MONITORING FOR TOTAL WATER CYCLE MANAGEMENT : THE WESROC EXPERIENCE

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ABSTRACT

In 2001, the Western Suburbs Regional Organisation of Councils (WESROC[3]) and Town of Cambridge identified the need for better management of stormwater quality and a need to address the associated strategic issues on a broad catchment basis across traditional local authority boundaries. To this end, a regional strategy for stormwater quality management was developed. The strategy drew together issues concerning the collection and management of stormwater over an area of 6400 ha of Perth's established western suburbs, with the aim of managing the quality of stormwater discharging to the Swan River, Indian Ocean, local wetlands and the groundwater system.

A key recommendation of the strategy was the implementation of an integrated stormwater quality monitoring program targeting identified priority catchments. This program commenced in winter 2003, and was extended in 2004 to include (in addition to stormwater) regional groundwater, river, lake and ocean water quality sampling at over 45 locations throughout the region.

The program has resulted in a comprehensive regional baseline water quality data set to assist WESROC's local government managers in assessing appropriate strategies to improve total water cycle management at both local and regional scales.

This paper describes the monitoring program undertaken, sampling results and interpretation, and implications for progressive urban water management in local government.

<u>**The views expressed in this paper are those of the authors and do not necessarily represent those of individual Councils, or the Western Suburbs Regional Organisation of Councils (WESROC).**</u>

[3] WESROC is comprised of the Cities of Nedlands and Subiaco, Towns of Claremont, Cottesloe and Mosman Park and the Shire of Peppermint Grove.

1. INTRODUCTION

The Western Suburbs Regional Organisation of Councils (WESROC) comprises the local governments of the Cities of Nedlands and Subiaco, Towns of Claremont, Cottesloe and Mosman Park, and the Shire of Peppermint Grove. In 2001, WESROC identified the need for better management of stormwater quality and a need to address the associated strategic issues on a broad catchment basis, and across traditional local authority boundaries. To achieve a comprehensive approach to the management of stormwater, a regional strategy for management of stormwater quality was developed (JDA, 2002). The Town of Cambridge, while not a formal member of WESROC, was a contributing participant for this study.

The strategy drew together issues concerning the collection and management of stormwater over an area of 6400 ha of Perth's established western suburbs, with the aim of managing the quality of stormwater discharging into the Swan River, Indian Ocean, local wetlands, and the groundwater system.

Two key recommendations of the strategy were identified. The first key recommendation was the implementation of an integrated monitoring program targeting identified priority catchments to establish baseline stormwater quality data from which suitable water quality criteria and targets could then be established. This approach to criteria and target setting is supported by ANZECC (2000). The second key recommendation was the implementation of a regional community water quality education program.

Historically, little data exists regarding stormwater quality in the Study Area, with previous government agency sampling of stormwater in the Perth Metropolitan Area not targeting WESROC as a priority region. To this end, in 2002 and 2003 stormwater quality monitoring programs were undertaken in the Town of Cambridge and City of Subiaco (JDA, 2003a&b). Following from these studies, WESROC, in partnership with the Swan Catchment Council and the Water Corporation, commissioned a comprehensive monitoring program for winter 2004, to investigate not only stormwater quality, but also groundwater, and receiving environment water quality, as part of extending the JDA (2002) strategy into a total water cycle approach to urban water management.

The sampling program has provided the most comprehensive regional set of water quality data and analysis within an established area of Perth (JDA, 2004) thus providing a sound basis for the development of appropriate targets and a means for which to asses future ameliorative actions. This paper details the results of this monitoring program, and provides interpretation of the results in terms of stormwater and shallow groundwater interaction, and existing water sensitive urban design practices being implemented by the local authorities.

2. STUDY AREA CHARACTERISTICS

The Study Area comprises approximately 64 km^2 and is generally bounded by the Indian Ocean to the west, Kings Park and the Mitchell Freeway to the east, Herdsman Lake to the north and the Swan River to the south (Figure 1). The area effectively forms a natural catchment grouping between the Swan River and the ocean. The area has a Mediterranean climate with mild wet winters and hot dry summers. Long term average rainfall is approximately 860 mm although since 1975 average annual rainfall has declined by almost 10%.

Elevation typically varies between 0 m and 30 mAHD, with Town of Cambridge's Bold Park in excess of 80 mAHD. The soils of the area are predominantly derived from calcareous Safety Bay Sand and sands derived from Tamala Limestone (Davidson, 1995). Outcrops of Tamala Limestone are evident in the north and south western parts of the Study Area. Localised deposits of peaty clay and peat occur in low lying areas, usually in association with wetlands

Surface drainage comprises a network of piped local drainage and Water Corporation Main Drainage, which discharge to a variety of receiving environments including the Swan River, Indian Ocean, Lakes (Monger, Herdsman, Jualabup, Claremont, Mabel Talbot, Perry, QE2 Medical Centre), compensating basins, infiltration basins, swales, and soakwells.

Maximum recorded groundwater levels vary from 0 mAHD near the coast and river to 14 mAHD on the north east boundary at Lake Monger. Seasonal groundwater variation is typically 1.0 m, and much of the area has considerable depth to groundwater and hence opportunity for infiltration of surface drainage.

