The removal of urban litter from stormwater conduits and streams: Paper 3 - Selecting the most suitable trap

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Abstract

A large quantity of urban litter is finding its way into the drainage systems to become an eyesore and a potential health hazard. Many of the traps currently installed are, however, extremely ineffective at trapping and storing urban litter. An extensive review of some 50 designs indicated that only seven showed much promise for South African conditions, although one or two other designs may be suitable for specialised installations. This paper describes the seven most promising options and recommends a trap selection procedure. A preliminary assessment of the seven most promising trapping structures concludes that three designs - two utilising declined self-cleaning screens and the other utilising suspended screens in tandem with a hydraulically actuated sluice gate - are likely to be the optimal choice in the majority of urban drainage situations in South Africa.

Introduction

Urban litter, defined as visible solid waste emanating from the urban environment (Armitage et al., 1998), and henceforth called simply "litter, is extremely difficult to trap and remove once it has entered the drainage system.

Although the central areas of most South African towns and cities are provided with the normal civil engineering services, poverty and mismanagement have often led to the partial collapse of such basic services as litter collection and removal. Furthermore, many millions of people live in informal settlements on the urban fringe where services are rudimentary or non-existent. Runoff from rainfall soon carries the litter into the drainage system. To compound the problem, even in areas where formal stormwater drainage conduits exist, they are often used as a form of refuse removal. Grids cannot be placed over stormwater drainage entrances for fear of blockage and consequential flooding, and when they are provided, they are frequently stolen. For many, the struggle for survival takes precedence over care of the environment.

In view of the above, the Water Research Commission of South Africa funded a four-year study into the removal of urban litter from stormwater conduits and streams (Armitage et al., 1998) looking particularly at the design of litter traps. Some 50 different designs from around the world were evaluated in terms of a number of general criteria including:

- the size of catchment that could be serviced by the device (which is related to the runoff and the litter loads);
- the typical cleaning frequency;
- the hydraulic head requirement for operation;
- the efficiency (expressed as a percentage of litter removed from the flow);
- the capital and operating costs; and
- any other features that might make the structure attractive or unattractive to the potential user.

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The traps investigated included: in-line screens, self-cleaning screens, booms, baffles, detention/retention ponds, and vortex devices. In the end, seven patented devices were identified as showing the most promise for South African conditions - although one or two other designs may be suitable for specialised installations.

A rational selection procedure, presented in this paper, was then developed to assist designers with the choice of the optimal trap for a particular situation. Finally, the seven patented devices were evaluated for possible installation in a typical (hypothetical) catchment.

The most promising litter trap designs

Side-entry catchpit trap (SECT)

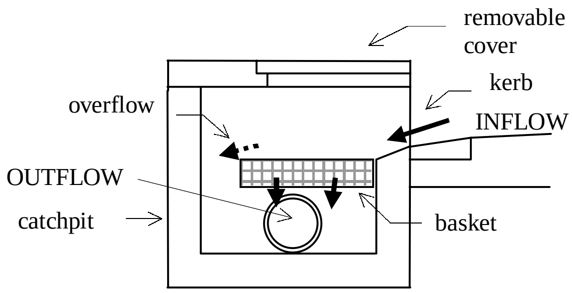


Figure 1
Cross-section through a typical SECT

A perforated tray is mounted on metal supports next to and underneath a catchpit opening (Fig. 1). Stormwater either flows through the perforations leaving the litter behind, or, if the perforations are blocked and/or the tray is full, the stormwater flows over the back wall of the tray. To remove the litter, the basket is either manually cleaned, or it is vacuum educted ("sucked" clean) and washed with water under high pressure (Melbourne Water, 1995).

The North Sydney litter control device (LCD)

A drop is provided in a pit between the invert of the inflow pipe and the invert of the outlet. This drop is in the order of a metre, which caters for removable baskets and a small gap below them. Above the removable litter baskets is an inclined trash rack with vertical bars. This trash rack is inclined towards the litter baskets to prevent the inflow from scouring out previously deposited litter. It is hinged so that it can be pushed back to enable easy removal of the litter baskets (Fig. 2) (Brownlee, 1995).

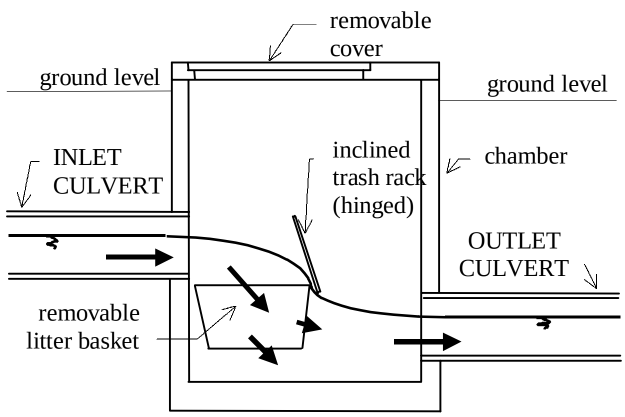


Figure 2
Section through a typical LCD

The in-line litter separator (ILLS)

A carefully shaped boom situated in the separator pit deflects the flow into the holding pit. Once in the holding pit, the flow is forced down under a suspended baffle wall and up over a weir before being returned to the separator pit downstream of the boom. The relatively large plan area of the holding pit ensures that the average vertical flow velocities are low enough to prevent carry-through of those objects, such as plastic bags, that have a negligible settling velocity (positive or negative) (Fig. 3).

