11. The selection of the trapping system

11.1 Introduction

The selection of the trapping system should form part of an overall catchment management plan (see Section 3.2). It will always be more cost effective and aesthetically more acceptable to reduce littering than to attempt to remove all the litter from the environment once it has got there. However, accepting that some litter will always escape into the drains, litter removal structures will always be required in and around urban areas. This section deals with the location and selection of these litter removal structures.

11.2 The location of the traps

The choice of trapping structure is site specific. The location of the traps is therefore the 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:

1. **Entry:** SECT.

2. **In-pipe (flow rates up to about 1 m^3/s):** CDS, ILLS, LCD.

3. **End-of-pipe:** LCD, CDS, SCS, Baramy®.

4. **Canal / stream:** Baramy®, SCS, UWEM, fences, nets, booms or baffles installed across slow flowing streams (or ponds).

It should be remembered that no trap is 100% effective. In fact, 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. In consequence, many traps are only designed to handle peak flow rates in the region of 1:1 month recurrence interval (ie. 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 eg. 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.

11.3 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:

- flow rate,
- allowable head loss,
- size,
- efficiency,
- reliability,
- ease of maintenance, and
- cost effectiveness.

The first three items on this list 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 1 m^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.

We may loosely categorise the better available technologies as follows:

1. Low flow, low head structures:

- **Small -** Side-entry catchpit traps (SECTs),
- **Medium** - ILLS.
- **Large -** CDS.

2. Low flow, high head structures:

- **Medium** - LCD.
- **Large -** Baramy®, SCS (pipe option).

3. High flow, low head structures:

- **Small -** Fences, nets, booms or baffles installed across wide drowned channels (or ponds),
- **Large -** UWEM, CDS (with high bypass ratio).

4. **High flow, high head structures:**

- **Medium -** Baramy®.
- **Large -** SCS (side-channel spillway option).

11.4 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 sub-catchment, and apply Equation 2-1 (see Section 2.6):

$$\mathbf{T = \Sigma f_{sci}.(V_i + B_i).A_i} \qquad \textbf{(Equation 2-1)}$$

where
- T = total litter load in the waterways (m^3/year)
- f_{sci} = street cleaning factor for each land use (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 (varies from 0,0 m^3/ha per year for poorly vegetated areas to about 0,5 m^3/ha per year for densely vegetated areas)
- B_i = basic litter load for each land use (commercial = 1,2 m^3/ha per year; industrial = 0,8 m^3/ha per year; residential = 0,01 m^3/ha per year)
- 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 and the treated flow volume versus the design capacity of the structure curve. These curves are shown schematically in Figure 11-1.

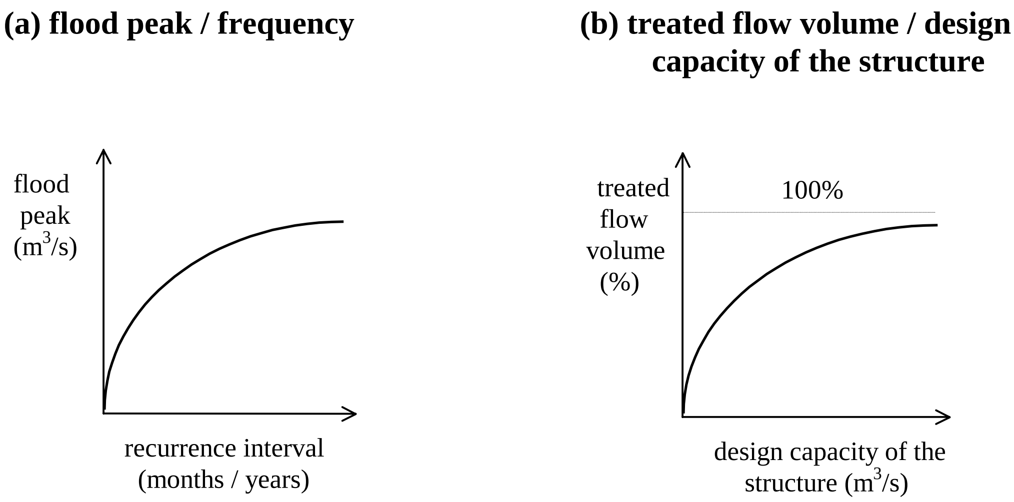

Figure 11-1 : Schematic flood peak / frequency and treated flow volume / design capacity of structure curves

The flood peak / frequency curve is well known. It is a plot of the flood peak in cubic metres per second (or litres per second) versus the inverse of the probability of excedence expressed in months or years and called the recurrence interval (R.I.). If a flow of, say, 1 m^3/s has a R.I. 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 versus its design capacity. The calculation is shown schematically in Figure 11-2. 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 a R.I. 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 we make the assumption (usually conservative) 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 proportion of flow 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 (eg. ILLUDAS, SWMM, WITWAT, CIVIL DESIGNER etc). Alternatively, a rough estimate may be obtained with the assistance of the well-known rational formula and 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. The reader is referred to any of the standard texts on urban hydrology for further information.

