Chapter 3 Summary of water sensitive urban design elements



3.1 Introduction

This chapter describes the **Water Sensitive Urban Design** (WSUD) elements for which detailed design procedures are presented in subsequent chapters. This Manual covers the most commonly used WSUD elements in Australia. Usually, a combination of these elements are used as a **treatment train** to effectively manage stormwater from a range of different land uses. The design procedures in Chapters 4–13 allow measures to be sized to target particular pollutant reductions (depending on their position in a treatment train).

Detailed design procedures are provided for the following WSUD elements:

- **sediment basins**
- **bioretention swales**
- **bioretention basins**
- sand filters
- swale/buffer systems
- constructed wetlands
- ponds
- **infiltration measures**
- **rainwater tanks**
- aquifer storage and recovery.

In addition, Chapter 14 describes a range of 'other measures' and covers topics such as proprietary products (including **gross pollutant traps, GPTs**), **porous pavements** and other treatment devices. GPTs are not included as a separate chapter because there are many proprietary products available and detailed designs are typically not required other than the selection of treatment flows. The selection of treatment flows and other design considerations when selecting a proprietary product are contained in other texts (e.g. Engineers Australia 2003).

The following sections provide brief descriptions of the WSUD elements covered. The selection and placement of the elements within a **catchment** should be determined during a concept design of a stormwater treatment strategy and its consideration is outside the scope of this document.

3.2 Sediment basins

Sediment basins are used to retain coarse sediments from runoff and are typically the first element in a treatment train. They are important in protecting downstream elements from becoming overloaded or smothered with sediments. They operate by reducing flow velocities and encouraging sediments to settle out of the water column.

They are frequently used for trapping sediment in runoff from construction sites and as pretreatments for elements such as **wetlands** (e.g. an inlet pond). They can be designed to drain during periods without rainfall and then fill during runoff events or to have a **permanent pool**.

Sediment basins can have various configurations including hard edges and base (e.g. concrete) or a more natural form with edge vegetation creating an attractive urban landscape element. They are, however, typically turbid and maintenance usually requires significant disturbance of the system.

Maintenance of sediment basins involves dewatering and dredging collected sediments. This is required approximately every five years, but depends on the nature of the catchment. For construction sites that produce very large loads of sediment, desilting is required more frequently.

Figure 3.1 Sedimentation basins can be installed into hard or soft landscapes.

Sediment basins should be designed to retain coarse sediments only (recommended particle size is 0.125 mm. As the highest concentrations of contaminants such as hydrocarbons and metals are associated with fine sediments, waste disposal costs for this material can be much higher. Therefore, other treatment measures that assimilate these pollutants into a substrate are usually used to target this material.

3.3 Bioretention swales

Bioretention swales (or biofiltration trenches) are bioretention systems that are located within the base of a swale. They can provide efficient treatment of stormwater through fine filtration, **extended detention** and some **biological uptake** as well as providing a conveyance function (along the swale). They also provide some flow retardation for frequent rainfall events and are particularly efficient at removing nitrogen and other soluble or fine particulate contaminants.

Bioretention swales can form attractive streetscapes and provide landscape features in an urban development. They are commonly located in the median strip of divided roads.

Figure 3.2 Bioretention swales are commonly located in median strips of roads and carparks

Runoff is filtered through a fine media layer as it percolates downwards. It is then collected via perforated pipes and flows to downstream waterways or to storages for reuse. Unlike infiltration systems, bioretention systems are well suited to a wide range of soil conditions including areas affected by soil salinity and saline groundwater as their operation is generally designed to minimise or eliminate the likelihood of stormwater exfiltration from the filtration trench to surrounding soils.

Any loss in runoff can be mainly attributed to maintaining soil moisture of the filter media itself (which is also the growing media for the vegetation). Should soil conditions be favourable, infiltration can be encouraged from the base of a bioretention system to reduce runoff volumes (see Infiltration measures).

Vegetation that grows in the filter media enhances its function by preventing erosion of the filter medium, continuously breaking up the soil through plant growth to prevent clogging of the system and providing **biofilms** on plant roots that pollutants can adsorb to. The type of vegetation varies depending on landscape requirements and climate. The filtration process generally improves with denser and higher vegetation.

3.4 Bioretention basins

Bioretention basins operate with the same treatment processes as bioretention swales except they do not have a conveyance function. High flows are either diverted away from a basin or are discharged into an overflow structure.

Like bioretention swales, bioretention basins can provide efficient treatment of stormwater through fine filtration, extended detention and some biological uptake, particularly for nitrogen and other soluble or fine particulate contaminants.

Bioretention basins have an advantage of being applicable at a range of scales and shapes and can therefore have flexibility for locations within a development. They can be located along streets at regular intervals and treat runoff prior to entry into an underground drainage system, or be located at outfalls of a drainage system to provide treatment for much larger areas (e.g. in the base of retarding basins).

