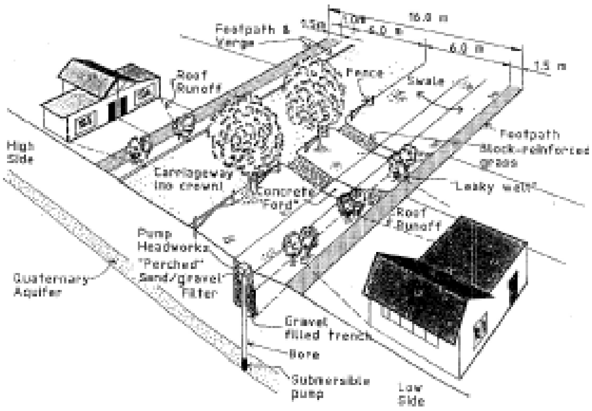
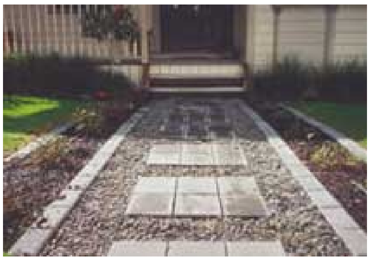
Water Sensitive Urban Design in the Sydney Region

PRACTICE NOTE 1

Water sensitive homes





Water sensitive homes are part of the contemporary trend towards more 'sustainable' solutions that protect the environment. The Water Sensitive Practice Notes series has been prepared to help keep builders, designers, renovators, homeowners and others abreast of this rapidly developing field.

Each practice note provides an overview of the subject, reviews the main design, installation and maintenance issues, gives details of products and includes diagrams, references and useful websites. This Practice Note introduces the whole series.

- **What is a Water Sensitive home?**
- **Why Water Sensitive?**
- **What are the options?**

Water sensitive homes

What is a water Sensitive home?

A water sensitive home is one in which the dwelling and its surrounding land are designed and used so as to minimise harmful impacts on the natural water cycle. It responds to natural site features, takes advantage of nature's own water supply (rain), uses water efficiently and helps keep our rivers and streams in good condition. It can also save money!

Why water sensitive?

Water sensitive homes help to counteract many of the negative impacts of urban development on the natural water cycle, such as increased flooding, accelerated sedimentation, poor water quality in urban watercourses, degraded aquatic systems and the high cost of providing urban water infrastructure. Often these problems have been compounded by traditional stormwater drainage practices.

By incorporating water sensitive measures in the design of new homes and the renovation of existing homes, it is possible to help:

- reduce flood risk in urban areas
- prevent erosion of waterways, slopes and banks
- improve water quality in streams and groundwater
- make more efficient use of water resources
- reduce the cost of providing and maintaining water infrastructure
- protect and restore aquatic and riparian ecosystems and habitats
- protect the scenic, landscape and recreational values of streams.

Differences from traditional practice

Traditional water supply, stormwater and wastewater practices have been largely based on centralised collection, conveyance and treatment of water flows. Whilst highly effective, these methods can also have major drawbacks, such as inefficient use of water resources, environmental degradation and rising infrastructure and maintenance costs.

By contrast, water sensitive urban design emphasises a more decentralised approach that is more attuned to natural environmental processes. It emphases on-site collection, treatment and utilisation of water flows as part of an integrated 'treatment train'.

Elements in the treatment train may include:

- using roof water for toilets, washing machines, garden watering or even hot water systems
- using runoff or wastewater for irrigation
- infiltrating stormwater to underground aquifers (in areas not affected by urban salinity hazard)
- using specially designed landscaping to cleanse runoff and conserve water.

The water sensitive home requires appropriate responses by designers to each individual site. This means that careful consideration must be given to site characteristics such as soil type, slope, water table, rainfall, salinity hazard and the scale and density of development.

New homes

There is enormous scope for designing new homes from scratch so that that they incorporate a variety of water sensitive measures. If designed as part of an overall site strategy, a water sensitive home can be cheaper than a conventional one, particularly when long-term water and environmental costs are considered. Ask your architect or designer to carefully consider these options.

Water sensitive homes

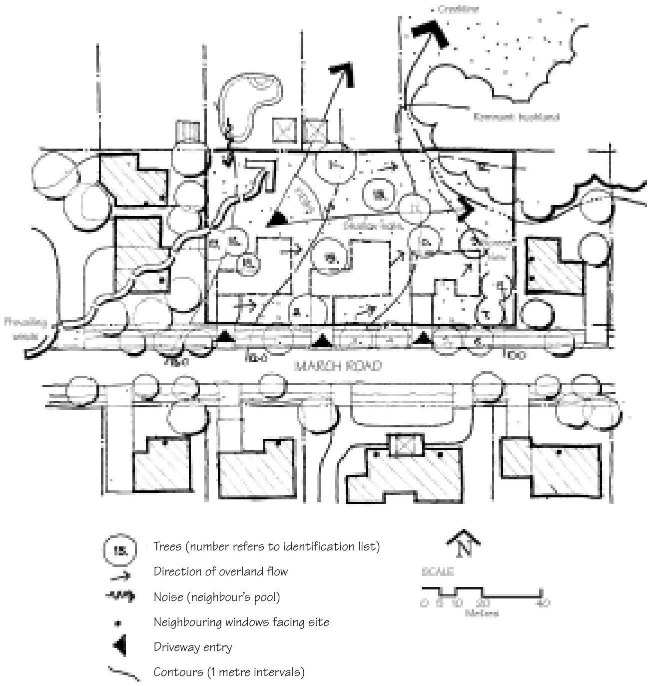
Existing homes

Converting or 'retrofitting' an existing home presents considerably more constraints than designing a new home. Water supply and drainage systems, paved areas and landscaping are already established, and may have many years of useful life left.

However, any renovation work that involves replacement or renewal of these assets should carefully consider the options for installing 'water sensitive' measures such as rainwater tanks, porous paving, filtration/ infiltration devices and landscape measures. Studies show that there can be significant long-term cost savings and environmental benefits.

Site planning

The first rule is *understand the site*! Before deciding where to place buildings, driveways and other structures, the wise designer identifies the opportunities and constraints of the site and integrates them into a 'whole site' approach.



Example of a site analysis plan

This allows existing problems to be dealt with and helps ensure that the final design is in tune with the site, its topography, climate, soils, salinity risk, vegetation and water cycle.

Practice Note 2 explains how to prepare an integrated site plan that responds positively to site constraints and opportunities. It gives a general guide to the wide range of factors that influence the design, layout, construction and on-going use and maintenance of a development site. Of particular interest are five simple design rules for reducing impacts on the site and the water cycle. Also covered are common mistakes and practical tips on how to avoid them.

Drainage design

Stormwater management is a fundamental consideration in the planning and design of urban development. Unfortunately, it is often treated as a subsidiary issue that is not addressed until the final stages of the planning and design process. By considering stormwater and drainage issues at the initial design phase it is possible to ensure viable stormwater management solutions that are compatible with other design objectives for the site.

Conventional drainage practices aim to collect and convey stormwater to the street drainage system with a minimum of nuisance, danger or damage. However, this causes rapid and concentrated stormwater discharges that contribute to increased flooding, erosion and sedimentation, and reduced stormwater quality. These problems can be reduced by alternative measures that delay stormwater discharges and reduce the total volume of stormwater discharged.

Practice Note 3 gives a general introduction to drainage design and the benefits of using alternative stormwater management measures.

Water sensitive homes

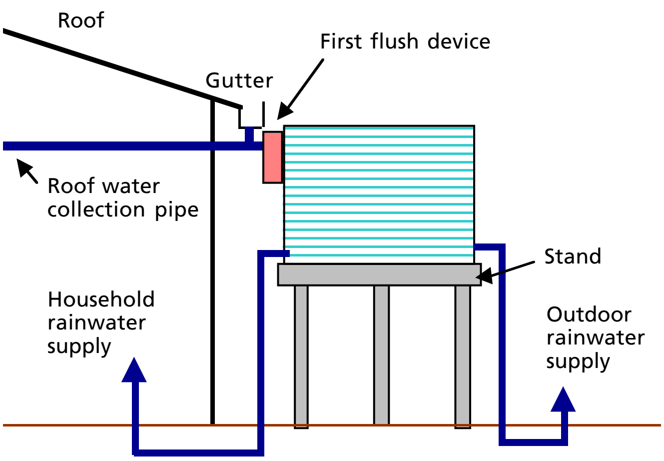
Rainwater tanks

There is currently an enormous resurgence of interest in using rainwater tanks due to their many economic and environmental benefits. Rainwater collected from roofs and stored in tanks is a excellent water source for toilets, washing machines, garden irrigation and even hot water systems. Tanks can be designed not only as a water source, but also to provide temporary stormwater detention.

Tank design generally needs to consider local climatic conditions. However, in urban areas, dual systems that are interconnected with the reticulated water supply are a very practical option that provide an assured supply. Extensive studies have shown that acceptable water quality can be maintained in domestic rainwater tanks in urban areas.

Benefits of rainwater tanks include reduced mains water demand, reduced water supply infrastructure costs, improved environmental flows downstream of water supply dams, and reduced concentration of stormflows in urban streams.

Practice Note 4 describes how to design and configure various types of domestic rainwater tank systems, including gravity systems, pressure systems and dual supply systems.

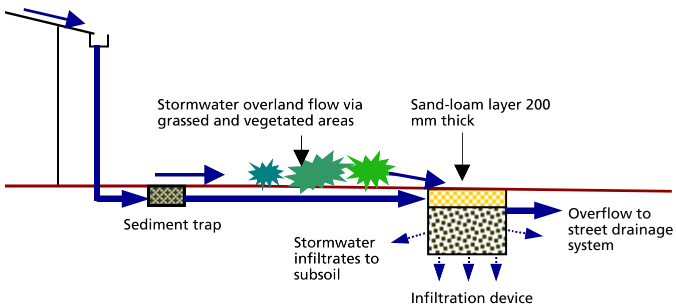


Configuration for a gravity rainwater tank system

Infiltration devices

Infiltration devices allow percolation of stormwater to the surrounding soil, whilst also providing temporary storage of storm runoff. They can have many benefits, including reduced concentration of stormflows, less reliance on piped drainage and increased groundwater recharge.

However, particular care needs to be taken to ensure that infiltration devices are appropriate for the site conditions. Design and placement needs to consider issues such as slope, soil permeability, reactivity to water, soil salinity, water table depth and proximity to buildings. Research has shown that infiltration is a very practical option for managing stormwater provided that these factors are correctly taken into account.



A typical infiltration strategy

Modern infiltration devices are designed and constructed so as to minimise clogging by silt material, and can be designed to overflow to landscaped areas or the street drainage system when their storage capacity is exceeded during major storms. A number of pollutant removal mechanisms operate within these devices, giving significant water quality benefits.

Practice Notes 5 explains how to design and configure stormwater infiltration devices, including leaky wells, retention trenches and infiltration basins.

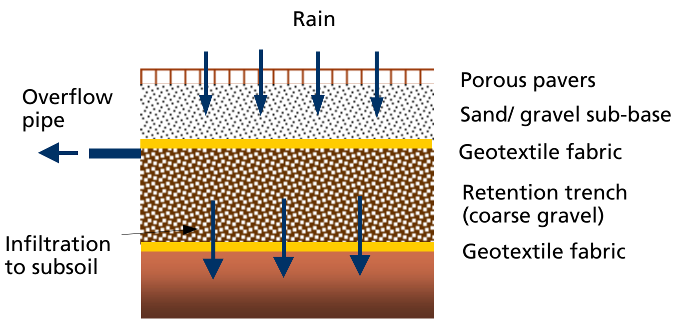
Paving

In urban areas, paved (or 'impervious') surfaces such as roads, driveways and courtyards cover a very significant area. These surfaces have many harmful impacts on the water cycle. They contribute to increased peak and total stormwater discharges, increased downstream flooding, streambank erosion, sewer surcharges, and the need for expensive infrastructure to mitigate nuisance flooding. Paved areas also reduce the volume of rainwater that infiltrates to the subsoil

The impacts of paved surfaces can be reduced by:

- limiting the area of paved surfaces
- directing stormwater runoff from paved surfaces to landscaped areas, gardens and lawns rather than to the street drainage system
- using porous paving systems.

Porous paving allows stormwater to percolate through a hard surface to a sub-base. This acts to filter stormwater.



Grid & modular porous paving system

Benefits include reduced peak stormwater discharges, increased groundwater recharge, improved stormwater quality and multiple-use of paved areas. Design and placement of porous paving needs to consider site conditions such as slope, soil conditions, salinity hazard and traffic volumes. A number of porous paving products are commercially available.

Practice Notes 5 describes a range of paving options that can manage and treat stormwater.

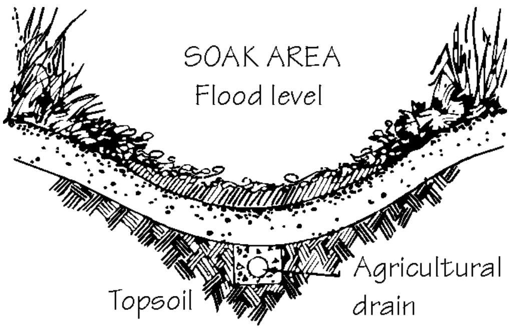
Landscape measures

A wide variety of landscape measures can be used to manage stormwater flows, utilise stormwater within the site, and minimise supplementary watering of landscaping. The careful design and placement of landscape measures can have many benefits for the water cycle, including reduced peak stormwater discharges, increased groundwater recharge, reduced erosion and sedimentation, increased retention of soil moisture and lower water costs. This is in addition to likely aesthetic and ecological benefits.

Practice Note 7 describes a variety of landscape measures, including:

- rock or gravel basins
- vegetated filter strips
- contour banks
- soak or bog areas
- wind and sun protection
- plant selection
- minimising lawn
- efficient irrigation.

For optimal results, these measures need to be undertaken in conjunction with careful site planning and drainage design, as well as appropriate landscape practices.



Soak areas can be designed for natural low points

Water sensitive homes

Landscape practices

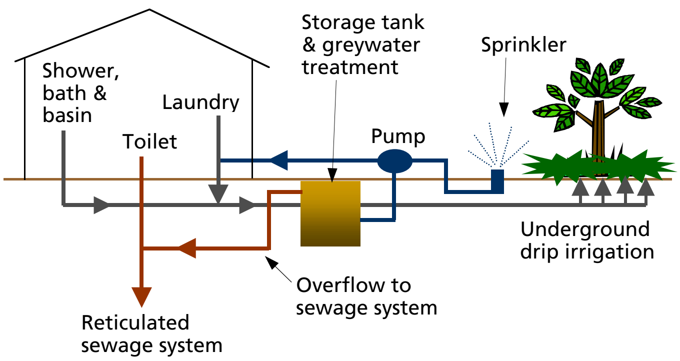
The way in which landscape practices are undertaken can also make a significant contribution to managing soil and water within the site. Relevant issues include soil preparation, planting, ongoing plant care, mulching and maintenance regimes

Practice Note 8 explains how to undertake landscape practices that promote efficient water use as well as good plant growth.

Wastewater reuse

The majority of water used for indoor domestic purposes is discharged after use as 'wastewater'. Wastewater can be collected by a reticulated sewage system and treated at a conventional wastewater treatment plant. Alternatively, it can be collected, treated and re-used on-site, thereby promoting more efficient water use. This has many significant economic and environmental benefits for the community. However, on-site reuse of domestic wastewater is subject to various restrictions due to concerns about effluent quality, maintenance and health issues.

Practice Note 9 gives a general introduction to the options available for on-site waste water treatment and re-use.

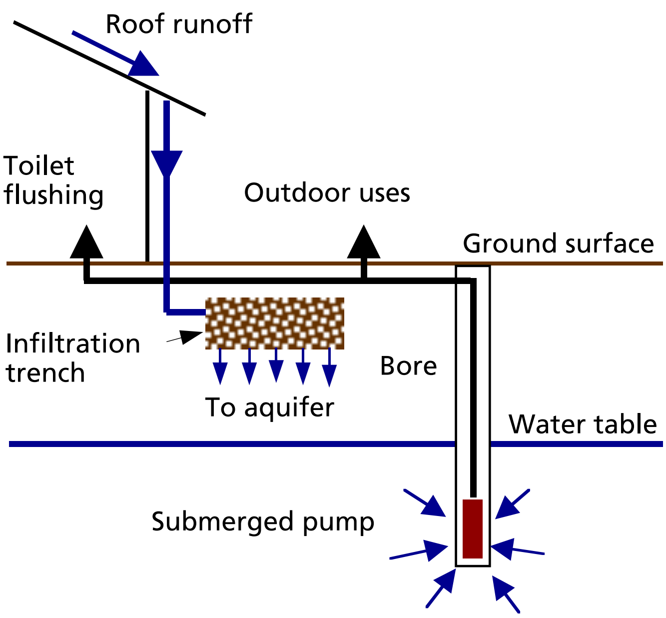


A secondary greywater reuse system

Groundwater

Groundwater extracted from bores can be an important water source for domestic use. Some urban areas occur over a suitable aquifer. Indeed, the use of groundwater in Australia for outdoor purposes is commonplace.

Groundwater quality varies from place to place, and may be unsuitable for domestic purposes. For example, groundwater can be saline or be contaminated by human activity. Where groundwater quality is unsuitable, artificial recharge of stormwater into the aquifer can sometimes be used to produce suitable water supplies. This process is known as aquifer storage and recovery.



Conceptual aquifer storage & recovery scheme

As well as positive benefits, groundwater utilisation schemes have the potential to cause adverse impacts on local groundwater levels and quality. Consequently, specialist advice is required from qualified personnel. In addition, approvals from relevant authorities are also required.

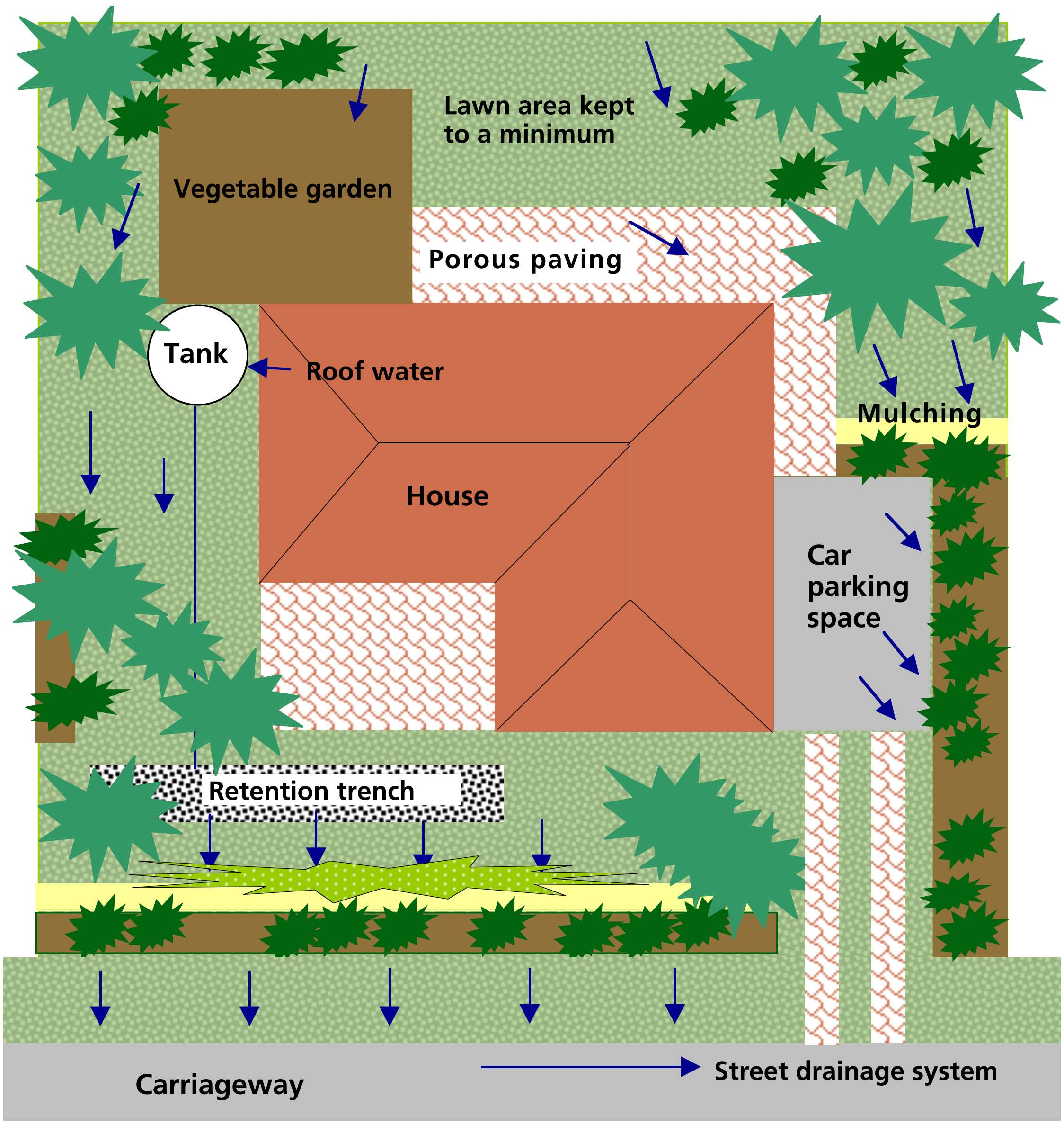
Practice Note 10 gives a general introduction to groundwater utilisation measures.

Water sensitive homes

Preparing an overall strategy

A combination of rainwater tanks, porous paving, filtration/ infiltration devices and landscape measures can be very efficient at reducing stormwater discharge, improving stormwater quality and reducing mains water demand. For maximum effectiveness, these measures need to be carefully designed as part of an overall strategy that considers local site conditions.

The figure below shows a possible overall strategy for a typical suburban home. A rainwater tank supplies rainwater for toilet flushing, washing machine, and for outdoor use. During prolonged or heavy rain, water overflows from the rainwater tank to a retention trench. Stormwater runoff from paths, driveways and lawns is directed to garden areas. Excess runoff from impervious surfaces is directed to the retention trench, or overflows to the street drainage system.



Example of an overall stormwater strategy for a typical suburban dwelling

Other practice notes

The other Water Sensitive Practice Notes in this series provide more detail on each of the topics referred to above. Their titles are:

- No. 2 Site Planning
- No. 3 Drainage Design
- No. 4 Rainwater Tanks
- No. 5 Infiltration Devices
- No. 6 Paving
- No. 7 Landscape Measures
- No. 8 Landscape Practices
- No. 9 Wastewater Reuse
- No.10 Groundwater
- No.11 Development Assessment
- No.12 Urban salinity
- No.13 Compliance mechanisms

To order copies, visit the Water Sensitive Urban Design in the Sydney Region website:

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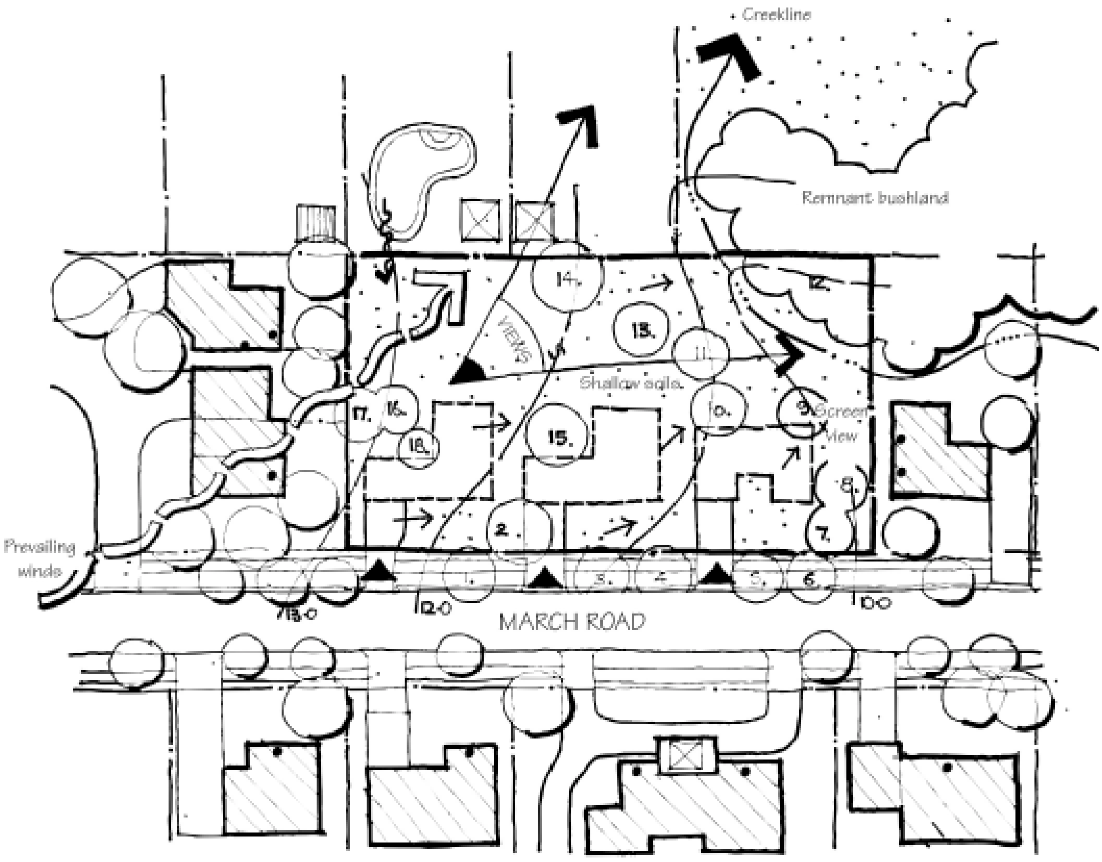
PRACTICE
NOTE 2

Site planning



Water sensitive development involves simple design and management practices that take advantage of natural site features and minimise impacts on the water cycle. It is part of the contemporary trend towards more ‘sustainable’ solutions that protect the environment.

This **Water Sensitive Practice Note** explains how to prepare an integrated site plan that responds positively to site constraints and opportunities.

- **Preparing an integrated site plan**
- **Minimising site disturbance**
- **Common mistakes & solutions**

Site planning

Before you start...

At the earliest stage in deciding where to place buildings, driveways and other structures, always look at the opportunities and constraints of the site and integrate them into a 'whole site' approach. Consider the existing natural features as a resource to be used to advantage, to be retained where possible and to be self-sustaining in the long term. It makes economic sense (cents) and promotes environmental stewardship.

Analyse the site

The first rule is *understand the site*! Collate information on all its natural, constructed and other features. This will help you utilise the site's attributes to best advantage, deal with existing or potential problems and design in tune with the site's soil, vegetation, water and rainfall.

The best way to take a 'whole site' approach is to prepare a Site Analysis. This is required to be submitted with most development applications. A Site Analysis is an essential input to:

- managing stormwater during the construction stage, as summarised in an Erosion and Sediment Control Plan (or Soil or Water Management Plan)
- optimising ongoing water management for the site, as summarised in a Water Management statement (or Integrated Water Cycle Plan).