The majority of land is urban with some pockets of commercial and industrial land associated with town centres. Large areas of POS occur at Perry Lakes and Bold Park in Town of Cambridge. Most urban areas are well established.

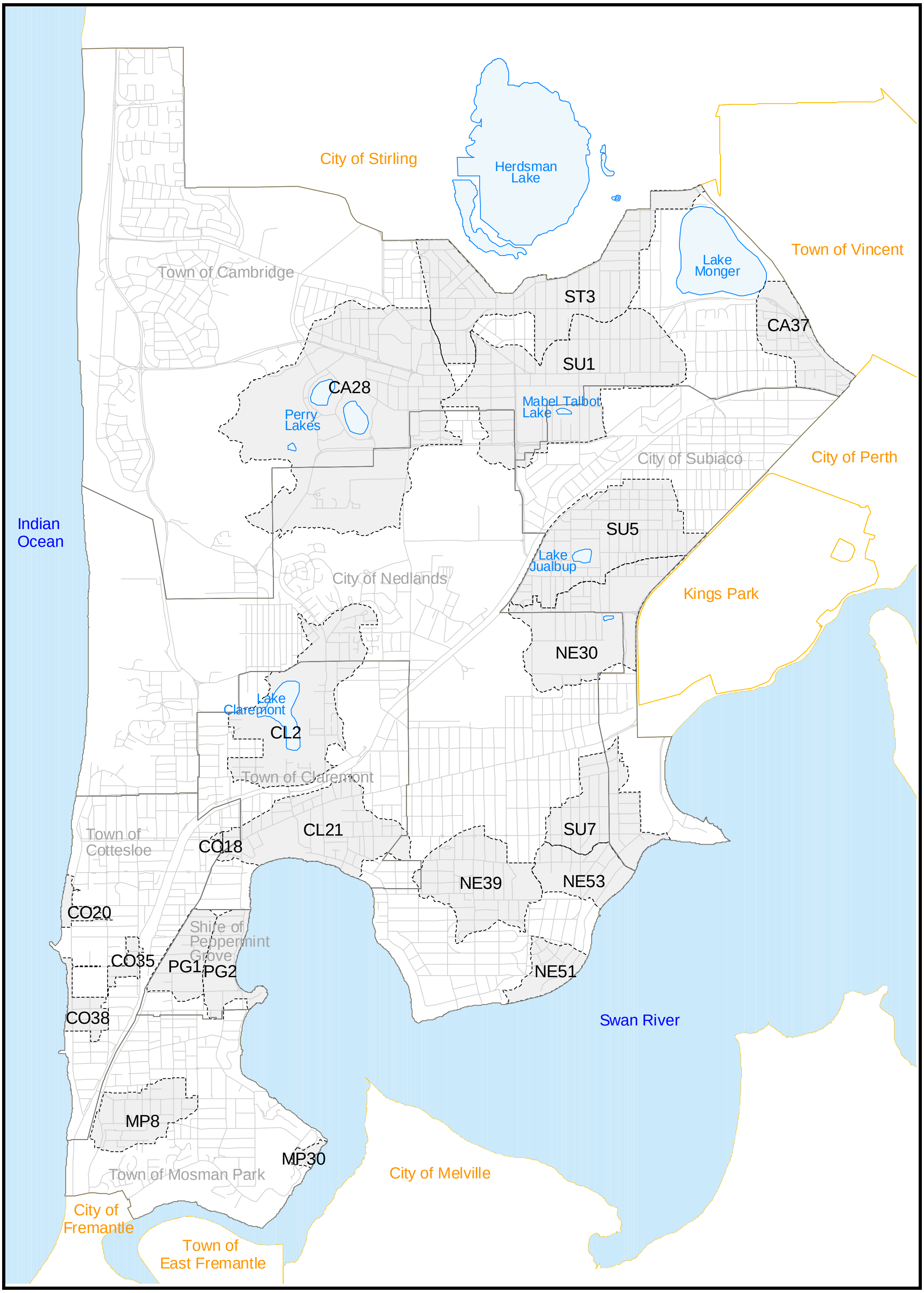

Figure 1 : Study Area and Priority Catchments for 2004 Monitoring Program

SAMPLING PROGRAM

Monitoring catchments were selected to provide good representation at a local authority level, provide good spatial representation over the whole Study Area (Figure 1) while attempting to monitor various urban settings or circumstances. Sites were generally based on priority catchments identified in JDA (2002). A total of 48 monitoring sites were selected over 18 catchments .delineated into 3 broad categories :

- Stormwater (23 sites) – monitoring urban stormwater discharge from a pipe drainage system
- Groundwater (12 sites) – monitoring groundwater quality within the superficial aquifer (existing monitoring & POS irrigation bores used with selection based on bores considered to represent water quality at the top of the superficial aquifer, where possible)
- Receiving Environment (13 sites) – monitoring of water bodies into which stormwater discharges including wetlands, the Swan River, and Indian Ocean.

Stormwater & groundwater are considered "pathways" for pollutants, as distinct from receiving waters.

