Environment Australia

Department of the Environment and Heritage

INTRODUCTION TO

URBAN STORMWATER MANAGEMENT

IN AUSTRALIA

PREPARED UNDER THE URBAN STORMWATER INITIATIVE

OF THE *LIVING CITIES* PROGRAM 2002

ISBN 0 642 548 323

The valuable contributions of John Wood, Executive Director of the Stormwater Industry Association Inc, and Tracy Kelly and Michael Moran of the Environment Australia Library, Canberra, are acknowledged.

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COMMONWEALTH ACTION ON STORMWATER

The Commonwealth Government through Environment Australia (part of the Department of the Environment & Heritage) is delivering three complementary funding programs to demonstrate ways to improve coastal and marine water quality.

A shared aim is to promote best practice and innovation in the policies and practices of organisations that have a substantial impact on water quality in coastal areas and cities.

The common strategy is the provision of funding as a catalyst for the construction of on-ground works. The funding is targeted to coastal councils, industry, water management organisations and state agencies.

The programs are:

CLEAN SEAS PROGRAM (Commonwealth component - CSP). The CSP supports sustainable stormwater and wastewater management. Since 1997, $30m has been committed to 35 nationally significant projects. Funding is from Natural Heritage Trust 1.

URBAN STORMWATER INITIATIVE (USI). Over $6m has been committed since 1999 for 9 demonstration projects. Funding is from the *Living Cities* program.

CLEANING OUR WATERWAYS INDUSTRY PARTNERSHIP PROGRAM (COWIPP). Over $2m has been committed since 2001 for 14 projects where industry is demonstrating innovative approaches to water management. Funding is from the *Living Cities* program.

The programs are an initial step by the Commonwealth in addressing the substantial cost of improving stormwater management across Australia.

Further information on the programs and projects is available at:

www.ea.gov.au/coasts/programs

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GLOSSARY

Adsorption	Bonding of metals and nutrients onto the surfaces of suspended particles, by way of physical, chemical and biological processes, and their removal by a process of sedimentation of the suspended particles.
Aeration	The injection of air through diffusers into water bodies, or rapid mechanical mixing of the surface of water bodies to promote entrainment of atmospheric air into the water column. A treatment process adopted in situations of high loading of oxygen demanding substances
Aerobic or Oxic Zone	An environment in which there is free oxygen.
Anaerobic or Anoxic Zone	An environment devoid of oxygen
Aquifer	Rock formation containing water in recoverable quantities.
Aquifer Recharge	The infiltration or injection of natural waters or recycled waters into an aquifer providing replenishment of the groundwater resource.
Aquifer Storage and Recovery	Injection of recycled water into aquifers for storage, which may be recovered later to meet water demands.
Baseflow	The underlying flow rate that cannot be directly attributed to storm events.
Basket	A simple steel mesh collection device placed in pits of gross pollutant traps to collect debris and rubbish.
Beneficial Use	The use of any element or segment of the environment that contributes to public benefit, welfare, safety, health or aesthetic enjoyment.
Best Management Practice (BMP)	Structural measures used to store or treat urban stormwater runoff to reduce flooding, remove pollution or to provide other amenities.
Biofilm	A gelatinous sheath of algae and micro-organisms, including benthic algae and bacteria, formed on gravel and sediment surfaces and surfaces of large plants.
Buffer Zones	A vegetated strip between the edge of a stream or drainage channel and a land use activity, designed to trap the lateral overland flow borne pollutants.
Catchment	A topographically defined area, drained by a stream such that all outflow is directed to a single point.
Channel	The bed and banks of a stream or constructed drain.
Colloids	Fine abiotic and biotic particles of typically 0.1 um to 1 nm in diameter.

Detention (Dry) Basins	A basin designed to temporarily detain, storm or flood waters, to attenuate peak flows downstream to acceptable levels.
Discharge	The volume of flow passing a predetermined section in a unit time.
Dissolved Oxygen (Do)	The level of dissolved oxygen in streams is a critical property sustaining aquatic biota, and in determining the risk of occurrence of anoxic conditions.
Drainage Network	The system of channels and pipes and overland flow pathways which drain a catchment area. Networks typically comprise a main drain, branch drains, and collector drains.
Effluent	Treated or untreated liquid waste flowing from agricultural and industrial processes, or from sewage treatment plants.
Effluent	Sanitary, industrial or agricultural discharge from wastewater treatment plants or treatment lagoons.
Environmental Flow	The release of water from storage to a stream to maintain the healthy state of that stream.
Event	A single precipitation and associated runoff occurrence.
Filter	A layer of granular material designed to intercept fine particulate material. It may be used as part of a subsoil drain, or as a structure to treat surface runoff prior to recharge of groundwater or discharge to a drain.
Floodway	Corridor of land identified as a major stormwater flow path, often is association with a minor (pipe or channel) flow path.
Geomorphology	Processes of weathering, flow and sediment transport which determine the pattern of drainage features across a catchment, and the equilibrium between sediment accumulation in channels and sediment re-suspension.
Geotextile	A thin, flexible permeable sheet of synthetic material used to allow the transmission of water through the pores of the material while preventing the transmission of soil particles.
Greywater	A combination of wastewater from the laundry, bathroom and kitchen.
Gross Pollutant Trap (GPTs)	A trap designed to intercept coarse particulate material (by sedimentation) and trash and debris (by screens or booms). GPTs may be incorporated into the inlet pits, collector drains or main drains.
Groundwater	Subsurface water from which wells, springs, or bores

	are fed.
Industry	Refers to the following sectors: commercial, manufacturing, processing, petroleum, power generation, tourism and mining.
Industrial Effluent	Liquid waste produced by industry and its processes.
Industrial Purposes	Use of recycled water by industry for purposes including cooling processes, operation of boilers, manufacturing and processing activities, washdown and cleaning, window washing, toilet and urinal flushing and other uses (eg. dust suppression and irrigation of grounds).
Impermeable Or Impervious Surface	The part of the catchment surfaced with materials which prevent infiltration of rainwater into the underlying soil and groundwater.
Infiltration Pit, Trench, Basin	A stone filled pit, trench or detention basin designed to enhance runoff infiltration into the subsoil and groundwater zones.
Integrated Catchment Management	Managing natural resources within a 'whole of system' approach. In a stormwater context, it requires a whole of catchment and total urban water cycle based design and management approach, with integral consideration of land and water processes and values.
Irrigation	The watering of crops, pasture, golf courses, parks, gardens and open spaces, which may involve using different applications (eg. drip, trickle, spray and flood).
Load-Based Licensing	A licensing, system, where charges are based on the type of discharge, the amount of discharge and the sensitivity of the receiving environment. This is instead of charges being based on a fixed fee.
Loading	The total mass of a pollutant discharged during a storm event. The term may also be used to describe the mass of pollutant intercepted (g/sq metre) by a device during a storm event, or on an annual basis.
Multiple Use	Facilities meeting a range of functions eg. urban waterways accommodating drainage, pollution interception, landscape, recreation and water supply functions.
Non-Potable Purposes	The use of water for purposes other than drinking, cooking, bathing and laundry: for example, irrigation of gardens, lawns and toilet flushing.
Off-Line and On-Line	Off-line facilities are located adjacent to but off the drain or major flow pathway, to treat low flows or the discharge of a branch drain. On-line or in-line

	facilities are located within the drain or major flow pathway to treat event flows.
On-Site and Off-Site	On-site facilities are located on individual residential or development blocks to enhance local detention and interception of runoff and pollutants. Off-site facilities are located on drainage networks to provide area-wide detention and interception of runoff and pollutants.
Oil Trap or Separators	A stilling tank configured to separate lighter oily matter, scums and hydrocarbons from stormwater.
On-Site Stormwater Detention (OSD)	A requirement for developers of land to compensate for increased runoff due to increases in imperviousness on blocks.
Overland Flow	The component of rainfall (excess) which is not removed by infiltration and discharges down the slope as surface flow.
Performance Bond	A risk premium paid to a financial institution to guarantee that funds are available for rehabilitation or restoration if the enterprise fails.
Permeable (Porous) Pavement	Pavements comprising materials which facilitate infiltration of rainwater and transfer to the underlying sub-soil.
Potable	Water of a quality suitable for drinking, cooking, bathing and laundry purposes.
Point Source and Non-Point Source Pollution	Point source is any discernible confined and discrete conveyance, including pipes, channels, conduits. Non-point source is a diffuse pollution source without a single point of origin or specific discharge point
Pollutant Retention	The proportion of pollutant load intercepted and retained by a device, either on an event or annual basis.
Pollution Control Ponds	A shallow pool of water, characterised by areas of emergent aquatic plants and open water, designed to intercept event discharges and enable adsorption and sedimentation of pollutants, and to support a diverse range of micro-organisms and plants associated with the breakdown of organic material and uptake of nutrients. The detention of event flows and settling of suspended particles and associated pollutants is a key component of pond pollutant interception processes.
Rainwater Tanks	Tanks used to collect and store rainfall from household roofs for beneficial use.
Recycled Water	Treated stormwater, greywater or black water

	suitable for a range of uses eg. toilet flushing. irrigation, industrial processing or other suitable applications.
Recycled Water	Appropriately treated effluent and urban stormwater.
Remobilisation	The transformation of sedimented pollutants by microbial or chemical processes into a dissolved form and transfer by diffusion from the sediment pore water into the water column.
Runoff	The portion of precipitation on a drainage area or surface that is discharged from the drainage area to drainage.
Sediment Trap	A structure designed to intercept and retain sediment transported by the flow.
Sedimentation	The physical process of settling of suspended particulates under forces of gravity. The sedimentation efficiency is a function of eddy forces in the settling basin, and the period of detention of flow in the basin.
Sewage	The used water of community or industry, containing dissolved and suspended matter.
Sewer Mining	Diversion and treatment of raw sewage for on-site purposes such as irrigation.
Sewer Overflow	The discharge of sewage to surface water or stormwater drainage as a result of sewage flow exceeding the sewer capacity (infiltration of rainwater), or sewer blockage.
Stormwater	All surface water runoff from rainfall, predominantly in urban catchments. Such areas may include rural residential zones.
Street Sweeping	The removal of particulates and litter from street surfaces by sweeping or vacuuming.
Subsidy	Non-repayable grant money.
Sub-catchment	A topographically defined area drained by a tributary or branch drain of a primary stream or main draining a catchment.
Subsurface Drain	A drain designed to intercept sub-soil water and thereby lower the soil water table.
Swales	A grassed open channel, designed to intercept and convey surface runoff to a drainage network inlet, promote infiltration, promote interception of particulate material by the vegetation, and to provide a landscape element.
Swirl Separator	A device which uses the flow energy to create a vortex, enhancing the separation by gravity of water

	and particulate materials.
Total Urban Water Cycle Based Management	The integrated management of all components of the hydrological cycle within urban areas (surface water, soil inter flow, groundwater, water supply and recycled wastewater) and the landscape to secure a range of social, economic and environmental benefits.
Treated Effluent	Liquid waste flowing from agriculture and industry processes, or sewage treatment plants, that has been subjected to screening, sedimentation, biological and chemical processes to improve its quality.
Wastewater	The used water of community, industry, or agriculture, containing dissolved and suspended matter.
Water Quality	The chemical, physical and biological condition of water.
Water Resource	The sources of supply of ground and surface water in a given area.
Water Sensitive Urban Design	Design of subdivisions, buildings and landscape which enhances the opportunities for at-source conservation of water, rainfall detention and use, infiltration, and interception of pollutants in surface runoff from the block.
Wetlands (Artificial)	A shallow pool of water, characterised by extensive areas of emergent aquatic plants, designed to support a diverse range of micro-organisms and plants associated with the breakdown of organic material and uptake of nutrients. Wetlands may be designed as permanent wet basins (perennial), or alternating between dry and wet basins (ephemeral), or combining these two systems (extended detention).

Sources: Australian Guidelines for Urban Stormwater Management in National Water Quality
Management Strategy, No. 10. Agriculture and Resource Management Council of Australia and New Zealand and Australian and New Zealand Environment and Conservation Council, 2000.

Draft Queensland Water Recycling Strategy. Queensland, Department of Natural Resources, 2001.

OVERVIEW

SCOPE

This introduction to urban stormwater management has been prepared by Environment Australia as part of the Living Cities Urban Stormwater Initiative. It outlines current challenges and approaches for improving urban stormwater management within a water cycle framework.

This is not a technical manual, rather an analysis of current trends, research and best practice for managing stormwater in Australia. It is a starting point for delving into a feature of our cities that has been often ignored, but is now recognised for its capacity to be both a major source of pollution or a major resource.

INTRODUCTION

Australians live in the driest inhabited continent. Managing scarce water resources requires a complete water cycle approach to protecting the country's unique ecosystems.

The variability of rainfall and runoff is more extreme than other parts of the world. Australians have made a large investment in stored water capacity to supply rural and urban users in this climate.[1] While stormwater runoff from the cities is about equal to the amount of drinking quality water that is supplied at considerable cost each year, little stormwater is captured, with most adding to the pollution of waterways.[2]

Urban stormwater is defined as runoff from urban areas, including the major flows during and following rain, as well as dry-weather flows.[3] Many factors influence the amount of stormwater and the contaminants that are transported by it, including:

Duration and intensity of rainfall.
Proportion of impervious surfaces.
Shape of the land.
Landuse.
Design and management of stormwater systems.[4]

In addition to washing contaminants from the atmosphere, rainfall in the form of stormwater runoff flushes material accumulated on surfaces including litter, dust and soil,

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[1] Dowsett, Brigid (1994). *The management of stormwater: from a problem to a resource*. Sydney Water Project, p. 1.
[2] Dowsett, p. 1.
[3] Agriculture and Resource Management Council of Australia and New Zealand, & Australian and New Zealand Environment and Conservation Council (1996). *Draft guidelines for urban stormwater management.* Canberra, p. 1.
[4] *Draft guidelines,* p. 1.

fertilisers and other nutrients, chemicals and pesticides, micro-organisms, metals, oils and grease into waterways.[5]

Overall, about 12% of Australia's rainfall finds its way into surface streams. By contrast, in highly urbanised zones up to 90% of the rainfall may flow into the stormwater system. These flows are complemented by dry weather drainage, flows from garden watering, washdowns and illegal discharges.[6] In some systems wet weather overflows from sewerage systems create significant health and environmental impacts on our waterways.

Sisters Creek coastal lagoon, North West Tasmania – polluted by combined stormwater and sewage discharges. Pollution is proving to be a risk to the environment, tourism and public health. The Commonwealth Government is providing funding of $3m in a partnership with the Sisters Beach and Boat Harbour communities, the Waratah-Wynyard Council and Tasmanian Government to address the problem.

In the past, the prime objective of urban stormwater management has been flood mitigation. Local councils can be held liable for flood damage caused by stormwater.[7]

Traditionally in Australia, stormwater has been transported separately from the sewerage system. Unlike sewage, stormwater has received little, if any, treatment. The aim has been to channel the stormwater as rapidly and invisibly as possible from within our urban areas to the nearest waterway, usually on the coast.[8]

The necessity to deal with both the quantity and quality of runoff is now recognised. The 'hard' engineering strategy for the management of stormwater is being modified by an increase in the application of Water Sensitive Urban Design (WSUD).[9] This strategy focuses on the sources of runoff and pollution and the tools to contain and reuse the water within urban housing, commercial and industrial areas.

Today we have the tools to focus on Ecological Sustainable Development (ESD) in stormwater management. Stormwater can be treated as a resource that can bring environmental, economic and social benefits to our urban areas. Rather than going to

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5 *Draft guidelines,* p. 1.
6 *Draft guidelines,* p. 1.
7 Commonwealth Environment Protection Agency (1993). *Urban stormwater: a resource too valuable to waste*. Canberra, p.21.
8 Dowsett p. 1.
9 Dowsett p. 1

waste and causing pollution, through capture, treatment and reuse, stormwater can become a major alternative to damming more rivers to ensure water supply.

CHAPTER 1

MAJOR ISSUES FOR URBAN STORMWATER SYSTEMS

ECOLOGICAL SUSTAINABLE DEVELOPMENT
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MANAGING STORMWATER QUALITY
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- Nutrients
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Management Interventions
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Management of receiving waters
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ECOLOGICAL SUSTAINABLE DEVELOPMENT

Ecological Sustainable Development (ESD) has been described as:

"Development that uses, conserves and enhances the community's resources so that ecological processes, on which life depends, are maintained and the total quality of life now and in the future can be increased".

National Strategy for Ecological Sustainable Development.
The National Strategy aims to develop water management policies based on an integrated approach to water resources, including total catchment management, public participation, and water allocations. To make these policies effective requires a mix of mechanisms based on: pricing, regulation, monitoring, institutional arrangements and property rights. In Australia's federal system this is a complex cocktail of responsibilities and funding arrangements.

In this context, the coastal zone is a major focus. It supports about 80% of the Australian population, with 96% living in cities and large towns. Many of these people are clustered in the coastal State capitals. Even so, although around 70% of Australia's coastline remains sparsely inhabited, the population of the non-metropolitan coastal zone has doubled in the last 20 years. In contrast, the Australian population as a whole grew by only one third.

In urban areas in most parts of Australia, the population engaged in residential, industrial, intensive agricultural, transport, and service activities is placing increasing pressure on waterways.

Many of the pressures are on estuaries. Here, the impacts of stormwater discharges will depend on the type of estuary. The well-flushed drowned river estuaries are generally least susceptible to stormwater pollution. The areas within drowned river valleys and barrier beach estuaries that tend to be most susceptible to pollution are at the tidal limit on the tributary watercourses. At these locations, pollutants have a long residence time that can result in algal growth and depressed oxygen concentrations. Coastal lakes are the most susceptible waterway due to the absence of tides. All types of waterway require an increased focus and resources to improve the management of the quantities and qualities of stormwater flowing into them to make up for a lack of action over decades when the issue was treated as “out of sight, out of mind”.[10]

Stormwater discharges at Port Adelaide, South Australia.
The Commonwealth is providing $800,000 to a working partnership with industry and the Port Adelaide Enfield Council to improve stormwater management in Adelaide’s largest concentration of factories and most diversely polluted waterway.

