6 Pollutant Control

6.1 Litter and Sediment Management

Figure 1. Gross pollutant trap upstream of Liege Street Wetland, Cannington. (Photograph: Department of Water 2004.)

Figure 2. Maintenance of a litter and sediment trap, upstream of Lake Goollelal, Kingsley. (Photograph: Department of Water 2006.)

Background

Litter and sediment management (LSM) systems are primary treatment measures that retain gross pollutants by physical screening or rapid sedimentation techniques. Gross pollutants generally consist of litter, debris and coarse sediments.

Litter includes human derived rubbish, such as paper, plastic, styrofoam, metal and glass. Debris consists of organic material including leaves, branches, seeds, twigs and grass clippings. Coarse sediments are typically inorganic breakdown products from sources such as soils, pavement or building materials. Gross pollutants are defined as debris items larger than 5 mm (Allison et al. 1997) and coarse sediments are defined as grain sizes greater than 0.5 mm diameter. Some of these pollutants are a threat to wildlife, degrade aquatic habitats, reduce aesthetic qualities, leach harmful pollutants and attract vermin.

Through the implementation of water sensitive urban design (WSUD) in stormwater management, the requirement for LSM devices has been significantly reduced, particularly due to the focus on retention of stormwater at-source and 'disconnecting' pollutant transport pathways. Non-structural control methods, such as litter collection programs, strategic bin design and placement, sediment controls on construction sites, street sweeping and minimising the use of deciduous plants in streetscape landscaping, also have significant potential to reduce litter and sediment inputs to the stormwater system. Refer to Chapter 7 for guidelines on these non-structural management measures.

Sediment can also be trapped using filtration techniques, such as buffer strips and swales, and infiltration and detention systems, such as infiltration basins and constructed wetlands, as described in BMPs 4.1, 3.1 and 5.2 in this chapter (refer to Table 2 in the Chapter 9 Introduction). These methods can also retain fine particles. Where implemented at-source, filtration and infiltration methods have the advantage of separating pollutants prior to being carried by flows into the stormwater system, thereby avoiding the difficulties associated with separating pollutants entrained in the flow.

Nevertheless, LSM systems still have a role to play in stormwater management to complement non-structural controls and as pre-treatment to other measures, such as constructed wetlands and bioretention systems, where upstream characteristics warrant their use.

LSM systems can be aesthetically unobtrusive as they require a relatively small footprint and can be situated below ground. They are suited for retrofitting to an existing piped drainage system, particularly in highly urbanised areas, and targeting specific problem areas with high loads of gross pollutants. Use of these systems assists in preventing blockages of drains and other conveyance based systems.

There are six commonly used LSM systems in Australia. These range from at-source treatment for the upper reaches of the catchment (e.g. side entry pit traps) to those intended for slow-moving waterways (e.g. litter booms) further down the catchment (Allison et al. 1997):

- **Side entry pit traps** are baskets fitted below the entrances to stormwater systems from road and carpark gutters. When stormwater passes through the basket into the side entry pit, material larger than the basket mesh (typically 5–20 mm) is retained. This material remains in the basket until it is cleaned out during required regular maintenance.
- **Litter control devices** are baskets sitting below the entry point of the inlet pipe. Water entering the baskets flows out through the openings, while debris larger than the pore size is retained. As debris builds up, it reduces the pore sizes, allowing smaller material to be caught.
- **Trash racks** consist of vertical or horizontal steel bars, typically 40–100 mm apart, fitted across stormwater channels or inlet and outlet pipes to receiving water bodies. When water passes through the trash rack, it retains material larger than the bar spacing. As material builds up behind the rack, finer material may also be collected.
- **Gross pollutant traps** (GPTs) typically consist of a sediment trap with a weir and trash rack at the downstream end. Flows enter a large typically concrete lined basin and are detained in the basin by a weir, decreasing flow velocities and encouraging sedimentation. The trash rack collects debris from flows overtopping the weir. GPTs servicing small catchments can be located below ground. These devices typically use a series of underground chambers, weirs, screens or baffles to control flows and trap sediments. An alternative below-ground system is a continuous deflective separation (CDS) device, which operates by diverting the incoming flow of stormwater and pollutants into a chamber that has a circular screen that induces a vortex to keep pollutants in continuous motion, preventing solids from ‘blocking’ the screen. The secondary flows induced by the vortex concentrate sediment in the bottom of the unit. Water passes through the screen and flows downstream.
- **Floating debris traps**, or litter booms, are made by placing partly submerged floating booms across waterways to trap highly buoyant and visible pollutants such as plastic bottles. The booms collect floating objects as they collide with it. Newer designs use floating polyethylene boom arms with fitted skirts to deflect floating debris through a flap gate into a storage compartment. Floating booms are not suited to fast moving waters. Additionally, the traps miss most of the gross pollutant load because only a small fraction of gross pollution remains buoyant for a significant length of time.
- **Sediment basins** may be concrete lined, or built as more natural ponds excavated from the site soils and stabilised with fringing vegetation. The basins consist of a widening and/or deepening of the channel so that flow velocities are reduced and sediment particles settle out of the water column. Macrophytes planted in and around the basin will assist in minimising the risk of sediment re-suspension. A pervious rock riffle or weir at the outlet may also assist filtering the water and preventing the conveyance of sediment downstream. Sediment basins are often used as pre-treatment to remove coarse sediment prior to flow entering a constructed wetland system.