In the event of particularly high flows through the stormwater conduit, the increased water levels on both sides of the boom causes it to float out of the way, ensuring that upstream flood levels are not affected by the structure, and the litter already trapped in the holding pit is not washed out. The boom is restrained by rods, which are attached to its upper surface and the walls of the chamber above the pipe inlet, in such a way that the boom is free to rotate about a hinge at the wall (Swinburne University of Technology, 1996).

The continuous deflective separation (CDS) device

The flow in a stormwater conduit is deflected into a circular pollutant separation and containment chamber. Gross pollutants are separated within the upper separation portion of the inner chamber with the aid of a perforated plate screen which allows the filtered water to pass through to a volute return system and back to the outlet pipe. The water and associated pollutant contained within the inner chamber are kept in continuous motion by the vortex action generated by the incoming flow. This has the effect of keeping the gross pollutant in the containment chamber from blocking the perforated plate screen. The heavier pollutants ultimately settle into the lower solids collection sump, whilst the flotsam floats on the surface of the containment chamber (Wong and Wooton, 1995) (Fig. 4).

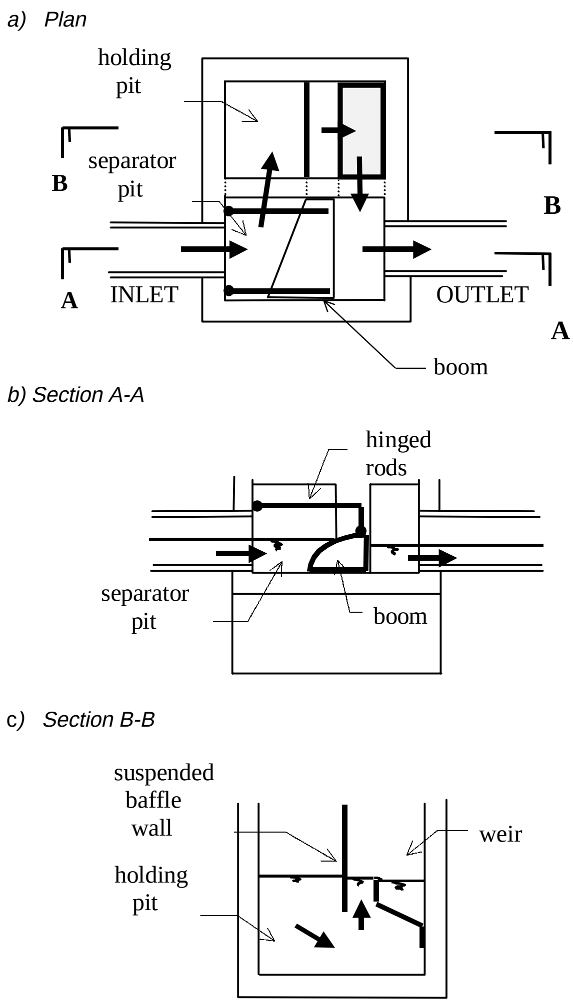


Figure 3
Plan of, and cross-sections through the ILLS

The Baramy® gross pollutant trap (BGPT)

Flow from a conduit is directed over a screen declined at an angle of about 20°. The water flows through the screen and either goes under the collection shelf (direct flow version), or around it (low profile version). The litter is separated from the water by the screen and is deposited on the collection shelf ready for removal by a skid-steer loader (Bobcat or similar) which gains access down a concrete ramp (Baramy) (Fig. 5).

The stormwater cleaning systems (SCS) structure

The SCS structure is similar to the BGPT except that the screen is mounted on the crest of a weir and is declined at approximately 45° below the horizontal. There are two alternative layouts: with the weir directly in the path of flow for small flows emanating from, say, a pipe; and with the weir lying parallel to the initial flow direction for the larger flows in canals. A settling basin can be provided upstream of the weir to trap the bed-load separately if required (Armitage et al., 1998) (Fig. 6).