MANAGING STORMWATER QUANTITY

Large stormwater flows invariably cause extensive pollution with high organic and sediments loads, sudden discharges from flooded sewers and growing piles of litter and rubbish being carried in drainage channels.[11] Where properties are regularly affected, flood mitigation works have been constructed. Alternatively, the properties have been resumed and buildings demolished to create open space for recreation and use as flood detention basins.

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[10] ***NSW Environment Protection Authority (1997).*** **Managing urban stormwater: Council handbook: draft November 1997.** ***Chatswood, NSW, p. 89.***

[11] ***Commonwealth Environment Protection Agency (1993)*. Urban stormwater: a resource too valuable to waste. *Canberra, p. 6.***

Increases in stormwater runoff volumes have resulted from increasing urbanisation and the accompanying growth of impervious surfaces. Up to 70% of the impervious area in urban catchments is set aside for transport (40-50% for roads). Effective planning of flow paths across urban areas can reduce the speed and increase filtering and infiltration of stormwater runoff. Combined with effective detention and retention basins, large loads of sediment can be intercepted before they impact on the ecosystems of urban waterways.

Minimising the runoff from frequent storm events minimises sediment runoff and sewage overflows. It also counteracts remobilisation of pollutants that have been captured in the 'treatment train' of stormwater measures. The optimum solution for managing an increased volume of runoff is to encourage infiltration, storage and reuse.

MANAGING STORMWATER QUALITY

With water being a national priority, the Council of Australian Governments representing the Commonwealth, State, Territory and Local Government in Australia at the highest level, has adopted a National Water Quality Management Strategy (NWQMS). This Strategy includes a major focus on water quality linked to Ecological Sustainable Development, that is:

"*To achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development*'.[12]

To achieve this objective, a three-tiered approach to water quality management - national, state, and local - is focused on regional catchments. In practice, each sphere of government uses its own water quality planning, environmental policy and regulatory tools to address the challenge.[13]

In a coordinated approach, long-term management of water resources calls for a collective vision. This vision needs to be based on:

A clear set of environmental values.
A good understanding of links between human activity and water quality.
Effective management frameworks, including:
Explicit goals for management.
An agreed level of protection to be achieved.

- Regulatory mechanisms (impact assessment).
- Reporting and monitoring arrangements.[14]

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[12] **Australian and New Zealand Environment and Conservation Council, & Agriculture and Resource Management Council of Australia and New Zealand (1999).** ***Australian and New Zealand guidelines for fresh and marine water quality (draft).*** **Environment Australia, Canberra.**
[13] *Australian and New Zealand guidelines.*
[14] *Australian and New Zealand guidelines.*

VISUAL WATER QUALITY

The most obvious aspect of a pollution problem is deteriorating visual water quality. Outbreaks of blue-green algae, piles of foam, significant fish kills, cloudy and highly coloured water, and oil slicks are examples of visual problems.
Floating inorganic debris and litter, such as steel drums, car tyres, bottles, aluminium cans and foam boxes, raise community concerns. They can harm wildlife and damage their natural habitats as well as threatening public safety.

Organic debris, such as leaves, timber, paper, cardboard and food will in the short term cause visual pollution. When this material decays, it releases nutrients. It may form rich organic sediment that can cause algal blooms.

Quality can also be affected by the temperature of waterways which may increase following urbanisation, as impervious areas act as efficient heat co temperature of stormwater runoff could rise between 5 and 10 deg further increase in temperature can occur if the riparian vegetation is removed. This temperature increase can slow the growth rates c invertebrates.[15]

Can't see the point of this one here – no reference to it in the neighbouring text

Algal blooms in a nutrient-enriched waterway discharging to Adelaide's Gulf of St Vincent, South Australia.

CONTAMINANTS AND NUTRIENTS

The contaminants in stormwater can be grouped according to their water quality impacts. They include:

- Suspended solids.
- Nutrients, primarily nitrogen and phosphorous.

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15 Sharpin, M.G. & Morrison, A.J. (1995). Towards ecologically sensitive drainage systems. In *Preprints of papers: the second international symposium on urban stormwater management 1995: integrated management of urban environments.*

- Biological and chemical oxygen demanding materials.
- Microganisms.
- Toxic organics.
- Trace organics.
- Toxic trace metals.
- Oils and surfactants.
- Litter.[16]

SUSPENDED SOLIDS

Suspended solids have two main constituents:
Organic, primarily from sewage.
Inorganic, primarily from surface runoff.

Turbidity from suspended solids reduces light penetration in water, affecting the growth of aquatic plants. When silts and clays settle, they may smother bottom dwelling organisms and disrupt their habitats. Since metals, phosphorous and various organics are adsorbed and transported with these particles, sediment deposits may lead to a slow release of toxins and nutrients in the waterway.[17]

NUTRIENTS

Potential sources of nutrients are:

- Sewage overflows.
- Industrial discharges.
- Animal wastes.
- Fertilisers.
- Domestic detergents.
- Septic tank seepage.

Excessive amounts of nutrients, such as nitrogen and phosphorous, can promote rapid growth of aquatic plants, including toxic and non-toxic algae.[18] This excessive growth results in:
Production, during the day, and consumption, during the night, of a large amount of oxygen by the plants. This wide variation can cause fish & marine organisms to die.

Biological smothering of other plant forms.

Deposition and formation of organic sediment.

The most effective management of nutrients once in the stormwater system is to settle out the silt and clay particles that have the nutrients attached to their surface. Up to 85% of phosphorus and 70 - 80% of nitrogen can be isolated as particulate matter. Although sediment traps collect some clay-sized particles, the majority are settled on the many

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[16] *Urban stormwater: a resource too valuable to waste*, p. 7.
[17] *Urban stormwater: a resource too valuable to waste*, p. 7.
[18] Dowsett. Brigid (1994). *The management of stormwater: from a problem to a resource.* Sydney Water Project, p. 9.

surfaces found in water pollution control ponds and constructed wetlands. These surfaces form a basis for microbial activity that can reduce the impact of pollutants. They are referred to as thin film bio-reactors.

OXYGEN DEMANDING MATERIALS

Sources of oxygen-demanding materials are biodegradable organic debris, such as decomposing food and garden wastes, and the organic material contained in sewage. Biological and chemical oxygen-depleting substances can cause water-borne diseases and present serious health risks. The biological and chemical oxygen demands of sewage overflowing into stormwater systems are high. If oxygen levels become too low, fish will die.[19]

MICRO-ORGANISMS

Bacteria and viruses found in soil and decaying vegetation, and faecal bacteria from sewer overflows, septic tank seepage and animal waste, are common contaminants in stormwater after heavy rain. Pathogens and micro-organisms, including bacteria, viruses and faecal coliforms, cause water-borne diseases. They can present serious health risks from cholera, typhoid, infectious hepatitis and a range of gastrointestinal diseases.[20]

TOXIC ORGANICS

These include garden pesticides, industrial chemicals and landfill leachate. They may cause long-term ecological damage and threaten human health.[21] Organochlorine pesticides, herbicides and insecticides can be accumulated in organisms and persist in the environment over long periods.[22]

TOXIC TRACE METALS

Heavy metals and some industrial chemicals can cause a severe impact on aquatic life. Industrial chemicals can enter stormwater from a number of sources including sewerage overflows, illegal dumping and accidental spillages.

Dust from brake and clutch linings of motor vehicles coupled with waste from degrading roadways and water pipes can inject ammonia, hydrogen sulphide and heavy metals (mercury, cadmium, lead and zinc) into the stormwater system. These metals can also be released from landfills through leaching and by poor agricultural practices.

OILS AND SURFACTANTS

Rubber from tyres and oil and grease washed from road surfaces, domestic and industrial sites, plus surfactants from detergents used for washing vehicles, are common sources of toxic pollutants in stormwater.[23]

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[19] Dowsett, p. 9.

[20] Dowsett, p. 9.
[21] Dowsett, p. 9.
[22] Dowsett, p. 9.
[23] *Urban stormwater: a resource too valuable to waste*, p. 7.

LITTER

This includes organic waste matter, paper, plastics, glass, metal and other packaging materials from paved areas in urban catchments.[24]

ALGAL BLOOMS

An algal bloom is caused by "the rapid excessive growth of algae, generally caused by high nutrient levels and favourable conditions".[25] Algae are a natural component of aquatic environments, and even when they are abundant, it is not necessarily a problem. Often a proliferation of microscopic algae can have beneficial effects on fisheries and aquaculture industries such as oyster or mussel farms by increasing the amount of food available. However, when algal blooms increase in intensity and frequency, the results can cause community concern, health problems, and in some cases can be catastrophic to the environment.[26]

Part of the algal bloom that forced the closure of Swan/Canning Estuary waterways in Perth, Western Australia, in 2000

Algal blooms can upset the natural balance of plant and animal ecosystems in a waterway or wetland. They can degrade recreation, conservation and scenic values, and interfere with economic uses such as fisheries and tourism. An over-abundance of algae can choke waterways, clog pipes, and block out the light to other plants, such as seagrasses. Excessive algal growth can eventually kill seagrass beds. When an algal bloom dies, the process of decay can use up all the available oxygen in the water, effectively suffocating other aquatic life. Some species of algae can produce toxins.[27]

Most strategies to address problems of algal blooms require reduction in the loads of phosphorous entering waterways from runoff. Planning on a catchment basis needs to consider pollutant loads from the various existing land uses and any proposed land uses in the whole catchment.

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[24] *Urban stormwater: a resource too valuable to waste,* p. 7.
[25] Water and Rivers Commission (1998). *Water Facts 6: algal blooms*. East Perth, p. 10.
[26] *Water Facts 6*, p. 10.
[27] *Water Facts 6*, p. 10.

MANAGEMENT INTERVENTIONS

COMMUNITY BENEFITS

A well-designed and integrated stormwater system can provide community benefits including:

- Minimising flooding of property.
- Protecting downstream water bodies from the contamination in urban runoff.
- Providing aesthetic values within the urban landscape.
- Providing recreational facilities on water bodies and in multiple use drainage corridors.
- Providing nature conservation habitat in urban areas for birds and other valued species.
- Providing water for reuse.[28]

To achieve these benefits there are three areas of focus:

1. Source control.
2. Interception during the passage of contaminants.
3. Management of receiving waters.

SOURCE CONTROL

The main approaches to minimising the impacts of the sources of pollution are:

1. Ensuring development is consistent with water sensitive urban design principles.
2. Minimising soil loss from construction sites and land development.
3. Careful location of sewer surcharge points to reduce discharges and minimise their impacts.
4. Minimising the area of impervious surfaces.
5. Street sweeping, litter trapping and pit cleaning.
6. Employing detention, storage and reuse facilities such as rainwater tanks.
7. Public education.[29]

Source control education techniques concentrate on making the public aware of issues such as:

1. Application of fertilisers, herbicides and pesticides to domestic gardens.
2. Car washing techniques, minimising the amount of water used and undertaking washing on pervious surfaces where possible.
3. Disposal of grass clippings and other organic matter from garden maintenance.
4. Removal of pet droppings, particularly from impervious surfaces.
5. Management of oil and other household chemicals.[30]

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[28] Cullen, Peter (1995). The Cinderella resource: urban stormwater in a dry country. In *Preprints of papers: the second international symposium on urban stormwater management 1995: integrated management of urban environments*, p. 12.
[29] Cullen, p. 12.

Education activities can include labelling drainage pits to indicate the waterway that is impacted by this stormwater drain entry.[31] Education of particular groups such as dog-owners, can play a key role in source control. The Environment Protection Authority (EPA) of New South Wales estimates the amount of dog faeces washing into Sydney's rivers from stormwater drains each year would fill more than 10 Olympic-sized swimming pools.[32]

The wet weather peak overflow problem from sewage pipes into stormwater drains and then waterways is a significant problem in most Australian cities. Water penetrates the sewerage system via illegal stormwater connections, surface runoff into sewer gullies, and cracked and broken pipes. The volume of water exceeds capacity, causing the designed sewer overflow relief points to discharge to waterways. Studies in the Sydney area have shown that there are up to 6,000 overflow points that are capable of discharging raw sewage into the stormwater system.[33]

CASE STUDY: IMPLEMENTING SOURCE CONTROL
Bayside Beaches, Melbourne.

Bayside is located on the eastern side of Port Phillip. It includes 20 kms of beaches, including some of the most popular around the Bay. A number of beaches are often closed following heavy rain when faecal pollution and litter from the urban stormwater system rises beyond safe contact levels for swimming. The Commonwealth's Clean Seas Program provided $120,000 to assist the City of Bayside and Melbourne Water to:
- Identify the sources of the contamination.
- Implement a program of litter minimisation and control.

Through sterol sampling, boating and fishing activities were identified as some of the sources of faecal pollution as well as sewer leaks and illegal connections of domestic sewerage lines to the stormwater system. Action has been taken to address these problems.

To minimise stormwater litter discharges:
- 16 in-pit traps were located at hot spots in commercial and retail centres.
- 32 cigarette butt bins were installed at problem sites (50% of the litter stream was tobacco related)
- 23 recycling bins were set up for cans and bottles.
- The Considerate Business Education Program was initiated to encourage

30 Sharpin, M.G., Morrison, A.J., & Goyen, A.G. (1995). Managing the stormwater environment. In *Environmental aspects of urban drainage: seminar proceedings, 22 August 1995*, ed. M.G. Sharpin. Stormwater Industry Association: Sydney.
31 Sharpin, Morrison & Goyen.
32 ***Beale, Bob & Woodford, James (1994). Our polluted waterways : now it's dangerous to drink.*** **Sydney Morning Herald*****, 29 July 1994.***
33 Booker, N.A., Priestley, A.J. & Ocal, G. (1995). Storm sewer overflow treatment technologies: a review of current processes. In *Preprints of papers: the second international symposium on urban stormwater management 1995: integrated management of urban environments*, p. 336.

shop keepers and their customers to improve their handling of waste.

The actions resulted in a considerable reduction in stormwater pollution from the targeted sites and provided an excellent demonstration project for other councils designing and implementing their stormwater management plans.

Bayside beaches litter source control, Melbourne, Victoria.

Through environment protection regulation, sewerage utilities are being forced to reduce sewer overflows, and eventually eliminate them. Management of storm sewer overflows means managing the sewer hydraulics and redirecting flows to minimise the impact of storms. Water Sensitive Urban Design can be a key tool in this process.

Whichever techniques for water management are selected they require a detailed understanding of the sewer network, catchment characteristics, receiving water quality and sensitivity, and urban landuse patterns. Solutions can range from simple detention basins, temporary storage, advanced physical and chemical treatment facilities, and removing and treating sewage locally for recycled water use (sewer mining).34

INTERCEPTION DURING THE PASSAGE OF CONTAMINANTS

Once pollutants are carried by stormwater from their source, the main approaches to interception are:

- Vegetated floodways.
- Gross pollutant traps.
- Wire baskets in sumps and kerb inlet pits.
- Filtration screens and sand filters.
- Oil and trash booms.
- Bio-retention and infiltration systems (e.g. swales);
- Water pollution control ponds.
- Wetlands.

[34] Booker, Priestly & Ocal, p. 336.

- Retarding basins.
- Detention basins.
- Buffer zones between development and receiving waters.[35]

MANAGEMENT OF RECEIVING WATERS

If the pollutants have escaped source control and interception measures in the treatment train, the main approaches to management of receiving waters are:

- Zoning of water-based uses.
- Monitoring and prohibition of water activities when quality is unsatisfactory.
- Zoning and treatment of foreshores to encourage appropriate uses.
- Maintenance of healthy ecosystems.[36]

NEW URBAN INFRASTRUCTURE

MULTIPLE USE CORRIDORS

Increasing numbers of urban authorities are moving to incorporate holistic approaches to water management. They are working with planners and developers to use new techniques in a field which has persisted with narrowly focused approaches first implemented in the early 1900s.

Councils in most cities of Australia have powers to levy developer charges to cover the costs of stormwater management infrastructure. Some councils and developers are examining opportunities to create multiple use corridors that provide both stormwater management and beneficial functions within Water Sensitive Urban Design (WSUD). The provision of stormwater infrastructure is being integrated with water supply, sewerage, electricity, communication, transport, recreational areas, waterways and wildlife corridors.

An ecologically-based stormwater planning and management approach recognises components of urban drainage systems as ecosystems in their own right. It also acknowledges that some natural ecosystems have been irreversibly modified in urban environments.

[35] Cullen, p. 12.
[36] Cullen, p. 12.

CHAPTER 2

STORMWATER MANAGEMENT

REGULATION

In Australia the responsibility for managing urban stormwater rests mainly with local government. However, State and Territory governments have overall responsibility for land and water use planning and management. A range of government agencies and statutory authorities are involved in waterway and catchment management. In some states, catchment management trusts or catchment management boards have been established to prepare plans, undertake works and encourage community participation.

Local government is increasingly obliged to consider issues relating to resource management incorporating national and state level policies.[37] Through the Intergovernmental Agreement on the Environment, State and Territory governments have undertaken to include national considerations such as Ecological Sustainable Development (ESD) and international undertakings relating to protecting wetlands and endangered species in their planning activities.[38]

[37] Agriculture and Resource Management Council of Australia and New Zealand, & Australian and New Zealand Environment and Conservation Council (1996). *Draft guidelines for urban stormwater management.* Canberra, p. 6.
[38] *Draft guidelines for urban stormwater management*, p. 7.

PRICING, COMPETITION AND INNOVATION IN URBAN WATER SUPPLIES

In many urban areas, drainage is the highest cost component of water infrastructure. However, some engineered practices are not the most cost effective options when external costs and impacts are taken into account.[39]

Port Phillip Bay, Melbourne, Victoria – endpoint for stormwater discharges.

In February 1994, the Council of Australian Governments (COAG) agreed to implement a strategic framework for important water reforms in Australia. These reforms cover a range of areas including water pricing, institutional arrangements, sustainable water resources management, and community consultation. The agreement was ratified by COAG in April 1995, when it agreed to a program of implementing these and other related reforms under National Competition Policy arrangements.

The water reform framework sets out requirements for:
- Wastewater management and water quality.
- Water related research.
- Public consultation and education.

