Analysis of Total Suspended Sediment and Total Nutrient Concentration data in the Mount Lofty Ranges to derive Event Mean Concentrations

Nigel Fleming, Jim Cox, Ying He, Shaun Thomas, Jacqueline Frizenschaf

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Executive Summary

Water quality models are used by catchment managers to better predict the impacts of future events, such as changes in land use. eWater Co-operative Research Centre's (CRC) Source Catchments modelling software is one of the new age water quanitity and quality catchment models available for such a purpose. It is designed to give managers of predominantly rural catchments an improved capacity to make informed decisions when changes in catchment management influence the quantity and quality of runoff to receiving waters. One of the more popular constituent generation models available in Source Catchments uses an event mean concentration (EMC) and dry weather concentration (DWC) approach. A previous model constructed for South Australia used generic data for constituent concentrations in runoff water leaving various land uses sourced from other parts of Austrlaia.

There has been a significant amount of local water quality data collected in the Mount Lofty Ranges in recent years with 21 water quality sites monitored over 3 years. This document is a collation of local data, to provide new EMC/DWC data which is more relevant for a greater range of land use categories than currently exist and provides higher spatial and temporal extent than previous reports.

The summary EMC/DWC data sets will be used to parameterise and validate the Source Catchments Model developed for the Mt Lofty Ranges Applications Project. Local information will improve the modelleded estimates of concentrations and loads of constituents, for baseline and a range of modelling scenarios. Further work could investigate seasonal impacts on EMC values.

The report recommends the following changes to the Event Mean Concentrations used in the Source Catchments model for the Mount Lofty Ranges:

land use		EMC (mg/L)		
		TSS	TN	TP
Conservation area	current	20	0.8	0.20
	updated	43	1.8	0.18
Grazing	current	140	1.6	0.28
	updated	184	2.1	0.24
Suburban	current	140	1.6	0.28
	updated	43	1.2	0.12

Across the range of land uses, new EMC values for TSS are comparable to previous values, new EMC values for TN are generally higher and for TP are generally lower than previous data used. This will allow more representative prediction of constituent generation from the Mount Lofty Ranges than has previously been possible.

1 Introduction

The eWater CRC's Source Catchment modelling platform previously known as E2 and WaterCAST has been applied in over 50 catchments across eastern Australia including the Mt Lofty Ranges (MLR) in South Australia.. During 2009-2010, the eWater CRC is applying these prototype products and its research expertise to real-world situations in 'focus' catchments across eastern Australia. For these product-application trials, the eWater CRC partner organisations have nominated catchments in Queensland, New South Wales, Victoria, Australian Capital Territory and South Australia.

A collaborative project between South Australian Research and Development Institute (SARDI), South Australian Environmental Protection Authority (EPA) and the eWater Co-operative Research Centre (eWater CRC) is tackling the following management issues in the South Australian MLR Applications project:

- water security, sediment and nutrient delivery in the MLR, South Australia. In particular the project will investigate:
- quantifying the constituent (sediment, N, and P) supply from the catchments;
- the benefits of policy and structural approaches aimed at mitigating the generation and delivery of these constituents in catchment runoff; and
- the effect of climate change on water security in these catchments; and
- a sensible framework to begin prioritising restoration activities across the catchments

This document reports initial data mining and analysis of local water quality datasets (21 in total) from the MLR for improving water quality parameters currently used in the Source Catchments modelling framework. The aim was to determine if an exhaustive search and analysis of all previous water quality data from the MLR will improve the modelling parameters.

2 Methods

2.1 Location

The MLR have some of the most critical and complex catchments in Australia, totalling around 1,640 km^2 in size. They are critical because they provide both storages (for River Murray water) and watersheds (for rainfall runoff) to supply Adelaide with water. They are complex because they have mixed land use including a range of agricultural, urban and conservation uses. This puts them at greater risk of reduced water quality due to contamination and makes environmental flow management more difficult.

Rainfall of 600 – 1200mm/yr and a range of geological landforms in the Mount Lofty Ranges (MLR) have generated variable soil types across the region. Hill slopes often have sandy loam to clay loam soils, with some hilltops and plateaux characterised by low fertility ironstone soils over deeply weathered rock on clay subsoils. Soils in the MLR are naturally acidic throughout while salinity and sodicity are relatively minor problems.

The catchment area in the MLR for metropolitan water supply is referred to as the Mt Lofty Ranges Watershed (the Watershed) and covers approximately 1,640 km^2. Unlike most other capital cities

in Australia, the Watershed is extensively developed for a wide range of activities. Around 90% of the land in the MLR Watershed is privately owned which greatly increases the potential risks to water quality. Due to the generally poor quality of water sourced from this system, water treatment is undertaken as part of the mains water supply system (Adelaide and MLR Natural Resources Management Board, 2008). This increases the cost of water supply due to sediment, nutrients, pathogens and other contaminants requiring extensive treatment regimes.

In an average year, Adelaide consumes around 216 GL of water. To supply this volume, the Region has 10 metropolitan water supply reservoirs of around 233 GL capacity. Reservoirs are commonly located on stream and fill with natural runoff. However, local catchment water is insufficient to satisfy demand and so water is pumped into the Region from the River Murray.In an average year this may be around 40% of all water used in the Region, although it may be as high as 90% in dry years. Reservoirs are not the only surface water storage in the MLR. The Region contains in excess of 22,000 farm dams with a total capacity of than 85 GL. On average, farm dams capture around 10% of annual surface water flow, although on a seasonal basis this can be more than 70% in some catchments over summer and autumn months.

The MLR has a long history of development for rural residential and urban living. This is ongoing, with significant urban expansions planned for the MLR in the South Australian government's 30-Year Plan for Greater Adelaide (SA Government 2010).

2.2 Current model framework

A popular constituent generation model in Source Catchments is the EMC/DWC model. The EMC is the flow-weighted average pollutant concentration over a storm event, while the DWC is the pollutant concentration measured during dry weather (i.e. baseflow). It is important to distinguish between the EMC and DWC because they can differ by more than an order of magnitude (Chiew and Scanlon 2002). EMCs and DWCs can vary with land-use, soil type, slope, climate and management practices in the catchment area.

The EMC and DWC concentrations in the Mt Lofty Source Catchments model are for total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN) and are allocated to nine landuse categories:

- conservation area
- managed forest
- plantations
- grazing
- broadscale agriculture
- rural residential
- suburban
- dense urban, and
- water

The suburban land use has been included although there are no land areas in the current model which are classified as suburban. The land use has been included as the model will be extended to neighbouring areas in the future. These new areas contain significant suburban land use areas.

The model calculates daily pollutant load as:

Pollutant Load = Surface Runoff x EMC + Baseflow x DWC.

The bulk of nutrient and sediment loads enter MLR water storages during storm events inthe wet winter period. These loads are represented by EMCs, and are the values reported here. While Baseflow x DWC represents a minor proportion of nutrient and sediment loads in the MLR, they are presented in this report.

2.3 Data Sources

Two types of data were sourced; primary land use and composite sampler.

2.3.1 Primary Land Use Sites

Primary land use data was data collected from sites which drained relatively small areas in upper catchments and, as implied by the name, relates to a single or primary land use. Catchment areas ranged from around 2 to 200 hectares. These were primarily research sites, where individual flow-weighted samples were collected by autosampler, and generally filtered prior to analyses to provide “dissolved” vs “particulate” analyte concentrations. In this report, the EMCs were only calculated on the total analyte concentrations. The research sites have been operated by a number of organisations, including SARDI, CSIRO, University of Adelaide, and EPA.

Details of the primary land use sites are shown in Table 1.

Table 1. Primary land-use monitoring site details

land use	area (ha)	annual rainfall (mm)	location	comment
apple orchard	64	1024	Lenswood	many dams in catchment
cherry orchard	8	1024	Lenswood	
vineyard	155	750	Charleston	water flows through earth channel
extensive grazing	263	544	Keyneton	
dryland dairy grazing	2.2	750	Flaxley	west area
	2.6	750	Flaxley	east area

2.3.2 Composite Sampler Sites

Composite sampler data has been sourced from a composite sampler monitoring programme, run by various state government agencies. Currently the majority of composite sampler sites are maintained by the Adelaide and Mount Lofty Ranges Natural Resource Management Board (AMLR NRM) and South Australia Water. Since the early 1990’s, composite samplers have been installed at a number of sites to collect samples for analysis of sediment and nutrients. Flow weighted samples have been collected at these sites and composited for weekly collection and analysis.

Flow weighting was carried out by sampling each time a set flow volume of flow was recorded, irrespective of the height of flow. Each incremental sample was collected into a single composite sample, which was collected weekly when the sampler was emptied and reset. The flow volume per sample was adjusted for expected flow in order to optimise sampling sensitivity and operational effectiveness of the autosamplers. The catchment areas ranged from about 5 to 300 km^2, and generally included a number of land uses. Data from the composite sampler monitoring programme has been analysed for significant trends in water quality over time by Water Data Services for various state agencies (Water Data Services 2002, 2003, 2004, 2006), although in-depth investigation of the full data set has not yet been undertaken.

Descriptions of the catchments of composite sampler sites are given in Table 2.

Table 2: Composite sampler monitoring site details

Location	site ID	area (km^2)	annual rainfall (mm)	major land uses (%)	
Aldgate Creek Railway Station	A5030509	7.8	1087	suburban rural residential utilities grazing	52 13 18 12
Brownhill Creek @ Adelaide Airport (Morphett Road)	A5040583	64.2	445	dense urban rural residential utilities grazing	40 20 13 7
Brownhill Creek @ Scotch College	A5040901	17.7	450	rural residential dense urban grazing utilities	28 25 11 8
Christie Creek @ DS Galloway Road	A5030547	37.8	443	dense urban rural residential utilities broadscale agric.	51 29 15 4
Cox Creek @ Uraidla	A5030526	4.1	1084	broadscale ann. hort. broadscale per.l hort. rural residential conservation area	28 23 16 13
Echunga Creek U/S Mt Bold Res.	A5030506	34.2	769	grazing conservation area rural residential intensive grazing	51 17 6 6
First Creek @ ds Botanic Gardens	A5040578	21.0	541	dense urban utilities	74 23
Kersbrook Creek U/S Millbrook Res.	A5040525	22.7	705	grazing conservation area managed forest farm dams	44 28 13 4

Lenswood Creek Lenswood	A5030507	16.7	1020	broadscale per.l hort. grazing conservation area rural residential	48 20 19 5
[a]Millbrook Intake U/S Reservoir	A5040508	29.9	854	grazing conservation area managed forest broadscale per.l hort.	44 28 13 3
Onkaparinga River – Hahndorf	A5031001	227.3	851	grazing broadscale per.l hort. conservation area broadscale agric.	43 7 12 7
Onkaparinga, Houlgraves Weir	A5030504	321.3	767	grazing broadscale per.l hort. conservation area rural residential	41 13 13 10
Scott Creek (Bottom)	A5030502	26.6	780	conservation area rural residential grazing utilities	46 28 18 4
Sixth Creek @ Castambul	A5040523	44.0	662	rural residential broadscaleagric. managed forest grazing	37 25 8 8
Sturt River @ ds Anzac Highway	A5040549	116.0	541	dense urban rural residential utilities grazing	41 17 13 7
Torrens River @ Holbrooks Rd	A5040529	201*	545	dense urban rural residential utilities broadscale agric.	29 18 12 8

*catchment area below reservoir. [a]This site also receives water transferred from the Murray river (interbasin transfer). Transferred water has been excluded from EMC calculations.

Locations of the composite sampler and primary land use sites are shown in Figure 1.

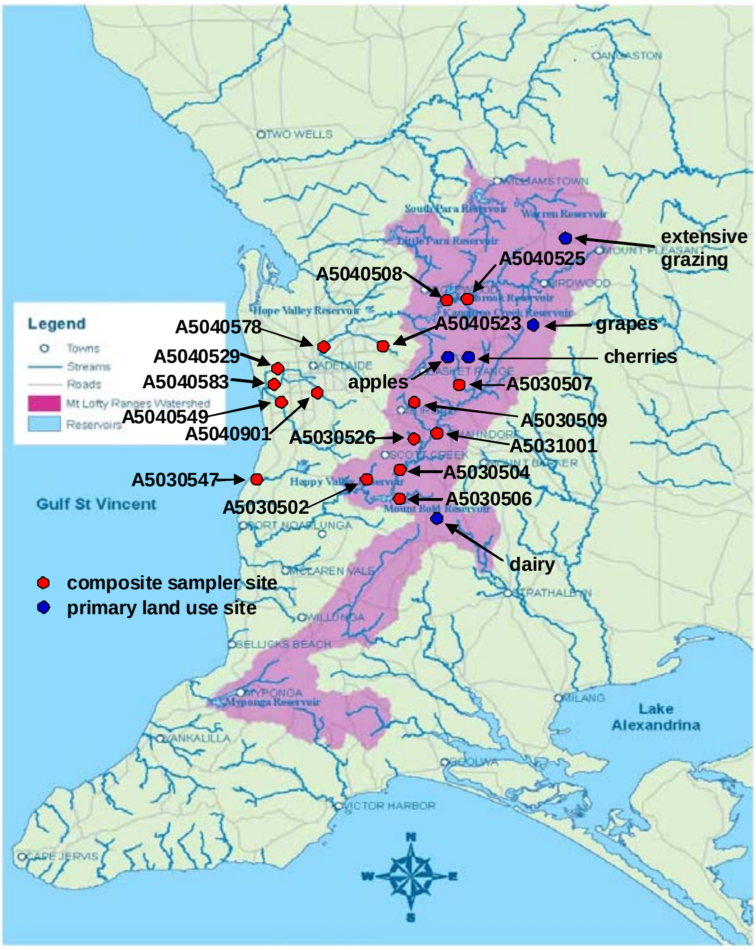


Figure 1. Composite sampler and primary land use sites in the Mount Lofty Ranges

2.4 Analyses

Samples were analysed by a NATA-accredited laboratory, most of the work being carried out by the Australian Water Quality Centre, Adelaide. In this report, EMCs and DWC's were determined for TSS, TN (sourced as either the parameter TN or the sum of Total Kjeldahl Nitrogen (TKN) and Oxidised Nitrogen (NO_x)), and TP.

