



Government of **Western Australia**  
Department of **Water and Environmental Regulation**

# Stormwater management manual for Western Australia

## Chapter 6 **Retrofitting**



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# Preface

A growing public awareness of environmental issues in recent times has elevated water issues to the forefront of public debate in Australia.

Stormwater is water flowing over ground or built-up surfaces and in natural streams and drains, as a direct result of rainfall over a catchment (ARMCANZ and ANZECC 2000). Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how the runoff quantity, and these pollutants, can best be managed from source to the receiving water bodies using the range of management practices available.

In Western Australia (WA), where there is a superficial aquifer, drainage channels can commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Stormwater management is unique in WA as both stormwater and groundwater may need to be managed concurrently.

Rainwater has the potential to recharge the superficial aquifer, either before runoff starts or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater, which supports consumptive use and groundwater-dependent ecosystems.

With urban, commercial or industrial development, the area of impervious surfaces within a catchment can increase dramatically. Densely developed inner urban-areas are almost completely impervious, which means less infiltration, the potential for more local runoff and a greater risk of pollution. Loss of vegetation also reduces the amount of rainfall leaving the system through the evapo-transpiration process. Traditional drainage systems have been designed to minimise local flooding by providing quick conveyance for runoff to waterways or basins. However, this almost invariably has negative environmental effects.

This manual presents a new comprehensive approach to management of stormwater in WA, based on the principle that stormwater is a resource – with social, environmental and economic opportunities. The community's current environmental awareness and recent water restrictions are influencing a change from stormwater being seen as a waste product with a cost, to a resource with a value. Stormwater management aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, protecting ecosystems and providing livable and attractive communities.

This manual provides coordinated guidance to developers, environmental consultants, environmental/community groups, industry, local government, water resource suppliers and State Government departments and agencies on current best management principles for stormwater management.

It is intended that the manual will undergo continuous development and review. As part of this process, any feedback on the series is welcomed and may be directed to the Urban Water Branch of the Department of Water and Environment Regulation at [urbanwater.enquiry@dwer.wa.gov.au](mailto:urbanwater.enquiry@dwer.wa.gov.au)

## Western Australian stormwater management objectives

### **Water quality**

To maintain or improve the surface and groundwater quality within the development areas relative to pre-development conditions.

### **Water quantity**

To maintain the total water cycle balance within development areas relative to the pre-development conditions.

### **Water conservation**

To maximise the reuse of stormwater.

### **Ecosystem health**

To retain natural drainage systems and protect ecosystem health.

### **Economic viability**

To implement stormwater management systems that are economically viable in the long term.

### **Public health**

To minimise the public risk, including risk of injury or loss of life, to the community.

### **Protection of property**

To protect the built environment from flooding and waterlogging.

### **Social values**

To ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

### **Development**

To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

## Western Australian stormwater management principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site-specific solutions and implement appropriate non-structural and structural solutions.

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## Summary

This chapter explains the issues that need to be addressed when retrofitting existing urban developments and individual stormwater management devices in urban areas throughout WA.

Retrofitting is installing or undertaking additional or alternative stormwater management devices or approaches in an existing, developed area.

Retrofitting can occur at the lot, block/neighbourhood or catchment scale. Redeveloping or upgrading existing developments and infrastructure presents opportunities for retrofitting.

Retrofitting can:

- reduce flooding risk
- improve public health and safety
- improve water quality
- restore and/or conserve environmental condition
- create more attractive and liveable neighbourhoods
- enhance the cultural values of the urban water landscape
- improve use of open space and enhance recreational opportunities
- improve community environmental awareness
- increase cost effectiveness
- demonstrate best management practices
- use stormwater as a valuable resource to reduce potable water use.

This chapter provides brief descriptions of several best management practices that are particularly relevant to retrofitting. It also provides case studies and examples that demonstrate how to undertake retrofitting projects.

Please refer to the *Decision process for stormwater management in WA* (Department of Water and Environmental Regulation 2017) when planning retrofitting projects.

# 1 Introduction

## 1.1 Aim of the retrofitting chapter

This chapter explains the issues that need to be addressed when retrofitting existing urban developments and individual stormwater management devices in urban areas throughout WA.

## 1.2 The target audiences

This chapter has been written primarily for:

- local and state government with responsibilities and interests in stormwater management (such as Departments of Water and Environmental Regulation; Biodiversity, Conservation and Attractions; and Planning, Lands and Heritage; Water Corporation, Main Roads WA, and Public Transport Authority) that may be upgrading existing stormwater management systems, developing catchment/regional management strategies, or assessing urban redevelopment proposals
- developers and their consultants who may develop proposals for urban redevelopment
- community groups or community members who may develop proposals to upgrade existing stormwater management systems, or develop catchment management plans.

## 1.3 Terminology and key definitions

**Exceedances per year (EY):** Expresses the number of times an event is likely to occur or be exceeded within any given year (Ball et al. 2016).

**Annual exceedance probability (AEP):** Expresses the probability or likelihood of an event being equalled or exceeded in any year, usually expressed as a percentage.

**Detention** is defined as the process of reducing the rate of off-site stormwater discharge by temporarily holding rainfall runoff (up to the design event) and then releasing it slowly, to reduce the impact on downstream water bodies and to attenuate urban runoff peaks for flood protection of downstream areas.

**Non-structural controls** are institutional and pollution prevention practices designed to prevent or minimise pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management. They do not involve fixed, permanent facilities and they usually work by changing behaviour through government regulation (e.g. planning and environmental laws), persuasion and/or economic instruments.

**Receiving water bodies** include waterways, wetlands, groundwater and coastal marine areas.

**Retention** is defined as the process of preventing rainfall runoff from being discharged into receiving water bodies by holding it in a storage area. The water may then infiltrate into groundwater, evaporate or be removed by evapotranspiration of vegetation and be used as a water source (e.g. by vegetation or for toilet flushing). Retention systems are designed to prevent off-site discharges of surface water runoff, up to the design event.

**Retrofitting** is the process of installing or undertaking additional or alternative stormwater management devices or approaches in an existing developed area.

**Source controls** are non-structural or structural best management practices to minimise the generation of excessive stormwater runoff and/or pollution of stormwater at or near the source and protect receiving environments.

**Structural controls** are permanent, engineered devices implemented to control, treat or prevent stormwater pollution and/or to reduce the volume of stormwater requiring management.

**Urban development** is residential, rural-residential, commercial and industrial development.

## 1.4 Background

Most urban development areas in WA have traditional (predominantly piped and drained) drainage systems to reduce the risk of flooding by expediting the removal of stormwater from developed areas and lowering groundwater tables in some areas. In existing urban areas, there is the opportunity to achieve more than the single outcome of flood mitigation. There is an increasing awareness of the need to manage water quality in stormwater management systems and an increasing realisation of the potential role of these systems as important environmental assets. Many measures designed for stormwater quantity control have inherent water quality management functions, while others can be retrofitted to serve the dual functions of stormwater quantity and quality management. For much of WA's urban areas, traditional stormwater infrastructure is nearing the end of its useful life and there is now the opportunity to replace these systems with the new multi-functional approaches to stormwater management discussed in this chapter.

To maximise the benefits of and opportunity for retrofitting, a whole-of-catchment planning approach is required. Planning for retrofitting should examine opportunities to improve management of stormwater at source, in transit and at end-of-pipe/catchment. Implementing numerous small-scale retrofit projects throughout the catchment can have a major overall impact on the health of receiving water bodies<sup>1</sup>. The key is to ensure that pollutant generation is minimised or prevented, pollutant transport pathways are 'disconnected', or pollutants are treated or captured before they reach the main drain or receiving water body. The National water quality management strategy promotes distributed, at-source control of both stormwater quantity and quality (ARMCANZ and ANZECC 2000). The role of at-source controls is paramount to the success of retrofitting. Preventing pollution and reducing the volume of stormwater requiring treatment are essential components of best practice stormwater management. Information on pollution prevention practices and community education for stormwater management is provided in Chapters 7 and 8, respectively.

The focus on source controls does not eliminate the need for in-system and end-of-pipe/catchment measures. End-of-pipe/catchment treatment measures may still be required in cases of high pollutant loading or contaminated soil or groundwater leading to residual impacts that cannot be cost-effectively mitigated by source or near-source controls. End-of-pipe/catchment techniques are also required in specific situations, such as where there are no retrofit opportunities elsewhere in the system, or treatment of water quality is required in the period before the source controls and treatment train measures take effect. This is particularly relevant for retrofitted systems where there may be some years before the accumulated contaminant sources in the drainage and groundwater systems are controlled.

Best practice is likely to include a combination of at-source, in-system and end-of-pipe/catchment measures. The guiding principle for retrofitting is the treatment train approach. A treatment train approach involves the implementation of a combination of different methods in sequence or concurrently to achieve the best management of stormwater. Different techniques remove different types of pollutants and a number of techniques are often required to treat the range of pollutants that may be present in stormwater. The treatment train approach provides a multiple barrier to protect water quality. This approach also reduces the loading

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<sup>1</sup> Receiving water bodies include waterways, wetlands, groundwater and coastal marine areas.

on individual stormwater management devices and increases the potential for stormwater management devices to function effectively, even during flooding events.

Retrofitting a traditional drainage system provides the opportunity to reduce changes to the natural water balance caused by development. The two main aims of retrofitting traditionally developed urban areas are to (adapted from Argue, 2004, and Department of Water and Environmental Regulation 2021):

- re-establish the total water balance within development areas relative to the pre-development conditions by reducing runoff through increased stormwater retention
- restore natural drainage systems as close as practicable to the pre-development state.

Retrofitting includes increasing temporary storage of stormwater, on-site re-use of water and increasing infiltration, for example by reducing the area of impervious surfaces. Impervious surfaces (such as bituminised and paved areas) that are directly connected to water bodies by stormwater pipes and drains can act as highways for runoff and potential pollutant transport. Impervious surfaces that convey runoff directly into water bodies (e.g. carparks draining directly to the street's drainage system that then discharges directly into a water body) can be disconnected and stormwater directed instead into permeable systems, such as soakwells, bioretention areas, swales, garden beds and vegetated open spaces, or the impervious surfaces can be replaced with pervious paving. Best practice stormwater management should retain and/or detain, and treat (if required) runoff and aim to infiltrate where the site condition is suitable. Retaining and detaining, and treatment of runoff reduces the impact on downstream water bodies (e.g. reduces erosion of waterways and drowning of wetland vegetation; reduces pollution of waterways, wetlands, and groundwater) and attenuates runoff peaks for flood protection of downstream areas.

It is important to note that pollution reduction is a primary objective for managing stormwater runoff from small/more frequent/ low-intensity rainfall events and 'first flush' storm events. For stormwater flows from major/rare/high-intensity rainfall events, the primary objective remains to reduce flooding of buildings, infrastructure and other assets. 'First flush' describes situations when pollutants (e.g. sediments, hydrocarbon, nutrients etc.) that have accumulated on impervious surfaces are transported at the beginning of a rainfall event.

This results in high pollution concentrations at the start of the runoff hydrograph, reducing to lower levels before the flood peak occurs (Argue, 2004). In particular, late dry/early wet season rains following long dry periods create high pollutant loads during runoff, where large volumes of materials such as litter, sediment and leaves that have accumulated on impervious surfaces are washed into the drainage system. This material can pollute receiving water bodies and result in impacts such as algal blooms and fish kills. Subsequent flow events effectively runoff 'cleaned' impervious areas and generally do not carry high concentrations of pollutants.

Detailed information on the guiding principles, objectives and approaches for stormwater management is provided in Chapter 2.

## 2 What is retrofitting?

Retrofitting is the process of installing or undertaking additional or alternative stormwater management devices or approaches in an existing developed area. These techniques include increasing storage and retention areas to reduce peak flows and using vegetated systems to facilitate pollutant treatment/filtration. Retrofitting can include both structural techniques (See Chapter 9) and non-structural techniques (See Chapter 7). Structural techniques include permanent, engineered devices implemented to control, treat, or prevent stormwater pollution and/or to reduce the volume of stormwater requiring management. Non-structural techniques are institutional and pollution prevention practices designed to prevent or minimise

pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management. They do not involve fixed, permanent facilities and they usually work by changing behaviour through government regulation (e.g. planning and environmental laws), persuasion and/or economic instruments (Taylor and Wong, 2002). The opportunity to improve on a traditional drainage system often arises during the redevelopment of older areas, or when the community initiates projects to improve the neighbourhood environment.

Retrofitting includes techniques implemented at a variety of scales:

1. Lot scale, for example:
  - maximising opportunities for capture and use of rainfall ‘on-site’ by techniques such as installing additional soakwells, rainwater tanks or garden bores
  - changing gardening practices, such as redesigning gardens to use catchment friendly techniques e.g. soil amendment, minimising grassed areas and replacing high water and fertiliser using plant species with native (preferably local provenance) plants
  - replacing impervious paving with pervious paving
  - installing oil water separators in commercial carparks and petrol stations.
2. Block and neighbourhood scale, for example:
  - removing kerbs from some sections of roads, such as where road runoff can flow into adjacent parkland
  - installing infiltration devices (e.g. ‘leaky’ sumps and gully / side entry pits) within roadways/road reserves
  - replacing impervious paving with pervious paving.
3. Catchment scale, for example:
  - rehabilitating open urban drains or removing sections of subsurface pipe and allowing surface flow through vegetated swales or ‘living streams’
  - installing infiltration devices throughout the catchment.

### 3 What will retrofitting achieve?

Retrofitting is intended to maintain or add to the benefits of traditional drainage (i.e. flood protection, retention and/or detention, and treatment). The multiple objectives of retrofitting are outlined below.

#### • ***Reduce flooding risk***

Retrofitting a catchment to increase retention and storage capacity, particularly higher in the catchment, prevents rapid collection downstream and results in reduced peak flows and better flood protection for residential areas.

Drain capacity needs to be considered when designing retrofit projects. There may be opportunities to reduce the required drain capacity by managing stormwater at or near source (see Chapters 7 and 9). Oversized open drains provide opportunity for implementing water quality and ecological restoration techniques, such as revegetation and habitat enhancement, without increasing the flood risk. Alternatively, increasing the size of the channel, where space is available, can offset the potential reduction in-drain capacity because of revegetation. Re-grading the typically steep banks of a trapezoidal drain through terracing or battering to create a gentle bank slope can increase the channel cross-sectional area. The gentle grade (maximum of 1 vertical: 4 horizontal) will assist with plant establishment as well as reduce the bank erosion risk. Natural waterways and drains that have been rehabilitated to ‘living streams’ have floodways that are able to store

and convey large flows. Broad, vegetated floodways result in increased storage volume, reduced flow velocities and greater area for infiltration, so that even larger rainfall events can be conveyed with little or no damage to the drainage system or receiving environments. For example, a large flood event that occurred in the retrofitted section of Bannister Creek, Lynwood, resulted in no damage to the restored waterway (see Figures 29 and 30 in Case Study 7.4). Increased compensation, storage and retention throughout the catchment, as well as improved integration of the stormwater system within public open space, will reduce the flood risk and downstream stormwater capacity requirements. An example is the Town of Victoria Park's stormwater management system outlined in Example 1.

### **Example 1**

The Town of Victoria Park (in Perth's southern metropolitan area) has developed an alternative method of stormwater management in response to a flooding problem in East Victoria Park. The flooding problem was caused by an existing sump (dry infiltration basin) on Patricia Street being too small for its catchment area. The problem was solved by installing five leach drain systems upstream of the sump to compensate flows. The stormwater is conveyed to a gross pollutant trap by pipes and then flows into the leach drain systems. The stormwater then infiltrates into the shallow aquifer. The Town has identified numerous sump sites within its boundaries with small to medium sized catchments that could be converted into other land uses such as public open space by using the above methodology. The existing sumps are unattractive, fenced-off blocks of land scattered throughout the town's area.

#### **• *Improve public health and safety***

Steep-sided drains present a potential safety risk, particularly to children who play near or attempt to climb into the drain and may fall down the bank. Retrofitting drains to 'living streams' involves reducing the grade of steep banks to a gentle slope and more natural waterway shape. A living stream has stable vegetated banks, diverse habitat and an ability to support a healthy ecosystem (see Section 6.2.9 and Case Study 7.4 for further information). Vegetation or fencing can be used in sections to form a barrier and discourage access to the water. Formalised access points, such as a crossing or riffle, can be used to allow public access to the stream at safer locations.

Retrofitting the drainage system can assist in the control of disease and nuisance vector insects (i.e. mosquitoes and midges) by reducing nutrient and pollution levels in stormwater and receiving water bodies. Shading cools the water, which reduces mosquito and midge numbers. Techniques that reduce the area of stagnant water, for example using flowing streams rather than stagnant pools, will also reduce the opportunity for mosquito breeding. Infiltrating or drawing down the water to prevent pooling for longer than four days will prevent completion of the mosquito larval life cycle. Refer to Chapter 9 for further detail on designing stormwater systems to reduce the risk of mosquitoes and midges.

#### **• *Improve water quality***

Retrofitting works can improve water quality by controlling pollutant inputs at source, reducing the mobilisation and conveyance of pollutants and treating stormwater by trapping or removing pollutants. The issue of water quality is not restricted to the main stormwater channels and receiving water bodies. Many minor tributaries and drains within the catchment can be a major source of pollutants. Historic sources of pollution, such as groundwater contamination seeping into stormwater channels, may continue to impact on water quality. Retrofitting projects need to be implemented in the context of a holistic approach to water management. Catchment management strategies, such as improved management of fertiliser use, are essential to address the problem at source to improve water quality in the long-term.

- ***Restore and conserve environmental condition***

One of the aims of retrofitting is to create a stormwater management system that also protects or restores environmental values. Retrofitting projects can incorporate revegetation and restoration of natural habitats (e.g. wetlands, waterways and bushland). Increasing the diversity of habitats in the urban landscape will result in improved biodiversity. Vegetated areas also improve stormwater treatment (e.g. nutrient removal) through increased stormwater filtration.

Retrofitting can increase stormwater retention/infiltration, which recharges the groundwater system. This can help restore groundwater dependent ecosystems, such as some wetlands that are degrading because of declining groundwater levels in response to low rainfall and high groundwater abstraction rates. Many waterways are also degraded because of the installation of dams and reduction in flows. Redirecting clean stormwater to provide environmental flows can potentially improve waterway health.

Infiltration of stormwater and re-use through garden bores can help manage the local water balance, limiting consequential environmental impacts from urban developments. Maintaining the water cycle balance can prevent problems associated with acid sulfate soils, salinity and waterlogging.

Research has shown that waterway biodiversity is significantly impacted by the amount of impervious surfaces directly connected (i.e. through pipes and drains) to waterways and the subsequent poor quality stormwater runoff (Walsh, 2004). Therefore, retrofitting projects that improve stormwater quality and/or ‘disconnect’ impervious surfaces can have positive benefits on the biological health of water bodies. Disconnection can be achieved by ensuring that stormwater does not discharge directly into water bodies (see Figure 1 for an example of direct connection to a wetland). For example, flow could be directed into bioretention systems or soakwells. Retrofitting projects should also aim to remove or rationalise the number of pipe and constructed channel outlets to waterways and wetlands. Outlets should be relocated so that runoff flows overland through vegetation towards waterways and wetlands (see Figure 2).