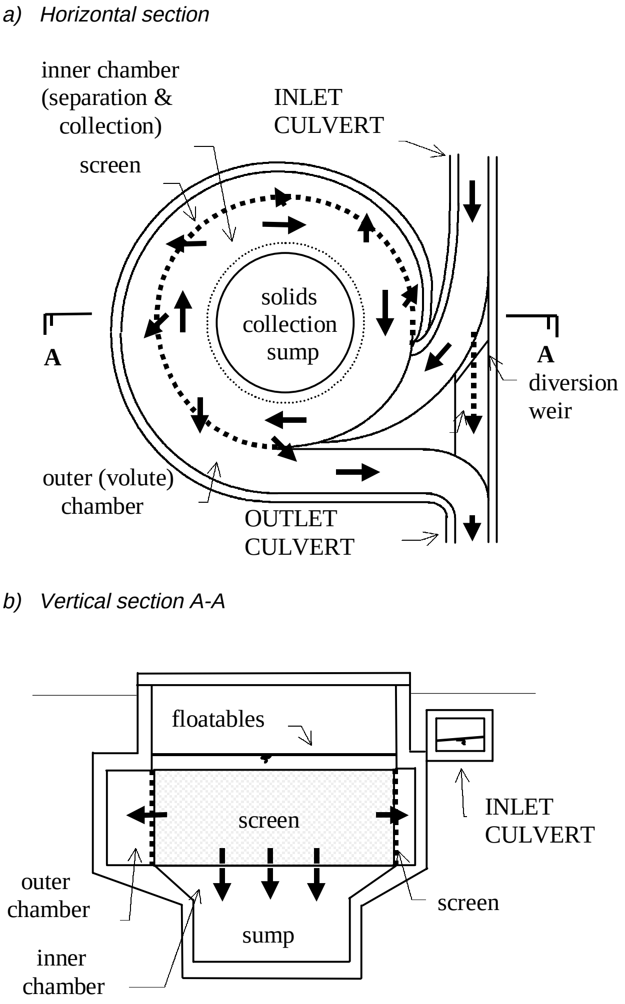


Figure 4
Horizontal and vertical sections through the CDS device

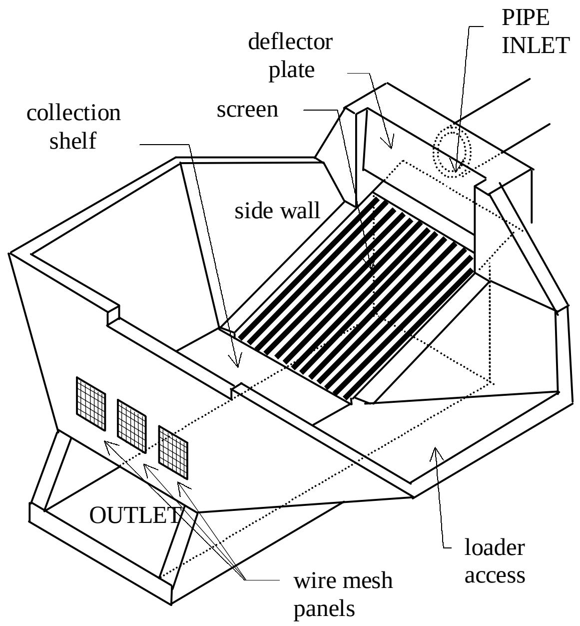


Figure 5
BGPT - typical direct flow version

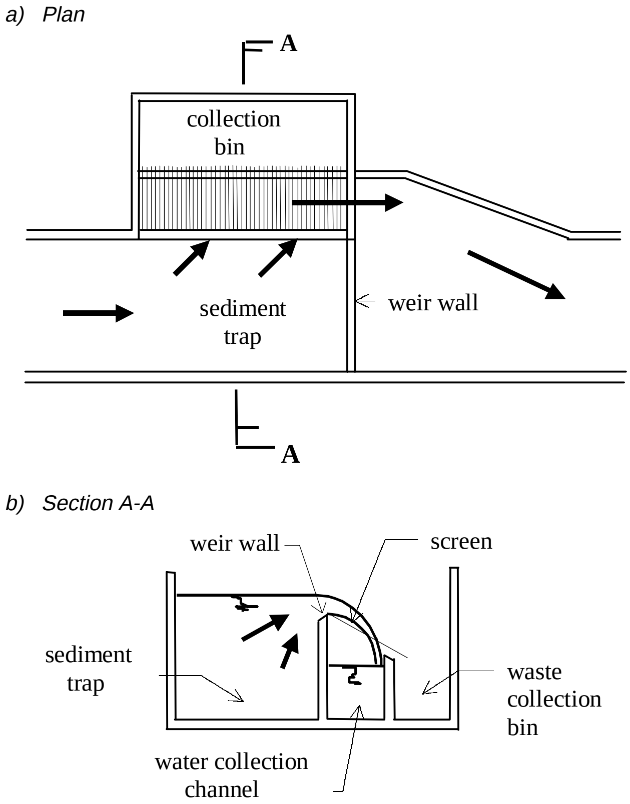


Figure 6
Plan of, and long-section through, the SCS structure

The urban water environmental management (UWEM) concept

A hydraulically controlled sluice gate is used to create the necessary head required to force the stormwater through a series of screens, under a suspended baffle wall and over a weir. In the event of a major flood coming down the channel, the sluice gate automatically lifts to pass the peak and prevent upstream flood levels from being raised higher than they would have been had there been no structure at all (Armitage et al., 1998) (Fig. 7).

The device is readily adapted to the removal of pollutants other than litter e.g. silt or sewage. It can be designed to handle very large flows. Its chief advantage however is that it can be applied in areas with flat gradients such as along the coast, as the head that is required to operate the trap is generated by the hydraulically operated sluice gate.

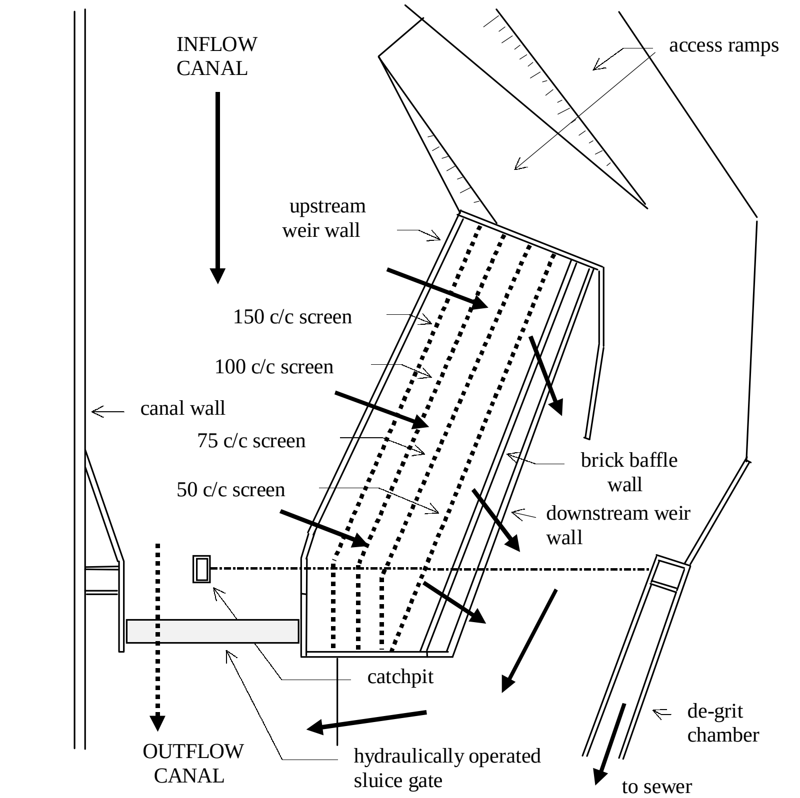
Other potential trapping structures

The investigation also indicated a potential application for some other devices in specialised situations. These included:

- booms (for the removal of surface material only);
- fences or nets across slow-flowing channels; and
- ponds / wetlands.

