值，现状水污染水平，水文分析）	地方政府的法律指引	＜300ha
4.小区层面 Subdivision	地区详细设计	遵守区域水管理策略汇总的目标，综合的区域分析，利用相关设计减少城市水污染、保护水资源，保护水系廊道、湿地等的生态社会价值，水资源的存储和资源的重复利用，确定具体布局和位置并提出实施措施	2003年德国斯图加特Hohlgrabenacker小区住宅设计指引	＜20ha
5.开发 Development	开发申请 建筑许可证	履行上层次的水保护策略，并采用定期监测的手段定期对开发区域进行监测。	评价体系保障	

(Source: WAPC 2



Note: The above diagram depicts the optimal process. In situations where there is existing zoning and a lack of guiding information, a flexible approach to implementation may be required. This is at the discretion of the WAPC on advice of the Department of Water.

澳大利亚WSUD规划体系层级

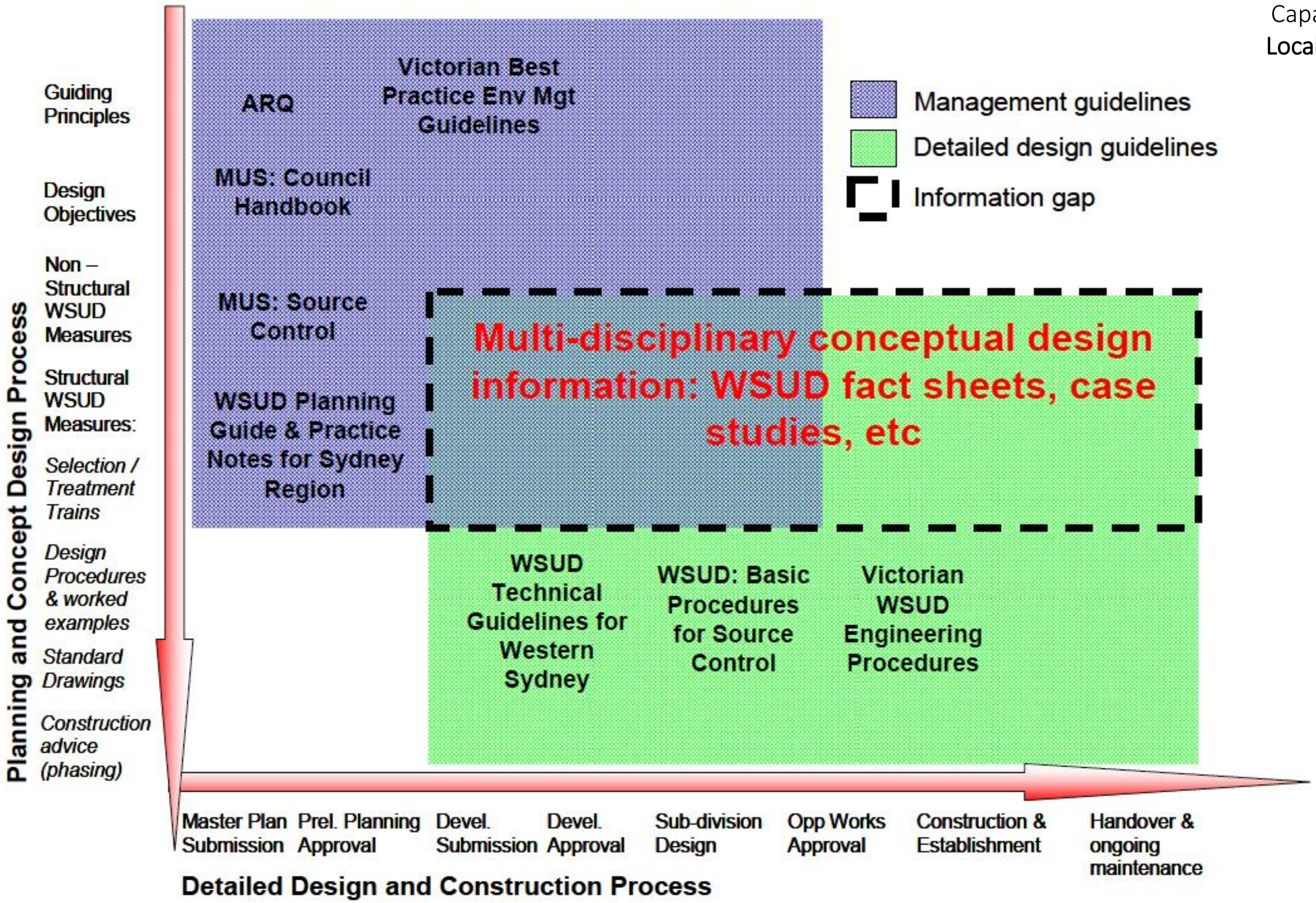
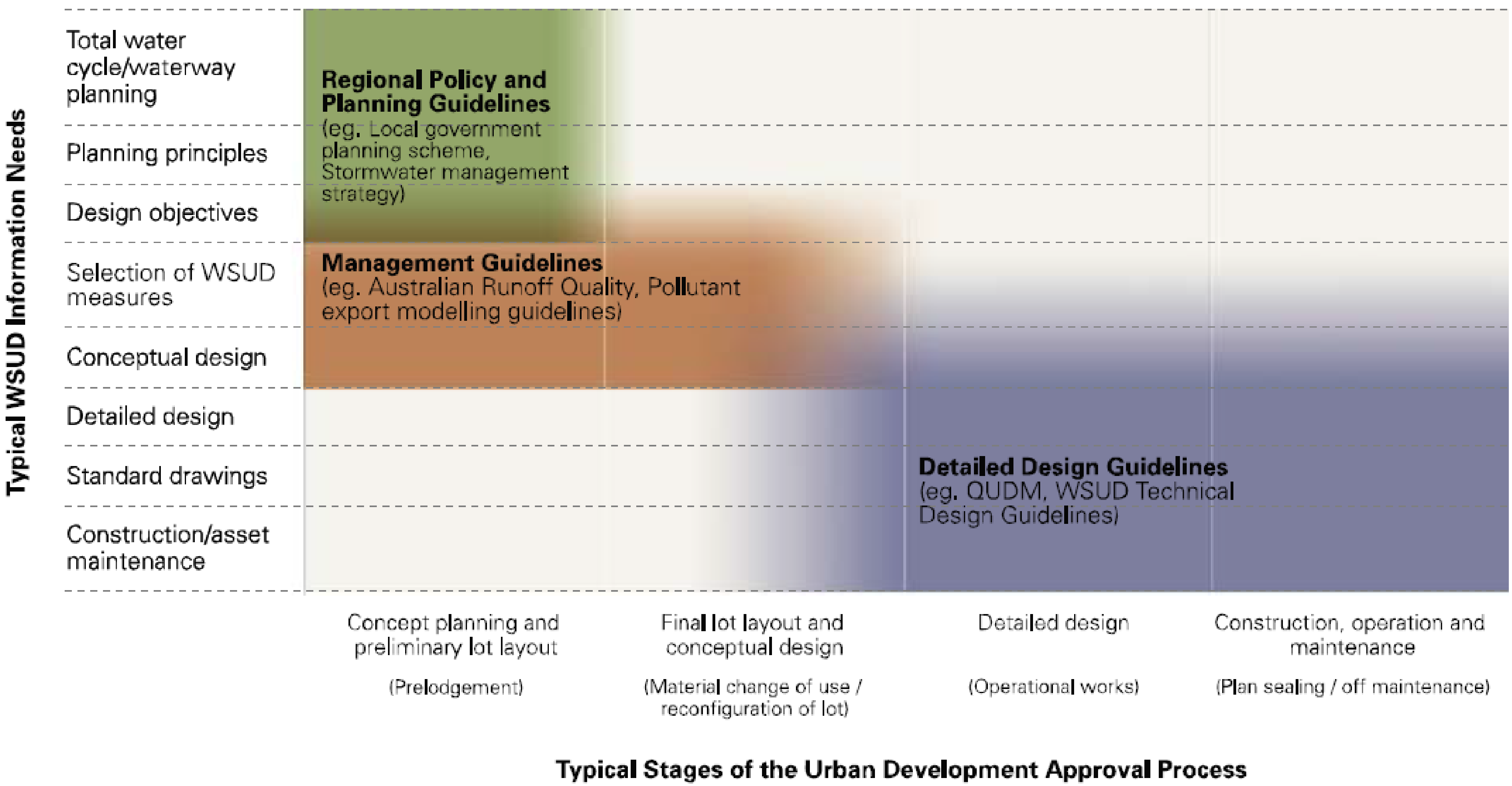


Figure 1: Guidelines relevant to the planning and project delivery process (adapted from Ecological Engineering 2005b)

澳大利亚WSUD规划体系层级

Figure 1.1 Applicable information tools and resources for different aspects of WSUD implementation



澳大利亚WSUD规划体系层级

Regional planning

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

District planning

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

Structure planning

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

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

澳大利亚WSUD规划体系

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;
Dam safety.

WSUD经济和社会环境效益

经济效益	社会与环境效益
节约资本成本：减少管道和排水沟投资成本	水文平衡：通过储存、渗透和蒸发的自然过程，达到自然水温的平衡
节约建设成本：通过生态的清洁过滤作用减少基础建设的成本	保护生态敏感区：在城市发展中保护生态敏感区
节约水质成本：通过保留和修复水系，帮助减少优化水质的成本	修复水系：恢复和增加城市的水系
节约开发商成本：减少开发商对排水设施的投资	降低影响：减少城市开发对自然环境的影响
	增加自然栖息地：增加生物多样性和郊区型大地景观
提升市场价值：整合水功能、临街的睡眠，打造公共开放空间网络，完善生态体系，提升人居环境，以获得更多的认同和更大的市场	补充地下水
	与城市和居住区景观系统融合
提升资源利用：虽然可能会提高居住区的建设成本，但可利用水道为社区提供更多的休闲康体设施，提供更多的公共开放空间	高质量的城市面貌
	联系：能够通过开放空间体系联系各个社区节点

Objectives

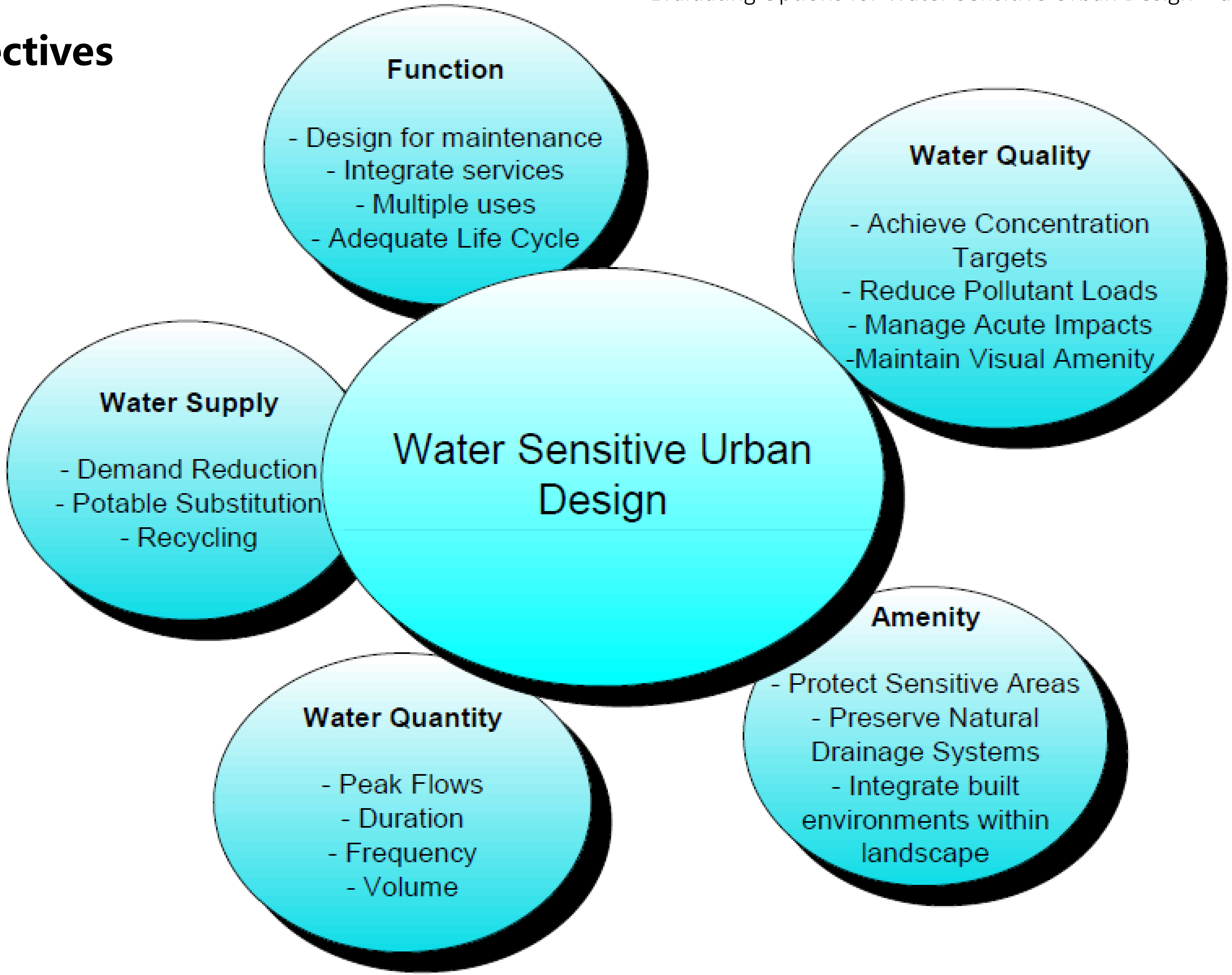


Figure 2-1 WSUD Objectives

Principles

1. Incorporate water resources as early as possible in the land use planning process;

2. Address water resource issues at the catchment and sub-catchment level;

3. Ensure water management planning is precautionary, and recognises intergenerational equity, conservation of biodiversity and ecological integrity;

4. Recognise water as a valuable resource and ensure its protection, conservation and reuse.

5. Recognise the need for site-specific solutions and implement appropriate nonstructural and structural solutions;

6. Protect ecological and hydrological integrity;

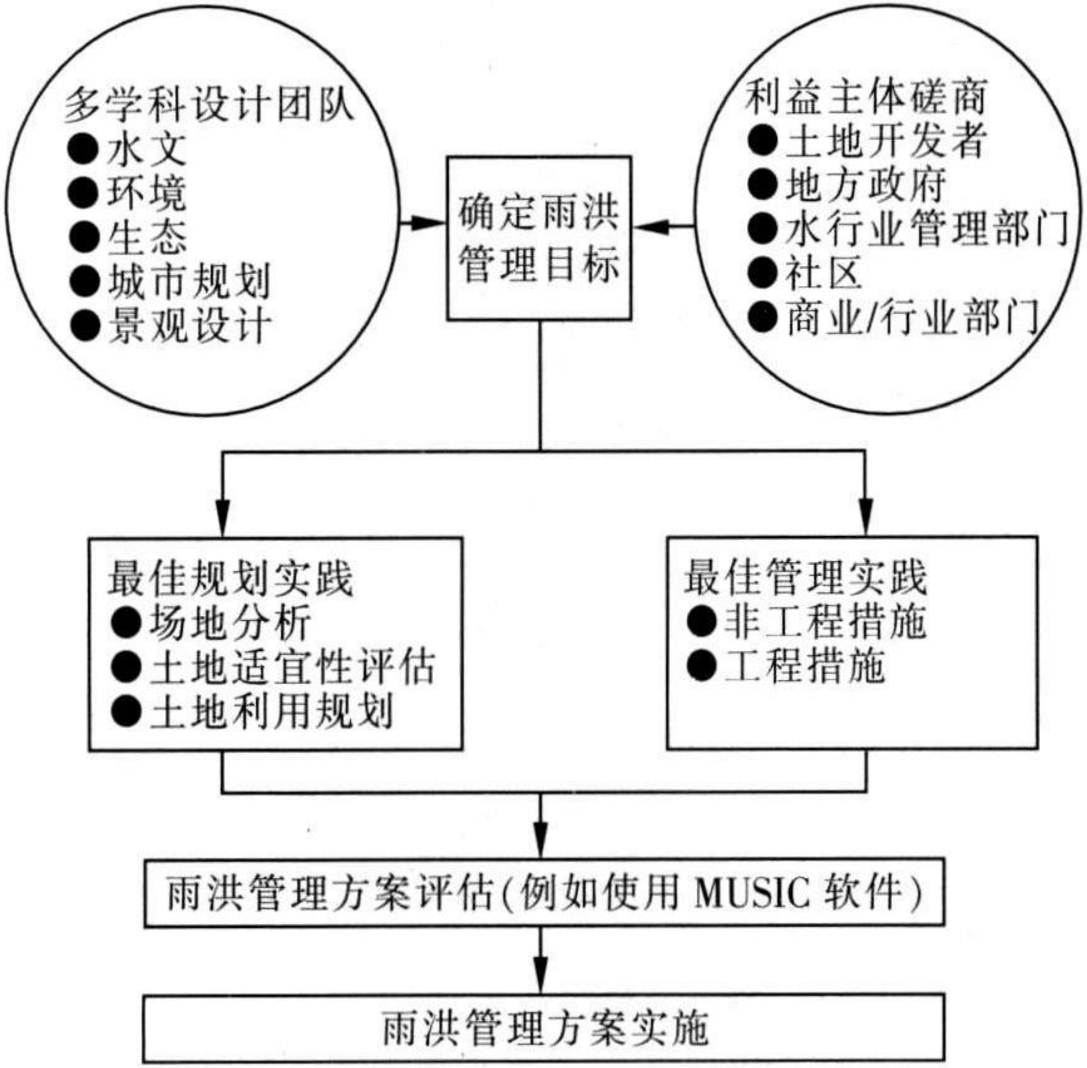
7. Integrate good science and community values in decision making; and Ensure equitable cost sharing.

Project Team

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

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

Process


多学科设计团队
●水文
●环境
●生态
●城市规划
●景观设计
确定雨洪管理目标
利益主体磋商
●土地开发者
●地方政府
●水行业管理部门
●社区
●商业/行业部门
最佳规划实践
●场地分析
●土地适宜性评估
●土地利用规划
最佳管理实践
●非工程措施
●工程措施
雨洪管理方案评估(例如使用MUSIC软件)
雨洪管理方案实施

澳大利亚WSUD规划体系操作阶段

操作阶段	概要
1.可行性研究	建设方：提交雨洪管理总体计划 水务局：审查 目标：总体规划要从源头上避免和控制城市发展对水环境的负面影响，如城市洪涝灾害，受纳水体水质，并符合区域长期规划
2.初步设计 3.详细设计 4.施工图设计	建设方及受咨询设计公司：按要求将工程报告、设计图纸、计算书、甚至数学模型提交水务局备案，并与政府主管部门（流域管理局\水务局\当地政府规划基建部门\环保部门）保持密切联系
5.审核	主管部门：发放许可文件（高难度工程会要求建设方聘请第三方咨询公司）
6.施工前	建设方：制定场地控制方案及相应设施以进行施工期雨洪管理
7.施工期间	水务局：对场地排入周边河道水体的雨洪所可能携带的冲刷泥沙和施工机械泄漏油污等进行严格监管

备注1：对与主管部门的监督，政府要求遵循相应法规和技术标准。建设方对主管部门的监管不当或失职行为可提出行政申诉，甚至启动法律起诉。

备注2：旧城改造工程中，由于受限于狭窄空间，当建设的设计方案不能容纳足够的WSUD的工程设施时，建设方要向水务局提出申请，经审批后，建设方可交付一定补偿金后得到豁免，补偿金最终将由水务局用于相应流域下的雨洪设施建设投资，以保证流域整体水量水质标准。

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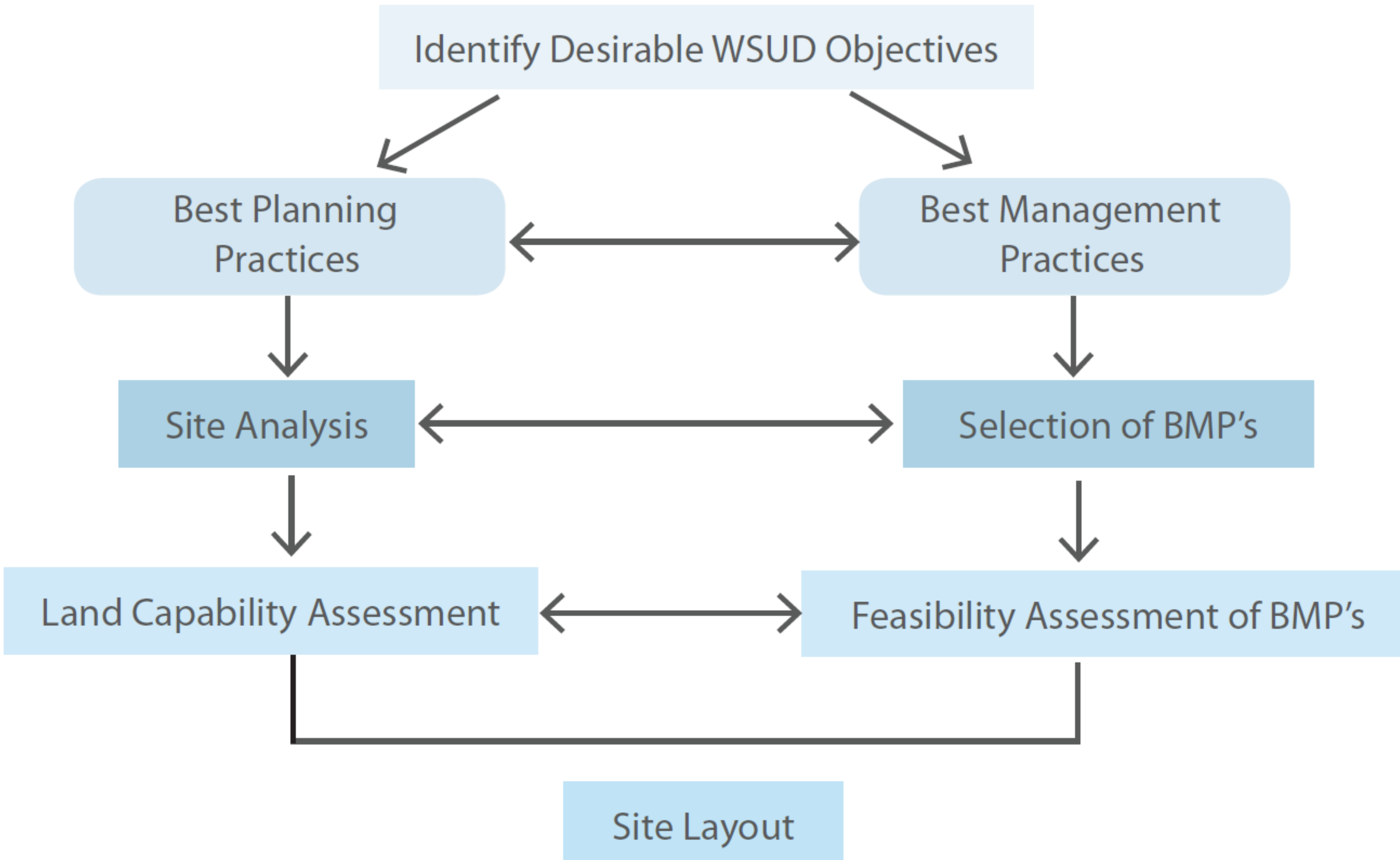
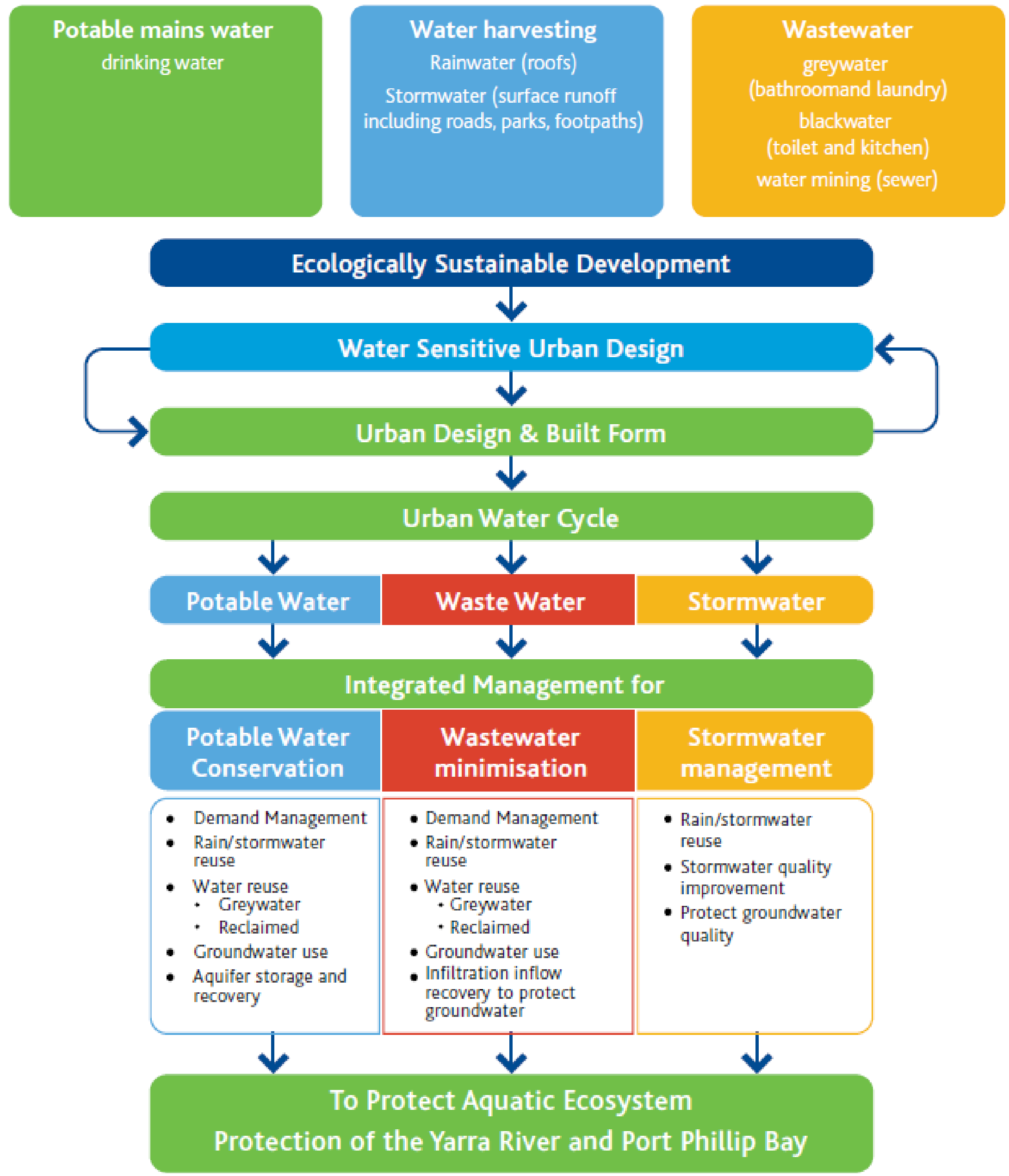
How WSUD achieves its aims



How WSUD achieves its aims



How WSUD achieves its aims

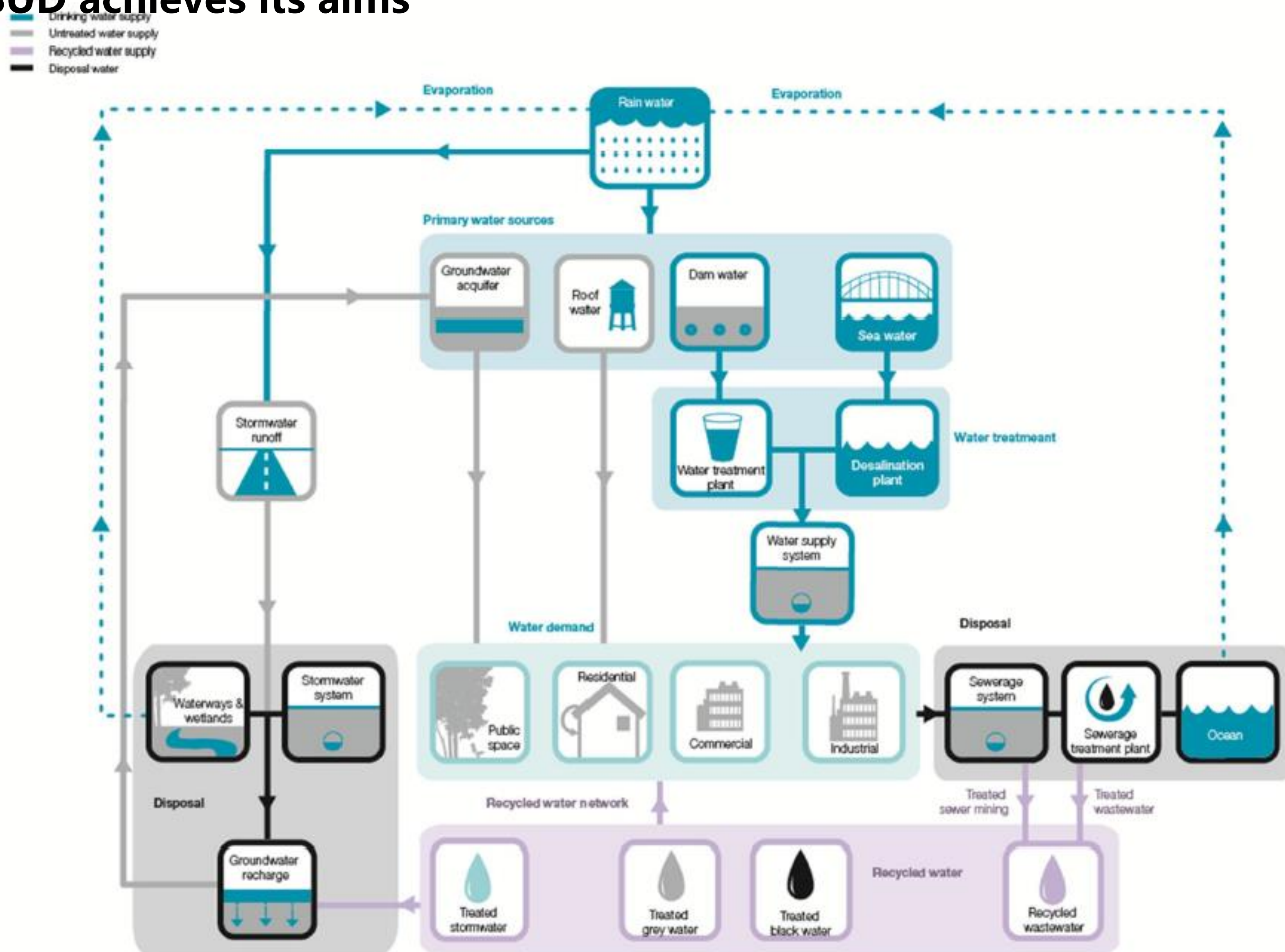


Figure 2 Integrated Water Management cycle

How WSUD achieves its aims

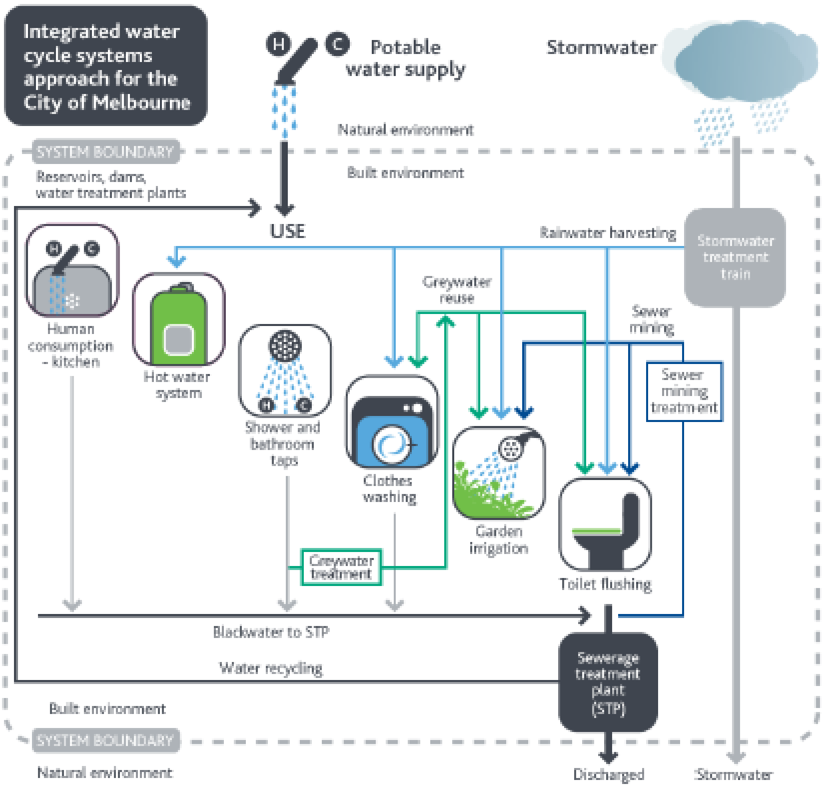


图3-2 水循环系统整合示意图

BMPs 是指城市设计的结构和非结构要素，以防止水污染，促进水的收集，处理，传递，存储和再利用的综合管理方案。

表3-4. WSUD技术的主要组件

用户	组件	雨水		废水	美学价值
		水质	滞留		
家庭	家庭雨水箱	✓	✓	–	–
	多孔铺装	✓	✓	×	×
	庭院布局与美化	✓	✓	×	×
开发商 规划者 建筑师 工程师	水路修复	✓	×	×	✓
	雨水箱	✓	×	×	×
	总污染物陷阱	✓	✓	×	●
	泥沙（沉淀）	✓	✓	●	✓
	池塘湖泊	✓	✓	–	
	植被洼地和缓冲带	✓	×	×	✓
	雨水花园	✓	×	×	✓
	雨水花园树坑	✓	×	×	✓
	表面湿地	✓	✓	●	✓
	潜流湿地	●	●	●	✓
	悬浮生长生物过程	×	×	✓	×
	固定生长生物过程	×	×	✓	×
	循环介质过滤器	×	×	✓	×
	沙子和深度过滤	×	×	✓	×
	膜过滤	×	×	✓	×
	消毒	×	–	✓	×

✓：主要用途；●：有影响，但非主要目的；×：无作用；–：不适应

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Process

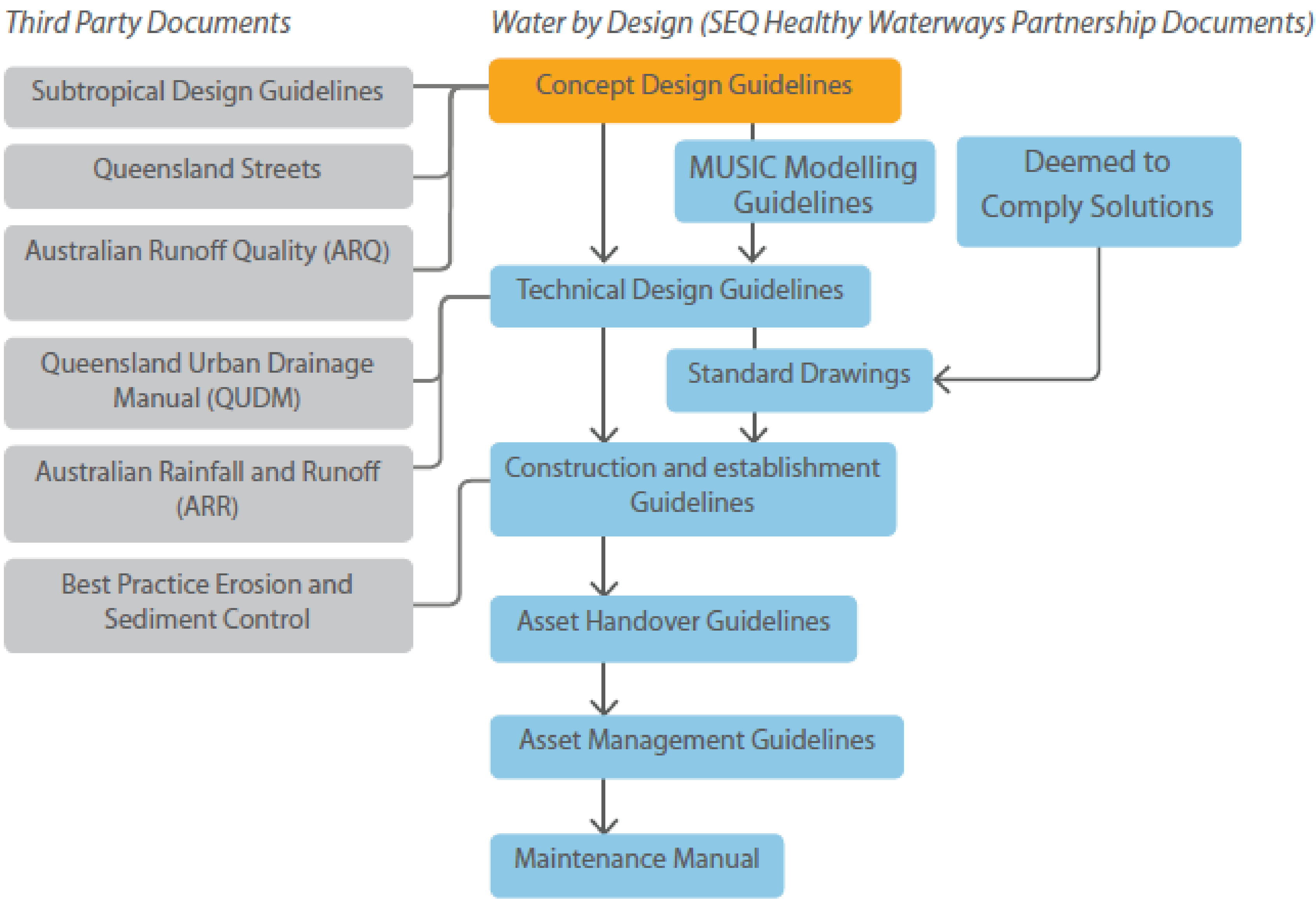
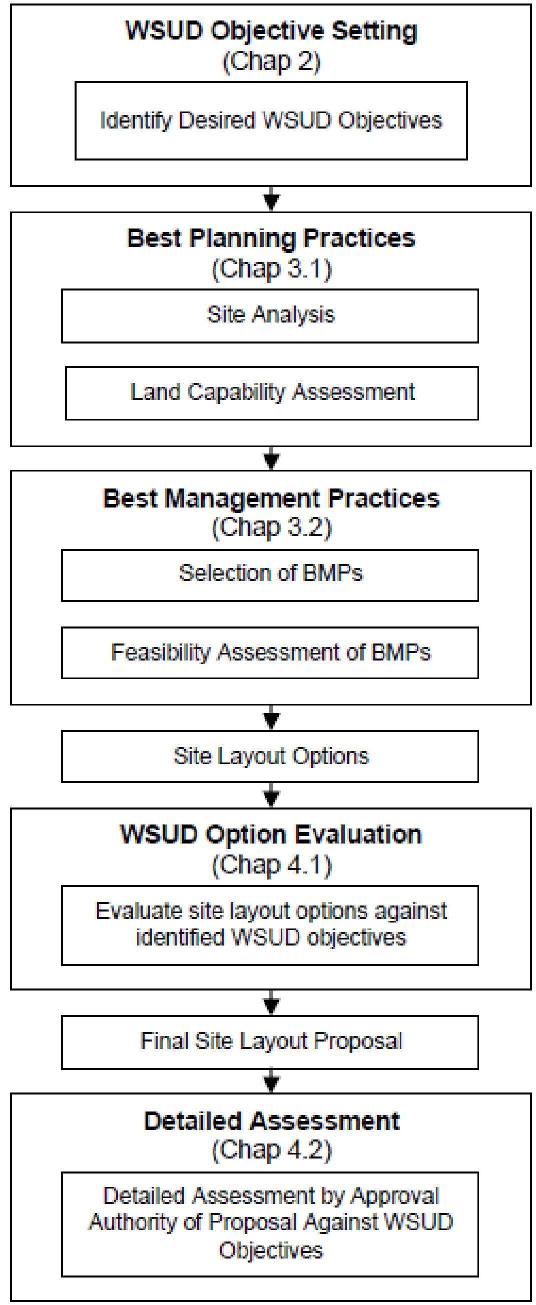


Figure 1 — Document map showing related guidelines and information resources

Process

Figure 2: Framework for implementing WSUD on Fairfield City Council projects

Process


WSUD Objective Setting
(Chap 2)
Identify Desired WSUD Objectives
Best Planning Practices
(Chap 3.1)
Site Analysis
Land Capability Assessment
Best Management Practices
(Chap 3.2)
Selection of BMPs
Feasibility Assessment of BMPs
Site Layout Options
WSUD Option Evaluation
(Chap 4.1)
Evaluate site layout options against identified WSUD objectives
Final Site Layout Proposal
Detailed Assessment
(Chap 4.2)
Detailed Assessment by Approval Authority of Proposal Against WSUD Objectives

Process

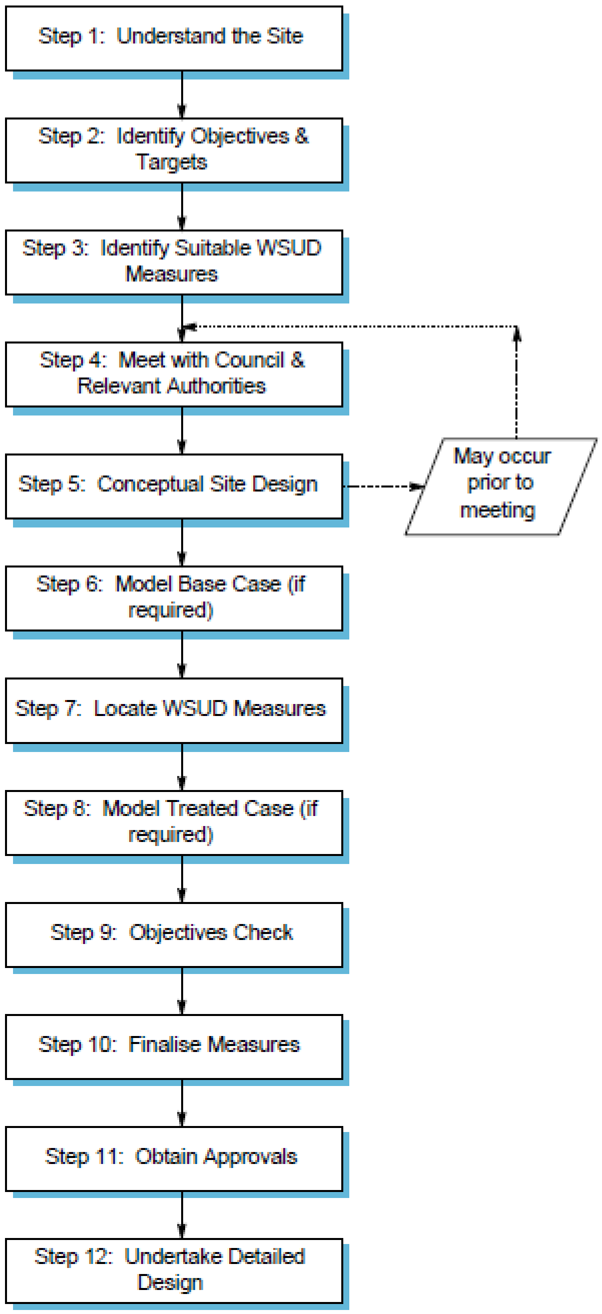
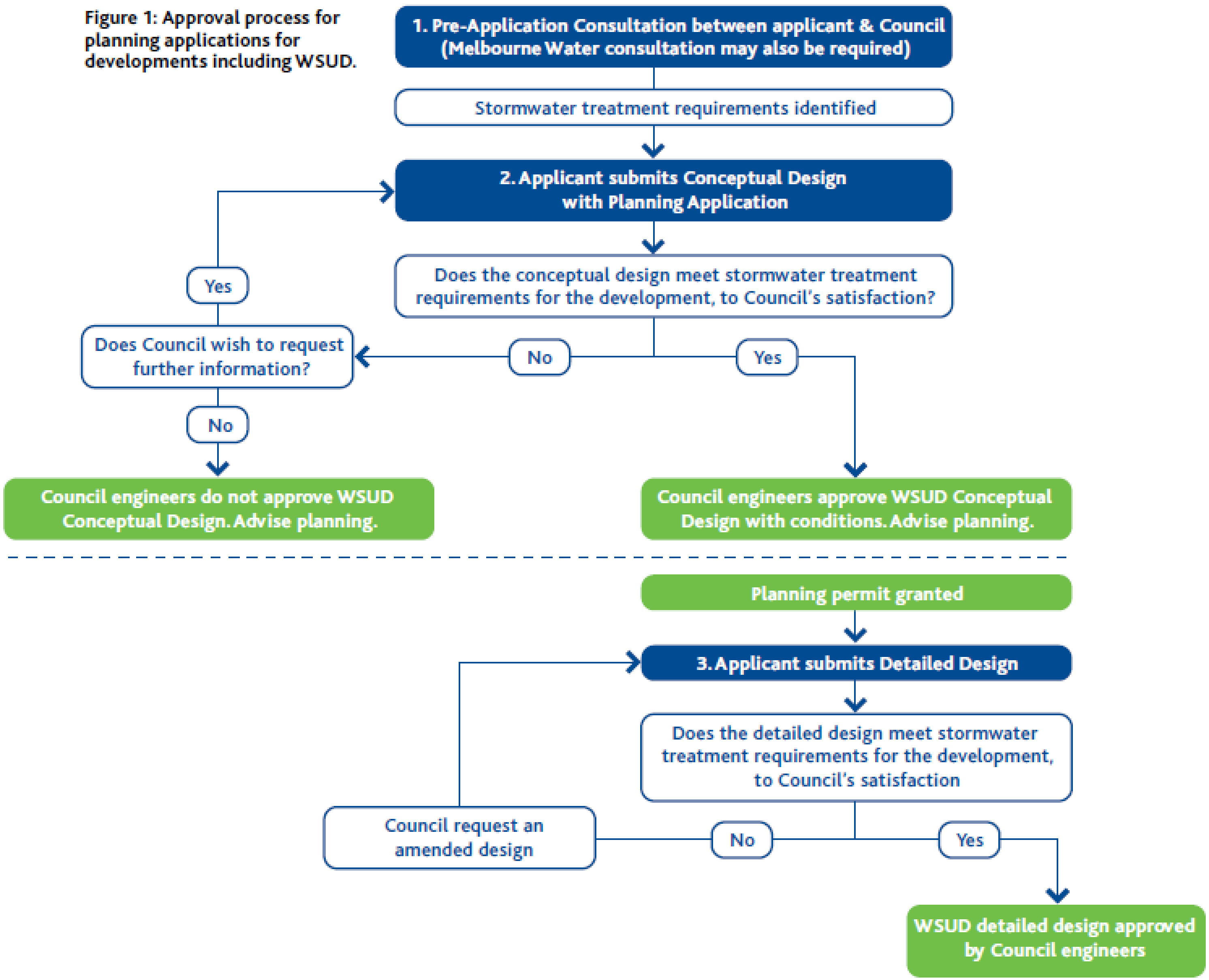


Figure 3.1 WSUD Decision Process Flowchart

Process

Figure 1: Approval process for planning applications for developments including WSUD.



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Brisbance City Council & Mereton Bay Waterways & Catchments Parnership & Australian Government

Process

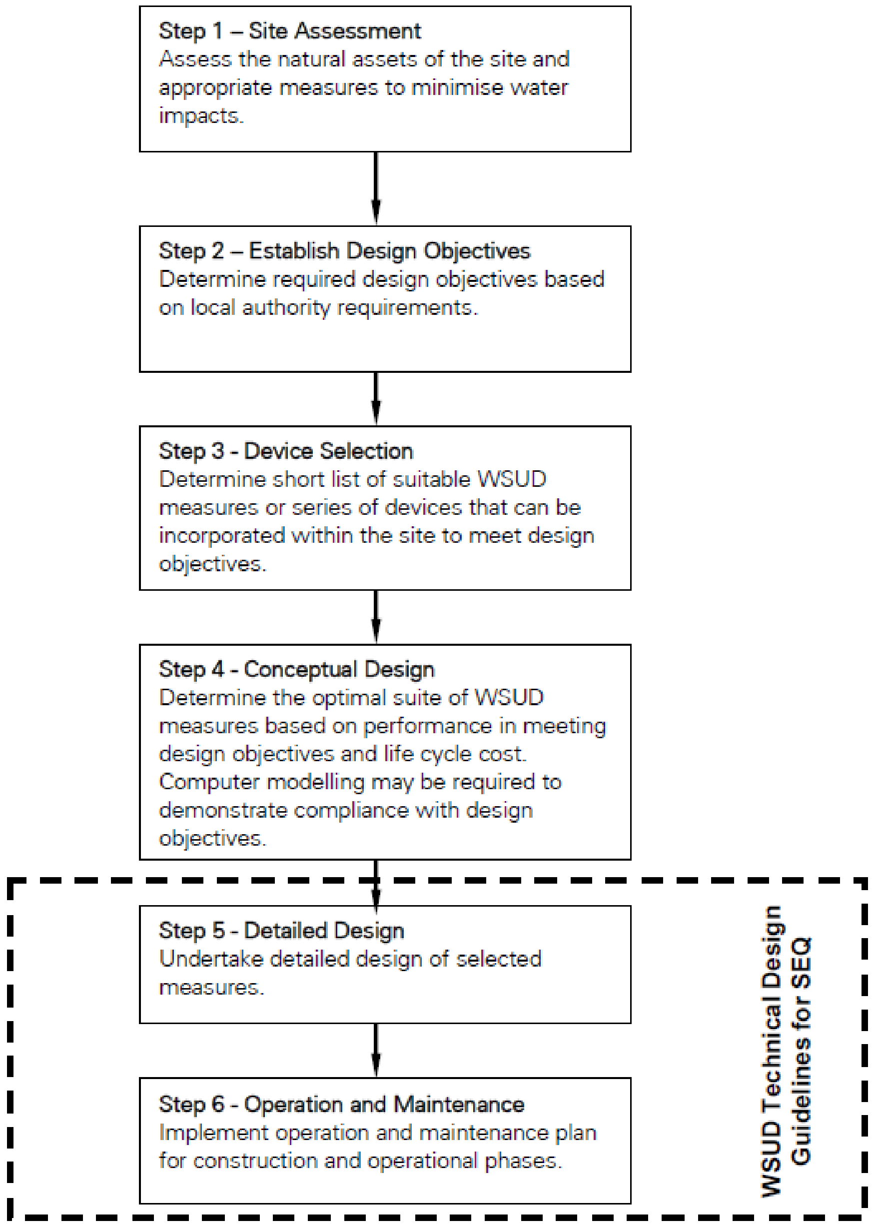
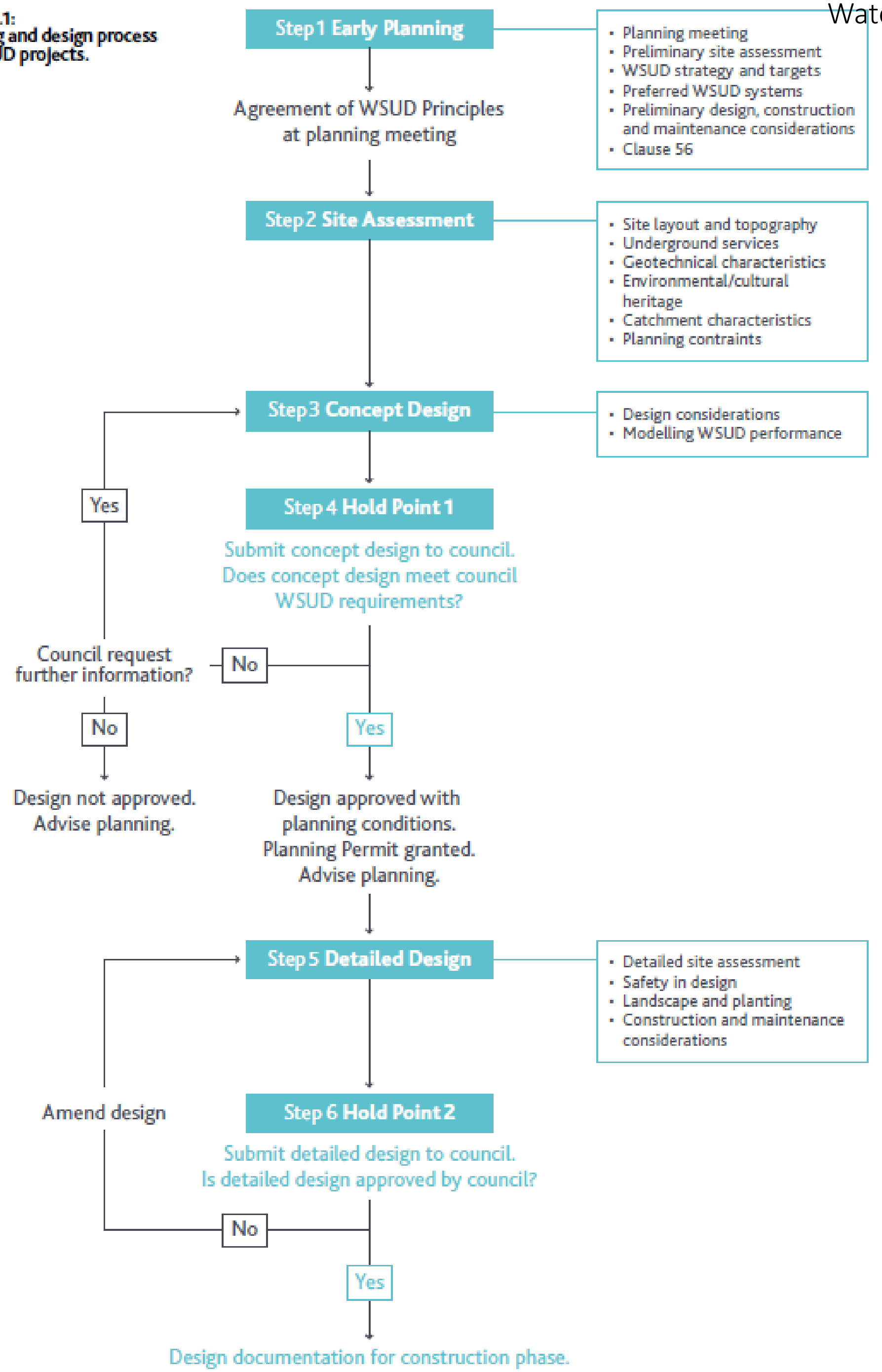


Figure 1.2 Example WSUD Planning Process

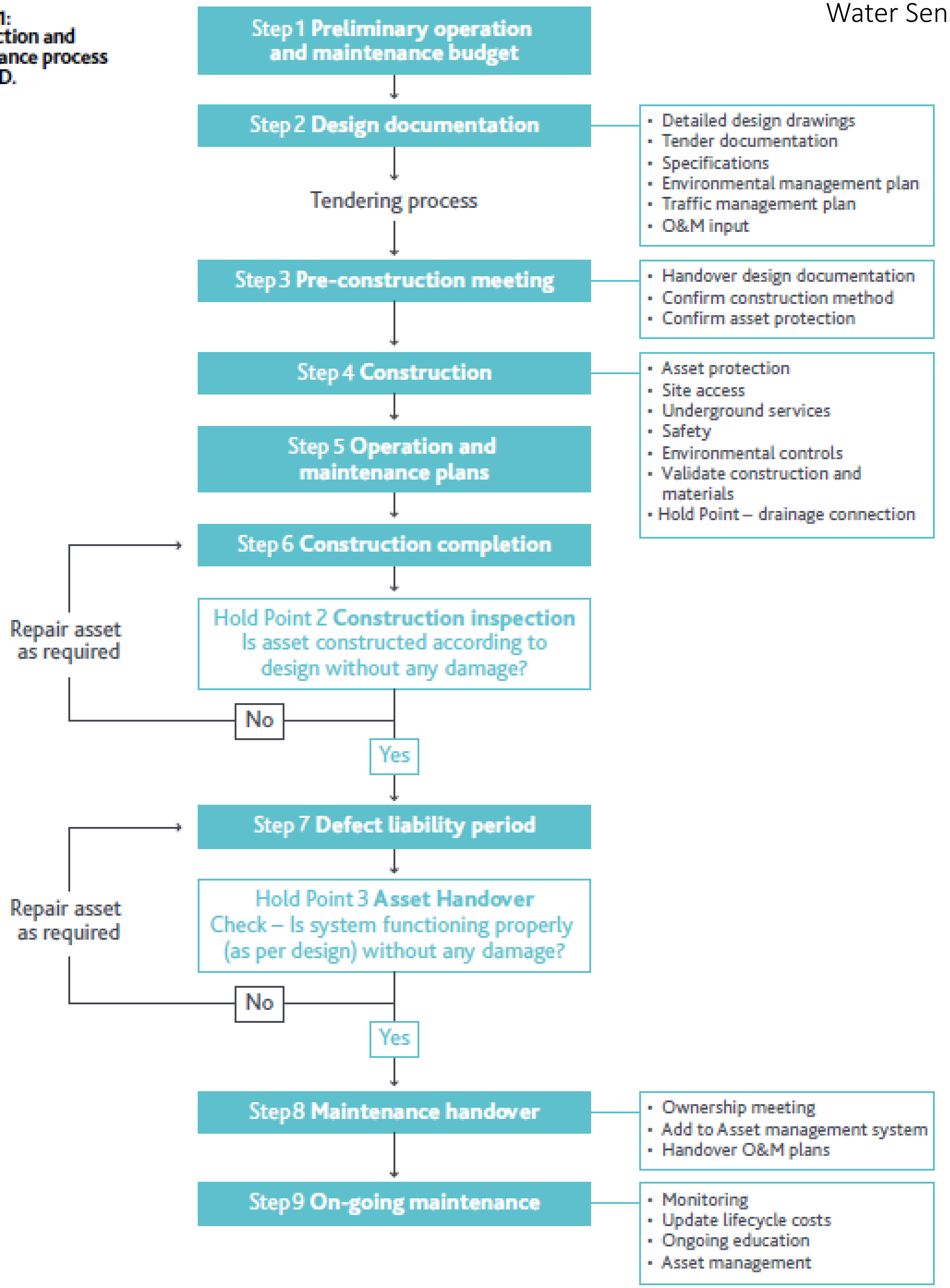
Process

Figure 2.1:
Planning and design process for WSUD projects.



Process

Figure 3.1: Construction and maintenance process for WSUD.



Process

1.Understand the most recent WSUD policy and regulations
理解最新的WSUD政策及规范

2.Indentify regionally and locally significant ecosystems and understand the site's context in relation to the protection and/or enhancement of these ecosystems, particularly riparian and wetland ecosystems associated with waterway corridors.
确定区域以及当地重要的生态系统并理解与保护或者改善这些生态系统相关的场地场景，尤其是与水系廊道联系的水边及湿地生态系统

3.Indentify environmental values and water quality objectives for key receiving waters within, and downstream of, the development.
确定与对核心接收水域内及发展下游的环境价值以及水的质量目标

4.Establish ecological condition and management requirements for key receiving waters within, and downstream of, the site.
为接收水域内及场地下游建立生态条件和管理要求

Process

5.Establish the site's existing hydrologic cycle and its regional context.
建立场地现有水循环及其区域环境

6.Understand the regional and local integrated water cycle infrastructure context.
理解区域及当地综合水循环基础设施环境

7.Understand the current and future flooding risk on, and downstream of, the site.
理解场地及场地下游的当前及未来洪水风险

8.Understand the site terrain and soils.
理解场地地形及土壤

9.Prepare a preliminary WSUD opportunities and constraints overlay.
准备一个预备的WSUD机遇与限制的叠加

Process

10.Detemine water conservation objectives.
决定水资源保护目标

11.Determine wastewater minimisation objectives.
决定污水最小化目标

12.Detemine stormwater management objectives.
决定雨水管理目标

13.Confirm WSUD design objectives with local council.
与当地议会确认WSUD设计的目标

Process

14.Integrate the conceptual design process.
综合概念设计流程

15.Undertake detailed site analysis.
着手场地设计的细节

16.Undertake quantitative modelling.
着手定量化模型

17.Prepare final conceptual site layout and present to the local council at a pre-lodgement meeting.
准备最终场地概念布局并在预提会议上向当地议会展示

Process

Table 2: Elements of the WSUD Project

<table>
<tr><th>Component</th><th>Description</th><th>Capacity building focus</th></tr>
<tr><td>WSUD Strategy</td><td>▪ High level information on water management in Fairfield
▪ Step-by-step process for implementing WSUD on a typical council project</td><td>▪ Knowledge and skills
▪ Policy and planning
▪ Planning and design</td></tr>
<tr><td>WSUD Policy</td><td>▪ Principles and objectives for WSUD</td><td>▪ Policy and planning
▪ Council commitment
▪ Corporate reporting</td></tr>
<tr><td>Fact Sheets</td><td>▪ Practical information on WSUD elements, including:
▪ Suitable locations
▪ Key design considerations
▪ Sizing curves
▪ Typical maintenance requirements
▪ Sources of further information
▪ Examples in Sydney</td><td rowspan="4">▪ Knowledge and skills
▪ Planning and design
▪ Implementation
▪ Operation and maintenance</td></tr>
<tr><td>Case Studies</td><td>▪ Case studies demonstrating the potential implementation of WSUD on typical council projects, including a park upgrade and a streetscape upgrade.</td></tr>
<tr><td>Supporting Information</td><td>▪ Soil specifications
▪ Vegetation lists
▪ Construction and maintenance cost information</td></tr>
<tr><td>Training</td><td>▪ Series of training workshops with Council</td></tr>
<tr><td>On Site Training</td><td>▪ In house training of key staff on the application of WSUD and modelling</td><td>▪ Organisational structure</td></tr>
<tr><td>Presentations to management</td><td>▪ Presentations to senior executive staff</td><td>▪ Organisational structure
▪ Council commitment</td></tr>
</table>

From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

Strategies

1.Water Conservation
水体保护

2.Wastewater Minimisation
污水最小化

3.Stormwater Management
暴雨雨水管理

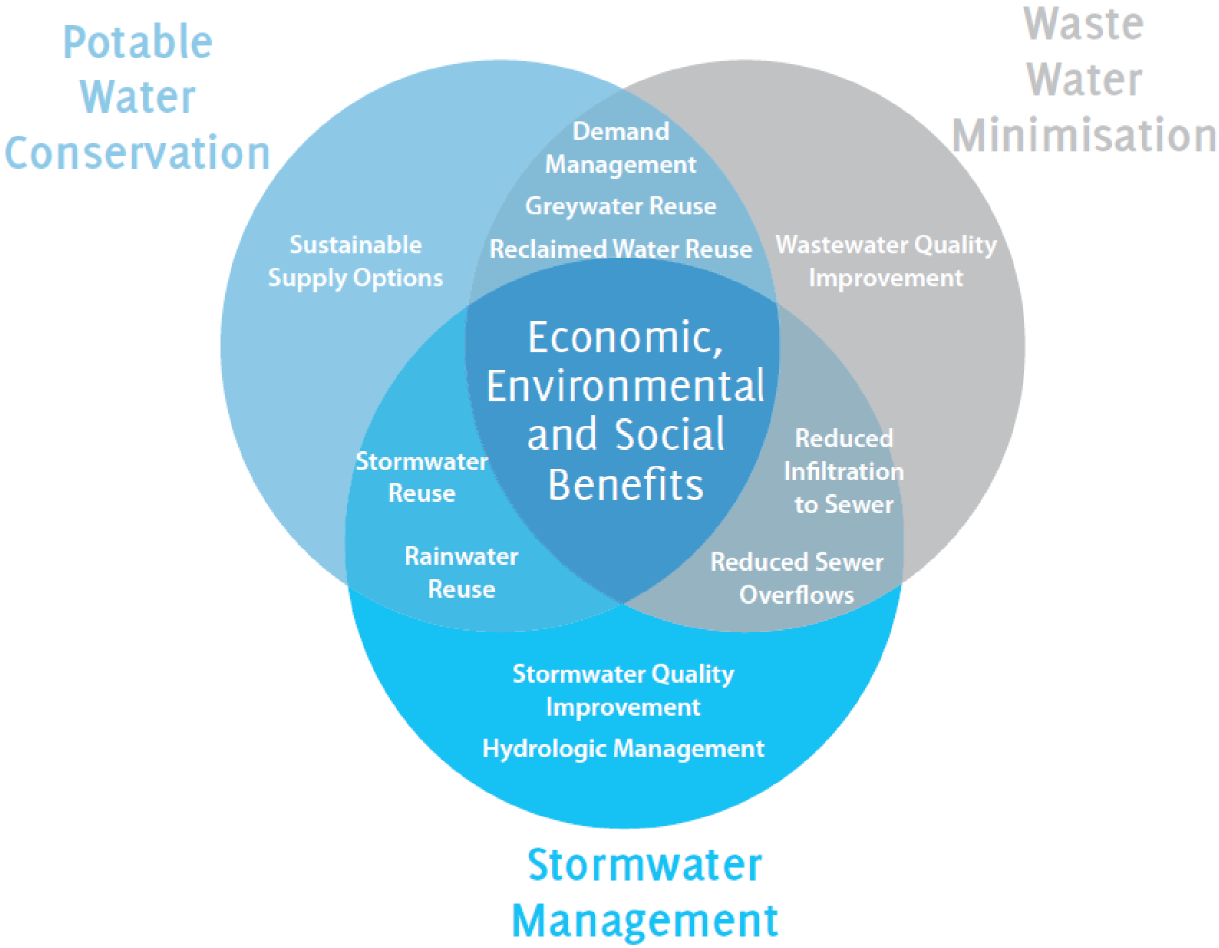


Figure 7 — Integrated Management of the Urban Water Cycle (Hoban and Wong, 2006)

From Concept Design Guidelines for Water Sensitive Urban Design (South East Queensland Healthy Waterways Partnership)

Strategies

1.Water Conservation 水体保护

Demand management

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

1. Education to achieve behavioural change with regard to:

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

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

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

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

Alternative water sources

Decision process for selecting alternative water sources

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

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

2. Conduct a site water balance:

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

3. Identify water reuse options:

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

4. Consider social aspects and human health:

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

5. Evaluate the impact on the natural environment:

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

6. Consider life cycle costing and economics:

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

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

Source: Landcom 2006.

