Table 3.1 - Summary of gross pollutant trapping devices

Device	Catchment area (hectares)	Estimated efficiency for gross pollutant removal	Recommended cleaning frequency	Head requirements	Comments on perforn
SEPT (Banyule)	0.1 -1	high	monthly	low	Need to be able to target pits with highes affected by entrances other than s
Baffled Pits	0.1-2	low to moderate	3 weeks	low	Uncertainty about suspended material retention
Trash Racks	20-500	low to moderate	monthly	mod/high	Inefficient during high flows due to the overflowing
Litter Control Devices (LCD)	2-150	moderate to high	weekly-monthly	high	Inefficient in high flows but collect mos medium flows
CDS devices	10-60	very high	3 monthly	low	Very efficient trapping devices but requirements are untest
GPTs	5-5000	low to moderate	1-6 monthly	mod/high	High flows problems like trash racks, de retention
Booms	>250	low	fortnight -monthly	low	Only trap floatables, inefficient in
Baramy Trap	10-50	unknown	monthly*	mod/high	Few data available
Diston	10-50	unknown	monthly*	mod	Few data available
Hinged boom	5-25	unknown	monthly*	low	Few data available
Townshend (S. Africa) trash rack	>400	moderate to high	each storm event	low	Good trapping device but no Au
Nel's (S. Africa) trap	>400	high	monthly*	high	Appears to trap well even for very large available

* estimated cleaning frequencies

4. STORM EVENT MONITORING

This chapter describes a monitoring program of urban stormwater pollutants during storm events. The primary focus of the program was gross pollutants; however, it was convenient for the personnel on site also to take water samples during storm events. Event monitoring was carried out over a two year period and involved measurements of discharge and mass of gross pollutants with specially designed samplers (Essery, 1994) at several locations in the study area. At the beginning of the field program, gross pollutants and discharges were measured at a pilot site to enable the scoping of the monitoring procedure and program for the project. Following the pilot study four small sites (3 to 150 hectares) representing residential, commercial and light industrial areas were selected for monitoring in an inner Melbourne suburb.

Water velocity and depth were measured continuously while during storm events, up to ten personnel collected gross pollutants and water samples. Analyses of the collected data indicate that considerable amounts of gross pollutants are moving through urban stormwater systems. The data also show that gross pollutant concentrations generally peaked before the hydrograph, however, most of the load is transported with the highest discharge. The data also show that more than two thirds of the gross pollutants collected were garden debris (leaf litter and twigs) and that higher proportions of paper and plastics came from the light industrial and commercial areas than from the residential areas.

4.1 INTRODUCTION

There are a large number of factors which could affect the amount of gross pollutants in stormwater. The purpose of this monitoring was to investigate the most important and influential variables. Factors which may influence gross pollutant loads in stormwater include:

- land-use type (eg. residential, commercial, light industrial, park-lands),
- rainfall event characteristics such as intensity and resulting drain discharges,
- population (permanent and transient),
- management practices (eg. street sweeping/vacuuming, availability of collection bins and regularity of cleaning, restrictions on what can be collected and recycling programs),
- education and awareness programs,
- time since the last runoff event,
- size and geometry of inlets and pipe networks,
- physical catchment characteristics (size, slope, surface characteristics, vegetation),
- seasonal variations, and
- wind intensity and direction.

Choosing the pollutant variables to be investigated in this study required a balance between the perceived importance of a factor for determining gross pollutant loads and the feasibility of monitoring their effects in a field monitoring program. The monitoring program was designed on the bias that land-use type and rainfall / discharge are the important factors governing gross pollutant transport.

It was intended to monitor catchments with uniform land-uses. An objective was also to monitor different land-uses, preferably from similar sized catchments located near each other. Uniform land-uses over a catchment allow the type and amount of material discharging from the catchment to be compared to that catchment's land-use. Similar sized catchments reduce scaling errors and by selecting catchments close to one another it is more likely that management practices, education programmes and rainfall distributions will be similar for all catchments.

The nature of small urban catchments is such that generally base-flows are relatively very small. Consequently, gross pollutant loads during dry conditions are very low (if not zero) as there is little or no water to carry gross pollutants. The monitoring was targeted at storm events because of the high contribution that storm-flows have on the total gross pollutant load.

4.2 PILOT STUDY

A pilot study was established to evaluate the feasibility of the gross pollutant samplers developed by Essery (1994) for Melbourne conditions (described in Section 4.5). The pilot study was performed over an eight month period and gave experience in operating the monitoring equipment and highlighted some limitations with the techniques which led to modifications to the monitoring program.

The pilot site had a catchment area of approximately 34 square kilometres of fully urbanised, primarily residential land-use. The monitoring location was approximately 15 kilometres east of central Melbourne and the equipment was installed at a footbridge over a concrete lined channel (six metres wide).

Two storm events were monitored for a sufficient duration for the data to be useful at the pilot site during an eight month period. During two other monitoring attempts the samplers became blocked with large tree branches early in the storms and prevented further data from being collected. In addition travel times from the University to the site were longer than expected and consequently the number of events monitored were less than originally planned. Predicting rainfall and getting on-site proved to be the most challenging aspect of the monitoring; several storms were missed through poor forecasting and several trips to the site were 'false alarms' (ie. no rain).

An important factor observed from the pilot investigation related to the length of time between storm warning and arriving on site. Due to the very fast response times of urban catchments, it is essential to be on site prior to the start of a rainfall, and consequently the travel time from the University to the site needs to be minimised. Travel took approximately 40-60 minutes to get to the pilot site, and in addition to the unreliability of the warning system, this proved too long and resulted in some storms being missed. In addition discharges at the site were too large for the monitoring equipment. The large open channel allowed large logs and debris to be carried in the flow and these blocked or caused damage to the monitoring equipment as shown in Photograph 4.1. It was concluded from experiences at the pilot site that future monitoring catchments need to be much smaller and closer to the University.

The main observations from the pilot monitoring were:
1. the flashy nature of urban catchments makes it difficult to monitor a catchment which is beyond 30 minutes travel time;
2. it is dangerous and physically difficult to keep the gross pollutant sampling equipment operating in large open channels; and
3. it is difficult to associate the types and loads of pollutants with land-use type in large catchments.

Based on these observations a new set of monitoring sites were selected.

Photograph 4.1 The pilot site with materials blocking the frames during high flow

4.3 OBJECTIVES OF THE STORM EVENT MONITORING

The load-monitoring field experiment described here was intended to improve our understanding of the loads, distribution and transport mechanisms of gross pollutants. The program had the following objectives:

- to establish loads of gross pollutants carried by stormwater during storm events;
- to identify factors influencing gross pollutant loads;
- to investigate the temporal variation of gross pollutant loads during storm events; and
- to investigate the types of material emanating from different land-use types.

The monitoring program gives an indication of the amount and the type of gross pollutants discharging from the experimental catchment and identifies the land-use types that contribute the most gross pollutants.

4.4 SITE SELECTIONS

The monitoring sites had to satisfy many criteria. They were required to be at locations which allowed sampling from a uniform land-use area, close to a different single land-use catchment, close to the university and have safe places for accessing the drains during rainstorms. It was intended to monitor as many land-use types as possible within the catchment as well as one at the outlet. Commercial, residential and light-industrial were perceived as the key land-use types for producing gross pollutants. These were also the classifications used by MMBW et al. (1989), Seymour (1993) and Cornelius et al. (1994). Therefore at least four monitoring sites were required, one to monitor each land-use and one downstream. In summary the characteristics for ideal monitoring sites were:

- small catchments with uniform land-use types (pipe size 450-600 mm);
- a series of 'small' catchments (5-30 ha) each with different land-use areas (eg. residential, light-industrial, commercial) within one larger catchment (100-200 hectare);
- feasible, safe and accessible sampling locations at the outlet of the 'small' and the 'large' catchments; and
- short travel times from the Parkville campus of the University of Melbourne.

Using these criteria it became obvious that it would be difficult to satisfy all of them. The most difficult criterion was to find single land-use catchments with feasible monitoring locations. Most catchments larger than 10 hectares have varied land-uses and therefore were excluded. Requiring three or four single land-use catchments near to each other, all with single but different land-uses, further reduced the possible areas.

4.4.1 Coburg monitoring sites

The monitoring sites were located approximately eight kilometres north of central Melbourne in the inner-city suburb of Coburg. The catchment area is 150 hectares, fully urbanised with primarily residential land-use. Monitoring was carried out at the catchment outlet as well as a residential (20 hectare), a light-industrial (2.5 hectare) and a mixed commercial (60%) and residential (40%) 16 hectare site, see Figure 4.1. Monitoring at the sub-catchments was performed in closed concrete pipes (diameters ranging from 680-750 mm) with access from manholes while monitoring at the catchment outlet was performed at the outlet of the closed drainage system (4m by 2m box culvert) to a natural creek.

Coburg City Council performs street sweeping, drainage pit cleaning and employs a litter officer. Street sweepers sweep the catchment daily along the two major commercial streets and fortnightly in the residential areas. The pit cleaning crews are on a six monthly rotation for all the pits in the council region. The litter officer collects visible litter from the main commercial areas and car parks daily. These practices are typical of local councils in Melbourne and continued throughout the monitoring period. The objective was to monitor the quantities of gross pollutants transported in the drainage network under typical conditions.