All sites had recorded flow and water quality data over the time periods covered. A time series of flow data was extracted from the flow data base for each site, and aggregated to a timestep suited to the water sampling strategy. At composite sampler sites, each sample was a weekly composite of flow-weighted samples, so a weekly timestep was used. At primary land use sites the time step was either 15 or 60 minutes.

2.5 Definition of EMC vs mean event concentration

EMC and mean event concentration are terms which are often used interchangeably, despite having different meanings. An EMC is the mean concentration of samples collected during the actual period of event flow, whilst mean event concentration is the mean concentration over the entire event (including baseflow), with no separation of event and baseflow concentrations. The data referred to as EMC values in this report are technically "mean event concentrations". However, the monitoring sites reported are dominated by event runoff with minimal baseflow and hence the values derived are a reasonable approximation of "EMC" values.

2.6 Calculation of EMCs

Two methods were used to calculate EMC values from this data set. The first method was used to determine the range and variability of the data set within and between sites. This was done uisng the Water Quality Analyser tool from the eWater CRC Catchment Toolkit and is described below. Individual EMC values were generated from each recorded event and each site. The second method was used to determine an overall representative EMC value for each site across all measured events in the data set, and made use of the specific measurement method employed at each monitoring site. This method is also discussed below.

2.6.1 EMC calculation method 1

In this procedure, EMC's were calculated using the Water Quality Analyser tool from the eWater CRC Catchment Toolkit (Tenakoon *et al.* 2007, http://www.toolkit.net.au/). The tool provides nine different methods to calculate loads from user supplied time series flow and concentration data. Among these methods are two techniques to calculate EMC's – Beale ratio and Stratified Sampling. EMC's were calculated by both methods and visually compared to plots of the raw data. From this, the Beale ratio was chosen as the most representative method of calculating EMCs. This is consistent with the findings of Chiew and Scanlon (2002) who undertook this exercise in South Eastern Queensland (SEQ). EMC's were calculated from events with a minimum of three sample concentrations, aiming to have samples on the rising, central, and falling parts of the hydrograph. The start and end points of an event were chosen arbitrarily in light of the above considerations. A typical hydrograph is shown in Figure 2.

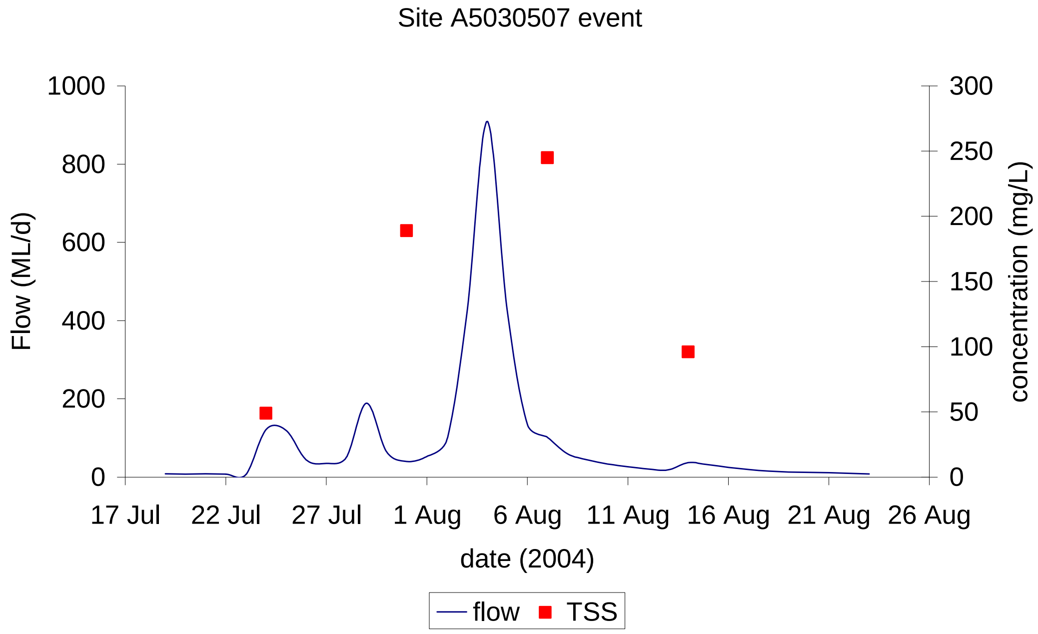


Figure 2. Flow event and TSS concentrations at site A5030507

In this case the event covered 35 days and totalled 3.18 GL of flow. Four samples were analysed to determine the EMC for TSS. This was found to be 133 mg/L using the Water Quality Analysis tool described above. Event Mean Concentrations were calculated from all qualifying events at each site and the data was collated. For an overall EMC calculation for the model, the median value of all EMC values calculated was taken as the overall EMC for a given site. For example, the mean EMC value of TSS for the site shown in Figure 1 (site A5030507) was 146 mg/L (Table 3).

2.6.2 EMC calculation method 2

To calculate EMC values by this technique, observed data was used as the reference point for nutrient and TSS load calculations at each site, across the entire monitoring period. This was feasible because of the rigorous techniques employed in the monitoring programme. Each water sample was located at an existent water gauging station, and was thus linked to high quality flow data. Flow-weighted water samples were taken from each monitoring site, that is, the flow meter directed a sampling signal to an autosampler each time a specified flow volume had passed the monitoring site. Each water sample was deposited into the composite tub of the autosampler. At weekly intervals the site was visited. At this time the water sample was mixed, subsampled and the sampler reset for the next round of sampling. Collected water samples were then analysed for various constituents, including TSS, TN and TP.

The monitoring programme collected flow and nutrient load data. Flow-weighted sampling linked each water sample to a known flow volume over a known time period. At some sites a large number of samples had been collected and analysed, and most sites had more than 500 samples e.g. site A5040523 had 684 sample results, from May 1996 to May 2009. From the data set, a flow volume was calculated for each sample. A load per sample was calculated by multiplying this flow volume by the measured concentration of TSS, TN and TP. Total loads for each site over the period of record were calculated as the sum of all sample loads. This gave a single figure which represented the most accurate load calculation for that site. To calculate an overall EMC value, the same flow volumes were multiplied by a constant (estimated EMC) to give another single load estimate. The estimated EMC was then optimised in a Microsoft Excel spreadsheet using the Solver function. This modified the estimated EMC value until the estimated load equalled the recorded load. The modified EMC was thus the best EMC estimate across the entire monitoring period. This method was used to optimise EMC values for TSS, TN and TP over all monitoring sites. These values are reported in Table 3.

EMC calculation method 1 was used to display the range and distribution of EMC values, but the overall EMC values as calculated by method 2 were used in the model simulations.

2.6.3 Calculation of Dry Weather Concentrations

Dry Weather Concentrations (DWC) were determined from samples analysed during baseflow, or non-event data. These were estimated as the average concentration of samples taken during the lowest decile of ranked flow intervals at each site. In most primary land use sites in the MLR there was no baseflow, so DWC's were instead estimated from comparable land uses and DWC's of composite sampler data.

3 Results and Discussion

Data from six primary land uses and 15 composite sampler sites were analysed (Tables 1 and 2). These sites included extensive grazing, orchards, vines, and dairy grazing as primary land uses. Runoff concentrations from these sites are likely to be higher at this small scale than the concentrations measured from larger areas, as sediment and nutrients are typically attenuated by deposition in stream sediments as the scale of measurement increases (Wollheim et al. 2006). If higher concentrations are measured at larger scales (e.g. composite sampler sites) then it is possible that in-stream processes have contributed to this increase, e.g. streambank erosion.

3.1.1 Primary Land Use sites

Results from primary land uses are presented in Figures 3 to 5. EMCs from composite sampler sites (larger scale) are presented in Figures 7, 9, 11, 13, 15 and 17. These catchments contain a

mixture of land uses, including broadscale agriculture, horticulture, suburban, conservation park, dense urban and rural residential use.

Figures 2 to 4 show box plots of EMC's for TSS, TN and TP from primary land uses. The central lines of the boxes are medians, the upper and lower bounds of the error bars are 10th and 90th percentiles, and the upper and lower bounds of the boxes are upper and lower quartile boundaries. Outliers are represented by individual plotted points.

The grape site had the highest EMC for TSS (Figure 3). This may be not be representative of vineyards in general, due to the earthen channel in which water flows to the monitoring point at that site. The cover crop between grape rows (pasture) is similar to that at the cherry and apple sites. Given the large proportion of area under cover crop, it would be expected that the TSS EMC for grapes would be similar to the cherries and apples.

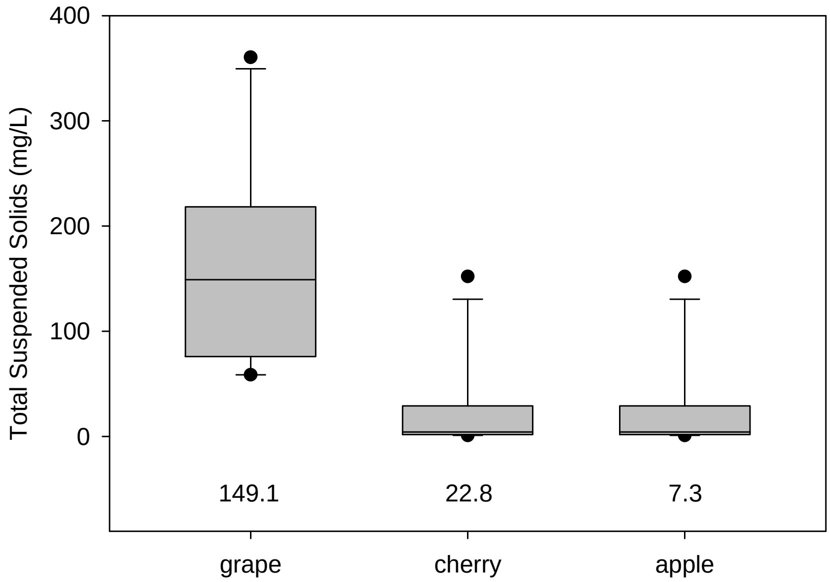


Figure 3. Box and whisker plots and median EMCs for Total Suspended Solids (TSS) from primary land use sites for which TSS data was available.

EMCs for TN were broadly comparable across primary land uses except for the cherry site which had higher values. There is no obvious explanation for the differences in TN EMC between horticultural land uses, as they all are irrigated perennial crops with pasture cover between rows. The lower value for extensive grazing may be linked to the dryland management system and lack of biological activity during the summer period.

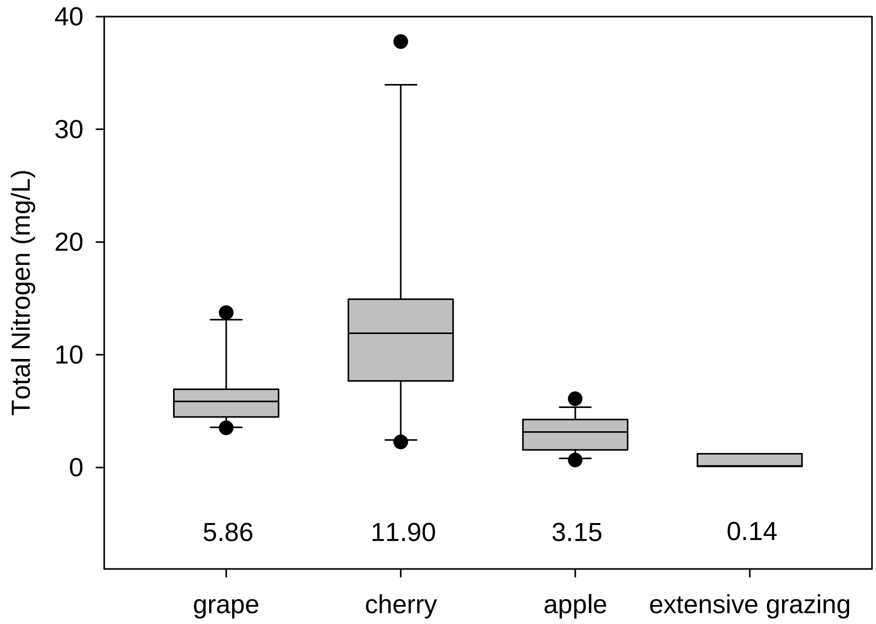


Figure 4. EMCs for Total Nitrogen (TN) from primary land use sites for which TN data was available.

EMCs of primary land use sites for TP were quite varied, with dairying vlaues higher than the other land uses. The range of TP values for dairying is consistent with published data on TP in runoff from dairy pastures. While the absolute rate of P fertiliser on dairy pastures may be similar to that on other land uses, this fertiliser is broadcast onto pasture rather than placed around trees. Broadcast fertiliser will interact with a greater area of surface soil, and hence may be more accessible for dissolution and transport in surface runoff.

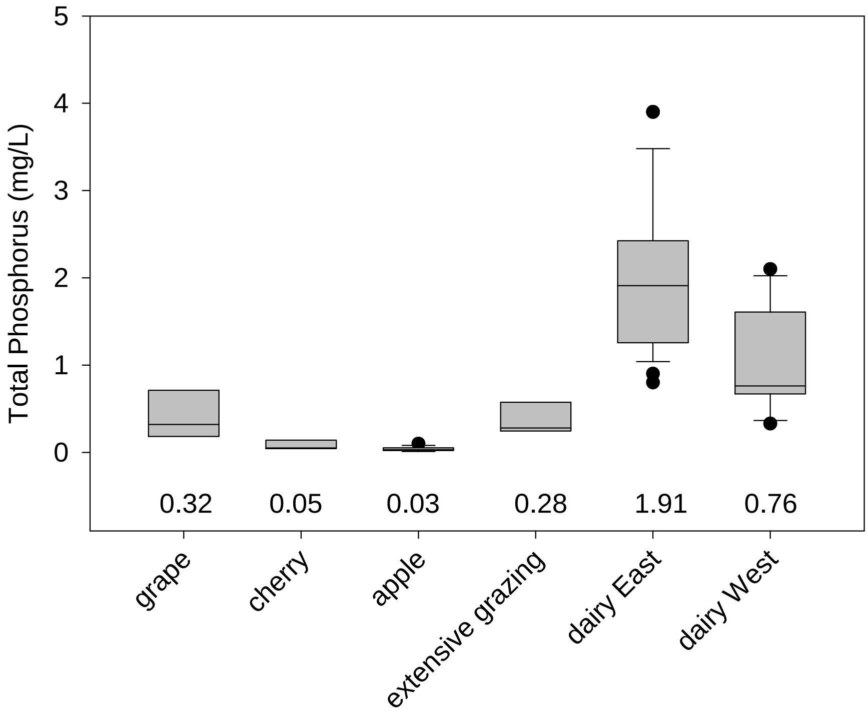


Figure 5. EMCs for Total Phosphorus (TP) from primary land use sites

3.1.2 Composite Sampler Sites

Figures 6 to 17 show land use proportions and box plots of EMCs for TSS, TN and TP from composite sampler sites, along with median EMCs. The findings are summarised in Table 3.

