Monitoring of a Gross Pollutant Trap in Centennial Park, Sydney, Australia

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by

James E Ball

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THE UNIVERSITY OF NEW SOUTH WALES
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Abstract Urban stormwater runoff is a transport medium for many contaminants from anthropogenic sources. There are many alternative treatment technologies available to remove some of these contaminants. The Centennial Park and Moore Park Trust with support from the NSW EPA Stormwater Trust installed a CDS gross pollutant trap immediately upstream of Musgrave Pond within Centennial Park. Reported herein are the results of a monitoring program aimed at assessing the treatment achieved by the gross pollutant trap.		
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1 INTRODUCTION

Over the last decade a substantial number of structural techniques have been developed for the management of stormwater quality. It is desirable that the impacts of these devices on stormwater quality be investigated to ensure that managers of stormwater systems have the information necessary for attainment of the desired management aims. The Centennial Park and Moore Park Trust sought and obtained support from the NSW EPA Stormwater Trust for the installation of a CDS Gross Pollutant trap on the Musgrave Avenue Stormwater Channel upstream of Musgrave Pond. This CDS unit being incorporated as part of the program of pond restoration within the grounds of Centennial Park. Part of the aim of this pond restoration program is an enhancement of water quality within the 26 ha of wetlands/ponds located in Centennial Park; water quality in these water bodies is impacted significantly by the stormwater flowing into the park from adjacent urban areas. As part of the activities associated with the installation of the CDS Gross Pollutant trap, The University of New South Wales (UNSW) has monitored the quality of stormwater in the Musgrave Stormwater Channel upstream and downstream of the CDS device. Reported herein are the results of this monitoring program.

2 CATCHMENT DESCRIPTION

2.1 Catchment Details

The Musgrave Avenue Pond in the south-east corner of Centennial Park receives stormwater runoff from an urban catchment located approximately four (4) kilometres to the south-south-east of the Central Business District of Sydney. As such, the catchment is situated on the western side of the Randwick City Council and the eastern side of Waverley Council. A location map for the catchment area is presented as Figure 1.

Topography within the catchment has a uniform gradient with elevations ranging from 98 m AHD at the highest point to 43.2 m AHD at the UNSW gauging station located within Centennial Park. The mean catchment slope is about five percent (5%) with the steepest slopes adjacent to Carrington Road and Queens Park.

Existing development within the catchment is comprised of highly urbanised residential areas with some recreational areas located at the downstream outlet of the catchment. Shown in Figure 2 are the land uses within the catchment area as defined by the two local government authorities. Most residential development in the catchment was built prior to the 1950s with subsequent development predominantly consisting of redevelopment into high density residential with multi-apartment residential blocks; this residential development covers approximately 60% of the catchment area. General commercial activities are centred along the main arterial roads such as Carrington Road, Frenchmans Road and Bronte Road in the upstream portions of the catchment and occupy less than 1% of the catchment area. Roads and associated concrete footpaths occupy about 15% of the catchment area or 14.9 km of roads and 3.6 km of small lanes and alleys. The public building category which occupies approximately 6% of the catchment area mainly consists of school and hospital buildings with some religious buildings. Finally, open space areas comprise 18% of the total catchment area which predominately are Queens Park and a small portion of Centennial Park. A summary of development within the catchment area is given in Table 1.

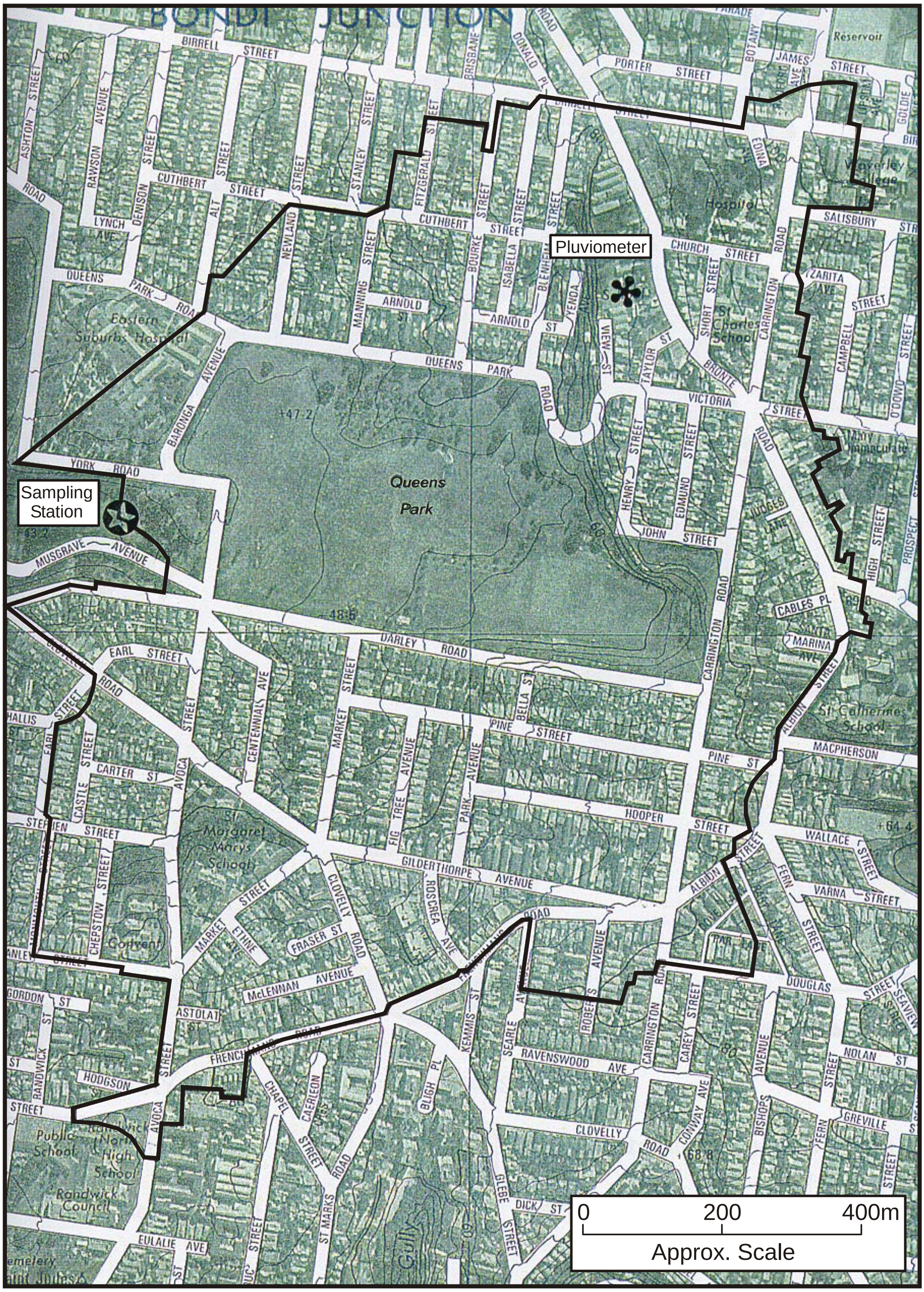

Figure 1 - Musgrave Avenue Stormwater Channel Catchment

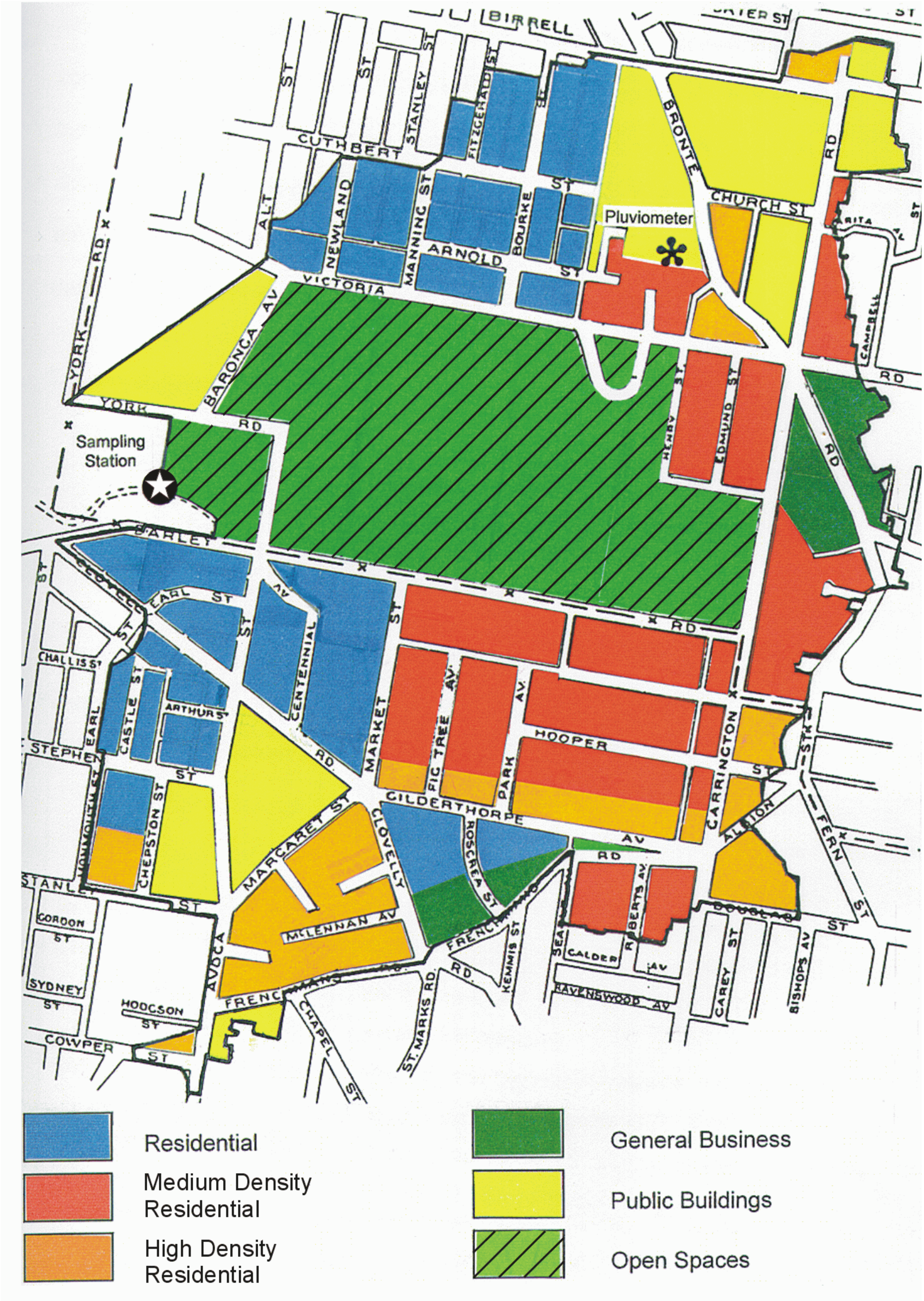

Figure 2 - Land Use Zoning

Table 1 - Land Uses within the Centennial Park Catchment Area

Land Use	Percentage Area
Open Space	18
Residential	60
General Business	1
Roads	15
Public Buildings	6

In general, the catchment is drained by separate sanitary sewer and stormwater drainage systems. The stormwater system consists of a series of pipes, box culverts, and open channels which ultimately discharge into Musgrave Pond in Centennial Park. Three authorities have management of the stormwater system; these authorities are

- Sydney Water Corporation — responsible, in general, for the open channels and pipes larger than 900 mm diameter;
- Randwick City — responsible, in general, for the pipes less than 900 mm diameter within the boundaries of Randwick City Council; and
- Waverley Council — responsible, in general, for the pipes less than 900 mm diameter within the boundaries of Waverley Council.