*Figure 1: Stormwater pipes entering Lake Monger, Wembley. (Photograph: Department of Environment, 2006)*



*Figure 2: Overland flow towards the Canning River, near Royal Street bridge, Thornlie. (Photograph: Department of Environment, 2006)*

Techniques to improve storage and retention/infiltration of stormwater in the catchment can reduce the velocity of water entering water bodies. Decreasing the ‘flashiness’ (where water levels rapidly peak and decline) and peak velocities of flows will decrease the potential for erosion of water bodies.

Improving water quality and removing lateral and longitudinal barriers to faunal movement, such as weirs, bunds and concrete banks, will also improve the health and biodiversity of waterways. Artificial drainage channels are often designed to convey minor to large flood events (e.g. 20%/10% AEP events or larger), resulting in isolation of the floodplain from the waterway and rare floodplain inundation. Many fish species and other aquatic fauna rely on annual flooding of the floodplain for breeding purposes and as a food source.

- ***Create more attractive and liveable neighbourhoods***

Using water sensitive urban design (WSUD) principles to retrofit an area enhances the social and environmental amenity of the urban landscape. Incorporating stormwater systems in public open space, rather than installing them in fenced-off drain/basin reserves, can make developments more desirable and marketable and increase property values. Property values adjacent to retrofitted drainage features, such as living streams and landscaped stormwater features (such as sumps and swales), have been shown to increase because of the increased amenity of the area. Case Study 7.4 discusses restoration works at Bannister Creek (Lynwood) that improved the recreational and aesthetic value of the area. It was estimated that the average values of nearby properties to the restored creek increased 4.4% (e.g. \$17,000 to \$26,000) more than properties adjacent to unrestored sections of Bannister Creek (Cooperative Research Centre for Water Sensitive Cities 2018). Linkages through the landscape can be formed through swales, waterways and riparian vegetation corridors, connecting communities through public open space. For more information, see the latest edition of Western Australian Planning Commission’s *Liveable Neighbourhoods*.

The visual amenity of the urban landscape can be enhanced by increasing the diversity of landforms (see Figure 3). For example, a meandering waterway or swale through parkland can create visual interest in an otherwise flat landscape. Restoring vegetation also improves the aesthetics of the stormwater system. Features of traditional drainage systems are often unaesthetic, consisting of uniform structures that provide little visual relief (such as straight line trapezoidal drains) and hard engineering (such as concrete erosion control mattresses, drop structures and poorly designed pipe outlets to waterways, wetlands and marine areas). These conflict with the natural environment and the landscaping undertaken to enhance



*Figure 3: Ascot Waters ‘amphitheatre’ soakwell, Ascot.  
(Photograph: Department of Environment, 2003.)*

public spaces. Retrofitting can result in the removal or enhancement of traditional artificial drainage structures, such as restoring weed infested trapezoidal drains to living streams with native (preferably local provenance) vegetation. Fenced basins/sumps are visually unappealing in public areas and can be enhanced through retrofitting; for example, by reshaping the banks to a gentle slope, revegetating with native (preferably local provenance) plant species and removing barrier fencing. Improving water quality also reduces the occurrence of unsightly and odorous algal blooms.

- ***Enhance the cultural values of the urban water landscape***

WSUD aims to protect and enhance the cultural values of the urban water landscape. Water and the landscape features it creates are often of spiritual significance and heritage value to Aboriginal people (Water and Rivers Commission, 2002a). Aboriginal sites, protected under the Aboriginal Heritage Act 1972, are often associated with water bodies, or may encompass an entire natural feature of the landscape, such as a waterway. Removing artificial barriers to stream flow, such as weirs, and restoring the connectivity of water flow is important in protecting Aboriginal values associated with waterways. It is important to consult with Aboriginal people so that heritage values and cultural sites can be protected. In particular, works involving excavating or driving objects into the bed and banks of water bodies are a significant issue for Aboriginal people. Aboriginal people often support water body rehabilitation projects as they also wish to achieve the same outcome of restoring and protecting these systems and maintaining the values of these areas for future generations (Water and Rivers Commission, 2002a).

The Western Australian Planning Commission's *Draft Planning for water guidelines* (WAPC 2022) recommends applying integrated water management approach to ensure that the environmental, social, cultural and economic values of water resources are recognised and maintained.

- ***Improve use of open space and enhance recreational opportunities***

Multiple use corridors are a feature of WSUD and result in more efficient use of urban land by linking the stormwater management system into landscaped public open space. For example, playing fields can also act as temporary stormwater detention areas and parks can incorporate swales and living streams. Walkways can be integrated with waterways, swales and vegetation corridors to create a passive recreation network. Some traditional drainage systems (e.g. fenced-off drains and sumps such as the compensating basin shown in Figure 4) can be retrofitted and incorporated into public open space, particularly if the systems are located adjacent to public open space (see Figure 5).



*Figure 4: Fenced compensating basin, Redgum Court, Kewdale. (Photograph: Swan River Trust, 2005)*



*Figure 5: Park adjacent to the compensating basin, Redgum Court, Kewdale. (Photograph: Swan River Trust, 2005)*

Improving water quality also improves the opportunity for water related recreation, such as canoeing and fishing, and decreases the occurrence of algal blooms that present a health risk. Areas like the lower Canning River catchment upstream of the Kent Street Weir (Perth) occasionally experience harmful blue-green algal blooms shortly after late summer/early autumn rainfall events. These blooms often occur after long, dry periods when large loads of material and associated nutrients have accumulated on impervious surfaces and this material is then conveyed by stormwater into the Canning River (Swan River Trust and Department of Environment, 2005). Retrofitting the catchment to trap or treat these pollutants, in association with non-structural measures to reduce pollutant inputs at source, can result in decreasing the occurrence of these algal blooms.

- ***Improve community environmental awareness***

Retrofitting projects that improve the aesthetics and environmental values of a stormwater system can result in significant changes to community perception and awareness of the environmental issues associated with urban stormwater. Rather than seeing a drain as a disposal system and stormwater as a waste product, a restored waterway integrated with public open space is more likely to be considered by the community as an asset and stormwater valued as a resource. Littering or pollution of an aesthetically pleasing and valued waterway is more likely to attract the attention of the community than the pollution of a weed infested or unsightly artificial drain. Involving the community in the initial planning and design of the retrofit project, as well as planting days or litter collection days (e.g. Clean Up Australia Day activities), will increase ownership of the site and reduce littering of the waterway.

Community awareness can also be increased through media associated with the retrofit project, such as interpretative and explanatory signage at the site, local community newsletters and newspaper articles. The community or school group could also be involved in the maintenance and monitoring of a stormwater treatment device such as a gross pollutant trap, where safety issues can be addressed.

- ***Increase cost effectiveness***

By retrofitting a traditional drainage system with a range of best management practices (BMP) techniques, the size of the required structural stormwater system can be reduced (Victorian Stormwater Committee, 1999). Reducing peak flows and maintaining more natural stormwater systems can reduce capital and maintenance costs of stormwater infrastructure (Victorian Stormwater Committee, 1999). Using stormwater as a water source, for example, by using rainwater tanks or through recharging and using groundwater supplies, reduces stormwater infrastructure requirements as well as demands on potable supplies. Retrofitting to achieve multiple uses offers cost benefits where land can be used for integrated stormwater management and passive recreation and contributes towards the required public open space provision of developments.

- ***Demonstrate best management practices (BMPs)***

Retrofit projects can be used as demonstration sites for specific stormwater management practices. There is a community expectation that government agencies will lead by example. Trialling new techniques and demonstrating the benefits of best practice stormwater management will encourage broader adoption of the techniques by other government agencies and developers. There is a range of positive publicity opportunities and promotional activities that could be associated with a best practice retrofit project, for example newspaper articles. The project could also be nominated for an environment award or assist accreditation under an environmental program, to demonstrate to stakeholders the organisation's commitments and achievements in environmental best practice. Examples of awards and programs include: Australian Water Association's WA Grahame Heal WSUD and WA Innovating for Sustainable Water and Environmental Outcomes Awards; Community Choice Awards; IPWEA WA Excellence Awards; Stormwater Industry

Association's National and State Awards; Housing Industry Association's GreenSmart® Program; and the Water Corporation's Waterwise Program.

- ***Utilise stormwater as a valuable resource to reduce potable water use***

The *Planning for water guidelines* (WAPC 2022) promote water conservation mechanisms that increase the efficiency of the use of water, including stormwater. This includes minimising the import and use of scheme water, promoting the use of rainwater, promoting the re-use and recycling of wastewater, reducing irrigation requirements, and promoting opportunities for localised supply. The State Government has brought on new drinking water supplies, put water efficiency measures in place and developed 'best practice' urban water management principles in the design of suburbs and infill developments (which use vacant land parcels within previously built areas). Water-saving programs have been highly successful in improving water efficiency and conservation, reducing annual per person water supplied from 185 kL to 126 kL since 2001 to 2018–19. A number of action items related to water conservation and efficiency outcomes have been set by the State Government (Waterwise Perth Action Plan 2019). Total water cycle management recognises that water supply, stormwater and sewage services are interrelated components of the whole water cycle. An integrated approach to managing these components can achieve many additional benefits, such as increased water conservation and re-use, compared with the traditional approach of managing them as separate entities.

Retrofitting projects can result in greater redirection of stormwater into the groundwater system, essentially making it available for use during drier periods through garden and council bores, while helping to conserve scheme water. Retrofitting projects can also include the installation of rainwater tanks that collect runoff from roofs, where the water can be used for non-potable purposes such as toilet flushing, washing machine use, vehicle washing and garden irrigation. In some circumstances, carpark runoff can be used for garden/ reserve irrigation. However, rainfall patterns need to be considered when garden irrigation is planned because large runoff storage tanks or supplementary water supplies might be required.

Further information about total water cycle management is provided in Chapter 2. Section 2.5.2 of Chapter 7 also provides a guideline for managing the total water cycle. Information about stormwater tanks and aquifer storage and recovery is provided in Chapter 9.

## 4 When are retrofitting techniques suitable?

WSUD should be implemented early in project planning, when land is initially being developed. Retrofitting should be considered in existing developed areas where the hydrologic, ecological and water quality requirements have not been adequately addressed. Planning in advance creates opportunities for retrofitting in areas reaching redevelopment potential. Urban renewal projects are becoming increasingly popular as a means to address the demands of population growth. Redevelopment of older residential, commercial and industrial areas provides an ideal opportunity to incorporate retrofitting measures into the redevelopment process. For more information on land use planning and development, see *Planning for Water Guidelines* (WAPC, 2022).

High-density developments typically result in increased impervious areas. To reduce the risk of flooding downstream areas, stormwater runoff from high-density developments should be minimised through the incorporation of measures such as pervious paving, soakwells, detention systems, bioretention systems and 'rain gardens' (e.g. roof gardens and carpark garden beds). Refer to Argue (2004) for examples of how to retrofit high-density developments at the lot, street and development scale.

The Department of Water and Environmental Regulation is encouraging the retention and detention of stormwater close to where it falls as rain to maximise infiltration and evapotranspiration opportunities,

rather than collection and downstream conveyance. This is possible in many new (greenfield) areas. However, infiltration opportunities may be limited in already established built-up areas with restricted space and access, especially in areas with clay, bedrock, high groundwater levels or steep slopes. Quantity management criteria are outlined in the Decision Process for Stormwater Management in WA (Department of Water and Environmental Regulation 2017).

Source control<sup>2</sup> is the most effective method to reduce nutrients and contaminants discharging into water bodies. However, this is a long-term process that may take many years to produce a measurable change, because of contaminants already present in the drainage system. The recommendations outlined in this chapter should be undertaken in conjunction with source control measures, such as cleaner production and community education. Many source controls are non-structural and can easily be used in a retrofit context. In established urban areas where stormwater quality needs to be improved, installation of some types of structural controls can be difficult and/or expensive because of space constraints and existing infrastructure (e.g. sewer pipes). For example, the use of constructed wetlands for removal of fine sediment and nutrients from established urban areas requires large land areas. Additionally, unlike structural controls, many non-structural controls can be quickly modified to take advantage of new opportunities or to respond to new priorities. Soluble pollutants, which are often difficult to treat through structural techniques, can be addressed through non-structural techniques involving behavioural change to prevent pollutants entering the stormwater system. Chapter 7 provides further information on non- structural controls, which can be applied in retrofit projects in combination with structural techniques.

## 5 Costs and resourcing

The costs associated with retrofitting a system, particularly with structural techniques, can be large. There are costs associated with site selection, site investigations, design, approvals, construction (such as earthmoving, infrastructure and vegetation) and project management. There are also ongoing costs associated with maintenance, monitoring and, if necessary, the cost of decommissioning. These life cycle costs should be included in project budgets and plans. More information about the costs of installing and maintaining non-structural and structural controls is provided in Chapters 7 and 9, respectively.

The costs associated with implementing non-structural techniques as part of a retrofit project can be relatively small and can result in savings or revenue in some cases. For example, techniques to reduce sediment pollution in stormwater may result in savings in terms of reduced loss of valuable topsoil and building/landscaping materials that may be washed off-site, as well as reduced maintenance costs to clean the stormwater system (refer to Section 2.1.1 of Chapter 7 for further information).

Limited data has been collected by Australian asset managers on life cycle costs of stormwater BMPs (Taylor, 2003), so a meaningful comparison of BMP costs with traditional drainage systems is difficult. Taylor (2003) provides a data recording sheet for collecting life cycle costs. In addition, very little information is available on triple bottom line assessment of stormwater BMPs.

### 5.1 Funding

Establishing a dedicated and stable source of funding for stormwater management is a critical component of ensuring the long-term viability of programs and public support. Exploration of funding options should occur early in the development of a region's stormwater management program. Secure, long-term funding

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<sup>2</sup> Source controls are non-structural or structural BMP to minimise the generation of excessive stormwater runoff and/or pollution of stormwater at or near the source and protect receiving environments.

is required to continue to maintain and monitor the stormwater management devices and programs. Short-term funding can lead to poor outcomes, such as gross pollutant traps that become a source of nutrients and contaminants because of lack of maintenance. Successfully establishing a funding program often requires a community education component to clearly demonstrate the need for stormwater management projects. See Section 2.4.1 of Chapter 7 for further information about funding programs for stormwater management.

## 5.2 Incentives

A good example of a funding system is the use of economic incentives that can operate under a property-based stormwater fee/utility. For example, such a funding mechanism can be structured so that properties with a large amount of directly connected impervious area (e.g. a traditional carpark) pay a relatively high fee, while properties with a small amount of directly connected impervious area (e.g. a carpark with bioretention systems) pay a relatively low fee. Such an arrangement provides a strong, ongoing economic incentive for WSUD for both developing areas and existing areas. It is also consistent with the ‘polluter pays’ and ‘user pays’ principles.

Integration of stormwater management techniques with public open space could also offer incentives in terms of more efficiently using land and freeing up land traditionally allocated to drainage. Retrofitting can reduce the size of, or eliminate the need for, traditional drainage features such as sumps, and create new opportunities for redevelopment in established areas.

Further information on funding, policy, regulatory and enforcement practices is provided in Section 2.4 of Chapter 7.

## 6 Retrofitting – how do you do it?

The *Decision Process for Stormwater Management in WA* (Department of Water and Environmental Regulation 2017) should be referred to when planning retrofitting projects. A flow chart showing the simplified design process for retrofitting projects is provided in Chapter 4 of the manual.

### 6.1 Planning stages

Retrofitting should be part of an overall stormwater management plan. The primary role of a stormwater management plan is to facilitate the coordinated management of stormwater within a catchment or local government area, to maximise the environmental, social and economic benefits of stormwater management practices. It is a particularly useful tool for improving stormwater management in established urban areas, where the process of land use planning for individual redevelopment sites is often not sufficient to improve stormwater management.

Part of the stormwater management plan process involves defining the problems and information requirements, including information on the catchment, stormwater system, receiving environments, land use patterns and activities, pollutants and stormwater threats. The process results in a list of recommended actions based on cost, effectiveness in protecting or enhancing the environmental, cultural and heritage values of the catchment and receiving environments, opportunities for implementation and capability of the stormwater manager to implement (Victorian Stormwater Committee, 1999). Chapter 5 outlines the process for preparing stormwater management plans.

#### 6.1.1 Identify the main objectives

As stormwater management is so multifaceted, the objectives of a retrofitting project should be clearly identified. Objectives can include environmental benefits (e.g. water quality improvements, hydrologic

modification and erosion control), habitat value (biodiversity and conservation), or anthropocentric benefits (e.g. aesthetics and recreation). Good designs can also include many secondary objectives that do not compromise the primary aims.

### 6.1.2 Identify and engage stakeholders

The early stage of a retrofitting project requires the identification and involvement of all stakeholders. In many sites in urban areas, there are likely to be many stakeholders that have a direct interest in the project and will need to be consulted, such as the local government authority, relevant State Government departments, catchment and community groups, nearby residents and industries, and traditional owners. See Water Note 30: Safeguarding Aboriginal heritage (Water and Rivers Commission, 2002a) and the Department of Planning, Lands and Heritage for more information on consulting with Traditional Owners and Aboriginal heritage sites and surveys. The identification of stakeholders and the development of a communications plan assist with streamlining the design and approvals processes. At this stage of the process, it is also good practice to identify long-term ownership and management responsibilities. Local governments and other service providers (such as Water Corporation, Main Roads WA, Public Transport Authority) own and manage urban stormwater infrastructure in the state.

In developed areas, WSUD requires greater community support and is often more difficult to implement than in new developments. For example, it is essential to gain the support of people that live adjacent to drains and sumps that are proposed for retrofitting works. Any work needs to be acceptable to adjacent landholders and must minimise adverse effects. For example, tall vegetation on the banks can obscure landholders' views and make them feel more vulnerable to intruders. Vegetation may also increase fire risks and provide a habitat for pests. Some nearby residents may also be actively involved in the area and may be able to contribute to the development of a project with local knowledge of issues such as litter, sedimentation, erosion, flora and fauna species and hydrologic patterns. Therefore, the decision process must consider community issues, such as public health and safety impacts (e.g. the control of disease vector insects).

### 6.1.3 Legislative requirements

Before any structural retrofitting works are planned, the following acts may need to be considered and the relevant approvals granted (Table 1).