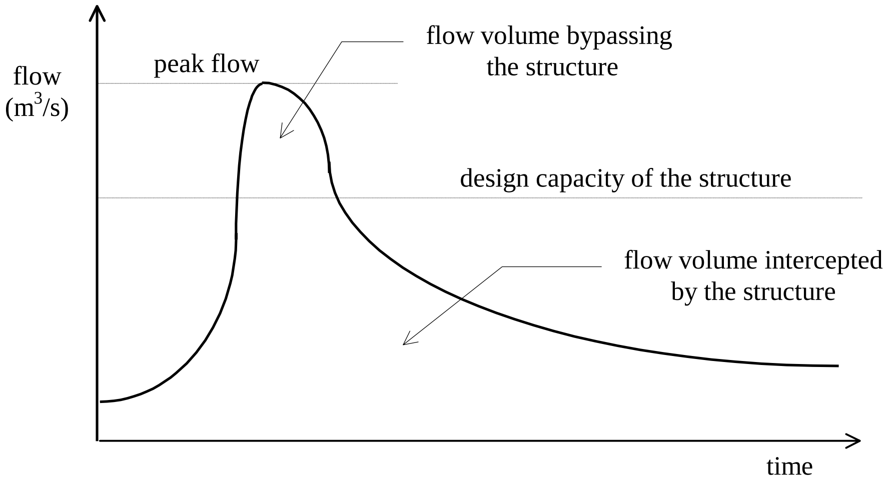

Figure 11-2 : Typical flood hydrograph indicating the relative volumes intercepted by, and bypassing the structure

5. Consideration is now given to the candidate trapping structures. Some preliminary information on the better structures currently available on the market is to be found in Section 10 and Appendix A. 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. The approximate minimum storage capacity of each trap may be determined from the maximum storm load estimated from Equation 2-2 (see Section 2.6):

$$\mathbf{S = f_s.T/\sum f_{si}} \qquad \textbf{(Equation 2-2)}$$

where S = storm load in the waterways (m^3/storm)

f_s = storm factor (varies from 1,0 for storms 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)

$\sum f_{si}$ = 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 R.I.s 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 Equation 11-1 (N.B. published SECT data gives overall efficiency directly):

$$\eta_o = \eta_s . \eta_f \qquad \textbf{Equation 11-1}$$

where

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

b) The storage capacity can be calculated by multiplying the proposed average cleaning frequency by the average estimated storm load (determined with the aid of Equation 2-2 above) and by the overall efficiency of the installation, and dividing this product by the average storm frequency during the wet season determined from municipal records. The storage capacity must be more than the minimum determined in step 6 above. The calculation is shown in Equation 11-2:

$$V_t = F_c . \eta_o . S_{av} / F_s \qquad \textbf{Equation 11-2}$$

where

V_t	=	proposed trap storage (m)
F_c	=	average cleaning frequency (days)
η_o	=	overall efficiency of the installation (fraction)
S_{av}	=	average estimated storm load (m)
F_s	=	average storm frequency (days)

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 good approximation is to simply subtract the average inflation rate from the average nominal interest rates). The capital recovery amount may then be determined from Equation 11-3:

$$A = P.i(1+i)^n/((1+i)^n-1) \qquad \textbf{Equation 11-3}$$

where

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

The effect of inflation is simply to make the initial payments higher, and the later payments lower (in real terms), but this will not change the overall picture.

d) The total volume of litter that the trap is likely to intercept at each design capacity is obtained by multiplying the total litter load determined in Step 3 above by η_o using Equation 11-4:

$$\mathbf{L = T.\eta_o} \qquad \textbf{Equation 11-4}$$

where
- L = load trapped by the structure (m^3/year)
- T = total litter load (m^3/year)
- 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 Equation 11-5:

$$\mathbf{C_t = A + C_c} \qquad \textbf{Equation 11-5}$$

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

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 Equation 11-6:

$$\mathbf{C = C_t / L} \qquad \textbf{Equation 11-6}$$

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

Unit costs in terms of R/kg or R/ha may be obtained by dividing the unit cost of litter removal by the standardised density of 95 kg/m^3, 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 is site specific and highly variable. Costs and efficiencies may vary considerably from site to site.

The litter removal process is summarised in Figure 11-3. The trap selection procedure is summarised in Figure 11-4. An example of an hypothetical trap selection is given in Appendix B.