A wide range of vegetation can be used within a bioretention basin, allowing them to be well integrated into a landscape theme of an area. Smaller systems can be integrated with traffic calming measures or parking bays, reducing their requirement for space. They are equally applicable to redevelopment as well as **greenfield sites**.

Bioretention basins are, however, sensitive to any materials that may clog the filter medium. Traffic, deliveries and washdown wastes need to be kept from bioretenion basins to reduce any potential for damage to the vegetation or the filter media surface.

3.5 Sand filters

Sand filters operate in a similar manner to bioretention systems except that they have no vegetation growing on their surface. This is because they are either installed underground (therefore light limits vegetation growth) or the filter media does not retain sufficient moisture. They are particularly useful in areas where space is a premium and treatment is best achieved underground. Due to the absence of vegetation, they require regular maintenance to ensure the surface of the sand filter media remains porous and does not become clogged with accumulated sediments.

Prior to entering a sand filter, flows are generally subjected to a pretreatment to remove litter, debris and coarse sediments (typically a **sedimentation** chamber). Following pretreatment, flows are spread over the sand **filtration media** and water percolates downwards to perforated pipes located at the base of the sand. The perforated pipes collect the treated water for conveyance downstream. During higher flows, water can pond on the surface of the sand filter and increase the volume of water that can be treated. Very high flows are diverted around sand filters to protect the sand media from scour.

Figure 3.3 Bioretention basins are applicable at a range of scales and can be integrated with an urban landscape.

Figure 3.4 Sand filters can be installed above or below ground.

3.6 Swale or buffer systems

Vegetated swales are used to convey stormwater in lieu of pipes and provide a desirable **buffer** between receiving waters (e.g. creek or wetland) and impervious areas of a catchment. They use overland flows and mild slopes to slowly convey water downstream. The interaction with vegetation promotes an even distribution and slowing of flows thus encouraging coarse sediments to be retained. Swales can be incorporated in urban designs along streets or parklands and add to the aesthetic character of an area.

The longitudinal slope of a swale is the most important consideration. They generally operate best with slopes of 2% to 4%. Milder sloped swales can tend to become waterlogged and have stagnant ponding, although the use of underdrains can alleviate this problem. For slopes steeper than 4%, **check banks** along swales can help to distribute flows evenly across swales as well as slow velocities. Dense vegetation and drop structures can be used to serve the same function as **check dams** but care needs to be exercised to ensure that velocities are not excessively high.

Swales can use a variety of vegetation types. Vegetation is required to cover the whole width of a swale, be capable of withstanding design flows and be of sufficient density to provide good filtration. For best treatment performance, vegetation height should be above treatment flow water levels. If runoff enters directly into a swale, perpendicular to the main flow direction, the edge of the swale acts as a buffer and provides pre-treatment for the water entering the swale.

3.7 Constructed wetlands

Constructed wetland systems are shallow, extensively vegetated water bodies that use **enhanced sedimentation**, fine filtration and pollutant uptake processes to remove pollutants from stormwater. Water levels rise during rainfall events and outlets are configured to slowly release flows, typically over three days, back to the water levels of dry weather.

Figure 3.5 Swale vegetation is selected based on required appearance and treatment performance.

Wetlands generally consist of an **inlet zone** (sediment basin to remove coarse sediments), a **macrophyte zone** (a shallow heavily vegetated area to remove fine particulates and uptake of soluble pollutants) and a high flow bypass channel (to protect the macrophyte zone).

Wetland processes are engaged by slowly passing runoff through heavily vegetated areas. Plants filter sediments and pollutants from the water and biofilms that grow on the plants can absorb nutrients and other associated contaminants. In addition to being important in stormwater treatment, wetlands can also have significant community benefits. They provide habitat for wildlife and a focus for recreation, such as walking paths and resting areas. They can also improve the aesthetics of a development and be a central feature in a landscape.

Wetlands can be constructed on many scales, from the size of a house block to large regional systems. In highly urban areas they can have a hard edge form and be part of a streetscape or forecourts of buildings. In regional settings they can be over 10 ha and provide significant habitat for wildlife.

Figure 3.6 Wetlands can be constructed on many scales.

3.8 Ponds

Ponds (or lakes) promote particle sedimentation, adsorption of nutrients by phytoplankton and ultraviolet (UV) disinfection. They can be used as storages for reuse schemes and urban landform features for recreation as well as wildlife habitat. Often wetlands will flow into ponds and the water bodies enhance local landscapes.

