# Chapter 7
# Structural Treatment Measures

## 7.1 Introduction

Stormwater structural treatment measures can be grouped into three categories: primary, secondary and tertiary.

**Primary treatment**
Physical screening or rapid sedimentation techniques. *Typical retained contaminants*: gross pollutants and coarse sediments.

**Secondary treatment**
Finer particle sedimentation and filtration techniques. *Typical retained contaminants*: fine particles and attached pollutants.

**Tertiary treatment**
Enhanced sedimentation and filtration, biological uptake, adsorption onto sediments. *Typical retained contaminants*: nutrients and heavy metals.

Many of the treatment measures described in this chapter are recent developments and are still undergoing field testing. There is a need for further long term performance monitoring of these techniques—some may demonstrate incidental environmental impacts not yet recognised. This, and the complexity of the pollutant retention processes involved, make estimating pollutant retention an imprecise science. As a result, refinements to treatment design parameters can be expected over time.

## 7.2 Selecting a stormwater treatment measure

The selection and implementation of structural treatment measures involves six steps. These are:

1 **Determine treatment objectives**: establish the pollutants of concern in the catchment (e.g. litter, sediments, nutrients) and the level of pollutant retention required.

2 **Develop treatment train**: assess the treatment processes required and appropriate measures and ordering, including any pre-treatment requirements (e.g. screening of coarse sediments or flow control).

3 **Site identification**: identify potential sites and site constraints (e.g. slopes and soil types).

4 **Short-list potential treatments**: identify all applicable treatments.

5 **Compare potential treatments**: compare all potential treatments for removal efficiency, maintenance requirements, social impacts and costs.

6 **Detailed design**: complete detailed design of the optimal treatment.

These Guidelines review the first five steps of this process. The detailed design process requires further, more site specific information and is outside the scope of these Guidelines. An example of determining an installation plan for litter traps within a municipality is also presented in Appendix A. It demonstrates a methodology for selecting and ranking treatment options using litter as the target pollutant.

### 7.2.1 Treatment objectives

The stormwater pollutant profile of any catchment area is determined largely by the area's land-use and stormwater management. For example, human derived litter can be a problem in commercial areas, whereas sediment run-off is often more prevalent in developing urban areas.

To isolate the pollutants of concern in any catchment, the designer needs to closely examine receiving water degradation in light of the area's land-use and current management practices. The performance objectives set out in Chapter 2 are a guide to the typical pollutant load reductions required to contribute to State Environment Protection Policy (SEPP) compliance.

In order to protect receiving waters, treatments may be required to reduce the impact of one or more of the following pollutant categories:

- **gross pollutants**: trash, litter and vegetation larger than five millimetres;
- **coarse sediment**: contaminant particles between 5 and 0.5 millimetres;
- **medium sediment**: contaminant particles between 0.5 and 0.062 millimetres;
- **fine sediments**: contaminant particles smaller than 0.062 millimetres;
- **attached pollutants**: those that are attached to fine sediments—specifically, nutrients, heavy metals, toxicants and hydrocarbons; and/or
- **dissolved pollutants**: typically, nutrients, metals and salts.

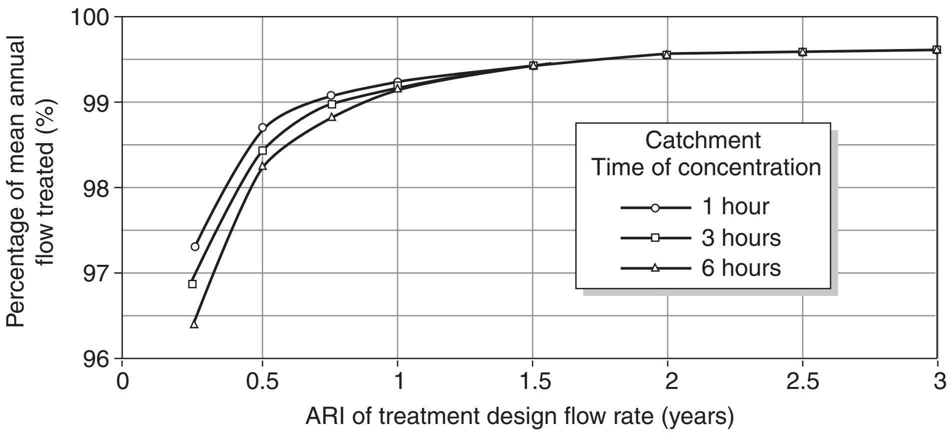


**Figure 7.1 Treatment design flows plotted against the percentage of mean annual flow treated for the Melbourne region (after Wong 1999).**

The treatment measures considered in these Guidelines have been assessed according to their trapping efficiency for each pollutant category.

The overall treatment effectiveness of a measure is a function of its pollutant removal rate and the volume of run-off treated. A high flow by-pass is generally designed into treatment measures for protection from large flood flows that could damage the device or scour and transport previously collected pollutants downstream. The maximum flow rate at which a treatment measure is designed to operate effectively is termed the *design flow*.

Selecting the design flow is a trade-off between the cost and space requirements of the device (a higher design flow will generally require a larger facility with additional costs) and the volume of water that could potentially by-pass the measure and avoid treatment. Figure 7.2 plots the volume of mean annual run-off that would be treated at or below the design flow rate for a range of design standards for several hypothetical catchments with different times of concentration using Melbourne rainfall data. For regions outside Melbourne there is a procedure to determine the appropriate relationship (Wong et al. 1999).

The plot shows that the curves are relatively independent of the time of concentration of the catchment and also that the incremental benefit of increasing the treated volume of run-off diminishes beyond a design flow rate of the 2 year ARI. Further, the plot suggests that generally the optimum operating range falls within a design flow rate of between 0.25 and 1.0 year ARI discharges.

### 7.2.2 Develop treatment train

Many pollutant treatments, particularly those targeting fine pollutants, require a number of measures used in sequence to be effective. Figure 2.3 illustrates a relationship between pollutant type and treatment processes. There is a clear relationship between pollutant

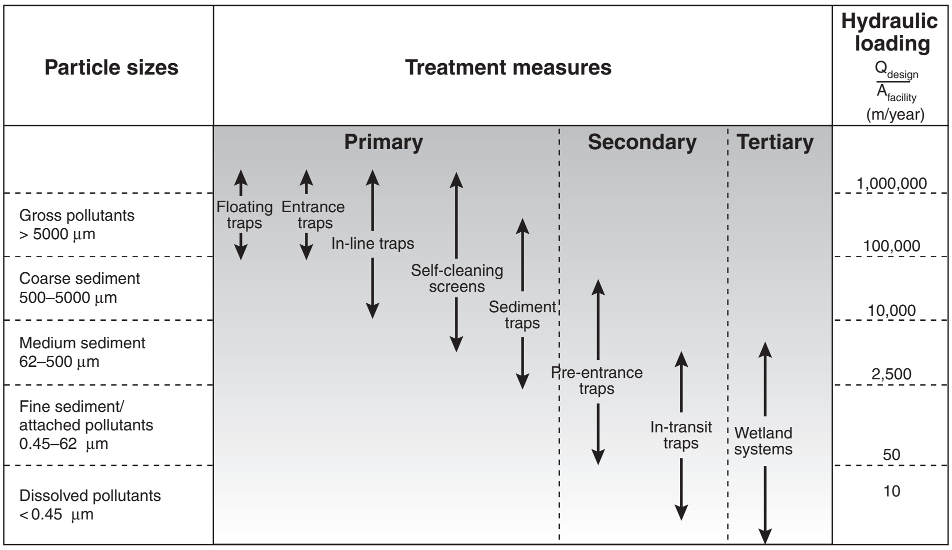


**Figure 7.2 Desirable design ranges for treatment measures and pollutant sizes (adapted from Wong 1999).**

size (gross to dissolved) and the appropriate process that can be employed to retain the pollutant. The treatment types in Figure 7.2 show the size range of pollutants that each treats effectively. By knowing the target pollutants appropriate treatment measures can be selected.

The figure also illustrates the approximate hydraulic loading rate for effective operation of the various treatments. The hydraulic loading rate is a function of the treatment process (either screening, sedimentation, enhanced sedimentation, filtration or biological uptake) and can be used to approximate the area required to install a facility given the design flow. This is useful to assess the space requirements for the various treatments.

The treatment train approach is particularly important when a measure requires pretreatments to remove pollutants that may affect the performance of the treatment measure. For example, wetland systems are often employed to protect receiving environments from the impact of excessive nutrients and heavy metals. However, wetlands will perform poorly if gross pollutants and coarse sediments are not removed prior to the wetland treatment. It is therefore important to select and order treatment measures appropriately to ensure that wetland systems are protected from gross pollutants and coarse sediments.

By taking this 'treatment train approach', as described in Chapter 2, the most effective sequence of the treatments can be determined.

## 7.2.3 Site identification

### Locating a treatment

When determining the location for stormwater treatment measures, many factors must be considered. One fundamental question is whether to adopt an 'outlet' or a 'distributed' approach.

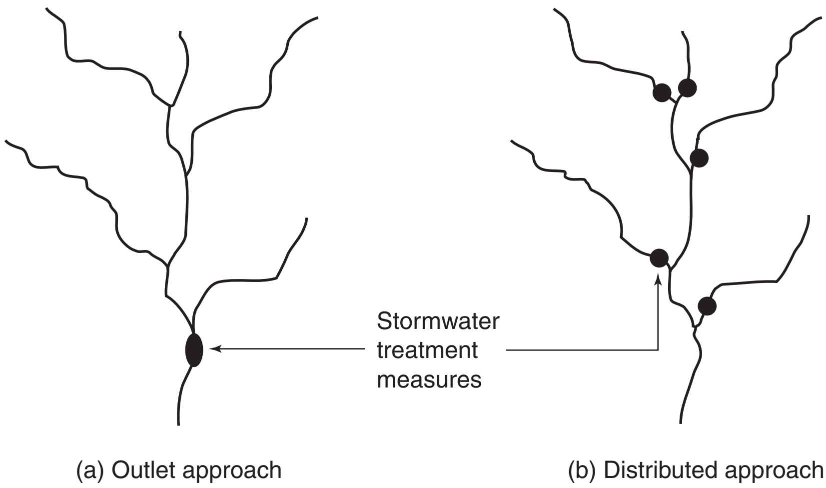


**Figure 7.3 Outlet and distributed approaches to stormwater treatment location.**

The traditional outlet approach involves constructing a single large treatment at the catchment's outlet. Although this 'single site' approach offers obvious maintenance advantages, it has the disadvantage of needing to treat very large volumes of water at a location sometimes far from the pollutant's source.

An alternative is the distributed approach. Here, a number of smaller and potentially different treatments are installed throughout a catchment.

A distributed approach to stormwater pollution treatment has many advantages over the outlet approach. These include:

- **improved protection**: water quality protection may be distributed along a greater length of the waterway;
- **localised treatment**: specific targeting of treatments may be directed at highly polluted sites;
- **distributed risk**: the distributed approach has a lower risk of overall system failure, as the failure of any single treatment will not usually significantly impact on the total treatment system performance;
- **improved removal efficiencies**: distributed treatments are typically located in areas of lower flow. Lower flow velocities and volumes and high pollutant concentrations in stormwater at these sites lead to higher operating efficiencies; and
- **staged implementation**: individual sites may be brought into operation in stages.

Typically, a distributed treatment scheme will incorporate a range of structural treatment types. To ensure optimal pollutant removal efficiency, a treatment train approach should be considered during each step of the design process—particularly where pre-treatment may be an issue.

### Site constraints

The characteristics of a particular site can limit the choice of treatment measures suited to the area. These constraints fall broadly into two categories-physical and social.

Physical site constraints can make construction difficult or impossible, and maintenance expensive. Factors to consider include:

- **topography**: e.g. steep slopes;
- **soils and geology**: e.g. erosivity, porosity, depth to bedrock or instability;
- **groundwater**: e.g. geochemistry and water table depth; and
- **space**: limited open space, proximity to underground services, e.g. gas, power.

Social constraints include issues of health and safety, aesthetics and impacts on recreation facilities. Factors to consider include:

- **odour problems**;
- **visual impacts**;
- **noise**;
- **physical injury**: resulting from unauthorised access to structures;
- **contamination**: infection, poisoning or injury caused by trapped pollutants or algal blooms; and
- **vermin**: e.g. mosquitoes, rats.

Many social issues can be addressed simply during the treatment design stage. This may involve development of occupational health and safety procedures for operations and maintenance staff, installation of warning signs, fencing around dangerous areas and so on.

## 7.2.4 Short-list potential treatments

A short list of potential treatment techniques that meet the requirements for the target pollutants and site constraints should be developed.

Various primary, secondary and tertiary treatment techniques are listed in Tables 7.1, 7.2 and 7.3 respectively, along with their pollutant retention efficiencies for a range of contaminants.

Specific pollutant retentions can be compared to the performance objectives set in Table 2.1. The pollutant retention efficiencies are based on the desirable hydraulic loading rate and are listed for all six pollutant categories: gross pollutants, coarse sediments, medium sediments, fine sediments, attached pollutants and dissolved pollutants.

Pollutant retention efficiencies are graded as follows:

- **very high (VH)**: 80 to 100 per cent of total pollutant load retained;
- **high (H)**: 60 to 80 per cent of total pollutant load retained;
- **moderate (M)**: 40 to 60 per cent of total pollutant load retained;
- **low (L)**: 10 to 40 per cent of total pollutant load retained; and
- **negligible (N)**: less than 10 per cent of total pollutant load retained.

These efficiency classifications allow the designer to quickly reject those techniques which have little impact on the target contaminants. For example, primary and secondary treatments would not be short-listed when specifically targeting dissolved nutrient or metal contamination—only tertiary treatments will have an impact in this case.

### 7.2.5 Compare potential treatments

Having established a short list, the treatment measures should be reviewed in detail to determine the best options. Factors to consider include maintainability and operability, pollutant retention, head requirements, cost and secondary benefits. These considerations are further described below.

Sections 7.7, 7.8 and 7.9 describe a wide range of treatment types. Each description presents a review of the treatment measure's operation, advantages, limitations, performance, costs and maintenance requirements.

#### Maintenance and operation

A poorly maintained treatment measure may not only perform badly; it may become a flood hazard or a source of pollution itself. Treatment measure operation and maintenance requirements vary widely. When assessing the treatment measure's maintainability and operability, the following issues should be considered:

- **ease of maintenance and operation**: the selected treatment should be easy and safe to maintain and operate;
- **extent of maintenance**: ensure the maintenance requirements are within the operator's capability;
- **access to the treatment site**: consider the ease of site access, when reviewing the treatment's maintenance requirements;
- **frequency of maintenance**: ensure that resources are available to carry out maintenance at the required frequency;

- **debris and pollutant clearing**: during clearing, the treatment should not require direct human contact with debris and trapped pollutants (automated clearing facilities are preferred); and

- **disposal**: consider the disposal of any waste from the treatment process.

### Pollutant retention

A closer look at the treatment measure's pollutant retention is required at this stage. Depending on issues of maintainability, operability, cost and head requirements, the overall pollutant retention efficiency for each specific target pollutant should preferably be as high as possible.

### Head requirements

Some treatments require large amounts of hydraulic head for operation. These are obviously not suitable for use in low lying areas with mild drain slopes.

Tables 7.1, 7.2 and 7.3 list the head requirements for primary, secondary and tertiary treatment types respectively. These have been classified as follows:

- **high**: more than 1 metre;

- **moderate**: between 0.5 and 1 metres; and

- **low**: less than 0.5 metres.

### Cost

Relative capital and maintenance costs for treatments are presented in Tables 7.1, 7.2 and 7.3. These are indicative rankings only; costs will vary according to catchment characteristics and rainfall.

Capital costs are based on the treatment's total installed cost per hectare of catchment. Broad approximations to give the reader a starting point are categorised as:

- **high (H)**: greater than $1500 per hectare of catchment;

- **moderate (M)**: between $500 and $1500 per hectare of catchment; and

- **low (L)**: less than $500 per hectare of catchment.

Maintenance costs are based on the cost per hectare per annum of the particular treatment type. Once again, broad estimates are categorised as:

- **high (H)**: greater than $250 per hectare of catchment per annum;

- **moderate (M)**: between $100 and $250 per hectare of catchment per annum; and

- **low (L)**: less than $100 per hectare of catchment per annum.

**Figure 7.4 Some treatment measures provide more benefits than just pollutant removal.**

Maintenance costs in this section include inspections, and routine maintenance and cleaning operations, but do not include any disposal costs associated with removed pollutants.

Detailed cost information can be obtained from the treatment suppliers.

### Secondary benefits

Certain treatment measures provide incidental benefits beyond the primary goal of removing the target pollutants.

Some treatment measures demonstrate the potential to remove pollutants other than the primary targets, e.g. a litter trap that also removes sediment. Other treatment types provide added benefits such as aiding flood control, ecological enhancement or provision of an educational resource. All such benefits need to be considered when selecting a treatment measure.

## 7.3 Primary stormwater treatment

There is a wide choice of primary treatment measures available, with an increasingly diverse range of treatment types being used throughout Australia. Primary treatment measures vary in size, cost and trapping performance by orders of magnitude.

New designs are evolving rapidly. There is generally a shortage of data relating to the trapping performance of the newer methods, making treatment comparisons difficult.

These Guidelines describe some 17 types of primary treatments identified at the time of publication. These have either been used extensively in Australia, or are becoming more frequently used and show promise for efficient pollutant removal.

The primary treatment measures described fall into one of five operating types:

1 **drainage entrance treatments**: grate entrance systems, side entry pit traps and baffled pits;

2 **in-line methods**: litter collection baskets, boom diversion systems, release nets, trash racks, gross pollutant traps, return flow litter baskets, and hydraulically operated trash racks;

3 **self-cleaning screens**: circular screens, downwardly inclined screens;

4 **floating traps**: flexible floating booms, floating debris traps; and

5 **sediment traps**: sediment settling basins and ponds, circular settling tanks, hydrodynamic separators.

### Drainage entrance treatments

Drainage entrance treatments involve either preventing the pollutants' entry into the stormwater drainage system, or capturing the pollutants at drainage entrance points. This can be achieved by either restricting the stormwater entrance size, capturing the pollutants as stormwater falls into the drainage system, or retaining the pollutants in the entrance pit.

Entrance treatments are generally located close to the pollutant source allowing the most polluted areas to be targeted. Use of entrance treatments can also help to reduce downstream pipe blockages.

### In-line devices

In-line methods use direct screening to retain gross solids by passing flow through a grid or mesh barrier assembly. As pollutants build up at the barrier, smaller material may also be retained due to the reduced effective pore size. There are various trapping methods using either baskets, prongs, racks or perforated bags.

These systems are generally simple to install and can retain large quantities of material. One limitation is the possibility of blockage. If the pores in the barrier are blocked, water levels may rise and spill collected pollutants downstream.

In-line non-screening devices direct stormwater into off-line chambers that collect pollutants by altering the hydraulics in the chamber. The systems divert flow and pollutants by means of a boom that is capable of rising during times of high discharge.

### Self-cleaning screens

The tendency of in-line screens to block is their main limitation. To improve in-line screen performance, there have been numerous attempts to design a self-cleaning trash screen.

Two self-cleaning designs have been used successfully: circular screens and downwardly inclined screens.

Developed in Victoria, circular screens induce a vortex that keeps pollutants continually in motion and this keeps the screen free of debris.

The second process, downwardly inclined screens, has been developed independently in New South Wales and South Africa. It involves angling a trash rack downstream. Gravity and the force of the water push the pollutants down the screen and onto a holding shelf.

#### Floating traps

Floating traps are generally intended to remove highly buoyant and visible pollutants such as plastic bottles. These are typically installed in the lower reaches of waterways where velocities are lowest.

The earliest boom designs were based on those used for oil slick retention. Floating traps generally consist of a partly submerged floating barrier fitted across the waterway, which either retains the pollutants or deflects them into a retention chamber. Floating traps have been employed for some time in Australia's major cities. More recent developments incorporate pollutant retention chambers and advanced trap clearing methods.

#### Sediment traps

There are a number of sediment traps available, ranging from simple 'swimming pool' designs to complex structures using vortices and secondary flows for sediment separation. Each trapping system aims to create favourable flow conditions for sedimentation. The swimming pool type sediment traps can be either concrete basins or more natural ponds constructed with site soils. They retain sediments by simply enlarging the channel so that water velocities are reduced. More complex sediment traps generate vortex flows, which enhance sedimentation through secondary flows. Sediment traps are ideal for pre-treatment of larger sediment particles prior to a constructed wetland system.

### 7.3.1 Summary of primary treatments

Table 7.1 presents a summary of the primary treatments reviewed in the Guidelines (Section 7.7). It presents relative estimates of the trapping performances, installation and maintenance costs per hectare, head requirements and approximate catchment area per unit treatment.

## 7.4 Secondary stormwater treatment

Secondary treatments are used to retain or remove coarse, medium and fine sediments from stormwater and can be divided into two broad categories:

**Figure 7.5 Swales (in this case, rock lined) promote infiltration, retard flows, improve water quality and can add to the local amenity.**

- **pre-entrance treatments**: filter strips, grass swales, triple interceptor pits, porous pavements and infiltration trenches; and
- **in-transit treatments**: infiltration basins, extended detention basins and sand filters.

## Pre-entrance treatments

Pre-entrance treatments either use infiltration techniques to separate out entrained sediments from stormwater before it enters the drainage network or use enhanced sedimentation to contain contaminants. Infiltration can be achieved in one of two ways—either by flowing the stormwater over vegetated land to encourage infiltration or by using purpose built infiltration structures.

Filter strips and grass swales are typical examples of flowing water over vegetation. Purpose built infiltration structures include infiltration trenches and porous pavements.

These methods have the advantage of separating out pollutants close to the source, thereby avoiding the difficulties of entrained flow pollutant removal.

| Device | Catchment area (ha) | Trapping efficiency | | | | | | Cleaning frequencies | Head requirements | Installation costs | Maintenance costs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | gross pollutants | coarse sediment | medium sediment | fine sediment | attached pollutants | dissolved pollutants | | | | |
| Grate and entrance screens | 0.1–1 | L | N | N | N | N | N | weekly | L | L | L/M |
| Side entry pit traps | 0.1–1 | M/H | L | N | N | N | N | monthly | L | L/M | M/H |
| Baffled pits | 0.1–2 | L | M | L/M | L | N | N | monthly | L | L/M | L/M |
| Litter collection baskets | 2–150 | M/H | L/M | N | N | N | N | weekly/monthly | M/H | M/H | M/H |
| Boom diversion systems | 10–40 | M | L/M | N/L | N | N | N | monthly | L | M | M/H |
| Release nets | 1–50 | M/H | N/L | N | N | N | N | weekly/monthly | L | L | L/M |
| Trash racks | 20–500 | L | N/L | N/L | N | N | N | monthly | L/M | M | L/M |
| Gross pollutant traps | 5–5000 | L/M | M/H | M | L | N | N | monthly/quarterly | H | H | M/H |
| Return flow litter baskets | 20–100 | M/H | M | L | N | N | N | monthly | L | M/H | L/M |
| Hydraulically operated trash racks | >10 | H/VH | L/M | N | N | N | N | weekly | L | L/M | M/H |
| Circular screens | 5–150 | VH | H | M | L/M | L | N | quarterly | L | H | M |
| Downwardly inclined screens | 5–500 | H/VH | N | N | N | N | N | monthly/quarterly | H | M/H | L/M |
| Flexible floating boom | >100 | N/L | N | N | N | N | N | weekly/monthly | L | L | M |
| Floating debris traps | >100 | L | N | N | N | N | N | weekly/monthly | L | L | M |
| Sediment settling basins | 10–500 | N | M/H | M | L | N/L | N | half-yearly | L | L/M | L/M |
| Circular settling tanks | 1–20 | L/M | H | M/H | M | L/M | N | monthly | L | H | M |
| Hydrodynamic separation | 5–100 | L/M | M/H | M | M | L/M | N | monthly | L | H | L/M |

N = negligible, L = low, M = moderate, H = High, VH = very high

**Table 7.1 Summary of primary treatments.**

### In-transit treatments

In-transit secondary treatments target entrained pollutants flowing through the stormwater system. These either use reduced water velocities to encourage sedimentation or direct filtration through a porous medium.

Reduced velocities are typically achieved using storage ponds, such as infiltration and detention basins. The direct filtration methods use sand filters to screen stormwater as it flows through the sand grains, leaving the pollutant in the sand. These can remove large quantities of pollutants, but require regular maintenance.

### 7.4.1 Summary of secondary treatments

Table 7.2 presents a summary of the secondary treatments reviewed in the Guidelines (Section 7.8). It shows relative estimates of the trapping performances, installation and maintenance costs per hectare, head requirements and approximate catchment area per unit treatment.