Other types of litter and sediment traps include (Victoria Stormwater Committee 1999):

- **Grate and side entrance screens**, which consist of metal screens that cover the inlet to the drainage network and prevent large litter items from entering and blocking the drain.
- **Baffled pits**, where a series of baffles are installed in a stormwater pit to trap floating debris and encourage sediments to settle.
- **Circular settling tanks**, consisting of a cylindrical concrete tank installed below ground that is divided into an upper diversion chamber and a lower retention chamber. A diversion weir at the inlet directs stormwater into the lower retention chamber where sediment settles to the base of the chamber. Flow

exits the chamber through a riser pipe. The inlet and outlet pipes are set at the same level, trapping some oil in the retention chamber.

- **Boom diversion systems**, where a floating boom diverts all low to medium flows into a screened off-line pollutant collection chamber, such as a baffled unit. Under high flow conditions, the boom floats and only deflects floating debris into the chamber, while the majority of flow passes under the boom and bypasses the trap.
- **Release nets** consist of a cylindrical sock made of netting that is secured over the outlet of a drainage pipe and captures all material larger than the pore size of the net. If the net becomes blocked or full, a mechanism is triggered to release the net from the pipe. The net moves downstream until it reaches the end of a short tether attached to the side of the drain that constricts the net opening and prevents the trapped pollutants from being released.

Performance efficiency

Manufacturers have developed a range of proprietary products designed to trap and separate litter and sediment from stormwater runoff. Most of these products have not been extensively independently tested in the field.

Removal efficiencies are often based on tests of scaled models in the laboratory or limited field testing. In addition, most gross pollutants cannot be sampled by traditional automatic samplers and have not been included in studies evaluating the impact of stormwater runoff on receiving waters.

Fletcher et al. (2003) reports the performance of litter and sediment management systems along with the rationale for these estimates and considerations for their application. Performance estimates for a range of pollutants are shown in Table 1.

While there is a lack of information regarding performance efficiencies locally, the failure to remove nitrogen and phosphorus, as shown in Table 1, is consistent with local studies reported in Martens et al. (2005), based on monitoring in Perth's western suburbs.

Table 1. Pollutant removal effectiveness (Fletcher et al. 2003)

Pollutant	**Expected removal**	**Comments**
Litter	10–30%	Depends on effective maintenance and specific design. 10% where trap width is equal to channel width, 30% where width is 3 or more times channel width.
Total suspended solids	0–10%	Depends on hydraulic characteristics; will be higher during low flow.
Total nitrogen	0%	Transformation processes make prediction difficult.
Total phosphorus	0%	Total phosphorus trapped during storm flows may be re-released during inter-event periods due to anoxic conditions.
Coarse sediment	10–25%	Depends on hydraulic characteristics; will be higher during low flow.
Heavy metals	0%	

Stormwater designers are recommended to check the claimed performance efficiency results of specific devices, examine the conditions the results were obtained under, ensure testing is independent and refer to guidelines, such as the Victoria Stormwater Committee (1999), for removal rate estimates in the absence of available data. For example, monitoring of a GPT capturing runoff from a 50 ha catchment in Coburg, Melbourne, over a period of 3 months found the unit trapped practically all gross pollutants (Allison et al. 1997). The device was also found to have minimal impact on flows in the drain. However, it should be noted that for the purposes of the study, the trap was cleaned after every storm, and the CDS unit was used as a downstream control in combination with side entry pit traps installed at all road drain entrances in the catchment.