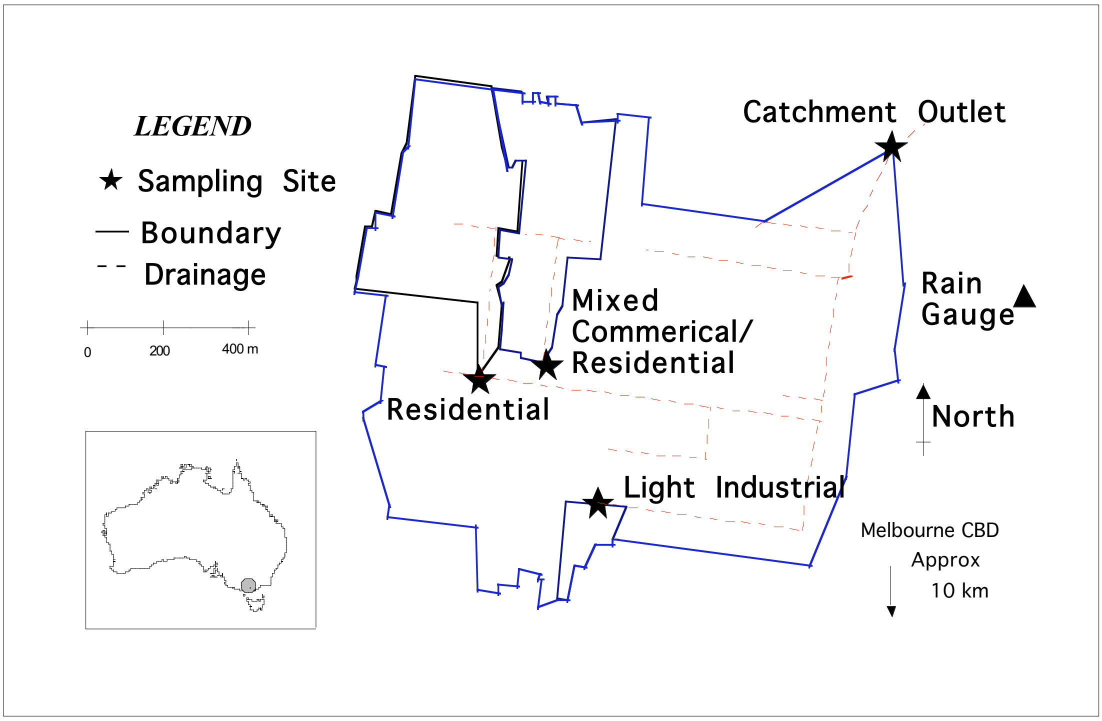


Figure 4.1 Catchment map of Coburg monitoring areas

4.5 METHODOLOGY FOR STORM EVENT SAMPLING

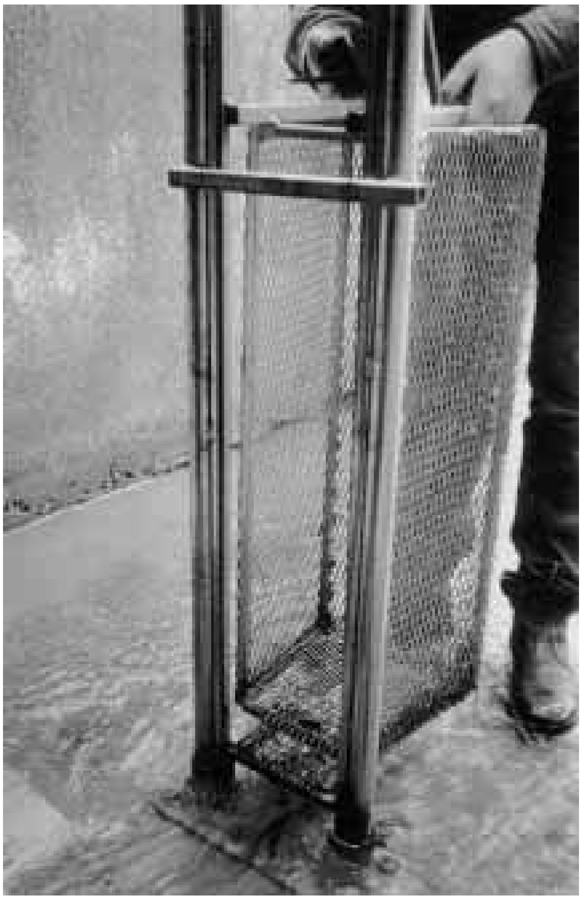
Monitoring involved predicting rain storms, transporting equipment and personnel onto site and installing monitoring equipment prior to significant discharge. Once runoff commenced personnel collected gross pollutant samples from within the flow with specially designed gross pollutant samplers (Essery, 1994) at varying time intervals.

Storm warnings:

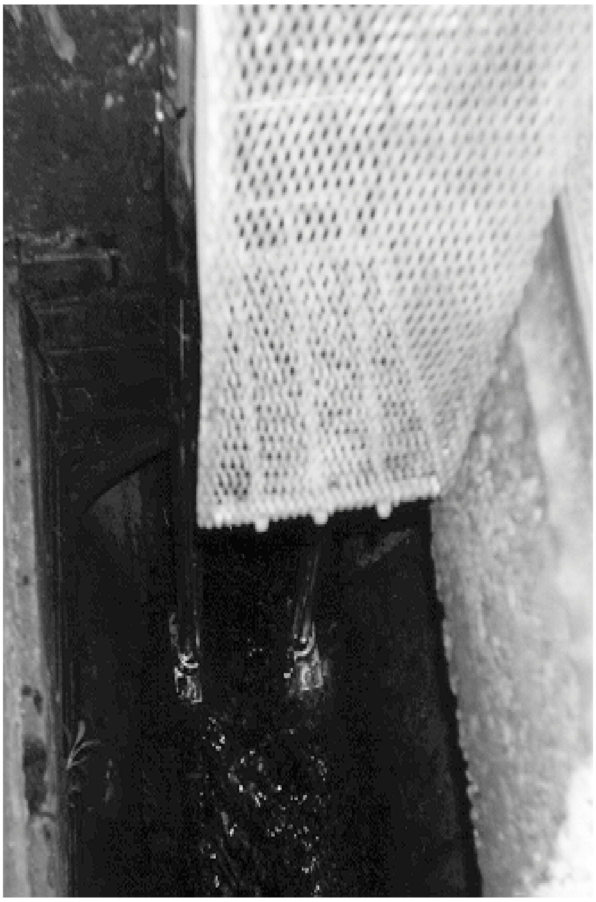
Warning of pending storms was given by a radar program known as PC-RAPIC (Bureau of Meteorology, 1994) which shows rain intensities of the surrounding area. Using the system, to which the authors had direct access, storms were tracked as they developed around the monitoring area. If rainfall was estimated to exceed five millimetres in the experimental catchment, equipment and personnel were moved on-site.

Gross pollutant samplers:

The gross pollutant sampler comprises three components: collection baskets, guide frames and base plates (Photograph 4.2). On arrival at the site, guide frames are fitted to the base plates (permanently fixed to the bed of the channel) and to support brackets located directly above the base plates. The collection baskets are then lowered into and raised out of the flow via the guiding frames. Material collected in the baskets is then placed into labelled bags for analysis.



Photograph 4.2 Essery's (1994) gross pollutant sampler showing collection basket, guiding frames and base plates



Photograph 4.3 Sampling device in operation at a sub-catchment

When the water level in the drain starts to rise the baskets are lowered into the path of the flow to collect suspended material which is greater than the 5 mm mesh in the baskets. The frequency of lowering and raising the baskets is governed by the amount of material being collected. The baskets remain in the water while they are not blocked with collected material. This period varied from 30 seconds to 10 minutes depending on the amount of material in the flow. Typically, samples are taken every one to five minutes during the rising limb of the hydrograph and every 10 to 20 minutes during the falling limb. For all sites except for the catchment outlet a single basket was installed. Photograph 4.3 shows the monitoring equipment installed at the residential site and Photograph 4.4 shows the equipment at the catchment outlet.

Photograph 4.4 Sampling devices in operation at the catchment outlet in Coburg.

Even though this method gives the most detailed information about gross pollutants (Essery, 1994), there are several assumptions that are made and therefore the results may contain errors. To investigate the load variation during storms the sampling baskets are lowered into and raised from the flow for discrete time intervals. While material is collected from the sampling baskets, after the baskets are removed from the flow, the samplers are not installed and the variation in loads is unknown. For this study the concentrations of gross pollutants is assumed to vary linearly between times when the baskets are in the flow. The method developed by Essery (1994) samples a sub-section of the cross section (typically 5% to 10%), because of the large loads in stormwater drains it is not possible to capture all material flowing down the drains. For this study the concentrations are assumed to be constant across the whole section because of the well mixed and highly turbulent flow conditions typically found in urban drains.

Water samplers:

Manual water samples were taken with integrated water samplers developed using the US DH-48 design as a guide (see description in Richards, 1982). The sample bottles were filled while the sampler was lowered and raised at a constant rate over the depth of the water, and therefore an integrated sample over the water column was taken.