## 7.5 Tertiary treatment types

Constructed wetland systems are generally the only treatment technique used for removal or retention of nutrients and fine sediments. This section describes and summarises the pollutant retention performance of constructed wetlands and provides some basic design information (Section 7.9). Sufficient design information is presented to enable preliminary sizing of a wetland system to meet the performance objectives set in Chapter 2. The detailed design is an involved process requiring the input of several disciplines such as hydrology, aquatic biology and landscape planning.

| Criteria | Value/ranking |
|---|---|
| Catchment area (hectares) | >10 |
| Trapping efficiency: gross pollutants | L/M |
| Trapping efficiency: coarse sediments | H |
| Trapping efficiency: medium sediments | M/H |
| Trapping efficiency: fine sediments | L/M |
| Trapping efficiency: attached pollutants | M/H |
| Trapping efficiency: dissolved pollutants | L/M |
| Head requirements | L/M |
| Installation costs | H |
| Maintenance costs | M |
| N = negligible, L = low, M = moderate, H = high, VH = very high | |

**Table 7.3 Constructed wetlands treatment performance.**

Sand filters that include a media layer with an adsorption capacity (e.g. peat or humus) could also be classified as tertiary treatment measures. This is a relatively recent innovation in sand filter design—until recently, sand filters have been classified as secondary treatment measures. A more detailed description of sand filters is included in Section 7.4.

| Device | Catchment area (ha) | Trapping efficiency | | | | | | Head requirements | Installation costs | Maintenance costs |
|---|---|---|---|---|---|---|---|---|---|---|
| | | gross pollutants | coarse sediment | medium sediment | fine sediment | attached pollutants | dissolved pollutants | | | |
| Filter strips | 0.1–1 | L/M | H | M/H | L/M | L/M | L | L | L | L |
| Grass swales | 0.1–5 | L | M/H | M | L/M | L/M | L | L | L | L |
| Triple interceptor pits | 0.1–1 | L/M | M | L/M | L | L | N | L/M | M | H |
| Porous pavements | 0.1–1 | L | H | M/H | M | M | L | L | M | L/M |
| Infiltration trenches | 0.1–5 | L | M/H | M | L/M | L/M | L | L | L | M/H |
| Infiltration basins | 10–100 | N | M/H | M | M | M | L | L | L/M | H |
| Extended detention basins | 10–500 | L | M/H | M | L/M | L/M | L | L | L/M | M/H |
| Sand filters | 1–50 | L | M/H | M/H | M | M | L | H | M/H | M/H |

N = negligible, L = low, M = moderate, H = High, VH = very high

**Table 7.2 Summary of secondary treatment performances.**

## 7.6 Flow management

Urbanisation has significant impacts on catchment hydrology, which in turn affects the physical and biological characteristics of waterways. Recent initiatives in integrated stormwater management have recognised the importance of water quality. However, the importance of managing the impact of changes in flows on receiving waterways must also be taken into account. The two main characteristics of urban development that alter flow regimes in waterways are:

- removed vegetation and increased impervious area in the catchment; and
- increased hydraulic efficiency within drainage lines and receiving waterways.

These characteristics increase both the magnitude and frequency of peak discharges, with the greatest impact resulting from increased hydraulic efficiency. There are opportunities to integrate both hydraulic capacity and waterway health objectives within a stormwater system. This is particularly so as limiting changes in peak discharge is a critical component of protecting aquatic ecosystems as well as reducing the incidence of flooding.

Section 7.10 outlines the objectives of effective flow management and presents a range of flow management techniques.

## 7.7 Primary treatment: index

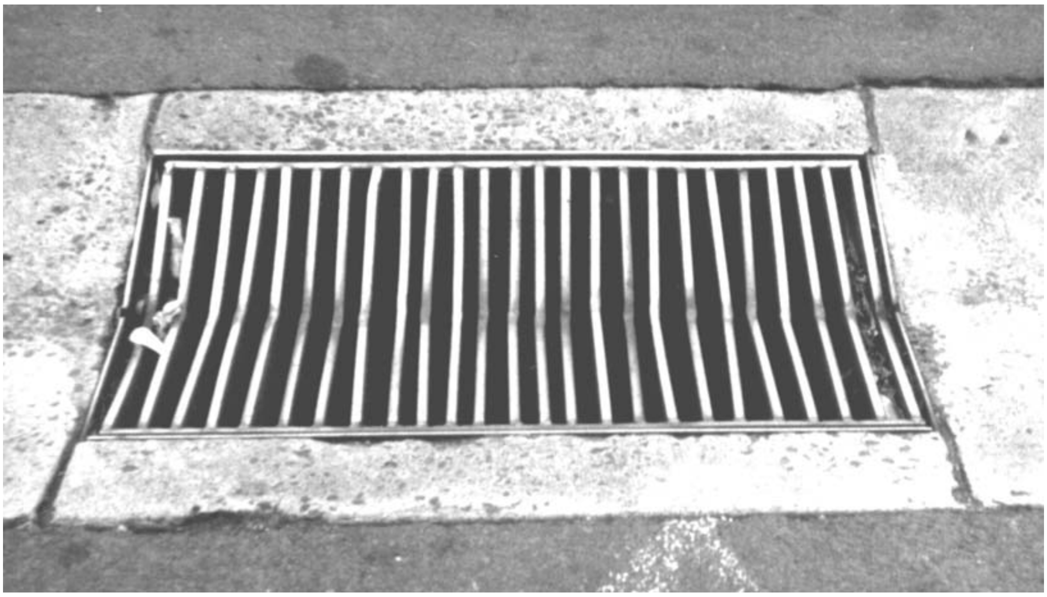

**Figure 7.6 Grated entrance screen.**

### Primary treatment Type 1: Grate and entrance screens

*Description*

Grate and entrance screens consist of sturdy metal screens that cover the inlet to the drainage network. Water passes between the screen bars, while gross pollutants are prevented from entering. Particularly suited to trapping large litter items, grate and entrance screens are typically used to prevent drain blockages.

*Advantages*

- inexpensive and easy to install;
- prevents drain blockages; and
- suitable for targeting specific problem areas.

*Limitations*

- only separates out large rubbish items;
- relies on effective street cleaning for pollutant removal;
- local flooding can occur if blocked; and
- smaller items of rubbish may be pushed through the grating by traffic.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L | coarse sediment | N | medium sediments | N |
| fine sediments | | attached pollutants | N | dissolved | N |
| installation costs | L | maintenance costs | L/M | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

### *Trapping performance*

The key function of entrance screens is to prevent pipe blockages by excluding gross pollutants from the drain network. Their performance efficiency depends heavily on effective street cleaning practices—infrequent street cleaning can lead to dispersion of trapped pollutants by either wind or traffic.

### *Cost considerations*

Installation costs of entrance grate and screens are low. If cleaning can be incorporated into regular street cleaning, no additional maintenance cost need apply.

### *Design considerations*

Entrance grates should be located in areas that are prone to pipe blockages or are known to contribute large amounts of gross pollutants. These include shopping centres and other busy commercial areas.

### *Maintenance*

Inspections for blocked screens may be necessary if flooding is a potential problem.

*See also*: Side entry pit traps, Street cleaning.

## Primary treatment Type 2: Side entry pit traps (SEPT)

### *Description*

Side entry pit traps (SEPTs) are baskets that are placed in the entrance to drains from road gutters. The baskets are fitted below the invert of the gutter, inside the drainage pit. Stormwater passes through the baskets to the drain, with material larger than the basket mesh size (5–20 millimetres) retained.

Material remains in the basket until removed during maintenance, either manually or by vacuum extraction. The traps are generally cleaned every four to six weeks in high litter load areas.

### *Advantages*

- prevents drain blockages;
- suitable for targeting specific problem areas;
- can be retrofitted into existing drainage systems;
- can be used as a pre-treatment for other measures;
- can retain fine material, as the basket pores block; and
- minimal visual impact, as SEPTs are installed underground.

### *Limitations*

- distributed traps may be maintenance intensive;

**Figure 7.7 Section view of a SEPT.**

- requires regular maintenance, due to the trap's limited holding capacity;
- previously caught material may be resuspended if overtopping occurs; and
- only suitable for road entrance installations.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | M/H | coarse sediment | L | medium sediments | N |
| fine sediments | N | attached pollutants | N | dissolved | N |
| installation costs | L/M | maintenance costs | M/H | head requirements | L |

N = Negligible, L= Low, M = Moderate, H = High, VH = Very high

### *Trapping performance*

Best suited to trapping coarse material, SEPTs can also retain finer contaminants as the basket pores block. SEPTs can trap significant quantities of gross pollutants and have the advantage of being suitable for targeting specific areas such as shopping centres, schools and car parks.

SEPTs can potentially capture up to 85 per cent of litter load and up to 75 per cent of the total gross pollutant load, if installed on all public road entrances to the stormwater system (see Allison et al. 1997). SEPTs' high maintenance requirements usually set a practical upper limit to the extent of SEPT application within a catchment. It is therefore imperative to choose those drain entrances that contribute the greatest gross pollutant loads to the drainage system, when locating SEPTs.

The monitoring of Allison et al. (1997) revealed that by careful selection of SEPT locations, it is possible to capture approximately 65 per cent of the litter and 50 per cent of total gross pollutant loads (litter and organic material), by locating SEPTs at only 40–50 per cent of the drainage entrances.

The overall SEPT trapping efficiency within an area is influenced by individual trap efficiencies, along with the amount of pollutants that successfully by-passes the SEPT network. Potential by-pass paths include direct roof run-off from buildings and drainage through grates located in private car parks or grassed areas.

### *Cost considerations*

SEPTs are generally inexpensive to install, but require considerable effort and cost to maintain. Individual traps costs between $60 and $450, depending on construction materials and design. Cleaning costs are typically between $5 to $25 per pit per clean. A significant factor in determining final SEPT cost and trapping performance is the overall SEPT application density used in the catchment.

### *Design considerations*

A range of SEPTs are manufactured to suit most applications. The pit size, depth and lid type are important factors when assessing a SEPT's suitability for a particular location. SEPTs are ideal for targeting specific pollution areas such as shopping centres and strips, schools and train stations. The main design issues are the selection of appropriate trap sites and deciding what proportion of pit entrances to cover.

In addition, the pits need to be of adequate size to allow a clear space at the rear of the basket to provide an overflow route should the basket become blocked.

### *Maintenance*

SEPTs are generally cleaned with a suction truck. The lid of the pit is lifted and the contents of the baskets vacuumed out. Typically, a crew of two operators and one truck can clean up to 50 traps per day. Frequency of cleaning depends on litter loads. Cleaning is required at intervals of 4–6 weeks in areas with high loads.

*See also*: Grated entrances.

### *References and further information*

Allison, R.A., Rooney, G.R., Chiew, F.H.S. and McMahon, T.A., 1997, 'Field trials of side entry pit traps for urban stormwater pollution control'.

Allison, R.A., Walker, T.A., Chiew, F.H.S, O'Neill, I.C. and McMahon, T.A., in press, *From Roads to Rivers: Gross Pollutant Removal From Urban Waterways*.

Hall, M.D. and Phillips, D.I., 1997, 'Litter generation and distribution in commercial and strip shop catchments'.

## Primary treatment Type 3: Baffled pits

### *Description*

Baffled pits (trapped street gullies or catch basins) are modified stormwater pits fitted with baffles. The baffles are specifically designed to encourage heavy sediments to settle and floating debris to remain in the pit (Gibson and Evernden 1992). Used widely in Europe and North America in both stormwater and combined sewer system applications, baffled pits have been most commonly used to reduce sediment loads to combined sewers. In Australia, they have been used in central business district of Sydney.

The contents of the pits are removed with a large diameter vacuum device during maintenance. In the Sydney City Council region, this is performed every three weeks.

### *Advantages*

- can be used as a pre-treatment for other measures;
- can be retrofitted into existing drainage systems, particularly on roads with high traffic volumes;
- minimal visual impact as installed underground; and
- can prevent odours exiting the drain.

### *Limitations*

- some designs have a potential to resuspend sediments;
- potential release of nutrients and heavy metals from sediments;
- potential for scouring of collected pollutants during high flows,
- requires regular maintenance, due to the trap's limited holding capacity;
- poor retention of material that is entrained in the flow;
- reduces or eliminates air supply to the drainage network downstream of the pit; and
- large retention pit capacity is required for effective pollutant removal.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L | coarse sediment | M | medium sediments | L/M |
| fine sediments | L | attached pollutants | N | dissolved | N |
| installation costs | L/M | maintenance costs | L/M | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

### *Trapping performance*

Baffled pits are best suited to trapping highly buoyant contaminants or heavy, easily settlable solids.

Conventional baffled pits often have limited sediment retention capacity due to the turbulence associated with inflows. Desorption of pollutants under anaerobic conditions

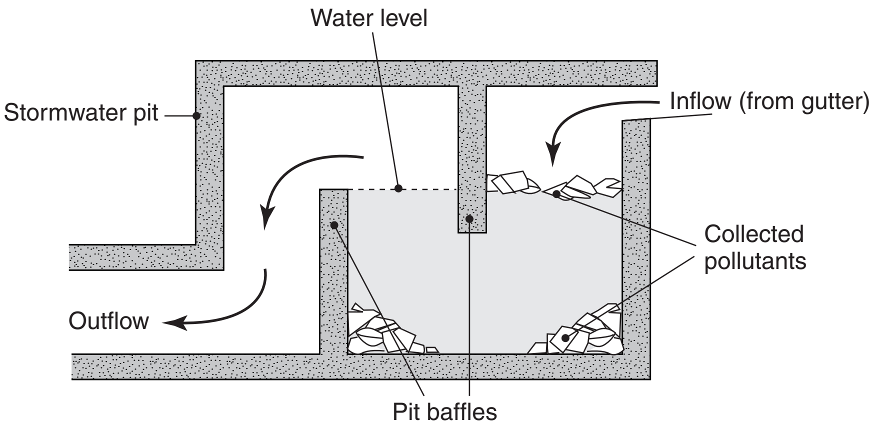


**Figure 7.8 Section view of a baffled pit.**

has also been reported. As a consequence, conventional baffled pits can discharge pollutants during and following large storm events, particularly if maintenance is poor.

Recent design developments have addressed a number of these concerns, particularly relating to minimising turbulence within the basin.

### *Cost considerations*
Baffled pits are inexpensive to install, but maintenance costs are moderate to high.

### *Design considerations*
There are no formal guidelines for baffled pit sizing, although Ontario Ministry of Environment and Energy (OMEE) (1994) suggests the following guidelines for a proprietary system:

- a maximum catchment area of 1 hectare; and
- a wet pool volume of 15 cubic metres per impervious hectare.

### *Maintenance*
Regular pit inspections are required to determine optimal cleaning frequencies. To prevent build-up that may lead to scouring, regular removal of trapped pollutants is an essential component of the treatment's success.

*See also*: Circular settling tank, Side entry pit traps, In-line litter separator.

### *References and further information*
Evernden, J., 1995, 'Trapped Street Gullies' in *Better Management Practices for Urban Stormwater.*

Gibson, T.G. and Evernden, J.A., 1992, *Trapped Street Gullies*.

Grottker, M., 1989, 'Pollutant Removal by Catch Basins in West Germany: State of the Art—New Design'.

Jarett, P. and Godfrey, P., 1995, *The Role of Catch Basins in Urban Stormwater Management*.

Ontario Ministry of Environment and Energy, 1994, *Stormwater Management Practices Planning and Design Manual*.

### Primary treatment Type 4: Litter collection baskets

*Description*

North Sydney City Council developed a stormwater litter trap in response to publicity surrounding a clean-up campaign in 1992 (Cooper 1992). By 1995 it had constructed nine devices (Brownlee 1995). The traps are located in pits in the drainage network, with catchment areas ranging from 2 to 145 hectares. Each consists of a steel frame supporting a metal basket of approximately one cubic metre. Large units can incorporate multiple baskets.

The basket, a sheet steel assembly with an array of 30 millimetre diameter holes in the sides, sits below the invert of the inlet pipe. Water falls into the basket and flows out through the holes. Pollutants larger than the basket's 30 millimetre pore size are retained. As the material builds up, the effective pore size is reduced, allowing smaller material to be caught (Hocking 1996).

To accommodate the basket, a one metre drop in the channel bed from inlet to outlet is required. This limits their applicability in low lying areas.

*Advantages*

- can be retrofitted into existing drainage systems;
- potentially useful in areas with high litter loads;
- easy to maintain;
- can be used as pre-treatment for other measures; and
- minimal visual impact as installed underground.

*Limitations*

- limited to sites where a one metre drop in the channel bed is possible;
- can cause upstream flooding if blocked;
- hydraulic head loss occurs, particularly for baskets installed in the base of pits;
- presents a possible source of odours and health risk to cleaning crews; and
- previously caught material may be resuspended if overtopping occurs.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | M/H | coarse sediment | L/M | medium sediments | N |
| fine sediments | N | attached pollutants | N | dissolved | N |
| installation costs | M/H | maintenance costs | M/H | head requirements | M/H |

N = negligible, L= low, M = moderate, H = high, VH = very high

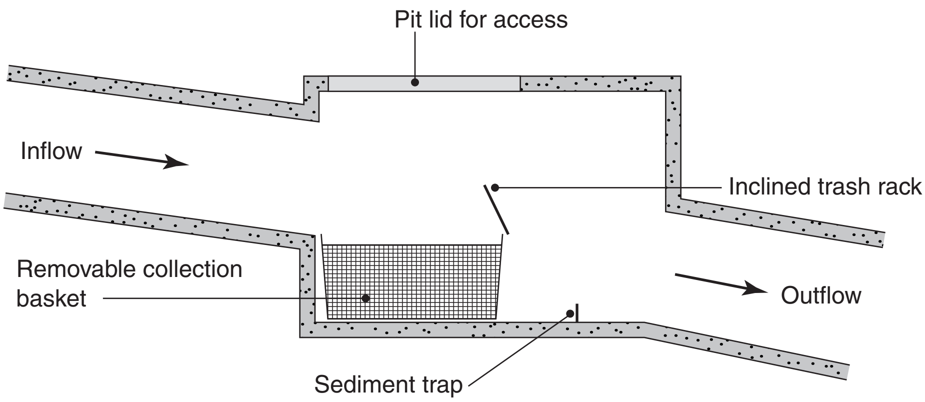


**Figure 7.9 Litter collection basket (after Brownlee 1995).**

### *Trapping performance*

The effectiveness of litter collection baskets in trapping gross pollutants varies greatly (Brownlee 1995, Hocking 1996). Problems with floating materials in tidal areas and high discharges are cited as possible reasons for material passing the traps. Inclined trash racks have also been used at the downstream end of particular litter control device installation, to collect material scoured from the baskets.

Effectiveness is highly dependent on cleaning frequency. With weekly cleaning, litter collection baskets can achieve capture rates of up to 80 per cent (Hocking 1996).

In addition to gross pollutants, litter collection baskets may also collect coarse sediment and gravel, as the pores of the collection basket are often covered with large gross pollutants (Hocking 1996).

### *Cost considerations*

Litter collection baskets are expensive to construct. Brownlee (1995) estimates installation costs of between $50,000 and $130,000 each for the nine installations in the North Sydney City Council area. Annual maintenance costs were estimated to be approximately $1200 per year per trap using monthly cleaning (Brownlee 1995).

### *Design considerations*

There are currently no formal design guidelines for litter baskets. The primary design consideration is to ensure that the baskets do not significantly impact on pit or pipe system hydraulics when fully blocked.

### *Maintenance*

Litter collection baskets require regular maintenance, particularly after major storm events and in early autumn in areas with deciduous trees.

The devices are cleaned by hoisting the collection basket out of the pit by crane, then dumping into a disposal truck. The design of the basket allows simple emptying of the contents into the disposal vehicle. Alternatively, the baskets may be emptied with vacuum plant. Sediment may also need to be removed from the control pit.

*See also*: Return flow litter baskets.

### *References and further information*

Brownlee, R.P., 1995, 'Evaluation of effectiveness and efficiency of North Sydney litter control device program'.

Cooper, G., 1992, 'Hayes Street litter control pit'.

Hocking, J., 1996, 'Evaluation of effectiveness and efficiency of Smoothey Park litter control device'.

## Primary treatment Type 5: Boom diversion systems

### *Description*

Boom diversion systems comprise of a vertically hinged floating boom located in the stormwater flow path. They were primarily designed to capture floating material, with syringes identified as the target pollutant. Under low to medium flow conditions, the boom diverts all of the flow to a screened off-line pollutant collection chamber. Floating pollutants are trapped in the chamber using a similar trapping technique to that used in baffled pits (refer Primary treatment Type 3) and heavy pollutants sink to the bottom of the chamber. Under high flow conditions, the boom raises and deflects only buoyant items. Under these conditions, the majority of the flow bypasses the trap under the boom and is prevented from scouring collected pollutants.

Cleaning is performed by routinely vacuuming the contents of the collection chamber—typically monthly, but it can be up to every three months. These devices are currently being tested in Victoria.

### *Advantages*

- simple to retrofit into existing drainage systems;
- can potentially retain small oil spills;
- minimal visual impact as installed underground; and
- precast units permit easy installation.

### *Limitations*

- booms capture only floating pollutant load during moderate to high flows;
- moving parts of the raiseable boom require inspection and maintenance;
- potential for scouring if excessive build-up of pollutants occurs; and
- potential breakdown of collected pollutants in wet sump.

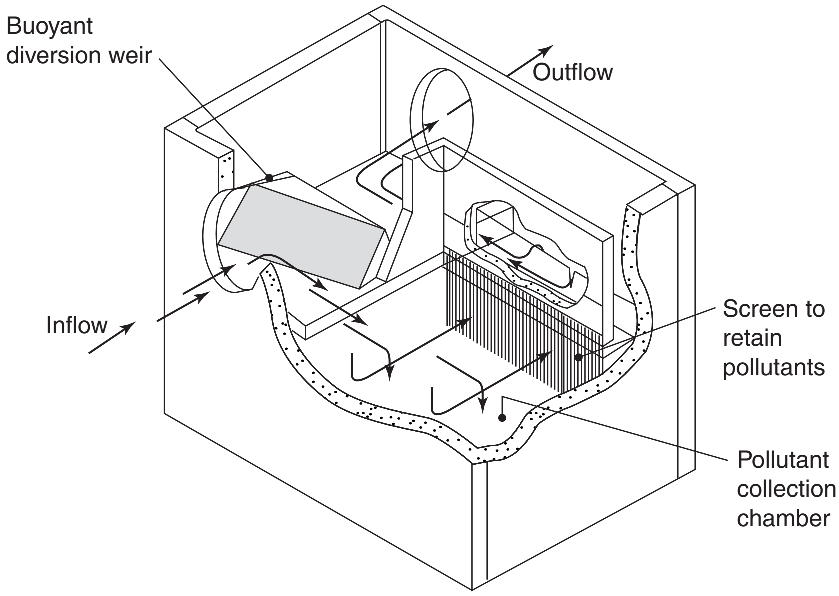


**Figure 7.10 Sketch of the in-line litter separator during low flows (CSR Humes 1999).**

| **Estimated treatment performance summary** | | | | | |
|---|---|---|---|---|---|
| gross pollutants | M | coarse sediment | L/M | medium sediments | N/L |
| fine sediments | N | attached pollutants | N | dissolved | N |
| installation costs | M | maintenance costs | M/H | head requirements | L |
| N = negligible, L= low, M = moderate, H = high, VH = very high | | | | | |

### *Trapping performance*

No field data are available on the trapping efficiency of boom diversion systems, however they have been reported as removing considerable quantities of pollutants. Laboratory observations report significant pollutant removal, but no data have been published.

Coarse sediments can easily settle and accumulate in the bottom of the retention chamber, while highly buoyant items remain trapped in its first stage. Under poor maintenance conditions, excessive sediment and pollutants may build up in the containment chamber. This can lead to pollutant scouring and remobilisation.

Several units are installed in Melbourne with some field data being collected.

### *Cost considerations*

Boom diversion systems involve moderate installation costs. Operational costs are moderate to high, as they generally require monthly cleaning.

### *Design considerations*

The devices need to be strategically located in urban systems, targeting those areas contributing the largest loads of floatable gross pollutants. The size of the collection chamber influences the holding capacity and hence the required cleaning frequency.

### Maintenance

Maintenance involves vacuuming the collected pollutants from the collection chamber. Inspection of the boom hinges and the inlet channel are also required.

*See also*: Baffled pits.

### References and further information

Phillips, D.I., 1997, 'A new GPT for urban drainage systems: the In-line Litter Separator'.

## Primary treatment Type 6: Release nets

### *Description*

Release net systems involve securing a net over the outlet of a drainage pipe. Stormwater flows through the net and material larger than the pore size of the net is retained. The net is in the shape of a cylinder and the length can vary from catchment to catchment. Gross pollutants collect in the netting until such time as the net becomes either blocked or so full as to affect upstream water levels. If upstream water levels rise, a mechanism is triggered that releases the net from the drain outlet. The net then detaches from the drain and moves a short distance downstream until the net opening chokes on a short tether which is fixed to the side of the drain.

### *Advantages*

- low installation costs;
- simple to install at pipe outlets;
- volume of netting and pore size can be easily altered; and
- easy to maintain involving no manual handling of pollutants.

### *Limitations*

- can be visually unattractive;
- could be exposed to vandalism; and
- potential odours from collected pollutants.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | M/H | coarse sediment | N/L | medium sediments | N |
| fine sediments | N | attached pollutants | N | dissolved | N |
| installation costs | L | maintenance costs | L/M | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

### *Trapping performance*

There are no independent performance data available for this type of system.

**Figure 7.11 Release nets installed on a Sydney drain outlet.**

The trapping performance will be directly related to the pore size of the netting and the frequency that the net releases from the drain outlet. The release frequency will be affected by the size of the netting (the length), the pollution loads and the cleaning frequency. The device is expected to remove the majority of gross pollutants during times when the nets remain fixed to the pipe outlet.

### *Cost considerations*

Compared to other primary treatments, release nets require small capital investment. Maintenance is expected to be at least monthly but will vary depending on the catchment and type of netting used.

### *Design considerations*

The key design question is the capacity of the net compared to the expected gross pollutant load from the catchment. If the net is too small it will release too often and pollutants will pass by. It may require some monitoring of early installations to determine the optimal net size for a particular catchment.