Strategies

1.Water Conservation
水体保护

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

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

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

Adapted from Landcom, 2004.

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

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

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

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

(Landcom, 2006).

Strategies

1.Water Conservation
水体保护

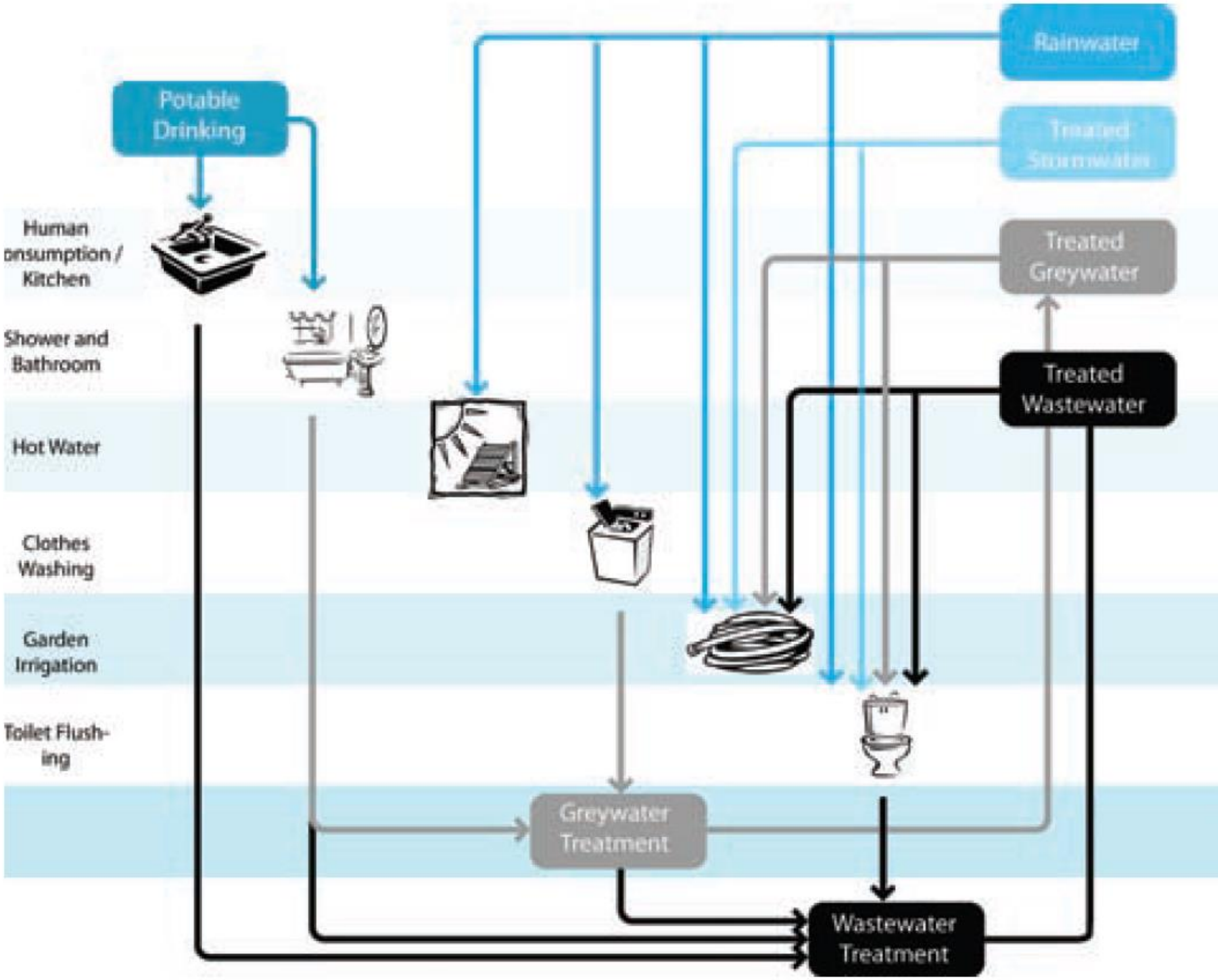


Figure 9 — Water harvesting, treatment and reuse options

Strategies

1.Water Conservation
水体保护

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

Strategies

1.Water Conservation
水体保护

Greenfield developments

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

Residential urban development or redevelopment

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

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

Mixed-use urban developments

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

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

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

High-rise residential development

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

Commercial developments

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

Strategies

2.Wastewater Minimisation
污水最小化

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

1. Reduce wet weather flows:

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

2. Reduce wastewater discharge from the development:

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

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

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

Strategies

3.Stormwater Management
暴雨雨水管理

Primary treatment BMPs

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

Gross pollutant capture devices

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

Sediment basins

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

Secondary treatment BMPs

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

Grass or vegetated swales

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

Sand filters

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

Strategies

3.Stormwater Management
暴雨雨水管理

Table 6 — Scale of Stormwater BMP Applications and Performance Effectiveness

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

H = High; M = Medium; L = Low

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

Strategies

3.Stormwater Management
暴雨雨水管理

Tertiary treatment BMPs

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

Bioretention systems

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

Constructed wetlands

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

Source control BMPs

Source control devices minimise the amount of stormwater entering systems.

Rainwater tanks

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

Porous pavements

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

Infiltration systems

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

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(South East Queensland Healthy Waterways Partnership)

Strategies

3.Stormwater Management
暴雨雨水管理

Bioretention systems vs constructed wetlands

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

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

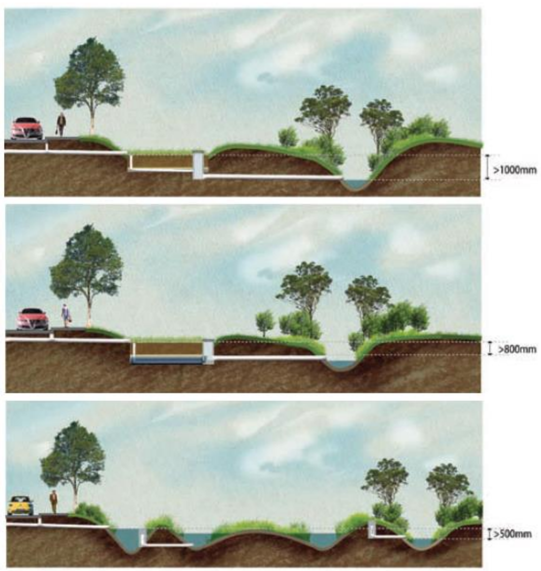


Figure 10 — Bioretention and constructed wetland systems differ in their requirements for minimum vertical fall from inflow pipes or channels to ensure unimpeded free draining outfall. The top image shows that a typical bioretention system requires at least 1000 mm to be able to drain into the receiving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

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

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

Strategies

3.Stormwater Management
暴雨雨水管理

Table 8 — Site Constraints for Stormwater BMPs

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

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

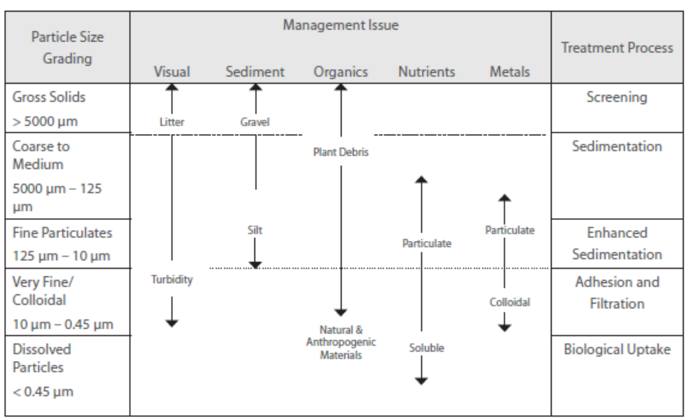


Figure 11 — Stormwater management issues, pollutants and treatment processes (Ecological Engineering, 2003)

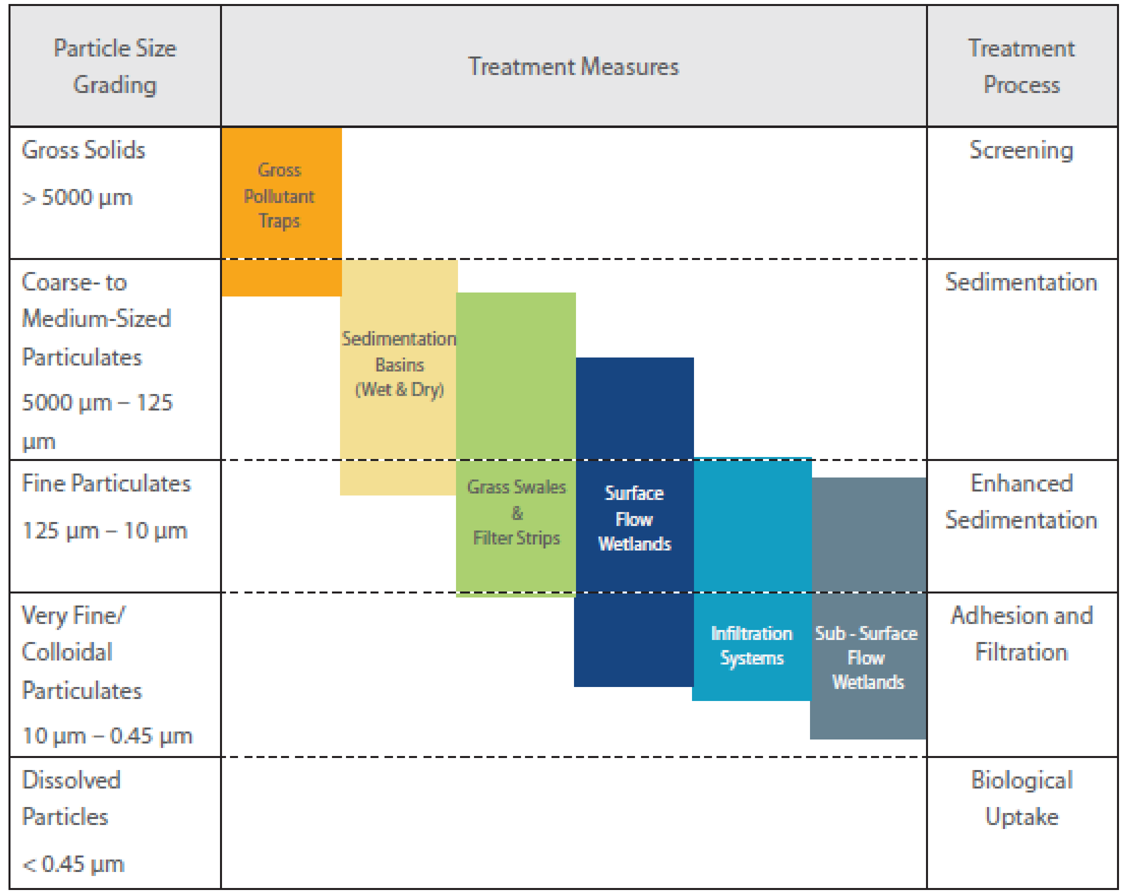
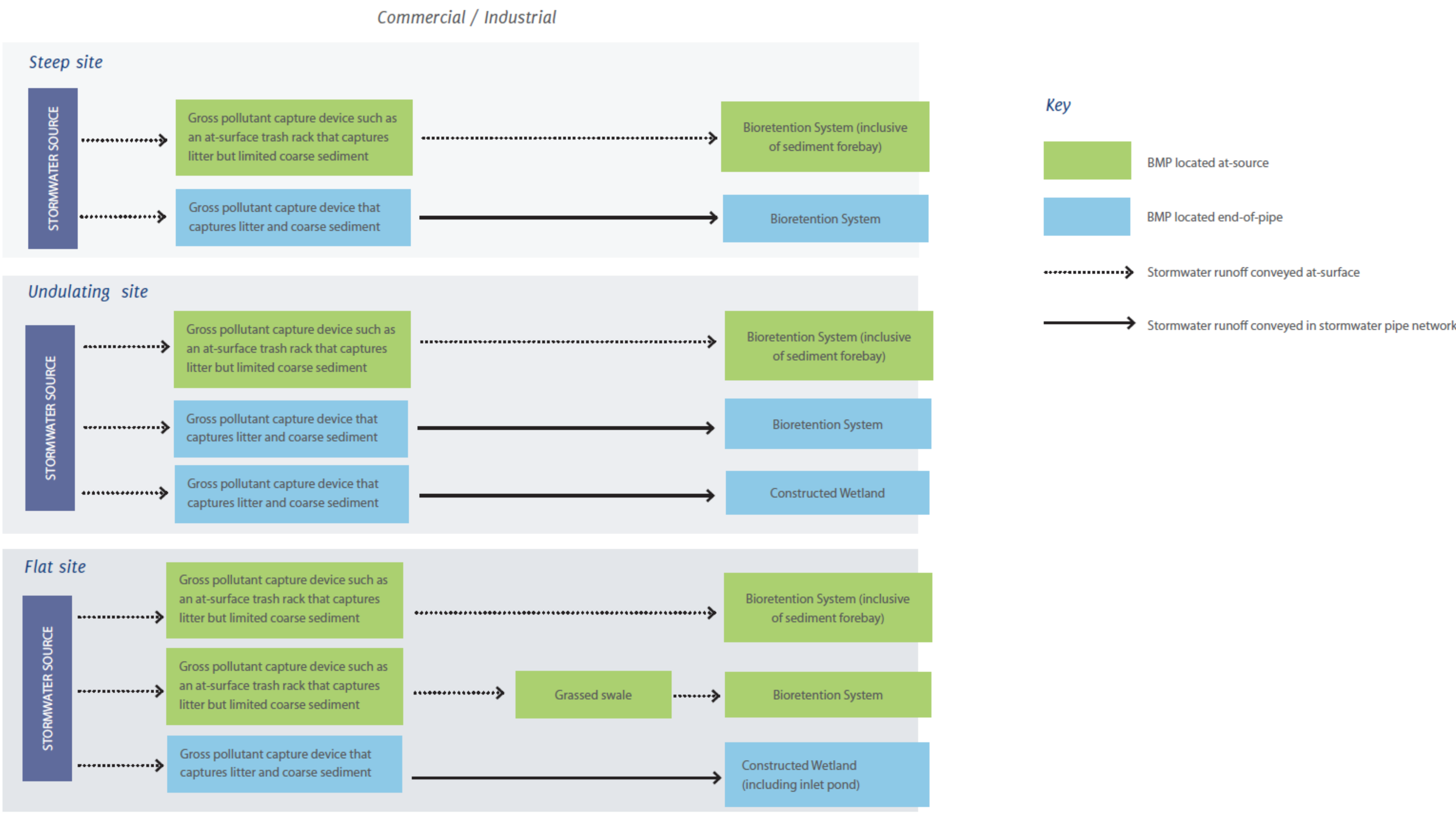


Figure 12— Pollutant ranges for stormwater BMP treatment measures (Ecological Engineering, 2003)

Strategies

3.Stormwater Management
暴雨雨水管理

Typical stormwater treatment trains



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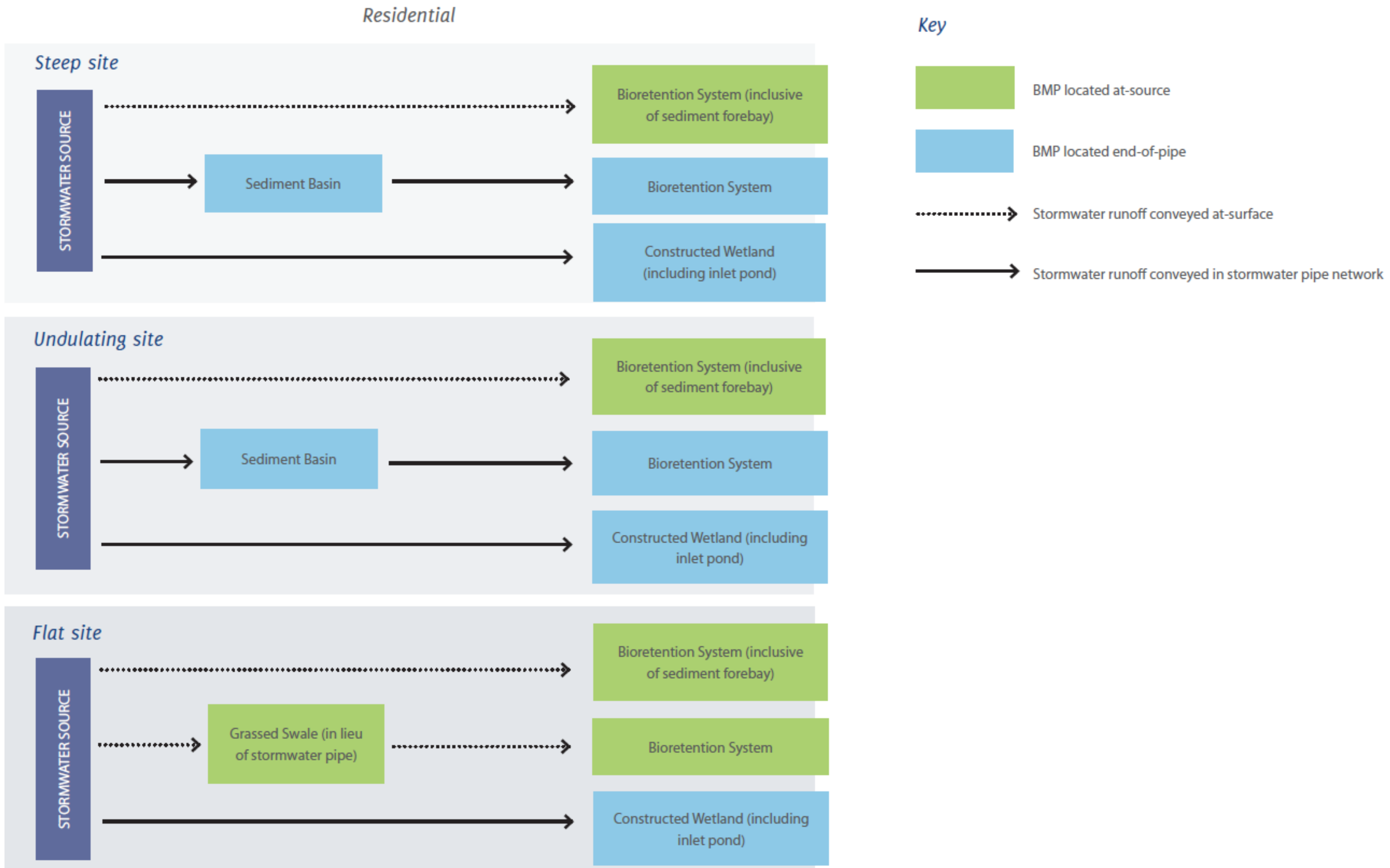
Strategies

3.Stormwater Management
暴雨雨水管理



Strategies

3.Stormwater Management
暴雨雨水管理

Treatment train assessment methods

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

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

Operation and maintenance considerations

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

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

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Strategies

3.Stormwater Management
暴雨雨水管理

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

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

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

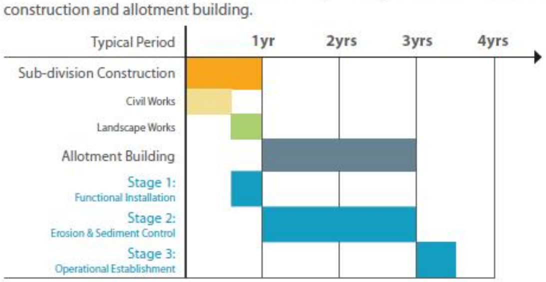

Figure 13 — Staged construction and establishment of a greenfield or infill project (Leinster, 2006)

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

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

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

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

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

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WSUD中的最佳规划实践是指场地评估和土地利用规划, 由于土地利用规划将改变场地的排水方式和水质, 因此它对雨水管理技术措施的选择和设计具有重要影响。在进行土地利用规划时, 应综合考虑场地及周边的气候、地质条件、排水形式以及其他重要的自然特征(湿地和残余植被)。其次, 对场地的土地承载力进行评估, 最后制定土地利用规划。在规划中要将雨洪管理作为重要考虑因子, 促进雨水管理方案的实施。例如, 降低道路竖向坡度以便于BMP技术在道路中的应用, 通过设计增加水体的可达性和降低绿地高程等。

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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

BPPs(Best Planning Practices)

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:

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

1.Public Open Space Networks公共开放空间网络

2.Housing Layout住宅布局

3.Road Layout道路布局

4.Streetscapes街道景观

BPPs(Best Planning Practices)

1.Public Open Space Networks公共开放空间网络

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.).

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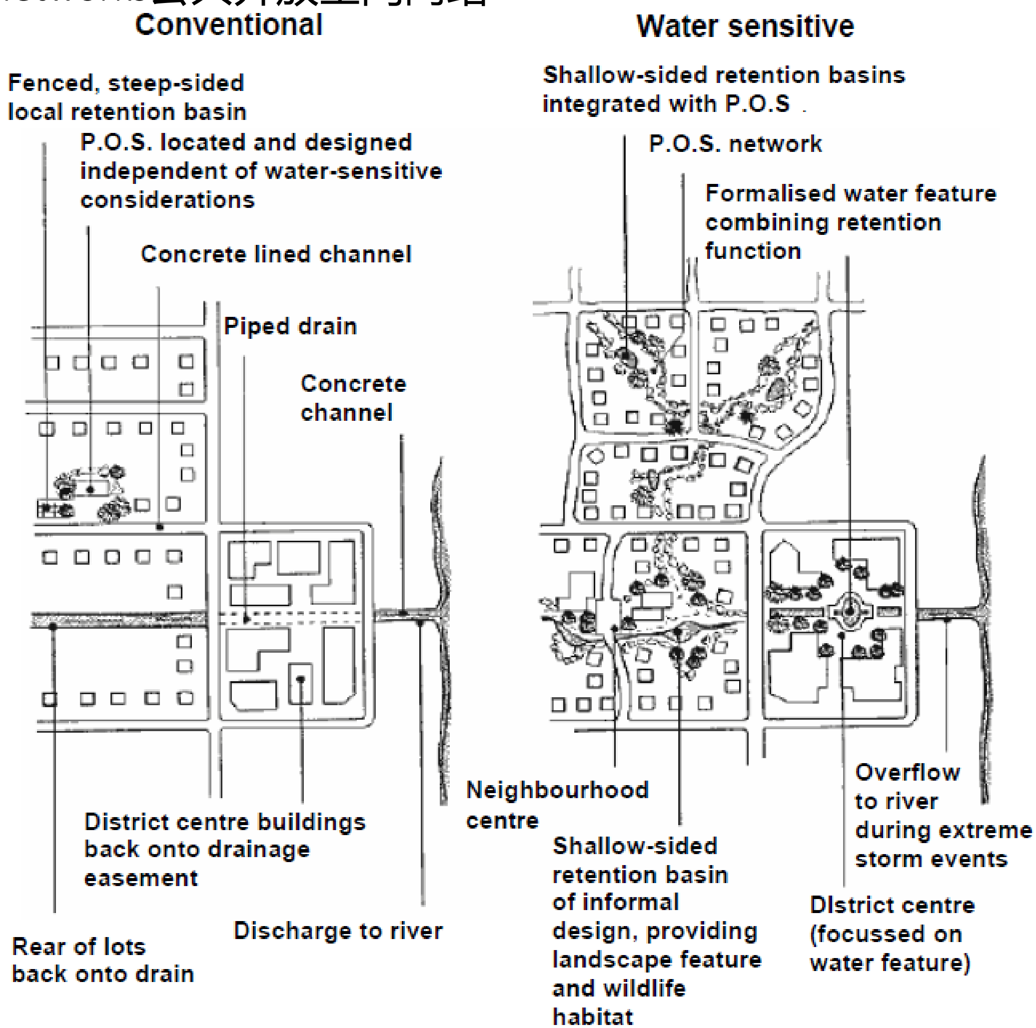
1.Public Open Space Networks公共开放空间网络



Source: Whelans et al in Engineers Australia (2006)

Figure 3-2 Networked Public Open Space Incorporated in Development

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2.Housing Layout住宅布局

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

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3.Road Layout道路布局

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 am8nity, 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.

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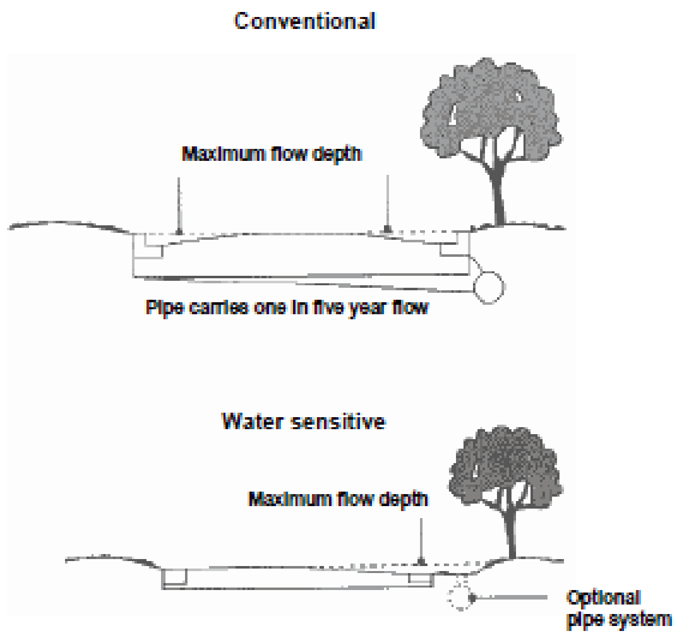
3.Road Layout道路布局



Source: Victorian Stormwater Committee (1999)

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

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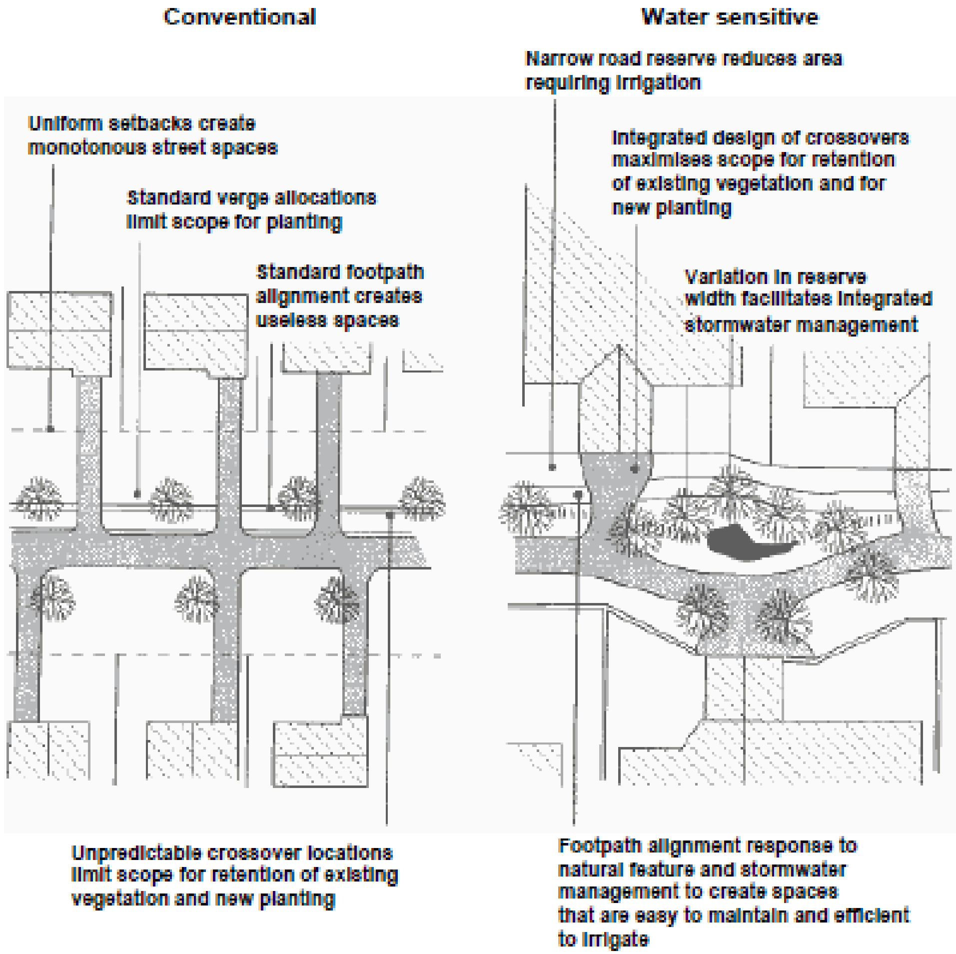
3.Road Layout道路布局



Source: Victorian Stormwater Committee (1999)

Figure 3-5 Conventional Versus Water-Sensitive Road Layout

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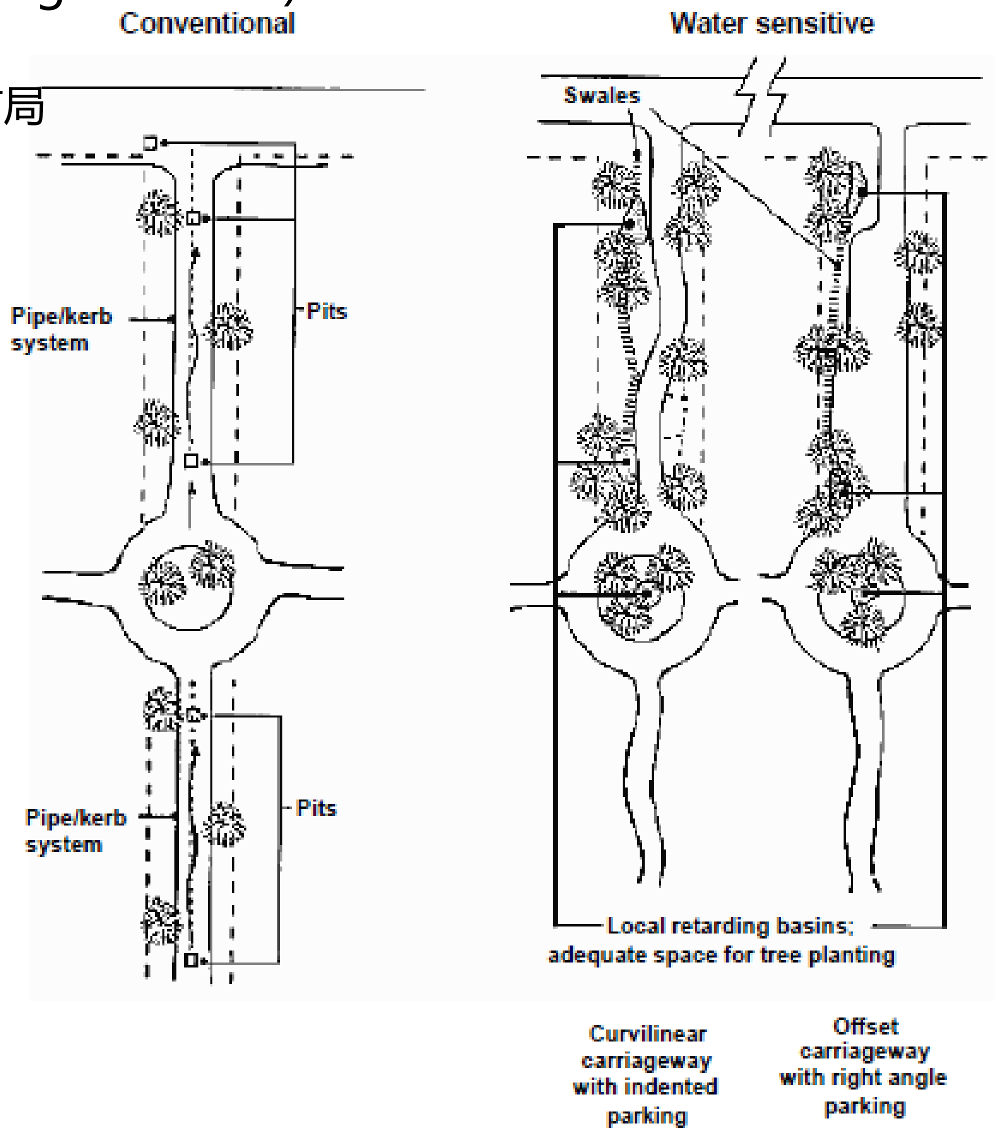
3.Road Layout道路布局



Source: Victorian Stormwater Committee (1999)

Figure 3-6 Verge Design and Management

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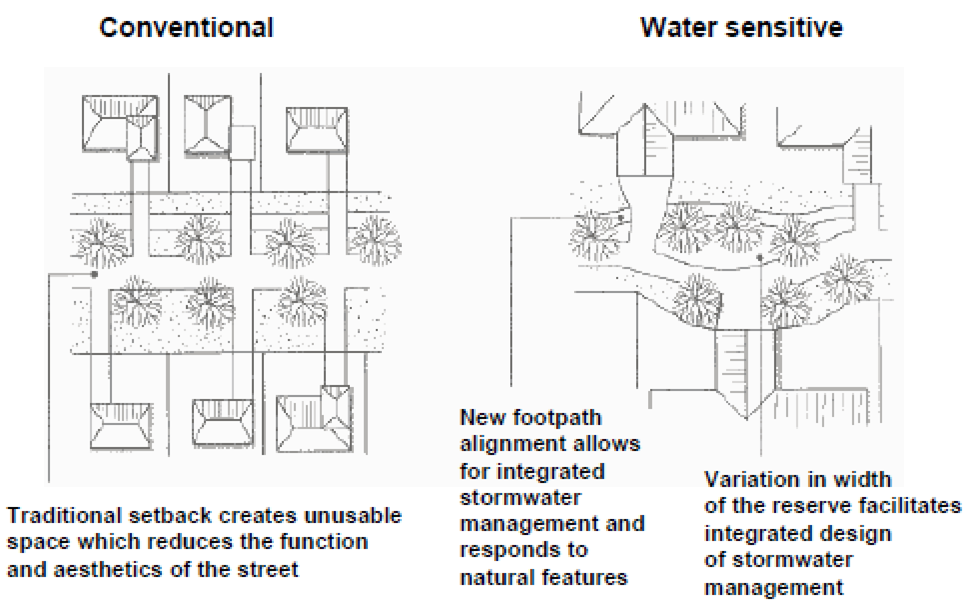
4.Streetscape街道景观

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 lotlines, local detention of stormwater in road reserves and managed landscaping.



Source: Victorian Stormwater Committee (1999)

Figure 3-7 Lot/Street Interface

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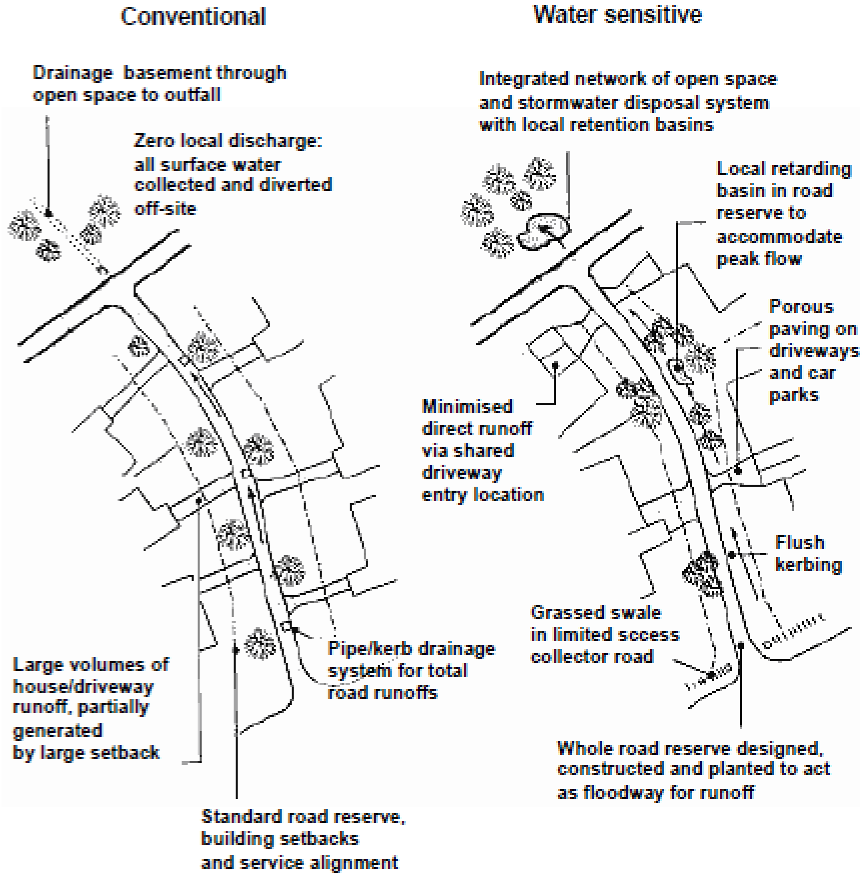
4.Streetscape街道景观



Source: Victorian Stormwater Committee (1999)

Figure 3-8 Streetscape Layout

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1.Steep and Undulating Sites起伏有坡度的场地

2.Flat Sites平地

3.Multiple Use Public Open Spaces多用处的公共开放空间

4.Street Layout and Streetscapes街道布局与街景

5.Symbiotic Land Use Clustering共生土地利用

6.Industrial Sites工业场地

7.Waterscapes as Public Art公共艺术中的水景

BPPs(Best Planning Practices)

BPP 1: Steep and Undulating Sites

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

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

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

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

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

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

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

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

End-of-pipe application of stormwater treatment

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

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

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

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

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

Coomera Waters, Gold Coast

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

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

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

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

See Case Study 5 for more information on this project.

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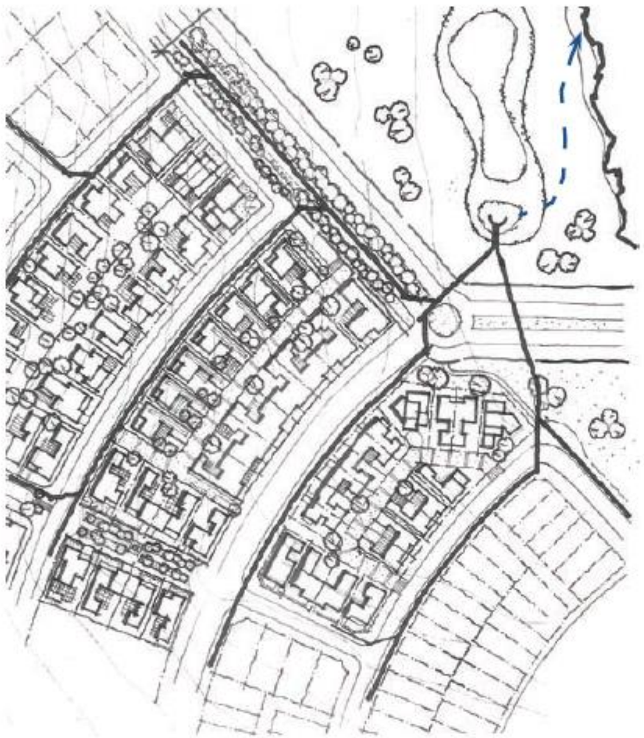
BPP 1: Steep and Undulating Sites



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

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BPP 2: Flat Sites

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

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

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

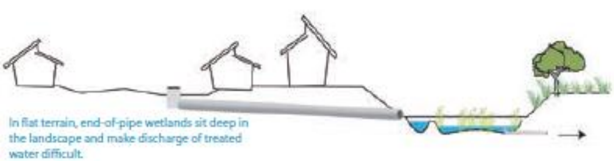

Figure 14 — Challenges treating stormwater on flat sites after it enters the pipe drainage network (Hoban, Eadie and Rowlands, 2007)

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

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

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

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

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BPP 2: Flat Sites

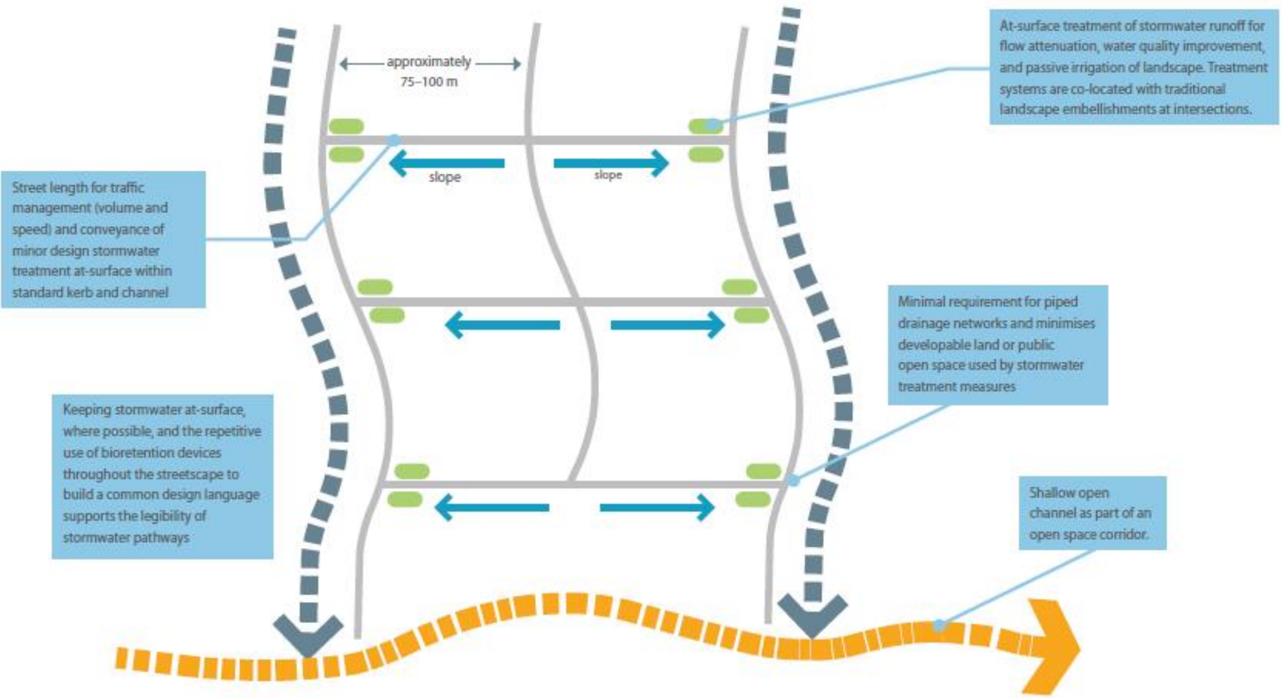

Figure 15 — Model water sensitive urban layout for flat sites

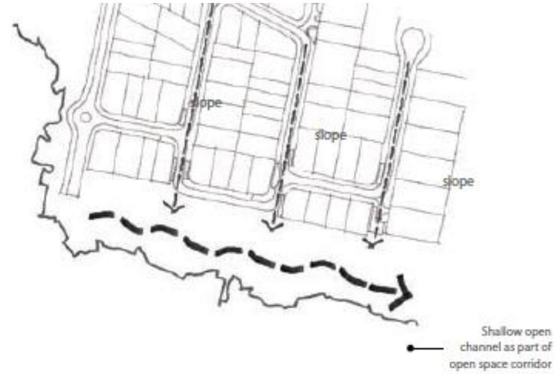

Figure 16 — Conceptual sketch applying model WSUD for flat sites

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

BPPs(Best Planning Practices)

BPP 2: Flat Sites

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

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

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

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

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

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

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

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

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BPP 2: Flat Sites

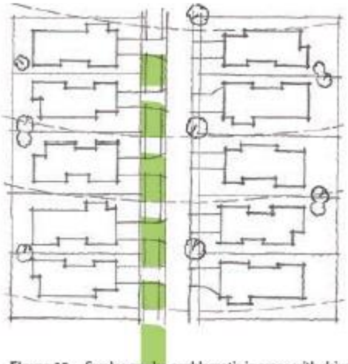


Figure 19— Swales can be problematic in areas with driveway crossovers and adjoining allotment owners

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

Bellvista, Sunshine Coast

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

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

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

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

See Case Study 4 for more details.

BPPs(Best Planning Practices)

BPP 3: Multiple Use Public Open Spaces

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

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

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

Stormwater quality systems in retarding basins

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

Further discussion is provided in BMP 9.

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

From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BPPs(Best Planning Practices)

BPP 3: Multiple Use Public Open Spaces

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

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

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

South Australian Museum Forecourt, Adelaide

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

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

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

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

(Allison and Taylor, 2004)

From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BPPs(Best Planning Practices)

BPP 4: Street Layout and Streetscapes

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

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

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

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

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

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

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

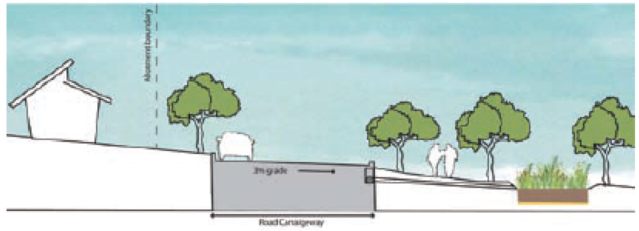


Figure 22 — WSUD street layout 1: Streets aligned parallel (or tangential) to contour and with open space corridor on 'low side' of the street

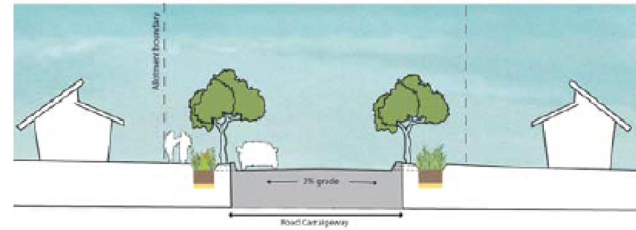


Figure 24 — WSUD street layout 3: Street on flat topography (< 1%) aligned to maximise east–west street orientation and with allotments on both sides of the street

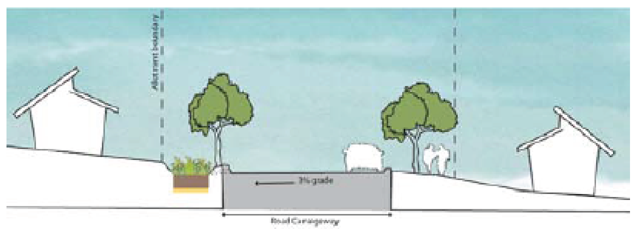


Figure 23 — WSUD street layout 2: Streets aligned parallel (or tangential) to the contour with allotments on both sides of street

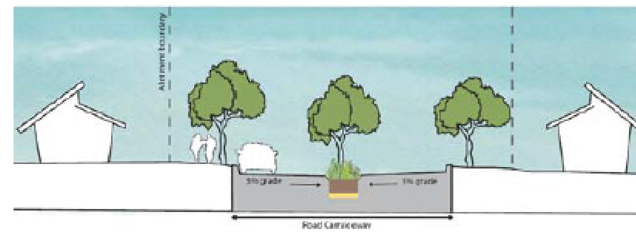


Figure 25 — WSUD street layout 4: Streets with centre medians on flat to gently undulating topography (< 5%) with allotments on both sides

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

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

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

These include ensuring:

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

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

BPPs(Best Planning Practices)

BPP 4: Street Layout and Streetscapes

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

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

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

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

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

BPPs(Best Planning Practices)

BPP 5: Symbiotic Land Use Clustering

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

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

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

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

Sources of recycled can be:

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

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

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

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

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

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

Examples of symbiotic land use clustering

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

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

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

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

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

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

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

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

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

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

Mixed use commercial and residential tower

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

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

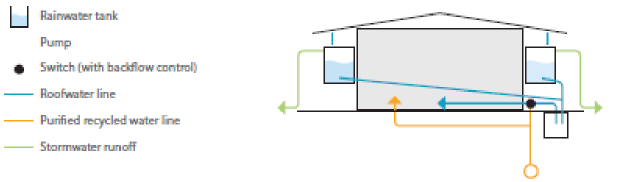
Strategic land-use planning processes informed by expertise in WSUD and, in particular, expertise in water recycling opportunities at regional, precinct, and allotment scales, should deliver:

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

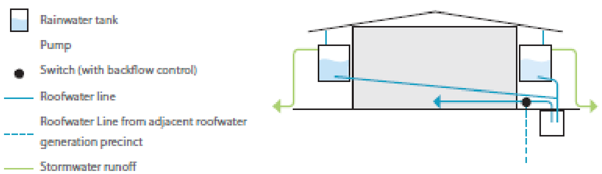
Conversely, a poorly informed strategic land use planning process is likely to limit future water recycling opportunities or, at least, make water recycling more costly than it needs to be.

BPPs(Best Planning Practices)

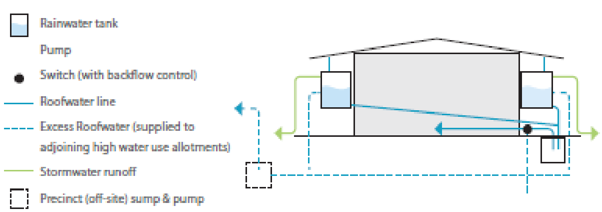
BPP 5: Symbiotic Land Use Clustering



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



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



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

Figure 26 — Water recycling opportunities for industrial and warehouse landuses

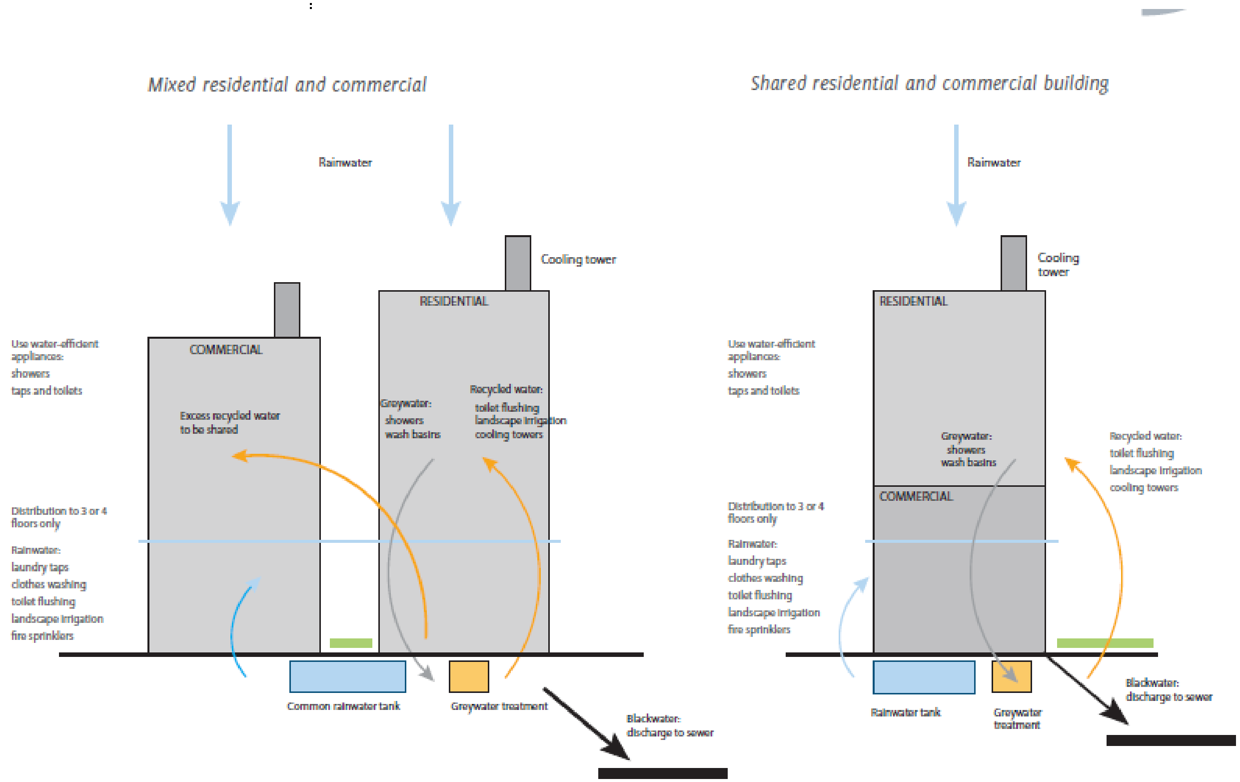


Figure 27 — Water recycling opportunities within buildings based on current building regulations

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

BPPs(Best Planning Practices)

BPP 6: Industrial Sites

The impacts of industrial development

Industrial development is typically characterised by:

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

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

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

Applying WSUD to industrial development

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

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

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

Structural separation

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

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

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

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

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

Stormwater harvesting

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

Raising awareness for tenants

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

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

Designing water sensitive industrial sites or precincts

Defining design objectives

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

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

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

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

Site appraisal

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

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

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

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

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

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

BPPs(Best Planning Practices)

BPP 6: Industrial Sites

Structural separation of work areas

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

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

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

Establishing a WSUD strategy for stormwater runoff

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

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

Table 10—Feasible stormwater treatment measures

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

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

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

Stormwater management in industrial precincts

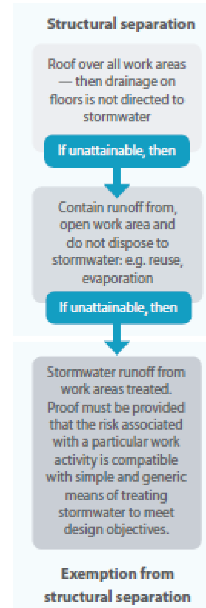
Developers of industrial precincts are required to provide treatment for stormwater runoff from road reserves and public areas, as well as for any untreated stormwater runoff from allotments. The pollutant profile of these areas is generally compatible with simple, conventional WSUD treatment measures.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

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

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

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

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



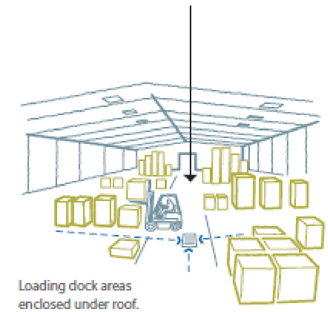


Figure 28 — Example of structural separation (source: SEQ HWP, 2007)

Key messages

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

From Concept Design Guidelines for Water Sensitive Urban Design (South East Queensland Healthy Waterways Partnership)

BPPs(Best Planning Practices)

BPP 7: Waterscapes as Public Art

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

Leonardo Da Vinci

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

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

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

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

Melbourne Docklands

'The Memory Line', Clear Paddock Creek, Sydney

BPPs(Best Planning Practices)

BPP 7: Waterscapes as Public Art

BMPs(Best Management Practices)

与北美和欧洲相同, 澳大利亚将雨洪管理的措施和技术手段称为最佳管理实践(BestM anagement Practice, 以下简称BMP)。BMP 通常分成工程性BMP(structura lBMP)和非工程性BMP(non- structural BMP)两类。工程性BMP是指运用各种处理技术和设施来控制雨洪过程中出现的污染和洪涝问题(见表1)。非工程性的BMP是指通过管理、制度或教育等非技术手段来实现雨洪管理的目标[8] (见表2)。

表 1 工程性最佳管理实践的类型和适用尺度

Tab 1 Type and app licab ility of BM P

工程性最佳管理实践	地块尺度	街区尺度	开放空间网络或地区尺度
将径流转移到种植床	√		
雨水滞留池 /再利用设计 (绿化或厕所用水)	√		
拦沙坑, 沉积阱	√		
渗滤和收集系统 (生物过滤系统)	√	√	√
渗透系统	√	√	√
乡土植被, 覆盖, 滴灌系统	√	√	√
透水铺装	√	√	√
缓冲带		√	√
建造的湿地		√	√
干燥滞洪区		√	√
垃圾截留设施 (立箅式雨水口)		√	
池塘和沉积阱		√	√
沼泽地, 洼地		√	√
湖			√
大颗粒污染物截留设施			√
恢复的水道 /排水沟			√
再利用设计 (开放空间灌溉和厕所用水)			√
城市森林			√

非工程性最佳管理实践	内容
环境和城市发展政策	地方、州级和联邦级环境和城市发展政策要鼓励生态可持续发展实践的广泛应用, 其中包括将水敏感城市设计和城市规划过程相结合
施工场地环境考虑因素	施工场地规划和管理的不足会增加雨洪径流中污染物的负荷。场地管理规划是一项减少场地建设时污染物产生的有效措施
教育和人员培训	包括人员培训在内的教育项目, 应促使各层次的人员在实践中产生有效的改变。培训应提供有效的工具或技术手段使得相关人员可以有能力在将来进行规划等活动
公众教育项目	公众教育项目将促使社会标准和行为的改变。个人行为的改变会对减轻城市发展对自然水文过程的影响起到积极作用。公众在了解相关问题后, 可以对政府、相关行业和开发商是否考虑对雨洪的影响进行监督
项目执行	经济处罚是对雨洪污染行为的一种有效震慑。这主要是环境保护部门和地方政府的主要职责。目前有很多关于测量项目执行有效性的研究

在确定和选择合适的工程性最佳管理实践时,
可以从以下5个方面考虑项目的目标:

1.流量控制。包括洪水管理、减缓流速和削减洪峰流量三方面内容。
2.水质改善。描述污染物去除的情况。
3.处理的有效性。包括BMP 平均径流减少比例和污染物去除的效率。MUSIC 软件等模拟工具可以提供快速评估的手段。
4.设计中的问题。需要在场地机会和限制的背景下考虑BMP 设计的细节, 例如地形、气候特征和可供建造的土地等。
5.成本因素。评估资金投入和维护成本。

BMPs(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. 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 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.

BMPs(Best Management Practices)

A Portable Water Demand Reduction Techniques

a. Water Efficient Appliances
b. Water Efficient Fittings
c. Rainwater Tanks
d. Reticulated Recycled Water
e. Stormwater Harvesting and Reuse
f. Greywater Treatment and Reuse
g. Changing Landscape Form
h. Water Use Education Programs
i. Aquifer Storage and Recovery

B Stormwater Maanagement Techniques

a. Sediment Basins
b. Swales and Buffer Strips
c. Bioretention Swales
d. Bioretention Basins
e. Sand Filters
f. Constructed Wetlands
g. Ponds and Lakes
h. Infiltration Systems
i. Aquifer Storage and Recovery
j. Porous Pavement
k. Retarding Basins
l.Green Roofs / Roof Gardens
m.Stream and Riparian Vegetation Rehabilitation
n.Water Quality Education Programs

C Cost Implications

BMPs(Best Management Practices)

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

From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)

1.Demand Management需求管理

2.Roofwater(Rainwater) Harvesting屋面水/雨水收集

3.Stormwater Harvesting暴雨收集

4.Wasterwater Treatment for Re-Use污水处理再利用

5.Gross Pollutant Capture Devices严重污染物捕获设备

6.Sedimentation Basins沉淀池

7.Grass or Vegetated Swales草或者植被洼地

8.Sand Filters碎石过滤器

9.Bioretention Systems生物滞留系统

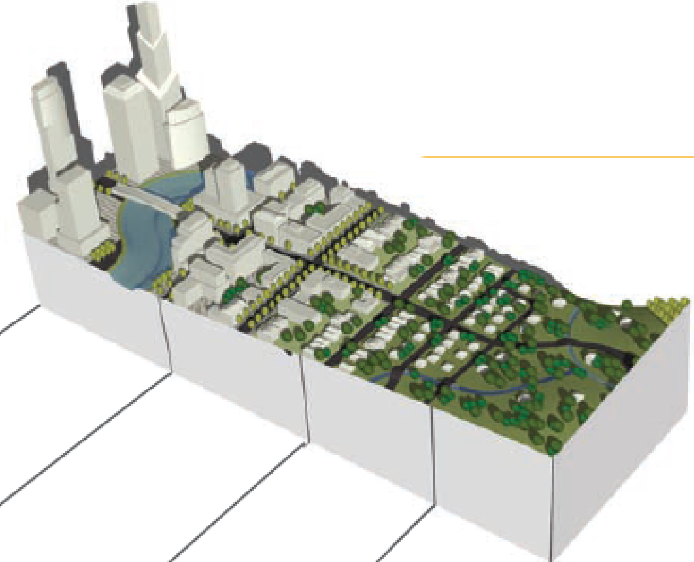
10.Constructed Wetlands人工湿地

11.Porous Pavements透水铺装

12.Infiltration Measures下渗措施

From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)



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

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

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

BMPs(Best Management Practices)

1.Demand Management需求管理

Description

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

Contribution of demand management to WSUD strategies

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

BMPs(Best Management Practices)

1.Demand Management**需求管理**

Who needs to know about demand management?

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

Considerations when incorporating demand management measures in a concept design

Statutory compliance requirements

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

Spatial (land take) requirements

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

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

BMPs(Best Management Practices)

1.Demand Management**需求管理**

Whole-of-lifecycle considerations

Capital and operating costs

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

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

Expected effective service life

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

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

Visual and aesthetic transformations over service life

Not applicable.

Decommissioning and/or re-installation requirements

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

Typical maintenance requirements

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

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

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

BMPs(Best Management Practices)

1.Demand Management**需求管理**

BMP performance risk considerations

Potentially constraining physical site characteristics

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

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

Poor design

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

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

Operational risks

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

BMPs(Best Management Practices)

2.Roofwater(Rainwater) Harvesting**屋面水/雨水收集**

Description

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

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

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

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

From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)

2.Roofwater(Rainwater) Harvesting**屋面水/雨水收集**

Contribution of roofwater (rainwater) harvesting to WSUD strategies

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

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

Who needs to know about roofwater (rainwater) harvesting?

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

From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)

2.Roofwater(Rainwater) Harvesting**屋面水/雨水收集**

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

Statutory compliance requirements

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

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

Spatial (land take) requirements

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

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

BMPs(Best Management Practices)

2.Roofwater(Rainwater) Harvesting**屋面水/雨水收集**

Whole-of-lifecycle considerations

Capital and operating costs

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

Expected effective service life

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

Visual and aesthetic transformations over service life

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

Decommissioning or re-installation requirements

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

Typical maintenance requirements

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

BMPs(Best Management Practices)

2.Roofwater(Rainwater) Harvesting**屋面水/雨水收集**

BMP performance risk considerations

Potentially constraining physical site characteristics

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

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

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

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

Poor design

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

Operational risks

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

BMPs(Best Management Practices)

3.Stormwater Harvesting**暴雨收集**

Description

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

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

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

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

BMPs(Best Management Practices)

3.Stormwater Harvesting暴雨收集

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

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

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

From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)

3.Stormwater Harvesting**暴雨收集**

Aquifer Storage and Recovery

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

The broad requirements of ASR systems include:

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

Factors to consider when choosing a suitable aquifer include:

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

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

BMPs(Best Management Practices)

3.Stormwater Harvesting暴雨收集

Contribution of stormwater harvesting to WSUD strategies

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

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

Who needs to know about stormwater harvesting?

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

BMPs(Best Management Practices)

3.Stormwater Harvesting暴雨收集

Considerations when incorporating stormwater harvesting in a concept design

Statutory compliance requirements

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

Spatial (land take) requirements

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

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

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

BMPs(Best Management Practices)

3.Stormwater Harvesting**暴雨收集**

Whole-of-lifecycle considerations

Capital and operating costs

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

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

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

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

Expected effective service life

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

BMPs(Best Management Practices)

3.Stormwater Harvesting**暴雨收集**

Whole-of-lifecycle considerations

Visual and aesthetic transformations over service life

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

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

Decommissioning or re-installation requirements

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

Typical maintenance requirements

Maintenance of stormwater harvesting systems includes maintaining:

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

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

BMPs(Best Management Practices)

3.Stormwater Harvesting**暴雨收集**

BMP performance risk considerations

Potentially constraining physical site characteristics

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

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

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

BMPs(Best Management Practices)

3.Stormwater Harvesting暴雨收集

BMP performance risk considerations

Poor design

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

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

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

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

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

Operational risks

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

BMPs(Best Management Practices)

4.Wasterwater Treatment for Re-Use**污水处理再利用**

Description

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

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

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

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

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

BMPs(Best Management Practices)

4.Wasterwater Treatment for Re-Use**污水处理再利用**

Description

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

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

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

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

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

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

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

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

BMPs(Best Management Practices)

4.Wasterwater Treatment for Re-Use**污水处理再利用**

Contribution of wastewater treatment for re-use to WSUD strategies

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

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

BMPs(Best Management Practices)

4.Wasterwater Treatment for Re-Use**污水处理再利用**

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

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

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

Statutory compliance requirements

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

Spatial (land take) requirements

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

From Concept Design Guidelines for Water Sensitive Urban Design (South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)

4.Wasterwater Treatment for Re-Use**污水处理再利用**

Table 12 — Summary of Wastewater Treatment Processes

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

BMPs(Best Management Practices)

4.Wasterwater Treatment for Re-Use**污水处理再利用**

Whole-of-lifecycle considerations

Capital and operating costs

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

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

Expected effective service life

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

Visual and aesthetic transformations over service life

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

Decommissioning or re-installation requirements

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

Typical maintenance requirements

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

BMPs(Best Management Practices)

4.Wasterwater Treatment for Re-Use**污水处理再利用**

BMP performance risk considerations

Potentially constraining physical site characteristics

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

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

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

Poor design

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

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

Operational risks

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

BMPs(Best Management Practices)

5.Gross Pollutant Capture Devices**严重污染物捕获设备**

Description

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

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

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

BMPs(Best Management Practices)

5.Gross Pollutant Capture Devices**严重污染物捕获设备**

Description

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

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

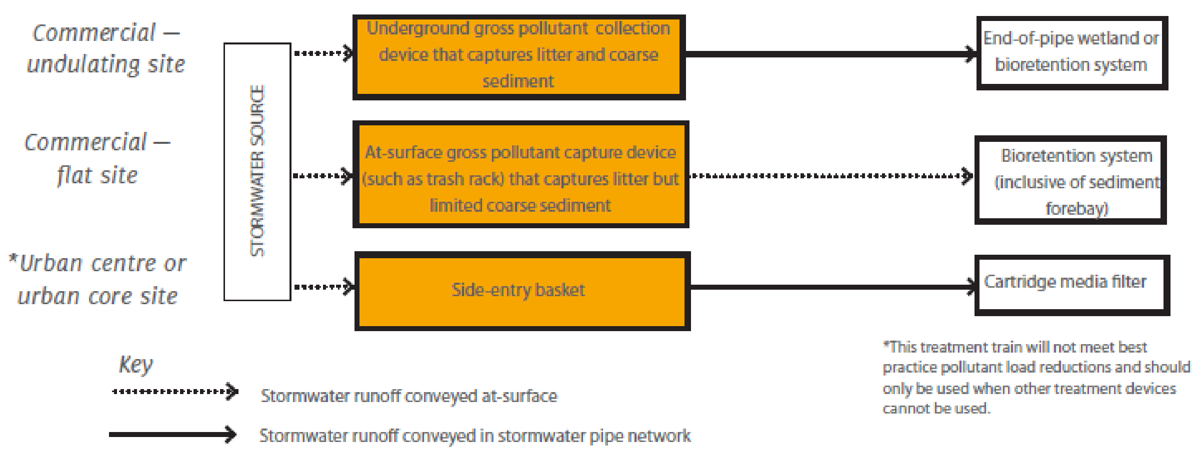


Figure 30 —Gross pollutant capture devices as part of stormwater treatment trains

BMPs(Best Management Practices)

5.Gross Pollutant Capture Devices**严重污染物捕获设备**

Contribution of gross pollutant capture devices to WSUD strategies

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

Who needs to know about gross pollutant capture devices?

