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

Stormwater management manual for Western Australia

Chapter 2 Understanding the context

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February 2004, updated May 2022

FIRST 115971

Acknowledgements

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Cover photo: Lake Goollelal City of Joondalup, WA (Source: Department of Water and Environmental Regulation)

Disclaimer

Preface

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, 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 commences 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 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 environmental awareness and 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 liveable 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

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 receivingenvironment.
- 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.

Contents

Summary

This chapter explains why stormwater management is important and the issues that face stormwater managers. Stormwater management requires careful planning, design and implementation to avoid a number of potential problems in the quality of the receiving natural and built environment. It is also important that stormwater management is considered in the context of the catchment and subcatchment, rather than focusing on the site level. This manual focuses on best management practice techniques that address these issues. An understanding of the following potential issues will help in the decision-making for appropriate policy and planning, source controls and in-system management measures:

- water quality in the receiving environment
- water quantity in the receiving environment
- healthy ecological communities
- flood management
- total water cycle management
- quality of life.

Considering this wide range of issues, an holistic approach to stormwater management is needed. The water cycle has complex interactions between surface flows, groundwater hydrology, water quality, channel form, aquatic habitat and riparian vegetation characteristics of a watercourse. The impact that the hydrological relationships in turn have on human health, recreation and quality of life are all factors to consider when determining what the community wants to achieve when managing stormwater. Effective management of stormwater means managing social, economic and environmental values in built environments (ARMCANZ and ANZECC 2000). This chapter also discusses the key roles and responsibilities for stormwater management in Western Australia (WA).

1 Why are built environments drained?

When rain falls on undeveloped land, most of the water will soak into the topsoil and slowly find its way to the nearest receiving waterway, wetland or groundwater. A small portion of rainfall in undeveloped catchments will become direct surface runoff and most of this will be generated by only a few intense rainfall events a year. Runoff moves slowly through the catchment because the ground surface is rough due to the presence of vegetation. This means that the effect of rainfall is spread out over hours and even days. Short, heavy storms have little impact on flow rates in surface receiving waters because the major movement of water to receiving surface waters is through groundwater.

When a catchment is developed, the proportion of land covered by impervious surfaces (roads, parking areas, compacted soils, roofs, driveways and pavements) is increased and this can reduce the area available for stormwater infiltration. Where stormwater has been traditionally managed through open drains and piped drainage, a significant portion of the rainfall volume can become direct runoff. However, new approaches in stormwater management aim to prevent pollution at the source, maximise infiltration to reduce stormwater runoff where site conditions are appropriate, recharge groundwater and minimise change to the natural water balance. The removal of catchment vegetation cover contributes to increased runoff, as there is reduced transpiration rates and less removal of water from the soil by plants. Therefore, retaining native vegetation is an important feature of stormwater management.

In traditionally drained built environments, there is a reduction in natural water catchment storage when floodplains and natural wetlands are in-filled for development. At the same time, paved surfaces are smoother than natural surfaces, so water can travel faster across the surface and will reach the receiving waters more quickly. In these conditions, waterways have to hold larger and often sudden or rapidly peaking runoff flows.

Groundwater is naturally very close to the surface over much of the Perth metropolitan area. To enable development and prevent seasonal inundation when groundwater levels rise in winter, drains have been installed to intercept and lower the peak groundwater table. In these areas, stormwater and groundwater management is inseparable and techniques to minimise the risk of pollution to stormwater will be different to areas where low groundwater levels allow stormwater infiltration close to the surface.

The effects of catchment urbanisation, using a traditional drainage approach on stormwater runoff characteristics, can be summarised as:

- increased peak discharges, runoff volume and velocity
- decreased response time
- increased frequency and severity of flooding
- change in characteristics of urban waterways from ephemeral to perennial systems (Wong et al., 2000).

Figure 1 shows the components of the water cycle or hydrological cycle. Figure 2 shows the changes in the water cycle as a result of urbanisation and demonstrates that infiltration is greatly limited in urban, industrial, commercial and residential catchments, and that runoff is greatly increased.

The changes in-stream hydrology geometry in response to urbanisation are shown in Figures 2, 3 and 4. The figures show that the increase in imperviousness results in greater runoff, and that receiving surface water volumes are likely to be greater.