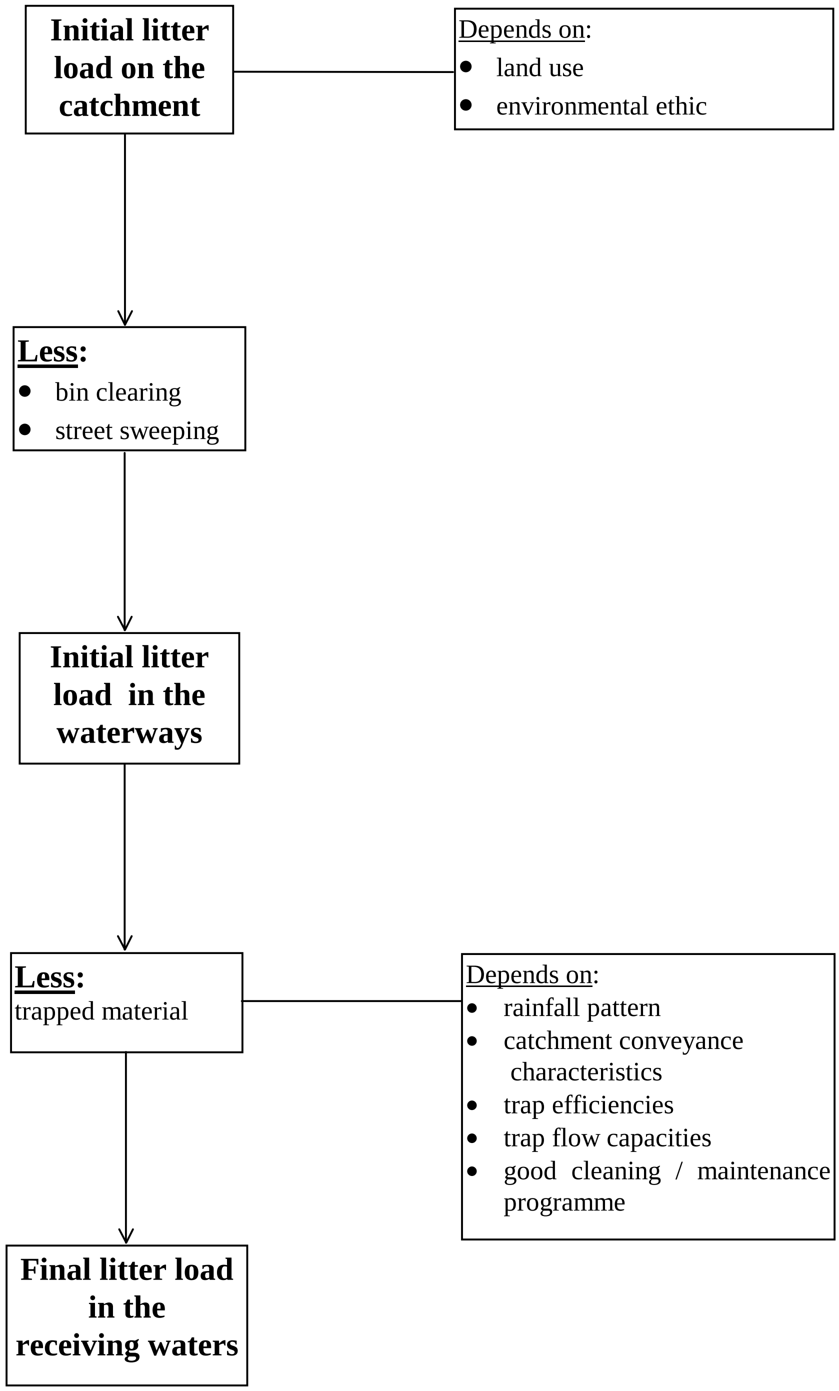

Figure 11-3 : The litter removal process

Step 1:
Identify each catchment with its associated drainage system

Step 2:
Identify and measure the area of each land use

Main categories:
- commercial
- industrial
- residential

Step 3:
Estimate the total litter load from Eq. 2-1:
$\mathbf{T = \Sigma f_{sci}.(V_i + B_i).A_i}$

For each land use, estimate:
- street cleaning factor
- vegetation load
- basic litter load

Step 4:
Carry out an hydrological assessment of:
- flood peak / frequency
- treated flow volume / design capacity

Step 5:
Consider candidate trapping structures

Main criteria:
- location
- flow rate
- allowable head loss
- size
- efficiency
- reliability
- ease of maintenance
- cost effectiveness

Step 6:
Determine the expected storm loads from Eq.2-2:
$\mathbf{S = f_s.T/\Sigma f_{si}}$

Estimate:
- storm factor
- the sum of all the storm factors

Step 7:
For each particular structure at each location, consider a range of design capacities and calculate for each:
a) the overall efficiency (Eq. 11-1) : $\mathbf{\eta_o = \eta_s.\eta_f}$
b) the storage capacity (Eq. 11-2) : $\mathbf{V_t = F_c.\eta_o.S_{av} / F_s}$
c) the capital recovery amount (Eq. 11-3) : $\mathbf{A = P.i(1+i)^n/((1+i)^n-1)}$
d) the total volume of litter trapped (Eq. 11-4) : $\mathbf{L = T.\eta_o}$
e) the annual cost of the structure (Eq. 11-5) : $\mathbf{C_t = A + C_c}$
f) the unit cost of litter removal (Eq. 11-6) : $\mathbf{C = C_t / L}$

Step 8:
Choose the most acceptable solution balancing:
- cost,
- efficiency,
- oil retention,
- sediment removal,
- aesthetics, etc

Input from all role players incl.:
- engineers
- environmental interest groups
- ratepayers
- local government

Figure 11-4 : Summary of the trap selection procedure