Cost

A life cycle cost method is recommended in assessing the true costs of LSM systems. This approach takes into consideration the capital costs as well as maintenance, servicing and spoil disposal costs over the life of the system.

Taylor (2005) details a range of costs for various LSM systems, but notes a very high degree of variability in most cost elements and urges caution in the use of the information provided.

Due to the high variability and lack of standardisation of available cost data, it is recommended that capital costs for individual LSM systems be assessed on a case by case basis. Annual maintenance costs presented in Taylor (2005) (cited as Weber 2001 and 2002) typically range in the order of 7 to 30% of the capital cost.

Design considerations

The principal design objective of LSM systems is to achieve a balance between the impact on the discharge capacity of the drainage system, the trapping efficiency of the unit and the capital and maintenance costs. The expected gross pollutant loading and trapping efficiency have a significant impact on the dimensions of the LSM system and its maintenance requirements.

The selection and positioning of LSM systems need to be strategic as these devices can be expensive to install and maintain. LSM systems should be used to target high litter generation areas, such as commercial areas. In areas with low litter generation rates, such as typically found in low density residential areas, source controls and non-structural methods are likely to be more cost effective. The recommended four steps to optimise the location of LSM systems are (adapted from Victoria Stormwater Committee 1999):

- Identify high litter generation areas from field inspections, examination of land use maps and consultation with council officers and community catchment groups.
- Determine the drainage pathways for each of the high litter generation areas from examination of drainage plans and field verification.
- Determine whether an at-source, in-transit or end-of-pipe LSM system would be most suitable for each area.
- Identify the most suitable and optimal locations for installing the LSM systems in order to achieve the maximum load of gross pollutants trapped per dollar spent on the project.

A guide to determining whether an at-source, in-transit or end-of-pipe LSM system is most suitable is provided below:

- **At-source LSM systems**, such as entrance litter baskets, are likely to be most suited to treat runoff from small sized high litter generation areas, for example a local commercial strip with up to ten shops. At-source systems should also be considered in medium sized high litter generation areas if runoff from the pollutant source areas flows to different drainage networks, or if the runoff combines with significant volumes of runoff from low litter generation areas downstream. In-transit LSM systems may not be cost effective in these cases as numerous units or a very large unit to treat high volumes of flow that carries low concentrations of litter may be required. The advantage of at-source systems is that the inlets that receive the most litter can be targeted. The disadvantage of distributed at-source systems is that the number of sites requiring maintenance is increased.

- **In-transit LSM systems** are generally most suitable to capture flows from medium to large sized high litter generation catchment areas (e.g. large shopping centres and light industrial areas with fast food outlets). In-line systems are most effective where the majority of the source area flows through one outlet and that outlet does not receive significant runoff from other low litter generation areas.
- **End-of-pipe LSM systems** are suited to medium to major high litter generation areas or where a number of smaller source areas are connected along the same drainage pathway.

The design of LSM systems must also consider that previously trapped material may be remobilised when high inflows causing turbulence or overflows occur.

There are also potential health risks to maintenance workers when handling litter and rubbish, particularly if contaminants have been left in an oxygen limiting environment (i.e. enclosed underground system) for an extended period. Retained water can become anaerobic due to decomposition of settled organics, possibly causing attached nutrients and heavy metals to become dissolved. Safety precautions in handling litter also need to consider potential needles and other sharp objects that may be in the trapped material. Due to the various potential health risks associated with handling litter, appropriate personal protective equipment should be used. Nuisance problems such as odour and mosquito breeding can also occur, particularly if the system is not operating correctly or if maintenance is required (e.g. removing accumulated litter). See Section 1.7.7 'Public health and safety' of the Introduction section of this chapter for more information on mosquito management.

Floating debris traps can also be visually unattractive.

