Gippsland Lakes Environmental Study

Technical Report

Report to the CSIRO/MU Project Team

Estimation of Sediment and Nutrient Loads into the Gippsland Lakes

Final Report

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1. SUMMARY

The following summarises the work undertaken by the Centre for Environmental Applied Hydrology at the University of Melbourne on the calculation of loads of total suspended solids (TSS), total phosphorous (TP) and total nitrogen (TN) into the Gippsland Lakes. The loads are required as input for the CSIRO ecological model and are produced at a daily level for the period from 1975-1999, and used in ecological modelling for the period July 1995-June 1999.

The methodology employed in computing loads is based on deriving relationships between the concentrations of transported material and a combination of discharge and other variables. This enables equations for each river to be developed that predict daily loads for any period where flow data are available. This approach is needed because there is insufficient data available for direct computation of loads during the modelling period. It also enables loads to be easily computed for any other period if required. The initial approach formed regressions on the basis of a consistent data set from the EPA, dating from the mid 1970s, and following standard procedures for establishing the statistical validity of the regression relationships. In a second stage, for some sites we stratified the data on the basis of discharge, separating out the lower flows and forming regressions on the higher flow data. For the lower flow data, a mean value of concentration was used. This approach was found to give more reliable load estimates for some rivers and constituents.

In addition to comparison with independent data sets, comparison between the initial and final approaches to modelling also acted as a form of sensitivity analysis to indicate the level of uncertainty expected in the load estimates. Uncertainty comes from two main sources. The first is statistical error resulting from the quality of the regression model fit to the data. This can be quantified mathematically. The second results from the extent to which the data used for derivation of the equations is representative of the true characteristics of water quality variability in the rivers, and in particular because of insufficient high flow samples. This uncertainty cannot be strictly defined but some understanding of its magnitude can be determined from a qualitative assessment of the sampling coverage, analysis of the data and comparisons such as those presented below.

Comparisons were made between the observed daily loads computed directly from the data during the period 1977 to 1990 and the predicted daily loads based on the original and "two part" regression relationships. These comparisons indicated that the two-part approach produces similar estimates to the original approach but is slightly better at the higher flows. Comparisons were also made, where possible, with data collected for other studies. This was generally for only a limited period or limited range of sites and constituents. Nevertheless, it provided an independent check on methodology. In all cases, the fits to independent data were almost as good as to the main data set used for derivation of the relationships indicating that the relationships are reliable.

Figure 1.1(a) shows the final predicted and observed loads for the Mitchell River. Figure 1.1(b) is an expansion of the lower flow showing that high quality fits are maintained for these lower loads. Figure 1.2(a), (b) and Figure 1.3(a), (b) show the same information for the Thomson River at Bundalaguah and Latrobe River at Kilmany South respectively. These figures illustrate that the final regression models are a sound representation of loads across the range of flows.

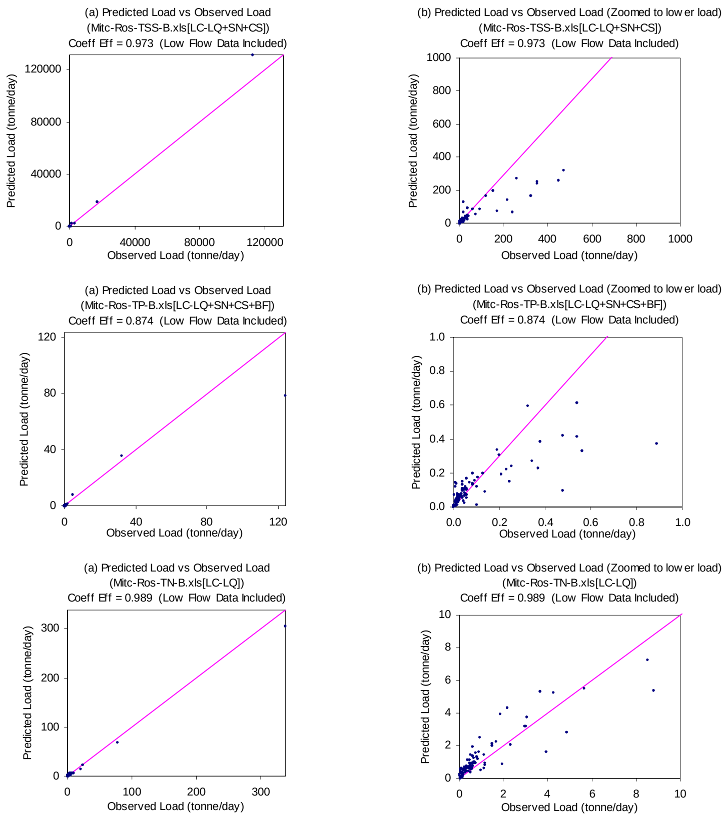

Figure 1.1: Final load efficiency plots for Mitchell at Rosehill (Method B: with flow stratification at Q=630ML/day)

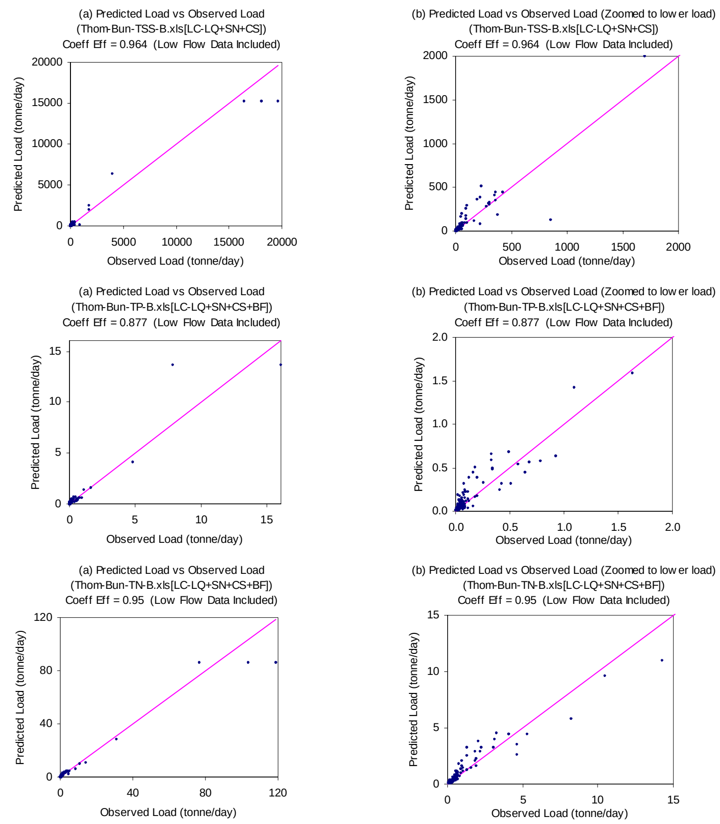

Figure 1.2: Final load efficiency plots for Thomson at Bundalaguah (Method B: with flow stratification at Q=1000ML/day)

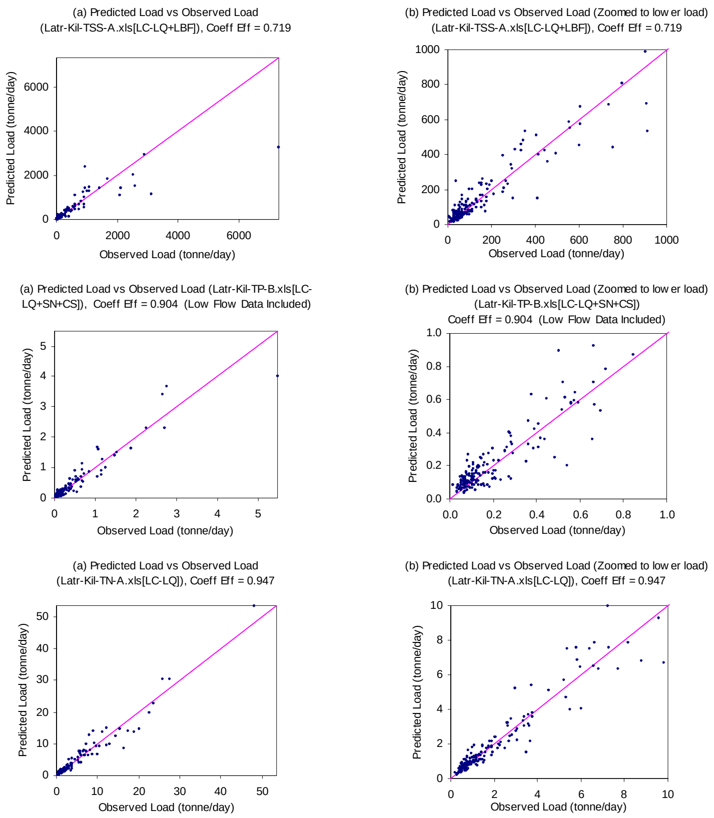

Figure 1.3: Final load efficiency plots for Latrobe at Kilmany South (Method A: without flow stratification for TSS and TN) (Method B: with flow stratification at Q=1000ML/day for TP)

For each of the rivers, there is an area downstream of the gauging station that provides some load to the Lakes but is not monitored. This load was estimated as described below and added to the loads into Lake Wellington, Lake Victoria and Lake King. The method used was to determine the areas draining into each of the river systems or directly to the lakes, downstream of the gauging station at which the load relationships were computed. The mix of land uses in these areas is similar to those in the Latrobe River catchment, excluding the irrigation areas. Long-term load estimates from the Latrobe River were converted into areal loading factors. These were compared to published values and found to be almost the same as "typical" long-term loads summarised in the literature. These areal factors were used to compute long-term annual loads from the ungauged areas. In order to allocate loads from the ungauged areas to particular years, the long-term averages were multiplied by the ratio of annual river loads computed as above for the particular year divided by the long-term average annual river loads for the full period of the load simulation (1975 to 1999). Daily loads were computed using a similar approach whereby the annual load was disaggregated on the basis of the proportion of annual river load occurring on a particular day. Loads from these ungauged areas make up approximately 20% of the total loads into the Gippsland Lakes and so are quite important from a management perspective.

The approach described above does not include contributions from the Macalister Irrigation District (MID) that flow into the rivers downstream of the gauging stations. Sinclair Knight Merz (SKM) was contracted as part of another study to develop daily modelling of TP and TN loads in all of the MID drains. They have provided their data to us for inclusion in the final load estimates for the Lakes. Daily loads (1978 to 1999) from all drains entering the streams flowing to Lake Wellington downstream of the gauging stations were added to the load estimates computed for the rivers to give a final set of loads for use in modelling. The one potential error in this approach is that the regression relationships for each river were derived from data between the mid 1970s and early 1990s. If there has been a significant change in TP and TN concentrations from the MID since that period, there may be some under/overestimation using the approach we describe because the drains entering upstream of the gauging stations may now carry different loads compared to during the period when the regression relationships were derived. This was explored by assessing whether there was any detectable change in the SKM estimates of average contaminant concentrations or load response between the different periods. No difference was detected.

Final load estimates were provided for the modeling on a daily basis for the period of interest (initially 1997 to 1999 and then extended to 1995-1999) but are available for the whole period from 1975 to 1999.

Table 1.1 summarises the average long-term annual loads results for the rivers entering the Gippsland Lakes and includes the SKM modelling estimates of loads entering the river systems downstream of the gauging stations. Independent estimates of annual loads in the Latrobe River were computed for the Rosedale gauging site by a number of authors (reported in Grayson, 1994). This site is upstream of the MID drains so a check can be provided by comparing the sum of estimates at Rosedale and SKM total estimates for drains into the Latrobe River with the estimates for Kilmany South (computed in this study). In this study, average annual loads at Kilmany South for TSS, TN and TP are 90,000 T/yr, 1,200 T/yr, and 120 T/yr respectively, while estimates from other studies are 60,000 to 140,000 T/yr (average = 100,000 T/yr), 1,000 to 1,500 T/yr and 100 to 160 T/yr respectively. This comparison indicates that the approach used here provides equivalent long-term estimates to those made by other authors.

The long-term average annual loads from the MID computed using the SKM approach are approximately 55-60 T/yr for TP and 140 T/yr for TN. To put these in perspective, the average annual loads from the rivers into Lake Wellington, excluding the MID are approximately 165 T/yr for TP and 1800 T/yr for TN. Therefore the MID makes up 25-30% of TP and less than 10% of TN into Lake Wellington on a long-term basis.

The SKM work did not include any estimates of TSS loads due to the lack of this type of data for the irrigation drains. We assessed several options for estimating TSS loads in the drains. Each was highly uncertain but generated loads that were always less than 10% (generally less than 5%) of the Latrobe River loads (i.e. only a few percent of total loads). TSS affects ecological response particularly through its effect on light attenuation, however this is an areas where the present ecological model is relatively simplistic and the error introduced by ignoring TSS loads from the MID drains downstream of the gauging stations was considered to be negligible.

Table 1.2 and Table 1.3 provide the final load estimates for the four-year period (July 1995 to June 1999) finally used in the ecological modelling, and the initial two year period from July 1997 to June 1999 respectively, including the MID and ungauged areas. It should be noted that for the two year period from July 1997 to June 1999 (initially used in the ecological modelling) three major storms accounted for approximately 71%, 53% and 53% of total TSS, TP and TN loads respectively and in general, flows during this period were lower than average, despite the flood of 1998. In addition, the rivers entering Lake King carried larger loads relative to those entering Lake Wellington (e.g. approximately equal loads), compared to the longer term averages (when loads into Lake King are approximately a third of those entering Lake Wellington). The modelling period was extended to include 1995-1997 in order to capture more typical flow periods, and some larger events entering from the western rivers.

Based on comparisons between measured and simulated loads, an assessment of the data quality, statistical soundness of the regression relationships, and discussions with SKM regarding their modelling of the MID, we can make a qualitative judgment about the maximum and likely errors in loads. For non-extreme flow conditions, we expect the error in load estimates to be of the order of +/- 20% and unbiased over time periods of months to years. This may possibly increase to as high as –40% +100% for individual events of very high magnitude (due to increasing uncertainty in flow estimates as well as concentration), but again the results should be unbiased in the longer term.

Table 1.1: Summary of long-term estimated annual loads into the Gippsland Lakes

River/ Catchment	CSIRO Eco Model Box Number*	Estimated Loads from Gauged Catchment (including MID Drains entering u/s of Gauge Site) (Tonnes/yr)			Estimated Loads from Ungauged Catchment (Tonnes/yr)			Estimated Loads from MID d/s of Gauged Catchment (Tonnes/yr)			Total Estimated Loads (Tonnes/yr)		
		TSS	TP	TN	TSS	TP	TN	TSS	TP	TN	TSS	TP	TN
Tambo	**No.7**	7,640	12	176	2,900	3	42	-	-	-	10,540	15	218
Nicholson	**No.8**	5,360	5	40	1,310	2	19	-	-	-	6,670	7	59
Mitchell	**No.8**	21,920	41	366	4,880	6	70	-	-	-	26,800	47	436
Mitchell-Avon	**No.2**	-	-	-	1,260	2	18	-	-	-	1,260	2	18
Lake King	**-**	**34,920**	**58**	**582**	**10,350**	**13**	**149**	-	-	-	**45,270**	**71**	**731**
Mitchell-Avon	**No.3**	-	-	-	1,350	2	20	-	-	-	1,350	2	20
Mitchell-Avon	**No.4**	-	-	-	1,350	2	20	-	-	-	1,350	2	20
Mitchell-Avon	**No.5**	-	-	-	5,790	7	84	-	-	-	5,790	7	84
Lake Victoria	**-**	-	-	-	**8,490**	**11**	**124**	-	-	-	**8,490**	**11**	**124**
Avon	**No.6**	25,740	19	166	10,230	12	148	-	1	7	35,970	32	321
Thomson	**No.6**	36,230	50	331	-	-	-	-	6	15	36,230	56	346
Latrobe	**No.6**	89,420	119	1,197	4,250	5	62	-	8	18	93,670	132	1,277
Lake Wellington	**-**	**151,390**	**188**	**1,694**	**14,480**	**17**	**210**	-	**15**	**40**	**165,870**	**220**	**1,944**
TOTAL	**-**	**186,310**	**246**	**2,276**	**33,320**	**41**	**483**	**-**	**15**	**40**	**219,630**	**302**	**2,799**

Table 1.2: Summary of estimated annual loads for the final four-year modelling period from July 1995 to June 1999

River/ Catchment	CSIRO Eco Model Box Number*	Estimated Loads from Gauged Catchment (including MID Drains entering u/s of Gauge Site) (Tonnes/yr)			Estimated Loads from Ungauged Catchment (Tonnes/yr)			Estimated Loads from MID d/s of Gauged Catchment (Tonnes/yr)			Total Estimated Loads (Tonnes/yr)		
		TSS	TP	TN	TSS	TP	TN	TSS	TP	TN	TSS	TP	TN
Tambo	**No.7**	6,930	9	141	2,630	3	34	-	-	-	9,560	12	175
Nicholson	**No.8**	3,380	4	27	830	1	13	-	-	-	4,210	5	40
Mitchell	**No.8**	18,590	35	350	4,140	5	68	-	-	-	22,730	40	418
Mitchell-Avon	**No.2**	-	-	-	1,060	1	17	-	-	-	1,060	1	17
Lake King	**-**	**28,900**	**48**	**518**	**8,660**	**10**	**132**	**-**	**-**	**-**	**37,560**	**58**	**650**
Mitchell-Avon	**No.3**	-	-	-	1,150	1	19	-	-	-	1,150	1	19
Mitchell-Avon	**No.4**	-	-	-	1,150	1	19	-	-	-	1,150	1	19
Mitchell-Avon	**No.5**	-	-	-	4,910	6	80	-	-	-	4,910	6	80
Lake Victoria	**-**	**-**	**-**	**-**	**7,210**	**8**	**118**	**-**	**-**	**-**	**7,210**	**8**	**118**
Avon	**No.6**	12,240	9	94	4,870	6	84	-	1	7	17,110	16	185
Thomson	**No.6**	24,520	40	270	-	-	-	-	5	13	24,520	45	283
Latrobe	**No.6**	82,130	112	1,084	3,900	5	56	-	8	18	86,030	125	1,158
Lake Wellington	**-**	**118,890**	**161**	**1,448**	**8,770**	**11**	**140**	**-**	**14**	**38**	**127,660**	**186**	**1,626**
TOTAL	**-**	**147,790**	**209**	**1,966**	**24,640**	**29**	**390**	**-**	**14**	**38**	**172,430**	**252**	**2,394**

Table 1.3: Summary of estimated annual loads computed for the initial two-year modelling period from July 1997 to June 1999

River/ Catchment	CSIRO Eco Model Box Number*	Estimated Loads from Gauged Catchment (including MID Drains entering u/s of Gauge Site) (Tonnes/yr)			Estimated Loads from Ungauged Catchment (Tonnes/yr)			Estimated Loads from MID d/s of Gauged Catchment (Tonnes/yr)			Total Estimated Loads (Tonnes/yr)		
		TSS	TP	TN	TSS	TP	TN	TSS	TP	TN	TSS	TP	TN
Tambo	**No.7**	12,200	15	211	4,620	4	50	-	-	-	16,820	19	261
Nicholson	**No.8**	5,920	6	41	1,450	2	19	-	-	-	7,370	8	60
Mitchell	**No.8**	27,600	42	387	6,150	6	75	-	-	-	33,750	48	462
Mitchell-Avon	**No.2**	-	-	-	1,580	2	19	-	-	-	1,580	2	19
Lake King	-	**45,720**	**63**	**639**	**13,800**	**14**	**163**	-	-	-	**59,520**	**77**	**802**
Mitchell-Avon	**No.3**	-	-	-	1,700	2	21	-	-	-	1,700	2	21
Mitchell-Avon	**No.4**	-	-	-	1,700	2	21	-	-	-	1,700	2	21
Mitchell-Avon	**No.5**	-	-	-	7,290	7	89	-	-	-	7,290	7	89
Lake Victoria	-	-	-	-	**10,690**	**11**	**131**	-	-	-	**10,690**	**11**	**131**
Avon	**No.6**	19,280	11	108	7,660	7	97	-	1	6	26,940	19	211
Thomson	**No.6**	14,590	23	157	-	-	-	-	5	11	14,590	28	168
Latrobe	**No.6**	29,480	47	388	1,400	2	20	-	7	16	30,880	56	424
Lake Wellington	-	**63,350**	**81**	**653**	**9,060**	**9**	**117**	-	**13**	**33**	**72,410**	**103**	**803**
TOTAL	**-**	**109,070**	**144**	**1,292**	**33,550**	**34**	**411**	**-**	**13**	**33**	**142,620**	**191**	**1,736**

2. INTRODUCTION

2.1 BACKGROUND

This report summarises the estimation of total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN) loads for all inputs into the Gippsland Lakes. The loads are required as input to drive the CSIRO ecological model and are produced at a daily level for the period from 1975-1999, and used in ecological modelling for the period July 1995-June 1999.

The Gippsland Lakes catchments and the locations of gauging/sampling stations are shown in Figure 2.1.

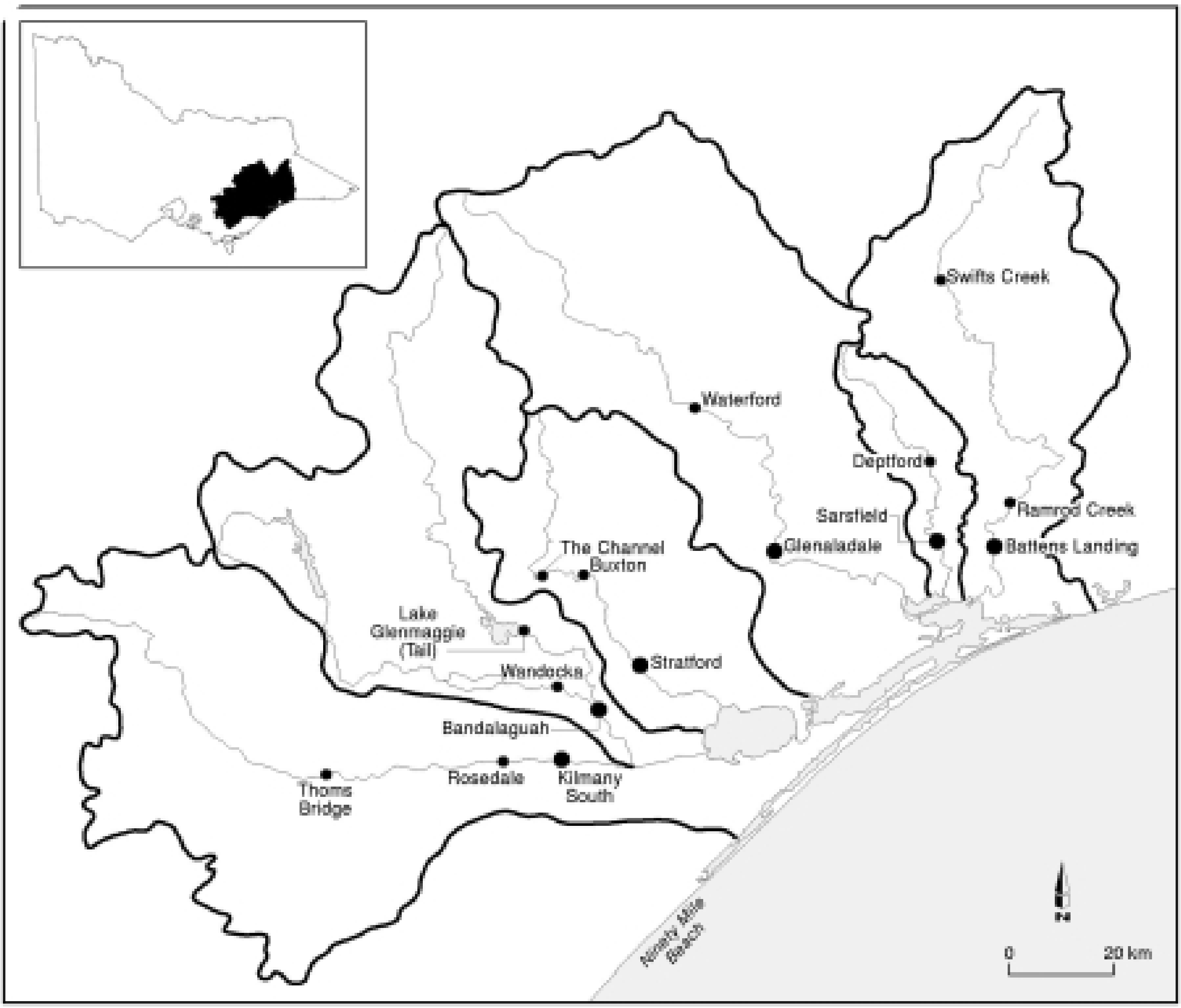

Figure 2.1: The Gippsland Lakes Catchments and the Locations of Gauging/Sampling Stations

2.2 SCOPE OF WORK

The load estimates are produced for each of the main rivers: Tambo, Nicholson, Mitchell, Avon, Thomson (downstream of the Macalister/Thomson confluence) and Latrobe Rivers, as well as the ungauged areas draining into the rivers and directly to the Lakes

In addition, load estimates are included for the Macalister Irrigation District that was computed as part of a separate study by Sinclair Knight Merz (SKM, 2000).

2.3 METHODS FOR ESTIMATING FLUVIAL CONSTITUENT LOADS

There are two basic ways to estimate river loads. The first is to use the recorded flow data (continuously measured on all streams in this case) and measurements or estimates of the concentration of contaminants, and produce loads. The second is to build a rainfall-runoff and contaminant simulation model of the whole catchment to simulate both flow and load. The errors associated with the second approach are likely to be much greater than the former and there is neither the time nor the appropriate data to enable the construction of such a model accurately. Consequently, we follow the first approach.

This approach requires estimates of discharge and of contaminant concentration. The former is measured in all incoming streams at locations close enough to the Lakes to capture the great majority of the flow. Contaminant concentration, however, is not measured continuously. For most of the rivers, water quality parameters are measured during the period of interest on a monthly basis at best (via the Victorian Water Quality Monitoring Network, VWQMN and other more local programs). It is possible to use these data directly and assume that the instantaneous values represent the average for the intervening period, so that a sum of the products of mean flow for the period and the measured concentration, represents the load. This method would produce highly uncertain results because the sampling interval is too long compared to the variability of the actual contaminant concentration. Also, several of the rivers do not have any data at the most downstream station, or for particular contaminants.

There are some periods over the past 25 years when more frequent sampling has been undertaken by the Victorian Environment Protection Authority (EPA) and direct computation of the loads using the method of integration should be reasonably accurate. The EPA has carried out load computation using the flow weighted concentration technique for these periods (1977/8, 1978/9, 1980/81, 1984/85, 1988/89, 1989/90). These do not match the ecological modelling period.

An alternative method, and the one followed hereafter, is to seek a correlation between discharge and contaminant concentration based on historic data, and use that, along with measured discharge, to estimate loads. The use of discharge as a surrogate for contaminant concentration is not ideal since there are many factors that create scatter and/or bias in the relationships (see e.g. Walling and Webb, 1981; Walling and Webb, 1988). Nevertheless, in this instance we have no option, and the availability of the EPA data will provide some test of whether the method produces realistic results.

In this work, we derive correlations between discharge and concentration that also take account of seasonality, baseflow and antecedent flow conditions. These additional factors (compared to just flow in the standard regression method) were introduced to obtain better properties of the residuals (i.e. reasonably homoscedastic, aperiodic, unbiased, un-correlated and normally distributed). For some streams, we also stratified the data into high and low flow periods because it was clear that different flow/concentration relationships were appropriate for each. The following sections describe the data available and the process of deriving sound relationships for load computation.

3. DATA SETS AVAILABLE

3.1 WATER QUALITY DATA

3.1.1 Water Quality Data Available

There are four main data sets available for the derivation of relationships between river discharge and contaminant concentration: the VWQMN, WaterWatch, the Catchment Management Authority (CMA) and Water Authorities, and the EPA. The WaterWatch data are generally from sites in the upper parts of the catchments, are commonly not associated with discharge stations, and are not consistently measured across all the rivers entering the Lakes. These data can therefore not be used in this analysis. The data from the CMAs and Water Authorities is generally weekly or better and are useful for particular sites, but are not available consistently across the catchments and do not necessarily cover all the parameters of interest. The VWQMN data is generally collected monthly and is available for some sites and some constituents. Discharge was separately obtained to match these data for use as a testing data set.

The data used for developing relationships in this work were collected by the EPA for the specific purpose of estimating loads into the Lakes for particular periods of interest (1977/8, 1978/9, 1980/81, 1984/85, 1988/89, 1989/90).

The EPA data during these periods comprise weekly to monthly fixed period sampling with additional measurement during storms. On average each station has about 80 to 200 observations. Table 3.1 below summarises the water quality data available for each river/station. These data provide a consistent data set for the derivation of discharge/concentration relationships.

The critical issues for minimising uncertainty in this method of load estimation are:

- the strength of the relationship between contaminant concentration and discharge (and additional variables), and
- whether the data available are representative of the conditions for which the predictions will be made.

In this case we are using data from the period 1976 to 1990 to estimate loads in the 1995 to 1999 period. Any major changes in catchment land use over that period may cause undefinable errors in the results. It is also possible that the range of flows over which the data are available do not match flows in the simulation period (i.e. some extrapolation becomes necessary). These potential problems will be discussed in more detail later.

The data were also checked to see if the range of flows where concentrations were measured covered the range of storms experienced in the 1995 to 1999 period. This was the case for all the rivers except the Nicholson, which was subject to a very large flood in June 1998 that was much larger than the maximum flow during sampling in the EPA data set.

Table 3.1: EPA water quality sampling stations used for derivation of predictive equations

River	Station Number	Station Name	Sampling Period	Ave. Sampling Frequency	Number of Observ-ations	Max. Mean Daily Discharge during Sampling(ML/d)	Appr. Dist. from River Mouth(km)
Tambo	**230100**	**Battens Landings***	**Oct 76 – Jun 90**	**Weekly – Monthly**	**187 (TSS) 185 (TP) 187 (TN)**	**65,883**	**20**
Nicholson	**230200**	**Sarsfield***	**Oct 76 – Jun 85**	**Semi-monthly – Monthly**	**79 (TSS) 78 (TP) 78 (TN)**	**5,529**	**15**
Mitchell	**240xxx**	**Rosehill***	**Jul 88 – Jun 90**	**Weekly**	**110 (TSS) 110 (TP) 111 (TN)**	**112,729**	**20**
	240300	Iguana Creek/ Glenaladale	Oct 76 – Jun 85	Semi-monthly – Monthly	79 (TSS) 80 (TP) 77 (TN)	-	40
Avon	**250xxx**	**Stratford***	**Jul 88 – Jun 90**	**Weekly**	**111 (TSS) 111 (TP) 111 (TN)**	**166,914**	**20**
	250400	Clydebank/ Chinns Bridge	Oct 76 – Jun 85	Semi-monthly – Monthly	76 (TSS) 78 (TP) 75 (TN)	-	10
Wellington Drain	250500	Cobains	Jan 77 – Jun 85	Semi-monthly – Monthly	49 (TSS) 51 (TP) 50 (TN)	-	-
Macalister	250800	Riverslea	Oct 76 – Jun 85	Semi-monthly – Monthly	78 (TSS) 80 (TP) 78 (TN)	-	60
Thomson	250900	Gibson Knox Bridge	Mar 77 – Jun 90	Weekly – Monthly	179 (TSS) 177 (TP) 178 (TN)	-	40
Thomson/ Macalister	**250700**	**Bundalaguah ***	**Nov 78 – Jun 90**	**Weekly – Monthly**	**135 (TSS) 133 (TP) 133 (TN)**	**39,209**	**30**
Latrobe	**260600**	**Kilmany South***	**Oct 76 – Jun 90**	**Weekly – Monthly**	**190 (TSS) 188 (TP) 189 (TN)**	**22,865**	**30**

* (and printed in **bold**) denotes water quality sampling stations chosen for estimating the constituent input into the Gippsland Lakes

3.1.2 Choice of Water Quality Sampling Station

If data from more than one water quality station along the same river was available, the station located nearest to the river mouth was chosen for the following reasons:

- there is no significant difference in the frequency of sampling and the quality of the data between/amongst the respective stations;
- the proximity of the station to the discharging point is important since the load estimates derived would be used directly as the input into the Lakes, provided that the station is located "reasonably close" to the discharging point;
- transfer/infilling of discharge data by correlation with an upstream station is possible but not so for the water quality data.

The only exception is for the Avon River, where the upstream sampling station at Stratford has been preferred to Clydebank (Chinns Bridge). This is due to the fact that Clydebank is frequently subjected to backwater effects from Lake Wellington which makes a stage-discharge relationship difficult to establish and hence no reliable streamflow data are available.

3.2 STREAMFLOW DATA

3.2.1 Streamflow Data Available

Table 3.2 below summarises the streamflow data available for each river/station. It is notable that not all the stations of interest have the necessary (or sufficiently complete and continuous) streamflow data for the purpose of regression analyses and load estimates. Simple flow correlation was carried out with nearby stations along the same river, and subsequently these missing periods were infilled or data was transferred from other sites. In general, the flow correlations yield R^2 of more than 0.8.