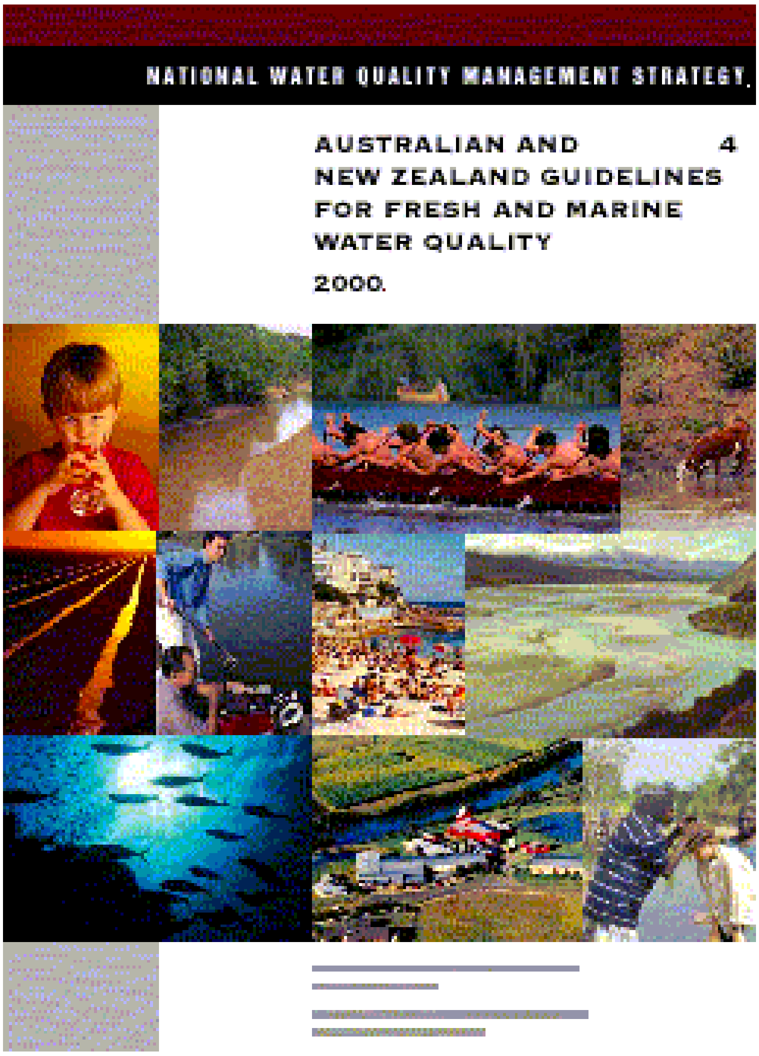
The goals of this framework are to:
- Encourage innovative practices in providing water services while recognising the need to retain economies of scale in infrastructure to ensure net public benefit.
- Provide a level of certainty for private investment in the water services market by specifying the regulatory framework (health, environment, financial, etc) in which potential new entrants will operate.
- Facilitate competition in water services.
- Ensure there is a transparent, sustainable and equitable approach to the pricing of water and wastewater services while still ensuring reliability and consistency in the quality and safety of water services.

This framework promotes innovation in stormwater storage and reuse as a supplement to existing water services, and the potential to eliminate the need for future new water supply dams which carry large penalties in infrastructure and environmental costs.

[39] *Draft guidelines for urban stormwater management,* p. 3.

NATURAL RESOURCE MANAGEMENT

The policy objective of the National Water Quality Management Strategy (NWQMS) is "to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development."[40] This objective is being pursued through a set of national technical guidelines on many aspects of the water cycle. Details are available at http://www.affa.gov.au/nwqms. One of the most relevant guidelines under the NWQMS is the Australian Guidelines for Urban Stormwater Management.



40 Australian and New Zealand Environment and Conservation Council, & Agriculture and Resource Management Council of Australia and New Zealand (1999). *Australian and New Zealand guidelines for fresh and marine water quality (draft).* Environment Australia, Canberra.

NATIONAL LAND AND WATER RESOURCES AUDIT

The National Land and Water Resources Audit has received $32M over five years as part of the Commonwealth's role in assisting natural resource management. The Audit is taking stock of Australia's natural resource base. It includes a National Water Resources Assessment. This Assessment focuses on the extent, supply capabilities and demand for water, including environmental needs.[41]

LANDUSE PLANNING

Under landuse planning, development control and resource management agencies work to a common, legally formalised hierarchy of mutually consistent planning instruments. Landuse and water allocation plans operate under a catchment planning umbrella that identifies the natural resources issues within particular catchments, the outcomes sought, and strategies for addressing them.[42]

INTEGRATED CATCHMENT MANAGEMENT

Natural Resource Management (NRM) is built around Ecological Sustainable Development, community empowerment, integrated management, targeted investment, accountability and minimising bureaucracy.[43] A fundamental first step in applying NRM in urban catchments is to establish agreed environmental values for receiving waters and their ecosystems.

Regional catchment management plans are a major part of integrated natural resource management. They can underpin investment strategies to avoid dissipating resources through fragmented structures and piecemeal investment in uncoordinated small-scale projects. This approach reinforces the concept that everyone, both urban and rural people, live in a catchment and are affected by, and affect the catchment.[44]

As part of the move to integrated NRM, integrated approaches to urban water services are emerging across Australia in response to conditions of financial accountability, limits to the sustainability of water use, and changing community attitudes to the protection of the environment and resource management. This change requires the integration of catchment management strategies.[45]

Guiding principles of Integrated Catchment Management (ICM) are:

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[41] Department of the Environment and Heritage (1999). *Unpublished submission presented to House of Representatives Standing Committee on Environment and Heritage Inquiry into catchment management*. *Draft*, p. 20.

[42] Farrier, David (1999). Legal models for integrated land and water planning and management. In *Second international river management symposium: speaker papers,* International River Management Symposium. Riverfestival: Brisbane, p. 115.

[43] State of Victoria (2000). *Unpublished submission to House of Representatives Standing Committee on Environment and Heritage Inquiry into catchment management*, p. 5

[44] State of Victoria. *Unpublished submission*, p. 10.

[45] Lawrence, I. & Reynolds, C. (1995). Integrated urban water planning. In *Preprints of papers: the second international symposium on urban stormwater management 1995: integrated management of urban environments, Melbourne, 11-13 July 1995.* Institution of Engineers: Canberra, p. 43.

- Total water cycle based planning and management.
- Total catchment based planning and management.
- Integration of subdivision and allotment design with stormwater management.
- Adoption of integrated infrastructure and service provision.
- Adoption of ESD approaches.
- Community involvement.[46]

To meet these principles, an ICM strategy describes:
- The water and related environmental values across the catchment.
- The stream flow and constituent loads that are sustainable at critical points across the catchment.

Permissible land uses and management practices which are consistent with meeting the sustainable loads and flows.[47]

Natural resource management at Hobart, Tasmania – treated stormwater and wastewater is redirected from discharging into the Derwent Estuary to irrigate crops.

The primary value of ICM is that it recognises that the effects of land and water use and environmental impacts are interconnected. It acknowledges that actions in the upper catchment will have cumulative impacts on other areas downstream and that a holistic approach to the planning and coordination of land and water management is essential. It can ensure conservation and maintenance of biodiversity. For example, tree planting for groundwater or riparian management can contribute to biodiversity conservation if habitat needs are considered in decisions about the locations and species chosen for planting.[48]

The catchment management approach is an effective way of engaging all the community, including those involved in landuse planning, natural resource management, primary production and conservation in working together to improve the overall management of

[46] Lawrence & Reynolds, p. 43.
[47] Lawrence & Reynolds, p. 43.
[48] Department of the Environment and Heritage, *Unpublished submission. Draft*, p. 8.

their local area. Introducing new management techniques and strategically investing in wastewater and stormwater reuse (water reclamation) technology can create regional economic drivers for agriculture and industry, changing stormwater quality problems into ESD opportunities.[49]

CASE STUDY: INTEGRATED CATCHMENT MANAGEMENT
Carrara Catchment, Gold Coast, South East Queensland

The Carrara catchment, of the Nerang River system and Moreton Bay, is suffering from environmental degradation including bank erosion, urban runoff, increased sediment loads and acid sulphate soils. Moreton Bay is exhibiting seagrass and wetland loss, the intrusion of urbanisation into wetland areas, localised harmful algal blooms and loss of biodiversity.

An Integrated Catchment Management approach by Gold Coast City Council, and development company, Nifsan, is based on a treatment train approach. Techniques used include trapping gross solids and sediment, using bioretention systems, oil and grease separators, cascading channels, source control measures, multi-purpose retarding basins and stream naturalisation and restoration processes.

The project serves as a demonstration site for the other 17 councils under the South East Queensland Regional Water Quality Management Strategy, and other regions undergoing similar development pressures around the Australian coast. Under the Urban Stormwater Initiative, the Commonwealth is providing over $1m to bring the project to fruition.

STORMWATER MANAGEMENT PLANNING

Although urban stormwater and treated wastewater are recognised increasingly as important economic resources, they are not widely used to augment supplies in expanding urban areas. Recent research and demonstration projects have shown that stormwater and treated wastewater can be exploited in a cost effective and environmentally sensitive manner for new urban developments.[50] In this context:

- Water reclamation can reduce potable water demand by as much as 50%.
- Properly managed stormwater flows provide important flow return to streams, offsetting the environmental impact of upstream water supply diversions and reducing the need for costly in-ground stormwater infrastructure.
- The enhanced use of natural drainage corridors and depressions can provide open space, landscaped and recreational areas and conservation benefits increasing the amenity of new urban developments (multiple use corridors).
- Treatment of stormwater and wastewater closer to source, minimises uncontrolled discharge of water containing high suspended solids, nutrients and organic material.[51]

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[49] Department of the Environment and Heritage, *Unpublished submission. Draft*, p. 8.
[50] MacCormick, A.B. (1995). Economically sustainable storm and wastewater reuse in new urban developments. In *Preprints of papers: the second international symposium on urban stormwater management 1995: integrated management of urban environments,* p. 459.
[51] MacCormick, p. 459.

In many cities in Australia, councils are required to develop a Stormwater Management Plan (SMP) to cover capital works, services, asset replacement programs and activities aimed at protecting environmentally sensitive areas and to promote ecological sustainability.[52]

Typically, the SMP identifies:
- The existing and future values of a catchment.
- Stormwater management objectives to protect these values.
- The range of land use constraints.
- The range of corridor or drainage measures related to flow, interception of pollutants, provision of open space and recreation, conservation areas, urban stormwater reuse requirements and retention of the natural values of urban streams.

RETROFITTING

The retrofitting of stormwater management systems is a major financial issue for Australian cities. Providing effective structural, stormwater management strategies within existing urban areas is generally expensive and often difficult due to site constraints.

MONITORING, EVALUATING AND REPORTING

The primary goal of monitoring is to characterise the prevailing water quality and ecological conditions in a stormwater system and receiving water bodies, test compliance with water quality objectives and assessment of development and management actions. Impact assessment requires good data before and after the management and development actions. A combination of physical, chemical and biological monitoring is advantageous, as the macroinvertebrates commonly used in biological monitoring respond to long-term water quality conditions, while physical and chemical monitoring reflects instantaneous conditions.

Pre-development monitoring is essential to understand the extent of the catchment problems. The opportunity to carry out this type of water quality monitoring pre-development, is often limited due to existing landuses.

Most urban land development classed as Green Field Development is on land used previously for agriculture. Often the catchment characteristics have been impacted upon. If there is urbanisation further up the catchment, considerable water quality problems may exist already.

One of the issues in managing and planning new areas is to accept the incoming water quality problems, and to address this issue plus the proposed development impacts, so that the final discharge water quality is improved downstream.

[52] NSW Environment Protection Authority (1997). *Managing urban stormwater: Council handbook: draft November 1997*. Chatswood, NSW, p. 4.

CASE STUDY: MECHANISMS FOR MONITORING, EVALUATING AND REPORTING
Melbourne, Victoria

Melbourne Water has developed a useful approach for reporting on water quality in the urban and rural waterways around Melbourne. Water quality monitoring results are compared to target values, for each individual waterway or segment of a waterway. The target values are defined in State Environment Protection Policies prepared by the Environment Protection Authority.[53]

The result is the 'Stream Water Quality Index', that rates water quality as 'very good' to 'very poor', depending on how results of sample analyses compare with the desired conditions.

RISK MANAGEMENT FOR WATER QUALITY

In several Australian cities, the public is regularly confronted by public health warnings about waterways and beaches impacted by effluent overflows after significant rainfall events. In the past, risk management and legal liability have only appeared to be targeted at threats from flooding rather than deteriorating coastal water quality. However, the Wallis Lake (Mid North Coast NSW) oyster pollution crisis, where there was a large number of hospitalisations and a death, raised a new awareness of the impacts of urban stormwater. It became clear that councils and State agencies ignore qualitative considerations in managing urban waterways at their own environmental, legal and financial risk as well as the risk of the economic base of industries including fishing, recreation and tourism.[54]

ACCOUNTABILITY

There are a range of stormwater accountability mechanisms being employed in Australia including:

STATE OF ENVIRONMENT REPORTS

Monitoring of catchment management programs (stormwater management is a component) is required to assess their effectiveness. Information generated as part of this assessment can be useful as input into State of Environment (SoE) reports.

CATCHMENT AUDITS

Catchment audits can be prepared, following completion of fieldwork data collection. A report (audit), summarising the findings of the data collection and fieldwork activities, is undertaken to highlight the key stormwater management issues, their location, nature and severity. Plans can be prepared noting the location of the management issues in each sub-catchment, which could also be noted on a geographical information system. An

[53] Melbourne Water (1999). *Waterways and drainage: operating charter*, p. 5.
[54] Eberhardt, Jan (1999). Partnerships leading to effective implementation. In *Second international river management symposium: speaker papers,* p. 104.

assessment of the relative importance of problem sources can be made, to assist with allocating priorities for management and funding.

STATEMENT OF JOINT INTENT (SOJI)

The NSW Healthy Rivers Commission has developed the concept of a 'Statement of Joint Intent' (SOJI), to ensure different government agencies are accountable to agreed goals and catchment strategies.[55] The basis of this approach is that:

Agreed actions are specified in terms of auditable processes and procedures.

Each state agency's responsibilities under the SOJI are publicly acknowledged by their Chief Executive Officers and included in annual performance reporting.
Council undertakings as part of the reporting statement are widely publicised in the local media to provide local communities opportunities to 'audit' their own local Council's performance in relation to catchment and stormwater plans.

An independent 'quality assurance' mechanism is put in place to ensure that action taken by all signatories truly reflects the commitment made as part of the SOJI.[56]

COMMUNITY / GOVERNMENT PARTNERSHIPS

Community / Government Partnerships involve commitments to consult and work together for improved environmental and resource management. However, this does not absolve governments from their responsibilities to make decisions and take action.[57]

COMMUNITY PARTICIPATION

There is no single community participation model, as each project brings a unique combination of geography, community profile and resource issues into play. Some methods of encouraging community participation include:

- In-depth interviews of key stakeholders.
- Site meetings.
- Environmental care groups.
- Public workshops.
- Indigenous participation.
- Involvement of other organisations, individuals and experts.

CASE STUDY: COMMUNITY PARTICIPATION - MOONEE PONDS CREEK LITTER INITIATIVE
Melbourne, Victoria

[55] Eberhardt, Jan (1999). Partnerships leading to effective implementation. In *Second international river management symposium: speaker papers,* p. 104.
[56] Healthy Rivers Commission, p. 105.
[57] Eberhardt, p. 105.

A recent study has shown that more than three million items of litter enter the Moonee Ponds Creek drainage system each year. Much of this litter ends up in the Yarra Estuary and Port Phillip Bay. This pollution of waterways and beaches is a hazard to aquatic life. It reduces amenity for residents and visitors, and threatens economic activities.

Community education is part of the remediation project at Moonee Ponds Creek, providing an opportunity to effectively control litter through a coordinated, catchment-based approach. It will serve as a demonstration model for other cities implementing stormwater management plans. The activities include:

- Initiation of a community litter education program - moving beyond a simplistic "technical fix" that relies only on structural measures.
- Coordinated mail-outs to households, tram advertising and targeted programs aimed at business and industry.
- A major clean-up day and other community activities including the involvement of Waterwatch groups and the Scientists in Schools program.
- Promotion through local and regional media.
- Community information signage where works are being carried out.

Clean-Up Australia is working with the project steering committee to attract business sponsorship for:

- Clean-up events involving councils, agencies and the community in the catchment.
- Implementation of a 'Waste Reduction Accreditation Program' with business in the catchment.

The project demonstrates the benefits of cooperation across government, private enterprise, research bodies and the community. The Commonwealth has provided funding of $925,000 to assist Melbourne Water, 4 local councils, the CRC for Catchment Hydrology, Clean-up Australia, Melbourne Airport and Melbourne Ports Corporation implement the project.

INDIGENOUS INVOLVEMENT

The preparation of catchment management and stormwater management plans, includes identifying Indigenous sites and social traditions, where they link to water management. This process involves participation and consultation with Indigenous communities and often brings with it an enrichment and better understanding of natural resource issues pre-development.

CONFLICT RESOLUTION

Stakeholders in stormwater management may hold conflicting objectives and this could disrupt the planning process. Where there are competing community interests, or real or perceived alternative solutions, there can be strong objections, and often the threat of litigation.

Stormwater managers can establish a process of consultation with stakeholders involving education and information material being distributed, so any debate can proceed with participants involved being better informed. At times, it may be necessary for mediation by a third party, or as a last resort, action in an environment court.

CHAPTER 3

URBAN STORMWATER CONNECTIONS TO NATURAL SYSTEMS

INTRODUCTION

Before urbanisation, most leaves, rotting vegetation, animal droppings, sticks, dust and sand, stayed more or less where they fell. Now the ecology of many urban waterways is changed forever. Excessive amounts of organic material are washed from expanses of sealed surfaces, accumulate and break down on the bottom of rivers and harbours. This process creates a stagnant environment, reducing the oxygen available for aquatic life.

The increased stormwater flows from urbanisation can accelerate stream velocities and cause severe stream channel erosion. Sediment washed off construction sites and other unsealed surfaces is discharged into the same waterways, causing increased siltation and affecting the local currents required to sustain a healthy environment. This can impact on natural wetlands and the biodiversity of waterways.[58] As well, litter pollution in the stormwater system increases risks to human health and can destroy food sources or the habitats of aquatic life.[59]

Stormwater and wastewater reuse in Brighton, Tasmania – helps reduce pollution of the Derwent Estuary and increase productivity on farmland.