In every case, flow velocities must be kept low at all times, and cleaning/maintenance is a big problem (see Armitage et al. (1998) for further information).

a) Plan (not to scale)



b) Section through the screens (not to scale)

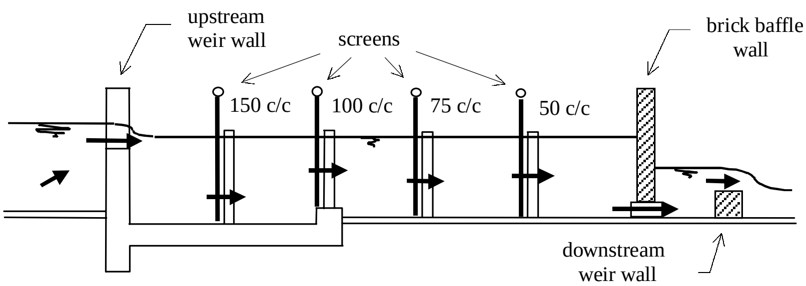


Figure 7
Plan of, and section through, the screens at the UWEM Pollution Control Works on the Robinson Canal, Johannesburg

The importance of trap location

The choice of trapping structure is site-specific. The location of the traps is therefore a key decision. Clearly, the closer to the source a trap is located, the smaller the flow and therefore the smaller the structure required. On the other hand, many more of these structures will be required to cover the entire catchment. The construction and maintenance of large numbers of smaller traps might well be greater than the construction and maintenance of one or two larger traps situated at the mouth of the main canal or the stream draining the entire catchment.

Trapping points and the typical associated structures may be loosely categorised as follows:

- entry (SECT);
- in-pipe (CDS, ILLS, LCD);
- end-of-pipe (LCD, CDS, SCS, BGPT); and
- canal / stream (BGPT, SCS, UWEM, fences or nets across streams, ponds and wetlands).

No trap is 100% effective. Furthermore, it is often more cost-effective to aim for a trap efficiency of, say, 70% and look to trap the balance at another point in the system. Many traps are only designed to handle peak flow rates in the region of 1:1 month recurrence interval (i.e. the structure is bypassed twelve times a year on average) to 1:2 years (which is the capacity of many conduits). The surplus flow - with its associated litter - is bypassed. Consideration should therefore be given to providing at least two lines of traps e.g. side-entry catchpits at key locations together with a number of in-pipe or end-of-pipe traps downstream.

Another important issue is access for cleaning and maintenance - particularly for the larger structures. Ease of maintenance is crucial. Trapping efficiency will rapidly fall to zero if the traps are not properly cleaned and maintained. In some instances, the cost of providing adequate access may be more than the structure itself.

The suitability of particular traps

Once suitable trapping points have been identified, the main criteria determining the suitability of a particular trap in that location are: the flow rate, allowable head loss, size, efficiency, reliability, ease of maintenance, and cost effectiveness. The first three items are site constraints, whilst the balance depend on the structure under consideration.

Considering only the site constraints, the available structures may be roughly divided into:

- "low flow" or "high flow";
- "low head" or "high head"; and
- "small", "medium" or "large".

where the division between "low" and "high" flow may be taken to be roughly 1m^3/s; the division between "low" and "high" head may be taken to be roughly 0.5 m; and structures may be described as "small" if they are contained wholly within the channel, "medium" if they are only slightly larger than the channel, and "large" if they require considerable extra space or if the channel must be widened.

The better available technologies may be loosely categorised as follows:

- low flow, low head structures ("small" - SECT, "medium" - ILLS, "large" - CDS);
- low flow, high head structures ("medium" - LCD, "large" - BGPT, SCS);
- high flow, low head structures ("small" - fences, nets, booms or baffles, "large" - UWEM, CDS); and
- high flow, high head structures ("medium" - BGPT, "large" - SCS).

TABLE 1
SUMMARY OF THE ATTRIBUTES OF THE SEVEN MOST PROMISING LITTER TRAPS

Device	Typical catchment area (ha)	Typical cleaning frequency	Head require-ment	Maximum efficiency (%)	Comments on performance
SECT	0.1 - 1	Monthly or after every major storm	Low (effectively)	59 - 76 (50 – 100% coverage respectively)	Need to be able to target the catchpits with the highest loads. The efficiency of the unit is strongly affected by the number of un-trapped catchpits and the cleaning frequency.
LCD	20 - 150	Monthly or after every major storm	High	25	Inefficient in high flows but collects most material at low to medium flows. Likely to be a relatively expensive option. Relatively easy to clean.
ILLS	5 - 25	Monthly or after every major storm	Low	25	Little data available. Likely to be a relatively expensive option. Moving parts may cause problems.
CDS	10 - 200	4 times a year	Low	99	Very efficient trapping device, but very expensive to install and tedious to clean.
BGPT	10 - 500	4 times a year	High	95	Little prototype data available, but shows considerable promise. Compact. Easy to clean.
SCS	>1	Monthly or after every major storm	High	95	Works well providing the head is available. Easy to clean.
UWEM	>400	After every major	Low (effectively)	90	The concept of generating head in-situ via a storm hydraulically actuated sluice shows considerable promise for use with other structures e.g. Baramy® , SCS.