Safety barriers may be required around LSM systems if they have steep sides or deep pools (children can drown in only 4 cm of water). To enable access and for public safety purposes, the bank slope of the trap or basin should typically be between 1:6 and 1:8 (refer to requirements of individual local authorities). Where the banks are too steep, railings, signage or vegetation can be used to discourage public access. If located within the floodway, railings should be aligned parallel to the main direction of flow so that they do not trap debris and contribute to flooding.

Vegetation can be used to disguise the LSM system, as well as prevent easy access to the structure. The appearance of a trap can be greatly improved by landscaping and the selection of construction materials. The use of local rock or coloured concrete in construction may also assist in minimising the visual impact.

Design guidelines

This section outlines important considerations when choosing a LSM system for site specific purposes. The guidelines are based on *Bringing Order to the Pollution Control Industry – issues in assessing the performance of gross pollutant traps* (Wong et al. 1999).

Location and layout

The factors to consider when assessing the suitability of a location for installing a LSM system are (adapted from Victoria Stormwater Committee 1999):

- the location of the LSM system in the treatment train and the presence of any other existing or proposed stormwater controls;
- the location in the drainage network relative to the identified high litter generation areas;
- stormwater system details (e.g. pipe sizes and gradients);
- space constraints such as the presence of underground services;
- vehicle access to the site for maintenance; and
- potential impacts on the community (e.g. disturbance during construction and maintenance, visual impacts, odours, or breeding of nuisance and disease vector insects).

The dimensions of a LSM system, the flow paths of stormwater through the system and the mechanisms used to intercept and retain gross pollutants are factors that determine its suitability for installation at a chosen site. Systems designed to capture both gross pollutants and sediment invariably require a larger area than systems designed to trap gross pollutants alone. This is due to the fact that sediment loads are often significantly higher than gross pollutant loads and the trapping mechanism involves flow retardation (i.e. expansion of the waterway to reduce flow velocity) to facilitate settlement of sediment.

The layout of the LSM system and the overflow path are important design considerations in ensuring adequate hydraulic performance of the trap under above-design and non-ideal flow conditions. The available space on-site will need to be compatible with the selected design discharge and the provisions for above-design and non-ideal flow operation.

Design flow

The appropriate design flow for a LSM system varies from one application to another.

The selection of the design discharge is primarily used to define the minimum height of the flow diversion or flow by-pass mechanism such that all flow at or below this design discharge will pass through the solids separation section of the LSM system. Flows in excess of the design discharge will either over pass or be diverted around the solid separation mechanism.

In LSM systems involving capture of sediment, principally by sedimentation, the minimum dimension of the sediment basin/chamber is set by matching the settling velocity of the targeted sediment size to the ratio of the design flow rate to the surface area of the basin. Remobilisation of settled sediments is an issue that may be addressed by setting the maximum flow velocity below that which is likely to cause re-entrainment.

The majority of storm events with the potential to mobilise and transport urban pollutants to receiving waters are events of relatively low rainfall intensity. This is demonstrated in Figure 3 which presents the overall percentage of the expected volume of the annual stormwater runoff treated by a LSM system, against the design standard of the system for urban catchments using a time of concentration of 1 hour (Wong et al. 1999).