[58] **Roesner, Larry A. & Brashear, Robert W. (1999). Are BMP criteria really environmentally friendly?, p. 1368**
[59] Jago, Richard A. (1999). An end-of-pipe approach to the control of urban litter. *Waterfall: journal of the Stormwater Industry Association*, 12, April 1999, p. 13.

The most common practice is to use detention basins to slow down the post-urbanisation flow. However, experience with these facilities shows that while they reduce downstream flooding, they are not effective at reducing the erosion in stream channels.[60]

Stormwater management requires a broader focus. Best practice needs to take into account the complex interactions between the hydrology, geomorphology, ecology, soil, landuse and cultural characteristics of a catchment and its watercourse network. Failure to understand these interactions may result in the implementation of well-intentioned management techniques that have a greater environmental impact, than that associated with untreated stormwater.[61]

In the management of the impacts of stormwater, the approach of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000) points to an approach that includes identifying:

- Receiving waters to be protected.
- Environmental values including:
  - Protection and maintenance of aquatic ecosystems.
  - Recreation, either passive or active.
  - Water supply for irrigation or stock.
  - Domestic water supply.
- Broad water quality objectives based on guidelines.
- Local conditions (and data) that may require some tailoring of the guidelines, for example:
  - the ecological character of waterways change from headwaters to estuary. Adopting a single objective for nutrients or sediment and applying it along the length of a system is unrealistic and could be counterproductive.
  - Occasionally naturally high concentrations of heavy metals occur in streams through no influence of urbanisation.

SOILS

Soil types have considerable influence on water quality. Before planning and designing for urban development and stormwater management systems, it is essential to test and analyse soil types within a catchment,

Excessive salinity is among major challenges in some developing areas. It is a form of soil degradation that indicates an imbalance in a catchment. It is caused when salts stored in the soil profile are mobilised and brought nearer the surface by rising water tables. The principal cause of rising water tables is the replacement of native woody vegetation with introduced crops and pastures, that use water at a lower rate. This results in "leaking" of surplus rainfall water into groundwater systems, causing water tables to rise. As water tables rise, they bring up dissolved salts from lower in the soil profile. These can be

[60] Roesner, Larry A. & Brashear, Robert W. , p. 1368.
[61] NSW Environment Protection Authority (1997*). Managing urban stormwater: Council handbook : draft November 1997*. Chatswood, NSW., p. 95.

washed into stormwater systems in excessive amounts eventually affecting the biodiversity of waterways and other environmental values.

ACID SULPHATE SOILS

Nationally there is an estimated 40,000 sq kms of coastal acid sulphate soils containing over 1 billion tonnes of sulphide compounds. Urban development, agricultural production and flood control works has acidified large areas of coastal catchments, resulting in significant environmental, social and economic costs.
In an undisturbed state, acid sulphate soils are harmless and are known as Potential Acid Sulphate Soils (PASS). However, when drained and exposed to air, PASS soils become actual Acid Sulphate Soils (ASS). After rainfall, sulphuric acid is produced in large quantities often with heavy metals. Toxic slugs are formed which enter stormwater systems and travel to the sea, killing aquatic life along the way. A sign of the impact of these effects of ASS has been large fish kills in NSW and Queensland.

A range of techniques is being trialed to remediate ASS sites. However, minimising soil disturbance appears to be the best strategy for reducing further threats of stormwater pollution.

Acid sulfate runoff in an agricultural drain, at Smithton, Tasmania.

VEGETATION

Removal or changes to vegetation affects the natural balance of ecosystems, including water flows. Vegetation reduces stormwater runoff and promotes absorption and infiltration. Plants take up water and stabilise groundwater levels. Naturally vegetated areas produce only about 10% runoff. In dense urban areas, up to 90% of rainfall ends up in stormwater runoff.

This urban runoff transports nutrient loads into remnant urban bushland, encouraging the growth of exotic weeds.

With urbanisation and the need to design for sustainable environments, vegetation is a key measure used by planners and landscape architects in emulating pre-development conditions.

A constructed stormwater treatment wetland at Lake Macquarie, New South Wales.

Riparian zones are part of this approach. These are vegetated buffer strips bordering water courses. Without a well-managed riparian zone, excessive sediment enters the stormwater system from overland flow or the erosion of channel banks. When this sediment discharges into waterways from the stormwater system, it tends to clog the streambed, smothering native flora, and destroying the egg-laying sites of fish.[62]

CASE STUDY: STORMWATER AND IRRIGATION REUSE SYSTEM AND RIPARIAN REMEDIATION
Lake Illawarra and Mullet Creek, Wollongong, NSW

Lake Illawarra is currently failing to meet standards for recreational use following heavy rain. Mullet Creek delivers the greatest proportion of pollutants into Lake Illawarra of any creek system in the lake's catchment.

[62] *Australian Water and Wastewater Association,* In House of Representatives Standing Committee on Environment and Heritage. *Inquiry into catchment management, Unpublished submissions*, p. 15.

Intense rainfall in Mullet Creek's upper catchment contributes to stormwater contamination problems and flooding in the lower reaches. In this lower zone, residential stormwater runoff contributes more nitrogen, phosphorus and suspended solids than industry.

In response, a stormwater flood control and reuse pond is being constructed alongside Mullet Creek. This will capture, treat and reuse stormwater on 3 sports ovals. An extensive community consultation process, based on a simple electronic decision support system, is supporting complementary source control and revegetation projects along the Creek.

The Commonwealth Urban Stormwater Initiative is providing over $300,000 to support this integrated approach to stormwater management.

COASTAL AND ESTUARINE ZONES

Poor water quality and sediment loads are the most serious pollution issues affecting Australia's coastal and marine environments. The 1995 State of the Environment Report found that pollution from the land contributes up to 80% of all marine pollution and is a major threat to the long-term health of coastal waterways. Stormwater affects ecological processes, public health and social and commercial use of marine resources.

A creek polluted by combined stormwater and sewage discharges enters the sea at **Sisters Beach, Tasmania.**

Coastal lakes, which have limited ocean water discharge, have been particularly affected by urban and rural runoff. Significant losses of saltmarsh and mangroves around urban areas, caused by land reclamation and stormwater pollution, are affecting fish and other sea life that use the mangroves as nurseries and feeding grounds.[63]

CASE STUDY: USING RIPARIAN ZONES AND CONSTRUCTED WETLAND SYSTEMS FOR STORMWATER MANAGEMENT
Lake Macquarie, NSW

Deforestation and urbanisation of the Lake Macquarie catchment has resulted in significant impacts on the water quality of the Lake. Major problems include:

Increased sediment loads and accelerated catchment erosion.
Elevated nutrient and bacterial levels.
Heavy metal pollution.
Litter pollution.
Loss of habitat.
Loss of aesthetic value.

An integrated stormwater management project in the catchment is using a multi-objective approach led by Lake Macquarie City Council. The project is being supported by Commonwealth funding of $448,000 under the Urban Stormwater Initiative.
Pollution control is being implemented at a range of sites surrounding the Lake. Measures include the construction of saltmarshes, mini-wetland systems and sediment traps. A number of simple, low cost treatment devices based on the current understanding of natural ecosystem processes are being trialed. Riparian plantings, source control campaigns and catchment management education with the community, residential developers and industry are complementary activities.

Australia has the world's largest area and greatest diversity of tropical and temperate seagrasses. However, elevated nutrients and sediments from stormwater runoff have caused serious diebacks of temperate seagrass beds in Southern Australia. Around half of the seagrass in the estuaries of New South Wales and the majority of seagrass in Victoria's Westernport Bay have been lost. Tasmania, the South Australian gulfs, and South-West Western Australia have also suffered serious declines in seagrass. Stormwater has also been a contributor to the major loss of seagrass in Hervey Bay in Queensland, causing a significant decline in the dugong population.

NATURAL WETLANDS

Water plants or macrophytes, are the main building block of wetlands. Emergent and submerged species assist a number of biological processes that enhance water quality. The plants:

- Add oxygen to the water.

[63] *Coasts and Clean Seas Initiative: Coastal "Hot Spots", Ocean Outfalls, Sewage, and Stormwater*, Bruce Gray, Local Water Quality Management Planning Program, Coastal Strategic Planning Program, Department of Environment and the Heritage, p. 2 iii.

- Attract suspended solids from the water column to the surfaces of the plant.
- Provide habitat for micro-organisms, invertebrates, fish and birds.[64]
- Provide surfaces for Biofilms to trap nutrients.

GROUNDWATER AQUIFERS

An aquifer is a permeable geological formation made up of rock or sediment that can contain and convey groundwater. Recharge of aquifers occurs naturally as rainwater infiltrates through overlying soils or below streams and lakes.

There are vast areas of these water basins across Australia. Aquifers are found in areas under a number of coastal cities including Perth, Adelaide, Newcastle and areas of Sydney. While aquifers have the ability to purify water via the activities of micro-organisms they need careful management to protect them from urban stormwater pollution.

[64] Sainty, Geoff (1999). Waterplants in constructed wetlands: getting it right or wrong. In Wood, J.A. (ed.) (1999). *Stormwater 2000: the green with the gold: conference proceedings 26-28 April 1999*. Stormwater Industry Association.

CHAPTER 4

FLOOD IMPACTS IN URBAN DEVELOPMENT

INTRODUCTION

As catchments are urbanised, the environmental impact of increased runoff from roads, roofs and other sealed surfaces can be significant. These changes from natural landscapes can have a number of effects on stream flow, including:

- More frequent flooding and erosion.
- Faster rising and falling flood levels.
- Increased flows in streams that are often dry.
- Reduced groundwater flow due to decreasing rainfall infiltration.

Loss of natural flood storage areas is occurring with encroachment of development on urban floodplains.[65] In this context, there is an increasing focus on retaining and reusing as much stormwater as possible while maintaining the flows that are necessary for the ecological integrity of waterways and groundwater systems.

The quantity of stormwater runoff from Australian cities is about equal to the amount of high quality imported water they use, so there is potential for expanded collection, storage and reuse of stormwater for non-drinking purposes. Urban stormwater is generally not of a high quality, but with treatment it can be used for:

- Toilet flushing.
- Hot water systems.
- Lawns, gardens and playing fields.
- Car washing.
- Fire extinguishing systems.
- Artificial lakes and wetlands.
- Industrial cooling towers.

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[65] Bewsher, D. & Still D. (1995) On-site stormwater detention in NSW: past, present and future. In *Preprints of papers: the second international symposium on urban stormwater management 1995: integrated management of urban environments, Melbourne, 11-13 July 1995*. Institution of Engineers: Canberra, p. 359.

- Recharging groundwater supplies.
- Some vegetable crops.[66]

Flood management strategies are being complemented by water conservation and water quality considerations. Some councils and water authorities are examining a scheme of transferable stormwater discharge rights for new developments. This would allow developers to purchase the right to discharge stormwater from other developers who have retained pre-development runoff flows though stormwater management techniques. This would result in an overall decrease in the cost of complying with an On-Site Detention (OSD) policy in some catchments. It would direct the cost of preventative measures onto those responsible for generating stormwater runoff.[67]

TRUNK DRAINAGE

PAST PRACTICES

The traditional approach to 'improving' a natural urban waterway, creek or overland flow path was to increase its capacity, which generally involves excavation, filling and lining large channels with grass or concrete. However, this can result in the destruction of habitats necessary to maintain a diverse aquatic ecosystem.[68] Pool and riffle zones, organic debris and aquatic flora may be removed and a uniform environment created. As a consequence, flow distribution and velocity characteristics are likely to be less variable. This can result in a reduced diversity of aquatic life.

Urban flood mitigation works such as levees with outlet gates or road embankments with culverts across estuaries can significantly alter the tidal regime and salinity of waterways. This can have a negative impact on mangroves, saltmarsh and seagrass habitats upstream of these barriers.

Increasingly new urban development is being planned and designed to increase their sustainability. Natural creeks and gullies are retained wherever possible as part of the stormwater and flood flow design, and modifications made in a sympathetic manner to manage water velocity and retention. Where treatment structures such as wetlands are created, they are often placed outside the natural stream channel (off-line) rather than interfering with the stream’s natural features. In these cases, wetlands should incorporate a bypass channel for high flows in large storms. The bypass will reduce the threat of wetlands being ’washed out’ with trapped sediment and pollutants being remobilised and deposited downstream.

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[66] Commonwealth Environment Protection Agency (1993). *Urban stormwater: a resource too valuable to waste*. Canberra, p. 2.
[67] *Urban stormwater: a resource too valuable to waste*, p. 11.
[68] Sharpin, M.G. & Morrison, A.J. (1995). Towards ecologically sensitive drainage systems. In *Preprints of papers: the second international symposium on urban stormwater management 1995: integrated management of urban environments*, p. 39.

RETENTION BASINS

On-site retention reduces the need for high cost infrastructure further down the catchment. Its feasibility depends on soil, groundwater, topography and climate.[69] Treatment train measures in a retention system could include:

- Urban lakes as biological treatment systems.
- Water pollution control ponds and wetlands acting as physical and biological treatment systems.
- Gross pollutant traps on stormwater channels intercepting litter, debris and coarse sediments.
- Temporary 'off-line' sediment detention ponds as part of land development works to intercept and treat stormwater from development sites before it is either discharged into the stormwater system or reused.
- Retention of natural creeks augmented by retardation basins in preference to the construction of trunk stormwater pipe systems and concrete-lined drains.[70]

RETARDATION BASINS

Dry retardation basins have either short or extended detention times. Those with short detention times aim to reduce peak storm flows from urbanised areas. Dry retardation basins are only marginally effective, in improving water quality, because the residence time (often less than two hours) may be too short to remove or moderate physical and chemical pollutants.[71] Dry retardation basins usually fill during large storms, they lack permanent water to maintain a biological community for treatment, and infrequent flushing may resuspend previously deposited sediments.[72]

Traditionally, retarding basins have been located in the middle reaches of a catchment, where watercourses are perennial and aquatic ecosystems are reasonably well developed. An alternative approach involves installation of numerous integrated controls in the upper reaches of water courses, where flows are generally ephemeral and aquatic ecosystems are less well developed. This maximises the length of protected watercourse and minimises any environmental impacts. However, construction and maintenance costs are usually higher.[73]

CASE STUDY:
Geographe Bay, WA

Geocatch, a community-based organisation in partnership with the Shire of Busselton and the assistance of $250,000 from the Commonwealth's Clean Seas Program has focused on reducing stormwater impacts on the Vasse River and Geographe Bay.

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[69] *Urban stormwater: a resource too valuable to waste,* p. 11.
[70] *Urban stormwater: a resource too valuable to waste,* p. 11.
[71] *Urban stormwater: a resource too valuable to waste,* p. 15.
[72] *Urban stormwater: a resource too valuable to waste,* p. 16.
[73] Sharpin & Morrison, p. 40.

The consortium has constructed a range of treatment devices including vegetating detention basins with wetland plants. The basins slow incoming water allowing sediments to settle and the plants to adsorb nutrients. As the basins fill up, the cleaner water on the top flows into the river.

STORMWATER DETENTION BASINS

Regional detention basins are typically designed into a residential development scheme, and ensure that the overall discharge from the scheme is held at pre-development levels, or even reduced to lower levels. These basins can also be retro-fitted within existing urban areas, or even into bushland settings.

Wet detention basins (ponds), with a permanent pool of water, have been designed to detain stormwater for gradual discharge. The pond helps improve water quality by sediment removal, uptake of nutrients from aquatic plants, chemical transformation and stormwater reuse.[74]

CASE STUDY: STORMWATER DETENTION AND REUSE SYSTEM
Hervey Bay, Queensland

Wide Bay Water at Hervey Bay is taking an innovative approach to managing stormwater impacts on coastal waterways while adding to reclaimed water resources for agriculture in the region.
Hervey Bay shares the Great Sandy Strait with the World Heritage- listed Fraser Island. The waterways are a prime calving ground for families of humpback whales. Tens of thousands of tourists visit each year to view the creatures. However, Hervey Bay's rapid growth is adding sediment from building sites, litter, including glass and plastics, oils, metal dust from brakepads and rubber from tyres to the cocktail of stormwater pollution entering the Bay.

Wide Bay Water is constructing a treatment scheme that will use detention ponds in the urban areas to store, filter and redirect stormwater into the sewerage system at night when there are low effluent flows. The stormwater will add to the volume of wastewater being reused to increase productivity on sugar and tea tree plantations surrounding the city.

The Commonwealth's Clean Seas Program is providing over $800,000 to support this innovative reuse of infrastructure.

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[74] Dowsett. Brigid (1994). *The management of stormwater: from a problem to a resource.* Sydney Water Project, p. 25.

Warning signs lining a stormwater detention basin at Hervey Bay

ON-SITE DETENTION

In long established urban areas the drainage system may well have 'evolved' rather than been planned for the extent of existing or future development. When most of the future development involves infilling the existing urban area, problems are likely to result from the increasing load (quantity and quality) on the stormwater drainage system. One management option is on-site stormwater detention (OSD).[75] Best practice in on-site detention involves:

- Maximising outflow at the onset of storms in order to conserve storage capacity.
- Quality enhancement through separation and treatment of first flushes.
- Use of screened outlets to closely control flow rate and capture litter, debris and sediment.
- Frequency-staged storage employing 'storage' in lawns and garden soils, depressions in public open spaces, open and covered pavements such as car parks, but in a staged fashion, so that each storage comes into operation only when the preceding one is full.
- Tailwater compensation to control discharge when the bed of a storage lies below the water surface in the receiving drain.
- Pump discharge regulation for controlling pumping from basement tanks in buildings.

The benefits of OSD are:

- It can be funded immediately (i.e. by the developer) and does not require capital outlays from stormwater management authorities.
- It protects downstream properties from increase in flooding resulting from new developments.
- Public land for larger detention basins may not be available adjacent to existing trunk drainage systems.

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[75] Ribbons, S., Warwick, M. & Knight, G. (1995). Section 94 contributions or on-site detention: Council's dilemma. In *Preprints of papers: the second international symposium on urban stormwater management 1995: integrated management of urban environments,* p. 27.

- The cost of upgrading existing drainage systems is often beyond the financial means of councils.
- The OSD system tackles the problem at its source, before the increased flows and pollution enters a major stormwater system and waterways.
- Some water quality improvements will result from deposition of coarse particles and the trapping of litter on inlet and outlet-protecting screens.[76]
- Groundwater recharge and reuse storage can reduce spills and water consumption releasing reservoir storage for environmental flows.