The following information below gives a general guide to the wide range of factors that influence the design, layout, construction and on-going use and maintenance of a development site. However, not all of the listed matters may be relevant to each individual site. Some of the information will ordinarily be part of the design-and-construct package for residential development (such as survey information for heights and tree location, location of underground services, etc.). Preparing a Site Analysis brings the information together earlier in the design process for greatest benefit.

Consider these factors

Your site analysis should indicate how each of the following constraints and opportunities (where applicable) affect the site.

Landform

- Topography is critical to the design and layout of buildings, stormwater controls and drainage. Show contours (1 metre intervals), survey benchmarks and areas of steep slope (>20%).
- Existing natural features (cliffs, rock outcrops).
- Orientation of site (northpoint, south-facing slopes).

Water

- Sources of water flowing onto the site and the general quality of that water.
- Drainage patterns, areas of concentrated run-off, ponding, flood prone land.
- Adjoining riparian zone if within 40 metres of a waterway.
- Characteristics of the site's downstream catchment (for example, bushland creek, sensitive wetland area, constructed stormwater drainage channel, etc).

Soils

- Depth of topsoil and subsoil.
- Soil (pH) - affects soil micro-organisms and nutrient availability for plants.
- Soil condition, fertility, whether it has been compacted, cut or filled.
- Erosion problems, contamination, potential acid sulfate soils or salinity.

Site planning

Plants

- Undertake a tree and/or bushland survey.
- Existing individual trees, stands of trees and massed shrub planting - show height, spread, condition and species name (common and scientific).
- Trees listed as 'significant' on council register.
- Existing ground levels around the base of trees.
- Weed species present, extent of weed infestation
- Plants that grow well on the site, or that are characteristic of the local area.
- Any threatened species or ecological communities present on the site or nearby land—refer to the local council for information.
- Trees and vegetation proposed to be removed.

Wildlife

- Habitats present on the site or nearby land.
- Potential to provide fauna habitat, such as niches in rockeries, ponds for frogs, habitat plants (nectar-bearing shrubs for small birds).

Climate

- Direction of pleasant and unpleasant summer and winter winds.
- Windbreaks and their likely permanence.
- Frost pockets.
- Areas of full or partial shade in winter and summer at 9am, midday and 3pm.
- Direction and extremity of bushfire threat.

Views

- Good and unsightly views from the site.
- Views into the site and privacy problems.
- Qualities of the site that are important in the view to and from the site (such as major trees).

Existing site features

- Location and uses of any existing buildings and structures on the site showing those to be removed and retained.
- Location and height of walls and fences built to the boundary.
- Heavily shaded areas from existing structures, mature trees or dominant landform, such as rock ledges.
- Archaeological and heritage sites.
- Any easements, rights-of-way and their restrictions.

Services

- Location of existing overhead and underground utility services (electricity, gas, telephone, water, sewer and stormwater drainage lines, inlets and collection points).

Use of adjacent land

- Location and uses of adjacent buildings.
- Rooftop ridge levels and floor levels of adjacent buildings.
- Potential for overlooking into and from window openings in walls adjacent to the development site.
- Potential for shading on adjacent properties.
- The form and character of adjacent and nearby development, including characteristic styles of buildings and landscaping, and bulk and scale of buildings.
- Street frontage features, such as street trees, poles, kerb crossovers, bus stops.
- Potential sources of nuisance dust or noise, such as flight paths, main roads, railway lines, quarries or mines.

Site planning

Planning controls

- Planning objectives, zoning, design criteria, lot size, site coverage and density controls, and other provisions in local environmental plans and development control plans.
- Restrictions on development due to hazards (such as flooding, landslip, land contamination).
- Controls on removing vegetation or trees or on earthworks.
- Building setbacks, building envelopes, height restrictions, view corridors.

Design rules

There are a number of basic rules to consider when preparing an integrated site plan. The emphasis is on minimising the impacts of development, managing construction activities and considering the on-going use and dynamics of the proposed development and the landscape it sits within. Each aspect is interrelated with the others. Adherence to the following principles will make a considerable contribution to reducing impacts on the natural water cycle.

1. Minimise disruption to landforms & drainage patterns

By minimising disruption to landforms and drainage patterns, you can avoid related impacts on vegetation, weed growth and loss of habitat, both on and off the site. Soil surface disturbance creates an immediate potential for:

- loss of topsoil by wind and water erosion
- sediment to be carried away and deposited downstream
- increased soil salinity
- changes to nutrient and moisture conditions in deposition zones – this may make existing plants unsuitable for the conditions, causing native plants to die or not regenerate and allowing weeds to establish and dominate
- long term effects on the pattern of runoff and infiltration for established areas of vegetation, damp spots, creeks and watercourses, thereby causing irreversible changes to natural systems.

2. Minimise disruption to existing vegetation

Maintaining existing vegetation avoids many soil and weed management problems, and helps conserve biodiversity.

- Minimise removal of plants and root systems as this makes the site prone to erosion, and can alter water table levels and cause mobilisation of soil salts in salinity hazard areas.
- Avoid increased light levels on bare soil as this encourages weed growth.
- Maintain the area's full ecological spectrum of plants as this helps to conserve habitats for all sizes of fauna, including insects, lizards, frogs and insectivorous birds. Their disappearance from gardens and their natural ability to help control pests can lead to the reliance on chemical control and detrimental impacts on other natural elements such as soil ecology.

3. Minimise impacts on neighbouring areas

This includes adjoining allotments as well as nearby natural areas, such as bushland areas, creeklines, swamps, lakes, beaches and foreshore areas.

- Consider your site as one part of the whole landscape. For example, large evergreen trees create useful summer shade, but may be unpleasant for neighbours in winter. Large root systems may invade and block leaking drainage pipes or damage driveways and kerbs. Well-placed plantings can protect areas from direct exposure to extremes of sun and wind.
- Avoid impacts on adjoining sensitive environments due to construction works, gradual accumulation of sediment, or exotic plants that become weeds and displace other plants.

- Manage construction works so as to minimise environmental impacts on soil, water, vegetation and air. Limit nuisances such as noise and waste. Make detailed plans to protect the site and adjoining properties prior to commencement of work. This will provide long-term benefits for on-going site use and management.
- Prevent sedimentation in creeks and drainage lines, as this can reduce flow capacity, increase localised flooding and cause property damage.

4. Prevent or repair ongoing problems

Some sites are already disturbed or experience problems caused by external activities. These may include soil loss, sediment deposits, potential acid sulfate soils, soil salinity, weed invasion, or risk from bushfire or other hazards. These must be factored into decisions affecting layout, construction materials and ongoing management.

- Carry out measures to reverse existing damage and control/ prevent further damage (for example, soil conditions or weed invasion).
- Choose building materials and planting species to suit site conditions (such as bushfire hazard and salinity hazard).
- Place pavement areas so as to redirect or reduce impact of large stormwater flows.
- Reduce reliance on supplementary garden watering by species selection and placement, grouping species with similar water needs, creating and utilising micro-climates to advantage, changing maintenance and watering regimes, or other horticultural practices.

For further details, see *Practice Note 2: Landscape Practices* and *Practice Note 3: Landscape Measures*.

5. Consider siting requirements

Buildings, utilities and stormwater measures have particular siting requirements.

- Position and orient buildings to take best advantage of solar access, views, microclimate and natural site features.
- Position driveways so as to minimise gradient. This reduces the velocity of runoff.
- If possible, site water tanks so that water can be fed by gravity.
- Filtration/ infiltration devices need to observe minimum separations from buildings. These vary according to soil conditions.
- Place porous paving in locations that will not receive significant amounts of sediment, debris or other material likely to hinder performance.
- Place landscaped areas in positions that will receive runoff from upstream areas. This will promote infiltration and filtering of runoff.

Special environmental conditions

The following environmental conditions require specific site planning and management responses. Contact your local council for detailed guidance, special requirements, or advice on other matters specific to your site or area.

Steep slopes

The greater the ground slope, the greater the speed of unimpeded stormwater runoff. Use contour banks, landscape mounds, grassed swales or other slope modifications to break the velocity and intensity of stormwater flow.

Soil surface disturbance and loss of topsoil is characterised by slow regeneration and continuing erosion on steeper land. Avoid or minimise ground disturbance, and regenerate ground cover as quickly as possible. For example, reusable organic matting can be used to contain topsoil.

Depending on geological conditions, steep slopes may also be associated with geotechnical instability. This may require soil stabilisation measures.

Site planning

Flooding

Flooding occurs on the floodplains of minor streams and major waterways. Urban drainage systems are also subject to localised flooding. Contact your local council for detailed information about likely incidence of flooding, and suitable flood protection measures, including siting, floor heights, building materials and flood proofing.

Soil salinity

Many areas in the Sydney region are subject to soil salinity hazard, particularly those with heavy clay soils. Development in salinity hazard areas requires special stormwater design measures. Contact your local council for detailed information about the location of salinity hazard areas.

Acid sulfate soils

Acid sulfate soils are widespread in estuarine areas such as mangroves, tidal flats, salt marshes or tea-tree swamps. If potential acid sulfate soils are identified, leave the ground undisturbed so that the acid conditions are not released. A pH of 4 or less allows oxidation to occur. The actual presence of acid sulfate soils can only be identified by detailed soil sampling and chemical analysis.

Bushfire risk

Development adjacent to and within bushland areas is at some risk of bushfire. Site layout, fuel reduced areas, planting 'ember catching screens', strategic placement of plants low in volatile oils, water storage and other techniques can be utilised. These landscape tools can be integrated with building location, design and use of materials so as to reduce the risk of damage.

Design for lifestyle

It is also important to create a pleasant living environment for the occupants. Some issues are common to all residential development irrespective of density. Where possible, consider opportunities for providing:

- outdoor entertainment or barbecue areas
- utility areas for clothes drying or storing waste, compost and recyclables
- access paths
- driveways, visitor car parking (may be available on street) and vehicle turning areas
- car washing bays to trap nutrients and grease, and direct soapy water to lawns or garden areas.

Some issues that should be considered in the site plan and layout are specific to particular lifestyle, age and interests groups. Examples include:

- children's play areas (require flat grassed areas)
- pet dogs (may require fencing to separate from garden beds)
- disabled access (requires graded and sealed paths around the site, and benched seating to give respite).

Over time, different areas may need to be adapted to changed conditions.

Common mistakes & solutions

Siting structures

- Place structures on sites that are already cleared. This will minimise ground disturbance.
- Set structures below the topmost point of a hill to reduce the intensity of wind exposure. Take advantage of established windbreaks or other natural features to create a pleasant microclimate.
- Reduce driveway, paths and other pavement areas to a minimum by re-dimensioning, choosing alternative materials or rationalising the layout so that some become multi-purpose (and more economic to construct).

Water Sensitive Urban Design in the Sydney Region

PRACTICE NOTE 2

Site planning

Minimising cut & fill

- Use natural ground levels where possible for siting houses and other structures.
- Use house construction techniques to accommodate slope (such as pole construction or split level design).
- Use pier-and-beam foundations rather than slab-on-ground construction to minimise ground and tree root disturbance.
- Design driveways to contour around slopes. Use grassed swales to direct flow towards vegetated areas at regular intervals (every 3 metres) as this reduces water volume and requires a smaller depression in the driveway profile.

Managing stormwater

- Slow down flow rates where possible to prevent erosion, promote infiltration and reduce reliance on supplementary watering and irrigation.
- Use permeable paving, pebble paths, infiltration trenches, swales, soakwells, terraced garden walls, mulched garden beds or other landscaping elements to slow down and infiltrate runoff (where soil conditions are appropriate).

Tree loss

- Assess the health, vigour and longevity of existing mature trees at the site planning stage. Existing trees may not tolerate construction activity in the root zone, resulting in decline in tree health, accelerated limb loss, pest and disease attack or complete demise. This can lead to injury or property damage.
- If removing trees, consider planting replacement trees that are deep-rooted species: This will help:
  - lower the water table and assist with problems of soil salinity
  - bind the soil and reduce soil erosion
  - decrease run-off velocities
  - filter nutrients and capture sediment.

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For further references, see Practice Note 7.

Other practice notes

Other Water Sensitive Practice Notes are available in this series:

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Site planning

Water Sensitive Urban Design in the Sydney Region

PRACTICE NOTE 3

Drainage design

Water sensitive development involves simple design and management practices that take advantage of natural site features and minimise impacts on the water cycle. It is part of the contemporary trend towards more 'sustainable' solutions that protect the environment.

This Water Sensitive Practice Note gives a general introduction to drainage design and the benefits of using alternative approaches.

- **Analysing the site**
- **Conventional site drainage**
- **Alternative strategies**

Drainage design

Introduction

Stormwater management is a fundamental consideration in the planning and design of urban development. Unfortunately, it is often treated as a subsidiary issue that is not addressed until the final stages of the planning and design process. By considering stormwater management at the initial design phase it is possible to ensure viable stormwater management solutions that are compatible with other design objectives for the site.

Site analysis

The best way to take a 'whole site' approach is to prepare a Site Analysis. For details, see *Practice Note 2: Site Planning*. Issues particularly relevant to drainage design are described below.

The site's topography will have a significant impact on the layout design. This is because stormwater drainage systems almost always rely on gravity. The layout of the development must be configured so as to allow excess stormwater to be gravity-drained to a drainage system.

Topography will also affect runoff onto the site from surrounding properties. Existing overland flow paths should be identified and retained. Where modifications to these are unavoidable, they should be designed so as to maintain existing hydrological conditions.

Drainage easements, natural watercourses and flood prone land should also be identified and considered in the design process. It needs to be borne in mind that drainage easements containing underground pipes can operate as overland flow paths during intense rainfall events. Buildings must be kept clear of drainage easements to ensure public safety and to allow maintenance access.

Consideration also needs to be given to local soil conditions. Relevant factors include absorption capacity, erosion potential, soil salinity and the possibility of soil contamination from past activities.

Adjoining properties

One of the basic principles of stormwater management is to avoid adverse stormwater impacts on other properties. Careful consideration must be given to controlling surface runoff and subsoil drainage to adjoining properties.

The redirection and concentration of stormwater flows onto neighbouring properties may constitute a 'nuisance' at common law, giving affected owners a legal right of redress.

Public safety

Stormwater runoff from rare and intense storm events can pose serious risks to life and property. It is essential that the design of overland flow paths, on-site detention storages and other stormwater management measures meet relevant safety criteria for pedestrians, vehicles and property damage.

Buildings and accessways should be located clear of overland flow paths, or designed to be compatible with the potential flood environment. Fencing and landscaping should be designed so as to minimise the potential for overland flow paths to be obstructed during rare and intense storm events.

Relevant design criteria can be obtained from your local council.

Floor levels & freeboard

Floor levels of habitable buildings must be designed so as to be above the expected water levels for overland flow paths, detention storages and flood prone land. Allowance also needs to be made for 'freeboard'. This is an additional vertical separation between the expected water level and the floor level, the value of which varies according to local conditions and the particular type of flood risk. Floor level and freeboard requirements can be obtained from your local council.

Conventional approaches

Conventional drainage practices generally involve rapid discharge of stormwater from the site to a public drainage system. These practices are described in detail in numerous publications (see references). The main objective is to collect and convey stormwater to the street drainage system with a minimum of nuisance, danger or damage. Roof runoff is discharged via small diameter pipes (usually 100 mm diameter), and surface stormwater is usually conveyed by overland flow. The public drainage system usually consists of a system of gutters, streets, pipes, culverts and channels owned and operated by the local council or other authority.

Where the site slopes towards the street, roof runoff and overland flow are drained directly to the street drainage system (see Figure 1). Where the site slopes away from the street, these are connected to the street drainage system or a receiving waterway via a drainage easement at the rear of the property (see Figure 2). The drainage easement generally incorporates a drainage pipe, and may also include a table drain on the ground surface for the collection of overland flow.

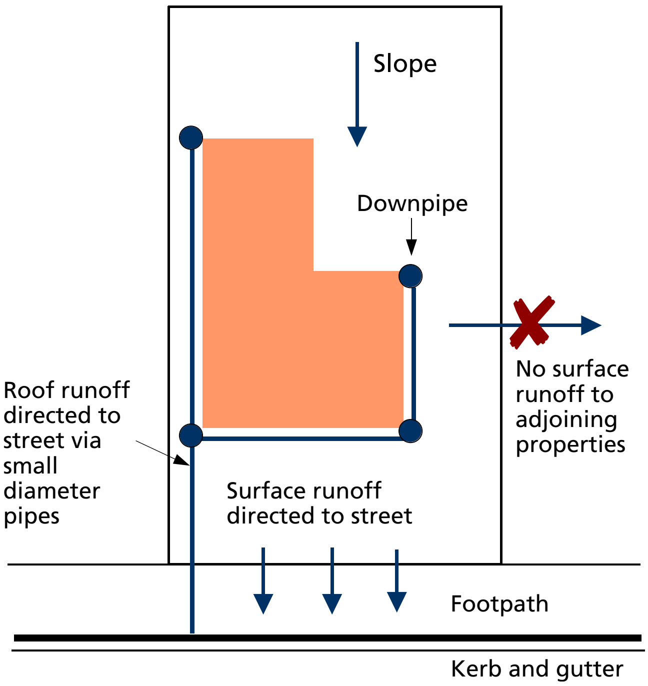

Fig 1: Conventional drainage - to street

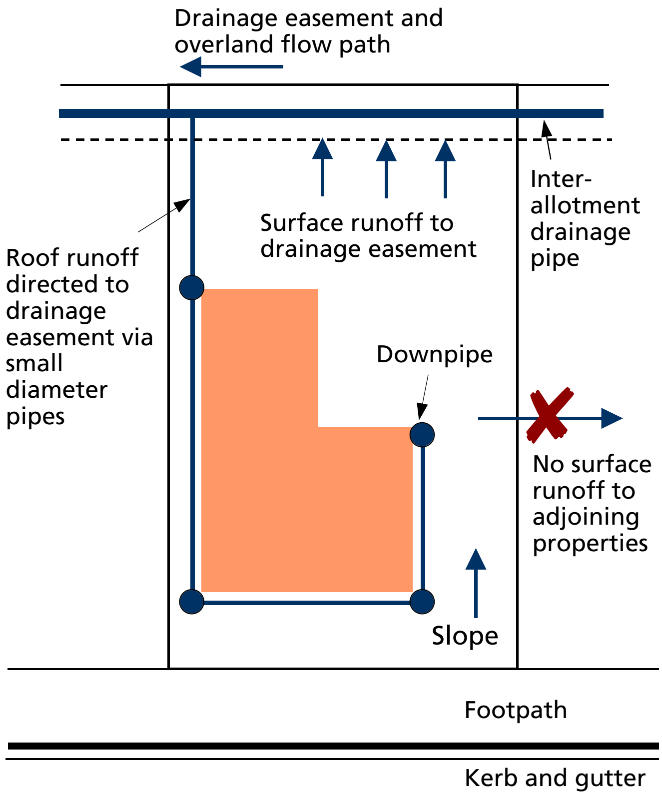

Fig 2: Conventional drainage - to rear of property

Problems with conventional practice

The majority of stormwater runoff in urban area is from impervious surfaces such as roofs, paved areas and roads. Except in the case of major storms, little or no runoff occurs from pervious surfaces such as lawns, gardens and landscaped areas. Urbanisation has dramatically increased the area of impervious surfaces. This in turn has resulted in increased peak discharges and greater volumes of runoff per storm.

The direct discharge of roofwater and overland flow to the street drainage system under conventional drainage practices causes rapid and concentrated discharges of stormwater. This contributes to increased flooding, erosion and sedimentation, and reduced stormwater quality. These problems can be reduced by measures that delay stormwater discharges and that reduce the total volume of stormwater discharged.

Drainage design

What's the alternative?

Alternative stormwater management measures, when used in conjunction with conventional practices, have many cost, aesthetic and environmental benefits. For example, roof runoff can be managed using rainwater tanks and filtration/ infiltration trenches. Paved areas can be minimised or replaced with porous paving. A variety of landscape measures and practices can also be applied. These measures reduce the volume of stormwater runoff and the rate at which it is discharged. Figure 3 shows how these measures can be combined on a typical residential lot. For further details on how to implement these measures, see the other Practice Notes in this series.

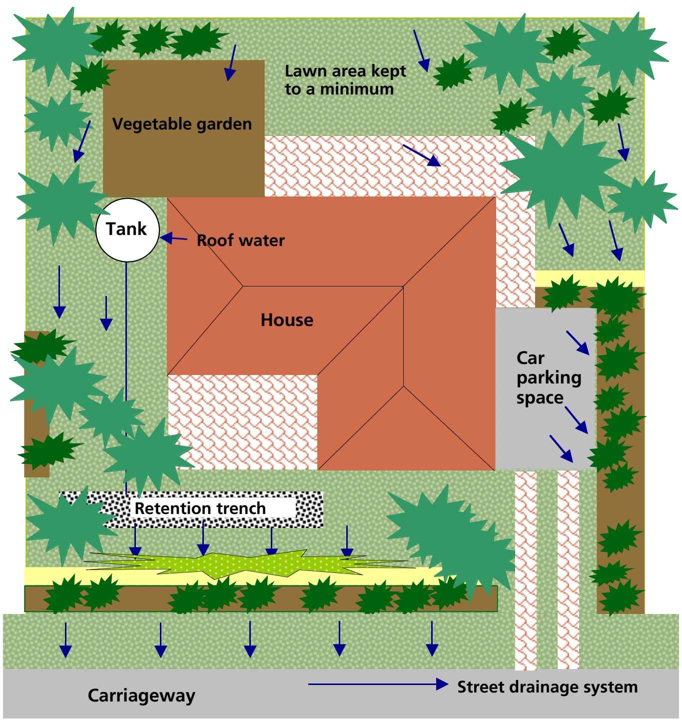

Fig 3: Example of an alternative drainage strategy

Useful websites

www.wsud.org

www.dbce.csiro.au/urbanwater

www.catchment.crc.org.au

www.eng.newcastle.edu.au/~cegak/Coombes

References

Argue, J.R. (1986). *Storm Drainage Design in Small Urban Catchments: a Handbook for Australian Practice*. (Special Report No. 34), Australian Road Research Board.

Argue, J.R. (2002). *On-site Retention of Stormwater: Introduction and Design Procedures*. Urban Water Resources Centre, University of South Australia, Adelaide.

Carleton, M.G. & Ing (1992). 'Stormflow reduction using site infiltration-detention', *Proc. International Symposium on Urban Stormwater Management*, Sydney, The Institution of Engineers, Australia.

Institution of Engineers Australia (1987). *Australian Rainfall and Runoff: A Guide to Flood Estimation*. 2 Volumes. IEA, Canberra.

Other practice notes

Other Water Sensitive Practice Notes are available in this series:

No. 1	Water Sensitive Homes
No. 2	Site Planning
No. 3	Drainage Design
No. 4	Rainwater Tanks
No. 5	Infiltration Devices
No. 6	Paving
No. 7	Landscape Measures
No. 8	Landscape Practices
No. 9	Wastewater Reuse
No.10	Groundwater
No.11	Development Assessment
No.12	Urban salinity
No.13	Compliance mechanisms

To order copies, visit the Water Sensitive Urban Design in the Sydney Region website:

www.wsud.org

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Water Sensitive Urban Design in the Sydney Region

PRACTICE NOTE 4

Rainwater tanks

Contents

Water sensitive urban development involves simple design and management practices that take advantage of natural site features and minimise impacts on the water cycle. It is part of the contemporary trend towards more 'sustainable' solutions that protect the environment.

This **Water Sensitive Practice Note** explains how to design and configure domestic rainwater tanks.

Rainwater tanks

Introduction

This Practice Note describes how to design and configure various types of domestic rainwater tank systems, including gravity systems, pressure systems and dual supply systems. There is currently a resurgence of interest in using rainwater tanks to partially supply domestic water demand in urban areas. This has followed increasing recognition of their environmental, stormwater management and water conservation benefits, as well as recent government policies to address urban water shortages, such as the Building and Sustainability Index (BASIX).

Urban water demand is typically met by importing large volumes of treated water from rivers and aquifers in neighbouring catchments, often across long distances and at considerable cost. At the same time, similar volumes of roof water are discarded unused via stormwater drainage systems that contribute to pollution of urban waterways, erosion, sedimentation and flooding impacts.

Whilst all mains water is treated to drinking water standards, as little as 1% of domestic water consumption is actually used for drinking. Toilet flushing, laundry, outdoor uses and hot water represent the bulk of domestic water consumption (about 85%). In most cases, these uses do not require water to be treated to such a high standard and can often be supplied at required water quality standards via a rainwater treatment train. Benefits include significant reductions in mains water consumption and substantial reductions in stormwater discharges.

Figures 1 and 2 show the proportions of household water used for various purposes in Sydney during 2003. The Figures reveal that drinking water is a very small proportion of total household water use. An effective strategy for use of rainwater that targets household water consumption types with greater volumes and frequency of water use, such as outdoor, toilet, washing machine (laundry) or hot water uses will significantly reduce mains water consumption.

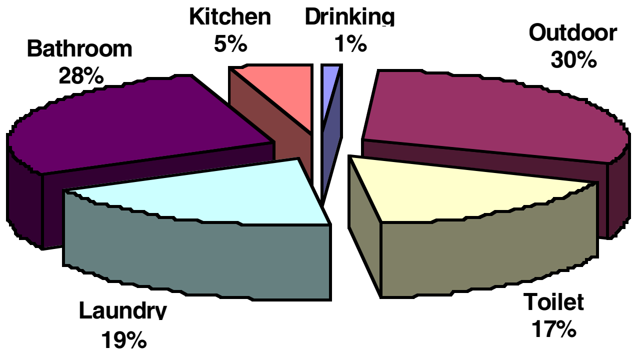

Fig 1: Single household water use categories

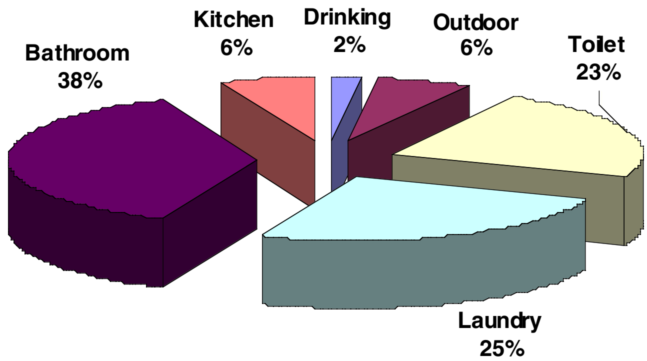

Fig 2: Multi-unit water use categories

It is incorrect to assume that using rainwater to supply outdoor uses alone will produce substantial mains water savings. The mismatch between seasonal rainfall and outdoor water use patterns often results in poor utilisation of rainwater resulting in long periods where rainwater tanks are full. This problem can be remedied by using rainwater to supply constant indoor uses such as toilet flushing, washing machines (laundry) and hot water that will consistently draw down the rainwater tank allowing rainwater to refill the tank more often. Combinations of different water use frequencies from rainwater tanks such as toilet flushing and outdoor uses can result in optimum mains water savings and large reductions in stormwater discharges.