**Table 1. Acts which may affect retrofitting proposals**

Agency	Relevant Acts	Requirements under the acts
Department of Biodiversity, Conservation and Attractions (DBCA)	<i>Conservation and Land Management Act 1984</i>	Applies to projects undertaken within lands managed by DBCA
	<i>Biodiversity Conservation Act 2016</i>	Protecting flora and fauna
Environmental Protection Authority (EPA)	<i>Environmental Protection Act 1986</i>	An environmental impact assessment may be required under Part IV
Local Government	<i>Health Act 1911</i> <i>Local Government Act 1995</i>	Development must be consistent with these acts
Department of Planning, Lands and Heritage (DPLH)	<i>Planning and Development Act 2005</i>	Development must be consistent with this act
	<i>Aboriginal Heritage Act 1972</i>	Approval is required for works that may impact on areas such as native vegetation or near water bodies, because of their association with Aboriginal heritage and culture.  Aboriginal heritage values and cultural sites must be protected, and disturbance minimised or avoided.
Swan River Trust (SRT)	<i>Swan and Canning Rivers Management Act 2006</i>	Approval is required from the Trust to undertake any developments within the Swan River Trust Management Area.
Water Corporation	<i>Water Services Act 2012</i> <i>Water Corporation Act 1995</i> <i>Metropolitan Water Authority Act 1982</i>	It is an offence under the <i>Water Services Act 2012</i> and the <i>Metropolitan Water Authority Act 1982</i> to interfere with any drainage system vested in the Water Corporation without seeking prior approval.

Agency	Relevant acts	Requirements under the acts
Department of Water and Environmental Regulation	<i>Environmental Protection Act 1986</i> Environmental Protection (Clearing of Native Vegetation) Regulations 2004	A clearing permit may be required under Part V, Division 2 of the <i>Environmental Protection Act</i> , unless an exemption applies under either the <i>Environmental Protection Act</i> or the Regulations
	<i>Waterways Conservation Act 1976</i>	Applies to development near prescribed waterway management areas
	<i>Water Services Coordination Act 1995</i> <i>Water Services Licensing Act 1995</i> <i>Water Agencies (Powers) Act 1984</i>	Regulates and licenses water service providers.
	<i>Rights in Water and Irrigation Act 1914</i>	A licence may be required to draw water from proclaimed groundwater and surface water areas.
	<i>Country Areas Water Supply Act 1947</i> <i>Metropolitan Water Supply, Sewerage and Drainage Act 1909</i>	Protection of proclaimed public drinking water source areas.

#### 6.1.4 Site investigations

Once stakeholder support has been achieved, the next stage is to start undertaking site investigations to determine the most appropriate BMP or suite of BMPs to use. The type and extent of investigations required will depend on the site and project. For the design of structural controls, topographical surveys, climate, hydrologic data (e.g. discharge ratings and groundwater levels), geotechnical data, monitoring for surface water and groundwater quality, fauna/flora assessment (including identification of weed species and fauna passage requirements) and testing for acid sulfate soils<sup>3</sup> should be minimum requirements.

Where non-structural controls are being implemented, additional information on the planning, regulatory, institutional and operational environment may also be required. For example, this may include community or industrial site surveys to collect information on people's awareness and behaviour in relation to stormwater management.

<sup>3</sup> Acid sulfate soil 'high risk' areas are documented in *Acid Sulfate Soils Planning Guidelines* (Western Australian Planning Commission, 2008).

### 6.1.5 Identify opportunities and constraints

There may be constraints restricting implementation of structural controls, including shallow or polluted groundwater, disturbance of acid sulfate soils, bioaccumulation of metals and other contaminants, limited land availability and the potential for mosquito breeding. Proponents must also check cultural and heritage values, including Aboriginal heritage, impacts on flora and fauna, pests, weeds, fish passage, erosion control, groundwater protection and a range of potential impacts on the community, including public health and safety. Existing knowledge and perceptions can be a barrier to implementing BMPs, for example the preference for traditional practices and the reluctance to trial new techniques. As discussed in Section 5, life cycle costs must also be considered. Retrofitting projects may offer opportunities to enhance the social and environmental values of the area and provide additional benefits, as outlined in Section 3.

#### **Groundwater issues**

Infiltration strategies should consider the risk to the quality of shallow groundwater aquifers. Stormwater from sites that have the potential to contain harmful pollutants and high nutrient concentrations must be pre-treated before infiltration or discharge off-site. Separation of stormwater runoff at source to minimise interaction of poor and good quality water is a recommended practice.

If groundwater monitoring shows that there is already groundwater contamination, that is the groundwater is polluted with physical, chemical or microbiological matter that has the potential to present a risk of harm to human health or environmental values, management measures are required to contain the plume. Infiltration opportunities may be limited as direct infiltration may increase groundwater transport (by increasing groundwater gradients) and increase the risk of interception of historic shallow contaminant sources (e.g. seepage well and buried wastes). Build-ups in pollutant loading throughout drainage systems, because of past land uses or limited implementation of structural and non-structural control measures, will result in delayed benefits from retrofitting projects to the receiving water body. A site investigation is required in order to make an informed decision about the best management measures. The design may include techniques to trap and treat a groundwater plume, for example by installation of a cut-off trench and direction of nutrient rich groundwater through a bioretention system or constructed wetland. Conversely, the design may include raising the invert of existing drainage channels that convey contaminated base flow, so that the channel does not intercept and facilitate contaminated groundwater transport. The feasibility and potential impact of these options, including the impact on dependent ecological systems, would need to be examined.

Rising groundwater and perched water tables can cause the accumulation of sulfates, sulfides, iron oxides and salt. Resulting soils have poor productivity and have the potential to cause significant downstream environmental problems if affected areas are drained. The sediments of some groundwater-dependent wetlands on the Swan Coastal Plain can acidify if the water table falls well below the base of the wetland because of dry weather, drainage or excessive groundwater pumping (Department of Water, 2015).

If maximum groundwater levels are near the surface (within 2 metres), then runoff from impervious surfaces generally should not enter a piped system directly, rather it should be initially treated (where required) and infiltrated where site condition is appropriate for infiltration. This is because most of the available separation to the maximum groundwater level, and therefore the opportunity to promote infiltration, is lost once runoff is directed into subterranean drainage systems. The runoff from the initial part of rainfall events should be infiltrated at the ground surface (e.g. a swale, infiltration cell, pervious paving or bioretention area) before the runoff from (generally) greater than one exceedance per year events enter a piped or overland flow system. Runoff should preferably flow through vegetation and soil to promote biological treatment and water uptake.

If groundwater levels are rising or have potential to cause waterlogging in a developed area, infiltration into

the ground may need to be significantly reduced and subsoil drains may be used to prevent this waterlogging. These subsoil drains should be set at the approved Controlled Groundwater Level. See Decision process for stormwater management in WA (Department of Water and Environmental Regulation 2017), Water resource considerations when controlling groundwater levels in urban development (Department of Water 2013) and the Specification: separation distances for groundwater controlled urban development (Institute of Public Works Engineering Australasia 2016) for more information on managing groundwater level including Controlled Groundwater Level.

### **Flooding issues**

Open drains and sumps/compensating basins can be retrofitted where there is adequate space, or the systems are larger than the required capacity. The Water Corporation is the owner of the majority of the main drainage network in the Perth metropolitan area and has a responsibility to meet the requirements of their operating licence (administered by the Economic Regulation Authority) with respect to flood mitigation. Any works in the stormwater system cannot compromise the flood capacity or protection of property. Additionally, the trend of increased urban infill may also raise the demand on drainage systems. The requirement to meet future flood control and mitigation expectations needs to be considered.

### **6.1.6 Deciding on the best approach**

To effectively retrofit a system, it is necessary to match the selected BMP with the site characteristics, including target pollutants and their transport pathways, and groundwater levels. For this selection to be successful, the designer needs to know something about the catchment (land use, current stormwater management practices, soil types, hydrology) and something about the pollutants (typical components, dominant transport pathways). If one of the objectives of the project is to improve water quality, it is essential that the water quality of the stormwater is known (or estimated) beforehand, as this will influence the choice of BMPs. Different processes are required for removing different pollutants and their components. If litter is a large problem (i.e. from high traffic or commercial areas), then an at-source gross pollutant trap (GPT) may be useful; however, its suitability for the catchment and expected inflows still needs to be considered. If high concentrations of hydrocarbons from street runoff are expected, then an oil and grit trap may be the best solution. Stormwater with a high amount of sediment or nutrients attached to sediment can be treated by using open retention/detention areas, for example vegetated swales, which encourage sedimentation or filtration. Stormwater with a high amount of dissolved nutrients can be treated with BMPs that encourage biofilm growth, such as bioretention systems and ephemeral constructed wetlands. Dissolved nutrients and pollutants can also be removed by using amended material and pervious paving. Table 2 details structural BMPs to use to target specific water quality issues. To complement the selected structural BMPs, non-structural BMPs need to be implemented. For example, gross pollutants can be managed through implementing improved site management practices, litter bin provision, street sweeping, litter collection, plant selection and maintenance and regulation practices. See Chapter 7 for more information on the selection and design of non-structural controls.

The sequencing of BMPs in the treatment train is important in achieving best management of stormwater. For example, gross pollutants and sediment can clog and reduce the performance of infiltration systems, constructed wetlands, pervious paving and swale drains. Pre-screening devices such as buffer strips, GPTs and sediment trapping areas can be installed before discharging stormwater runoff to downstream treatment systems.

Many drains were built in the early 1900s and some are over-designed. Maintenance practices, such as clearing and removing accumulated sediment from drains, have resulted in some drains being much larger than their original design. Where drains are oversized, then retrofitting to increase compensation, enhance habitat, restore vegetation and improve water quality is an option. However, where space is restricted and maximum facility capacity is required, the drain may be unsuitable for structural retrofitting. Where space

is at a premium, alternatives such as retrofitting the catchment to reduce discharges to the constrained channel, or relocating infrastructure to widen the drainage reserve should be examined.

**Table 2. Tools for targeting key parameters to improve water quality**

BMP		Provide habitat	Improve aesthetics	Improve Water Quality							Issues	
				Reduce total suspended solids	Reduce litter	Reduce particulate total nitrogen, total phosphorus	Reduce dissolved nutrients	Increase oxygen	Reduce hydrocarbons	Reduce heavy metals	Reduce bacteria	Increase risk of mosquitoes
GPTs				✓	✓	~			~	~		✓
Trash racks etc.					✓							✓
Grass swales			✓	✓		✓	~		~	~		
Filter strips	~	✓	✓	✓	✓	✓	~			~		
Sand filters				✓		✓						
Oil and grit traps									✓			
Riffles	✓	✓	✓	✓				✓				
In-stream plants	✓	✓	✓	✓		~	✓	✓				
Soil amendments							✓					
Permeable/ porous paving							✓			✓		
Bioretention systems	✓	✓	✓	✓			✓					
Infiltration areas				✓		✓				✓		
Open water (UV exposure)	✓	✓									✓	✓
Constructed wetlands	✓	✓	✓	✓		✓	✓	✓				✓
Sediment basins				✓	✓	✓			~	~		✓

✓ denotes parameter/issue is applicable to this BMP

~ denotes parameter/issue is applicable to some extent to this BMP

## 6.2 Implementation

Chapters 7 and 9 identify a number of techniques that are potentially applicable to retrofit projects and provide detailed BMP guidelines. Structural controls, such as stormwater infiltration systems, swales, 'living streams', bioretention systems, GPTs, oil water separators and constructed wetlands are outlined in Chapter 9. Brief descriptions of several BMPs that are particularly relevant in a retrofit context are provided below.

### 6.2.1 Rainwater storage systems

Rainwater tanks, enlarged-gutter storage or similar systems store water that is collected on a roof. They can be used at a lot scale or development scale for water capture and re-use, hence taking pressure off scheme water supply. However, these systems need to be maintained to ensure that they do not become breeding habitats for mosquitoes. The water quality is significantly impacted by the maintenance of the guttering and rainwater tank. A first flush system and gutter guards or screens over inlets should be installed and gutters cleaned regularly to reduce the amount of debris entering the tank. The Department of Health (WA) supports the use of rainwater tanks in urban areas for non-potable uses. Roof runoff is suitable for toilet flushing and washing machine use. It may also be suitable for some hot water systems. The Department of Health advises that unless adequately treated, rainwater is not reliably safe to drink. Further information is provided in the Department of Health, Water Corporation and Department of Water and Environmental Regulation's websites. More information about using rainwater tanks is provided in Chapter 9.

### 6.2.2 Infiltration systems

Infiltration systems include a number of devices, such as soakwells, soakage areas (e.g. basins and retention trenches), leaky gully/side entry pits, swales, pervious paving and bioretention systems, designed to promote stormwater permeation into the soil profile. A number of these techniques are discussed in more detail in subsequent sections. Correctly designed infiltration systems remove pollutants from stormwater through the processes of adsorption, filtration and microbial decomposition. Infiltration devices can be installed at source to help maintain the local water balance and minimise the volume of runoff that can potentially carry pollutants from the site. This approach has a number of environmental and economic benefits, including reduced peak stormwater flows, reduced downstream flooding, reduced stormwater drainage capital costs, improved groundwater recharge and improved stormwater quality (Coombes, 2003).

Existing stormwater devices can be retrofitted to introduce more on-site infiltration. For example, solid base manholes, gullies and side entry pits can be modified (e.g. by coring out a hole in the base of the pit, as shown in Figure 6) to allow for infiltration, or existing devices can be supplemented with additional soakwells or infiltration cells/leach drains. This allows for on-site infiltration, while still maintaining a stormwater detention function, with larger runoff events accommodated by overflow systems. Figure 19 of Case Study 7.1 provides a concept design of a retrofitted gully with a soakwell added to the system. The base of the unit may need to be covered by a grate to prevent the permeable base material (e.g. blue metal) being sucked up by educting equipment and the unit being destabilised (Todd, B., 2005, pers. comm.<sup>4</sup>).

The infiltration of roof runoff is widely practised in WA, where the majority of urban development is located on the highly permeable, sandy soil of the coastal plains. Roof runoff is directed into soakwells, infiltration cells/leach drains or gravel-filled trenches where the stormwater infiltrates into the ground. However, galvanised iron roofs have been identified as being a potential source of zinc and cadmium contamination of stormwater. Infiltration systems for treating runoff from more general areas such as streets and carparks can also be integrated into landscaping features.

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<sup>4</sup> Personal communication with Bill Todd, Technical Engineering Officer, Town of Victoria Park, 2005.

The design of an infiltration system should consider the site conditions, particularly the soil hydraulic conductivity and groundwater quality and levels, as well as the pollutant types and rainfall characteristics of the catchment. Infiltration may be constrained in areas with high water tables, low permeability or steep sites such as scarp slopes, and may not be suitable in areas with waterlogged soils, contaminated groundwater or rising salinity. However, infiltration is particularly suitable in sandy areas with lower (greater than 2 metres to the annual maximum groundwater level) groundwater tables. The effectiveness of the system decreases dramatically if the soil infiltration rate or the system's permanent storage volume are incompatible with the rate and volume of inflow. Infiltration devices should be designed to accommodate small rainfall events (e.g. very frequent to frequent events as defined in ARR 2019). The devices are not usually designed to infiltrate major events (e.g. less frequent) or to provide the primary function of flood control (although decreased flooding can be a benefit). Lack of appropriate maintenance, resulting in clogging, is one of the main causes of reduced effectiveness over time. The appropriate positioning of infiltration systems within the stormwater treatment train is also important. Pre-screening devices to prevent gross pollutants and sediment clogging the infiltration system may be required. More information about infiltration systems is provided in Chapter 9.

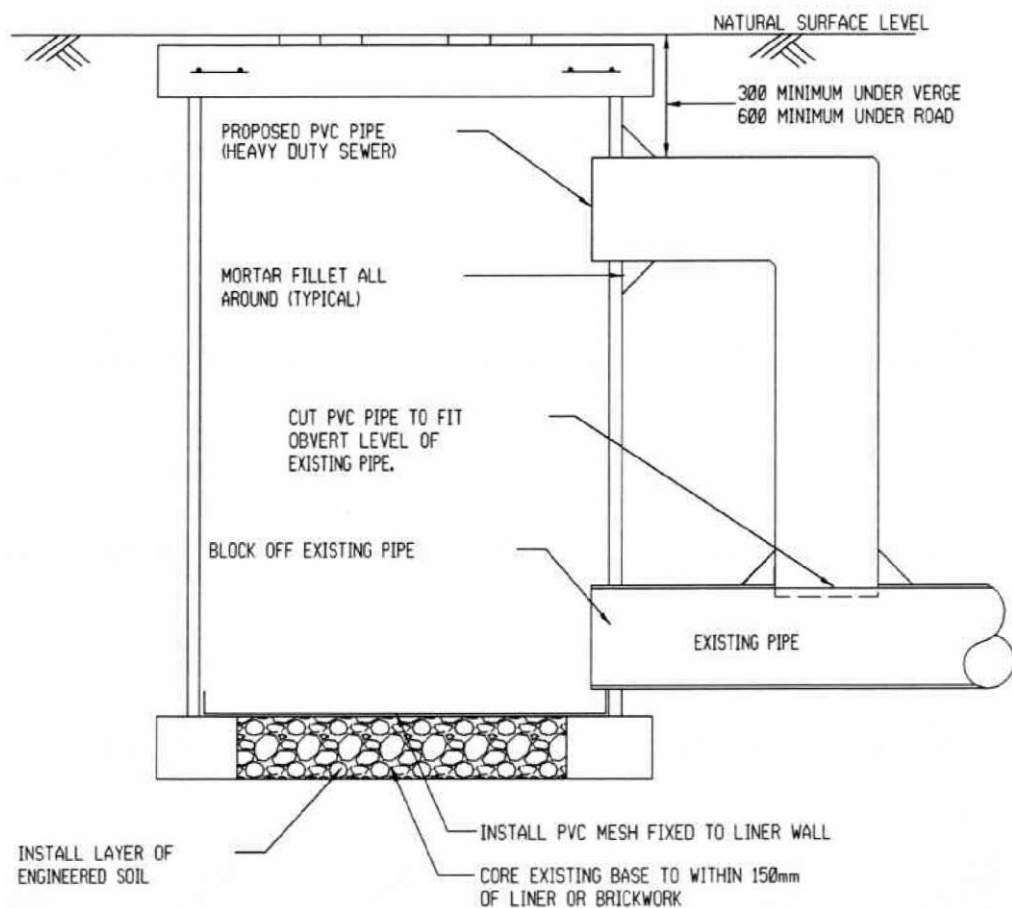


Figure 6: Retrofitting option for solid base pits. (Supplied by B. Todd, Town of Victoria Park.)

### 6.2.3 Pervious paving

Permeable/porous (collectively termed pervious) paving may be suitable in trafficable and non-trafficable areas where there is existing bitumen or concrete. Roads, carparks, footpaths and other hard surface areas (such as paving surrounding buildings) are typically impermeable and result in high runoff rates during a storm event. Pervious paving can either be produced by placing permeable material between widely spaced impermeable pavers, or by installing porous paving.

The use of pervious surfaces (e.g. porous paving or vegetation) is particularly important around buildings that do not have roof gutters (which is a common feature of buildings in the north of the state) (see Figure 7). The pervious surfaces will prevent soil erosion that can be caused by large volumes of water running directly off the roof onto the ground during intense rainfall events.