### *Maintenance*

Maintenance is performed by manually releasing the nets from the pipe, lifting (using a small crane) the tethered net bag on to a removal truck and fitting the pipe with a clean net. Typically two nets are provided per installation so that pollutants can remain inside the net until disposed of.

The initial stages of operation should be monitored to determine the frequency of maintenance. Monitoring would also include an inspection of the release catch to ensure its operation.

## Primary treatment Type 7: Trash racks

### *Description*

Trash racks are installed in storm drainage channels to intercept floating and submerged objects. They generally consist of either vertical or horizontal steel bars (typically spaced 40 to 100 millimetres apart) and are cleaned manually. Trash racks provide a physical barrier in the stormwater flow path, retaining pollutants larger than the bar spacings. As material builds up behind the trash rack finer material also accumulates (Nielsen and Carleton 1989).

Trash racks can be either on-line or off-line. On-line trash racks are placed within an existing channel or drainage system. As these fit within the existing bounds of the drainage system, this is usually the preferred option for established urban areas where space is limited.

Off-line arrangements consist of a flow diversion mechanism that directs low and medium flows into the trash rack, while high flows bypass the structure. This enables contaminant material from the majority of flows to be retained, whereas on-line structures are prone to overtopping. Under conditions of high flow, on-line systems can lose the waste collected since the last cleaning.

### *Advantages*

- may be used to trap litter upstream of other treatment measures or waterways;
- can be retrofitted into existing drainage systems;
- collects litter at a single location rather than over a large area;
- simple to construct; and
- can also trap coarse sediments when the trash rack becomes partially blocked.

**Figure 7.12 Trash rack (Cup and Saucer Creek, Sydney).**

### *Limitations*

- can cause upstream flooding;
- previously caught material may be entrained if overtopping occurs;
- difficult to maintain and requires manual maintenance;
- appearance of the rack and trapped litter can be obtrusive;
- presents a possible source of odours and health risk to cleaning crews; and
- material may be resuspended due to tidal effects in tidal channels.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L | coarse sediment | L/N | medium sediments | L/N |
| fine sediments | N | attached pollutants | N | dissolved | N |
| installation costs | M | maintenance costs | L/M | head requirements | L/M |

N = negligible, L= low, M = moderate, H = high, VH = very high

### *Trapping performance*

The main disadvantage of the trash rack is its inability to self-cleanse (Nielsen and Carleton 1989; Beecham and Sablatnig 1994; Freeman 1996). Although trash racks are designed to continue operating while partially blocked, trash rack overtopping is common (McKay and Marshall 1993).

As more material is retained behind the trash rack's bars, less water can pass through. The water level behind the trash rack rises until the bars are overtopped. When water flows over the top of the rack, it carries not only incoming gross pollutants but also gross pollutants that have accumulated behind the screen. The backwaters behind a blocked trash rack reduce flow velocities and allow sediments to settle, further contributing to the blockage.

Trash racks have been installed in almost all major cities in Australia. Limited performance data suggest trapping efficiencies between 5 and 14 per cent for floating items (McKay and Marshall 1993).

There have been various failed attempts to develop a self-cleaning trash rack. Techniques have included: widening the bar spacing and angling the screen to the flow (Nielsen and Carleton 1989); angling the rack across the channel bed; using horizontal bars along the rack; and a combination of angling the rack and horizontal bars along the rack (Beecham and Sablatnig 1994; Sim and Webster 1992). Vibrating the trash racks has also been tested.

Designs have been developed which provide for gross pollutants to be pushed by the flow along the racks to a collection point. Results have shown only minor improvements for these configurations.

### Cost considerations

Trash racks can be expensive to install and maintain. Three racks in Sydney cost between $215,000 and $305,000 each to install and between $22,000 and $70,000 each to maintain annually. These were installed in catchment areas of between 50 and 500 hectares in size.

### Design considerations

The original design for trash racks involved a rack across a channel fitted with vertical bars (Beecham and Sablatnig 1994; Phillips 1992; Willing and Partners 1992a).

More advanced trash rack configurations have been developed over the years, including a stepped and staggered trash rack proposed by Freeman (1996).

### Maintenance

The required maintenance program for trash racks is to clean either on demand or during programmed works. Although manual cleaning of trash racks is expensive, time consuming and potentially dangerous, no automated techniques have been developed to date.

*See also*: GPTs, Hydraulically operated trash rack, Downwardly inclined screens.

### References and further information

ACT Government, 1994, *Urban Stormwater: Standard Engineering Practices*.

Beecham, S.G. and Sablatnig, S.J. 1994, 'Hydraulic modelling of stormwater trash racks'.

Freeman, G., 1996, 'Off-line improvement of in-line stormwater quality controls'.

McKay, P. and Marshall, M., 1993, *Backyard to Bay: Tagged Litter Report*.

Molinari, S. and Carleton, M., 1987, 'Interception and collection of litter in urban waterways'.

Nielsen, J.S. and Carleton, M.G., 1989, 'A study of trash and trash interception devices on the Cooks River catchment, Sydney'.

Phillips, B.C., 1992, 'A review of design procedures for gross pollutant traps and water pollution control ponds'.

Sim, R.I. and Webster, J.L., 1992, 'Performance of trash rack on Cup and Saucer stormwater channels'.

Willing and Partners, 1992a, *Design Guidelines for Gross Pollutant Traps*.

## Primary treatment Type 8: Gross pollutant traps

### Description

A gross pollutant trap (GPT) is a sediment trap with a trash rack, usually constructed of vertical steel bars, located at the downstream end of the trap. GPTs are primarily designed to remove litter, debris and coarse sediments. They generally consist of a large concrete lined wet basin upstream of a weir, with a trash rack located above the weir (Willing and Partners 1992a).

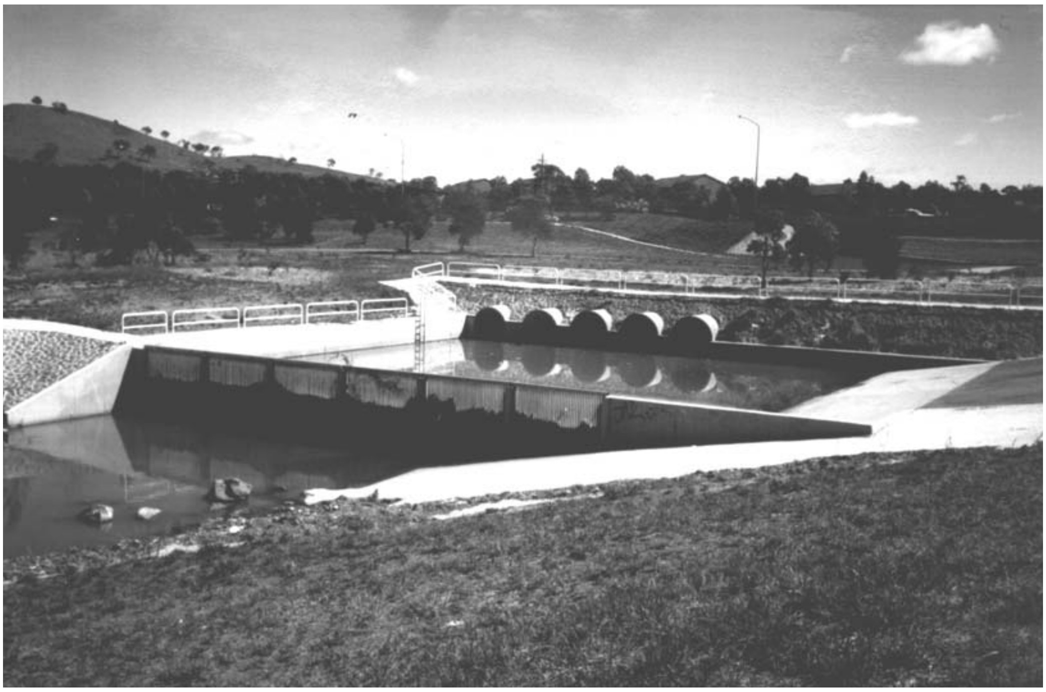

**Figure 7.13 Gross pollutant trap, Tuggeranong Lake, Canberra.**

GPTs permit coarse sediments to settle to the bottom by decreasing the stormwater flow velocity. This is achieved by increasing the width and depth of the channel in the GPT wet basin. The trash rack at the downstream end of the basin is intended to collect floating and submerged debris in the same way as a conventional trash rack.

*Advantages*

- can provide coarse sediment and gross pollutant pre-treatment for other stormwater treatments;
- small traps can be located underground, minimising visual impacts; and
- offers a larger rack area than conventional trash racks, thereby improving removal rate.

*Limitations*

- the trash rack can suffer blockages;
- high construction costs;
- difficult and expensive to clean;
- hydraulic head loss occurs through the trash rack;
- can cause upstream flooding during trash rack blockages;
- the appearance of the rack and trapped litter can be obtrusive;
- potential breakdown of collected pollutants in wet sump;

- retrofitting can be difficult due to land and topographic requirements; and
- previously caught material may be resuspended if overtopping occurs.

| Estimated treatment performance summary | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L/M | coarse sediment | M/H | medium sediments | M |
| fine sediments | L | attached pollutants | N | dissolved | N |
| installation costs | H | maintenance costs | M/H | head requirements | H |
| N = negligible, L= low, M = moderate, H = high, VH = very high | | | | | |

### *Trapping performance*

Although similar in principle, gross pollutant traps have some operational advantages over conventional trash racks. Entrance channels to the GPT are widened to match the width of the sedimentation basin. This ensures the trash rack located on the downstream end of the basin provides more trash rack area for a given stormwater channel width than conventional trash racks. This presumably results in improved performance and fewer blockages.

GPTs are primarily sized according to sediment retention capacity. Better performance for coarse rather than fine sediments is reported, however only a few studies have investigated their trapping efficiencies.

### *Cost considerations*

GPTs are expensive structures to construct, mainly because of their size. A large proportion of the building costs relate to infrastructure costs such as access roads. This means that larger GPTs demonstrate reduced cost per hectare of catchment. GPT maintenance is also an expensive operation. This can involve heavy machinery for sediment removal and manual labour for trash rack cleaning.

### *Design considerations*

The GPT comprises three basic functional elements: a trash rack, an apron and a slow draining pool as a sediment trap. This may be a permanent pool, or it may drain to a dry condition. A litter drying area and a flow bypass for cleaning may also be incorporated into the design. Smaller GPTs can be installed below ground to reduce visual impacts. Configurations can be based on the ACT Government guidelines (1994).

The design techniques used for sediment traps (refer Appendix B) may be applied to the sediment storage component of a GPT. The GPT's trash rack may be sized using the conventional trash rack design approach.

### *Maintenance*

GPT maintenance is an essentially manual task involving frequent litter removal and can prove to be a considerable cost. This usually involves manual scraping of pollutants from the screen or a frequent (e.g. monthly) basis. Removing the collected sediment involves dewatering the wet basin, then using a machine to remove the material (ACT Government 1994). Typically this is done every six months.

*See also*: Trash racks, Sediment settling basin.

### *References and further information*

ACT Government, 1994, *Urban Stormwater: Standard Engineering Practices*.

Freeman G., 1995, 'Off-line improvement of in-line stormwater quality controls'.

Sim, R.L. and Webster, J.L., 1992, 'Performance of a trash rack on Cup and Saucer Creek stormwater channel'.

Southcott, P.H., 1995, 'A case study of a minor gross pollutant trap'.

Willing and Partners, 1992a, *Design Guidelines for Gross Pollutant Traps*.

## Primary treatment Type 9: Return flow litter baskets

### *Description*

The return flow litter basket comprises an inlet area with weir, leading to a labyrinth litter basket assembly. Water passes through the labyrinth, exiting very near the inlet weir. This device uses the force of 'return flow' water leaving the collection basket to produce a 'hydraulically driven barrier' to divert incoming water into the collection basket. The process operates for all flows except large floods, when flows greater than the basket capacity by-pass the system to avoid scouring of collected pollutants.

The submerged outlet permits some oils and grease to be retained in the pollutant collection chamber. The device is intended to be installed in existing pipe systems, with minimal disturbance to the flow capacity or established flow patterns.

### *Advantages*

- can be retrofitted into existing drainage systems;
- hydraulically driven barrier minimises head losses;
- can operate in a range of pipe slopes; and
- only requires standard maintenance plant.

### *Limitations*

- potentially large structure requiring substantial area for installation; and
- potential breakdown of collected pollutants.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | M/H | coarse sediment | M | medium sediments | L |
| fine sediments | N | attached pollutants | N | dissolved | N |
| installation costs | M/H | maintenance costs | L/M | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

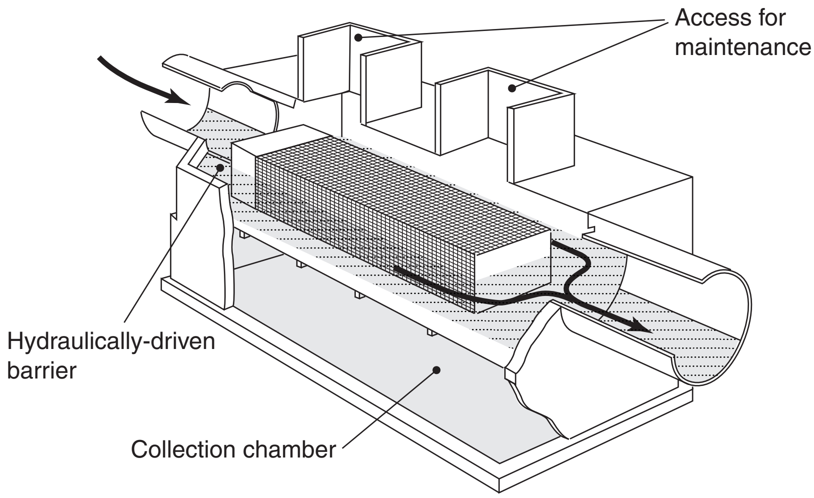


**Figure 7.14 Return flow litter baskets (after Ecosol 1997).**

### *Trapping performance*

There are few field data available on the performance of these devices, although laboratory tests have shown encouraging results. Several devices have been installed in South Australia and data are being collected.

### *Cost considerations*

Installation costs are estimated to be moderate to high, depending on site constraints. Maintenance costs are undetermined at this stage.

### *Design considerations*

The key design consideration is the sizing of the basket and pollutant retention chamber. This depends on the catchment flow characteristics and the expected pollutant loads. This size will also affect the cleaning frequency required.

### *Maintenance*

Maintenance is performed by lifting the basket with standard plant on to a collection vehicle. Alternatively, pollutants may be removed with vacuum plant. The cleaning frequency is currently unknown, but expected to be in the order of monthly.

*See also*: Litter collection baskets.

## Primary treatment Type 10: Hydraulically operated trash racks

### *Description*

Developed in South Africa in 1996, this device uses a hydraulically driven sluice gate to control hydraulic conditions. Stormwater is filtered through a series of vertical screens before flowing under a fixed brick baffle wall, then over a weir (Armitage et al. in press). The hydraulically operated sluice gate is activated during flood conditions, allowing flood waters to pass through the device without disturbing the collected pollutants.

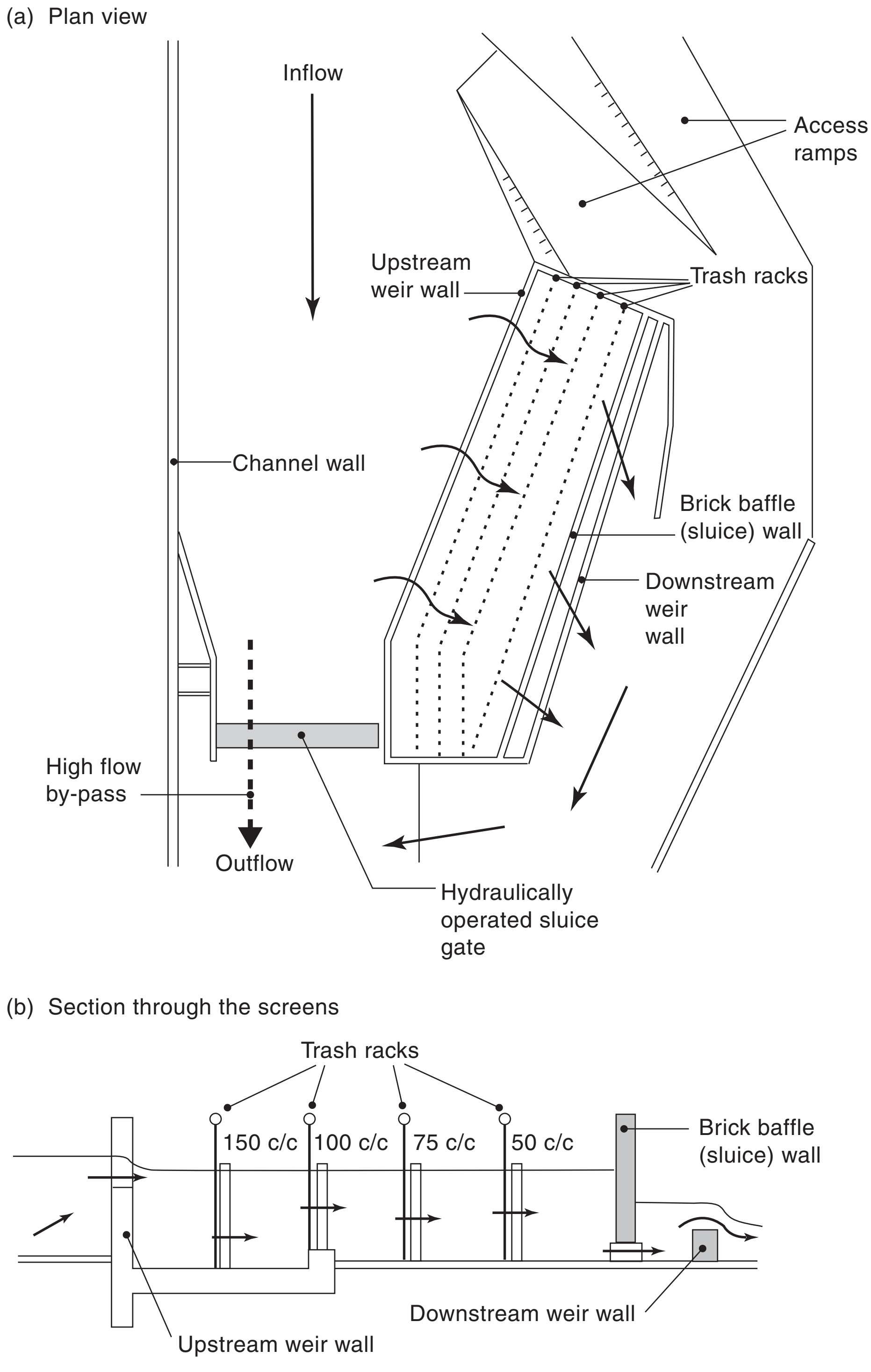


**Figure 7.15 Hydraulically operated trash racks (after Townshend 1996).**

The screen assembly is positioned with the coarsest screen (150 millimetre bar spacings) upstream and the finest (50 millimetre bar spacings) on the downstream side. The South African structures also have sedimentation basins built into the device to further improve pollutant retention.

### *Advantages*

- minimal head losses, permitting installation in mildly sloped channels;

- high flow by-pass avoids pollutant scouring;
- flow through the screens is maximised and regulated by the hydraulic sluice gate;
- presents a larger screen area to the flow than conventional trash racks; and
- suitable for installation in large open channels.

*Limitations*

- maintenance intensive, requiring screen cleaning and sluice gate inspection/ maintenance;
- potentially large structure requiring substantial area; and
- the appearance of the rack and trapped litter can be obtrusive.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | H/VH | coarse sediment | L/M | medium sediments | N |
| fine sediments | N | attached pollutants | N | dissolved | N |
| installation costs | L/M | maintenance costs | M/H | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

*Trapping performance*

This assembly presents a larger screen area to the flow than conventional trash racks and presumably captures more gross pollutants. It also provides water level control to avoid overtopping of the screens, further improving pollutant retention. High trapping efficiencies are reported in South Africa.

One South African structure installed on a 10 metre wide channel, can reportedly pass approximately 15 cubic meters per second through the trash rack before the flood control gate needs to be opened. The trapping performance is greatly improved compared to conventional trash racks, due to the flow regulation provided by the sluice gate.

The trapping performance is also greatly influenced by the cleaning frequency. It is essential that the structure is clean prior to large stormflows.

*Cost considerations*

Considering their ability to treat large catchment areas with a high pollutant removal efficiency, these devices may be more cost effective than conventional trash rack designs.

*Design considerations*

There are several design parameters which determine the traps' effectiveness. The flow rate at which the flood relief gate opens, the screen bar spacings and the size of the collection area.

### *Maintenance*

Intensive maintenance of this measure is required to ensure filter screens are clean—particularly before large stormflows. The screens are designed to be raised in their frame, allowing the debris to be easily removed by raking. This is currently performed manually, which is a laborious and potentially dangerous task. By increasing the space between the screens, automated techniques may be feasible.

*See also*: Trash racks.

### *References and further information*

Armitage, N.P., Rooseboon, A., Nel, C. and Townshend, P., in press, 'The removal of trash from stormwater conduits'.

Townshend, P., 1996, 'Robinson Canal: Johannesberg, Pollution Control Works'.

## Primary treatment Type 11: Circular screens

### *Description*

A circular screen is used to achieve separation of incoming stormwater from gross pollutants which are contained in a separation chamber. Solids within the chamber are kept in continuous motion and are prevented from 'blocking' the screen. This is achieved by a hydraulic design that ensures the circular flow force on an object is significantly higher than the centrifugal force driving the object to the chamber wall. Floating objects are kept in continuous motion on the water's surface, while the heavier pollutants settle into a containment sump.

### *Advantages*

- very high removal rate;
- low head requirements;
- can be retrofitted into existing drainage systems;
- minimal visual impact as typically installed underground;
- traps coarse sediment, with some fine sediment also retained;
- units with submerged screens can also retain oils; and
- minimal maintenance requirements.

### *Limitations*

- expensive to install;
- potentially large structure requiring substantial area and depth; and
- potential breakdown of collected pollutants in wet sump.

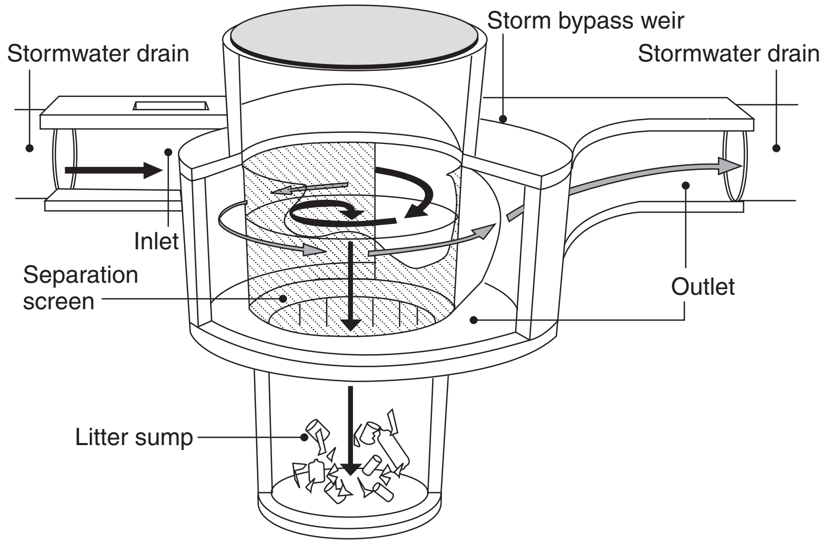


**Figure 7.16 Continuous deflective separation trapping system (after CDS Technologies 1997).**

| **Estimated treatment performance summary** | | | | | |
|---|---|---|---|---|---|
| gross pollutants | VH | coarse sediment | H | medium sediments | M |
| fine sediments | L/M | attached pollutants | L | dissolved | N |
| installation costs | H | maintenance costs | M | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

### *Trapping performance*

Field monitoring by Allison et al. (1996) suggests that circular screen devices are efficient gross pollutant traps. During the twelve months of monitoring, practically all gross pollutants transported by the stormwater were trapped by the CDS device.

Longer term trapping rates will be determined by the height of the bypass weir. Typical installations accommodate at least a one-in-six-months storm prior to overflow. This would ensure that at least 95 per cent of annual discharge is treated, with a similar proportion of all gross pollutants captured.

Monitoring by Walker et al. (1999) suggests that the devices also retain significant quantities of sediment. Ninety per cent of the sediment recovered from the collection sump was smaller than the screen mesh size. In addition, up to 70 per cent retention of suspended sediment by the device was reported during the early flows of a run-off event.

### *Cost considerations*

Circular screen self-cleaning racks are expensive to install, requiring complex construction methods. Maintenance costs, on the other hand, are small because of the simple, infrequent maintenance requirements. Factory built smaller units are now also available.

### *Design considerations*

A diversion structure upstream of the unit diverts flow to the collection chamber and acts as a by-pass weir during flow events exceeding design conditions.

The height of the weir determines the frequency of stormwater by-pass. The height of the weir depends on a number of factors, including the topography of the site, depth of cover of the existing pipe and the discharge capacity of the stormwater system. The diversion weir is typically designed to divert at least 95 per cent of annual discharge through the separation chamber (Wong et al. 1996).

### *Maintenance*

Material collected in the separation chamber can be removed in three ways. The sump can be fitted with a large basket that collects sinking material—this can be lifted with a crane on to a removal truck. Alternatively, the contents of the sump can be extracted with a vacuum pump. For very large installations, a 'clam grab' can be used with a crane to remove pollutants. A two- to three-monthly cleaning frequency is recommended.