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

BMPs(Best Management Practices)

5.Gross Pollutant Capture Devices**严重污染物捕获设备**

Considerations when incorporating gross pollutant capture devices in a concept design

Statutory compliance requirements

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

Spatial (land take) requirements

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

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

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

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

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

From Concept Design Guidelines for Water Sensitive Urban Design (South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)

5.Gross Pollutant Capture Devices**严重污染物捕获设备**

Whole-of-lifecycle considerations

Capital and operating costs

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

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

Expected effective service life

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

Visual and aesthetic transformations over service life

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

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

Decommissioning or re-installation requirements

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

Typical maintenance requirements

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

BMPs(Best Management Practices)

5.Gross Pollutant Capture Devices**严重污染物捕获设备**

BMP performance risk considerations

Potentially constraining physical site characteristics

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

Poor design

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

Operational risks

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

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

BMPs(Best Management Practices)

6.Sedimentation Basins**沉淀池**

Description

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

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

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

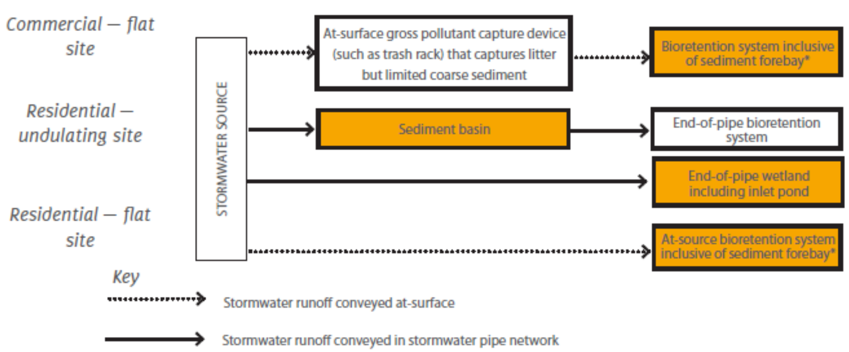


Figure 31 —Sediment basins (and sediment forebays) as part of stormwater treatment trains

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

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

BMPs(Best Management Practices)

6.Sedimentation Basins沉淀池

Contribution of sedimentation basins to WSUD strategies

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

Who needs to know about sedimentation basins?

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

BMPs(Best Management Practices)

6.Sedimentation Basins**沉淀池**

Considerations when incorporating sedimentation basins in a concept design

Statutory compliance requirements

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

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

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

Spatial (land take) requirements

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

BMPs(Best Management Practices)

6.Sedimentation Basins**沉淀池**

Whole-of-lifecycle considerations

Capital and operating costs

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

Expected effective service life

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

Visual and aesthetic transformations over service life

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

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

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

BMPs(Best Management Practices)

6.Sedimentation Basins沉淀池

Decommissioning or re-installation requirements

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

Typical maintenance requirements

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

BMP performance risk considerations

Potential constraining physical site characteristics

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

Poor design

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

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

Operational risks

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

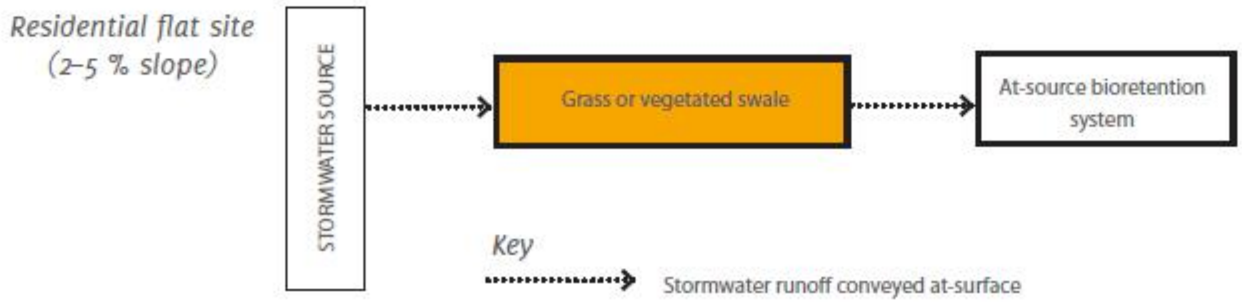
BMPs(Best Management Practices)

7.Grass or Vegetated Swales**草或者植被洼地**

Description

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

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



BMPs(Best Management Practices)

7.Grass or Vegetated Swales**草或者植被洼地**

Contribution of grass or vegetated swales to WSUD strategies

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

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

Who needs to know about grass or vegetated swales?

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

BMPs(Best Management Practices)

7.Grass or Vegetated Swales**草或者植被洼地**

Considerations when incorporating grass or vegetated swales in a concept design

Statutory compliance requirements

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

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

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

Spatial (land take) requirements

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

From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)

7.Grass or Vegetated Swales**草或者植被洼地**

Whole-of-lifecycle considerations

Capital and operating costs

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

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

Expected effective service life

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

Visual and aesthetic transformations over service life

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

Decommissioning or re-installation requirements

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

Typical maintenance requirements

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

BMPs(Best Management Practices)

7.Grass or Vegetated Swales**草或者植被洼地**

BMP performance risk considerations

Potentially constraining physical site characteristics

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

Poor design

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

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

Operational risks

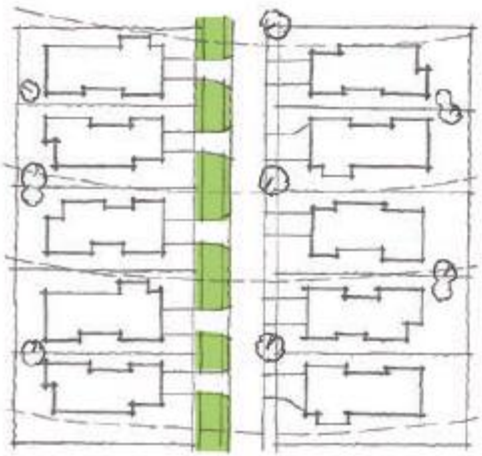
Routine removal of accumulated sediments, litter and weeds from the grass or vegetated swales is critical to the system's conveyance and treatment performance. This is a simple task and should be well within the capacity of most local governments or community-based asset management teams.

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

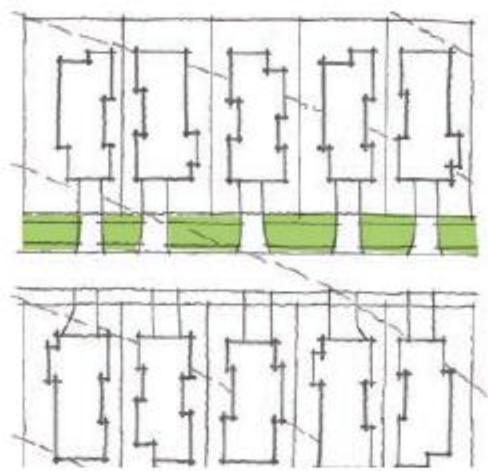
From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)

7.Grass or Vegetated Swales草或者植被洼地



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



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

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

BMPs(Best Management Practices)

8.Sand Filters**碎石过滤器**

Description

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

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

Contribution of sand filters to WSUD strategies

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

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

BMPs(Best Management Practices)

8.Sand Filters**碎石过滤器**

Who needs to know about sand filters?

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

Considerations when incorporating sand filters in a concept design

Statutory compliance requirements

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

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

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

Spatial (land take) requirements

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

BMPs(Best Management Practices)

8.Sand Filters**碎石过滤器**

Whole-of-lifecycle considerations

Capital and operating costs

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

Expected effective service life

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

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

Visual and aesthetic transformations over service life

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

Decommissioning or re-installation requirements

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

Typical maintenance requirements

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

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

From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)

8.Sand Filters**碎石过滤器**

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

Proprietary Media Filters

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

BMPs(Best Management Practices)

9.Bioretention Systems**生物滞留系统**

Description

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

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

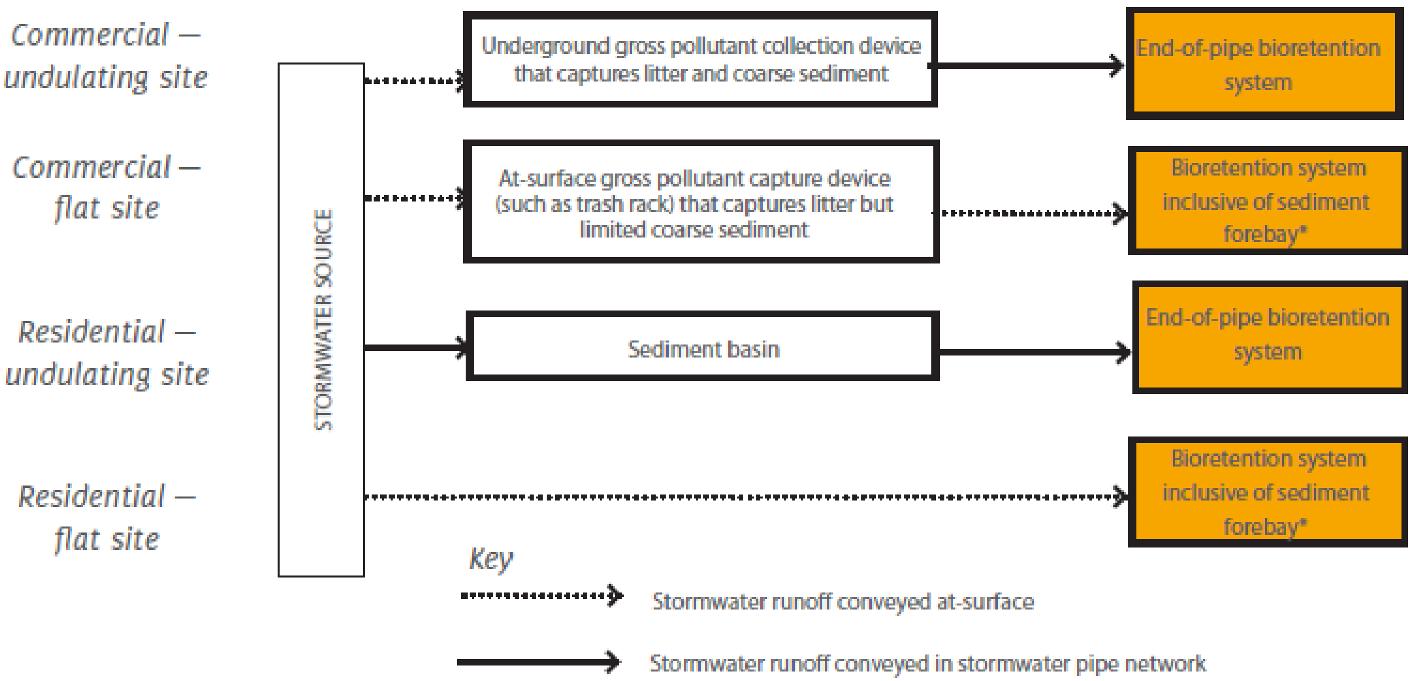
From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)

9.Bioretention Systems**生物滞留系统**

Contribution of bioretention systems to WSUD strategies

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



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

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

BMPs(Best Management Practices)

9.Bioretention Systems生物滞留系统

Who needs to know about bioretention systems?

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

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

BMPs(Best Management Practices)

9.Bioretention Systems生物滞留系统

Considerations when incorporating bioretention systems in a concept design

Statutory compliance requirements

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

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

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

Spatial (land take) requirements

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

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

BMPs(Best Management Practices)

9.Bioretention Systems**生物滞留系统**

Whole-of-lifecycle considerations

Capital and operating costs

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

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

Expected effective service life

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

BMPs(Best Management Practices)

9.Bioretention Systems**生物滞留系统**

Whole-of-lifecycle considerations

Visual and aesthetic transformations over service life

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

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

Decommissioning or re-installation requirements

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

BMPs(Best Management Practices)

9.Bioretention Systems**生物滞留系统**

Whole-of-lifecycle considerations

Typical maintenance requirements

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

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

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

BMPs(Best Management Practices)

9.Bioretention Systems生物滞留系统

BMP performance risk considerations

Potentially constraining physical site characteristics

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

Poor design

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

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

Operational risks

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

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

From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)

9.Bioretention Systems生物滞留系统

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

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

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

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

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

BMPs(Best Management Practices)

10.Constructed Wetlands**人工湿地**

Description

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

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

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

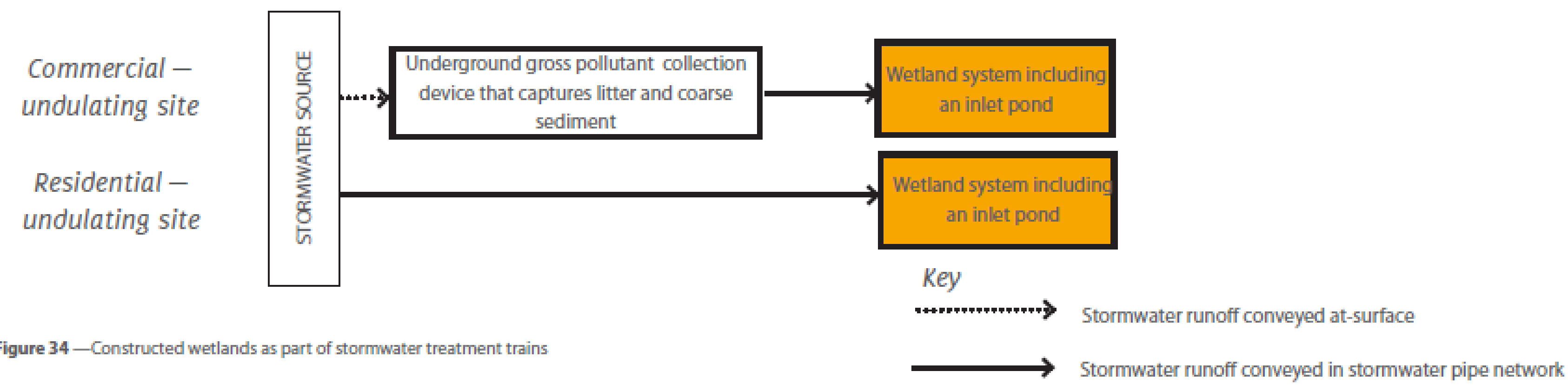


Figure 34 —Constructed wetlands as part of stormwater treatment trains

BMPs(Best Management Practices)

10.Constructed Wetlands**人工湿地**

Contribution of constructed wetlands to WSUD strategies

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

Who needs to know about constructed wetlands?

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

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

BMPs(Best Management Practices)

10.Constructed Wetlands**人工湿地**

Considerations when incorporating constructed wetlands in a concept design

Statutory compliance requirements

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

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

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

Spatial (land take) requirements:

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

BMPs(Best Management Practices)

10.Constructed Wetlands**人工湿地**

Whole-of-lifecycle considerations

Capital and operating costs

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

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

Expected effective service life

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

Visual and aesthetic transformations over service life

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

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

BMPs(Best Management Practices)

10.Constructed Wetlands**人工湿地**

Whole-of-lifecycle considerations

Decommissioning or re-installation requirements

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

Typical maintenance requirements

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

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

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

BMPs(Best Management Practices)

10.Constructed Wetlands**人工湿地**

BMP performance risk considerations

Potentially constraining physical site characteristics

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

Poor design

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

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

Operational risks

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

BMPs(Best Management Practices)

11.Porous Pavements**透水铺装**

Description

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

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

Contribution of porous pavements to WSUD strategies

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

Who needs to know about porous pavements?

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

BMPs(Best Management Practices)

11.Porous Pavements**透水铺装**

Considerations when incorporating porous pavements in a concept design

Statutory compliance requirements

Statutory compliance requirements do not apply to porous pavements.

Spatial (land take) requirements

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

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

BMPs(Best Management Practices)

11.Porous Pavements**透水铺装**

Whole-of-lifecycle considerations

Capital and operating costs

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

Expected effective service life

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

Visual and aesthetic transformations over service life

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

Decommissioning or re-installation requirements

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

Typical maintenance requirements

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

BMPs(Best Management Practices)

11.Porous Pavements**透水铺装**

BMP performance risk considerations

Potentially constraining physical site characteristics

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

Poor design

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

Operational risks

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

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

BMPs(Best Management Practices)

12.Infiltration Measures**下渗措施**

Description

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

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

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

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

BMPs(Best Management Practices)

12.Infiltration Measures**下渗措施**

Contribution of infiltration measures to WSUD strategies

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

Who needs to know about infiltration measures?

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

Considerations when incorporating infiltration measures in a concept design

Statutory compliance requirements

Statutory compliance requirements do not apply to infiltration measures.

Spatial (land take) requirements

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

BMPs(Best Management Practices)

12.Infiltration Measures**下渗措施**

Whole-of-lifecycle considerations

Capital and operating costs

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

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

Expected effective service life

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

Visual and aesthetic transformations over service life

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

Decommissioning or re-installation requirements

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

Typical maintenance requirements

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

BMPs(Best Management Practices)

12.Infiltration Measures**下渗措施**

BMP performance risk considerations

Potentially constraining physical site characteristics

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

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

Poor design

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

Operational risks

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

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

From Concept Design Guidelines for Water Sensitive Urban Design
(South East Queensland Healthy Waterways Partnership)

BMPs(Best Management Practices)

Life circle cost

ASSET	ASSET PARAMETERS	CONSTRUCTION[1]	MAINTENANCE ESTABLISHMENT (FIRST TWO YEARS)	MAINTENANCE ONGOING	RENEWAL
WETLANDS[2]	< 500 m^2 500 to 10,000 m^2 > 10,000 m^2	\$150/m^2 \$100/m^2 \$75/m^2		\$10/m^2/yr \$2/m^2/yr \$0.5/m^2/yr	No data
SEDIMENT BASINS[2]	< 250 m^2 250 to 1000 m^2 > 1000 m^2	\$250/m^2 \$200/m^2 \$150/m^2		\$20/m^2/yr \$10/m^2/yr \$5/m^2/yr	Remove and dispose of: Dry waste = \$250/m^3 Liquid waste = \$1,300/m^3
ON-STREET RAINGARDENS[3]	< 50 m^2 50 to 250 m^2 > 250 m^2	\$2000/m^2 \$1000/m^2 \$500/m^2		\$30/m^2/yr \$15/m^2/yr \$10/m^2/yr	Minor reset = \$50 to \$100/m^2
BIORETENTION BASINS[3]	< 100 m^2 100 to 500 m^2 > 500 m^2	\$1000/m^2 \$350/m^2 \$250/m^2		\$5/m^2/yr	No data
TREE PITS[3]	< 10 m^2 total 10 to 50 m^2 total > 50 m^2 total	\$8000/m^2 \$5000/m^2 \$1000/m^2	Two to five times ongoing maintenance cost	No access issues = \$150/asset/yr Traffic issues or specialist equipment required = \$500/asset/yr	No data
GRASS SWALES AND BUFFER STRIPS[4]	Seeded – no subsoil drain Seeded – subsoil drain Turfed – no subsoil drain Turfed – subsoil drain Native grasses established	\$15/m^2 \$25/m^2 \$20/m^2 \$35/m^2 \$60/m^2		\$3/m^2/yr	No data
VEGETATED SWALES AND BIORETENTION SWALES[4]		150/m^2		\$5/m^2/yr	No data
IN-GROUND GPTS	< 300 L/s 300 to 2000 L/s > 2000 L/s	\$50,000/asset \$150,000/asset \$250,000/asset	N/A	Inspection = \$100/visit Cleanout = \$1000/visit	No data

1 Includes planning and design
2 Area at normal water level
3 Area of filter media at bottom of extended detention
4 Total vegetated area

Evaluation & Assessment

Assessed at two quite distinct levels:

WSUD option evaluation: providing guidance to WSUD designers on how to evaluate a range of potential WSUD options;

WSUD option assessment: providing guidance to a consent authority (e.g. Local Government) on how to evaluate a specific WSUD proposal submitted by a developer.

Evaluation & Assessment

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).

Evaluation & Assessment

WSUD Option Evaluation

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

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 & Assessment

WSUD Option Evaluation

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).

Evaluation & Assessment

WSUD Option Evaluation

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.

Evaluation & Assessment

WSUD Option Evaluation

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 outside of residential premises).

Evaluation & Assessment

WSUD Option Evaluation

Social (i.e. 'use values' that relate to people's quality of life)	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).

Evaluation & Assessment

WSUD Option Evaluation

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.

Evaluation & Assessment

WSUD Option Assessment

The formalised Assessment process is beneficial to determine whether a proposed strategy is suitable and/or appropriate in terms of the defined principles and objectives.

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.

Evaluation & Assessment

WSUD Option Assessment

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;
- 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.

Evaluation & Assessment

WSUD Option Assessment

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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

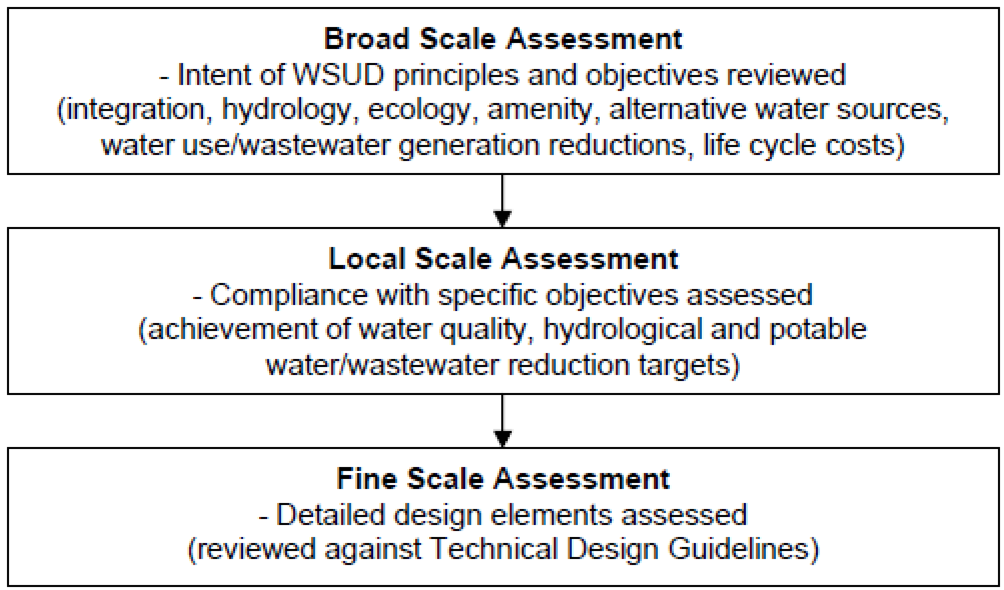


Figure 4-1 Assessment Hierarchy

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

1.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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

1.Broad Scale Assessment

In regard to these broad scale assessments, there are numerous examples within Australia of largescale 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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

1.Broad Scale Assessment

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		

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.1 Overview

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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.2 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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.2 Site Stormwater Treatment Suitability Assessment

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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.2 Site Stormwater Treatment Suitability Assessment

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 4-3 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	

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.2 Site Stormwater Treatment Suitability Assessment

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

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.3 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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.3 Stormwater Treatment Train Assessment - overview

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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.3 Stormwater Treatment Train Assessment – 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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.3 Stormwater Treatment Train Assessment – treatment processes

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

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.3Stormwater Treatment Train Assessment – treatment processes

It 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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.4 Potable Water / Wastewater Assessments

The key issues to consider in the context of local scale assessments of the potable water andm 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;
  Are there any specific public-health issues which would constrain or preclude certain recycled water applications.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.5 Combined Stormwater, Water and Wastewater Assessment

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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

2.Local Scale Assessment

2.5 Combined Stormwater, Water and Wastewater Assessment

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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

3.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.

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

3.Fine Scale Assessment

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*

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

3.Fine Scale Assessment

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

Evaluation & Assessment

WSUD Option Assessment

Assessment Process

Table 4-7 WSUD BMP Functionality Assessment

3. Fine Scale 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										Ideally suited	Ideally suited								
Water Efficient Fittings										Ideally suited	Ideally suited								
Rainwater Tanks	May assist	May assist	May assist	May assist	May assist	Ideally suited	Ideally suited	May assist	Ideally suited	Ideally suited	Ideally suited		May assist		May assist			Ideally suited	(grey)
Reticulated Recycled Water									Ideally suited	Ideally suited	Ideally suited		May assist		May assist			Ideally suited	May assist
Greywater Treatment/Reuse									Ideally suited	Ideally suited	Ideally suited		May assist		May assist			Ideally suited	May assist
Stormwater Harvesting/Reuse	May assist	May assist	May assist	May assist	May assist	May assist	Ideally suited	Ideally suited	Ideally suited	Ideally suited		May assist	May assist	May assist	May assist		May assist	Ideally suited	May assist
Changing Landscape Form	May assist			May assist	May assist	May assist		May assist	Generally unsuitable	Ideally suited		May assist	Ideally suited	May assist	Ideally suited	Ideally suited	May assist	Ideally suited	May assist
Water Use Education Programs	May assist	May assist	May assist	May assist	May assist					Ideally suited	Ideally suited				Ideally suited			Ideally suited	
Stormwater Management Techniques																			
Sediment Basins	Ideally suited	May assist	Generally unsuitable	May assist	Ideally suited	May assist	Ideally suited	May assist	May assist			Ideally suited	Ideally suited	May assist	May assist	May assist	Ideally suited	Ideally suited	Generally unsuitable
Bioretention Swales	Generally unsuitable	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited	May assist		Generally unsuitable	Generally unsuitable		Ideally suited	Ideally suited	May assist	May assist	May assist	Ideally suited	Ideally suited	Ideally suited
Bioretention Basins	Generally unsuitable	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited		May assist	May assist		Ideally suited	Ideally suited	Ideally suited	May assist	May assist	Ideally suited	Ideally suited	May assist
Sand Filters	Generally unsuitable	Ideally suited	Ideally suited	Ideally suited	Ideally suited	May assist	May assist		May assist			May assist	May assist	May assist	May assist	May assist	Ideally suited	Ideally suited	May assist
Swales	Ideally suited	Ideally suited	May assist	May assist	Ideally suited	Ideally suited	May assist		Generally unsuitable	Generally unsuitable		Ideally suited	Ideally suited	May assist	May assist	May assist	Ideally suited	Ideally suited	Ideally suited
Buffer Strips	Ideally suited	Ideally suited	May assist	May assist	Ideally suited	Ideally suited	May assist		Generally unsuitable	Generally unsuitable		Ideally suited	Ideally suited	Ideally suited	May assist	May assist	Ideally suited	Ideally suited	Ideally suited
Constructed Wetlands	Generally unsuitable	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited	May assist	May assist		Ideally suited	Ideally suited	Ideally suited	May assist	May assist	Ideally suited	Ideally suited	Generally unsuitable
Ponds and Lakes	Generally unsuitable	Ideally suited	May assist	May assist	Ideally suited	Ideally suited	Ideally suited	Ideally suited	May assist	May assist		Ideally suited	Ideally suited	May assist	May assist	May assist	Ideally suited	Ideally suited	Generally unsuitable
Infiltration Systems	Generally unsuitable	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited	May assist	May assist	May assist	May assist		Ideally suited	Ideally suited	May assist	May assist	May assist	Ideally suited	Ideally suited	May assist
Porous Pavements	Generally unsuitable	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited	May assist	May assist	May assist		Ideally suited	Ideally suited	May assist	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited
Aquifer Storage and Recovery	Generally unsuitable	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited	Ideally suited		Ideally suited	Ideally suited	May assist	May assist	May assist	Ideally suited	Ideally suited	May assist
Water Quality Education Programs	May assist	May assist	Generally unsuitable	May assist	May assist									May assist	Ideally suited	May assist		Ideally suited	

Practice/Measure ideally suited
Practice/Measure may assist
Measure generally unsuitable
Not applicable

Risk & Issues

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.

Risk & Issues

1. Rainwater Capture and Reuse

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.

Risk & Issues

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

Risk & Issues

2. Wastewater, Stormwater and Greywater Reuse

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

Risk & Issues

2. Wastewater, Stormwater and Greywater Reuse

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
- Guidance on managing health risks associated with recycled water
- Guidance on managing the environmental risks associated with recycled water
- Guidance on monitoring
- Guidance on Consultation and communication

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

Risk & Issues

2. Wastewater, Stormwater and Greywater Reuse

- A framework for the management of recycled water quality and use

  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.

Risk & Issues

2. Wastewater, Stormwater and Greywater Reuse

- **Guidance on managing the environmental risks associated with recycled water, including consideration of:**
  - Risk assessments;
  - Preventative measures;
  - 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;
  - 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;
  - Public crisis communication.

Risk & Issues

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;
- 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.

Risk & Issues

3. Stormwater Treatment

•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.

Risk & Issues

3. Stormwater Treatment

•**Construction & 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.

Risk & Issues

3. Stormwater Treatment

•**Construction & Establishment;**

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 allotmentscale 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).

Risk & Issues

3. Stormwater Treatment

•**Construction & Establishment;**

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.

Risk & Issues

3. Stormwater Treatment

- Construction & Establishment;

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

Risk & Issues

3. Stormwater Treatment

•Erosion/ 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.

Risk & Issues

3. Stormwater Treatment

•Erosion/ Scour;

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).

Figure 5-2 Examples of Erosion within Constructed Wetlands

Risk & Issues

3. Stormwater Treatment

•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.

Risk & Issues

3. Stormwater Treatment

- **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.

Risk & Issues

3. Stormwater Treatment

•**Maintenance.**

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.

Risk & Issues

3. Stormwater Treatment

•Maintenance.

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

Risk & Issues

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/.

Monitoring Consideration

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;**
- **To assess the performance of individual WSUD measures.**

Monitoring Consideration

1. Background

CHS

Monitoring Consideration

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.

Monitoring Consideration

2. Monitoring Objectives

CHS

Monitoring Consideration

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.

Monitoring Consideration

3. Monitoring Protocols

CHS

Monitoring Consideration

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.

Monitoring Consideration

4. Assessment, Accreditation and Asset Handover

CHS

Monitoring Consideration

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.

Maintenance Manual

Maintenance staff need easy access to all parts of WSUD elements:

Access tracks should be designed to cater f or the type of equipment that will be used to remove sediment or do other maintenance work.

In bioretention systems, inspection openings at the end of perforated pipes need to be part of the initial design. This allows maintenance staff to check sediment build-up and water level fluctuations. Infiltration tests should be undertaken periodically.

Ensure that inspection openings have been angled to allow jetting to occur into accumulated sediment which will then wash back down the pipe (rather than jetting from behind built-up sediment).

Maintenance Manual

1. Vegetation Management
2. Wetland and Pond Management
3. Sediment
4. Mulch
5. Street tree pits

Maintenance Manual

1. Vegetation Management

It takes two summers and a subsequent autumn season to establish vegetation. After that, vegetation management is required for the life of the WSUD asset, and needs to be scheduled accordingly. Where dense planting is required, it is generally best to use a combination of ground covers and other plants. For information on using specific plant species, refer to Appendix A of the WSUD engineering procedures: Stormwater manual.

It is also important to select vegetation appropriate to the equipment available for maintenance and to carry out planting accordingly. In ponds and wetlands, plants can be used to stabilise banks and may need to be included in designs where there is the potential for erosion. In inlet zones, dense planting around the waterline can make public access difficult, and as such, can minimise the risks of drowning. It can also make the landscape more attractive and screen basins which can be typically turbid.

Maintenance Manual

2. Wetland and Pond Management

Often wetlands and ponds are designed with a number of objectives supplementary to stormwater management, such as providing habitats or improving local amenity.

To protect wetlands and ponds, it is critical to undertake regular maintenance on the upstream sediment basin. Any build-up of coarse sediments in wetlands is generally caused by poor design or poor maintenance of the sediment basin. The design also needs to accommodate fluctuations in water levels.

To avoid the occurrence of algal blooms, ponds and wetlandss should be designed to have a proper flowthrough of water. Design considerations to minimise the risk of algal blooms are outlined later in this manual and in Melbourne Water's Constructed shallow lake systems — Design guidelines for developers.

The size of the weltand or pond needs to relate to the size of the catchment to ensure adequate flushing and turnover of water. Smaller elements are cheaper to maintain but the element must still be 1—2 per cent of the catchment it is treating to be effective.

To minimise the potential for mosquito breeding, refer to the WSUD Engineering Procedures Stormwater Manual.

Maintenance Manual

3. Sediment

All wetlands, ponds and sediment basins should be designed to have an area for stockpiling wet material that is removed during maintenance. Removing dry material is much cheaper than wet material.

Maintenance Manual

4. Mulch

If there are plans to mulch swales or bioretention systems, designs need to make sure that run-off does not wash these mulches into drains where they could create blockages. Good design, as well as avoiding mulches that float, can make sure the mulch stays on site.

Maintenance Manual

5. Street tree pits

The most important design considerations are selecting the right species for the site and the best filter material to ensure the appropriate infiltration rate of water through the media. It is also useful to identify existing services located near the site.

Maintenance Manual

Inspection frequency

In most cases, newly constructed components of WSUD elements will need inspection after rainfall to ensure they are working properly. After settling-in, all elements should be inspected every three to six months. This frequency seems to be the most cost-effective without sacrificing environmental effectiveness. Areas of high litter loads may need more regular inspection.

In particular, inlets should be regularly checked and cleared to prevent debris and sediment build-up. For example, if building sites in a catchment are poorly managed, the stormwater running off these sites will carry a great deal of debris and sediment into nearby ponds, wetlands, raingardens or vegetated swales. Built-up debris and sediment can smother plants, damage filtering capabilities and reduce the volume of water that can be stored or treated. It can block inlets or outlets, making sites smelly, unattractive and ineffective.

Maintenance Manual

Inspection frequency

Raingardens, wetlands and vegetated swales will need more maintenance while their plants are becoming established (the first two summers followed by a subsequent autumn season). Weed removal and replanting may be required.

Maintenance checklists have been developed as part of the WSUD Engineering Procedures. They are included in this manual on the inside back cover. Photocopy these checklists to use when inspecting WSUD sites so you build a record of their condition and the quantity of pollutants removed over time.

Table 1: Maintenance considerations for asset handover.

This table is derived from the full Asset Handover Checklist in the *WSUD engineering procedures manual*, page 43.

Maintenance	Yes	No
Are maintenance plans provided for each asset?		
Has inspection and maintenance been undertaken as specified by the maintenance plan?		
Are inspection and maintenance forms provided?		
Has the asset been inspected for defects?		

Maintenance Manual

SEDIMENT BASINS

Main tasks

- Make sure the erosion protection (plants, rocks or other) around the inlet is operating as designed.
- Check for and remove any built-up sediment.
- Make sure the outlet zone is clear of vegetation and debris.

Primary target

- Sediment

Secondary targets

- Organics
- Litter

On site

Soon after construction, inspect the inlet zone after storms to make sure the erosion protection is working properly.

Sediment should be removed about every five years, but this depends on the nature of the catchment. As a general guide, sediment should be removed once the sedimentation basin is half full.

In catchments where there is a lot of construction work, large loads of sediment can be washed into the stormwater system unless it is properly controlled on each building site. In these areas, sediment basins will need to be cleared out more frequently.

Remove organic and inorganic debris and litter whenever you see them on the site.

Maintenance costs

Ponds, sediment traps and sedimentation basins typically cost between three and six per cent of the construction cost to maintain each year.

Generally, there is a very strong correlation between typical annual maintenance costs and the surface area of the basin. Put simply: smaller basins are cheaper to maintain.

Maintenance costs are low in most years, but higher when desilting is done or aquatic weeds need to be removed.

Maintenance Manual

PONDS AND LAKES

Main tasks

- Check for endangered species.
- Inspect the inlet zone for scour after large storms.
- Unclog outlets.
- Remove litter and debris.
- Control weeds and pests.
- Replant edging plants where needed.

Primary target

- Fine sediment
- Metals

On site

For ponds and lakes, most of the maintenance work is needed around the inlet zone.
Remove litter, weeds and debris whenever you see them on the site.
Replant edging plants as necessary.

Maintenance costs

Dealing with algal bloooms is essentially a design and management issue, rather than a maintenance one. For further information on algal blooms, refer to the comprehensive document Design guidelines for shallow lake systems, produced by Melbourne Water and available from its library on its website at:

www.melbournewater.com.au/content/library/rivers_and_creeks/wetlands/Design_Guidelines_For_Shallow_Lake_Systems.pdf

Ponds, sediment traps and sedimentation basins typically cost between three and six per cent of the construction cost to maintain each year. Generally, there is a very strong correlation between typical annual maintenance costs and the surface area of the basin or pond. Put simply: smaller ponds are cheaper to maintain.

Maintenance Manual

WETLANDS

Main tasks

- Inspect the inlet zone for scour after large storms.
- Unclog any outlets; remove vegetation litter, debris and sediment.
- Control pests and weeds.
- Replant edging plants if needed.
- Check and maintain water plants.
- Manage vegetation
- Remove litter

Primary target

- Fine-to-medium sediments
- Nutrients
- Metals
- Bacteria

On site

The maintenance tasks for wetlands are similar to ponds and lakes.

However in wetlands, maintenance staff also need to look out for any build-up of coarse sediments. The inlet zone of a wetland needs the same maintenance as a sedimentation basin. Scour and erosion at the inlet can also create problems, so it is important to inspect all inlets after large storms.

The most intensive maintenance effort will be needed during the first two summers and subsequent autumn season while plants are becoming established. This will involve weed control and replanting where necessary. When checking plant densities, aim to have 70—80 per cent of the ground covered after two growing seasons (two years).

To help wetland plants establish, keep the water level shallow and constant for the first six to eight weeks. After that, the plants should be strong enough to survive in deeper water, so the wetland can be gently filled to its normal operating water level.

Large wetland systems will need tailor-made detailed maintenance schedules, which include a brief explanation of how the wetland operates and a list of main items or areas to check during each inspection.

Maintenance Manual

WETLANDS

Main tasks

- Inspect the inlet zone for scour after large storms.
- Unclog any outlets; remove vegetation litter, debris and sediment.
- Control pests and weeds.
- Replant edging plants if needed.
- Check and maintain water plants.
- Manage vegetation
- Remove litter

Primary target

- Fine-to-medium sediments
- Nutrients
- Metals
- Bacteria

Maintenance costs

To cost wetlands, the treatment device includes an inlet zone sediment basin/pond and macrophyte zone, without a gross pollutant trap.

Wetlands typically cost between two and six per cent of the construction cost to maintain each year. Generally, there is a very strong correlation between Typical Annual Maintenance costs and the surface area of the wetland. Put simply: smaller wetlands are cheaper to maintain.

Maintenance costs increase where:

- there are introduced aquatic weeds
- sediments are contaminated
- upstream control of sediment is poor
- access is difficult
- dewatering areas are limited.

Maintenance Manual

SWALES OR BUFFER SYSTEMS

Main tasks

- Control weeds and pets
- Make sure water flows into, and through the system.
- Prevent or remove channelisation.
- Remove any accumulated sediment.
- Remove litter and devris.

Primary target

- Coarse sediments
- Some nutrients (Total Phosphorous)
- Litter
- Organics

On site

To operate successfully, the plants in a swale or buffer system need to be wellestablished and dense, and managed well to prevent erosion.

The plants need to be grouped close together so any runoff water will flood or seep through, rather than establishing little flow channels (known as rills) which might erode the swale surface.

Maintaining the health and density of vegetation is vital, particularly in the early stages. New plantings will need to be maintained for at least 6 months. Tasks include regular watering, weeding, replacing dead plants, monitoring and controlling pests, and removing rubbish.

Any scour at inlets (if the swale does not have distributed inflows) needs to be monitored closely. Litter, debris and sediment can build up at the inlet points. Litter and debris also need to be removed from the surcharge pits.

Check overflow pits for structural faults. Check the pits are functioning properly.

Grass clippings need to be disposed in green waste or compost systems. Areas damaged by wheel ruts need be restored to re-establish contours.

Maintenance Manual

SWALES OR BUFFER SYSTEMS

Main tasks

•Control weeds and pets
•Make sure water flows into, and through the system.
•Prevent or remove channelisation.
•Remove any accumulated sediment.
•Remove litter and devris.

Primary target

•Coarse sediments
•Some nutrients (Total Phosphorous)
•Litter
•Organics

Maintenance costs

Maintenance costs tend to be higher in the first five years, while the swale or buffer is becoming established.

•Grassed swales cost about \$2.50—\$3.13/m2/year to become established(but if residents mow regularly, there is less cost to local authorities).
•Vegetated swales cost about \$9/m2/year.

After five years, the cost for grass swales decreases to roughly \$0.75—\$1.50/m2/year.

Maintenance Manual

RAINGARDENS (Bioretention systems and swales)

Main tasks

- •Make sure water flows into, and through the system during storms.
- •Prevent or remove channelisation.
- •Remove weeds and replace dead plants.
- •Remove accumulated sediment, litter and devris.
- •Remove clogged filtration material and replace with new material.
- •Test filtration capacity if visible problem or every five years
- •Check drainage pipes.

On site

To operate successfully, the plants in a bioretention system need to be wellestablished and dense.

The plants need to be grouped close together so any runoff water will flood or seep through, rather than establishing little flow channels (known as rills) which might erode the surface. Mulch should prevent erosion.

Maintaining the health and density of vegetation is vital, particularly in the early stages. High-density planting will also ensure a uniform root zone in bioretention systems.

New plantings will need to be maintained for at least six months. Tasks include regular watering, weeding, replacing dead plants, monitoring and controlling pests, and removing rubbish.

Any scour at inlets needs to be monitored closely. Litter, debris and sediment can build up at inlet points. Litter and debris also need to be removed from surcharge pits.

Check overflow pits for structural faults. Check the pits are functioning properly.

If the fitration capacity is reduced significantly, the filter material should be replaced, along with new plants and mulch.

Maintenance Manual

RAINGARDENS (Bioretention systems and swales)

Primary target

- Fine-to-medium sediment
- Nutrients
- Organics
- Metals

Maintenance costs

The Typical Annual Maintenance cost for a bioretention system is approximately five to seven per cent of the construction cost. Maintenance costs are likely to be higher in the first few years due to the intensive effort needed to establish the system.

The maintenance cost for mature bioretention systems is similar to swales: $2.50/m2 for grassed systems and $9/m2 for vegetated systems using native vegetation.

Maintenance Manual

STREET TREE PITS (Bioretention systems)

Main tasks

- Remove leaves, litter and fine sediment from surface.
- Remove caked sediment from surface.
- Prune tree as necessary.
- Test filtration capacity if visible problem, or every five years.

Primary target

- Fine-to-medium sediment
- Nutrients
- Organics
- Metals
- Litter

On site

Street trees can be used as small-scale bioretention system in streetscapes where there is limited vegetation or landscaping for linear swales or largerscale rain gardens. This is particularly relevant for town centres where space is limited and hard stand areas dominate the landscape.

Check the pits are functioning properly.

Check inlets for scour and sediment. Remove litter and debris.

Over time, the filter media will accumulate fine sediments. It should be replaced when its infiltration capacity is reduced significantly. If the filter material becomes clogged, the tree will be unable to thrive.

It is also important to check there is enough filter material in the tree pit.

Maintenance costs

The typical annual maintenance cost of a tree pit is five to seven per cent of the total construction costs.

Maintenance Manual

INFILTRATION SYSTEMS

Main tasks

- Ensure pre-treatment is operating effectively.
- Maintain plants if present.

Primary target

- Fine-to-medium sediment
- Nutrients
- Metals

On site

Infiltration systems differ from raingardens in that water infiltrates into the surrounding soil, rather than entering the piped stormwater systems. Infiltration systems may have plants or simply use an infiltration medium such as sand. The most important aspect of maintaining infiltration systems is to make sure the WSUD element used for pre-treatment is operating effectively.

Check that sediment is not clogging the system. Surfaces need to be cleared of debris and sediment periodically to maintain system functions.

Check the infiltration rates to make sure the system is functioning properly.

Maintenance costs

Typical Annual Maintenance costs for infiltration systems can range from approximately five to 20 per cent of the construction cost. There is a strong correlation between the Total Annual Maintenance cost and the total acquisition cost. Put simply, the more these systems cost to build, the more they cost to maintain.

Maintenance Manual

ANNUAL MAINTENANCE COSTS

Until recently, detailed data about actual costs incurred by owners of these elements has not been available. We now have the results of a number of studies into maintenance costs. The costing estimates in this manual are the best that could be generated given the information available collected from around Australia. For some measures such as buffer strips, bioretention systems and infiltration systems, the data is very limited.

These estimates will be refined over time as local governments and developers record detailed costs involved in maintaining WSUD elements.

To minimise costs, managers could investigate the potential of working with community groups on maintenance tasks.

All figures and calculations used in this manual are derived from real data for maintenance costs loaded into the computer software called MUSIC (Model for Urban Stormwater Improvement Conceptualisation), developed by the CRC (Cooperative Research Centre) for Catchment Hydrology's Urban Stormwater Quality Program. The rates can also be found in the Users Guide to MUSIC at www.toolkit.net.au.

Maintenance Manual

ANNUAL MAINTENANCE COSTS

Table 2: Typical maintenance costs for various WSUD stormwater treatment devices.

Treatment devices	Typical annual maintenance (TAM) cost	Correlation
Constructed wetlands	TAM ($2004) = 6.831 x (A)0.6435	R2= 0.76; p< 0.01; n= 21
Vegetated swales	TAM ($2004) = 48.87 x (TAC)0.4407	R2= 0.94; p= 0.03; n= 4
Buffer strips	TAM ($2004) = 48.87 x (TAC)0.4410	R2= 0.94; p= 0.03; n= 4
Bioretention systems	TAM ($2004) = 48.87 x (TAC)0.4410	R2= 0.94; p= 0.03; n= 4
Ponds and sediment basins	TAM ($2004) = 185.4 x (A)0.4780	R2= 0.92; p= 0.04; n= 4
Infiltration systems	TAM ($2004) = 30.15 x (TAC) 0.4741	R2= 0.80; p= 0.04; n= 5

Note: the size/cost relationships for TAM, TAC and RC are derived from a combined data set involving vegetated swales, buffer strips and bioretention systems. There is insufficient data to analyse swales on their own.

A = surface area of treatment zone/ basin/ infiltration system in m2.

TAC = total acquisition cost.

R2 = explanation of variance

p = significance

n = number of samples p is derived from.

Maintenance Manual

SEDIMENT BASINS maintenance checklist

INSPECTION ITEMS	YES	NO	ACTION NEEDED (details)
Is there litter within inlet or open water zones?			
Is there sediment in the inlet zone that needs removal? (Record depth. Remove if it fills >50% of basin.)			
Is the overflow structure integrity satisfactory?			
Is there evidence of dumping (building waste, oils, etc.)?			
Is the condition of terrestrial vegetation satisfactory (record density, weeds, etc.)?			
Are there weeds needing removal from within basin?			
Is there settling or erosion of bunds/batters?			
Is there damage or vandalism to structures?			
Is the outlet structure free of debris?			
Is the maintenance drain operational?			
Comments:			

Source: WSUD Engineering Procedures: Stormwater CSIRO 2005

Maintenance Manual

PONDS
maintenance checklist

INSPECTION ITEMS	YES	NO	ACTION NEEDED (details)
Is there litter within inlet or open water zones?			
Is there sediment within the inlet zone that needs removal? (Record depth. Remove if it fills >50% of basin.)			
Is the overflow structure integrity satisfactory?			
Is there evidence of dumping (building waste, oils etc.)?			
Is any replanting required?			
Does any of the submerged or floating vegetation need to be removed or harvested?			
Is there settling or erosion of bunds/batters?			
Is there damage or vandalism to structures?			
Is the outlet structure free of debris?			
Is the maintenance drain operational?			
Comments:			

Source: WSUD Engineering Procedures: Stormwater CSIRO 2005

Maintenance Manual

CONSTRUCTED WETLANDS maintenance checklist

INSPECTION ITEMS	YES	NO	ACTION NEEDED (details)
Is sediment accumulating at inflow points?			
Is there litter within inlet or macrophyte zones?			
Is there sediment within the inlet zone that needs removal? (Record depth. Remove if it fills >50% of basin.)			
Is the overflow structure integrity satisfactory?			
Is there evidence of dumping (building waste, oils etc.)?			
Is the terrestrial vegetation in satisfactory condition? Record density, weeds, etc.			
Is replanting needed?			
Is there settling or erosion of bunds/batters?			
Is there evidence of isolated shallow ponding?			
Is there damage or vandalism to structures?			
Is the outlet structure free of debris?			
Is the maintenance drain operational?			
Does the system need to be reset?			

Comments:

Maintenance Manual

SWALES AND BUFFER STRIPS maintenance checklist

INSPECTION ITEMS	YES	NO	ACTION NEEDED (details)
Is sediment accumulating at inflow points?			
Is there litter within the swale?			
Is there erosion at inlet or other structures (eg, crossovers)?			
Has there been damage from traffic?			
Is there evidence of dumping (eg, building waste)?			
Is the vegetation in satisfactory condition (eg, density, weeds)?			
Is replanting needed?			
Is mowing needed?			
Is sediment accumulating at outlets?			
Are drainage points clogged? Record sediment or debris.			
Is there evidence of ponding?			
Is set down from the kerb still possible?			
Comments:			

Source: WSUD Engineering Procedures: Stormwater CSIRO 2005

Maintenance Manual

RAINGARDENS
maintenance checklist

INSPECTION ITEMS	YES	NO	ACTION NEEDED (details)
Is sediment accumulating at inflow points?			
Is there litter within the swale?			
Is there erosion at inlet or other structures (eg, crossovers)?			
Has there been damage from traffic?			
Is there evidence of dumping (eg, building waste)?			
Is the vegetation in satisfactory condition (eg, density, weeds)?			
Is replanting needed?			
Is mowing needed?			
Are drainage points clogged? Record sediment or debris.			
Is there evidence of ponding?			
Is set down from the kerb still possible?			
Is there damage or vandalism to structures?			
Is there visible surface clogging?			
Has the drainage system been inspected?			
Does the system need to be reset?			

Comments:

Maintenance Manual

STREET TREE PITS
maintenance checklist

INSPECTION ITEMS	YES	NO	ACTION NEEDED (details)
Is sediment accumulating at inflow points?			
Is there litter within the pit?			
Is there erosion at inlet or other structures?			
Has there been damage from traffic?			
Is there evidence of dumping (eg, building waste)?			
Is the vegetation in satisfactory condition?			
Is replanting needed?			
Is there evidence of ponding?			
Is there damage or vandalism to structures?			
Is there visible surface clogging?			
Has the drainage system been inspected?			
Does the system need to be reset?			

Comments:

Source: WSUD Engineering Procedures: Stormwater CSIRO 2005

Maintenance Manual

INFILTRATION SYSTEMS maintenance checklist

INSPECTION ITEMS	YES	NO	ACTION NEEDED (details)
Is there evidence of sediments accumulating in the pre-treatment zone? Does is need removal?			
Is there erosion at inlet or other structures?			
Is there evidence of dumping (eg, building waste)?			
Are there weeds present?			
Are drainage points clogged? Record sediment or debris.			
Is there damage or vandalism to structures?			
Is there visible surface clogging?			
Has the drainage system been inspected?			
Does the system need to be reset?			
Comments:			

Source: WSUD Engineering Procedures: Stormwater CSIRO 2005

Case Studies

无花果小区
林恩布鲁克林房地产
高嘉华市政广场
维多利亚港
墨尔本皇家公园人工湿地与雨水收集回用系统
澳大利亚奥罗拉新城开发
澳大利亚维多利亚伯恩赛德公共空间恢复重建
澳大利亚Bellamack新开发住宅
澳大利亚墨尔本山谷胡社区
澳大利亚谢珀顿雅逸小区
澳大利亚埃平北小区
Council House 2, Melbourne
Victoria Park, Sydney
Yatala, Gold Coast
Bellvista, Sunshine Coast
Coomera Waters, Gold Coast
WSUD in the Planning Phase – Renwick
WSUD in the Implementation Phase – The Ponds/Prince Henry

Case Studies

无花果小区

纽卡斯尔，新南威尔士州

启示：
项目原址污染严重，合理的WSUD项目不仅改善了污染状况，促进了生态环境的可持续发展，还显示出了显著的经济效益

4.1.1 方案概况

无花果小区（Figtree Place）位于纽卡斯尔市中心，是一个拥有 27 套社区廉租房的开发项目。项目于 1998 年开始施工，占地 0.6 公顷。该项目的原址是一个主要公交车站，由于服务的汽车数量多以及碳氢化合物的严重渗漏，污染地下危及地下水。无花果小区项目通过简单的 WSUD 最佳管理实践措施，不仅获得了显著的经济效益，对生态环境的可持续发展更是意义重大，也因此成为示范项目。

图 4-2 不同天气情况下的滞洪区域（左为晴天，右为雨天）
Fig. 4-2 Figtree Place detention basin under dry and wet conditions
资料来源：Evaluating Options for Water Sensitive Urban Design – A National Guide

Case Studies

无花果小区

纽卡斯尔，新南威尔士州

4.1.2 水敏感城市设计分析

WSUD 特征：

雨水蓄水池、注水池；

雨水渗滤系统；

再利用的雨水用于提供冲水马桶用水、家庭热水供应、绿化灌溉和公交车清洗；

WSUD 成果：

家庭热水供应满足澳大利亚饮用水标准；

总节水总量达到 60%；

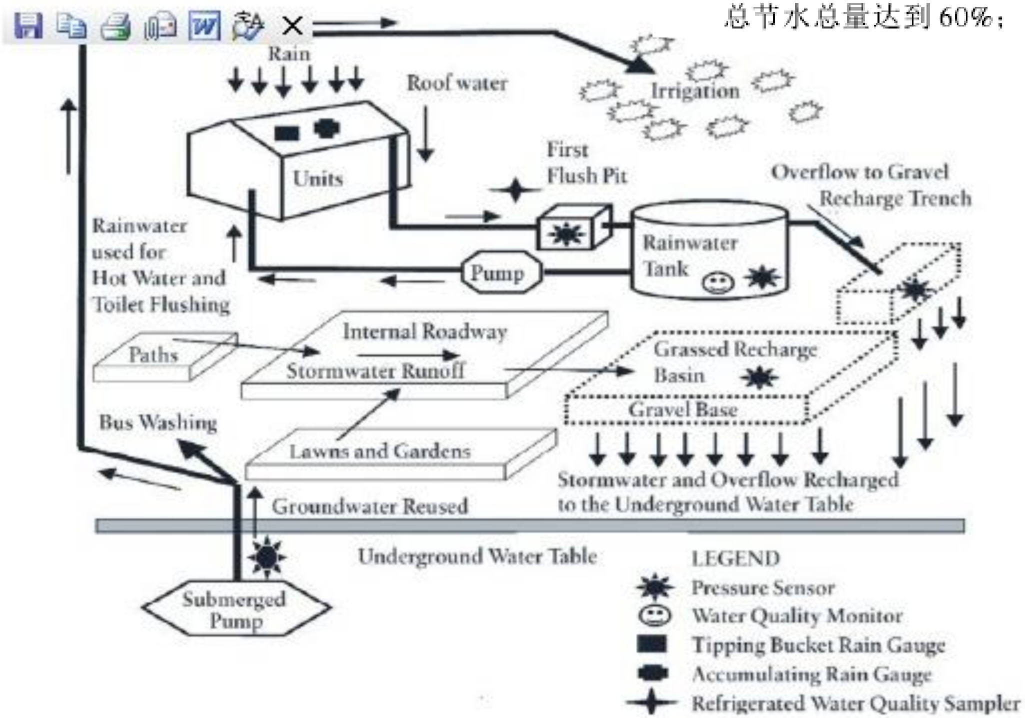


图 4-1 无花果小区水敏感设计

Fig. 4-1 WSUD of Figtree Place

资料来源：Water Sensitive Urban Design Site Development Guidelines and Practice Notes

该项目的雨水收集再利用方法很简单。 建于地下的蓄水池收集屋顶雨水来供应冲水马桶用水和家庭热水用水；草地下面设有补注蓄水层及补注池，用来供应绿化灌溉用水和公交车清洗。具体措施如下（见图 4-1）：

（1）屋顶上收集的雨水通过雨水管道，经过初期雨水池，进入到地下蓄水池。带有压力传感功能的水泵把水抽上来，供应冲水马桶用水和家庭热水。该项目共拥有 4 个矩形蓄水池，容量为 9～15 公升，每个蓄水池都包括一个进口（用于接收来自初期雨水池的水）、一个淤泥清理室、一个低水位监测器、一个出口（用于供应家庭用水）和一根多孔管道（用于将多余的水输送到补注池）。当蓄水池水位过低时，水位检测仪就会激活感应器往蓄水池中注水。[15]当蓄水池水位过高时，多余的水就会溢出并流入沙滤区，补注蓄水层。另外，蓄水池还配有故障-安全系统，当蓄水池水位过低或者电力供应中断时，会自动切换用水系统，以保证居民的正常使用。

（2）草坪、花园等绿化景观及道路上的雨水流入补注池，通过水泵为绿化灌溉和公交车清洗提供水源。补注池面积约为 250 平方米，上层为草坪，草坪下面有 750 毫米深的沙滤层。（见图 4-2）

（3）通过热水系统，家庭热水用水可以达到澳大利亚饮用水标准。

项目建成后，雨水收集再利用可以供应 50%的家庭热水用水和冲水马桶用水，100%的绿化灌溉用水和 100%的公共汽车清洗。总的来说，与传统的雨水管理系统相比，无花果小区的经济效益可观（开发成本和维护费用都更低），而且在提高水质和节水方面（节水总量达到 60%）更是效果显著。

Case Studies

林恩布鲁克林房地产

墨尔本，维多利亚州

启示：
WSUD是一个复杂的系统工程，只有通过对各个部分的合理联系和组织，并形成完整“链条”，才能达到具有高效能的设计效果。

项目概述
林布鲁克住宅开发项目位于澳大利亚墨尔本东南郊约35公里，整个小区开发面积 1700 公顷。作为示范区，55 公顷采用了 WSUD（以水为核心的城市设计）。
该设计的目的是通过收集利用雨水，有效地保护水资源，同时在暴雨季节大大减轻下游排水管道的压力，从而节省整个城市基础设施的建设费用。
为了保护接受水环境，缓解和处理暴雨雨水的影响，公共开放空间、道路、景观要素、建筑设计和排水系统相结合，形成三个连续的层次。

项目类型：WSUD 城市住宅开发
项目规模：271 套住宅
项目成本：271 套住宅的开发成本大约为800 万澳元
实施时间：WSUD 概念开发始于1999 年7 月，发起人为墨尔本水资源公司，开发商为城市与地区土地公司（URLC）
竣工时间：2000 年8 月
销售时间：2000 年2 月开始销售。由于开发商以雨水管理作为卖点，该住宅区的销售比其他楼盘要好得多。
奖项：澳大利亚城市开发学会颁发的优秀奖和合作研究中心联合会技术变革奖。

监测结果
WSUD 与林布鲁克住宅区的普通排水系统进行了比较，包括雨水数量和质量、建设成本、WSUD 的维护和社区接受。
监测结果显示，该系统表现良好：雨水通过该系统有效排出，经过适当的过滤后，在排入当地排水管道之前变得更清洁了。
城市雨水环境管理标准（维多利亚雨水委员会1999 年发布的标准）要求氮含量减少45%、磷含量减少45%、悬浮固体物减少80%。而林布鲁克的初期监测结果显示，各种指标都好于该标准，氮含量减少了60%、磷含量减少了80%，悬浮物减少了90%。

Case Studies

林恩布鲁克林房地产

墨尔本，维多利亚州

项目设计
初级处理:
在每户住宅的宅前绿地和入口道路设置植草洼地、填充砂砾的沟渠，形成绿化过渡带，收集、过滤和运送建筑屋顶和场地内的径流，再通过直径150mm的PVC管道，沿支路引向主要道路。
二级处理:
主要道路宽度为16米，中央绿岛两侧的道路横向坡度向中央倾斜，取消道路缘石和排水沟，使径流向中央绿岛汇集，通过砂砾沟渠等生态过滤系统滞留部分径流，并将其与径流继续运送到公共开放空间。
三级处理:
在主要道路的生态渗透系统下游设置开放空间，通过绿化、渗透系统和湿地，暴雨雨水经过进一步处理后排放到观赏性的人工湖中，再经过重力自流沟渠将其收集，用于景观绿化的浇灌。

（1）位于次级道路上的浅草沟和砾石沟系统(Grass swale and gravel trench system)对径流进行收集、渗滤并传输到主干道。屋顶上的径流则由管道直接进入地下该地下排水系统。

（2）径流继续通过在主干道的隔离带中设置的生物滞留系统(Bio-retention system)，利用植被进行渗滤并由下部管道被传送到湿地和湖泊系统(Wetland and lake system)。（见图 4-4）

（3）经过湿地和湖泊系统(Wetland and lake system)径流才会进入到湖泊和当地水系。在湖泊一侧的渗滤系统(Infiltration system)则可通过自重供给从湖里获得经过处理的水，以保证提供足够的水来灌溉城市公园。

图 4-4 林恩布鲁克房地产的生物过滤系统

Fig. 4-4 Bioretention system in Lynbrook Estate

资料来源：Evaluating Options for Water Sensitive Urban Design – A National Guide

Case Studies

林恩布鲁克林房地产

墨尔本，维多利亚州

启示：
WSUD是一个复杂的系统工程，只有通过对各个部分的合理联系和组织，并形成完整“链条”，才能达到具有高效能的设计效果。

面临的挑战
开发商面临的主要挑战是要尽量使雨水系统的 WSUD 因素看上去和普通系统一样，而委员会则更关心社区对系统的功能与外观设计的长期反应：他们不希望系统将来的维护费用太高。城市与地区土地公司还担心，如果该系统与普通排水系统区别太大，潜在买主可能不愿购买这样的住房。
然而要使人们放心，必须要有独特的解决方案。在这个案例中，开发商首先要做的就是说服承包商和分包商支持这种非常规的设计，但在安装费用以及材料费用上不要提高太多，同时还要达到质量标准，这一目标在林布鲁克项目上得到了实现。该系统的建设成本与普通排水系统基本相同，由于在排入当地排水沟和海湾之前，不再需要更高标准的处理，因此还节约了成本。
另一个挑战是，必须要求建筑商和交易商改变现场管理，以便尽量减少和控制建筑工地的垃圾、污染物和沉淀物的移动。在施工单位开始施工之前，城市和地区土地公司向所有建筑商分发有关 WSUD 的宣传册，建筑工地附近的洼地用围栏围住，并用路标标示禁止施工车辆通行。

项目效果
由于在推广方面加大了美学及环境方面的宣传力度，住宅销售提高迅速，从每月销售 12 套提高到30 套。
该项目吸引了全澳大利亚的开发商、委员会及排水沟管理机构和环境决策者的关注。林布鲁克住宅项目已经荣获多种奖项，并成为澳大利亚雨水管理的一个典范。

该系统的安装成本虽然和普通排水系统差不多，但环保效果要好得多，节约是相当明显的。
首先，雨水在进入当地排水管道和海湾之前不再需要高水平的处理，因为它已将垃圾过滤掉。总之，通过渗漏、过滤、雨水池、洼地及湿地等处理方法和技术，这一节水系统能够带来良好的生态效果，对水资源和环境保护起到积极作用，这些措施对城市更新非常有吸引力。

Case Studies

林恩布鲁克林房地产

墨尔本，维多利亚州

项目效果
由于在推广方面加大了美学及环境方面的宣传力度，住宅销售提高迅速，从每月销售 12 套提高到30 套。
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Case Studies