*Figure 7: Pervious surface underneath a gutterless roof, Shire of Broome offices, Broome. (Photograph: Allan Ralph, Shire of Broome, 2005.)*

Overseas experience in the use of pervious paving has shown that clogging can occur between 5 and 10 years after installation, so cleaning of the paving is essential (Dierkes et al., 2002). The pervious paving not only allows for infiltration but can improve the water quality. More information is provided in Chapter 9 and in *Water Sensitive Urban Design: Basic Procedures for 'Source Control' of Stormwater – A Handbook for Australian Practice* (Argue, 2004).

Australia's first street where traditional bitumen has been replaced with permeable pavement and permeable sub-base is on Smith Street in Manly, Sydney. The *Manly stormwater treatment and re-use* project involved permeable pavement, biological treatment and re-use of stormwater collected from parking areas along the North Steyne on Ocean Beach, Manly. Gutters in the street were eliminated to attenuate flow, increase infiltration and reduce the transportation of pollutants. Treated stormwater was reused for irrigation.

### 6.2.4 Gross pollutant traps

GPTs are effective in removing gross pollutants such as litter, vegetation debris and sand that are typically found in urban catchments. Like any structural BMP, GPTs need to be well maintained otherwise they are at risk of becoming a source of poor water quality and may even impede water flow, causing flooding. A variety of GPTs are available and selection may depend on cost effectiveness, expected flow rates and maintenance requirements. More information about GPTs is provided in Chapter 9.

#### Example 2

Various types of gross pollutant traps have been installed by the City of Belmont. A Rocla® Defender™ was installed in 1997 and has been successful in trapping solids in runoff from roads and stables near Epsom Ave, Ascot. The city has also installed a gross pollutant trap (prefabricated system with sedimentation and screening) near Mathieson Road/Ascot Racecourse, Ascot, to trap solids before discharge into a series of nutrient stripping ponds. A Geotrap pit was installed at Forbes Street, Ascot, near the Swan River foreshore. In 2003, the City installed a Wormall's Ecobite stormwater pollution pit at Faulkner Park off Wright Street to trap solids and hydrocarbons before the runoff entered the lakes in the park (Tan, P., 2003, pers. comm.<sup>5</sup>). Another Wormall's Ecobite stormwater pollution trap was installed on the pipe system at Ford Street to trap solids in the runoff before they discharged into the river (Tan, P., 2003, pers. comm.).

#### Example 3

In conjunction with the City of Bayswater, the former North Metropolitan Catchment Group (NMCg)<sup>6</sup> installed a continuous deflective separator (CDS) unit at Wotton Street in the Bayswater industrial area in 1999. Continuous deflective separator units are reported to be very effective at removing litter and debris from stormwater to a particle size of 5 mm. In 2002, the former Bayswater Integrated Catchment Management Group analysed the proportions of solids trapped by the CDS (Warner, undated). The main component of the trapped waste was organic matter and sediment (>95%). Visual inspection found that the solids were trapping hydrocarbons and the report recommended that absorbent pillows be used to increase hydrocarbon removal. The CDS unit was maintained annually and the report recommended that the unit is emptied two or three times per year, as the unit contents were believed to be increasing the nitrogen and phosphorus contents in the stormwater via decomposition.

### 6.2.5 Swales

Swales can be part of the integrated stormwater treatment train, with their use matched to expected pollutant types and forms (Fletcher, 2002). An example of the integration of a grass swale within the grounds of Broome Senior High School is shown in Figure 8. Grass swales may be suitable for removal of particulate contaminants in lower flows and swales planted with sedges may be more suitable for higher flows (Fletcher, 2002). Vegetated swales should be planted with local native plant species to enhance biodiversity, reduce the need for fertiliser application or watering and reduce the spread of weed species to receiving environments via stormwater flows.

Although some studies in Australia have shown that grassy and native vegetated filter strips are not generally

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<sup>5</sup> Personal communication with Patrick Tan, City of Belmont, 2003.

<sup>6</sup> Previously the North East Corridor Committee.

very effective at trapping dissolved nutrients, they are generally more effective at removing sediment and nutrients attached to this sediment (Price and Lovett, 1999). Swale cross-sections should be as uniform as possible to minimise scouring and maximise contact between water and vegetation. If slope is an issue, erosion can be prevented and the effectiveness of vegetated swales enhanced by installing riffles at intervals along the channel length. These riffles maximise the detention time within the swale, decrease the velocities and better promote particulate settling. As with road verges and median strips, swales also need to be maintained so they do not become a source of contamination from fertilisers, grass clippings, pesticides or other pollutants (see Section 2.2.7 of Chapter 7). More information about the design and effectiveness of swales is provided in Chapter 9.



Figure 8: Retrofitted grass swale, Broome Senior High School, Broome. (Photograph: Department of Environment, 2005.)

### 6.2.6 Bioretention systems

Bioretention systems are either grassed or landscaped swales promoting infiltration into specific treatment media. In clay soils, the bioretention system may include underground slotted pipes allowing for conveyance of the infiltrated water for further treatment downstream. Systems may also be lined with impervious material or geotextile, ensuring that there is no impact to groundwater, if that is the design objective.

#### Example 4

Bioretention systems used in Lynbrook Estate (Victoria) showed a 66% reduction in soluble phosphorus attributed to rapid adsorption of the phosphorus to the finely graded sediment in the bioretention systems (Lloyd *et al.*, 2002). Comparison of conventional piped stormwater systems with bioretention systems found that the bioretention systems out-performed the conventional systems with respect to water quality improvements (suspended solids, total nitrogen and phosphorus) because of flow reduction and filtration of the flow into the underlying soils (Lloyd *et al.*, 2002).

Lessons can be learned from national experience where many systems fail to achieve design objectives because of damage caused during the development's construction phase. For example, bioretention systems should be protected from traffic to avoid compaction, which reduces the hydraulic conductivity and results

in performance failure. Furthermore, systems should be protected from the high amounts of sediment produced during the construction phase of estates/subdivisions, which can clog the system. This can be done through sediment controls, such as silt fencing, or providing a protective ‘cover’ (such as a geofabric) over the bioretention system during the construction phase (Coombes, 2003). Alternatively, the bioretention system can be left to act as a sediment trap during the construction phase and then converted to a vegetated bioretention system after housing construction is complete. More information about bioretention systems is provided in Chapter 9.

### 6.2.7 Roads

Typical bitumen and other hardstand roads can be retrofitted to improve the quality and quantity of runoff. Rather than collecting and piping stormwater runoff from roads, the road drainage system can be ‘disconnected’ and on-site infiltration can be introduced. The road reserve can be used to restore or maintain the pre-development runoff characteristics of the site at a street scale for generally at least up to a 1 EY event. Retention and detention measures can be implemented in the road reserve, such as swales, soakwells and other controls to promote infiltration and evapotranspiration. For example, see Case Study 7.1: Town of Mosman Park – Total Water Cycle Project case study for information about retrofitting road drainage with combination gullies/soakwells. Kerbs can be replaced with flush kerbing (e.g. by grinding existing precast barrier kerbs down to the road level), allowing for infiltration of runoff into the road verge or into roadside or median strip vegetated swales (see Figures 9 and 10). If vehicular movement into the verge or swale area is not desirable, then traditional raised kerbs can be replaced with timber or concrete bollards (see Figure 9), or cuttings/openings can be made into the existing kerbing to allow water to pass through at specific locations. Retrofitting road verges or median strips to incorporate swales will not be possible in some situations, because of existing footpaths, above- and below-ground services and street trees.

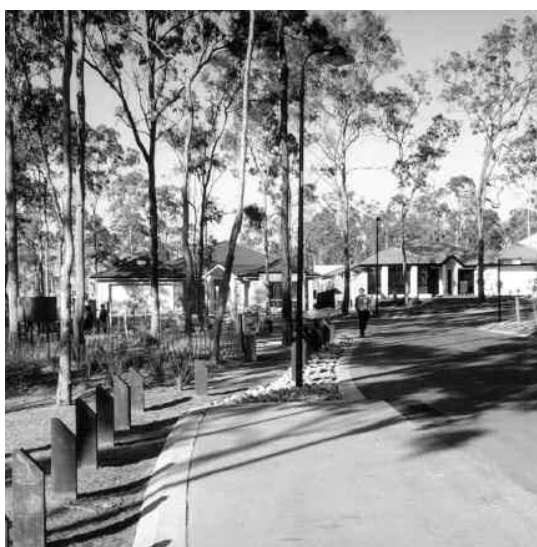


Figure 9: Example of flush kerbing and grass swales, Brisbane. (Photograph: Department of Environment, 2002)



Figure 10: Example of a kerbless road and swale, Dampier Road, Karratha. (Photograph: Department of Environment, 2006)

Road design should include best management of vegetated road verges and median strips, particularly in regards to plant selection, fertiliser, pesticide and water application and mowing (see Section 2.2.7 of Chapter 7). Exotic deciduous trees on road verges and median strips should be replaced with native (preferably local provenance) plants. The bulk leaf drop in late autumn/early winter can block stormwater systems, increasing treatment and maintenance requirements (see Figure 11). These leaves are also delivered directly to water bodies via the stormwater system. See Section 6.2.8 *Revegetating options* for a discussion of some environmental problems caused by deciduous trees. Deciduous trees should be retained at sites



*Figure 11: Leaf litter entering stormwater network in Perth Central Business District. (Photograph: Department of Environment, May 2004)*

where they are providing a passive solar design or heritage value function. Runoff from roads with high traffic flows may contain high levels of pollutants and may require some pre-treatment such as incorporating overland flow through vegetated swales. In addition to traffic volume, the type of road surface and its condition, vehicle type, verge condition and surrounding land uses can all influence the amount of pollutant loading to stormwater runoff (Davies et al., 2000). Road runoff can be a source of litter, sediment, nutrients, hydrocarbons and also heavy metals from brake and tyre wear and fuel combustion. Studies have shown that copper, lead and zinc are often highly concentrated at intersections with traffic lights where sudden braking can increase brake and tyre wear (reported in Davies et al., 2000). More information on the maintenance of roads and

pavements is provided in Sections 2.2.1 and 2.2.5 of Chapter 7.

## 6.2.8 Revegetating options

Introduced species (particularly weeds and exotic deciduous plants) within and next to inland water bodies should be replaced with native (preferably local provenance) plants. Exotic deciduous trees drop all of their leaves over a short period, delivering a bulk of organic material to water bodies in late autumn/early winter (see Figure 12). The large load and soft composition means that the leaves decompose too fast for many native macroinvertebrates to assimilate, compared with the more refractory nature of native leaves, resulting in a large release of nutrients (Water and Rivers Commission, 2002b). Additionally, the dense form provided by some deciduous trees in the spring and summer period can inhibit the growth of understorey plants (Water and Rivers Commission, 2002b).



*Figure 12: Leaf litter from exotic deciduous trees directly entering a pond. (Photograph: Department of Environment, May 2004)*

Vegetated waterways and wetlands and their buffers help to attenuate stormwater flows and filter pollutants, as well as increase biodiversity values. Vegetated areas decrease runoff and increase stormwater use on-site through increased infiltration, rainfall interception and evapotranspiration. Techniques include preserving trees during construction, revegetation with high water use native vegetation and urban forestry.

The *River Restoration Manual* (Water and Rivers Commission/Department of Environment, 1999-2003) and *A Guide to managing and restoring wetlands in Western Australia* (Department of Environment and Conservation, 2012) provide information about revegetating natural waterways and wetlands, respectively. Section 2.2.7 of Chapter 7 provides more information about maintenance of gardens and reserves.

Chapter 9 provides guidelines on using vegetation for surface and groundwater management and to offset potential changes to the local water balance through urbanisation.

### Example 5

With assistance from the Two Rivers Catchment Group, the City of Belmont undertook stream restoration work on a 1 km open section of the South Belmont Main Drain which was originally a natural creekline. This work has included removal of exotic species, re-establishment of native vegetation to help stabilise eroding embankments, and the construction of an artificial wetland and weir on the foreshore (Figure 13). This has been successful in preventing nutrient-laden sediments from discharging into the Swan River (King, J., 2004, pers. Comm<sup>7</sup>).



Figure 13: Adachi Park at outfall of South Belmont Main Drain. (Photograph: J. King, City of Belmont, September 2004)

## 6.2.9 Living streams

The protection of existing waterways and the restoration of degraded waterways or drains are important techniques for improving stormwater management in our urban environments.

When undertaking urbanisation of rural land or retrofitting in existing urban areas, this would mean the conversion of existing constructed drains into ‘natural’ meandering streams. Revegetation and reshaping of drains can restore the many values of a natural or ‘living’ stream. A living stream achieves multiple outcomes, including creating a healthy ecosystem, improving water quality, conveying floodwaters and creating an attractive landscape feature for the residential community (Water and Rivers Commission, 1998b).

In natural waterways, the shape and size of the channel and extent of vegetative growth in the channel are in balance with the discharge characteristics. In the ‘living streams’ approach, constructed channels are designed to mimic natural streams, with high flows accommodated along the vegetated streamline and its floodway. For example, the earthworks undertaken as part of the drain rehabilitation works at Bannister Creek initially resulted in an oversized channel (see Case Study 7.4). Vegetation growth then narrowed the low flow channel to be in balance with the typical annual flood flow. The aim of drain revegetation projects is to maximise channel ‘roughness’<sup>8</sup> at low flows, while managing roughness at higher flows. Infiltration, detention and treatment of the stormwater through contact with vegetation are maximised at base flow and during low-intensity rainfall events. During high rainfall events, flood protection is maintained by conveyance in the floodway. Flow velocities can be reduced and flood storage maximised for high flows by providing a broad vegetated floodway.

Healthy fringing vegetation provides wildlife habitat, ecological corridors, erosion control and biofiltering of pollutants, which is particularly important in WA where a high proportion of nutrients is in soluble form. A living stream is a complex ecosystem, supporting a wide range of plants and animals. It has stable vegetated banks with many plant species and provides habitats for animals such as frogs, fish and waterbirds. Plants that generate shade and have hard leaves are essential elements of healthy stream ecosystems.

Rock or log riffles can be installed along the stream to help stabilise the streambed and aerate flows. Unlike traditional weirs and drop structures, riffles do not block the migration of fish and other aquatic fauna and

<sup>7</sup> Personal communication with James King, City of Belmont, 2004.

<sup>8</sup> ‘Roughness’ refers to the channel resistance to flow created by the bed paving material and vegetation, logs, rocks, etc. in the channel. In hydraulic calculations, roughness is denoted as Manning’s ‘n’.

they enhance the habitat diversity of the waterway. Riffles create pools, which are a focus for fish and are typically a refuge for aquatic fauna during the dry season. In-stream large woody debris (logs and branches) are a feature of natural waterways and important for providing stable habitats, food sources and shelter for aquatic fauna. Figures 14 and 15 show Geegelup Brook, Bridgetown, which is a natural waterway that had been modified into an artificial stormwater drain. Low riffle structures were used to create pools and control the steep grade of the brook, the banks were reshaped and the brook and floodplain were revegetated.



*Figure 14: Geegelup Brook, Bridgetown, before restoration works – a weed infested trapezoidal drain. (Photograph: Department of Environment, 2003)*



*Figure 15: Geegelup Brook, Bridgetown, after restoration works. (Photograph: Department of Environment, 2003)*

Design guidelines for living streams are provided in Chapter 9. Case studies in Sections 7.4 and 7.5 provide some information on living streams retrofitting projects.

#### 6.2.10 Constructed wetlands

Where high concentrations of soluble material are expected, constructed wetlands or bioretention systems are recommended. This is especially relevant on sandy coastal plain sites where the proportion of dissolved nutrients is typically high. Appropriately designed and constructed wetlands can act as preliminary filters, stripping the water of nutrients and other pollutants, including micro-pollutants, before the water is released into natural wetlands, waterways or estuaries.

New constructed wetlands should be ephemeral. However, some constructed wetlands contain sections of permanent water, either because of year-round water supply from existing drains that intercept the groundwater and discharge into the wetland, or the retrofitting of drains or basins that intercept the groundwater.

Well-designed (and well-vegetated) constructed wetlands that mimic the ephemeral character of our natural wetlands are effective water pollution filters because in-stream and fringing aquatic vegetation provide an ideal structure for the growth of biofilm, which assimilates dissolved nutrients. Wetland plants can also improve water quality by encouraging sedimentation and filtration of nutrients and pollutants (through stems and leaves), oxygenating their root zone, providing shade and, to some extent, by using nutrients when in the growth phase.

A wetland designed with alternating deep and shallow zones, perpendicular to the water flow, can promote various chemical reactions, such as mineralisation, nitrification and denitrification processes, to transform and eventually remove nitrogen from the system.

Pre-treatment for removal of gross pollutants and sediment should be installed upstream of the constructed wetland. This ensures that the performance of the vegetated system is not reduced by clogging. A pre-treatment or entry control device, such as a bubble-up or deeper wetland zone, can buffer high flows that could result in erosion, damage to vegetation and biofilms, or re-suspension of sediment.

Constructed ephemeral wetlands can provide flora and fauna habitat in areas where many natural wetlands have been cleared, drained or filled. Case study 7.6 provides information on a constructed wetland retrofitting project. More information about ephemeral systems is provided in Chapter 9.

#### **Example 6**

In 2001, the City of Canning constructed the Black Creek Wetland (Station Street wetland) on a previously linear trapezoidal section of the Black Creek Branch Drain at Station Street, Cannington. The project was undertaken in partnership with Main Roads, Water Corporation, Rotary Club of Welshpool, Friends of Queens Park Bushland and the community, with assistance from environmental consultant Karl Karu. The wetland was designed to cater for the increased stormwater runoff from the extension of Orrong Road. Its dual purpose was to provide an area for sedimentation of particulate material from the Black Creek Branch Drain and to provide improved habitat, with water depths and island heights especially built to cater for the needs of various water birds. The site was heavily infested with watsonia, with 100% coverage at some locations. The watsonia was removed by 'peeling' the weeds off the surface with machinery, which was very successful. Some problems were experienced early in the construction phase after it was discovered that the soil pH necessitated soil amendment and a re-consideration of plant species. Macroinvertebrate monitoring has shown that a number of sensitive insects are present, which are indicative of improved water quality. The City of Canning received a grant from Nestlé to install interpretive signage at the site that will explain aspects of this ecological system. In addition, Park Engineers Pty Ltd were supplying resources to construct a viewing platform.

### **6.2.11 Detention and retention basins**

Detention and retention basins were developed principally for stormwater quantity control. It is only in recent times that many of these basins have been designed and retrofitted for use close to runoff sources, for both stormwater quantity and quality management (Water and Rivers Commission, 1998a). Detention basins retard flows by holding water and releasing it to the downstream system over a longer period, whereas retention basins are an end point for stormwater flow, which infiltrates and evaporates from the basin.