3.1.2.1 EMC values sorted by proportion of broadscale agriculture

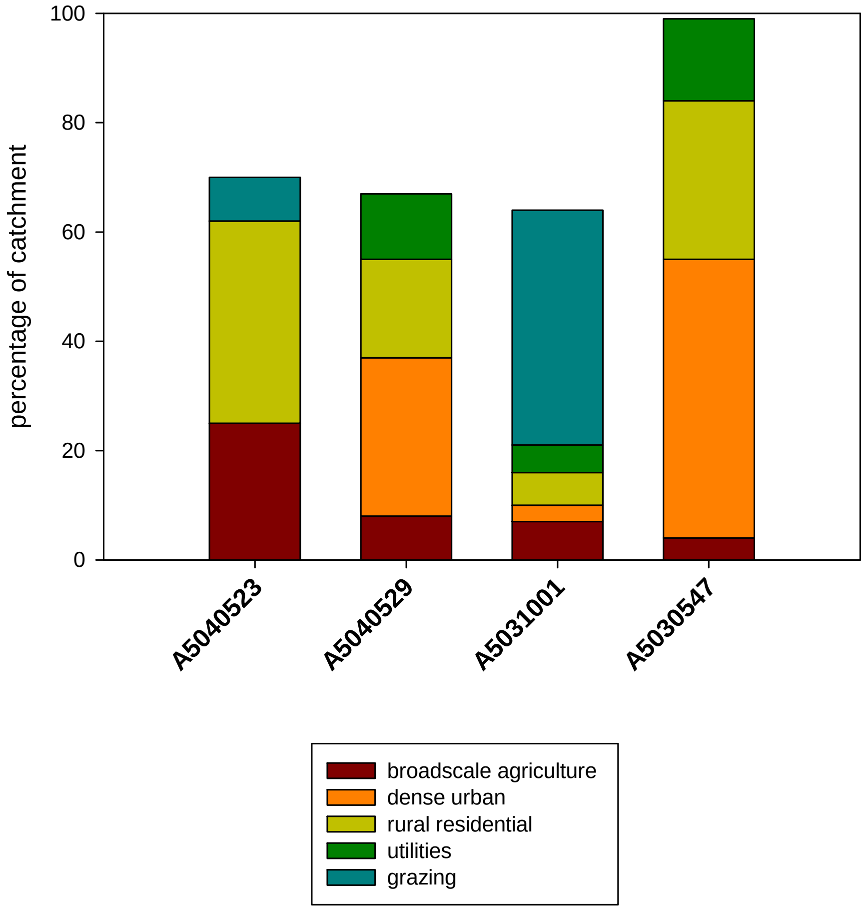


Figure 6. Land uses of composite sampler catchments sorted on proportion of broadscale agriculture.

EMC values for TSS, TN and TP are consistent between sites, with the execption of TN at site A5031001, which is considerably higher than the other sites. This may be due to the dominant land use at this site being extensive grazing. Nitrogen input from the clover component of pasture in extensive grazing may account for the higher TN values at this site. The final EMC value for grazing is 2.1 mg/L (refer section 3.4) and this is consistent with site A5031001 which has a higher EMC for TN.

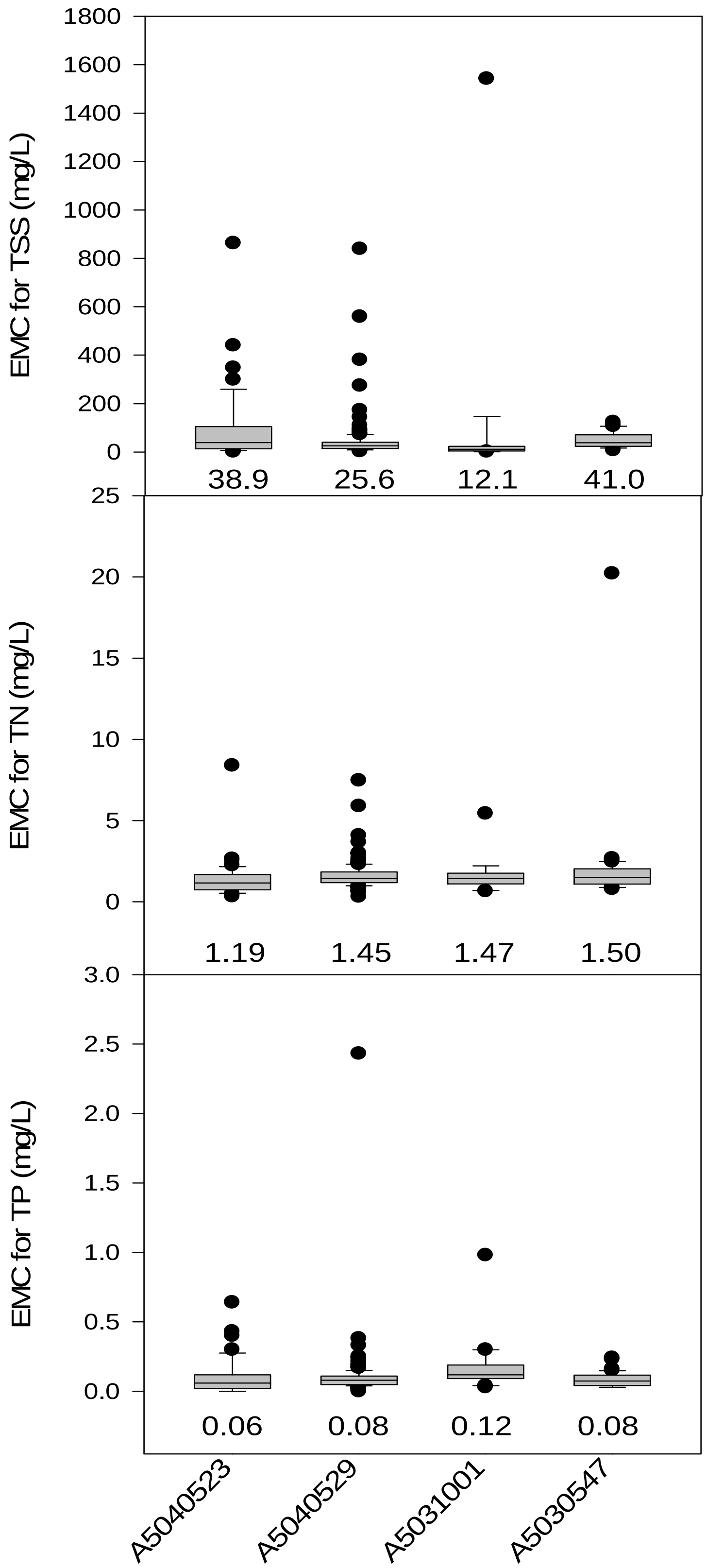


Figure 7. Box and whisker plots and median EMCs of composite sampler sites. Sites are sorted on proportion of broadscale agriculture.

3.1.2.2 *EMC values sorted by proportion of perennial horticulture*

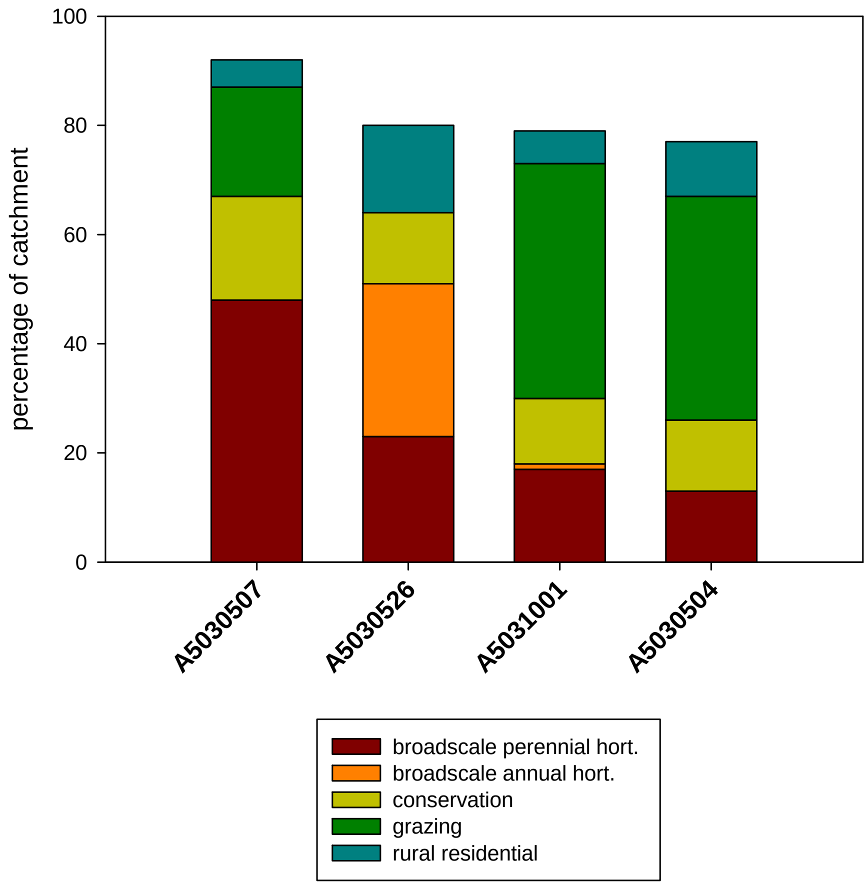


Figure 8. Land use proportions of broadscale perennial horticulture sites. Composite sampler catchments are sorted on proportion of broadscale perennial horticulture.

Site A5030526 contains significant areas of annual horticulture. This tends to produce lower water quality as shown in Figure 9.

EMCs of TSS, TN and TP for broadscale perennial horticulture sites are surprisingly consistent, with the exception of site A5030526. This site contains annual horticulture which has produced elevated TSS, TN and TP concentrations. This is consistent with management activities related to annual horticulture, such as multiple cultivations per year, and also harvesting of some crops during winter when the soil is wet.

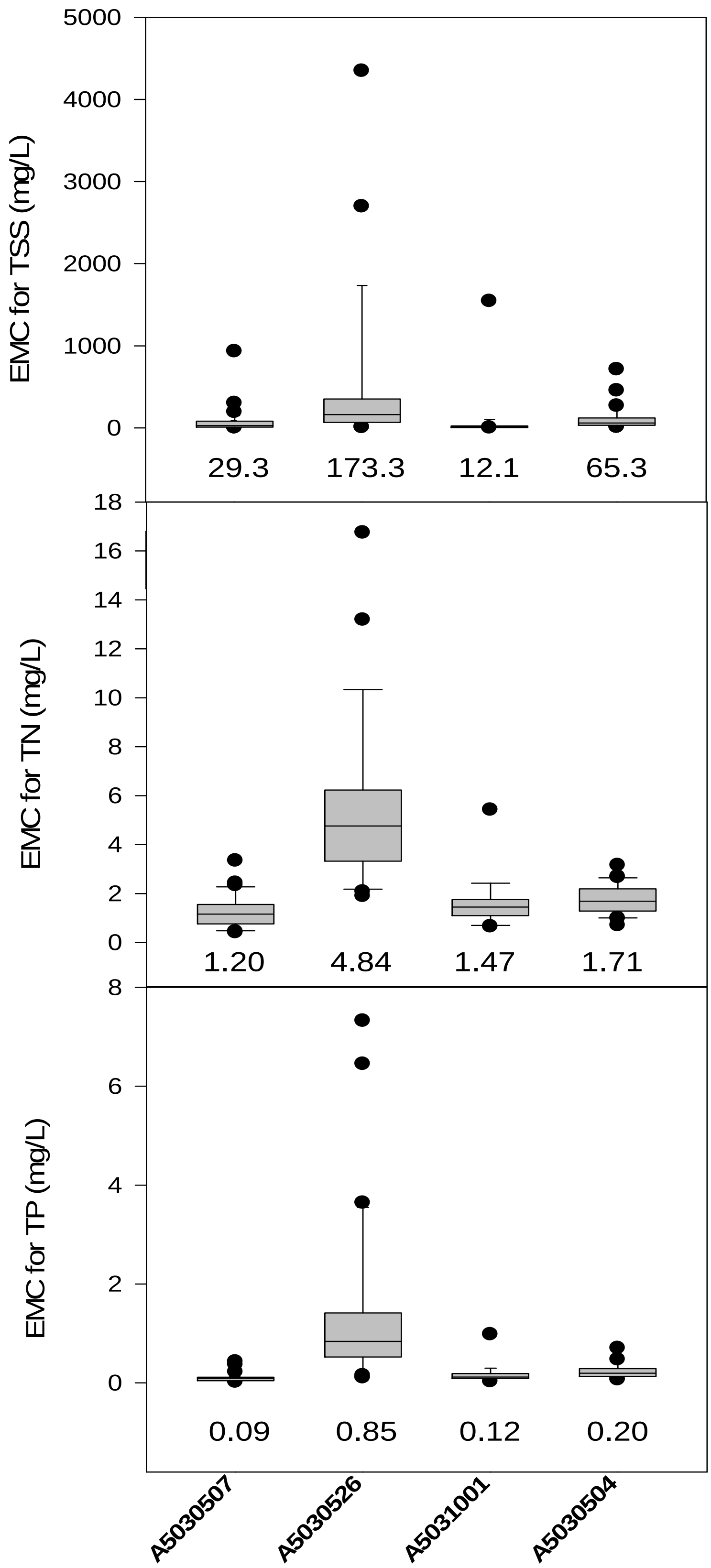


Figure 9. Box and whisker plots and median EMCs of composite sampler sites. Sites are sorted on proportion of broadscale perennial horticulture.