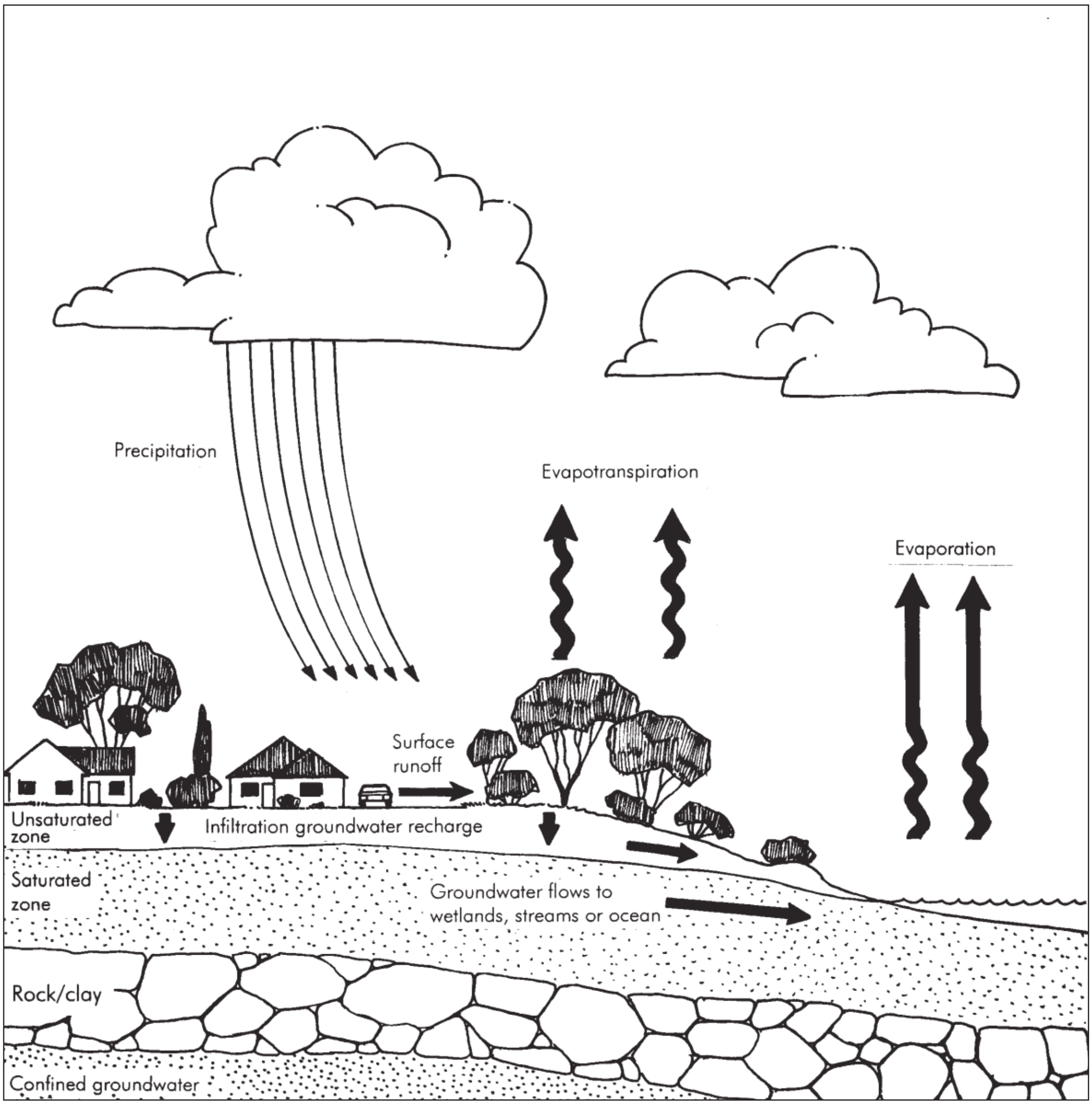

Figure 1: The hydrological cycle

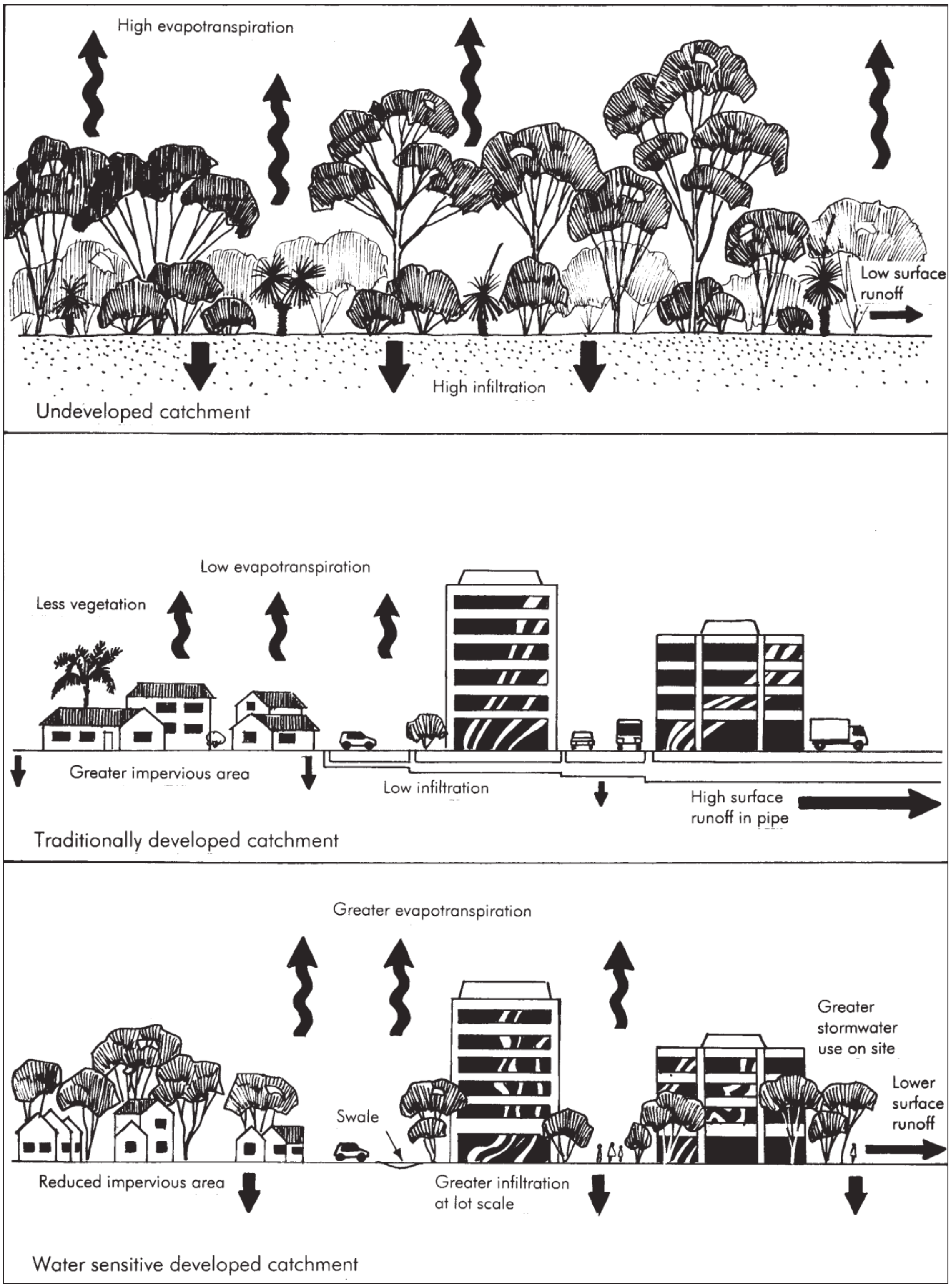

Figure 2: Effect of development on the catchment hydrology for low intensity rainfall events

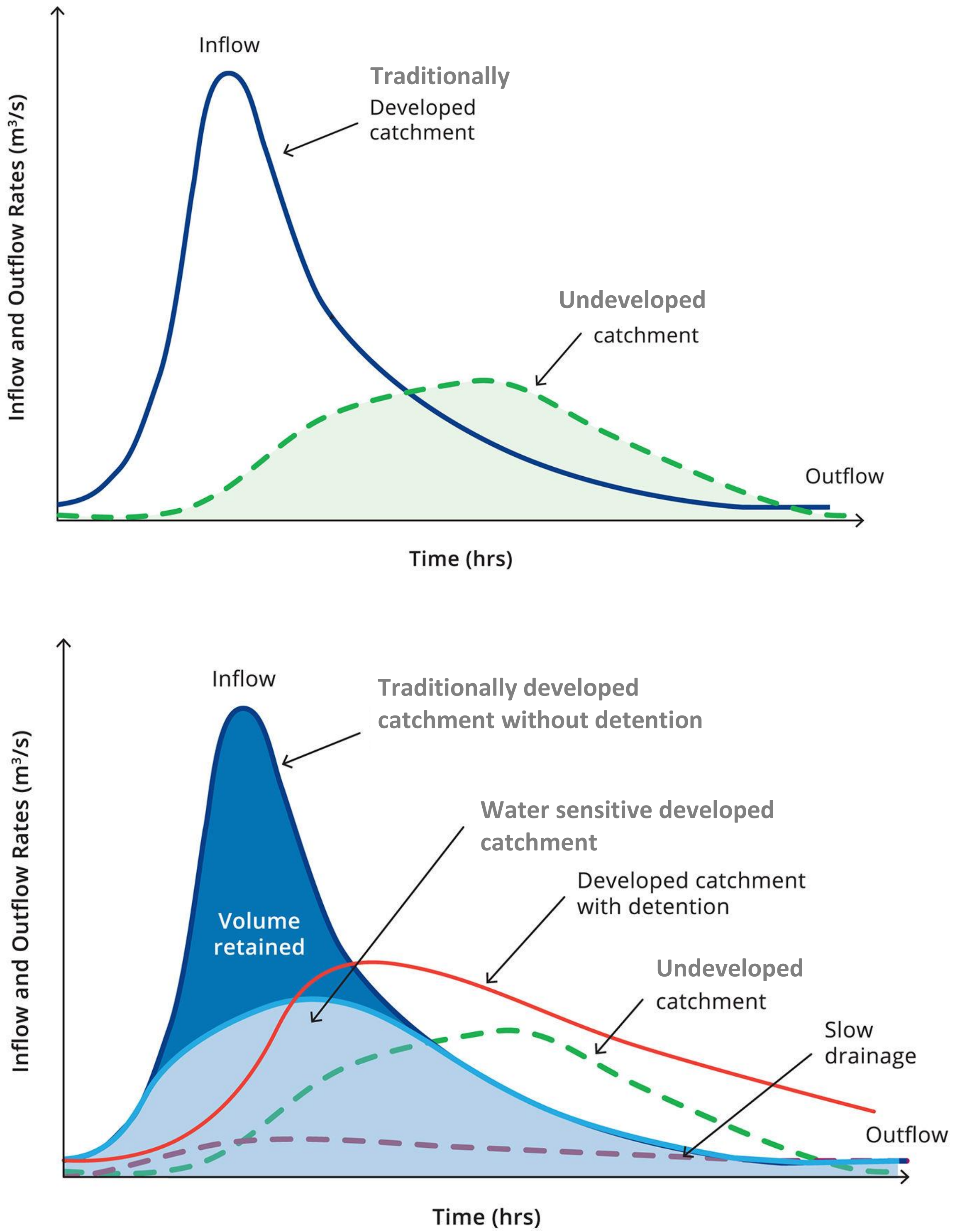

Figure 3: Differences in-stream flow hydrographs between traditional land development and water sensitive development (source: modified from Australian Rainfall and Runoff 2019)