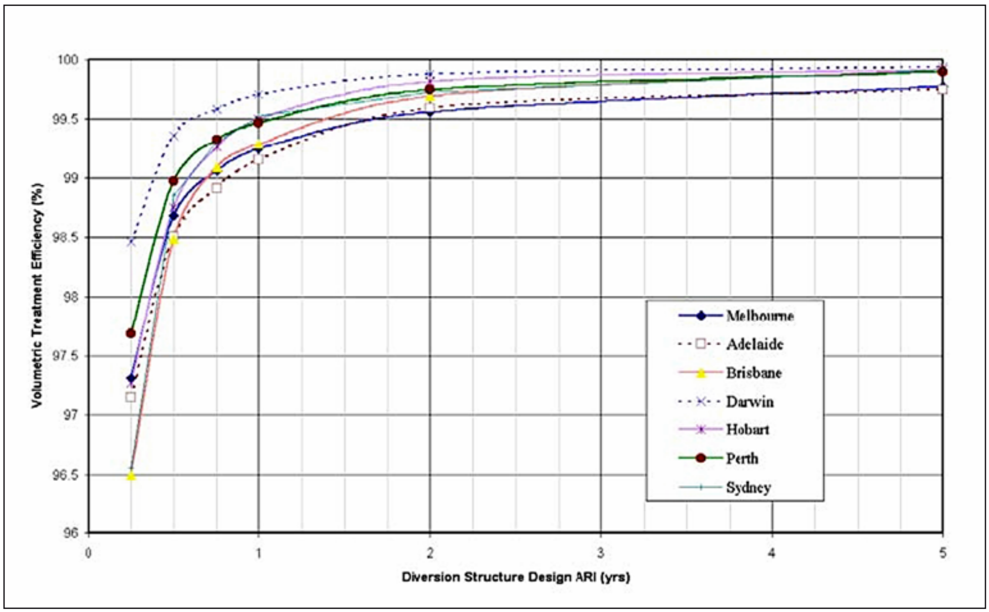

Figure 3. Treatment efficiency for various design ARIs. (Source: Wong et al. 1999.)

The volumetric treatment efficiency listed on the vertical axis of Figure 3 defines the percentage of the expected annual volume of runoff which can be expected to flow through the LSM system at a rate which is lower than the design discharge of the system. Analyses were carried out for catchments of different sizes with critical storm durations of 0.5, 1, 3 and 6 hours. The results for each of these cases were found to be similar in that most devices can be expected to treat over 95% of the expected annual runoff volume when designed for a 0.25 year average recurrence interval (ARI) peak discharge. The corresponding volumetric treatment efficiency for a device designed for a 1 year ARI peak discharge is approximately 99%.

These results are applicable to any type of hydraulic structure and clearly demonstrate that the design standard of structures need not be set excessively high to gain significant benefits in the overall proportion of stormwater treated.

All LSM systems are required to operate satisfactorily for larger events up to the discharge capacity of the stormwater drainage system in which the LSM systems are placed. The same operating criterion applies in the event of non-ideal conditions associated with situations when excessive inflow of gross pollutants has resulted in the trapping mechanisms being compromised or blocked. Above-design and non-ideal operation criteria include provision of the following:

- a controlled and predictable flow path for stormwater in excess of the design discharge (with predictable energy loss associated with these flow conditions);
- minimum reduction in the discharge capacity of the stormwater drainage system under above-design flow or non-ideal flow conditions; and
- protection of trapped material from being entrained with the flow and consequently transported out of the structure to the receiving waters.

Trapping efficiency

The trapping efficiency is defined as the proportion of the total mass of gross pollutants transported by stormwater that is retained by the LSM system. Common presentations of trapping efficiency data include reports of the weight or volume of gross pollutant removed. These reports are often provided without accompanying information that will enable computation of a mass balance between gross pollutant captured and that which has passed through the LSM system, making comparisons of different systems difficult.

While it is difficult to monitor field installations to satisfy a mass balance criterion, other data related to catchment area, rainfall, stormwater flow, and frequency and duration of above-design conditions, in association with the clean-out data, are helpful in developing a common basis for comparing performance.

Performance data for most LSM systems are confined to hydraulic behaviour under ideal conditions and without the interaction of the flow with urban derived litter and gross solids. This is considered inadequate for assessing the suitability and reliability of LSM systems in field conditions.

Continuous recording of water levels can often be used to assess the performance of a LSM system by identifying periods of non-ideal operating conditions. For example, observing the rate at which the water level in a GPT recedes at the conclusion of a storm event allows an assessment of the degree of blockage in the separation screen of the trap. Similarly, comparison of water levels on the upstream and downstream sides of a screen can often be used to estimate deterioration of the performance of the unit.

Gross pollutant characteristics and loading

Estimates of the gross pollutant loads are required when designing litter and sediment traps.

The composition by mass of gross pollutants and litter for Coburg, a suburb of Melbourne, is presented in Figures 4 and 5. Coburg is considered a typical example of inner city suburbs in Australian capital cities. The study found that in all land use types, a major proportion of the total gross pollutant load is made up of organic material such as leaves, twigs and grass clippings. When the gross pollutant data were sorted to examine the composition of litter, paper and plastics were found to be the dominant types.

