CHAPTER 8

GROSS POLLUTANT AND SEDIMENT TRAPS

Robin Allison and David Pezzaniti

8.1 INTRODUCTION

8.1.1 Purpose of Chapter

This chapter provides a description of the types and operating principles of gross pollutant traps (GPTs) and sediment traps available in Australia and suggests an approach to their selection to help ensure successful operation.

8.1.2 Scope of Chapter

Previous chapters in Australian Runoff Quality describe pollutants carried in urban stormwater, methods to minimise pollutant export through clever urban designs and setting pollutant discharge criteria to protect downstream water bodies. This chapter is the first in a series that focuses on treatments that can be employed to capture and remove pollutants carried by urban stormwater.

GPTs represent a significant public investment in the capital cost of the device as well as ongoing cleaning and maintenance costs. There are many styles and makes of GPTs and sediment traps. The broad mode of operation, advantages and limitation are discussed here. The main focus of this chapter is to outline important consideration when choosing a GPT or sediment trap for a particular purpose and site.

The primary purpose of GPTs is to remove gross pollutants (litter and debris greater than 5 mm) and coarse sediments (these are further defined in Chapter 2). While most GPTs capture both categories of pollutants, there are some that target litter and debris exclusively and others that are designed only for sediment removal. This chapter considers both categories of GPTs collectively and then discusses the several exceptions separately.

Few independent performance data are available for most types of GPTs. Proprietary information should be scrutinised carefully. This chapter poses some questions to allow the reader to specify a suitable type of GPT and select an appropriate device from the many available.

8.1.3 Structure of Chapter

This chapter describes how to locate GPTs and sediment traps and specify their performance to optimise pollutant capture. It then provides an overview of different types of devices and their operating principles used around Australia.

Figure 8.1 Litter accumulation in Merri Creek, Melbourne (source: R. Allison).

The chapter then concludes with an approach to selecting a GPT, highlighting important considerations to help ensure the systems will meet specified pollutant discharge objectives.

8.2 BACKGROUND

There are two broad approaches to stormwater management: source control water sensitive- urban design (WSUD), and traditional conveyance structural drainage.

Gross pollutant traps (GPTs) and sediment traps serve as a component of traditional conveyance drainage networks. They reduce quantities of litter, debris and coarse sediments from discharging to receiving waters or to downstream treatment measures (Figure 8.1). Often GPTs are installed to address specific problems in existing drainage networks and must accommodate existing constraints.

GPTs were developed in the ACT to provide pre-treatment for ponds and wetlands that were otherwise smothered by coarse sediment and visually affected by litter and debris. Early designs involved concrete basins with vertical trash racks for debris retention. These were developed for large catchments near outlets into lakes and wetlands. GPTs then evolved to suit smaller catchments and can be installed further upstream and used to target high litter and debris generation areas.

A WSUD approach to stormwater management reduces the need to employ GPTs, because the connectivity of the drainage system is reduced and larger contaminants are filtered from flows before reaching waterways. However, GPTs often play an important role in WSUD as pre-treatments for measures such as wetlands and bioretention systems, by removing coarse material and preventing downstream measures from becoming overloaded.

The design of GPTs has evolved considerably since their inception in Australia in the 1980s. Most current designs are proprietary products and available off the shelf. The most pressing issue for managers of stormwater systems is specifying the requirements of a GPT and selecting an appropriate GPT for a particular location from a wide range of available products that employ various processes.

8.3 GPTS AS PART OF A TREATMENT SYSTEM

GPTs or sediment traps can operate in isolation to protect immediate downstream receiving waters or as part of a more comprehensive treatment system. When acting in isolation they are used primarily for aesthetic reasons, to protect downstream waters from litter or to address specific items such as syringes.

In integrated treatment systems (or treatment trains), they are the most upstream measure and are important to protect the integrity of downstream treatments (such as wetlands) by removing the coarsest fraction of contaminants.

A poorly performing GPT (due to poor design or inadequate maintenance) can result in litter, debris and coarse sediments smothering downstream treatments and impacting on their operation (for example, smothering vegetation in a macrophyte system). In addition, litter can detract from attractive stormwater treatments such as wetlands and reflect poorly on the overall treatment system.

A poorly maintained GPT can hold gross pollutants for some time, during which some types of GPTs can transform collected contaminants into more bio-available forms. Small flows through the collected pollutants can then leach transformed pollutants downstream, where they can be detrimental, in some cases causing more problems than if a GPT was not installed.

For these reasons the selection and maintenance of GPTs are a critical components of an overall stormwater management system.

The location of a GPT in a broader catchment stormwater management system needs to be accounted for when setting treatment objectives and selecting an appropriate type of GPT.

8.4 LOCATING A GPT

When determining the location for a GPT its relevance to other stormwater treatment measures in the catchment should be considered. A location for a GPT or sediment trap should be complementary to other treatment measures and be consistent with the strategic catchment treatment objectives. In addition, other factors such as topography, available space and proximity to pollutant source areas determine the best location for a GPT and its catchment size.

There are two approaches for locating GPTs: an 'outlet' and a 'distributed' catchment approach. An outlet approach uses a single device to treat a whole catchment (up to 200 ha, more in some cases). A distributed approach targets smaller individual catchments with many traps – for example, placing traps into each entry pit in a drainage network.

There are advantages and limitations with both systems. The trade-off is between isolating catchments with the highest pollutant concentrations and minimising maintenance and construction costs.

An outlet approach has the advantage of a single location for maintenance and construction. This has advantages for monitoring the required frequency for cleaning, monitoring the trap's performance and cost savings associated with maintenance. However, if left too far downstream large volumes of water may need to be treated at a location sometimes far from the pollutant source, often with poor efficiency.

A distributed approach has the advantage of a number of smaller and potentially different treatments installed throughout a catchment. It enables pollutant sources to be targeted effectively and treat only water that is expected to contain sufficient pollutants. In this way lower flow velocities and volumes and high pollutant concentrations at these sites lead to higher operating efficiencies.

A network of distributed traps can represent a significant maintenance burden. Implementing a cost-effective maintenance regime can be difficult, because each trap usually has different loading rates; some will be overburdened and others will have loads that do not warrant cleaning.

An optimal catchment size is suggested to be between 10 and 100 ha for a GPT. Lloyd and Wong (2003) suggest that catchment sizes smaller than 10 ha may incur a disproportionately high maintenance cost and GPTs on very large catchments are likely to have low trapping efficiencies. However, in some cases GPTs can be required for small catchments (less than 10 ha) that drain directly to adjoining receiving waters.

8.4.1 Site constraints

The characteristics of a particular site can severely limit the choice of treatment GPT suited to an area. Constraints fall broadly into categories of physical and social.

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

- topography: e.g. steep or mild slopes (in sites with steep grades (>2%) GPT may not operate effectively, while on mild slopes (<0.25%) headlosses can cause local flooding)
- soils and geology: e.g. depth to bedrock or instability (can increase construction costs)
- groundwater: e.g. geochemistry and water table depth
- space: limited open space, proximity to underground services (e.g. gas, power)
- access: can make maintenance difficult and expensive, particularly in areas with heavy traffic.

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

- odour problems: depends on the type of GPT and surrounding land uses
- visual impacts: underground versus above-ground and local landscaping
- safety concerns: resulting from unauthorised access to structures or infection, poisoning or injury caused by trapped pollutants
- vermin: e.g. mosquitoes, rats.

Many social issues can be addressed simply during the 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 consultation with affected stakeholders.

Each type of GPT will address these issues differently and relevant issues should be considered for each installation.

8.5 SPECIFYING GPT PERFORMANCE

Specifying the objectives for a GPT or sediment trap is an important step for ensuring that it operates as intended. The specification should include details and consideration of the following:

- treatment objectives
- design flows
- flood capacity
- trapped pollutant storage
- maintenance requirements.

Each of these issues is described further below.

Of particular importance for specifying a GPT is the maintenance type, frequency and capacity of the purchaser to conduct it. Maintenance is an ongoing requirement. A poorly maintained GPT can contaminate downstream waterways. This is the most common mode of failure.

8.5.1 Treatment objectives

The stormwater pollutant profile of a catchment area is determined largely by the area's land use and stormwater management measures (e.g. conveyance or WSUD). For example, human-derived litter can be a problem in commercial areas, whereas sediment runoff is often more prevalent in developing urban areas.