Samples were taken every 7 weeks (Figure 2), on average, however final stormwater sampling was delayed until mid November due to the lack of spring rainfall. A total of 169 samples were analysed for Electrical Conductivity, Total Dissolved Solids (TDS), pH, selected metals (Cadmium, Copper, Lead, Zinc) and nutrients (Nitrogen, Phosphorus).

Daily and monthly rainfall totals for 2004 at Swanbourne Bureau of Meteorology (BoM) Station (Site 9215) are shown in relation to monitoring dates in Figure 2. Rainfall to the end of November 2004 was 582 mm, which is estimated to be approximately 10% less than the average since 1975. Daily rainfall totals in relation to each monitoring occasion indicates that a variety of events were monitored. Stormwater monitoring which commenced in May was likely to have captured the "first flush" event for winter.

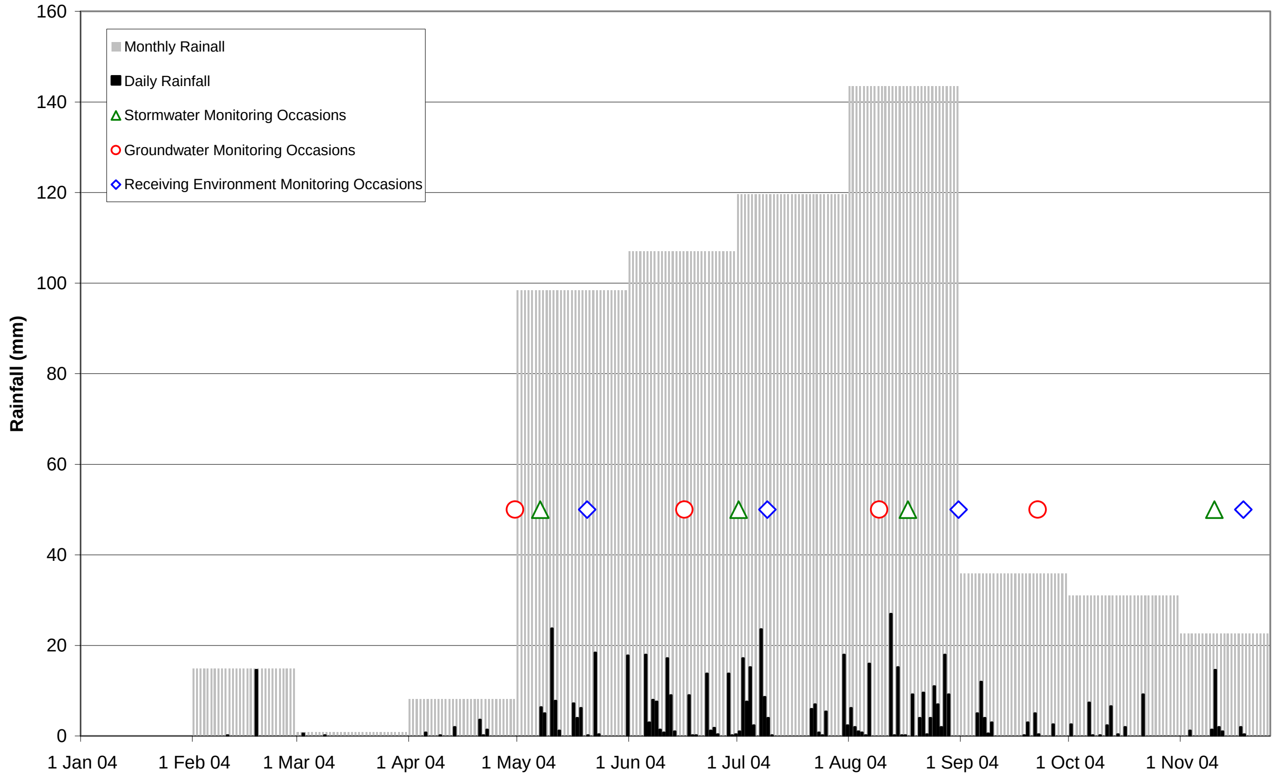

Figure 2 : Sampling Occasions and Swanbourne Daily and Monthly Rainfall Data

3. SUMMARY OF WATER QUALITY RESULTS

Summary water quality results are presented in Table 1 compared to mean concentrations for urban stormwater estimates in Australia (IEAust, 2003). Monitoring data for TN and TP at the regional level are presented in Figures 3 and 4.