The disadvantages of OSD are:

- Regulations, and design methods adopted by councils are sometimes over-simplistic (and can therefore be unfair to developers).
- Under some hydrological conditions, storage's located in the lower parts of catchments can increase flow rates downstream due to lags in the system.
- Maintenance is a major problem, and OSD places a large administrative burden on councils and a possibly an onerous duty on property owners to ensure regular de-silting.
- It provides little scope for stormwater pollution reduction, especially for dissolved pollutants, and those attached to fine sediment particles.[77]

ENERGY DISSIPATORS

Restraining flow to stop erosion of stream banks and channels is often necessary, where natural slopes increase velocity. In nature, streams stabilise when the energy flow forces are dissipated, eg. in pools and riffles. In engineered channels, in streams that have increased flows, or in cases where the channels are restricted and directed under culverts or into pipes, it is often necessary to reduce velocity by constructing energy dissipaters to stop erosion. Dissipaters can be 'natural' (rocks, trees and grass) or 'engineered' (concrete blocks and timber bollards).

[76] Bewsher, D. & Still D., p. 361.
[77] Upper Parramatta River Catchment Trust (1994). *On-site stormwater detention handbook*. Sydney.

CHAPTER 5

WATER SENSITIVE URBAN DESIGN

INTRODUCTION

The water cycle is a complex interaction of rainfall, evapo-transpiration, overland flow and groundwater flow. Water Sensitive Urban Design (WSUD) grew out of a recognition of the linkages in the water cycle between urban development, stormwater systems and the quality of downstream ecosystems.[78] WSUD is based on a holistic approach to water cycle management and regional natural resource management. These approaches can be linked to catchment management networks and strategies. They feed into planning by individual councils and then into their operational and works programs and forward budget allocations.

Lynbrook, Melbourne, Victoria – water sensitive urban design being applied in an estate developed by the Victorian Land and Regional Development Corporation.

[78] Natural Heritage Trust Waters and Rivers Commission. Techniques to Improve Urban Stormwater Quality: workshop notes, The Institution of Engineers Australia, p. 5.

The application of water sensitive planning and management principles involves incorporating water resource issues early in the landuse planning process. It addresses water resource management at the catchment, suburban, precinct, cluster and allotment scale. WSUD makes the entire stormwater treatment network part of the urban fabric via multiple use corridors and best management practice (BMP) treatment trains. Vegetated swales, filter strips, extended detention basins and constructed wetlands are all part of fully functioning stormwater treatment systems. It maximises infiltration and on-site storage, treatment and reuse and utilises natural runoff channels where appropriate.

If regulators set a target for permissible allotment discharges of stormwater, then designers will examine options for reusing stormwater in toilets, hot water systems, irrigation systems and infiltration zones. More sustainable landscaping, roof gardens, bio-retention, water tanks, better road drainage design and better planning become options for achieving the targets. Reduced stormwater discharge means less stress on creeks and rivers, resulting from reduced erosion, sedimentation and flooding.

WSUD builds on a multi-disciplinary approach. For instance, landscape architects can combine with ecologists to select a range of natural wetland species that enhance pollutant removal and create attractive residential and industrial estates.[79] Planners can incorporate multiple-use corridors to provide stormwater infiltration, filtering and flow paths and dry weather recreation areas. The community can play a role in defining the types of passive recreational pursuits and water features that are most attractive. Engineers can provide designs that function effectively as stormwater management systems, ensuring minimal risk of flooding and disease while protecting ecosystems.[80]

Aritst's impression of the '**Inkerman Oasis" apartment development, Melbourne, Victoria,** that incorporates water sensitive urban design.

[79] Natural Heritage Trust Waters and Rivers Commission, p. 3.
[80] Natural Heritage Trust Waters and Rivers Commission, p. 3.

Natural processes which control runoff, are in constant change. Typically, streams change course, natural erosion occurs, and vegetation and soil permeability change with the seasons. When humans alter the land within a catchment, the changes to the natural processes accelerate, creating a need for constructed stormwater management systems.[81] However, if WSUD is implemented then there can be long term savings in overall water management infrastructure. Water utilities faced with the decision to expand water distribution and stormwater infrastructure (headworks) to meet the needs of extra population, need to make a comparison between the lifecycle cost of:

New and existing infrastructure required to meet the (conventional) additional water supply demand and additional stormwater load.

New practices which decrease potable water consumption and stormwater load, and encourage water reuse and environmental sustainability.

A comparative analysis of economic externalities, such as environmental and social consequences of traditional and WSUD systems, is crucial. Of all landuse changes that affect an area's hydrological cycle, urbanisation is the most important. However, other landuse changes within a catchment such as agriculture, forestry and mining also alter the hydrological cycle and create a need for stormwater management.

CASE STUDY: MORETON BAY INTEGRATED STORMWATER DEMONSTRATION PROJECT
Brisbane, Queensland.

Sections of Brisbane River flowing into Moreton Bay have sediments with concentrations of pollutants up to 35 times above safe levels. The Bay contains a Ramsar wetland and supports migratory birds, dugongs and turtles. It also is under pressure from a rapidly growing urban population and intensive agricultural development in the catchment.

The project has established wetland / wetpond stormwater treatment facilities to trial structural approaches supported by community and industry education campaigns to improve discharges to the Bay.

The project has received $970,000 from the Commonwealth's Clean Seas Program.

TREATMENT TRAINS

BEST MANAGEMENT PRACTICES

In most catchments, a number of water quality management measures may be implemented in series, forming a stormwater treatment train based on:

[81] Evangelisti & Associates, Landvision & V.& C. Semeniuk Research Group (1995). Water resources management study: Middle Canning catchment (stage 1, volume 1). Perth, p. 51.

- Avoiding pollution wherever possible through appropriate control of the pollutant source.
- Minimising stormwater pollution by in-transit measures.
- Managing the effects in receiving waters as a last resort.[82]

The ‘treatment train’ approach to integrated stormwater management improves the overall performance of a water quality treatment system. Generally, the more ‘best management practices’ (BMP's) incorporated into the system, the better the performance. However, BMP's will fail if poorly located within the treatment train or not properly maintained.

SOURCE CONTROLS

This series of measures in a treatment train can include:

- Community awareness (education) programs.
- Improved landuse planning and regulation.
- Tightening permissible discharges and licensing provisions.
- Providing incentives for adopting innovations and best practice.
- Improving street cleaning effectiveness.
- Controlling and treating sewage overflows.
- Isolating high pollutant source areas for extra attention.
- Encouraging and enforcing construction site management.
- Enhancing and monitoring landfill management.
- Installing and cleaning litter traps.
- On-site detention / retention applications.
- Seriously exploring stormwater infiltration and reuse options.
- Rehabilitating, expanding and protecting buffer zones.[83]
- Examining opportunities for discharge rights trading.

IN-TRANSIT CONTROLS

This series of measures in the treatment train can include:

- Gross pollutant traps.
- Swale systems.
- Detention basins.
- Ponds and wetlands.[84]

ENTERING RECEIVING WATERS

This series of measures in the treatment train can include:

- Gross pollutant traps.
- Catch basins.
- Floating booms.

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[82] Moore, Linda (1998). A manual for managing urban stormwater quality in Western Australia. In *Stormwater: keeping it clean: conference proceedings*, 27 October 1998, ed. John Anderson Wood. Stormwater Industry Association, Sydney, p. 2.

[83] Moore, p. 2.

[84] Moore, p. 2.

- Ponds and wetlands.
- Receiving waters management e.g. aeration, phoslock clay.[85]

Within these processes, there are generally 3 levels of treatment:

Primary

- Screening of gross pollutants.
- Sedimentation of coarse particles.

Secondary

- Sedimentation of fine particulates.
- Filtration.

Tertiary

- Enhanced sedimentation and filtration.
- Biological uptake.
- Absorption on to sediments.

In most circumstances, a treatment train approach is appropriate to optimise pollutant removal. The types of primary, secondary and tertiary treatment systems are described in Chapters 6, 7 and 8.

STORMWATER MANAGEMENT PLANNING

Best practice stormwater management for land development is implemented by the developer in harmony with the local council's stormwater management scheme and the catchment management plan. Both are based on the principles of ecologically sustainable development. Land developers and builders are generally responsible for ensuring that their development does not result in significant worsening of existing stormwater management problems. Urban land developments should only occur in areas where a land capability assessment has indicated that stormwater management practices are capable of achieving this objective.

Developers are encouraged to improve existing stormwater systems (eg. degraded creeks) and avoid using natural waterways or natural wetlands for stormwater treatment purposes. Alternatively, development using WSUD principles based on total water cycle management can be attractive to prospective purchasers, increase the value of adjacent land, and may avoid expensive new infrastructure. The value of land adjacent to stormwater treatment measures, such as water quality control ponds and constructed wetlands, is usually higher than for land adjacent to a conventional drain.

CASE STUDY: WSUD DEVELOPMENT
Kogarah Town Square, Sydney, NSW

Urban renewal of Kogarah Town Square involves the construction of 220 residential apartments, 225 parking spaces, commercial retail space and a public library. The development is situated on the ridge between the densely urbanised catchments of the Cooks River and the Georges River which flow into Botany Bay. Both the rivers and the

[85] Moore, p. 2.

Bay are degraded. They are under pressure from increasing urban consolidation, traffic densities and industrial activities.

The project aims to reduce the impact of stormwater through conservation and efficiency by:

- Reducing the reliance on mains water.
- Managing stormwater quantity and quality through capture, reuse and treatment.

Stormwater filtration will occur through a specially designed garden bed. In periods of high stormwater flow, surge tanks will regulate the water flow prior to discharge into the stormwater system. Of the 7,500 kilolitres of rain that falls on the site annually, 85% is captured and used.

About 60% is used to flush toilets, the remainder to irrigate the gardens in the courtyards, while 25% passes through the gardens and is purified and stripped of most of the nutrients. The reuse scheme separates the dirtiest water from the Town Square pavement and treats it separately from the relatively clean water from the roofs. The water reuse within the development represents a saving in the order of 17% of mains water.

The project has been supported by the Commonwealth's Urban Stormwater Initiative with $629,000 in partnership with Kogarah Council, Sydney Water and the development company, High Trade Pty Ltd.

CHAPTER 6

PRIMARY CONTROLS FOR POLLUTION MANAGEMENT

INTRODUCTION

Historically, stormwater management has focused on end-of-pipe and structural solutions, such as gross pollutant traps and artificial drainage channels. Now, best management practice is moving towards solutions closer to the pollution source and an integration of structural and non-structural solutions. However, this process can be slowed by attitudes ingrained from the many decades under the old systems. Potential pollutants such as vegetation, that makes up to 80% of the non-particulate solids in runoff, are still looked on as ‘natural material’, that belongs in the landscape and mistakenly by extension in the drainage system.

A Sydney beach stormwater drain with litter net at **Manly, New South Wales.**

Leaf litter is not at all natural in the quantities that reach urban drainage systems. Under natural processes the vast majority of the material remains in the forest floor layer, holding runoff for slow release and gradually decaying to return nutrients to the soil. In the urban setting, the tree and shrubs are often as dense as it might have been prior to European settlement. However, now many drop leaves onto roofs, paved areas and manicured lawns. They are washed into drainage systems where they can deplete oxygen in waterways and create odours and water soluble compounds that impact on aquatic life.[86]

The community generally regards litter in stormwater as ugly. Many also mistakenly believe that litter has little environmental impact because it consists of benign materials in use every day. The litter stream includes millions of cigarette butts that persist for up to 20 years. They are rich in carcinogens and can be swallowed by aquatic animals.

Litter is unsightly, environmentally damaging and can cause blockages to stormwater management systems. For instance, drink cans made of aluminium are chemically reactive, highly toxic in some phases and may degrade in the low pH of anaerobic zones. Medical and sanitary waste and glass bottles, usually in fragments, are a hazardous feature of bottom muds.[87] A high proportion of all litter, sinks to the bed where it binds the surface or becomes embedded in sediments, to disrupt the activity of bottom dwellers.

Plastics now dominate the stormwater litter stream and can take over a century to decompose. If an aquatic animal dies after swallowing plastics, it decomposes long before the litter, which floats on to threaten more animals. Polystyrene also floats down stormwater drains and into the sea. It can lodge in gills and obstruct the guts of susceptible species.

The aesthetic effect of litter has a profound influence upon the value people attach to their waterways. This could alone, justify the removal of these materials from stormwater, but the case for serious underlying water quality impact by these materials is even stronger.[88] Litter and debris can have significant economic impacts in tourism areas and in marine engines through their intakes. The bulk of this marine litter comes from stormwater.[89]

GROSS POLLUTANT

Methods of reducing gross pollutant impacts include:

- Preventative measures (education and awareness) including drain labelling, working with manufacturers to reduce packaging and encouraging recycling.
- Removal of gross pollutants (street cleaning).

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[86] Nicholas, p. 23.

[87] Nicholas, D.I. (1997). Primary treatment of stormwater runoff: its place in the scheme of things. In *Science and technology in the environmental management of the Hawkesbury-Nepean Catchment: proceedings, 10-11 July 1997*, eds. Steven Riley, Wayne Erskine & Surendra Shrestha. Institution of Engineers and the Geographical Society of New South Wales: Sydney, p. 23.

[88] Nicholas, p. 24.

[89] Allison, R.A., Walker, T.A., Chiew, F.H.S., O'Neill, I.C., & McMahon, T.A. (1998). *From roads to rivers: gross pollutant removal from urban waterways*. Cooperative Research Centre for Catchment Hydrology: Clayton, Vic.

- Capture of gross pollutants in the drainage system.
- Bio-remediation of pollutants (mainly applicable to nutrients and heavy metals).
- Remedial clean-up methods.[90]

Before a particular stormwater treatment technique or treatment train can be determined, characteristics of the catchment area, objectives for the receiving waters, soil and groundwater requirements have to be considered.

Despite education, awareness and street cleaning programs, large amounts of gross pollutants are reaching and degrading waterways. A catchment study in Sydney showed that previous estimates of the number of litter items moving through the stormwater systems can be significantly underestimated, and that organic material and sediment are consistently the main components of gross pollutant loads.[91]

The results from the study indicated that about three-quarters of gross pollutants is organic material, mainly leaves and twigs. This was observed consistently across different land-use types. However, despite the large amounts of organic gross pollutants transported by stormwater, they are not a major source of nutrients (Total Phosphorous and Total Nitrogen).[92]

In the study, only 20 percent of the litter and less than 10% of the organic material transported by the flow in urban waterways, was transported as floating material. This indicates that floating gross pollutant traps (e.g. booms) only capture small fractions of the gross pollutants being transported.[93]

Outcomes from the study's monitoring program indicate that gross pollutant concentrations generally peak before the peak of the storm (first flush effect) as the stormwater flow initially collects surface pollutants deposited since the last rainfall event or street sweeping. However, most of the gross pollutant load is transported during peak discharges. To capture the maximum amount of gross pollutants, trapping systems may need to be designed to treat high discharges but these could take up large areas of expensive urban land.[94]

Although gross pollutant loads and concentrations vary considerably during runoff events, the composition of the gross pollutants remains relatively consistent. This suggests that organic and other litter materials are transported in similar ways through drainage networks. It is therefore not possible to capture exclusively one component of gross pollutants by only treating one part of the storm event, for example capturing most of the litter by removing the first part of the runoff.[95]

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[90] Allison, R.A., p. 6.
[91] Allison, R.A., p. 82.
[92] Allison, R.A., p. 82.
[93] Allison, R.A., p. 82.
[94] Allison, R.A., p. 82.
[95] Allison, R.A., p. 82.

In the catchment study, litter items mostly entered the drainage network from commercial areas. This is mainly due to the actions of pedestrians and motorists. They contributed large quantities of plastic and paper items, especially food and drink items and very high numbers of cigarette related items (approximately 35% of the total number of items).[96]

Results suggest that appropriately designed and properly sited treatment trains can mitigate stormwater impacts on stream communities. However, the resulting aquatic communities differ greatly from those in undeveloped catchments and reflect a fundamental alteration in stream biodiversity.

GROSS POLLUTANT TRAPS

Gross pollutant traps (GPT's) are designed to trap litter, debris and coarse sediments in drains.[97] The traps are often large concrete structures. Sometimes they are complemented by a weir or upstream swales along a stream bank.

Litter from a gross pollutant trap installed on the Ross River Creek, Townsville, Queensland.

GPT's range from quite simple screens, which might be used for a single inlet pit, to structures which straddle channels and may have a twenty-metre footprint. They are designed to remove coarse materials from the mid-range rainfall events accounting for the majority of total runoff. Generally they are designed with combinations of screening, stilling, settlement, flotation and flow separation techniques. Some also catch fine particles by filtration through the coarser material already retained.[98] All require regular maintenance.

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[96] Allison, R.A., p. 82.
[97] Commonwealth Environment Protection Agency (1993). *Urban stormwater: a resource too valuable to waste*. Canberra, p. 11.
[98] Nicholas, p. 24.

The principle design stages for GPT's are:

- Providing monitoring data for pollutant load estimation and storage sizing.
- Selecting the desirable sediment and litter capture sizes for particular catchment characteristics.
- Selecting the storm frequency to be accommodated.
- Site location considerations for selecting exposed or enclosed traps.
- Aesthetic acceptability.
- Devising a maintenance schedule to limit chemical and biochemical activity between services.
- Providing ease, frequency and safety of maintenance.
- Installation and operating costs.[99]

CASE STUDY: STORMWATER LITTER CONTROL
Cudgen Creek, Kingscliff, NSW
Litter and other pollutants were being discharging into Cudgen Creek from the urban stormwater system. The pollution was fouling the coastal waterways at Kingscliff, a popular family holiday destination on the north coast of NSW.
In partnership with on-ground action Tweed Shire Council and local high school students, the Commonwealth provided $85,000 from the Clean Seas Program to:

- Install 2 gross pollutant traps.
- Establish a community awareness program.

The traps were trapping pollutants, made up mainly of grass clippings, leaf litter and sediments, at the rate of 2.4 tonnes per year.

A media campaign was launched based around the students' analysis of the constituents of the traps.Two years after the campaign, 84% of respondents to a survey were able to indicate how they had changed their individual practices to reduce impacts on stormwater.