To isolate pollutants in any catchment, the designer needs to examine receiving water degradation in light of the area's land use and current management practices (refer to Chapter 7 for determining water quality criteria). For GPTs these are primarily:

- **gross pollutants**: litter and vegetation larger than 5 mm
- **sediment**: particles larger than 0.125 mm.

Treatment objectives may be more specific and concerned with only one component of the pollutant load, such as syringes in coastal areas.

To objectively assess various GPTs, criteria need to be developed that outline the aims of the GPT or sediment trap. These can range from reducing:

- one component of litter (e.g. floating visible litter, or syringes)
- a proportion (e.g. 70%) of litter on a catchment wide scale
- a proportion (e.g. 70%) of litter and organic material, or
- just coarse sediments.

For example, Melbourne Water usually has the objective of reducing 70% of the litter load in a catchment, or capturing litter greater than 20 mm with treatment of all flows up to the 1 in 3 month peak flow (Melbourne Water 2002). These objectives may vary depending on the beneficial uses and threats to a receiving water body.

In addition, sediment removal rates can be specified. For example, removing 90% of all material greater than 0.125 mm in size for up to a one year average recurrence interval would be a typical requirement for a coarse sediment trap.

GPT removal rates

There are many optimistic claims by vendors on their removal rates for litter and other constituents. It is recommended to check any claims, ensure testing is independent and refer to guidelines (e.g. Victorian Stormwater Committee, 1999) for removal rate estimates when no other data is available. References should also be sought from previous installations or from performance assessment studies (see Section 8.7).

8.5.2 Operating design flows

The overall treatment effectiveness of a GPT is a function of its pollutant removal rate for flows that pass through a trap and the volume of runoff treated. A high flow bypass is usually adopted to protect GPTs from large flood flows that could damage the device or scour and transport previously collected pollutants downstream. The maximum flow rate at which a GPT is designed to operate effectively is termed the design flow.

Selecting a design flow rate is a trade-off between the cost and space requirements of the device (a higher design flow will usually require a larger facility with additional costs) and the volume of water that could potentially bypass the measure and avoid treatment. Chapter 7 discusses the selection of appropriate treatment flows for stormwater treatment measures. Typically a three-month average recurrence interval (ARI) is an appropriate design flow rate because it will result in treatment of a significant portion of flow (i.e. >95% see Figure 8.2) without the excessive cost of sizing a GPT for

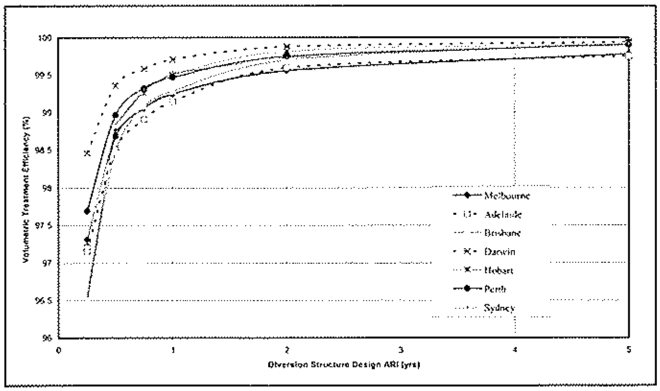

Figure 8.2 Treatment design flow plotted against percentage of annual flow volume treated for Australian cities (after Wong *et al.* 1999)

larger peak flow rates (a reasonable estimation of a 3-month flow is 50% of a 1-year ARI peak flow rate).

8.5.3 Flood capacity

Every GPT should be designed with provision for a high-flow bypass system. The bypass should protect the operational integrity of the trap during floods, ensure no flooding is caused by the trap in surrounding areas and prevent excessive scour of collected pollutants in a trap. It is important that a hydraulic analysis of the drainage systems incorporating a GPT is performed. This analysis needs to include the headloss of the GPT and diversion weir under flood conditions.

Typically GPTs will operate with a bypass system that is designed to divert the treatment flows into a separation chamber. Flows higher than this are diverted over or around a diversion weir (there are a few variations of diversion weirs including solid walls, perforated plates, staggered vanes and flow-induced diversions – see Figures 8.3 and 8.4). Alternative bypass techniques include a release mechanism for a net system, triggered by increasing upstream flow levels (Figure 8.5). The design of a bypass system should be checked to assess impacts on the local drainage system and consequences on flooding

8.5.4 Trapped pollutant storage

Two main issues should be considered in relation to storage of collected pollutants in a GPT:

- the nature of the collected pollutants (i.e. either free draining or wet sump)
- the size of the collection and holding chamber (and relationship with maintenance frequency).

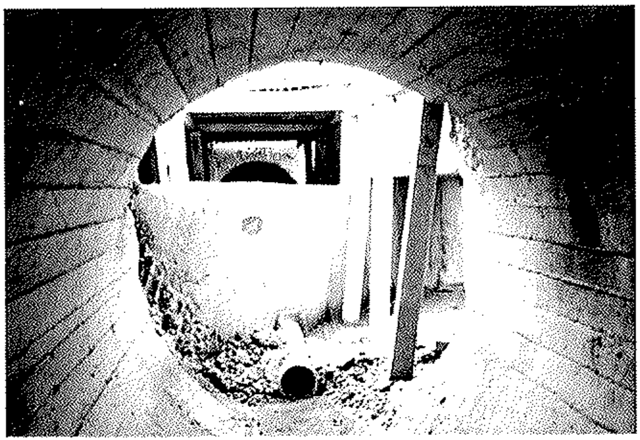

Figure 8.3 Solid diversion weir during construction of an underground GPT – looking downstream. Coburg, Victoria (source: R. Allison).

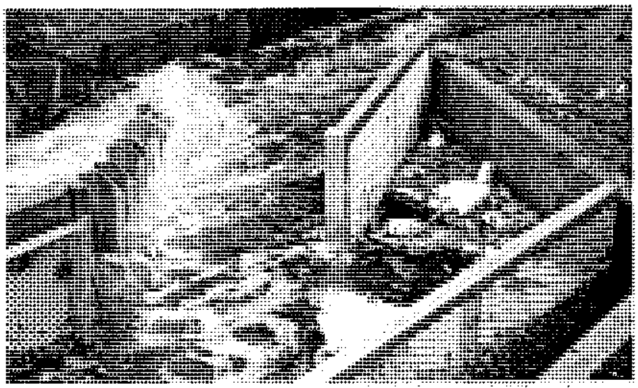

Figure 8.4 Vane style diversion weir, Sebastopol, Victoria (source: A. Miller)

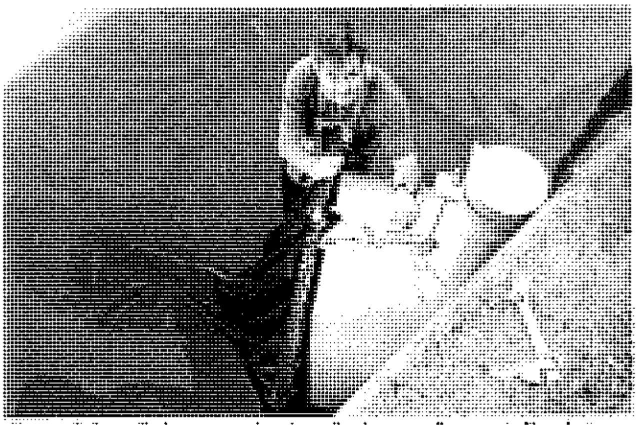

Figure 8.5 Release mechanism for bypass for a net, Frankston, Victoria (source: J. Lewis).

Trapped pollutant containment

Holding trapped pollutants until removal is achieved by containing pollutants in a wet sump (in baskets or chambers – Figure 8.6) or by storing pollutants in baskets, nets or behind screens that are free draining.

The continuous wet conditions in a pollutant containment sump and possibly limited turn over, mixing or aeration can lead to organic material decomposition, with depleted oxygen levels creating severe reducing conditions. Under these conditions collected pollutants can be transformed from a relatively innocuous state to highly bio-available forms that are then released to downstream waters with any through flow (trickle flows).

This can be addressed by providing downstream nutrient reduction treatment (e.g. wetlands or bioretention systems) to prevent the bio-available pollutants from impacting on receiving waterways. The transformation and release of these pollutants will occur mainly when there are low flows and therefore the capacity of a downstream treatment system should be sufficient to cope with the loading rates from leached pollutants.