The recommended selection procedure

Once the designer has some idea of the potential trapping point and associated structures, the recommended selection procedure is as follows:

1 Identify each catchment with its associated drainage system/ waterways. It may be necessary to divide the catchments into sub-catchments depending on the number, type and location of structures envisaged.

2 Identify and measure the area of each land use (A_i) within each catchment (the main categories being commercial, industrial and residential).

3 Estimate the total litter load (T) in each catchment area. In the unlikely event that there are existing litter traps of known efficiency already operating in the catchment/s, information gleaned from these traps would be used to estimate the total litter load/s. Otherwise, estimate the street cleaning service factor (f_{sci}), the vegetation load (V_i) and the basic litter load (Bi) for each land use in each catchment or subcatchment, and apply Eq. (1):

$$T = \Sigma f_{sci}.(V_i + B_i).A_i \qquad (1)$$

where:

T = total litter load in the waterways (m^3/yr)

f_{sci} = street cleaning factor for each land use (according to provisional South African data, this varies from 1.0 for regular street cleaning to about 6.0 for non-existent street cleaning/complete collapse of services)

V_i = vegetation load for each land use (m^3/yr) (according to provisional South African data, this varies from 0.0 m^3/ha·yr for poorly vegetated areas to about 0.5 m^3/ha·yr for densely vegetated areas)

B_i = basic litter load for each land use (m^3/yr) (according to provisional South African data:
commercial = 1.2 m^3/ha·yr
industrial = 0.8 m^3/ha·yr
residential = 0.01 m^3/ha·yr)

A_i = area of each land use (ha)

4 For each potential trap site, carry out an hydrological assessment of the flood peak versus frequency curve (Fig. 9) and the treated flow volume versus the design capacity of the structure curve (Fig. 10).

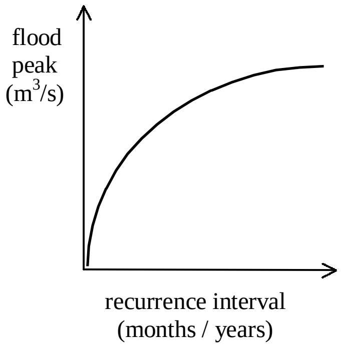


Figure 9
Schematic flood peak/frequency curve

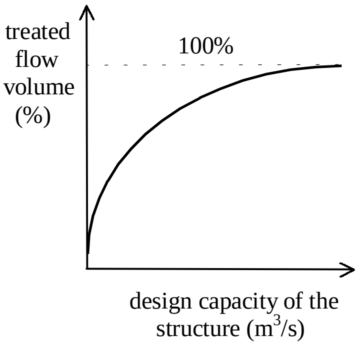


Figure 10
Schematic treated flow volume/design capacity of structure curve

The flood peak / frequency curve is a plot of the flood peak in m^3/s vs. the inverse of the probability of exceedance expressed in months or years and called the recurrence interval (RI). If a flow of, say, 1 m^3/s has a RI of 2 years, then it means that a flow of 1 m^3/s will only be exceeded once every two years on average. Alternatively there is a 50% probability of a flow of 1 m^3/s being exceeded in any one year.

The treated flow volume/design capacity of the structure curve expresses the percentage of the total flow volume intercepted by a structure vs. its design capacity. The calculation is shown schematically in Fig. 11.

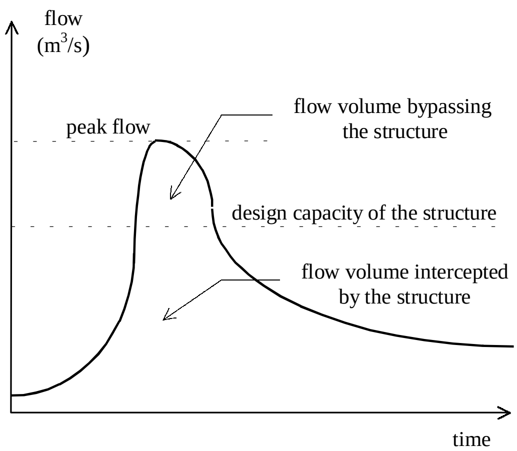


Figure 11
Typical flood hydrograph indicating the relative volumes intercepted by, and bypassing the structure

Its significance lies in the fact that trapping structures are seldom designed to handle the maximum expected flood peak. Usually they are designed to handle a much lower flow - typically with an RI in the order of a few months - on the assumption that the total flow volume bypassing the structure will be a relatively small percentage of the total. If the assumption (usually conservative) is made that the concentration of litter is constant (it usually decreases with high flows), then the overall trapping efficiency of the structure at any design capacity can be calculated from a knowledge of the proportion of flow passing through the structure. Once this is known, considerable cost savings can often be made at the expense of a minimal drop in efficiency by selecting a smaller structure with a slightly higher bypass ratio.

The hydrological assessment would typically be carried out with the assistance of one of the numerous urban hydrology computer packages. Alternatively, a rough estimate may be obtained with the assistance of the well-known rational formula by assuming triangular shaped hydrographs with flood durations of three times the time of concentration. Care must be taken to ensure that the capacities of any conduits are taken into account.