Water samples were collected every 10 to 15 minutes during runoff events. After the events the samples were transported to the University if Melbourne where they were refrigerated until they were taken to a NATA certified laboratory (Water EcoScience, Victoria) and analysed for TSS, TP and TN.

Hydrologic data:

An automatic rain gauge had been installed by Melbourne Water approximately 500 metres from the catchment outlet (see Figure 4.1). Six minute rainfall data were available from the gauge.

Discharge at each monitoring station was estimated using data recorded with ultrasonic Doppler instruments (*Starflow* units; Unidata, 1994) that measure water depth and velocity. Water velocity is measured by recording the Doppler shift between a continuously emitted beam and the consequent reflected beams from particles and small air bubbles carried in the water. The Doppler shift can be directly related to the water velocity and is computed in the software of the instruments (Unidata, 1994). Water depth is estimated using a pressure transducer that measures the hydrostatic pressure of the water above the instrument.

The instruments are fixed to the bed of the channel where the channel beds are smooth upstream of the gross pollutant samplers. Data are recorded every two minutes with discharge estimated as the recorded velocity multiplied by the area of the flow. The instruments are permanently fixed to the channels at the four small sites and downloaded weekly to give continuous discharge measurements. At the catchment outlet, where vandalism was a potential problem, it was not possible to leave an instrument installed permanently. The discharge monitoring equipment was installed on arrival at the site before the monitored events.

4.5.1 Laboratory analysis

Material collected in the field was transferred from the sample bags to a laboratory oven (at 60 degrees Celsius) for at least 24 hours. Higher temperatures tended to melt or burn litter items and therefore a cooler, longer drying cycle was used compared to typical laboratory drying procedures at 104 degrees Celsius. The material was then sorted into classifications and each sorted classification was weighed. The classifications were derived from classifications previously used in other Australian studies (Nielsen & Carleton, 1989; Essery, 1994; and MMBW et al., 1989). Classifications used in this study were:

organic materials (mainly leaves and twigs),
plastics (food and drink containers, sheeting),
paper (newspapers, cardboard, food and drink containers),
metals (cans and foil),
glass (bottles, jars), and
others (cloth and miscellaneous items).

The classifications used here allow insight into the possible origins of particular gross pollutants (eg. plastics items from human activities; organic materials from vegetation) and six classifications were within the sorting times and resources of this project.

4.6 CHALLENGES IN STORM EVENT MONITORING

There are limitations in arranging for up to ten people to monitor storms given they need to be on site before rainfall commences. In addition, as personnel are volunteers, the number of ‘false alarms’ needs to be minimised to maintain morale (so they will volunteer again).

The main difficulty is predicting when and whether a storm event will occur on the monitored catchments and this caused several events to be missed because of either the time to get personnel on site or by missing storms altogether. Other problems included rainfall at night and insufficient rainfall. However, this type of monitoring gives the most detailed information about gross pollutant movement during stormwater events (Essery, 1994).

4.7 RESULTS FROM STORM EVENT MONITORING

After 12 months of monitoring (October 1994 to October 1995), two storm events had been fully monitored (ie. all four sites monitored together) and the mixed commercial/ residential site monitored for six events. The monitoring results highlight some of the limitations involved with storm event monitoring, but, do allow further insights into the transport of pollutants in stormwater systems during runoff events. The monitoring also gives an indication of the different types and amounts of materials transported from different land-use areas, however the results should be treated with caution because of the limited number of monitored storm events.

4.7.1 Variation of gross pollutant loads during storm events

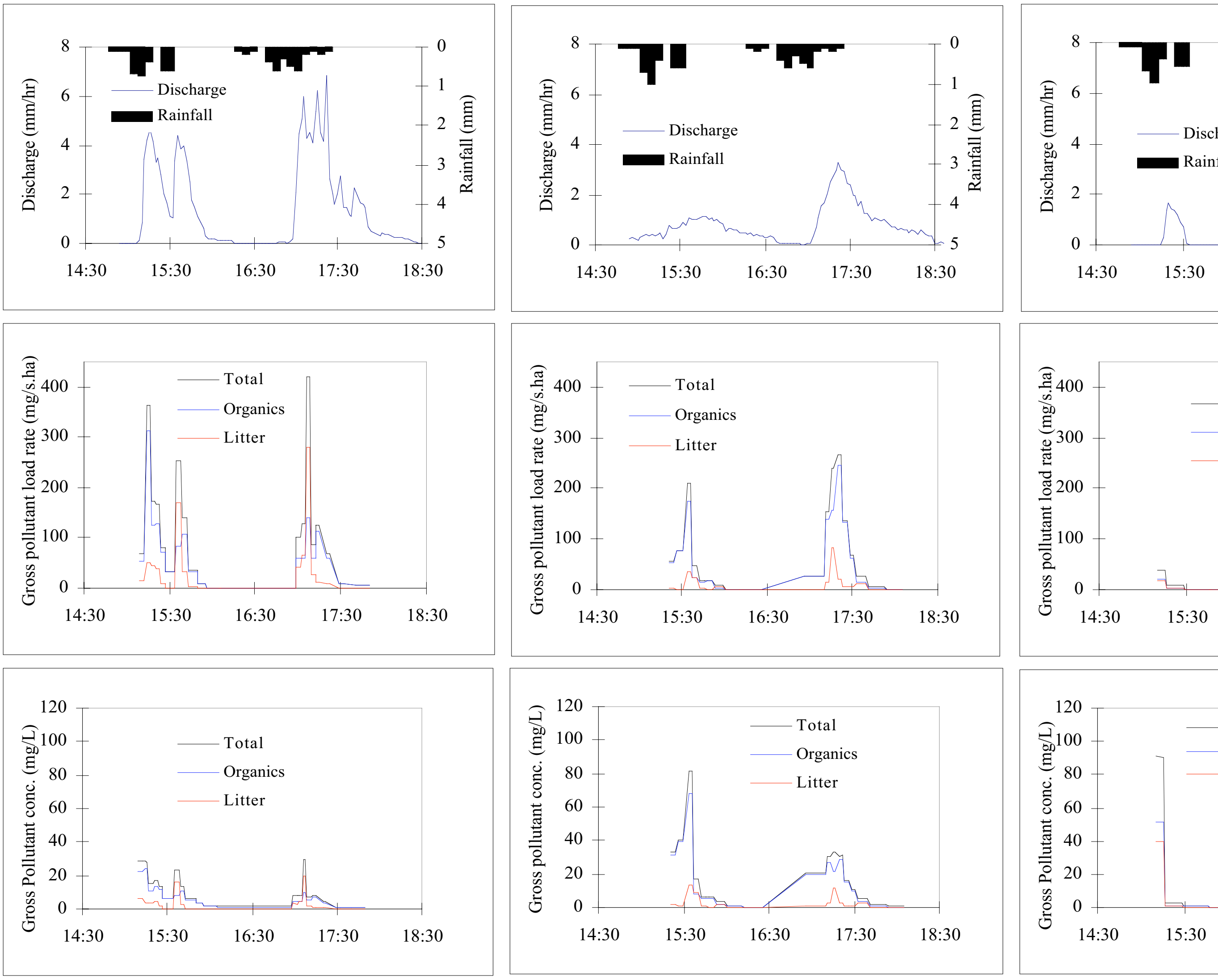
Monitoring was carried out at four sites for two storms in early 1995 and data for rainfall, discharge and gross pollutant loads were obtained during the monitoring. The hyetographs, hydrographs and gross-pollutographs for the two events are shown in Figures 4.2 to 4.5.

After gross pollutants were placed into plastic bags during monitoring they were taken to the university laboratory where they were dried and weighed to obtain the dry masses of material collected over the various time intervals. These results in conjunction with the discharges were used to estimate the gross pollutant concentrations during events. Loads were estimated by assuming the temporal variations of concentrations and loads were constant during the time the baskets were in the flow (usually relatively short periods) and a linear variation during times when the baskets were not in the flow.

Plots of gross pollutant concentrations during the storm events (Figures 4.2 to 4.5) suggest that the highest concentrations occur during the early stages of runoff and generally peak before the hydrographs. This trend was similar at all sites. However, the highest load-rate occurred mostly during peak discharges, therefore, it is important to consider treating the highest flows with any treatment strategy for maximum gross pollutant capture. A similar trend was observed by Essery (1994) in a Sydney monitoring program, which is the only other Australian information available. The high concentrations at the beginning of a runoff event can be as a result of one of two processes. During dry conditions gross pollutants migrate and accumulate in the drainage channels as a result of base-flows, wind or dumping. Alternatively, after the preceding rainfall event, material falls from within the flow during the recession limb of the hydrograph as the flow cannot support the material in suspension. This will also enhance the amount of material that accumulates in or near the conveyance channels which will be readily available for the subsequent runoff event.

Data from the event of 27-1-95 show that subsequent rain-storms, during the same day, display similar concentrations and loads to those observed earlier in the day. This would suggest that the loads in the catchment are not completely ‘flushed’ by a single storm event and that treatments should be able to cope with multiple events to maximise pollutant capture. However, within each individual event the time when the concentrations are highest is early in the hydrograph (on the rising limb) and the time when the most load is transported is during the highest discharge. These observations suggest that the quantity of rainfall and runoff volume play an important role in determining gross pollutant loads and are in agreement with the results presented from a Sydney monitoring study by Essery (1994).