Regional detention and retention basins have been used extensively in urban development to attenuate urban runoff peaks for flood protection of downstream areas. They generally fall into the category of in-transit control measures. The attenuation of stormwater runoff has the environmental benefit of reducing erosion of natural creeks by controlling discharge rates. There are opportunities for retrofitting basins to provide water quality and habitat enhancement functions. For example, the banks of basins can be reshaped and graded to a gentle slope, the basin revegetated with local native plant species, and logs or ceramic pipes installed to provide habitat for frogs. Guidelines for building frog-friendly habitat are provided by the WA Museum's Alcoa Frog Watch Program (refer to Western Australian Museum's website). To provide a suitable grade for revegetation, it is recommended that banks be graded to a maximum slope of 1:4. Limited space constrains opportunities for providing gentle slopes. However, steep slopes can be retrofitted through the use of techniques such as terracing or by combining the battering with organic matting or other soil reinforcement materials that assist vegetation establishment. For public safety, it is recommended that banks of water bodies be graded to no steeper than 1:6. More information about basins is provided in Chapter 9.

### Example 7

An infiltration basin (which used to receive stormwater runoff from a 12 ha catchment) adjacent to the White Gum Valley in the City of Fremantle was a fenced-off sump, typical of other stormwater sumps in Perth. Infiltration basins are common features in the Perth urban landscape, ensuring that stormwater is infiltrated into the ground to reduce drainage requirements. Unfortunately, these sumps often become maintenance burdens for councils and unsightly blights on the landscape for local communities – fenced off, with steep sides and overgrown with weeds they are regarded as unsafe and an attractor for antisocial behaviour. Proposals from the design team led by Josh Byrne & Associates included the landscaping of the basin as a community asset while maintaining its current drainage function and infiltration capacity. The proposal considered examples of infiltration cells used by other local authorities, which became a key part of the business case. A major driver for the conversion of the sump was the creation of a usable public open space and the increase in tree canopy. The conversion required significant capital investment which was funded by the former Land Corp (now DevelopmentWA) and City of Fremantle. The total cost of \$500,000 included \$450,000 for civil works and the storage cells, and a further \$50,000 for landscaping. The business case for Land Corp was the creation of a new amenity for the development and both existing and new community residents while for Council it was an opportunity to demonstrate best practice and create a new community asset. As an outcome from this retrofitting project, an existing fenced drainage sump was converted into an attractive biodiverse open landscape with local native species and is now public open space with full pedestrian access (CRC for Water Sensitive Cities, 2017)



*Figure 16: White Gum Valley Infiltration Sump, City of Fremantle before rehabilitation works (Photo: Josh Byrne & Associates 2015)*



*Figure 17: White Gum Valley Infiltration Sump, City of Fremantle after rehabilitation works (Photo: DevelopmentWA 2019)*

### 6.2.12 Retrofitting existing permanent water bodies

Permanent water bodies are often constructed because of the public's attraction to views of open water. However, construction of permanent water bodies, such as artificial ponds and lakes and modified natural wetlands, is generally not recommended because of the commonly associated water supply, water quality and public health issues. Ponds and lakes can become breeding grounds for mosquitoes and midges, or become infested with algae. These problems may be a result of poorly designed systems or high nutrient inputs from the catchment to the water body. Poor design can create stagnant, shallow, warm water which provides ideal conditions for breeding of disease vector insects. Construction and modification of permanent water bodies may disturb acid sulfate soils, generating large amounts of sulfuric acid and leaching contaminants naturally occurring in the soils, such as arsenic, aluminium and heavy metals. The water level of some permanent water bodies is artificially maintained during the dry season by topping up with groundwater, which is an inefficient use of water resources. If the groundwater pumped into these lakes and ponds is nutrient rich or contaminated with other pollutants, it can cause further water quality problems.

A number of in-system management measures are available to improve the water quality, health and environmental value of existing permanent water bodies, including artificial and modified natural systems. A commonly used intervention method is flow modification, for example topping up lakes, transferring water between lakes or periodically drying out lakes. Other methods include altering the shape or depth of the water body, excavating sediment deposits and planting or harvesting vegetation. Aerators, amended soils, oxygenation, ultrasonic devices and bioremediation methods have been trialled to treat water bodies that have poor water quality. These remediation techniques should be part of an integrated approach that determines the causes of the water quality problems, and then seeks to remove these causes.

It is important to identify pollutant sources to select the best approaches to managing the water body. Different approaches are required depending on whether the pollutants are derived from the catchment or if there is an internal supply of pollutants from the sediments. Processes such as mixing and stratification also need to be considered. Good data collection helps to correctly identify the causes of water quality problems, as well as assess the effectiveness of any remedial action taken. Remedial actions can have negative effects if they are applied incorrectly or without a good knowledge of the overall system, for example:

- topping up lakes with bore water that is high in nutrients can result in further water quality problems
- changing water levels or water salinity can be detrimental to existing vegetation
- removing aquatic vegetation can create conditions suitable for serious algal blooms.

Priorities and measures for catchment management and treatment train approaches to pollutant loads can be addressed through the development of stormwater management plans. See Chapter 5 for information on the development of stormwater management plans. Non-structural measures to reduce pollutant sources throughout a catchment are provided in Chapter 7. Controlling fertiliser inputs, which commonly enter lakes and ponds through runoff from surrounding parks and gardens, is essential in reducing the occurrence of algal blooms. For information on best management of parks and gardens, see Section 2.2.7 of Chapter 7. Structural measures to reduce pollutant loads at source, in-system and end-of-pipe are discussed in Chapter 9.

Modification of natural wetlands must comply with the wetland management category objectives, relevant legislation and the environmental harm and unauthorised land clearing provisions of the *Environmental Protection Act 1986* and any approved wetland management plans. Information about the management of natural wetlands is provided in *A Guide to managing and restoring wetlands in Western Australia* (Department of Environment and Conservation, 2012). Information about the management of natural waterways is provided in the River Restoration Manual (Water and Rivers Commission/ Department of Environment, 1999–2003), available at Department of Water and Environmental Regulation's website.

**Physical modification** of an artificial or previously modified water body can help improve its health. The system can be changed to an ephemeral system by removing impermeable lining, ceasing additions of water during the dry season, or raising the basin invert so that it does not intersect the groundwater table. By allowing the water body to dry out, as occurs with many natural wetland systems, algal and nuisance insect problems can be reduced. Direct stormwater discharges (i.e. via pipes or constructed channels) into the water body should be avoided and runoff overflow should only enter water bodies by overland flow paths across vegetated surfaces, to filter out much of the organic matter and nutrients before it reaches the main water body. More information about vegetated filter strips and swales is provided in Chapter 9

Most aquatic fauna and most important bio-chemical processes that promote healthy nutrient cycling depend on the presence of sufficient dissolved oxygen concentrations in the water column. When dissolved oxygen levels are high, aerobic decomposition and recycling processes can function efficiently to break down

organic matter and remove nutrients from the system. Under low oxygen conditions, nutrients are released from the sediments, which can fuel phytoplankton blooms.

Water bodies may become deficient in oxygen through incomplete mixing, such as stratification caused by temperature gradients, which reduces the transfer of oxygen from the air-water interface to deeper waters. Another common cause of poor oxygen concentrations is high biological or chemical oxygen demand, such as respiration of an algal bloom at night. The simultaneous combination of these two conditions is often responsible for the worst cases of hypoxia.

**Aeration** and **oxygenation** devices seek to address this lack of oxygen in two ways: directly increasing oxygen concentrations of the water, or encouraging transfer of oxygen from the atmosphere. An example of the former is hypolimnetic oxygenation, which is currently used in the Canning River above the Kent Street Weir (see Example 8). The second process is much more commonly used and can be performed by passive structures, such as riffles, cascades and waterfalls, or by mechanical devices (see Example 9). Mechanical devices can use a variety of ways to encourage mixing, such as: specially designed paddles or rotors; jets of water; curtains of bubbles rising from the bottom to encourage destratification; and spraying water into the air. Each situation needs to be assessed to ensure the selected device is appropriate and can achieve the desired goals. Additionally, aerators that encourage mixing can minimise still water that provides ideal conditions for mosquito and midge breeding, and which may favour the rapid growth of blue-green algae. The presence of sulfidic sediment such as iron monosulfide should be investigated before undertaking an aeration or oxygenation project because of the potential acidification that can occur when these sediments are exposed to oxygen.

#### **Example 8**

Oxygenation trials were undertaken on the Swan and Canning Rivers with the aim of modifying the river conditions so that the occurrence of phytoplankton blooms was reduced (Swan River Trust and Water and Rivers Commission, 2000). These systems have sediment derived nutrients (as well as nutrients from drainage inputs). Salinity stratification occurs in the Swan River, whereas temperature stratification occurs in the Canning River, which is a freshwater system above the Kent Street Weir. Stratification reduces mixing of oxygen from the surface layer to the deeper layer of the water column, which can result in low oxygen or anoxic conditions in the bottom waters. The two oxygenation plants installed on the bank of the Canning River and the mobile barge unit used on the Swan River worked by pumping low-oxygen water out of the river, adding pure oxygen and then returning the high-oxygen water to the bottom of the river. The advantage of this approach was that it minimised disturbance to bottom sediments or stratification, and allowed the oxygenated water to be directed to the river bottom where it is most required. The Canning project site was initially the pilot plant to research the technique and assess its potential application to the Swan River. Oxygenation in the Canning River Kent Street Weir pool achieved significant increases in oxygen concentrations, reduced nutrient concentrations and positively impacted aquatic fauna, but did not prevent algal blooms (Swan River Trust, 2003b). Further information on the Swan-Canning Cleanup Program oxygenation trials is provided in River Science Issues 13, 14, 15 and 18, available at Department of Water and Environmental Regulation's [website](#).

### Example 9

Tomato Lake is a 7 ha former natural wetland situated in Kewdale, City of Belmont, which has been highly modified for stormwater management purposes. It is surrounded by 9 ha of parks and recreation reserve. The City of Belmont trialed two new aeration systems in Tomato Lake over a two-year period between the summers of 2003 and 2005 to improve water quality. The aerators operated for 12 hours per day in winter and 24 hours per day in spring, summer and autumn. The aerators replaced an original agitator unit that was installed in the lake in 1999, as the aerators were more cost-effective.

Within four weeks of installation of the aerators, visibility in the water improved from almost zero to being able to see the bottom of the lake in shallow areas. The night time dissolved oxygen levels also increased from 3.6 to 10.3 mg/L. Some of the benefits to be gained from installing the aerators include:

- circulation of the lake water
- increased oxygen in the water for aquatic organisms
- reduced anaerobic (low oxygen) decomposition and therefore reduced odour
- reduced water temperature and reduced evaporation
- reduced potential for Botulism bacteria, which thrive in warm temperature and low-oxygen conditions
- reduced incidence and severity of blue-green algae
- improved water clarity
- removal of some excess nutrients (primarily nitrates).

The effectiveness of the aeration systems in Tomato Lake will be monitored through the City of Belmont's Tomato Lake Water Quality Monitoring Program. Data has been collected since 1998 to determine the effectiveness of water quality improvement initiatives such as the installation of aerators, bacterial application for nutrient reduction and foreshore revegetation.

**Absorbent materials** can be used to bind dissolved nutrients, reducing their availability to phytoplankton. Rare earth modified clays (such as Phoslock™, see Example 10) and hydrotalcites (which may be synthesised from industrial waste materials such as red mud and fly ash) are the most suitable materials for removing phosphorus from lakes or impounded rivers (Douglas et al., 2004). However, it would have to be demonstrated that there would be no significant human health or ecotoxicological effects from its intended application. The cost of this method of treatment may be high, depending on the scale of application and selected absorbent, so the causes of water quality problems need to be well understood to ensure that this is the most appropriate method of treatment.

Zeolite clays are known for their capacity to bind nitrogen in the form of ammonium. Factors that have been demonstrated to determine the uptake capacity of ammonium by zeolite include the physical and chemical properties of zeolite, such as grain size, porosity, pH, the presence of competing species and the exchangeable ion within the zeolite. The main advantage is their porous structure that allows colonisation by bacteria, which in the right environment assist in the conversion of ammonium to nitrogen as gas that is released to the atmosphere.

### Example 10

Phoslock™ was developed to prevent the release of sediment derived phosphorus. A slurry of Phoslock™ was sprayed on the water surface of an 800 metre reach of the Canning River during January 2000. The trial demonstrated that Phoslock™ was effective in removing dissolved phosphorus from the water column and sediments (Swan River Trust and Water and Rivers Commission, 2001). The clay particles bind dissolved phosphorus as they settle through the water column and form a reactive layer on the sediment that continues to bind phosphorus. Further information on the Phoslock™ trials undertaken as part of Swan-Canning Cleanup Program is available in River Science No. 17 on Department of Water and Environmental Regulation's website. Phoslock™ has not been tested in natural wetlands, so the potential impacts, such as modification of the benthic environment through blanketing and changing the physio-chemical environment and habitat, have not been assessed. Therefore, Phoslock™ currently is not recommended for use in natural wetlands.

**Bioremediation** (or bio-augmentation) involves either creating conditions that encourage the growth of natural (in situ) bacteria or adding high concentrations of bacteria to a water body in order to consume nutrients and outcompete algae for their food source. The natural bacterial population in a water body can be severely reduced by a number of factors such as competition for their food sources by excessive algal growth or deoxygenation during algal decomposition. The conditions contributing to high algal concentrations need to be well understood before selecting bioremediation as a management tool.

Broadcasting bacteria into the natural environment may be ineffective if the conditions causing their depletion are not addressed. Additionally, adding large amounts of bacteria would substantially increase the oxygen demand and is not a suitable approach if there are already problems in the water body associated with low dissolved oxygen levels. Bacteria is already present in water bodies and some enhancement of their growth conditions is usually all that is required in order to restore a healthy population. For example, low aerobic bacterial numbers may be a result of low oxygen concentrations associated with excessive nutrient loading. Aerobic bacterial numbers should naturally increase, without additives, if the nutrient supply is addressed. In some cases where toxic compounds that are difficult to break down are present, for example because of industrial pollution, specialised bacteria can be added that have been developed to treat these compounds. Research into the long-term effectiveness and maintenance requirements of bioremediation to improve the quality of water bodies is required.

### Example 11

A bioremediation trial was undertaken at Tomato Lake by the City of Belmont to address toxic blue-green algal blooms at the lake, which were common occurrences. The lake was fed with high concentrations of nutrient-consuming bacteria four days per week every summer and aerated from 1999–2003. A report on water and soil quality at Tomato Lake is prepared every six months. Significant reductions in total nitrogen concentrations were measured during this period. Monitoring through visual observation found that the severity and duration of blue-green algal blooms was significantly reduced and the abundance of aquatic fauna increased. Water clarity improved dramatically, from black water with virtually no visibility to clear water with the bottom of the lake visible. The bacterial mix applied to the lake was also able to break down hydrocarbons that washed into the lake from road drains. Bacteria application ceased in 2003 and was replaced with a more cost-effective enzyme product that boosts naturally occurring bacteria.

## 6.3 Performance monitoring and maintenance

### Monitoring

The pollutant removal effectiveness and performance of structural controls is not well understood in WA, particularly on the Swan Coastal Plain. This is because most research has been conducted in the Eastern States, where the climate and hydrogeology is very different to that of the Swan Coastal Plain. The highly permeable sands, high amount of dissolved nutrients and pollutants, and shallow groundwater experienced in many parts of the Swan Coastal Plain are very different to the conditions experienced in the Eastern States. Therefore, the performance curves that have been developed in the Eastern States cannot be directly applied to the majority of urban development in WA.

The Cooperative Research Centre for Catchment Hydrology has developed a *Model for Urban Stormwater Improvement Conceptualisation* (MUSIC), which is based on this Eastern States research, to assess the performance of a treatment train in an urban context. However, the researched performance curves embedded in this model focus on physical processes that primarily remove particulates. Further research and development is required for consideration of dissolved nutrients, where biological processes are likely to be more relevant (Fletcher et al., 2001; Taylor et al., 2005). The hydrological component of the model is based on a hill slope process description that cannot be applied on the Swan Coastal Plain, which is characterised by a dual groundwater system (one perched ephemeral system and a deeper perennial system). A conceptual decision support tool known as Urban Nutrient Decision Outcomes (UNDO) has been developed to evaluate nutrient reduction decisions for urban developments on the sandy Swan Coastal Plain in south-west WA. It is designed for ease-of-use by urban development proponents and for assessment by local and State Government authorities. The UNDO tool is web-based, and provides users with the ability to implement a range of structural or non-structural design options to evaluate and reduce nutrients exported from an urban development.

The evaluation of the performance of stormwater management measures, especially those implemented as retrofits, should account for occurrences upstream of the system that could overload the system and make it appear to fail. For example, sediment removal systems should be installed before infiltration systems, to reduce the likelihood of blockage of the infiltration systems. These risks should be understood and not become deterrents. They highlight the importance of also undertaking source controls. Monitoring of stormwater treatment measures will also need to consider the impact of groundwater quality on the performance results.

Not only will many structural controls have a direct effect on water quality improvement, but they can also add value to a system, for example by improving the aesthetics of an area. This can increase the value of the system to the community and result in indirect benefits, such as reduced littering and increased protection of the area by local environmental groups. These indirect benefits could also be monitored, for example by monitoring changes to property values or conducting surveys of local residents and community groups.

Given that retrofitting in WA has been limited to date, a performance monitoring and evaluation plan should be developed for all projects during the planning stages. Performance monitoring will not only assist the project team in determining whether their desired project outcomes have been met, but it will also be useful for other stormwater managers when preparing their own retrofitting projects. Chapter 10 provides a process for determining how to monitor and evaluate structural and non-structural controls.

### Maintenance

Maintenance requirements, from the construction phase through to the expected lifetime of the technique/s, need to be factored into the design phase of a retrofit project.

Stormwater treatment measures must be managed over the implementation phase, particularly at development sites where building activities can result in overloading of the system with sediment and other pollutants. For example, experience from the Eastern States shows that the installation and planting of swales should not be completed until after properties have been developed and building construction completed.

A management plan that details maintenance issues and associated timelines, costs and responsibilities, such as plant replacement, weed control and litter and sediment removal, needs to be prepared. Where applicable, a weed management program, from site preparation to follow-up targeted weed eradication, is strongly recommended. Refer to Chapter 7 for information on maintenance of gardens and reserves (Section 2.2.7), litter management (Sections 2.2.3 and 2.2.4) and sediment management (Section 2.1.1).