*See also*: Sediment removal, Secondary treatments.

### *References and further information*

Allison, R.A., Wong, T.H.F. and McMahon, T.A., 1996, 'Field trials of the polluted stormwater pollution trap'.

Walker, T.A., Allison, R.A., Wong, T.H.F. and Wootton, R.M., 1999, *Removal of Suspended Solids and Associated Pollutants by a CDS Gross Pollutant Trap*.

Wong, T.H.F., Wootton, R.M. and Fabian, D., 1996, *A Solids Separator Using a Continuous Deflective System*.

## Primary treatment Type 12: Downwardly inclined screens

### *Description*

This measure comprises a downwardly inclined trash rack, with a pollutant holding shelf at its base. Stormwater is introduced from pipe outlets at the top of end of the assembly. The water falls between the trash rack bars, while pollutants larger than the gap width are trapped on the rack. The force of the flowing water and gravity cause the pollutants to slide down the rack on to the holding shelf at the foot of the rack. Racks are typically inclined between 20 and 45 degrees from horizontal.

The device is constructed so that maintenance can be performed with standard plant. Maintenance access is achieved via a ramp. The holding shelf allows water to drain from collected material. This simplifies the cleaning process and prevents material being stored in anaerobic conditions, which can lead to contaminant breakdown.

Independent research programs in Australia and South Africa have developed devices that are very similar. The Australian devices are intended for drains generally smaller than 1500 millimetres in diameter (Baramy 1997) using a rack inclined at approximately 20 degrees from horizontal. Some larger devices are also being developed.

The South African devices (Manly Hydraulic Laboratory 1994) cater for similar pipe sizes along with much larger channels. With screens inclined at angles typically 45 degrees

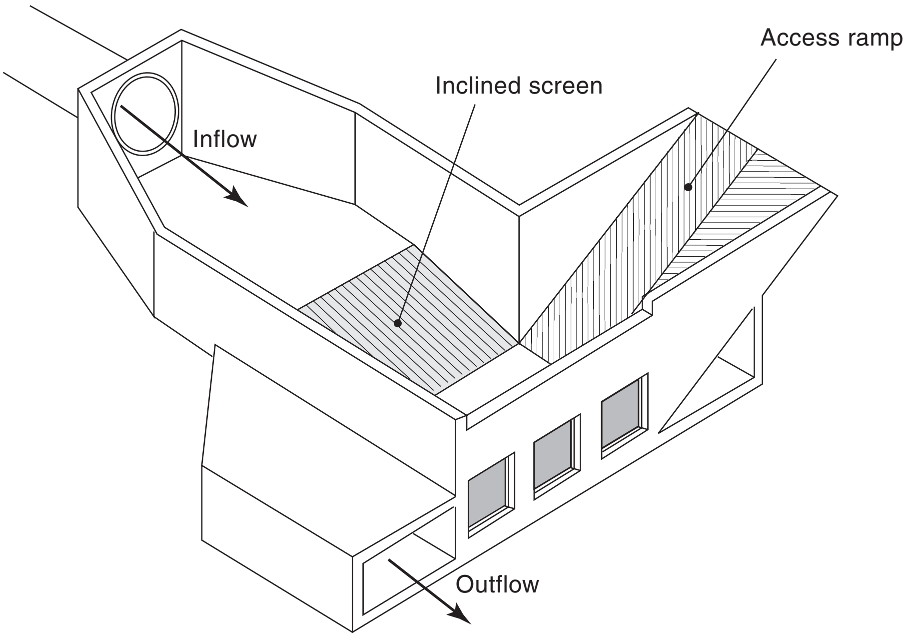


**Figure 7.17 Downwardly inclined screen pollutant trap (after Baramy 1997).**

from horizontal, these devices require more head to operate than the Australian version. The South African devices allow for installation off-line to the main channel and can be installed in very large open channels.

### *Advantages*

- screen is kept free from blockages so flooding is avoided;
- pollutants are kept dry before removal;
- easy to maintain with standard plant;
- relatively simple to install; and
- potentially high trapping efficiencies.

### *Limitations*

- limited to sites where a suitable drop in the channel bed is possible; and
- potentially large structure requiring substantial area.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | H/VH | coarse sediment | N | medium sediments | N |
| fine sediments | N | attached pollutants | N | dissolved | N |
| installation costs | M/H | maintenance costs | L/M | head requirements | H |

N = negligible, L= low, M = moderate, H = high, VH = very high

### *Trapping performance*

Extensive laboratory testing (Manly Hydraulic Laboratory 1994) and field experience in South Africa suggests this is a highly effective trash rack, due to its non-blocking nature.

In addition to the rack's self-cleaning nature, blockages are further prevented by a hydraulic jump that forms up the trash rack. This jump helps break up the pollutants on the rack's surface and move them down into the collection basket (Armitage et al. 1998).

The rack's bar spacing may allow some smaller material to pass through. Bars are typically spaced at approximately 30–50 millimetre centres.

Being off-line to the main channel, the South African designs permit very large flood flows to bypass the system, leaving collected pollutants undisturbed.

To date, no Australian field data have been collected describing the trapping performance of this measure.

### *Cost considerations*

Installation costs for these types of racks are moderate to high, depending on the location of the device. Maintenance costs are relatively low, due to the trap's self-cleaning nature. Only infrequent cleaning is required.

### *Design considerations*

These devices are only suitable for locations that can accommodate a drop in the drainage line. This limits there applicability in low lying areas.

Australian and South African designs differ in rack angles, in-line and off-line options and the size of catchments they are designed to treat.

### *Maintenance*

There is limited information available describing the maintenance requirements of downwardly inclined screens. They are expected to have very high trapping efficiencies for gross pollutants and can therefore expect to produce large volumes of material for collection. The trap's self-cleaning nature and the fact that pollutants are kept dry minimises the cost of this operation.

*See also*: Trash racks.

### *References and further information*

Armitage, N.P., Rooseboon, A., Nel, C. and Townshend, P., 1998, *The Removal of Urban Litter From Stormwater Conduits and Streams.*

Baramy Engineering, 1997, Product description, Katoomba, NSW.

Manly Hydraulic Laboratory (MHL), 1994, Hydraulic Model Studies of Grate, Lintel and Modified Gully Pit Designs for Pyrmont Redevelopment.

## Primary treatment Type 13: Flexible floating booms

### *Description*

The flexible floating boom comprises a string of partly submerged floating booms located across a waterway. Originally designed as an oil slick retention device, the boom collects

**Figure 7.18 Flexible floating boom on the Yarra River, Melbourne.**

floating objects as they collide with it. The performance of any boom is greatly influenced by the flow conditions of the waterway. Floating booms are best suited to very slow moving waters and perform best with highly buoyant pollutants such as plastic bottles and polystyrene.

### *Advantages*

- enhances aesthetics and recreation potential of downstream waterways;
- mobile and may be appropriate for retrofitting into existing areas;
- collects litter at a single location rather than over a large area; and
- able to rise and fall with changes in flow or tide.

### *Limitations*

- gross pollutants may be swept past the boom by tide movement, winds or high flows;
- booms can only capture floating pollutant load;
- maintenance is difficult, with most boom assemblies cleaned by boat;
- spanning of the entire waterway width may be difficult;
- booms may break away from the banks during high flows; and
- the appearance of the boom and trapped litter can be obtrusive.

| **Estimated treatment performance summary** | | | | | |
|---|---|---|---|---|---|
| gross pollutants | N/L | coarse sediment | N | medium sediments | N |
| fine sediments | N | attached pollutants | N | dissolved | N |
| installation costs | L | maintenance costs | M | head requirements | L |
| N = negligible, L= low, M = moderate, H = high, VH = very high | | | | | |

### *Trapping performance*

Despite early claims of high trapping efficiency, it has been recognised that during high flows the gross pollutant retaining performance of floating booms is greatly reduced. This is because material may be forced over and under the boom (Horton et al. 1995; Gamtron 1992), or the boom may break away from the banks.

The boom's litter retention properties can be improved by angling it across the channel to allow collected trash to accumulate on one side of the channel, away from high velocity areas (Horton et al. 1995). Mesh skirts are also useful (Horton et al. 1995). Regardless of these modifications, litter loss during high flow conditions may still occur.

The floating boom is only effective in retaining gross pollutants that float. As this represents less than 20 per cent of litter and 10 per cent of vegetation, this suggests a limited performance for floating boom applications.

Despite the boom's inefficiencies during high flows and with submerged pollutants, they have been reported to trap large quantities of gross pollutants. It has been reported that between 100 and 370 cubic metres of gross pollutants have been removed annually from booms in Melbourne (State Pollution Control Commission 1989). Gamtron (1992) quotes annual capture rates of between 24 and 71 kilograms per hectare from four booms in Sydney.

### *Cost considerations*

Flexible floating booms are comparatively inexpensive to purchase and installation is simple. Operating costs can be expensive due to the difficulty of boom cleaning operations and the necessity for continuous monitoring.

### *Design considerations*

As described earlier, boom performance can be improved by angling the boom across the channel. In addition, the trash may be collected in a mesh container attached to the side of the channel. Located within easy reach of the bank, this will retain trash during high flows and permit easier cleaning (Freeman 1995).

Waterway width and water traffic generally prevent the boom spanning the entire width of the waterway. It is therefore critical to locate a boom where the flow paths will ensure optimal boom performance.

### *Maintenance*

Floating booms generally require manual cleaning. Trash accumulated in the boom is usually collected with a trench digger or by using a boat and pitch forks. Cleaning is usually on demand.

Small booms can be pulled to one bank, where material can be accessed manually from land. Booms angled across the flow are intended to transfer collected material to a collection area that is accessible from land. This has been successful with some small booms, but not for most installations (Horton et al. 1995).

More recently, techniques have been developed to collect pollutants from behind the boom using an underwater vacuum device. This requires manual operation and is only suitable for shallow waters.

*See also*: Floating debris traps.

### *References and further information*

Freeman, G., 1995, 'Off-line improvement of in-line stormwater quality controls'.

Gamtron Pty Ltd, 1992, *Performance Assessment of Four Rubbish Interception Booms*.

Horton, P.R., Cox, R.J. and Wilkinson, D.L., 1995, 'Stormwater boom performance assessment and enhancement'.

McKay, P. and Marshall, M., 1993, *Backyard to Bay: Tagged Litter Report*.

State Pollution Control Commission, 1989, *Pollution Control Manual for Urban Stormwater.*

## Primary treatment Type 14: Floating debris traps

### *Description*

Floating Debris Traps (FDTs) have evolved from booms and use the same operating principles, but have enhanced material retention capabilities and are easier to clean.

The traps use floating polyethylene boom arms fitted with skirts to deflect floating debris through a flap gate into a collection chamber. The flap gate prevents collected floatables escaping during high winds or changing tidal conditions. A sliding gate on the downstream end of the trap provides access for cleaning. A specially designed basket is used to collect material as it flows through the open gate.

### *Advantages*

- enhances aesthetic and recreation potential of downstream waterways;
- improved retention of collected pollutants;
- mobile and may be appropriate for retrofitting into existing areas;
- collects litter at a single location rather than over a large area; and
- able to rise and fall with changes in flow or tide.

**Figure 7.19 Plan view of floating debris trap.**

*Limitations*

- gross pollutants may be swept past the boom by tide movement, winds and high flows;
- booms can only capture floating pollutant load;
- maintenance is difficult, with most boom assemblies cleaned by boat;
- complete boom spanning of the waterway may be difficult;
- booms may break away from the banks during high flows; and
- the appearance of the boom and trapped litter can be obtrusive.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L | coarse sediment | N | medium sediments | N |
| fine sediments | N | attached pollutants | N | dissolved | N |
| installation costs | L | maintenance costs | M | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

*Trapping performance*

There is little data describing the trapping efficiency of FDTs. It is likely that the FDT suffers similar problems of material loss during high flow and wind conditions, as experienced by the floating boom. FDTs may have better material retention in changing wind or tidal conditions.

### *Cost considerations*

FDTs can be moderately expensive to purchase, but are simple to install. As with floating booms, regular monitoring and on-water removal of collected material is required, making maintenance difficult and expensive.

### *Design considerations*

As the width and boating use of most waterways generally prevents floating debris traps from spanning the complete width of a waterway, the location of the trap is critical to its performance. Governed by discharge, tide or wind conditions, the waterway's 'natural' flow paths for floating gross pollutants can either direct pollutants into or away from the trap. Knowledge of the installation site's natural flow paths and wind directions is recommended prior to installing FDTs.

### *Maintenance*

During cleaning, a sliding gate at the downstream end of the trap is opened, releasing the material to a purpose built collection basket. Once full, a specially designed barge fitted with a crane lifts the basket on-board. The basket is then taken away for disposal. Continuous monitoring of pollutant build-up is required to ensure cleaning is performed with sufficient regularity.

*See also*: Flexible floating booms.

## Primary treatment Type 15: Sediment settling basins and ponds

### *Description*

Sediment settling basins are structures designed to trap coarse sediment. These can be used in isolation in the stormwater system, or as a pre-treatment upstream of other treatment measures. The basins can take the form of a formal 'tank' (usually concrete) or a less formal pond (usually earth). Sedimentation is encouraged in the basin by enlarging the channel so that water velocities are reduced to a point where sedimentation can occur.

### *Advantages*

- simple design, making construction easy; and
- reduces stormwater coarse sediment loads.

### *Limitations*

- potential breakdown of collected pollutants in wet sump;
- limited removal of fine sediments or soluble pollutants;
- potentially large structure requiring substantial area; and
- possible source of sediments due to scouring during large floods.

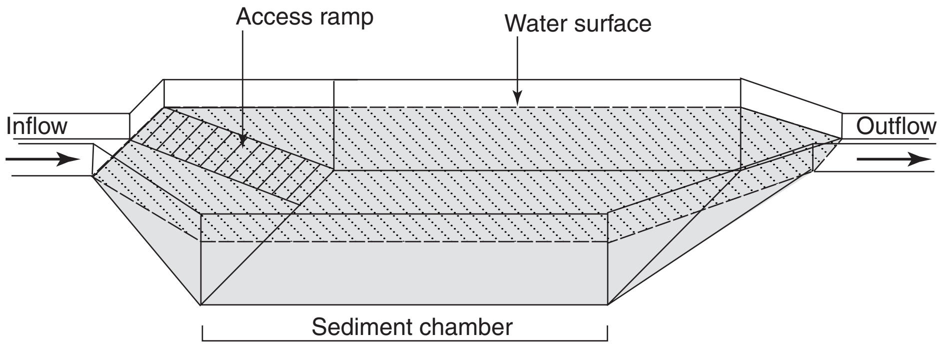


**Figure 7.20 Sediment settling basin.**

| **Estimated treatment performance summary** | | | | | |
|---|---|---|---|---|---|
| gross pollutants | N | coarse sediment | M/H | medium sediments | M |
| fine sediments | L | attached pollutants | N/L | dissolved | N |
| installation costs | L/M | maintenance costs | L/M | head requirements | L |
| N = negligible, L= low, M = moderate, H = high, VH = very high | | | | | |

### *Trapping performance*

Originally designed and developed in Canberra, the primary design technique for sediment traps was developed by Willing and Partners (1992a, 1992b). This is detailed in ACT Government (1994). The technique has been applied in other areas and there is anecdotal evidence that the sediment trapping is less efficient than that observed in the Canberra trials.

Limited monitoring of sediment traps has been undertaken in Australia.

### *Cost considerations*

Both the installation and maintenance costs of the sediment settling basins are low to moderate.

### *Design considerations*

Sediment settling basins differ from wetlands, in that they primarily rely on physical settling rather biological means of pollutant removal. Sometimes known as sediment forebays, pond type sediment traps are usually of an informal shape. These are often located at the upstream end of wet basins or wetlands to provide coarse sediment removal.

Incorporated as part of a wet basin or wetlands treatment system, sediment settling basins appear as deeper pools upstream of a shallower area. Macrophytes (aquatic plants) may be used to minimise the potential for sediment resuspension and prevent the conveyance of material to the pond outlet. Pervious outlets, such as rock walls, can also be used to help filter the water and provide water level variations.

Sedimentation basin sizing is based on the settling velocity of the design particle, during the design storm event. More detailed design methods are outlined in Appendix B.

### *Maintenance*

Accumulated sediment needs to be removed regularly to prevent scouring during storms. Sediment removal becomes critical when the storage volume has been reduced by half. The best method of sediment removal is expected to involve draining the trap, followed by the use of backhoes or similar equipment. Regular inspection will help determine maintenance needs. Generally, sediment removal is required every three to six months.

*See also*: Circular self-cleaning screens, Hydrodynamic separation, Gross pollutant traps, Circular settling tanks.

### *References for further information*

ACT Government, 1994, *Urban Stormwater: Standard Engineering Practices*.

Auckland Regional Council, 1992, *Design Guideline Manual: Stormwater Treatment Devices*.

Ontario Ministry of Environment and Energy, 1994, *Stormwater Management Practices Planning and Design Manual*.

Schueler, T.R., 1987, *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*.

Schueler, T.R., Kumble, P.A. and Heraty, M.A., 1992, *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Non-Point Source Pollution in the Coastal Zone*.

Willing and Partners Pty Ltd, 1989, *Gross Pollutant Trap Design Guidelines*.

Willing and Partners Pty Ltd, 1992a, *Design Guidelines for Gross Pollutant Traps*.

Willing and Partners Pty Ltd, 1992b, *Gross Pollutant Trap Design Manual.*

## Primary treatment Type 16: Circular settling tanks

### *Description*

Circular settling tanks have been primarily designed for sediment and oil retention, although floatables and other gross pollutants may be retained during low to moderate flows.

The tank is cylindrical in shape and divided into two areas: an upper diversion chamber and a lower retention chamber. Stormwater is directed by a diversion weir into the lower retention chamber and exits the chamber through an outlet riser pipe. Sediments collect in the base of the retention chamber. The diversion weir directs flow to by-pass the retention chamber in the event of high flows. As the inlet and outlet pipes are set at the same elevation, some oil retention is achieved in the lower chamber (Weatherbe et al. 1995).

### *Advantages*

- retains a high proportion of sediments;
- protects collected material from scouring;
- can also collect oils and grease;

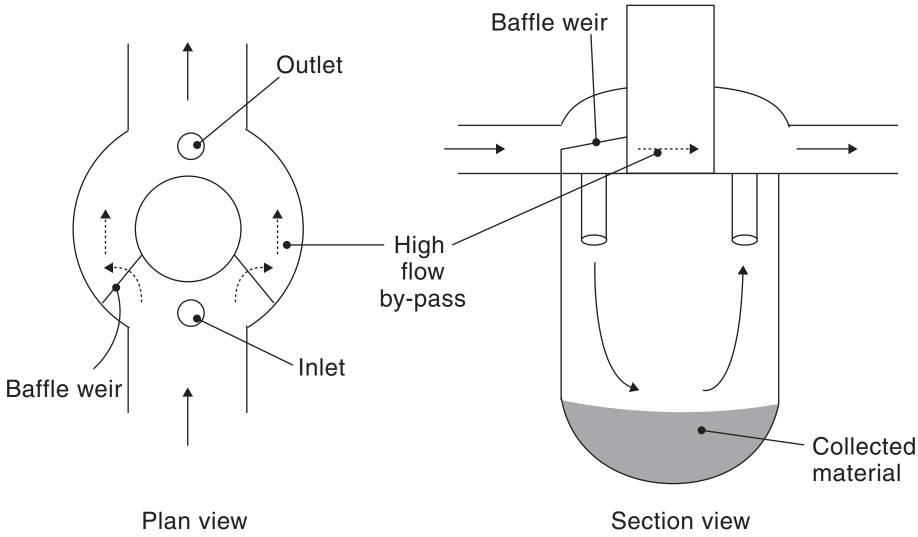


**Figure 7.21 Circular settling tank (after CSR Humes 1997).**

- suitable for targeting specific problem areas; and
- can be retrofitted into existing drainage systems.

*Limitations*

- high initial costs; and
- gross pollutants may block inlet downpipe.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L/M | coarse sediment | H | medium sediments | M/H |
| fine sediments | M | attached pollutants | L/M | dissolved | N |
| installation costs | H | maintenance costs | M | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

*Trapping performance*

A series of laboratory experiments lead to the development of circular settling tanks in the early 1990s (Marsalek 1993; Marsalek et al. 1994). A number of North American field studies have investigated the unit's sediment retention capabilities. Bryant et al. (1995) showed field installations achieving retention of 80 per cent of all sediments.

*Cost considerations*

Circular settling tanks are expensive to install, but maintenance costs are moderate.

*Design considerations*

A key design issue is to adequately size the units to achieve the desired by-pass frequency. A 25 millimetre drop is required between the inlet and outlet channel beds for operation. This should be easily met in most situations.

### *Maintenance*

Routine vacuum removal of the retention chamber is required—typically, monthly.

*See also*: Other sediment treatments, In-line litter separator, Baffled pits.

### *References and further information*

Bryant, G., Misa, F., Weatherbe, D. and Snodgrass, W., 1995, 'Field monitoring of stormceptor performance'.

Marsalek, J., 1993, *Laboratory Testing of Stormceptor I*.

Marsalek, J., Long, R. and Doede, D., 1994, *Laboratory Development of Stormceptor II*.

Weatherbe, D.G., Bryant, G. and Snodgrass, W., 1995, 'Performance of the Stormceptor water quality inlet'.

## Primary treatment Type 17: Hydrodynamic separators

### *Description*

Hydrodynamic separation units induce a vortex in the stormwater flow as it enters a large separation chamber. The system relies on the secondary flows, caused by the vortex action, to concentrate sediments in the bottom of the unit.

Hydrodynamic separation units available in Australia fall into two design categories. The first simply treats the stormwater and retains the separated pollutants within the unit until it is cleaned. The second incorporates a separate drain line for the contaminants (refer Figure 7.20).

This design features two outlet lines. One carries a high volume, low concentration flow (the 'water' line), while the other is intended to remove most of the pollutants with a small amount of the flow. This is discharged into the sewerage system.

The dual outlet device is effectively self-cleaning and requires minimal maintenance. A sewer line with sufficient capacity to cope with additional flows during wet weather is required close by.

The dual outlet units can also be fitted with racks that screen the incoming water and direct gross pollutants to the sewerage system. The racks are prevented from blocking by a reverse flush system that is activated by rising water level.

### *Advantages*

- high sediment removal rates; and
- can incorporate return flows to sewers to minimise cleaning.

### *Limitations*

- expensive and complex to install;
- removal rates fall with increasing stormwater flow; and
- lack of Australian performance data.

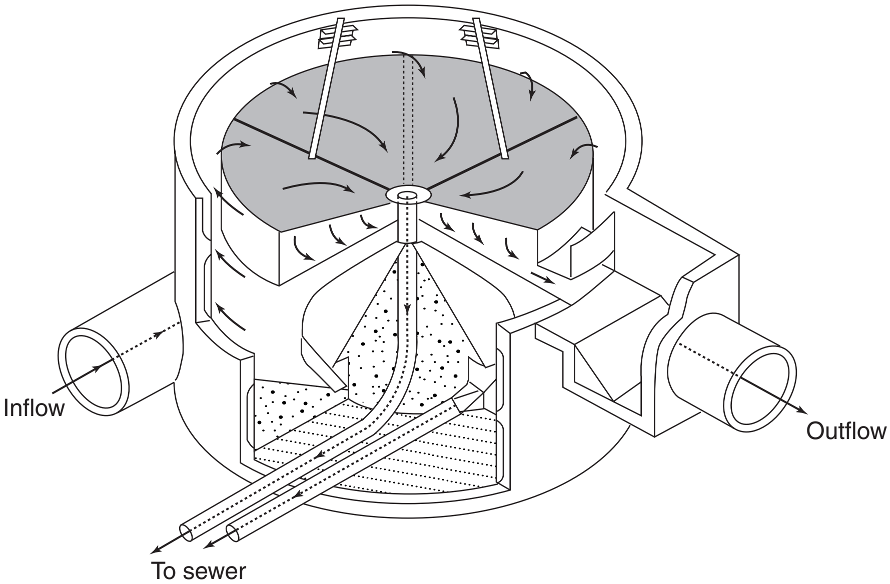


**Figure 7.22 A hydrodynamic separator (Storm King®, after Hydro Australasia).**

| **Estimated treatment performance summary** | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L/M | coarse sediment | M/H | medium sediments | M |
| fine sediments | M | attached pollutants | L/M | dissolved | N |
| installation costs | H | maintenance costs | L/M | head requirements | L |
| N = negligible, L= now, M = moderate, H = high, VH = very high | | | | | |

### *Trapping performance*

Extensive experience with vortex separation used in combined sewer overflows has been reported in USA and Europe. It is generally regarded as an efficient means of removing sediments, although there has been limited experience with discrete stormwater system applications.

Hydrodynamic separators have been employed in combined sewer overflows in the United Kingdom since the 1960s. Since then, American, German and British researchers have developed enhanced designs with improved sediment retention (Brombach et al. 1993).

One of the British devices previously used for combined sewer overflows in the northern hemisphere is currently promoted in Australia for stormwater applications. All such devices use similar principles and can be expected to remove significant quantities of sediments.

### *Cost considerations*

Hydrodynamic separators demonstrate high installation costs because of the complex construction requirements. Once installed, maintenance demands vary depending on the specific unit selected.

### *Design considerations*

The units are sized for hydraulic conditions and expected pollutant loads. The unit's size will have a direct impact on the required cleaning frequency.