In areas where wetlands are not feasible (e.g. very steep terrain), ponds can be used for a similar purpose of water quality treatment. In these cases, ponds should be designed to settle fine particles and promote submerged macrophyte growth. Fringing vegetation, while aesthetically pleasing, contributes little to improving water quality. Nevertheless, it is necessary to reduce bank erosion. Ponds still require pretreatment such as sediment basins that need maintaining more regularly than the main, open water body. Poorly designed ponds can experience regular algal blooms. Reducing the risk of algal blooms is an integral component of design.

Ponds are well suited to steep, confined valleys where storage volumes can be maximised. Some limitations for ponds can be site specific, for example proximity to airports, as large

Figure 3.7 Ponds are popular landscape features in urban areas.

numbers of flocking birds can cause a disturbance to nearby air traffic. They also require regular inspection and maintenance to ensure that their aesthetic value is not diminished.

3.9 Infiltration measures

Infiltration measures encourage stormwater to infiltrate into surrounding soils. They are highly dependant on local soil characteristics and are best suited to sandy soils with deep groundwater. All infiltration measures require significant pretreatment of stormwater before infiltration to avoid clogging of the surrounding soils and to protect groundwater quality.

Infiltration measures generally consist of a shallow excavated trench or 'tank' that is designed to detain a certain volume of runoff and subsequently infiltrate to the surrounding soils. They reduce runoff as well as provide pollutant retention on site. Generally these measures are well suited to highly permeable soils, so that water can infiltrate at a sufficient rate. Areas with lower permeability soils may still be applicable, but larger areas for infiltration and detention storage volumes are required. In addition, infiltration measures are required to have sufficient set-back distances from structures to avoid any structural damage. These distances depend on local soil conditions.

Infiltration measures can also be vegetated and provide some landscape amenity to an area. These systems provide improved pollutant removal through active plant growth improving filtration and ensuring the soil does not become 'clogged' with fine sediments.

3.10 Rainwater tanks

Rainwater tanks collect runoff from roof areas for subsequent reuse that reduces the demand on potable mains supplies and reduces stormwater pollutant **discharges**. In addition, they serve to retard a flood provided adequate temporary storage is available either through appropriate sizing (e.g. small tanks that are drawn down frequently can offer significant retention of roof runoff) or through temporary detention storage.

Figure 3.8 Infiltration systems are best suited to sandy soils with deep groundwater.

Figure 3.9 Rainwater tanks are available in a range of sizes and shapes.

There are many forms of rainwater tanks available. They can be incorporated into building designs so they do not affect the aesthetics of a development. They can also be located underground or some newer designs incorporate tanks into fence or wall elements or as part of a gutter system itself.

To improve the quality of the stored water, tanks can be fitted with '**first flush diverters**'. These are simple mechanical devices that divert the first portion of runoff volume (that typically carries debris) away from the tank. After the first flush diversion, water passes directly into the tank.

Collected roof water is suitable for direct use for garden irrigation or toilet flushing with no additional treatment. Tank water can also be used in hot water systems, although some additional treatment may be required to reduce the risk of pathogens depending on the design of the system. This generally involves UV disinfection and ensuring that a hot water service maintains a temperature of at least 60°C.

Tanks are generally sized for the demand they are intended for. For example, if tank water is intended to be used for toilet flushing and hot water systems, a desired level of **reliability** can be achieved with the selection of an appropriately sized tank given a site's rainfall pattern and the area of roof that drains to the tank. In most cases, where potable water is available, a connection to potable water supplies is recommended to ensure a high degree of reliability and provide a secondary source of supply.

Roof runoff that is reused also prevents stormwater pollutants (generated on roofs) from washing downstream. Depending on the roof area directed to the tank and the proportion of runoff reused, significant pollutant reductions can be made.

3.11 Aquifer storage and recovery

Aquifer Storage and Recovery (ASR) is a means of enhancing water recharge to underground aquifers through either pumping or gravity feed. It can be a low cost alternative to store water compared to surface storages. Excess water produced from urbanisation during wet periods (e.g. winter) can be stored underground and subsequently harvested during long dry periods to reduce reliance on mains supply.

Harvesting urban runoff and diverting it into underground groundwater systems requires that the quality of the injected water is sufficient to protect the beneficial uses of the receiving groundwater. The level of treatment required depends on the quality of the groundwater. In most instances the treatment measures described in this Manual will provide sufficient treatment prior to injection.

The viability of an ASR scheme is highly dependant on the underlying geology of an area and the presence and nature of aquifers. There are a range of aquifer types that can accommodate an ASR scheme including fracture unconfined rock and confined sand and gravel aquifers. Detailed geological investigations are required to establish the feasibility of any ASR scheme. This Manual provides an overview of the main elements of the system and directs readers to more specific guidance documents.

3.12 References

Engineers Australia (2003). *Australian Runoff Quality Guidelines*, Draft, June.