### Example 12

Maintenance is a controversial issue with some local governments and asset managers. The uncertainty about ongoing maintenance costs is a deterrent to many developers and local councils in WA to implement WSUD. The Cooperative Research Centre for Catchment Hydrology has produced a report on the costs of maintenance and community acceptance of WSUD from experience in Lynbrook Estate (Victoria). Costs of maintaining vegetated swales reduce as the system becomes more self-sustaining. For example, the maintenance costs associated with a vegetated swale dropped from \$9.00/m<sup>2</sup>/year to \$1.50/m<sup>2</sup>/year<sup>9</sup>, with a similar pattern of reduction in costs being expected for the vegetated sections of constructed wetlands (Lloyd *et al.*, 2002). Some maintenance costs can remain constant over time, such as the costs of maintaining a grassed swale at \$2.50/m<sup>2</sup>/year<sup>10</sup>. Community surveys in Victoria showed that 90 per cent of the community were supportive of the integration of landscaped and grassed bioretention systems into the landscape for stormwater purposes (Lloyd *et al.*, 2002). Furthermore, surveys have shown that 60 per cent of the community would be willing to pay extra for WSUD implementation, such as a fee of \$25/year (Lloyd, 2002).

<sup>9</sup>The costings used in this example are from around 2000. Please adjust the costings for present day.

Structural techniques, such as side entry pits and GPTs, require regular inspection and monitoring to determine the optimal frequency and timing of cleaning. Maintenance is essential to ensure the device does not become a source of pollutants. For example, nutrients in an organic form can be converted to a bioavailable form in the anoxic environment of an unmaintained trap. Remobilisation of trapped pollutants or bypassing because of a lack of storage volume in an unmaintained trap could also result in the supply of pollutants to the stormwater system. Disposal of effluent/wastes from cleaning activities also needs to be considered. Such wastes should be assessed to determine the correct form of disposal, in consultation with operators of liquid and soil waste disposal facilities. Wastewater from maintenance activities should not be discharged to the stormwater system.

<sup>9</sup> From Lloyd *et al.* (2002), from maintenance costs records from Kinfauns Estate, Victoria.

<sup>10</sup> From Lloyd *et al.* (2002), based on figures from VicRoads.

### Example 13

The City of Canning reviewed its gully educting program. Its study found that the educted liquid that was returned to the gullies (standard practice in Australia) was often concentrated with nutrients, metals and hydrocarbons. The City of Canning (through contractors) disposes all produced solid and liquid wastes to landfill (Morrison, P., 2003, pers. comm.<sup>11</sup>). The city also commissioned a report for its entire catchment, compiling a rating matrix and prioritising subcatchments for gross pollutant production.

Some pollutant traps may be at risk of filling with tree roots. Access to clean and maintain the device should be considered when evaluating treatment options. If you cannot clean and maintain a device, it may not be suitable for installation. However, alternatives that provide pre-treatment can reduce the need for maintenance, such as a gross pollutant and sediment trap installed before the entry to an infiltration system. Alternatively, the device may require periodic removal and replacement.

Wetlands and infiltration systems (such as detention basins) need regular inspection for sediment build-up and, if necessary, removal of this sediment. Online vegetated systems (i.e. systems that are part of the main stormwater conveyance network) need to be periodically inspected to ensure that prolific growth of plants does not block the channel or choke the system. Branches or plants that are dislodged during high flows and transported downstream may need to be cleared if they become trapped and form a debris dam or block a culvert.

Maintenance activities present an opportunity for community education, such as involving school or community groups in cleaning gross pollutant traps (GPTs) (where safety concerns can be addressed), or publicising the statistics of materials removed from the trap.

See Section 2.2.2 of Chapter 7 for more information on maintenance of the stormwater network. Maintenance requirements of structural controls are outlined in Chapter 9.

### Limit the use of lawn and avoid using fertilisers and pesticides around water bodies

It is essential that water bodies are not surrounded by highly fertilised lawns grown to the water's edge. Green lawn often requires large amounts of fertiliser to maintain aesthetic appeal. Fertiliser use may result in the direct application of nutrients to the water body by either being washed directly into the water from lawn surface runoff or by being inadvertently applied within the fringe area, potentially exacerbating nutrient problems. Other lawn maintenance requirements such as mowing can result in grass clippings entering the water, which subsequently decay and add further nutrients to the system. Local native plants are a cost-effective, aesthetically pleasing and sustainable alternative to lawn around the perimeter of the water body. Most native plants require very little extra nutrients in the form of fertilisers, little extra watering (except in initial establishment phases) and will provide habitat for native fauna. If lawn is an essential feature of the surrounds of a waterway or water body, it is recommended that a Nutrient Management Plan be written. It is also important to limit pesticide use near water bodies. See *Herbicide use in wetlands* (Water and Rivers Commission, 2001), which outlines acceptable pesticide use near waterways and wetlands. See Section 2.2.7 of Chapter 7 for more information about maintenance of gardens and reserves.

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<sup>11</sup> Personal communication with Peter Morrison, Senior Environmental Health Officer, City of Canning, 2003.

## 7 Case studies

### 7.1 Town of Mosman Park total water cycle project

#### **Project description**

A number of projects were undertaken by the Town of Mosman Park to address decreasing groundwater quality because of salt-water intrusion and flooding problems, as a result of inadequate stormwater management. The objectives of the projects were to maximise infiltration across the superficial aquifer, reduce demand on the aquifer, minimise local flooding and minimise pollution of groundwater and the Swan River. These projects were supported by policy statements and local laws to provide the regulatory framework for adopting the council's approach to water resource management.

The Town of Mosman Park is on the Leighton Peninsula between the Indian Ocean to the west and the Swan River to the south and east. The town has a total area of 4.5 km<sup>2</sup>, with 1 km<sup>2</sup> being public land vested for the purposes of recreation, much of it irrigated for recreational activities such as the Mosman Park Golf Course at Chidley Point. It is predominantly residential with a density of R20 or less, with a commercial area along Stirling Highway.

The town is on highly permeable sands of the Cottesloe Soils. Alluvial soils are found along foreshore areas and are generally grey sandy deposits.

There are 39 subcatchments within the council and a series of natural surface water channels that travel along the original dune valleys. These channels have been the cause of most local flooding problems because designated flood paths were not established. The superficial freshwater aquifer is perched above a saltwater lens. The freshwater source is rainwater that has infiltrated through the sandy soils or has traversed along the peninsula from the north, while the salt water connects the Swan River and the Indian Ocean beneath the peninsula. There is a thin layer of sedimentary clays on the eastern side of the peninsula, which provides an interlayer between the lenses; however, most of the fresh water floats directly on the saltwater lens. The aquifer varies in thickness from 16 m in the area beneath Memorial Park, to less than 2 m adjacent to the river and ocean. The freshwater superficial aquifer at Leighton Peninsula is a unique and finite resource. If too much water is withdrawn from the superficial aquifer, salt water will intrude from the ocean and river into the groundwater.

The council also wanted to ensure that any water entering the aquifer remains clean and unpolluted. Pollution sources could potentially include fertiliser runoff from golf courses, parks, gardens and domestic use. Other pollutant sources may include past industrial land uses, landfill, runoff from road pavements and leakage from underground pipes and tanks.

The stormwater was previously collected and directed into stormwater pipes leading to outfalls into the Swan River. The infrastructure was limited to grated gullies, undersized pipe networks and traditional sumps. A number of the sumps had been filled in because of development pressure. There were pipe networks under private property without sufficient protection by easement and little consideration for design criteria such as hydraulic gradelines, etc. There were 16 river outlets and 22 infiltration basins and compensating basins. There were no GPTs but there were many soakwells within verges and carparks. The major problem for the community was the resultant localised flooding because of the insufficient capacity of the stormwater management system.

## **Approaches implemented**

The implemented strategies were:

- conduct an audit and create a database of all drainage and irrigation assets; this information was also placed on the council's geographic information system
- reduce water use by monitoring irrigation systems to optimise the efficiency of turf watering regimes and replacing inefficient irrigation systems
- maximise stormwater infiltration to increase aquifer recharge by installing retrofit infiltration devices across the municipality
- seek alternative water supplies, including investigating wastewater re-use
- decrease local flooding by retrofitting or replacing traditional drainage structures
- maximise pollutant capture by utilising both at source and in-system controls and end-of-pipe methods.

### ***Maximising infiltration:***

The new strategy adopted by the council was to infiltrate stormwater at as many sites as possible. On-site infiltration was included in the Town of Mosman Park local laws. A specially designed combination grate and side entry gully placed over a deep soak well was installed in the highest priority catchments with respect to incidence of local flooding (see Figure 18). The combination gully/soakwells continue to be installed as the road network is resurfaced. These systems were designed to meet the requirements of a 20 per cent AEP storm event of 10-minute duration. This accommodates the soakage requirements for 1 cubic metre of soakage volume per 80 m<sup>2</sup> of pavement area, assuming 100 per cent runoff. The combination gully/soakwell allows capacity to be retrofitted into the catchment within existing pavements. This minimises service clashes and ensures discharge from a full unit does not escape from the pavement area flood path.

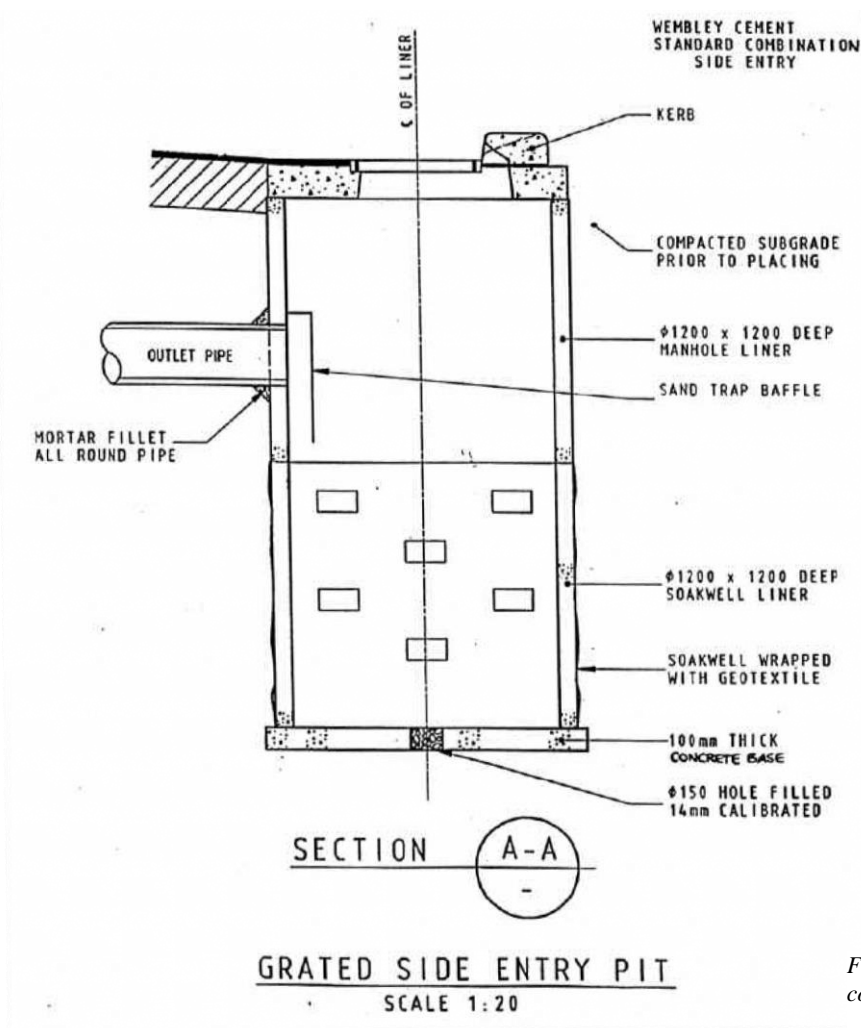


Figure 18: Standard combination gully/soakwell.

In addition to the combination gully/soakwells, either traditional sumps, subterranean infiltration buffer banks or shallow swale infiltration basins were installed in parks, reserves and wide road verges to maximise infiltration across the council. Combinations of the above systems were sometimes used. For example, a subterranean infiltration facility was installed at Centenary Park, Mosman Park (see Figures 19 and 20) and a shallow swale recharge bore was constructed in Stringfellow Park (see Figure 21).



Figure 19: Original sump, Centenary Park, Mosman Park. (Photograph: Martyn Glover, Town of Mosman Park)



Figure 20: Completed subterranean infiltration facility, Centenary Park, Mosman Park. (Photograph: Martyn Glover, Town of Mosman Park)



Figure 21: Shallow swale, Stringfellow Park, Mosman Park. (Photograph: Martyn Glover, Town of Mosman Park)

Other related projects include:

- a GPT trial
- a catchment pollution discharge trial
- installation of pollutant traps on all river outlets.

Additionally, the Town of Mosman Park was involved in the development of the *Regional strategy for management of stormwater quality*. The strategy was developed by the Western Suburbs Regional Organisation of Councils (WESROC), comprising the Cities of Nedlands and Subiaco, Towns of Claremont, Cottesloe and Mosman Park, and the Shire of Peppermint Grove. In 2001, WESROC and Town of Cambridge identified the need for better management of stormwater quality and a need to address the associated strategic issues on a broad catchment basis across traditional local authority boundaries. A regional strategy for stormwater quality management was developed to draw together issues concerning the collection and management of stormwater over a 6400 ha area of Perth's established western suburbs, with the aim of managing the quality of stormwater discharging to the Swan River, Indian Ocean, local wetlands and the groundwater system.

The strategy made two key recommendations. The first key recommendation was the implementation of an integrated monitoring program targeting identified priority catchments, to establish baseline stormwater quality data from which suitable water quality criteria and targets could be established. The second key recommendation was the implementation of a regional community water quality education program.

## **Result /achievements**

The projects resulted in:

- a 10-30 per cent reduction in turf irrigation over the summer months
- infiltration of 95 per cent of all stormwater in the municipality. Infiltration is now evenly spread across the peninsula and discharge to the Swan River has been minimised.
- decreased incidents of local flooding. There were 21 local flooding sites shortly after the January 2000 storms. This was reduced to only five local flooding sites in March 2003. By March 2005, all of the flooding issues had been resolved
- achievement of the target to decrease direct stormwater discharge to the Swan River to less than 5 per cent. All river outfalls are now serviced by pollutant traps. Recent monitoring in Mosman Bay has indicated that the pollutant levels in the discharge have been reduced by more than 90 per cent for all pollutants. Results from the Caporn Street catchment trial indicated that the council's treatment train of street sweeping, interceptor gull/soakwells and end-of-pipe GPTs removes 99.5 per cent of particle bound pollutants from the stormwater
- longer-term monitoring will be required to determine the project's impacts on stormwater and groundwater quality.

## **Challenges**

The three major challenges were to:

- improve the groundwater quality, to secure the future quality of council parks and reserves
- provide sufficient retrofitted infiltration facilities, to minimise local flooding
- convince the community that the work was necessary and needed their input to succeed.

## **Resources**

The costs<sup>^</sup> of the project to date are included in Table 3.

**Table 3: Construction and maintenance costs of works undertaken under the Town of Mosman Park Total Water Cycle Project**

Year	1995/96	1996/97	1997/98	1998/99	1999/2000	2000/01	2001/02	2002/03	Average
<b>Maintenance</b>									
<b>Drainage</b>	\$10,353	\$12,694	\$21,666	\$15,027	\$33,620	\$30,557	\$47,272	\$37,887	<b>\$26,135</b>
<b>Gully cleaning</b>	\$6,717	\$4,459	\$4,282	\$11,214	\$26,766	\$13,485	\$22,221	\$20,490	<b>\$13,704</b>
<b>Sumps</b>	\$11,713	\$6,004	\$6,327	\$2,129	\$24,349	\$13,635	\$22,311	\$20,020	<b>\$13,311</b>
<b>Road sweeping</b>	\$20,868	\$19,727	\$21,985	\$24,282	\$24,931	\$23,491	\$26,806	\$19,268	<b>\$22,670</b>
<b>Bores</b>	\$163	\$0	\$640	\$6,868	\$15,269	\$9,117	\$11,257	\$7,468	<b>\$6,348</b>
<b>Sub total</b>	<b>\$49,814</b>	<b>\$42,884</b>	<b>\$54,900</b>	<b>\$59,520</b>	<b>\$124,935</b>	<b>\$90,285</b>	<b>\$129,867</b>	<b>\$105,133</b>	<b>\$82,167</b>
<b>Construction</b>									
<b>Drainage</b>	\$33,722	\$47,875	\$49,994	\$19,684	\$37,471	\$56,590	\$29,188	\$50,750	<b>\$40,659</b>
<b>Sumps</b>	\$9,275	\$0	\$15,598	\$159,555	\$83,229	\$55,707	\$35,318	\$17,305	<b>\$46,998</b>
<b>Bores/irrigation</b>	\$38,478	\$18,184	\$197,473	\$211,025	\$24,120	\$34,342	\$206,326	\$35,000	<b>\$95,619</b>
<b>Sub total</b>	<b>\$81,475</b>	<b>\$66,059</b>	<b>\$263,065</b>	<b>\$390,264</b>	<b>\$144,820</b>	<b>\$146,639</b>	<b>\$270,832</b>	<b>\$103,055</b>	<b>\$183,276</b>
<b>Total</b>	<b>\$131,289</b>	<b>\$108,943</b>	<b>\$317,965</b>	<b>\$449,784</b>	<b>\$269,755</b>	<b>\$236,924</b>	<b>\$400,699</b>	<b>\$208,188</b>	<b>\$265,443</b>

<sup>^</sup>The costings used in this example are from around 1995-2003. Please adjust the costings for present day.

Note: This chart does not include upgrades that were part of roadworks. It is estimated that this was an additional \$370,000 of expenditure for associated gullies, manholes and pipework.

The individual maintenance interval and costs per unit are:

- sweeping – monthly (\$150/km/year)
- gully eduction – bi-annually (\$28/gully/year)
- sump cleaning – annually (\$300/sump/year)
- infiltration facilities – annually (\$250 to \$1200/year, dependent on size of facility).

#### References/further information

Glover, M. and Chalmers, L. 2003, *Town of Mosman Park – A total water cycle approach to reduce water use and improve stormwater management*.

Highman, S. 2004, *Caporn Street, Mosman Park – A Total Catchment Review*, Final Year Thesis, Faculty of Engineering and Computing, Curtin University of Technology.

JDA Consultant Hydrologists 2002, *Regional Strategy for Management of Stormwater Quality for Western Suburbs Regional Organisation of Councils*, Report to WESROC.

Martens, S., Davies, J., O'Donnell, M. and Zuvela, P. 2005, *Monitoring for Total Water Cycle Management: The WESROC Experience* Paper presented to the 2005 Public Works Engineering State Conference, Perth, WA.

## 7.2 Busselton stormwater management

### Project description

The Lower Vasse River and the Vasse-Wonnerup wetland system near Busselton experienced very poor water quality. The Lower Vasse River had been greatly changed from its original state through alterations to flow, widening of the channel, removal of native vegetation and development in the catchment. Most of the rivers in the Geographe catchment once flowed through the Lower Vasse River and the Vasse-Wonnerup wetland system, but many have been diverted via drains directly to Geographe Bay. Floodgates were also installed to prevent flooding. River diversion and construction of floodgates had decreased flushing, resulting in an accumulation of nutrients. A Geographe Catchment management strategy was developed to address problems in the catchment (see Geographe Catchment Council, 2000).