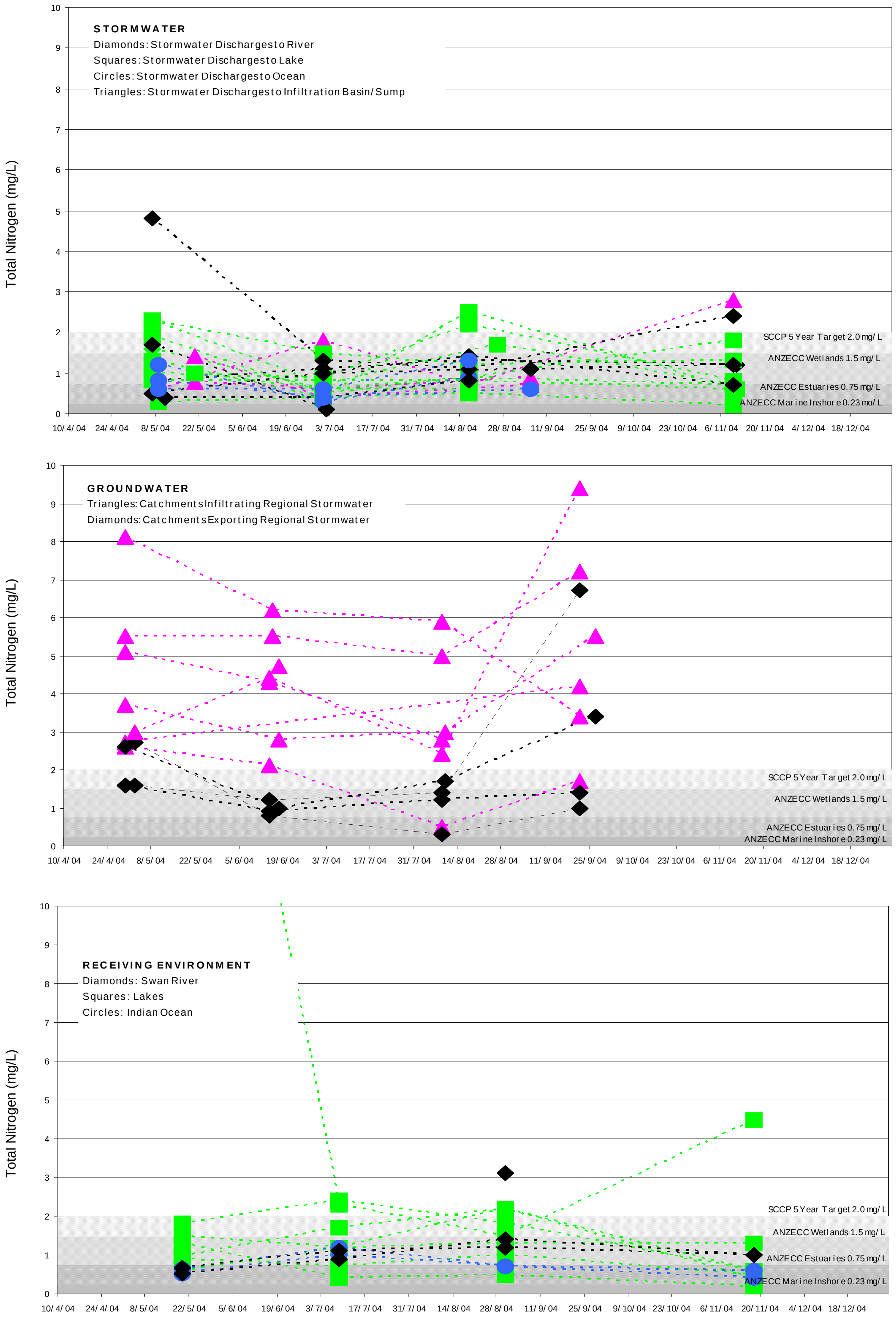

Figure 3 : Sample Regional Level Monitoring Data : Total Nitrogen (mg/L)