System overview

Rainwater harvesting systems and treatment trains can include a variety of elements that can be chosen to suit the desired domestic rainwater uses. Principal elements (as shown in Figure 3) include:

- roof gutters
- first flush device or filter sock
- rainwater tank
- leaf diverters
- pump
- inline filter or UV disinfection
- overflow to garden areas, infiltration trenches and street drainage system.

The choice of elements used is optional, and is dependent on user choice and the intended use of rainwater. For example, a rainwater treatment train for supply to outdoor and toilet uses could comprise a leaf diverter (in areas with trees), a rainwater tank and a pump, whilst a treatment train for supply to laundry, toilet, hot water and outdoor uses could comprise a leaf diverter, a first flush device, a rainwater tank and a pump. However, a rainwater treatment train that supplies all household water demands might also include a first flush device to remove sediments, with an inline filter and UV disinfection on the drinking water supply line. Note that the NSW Department of Health does not prohibit the use of rainwater for any household purpose, but recommends that an adequately treated reticulated water supply should be used for drinking purposes where available.

Depending on site conditions, user requirements and budget, rainwater tank systems can be installed using a variety of different configurations, including:

- installation of tanks above or below ground
- using gravity or pressure systems
- using dual water supply systems
- including a detention volume inside the tank for additional stormwater management.

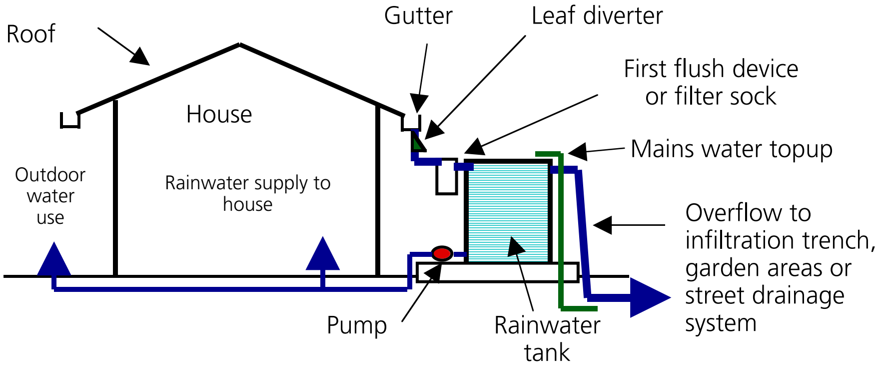

Fig 3: Elements of a domestic rainwater system (the rainwater treatment train)

Dual supply systems

A dual water supply system utilises both rainwater and mains water. In this system, a rainwater tank can be topped up with mains water when the tank level is low (due to dry weather or high usage). This ensures a reliable water supply, whilst also providing significant mains water savings and stormwater management benefits.

Required tank capacity will depend on the number of persons in the household, water use, rainfall and roof area. In areas with mains water supply available, rainwater tanks with capacities of 1,000 – 5,000 litres are generally sufficient. Smaller tank sizes can also provide considerable benefits. When designing the tank system, provision should be made for each of the following storage components (see Figure 4):

- minimum storage (or mains water top up zone) to ensure that water supply is always available
- rainwater storage zone
- air gap for additional stormwater management and backflow prevention
- anaerobic zone (water is drawn from above this zone to ensure that it is free of sediment).

Rainwater tanks

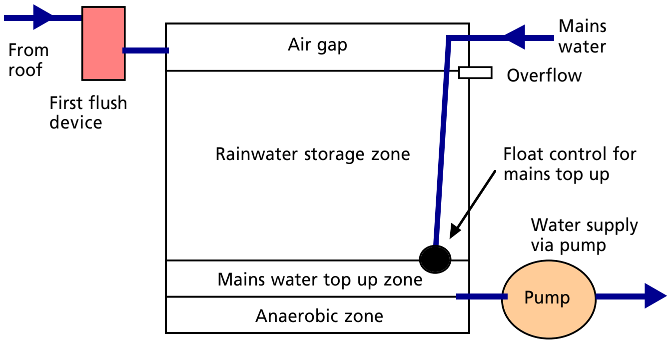

Fig 4: Storage components for a dual supply system

The minimum storage volume (mains water top up zone) is usually the maximum daily water use that is expected from the tank, less the potential daily top up volume of mains water (about 250-750 litres). If the volume of stored water falls below the minimum storage volume, the shortfall can be overcome by topping up the tank with mains water to the required level. A simple float valve system can be installed to do this automatically.

The rainwater storage zone comprises the total volume available in the tank to store rainwater below the overflow pipe. The air gap between the overflow pipe and the top of the tank can be used to provide 'stormwater detention', thereby delaying the delivery of excess roof water to the drainage system. The rainwater storage zone and the overlying air gap provide both stormwater retention and detention. Note that the air gap provides the highest level of backflow prevention in accordance with Australian Standard ASNZ3500.1.2.

Figure 5 shows the configuration for a dual water supply system with mains water trickle top up.

Tank water is directed to indoor and/or outdoor fixtures via a small pump. When tank levels are low (such as during prolonged dry weather), the tank is topped up with mains water via a trickle system. This reduces peak demand on the mains water distribution network. The tank can be bypassed in the event of a pump or power failure. Australian Standards and national practice allows an internal top up arrangement for rainwater tanks, however Sydney Water Corporation currently requires an external top up system to be installed. Note that plumbing requirements for installation of dual water supply systems (rainwater and mains water) are subject to variation. The reader is advised to check the plumbing guidelines provided by Sydney Water Corporation (*Guidelines for Rainwater Tanks on Residential Properties*) and by the Committee on Uniformity of Plumbing and Drainage Regulation in NSW (*Guidelines for Plumbing Associated with Rainwater Tanks in Urban Areas Where a Reticulated Potable Water Supply is Installed*).

A dual water supply system may also include a mains water bypass system rather than a mains water trickle top up arrangement. In this system a solenoid valve is used to switch between mains and rainwater supplies. When the rainwater storage is empty or in the event of a pump or power failure, the solenoid valve is open allowing all household water demand to be supplied with mains water. If rainwater is available in the tank the solenoid valve is closed allowing the pump to deliver rainwater to the household (see Figure 6).

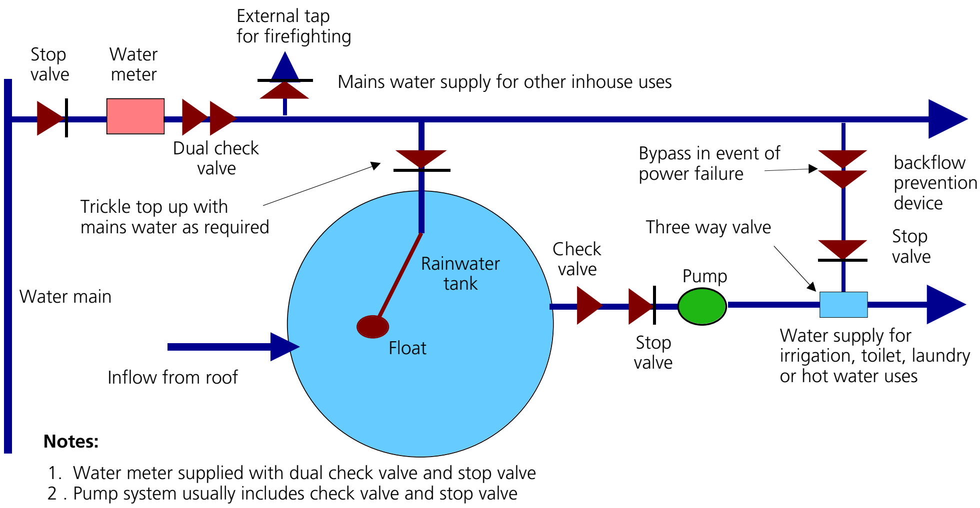

Fig 5: Configuration for a dual supply system with mains water trickle top up

Rainwater tanks

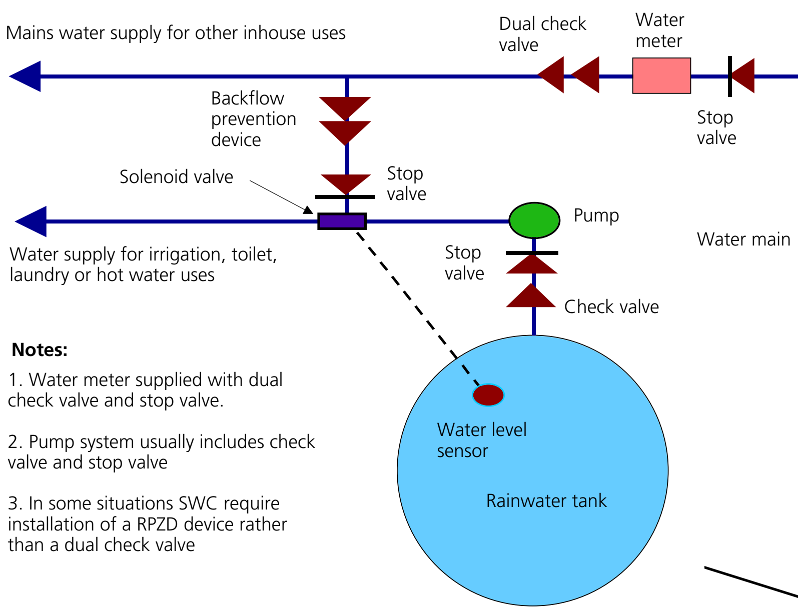

Fig 6: Configuration for a dual supply system with mains water bypass

Note that Figure 6 shows the use of two backflow prevention devices (as does Figure 5). In some cases Sydney Water Corporation may require the installation of a Reduced Pressure Zone Device (RPZD) for backflow prevention when the bypass configuration is employed. An RPZD will be required by Sydney Water for dual supply systems where an underground tank is installed.

Although it is commonly perceived that a rainwater tank will take up a large amount of allotment area, the reality is quite different with a 1,000 litre tank occupying an area less than 2 square metres and a 5,000 litre tank occupying an area of about 2 - 3 square metres.

Pressure systems

A pressure system involves using a pump to deliver rainwater to household or garden fixtures. Pressure systems are required where the tank cannot be installed at a sufficient height to provide acceptable pressure (see Figure 3), or if the tank is installed underground (see Figure 7).

Gravity systems

The installation of a rainwater tank system that relies on gravity to supply rainwater to the household and the garden will involve placing the rainwater tank on a stand or at a height greater than intended end uses as shown in Figure 8. The use of gravity to supply rainwater at low pressure to the household is common in rural areas and for the use of small rainwater tanks that supply outdoor and/or indoor water uses in urban areas.

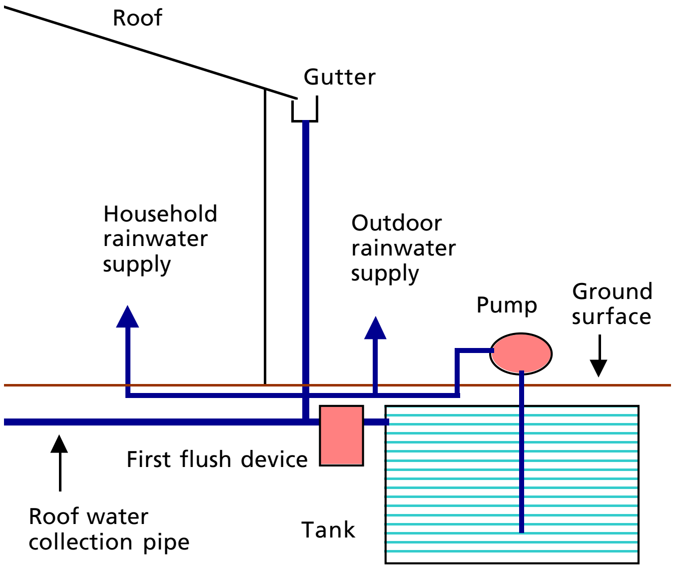

Fig 7: Configuration for a pressure system on an underground rainwater tank

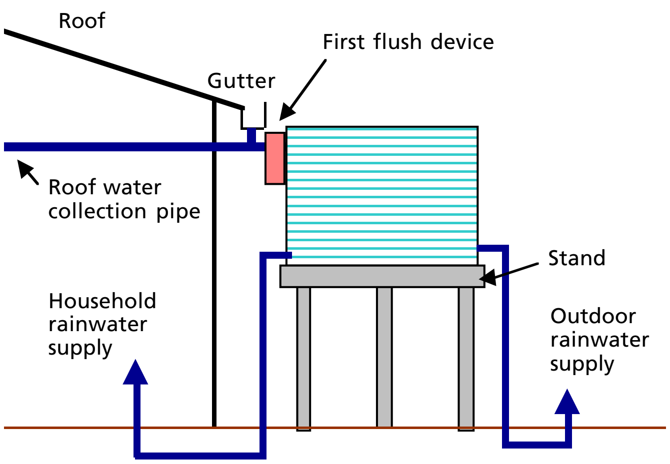

Fig 8: Configuration for a gravity system

Rainwater tanks

In a gravity system, rainwater is collected from the roof and directed to the tank. All connections to outdoor and household fixtures depend on gravity alone. Water pressure at each fixture is governed by the difference in height between the tank and the fixture.

To achieve a water pressure similar to that of normal mains water, the tank needs to be positioned at least 20 metres vertically above fixtures. This is generally not practicable. However, many household water uses such as toilets, laundry tubs and garden hoses do not require such high water pressures. Gravity systems are often adequate for these purposes.

First-flush devices

A first-flush device separates the first part of rainfall from entering the rainwater tank (see Figure 9).

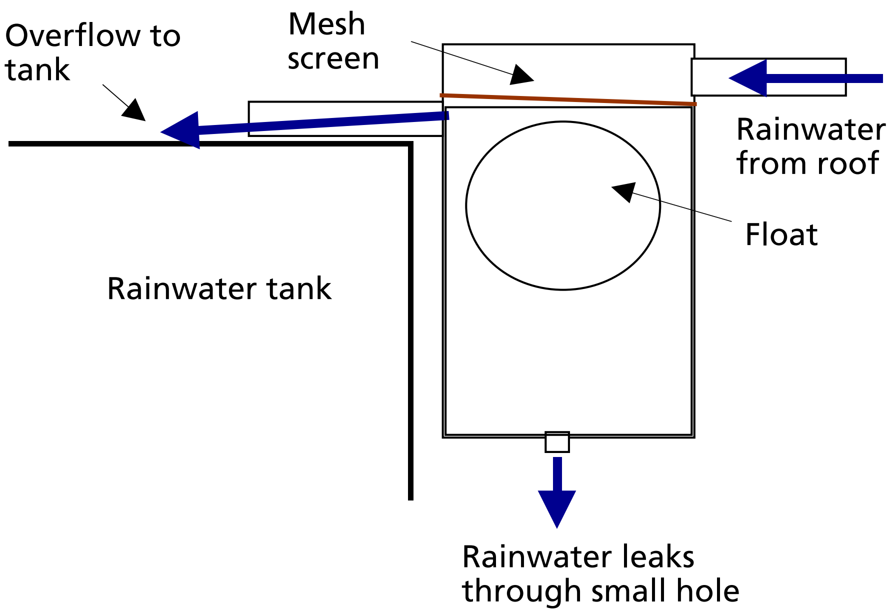

Fig 9: Basic design features of a first flush device

The use of a first flush device will prevent some of the sediment and debris from roofs or gutters from entering the rainwater tank. The device operates by filtering roof runoff through a mesh screen to capture leaves and debris. The first part of runoff is stored in the chamber to slowly trickle through a small hole whilst cleaner water at the top of the chamber passes into the rainwater tank.

The performance of first flush devices has often been misunderstood. Research from the University of Newcastle shows that first flush devices with capacities of up to 20 – 25 litres are successful at separating significant proportions of sediment and debris from rainwater. Larger first flush devices do not produce considerable additional improvement in rainwater quality. Indeed large first flush devices dramatically reduce the volume of rainwater that gets into a tank.

Note that a number of variations on the design shown in Figure 9 are available, as are alternative methods of removing sediment and debris from rainwater (such as filter socks).

Roofs & gutters

Rainwater collected from roofs painted with lead-based or tar-based paints, or from asbestos roofs should not be used for drinking water supplies. Galvanised iron, Colorbond™, Zincalume™, slate or ceramic tiles provide acceptable water quality. *Australian Standard AS4020 Products for use in Contact with Drinking Water* provides guidance on acceptable materials for roof catchments that supply drinking water. Special roof guttering is not required. Normal guttering is sufficient provided that gutters are kept clear of leaves and debris.

Water quality

There is growing scientific evidence to confirm traditional knowledge and practice that water sourced from rainwater tanks is acceptable for most household uses. For example, research undertaken by the University of Newcastle has shown that domestic roof water stored in rainwater tanks is of acceptable quality for toilet, washing machine (laundry), hot water and outdoor uses. The processes improving rainwater quality in the rainwater treatment train include:

- exposure to ultra violet light, heat, and desiccation on the roof top destroy bacteria
- first flush devices or filter socks can limit the transfer of sediment and debris to rainwater tanks
- mesh screens on all inlets and outlets to rainwater tanks will exclude animals from entering tanks, thereby minimising the possibility of harmful bacteria entering tanks
- most bacteria in rainwater tanks are trapped at the water surface
- settlement processes remove sediments, metals and bacteria from rainwater
- biofilms (slime) and sludge in the tanks remove organics, bacteria and metals from rainwater
- hot water systems and pumps may also help eliminate bacteria from rainwater supplies.

This research has also revealed that rainwater used in hot water systems is compliant with the *Australian Drinking Water Guidelines* provided that temperature settings greater than 50°C are maintained. Laboratory experiments also established that bacteria and pathogens are rapidly eliminated from water heated to 60°C. This result is consistent with the requirements of Australian Standard AS3500.2.4 that domestic hot water systems should be set at 60°C to eliminate bacteria from mains water systems, and that hot water should be delivered to the house at a non-scalding temperature of 50°C. Pathogens are not commonly found in rainwater tanks (Cunliffe, 2004).

It is not recommended that rainwater be used for drinking in high density urban areas unless it is passed through an approved filtration or disinfection system. Such a system should be sufficient to remove possible residual contamination from accumulated soil and leaves in gutters, faecal material (deposited by birds, lizards, rodents and possums) and dead animals on roofs or in gutters that may not be removed from the rainwater treatment train. Acceptable water quality can be maintained by:

- installing mesh screens over all inlets and outlets to prevent leaves, debris and mosquitoes from entering the tank
- installing a first-flush device or a filter sock to remove a proportion of sediment and debris from roof water
- regularly removing leaves and debris from roof gutters
- only cleaning rainwater tanks when sediment levels become unacceptably deep
- drawing water from the tank above the anaerobic/ sediment layer
- ensuring that the hot water service is set at 60°C (where rainwater is used in hot water system).

Regulatory issues

Health departments

State government health departments do not prohibit the use of rainwater for drinking or other purposes. However, they do recommend proper use and maintenance of rainwater tanks, and provide various guidelines, particularly on drinking water quality (see Cunliffe, 2004). No guidelines exist for outdoor, toilet, laundry and hot water uses. The NSW Health Department does not recommend the use of rainwater for drinking in urban areas where an adequately treated reticulated water supply exists. The Commonwealth Government's *EN Health Guidelines* provide advice on the management of rainwater tanks.

Rainwater tanks

Water supply authorities

Water supply authorities cannot prohibit the use of rainwater on private land. However, they do require the installation of an appropriate backflow prevention device to prevent possible contamination of mains water by rainwater. Sydney Water Corporation provides guidelines for plumbing configurations of rainwater tanks on residential properties (see www.sydneywater.com.au).

Local councils

Rainwater tanks and stormwater retention devices may require development consent if they exceed certain requirements relating to size, height, siting and other matters, as specified in the 'exempt development' provisions under State Environmental Planning Policy No.4. Local councils usually require that the plumbing configurations for rainwater tanks are consistent with the requirements of the Committee for Uniformity of Plumbing and Drainage Regulations (CUPDR). Note that CUPDR Circular 18 addresses the installation of rainwater tanks. If a development application is required (for example, for a tank with a capacity exceeding 10,000 litres), details should be provided as to:

- location and relationship to nearby buildings
- configuration of inlet, outlet and overflow pipes
- storage capacity, dimensions, structural details and proposed materials
- the purposes for which the stored water is intended to be used.

For further details, contact your local council.

Design standards

Chapter 7 of the *Australian Drinking Water Guidelines* (NHMRC, 2003) contains guidance on the management of small potable water supplies. Cunliffe (2004) provides a complete coverage of the topic. There are no recognised standards for the use of rainwater for secondary quality purposes.

Australian Standard *AS/NZ 3500.1.2-2003: National Plumbing and Drainage - Water Supply - Acceptable Solutions* provides guidance on the design of rainwater systems. The standard categorises cross connection between mains water supply and a domestic roof water tank as a low hazard connection. This requires a non-testable backflow prevention device (such as a dual check valve). If a higher level of backflow prevention is required for a greater hazard rating the following approaches can be used:

- no physical connection between the tank and the mains water system
- an air gap
- an approved backflow prevention device.

An air gap refers to a physical separation between the mains water and rainwater supplies within or above the tank. This is a simple, reliable and maintenance-free solution. Testable backflow prevention devices such as RPZDs are mechanical devices that separate mains and other water supplies. Testable devices require regular servicing. Australian Standard AS/NZ 3500.1.2-2003 provides guidance on the design of dual supply systems that utilise an air gap or a RPZD. An RPZD is required by Sydney Water for dual supply systems where an underground tank is installed. The CUPDR circular 18 and the Sydney Water Corporation *Guidelines for Rainwater Tanks on Residential Properties* also provides advice on plumbing configurations for rainwater tanks. *Australian Runoff Quality*, published by Engineers Australia, also provides guidance on the use of rainwater tanks.

Rainwater tanks

Materials & products

Concrete

Concrete tanks can be purchased in a ready-made form or constructed on-site. They can be placed above or below ground. Concrete tanks can be subject to cracking although careful construction techniques will minimise the potential.

Fibreglass & plastic

Fibreglass tanks are constructed from similar materials as fibreglass boats and can be used in above-ground installations. Plastic or poly tanks are constructed using food-grade polyethylene that is UV stabilised and impact modified. These tanks are strong and durable. They can be used above or below ground depending on their design.

Metal

Galvanised iron tanks are constructed from steel with a zinc coating, and can be used in above-ground installations. These tanks are strong and durable, but can be subject to corrosion if copper pipe for the household water service is directly connected to the tank. The first section of plumbing connected to the tank should be UPVC or other non-metallic material. Zincalume™ tanks are constructed from steel with zinc and aluminium coating. They are similar to galvanised iron tanks.

Aquaplate™ tanks are made from Colorbond™ lined with a food grade polymer. They can be used in above-ground installations. These tanks are strong, durable and corrosion resistant. When cleaning the tank, it is important to avoid damaging the polymer lining.

Maintenance

A rainwater tank system requires very little maintenance provided that the tank is correctly installed. Regular maintenance tasks are:

- cleaning the first flush device every 3-6 months
- removing leaves and debris from gutters and the inlet mesh on the tank every 3-6 months
- checking sediment level in the tank every 2 years.

Tanks require occasional cleaning. The frequency of cleaning will depend on the amount of sediment and debris that enters the tank. A first flush device and adequate mesh screens on all tank inlets and outlets will ensure that the majority of sediment and debris does not enter the tank. This will reduce the frequency of cleaning to every 10 years or so.

Costs & savings

Tank costs vary from place to place. Indicative 2004 prices (without installation) are as follows.

Material	Capacity (litres)					
	500	1,000	2,400	3,200	4,500	9,000
Aquaplate™ round	$250	$380	$670	$765	$795	$1,535
Aquaplate™ slimline	$285	$775	$1,466	$1,555	$1,685	-
Polymer	$340	$462	$530	$750	$950	$1,460
Concrete	-	-	-	-	$1,500 - $5,000	$2,300 - $7,500

Small household pumps with pressure control can be purchased for $340 to $620.

Installation costs for rainwater tanks can be highly variable. The cost to fully install a 4,500 litre above ground rainwater tank for indoor and outdoor use can range from $1300 to $3,500. Underground installation will usually add about at least $2000 to the cost. This system can provide the home owner with water savings of about $50 to $110 per year, reduce stormwater discharges to the environment, reduce water demand on rivers and dams, and improve water quality in downstream stormwater catchments.

Rainwater tanks

Rainwater tank performance

Some design considerations for a rainwater harvesting system are presented in this section. It is assumed that a home owner intends to build a new house that will have three occupants in the North Ryde area. Annual water demand in the household will be 225 kilolitres. The allotment has a land area of 450 m^2 with 70% of the area being impervious, and 150 m^2 of the roof catchment can be connected to a rainwater tank. The BASIX building sustainability index requires that water use in the new house be reduced by 40%. The performance of a variety of tank sizes and rainwater uses for the house has been simulated using the PURRS (Probabilistic Urban Rainwater and Wastewater Reuse Simulator) Model. The results are shown in Figure 10.

Figure 10 shows that mains water savings from use of rainwater tanks increases rapidly for small rainwater tanks and increases in mains water savings diminish with larger tank sizes. Larger rainwater tanks do not produce equally larger water savings. In this situation the optimum rainwater tank size for mains water savings appears to be between 2,000 and 5,000 litres. The annual reductions in stormwater runoff volumes are shown in Figure 11.

Figure 11 shows that the optimum sized rainwater tank for reducing stormwater runoff volumes is between 2 and 5 kilolitres. Reductions in stormwater runoff volumes at the allotment are the most significant factor for the reduction in catchment scale peak stormwater discharges that will help mitigate flooding impacts and improve in urban stormwater quality.

The optimum rainwater tank size for reductions in mains water savings and stormwater runoff is between 2 and 5 kilolitres. However the designer will also desire to reduce the installation costs of the rainwater tank and minimise the land area used by the rainwater tank. Specification of a rainwater tank with a capacity less than 4,000 litres will allow the installation of an above ground tank thereby significantly reducing installation costs. Use of a slimline tank will minimise the effective land area used by the rainwater harvesting solution.