林恩布鲁克林房地产

墨尔本，维多利亚州

WSUD 特征：

雨水处理形成完整“链条”；

渗滤系统、生物过滤系统和人工湿地；

WSUD 成果：

显著降低雨水中的污染物含量；

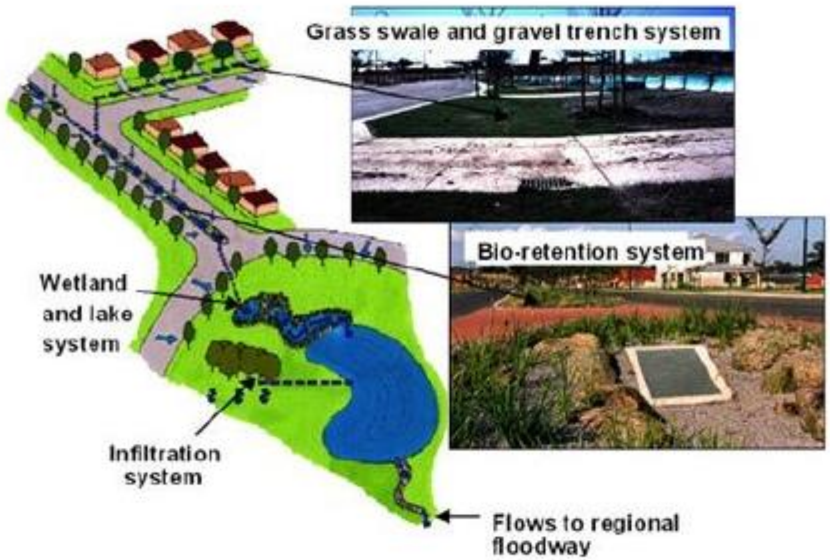


图 4-3 林恩布鲁克房地产水敏感城市设计示意图

Fig. 4-3 Schematic plot of WSUD in Lynbrook Estate

资料来源：A case study in WSUD - Lynbrook Estate, Melbourne, Australia

Case Studies

高嘉华市政广场

悉尼，新南威尔士州

启示：
该项目是一个示范项目，具有示范、引导和教育作用。通过示范项目来了推动WSUD的理念与实践被更多的设计师、学者和公众所接受。

图 4-5 高嘉华市政广场鸟瞰图

Fig. 4-5 Bird View of Kogarah Town Square

资料来源：Olsson Associates Architects Pty Ltd http://www.olssonassociates.com.au/projects/urban/design/kogarah_ts/

高嘉华市政广场（Kogarah Town Square）位于悉尼 CBD 南部方向 14 公里处，是一个中等密度的居住区。拥有 193 套公寓，大约 4500 平方米的商业和零售用地，一个图书馆以及一个市政广场。[17]（见图 4-5）该项目的本质内涵是为居民提供一个学习、生活、工作和休闲的场所，充满生机与活力，并有助于促进人际交往。项目由于 WSUD 技术的应用、太阳能光电板的集成应用和被动式建筑设计，已经成为可持续发展的示范性项目。

Case Studies

高嘉华市政广场

悉尼，新南威尔士州

WSUD 特征：

雨水收集和再利用；

收集的雨水主要用于提供冲水马桶用水、洗车和水景用水；

使用高效能的节水装置；

WSUD 成果：

85%的雨水被收集再利用；

收集的雨水的 60%被用于冲水马桶用水、洗车和水景用水；

该项目的水敏感设计主要包括三方面：地面雨水利用、屋顶雨水利用和高效能节水装置的使用。（见图 4-6）

（1）地面雨水利用：地面雨水由于冲刷道路和场地，其中所含污染物和垃圾较多，所以该部分雨水首先被收集到距地面较高的雨水收集箱中，进行沉淀和过滤处理以去除其中较大的污染物和垃圾。然后，经过初步处理的雨水通过水泵加压的方式输送到庭院用以绿化景观灌溉。通过绿化景观中植物的生物过滤功能，雨水中剩余的较小污染物也被去除。经过这一系列步骤的处理，此时的雨水已经可以达到一定的水质要求。最后，完全处理的雨水被储藏在单独的水箱中，为其他水箱补给水源。

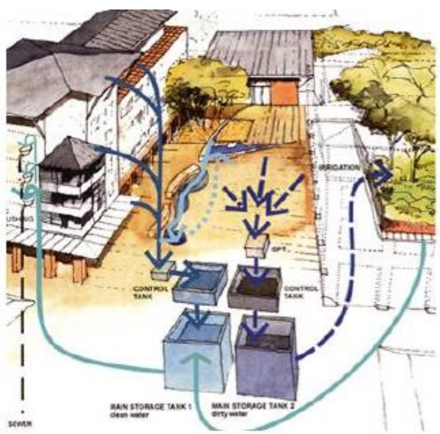


图 4-6 高嘉华市政广场雨水收集利用示意图

Fig. 4-6 Schematic plot of WSUD

资料来源：Olsson Associates Architects Pty Ltd http://www.olssonassociates.com.au/projects/urban/design/kogarah

（2）屋顶雨水利用：不同于地面雨水，屋顶和楼台上的雨水是直接滴落的，该部分雨水比较干净满足一定的水质要求，可以直接提供给居民作为非饮用水使。雨水首先通过雨落管输送流入到距地面较高的雨水收集箱中，然后再流入到于地下停车场下方的距地面较低的雨水收集箱中。雨水经过过滤网过滤后，用泵加压输送到周边建筑中，主要为冲水马桶、洗车和庭院景观提供水源（见图 4-7、4-8）。其中冲水马桶所需 70%的水是由雨水再利用提供的。

（3）项目中使用了高效能的节水装置，包括淋浴喷头和节水龙头等，减少了 42%的用水总量。

由于合理的水敏感城市设计，该项目使得 85%的雨水被收集再利用，这其中的 60%用于冲水马桶供水、洗车和庭院景观用水。最重要的是，作为示范项目，该项目将雨洪管理的方法和过程在庭院水景旁展示出来，居民可以通过图示来了解。[17]

图 4-7 利用雨水灌溉屋顶花园

Fig.4-7 Using stormwater to irrigate the roof garden

资料来源：悉尼高嘉华城市中心再开发

图 4-8 雨水收集再利用于景观用水

Fig.4-8 Using storemwater in Landscapes

资料来源：悉尼高嘉华城市中心再开发

Case Studies

维多利亚港

墨尔本，维多利亚州

启示：
该项目发挥了WSUD雨洪管理与景观结合的能力，展示了WSUD在公共开放空间的优势，为其他城市的海滨设计和开发提供了新思维和新途径。

维多利亚港位于墨尔本的达克多区（Docklands）,这个目前正在进行的澳洲规模最大的海滨开发项目享有盛名，被赞誉为“皇冠上的宝石”。达克多区是墨尔本的重要组成部分，维多利亚港是受旅客、居民及商业投资者欢迎的海滨社区。整个维多利亚港项目场地占地约 30 公顷，目前居住人口为 15000 人，2021 年建成后居住人口可达到现在的两倍。项目完工后将成为一个拥有 3 公里河岸，融合了住宅、办公、商业、公共开放空间等的活力地带。（其中包括商业区域 350000 平方米，零售区域 21615 平方米，混合用途区域 24000 平方米，住宅 2800 套，社区设施区域 8000 平方米，公园绿地和海滨长堤。）[18] （见图 4-9）

图 4-9 墨尔本维多利亚港项目模型
Fig. 4-9 Model of Victoria Harbour in Melbourne
资料来源：ASPECT Studio
http://aspectstudios.com.cn/?p=2762

Case Studies

维多利亚港

墨尔本，维多利亚州

出于对干旱和水资源短缺的考虑，该项目在公共开放空间的设计中引入了水敏感城市设计理念，以达到减少绿化灌溉用水量的目标。不同规模的水敏感城市设计元素被广泛使用，其中包括雨水收集再利用、生物过滤系统及人工湿地等。另外，改善雨水水质是维多利亚港城市水敏感设计的另一个关键目标，确保雨水不会对维多利亚港和雅拉河造成污染。因此，在设计时，考虑利用 WSUD 元素，

在场地中将雨洪管理设施与景观相结合，对雨水进行滞留及存储。（见图 4-10）

WSUD 特征：

雨水收集和再利用；

人工湿地；

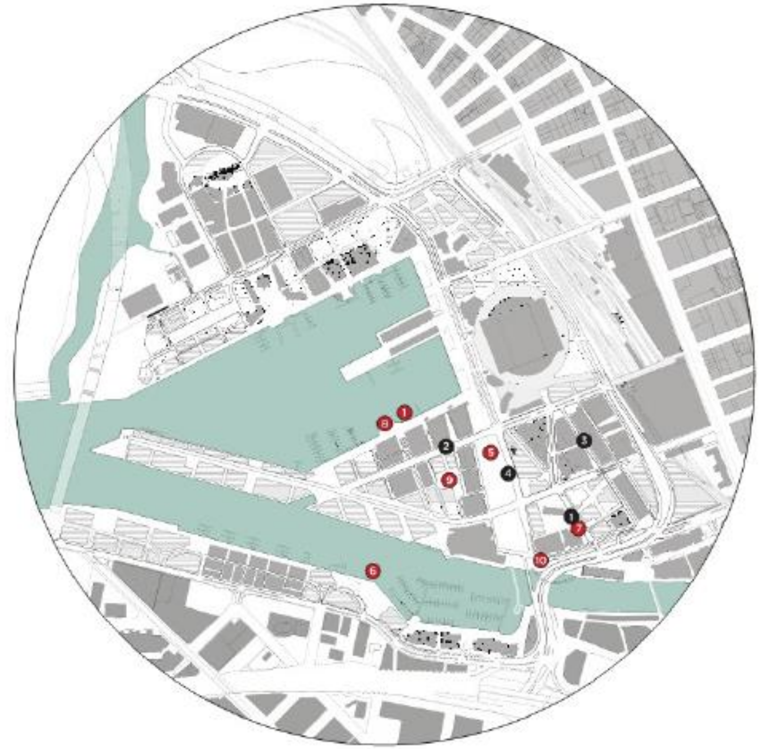
生物过滤系统；

雨洪管理设施与景观相结合；

WSUD 成果：

减少了公共开放空间中景观灌溉用水；

保护了城市水系；



1.巴特曼道——树池 (Batman's Hill Drive)	6. 普安公园——雨水花园、雨水存储 （Point Park）
2. 波尔克街——树池 （Bourke Street）	7. 巴特曼道——生物过滤洼地 （Batman's Hill Drive）
3. 维利街——树池 （Village Street ）	8. 水广场花园 （Water Plaza Gardens）
4. 码头散步路——树池 （Harbour Esplanade）	9. 维多利亚绿地——雨水存储 （Victoria Green）
5. 达克多公园——湿地、雨水存储 （Docklands Park）	10. 巴特曼河口

图 4-10 维多利亚港公共空间水敏感城市设计

Fig. 4-10 SUD of public space open space in Victoria Harbour

资料来源：Docklands Public Realm Plan

Case Studies

Goulburn Valley 货运物流中心雨洪管理总体规划

Greater Shepparton市位于墨尔本市北约 150km，为维多利亚州的主要农产品和制造中心之一。为进一步扩大区域的物资集散量，当地市政府拟投资 8300 万澳元新建 Goulburn valley 货运物流中心，该土地开发项目占地面积约 0.22km^2，工程分 6 期建成。

本文作者作为专业主要设计人，于 2010–2011 年参与项目的雨洪管理总体规划编制及设计工作，主要内容包括：排水系统，道路及铁路排洪涵洞，雨洪调蓄水库，雨洪水质处理系统（包括房顶雨水储集罐，GPT，底部设有生态透水槽的排水草沟，泥沙沉蓄池和人工湿地）。

设计中应用了多种水文、水力数学模型进行分析计算，主要软件模型包括 RAFTS（水文），MIKE21（二维洪水淹没区水力）、HECRAS（一维开敞河道水力）、DRAINS（一维河道，排水管线，泵站）和 MUSIC （雨水水质模拟）等。

其中的 MUSIC 模型是由澳大利亚政府支持的科研机构开发并被主管部门认可的模拟雨洪水质及水质处理设施效率的数学模型，作为工程咨询公司进行雨洪水质处理系统概念设计和政府主管部门对设计审核的主要工具，在澳大利亚被广泛应用。在运行程序时须选用输入具有代表性年份 6 分钟时段长历时（至少 3 个月，或至几十年）降雨量实测序列，通过径流演进及不同地表的污染物生成特性曲线，模拟长期降雨过程中城市开发所产生的主要污染物的相应浓度和含量，并估算各个水质处理设施及整体水质处理体系的效率，同时得出下游排出口处的水质数据，以确认经处理后的水质达到设计要求。

图 1　拟建货运物流中心及设计雨洪排水系统

Case Studies

Goulburn Valley 货运物流中心雨洪管理总体规划

3.2 现状水文及排水条件

开发项目处于Goulburn河洪涝区范围内，11 号排水沟在中间由南而北穿过，目前用地为农业耕地。Goulburn河主河道位于东侧，其间虽有标准较高的铁路路基与拟建物流中心间隔，但发生超 20 年一遇洪水时，漫滩洪水将会通过现有铁路涵洞向西侧漫溢，后和 11 号排水沟来水一起向北缓排。11 号排水沟全长约 8 5km，设计排涝标准为 10 年一遇，上游流域同属农业耕地，流域面积约为 17 11 km^2。Goulburn洪涝区由Goulburn Broken 流域管理局负责，而 11 号排水沟则归当地Goulburn Murray 水利局管理。

MIKE21 模拟的拟建物流中心现状 100 年一遇洪水淹没图见下图 2，铁路东西两侧的 100 年一遇洪水位分别为海拔 113 5m 和 113 1m。

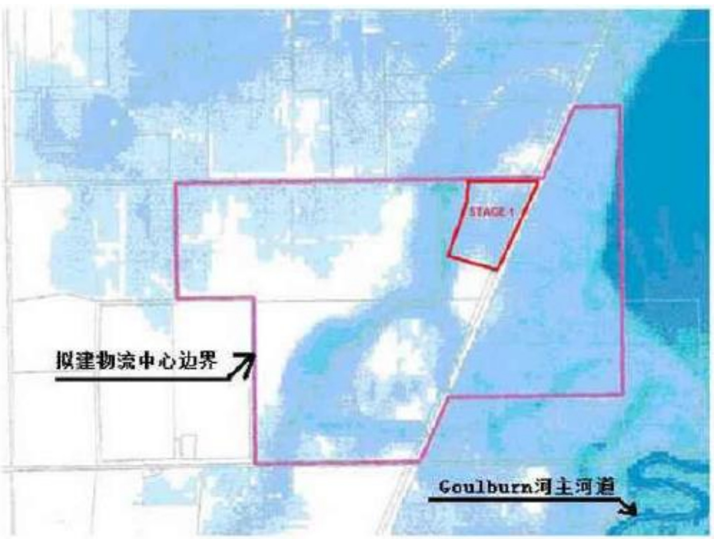


图 2 拟建物流中心现状 100 年一遇洪水淹没图（MIKE21 二维洪水数学模型）

3 3 设计雨洪排水系统

拟建物流中心将新建大片的硬化地面和道路以用于大型运输车、集装箱吊装机，仓库及附属服务设施的运行。建成后的房屋及道路将改变地表的雨水渗透特性，非透水地表增至约 80%，将会导致地表径流量增加。

为达成雨洪水量及水质管理的设计目标，新建物流中心的雨洪排水系统设计采用了如下的方案和措施：

●通过物流中心地形及坡度设计收集控制新建项目范围内雨洪。每一开发地块内的雨水排入 10 年一遇排涝标准的地下雨水管道，后排入贯穿整个物流中心的道路排水草沟系统。流向由北向南的排水草沟系统和上游已有的 11 号排水沟一并汇入物流中心南边界的新建东西向排水草沟，后穿过扩建的铁路涵洞排入东侧人工湿地和调蓄水库，经水量控制和水质处理后排入 Goulburn 河。

●物流中心地面设计标高 113 5m（100 年一遇洪水位 113 1m+0 5m 安全裕度）。

●排水草沟系统的设计标准为 10 年一遇排涝，100 年一遇防洪。受平缓地形限制，排水草沟的设计纵比降很小，仅仅在 0 2%左右，这会导致雨水在沟底产生局部积水洼，为蚊子等有害飞虫的大量滋生提供了条件。为此在排水草沟的底部设计了 0 5m 宽×0 6m 深的生态透水槽，一来排水草沟的积水可以渗入透水槽排走，二来生态槽也会有效地吸收雨水中的氮，磷等污染物。同时排水草沟系统也能对局部雨洪调蓄发挥一定的作用。

●铁路线东侧新建一座设计库容为 1 4 x 10^6m^3的雨洪调蓄水库（池），确保现有 11 号排水沟 上游的 100 年一遇洪水位在项目建成后较现在没有增加，并保证自水库（池）出水管道排入 Goulburn河排放点 （Legal Discharge Point）的流量不超过管理部门核定的许可流量。由于在河道漫流区建设大型构筑物会导致河滩滞洪空间的减少，Goulburn Broken 流域管理局要求新建调蓄水库设计标准不得高于 20 年一遇，围坝坝顶高度和目前土质堤防部分标准一致。

●道路及铁路涵洞按 100 年一遇防洪标准设计。铁路涵洞处安装自动水质和水位遥测装置以及闸门，其作用主要是：在正常情况下，闸门开启，西侧的 3 个月一遇低流量可直接进入东侧湿地系统，经水质处理后排入调蓄水库；超过的 3 个月一遇标准的短历时雨洪直接进入调蓄水库；当 Goulburn 河发生超过 20 年一遇的洪水时，调蓄水库将被淹没，闸门将自动关闭，防止洪水向西侧倒灌。另当物流中心中发生严重的油污泄漏时，闸门将关闭，防止油污对人工湿地的污染和破坏。

●雨洪水质处理系统，自上游到下游依次为GPT，底部带有生态透水槽的排水草沟，和一个面积约 $5x10^4m^2$的人工湿地。人工湿地将处理 3 个月一遇标准的雨洪流量，超过的流量将直接排入调蓄水库。

●持续 3 年的水质检测，评估开发项目对自然水环境的影响程度。

Case Studies

Tempe Recreation Reserve Redevelopment

Project Outcomes:

Organisational:

The project tested Marrickville Council's capability for implementing alternative water management solutions where there was identified risk, technical and knowledge issues. The effort required to resolve the design and technical constraints greatly contributed to understanding of water management issues across the project team. It also identified where corporate knowledge was inadequate, and enabled Marrickville Council to seek the best advice as appropriate.

Environmental:

Environmental benefits of wetlands for this project are:

- Iconic landscape feature that has high visual enhancement qualities for reclaimed land area
- Functions as separation item between different recreation uses that could be otherwise in conflict
- Functions as water filtration and storage/detention area
- Small additional habitat space on migratory bird route
- Reuse of existing structure for environmental education space, with the wetlands as a demonstration site

Case Studies

Tempe Recreation Reserve Redevelopment

Technical:
WSUD features: built elements of the stormwater management system:

- Bioswales through carpark
- Split system wetlands – freshwater & saltmarsh

WSUD features: Education items:

- 'Enviro-hut' education shelter – adaptive reuse of existing picnic shelter for explanatory signage of stormwater management system
- Simulated stormwater management elements in play area as education device to explain site elements

Successes: Wetlands, bioswales, transplantation of river plants to constructed wetlands area.
Difficulties: adaptive reuse of existing drainage elements (mostly pits, pipes and pumps) to new project requirements, control of saltmarsh establishment (weed spp, rate of cover)
Education items not yet constructed. Too early to evaluate for failures.
External assistance: consulting hydraulic engineers, wetlands designers, ecologist

Transferable:
The context and objective of project should always be revisited. For the technically demanding and highly constrained components of the project, sometimes the reason for doing the work was forgotten amongst the detail of resolving the problems and issues.

Background data and long-term records came critical to plan for future use. Always produce a maintenance manual for the built elements. Education of the maintenance staff is also critical to the success of the work. Don't forget soil testing, tide-mapping and pre-ordering plants!

Difficulties Encountered: Obtaining statutory approvals for adjacent work that was critical to delivery of the WUSD elements. There was a mismatch between understanding the needs of other departments, and translating the technical detail to match their requirements. Unknown site conditions also pose some technical difficulties.

Case Studies

Tempe Recreation Reserve Redevelopment

Tempe Reserve – beginning of project 1997 Tempe Reserve – landscape
concept overlay

Tempe Reserve Landscape Concept Plan 2000

Case Studies

Tempe Recreation Reserve Redevelopment

Wetlands site – construction beginning 2001

Freshwater wetlands – April 2003

Freshwater wetlands – planting complete July 2002

Saltmarsh at high tide

Case Studies

Bellair Street Raingardens

Project summary

WSUD Type:	Raingarden tree pits
Scale:	Streetscape
Land Use:	Residential
Constraints:	Space, Topography, Vegetation
Cost:	$272,000
Performance:	Stormwater quality – 47.2%TN, 74.9%TP, 88.7%TSS, 100% Gross Pollutants

Site description

Location

The project is located in Bellair Street, Kensington, between Arden Street and Ormond Street as circled right.

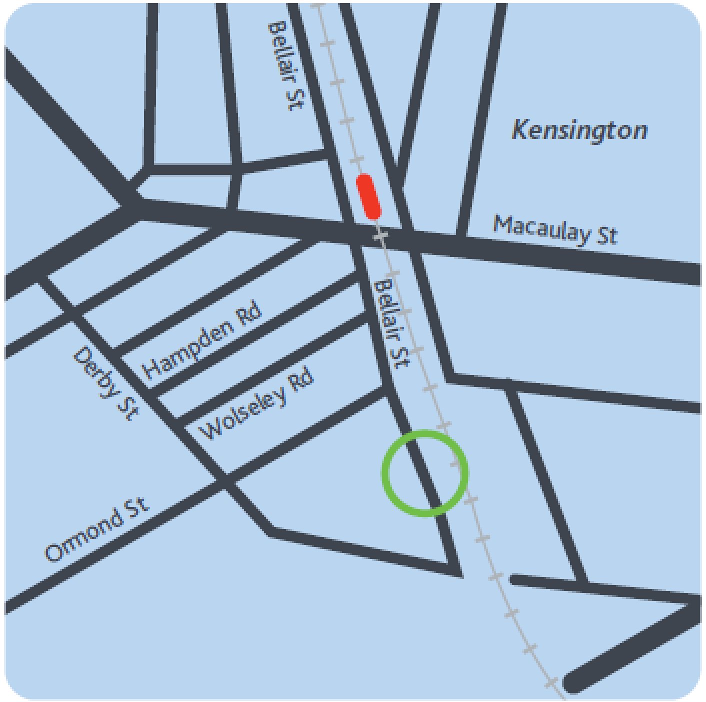


Figure 1. Map showing location of the Bellair St, Kensington WSUD Raingardens

Case Studies

Bellair Street Raingardens

Site area

The road reserve is approximately 280m long by 15m wide.

Site land use

Bellair Street is a low density residential street with residential properties abutting the western edge and a railway reserve on the eastern edge.

The project proposed to:

- Renew the road surface, kerb and channel and footpath
- Replace some mature street trees suffering from structural defects and poor health.

Catchment description

The treatable catchment is 6540m^2, comprising the road reserve and abutting residential properties. The existing stormwater drainage system was used where available, however sections of new drainage were still needed. The high point is situated between Tennyson St and Arden St.

Part of the drainage runs to the existing drain in Arden St. The remainder was directed north to connect to the existing drain in Bellair St near the corner of Tennyson St. The treated water will ultimately enter Moonee Ponds Creek.

Topography/Terrain

Bellair St is relatively flat with a slight high point between Tennyson and Arden St.

Tennyson St slopes down to Bellair St from Southey St, forming part of this treatment catchment.

Site constraints

- Drainage gradients were limited by the relatively flat site topography
- Shallow stormwater pipe exist for approximately half of the site, with the rest requiring new stormwater pipe connection
- Not all existing trees could be removed, due to community request
- WSUD pit location and number was optimised to maximise parking and tree spacing
- Existing bluestone channel pitchers needed to be replaced
- Parking spaces were not to be reduced.

Case Studies

Bellair Street Raingardens

WSUD Design

Objectives

The project objectives were to:

- Treat the street as holistically as possible;
- Upgrade the streetscape and renew infrastructure and vegetation;
- Treat stormwater to best practice;
- Maximise WSUD treatment size whilst not reducing available parking; and
- Ensure a low cost design.

Opportunities

If possible, the removal of all existing trees would:

- Provide a consistent aesthetic for the streetscape renewal (which also included the road, footpath, kerb and channel in addition to the tree renewal)
- Allow easier civil works.

The project also offered the opportunity to design and trial a larger version of the tree pit raingarden in a residential street setting. This context would require a less intensive treatment then the City of Melbourne's CBD tree pits thus a lower cost, raingarden that was not grated could be used.

Design development

Through extensive community consultation, the design was altered to allow four healthy plane trees to remain.

The kerb outstand raingarden also proved too difficult to include due to steep level changes and pedestrian crossing issues at a street intersection.

Final design

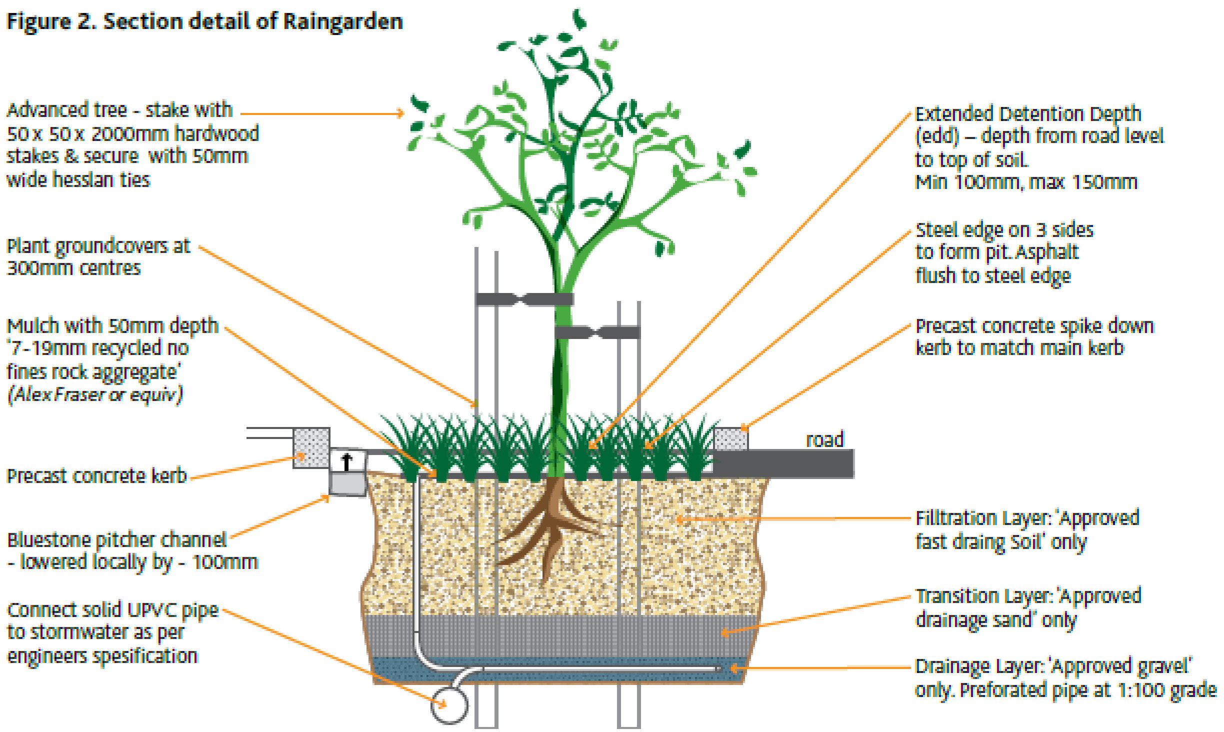
The final design included 19 raingardens, four less then the original concept design. It also excluded the kerb outstand raingarden.

Six of the raingardens required a reduced filter media depth due to the shallow depth of the existing stormwater pipe that was used to drain the raingardens. The final design still met the stormwater quality best practice treatment targets.

Case Studies

Bellair Street Raingardens

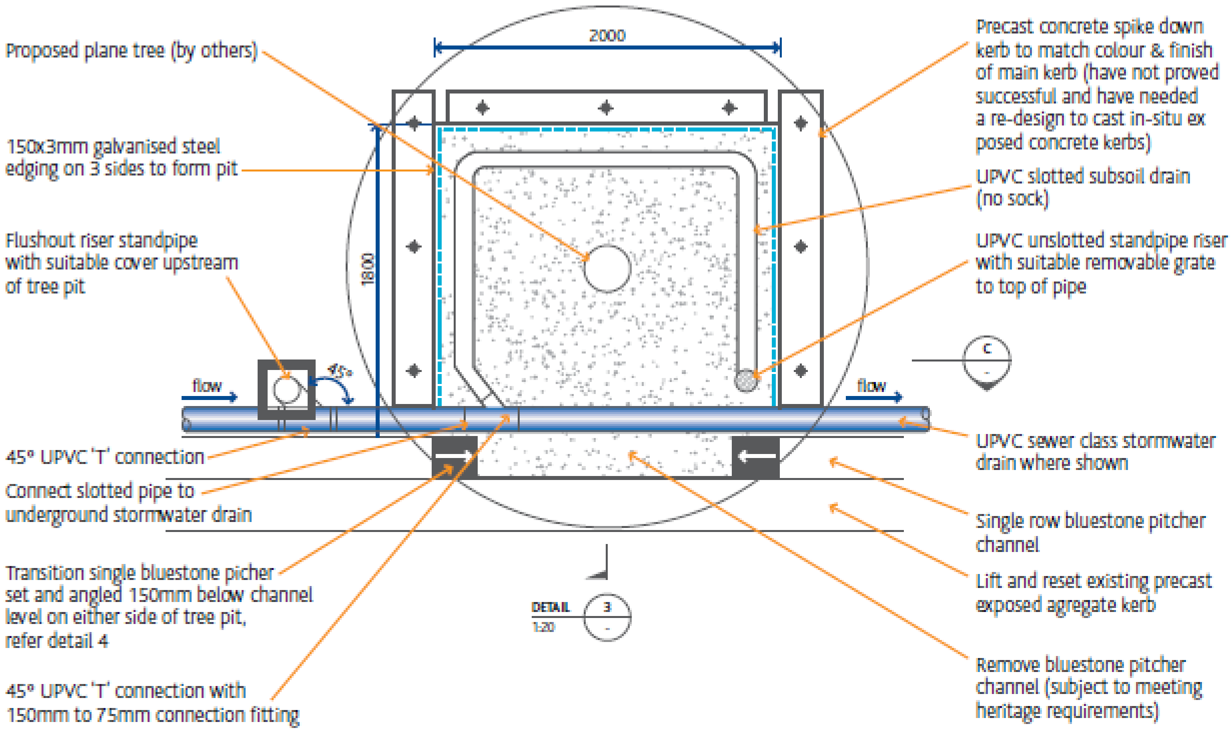
Figure 2. Section detail of Raingarden



Case Studies

Bellair Street Raingardens

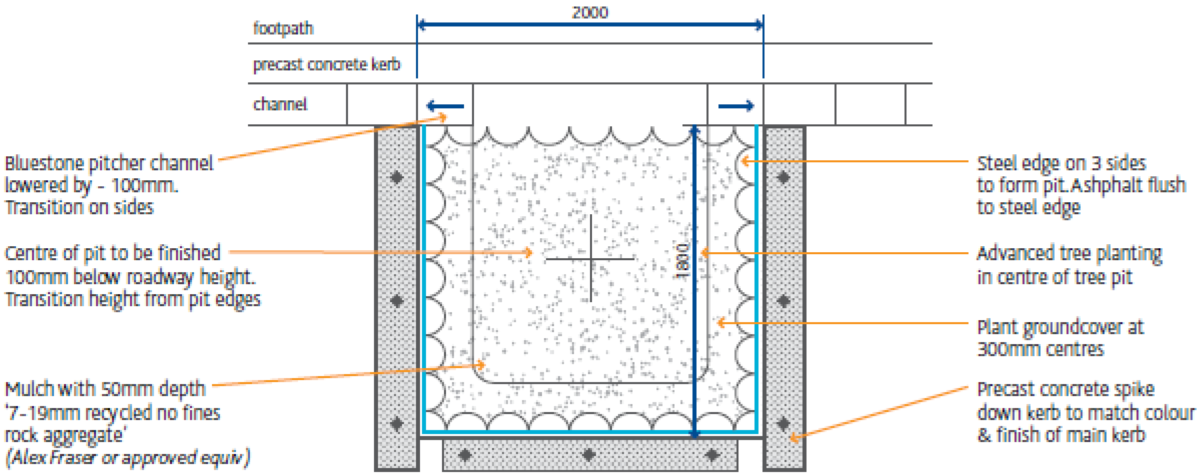
Figure 3. Plan view of raingarden showing drainage layout



Case Studies

Bellair Street Raingardens

Figure 4. Plan view of raingarden showing surface details



Case Studies

Bellair Street Raingardens

Cost and timelines

The construction and installation costs of the raingardens have been kept at a minimum totaling approximately $1,300 per square metre. This cost can be further reduced where new stormwater drainage and boring is not required.

Table 1. Project cost and timelines

Task	Cost ($)	Completion dates	Undertaken by
Investigation (including concept design)	8,000	Late 2007	City of Melbourne Landscape design team with assistance from Melbourne Water
Detailed Design – WSUD	9,000	Feb 2008	City of Melbourne Engineering Services Group / Citywide / Connell Wagner
Detailed Design – Conventional	15,000	Feb 2008	City of Melbourne Engineering Services Group / Citywide / Connell Wagner
Construction – WSUD	90,000	June 30, 2008	City of Melbourne Engineering Services Group / Citywide / Ruccia Paving
Construction – Conventional	150,000	June 30, 2008	City of Melbourne Engineering Services Group / Citywide / Ruccia Paving
Implementation – (non-structural)		June 2008	City of Melbourne Tree Planning & WSUD Officer
Consultation/ Community Engagement		Feb – June 2008	City of Melbourne Tree Planning
Other (e.g. Evaluation)		July – Dec 2008	City of Melbourne Tree Planning & WSUD officer
Total cost	**272,000**		

Case Studies

Bellair Street Raingardens

Performance

The WSUD design exceeded the 'best practice' stormwater quality pollutant load reduction targets, as evaluated by the stormwater quality model, MUSIC.

Table 2 below show the MUSIC model results.

Table 2. MUSIC modelling

Pollutant	Treatment performance (kgs reduced)	Treatment performance (% reduced)	Best Practice Target (% reduced)
Total Suspended Solids	565.7	88.7	80
Total Phosphorous	0.987	74.9	45
Total Nitrogen	4.51	47.2	45
Gross Pollutants	122	100	70

Note: Load reductions are based on the 'typical urban annual load', as modelled by MUSIC.

Greenhouse impact

There are no ongoing CO_2 emissions from this project. Embodied energy impacts exist from:

- Material choice (e.g. PVC pipes, sand and gravel)
- Transport.

Risk management/issues

The construction of raingardens into the streetscape falls into the usual scope of works for streetscapes and does not therefore pose any greater risk to traffic or pedestrians than usual civic works.

The sunken design of the raingardens has been mitigated as a pedestrian risk by the use of mulch topping and dense planting. This will need to be maintained.

The end use of the water is not for reuse purposes. It will be entering the stormwater and ultimately the waterway and will not be directly in contact with people. This negates the need to treat to high Class A standards. The design of the raingardens will treat the stormwater to a standard that reduces the risk to the environment by removing pollutants that would have otherwise entered the waterways.

Case Studies

Bellair Street Raingardens

Applicability

The project was designed so this form of raingarden could be used in other residential streetscapes outside the CBD area, where new trees need to be installed in the parking lane.

Post-project reflection

The exclusion of the kerb-outstand raingarden is regrettable. This could be avoided in the future by:

- Improved analysis of level changes between footpath, road and raingarden surface
- Firm Council policy on pedestrian safety for such systems.

Maintenance requirements and issues

WSUD tree pit maintenance tasks are described in the table below.

Table 3. WSUD Tree Pit Maintenance Tasks

Parks Activity reports	Every 12 weeks	
ESG Activity reports	Every 12 months	
Inspection items	**Works tasks**	**Frequency**
Sediment accumulation at inflow points?	Remove or suck out sediments. Notify council if recurring problem to enable investigation of sediment source	12 weeks
Litter within pit?	Remove litter	4 weeks
Erosion at inlet or around tree?	Investigate why erosion is occuring. Top-up missing gravel mulch, top-up missing media (FAWB specification)	4 weeks
Traffic damage present?	Repair / replace missing or damaged parts Bollards needed?	4 weeks
Evidence of dumping (e.g. building waste)?	Re-instate media and vegetation as required to original specifications (FAWB specification).	4 weeks

Case Studies

Bellair Street Raingardens

Inspection items	Works tasks	Frequency
Tree condition satisfactory (Foliage, bark, roots)?	Weed growth should be minimal. Spray with herbicide if necessary	4 weeks
Replanting required?	Re-instate and water as necessary.	4 weeks
Clogging of drainage points (sediment or debris)?	Remove leaves, litter or sediments	4 weeks
Evidence of ponding?	Rack top layer of the media and replace by sandy soil (FAWB specification). Infiltration testing may be required	12 weeks
Set down from pit cover still present?	Maintain / reinstate as per design level.	12 weeks
Damage/vandalism to structures present?	Repair / replace missing or damaged parts. Talk to an enforcement officer	12 weeks
Surface clogging visible?	Testing of infiltration media to ensure performance as specified.	12 months
Drainage system inspected?	Lift lids and inspect pits.	12 months
Resetting of system required?	Engage designer / consultant	5 -10 years

Case Studies

Bellair Street Raingardens

Diagrams of treated areas

Case Studies

Cottesloe Aquifer Recharge

Land use / development type	Scale
Retrofitting	Precinct

Stormwater controls	Scale
Infiltration basins	Street
Litter and sediment traps	Street
Non-structural strategy – education	Structure plan area

Water reuse	Scale
Managed aquifer recharge	Structure plan area

Local government
Town of Cottesloe

Declining rainfall recharge and increased demand for groundwater use has escalated the need for more sustainable groundwater management in the Perth metropolitan area by local government and water managers.

The Mosman-Cottesloe Peninsula is underlain by a thin fresh groundwater lens overlying salt water. The Peninsula is subject to saltwater intrusion due to reduced rainfall and a large number of uses including private schools, golf courses, parks and recreation reserves. Monitoring of the salinity levels has indicated a rise in the salinity within the groundwater.

In an effort to improve groundwater quality and prevent the intrusion of saltwater the Town of Cottesloe developed the aquifer recharge project with support from the Federal Government under the National Water Initiative. Issues such as risk of aquifer collapse, saltwater intrusion, polluted stormwater, ocean outfall discharge, and more sustainable household and garden water consumption were addressed by the Town of Cottesloe in their aquifer recharge project. Along with environmental benefits, the project also aimed to increase the community's awareness of local water resource management and use issues, as well as promote water efficient technologies.

The Cottesloe Aquifer Recharge project covers an area of approximately 4 km². It is designed to hold and infiltrate a one in five year flood event. In the event of a one in one hundred year flood event, the ten pre-existing ocean outfalls will assist in the drainage of the stormwater. These outfalls have been closed but can be easily re-opened for an extreme rainfall.

Key Project Features

- Pollutants are managed by seven underground sumps (see illustration below) and 400 stormwater pits which act as gross pollutant traps and aid stormwater infiltration for aquifer recharge
- Reduced risk of saltwater intrusion and collapse of the aquifer
- The 'Think water' education program was successful in reducing private groundwater use and decreasing the installation of new bores.

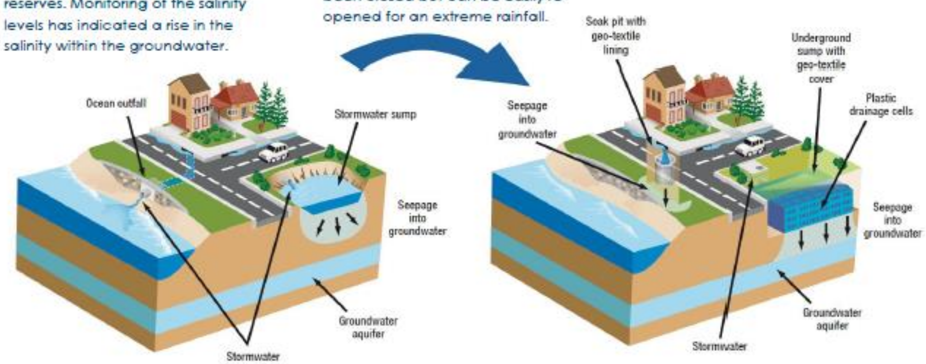


Image courtesy of Town of Cottesloe

Development Costs[1]

Design costs	$120,000
On-site supervision	$100,000
Survey / site costs	$80,000
Installation of soak pits	$896,000
Ocean outfall close downs	$400,000
Open sump replacements	$700,000
Public education program funded by Department of Water	$100,000
Total	**$2,396,000**

[1]All costs are an approximation given for guidance purposes only

Maintenance Costs

Pit cleanout[1]	$20 / pit

[1]Pit cleanouts are undertaken opportunistically

Outcomes

Approximately 180 ML per year of untreated stormwater was directed into ten ocean outfalls prior to the development of the Cottesloe Aquifer Recharge project. As a result of using the stormwater for aquifer recharge, the ten ocean outfalls no longer discharge in small and minor events.

The 'Think Water' education program was funded to run for three years and has been able to reach out to the community with the aim of raising awareness about conserving water and reducing pollutants entering the groundwater. The program produced brochures on water quality and quantity, fridge magnets, a word sleuth, a bumper sticker, a sheet of stickers with a Think Water theme and an illustration showing what installations the council were undertaking. A local plants growing guide was developed to help residents design their own local gardens. Town of Cottesloe residents were also entitled to a native plant subsidy scheme allowing the residents to purchase 80 seedlings at a subsidised price to encourage water wise gardening.

Image courtesy of Town of Cottesloe

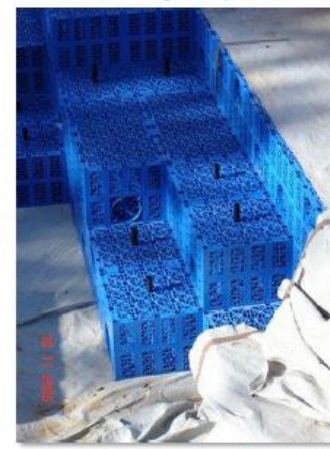


Image courtesy of Town of Cottesloe

Image courtesy of Town of Cottesloe

Image courtesy of Town of Cottesloe

Case Studies

Kwinana Water Reclamation Plant

Land use / development type	Scale
Industrial development	Commercial and industrial lot

Water reuse	Scale
Blackwater reuse	Precinct

Local government	Location
Town of Kwinana	Mason Road

Industry is a large consumer of water within the state of Western Australia with 19% of the integrated water supply system going to business and commercial users. In Western Australia the largest concentration of industrial activity is found in the Kwinana industrial area. Applying the principle of fit-for-purpose use means that the demand on scheme and groundwater can be minimised by utilising recycled wastewater or drainage water which is suitable for non-drinking purposes when appropriately treated.

In 2004 the Water Corporation commenced the operation of the Kwinana Water Reclamation plant (KWRP) within the Town of Kwinana in an effort to reduce the need for bore and scheme water use within the industrial area. At full capacity approximately 24 megalitres a day of treated wastewater from the Woodman Point Wastewater Treatment Plant is piped to KWRP and processed through microfiltration and reverse osmosis processes. Once treated, 16.7 megalitres of high quality process water is piped to a number of various industries within the Kwinana industrial area each day at a price which is cheaper than scheme water.

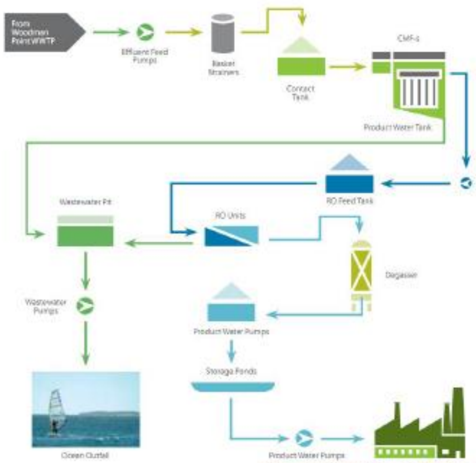


Image courtesy of Water Corporation

Key Project Features

- Fit-for-purpose water supply
- Recycling of treated wastewater for industrial use which reduces the demand for scheme and bore water use
- Decreased volume of treated wastewater is discharged directly into the ocean
- Produces high quality industrial water with less than 50 mg/L total dissolved solids

Image courtesy of Water Corporation

Development Costs

Overall construction cost of plant and pipelines	$28 million

Issues

Wastewater from the Kwinana Water Reclamation Plain is piped into the Sepia Depression Outlet Landline (SDOOL) and discharged 4 km offshore. An environmental monitoring program is carried out at the ocean outfall to ensure there is no harm to the marine and coastal environment through the Perth's Long-term Ocean Outfall Monitoring (PLOOM) program. Contaminants such as heavy metals, pesticides, nutrients, and pathogens are all monitored closely. The monitoring program along with a management plan was developed to ensure that the ecological and social values of the marine waters are maintained within the vicinity of the Sepia Depression.

Image courtesy of Water Corporation

Image courtesy of Water Corporation

Outcomes

The 2010 annual report of the SDOOL released by the Water Corporation revealed that the monitoring has not detected any harmful effects on the marine environment.

It is estimated that approximately six gigalitres per year of scheme water has been replaced by the KWRP.

In 2005 the Water Corporation received an AWA Environmental Merit Award which gave recognition for the environmental benefits provided by the Kwinana Water Reclamation Plant.

Image courtesy of Water Corporation

Case Studies

The Green at Brighton

Land use / development type	Scale
Residential	Residential lot
Public open space	Precinct

Stormwater controls	Scale
Swales	Street

Efficient use of water	Scale
Waterwise landscaping	Structure plan area

Water reuse	Scale
Community bores	Structure plan area

Site conditions	
Soils	Sand
Groundwater	> 5 m
Slope	< 10 %

Local government	Location
City of Wanneroo	Landbeach Boulevard

The Australian Bureau of Statistics estimated that the Perth metropolitan area had a growth of 3.2 per cent in 2008-09. This population growth rate is the fastest of any metropolis in Australia.

There has been a lack of rainfall runoff in Perth and availability of groundwater is declining, particularly in the north west corridor due to the supply of drinking water from the Gnangarra mound.

'The Green' at Brighton is the fourth village of Satterley's Brighton development in the City of Wanneroo. Approximately 1,100 lots and 10 public open spaces are located within the development area.

The development has installed a reticulated non-drinking water or dual reticulation system which delivers non-drinking water supply for the irrigation of public open spaces and private spaces using groundwater from the superficial aquifer. An onsite weather station with moisture sensors is connected to five bores and has a central controller which determines the watering schedule. The system is pressurised only between 10pm and 6am to reduce water loss through evaporation.

Image courtesy of UDIA

Key Project Features

- Reticulated non-drinking water supply of groundwater for irrigation of public open spaces and domestic gardens which is controlled by a central control system
- Waterwise landscaping utilised within public open spaces and promoted to residents through waterwise landscaping packages
- Homes installed with WELS rated appliances
- Swales used to aid infiltration
- Community marketing campaign aimed at educating the local community

Image courtesy of the Water Corporation

Development Costs[1]

Weather station	$25,000
Computer and software	$30,000
Dual reticulation	$2,500 - $3,000 / lot
Waterwise landscaping	$8,000,000 - $12,000,000

[1]All Costs are site specific and are an approximation given for guidance purposes only

Image courtesy of UDIA

Issues

The Green is located within a protected drinking water source area P3 protection area.

Outcomes

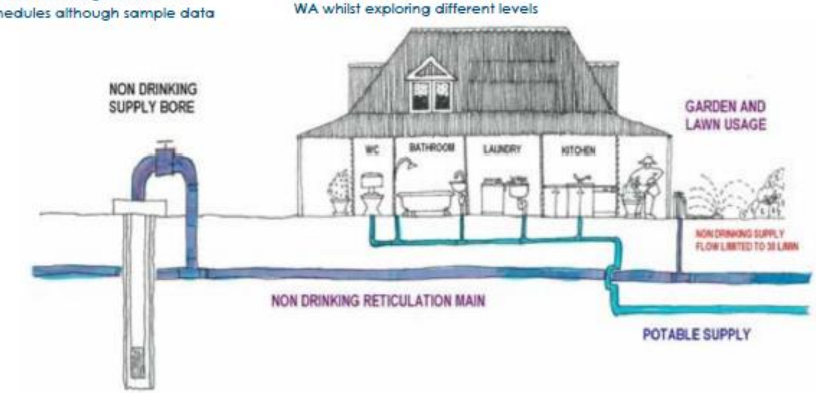
The project has significantly improved our understanding of the regulation, operation and maintenance of non-drinking water schemes in Western Australia. The project overcame several significant challenges such as financial, regulatory, health, and complicated approvals processes. The results of community marketing campaign revealed that the community are supportive of the project.

Water efficiency monitoring within The Green is still in its early stages due to the rolling construction schedules although sample data from select homes have indicated that household use of water has possibly been reduced by over 50% in comparison to the Perth Metropolitan average.

The monitoring of groundwater usage in public open spaces indicated that the water usage is decreasing with most of the public open spaces using below the allocated level with target levels being approached.

The Green project enabled the establishment of a central point of expertise for non-drinking water in WA whilst exploring different levels of service to make schemes cost competitive.

In order to assess the merit of dual water supply schemes the Water Corporation in collaboration with the Department of Water established a structured approach. Industry wide guidelines were developed in to assist developers in the design and construction of duel reticulation schemes. The draft guideline is available from the Department of Water and is valid until the October 2011 when it will be formally reviewed.



Case Studies

Capricorn

Land use / development type	Scale
Residential development	Residential lot
Commercial development	Commercial lot
Public open space	Precinct (subdivision)

Stormwater controls	Scale
Swales	Street
Raingardens	Street
Living streams	Precinct (subdivision)
Retention of native vegetation and landform	Precinct (subdivision)

Efficient use of water	Scale
Waterwise landscaping	Precinct (subdivision) Residential lot Street

Site conditions	
Soils	Sand
Groundwater	> 5 m
Slope	< 10 %

Local government	Location
City of Wanneroo	Two Rocks Road

In 2010 the Australian Bureau of Statistics estimated that the Perth metropolitan area had a growth of 3.2 per cent in 2008-09. This population growth rate is the fastest of any metropolis in Australia. Western Australia was also the fastest growing state or territory in Australia.

With such high growth rates the demand for land and housing increases. These pressures include securing water supply and improved management of stormwater systems.

In an effort to conserve water and achieve better urban water management outcomes, Capricorn Village Joint Venture partners Yanchep Sun City Pty Ltd and the Capricorn Investment Group Pty Ltd initiated the Capricorn development which began construction in 2005 in the City of Wanneroo. Capricorn is approximately 220 Ha and will deliver around 2,200 lots. Water sensitive urban design features are evident throughout the development. The site is predominantly sandy soils with depth to groundwater of over 5 m and moderate grades across the site.

Key Project Features

- Vegetated swales designed to detain and treat stormwater runoff prior to infiltration
- Living streams designed to convey stormwater from larger, infrequent events whilst providing habitat diversity
- Raingardens installed within residential lots and within the local road network to treat stormwater and aid infiltration
- Waterwise landscaping promoted to residents with incentives and implemented within public open spaces
- Retention of existing native vegetation incorporated into road verges and public open spaces

Image courtesy of Cossill and Webley

Development Costs[1]

Raingardens	$140 / m²
Living streams	$30 / m²
Vegetated swale[2]	$80 / m²

[1]All Costs are site specific and are an approximation given for guidance purposes only
[2]Swales are catchment specific and the cost above is given as a guideline only

Maintenance Costs[1]

Garden beds	$5 - $20 / m² / yr
New Trees	$10 / tree / yr
Existing trees	$30 / tree / yr
Living Streams (reed bed)	$1 / m² / yr

[1]All Costs are site specific and are a broad approximation given for guidance purposes only

Outcomes

In 2010 the Housing Industry Association of WA awarded Capricorn the GreenSmart Community Award. The Development was also one of the State's first to receive EnviroDeveloper Certification.
More recently Capricorn was awarded the Sustainable Urban Development award by the Urban Development Institute of Australia (UDIA).

Image courtesy of Cossill and Webley

Image courtesy of Cossill and Webley

Image courtesy of Cossill and Webley

Image courtesy of Cossill and Webley

Image courtesy of Cossill and Webley

Case Studies

Liege Street Wetland

Land use / development type	Scale
Retrofitting	Precinct (subdivision)

Stormwater Controls	Scale
Constructed Wetland	Precinct (subdivision)

Local Government
City of Canning

Historical land use practices in urban, industrial, and agricultural areas have resulted in high nutrient loading within Perth's drainage network which ultimately flows into the Swan Canning river system. In recent times high nutrient levels have led to algal blooms and fish kills.

In an effort to reduce nutrient loading into the Canning River, the Swan River Trust in partnership with the City of Canning, South East Regional Centre for Urban Landcare (SERCUL), Department of Environment and Conservation, Water Corporation and Two Rivers Catchment Group developed the Liege Street Demonstration Constructed Wetland. The wetland was designed by Syrinx Environmental Pty Ltd and was constructed in 2004.

Located at Carden Drive in Cannington the constructed wetland was the first substantial project of the Drainage Nutrient Intervention Program (DNIP). The project has been successful in reducing nutrients entering the Canning River from a major urban catchment with an area of 530 ha.

Image courtesy of the Swan River Trust

Image courtesy of Syrinx

Image courtesy of Syrinx

Key Project Features

- Retrofitting of an area of public open space into a constructed wetland (approximately 1 ha) to improve stormwater quality
- Improvement in stormwater quality from the urban catchment before entering the Canning River
- Design of the wetland ensures that during high flows, the water will be conveyed quickly through the wetland to minimise the risk of flooding
- Creation of a passive recreation area for public use which also has educational benefits for the community

Image courtesy of SERCUL

Development Costs

Conceptual design and construction/ revegetation specifications	$63,000
Construction [1]	$726,000
Planting and restoration activities [2]	$74,000
Total (ex GST)[3,4,5,6]	**$863,000**

[1] Approximate figure, includes in-kind funding
[2] Includes supervision time but does not account for volunteer time (not tracked but significant)
[3] Construction/revegetation costs only relate to wetland design and implementation and not landscape elements (eg signage, boardwalks, paths, seating, etc)
[4] costs in 2004-05
[5] SRT, Water Corporation, City of Canning staff time for planning not quantified
[6] Costs relate to implementation of both the ~1ha wetland and the entire ~4ha site in which the wetland is located

Maintenance Costs[1,2]

2005/2006	$30,200
2006/2007	$30,300
2007/2008	$20,200
2008/2009	$24,600
2009/2010	$24,100
2010/2011	$21,100

[1] All figures are an approximation of costs which includes supervision time but does not account for volunteer time and excludes GST. Planning and management for staff at Swan River Trust, Water Corporation, and City of Canning have not been quantified
[2] Costs relate to maintenance of both the ~1 ha wetland and the entire ~4ha site in which the wetland is located

Issues

The wetland is located within the once degraded Bush forever Site 224.
High to moderate acid sulphate soils exist on site.
Flows with elevated levels of nutrients and other pollutants from a large urban catchment are conveyed into the Canning River.

Image Courtesy of Swan River Trust

Image Courtesy of Syrinx

Outcomes

In 2006 the project was awarded the Stormwater Industry Association National Award for Excellence in Stormwater Management. It also received a Western Australian Environment Award in the Bush, Land and Waterways category.

Initial reports in 2007 revealed the wetland had performed and reached its short term targets for nitrogen and phosphorus removal during base flows. Turbidity, algae and heavy metal concentrations also measured favourably against the National ecosystem protection guidelines with the exception of zinc levels. Measurements within the sedimentation forebay were exhibiting high levels of metal accumulation indicating the effectiveness of its design to reduce pollutants.

The site has also become a place where many species of fauna can be seen. Nesting turtles and birds are a strong indication of the success of the project in creating habitat.

Currently the upland vegetation is in good condition with around 70 different native species. Approximately 70-95% native vegetation cover occurs in 70% of the upland zone. In recent years there has been a decline in the coverage of emergent macrophytes across the vegetated areas of the wetland believed to be a result of high organic loading, insufficient aeration and iron and sulphate presence. The resultant recent unfavourable conditions for plant growth are impacting on the water quality treatment efficiency and ecology of the wetland.

Action is now occurring to better understand the working of the wetland and work is being planned to rectify the issues. It is now considered that inline and passive systems need to be designed to reduce the proportion of permanently inundated surface flow area. Sub surface and wet/dry basins may prove to be more effective approaches.

Along with environmental benefits, the Liege Street Wetland has provided a place for passive recreation and educational opportunities for the community.

Contact details for further information

Case Studies

The Grove: Leading, Learning, Living

Land use / development type	Scale
Commercial	Lot
Retrofitting	Lot

Stormwater controls	Scale
Dry / ephemeral detention area	Precinct & lot
Litter and sediment traps	Precinct & lot
Biofilter	Precinct & lot
Non structural strategies - education	Structure plan area & precinct

Efficient use of water	Scale
Waterwise landscaping	Lot
Water efficient fixtures and fittings	Lot

Water reuse	Scale
Managed aquifer recharge	Structure plan area
Green walls	Lot
Greywater reuse	Lot
Blackwater reuse	Lot
Rainwater storage and reuse	Lot
Stormwater harvesting and reuse	Precinct

Local government	Location
Shire of Peppermint Grove	1 Leake Street, Peppermint Grove

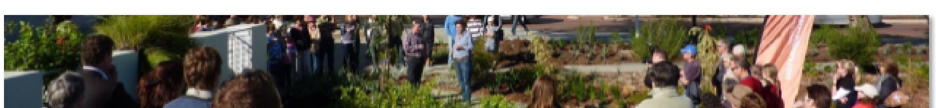
The Town of Cottesloe, Town of Mosman Park and the Shire of Peppermint Grove have worked collaboratively to develop a high-profile environmentally sensitive demonstration project. – The Grove: Leading Learning, Living.

Not only does the building target water efficiency, but it also serves as a 'living' educational tool.

Scheme water use at The Grove has been reduced significantly. Rainwater is captured, stored and treated for in-house use onsite. Waterless urinals and a number of low / limited flow water fixtures and fittings have also been installed at The Grove. Wastewater is captured, treated, and used onsite for irrigation. During the hotter months, some water is diverted to the thermal maze to aid cooling of the building.

Historically, stormwater flows from the 20 ha catchment were not treated. Now, primary treatment occurs through a gross pollutant trap prior to entering a pump-out tank. Secondary treatment sees the stormwater being pumped to a number of subsurface flow sedgebeds which utilise native plants to remove of nutrients, suspended solids, biological oxygen demand and heavy metals. The flows then drain into the vegetated ephemeral wetland where treated flows are recharged to the local aquifer.

Landscaping consists of a range of low water use, habitat comprised of Western Australian plant species. Green walls have been constructed around parts of the building which reduce the overall temperature of the building.



Key Project Features

- Grey water, yellow water and brown water is separated at each of the source points to optimise efficiency of wastewater treatment
- Potable and non-potable use of harvested rainwater
- Waterless urinals and many low flow water fixtures and fittings
- Stormwater quality improved prior to infiltration into the local aquifer
- Environmentally focused community education and engagement program
- Ephemeral wetland with local vegetation provides habitat and treats stormwater flows
- Green walls reduce heat island effect
- Habitat provided using waterwise landscaping

Development Costs[1]

Rainwater harvesting system	$494,400
Wastewater treatment and reuse system	$320,300
Waterless urinals	$1,100
Water efficient fixtures and fittings	$5,600
Urine separating toilets	$21,400
Thermal maze	$427,600
Community education and engagement program	$549,700
Green Walls	$2,000 / m²

[1]Costs are site specific and are an approximation given for guidance purposes only

Image courtesy of The Grove Library

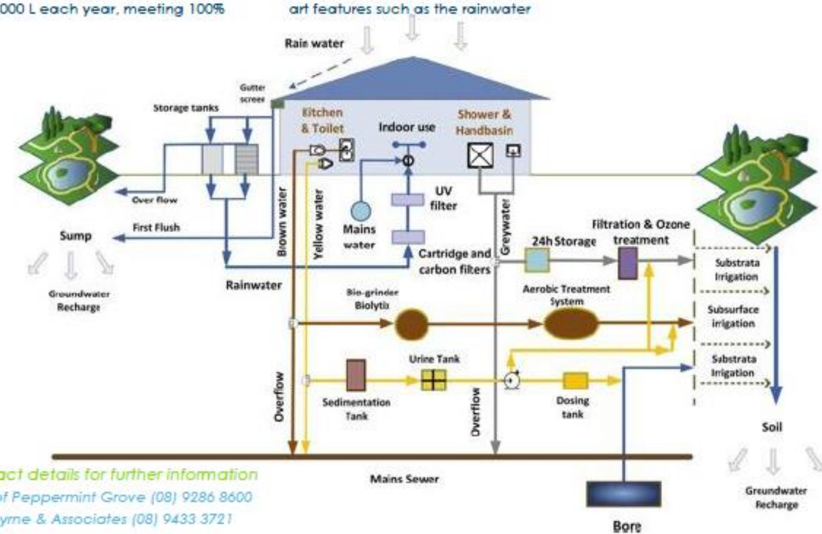
Outcomes

At the state level, the building is the first to incorporate yellow water diversion to an onsite wastewater treatment system. In the Perth metropolitan area it is the first public building which harvests rainwater for internal potable use (within a scheme water serviced area), treats wastewater onsite, and utilises groundwater and rainwater for heat exchange.

The 258 kL rainwater storage system is estimated to reduce the demand on the mains water supply by 730,000 L each year, meeting 100% of the internal water demand. The water-efficient fixtures alone are estimated to save 175,000 L each year. Additionally, the draw on groundwater is expected to reduce by an estimated 700,000L through using onsite treated wastewater for irrigation purposes.

A large part of The Grove project is aimed at educating the community about ecologically sustainable development (ESD). The design of the building has incorporated 'viewing windows' to allow visitors to see the state-of-the-art features such as the rainwater first flush chambers. User friendly interpretive signage, web-based material and fact sheets have been developed to aid community education about ESD. Community forums, workshops, events and activities which promote community understanding and enthusiasm towards ESD are also provided by the Grove Library.

A suite of detailed factsheets on the ESD features at The Grove are available from [The Grove Precinct website](#).



ontact details for further information
ire of Peppermint Grove (08) 9286 8600
ssh Byrne & Associates (08) 9433 3721

Case Studies

Evermore Heights

Land use / development type	Scale
Residential development	Lot
Public open space	Precinct

Stormwater controls	Scale
Swales	Street & precinct
Biofilters	Street & lot
Pervious paving	Lot
Infiltration basins	Precinct
Retention of native vegetation	Structure plan area
Non-structural strategies – education	Structure plan area
Non-structural strategies – regulatory and enforcement program	Structure plan area

Efficient use of water	Scale
Water efficient fixtures and fittings	Lot
Waterwise landscaping	Precinct, street & lot

Water reuse	Scale
Rainwater storage and reuse	Lot
Community bores	Structure plan area

Site conditions	
Soils	Sand
Groundwater	2m < 5m
Slope	< 10 %

Local government	Location
City of Rockingham	Numbat Approach, Baldivis

Evermore Heights, co-developed by Satterley Property Group Pty Ltd and LandCorp, is a 374 lot estate with water sensitive urban design features from in-house to public open spaces.

Residents have access to a dual reticulation system which draws groundwater for irrigating public open spaces and residential gardens.

The weather station, which controls the irrigation times and duration, is located at a local primary school and doubles as an educational tool for the local school children.

Homes have been equipped with WELS rated appliances and waterwise landscaping has been promoted through incentive packages which encourage new purchasers to plant low water tolerant species. A particular incentive package included a free 3000L rainwater tank which plumbs non-potable water to the laundry (cold tap) and toilets. Design guidelines include the requirement for permeable paving where hard landscaping is required within gardens.

Raingardens are located within allotments and the road network and treat flows up to the 3 month average recurrence interval (ARI) event. Larger stormwater flows, up to the 10 year ARI, are directed into swales located within public open spaces. The swales have been lined with a nutrient absorbing filter media and vegetated with native water tolerant species to treat stormwater prior to infiltration. Large infiltration basins, located in public open spaces are designed to receive and infiltrate up to the 100 year ARI event.

Two areas of high quality vegetation were identified and retained as natural areas within the estate's public open space. Native species were planted as supporting understory in these areas. All public open spaces and streetscapes utilise waterwise landscaping.

Key Project Features

- A reticulated non-drinking water scheme irrigates residential lots and public opens spaces
- Weather station also used as an educational tool for local school children
- Rainwater harvesting and in-house use
- Waterwise landscaping in all private dwellings and public open spaces
- Raingardens constructed within residential lots and the local road network
- Nutrient absorbing filter media added to the soils of vegetated swales to aid treatment of stormwater during infiltration
- Infiltration basins designed to receive and infiltrate stormwater up to 100 year ARI event
- Retention of a number of mature trees and native bush areas

Construction Costs[1]

Dual reticulation	$2,500 per lot
Rainwater tank (3000L)	$3,000 each
Residential biofilter	$500
Waterwise residential landscaping	$7,000 per lot
Swale earthworks	$15,000 - $20,000 / swale
Weather station	$25,000
Weather station computer and Software package	$30,000

[1]All costs are site specific estimates given for guidance purposes only

Image courtesy of Landscaping Australia

Issues

A number of challenges emerged during the development of Evermore Heights. Collaboration with agencies and other stakeholders was necessary to resolve challenges such as the establishment of a workable governance model, determining the real cost of schemes, understanding health and regulatory risks, service provision, security and reliability of sources longer term, and water efficiency at a community scale. Other challenges included understanding the marketing advantages that pioneering sustainability initiatives has within the community, and monitoring the impact of non-potable water supply with accuracy.