3.1.2.3 EMC values sorted by proportion of dense urban area

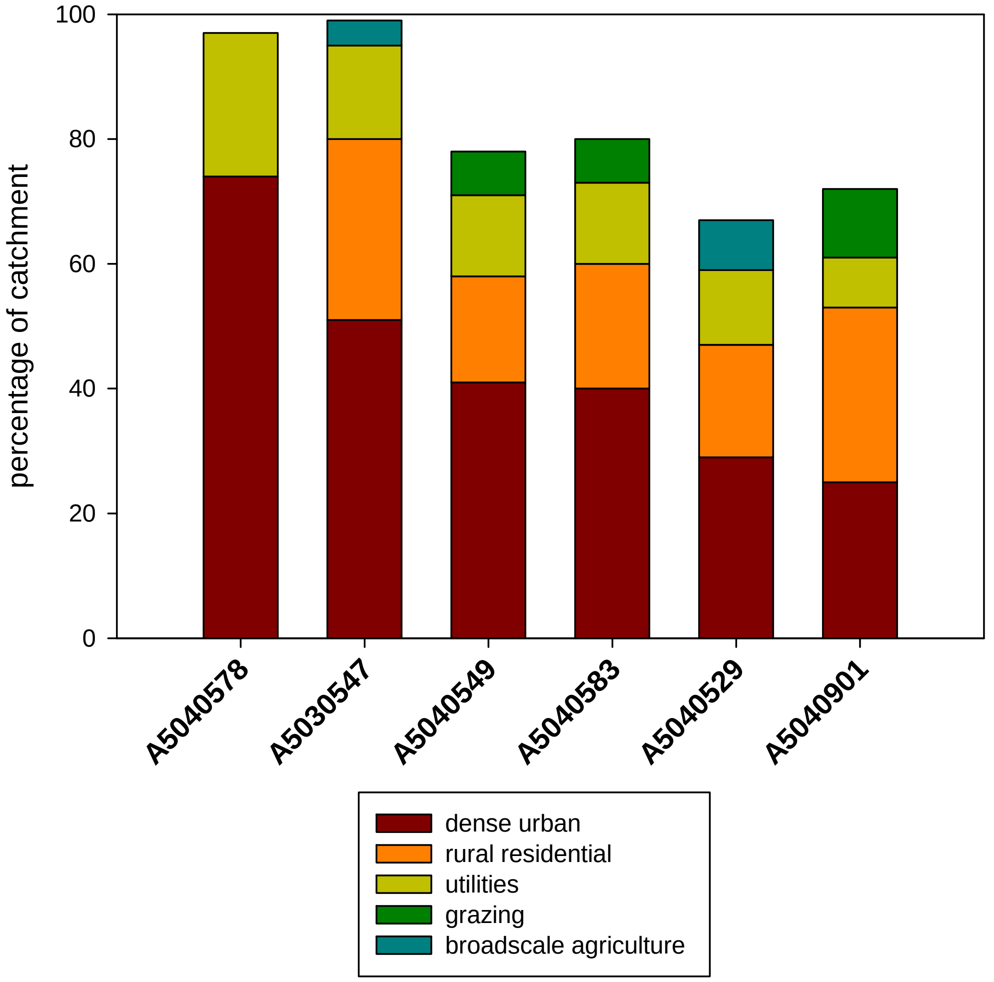


Figure 10. Land uses of composite sampler catchments sorted on proportion of dense urban area.

EMCs of TSS, TN and TP for dense urban sites are consistent between sites, and among the lowest of the measured land uses. The EMC's for TSS and TP are lower than those found by Chiew and Scanlon (2002) while the TN EMC is close to the median of their range. It is not certain at present why the TSS and TP values are lower than those found by Chiew and Scanlon, other than a different evironment with less intense rainfall events.

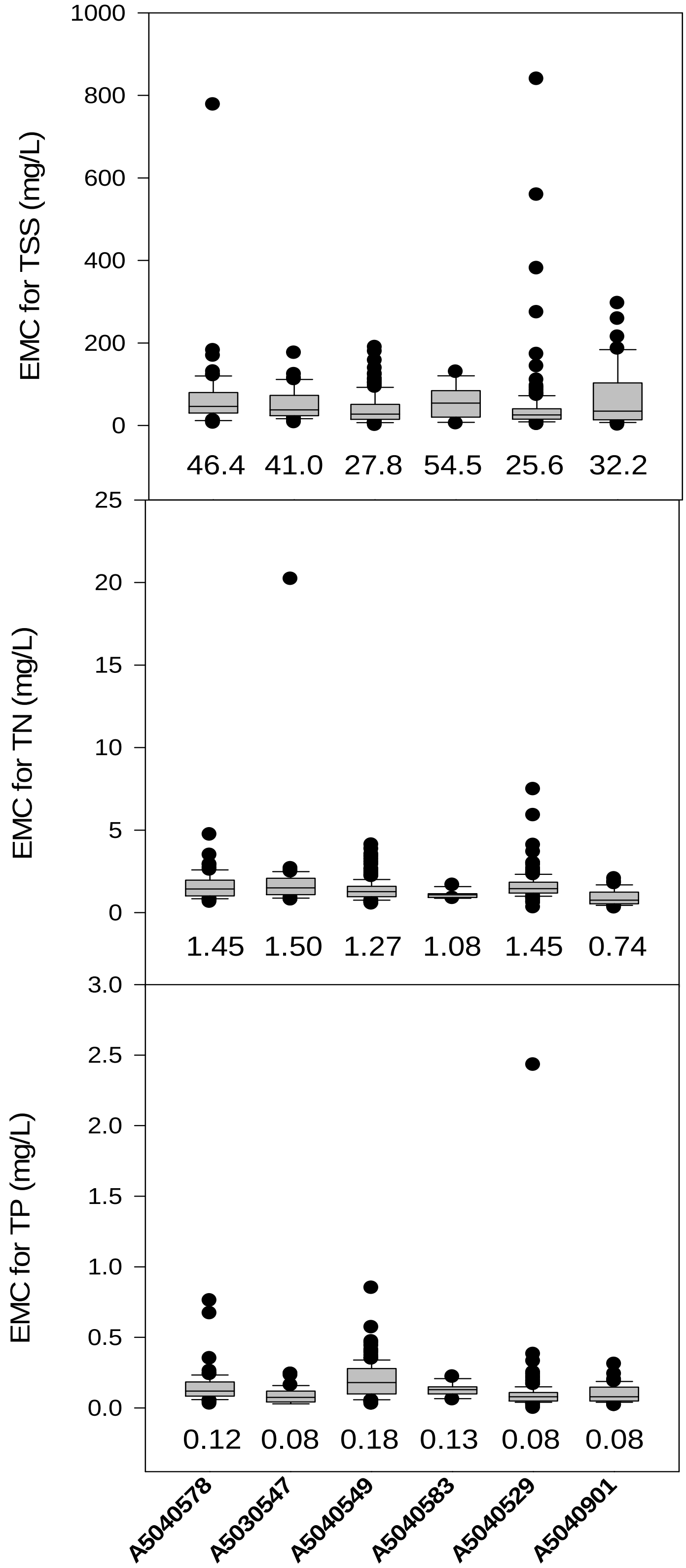


Figure 11. Box and whisker plots and median EMCs of composite sampler sites. Sites are sorted on proportion of dense urban area.

3.1.2.4 EMC values sorted by proportion of grazing area

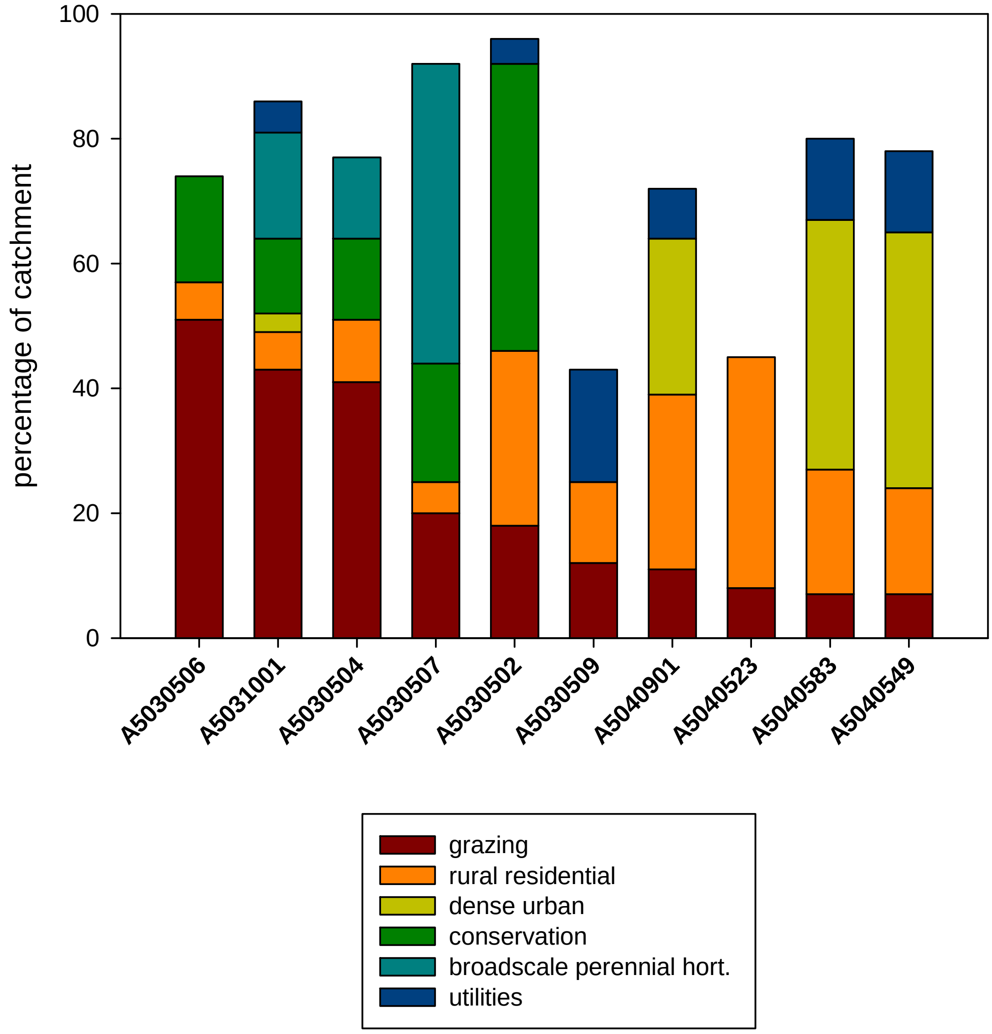


Figure 12. Land uses of composite sampler catchments sorted on proportion of grazing.

EMCs of TSS, TN and TP for grazing sites are moderately consistent and comparable to other land uses. EMC values for TSS and TP are generally lower than those of Chiew and Scanlon, while TN values are similar.

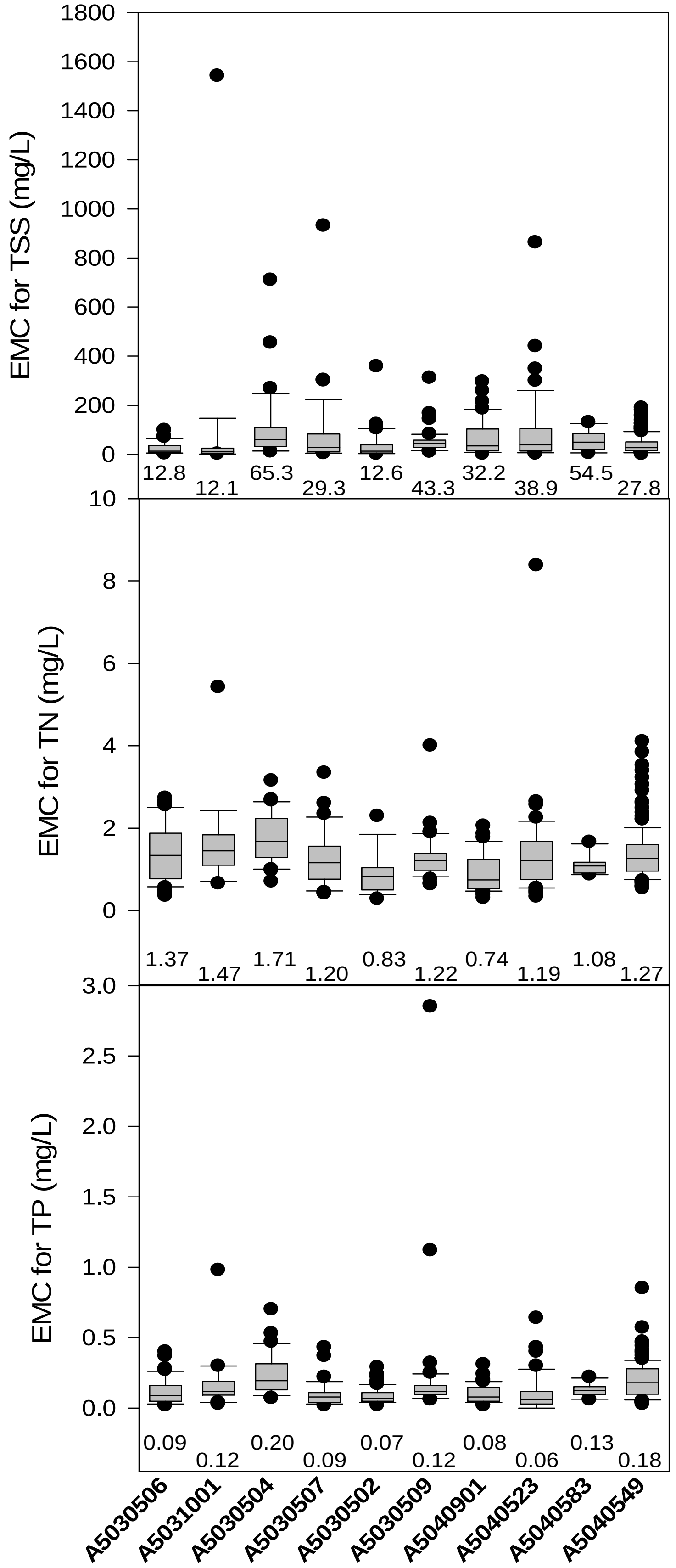


Figure 13. Box and whisker plots and median EMCs of composite sampler sites. Sites are sorted on proportion of grazing area