Details of the trunk drainage system which is essentially that portion of the stormwater drainage system operated by Sydney Water Corporation are shown in Figure 3.

2.2 Catchment Monitoring

Long-term rainfall records around the catchment area have been collected by

- Sydney Water Corporation at Paddington (1956 to date),
- UNSW at Avoca Street and Storey Street, Kingsford, (Feb 1977 to date), and
- Bureau of Meteorology at Kingsford Smith Airport (1960 to date).

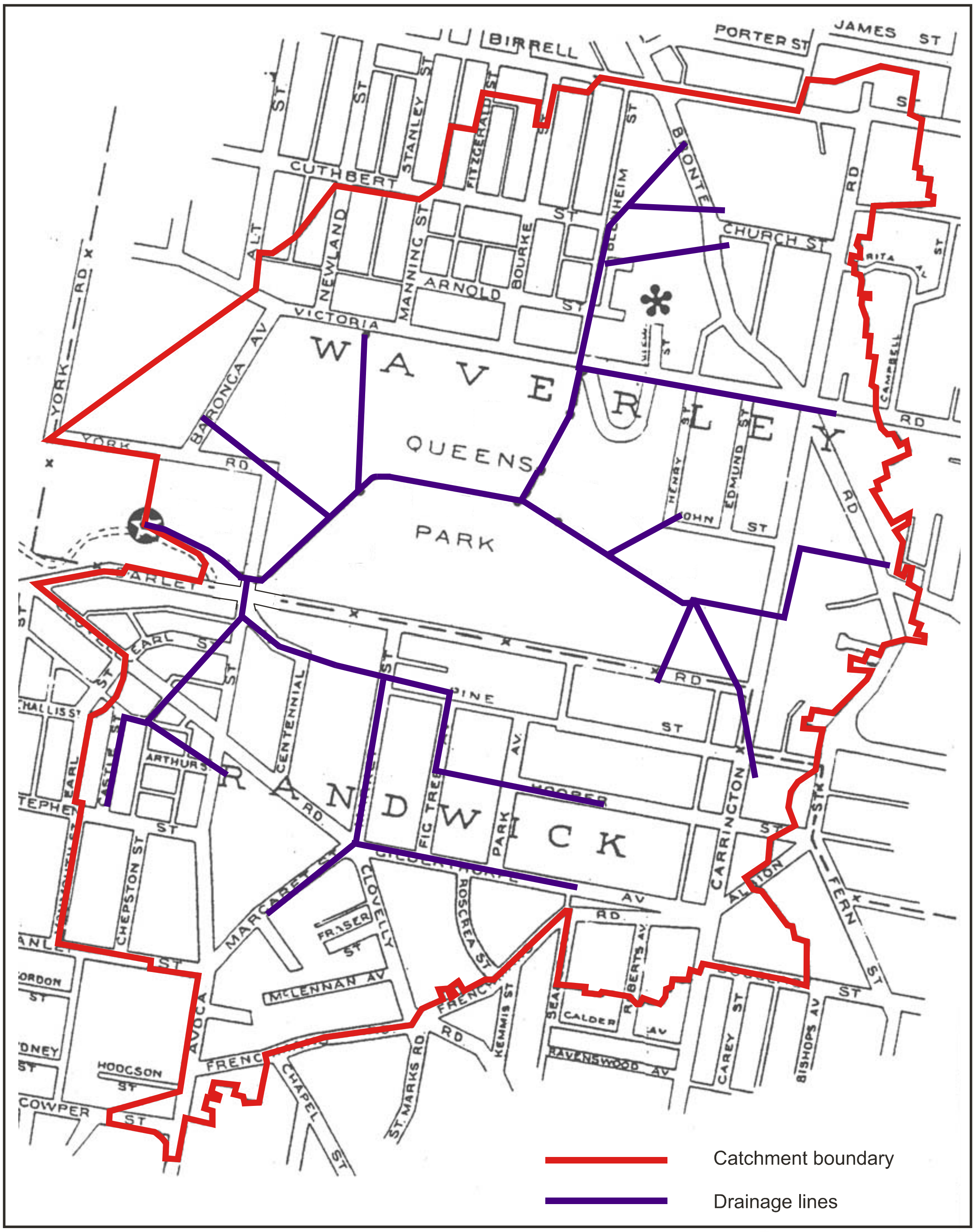

Figure 3 - Stormwater Drainage System

As a result of studies undertaken by students in the School of Civil and Environmental Engineering at The University of New South Wales, two additional rainfall gauges have been installed. These additional gauges are within the catchment boundaries of the Musgrave Avenue Stormwater Channel and are located at Waverley Public School and the UNSW gauging station within Centennial Park. Both of these locations are noted on Figure 3.

In addition to the rainfall gauges, UNSW installed a gauging station on the Musgrave Avenue Stormwater Channel within Centennial Park. Equipment within this gauging station for this study consisted of

- Data logger: This instrument controls the sensors and stores the recorded signals for downloading via cellular telephone to the School of Civil and Environmental Engineering hydrological archives. A Hydromace 2000 was used for this study as the data logger.
- Ultrasonic level sensor: The ultrasonic sensor installed for this study was a Milltronic sensor capable of level detection over a range of 0.25 to 5.0 m with a measurement response of 17 mm/s.
- 2 Automatic grab samplers: For this project, Gamet automatic samplers were installed upstream and downstream of the CDS gross pollutant trap. The sampling protocol was such that when the flow level reached 0.07 m, approximately 0.04 m above normal low flow levels, the upstream sampler would be activated which in turn would activate the downstream sampler. The sample volume collected was 1 L with a maximum of 24 samples collected at constant 10 minute time intervals during an event.

An important aspect of managing a gauging station is the development of a rating curve for the transformation of the recorded level to a flow rate. For the upstream gauging station, the rating curve was developed using the technique presented by Tilley et al. (1999); this rating curve is shown in Figure 4. The basis of the technique presented by Tilley et al. (1999) is the continuous monitoring of flow levels and subsection velocities. This has the advantage of ensuring that the cross sectional area of a subsection is known at the time of the velocity determination and hence overcomes the disadvantage associated with conventional techniques where the level is determined from an average of the level at the start and end of the gauging traverse. Flows from catchments with a rapid response, such as urban catchments, typically have significant changes in flow depth during the time taken for a gauging traverse and, hence, additional uncertainty in the resultant relationship between stage and discharge at the monitoring point. Tilley et al. (1999) suggest that this uncertainty is reduced through the application of their technique.

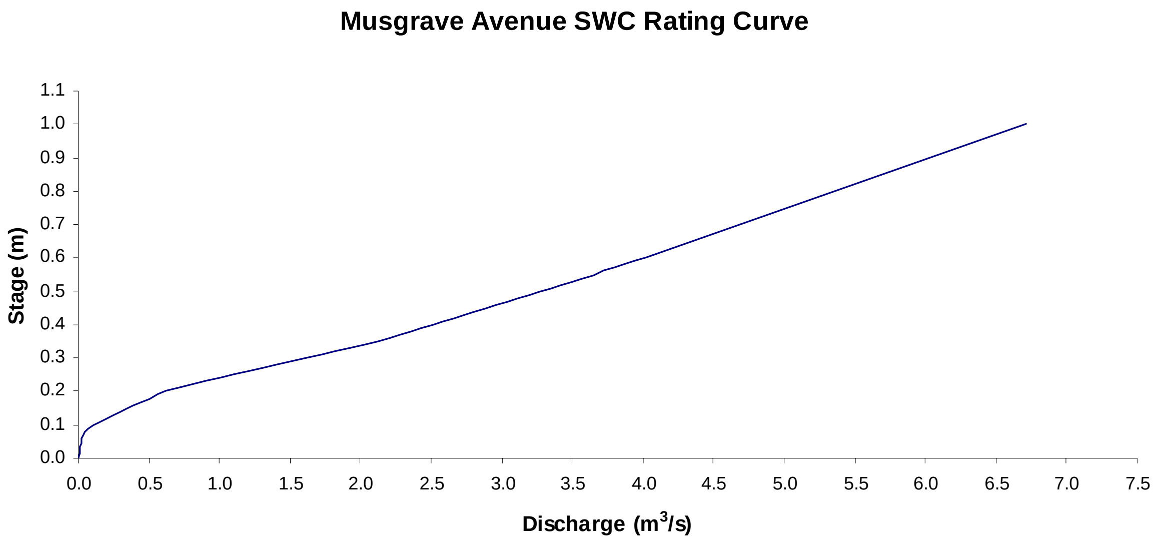

Figure 4 - Musgrave Avenue Stormwater Channel Gauging Station Rating Curve

3 MONITORING RESULTS

3.1 Overview

Monitoring of flows in the Musgrave Avenue Stormwater Channel by the School of Civil and Environmental Engineering as been undertaken since 1995. For short durations within this time period, water quality monitoring has been undertaken also. One period when water quality samples were collected was during 2002 and 2003. During this period, as noted earlier, samples were collected upstream and downstream of the CDS gross pollutant trap installed on the Musgrave Avenue stormwater channel. The events sampled occurred on the following dates

- Early Morning of 11th November 2002;
- Late Afternoon of 11th November 2002;
- Early Morning of 21st November 2002;
- Midday of 26th December 2002; and
- Morning of 2nd June 2003

Discussed in the following sections are these events and the collected data. For the water quality data, the results provided for each event include:

- A summary of the quantity of runoff for the event;
- A hydrograph showing the runoff during the event;
- A table of the event mean concentrations for the various constituents examined; and
- The constituent loadographs for each event.

At the conclusion of the discussion of the individual events, a summary table is provided together with the exceedance probability associated with each constituent.

3.2 Events

3.2.1 Event 1 - 15th November 2002

The first runoff event occurred during the early morning of 15th November 2002. Rainfall commenced about 3:00am and continued until nearly 4:00am with a total of 0.6mm rainfall being recorded at the Centennial Park rain gauge. Surface runoff for this event occurred between 3:30am and 4:40am. The runoff hydrograph for this event is shown in Figure 5. This was not a significant event but, nonetheless, did manage to initiate grab sample collection. The average rainfall intensity throughout this storm event was not determined due to its small magnitude.

Shown in Figures 6 and 7 are the loadographs upstream and downstream of the CDS Gross Pollutant Trap respectively for this event. Presented in Table 2 are the event mean concentrations determined for each metal examined, the total phosphorous and the total suspended solids.