However, Figure 10 shows that rainwater tanks at this site will not reduce mains water demand by the 40% required by BASIX. It is proposed to also install

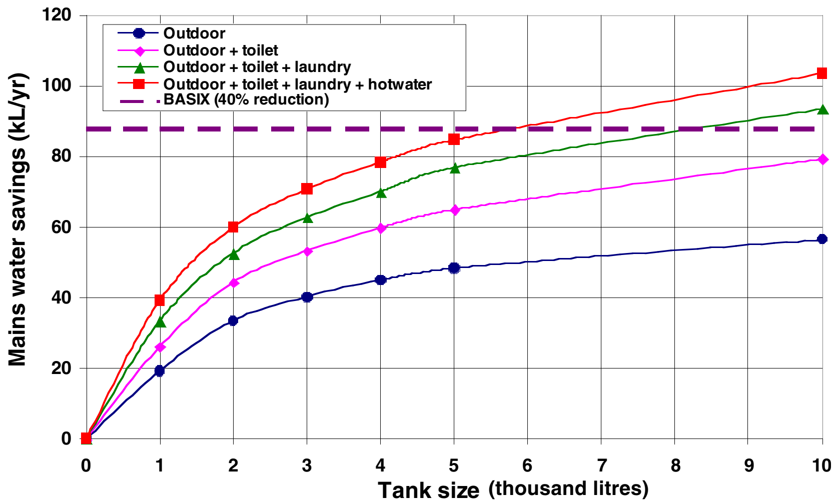

Fig 10: Mains water savings provided by rainwater tanks at North Ryde

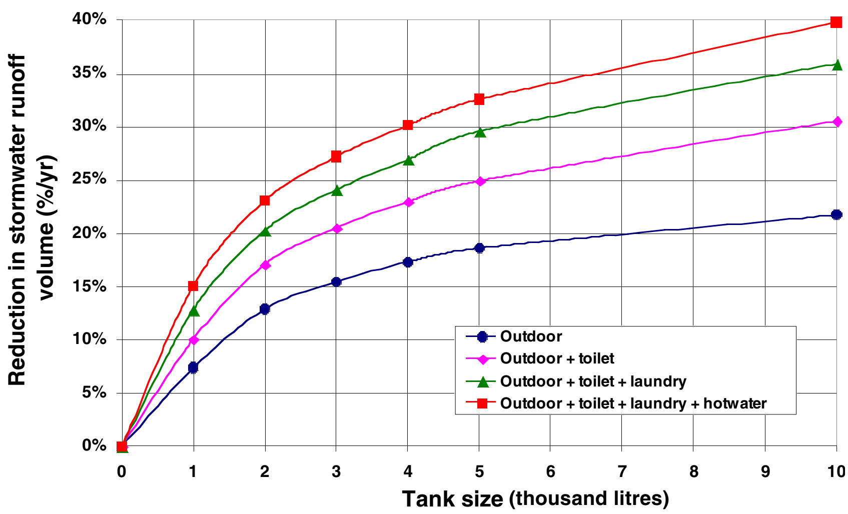

Fig 11: Reductions in annual stormwater runoff volumes provided by rainwater tanks at North Ryde for a 150 m^2 roof catchment

low flow showers, 6/3 dual flush toilets and tap flow restrictors that will reduce water use by 16%. Therefore, the rainwater harvesting system will need to reduce water use by at least 24%. Selection of a 3 kilolitre rainwater tank to supply outdoor, toilet and laundry (washing machine) uses will reduce water use by 29% and will also reduce stormwater runoff volumes by 24%. The designer should note that a wide range of rainwater harvesting solutions are possible, but performance of rainwater tanks will vary widely depending on water useage patterns, extent of roof area and the site's average rainfall.

Useful websites

Water Sensitive Urban Design in the Sydney Region Project: www.wsud.org

BASIX Sustainable Building Index: www.basix.nsw.gov.au

Peter Coombes, University of Newcastle: www.eng.newcastle.edu.au/~cegak/Coombes

Environment Australia: www.greenhouse.gov.au/yourhome

Michael Mobbs: www.sustainablehouse.com.au

BDP Environment Design Guide: The Royal Australian Institute of Architects

Sydney Water Corporation: www.sydneywater.com.au

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Other practice notes

Other Water Sensitive Practice Notes are available in this series:

No. 1	Water Sensitive Homes
No. 2	Site Planning
No. 3	Drainage Design
No. 4	Rainwater Tanks
No. 5	Infiltration Devices
No. 6	Paving
No. 7	Landscape Measures
No. 8	Landscape Practices
No. 9	Wastewater Reuse
No.10	Groundwater
No.11	Development Assessment
No.12	Urban salinity
No.13	Compliance mechanisms

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www.wsud.org

Principal Author: Peter Coombes. Design and Layout by Planning Plus.

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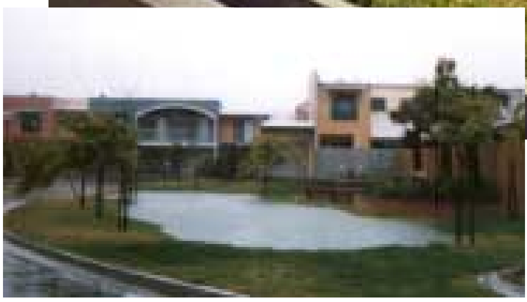
PRACTICE NOTE 5

Infiltration devices



Infiltration basin under normal conditions (above), and during heavy rain (left).

Water sensitive development involves simple design and management practices that take advantage of natural site features and minimise impacts on the water cycle. It is part of the contemporary trend towards more 'sustainable' solutions that protect the environment.

This Water Sensitive Practice Note explains how to design and configure stormwater infiltration devices.

- **Leaky wells**
- **Retention trenches**
- **Infiltration basins**

Infiltration devices

Introduction

This Practice Note describes various types of stormwater infiltration devices for dwellings and other small-scale development. There is growing interest in infiltration as an alternative or supplement to conventional drainage techniques (where site conditions permit) due to its many environmental and economic benefits. These may include reduced peak stormwater flows, reduced downstream flooding, reduced stormwater drainage capital costs, improved groundwater recharge and improved stormwater quality.

For locations within a salinity hazard area, please consult your local council before undertaking design work as some infiltration techniques may not be appropriate within such areas.

Conventional stormwater practice typically involves discharging stormwater to a constructed street drainage system. Such systems are highly effective for removing stormwater from the site, but can also contribute to flooding risk, erosion and sedimentation and water quality decline in downstream catchments. Prior to the construction of urban drainage systems in the late 19th Century, one of the most common methods for managing stormwater was on-site gravel infiltration pits. These provided temporary storage, and allowed stormwater to percolate to the surrounding soil at a rate limited by the soil's hydraulic conductivity.

Modern infiltration devices are much more efficient than their traditional counterparts. They are constructed so as to minimise clogging by silt material, and can be designed to overflow to landscaped areas or the street drainage system when their storage capacity is exceeded during major storms. A number of pollutant removal mechanisms operate within infiltration devices, including adsorption, filtration, microbial decomposition in the gravel layer and trapping of sediment in the pre-treatment areas. If correctly designed, an infiltration device can remove approximately 90% of sediment, 60% of phosphorus and 60% of nitrogen from stormwater.

This Practice Note draws upon the latest design and performance research for Australian conditions (see References below). The research results confirm that infiltration is a very practical option for managing stormwater provided that site conditions such as slope, soil salinity, soil permeability and reactivity to water are correctly taken into account.

System overview

Infiltration devices can be used to manage stormwater runoff from roofs, paved surfaces, rainwater tank overflows and grassed and vegetated areas (see Figure 1). Runoff from each of these sources can be directed by pipes and overland flow to an infiltration device. Prior to entering an infiltration device, the stormwater must receive pre-treatment. This removes sediment and other material, improves the quality of runoff and helps minimise the risk of clogging the infiltration device.

Infiltration is best applied as part of an overall strategy for managing stormwater on the property. The effectiveness of infiltration is improved with the use of complementary measures such as rainwater tanks, porous paving and landscape measures (see Practice Notes 4, 6 and 7 respectively). For example, mulching, contour banks, garden beds, vegetation and other landscape measures can be used to encourage infiltration and provide pre-treatment of runoff.

There are a number of options for using stormwater infiltration on residential properties. The most commonly used devices are:

- leaky wells
- retention trenches
- infiltration basins
- infiltration cells
- seepage pipes.

These devices are described below.

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PRACTICE NOTE 5

Infiltration devices

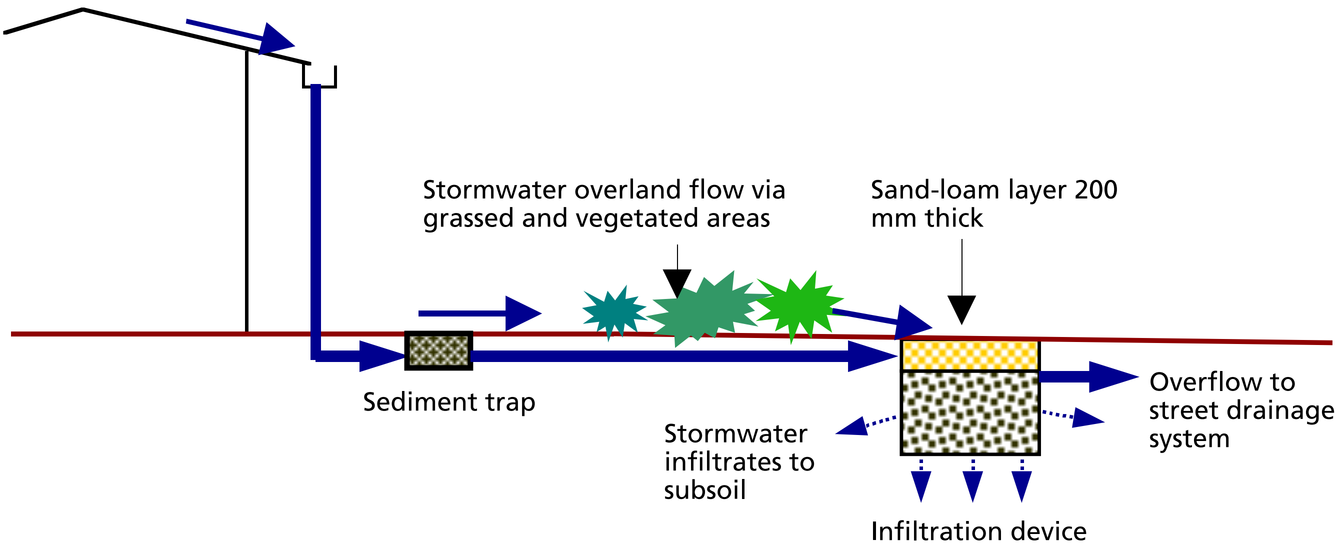

Fig 1: A typical infiltration strategy

Types of devices

Leaky wells

A leaky well consists of a vertical perforated pipe with a lid at the ground surface and an open bottom. Stormwater enters via an inlet pipe at the top and an overflow pipe caters for excess stormwater. The holes in the walls and the open bottom are covered with geotextile fabric to cleanse stormwater as it percolates into the surrounding soil (see Figure 2).

Leaky wells store stormwater until it can percolate to the surrounding soil. Before entering the device, all stormwater should be filtered by a sediment trap to remove sediment, leaves and debris. An advantage of the leaky well is that the accessible chamber allows sediment to be readily removed. Consequently it is more resistant to failure due to clogging. Note that the dimensions shown in Figure 2 are nominal.

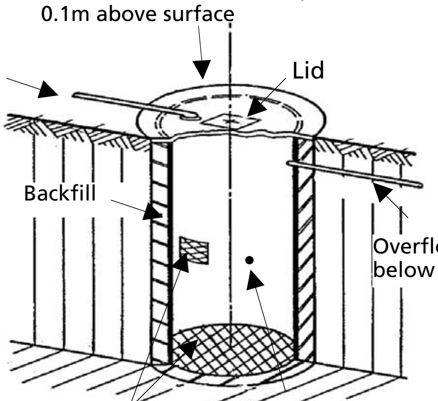

Fig 2: The leaky well infiltration system

Infiltration devices

Retention trenches

A retention trench consists of a trench lined with geotextile fabric and filled with coarse gravel, and placed under a 300 mm layer of sand or loam. Stormwater is conveyed to the trench via an inflow pipe after passing through a sediment trap. A perforated distribution pipe allows stormwater to percolate to the gravel. An overflow pipe directs excess flow during very heavy rain to the street drainage system (see Figure 3).

The sediment trap prevents clogging of the trench with sediment, leaves and debris, whilst the geotextile fabric cleanses the stormwater as it percolates from the trench to the surrounding soil. The detailed design for a retention trench can vary provided it includes the basic elements referred to above. Note that the dimensions shown in Figure 3 are nominal.

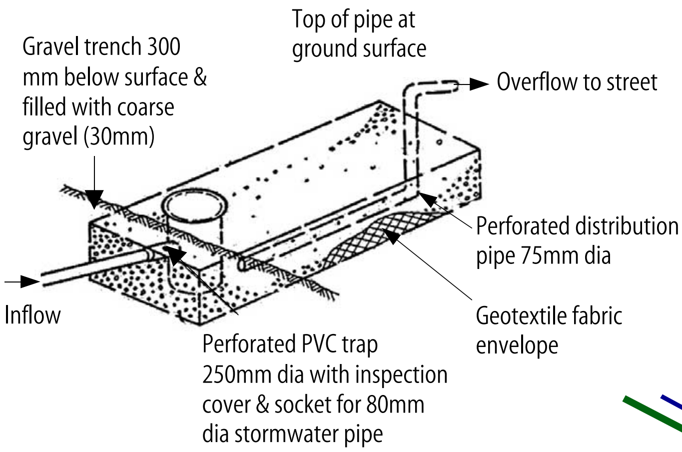

Fig 3: Design for a retention trench

Infiltration basins

An infiltration basin collects and stores stormwater runoff until it infiltrates to the surrounding soil and evaporates to the atmosphere. By removing a portion of stormwater runoff, infiltration basins reduce stormwater peak discharges and volumes to downstream catchments. They also improve the quality of stormwater discharged to the receiving environment.

An infiltration basin is designed as a depression with good grass coverage over a layer of coarse gravel surrounded by geotextile fabric. A 300 mm layer of topsoil is usually placed between the gravel layer and the grassed surface. Stormwater entering the basin is filtered to remove sediment, leaves and debris by sediment traps, vegetated areas or specially designed gutter systems. Stormwater fills the basin and the gravel layer, percolates to the soil and overflows to the street drainage system when the basin fills.

A schematic diagram for an infiltration basin is shown in Figure 4. Infiltration basins are more suitable for larger lots where there is plenty of space. Their design should be well-integrated with landscape measures (see *Practice Note No. 7*).

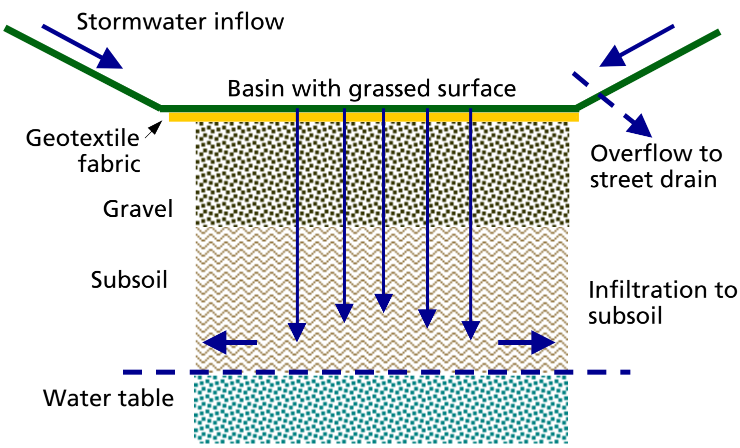

Fig 4: Design for an infiltration basin

Infiltration cells

An infiltration cell is a modular plastic cell (similar to a milk crate) that can be used in a retention trench instead of gravel fill. As with a retention trench, infiltration cells are surrounded with geotextile fabric and placed under a 300 mm layer of sand or loam. An infiltration cell generally has a greater volume of void space than a conventional gravel-filled retention trench. Consequently it can provide a greater storage volume per unit of area.

Seepage pipes

A seepage pipe is a pipe with pervious walls that allows stormwater to percolate into the surrounding soil. Seepage pipes are installed in a similar fashion to retention trenches. The pipe is surrounded by sand or gravel in a trench and covered with sand or loam to a thickness of 300 mm (see Figure 5).

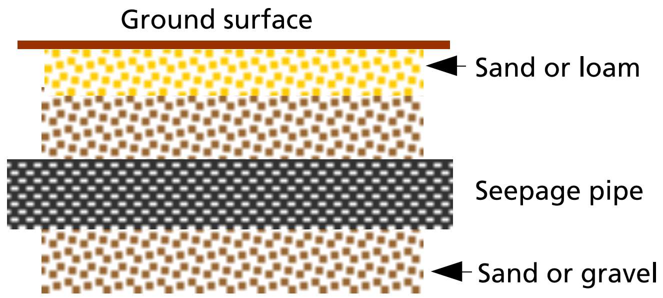

Fig. 5: Design for a seepage pipe

Design issues

Unsuitable soils

Infiltration devices must be avoided or carefully designed in areas with:

- high water table levels
- soil salinity hazard
- wind blown or loose sands
- clay soils that collapse in contact with water
- soils with a hydraulic conductivity of less than 0.36 mm/hr.

Soil assessment and permeability testing must be undertaken as part of the design process for infiltration devices. For details about the location of soil salinity hazard areas, contact your local council.

Clearance from buildings

Soils can shrink or swell depending on their clay and water content, presenting potential problems for building foundations. However, research shows that only minimum soil movement is associated with the intermittent release of stormwater from infiltration devices. The possibility of an infiltration device impacting on the structural integrity of a building can be eliminated by observing minimum clearances. The recommended minimum separation between an infiltration device and a building for various soil types is shown in the following table.

Soil type	Hydraulic conductivity	Clearance
Sand	>180 mm/hr	1 m
Sandy clay	180 – 36 mm/hr	2 m
Medium clay	36 – 3.6 mm/hr	4 m
Reactive clay	3.6 – 0.036 mm/hr	5 m

Infiltration devices

Slope

Infiltration devices should not be installed on steep slopes. An upper limit of 5% slope has been imposed under British conditions. Installation of infiltration devices on slopes greater than 5% is not recommended unless a detailed engineering analysis is undertaken at the design stage.

Rock & shale

Infiltration devices should not be placed in rock that has little or no permeability. Studies have shown that infiltration is possible in severely weathered or fractured rock (for example, sandstone). Engineering testing is essential in these circumstances to ensure that the rock will accept infiltration. In the case of shallow soil cover, testing is required to ensure that seepage does not cause any hazards or nuisance to downstream sites.

Water tables

The presence of a high water table can limit the potential effectiveness of infiltration devices. Infiltration devices can be successful in areas with high water tables provided the water table is stable. Infiltration is not recommended for areas where the water table is rising or the salinity of ground water is increasing.

Sediment

Sediment can be deposited on roofs from the atmosphere at approximately 2 kg per 100 square metres of roof area per annum. It can also be deposited from runoff on other surfaces in established suburbs at about 0.7 tonnes per allotment per year. The management of sediment is therefore a very important issue in the design and construction of infiltration devices.

Special measures must be implemented to provide pre-treatment for stormwater containing sediment, leaves or other debris before it enters an infiltration device. For example, runoff from roof downpipes should be directed to an effective sediment trap. Runoff from impervious surfaces such as paved areas, courtyards, walkways and driveways should be directed to grassed surfaces, vegetated areas or a sand-loam layer that is at least 200 mm thick. The only direct input to an infiltration device should be overflow from a roofwater tank, since the tank serves to remove sediment and other matter (see *Practice Note 4: Rainwater Tanks*).

Sizing infiltration devices

Many councils require infiltration devices to be designed with sufficient capacity to store the inflow for a one-in-three months average recurrence interval design storm, with an emptying time of less than 24 hours. For example, in the Newcastle area, an infiltration device filled with gravel (30 mm nominal particle size) and a catchment roof area of 150 square metres will need to have the following volumes:

- 2.5 cubic metres in a sandy soil
- 3.8 cubic metres in a sandy-clay soil
- 4.5 cubic metres in a medium clay soil.

Contact your local council for specific design requirements in your area.

In medium clay soils a low-level overflow pipe may need to be installed to ensure an emptying time of 24 hours. This is illustrated in Figure 6.

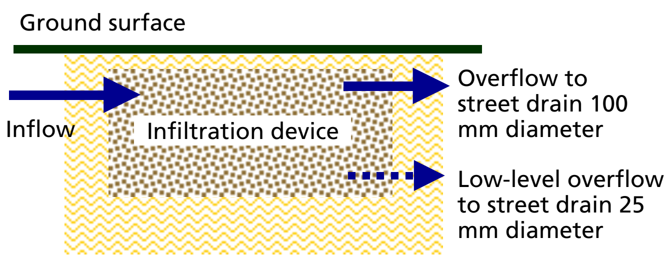

Fig 6: Low-level overflow for clay soils

Costs

The cost to install a retention trench can vary considerably. However, an indicative cost is about $80 per cubic metre (2002). This includes gravel and backfilling ($30 per cuubic metre), excavation ($30 per cubic metre) and geotextile fabric and plumbing ($20 per cubic metre).

Useful Websites

Atlantis: www.atlantiscorp.com.au

Rocla Pipes: www.rocla.com.au

James Hardie Industries: www.jameshardie.com.au

University of South Australia: www.unisa.edu.au

University of Newcastle: www.eng.newcastle.edu.au/~cegak/Coombes

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Other practice notes

Other Water Sensitive Practice Notes are available in this series:

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Principal Author: Peter Coombes. Design and Layout by Planning Plus.

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Infiltration devices

Paving

Some of the many options for porous paving

Water sensitive development involves simple design and management practices that take advantage of natural site features and minimise impacts on the water cycle. It is part of the contemporary trend towards more 'sustainable' solutions that protect the environment.

This Water Sensitive Practice Note describes how to design and install paving so that it manages and treats stormwater.

- **Asphalt porous paving**
- **Grid & modular paving**
- **Design & maintenance**

Paving

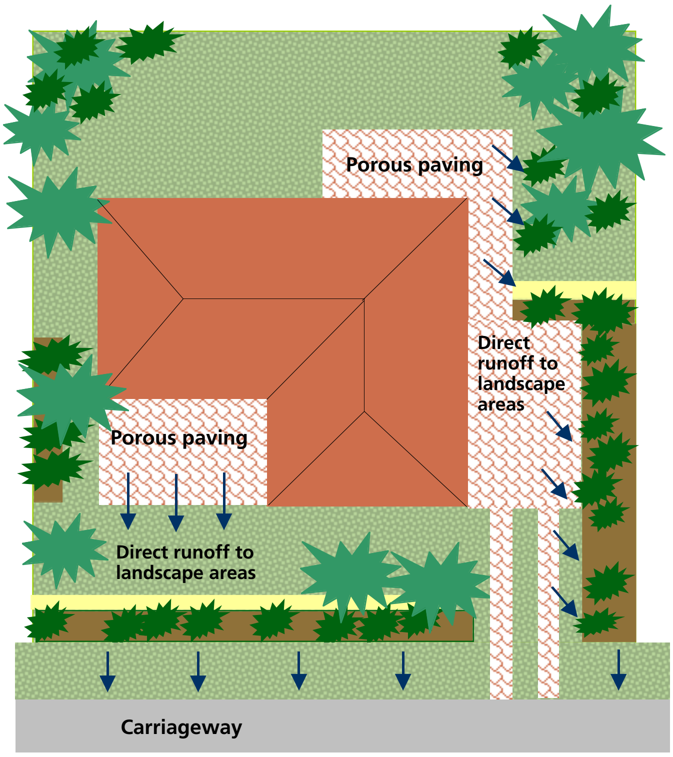
Introduction

Urbanisation causes a significant increase in the area covered with paved (or 'impervious') surfaces, such as roads, driveways, courtyards, etc. Paved surfaces can have significant adverse impacts on the water cycle. They contribute to increased peak and total stormwater discharges, increased downstream flooding, streambank erosion, sewer surcharges, and the need for expensive drainage infrastructure. Paved areas also reduce infiltration to the subsoil. These impacts can be reduced by:

- limiting the area of paved surfaces
- directing stormwater runoff from paved surfaces to landscaped areas, gardens and lawns rather than to the street drainage system
- using porous paving systems.

The application of these methods to a typical residential lot is shown in Figure 1. Special design measures may be needed in salinity hazard areas.

Fig 1: Paving strategy for typical suburban lot



What is porous paving?

Porous paving is an alternative to conventional impermeable pavements with many stormwater management benefits. These surfaces allow stormwater to be filtered by a coarse sub-base, and may allow infiltration to the underlying soil.

A number of porous paving products are commercially available including:

- pavements made from special asphalts
- concrete grid pavements
- concrete, ceramic or plastic modular pavements.

Porous paving can be utilised to promote a variety of water management objectives, including:

- reduced (or even zero) peak stormwater discharges from paved areas
- increased groundwater recharge
- improved stormwater quality.
- reduced area of land dedicated solely for stormwater management.

Asphaltic paving

Asphaltic porous paving is laid on a sand/gravel sub-base over natural soil (see Figure 2).

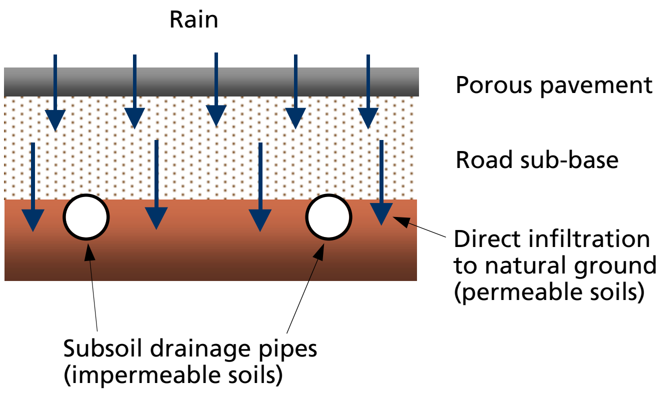


Fig 2: Asphaltic porous paving systems

Rainfall percolates through a porous asphalt layer to the road sub-base, where it is stored until it infiltrates to the surrounding soil. When installed in impermeable soils, subsoil drainage pipes are placed below the road sub-base to allow stormwater to overflow into the street drainage system.

Early porous paving, typically asphalt, relied on percolation of stormwater through the pavement and storage in the sub-base prior to infiltration to the soil. They were often subject to failure due to sediment clogging, and are less recommended than newer porous paving products.

Grid & modular paving

More recent porous paving designs overcome the deficiencies of the earlier asphalt porous paving products. They include:

- concrete grids poured in-situ
- precast concrete grids
- concrete, ceramic or plastic modular pavers.

These products generally contain surface voids that are filled with sand or gravel. Stormwater filters through these voids to a sand or gravel sub-base, thereby cleansing the stormwater. Gravel retention trenches and geotextile fabric can also be installed, thereby creating a very effective stormwater treatment chain. During heavy rain, excess stormwater overflows to the street drainage system when the trench becomes full (see Figure 3).

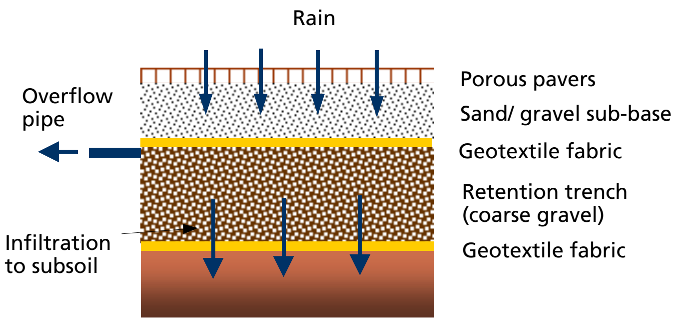


Fig 3: Grid & modular porous paving systems

Grass may also be grown in voids, but this is generally unsuccessful due to insufficient soil depth and nutrients, heavy wear and tear and retained heat in the pavers. In very low traffic areas, consider using turf rather than porous paving.

Plastic modular block pavers retain less heat than concrete ones, making them more suitable in hotter locations or climates.