### *Maintenance*

With simple units, maintenance involves removing collected pollutants with vacuum plant. If a foul water outlet is fitted, simple inspection of the unit to ensure the foul water outlet is operational is the only maintenance required.

*See also*: Continuous deflective separation, Circular settling tanks.

### *References and further information*

Brombach, H., Xanthopoulos, C., Hahn, H.H. and Pisano, W.C., 1993, 'Experience with vortex separators for combined sewer overflow control'.

Harwood, R. and Saul, A. J., 1996, *Field Testing of a Storm King With Swirl Cleanse Hydrodynamic Separator Combined Sewer Overflow: Summary Report*.

Pisano, W.C., 1988, 'Swirl concentrators revisited: the American experience and new German technology'.

# 7.8 Secondary treatment: index

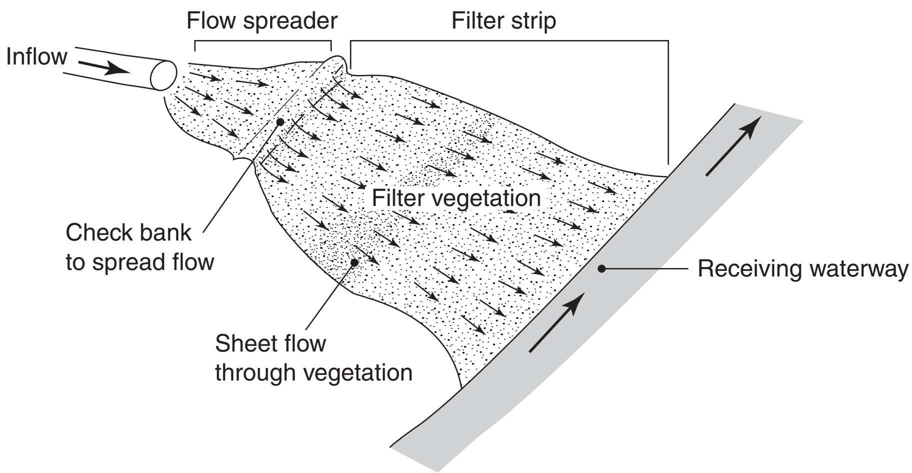


**Figure 7.23 Filter strips.**

## Secondary treatment Type 1: Filter strips

*Description*

Also known as buffer zones or strips, filter strips are grassed or vegetated areas that treat shallow overland flow before it enters the drainage network. Often located adjacent to waterways, this treatment measure is primarily intended to remove sediment and hydrocarbons.

Filter strips initially immobilise pollutants, by binding them to organic matter and soil particles. Ultimate pollutant removal is achieved by settling, filtration and infiltration into the subsoil. Certain pollutants, such as hydrocarbons, may be digested and processed by the soil micro-organisms in the filter strip. Consequently, adequate contact time between the run-off and the vegetation and soil surface is required to optimise pollutant removal.

Filter strips also reduce run-off volumes and attenuate storm flows. With appropriate vegetative cover and diversity, filter strips can provide a habitat corridor for wildlife. Additional benefits of filter strips include improved landscape and habital values.

*Advantages*

- infiltration can reduce and delay storm run-off;
- can achieve high removal rates;
- retains pollutants close to source;
- can improve the aesthetic appeal of an area; and
- relatively inexpensive to construct.

*Limitations*

- limited removal of fine sediment and dissolved pollutants;

- requires considerable land areas with limited public access;
- a sunny aspect is required for plant growth, limiting its application in shaded areas;
- effectiveness is reduced for concentrated flows and high flow depths;
- flow spreaders are required for slopes greater than 5 per cent;
- only suitable for gentle slopes (less than 5 per cent); and
- regular inspections are required.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L/M | coarse sediment | H | medium sediments | M/H |
| fine sediments | L/M | attached pollutants | L/M | dissolved | L |
| installation costs | L | maintenance costs | L | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

*Trapping performance*

Based on a nine minute average residence time, the reported pollutant retentions are listed in Table 7.4.

| Pollutant | Retention (%) | Pollutant | Retention (%) |
|---|---|---|---|
| Suspended solids | 83 | Lead | 67 |
| Oil and grease | 75 | Total phosphorus | 29 |
| Iron | 72 | Total nitrogen | Negligible |

**Table 7.4 Pollutant retention rates for filter strips (Horner et al. 1994).**

More Australian performance data are required to properly assess pollutant removal rates.

*Cost considerations*

Installation and maintenance costs for filter strips are both low.

*Design considerations*

Pollutant uptake by the filter strip vegetation is negligible; its primary purpose is to act as a physical filter. The choice of plant species will be related to local soil and climatic conditions. The goal is to generate a dense vegetation growth to maximise filtration and minimise erosion. Dense vegetation coverage of the filter strip can also improve the area's habitat value, run-off attenuation and aesthetics.

Flow entering the filter strip should be evenly distributed as sheet flow across its upstream end. Filter strips should not receive direct discharges from stormwater pipes or adjacent impervious areas—these should be pre-treated with energy dissipaters and/or flow spreaders as required.

Flow spreaders such as a shallow weir, rip-rap mattresses, a stilling basin or perforated pipes may be located across the width of the strip. A strip of turf can be placed immediately downstream of the level spreader, to assist flow spreading during the establishment period of the downstream seeded area. Filter strips should not receive flow until the vegetation is established.

There are no comprehensive guidelines on the design of filter strips and a number of 'rules of thumb' have been developed (Horner et al. 1994; Schueler et al. 1992), which are outlined in Appendix C.

### *Maintenance*

The most important maintenance consideration is to preserve the vegetation cover of a filter strip. Maintenance activities can include watering, reseeding, weeding or fertilising the area. Regular inspections are required to assess the condition of the vegetation cover, the presence of any channelisation and weed problems.

*See also*: Grass swales, Infiltration trenches.

### *References and further information*

Auckland Regional Council, 1992, *Design Guideline Manual: Stormwater Treatment Devices*.

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## Secondary treatment Type 2: Grass swales

### *Description*

Swales are grass-lined channels often used in low density residential developments as an alternative to kerb and gutter, or as a pre-treatment to other measures. These are similar in many ways to filter strips, but are used to convey run-off. They can also be used in road medians and verges, car park run-off areas, parks and recreation areas.

**Figure 7.24 Grass swales.**

Pollutant removal is achieved in much the same way as filter strips, although grass swales convey more flow and may therefore achieve lower removal rates.

Grass swales initially immobilise pollutants, by binding them to organic matter and soil particles. Ultimate pollutant removal is achieved by settling, filtration and infiltration into the subsoil. Certain pollutants, such as hydrocarbons, may be digested and processed by the soil micro-organisms in the swale. Consequently, adequate contact time between the run-off and the vegetation and soil surface is required to optimise pollutant removal.

Grassed swales can reduce run-off volumes and peak flows and enhance infiltration.

*Advantages*

- can reduce and delay storm run-off;
- retains particulate pollutants close to source;
- more aesthetically appealing than kerb and gutter; and
- relatively inexpensive to construct.

*Limitations*

- limited removal of fine sediment and dissolved pollutants;
- requires larger land area than kerb and gutter, with certain activities restricted (e.g. car parking);
- sunny aspect is required for plant growth, limiting its application in shaded areas;

- only suitable for gentle slopes (less than 5 per cent); and
- regular inspections are required.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L | coarse sediment | M/H | medium sediments | M |
| fine sediments | L/M | attached pollutants | L/M | dissolved | L |
| installation costs | L | maintenance costs | L | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

### *Trapping performance*

Grass swales can achieve high removal rates, although limited Australian data exists.

### *Cost considerations*

Installation and maintenance costs for grass swales are both low.

### *Design considerations*

Generally, design considerations for grass swale areas are similar to those for filter strips (refer Secondary treatment Type 2: Filter strips).

Swales adjacent to roads may be compacted by vehicular traffic, which may cause reduced infiltration rates.

There are no comprehensive guidelines for the design of swales and a number of 'rules of thumb' have been developed (Horner et al. 1994; Schueler 1992). A number of design techniques for sizing swales are presented in Appendix C.

### *Maintenance*

The most important maintenance consideration is to preserve the vegetation cover of a swale. Maintenance activities can include watering, reseeding, weeding or fertilising the area. Regular inspections may be required to assess the vegetation cover, the presence of any channelisation and weed problems.

*See also*: Filter strips, Infiltration trenches.

### *References for further information*

Auckland Regional Council, 1992, *Design Guideline Manual: Stormwater Treatment Devices*.

Camp Dresser and McKee, 1993, *California Storm Water Best Management Practice Handbooks: Municipal*.

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## Secondary treatment Type 3: Triple interceptor pits

### *Description*

Triple interceptors, also known as oil-grit separators, generally comprise three underground retention chambers designed to remove coarse sediments and retain oils. The first chamber is used for sedimentation and removal of large debris. This chamber contains a permanent pool of water and a well screened orifice which allows regulated flow into the second chamber.

The second chamber is used for oil retention. This chamber also contains a permanent pool of water. An inverted elbow pipe in the second chamber permits regulated flow into the third chamber. The inverted pipe collects water from deep in the permanent pool, leaving any oil contaminants floating on the surface. This remains trapped on the surface of the water until it is removed or absorbed by sediment particles which settle.

The third chamber is used to collect and disperse flow into the stormwater drain network or an infiltration basin. This chamber contains an orifice outlet, which is often raised to create a third settling pool and regulate outflow from the unit.

### *Advantages*

- appropriate for treating stormwater from areas with significant vehicular pollution (e.g. parking lots);
- can also trap litter;
- can treat stormwater from areas storing or handling petroleum products (e.g. service station and petroleum depots);
- can be retrofitted into existing drainage systems; and
- minimal visual impact as installed underground.

### *Limitations*

- limited removal of fine sediment or soluble pollutants;
- turbulent conditions in the pit may resuspend particles or entrain floating oil (a high-flow bypass can avoid this problem);

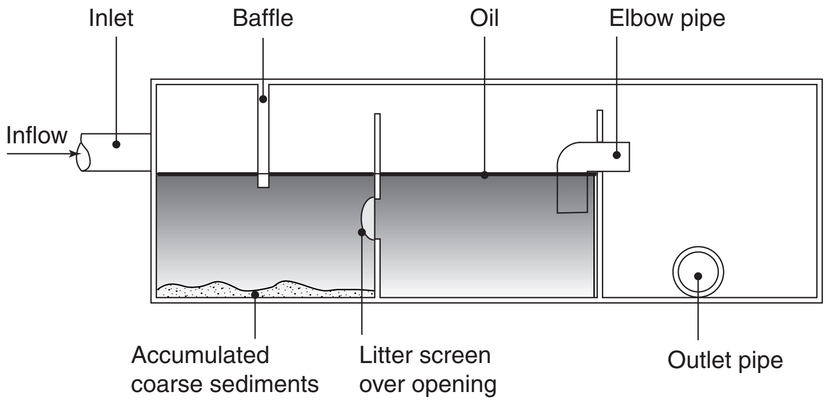


**Figure 7.25 Triple interceptor device.**

- trapped debris is likely to have a high concentration of pollutants, possibly toxic. Trapped debris may potentially release some pollutants into the stormwater;
- requires regular cleaning to achieve design objectives; and
- can pose a potential safety hazard for maintenance personnel.

| **Estimated treatment performance summary** | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L/M | coarse sediment | M | medium sediments | L/M |
| fine sediments | L | attached pollutants | L | dissolved | N |
| installation costs | M | maintenance costs | H | head requirements | L/M |
| N = negligible, L= low, M = moderate, H = high, VH = very high | | | | | |

### *Trapping performance*

Triple interceptors have been reported to have relatively poor pollutant removal performance. This has been attributed to poor maintenance and the passage of high flows through the device (Galli 1992). They have often been found to be expensive to operate, due to their high maintenance requirements (Ontario Ministry of Environment and Energy 1994). They have not been widely used in Australia.

### *Cost considerations*

Capital costs for baffled pits are moderate, but maintenance costs are high.

### *Design considerations*

Ontario Ministry of Environment and Energy (OMEE) (1994) provides the following general guidelines for the design of triple interceptors:

- *Run-off segregation*: Only run-off from areas which are likely to have oil contaminated run-off (e.g. filling areas on a service station site) should be directed to the separator. This will reduce the size of the separator required. Appropriate use of bunding in such areas may help segregate oil contaminated run-off from 'clean'.

- *High flow bypass*: The separator should be designed to accept low flow only, with a high flow bypass installed to provide for the residual flow up to the capacity of the pipe system.
- *Inter chamber screening*: Ensure that orifice between primary and secondary chambers is effectively screened. This should generally not allow debris greater than 5 millimetres in diameter to enter the second chamber. It should be easily accessible and easily removed for cleaning.
- *Maintenance access*: Easy access is required for inspection and cleaning. Each chamber could have its own inspection entrance, with step rings leading to the bottom of the chamber.

### *Maintenance*

Triple interceptors need to be cleaned frequently to keep accumulated oil and grit from escaping. The recommended cleaning frequency is every month. A vacuum pump tanker can be used to pump out the contents of each chamber. The turbulence of the vacuum pump in the chamber produces a water/sediment slurry that can then be transferred to the tanker.

Without regular maintenance, the system quickly reaches capacity. Oil and solid pollutants are re-entrained into the flow, rendering the device ineffective. Regular inspections should be made to assess sediment and oil levels along with outflow oil concentrations.

*See also*: Baffled pits, Sediment traps.

### *References and further information*

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## Secondary treatment Type 4: Porous pavements

*Description*

Porous pavements are suitable for areas with light traffic loads such as car parks. They allow run-off to infiltrate through the pavement's surface to the underlying soil, rather than simply running off the pavement.

There are two broad groups of porous pavements. The first uses deep, open-graded asphalt/concrete pavements with a large proportion of the normal fine aggregate material excluded. The second uses modular paving, which presents large 'gaps' between impervious paved areas for infiltration.

These pavements may be located above a deep gravel layer or reservoir, which in turn, is bedded on a sand filter layer. Run-off percolates through the porous pavement into the gravel reservoir and into the sand filter below.

Removal of particulate and some dissolved pollutants is achieved by filtration and adsorption on to soil particles. Moderate soil infiltration rates are required—low rates will result in long infiltration periods, while high rates may cause groundwater pollution.

*Advantages*

- retains pollutants close to source;
- reduces site run-off, attenuates flood peaks and increases groundwater flow rates; and
- can be aesthetically more pleasant than conventional drainage channels.

*Limitations*

- can only support light traffic loads;
- pavement clogging can reduce effectiveness;
- possible risk of groundwater contamination; and
- only suitable for mildly sloped sites.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L | coarse sediment | H | medium sediments | M/H |
| fine sediments | M | attached pollutants | M | dissolved | L |
| installation costs | M | maintenance costs | L/M | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

*Trapping performance*

Porous pavements applications have high reported failure rates (Schueler et al. 1992; Galli 1992). This is due to sediment clogging of the pavement surface. Pre-treatment for sediment removal is not possible for urban pavement run-off, although overland flow could be pre-treated with grass filter strips.

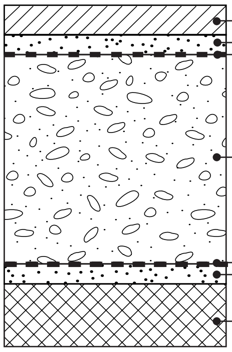


**Figure 7.26 Porous pavements.**

### *Cost considerations*

Capital and maintenance costs of porous pavement systems are both moderate to high.

### *Design considerations*

Porous pavement site selection and design techniques may be based on those used for infiltration trenches (refer Secondary treatment Type 4: Infiltration trenches). This includes development of the geometry of the rock reservoir.

The factors that will maximise the likely success of a porous pavement include:

- low traffic volumes and light vehicle weights;
- low sediment loads;
- at least moderate soil infiltration rates; and
- regular and appropriate maintenance of the pavement's surface.

Additional considerations include the need for the sub-soil to be able to support saturated load conditions. Other sizing techniques are described in Schueler (1987) and Maryland Department of the Environment (1984).

### *Maintenance*

Regular pavement surface maintenance is essential for porous pavements. Inadequate maintenance has been a cause of the high failure rate for these devices.

Collected pollutants need to be regularly removed from the aggregate to ensure optimal infiltration. Methods for removing collected pollutants include high suction vacuum sweepers or high pressure jet hoses. The pavement should also be inspected for holes, cracks or excessively blocked areas.

*See also*: Filter strips, Infiltration trenches.

### *References and further information*

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## Secondary treatment Type 5: Infiltration trenches

### *Description*

An infiltration trench is a shallow, excavated trench filled with gravel or rock, into which run-off drains. Stormwater exfiltrates from the trench into the surrounding soil, while particulates and some dissolved pollutants are retained in the trench.

The trench is lined with a layer of geotextile fabric, to prevent soil migration into the rock or gravel fill. The top surface of the fill is also covered with a layer of fibre fabric, then finished with a shallow layer of topsoil.

Local soil geochemistry and grading determine the infiltration trench's ability to remove particulate and dissolved pollutants. The trenches increase the soil moisture levels, groundwater flow rates and reduce stormwater flow velocities.

### *Advantages*

- reduces peak run-off rates and volumes, and recharges groundwater; and
- retains pollutants prior to discharge into the drainage or groundwater system.

### *Limitations*

- pollutants and sediment may clog the gravel and infiltration surface;
- groundwater contamination and low dissolved pollutant removal may occur in coarse soils; and
- cannot be located on steep slopes, loose or unstable areas.

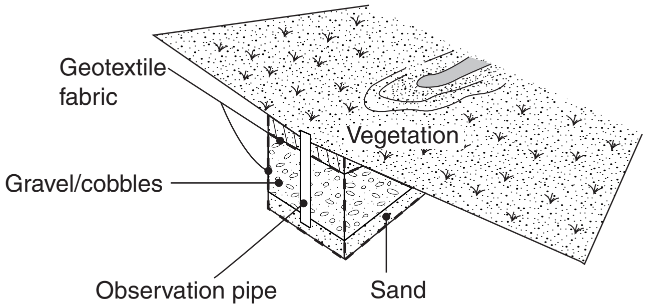


**Figure 7.27 Infiltration trench.**

| **Estimated treatment performance summary** | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L | coarse sediment | M/H | medium sediments | M |
| fine sediments | L/M | attached pollutants | L/M | dissolved | L |
| installation costs | L | maintenance costs | M/H | head requirements | L |
| N = negligible, L= low, M = moderate, H = high, VH = very high | | | | | |

### *Trapping performance*

More data are required to assess the pollutant retention capabilities of infiltration trenches.

### *Cost considerations*

Capital costs associated with infiltration trenches are low, but maintenance costs can be moderate to high, particularly in fine soil areas.

### *Design considerations*

Infiltration trenches are highly susceptible to blockage problems. They are only suitable for use in areas where sediment yields are controlled, such as established urban areas.

A grass buffer or filter is often located upstream of the trench to remove coarse particulate matter. An overflow berm may be located on the downstream side of the trench to encourage ponding of water over the trench to increase infiltration.

Key design issues are the treatment flow rate, surrounding soil infiltration rates, porous media type and size and the potential for clogging. More design information is presented in Appendix D.

### *Maintenance*

To avoid clogging of the porous media, regular maintenance of infiltration trenches is crucial. Clogged media are cleaned by removing and washing the material and replacing the top fibre fabric layer.

Periodic inspections to detect early signs of clogging are also required. Surface ponding, water remaining in the trench for extended periods or sediment accumulation in the top layer are all early warnings of porous media clogging.

*See also*: Filter strips, Grass swales, Sand filters, Infiltration basins.

### *References and further information*

Auckland Regional Council, 1992, *Design Guideline Manual: Stormwater Treatment Devices.*

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## Secondary treatment Type 6: Infiltration basins

### *Description*

Stormwater infiltration basins are open excavated basins designed to retain storm flows, infiltrating run-off through the floor of the basin. They rely on suitable soil conditions for effective operation. Infiltration basins remove sediment and some dissolved soluble pollutants from stormwater run-off. Pollutant removal occurs principally through filtration and the adsorption of soluble pollutants on to soil particles.

They are intended to overflow during large storms. Unlike infiltration trenches, infiltration basins do not include a gravel or rock fill. If properly designed and maintained, infiltration basins reduce downstream run-off volumes and velocities.

### *Advantages*

- removes particulates and some dissolved pollutants; and
- reduces peak run-off rates and volumes, and recharges groundwater.

### *Limitations*

- only suitable in areas with specific soil types;
- sediment may clog the infiltration surface-pre-treatment may be required;
- groundwater contamination and low dissolved pollutant removal may occur in coarse soils;

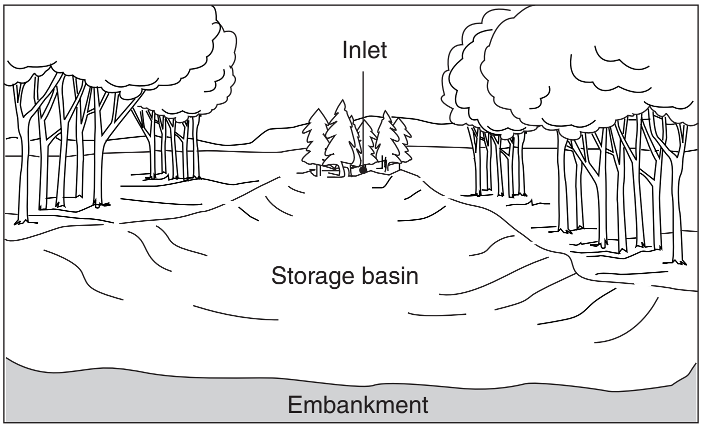


**Figure 7.28 Infiltration basins.**

- cannot be located on steep slopes, loose or unstable areas;
- maintenance activities such as mowing can compact the surface and clog the infiltration system; and
- large land areas may be required.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | N | coarse sediment | M/H | medium sediments | M |
| fine sediments | M | attached pollutants | M | dissolved | L |
| installation costs | L/M | maintenance costs | H | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

### *Trapping performance*

A high failure rate for infiltration basins has been reported in north-eastern United States (Galli 1992). This has been primarily due to surface clogging and inappropriate design. Pre-treatment to remove coarse sediment, such as sediment traps, may be appropriate to minimise the probability of clogging.

Clogged infiltration basins are difficult to restore, but may be converted to other measures such as detention basins or constructed wetlands.

Large flows to infiltration basins may only be accommodated in areas with very high permeability soils. The potential for groundwater pollution should be considered under these circumstances.

### *Cost considerations*

Infiltration basin capital costs range from low to moderate, depending on land acquisition requirements. Maintenance costs can be high. Inadequate maintenance has been a cause of the high failure rate for these basins.

### *Design considerations*

Site selection criteria for the infiltration basin are similar to those used for infiltration trenches (refer Secondary treatment Type 6: Infiltration trenches). Typically, soil hydraulic loading rate and conductivity are key design factors.

### *Maintenance*

Maintenance of infiltration basins is essential for beneficial operation. Maintenance activities include removal of deposited sediment and tilling of the basin bed to improve infiltration. In addition, regular inspections are required to monitor: the duration of ponding in the basin; the basin floor to check for signs of erosion, sediment deposition and grass growth; and the spillway's structural stability.

*See also*: Infiltration trenches, Detention basins.

### *References and further information*

Auckland Regional Council, 1992, *Design Guideline Manual: Stormwater Treatment Devices*.

Camp Dresser and McKee, 1993, *California Storm Water Best Management Practice Handbooks: Municipal*.

Galli, J., 1992, *Current Assessment of Urban Best Management Practices, Analysis of Urban BMP Longevity in Prince George County.*

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## Secondary treatment Type 7: Extended detention basins

### *Description*

Extended detention basins store run-off for periods of one to two days, then drain between storm events. There are many different basin designs; all incorporate a water retention barrier or embankment and a water outlet structure. The water outlet provides a controlled discharge of collected water in the basin.

Pollutant removal is achieved through sedimentation. The pollutant removal efficiency of these basins depends on the stormwater residence time and the amount of run-off

**Figure 7.29 Extended detention basin.**

detained in the basin. The longer the residence time and the more water stored by the basin, the better the performance.

*Advantages*

- appropriate in areas where conditions are not suitable for constructed wetlands;
- offers potential for multiple use, if the basin drains between storm events (e.g. sports field or park); and
- detains flows and attenuates downstream flood peaks.

*Limitations*

- provides only limited removal of fine sediment or dissolved pollutants;
- efficiency falls for events smaller than the design event;
- outlet structures are prone to clogging;
- potential for erosion and resuspension of deposited sediment; and
- large land areas may be required.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L | coarse sediment | M/H | medium sediments | M |
| fine sediments | L/M | attached pollutants | L/M | dissolved | L |
| installation costs | L/M | maintenance costs | M/H | head requirements | L |

N = negligible, L= low, M = moderate, H = high, VH = very high

### Trapping performance

Due to the absence of a permanent pool in the floor of the basin, resuspension of sediment can occur during storm events. Overall, the pollutant retention provided by an extended detention basin is lower and less reliable than that offered by a constructed wetland.

There are currently no techniques available for predicting the pollutant retention of extended detention basins. Optimal reported performance occurs for a retention time of 24 to 40 hours. Stahre and Urbonas (1990) quote the following pollutant retention rates for a 40 hour retention:

| Pollutant | Retention (%) | Pollutant | Retention (%) |
|---|---|---|---|
| Suspended solids | 50 to 70 | Total phosphorus | 10 to 20 |
| Oil and grease | 50 to 70 | Total nitrogen | 10 to 20 |
| Lead | 75 to 90 | Bacteria | 50 to 90 |
| Zinc | 30 to 60 | Chemical oxygen demand | 20 to 40 |

**Table 7.5 Pollutant retention rates for extended detention basins (40 hour retention). Source: Stahre and Urbonas 1990.**

### Cost considerations

Capital costs are low to moderate, although maintenance costs are moderate to high.