Table 3.2: Streamflow gauging stations

River	Water Quality Sampling Station Name	Streamflow Gauging Station Number (Contributing Catchment Area)	Streamflow Gauging Station Name	Gauging Period	Treatment of Flow Data
Tambo	Battens Landings	223209 (2,781km^2)	Battens Landings	Jan 77 – Jan 79	Transfer (Tamb@Bat,Coeff=1.00)
		223205 (2,681km2)	**Downstream of Ramrod Ck.***	**Jan 75 – Sep 99**	
Nicholson	Sarsfield	223210 (471km^2)	Sarsfield	Sep 77 – Nov 82	Transfer (Nich@Dep,Coeff=1.68) then infill (Tamb@Bat,Coeff=0.31)
		223204 (287km^2)	**Deptford***	**Dec 72 – Oct 99**	
Mitchell	Rosehill	224217 (4,413km^2)	Rosehill	Oct 76 – Jan 79	Transfer (Mitc@Gle,Coeff=1.03) then infill (Tamb@Bat, Coeff =1.36)
		224203 (3,903km^2)	**Glenaladale***	**Jan 75 – Sep 99**	
Avon	Stratford	**225201 (1,485km^2)**	**Stratford***	**Nov 76 – Oct 99**	-
Thomson/ Macalister	Bundalaguah	**225232 (3,538km2)**	**Thomson @Bundalaguah***	**Nov 76 – Oct 99[1]**	Infill (Thom@Wan+Maca@LGT, Coeff =1.05)
		225212 (1,417km^2)	Thomson @Wandocka	Mar 77 – Nov 99	
		225204 (1,891km^2)	Macalister @Lake Glenmaggie (Tail)	Jan 75 – Jun 97	
Latrobe	Kilmany South	226227 (4,464km^2)	Kilmany South	Dec 76 – Nov 99[2]	Transfer (Latr@RosM+Latr@RosA, Coeff =1.03) Then infill (Thom@Bun. Coeff =1.18)
		226228 (4,144km2)	**Rosedale (Mainstream)***	**Apr 75 – Nov 99**	
		226224 (4,144km2)	**Rosedale (Anabranch)***	**Feb 77 – Nov 99**	

* (and printed in **bold**) denotes streamflow gauging stations chosen as main source of discharge data subject to appropriate treatment

[1] denotes 7 years of continuous discharge data-gap exists between Jul 89 and Jun 96

[2] denotes 17 years of continuous discharge data-gap exists between Jan 79 and Jun 96

The decision of whether to transfer the correlated streamflow data entirely from the nearby station to the station of interest, or merely to infill the streamflow data gaps found at the station of interest using the correlated streamflow data from the nearby station, depended on the following criteria:

- If the streamflow data at the station of interest covers at least ⅔ of the total water quality sampling occasions, and is complete and continuous for the ecological modeling period, then the streamflow data at the station was retained. Correlated streamflow from the nearby station was then used to infill the remaining data gaps;
- If the streamflow data at the station of interest covers at least ⅔ of the total water quality sampling occasions, but is not available or incomplete for the ecological modeling period, then the entire streamflow data at the station of interest was replaced by the correlated streamflow data from the nearby station, provided always that the nearby station has a significantly better data coverage than the station of interest;
- If the streamflow data at the station of interest covered less than ½ of the total water quality sampling occasions, then irrespective of whether the streamflow data is complete and continuous for the ecological modeling period or not, the entire streamflow data at the station of interest was replaced by the correlated streamflow data from the nearby station, provided always that the nearby station has a significantly better data coverage than the station of interest.

While the emphasis of the work is to obtain an accurate and continuous constituent load estimates as input for the ecological modeling period, attempts were made to infill some intermittent minor data gaps of the order of months outside that modelling period. Such infill was considered necessary to facilitate computation of the long-term average flows and hence the long-term average estimated loads.

3.2.2 Baseflow

Baseflow may be an important explanatory/predictive variable in estimating the constituent concentration. This is because the constituent concentrations (and loads) carried by a river, under the same mean daily discharge, may not be the same under different baseflow conditions.

Baseflow was derived using a digital filter based method (Boughton, 1993; Chapman and Maxwell, 1996) as documented in the Hydrological Recipes (Grayson et al., 1996). The equation is:

$$q_{b(i)} = \frac{k}{1+C} q_{b(i-1)} + \frac{C}{1+C} q_{(i)}$$

subject to $q_{b(i)} \le q_{(i)}$

where k is a filter parameter given by the recession constant of the hydrograph, which is taken as 0.95 and C is a calibration parameter that enables the shape of the separation to be altered, which is taken to be 0.15 in the absence of calibration data.

3.2.3 Antecedent Discharge

Antecedent discharge was considered as a rational explanatory/predictive variable. This is because the constituent concentrations (and loads) in the rivers are proportional to the storage/availability of the constituents in the catchment, and higher antecedent discharge would result in exhaustion of supply, thus resulting in lower constituent concentration in the rivers.

The average of the previous 30 days mean daily discharge was adopted as the representative antecedent discharge for the present work. There is no reason why the average of the previous 15 days or 60 days discharge should not be used, as long as the choice of such duration satisfies the rationale that the accumulation of the constituents within the catchment and the subsequent storm wash off are catchment processes having time scale in the order of several weeks to a few months.

4. THE REGRESSION APPROACH FOR LOAD ESTIMATION

4.1 SIMPLE LINEAR REGRESSION

In the regression method, the relationship found between the measured concentration and mean daily flow (and other explanatory/predictive variables) was used to estimate mean daily concentration of the constituent. The regression was initially carried out as a simple linear regression between concentration and flow. It was then further modified into a multiple linear regression to establish relationships with other explanatory/predictive variables, and at some sites, the flow data were stratified into high and low flows and separate regressions derived for each data set.

The regression analyses of total phosphorous (TP) for Mitchell River @ Rosehill is used to illustrate the details and procedure adopted for identification of the best regression model. The procedure is detailed step by step and can be skipped over by those readers familiar with regression modelling. Appendix A-1 contains the final regressions for all the sites and all constituents including the residual plots and the predicted versus observed concentrations plots, whereas Appendix A-2 contains the final plots of predicted versus observed loads.

4.1.1 Initial Linear Regression

The raw records from the EPA provide TP concentration in mg/L from Jul 88 to Jun 90 on a weekly basis. A total of 110 samplings/observations were available. The mean daily discharges corresponding to the sampling days were extracted and adopted in the analysis.

Initially, a simple linear regression was formed between the TP concentration and the mean daily flow with coefficients determined by ordinary least squares (OLS), yielding the following equation and model statistics:

$$C = 0.00000982Q - 0.00325$$

$$E = 0.87,\ R^2 = 0.87,\ \text{F-Stat} = 716,\ \text{t-Stat} = 26.8,\ n = 110$$

where C is the TP concentration in mg/L and Q is the mean daily flow in ML/day, E is the coefficient of efficiency as defined by Nash and Sutcliffe, 1970 in the real domain (see below), R^2 is the coefficient of determination in the model domain, F-Stat is the overall F-test statistic, t-Stat is the t-test statistic for the explanatory/predictive variables and n is the sample size.

Figure 4.1 plots the TP concentration against the mean daily flow of the C-Q model, indicating the relationship between the two appears slightly non-linear.

In this example, no outlier was detected in the plot. Should there be any outlier visually significant, further checks into the data would be carried out to ascertain the nature of the outlier. Outliers attributed to obvious measurement or recording error were eliminated, others were retained.

4.1.2 Statistical Tests and Overall Measures of Model Performance

The overall F-test is normally used to determine if the regression relationship is statistically significant, i.e. that the apparent relationship between y and x is not due to chance alone. A model would be statistically significant if the F-statistic is larger than a specific critical F-value, which varies depending on the degrees of freedom for the numerator (regression) and the degrees of freedom for the denominator (residual), and upon the level of significance (α).

In addition, the t-test is performed for each explanatory variable to determine if the coefficient for that variable is significantly different from zero. A variable is thus statistically significant if the t-statistic is larger than a specific critical t-value, which varies depending on the total degrees of freedom, which is (n – 1). A commonly acceptable level of significance (α) of 5% is adopted in this work.

In this example, with n = 110, the total degree of freedom is 109, and the degree of freedom for the regression and the residual are 1 and 108 respectively. The critical F-value and the absolute critical t-value are thus 3.9 and 2.0 respectively. With an F-statistic of 716 and a t-statistic of 26.8, the model and the coefficient of its explanatory/predictive variable are thus considered to be statistically significant.

As a guide, with n ranging from 80 to 200, and the degrees of freedom for the regression ranging from 1 to 5 in this work, the critical F-value would fall between a value of about 2.2 to 4.0 whereas the absolute critical t-value would remain at about 2.0 for α = 5%.

The coefficient of determination (R^2) is a measure of the percent of the variation in the response variable that is accounted for by the variation in the explanatory/predictive variables. However, there is no general rule for what is too low for an R^2 for a useful regression equation.

A regression model that accounts for a large amount of the variation in the response variable and has coefficients that are statistically significant is highly desirable. However, decisions about model adequacy cannot, and should not, be made on the basis of these criteria alone. A large R^2 or significant F-statistic does not guarantee that the data have been fitted well. As one common pitfall in regression analysis is to base decisions about model adequacy solely on the regression summary statistics – principally R^2 and the F-test or the t-test results (Helsel and Hirsch, 1992).

The coefficient of efficiency (E) is introduced as an additional measure of the model performance. It is defined as:

$$E = \frac{\sum_{i=1}^{n}(OBS_i - \overline{OBS})^2 - \sum_{i=1}^{n}(EST_i - OBS_i)^2}{\sum_{i=1}^{n}(OBS_i - \overline{OBS})^2}$$

Where OBS_i and EST_i are the observed and estimated concentration respectively, and $\overline{OBS}$ is the mean value of all the observed concentrations. The coefficient expresses the proportion of variance of the observed concentration that is explained by the model (Nash and Sutcliffe, 1970), providing a measure of closeness of the plot of the estimated concentrations (in actual unit of mg/L after bias correction due to re-transformation of data) vs. the observed concentrations (in actual unit of mg/L) to the 1:1 line. The application of E, which is a measure of the 1:1 line is considered to be a more sensible indicator of the model performance in predicting the observed concentrations, as compared to the R^2 which is a measure of the best-fit line. Moreover, E which is computed by first converting the data into the real domain with bias correction, rather than in the model domain itself, makes it a better measure over R^2. Consequently, the coefficient of efficiency (E) is used as a measure of model performance in this work, instead of the coefficient of determination (R^2).

4.1.3 Statistical Constraints

There are several formal requirements associated with linear regression. The necessity of satisfying them is determined by the purpose to which the regression is put. They are that:

- the model form is correct, i.e. y is linearly related to x
- samples used to fit the model are representative of the data of interest
- residuals are homoscedastic (i.e. the variance of the residuals is constant with respect to x, time or the predicted values)
- residuals are independent (i.e. there is no auto-correlation or serial correlation)
- residuals are stationary and unbiased
- residuals are normally distributed

The assumption of a normal distribution is required only when testing of hypotheses and estimating confidence or prediction intervals are involved.

4.1.4 Transformation of Variables

With a level of significant (α) of 5%, the F-statistic has shown that the C-Q model is statistically significant, and the t-statistic has indicated that the coefficient for the explanatory/predictive variable is significantly different from zero.

However, based on Figure 4.1, the non-linearity indicates that the model form is inappropriate. Whereas graphical inspection of the residual time series plot in Figure 4.2(a) reveals strong trend of seasonality, the residual vs. predicted plot in Figure 4.2(b) indicates non-linearity and heteroscedasticity, and the residual normal plot in Figure 4.2(c) suggests non-normality. The prediction efficiency plot is shown in Figure 4.2(d). Although it looks good, with an E value as high as 0.87, the model could not be accepted due to its violation of the basic regression assumptions.

Transformation of the variables was therefore necessary. Log transformation was chosen as the simplest means of correcting heteroscedasticity of the residuals. Regression analyses were then attempted for two transformed models: the C-LQ model and the LC-LQ model.

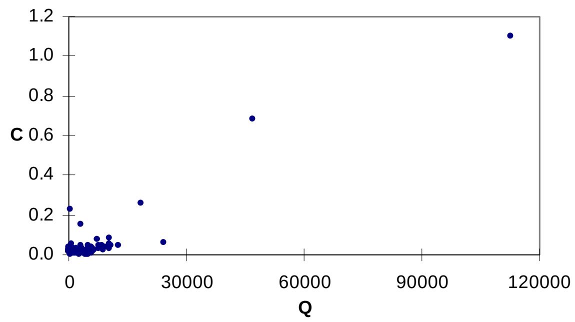

Figure 4.1: Concentration vs. discharge plot of the C-Q model (TP for Mitchell at Rosehill)

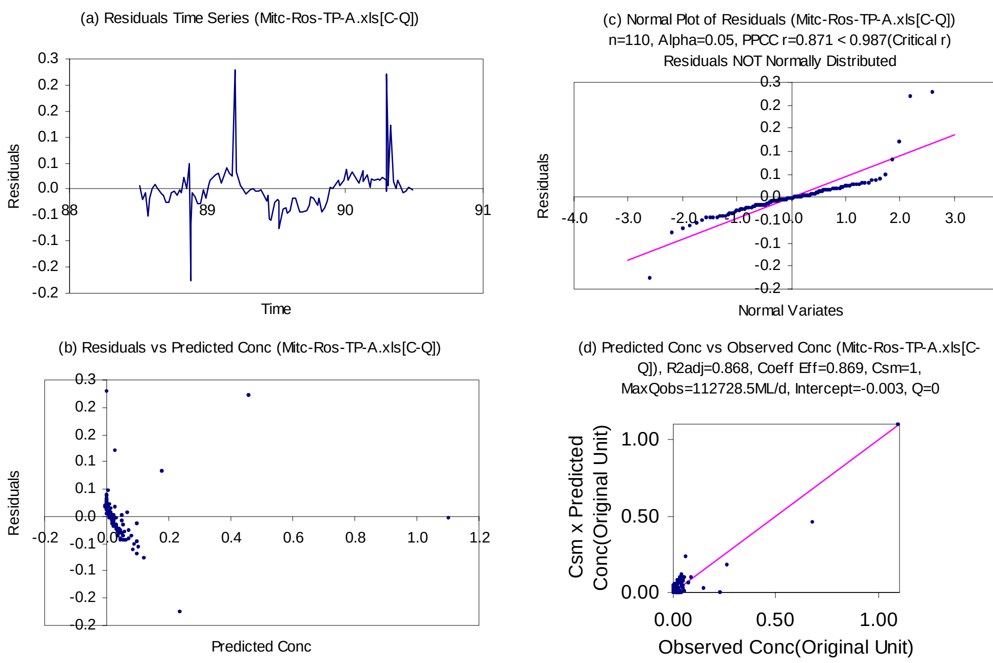

Figure 4.2: Residual and efficiency plots of the C-Q model (TP for Mitchell at Rosehill)

The C-LQ model yielded the following equation and model statistics:

$$C = 0.078 \log(Q) - 0.211$$

$$E = 0.15, \; R^2 = 0.14, \; \text{F-Stat} = 19, \; \text{t-Stat} = 4.3, \; n = 110$$

With a level of significance (α) of 5%, the F-statistic indicates that the C-LQ model is statistically significant, and the t-statistic indicates that the coefficient for the explanatory/predictive variable is significantly different from zero.

Figure 4.3 plots the TP concentration against the logarithm of the mean daily flow, indicating the relationship between the two appears non-linear.

Figure 4.4(a) and Figure 4.4(b) show plots of the residuals against time and the predicted concentration for the C-LQ model. The residual time series still reveals significant seasonality while the residual vs. predicted plot again indicates heteroscedasticity. The residual normal plot in Figure 4.4(c) suggests non-normality. The prediction efficiency plot in Figure 4.4(d) shows less than satisfactory prediction, with E value as low as 0.15. In any case, the model could not be accepted due to its violation of the basic regression assumptions.

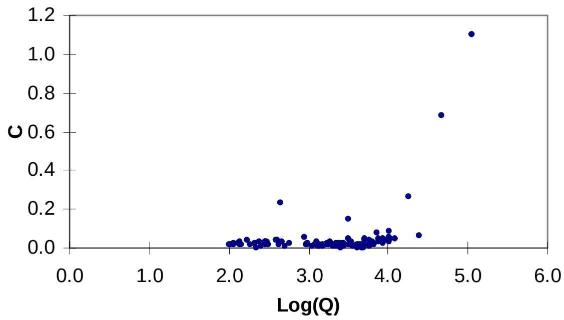

Figure 4.3: Concentration vs. discharge plot of the C-LQ model (TP for Mitchell at Rosehill)

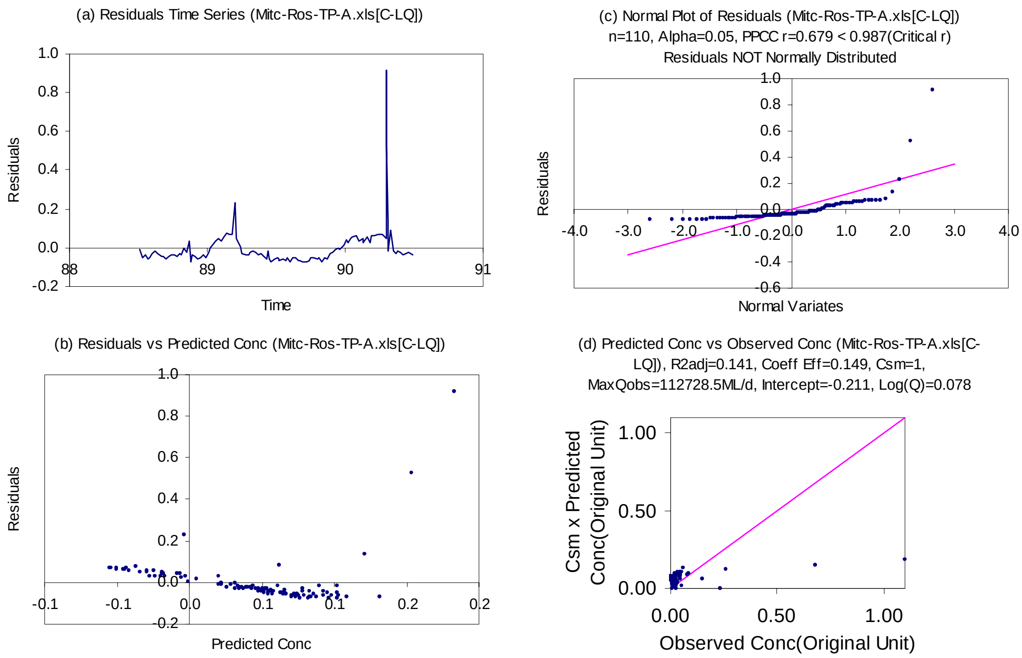

Figure 4.4: Residual and efficiency plots of the C-LQ model (TP for Mitchell at Rosehill)

Reforming the regression with log transformation for both the dependent variable C and the explanatory/predictive variable Q yielded the following equation and model statistics :

$$\log(C) = 0.192 \log(Q) - 2.320$$

$$E = 0.07,\ R^2 = 0.07,\ \text{F-Stat} = 10,\ \text{t-Stat} = 3.1,\ n = 110$$

With a level of significant (α) of 5%, the F-statistic indicates that the LC-LQ model is statistically significant, and the t-statistic indicates that the coefficient for the explanatory/predictive variable is significantly different from zero.

Figure 4.5 plots the logarithm of the TP concentration against the logarithm of the mean daily flow, showing some slight improvement in the linear relationship between the two.

When the corresponding residual plots for the LC-LQ model are visually investigated, the residual vs. predicted plot in Figure 4.6(b) has clearly improved, indicating homoscedasticity. However, the residual time series in Figure 4.6(a) is seen to still contain some seasonal trend, whereas the residual normal plot in Figure 4.6(c) suggests non-normality. The prediction efficiency plot is giver in Figure 4.6(d), showing a poor E value of 0.07.

The LC-LQ model has shown promising improvement in fulfilling the basic requirements of a regression model, as compared to the previous two models. However, the seasonality component needs to be removed.

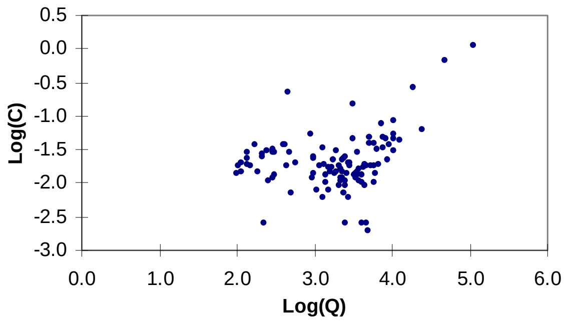

Figure 4.5: Concentration vs. discharge plot of the LC-LQ model (TP for Mitchell at Rosehill)

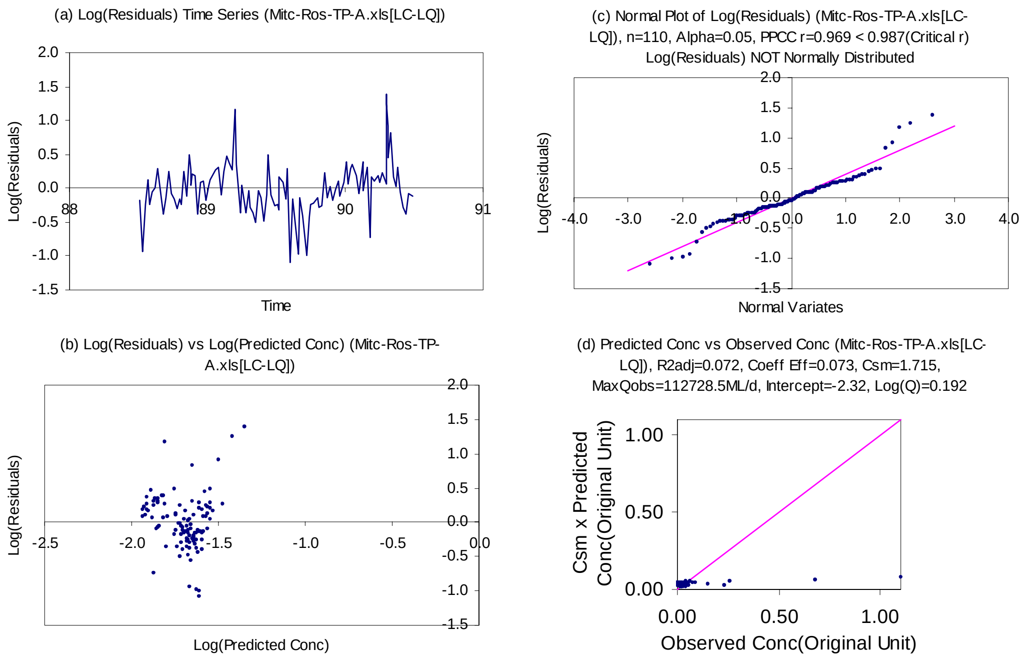

Figure 4.6: Residual and efficiency plots of the LC-LQ model (TP for Mitchell at Rosehill)

4.2 MULTIPLE LINEAR REGRESSION

The residual time series of the LC-LQ regression suggest seasonality or periodicity. This is confirmed by plotting the residuals against the month of the year as shown in Figure 4.7, which shown a tendency toward higher residuals in the summer and lower residuals in the winter.

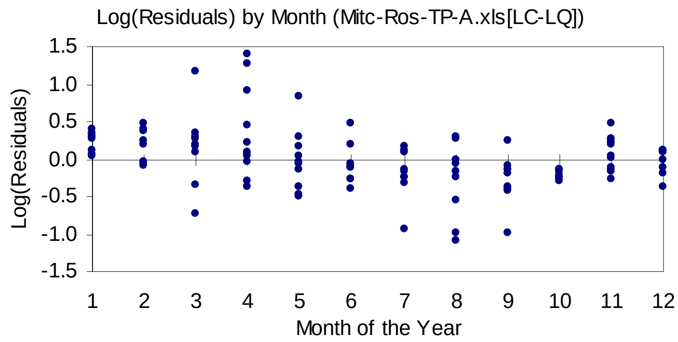

Figure 4.7: Residual against month of the year plot of the LC-LQ model (TP for Mitchell at Rosehill)

4.2.1 Seasonality

One of the methods in dealing with seasonality is to standardise each residual by the mean and standard deviation of residuals for each respective month, as suggested by Salas, 1993. However, it is envisaged that insufficient sampling points are available for calculating acceptable monthly means and standard deviations. The method also suffers a loss of information because the mean residual for a given month is usually similar to that for the neighbouring months.

An alternative method is therefore adopted by recasting the LC-LQ model into a multiple linear regression model by including sinusoidal trigonometric terms as additional explanatory/predictive variables (Helsel and Hirsch, 1992). Thus, the following multiple regression model was achieved:

$$\log(C) = 0.480 \log(Q) + 0.388 \sin(M) + 0.149 \cos(M) - 3.256$$

$$E = 0.50, \; R^2 = 0.37, \; \text{F-Stat} = 22, \; \text{t-Stats} = 7.4, 7.1 \; \& \; 3.2, \; n = 110$$

where $M = 2\pi\omega/12$ and ω is the month of the year.

With a level of significance (α) of 5%, the F-statistic has shown that the LC-LQ+SN+CS model is statistically significant, and the t-statistics indicate that the coefficients for all the explanatory/predictive variables are significantly different from zero.

Graphical inspection of the residual plots for the LC-LQ+SN+CS model (Figure 4.8(a), (b) and (c)) indicates that the seasonal component has now been accounted for by the multiple linear regression model. The residual vs. predicted plot has remained good, satisfying homoscedasticity, and the residual normal plot suggests normality. A look at the prediction efficiency plot, as shown in Figure 4.8(d), shows promising prediction capability, with an E value of 0.50. Note that there are some apparently high concentrations that are not well predicted. These are important if they occur at high flows, but if they occur during low flows, their effect on loads is minimal. Figure 4.9 shows the predicted versus observed loads for TP using the LC-LQ+SN+CS model and indicated good model performance.

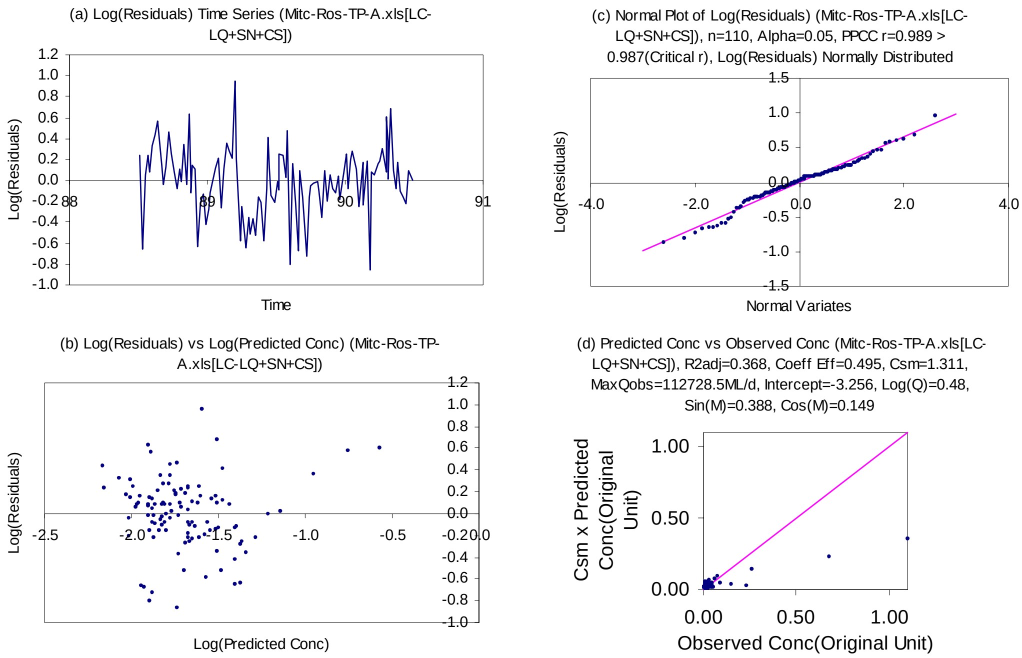

Figure 4.8: Residual and efficiency plots of the LC-LQ+SN+CS model (TP for Mitchell at Rosehill)

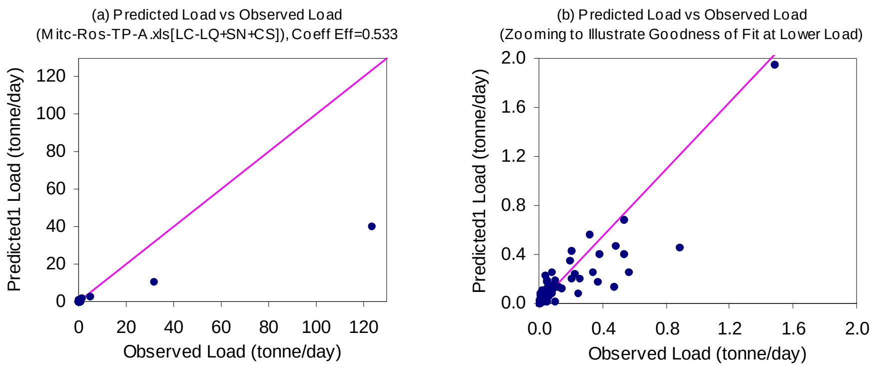

Figure 4.9: Predicted vs. observed loads of the LC-LQ+SN+CS model (TP for Mitchell at Rosehill)

The new model is now ready for acceptance because it has satisfied basic statistical constraints, i.e. it is has the correct model form; the residuals are homoscedastic and normally distributed based on graphical visualisation. Still there may be room for improvement by incorporating other explanatory variables. Those used in this analysis are described below.

4.2.2 Baseflow

In an attempt to explain as much as possible of the variation observed in the response variable, leaving as little variation as possible to the unexplained "noise", additional explanatory variables were included and tested, building up from the basic LC-LQ model. We considered explanatory/predictive variables that were expected to have some effects on the dependent variable (concentration), based on current scientific knowledge and experience. In this work, we consider the baseflow and the antecedent discharge to be relevant.

Baseflow was included as an additional explanatory/predictive variable. Two other baseflow related parameters were similarly considered - the logarithmic transformed baseflow and the baseflow index. The baseflow index is defined as:

$$BaseflowIndex_i = \frac{Baseflow_i}{MeanDailyDisch\arg e_i}$$

Because baseflow, log(baseflow) and baseflow index are attributed to the same hydrological process, and thus highly correlated, the three variables were not introduced into a model together, but individually, with and without the sinusoidal trigonometric terms.

4.2.3 Antecedent Discharge

Antecedent discharge was also computed as a possible explanatory variable. It was represented by the average of the previous 30 days mean daily discharge, and its associated parameters – the logarithmic transformed antecedent discharge and the Q_{30} ratio. The Q_{30} ratio is defined as:

$$Q_{30}ratio = \frac{MeanDailyDisch\arg e_i}{AntecedentDisch\arg e_i}$$

While the mean daily discharge, the baseflow and the antecedent discharge (and their associated parameters) may be highly correlated to each other (say $r > 0.8$), they are carrying pieces of information from different hydrological processes. Hence, there is no reason why they should not be included together in the same model.

4.3 MODEL RESULTS

With the inclusion of baseflow and antecedent discharge, an additional 30 multiple linear regression models were obtained, making up a total of 34 possible models.

All the additional 30 regression models were analysed in the same manner as the first 4 models, and statistical tests, measures of model performance and residual plots were carried out. The results of TP for Mitchell at Rosehill are tabulated in Table 4.1.