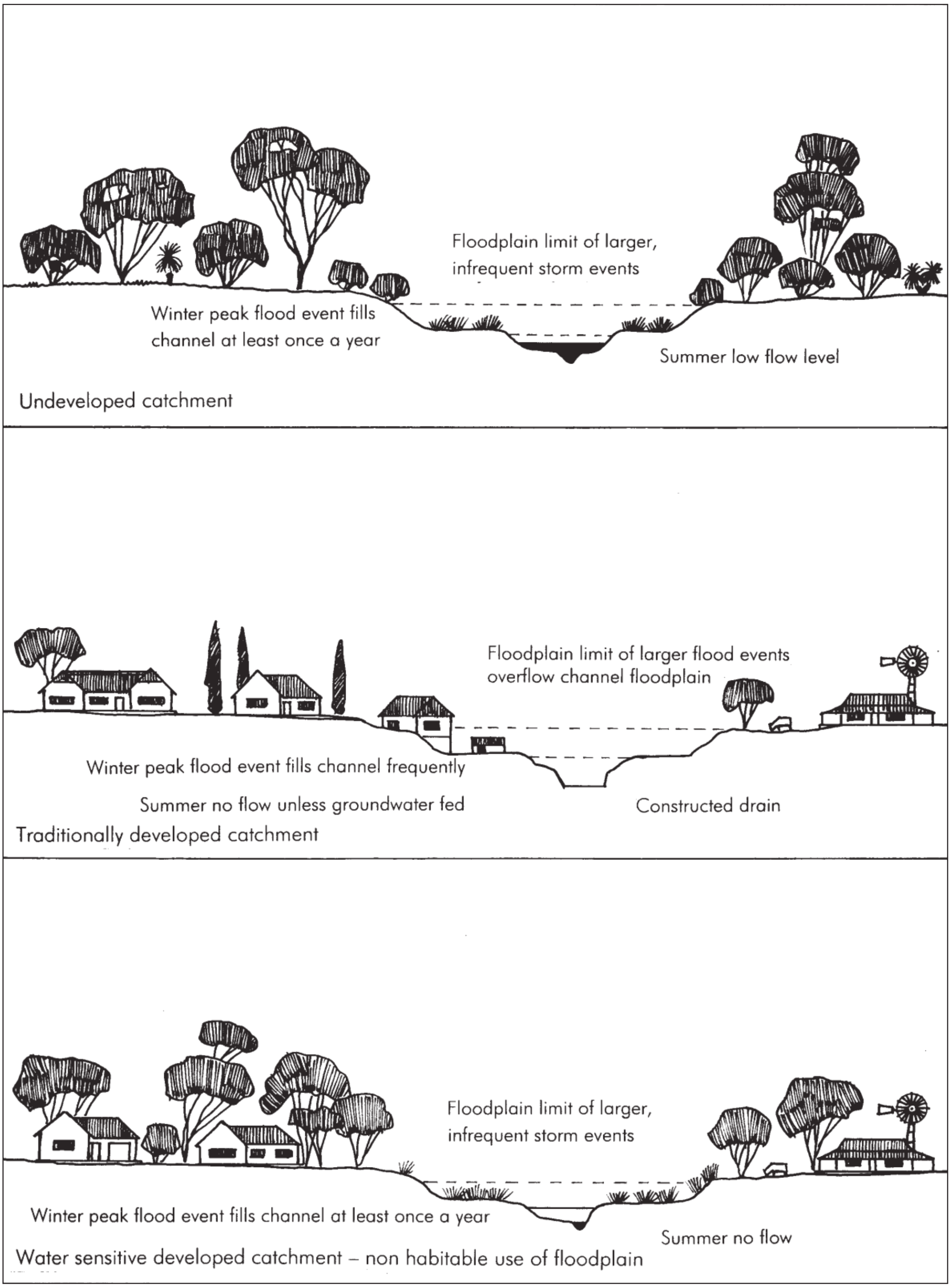

Figure 4: Response of stream geometry to traditional land development and water sensitive development

2 How are built environments drained?

Stormwater systems in WA were originally developed in response to flood prevention, to control groundwater levels and to enable development to occur. Consequently, the traditional emphasis of stormwater management has been one of efficiently collecting and conveying runoff and groundwater from residential, commercial and industrial areas into nearby lower areas such as natural waterbodies, wetlands, streams, rivers, estuaries and the marine environment. Conveyance has employed a combination of underground pipes and linear 'engineered' overland flow paths. Little or no consideration has traditionally been given to the 'downstream' consequences of a conveyance-dominated approach.

Residential development on the Swan Coastal Plain has differed from other areas in Australia, in that there has been a requirement for a portion of rainwater that falls on a property to be retained and infiltrated using soakwells where soil conditions are appropriate. In addition, dry flood retention or detention basins were often scattered across suburbs, usually one in every few streets throughout residential areas, which allowed stormwater to be stored throughout the catchment rather than in a single, end-of-catchment storage system. The stormwater then penetrates the soil and recharges the superficial aquifer. These approaches have resulted in significant benefits to the quality and quantity of stormwater; however, they are not enough to protect stormwater quality because there are still significant areas of urban surfaces such as roads and commercial areas that direct stormwater to drains and waterways.

A new approach termed 'water sensitive urban design' (WSUD) was developed in the late 1980s for urban planning and design. WSUD is a planning and design approach that incorporates the sustainable management and integration of stormwater, groundwater, wastewater and water supply into the built form of houses, allotments, streets, suburbs and master-planned communities (DWER 2017). The emphasis of WSUD has been on stormwater as a valuable resource rather than the conveyance and disposal of traditional systems. The WSUD experience gained in WA over the past decades has been incorporated into this manual, and in particular in Chapter 4.

Contemporary stormwater management is aimed at reducing the impacts of development on the natural water cycle (Victorian Stormwater Committee 1999; ARMCANZ and ANZECC 2000; Institution of Engineers Australia 2003). Stormwater management now emphasises stormwater quality, health of aquatic ecosystems and public amenity, in addition to managing stormwater quantity. By necessity, stormwater management needs to be broadly based, requiring multidisciplinary inputs.

A notable shift has also occurred in the reduced emphasis on 'end of pipe' water quality treatment solutions, and an increased emphasis on the application of preventive measures (Victorian Stormwater Committee 1999; ARMCANZ and ANZECC 2000).

These include:

- retention of existing natural drainage lines (i.e. natural bio-chemical treatment processes)
- at-source, non-structural controls (e.g. education, council maintenance practices)
- use of small-scale infiltration systems (e.g. distributed infiltration to address small, very frequent to frequent runoff events at little additional cost i.e. down to less than one exceedance per year events).

3 What are the issues?

Stormwater management requires careful planning, design and implementation to avoid potential problems in the quality of the receiving natural and built environment. It is also important that stormwater management is considered in the context of the catchment and subcatchment, rather than focusing on the site level. This manual focuses on best management practice techniques that help address these issues and it is important to note that some of these issues are also associated with traditional conveyance systems. An understanding of the following potential issues will help in the decision-making for appropriate policy and planning, source controls and in-system management measures:

- water quality in the receiving environment
- water quantity in the receiving environment
- groundwater management
- flood management
- healthy ecological communities
- quality of life
- total water cycle management.

3.1 Water quality in the receiving environment

The conveyance stormwater drainage system was designed on the assumption that stormwater would remain benign in nature as it passed through the urban catchment. However, the built environment has many sources of pollutants that can contaminate the runoff as it passes through the catchment. The runoff can become contaminated with metals, oils and petrol from vehicles, organic debris, litter, silt and dust, fertilisers, animal waste, pesticides from gardens, and detergents from car washing. In conveyance drainage systems, the contaminated water is then discharged directly into waterways and other receiving water bodies.

There are many reasons to ensure that stormwater quality remains clean. In WA, some of our drinking water is harvested from beneath urban environments. Hence, it is in the community’s interest to ensure that the stormwater is kept clean and infiltrated as close as possible to the point where it falls as rain, before it becomes contaminated. Present methods of treatment do not remove all contaminants that may leach from developed areas into the watertable. Across the Perth-Peel metropolitan area, there are an estimated 190,000 garden bores with a combined abstraction of up to 82 gigalitres (GL) per year from shallow groundwater (DWER 2021). If not properly managed, the quality of infiltrated stormwater will affect abstracted water used on gardens and other areas. The importance of protecting the biodiversity of our urbanised environments is fundamental for healthy environments and society. Ensuring that best management practices are in place is essential. For example, if detergents and oils enter our drains and waterways, they can cause damage to the waterproofing on birds’ feathers or prove toxic to birds when preening. They can also deplete water oxygen levels as the oils and detergents break down, causing fish deaths and changes in algal communities.