Table 2 - Event 1 EMC Values

Site	**SS** (mg/L)	**Fe** (mg/L)	**Cr** (:g/L)	**Cu** (:g/L)	**Mn** (:g/L)	**Ni** (:g/L)	**Pb** (:g/L)	**Zn** (:g/L)	**P** (:g/L)
U/S	312	4.64	6	131	242	9	143	810	1510
D/S	141	5.88	5	101	99	7	130	554	1264

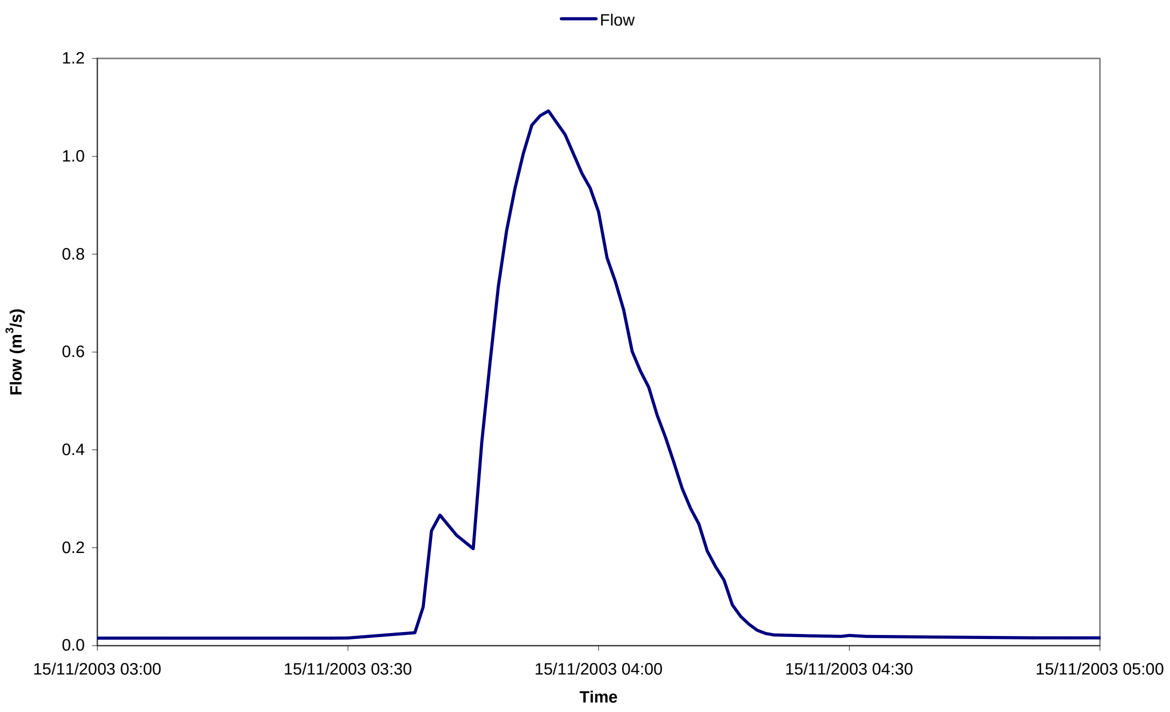

Figure 5 - Hydrograph for Event 1

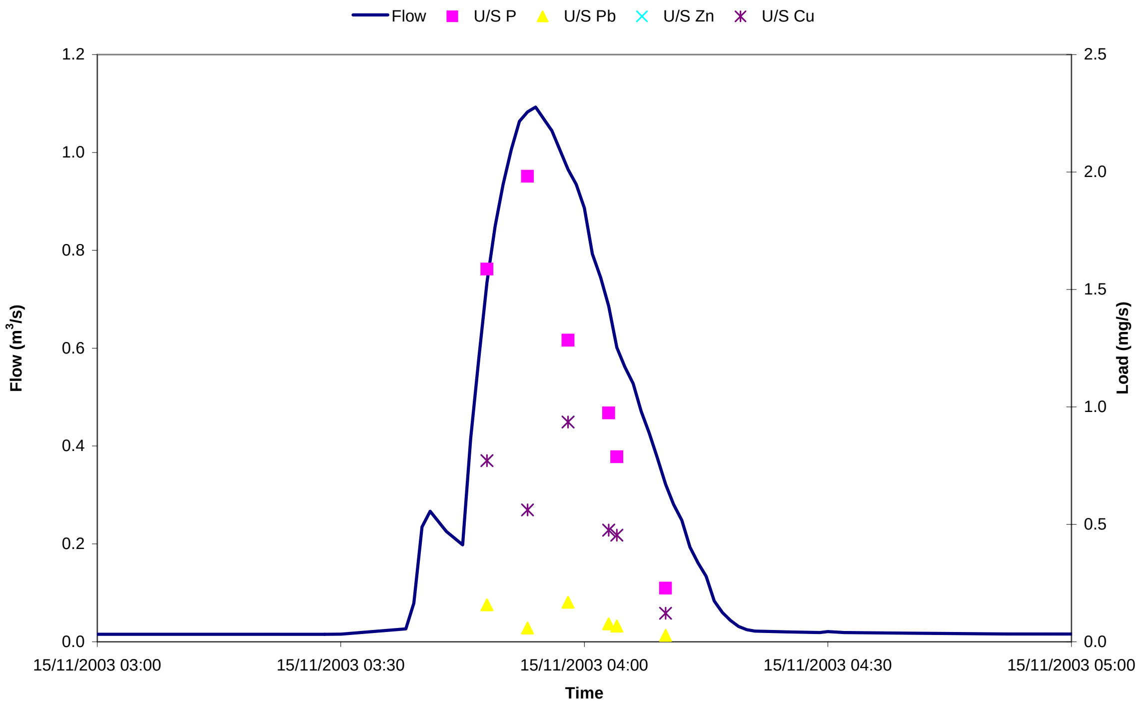

Figure 6 - Upstream Loadographs for Event 1

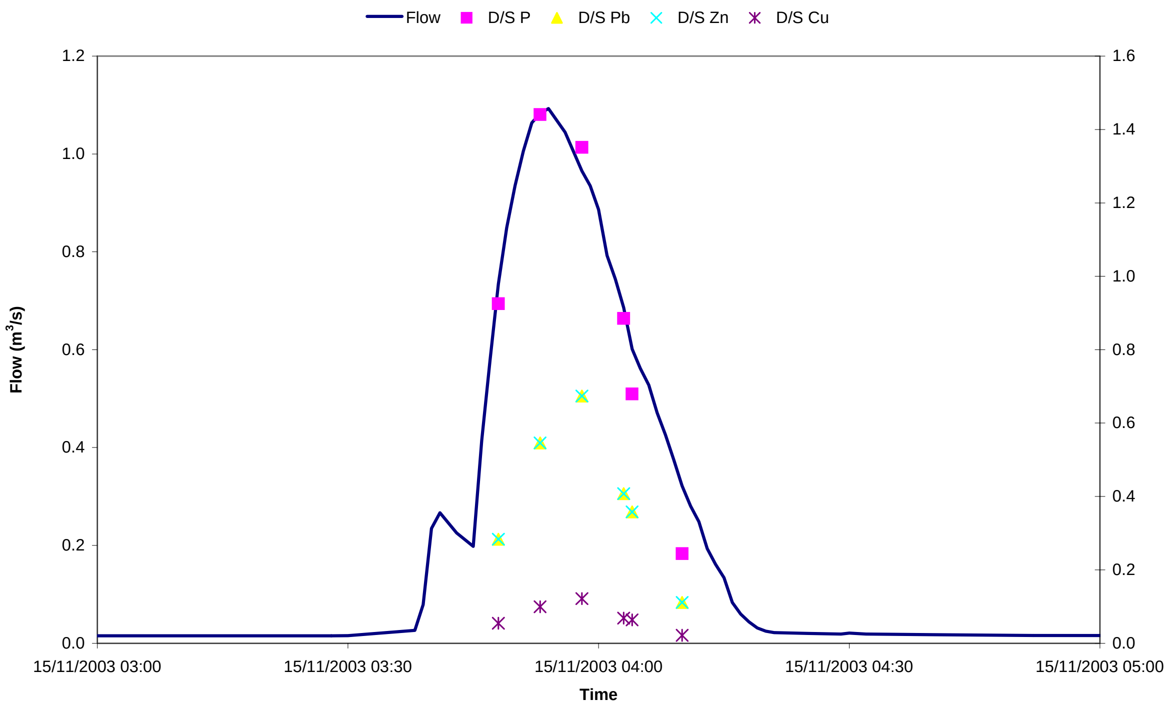

Figure 7 - Downstream Loadographs for Event 1

3.2.2 Event 2 - 15th November 2002

The second runoff event occurred during the afternoon of 15th November 2002. Rainfall commenced about 11:00am and continued until nearly 5:00pm with a total of 3.4mm rainfall being recorded at the Centennial Park rain gauge. While rainfall occurred over a six hour period, the most significant portion of the rainfall occurred in the period between 3:30pm and 5:0pm when 2.0mm of the total rainfall was recorded. It was this burst of rainfall that resulted in the development of surface runoff from the catchment which triggered the collection of grab samples at the gauging station. Surface runoff for this event occurred between 4:14pm and 6:04pm. The runoff hydrograph for this event is shown in Figure 8. This was not a significant event but, nonetheless, did manage to initiate grab sample collection. The average rainfall intensity throughout this storm event was not determined due to its small magnitude.

Shown in Figures 9 and 10 are the loadographs upstream and downstream of the CDS Gross Pollutant Trap respectively for this event. Presented in Table 3 are the event mean concentrations determined for each metal examined, the total phosphorous and the total suspended solids.

Table 3 - Event 2 EMC Values

Site	**SS** (mg/L)	**Fe** (mg/L)	**Cr** (µg/L)	**Cu** (µg/L)	**Mn** (µg/L)	**Ni** (µg/L)	**Pb** (µg/L)	**Zn** (µg/L)	**P** (µg/L)
U/S	70.3	4.63	2	51	26	3	26	243	492
D/S	48.6	1.42	1	51	35	3	38	270	574

3.2.3 Event 3 - 21st November 2002

This runoff event occurred during the early morning of 21st November 2002. Rainfall commenced about 00:20am and continued until just after 2:00am with a total of 3.8mm rainfall being recorded at the Centennial Park rain gauge. Surface runoff for this event occurred between 0:40am and 3:00am although some minor flows did occur after this time. The runoff hydrograph for this event is shown in Figure 11. As shown in this figure, runoff occurred in three distinct bursts with each burst corresponding to a period of more intense rainfall. As with previous