Outcomes

The developers of Evermore Heights targeted a 50% reduction in the average household consumption rate for Perth's scheme water. The development surpassed this with a 68% reduction in scheme water use. The dual reticulation scheme is estimated to reduce domestic use of potable water within Evermore Heights by 56% alone. Over 150 homes had the free 3000L rainwater tank installed as a part of the new purchaser's incentive package.

The dual reticulation schemes at Evermore Heights and The Green at Brighton have been the catalyst for the Water Corporation's development of new policy and governance arrangements regarding alternative non-drinking water supplies.

Image courtesy of Landscaping Australia

Contact details for further information
Satterley Property Group Pty Ltd (08) 9368 9000
LandCorp (08) 9482 7499
City of Rockingham (08) 9528 0333
Cossill & Webley (08) 9422 5800

Case Studies

Fiona Stanley Hospital

Land use / development type	Scale
Hospital	Precinct
Stormwater controls	**Scale**
Landscaped flood storage areas	Precinct (>20,000m³)
Underground Infiltration tanks	Precinct
Roof gardens	Precinct (18600m²)
Efficient use of water	**Scale**
Waterwise landscaping	Across the site
Water reuse	**Scale**
Rainwater and RO waste reuse for toilet flushing	860 toilet suites
Irrigation of landscape	6000 kL reservoir
Site conditions	
Soils	Sand
Local government	**Location**
City of Melville	Murdoch Drive

The construction of the Fiona Stanley Hospital has incorporated water sensitive urban design principles at a precinct scale to deliver a fully integrated landscape and water management strategy that enhances the connection between people and the natural environment. It successfully demonstrates that demand for scheme and groundwater can be minimised through using natural systems, recycling and efficiency.

The total site area is 32 hectares. This includes 18,600m² of two tier roof gardens, 16,500m² of public open space and 5 ha of bushland, landscaped parks and gardens.

The landscape design provides open spaces for conservation and protection of the environment, passive recreation, amenity and integrated stormwater management. The landscape strategy retains existing vegetated areas and topography and provides a habitat for the Carnaby's Black Cockatoo as well as other fauna.

By maintaining the topography of the site, the strategy is able to utilise the existing hydrology and natural systems, infiltrating stormwater from major events into low points, Lake Park and the bushland, and recharging the groundwater resources in the superficial aquifer. On site infiltration is further facilitated via underground concrete infiltration tanks. The design permits construction over the tanks.

Roof gardens assist with:

- the reduction of stormwater run-off and peak flows;
- filtration of the stormwater through the soil profile before entering the stormwater network;
- retention of rainfall within the engineered soil profile for use by plants, reducing irrigation demand.

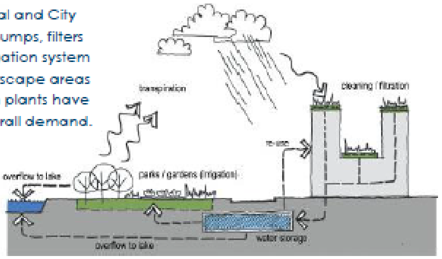
The roof gardens also improve air quality, reduce noise pollution and provide habitat for birds and insects.

Other water sensitive urban design measures include the use of rainwater and wastewater from the central building's Reverse Osmosis (RO) water plant in the hospital for toilet flushing; the use of water efficient fixtures; and native planting.

The irrigation design features two water mains for the hospital and City of Melville with separate pumps, filters and control gear. The irrigation system to roof gardens and streetscape areas can be switched off when plants have established to reduce overall demand.

Key Project Features

- 100yr 72hr average recurrence rainfall (ARI) stormwater managed on site via infiltration, reuse and evapotranspiration
- Pollution control (debris and hydrocarbon capture via gross pollutant traps) installed to capture the first flush from impervious areas
- Stormwater captured and stored on site for irrigation purposes
- 10% of scheme water use is recovered and combined with RO wastewater for toilet flushing
- Reduced scheme water consumption and flow to sewers
- Retention of vegetation, landscape and optimisation of urban form
- Integration of stormwater management in to landscape and bushland conservation areas, allowing for infiltration and recharge of the superficial aquifer.



Issues

No drainage connections were available to accommodate stormwater removal offsite so the system has therefore been designed to manage stormwater onsite up to the 1% annual exceedance probability (AEP) event.

Topography separated the precinct into three distinct catchment low points. The proposed main hospital building footprint was located on site's lowest point which created a number of challenges for stormwater management.

Due to large impervious areas for the buildings and car parks, stormwater management needed to be carefully designed in accordance with WSUD principles to manage the 'small events' in conjunction with the requirement to also manage major flood events on site.

Pollution control devices (gross pollutant traps) were installed to capture the first flush impacts, including debris and hydrocarbons, from impervious areas during construction. After capture of the small event flows, stormwater bypasses into underground infiltration tanks and landscaped basins

Image courtesy of Brookfield Multiplex

Outcomes

The fully integrated stormwater management system delivers the objectives of a contemporary health campus by enhancing the connection between people and the natural environment.

Irrigation and water for hospital purposes is continually monitored for quality. Recycling 10% of maximum estimated daily potable water use will save approximately 40ML per year.

Careful design and planning ensured that the development could make the best use of existing natural systems and maintain the original site hydrology.

The strategy protects the existing ecological habitat and creates additional green spaces and habitat which assist in the management of urban heat island effects.

Image courtesy of Brookfield Multiplex

Case Studies

Parkfield Lake and Public Open Space retrofit

Land use / development type	Scale
Public Open Space Retrofitting	Lot
	Lot

Stormwater controls	Scale
Bioretention area	Lot
Bubble-up pits	Lot

Efficient use of water	Scale
Waterwise landscaping	Lot

Water reuse	Scale
Constructed stream and lake water recycling	Lot

Water quality treatment	Scale
Native vegetation	Lot
High PRI filter media	Lot
Lateritic gravel mulch	Lot
Aeration of lake and stream water	Lot

Site conditions	
Groundwater	Shallow, directly conneced to POS
Slope	Steep slopes within park

Local government	Location
City of Kwinana	Bertram

Parkfield public open space was originally developed as part of an old residential development. The park which is in the suburb of Bertram included a central water body and surrounding landscaping. The original design was for the water body to function as a compensating basin.

The lake was maintained through its direct connection to groundwater and the surrounding public open space was constructed with steep turfed slopes. While no water quality issues were initially present, algal blooms occurred after a number of years. These algal blooms are thought to be caused by legacy nutrients occurring in groundwater likely to be associated with previous market garden usage within the locality and nutrient loads from surrounding urban development, stormwater and park runoff.

The park and surrounding road system was also subject to repeated flooding resulting in safety hazards. The safety hazards as well as the algal blooms and water quality were of concern to the community.

To address the community concerns and the range of complex surface water, groundwater and health and safety issues, the City of Kwinana, in partnership with the Peel-Harvey Catchment Council, engaged TME consultants to investigate these issues and design and retrofit a public open space solution to improve the environmental, flood storage, aesthetic and recreational values of Parkfield public open space.

The water body was of high value to the local residents and there was a strong preference for a water body in the final design.

The retrofit landscape design utilises native vegetation planting around the installed biofilter and general parkland. A natural rocky channel has been designed to connect the stream to the lake. The lake and channel are disconnected from the groundwater and stormwater systems.

The biofilter basin and surrounding area also provide the required storage to alleviate flooding.

Parkfield Lake was previously subject to flooding and dangerous algal blooms

Key Project Features

- Biofilter planted with locally native species for storage of 1 in 10 year average recurrence interval (ARI) stormwater event to address downstream flood constraints
- High Phosphorus Retention Index (PRI) soil and nutrient absorbing filter media added to the soils of the biofilter and topped with lateritic gravel mulch to aid treatment of stormwater during infiltration
- Subsoil drainage system beneath biofilter to separate nutrient rich groundwater from surface water
- Provision for separate treatment of nutrient rich groundwater system downstream
- Construction of rock-lined flow path and lake to replace existing water features, maintained with low-nutrient groundwater abstracted from a deeper confined aquifer and recycled using pump system
- Use of native plants and rocky drops within lake and channel to provide additional fauna habitat, and improve aesthetic value through aeration
- Inclusion of active open space, with entry pits around the edge of the lake to capture runoff from

Issues

Algal blooms were caused by the discharge of nutrient rich, untreated groundwater and urban stormwater runoff into the Parkfield Lake. Due to the need to maintain the aesthetic quality and value of the location for the community, adequate treatment of groundwater could not be undertaken at the site due to the lack of space. A subsoil system was constructed to allow treatment of groundwater further downstream where more space was available and to separate rising groundwater from the surface water system to alleviate flooding and the development of wet areas.

The new design incorporated a smaller constructed lake and stream to meet community expectations, including a pumping system to circulate water and minor rocky waterfalls assisting with aeration and prevent algal blooms while providing 'white noise' for a relaxing environment.

Development Costs[1]

Subsurface drainage	$100,000
Filter media (supply)	$ 30,000
Bioretention area planting	$ 15,000
Landscape & irrigation works	$430,000
Bulk earthworks, dewatering	$250,000

[1]All Costs are site specific and are an approximation given for guidance purposes only

Outcomes

TME and the City of Kwinana successfully retrofitted a water sensitive public open space that maintained the water features of the previous design valued strongly by the community, while managing flood issues through the provision of effective stormwater detention and water quality treatment through the development of a bioretention area.

Management of groundwater was achieved through a subsoil drainage system to separate groundwater from surface systems and through the use of a high PRI media in the soils of the bioretention area to allow some treatment of highly eutrophic groundwater.

The construction of a water sensitive public open space has provided an opportunity to create a more useable active open space by regrading existing steep sloped areas to a more flattened form that is appropriate for recreation and that maximises visual amenity, access to and interaction with the water.

The design provides fauna habitat, reduces invasive weeds, and enhancing water quality treatment of stormwater by providing a buffer to fertiliser run-off, lawn clippings and other additional nutrient sources.

ontact details for further information:
alibre Consulting (formerly TME) (08) 9791 4411
ity of Kwinana (08) 9439 0200
eel-Harvey Catchment Council (08) 6369 8800

Australian Government
This project is supported by the Swan River Trust, through funding from the Australian Government.

Case Studies

PEEL-HARVEY

WATER SENSITIVE URBAN DESIGN TOUR

Aimed at improving management of our water resources.

SITE DESCRIPTIONS

www.peel-harvey.org.au

www.newwaterways.com.au

Case Studies

PEEL-HARVEY water sensitive urban design tour

SITE LOCATIONS

1. **QUANDONG PARK -** Seascapes, Halls Head
   position: E376432 N6397650
   32° 33' 06"S 115° 41' 02"E

2. **SANTALUM CIRCUS -** Seascapes, Halls Head
   position: E375816 N6396418
   32° 33' 45"S 115° 40' 36"E

3. **NORTH PORT STAGE 12 -** Linville Street & Boxgum Link, Port Bouvard, Wannanup
   position: E373342 N6392907
   32° 35' 38"S 115° 39' 01"E

4. **CHANNEL VIEW -** Port Bouvard, Dawesville
   position: E372218 N6391488
   32° 36' 24"S 115° 38' 18"E

5. **ENCHANTRESS LANE & ESTUARY RD** - Dawesville
   position: E372603 N6391202
   32° 36' 33"S 115° 38' 32"E

6. **SNAKE DRAIN -** Mariners Cove, Dudley Park
   position: E381269 N6397255
   32° 33' 20"S 115° 44' 07"E

7. **ALCOA WETLAND -** Pinjarra Road, Pinjarra
   position: E393929 N6389555
   32° 37' 35"S 115° 52' 10"E

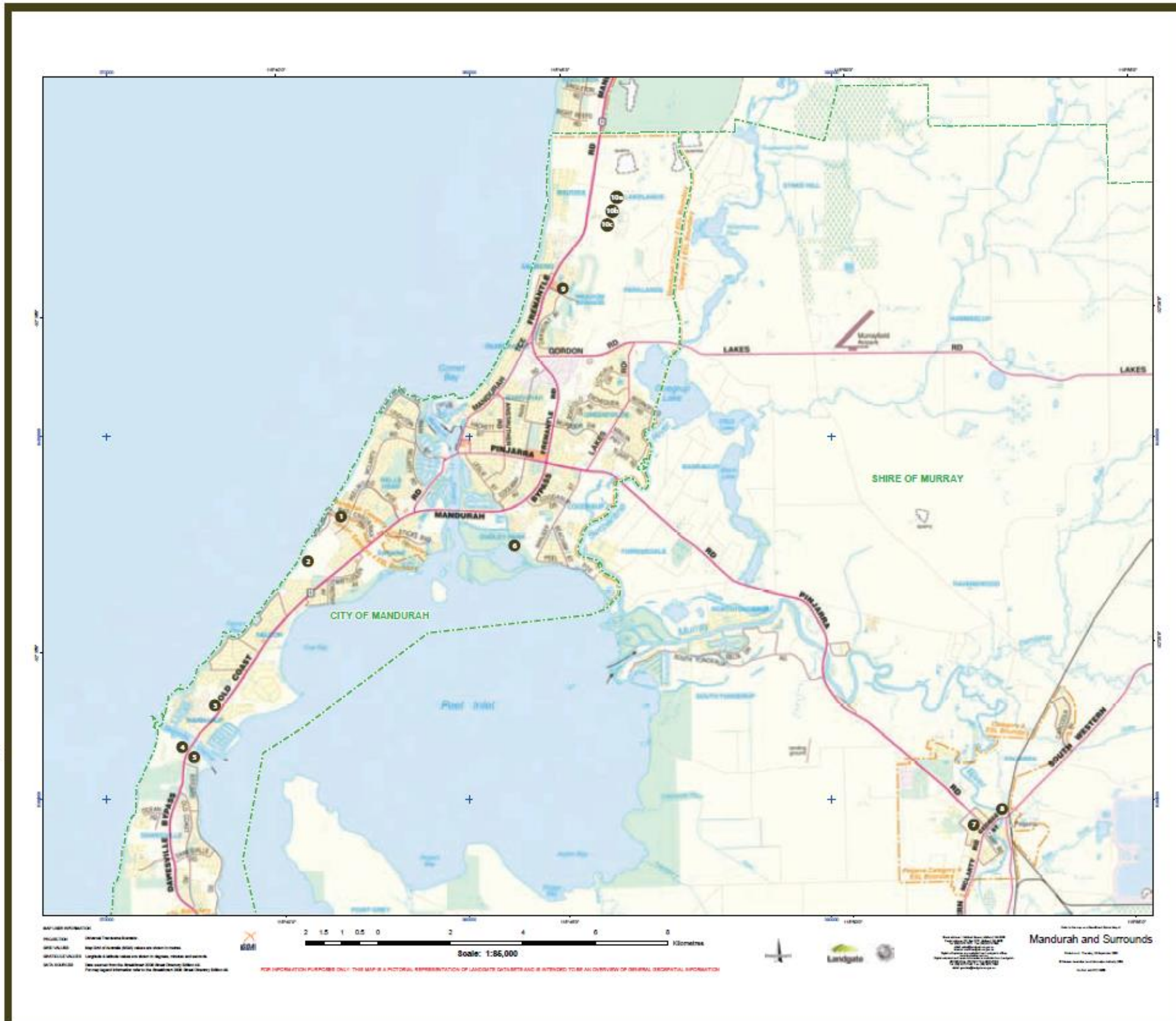
8. **CANTWELL PARK -** South West Highway, Pinjarra
   position: E394600 N6389432
   32° 37' 39"S 115° 52' 35"E

9. **MEADOW SPRINGS DRIVE -** Meadow Springs
   position: E383260 N6403703
   32° 29' 52"S 115° 45' 26"E

10a. **LAKELANDS -** Jane Kennaugh Reserve, Loretta Parkway
   position: E384056 N6407041
   32° 28' 05"S 115° 45' 60"E

10b. **LAKELANDS -** Yindanna Lane
   position: E384116 N6406040
   32° 28' 37"S 115° 46' 02"E

10c. **LAKELANDS** -Ballard Meander
   position: E384170 N6405594
   32° 28' 51"S 115° 46' 02"E



Case Studies

PEEL-HARVEY water sensitive urban design tour

SITE 1		QUANDONG PARK, SEASCAPES, HALLS HEAD
SITE 2		SANTALUM CIRCUS, SEASCAPES, HALLS HEAD
SITE 3		NORTH PORT STAGE 12, LINVILLE STREET & BOXGUM LINK, PORT BOUVARD, WANANNUP
SITE 4		CHANNEL VIEW, PORT BOUVARD, DAWESVILLE
SITE 5		ENCHANTRESS LANE & ESTUARY ROAD, DAWESVILLE
SITE 6		SNAKE DRAIN, MARINERS COVE, DUDLEY PARK
SITE 7		ALCOA WETLAND, PINJARRA ROAD, PINJARRA
SITE 8		CANTWELL PARK, SOUTH WEST HIGHWAY, PINJARRA
SITE 9		MEADOW SPRINGS DRIVE, MEADOW SPRINGS
SITE 10	A	JANE KENNAUGH RESERVE, LORETTA PARKWAY LAKELANDS
	B	YINDANA LANE, LAKELANDS
	C	BALLARD MEANDER, LAKELANDS

Case Studies

PEEL-HARVEY water sensitive urban design tour

Site 1 Quandong Park, Seascapes, Halls Head

Quandong Park is bordered by Quandong Parkway and Asper Way, in Halls Head.

It is a seaside development, with construction of shopping and lifestyle facilities currently under way. The Quandong trees in and around the development have been retained due to their cultural and environmental significance. Some of the mature trees are up to 200 years old.

Key site objectives include:

- Flood protection for the surrounding development - the overall public open space design will accommodate a 1 in 100 year event
- Infiltration of stormwater on site
- Stormwater quality management to protect the Peel-Harvey catchment and costal areas

Best management practices include:

- Bottomless manhole infiltration features at primary source points to quickly disperse large amounts of water (A)
- Median swales with vegetated bioretention areas which assimilate nutrients in stormwater runoff (B)
- Gross pollutant traps at the kerb line for ease of access and maintenance (C)
- Flush kerbing around the public open space to distribute storm water evenly and minimise need for piped systems (D)
- Rock waterfall features at the stormwater bubble up points act as a gross pollutant trap whilst calming flows (E)
- Atlantis infiltration systems to retain smaller infrequent events underground and replenish groundwater aquifiers, ensuring public amenity of active playing spaces is not compromised (F)

When it rains, water is initially stored in the bottomless entry pits in the street network. If this capacity is exceeded, water then flows out of the bubbleup into the rock waterfall. In extremely large events, water is retained in the amphitheatre in underground storage cells and infiltrated over a period of a few hours to a day.

Other objectives achieved include:

- Vegetation and biodiversity protection by retaining the quandong trees in and around the development (G)
- High quality public amenities (H)
- Incorporation of local artwork (I)

NOTE: this public open space area was originally irrigated with treated wastewater which supported the larger than usual areas of turf.

Case Studies

PEEL-HARVEY water sensitive urban design tour

Site 2 Santalum circus, Seascapes, Halls Head

Santalum Circus is in the Seascapes development on the western side of Old Coast Road in Halls Head.

This public open space area provides a water quality treatment and water quantity management function, while also providing space for active recreation. This is achieved via the landscape design and is complemented by a children's playground and covered picnic area with tables.

Key site objectives include

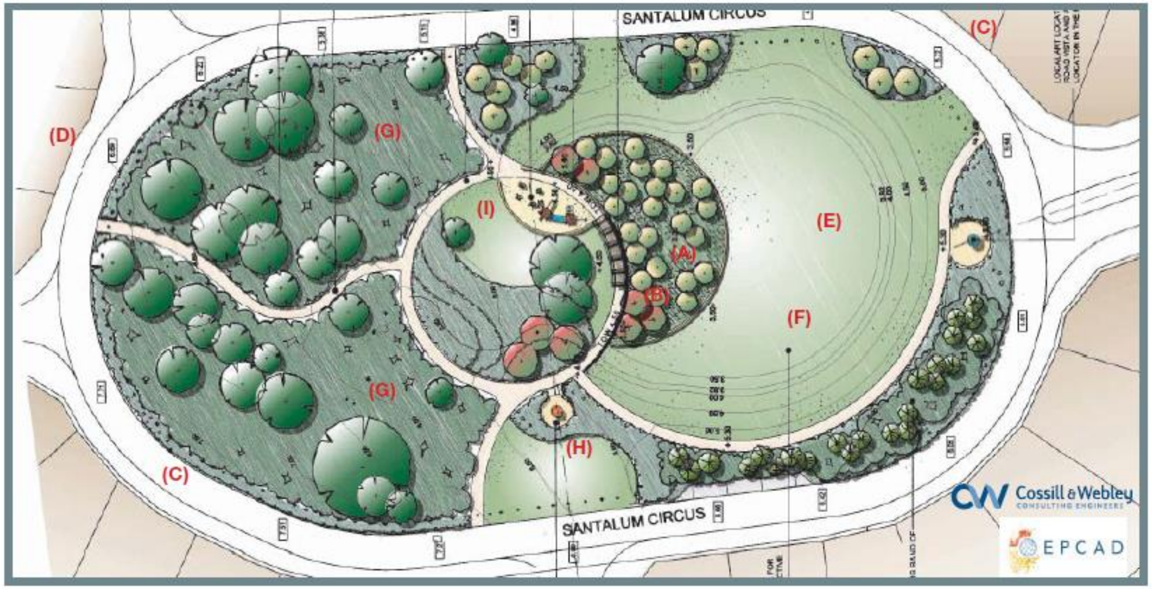
- Management of low flows to achieve recharge and treatment of stormwater from the surrounding development
- Detention of stormwater to achieve flood protection objectives

Best management practices include:

- Wet detention area to facilitate recharge of treated stormwater to the groundwater store **(A)**
- Bubble ups to distribute stormwater to be infiltrated **(B)**
- Flush kerbing to direct stormwater flows to vegetated areas **(C)**
- Protection of the public open space area during house construction by sediment fences **(D)**
- Detention of larger flows in active public open space area **(E)**

Other objectives achieved include:

- Provision of sufficient area for active recreation **(F)**
- Retention and revegetation of local bushland **(G)**
- Incorporation of local art **(H)**
- Community meeting places and facilities **(I)**



Case Studies

PEEL-HARVEY water sensitive urban design tour

Site 3 North Port Stage 12, Linville Street & Boxgum link, Port Bouvard, Wanannup

North Port development is located to the north of the Dawesville Channel in Wannanup. Stage 12 can be accessed via Linville St and Boxgum Link.

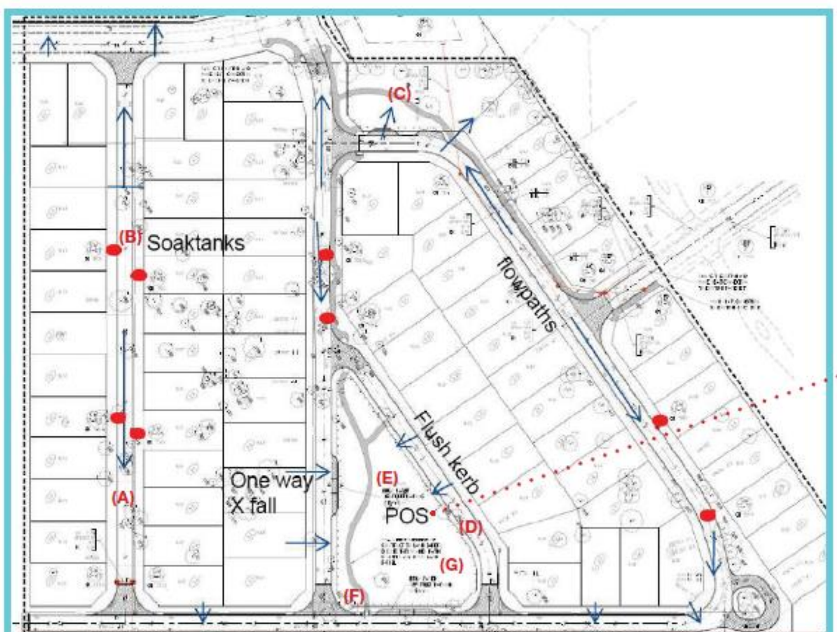
A key factor in the design of the development was the achievement of water sensitive urban design objectives to minimise its impact on the nearby Peel Inlet.

Site objectives include:

- Maximise local infiltration
- Diversion and detention of the first flow runoff (which contains high amounts of pollutants)
- Minimising the amounts of impervious areas to increase infiltration
- Integration of stormwater treatment systems into the urban form
- Minimise runoff velocities to prevent erosion

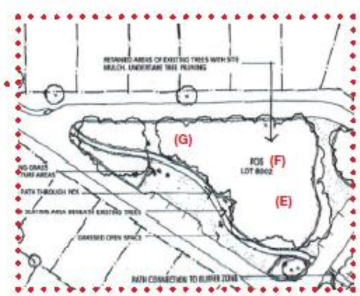
Best management practices include:

- Incorporation of weep holes, aggregate (metal bed) and traps within all gully and side entry pits to maximise local infiltration, detain all first flow runoff and minimise the volumes and areas required for detention basins **(A)**
- Over depth manholes and propriety drainage cells to achieve a “no flow” system of infiltration **(B)**
- Incorporation of swales to facilitate stormwater treatment and infiltration **(C)**
- Flush kerbing where adjacent to public open space areas or large medians; to direct stormwater to infiltration areas **(D)**



Other objectives include:

- Design of public open space to accommodate infiltration of stormwater without detriment to public amenity or environmental values **(E)**
- Retention of existing local native bushland and landform to reduce and filter runoff **(F)**
- Conservation of water through minimising turfed areas **(G)**



Public open space (POS)

Case Studies

PEEL-HARVEY water sensitive urban design tour

Site 4 Channel View, Port Bouvard, Dawesville

Channel View is in the Southport precinct of Port Bouvard which surrounds the prestigious 'Cut' Golf Course and neighbours the Indian Ocean. It is located on the western side of Old Coast Road, immediately south of the Dawesville Channel.

It has been built on an area sensitive to nutrient loading and contamination discharge. In order to prevent further negative environmental impacts in the area, special attention was given to the implementation of water sensitive urban design principles, particularly to prevent nutrients from mobilising to the nearby estuary.

Key site objectives include:

- Infiltration and treatment of stormwater
- No direct discharge of stormwater to the estuary

Best management practices include:

- Lot level infiltration to reduce the need for a piped stormwater system **(A)**
- Water sensitive road design including flush and broken kerbing and incorporating soak tanks to increase onsite infiltration **(B)**
- A bioretention system with rockfall to slow water flows and treat frequent stormwater events prior to discharge to the receiving environment **(C)**
- A bubble up feeds into grassed swale area to increase onsite infiltration **(D)**

Other objectives achieved include:

- Incorporation of public art **(E)**
- Vegetation regeneration and retention **(F)**
- Provision of a public area which maximises community use of the area and allows access to the estuary **(G)**

Case Studies

PEEL-HARVEY water sensitive urban design tour

Site 5 Enchantress Lane & Estuary Road, Dawesville

Channel Heights is a small development, located as its name suggests, on the Dawesville Channel.

It comprises 66 single residential blocks ranging from 540sqm to 1000sqm. The development lies on the south side of the Dawesville Channel and entrance is gained by taking the first left onto Estuary Road after crossing the Dawesville Bridge.

Key site objectives include:

- Infiltration of stormwater as close to source as possible
- Treatment of stormwater prior to its discharge to the estuary

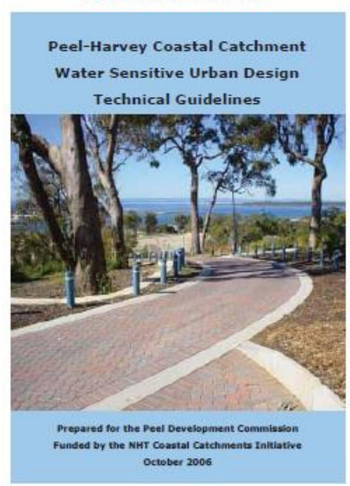
Best management practices include:

- Flush kerbing, vegetation retention and meandering pathways to slow water flowing down the roads and allow for greater infiltration **(A)**
- A small park with a bubble up system in a small vegetated area serves to effectively contain stormwater flows and includes soak tanks for larger flows from the upper street system **(B)**
- A no pipe system has been used to promote increased infiltration throughout Enchantress Lane **(C)**

Other objectives achieved include:

- Provision of community infrastructure (barbeques) in the small area of public open space **(D)**
- Subdivision design which retains and celebrates the landform and landscape values **(E)**

Channel Heights is pictured on the cover of the Peel-Harvey WSUD Technical Guidelines.



Case Studies

PEEL-HARVEY water sensitive urban design tour

Site 6 Snake Drain, Mariners Cove, Dudley Park

Mariner's Cove is located immediately south of Mandurah Road, off Mariner's Cove Drive within 5 minutes of the Mandurah Town Centre.

The snake drain is located on Darwin Terrace on the edge of the internationally significant Creery Wetlands, a key component of the Ramsar listed Peel-Yalgorup System. The protection of these wetlands, having consideration of the shallow depth to groundwater and predominantly clay soils were key elements guiding the design of this area.

Key site objective:

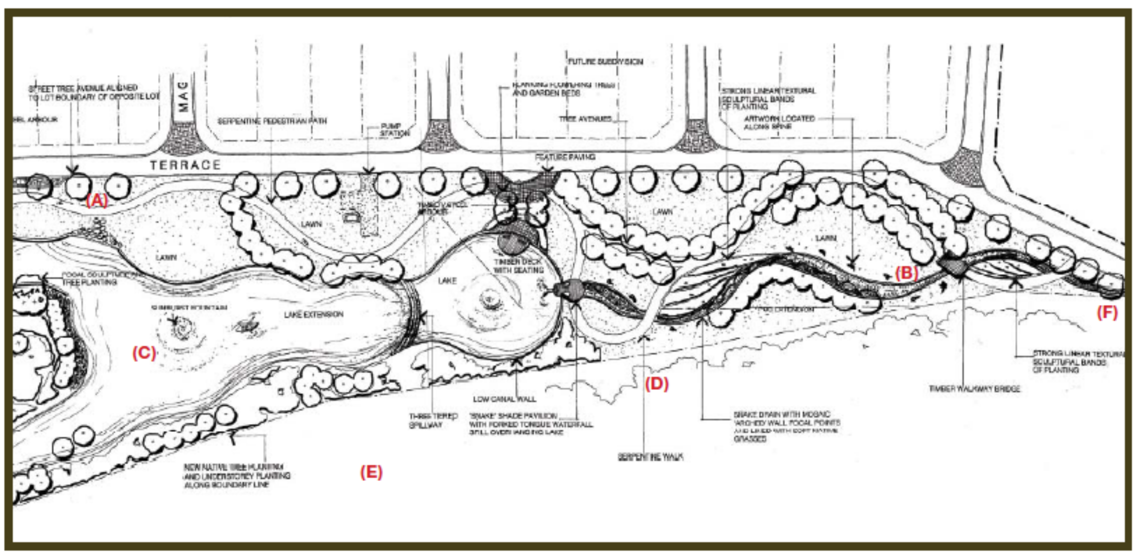
- Water quality management to ensure treatment of stormwater prior to discharge

Best management practices include:

- Gross pollutant traps to prevent litter and other pollution from reaching the wetlands **(A)**
- Lineal swale to retain and convey stormwater by allowing for nutrient assimilation **(B)**
- A constructed lake, to retain and treat stormwater **(C)**
- Retention of native vegetation and revegetation to protect the health of the nearby Ramsar listed Creery Wetlands **(D)**

Other objectives achieved include:

- Vegetation and biodiversity protection - Just under 50% of the site was ceded for the Creery Wetlands Nature Reserve **(E)**
- Controlled and responsible human access to Creery Wetlands **(F)**
- Successful education program on small lot concepts for the City of Mandurah Councillors and Senior Executive



Case Studies

PEEL-HARVEY water sensitive urban design tour

Site 7 Alcoa Wetland, Pinjarra Road, Pinjarra

Alcoa Pinjarra Wetland Restoration Project is located on Pinjarra Road, Pinjarra.

The restoration project is a partnership between Alcoa, Peel-Harvey Catchment Council, Greening Australia and the Shire of Murray with funding provided by Alcoa, South West Catchments Council (with support from the Australian and Western Australian Governments) and the Peel Development Commission.

Formerly a wetland, this degraded reserve had been filled and channelised to form an urban drain. The choice of this site for the restoration project was based on many factors including that it conveys more than 20% of the Pinjarra town site stormwater which is discharged directly into the Murray River approximately 500m downstream. The site also had significant remnant vegetation and an indigenous cultural history, and due to the size of the reserve there was room to undertake a large scale intervention, which is often difficult in an urban area.

The project altered the drainage infrastructure to reinstate the former wetland functions of the site; assisting with nutrient stripping through encouraging sedimentation and nutrient uptake by native sedges, rushes, shrubs and trees planted on the banks. An important design specification of the project was to maintain the conveyance capacity in high flows while slowing down the water in low flow periods. The wetland design and modelling was undertaken by Syrinx Environmental.

Key site objective:

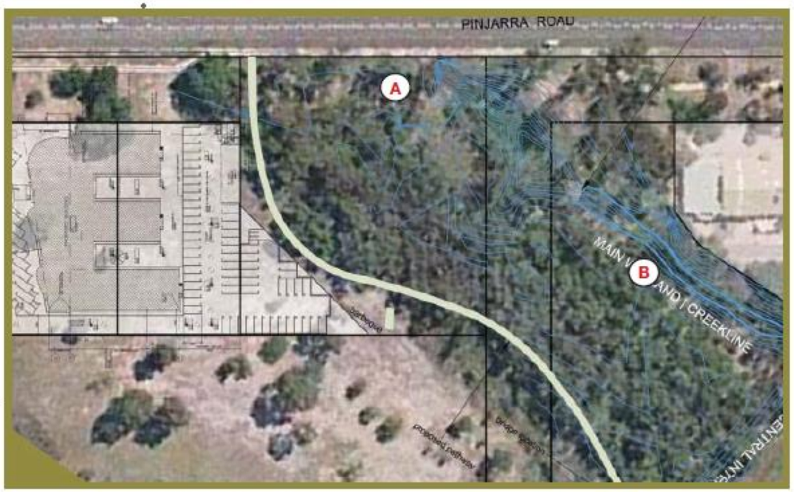
- Improved water quality and quantity management of an existing drainage system via construction of a wetland area

Best management practices include:

- Redesign of the creekline and wetland to slow water flows, increase retention times and improve habitat values without compromising flood conveyance of the system **(A)**
- Rehabilitation of existing wetland vegetation including weed control (primarily Watsonia, Japanese Pepper and Flame Trees), and revegetation along the main wetland/creekline and the central and southern-most intersecting creeklines **(B)**

Other objectives to be achieved include:

- Amenity improvements including a path and barbeque with a bridge over the central intersecting creek
- In the longer term, interpretive signage will be installed along the pathway with the intention of engaging people visiting the site and increasing interest in the project



(Design and diagrams by Syrinx Environmental)

Case Studies

PEEL-HARVEY water sensitive urban design tour

Site 8 Cantwell Park, South West Highway, Pinjarra

Cantwell Park is located on the South West Highway, Pinjarra.

This project is a hard engineering, end of pipe retrofit solution to improve stormwater management. This engineering approach was taken in response to limited public space, high slopes and the need to remove oil and sediment from the stormwater.

Key site objective:

- In-system pollution control which is able to treat 80% of the total stormwater flow from the catchment

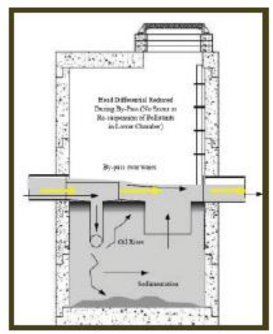
Best management practices include:

- Gross pollutant traps and oil / grit separator to capture and retain a range of contaminants from stormwater generated from carparks, industrial and commercial sites, roads and highways, petrol stations and high/medium density residential developments. Suspended solids, sediment, oil, grease and debris are retained in a centrally located solids catchment chamber **(A)**
- Retrofitting of existing manhole chambers and drain and curb inlet treatment so that stormwater enters the inlet grate or curb inlet and is channelled into the separation chamber **(B)**

Other objectives include:

- Monitoring of results for research and development - Initial monitoring of the drain outlet was completed in May 2007 to capture the 'first flush' event

high flow



low flow

Case Studies

PEEL-HARVEY water sensitive urban design tour

Site 9 Meadow Springs Drive, Meadow Springs

The Meadow Springs development is located about 4km to the north of the Mandurah City Centre.

It is a well established estate located within and around a championship golf course. It also features an established shopping centre and school.

The development design has embraced the concept of water sensitive urban design throughout. This area of public open space is located at the corner of Meadow Springs Drive and Oakmont Avenue.

Key site objective:

- Infiltration and detention of stormwater

Best management practices include:

- Vegetated swales with bubble up to aid treatment and infiltration **(A)**
- Alternate kerb arrangements to direct stormwater flows **(B)**
- A reduced pipe network in the streets, with stormwater being managed largely via road and kerb design
- Grassed infiltration basin to retain larger stormwater events **(C)**

Other objectives achieved include:

- Vegetation retention and revegetation are featured throughout Meadow Springs to conserve local bushland and biodiversity **(D)**
- High public amenity of parkland and facilities **(E)**

Case Studies

PEEL-HARVEY water sensitive urban design tour

Site 10-A Jane Kennaugh Reserve, Loretta Parkway Lakelands

Jane Kennaugh Reserve, Lakelands Private Estate is located off Mandurah Road, on Catalina Drive.

Priority has been given to enhancing and preserving the natural features and habitat potential of the site, such as preservation of local tuart trees and wetland features where possible. Water sensitive urban design objectives have been a key driver for the final form of the development, which successfully integrates water into the streetscape and series of parks. One such park is Jane Kennaugh Reserve on Loretta Parkway and Ada Lane.

Key site objective:

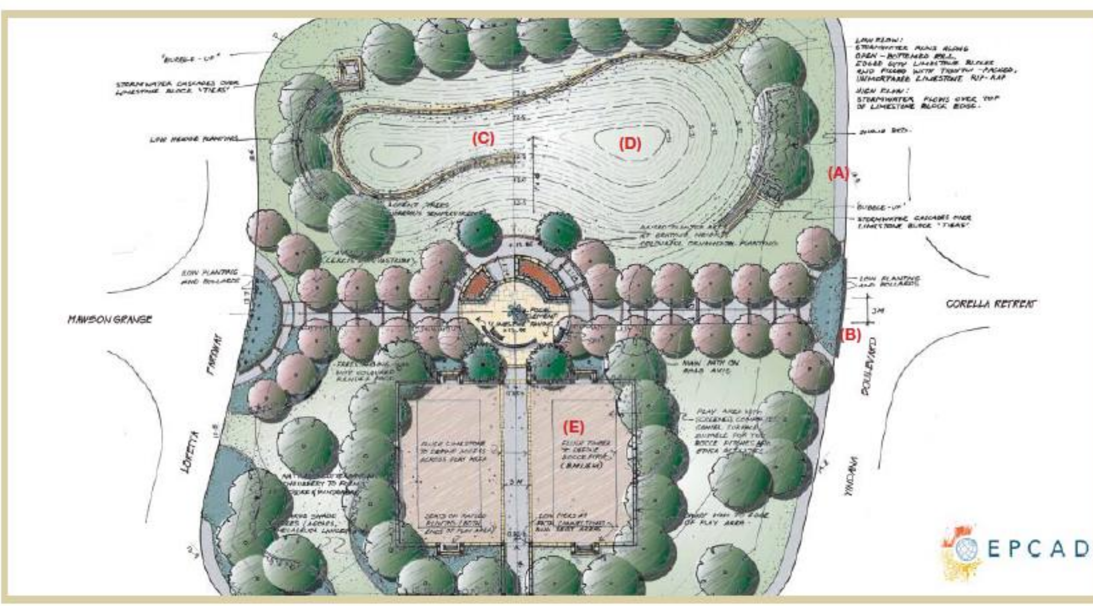
- Improved landscaping and integration of water and amenity into public open space and the urban form

Best management practices include:

- Flush kerbing to disperse stormwater flows at point of contact **(A)**
- Upstream lineal infiltration cells and leaky pits in road verges to reduce the need for piping and enhance stormwater infiltration **(B)**
- A bubble up which flows into a rock waterfall and feeds into a swale at the north of the park to aid infiltration and treatment. The park itself acts as an overland flow path in larger rainfall events **(C)**
- Application of fly ash to amend soils under public open space and minimise transfer of nutrients to the groundwater **(D)**

Other objectives include:

- High amenity public space with community facilities **(E)**



Case Studies

PEEL-HARVEY water sensitive urban design tour

Site 10-B Yindana Lane, Lakelands

The Peet Ltd Lakelands
Private Estate development maximises onsite infiltration by installing over depth access chambers, soakwells, underground storage cells, and storm tech units in the street network and in some lots.

Another water sensitive urban design park is located on Yindana Lane and Nullewa Parkway, Lakelands. This park contains a lake used to irrigate the surrounding public open space.

Key site objective:

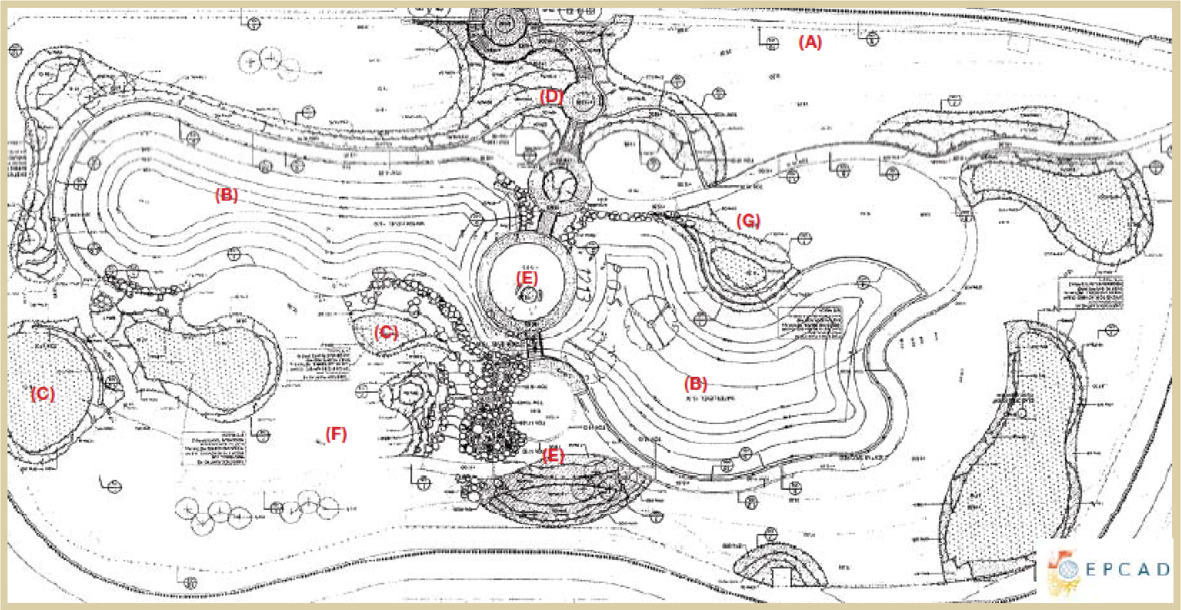
- Improved water use efficiency through storage and reuse of stormwater and smart irrigation practices

Best management practices include:

- Flush kerbing to disperse stormwater at point of contact (A)
- Capture of stormwater for reuse (B)
- Bush bioretention filters and lineal drainage swales (C)

Other objectives include:

- Use of native planting to minimise water use (D)
- Retention of local tuart trees and introduction of wetland features (E)
- High amenity passive recreation space (F)
- Enhancing and preserving the natural features of the site (G)



Case Studies

PEEL-HARVEY water sensitive urban design tour

Site 10-C Ballard Meander, Lakelands

Lakelands Private Estate development also contains an area of public open space on Ballard Meander.

This area contains a kickabout space, tennis hit-up wall, informal cricket pitch and an adventure playground with barbeques, tables and seats.

Key site objectives:

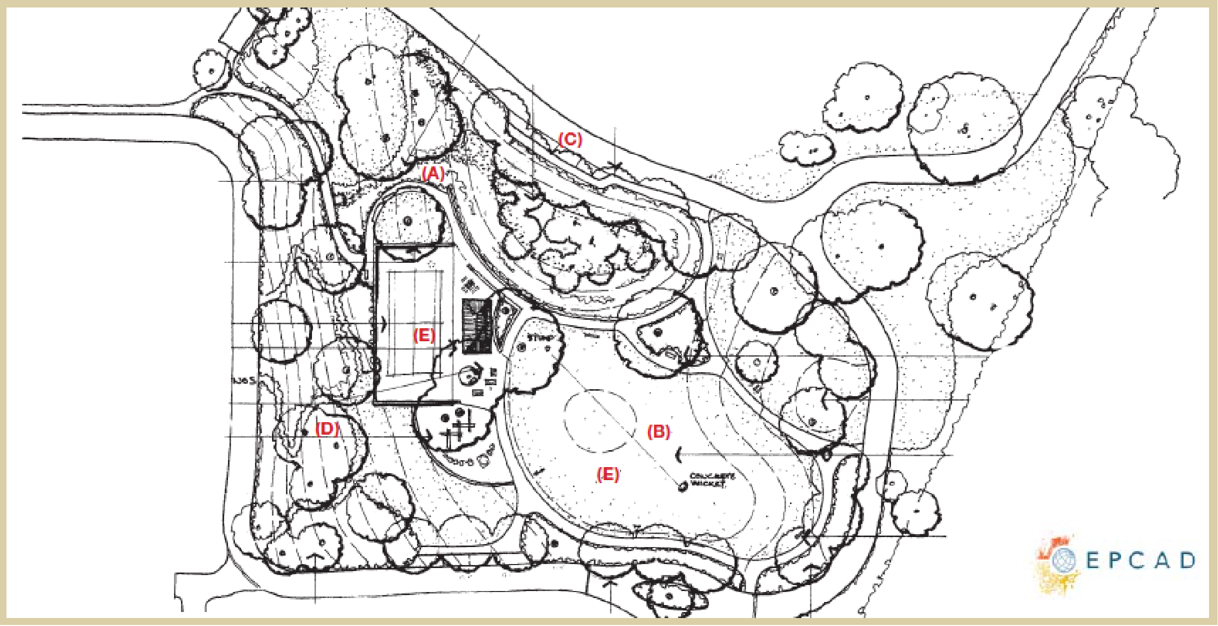
- Infiltration and detention of large stormwater events
- Treatment and retention of smaller stormwater events
- Retention of native trees

Best management practices include:

- Infiltration and treatment of low velocity stormwater events via bubbleups, rockfalls and vegetated areas **(A)**
- Grassed infiltration basin for larger events within active recreation area **(B)**
- Flush kerbs to disperse stormwater at point of contact **(C)**

Other objectives include:

- Retention of native vegetation **(D)**
- Active and passive recreation areas **(E)**
- Limited reticulation of native garden areas



Case Studies

WSUD tour_South-eastern perth metro site descriptions

Sites in City of Gosnells:

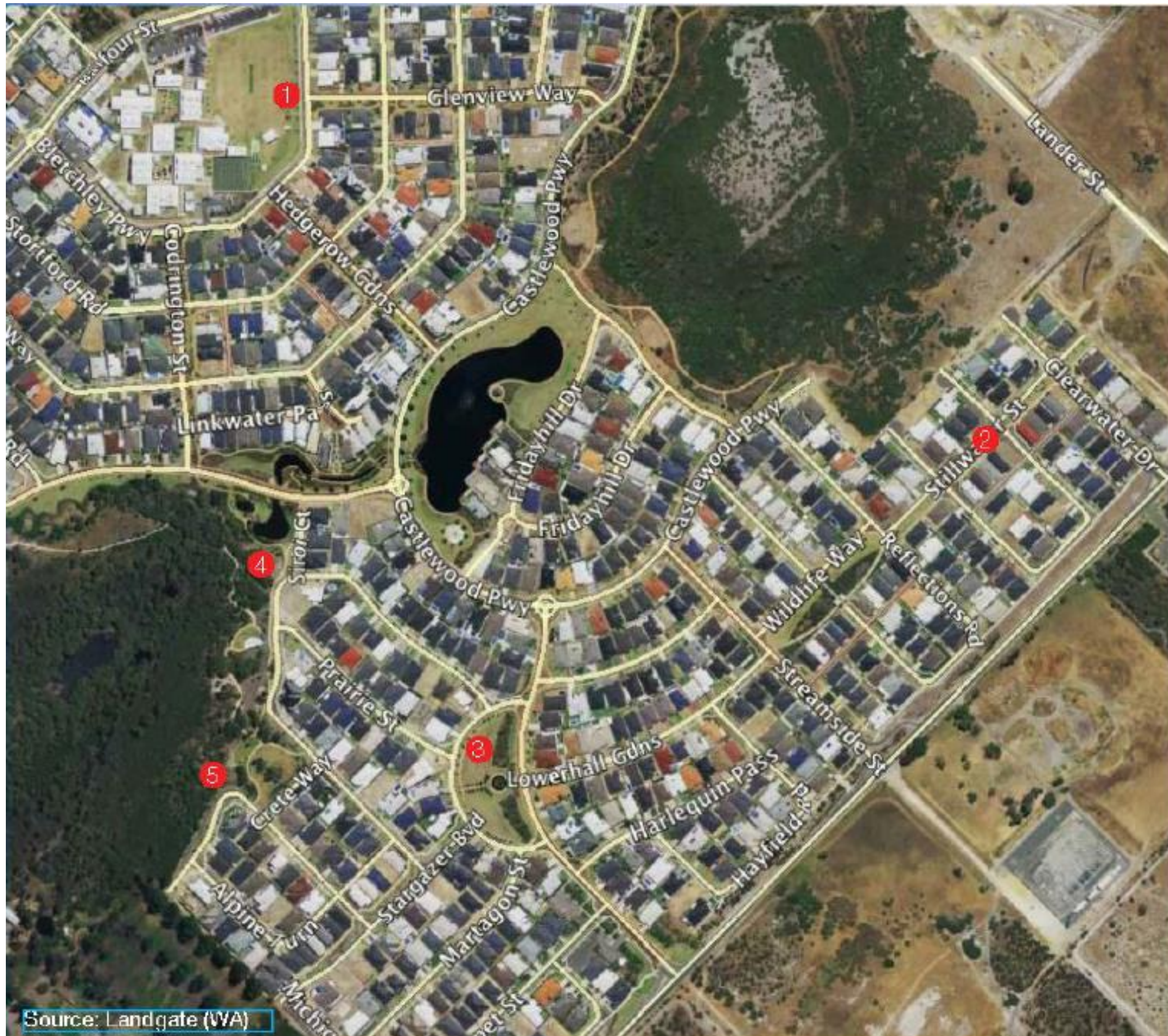
1 **Glenview Way, Southern River**
Latitude: 32°6'8.12"S Longitude: 115°56'54.99"E

2 **Stillwater Street, Southern River**
Latitude: 32°6'18.92"S Longitude: 115°57'23.08"E

3 **Flowerfield Loop, Southern River**
Latitude: 32°6'30.31"S Longitude: 115°57'2.29"E

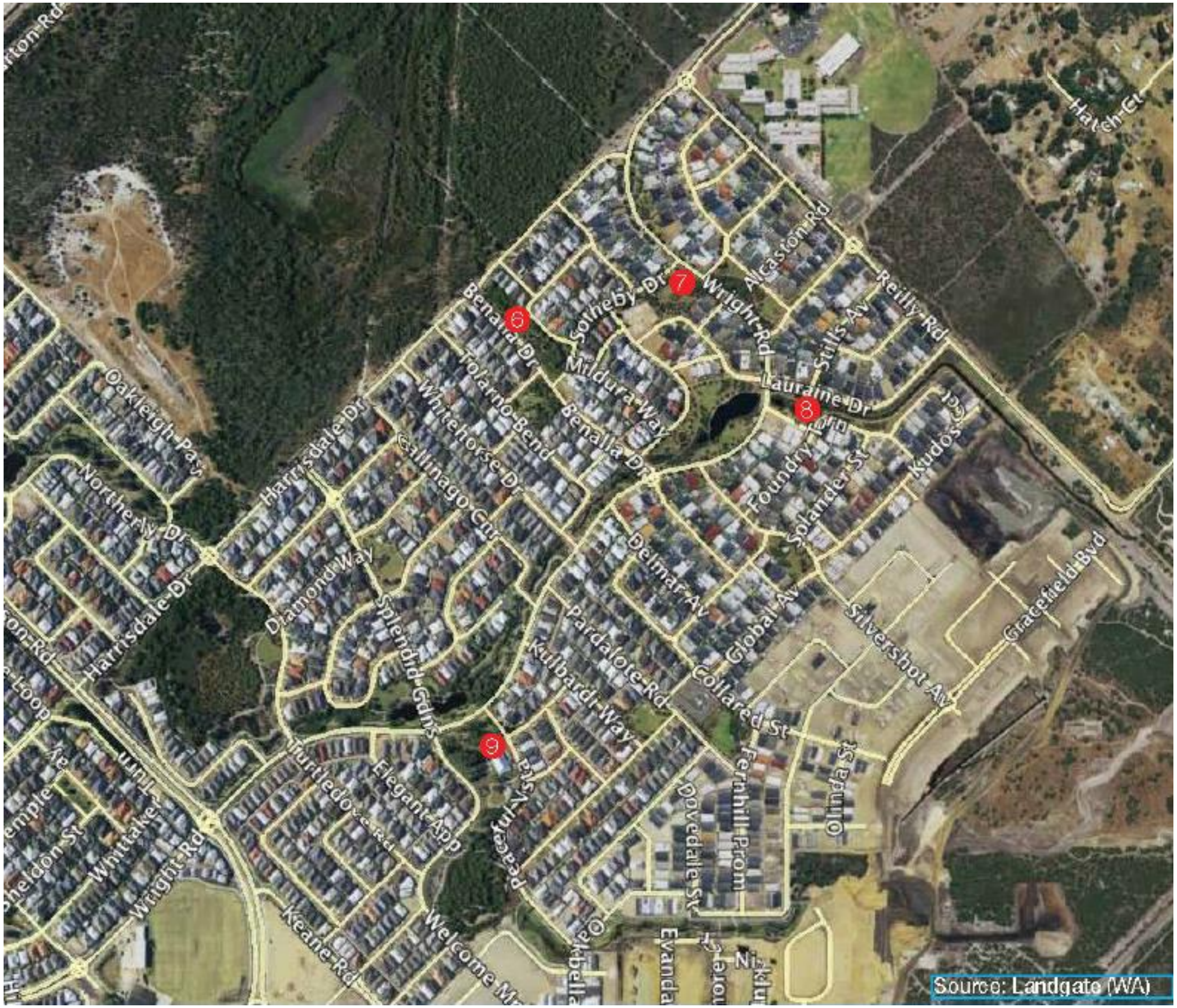
4 **Siroi Court Southern River**
Latitude: 32°6'23.24"S Longitude: 115°56'54.40"E

5 **Panther Elbow, Southern River**
Latitude: 32°6'31.26"S Longitude: 115°56'52.44"E



Case Studies

WSUD tour_South-eastern perth metro site descriptions



Sites in City of Armadale:

6 **Benalla Drive, Harrisdale**
Latitude: 32°6'55.14"S Longitude: 115°55'47.75"E

7 **Sotheby Drive & Wright Rd, Harrisdale**
Latitude: 32°6'53.10"S Longitude: 115°55'57.49"E

8 **Lauraine Drive, Harrisdale**
Latitude: 32°6'58.93"S Longitude: 115°56'5.90"E

9 **Peaceful Vista, Harrisdale**
Latitude: 32°7'21.47"S Longitude: 115°55'46.68"E

Case Studies

WSUD tour_South-eastern perth metro site descriptions

Site 1 Glenview way, Southern River

The road reserves located at the corner of and along **Glenview Way** and **Bletchley Parkway** have been constructed to provide a stormwater conveyance function using best practice WSUD principles. Flush kerbing bordering the road allows stormwater generated during small rainfall events to flow into grassed swales contained within adjacent verges. This design maximises local infiltration of runoff, thereby contributing to the maintenance of pre-development hydrological conditions, as well as providing a conveyance function. Swales also provide physical and biochemical water quality treatment via deposition and filtration of sediments and nutrient uptake. Bubble-up pits are also contained within the grassed swales as part of conveyance of minor stormwater flows piped from surrounding access streets.

Runoff generated during major rainfall events from these streets is conveyed by pipe to the most northern POS site in the precinct and then directed to the adjacent conservation category wetland buffer zone, which has been revegetated to provide additional water quality treatment.

Key site objectives:

- Detention and treatment of small rainfall events to achieve water quality objectives
- Multiple use of school parkland and optimal pedestrian access

Best management practices include:

- Grassed swales (A)
- Bubble up pits (B)
- Flush kerbing to direct stormwater to the public open space and bioretention basin (C)

Other objectives include:

- Infiltration of small events at source
- Increased amenity of streetscapes
- Low maintenance WSUD treatments

Case Studies

WSUD tour_South-eastern perth metro site descriptions

Site 2 Stillwater Street, Southern River

The **Stillwater Street** site in Bletchley Park is characterised by three walled bioretention basins in the verge along the street. The basins are connected to the road by side entry pits and pipes. The bioretention basins are planted with native vegetation for water quality improvement and are designed to treat and infiltrate stormwater runoff generated from the 1 year ARI event on-site.

Stormwater runoff generated in major rainfall events is directed overland into the nearby conservation category wetland.

Key site objectives:

- Infiltration of stormwater at source to maintain local hydrology
- Improved water quality through treatment by native vegetation

Best management practices include:

- Walled bioretention basins in side verges which manage small rainfall events (A)
- Grassed swales (B)
- Bubble up pit (C)
- Major flows are directed to adjacent conservation category wetlands (D)

Case Studies

WSUD tour_South-eastern perth metro site descriptions

Site 3 Flowerfield Loop, Southern River

Flowerfield Loop borders a public open space (POS) area of Bletchley Park Estate which is characterised by a bioretention basin and retained native vegetation. The bioretention basin has been designed to treat local runoff generated during small rainfall events via native vegetation. The basin provides flood protection during rainfall events through detention of minor flows.

Native vegetation was retained within the bioretention basin to enhance the sense of place and provide some native fauna habitat. The vegetation also improves water quality of stormwater runoff before infiltrating into the Superficial aquifer.

Flowerfield Loop POS provides recreational amenity for local residents, incorporating WSUD treatments into a local park, enhancing the local connection to landscape and providing space for passive, non-structured recreation.

Key site objectives:

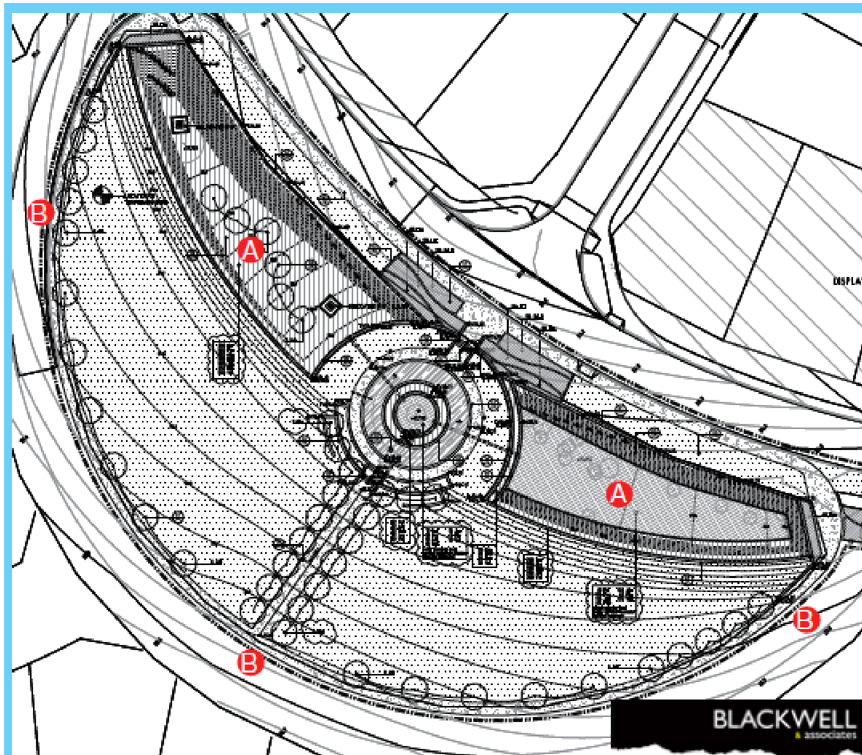
- Detention and treatment of small rainfall events to achieve water quality objectives
- Detention of small rainfall events to provide for serviceability
- Retention of native vegetation to enhance sense of place

Best management practices include:

- Bioretention basin for treatment of small events (A)
- Flush kerbing to direct stormwater to the public open space and bioretention basin (B)

Other objectives include:

- Retention of mature native vegetation for provision of faunal habitat
- Amenity in public open space for local residents via seating, shading and grassed areas



Case Studies

WSUD tour_South-eastern perth metro site descriptions

Site 4 Siroi Court, Southern River

The Siroi Court site comprises multiple WSUD best practices. This includes the innovative use of a constructed treatment lake for the storage and treatment of shallow groundwater for public open space (POS) irrigation, a biofiltration basin to treat stormwater runoff generated from adjacent roads during small events, and a revegetated buffer zone to rehabilitate adjacent conservation category wetland, Balannup Lake.

The constructed treatment lake, located at the end of Siroi Court, receives and stores groundwater pumped from the superficial aquifer, which undergoes initial treatment via aeration. A constructed watercourse connects this lake to a larger irrigation lake located within a POS area on Castlewood Parkway, and provides additional treatment to groundwater through further aeration and the settling of suspended solids. Treated groundwater is subsequently stored in the larger lake and utilised for irrigation of vegetated POS areas throughout the precinct. The constructed lakes and watercourse serve multiple purposes by providing treatment and storage of groundwater for irrigation; providing amenity to local residents; and providing habitat for local fauna.

A biofiltration basin located next to the constructed treatment lake functions as a water quality treatment system for stormwater runoff generated in small events from adjacent road reserves. Nearby tree pits and flush kerbing along Castlewood Parkway are also best practice stormwater management, which act to maximise local infiltration and water quality treatment of stormwater runoff from the local road network.

Another key feature of this site is the revegetated zone adjacent to the constructed treatment lake, biofiltration basin and Tiger Circle road reserve which separates and buffers the development from the Balannup Lake conservation category wetland. The buffer zone has been planted with locally native species to facilitate the rehabilitation of the wetland and habitat of native flora and fauna, as well as protecting it from impacts resulting from the development.

Key site objectives:

- Vegetated buffers to adjacent important wetlands
- Treatment, storage and use of groundwater for POS irrigation
- On-site stormwater infiltration and treatment

Best management practices include:

- Constructed treatment lake (A) and constructed watercourse lake (B) for treatment of groundwater before entering irrigation lake (C)
- Biofiltration basin (D)
- A revegetated buffer to the wetland beyond (E)
- Public open space irrigated by treated groundwater (F)
- Flush kerbing (G)
- Tree Pit (H)

Other objectives include:

- Provision of amenity for local residents through maintained public open space including grass, paths and playgrounds
- Creation of fauna habitat

Case Studies

WSUD tour_South-eastern perth metro site descriptions

Site 5 Panther Elbow, Southern River

Panther Elbow is a local street within the Bletchley Park Estate which borders a Bush Forever site and conservation category wetland, Balannup Lake. It also borders a passive public open space (POS) area which incorporates existing mature native vegetation and provides flood detention for runoff generated during major rainfall events. Underground storage cells have also been installed on the border of the POS area to infiltrate road runoff generated from the 1 year ARI event at source, and maintain local hydrological conditions. Underground cells are connected to the major POS detention area via a bubble up pit. Tree pits are also located within Panther Elbow and connecting streets and are designed to treat the first 5 mm of stormwater runoff generated from rain events.

Overall, the POS has been developed to maximise amenity for local residents, provide a drainage function, and create a connection with surrounding natural bushland and wetlands.