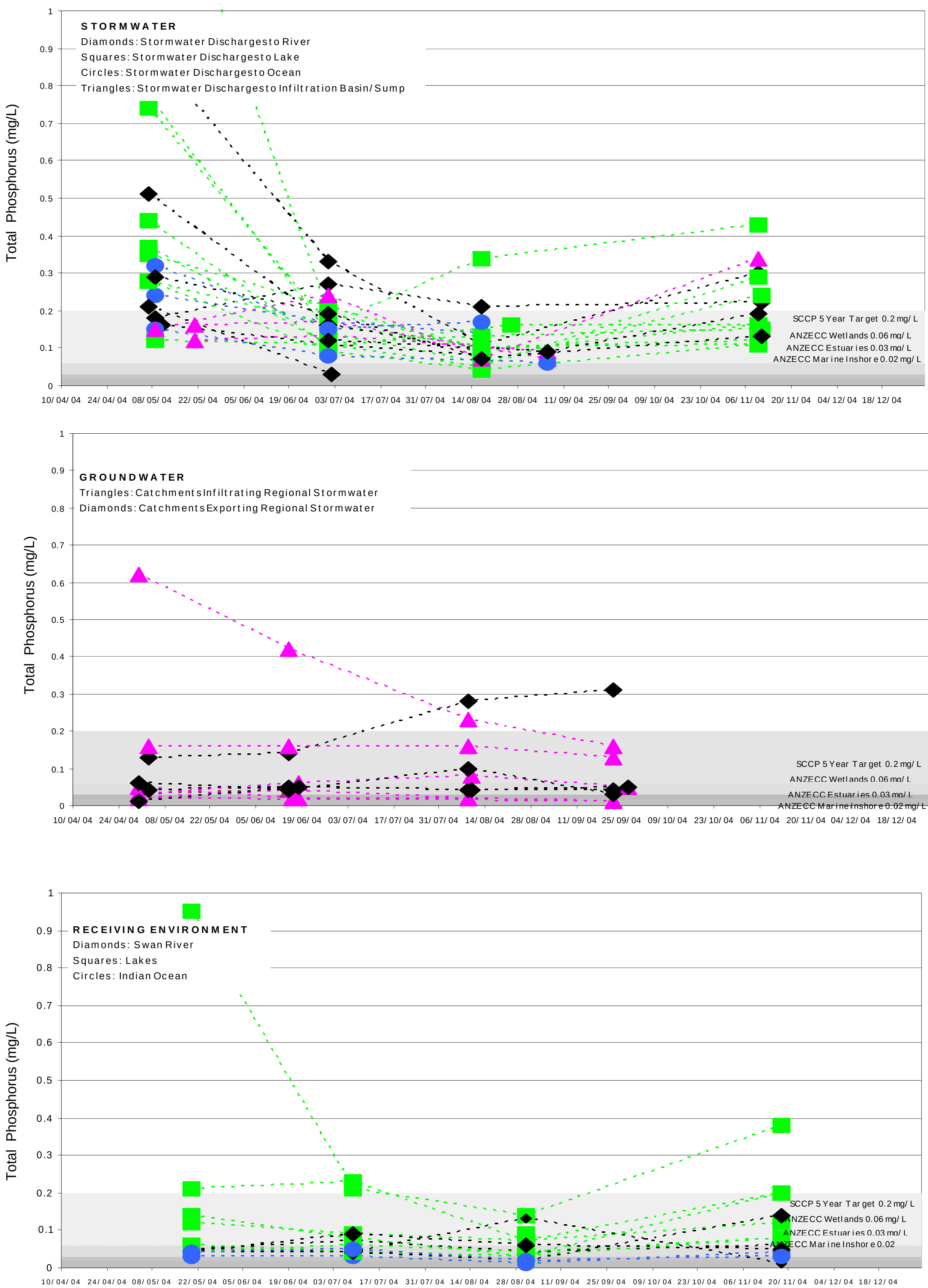

Figure 4 : Sample Regional Level Monitoring Data : Total Phosphorus (mg/L)

Mean TN was greater in groundwater (3.4 mg/L) than in stormwater (1.1 mg/L). Mean stormwater TN (1.1 mg/L) was less than mean ARQ stormwater TN (2.7 mg/L). Receiving environment TN (1.7 mg/L) was less than SCCP 5 year target (2 mg/L), but exceeded ANZECC (2000) criteria (Figure 3).

Mean TP was less in groundwater (0.1 mg/L) than in stormwater (0.21 mg/L). Mean stormwater TP (0.2 mg/L) was less than mean ARQ stormwater TP (0.29 mg/L). Analysed metals concentrations in groundwater, surface water and receiving waters are all less than ARQ stormwater concentrations (Table 1).

The results support the findings of Appleyard (1993) and McFarlane (1983) that stormwater quality in Perth is generally better than in the eastern states cities of Australia. The reasons for this may include factors which influence local processes including rainfall seasonality, climate, topography, soil type, catchment behaviour, fertiliser application rates, vehicle movements etc. The evolution of local stormwater management practices may also be a factor.

In areas where infiltration is the dominant method of stormwater disposal by WESROC local authorities, groundwater TN values were found to be significantly higher than stormwater TN values, suggesting infiltration is unlikely to be a causal mechanism. Sharma et al (1996) estimated up to 32% of annual applications of nitrogen leach below the root zone at the domestic scale. Hence residential POS fertiliser applications moving vertically through the soil profile rather than infiltration of local authority stormwater is considered more likely to be the source of Nitrogen in shallow groundwater.

For TP, groundwater has considerably lower concentrations than stormwater, despite infiltration systems having been used for many years. This indicates TP is being bound in the soil profile, both in domestic gardens and at local authority infiltration basins. Sharma et al (1996) estimated phosphorus leaching as less than 0.1% of annual application at the domestic scale.

With respect to the first flush at start of winter, stormwater showed a more marked effect for TP than TN. Mosman Park showed generally lower stormwater TP values and variability compared to other local authorities. This may be a result of the extensive use of deep bottomless manholes in the local authority to maximise infiltration opportunity.

At a regional scale, stormwater monitoring results compared favourably to Swan Canning Cleanup Program 5 year targets (Swan River Trust, 1999) of 0.2 mg/L for TP and 2.0 mg/L for TN. For stormwater, almost all catchments had TN mean concentrations within SCCP values, with the majority of catchments also having TP within SCCP target values.

Average salinity of stormwater (400 mg/L) compares with approximately 20 mg/L in rainfall. Higher salinity in groundwater is associated with concentration by evaporation and solution within the soil profile. Receiving environment salinity is weighted by marine salinity at the ocean sampling points.