Figures 4.2 to 4.5 show that the mixed commercial/ residential catchment delivers the most gross pollutants to the stormwater system. Although the peak concentrations of gross pollutants were lower than the residential and light-industrial catchments, the higher runoff volumes from the commercial area transported more gross pollutants than any other monitored area (and at a higher load-rate). The high loads and load-rates suggest that commercial areas should be the first areas to be considered for reduction strategies.



Mixed commercial/ residential site (b) Residential site (c) Light-industri

Figure 4.2 Hyetographs, hydrographs and pollutographs for the three sub-catchments (27-1-95)

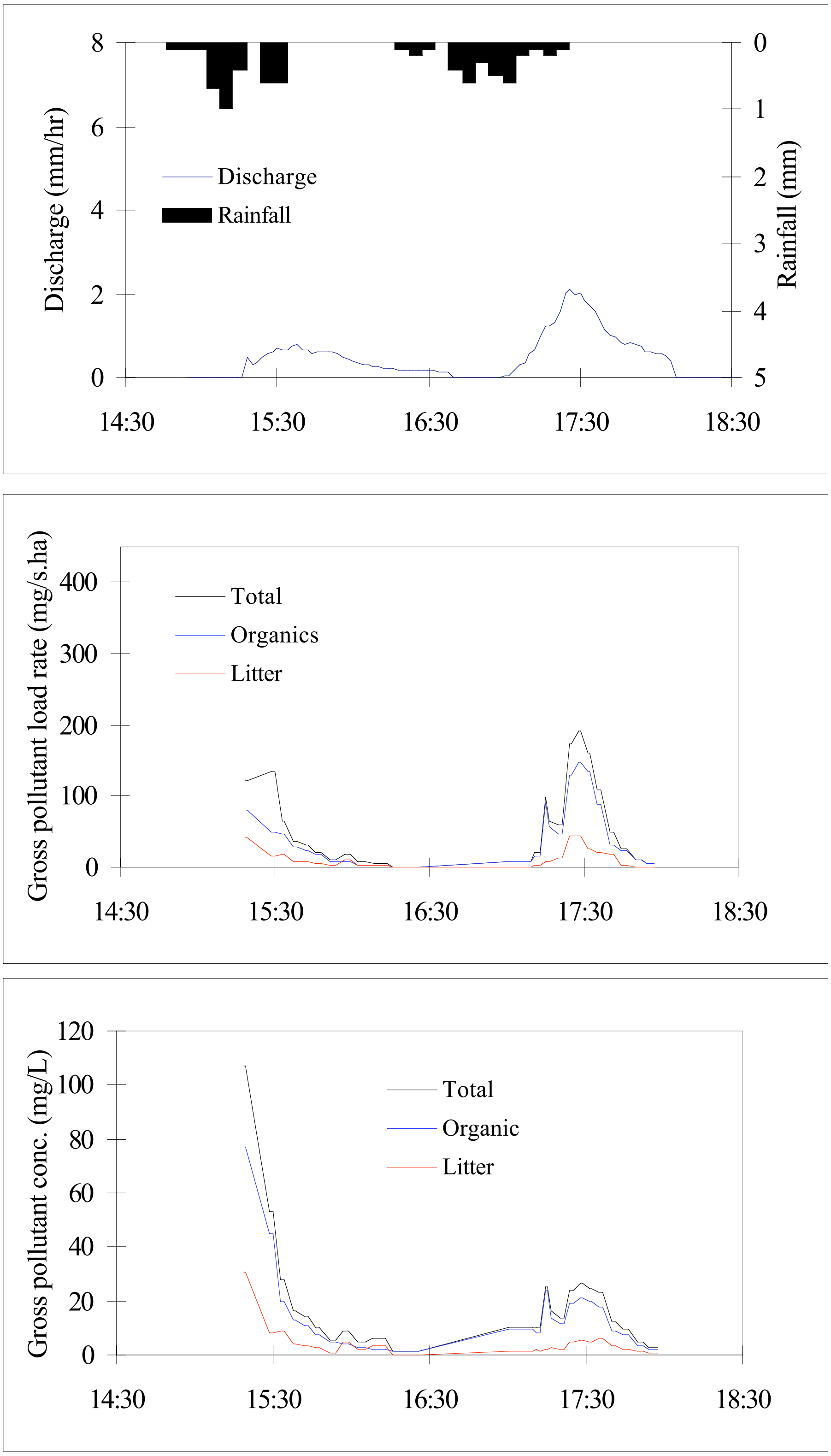
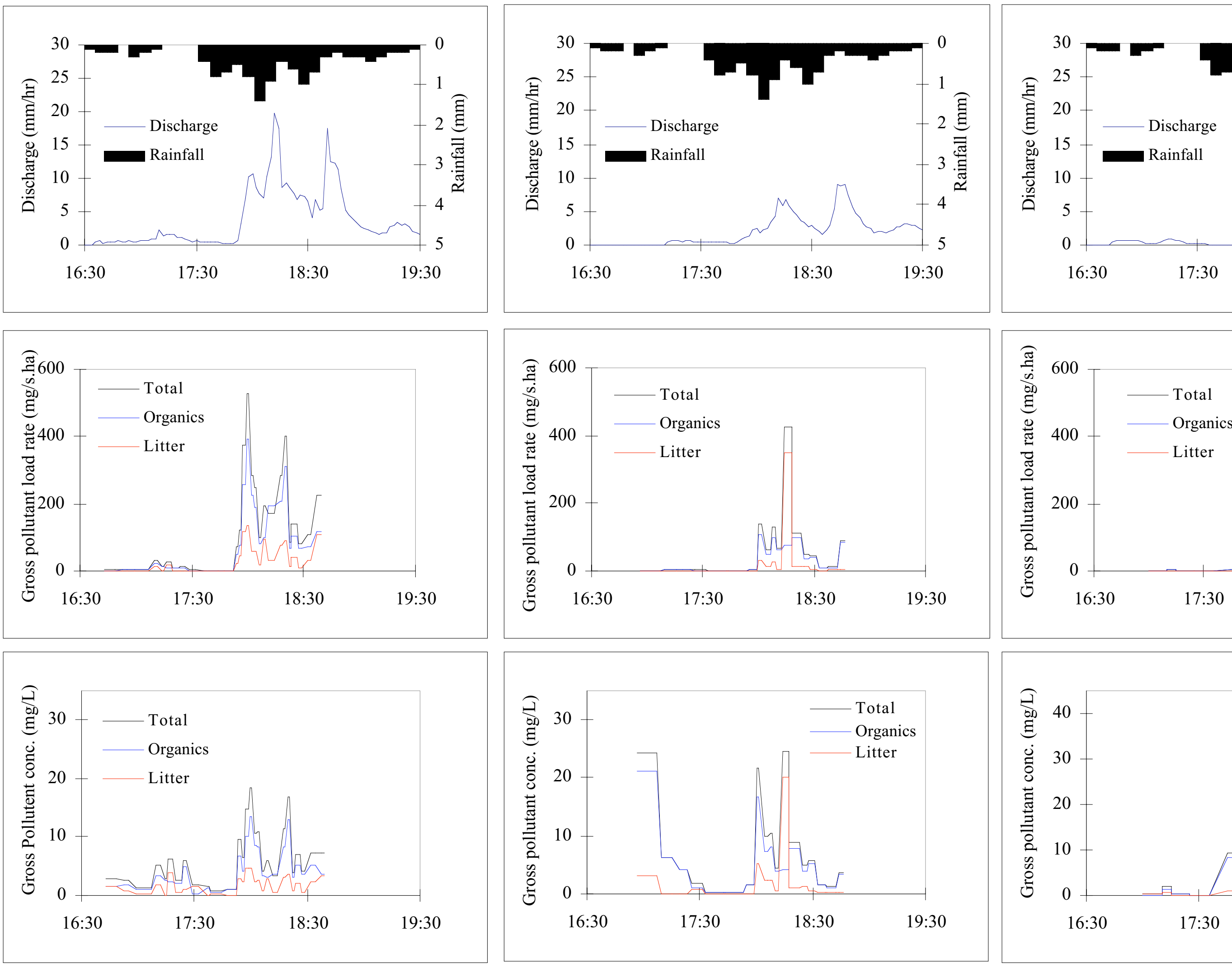


Figure 4.3 Hyetograph, hydrograph and pollutographs for the catchment outlet (27-1-95)



(a) Mixed commercial/ residential site (b) Residential site (c) Light-industrial

Figure 4.4 Hyetographs, hydrographs and pollutographs for the three sub-catchments (6-4-95)