Increased volumes, peak discharges and velocities usually associated with traditional conveyance in stormwater management results in significant mobilisation of pollutants and their consequential accumulation in receiving water bodies. Polluted runoff has been identified as the most significant contributor to the deterioration of water quality in natural and artificial waterways in many parts of WA (Welker 1995).

There are three major categories of pollutant mobilisation, transport and interception pathways and processes, having major implications for the selection and design of management measures. They relate to porous deep soil, clay/loam shallow soil and impervious areas (e.g. roofs and pavements). The first category is porous sands, commonly found on the Swan Coastal Plain. This soil type rapidly infiltrates rainfall at source, filtering out particulate material but facilitating through-flow of fine colloidal organic material and dissolved forms of nutrients and toxicants to groundwater. Discharges for these areas will be predominantly via groundwater. The primary pollutant interception mechanism will be through biofilm on sediments of soaks, natural waterways or ephemeral wetlands.

The second category is the podsolic loam soils over heavy clay subsoils (very common in Eastern States cities but having similar properties to iron podzols, peats and clays found at Hazelmere and Helena Valley in Perth). These systems have limited rates of infiltration and lead to a high incidence of surface overflow. Nutrients, metals and organic material are rapidly adsorbed onto the surfaces of suspended solids and are transported to the receiving waterways and wetlands. The primary pollutant mechanism is sedimentation of suspended solids and oxidation of organic materials.

The third category is the impervious areas common to all urban areas. These systems have extreme peak discharge rates and high rates of delivery of pollutants to receiving waters in the absence of natural interception components. They are high in suspended solids, heavy metals and vehicle emissions. The primary pollutant interception mechanism is sedimentation of suspended solids and oxidation of organic material and nutrients in the sediments (Breen and Lawrence 2006).

The majority of urban pollution (apart from trace metals) generally comes from diffuse (non-point) sources dispersed over large areas, with the remainder coming from point sources such as effluent outlets. With urbanisation, pollutant concentration levels may generally increase in many areas. Transport-related surfaces (roads, driveways and carparks) comprising up to 70 per cent of the impervious surface area in built catchments, represent a significant contributor of suspended solids, trace metals, polycyclic aromatic hydrocarbons and nutrients. Urban commercial activities have been identified as the main source of litter generation (Wong et al. 2000).

Stormwater pollutants originate from a variety of non-point sources, including motor vehicles, construction activities, erosion and surface degradation, spills and leachates, miscellaneous surface deposits and atmospheric deposition. Table 1 summarises the common sources of the various potential pollutants. In terms of ecological impact, the most significant potential pollutants are suspended solids/sediment, oxygen demanding material (i.e. organic material, including leaf litter), nutrients and micro-organisms. Oils, surfactants and litter also have ecological impacts in addition to a more immediate aesthetic impact (Wong et al. 2000). While substances such as suspended solids and nutrients are important in the healthy functioning of the aquatic ecosystem, excessive concentrations of these substances in natural waterbodies is detrimental. An increase in suspended solids results in a decrease in the availability of light through the water column. Large inputs of nutrients can cause excessive algal growth, which will lead to decreased oxygen levels and light availability. The resultant bloom's algal species could be toxic, leading to closure of the waterbody (Hosja et al., 1994). Other forms of aquatic flora and fauna are affected by decreases in light and oxygen levels, gradually causing an overall deterioration of the waterbody. The short-term impact of toxic contaminants such as heavy metals is organism mortality, while the long-term impacts are associated with chronic exposure and bio-accumulation of contaminants through the food chain (Wong et al. 2000).

As significant amounts of organic and inorganic pollutants are bound to sediment, the minimisation and control of sediment in runoff, principally by minimising runoff as close to its source as possible, is now a fundamental component of effective stormwater quality management (Wong et al., 2000).

Dry weather flows in stormwater systems can originate from groundwater, garden watering, commercial/industrial processes and associated activities, leaking water or reticulated sewerage pipes and illegal discharges. Dry weather flows tend to be less prevalent in sandy soils, except in sandy areas where drainage systems are cut into the groundwater table and therefore flow all year. Overflow from septic tanks also becomes a part of flows via groundwater input during wet and dry weather conditions. Water from these sources has a higher potential to contribute to pollutant loading and steps to deal with these flows need to be taken separately, but in conjunction with, measures to manage flows from rainfall events.

Table 1. Common sources of pollutants and pressures to stormwater (ARMCANZ and ANZECC 2000)

Potential pollutant/pressures	Common source
Sediment	Soil erosion during land development, building Stream bed/bank erosion Particulates from pavement and vehicle wear Re-suspension of previously sedimented material Atmospheric deposition of particulates Spillage/illegal discharge of particulates Discharge of organic matter (e.g. leaf litter, grass) Particulates from car washing Particulates from the weathering of buildings/structures
Nutrients	Weathering of bedrock Erosion of soils having adsorbed nutrients Release from sediments as a result of decomposition of organic material Runoff and leaching of fertiliser Sewer overflows/septic tank leaks Animal/bird faeces emissions and wash-off Detergents from car washing Spillage/illegal discharge Atmospheric deposition Algae and plant decomposition Leaching of excessive nutrients from agricultural and horticultural land uses
Oxygen demanding substances	Wash-off of organic matter from urbanised environment and agriculture Atmospheric deposition Sewer overflows/septic tank leaks, sewage effluent discharge Animal/bird faces emissions and wash-off Spills/illegal discharges
pH (acidity)	Atmospheric deposition Industrial spillage/illegal discharge Wash-off of organic material and decomposition Erosion of roofing material Mobilisation of acid sulfate soils as a result of drainage or soil stripping
Micro-organisms (including pathogens)	Animal/bird faces emissions and wash-off Sewer overflows/septic tank leaks, sewage effluent discharge Wash-off of organic material and decomposition

Toxic organics	Wash-off, drift of pesticides, erosion of soil having adsorbed herbicides Spillage/illegal discharge Sewer overflows/septic tank leaks, sewage effluent discharge
Heavy metals	Atmospheric deposition of particulates Particulates from vehicle wear and emissions Sewer overflows/septic tank leaks, sewage effluent discharge Particulates from weathering of buildings/structures Release from sediments as a result of decomposition of organic material Industrial spillage/illegal discharge
Gross pollutants (litter and debris)	Pedestrians and vehicle emissions, wear, littering Spills from waste collection systems Leaf-fall from trees Disposal of lawn clippings Spills and accidents
Oils and surfactants	Weathering of asphalt pavements, release from sediments, spillage/illegal discharges, emissions, leaks from vehicles, surfactants from car washing Discharge of organic matter high in natural oils Organic matter Contaminated runoff from light industrial areas and service stations
Increased water temperature	Removal of riparian vegetation
Runoff from impervious surfaces	Wastewater effluent discharges
Salinity	Discharge of groundwater that is high in salinity as a result of drainage, or elevation of the groundwater level as a result of urbanisation

3.2 Water quantity in the receiving environment

If runoff from built environments is not correctly managed there can be an increase in the volume and rate of water flowing into and through natural waterways, causing erosion of stream banks and vegetation. There may be a change in urban waterways from ephemeral to perennial systems, which will have consequences on its ecology and channel form. Increased erosive forces caused by increased water quantity and velocities may change the waterway channel form. This can result in deeper or wider channels and erosion of banks and the channel bed. The channel may also move laterally to accommodate the flows. Undermining of the banks by the changed hydrology can cause a loss of riparian vegetation that holds the banks and exacerbate the problems. The erosion of bank material also leads to sedimentation of downstream waterways and estuaries that can cause ecological loss and in some cases may cause problems to our use of waterways for navigation. Engineered infrastructure can also cause changes in hydrology, flow regimes and sediment movements.

A summary of the effect of increased imperviousness on waterway ecology and systems are highlighted in Table 2.