Porous paving is an excellent stormwater management measure for low-traffic surfaces in driveways and car parks. Unfortunately history has shown many failures due to poor design, construction and maintenance practices. Consequently, the following design and maintenance issues need to be carefully addressed.

Clogging

Partial or total clogging with sediment and oil is a major potential cause of failure, and must be avoided. Clogging can occur during or immediately after construction, or through long-term use. The likelihood of clogging can be avoided by the following measures.

- Do not install porous paving in positions that are likely to receive large quantities of sediment and debris washed down by stormwater, or windblown sand or other material.
- Carefully protect porous paving from sediment inputs during construction.
- Do not use porous paving for accessways with high traffic volumes or with regular heavy vehicle traffic.
- Undertake regular vacuum sweeping or high pressure hosing to remove sediment (direct runoff to grassed areas).
- Install sediment traps, vegetated filter strips or specially designed gutter systems to pre-treat stormwater inputs to remove sediments.

Paving

Infiltration capacity

Porous paving sometimes has a poor reputation of having insufficient infiltration capacity. In most cases this can be attributed to sediment-induced clogging, soils with insufficient infiltration capacity and designs with insufficient storage volume. These problems can be readily overcome by using modern design practices to:

- provide a retention trench below the sub-base
- provide an overflow to the street drainage system or other stormwater management measure
- limit the runoff area contributing stormwater to the porous paving surface.

Aquifer contamination

Porous paving can, in some cases, result in a risk of contamination of shallow aquifers by toxic materials derived from asphalt, vehicular traffic and road use. This risk can be minimised or eliminated by following the following deign principles.

- Do not construct porous paving over shallow aquifers.
- Do not use porous paving on streets with high traffic volumes.
- Install a sand sub-base over a retention trench with geotextile fabric lining to capture contaminants.

Structural integrity

If properly installed, porous pavements have similar load bearing and design life performance to conventional pavements. Impairment of the structural integrity of porous paving by traffic loads or heavy vehicles can be avoided by adhering to relevant design and construction specifications.

Slopes

Porous paving should not be constructed on slopes greater than 5% unless an engineering design is completed to assess the impact of the paving system on downstream environments and the stability of surrounding areas.

Unsuitable soils

Porous paving must be carefully designed in areas with:

- high water table levels
- soil salinity hazard
- wind blown or loose sands
- clay soils that collapse in contact with water
- soils with a hydraulic conductivity of less than 0.36 mm/hr.

Soil assessment and permeability testing must be undertaken as part of the design process for porous paving. For details about the location of soil salinity hazard areas, contact your local council.

Rock & shale

Porous paving should not be placed over rock that has little or no permeability. Studies have shown that infiltration is possible in severely weathered or fractured rock (for example, sandstone). Engineering testing is essential in these circumstances to ensure that the rock will accept infiltration. In the case of shallow soil cover, testing is required to ensure that seepage does not cause any hazards or nuisance to downstream sites.

Paving

Suitable locations

Porous paving can be utilised in streets with low traffic volumes (such as cul-de-sacs), car parks and for paving within residential and commercial development. Acceptable performance can be achieved provided that the correct design and construction procedures are followed, including any manufacturer's recommendations

Maintenance

Concrete grid, ceramic and modular plastic block pavers require less maintenance than asphaltic porous paving as they are less easily clogged. They are also easier to repair. The performance and life of these pavements can be increased by regular vacuum sweeping or high pressure hosing (once every three months) to remove sediments.

As with traditional pavements, asphalt porous paving requires occasional resurfacing. Concrete grid, ceramic and plastic modular blocks require a maintenance schedule similar to that for conventional road surfaces. This involves retaining the pavers and replacing part of the sand layer to remove contaminants.

Indicative water quality

The contaminant removal processes in porous pavements include adsorption, straining, bioreaction and microbial decomposition. Correctly designed and maintained porous paving will retain approximately:

- 80% of sediment
- 60% of phosphorus
- 80% of nitrogen
- 70% of heavy metals
- 98% of oils and greases (with a sand sub-base).

Studies show that oils and greases are subject to microbial decontamination in porous paving. The addition of sand filters and retention trenches with geotextile fabric lining (see *Practice Note 5: Infiltration Devices*) further increases the effectiveness of porous paving as a stormwater treatment measure.

Costs

Construction cost of porous paving is similar to that of traditional pavement and is less than the cost of traditional paving when savings in stormwater infrastructure in considered. Research shows that porous paving can be up to three times less expensive than traditional road and stormwater management approaches.

Construction costs for porous paving are similar to that for traditional paving materials, and are less than the cost of traditional paving when savings in stormwater infrastructure are considered. When installed as part of an integrated stormwater management system, porous paving can be up to three times less expensive than traditional road and stormwater management approaches.

Useful websites

Atlantis: *www.atlantiscorp.com.au*

Rocla Products: *www.rocla.com.au*

University of South Australia: *www.unisa.edu.au*

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- No. 1 Water Sensitive Homes
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Water Sensitive Urban Design in the Sydney Region

PRACTICE NOTE 7

Landscape measures

Landscape measures used in conjunction with infiltration in the centre of a boulevard

Water sensitive development involves simple design and management practices that take advantage of natural site features and minimise impacts on the water cycle. It is part of the contemporary trend towards more 'sustainable' solutions that protect the environment.

This **Water Sensitive Practice Note** describes a variety of landscape measures that can be used to manage stormwater flows, utilise stormwater within the site and minimise supplementary watering.

- **Gravel basins & channels**
- **Filter strips, banks & soaks**
- **Minimising lawn**
- **Efficient irrigation**

Landscape measures

Introduction

This Practice Note describes a variety of landscape measures that can be used to manage stormwater flows, utilise stormwater within the site and minimise supplementary watering of landscaping. These include:

- rock or gravel basins
- vegetated filter strips
- contour banks
- soak or bog areas
- wind and sun protection
- plant selection
- minimising lawn
- efficient irrigation

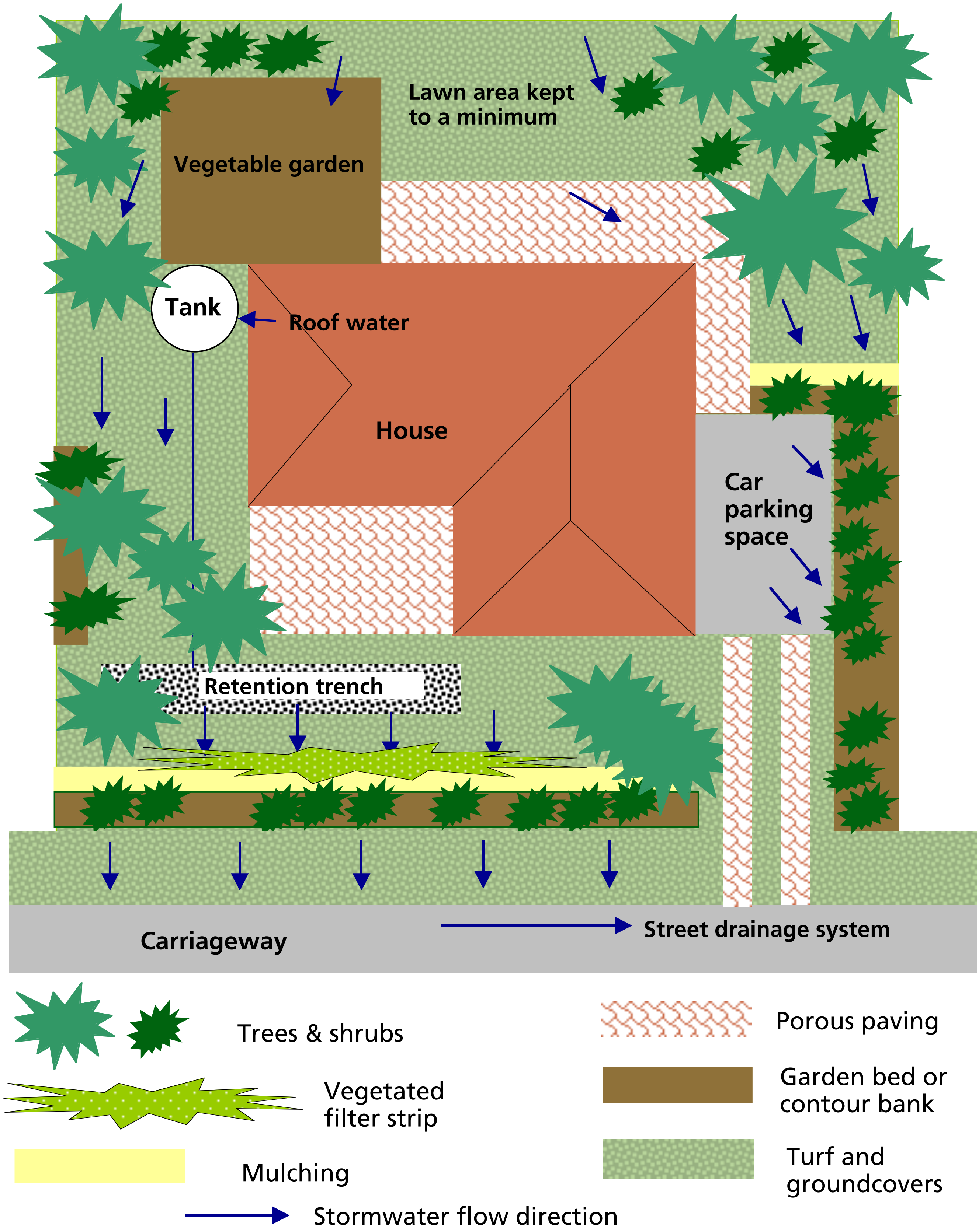
For optimal results, these measures need to be undertaken in conjunction with careful site planning (see Practice Note 2) and drainage design (see Practice Note 3), as well as appropriate landscape practices (see Practice Note 8).

Overall design issues

The design and installation of water sensitive landscape measures needs to be undertaken as part of planning for an integrated functional system for the whole site. Specific issues that need to be considered include the following.

- **Integrated planning:** Landscape measures should be designed in conjunction with the other stormwater management measures. Expected flows and discharge rates should be factored into the design criteria, layout, earth shaping and the selection of plants and other materials.
- **Diversification:** Aim to create a diverse system within the landscape that is not reliant on a single device to manage stormwater. This will allow other parts of the landscape to adequately deal with stormwater flows in the event of failure or exceedance of design capacity, For example, a gravel-lined pond collects overflow from a water tank – spills over to a turfed filter strip – drains gently to a series of drainage swales spot-planted with species that tolerate temporarily saturated soil – drains to a soak area … and so on! This interconnecting system collects flow at a point source, reduces its speed and allows it to progressively infiltrate the soil, thereby reducing the risk of erosion, sedimentation and flooding.
- **Water tanks:** The overflow point from water tanks needs to be positioned so that it does not cause erosion or other damage, such as localised inundation of fragile plants.
- **Vegetated filter strips & turfed areas:** These will become compacted by foot or vehicular traffic, reducing the soil's ability to take up water. Erosion of the surface is also likely, leading to soil loss and downstream sedimentation.
- **Paved areas:** Always consider the safety of users when minimising impervious paved areas. The most frequently used paths (for example, to the front door) must be laid securely on a well prepared base. This prevents pockets of settlement and loose or uneven surfaces that can become a hazard, particularly to the frail or aged.
- **Grey water:** The use of domestic grey water as part of an irrigation or disposal system should not be applied consistently to one area as this can cause a build-up of salts and other contaminants that can alter the pH and ecology of the soil and affect plant health. It is important to know the soil's characteristics, infiltration and capacity rates before relying on such a system.

Landscape measures



An integrated suite of stormwater management measures on a typical urban allotment. The landscape design is an integral part of the overall system.

Landscape measures

Rock or gravel basins

Rock, stone or gravel can be used to line stormwater basins or channels. This can act to slow the rate of flow, dissipate energy and prevent surface erosion. It is a particularly useful method for managing concentrated stormwater discharges due to topography or from adjoining properties, stormwater easements, downpipes or water tank overflow pipes.

Locally-sourced rock should be used wherever possible as this will minimise energy inputs and allow the design to blend with the local landscape. Rock should not be removed from undisturbed areas as this destroys fauna habitat and promotes erosion. Obtain rock from on-site excavation works, other local construction sites or a local quarry. Avoid using blue metal as runoff from it will alter the soil pH.

On steeper slopes, rocks or stones need to be adequately secured to prevent dislodgment and downslope movement.

The size and composition of rocks or boulders must remain in proportion to the scale and style of the project and the site. Larger sites can accommodate larger features and unit materials without being overwhelmed, although it is possible to contain some large elements within a smaller area provided that it is cohesively designed.

Large pebbles or deep beds of gravel can be used to complement landscape themes. They can be used as an alternative to organic mulches for preventing soil moisture loss.

Vegetated filter strips

Vegetated filter strips are strips of grasses and shrubs placed across stormwater water discharge routes. They act to remove pollutants by filtering stormwater runoff, enabling limited infiltration and reducing stormwater discharge velocities.

Filter strips must receive stormwater as sheet flow. Concentrated flow will scour the surface and is likely to dislodge groundcover and plant roots, leading to failure. To ensure sheet flow, minimise the length of unobstructed stormwater discharge upstream of the strip.

Factors such as width of the strip, gradient, soil permeability and density of vegetation influence the effectiveness of filter strips. Various combinations of these variables are possible depending on site features (natural slope, soil properties, choice and placement of plants), and how the filter strip fits into the overall scheme for the site.

Wider strips can hold greater volumes of water, as will those with higher embankments on the downslope side. Filter strips on land with a slope less than 5% are better able to trap sediment. Soil that is friable and with an open pore structure allows greater infiltration of water, compared to compacted and heavy soils. Using vegetation to act as a baffle to slow down stormwater flow must be balanced against obstruction of flow that may cause backing up of waters and localised flooding. Plant species chosen must be capable of withstanding conditions of periodic saturation of soil, foliage or trunk.

Filter strips need to be regularly monitored and checked after major storm events. They may require periodic repair, mowing, replanting and sediment removal to remain effective.

Because they offer a form of garden bed (and possibly an area of turf for casual recreation), vegetated filter strips are recommended for low and medium density urban areas as a multi-purpose landscape element.

Landscape measures

Contour banks

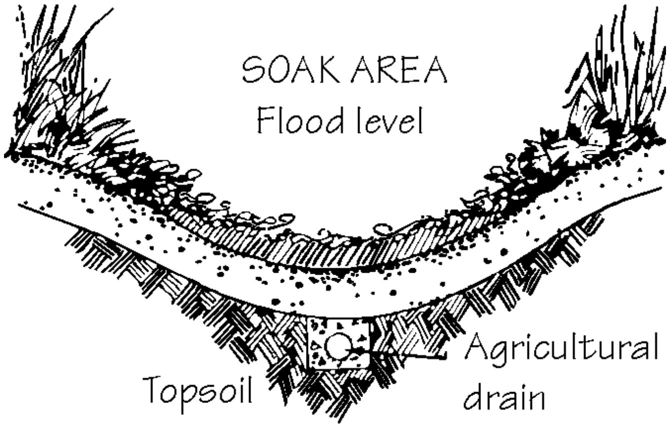
Contour banks are low earth mounds placed perpendicular to the direction of overland stormwater flow. They are very effective for reducing stormwater peak discharges and volumes, promoting infiltration and controlling erosion. On larger sites they can be used in series, and to link other landscaped areas in a system of stormwater control and harvesting. Combinations of contour banks, mulching and vegetated filter strips provide a very effective suite of stormwater management measures.

Contour banks are usually quite resilient, and require little or no maintenance. Special attention may be required to establish vegetation (shrubs, turf, grass and other groundcovers) on the contour banks. If constructing a larger dimensioned bank wall (for example, on a steep site or where large volumes of stormwater need to be accommodated), avoid planting trees on the bank as their large root systems will destabilise the earthen embankment.

Sediment may need to be removed from the upstream side of the bank from time to time. Accumulated sediment will smother low-growing vegetation, and will restrict the efficiency and carrying-capacity of the system. Provided that it is free of contaminants, collected sediment can be used to supplement topsoil elsewhere on the site. Ensure that all relocated sediment is contained and stabilised (such as with mulch or organic matting) to prevent it being the subject of further erosion.

Soak or bog areas

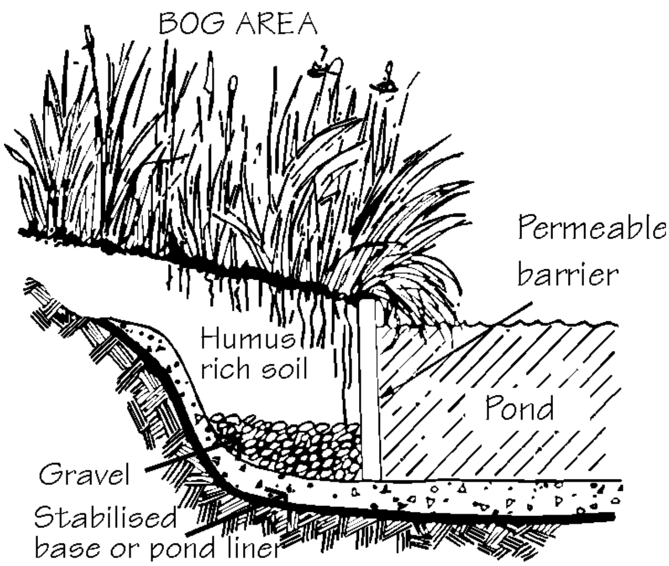
Many sites contain natural depressions or low points containing species that indicate temporary bogginess (for example, sedges, swamp grasses, frogs, water dragons and dragonflies). Consider utilising such sites within the system rather than altering existing drainage patterns, thereby promoting retention of valuable habitat.



The creation of an area that holds water as a temporary wetland is dependent on underlying geology, water table height, potential or existing soil salinity, quality and quantity of water received into the soak area and the type of vegetation it contains. Other landscape devices may be better suited to the site and location of the detention feature.

Avoid any dramatic alteration to the quality and volume of water. Replication of this system elsewhere, given the same geological, soil and drainage conditions, is also possible with careful observation, design and monitoring.

An artificial soak or bog area can also be built at the edge of a pond. This can act as a refuge for fish and other pond creatures when the water level is low.



Landscape measures

The practicality and appropriateness of establishing a soak or bog area will depend on whether there is likely to be any impacts on buildings, soil structure or ecosystem values. Further issues are outlined below.

Expected stormwater volumes

The site may have a small catchment, such as a car parking area or turning circle. This needs to be reflected in the dimensions of the soak area. Maturing vegetation with growing trunks will displace some volume of water as it is received, but this can be taken up more quickly with the more extensive root system and transpiration rate of the larger plant structures.

Plant species selection

Species choice is dependent on the function of the constructed soak area. Some plants are more tolerant of contaminants. For example, runoff from a car washing area can be collected and infiltrate in a separate area that acts as a buffer to other, more sensitive plantings. Select species that will withstand periods of soil saturation and anaerobic conditions.

The species best suited to the site's soil and climatic conditions are those that grow naturally within the local area. In most cases, preference should be given to local provenance species. Exceptions may be required where species do not tolerate a manufactured or disturbed soil profile, or a high nutrient or sediment loading from urban stormwater flows.

Always check with your local council or regional botanical gardens that plants chosen are not environmental weeds in your area.

The following lists includes a combination of native and exotic plants that could be used as part of an ornamental planting scheme. They are suited to conditions of silty or uncompacted soils with some organic matter and a pH of 5-7.

Matting plants

These species colonise and stabilise the edges of soaks, dams, ponds or wherever water levels may fluctuate, inundating them for a brief period.

Blechnum penna-marina (Alpine Water Fern)
Cotula coronopifolia (Water Buttons)
Crassula helmsii (Swamp Crassula)
Isotoma fluviatilis (Swamp Isotome)
Lilaeopsis brasiliensis
Marsilea species (Nardoo)
Mazus pumilo (Swamp Mazus)
Montia australasica (White Purslane)
Myriophyllum species. (Milfoil)
Pratia species.
Ranunculus inundatus (River Buttercup)
Sphagnum species (Moss)
Viola hederacea (Native Violet)

Low growing plants & shrubs

Colocasia antiquorum (Taro)
Caltha palustris (Marsh Marigold)
Cyperus papyrus (Sedge)
Drosera species (Sundew)
Iris ensata (syn *I. kaemferi*) (Japanese Flag Iris)
Iris pseudacorus (Yellow Flag Iris)
Nymphoides crenata (Wavy Marshwort)
Sagittaria sagittifolia
Thalia dealbata (Water Canna)
Triglochin striata (Streaked Arrowgrass)

Trees & larger shrubs

Check for the local species that suit your site and locality.

Allocasuarina species (Sheoak)
Baekea species
Callistemon species (Bottlebrush)
Casuarina species (River Oak, Swamp Oak)
Eucalyptus species (Gum Tree)
Leptospermum species (Tea-Tree)
Melaleuca species (Paperbark)

Maintenance of soak areas

The biggest threat to a soak or bog area is contaminated waters, so the selection of plants is dependent on the role of the soak area. For example, if it is to collect stormwater directly from paved areas with car traffic, only the hardiest species are likely to survive. More filtered or cleaner waters in a less polluted situation will allow a greater diversity of species to be selected.

Stormwater pollutants

Stormwater quality is adversely affected by fertilisers from gardens and lawns and oily deposits made by cars on sealed surfaces. Stormwater pollutants, including nitrogen, phosphorous, potassium and other substances, are eventually deposited in the soil, and are toxic to some plants, especially native species. Stormwater pollutants also encourage weeds and the growth of algae in ponds, thereby displacing other less vigorous plants.

Regular monitoring

Check for excess build-up of sediment, especially after major storm events. Silty deposits may smother smaller matting plants, preventing regeneration. Remove any litter or other inorganic debris.

Wind & sun protection

Providing protection from harsh climatic forces makes garden areas more pleasant and reduces moisture loss from soil and plant tissue. Wind and sun exposure helps to strip moisture from leaves, requiring the plant to use greater levels of available soil moisture than in less exposed conditions. In addition, soil moisture levels are reduced by high rates of evaporation. This can unnecessarily stress the plant’s physiology.

A multi-rowed windbreak planted in staggered heights can offer leeward protection equivalent to about 7 times the height of the plantings. Plant garden beds on the leeward side of any existing clump or row of trees, as this will take advantage of existing wind protection. Do not plant directly underneath the canopy of established trees as the ground disturbance is likely to compromise the health and functioning of their root zone.

As part of overall site planning, locate trees so as to provide seasonal shade to garden areas with softer plants, outdoor entertaining areas and to north- and west-facing walls of the house. Deciduous trees allow winter sun to penetrate whilst helping to break wind flow with their network of branches. Evergreen trees need to be more strategically placed so that they do not cast deep shade on living areas of the house and garden.

Consider erecting a lattice screen or other structure if there is insufficient room to plant a screen for sun or wind protection. This may double as a boundary fence. A wire fence can support climbing plants providing a privacy screen as well as sun and wind protection. Shrubs can cover the lower part of the fence whilst the climber occupies the top. With solid walls that face north or west, consider the effects of light reflection and heat radiation during the hotter months. Protection structures may need approval depending on their location, scale, construction or other specifications – check with your local council.

Species selection

Planting a variety of species will help ensure that there is not a complete loss of screen planting in the event of unfavourable circumstances such as prolonged drought, attack by a host-specific pest or disease or unsuitable growing conditions. Unless a formal avenue of a single species is required for a landscape theme or style, choose hardy specimens from various genera with a mixture of habits, but with similar horticultural, watering and soil fertility requirements.

If space allows, plant 3–5 rows with staggered spacings along the rows. Place the taller growing species in the centre row and shorter ones to the outside rows: this reduces the effects of turbulent eddies on the leeward side. Calculate spacings of plants to roughly two-thirds of their expected mature canopy width.

Some tree species are genetically more prone to branch loss or have earned a reputation as 'branch droppers'. This may be due to weak structural growth patterns, or susceptibility to pests and disease attack. Seek advice from your local native plant supplier for the most suited mix of species.

Maintenance

A newly planted windbreak will require closer attention during the first two growing seasons to ensure establishment of a balanced root system that is well anchored and widely spread. Depending on local soil and climatic conditions a regime of deep waterings and a 80-100 mm layer of organic mulch will encourage this. The mulch should be topped up annually to help suppress competitive weed growth, stabilise soil temperature and reduce moisture loss.

If planting trees close to houses or water tanks, keep the roof clear of overhanging vegetation and check roofs and gutters weekly for leaves and other debris.

Check plantings after storm events and prune any broken limbs back to major branch junctions. In the event of severe damage, seek professional advice regarding tree surgery or removal. Replacement strategies may be needed to restore the functional nature of the plantings.

Plant selection

Select plants suited to the site's soil and microclimatic conditions. Some species are able to withstand low soil moisture or high wind exposure due to special adaptations such as hard leaf tissue, small leaves, deep root systems, deciduous leaves, silvery or furry leaves (or combinations of these).

Local native plants have evolved to handle local conditions. Other Australian natives also cope with very little water. Some exotic plants from the Mediterranean region, California and Southern Africa are able to survive on limited water and a range of soil conditions.

Some plants are so well adapted to severe conditions that they can colonise and dominate native bush areas. Check with your local council, landcare group, regional botanical gardens or native plant nursery that plants chosen for your site (including native species from other parts of Australia) are not environmental weeds or declared noxious weeds.

Explore your neighbourhood to find out which species grow well, including street trees and other rarely watered plantings.

Group plants with similar water needs together so that watering schedules can suit different parts of the garden. Examples of different levels of water use include the following.

- *High use*: lawns, leafy vegetables, soft-fruit trees, exotic shrubs like azaleas and camellias, flowering herbaceous annuals and many bulbs.
- *Medium use*: hardy vegetables like pumpkins and potatoes, hardy fruit trees and vines like nut trees and grapes, many herbs, some exotic shrubs, most grey-leaved or tomentose (hairy) plants, roses and daisies.
- *Low use*: most Australian natives including banksias, grevilleas, hakeas, wattles and eucalypts. Succulents and cacti and some exotic ornamentals such as bougainvillea also fall within this category.

Place plants in the areas of the garden that suit the conditions provided. For example, place moisture-loving plants in protected spots with deeper soils, and hardy silvery-leaved plants in full sun, all with layers of mulch on the surface.

Landscape measures

Minimising lawn

Turf grasses are shallow-rooted groundcovers that generally require regular watering to maintain a green leaf cover. Compared to garden beds, lawn areas require significantly more water, fertiliser and maintenance per unit area to maintain healthy growth. Lawn areas also require greater inputs of energy, time and money. Fertiliser costs money and adds to the nutrient burden in run-off. Mowing is time-consuming and motors rely on petrol or electricity, adding to environmental pollution.

Rationalising the size and design of lawn areas can be easily undertaken, resulting in significant reductions in water use. There are many options....

- Replace lawn areas with vegetable patches, garden beds, screen planting, or a shade tree and garden bench.
- Site turfed areas closer to the house for more efficient watering from roofwater tanks.
- Choose other groundcovers and low-growing shrubs for a green outlook.
- Use other pervious surfaces for trafficked areas, such as mulch, gravel or permeable paving units. This will avoid the need to repeatedly repair worn out tracks across the turf.
- Alter maintenance practices to encourage deeper root growth (reduced mowing frequency, higher blade height, less frequent but deeper watering).
- Replace with grass species that are slower growing and require less water to remain green. Check with your local supplier for native and introduced grasses that suit local conditions.