Table 4.1: Results of the regression analyses (TP for Mitchell at Rosehill)

Mitchell River @ Rosehill (Station No. 240xxx)
TP

Max Qobs = 112729 ML/d; No. of Obs (n) = 110; Alpha = 0.05

Model No.	Model	No.Para	R2adj	Coeff Eff	F-Value	Normality	Csm	Intercept	tStatInt	Coeff(2)	t-Stat(2)	Coeff(3)	t-Stat(3)	Coeff(4)	t-Stat(4)	Coeff(5)	t-Stat(5)	Coeff(6)	t-Stat(6)	Graphical Inspection of Residual Plots: Non-Uniformity	Hetero-Scedasticity	Seasonality	Non-Normality	Model Rejection/Selection: Stage 1	Stage 2	Stage 3
18	LC-LQ+SN+CS+LQ30	5	0.39	0.62	18	NO	1.29	-2.901	-10.5	0.634	6.3	0.345	5.9	0.146	3.2	-0.26	-2							Y	Y	1
4	LC-LQ+SN+CS	4	0.37	0.5	22	YES	1.31	-3.256	-15.2	0.48	7.4	0.388	7.1	0.149	3.2									Y	Y	2
19	LC-LQ+SN+CS+Q30R	5	0.42	0.16	21	NO	1.29	-2.798	-11.2	0.318	4	0.294	4.9	0.129	2.8	0.049	3.2							Y	Y	3
1	C-Q	2	0.07	0.07	716	NO	1	-0.003	-0.7	0	26.8									X	X	X	X	Y	X	
5	LC-LQ+BF	3	0.35	0.44	31	NO	1.36	-1.276	-5.6	-0.21	-2.7	0	6.9										X	Y	X	
9	LC-LQ+LQ30	3	0.18	0.24	13	NO	1.49	-1.781	-7.4	0.563	4.9	-0.531	-3.8									X		Y	X	
6	LC-LQ+LBF	3	0.12	0.19	9	NO	1.59	-2.082	-9.5	0.925	3.4	-0.839	-2.7									X	X	Y	X	
2	C-LQ	2	0.14	0.15	19	NO	1	-0.211	-3.5	0.078	4.3									X	X	X	X	Y	X	
3	LC-LQ	2	0.07	0.07	10	NO	1.72	-2.32	-11.2	0.192	3.1											X	X	Y	X	
24	LC-LQ+BF+Q30R	4	0.41	0.07	26	NO	1.32	-1.283	-5.8	-0.209	-2.8	0	4.7	0.051	3.2								X	Y	X	
29	LC-LQ+SN+CS+BF+LQ30	6	0.45	0.81	19	NO	1.27	-2.127	-6.4	0.254	1.8	0.239	3.9	0.121	2.7	0	3.7	-0.168	-1.3					X		
20	LC-LQ+SN+CS+BF+Q30	6	0.44	0.73	18	NO	1.28	-2.302	-7.2	0.136	1.2	0.258	4.2	0.12	2.7	0	4	0	-0.1					X		
14	LC-LQ+SN+CS+BF	5	0.45	0.72	23	NO	1.28	-2.293	-7.4	0.132	1.3	0.258	4.3	0.12	2.7	0	4.1							X		
23	LC-LQ+BF+LQ30	4	0.37	0.64	22	NO	1.33	-1.12	-4.7	0.019	0.1	0	5.9	-0.265	-2									X		
21	LC-LQ+SN+CS+LBF+LQ30	6	0.38	0.63	14	NO	1.29	-2.987	-10.5	0.787	2.8	0.345	5.9	0.148	3.2	-0.113	-0.3	-0.223	-1.3					X		
34	LC-LQ+SN+CS+BFI+LQ30	6	0.38	0.63	15	YES	1.29	-3.031	-9	0.708	4.8	0.342	5.9	0.142	3	0.16	0.7	-0.332	-2					X		
15	LC-LQ+SN+CS+LBF	5	0.38	0.6	17	YES	1.3	-3.09	-13	0.835	3.5	0.364	6.4	0.153	3.3	-0.422	-1.6							X		
31	LC-LQ+SN+CS+LBF+Q30	6	0.38	0.58	14	YES	1.3	-2.934	-10.1	0.898	3.6	0.361	6.4	0.161	3.4	-0.558	-1.8	0	0.9					X		
30	LC-LQ+SN+CS+BF+Q30R	6	0.47	0.57	20	NO	1.27	-2.141	-6.9	0.08	0.8	0.216	3.5	0.112	2.6	0	3.3	0.034	2.2					X		
16	LC-LQ+SN+CS+BFI	5	0.37	0.51	17	YES	1.31	-3.07	-9.1	0.454	6.1	0.381	6.8	0.152	3.2	-0.131	-0.7							X		
33	LC-LQ+SN+CS+BFI+Q30	6	0.36	0.5	13	YES	1.3	-2.967	-7.2	0.423	4.1	0.381	6.8	0.156	3.2	-0.17	-0.8	0	0.4					X		
17	LC-LQ+SN+CS+Q30	5	0.36	0.49	16	YES	1.31	-3.246	-13.8	0.475	5.8	0.389	7	0.15	3.1	0	0.1							X		
11	LC-LQ+BF+Q30	4	0.35	0.48	20	NO	1.36	-1.347	-5.3	-0.176	-1.9	0	6.9	0	-0.8									X		
28	LC-LQ+BFI+LQ30	4	0.18	0.26	9	NO	1.48	-2.059	-6.1	0.712	4.2	0.313	1.2	-0.668	-3.7									X		
12	LC-LQ+LBF+LQ30	4	0.17	0.25	8	NO	1.49	-1.786	-7.4	0.623	2.1	-0.092	-0.2	-0.501	-2.6									X		
25	LC-LQ+LBF+Q30	4	0.12	0.18	6	NO	1.59	-1.935	-6.7	0.977	3.4	-0.959	-2.8	0	0.8									X		
7	LC-LQ+BFI	3	0.08	0.1	6	NO	1.66	-1.9	-5.4	0.139	1.9	-0.316	-1.5											X		
27	LC-LQ+BFI+Q30	4	0.07	0.09	4	NO	1.66	-1.877	-4.2	0.132	1.2	-0.324	-1.4	0	0.1									X		
8	LC-LQ+Q30	3	0.07	0.08	5	NO	1.7	-2.388	-9.7	0.224	2.5	0	-0.5											X		
32	LC-LQ+SN+CS+LBF+Q30R	6	0.41	0.05	16	NO	1.29	-2.805	-11.1	0.233	0.7	0.294	4.8	0.127	2.8	0.089	0.3	0.052	2.8					X		
22	LC-LQ+SN+CS+BFI+Q30R	6	0.41	-0.04	16	NO	1.29	-2.905	-8.8	0.327	4	0.294	4.9	0.126	2.7	0.095	0.5	0.052	3.1					X		
10	LC-LQ+Q30R	3	0.29	-2.2	23	NO	1.42	-1.889	-9.6	0.023	0.4	0.086	5.8											X		
26	LC-LQ+LBF+Q30R	4	0.28	-3.12	15	NO	1.41	-1.916	-9.5	-0.19	-0.6	0.227	0.6	0.094	4.9									X		
13	LC-LQ+BFI+Q30R	4	0.28	-3.32	15	NO	1.42	-2.077	-6.6	0.04	0.6	0.161	0.8	0.091	5.6									X		

Legends :

X (pink)	Model Rejected in Stage 1 (Test Statistics : F-Value > 4 and |t-Stat| > 2)
X (orange)	Model Rejected in Stage 2 (Inspection of Residual Plots)
X (dark orange)	Model Rejected in Stage 3 (Coefficient of Efficiency < 0)
Y (yellow)	Criterion Relaxed for Specific Reason (e.g. either of the t-Stat for seasonality (Sin/Cos) is not significantly different from zero; or a particular criterion is not complied by all the remaining models)
Y (light green)	Model Accepted
1	Best Model Selected (Main Cirteria : Coefficient of Efficiency, Parsimony)
2	2nd Best Model Selected (If Coefficient of Efficiency of several models come close within 0.05 range, then the most parsimonous model is preferred; where seasonality (Sin & Cos) is considered as one pa

4.4 BIAS CORRECTION

Many studies since the mid 1980s have pointed out that the traditional "rating curve" retransformation method, by exponentiating the estimated logarithms of constituent concentrations, in order to obtain the estimated mean constituent concentrations would actually yield the median estimate of the concentrations. The method is thus highly biased and may lead to the severe underestimation of concentrations (and loads). The bias is introduced in the retransformation from the "log space" where regression estimates are derived, to the "real space" which is the realm of interest (Cohn et al., 1989).

Various methods have since been proposed to compensate for this bias, amongst others the parametric methods of quasi maximum likelihood estimator (QMLE) suggested by Ferguson, 1986 and the minimum variance unbiased estimator (MVUE) originally developed by Bradu and Mundlak, 1970 and strongly promoted by Cohn et al., 1992; Cohn et al., 1989, as well as the non-parametric smearing estimator (SME) of Duan, 1983.

Helsel and Hirsch, 1992 reviewed these bias correction methods. They concluded that the QMLE assumes normality in the residuals, and is only a good estimator when the sample size is large (n>30) and the true population standard deviation is small (σ<0.5), otherwise overcompensation for the bias results; whereas the MVUE is complex and its validity also depends on the normality of the residuals, which can never be assured in practice. Thus the SME was recommended as the most generally applicable approach due to its simplicity and robustness to the distribution of residuals. In the case of log transform it is:

$$\hat{C} = 10^{[a_0 + a_1 \log(Q) + ...]} \bullet \frac{\sum_{i=1}^{n} 10^{e_i}}{n}$$

The smearing estimator only requires the assumption that the residuals are independent and homoscedastic. It is based on each of the residuals being equally likely, and smears their magnitudes in the original units across the range of the explanatory variables. This is done by re-expressing the residuals from the regression in log domain into the original units, and computing their mean. This mean is the "bias correction factor" to be multiplied by the median estimate for all the explanatory variables. Even when the residuals in the log units are normal, the smearing estimator performs very nearly as well as the MVUE.

Hence the smearing estimator was adopted in this work as the bias corrector.

4.5 SELECTION OF BEST MODEL

4.5.1 Stratification by Flow

For each river site and each variable (TSS, TP, TN), the water quality data were assessed to determine whether there appeared to be marked differences in the relationships between discharge and concentration during low and high flows. There was some evidence of such differences for the following sites and variables as shown in Table 4.2 below:

Table 4.2: Sites and variables showing marked differences in the concentration-discharge relationship during low and high flows

River @ Station	Variables	Approximate Low/High Flow Cut-Off	
		Log Q	Q (ML/day)
Mitchell @ Rosehill	TSS, TP, TN	2.8	630
Avon @ Stratford	TSS, TP, TN	3.2	1,585
Thomson @ Bundalaguah	TSS, TP, TN	3.0	1,000
Latrobe @ Kilmany South	TP	3.0	1,000

In such cases, the data were separated into two groups based on discharge, and the regression procedure used previously on all of the data was applied to the higher flow data. The best regression model was determined using the same approach described above. For the low flow data, simple averages were computed. These "two part" relationships were then used to compute loads. Comparisons between the observed daily loads computed directly from the EPA data and the predicted daily loads based on the original and "two part" regression relationships show that the two-part approach produces better estimates, particularly at high flows.

4.5.2 Model Elimination/Selection Criteria

Four stages of model elimination/selection were conducted. Only models passing the earlier stage would be further considered in the next stage.

Stage 1 – Eliminate models that were statistically insignificant using the F-test and/or models containing any insignificant individual explanatory/predictive variables using the t-test.

Stage 2 – Eliminate models that violate the regression assumptions, based on graphical inspection of the residual plots. Models having residuals that are periodic, heteroscedastic and/or not normally distributed were rejected.

Stage 3 – Eliminate models which perform poorly based on the coefficient of efficiency, E. Models yielding negative E values were discarded.

Stage 4 – Select models based on the coefficient of efficiency, E. If more than one model yields an E value within the range of 0.05 of the highest E value, the principle of parsimony was applied. Models including the two sinusoidal trigonometric terms (Sin(M)+Cos(M)) are considered as having one additional explanatory/predictive variable.

4.5.3 Summary of the Selected Models

A summary of the selected best models for all the 18 analyses are listed in Table 4.3 below. The final adopted model for each case is printed in bold face.

Table 4.3: Selected best models

Site	Con-sti-tuent	Me-thod	Selected Model	Sam-ple Size, n	R^2	Coeff. of Eff. (Conc.) +	Coeff. of Eff. (Load) #	Cut-off Flow (ML/d)	Low Flow Ave.Conc./ High Flow Min.Conc. (mg/L)	High Flow Conc. Cap (mg/L)
Tambo @ Battens Landings	TSS	**A**	**LC-LQ***	**187**	**0.42**	**0.67**	**0.998**	-	-	-
		B	-	-	-	-	-	-	-	-
	TP	**A**	**LC-LQ***	**185**	**0.23**	**0.28**	**0.98**	-	-	-
		B	-	-	-	-	-	-	-	-
	TN	**A**	**LC-LQ***	**187**	**0.27**	**0.27**	**0.99**	-	-	-
		B	-	-	-	-	-	-	-	-
Nicholson@ Sarsfield	TSS	**A**	**LC-LQ***	**79**	**0.42**	**0.06**	**-0.80**	-	-	**200**
		B	-	-	-	-	-	-	-	-
	TP	**A**	**LC-LQ+SN+CS+BFI***	**78**	**0.33**	**0.49**	**0.94**	-	-	-
		B	-	-	-	-	-	-	-	-
	TN	**A**	**LC-LQ***	**78**	**0.25**	**0.33**	**0.95**	-	-	-
		B	-	-	-	-	-	-	-	-
Mitchell @Rosehill	TSS	A	LC-LQ+SN+CS+LQ30	110	0.66	0.94	0.95	-	-	-
		B	**LC-LQ+SN+CS***	**83**	**0.80**	**0.97**	**0.97**	**630**	**4.3**	-
	TP	A	LC-LQ+SN+CS+LQ30	110	0.39	0.92	0.68	-	-	-
		B	**LC-LQ+SN+CS+BF***	**83**	**0.54**	**0.86**	**0.87**	**630**	**0.030**	-
	TN	A	LC-LQ+SN+CS+LQ30	111	0.20	0.67	0.84	-	-	-
		B	**LC-LQ***	**84**	**0.45**	**0.86**	**0.99**	**630**	**0.27**	-
Avon @ Stratford	TSS	A	LC-LQ+BF+LQ30	111	0.69	0.69	0.75	-	-	-
		B	**LC-LQ***	**15**	**0.82**	**0.75**	**0.78**	**1,585**	**6.8**	-
	TP	A	LC-LQ+BF+Q30	109	0.35	0.56	0.73	-	-	-
		B	**LC-LQ+LQ30***	**14**	**0.55**	**0.67**	**0.78**	**1,585**	**0.032**	-
	TN	A	LC-LQ+SN+CS+BF	111	0.49	0.81	0.96	-	-	-
		B	**LC-LQ+LQ30***	**15**	**0.67**	**0.86**	**0.96**	**1,585**	**0.37**	-
Thomson @ Bunda-laguah	TSS	A	LC-LQ+SN+CS+LBF	135	0.55	0.83	0.93	-	-	-
		B	**LC-LQ+SN+CS***	**51**	**0.61**	**0.84**	**0.96**	**1,000**	**21.3**	-
	TP	A	LC-LQ+SN+CS+LBF	133	0.38	0.42	0.86	-	-	-
		B	**LC-LQ+SN+CS+BF***	**50**	**0.53**	**0.71**	**0.88**	**1,000**	**0.087**	-
	TN	A	LC-LQ+SN+CS+LBF	133	0.36	0.61	0.87	-	-	-
		B	**LC-LQ+SN+CS+BF***	**51**	**0.69**	**0.85**	**0.95**	**1,000**	**0.56**	-
Latrobe @ Kilmany South	TSS	**A**	**LC-LQ+LBF***	**190**	**0.29**	**0.44**	**0.72**	-	-	-
		B	-	-	-	-	-	-	-	-
	TP	A	LC-LQ+LBF	187	0.10	0.15	0.82	-	-	-
		B	**LC-LQ+SN+CS***	**117**	**0.31**	**0.23**	**0.90**	**1,000**	**0.115**	-
	TN	**A**	**LC-LQ***	**188**	**0.49**	**0.52**	**0.95**	-	-	-
		B	-	-	-	-	-	-	-	-

* Final selected model are printed in **bold**.
\+ R^2 and coefficient of efficiency for concentration are calculated based on the sample used for regression analysis, e.g. R^2 and coefficient of efficiency for concentration for Method A are based on all samples whereas those for Method B are based on samples above the cut-off flow only.
\# Coefficient of efficiency for load for both Method A and Method B are calculated using all samples from both high flow and low flow.

5. SIMULATION OF CONCENTRATION AND LOAD

The mean daily concentrations for each water quality constituent at the 6 sites were estimated using the final adopted models. To these were added estimates of loads from the areas downstream of the gauging stations and from the MID (based on estimates provided by Sinclair Knight Merz). These estimates are described below and final results of loads for the ecological modeling period, and in the longer term, are discussed.

5.1 LOAD ESTIMATES FROM AREAS DOWNSTREAM OF THE SAMPLING STATIONS

For each of the rivers, there is an area downstream of the gauging station that provides some load to the Lakes but is not monitored. This load is estimated as described below and added to the loads into Lake Wellington, Lake Victoria and Lake King.

The method used was to determine the areas draining into each of the river systems or directly to the lakes, downstream of the gauging station at which the load relationships were computed. The mix of land uses in these areas is similar to those in the Latrobe River catchment, excluding the irrigation areas. Long-term load estimates from the Latrobe River were converted into areal loading factors. These were compared to published values and found to be almost the same as "typical" long-term loads summarised in the literature (e.g. from the NEXUS data base). These areal factors were used to compute long-term annual loads from the ungauged areas.

In order to allocate loads from the ungauged areas to particular years, the long-term averages were multiplied by the ratio of annual river loads computed as above for the particular year divided by the long-term average annual river loads for the full period of the load simulation (1975 to 1999). Daily loads were computed using a similar approach whereby the annual load was disaggregated on the basis of the proportion of annual river load occurring on a particular day. Loads from these ungauged areas make up approximately 20% of the total loads into the Gippsland Lakes and so are quite important from the management perspective.

5.2 LOAD ESTIMATES FROM THE MACALISTER IRRIGATION DISTRICT BY SINCLAIR KNIGHT MERZ

The approach described above does not include contributions from the MID that flow into the rivers downstream of the gauging stations. Sinclair Knight Merz were contracted as part of another study for Southern Rural Water and the West Gippsland Catchment Management Authority to develop daily modelling of TP and TN loads in all of the MID drains (SKM, 2000). They have provided their data to us for inclusion in the final load estimates for the Lakes. Daily loads (1978 to 1999) from all drains entering the streams flowing to Lake Wellington downstream of the gauging stations were added to the load estimates computed for the rivers to give a final set of loads for use in the ecological modelling. The one potential error in this approach is that the regression relationships for each river were derived from data between the mid 1970s and early 1990s. If there has been a significant change in TP and TN concentrations from the MID since that period, there may be some under/overestimation using the approach we describe because the drains entering upstream of the gauging stations may now carry different loads compared to during the period when the regression relationships were derived. This was explored by assessing whether there was any detectable change in the SKM estimates of average contaminant concentrations or load response between the different periods. No difference was detected.

The SKM work did not include any estimates of TSS loads due to the lack of this type of data for the irrigation drains. We assessed several options for estimating TSS loads in the drains. Each was very uncertain but generated loads that were always less than 10% (generally less than 5%) of the Latrobe river loads (i.e. a few percent of total loads to Lake Wellington). Given that TSS is not of itself particularly important to the ecological relationships, at this stage no TSS loads have been included from the MID drains.

5.3 COMPARISON WITH THE EPA DIRECT LOAD COMPUTATION

The method of direct integration of measured flow and concentration is generally considered to be the most accurate method to estimate loading at all time scales if “sufficient data” are collected to describe the changes in water quality. Ideally, a full integration design typically includes fixed period, manually collected, monthly or semi-monthly samples supplemented with many miscellaneous samples collected during high flows, with 100 to 200 samples per year per site. Loads calculated by the integration method are often used as a reference to evaluate results from other methods (Robertson and Roerish, 1999).

The EPA has carried out load computation by the integration method using the flow weighted concentration technique for the 18 data sets or their equivalent in Table 3.1. However, not all the data sets constitute a “sufficient data“ set. In particular, some stations have low sampling frequency and some do not reflect the variability in water quality for high flow events in some years.

An attempt was made to compare the load estimates using the regression models with the EPA flow weighted integration method. The summary of load comparison for the Tambo River is presented in Table 5.1. The Tambo has been chosen because it is a particularly good example in illustrating the effects of water quality sampling on the load estimates and comparison. Appendix B-1 contains tables for all the other sites.

Given water quality data sets available and the current state-of-the-art in fluvial suspended sediment and nutrient load estimation techniques, any method which is able to come up with prediction within a factor of about 0.5 to 2.0, should be considered satisfactory.

Based on the above load comparison, it is seen that the load estimates for all the 3 constituents for Mitchell, Thomson and Latrobe are close to the desirable range of 0.5 to 2.0 for the 6 annual periods. The only occasions when the factor falls outside the range are TP for Mitchell River in 77/78and TP for Thomson River in 84/85, but with marginal over estimation factors of 2.8 and 2.5 respectively. For the Avon River, over prediction occurs for all the constituents of TSS, TP and TN, for the estimates of 77/78 and 84/85. The other two stations: Tambo and Nicholson Rivers both contain many instances of over estimation, with TSS for Nicholson River being the worst at an unusually high factor of 66 in 84/85.

Table 5.1: Summary of load comparison for Mitchell at Rosehill with loads estimated by the EPA flow weighted integration method

Site	Consti-tuent	Method	Load Estimates (Tonnes/year)						
			77/78	78/79	80/81	84/85	88/89	89/90	Average
EPA WQ Sampling Station used for Comparison			Tambo @ Battens Landing	Tambo @ Battens Landing	Tambo @ Battens Landing	Tambo @ Battens Landing	Tambo @ Battens Landing	Tambo @ Battens Landing	-
EPA WQ Sampling Frequency			Semi-monthly	Monthly	Monthly	Monthly	Weekly	Weekly	-
EPA WQ Sampling Coverage			Some high flows not sampled	Good	Most high flows not sampled	The only high flow not sampled	Good	Good	-
Max Flow recorded during EPA WQ Sampling Period (ML/d)			59,000	4,200	1,000	43,000	66,000	20,000	-
Max Flow captured with EPA WQ Sampling Point (ML/d)			24,000	1,600	170	2,200	66,000	9,400	-
Tambo @ Battens Landing	TSS	EPA	21,172	1,737	49	874	5,074	4,359	5,544
		CEAH (Factor)	45,002 **(2.1)** ov	1,051 (0.61)	267 **(5.4)** ov	12,148 **(13.9)** ov	17,573 **(3.5)** ov	5,655 (1.3)	13,616 **(2.5)** ov
	TP	EPA	29	2.6	0.2	3.7	9.4	14	9.9
		CEAH (Factor)	54 (1.9)	3.2 (1.2)	1.1 **(5.5)** ov	17 **(4.6)** ov	21 **(2.2)** ov	11 (0.8)	18 (1.8)
	TN	EPA	403	87	4.0	84	150	217	156
		CEAH (Factor)	778 (1.9)	54 (0.62)	19 **(4.8)** ov	251 **(3.0)** ov	295 (2.0)	180 (0.83)	263 (1.7)

ov denotes load estimates with a factor of more than 2.0 (over prediction).

However, the above comparison, with some occasions of over estimation may not provide a true picture of the accuracy of the load prediction using the regression approach. A closer look at the plots of EPA water quality sampling points superimposed on the hydrographs for each of the annual sampling period at each site reveal an interesting insight into the common pitfalls of load computation using the integration method.

As an illustration, the water quality sampling distribution for Tambo River for the six annual periods are depicted in Figure 5.1. Appendix B-2 is supplemented with plots of the water quality sampling distributions for all the other sites. The comparison factors for TSS for each of these periods are 2.1(77/78), 0.6(78/79), 5.4(80/81), 14(84/85), 3.5(88/89) and 1.3(89/90), all but one are larger than unity. Because the sampling strategies of fixed period without high flows were adopted in the EPA data collection, chances are that many high flow (and usually high concentration) events were not sampled, especially when the fixed period is long (e.g. monthly). This has obviously resulted in under-estimation of the loads in the EPA computation using the flow weighted concentration-integration method, and hence comparison factors that larger than unity. The extent of under prediction is made worse if the missing high concentration samples coincide with flood hydrograph persisting for more than a few days. This explains why the factors for 84/85 and 80/81 (when sampling frequency is monthly and high flow events coverage is not good) are amongst the highest, and that of 89/90 (when sampling frequency is weekly and high flow events coverage is good) is close to unity.

Inspection of other cases involving high factors has yielded similar results. In the cases where sampling frequency is higher and data coverage is better, the comparisons were usually excellent and we believe our estimates are overall unbiased.

5.4 COMPARISON WITH OTHER DATA

Comparison was made with independent data sets gathered by the EPA, VWQMN and WGCMA, essentially by plotting the predicted versus observed loads and computing the coefficient of efficiency. For Tambo and Nicholson Rivers, no water quality data was available at the same location where modelling was performed, but comparison was made using data from locations nearest to the modelling sites.

Table 5.2 presents the summary of the load efficiency for all constituents for the six rivers available for comparison, while Figure 5.2 shows the example plots of predicted versus observed loads for the Mitchell River. Plots for all the other rivers are given in Appendix A-2.

In general, the model predicted loads are very good in terms of the coefficient of efficiency. Only TSS and TP at Nicholson River show negative values for the coefficient of efficiency. It is noted that the range of these independent data sets is limited to days with low to average flows (and loads), thus the performance of the model in predicting/extrapolating loads during higher flow events cannot be assessed.

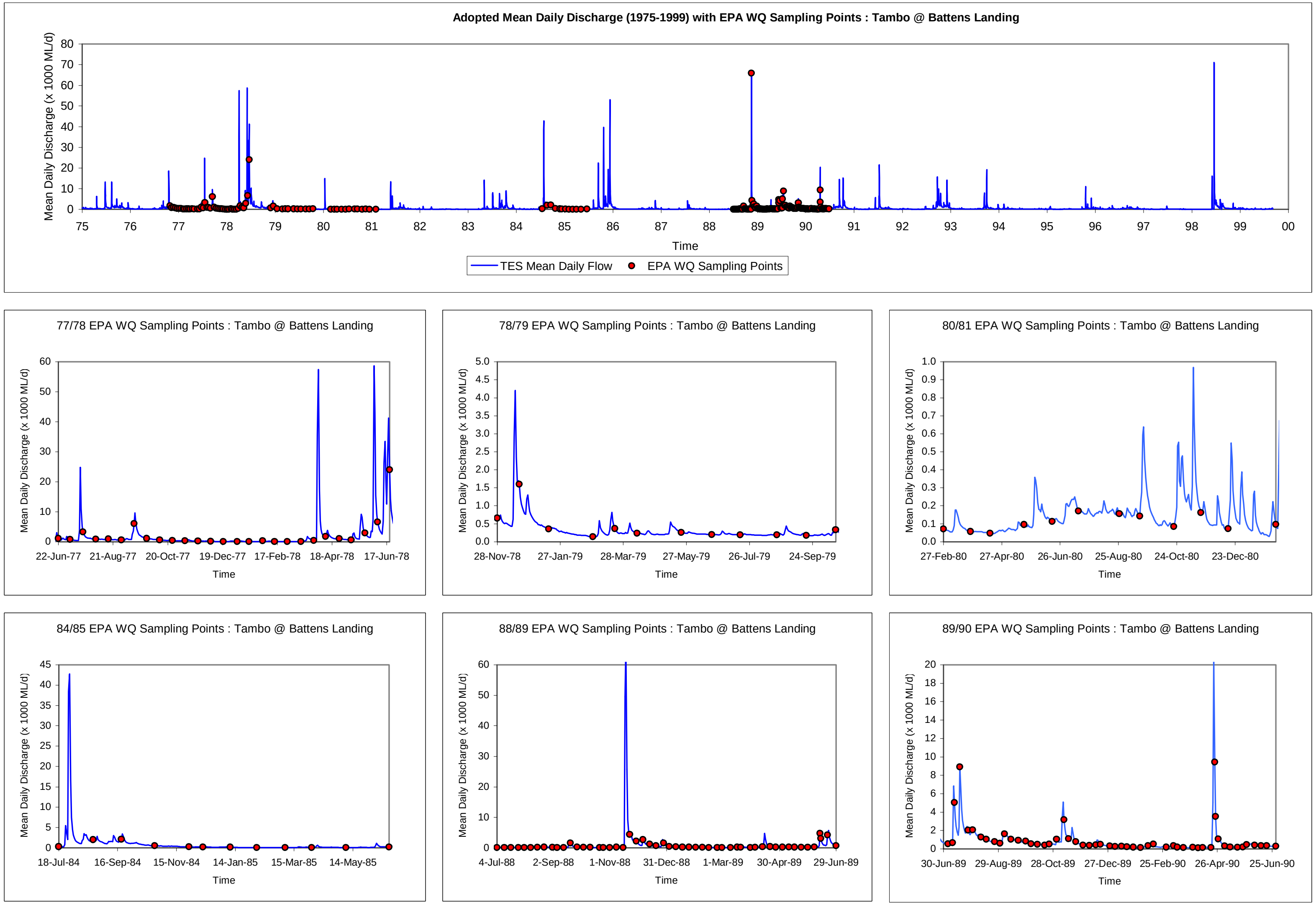

Figure 5.1: EPA WQ sampling points superimposed on mean daily discharge hydrographs (Tambo at Battens Landings)

Table 5.2: Summary of load efficiency verification against independent water quality data sets

River	Cons-tituent	Calibration Stage				Verification Stage			
		Source of WQ Data	WQ Sampling Period (Sample Size)	Max Sampling Flow (ML/d)	Coeff. of Efficiency	Source of WQ Data	WQ Sampling Period (Sample Size)	Max Sampling Flow (ML/d)	Coeff. of Efficiency
Tambo	**Station**	Battens Landing				D/s of Ramrod Ck. (~15km up/s of Battens Ldg.)			
	TSS	EPA	Oct76-Jun90 (187)	66,000	0.998	VWQMN	Oct78-Oct98 (145)	4,100	0.36
	TP	EPA	Oct76-Jun90 (185)	66,000	0.98	VWQMN	Oct78-Oct98 (144)	4,100	0.72
	TN	EPA	Oct76-Jun90 (187)	66,000	0.99	VWQMN	Jan79-Oct98 (143)	4,100	0.79
Nicholson	**Station**	**Sarsfield**				**Deptford (~20km up/s of Sarsfield)**			
	TSS	EPA	Oct76-Jun85 (79)	5,500	-0.8	VWQMN	Nov93-May99 (67)	440	-43.8
	TP	EPA	Oct76-Jun85 (78)	5,500	0.94	VWQMN	Nov93-May99 (67)	440	-1.3
	TN	EPA	Oct76-Jun85 (78)	5,500	0.95	VWQMN	Nov93-May99 (67)	440	0.93
Mitchell	**Station**	**Rosehill**				**Glenaladale (~20km up/s of Rosehill)**			
	TSS	EPA	Jul88-Jun90 (110)	113,000	0.97	EPA + VWQMN	Oct76-May99 (232)	34,000	0.84
	TP	EPA	Jul88-Jun90 (110)	113,000	0.87	EPA + VWQMN	Oct76-May99 (232)	12,000	0.52
	TN	EPA	Jul88-Jun90 (111)	113,000	0.99	EPA + VWQMN	Oct76-May99 (231)	34,000	0.76
Avon	**Station**	**Stratford**				**Stratford**			
	TSS	EPA	Jul88-Jun90 (111)	167,000	0.78	VWQMN	Jan93-Sep99 (80)	2,300	0.76
	TP	EPA	Jul88-Jun90 (109)	167,000	0.78	VWQMN	Jan93-Sep99 (79)	2,300	0.90
	TN	EPA	Jul88-Jun90 (111)	167,000	0.96	VWQMN	Jan93-Sep99 (80)	2,300	0.89
Thomson/ Macalister	**Station**	**Bundalaguah**				**Bundalaguah**			
	TSS	EPA	Nov78-Jun90 (135)	39,000	0.96	N/A	N/A	N/A	N/A
	TP	EPA	Nov78-Jun90 (133)	39,000	0.88	WGCMA	Feb98-Aug99 (151)	51,000	0.41
	TN	EPA	Nov78-Jun90 (133)	39,000	0.95	WGCMA	Aug98-Aug99 (57)	51,000	0.98
Latrobe	**Station**	**Kilmany South**				**Kilmany South**			
	TSS	EPA	Oct76-Jun90 (190)	23,000	0.72	N/A	N/A	N/A	N/A
	TP	EPA	Oct76-Jun90 (187)	23,000	0.90	WGCMA	Feb98-Aug99 (167)	7,800	0.50
	TN	EPA	Oct76-Jun90 (188)	23,000	0.95	WGCMA	Jul98-Aug99 (57)	7,800	0.88

N/A denotes data not available.