Nutrient enrichment was the major issue for these systems, with the occurrence of severe algal blooms during the warmer months. The impacts of contaminants on waterways from urban areas was also an issue of concern for the local community. As part of the concentrated effort to address the cause of the water quality problems in the Vasse Estuary and River, the Shire of Busselton and GeoCatch upgraded the existing stormwater system to improve treatment of stormwater before discharging into waterways. The project focused on implementation of best practice stormwater management techniques on stormwater drains in urban areas of Busselton (see Figure 22).

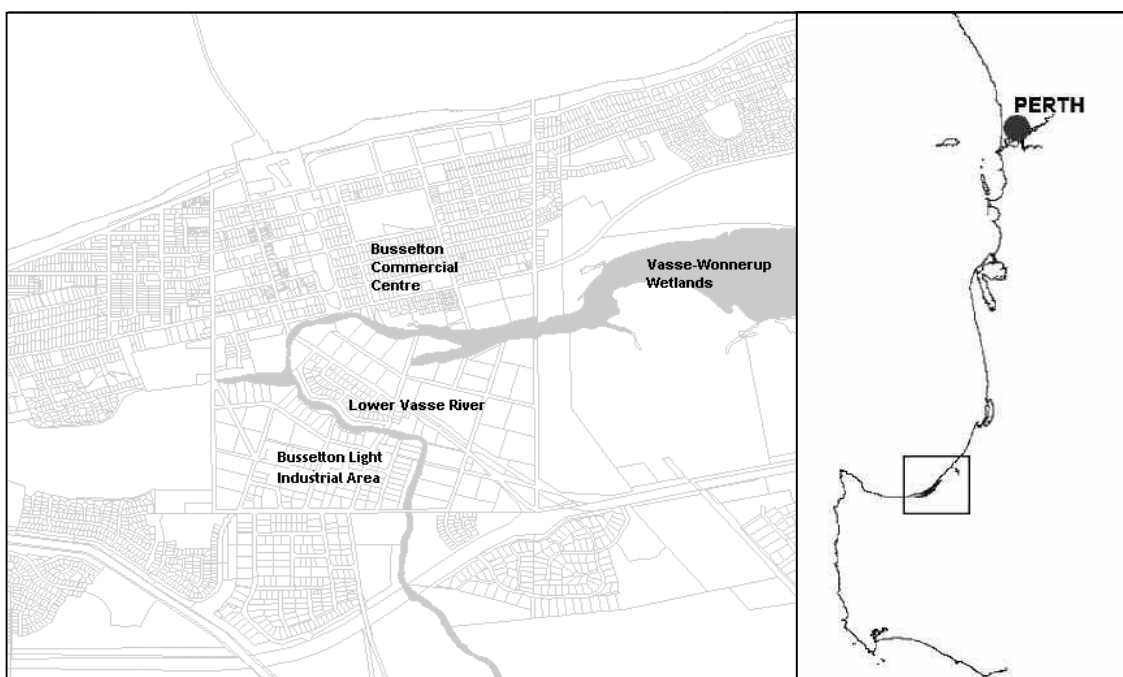


Figure 22: Busselton Stormwater Management Project Area.

The project area is on the Swan Coastal Plain where deep sands are the dominant soil type. The area is very flat, with groundwater generally close to the surface and most wetlands are expressions of the groundwater. The hydrology of the area has been greatly modified to allow the town of Busselton to develop on previously flood-prone land.

### References/further information

Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and

Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT.

ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at [www.waterquality.gov.au/anz-guidelines](http://www.waterquality.gov.au/anz-guidelines)

Geographe Catchment Council 2000, *Geographe Catchment Management Strategy*, GeoCatch, Natural Heritage Trust and Water and Rivers Commission, Perth, WA.

### **Approaches implemented**

Structural control devices were installed at 24 sites on stormwater drains that discharge to the Vasse River and Estuary system and out to Geographe Bay. The major structural control type implemented was construction of vegetated stormwater detention basins, which aimed to slow water movement, filter nutrients and facilitate sediment deposition. Other structural controls included interceptor devices and separators to remove oils and grit from stormwater before it enters the river, vegetated swales, GPTs and river foreshore revegetation to intercept runoff from parkland. Upgrades and alterations to the stormwater network were also required to improve efficiency of the network and to divert stormwater through structural controls.

Raising community awareness of the impacts of stormwater on local waterways and how they can contribute to stormwater management was an important part of this project. Based on a successful project in the neighbouring Leschenault catchment, a Clean Drains campaign is being coordinated through the GeoCatch Ribbons of Blue Program. The aim of the project is to increase student and community awareness about street runoff and household drains that carry a range of pollutants into the rivers, wetlands and Geographe Bay. Through the use of a display and distribution of educational materials, greater recognition of the potential impacts of everyday activities was promoted. Promotional material for the Clean Drains awareness campaign included T-shirts, stickers, posters and fridge magnets with the slogans 'Don't let your Bay go down the drain' and 'Keep our Bay healthy – take care in the catchment'.

Stormwater information sessions and tours were available to all school classes in the catchment. Students learnt about the difference between water movement in a naturally vegetated area and an urban area, and about the different types of pollutants carried in stormwater. They also learnt about what they could do to help keep stormwater as clean as possible, and visited sites where structural controls have been installed. Students took home the messages to their families and friends.

Students also painted colourful designs including the words 'drains to the bay' or 'clean water only' around drains. The bright, eye-catching designs draw people's attention to the stormwater issue and increased the students' awareness and ownership of the problem.

### **Results/achievements**

This project had become a demonstration initiative, providing many learning outcomes that could be shared with others. It has improved the capacity of the Shire of Busselton to manage stormwater throughout the shire, and to make improved recommendations to developers.

The major structural control type implemented was construction of stormwater detention basins. These basins were revegetated and are now well established, providing additional habitat for waterbirds in the local area.

Water quality monitoring of drains and basins was undertaken in 2002 to investigate the effectiveness of

stormwater detention basins and to determine the levels of pollutants in stormwater. Monitoring of drains in 2003 aimed to determine levels of pollutants in drains without any structural controls installed, with the aim of guiding future management, and to further investigate the effectiveness of the Fairlawn Street detention basin. Year 11 Biology students from McKillop Catholic College assist with monitoring through the Ribbons of Blue program to improve understanding of stormwater management issues.

Only the Fairlawn Street detention basin indicated significant pollutant removal effectiveness, with output concentrations of nitrogen, phosphorus and suspended solids generally lower than input concentrations. This was most evident for total nitrogen, where all samples in outflows were lower than those in inflows. Table 4 shows a comparison of average concentrations of total nitrogen, total phosphorus and total suspended solids in inflows and outflows for this detention basin. The Fairlawn Street detention basin differs from the others as it has an elongated shape and has more established in-stream vegetation. The pollutant removal effectiveness of the other detention basins cannot be fully assessed because of limitations of the monitoring program.

**Table 4. Comparison of nutrients and suspended solids in inflows and outflows for Fairlawn Street Detention Basin, Busselton**

Indicator	Average inflow concentration (mg/L)	Average outflow concentration (mg/L)	Reduction (%)
Total nitrogen	2.5	1.3	48
Total phosphorus	0.09	0.07	22
Total suspended solids	14.0	10.0	29

The monitoring suggests that the desired shape for stormwater treatment basins is a widened drain with minimal permanent storage of water and maximum perennial in-stream vegetation, that is an ephemeral living stream. Retrofitting drains into living streams may therefore be preferable to building more detention basins in the Busselton area. The most effective systems for improving water quality entering Geographe Bay are probably the natural wetlands in the Busselton area. It may be a more efficient management option to protect and enhance the natural functions of the Busselton wetlands as the town expands, rather than constructing detention basins, for example, by re-establishing a well-vegetated wetland buffer.

Although nutrient levels were sometimes elevated during storm event sampling, overall nutrient concentrations were low to moderate for stormwater drains in the Busselton area. Stormwater contained undetectable or acceptable concentrations for most toxicants, including hydrocarbons, pesticides, volatile organic compounds and arsenic. Surfactants were detected in Frederick Street and Strelly Street drains but no guideline is available for this parameter. While hydrocarbons were not detected, a distinct petroleum smell was noted at Fairlawn Street drain, which discharges opposite a service station, on several sampling occasions. Hydrocarbons are very volatile and difficult to monitor, but it is important to continue to monitor their presence at this site.

Some heavy metal concentrations were of concern, particularly chromium, copper, lead and zinc (Figure 23). Most drains significantly exceeded the ANZECC and ARMCANZ (2000) copper guideline of 0.014 mg/L. West Street and Ford Road drains had elevated levels of chromium and lead. All monitored drains had zinc levels much higher than the ANZECC and ARMCANZ (2000) guideline of 0.008 mg/L. Raising awareness within the business community may be beneficial in managing this problem.

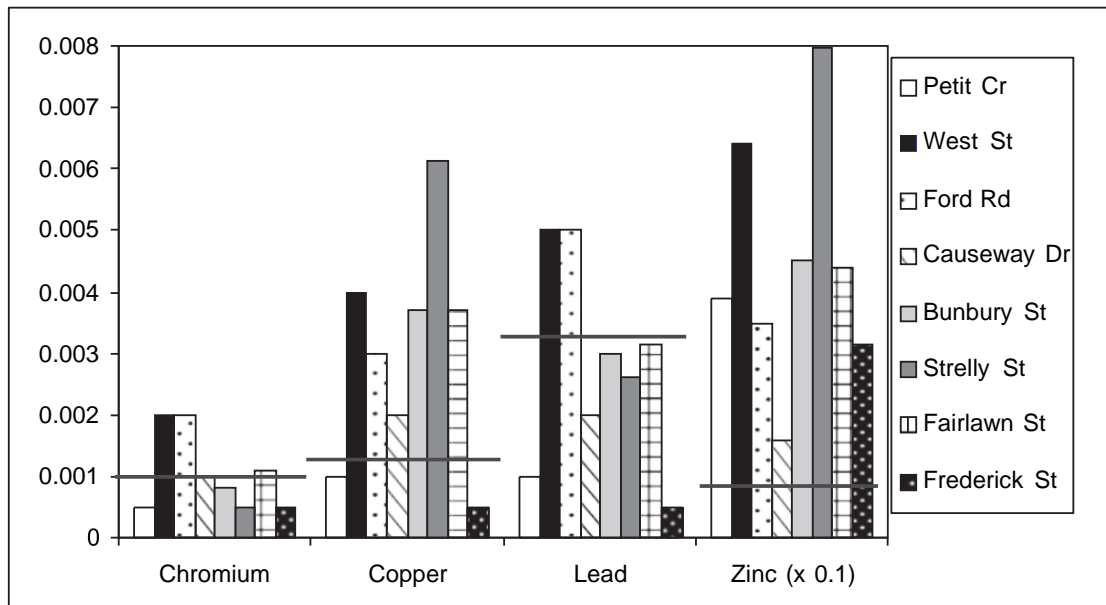


Figure 23: Average heavy metal concentrations found in Busselton stormwater drains in 2002–03. Lines indicate guidelines for protection of aquatic ecosystems (ANZECC and ARM CANZ 2000).

## Challenges

The high watertable in the Busselton area restricted the construction period for on-ground works to two months in late summer. It was difficult for the Shire of Busselton to complete all of the works in this short period, which increased the duration of the project. The high watertable and space constraints in the existing developed areas also restricted the range of improvements that could be implemented.

## Resources

Under an agreement with the former Water and Rivers Commission, the Australian Government's Coasts and Clean Seas program committed \$250,000 towards implementing the Busselton Stormwater Management Project. The Shire of Busselton managed the design and construction works, utilising \$170,000 of the funding. GeoCatch were responsible for project coordination, monitoring, revegetation activities and community promotional activities. Initially, this project did not include a budget for maintenance of the structural controls, which is a necessary project component. These funds were subsequently clearly allocated in the work plan.

This project received a WA Coastal Award in 2002 in the category of Outstanding Coastal Project.

## 7.3 Bayswater Main Drain catchment

The former North Metropolitan Catchment Group (NMC12) had undertaken in-drain measures in the Bayswater Main Drain catchment with the aim of improving stormwater quality and creating habitat. The group has undertaken works at various sites throughout the catchment, including revegetating the banks and in-stream sections of the Bayswater Main Drain at Paterson Street, Bayswater, and realigning the drain to create a meandering flow path (see Figures 24 to 25). The aims of the project were to restore native

<sup>12</sup> The Bayswater Integrated Catchment Management Group merged with Bennet Brook Catchment Group in 2002 to form the North East Catchment Committee (NECC). The NECC was then renamed the North Metropolitan Catchment Group (currently the site under the Eastern Regional Metropolitan Council).

vegetation, create habitat for local fauna and reduce stormwater nutrient levels. The drain was bound by the backs of residential properties on the southern side and parkland on the northern side. The drain consisted of numerous weed species that were sprayed annually, which resulted in bare banks. The parkland consisted of a large expanse of grass, bordered by *Ficus* trees (introduced).



*Figure 24: Paterson Street drain, Bayswater, after earthworks. (Photograph: Rosemary Glass, formerly of Bayswater Integrated Catchment Management Group)*



*Figure 25: Revegetated drain, Paterson Street drain, Bayswater. (Photograph: Debbie Besch, NMCG)*



*Figure 26: Revegetated area and parkland, Paterson Street Drain, Bayswater. (Photograph: Debbie Besch, NMCG)*

The proximity of residential properties limited the extent of earthworks and the choice of vegetation. There was only a narrow 3 m strip between residential properties and the top of the bank. It was not possible to alter the slope on this side, so it remains at 1:1. To ensure public safety on the bank bordering the park, the slope was contoured to 1:3. Local residents were extensively consulted on the suitable types of vegetation. The selected species had to be colourful, have visual appeal and be less than 1 m tall or medium sized with single-stem trees to allay fears of providing concealing areas for intruders. Trees were planted so that there would be no overhang of branches over residents' properties. The base of the drain was planted with wetland plants that would not spread rapidly and block the channel. The channel was also planted to block child access to the water, at the request of local residents. One lesson learnt from the project was that, because of

the lack of shade for young seedlings (as larger plants were not present), ground covering species are needed early in rehabilitation to shade the ground, minimise weeds and maximise plant survival.

Involvement and support from the local community was found to be very important, particularly with respect to preventing and reporting vandalism. A wide diversity of macroinvertebrates have been found every year in the water body during the Ribbons of Blue ‘Snapshots’ sampling events conducted with local schools, which is indicative of a healthy water body. Numerous native frog and bird species have also been observed. Work will be undertaken at the site to monitor the success of the wetland plant species in removing pollutants from stormwater. Their affect on the hydraulic capacity of the drain will also be assessed (Besch, D., 2003, pers. comm.<sup>13</sup>).

Other work in the Bayswater Main Drain catchment has included the creation of wetland habitats at the Russell Street compensating basin in a commercial area of Morley (Figure 27) and the Mooney Street compensating basin in an industrial zone of Bayswater. A continuous deflective separator was also installed in an industrial zone in Bayswater (see Example 3).



Figure 27: Straight drain converted to a vegetated compensating basin, Russell Street, Morley. (Photograph: Debbie Besch, NMCG)

## 7.4 Bannister Creek drain to living stream project

### Project description

A drain retrofit project was undertaken on about a 350 m reach of Bannister Creek, adjacent to Bywood Way in Lynwood in Perth’s southern metropolitan region (Figure 28). The Bannister Creek catchment area is 23 km<sup>2</sup> and includes the suburbs of Canning Vale, Lynwood, Ferndale and Parkwood. The creek is one of the main tributaries of the Canning River and was originally a series of wetlands, but was modified to a main drain in 1979. The soils of the Bannister Creek catchment are predominantly Bassendean Sands. However, the lower reach of the creek, where the rehabilitation reach is located, consists of sandy soils overlaying clayey swamp flats.

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<sup>13</sup> Personal communication with Debbie Besch, North East Catchment Committee, May 2003.

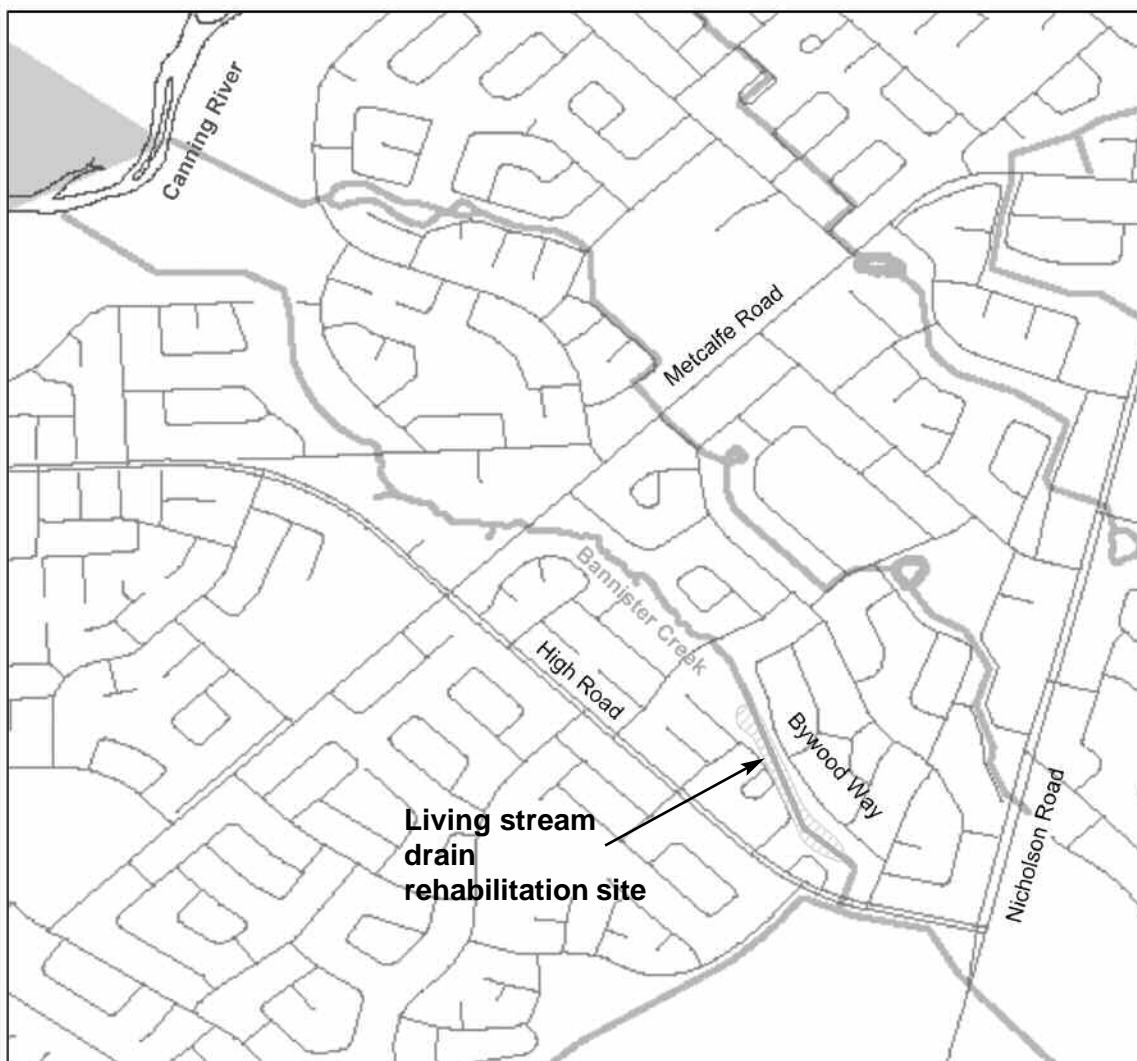


Figure 28: Location of Bannister Creek Living Stream Project.