Key site objectives:

- Detention of stormwater to achieve flood protection objectives
- Infiltration and treatment of small rainfall events

Best management practices include:

- Tree pits (A)
- Flush kerbing to direct stormwater flows to vegetated areas (B)
- Underground storage cells (C)
- 2 bubble-up pits connecting the adjacent POS detention area to the Balannup drain. The southern grate is an inlet bubble-up pit, connected to the northern grate, an outlet bubble up pit, by a small v-drain. By planting the v-drain, some water quality treatment is being provided to stormwater that is conveyed between the POS and the Balannup drain outlet pipe and thus the drain also acts as a swale (D)

Other objectives include:

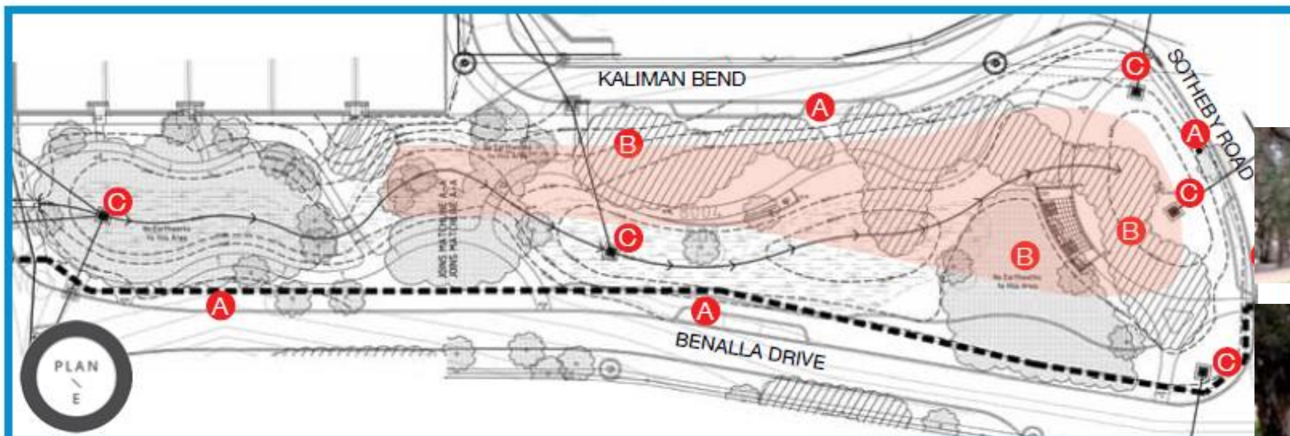
- Retained mature native trees
- Useable public open space providing an appropriate connection to the Bush Forever site

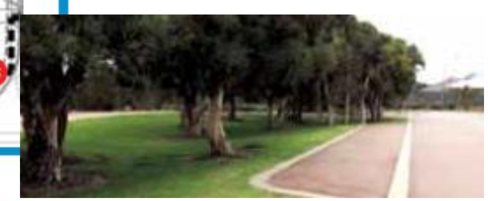
Case Studies

WSUD tour_South-eastern perth metro site descriptions

Site 6 Benalla Drive, Harrisdale

The public open space (POS) bordered by **Benalla Drive** in Vertu Estate is characterised by the expanse of native vegetation retained on site. The retention of native vegetation has significantly reduced the irrigation needs of the site, as well as providing attractive public amenity and habitat for local fauna. The POS achieves multiple objectives through its capacity to treat, detain and infiltrate stormwater runoff as well as provide recreational amenity. Runoff is conveyed to the POS through the use of WSUD systems such as flush kerbing and grassed swales surrounding the detention areas containing native vegetation. The naturally vegetated detention area in the centre of the POS site improves the water quality of stormwater runoff before infiltration to groundwater The meandering design of swales and connecting flow paths through the POS has been used to maximise local infiltration.





Key site objectives:

- Maximise local infiltration through a meandering flow path through grass and shrubs (shaded area of map).
- Water quality treatment of small events in vegetated areas.

Best management practices include:

- Flush kerbing adjacent to public open spaces to direct stormwater to infiltration areas (A)
- Vegetated detention area (B)
- Bubble-up pits (C)

Other objectives include:

- Retained native vegetation to reduc irrigation needs
- Public amenities:
  - Seating
  - Playgrounds
  - BBQs
  - Pathways and bridges through the natural vegetation

Case Studies

WSUD tour_South-eastern perth metro site descriptions

Site 7 Sotheby Drive & Wright Rd, Harrisdale

The public open space (POS) on the corner of **Sotheby Drive** and **Wright Road** in Vertu Estate features a round grassed space which provides a dual function to provide attractive public amenity as well as detention of stormwater runoff for flood protection. Best practice stormwater treatment is achieved at this site through the use of grassed swales and flush kerbing along the boundaries of the POS. These provide conveyance and allow maximum local infiltration. Bioretention basins planted with native vegetation improve the quality of stormwater before infiltration. Bubble-up pits are included within both grassed areas and areas containing native vegetation as part of conveyance of minor stormwater flows to the POS for detention and treatment. Subsoil drains have also been installed to control local groundwater levels.

Key site objectives:

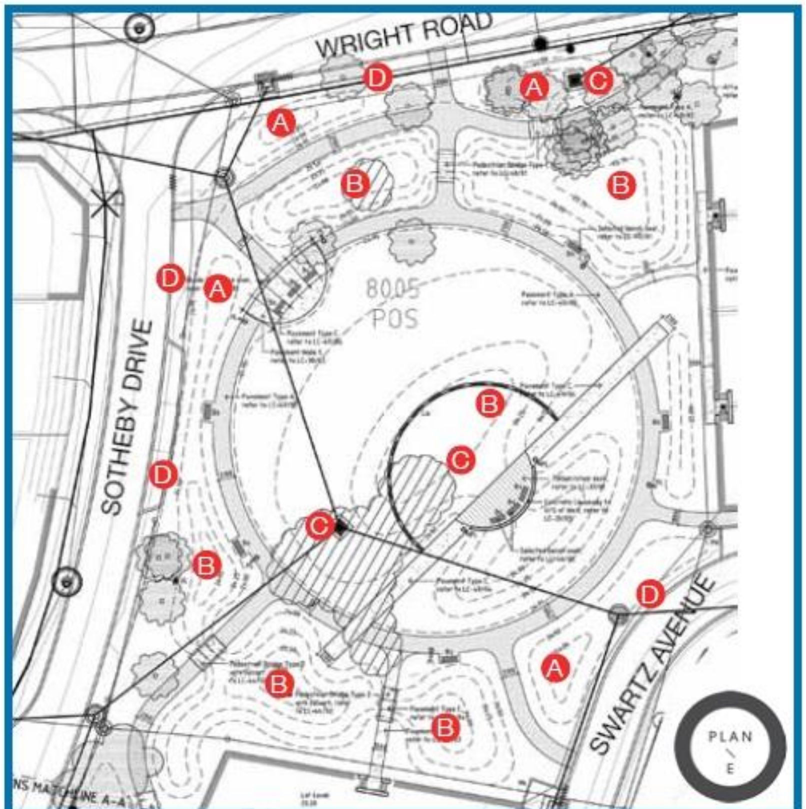
- To create an aesthetically pleasing public open space with the added benefits of managing small and large rainfall events

Best management practices include:

- Grassed swale (A)
- Vegetated bioretention basin (B)
- Bubble up pit (C)
- Flush kerbing (D)

Other objectives include:

- Retention of native mature vegetation (paperbarks)
- Large events flow to active area of public open space
- Public amenities
  - Seating and BBQ
  - Shade
  - Pathways around the grassed areas

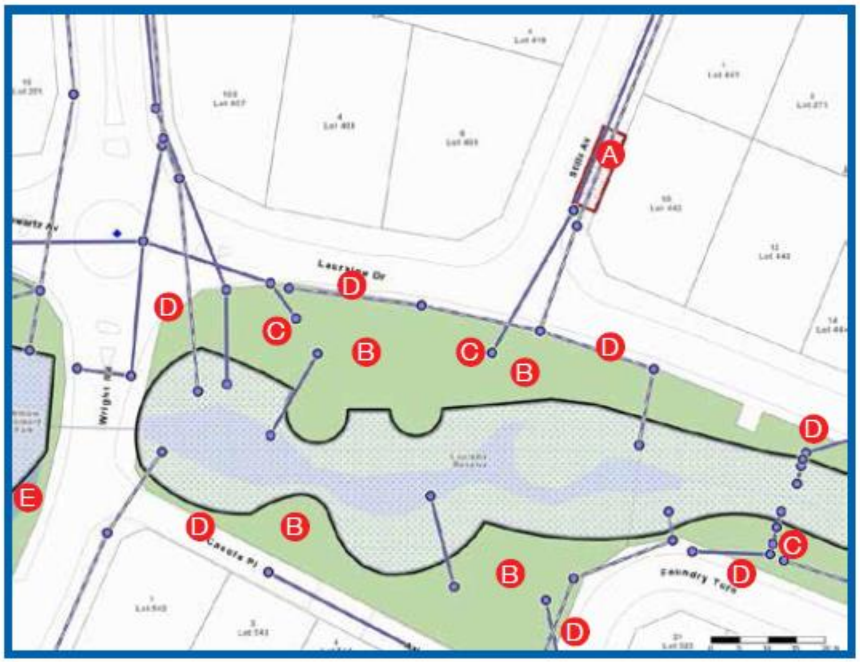


Case Studies

WSUD tour_South-eastern perth metro site descriptions

Site 8 Lauraine Drive, Harrisdale

Lauraine Drive public open space (POS) in Vertu Estate is characterised by the Balannup Drain which runs through its centre. Stormwater from the street network is treated in a bioretention basin in Stills Avenue, before flowing into the POS. Flush kerbing along Lauraine Drive allows local runoff from rainfall events to be infiltrated within the grassed swales and vegetated areas of the POS, and thus close to source. Major events will overflow to the drain, after being detained by a series of constricting culverts. The retention of native vegetation and the planting of additional native vegetation provides a nutrient stripping function to the drain. Soft edge treatment of the drain west of Wright Road is preferred to the walled treatment east of Wright Road; however, the lack of grade across this area is noted as providing challenging conditions. Shallow groundwater is also controlled in the area through subsoil drainage.



Drainage line - subsoil

Drainage line

Key site objectives:

- Management of rainfall from small and large events before entering Balannup Drain (shaded area)
- Creating an interactive public open space incorporating existing natural bushland

Best management practices include:

- Bioretention basin in non-active frontage (A)
- Grassed swale (B)
- Bubble-up pits to grassed swales (C)
- Flush kerbing (D)
- Soft edge treatment of drain (E)

Other objectives include:

- Retained native vegetation
- Some nutrient stripping vegetation within the walled drainage channel
- Amenities:
  - Seating
  - Picnic tables
  - BBQs
  - Playground

Case Studies

WSUD tour_South-eastern perth metro site descriptions

Site 9 Peaceful Vista, Harrisdale

The public open space (POS) area located along **Peaceful Vista** in Heron Park Estate incorporates an existing conservation category wetland into its design, with a focus on retention and revegetation of native plants and trees, in conjunction with localised stormwater management. Grassed basins throughout the POS allow for local infiltration of road runoff generated from small rainfall events, while larger detention areas including native vegetation have been incorporated into the site to allow water quality treatment and provide flood protection. In addition to providing a drainage function, this POS also provides significant amenity to local residents, as well as habitat for native fauna within and adjacent to the wetland.

Key site objectives:

- Creating a space which incorporates public amenities within the natural vegetation while managing stormwater as close to source as possible

Best management practices include:

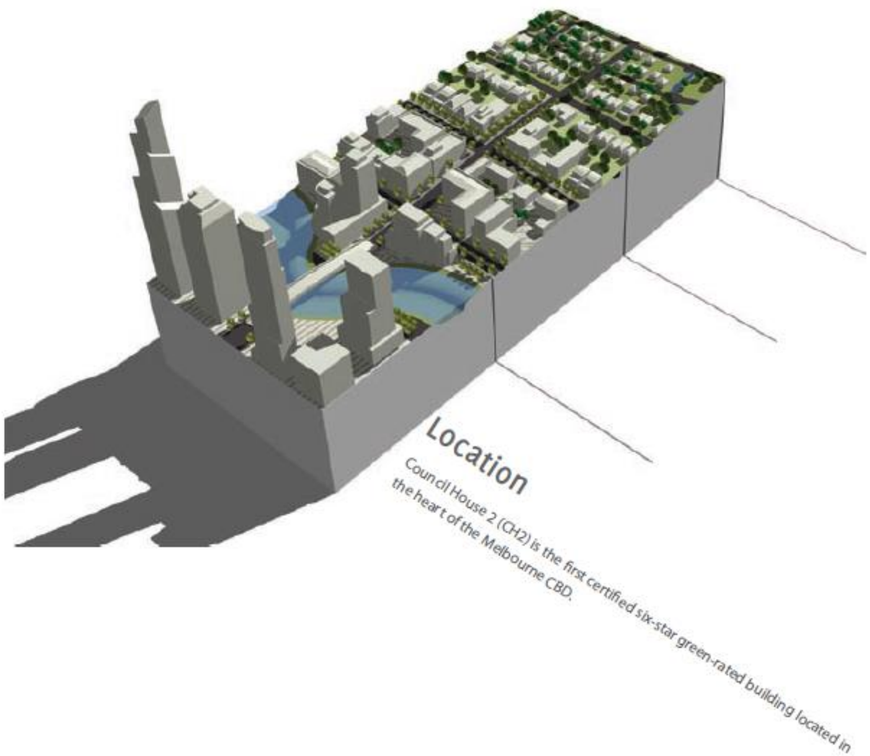
- Grassed drainage basins for small rainfall events (A)
- Conservation category wetland rehabilitated with native tubestock planting (B)
- Buffer to conservation category wetland (C)
- Detention basin with retained trees and vegetated swales to manage large rainfall events (D)
- Flush kerbing (E)

Other objectives include:

- Retention of mature trees
- Public amenities:
  - Seating and play areas dotted around the public open space
  - BBQs and picnic facilities
  - Small amphitheatre with shade and backdrop for small community events
- Water quality treatment
- Protection of conservation and natural values

Case Studies

Council House 2, Melbourne



Project characteristics

Project type:
Commercial redevelopment

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

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

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

Building and dwelling densities:
10-storey commercial office building housing approximately 540 staff

Project team composition

Architect

Landscape Architect

Civil Engineer

Ecological Engineer

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

Case Studies

Council House 2, Melbourne

Project overview

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

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

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

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

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

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

Case Studies

Council House 2, Melbourne

WSUD objectives

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

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

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

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

Site characteristics

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

Case Studies

Council House 2, Melbourne

WSUD solution

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

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

(City of Melbourne, 2008c)

Best Planning Practices employed

The WSUD BPPs employed in the project include:

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

Case Studies

Council House 2, Melbourne

Best Management Practices employed

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

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

Case Studies

Council House 2, Melbourne

Successes

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

Lessons learnt

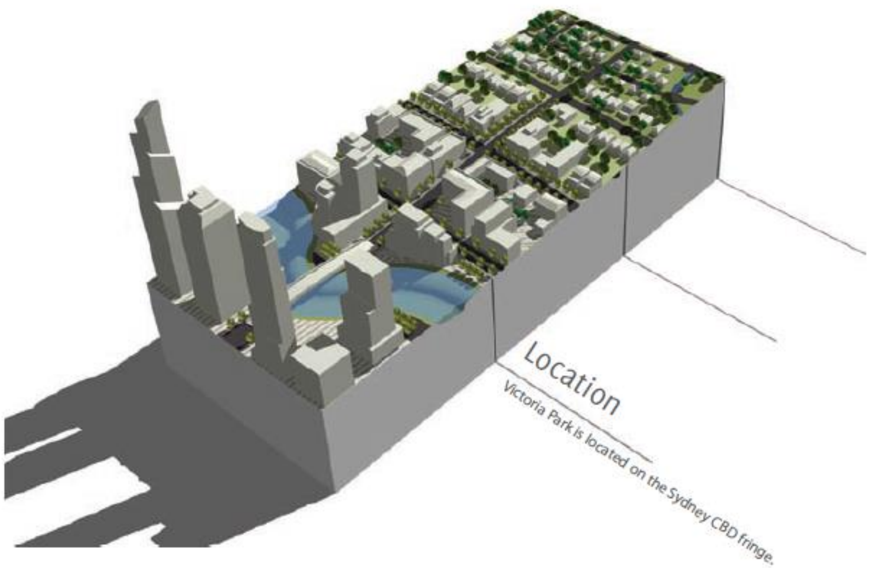
Water use assumptions and projections for CH2, together with anticipated costs, benefits and savings, indicate the need for integration of considerations of water conservation throughout design and operation. Currently, there is no viable payback for installing water recycling technologies due to the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

Case Studies

Council House 2, Melbourne

Case Studies

Victoria Park, Sydney



Project characteristics

Project type:
Brownfield

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

Site area:
24 ha

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

Project Team Composition

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

Others: Site Remediation Specialist / Public Artist

Case Studies

Victoria Park, Sydney

Project overview

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

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

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

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

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

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

Case Studies

Victoria Park, Sydney

WSUD objectives

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

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

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

Site characteristics

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

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

Case Studies

Victoria Park, Sydney

WSUD Solution

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

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

Case Studies

Victoria Park, Sydney

Best Planning Practices employed

The WSUD BPPs employed in the project include:

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

- *BPP 3: Integration of WSUD in Multiple Use Public Open Spaces* — The amenity of the public open space network is maximised by adopting an at-source and at-surface approach to management of stormwater runoff within streetscapes, thereby not encumbering the carrying capacity of the principle public park spaces with landscapes providing a stormwater management function.

- *BPP 4: Street Layout and Streetscapes* — Streets are designed with sufficient width to accommodate stormwater management within centre medians, parallel parking in both directions, one lane vehicle movement in both directions and pedestrian movement within the verges. Streets are graded to deliver stormwater runoff to the centre medians as sheet flow through specially designed kerb elements known as 'dolphins'. Longitudinal grades of streets are designed to convey flood flows through the site as a combination of bioretention swale, pipe and surface flow.

- *BPP 7: Waterscapes as Public Art* — A public art installation in the project's central park using treated stormwater celebrates the amenity value of urban stormwater in the urban environment.

Case Studies

Victoria Park, Sydney

Best Management Practices employed

The WSUD BMPs employed in the project include:

- *BMP 1: Demand Management*—The planting palette for landscapes was selected to be resilient to local free-draining soils and endemic to the local area, while being aesthetic and enhancing a sense of place.

- *BMP 3: Stormwater Harvesting* — Treated stormwater is collected from bioretention swales within a holding tank for use in the public art installation (additional treatment is provided by non-chemical electromagnetic filtration). Back-up water supply is provided by groundwater drawn from local un-confined alluvial (sand) aquifer. Treated stormwater is used to recharge the local un-confined alluvial (sand) aquifer and is recovered for irrigating public realm landscapes.

- *BMP 9: Bioretention Systems* — Bioretention swales are incorporated within the centre median of all east–west oriented streets.

Case Studies

Victoria Park, Sydney

Successes

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

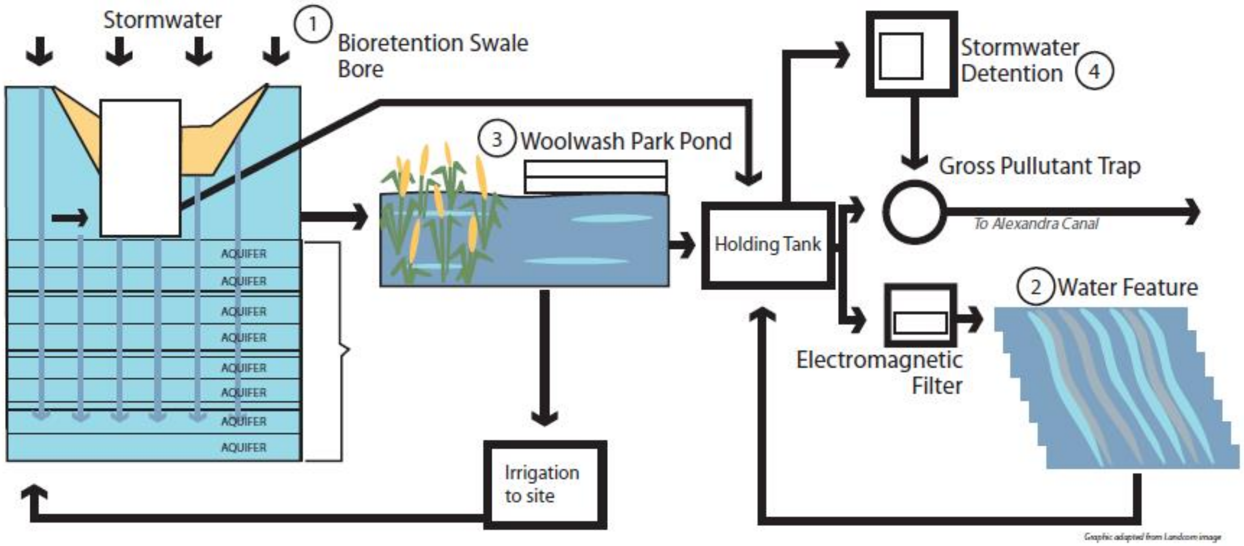
Lessons learnt

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

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

Case Studies

Victoria Park, Sydney



Case Studies

Yatala, Gold Coast

Project characteristics

Project type:
Greenfield

Landuse:
Industrial area development

Site area:
61.5 ha

Project team composition

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

Case Studies

Yatala, Gold Coast

Project overview

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

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

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

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

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

Case Studies

Yatala, Gold Coast

WSUD objectives

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

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

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

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

Site characteristics

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

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

Case Studies

Yatala, Gold Coast

WSUD solution

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

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

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

Case Studies

Yatala, Gold Coast

Best Planning Practices employed

The WSUD BPPs recommended for this project included:

- *BPP 1: Steep and Undulating Sites* — For conceptual planning purposes, all areas of the site with a slope of greater than 15% were considered unsuitable for development due to the likely costs of development and potential visual impact as a result of large cuts, batters, and retaining walls.
- *BPP 2: WSUD on Flat Sites* — Combinations of at-source and end-of-pipe applications of bioretention were used as the best stormwater treatment outcome. The conceptual design recognised the advantages of a distributed at-source system of bioretention treatment devices are that the number of allotments connected to each device can be minimised. This is a benefit for the establishment timeframe, commissioning, and hand-over to council.
- *BPP 4: Street Layout and Streetscapes* — Topography was recognised as a constraint on any proposed road networks within the site. The preliminary concept design studies identified a potential road network that would support either at-source or end-of-pipe bioretention, depending on grade.

Case Studies

Yatala, Gold Coast

Best Management Practices employed

The WSUD BMPs employed in this project include:

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

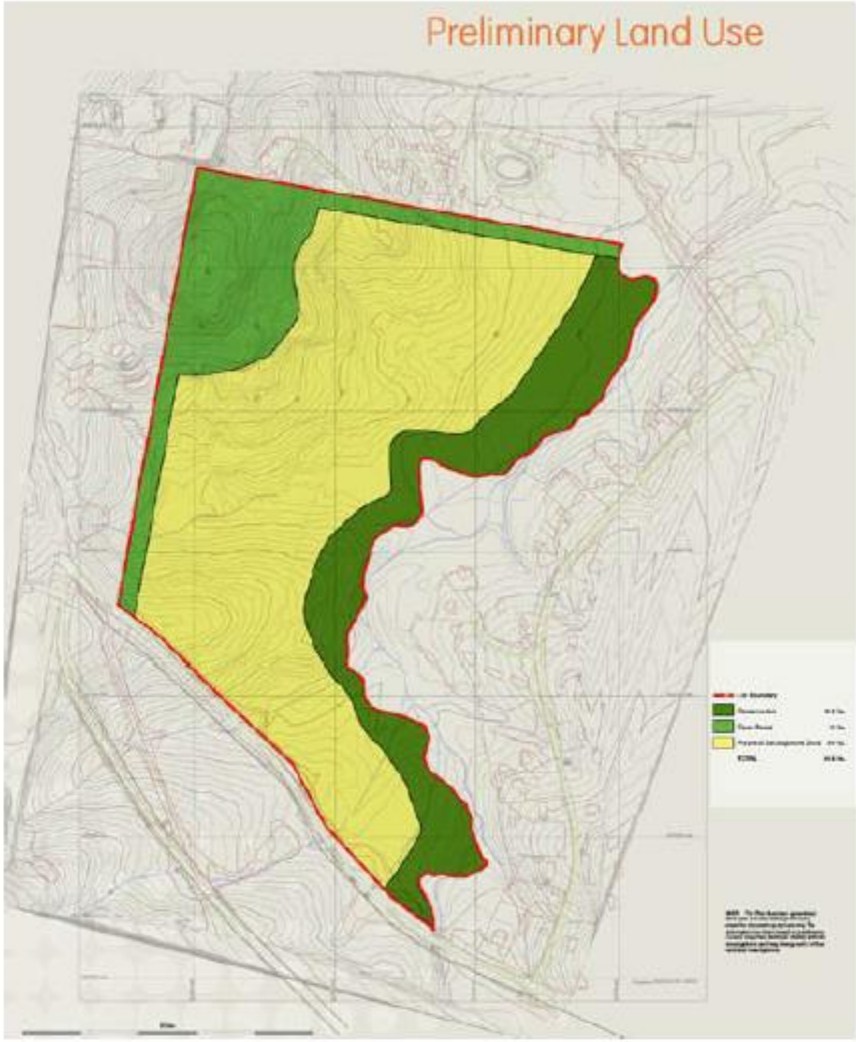
- *BMP 9: Bioretention Systems*—All of the site's impervious areas, including the overflow from rainwater storage devices, discharge to bioretention devices that are not less than 2.5% of the total contributing catchment.

Case Studies

Yatala, Gold Coast

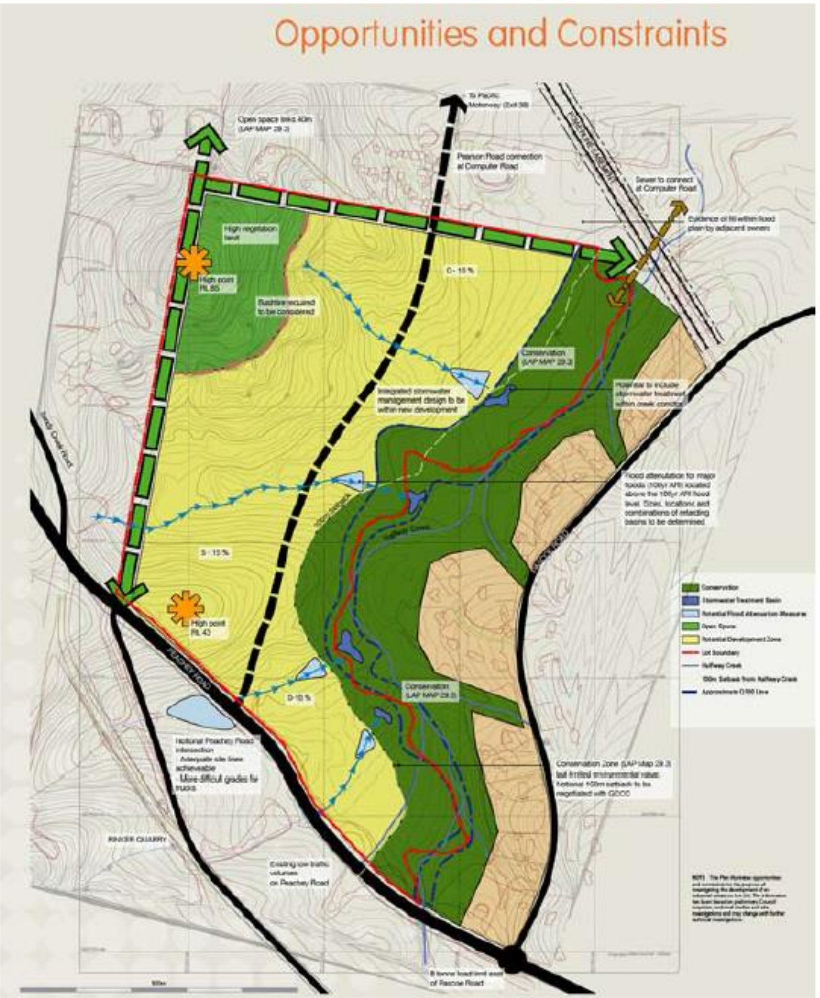
Successes

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



Case Studies

Yatala, Gold Coast



Case Studies

Bellvista, Sunshine Coast

Project characteristics

Project type:
Greenfield

Landuse:
Urban residential development

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

Building and dwelling densities:
405 residential lots with allotment sizes ranging from 300–700 m². The development density is approximately 15 lots/ha.

Project team composition

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

Case Studies

Bellvista, Sunshine Coast

Project overview

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

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

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

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

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

Case Studies

Bellvista, Sunshine Coast

WSUD objectives

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

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

Site characteristics

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

Case Studies

Bellvista, Sunshine Coast

WSUD solution

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

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

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

Case Studies

Bellvista, Sunshine Coast

Best Planning Practices employed

The WSUD BPPs employed in the project include:

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

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

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

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

Case Studies

Bellvista, Sunshine Coast

Best Management Practices employed

The WSUD BMPs employed in the project include:

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

Case Studies

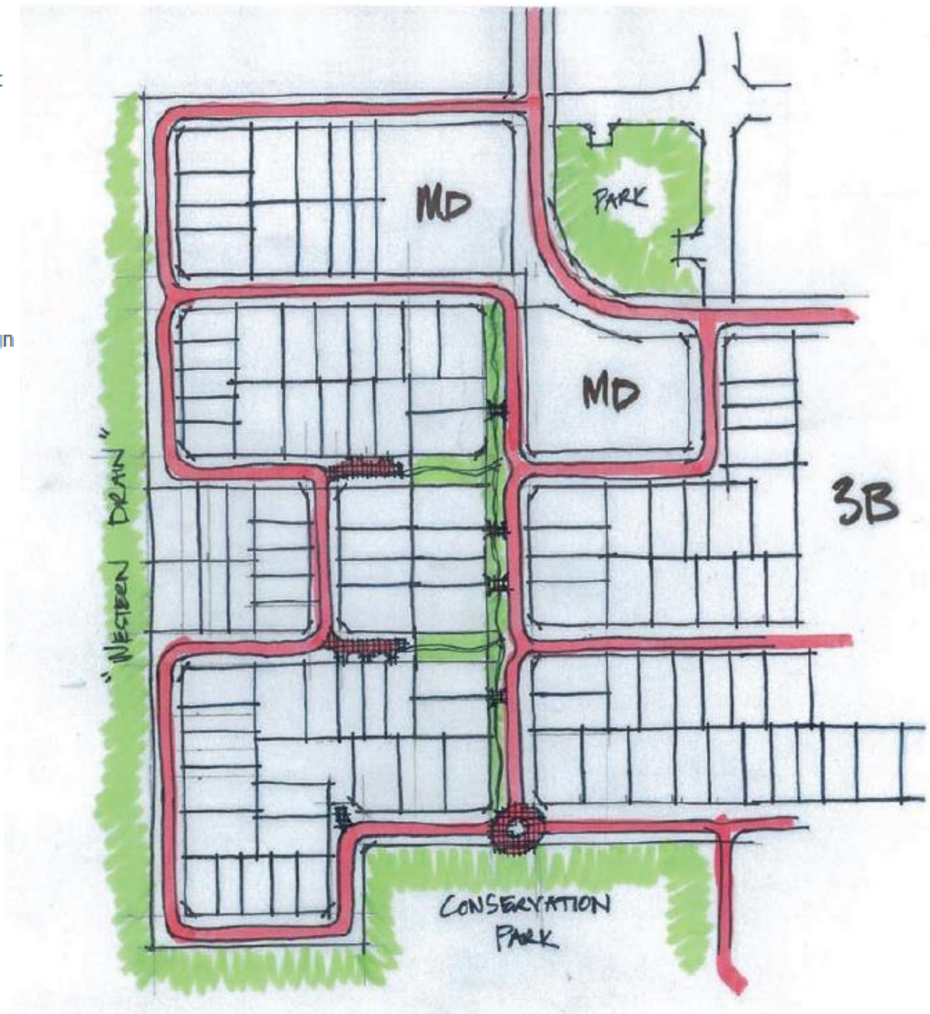
Bellvista, Sunshine Coast

Successes

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

Lessons learnt

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



Case Studies

Bellvista, Sunshine Coast

Case Studies

Coomera Waters, Gold Coast

Project characteristics

Project type:
Greenfield

Landuse:
Residential development

Site area:
476 ha

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

Project team composition

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

Case Studies

Coomera Waters, Gold Coast

Project overview

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

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

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

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

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

Case Studies

Coomera Waters, Gold Coast

WSUD objectives

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

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

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

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

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

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

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

Case Studies

Coomera Waters, Gold Coast

Site characteristics

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

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

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

Case Studies

Coomera Waters, Gold Coast

WSUD solution

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

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

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

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

Case Studies

Coomera Waters, Gold Coast

Best Planning Practices employed

The WSUD BPPs employed in the project include:

- *BPP 1: WSUD on Steep and Undulating Sites* — At-source and at-surface treatment in the form of vegetated and bioretention swales as well as road reserve bioretention rain gardens have been adopted at Coomera Waters. Where the adoption of these treatment solutions was not possible due to steeper topography, conventional collection and conveyance systems were installed with downstream wetlands and bioretention rain gardens collecting and treating the stormwater in public open space areas.

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

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

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

Case Studies

Coomera Waters, Gold Coast

Best Management Practices employed

The WSUD BMPs employed in the project include:

- *BMP 1: Demand Management* — Demand management is being achieved by water-efficient fittings and appliances and community education on water conservation.
- *BMP 2: Roofwater (Rainwater) Harvesting* — Roofwater is harvested in rainwater tanks, which are plumbed to relevant indoor uses.
- *BMP 4: Wastewater Treatment for Re-Use* — Recycled treated wastewater is delivered to households via a dual reticulation system to supply toilets and for garden irrigation.
- *BMP 7: Grass or Vegetated Swales* — Grassed swales are used as conveyance systems in the development. Because of the high number of driveway crossovers along local streets, shallow swale profiles were used (1 in 9 batters and maximum depth 0.22 m) allowing each driveway crossover to have the same profile as the swale. This avoided culverts under each driveway crossover.
- *BMP 9: Bioretention Systems* — Bioretention swales and bioretention raingardens are incorporated within the development in the road reserve, as well as in public open spaces.
- *BMP 10: Constructed Wetlands* — Constructed wetlands are integrated into precinct-level and regional-level parks as both stormwater management systems and as landscaped focal points, which residents are actively encouraged to experience.

Case Studies

Coomera Waters, Gold Coast

Successes

A multidisciplinary approach and extensive stakeholder consultation at the concept design phase of the project accessed leading-edge WSUD expertise and integrated WSUD principles at every level of the planning process. Following conceptual design, an integrated design approach was adopted to ensure the WSUD objectives and intent conceived as part of the urban conceptual design phases were delivered through the design, documentation, and construction.

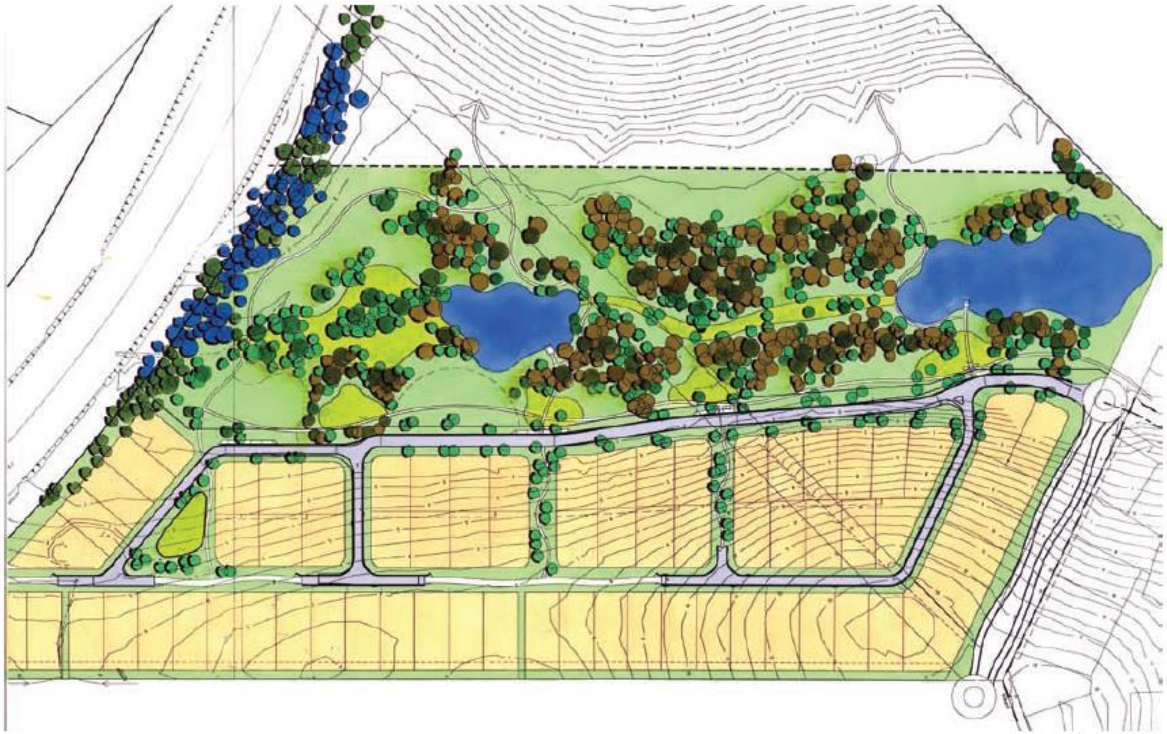
One of the important outcomes of the planning and design of Coomera Waters was the inclusion and successful collaboration with Gold Coast City Council throughout. This inclusive approach is certain to be replicated in other projects throughout Queensland by building on the experience and knowledge gained through this project, which has already attracted attention from the industry.

Lessons learnt

- Filter media protection using filtercloth and turf was used at Coomera Waters and has been a successful approach for protecting the filter media during construction.
- Bioretention swales can be successfully incorporated with driveways by providing local access shared driveways. This also reduced the risk of residents filling or changing the conveyance property of the swales.

Case Studies

Coomera Waters, Gold Coast



Case Studies

City of Busselton
Geographe Bay

traditional family home

Case Study No.1

Single Dwelling

The strategy demonstrated is to direct run-off from the roof and other impervious areas to a rain water tank and rain garden feature. In addition to treating stormwater the rain garden will provide a landscape feature that is an integral part of the landscape of the site.

This diagram presents one possible strategy for stormwater collection and treatment at a typical family home

Case study No. 1: STORM rating equation

Roof area 250m² + Impervious area 150m² − Soakwell 1.0m³ − Rainwater tank * 5m³ − Landscaping 29m² = STORM rating achieved 103%

City of Busselton
Geographe Bay

2 per unit

Case Study No.2

Grouped Dwelling

This strategy directs each unit's roof run-off to a tank with additional capacity than just for storm water events for toilet flushing, and direct run-off from paved areas to bioretention systems.

A site Storm rating of more than 100% can be achieved and potable water demand is reduced through re-use of rain water for toilet-flushing. The bioretention system will form part of the garden landscape.

This diagram presents a strategy for stormwater collection, treatment and re-use within a unit development

Case study No. 2: STORM rating equation

Roof area 600m² + Impervious area 350m² − Soakwells 8m³ − Rainwater tank 6m³ 4 tanks − Landscaping 68m² = STORM rating achieved 102%

Case Studies

commercial/ mixed use

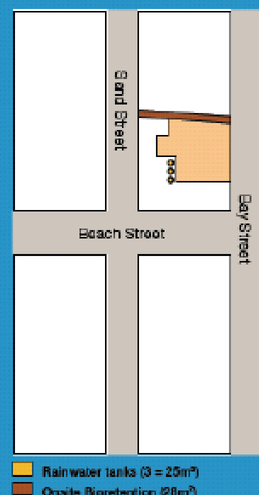
Case Study No.3

City of Busselton
Geographe Bay

Commercial / Mixed Use / Apartments

This strategy utilises a combination of rainwater tanks and rain gardens as treatment options. Rainwater tanks collect roof run-off for toilet flushing and other on-site re-use. In addition, bioretention systems along the driveway collect some roof run-off and treat pavement and driveway run-off.

This diagram presents a strategy for stormwater collection, treatment and re-use at an apartment block.



commercial/ mixed use

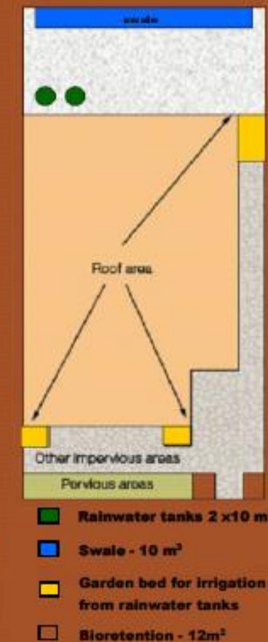
Case Study No.4

Industrial Development

This strategy directs run-off from the roof to rainwater tanks bioretention systems. Due to limited space available, a combination of planter box and 'in-ground' bioretention systems is used. The bioretention systems form part of the garden landscape.

Planter boxes are more versatile than 'in-ground' systems as they can be retrofitted to existing developments.

This diagram presents a strategy for stormwater collection, treatment, and re-use at a typical warehouse/wholesale site.



Case study No. 3: STORM rating equation

Roof area $3500m^2$ + Impervious area On site $750m^2$ − Swales & Soakwells $16m^3$ − Rainwater tanks * $3 \times 25m^3$ − Onsite Bioretention $12m^2$ = Total STORM rating achieved 103%

Case study No. 4: STORM rating equation

Roof area $1400m^2$ + Impervious area $850m^2$ − Rainwater tanks * $2 \times 10m^3$ − Trafficable soakwell $12m^3$ − Bioretention system and swale $13m^2 + 10m^3$ = STORM rating achieved 102%

*This size of tank will only provide for stormwater management, larger tanks will be required for rainwater harvesting

Case Studies

Residential

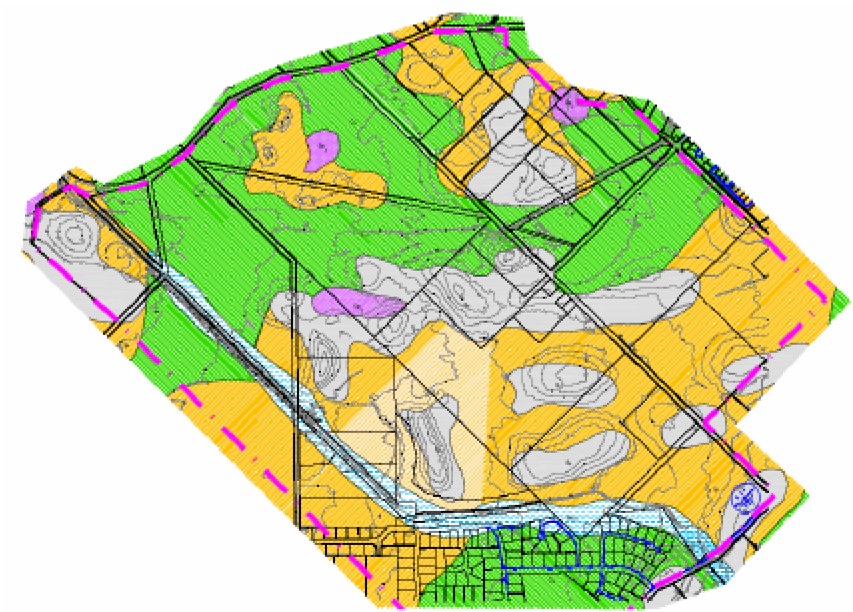
The following is a worked example which briefly outlines the buildup of information overlays and how this is used to derive an overall WSUD design philosophy. The sizing, location and number of structural controls is specific for any given site and the designs are purely indicative and would need to be the subject of detailed site investigations and hydraulic modelling.

Step 1: Aerial assessment

Aerial photography showing the site subject to residential development. Note the degraded creeklines which cross the site from east to west.

Step 2: Soil types

Extract from the Environmental Geology 1:50,000 mapsheet for the area showing broad soil types. The site is characterised by low sandy Bassendean dunes (S8) and thin Bassendean sands (S10) overlying sandy clay Guildford Soils (Cs). The area is interspersed with watercourses (Msc1) and peat rich sands (SP2) – which implies wetland features.

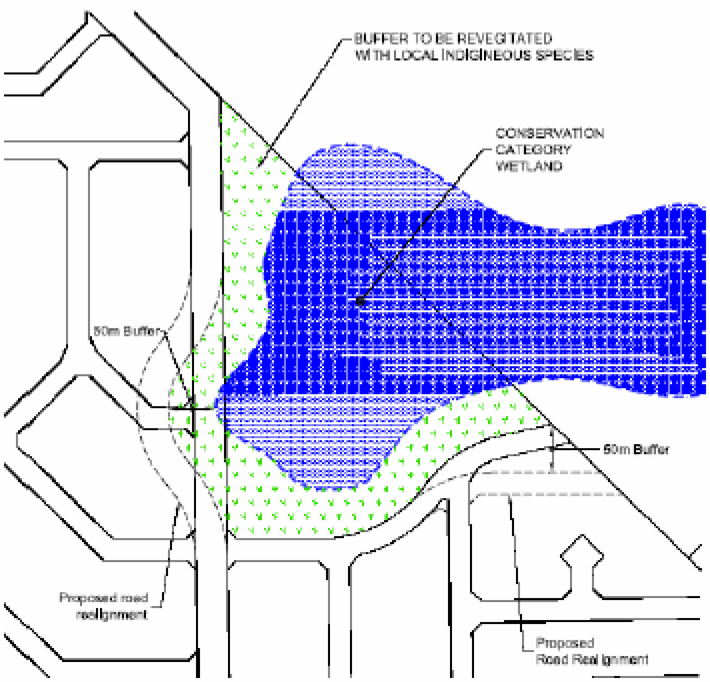


Case Studies

Residential

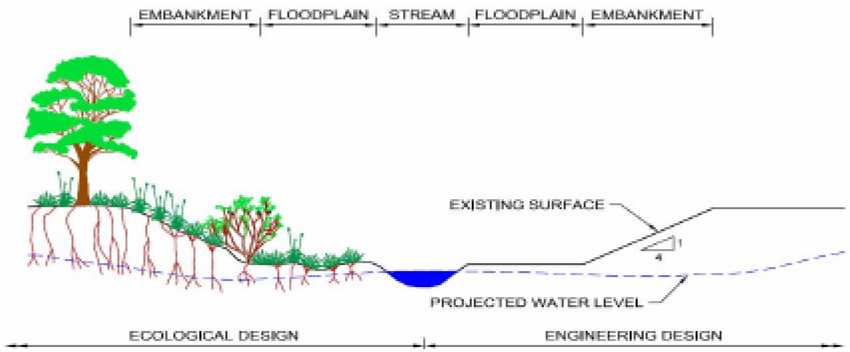
Step 3: Approximate wetland extent

Field investigation results in the delineation and reclassification of an important wetland to 'Conservation' category. A nominal 50m buffer zone will need to be incorporated within the future residential layout. The buffer is not to include irrigated and fertilised turf, but will be revegetated with locally indigenous species suited to the soils of the area to assist interception and uptake of nutrients. The wetland will become an integral component of a future Multiple Use Corridor for the estate (see Step 6).



Step 4: Vegetation layout relative to engineering design

Little more than surface drains, the existing creeklines which naturally drain the site are to be retained and restored to 'living streams'. These creeks will be reconstructed to provide the necessary hydraulic functions, but will also be ecologically designed to provide wetland habitat and provide for biofiltration. Once restored, the creeklines will become focal points within the estate for passive recreation and will accommodate suitably designed and located bike and walk pathways.



Case Studies

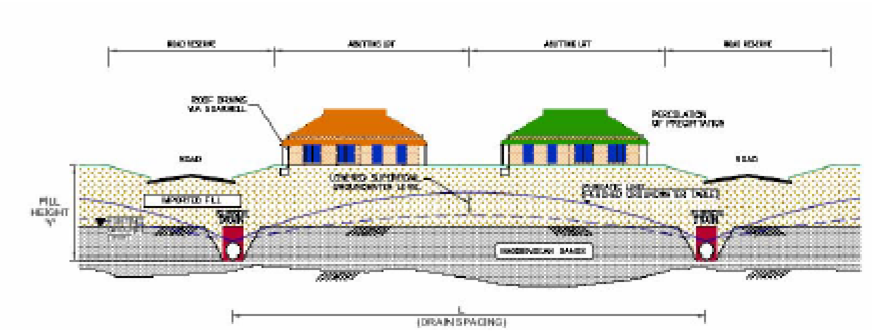
Residential

Step 5: Fill height to drain spacing

As the site is subject to extensive winter waterlogging (Guildford clays and loams), fill will be required to achieve adequate separation distances between building footings and perched watertables (once fill is placed). Fill is commonly a major expense for urban development in palusplain areas (Guildford soils subject to waterlogging) and efforts to reduce the amount required is desirable and cost effective. Subsoil drainage promotes onsite infiltration, reduces the amount of fill required, promotes groundwater storage and hence reduces peak stormwater discharge and, when combined with appropriate soil amendment, can reduce phosphorus export from the site.

The use of permeable Spearwood Sands (yellow sand) with a phosphorus retention index (PRI) greater than 15 is specified for use as imported fill. This means that soakwells can now be used at the lot-level and bottomless side entry pits and swales at the street-level to promote onsite infiltration.

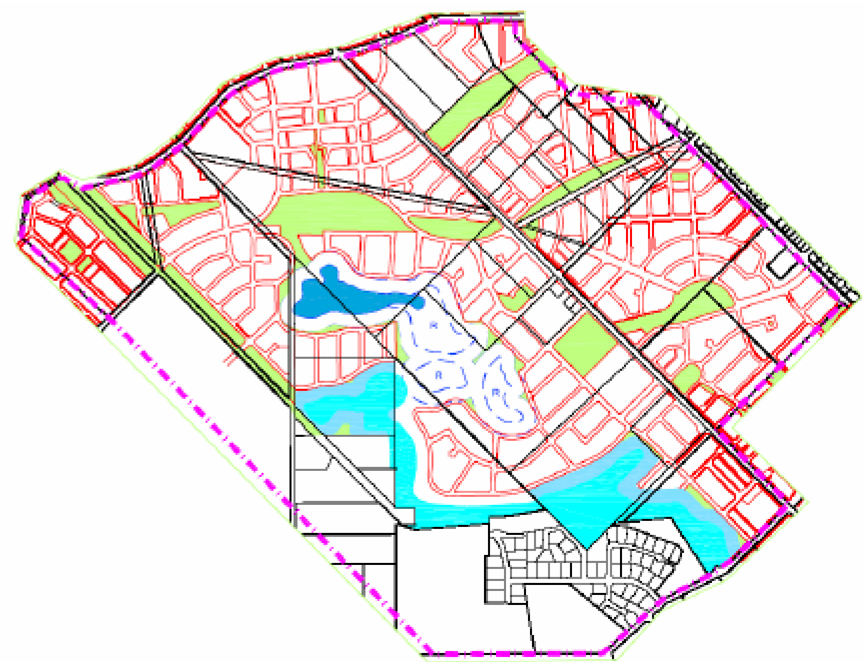
Subsoil drainage systems will ultimately discharge via bubble-up pits to floodplain/levee systems associated with the restored creeklines.



Step 6: Structure plan layout

The final estate layout starts to take shape and becomes the basis for Structure Planning and/or Subdivision design.

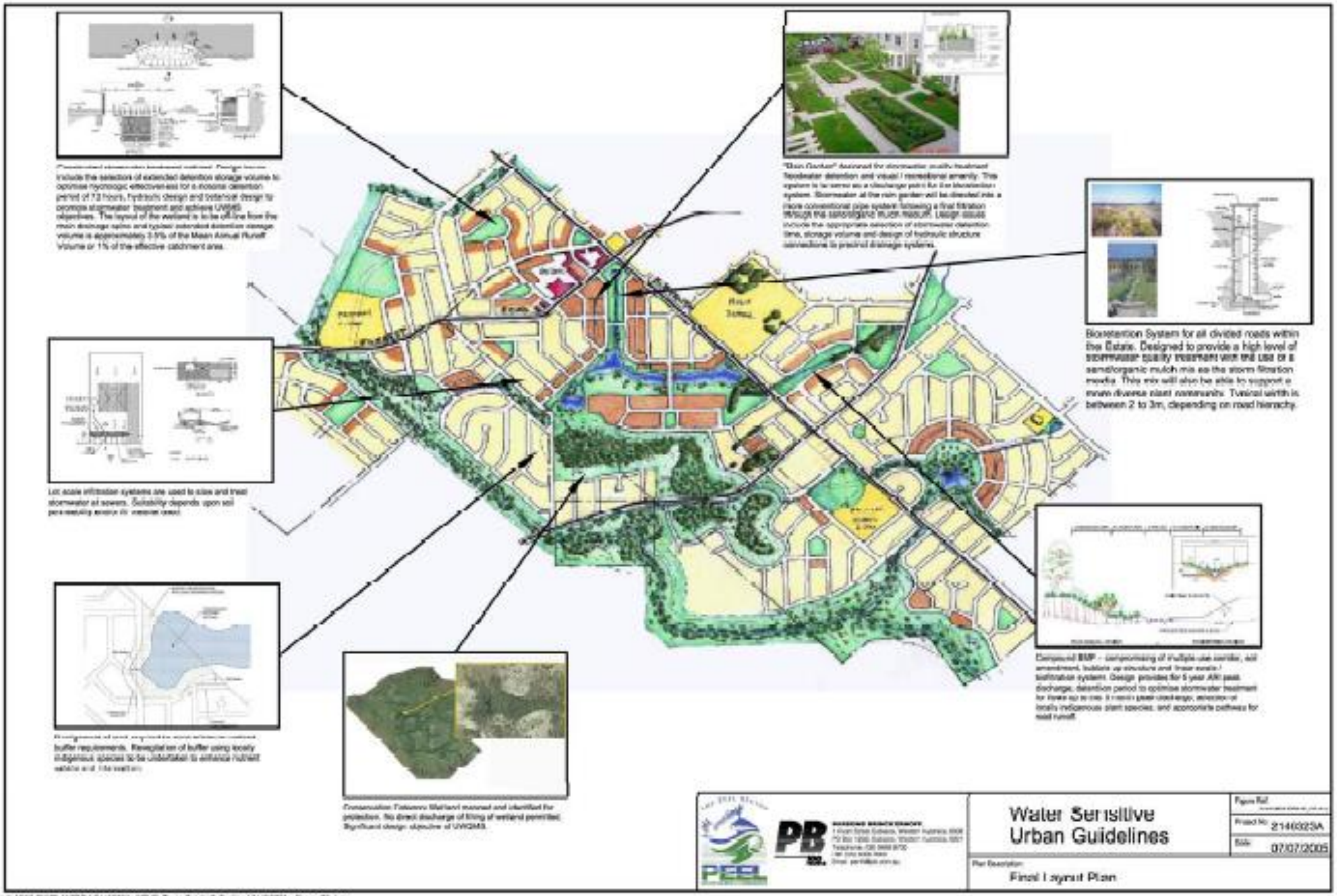
Road lengths are kept to a minimum to 'spread' stormwater volumes and promote onsite infiltration. Multiple use corridors are established around the restored creeklines and wetland chain and provide permeability and walkability for the future estate. Corridor linkages to the major river in the area are re-established.



Case Studies

Residential

Step 7: Final estate layout



Case Studies

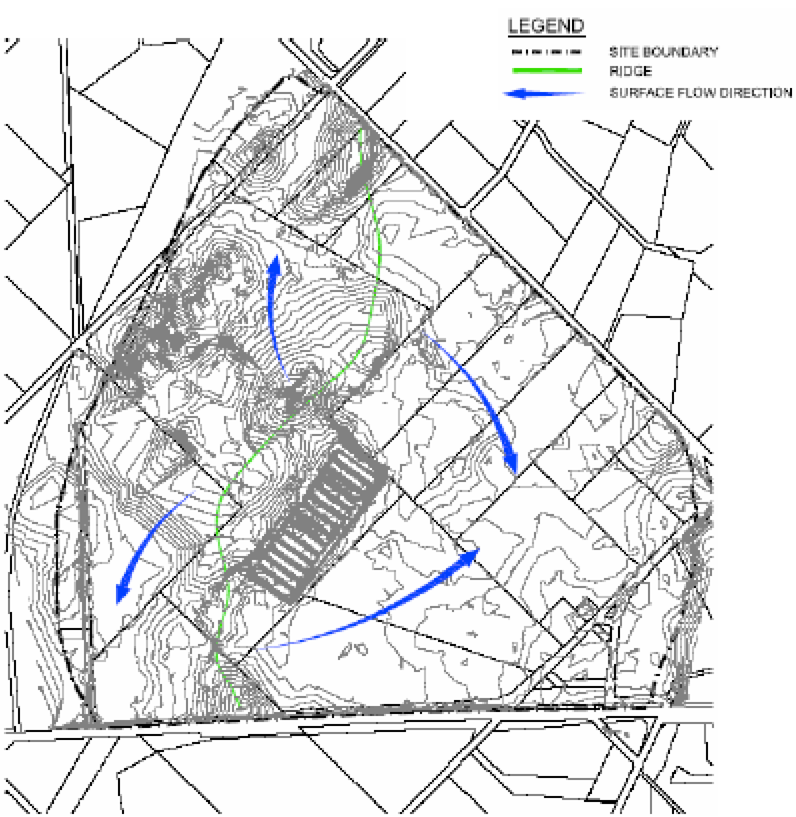
Commercial

The following is a worked example which briefly outlines the buildup of information overlays and how this is used to derive an overall WSUD design philosophy. The sizing, location and number of structural controls is specific for any given site and the following designs are purely indicative and would need to be the subject of detailed site investigations and hydraulic modelling.

Step 1: Surface flow

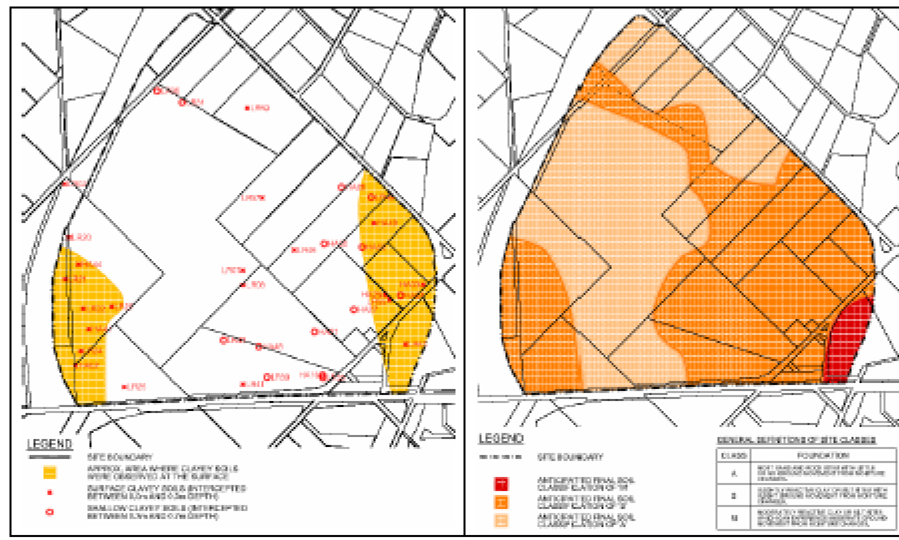
The area has a history of drainage problems. Factors contributing to this include a high water table, clay subsoils and a relatively flat terrain.

Topography for the site shows it can be effectively divided into two distinct surface water subcatchments.



Step 2: Soil profile & Step 3: Site classification zones

Contrary to the above surface water divide, geotechnical surveys determine that the subsoil clay surface across the site is uneven and slopes. This means shallow groundwater flows in a northerly direction. The surface and subsurface drainage systems therefore need to be considered with this mind.

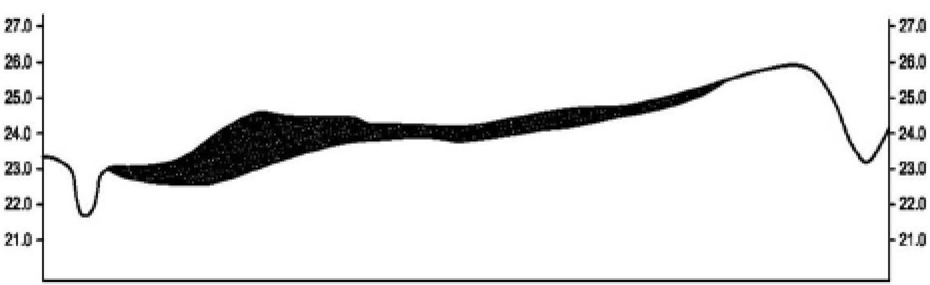


Case Studies

Commercial

Step 4: Sub-surface flow

Further geotechnical testing is undertaken across the site to determine the suitability of the onsite soils for the construction of building footings. Testing confirms the site comprises a thin veneer of Bassendean Sands (generally <1m) overlying Guildford clays.



Step 5: Road networks

Vehicular access to the commercial estate is important for the viability of the development. The major feeder road provides the conceptual 'spine' for the development and future drainage design. In major storms (>30 years) the roadway will become the flood outlet as the drainage system will inevitably backup. Two detention basins (B1 & B2) are required to achieve the 1:10 year pre-development stormwater retention design objective for a commercial estate.

Case Studies

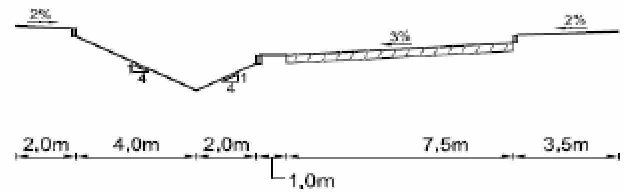
Commercial

Step 6: Flood paths and drain cross sections

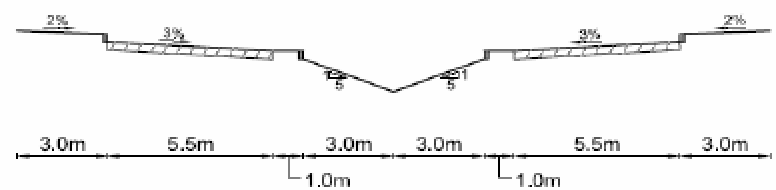
As the site is subject to extensive winter waterlogging (Guildford clays and loams), fill will be required to achieve geotechnical requirements for building footings. Subsoil drainage is not possible because the quantities of fill that would be required across the site are prohibitively expensive.

Some sand fill is, however, required to enable reshaping of the site surface contours to enable the surface drainage system to drain towards the outlet (at B2). The road hierarchy is designed and road lengths are kept to a minimum to reduce peak discharge rates as much as possible.

Events grater than 1:10 year are designed to overspill basin B2 and inundate the low point of the site (an ephemeral wetland), rather than nearby properties. The frequency and duration of this inundation and quality of stormwater will not adversely impact the ephemeral wetland.



Typical Single Lane Configuration



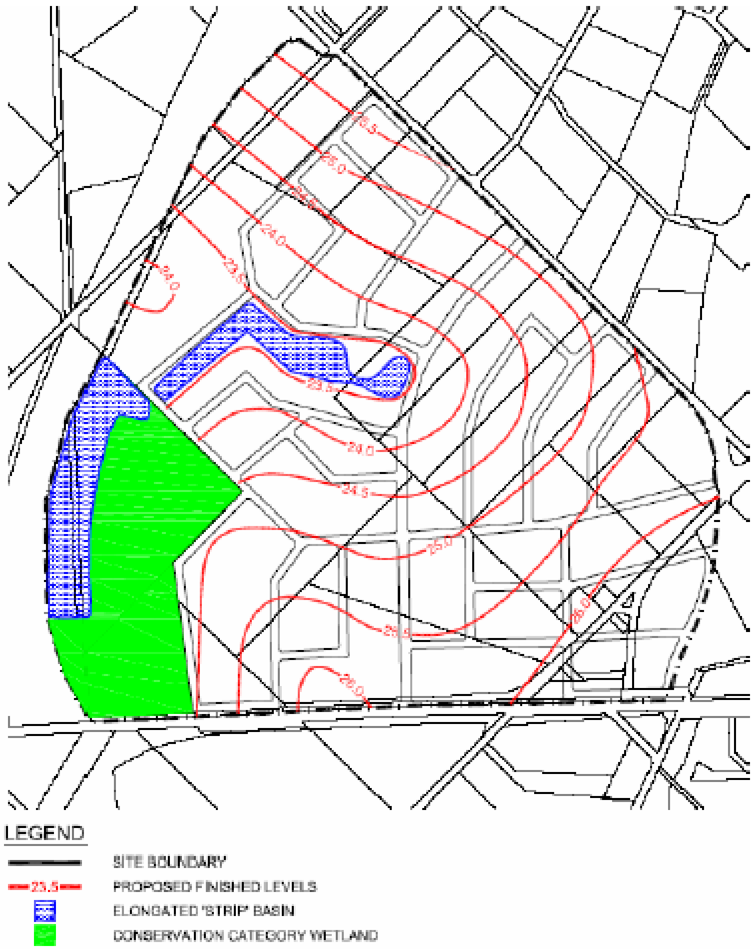
Typical Divided Road with Central Biofiltration / Swale

Case Studies

Commercial

Step 7: Road networks and proposed finished levels

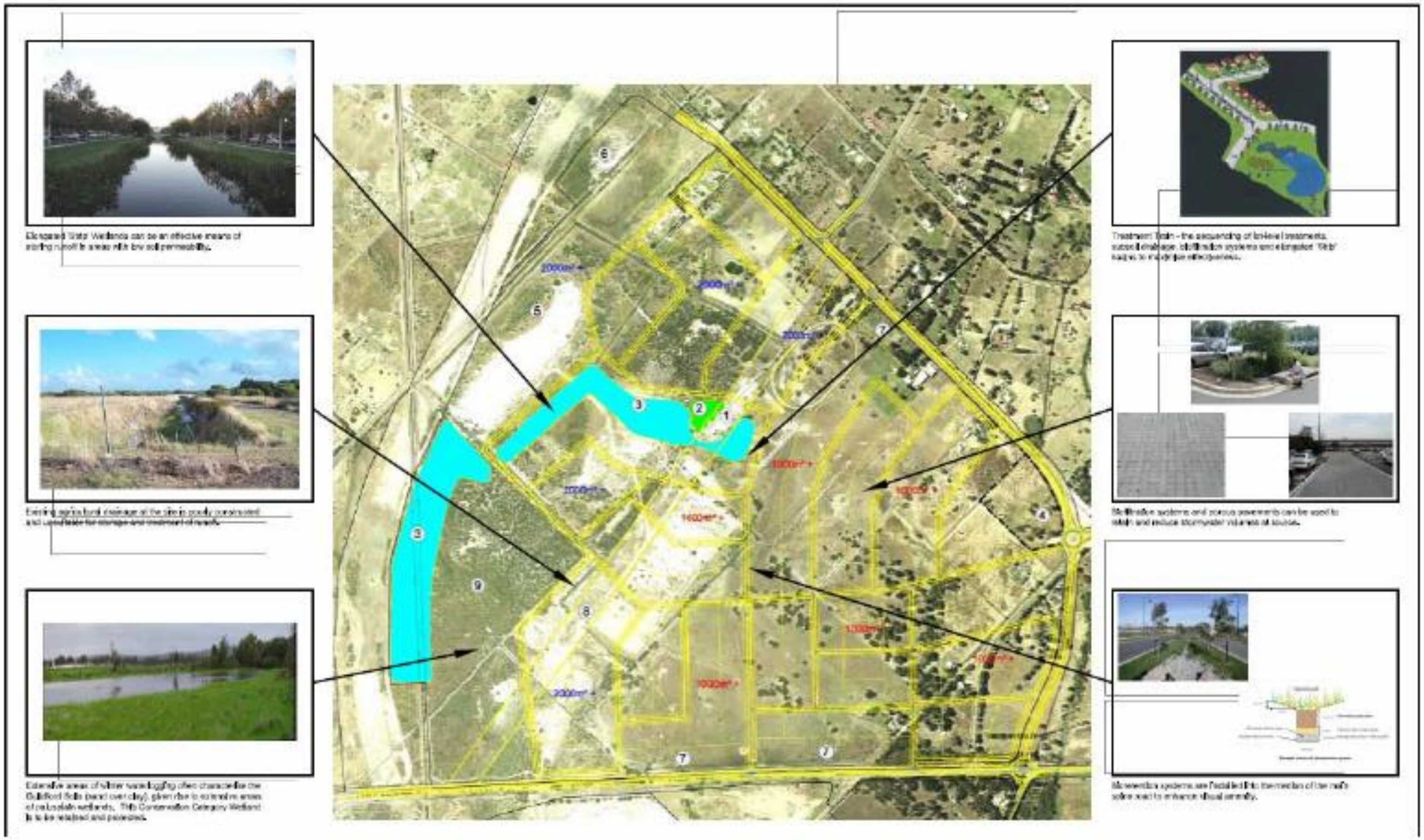
Single lane and divided road reserves are designed to incorporate biofiltration swales to promote onsite infiltration.