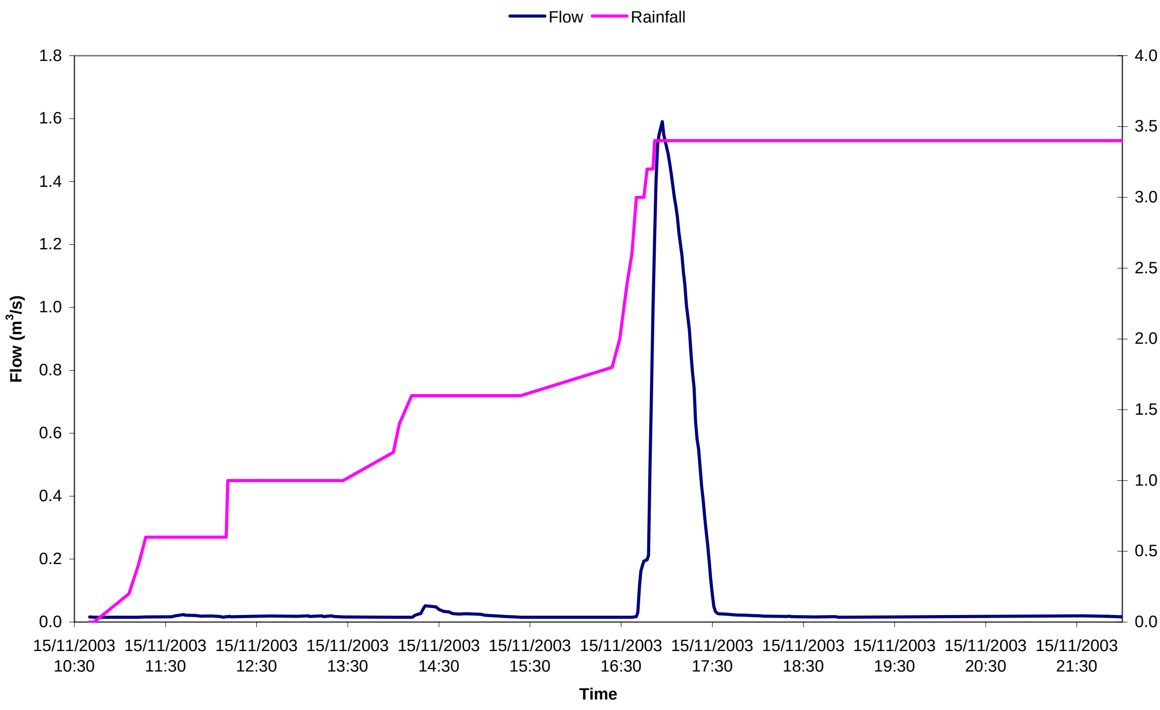

Figure 8 - Hydrograph for Event 2

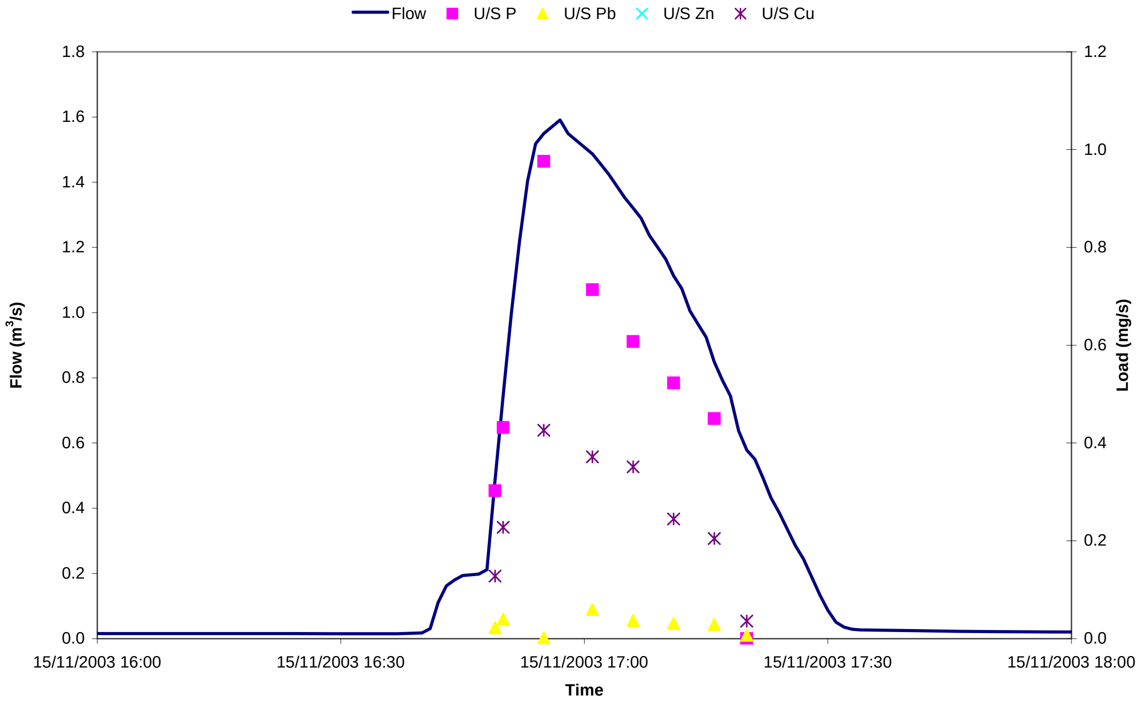

Figure 9 - Upstream Loadographs for Event 2

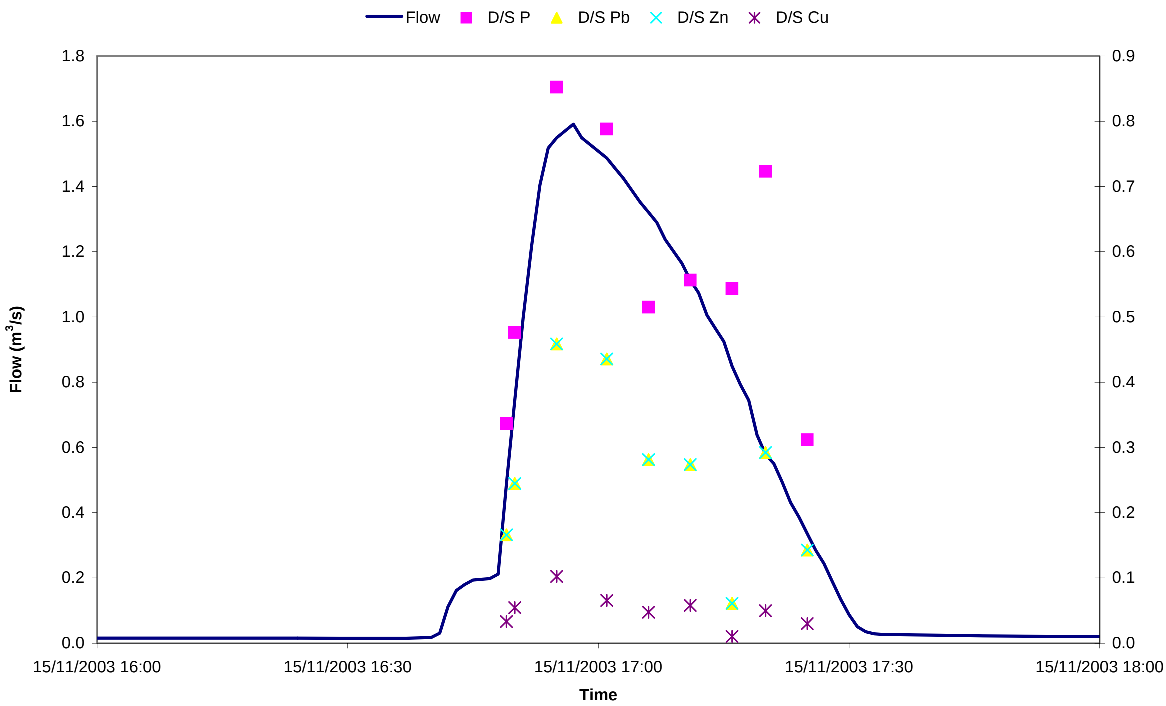

Figure 10 - Downstream Loadographs for Event 2

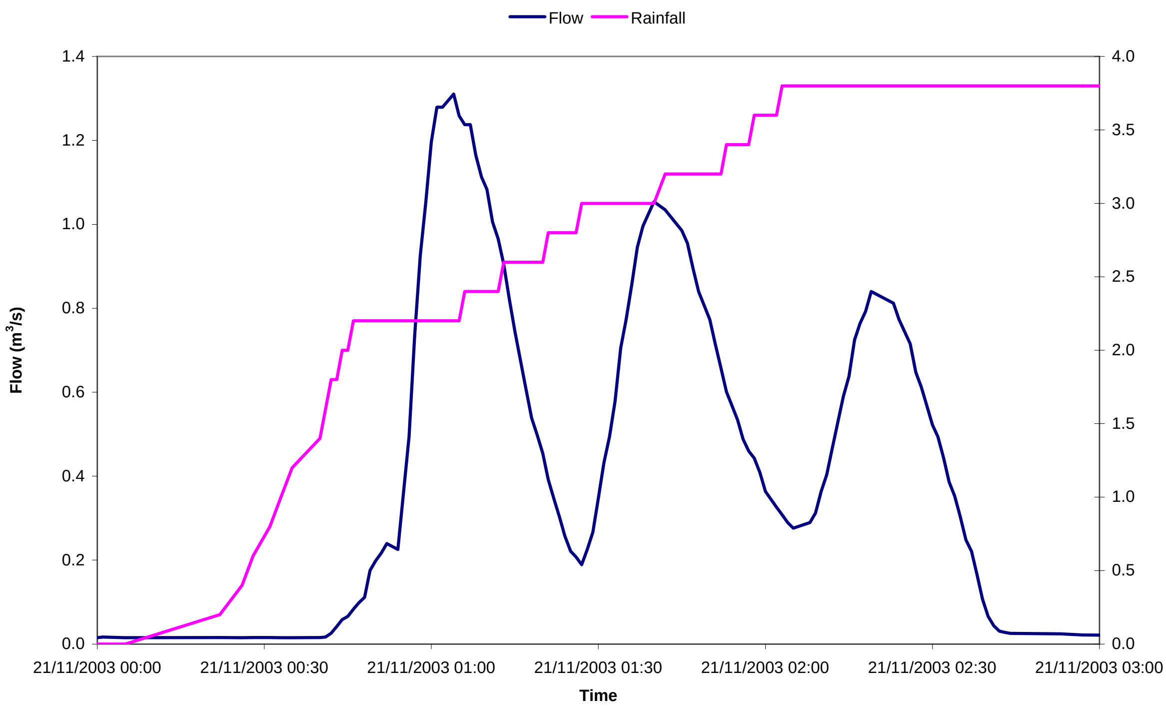

Figure 11 - Hydrograph for Event 3

events, this was not a significant event but, nonetheless, did manage to initiate grab sample collection. The average rainfall intensity throughout this storm event was not determined due to its small magnitude.

Shown in Figures 12 and 13 are the loadographs upstream and downstream of the CDS Gross Pollutant Trap respectively for this event. Presented in Table 4 are the event mean concentrations determined for each metal examined, the total phosphorous and the total suspended solids.