When installing as a stand-alone GPT (i.e. without downstream treatment measures) the impact on downstream

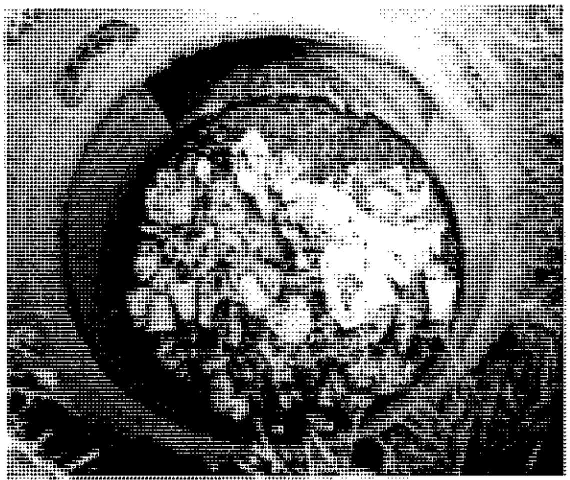

Figure 8.6 Pollutants contained in a wet sump, Melbourne, Victoria (source: R. Allison)

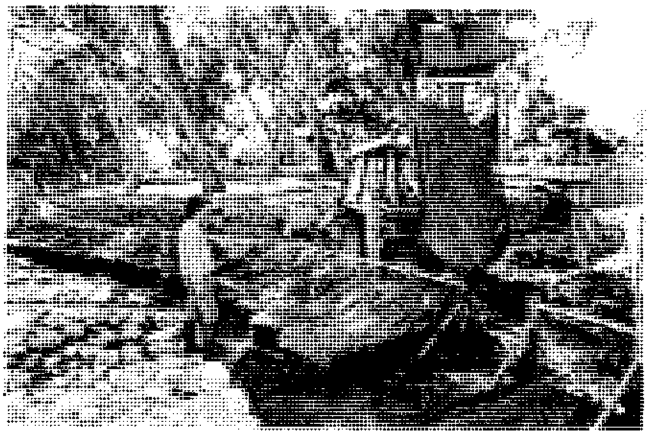

Figure 8.7 Pollutants retained in a free draining state. Adelaide, South Australia (source: A. Thomas)

waterways from release of potentially bio-available pollutants from wet sumps should be considered. In some cases, it may be the only option for a GPT. If so, low flow treatment systems downstream should be considered.

Free draining GPT containment areas do not have the same issues of pollutant transformation in anaerobic conditions (Figure 8.7). However, they can have more visual and odour issues associated with them. The merits of each system need to be considered.

Pollutant holding capacity

A GPT with insufficient size will fill and bypass too frequently or require cleaning too frequently to be practical or affordable. A GPT that is sized to store pollutants for a long time will be very large and therefore require significant extra space and cost. Long storage times also increase the chance of pollutants transforming into bio-available forms during storage. Typically GPTs should be sized for cleaning between 4 and 12 times a year.

To estimate the size of a required storage and containment chamber, catchment gross pollutant loads can be estimated, a required maintenance frequency selected and an appropriate pollutant holding capacity can be determined.

Loads can be estimated using a simple decision support system (e.g. Allison *et al.* 1998a) that requires rainfall and land use information. If there is no other data, the values in the Table 8.1 could be adopted (based on Melbourne conditions adapted from Allison *et al.* 1998a). Note that litter and gross pollutants (litter and vegetation) are listed. This is because the holding capacity (and disposal costs) depends on the gross pollutant load rather than just the litter component. No GPTs can distinguish between litter and organic material. Therefore, to remove litter they must collect debris in the same way.

Table 8.1 Approximate litter and gross pollutant loading rates for Melbourne (refer to Cbapter 3, from Allison *et al.* 1998a)

LANDUSE TYPE	LITTER[1] Volume (Litre/ha/year)	LITTER[1] Mass[2] (kg/ha/year)	GROSS POLLUTANTS[3] Volume (Litre/ha/year)	GROSS POLLUTANTS[3] Mass[2] (kg/ha/year)
Commercial	210	56	530	135
Residential	50	13	280	71
Light-industrial	100	25	150	39

[1] Litter is defined as anthropogenic materials larger then 5 mm.

[2] Mass is a wet mass, i.e. the mass expected when removed from a litter trap and drained of excessive water.

[3] Gross pollutants contain vegetation as well as anthropogenic litter (not sediments).

Gross pollutant loads should be used to estimate a desirable cleaning frequency by dividing the estimated annual loading rates by the required cleaning frequency.

8.5.5 Maintenance requirements

A poorly maintained treatment measure may not only perform badly, it may become a flood hazard or a source of pollution itself. Maintenance is the most commonly overlooked aspect of GPT selection, yet it is one of the most important for gross pollutant reduction.

GPT operation and maintenance requirements vary widely. When assessing a 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
- **access to the treatment site**: consider the ease of site access, including road closures, when reviewing the treatment's maintenance requirements
- **frequency of maintenance**: ensure that resources are available to carry out maintenance at the required frequency
- **disposal**: consider the disposal of any waste from the treatment process.

The ease of maintenance relates to the systems and equipment required to clean a GPT. Cleaning systems range from manual hauling of collected pollutants, vacuuming collected pollutants (Figure 8.8), using a crane to retrieve collected pollutants from a basket or net (Figures 8.9 and 8.10) or using large excavators with 'clam shell retrievers' (Figures 8.11 and 8.12) to remove pollutants from large GPTs.

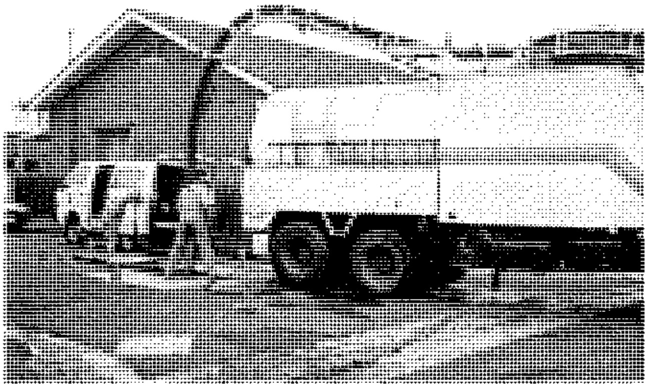

Figure 8.8 GPTs are commonly located under roads in highly urban catchments. Here a GPT is cleaned with a large vacuum system. Coburg, Victoria (source: R. Allison).

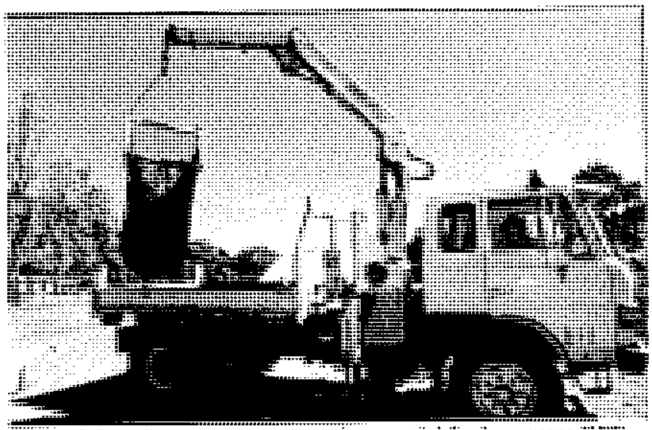

Figure 8.9 Simple maintenance is essential for long-term GPT operation. Here a truck-mounted crane removes nets (source: www.nettech.com.au).

Figure 8.10 Baskets located in sumps are also used to collect pollutants, and are removed by crane. Coburg, Victoria (source: R. Allison)

A type of cleaning system that suits a particular location or servicing agency should be specified when tendering for GPTs. Occupational health and safety issues should also be covered, including avoiding human contact with collected pollutants (for safety reasons) and for maximum lifting loads.

Of prime concern for maintenance is the ease of access to the site for cleaning. This is particularly relevant for inner city sites that are constrained and may have traps located below roads or other well-used areas. Access considerations should be specified as a requirement for tenderers and the costs of any traffic management measures considered.

Acceptable maintenance frequencies should also be specified for tenderers. This relates to the holding capacity of a GPT as discussed earlier.

Disposal costs should also be considered as part of a GPT operation. These can be considerable depending on the haulage distance and the classification of collected material.