5 Consideration is now given to the candidate trapping structures. Once a preliminary selection has been made, the patent holders/suppliers should be contacted for more up to date information on design and cost.

6 Storm litter loads may be estimated from Eq. (2):

$$S = f_s.T/\Sigma f_{si} \qquad (2)$$

where:

- S = storm load in the waterways (m^3/storm)
- f_s = storm factor (according to provisional South African data, this varies from 1.0 for a storm occurring less than a week after a previous downpour; to about 1.5 for a storm occurring after a dry period of about three weeks; to about 4.0 for a storm occurring after a dry period of more than about three months)
- Σf_{si} = the sum of all the storm factors for all of the storms in the year (since this information is generally not available, a suggested alternative is to count the average number of significant storms in a year and multiply by 1.1)

7 The cost-effectiveness of the candidate structures may now be determined by means of an economic analysis. There are many ways of carrying out this economic analysis, but the simplest is described below:

a) For each particular structure, consider several design capacities with RIs varying between, say, 1:1 month (the structure is bypassed twelve times a year) to 1:2 years (which is the capacity of many pipe conduits). For each design capacity, obtain an estimate of the overall efficiency of the trap by multiplying the published trap efficiency by the percentage of flow volume treated by the structure, as previously determined in step 4. above, using Eq. (3):

$$\eta_o = \eta_s.\eta_f \qquad (3)$$

where:
η_o = overall efficiency of the installation
η_s = published efficiency of the structure
η_f = treated flow volume expressed as a fraction of the total flow

b) The required storage capacity can be calculated by multiplying the proposed average cleaning frequency in days by the average estimated storm load, S_{av} (determined with the aid of Eq. (2) above utilising a typical storm factor f_s for the area) and by the overall efficiency of the installation, and dividing this product by the average storm frequency (in days) during the wet season determined from municipal records. The calculation is shown in Eq. (4):

$$V_t = F_c . \eta_o . S_{av} / F_s \quad (4)$$

where:
V_t = required trap storage (m^3)
F_c = average cleaning frequency (d)
η_o = overall efficiency of the installation
S_{av} = average estimated storm load (m^3)
F_s = average storm frequency (d)

The storage capacity must also be more than the maximum storm load, S_{max}, which is determined from Eq. (2) utilising the maximum expected value of f_s.

c) For each particular type and size of structure, decide on the repayment period, and estimate the capital cost and the real interest rate (a reasonable approximation is to subtract the historic average inflation rate from the historic average nominal interest rate). The capital recovery amount may then be determined from Eq. (5):

$$A = P.i(1+i)^n/((1+i)^n-1) \quad (5)$$

where:
A = capital recovery amount (R/yr)
P = capital cost of the structure (R)
i = interest rate (expressed as a fraction)
n = repayment period (years)

Owing to inflation, the initial payments will be higher than the later payments in real terms, but this does not change the overall picture.

d) The total volume of litter that the trap is likely to intercept each year at each particular design capacity is obtained by multiplying the total litter load estimated in Step 3 above by the overall efficiency of the installation using Eq. (6):

$$L = T.\eta_o \quad (6)$$

where:
L = load trapped by the structure (m^3/yr)
T = total litter load (m^3/yr)
η_o = overall efficiency of the installation

e) The total annual cost of the structure is obtained by adding the annual capital recovery amount to the annual cost of cleaning and maintaining the structure using Eq. (7):

$$C_t = A + C_c \quad (7)$$

where:
C_t = total annual cost of the structure (R/yr)
A = capital recovery amount (R/yr)
C_c = annual cost of cleaning and maintaining the structure (R/yr)

f) The unit cost of litter removal for any particular structure and design capacity is obtained by dividing the total annual cost of the structure by the estimated annual load that will be trapped by the structure as expressed in Eq. (8):

$$C = C_t / L \quad (8)$$

where:
C = unit cost of litter removal (R/m^3)
C_t = total annual cost of the structure (R/yr)
L = load trapped by the structure (m^3/ha·yr)

Unit costs in terms of R/kg or R/ha may be obtained by dividing the unit cost of litter removal by the litter density, or by dividing the total annual cost of the structure by the catchment area respectively.

8 In theory, the trapping system may now be optimised to give the lowest overall unit cost of removal. In reality, a balance must be struck between the desire to achieve the lowest overall unit cost of removal, and the overall objective of removing as much litter from the aquatic system as is reasonably possible - in other words, achieving the maximum efficiency. This is a political decision which requires input from all the role players concerned with the removal of litter from the environment, including engineers, hydrologists, aquatic scientists, environmental interest groups, ratepayers and local government. One further caution: data on trapping structures are site-specific and highly variable. Costs and efficiencies may vary considerably from site to site.

The litter removal process is summarised in Fig. 12. The trap selection procedure is summarised in Fig. 13.