Table 4 - Event 3 EMC Values

Site	SS (mg/L)	Fe (mg/L)	Cr (:g/L)	Cu (:g/L)	Mn (:g/L)	Ni (:g/L)	Pb (:g/L)	Zn (:g/L)	P (:g/L)
U/S	35.5	3.21	2	88	43	4	56	436	694
D/S	38.0	1.55	2	67	91	4	44	314	565

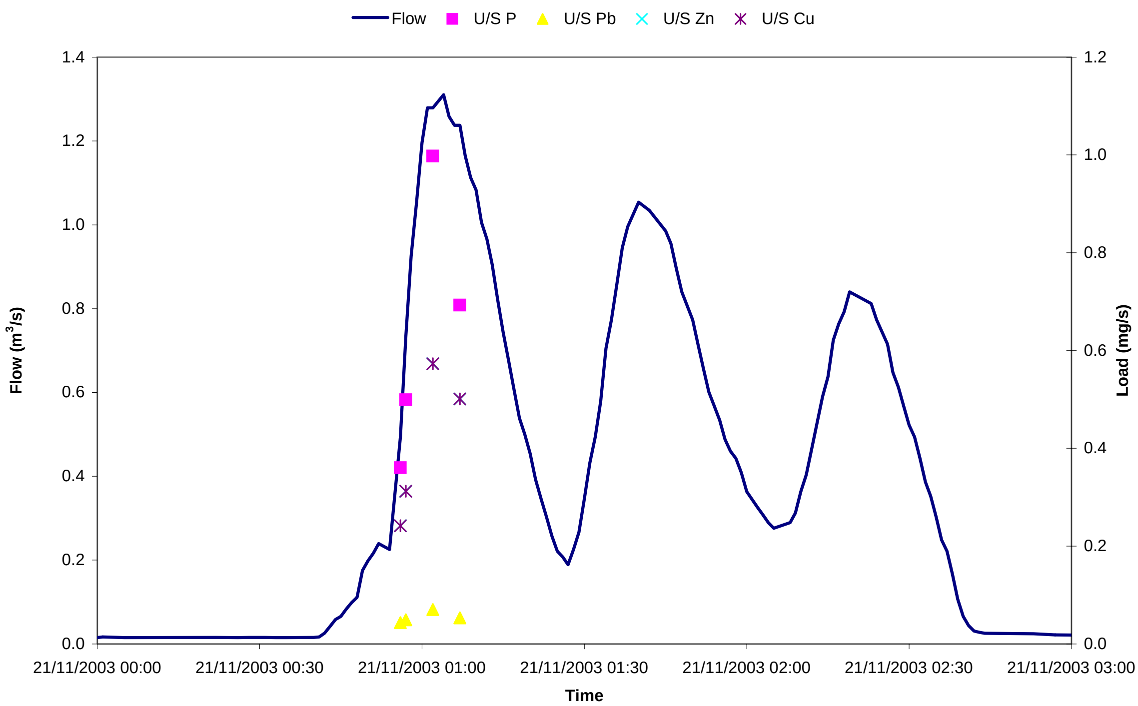

Figure 12 - Upstream Loadographs for Event 3

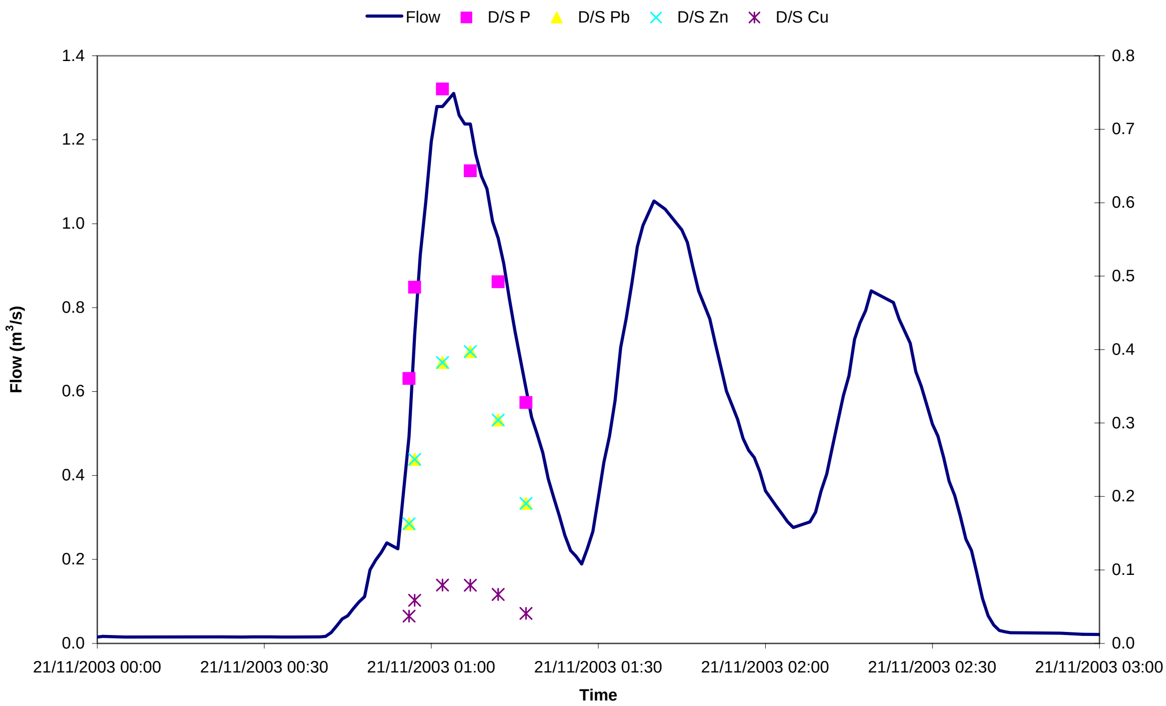

Figure 13 - Downstream Loadographs for Event 3

3.2.4 Event 4 - 27th December 2002

This runoff event occurred during 27th December 2002. Rainfall commenced about 10:00am and continued until nearly 3:00pm with a total of 7.2mm rainfall being recorded at the Centennial Park rain gauge. Surface runoff for this event commenced about 10:35am and continued until approximately 10:00pm. As shown in Figure 14 where the runoff hydrograph for this event is presented, the majority of the surface runoff occurred between 10:35am and 2:30pm. This was a more significant event but the average rainfall intensity throughout this storm event was only approximately 1.5mm/h. This intensity is not large and would be expected to occur frequently.

Shown in Figures 15 and 16 are the loadographs upstream and downstream of the CDS Gross Pollutant Trap respectively for this event. Presented in Table 5 are the event mean concentrations determined for each metal examined, the total phosphorous and the total suspended solids.