Figure 8.11 Excavator mounted 'clam shell' type cleaning operation. Brighton, Victoria (source: www.cdstech.com.au)

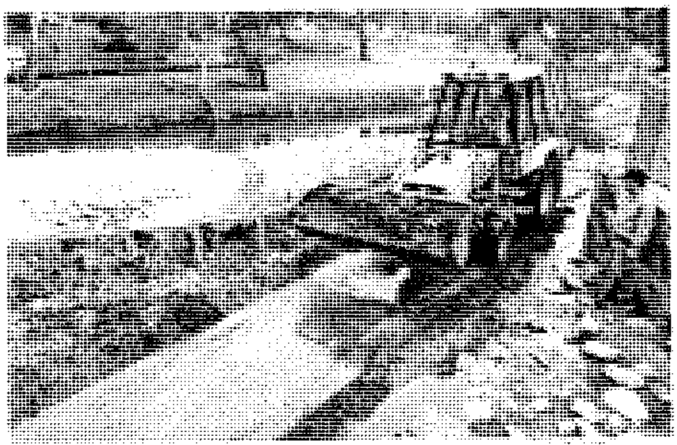

Figure 8.12 Excavators can be used to clean above-ground GPTs. Adelaide, South Australia (source: A. Thomas)

8.6 TYPES OF GPTs

There is a wide choice of GPTs available, with an increasingly diverse range of treatment types used throughout Australia. GPTs vary in size, cost and trapping performance by orders of magnitude. GPTs are continuously being developed and modified as vendors research the operation of their traps and respond to treatment requirements. There are no treatment parameters that all GPTs follow.

New designs are evolving rapidly. There is usually a shortage of data relating to the trapping performance of the newer methods, making treatment comparisons difficult (Wong *et al.* 1999).

This chapter describes the principles of operation for five categories of GPTs and sediment traps. Product information is available at several websites that are intended as 'product registers' for GPTs and can be updated as new products emerge. Many local authorities have their own product lists and these should be consulted. Reference is made to the following product register sites:

- Stormwater Industry Association – Victorian Chapter - www.siavictoria.info/
- NSW EPA - www.epa.nsw.gov.au/stormwater/usp/contract.htm
- International Stormwater Best Management Practice (BMP) database - www.bmpdatabase.org/
- US EPA - Urban Stormwater Best Management Practices Study - www.epa.gov/ost/stormwater

The descriptions of GPTs and sediment traps are divided into five operating types:

- **drainage entrance treatments**: grate entrance systems, side entry pit traps and gully pit traps
- **direct screening devices**: litter collection baskets, release nets, trash racks, return flow litter baskets, and channel nets
- **non-clogging screens**: circular and downwardly inclined screens
- **floating traps**: flexible floating booms, floating debris traps
- **sediment traps**: sediment settling basins and ponds, circular settling tanks, hydrodynamic separators.

8.6.1 Drainage entrance treatments

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

Entrance treatments are usually located close to a pollutant source, allowing the most polluted areas to be targeted. Use of entrance treatments can also help reduce downstream pipe blockages, which was their original intended use.

Figure 8.13 Early designs of entrance traps used coarse mesh plastic trays and were intended to prevent pipe blockages. Heidelberg, Victoria (source: R. Allison)

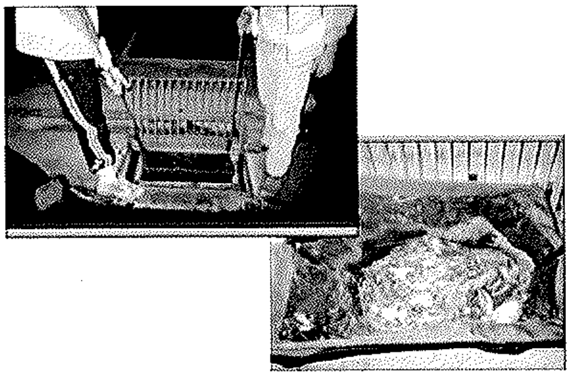

Figure 8.14 Recent entrance traps used fine mesh bags to collect finer material (source: www.ingalenviro.com)

However, maintenance can involve numerous locations and the size of inlets can limit the capacity of traps, thus requiring more frequent cleaning. Entrance treatments are free draining as collected pollutants are suspended above the base of a drainage pit.

Early designs of entrance treatments used plastic or wire mesh with relatively coarse pores (10—50 mm) as shown in Figure 8.13. More recent designs use fine mesh bags or nets that can contain much finer material including gravels and coarse sediments (Figure 8.14).

Maintenance involves lifting an access lid and removing collected pollutants manually or with a vacuum system (Figure 8.15). Cleaning times can be governed more from gaining access to the many pits than the actual pollutant removal task.

While entrance treatments can target specific high pollutant generation areas, their size and accessibility is governed by existing drain conditions. Often in low-lying areas the depth of drain entrances limit their applicability because pits can be too shallow to provide sufficient pollutant storage. Another issue for established urban areas is the presence of connections to the drainage network that do not connect via street entrances. Examples include private carparks, roof areas and illegal connections that discharge directly into stormwater pipes and receive no drainage entrance treatment. The extent of these entrances for a particular drainage system are unknown, but they are likely to be more common in older urban areas.

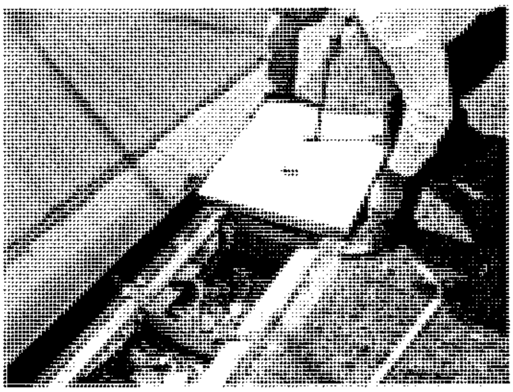

Figure 8.15 Lifting access lids can represent a significant cost to maintaining entrance treatments. Sunshine, Victoria (source: R. Allison)

8.6.2 Direct screening devices

Direct screening traps retain gross solids by passing flow through a grid, mesh, rack or net barrier assembly with flows perpendicular to the screening surface. As pollutants build up behind a barrier, smaller material than the pore sizes may also be retained due to the reduced effective pore size. There are various trapping methods using baskets, prongs, racks or perforated bags, and this category of GPT contains the most products.

Direct screening devices are installed in drainage lines (usually in pipes) with catchment areas typically between 5 and 200 ha. However, much larger catchments are sometimes targeted, although usually with lower trapping efficiencies. While most of the direct screening devices are installed 'in line' most are located next to drainage pipes and have treatment flows diverted into them via diversion weir arrangements. Flow rates above treatment flows overtop the diversion weirs and bypass treatment. This is a way to protect collected pollutants from scour and the device from damage. The configuration of diversion weirs can vary and includes solid walls, slotted pipes, staggered vanes and diversions forced by outflows from collection chambers. In each case the intention of the bypass system is the same.

Some direct screening traps are located completely within channels (Figure 8.16). This is mainly because of space limitations or the scale of the channels. Older designs located within channels were prone to scouring of collected pollutants and subsequent transport downstream when overtopped (Figure 8.17). Newer in-channel designs have means of retaining gross pollutants during flood events, typically with nets, and are designed to withstand the forces associated with floods.

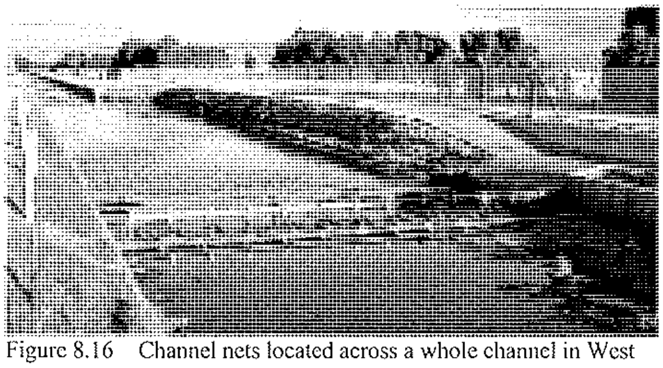

Figure 8.16 Channel nets located across a whole channel in West Torrens, South Australia (source: D. Pezzaniti)

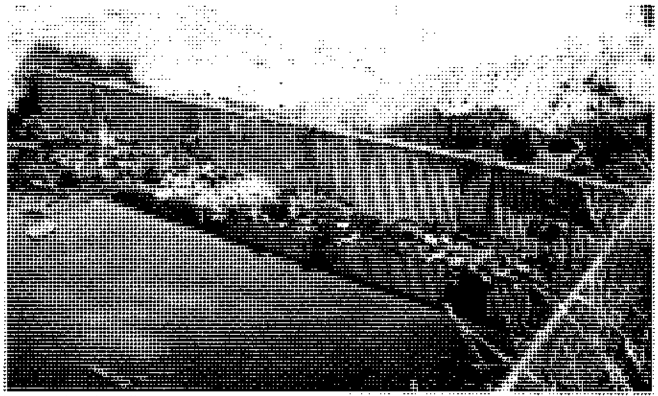

Figure 8.17 Direct screening device can be prone to blockage and overtopping. Broadmeadows, Victoria (source: R. Allison).