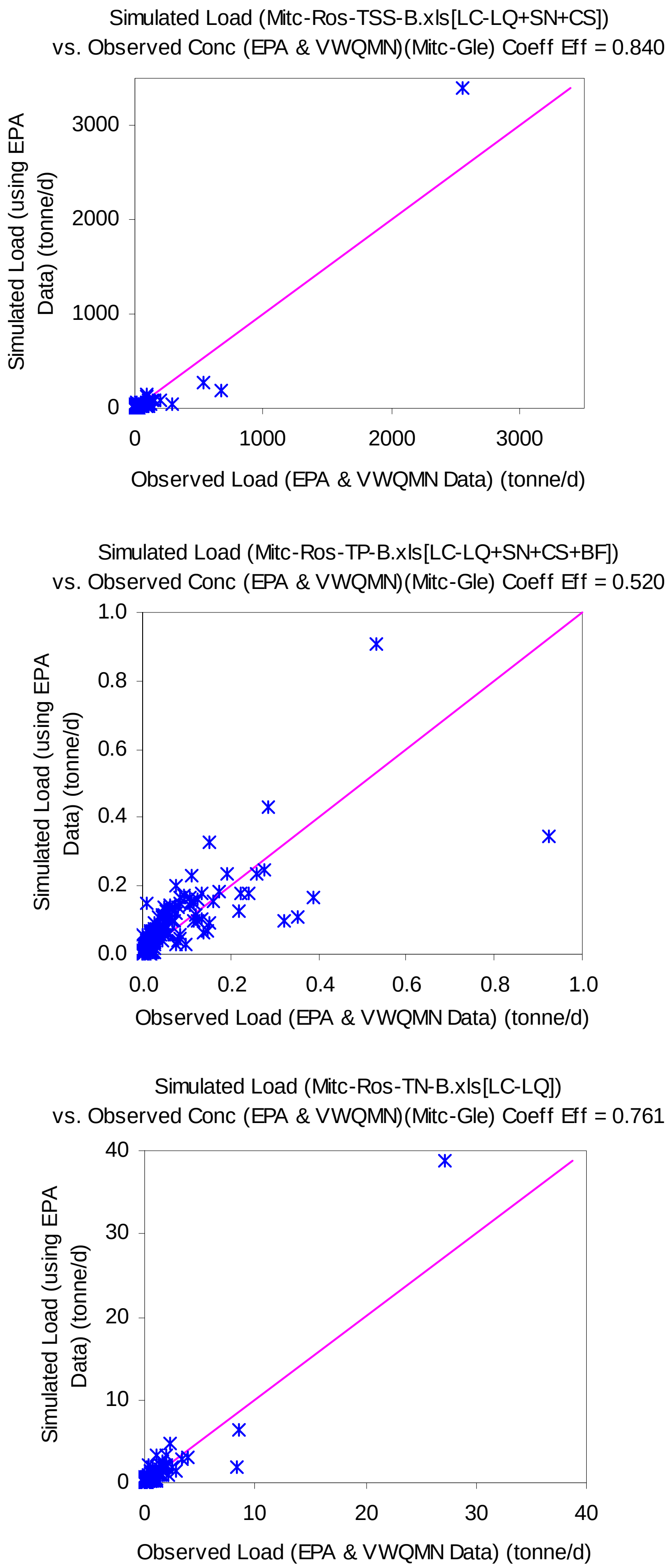

Figure 5.2: Comparison of predicted vs. observed loads for Mitchell River using EPA and VWQMN data

Independent estimates of average annual loads in the Latrobe River were computed for the Rosedale gauging site by a number of authors (reported in Grayson, 1994). This site is upstream of the MID drains so a check can be provided by comparing the sum of estimates at Rosedale and SKM total estimates for drains into the Latrobe River with the estimates for Kilmany South (computed in this study) plus the SKM estimates for drains entering downstream of Kilmany South. This comparison is included in Table 5.3 and indicates that the approach used here provides similar results to estimates made by other authors.

Table 5.3: Comparison of long-term average load estimates for the Latrobe River

Constituent	This Study (Tonnes/year)	Other Studies (Tonnes/year)	
		Range	Average
TSS	90,000	60,000-140,000	100,000
TP	127	100-160	130
TN	1,220	1,000-1,500	1,250

5.5 LOAD ESTIMATES FOR THE ECOLOGICAL MODELLING PERIOD

A summary of the load estimates for the extended and initial ecological modeling periods of July 1997 to June 1999 and July 1995 to June 1999, respectively, are presented in Table 5.4 and Table 5.5 below.

The effects of storms in delivering the TSS, TP and TN loads for the initial two-year CSIRO ecological modeling period of July 1997 to June 1999 are illustrated in Table 5.6 for the case of Mitchell River @ Rosehill. It is noteworthy that the vast majority (86%, 68%, 64% for TSS, TP and TN respectively) of the total estimated loads for the period were delivered in the three largest selected storm events, lasting approximately 39 days in total. In other words, the remaining 691 days (which include other smaller storms) accounted only for 14%, 32% and 36% of TSS, TP and TN loads respectively.

Similar tables illustrating the effects of storms in delivering loads during this period are provided in Appendix C. For the entire Gippsland Lakes, the overall average delivery during the three largest selected storms for the July 1997 to June 1999 period are approximately 71%, 53% and 53% of the total TSS, TP and TN loads respectively.

In addition to the influence of a few storms on total loads over the 1997-1999 period, the relative contributions of loads into Lake King and Lake Wellington were not representative of longer term averages. In general, loads into Lake King are approximately one third of those into Lake Wellington. In order to have a more representative data set of loads for modelling, the period was extended to include July 1995 to June 1997. As can be seen from the hydrographs in Appendix B-2, this includes more typical flow periods as well as some larger events for the rivers entering Lake Wellington.

Table 5.4: Summary of estimated annual loads for the four-year modelling period from July 1995 to June 1999

River/ Catchment	CSIRO Eco Model Box Number*	Estimated Loads from Gauged Catchment (including MID Drains entering u/s of Gauge Site) (Tonnes/yr)			Estimated Loads from Ungauged Catchment (Tonnes/yr)			Estimated Loads from MID d/s of Gauged Catchment (Tonnes/yr)			Total Estimated Loads (Tonnes/yr)		
		TSS	**TP**	**TN**	**TSS**	**TP**	**TN**	**TSS**	**TP**	**TN**	**TSS**	**TP**	**TN**
Tambo	**No.7**	6,930	9	141	2,630	3	34	-	-	-	9,560	12	175
Nicholson	**No.8**	3,380	4	27	830	1	13	-	-	-	4,210	5	40
Mitchell	**No.8**	18,590	35	350	4,140	5	68	-	-	-	22,730	40	418
Mitchell-Avon	**No.2**	-	-	-	1,060	1	17	-	-	-	1,060	1	17
Lake King	**-**	**28,900**	**48**	**518**	**8,660**	**10**	**132**	-	-	-	**37,560**	**58**	**650**
Mitchell-Avon	**No.3**	-	-	-	1,150	1	19	-	-	-	1,150	1	19
Mitchell-Avon	**No.4**	-	-	-	1,150	1	19	-	-	-	1,150	1	19
Mitchell-Avon	**No.5**	-	-	-	4,910	6	80	-	-	-	4,910	6	80
Lake Victoria	**-**	-	-	-	**7,210**	**8**	**118**	-	-	-	**7,210**	**8**	**118**
Avon	**No.6**	12,240	9	94	4,870	6	84	-	1	7	17,110	16	185
Thomson	**No.6**	24,520	40	270	-	-	-	-	5	13	24,520	45	283
Latrobe	**No.6**	82,130	112	1,084	3,900	5	56	-	8	18	86,030	125	1,158
Lake Wellington	**-**	**118,890**	**161**	**1,448**	**8,770**	**11**	**140**	**-**	**14**	**38**	**127,660**	**186**	**1,626**
TOTAL	**-**	**147,790**	**209**	**1,966**	**24,640**	**29**	**390**	**-**	**14**	**38**	**172,430**	**252**	**2,394**

Table 5.5: Summary of estimated annual loads for the initial two-year modelling period from July 1997 to June 1999

River/ Catchment	CSIRO Eco Model Box Number*	Estimated Loads from Gauged Catchment (including MID Drains entering u/s of Gauge Site) (Tonnes/yr)			Estimated Loads from Ungauged Catchment (Tonnes/yr)			Estimated Loads from MID d/s of Gauged Catchment (Tonnes/yr)			Total Estimated Loads (Tonnes/yr)		
		TSS	TP	TN	TSS	TP	TN	TSS	TP	TN	TSS	TP	TN
Tambo	**No.7**	12,200	15	211	4,620	4	50	-	-	-	16,820	19	261
Nicholson	**No.8**	5,920	6	41	1,450	2	19	-	-	-	7,370	8	60
Mitchell	**No.8**	27,600	42	387	6,150	6	75	-	-	-	33,750	48	462
Mitchell-Avon	**No.2**	-	-	-	1,580	2	19	-	-	-	1,580	2	19
Lake King	**-**	**45,720**	**63**	**639**	**13,800**	**14**	**163**	**-**	**-**	**-**	**59,520**	**77**	**802**
Mitchell-Avon	**No.3**	-	-	-	1,700	2	21	-	-	-	1,700	2	21
Mitchell-Avon	**No.4**	-	-	-	1,700	2	21	-	-	-	1,700	2	21
Mitchell-Avon	**No.5**	-	-	-	7,290	7	89	-	-	-	7,290	7	89
Lake Victoria	**-**	**-**	**-**	**-**	**10,690**	**11**	**131**	**-**	**-**	**-**	**10,690**	**11**	**131**
Avon	**No.6**	19,280	11	108	7,660	7	97	-	1	6	26,940	19	211
Thomson	**No.6**	14,590	23	157	-	-	-	-	5	11	14,590	28	168
Latrobe	**No.6**	29,480	47	388	1,400	2	20	-	7	16	30,880	56	424
Lake Wellington	**-**	**63,350**	**81**	**653**	**9,060**	**9**	**117**	**-**	**13**	**33**	**72,410**	**103**	**803**
TOTAL	**-**	**109,070**	**144**	**1,292**	**33,550**	**34**	**411**	**-**	**13**	**33**	**142,620**	**191**	**1,736**

Table 5.6: Effects of loads delivery during 3 selected storms for the initial two-year ecological modelling period of July 1997 to June 1999 for Mitchell at Rosehill

Period	Description	Method of Load Estimation: Method A1 Without Flow Stratification	Method of Load Estimation: Method B2 With Flow Stratification (With forced min high flow conc.)
Overall Modelling Period 01Jul 97 to 30Jun99 (730 days)	**TSS**	50,500	**55,202 (109%)**
	TP	61.7	**83.5 (135%)**
	TN	502	**775 (154%)**
	Q(total)	1,296,065	
	Q(max daily)	81,782	
	Prob. (exceedence)	0.02%	
	Date(max storm)	24Jun98	
Storm Event 22Jun98 to 04Jul98 (13 days)	**TSS**	37,828	**38,649 (102%)**
	TP	31.1	**42.8 (138%)**
	TN	215	**310 (144%)**
	Q(total)	204,975	
	Q(max daily)	81,782	
	Prob. (exceedence)	0.02%	
	Date(max storm)	24Jun98	
Storm Event 22Sep98 to 03Oct98 (12 days)	**TSS**	5,434	**7,976 (147%)**
	TP	8.4	**11.4 (136%)**
	TN	70	**153 (219%)**
	Q(total)	165,304	
	Q(max daily)	45,427	
	Prob. (exceedence)	0.14%	
	Date(max storm)	24Sep98	
Storm Event 05Jul98 to 18Jul98 (14 days)	**TSS**	647	**1,089 (168%)**
	TP	1.7	**2.2 (129%)**
	TN	18	**33 (183%)**
	Q(total)	70,825	
	Q(max daily)	19,130	
	Prob. (exceedence)	0.74%	
	Date(max storm)	07Jul98	
Period Combining All the 3 Storm Events above (39 days)	**TSS**	43,909	**47,714 (109%) <86%>**
	TP	41.3	**56.4 (137%) <68%>**
	TN	302	**496 (164%) <64%>**
	Q(total)	441,104	
	Percentage of Q(total)	34%	
Remaining Period Outside of the 3 Storm Events above (691 days)	**TSS**	6,591	**7,488 (114%) <14%>**
	TP	20.4	**27.1 (133%) <32%>**
	TN	200	**279 (140%) <36%>**
	Q(total)	854,961	
	Percentage of Q(total)	66%	

Values in **bold** are based on the final adopted method for load estimation.
All load estimates are in tonnes and all Qs are in ML/day.
Percentages in ( ) are load variation based on ratio of Method B estimates upon Method A estimates.
Percentages in < > are proportion of load of a particular period upon the overall CSIRO modelling period of Jul97-Jun99.

5.6 LOAD ESTIMATES FOR 1975 TO 1999

Load estimates for the entire simulation period of 1975 to 1999 are not the main focus of this work. Nevertheless, they are useful in providing a historical perspective for better understanding of the distribution and trend in the delivery of loads. Table 5.7 presents a summary of the long-term estimated loads into the Gippsland Lakes.

Table 5.7: Summary of long-term annual estimated loads into the Gippsland Lakes

River/ Catchment	CSIRO Eco Model Box Number*	Estimated Loads from Gauged Catchment (including MID Drains entering u/s of Gauge Site) (Tonnes/yr)			Estimated Loads from Ungauged Catchment (Tonnes/yr)			Estimated Loads from MID d/s of Gauged Catchment (Tonnes/yr)			Total Estimated Loads (Tonnes/yr)		
		TSS	TP	TN	TSS	TP	TN	TSS	TP	TN	TSS	TP	TN
Tambo	**No.7**	7,640	12	176	2,900	3	42	-	-	-	10,540	15	218
Nicholson	**No.8**	5,360	5	40	1,310	2	19	-	-	-	6,670	7	59
Mitchell	**No.8**	21,920	41	366	4,880	6	70	-	-	-	26,800	47	436
Mitchell-Avon	**No.2**	-	-	-	1,260	2	18	-	-	-	1,260	2	18
Lake King	-	**34,920**	**58**	**582**	**10,350**	**13**	**149**	-	-	-	**45,270**	**71**	**731**
Mitchell-Avon	**No.3**	-	-	-	1,350	2	20	-	-	-	1,350	2	20
Mitchell-Avon	**No.4**	-	-	-	1,350	2	20	-	-	-	1,350	2	20
Mitchell-Avon	**No.5**	-	-	-	5,790	7	84	-	-	-	5,790	7	84
Lake Victoria	-	-	-	-	**8,490**	**11**	**124**	-	-	-	**8,490**	**11**	**124**
Avon	**No.6**	25,740	19	166	10,230	12	148	-	1	7	35,970	32	321
Thomson	**No.6**	36,230	50	331	-	-	-	-	6	15	36,230	56	346
Latrobe	**No.6**	89,420	119	1,197	4,250	5	62	-	8	18	93,670	132	1,277
Lake Wellington	-	**151,390**	**188**	**1,694**	**14,480**	**17**	**210**	-	**15**	**40**	**165,870**	**220**	**1,944**
TOTAL	**-**	**186,310**	**246**	**2,276**	**33,320**	**41**	**483**	**-**	**15**	**40**	**219,630**	**302**	**2,799**

5.7 STATEMENT OF CONFIDENCE

5.7.1 Statistical Error Analysis

An error analysis was conducted to estimate the general magnitude of the uncertainty in predicted loads, by assuming normally distributed errors in the regression relationships and using these to compute errors in loads, assuming no error in flows. The results are presented in Table 5.8. However it must be recognised that it does not account for all the uncertainty in estimated load. Potential sources of error include:

(1) Uncertainty associated with scatter about the regression relationship, characterised by the residual standard deviation (see e.g. a residual figure);
(2) Uncertainty associated with the coefficients of the regression relationship itself;
(3) Bias under certain flow conditions due for example to any remaining effects of non-linearity; and
(4) Uncertainty in the discharge leading to additional errors when concentrations are converted to loads.

We believe that (3) is small as the regression residuals are well behaved. Discharge uncertainty affects both the prediction of concentration by contributing to scatter about the regression relationships (1) and also the conversion of concentration to load (4). We believe that the effect of flow uncertainty on the prediction of the concentration is fairly well accounted for in (1). We also believe that for typical flow conditions the effect of model uncertainty is small; however, it could become significant for high flows, especially because there are few data defining the regression relationship under high flow conditions. the results in Table 5.8 only account for (1). (2) and (4) could add significantly to the uncertainty in load for high flow conditions; however, it is difficult to assess the high flow errors due to the limited data for these conditions. In addition, errors in estimated loads from the ungauged catchment and the MID are not quantified.

It also needs to be stated that the error standard deviations presented inTable 5.8 for accumulated errors should not be used for standard statistical inferences (e.g. calculation of confidence intervals). This is because the shape of the error distribution is unknown (it depends on the flow distribution as well as the original regression characteristics) and because errors are assumed independent at daily time-scales, which is probably not the case, even though they are independent at the sampling time-scales.

Table 5.8: Results of Error Analysis for Daily and Total Load Estimates

Site	Con-sti-tuent	Me-thod	Selected Model	% Error in Daily Load Estimate (Regression Part)	% Error in Daily Load Estimate (Low Flow Part)	% Error in 25-year (75-99) Long-term Total Load Estimate	% Error in 4-year (95/99) Total Load Estimate	% Error in 2-year (97/99) Total Load Estimate
Tambo @ Battens Landings	TSS	A	LC-LQ*	95%	-	11%	42%	48%
		B	-	-	-	-	-	-
	TP	A	LC-LQ*	71%	-	6%	21%	27%
		B	-	-	-	-	-	-
	TN	A	LC-LQ*	50%	-	4%	13%	18%
		B	-	-	-	-	-	-
Nicholson	TSS	A	LC-LQ*	150%	-	16%	61%	69%

@ Sarsfield		B	-	-	-	-	-	-
	TP	**A**	**LC-LQ+SN+CS+BFI***	**62%**	**-**	**8%**	**28%**	**33%**
		B	-	-	-	-	-	-
	TN	**A**	**LC-LQ***	**43%**	**-**	**4%**	**13%**	**17%**
		B	-	-	-	-	-	-
Mitchell @Rosehill	TSS	A	LC-LQ+SN+CS+LQ30	-	-	-	-	-
		B	**LC-LQ+SN+CS***	**64%**	**50%**	**16%**	**24%**	**33%**
	TP	A	LC-LQ+SN+CS+LQ30	-	-	-	-	-
		B	**LC-LQ+SN+CS+BF***	**78%**	**139%**	**8%**	**17%**	**29%**
	TN	A	LC-LQ+SN+CS+LQ30	-	-	-	-	-
		B	**LC-LQ***	**77%**	**25%**	**4%**	**13%**	**22%**
Avon @ Stratford	TSS	A	LC-LQ+BF+LQ30	-	-	-	-	-
		B	**LC-LQ***	**88%**	**58%**	**35%**	**52%**	**65%**
	TP	A	LC-LQ+BF+Q30	-	-	-	-	-
		B	**LC-LQ+LQ30***	**78%**	**59%**	**12%**	**26%**	**42%**
	TN	A	LC-LQ+SN+CS+BF	-	-	-	-	-
		B	**LC-LQ+LQ30***	**41%**	**46%**	**6%**	**12%**	**20%**
Thomson @ Bunda-laguah	TSS	A	LC-LQ+SN+CS+LBF	-	-	-	-	-
		B	**LC-LQ+SN+CS***	**67%**	**48%**	**5%**	**10%**	**22%**
	TP	A	LC-LQ+SN+CS+LBF	-	-	-	-	-
		B	**LC-LQ+SN+CS+BF***	**59%**	**58%**	**2%**	**4%**	**8%**
	TN	A	LC-LQ+SN+CS+LBF	-	-	-	-	-
		B	**LC-LQ+SN+CS+BF***	**35%**	**33%**	**1%**	**3%**	**6%**
Latrobe @ Kilmany South	TSS	**A**	**LC-LQ+LBF***	**51%**	**-**	**2%**	**6%**	**4%**
		B	-	-	-	-	-	-
	TP	A	LC-LQ+LBF	-	-	-	-	-
		B	**LC-LQ+SN+CS***	**39%**	**46%**	**1%**	**3%**	**2%**
	TN	**A**	**LC-LQ***	**27%**	**-**	**1%**	**2%**	**2%**
		B	-	-	-	-	-	-

* Final selected model are printed in **bold**.

Based on Table 5.8, it is clear that the statistical error in long-term load estimates is generally less than 20%, except for TSS in the Avon River where the error is 35%. Errors in loads for the Latrobe and Thomson Rivers are generally less than 10%. For the 4-year ecological modelling period , statistical errors are generally less than 20% for nutrients, although there is greater uncertainty in TSS, particularly for the Nicholson, Tambo and Avon Rivers. Again, the errors in loads from the Thomson and Latrobe Rivers are lower, essentially due to the largely regulated flows in the Thomson and Latrobe Rivers. For the more flashy “Eastern” rivers, high error variances associated with days of extraordinarily high flows (and concentrations) will result in higher percentage errors in the total loads.

Statistical errors in loads for individual days are much higher (around 50% in general) while the error in days of extreme flows may be higher still, due to greater uncertainty in both flows and concentrations. Nevertheless, overall the errors are expected to be unbiased, and it is important to note that the ecological model responds to loads over time scales of weeks to months.

5.7.2 Qualitative Error Judgement

Where comparisons between measured and simulated loads have been possible, the load estimates fall within these statistical error ranges. Based on comparisons between measured and simulated loads, an assessment of the data quality, statistical soundness of the regression relationships, and discussions with SKM regarding their modelling of the MID loads, we can make a *qualitative* judgment about the maximum and likely errors in loads.

For non-extreme flow conditions, we expect the error in load estimates into the western and eastern systems to be of the order of +/- 20% and unbiased over time periods of months to years. This may possibly increase to as high as –40% +100% for individual events of very high magnitude (due to increasing uncertainty in flow estimates as well as concentration), but again the results should be unbiased in the longer term.

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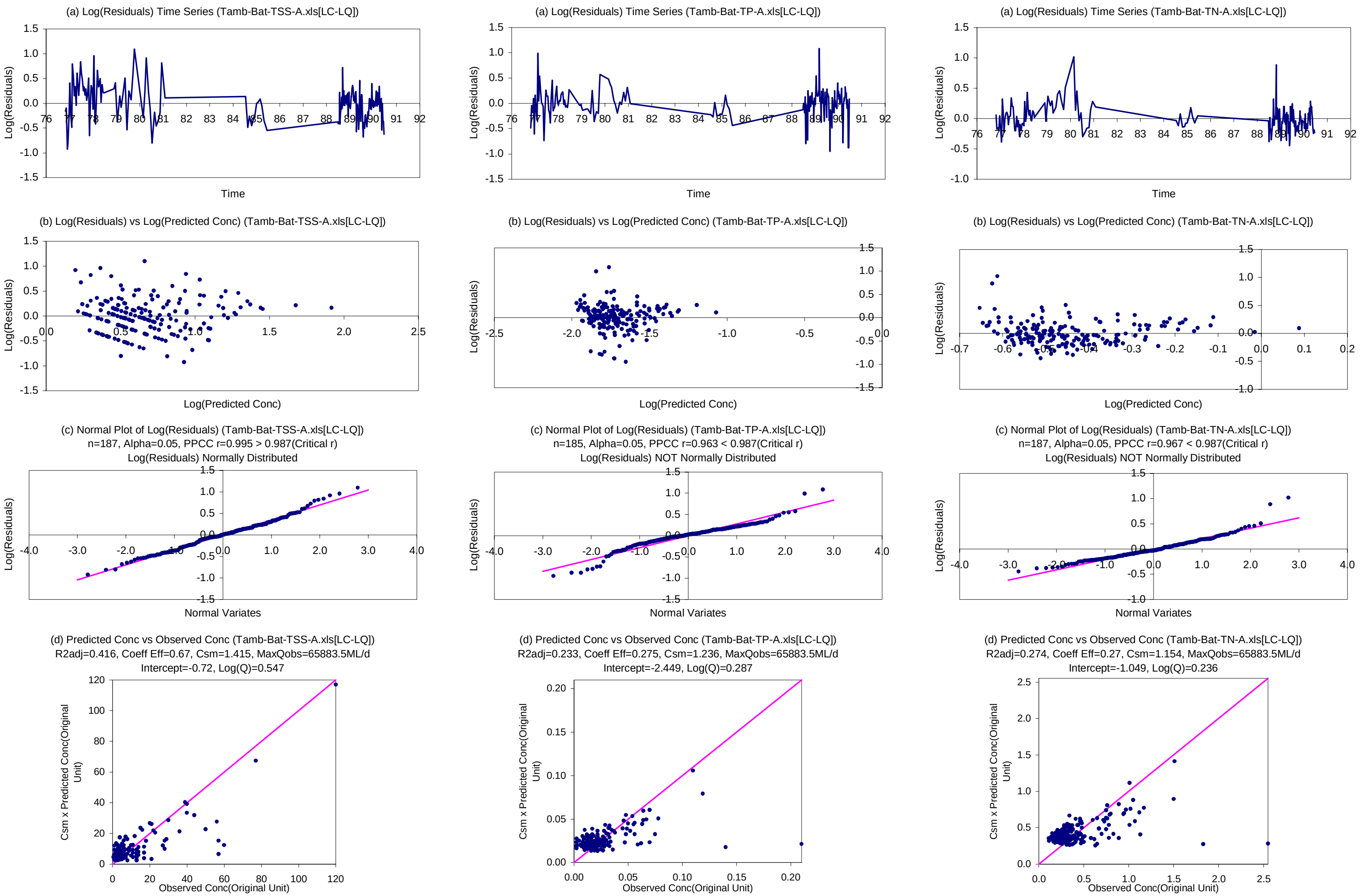
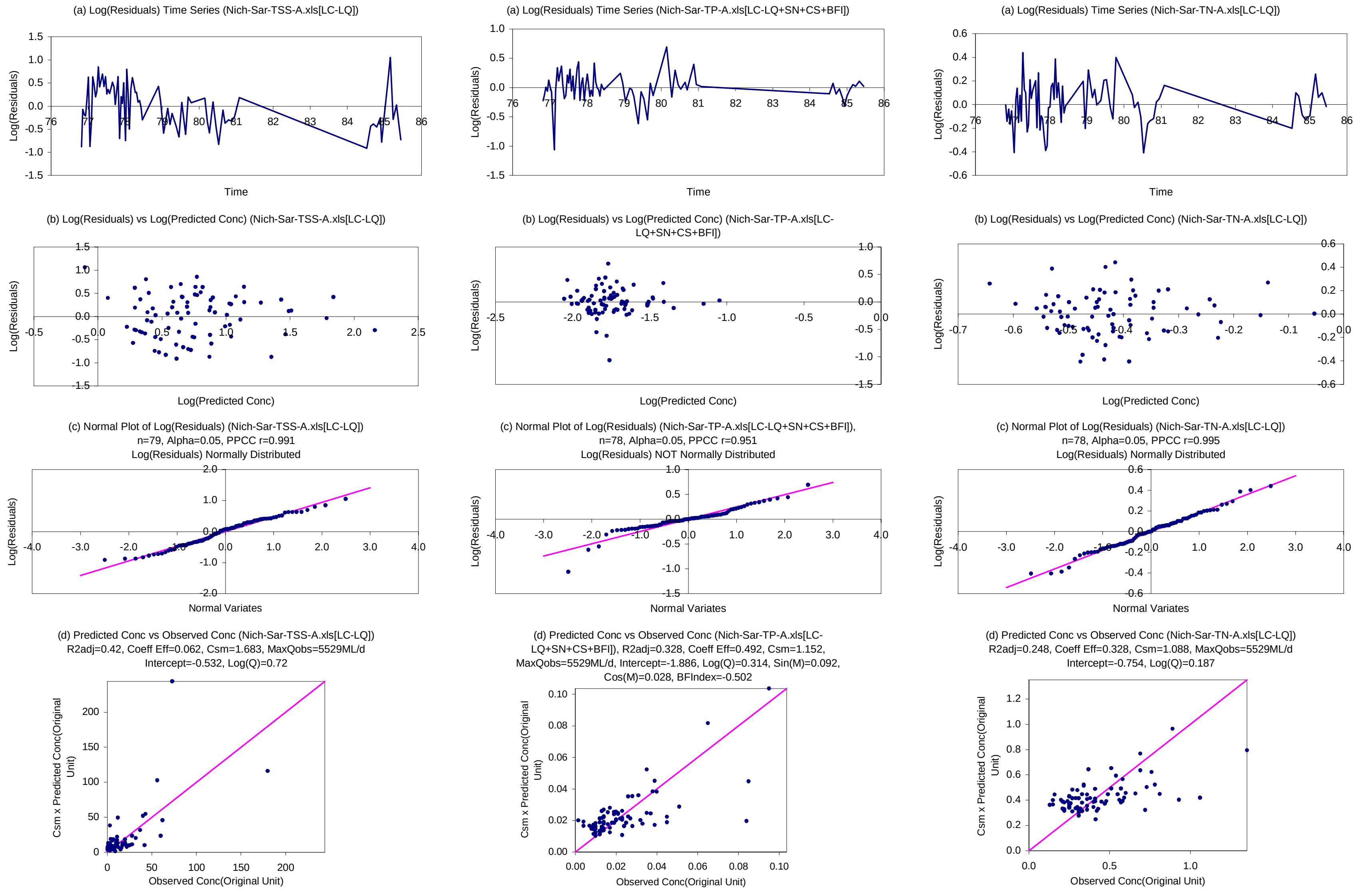
APPENDIX A-1

Appendix A-1(i): Final Residual and Concentration. Efficiency Plots for Tambo @ Battens Landing (Method A: Without Flow Stratification)

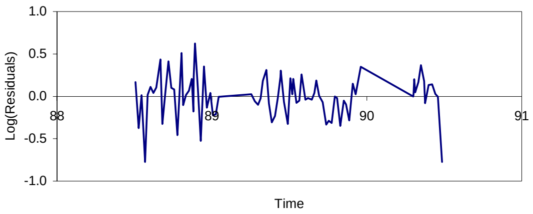


Appendix A-1(ii): Final Residual and Concentration Efficiency Plots for Nicholson @ Sarsfield (Method A: Without Flow Stratification)

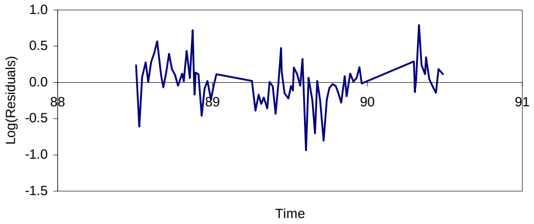


Appendix A-1(iii): Final Residual and Concentration Efficiency Plots for Mitchell @ Rosehill (Method B: With Flow Stratification at Q=630ML/day)

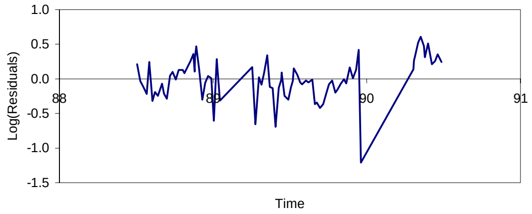
(a) Log(Residuals) Time Series (Mitc-Ros-TSS-B.xls[LC-LQ+SN+CS])



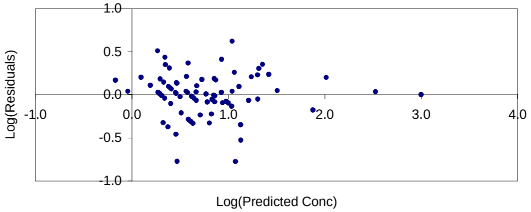
(a) Log(Residuals) Time Series (Mitc-Ros-TP-B.xls[LC-LQ+SN+CS+BF])



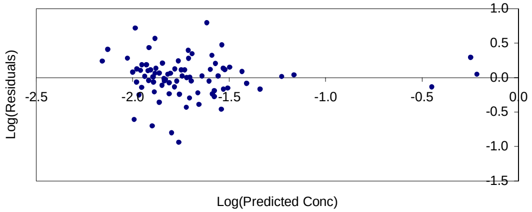
(a) Log(Residuals) Time Series (Mitc-Ros-TN-B.xls[LC-LQ])



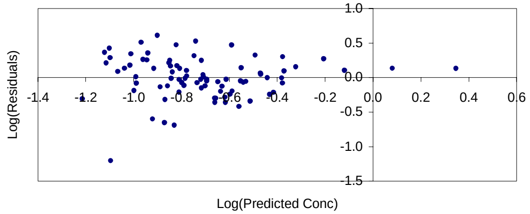
(b) Log(Residuals) vs Log(Predicted Conc) (Mitc-Ros-TSS-B.xls[LC-LQ+SN+CS])



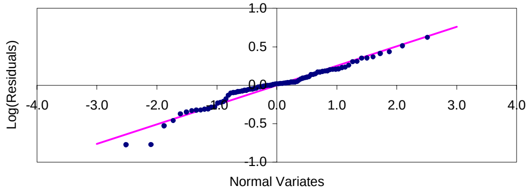
(b) Log(Residuals) vs Log(Predicted Conc) (Mitc-Ros-TP-B.xls[LC-LQ+SN+CS+BF])



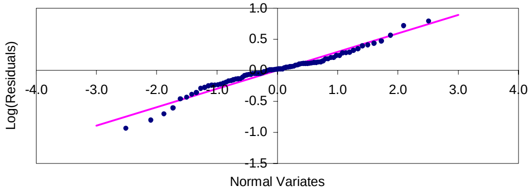
(b) Log(Residuals) vs Log(Predicted Conc) (Mitc-Ros-TN-B.xls[LC-LQ])



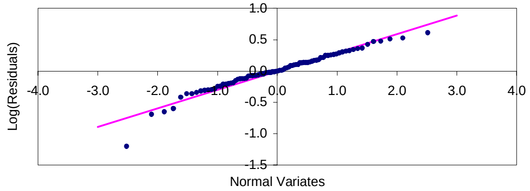
(c) Normal Plot of Log(Residuals) (Mitc-Ros-TSS-B.xls[LC-LQ+SN+CS]), n=83, Alpha=0.05, PPCC r=0.981 < 0.985(Critical r), Log(Residuals) NOT Normally Dist'ed