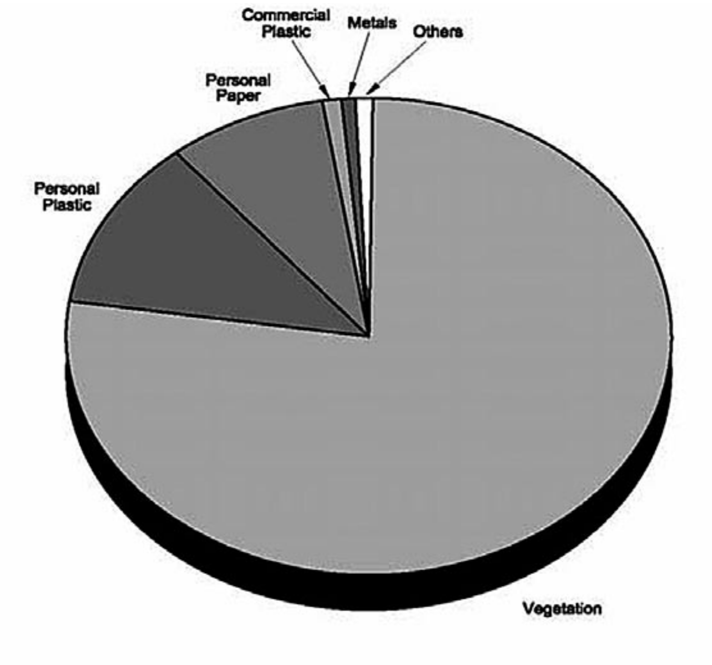

Figure 4. Composition of urban gross pollutants by mass. (Source: Allison et al. 1997.)

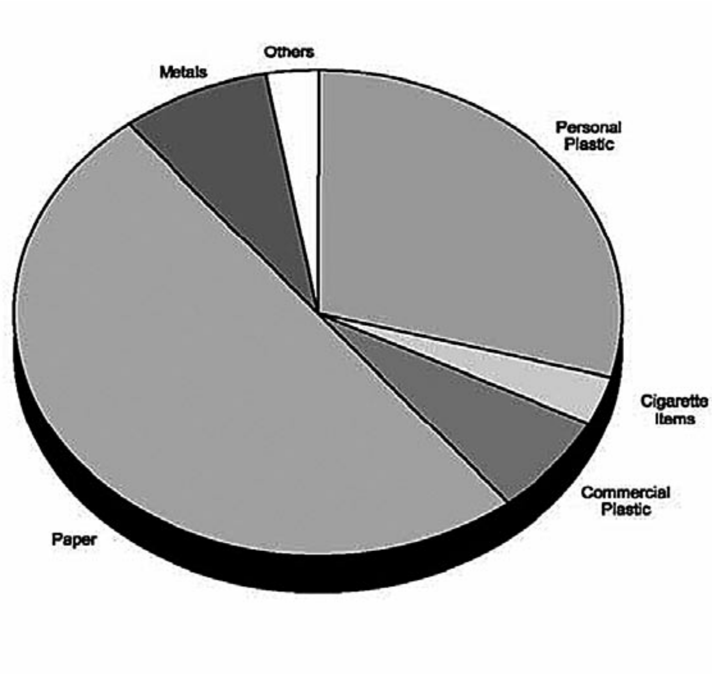

Figure 5. Composition of urban litter by mass. (Source: Allison et al. 1997.)

Studies by Allison et al. (1997, 1998a, 1998b) for the Coburg catchment provided nominal annual gross pollutant (i.e. material greater than 5 mm in size) load estimates of approximately 90 kg/ha/yr (wet weight). In their analysis, it was found that the typical pollutant density (wet) is approximately 250 kg/m^3 and the wet to dry mass ratio is approximately 3.3 to 1. This gives the expected volume of total gross pollutant load as approximately 0.4 m^3/ha/yr. The results of these studies can be applied to estimate gross pollutant loads in cities with similar rainfall and runoff patterns.

Stormwater runoff in suburbs on the Western Australian coastal plain are likely to have lower loads of gross pollutants due to the higher infiltration rate and lower direct connectivity of the runoff pathways compared to Melbourne. The higher infiltration rate reduces surface water discharge and hence the potential for gross pollutant transport.