### Design considerations

Basin design should aim to maximise the retention time for as broad a range of storm sizes as possible while providing a safe environment for the public to enjoy. The outlet control is an important consideration, as is the hydrology of the catchment, while consideration of side slopes, fencing and controlling pests is also important.

Two common operational problems occur with basin outlets. Firstly, the outlet may be too large, resulting in only partial filling of the basin and reduced residence times. Secondly, the outlet may become blocked by debris, extending the detention time and resulting in boggy conditions on the floor of the basin.

There are three types of outlets commonly used: weirs, perforated risers and reverse slope pipes.

The flow attenuation features of extended detention basins can be used to advantage during relatively infrequent hydrological events. By incorporating a two-stage outlet, the basin may be designed to accommodate design storm run-off for an extended period, and a flood mitigation storm (e.g. 100 year ARI) for a short period. In addition to flood control, detention also results in some removal of coarse sediment. More detailed design information is presented in Appendix E.

For selected extended detention basins there is also a potential to transform the system into a constructed wetland system (described in Section 7.9) without large capital investment. This can provide addition water quality improvement as well as providing for flood detention and improved wildlife habitat.

### *Maintenance*

Maintenance is essential for the satisfactory operation of a detention basin. The outlet structure must be routinely inspected and kept free from debris. This is particularly important after storm events. Regular inspection will also indicate when clearing of the accumulated basin sediment is required.

*See also*: Sediment settling basins.

### *References and further information*

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## Secondary treatment Type 8: Sand filters

### *Description*

Sand filters comprise a bed of sand or other media through which run-off is passed. The filtered run-off is then collected by an underdrain system.

Sand filters are often constructed within a formal tank. Although sand is most commonly used as the filter media, peat, limestone and topsoil have also been used. The filters are provided with an upstream pre-treatment system to remove coarse sediment and ensure even inflow distribution across the filter.

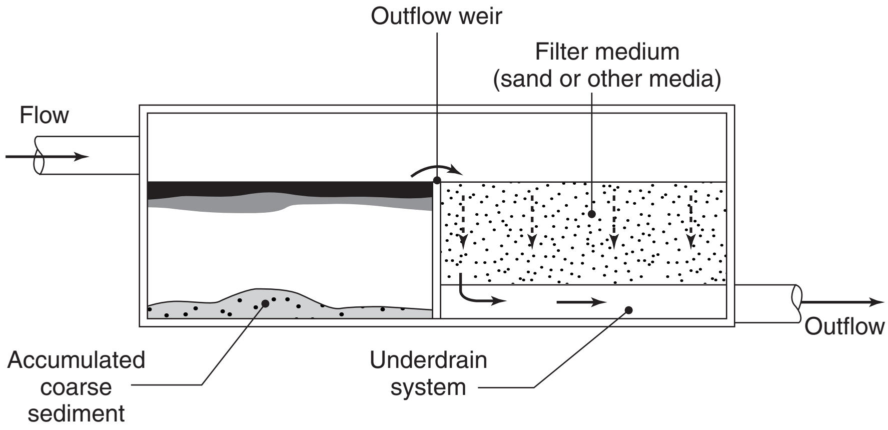


**Figure 7.30 Sand filters.**

Sand filter pre-treatment system is generally intended to trap sand and gravel, while the filter itself removes finer silt and clay particles. These pre-treatments can incorporate top-soil and grass cover and can treat flow from floodways or piped systems.

There are two basic scales of sand filters: large (up to 25–50 hectares) and small (less than 2 hectares). Small sand filters are located in underground pits or chambers and are generally best suited to highly impervious catchments.

### *Advantages*

- can be retrofitted into existing systems (including underground installations);
- retains coarse and fine sediments; and
- appropriate in areas where condition are not suitable for constructed wetland.

### *Limitations*

- requires upstream litter and coarse sediment removal to minimise clogging;
- easily clogged—the filter's effectiveness is highly dependent on maintenance frequency;
- high head loss and relatively low flow rates through the filter;
- large sand filters without grass cover may be unattractive; and
- not suitable for disturbed catchments or catchments with high sediment yields.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L | coarse sediment | M/H | medium sediments | M/H |
| fine sediments | M | attached pollutants | M | dissolved | L |
| installation costs | M/H | maintenance costs | M/H | head requirements | H |

N = negligible, L= low, M = moderate, H = high, VH = very high

### *Trapping performance*

The actual performance of a sand filter will depend on the characteristics of the inflow sediments. This can relate to catchment geology and soil type—for example, a clay soil catchment area may require a larger sized filter. The influence of soil type can be expected to decrease with catchment impervious fraction (Auckland Regional Council 1992).

More performance data are required to assess sand filter performance in Australian conditions.

### *Cost considerations*

Sand filter capital and maintenance costs are both moderate to high.

### *Design considerations*

Sand filter design and sizing techniques are presented in Appendix F.

### *Maintenance*

Sand filter maintenance involves routine removal of the collected sediments. Drying of the sediment may be required prior to disposal. In addition, the filter surface should be raked regularly to remove sediment and to break up any crusts. When necessary, the top 50 to 100 millimetre layer of the filter media should be removed and replaced.

If the filter is not cleaned frequently, the entire filter media may need to be replaced due to migration of sands within the media. Frequent maintenance can prove more cost-effective in the long term.

To determine the required cleaning frequency, regular filter inspections are necessary to check for signs of blockage. These can include ponding, surface clogging and increased depth of sedimentation in the settling tank.

*See also*: Infiltration trenches.

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# 7.9 Tertiary treatment: index



## Key references

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**Figure 7.31 A typical constructed wetland in Melbourne.**

## 7.9.1 Constructed wetland systems

*Description*

A constructed wetland system generally comprises two principal components:

- *the pond*: a relatively deep open water body with edge and possibly submergent macrophytes (aquatic plants).
- *the wetland*: or macrophyte zone; a permanent or ephemeral shallow water body with extensive emergent vegetation. Specific zones of vegetation will occur throughout the wetland; each zone's vegetation is generally determined by the area's water depth and frequency and duration of inundation.

The pond is generally located upstream of the wetland, with the system often incorporating primary pre-treatments at the inlet to provide coarse sediment and gross pollutant removal. The relative ordering and sizing of the pond/wetland components within the constructed wetland system may vary to suit local conditions.

Constructed wetland systems are generally built on catchments larger than ten hectares. Three key pollutant retention processes occur in constructed wetland systems:

- sedimentation;
- fine particle filtration; and
- nutrient uptake by sediments, biofilms (layers of bacteria and micro-organisms on submerged plant and other surfaces) and macrophytes.

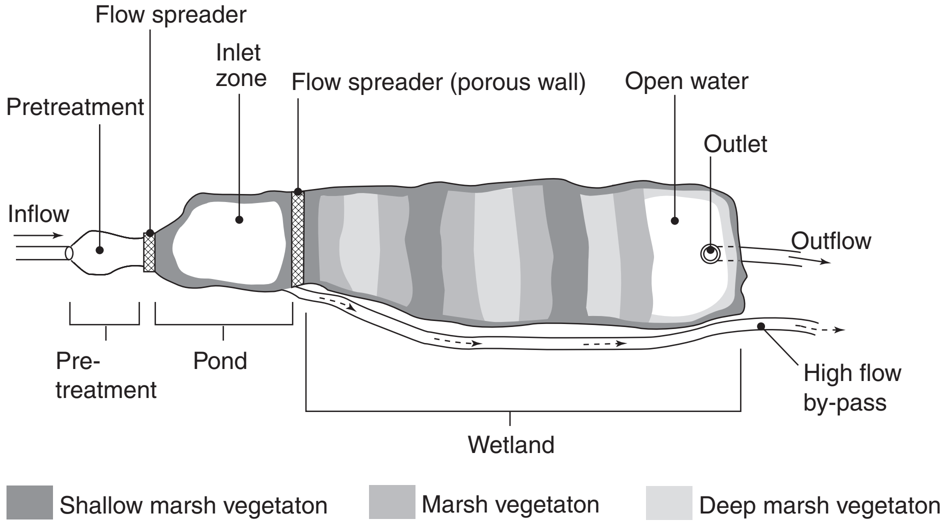


**Figure 7.32 Schematic representation of a constructed wetland system.**

The constructed wetland systems is illustrated schematically in Figure 7.32.

Although the pond and wetland areas contribute uniquely to the system's overall pollutant treatment and removal process, both share two common functions:

- provision of vegetated zones that help prevent oxygen depletion and subsequent release of phosphorous from sediments; and
- provision of open water areas for ultra violet (UV) exposure, which encourages bacteria die-off.

The specific functions unique to the pond and wetland areas are described in Table 7.6

| Pond functions | Wetland functions |
|---|---|
| ▪ Traps 'readily settlable' solids: pond areas generally trap solids down to coarse and medium silt size range. Sedimentation is further enhanced by the edge macrophytes. | ▪ Traps dissolved pollutants: this is primarily achieved by adsorption and biofilm growth on macrophytes. |
| ▪ Traps adsorbed pollutants: silt particles trapped in the pond system may also retain adsorbed pollutants. | ▪ Traps fine suspended solids by enhanced sedimentation within the wetlands densely vegetated, shallow waters. |
| ▪ Provides hydrologic and hydraulic management: pond areas buffer and distribute water movements within the wetland system. | ▪ Transforms organic components: reduces the biological availability of organic material. |
| ▪ Provides sediment aeration: edge macrophytes aerate sediments. | ▪ Encourages biofilm growth: vegetation and other surfaces provide a substrate for biofilm growth which enhances fine sediment retention. |
| | ▪ Provides plant litter zones: wetlands provide an area for macrophyte plant litter to accumulate. |

**Table 7.6 Principal pollutant removal functions of pond and wetland systems.**

The proportion of pond to wetland in a constructed wetland system will vary depending on the nature of the inflows, particularly the suspended sediment sizes.

**Figure 7.33 Inlet zone providing coarse sediment capture, Ruffeys Creek, Doncaster.**

**Figure 7.34 Looking downstream into the shallow marsh zone from the porous rock flow spreader, Ruffeys Creek, Doncaster.**

**Figure 7.35 Wetland in Ruffeys Creek, Doncaster, showing open water and deep marsh zones.**

**Figure 7.36 Lake downstream of Ruffeys Creek wetland system.**

For systems principally treating coarse material, the pond will provide the main treatment area. Under these conditions, the role of the wetland area is primarily to remove the dissolved or finely dispersed pollutants released from the pond sediments.

Conversely, constructed wetland systems treating largely dissolved or finely dispersed pollutants will achieve most pollutant retention within the wetland area. In these situations, the pond acts as a pre-treatment system, removing coarse sediment that may damage the wetland vegetation.

Wetland vegetation is critical to the performance of a constructed wetland system. The functions performed by wetland vegetation vary according to flow conditions. Table 7.7 compares the functions of vegetation under baseflow and storm event flow conditions.

| **Vegetation Functions** | |
|---|---|
| **Baseflow conditions** | **Storm event flow** |
| ▪ Nutrient conversion: wetland vegetation acts as substrata for epiphytes.† Epiphytes convert soluble nutrients into particulate organic material, which can settle out and enter the sediments. This is a short term process occurring over days to weeks.<br><br>▪ Nutrient consolidation: nutrients trapped in the sediments are progressively taken up into the macrophyte biomass. This is a medium term process occurring over months to years.<br><br>▪ Organic sediment and peat development: macrophyte debris provides a source of particulate biomass, which is returned to the wetland sediment. This is a long term process occurring over years to decades, resulting in the development of organic sediment and peats. | ▪ Promotes even distribution of flows: vegetation spreads the flow across a wide surface area.<br><br>▪ Promotes sedimentation of larger particles: by decreasing flow velocities through even flow distribution.<br><br>▪ Improves retention of smaller particles: plant surfaces provide a greater area for adhesion of smaller particles.<br><br>▪ Protects sediments and banks from erosion: plants and their root systems hold sediments together and prevent scour.<br><br>▪ Increases the system hydraulic roughness: helps attenuate destructive storm flows. |
| † Epiphyte: A plant that grows on another plant, not in a parasitic way, but using it merely as a supporting base.<br>Source: Somes, Breen and Wong 1995. | |

**Table 7.7 Treatment functions of vegetation in a constructed wetland system.**

*Advantages*

- can potentially achieve high sediment and nutrient retention efficiencies;
- can be incorporated into the urban landscape, providing improved habitat, recreational and visual amenity;
- can include a flood storage to attenuate downstream flows;
- can potentially be retrofitted into existing flood retarding basins; and
- can be designed as either a permanently wet or ephemeral system.

*Limitations*

- either pre-treatment or removal mechanisms are required at the inlet to remove coarse sediment and litter;
- large land areas are required for construction;
- where either treatment or other multiple use objecties require permanently wet areas or open water, reliable inflow is needed;
- treatment performance is highly sensitive to hydrologic and hydraulic design;

- can take up to three years to achieve optimal performance;
- potential impact on public health and safety; and
- may contribute to groundwater pollution, or groundwater may impact on the wetland.

**Estimated treatment performance summary**

| | | | | | |
|---|---|---|---|---|---|
| gross pollutants | L/M | coarse sediment | M/H | medium sediments | M/H |
| fine sediments | L/M | attached pollutants | M/H | dissolved | L/M |
| installation costs | H | maintenance costs | M | head requirements | L/M |

N = negligible, L= low, M = moderate, H = high, VH = very high

*Cost considerations*

Constructed wetlands require relatively large areas of land, so construction costs are high in built-up areas. The cost of vegetation establishment is also high, although maintenance cost are moderate.

*Maintenance*

An operation and maintenance plan should be prepared for all constructed wetlands. This plan should address the wetland's entire 'life cycle' and can include:

- **construction and commissioning**: proper environmental management during the wetland construction and commissioning period;
- **sediment and litter removal**: removal of sediment and litter from the inlet zone or primary pre-treatment will be required on a regular basis. Litter should not be allowed to accumulate excessively after a storm, otherwise breakdown products may pollute the water;
- **weed maintenance**: this is particularly critical during construction and commissioning; and
- **de-commissioning**: a major refit or decommissioning will be required when the wetland reaches its design life.

The frequency of maintenance may be reduced by incorporating pre-treatment upstream of the wetlands system to remove coarse sediment and litter. If a pre-treatment measure is not included in the wetland system design, wetland sediment removal is expected to be required every three to six months, which results in unacceptable disturbance. This falls to a frequency of between ten to thirty years in systems that incorporate sediment removal as a pre-treatment, which all new wetland systems should do.

The ability to draw down the wetland inlet zone during sediment removal should also be considered during the design phase.

To minimise maintenance costs, the wetland can also be designed for mechanised sediment removal—possibly by incorporating submerged berms.

Macrophyte harvesting is not considered necessary to maintain the long term nutrient retention capacity of the constructed wetland system. However, occasional harvesting may be desirable to maintain a vigorous vegetation cover.

Inspections should be carried out as part of an overall system maintenance program. Along with providing a general monitor of the health and diversity of the vegetation, inspections provide the opportunity to detect specific site problems. These can include the accumulation of sediment, plant debris, litter or oils; infestation of weeds; mosquito and other pest problems; algal blooms; and scouring. Inspections will also help assess the wetland systems' performance in achieving its stated objectives.

Many weed species are transported during flood events. As a result, inspection should occur after each major event. This also provides the opportunity to locate any physical damage caused by high flows.

### 7.9.2 Design of wetland systems

Constructed wetland systems satisfy many urban design objectives in addition to improving stormwater quality. For example, they provide passive recreational and landscape values, wildlife habitat and flood control. Early identification of multiple use priorities is critical for the design of effective wetlands systems. The design process is often a balance between effective stormwater pollution abatement and landscape, botanical and habitat functions.

These guidelines focus on the pollution abatement functions of constructed wetland systems. This is an evolving field and there is little other guidance available. However, it is recognised that constructed wetland systems require multi-disciplined design teams to address the range of objectives for each proposed wetland system. More general discussion of the multi-purposes of wetland systems can be found in NSW Department of Land and Water Conservation (1998).

The treatment capability of a wetland system depends on how much run-off is treated (i.e. the size of the wetland) and the level of pollutant removal afforded to the treated run-off (a function of the vegetation and basin layout). The volume of run-off a wetland system treats is termed its 'hydrologic effectiveness' and is a function of the detention time, the volume of the wetland system and the characteristics of the rainfall and run-off. The hydrologic effectiveness is maximised (i.e. the most water is treated) when either the storage volume is increased or the detention time reduced.

Design objectives for an efficient wetland system for stormwater pollutant removal include:

- **establishment of uniform flow**: ensure uniform flow distribution through the wetland. In particular, minimise flow 'short-circuiting' and stagnant areas in the wetland;

- **maximisation of macrophyte contact time**: to enhance sedimentation, maximise the contact time with macrophytes by encouraging healthy vegetation and low flow velocities;
- **establishment of adequate wetland pre-treatment**: ensure coarse sediment and litter is removed upstream of the wetland;
- **minimisation of organic loading**: minimise loading of organic matter to ponds and open water areas; and
- **factoring in of maintenance**: provide for operations and maintenance needs, particularly sediment removal and weed management.

To meet these objectives, twelve primary areas of design must be addressed. These areas are reviewed in the following sections:

1 Location

2 Sizing

3 Pre-treatments

4 Morphology

5 Outlet structures

6 Macrophyte planting

7 Maintenance

8 Loading of organic matter

9 Safety issues

10 Multiple uses

11 Groundwater considerations

12 Mosquito control

After a site has been selected, more detailed design issues may be considered. These will address more site specific issues and include the consideration of:

- catchment area and the distribution of soils within the catchment;
- site soil characteristics;
- catchment infiltration capacity;
- pollutant sources and pollutant loads;
- the nature of pollutants entering the catchment;

- catchment hydrology; including peak flows, volumes, flow variability and seasonality; and
- water quality and other wetland objectives.

### Wetland system design consideration No. 1: Location

There are many considerations when deciding where to position a wetland system that reflect the multi-objectives of the system. Factors include the surrounding land-uses, available space, aesthetic values, wildlife considerations and the best location for improving stormwater quality. Issues described here relate directly to the stormwater treatment objectives of the system. These issues would then need to be weighed up against other objectives for the wetland system.

In locating a wetland system it is essential that the wetland be protected from large flood flows. These can scour sediments and destroy vegetation. Provision of a high flow bypass channel is a means of reducing this risk, while still treating all flows up to a threshold.

Three potential ways of providing a high flow bypass are shown in Figure 7.37. The selection of a particular system may be based on an economic comparison, which will be partially dependent on flow rates and topography.

The first way (option (a)) provides a high flow by-pass around a wetland system located on the natural drainage path.

The second way (option (b)) locates the pond only on the natural drainage path. Downstream of the pond, all but flood flows are directed into a wetland via a low flow by-pass. Flood flows are directed away from the wetland, along the natural drainage path.

The final example (option (c)) diverts all except the flood flows into a wetland system, located on a low flow by-pass away from the natural channel. Once again, flood flows are directed away from the wetland system, along the natural drainage path.

If topographic constraints preclude the provision of a high-flow by-pass, the wetland system can be designed to attenuate inflows. To minimise permanent damage to the macrophytes the velocities throughout the wetland should never exceed *two metres per second* during infrequent storm events (e.g. the 100 year ARI event).

It is generally accepted that the biofilms attached to the macrophytes will be lost under these conditions. The macrophytes will, however, provide a degree of armouring to the sediments, helping to minimise sediment scouring.

Low flow through the wetland can also pose problems. Where annual rainfall is low, there may not be sufficient flows to maintain a permanent water body. In these areas ephemeral wetlands may be more appropriate or supplementary flow may be required during dry periods.

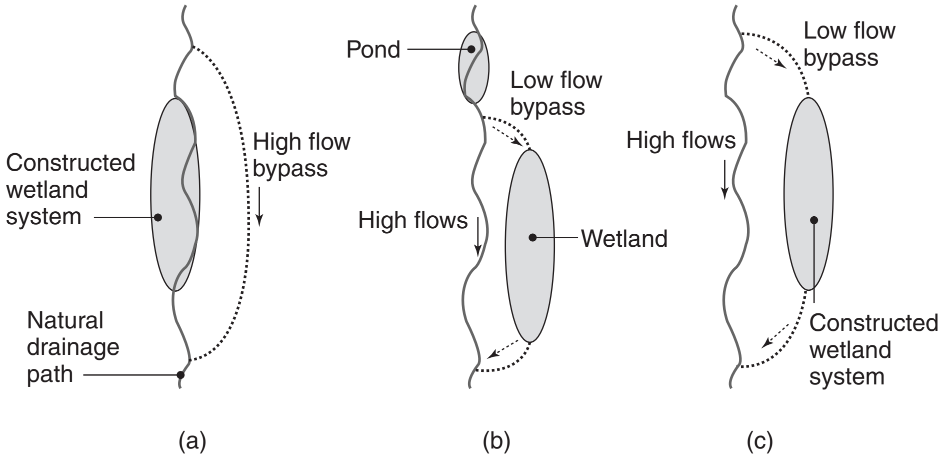


**Figure 7.37 Options for high flow by-passes for wetland systems.**

One potential option for locating wetlands is in existing retarding basins. This can be effected without large capital investment. Such systems can then provide for improved stormwater quality in addition to their flood retention function. However, there are a number of issues that need to be considered for detention basin retrofits. These include: the available space on the floor of the basin, incoming pipe levels and flow rates, existing uses within the basin (including any areas of environmental significance), and impact on flood storage volumes as well as public safety considerations.

### Wetland system design consideration No. 2: Sizing

The sizing of constructed wetland systems is affected by a number of factors including:

- the nature of the inflows, particularly their sediment grading, geochemistry, and hydrology;
- the ionic composition of the wetland waters; and
- the geometry and macrophyte planting scheme of the wetland system.

The key elements to be sized in a constructed wetland system are the temporary and permanent storage volumes of the pond and wetland areas, as indicated in Figure 7.38.

If the constructed wetland system is constructed as a single water body, the distribution of these volumes between pond and wetland areas will need to be considered.

The principal purposes and sizing criteria for pond and wetland area storage volumes differ and are described below.

#### *Pond storage volumes*

- **temporary flood storage**: can be used for attenuating peak flows up to the 100 year ARI event. This volume can be sized using a rainfall run-off model to meet flood mitigation criteria;

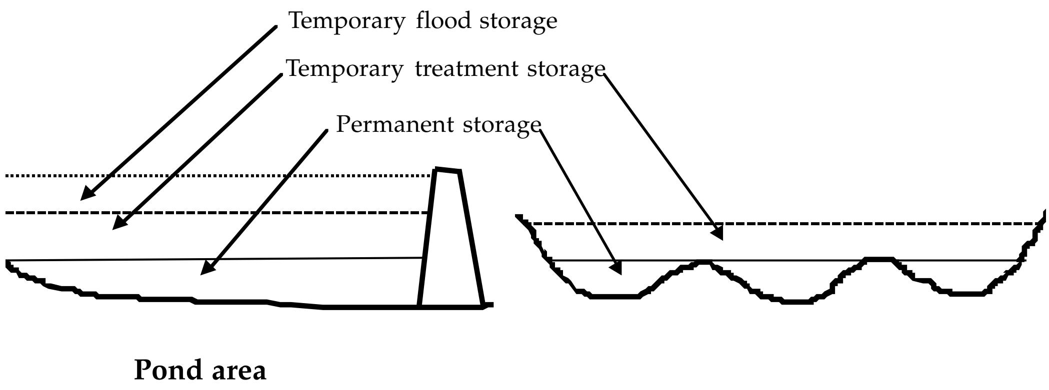


**Figure 7.38 Definition sketch for wetland system volumes.**

- **temporary treatment storage (or extended detention storage)**: can be used to enhance the hydraulic residence time of the permanent storage to improve coarse particulate sedimentation. It can also be used to attenuate flows to protect the downstream wetland; and

- **permanent storage**: intended principally for sedimentation. Ideally, the size of this volume will depend on the size and mineralogy characteristics of the inflow particles—particularly their adsorption capacity.

*Wetlands storage volumes*

- **temporary storage**: the principal function of this volume is to provide a variable wetting–drying cycle. This encourages a diverse, dense macrophyte growth, which increases the total area available for enhanced sedimentation by the macrophytes; and

- **permanent pool**: an essentially permanent volume, designed to encourage biofilm growth on the macrophytes and the continuation of the sedimentation processes.

To determine the size of temporary and permanent storage volumes of the pond and wetland, detailed design information is required for elements such as the hydrology of the catchment, the target pollutant and the geometry of the wetland system. Discussion of these issues can be found in Wong et al. (1998) and design guides in Wong et al. (1999).

A preliminary sizing technique has been developed that estimates the required wetland system area for particular pollutant removal rates (Mudgway et al. 1997; Duncan 1997a, Duncan 1997) (see Appendix G).

This technique uses graphical plots of pollutant retention versus surface area of the wetland system for a range of annual run-off values. By knowing the required pollutant retention and the catchment's annual run-off, the surface area of the wetland system can be estimated.