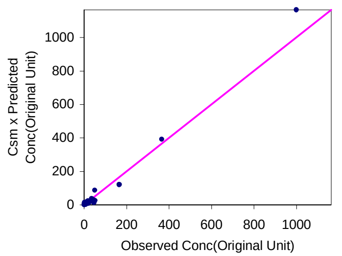
(c) Normal Plot of Log(Residuals) (Mitc-Ros-TP-B.xls[LC-LQ+SN+CS+BF]), n=83, Alpha=0.05, PPCC r=0.979 < 0.985(Critical r), Log(Residuals) NOT Normally Dist'ed



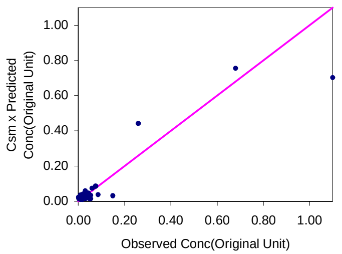
(c) Normal Plot of Log(Residuals) (Mitc-Ros-TN-B.xls[LC-LQ]), n=84, Alpha=0.05, PPCC r=0.976 < 0.985(Critical r) Log(Residuals) NOT Normally Distributed



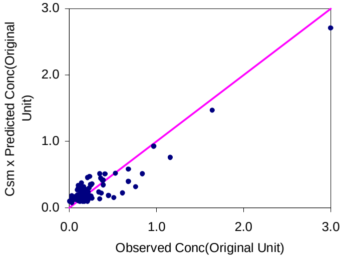
(d) Predicted Conc vs Observed Conc (Mitc-Ros-TSS-B.xls[LC-LQ+SN+CS]), R2adj=0.799, Coeff Eff=0.969, Csm=1.163, MaxQobs=112728.5ML/d, Intercept=-3.545, Log(Q)=1.247, Sin(M)=0.374, Cos(M)=0.16



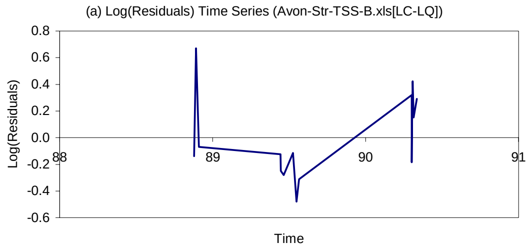
(d) Predicted Conc vs Observed Conc (Mitc-Ros-TP-B.xls[LC-LQ+SN+CS+BF]), R2adj=0.544, Coeff Eff=0.862, Csm=1.239, MaxQobs=112728.5ML/d, Intercept=-3.029, Log(Q)=0.348, Sin(M)=0.24, Cos(M)=0.101, BFlow=0

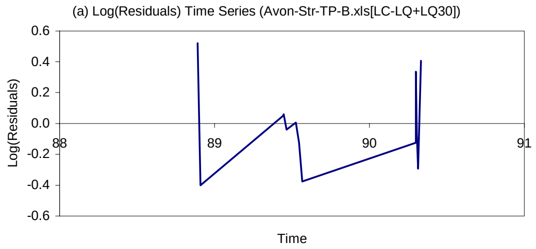


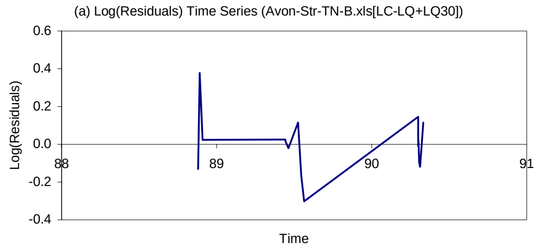
(d) Predicted Conc vs Observed Conc (Mitc-Ros-TN-B.xls[LC-LQ]), R2adj=0.446, Coeff Eff=0.856, Csm=1.218, MaxQobs=112728.5ML/d, Intercept=-3.196, Log(Q)=0.701

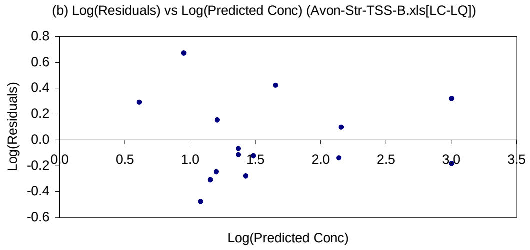


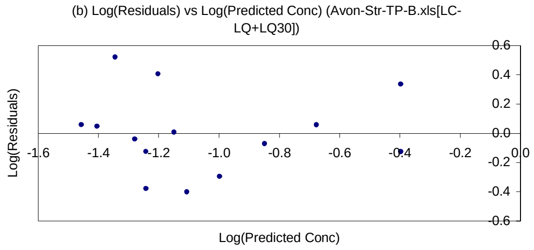
Appendix A-1(iv): Final Residual and Concentration Efficiency Plots for Avon @ Stratford (Method B: With Flow Stratification at Q=1585ML/day)

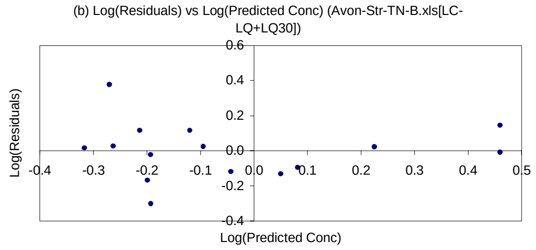


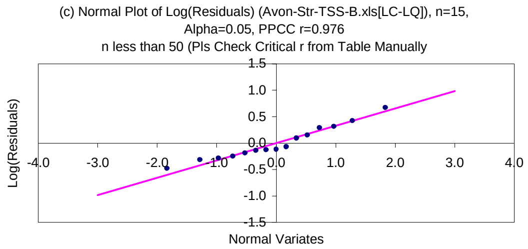


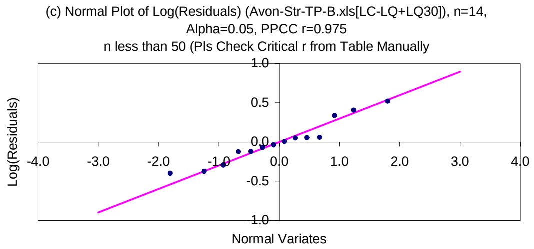


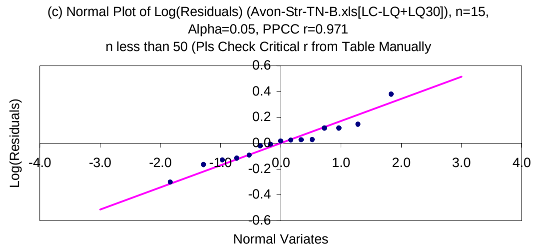


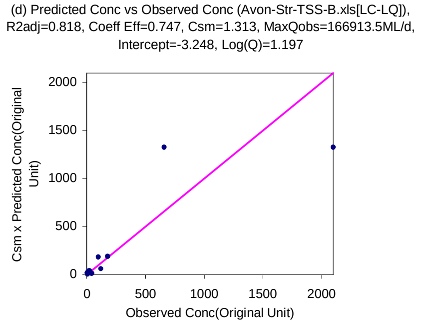


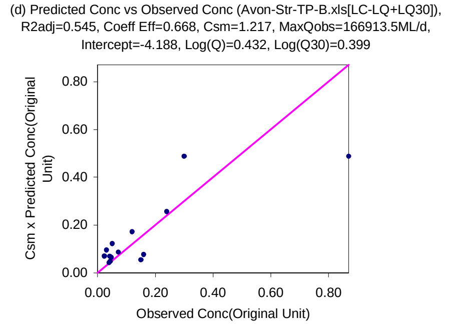


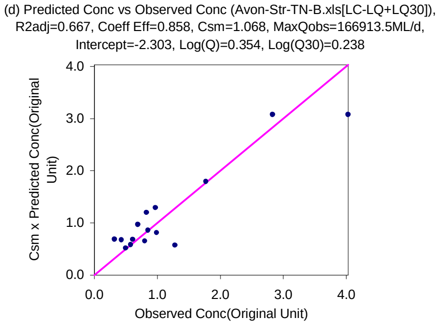






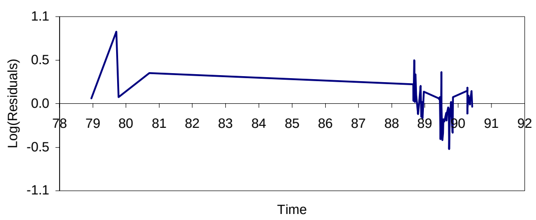




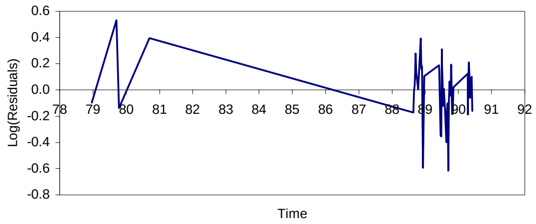


Appendix A-1(v): Final Residual and Concentration Efficiency Plots for Thomson @ Bundalaguah (Method B: With Flow Stratification at Q=1000ML/day)

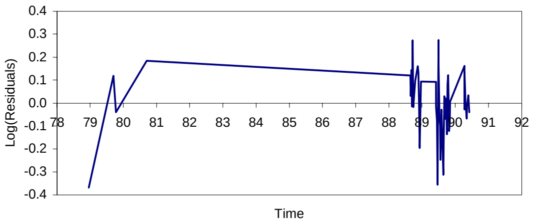
(a) Log(Residuals) Time Series (Thom-Bun-TSS-B.xls[LC-LQ+SN+CS])



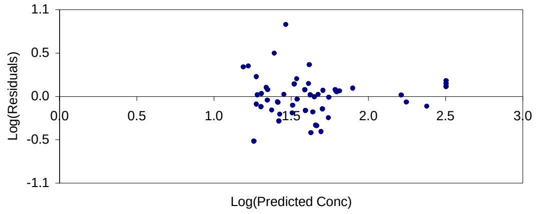
(a) Log(Residuals) Time Series (Thom-Bun-TP-B.xls[LC-LQ+SN+CS+BF])



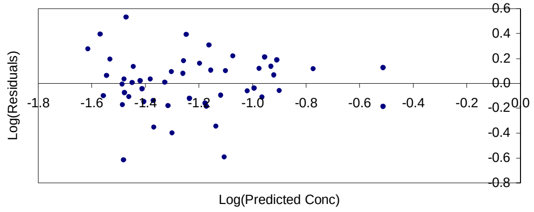
(a) Log(Residuals) Time Series (Thom-Bun-TN-B.xls[LC-LQ+SN+CS+BF])



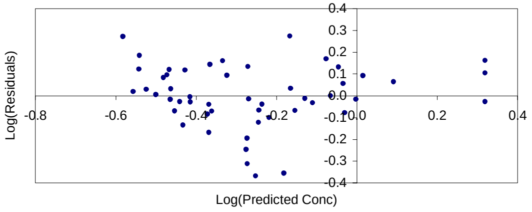
(b) Log(Residuals) vs Log(Predicted Conc) (Thom-Bun-TSS-B.xls[LC-LQ+SN+CS])



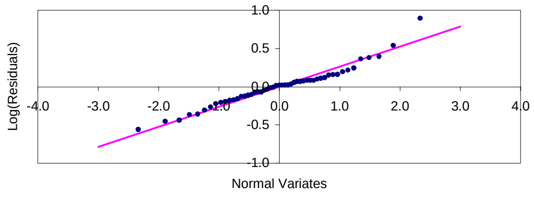
(b) Log(Residuals) vs Log(Predicted Conc) (Thom-Bun-TP-B.xls[LC-LQ+SN+CS+BF])



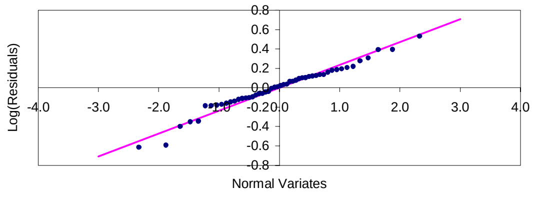
(b) Log(Residuals) vs Log(Predicted Conc) (Thom-Bun-TN-B.xls[LC-LQ+SN+CS+BF])



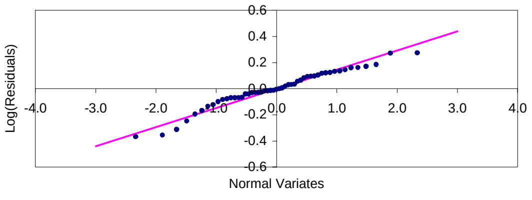
(c) Normal Plot of Log(Residuals) (Thom-Bun-TSS-B.xls[LC-LQ+SN+CS]), n=51, Alpha=0.05, PPCC r=0.975 < 0.977(Critical r), Log(Residuals) NOT Normally Dist'ed



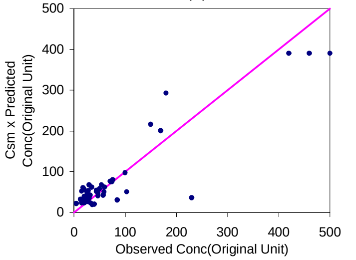
(c) Normal Plot of Log(Residuals) (Thom-Bun-TP-B.xls[LC-LQ+SN+CS+BF]), n=50, Alpha=0.05, PPCC r=0.984 > 0.977(Critical r), Log(Residuals) Normally Distributed



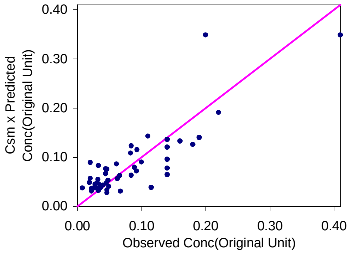
(c) Normal Plot of Log(Residuals) (Thom-Bun-TN-B.xls[LC-LQ+SN+CS+BF]), n=51, Alpha=0.05, PPCC r=0.98 > 0.977(Critical r), Log(Residuals) Normally Distributed



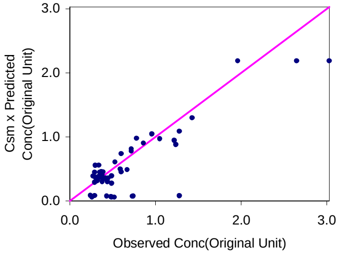
(d) Predicted Conc vs Observed Conc (Thom-Bun-TSS-B.xls[LC-LQ+SN+CS]), R2adj=0.607, Coeff Eff=0.841, Csm=1.223, MaxQobs=39208.6ML/d, Intercept=0.01, Log(Q)=0.487, Sin(M)=0.284, Cos(M)=-0.019



(d) Predicted Conc vs Observed Conc (Thom-Bun-TP-B.xls[LC-LQ+SN+CS+BF]), R2adj=0.53, Coeff Eff=0.713, Csm=1.134, MaxQobs=39208.6ML/d, Intercept=-2.729, Log(Q)=0.52, Sin(M)=0.372, Cos(M)=-0.013, BFlow=0

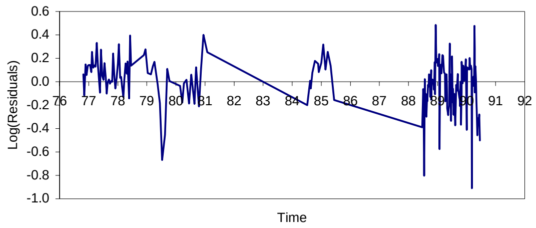


(d) Predicted Conc vs Observed Conc (Thom-Bun-TN-B.xls[LC-LQ+SN+CS+BF]), R2adj=0.693, Coeff Eff=0.849, Csm=1.05, MaxQobs=39208.6ML/d, Intercept=-1.757, Log(Q)=0.489, Sin(M)=0.234, Cos(M)=-0.064, BFlow=0

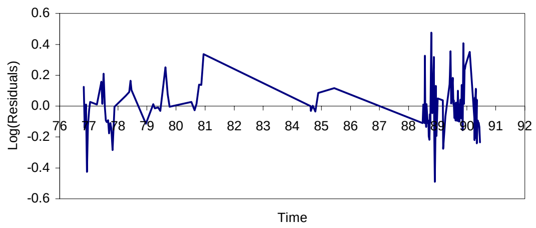


Appendix A-1(vi): Final Residual and Concentration Efficiency Plots for Latrobe @ Kilmany South (Method A: Without Flow Stratification for TSS & TN) (Method B: With Flow Stratification at Q=1000ML/day for TP)

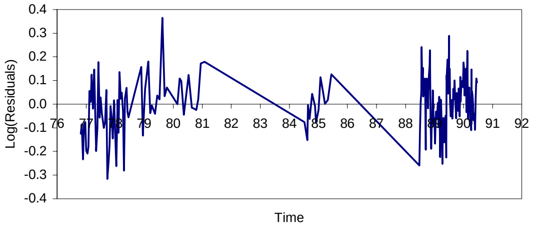
(a) Log(Residuals) Time Series (Latr-Kil-TSS-A.xls[LC-LQ+LBF])



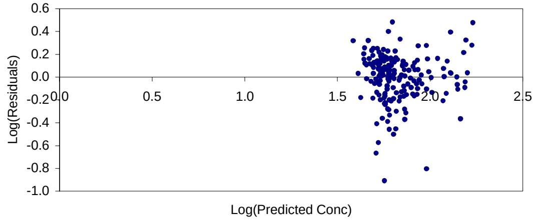
(a) Log(Residuals) Time Series (Latr-Kil-TP-B.xls[LC-LQ+SN+CS])



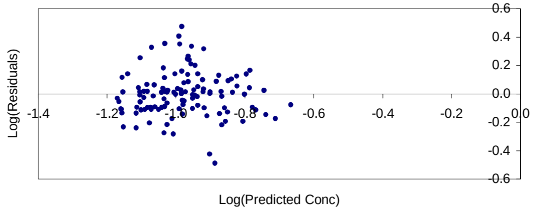
(a) Log(Residuals) Time Series (Latr-Kil-TN-A.xls[LC-LQ])



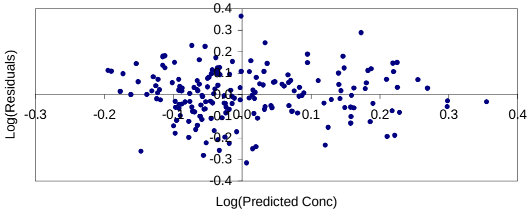
(b) Log(Residuals) vs Log(Predicted Conc) (Latr-Kil-TSS-A.xls[LC-LQ+LBF])



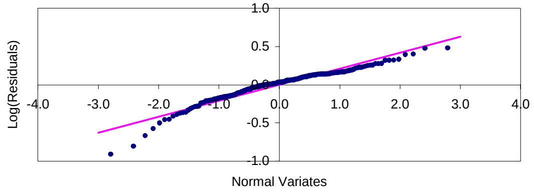
(b) Log(Residuals) vs Log(Predicted Conc) (Latr-Kil-TP-B.xls[LC-LQ+SN+CS])



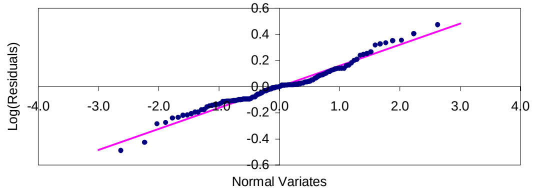
(b) Log(Residuals) vs Log(Predicted Conc) (Latr-Kil-TN-A.xls[LC-LQ])



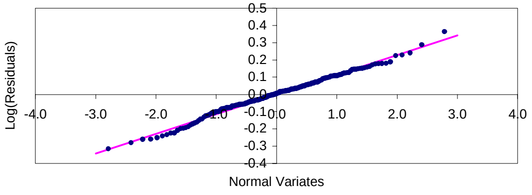
(c) Normal Plot of Log(Residuals) (Latr-Kil-TSS-A.xls[LC-LQ+LBF]), n=190, Alpha=0.05, PPCC r=0.968 < 0.987(Critical r), Log(Residuals) NOT Normally Dist'ed



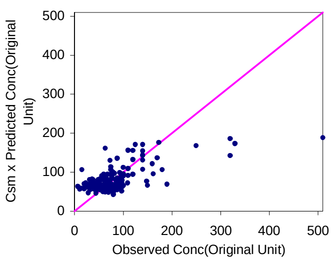
(c) Normal Plot of Log(Residuals) (Latr-Kil-TP-B.xls[LC-LQ+SN+CS]), n=117, Alpha=0.05, PPCC r=0.986 < 0.987(Critical r), Log(Residuals) NOT Normally Dist'ed



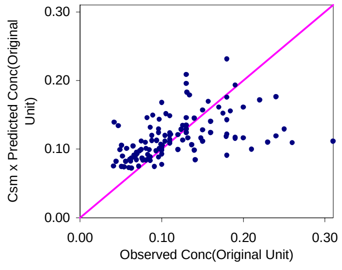
(c) Normal Plot of Log(Residuals) (Latr-Kil-TN-A.xls[LC-LQ]), n=188, Alpha=0.05, PPCC r=0.996 > 0.987(Critical r) Log(Residuals) Normally Distributed



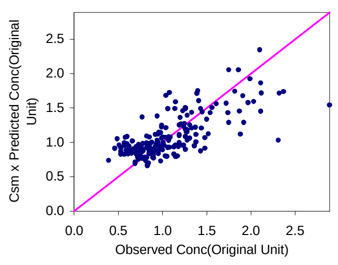
(d) Predicted Conc vs Observed Conc (Latr-Kil-TSS-A.xls[LC-LQ+LBF]), R2adj=0.294, Coeff Eff=0.445, Csm=1.104, MaxQobs=22864.7ML/d, Intercept=0.9, Log(Q)=0.763, Log(BFlow)=-0.495



(d) Predicted Conc vs Observed Conc (Latr-Kil-TP-B.xls[LC-LQ+SN+CS]), R2adj=0.31, Coeff Eff=0.226, Csm=1.072, MaxQobs=22864.7ML/d, Intercept=-1.932, Log(Q)=0.287, Sin(M)=0.036, Cos(M)=0.102

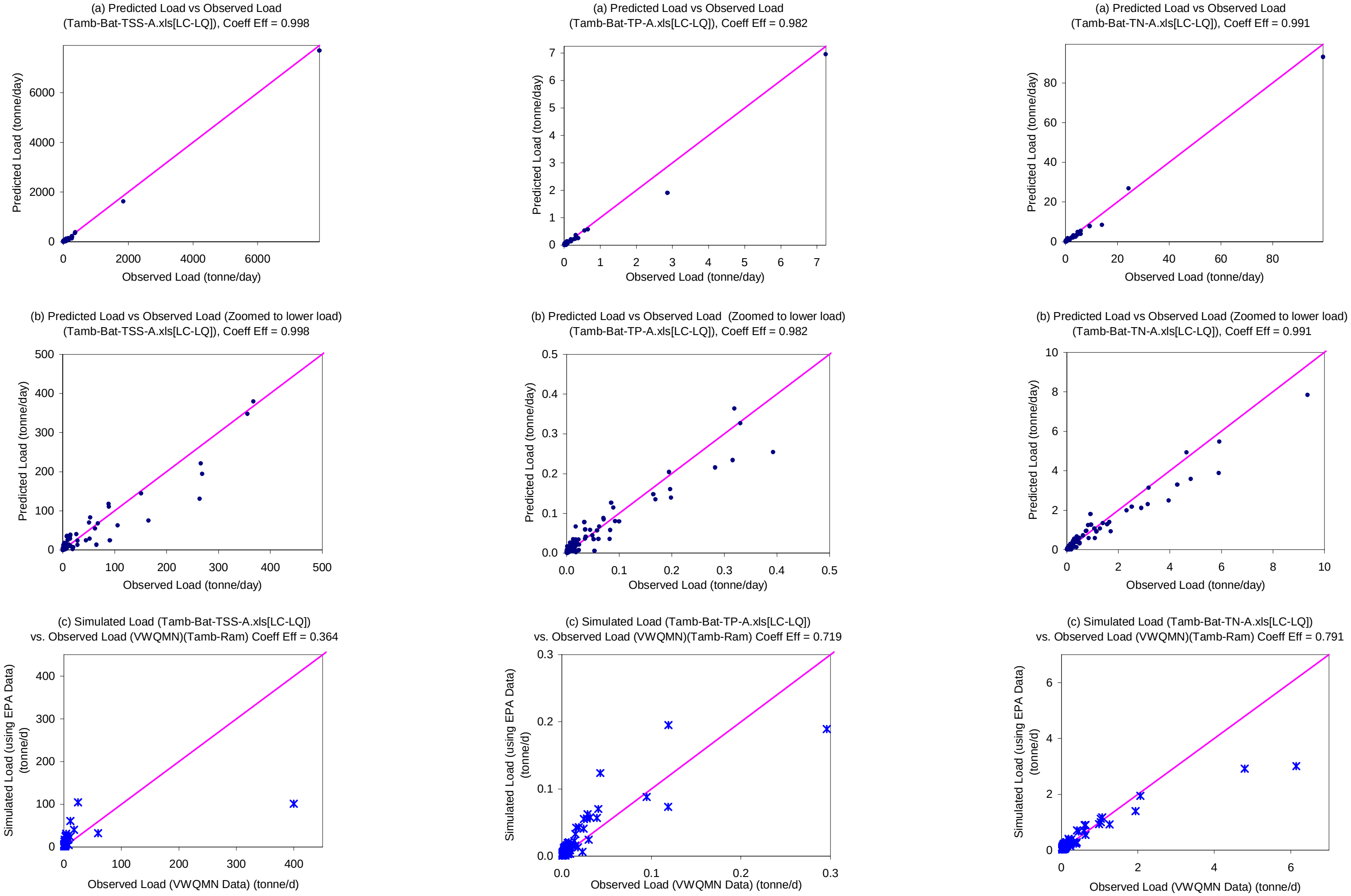


(d) Predicted Conc vs Observed Conc (Latr-Kil-TN-A.xls[LC-LQ]), R2adj=0.488, Coeff Eff=0.525, Csm=1.034, MaxQobs=22864.7ML/d, Intercept=-0.958, Log(Q)=0.301

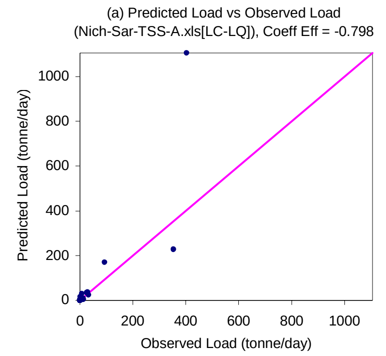


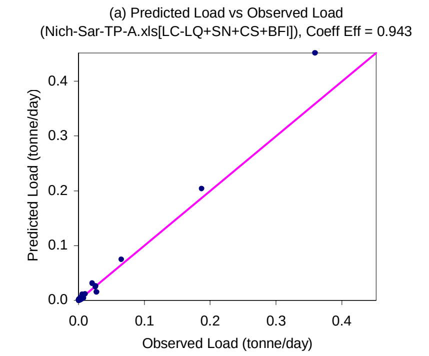
APPENDIX A-2

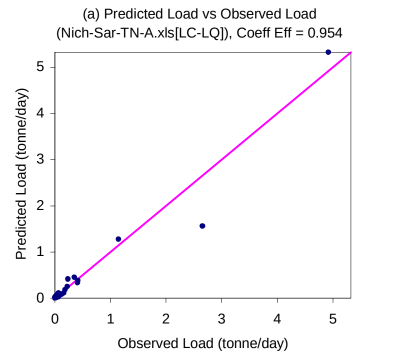
Appendix A-2(i): Final Load Efficiency Plots for Tambo @ Battens Landing (Method A: Without Flow Stratification)

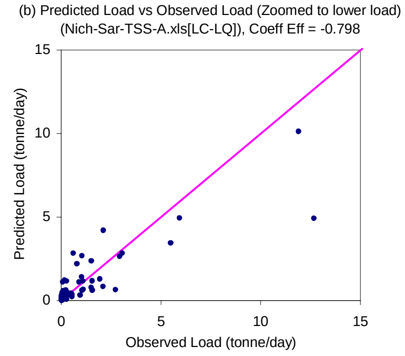


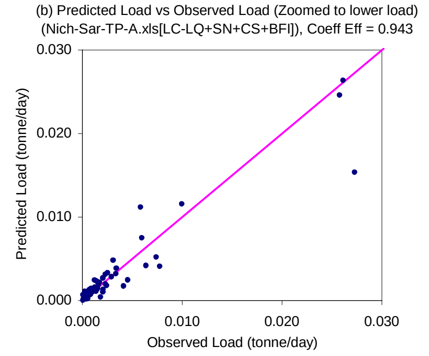
Appendix A-2(ii): Final Load Efficiency Plots for Nicholson @ Sarsfield (Method A: Without Flow Stratification)

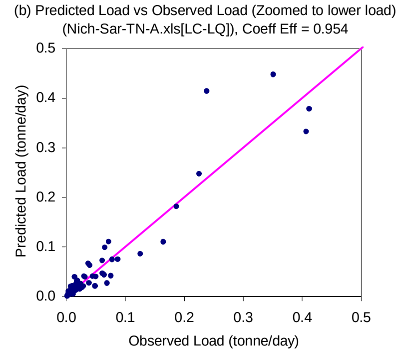


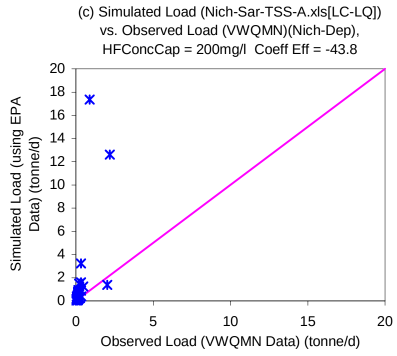


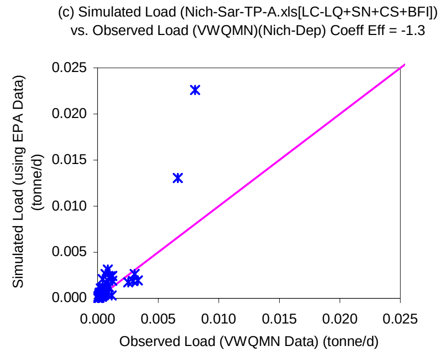


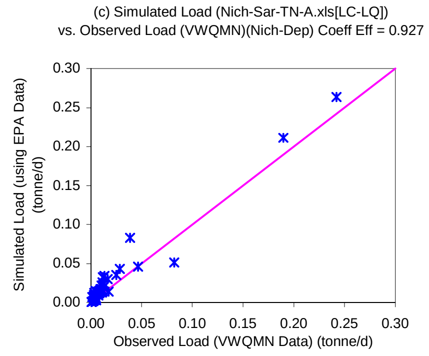




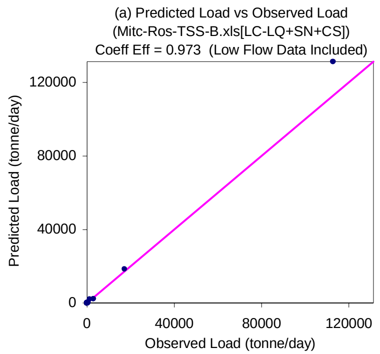


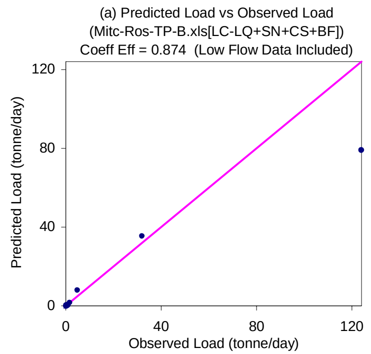


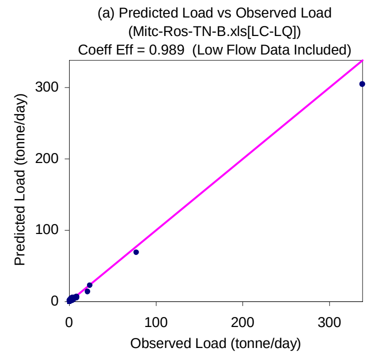


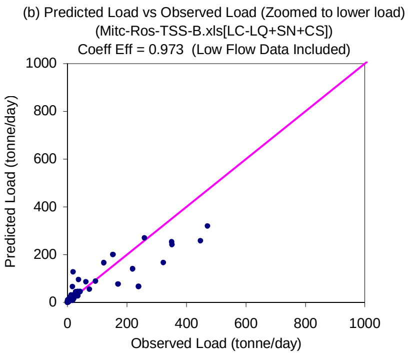


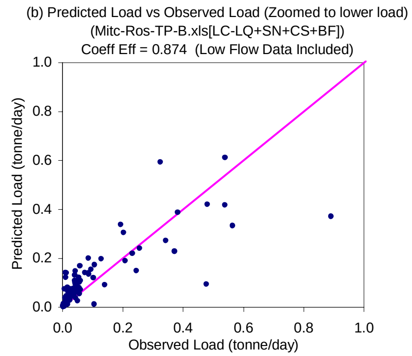
Appendix A-2(iii): Final Load Plots for Mitchell @ Rosehill (Method B: With Flow Stratification at Q=630ML/day)