Direct screening devices can be installed above or below ground and this typically determines whether pollutants are retained in a wet sump (underground units) or free draining. An advantage of underground systems is the ability to locate them in highly developed urban areas with little or no visual impact. Limitations with underground traps include the potential transformation of pollutants into more bio-available forms in wet sumps (as discussed earlier) and an 'out-of-sight out-of-mind' mentality towards maintenance.

While above-ground systems have a larger visual impact, this can be exploited and used to raise public awareness of stormwater pollution and urban waterway protection. There are obvious benefits for monitoring collection rates, keeping material in an aerobic state and simplified cleaning procedures for above-ground GPTs. However, consideration should be given to health and safety issues associated with exposed systems that are easily accessible to the public.

Coarse sediments can be retained by many direct screening devices, particularly below-ground installations. Underground GPTs can act as a sump and collect bed load sediment as it is transported through the drainage network.

Some above-ground GPTs, such as trash racks and those with solid diversion weirs, can collect considerable quantities of coarse sediment as it settles out when flows are backed up behind an obstruction and flow velocities fall significantly. Predicting removal rates is difficult and depends on local conditions.

Cleaning systems for direct screening GPTs involves removing material that has collected behind the screening surfaces (or in sumps) and cleaning the screen of debris (Figure 8.18). Collected pollutants can be removed with vacuum machines, small excavators, small truck-mounted cranes for nets or larger cranes to lift baskets from sumps.

Cleaning debris from screens can represent a more substantial task. It involves manual scraping of the screen surface to remove entangled debris, or knocking debris from

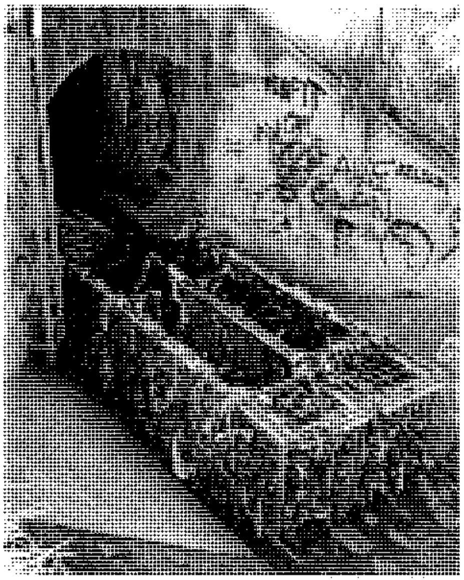

Figure 8.18 Cleaning debris from blocked screens can be an time consuming and expensive task. Collingwood, Victoria (source: R. Allison).

the screen, depending on the type of screen arrangement. Cleaning a screen of debris is a critical component of maintenance for direct screening GPTs so they can collect gross pollutants with maximum efficiency at the start of the next storm event.

8.6.3 Non-clogging screens

The tendency of in-line screens to block is their main limitation. To improve screen performance, numerous attempts have been made to design a non-clogging trash screen. The principle is to align flows tangentially to the screen surface, thus encouraging flows to move debris along the screen while flows move through the screen. The configuration of the screen face must also be appropriate for a device to remain free of blockages during storm events.

The main advantage of non-clogging screens is that they maintain flows through a trap for the duration of a storm event, thus treating more runoff volume for any given storm event. Direct screening GPTs tend to have reduced flows through the device with increasing load accumulation progressively leading to early system bypass (if not maintained regularly) compared with non-clogging screens.

Only a few GPTs have non-clogging screens. These direct flows along or around a screen such that the flows maintain a tangential direction to the screen face. In addition, screens are aligned such that blockages of material are minimised.

Two types of non-clogging screens include an underground and an above-ground device. Underground systems use circular screens with rotating flows in a collection sump (Figure 8.19), whereas above-ground systems use a drop in the channel bed to force flows down an inclined screen (Figure 8.20). They share the advantages and limitations associated with above-ground and underground direct screening GPTs for maintenance and collected pollutant breakdown.

Non-clogging screen GPTs have pollutant holding chambers or areas, much the same way as direct screening GPTs. They are also cleaned in similar ways to direct screening traps (with vacuum systems, sump basket retrieval or small excavators).

Figure 8.19 Installation of a circular screen in an underground GPT to encourage tangential flow paths along the screen. Coburg, Victoria (source: R. Allison)

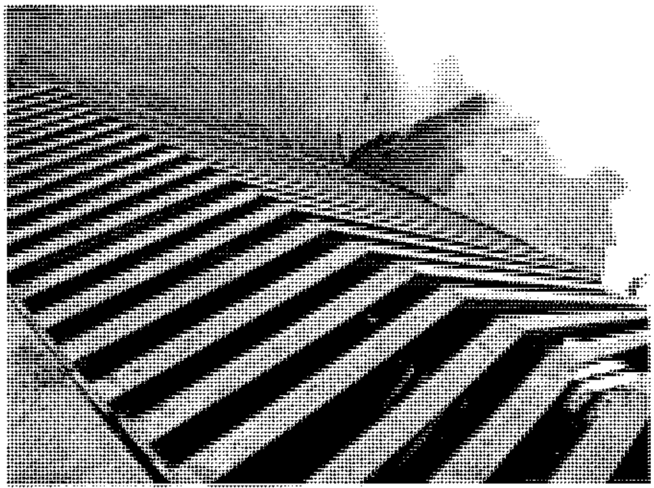

Figure 8.20 Looking down a litter screen in the direction of flow. The downward inclination encourages litter to move along the screen, leaving it free to pass flows. Huntingdale, Victoria (source: T. Wong)

8.6.4 Floating traps

Floating traps are usually intended to remove highly buoyant and visible pollutants such as plastic bottles. These are typically installed in lower reaches of waterways where velocities are lowest and where upstream attempts of litter control have been exhausted. One benefit of floating traps is their high visibility and use as a public education and awareness tool.

As their name suggests, floating traps target only the most buoyant material. For litter this is typically 10% of the total load (Allison *et al.* 1998b).

The earliest boom designs were based on those used for oil slick retention (Figure 8.21). Floating traps usually consist of a partly submerged floating barrier fitted across the waterway, which retains the pollutants or deflects them into a retention chamber. More recent developments incorporate pollutant retention chambers and advanced trap-cleaning methods (Figure 8.22).

Floating GPTs have the advantage of portability and can be repositioned to areas that tend to collect litter (in eddies along rivers for example). Maintenance is easily monitored because of their high visibility.

The main limitations with floating traps relate to their

Figure 8.21 Early designs of floating traps were based on oil retention booms and prone to wind scour of collected pollutants. Richmond, Victoria (source: R. Allison)

Figure 8.22 Recent floating traps incorporate holding chambers for improved litter retention from wind and tide movements. Richmond, Victoria (source: R. Allison)

limited holding capacity, poor capture efficiency during high flows and maintenance difficulties. Recent designs incorporate submerged barriers suspended below floating traps and pollutant retention chambers, in an attempt to increase holding capacity and prevent losses from wind or tidal movements. However, when flow velocities increase, this material is often washed out from beneath a trap or entrained in the flow around the boom arms.

Floating traps are typically maintained from boat access, which can be time consuming and expensive. Some small booms are manually cleaned with vacuum devices. Specially designed barges are now used to streamline this process. Flood flows can present difficulties for floating traps positioned in the lower reaches of waterways, subjecting them to large forces, and their inability to bypass high flows. Their structural integrity can be compromised when subjected to high velocities and this reinforces the importance of site selection in slow-moving waterways.

Siting of floating traps is a key consideration. The main issues include selecting areas where flow velocities are low, where litter tends to accumulate, where they are protected from high flows and not in the way of waterway traffic.