Relationships are presented in Figure 7.39 for three pollutants; suspended solids (SS), total phosphorus (TP) and total nitrogen (TN). Each plot includes three curves describing

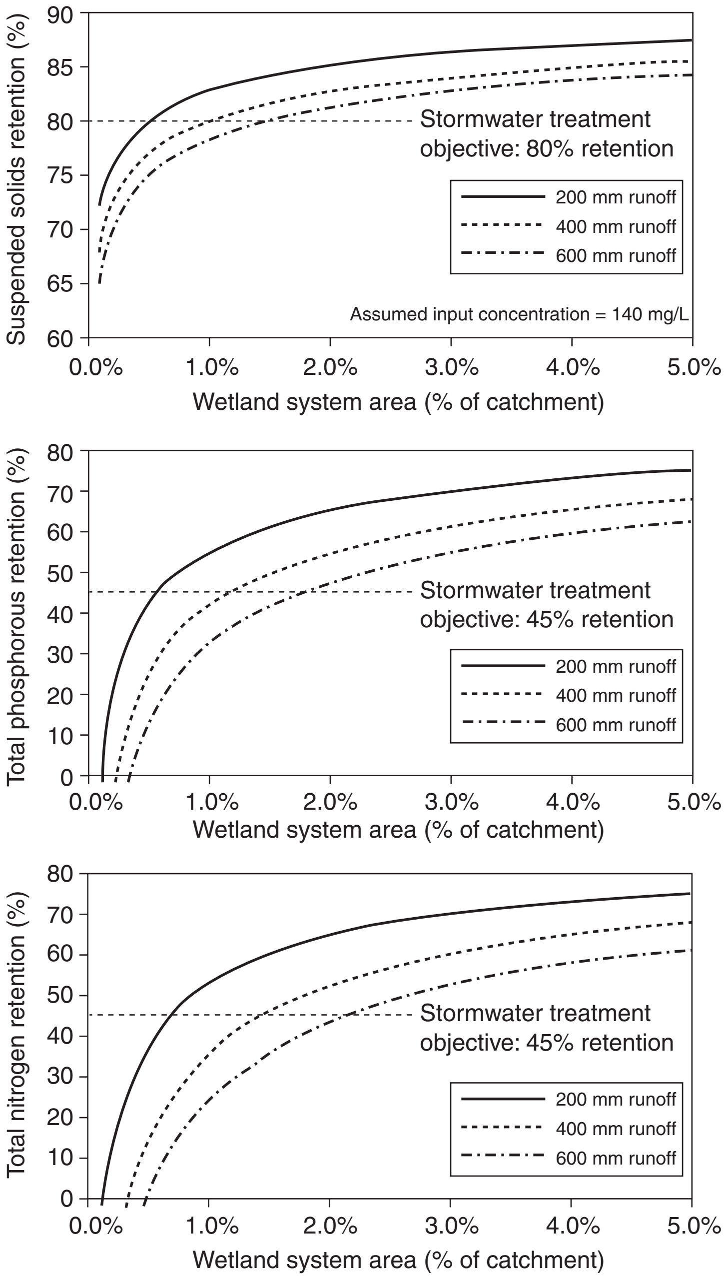


**Figure 7.39 Pollutant retention versus wetland system area for a range of run-off depths.**

pollutant retention for three grades of average annual run-off; low (200 millimetre), medium (400 millimetre) and high (600 millimetre). This range should cover the most likely run-off values experienced in the urban areas of Victoria.

Table 2.1 in Chapter 2 lists the pollutant retention rates needed to meet SEPP requirements for a range of pollutants. By examining the intersection between these retention performance goals and the retention curves, the approximate size of the wetland system can be determined.

Once the total surface area of the constructed wetland system has been estimated, the area needs to be distributed between pond and wetland. A distribution ratio of approximately 30 per cent pond to 70 per cent wetland is appropriate for average inflow conditions. An increased wetland area may be appropriate when inflows have a large dissolved or colloidal fraction. If the inflow contains mainly coarse particulate material, an increased pond area will be more appropriate.

In areas with low rainfall and run-off it will be necessary to increase the ephemeral areas of the wetland in order to maintain successful vegetation cover.

Size is obviously not the only factor which must be taken into account when considering the design of constructed wetlands. The retention performance shown in Figure 7.39 is based upon wetlands which satisfy a number of important performance related design criteria. These include: incorporating multiple cells, having length to width ratios greater than 3:1, providing vegetated areas, incorporating permanent pools, and providing for flood storage.

It is crucial to ensure the system will not be prone to hydraulic short circuiting and that the basin morphology and water regime are compatible with the growth requirements of aquatic plants.

Some caution should be taken in predicting the performance and size of constructed wetlands. The pollutant retention performance of a constructed wetland will vary with the inflow concentration of pollutants. For higher inflow concentrations, the percentage pollutant retention will be higher for a given volume than that for lower inflow concentrations. In addition, the performance of a specific wetland configuration may vary considerably depending on a range of internal and external factors. These may not be readily quantifiable during the design phase.

#### Wetland system design consideration No. 3: Pre-treatments

Coarse sediment passing beyond the pond area to the wetland may change the wetland's depth profile and damage its macrophyte zones. Removal of coarse sediment upstream of the wetland area can be achieved by either:

- installing a sediment and litter trap upstream of the wetland system; or
- using the pond as a coarse sediment trap.

A purpose built sediment and litter trap has a number of advantages over the second option. From an operational perspective, it is likely to result in lower relative maintenance costs and improved removal efficiency.

The option of using a pond as a sediment trap, on the other hand, presents a number of maintenance difficulties. Aside from the reduced retention efficiencies and higher costs, maintenance of the pond may impact on aquatic fauna and flora. There may also be community concerns regarding the disturbance of a 'natural' resource.

### Wetland system design consideration No. 4: Morphology

The morphology to be adopted for a particular site will often depend on the site-specific topographic conditions. Short-circuiting is one of the primary reasons for poor performance of constructed wetland systems. The 'hydraulic efficiency' is a term used to describe the extent to which plug flow conditions (i.e. those where the flows move evenly through the wetland) are found. A high hydraulic efficiency means there are few stagnant areas and short circuiting is minimised.

| **Pond area morphology** |
|---|
| Key objective: to maximise the effective hydraulic residence time |
| Appropriate morphologies<br>▪ Pond topography: appropriate pond topography can maximise the effective hydraulic residence time:<br>– establish a uniform pond cross-section;<br>– appropriately locate the pond's inlet and outlet;<br>– the pond length:width ratio should be within the range of 3:1 to 10:1; and<br>– incorporate baffles, islands, rock walls and macrophytes to reduce velocities and distribute flow.<br>▪ Energy dissipation: dissipate hydraulic energy at the pond entrance to reduce inflow velocities and distribute flows across the entire pond area.<br>▪ Short circuiting: minimise flow short circuiting, so that a uniform flow distribution can be achieved.<br>▪ Wind mixing: consider the effects of wind and wind water mixing. Wind mixing can lead to erosion, which may propagate short circuiting.<br>▪ Pond depth: pond depth should be kept between 1.5 and 2 metres. At this depth maintenance demands and macrophyte growth are minimised, while still avoiding stratification.<br>▪ Maximum side slope: in unfenced areas, side slopes should be graded no steeper than 8:1 for safety reasons. The grade should remain consistent above and below the water surface. If the banks are evenly graded, mosquito problems will be minimised. |

**Table 7.8 Pond area morphology.**

A strong emphasis needs to be placed on hydraulic issues during the design phase. This includes the shaping of both the pond and wetland to prevent stagnant zones and maximise the hydraulic efficiency. Appropriate morphologies for ponds and wetlands in a constructed wetland system are summarised in Tables 7.8 and 7.9.

### Wetland system design consideration No. 5: Outlet structures

The hydraulic characteristics of an outlet structure determine a wetland system's range of water depths and duration of inundation, termed the 'hydraulic regime' of a wetland system. Water level variations, including wetting and drying, are needed to regulate and maintain the wetland vegetation. They also significantly influence the organic content and nutrient cycling in sediments.

It is also important to be able to vary water depths during vegetation planting and establishment, and also for maintenance operations, such as weeding. A wide variation of water levels can facilitate dense vegetation growth that prevents weed infestation and provides many surfaces for sediment adhesion which enhances pollutant removal.

In summary, the outlet structure is an important consideration for:

- providing a diverse hydrologic regime;
- facilitating vegetation planting;

### Wetland area morphology

Key objective: to achieve uniform flow distribution and macrophyte diversity

Appropriate morphologies

- Flow velocity: to minimise re-suspension of sediments and loss of biofilm, flow velocities should be retained to below 0.2 metres per second during design storms.
- Depth zones: a range of depth zones can be provided perpendicular to the flow path, generally less than 60 centimetres deep. This will encourage macrophyte diversity and a healthy, dense vegetation growth.
  Macrophyte zones should also be established perpendicular to the flow path. The species within each zone will vary according to the zone's depth, drying cycle and turbidity.
- Macrophyte beds: planting of different macrophyte species across a flow path should be avoided. This will minimise the development of preferential flow paths, caused by flow resistance variations between macrophyte species.
- UV disinfection areas: the open areas between macrophyte zones should be generally deeper than 1.2 to 1.5 metres to minimise macrophyte growth.
- Wetting and drying cycles: a range of wetting and drying cycles across the wetland area will help establish macrophyte diversity.
- Stagnation problems: poorly mixed zones should be minimised to avoid oxygen depletion and related problems. An array of open and closed water areas can be provided to encourage mixing flows.
- Macrophyte substrate: to assist the establishment of macrophytes, topsoil should be provided as a substrate.
- Side slopes: in unfenced areas, side slopes should be graded no steeper than 8:1 for safety reasons. The grade should remain consistent above and below the water surface. If the banks are evenly graded and predator species have sustainable habitat and access to all areas, mosquito problems will be minimised.

**Table 7.9 Wetland area morphology.**

- optimising vegetation growth during construction;
- maintaining diverse vegetation zones;
- providing weed and mosquito control; and
- facilitating wetland operation to optimise water quality improvement.

Four types of outlet are: risers, weirs, culverts and siphon outlets. Each outlet type influences the hydrologic regime depending on the catchment hydrology and basin morphology.

Figure 7.40 demonstrates the importance of an outlet structure for the hydraulic regime (water level variations) of a wetland system and hence the range of vegetation types that can be established. It shows results of a simulation of the hydraulic regime for a range of outlet structures for a wetland in Melbourne (Wong et al., 1998).

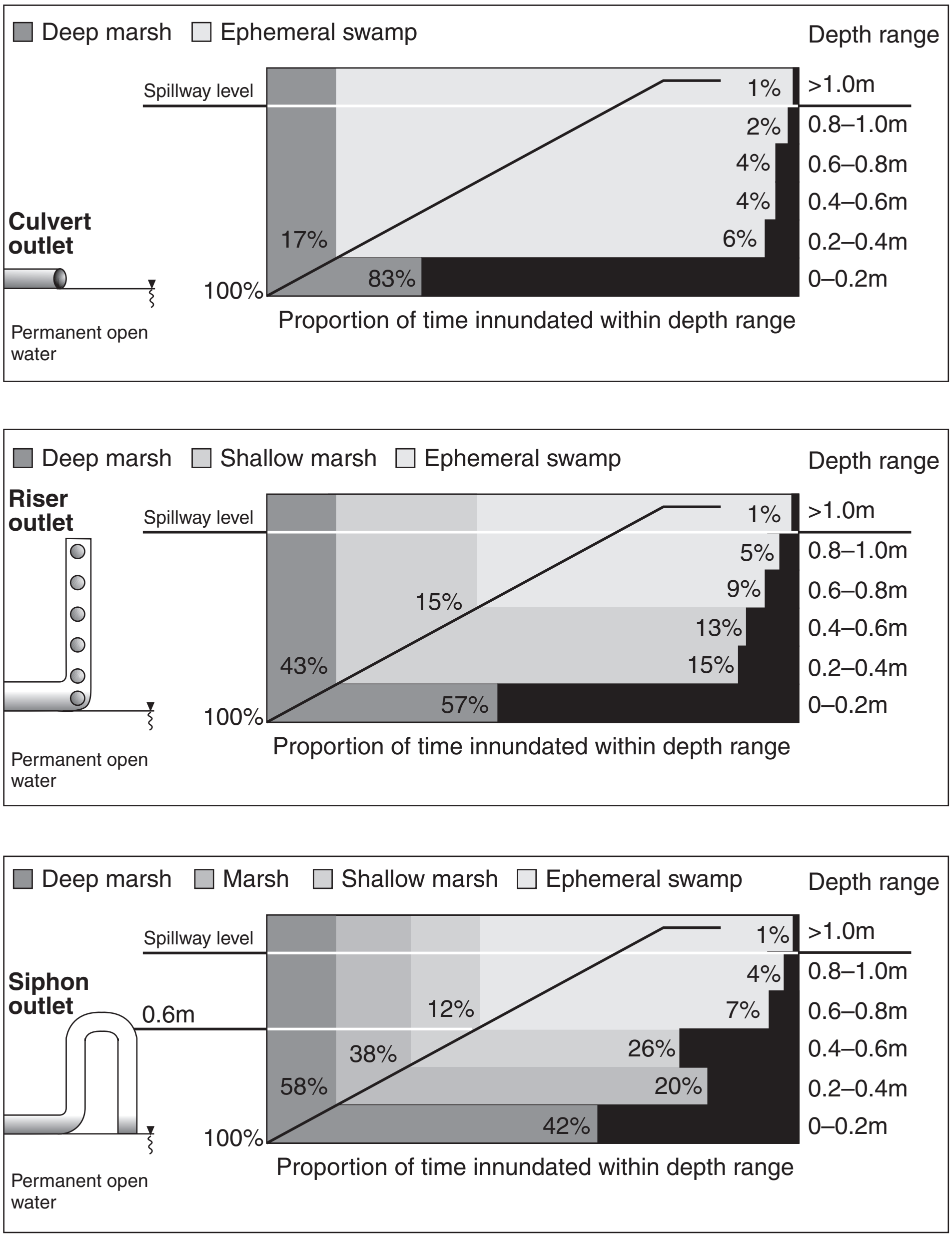


**Figure 7.40 Hydrologic regimes for different outlet types (Wong et al. 1998).**

Contrary to common practice, weirs and culverts are not considered suitable outlets for wetlands because they do not achieve an appropriate range of water level fluctuations in the wetland. This leads to a low diversity in wetland vegetation with ephemeral species occurring above the water surface and deep marsh species below the water surface.

Figure 7.40 shows that for the culvert outlet structure (similar to a weir), water depth is between 0 m and 0.2 m for a significant portion of the time. This results in a lack of diverse vegetation zones, with a distinct boundary between 'wet' and 'ephemeral' vegetation zones leaving no suitable conditions for shallow marsh species.

Figure 7.40 also shows the hydraulic regime for the same wetland fitted with both a riser and a siphon outlet structure. Both of these outlet types demonstrate an increase in the

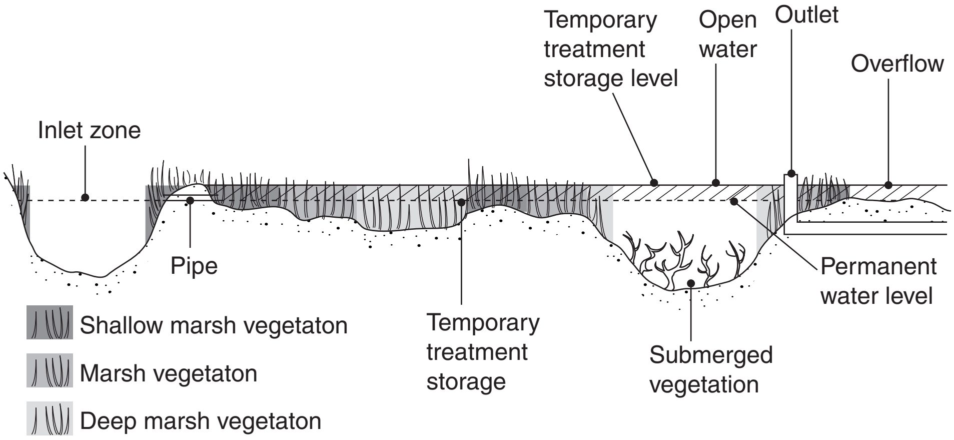


**Figure 7.41 An example layout of macrophyte planting zones.**

inundation frequency of deeper areas, and would assist the establishment of shallow marsh vegetation in addition to ephemeral and deep marsh plants. These outlet structures would therefore promote more diverse vegetation and improved pollutant removal compared to weir or culvert outlets.

Further information on outlet types for wetland systems is presented in Wong et al. (1998) and Somes et al. (1995) and in NSW Department of Housing (1998).

### Wetland system design consideration 6: Macrophyte planting

Macrophyte establishment is required in both the pond and wetland areas of the wetland system as shown in Figure 7.41.

Macrophyte planting in the pond area is generally limited to the edge of the system and at its inlet. Macrophytes at the pond inlet enhance sedimentation provided flow velocities are sufficiently low. Pond edge macrophytes assist with the aeration of sediments. Macrophytes within the pond system can also be used to encourage uniform flow distributions.

Macrophyte planting within a wetland area on the other hand, is far more extensive. Macrophytes are typically planted in zones or beds perpendicular to the direction of flow. Macrophyte coverage typically extends across around 75 per cent of the wetland area and is graded into three 'bands', each incorporating different macrophyte species according to the band's depth (refer to Appendix H).

The principal purpose of establishing these 'depth bands' is to achieve uniform flow across the system and to encourage macrophyte diversity.

The bands can be described to as:

- **shallow marsh**: 0 to 20 centimetres deep;
- **marsh**: 20 to 40 centimetres deep; and

- **deep marsh**: 40 to 60 centimetres deep.

The remaining 25 per cent of the wetland area is left macrophyte free. The purpose of these open water zones is to allow ultraviolet (UV) disinfection and oxygenation.

Successful planting of wetland habitats is critical to wetland performance and depends on six main factors:

1 planting design

2 site preparation

3 supply of planting stock

4 planting

5 water level control

6 establishment period maintenance.

### *1 Planting design*

The pollutant retention mechanisms occurring within the wetland area—enhanced sedimentation, filtration, adsorption and biofilm growth—all depend on the establishment of a dense growth of healthy vegetation. Planting density is also a major factor in determining wetland planting success. The greater the planting density, the less competition from weeds and the faster the system becomes fully operational.

The species growth density should be considered both above and below the normal water level. If the wetland basin is designed to allow for a water level increase during event flows, the above-normal water level plant growth can also play a filtration role.

Depending on the particular species, optimum planting densities can vary between nine and twenty-five plants per square metre (50 to 25 centimetre plant centres). Larger spreading species normally occurring in deeper water can typically be planted at lower densities than smaller species more common in shallow areas.

Selecting the most appropriate plant species requires striking a balance between each species' suitability for a particular depth range or hydrological conditions, against its ability to enhance a particular treatment process. Observation of the natural distribution of species can usually help identify the most appropriate species for each zone's depth, frequency and duration of inundation.

### *2 Site preparation*

The provision of a well prepared substratum that encourages macrophyte growth while controlling weed and non-target plant propagation, is essential.

The successful propagation of wetland plants requires an adequate covering of top soil—usually about 20 centimetres.

| Plant source | Advantages | Disadvantages |
|---|---|---|
| Seed | ▪ Inexpensive, due to low labour intensity.<br>▪ Suitable for large areas. | ▪ Potential for low germination rates.<br>▪ Long lead-times for plant establishment. |
| Rhizomes (bulbs) | ▪ Higher survival rate than seed. | ▪ Labour intensive, therefore costly. |
| Transplanting | ▪ Instant plant community.<br>▪ Very short lead time. | ▪ Labour intensive, therefore costly<br>▪ Weeds may be imported to target site.<br>▪ Difficult to achieve uniform cover. |
| Nursery propagated material | ▪ Precise control over what species is planted.<br>▪ Vegetation establishes quickly. | ▪ Labour intensive, therefore costly.<br>▪ Requires long lead time (6–12 months) for propagation. |
| Soil cores | ▪ Diverse and complex community developed in a short period. | ▪ Excavation, transport and replanting of cores is laborious and expensive. |

**Table 7.10 Sources of wetland plants: advantages and disadvantages of each source (after Hammer 1992).**

Weed infestation, particularly if construction is in established channels, can be one of the biggest challenges in establishing wetland vegetation. Weed control can be achieved by physical removal using either machinery, manual labour or herbicides. Glyphosate is a recommended herbicide as it quickly adsorbs to soil particles and breaks down. To maximise the effectiveness of spraying, the site should be as dry as possible, because wet conditions will allow many wetland weeds to survive.

### *3 Supply of planting stock*

Wetland plants may be sourced from a range of locations: seed stock, rhizomes (bulbs), transplanting, nursery propagated material, and soil cores taken from existing wetland sites.

The source of plants chosen will affect the total cost of the project, the time taken for plants to establish, the variety of plants available and the extent of weed control required. Alternative sources of plants are described in Table 7.10.

**Seeds**: this is the least expensive method of establishing wetland vegetation. Wetland plants have low seed germination rates, so seed planting can result in long lead times for the establishment of mature plants. The use of seed is only recommended for large sites, where planting and planting stock costs will be high.

**Rhizomes**: these have the advantage of offering a larger unit of biomass per plant, so they are established more quickly than seeds. Rhizome harvesting sites, however, may be limited and the harvesting itself will damage the source site. Harvesting and planting is labour intensive, so this approach is costly.

**Transplanting**: the transplanting of plant material from existing vegetation stands will establish vegetation very quickly at a new site. Once again, the transplant exercise is labour intensive, so it attracts higher costs. Transplanting also brings with it the hazard of weed importation from the source site.

**Nursery propagated material**: using nursery propagated plants is the most common and preferred method for establishing vegetation in wetlands. Although long lead times are required for propagation, propagated material offers a low risk of disease, a high level of control over the species planted and rapid establishment at the required density. A lead time of six to twelve months is often required when ordering wetland tube stock.

**Soil cores**: these consist of 100 millimetre diameter cores containing seeds, roots and rhizomes, which are taken from an existing wetland and transplanted to the new site. This can be an expensive alternative, often with limited suitable source sites available for core excavation.

### *4 Planting*

The planting technique chosen is normally determined by the type of planting stock, the local terrain and site conditions. Appropriate planting is vital to the functionality of the wetland system and is usually undertaken by a specialist contractor.

The key to successful planting is to minimise damage to the stock during planting. As a result, sensitive planting procedures typically rely considerably on manual labour.

### *5 Water level control*

The establishment conditions for many wetland plant species are often very different to their typical growing conditions.

Prior to planting, it is usually necessary firstly to flood the system, then reduce the water levels. A water depth of less than 20 centimetres is typically required during the establishment of even the largest of emergent macrophytes. Good control over water level fluctuations is crucial during this phase.

### *6 Establishment period maintenance*

During the establishment phase, plant growth and condition should be monitored closely. It is during this period that plantings are most vulnerable to impacts and damage. Factors that need particularly close attention include:

- water level;
- weed invasion; and
- animal damage.

More information on planting wetlands can be found in Somes et al. (1995).

### Wetland design consideration No. 7: Maintenance

The morphology and typically large size of wetlands can make maintenance access difficult. It is important, therefore, that operations and maintenance considerations be addressed during the design of the wetland.

For further details refer to the 'Maintenance' section outlined in 7.9.1.

### Wetland design consideration No. 8: Loading of organic matter

Organic material can smother wetland sediments, creating anaerobic conditions, which can lead to the release of phosphorous. Minimising organic matter loading to a constructed wetland is important for the minimisation these impacts (refer Lawrence and Baldwin 1996).

Reducing organic matter inputs to the wetland is best achieved by source control or pretreatments. If the control of organic matter loads cannot be achieved using these techniques, it may be necessary to increase the surface area of the wetland—in effect, to 'dilute' to the organic loading. An alternative technique is to incorporate regular wetting and drying cycles in the wetland system maintenance. Drying the organic sediments increases the rate of organic degradation and progressively renders the phosphorus less available.

### Wetland design consideration No. 9: Safety issues

There are a range of safety issues that require consideration when designing constructed wetlands. Most specifically, these relate to the potentially hazardous areas around the pond area inlet and outlet—areas of high water velocities and steep sloped banks. Potential solutions include the use of safety rails or barriers, signage and water velocity control techniques. Inlets and outlets can also be designed to avoid trapping fauna.

Occupational health and safety considerations for maintenance staff should be considered carefully during the design stage.

### Wetland design consideration No. 10: Multiple uses

Constructed wetland systems can often be designed for multiple uses. Wetland systems that incorporate multiple uses can increase the value of adjacent land and hence the benefit–cost ratio of the stormwater system.

Multiple objectives should be evaluated during the design development phase. Involving communities and stakeholders in the design process can often help achieve these multiple use objectives.

Care should be taken, however, to avoid compromising the primary objective of a stormwater treatment system—to achieve enhanced stormwater quality—in the quest to meet the demands of other beneficial uses.

### Wetland design consideration No. 11: Groundwater considerations

Groundwater inflows and outflows can have a significant effect on a constructed wetland system. Groundwater chemistry can affect water quality and processes such as sedimentation and vegetation growth. Wetlands may need either to be isolated from the groundwater influence or designed to accommodate its influence.

### Wetland design consideration No. 12: Mosquito control

Mosquitoes proliferate in stagnant shallow water, usually less than 40 centimetres deep. Techniques for minimising mosquito problems include:

- **bank grading**: evenly graded side slopes will minimise the potential for localised ponding;
- **water depth control**: management of water depth, particularly during summer;
- **minimisation of stagnation zones**: avoiding the development of zones with poor water movement;
- **reduction of litter**: minimising litter input to the wetland, as mosquitoes can breed in litter; and
- **predation**: designing the wetland system as a viable ecosystem that includes predators of mosquito larvae.

Artificial control techniques can also be used including aerators, sprinklers and sprays. A mosquito risk analysis can be undertaken (NSW Department of Housing 1998; Wong et al. 1998).