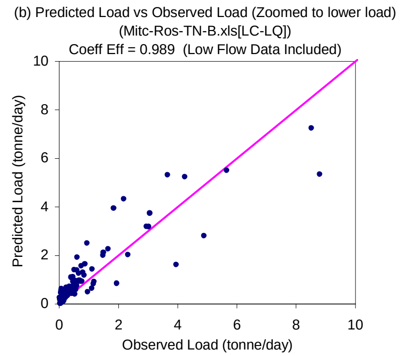


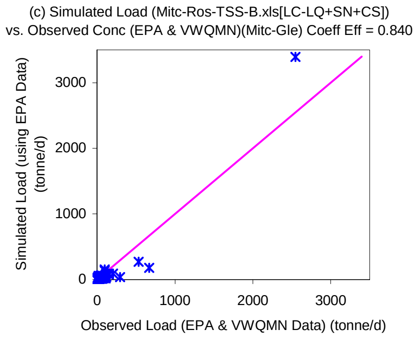


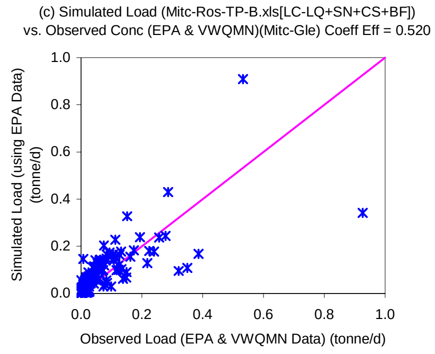


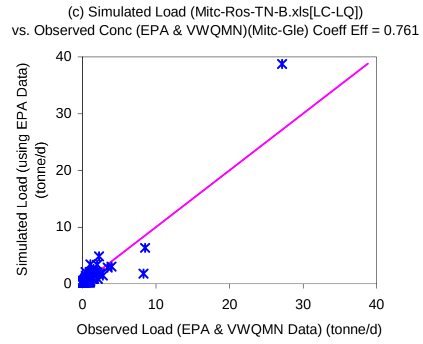






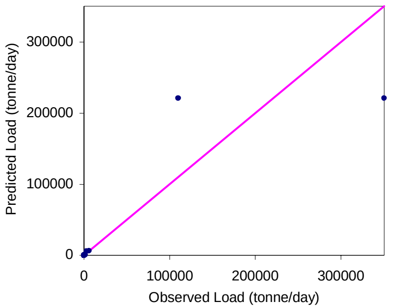




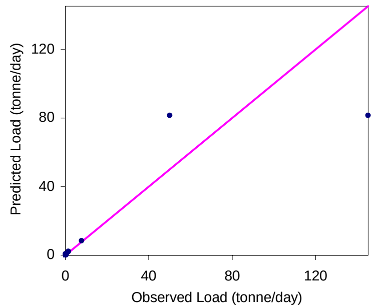


Appendix A-2(iv): Final Load Efficiency Plots for Avon @ Stratford (Method B: With Flow Stratification at Q=1585ML/day)

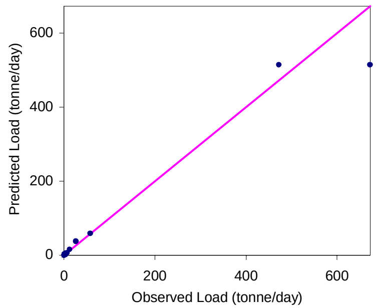
(a) Predicted Load vs Observed Load (Avon-Str-TSS-B.xls[LC-LQ])
Coeff Eff = 0.782 (Low Flow Data Included)



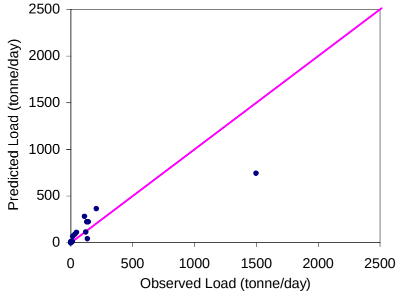
(a) Predicted Load vs Observed Load (Avon-Str-TP-B.xls[LC-LQ+LQ30]),
Coeff Eff = 0.783 (Low Flow Data Included)



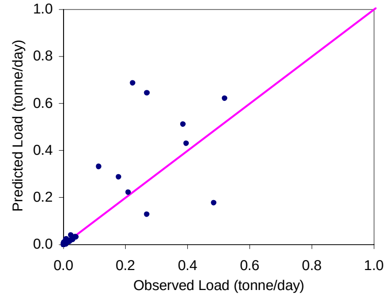
(a) Predicted Load vs Observed Load (Avon-Str-TN-B.xls[LC-LQ+LQ30]),
Coeff Eff = 0.959 (Low Flow Data Included)



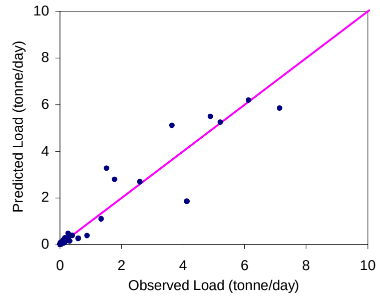
(b) Predicted Load vs Observed Load (Zoomed to lower load)
(Avon-Str-TSS-B.xls[LC-LQ])
Coeff Eff = 0.782 (Low Flow Data Included)



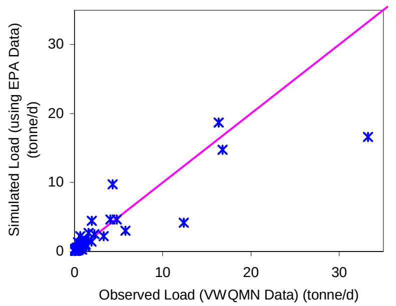
(b) Predicted Load vs Observed Load (Zoomed to lower load)
(Avon-Str-TP-B.xls[LC-LQ+LQ30])
Coeff Eff = 0.783 (Low Flow Data Included)



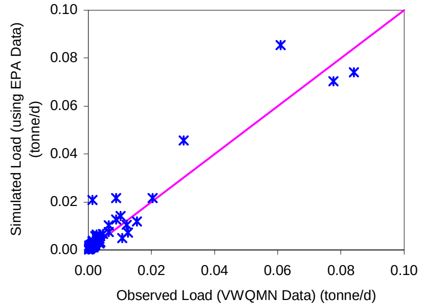
(b) Predicted Load vs Observed Load (Zoomed to lower load)
(Avon-Str-TN-B.xls[LC-LQ+LQ30])
Coeff Eff = 0.959 (Low Flow Data Included)



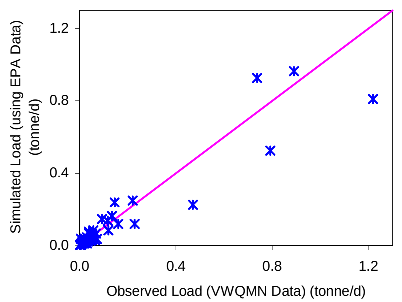
(c) Simulated Load (Avon-Str-TSS-B.xls[LC-LQ])
vs. Observed Conc (VWQMN)(Avon-Str) Coeff Eff = 0.763



(c) Simulated Load (Avon-Str-TP-B.xls[LC-LQ+LQ30])
vs. Observed Conc (VWQMN)(Avon-Str) Coeff Eff = 0.895

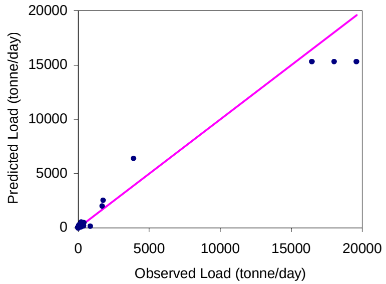


(c) Simulated Load (Avon-Str-TN-B.xls[LC-LQ+LQ30])
vs. Observed Conc (VWQMN)(Avon-Str) Coeff Eff = 0.885

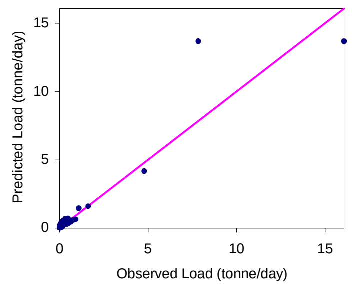


Appendix A-2(v): Final Load Plots for Thomson @ Bundalaguah (Method B: With Flow Stratification at Q=1000ML/day)

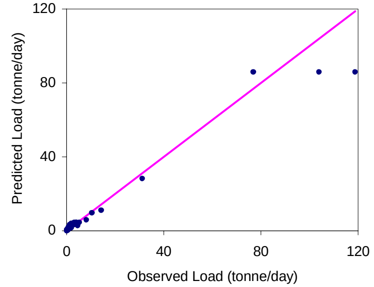
(a) Predicted Load vs Observed Load
(Thom-Bun-TSS-B.xls[LC-LQ+SN+CS])
Coeff Eff = 0.964 (Low Flow Data Included)



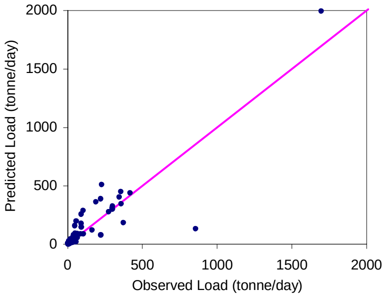
(a) Predicted Load vs Observed Load
(Thom-Bun-TP-B.xls[LC-LQ+SN+CS+BF])
Coeff Eff = 0.877 (Low Flow Data Included)



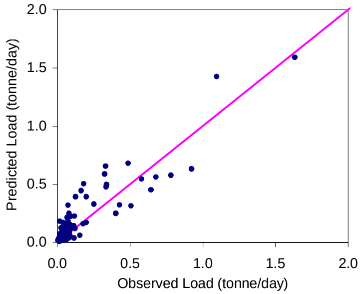
(a) Predicted Load vs Observed Load
(Thom-Bun-TN-B.xls[LC-LQ+SN+CS+BF])
Coeff Eff = 0.95 (Low Flow Data Included)



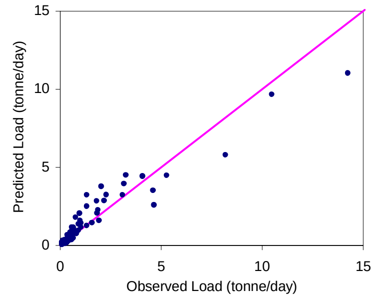
(b) Predicted Load vs Observed Load (Zoomed to lower load)
(Thom-Bun-TSS-B.xls[LC-LQ+SN+CS])
Coeff Eff = 0.964 (Low Flow Data Included)



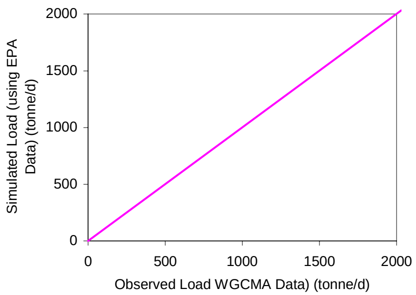
(b) Predicted Load vs Observed Load (Zoomed to lower load)
(Thom-Bun-TP-B.xls[LC-LQ+SN+CS+BF])
Coeff Eff = 0.877 (Low Flow Data Included)



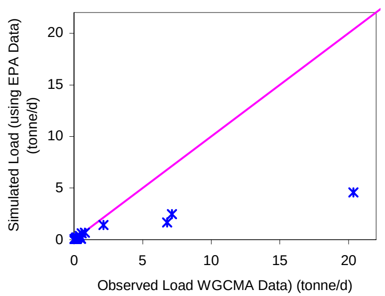
(b) Predicted Load vs Observed Load (Zoomed to lower load)
(Thom-Bun-TN-B.xls[LC-LQ+SN+CS+BF])
Coeff Eff = 0.95 (Low Flow Data Included)



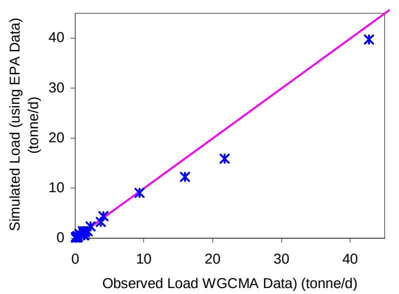
(c) Simulated Load (Thom-Bun-TSS-B.xls[LC-LQ+SN+CS])
vs. Observed Load (WGCMA)(Thomson-Bun)
Coeff Eff = Verification Data Not Available



(c) Simulated Load (Thom-Bun-TP-B.xls[LC-LQ+SN+CS+BF])
vs. Observed Load (WGCMA)(Thomson-Bun) Coeff Eff = 0.412

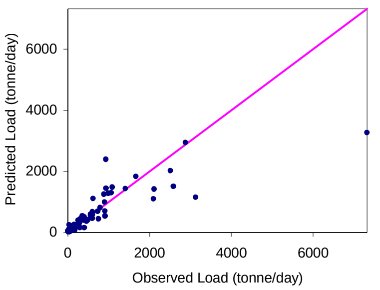


(c) Simulated Load (Thom-Bun-TN-B.xls[LC-LQ+SN+CS+BF])
vs. Observed Load (WGCMA)(Thomson-Bun) Coeff Eff = 0.976

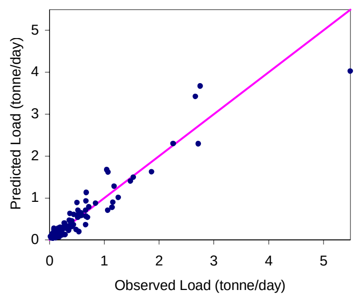


Appendix A-2(vi): Final Load Efficiency Plots for Latrobe @ Kilmany South
(Method A: Without Flow Stratification for TSS & TN) (Method B: With Flow Stratification at Q=1000ML/day for TP)

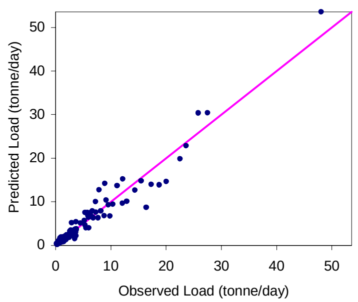
(a) Predicted Load vs Observed Load
(Latr-Kil-TSS-A.xls[LC-LQ+LBF]), Coeff Eff = 0.719



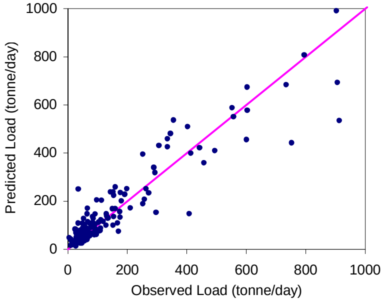
(a) Predicted Load vs Observed Load (Latr-Kil-TP-B.xls[LC-LQ+SN+CS]),
Coeff Eff = 0.904 (Low Flow Data Included)



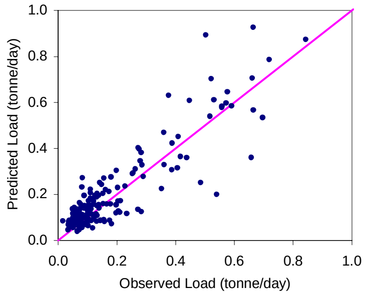
(a) Predicted Load vs Observed Load
(Latr-Kil-TN-A.xls[LC-LQ]), Coeff Eff = 0.947



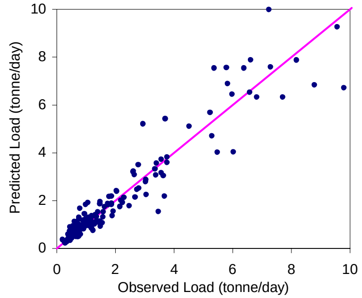
(b) Predicted Load vs Observed Load (Zoomed to lower load)
(Latr-Kil-TSS-A.xls[LC-LQ+LBF]), Coeff Eff = 0.719



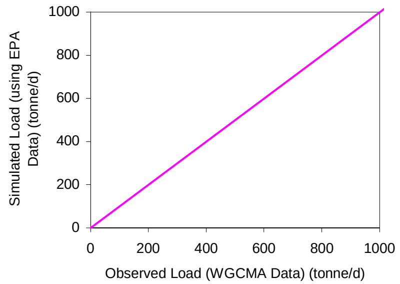
(b) Predicted Load vs Observed Load (Zoomed to lower load)
(Latr-Kil-TP-B.xls[LC-LQ+SN+CS])
Coeff Eff = 0.904 (Low Flow Data Included)



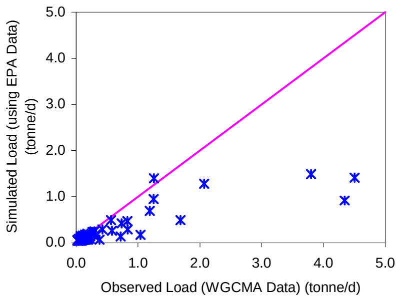
(b) Predicted Load vs Observed Load (Zoomed to lower load)
(Latr-Kil-TN-A.xls[LC-LQ]), Coeff Eff = 0.947



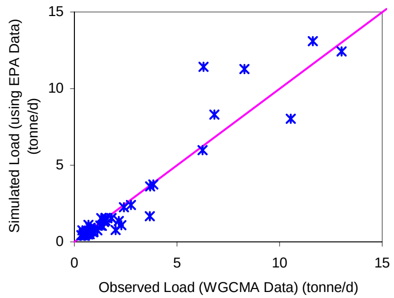
(c) Simulated Load (Latr-Kil-TSS-B.xls[LC-LQ+SN+CS])
vs. Observed Load (WGCMA)(Latr-Kil)
Coeff Eff = Verification Data Not Available



(c) Simulated Load (Latr-Kil-TP-B.xls[LC-LQ+SN+CS])
vs. Observed Load (WGCMA)(Latr-Kil) Coeff Eff = 0.497



(c) Simulated Load (Latr-Kil-TN-B.xls[LC-LQ])
vs. Observed Load (WGCMA)(Latr-Kil) Coeff Eff = 0.880



APPENDIX B-1

Appendix B-1(i): Summary of Load Comparison for Tambo @ Battens Landing

Site	Constituent	Method	Load Estimates (Tonnes/year) 77/78	78/79	80/81	84/85	88/89	89/90	Average
EPA WQ Sampling Station used for Comparison			Tambo @ Battens Landing	Tambo @ Battens Landing	Tambo @ Battens Landing	Tambo @ Battens Landing	Tambo @ Battens Landing	Tambo @ Battens Landing	-
EPA WQ Sampling Frequency			Semi-monthly	Monthly	Monthly	Monthly	Weekly	Weekly	-
EPA WQ Sampling Coverage			Some high flows not sampled	Good	Most high flows not sampled	The only high flow not sampled	Good	Good	-
Max Flow recorded during EPA WQ Sampling Period (ML/d)			59,000	4,200	1,000	43,000	66,000	20,000	-
Max Flow captured with EPA WQ Sampling Point (ML/d)			24,000	1,600	170	2,200	66,000	9,400	-
Tambo @ Battens Landing	**TSS**	**EPA**	21,172	1,737	49	874	5,074	4,359	5,544
		CEAH(A1)#	45,002	1,051	267	12,148	17,573	5,655	13,616
		(Factor A1)*	**(2.1)** ^{ov}	(0.61)	**(5.4)** ^{ov}	**(13.9)** ^{ov}	**(3.5)** ^{ov}	(1.3)	**(2.5)** ^{ov}
		CEAH(B2)	-	-	-	-	-	-	-
		(Factor B2)*	-	-	-	-	-	-	-
	TP	**EPA**	29	2.6	0.2	3.7	9.4	14	9.9
		CEAH(A1)#	54	3.2	1.1	17	21	11	18
		(Factor A1)*	(1.9)	(1.2)	**(5.5)** ^{ov}	**(4.6)** ^{ov}	**(2.2)** ^{ov}	(0.8)	(1.8)
		CEAH(B2)	-	-	-	-	-	-	-
		(Factor B2)*	-	-	-	-	-	-	-
	TN	**EPA**	403	87	4.0	84	150	217	156
		CEAH(A1)#	778	54	19	251	295	180	263
		(Factor A1)*	(1.9)	(0.62)	**(4.8)** ^{ov}	**(3.0)** ^{ov}	(2.0)	(0.83)	(1.7)
		CEAH(B2)	-	-	-	-	-	-	-
		(Factor B2)*	-	-	-	-	-	-	-

# denotes method adopted for final load estimation.
* denotes factor computed based on ratio of CEAH (This Study) estimates upon EPA estimates.
^{ov} denotes load estimates with a factor of more than 2.0 (over prediction).
A denotes load estimates without flow stratification based on multiple linear regression analyses using all high & low flow data.
B denotes load estimates with flow stratification based on multiple linear regression analyses using high flow data only and taking average concentration for low flow data.
1 denotes load estimates without any adjustment to the predicted concentration.
2 denotes load estimates with some minor adjustments to the predicted concentrations (e.g. high flow min. conc. and high flow conc. cap).

Appendix B-1(ii): Summary of Load Comparison for Nicholson @ Sarsfield

Site	Constituent	Method	Load Estimates (Tonnes/year)						
			77/78	78/79	80/81	84/85	88/89	89/90	Average
EPA WQ Sampling Station used for Comparison			Nicholson @ Sarsfield	Nicholson @ Sarsfield	Nicholson @ Sarsfield	Nicholson @ Sarsfield	-	-	-
EPA WQ Sampling Frequency			Semi-monthly	Monthly	Monthly	Monthly	-	-	-
EPA WQ Sampling Coverage			Some high flows not sampled	The only high flow not sampled	Most high flows not sampled	Most high flows not sampled	-	-	-
Max Flow recorded during EPA WQ Sampling Period (ML/d)			21,000	3,700	150	13,000	20,000	17,000	-
Max Flow captured with EPA WQ Sampling Point (ML/d)			5,500	640	30	600	-	-	-
Nicholson @ Sarsfield	TSS	**EPA**	6,881	509	5.0	119	-	-	1,879
		CEAH(A1)	53,416	1,787	46	13,514	16,656	16,442	17,190
		(Factor A1)*	**(7.8)** ^{ov}	**(3.5)** ^{ov}	**(9.2)** ^{ov}	**(114)** ^{ov}	-	-	**(9.1)** ^{ov}
		CEAH(A2)#	29,225	1,787	46	7,902	7,121	8,978	9177
		(Factor A2)*	**(4.2)** ^{ov}	**(3.5)** ^{ov}	**(9.2)** ^{ov}	**(66)** ^{ov}	-	-	**(4.9)** ^{ov}
	TP	**EPA**	5.2	0.7	0.07	0.4	-	-	1.6
		CEAH(A1)#	28	2.0	0.2	7.1	8.3	10	9
		(Factor A1)*	**(5.4)** ^{ov}	**(2.9)** ^{ov}	**(2.9)** ^{ov}	**(17.8)** ^{ov}	-	-	**(5.6)** ^{ov}
		CEAH(B2)	-	-	-	-	-	-	-
		(Factor B2)*	-	-	-	-	-	-	-
	TN	**EPA**	80	15	0.8	10	-	-	27
		CEAH(A1)#	181	20	2.7	56	50	65	62
		(Factor A1)*	**(2.3)** ^{ov}	(1.3)	**(3.4)** ^{ov}	**(5.6)** ^{ov}	-	-	**(2.3)** ^{ov}
		CEAH(B2)	-	-	-	-	-	-	-
		(Factor B2)*	-	-	-	-	-	-	-

# denotes method adopted for final load estimation.
* denotes factor computed based on ratio of CEAH (This Study) estimates upon EPA estimates.
^{ov} denotes load estimates with a factor of more than 2.0 (over prediction).
A denotes load estimates without flow stratification based on multiple linear regression analyses using all high & low flow data.
B denotes load estimates with flow stratification based on multiple linear regression analyses using high flow data only and taking average concentration for low flow data.
1 denotes load estimates without any adjustment to the predicted concentration.
2 denotes load estimates with some minor adjustments to the predicted concentrations (e.g. high flow min. conc. and high flow conc. cap).

Appendix B-1(iii): Summary of Load Comparison for Mitchell @ Rosehill

Site	Constituent	Method	Load Estimates (Tonnes/year)						
			77/78	78/79	80/81	84/85	88/89	89/90	Average
EPA WQ Sampling Station used for Comparison			Mitchell @ Iguana Creek	Mitchell @ Iguana Creek	Mitchell @ Iguana Creek	Mitchell @ Iguana Creek	Mitchell @ Rosehill	Mitchell @ Rosehill	-
EPA WQ Sampling Frequency			Semi-monthly	Monthly	Monthly	Monthly	Weekly	Weekly	-
EPA WQ Sampling Coverage			Some high flows not sampled	Some high flows not sampled	Some high flows not sampled	Some high flows not sampled	Good	Good	-
Max Flow recorded during EPA WQ Sampling Period (ML/d)			60,000	12,000	9,600	33,000	24,000	110,000	-
Max Flow captured with EPA WQ Sampling Point (ML/d)			33,000	7,100	4,900	11,000	24,000	110,000	-
Mitchell @ Rosehill	**TSS**	**EPA**	48,960	18,829	1,266	16,466	15,363	109,217	35,017
		CEAH(A1) (Factor A1)*	53,640 (1.1)	7,378 (0.39)	2,232 (1.8)	8,509 (0.52)	15,718 (1.02)	223,971 **(2.1)**[ov]	51,908 (1.5)
		CEAH(B2)# (Factor B2)*	70,980 (1.5)	8,106 (0.43)	2,407 (1.9)	9,017 (0.55)	14,151 (0.86)	164,130 (1.5)	44,799 (1.3)
	TP	**EPA**	46	30	7.7	27	30	152	49
		CEAH(A1) (Factor A1)*	72 (1.6)	22 (0.73)	8.6 (1.1)	20 (0.74)	38 (1.3)	135 (0.89)	49 (1.0)
		CEAH(B2)# (Factor B2)*	128 **(2.8)**[ov]	24 (0.80)	14 (1.82)	25 (0.93)	35 (1.17)	157 (1.03)	64 (1.3)
	TN	**EPA**	492	376	79	288	304	615	359
		CEAH(A1) (Factor A1)*	506 (1.03)	181 (0.48)	99 (1.3)	212 (0.74)	309 (1.02)	687 (1.1)	332 (0.92)
		CEAH(B2)# (Factor B2)*	758 (1.5)	232 (0.62)	132 (1.7)	307 (1.07)	337 (1.11)	725 (1.2)	415 (1.16)

# denotes method adopted for final load estimation.
* denotes factor computed based on ratio of CEAH (This Study) estimates upon EPA estimates.
[ov] denotes load estimates with a factor of more than 2.0 (over prediction).
A denotes load estimates without flow stratification based on multiple linear regression analyses using all high & low flow data.
B denotes load estimates with flow stratification based on multiple linear regression analyses using high flow data only and taking average concentration for low flow data.
1 denotes load estimates without any adjustment to the predicted concentration.
2 denotes load estimates with some minor adjustments to the predicted concentrations (e.g. high flow min. conc. and high flow conc. cap).

Appendix B-1(iv): Summary of Load Comparison for Avon @ Stratford

Site	Constituent	Method	77/78	78/79	80/81	84/85	88/89	89/90	Average
			Load Estimates (Tonnes/year)						
EPA WQ Sampling Station used for Comparison			Avon @ Clyde-bank	Avon @ Clyde-bank	Avon @ Clyde-bank	Avon @ Clyde-bank	Avon @ Stratford	Avon @ Stratford	-
EPA WQ Sampling Frequency			Semi-monthly	Monthly	Monthly	Monthly	Weekly	Weekly	-
EPA WQ Sampling Coverage			Some high flows not sampled	Some high flows not sampled	Some high flows not sampled	Most high flows not sampled	Good	Good	-
Max Flow recorded during EPA WQ Sampling Period (ML/d)			82,000	12,000	260	52,000	32,000	170,000	-
Max Flow captured with EPA WQ Sampling Point (ML/d)			22,000	1,200	120	600	32,000	170,000	-
Avon @ Stratford	**TSS**	**EPA**	56,257	1,966	235	1,147	10,358	261,035	55,166
		CEAH(A1) (Factor A1)*	56,128 (1.00)	1,132 (0.58)	184 (0.78)	11,370 **(9.9)**^{ov}	4,939 (0.48)	330,697 (1.3)	67,408 (1.2)
		CEAH(B2)# (Factor B2)*	141,236 **(2.5)**^{ov}	1,592 (0.81)	141 (0.60)	33,738 **(29)**^{ov}	12,232 (1.2)	243,931 (0.93)	72,145 (1.3)
	TP	**EPA**	31	2.3	0.7	1.8	17	95	25
		CEAH(A1) (Factor A1)*	82 **(2.7)**^{ov}	2.8 (1.2)	0.7 (1.0)	10.4 **(5.8)**^{ov}	7.2 (0.42)	72 (0.76)	29 (1.2)
		CEAH(B2)# (Factor B2)*	141 **(4.5)**^{ov}	3.6 (1.6)	0.7 (1.0)	21 **(12)**^{ov}	14 (0.82)	68 (0.72)	41.4 (1.7)
	TN	**EPA**	169	60	10	25	231	778	212
		CEAH(A1) (Factor A1)*	764 **(4.5)**^{ov}	52 (0.87)	6 (0.60)	219 **(8.8)**^{ov}	146 (0.63)	790 (1.02)	330 (1.6)
		CEAH(B2)# (Factor B2)*	1,035 **(6.1)**^{ov}	42 (0.68)	8 (0.80)	219 **(8.7)**^{ov}	149 (0.64)	574 (0.74)	338 (1.6)

\# denotes method adopted for final load estimation.
* denotes factor computed based on ratio of CEAH (This Study) estimates upon EPA estimates.
^{ov} denotes load estimates with a factor of more than 2.0 (over prediction).
A denotes load estimates without flow stratification based on multiple linear regression analyses using all high & low flow data.
B denotes load estimates with flow stratification based on multiple linear regression analyses using high flow data only and taking average concentration for low flow data.
1 denotes load estimates without any adjustment to the predicted concentration.
2 denotes load estimates with some minor adjustments to the predicted concentrations (e.g. high flow min. conc. and high flow conc. cap).

Appendix B-1(v): Summary of Load Comparison for Thomson @ Bundalaguah

Site	Constituent	Method	Load Estimates (Tonnes/year)						
			77/78	78/79	80/81	84/85	88/89	89/90	Average
EPA WQ Sampling Station used for Comparison			Thomson @Gibson Knox	Thomson @Bunda-laguah	Thomson @Bunda-laguah	Thomson @Gibson Knox	Thomson @Bunda-laguah	Thomson @Bunda-laguah	-
EPA WQ Sampling Frequency			Semi-monthly	Monthly	Monthly	Monthly	Weekly	Weekly	-
EPA WQ Sampling Coverage			Some high flows not sampled	Some high flows not sampled	Some high flows not sampled	Some high flows not sampled	Some high flows not sampled	Good	-
Max Flow recorded during EPA WQ Sampling Period (ML/d)			43,000	15,000	5,700	12,000	8,900	39,000	-
Max Flow captured with EPA WQ Sampling Point (ML/d)			16,000	5,800	1,200	2,200	7,900	39,000	-
Thomson/ Macalister @ Bunda-laguah	TSS	EPA	199,843	39,415	4,684	13,168	17,899	139,512	69,086
		CEAH(A1) (Factor A1)*	148,459 (0.74)	17,399 (0.44)	5,026 (1.07)	19,845 (1.5)	16,975 (0.95)	54,108 (0.39)	43,635 (0.63)
		CEAH(B2)# (Factor B2)*	176,166 (0.88)	16,848 (0.43)	5,053 (1.08)	19,752 (1.5)	17,877 (1.00)	65,527 (0.47)	50,204 (0.73)
	TP	EPA	142	32	17	17	36	131	63
		CEAH(A1) (Factor A1)*	92 (0.65)	32 (1.00)	13 (0.76)	30 (1.8)	30 (0.83)	64 (0.49)	44 (0.70)
		CEAH(B2)# (Factor B2)*	108 (0.76)	35 (1.09)	17 (1.00)	42 **(2.5)** ov	37 (1.03)	88 (0.67)	55 (0.87)
	TN	EPA	785	277	97	140	263	1058	436
		CEAH(A1) (Factor A1)*	879 (1.1)	221 (0.80)	105 (1.08)	262 (1.9)	242 (0.92)	503 (0.48)	369 (0.85)
		CEAH(B2)# (Factor B2)*	727 (0.93)	220 (0.79)	107 (1.10)	278 (1.8)	255 (0.97)	577 (0.55)	361 (0.83)

# denotes method adopted for final load estimation.
* denotes factor computed based on ratio of CEAH (This Study) estimates upon EPA estimates.
ov denotes load estimates with a factor of more than 2.0 (over prediction).
A denotes load estimates without flow stratification based on multiple linear regression analyses using all high & low flow data.
B denotes load estimates with flow stratification based on multiple linear regression analyses using high flow data only and taking average concentration for low flow data.
1 denotes load estimates without any adjustment to the predicted concentration.
2 denotes load estimates with some minor adjustments to the predicted concentrations (e.g. high flow min. conc. and high flow conc. cap).