8.6.5 Sediment traps

Sediment erosion and transport control is another important area of water management. In the past, much attention has been given to sediment management. Most state and local government authorities have produced manuals and guidelines relating to management of sediment. Local conditions and soil type influence the way in which sediment is managed. Local documentation should be considered when investing in or designing measures for sediment control e.g. NSW Department of Housing (1998).

Sediment in runoff can result in adverse physical and chemical impacts (see Chapter 2). There are many physical measures for sediment management in runoff, ranging from source control (including construction practices), street sweeping to sediment traps and settling basins. When assessing options, the magnitude of sediment loads during and after development activities should be considered.

Sediment loads from urbanising catchments vary considerably. For example, NSW Department of Housing (1998) reports soil loss from residential developments during construction of 470 t/ha/yr, whereas a study in Brisbane (BCC 2001) reports gross pollutant load rates of 355 kg/ha/yr (wet), of which sediment represented approximately 80%. Compounding this variation, fine sediment in suspension is not retained by GPTs and can represent a significant proportion of the total sediment load. Marsalek (1992) categorised expected sediment loads according to catchment characteristics (Figure 8.24). Methods for estimating soil erosion are well established (NSW Department of Housing 1998) while some authorities have produced charts based on local knowledge (ACT Government 1994).

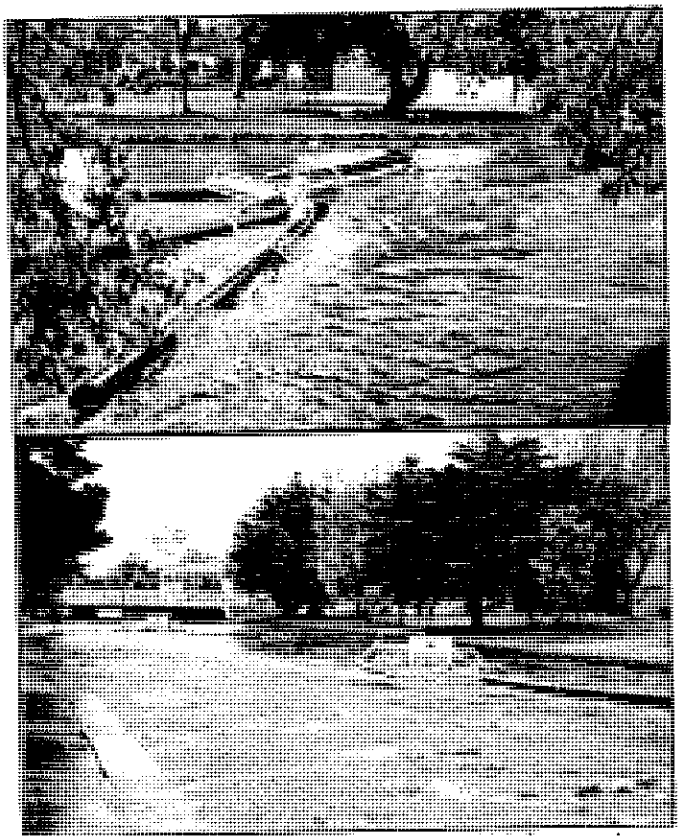

Figure 8.23 Floating traps can be subjected to high forces and velocities during flood events that can compromise their structural integrity. Elwood, Victoria (source: R. Allison)

There are a number of sediment traps available to control sediment transport once mobilised. These range from simple earthen or concrete basin designs to complex structures using vortices and secondary flows for sediment retention. Each

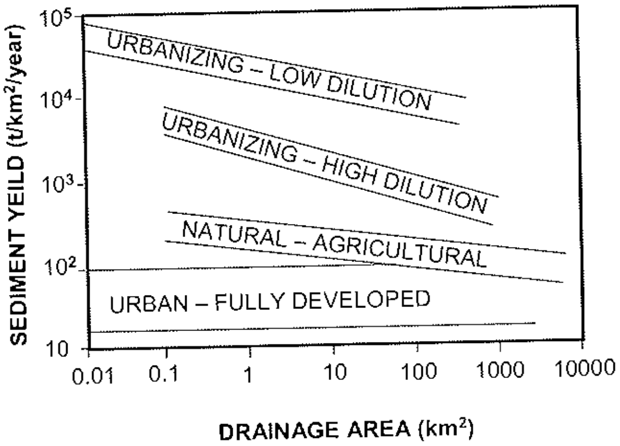

Figure 8.24 Estimated sediment yield from urbanising areas (source: Marsalek 1992)

trapping system aims to create favourable flow conditions for sedimentation, but the footprint per unit of flow for each device varies depending on the processes employed.

The two processes of sediment removal involve employing fine screening or secondary flow motions (e.g. Smisson 1967; Brombach et al. 1993; Wong *et al.* 1996) and others use simple sedimentation processes (e.g. Willing and Partners 1992). Devices using secondary flow patterns or screening systems, including direct screening and non-clogging screen GPTs, are typically proprietary products and design information is limited.

The basin type sediment traps can be concrete basins (Figure 8.25) or more natural ponds constructed with site soils (Figure 8.26). They retain sediments by simply enlarging a channel so that velocities are reduced and sediments settle to the bottom.

There are also smaller scale sediment traps which can be fitted into stormwater drainage pipe network systems including some proprietary products.

Proprietary products are usually maintained with vacuum equipment. For simple basin sediment traps, maintenance is performed by excavating collected sediments following dewatering of the basin or pond. This can involve significant works and disturbance to an area. Therefore, sediment traps (or basins) are designed for maintenance frequencies of one to five years, depending on the catchment disturbance and activities.

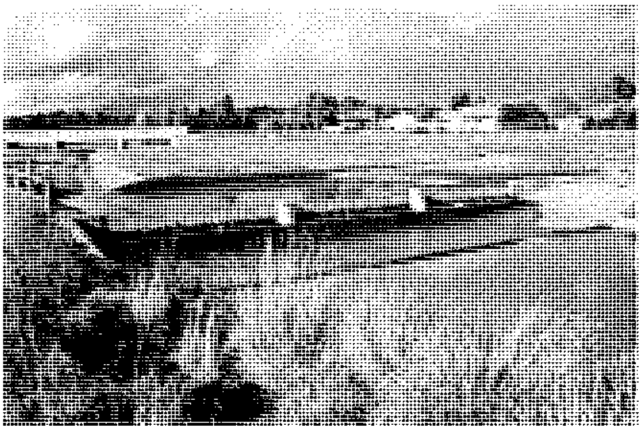

Figure 8.25 Concrete sediment basin upstream of trash racks are extensively used in Canberra to remove coarse sediments. Girralang Creek, ACT (source: I. Lawrence).

Figure 8.26 Sediment traps can also be well landscaped and integral with other treatment such as wetlands. Perth, Western Australia (source: T. Wong)

The cleaning procedure involves dewatering the basin, removing sediments and re-establishing the area. The nature of collected pollutants can determine their suitability for disposal. Sediment traps are typically designed for coarse sediments only (typically larger than 0.125 mm) and this material is expected to have relatively low quantities of contaminants but should nevertheless be monitored during maintenance.

A basic sizing procedure for sediment settling basins is provided below based on theoretical sedimentation velocities.

Sizing sediment basins

The process of sedimentation removes the heavier sediments from the water column. Sediment basin dimensions are designed so that flow velocities provide sufficient detention time for suspended particles to settle to the bottom of a basin. The specification of the basin area (A) may be based on the expression by Fair and Geyer (1954) for wastewater sedimentation basin design:

$$R = 1 - \left(1 + \frac{1}{n}\frac{v_s}{Q/A}\right)^{-n} \qquad - \qquad 8.1$$

where R is the fraction of initial solids removed

v_S is the settling velocity of particles

Q/A is the hydraulic loading

n is the turbulence parameter.

The above equation is strictly applicable for systems with no permanent pool (i.e. dry basins), and may be rewritten as follows (Equation 8.2) to account for the effect of the permanent pool storage. The permanent pool influences the flow velocity in the detention basin but not the detention period required to allow the particle size to settle below the invert of the outlet structure.

$$R = 1 - \left[1 + \frac{1}{n} \cdot \frac{v_s\left(S_p + S_e\right)}{Q \cdot d}\right]^{-n} \qquad - \qquad 8.2$$

where R is the fraction of initial solids removed

v_S is the settling velocity of particles

Q is the design flow rate

n is the turbulence parameter

d is the depth range of the extended storage

S_p is the volume of the permanent pool

S_e is the volume of the extended detention.