The studies also found that a high proportion of the total gross pollutant load consists of vegetation (i.e. leaves) and that urban derived litter, food and drink refuse (from fast food consumers) and cigarette refuse, constitutes approximately 30% of the total gross pollutant load. These items entered the drainage network mainly from commercial areas. Data have indicated that approximately 10% of gross pollution remains buoyant for a significant length of time.

The study by Allison et al. (1997) found that gross pollutant concentrations are highest during the early stages of runoff; however most of the load is transported during periods of high discharge. Similar loads and concentrations of gross pollutants were found in runoff from different storms that occurred on the same day. Therefore, LSM systems should aim to treat the maximum possible discharge and be able to accommodate multiple storms in one day.

Minimum dimensions

The minimum dimensions of the LSM system are dependent on the expected rate of sediment and gross pollutant exported from the catchment and the capture efficiency.

Efficient traps with small capacity for containment of trapped material require a high frequency of clean-out if the integrity of their trapping mechanism is not to be compromised.

Maintenance

Regular inspection and cleaning of LSM systems is essential to maintain their performance and prevent the devices from blockages or releasing pollutants. Poorly maintained devices can increase the risk of upstream flooding (Engineers Australia 2006).

The device should have a site specific maintenance plan, providing guidance on a suitable inspection regime, maintenance practices (including guidelines on the equipment to be used, health and safety procedures, waste disposal arrangements, etc.) and responsibilities. These plans should be prepared in consultation with relevant maintenance personnel. Health and safety procedures need to address handling trapped litter that may contain needles and other sharp objects.

Frequent inspection is initially necessary following installation of the device to develop an appropriate inspection and cleaning regime. Maintenance schedules should not be fixed, but reviewed regularly to reflect the performance outcome from ongoing monitoring and optimise the maintenance regime. Flexibility of the maintenance regime is required given the seasonality and uncertainty of rainfall patterns and pollutant accumulation rates. Inspection and cleaning (if required) immediately prior to the wet season is essential.

Opinions on the frequency and timing of cleaning vary. However, experience suggests that fixed interval cleaning by contract cleaners, combined with regular council audits may be the best combination in most instances. It means that the LSM systems are being cleaned and the costs are budgeted for. A notable exception is where the systems are situated above ground and pollutant build-up can be easily sighted, in which case cleaning on ‘demand’ may be more effective. Where wet sumps are installed, trapped pollutants may break down and release contaminants and nutrients back into the stormwater system. Under these circumstances, cleaning may need to be undertaken much more frequently. Stormwater managers are required to critically assess the adequacy of manufacturers’ recommended maintenance schedules.

The type of land use and industries upstream of the LSM system should be considered in predicting what types of pollutants are likely to be trapped in the device or sediments. Sediments in open basins may contain iron monosulphide black oozes and will require special removal techniques to prevent oxygenation and subsequent acid release and deoxygenation of the water body. In regions like Perth, there is evidence to suggest that accumulated sediments in urban areas are enriched with nutrients, heavy metals and hydrocarbons (Swan River Trust 2003). Management of handling, drying and final disposal of materials removed during desilting operations needs to be considered. Spoil excavated from sediment basins should be placed where it can not wash back into the basin or release contaminants back into the stormwater system. Areas disturbed by maintenance activities should be stabilised upon completion of the sediment removal works. Refer to BMP 2.2.2 'Maintenance of the stormwater network' in Chapter 7 for further guidance on managing sediments removed from the stormwater system.

Suitable equipment to extract the waste from the stormwater system needs to be used (e.g. for enclosed drains and pits, machinery that operates via suction rather than flushing). If the trap requires dewatering in order to remove solids settled at the base, then discharge of the liquid contents to the sewerage system or a wastewater tanker will need to be arranged. Depending on whether pollutants are collected on a solid surface or in a basket or sump, traps can be cleaned by hand or loader, by removing baskets by a crane truck, or by removing the contents of a sump with a vacuum truck.

An important factor is that there must be ready access to the device for the required type and size of vehicle. This service must be available in the area where the device is installed, otherwise transport costs become significant and there is the temptation to clean traps less frequently than required. The filter medium of some types of traps may need to be occasionally replaced if degraded or clogged.

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