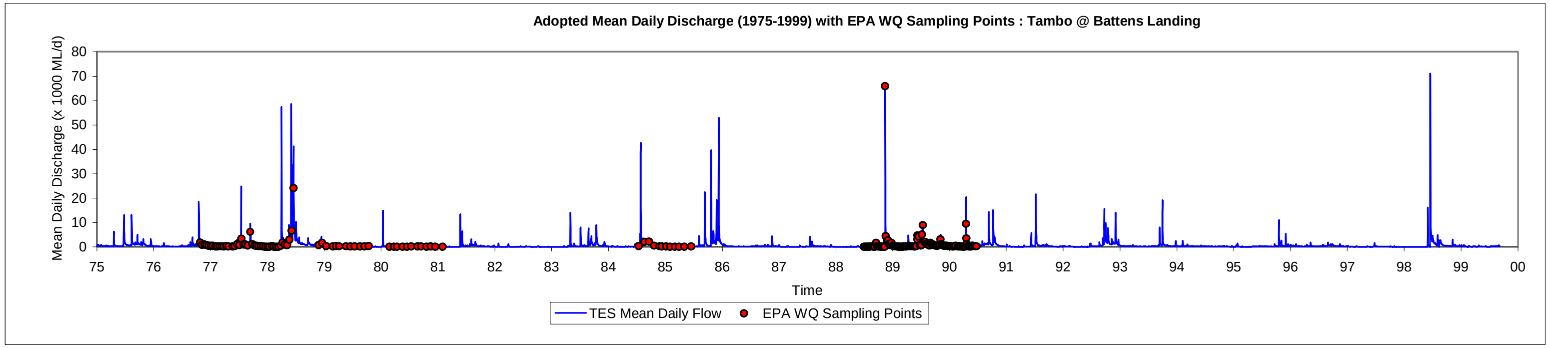
Appendix B-1(vi): Summary of Load Comparison for Latrobe @ Kilmany South

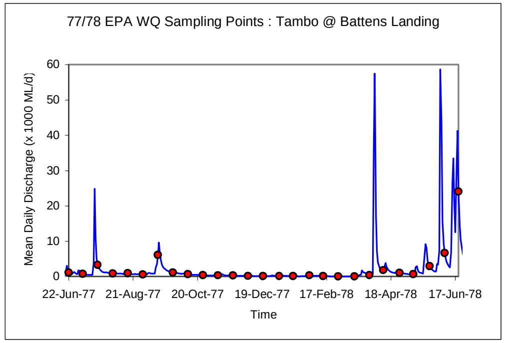
Site	Consti-tuent	Method	Load Estimates (Tonnes/year)						
			77/78	78/79	80/81	84/85	88/89	89/90	Average
EPA WQ Sampling Station used for Comparison			Latrobe @Kilmany South	Latrobe @Kilmany South	Latrobe @Kilmany South	Latrobe @Kilmany South	Latrobe @Kilmany South	Latrobe @Kilmany South	-
EPA WQ Sampling Frequency			Semi-monthly	Monthly	Monthly	Monthly	Weekly	Weekly	-
EPA WQ Sampling Coverage			Some high flows not sampled	Good	Some high flows not sampled	Some high flows not sampled	Good	Good	-
Max Flow recorded during EPA WQ Sampling Period (ML/d)			83,000	8,300	11,000	9,100	8,300	16,000	-
Max Flow captured with EPA WQ Sampling Point (ML/d)			23,000	7,500	4,700	5,300	8,300	15,000	-
Latrobe @ Kilmany South	**TSS**	**EPA**	221,226	60,985	38,517	47,014	52,290	64,853	80,814
		CEAH(A1)# (Factor A1)*	205,980 (0.93)	48,634 (0.80)	67,160 (1.7)	71,860 (1.5)	56,188 (1.07)	94,820 (1.5)	90,774 (1.1)
		CEAH(B2) (Factor B2)*	- -	- -	- -	- -	- -	- -	- -
	TP	**EPA**	223	80	66	56	74	120	103
		CEAH(A1) (Factor A1)*	217 (0.97)	73 (0.91)	94 (1.4)	99 (1.8)	83 (1.1)	128 (1.07)	116 (1.1)
		CEAH(B2)# (Factor B2)*	201 (0.90)	75 (0.94)	87 (1.3)	94 (1.7)	82 (1.11)	132 (1.10)	112 (1.09)
	TN	**EPA**	2,244	913	709	571	704	1,418	1,093
		CEAH(A1)# (Factor A1)*	2,462 (1.1)	655 (0.72)	906 (1.3)	973 (1.7)	744 (1.06)	1,304 (0.92)	1,174 (1.07)
		CEAH(B2) (Factor B2)*	- -	- -	- -	- -	- -	- -	- -

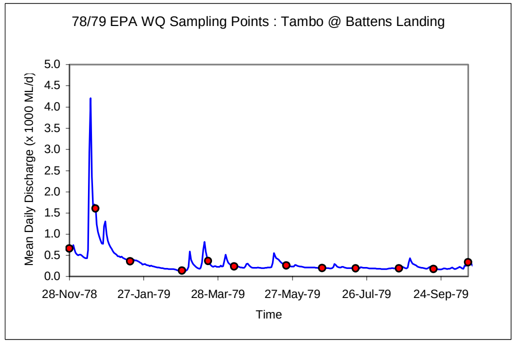
# denotes method adopted for final load estimation.
* denotes factor computed based on ratio of CEAH (This Study) estimates upon EPA estimates.
^{ov} denotes load estimates with a factor of more than 2.0 (over prediction).
A denotes load estimates without flow stratification based on multiple linear regression analyses using all high & low flow data.
B denotes load estimates with flow stratification based on multiple linear regression analyses using high flow data only and taking average concentration for low flow data.
1 denotes load estimates without any adjustment to the predicted concentration.
2 denotes load estimates with some minor adjustments to the predicted concentrations (e.g. high flow min. conc. and high flow conc. cap).

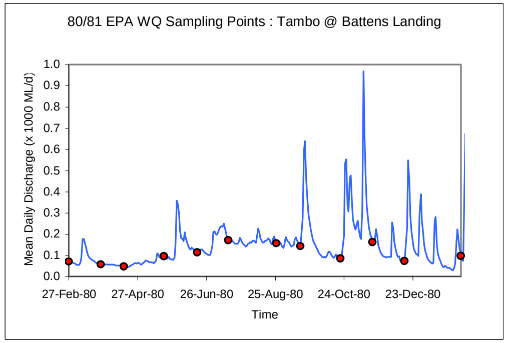
APPENDIX B-2

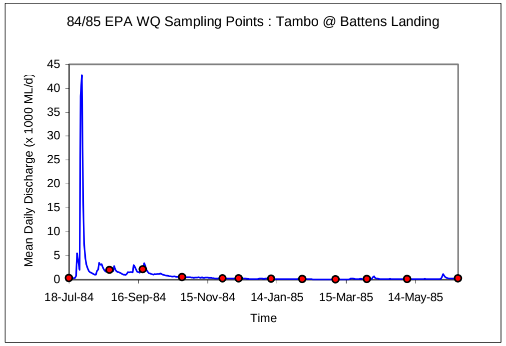
Appendix B-2(i): EPA WQ Sampling Points Superimposed on Mean Daily Discharge Hydrographs for Tambo @Battens Landings

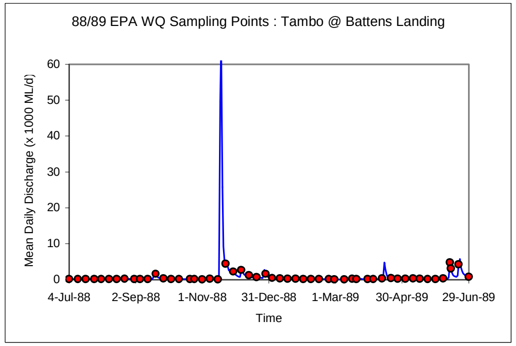


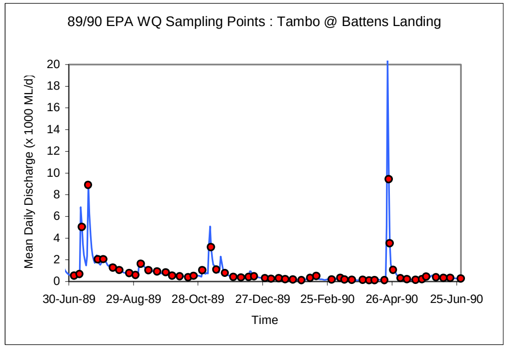




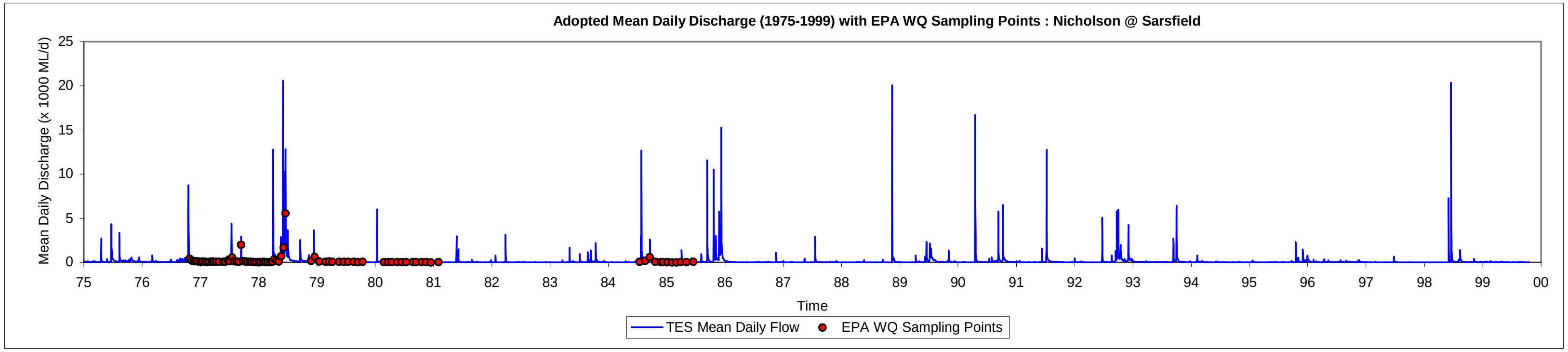


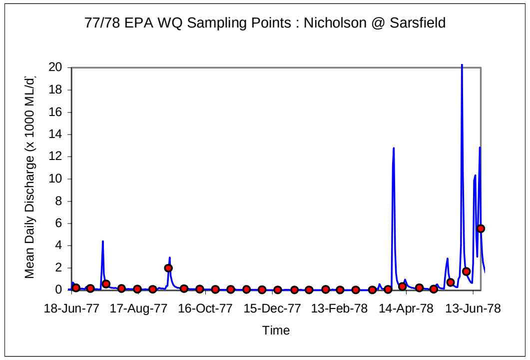


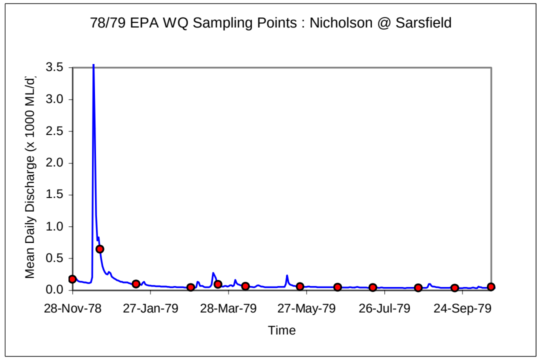


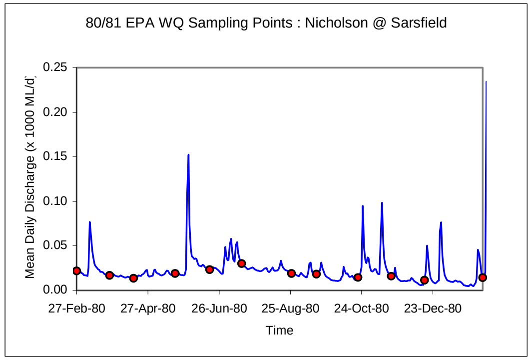


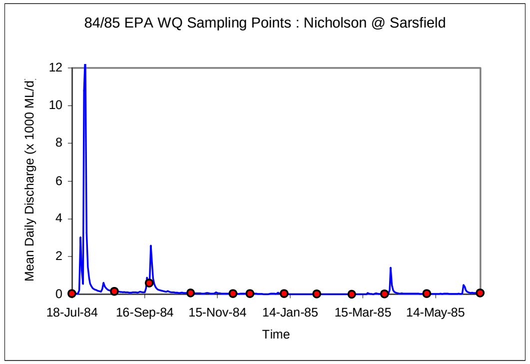
Appendix B-2(ii): EPA WQ Sampling Points Superimposed on Mean Daily Discharge Hydrographs for Nicholson @ Sarsfield

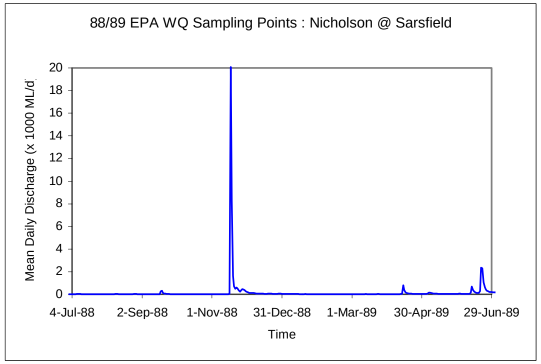


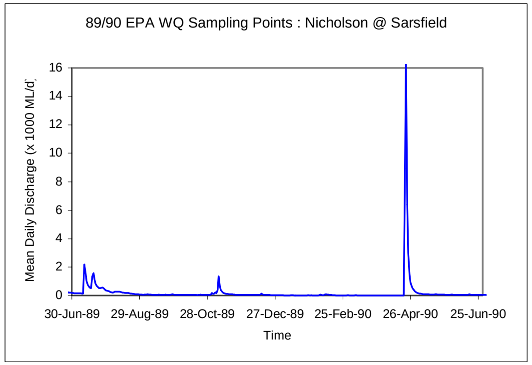




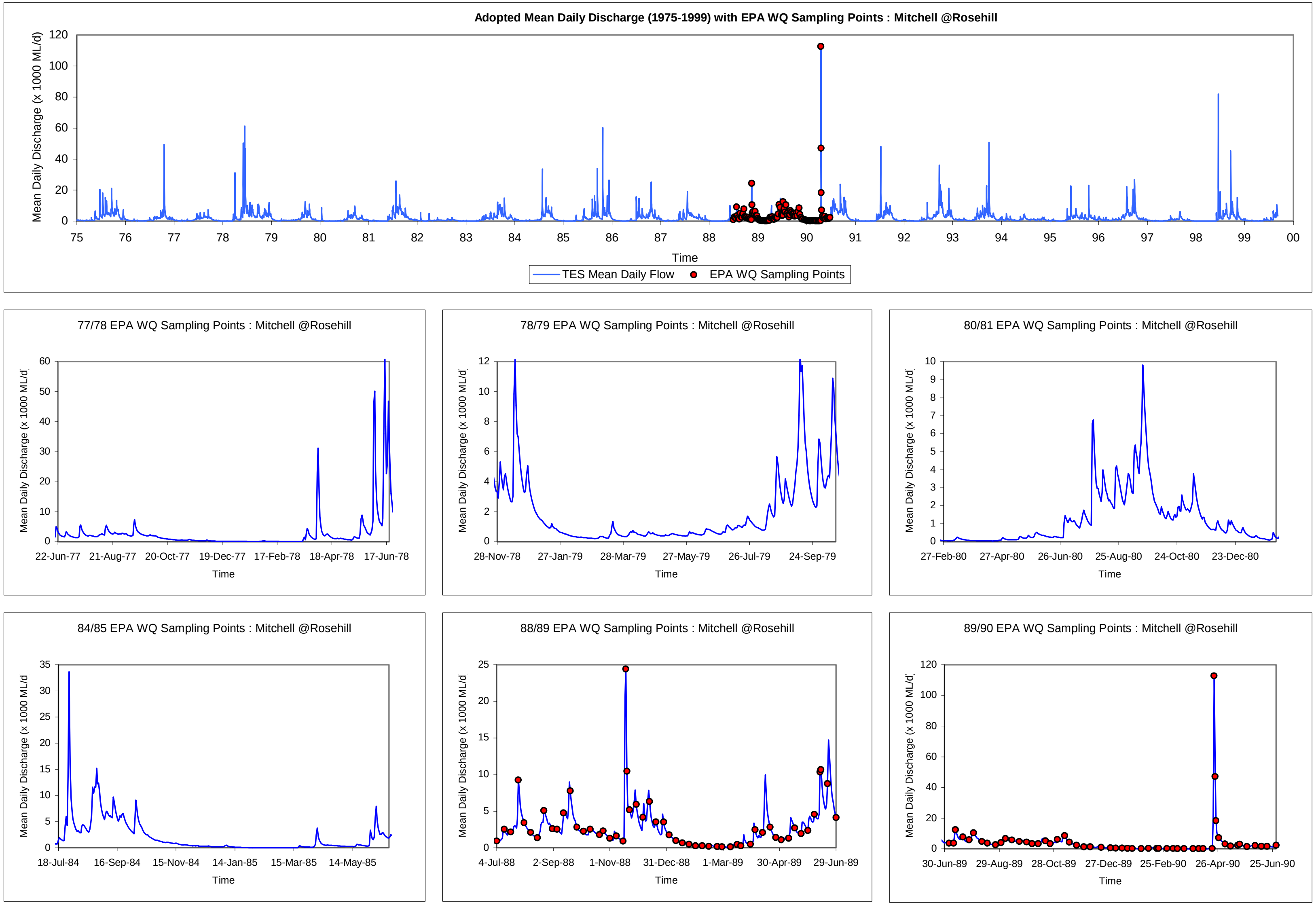




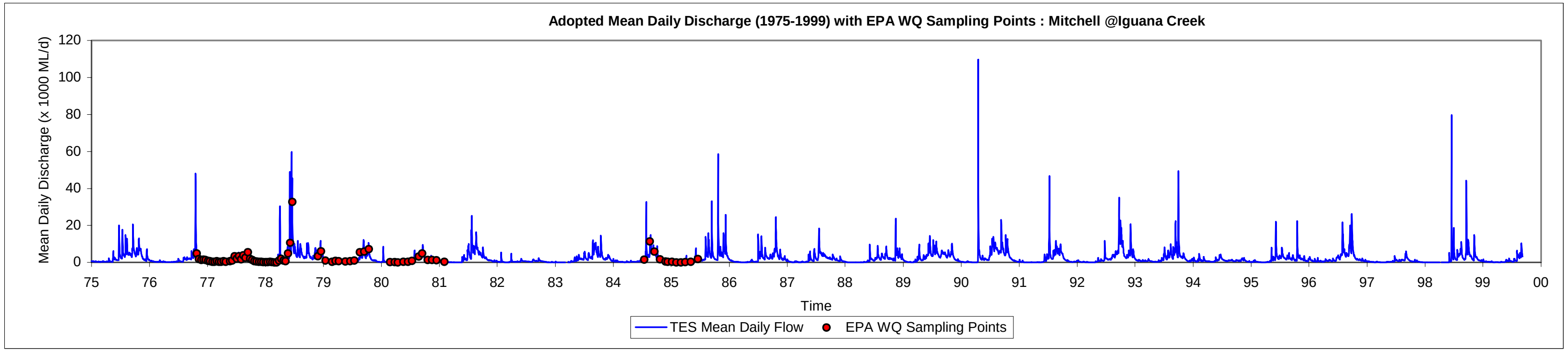


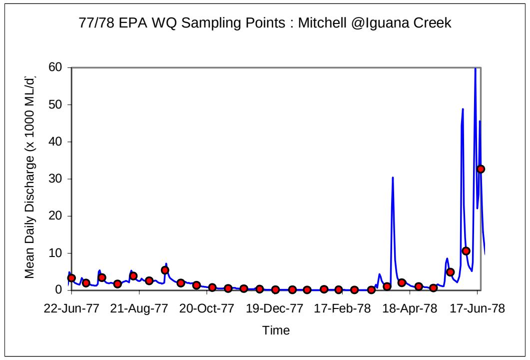


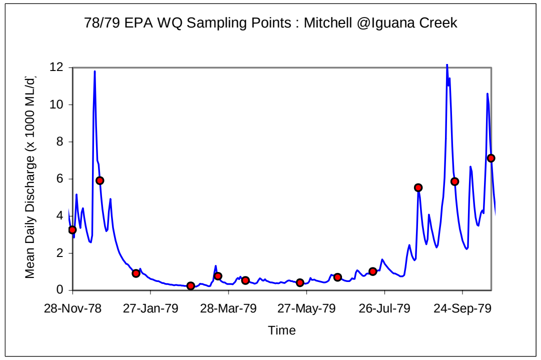
Appendix B-2(iii-a): EPA WQ Sampling Points Superimposed on Mean Daily Discharge Hydrographs for Mitchell @ Rosehill

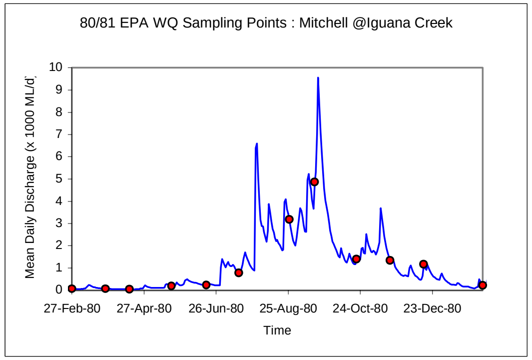


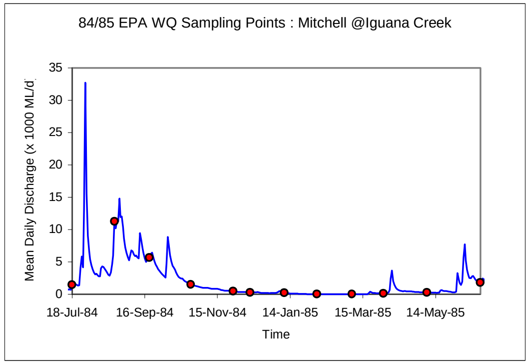
Appendix B-2(iii-b): EPA WQ Sampling Points Superimposed on Mean Daily Discharge Hydrographs for Mitchell @ Iguana Creek

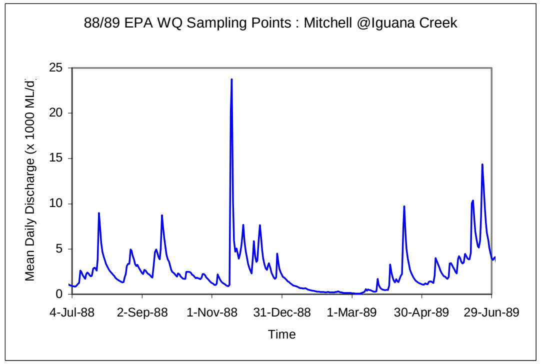


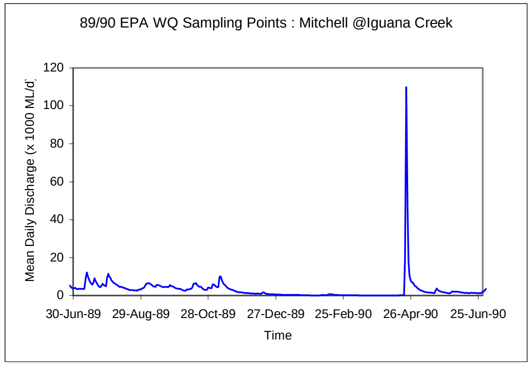




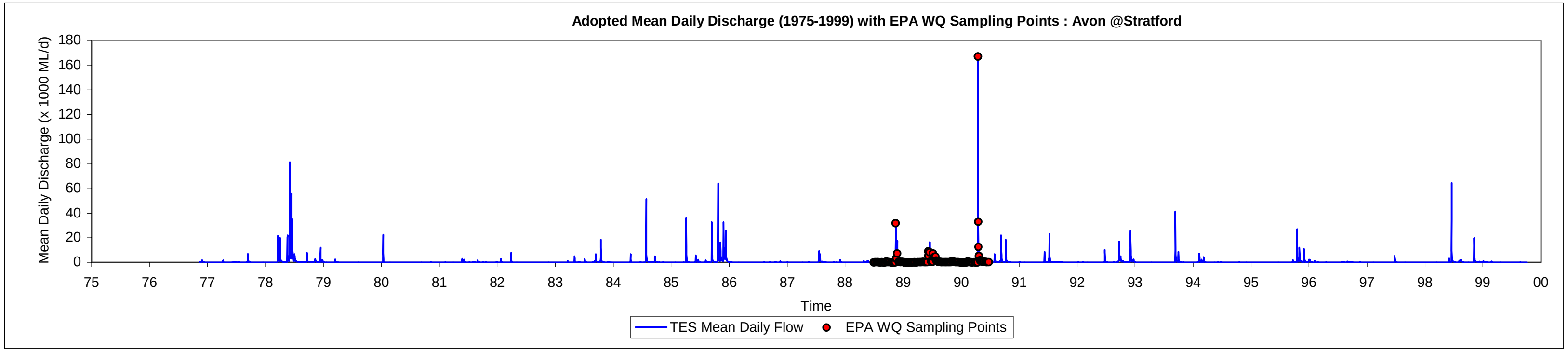


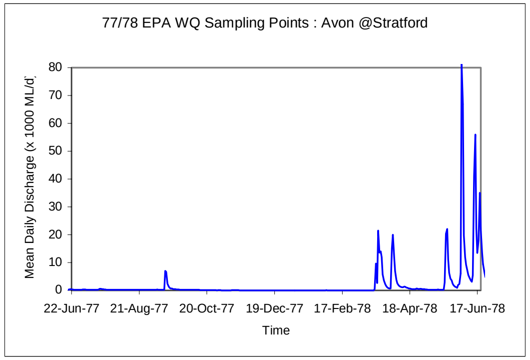


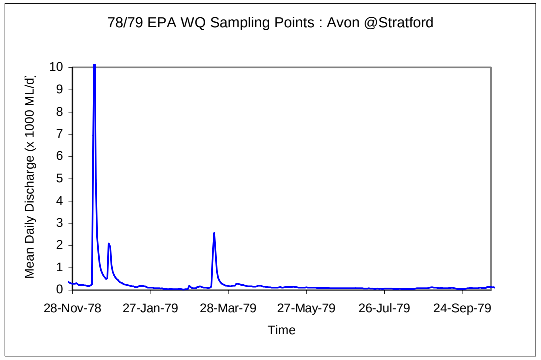


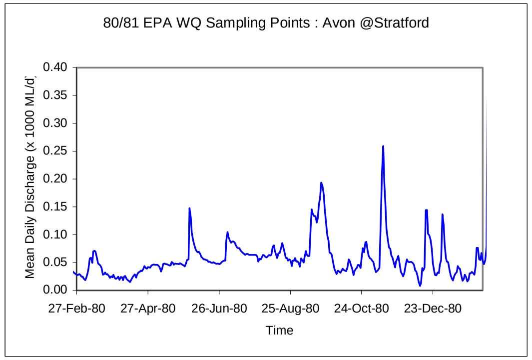


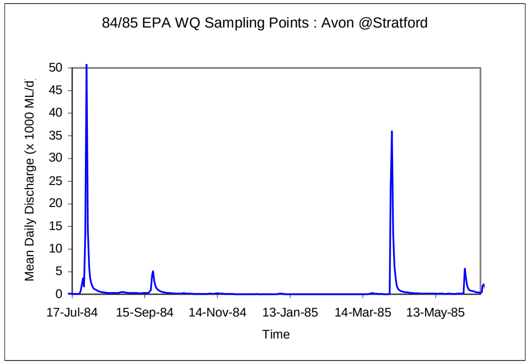
Appendix B-2(iv-a): EPA WQ Sampling Points Superimposed on Mean Daily Discharge Hydrographs for Avon @ Stratford

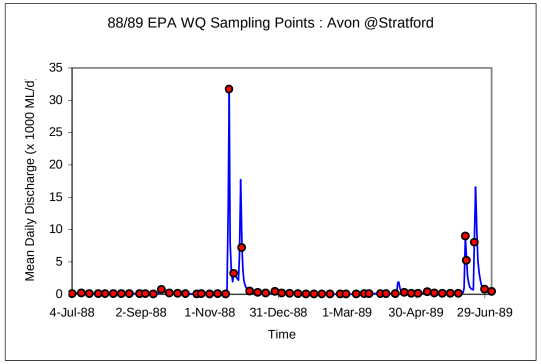


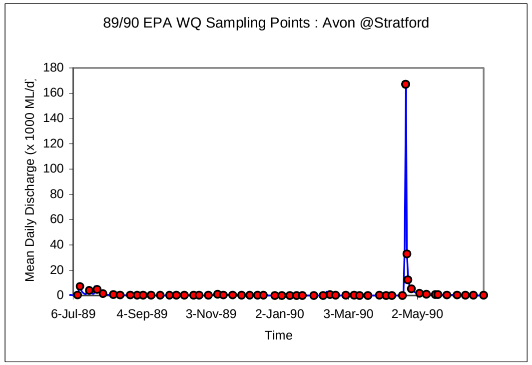




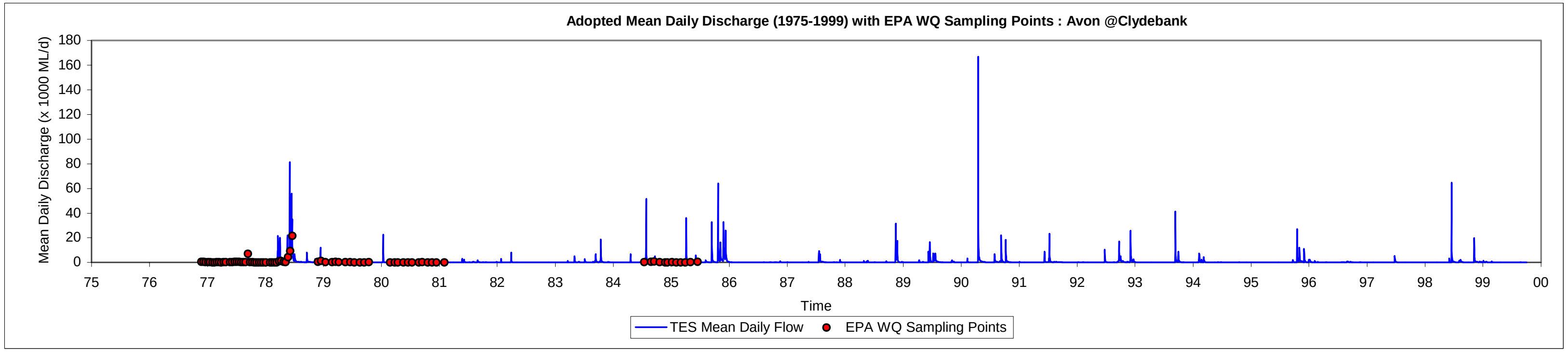


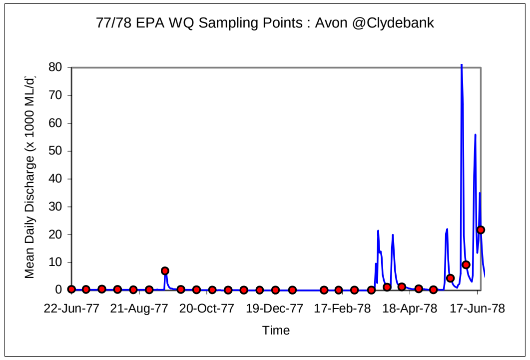


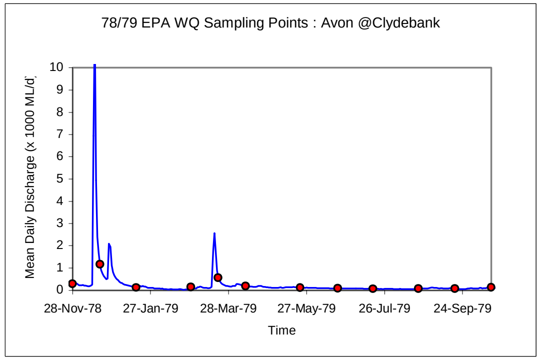


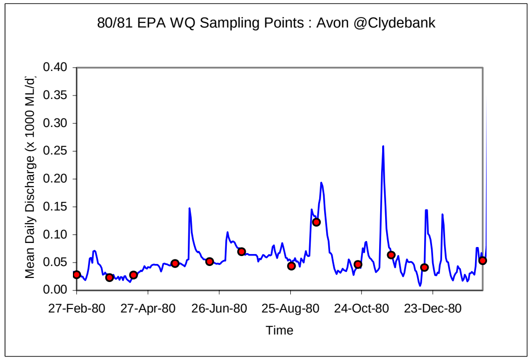


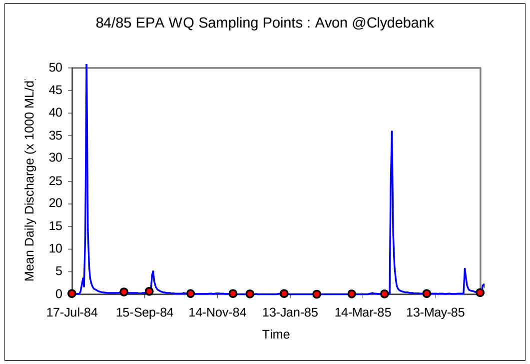
Appendix B-2(iv-b): EPA WQ Sampling Points Superimposed on Mean Daily Discharge Hydrographs for Avon @ Clydebank