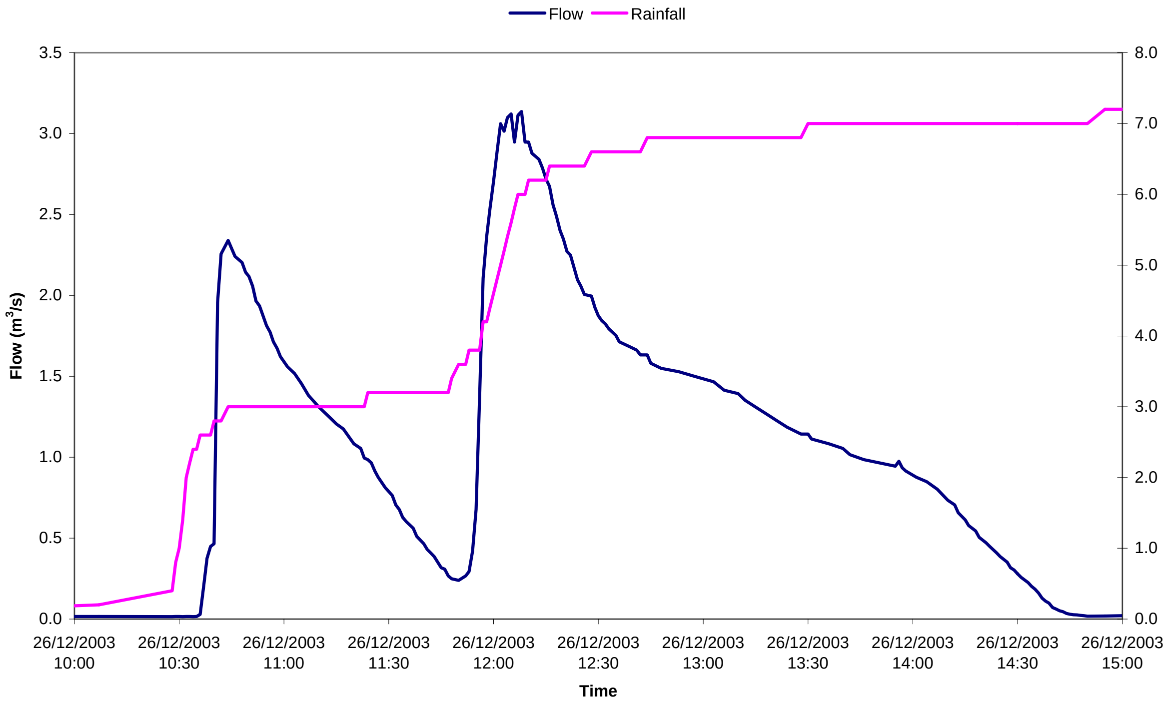

Figure 14 - Hydrograph for Event 4

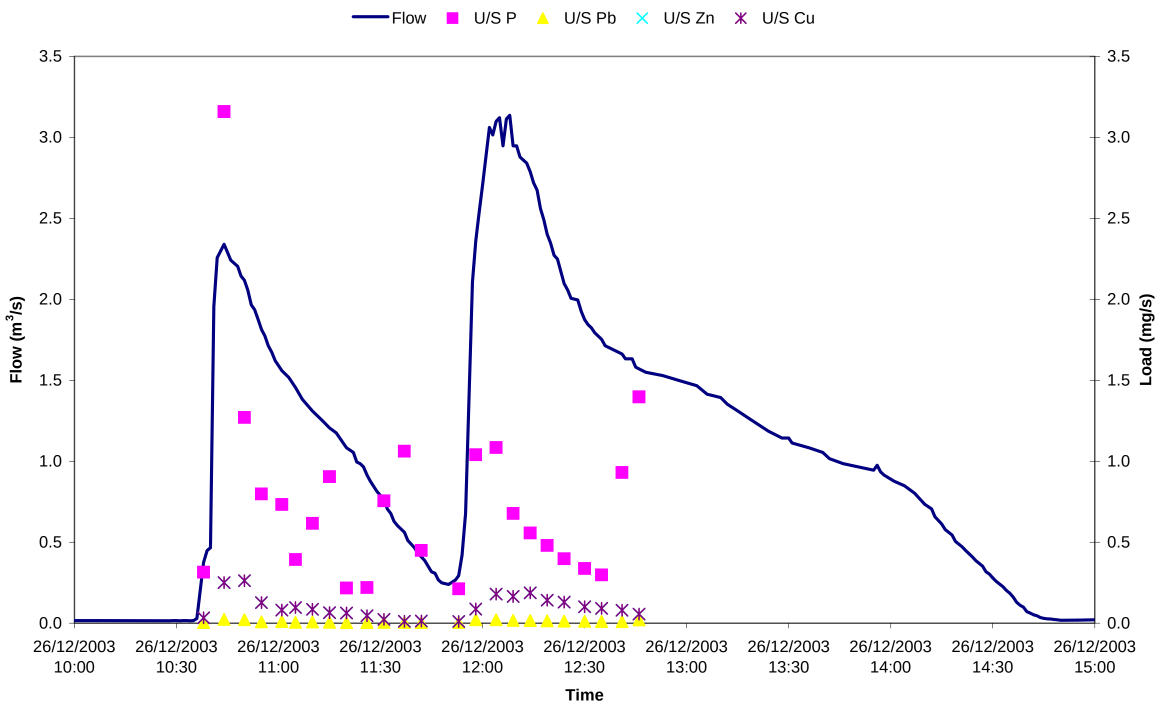

Figure 15 - Upstream Loadographs for Event 4

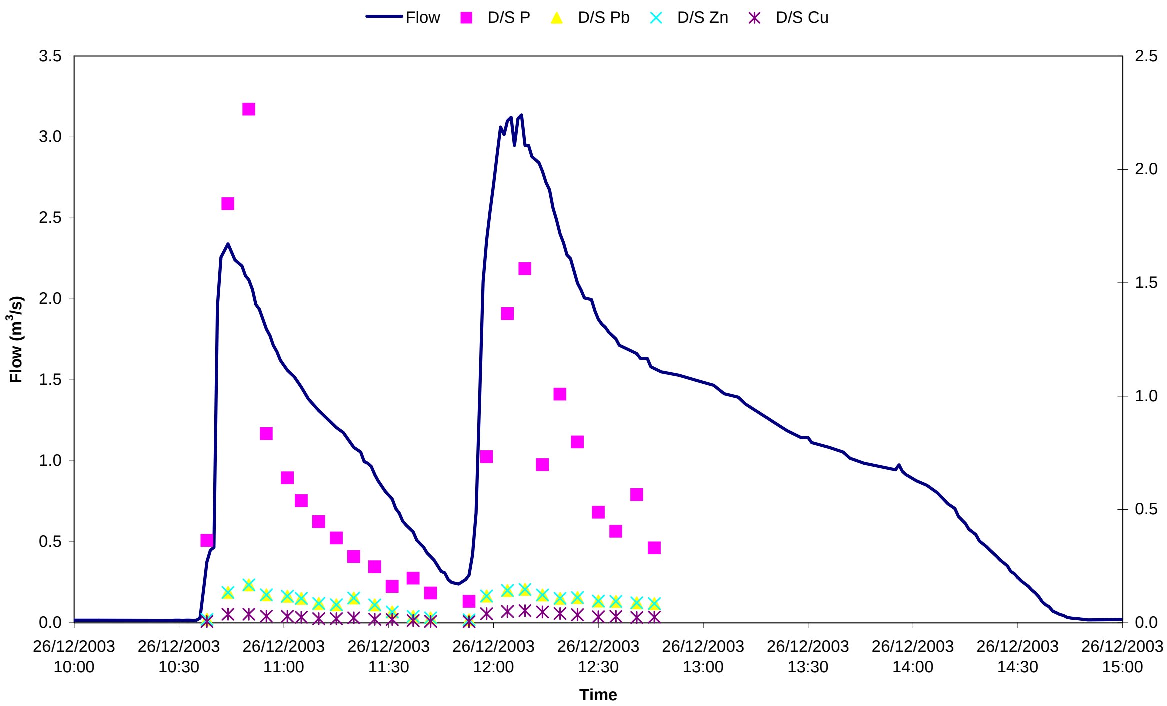

Figure 16 - Downstream Loadographs for Event 4

Table 5 - Event 4 EMC Values

Site	**SS** (mg/L)	**Fe** (mg/L)	**Cr** (:g/L)	**Cu** (:g/L)	**Mn** (:g/L)	**Ni** (:g/L)	**Pb** (:g/L)	**Zn** (:g/L)	**P** (:g/L)
U/S	70.8	0.10	0	19	16	0	44	229	489
D/S	44.1	0.26	0	16	15	1	9	57	426

3.2.5 Event 5 - 2nd June 2003

The last runoff event monitored occurred during the early morning of 2nd June 2003. Rainfall commenced about 11:00pm on the 1st June and continued until nearly 7:30am with a total of 19.2mm rainfall being recorded at the Centennial Park rain gauge. While rainfall occurred over an eight hour period, the most significant period of rainfall occurred around 4:00am when the average intensity over a 30 minute period was 8.3mm/h.

Surface runoff for this event occurred in two distinct bursts with the first burst commencing at 1:30am and the second burst ending at approximately 4:00pm. The runoff hydrograph for this event is shown in Figure 17. As shown in this figure, the second burst is the more significant of the two. However, the first burst of runoff was of sufficient magnitude to trigger the collection of grab samples and therefore only the rising limb of the second burst of runoff was sampled. It should be noted that runoff continued between the two bursts of runoff and hence the two bursts were not considered to be independent.

Shown in Figures 18 and 19 are the loadographs upstream and downstream of the CDS Gross Pollutant Trap respectively for this event. Presented in Table 6 are the event mean concentrations determined for each metal examined, the total phosphorous and the total suspended solids. It should be noted that for this event, all of the downstream EMCs calculated are greater than the upstream EMCs. Some doubt on the representativeness of these data, therefore, is warranted. While the higher downstream values may be due to processes within the GPT, it is possible that the chemical analyses were contaminated.

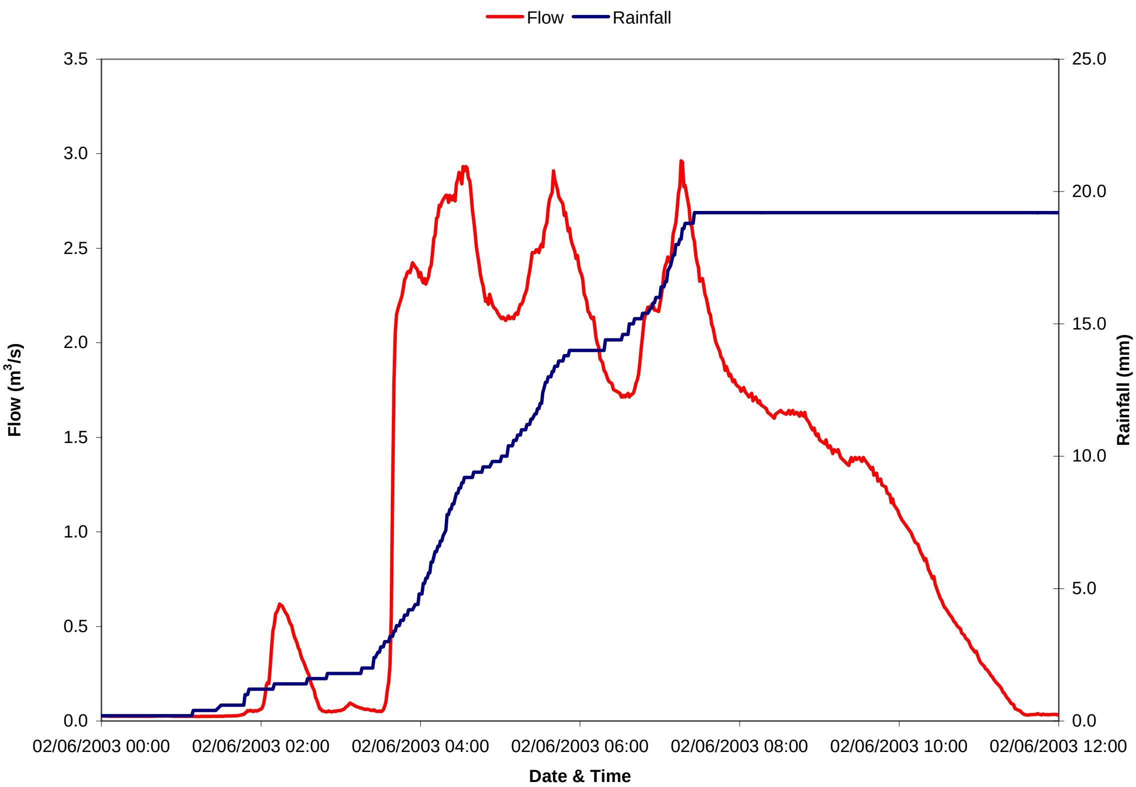

Figure 17 - Hydrograph for Event 5

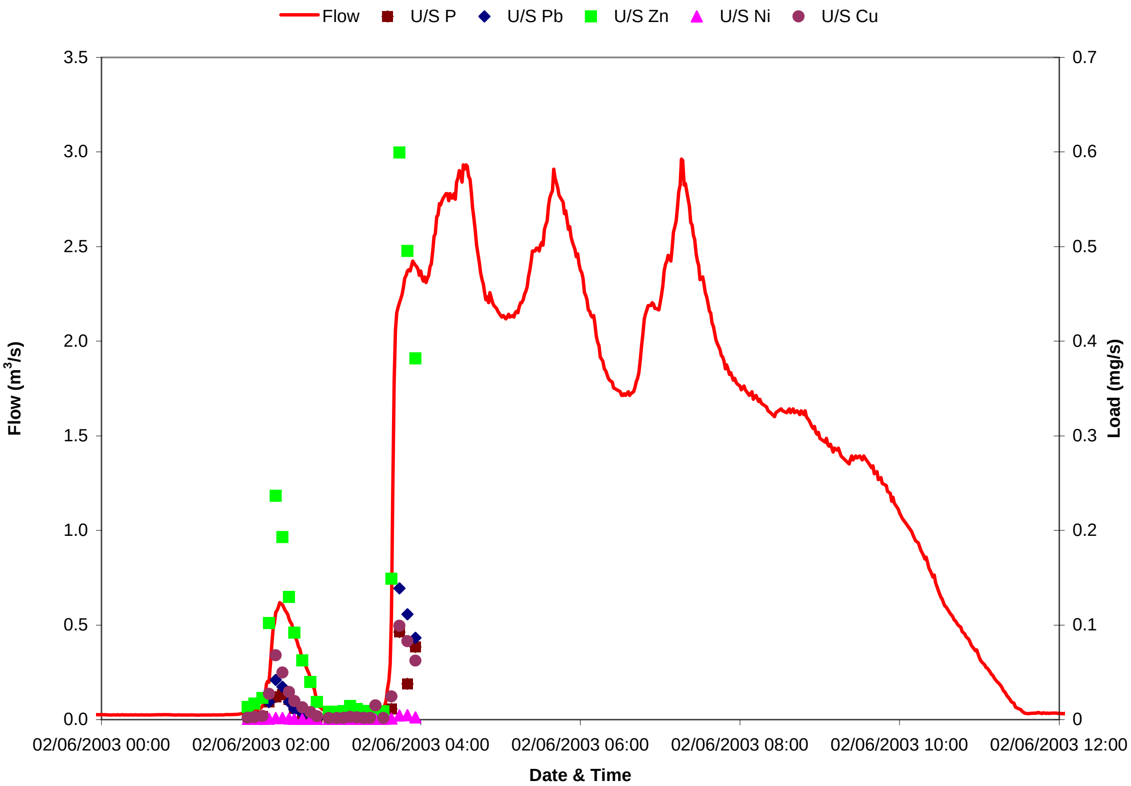

Figure 18 - Upstream Loadographs for Event 5

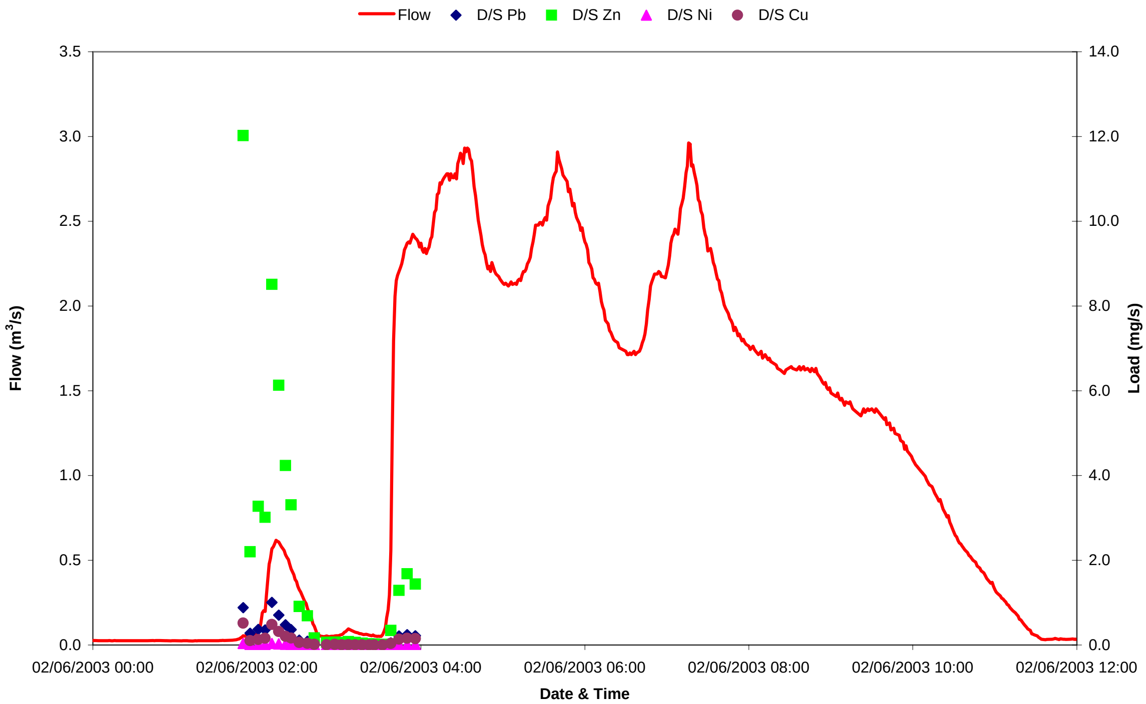

Figure 19 - Downstream Loadographs for Event 5

Table 6 - Event 5 EMC Values

Site	SS (mg/L)	Fe (mg/L)	Cr (:g/L)	Cu (:g/L)	Mn (:g/L)	Ni (:g/L)	Pb (:g/L)	Zn (:g/L)	P (:g/L)
U/S	132.9	1.00	1	44	26	2	44	229	152
D/S	376.7	8.41	12	206	128	15	417	3671	818