3.1.2.5 EMC values sorted by proportion of rural residential area

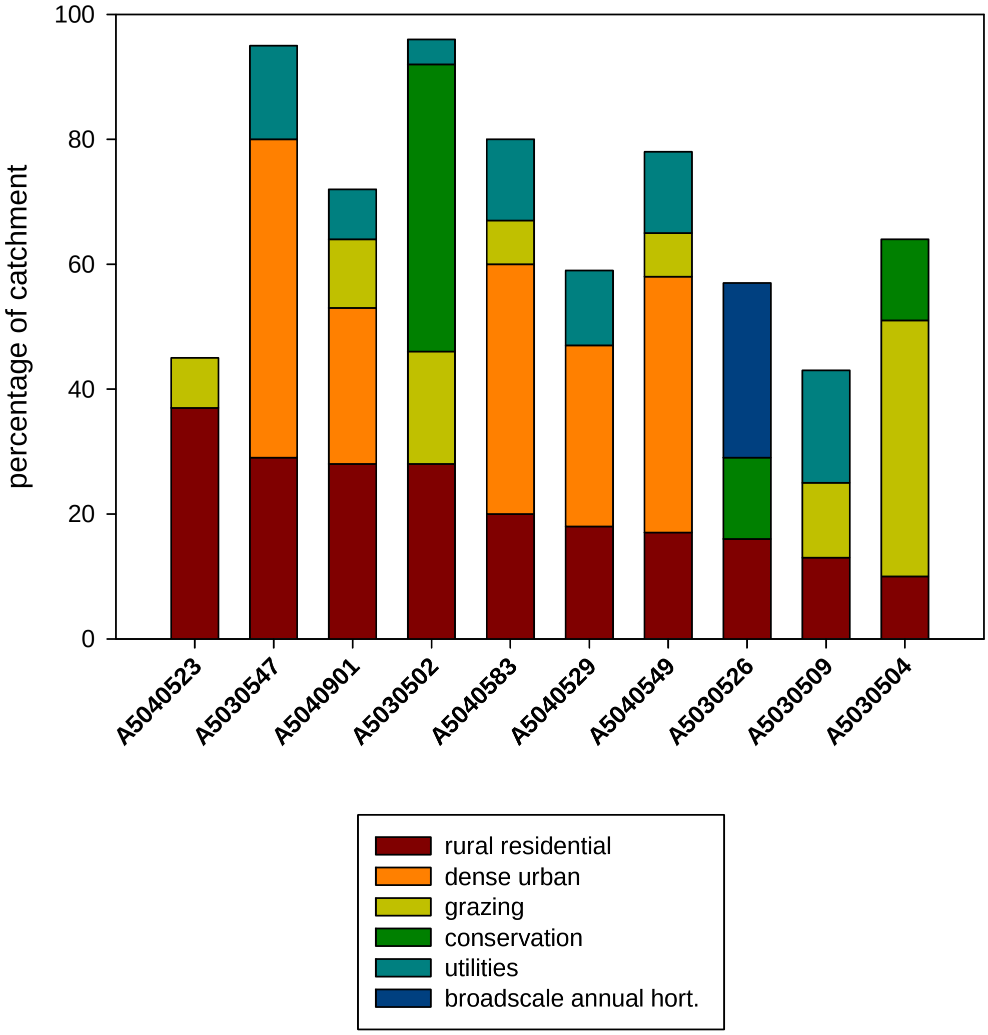


Figure 14. Land uses of composite sampler catchments sorted on proportion of rural residential area

EMCs of TSS, TN and TP for rural residential sites are relatively consistent, with the exception of site A5030526. This site also contains annual horticulture and has elevated TSS, TN and TP concentrations. Data from site A5030526 has been excluded from estimates of EMCs for rural residential areas.

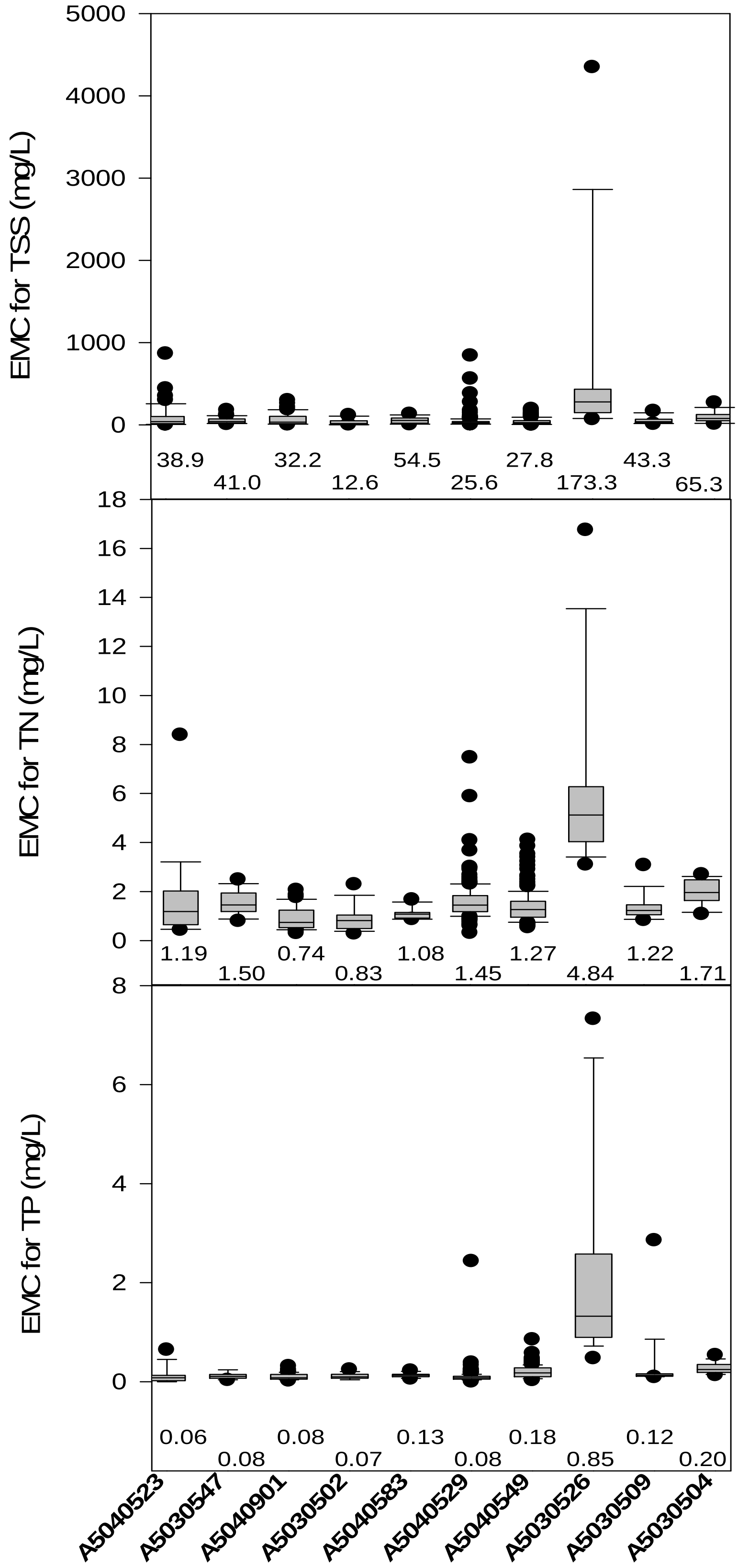


Figure 15. Box and whisker plots and median EMCs of composite sampler sites. Sites are sorted on proportion of rural residential area.

3.1.2.6 EMC values sorted by proportion of conservation area

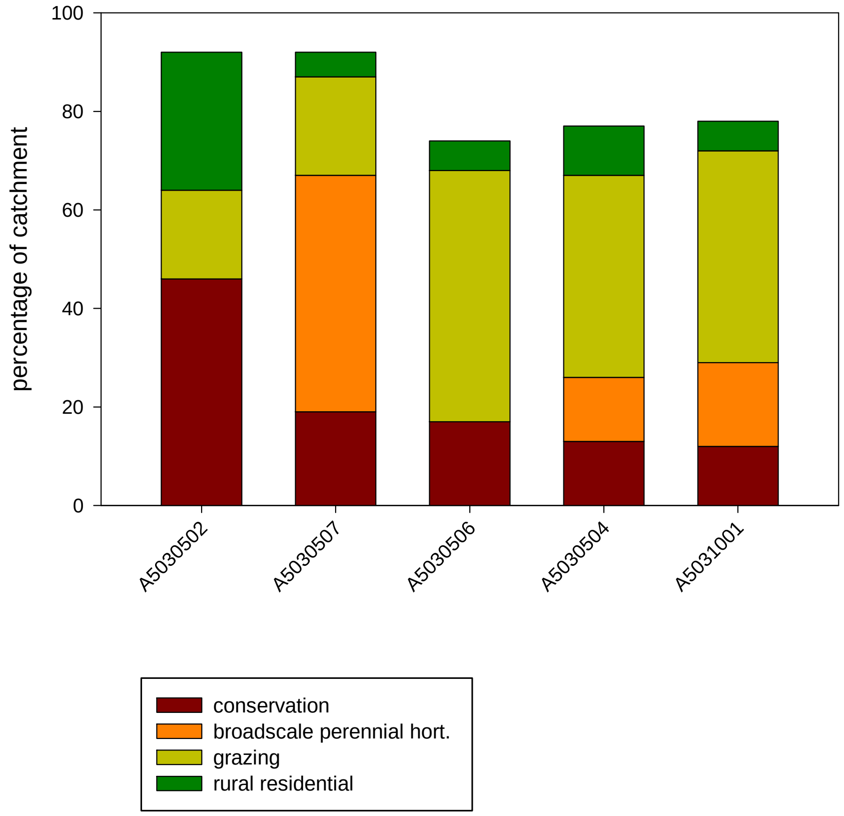


Figure 16. Land uses of composite sampler catchments sorted on proportion of conservation area.

EMCs of TSS, TN and TP for conservation areas were fairly consistent and all quite low. This is consistent with the undisturbed nature of conservation area and the relativly low EMC values, which are similar to those found by Chiew and Scanlon (2002).

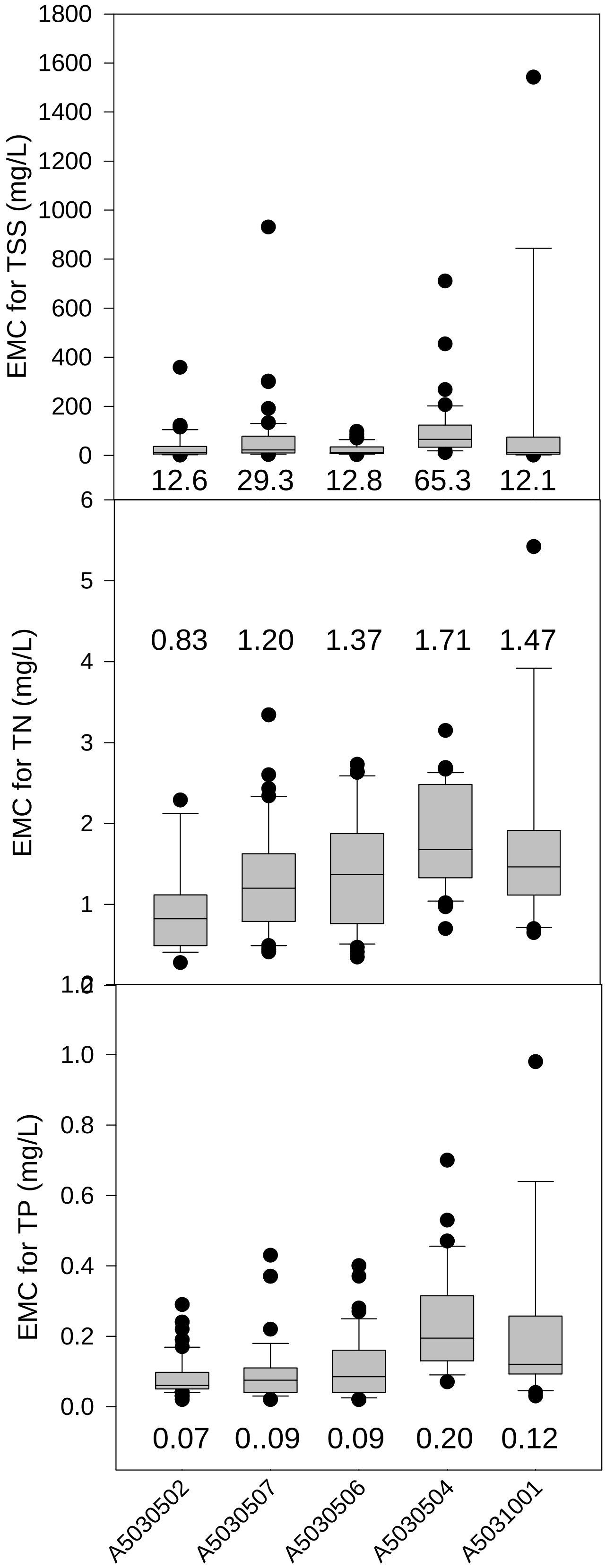


Figure 17. Box and whisker plots and median EMCs of composite sampler sites. Sites are sorted on proportion of conservation area.

The charts presented above show the magnitude and range of EMC values calculated for flow events using the Beale ratio method. Table 3 shows EMC values for individual sites calculated by the second method (optimisation of EMC to match observed load), in order to determine a single most representative value for each site.