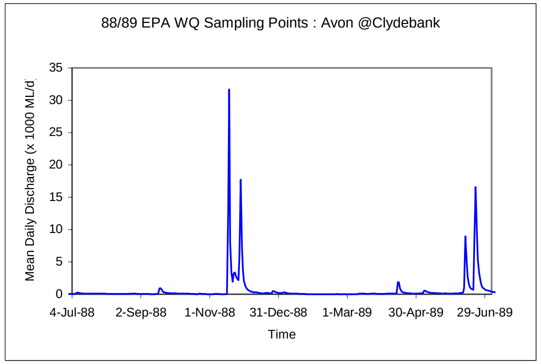


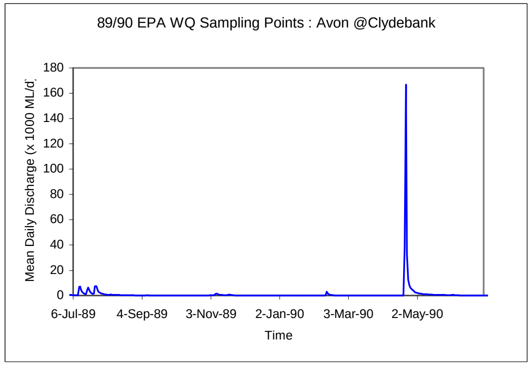




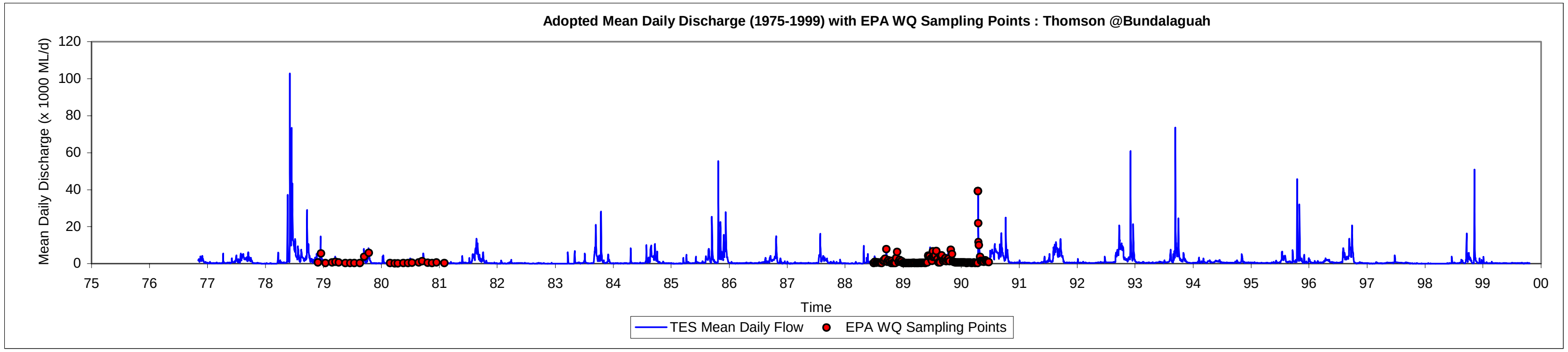


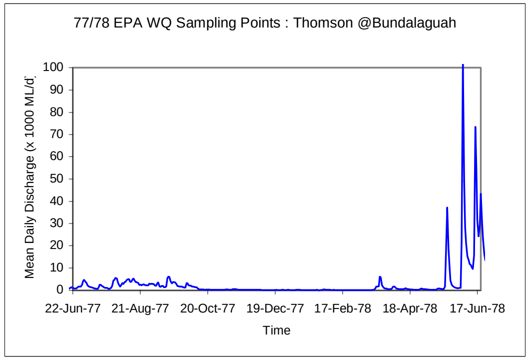


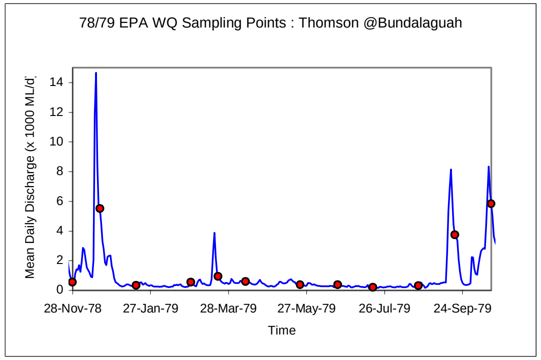


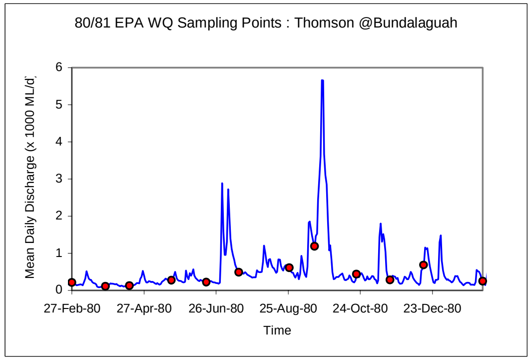


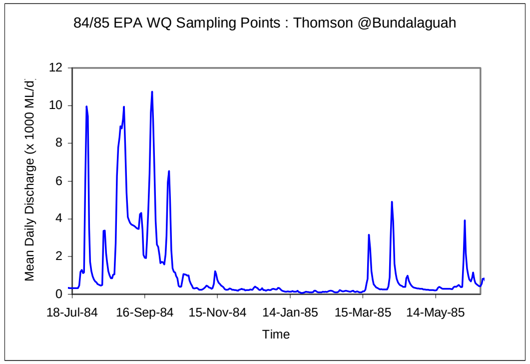
Appendix B-2(v-a) : EPA WQ Sampling Points Superimposed on Mean Daily Discharge Hydrographs for Thomson @ Bundalaguah

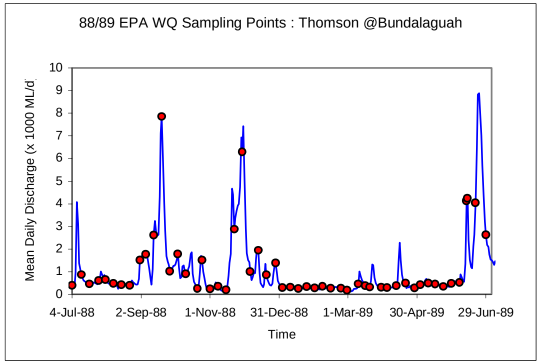


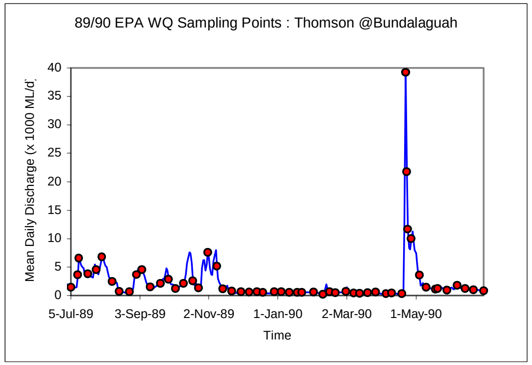




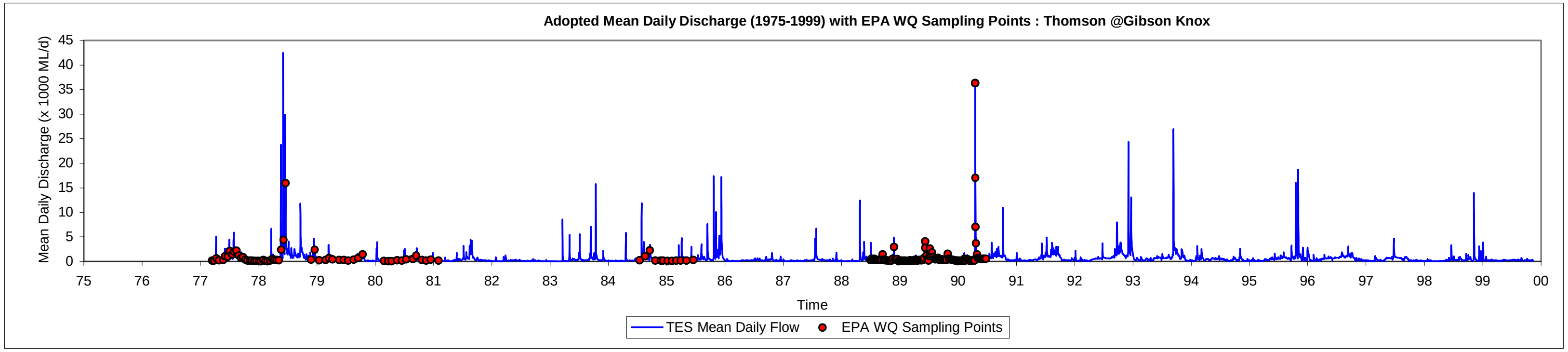


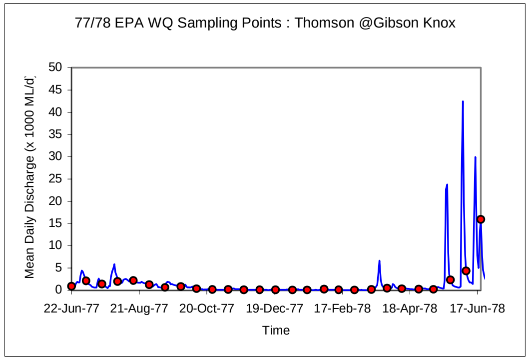


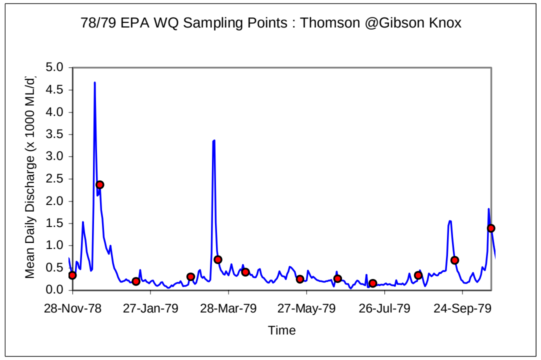


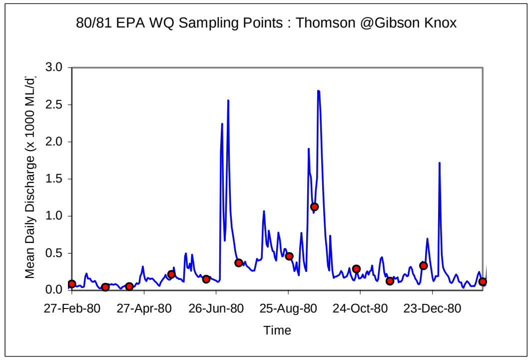


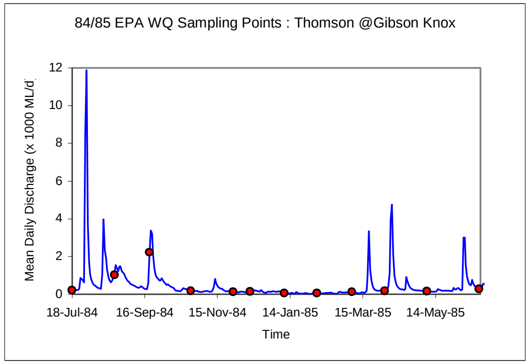
Appendix B-2(v-b): EPA WQ Sampling Points Superimposed on Mean Daily Discharge Hydrographs for Thomson @ Gibson Knox

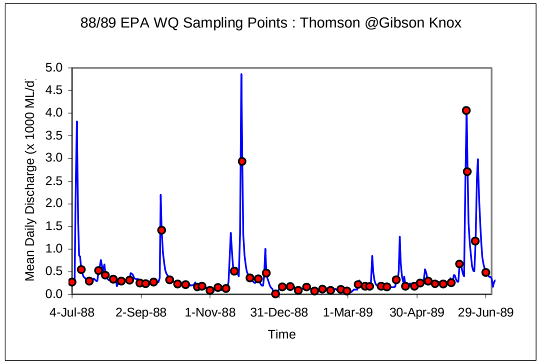


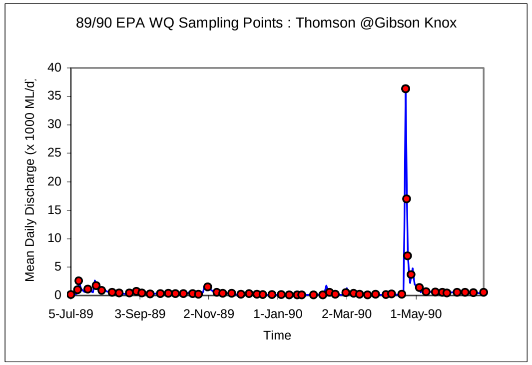




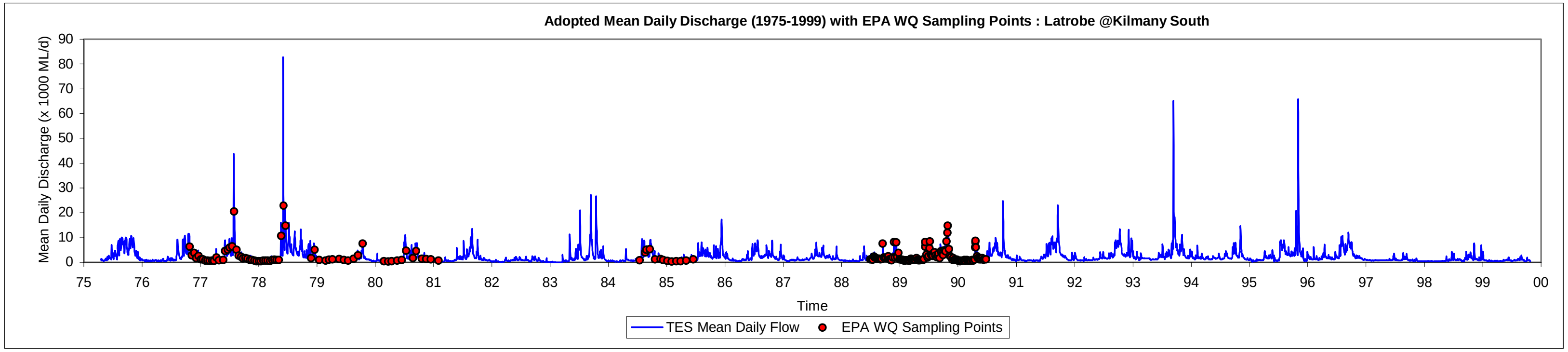


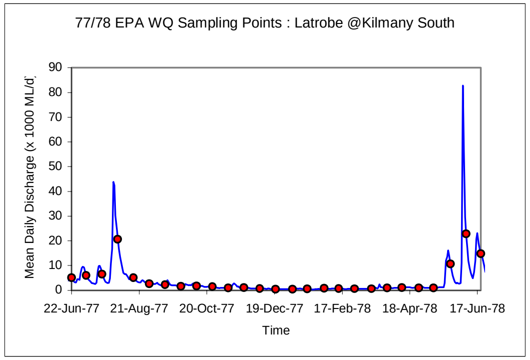


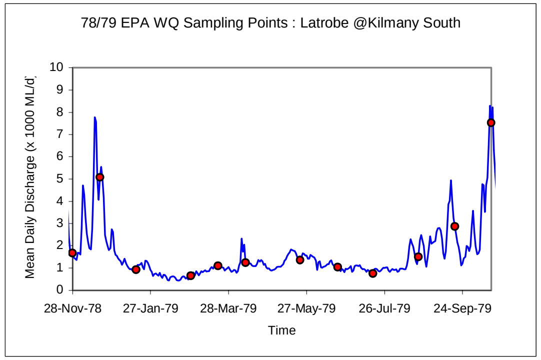


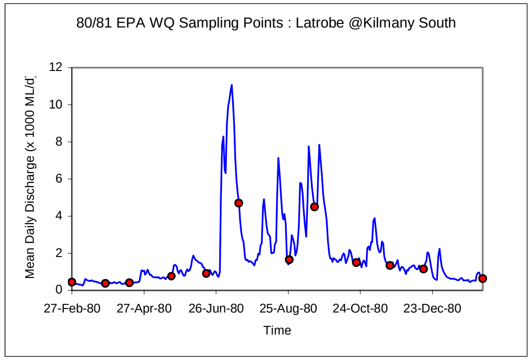


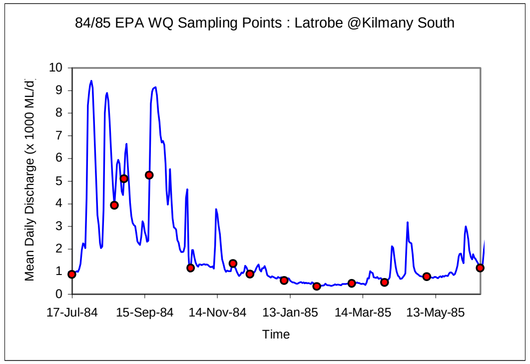
Appendix B-2(vi): EPA WQ Sampling Points Superimposed on Mean Daily Discharge Hydrographs for Latrobe @ Kilmany South

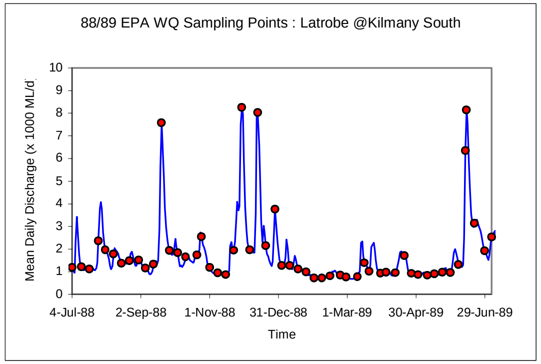


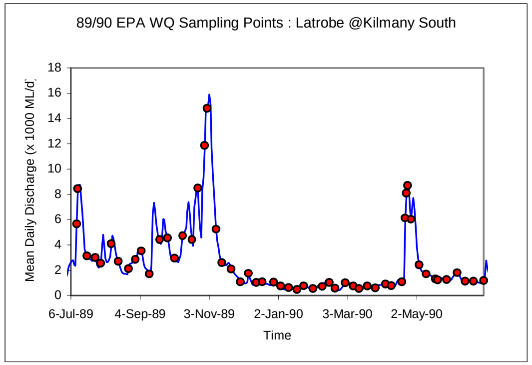












APPENDIX C

Appendix C(i) : Summary of Load Estimates for July 1997 to June 1999 for Tambo @ Battens Landing

Period	Description	Method of Load Estimation Method A1 Without Flow Stratification	Method B2 With Flow Stratification (With forced min high flow conc.)
Overall Modelling Period 01Jul 97 to 30Jun99 (730 days)	**TSS TP TN**	**24,393 29.1 421**	- - -
	Q(total) Q(max daily) Prob. (exceedence) Date(max storm)	493,495 71,052 0.01% 23Jun98	
Storm Event 22Jun98 to 06Jul98 (15 days)	**TSS TP TN**	**20,063 19.5 266**	- - -
	Q(total) Q(max daily) Prob. (exceedence) Date(max storm)	213,244 71,052 0.01% 23Jun98	
Storm Event 06Jun98 to 12Jun98 (7 days)	**TSS TP TN**	**1,163 1.7 25**	- - -
	Q(total) Q(max daily) Prob. (exceedence) Date(max storm)	28,362 16,139 0.39% 08Jun98	
Storm Event 07Aug98 to 18Aug98 (12 days)	**TSS TP TN**	**647 1.3 20**	- - -
	Q(total) Q(max daily) Prob. (exceedence) Date(max storm)	29,727 4,867 1.7% 09Aug98	
Period Combining All the 3 Storm Events above (34 days)	**TSS TP TN**	**21,873 <90%> 22.5 <77%> 311 <74%>**	- - -
	Q(total) Percentage of Q(total)	271,333 55%	
Remaining Period Outside of the 3 Storm Events above (696 days)	**TSS TP TN**	**2,520 <10%> 6.6 <23%> 110 <26%>**	- - -
	Q(total) Percentage of Q(total)	222,162 45%	

Values in **bold** are based on the final adopted method for load estimation.
All load estimates are in tonnes and all Qs are in ML/day.
Percentages in ( ) are load variation based on ratio of Method B estimates upon Method A estimates.
Percentages in < > are proportion of load of a particular period upon the overall CSIRO modelling period of Jul97-Jun99.

Appendix C(ii) : Summary of Load Estimates for July 1997 to June 1999 for Nicholson @ Sarsfield

Period	Description	Method of Load Estimation: Method A1 Without Flow Stratification	Method of Load Estimation: Method A2 Without Flow Stratification (With high flow conc. cap)
Overall Modelling Period 01Jul 97 to 30Jun99 (730 days)	**TSS**	26,025	**11,847 (46%)**
	TP	**12.5**	-
	TN	**81**	-
	Q(total)	95,458	
	Q(max daily)	20,367	
	Prob. (exceedence)	0.02%	
	Date(max storm)	23Jun98	
Storm Event 22Jun98 to 02Jul98 (11 days)	**TSS**	22,009	**8,606 (39%)**
	TP	**9.3**	-
	TN	**52**	-
	Q(total)	46,612	
	Q(max daily)	20,367	
	Prob. (exceedence)	0.02%	
	Date(max storm)	23Jun98	
Storm Event 06Jun98 to 11Jun98 (6 days)	**TSS**	3,295	**2,520 (76%)**
	TP	**2.2**	-
	TN	**13**	-
	Q(total)	13,958	
	Q(max daily)	7,284	
	Prob. (exceedence)	0.25%	
	Date(max storm)	08Jun98	
Storm Event 09Aug98 to 23Aug98 (15 days)	**TSS**	412	**412 (100%)**
	TP	**0.4**	-
	TN	**5**	-
	Q(total)	7,425	
	Q(max daily)	1,409	
	Prob. (exceedence)	1.6%	
	Date(max storm)	18Aug98	
Period Combining All the 3 Storm Events above (32 days)	**TSS**	25,716 <99%>	**11,538 (45%) <97%>**
	TP	**11.8 <94%>**	-
	TN	**69.5 <86%>**	-
	Q(total)	67,995	
	Percentage of Q(total)	71%	
Remaining Period Outside of the 3 Storm Events above (698 days)	**TSS**	309 <1%>	**309 (100%) <3%>**
	TP	**0.7 <6%>**	-
	TN	**11.5 <14%>**	-
	Q(total)	27,463	
	Percentage of Q(total)	29%	

Values in **bold** are based on the final adopted method for load estimation.
All load estimates are in tonnes and all Qs are in ML/day.
Percentages in ( ) are load variation based on ratio of Method B estimates upon Method A estimates.
Percentages in < > are proportion of load of a particular period upon the overall CSIRO modelling period of Jul97-Jun99.

Appendix C(iii) : Summary of Load Estimates for July 1997 to June 1999
for Mitchell @ Rosehill

Period	Description	Method of Load Estimation	
		Method A1 Without Flow Stratification	Method B2 With Flow Stratification (With forced min high flow conc.)
Overall Modelling Period 01Jul 97 to 30Jun99 (730 days)	**TSS** **TP** **TN**	50,500 61.7 502	**55,202 (109%)** **83.5 (135%)** **775 (154%)**
	Q(total) **Q(max daily)** **Prob. (exceedence)** **Date(max storm)**	1,296,065 81,782 0.02% 24Jun98	
Storm Event 22Jun98 to 04Jul98 (13 days)	**TSS** **TP** **TN**	37,828 31.1 215	**38,649 (102%)** **42.8 (138%)** **310 (144%)**
	Q(total) **Q(max daily)** **Prob. (exceedence)** **Date(max storm)**	204,975 81,782 0.02% 24Jun98	
Storm Event 22Sep98 to 03Oct98 (12 days)	**TSS** **TP** **TN**	5,434 8.4 70	**7,976 (147%)** **11.4 (136%)** **153 (219%)**
	Q(total) **Q(max daily)** **Prob. (exceedence)** **Date(max storm)**	165,304 45,427 0.14% 24Sep98	
Storm Event 05Jul98 to 18Jul98 (14 days)	**TSS** **TP** **TN**	647 1.7 18	**1,089 (168%)** **2.2 (129%)** **33 (183%)**
	Q(total) **Q(max daily)** **Prob. (exceedence)** **Date(max storm)**	70,825 19,130 0.74% 07Jul98	
Period Combining All the 3 Storm Events above (39 days)	**TSS** **TP** **TN**	43,909 41.3 302	**47,714 (109%) <86%>** **56.4 (137%) <68%>** **496 (164%) <64%>**
	Q(total) **Percentage of Q(total)**	441,104 34%	
Remaining Period Outside of the 3 Storm Events above (691 days)	**TSS** **TP** **TN**	6,591 20.4 200	**7,488 (114%) <14%>** **27.1 (133%) <32%>** **279 (140%) <36%>**
	Q(total) **Percentage of Q(total)**	854,961 66%	

Values in **bold** are based on the final adopted method for load estimation.
All load estimates are in tonnes and all Qs are in ML/day.
Percentages in ( ) are load variation based on ratio of Method B estimates upon Method A estimates.
Percentages in < > are proportion of load of a particular period upon the overall CSIRO modelling period of Jul97-Jun99.

Appendix C(iv): Summary of Load Estimates for July 1997 to June 1999 for Avon @ Stratford

Period	Description	Method of Load Estimation	
		Method A1 Without Flow Stratification	Method B2 With Flow Stratification (With forced min high flow conc.)
Overall Modelling Period 01Jul 97 to 30Jun99 (730 days)	**TSS**	13,197	**38,565 (292%)**
	TP	11.2	**21.8 (195%)**
	TN	205	**217 (105%)**
	Q(total)	292,823	
	Q(max daily)	64,556	
	Prob. (exceedence)	0.05%	
	Date(max storm)	24Jun98	
Storm Event 22Jun98 to 04Jul98 (13 days)	**TSS**	10,782	**34,983 (324%)**
	TP	6.2	**15.9 (256%)**
	TN	125	**147 (118%)**
	Q(total)	124,967	
	Q(max daily)	64,556	
	Prob. (exceedence)	0.05%	
	Date(max storm)	24Jun98	
Storm Event 11Nov98 to 22Nov98 (12 days)	**TSS**	1,260	**2,698 (214%)**
	TP	1.2	**2.0 (167%)**
	TN	30	**2.5 (83%)**
	Q(total)	45,209	
	Q(max daily)	19,834	
	Prob. (exceedence)	0.42%	
	Date(max storm)	13Nov98	
Storm Event 07Jun98 to 13Jun98 (7 days)	**TSS**	205	**92 (45%)**
	TP	0.2	**0.3 (150%)**
	TN	4.4	**3.3 (75%)**
	Q(total)	9,110	
	Q(max daily)	3,217	
	Prob. (exceedence)	2.8%	
	Date(max storm)	09Jun98	
Period Combining All the 3 Storm Events above (32 days)	**TSS**	12,246	**37,773 (308%) <98%>**
	TP	7.6	**18.2 (239%) <83%>**
	TN	160	**175 (109%) <81%>**
	Q(total)	179,287	
	Percentage of Q(total)	61%	
Remaining Period Outside of the 3 Storm Events above (698 days)	**TSS**	951	**792 (83%) <2%>**
	TP	3.6	**3.6 (100%) <17%>**
	TN	45	**42 (93%) <19%>**
	Q(total)	113,536	
	Percentage of Q(total)	39%	

Values in **bold** are based on the final adopted method for load estimation.
All load estimates are in tonnes and all Qs are in ML/day.
Percentages in ( ) are load variation based on ratio of Method B estimates upon Method A estimates.
Percentages in < > are proportion of load of a particular period upon the overall CSIRO modelling period of Jul97-Jun99.

Appendix C(v): Summary of Load Estimates for July 1997 to June 1999 for Thomson @ Bundalaguah

Period	Description	Method of Load Estimation: Method A1 Without Flow Stratification	Method of Load Estimation: Method B2 With Flow Stratification (With forced min high flow conc.)
Overall Modelling Period 01Jul 97 to 30Jun99 (730 days)	**TSS** **TP** **TN**	32,516 43.0 334	**29,183 (90%)** **46.4 (108%)** **314 (94%)**
	Q(total) **Q(max daily)** **Prob. (exceedence)** **Date(max storm)**	511,169 50,868 0.08% 14Nov98	
Storm Event 12Nov98 to 30Nov98 (19 days)	**TSS** **TP** **TN**	19,653 15.7 121	**16,576 (84%)** **13.1 (83%)** **96 (79%)**
	Q(total) **Q(max daily)** **Prob. (exceedence)** **Date(max storm)**	142,316 50,868 0.08% 14Nov98	
Storm Event 20Sep98 to 02Oct98 (13 days)	**TSS** **TP** **TN**	3,808 4.0 41	**3,173 (83%)** **5.2 (130%)** **37 (90%)**
	Q(total) **Q(max daily)** **Prob. (exceedence)** **Date(max storm)**	60,293 16,422 0.73% 26Sep98	
Storm Event 03Oct98 to 31Oct98 (29 days)	**TSS** **TP** **TN**	2,901 4.3 38	**2,767 (95%)** **6.6 (153%)** **43 (113%)**
	Q(total) **Q(max daily)** **Prob. (exceedence)** **Date(max storm)**	76,097 5,821 5.5% 10Oct98	
Period Combining All the 3 Storm Events above (61 days)	**TSS** **TP** **TN**	26,362 24.0 200	**22,515 (85%) <77%>** **24.9 (104%) <53%>** **176 (88%) <56%>**
	Q(total) **Percentage of Q(total)**	278,687 55%	
Remaining Period Outside of the 3 Storm Events above (669 days)	**TSS** **TP** **TN**	6,154 19.0 134	**6,668 (108%) <23%>** **21.5 (113%) <46%>** **138 (103%) <44%>**
	Q(total) **Percentage of Q(total)**	232,482 45%	

Values in **bold** are based on the final adopted method for load estimation.
All load estimates are in tonnes and all Qs are in ML/day.
Percentages in ( ) are load variation based on ratio of Method B estimates upon Method A estimates.
Percentages in < > are proportion of load of a particular period upon the overall CSIRO modelling period of Jul97-Jun99.

Appendix C(vi): Summary of Load Estimates for July 1997 to June 1999
for Latrobe @ Kilmany South

Period	Description	Method of Load Estimation: Method A1 Without Flow Stratification	Method of Load Estimation: Method B2 With Flow Stratification (With forced min high flow conc.)
Overall Modelling Period 01Jul 97 to 30Jun99 (730 days)	**TSS** **TP** **TN**	**58,966** 93.7 **777**	- **94.0 (100%)** -
	Q(total) **Q(max daily)** **Prob. (exceedence)** **Date(max storm)**	763,898 7,750 4.9% 15Nov98	
Storm Event 11Nov98 to 25Nov98 (15 days)	**TSS** **TP** **TN**	**6,369** 8.0 **74**	- **8.5 (106%)** -
	Q(total) **Q(max daily)** **Prob. (exceedence)** **Date(max storm)**	50,981 7,750 4.9% 15Nov98	
Storm Event 26Dec98 to 06Jan99 (12 days)	**TSS** **TP** **TN**	**4,202** 5.4 **47**	- **5.8 (107%)** -
	Q(total) **Q(max daily)** **Prob. (exceedence)** **Date(max storm)**	34,606 6,983 6.5% 29Nov98	
Storm Event 07Jan99 to 19Jan99 (13 days)	**TSS** **TP** **TN**	**1,964** 2.9 **25**	- **3.2 (110%)** -
	Q(total) **Q(max daily)** **Prob. (exceedence)** **Date(max storm)**	21,958 4,328 13% 10Jan99	
Period Combining All the 3 Storm Events above (40 days)	**TSS** **TP** **TN**	**12,536 <21%>** 16.3 <17%> **146 <19%>**	- **17.5 (107%) <19%>** -
	Q(total) **Percentage of Q(total0**	107,545 14%	
Remaining Period Outside of the 3 Storm Events above (690 days)	**TSS** **TP** **TN**	**46,430 <79%>** 77.4 <83%> **631 <81%>**	- **76.5 (99%) <81%>** -
	Q(total) **Percentage of Q(total)**	656,353 86%	

Values in **bold** are based on the final adopted method for load estimation.
All load estimates are in tonnes and all Qs are in ML/day.
Percentages in ( ) are load variation based on ratio of Method B estimates upon Method A estimates.
Percentages in < > are proportion of load of a particular period upon the overall CSIRO modelling period of Jul97-Jun99.