A preliminary assessment of the seven most promising litter traps

The trap selection procedure was applied to a hypothetical catchment making the following assumptions:

- the catchment comprises the CBD of a medium-sized town (50% commercial, 30% industrial, 20% residential);
- the catchment area is 100 ha (1 km^2);
- it is situated in the summer rainfall area of South Africa with a mean annual precipitation = 850 mm;
- the topography and layout permits the installation of any of the seven most promising litter traps;
- the underground drainage system is designed for 1:2 year recurrence interval (RI) storms;
- there are 400 catchpits (a density of 4/ha);
- there is regular street cleaning;
- there is no vegetation load;
- the runoff coefficient is 0.7 (70% of the storm rainfall is transported by the drainage system during the storm);

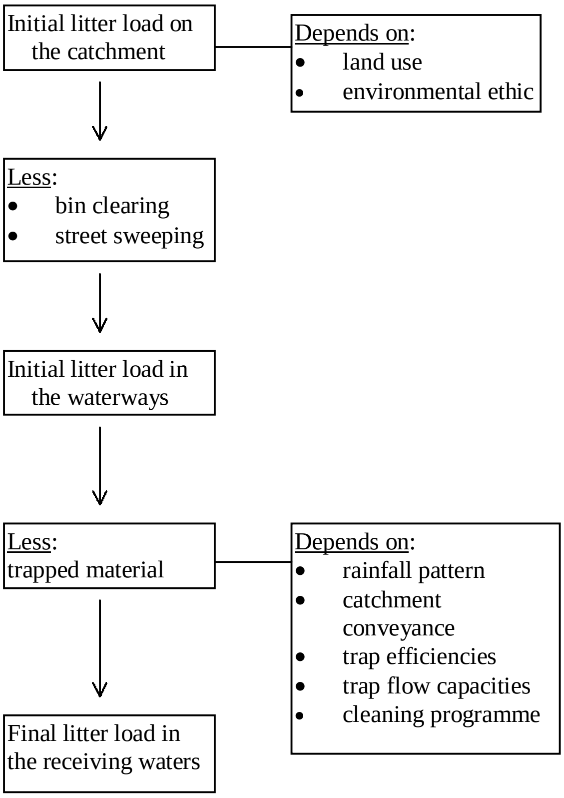


Figure 12
The litter removal process

- the time of concentration of the rainfall (the time theoretically taken for a rain drop falling on the most remote point of the catchment to reach the trap) = 30 min;
- there are 50 significant rainfall events (more than 1 mm rainfall) a year concentrated in the summer rainfall season;
- only recurrence intervals of 1:1 month and 1:2 years need be considered; the associated critical rainfall intensities were assumed to be 21 and 51 mm/hr respectively;
- the economic analysis is to be carried out assuming a repayment period of 20 years and a real interest rate (after taking inflation into account) of 6%.

TABLE 2
THE SEVEN MOST PROMISING LITTER TRAPS RANKED IN ORDER OF UNIT COST

#	Device	Traps	η(%)	R/m³
1	Baramy® (1:1 month RI)	1	86	137
2	SCS (1:1 month RI)	1	86	185
3	UWEM (1:1 month RI)	1	81	227
4	Baramy® (1:2 year RI)	3	95	270
5	SCS (1:2 year RI)	1	95	307
6	UWEM (1:2 year RI)	1	90	323
7	SECTs (50% coverage)	200	59	1 932
8	SECTs (100% coverage)	400	78	1 986
9	CDS (1:1 month RI)	3	89	2 157
10	ILLS	20	25	2 198
11	LCD	-	25	3 860
12	CDS (1:2 year RI)	6	99	3 874

From this information, the total litter load for typical South African conditions was estimated to be 84.2 m^3/yr. Applying the Rational Method to the hypothetical catchment gave a 1:1 month peak flow of approximately 4 m^3/s, and a 1:2 year peak flow of approximately 10 m^3/s.

The outcome of this analysis is summarised in Table 2. Unit costs per tonne of litter removed are obtained by dividing by the density of litter (according to Armitage et al., 1998, this is typically 0.095 kg/m^3).

With the assumed catchment data and the latest cost data to hand, it appears that:

- The Baramy®, SCS and UWEM devices have a lower unit cost than the remaining four structures.
- The CDS unit offers a very high removal efficiency, but at a high unit cost. Unit costs may, however, be brought down if high bypass ratios are used.
- SECTs offer the advantage of being a potential catchment management tool as they show where the bulk of the litter is being generated.
- The ILLS and LCD structures appear on the surface to be costly, but have the advantage that they are small and can be installed under streets in confined spaces. The ILLS has the additional advantage that it requires very little head.

In addition, though not considered in the evaluation above, fences, nets, weirs, booms or baffles may be the most cost-effective structures of all, provided a suitable slow-flowing stream or pond is available. A major problem with these devices is cleaning and maintenance. Ideally it should be possible for the channel to be periodically drained for cleaning and maintenance purposes. Another avenue to explore is a mix of technologies. For example, the hydraulically actuated sluice gate that is used in the UWEM approach could be used to generate the required head to run a BGPT or a SCS structure.

Table 2 must not be read as valid for every situation. The results of the analysis will be strongly influenced by the site location and conditions. Furthermore, cost is not the only consideration. Lack of head may rule out the BGPT and SCS devices. Lack of space may rule out the UWEM approach. The desire for a catchment management tool may favour the choice of SECTs. A requirement for exceptionally high removal efficiency may prompt the installation of a CDS unit. A small catchment may be best served by an ILLS or LCD. **The final choice of trapping structure will be specific to each site and situation**.

Most sites in South Africa would probably be best served by SECTs installed in key catchpits around the CBD, and a BGPT, SCS or UWEM unit installed on the main outlet conduit to the catchment, with head provided by a hydraulically actuated sluice gate if required.

Conclusions

This paper presents a rational method of determining the optimal litter trapping system and shows the outcome if this method is applied to the seven most promising traps of some 50 that were evaluated as part of the Water Research Commission of South Africa study into the removal of urban litter from stormwater conduits and screens. Three designs - two utilising declined self-cleaning screens (the Baramy® Gross Pollutant Trap and the Stormwater Cleaning Systems structure), and the other utilising suspended screens in tandem with an hydraulically actuated sluice gate (the Urban Water Environmental Management concept) - are likely to be the optimal choice in the majority of urban drainage situations in South Africa.