The Table on page 10 provides brief details on a variety of readily available low maintenance ground covers that can be used to replace conventional lawns. They are all well adapted to coast and ranges of New South Wales.

Efficient irrigation

Only install irrigation systems if it is needed. Landscape measures that collect and utilise stormwater by slow infiltration can replace reliance on supplementary water. Irrigation will generally not be required if plant species are carefully chosen to suit the soil, climate, aspect and microclimate, and appropriate planting and maintenance techniques are implemented.

However, some gardeners have high expectations, or a preference for species that do not thrive with natural rainfall. The aim in this case is to apply water in the most efficient manner. Points that need to be considered regarding the choice of irrigation system, its installation and use, are outlined below.

- Match the system's design and specifications to the conditions on your site, including water source and quality, soil types and depth, moisture infiltration rates, evapotranspiration rates, frequency and intensity of rainfall, slope, plant choice and layout. Consult an irrigation specialist for a tailor-made efficient system.
- Re-fit an existing system with the most efficient low-flow fittings (jets, sprays and nozzles, etc.). Fix any leaks from joiners, hoses and pipes. Rationalise its layout. Adjust it to suit the changing requirements of plants as they mature (generally reduced water demand).
- Connect each garden area to separate valves to create 'hydrozones'. Plants grouped with similar water needs are precision-watered to suit them. Lawn areas will require the most water.
- Water according to the weather and plant needs, not to a fixed time schedule. Install soil moisture indicators as a guide. Allow soils sensors to override an automated system.
- Reduce the frequency of watering so that plants become less reliant on irrigation. Monitor plants individually and replace systematic watering with manual watering of stressed plants.

Landscape measures

Name	Description	Location	Soil	Sun	Watering	Mowing	Use	Establishment
Dryarna flavius	Aust. native turf	Dry or boggy conditions	Any	Full sun to part shade	Drought tolerant	None or very little	Can filter grey-water	Turf rolls available. Needs watering in first 3-6 weeks
Sporobolus virginicus Nather's green	Prostrate fine leaf native grass	Dry or boggy conditions, handles heat & light frost	Many (prefers sandy)	Full sun to part shade	Drought tolerant	Few times per year	High traffic. Can filter grey water	Propagate from small tubes or plant division
Phyla nodiflora Lippia, Fog Fruit	1-3cm high creeper, up to 2m wide. 2cm lilac flower most of year	Tropical, sub-tropical & temp. regions. Frost resistant	Tolerates waterlogging & salt spray	Full sun to part shade	Some during warmer months	None	High traffic	Propagate from rooted runners or plant division
Dichondra repens Kidney Weed	Rapid growing, 1-2cm high 1m wide. Small green-yellow flower in Spring	Moist areas. Does not tolerate cold climates	Well drained soil	Sun or shade	None/ low	A few times a year	Takes mild traffic; recovers well after wear; good around edges/strips	Propagate from plant division, seed (purchase from native plant nurseries) or tube stock. Can be invasive–don't plant near less vigorous plants
Mazus pumilio Swamp Mazus	Forms a dense mat 1m wide. Small white-violet flowers in Spring	Frost resistant	Tolerates moist boggy soils	Sun or partial shade	Survives on rainfall if in correct position	None to few	Tolerates foot traffic in moist, shaded areas	Propagate from plant division or plants–purchased from native nursery
Chamaemelum nobile 'Treneague' Lawn Chamomile	Non-flowering 5-10cm high	Warm & cold climate	Most soil types	Moderate sun	Very low water needs once established	When necessary	Good companion plant. Use as a tea, shampoo & fertiliser	Propagate from plant division, seeds or plants. Needs considerable weeding while establishing.
Mentha pulegium var. 'Decumbens' Pennyroyal	2-3cm high, spreads 70 cm/yr. Red-purple flowers in Summer, fragrant when stepped on	Grows in warm & cold climate	Grows in all soil types, preferring moist area	Full sun to part shade	Only in extreme heat. Not drought tolerant	None	Suited to high traffic	Propagate from runners (cut stem pieces that have rooted & replant), plant division, seeds or plants–purchase from herb nursery
Mentha requenii Corsican Mint	3-6cm high green cushion, hardy, tiny flowers early Summer, fragrant when stepped on	Suited to growing among stones in a path	Well drained, mildly enriched & moist soil	Full sun or light shade	Low water needs	None	Can stand some traffic	Propagate from plants (set in early Spring) or plant division (in Spring)
Thymus serpyllum Wild Thyme	3-12cm high carpet, aromatic leaves, rosy to white flowers	Grows in warm & cold climates	Suited to dry, well drained soil as well as damp clay	Full sun	None to low	Withstands mowing but not usually needed	Suited to occasional trampling. Herb that can be used to for tea	Propagate from seeds, cuttings (rooted stem sections) or plants (in Spring, 20-40cm apart). Apply manure or compost in Autumn & Spring
Myoporum parvifolium 'prostrate form' Creeping Boobialla	4cm high. 1-2m wide. Small white or pink flowers in Spr-Sum	Ideal for coastal areas. Frost hardy. Salt tolerant	Any soil with good drainage	Full sun	Drought tolerant	None required	Good for weed suppression	Propagate from plants (from native nurseries) or firm tip cuttings (harder areas of the plant stem)

Low maintenance groundcovers that can be used to replace lawns. *Source: Friends of the Earth*.

- Install drip systems for sparsely distributed plants and underground or surface leak systems for dense garden beds as they are the most efficient irrigators—there is less vapour loss from spray or misdirected water.
- With spray systems, avoid overlapping areas or directing it onto paths and driveways.
- Ensure that the water is directed to the roots as much as possible.
- Set a timer to turn off watering systems if it is not automated. Adjust according to the season and plant needs.
- Maintain the whole system routinely, inspect for blockages, repair leaks and replace worn parts.

Irrigation is best done in combination with mulching of garden beds to conserve applied water. Always avoid over-watering to the point where the soil is saturated and excess water flows away from where it is intended.

The costs and maintenance of an efficient irrigation system should be measured against the benefits. Consider redesigning and replacing with plants that have less demand for constant supplementary water.

Useful websites

Environment Australia (2001). *Your Home: Technical Manual and Consumer Guide*: www.greenhouse.gov.au/yourhome

Friends of the Earth (Sydney): www.homepages.tig.com.au/~foesyd/SustainableConsumption/garden/gardenhome

Australian web site dedicated to promoting better water conservation: www.savewater.com.au

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Water Sensitive Urban Design in the Sydney Region

PRACTICE NOTE 8

Landscape practices

Water sensitive development involves simple design and management practices that take advantage of natural site features and minimise impacts on the water cycle. It is part of the contemporary trend towards more 'sustainable' solutions that protect the environment.

This **Water Sensitive Practice Note** explains how to undertake landscape practices that promote efficient water use and good plant growth.

- **Soil preparation**
- **Planting, mulching & plant care**
- **Ongoing landscape maintenance**

Landscape practices

Soil preparation

Preparation of the soil is dependent on soil type and site conditions. There are three main types of soil:

- sandy soils that drain rapidly
- clay soils that hold water
- loamy soils containing a mixture of coarse and fine particles.

Soil texture determines the soil's ability to retain water for use by plants. Fine-textured clay soils hold the most water due to the greater surface area around soil particles. These soils may be unsuitable for some types of plants. Sandy soils may dry out quickly in dry weather. Loamy soils that contain plenty of organic matter are ideal for plant growth. Check with your local plant nursery for advice on local soil types and soil testing.

It is best to use plants that are suited to the site's soil conditions. Adding a veneer of the best 'garden mix' is not recommended as this will discourage roots to penetrate deeply into the soil below. Hardy, deep rooted plants can help break up poor soils. Organic matter can be added to soil to encourage microbial and worm activity, thereby improving soil condition and moisture retention.

Potential acid sulfate soils and salinity are major soil problems. Check with your local council to see if your site could be affected, and whether any specialised strategies are required. Careful design, construction and on-going management techniques for building, drainage and landscaping works are necessary in these situations.

If soils have been compacted by construction work or vehicles, remediation can be undertaken to open up pore spaces, promote aeration, and improve water infiltration and holding abilities.

There are a number of soil additives that can be used to improve general soil performance. Always seek specialised advice as to the correct rates and situations for application. Common soil additives include the following.

- **Wetting agents** for hydrophobic ('non-wetting') soils, including some sandy soils and soils with lots of organic matter. Watering results in beads of water running-off rather than soaking into the root system. The wetting agent can be mixed with backfill at planting times, or applied later.
- **Gypsum** may be added to dispersive or sodic clay soils. Always test the soil to see if it is needed and to determine the correct application rate.
- **Water-storing crystals** can hold hundreds of times their weight in water. When mixed with water they form a soft gel and retain water. This provides a reservoir of moisture for plant roots during dry periods.

Where construction or landscaping works cut into the soil subgrade, apply the saved topsoil (scraped and stockpiled prior to commencement of work) to a depth of at least 150 mm for turf areas, or 400 mm for garden beds. Roughen the surface before applying the topsoil layer, and water with a fine spray prior to planting to eliminate air pockets.

To avoid compaction of heavy clay soils after rain, allow 2-3 days for free drainage before tilling or using mechanical means to work the ground.

Any additional soil required for landscaping works should be specified to satisfy Australian Standard AS 4419 *Soils For Landscaping and Garden Use*, or current standard. This sets requirements for bulk density, organic matter, weed content, wettability, pH, electrical conductivity, ammonium toxicity, phosphorous content, dispersibility, toxicity, nitrogen drawdown, permeability, soil texture and large particles.

Select the range that suits the proposed type of plants for the site. For example, Australian native plants have different requirements and tolerances. As a guide do not use any soil with more than 20% organic matter in it

Pre-planting

Those parts of the site that are to be landscaped should have all weeds removed prior to the commencement of landscaping work. Use hand tools on smaller weeds. As a last resort, apply herbicide by spot application to larger, perennial or vigorous weeds.

Backfill retaining walls and make other garden beds after brickwork, electrical and drainage works and adjoining pavements have been completed. Apply water to settle the soil down and eliminate air pockets. This must be done with a fine gentle spray to prevent surface erosion.

Mulch should be applied to each area left unplanted in the event that planting is delayed by more than one week from backfilling or other soil preparation.

Planting

Stock selection

The key issues in selecting trees are:

- the trunk has adequate stem taper and is self-supporting in its container
- good root occupancy of the root ball
- no girdling or kinking of roots within the root ball
- roots fill the container without being over-grown
- trees are free from included bark (unless this is typical of the species and is known not to lead to structural failure)
- there is adequate root volume to support and sustain the above-ground sections.

Stock selection should be based on Clarke (1996) *Purchasing Landscape Trees: a Guide to Assessing Tree Quality*.

Tubestock generally give faster growth, but semi-mature seedlings need less watering.

Hardening off plants

Arrange delivery of plants to a location within the locality of the site at least four weeks before planting out. Maintain plant root systems moist at all times, giving particular attention to watering during the on-site installation period before and during planting.

Planting guidelines

To avoid damage to trunks and root zones of retained vegetation, use hand tools and barrows in adjacent areas. Undertake planting according to any landscape plans and drawings for the site and observe the following guidelines.

- Ensure that there is an adequate depth of drained soil for the stock size to be used.
- Do not plant if the air temperature is over 35°C or if the soil is waterlogged.
- Relocate existing turf or mulch. At each planting site set aside mulching materials if already applied.
- The planting holes are to be a minimum of twice the width of the container and to the depth of the root ball. For tube stock excavate to a depth equal to the root column and, if possible, to a width of 500 mm.
- The sides of the hole should be rough (not smooth) to promote new root growth.
- Organic matter must not be placed in the bottom of the hole or in the backfill.
- Ensure that all containers are fully removed from the root ball and the hole. No part of the plant should be damaged during this process.
- Depending on container size, remove or gently roughen the outer 5-10 mm of the root ball of trees.
- The plant should be centred in the hole and then backfilled with site soil in good tilth.
- The top of the root ball must be level with the finished level of the soil and must remain so.

Landscape practices

- If fertiliser is to be added it should be placed in the upper section of the backfill. The type of fertiliser, rate of application and area should be to the manufacturer's instructions.
- The backfill must be placed around the root ball to ensure good root contact without being overly compacted.
- Place remaining excavated soil as a mound around the edge of the root ball to create a watering well. This helps retain water.
- Water each plant within one hour of planting. As a rule of thumb, apply one litre of water for every litre of container volume. Apply the water through the root ball, but not so as to damage the plant or dislodge the root ball. For containerised stock up to 45 litres, water the plant bringing the growing medium to container capacity within one hour of planting. For stock over 45 litres ensure that the root ball is moist and that plants are not wilting.
- Depending on soil moisture conditions, additional water may be applied to the soil surrounding the root ball.
- Apply organic mulch to a minimum radius of 500 mm from the trunk, and to a depth of 75 mm.
- If tree protection measures are required such as tree guards or marker stakes, these must be installed so that no damage is done to the trees. In most situations, trees should not be tied to stakes (that is, trees should be self-supporting when purchased—see *Stock Selection* above). Where additional support is required, two or three stakes should be used. These should be driven into the soil beyond the root ball and not interfere with branches or foliage. Trees should be attached with jute webbing or other flexible material that will not damage the plant. The ties must be low enough to allow trunk movement but high enough to provide support for the root ball.
- Remove all other ties and labels from the plants.

On-going plant care

Maintenance period

Specify a pre-determined maintenance period (up to two years from completion of landscaping works) for establishment of landscaping. During this period, missing, dead or unhealthy plants should be replaced with identical species of similar size and quality at the contractor's expense.

Watering

Deeply water all new plantings at least once a week for the first three months, once a fortnight for the next six months and once a month for the subsequent six months. Adjust this frequency to suit local soil, climatic and weather conditions, such as falls of heavy rain. Water should be applied to the root ball and surrounding soil.

Weed removal

Undertake periodic weed removal at least once a month. Hand weeding young plants is recommended as it causes less ground disturbance. Removing weeds whilst still immature limits their ability to establish a wide root network, set seed and spread vegetatively. Herbicide could be used selectively to control the re-emergence of persistent weeds by using cut-and-paint techniques or an applicator where appropriate.

Moderating plant growth

Lightly tip-prune flowering shrubs at the end of their main flowering period to encourage bushy growth. Keep groundcovers 150 mm from tree trunks to allow inspection of the tree trunk. Grasses need to be kept approximately 1m away from new plants for one to two years to prevent competition.

Removing tree stakes

Remove stakes from newly planted trees after the completion of their first growing season. Take care not to cause any damage to the trees.

Landscape practices

Mulching

Mulching has many benefits to plant health and water conservation. As well as reducing evaporation, it suppresses weed germination and growth (by reducing light penetration to the soil surface) and stabilises soil temperature (beneficial to root development and soil organisms). Organic mulch slowly breaks down to supply soil nutrients. Use the following guidelines to help ensure efficient water use and good plant growth.

- Apply 75-100 mm of organic mulch over the surface as a blanket on massed plantings. Top up annually. Keep mulch at least 150 mm away from trunks and stems to prevent rot.
- Use a mixture of textures to allow water to pass through. A combination of chipped bark and leaves decomposes at different rates and supplies a variety of minerals and nutrients.
- Avoid introducing pests and diseases from mulch imported to the site. Obtain materials that satisfy Australian Standard AS 4454 *Composts, Soil Conditioners and Mulches,* or current standard.
- Do not apply fresh organic products directly to the soil (such as sawdust, woodchips and pinebark). These materials extract soil nitrogen ('nitrogen drawdown'), competing with plant uptake and causing sickly plants. Add fertiliser (manure or blood and bone) before application, or compost the material before use.
- Inorganic mulch can be used, but does not add humus and nutrients to the soil. Use crushed rock, gravel and brick, silicon chip, coarse river sand, scoria or river pebbles to complement landscape themes or where loose materials may be blown away. Avoid blue metal as this can alter soil pH. Use to a depth of about 50 mm to allow water penetration.
- Mulch matting can be used on slopes where other mulches may slip. When pegged in position, the mat forms a stable surface whilst trees, shrubs and groundcovers establish. Plants can be pocket planted through the matting. Use 100% organic matting, such as jute. The matting must not contain inorganic fibre such as nylon.
- If using an irrigation system, install an underground or surface drip system to make sure the water reaches the soil below the mulch.
- Avoid using mulch in areas where it is likely to be washed away by surface flow during heavy rain.

Maintenance regimes

After rain

Avoid walking or driving over wet ground as heavy soils are easily compacted when wet. Soil compaction significantly reduces infiltration rates.

Avoid disturbing plant foliage immediately after rain as plant diseases are more easily transmitted into damaged leaf tissue when moist.

Check for soil erosion, and repair erosion points before they magnify. Identify the cause and undertake corrective measures (redirect drainage, disperse flow and reduce velocity). Check for sediment build-up in vegetated filter strips, drainage swales, soak areas and ponds. Collect sediment and stabilise in areas that are less prone to erosion.

Weeding

Regularly control weeds to reduce competition for both soil moisture and nutrients. Hand-pull or hoe weeds when they are young. Remove weeds before they set seed for the next generation.

Avoid broad-scale herbicide application as this may wash-off into water courses and affect aquatic fauna. If persistent woody weeds do not respond to manual methods, cleanly cut near the stem base stem and paint with herbicide on the fresh wound. Use herbicides only in accordance with the manufacturer's instructions.

Landscape practices

Watering

Newly planted areas will require more water than established plants. The first growing season is the most crucial for good root establishment. New plants need to be monitored, especially in weather extremes. Use the following guidelines to help ensure efficient and effective watering.

- Apply slow waterings to encourage deep root penetration
- Decrease watering frequency as plants settle in.
- For maximum watering efficiency, group plants together that have similar watering needs together ('hydrozoning').
- Take care that the underlying subsoil is not saturated as this can be a cause of wilting leaves. Rectify by improving subsoil drainage or using species that can cope with the conditions.
- Water according to soil moisture and plant needs rather than to a fixed schedule. Test the soil 50 mm below the mulch to see if it is dry before applying water.
- Divide garden beds into sections and alternate between them at watering times, concentrating on one with deep soakings.
- Minimise evaporation by watering in the early morning or late afternoon. Apply water to the roots rather than the foliage, as some plants are susceptible to pest and fungal diseases if left with damp leaves, especially overnight.
- Avoid watering in windy conditions as much water is lost to spray drift.
- If using a handheld hose, use a trigger-operated nozzle to control flow whilst moving between plants.

Care of plants

Protect young plants, especially ornamentals that have large or soft leaves, by shading from strong sun or wind. Use shade cloth or a tee-pee of branches cut from prunings. This reduces moisture loss from their leaves.

Thin out fruit on deciduous trees. Thin apples, peaches, plums to about 20-30 cm apart.

Let cane berries and fruit trees go dry after harvest and water only if the leaves wilt. Well-established and mulched plants should be able to withstand this regime. Let roses develop hips by not dead-heading flowers.

Avoid excessive use of nitrogen-rich fertilisers as this stimulates leaf growth and increases water demand.

Pruning

Minimise pruning by not forcing plants with lush lengthy growth that becomes wayward. This soft growth is more prone to drying out in hot winds and, if not hardened by the end of the growing season, can be damaged in the colder months.

Pruning may be necessary for shaping, crown lifting or the removal of dead or diseased limbs on trees. For a useful guide, see Australian Standard AS 4373 *Pruning of Amenity Trees*.

Recycle any disease-free prunings back into the landscape as mulch so as to return the stored nutrients to the soil.

Grassed areas - watering

Grassed areas are the biggest user of water. Consider reducing size of lawns, substituting with other groundcovers or converting to a less water-dependent garden bed. For further details, see *Practice Note 7: Landscape Measures* in this series.

Give lawn areas a good soaking rather than frequent shallow waterings. During prolonged dry

Landscape practices

periods it may be necessary to water every third day to the equivalent of 15 mm of rain. Use a cup to measure how much water has been applied.

For summer-dormant turf species, restrict foot traffic whilst the turf is dormant.

Grassed areas - mowing

Mow less often. Where possible, use a hand-pushed mower—a great incentive to reduce lawn areas!

Set mower blades higher. Aim to cut only the top one-third of the grass. Mowing too low weakens the grass, increases susceptibility to weeds and pest damage, and increases evaporation from the soil.

Use a mulching mower to recut the grass finely, self-mulch the lawn and return soil nutrients.

Mow when the grass is dry to allow clippings to filter down to the soil for self-mulching without clumping.

Avoid fertiliser application as this stimulates leaf growth, increasing moisture loss and nutrient-enriched run-off. It also requires more frequent mowing.

Grassed areas - maintenance

- Aeration helps water penetrate to the root zone. This can be done by inserting the prongs of a garden fork to a depth of at least 10 cm in a regular pattern over the surface of the lawn, or use a motorised roller with spikes.
- De-thatch the lawn. Lawns that grow by creeping stems sometimes form a thick layer of stems and leaves under the green parts, called thatch. Remove this layer using a special mower (available for hire) to improve water penetration. This is best done between spring and early summer or in autumn.
- Organic fertilisers, such as fishmeal, seaweed extracts and pelletised poultry manure help stimulate microbial activity that removes thatch naturally.

Other issues

Swimming pools

Swimming pools loose an enormous quantity of water through evaporation. In a shaded wind-protected setting evaporative loss may be about 15 mm per week over the surface. For a 60 m^2 pool this is about 3700 litres per month! The same sized pool in a hot, sunny, windy site looses about four times that amount. A pool cover can cut potential losses by more than 90%, and reduce the need for chemical additions and pump and filter use. Pool covers are commercially available as either floating or fixed covers that satisfy budget, use and safety needs.

Gutters

Prune back overhanging branches and remove leaf and other debris from roofs and gutters to reduce possible contamination of water collection tanks and systems.

Car washing

Washing cars or boats on lawns prevents water and detergent from entering the stormwater drainage system. Lawns and garden beds have a limited ability to absorb nutrients contained in detergents. Wash the car in a different location each time. If the lawn deteriorates or becomes water-logged, your vehicle may be compacting the soil or the nutrient levels may be too high. Aerate the soil and rest it by taking the car to a commercial car wash for a few months. Select a car wash that recycles water and detergent.

Regular maintenance

Sweep paths and driveways rather than using a hose. Maintain and repair leaking taps, hoses and other fittings of watering systems.

Landscape practices

Useful websites

Environment Australia (2001). *Your Home: Technical Manual and Consumer Guide*: www.greenhouse.gov.au/yourhome

Friends of the Earth (Sydney): www.homepages.tig.com.au/~foesyd/SustainableConsumption/garden/gardenhome

Australian web site dedicated to promoting better water conservation: www.savewater.com.au

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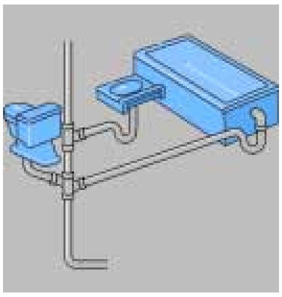
WSUD Water Sensitive Urban Design in the Sydney Region

PRACTICE NOTE 9

Wastewater reuse

On-site waste water treatment options include septic tanks, aerated wastewater treatment systems and composting toilets.



Water sensitive development involves simple design and management practices that take advantage of natural site features and minimise impacts on the water cycle. It is part of the contemporary trend towards more 'sustainable' solutions that protect the environment.

This Water Sensitive Practice Note gives a general introduction to the options available for on-site waste water treatment and re-use.

- **Septic tanks**
- **Aerated wastewater systems**
- **Greywater reuse systems**

Wastewater reuse

Introduction

The majority of water used for indoor domestic purposes is discharged after use as 'wastewater'. Wastewater can be collected by a reticulated sewage system and treated at a conventional wastewater treatment plant. Alternatively, it can be collected, treated and re-used on-site, thereby promoting more efficient water use. This has many significant economic and environmental benefits for the community. However, on-site reuse of domestic wastewater is subject to various restrictions due to concerns about effluent quality, maintenance and health issues.

Types of wastewater

There are two main types of domestic wastewater:

- blackwater - wastewater from the toilet
- greywater - all other domestic wastewater, including wastewater from bathrooms, kitchens and laundries.

A typical household discharges approximately 35 litres of blackwater, and 105 litres of greywater, per person per day. The potential for on-site treatment and reuse will depend on its quality. Greywater contributes about 65% of the volume of domestic wastewater, 70% of the phosphorus, and 63% of the BOD (biological oxygen demand), whilst blackwater contributes about 35% of the volume of wastewater, 61% of suspended solids, 82% of nitrogen and 37% of BOD.

The potential presence of pathogens in greywater is substantially lower than in blackwater. However, several authors have shown that greywater may contain pathogens. Thus, both greywater and blackwater require adequate treatment before on-site reuse.

On-site treatment and reuse options include septic tanks, aerated systems, and greywater reuse systems. These options are mainly applicable to rural and rural-residential locations.

Septic tanks

Septic tanks are widely used throughout Australia in areas without reticulated sewerage. About 12% of all households nationally rely on septic tanks. The conventional system involves the underground installation of a concrete tank and an absorption trench (see Figure 1).

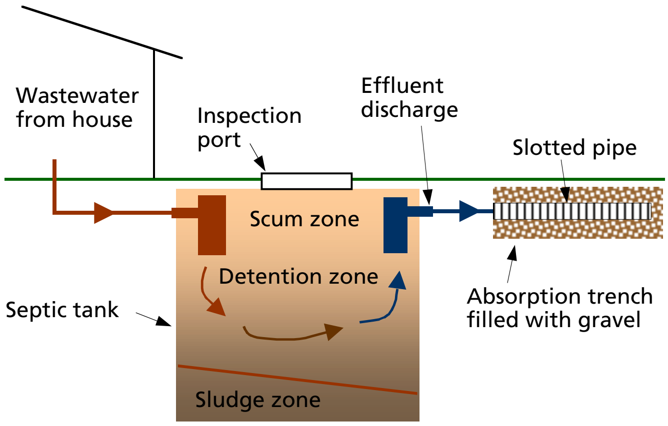


Figure 1: Septic tank & absorption trench

Wastewater is partially treated in the septic tank by anaerobic processes. These remove about 30% of phosphorus, 20% of nitrogen, 60% of suspended solids, 50% of BOD, and reduce the concentration of biological contaminants. Final treatment occurs via an absorption trench. The effluent then percolates to the soil where it is subject to further contaminant removal processes by soil organisms before reaching surface or ground waters.

Guidance for the design of septic tanks and the disposal of effluent from on-site wastewater treatment systems is provided in Australian Standards AS1546 and AS1547 respectively. Installation of a septic tank requires approval from the local council. Ongoing operation also requires council approval and regular inspection.

About 40% of septic systems have been found to be not operating correctly, thereby contributing nutrients to waterways and causing significant water management problems. Common reasons for failure of septic tank and absorption trench systems are:

- the volume of wastewater discharged to the septic tank is greater than its design volume
- failure to periodically remove sludge from the septic tank
- insufficient area of absorption trench to accept effluent from the septic tank
- inappropriate soil type for absorption of effluent.