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# 7.10 Flow management: index

### 7.10.1 Objectives and principles of flow control

Catchment urbanisation leads to increases in the volume and rate of stormwater run-off. This is due to an increase in the amount of impervious surfaces and improved hydraulic efficiencies in the stormwater conveyance system. These changes affect receiving environments by altering velocity profiles, suspended load and bedload characteristics, and by increasing turbulence. This can result in ecosystems dominated by a limited number of species that can withstand the environmental stresses associated with an urbanised catchment.

Carefully developed flow management strategies can provide opportunities to both minimise flood risk, and protect or enhance receiving water ecosystems and local amenity.

Strategic catchment planning should include the following objectives and principles:

- **impact minimisation**: minimise waterway disturbance caused by the alteration to flow regimes during catchment urbanisation and drainage management programs;
- **natural drainage system protection**: protect channel form and aquatic ecosystems from flow-related impacts. Reductions in run-off volume and flow rate are key factors in reaching this objective—the peak discharge of the 1.5 year ARI should be limited to that of pre-urbanisation level. Strategies to limit the direct connection of impervious areas to aquatic ecosystems can provide flow management benefit for aquatic habitat protection as well as water quality improvements; and
- **integrated stormwater management**: adopt an integrated approach to stormwater system management that meets both hydraulic capacity and waterway protection objectives.

There is considerable scope to incorporate these objectives into the overall design of stormwater drainage systems during the planning phase for new urban development. However, in established urbanised catchments, the opportunities are often limited. Modifying the existing stormwater drainage infrastructure will require catchment managers to be opportunistic in identifying short term and long term priorities for protection and rehabilitation of urban aquatic ecosystems.

This section describes a number of general techniques for managing flow related impacts of urbanisation. Flow management design tools are provided as examples of some of these techniques.

### 7.10.2 Flow management techniques

A range of techniques are available for managing flow and flow-related impacts within urban areas. Flow management techniques range from localised site controls to flow detention systems at the sub-catchment scale. The choice of techniques is catchment dependent—in many cases a combination of techniques will be most effective.

### 1 Maintaining natural drainage

Maintaining the natural drainage system is often the most effective and least expensive way to minimise flow impacts. This is most easily adopted in greenfield sites. Where possible:

- maintain natural channels and flood plains, or incorporate natural channels into the design of hybrid channels (see point 4); and
- use swale drains, check banks and grass buffers as part of the stormwater conveyance system to improve water quality and reduce peak discharges.

### 2 Run-off control

Run-off control measures can be used to treat run-off from roofs and other areas that are highly impervious. These measures include reducing or minimising the impervious area that is directly connected to the underground stormwater system, on-site stormwater reuse, and using detention basins and infiltration systems. Source run-off control should be used to complement other measures, rather than as the only solution.

Run-off control techniques include:

- **local collection and detention**: design access places and road crossfalls to direct run-off to local collection and detention areas;
- **minimising the extent of paving**: use porous pavements, incorporate shorter drive-ways, smaller road widths, and footpaths on only one side of the road;
- **housing run-off**: concentrate domestic run-off for treatment to one or two points in the development;
- **grass swales**: provide areas of grass swales along verges, to reduce flow velocities or to permit stormwater infiltration;
- **roadway design**: design roadways and parking areas to incorporate detention areas and vegetation; and
- **public area design**: integrate infiltration/detention basins in public open areas. Locate local public open space at the base of cul-de-sacs to accommodate local run-off.

### 3 Distributed storages

Small storages distributed throughout a catchment help to reduce peak flow rates and provide a greater degree of protection than one large storage at the outlet. These can be used either in combination with natural channels, or as an alternative flow management measure. Storages can be readily retrofitted to existing urban environments, subject to land availability.

*Retarding basin design*

Retarding basins are commonly used in urban catchments and are often designed to limit downstream flooding impacts from catchment development. Commonly, retarding basins are designed to attenuate the peak 100 year ARI discharge to pre-development level. However, designing retarding basins to also attenuate the 1.5 year ARI flow to pre-development level can benefit receiving waters without compromising drainage and flood protection requirements. The design of new retarding basins or retrofitting existing basins can range from minor modifications of conventional outlet design to the full implementation of water pollution control wetlands within the retarding basins.

### 4 Hybrid channels

To ensure flood protection, traditional stormwater management has increased the hydraulic discharge efficiency of urban land and waterways, with little consideration of flow velocity.

However, it is possible to design channel modifications that protect aquatic ecosystems and provide flood protection by constructing a 'natural' low flow channel within a high flow channel. Appropriate design can also offer aesthetic and water quality benefits (see Flow management design tool No. 4).

## 7.10.3 Flow management design tools

### Flow management design tool No. 1: Filter strip

Stormwater management using filter strips/buffer strips involve the discharge of impervious area run-off laterally to the creek via a zone of densely vegetated ground cover. Filter strips promote infiltration, filtration and attenuation of stormwater run-off. Uncontrolled overland flows are discouraged thereby reducing the risk of flow channelisation and erosion. For further detail see Appendix C.

*Design considerations*

- dense, evenly distributed ground cover should be promoted;
- minimum height of vegetation should exceed maximum depth of overland flow expected;
- excessive shading by trees with dense canopy which may result in a patchy distribution of ground cover should be avoided;
- uniform flow should be discharged from impervious areas to filter strip (Figure 7.42);
- flow spreaders in the form of check dams and benches need to be constructed at regular intervals along the face of the filter strip if slope exceeds 5 per cent (Figures 7.43);
- areas of a filter strip where flows may naturally converge should be underlaid by rocks and geotextile fabric prior to planting to provide additional protection against erosion;

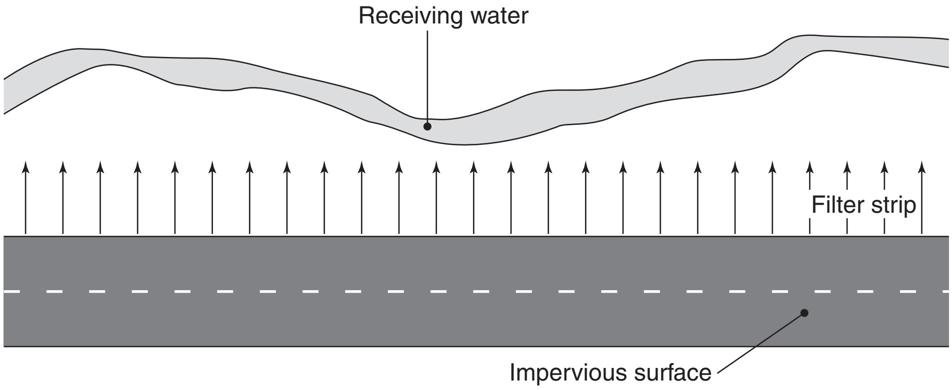


**Figure 7.42 Plan illustration of filter strip run-off management option.**

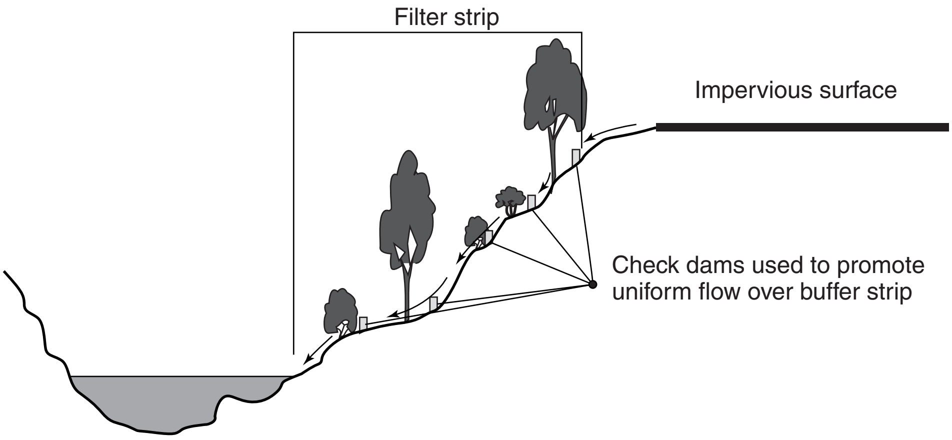


**Figure 7.43 Section illustration of filter strip management option.**

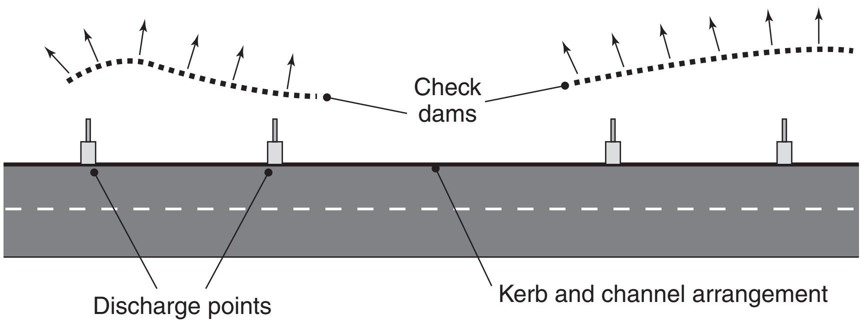


**Figure 7.44 Plan illustration of kerb and channel and filter strip run-off management option.**

- in circumstance of steep slope, it may sometimes be more appropriate to collect road run-off by means of the conventional kerb and channel arrangement and discharge the run-off at locations where slopes do not exceed 17 per cent (Figures 7.44 and 7.45); and
- when a road crosses a creek line, it is often more appropriate to run the filter strip parallel to the creek line and pipe the flows to the filter strip (Figure 7.46).

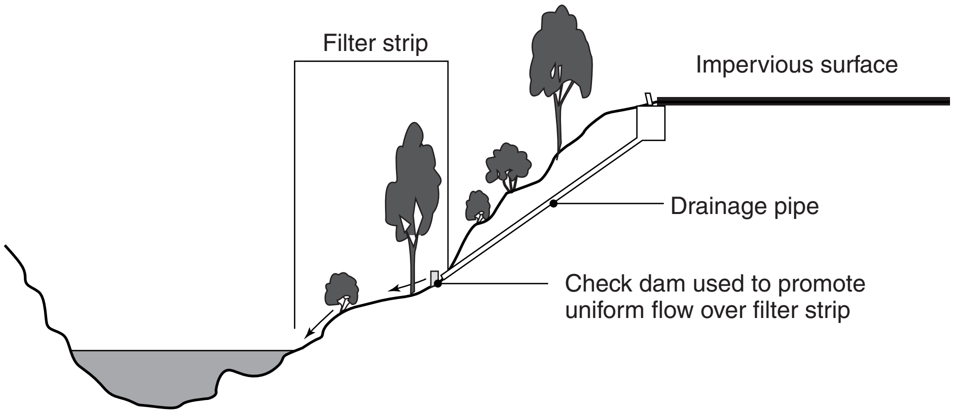


**Figure 7.45 Section illustration of kerb and channel and filter strip run-off management option.**

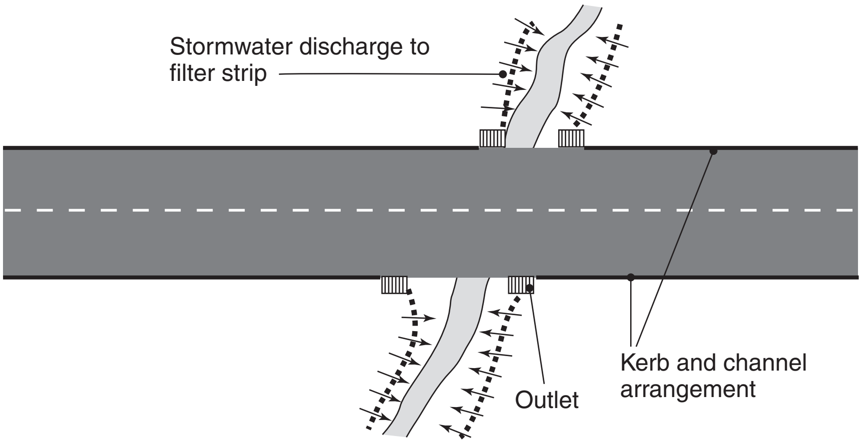


**Figure 7.46 Plan illustration of kerb and channel and buffer strip along creek.**

## Flow management design tool No. 2: Swale drain

A swale drain is a more suitable option when the conveyance of run-off to a designated discharge point is required. Grass swales can attenuate stormwater run-off and promote infiltration during minor storm events. Run-off is discharged from an impervious area into a swale drain as illustrated in Figure 7.47. If the slope and terrain between the impervious area (e.g. road) and the receiving water is too steep or undulating a combination of swale drain and discharge pits may be used. For further detail see Section 7.8.

### *Design considerations*

- the slope and width of the swale drain should be designed to avoid flow velocity above 0.3 m/s for the 1 year ARI event and 1 m/s for the 100 year ARI event;
- the longitudinal slope of the swale should not exceed 4 per cent;
- side slopes should not exceed 1(v):3(h);
- if the slope of the terrain to the receiving water exceeds 4 per cent, discharge pits should be located at regular intervals (e.g. 1 km intervals), at which the stormwater is conveyed to the creek via a pipe outlet. An energy dissipater or flow distributor

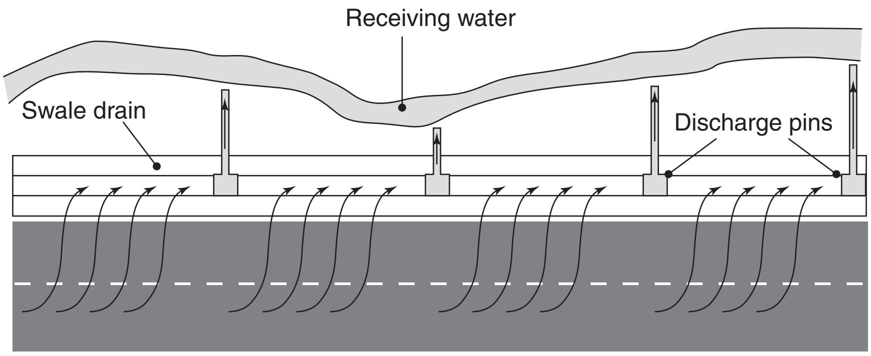


**Figure 7.47 Plan illustration of swale drain run-off management option.**

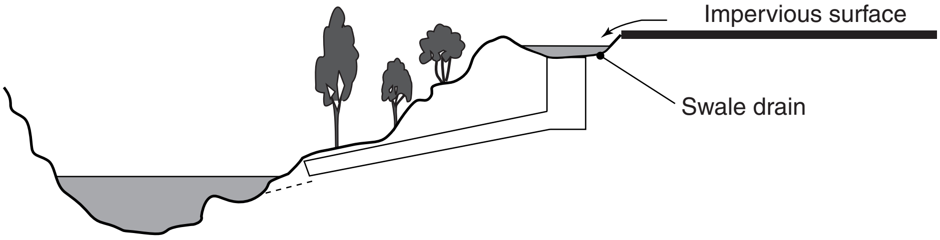


**Figure 7.48 Section illustration of swale drain run-off management option.**

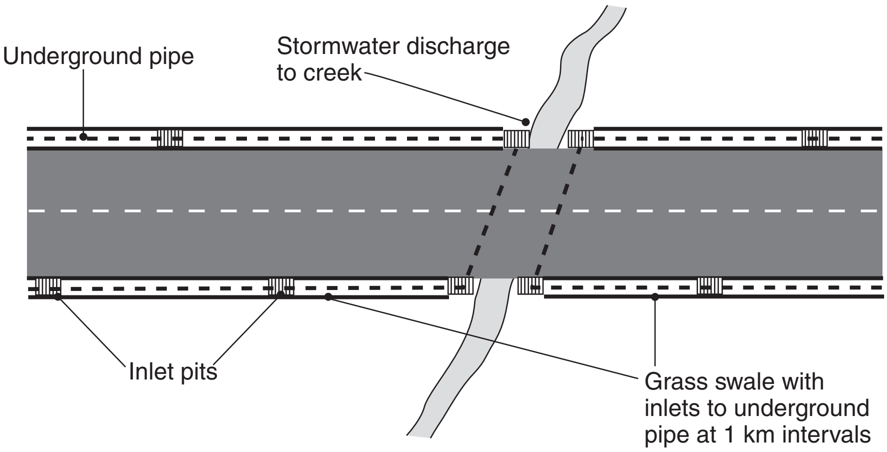


**Figure 7.49 Plan illustration of swale drain/drainage pit option.**

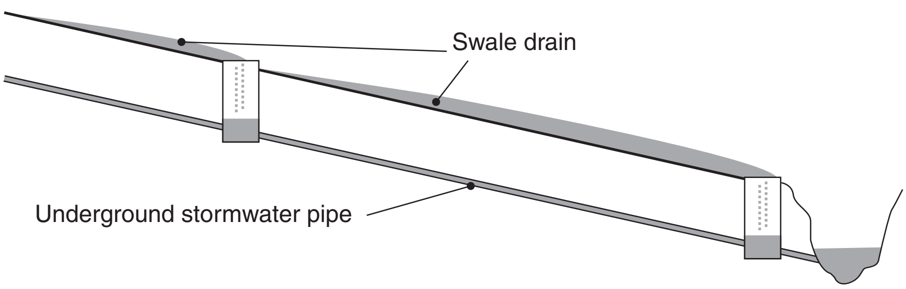


**Figure 7.50 Longitudinal illustration of swale drain/underground pipe system.**

should be located at the outlet to reduce flow impact at the entry point to the receiving water (Figures 7.47 and 7.48);

- flat terrain may be required under drains to avoid ponding of surface water;
- if the vertical alignment of the road is relatively steep, swale drains can be used to convey run-off from small sections of the road into a more formal drainage system consisting of inlet pits and an underground pipe (Figures 7.49 and 7.50);
- mowing should be kept to a minimum. Mower blades should be set at the highest level to maximise the height of the vegetation in the water column during run-off events; and
- swales can be used as a pre-treatment for other stormwater treatment measures.

### Flow management design tool No. 3: Distributed sub-catchment storages

Small storages distributed throughout a catchment delay run-off and reduce peak flows further downstream. Distributed storages may consist of dry detention basins, wet detention basins or wetlands (Figure 7.51). For further detail see Section 7.8.

Several small storages, distributed on catchment tributaries, are recommended in preference to a smaller number of larger storages. Storages may be either dry basins, reserves, wetlands or lakes. The storages should be sized so that peak flows up to a 1.5 year ARI event are attenuated to pre-development level. Where possible, storages should be designed to achieve not only water flow control but water quality treatment, amenity and landscape benefits.

#### *Design considerations*

- length to width ratio should be greater than 2 (L):1(W);
- pre-screening of gross pollutants is recommended;
- a by-pass system for high flows is highly recommended;
- basin sizing should be based on a balance between the annual proportion of rainfall to be detained and the desired detention time;
- flood routing analysis should be undertaken to determine the degree of flood peak attenuation and shift in time of peak discharge in receiving waterways. The effect of co-incident release of detained waters from multiple storages and subsequent rainfall events needs to be considered;
- promoting uniform distribution of inflow volume within basin—inadequate selection of the size and shape of the detention system or design of outlet will result in short-circuit flow paths and dead zones;

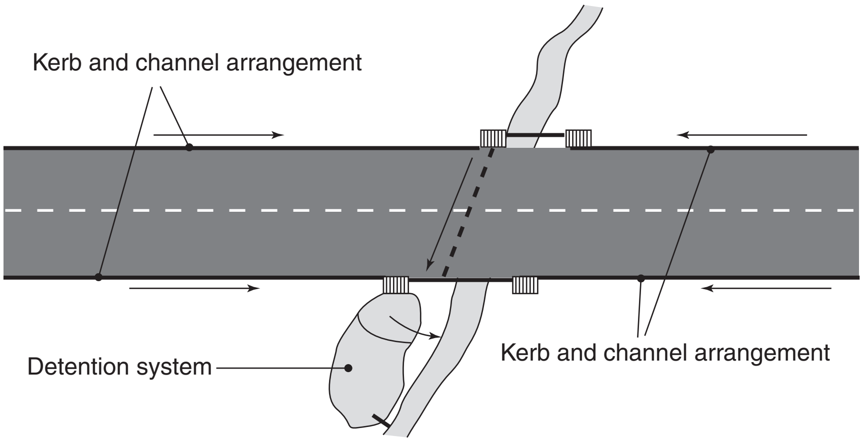


**Figure 7.51 Plan illustration of kerb and channel arrangement directing flow into a constructed wetland.**

- protecting outlet structures against blockage;
- if incorporating a wetland system into the design, ensuring the botanical design matches the wetness gradient of each vegetated zone in the system; and
- in steep terrain, designing detention basins as a series of cells.

### Flow management design tool No. 4: Hybrid channels

Hybrid channels consist of a low flow channel providing habitat for aquatic organisms and a grassed high flow channel which is hydraulically efficient for flood protection purposes.

Figure 7.52 illustrates the layout of a hybrid channel. Here, a natural low flow channel is incorporated within a modified waterway providing aquatic habitat while maintaining a hydraulically efficient high flow channel.

The low flow section of a hybrid channel should be designed to provide a range of substrate conditions and avoid excessive entrainment of bed materials. Pool and riffle sequences should be used to provide habitat diversity and refuge sites for in-stream fauna. Owing to the limited supply of bed materials such as cobbles and gravels in urban catchments, it is important that the low flow channel be designed to maintain these materials by keeping flow velocity to below 0.7 m/s for the 1 year ARI event. Finer materials, which are easily transported at this velocity, are readily replenished during low flow conditions. Occasional flushing and entrainment flows are considered necessary for maintenance of ecosystem health by removing fine sediment from interstices in gravel beds. Natural woody debris may be provided in the low flow channel where appropriate.

#### *Design considerations*

- large woody debris and pool and riffle sequences should be included in the low flow channel;

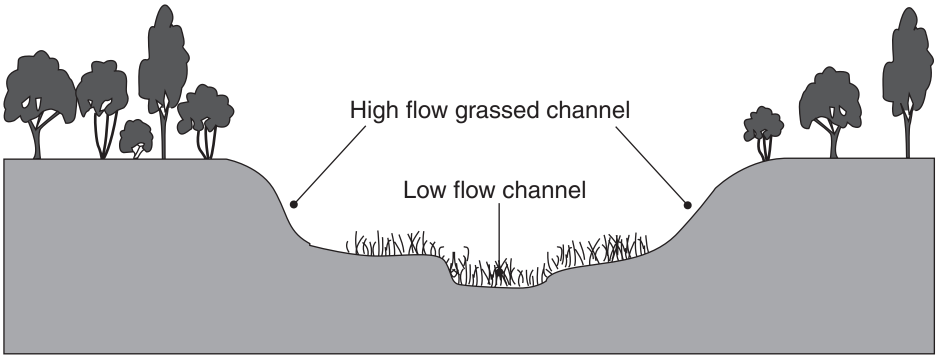


**Figure 7.52 Provision of a natural low-flow channel within a hydraulically efficient urban waterway.**

- aquatic vegetation can be use to stabilise substrate and provide variation in habitat in the low flow channel;
- the low flow channel should be designed such that the flow velocity for the 1.5 year ARI peak discharge is only just sufficient to entrain the riffle substrate;
- flow velocity should not be able to displace large rocks (i.e. between 150 to 200 mm) that may have been placed in the channel as part of stabilisation works;
- high flow channel should be grassed, providing a hydraulically efficient waterway; and
- high flow channel should be sized according to the 100 year ARI event

### Flow management design tool No. 5: Retrofitting grassed floodways

Grassed floodways are commonly used to provide efficient flow conveyance of run-off up to the 100 year ARI event. These floodways typically consist of a low flow pipe (of 2 year ARI capacity) overlaid by a wide trapezoidal grassed channel as shown in Figure 7.53. Retrofitting grassed floodways involves the diversion of low flows into re-established natural channels without compromising the flood protection associated with the grassed floodway. The re-established natural channel provides habitat and continuity of the aquatic ecosystem (Figure 7.54).

#### *Design considerations*

- divert low flow from existing 2 year ARI pipe into re-established 'natural' channel (Figure 7.54);
- use grated entry pits placed at regular intervals along the 2 year ARI pipe to allow flood water to inflow into the low flow pipe;
- re-establish natural channel with 1 to 1.5 year ARI discharge capacity;
- pool and riffle sequences should be included in the re-established natural channel; and
- aquatic vegetation can be use to stabilise substrate and provide variation in habitat in the re-established natural channel

**Figure 7.53 Grassed floodway suitable for re-establishment of low flow channel.**

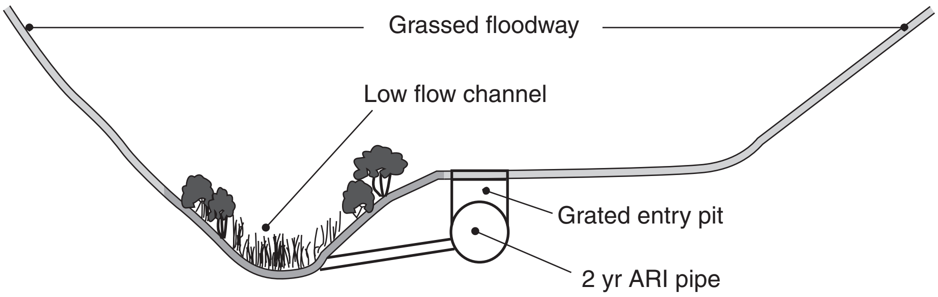


**Figure 7.54 Cross-section of a grassed floodway combined with a re-established natural low flow channel.**