Table 2. The effect of increased imperviousness on waterway ecology and system processes

Increased imperviousness leads to:	Flooding	Habitat loss	Erosion	Channel widening	Stream bed alteration
Increased volume	✓	✓	✓	✓	✓
Increased peak flow	✓	✓	✓	✓	✓
Increased peak duration	✓	✓	✓	✓	✓
Increased stream temperature		✓			
Decreased base flow		✓			
Sediment loading changes	✓	✓	✓	✓	✓

In some cases, the efficiency of conveyance drainage systems results in less water being received by waterways and wetland environments. Natural flows may be diverted away from receiving waters or the efficiency of the drainage system means that the water is removed too quickly from the environment. Many waterways and wetlands receive water from groundwater as well as overland flow. Removal of water from a catchment through traditional piped drainage systems can result in less groundwater contribution because of the reduced recharge of the groundwater. As a result, the groundwater contribution or base flow in the waterbodies is reduced. This may have an effect on the geomorphological processes such as the ability of the waterway to retain its form (such as pools and riffles), as well as ecological impacts. Maintaining the natural hydrology of waterways and wetlands in the urban environment is an important factor in stormwater management.

3.3 Groundwater management

Groundwater is the water that is held in fully saturated pore spaces and fractures of soil and rock. Under natural conditions groundwater moves very slowly and flows under the influence of gravity, moving from where the rainfall soaks into the groundwater, in some case into wetlands and rivers and eventually out to sea.

The top of the saturated groundwater level is known as the watertable. The depth to the watertable varies according to location, geology, season and long-term climate variations. Regional groundwater levels were mapped in the *Perth Groundwater Atlas* and are now available online as *Groundwater Map* on the department’s website (DWER 2021). However, the atlas was developed for bore construction and is not of sufficient level of accuracy for land development design.

During the dry summer season on the Swan Coastal Plain, the watertable drops in response to reduced recharge by rainfall, the increased rate of evapotranspiration by plants and general evaporation from groundwater-fed wetlands. In winter, rainfall replenishes the groundwater and the watertable rises, coming to the surface in some low-lying areas. Many wetlands in south-west WA are surface expressions of the watertable. Water levels in these wetlands rise and fall seasonally with the watertable (Figure 5). Seasonal drying is natural for many wetlands and the flora and fauna has adapted to these ephemeral cycles. Larger variations than the normal seasonal fluctuations can damage groundwater-dependent ecosystems. The watertable and wetlands also respond to longer-term climate trends.

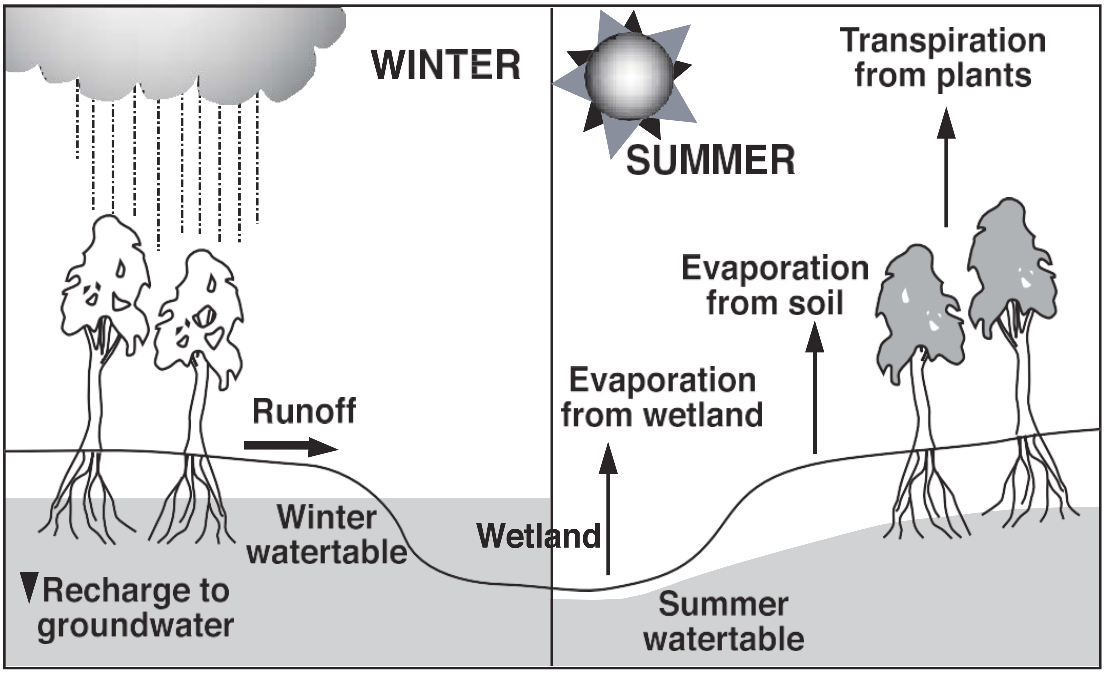

Figure 5: The seasonal groundwater cycle

The watertable is naturally very close to the surface in some areas of the Swan Coastal Plain, where the aquifer is full and levels are regulated by evaporation of wetlands. Traditionally, to facilitate development in areas of high groundwater, drains were constructed to remove the groundwater when it reached a predetermined level, to reduce the risk of damage to infrastructure through inundation or flooding. These drains typically have flow in winter as the groundwater level rises; while in summer, the lower watertable levels mean that only a very small amount of groundwater enters these drains. These drains were directed to the nearest watercourse; however, because of impacts on receiving water bodies this practice is no longer acceptable.

Fortunately, there are many options available to ensure that stormwater remains clean, and the groundwater-dependent ecosystems are not damaged. *Integrating stormwater management including decision process for stormwater management in WA* (Chapter 4), *Non-structural controls* (Chapter 7) and *Structural controls* (Chapter 9) look at appropriate planning, design, and implementation of water management systems (e.g. provision of bioretention retention and treatment, and water re-use systems), which provide alternatives to groundwater interception strategies.

3.4 Flood management

Flooding is a natural feature of our environment and is essential to maintain the physical form and ecological health of our waterways. In a highly impervious built environment, stormwater that would infiltrate the soil in an uncleared catchment instead remains on the surface and increases the risk of flooding. Instead of optimising the rate of retention, the traditional way of dealing with the risk of local flooding has been to move the water quickly from the area of risk. While the traditional drainage system has reduced the risk of flooding over time, it has become apparent that there are many other stormwater management issues and impacts emerging through poor catchment management and/or the traditional piped drainage systems. The magnitude and nature of these impacts and issues are specific to individual catchments and can be influenced by other factors such as pre-development land uses.

Preferred ways to manage stormwater are discussed extensively in Chapters 7 and 9. By maximising retention of stormwater, the social and economic benefits increase because flooding can cause significant damage to property, infrastructure and can even present a risk to our health and lives.

In summary, the benefits of controlling flooding are:

- reduced damage to property and associated financial and personal costs
- reduced risk of loss of life and health risks
- reduced risk of water pooling in sealed or heavy clay areas causing mosquito breeding sites and other health hazards
- increased potential for land development in low-lying areas.

3.5 Healthy ecological communities

It is important to note that flooding is a natural part of our waterway environment. The periodic changes in water level are crucial to the flora and fauna in floodplain rivers and are the primary source of productivity. Nutrients and particulate material are laterally exchanged between the floodplain and channel. Reproduction and other life cycles are also linked to this regular flooding.

Aquatic habitats may be lost through changes to the natural hydrology, changes in the bed material and bed shape of waterways, removal of in-stream objects such as snags and aquatic plants, and drainage of wetlands and floodplains. Damage to aquatic habitats causes a decrease in biodiversity.

Collecting and exporting the rainfall off-site results in less groundwater recharge. This can result in the decline of some waterways and groundwater-dependent wetlands.

Urbanisation has traditionally reduced the diversity of flora and fauna in receiving water bodies. This in turn has brought about a change in the composition of the ecological communities with some sensitive species being less abundant or being lost from that area. The change in ecological community structure may also allow pest species tolerant to the altered conditions to proliferate. Problems with drainage infrastructure, such as bridges and culverts, may also alter flow patterns and fauna movement (ARMCANZ and ANZECC 2000).