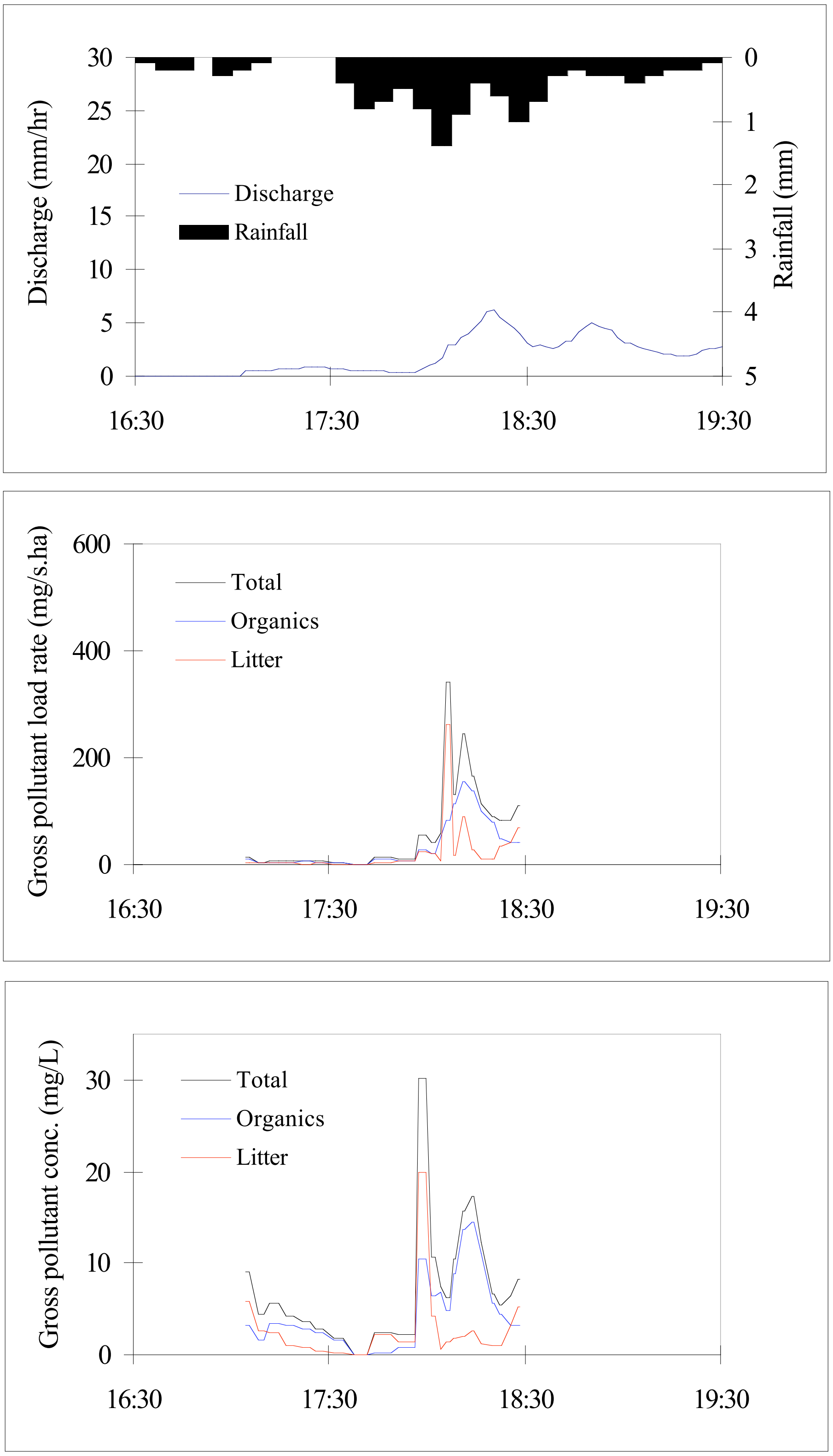


Figure 4.5 Hyetograph, hydrograph and pollutographs for the catchment outlet (6-4-95)

4.7.2 Gross pollutant loads from different land-use types

In addition to rainfall and runoff volumes the amount of litter and organic gross pollutants transported for each of the two storms from each land-use area are presented in Tables 4.1(a) and 4.1(b). Gross pollutant loads are presented as dry mass per hectare of catchment.

Table 4.1(a) Loads of gross pollutants from monitoring on 27 January 1995

SITE	AREA	RAIN	RUNOFF	LITTER MATERIAL	ORGANIC MATERIAL	TOTAL LOAD
	ha	mm	mm	g/ha DRY	g/ha DRY	g/ha DRY
Mixed commercial/ residential	15.8	7.0	3.4	116	254	371
Residential	20.2	7.0	2.0	43	248	292
Light-industrial	2.5	7.0	1.3	162	79	242
Catchment outlet	150.0	7.0	2.2	77	276	353

Table 4.1(b) Loads of gross pollutants from monitoring on 6 April 1995

SITE	AREA	RAIN	RUNOFF	LITTER MATERIAL	ORGANIC MATERIAL	TOTAL LOAD
	ha	mm	mm	g/ha DRY	g/ha DRY	g/ha DRY
Mixed commercial/ residential	15.8	12.0	8.3	410	162	572
Residential	20.2	12.0	4.6	127	181	308
Light-industrial	2.5	12.0	2.3	20	44	63
Catchment outlet	150.0	12.0	7.3	163	245	407

Monitoring from two storm events (see Table 4.1 a & b) indicate that the organic material (mainly leaves and twigs) loads are similar at all sites except the light-industrial catchment which produced approximately one quarter of the material. The commercial area has higher amounts of litter (mainly paper and plastics) than the residential area. Approximately two-thirds of the gross pollutants in the residential area are natural materials, but, the commercial area appears to produce similar amounts of organic and litter material.

Table 4.2 Extrapolated gross pollutant mass balances for the two events monitored

SITE	AREA	EXTRAPOLATED LOADS FOR AN EVENT ON 27-1-95				EXTRAPOLATED LOADS FOR AN EVENT ON 6-4-95		
	ha	Litter (dry kg)	Debris (dry kg)	Total (dry kg)		Litter (dry kg)	Debris (dry kg)	Total (dry kg)
Catchment outlet*	150	12	41	53		24	37	61
Commercial**	38	7	16	23		26	10	36
Residential (with commercial)**	25							
Residential	71	3	18	21		9	13	22
Light-industrial	8	1.3	0.6	1.9		0.2	0.3	0.5
Open parklands***	8	0.3	2.0	2.3		1.0	1.4	2.5
Sum of individual areas	150	12	36	48		36	25	61

*values measured not extrapolated
**the combination of the residential and commercial catchments was used with the results from the mixed catchment in Table 3.1
***parklands are assumed to produce the same quantities as residential areas

Using results from the single land-use catchments, loads are extrapolated to estimate the load for the catchment outlet and the results show that the extrapolated loads are comparable to the loads monitored at the catchment outlet (within 10% for total loads; Table 4.2). This implies that the methodology used in the study (and by Essery, 1994) and the assumptions made are reasonable for the measured data. The catchment land-uses for the large downstream catchment were estimated as 25% commercial, 65% residential, 5% light industrial and 5% park-lands.

4.7.3 Composition of gross pollutants from different land-use types

The composition of the collected gross pollutants varied significantly between sites, the proportions of each category (by mass) are presented in Figure 4.6. Organic material (mainly leaf litter and twigs) was the largest component collected at all sites (65% to 85% by mass) except for the light industrial catchment in the first event (when one large paper object was captured that distorts the results). The composition of the remaining material was mainly plastics and paper. The mixed commercial/ residential catchment had the highest proportions of paper but surprisingly the residential catchment had the largest proportion of plastics in the second monitored event. These data show similar proportions to other reported data (eg. Nielsen & Carleton, 1989; MMBW et al., 1989; Gamtron, 1992 and; Cornelius et al., 1994).

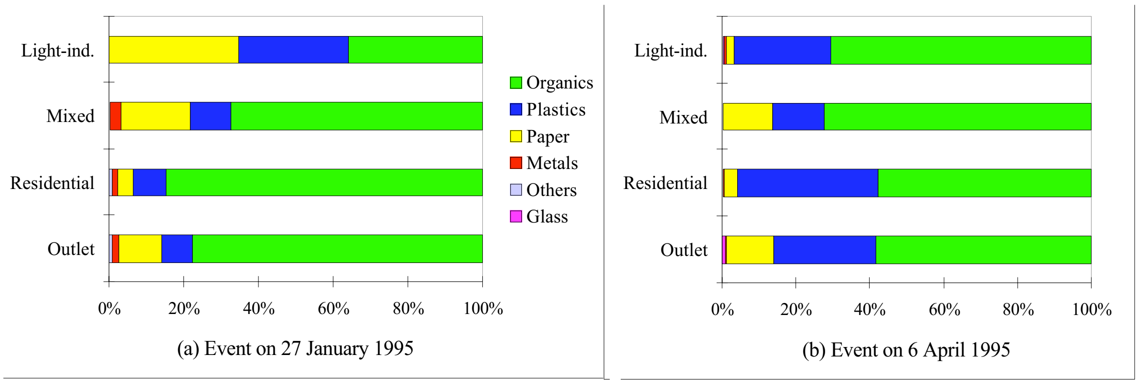


Figure 4.6 Composition of collected material from different land-use areas for both monitored events

The plots in Figures 4.2 to 4.5 also show that the proportions of litter to debris did not change considerably during the runoff events although the actual concentrations and loads varied considerably. This implies that both litter and debris are transported in a similar fashion during runoff events.