3.3 Summary

Shown in Tables 7 and 8 is a summary of the range of EMC values determined for each of the events. The median value of the EMC for each constituent is shown also in this table. Consistent with Duncan (2003), a log-normal probability distribution was fitted to the range of EMC values obtained for each constituent. These distributions have been plotted along with the raw EMC values against the exceedance probabilities for both the upstream and downstream data. These distributions are shown in Figures 20 to 25.

A wide range of values can be seen to be associated with the constituents throughout the monitoring period. This is thought to be due to factors such as variation in dry time between events allowing for different quantities of pollutant build-up, and also to be due to the variation in the quantity of rainfall, differences in the rainfall intensity, and different volumes of runoff occurring.

The use of the fitted probability distributions to the upstream and the downstream data enable an assessment of the likely performance of the Gross Pollutant Trap as a treatment device. When considering the performance of the Gross Pollutant Trap in removing the trace metals and nutrients considered herein, it should be noted that the majority of these constituents in stormwater runoff are in a particulate form associated with particulates less than 200:m (see, for example, Ball and Abustan, 2000, Ball et al., 2000, and Brockbank et al., 1998). However, the Gross Pollutant Trap installed on the Musgrave Avenue Stormwater Channel was designed to capture gross pollutants (typically greater than 1mm in size) rather than fine particulates.

Table 7 - Summary of Upstream Runoff Quality

Constituent	**EMC Range** (:g/L)	**Median EMC** (:g/L)
Suspended Solids (mg/L)	35.5 - 312.6	70.8
Iron	98. - 4636.	1000.
Chromium	0 - 6	2
Copper	19 - 131	51
Manganese	16 - 242	26
Nickel	0 - 9	3
Lead	7 - 143	44
Zinc	61 - 810	243
Phosphorous	152 - 1510	492

Table 8 - Summary of Downstream Runoff Quality

Constituent	**EMC Range** (:g/L)	**Median EMC** (:g/L)
Suspended Solids (mg/L)	38.0 - 376.7	48.6
Iron	262 - 8411	1550
Chromium	0 - 5	2
Copper	16 - 206	67
Manganese	15 - 128	91
Nickel	1 - 15	4
Lead	9 - 417	44
Zinc	57 - 3671	314
Phosphorous	426 - 1264	574