It is important that as much remnant vegetation is retained for biodiversity and water quality values during the planning phase of subdivisions. Management plans can help ongoing maintenance in built areas. Retaining vegetation can help maximise retention, act as buffers to our waterways and wetlands and ensure the structural integrity of the waterways.

Retaining as much vegetation as possible will contribute to the water quality of the Swan-Canning River system and other waterways and wetlands in the state.

3.6 Quality of life

The quality of an environment can be greatly influenced by the way stormwater is managed. Carefully designed stormwater systems can help contribute to attractive and liveable communities. Chapter 4 provides ideas on how stormwater can be managed in an urban environment to achieve multiple outcomes, such as natural streams, multiple use corridors and attractive public open space. If stormwater is managed poorly, it can affect our lifestyle and health. Specific design elements that help minimise health and safety risks are discussed in Chapters 7 and 9.

Inadequate catchment and stormwater management can pose a public health risk. Stormwater treatment systems that have water for more than three to four days can harbour mosquitoes and midges. Mosquitoes are normally just a nuisance, but occasionally may be a health hazard because of mosquito borne diseases such as Ross River Virus and Murray Valley encephalitis.

Chapter 3 discusses the issue of adequate planning to ensure that buffers are provided around waterways and wetlands. Design criteria to ensure that stormwater systems minimise the risk of mosquito breeding are discussed in Chapter 9. When forming stormwater management plans for an area, decisions will need to be made on the risks of mosquito-borne diseases, flooding, social and environmental factors.

Traditional drainage can have potential public hazard risks, because of the often steep sides of trapezoidal drains and detention basins and sumps, requiring fencing or other protective measures.

Collecting and exporting the rainwater off-site results in less groundwater recharge in built-up areas. A drop in groundwater levels can affect the performance of domestic and public supply bores. A recharge of stormwater close to source ensures a replenishment of this valuable resource.

There is a loss in the variety of uses available to the community (e.g. recreation) if the water quality is degraded or stormwater treatment systems detract from the aesthetics of an area.

3.7 Total water cycle management

Stormwater management requires consideration of the whole water cycle. Water supply, sewerage and stormwater activities have traditionally been managed separately in water authorities. This limits the ability to see them as resources and to achieve the benefits gained from their consideration as a whole. Total water cycle management, or integrated water cycle management, recognises that water supply, stormwater and sewage services are interrelated components of catchment systems, and therefore must be dealt with using an holistic water management approach that reflects the principles of ecological sustainability. Water efficiency, re-use and recycling are integral components of total water cycle management and should be practised when any water is extracted from river and groundwater systems.

The water cycle is an endless global process of water circulation that involves:

- precipitation (rainfall)
- flows, including infiltration into aquifers
- interception and storage (dams and aquifers)
- treatment and supply
- water use
- management, treatment and transfer of stormwater or wastewater
- discharge to rivers and oceans
- evaporation and transpiration
- cloud formation (then the cycle begins again with precipitation).

The cycle is a continuous whole, yet utilities have historically separated management of water supply systems from wastewater and stormwater systems. Recent advances in water treatment technology and urban planning have increased the number of water supply options available to utilities and consumers.

Furthermore, the scarcity of water in some areas has meant that solutions must be found beyond augmenting the traditional 19th century water supply infrastructure to satisfy end-use requirements. A sustainable water supply needs to consider the entire global process of the water cycle.

The technology now exists to shortcut the total water cycle and capture and re-use previously harvested water resources, such as wastewater and stormwater, without waiting for the cycle of evaporation and precipitation to be completed. Essentially, water conservation calls for an holistic appreciation of the total water cycle. Water conservation is therefore inextricably linked to water re-use.

Stormwater is also a valuable water resource that, if managed appropriately, can be used to supplement household, commercial/industrial, streetscape and parkland water supply needs, while ensuring the maintenance of the groundwater aquifer supply and surface water ecosystems. Appropriate total water cycle management will consider the seasonality of rainfall. For example, winter rain in Perth would need to be stored for irrigation over summer when little rainfall is received. In most cases in Perth, recharge to groundwater on-site acts as a suitable storage for rainfall that can be drawn over summer and does not present problems of loss of water through evaporation that would occur through storage ponds.

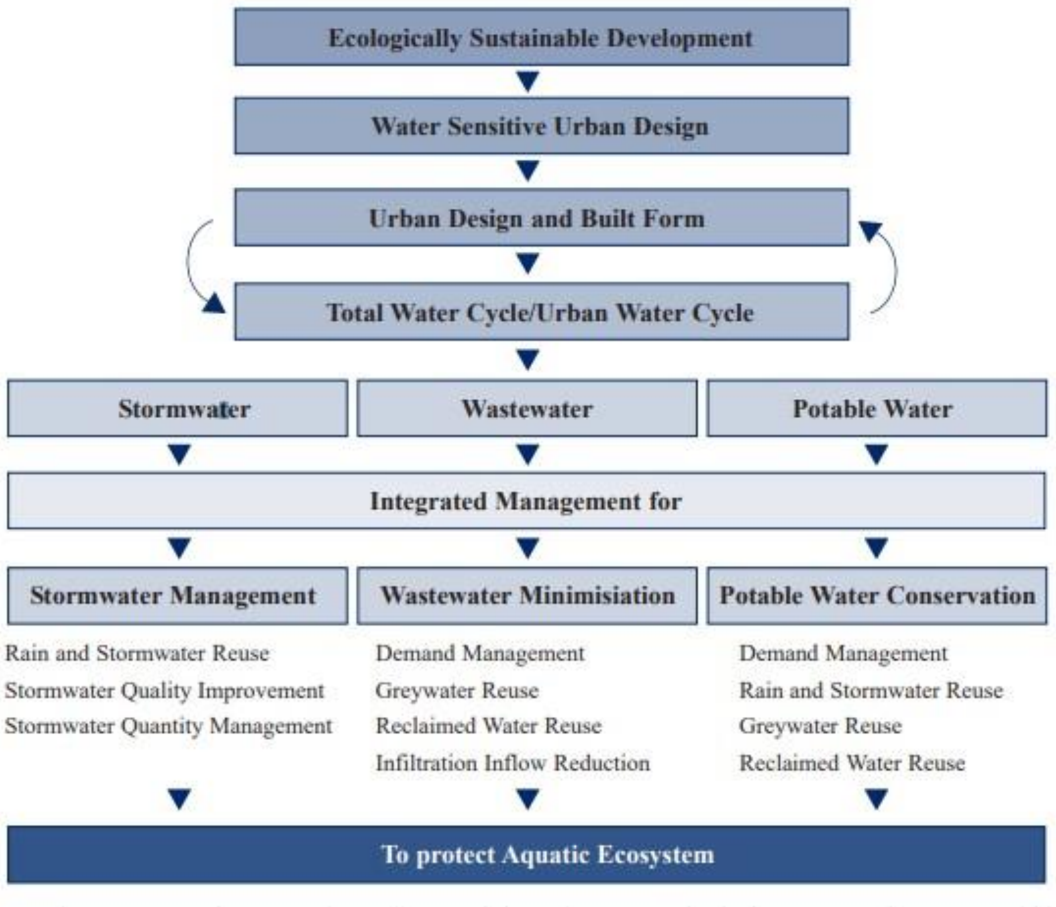

Figure 6: Interactions between ESD, WSUD and the Urban Water Cycle (Ecological Engineering, 2003)

4 What do we want to achieve when managing stormwater?

Considering the wide range of issues that arise when managing stormwater in the environment, a holistic approach needs to be taken in stormwater management. The water cycle has complex interactions that exists between surface flows, groundwater hydrology, water quality, channel form, aquatic habitat and riparian vegetation characteristics of a watercourse. The impact that the hydrological relationships in turn have on human health, recreation and quality of living are all factors to consider when determining what the community wants to achieve when managing stormwater. Effective management of stormwater means managing social, economic and environmental values in built environments (ARMCANZ and ANZECC 2000).