4.7.4 Water quality from different land-use types

The collected concentration data for TSS, TN, TP are presented in Appendix A. The concentrations of TP (0.3 to 0.6 mg/L) and TN (1.5 to 4 mg/L) were similar for all catchments. Total suspended solids concentrations appeared higher at the mixed commercial/ residential site and the catchment outlet (up to 400 mg/L) compared to the other sites (up to 150 mg/L). These values lie approximately in the middle of the large range of values reported in the literature for fully developed urban areas (see for example, Cordery, 1977; Athayde et al., 1983 and; Mudgway et al., 1996).

High nutrient and sediment pollutant concentrations during the early part of the hydrograph were only evident in the mixed commercial/ residential site and to a lesser extent the catchment outlet. The light-industrial and residential sites appeared to have reasonably uniform concentrations throughout the runoff.

4.8 CONCLUSIONS FROM STORM EVENT MONITORING

This chapter described the methods and equipment used to monitor discharge, gross pollutants and water quality parameters during storm events. A pilot study illustrated how site selection is critical for this type of monitoring. The sites should have catchment areas less than 200 hectares, must have safe access at all times, be close to where the monitoring personnel are located and ideally have (as close as possible to) uniform land-use types.

The main challenge with the monitoring program is predicting when and whether a rain event will fall on the monitoring sites (and to a lesser extent arranging for personnel to be at the monitoring sites). Nevertheless, the monitoring technique described in this chapter gives very detailed information about gross pollutant transport and it can be successfully carried out, particularly when enthusiastic personnel are available.

After an initial pilot study, monitoring was carried out during two events at four sites and one site was monitored for six storm events over a 12 month period. Observations from the limited data set suggest that:

- organic material (leaves and twigs) contribute at least two thirds of gross pollutant loads in all areas except light-industrial areas where figures are inconclusive;
- there are higher amounts of litter (paper and plastics) transported from commercial areas than residential and light-industrial areas;
- the composition of gross pollutants during events appears to remain relatively constant compared to the concentration and load fluctuations; and
- gross pollutant concentrations are generally highest during early stages of runoff, but the most load is transported during times of high discharge.

This monitoring indicates that stormwater channels are very effective media for conveyance of catchment derived gross pollutants and that discharge and pollutant conditions change and vary considerably in stormwater drains. This suggests that a flexible solution to gross pollutant problems in stormwater is required and that the treatments should aim to treat the maximum discharge possible and be able to treat multiple storms in a day.

5. CDS DEVICE AND SEPT FIELD TRIALS

This chapter describes the methodology of field experiments designed to determine the effectiveness of two promising gross pollutant trapping systems namely, CDS devices and side entry pit traps (SEPTs). The following chapters present and discuss the results from this monitoring in three parts: gross pollutant loads, the CDS device performance, and SEPT performance.

A CDS pollution trap as well as SEPTs were monitored in the same 50 hectare urban catchment in an inner suburb of Melbourne. The two methods trap stormwater gross pollutants in different ways. CDS devices are large in-transit traps that separate and collect pollutants from the flow (see Section 3.1.6). On the other hand, SEPTs are located inside side entry pits and capture gross pollutants as they fall into the pit with road runoff (Section 3.1.2). CDS devices have relatively large construction costs and low maintenance costs, whereas the SEPTs have low installation costs but require more regular maintenance.

Extensive laboratory experiments (Wong & Wootton, 1995) have shown the CDS device to be very efficient at trapping debris without blocking or restricting the flow. However, little is known about the trapping efficiency, clean-out requirements or flow characteristics of a CDS device in the field. SEPTs are being widely used in Australia, however, no field trapping efficiency data existed before these experiments.

Monitoring involved continuous measurements of discharge, cleaning the devices at regular intervals and analysing collected materials in a laboratory. By installing the two systems in the same catchment the characteristics (trapping efficiency and the amount and type of material collected) of each method were able to be compared. Cleaning frequencies for the two systems and the optimal distribution of SEPTs were also examined and provide useful information for stormwater system managers.

5.1 INTRODUCTION

The field trials began as a Melbourne Water investigation into the performance of a CDS device in Collingwood. The CRCCH became involved after a restructure at Melbourne Water and the project was moved to Coburg. It was intended to conduct the trials in the same area as the previous gross pollutant monitoring (Chapter 4). Soon after, Moreland City Council and the Merri Creek Management Committee joined the team. Finally, Banyule City Council were approached to provide SEPTs for the purpose of their assessment. A feature of this project was the range of parties it brought together and the success with which they worked together. Partners in the project were:

University of Melbourne	Melbourne Water
CRC for Catchment Hydrology	Commonwealth EPA
Moreland City Council	Merri Creek Management Committee
Streamline Australia	CDS Technologies (formerly Pollutec)
Banyule City Council	

5.2 OBJECTIVES OF THE TRAP-MONITORING

The following objectives were set to compare the two trapping techniques:

- to determine the trapping effectiveness, hydraulic performance and operating requirements of a CDS device;
- to determine the trapping efficiency of SEPTs and the distribution of loads caught by individual traps; and
- to increase our knowledge of the types and amounts of litter and debris that reach stormwater drains.

5.3 LOCATION OF TRIALS

The location for the field experiments was in Coburg, Victoria (see Figure 5.1) in the same catchment as the previous storm event monitoring. The CDS device was installed at the junction of two streets adjacent to a main drain (1220 mm diameter). The catchment area is approximately 50 hectares (35% commercial and 65% residential land-use) with 192 road entrances to the drainage system. Management practices in the catchment are described in Section 4.4 and include street sweeping, pit cleaning and litter officers. The site was chosen because it satisfied the criteria of being inside the previously monitored areas in Coburg (Chapter 4), having an appropriate catchment size for available funds, and having access for construction, monitoring and maintenance.

Figure 5.1 Location of field trials, Coburg, Victoria

5.4 CDS PERFORMANCE ASSESSMENT

To investigate the operating performance of the CDS device, measurements of discharge and water levels upstream and downstream of the device were made and trapped material was removed from the device and analysed. Water samples were also collected from upstream, downstream and in the sump of the device and tested for various water quality parameters to examine any influence of the trap on the passing stormwater. To examine the long term operational requirements of the CDS device, two cleaning methods were examined.

The CDS device was monitored to provide estimates of:

the trapping efficiency of the CDS device (for gross pollutants);
the flow capacity of the CDS device and head losses through the system;
the types and amounts of material being transported by the stormwater system;
the potential nutrient contribution of organic gross pollutants to receiving waters;
any water quality changes to the stormwater caused by the CDS device; and
the cleaning requirements for the device during typical operating conditions.

Velocity and flow depth instrumentation were installed upstream, downstream and across the diversion weir of the CDS device to estimate the discharge that flowed through the collection chamber and the discharge that bypassed the unit (over the diversion weir). The trap was cleaned as soon as feasible after every storm event and the collected material was then sorted and weighed in the laboratory.

Discharges were estimated every two minutes with acoustic Doppler instruments that measure water depth and velocity (at A & C, Figure 5.2; Unidata Australia, 1994). Additional pressure transducers were installed across the top of the diversion weir (at B, Figure 5.2; Tain, 1993) that measure water depth. From these data discharge over the weir was estimated.

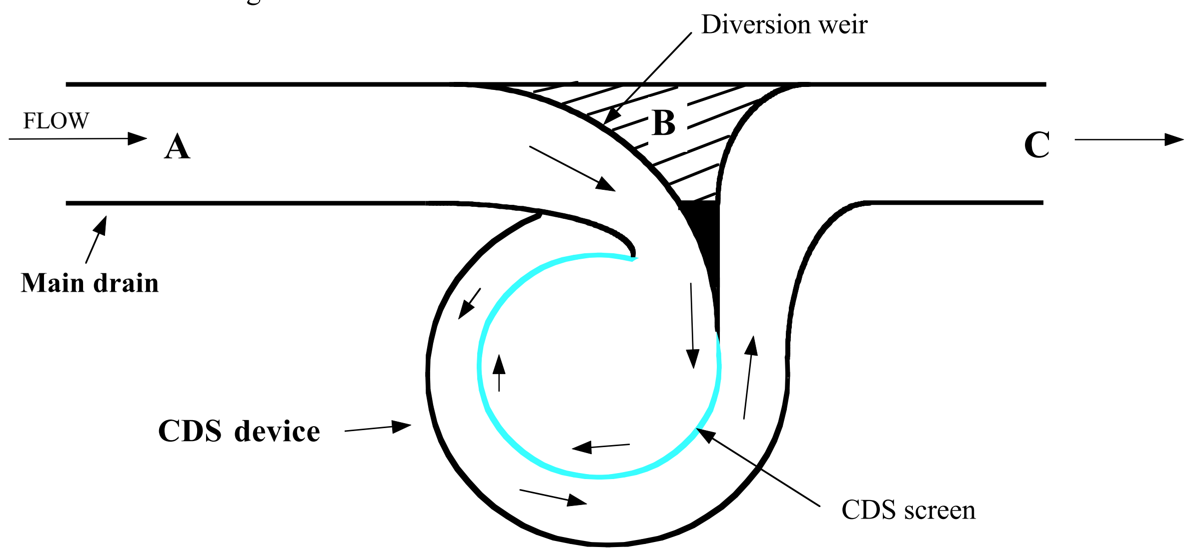


Figure 5.2 - Location of instrumentation around the CDS device at the field site

There are two mechanisms for material to pass the CDS device: flows that overtop the diversion weir by-passing the CDS trap and carrying pollutants downstream, and material that passes through the device's screen. Times and discharges when the diversion weir was overtopped were recorded and compared with the discharge through the device. During times when the diversion weir is not overtopped the only pathway for material is through the CDS screen. Gross pollutants are defined in this study as material retained by a 5 millimetre screen which is the size of the CDS screen. Therefore, by definition, gross pollutants can not pass through the CDS screen. This implies that by-pass via the diversion weir is crucial for determining the trapping efficiency of the CDS unit and instrumentation was designed with this in mind.