The previous 6 graphs show that EMC values are comparable for the bulk of land uses, with some notable exceptions. Firstly that undisturbed land use (conservation) has lower EMC values than most other land uses, and secondly that a land use with relatively high fertiliser input and frequent cultivation (annual horticulture) has higher EMC values than other land uses. This trend of increasing EMC values with increasing intensity of land use is consistent with numerous reports of runoff water quality in the literature.

Many of the EMC values calculated for composite sampler sites were quite similar. This may be due to the fact that most sites had catchments containing a mixture of land uses, with few sites having a single land use. However, site A5030526 contained a mixture of land uses, but water qualtiy parameters were dominated by a single land use – annual horticulture – which had a disproportionate effect on water quality at that site. This is an example of a specific land use showing a measureable effect, even in a catchment of mixed land uses.

While the relative ranking of EMC values described in this report is similar to that found in other studies, a critical finding is the calculation of actual EMC values from data sourced in South Australia. This will aid in calibrating water quality simulations in the MLR watershed.

Calculated EMC values for composite sampler sites are shown in Table 3. These will be used for validation of model output concentrations and loads – ideally the simulated water quality will be similat to that measured, as the EMC values for individual land uses were derived from these sites.

Table 3. Calculated EMC values from composite sampler sites

Location	site ID	EMC (mg/L)			no. of events
		TSS	TN	TP	
Aldgate Creek Railway Station	A5030509	27	1.34	0.08	47
Brownhill Creek @ Adelaide Airport (Morphett Road)	A5040583	45	1.06	0.14	11
Brownhill Creek @ Scotch College	A5040901	60	0.89	0.09	41
Christie Creek @ DS Galloway Road	A5030547	74	1.47	0.11	41
Cox Creek @ Uraidla	A5030526	308	5.26	0.93	34
Echunga Creek U/S Mt Bold Res.	A5030506	43	1.82	0.18	44
First Creek @ ds Botanic Gardens	A5040578	82	2.52	0.12	66
Kersbrook Creek U/S Millbrook Reservoir	A5040525	60	2.13	0.22	44
Lenswood Creek Lenswood	A5030507	146	1.56	0.13	55
Onkaparinga River – Hahndorf	A5031001	300	2.84	0.31	20
[a]Onkaparinga, Houlgraves Weir	A5030504	67	1.27	0.17	35
Scott Creek (Bottom)	A5030502	54	1.09	0.12	44
Sixth Creek @ Castambul	A5040523	131	1.58	0.13	47
Sturt River @ ds Anzac Highway	A5040549	56	1.54	0.24	148
Torrens River @ Holbrooks Rd	A5040529	148	1.90	0.20	175

*catchment area below reservoir. [a]This site also receives water transferred from the Murray river (interbasin transfer). Transferred water has been excluded from EMC calculations.

3.2 Calculation of EMCs for individual land uses from composite sampler data

Sample concentrations were available from gauging stations which were located across a range of catchment sizes, either at the end or part-way up the catchment. In all cases the catchment area was a mosaic of land uses, typical of the MLR. A number of sites had around 50% of one land use, and one site had 75% of a single land use, but most catchments contained a variety of land uses, mostly comprising less than 25% of the area. Figure 18 shows the EMC values for each of the three constituents – TSS, TN and TP. Data is plotted from composite samplers located in catchmentswhich contain significant proportions of the land uses shown on the x, y and z axes. The size of the circle represents the size of each catchment. The colour of each circle represents the calculated EMC value for that site compared to the mean of the plotted data. For example, in Figure 17 the two largest catchments (largest circles) had EMC values for TSS which were more than 20% less than the mean EMC for TSS across the plotted sites (green circles).

Figure 18 shows that in catchments containing dense urban areas, TSS EMCs differed markedly between catchments. This was not related to catchment size, as larger catchments had higher and lower values, within a relatively close grouping of land-use. EMCs for TN, however, were quite consistent (within 20% of the mean) across almost all of the catchments. Charts of this type for TSS, TN and TP of all catchments are presented in Appendix 1.

Simple estimation was used to determine the EMCs of catchments containing multiple land uses. Where a catchment contained only one land use, deriving a representative EMC value was simple. However, all of these catchments had multiple land uses within them. Where a land use comprised a significant area in only one catchment, then EMCs of that catchment were taken as representative of that land use. For example, broadscale agriculture made up 25% of site A5040523 while the next highest proportion was 8% of site A5040529. In this case, the EMCs for site A5040523 were taken to represent broadscale agriculture.

Where a land use comprised a significant proportion of numerous catchments, then the average of the relevant EMCs for each catchment was used to represent that particular land use. EMC values for primary land uses were not included in this summary. This is because they may be unrealistically higher than those from other sites due to their smaller scale of measurement. Data from these sites will be included in this data set once the effect of delivery ratios across the relevant scales of measurement in the MLR has been determined.

Calculated EMCs and DWCs for land uses in the MLR from composite sites are shown in Table 4.

In general, EMC values for TSS, TN and TP increased with increasing intensity of agricultural or horticultural management. This is consistent with much published information, with the least intensive land use (Conservation area) producing the lowest EMC values. Annual horticulture and intensivie grazing produce some of the highest EMC values.

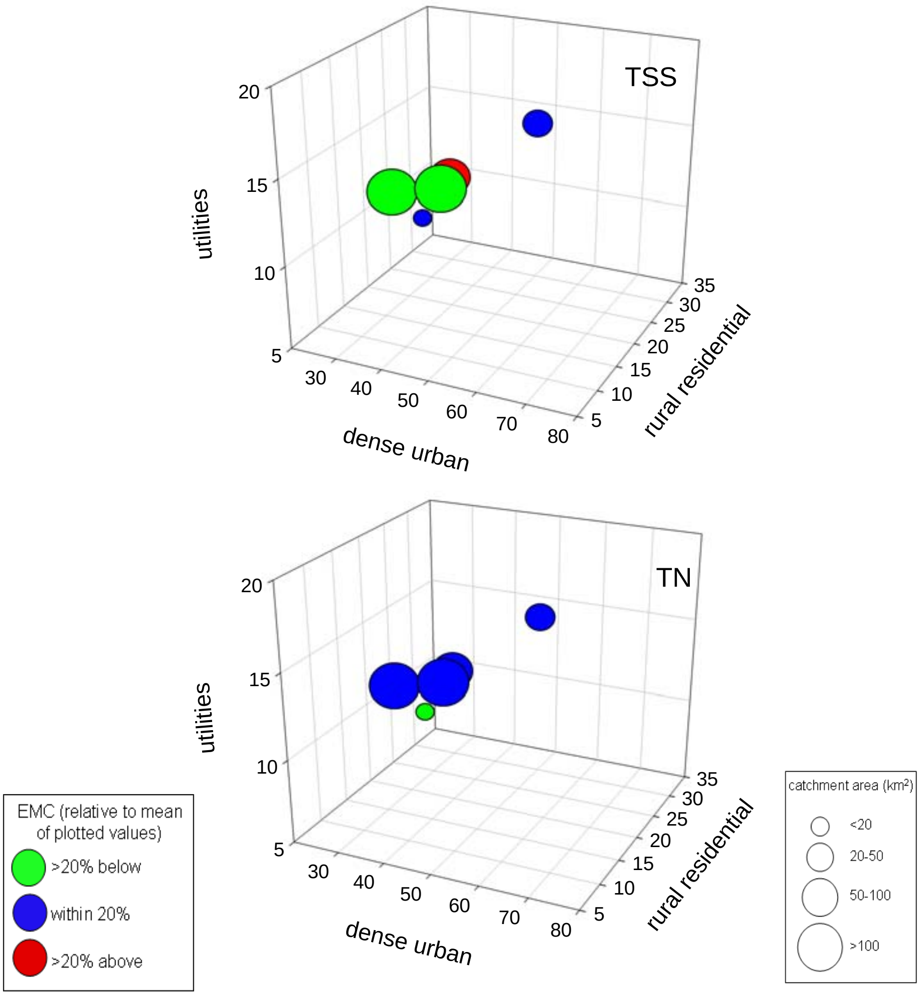


Figure 18. EMC, size and percentage land use of catchments containing dense urban areas. Each data point is the median EMC from a catchment. The three largest land uses for each catchment are plotted on x, y and z axes. The size of each circle indicates the size of the catchment. The colour of each dot indicates the EMC in relation to the mean of the values plotted.

Table 4. EMCs and DWCs of Total Suspended Solids (TSS), Total Nitrogen (TN) and Total Phosphorus (TP) for land use categories in the MLR.

landuse	TSS (mg/L)		TN (mg/L)		TP (mg/L)	
	EMC	DWC	EMC	DWC	EMC	DWC
Conservation area	43	10	1.8	0.6	0.18	0.05
Managed forest	66	23	2.1	1.0	0.16	0.11
Grazing	184	12	2.1	0.8	0.24	0.23
Intensive grazing*	300	10	2.8	2.2	0.60	0.50
Broadscale agriculture	131	10	1.6	0.7	0.13	0.04
Broadscale annual horticulture	308	21	5.3	3.4	0.93	0.34
Broadscale perennial horticulture	146	12	1.6	1.1	0.13	0.10
Surburban	27	23	1.3	0.8	0.08	0.09
Rural Residential	131	10	1.6	0.7	0.13	0.04
Dense Urban	61	14	1.8	1.5	0.10	0.08
Utilities	40	12	1.3	1.3	0.12	0.07
Water Bodies	0	0	0	0	0	0
Wetlands	0	0	0	0	0	0

*estimated primary land uses of Grazing and Intensive grazing. To be refined pending further analysis of composite sampler data.

3.3 Comparison of calculated EMCs and DWCs to published values

The most relevant Australian published values to the MLR are the median values reported by Chiew and Scanlon (2002) for Southeast Queensland (SEQ). They are presented with comparable calculated EMCs for the MLR in Table 5.

While there are great differences between the MLR and SEQ in climate and farming systems, some EMCs are surprisingly similar, for example the TSS EMC for Grazing is 184 mg/L in the MLR and 140 mg/L in SEQ. In general, MLR values of TP are lower than SEQ, values of TN are higher than SEQ and EMCs of TSS are variable in relation to SEQ.

Table 5 EMCs for comparable land uses in the Mount Lofty Ranges (normal font) and South East Queensland (italic font).

Landuse	TSS (mg/L)		TN (mg/L)		TP (mg/L)	
	EMC	DWC	EMC	DWC	EMC	DWC
Dense Urban	61	14	1.8	1.5	0.10	0.08
Q Urban	*130*	*7*	*0.28*	*0.11*	*1.60*	*1.50*
Conservation area	43	10	1.8	0.6	0.18	0.05
Q Natural Bush	*32*	*7*	*0.10*	*0.03*	*0.80*	*0.50*
Managed forest	66	23	2.1	1.0	0.16	0.11
Q Managed Forest	*32*	*7*	*0.10*	*0.03*	*0.80*	*0.50*
Grazing	184	12	2.1	0.8	0.24	0.23
Q Grazing	*140*	*10*	*0.34*	*0.07*	*2.70*	*0.70*
Broadscale agriculture	131	5	1.6	0.5	0.13	0.02
Q Cropping	*200*	*10*	*0.50*	*0.07*	*4.00*	*0.70*

With regard to international values, the EMC's most relevant to MLR land uses are presented with data from Harper (1998) and from Line *et al.* (2002) in Appendix 2.

EMCs calculated for the MLR are sometimes higher and sometimes lower than those of Harper (1998) and Line *et al.* (2002) for TSS, TN and TP, but are generally comparable.

Table 6. EMCs for comparable land uses in the Mount Lofty Ranges (normal font) and South East Queensland (italic font).

Landuse	TSS (mg/L)		TN (mg/L)		TP (mg/L)	
	EMC	DWC	EMC	DWC	EMC	DWC
Dense Urban	61	14	1.8	1.5	0.10	0.08
H Urban	*130*	*7*	*1.60*	*1.50*	*0.28*	*0.11*
Conservation area	43	10	1.8	0.6	0.18	0.05
H Natural Bush	*32*	*7*	*0.80*	*0.50*	*0.10*	*0.03*
Managed forest	66	23	2.1	1.0	0.16	0.11
H Managed Forest	*32*	*7*	*0.80*	*0.50*	*0.10*	*0.03*
Grazing	184	12	2.1	0.8	0.24	0.23
H Grazing	*140*	*10*	*2.70*	*0.70*	*0.34*	*0.07*
Broadscale agriculture	131	5	1.6	0.5	0.13	0.02
H Cropping	*200*	*10*	*4.00*	*0.70*	*0.50*	*0.07*

3.4 Comparison of calculated EMCs and DWCs values to those currently used in Source Catchments

EMCs used in the current version of the MLR Source Catchments project (WBM 2006) were largely adapted from Chiew and Scanlon (2002). Table 7 shows current EMCs and DWCs (normal font) and the equivalent values calculated from local data (bold font).

Table 7. EMCs and DWCs for Total Suspended Solids (TSS), Total Nitrogen (TN) and Total Phosphorus (TP) currently used in MLR Source Catchments model (normal font), and comparable values calculated from local data (bold).