4.1 Stormwater management objectives for WA

A multiple-objective approach has been adopted to stormwater management in Western Australia in line with the *National water quality management strategy* (ARMCANZ and ANZECC 2000) as provided in the preface section:

Water quality

Stormwater managers should aim to maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions. The stormwater should be protected as close to source as possible, by infiltration to the groundwater where the soil conditions and depth to groundwater permit. If this is not possible, water quality should be protected via in-system treatment approaches before it enters the receiving water bodies.

Water quantity

Stormwater managers should aim to maintain the total water cycle balance within development areas relative to the pre-development conditions. By managing the quantity and rate of delivery of surface flow, water quality and the impact on groundwater aquifers and other receiving waterbodies is reduced.

Water conservation

Stormwater managers should aim to have effective use of water in the urban system. Reducing demand and maximising the efficiency of water use contribute to water conservation. Re-use of stormwater runoff f or supplementing water requirements by the household, commercial premises, street landscaping and parklands should be factored into stormwater management design and planning. The recharge of groundwater aquifers with stormwater also needs to be maximised as a water conservation objective, to ensure long-term sustainable supply of groundwater for domestic and public use.

Ecosystem health

Stormwater management should protect, maintain and restore waterway, wetland, estuarine and coastal biodiversity. Managers need to enhance ecosystem health and protect existing values of waterways, wetlands, estauries, marine and associated vegetation from development impacts.

Economic viability

It is important that the long-term economic viability of a stormwater management system is considered in the development of a stormwater management strategy. If the maintenance costs of treatment devices are difficult to afford on an ongoing basis, this may detract from the effectiveness of devices in the long-term (ARMCANZ and ANZECC 2000). In many cases, the perceived cost of alternative stormwater treatment systems results in reluctance to change. However, in reality or when demonstrated, the long-term costs may be significantly lower than conventional systems. In addition, the value of stormwater in the built environment is taken into account and reflects its true social, environmental and economic contributions.

Public health

One of the key roles of stormwater management is to improve the safety of our urban environment. There are a number of issues that may be considered to minimise risk to public health and safety. These include the risk to:

- public health from mosquitoes from constructed wetlands and wetland systems
- the community and property from flooding
- the public and operational personnel of injury from structural controls infrastructure
- people caught in waterways during floods.

Protection of property

One of the key reasons for stormwater management arising was to protect the built environment from flooding and waterlogging. The cost of damage to property includes financial and personal costs and it is important to ensure that our urban environments have minimal risk of damage from water.

Social values

To ensure that community social, aesthetic and cultural values are recognised and maintained when managing stormwater. Changes in community values and expectations have meant that in terms of stormwater management, it is no longer adequate to consider flood protection alone. Community values now encompass concern for improved access to open space and a variety of recreation opportunities, quality of life, aesthetic living environment, conservation of Aboriginal heritage sites, environmental protection and ecologically sustainable development.

This evolution of community values is addressed by the multiple-objective approach that is being taken in stormwater management. The standard of environmental and amenity quality now needs to be considered equally with that of flood protection.

Development

The way we manage new developments and maintain existing areas is important to ensure that our environment and communities are sustainable. Cost-effective and best management practice stormwater management should be implemented through planning and development in accordance with sustainability and precautionary principles.

5 How will we achieve these stormwater management objectives?

5.1 The stormwater management framework

This chapter looks at how the objectives for stormwater management in WA are achieved. The stormwater management framework has a number of components that make up the policy and planning context and the delivery framework for achieving the objectives for stormwater management in WA. The principles and objectives are implemented through three key areas – the state planning framework, the state policy framework and the delivery approaches – which together contribute to sustainable stormwater management.

The stormwater management framework components that contribute to the desired stormwater management objectives are

- stormwater management principles
- delivery approaches
- policy framework
- state planning framework.

5.2 Principles for stormwater management in WA

In WA, there are a number of principles that underpin the objectives for stormwater management as provided in the preface section. These principles should be addressed when undertaking the planning and implementation of stormwater management.

5.3 The approaches for stormwater management

The approaches provide planners, developers and government with a guide to implementing the objectives and principles of stormwater management. These eight approaches are the checklist for on-ground implementation and are based on the objectives for WSUD (CSIRO 1999). Some example techniques showing how they can be achieved are also given. Details on design guidelines for source controls, non-structural and structural techniques are presented throughout the manual.

Protect water quality *Stormwater remains clean and retains its high value* Implement best management practice on-site Implement non-structural controls, including education and awareness programs Install structural controls at source or near source Use in-system management measures Undertake regular and timely maintenance of infrastructure and streetscapes
Protect infrastructure from flooding and inundation *Stormwater runoff from infrequent high-intensity rainfall events is safely stored and conveyed* Safe passage of excess runoff from large rainfall events towards watercourses and wetlands Store and detain excess runoff from large rainfall events in parks and multiple use corridors Safely convey excessive groundwater to the nearest watercourse

Minimise and/or maintain runoff to predevelopment condition *Slow the migration of rainwater from the catchment and reduce peak flows* Retain and infiltrate (where site condition permits) rainfall within property boundaries Use rainfall on-site or as high in the catchment as possible Maximise the amount of permeable surfaces in the catchment Use non-kerbed roads and carparks Plant trees with large canopies over sealed surfaces such as roads and carparks
Maximise local infiltration *Fewer water quality and flooding problems* Minimise impervious areas Use vegetated swales Use soakwells and minimise use of piped drainage systems Create vegetated buffer and filter strips Recharge the groundwater table for local bore water use
Make the most of nature's drainage *Cost-effective, safe and attractive alternatives to pipes and drains* Retain natural channels and incorporate into public open space Retain and restore riparian vegetation to improve water quality through bio-filtration Create riffles and pools to improve water quality and provide refuge for local flora and fauna Protect valuable natural ecosystems Minimise the use of artificial drainage systems
Minimise changes to the natural water balance *Avoid summer algal blooms and midge problems and protect our groundwater resources* Retain seasonal wetlands and vegetation Maintain the natural water balance of wetlands No direct drainage to conservation category wetlands or their buffers, or to other conservation value wetlands or their buffers, where appropriate Recharge groundwater by stormwater infiltration
Integrate stormwater treatment into the landscape *Add value while minimising development costs* Public open space systems incorporating natural drainage systems WSUD approach to road layout, lot layout and streetscape Maximise environmental, cultural and recreational opportunities
Convert drains into natural streams *Lower flow velocities, benefit from natural flood water storage and improve waterway ecology* Create stable streams, with a channel size suitable for one exceedances per year to about 50 per cent annual exceedance probability rainfall events, equivalent to a bank-full flow Accommodate large and infrequent storm events within the floodplain Create habitat diversity to support a healthy, ecologically functioning waterway

A stormwater management hierarchy approach for managing urban stormwater is taken in Western Australia.

The hierarchy will help guide which approaches are appropriate for specific situations and is an evolution of the stormwater management hierarchy in the *National water quality management strategy* (ARMCANZ and ANZECC 2000) to meet local conditions.

The stormwater management hierarchy applied in WA is:

- **retain and restore natural drainage lines** – retain and restore existing valuable elements of the natural drainage system, including waterway, wetland and groundwater features and processes
- **implement non-structural source controls** – minimise pollutant inputs principally via planning, organisational and behavioural techniques to minimise the amount of pollution entering the drainage system
- **minimise or maintain runoff to pre-development conditions**– retain or re-use rainfall as high in the catchment as possible. Install structural controls at or near the source to treat (where required), and minimise pollutant inputs and the volume of stormwater
- **use in-system management measures** – includes vegetative measures, such as swales and riparian zones, and structural quality improvement devices such as gross pollutant traps.

These steps require the preservation of the valuable features of the water environment, control of the pollution at the source, and only proposes management measures within stormwater systems for residual impacts that cannot be cost-effectively mitigated by source or near source controls. Further details on stormwater management approaches are provided in the *Decision process for stormwater management in WA 2017* which is a component of Chapter 4 of this manual.

5.4 Related state and national strategies

One of the key mechanisms for achieving the outcomes for stormwater management is to ensure that the stormwater objectives meet and contribute to other natural resource management policies and strategies.

These strategies in turn assist in the implementation of the desired stormwater management outcomes. A brief discussion of national, state and regional strategies that are relevant to stormwater management follows.