Field-settling velocities are often significantly lower than laboratory-derived settling velocities, owing to natural turbulence created by wind and aquatic fauna in the water body. It is often suggested that settling velocities of half the theoretical velocities of sediments should be adopted in sizing sedimentation basins. Table 8.2 lists typical settling velocities of sediments.

8.7 GPT PERFORMANCE ASSESSMENT

It is extremely difficult to validate the performance of a GPT. Independent data should be sought wherever possible.

The amount of material captured in existing GPT installations is useful only as a general guide to performance. These commonly collected data can, however, be useful for efficient maintenance scheduling.

GPT removal rates are a function of the amount of runoff treated (i.e. the quantity of flow diverted into a GPT compared with that which bypasses) and the pollutant removal rate for flows that go through a GPT (i.e. treated flows).

There are three broad ways of assessing the gross pollutant removal performance of a GPT. Field monitoring can be performed, although this can be time consuming, expensive and sensitive to individual catchment characteristics and rainfall patterns (limiting transferability of results). Physical scale models can be constructed in laboratories and computer simulations of performance can be conducted. However, both have limitations in representing the characteristics and variation of gross pollutants.

Advantages and disadvantages of the three methods are discussed in the next sections.

8.7.1 Field monitoring of GPTs

Many people mistakenly report the amount caught in a GPT as a representation of its trapping performance. However, as loads vary considerably between catchments and storm events, a large amount caught does not necessarily represent a well performing GPT. Only field studies that assess the quantity of material that passes downstream compared with that caught by a GPT produce an effective assessment of performance.

The amount of material passing a GPT (through the device or via bypass) can be assessed by quantifying the bypass flows (e.g. with flow sensors) and extrapolating gross pollutant loads from flow data, or by using a trapping device downstream (e.g. another GPT). Quantities of material trapped in a GPT can then be compared with that which flowed downstream.

Field monitoring needs to assess a device during several events, particularly to establish the conditions under which bypass will occur (related to the inflow rate or the amount of material previously captured). In general, at least six and preferably ten events of varying intensity and duration (at least one event should be large enough to bypass the unit) should be monitored to give a good representation of trapping performance.

Field monitoring can be an expensive and difficult exercise. Therefore, few performance studies have been conducted that monitor gross pollutant loads downstream of a GPT (which provide the best assessment of trapping performance).

8.7.2 Physical laboratory models of GPTs

Physical hydraulic scale models of GPTs can be useful for optimising the hydraulics of a GPT during the development stages. However, physical hydraulic scale modelling results are usually unsuitable for determining capture performance because it is often not possible to derived comparably scaled gross pollutants.

Table 8.2 Settling velocities under ideal conditions (Maryland Department of Environment 1987)

Classification of particle size range	Particle diameter (μm)	Settling velocities (mm/s)
Very coarse sand	2000	200
Coarse sand	1000	100
Medium sand	500	53
Fine sand	250	26
Very fine sand	125	11
Coarse silt	62	2.3
Medium silt	31	0.66
Fine silt	16	0.18
Very fine silt	8	0.04
Clay	4	0.011

The difficulty relates to the scalability of gross pollutants for a laboratory trial that would adequately represent the range of specific gravities and shapes of typical urban gross pollutants. In many instances, hair and very fine material cause screen blockages in GPTs, resulting in frequent bypass. These materials are difficult to scale down to an appropriate size to suit a scale physical model. When large material is used in laboratory models, it tends to overestimate trapping performance. In addition, it is often difficult to simulate the changing nature of gross pollutants because they can change their buoyancy and shape during storm events.

However, there are instances where hydraulic modelling using actual pollutants obtained from the field is acceptable for certain types of structures. When tests can be conducted at full scale, such as for road surface gully pit (or side entry pit) gross pollution traps, results are expected to be reliable.

Note that traditional scale modelling of hydraulic structures that don't involve pollutants is still valid. An example is scale modelling of a GPT in a blocked or full condition for determining hydraulic headloss characteristics.

8.7.3 Computer simulation of GPT performance

The use of Computational Fluid Dynamic (CFD) models for simulating performance of hydraulic structures is a well-established but specialised, field of investigation. These models are used extensive in Europe and the USA to simulate performance of swirl concentrators for sewage separation. Modelling capabilities include tracking solids of different specific gravity within a three-dimensional space and they can be useful in defining the performance of GPTs in trapping solids through the process of settling and screening. The trapping of particles smaller than the screen size can be simulated as will the possible remobilisation of trapped material during above design flow conditions. CFD modelling can also simulate progressive blocking of screens as well.

It is envisaged that CFD modelling can be used in conjunction with physical modelling of GPT to provide a common platform for benchmarking these devices. Elements of physical scale modelling can be used to define fluid dynamics and particle motion for selected flow conditions and particle characteristics. The results from the physical model can then be used to calibrate a CFD model such that the model can subsequently be used to simulate the performance of GPTs under varying steady and unsteady hydraulic loading conditions and gross solids characteristics.

8.8 SELECTING A GPT

A decision of which type (and brand) of GPT to select is a trade-off between the life cycle costs of the trap (i.e. combined capital and ongoing costs), and its expected pollutant removal performance considered against the values of the downstream water body and any other social considerations.

A life cycle cost approach is recommended. This approach allows the ongoing cost of operation to be considered and the benefits of different traps to be assessed over a longer period. The overall cost of a GPT is often determined by the maintenance costs rather than the initial capital costs.

The decision should be taken in consultation with operational staff (the people who will clean it) as well as local community representatives (the people who will be affected by it). Consultation at an early stage will reduce the chance of issues relating to its acceptance or operational issues arising later, avoiding costly remedial works.

This section highlights issues that should be considered. The issues raised are primarily based on experience with existing GPT installations. A condensed checklist of pertinent points on which to compare GPTs is provided at the end of the chapter.

8.8.1 Life cycle costs

Life cycle costs are a combination of the installation and maintenance costs and provide an indication of the true long-term cost of the infrastructure. It is particularly important to consider life-cycle costs for GPTs because maintenance costs can be significant compared with the capital costs of installation. Version 3 of the MUSIC model (CRC for catchment Hydrology, 2005) provides a methodology that can be used to estimate life cycle costs for GPTs (see Chapter 14).

To determine life cycle costs, an estimated duration of the project needs to be assumed (e.g. 20 or 25 years) or if the trap is to control pollutants during the development phase only (for example, a sediment trap) it may be three to ten years.

Life cycle costs can be estimated for all traps and then, with consideration of the other influences (expected pollutant removal, social, etc.), the most appropriate trap can be selected.

8.8.2 Installation costs and considerations

Installation costs include the cost of supply and installation of a GPT. These prices should be evident on proposals for GPT installations but it is important to check that all installation costs are included. Variables related to ground conditions (such as rock or groundwater conditions) or access issues may vary construction costs significantly. Cost implications should be assessed. The likely occurrence of these issues should be weighed up when estimating total installation cost.

Tenders should cover:

- price for supply and installation (not just supply)
- provision for rock or difficult ground conditions
- proximity to services (and relocation costs)
- required access and traffic management systems for construction.

A true installation cost should then be used when estimating life cycle costs.

Ensuring that the trap will suit local conditions is as important as calculating true installation cost. Issues that should be assessed to ensure that a GPT will suit the area include:

- the size of the unit
- hydraulic impedance caused by the trap
- particular construction issues.

More details of the points to consider are outlined below.

Size of the unit (footprint, depth)

Litter traps vary considerably in size, which must therefore be factored into the choice of location. Considerations when assessing the size of traps include:

- required footprint (plan size of trap and diversion)
- depth of excavation (to the bottom of the sump in some cases) – rock can substantially increase installation costs
- sump volume required
- proximity to groundwater
- location of any services that impact construction and likely cost for relocation (e.g. power, water, sewer).

Hydraulic impedance/ requirements

Some litter traps require particular hydraulic conditions to operate effectively. For example, some traps require a drop in a channel bed. Such requirements can affect the suitability of traps in a particular area.

Other considerations are possible upstream impacts on flow and a hydraulic gradeline because of the installation of the trap. This can increase the risk of flooding. Traps should be designed to avoid increasing the risk of flooding during high flows. If a trap increases the risk of flooding above acceptable limits it should not be considered further.

Other construction issues

For each specific location there will be several other considerations and points of clarification that may sway a decision on which trap is the most suitable. These include:

- Does the cost include diversion structures that will be required?
- Is specialist equipment required for installation (e.g. special formwork, cranes or excavators) and what cost implications do these have?
- Is particular below-ground access required, will ventilation and other safety equipment be needed – at what cost?
- Will the trap affect the aesthetics of an area – will landscape costs be incurred after the trap installation – if so, how much?
- Will the trap be safe from interloper or misadventure access?