Table 1 : Monitoring Results Summary

Parameter	Unit	Mean 2004 Monitored Concentration			Mean ARQ (IEAust 2003) Stormwater Concentration
		Groundwater	Receiving Environment	Stormwater	
pH	-	7.6	8.0	7.0	6.8
Conductivity	mS/cm	1.4	23.2	0.6	-
TDS	mg/L	890	15750	400	-
TN	mg/L	3.4	1.7	1.1	2.7
TP	mg/L	0.10	0.10	0.21	0.29
Cadmium	mg/L	0.0001	0.0008	0.0001	0.0044
Copper	mg/L	0.002	0.002	0.009	0.05
Lead	mg/L	0.002	0.003	0.006	0.15
Zinc	mg/L	0.065	0.049	0.12	0.53

4. ESTIMATION OF NUTRIENT EXPORT RATES

Stormwater

Stormwater TP and TN export rates were estimated for each catchment in which stormwater was monitored. Estimates were made by assumed monthly flow concentrations from sampling results, total monthly runoff volumes calculated from monthly rainfall and an estimated equivalent impervious area for each catchment. Average stormwater nutrient export rates were estimated as 2.1 kg TN/ha/yr and 0.40 kg TP/ha/yr.

The estimates are based on limited sampling, and should be considered indicative only. The results are generally comparable to Tan (1991) estimates of 2.53 kg TN/ha/yr and 0.40 kg TP/ha/yr. The results are also comparable to previous estimates in JDA (2003a & b) for winter 2003 monitoring programs undertaken for the City of Subiaco and Town of Cambridge.

These export rates represent less than 10% of nutrient loadings (inputs) to the environment. The major part of the inputs are either absorbed into the soil profile or exported through the shallow groundwater.

Australian Runoff Quality (IEA, 2003) reports significantly greater loadings for typical urban catchments of 20 kg TN/ha/yr and 1 kg TP/ha/yr, based on data from eastern states catchments, as a result of higher TP and TN concentrations in stormwater and higher runoff rates.

Groundwater

Groundwater nutrient export rates could be estimated from this data using groundwater flow equations. Nutrient export in groundwater is likely to be greater than in surface water. This is a major difference between Perth and eastern states cities which needs to be taken into account in formulating urban pollutant management strategies in Perth.

5. IMPLICATIONS FOR LOCAL AUTHORITIES

Infiltration Systems

On the above basis, infiltration of stormwater within WESROC is supported as a recommended BMP, particularly when viewed in the context of total water cycle management and low availability of groundwater in some areas.

Gross Pollutant Traps

A GPT located at Cottesloe Beach was monitored simultaneously upstream and downstream on three occasions during the sampling period. Example results are shown in Figure 5 for TN and Cu.

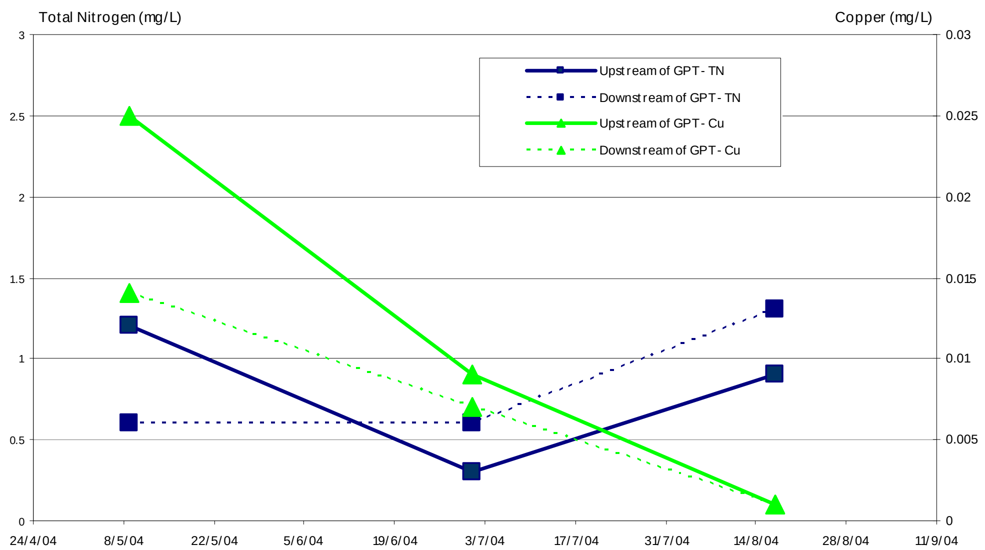

Figure 5 : GPT Performance Monitoring Data - Total Nitrogen (mg/L) and Copper (mg/L)

In summary the results indicated the GPT performance to be better at reducing metal concentrations than nutrients. The best performance of the GPT appeared to occur at the time of the first flush and performance appeared to reduce in efficiency as winter progressed. By the third sampling occasion TN was being exported from the GPT (i.e. greater concentration downstream than upstream).

On the basis of the above result and a similar previous finding in JDA (2003a), regular monitoring and review of GPT eduction frequencies and timings should be undertaken by local authorities with a view to optimising field performance of these units. Optimum eduction frequencies will vary depending on unit type and size, and catchment characteristics.

Street Sweeping

Given the number of management factors potentially impacting nutrient and metal concentrations, the contribution of street sweeping and its frequency to this achievement is difficult to quantify directly from this study, particularly as no historical knowledge of stormwater quality without street sweeping is known.

Figure 6 and Figure 7 however present a summary of street sweeping frequencies, gully eduction, fertilising frequencies and major road densities plotted in relation to stormwater quality for TP and Zn respectively.