There are two principle types of GPTs - those that hold their pollutant load in the 'dry' state, and those that hold it 'wet'. ' Dry' traps are generally cheaper to maintain because of the lower costs for litter disposal (removal to landfill). 'Wet' traps are generally efficiently cleaned using eductor suction equipment, but the wet waste is toxic, and many authorities require it to be treated or disposed of under environmental safeguards for liquid waste.

[99] Nicholas, p. 24.

‘Wet’ traps which are not regularly maintained can add to the pollutant load due to biochemical reactions between pollutants (dissolved and in suspension in the collection chamber) washing out of the trap in the next storm.

In Australia, there are a number of traps that are either commercially available or have the support of standard designs, including the following:

- Canberra University, Willings – large concrete steel stilling basin.
- Department of Public Works, North Sydney Council – on-line chamber, punch perforated steel skip.
- Baramy – precast concrete self cleansing through slotted steel grate.
- Copatrawl – nylon meshed sock installed on–line in a chamber.
- CDS Technologies, Swirl Separator – screen based off-line using cyclone principles.
- Rocla Stormceptor - precast on-line trap and wet chamber.
- Swynburne in line litter separator – floating boom diverter to off-line settlement well.
- Stormwater Systems Filtration Boom – end of pipe net curtain.
- Net Tech - end-of-pipe net bag.
- Humeceptor – precast on-line with wet storage well.
- Nicholas Ski-Jump – screen based on-line end–of-pipe dry store.
- Ecosol range of filtering, retention and storage units.[100]
- Enviropod - retrofitted gully basket.
- Storm Filter - uses several filter cartridges to extract a range of pollutants.
- SPEL Stormceptor – series of chambers to trap grit, sludge, fuel and oil.

LITTER BASKETS

Use of litter baskets in drainage systems is becoming common practice in urban areas in Australian cities. Entry gates to drains below streets can be either side-entry or horizontal grates. Side-entry has been favoured in Australian cities because of rainfall intensity. Side entry pit traps (SEPT's) are baskets that are placed inside the entrances to the drainage system from road gutters.[101]

SEPT's can trap significant quantities of gross pollutants. They are cheap to install and can be used to target specific areas because they can be installed on individual drainage entrances. They can capture up to 85% of the litter load and up to 75% of the gross pollutant load entering the drainage system.[102] There is an increasing tendency to replace traditional side entry systems with either grate or modified side-entry designs that perform a limited amount of litter and debris trapping functions.

Litter baskets have limitations including:

- Potential to aggravate upstream flooding if blocked by litter and vegetation.
- Potential odours and health risk to workers when handling trash.
- Trapped material may be re-mobilised.

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[100] Nicholas, p. 24.
[101] Allison, R. A., p. 82.
[102] Allison, R. A., p. 82.

- Moderate to high maintenance costs.

TRASH RACKS

Trash racks are a form of gross pollutant trap that have a steel grating or bars across the stormwater flow path to collect litter. They are not designed to collect fine particles or suspended solids. This form of trap has aesthetic limitations, and debris collected on the rack may block the flow, causing up-stream flooding and odours. Like all trap systems, their effectiveness is limited to the frequency of their maintenance.

A trash interception device at Manly, New South Wales.

FLOATING BOOMS

Floating booms can be deployed for a variety of pollution management roles including collection of oils and litter. Booms have difficulty trapping material which is partly submerged. They need space and low water velocities to effectively trap most floating debris.

CATCH BASINS

Catch basins or catch traps are stormwater pits with a depressed sump that accumulates sediment. They can catch larger 'heavy' sediments and non-floatable materials in a stormwater system, and are generally used in the following situations:
Upstream of other stormwater treatment measures to enhance their performance.
Retrofitting into existing areas, particularly on roads with high traffic volumes.

Catch basins / traps have limitations such as:

- Potential for re-suspension and release of nutrients and heavy metals from sediments.
- Moderate to high cleaning costs.

Catch basins / traps can be combined with litter baskets to increase the trapping efficiency by collecting floatable litter and debris.

OIL AND GRIT ARRESTORS

Oil and sediment arrestors can have different design and operating dynamics, ranging from plate separators, to vortex, swirl and dynamic separators. The separated materials are either collected or delivered to a nearby sanitary sewer. Oil and sediment separators are often sited in car parks and other points of high traffic density in commercial centres.

CHAPTER 7

SECONDARY & TERTIARY TREATMENT FOR POLLUTION CONTROL

INTRODUCTION

Managing stormwater runoff is often thought of in terms of structural measures including:

- Multi-purpose water management corridors.
- Detention and retention basins.
- Artificial wetlands.
- Gross pollutant traps.
- Stormwater reclamation systems.

These highly visible measures can be combined with non-structural measures, including:

- Land use zoning.
- Limits on the proportion of hard surfaces in housing estates and allotments.
- Vegetated buffers and setbacks.
- Industrial and transport spill control programs.
- Road maintenance and sweeping programs.
- Public education.
- Control of pet faeces through regulations and providing public bag dispensers.
- Drain labelling.

A number of the structural and non-structural controls focus on increasing stormwater infiltration where the soil and groundwater conditions are appropriate.

INFILTRATION

There is increasing stormwater runoff with the growing proportion of hard surfaces accompanying urban expansion and consolidation. Communities are turning to infiltration into the groundwater system to manage growing stormwater flows. Pre-treatments are usually needed to avoid groundwater pollution from dissolved pollutants. Sand filters, grassed swales and porous pavements, can be effective treatment techniques, especially in car parks, commercial and industrial sites. Roof runoff, which is relatively clean, can be directly infiltrated into the soil near a building by connecting the downpipe to a subsoil drain system with an overflow for large events.[103]

In Perth, sandy soils allow road runoff to be directed towards numerous local infiltration basins that are no more than fenced excavations. Depending upon the pollutant load, these filters require periodic maintenance by removing the surface layer of sand holding oils and sediments. Similarly, porous pavers require regular cleaning to remain effective.

INFILTRATION BASINS

Stormwater infiltration basins work by seepage through the floor. They enhance water quality through filtration and absorption of soluble pollutants onto soil particles. They can also provide flood protection and reduce storm flow velocities to minimise sediments discharging into waterways.

CASE STUDY: 'S.P.A.R.S' INFILTRATION AND PURIFICATION -Concord, Sydney, NSW

The Atlantis Corporation has tested an infiltration system based on drainage cells. They call it SPARS - Stormwater Purification And Reuse System.[104]

A trial has been conducted involving Concord Council and the Environment Protection Authority (EPA), with assistance from the NSW Government's Stormwater Trust. The area chosen included five streets near Powells Creek, which flows into Homebush Bay near the Sydney Olympic site.[105]

The SPARS system involved constructing a road shoulder of porous paving and grass blocks able to quickly absorb runoff. After the runoff has filtered through this medium, it moves into biologically engineered soil below. From there, the runoff is collected in drainage tanks, which continue the purification process and divert water into nearby retention tanks. The technology captures and filters the initial runoff that contains the

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[103] Sharpin, M.G. & Morrison, A.J. (1995). Towards ecologically sensitive drainage systems. In Institution of Engineers. National Committee on Water Engineering (1995). *Preprints of papers: the second international symposium on urban stormwater management 1995: integrated management of urban environments, Melbourne, 11-13 July 1995*. Canberra, p. 40.
[104] Atlantis 'S.P.A.R.S' Concord trial starting soon. (1999). *SIA Bulletin,* 62, p. 6.
[105] Atlantis, p. 6.

pollutants. The contaminated stormwater is filtered, purified, then stored in sub surface tanks and reused to irrigate the surrounding parkland.[106]

Another infiltration treatment involves swales. These are open, grass-lined channels that receive runoff from roads and other impervious surfaces. Small check dams can be added to slow velocities and increase pollutant removal.

Infiltration swale on the entrance boulevarde to the Lynbrook housing development, Melbourne, Victoria.

Bio-swales are grass swales with enhanced infiltration and pollution removal capabilities. Under the grass they usually incorporate coarse gravel, perforated sub-soil drainage pipes and geofabric (manufactured textile). The filtered water is collected and dispersed to the ground water table via sub-soil pipes. Excess water can be collected for reuse.

Permeable paving materials, such as porous asphalt or porous concrete, are surfaces that mimic natural infiltration. They can be particularly effective by allowing water infiltration close to the source of stormwater runoff.

Permeable surfaces can also be designed with reinforced turf and open-celled pavers, and concrete or plastic grids with voids that are filled with topsoil or aggregate.[107] Heavy metals are bound in the upper part of the soil and most of the pollution is held in the geotextile layer of the pavers.[108]

CASE STUDY: BIO-FILTRATION - MANLY STORMWATER TREATMENT AND REUSE PROJECT
Sydney, NSW

Manly has a high concentration of residents and visitors. Its extensive area of hard surfaces create large volumes of stormwater loaded with nutrients, hydrocarbons, heavy metals, toxicants and litter. These discharge to the surf zone at Manly's famous beaches. Beach signage warns swimmers about the risks from this pollution up to three days after rain.

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[106] Atlantis, p. 6.
[107] U.S. Green Building Council, U.S. Department of Energy, Public Technology (Inc.) & U.S. Environmental Protection Agency (1996). *Sustainable building technical manual: green building design, construction and operation*. Annapolis Junction, Md.: USA.
[108] Dowsett, Brigid (1994). The management of stormwater: from a problem to a resource, Sydney Water Project, p. 24.

To improve stormwater quality, interception devices are fitted inside and outside existing stormwater drains to prevent litter and sediment from entering. Oils, fine sediments and grease are also filtered from the stormwater. Vacuum street sweeping is being increased to suck up many of the pollutants that have been stopped from entering the drainage system.

A section of road has been paved with Rocla ecopavers as used at the Olympic Stadium. This is part of a trial of a range of infiltration techniques.

At the beach carpark, Atlantis porous paving has been placed along the road verge to reduce stormwater flow and to provide filtration through a special material called bio-soil. The stormwater is stored and treated in Atlantis tanks underneath the beach parkland. It is then irrigated onto the heritage Norfolk Island Pines lining the beachfront.

A public education campaign supports the pollution control infrastructure, and emphasises the role residents and the 7 million visitors a year can play in handling their litter properly.

The whole project is being used as a demonstration of innovation and best practice by the Commonwealth Urban Stormwater Initiative that provided catalytic funding of $545,000 for the scheme.

WATER QUALITY CONTROL PONDS

Constructed pollution control ponds, or wet detention basins, are largely open water bodies of several metres depth. They have relatively cheap capital and operating costs, although they do require a large area of suitable land.[109] Water quality ponds can suffer from either pollutant or storm overload. Mosquitoes may become a problem if not factored into the design.

CONSTRUCTED WETLANDS

Usually wetlands are developed with one or more of the following objectives in mind:
To improve downstream water quality.
To improve landscape amenity.
To provide recreational opportunities, usually passive.
To create fauna and flora habitat.
To provide opportunities for stormwater harvesting, sometimes combined with aquifer storage and recovery.
To provide a degree of flood retention.

As a general rule, the more constructed wetlands resemble local natural wetlands, the higher the probability that they will develop into healthy ecosystems that are productive diverse and resilient. When an ecosystem is productive, it means that there is a significant biomass of plants and microscopic algae, that take up nutrients and provide habitat and food for animals. When an ecosystem is diverse it has a large range of animal, plant and microbial species, that promote materials transfer and decomposition of organic material.

Constructed Wetland near an industrial estate in Townsville, Queensland.

Wetland ecosystems that are resilient are able to accommodate seasonal variability in inflows and water level changes.[110]

Once established, constructed wetlands should be able to maintain themselves indefinitely through growth and reproduction of all species of plants and animals with minimal on-

[109] Cullen, Peter (1995). The Cinderella resource: urban stormwater in a dry country, p. 11.
[110] Natural Heritage Trust Waters and Rivers Commission. Techniques to Improve Urban Stormwater Quality: workshop notes, The Institution of Engineers Australia, p. 62.

going maintenance. Ongoing maintenance of constructed wetlands may need to include some level of litter removal, weed control, fire control and mosquito control to ensure that their aesthetic and amenity functions are not diminished.[111]

WETLAND PERFORMANCE

Water quality improvement in wetlands or basins primarily relies on suitable design, moderate loadings, and adequate residence time.[112] Although stormwater pollution control ponds and wetlands both have value in intercepting and treating stormwater, wetlands have proved to be a superior treatment option on the basis of pollutant removal, lower removal time and a smaller footprint area.

Constructed wetlands are suited to removing fine particles and soluble contaminants. Wetland plants can take up nutrients, use them for growth and release chemicals such as nitrogen into the atmosphere. They can treat heavy metals and break down organic pesticides or kill disease-producing organisms.

CASE STUDY: STORMWATER QUALITY IMPROVEMENT WITH WETLANDS
Port Phillip, Melbourne, Victoria.

The rapid growth of south east Melbourne is leading to increased runoff and deterioration in the health of urban waterways. The Victorian Government has set a target of reducing stormwater discharges of nitrogen across Melbourne into Port Phillip Bay by 500 tonnes by 2010. CSIRO research shows that stormwater is the major source of toxicants, pathogens, litter and sediments discharged into the Bay.

Assisted by $3.5m funding from the Commonwealth's Clean Seas Program, Melbourne Water is constructing a series of 10 wetlands within the Cities of Casey, Kingston and Greater Dandenong. Innovative water sensitive urban design is also being employed in some housing estates and freeway developments.

The wetlands treat the base flows of catchments by bringing the urban runoff back towards the profile of rural runoff. The stormwater is directed through substantial areas of ephemeral, shallow and deep marshes.

The sites will work as part of a treatment train. Primary treatment of sediment and litter is being conducted at source through education campaigns, installation of traps at strategic locations and detention and stilling ponds and carbon filters in front of the pool and riffle and constructed marsh features.

Some 635,000 plants are being established in the wetlands to filter stormwater and create havens for native wildlife and provide an attractive location for recreation in the urban corridors.

[111] Natural Heritage Trust Waters, p. 62.
[112] Dillon, P.J. & Pavelic, P. (1996). Guidelines on the quality of stormwater and treated wastewater for injection into aquifers for storage and reuse. Urban Water Research Association of Australia, p. 13.

Large scale constructed wetlands in Melbourne, Victoria.

Constructed wetlands need to be supported by strong source control measures focused on land management and pollution control. Farmers on the rural urban fringe can contain and treat runoff through detention and reuse ponds. Builders can protect topsoil from erosion by the use of silt fences. Education campaigns with urban residents, industry, and road authorities can prevent wastes and sediment washing into stormwater systems.

Constructed wetlands have become popular with developers as they add an aesthetic element to residential and industrial estates while treating stormwater runoff. However, care needs to be taken that they don't become a site for the establishment and spread of noxious weeds.

Constructed wetlands need to be designed with safety provisions to minimise the risk of children drowning and avoid stagnant pools that may become mosquito breeding grounds. Care also needs to be taken that constructed wetlands do not become a haven for rats and snakes and even crocodiles in tropical urban areas.

These challenges are surmountable with intelligent wetland design. This is occurring in harmony with the move to multiple use corridors in new housing or industrial estates as part of water sensitive urban design (WSUD). Using this approach, wetlands are sometimes located on small sites to treat runoff from a cluster of houses or effluent or stormwater from industrial sites for recycling.

Many people have been attracted to constructed wetlands because they see them as a 'natural' solution to water quality threats to coastal waterways. However, the wetland will require human intervention to protect and maintain it in a highly urbanised environment that has significant differences to a 'natural' catchment. Placement of sediment and litter traps in front of wetlands can increase their effectiveness and reduce maintenance requirements.

Occasionally, complete wetland reconstruction may be required due to siltation from urban runoff. When the time comes it can cause angst for local residents. They frequently forget that this was not a natural feature even though the constructed wetland may have attracted a diversity of bird and animal life.

CASE STUDY: WETLANDS AND TREATMENT PONDS
Cleveland Bay, Townsville, Qld

Improving stormwater quality from tropical catchments draining into the Great Barrier Reef is a major challenge. The 1998 Reefs at Risk Report identified Cleveland Bay as a “high risk” location. It is the only part of the Great Barrier Reef Marine Park where urban development is the major source of pollution. Ross and Louisa Creek discharge to the Bay, part of the Great Barrier Reef World Heritage Area and a dugong protection zone.

The Commonwealth Government has provided $962,500 to a consortium led by Townsville City Council to undertake water quality improvement works on Ross and Louisa Creek.

A lake system located in the upper Ross Creek catchment has recorded the highest levels of Anabaena algal density in Australia. The Creek is being polluted by leachate from contaminated sites, residential and industrial stormwater, litter from the Central Business District and sediment from high intensity rainfall. To manage the problem, low to medium stormwater flows will be treated in stormwater ponds. The ponds will remove heavy metals, organic matter, bacteria and nutrients. Nettech Gross Pollutant Interceptor Traps, permanent water monitoring stations and sediment remediation techniques will be trialed. If successful, they may be used as pollution control measures in other tropical localities.

In Louisa Creek, Townsville City Council is constructing small treatment wetlands, each tailored to specific design constraints, including:

A long dry season.
Low lying catchment.
Limited ground or surface water storage.
Narrow residential and industrial drainage corridors.
Tropical monsoon events.
The need to avoid attracting crocodiles in urban areas.
The need to avoid attracting large waterbirds to the wetlands as it is close to an air force base flight path.

Wetlands are being spaced along the watercourse to split the contaminant load and enhance fisheries habitat values. They also have major bypass channels to cope with tropical storms.

FLOW DISTRIBUTION

One of the more challenging hydraulic and engineering aspects of constructed wetlands is to achieve a distributed flow through macrophyte plant beds. Channels can easily form, particularly as a result of occasionally high flows. Short-circuiting of the flows within the system can destroy the pollutant removal effectiveness.