Case Studies

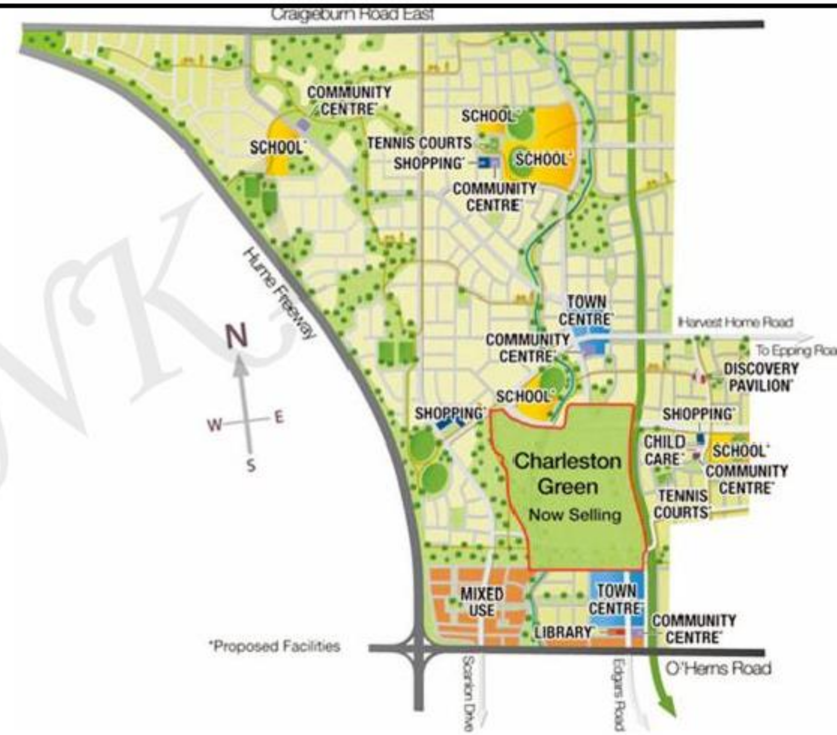
Commercial

Step 8: Final estate layout



Case Studies

澳大利亚奥罗拉新城开发

项目名称	类型	现状条件	图片
澳大利亚奥罗拉	新城开发	面积：650ha，区域将容纳 2500 人居住。规划要求建成混合居住的节能型住区，绿色廊道、雨水综合管理项目将被设计。	

Case Studies

澳大利亚维多利亚伯恩赛德公共空间恢复重建

澳大利亚维多利亚伯恩赛德	公共空间恢复重建	面积约 35ha。出于保护现状湿地以及净化流入港口的水质的需要，WSUD 被认为是规划建设的核心内容。规划设计了 32ha 的公共空间以及 1.7ha 的湿地。

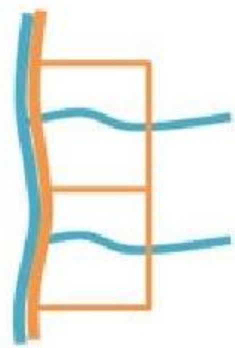
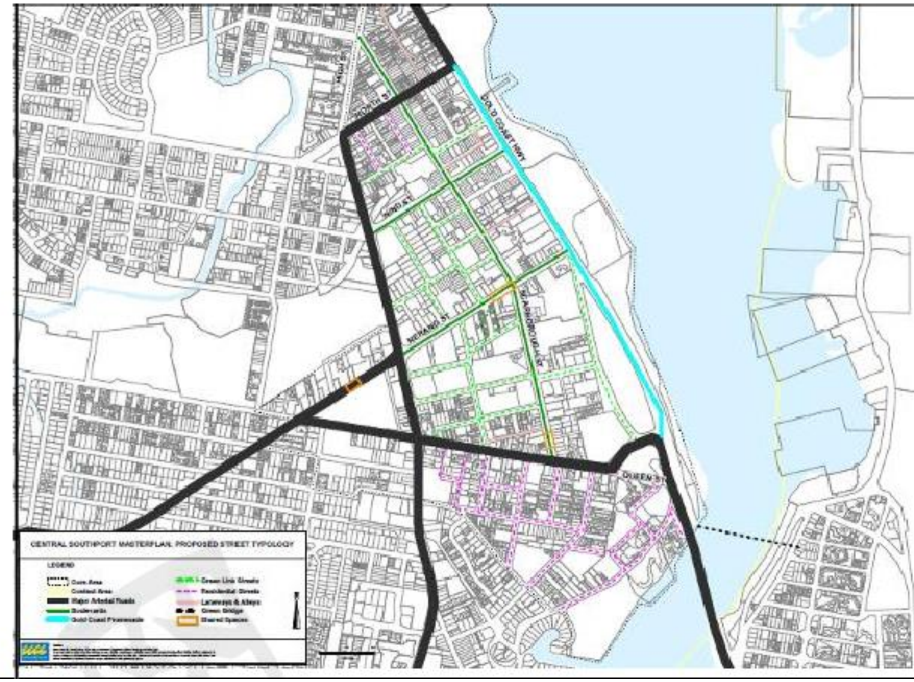
Case Studies

澳大利亚Bellamack新开发住宅

澳大利亚 Bellamack	新开发住宅	总面积：118.6ha 现状自然条件较好，规划要求城市开发面积为 75ha。规划要求保留现状生态特色，建设可持续住宅区。

Case Studies

道路布局模式

模式一		黄金海岸南港区规划	

Case Studies

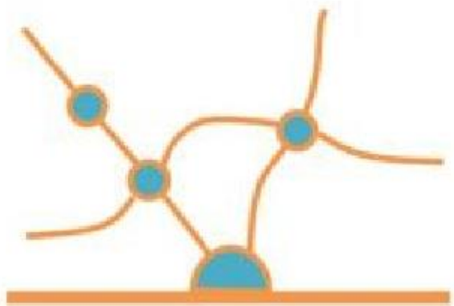
道路布局模式

模式二		荷兰 Duyfrak	

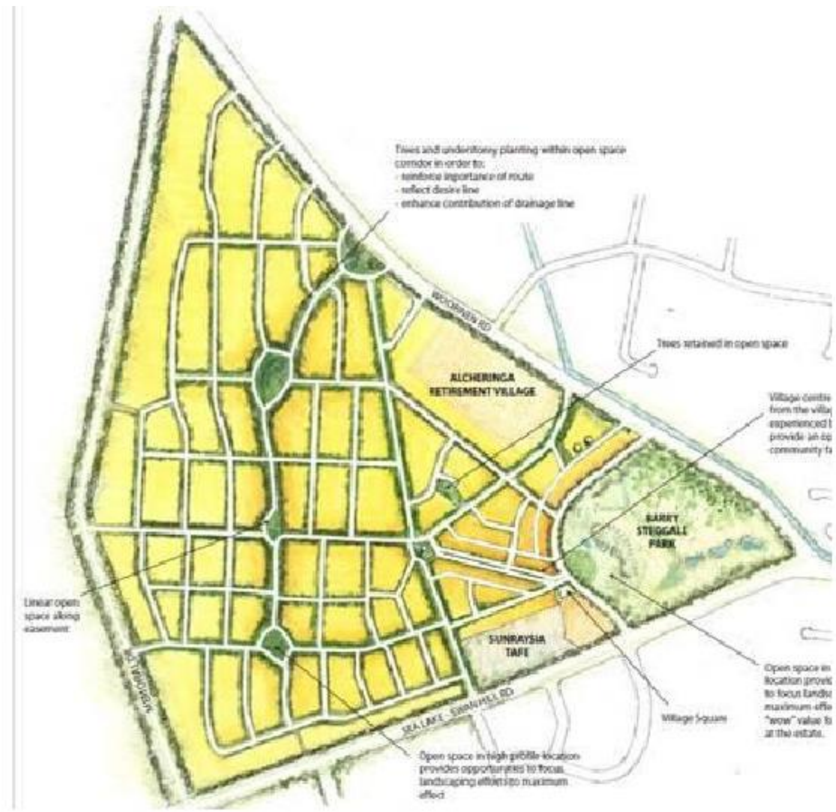
Case Studies

道路布局模式

模式三



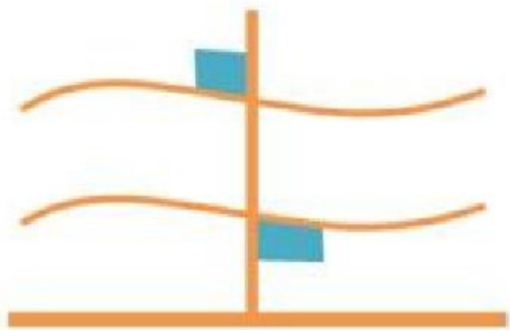
澳大利亚塔桥山小区



Case Studies

道路布局模式

模式四

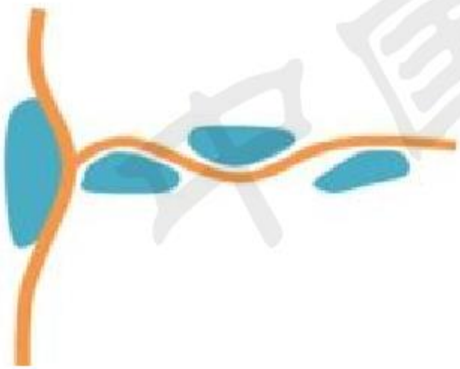


墨尔本埃平北小区

Case Studies

道路布局模式

模式五

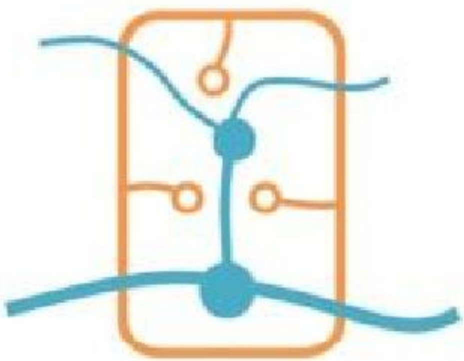


澳大利
亚奥罗拉

Case Studies

道路布局模式

模式六



昆士兰伊普斯威奇

Case Studies

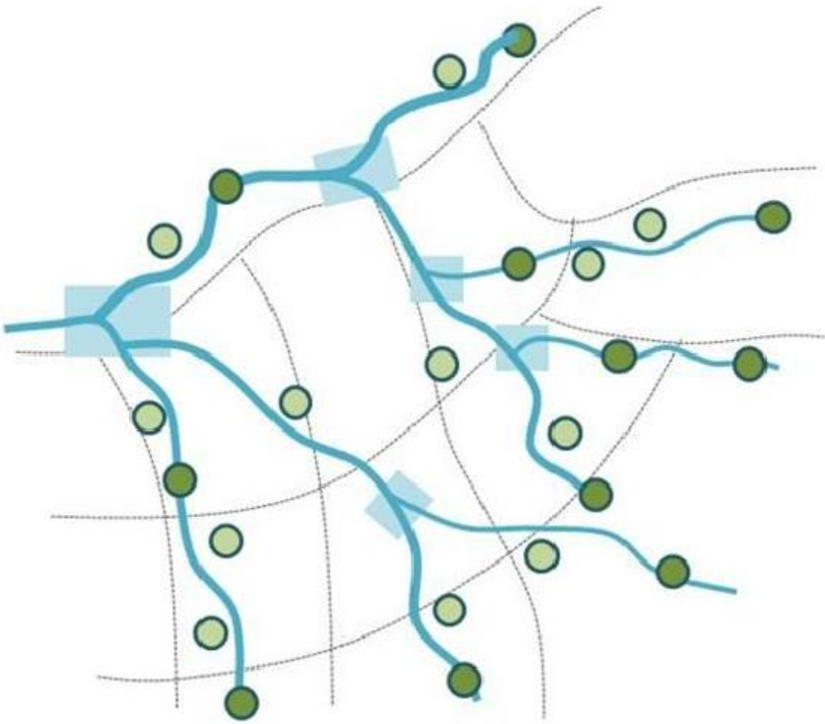


图 3-7 水生态体系示意图

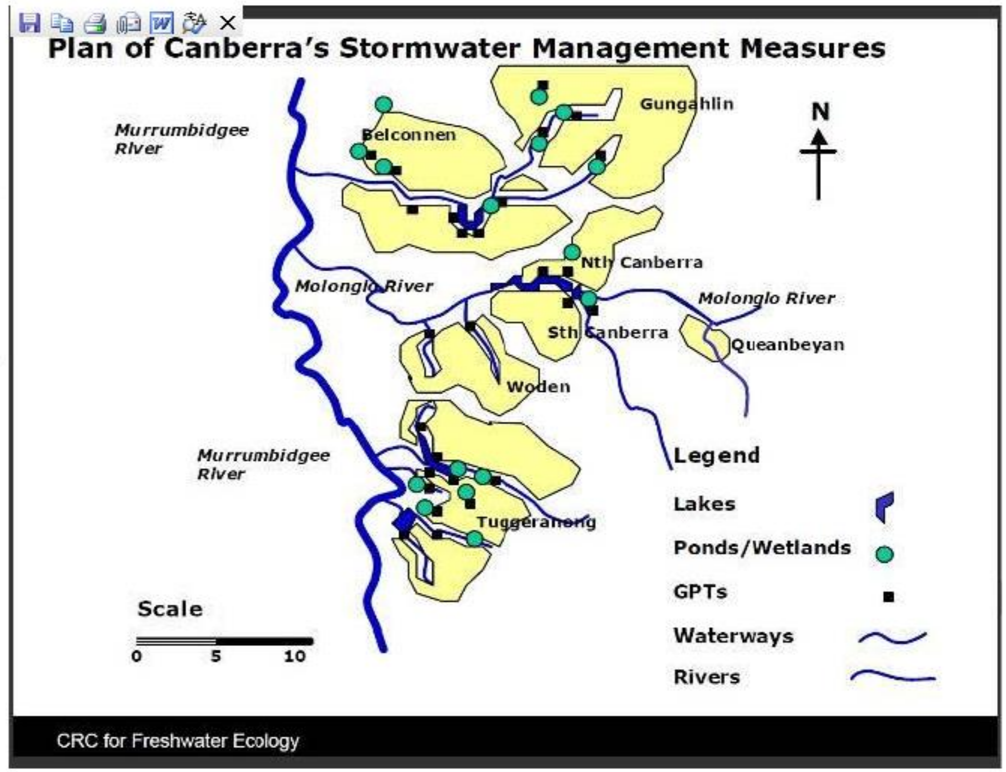


图 3-8 堪培拉水敏要素布局图[59]

Case Studies

公共开放空间布局—澳大利亚墨尔本山谷胡社区

独立式公共开放空间布局		节约成本但景观效果不佳，管道压力较大	墨尔本山谷胡社区	

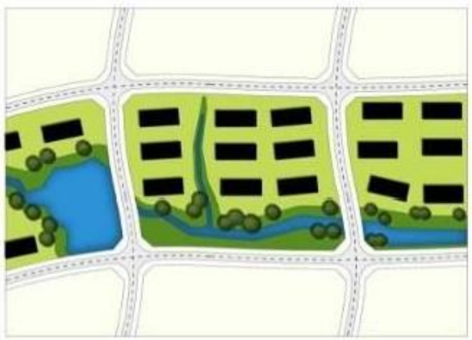
Case Studies

公共开放空间布局—澳大利亚谢珀顿雅逸小区

点式公共开放空间布局		提升空间品质，缓解管道压力但须较高成本	墨尔本谢珀顿雅逸小区	

Case Studies
公共开放空间布局—澳大利亚埃平北小区

集成式公共开放空间布局



提升环境品质，缓解管道压力

墨尔本埃平北小区

Case Studies

Biofilters in the Shire of Serpentine Jarrahdale (100 Pages)

Case Studies

City of Kwinana Parkfield Lake Retrofit (60 Pages)

Case Studies

A Business Case for Best Practice
Urban Stormwater Management

Version 1.1 – September 2010

waterbydesign

Case Studies

A Business Case for Best Practice Urban Stormwater Management: Case Studies

Version 1.1 – September 2010

A companion document to A Business Case for Best Practice Urban Stormwater Management

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Case Studies

Case Studies

Water Sensitive Urban Design

Principles and Inspiration for Sustainable Stormwater Management in the City of the Future

- Manual –

Published by jovis jovis Verlag GmbH, Kurfürstenstraße 15/16, D-10785 Berlin,
in March 2011
ISBN 978-3-86859-106-4

Case Studies

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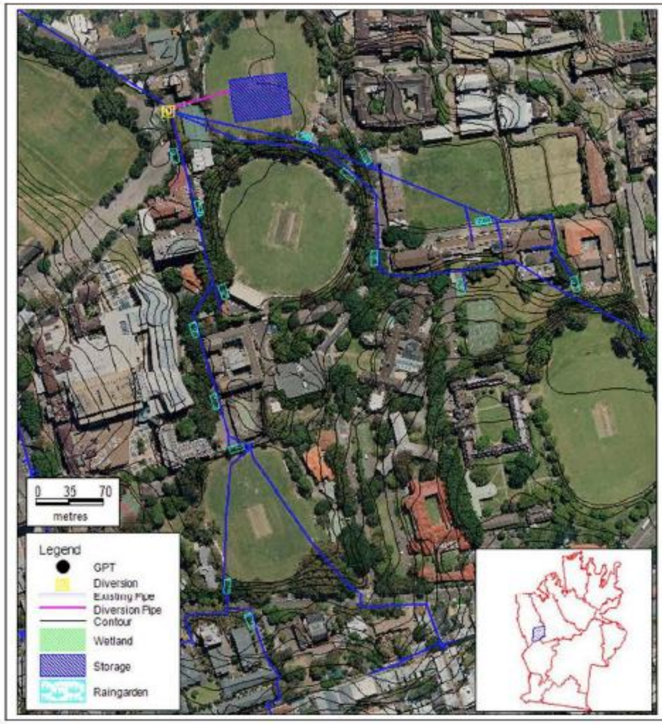
Sydney University: WSUD & Stormwater Harvesting Opportunity

Description: Distributed raingardens throughout campus treating stormwater runoff from hardstand area before entry into piped network and harvesting to a u/g storage located near Sydney University Oval No. 2 (currently represented as a flooding hotspot) for local reuse.

Opportunity to develop a University wide stormwater harvesting and reuse strategy with storages sized to meet POS.

The WSUD and stormwater harvesting system consists of the following elements:

- Diversion(s) from main drains
- directing upstream flows to POS via raingardens
- underground storage (as part of local stormwater harvesting system)



Concept Infrastructure

WSUD element	Preliminary sizing
GPT	CDS Unit
Raingarden	1600 m2
Storage (Type/ volume)	u/g / 1.4 ML

Pollutant Removal

Pollutant	Annual Load removed (tonnes)
TSS	23.76
TN	0.23
TP	0.04
Gross Pollutants	5.76

Stormwater Harvesting

Source-Demand	Measure
Catchment area	33.2 ha
Source Yield	222 ML
Reliability	52%
POS Demand	72 ML

Levelised Cost

Parameter	Unit	Cost	Benchmark Costs (PW)
Harvested SW volume	$/kL	1.56	$10.8/kl
TN removed	$/kg	495.86	$2000/kg

Synergies

Flood
Utilisation of nominated POS area for retarding basin to alleviate flooding for Orphan School Drain

Amenity

Current Amenity value

- Areas of combined active & passive open space throughout university

Landscape Amenity Potential

- Greening of POS
- WSUD features throughout university to enhance landscape
- Educational benefits

Additional Infrastructure

Earthworks to create flood storage

Figure 31 Example major public open space opportunity template

Draft

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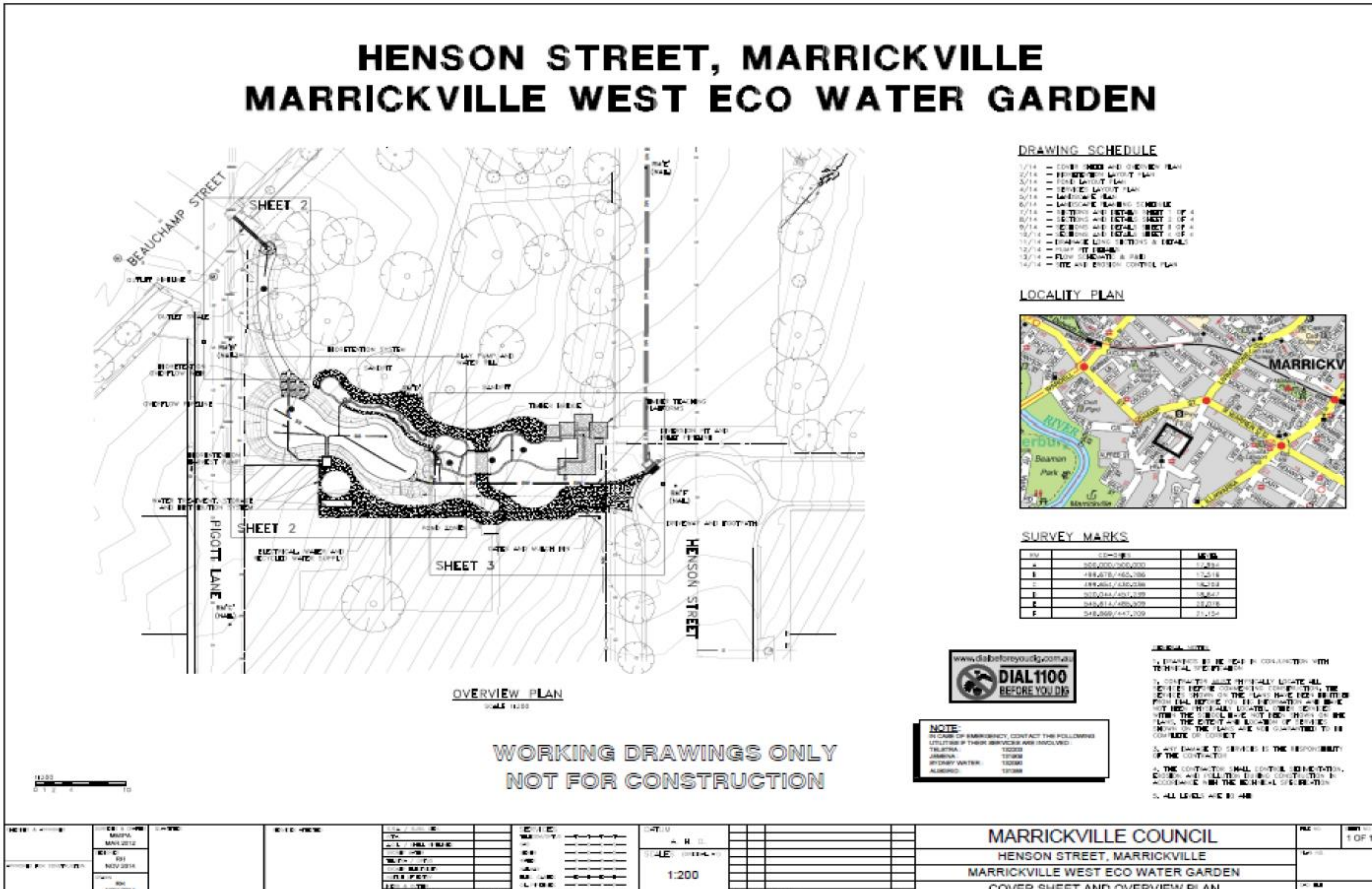

HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
BEAUCHAMP STREET
SHEET 2
SHEET 2
SHEET 3
PIGOTT LANE
HENSON STREET
OVERVIEW PLAN
DRAWING SCHEDULE
LOCALITY PLAN
MARRICKV
Beamon Park
SURVEY MARKS
www.dialbeforeyoudig.com.au
DIAL1100 BEFORE YOU DIG
NOTE:
WORKING DRAWINGS ONLY
NOT FOR CONSTRUCTION
MARRICKVILLE COUNCIL
HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
COVER SHEET AND OVERVIEW PLAN
1:200
1 OF 14

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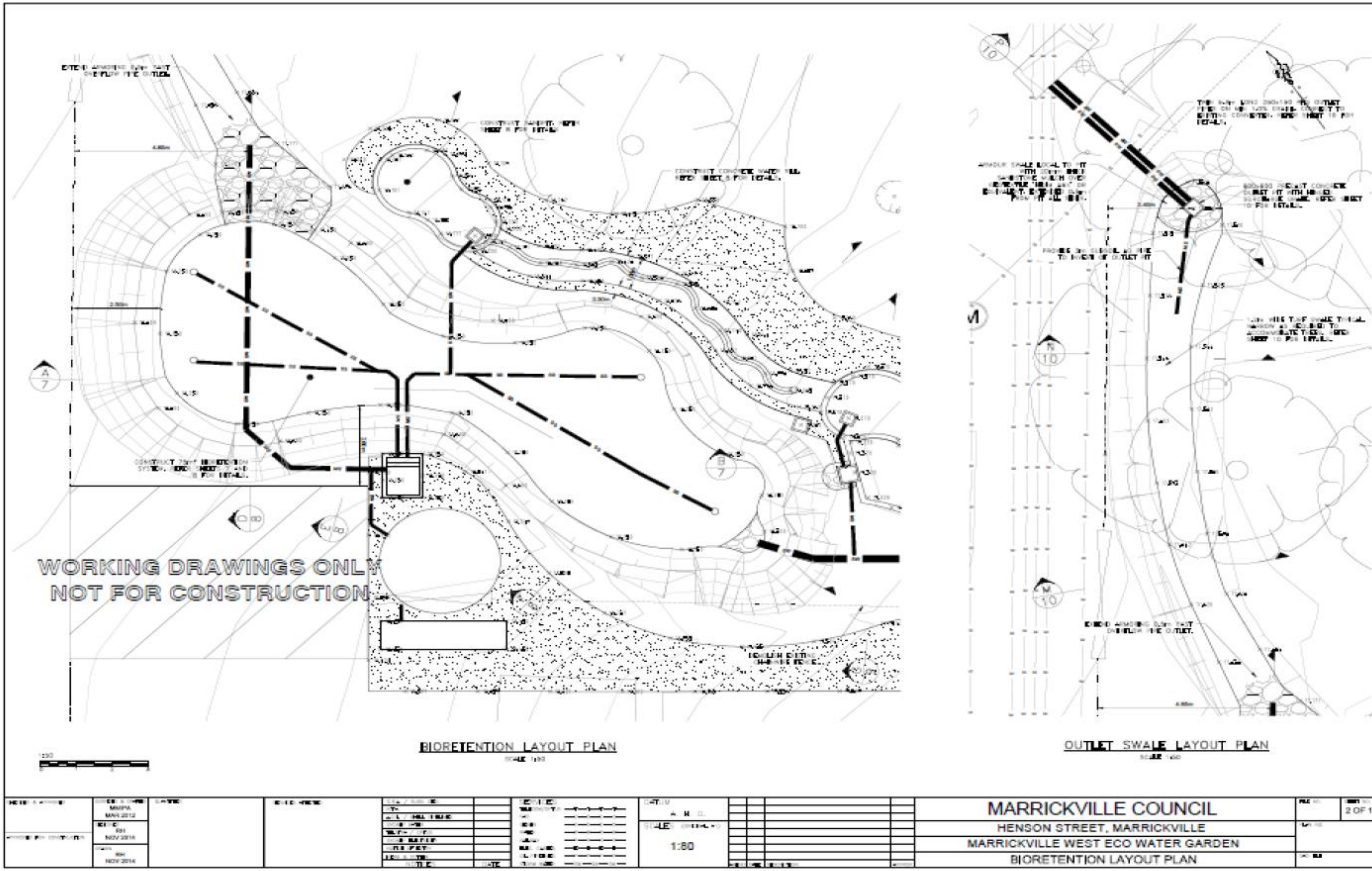

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BIORETENTION LAYOUT PLAN
OUTLET SWALE LAYOUT PLAN
MARRICKVILLE COUNCIL
HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
BIORETENTION LAYOUT PLAN
1:80
2 OF 14

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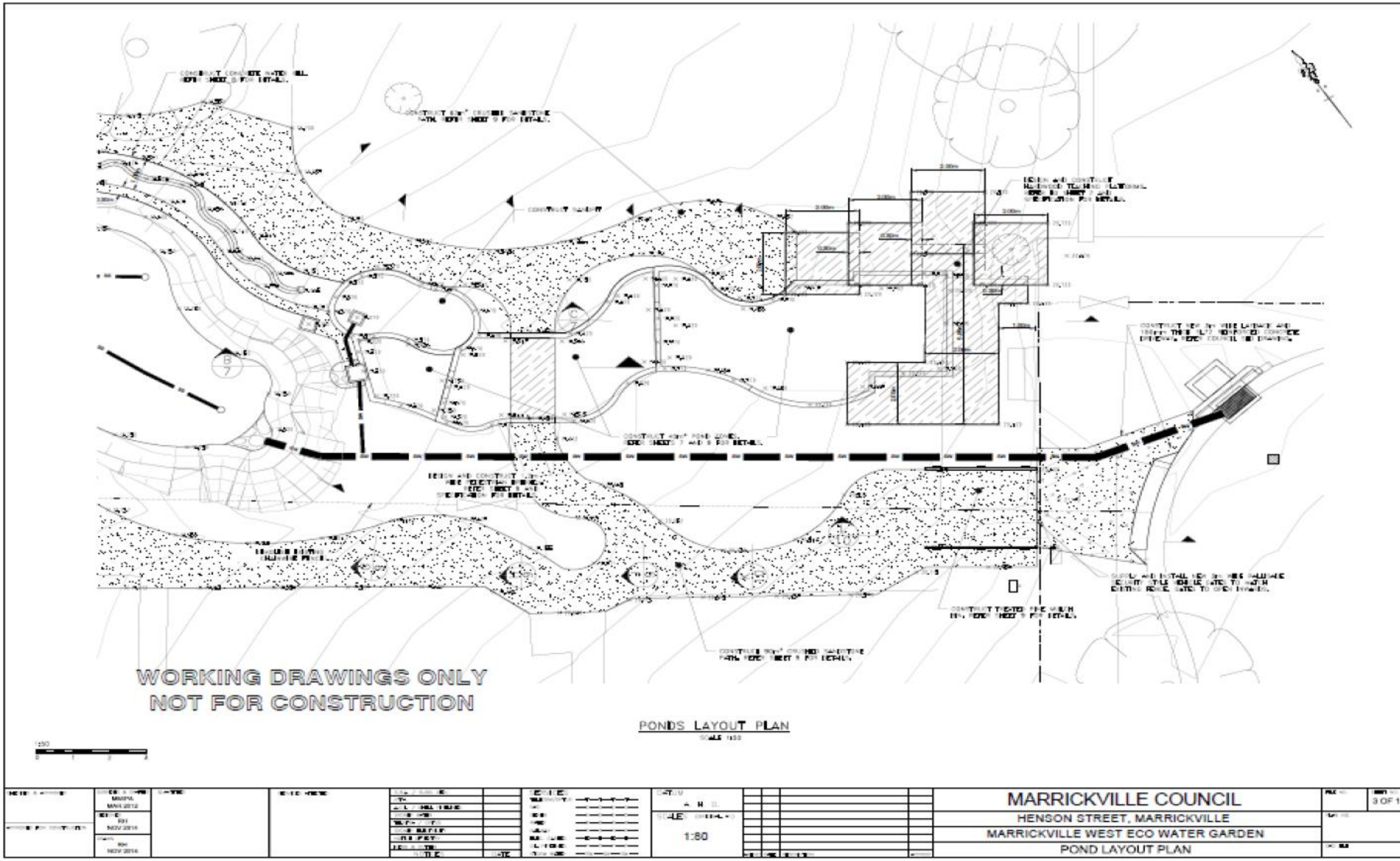
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PONDS LAYOUT PLAN
MARRICKVILLE COUNCIL
HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
POND LAYOUT PLAN
1:80
3 OF 14

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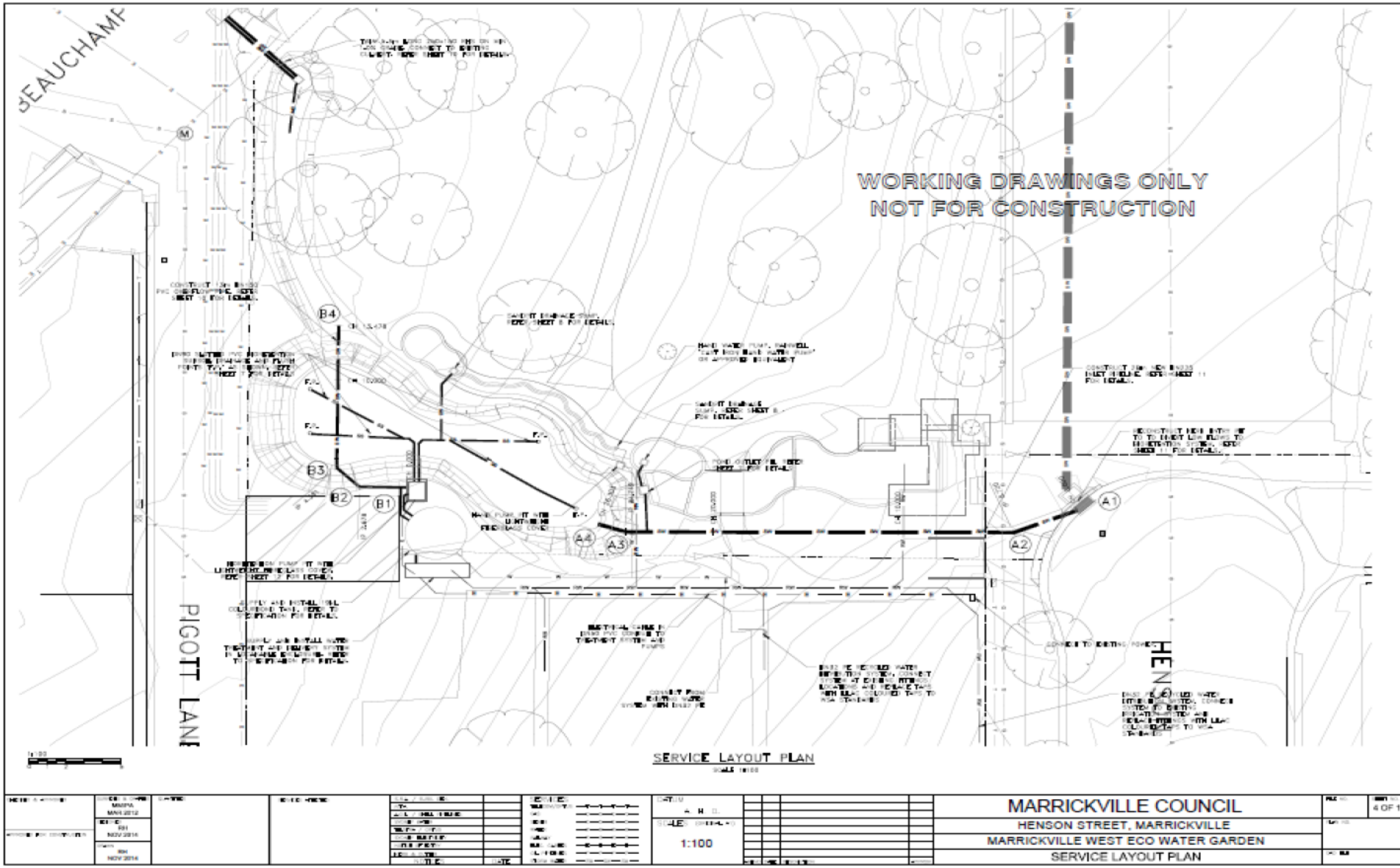

BEAUCHAMP
PIGOTT LANE
HENS
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B4
B3
B2
B1
A4
A3
A2
A1
SERVICE LAYOUT PLAN
MARRICKVILLE COUNCIL
HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
SERVICE LAYOUT PLAN
1:100
4 OF 14

Draft

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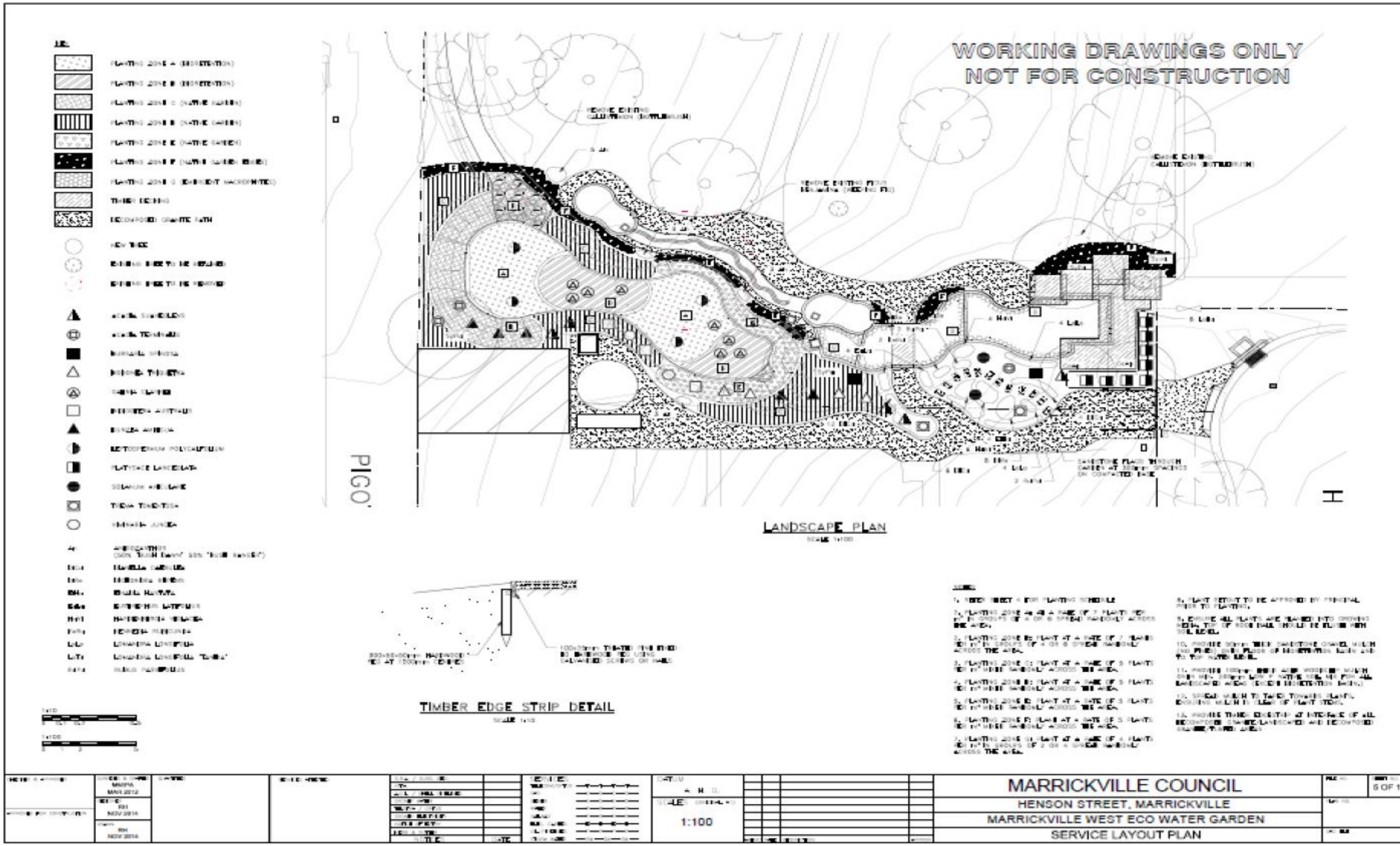

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LANDSCAPE PLAN
TIMBER EDGE STRIP DETAIL
MARRICKVILLE COUNCIL
HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
SERVICE LAYOUT PLAN
1:100
6 OF 14

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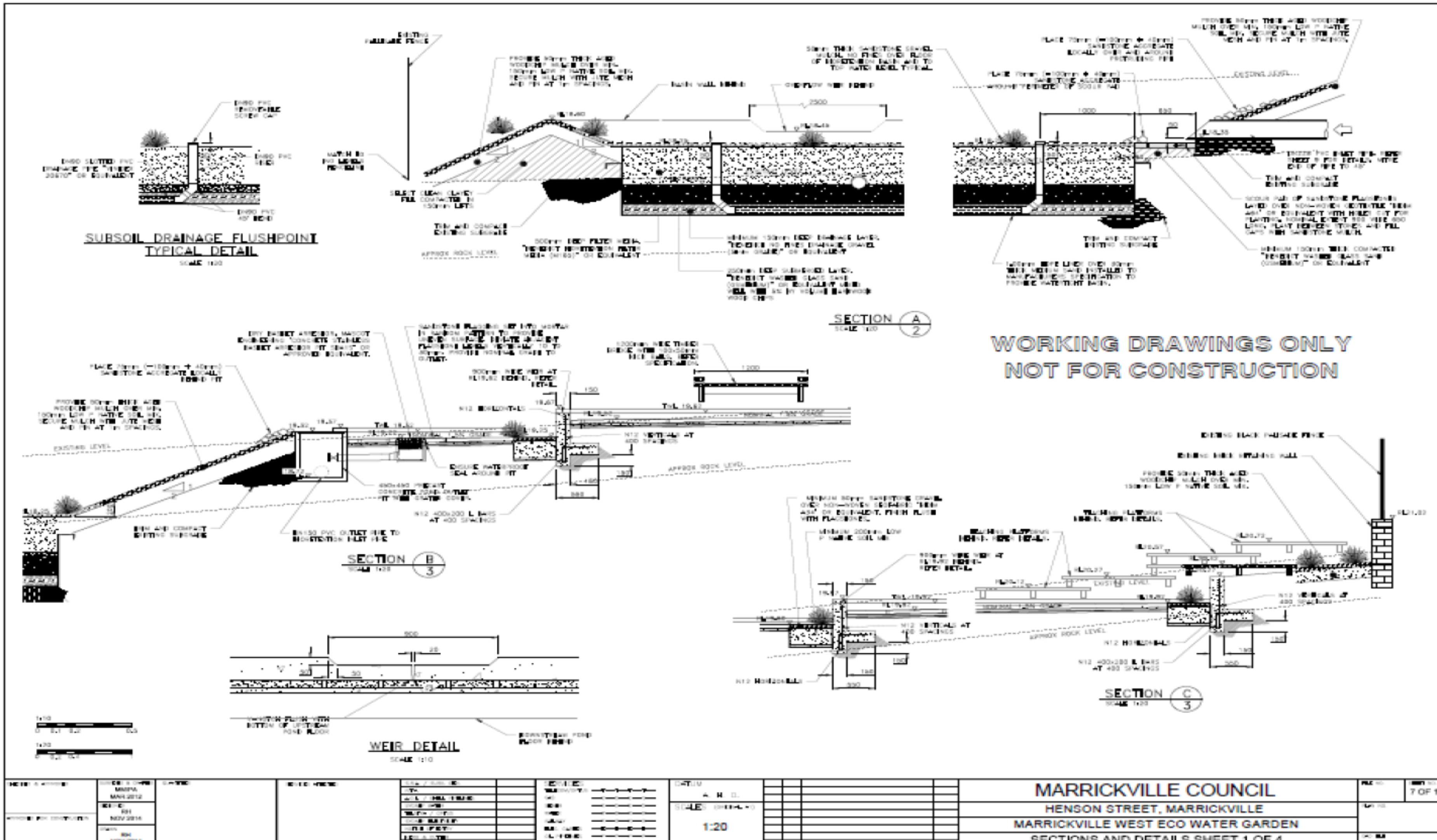

SUBSOIL DRAINAGE FLUSHPOINT
TYPICAL DETAIL
SECTION A 2
SECTION B 3
SECTION C 3
WEIR DETAIL
SCALE 1:10
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1:20
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HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
SECTIONS AND DETAILS SHEET 1 OF 4
7 OF 14

Draft

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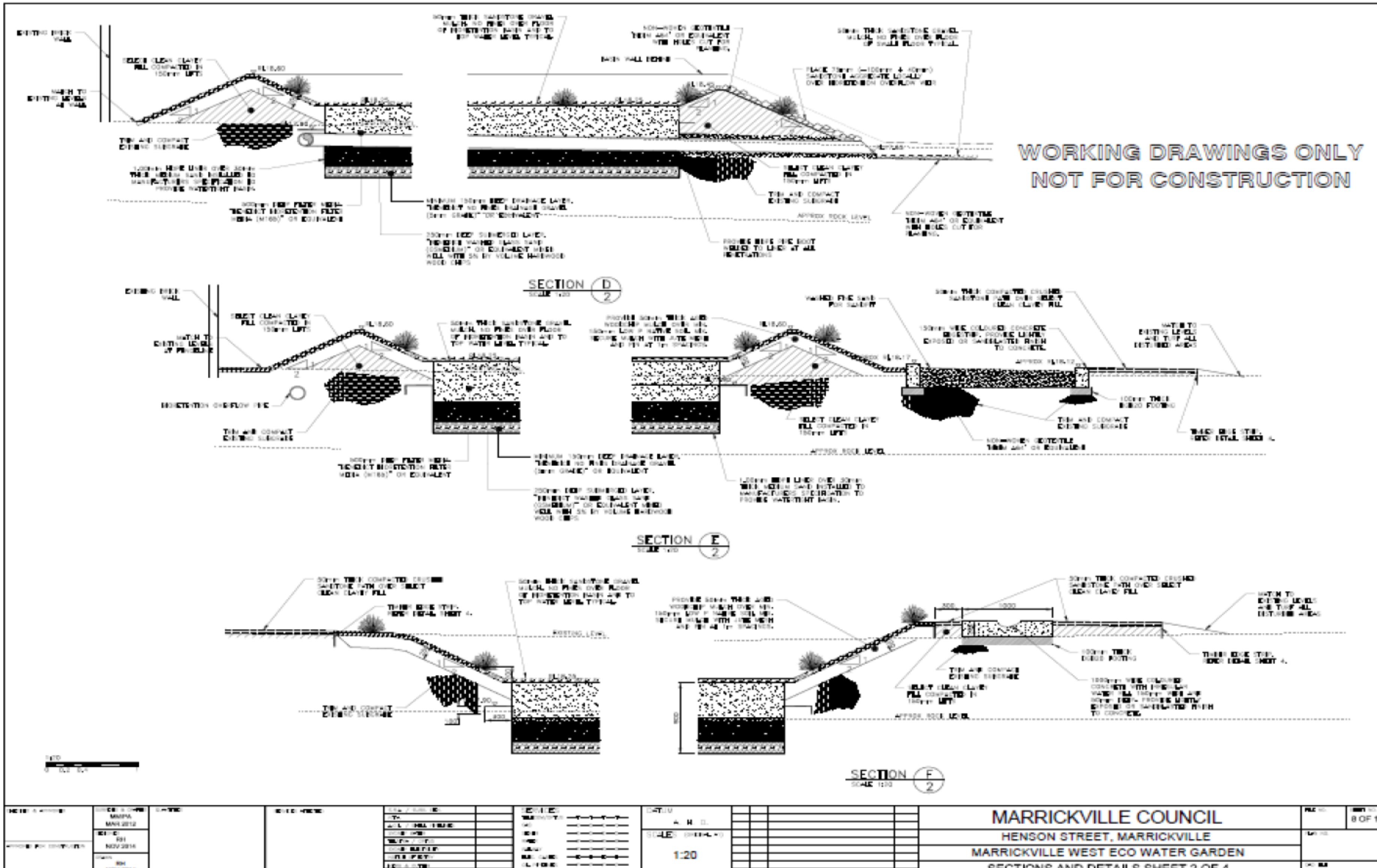
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SECTION E 2
SECTION F 2
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HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
SECTIONS AND DETAILS SHEET 2 OF 4
1:20
8 OF 14

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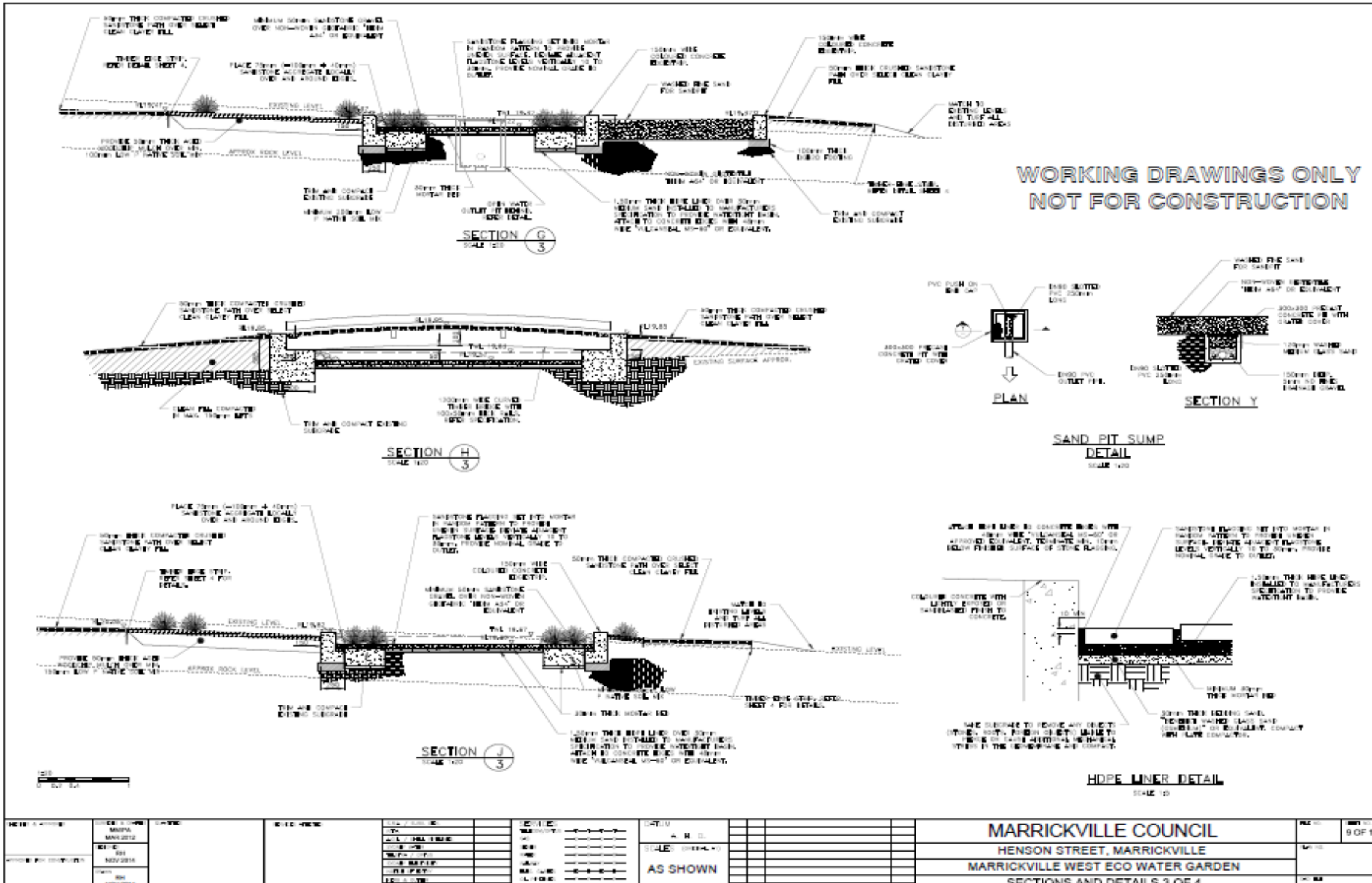
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NOT FOR CONSTRUCTION
SECTION G 3
SECTION H 3
SECTION J 3
PLAN
SECTION Y
SAND PIT SUMP DETAIL
HDPE LINER DETAIL
MARRICKVILLE COUNCIL
HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
SECTIONS AND DETAILS 3 OF 4
AS SHOWN
9 OF 14

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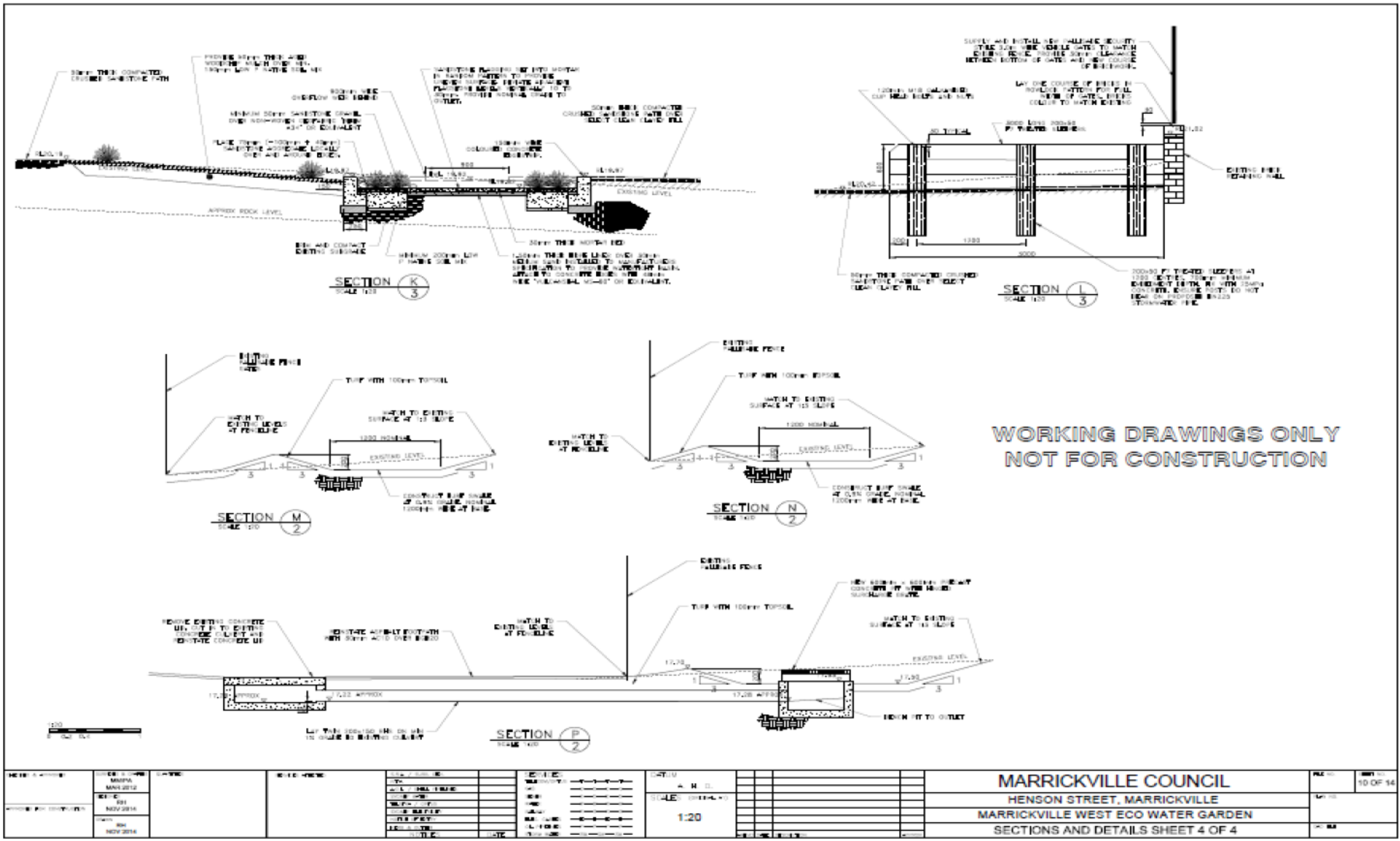

SECTION K 3
SECTION L 3
SECTION M 2
SECTION N 2
SECTION P 2
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1:20
10 OF 14
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HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
SECTIONS AND DETAILS SHEET 4 OF 4

Draft

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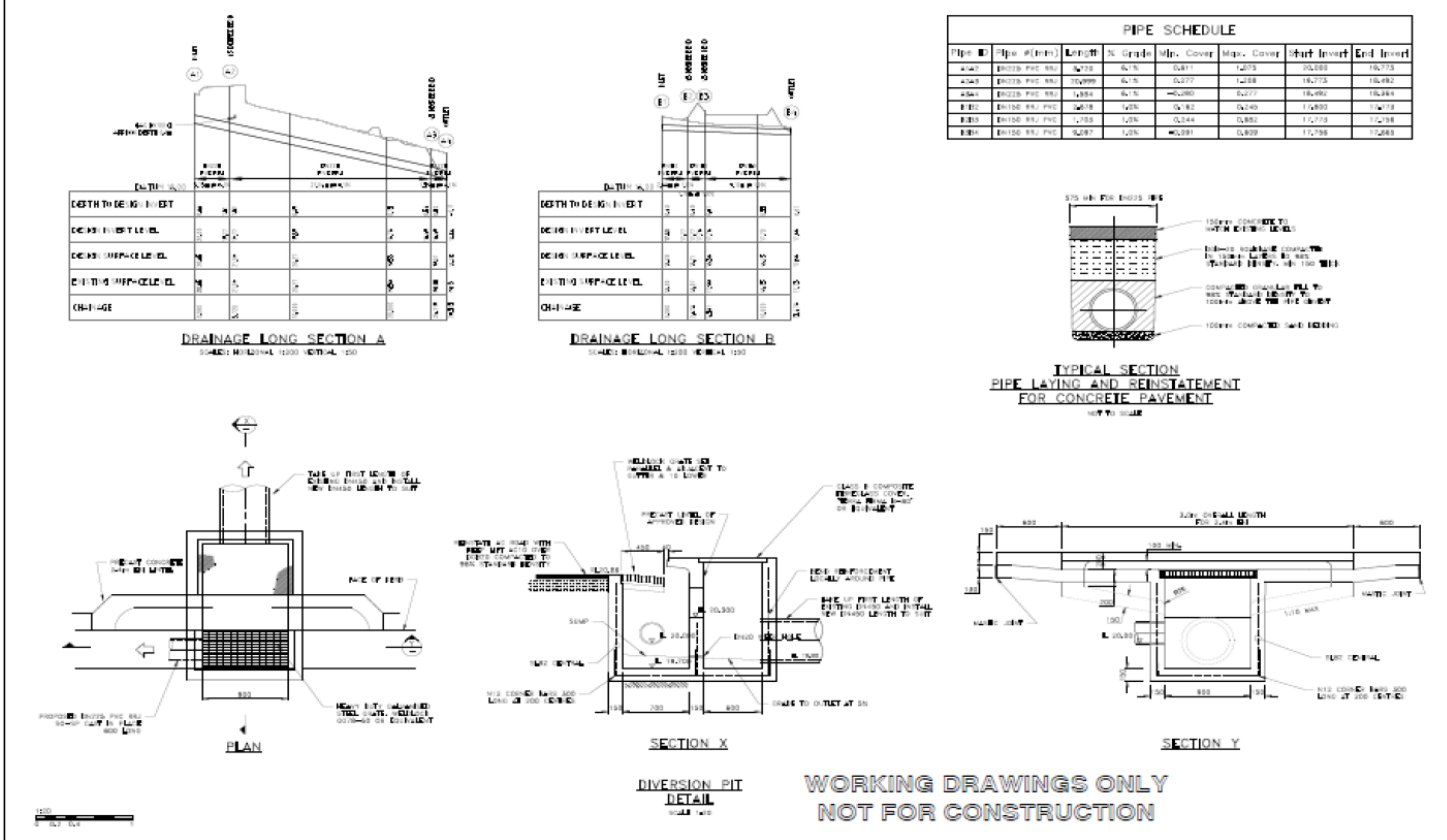

PIPE SCHEDULE

Pipe ID	Pipe Ø(mm)	Length	% Grade	Min. Cover	Max. Cover	Start Invert	End Invert
A1A2	DN225 PVC RRJ	8.729	0.1%	0.611	1.075	20.000	19.775
A2A3	DN225 PVC RRJ	20.999	0.1%	0.277	1.208	19.775	19.492
A3A4	DN225 PVC RRJ	1.884	0.1%	−0.290	0.277	19.492	19.364
B1B2	DN150 RRJ PVC	2.678	1.0%	0.182	0.245	17.800	17.778
B2B3	DN150 RRJ PVC	1.703	1.0%	0.244	0.882	17.775	17.758
B3B4	DN150 RRJ PVC	9.087	1.0%	−0.091	0.809	17.758	17.665

SCALES: AS SHOWN

MARRICKVILLE COUNCIL

HENSON STREET, MARRICKVILLE

MARRICKVILLE WEST ECO WATER GARDEN

DRAINAGE LONGSECTIONS AND DETAILS

SHEET NO. 11 OF 14

Draft

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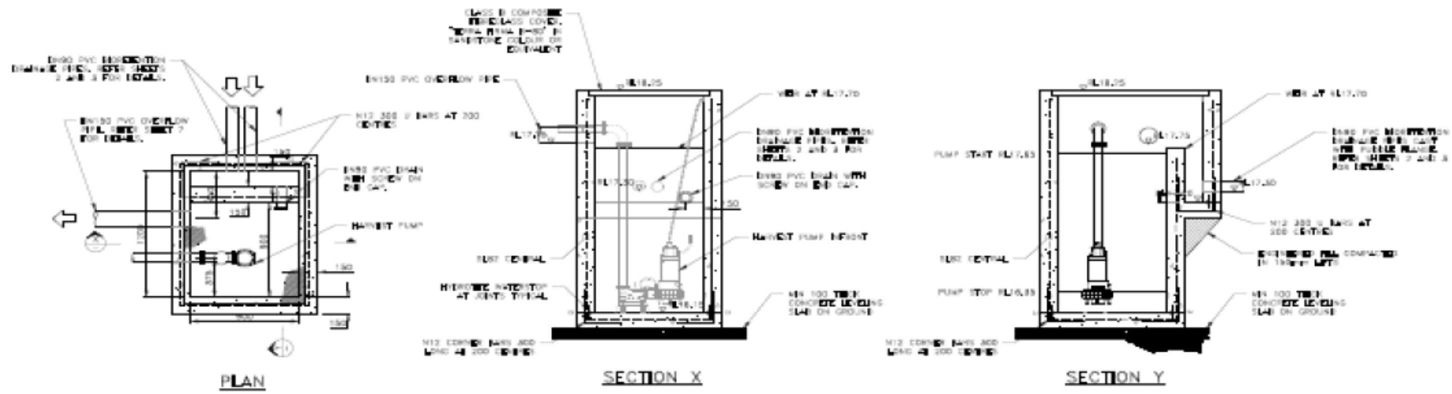

BIORETENTION PUMP PIT DETAIL

SCALE 1:20

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HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
SECTIONS AND DETAILS SHEET 4 OF 4

SCALES 1:20

12 OF 14

Draft

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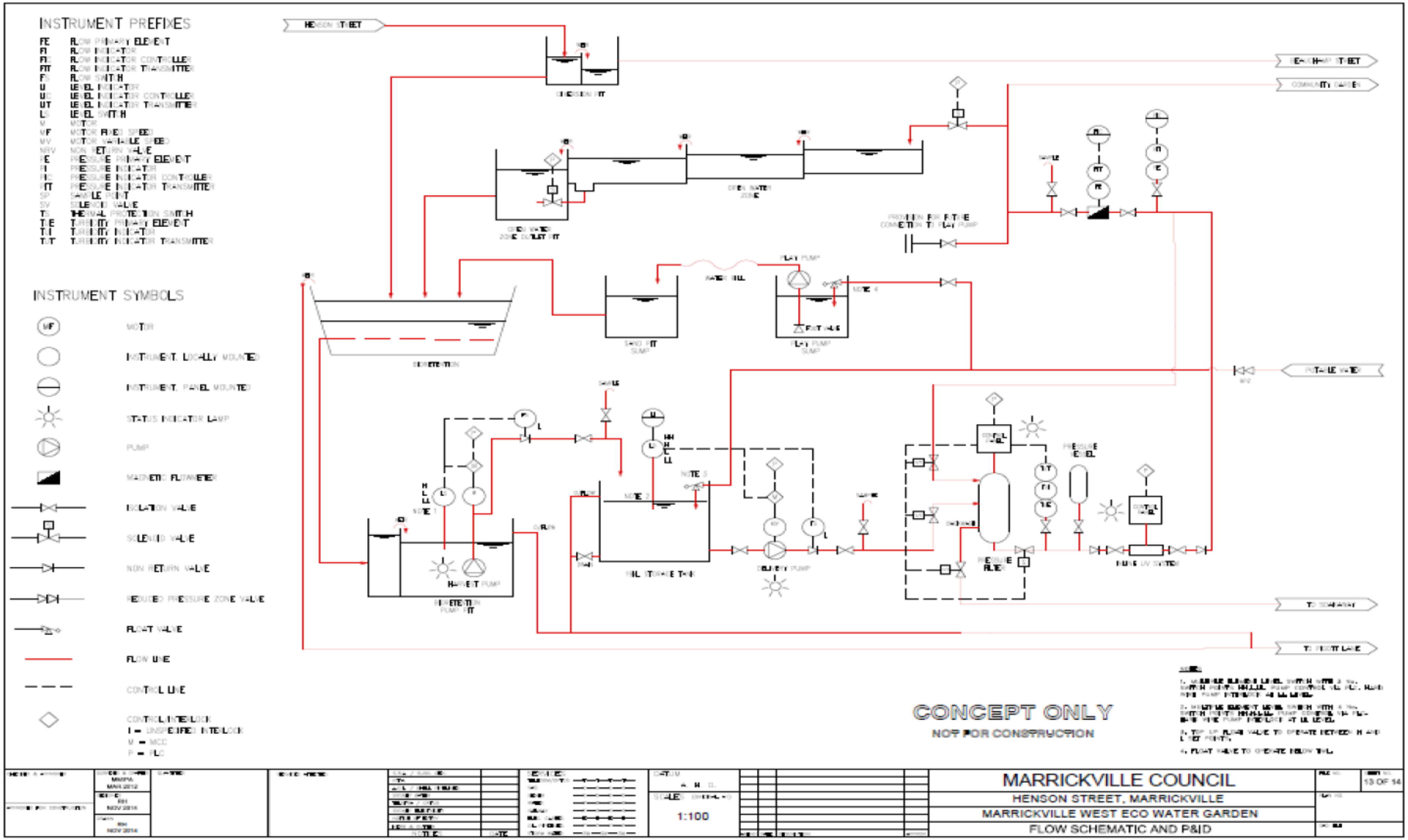

INSTRUMENT PREFIXES
INSTRUMENT SYMBOLS
HENSON STREET
BIORETENTION
CONCEPT ONLY
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HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
FLOW SCHEMATIC AND P&ID
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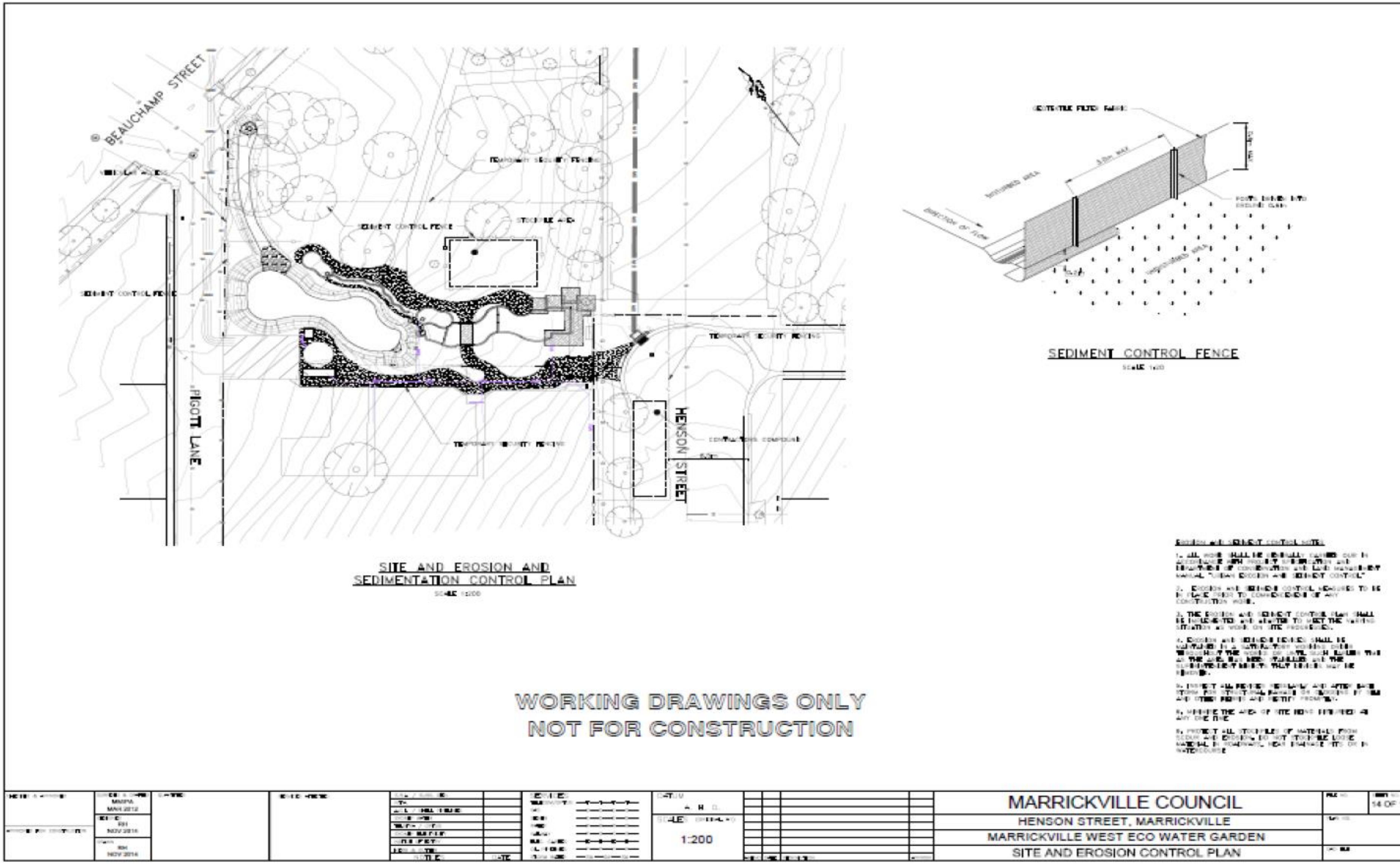

BEAUCHAMP STREET
PIGOTT LANE
HENSON STREET
SEDIMENT CONTROL FENCE
SITE AND EROSION AND SEDIMENTATION CONTROL PLAN
WORKING DRAWINGS ONLY
NOT FOR CONSTRUCTION
1:200
MARRICKVILLE COUNCIL
HENSON STREET, MARRICKVILLE
MARRICKVILLE WEST ECO WATER GARDEN
SITE AND EROSION CONTROL PLAN
14 OF 14

Draft

SSSSS

SYDNEY METROPOLITAN CATCHMENT MANAGEMENT AUTHORITY
TYPCIAL DRAWINGS FOR WSUD

SCHEDULE OF DRAWINGS	
D01	COVER SHEET AND DRAWING LIST
D02	BIORETENTION SYSTEM - FLAT SITE
D03	BIORETENTION SYSTEM - STEEP SITE
D04	BIORETENTION SYSTEM - FOOTPATH
D05	BIORETENTION SYSTEM - ROADWAY
D06	BIORETENTION DETAILS - 1
D07	BIORETENTION DETAILS - 2
D08	BIORETENTION DETAILS - 3
D09	BIORETENTION GUIDELINE SPECIFICATIONS
D10	SWALE - FLAT SITE
D11	SWALE - STEEP SITE
D12	SWALE – DETAILS

ABBREVIATIONS

NSL - NATURAL SURFACE LEVEL
FSL - FINISHED SURFACE LEVEL
U/S - UP STREAM
D/S - DOWN STREAM
IL - INVERT LEVEL
CL- COVER LEVEL
RL - REDUCED LEVEL
RCP - REINFORCED CONCRETE PIPE

GENERAL NOTES

A. THESE DRAWINGS HAVE BEEN DEVELOPED AS EXAMPLES AND REPRESENT TYPICAL WSUD TREATMENT SYSTEMS.

B. THE PURPOSE OF THESE DRAWINGS IS TO PROVIDE DESIGN GUIDANCE ON KEY DETAILS; HOWEVER THEY ARE NOT A STAND-ALONE DESIGN RESOURCE. THEY SHOUD BE READ IN CONJUNCTION WITH OTHER DESIGN GUIDELINES INLCUDING:
- WSUD.ORG "WSUD INTERIM REFERENCE GUIDELINE – CONCEPT DESIGN"
- WSUD.ORG "WSUD INTERIM REFERENCE GUIDELINE – TECHNICAL DESIGN" (WHEN AVAILABLE)
- WSUD.ORG "WSUD INTERIM REFERENCE GUIDELINE – CONSTRUCTION AND ESTABLISHMENT FOR SWALES, BIORETENTION SYSTEMS AND WETLANDS"
- WATER BY DESIGN "CONCEPT DESIGN GUIDELINES FOR WSUD"
- WATER BY DESIGN "TECHNICAL DESIGN GUIDELINES"
- WATER BY DESIGN "CONSTRUCTION AND ESTABLISHMENT GUIDELINES FOR SWALES, BIORETENTION SYSTEMS AND WETLANDS"

C. THESE DRAWINGS ARE INTENDED FOR A TECHNICAL AUDIENCE INCLUDING CIVIL/ENVIRONMENTAL ENGINEERS AND OTHER DESIGN PROFESSIONALS.