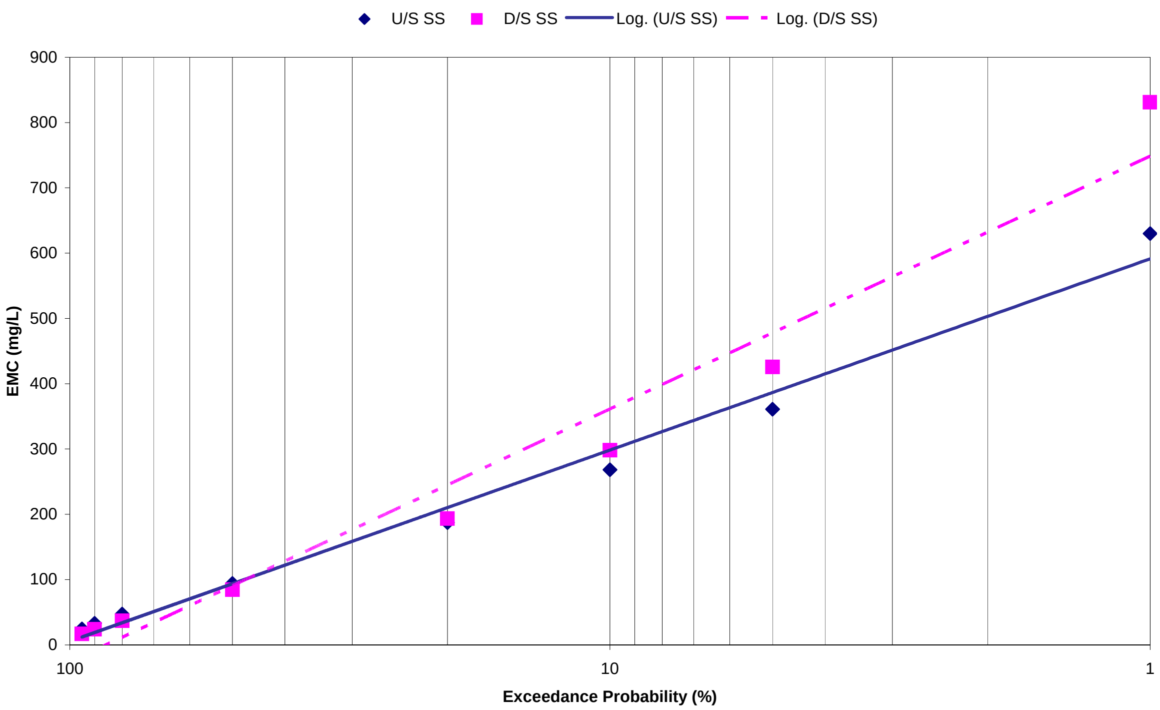

Figure 20 - EMC for Suspended Sediment

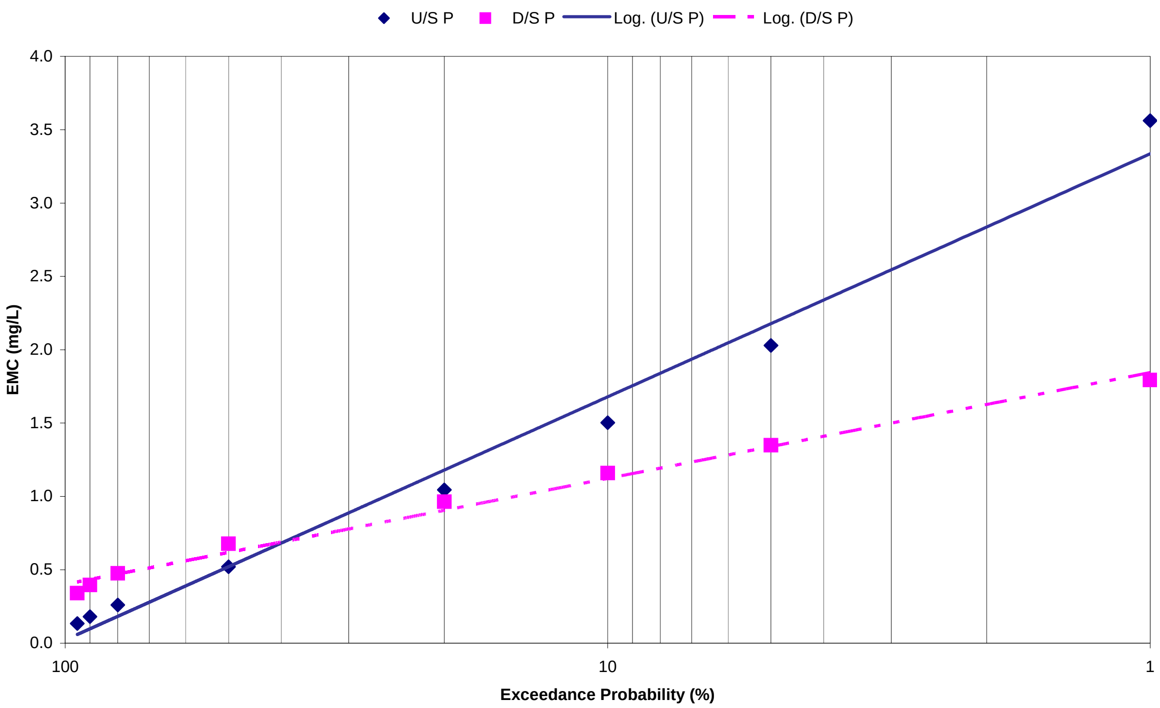

Figure 21 - EMC for Phosphorous

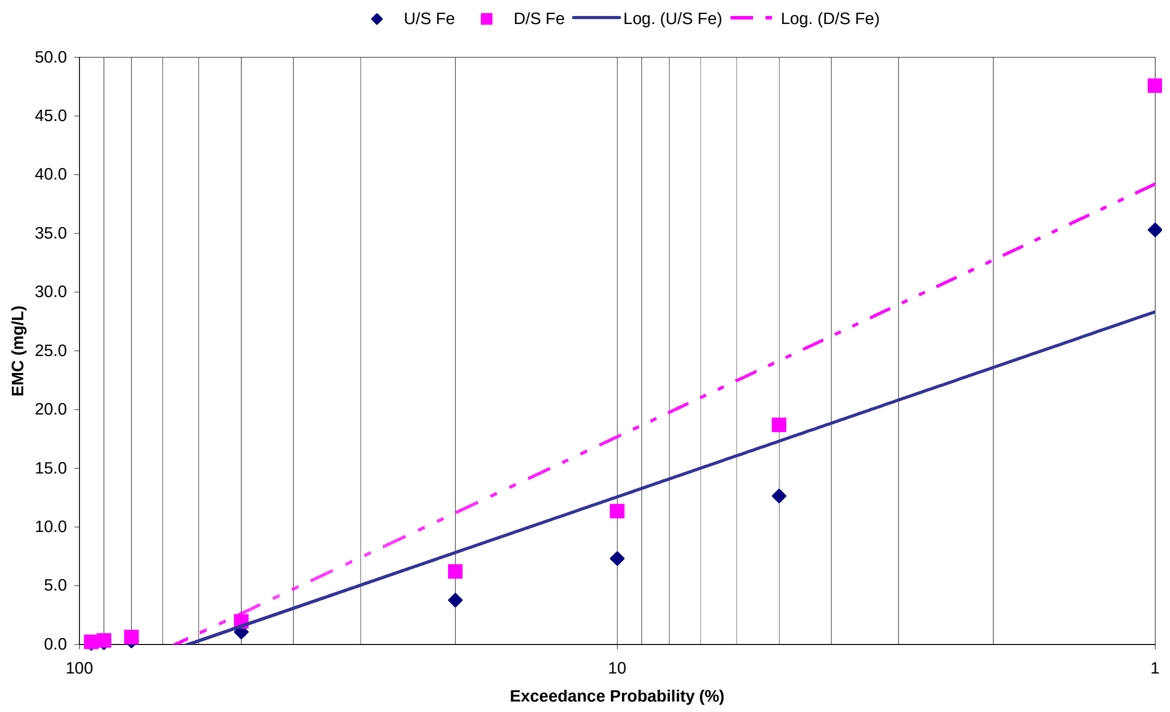

Figure 22 - EMC for Iron

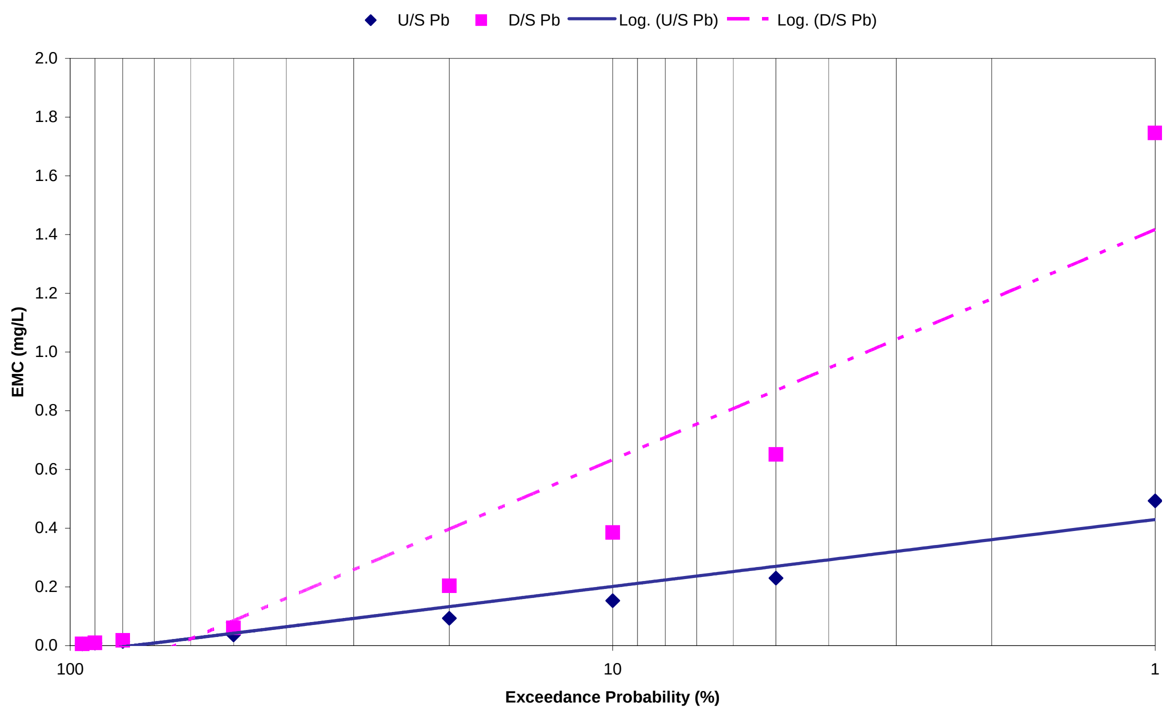

Figure 23 - EMC for Lead

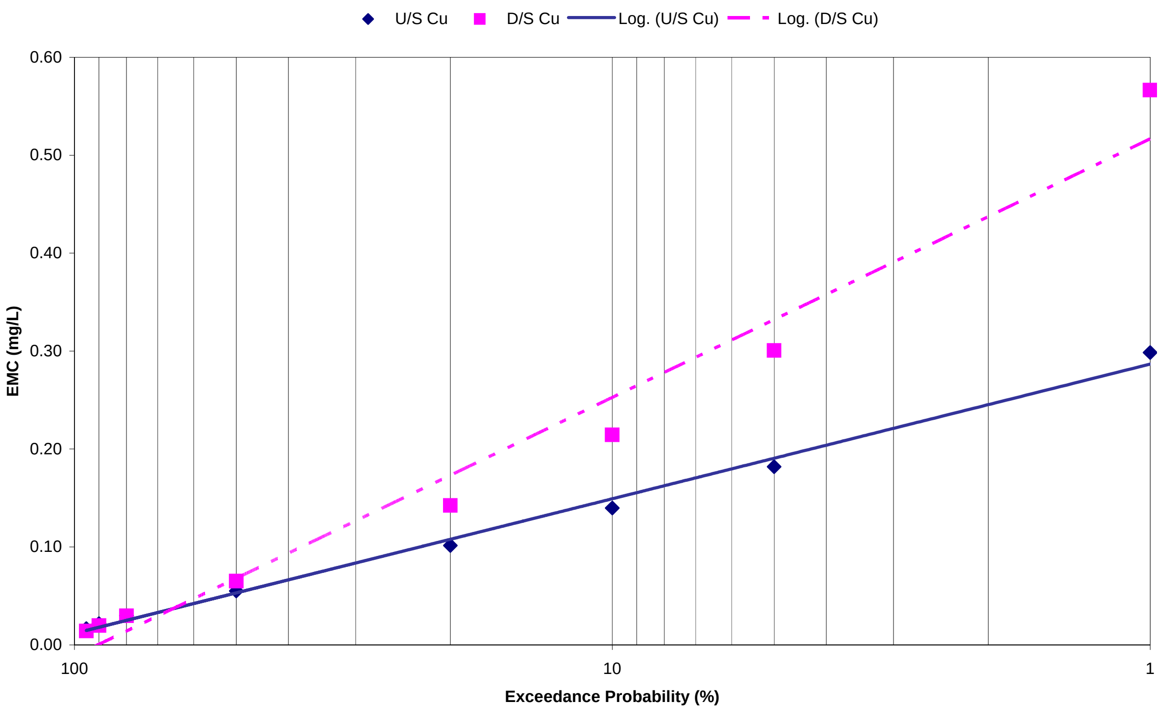

Figure 24 - EMC for Copper

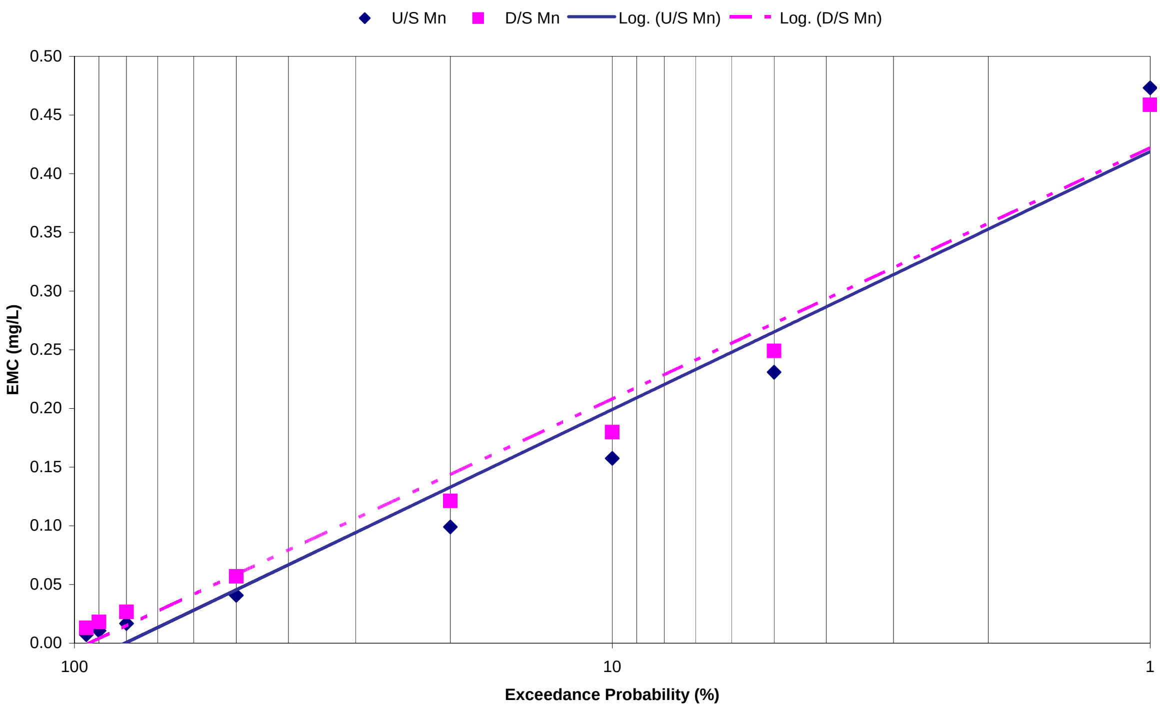

Figure 25 - EMC for Manganese

As shown in Figures 20 to 25, with the exception of the nutrient phosphorous, the fitted probability distributions for the EMCs resulted in the less frequent occurrences having higher EMCs downstream of the Gross Pollutant Trap than upstream of the Gross Pollutant Trap. For the more frequent EMCs, however, the fitted probability distributions in general resulted in lower EMCs downstream of the Gross Pollutant Trap compared to the EMC upstream of the Gross Pollutant Trap. Phosphorous is an exception again as the downstream EMCs for phosphorous are higher for the more frequent EMC values.

Within the scope of the monitoring undertaken, it is not possible to ascertain exact reasons for the effect. However, potential causes for this effect include

- Reactions occurring within the Gross Pollutant Trap; and

- A statistical bias introduced by the downstream samples collected during event 5.

It is suggested that further research be undertaken to confirm the reason. This research would need to consider the processes occurring within the collection chamber of the Gross Pollutant Trap in the first case and a continuation of the monitoring to increase the sample size in the second case.

4 CONCLUSIONS

During 2002 and 2003 , water quality samples were collected at UNSW's gauging station on the Musgrave Avenue Stormwater Channel. These samples were collected upstream and downstream of the CDS gross pollutant trap installed on the Musgrave Avenue stormwater channel. The events sampled occurred on the following dates

- Early Morning of 11th November 2002;
- Late Afternoon of 11th November 2002;
- Early Morning of 21st November 2002;
- Midday of 26th December 2002; and
- Morning of 2nd June 2003

Analysis of the data consisted of determining the Event Mean Concentrations and fitting log-normal probability distributions to the data. Consideration of these distributions indicates that, in general, the Gross Pollutant Trap reduced constituent Event Mean Concentrations for the higher exceedance probabilities (ie Event Mean Concentrations that would be expected to occur regularly) but that for low exceedance probabilities (ie Event Mean Concentrations that would be expected to occur rarely) the downstream Event Mean Concentration was higher than the upstream Event Mean Concentration. The nutrient Phosphorous was an exception to this generalisation with the reverse situation occurring for this constituent; for the frequent Event Mean Concentrations, the downstream Event Mean Concentration was higher than the upstream Event Mean Concentration while for the rarer Event Mean Concentrations, the downstream Event Mean Concentration was lower than the upstream EMC.

To resolve reasons for this it is suggested that the monitoring be continued to enable an extension of the existing sample size. In addition it is suggested that research into processes occurring within the collection chamber of the Gross Pollutant Trap be considered.

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