Aerated systems

There are a number of different aerated wastewater treatment systems available for on-site management and reuse of wastewater. These systems rely on mechanical devices to mix, aerate and pump the effluent, subjecting it to accelerated aerobic and anaerobic decomposition using one or two tanks (see Figure 2).

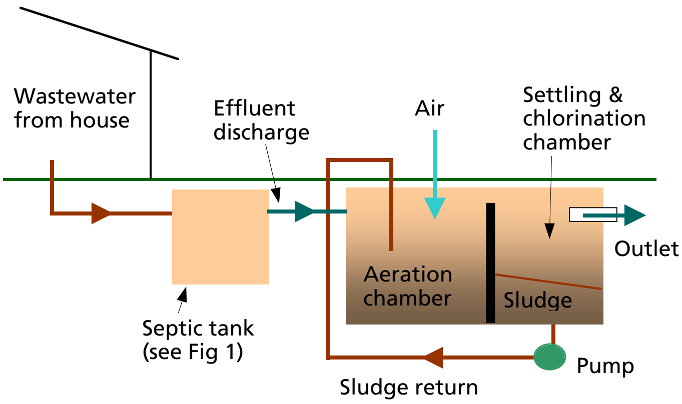


Fig 2: Aerated wastewater treatment system

Provided that the required management and maintenance regimes are adhered to, including periodic sludge removal, the effluent should be clear and odourless, and meet NSW Department of Health guidelines. Effluent quality should be better than 30 mg/l suspended solids concentration, 20 mg/l BOD_5, 0.5 mg/l free residual chlorine and 10 organisms per 100 ml for faecal coliforms. It can then be disposed of by surface or underground irrigation. A minimum irrigation area of 200 m^2 is usually required.

Greywater reuse systems

There are two main types of greywater reuse systems: primary and secondary systems In a primary system, greywater is collected and distributed by gravity or a pump for underground lawn and garden watering (see Figure 3).

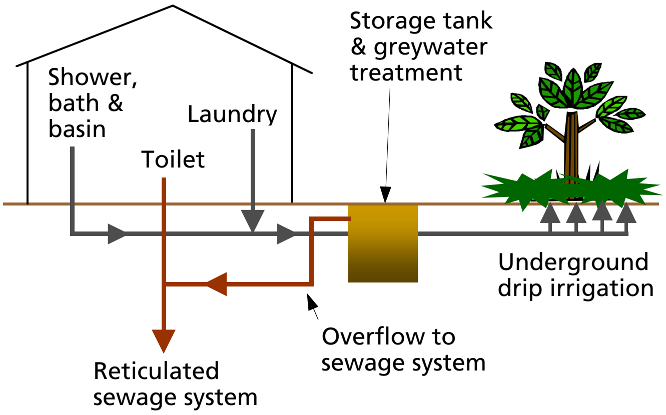


Fig 3: Primary greywater reuse system

Careful selection of detergents and washing products is required to minimise possible harmful impacts on plants or soil due to accumulation of salts, nutrients and trace metals. A guide to suitable detergents is provided by Mobbs (1998). As untreated greywater may contain harmful bacteria, it should not be applied directly to vegetables.

Secondary systems incorporate a storage tank for greywater treatment. This supplies greywater for toilet flushing and garden irrigation via a pump (see Figure 4). The system can also supply underground drip irrigation of garden areas.

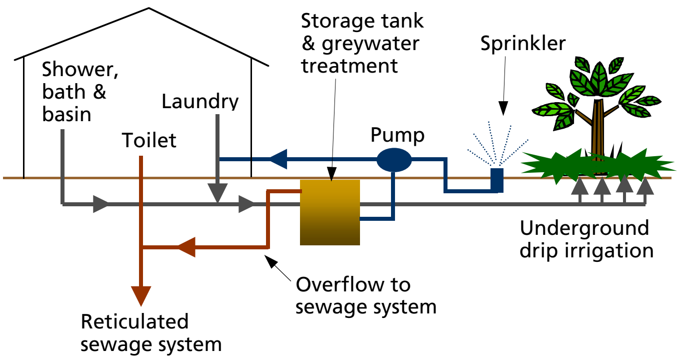


Fig 4: Secondary greywater reuse system

Wastewater reuse

Costs

Construction costs for wastewater systems can vary considerably. Palmer *et al* (2001) found that the average cost to install a septic system is $4,300, and the average cost of traditional reticulated sewage systems is $13,800 per allotment. The cost to install an aerated wastewater system is approximately $6,000-$8,000 with a maintenance cost of $260 per annum.

Useful contacts

CSIRO Urban Water Program: *www.dbce.csiro.au/urbanwater*

Michael Mobbs: *www.sustainablehouse.com.au*

BDP Environment Design Guide: The Royal Australian Institute of Architects

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Water Sensitive Urban Design in the Sydney Region

PRACTICE NOTE 10

Groundwater

Installing a groundwater bore

Water sensitive development involves simple design and management practices that take advantage of natural site features and minimise impacts on the water cycle. It is part of the contemporary trend towards more 'sustainable' solutions that protect the environment.

This Water Sensitive Practice Note gives a general introduction to groundwater utilisation measures.

- **Bores**
- **Groundwater extraction**
- **Aquifer storage & recovery**

Groundwater

Introduction

Groundwater extracted from bores can be an important water source for domestic use. Many urban areas occur over a suitable aquifer. Indeed, the use of groundwater in Australia for outdoor purposes is commonplace.

Groundwater quality varies from place to place, and may be unsuitable for domestic purposes. For example, groundwater can be saline or be contaminated by human activity. Where groundwater quality is unsuitable, artificial recharge of stormwater into the aquifer can sometimes be used to produce suitable water supplies. This process is known as aquifer storage and recovery. Many authors have described successful aquifer storage and recovery projects (see references).

As well as positive benefits, groundwater utilisation schemes have the potential to cause adverse impacts on local groundwater levels and quality. Consequently, specialist advice is required from qualified personnel. In addition, approvals from relevant authorities are also required.

Bores

A groundwater bore comprises a well driven into the ground to a depth exceeding the water table (the uppermost level of strata that is saturated by groundwater). Water-bearing strata beneath this level (such as rock or sand) is termed an aquifer. The depth of the water table and aquifers varies considerably from place to place in response to geological and climatic conditions, and can also vary seasonally.

A pump system is required to extract groundwater from the aquifer. Bores are installed by specialist drilling contractors. The principal components of a bore are illustrated in Figure 1.

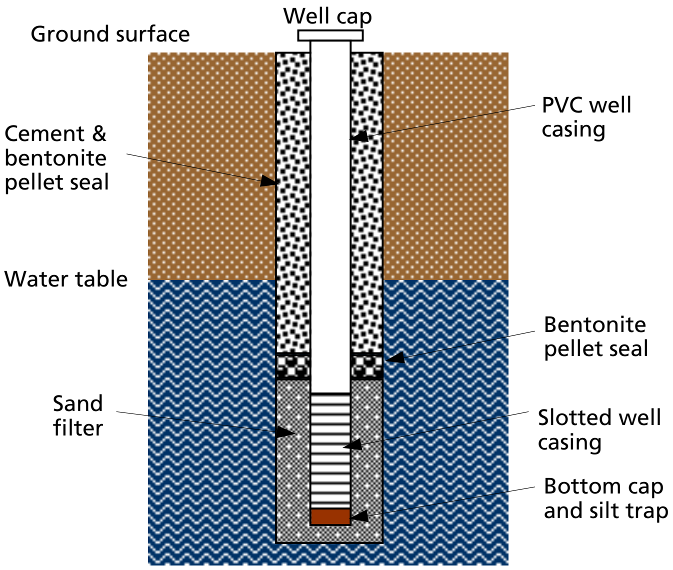

Fig 1: Components of a groundwater bore

Groundwater extraction

A conceptual groundwater extraction scheme is shown in Figure 2. Groundwater is extracted from an aquifer using a submerged pump placed in the bore. It is subsequently passed through a filter to remove sediments or contaminants. The extracted water is used for outdoor uses and toilet flushing.

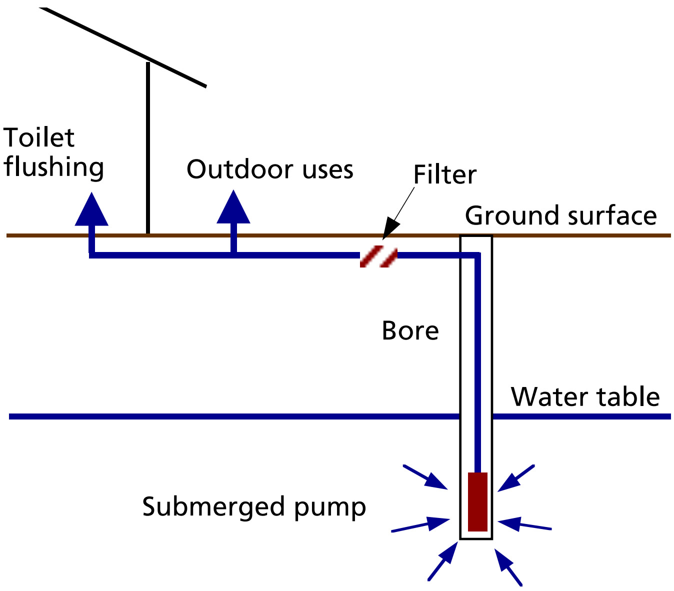

Fig 2: Conceptual groundwater extraction scheme

Aquifer storage & recovery

Aquifer storage and recovery involves the injection of treated stormwater into a suitable aquifer. This water is stored in the aquifer for extraction and reuse at a later time. A conceptual aquifer storage and recovery scheme is shown in Figure 3.

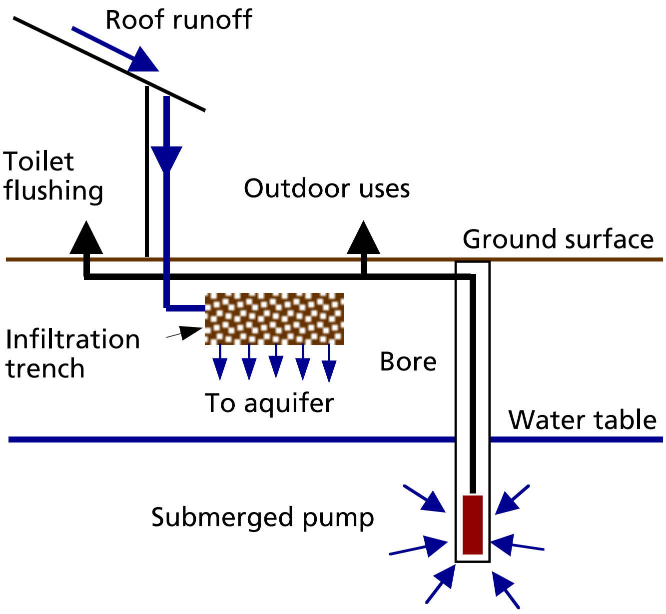

Fig 3: Conceptual aquifer storage & recovery scheme

There are three essential criteria that must be satisfied by an aquifer storage and recovery scheme.

- *Pre-treatment*: rainwater must be suitably treated prior to aquifer injection in order to prevent groundwater contamination. Domestic roof water is generally of acceptable quality provided that it is passed through a sand-gravel filter.
- *Water balance*: aquifer extraction and recharge must be balanced on an annual basis. This will ensure that long-term ground water levels are maintained.
- *Suitability for use*: the quality of water extracted from the aquifer must be suitable for the proposed use.

Satisfying each of the above requires specialist investigation, advice and management.

Consequently, aquifer storage and recovery will generally only be appropriate for larger housing developments. However, where installed, it can produce significant water management benefits including:

- flood mitigation
- reduced mains water demand and costs
- restoration of groundwater levels
- improved stormwater quality
- reduced groundwater salinity.

Approvals

An access licence under the *Water Management Act 2000* is required to extract groundwater from an aquifer. Such licences are administered by the Department of Infrastructure, Planning and Natural Resources (DIPNR).

Because of the need for an access licence, a development application for housing or other development involving groundwater extraction or aquifer storage and recovery is classed as 'integrated development'. This means that the application is required to be referred by the local council to DIPNR for its 'general terms of approval' regarding the access licence.

Consultation with the Environment Protection Authority is advised regarding aquifer injection and the need for an environment protection licence under the *Protection of the Environment Operations Act 1997*.

Development applications should be supported by detailed documentation that addresses relevant hydrological, hydrogeological, soil contamination and public health issues. This must be prepared by personnel having appropriate qualifications, expertise and experience.

Useful websites

CSIRO Urban Water Program: www.dbce.csiro.au/urbanwater

CRC for Catchment Hydrology: www.catchment.crc.org.au

Atlantis Corp.: www.atlantiscorp.com.au

Rocla Concrete Products: www.rocla.com.au

James Hardie Industries: www.jameshardie.com.au

Royal Australian Institute of Architects: BDP Environment Design Guide

University South Australia: www.unisa.edu.au

University of Newcastle, Peter Coombes: www.eng.newcastle.edu.au/~cegak/Coombes

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Other practice notes

Other Water Sensitive Practice Notes are available in this series:

No. 1 Water Sensitive Homes
No. 2 Site Planning
No. 3 Drainage Design
No. 4 Rainwater Tanks
No. 5 Infiltration Devices
No. 6 Paving
No. 7 Landscape Measures
No. 8 Landscape Practices
No. 9 Wastewater Reuse
No.10 Groundwater
No.11 Development Assessment
No.12 Urban salinity
No.13 Compliance mechanisms

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www.wsud.org

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Water Sensitive Urban Design in the Sydney Region

PRACTICE NOTE 11

Design & assessment

Water sensitive development involves simple design and management practices that take advantage of natural site features and minimise impacts on the water cycle. It is part of the contemporary trend towards more ‘sustainable’ solutions that protect the environment.

This practice note provides a general understanding of the design and assessment provisions outlined in the *Water Sensitive Planning Guide for the Sydney Region*. It is intended that the provisions will be incorporated in local and regional planning controls, with appropriate modifications to suit local circumstances.

- **Design elements**
- **Objectives & performance standards**
- **Management measures**

Design & assessment

Introduction

The *Water Sensitive Planning Guide for the Sydney Region* presents design and assessment provisions that set benchmarks for better water cycle design and performance.

The provisions are intended to be applied:

- to all urban development types
- in greenfield, redevelopment and infill settings
- at the subdivision and lot scales.

The provisions can be readily incorporated by councils in planning documents such as local plans or development control plans. Councils will need to adapt the provisions to suit local circumstances.

Design elements

The provisions are structured around ten design elements, each relating to a specific issue.

- Integrating the design
- Respecting the site
- Conserving water
- Preventing increased flooding
- Preventing increased stream erosion
- Maintaining water balance
- Reducing ecotoxic risk
- Controlling stormwater pollution
- Managing the construction site
- Ensuring long-term effectiveness

Each Element defines the issue, explains why it is important, and specifies outcomes that the development should achieve. Five of the Elements specify quantitative performance standards. Water management measures that may be effective in achieving the outcomes are identified, together with better practice guidelines on how these measures should be applied.

Performance-based format

The provisions adopt a performance-based format rather than requiring designers to adopt particular water management measures. This permits designers to select measures that are appropriate for the site, and which achieve objectives and performance standards in the most effective way.

Multiple objectives

In many instances, the application of a particular water management measure can contribute to achievement of the objectives and performance standards for several Design Elements. For example, provision of a roofwater tank will not only help conserve water, but may assist performance relating to water quality, urban flooding and stream erosion. This reinforces the need for a design approach that considers the inter-relationships between each of the ten design elements.

DESIGN ELEMENT:

Integrating the design

Water sensitive design seeks to integrate all issues that affect the water cycle on a development site, including water supply, stormwater, waste water and site constraints. An integrated approach enables the designer to avoid adverse impacts, and to utilise measures that achieve multiple objectives.

Objective

This Element seeks to promote full consideration of the site’s constraints, opportunities and context at the earliest stages in the design process. This will ensure that water management measures are selected having regard to site conditions and likely effectiveness.

Assessment

Proposals are assessed qualitatively according to the adequacy of the proposed measures in meeting the objectives, and their consistency with relevant better practice guidelines.

Design & assessment

Information requirements

A site analysis must be prepared for all development proposals (see *Practice Note 2*).

For small-scale development (generally comprising less than 15 dwellings), a water management statement must be prepared. This summarises proposed water management measures and their expected performance.

For larger developments, an integrated water cycle plan is required. This shows how the proposal integrates all relevant issues and responses affecting the water cycle.

DESIGN ELEMENT: Respecting the site

Urban development generally results in the modification of natural land and water features. However, it is possible to 'design with nature' and retain many natural elements within the fabric of the city, or to restore or reconstruct elements that have been degraded or lost.

The retention, restoration and emphasis of natural site features provides many benefits, including aesthetic benefits, reduced risk from natural hazards, maintenance of biodiversity and protection of local uniqueness.

Objective

This Element seeks to retain, restore and minimise disturbance to natural landforms, watercourses, natural drainage patterns, native vegetation and other natural landscape features. An essential outcome is that the layout, siting and design of development responds appropriately to site constraints and hazards.

Assessment

Proposals are assessed qualitatively according to the adequacy of the proposed measures in meeting the objectives, and their consistency with relevant better practice guidelines.

Design response

A wide variety of site selection, siting, design and construction practices can be used to help retain, restore or minimise disturbance to natural landforms, watercourses and native vegetation. These measures can be applied to at both the subdivision and building stages of development.

DESIGN ELEMENT: Conserving water

Water is our most precious resource. Existing urban water supply systems are approaching their limits, there is little potential to tap new water supply sources and there are growing community demands to increase environmental flows downstream from supply dams. As the urban population increases, we therefore need to make more efficient use of water. New development, redevelopment and alterations to existing buildings can contribute to environmental sustainability by incorporating a variety of water efficiency measures.

Objective

This Element seeks to achieve more efficient use of water and specifically, reduced mains water consumption.

Design & assessment

Assessment

Proposals are assessed against a quantitative performance standard. Expected average daily mains water consumption generated by the development must not exceed:

- for single dwelling-houses—70% of that which would be generated if no water conservation measures were applied (i.e., a '30% reduction')
- for other development—50% of that which would be generated if no water conservation measures were applied (i.e., a '50% reduction')

Design response

Rainwater tanks (see *Practice Note 4*) and water-efficient fixtures and appliances are particularly suitable measures for satisfying this Element. Landscape practices may also provide subsidiary benefits (see *Practice Note 8*).

Surface hardening

DESIGN ELEMENT:

Preventing increased flooding

Urban development results in the replacement of natural soil profiles and vegetation by buildings, roads and other impermeable surfaces. This 'surface hardening' produces more runoff and less infiltration to the soil. It also causes runoff to be discharged within a shorter period. The result is increased urban flooding during infrequent, high-magnitude storms.

Objective

This Element seeks to ensure that development does not contribute to increased flooding risk, and that it is compatible with the design capacity of existing stormwater systems.

Assessment

Proposals are assessed against a quantitative performance standard. Detention storage volume must not be less than the minimum amount specified in the council's on-site detention policy (or equivalent document).

Design response

Detention devices are a particularly suitable measure for satisfying this Element. Other measures that may provide subsidiary benefits include:

- extended detention devices
- roofwater tanks (see *Practice Note 4*)
- infiltration devices (see *Practice Note 5*)
- filtration and bioretention devices.

Site conditions such as heavy clay soils and soil salinity require special design considerations, and may constrain or exclude the application of some measures such as infiltration devices.

Design & assessment

DESIGN ELEMENT: Preventing increased stream erosion

'Surface hardening' resulting from urban development also affects stream behaviour during moderate rainfall events. During events that occur on average every 1 - 2 years, highly erosive stream flows may be generated, leading to rapid stream widening, increased streambank and channel erosion and degradation of aquatic habitats. These effects can be counteracted by the provision of 'extended' detention storage.

Objective

This Element seeks to ensure that development does not increase peak stormwater flows during moderate rainfall events. This will ensure that the development does not contribute to increased risk of damage to streambanks and riparian habitat.

Assessment

Proposals are assessed against a quantitative performance standard. Extended detention storage volume must not be less than the minimum amount specified in the council's extended detention policy (or equivalent document).

Design response

Extended detention devices are a particularly suitable measure for satisfying this Element. Other measures that may provide subsidiary benefits include:

- detention devices
- roofwater tanks (see *Practice Note 4*)
- infiltration devices (see *Practice Note 5*)
- filtration and bioretention devices.

Site conditions such as heavy clay soils and soil salinity require special design considerations, and may constrain or exclude the application of some measures such as infiltration devices.

DESIGN ELEMENT: Maintaining water balance

A further effect of 'surface hardening' is to alter the relative balance between runoff and infiltration. Infiltration is generally reduced, and the volume of surface runoff increased. This can cause:

- reduced stream flow and poor water quality during dry periods
- dieback and weed growth in bushland
- detrimental effects on wetlands, coastal lagoons and other aquatic environments.

Maintenance of natural water balance can be promoted by measures that capture stormwater and infiltrate it to the soil or make it available for human use.

Objective

This Element seeks to maintain the natural balance between runoff and infiltration. This will help prevent adverse impacts on environments that are sensitive to increased stormwater volumes (for example, bushland, wetlands and coastal lagoons).

Assessment

Proposals in sensitive locations are assessed against a quantitative performance standard. Expected post-development stormwater volume generated from the site during a typical rainfall year must not exceed 90% of the volume that would be expected if no measures were applied to reduce stormwater volume.

Design response

Suitable measures may include:

- roofwater tanks (see *Practice Note 4*)
- infiltration devices (see *Practice Note 5*).

The suitability of management measures will depend largely on site conditions. For example, Infiltration devices may not be suitable in areas with heavy clay soils or urban salinity hazard, or which have native bushland on lower slopes.

Design & assessment

DESIGN ELEMENT:

Reducing ecotoxic risk

The use of toxic substances involves a risk that these substances will find their way into soils, streams and groundwater. This may cause long-term damage to aquatic, estuarine and marine ecosystems, and also has important public health implications (for example, fish supplies).

Perhaps one of the most widespread uses of toxic substances in the urban environment is the application of chemical pesticides to control termite infestation in buildings, particularly residential buildings. In recent years, there has been a considerable reduction in the toxicity of pesticides that may be lawfully used for termite control. Nevertheless, there is significant scope to reduce the need to apply pesticides through the application of termite-resistant building design.

Objective

This Element seeks to reduce potential risks to the environment arising from the release of toxic chemicals into soil and water. A particular aim is to reduce reliance on chemical pesticides for the control of termite infestation in buildings

Assessment

Proposals are assessed qualitatively according to the adequacy of the proposed measures in meeting the objectives, and consistency with relevant better practice guidelines.

Design response

Suitable measures may include:

- termite-resistant building design (for residential development)
- chemical spill prevention measures (for development involving the transport, storage or handling of toxic chemicals).

DESIGN ELEMENT:

Controlling stormwater pollution

'Surface hardening' also significantly increases the potential for pollutants to be washed from roads, roofs and paving during regular rainfall events (those that occur on average every 3 - 6 months). Significant water quality improvements can be achieved by configuring a sequence of treatment measures (a 'treatment train'). Some measures may provide a variety of subsidiary benefits, such as urban flood control and water conservation.

Objective

This Element seeks to ensure water quality treatment of stormwater flows during regular rainfall events. This will support the achievement of detailed stormwater treatment objectives contained in adopted stormwater management plans.

Assessment

Proposals are assessed against a quantitative performance standard. Expected average annual post-development pollutant loads from the site must not exceed values adopted by the council's Stormwater Management Plan (such as for litter, suspended solids, phosphorus and nitrogen).

Design response

Suitable measures may include:

- roofwater tanks (see *Practice Note 4*)
- infiltration devices (see *Practice Note 5*)
- filtration and bioretention devices
- porous paving (see *Practice Note 6*)
- grassed swales
- ponds and wetlands.

The suitability of treatment measures will depend largely on site conditions. For example, infiltration devices may not be suitable in areas with heavy clay soils or which are affected by urban salinity hazard. Grassed swales may not be suitable on steep sites.

DESIGN ELEMENT:

Managing the construction site

Building and construction activities have a large impact on downstream waterways. Eroded sediment and construction waste may cause blocked stormwater pipes, silted streams, poor water quality, degraded aquatic communities and increased urban flooding. Due to the large number of construction sites, even small amounts of pollution from individual sites may have significant cumulative effects.

Objective

This Element seeks to manage environmental and public safety risks during construction work, to control erosion and stabilise exposed soil surfaces, and to prevent damage to stormwater devices installed prior to site works.

Assessment

Proposals are assessed qualitatively according to the adequacy of the proposed measures in meeting the objectives, and consistency with relevant better practice guidelines.

Design response

In the case of small-scale development, it will be necessary to install and maintain erosion and sediment control measures in accordance with an approved erosion and sediment control plan. For larger proposals (where the area of soil surface disturbance exceeds 2,500 square metres), it will be necessary to install and maintain erosion, sediment and pollution control measures in accordance with an approved soil and water management plan.

For further information about requirements, contact your local council.

DESIGN ELEMENT:

Ensuring long-term effectiveness

On-site water management measures serve not only the immediate site, but provide benefits to the downstream catchment. Their failure may have critical consequences if public water infrastructure systems have been designed on the assumption that on-site measures will continue to operate effectively.

In such cases, mechanisms are required to ensure proper maintenance and operation. The design integrity and effectiveness of on-site measures needs to be enduring on an intergenerational timeframe. This requires strong forms of enforcement and compliance controls, complemented by appropriate community education programs.

Objective

This Element seeks to ensure that essential on-site stormwater management measures are not removed or rendered ineffective, and will continue to operate in accordance with design specifications into the future.

Compliance mechanisms

To achieve the objectives, the council will apply strict enforcement mechanisms such as requiring regular inspection or certification of on-site stormwater management measures, requiring covenants on the title of the land, and enforcing these (*see Practice Note 13*).

Supporting mechanisms may also be adopted, including educational programs, inspection, programs, periodic audits, databases and, where necessary, appropriate enforcement action.

Design & assessment

Putting it all together

Each development proposal will require a suite of measures that responds appropriately to all ten Design Elements, site conditions, the type and scale of development, cost and other factors.

For example, a detached dwelling-house located on a sloping site with heavy clay soils and moderate-high soil salinity hazard might adopt the following suite of measures:

- raised-floor construction
- termite-resistant building design
- roofwater tank
- bioretention device with a lined sub-base
- water-efficient fixtures and appliances
- landscape practices
- erosion and sediment control measures.

A detached dwelling-house located on sandy soils might require a different combination of measures, as would high-density residential proposals, or commercial and industrial development.

Assessing performance

The extent to which a development proposal meets the quantitative performance standards is required to be assessed in accordance with Appendix 2 of the *Water Sensitive Planning Guide*. Appendix 2 also assists designers to select the most effective combination of water management measures for the site. The Appendix is technical in nature, and will be of most interest to hydrological engineers. It incorporates tables and graphs to guide the user through the assessment and selection process.

To assist the assessment process, an internet-based program called the Building Sustainability Index (BASIX) is currently being developed. BASIX will allow developers and council officers to undertake and assess the preliminary design of water management systems for small-scale development.