The results do not show significantly lower concentrations of nutrient and metals for City of Subiaco and Peppermint Grove catchments which are swept more frequently than other councils. This does not however mean street sweeping is inefficient in removing pollutants. Furthermore, other factors are considered from a local authority perspective when determining the desired frequency of sweeping. Nonetheless, street sweeping is an integral part of a treatment train approach to stormwater management and stormwater quality results for these councils may have been considerably worse without the frequency of sweeping currently adopted. Results may be influenced by a considerable number of factors including sweeper type, gully eduction frequency, deciduous trees, traffic loadings and on-street parking reducing access to road gutter.

With respect to metal concentrations, results show that the highest metal concentrations generally occurred in catchments with higher density of major roads (defined as primary and secondary). This indicates any review of sweeping frequencies should focus on targeting high traffic areas, particularly if these catchments directly discharge to a receiving water body.

Trialling of various street sweeping practices and frequencies may be a method of optimising performance efficiency and operating expenditure by local authorities in this area.

POS Fertiliser Application

The effect of local authority fertiliser application and frequency is difficult to isolate and quantify directly though the study.

As all local authorities within WESROC region use phosphate free fertilisers for irrigation of POS areas, this indicates the source of TP in stormwater is likely to be from domestic application of garden fertiliser rather than council operations. Similarly, residential POS fertiliser application of TN moving vertically through the soil profile at the lot scale rather than infiltration of local authority stormwater runoff is considered likely to provide a greater source of nitrogen in groundwater.

It is recommended that education campaigns target domestic fertiliser application as the key issue for urban water quality improvement. Campaign should target the groundwater as the major nutrient pathway rather than stormwater.

6. POLLUTANT PATHWAYS AND WATER QUALITY TARGETS

The current approach adopted in the eastern states of Australia is to set reductions on stormwater pollutant loads as a percentage of what a development would discharge if it was implemented without any active water quality management. For nutrients, targets are typically set at approximately a 50% reduction.

The local applicability of this form of target is currently in debate within Western Australia.

The differences highlighted in this paper should be considered by local authorities prior to application of WSUD technologies based on eastern states research and performance testing which may not be relevant to Perth.

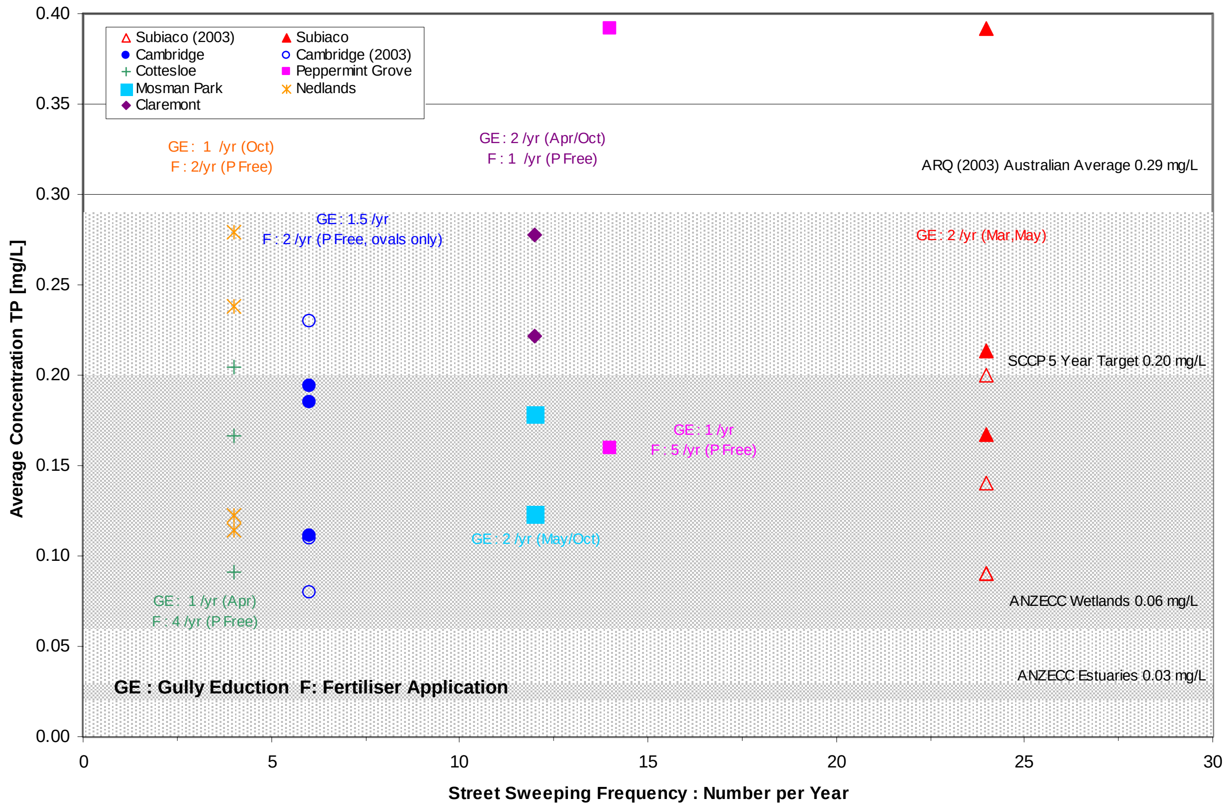

Figure 6 : Total Phosphorus Concentration vs Street Sweeping, Fertilising, and Gully Eduction Frequency