- Do the lids/covers have sufficient loading capability (particularly when located within roads) – what is the cost of any increase in load capacity and will it increase maintenance costs?
- Will the trap be decommissioned (e.g. after the development phase) and what will this cost – what will remain in the drainage system?
- Are there tidal influences on the structure and how will they potentially affect performance or construction techniques?
- Will protection from erosion be required at the outlet of the device (particularly in soft bed channels), and what are the cost implications?

8.8.3 Maintenance costs and considerations

Maintenance costs, which are sometimes the most critical variable, can be more difficult to estimate than installation costs. Variations of the techniques used, the amount of material removed and the unknown nature of the pollutants exported from a catchment (thus disposal costs) all influence maintenance costs. It is therefore imperative to carefully consider the maintenance requirements and estimate costs when selecting a GPT or sediment trap. Tenderers should be asked to quote annual maintenance prices.

One important step is to check with previous installations by contacting the owners and asking their frequency of cleaning and annual operation costs (vendors can usually supply contact information).

Maintenance activities should not require manual handling of collected pollutants because of safety concerns with hazardous material.

Maintenance considerations for GPTs and sediment traps: are listed below

- Is special maintenance equipment required (e.g. large cranes, vacuum trucks or truck-mounted cranes)? Does this equipment need to be bought or hired, at what cost?
- Is special inspection equipment needed (e.g. access pits)?
- Are any services required (e.g. washdown water, sewer access)?
- Are there overhead restrictions (e.g. powerlines or trees)?
- Does the water need to be emptied before the pollutants? If so, how will it be done, where will it be put and what will it cost?
- Can the device be isolated for cleaning (especially relevant in tidal areas)?
- Are road closures required and how much disturbance will this cause?
- Are special access routes required for maintenance (e.g. access roads or concrete pads to lift from), and what are these likely to cost?
- Is there a need for dewatering areas (e.g. for draining sump baskets) and what implications will this have?

Disposal costs

Disposal costs depend on whether the collected material is retained in wet or free-draining conditions. Handling of wet material is more expensive and requires sealed handling vehicles.

- Is the material in a wet or dry condition and what cost implications are there?
- Are there particular hazardous materials that may be collected and will they require special disposal requirements (e.g. contaminated waste)? What cost implications are there?
- What is the expected load of material and what are likely disposal costs?

Occupational health and safety

- Is there any manual handling of pollutants and what will safety equipment cost?
- Is entering the device required for maintenance and operating purposes – will this require confined space entry? What are the cost implications on the maintenance cycle (for example, minimum of three people onsite, safety equipment such as gas detectors, harnesses, ventilation fans and emergency oxygen)?
- Are adequate safety features built into the design (e.g. adequate step irons and inspection ports) or will these be an additional cost?

8.8.4 Miscellaneous considerations

Social considerations can be an important component of the selection of a GPT. Consultation with key stakeholders is fundamental to selecting an appropriate GPT. Influences on the decision process may include:

- potential odour concerns at a location
- likelihood of pests and vermin such as mosquitoes or rats
- suitability of the GPT materials, particularly in adverse environments (e.g. marine)
- impact on the aesthetics of an area
- education and awareness opportunities
- potential trapping of fauna (e.g. turtles, eels and fish).

These issues should be considered early in the selection process and taken into account when finalising a GPT type.

8.9 CHECKLIST FOR SELECTING A GPT

A checklist is provided in Appendix A as a quick reference to the main issues related to selecting a gross pollutant or sediment trap.

8.10 REFERENCES

ACT Government, (1994), *Standard Engineering Practices: Urban Stormwater*, Ed.1, ISBN 0 644 332 74 3.

Allison R.A., Chiew F.H.S. and McMahon T.A., (1998), *A decision-support-system for determining effective trapping strategies for gross pollutants*, Report 98/3, Cooperative Research Centre for Catchment Hydrology.

Allison R.A., Walker T.A., Chiew F.H.S., O'Neill I.C. and McMahon T.A., (1998), *From Roads to Rivers: Gross pollutant removal from urban waterways*, Report 98/6, Cooperative Research Centre for Catchment Hydrology.

Brisbane City Council, (2001), SQIDs Monitoring Program Stage 4, Revision 1, Unpublished report.

Brombach H., Xanthopoulos C., Hahn H.H. and Pisano W.C., (1993), *Experience with vortex separators for combined sewer overflow control*, Water Science and Technology, Vol. 27, No. 5-6.

CRC for Catchment Hydrology, (2005), *MUSIC User Guide*, Version 3, May 2005

Fair G.M. and Geyer J.C., (1954), *Water Supply and Waste Disposal*, John Wiley and Sons, New York, Vol. 2.

Lloyd S.D. and Wong T.H.F., (2003), *Cost-Benefit Analysis of Structural Stormwater Management Strategies*, 3rd Pacific Stormwater Conference, Auckland, New Zealand, May.

Marsalek, J., (1992), Overview of sediment issues in urban drainage, *Proceedings*, First International Symposium on Urban Stormwater Management. I E Aust, Sydney.

Maryland Department of Environment, (1987), *Design Procedures for Stormwater Management Extended Detention Structures*, Baltimore, USA.

Melbourne Water, (2002), Selecting Litter Traps, draft report, unpublished.

NSW Department of Housing, (1998), *Managing Urban Stormwater: Soils and Construction*, (3rd Edition), ISBN 0731310969.

Smisson B., (1967), *Design, construction and performance of vortex overflows*, Institution of Civil Engineers Symposium on Storm Sewage Overflows, London.

Victorian Stormwater Committee, (1999), *Urban Stormwater: Best Practice Environmental Management Guidelines*, CSIRO Publishing, ISBN 0 643 06453 2.

Willing and Partners Pty Ltd, Water Resources Division, (1992), *Design Guidelines for Gross Pollutant Traps*, for ACT Planning Authority, Project No. 3015.

Wong, T.H.F, Wootton R. M. and Fabian D., (1996), A Solid Separator using a Continuous Deflective System, *Proceedings*, 7th International Conference on Urban Storm Drainage, Hanover, Germany.

Wong T.H.F., Wootton R., Argue J.R. and Pezzaniti D., (1999), *Bringing Order To The Pollution Control Industry:- Issues In Assessing The Performance Of Gross Pollutant Traps*, International Congress on Local Government Engineering and Public Works. ISBN 0-9586804-9-3.

APPENDIX 8A

CHECKLIST FOR SELECTING A GPT

This checklist has been designed to help stormwater managers identify relevant issues related to the purchase of a gross pollutant trap.

1. GENERAL

	YES	NO
• Is space available for the device (i.e. required footprint, access routes, services)?	☐	☐
• Does the location suit catchment treatment objectives (e.g. position in a treatment train)?	☐	☐
• Is the holding chamber suitable (wet or dry retention)?	☐	☐
• Are there sufficient safety precautions (i.e. preventing entry, access for cleaning)?	☐	☐
• Is the visual impact satisfactory (and odour potential)?	☐	☐
• Is the treatment flow sufficient to meet treatment objectives?	☐	☐
• Has the flooding impact been satisfactorily addressed?	☐	☐
• Has sufficient consultation taken place with operational staff and the local community?	☐	☐
• Is the expected pollutant removal rate sufficient to meet treatment objectives (consult with owners of existing installations if required)?	☐	☐

2. INSTALLATION

	YES	NO
• Does the price include installation?	☐	☐
• Are there sufficient contingencies for ground conditions (e.g. rock, shallow water table, soft soils etc.)?	☐	☐
• Have relocation of services been included?	☐	☐
• Are sufficient access or traffic management systems proposed as part of construction?	☐	☐

What are the cost implications of these points? $____________

3. MAINTENANCE

	YES	NO
• Is the method of cleaning applicable to local conditions (eg, OH&S issues, isolation of the unit from inflows etc.)?	☐	☐
• Are the maintenance (cleaning) techniques suitable for the responsible organisation (i.e. required equipment, space requirements, access, pollutant draining facilities etc.)?	☐	☐
• Is a maintenance contract included in the proposal?	☐	☐
• Is the size of the holding chamber sufficient (for a maximum of 12 cleans per year)?	☐	☐
• Have disposal costs been accounted for?	☐	☐

What are the cost implications of these points? $____________