Water management statements

Development applications are required to be supported by a water management statement that:

- shows calculations for the 'site impermeability indicator' (see Appendix 1 of the *Water Sensitive Planning Guide*)
- briefly describes the proposed water management measures for the site
- provides expected performance information for each of the five design elements that have quantitative performance standards.

Expected performance information must be calculated in accordance with Appendix 2 of the *Water Sensitive Planning Guide*, or by using BASIX when it becomes available. It is proposed that BASIX will be able to generate simple assessment reports.

Other practice notes

Other Water Sensitive Practice Notes are available in this series:

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Water Sensitive Urban Design in the Sydney Region

PRACTICE NOTE 12

Urban salinity

A salt-damaged public building in Western Sydney

Water sensitive development involves simple design and management practices that take advantage of natural site features and minimises impacts on the water cycle. It is part of the contemporary trend towards more 'sustainable' solutions that protect the environment.

This Water Sensitive Practice Note gives a general introduction to urban salinity issues and their management in relation to water smart practices.

- **Causes of urban salinity**
- **Managing salinity processes**
- **Design & construction principles**

Urban salinity

Introduction

Salt is a natural part of the Australian landscape. Areas of naturally high soil or water salinity exist throughout the continent. However, it is increasingly recognised that land management practices may enlarge the area of land affected by salinity. Conversely, salinity is having a greater impact on human activities and development.

While salinity is widely recognised as a problem in agricultural areas, the impacts of salinity are also being felt in urban areas. Urban salinity is now recognised as a growing problem with potentially high costs to affected communities. Impacts go beyond the degradation of vegetation and soils. If unmanaged, urban salinity can result in significant problems for a variety of urban assets, including buildings, roads, underground services, parks and gardens.

Salinity is an issue for large areas of Sydney, particularly on the Cumberland Plain. Possible sources of salt are:

- *geology*—Wianamatta Shales, which occur extensively in the region, have a naturally high fossil (connate) salt content
- *climate*—the region's rainfall contributes approximately 10 to 20 kilograms of salt per year to each hectare of land.

A draft *Salinity Hazard Map for Western Sydney* was released in December 2000 by the Department of Land and Water Conservation. The map, and the models that support it, indicate that salinity may occur throughout the region. It should be noted that salinity has been observed in areas of shale in other parts of the Sydney region. Salinity may also need to be considered in other areas with similar geology and climate characteristics.

Causes of urban salinity

Salinity occurs when salts found naturally in soil or groundwater are mobilised. The processes of capillary rise and evaporation concentrate the mobilised salts at the ground's surface. Such movements are caused by changes in the natural water cycle. Development, infrastructure and resources in contact with mobilised salt in soil or groundwater may be adversely affected.

In urban areas the processes which cause salinity are intensified by the increased volume of water added to the natural system. Additional water comes from irrigation of gardens, lawns and parks, from leaking underground pipes and pools, and from concentrated infiltration of stormwater. Urban salinity can also be triggered by changes in stormwater distribution and flow. For example, salinity outbreaks may be related to impedance of sub-surface water flows by roads or structures, or poor drainage conditions on a site.

Urban salinity may damage vegetation in a manner similar to that observed in rural areas. It may affect lawns, playing fields and gardens. It can also place additional stress on remnant natural areas such as bushland, wetlands, rivers and creeks.

Fig 1: Salt-affected land in Western Sydney

Urban salinity

Urban salinity may affect built infrastructure, due to the chemical and physical impacts of salt on concrete, bricks and metal. Salt moves into the pores of bricks and concrete when these materials are exposed to damp, salt-laden soils. The salt then becomes concentrated as the water evaporates from the material. Over time, this can cause substantial corrosion and damage the material's structure. Salinity damage can appear in a number of forms, including:

- bricks that are crumbled, eroded or flaking
- mortar that is powdered
- concrete that is cracked or corroded.

Salt within the material may also have a corrosive effect on steel reinforcing.

Fig 2: Salt-affected buildings in Western Sydney

Underground service pipes, such as those used for water supply or sewerage, may be damaged. Leakage from pipes and corroded joints may also contribute to salinisation processes.

Waterlogging and salts associated with urban salinity have a considerable impact on roads and pavements. Physical and chemical degradation of the road base may occur, causing it to become more susceptible to cracking, pot-holing and eventual failure.

Fig 3: Salt-affected roads in Western Sydney

Urban salinity also affects stormwater infrastructure, causing problems such as erosion of swales and detention basins, and damage to concrete channels or pipes. The design of stormwater infrastructure may result in impeded groundwater flows, or may intercept groundwater, resulting in saline discharge through the stormwater system.

Much of the cost of urban salinity will be borne by local government in the form of increased repair and replacement of infrastructure, decreased useability of assets and the environment, increased environmental management obligations, and a potentially reduced rate base. Without appropriate management, urban salinity may become a significant future cost to government and the community.

Fig 4: Salt-affected stormwater infrastructure in Western Sydney

Managing urban salinity as a development issue

Urban salinity is a complex problem that can operate at both a local and regional scale. Because of the significant changes to surface and groundwater systems that result from urban development, mapping the potential occurrence and impact of urban salinity is difficult. Additionally, there are lags between cause and effect, both in time and distance, making it difficult to undertake modelling. As salinity problems can change substantially over time, it is difficult to predict exactly where salinity will occur and how it will respond to the changing environmental conditions associated with development.

It is also important to recognise the two-way relationship between development and salinity. Salinity may not only have an impact on the development, as discussed above, but the impact of development on salinity should also be given equal consideration.

Urban development may contribute to salinity problems in the following ways.

- *Exposure of sodic or saline sub-soils*—the processes of cut and fill, particularly for slab-on-ground construction, disturbs the upper layers of the soil. If the lower soil profile has saline or sodic properties, salinity problems and erosion can result. This effect may also be to bring the land surface closer to the water table.
- *Increase in the level of regional groundwater*—urban development tends to increase the amount of water entering the natural system, such as by irrigation of parks and gardens, leaking stormwater and sewer pipes, and changes in stormwater flows and concentrations. In addition, soil compaction and filling changes permeability and soil drainage, and can contribute to the creation of perched water tables.

- *Changes to soil groundwater flow*—by changing the way that groundwater flows through the soil, development may cause sub-soil salinity to be expressed at the surface. For example, groundwater levels may be raised as a consequence of roads, house slabs, retaining walls or trenches that impede or intercept the soil water flow, cause compaction, or create hydraulic pressure.
- *Disturbance of sensitive areas*—some areas exist in a delicate balance such that, once disturbed, they are difficult to restore and can rapidly deteriorate. For example, removal or disturbance of established salt-resistant vegetation in riparian corridors can increase erosion. Due to their high salinity levels, such areas can be very difficult to revegetate and stabilise.

Understanding salinity processes

To effectively manage urban salinity it is important to understand and manage the processes by which it occurs, and in particular, the role of the water cycle.

Over the last decade there has been widespread reliance on a single model to explain salinity processes. This model, developed following studies in northern Victoria, is based on the idea that removal of vegetation from hills and slopes causes an increased flow of water to saline groundwater ('recharge'). Saline groundwater then begins to rise, emerging at low-lying areas in the landscape ('discharge').

Until recently, most assumptions about how to best manage salinity are derived from this model. In particular, the model promotes the view that planting deep-rooted vegetation in key 'recharge' areas will address low-land problems. However, questions are now being raised as to the general applicability of the model and the management strategies based on it.

As part of the production of the draft Salinity Hazard Map for Western Sydney, the Department of of Infrastructure, Planning and Natural Resources (DIPNR, formerly Department of Land and Water Conservation) has developed a number of alternative models for processes that may be contributing to urban salinity. These are discussed in the draft guidelines and technical report that accompany the map. Relevant processes include:

- localised concentration of salinity through flow in shale landscapes
- surface interactions from deep groundwater
- areas of deeply weathered soil landscapes.

It must be noted that these processes may occur on a site individually, or in combination with each other.

In these models, separate 'recharge' and discharge' areas are not defined. Instead, the entire landscape can be considered as a recharge area, and the particular processes operating on a site, at a particular time, determine the location of discharge areas.

In order to select the most appropriate and effective management response for a site, it is necessary to identify the processes causing salinity at the site. Consequently, site-specific investigations will be necessary within salinity hazard areas to identify and understand the potential processes present at the site, as well as potential interactions between these processes and the proposed development, including stormwater management systems.

If no investigations are available it may be useful to undertake some salinity investigations for the site as part of the stormwater design process. Appropriate site-specific investigations for urban salinity are discussed in the booklet, Site Investigations for Urban Salinity. This booklet and further information about the need for and use of salinity investigations are available from the Department of Intrafrastructure, Planning and Natural Resources.

Stormwater management in salinity hazard areas

Stormwater management is a very important issue in salinity hazard areas due to the role of water in all salinity problems. The information provided below is general. It is highly recommended that a professional be consulted regarding specific drainage and stormwater requirements or alterations. This is particularly important in areas with reactive clay, where changes in soil moisture levels can cause serious damage to structures.

Correct drainage on a site helps to protect foundations, footings and walls from salt attack. Salinity problems generally occur in areas where water accumulates, or which are subject to continuous wetting and drying cycles. Examples include situations in which:

- natural through-flow or surface flow is impeded by buildings, retaining walls or land resurfacing
- water does not drain away due to the slope of the ground or paving on the site
- gardens or landscaping are sited directly against buildings.

The design and maintenance of development in areas potentially affected by urban salinity should take these factors into account. Damp soils have been found to contribute to salinity problems in areas with even mildly saline soils.

Salinity hazard needs to be carefully considered when developing on-site stormwater or wastewater treatment options. In particular, the use of infiltration and irrigation to manage water needs to be reviewed. Additionally, in areas with rising water tables and groundwater salinity, the recharge from such systems may be undesirable. In most cases, some site-specific investigations will be needed to predict likely impacts, as discussed above. In the case of on-site wastewater treatment, the salt load of the water, surface concentration over time, and impact on potential soil or groundwater salinity needs to be well investigated.

Stormwater detention structures or artificial wetlands with some holding capacity may need to be constructed with impermeable linings to avoid the infiltration of water to the surrounding landscape or to groundwater. When choosing a lining, the possibility that on-site clays may be saline should be investigated before they are selected for this purpose. An impermeable geotech fabric may be a better choice in such situations.

It is also important to consider the impact of any earthworks or reshaping required by the design or construction of stormwater infrastructure, as this may result in exposure of saline or sodic sub-soils. Once disturbed, these soils are very hard to stabilise and problems associated with tunnel erosion and poor revegetation may result.

Reshaping of creeks lowers the surface closer to the watertable and removes vegetation believed to be important in maintaining a lowered watertable in these areas. As a result, discharge or capillary rise may cause surface concentration of salts.

The relationship between the proposed stormwater system, sub-surface flows and the groundwater system also needs to be considered. It is possible for pipes or channels to impede flow causing accumulation of water and concentration of salts.

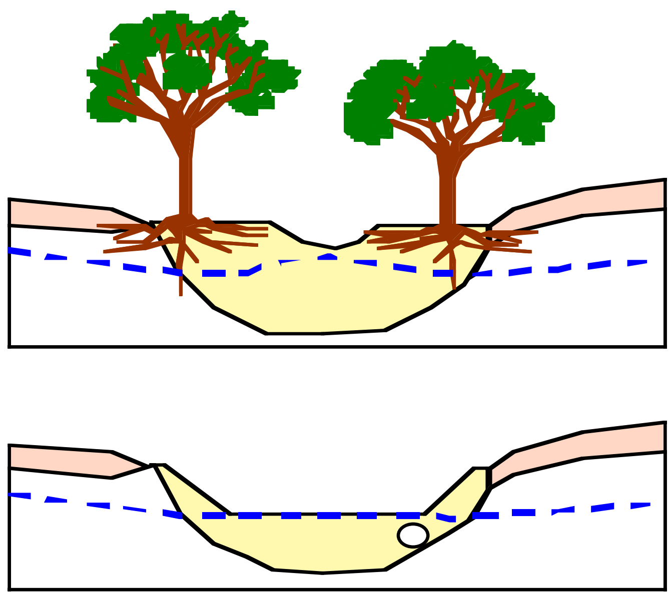

Fig 5: Urban salinity and stormwater channels

PRACTICE NOTE 13

Compliance mechanisms

Examining an on-site stormwater management sysytem

Water sensitive development involves simple design and management practices that take advantage of natural site features and minimises impacts on the water cycle. It is part of the contemporary trend towards more 'sustainable' solutions that protect the environment.

This Water Sensitive Practice Note explains why councils need to utilise a variety of compliance mechanisms to ensure that on-site water management measures are properly maintained, and that they continue to operate as intended.

- **Enforcing maintenance**
- **Education programs**
- **Setting up systems**

Compliance mechanisms

Why enforce maintenance?

Water sensitive urban design (WSUD) provides benefits to individual property owners, the broader community, the natural environment and future generations. WSUD features on both public and private properties therefore need to be maintained and protected.

If WSUD features are installed as a condition of development consent, the local council has a duty of care to the community to ensure that the condition continues to be complied with. The community relies upon the continuing operation of those WSUD features to provide a range of benefits. Water infrastructure will be designed and built, and the local environment managed, assuming that all WSUD features continue to function as designed.

If WSUD features fail to function, either through a lack of maintenance or accidental or deliberate action that makes them ineffective, the broader community and the environment will suffer losses or damage. Failures on even one property can have an adverse impact on neighbouring properties. The cumulative effect of failures on multiple properties can cause adverse impacts to be more significant and widespread.

In 1998 similar considerations led the NSW Government to introduce the SepticSafe program. This is a package of local government regulatory reforms and guidelines that enables councils to more effectively regulate and supervise the performance of small on-site domestic sewage management facilities.

Audits of on-site stormwater detention (OSD) systems and on-site septic tanks in western Sydney's Upper Parramatta River and Hawkesbury Nepean catchments in the mid 1990s found that, with no education and enforcement program in place, only 10% of systems were fully effective. Recent OSD audits in the Upper Parramatta River catchment, where a formal education and enforcement program has operated for some years, show a marked increase in the percentage of OSD systems that are properly maintained.

Enforcement of most of society's rules and laws depends upon the overwhelming majority of people willingly complying when they are made aware of what they are required to do or not do. The role of an education and enforcement program is to encourage voluntary compliance whilst, at the same time, ensuring that everyone ultimately must 'do the right thing'.

Making maintenance easier

Good maintenance starts with good design. A well-designed WSUD feature will be easy, safe and economical to inspect, clean and refurbish.

Good maintenance also depends upon good construction. This requires good construction techniques and careful regard to the design plans. Unfortunately, many stormwater measures are often deficient in both regards.

A useful approach adopted by the four local councils in the Upper Parramatta River catchment to help ensure that OSD systems are constructed in accordance with the design plans, is to (a) only accept OSD designs from accredited engineers, surveyors and hydraulic consultants, and (b) require that the OSD designer certifies that the completed OSD system will perform as designed.

To help ensure that OSD systems in the Upper Parramatta River catchment are maintained so that they continue to operate as designed, a formal maintenance education and enforcement program has been established and operated for some years.

Compliance mechanisms

Components of a compliance program

Based on experience with OSD and SepticSafe, the following are considered to be key component measures for a proper education and enforcement program for WSUD infrastructure.

- *Acceptance of responsibility*—a council needs to resolve to establish and operate a formal education and enforcement program.
- *Determination to enforce*—a council must be willing and determined to enforce its development consent conditions and the requirements specified in covenants.
- *Adequate staff resources*—sufficient staff and financial resources must be provided to operate the program.
- *Clear accountability*—a nominated council officer must be responsible for establishing and operating the program, and delivering the desired outcomes.
- *Database*—a database should be established containing details of all properties with WSUD features.
- *Data entry*—a procedure is required to ensure that details of all new WSUD features are promptly entered into the database.
- *Covenants*—properties with WSUD features should have a covenant and a restriction on use of land placed on the property title.
- *Inspections*—properties with WSUD features must be regularly inspected by a council stormwater inspector.
- *Advice on required maintenance*—a written report should be provided to each property occupier and owner at the time of the inspection listing any repairs or maintenance that are required.
- *Follow up*—councils must follow up on inspections to ensure that maintenance is carried out.
- *Education*—new owners should be educated about their maintenance responsibilities.
- *Audits*—periodic audits of properties with WSUD features are vital to assess how well they are being maintained and how successful the overall education and compliance program is operating.

Enforcing consent conditions

Whilst many development consent conditions relate to the construction phase, others are intended to be complied with on an ongoing basis. Examples of the latter type include operating hours, permitted uses, landscaping maintenance, checking of fire safety systems and on-site stormwater detention (OSD) maintenance. Unfortunately, limited staff resources mean that many local councils are unable to consistently ensure compliance with that ongoing consent conditions.

An informal survey of Sydney councils some years ago found that a majority require OSD on new development, but virtually none check to see if the constructed OSD systems are still working.

A necessary first step is therefore for local councils to accept that the imposition of any ongoing consent condition makes them responsible for ensuring ongoing compliance with that condition. Councils unwilling to accept that responsibility should not impose ongoing conditions. However, the extent of a council's ongoing involvement can be reduced if the development consent requires the submission of regular certification of the performance of the WSUD features.

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Staff & financial resources

It is unrealistic and irresponsible to presume that an education and enforcement program for WSUD features can be established and operated by existing staff, in addition to their present duties. Additional staff and financial resources will always be required. Work pressures on council staff are such that maintenance is the first activity to be deferred if combined with other responsibilities.

Funding an education and enforcement program for WSUD features can be a particular challenge because development application fees only cover the cost of assessing the applications and ensuring the development is constructed in accordance with the development consent. Application fees do not cover the cost of ensuring ongoing compliance with consent conditions.

The Upper Parramatta River Catchment Trust funds its education and enforcement program for OSD systems from service charges levied on all catchment properties. Many councils impose an 'environmental levy' or similar. Special rates of this nature can provide a dedicated source of funds to support an education and enforcement program. Otherwise, such programs will need to be funded from general rate revenue, which is reliant upon year-to-year council decisions.

Covenants

The ability to ensure that WSUD features are being properly maintained is greatly strengthened by title restrictions. Before a final approval is issued or any subdivision plan is released, a 'positive covenant' and a 'restriction on use of land' in favour of the council should be created on the title of every property with a WSUD feature. Such instruments are created by the Land Titles Office upon request. Samples and other useful information can be found in Appendix B2 to B7 in the *OSD Handbook* (UPRCT, 1999). Whilst these samples relate to OSD systems, they are readily applicable to other types of WSUD features.

Positive covenants and restrictions on use of land make it easier for councils to ensure proper maintenance of WSUD features without having to take action in the Land and Environment Court.

The covenant requires the registered owner of the land to clean and maintain the facility, permit council officers to enter and inspect the facility, and comply with any written notice. Furthermore, if the owner fails to comply with a written notice, the covenant empowers the council to carry out any necessary work and recover its costs in a court. A restriction on the use of land prohibits the owner from altering the facility without the council's written consent.

Clear accountability

Closely related to adequate resourcing is the need for a nominated officer to have clear accountability for running the education and enforcement program. Someone must be able to be held responsible for ensuring that WSUD features in the council's area continue to function as was intended when they were designed, approved and constructed. This accountability should be explicitly stated in the nominated officer's position description and performance indicators.

Databases

Any education and enforcement program for WSUD features requires a WSUD database to be established and maintained. This must contain:

- data on all the properties with WSUD features
- andowner's name and address
- key details of the WSUD features
- design plan and council file numbers
- records of inspections carried out

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- outcomes of requested maintenance work
- a procedure to ensure that details for all sites with new WSUD features are entered into the database, either at the time of consent or when the completed development is 'signed off'.

The Upper Parramatta River Catchment Trust has recently developed a sophisticated OSD database that can be accessed by the four councils within the Trust's area via the Trust's web site. As well as satisfying the above requirements, the database has the following features:

- automatic scheduling of inspections and re-inspections
- ability to access via e-mail
- security controls that limit access to those authorised to access certain sections
- automatically advises database supervisor and council management of escalating seniority if maintenance request letters are not issued within a specified time after each inspection
- a Personal Digital Assistant (PDA) that asks the inspector a series of questions during the site inspection
- automatic generation of a maintenance request report or letter by the PDA using answers given during each inspection
- ability to print a maintenance request report at the time of the inspection
- ability to generate reports by local government area, by catchment, by system type, by status and most common problems
- can accommodate extra catchments and local government areas.

The OSD database has been designed to be used in other areas. If there is sufficient interest, the Upper Parramatta River Catchment Trust may arrange to modify the OSD database to accommodate a range of WSUD features. Please contact the Trust on 02 9891 4633 to register an interest.

Education

Whilst the first owner of a property with WSUD features may be aware of their existence and maintenance requirements, subsequent owners and tenants are generally not informed when they take possession. However, it has been found that when owners and occupiers are informed about the on-site facilities of their property, most are very interested and are quite willing to undertake necessary maintenance.

Preferably, the council stormwater inspector should meet the new owner on site within two months of change of ownership to explain the benefits of the WSUD features (both for the owner or occupier and the broader community), its key features, how they function and how to carry out proper maintenance. A simple brochure explaining how various WSUD features work can be very useful. Such meetings with new owners are extremely cost effective because, by helping establish a sound maintenance regime at the outset, they can save the council a great deal of time and effort later on.

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Regular inspections

Physical inspection of properties with WSUD features is the key element in a maintenance education and enforcement program. Inspections are important because they:

- educate landowners about WSUD and the importance of proper maintenance
- provide an opportunity for owners to learn how to maintain their WSUD features
- highlight the importance that the council places on WSUD
- prompt owners to do maintenance that would not otherwise have been carried out
- help councils understand community knowledge and awareness of WSUD
- identify common design and construction faults
- provide early warning of major problems.

The inspector should be a council employee or an authorised contractor since inspections are undertaken on behalf of the council under the terms of a development consent or covenant. The use of casual staff is not favoured because the efficiency and effectiveness of an inspector grows over time. A mature person is likely to be more successful. Some understanding of hydraulics and stormwater is required.

The position suits a semi-retired engineer, plumber or mature-age student. The inspector must be willing to work flexible hours. For educational purposes and access, it is very desirable for the property owner to be present when the inspector calls. This is more likely to be possible in the evening (especially in summer or at the weekend.

Finally, the inspector must be self-motivated and well organised because he or she works on their own in the field for several days at a time.

For safety reasons the inspector is not allowed to enter any confined space whilst doing the inspections. A remote access camera can be inserted into a confined space to inspect the condition of its interior.

Each property with WSUD features should be inspected every 18 months, and within two months of a change of ownership. More frequent inspections may be required if necessary to encourage the owner for carry out maintenance. With experience, less frequent inspections may be warranted for properties with well-maintained WSUD features.

To ensure that all WSUD properties are inspected regularly, inspections are best scheduled automatically using a scheduling feature in the WSUD database. The Upper Parramatta River Catchment Trust's OSD database has this facility. It also tracks completion of requested maintenance work and follow up if the work is not carried out.

Property occupiers must be given adequate notice of the intention to carry out an inspection. In the Upper Parramatta River Catchment Trust, colourful and distinctive leaflets are delivered two weeks and then a few days before the planned OSD inspection date. The leaflets note the date and time of the proposed inspection and ask occupiers to phone the inspector to arrange access or a more suitable time.

The inspector needs to obtain, and bring to each inspection, a copy of the approved or (preferably) the work-as-executed layout plan of the WSUD features. It is useful to bring a second copy to give to the owner because most owners will not have

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seen such a plan. Many WSUD features are closely integrated into the property's landscaping and, after some years, key WSUD elements may not be readily apparent without the layout plan. In an ultimate inspection program, the plans of the WSUD features would be available electronically at the site via mobile phone and a copy could be printed out if required.

An inspection checklist is essential for thorough and systematic inspections. It is also useful to have a coded set of common maintenance actions. Each code can be related to a brief pre-prepared paragraph describing the action so that a computer can generate a maintenance request letter from a series of codes noted during the inspection.

Enforcing maintenance

The inspector discusses and explains to the property owner or occupier (if he or she is present) any maintenance work required on the WSUD features. A brief written report should be provided to each property owner or occupier upon completion of the inspection listing the repairs or maintenance required. If the report cannot be provided immediately it should be mailed the next business day. Lengthy delays in issuing the maintenance request reports undermine the credibility of the maintenance education and enforcement program.

As the legal obligation to maintain the WSUD features rests with the registered landowner, and many properties are tenanted, the council will need to formally write to the owner with a copy of the maintenance request report.

The maintenance request reports ask the recipient to advise the council when the work has been carried out. Some re-inspections are needed to ensure that the work has been completed and carried out properly.

If the requested maintenance work is not carried out within a reasonable period, a second, more insistent letter should be sent to the registered property owner. If, after a further period, the requested maintenance work has still not been carried out, the council should take legal action to enforce its consent conditions. Alternatively, if there is a covenant in favour of the council, the council has the option to enter the land, carry out the necessary repairs or maintenance and then recover its costs through a relatively simple legal action. Where this is necessary, councils should publicise its action to encourage all landowners to comply with future maintenance requests.

Periodic audits

Like any program, a WSUD maintenance education and compliance program will require ongoing monitoring, review and adjustment. As the aim of the program is to ensure that WSUD features are being properly maintained, it is best monitored by having an independent party conduct audits of a random selection of properties with WSUD features. In order that conclusions can be validly drawn about the overall program, the audit should examine WSUD features on a sufficiently large number of properties covering the full range of property types. Care should be taken not to bias the results by only auditing properties that have been recently inspected.

Audit results should be presented in a simple form, such as the percentage of audited properties in categories, such as:

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- well maintained - fully effective
- partly maintained - partly effective
- not maintained - minimally effective, but could be made fully effective if properly maintained
- rendered inoperative - ineffective, requires major repairs or reconstruction to restore effectiveness.

A simple categorisation such as this facilitates the analysis of trends over a series of audits and comparison of audit results from different areas and programs. The audits should be repeated every 3 to 5 years, or before any major change to the program. As well making a quantitative assessment, landowners or occupiers should be interviewed to identify key reasons why their WSUD features are, or are not, being well maintained. It would also be very useful to identify any special WSUD features or elements that are commonly not being well maintained. This may indicate design or construction shortcomings that can be rectified in future WSUD features.

Useful tools

- A computer-based database of properties with WSUD features, accessible via the internet.
- Copies of plans of constructed WSUD features to help locate key elements during inspections.
- An inspection checklist with a coded list of maintenance or remedial actions to facilitate inspections and follow up.
- An explanatory brochure outlining common WSUD features, their benefits, simple maintenance procedures and obligations on property owners.
- A leaflet advising of an imminent inspection and a 'sorry we missed you' card to help arrange inspections.
- A remote access camera for easy and safe inspection of confined spaces in pits, tanks, wells.
- Articles in local newspapers highlighting the importance of proper maintenance of WSUD features.
- Prizes or other forms of public acknowledgment for owners who maintain WSUD features to a very high standard.

Useful websites

www.uprct.nsw.gov.au/osd

www.dlg.nsw.gov.au/dlg/dlghome

References

Upper Parramatta River Catchment Trust (1999). *On-site Stormwater Detention Handbook* 3rd Edition. UPRCT, Parramatta.

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