WATER HARVESTING

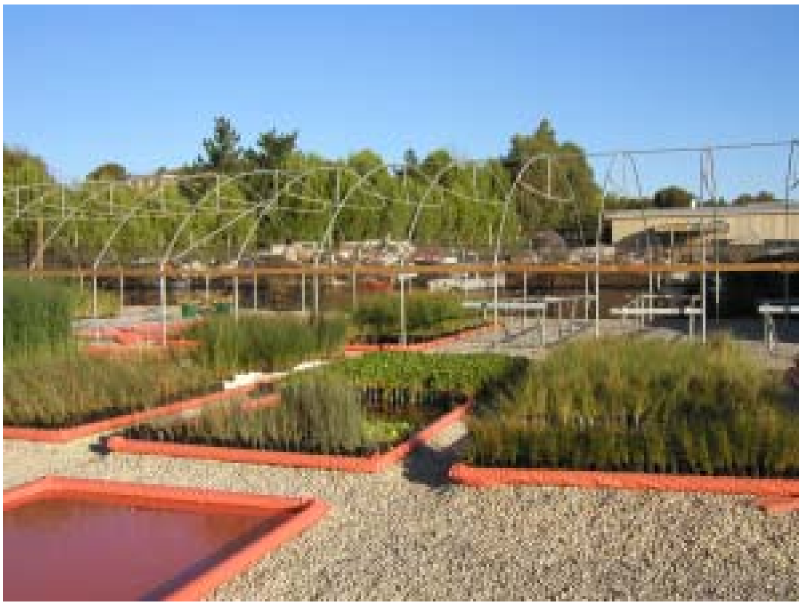
The feasibility of water harvesting from urban stormwater wetlands rests upon three conditions:

1. The water must be of sufficiently high quality for users.
2. The water supply must have sufficient reliability and volume to justify the expense of extraction infrastructure.
3. Water extraction must not adversely affect the water quality improvement function of the wetland. Water quality improvement rests, to a large degree, on the health of the aquatic vegetation and aquatic plants are sensitive to water level fluctuations.

CASE STUDY; WATERWAYS NURSERY REUSE

Adelaide, South Australia

Commercial plant nurseries are high users of water. Wastewater containing high levels of nutrients and chemicals often drains into stormwater collection systems. At the Waterways Nursery, a closed loop system will trap rainwater and recycle stormwater and wastewater after treatment in a small on-site wetland and sand filter. A monitoring system will control irrigation to maximise the use of rainwater and reclaimed water.
The Commonwealth's Cleaning Our Waterways Industry Partnership Program is providing over $44,000 to develop this nursery into a demonstration project for the industry.



Just Parks and Gardens Waterway Nursery, South Australia.

IN-LAKE TREATMENTS

AERATION

Tertiary treatment of stormwater can be undertaken by artificial means, by aeration, where particularly high nutrient loads may cause algal blooms. Oxygeneration is a form of treatment, which has been developed from techniques used in sewage treatment processes. This approach has been used successfully in Western Australia to treat toxic algal blooms in combination with a clay (CSIRO's phoslock) that seals nutrient rich sediment into the riverbed to impede nutrient cycling through the water column.

CASE STUDY: CANNING RIVER OXYGENATION
Perth, WA

Oxygenation trials have been focused on sections of the Canning River where several major stormwater drains flow into the River's system. The chief water quality problems of these reaches of the River are:

Toxic blue green algae which can close the River to all recreational use.
Algae and thermal stratification causing oxygen depletion.
High nutrient concentrations in the water column and sediments.
River flow in the Canning in summer is minimal and wind mixing is not sufficient to return oxygen to the water column faster than it is being used. As a result, dissolved oxygen concentrations, especially close to the bottom, drop to almost zero.

The oxygenation and phoslock trials have been conducted with 2 plants based on the river bank with assistance of $319,000 from the Commonwealth Government's Clean Seas Program, While trials are proceeding, initial results show favourable control of the effects of phosphorous and nitrogen.

FLOCCULATION

The removal of fine colloidal suspended pollutants can be difficult with current stormwater settling techniques. A flocculating agent can be introduced to combine the particles so they settle out. There are a number of commercially available flocculants, however, they all leave a trace residue that can be a pollutant requiring management.

Electro-flocculation techniques have been developed which overcome many of these problems. They are of particular value on construction sites, where treatment of retention water is necessary prior to discharge to the stormwater system.

PURIFICATION

Stormwater may be required to be purified to potable water quality for health reasons. While expensive, it can undergo micro-filtration and ultra violet treatment to this standard.

ROOF GARDENS

In cities, roofs cover 40-80% of the surface.[113] This prevents infiltration and increases stormwater runoff.

A number of countries in Europe have acknowledged this problem and have legislated that all public buildings should be covered with a roof garden. The German Government, contributes 50% to the cost of building a roof garden on either private or public buildings.[114] Roof gardens absorb about 76 litres of water per square metre of garden area.[115] Super-imposed loads on the roof structure, plus retained rainwater, means that the roof needs to be designed to the extra loading.

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[113] Urriola, Humberto (1999). Roof gardens: an environmental asset. In Wood, J.A. (ed.) (1999). Water sensitive design & stormwater re-use: seminar proceedings, 31 March 1999. Stormwater Industry Association: Sydney, p. 1.
[114] Urriola, Humberto, p. 1.
[115] Urriola, Humberto, p. 1.

CHAPTER 8

SEDIMENT AND EROSION CONTROL

INTRODUCTION

There are two parts to an effective water quality management strategy for an urban development. The first phase involves the installation of erosion and sediment control measures during construction, when the sediment export potential is at its greatest. The second phase of a management strategy involves the construction of treatment trains to improve the quality of post development runoff.[116]

Sediment research, points to the following water quality and ecological processes in Australian waters:

- Systems heavy in suspended solids, with adsorption of nutrients, metals and pesticides attached to surfaces of suspended solids.
- Turbidity associated with suspended solids blocking light and adsorbing solar radiation that exacerbates temperature stratification in water bodies.
- Low organic carbon levels and a high proportion of refractory carbon, limiting microbial-driven nutrient release.

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[116] Sharpin, M.G. & Morrison, A.J. (1995). Towards ecologically sensitive drainage systems. In *Preprints of papers: the second international symposium on urban stormwater management 1995: integrated management of urban environments, Melbourne, 11-13 July 1995*. Institution of Engineers: Canberra, p. 40.

- Highly variable flows, with significant events driving major exports of pollutants, followed by extended period of low flows.
- Sediments as the major store of pollutants, and the moderator of water quality in the water column.
- Poor mixing of water caused by periods of low flow and high temperatures, creating sharp temperature gradients.
- Poor mixing conditions depressing oxygen transfer, exacerbating sediment nutrient release processes.
- Time-based interception, storage and remobilisation of flow constituents, often associated with land use and management practices.
- Trophic systems, affected by sunlight extinction limiting photosynthesis, and variable flows (water levels) limiting plant habitats (biomass).

Large civil works and building sites in fully developed inner city areas can provide challenges in controlling stormwater pollution. There is increased risk of sediment pollution where building materials such as sand, fill material and topsoil are delivered and temporarily stored on pavements and roadsides.

Other threats arise when concrete conveying pumps, delivery tubes, hoses, trucks and delivery bins are washed out. This acidic, heavily polluted, sediment causes severe problems in stormwater systems and kills aquatic organisms. Litter, pesticides, acid washes, paints, solvents and construction adhesives also pose risks.

Clearing and earthmoving increases erosion by as much as 40,000 times the rate occurring in undisturbed sites. Many states and regions have legal requirements for erosion and sediment control. These laws have been supplemented by national stormwater guidelines.

SOIL CONSERVATION

The key protector of soils is vegetation. Erosion is generally high wherever the vegetation has been disturbed and rainwater is concentrated. The problem increases as 'marginal' lands are developed as urban centres grow. Most land degradation associated with urban development results from erosion by water, salinity and acid sulphate soils. Wind is a factor on sandy soils in exposed coastal zones.

The damage from poor conservation practices is easily recognisable. However, environmental damage tends to accumulate slowly. It is often only after scientific evidence brings to light the loss of flora and fauna species, that community concern is raised and action is taken.

Soil erosion has particular consequences for aquatic environments, causing:

- Degradation of marine habitats.
- Increased turbidity in streams and water bodies.
- Increased salinity on land and in water bodies.
- Increased frequency and damage caused by flooding.

- Reduced aesthetic values of bushland and water bodies.

SOIL LOSS

Stormwater managers and designers can calculate the anticipated soil loss which is likely to occur during development, and use this information to take protective measures to contain the problem. These calculations can assist in assessing the erosion risk, selecting controls, sizing of sediment and retarding basins, and provide comparative catchment analysis.

SEDIMENT TRAPS

Sediment traps are temporary control measures used to retain coarse suspended particles. Finer particles and soluble materials pass through them. Sediment traps are easy to construct, relatively inexpensive and easily moved as construction work proceeds. The most common forms of sediment traps are straw bales and sediment fences using geotextile fabrics.

WIND EROSION

Wind erosion can cause soil particles to become airborne and then settle out as dust where it will be washed into stormwater systems in the next downpour. In Australia, intense rainfall immediately after bushfires can result in the flow of large sediment and organic ash loads into water bodies.

VEGETATION STABILISATION

Vegetation stabilisation can reduce potential soil loss by reducing raindrop impact, storm run-off velocity and wind erosion. Techniques include:

BRUSH AND STRAW MULCHES

A variety of innovative proprietary methods have been developed by organisations specialising in soil erosion protection. Commonly these systems are spray applied, use organic materials, and are bound with emulsions which slowly degrade. These systems generally use brush or straw, and can be applied at controlled thicknesses, depending upon the slope and erodibility of the soil.

EROSION BLANKETS AND GEO-TEXTILES

Soil protection can be 'rolled out' in the form of organic blankets and synthetic woven geo-textiles. These are generally installed to allow permanent establishment of vegetation using prepared tube stock and semi advanced tree cover. This form of soil erosion control is generally used where there is possible high velocity flows, such as creek and stream bank protection.

SUB-SOIL DRAINAGE

Sub-soil drainage systems can take a variety of forms. Common types are:

- Rubble drains.
- Perforated or slotted pipes.
- Strip drains with a cellular core wrapped in a geo-textile filter fabric.

Sub-soil drainage can be used to assist with stormwater surface flow management and infiltration control. It can improve the environment for growing protective vegetation and improve soil stability on steep slopes. Sub-soil drainage is increasingly being used in Water Sensitive Urban Design to underlay grassed swales in streetscapes and carry stormwater to settling and reuse treatment ponds and wetlands.

STREET SWEEPING / VACUUM CLEANING

Traditionally, street sweeping as a treatment-based control measure for removing litter and reducing overall heavy metal loads and coarse sediments, has not been a very cost efficient management system. However, recent technical advances in vacuum suction cleaning have made it more competitive. In the future, pollution on some high use freeway and road systems may require vacuum cleaning to protect sensitive local water bodies, if other measures cannot be designed in or retrofitted.

Stormwater runoff from road surfaces is one of the many contributors to the non-point source pollution load. Tiny particles are proving difficult to capture in current stormwater pollution devices. The stormwater load contains significant quantities of heavy metals, which are a threat to aquatic environments.

Recent monitoring in California indicates that automotive disk brake pad wear is one of the major sources of copper metal loading being washed down stormwater drains into San Francisco Bay. Diesel exhaust from buses and trucks is also a significant source of heavy metal pollution.[117]

Gross pollution is typically, gathered into the stormwater system from the street during bursts of rain or wind, or both. It is suggested that unless street sweeping is conducted just prior to or during these 'deposition' periods, the bulk of pollution will not be collected. It follows that very short sweeping and vacuuming cycles are required in order to ensure that street sweeping is effective, as a 'source' method for pollution control.[118]

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[117] James, R. & Whitman, K. (1995). Stormwater and watershed management in the Santa Clara Valley. In *Preprints of papers: the second international symposium on urban stormwater management 1995: integrated management of urban environments,* p. 103.
[118] *Nilson B., Silby, N., Argue, J.R. (1995). An investigation into source control of gross pollution. In* Eighth national local government engineering conference: "Local government engineers: serving the community", Gold Coast, 27 August to 1 September 1995: conference papers*. Institute of Municipal Engineering: Melbourne.*

CHAPTER 9

STORMWATER RE-USE

INTRODUCTION

Stormwater runoff from Australian cities is about equal to the amount of high quality imported water they use.[119] As more than 50% of high quality water piped to urban areas is used for lower quality purposes, such as garden watering and toilet flushing, there is potential for expanded collection, storage and reuse of stormwater for non-drinking purposes.[120]

RESEARCH EXAMPLE: MEAN ANNUAL RUNOFF, DEVELOPED SURFACE AND GROUNDWATER RESOURCES AND GROSS WATER CONSUMPTION IN AUSTRALIA'S METROPOLITAN REGIONS, (GIGALITRES).

CITY	***WATER REGION MEAN ANNUAL RUNOFF AVERAGE YIELD OF DEVELOPED SURFACE SOURCES GROUNDWATER PRODUCTION GROSS WATER CONSUMPTION***
Brisbane	1860 555 60 331
Sydney	3900 581 11 620
Melbourne	1650 548 19 479
Adelaide	441 109 44 251

[119] Commonwealth Environment Protection Agency (1993). *Urban stormwater: a resource too valuable to waste*. Canberra. EPA, Feb 1993. p. 2.
[120] *Urban stormwater: a resource too valuable to waste*, p. 2.

Perth	1260 213 226 369

Source: CSIRO and NSW Department of Land and Water Conservation. Wastewater Re-Use, Stormwater and the National Water Reform Agenda, 1997, p. ii.

Optimum use of all water requires a single, integrated resource management framework.[121] While stormwater is an obvious alternative source of water it has not been exploited to any large extent in Australia, where only 3% is reused compared to 11% of municipal wastewater. Treated sewage effluent is considered a more reliable source of reclaimed water than urban stormwater, which occurs in varying volumes and frequency. Nevertheless, urban stormwater offers a large potential resource, securing environmental and economic benefits through storage and reclamation. The technique can prevent water pollution and minimise the need to dam natural watercourses to supply increased potable water supplies for non-potable purposes.

In urban areas, improvements in landscaping, better flow regulation and new treatment technologies are increasing the scope for reclamation and stormwater management. Relative costs of these options are falling, benchmarked against the increasing environmental and economic costs of doing nothing i.e. increases in potable water supplies or demand management. A more sophisticated water market in urban areas is providing demand for water qualities for different uses.

Without increased water reclamation, growing demands for water resources by urban users require increasing volumes to be imported from water harvesting catchments, or extracted from groundwater aquifers. The marginal costs for imported water rise as less accessible catchments are exploited, sometimes with severe disruption to non-urban communities. Yet the resource potential of stormwater is only just beginning to be recognised.[122]

Stormwater recycling can be encouraged at minimum cost to government. Rainwater tanks connected to roofs provide a valuable source of water for gardens, toilet flushing, washing and hot water. Stormwater storage underground, which could form part of an on-site stormwater retention / detention system, can also be incorporated into buildings. Incentives can be promoted to developers and home owners to store and recycle stormwater, by providing rebates on their current water and sewer charges. Local Government can play a major role in encouraging the use of reclaimed stormwater. Development consents can require stormwater storage for toilet, garden, washing and hot water use.

[121] *Urban stormwater: a resource too valuable to waste*, p. 3.
[122] *Urban stormwater: a resource too valuable to waste*, p. 3.

WATER TANKS

Water tanks connected to roofs in urban areas can significantly reduce the volume of stormwater entering the drainage system, if applied across catchments. If the collected water is used for non-drinking purposes, it can reduce the demand upon the public reticulation system. Already more than 1 in 5 Australians depend on tank water for their drinking supply, often using first flush filters.

Recent research by the University of Newcastle, commissioned by the Upper Parramatta River Catchment Trust (UPRCT), has resulted in modelling of water tanks to provide on-site stormwater detention (OSD) capacity, as well as retention qualities. By providing both stormwater retention for reuse purposes, and detention capacity to reduce peak flow from storm events, tanks are an effective source control tool in managing stormwater at the household scale.

Other studies by the University of Newcastle have demonstrated that stormwater held in tanks improves the quality of stormwater discharges, eliminating contamination by metals and chemicals. This result supports the assumption that flocculation, settlement and bio-reaction processes operate within rainwater tanks.

Recent innovations in rainwater tank design, both in the use of plastics and cost effective manufacturing processes, have seen new tank shapes become commercially available. One recent example is the Freewater Modular System that provides interconnected tank panels which are 200 mm wide, allowing use as fencing panels, screen walls or building wall panels, giving space saving and design flexibility domestic water storage.

In field testing, the use of rainwater tanks for household garden watering and toilet flushing, reduced the stormwater export from a Canberra catchment by 20%.[123] An increased role for tanks as part of the existing potable water distribution system, combined with stormwater reclamation has been demonstrated by the CSIRO Urban Water Program.

A new approach for roof water retention, is to provide storage gutters at the eaves, acting as a linear tank. This assists distribution by providing supply take-off from any point in the perimeter gutter for low-pressure water for toilet flushing and irrigation. In Sydney the storage gutter system saves 27% of the potable water supply to an average household, and when used in new building construction is cost neutral. Being part of the roofline, there is little need for pumping and there is no need for tank stands and reduction of precious yard space. The system can be applied to existing homes, as a replacement gutter system. The storage gutter is an Australian patented system called Rainsaver.[124]

[123] McAlister, Tony (1999). Stormwater reuse: a balanced assessment. In *Stormwater 2000: the green with the gold: conference proceedings 26-28 April 1999*, ed. J.A. Wood. Stormwater Industry Association.

[124] Smith, Frank (1999). Stormwater recycling and OSR – Rainsaver. In *Water sensitive design & stormwater re-use: seminar proceedings, 31 March 1999*, ed. J.A. Wood. Stormwater Industry Association: Sydney, p. 1.

Testing and monitoring in selected development projects to date, has shown that rainwater used in hot water systems for temperatures between 55 degrees C and 63 degrees C was compliant with the Australian Drinking Water Guidelines (1996). Hot water systems pasteurise rainwater to produce acceptable water quality.

Research by the University of Newcastle, has shown that rainwater tanks when used with toilets, garden irrigation and hot water use, reduce the reliance upon mains supply by up to 65%.[125] Many industrial processes, including general wash down requirements, can use stored rainwater and / or treated stormwater.