Urbanisation in the Bannister Creek catchment has resulted in a high proportion of impervious surfaces and a traditional drainage system designed to quickly remove stormwater runoff. The increased volume and velocity of waters draining to the creek has resulted in erosion problems and pollution of the waterway. Pollution sources include fertiliser runoff from golf courses, parks and gardens; domestic pet faeces; industrial waste discharge; motor vehicle residues; domestic pesticide and chemical use; landfill; and leakage from underground pipes and tanks (Fisher, 1999). The hydrology and structure of Bannister Creek has been greatly altered. The loss of wetland systems and riparian vegetation has resulted in decreased habitat, the loss of plant and animal communities and a decrease in the natural capacity of the waterway to buffer floods and pollutants.

In response to community concern over pollution of the waterway, the Bannister Creek Catchment Group (BCCG) was formed in 1996 to 'coordinate integrated natural resource management over the whole of the Bannister Creek catchment'. Rehabilitation of the creek was one of the projects initiated by the BCCG.

The aim of the project was to transform a straight section of drain (Figure 29) into a living stream, while maintaining the function of the waterway to convey stormwater from the urban and industrial catchment into the Canning River. As the creek is within a recreational reserve, enhancement of the creek aesthetics was also an objective.

## Approaches implemented

In November 2000, large volumes of soil previously imported in the 1970s as part of urban development were removed from the site to create a 'meandering' creek and to reshape the steep banks to a gentler slope suitable for planting (Figure 30). Riffles were built to aerate flows and create habitat. Erosion control matting was used to stabilise sections of the stream banks and the area was revegetated.



*Figure 29: Bannister Creek before restoration works (1999) – a straight trapezoidal drain with steep grassed banks and high velocity flows. (Photograph: former Department of Environment)*



*Figure 30: Bannister Creek post-engineering (restoration) works summer 2001. The channel was realigned to create a winding creek and the banks reshaped to a gentle slope and stabilised. (Photograph: former Department of Environment)*

The BCCG have undertaken numerous source control activities to reduce pollution of the creek. These activities have included:

- development of a turf nutrient management plan and monitoring of soil nutrient requirements to determine appropriate fertiliser application regimes (Fisher, 1999)
- a survey of residents adjacent to Bannister Creek, as part of the 1997 BCCG phosphorus reduction campaign to determine community awareness of the impact of their actions and attitudes to change their actions to improve the water quality of Bannister Creek.

The City of Canning also undertook an industrial audit of light industrial premises in 1997 to determine levels of awareness of stormwater risks, washdown and drainage practices and emergency clean-up procedures.

Other community education and awareness raising activities have included:

- mapping, aerial photos, macroinvertebrate monitoring, flora and fauna surveys, foreshore surveys and reports completed to evaluate and report the project results
- tours of the rehabilitation reach as a demonstration site of stormwater management
- bus tours, forums and workshops to educate stakeholders and the community
- pamphlets about stormwater management and drains distributed in the catchment
- awareness raising by visiting over 600 businesses and industries in the catchment
- nine schools have been involved in the rehabilitation project, including four schools undertaking Ribbons of Blue monitoring
- pollution response education
- cleaner production training

- articles in local and state newspapers and on television
- production of the quarterly BCCG newsletter.

The BCCG has reached a wide audience – about 4,000 people have had some level of involvement in the project.

## Results/achievements

The channel realignment and bank stabilisation works have been very successful. A storm event in winter 2001 caused severe damage to the main drain structure upstream of the demonstration site (Figure 31), while the newly rehabilitated ‘living stream’ section of the channel carried the increased flow without any significant damage (Figure 32).



*Figure 31: Flood damage of the trapezoidal drain upstream of the rehabilitation reach of Bannister Creek. (Photograph: former Department of Environment)*



*Figure 32: Bannister Creek 2004. Revegetation was undertaken to reduce water velocity, control erosion and rehabilitate the drain into a living stream. Flooding resulted in no significant damage to the creek. (Photograph: Georgia Davies, BCCG)*

Macroinvertebrate sampling was carried out in spring 1999 before the restoration works, and in spring 2001 following restoration works. The sampling was a snapshot and replicate sampling has not been undertaken. Habitat diversity at the site was significantly increased by the restoration works, including the creation of pools, riffles, macrophyte zones and runs. Increased habitat diversity is linked to increased species diversity. There was a greater abundance and diversity of taxa present post-restoration than pre-restoration. A 55 per cent increase in the number of taxa present was found post-restoration works (17 taxa compared with 11 pre-works). There was an increase in the number of macroinvertebrates that are indicators of healthy waterways, such as damselflies, dragonflies and caddis flies. Additionally, a significant increase in birdlife, turtles and other wildlife in the area has been observed since the restoration works.

The retrofitting project at Bannister Creek is part of a broader program to improve the health of the catchment. Other activities include extensive areas of weed eradication, revegetation and remnant bush and creekline restoration, as well as establishment of a local community herbarium. The Bannister Creek Management Plan (November 1998) was prepared as a guideline for all stakeholders. The project has been successful because of the high investment in partnership building with various stakeholders and the high level of community involvement and skill development.

The recreational and aesthetic value of the area has been improved, including construction of a pathway and viewing platform that have resulted in less vandalism and foot traffic in the restoration area.

This project helped the BCCG win the River Rats Living Stream Award in 2001 and be runner-up in the Natural Heritage Trust (NHT) Rivercare Award for 2001. The success of this project has led to an extension of the site. Stage 2 of the living stream project, involving enhancement of a 120 m reach immediately downstream of initial works, commenced in March 2004.

## Challenges

As the site forms part of the main drainage network, concerns were raised that the selected rehabilitation techniques would increase flooding on Bannister Creek. Other challenges to implementing the project arose from traditional drain management practices, reluctance to trial new techniques and a focus on conveyance rather than water quality or ecosystem values.

An advantage of this site was the wide drainage reserve that enabled the channel to be widened to reduce the bank slopes and offset any decreased flood capacity because of revegetation. Some drains have a narrow reserve and this limits the scope to undertake restoration works. However, where drainage is integrated with public open space, there are often opportunities to achieve multiple benefits by rehabilitating the drain.

## Resources

The BCCG has received nearly \$1 million in funding since its formation in 1996. This funding has been used for a variety of projects within the Bannister Creek catchment and includes salaries and administration costs, as well as all on-ground works and education programs. The engineering works cost \$110,000 to remove 13,000 cubic metres of fill and \$2,500 to build the riffles (see Table 5). The City of Canning undertook the works in-house and used the fill for other projects, for example road building. The cost is relative to traditional drainage practices. For example, drop structures can cost in excess of \$100,000. It is far cheaper and easier to implement best practice stormwater management in the planning and design phase of a project, rather than retrofit a poorly designed or traditional system.

The following table shows the costs for various engineering items. This includes all earthworks, bulk mulching, retaining walls and balustrades. Volunteer labour and items of a landscaping nature, such as jute matting and planting, are not included.

**Table 5. Cost<sup>a</sup> of engineering works for Bannister Creek Drain to Living Stream Project (Leek, 2001)**

Activity	Quantity	Cost
Cut to fill	1,200 BCM	
Excavate and cart surplus	13,000 BCM	\$110,000
Strip top cover		\$8,500
Drainage alterations		\$73,000
Supply mulch and spread		\$12,000
Construct riffles		\$2,500
Retaining walls and balustrades		\$32,000
<b>Total</b>		<b>\$238,000</b>

<sup>a</sup>The costings used in this table and 'resources' subsection are from around 2001. Please adjust the costings for present day.

The quantity of soil carted from the site was about 13,000 BCM (bank cubic metres) which approximates 22,000 tonnes or 1,000 semitrailer loads of material.

The BCCG and the City of Canning had undertaken the project with support from former Department of Environment (now Department of Water and Environmental Regulation), Water Corporation, Swan Catchment Urban Landcare Program, Alcoa, the Natural Heritage Trust and the local community. The project was part of the broader Swan-Canning Cleanup Program and Swan Region NRM strategy.

## References/further information

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## 7.5 Coolgardie Drain to living stream project

### Project description

As part of a collaborative project, the Two Rivers Catchment Group<sup>14</sup>, City of Belmont, former Department of Environment (now Department of Water and Environmental Regulation), Garvey Park Friends Group and Boral Resources WA have restored the Coolgardie Drain in Garvey Park, Ascot (Figures 33 and 34). The main objective of the project was to create a 'living stream' to enhance the habitat value of the site.

This work involved stream realignment, bank revegetation and riffle construction to create two distinct habitats – one for fresh water from the drain and one that has a tidal (saline) influence.



Figure 33: Coolgardie Drain before living stream project. (Photograph: J. King, City of Belmont)



Figure 34: Coolgardie Drain in April 2004, two years after the earthworks. (Photograph: J. King, City of Belmont)

### Approaches implemented

The project was conceived in late 1999 when the concept to turn the Coolgardie Drain into a living stream was proposed to the City of Belmont. The concept was put forward in the *Garvey Park and Swan River Foreshore Restoration and Concept Plan* (Ecoscape, 1999). The 500 m stretch of drain was previously linear and narrow, with limited habitat value. The 24 ha catchment is a mixture of residential and light industrial.

The project commenced in 2000 with planning, collection of baseline information on fauna, weed management and seeking funding from the Swan Alcoa Landcare Program<sup>15</sup> and corporate sponsorship from Boral Resources WA. The earthworks and riffle were designed by the former Department of Environment and earthworks commenced in April 2002.

<sup>14</sup> Then known as the Belmont-Victoria Park Catchment Group, before the merger with the Canning Plain Catchment Group.

<sup>15</sup> Swan Alcoa Landcare Program (SALP) – a joint initiative between Alcoa World Alumina Australia and the Swan River Trust.

The drain was modified by sculpting and battering the banks to create a meandering stream with some open water areas and stands of native shrubs and sedges. A riffle was constructed to separate the freshwater habitat from tidally influenced habitat. About 22,000 native plants were planted in 2002 and a further 18,000 in 2003. Additional plants have been planted since 2003 to increase diversity and fill in gaps. The revegetation area has been extended during 2003–05 to cover the floodplain area and link the living stream with remnant wetland vegetation to the south. The City of Belmont, with assistance from the Two Rivers Catchment Group, continues to maintain the area by eradicating weeds (mainly by spraying) and planting native plants.

Further work will involve restoring the vegetation on the island in front of the drain inlet pipe and additional stream infill and buffer planting to increase plant density and improve habitat.

### **Results/achievements**

About 45,000 wetland and dryland trees, shrubs, sedges and rushes have been planted and 4,500 tonnes (or 3000 cubic metres) of clay has been removed to create the living stream.

The project has been successful in encouraging local government, State Government, industry and community groups to work together in creating a valuable environmental asset. The project has involved a considerable number of volunteers, been a focus of a number of Swan River Trust Corporate Care Days and has received good publicity in the local media.

Macroinvertebrate and water quality monitoring has commenced, with an aim to determine the type and amount of pollutants entering the Swan River from the Coolgardie Drain and to assess the impacts of the restoration and revegetation techniques.

### **Challenges**

One particular sedge species (*Carex* species) did not have a high success rate, possibly because of site acidity, but all other revegetation works were successful. The planting survival rate has been excellent, at about 90 per cent. Controlling the weed Wild Gladiolus (*Gladiolus undulatus*) has been a major challenge.

The Coolgardie Drain retrofit project was undertaken before recent awareness of acid sulfate soils (ASS) issues. The drainage realignment caused ASS oxidation within the channel and banks at a few locations in the upper section of the drain, resulting in acidic soil conditions. The City of Belmont initially had problems stabilising the banks, which had excessive soil acidity; however, these areas have now been stabilised using hardier sedge species (*Juncus kraussii* and *Isolepis nodosa*). The project site highlights the need to assess the risk of ASS disturbance, particularly in those areas identified as susceptible to ASS. Acidity issues can be managed if ASS are first identified and disturbed soils neutralised before re-use.

### **Resources**

This project was a collaborative effort between the City of Belmont, the Two Rivers Catchment Group, Garvey Park Friends Group and the former Department of Environment. The City of Belmont provided about 50 per cent of the project funding, with the remainder primarily originating from Swan Alcoa Landcare Program funding. There was also considerable assistance from Boral Resources WA and contributions from the other project partners.

### **References/further information**

Contact the City of Belmont for further information.

## 7.6 Liege Street wetland

### Project description

The Swan River Trust in partnership with the City of Canning, the former Department of Conservation and Land Management, Water Corporation and the South East Regional Centre for Urban Landcare (SERCUL) constructed the Liege Street wetland in Cannington. The main aim of the constructed wetland is to treat nutrient-enriched stormwater and groundwater from two main drains (and one local council drain) before it is discharged into the Canning River. Improvements to the habitat and aesthetics of the area are also objectives of the wetland.

The Liege Street Main Drain catchment is about 530 ha. The catchment is covered by the City of Canning and includes the suburbs of Cannington, East Cannington, Queens Park and a small portion of Welshpool. The upper portion of the catchment is mainly set aside for residential land use while the lower portion is dominated by a commercial area, including the large Westfield Carousel Shopping Centre. The catchment is dissected by the Perth to Armadale railway line and some major roads, including Albany Highway at the lower end of the catchment and Welshpool Road towards the top of the catchment.

The Liege Street drain outfall is an artificial system, which was constructed in 1992/93. The drain lies within the Canning River Regional Park, which is managed by the Department of Conservation and Land Management.

Water quality monitoring of both Liege Street and Cockram Street drain outfalls shows that the drains have elevated levels of nitrogen and phosphorus. The two drains meet upstream of the existing dual-use pathway (which was retained) before delivery into the Canning River, just more than 2 km upstream of the Kent Street Weir. This area of the river frequently experiences algal blooms, so reducing nutrient delivery into this section of the river is a key objective of the Swan-Canning Cleanup Program.

### Approaches implemented

The former Swan River Trust received \$750,000 in 2003 to implement on-ground works in the Canning Plain catchment, with the aim to immediately reduce the amount of nutrients being discharged into the Canning River, while catchment management activities were taking effect. In mid-2003, discussions with the land and drainage service managers identified that the area defined by the outfalls of the Liege Street and Cockram Street main drains and the dual-use footpath had sufficient capacity for restoration works. Water quality monitoring since 1999 had shown that these two drains were nutrient enriched and although located in the Canning River Regional Park, the area was also of poor habitat and aesthetic value (see Figure 35).

In late 2003, a stakeholder workshop was held to discuss concept designs and by early 2004 a Project Steering Committee had been formed to oversee the project management, design, construction and maintenance phase of the wetland. The consultants Syrinx Environmental Pty Ltd designed the wetland in consultation with the project partners.

Earthworks began in April 2004, restoring a total of 350 m of linear drainage line into a 3 ha wetland consisting of a combination of sumplands, pools, islands and floodplain. The first phase of revegetation commenced in July 2004, with over 50,000 plants being planted into both the wetland and uplands areas by the end of spring 2004.

The design includes a sediment forebay for collecting sediment, a series of clay-lined ponds and densely vegetated sumplands, a raised weir to create the former floodplain and the trial of a subsurface flow filter bed.

The project has now moved into the short-term maintenance phase, with all project partners committing to

a Maintenance Plan and Memorandum of Understanding. It was recognised that an education and communication component is also important to encourage land use changes throughout the catchment, so preparation of an Education Plan commenced in 2005.

### Results/achievements

The site has already received recognition in the media and has been the focus of a number of Corporate Care planting and weeding activities. There has also been successful collaboration between local and State Government working with the community towards a common goal of water quality and habitat improvement.

An extensive monitoring and evaluation program has commenced that will fill vital knowledge gaps in the performance of constructed wetlands in improving water quality. The site has already seen the return of a variety of fauna, including swans, native ducks, egrets, ibis, pelicans and long neck turtles (see Figure 35 and 36).



*Figure 35: Pre-works – outlet with floating plant, azolla. (Photograph: Department of Environment , March 2004)*



*Figure 36: Constructed wetland. (Photograph: Tom Atkinson, SERCUL, April 2005)*

### Challenges

Because of the variety of partners with diverse interests, some changes in design were required during the construction phase. This resulted in construction delays while all project partners reached agreement to the proposed changes. Because of these delays, a substantial amount of earthworks were undertaken after the winter rains had commenced. This resulted in some extra earthwork expenses but produced a wetland that is valuable to all project partners

### Resources

The wetland planning, design, construction and planting cost about \$550,000<sup>^</sup>, with the majority of funding coming from the Swan River Trust's Drainage Nutrient Intervention Program. However, the City of Canning also contributed an additional amount of nearly \$300,000 in-drain sediment disposal costs, restoration of the local council drain and works supervision. Other project partners also contributed a considerable amount of in-kind contribution to the project

<sup>^</sup>The costings used in this example are from about 2003. Please adjust the costings for present day.

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## Useful internet sites

[bmpdatabase.org](http://bmpdatabase.org)

National Stormwater Best Management Practices (BMP) Database. An American website that provides access to BMP performance data in a standardised format for over 190 BMPs.

[www.cwp.org/](http://www.cwp.org/)

Retrofitting information from the USA Centre for Watershed Protection.

[www.stormwater.asn.au](http://www.stormwater.asn.au) Stormwater Industry Association website.

## Reference details

The recommended reference for overall manual is:

Department of Water and Environmental Regulation and Department of Biodiversity, Conservation and Attraction 2004-2007, *Stormwater Management Manual for Western Australia*, updated 2022, Government of Western Australia, Perth, available [www.dwer.wa.gov.au](http://www.dwer.wa.gov.au)

The recommended reference for this chapter is:

Department of Water and Environment Regulation and Department of Biodiversity, Conservation and Attraction, 2006, *Retrofitting, Stormwater Management Manual for Western Australia*, updated 2022, Government of Western Australia, Perth available [www.dwer.wa.gov.au](http://www.dwer.wa.gov.au)

## Acronyms

AEP	Annual exceedance probability
EY	Exceedances per year
BMP	Best management practice
CDS	Continuous deflective system
EMRC	Eastern Metropolitan Regional Council
GPT	Gross pollutant trap
NMCG	North Metropolitan Catchment Group
SCCP	Swan-Canning Cleanup Program
SRT	Swan River Trust
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
WSUD	Water sensitive urban design