D. WSUD SYSTEMS REQUIRE SITE-SPECIFIC ANALYSIS, DESIGN AND DRAWINGS PRIOR TO CONSTRUCTION.

E. SITE-SPECIFIC INVESTIGATIONS NEED TO INCLUDE LOCAL TOPOGRAPHY, SOILS, LANDSCAPE, SERVICES AND OTHER RELEVANT SITE FEATURES.

F. WSUD SYSTEMS WITH STRUCTURAL ELEMENTS (E.G. RETAINING WALLS) REQUIRE SITE-SPECIFIC STRUCTURAL DESIGN INPUT.

G. WSUD SYSTEMS REQUIRE INTEGRATION WITH SURROUNDING OPEN SPACE, BASED ON SITE-SPECIFIC ANALYSIS.

H. WSUD SYSTEMS ALSO REQUIRE APPROPRIATE PLANT SPECIES TO FUNCTION CORRECTLY. THESE DRAWINGS DO NOT SPECIFY PLANT SPECIES.

I. WSUD SYSTEM DESIGN NEEDS TO ACCOUNT FOR MAINTENANCE AND OHS REQUIREMENTS OF ASSET OWNER

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A	29/06/2011	PRELIMINARY
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WSUD TYPICAL DRAWINGS
COVER SHEET AND
DRAWING LIST

AS SHOWN	2310	D01	A3
1 OF 12	N/A		

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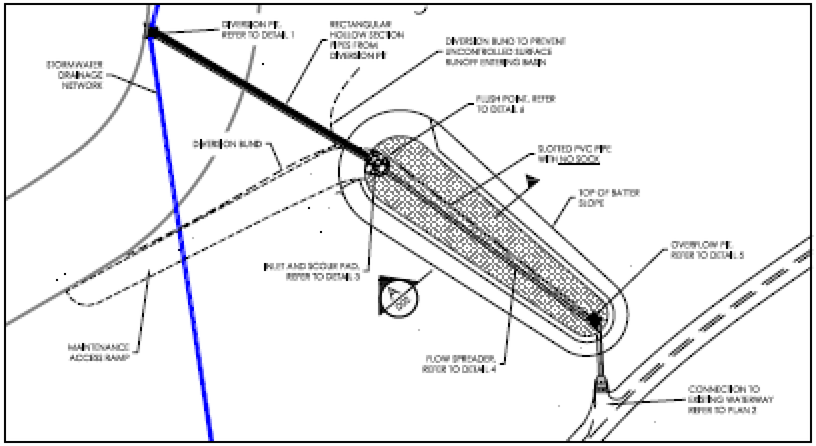
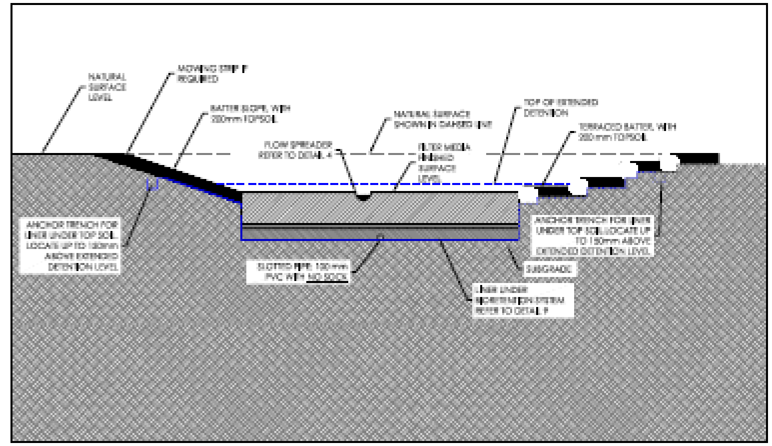


PLAN 1
TYPICAL BIORETENTION SYSTEM - FLAT SITE
SCALE 1:200



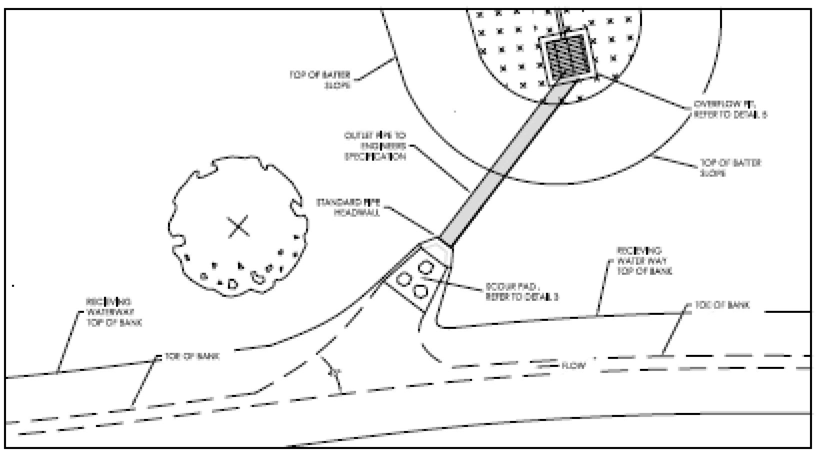
SECTION A / D02
SCALE 1:40

Design notes:

- At flat sites, keep inlet systems as shallow as possible to avoid basin or outlet structures becoming too deep
- Where treated flows drain to a natural waterway, ensure that the outlet can connect into the stream without lowering the bed level. Refer BCC (2003) for waterway outlet structure design guidelines
- In some cases it may be possible to "chase grade" upstream or downstream of the bioretention system. Keep pipe slopes to minimum 0.5% grade (preferably 1%)
- To minimise the depth of inlets:
  - Optimise diversion rate to deliver only low flows to the treatment system, bypassing high flows
  - Consider swales instead of pits and pipes
  - Consider box culverts instead of circular pipes and consider RHS's for small inflows
- To minimise the depth of outlets:
  - Keep filter media to 400 mm minimum depth
  - Expand filter area to compensate for shallower depth
  - Consider the use of a saturated zone (not shown here) to minimise the depth of the outlet pipe. Refer FAWB (2009) for details of saturated zone configurations
- Batter slopes should be consistent with local Council maintenance requirements and guidelines
- Long slopes may be prone to erosion. Consider bunds to control local runoff and erosion protection on internal batters
- Consider a flow spreader in long and large systems to evenly distribute flows across the filter surface

References:

- Facility for Advancing Water Biofiltration (FAWB) 2009 "Stormwater Biofiltration Systems Adoption Guidelines" Monash University
- Brisbane City Council (BCC) 2003 "Stormwater Outlets in Parks and Waterways"



PLAN 2
OUTLET TO A WATERWAY
SCALE 1:50

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B	12/08/2011	50% FOR REVIEW
C	23/09/2011	FINAL

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WSUD TYPICAL DRAWINGS
BIORETENTION SYSTEM
- FLAT SITE

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2 OF 12	N/A		

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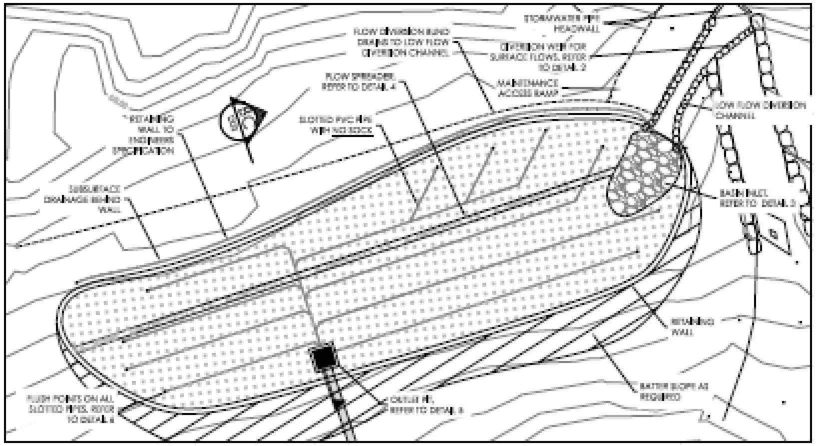
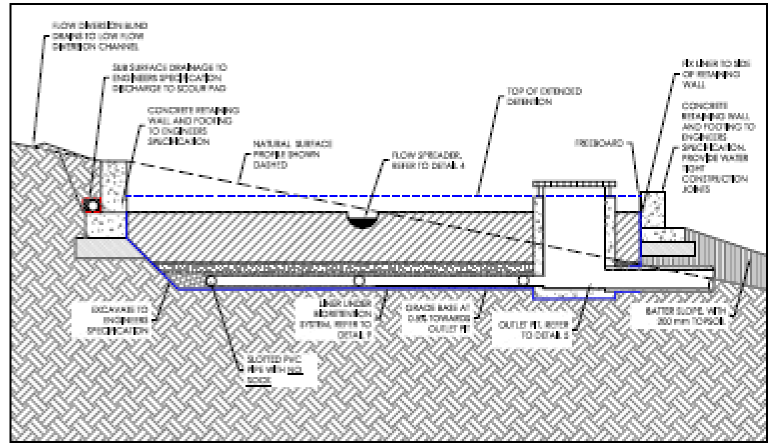


PLAN 3
TYPICAL BIORETENTION SYSTEM - STEEP SITE
SCALE 1:100



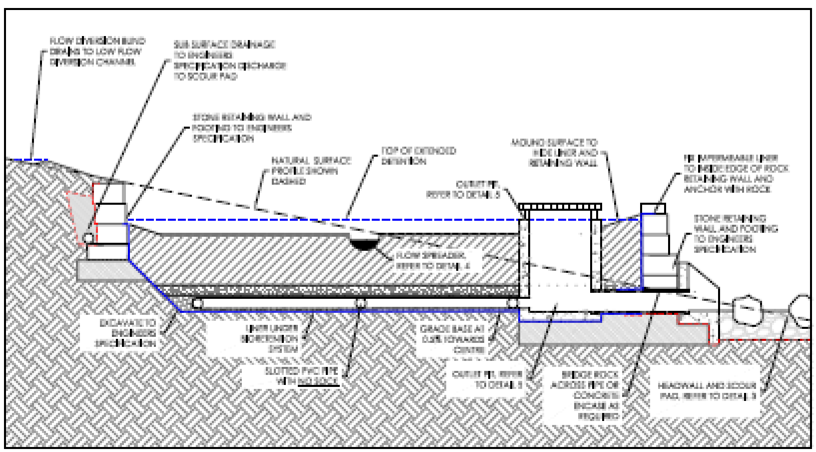
SECTION B / D03
SCALE 1:20

Design notes:

- At steep sites, high velocity flows can easily cause scour and erosion. Energy dissipation and scour protection are key considerations. Refer BCC (2003) for energy dissipater and scour pad design guidelines
- To minimise velocities in the bioretention system:
  - Consider the use of drop structures upstream
  - Include scour protection at all inlets
- Where revegetation is required on steep slopes, use jute mesh pinned in place to retain mulch and protect the slope during vegetation establishment
- Minimise wall heights to 900 mm (to soft fall) for public safety
- Retaining walls require design input from a structural engineer
- It should be possible to avoid exporting excess spoil from site. Consider the cut/fill balance and adjust system levels to achieve desired result
- Construction and maintenance access can be difficult - consider early in the design stage
- Batter slopes should be consistent with local Council maintenance requirements and guidelines
- Long batter slopes may be prone to erosion. Consider bunds to control local runoff and erosion protection on external batters
- Consider a flow spreader in long and large systems to evenly distribute flows across the basin
- Freeboard is recommended as 50mm above the maximum water level in the basin required to convey the peak inflow into the outlet pit when the outlet pit grate is 50% blocked.
- In large systems, consider an emergency overflow weir in case of outlet blockage. Locate at cut/fill interface where possible
- Also bring maintenance access in at cut/fill interface where possible

References:

- Brisbane City Council (BCC) 2003 "Stormwater Outlets in Parks and Waterways"



SECTION C / D03
SCALE 1:20

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A	29/06/2011	PRELIMINARY
B	12/08/2011	50% FOR REVIEW
C	23/09/2011	FINAL

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WSUD TYPICAL DRAWINGS
BIORETENTION SYSTEM
- STEEP SITE

AS SHOWN	2310	D03	A3
3 OF 12	N/A		

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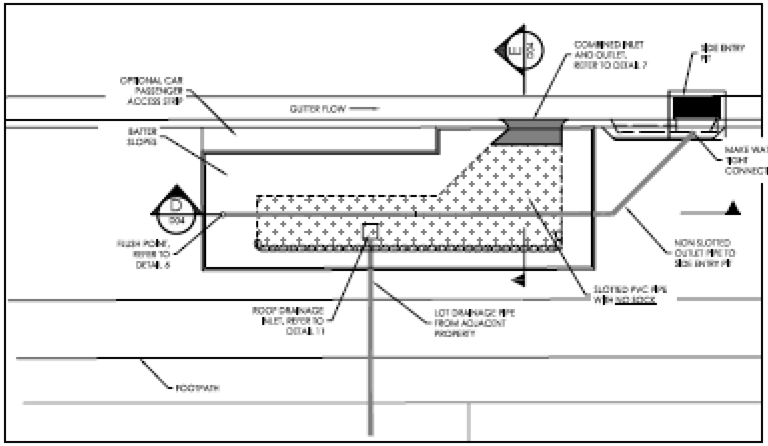
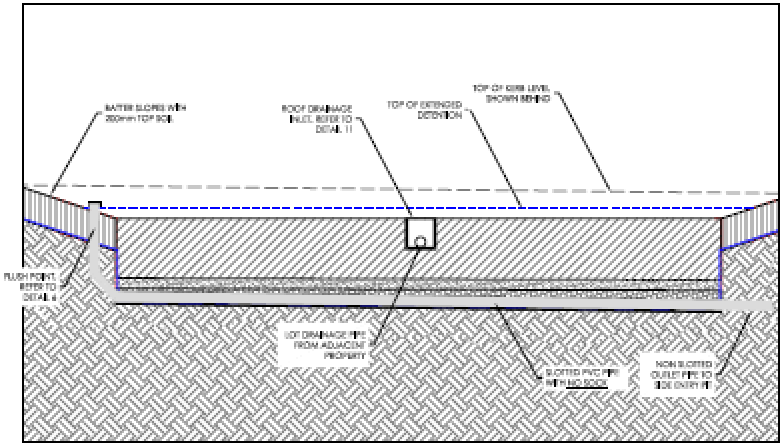
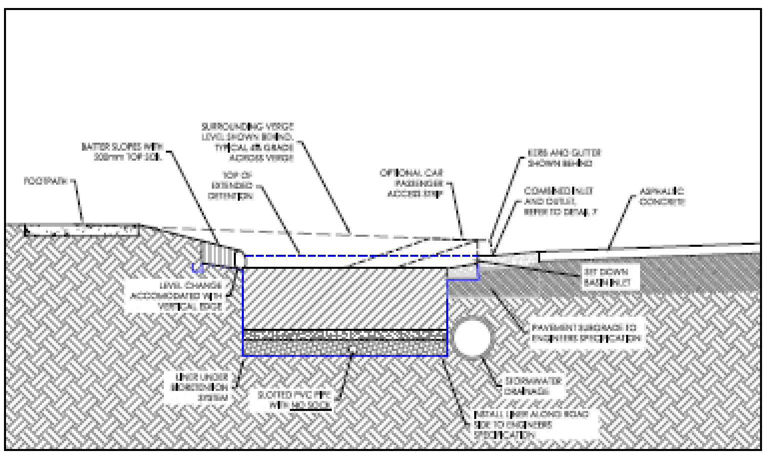


PLAN 4
TYPICAL BIORETENTION SYSTEM - FOOTPATH
SCALE 1:40



SECTION D D04
SCALE 1:20



SECTION E D04
SCALE 1:20

Design notes:

- Services are often located within the road verge. Consider existing utility locations and/or allocations for future works when locating WSUD measures
- In the footpath, pedestrian safety and amenity are key considerations. Minimise trip hazards by clearly delineating sudden level changes. Delineate edges with features such as bollards or dense planting to discourage pedestrian access
- Consider where people need to cross the verge - for example where there is parallel parking
- Specify appropriate vegetation in streetscapes for traffic/pedestrian visibility
- Where trees are specified, use a minimum filter depth of 800 mm
- Next to roads and other structures, a liner is normally recommended to prevent exfiltration
- Allow for extended detention. To minimise the drop to the system surface, the extended detention zone could be filled with coarse gravel or rock mulch.
- Small inlets can clog easily. Make inlets as large as possible and provide space for accumulation of sediment and leaf litter
- Where streets are 5% and steeper, the designer needs to carefully consider level changes across the basin
- Where batter slopes occupy a large part of the basin footprint consider opther options such as a step down to the basin surface to maximise the filter area

References:

- Parramatta City Council's WSUD Standard Drawings include several more examples of streetscape bioretention systems

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WSUD TYPICAL DRAWINGS
BIORETENTION SYSTEM
- FOOTPATH

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4 OF 12	N/A		

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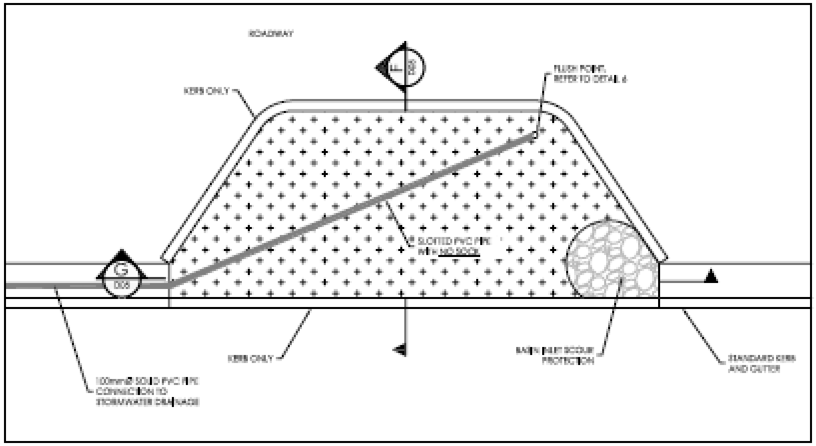
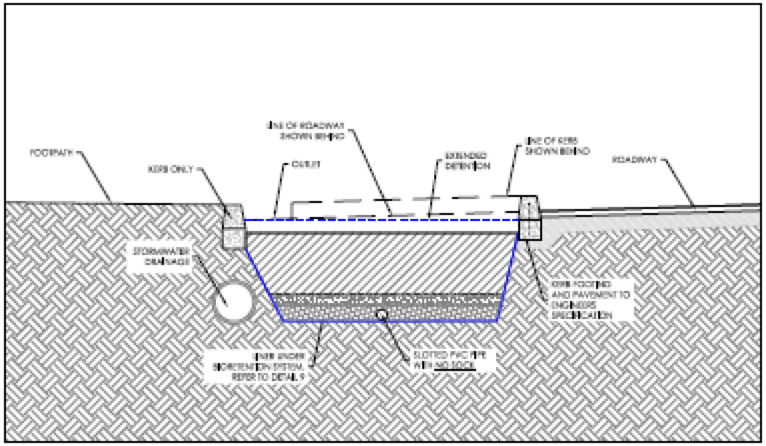
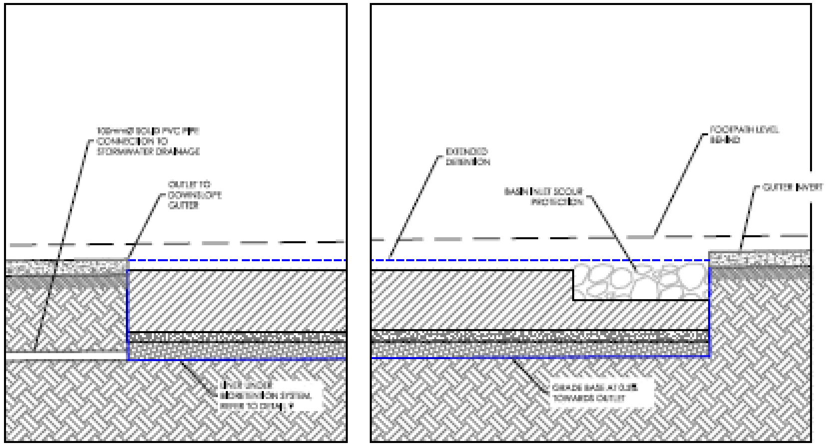


PLAN 5
TYPICAL BIORETENTION SYSTEM - ROADWAY
SCALE 1:20



SECTION F / D05
SCALE 1:20



SECTION G / D05
SCALE 1:10

Design notes:

- In the roadway, key considerations are traffic and drainage
- Road edges need to be designed to exclude cars and prevent traffic damage
- Remember that the road is often a flowpath in major storm events. Estimate design flows and velocities and consider how these flows will be accommodated
- Specify appropriate vegetation in streetscapes for traffic/pedestrian visibility
- The drawings show the typical location of stormwater drainage pipes within the street, however other services are also often located within the roadway. Consider existing utility locations and/or allocations for future works when locating WSUD measures.
- Next to roads and other structures, a liner is normally recommended to prevent exfiltration
- Allow for extended detention. To minimise the drop to the system surface, the extended detention zone could be filled with coarse gravel or rock mulch
- Small inlets can clog easily. Make inlets as large as possible and provide space for accumulation of sediment and leaf litter
- Employ bicycle-friendly design principles. Refer RTA (2005)
- Kerbs and footings in the roadway must be designed to withstand vehicle impact

References:

- Parramatta Council's WSUD Standard Drawings include several more examples of streetscape bioretention systems
- NSW Roads and Traffic Authority (RTA) 2005 "NSW Bicycle Guidelines"

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WSUD TYPICAL DRAWINGS
BIORETENTION SYSTEM
- ROADWAY

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5 OF 12	N/A		

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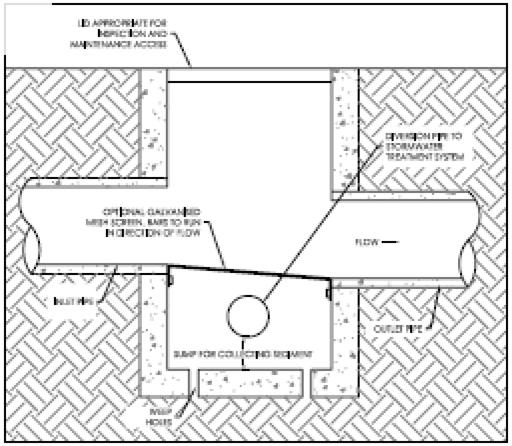
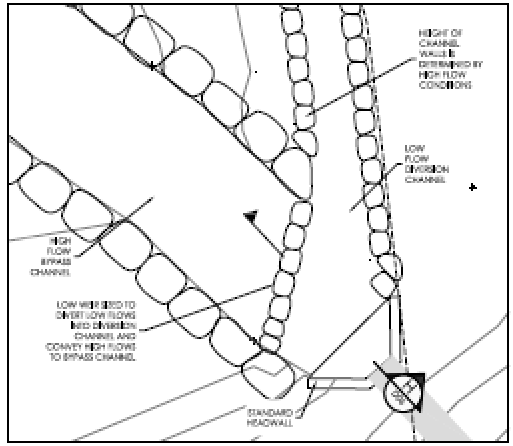
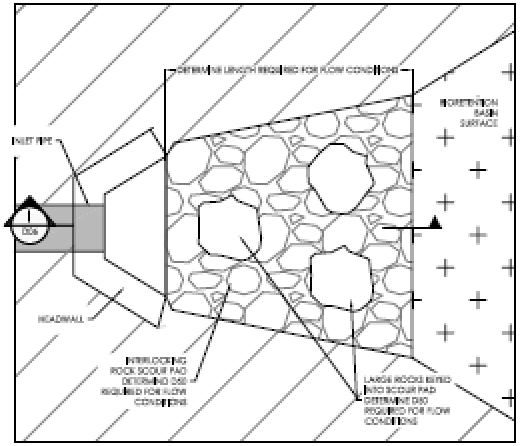


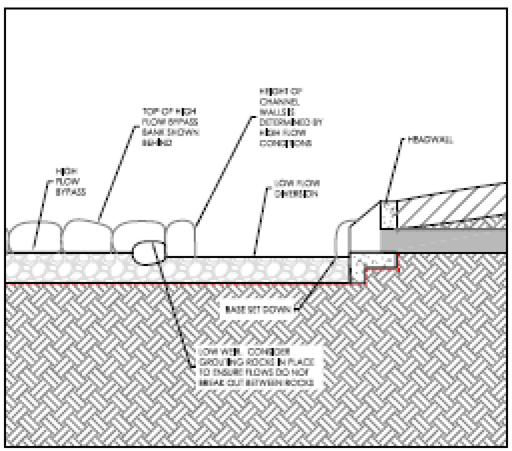
DETAIL 1
TYPICAL DIVERSION SYSTEM FOR PIPED FLOWS
NTS



DETAIL 2
TYPICAL DIVERSION SYSTEM FOR SURFACE FLOWS
NTS



DETAIL 3
TYPICAL INLET FOR A LARGE SYSTEM
SCALE 1:10



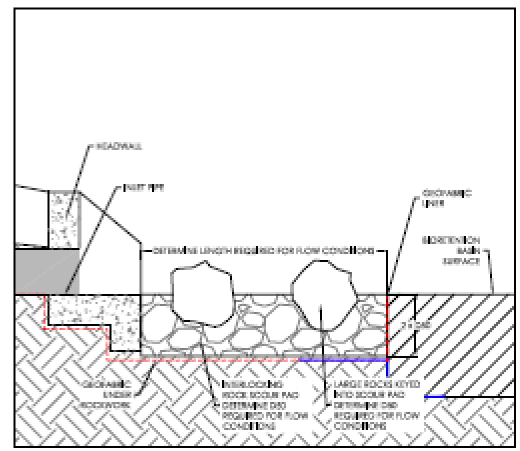
SECTION H / D06
SCALE 1:20

Design notes:

- Wherever possible, divert low flows into bioretention systems and bypass high flows
- Optimise the diversion flowrate to balance treatment performance with design flow. A low design flow may reduce the treatment performance (due to significant bypass); however a high design flow will increase the size of all structures.
- Diversion pits are key points where maintenance is often required - consider access and maintenance techniques. Galvanised mesh screens and sumps will require period maintenance to remove accumulated material
- Weirs can also be used to divert low flows within stormwater pits; however check the hydraulic grade line to avoid flooding impacts upstream
- For scour pad design guidelines, refer BCC (2003)
- In large systems where the scour pad depth (2 x D50) approaches the filter depth, consider the interface between the scour pad and the filter to minimise flows short-circuiting through the scour pad

References:

- Brisbane City Council (BCC) 2003 "Stormwater Outlets in Parks and Waterways".



SECTION I / D06
SCALE 1:10

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A	29/06/2011	PRELIMINARY
B	12/08/2011	50% FOR REVIEW
C	23/09/2011	FINAL

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WSUD TYPICAL DRAWINGS
BIORETENTION SYSTEM
DETAILS (1)

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6 OF 12	N/A		

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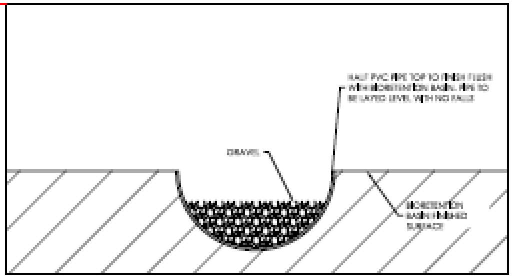
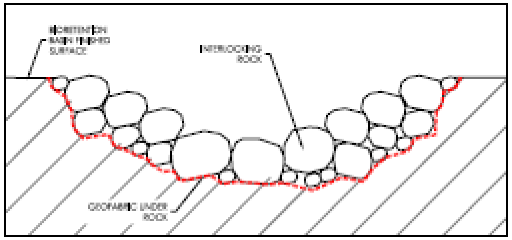
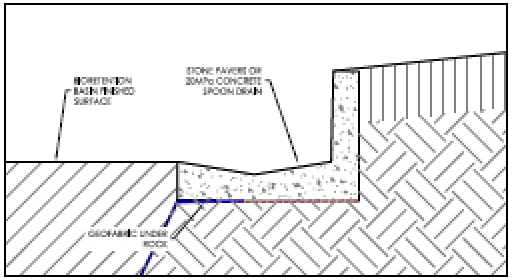


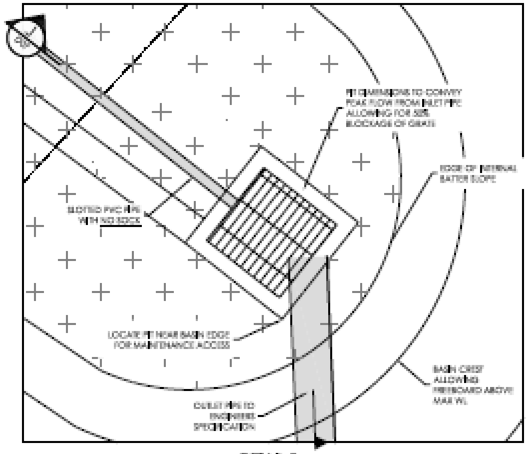
DETAIL 4A
TYPICAL FLOW SPREADER OPTION 1
SCALE 1:4



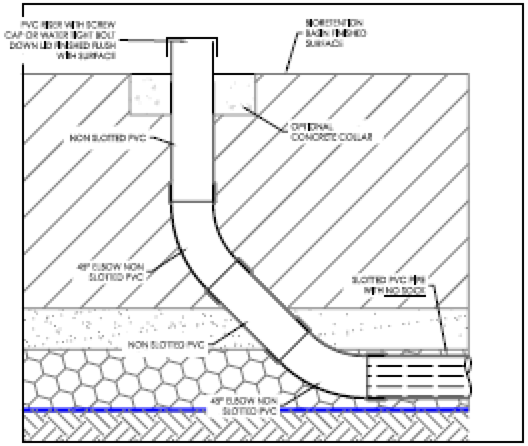
DETAIL 4B
TYPICAL FLOW SPREADER - OPTION 2
SCALE 1:4



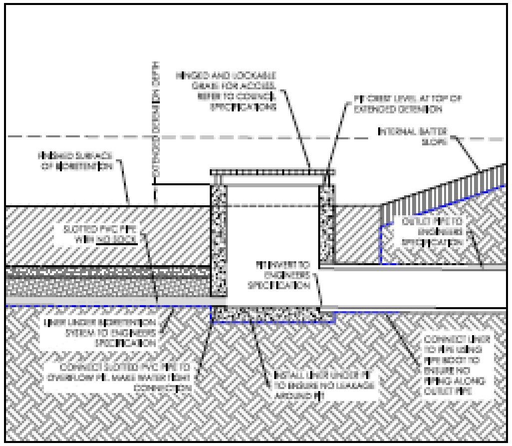
DETAIL 4C
TYPICAL FLOW SPREADER - OPTION 3
SCALE 1:4



DETAIL 5
TYPICAL OVERFLOW PIT FOR A LARGE SYSTEM
SCALE 1:50



DETAIL 6
TYPICAL FLUSHING POINT AND SUBSOIL DRAIN
SCALE 1:20



SECTION J / D07
SCALE 1:10

Design notes:

- Flow spreader channels are recommended in large systems to help distribute inflows over the whole filter area
- Size flow spreader channels to convey approximately 10% of the design flow
- For calculating design flows through the filter and into the slotted pipes, refer HWP (2006)
- Flushing points are recommended on all subsoil drains
- Consider the preferences of the asset owner in designing flushing points, including the preferred location, type of cap and use of concrete surround
- Slotted pipes are recommended at a minimum spacing of 5 m. Where a system requires a large number of slotted pipes, use a collection pipe (e.g. 225 mm non-slotted) to pick up all the slotted pipes and connect into the outlet pit
- The floor of the basin can be contoured to drain towards the slotted pipes
- For sizing overflow pits, refer HWP (2006)
- In large systems, consider multiple overflow pits to convey design flows
- Freeboard is recommended as 50mm above the maximum water level in the basin required to convey the peak inflow into the outlet pit when the outlet pit grate is 50% blocked.
- If there is no liner, or if a stabilised clay liner is used instead of a sheet membrane liner, two cut off collars should be formed around the outlet pipe

References:

- Healthy Waterways Partnership (HWP) 2006 "Water Sensitive Urban Design Technical Design Guidelines for South East Queensland". Check Water by Design website (www.waterbydesign.com.au) for latest update.

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WSUD TYPICAL DRAWINGS
BIORETENTION SYSTEM
DETAILS (2)

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7 OF 12	N/A		

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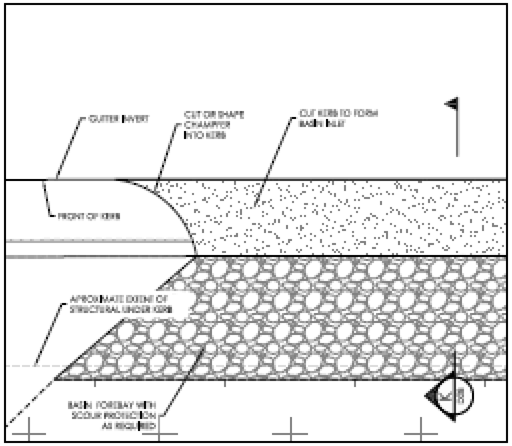
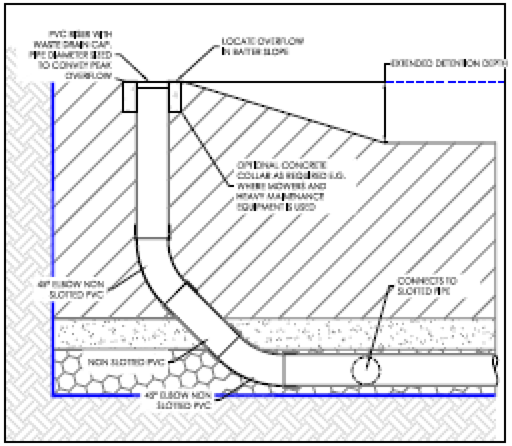
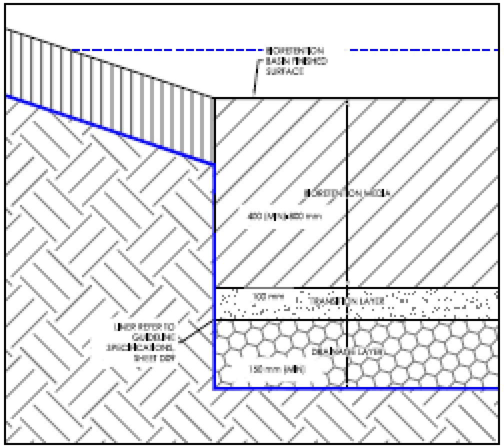


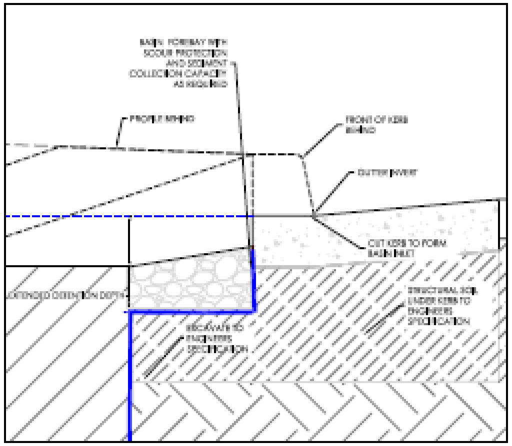
DETAIL 7
TYPICAL COMBINED INLET/OUTLET FOR STREETSCAPE SYSTEM
SCALE 1:5



DETAIL 8
TYPICAL OVERFLOW PIT FOR A SMALL SYSTEM
NTS



DETAIL 9
TYPICAL SOIL PROFILE
NTS



SECTION K / D08
SCALE 1:5

Design notes:

- Use a liner where it is important to exclude exfiltration. Refer D09 for more information
- Where surrounding soils are highly impermeable or exfiltration is acceptable, liners are generally not required
- Install a layer of geotextile under the liner, to minimise the risk of liner damage (e.g. by angular rocks in the subsoil)
- Also install a layer of geotextile before laying soil media layers where there is no impermeable liner, to prevent in-situ soil from mixing into the bioretention system, particularly fine material which may be washed out
- Geotextile fabrics should not be used between the filter media, transition and drainage layers in bioretention systems due to the risk of clogging. The soil specifications are designed to limit the migration of particles through the system.
- Geotextile socks should also never be installed on the slotted drainage pipes
- Filter media should be installed in two lifts unless the depth is less than 500 mm.
- Filter media can be lightly compacted - maximum one pass with a vibrating plate or equivalent. Under no circumstance should heavy compaction or multiple-passes be made. Refer FAWB (2008) for more information.

References:

- Facility for Advancing Water Biofiltration (FAWB) 2008 "Guidelines for soil filter media in bioretention systems". Check FAWB website () for latest revision.

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A	29/06/2011	PRELIMINARY
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WSUD TYPICAL DRAWINGS
BIORETENTION SYSTEM
DETAILS (3)

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SOIL MEDIA
Soil media for bioretention systems should meet the *Facility for Advanced Biofiltration Guidelines for Soil Filter Media in Bioretention Systems*. These guidelines can be downloaded from http://www.monash.edu.au/fawb/products/obtain.html. Please download the latest version, as the guidelines are periodically updated to reflect recent research findings.

A summary of FAWB's current specifications, (Version 2.01, March 2008), is provided here for reference:

Filter Media Specification:
In general the filter media should be a loamy sand with an appropriately high permeability under compaction and should be free of rubbish, deleterious material, toxicants, declared plants and local weeds, and should not be hydrophobic. The filter media should contain some organic matter for increased water holding capacity but be low in nutrient content.

Hydraulic conductivity = 100-300 mm/hr, as measured using the ASTM F1815-06 method. Note that when modeling in MUSIC the modelled hydraulic conductivity should be be 50% of the specified hydraulic conductivity.

The filter media should be well-graded i.e., it should have all particle size ranges present from the 0.075 mm to the 4.75 mm sieve (as defined by AS1289.3.6.1 - 1995). There should be no gap in the particle size grading, and the composition should not be dominated by a small particle size range. An ideal particle size distribution is as follows:

- Clay & Silt (<0.05 mm) <3%
- Very Fine Sand (0.05-0.15 mm) 5-30%
- Fine Sand (0.15-0.25 mm) 10-30%
- Medium to Coarse Sand (0.25-1.0 mm) 40-60%
- Coarse Sand (1.0-2.0 mm) 7-10%
- Fine Gravel <3% (2.0-3.4 mm)

Organic Matter Content – less than 5% (w/w).

pH – as specified for "natural soils and soil blends" 5.5 – 7.5 (pH 1:5 in water).

Electrical Conductivity (EC) – as specified for "natural soils and soil blends" <1.2 dS/m.

Phosphorus - <100 mg/kg

Transition Layer Specification:
Transition layer material should be a clean, well-graded sand/coarse sand material containing little or no fines

Drainage Layer Specification:
The drainage layer should be a clean, fine gravel, such as 2-5 mm washed screenings

Note that the filter media, transition layer and drainage layer specifications are designed to minimise the migration of fines through the bioretention system, without the use of geotextiles.

MULCH
Mulch is not essential in bioretention systems, but can assist with moisture retention and weed suppression, particularly during plant establishment. Where the depth to the system surface is an issue, mulch can also be used to raise the effective surface level, while still allowing for extended detention within its void spaces. Note that the mulch layer will reduce the extended detention storage volume and reduce the treatable volume of stormwater.

The most appropriate mulch in a bioretention system is a non-floating material such as crushed rock, gravel or hardwood chips.

In large systems established off-line, floating mulch could be used during the establishment phase, providing that it breaks down quickly before the system is placed on-line.

DRAINAGE PIPES
In bioretention systems, the recommended material for subsoil drainage pipes is slotted 100 mm PVC-U (consistent with AS/NZS 1254). Joints should be solvent cement glued to ensure stability, and wherever possible, bends should be 45 degrees, to ensure that the pipe can be effectively flushed in the event of a blockage.

Perforated plastic pipe ("ag" pipe) is not recommended due to the risk of compression and blockage.

LINERS
Not all bioretention systems need to be lined, however where the system needs to be water-tight, a pond liner is recommended: 0.75 mm (30 mil) polyethylene or equivalent.

Builders plastic (standard 200 micron) can also be used to line a small system where some exfiltration is tolerable.

SCOUR PROTECTION
Scour protection is usually constructed in rock, with the rock size specified according to the expected flow velocity.

Place a non-woven geotextile fabric beneath all rock work. Grout rock in place to ensure stability.

VEGETATION
Vegetation for bioretention systems needs to be able to withstand periodic inundation, as well as dry conditions between rain events. The filter media is a sandy, well-drained soil.

The vegetation in a bioretention system plays an important role in pollutant removal and in maintaining the hydraulic conductivity of the filter media. Dense vegetation is important to maintain treatment performance. Ideal plants for bioretention systems are those with extensive fibrous root networks.

Suitable plants may include trees, shrubs, sedges, grasses and groundcovers. Note that trees generally require a greater depth of filter media than smaller plants. Vegetation selection should consider the points above, as well as site-specific issues such as sun/shade, exposure and aesthetics. Locally native species are recommended where possible.

Plants in 50 mm tubes or hiko cells are generally suitable for planting in bioretention systems. Smaller seedlings may require a longer establishment period. The recommended planting density is a minimum of 6-8 plants per sqm.

KEY INSPECTION/HOLD POINTS
During construction, it is recommended that the designer undertake inspections at key points, to ensure that bioretention systems are installed according to their design intent. The following hold points are recommended for inclusion in design drawings/specifications (subject to site-specific requirements):

- Completion of bulk earthworks and inspection of subgrade
- Installation of geotextile and/or liner as appropriate
- Installation of diversion pits and pipes
- Installation of overflow pit and pipe
- Installation of slotted pipes and flushing points
- Installation of drainage layer
- Installation of transition layer
- Installation of filter media
- Completed works, including scour pads, mulch and planting

At each stage, check the finished levels as well as the quality of completed work.

ESTABLISHMENT
It is recommended that bioretention systems be established off-line wherever possible. This allows vegetation to establish without being impacted by high stormwater flows.

Design drawings need to show temporary works for the establishment phase, such as a temporary cover on a diversion inlet, temporary irrigation and temporary erosion control.

Further information on the establishment phase is available in the Water by Design "Construction and Establishment Guidelines: Swales, Bioretention Systems and Wetlands" and the wsud.org "WSUD Interim Reference Guideline – Construction and Establishment for Swales, Bioretention Systems and Wetlands".

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A	29/06/2011	PRELIMINARY
B	12/08/2011	50% FOR REVIEW
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WSUD TYPICAL DRAWINGS
BIORETENTION
GUIDELINE SPECIFICATIONS

AS SHOWN	2310	D09	A3
9 OF 12	N/A		

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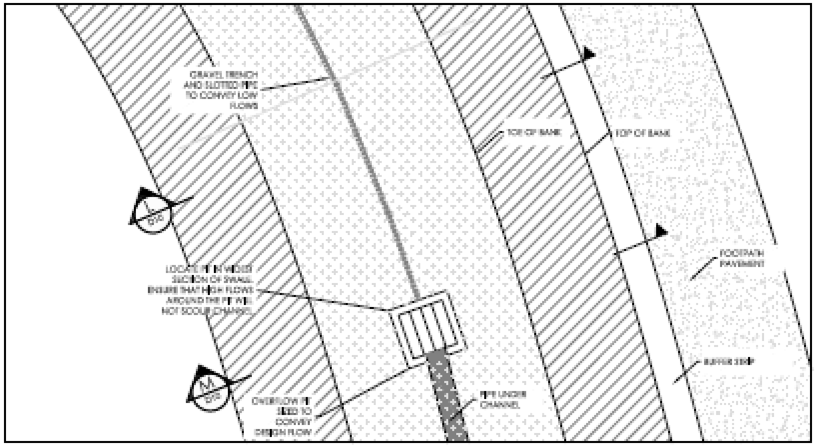
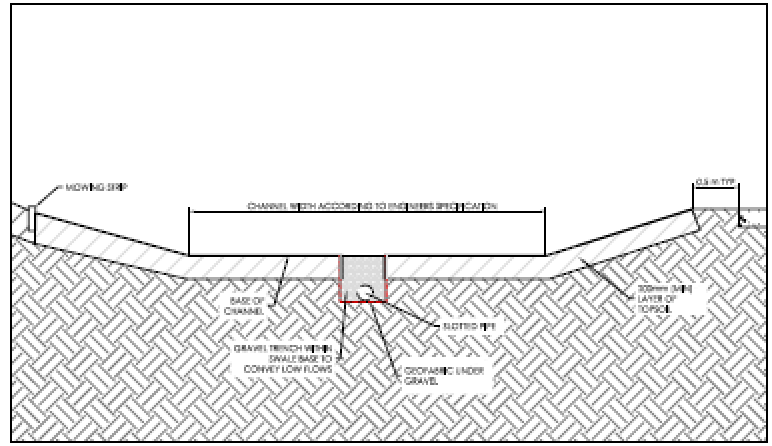
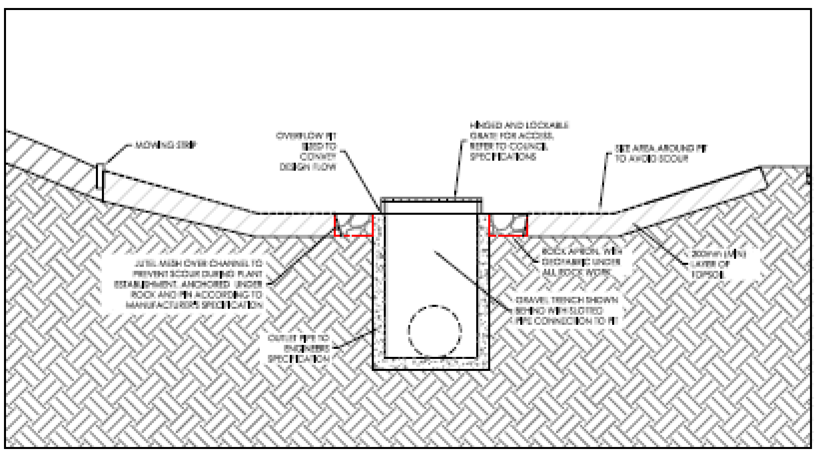


PLAN 5
TYPICAL SWALE FOR A FLAT SITE
NTS



SECTION L / D10
NTS



SECTION M / D10
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Design notes:

- Permanent ponding and waterlogging can be an issue in flat swales, where the longitudinal slope is 1% or less.
- Low flow drainage (as shown) is recommended to minimise this problem. Consider multiple slotted pipes in large swales or where the grade is less than 0.5%
- Where swales are incorporated in street verges, other key issues include:
  - cross-sectional dimensions need to accommodate pathways, etc. to meet local authority guidelines
  - crossing points - refer D12 for driveway crossing detail
  - inflows from neighbouring allotments - refer D12 for detail of a surcharge pit, appropriate for connecting allotment drainage pipes into swales
  - protection from vehicular damage. Consider bollards or other barriers to prevent vehicle entry
  - a root barrier may be required where the swale includes trees planted next to roadways or other infrastructure
- Refer HWP (2006) for further design guidance

References:

- Healthy Waterways Partnership (HWP) 2006 "Water Sensitive Urban Design Technical Design Guidelines for South East Queensland". Check Water by Design website (www.waterbydesign.com.au) for latest update.

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WSUD TYPICAL DRAWINGS
SWALE FOR A FLAT SITE

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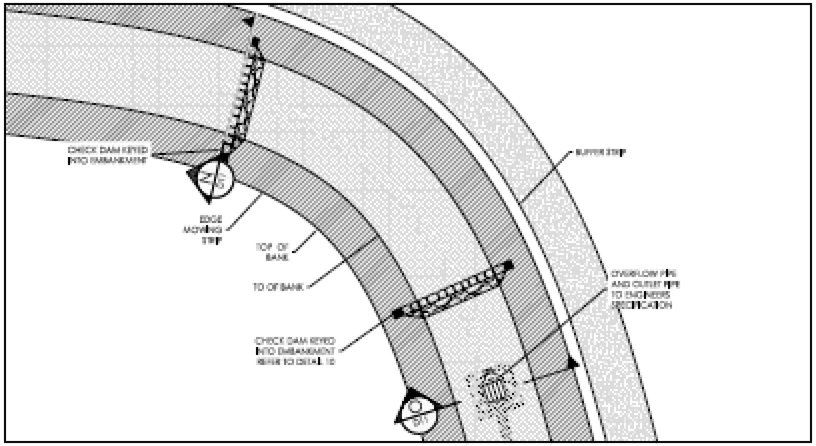
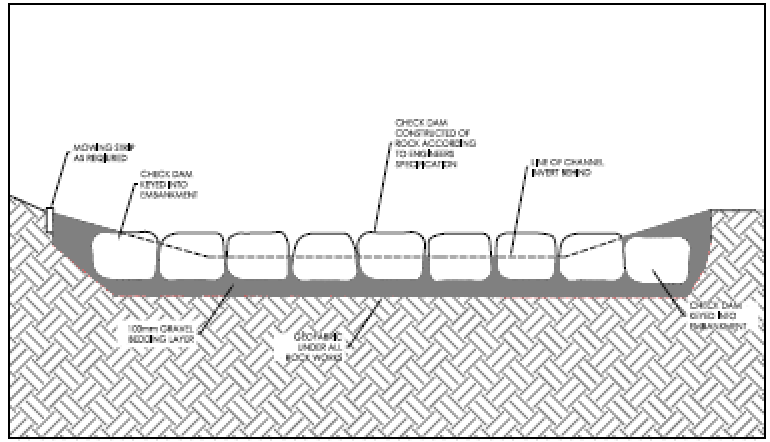
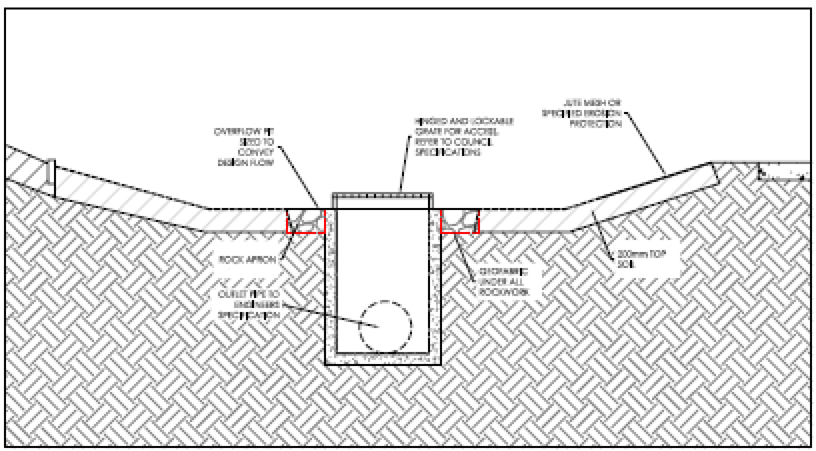


PLAN 6
TYPICAL SWALE FOR A STEEP SITE
NTS



SECTION N / D11
NTS



SECTION O / D11
NTS

Design notes:

- Scour and erosion can be an issue in steep swales, where the longitudinal slope is 4% or greater.
- Check dams (as shown) are recommended to minimise this problem
- In steep swales, scour and erosion can also occur around overflow pits and other structures - scour protection is recommended as shown
- Refer HWP (2006) for further design guidance

References:

- Healthy Waterways Partnership (HWP) 2006 "Water Sensitive Urban Design Technical Design Guidelines for South East Queensland". Check Water by Design website (www.waterbydesign.com.au) for latest update.

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WSUD TYPICAL DRAWINGS
SWALE FOR A STEEP SITE

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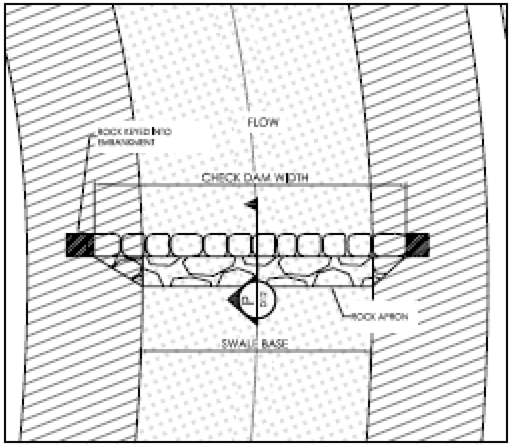
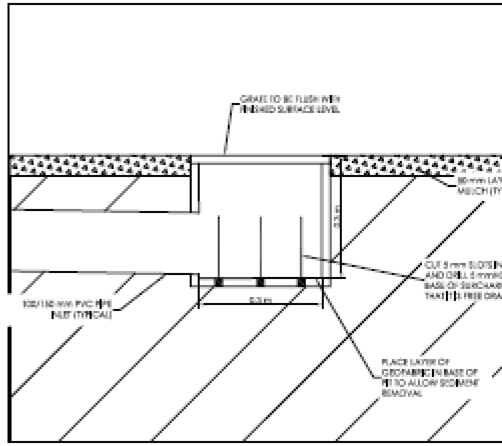
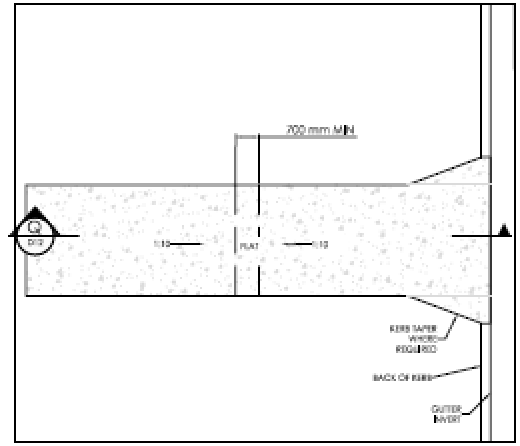


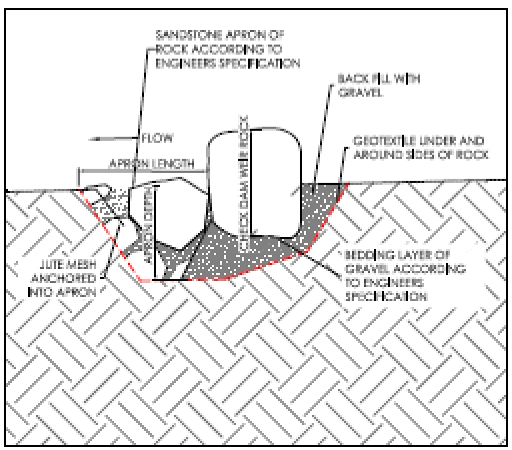
DETAIL 10
TYPICAL CHECK DAM
NTS



DETAIL 11
TYPICAL SURCHARGE INLET FOR ROOF DRAINAGE
SCALE 1:5



DETAIL 12
TYPICAL DRIVEWAY CROSSING
NTS



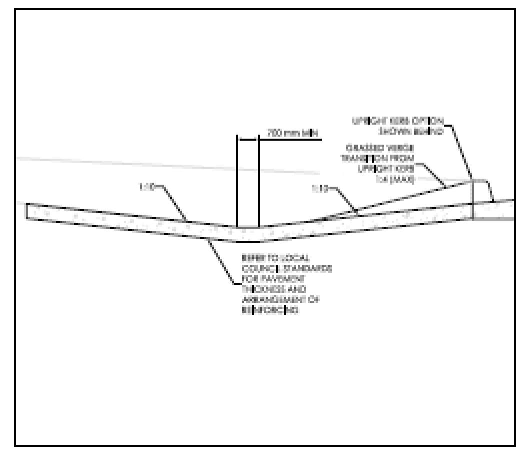
SECTION P
NTS

Design notes:

- For guidance on sizing and spacing of check dams, refer HWP (2006)
- Check dams can also be constructed from other materials - e.g. logs, wood or concrete
- All check dams require careful installation to ensure they are built to the correct levels and will be stable under design flow conditions
- Surcharge inlets are suited to runoff that is from roofs and free from debris. Surface water should be drained via a different method.
- A relief point should be provided where there is a risk that the surcharge inlet blocks and causes ponding on the upstream property
- HWP (2006) recommends a maximum slope of approximately 1 in 9 for an at-grade driveway crossing
- Refer to Australian Standard 2890 for driveway design standards

References:

- Healthy Waterways Partnership (HWP) 2006 "Water Sensitive Urban Design Technical Design Guidelines for South East Queensland". Check Water by Design website (www.waterbydesign.com.au) for latest update.



SECTION Q
NTS

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WSUD TYPICAL DRAWINGS
SWALE DETAILS

AS SHOWN | 2310 | D12 | A3
12 OF 12 | N/A