When the diversion weir was overtopped the significance of any material passing the trap was estimated from how much discharge went over the diversion weir compared to the volume that went through the device. This gave no indication of the amount of gross pollutants that were transported downstream but provided an insight to the discharge proportion that bypassed the unit.

The intention was to clean the CDS device after single storm events so that loads could be compared with storm characteristics. A storm event was defined for cases when the flow in the pipe reached a maximum depth of more than 150 mm (corresponding to approximately two to three millimetres of rainfall on the catchment). The material that collected in the CDS trap was removed and transported to the University of Melbourne for analysis. The results are discussed in Chapter 6.

The cleaning frequency of the CDS device is critical for determining its feasibility for future installations. For the last six months of the experiments the unit operated with the recommended cleaning frequency of three months. During this period water samples from upstream, downstream and in the sump of the device were taken routinely. These were taken to investigate the potential breakdown of collected pollutants in the sump and any influence they may have on the passing stormwater. The water samples were analysed for TP, TN and TSS. Automatic water samplers were also installed upstream and downstream of the CDS device (at A and C in Figure 5.2) and allowed water samples to be taken during runoff events. These data, in addition to the low flow data, give insights into the effect of the CDS device and collected pollutants on the stormwater passing through the system and the results are discussed in Chapter 7.

There were two methods used to clean the CDS device: a large vacuum device (150 mm diameter) attached to a powerful suction pump; and a basket installed in the sump of the chamber which was lifted. Each method was used after approximately three months of operation. The plant requirements, approximate costs and proportion of the load that was removed by each method were estimated.

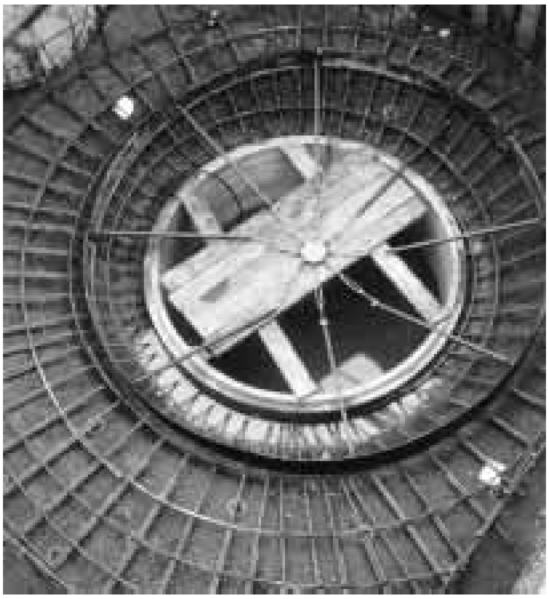
CDS device construction:

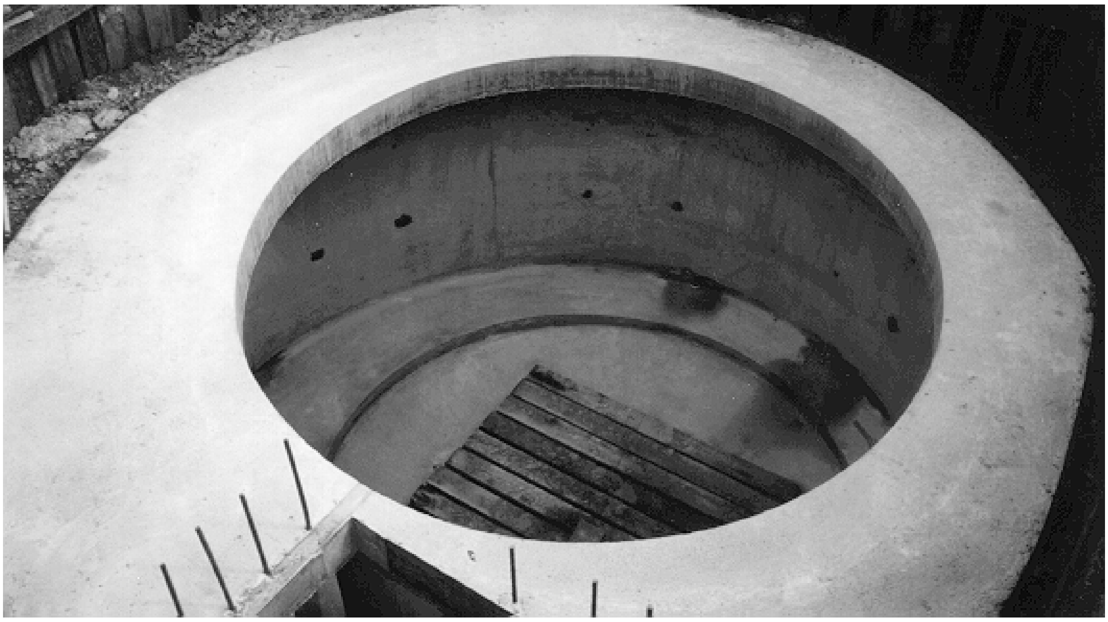
The construction of the CDS unit took about 12 weeks, however, the majority of the construction was carried out while keeping the existing stormwater system in operation. The unit was firstly constructed alongside the stormwater pipe and all necessary structural work was completed before breaking into the existing stormwater system for connection to the CDS unit. During construction a small road was closed and water, gas and telephone services relocated. The total construction cost for the device was $230,000 (1996 prices).

The construction commenced with excavation of land adjacent to the stormwater pipe (Photograph 5.1). Next, the steel reinforcements for the base of the CDS unit were laid and concreted (Photograph 5.2). In addition, the separation sump, which is made of a standard precast pipe, was also fitted to the base.

The shell of the separation chamber was then cast as shown in Photograph 5.3 after which the separation screens were installed in the separation chamber. The separation screens were delivered in sheets and were mounted in the separation chamber with standard stainless steel bolts (Photograph 5.4). As the main structure neared completion, the existing 1220 mm diameter pipe was cut open in preparation for its connection to the CDS unit. Photograph 5.5 shows the stormwater pipe exposed and preparations made to extend the CDS unit diversion structure into the pipe. Photograph 5.6 shows the completed unit fully contained underground.


Photograph 5.1 Excavation down to the floor of the chamber,(6x6x4 meters)


Photograph 5.2 Sump in place and the floor reinforcement tied


Photograph 5.3 Shell of the chamber where the screens will be placed

Photograph 5.4 Fitting the separation screens

Photograph 5.5 Construction adjacent to the drain

Photograph 5.6 The final product at road level

Cleaning and laboratory methods:

Cleaning the CDS unit was only possible after at least 36 hours of dry weather (to ensure low inflows to the CDS unit). The cleaning process involved removing floating material with a swimming pool leaf-scoop, pumping out the water from in the chamber (approximately 45 cubic meters) and then manually removing the sump materials (using a rope and bucket), see Photograph 5.7. To enter the unit for cleaning all personnel were required to have completed a confined space entry course (Casey TAFE, 1996) and were required to follow Melbourne Water guidelines for confined space entry (Melbourne Water, 1995b). On all occasions the cleaning process involved at least three people and took between two and three hours.

Removed material was then transported to the University of Melbourne where it was placed into baskets and left to drain overnight. The material was then sorted into the following seven classifications for floating and sump material and then samples of the material were oven dried.

- personal plastic - from pedestrians, motorists or residents (eg. food & drink containers, shopping bags, cigarette packet wrappers);
- commercial plastic - from business activity (eg. packing polystyrene, wrapping straps);
- personal paper - from personal use (eg. newspapers, bus tickets, food & drink containers);
- commercial paper - cardboard etc.;
- metals - foil, cans;
- organic material - leaf litter and any vegetative material; and
- others - cloth, glass and unidentifiable objects.

These classifications are slightly different from those used in Chapter 4 (Section 4.5.1). Glass is no longer a classification because there was rarely any glass in the earlier monitoring (glass items were included in the *others* classification). Plastics and paper are split into personal and commercial items to further indicate possible sources of the material. Personal items include those used by pedestrians, residents and motorists, including any food and drink items, cigarette items and newspapers. Commercial items are those associated with businesses in the area and typically consist of packing foam and strapping, cardboard and plastic sheeting.

Photograph 5.7 Manually cleaning the CDS unit

Photograph 5.8 Sorting gross pollutants in the laboratory

After sorting (Photograph 5.8), the volume of each classification was determined and the samples weighed and then sub-samples from different classifications were taken and dried to establish the wet to dry ratios. In addition, samples of the organic gross pollutants (mainly leaves and twigs) from each clean-out were analysed for the TP and TN content (by percentage) at a NATA certified laboratory (Water EcoScience, Victoria).