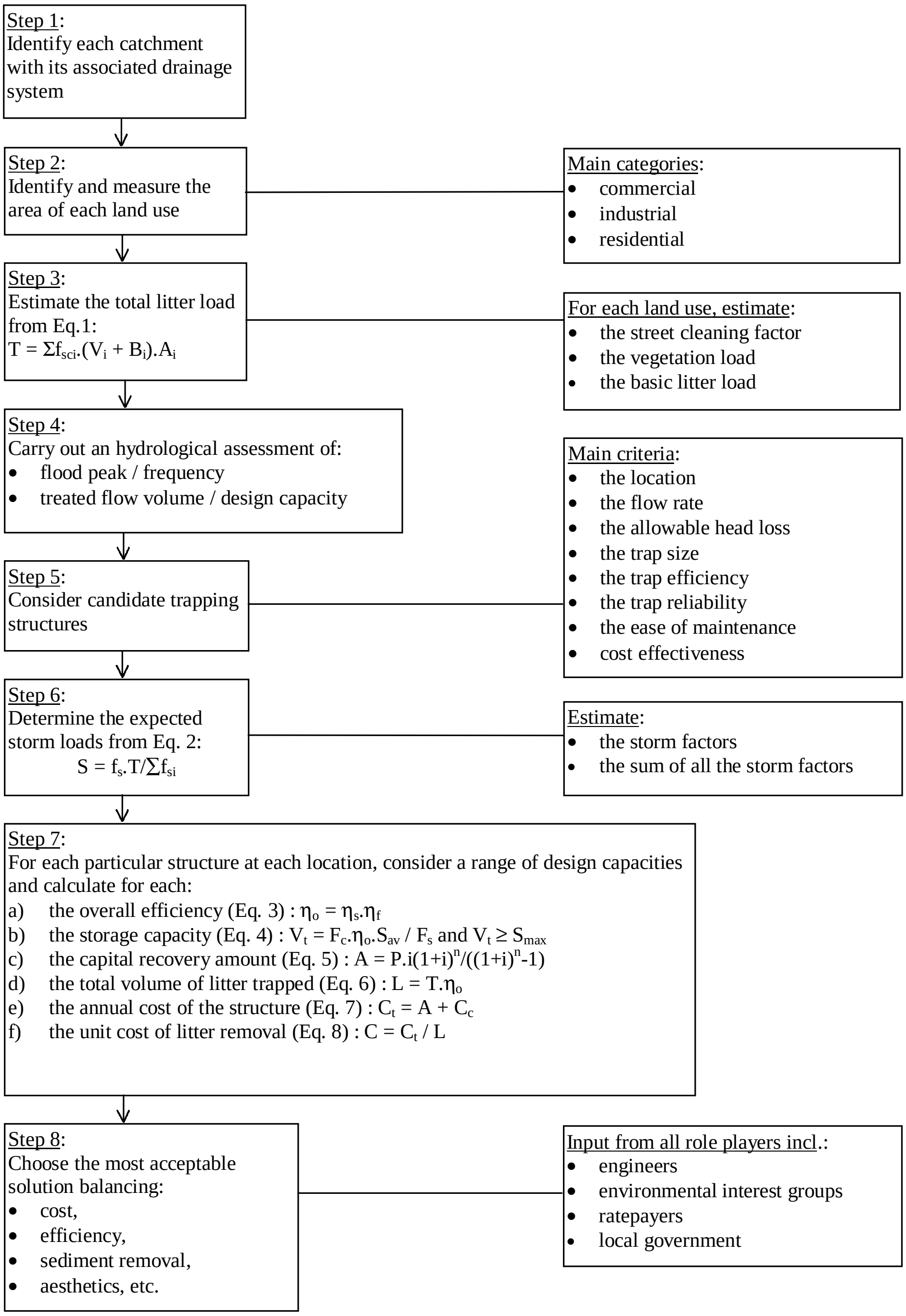


Figure 13

Summary of the trap selection procedure

Disclaimer

Most of the more successful structures have been patented and are available only from approved suppliers. Mention of a trade name does not indicate that either the Water Research Commission or the authors necessarily support the product in question. They are described in this paper in an attempt to indicate some of the best available technologies. There may of course be other structures, not described in this paper, that might remove litter from drainage systems more efficiently and effectively than those described herein.

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References

ARMITAGE N, ROOSEBOOM A, NEL C and TOWNSHEND P (1998) The Removal of Urban Litter from Stormwater Conduits and Streams. WRC Report No. TT 95/98, Pretoria.

BARAMY. Undated promotional literature, Baramy Engineering Pty. Ltd., Katoomba, New South Wales, Australia.

BROWNLEE RP (1995) Evaluation of Effectiveness and Efficiency of North Sydney Council Litter Control Device Program. *Proc. 2nd Int. Symp. on Urban Stormwater Management*, Melbourne, Australia.

MELBOURNE WATER WATERWAYS AND DRAINAGE GROUP (1995) A Guide to Current Technology for Removing Litter and Sediments from Drains and Waterways. Melbourne Water, Australia.

SWINBURNE UNIVERSITY OF TECHNOLOGY (1996) In-line Litter Separator Research and Development Project 1996/8, Waste Management Council of Victoria, Australia.

WONG THF and WOOTTON RM (1995) An innovative gross pollutant trap for stormwater treatment. *Proc. 2nd Int. Symp. on Urban Stormwater Management*, Melbourne, Australia.