WATER HARVESTING AND IRRIGATION
Past studies suggest that as long as the focus is on the cost of stormwater or the current price of reticulated water supply, then stormwater reuse will be apparently uneconomical, due to the heavily subsidised nature of the reticulated supply. This comes about because there are costs that are often not included in the charged price for reticulated mains water, such as:

Land developer capital costs.
Inadequate expenditure on asset replacement.
Ongoing environmental impact costs, levies and expenses.[126]

When the complete range of other issues are factored into costing considerations, stormwater reuse becomes economically attractive.127 These other factors are:

The savings that are gained through the reduction in non-point source pollutants, especially sediment loads, and the reductions in peak stormwater flows, achieved by stormwater reuse. These savings occur firstly through the need for reduced water supply reticulation and stormwater drainage infrastructure if extensive on-site stormwater reuse is practiced. There are also likely to be considerable savings due to the removal of the requirement to ‘clean up’ waterways of sediment, nutrients and debris that accumulate downstream of urban developments.

The cost of maintaining environmental flows in rivers that are impacted by dam storage's.

The financial benefits, often of an intangible nature, gained by the multi-use of waterway corridors for recreation, environmental enhancement and stormwater storage and reclamation purposes. These benefits are typically manifest in greater property values in areas where such management practices are applied.[128]

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[125] Coombes, P.J., Kuczera, G., Argue, J.R., Cosgrove, F., Arthur, D., Bridgeman, H.A., & Enright, K. (1999). Design, monitoring and performance of the water sensitive urban redevelopment at Figtree Place in Newcastle. In *Proceedings of the 8th international conference on urban storm drainage, Sydney Hilton Hotel, Sydney, Australia, 30 August - 3 September 1999*, eds. Ian B. Joliffe & James E. Ball. Institution of Engineers, p. 1326.
[126] McAlister, Tony.
[127] McAlister, Tony.
[128] McAlister, Tony.

CASE STUDY: STORMWATER HARVESTING AND TREATMENT
St. Kilda, Melbourne, Victoria

A $12m CSIRO study of the water quality in Port Phillip Bay revealed that stormwater is the primary threat to its biodiversity. An estimated 7,000 tonnes of waterborne and dissolved nitrogen compounds enter Port Phillip Bay in stormwater each year. At St Kilda, local Waterwatch groups have identified high levels of nitrates and low levels of oxygen in the stormwater inflow as a major threat to a local colony of fairy penguins.

As a first for Victoria, a system designed by Integrated Eco-Villages will result in stormwater and greywater being recycled using an aeration tank and wetlands. The first flush stormwater from a new housing development of 236 units ('The Inkerman Oasis') will be trapped, treated, filtered and cleaned by a 400 square metre subsurface flow wetlands and 100 square metre sand filter. It will be combined with the recycled, domestic greywater and used for garden irrigation and toilet flushing. A roof garden on top of the sub-basement car park will contribute to reducing greenhouse emissions, provide insulation, minimise stormwater runoff and receive nutrient rich recycled water. Garden beds, grassed areas and subsurface wetlands will remove nutrients from stormwater, preventing their entry into urban waterways and Port Phillip Bay.

Compared to current building designs, the reuse of first flush stormwater will reduce the amount of potable water required in the development by up to 45%. It is estimated that stormwater catchment, treatment and reuse will directly prevent nearly 7 tonnes each of nitrogen and phosphates entering Port Phillip Bay each year. The project is a partnership between Inkerman Development Pty Ltd, the City of Port Phillip, applied research organisations and the community.

AQUIFER STORAGE AND RECOVERY

Aquifer Storage & Recovery (ASR) involves the harvesting of surplus stormwater from a variety of sources. It is temporarily stored in a suitable aquifer, and then retrieved for potable, irrigation or industrial applications.[129] ASR provides a viable alternative to reservoirs in areas where land values and evaporation rates are high, catchment areas are intensively developed. In urban areas of semi-arid regions disposal of treated wastewater and urban stormwater runoff is considered wasteful, and some form of treatment and storage is required to tap these potential resources. Artificial recharge of aquifers using infiltration basins has been practised for many years where soils are permeable and aquifers are unconfined.[130]

A confined aquifer can be a water body with limited additional capacity, due to pressure. Research and development in Australia over the past few years has focused on the injection, storage and recovery of stormwater and treated domestic water into shallow

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[129] Gerges, N.Z. *Aquifer storage and recovery: type and selection of aquifer*. Primary Industry and Resources.
[130] Dillon, P.J. & Pavelic, P. (1996). *Guidelines on the quality of stormwater and treated wastewater for injection into aquifers for storage and reuse*. Urban Water Research Association of Australia. p. 1.

unconfined and deep confined aquifer systems, using injection wells and infiltration trench methods.[131] Usually the input water is pre-treated in a wetland.[132]

Stormwater is often of lower salinity than the natural groundwater. When injected into an aquifer, treated stormwater forms a 'bubble' or 'lens' around the base of the injection pipe. There is generally some mixing of the two waters at the margins of the lens. Because migration of groundwater is small, and generally only in the order of a few metres per year, the bubble will usually be retained around the injection well.

Confined aquifers are generally a stable and predictable environment for storage.[133] Aquifers targeted for recharge are usually sedimentary (carbonate, gravel and sand), with various degrees of consolidation, but may also include fractured rock.[134] Monitoring is an integral part of recharge operation, and it may be undertaken to better understand processes or for regulatory control. It is normal for each site to have several observation wells, and for injected waters and ground waters to be sampled regularly.[135] The longest operating site for stormwater re-charge into an aquifer is at Mount Gambier, South Australia, which has been recharging the groundwater via drainage wells for over 100 years. The rate at which new sites have been established in South Australia has been accelerating.[136]

CASE STUDY: COMMERCIAL REUSE
PARAFIELD PARTNERSHIPS URBAN STORMWATER INITIATIVE SALISBURY, SOUTH AUSTRALIA

Urbanisation has contributed to the discharge of an estimated 5000 megalitres per annum of polluted stormwater into the Barker Inlet. The Barker Inlet is a sensitive marine ecosystem. It is a fish breeding ground and nursery for much of South Australia's marine fisheries. Residential and industrial growth in the Barker Inlet catchment, particularly from the City of Salisbury, is placing pressure on the water quality of the Inlet and the Gulf of St Vincent. It is also placing increasing demands on potable water supplies from the Murray River.

This project captures and treats urban stormwater for reuse in G.H. Michell & Sons Woolscour, local industry and horticultural irrigation. Up to 1.5 billion litres per annum of Adelaide mains water, mostly from the Murray River, will be replaced by high quality stormwater runoff from the urban area will be harvested and treated in bird-proofed reed bed ponds on the Parafield Airport - a world first for an aviation facility.

The cleaned stormwater will be supplied direct from the treatment ponds to users during operating periods. Surplus water will be injected into underground aquifers for storage. It can be recovered during dry periods for use in the wool processing operation and by other

131 Gerges, N.Z.
132 Gerges, N.Z.
133 Gerges, N.Z.
134 Dillon & Pavelic, p. 3.
135 Dillon & Pavelic, p. 3.
136 Dillon & Pavelic, p. 3.

users in the Salisbury area. Aims of the project include a 90% reduction in both the volume and nutrient pollution loads of stormwater entering the Barker Inlet, and a reduction of 1000 million litres of water extracted from the River Murray annually.

Large netted wetland at Parafield Airport, Adelaide, South Australia.

CHAPTER 10

SOME FUTURE STORMWATER MANAGEMENT OPTIONS

INTEGRATED CATCHMENT MANAGEMENT

Stormwater management is one aspect of natural resource management. It focuses on catchments and sub-catchments, straddles local government boundaries and even States, e.g. the Murray Darling Basin. Establishing responsibilities for stormwater, and linking that responsibility to planning and management varies from state to state and city to city. Generally local government is responsible. In some regions catchment authorities / boards / trusts develop policies and strategies and then go on to construct and monitor treatment infrastructure and source control measures.

The regional catchment management planning process provides a mechanism for ensuring that all funding for natural resource management is directed to key areas. This avoids dissipating resources through fragmented structures and piecemeal investment in uncoordinated projects.[137] Bringing the stakeholders together, including the existing water utilities, is an important role of catchment organisations.

STORMWATER INFRASTRUCTURE FUNDING

To be fully effective, catchment organisations need access to secure funding, e.g. the Catchment Water Management Boards in South Australia have an annual levy. It enables the community to plan long-term strategies and the capacity to enter into partnerships

[137] State of Victoria (2000). *Unpublished submission to House of Representatives Standing Committee on Environment and Heritage Inquiry into catchment management*, p. 10.

with industry and local government and to maximise the opportunities provided by Commonwealth and State Government funding e.g. projects funded by the NSW Government's Urban Stormwater Program have stopped an estimated 4300 truckloads of pollution entering waterways each year.[138]

ENVIRONMENTAL MANAGEMENT BONDS

Environmental Management Bonds are regularly applied by environmental agencies and local government, when approving development. While constructing new housing estates the developer may be responsible for environmental performance (staged land releases), prior to completion and handover to the local council. For example, the developers of the Harrington Park Estate in Sydney, places a $500 bond on each home site purchaser to ensure that their builders do not breach Environment Protection Authority pollution control guidelines. In turn, the owners pass this bond condition on to their builders, who also then place this condition upon their subcontractors. This means that the polluter pays the penalty.

GREEN FIELD DEVELOPMENT

The primary aims of stormwater management in new subdivisions is to reduce peak flows, minimise pollution and provide opportunities for stormwater reuse.[139] It is now accepted that a well-engineered residential suburb is one in which:

The risk of flooding is low.
Recreational waterways are healthy.
Stormwater replaces some mains water uses.[140]

However any attempt to develop a common practice for stormwater management in Australian residential subdivisions needs to recognise the great diversity of environmental, economic, social and political climates across regions. These include:

- Rainfall and evaporation that is highly variable.
- Wide range of soil types and terrain.
- Variety of relevant geological conditions, including presence or absence of groundwater.
- Variety of housing forms.
- Variety in water available for gardens and other water-dependent amenities.
- Water price and policy differences.
- Differences in types and levels of pollution generated in urban areas.
- Different community environmental values.[141]

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138 State of Victoria. *Unpublished submission*, p. 10.
139 Argue, J.R. (1995). Stormwater management in Australian residential development: towards a common practice. In *Preprints of papers: the second international symposium on urban stormwater management 1995: integrated management of urban environments, Melbourne, 11-13 July 1995*, Institution of Engineers. Canberra, p. 425.
140 Argue, p. 425.
141 Argue, p. 425.

A goal for new development is to ensure that the post-development peak discharge rate, volume, timing and pollutant load does not exceed pre-development levels. However, best management practices (BMPs) are not 100 percent effective in removing stormwater pollutants. For this reason, government agencies in each region have set performance standards that are based on risk analysis and feasibility of implementation.142 Some of the performance standards are based on achieving water quality targets in regional waterways.

CASE STUDY: "LYNBROOK" WSUD HOUSING ESTATE
South East Melbourne, Victoria

Lynbrook Estate is a greenfield residential development 35 kms from the centre of Melbourne. The Urban & Regional Land Corporation, Melbourne Water and the CRC for Catchment Hydrology are implementing a range of water sensitive urban design (WSUD) techniques here to protect the waters of Port Phillip Bay. A feature of the stormwater system is the use of swales and an underground gravel trench system to collect, infiltrate and convey runoff to a treatment wetland.

Initial performance figures indicate excellent water quality results, cost neutral construction and double the sales rate compared to commensurate estates with traditional stormwater treatment.

PRIVATE PROPERTY PIPE CERTIFICATION

Stormwater pollution of waterways as a result of sewer overflows is mainly caused by cracked and leaking pipes and illegal cross connection with stormwater drains on private property. It has been suggested that requiring all urban household sewer and stormwater pipe systems to be certified as being fault free upon sale of property would address this problem. It would put the onus on the household drainage system being maintained by the property owner.

INNOVATIVE MANAGEMENT APPROACHES

The CSIRO has launched a collaborative research project aimed at devising better water, wastewater and stormwater services in urban environments.[143] The program involves

Reviewing the existing system, starting with an analysis of contaminant and nutrient flow in water, stormwater and wastewater. A detailed audit has been conducted of domestic water use that accounts for 70% of urban water use, and an analysis of the life cycle costs of assets.

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[142] *Evangelisti & Associates, Landvision & V.& C. Semeniuk Research Group (1995).* Water resources management study: Middle Canning catchment (stage 1, volume 1). *Perth, p. 98.*
[143] CSIRO develops urban water systems program. *SIA Bulletin,* 62, February 1999, p. 1.

Developing scenarios of the way in which urban water systems might be provided in future. An industry reference group of water company representatives, pipeline manufacturers, environmentalists, regulators, academics and water resource managers works alongside CSIRO scientists to 'reality check' the alternatives, to ensure they are feasible and cost effective. A test site and water model is used to help model theoretical concepts and constraints.[144]

DEMAND MANAGEMENT

Demand management has the advantage of reducing water consumption and hence discharges to waterways. Demand management techniques can include:

- Allowances for stormwater retention & reuse.
- Water saving household appliances.
- Electronic controlled, soil moisture meter sensing irrigation systems.
- Electronic metering & householder information systems.
- Reduction in reticulation water supply pressure/leakage controls.
- Reduction in wastewater generation.

POROUS PAVEMENTS

Using porous paving to increase infiltration in carparks, shopping centres, housing clusters, sports grounds, commercial zones and industrial complexes, can have beneficial effects in the uptake of heavy metals as well as reducing runoff. Extensive testing and field trials in Germany has found that heavy metal concentrations are caught and locked into the upper crevices of the porous pavers, with no impacts from heavy metals causing soil contamination at levels below the prepared sub-grade material.

BIO-BASINS

Bio-Basins are planted and shaded infiltration basins which trap polluted stormwater. The basin surface appears 'dry' as its surface is gravel and there are no ponds for mosquitos to breed. The Bio-basin contains specialised wetland plants that act upon the water pollutants in much the same way they do in natural wetlands. Larger detained pollutant particles settle out to allow the natural bacteria processes to occur.

Bio-Basins are easier to maintain and manage than constructed wetlands, but must be protected from fine sediment loads which could eventually clog the system. The Bio-Basins concept is new, and until some long term monitoring of performance is available, it should be treated as experimental. They could be developed as a hybrid system of infiltration, detention, treatment and reuse storage. Bio-Basins could be placed under car-parks, parklands and garden nature strips, and in dense urban areas, particularly in urban renewal projects where site restrictions limit other water quality management techniques.

[144] *SIA Bulletin*, p. 1.

EDUCATION

MASS MEDIA

A combination of mass media approaches is being used in a number of States to achieve long term behavioral change. Techniques include the use of community advocates, media releases, the Internet, radio talk back, community events and seminars. The needs of regional and ethnic communities are being addressed, as are schools through awareness-raising campaigns on stormwater management.

INDUSTRY PROGRAMS

The key industry targets include:

- Motor vehicle servicing.
- Construction.
- Horticulture.
- Landscaping.
- Painting and decorating.
- Manufacturing.

CASE STUDY: HOLDEN RECYCLED STORMWATER PROJECT
Elizabeth, Adelaide, South Australia

The Holden car plant is part of a project to reduce polluted urban stormwater flowing into the Little Para River, one of South Australia's most stressed waterways. The catchment surrounding the River releases about 300 million litres of untreated stormwater into the Barker Inlet and Gulf St Vincent every year. Barker Inlet is listed under Australia's Directory of Important Wetlands. It is an essential breeding ground for dolphins, fish and shellfish.

The stormwater is being diverted to the City of Salisbury's Karuna Park constructed wetlands for filtration. Clean water will be piped back to Holden and other industries for reuse. Surplus recycled water will be injected into aquifers to meet bore water demand during dry spells.

The Commonwealth is providing $629,000 towards this $3m project under the Cleaning Our Waterways Industry partnership Program in partnership with Holden, the City of Salisbury, the SA Dept of Industry & Trade, and the Northern Adelaide and Barossa Catchment Water Management Board.

The Holden car plant, Adelaide, South Australia.

COMMUNITY EDUCATION

There are a number of examples of successful campaigns that link community action with reducing stormwater pollution. This is in addition to litter reduction programs by the Keep Australia Beautiful Foundation, Tidy Towns, and Clean-Up Australia. Examples are:

- Drain Marking - stencilling messages and symbols on drains as a reminder that pollutants flowing down stormwater systems end up in natural waterways eg. the 'Yellow Fish Road' drain marking program.[145]
- Adopting a creek or waterway - these programs work to link residents of a catchment with business and local government in taking unified protection measures eg. 'Kids, Companies & Creeks' in Sydney.
- Sub-catchment Audits – voluntary participation by businesses in council or water authority audits assists managers identify cleaner production techniques.
- Mass media campaigns - the NSW Stormwater Trust "Drain is Just for Rain" education campaign reports that 9 out of 10 people could now nominate something they could do to prevent stormwater pollution.
- Stormwater pollution monitors - display boards are placed in catchment "hot spots" to indicate storm drain water quality. They can also indicate the amount of pollutants removed from drains by treatment trains.

POLICY CONSIDERATIONS

In its report to the Sustainable Land and Water Resources Management Committee and the Council of Australian Governments (COAG) National Water Reform Taskforce, the CSIRO recommends a range of policy instruments to address the stormwater management problem, including:

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[145] McAlister, Tony (1999). Stormwater reuse - a balanced assessment. In *Stormwater 2000: the green with the gold: conference proceedings 26-28 April 1999*, ed. J.A. Wood. Stormwater Industry Association.

- There should be reform of drainage rating systems so that charges more accurately reflect the costs of stormwater management programs.
- Extensive reform of the institutional structures for stormwater management to complement the corporatisation of water utilities and to create explicit roles for State and Local Government.
- In all jurisdictions, responsibilities at State level for setting the broad water resource and environmental policies affecting the rural-urban fringe, such as environmental quality targets, need to be separated from those of detailed stormwater catchment planning and management undertaken by urban catchment management bodies.
- Stormwater management programs should be established for all major urban catchments. There is a need for stormwater management to be undertaken at either the metropolitan scale or at the major urban catchment scale.
- Urban catchment bodies should have the power to obtain revenue either from local government or though direct charges on the private and public sectors, employ staff and commission works.
- Stormwater targets should be set with reference to the National State of the Environment Reporting System.
- A water quality strategy should identify environmental values and complementary integrated catchment management activities and stormwater infrastructure.
- Among the roles of the Commonwealth should be the provision of grants for capital works that demonstrate methods for integrated stormwater management.

STATE OF ENVIRONMENT REPORTING

National, State and Local Environment Reports can influence stormwater management by targeting the need for integrated planning and monitoring, priority on-ground works, regulatory changes and source control activities.

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