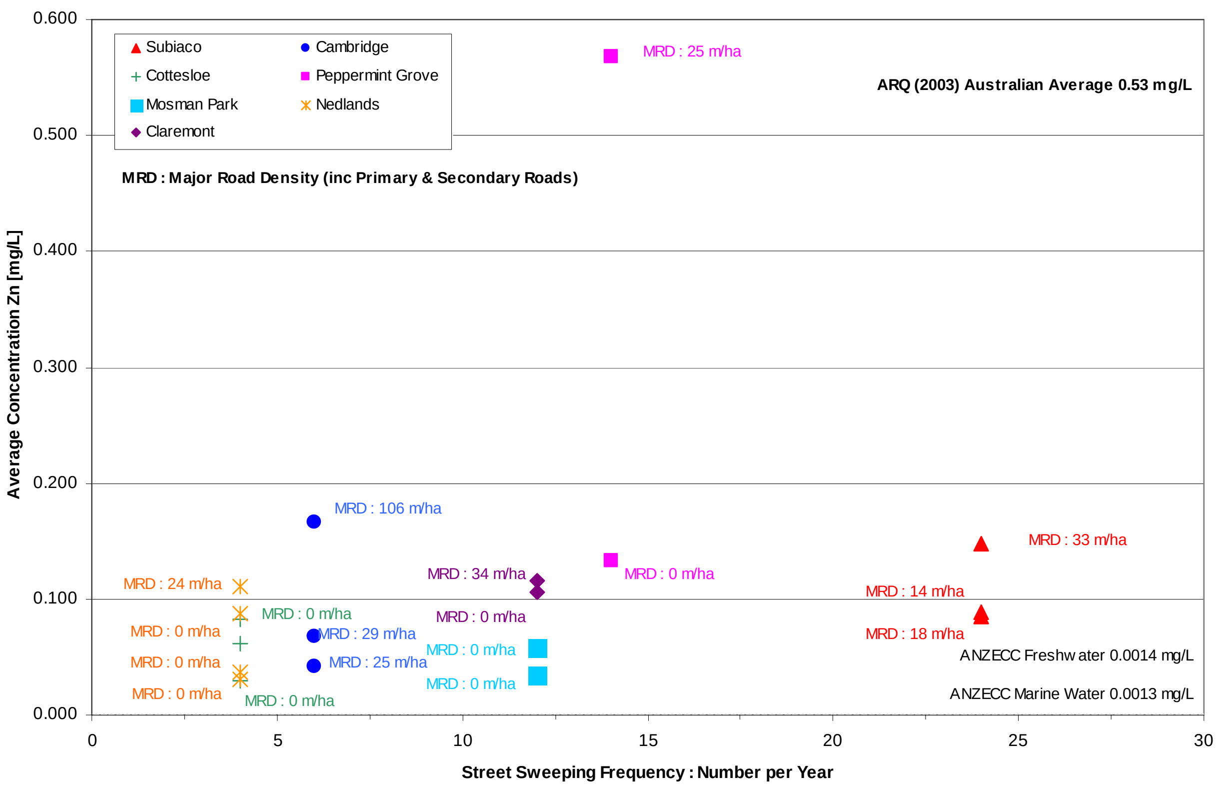

Figure 7 : Zinc Concentration vs Street Sweeping and Major Road Density

The Department of Environment's current review of environmental standards and criteria as part of the revision of the Stormwater Management Manual for WA would be assisted by incorporation of the data collected on behalf of WESROC provided in this paper.

This may lead to a better understanding of pollutant sources, pollutant pathways and an informed decision as to whether to focus on surface or groundwater pathways in Perth.

7. CONCLUSIONS

The Western Suburbs Regional Organisation of Councils (WESROC) and Town of Cambridge have taken a proactive approach to urban stormwater management and its role within the local total water cycle. This approach has seen the development of a regional strategy for the management of stormwater quality (JDA, 2002) and more recently a co-ordinated program of sampling, monitoring, and analysis across local authority boundaries (JDA, 2004).

The water quality data collected for this study by WESROC arguably represents the best recent regional set of data within an established area of Perth, and provides a sound basis from which management practices within the region can be assessed based on a site specific local dataset, and a shared understanding in management of local hydrologic processes.

Study outcomes have reinforced the significant difference between Perth urban stormwater quality and eastern states catchments and need for caution in applying WSUD technologies, the regions general compliance to SCCP target values for TN and TP, and highlighted fertiliser application moving vertically through the soil profile at the lot scale as the more likely contribution to groundwater nutrient concentrations than local authority management practices such as infiltration. The results support the need for source control initiatives and a whole of catchment management approach to stormwater management.

This approach to assessing urban stormwater management in the context of the total water cycle provides a framework for implementation by other local authorities and regional councils of the Swan Coastal Plain.

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