Landuse	TSS (mg/L)		TN (mg/L)		TP (mg/L)	
	EMC	DWC	EMC	DWC	EMC	DWC
Conservation area	20 **43**	7 **10**	0.8 **1.8**	0.4 **0.6**	0.20 **0.18**	0.03 **0.05**
Managed forest	20 **66**	7 **23**	0.8 **2.1**	0.4 **1.0**	0.20 **0.16**	0.03 **0.11**
Plantations	20 **66**	7 **23**	0.8 **2.1**	0.4 **1.0**	0.20 **0.16**	0.03 **0.11**
Grazing	140 **184**	10 **12**	1.6 **2.1**	0.7 **0.8**	0.28 **0.24**	0.07 **0.23**
Broadscale agriculture	140 **131**	10 **10**	2.1 **1.6**	0.7 **0.7**	0.36 **0.13**	0.07 **0.04**
Broadscale annual horticulture	**308**	**21**	**5.3**	**3.4**	**0.93**	**0.34**
Broadscale perennial horticulture	**146**	**12**	**1.6**	**1.1**	**0.13**	**0.10**
Rural Residential	140 **131**	10 **10**	1.6 **1.6**	0.7 **0.7**	0.28 **0.13**	0.07 **0.04**
Suburban	140 **27**	10 **23**	1.6 **1.3**	0.7 **0.8**	0.28 **0.08**	0.07 **0.09**
Dense Urban	140 **61**	10 **14**	1.6 **1.8**	0.7 **1.5**	0.28 **0.10**	0.07 **0.08**
Utilities	**40**	**12**	**1.3**	**1.3**	**0.12**	**0.07**
Water	0	0	0	0	0	0

Some EMCs calculated for the MLR are comparable to values used in the current model (e.g. TN for Conservation area and for Grazing). However, for many land use categories the EMCs calculated from the MLR data are different to those reported by Chiew and Scanlon (2002). For example, TSS for Grazing has an existing EMC of 140 mg/L and a calculated EMC of 31 mg/L. These differences are not surprising as the existing values were largely based on water quality monitoring of semi-tropical rivers (SEQ). The local EMCs will give quite different estimates of the

modelled water quality concentrations and loads. This will be important in assessing the effect of changing land use on water quality within the MLR rivers using the Source Catchments model. The TN and TP EMCs for Suburban and Dense urban land uses are quite similar. This is likely due to the lack of base flow in these land uses, so any flow in summer months may flush constituents from waterways.

It is proposed to both adjust existing EMCs and expand the number of land use categories. This is based on the difference between existing EMCs and calculated ones, and typical land use combinations found in the watershed. Proposed values are shown in Table 8.

Table 8. EMCs and DWCs of Total Suspended Solids (TSS), Total Nitrogen (TN) and Total Phosphorus (TP) for proposed land use categories in the MLR Source Catchments model.

	TSS		TN		TP	
Landuse	**EMC**	**DWC**	**EMC**	**DWC**	**EMC**	**DWC**
	mg/L					
Conservation area	43	10	1.8	0.6	0.18	0.05
Managed forest	66	23	2.1	1.0	0.16	0.11
Plantations	66	23	2.1	1.0	0.16	0.11
Grazing	184	12	2.1	0.8	0.24	0.23
Intensive grazing	300	10	2.8	2.2	0.60	0.50
Broadscale agriculture	131	10	1.6	0.7	0.13	0.04
Broadscale annual horticulture	308	21	5.3	3.4	0.93	0.34
Broadscale perennial horticulture	146	12	1.6	1.1	0.13	0.10
Rural Residential	131	10	1.6	0.7	0.13	0.04
Dense Urban	61	14	1.8	1.5	0.10	0.08
Surburban	27	23	1.3	0.8	0.08	0.09
Utilities	40	12	1.3	1.3	0.12	0.07
Water Bodies	0	0	0	0	0	0
Wetlands	0	0	0	0	0	0

4 Conclusions

This work provides a detailed analysis and summary of water quality data for the Mount Lofty Ranges, South Australia. The data utilised has been of high quality – chemical analyses of flow-weighted composite samples taken at 16 gauging stations across the MLR. Most stations have at least 10 years of weekly composite sample analyses.

Revised EMC and DWC values have been presented for the MLR in South Australia. Values for TN and TP are generally comparable to those reported interstate. However, there are considerable differences in EMC values of TSS for some land uses. In particular; conservation area, managed forestry and plantations have higher EMC values for TSS than reported elsewhere, while suburban and dense urban have lower TSS EMC values than reported elsewhere.

Existing EMCs should be updated with the values presented in this report. This will allow calibration of water quality modelling to reflect calculations based on local water quality data.

Categories of Intensive grazing, Annual horticulture, Perennial horticulture and Suburban should be created to further reflect the specific patterns of land use in the MLR.

Data presented in this report results from the first major analysis of the composite sampler database for modelling purpose. This is a significant step in the further utilisation of data which has been rigorously gathered at significant effort and expense.

Utilising local EMC data will provide a more accurate estimate of catchment constituent loads. This will be important in assessing the effect of changing land use on water quality within the MLR into the future,

5 References

Adelaide and MLR Natural Resources Management Board (2008) Regional Natural Resources Management Plan, June 2008. http://www.amlrnrm.sa.gov.au/PolicyandPlanning/RegionalNRMPlan.aspx accessed 10 September 2010.

Chiew F. and Scanlon P. (2002*) Estimation of pollutant concentrations for EMSS modelling of the South-East Queensland region.* Technical Report 02/2. CRC for Catchment Hydrology, February 2002.

Harper H.H. (1998). *Stormwater chemistry and water quality.* http://www.stormwaterresources.com/Library/045PlChemistry.pdf

Lin J. P. (2004). *Review of published export coefficient and event mean concentration (EMC) data.* WRAP Technical Notes Collection (ERDC TN-WRAP-04-3), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/wrap

Line D. E., White, N. M., Osmond, D. L., Jennings, G. D., and Mojonnier, C. B. (2002). *"Pollutant export from various land uses in the Upper Neuse River Basin,"* Water Environment Research 74:100-108.

South Australian Government (2010) *The 30-Year Plan for Greater Adelaide*. http://www.dplg.sa.gov.au/plan4adelaide/html/plan.cfm , accessed 10 September 2010.

Tenakoon S.B., Marsh N. and Arene S. (2007) *A Software Tool for the Estimation of Pollutant Loads in Rivers and Streams Using Time Series Data.* MODSIM07 conference, Christchurch New Zealand.

Teoh K 2002, *Estimating the impact of current farm dams development on the surface water resources of the Onkaparinga catchment,* Department of Water, Land & Biodiversity Conservation, Adelaide.

Water Data Services (2002) *Data Summary of Water Quality Loads for the Nutrient Budget Study.* Water Data Services 2002. (Onkaparinga and Torrens Composite sites).

Water Data Services (2003) *Trend and Excursion analysis of the composite sample data for the NBS study*. Water Data Services 2003.

Water Data Services (2004) *Review of the Water Quality Data 1999 to 2003 for Onkaparinga Catchment Water Management Board*. Water Data Services 2004.

Water Data Services (2006) *Review of the Water Quality Data 1996 to 2005 for Patawalonga and Torrens Catchment Water Management Boards*. Water Data Services 2006.

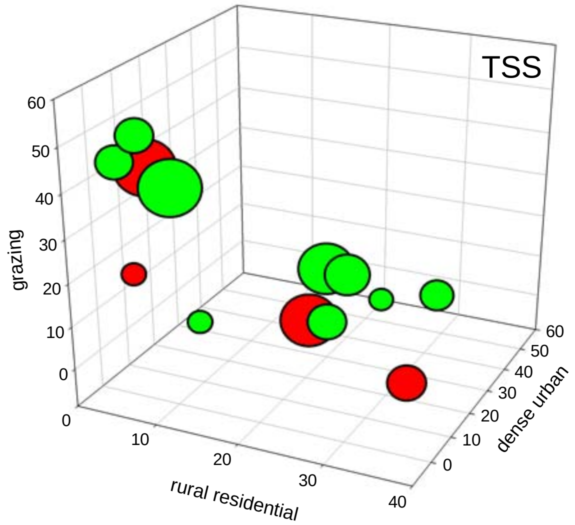
WBM (2006) *Mt Lofty Ranges Storage Catchments - EMSS to E2 Conversion Report.* Document R.B15199.002.00.doc, WBM Proprietary Limited, Queensland, July 2006.

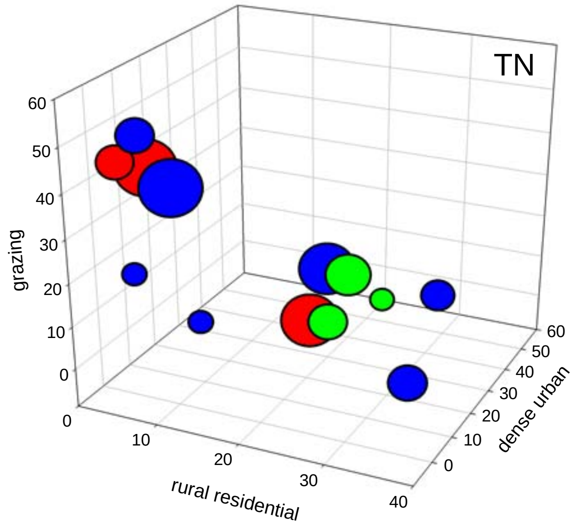
Wollheim W.M., Voosmarty C.J., Peterson B.J., Seitzinger S.P. and Hopkinson C.S. (2006) *Relationship between river size and nutrient removal.* Geophysical Research Letters 33:6410-641

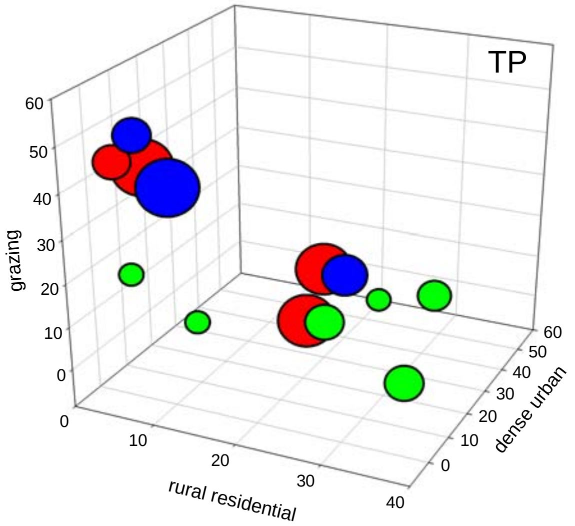
Appendix 1

EMC, size and percentage land use of catchments containing various land uses. Each data point is the median EMC from a catchment. The three largest land uses for each catchment are plotted on x, y and z axes. The size of each circle indicates the size of the catchment. The colour of each dot indicates the EMC in relation to the mean of the values plotted.

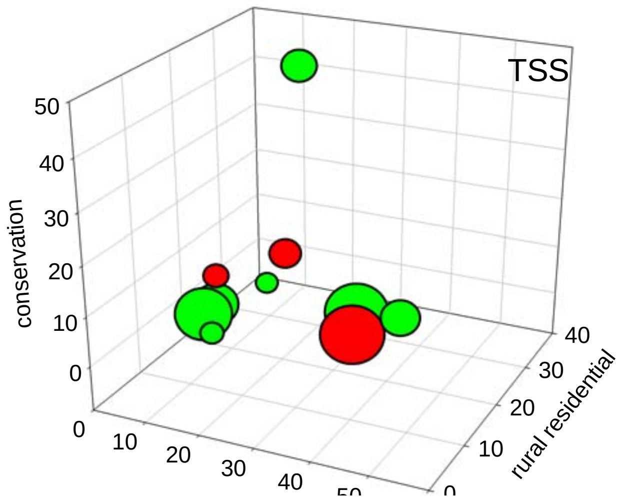
Rural Residential







Grazing


TSS
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20
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0
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20
30
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rural residential
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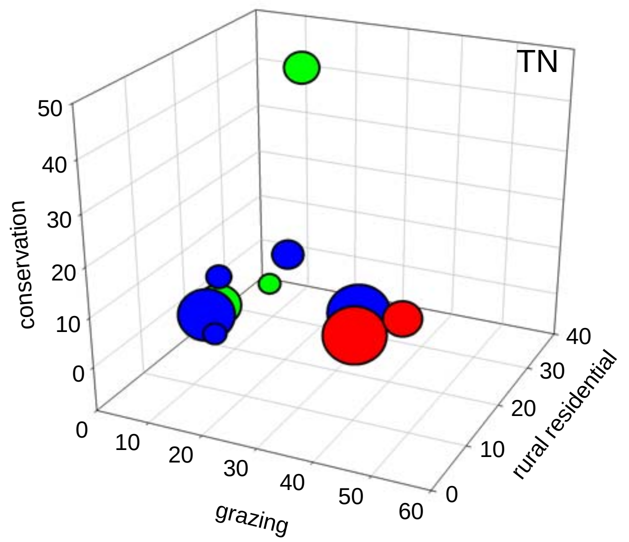
30
20
10


TN
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grazing
rural residential
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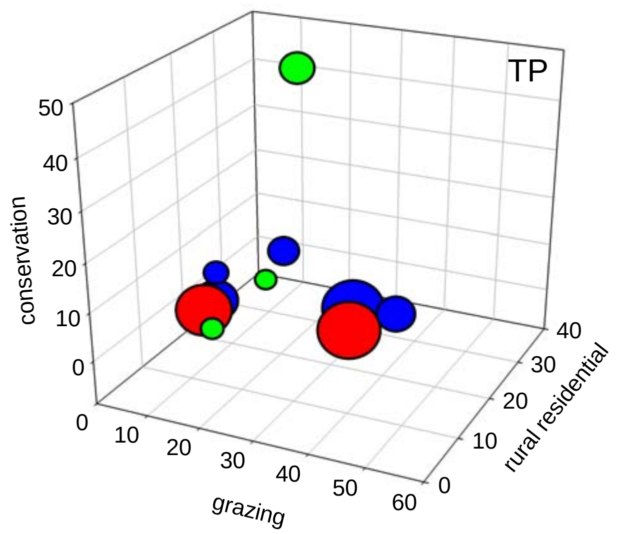
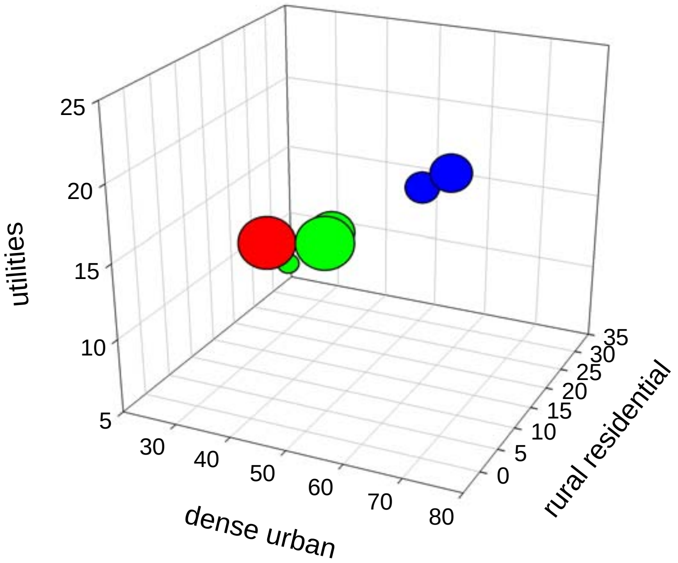
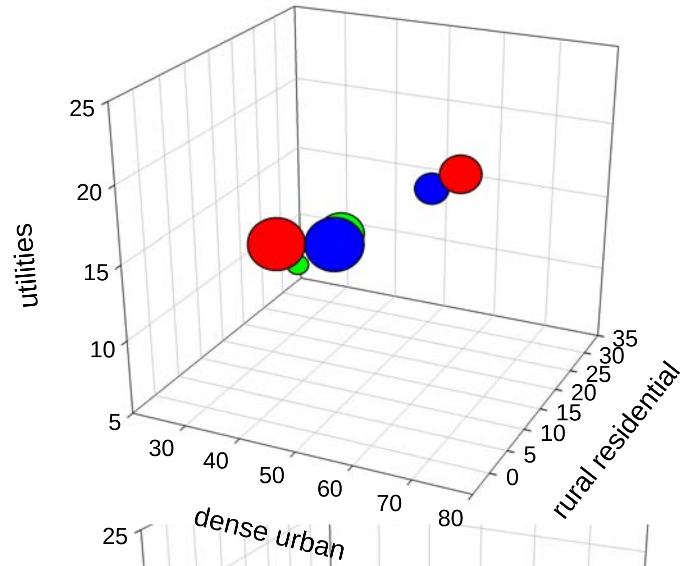
20
10
0