During cleaning, gross pollutants were collected using a wire leaf rake and consequently much of the sediment was left at the bottom of the sump and was removed by vacuum at the end of the manual cleaning. A sample of the collected sediments was taken and analysed for size gradings to indicate the retention capabilities of the CDS device.

Hydrological data collection:
Discharges were estimated using automatic data loggers (Unidata, 1994) that record water depths and velocities every two minutes and rainfall data came from an existing Melbourne Water pluviograph station located nearby (Figure 4.1; six minute data). The upstream and downstream discharge data loggers enabled a check of mass balances to ensure reliable data. Maintenance involved regular equipment checks, data retrieval and battery changes (at least weekly). Collected data were checked for soundness and stored at the University of Melbourne. Calibrations were performed on the monitoring equipment prior to field installations and included:

- laboratory depth calibrations of pressure transducers, and
- laboratory discharge calibrations of Unidata flow monitoring instruments in laboratory flumes.

The velocities recorded by the Starflow instruments were checked in the field with a hand-held propeller current meter.

Each time data were retrieved from data loggers the information was checked for:
- missing or spurious data
- consistency between instruments (eg. upstream and downstream flow meters), and
- flow events to determine cleaning times.

Water sample collection:
Water samples were collected during storm events and dry weather flows to assess the influence of the CDS unit upon water quality. Samples were collected from upstream, downstream and in the sump of the CDS unit and were tested for TN, TP and TSS concentrations.

To collect the samples automatic water samplers (ISCO, Model 1680, undated) were installed upstream and downstream of the CDS unit. Both samplers were triggered by water depths of more than 100mm. Once triggered, water samples were taken at ten minutes intervals for approximately 5 hours throughout the storm event. The water was pumped into 500ml sample bottles via a suction hose attached to the bottom of the drain. This method of storm water sampling eliminated the requirement for on-site personnel during storm events.

In addition to the storm event sampling, low-flow water samples were routinely collected manually from upstream, downstream and at three depths (1m, 2.5m and the bottom of the sump) within the collection chamber of the CDS unit.

All water samples were analysed for TN, TP and TSS using a Merck SQ200 Photometer water quality testing unit (Merck, undated). In addition, some samples were tested at a NATA certified laboratory (Water EcoScience, Victoria) to check the validity of the results obtained with the Merck instrument. The Merck device was cheaper and allowed more samples to be analysed. Comparisons between the Merck unit and the certified laboratory results were performed by duplicating analysis of some samples.

5.5 SEPT PERFORMANCE ASSESSMENT

In the second part of the monitoring, SEPTs were installed at each publicly owned road entrance to the drainage system in the experimental catchment. After set periods (either two or four weeks) material was cleaned from in the SEPTs and the downstream CDS device during the same day. Collected material was taken to the University of Melbourne where it was then sorted and dried. Analysis of the trapped material allowed estimates of trapping performances.

Objectives for testing the SEPTs were to provide estimates of:

- the trapping efficiency of SEPTs for typical cleaning frequencies;
- the distribution of various gross pollutants that reach the stormwater system; and
- the optimum locations for SEPTs for future installations.

All of the publicly owned road entrances to the drainage system were installed with SEPTs (Figure 5.3). Privately owned entrances were not considered because of access problems for regular maintenance. Privately owned entrances represented a small proportion of the total entrances (approximately 5%), but the actual number could not be determined.

The high trapping efficiency of the CDS unit (see Chapter 7) makes it an ideal monitoring device for the SEPTs provided that both systems are cleaned at the same time. The trapping performance of the SEPTs was estimated by analysing the material (composition and masses) that the baskets collected and comparing it to the material that was caught in the downstream CDS device.

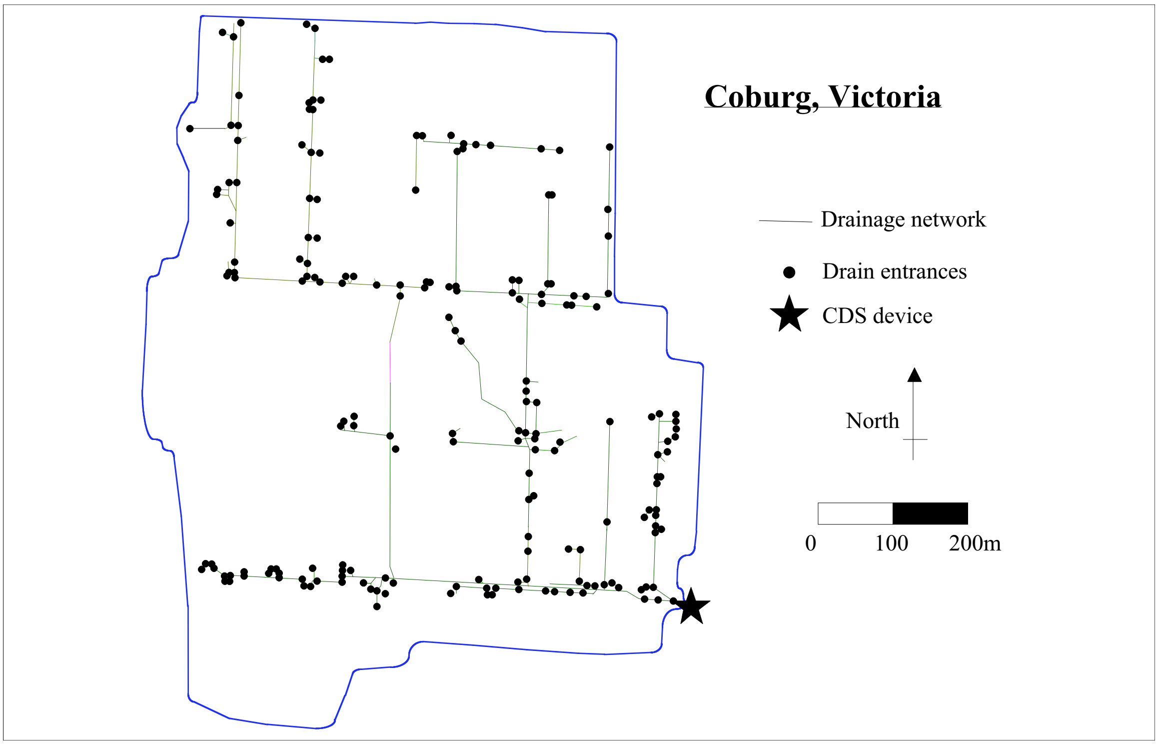


Figure 5.3 Drainage pit entrances to the experimental catchment (SEPT installations)

By installing the SEPTs on all feasible entrances it was possible to investigate trapping efficiencies for different numbers of SEPTs (eg. the difference between trapping efficiencies for 100% of feasible entrances fitted with traps and with only 50% fitted with traps). Comparisons of trapped material in each SEPT with the catchment land-use type was then performed and allowed recommendations for locating future installations of SEPTs.

SEPT installations:

The SEPTs used for the field experiment were the Banyule City Council traps (see Section 3.1.2) and these were installed on the three entrance types located in the experimental catchment (side entry pits, side entry pits fitted with grates and grills). Installing the SEPTs involved drilling four holes into the concrete drainage pit walls, inserting step irons, and fixing the collection baskets to the step irons with tie wire. On average each installation took between 15-20 minutes to complete (Photograph 5.9).

Once the SEPTs were installed, all the traps and the CDS unit were cleaned for the start of the first monitoring period.

Initial investigations of council stormwater plans revealed approximately 100 entrances in the experimental catchment, but a detailed field inspection yielded approximately double this (192). This highlighted the importance of detailed field inspections prior to installing a SEPT system.

Photograph 5.9 Installing Banyule City Council side entry pit traps in Coburg

Cleaning and laboratory methods:

The traps were cleaned (either fortnightly or monthly) and the CDS unit was also cleaned on the same day. Results from analysing material caught by individual SEPTs enabled a detailed analysis of the origin of gross pollutants that enter the stormwater system.

During cleaning, up to six personnel (in three groups) manually removed collected pollutants from each SEPT and placed the contents into labelled bags. SEPTs were accessed via pit covers that could be removed by hand. Specially designed devices (essentially large tongs) were used to remove the larger material and then any remaining material was removed by hand. The six personnel took between four and five hours to complete the clean-out of 192 traps. The CDS device was then cleaned directly after the SEPTs (as described in Section 5.4.1) to ensure there was no rainfall between cleaning the two systems.

The contents of each of the SEPTs was sorted into eight classifications. The same classifications as for the CDS device monitoring were used, however, paper was further split to include junk-mail items (as part of a parallel study, LeCouteur et al., 1997). This was not possible in the earlier monitoring because the paper material that reached the CDS device was broken up and identification was limited. Random samples from each category were oven dried so that wet to dry mass ratios could be established and thus dry mass could be compared to that collected by the CDS trap. In addition, for the first clean-out of the SEPTs, a more detailed classification (21 categories) of the material was performed to investigate the origins of the material. This also formed part of the work by LeCouteur et al. that investigated the life cycle of free advertising material and its relation to stormwater. To complement the detailed classification an item count was performed and provided additional information about the trapped gross pollutants (10,901 items were counted). This detail of analysis was not possible for subsequent clean-outs because it was too time consuming for the available resources.