5.4.1 National strategies

National strategy for ecologically sustainable development (under review)
The *National strategy* for ecologically sustainable development (Commonwealth of Australia 1992) sets out national objectives and principles for development that improves the total quality of life while maintaining the ecological processes on which life depends. The principles of ecologically sustainable development (ESD) are listed as:

- the precautionary principle – if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation
- intergenerational equity – the present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations
- conservation of biological diversity and ecological integrity – conservation of biological diversity and ecological integrity should be a fundamental consideration
- improved valuation, pricing and incentive mechanisms – environmental factors should be included in the valuation of assets and services.

The application of ESD to management of stormwater therefore aims '*to develop and manage in an integrated way, the quality and quantity of surface and groundwater resources and to develop mechanisms for water resource management which maintain ecological systems while meeting economic, social and community needs*' (ARMCANZ and ANZECC 2000).

National water quality management strategy (Australian Government 2018)

The purpose of the *National water quality management strategy* (NWQMS) is to protect the nation's water resources by maintaining and improving water quality, while supporting dependent aquatic and terrestrial ecosystems, agricultural and urban communities, and industry. It is to develop and maintain a voluntary, nationally coordinated framework, supported by all Australian governments, to facilitate water quality management for the productive and sustainable use of Australia's water resources and to protect community values such as aquatic ecosystems. The NWQMS consists of nationally agreed policies, guidelines and tools to assist governments, and other organisations and institutions, to manage water quality, taking account of local conditions and community values. Community values are also known as 'environmental values' or 'beneficial uses'.

The NWQMS aims to assist water resource managers to understand and protect (which could be maintain or improve) water quality so that it is fit-for-purpose; that is, water that is suitable for the desired values and uses and the specific local conditions. The NWQMS can also support the integration of water quality into water quantity planning. A range of tools and guiding documents to assist in improving water quality and reducing pollution are available under the NWQMS. More information about the NWQMS is available on the NWQMS website.

Australian guidelines for urban stormwater management

The Australian guidelines for urban stormwater management (ARMCANZ and ANZECC 2000), a component of the former NWQMS 1992, provides a nationally consistent approach for managing urban stormwater in an ecologically sustainable way. The guidelines outline current best practice in stormwater planning and management in Australia.

The broad principles leading to effective stormwater management, as listed in the 'Australian Guidelines' are:

- hydrology – minimise the impact of urbanisation on the hydrology of a catchment, including base and peak flow
- water quality – minimise pollution entering the stormwater system and remove any residual pollution
- vegetation – maximise the value of indigenous riparian, floodplain and foreshore vegetation
- aquatic habitat – maximise the value of physical habitats to aquatic fauna within the stormwater system.

National urban water planning principles

The Council of Australian Governments adopted the *National urban water planning principles* in 2008 and reviewed in 2013/14. The principles provide Australian governments and water utilities with the tools to better plan the development of urban water and wastewater service delivery in a sustainable and economically efficient manner. One of the principles is to 'manage water in the urban context on a whole-of-water-cycle basis'. The management of potable water supplies should be integrated with other aspects of the urban water cycle, including stormwater management, wastewater treatment and re-use, groundwater management and the protection of public and waterway health (Australian Government 2019).

5.4.2 State strategies

Wetland protection policies and guidelines

WA has an enormous diversity of wetlands occurring across the state from the coastal edges to inland environments. These range from tidal mangroves, sand and mudflats (mainly where there are marine influences) through to wetland types including swamps, marshes, damplands, salt lakes, springs and claypans from the coast and inland area. These support a rich natural heritage of plant and animal life and have many related values including recreation, tourism, fisheries, water supply and flood mitigation. The Government of Western Australia recognises the fundamental importance of sustaining the environment upon which the social and economic development of this state is based. Wetlands form a vital living part of our environment. It is essential that they be conserved and wisely managed (Government of Western Australia 1997).

Wetlands should be managed and protected in accordance with the following policies and guidelines:

1. *Wetlands conservation policy for Western Australia* (Government of Western Australia 1997)
2. *Draft Guideline for the determination of wetland buffer requirements* (WAPC 2005)
3. *Environmental factor guideline: Inland waters* (Environmental Protection Authority 2018)
4. *Chapter B4 Wetlands in environmental guidance for planning and development – Guidance statement 33* (Environmental Protection Authority 2008), which is currently being reviewed
5. *Draft State planning policy 2.9 Planning for Water* (WAPC 2022)
6. *Draft Planning for water guideline* (WAPC 2022).

5.4.3 Regional strategies

Natural resource management strategies

Natural resource management (NRM) is '*The ecologically sustainable management of the state's land, water, air and biodiversity resources for the benefit of existing and future generations, and for the maintenance of the life support capability of the biosphere* (Government of Western Australia, no date). NRM has been adopted across Australia, in recognition of the complex set of interrelated systems, natural and human, that comprises the catchment environment. NRM embraces:

- a holistic approach to NRM within catchments, marine environments and aquifers, with linkages between water resources, vegetation, land use, and other natural resources recognised
- integration of social, cultural, economic and environmental issues
- cooperation and coordination between landholders, community groups including aboriginal community, government agencies and other natural resource users and managers within the catchment
- community consultation and participation (Government of Western Australia no date).

The State NRM office was established in 2003 by the Western Australian Government to facilitate the coordinated delivery of natural resource management in Western Australia, and manages the State NRM Program. The State NRM Program covers the portfolios of Agriculture and Food, Environment and Water. The program assists to maintain or enhance the condition of the state's land, water (terrestrial and marine) and biodiversity assets so that they continue to provide economic, environmental, social and cultural benefits to Western Australians (DPIRD 2017). The Department of Primary Industries and Regional Development released the *Western Australian NRM Framework* in 2018. One of the strategies of this framework is to maintain and enhance water assets by protecting waterways (including estuaries and floodplains), wetlands and groundwater systems that support ecosystem health, water availability and biodiversity. Water is fundamental to life and public health, drives and facilitates economic development and provides social opportunities. Water has a special cultural and spiritual value for Aboriginal people. Within an NRM framework, the potential exists for using non-engineered solutions to manage stormwater that has complementary benefits such as protection of biodiversity, enhanced value of ecosystem services and improved quality of life for residents.

An NRM approach provides the means to assess the biophysical impacts of water management and the interactions of these impacts with social and cultural aspects of urban life.

In WA, there are seven NRM bodies: Perth NRM, Wheatbelt NRM, Peel Harvey Catchment Council, South West Catchment Council, South Coast NRM, Northern Agricultural Catchment Council, and Rangelands NRM. These bodies work with the local, State and Commonwealth governments in partnership with community to deliver key projects. Work is guided by the NRM's newly developed regional strategies as part of the current Federal Regional Landcare Partnerships program (RLP 2018 – 2023) and aims to ensure that key national and state environmental policies, and programs are addressed in the regions.

5.5 The planning framework and stormwater management

The first version of *Stormwater management manual for Western Australia* (DoW 2004–07) was published before *Better urban water management* (WAPC 2008). Detailed information on WA's current planning system is provided in *Introduction to the Western Australian planning system* (DoP 2014) or by contacting the Department of Planning, Lands and Heritage.

Please refer to Draft *State planning policy (SPP) 2.9 Planning for water* (WAPC 2022) and the associated Draft *Planning for water guidelines* (WAPC 2022), that provide the current policy, framework, process and guidance for how water resources should be considered at each land planning stage. The guidelines provide support for decision-making authorities, proponents and referral agencies to implement SPP 2.9. The SPP and guidelines assist regional, district and local land use planning, as well as subdivision and development phases of the planning process.

Where *Better urban water management* guidelines *2008* or *Planning for water guidelines 2022* is not applicable (e.g. Australian or State Government's major and strategic projects; projects or programs conducted by service providers or infrastructure managers such as Public Transport Authority, Mainroads WA, Water Corporation), planning and design of water management systems is generally guided by specific teams, such as a project reference group or technical advisory group. The planning and design follow the established processes (e.g. memorandum of understanding, partnership agreement, suitable partnering arrangements or agency referral and consultation) consistent with the relevant agencies' planning frameworks, policies and guidelines.

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