TP
conservation
50
40
30
20
10
0
0
10
20
30
40
50
60
grazing
rural residential
40
30
20
10
0

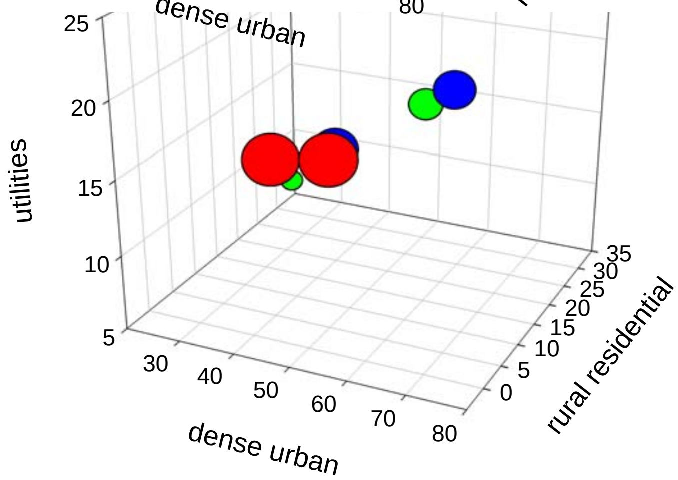
Dense Urban



TSS

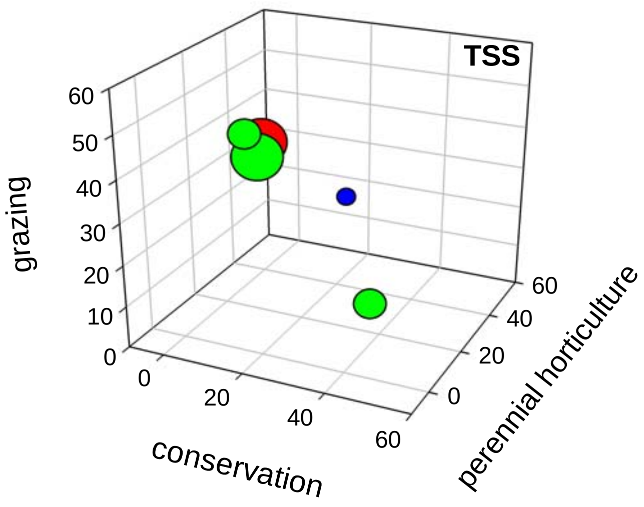


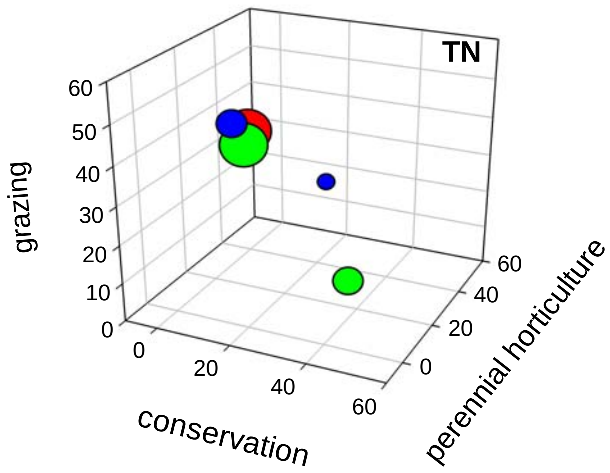
TN

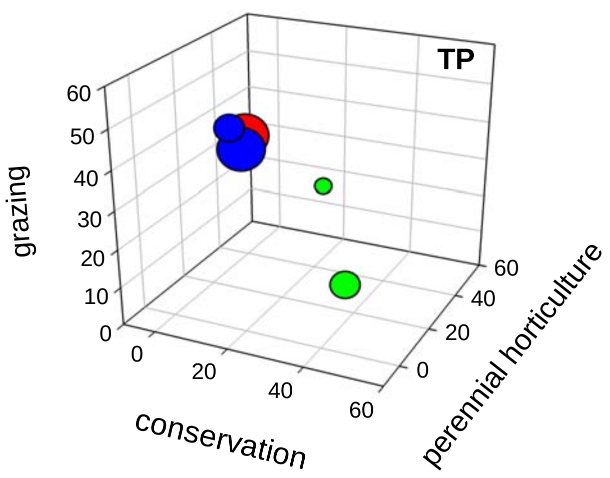


TP

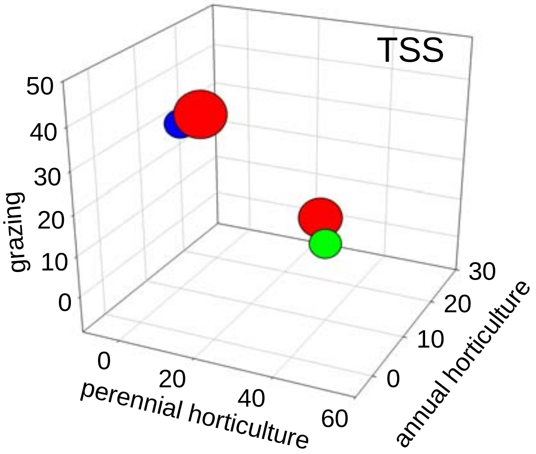
Conservation Area

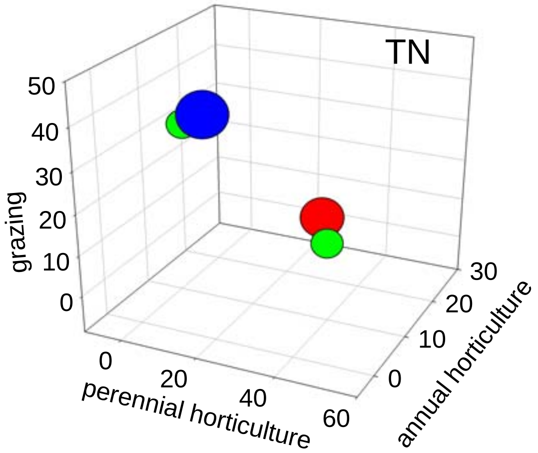


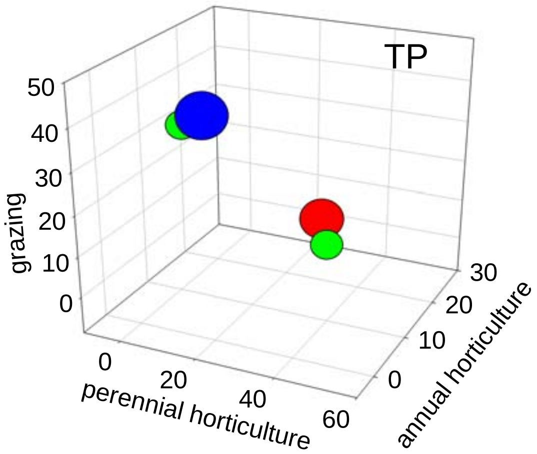




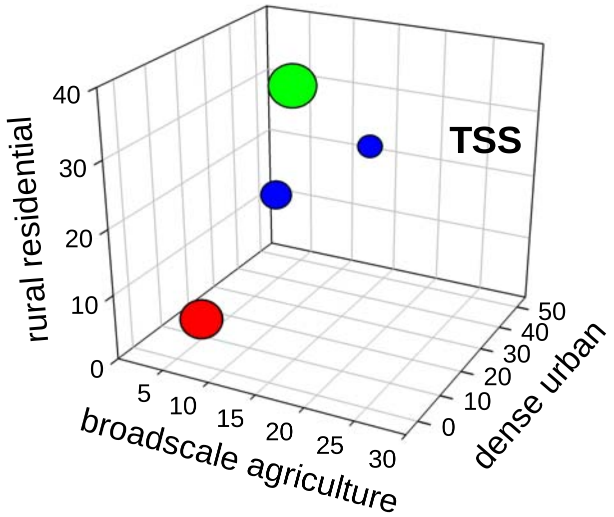
Perennial Horticulture

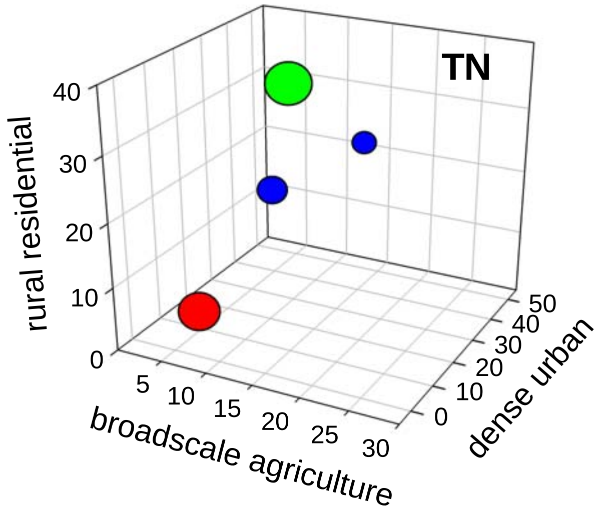


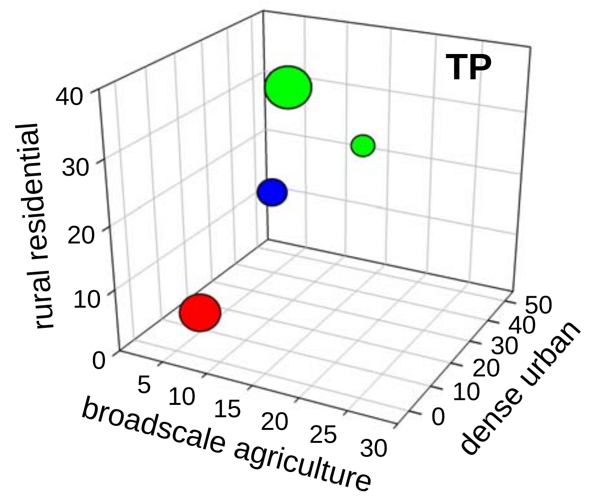




Broadscale Agriculture







Appendix 2

EMCs calculated for the MLR in normal font and those published by Line *et al.* (2002) for relevant land uses (in italics).

landuse	EMC (mg/L)		
	TSS	TN	TP
Conservation area	43	1.8	0.18
L Wooded	*113*	*1.47*	*0.25*
Managed forest	66	2.1	0.16
Grazing	184	2.1	0.24
L Pasture	*84*	*3.61*	*1.56*
Broadscale agriculture	131	1.6	0.13
Broadscale annual horticulture	308	5.3	0.93
Broadscale perennial horticulture	146	1.6	0.13
Rural Residential	131	1.6	0.13
L Residential	*42*	*1.97*	*0.4*
Dense Urban	61	1.8	0.10
L Industrial	*170*	*1.30*	*0.23*

Overseas, Lin (2004) reviewed American land use values for EMCs and DWCs as shown below

EMCs of Select Constituents Measured for Various Land Uses in Central and South Florida. From Lin (2004), after Harper (1998).

Land Use	EMC (mg/L) TN	TP	TSS
Low-density residential	1.77	0.18	19.1
Single family residential	2.29	0.30	27.0
Multi-family residential	2.42	0.49	71.7
Low-intensity commercial	1.18	0.15	81.0
High-intensity commercial	2.83	0.43	94.3
Industrial	1.79	0.31	93.9
Highway	2.08	0.34	50.3
Pasture	2.48	0.476	94.3
Citrus	2.05	0.14	16.3
Row crops	2.68	0.56	-
General agriculture	2.32	0.34	55.3
Open space	1.25	0.05	11.1
Mining	1.18	0.15	93.9
Wetland	1.6	0.19	10.2
Open water/lake	1.25	0.11	3.1

Mean and Median EMCs for Various Land Uses in the Upper Neuse River Basin, North Carolina. Adapted from Line *et al.* (2002) after Lin (2004).

Land Use	Event Mean Concentration (mg/L)					
	TN		TP		TSS	
	Median	Mean	Median	Mean	Median	Mean
Residential	1.97	6.71	0.40	0.59	42	73
Golf Course	6.13	7.87	0.82	1.07	150	202
Industrial	1.30	1.85	0.23	0.27	170	231
Pasture	3.61	4.76	1.56	2.14	84	151
Construc-tion-I[1]	1.35	1.29	0.21	0.43	2,143	3,491
Construc-tion-II[2]	2.37	6.69	0.21	0.28	985	1,453
Wooded	1.47	4.58	0.25	0.35	113	487

[1] Construction I – clearing, grubbing, and grading of former wooded/agricultural land.
[2] Construction II – installation of roads, storm drainage, and housing.