Department of Science, Information Technology, Innovation and the Arts

A framework for selecting the most appropriate load estimation method for events, based on sampling regime

Final report
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Prepared by:
Water Quality and Investigation
Environmental Monitoring and Assessment Science
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Summary

Reliable estimates of waterway pollutant loads from monitoring data are required to validate and refine catchment models, predict and regulate regional load exports, set meaningful targets to reduce contaminant loads, make informed decisions about catchment management practices, and evaluate the effectiveness of management actions. There are numerous methods that may be applied to estimate pollutant loads and results from the application of each method can vary by orders of magnitude for poorly sampled events. In such circumstances, the selection of an appropriate load estimation method requires an understanding of contaminant behaviour and may require the application of several estimation methods, for a single event, to achieve an accurate estimate. This can mean that load estimation is a time consuming process that often requires expert input and is associated with a certain degree of subjectivity. There is a need to establish an automated means of calculating loads using large data sets. A report prepared for the Department of Environment and Resource Management (DERM) by Marsh (2011) investigated methods to select load estimation methods and recommended implementation of a framework for selecting an appropriate load estimation method, based on the sampling regime and distribution of samples across an event (sample distribution). This approach has a number of advantages as it uses existing event monitoring data sets to determine the most accurate load estimation methods for each sampling scenario and provides a relative measure of error that is able to be consistently applied between methods. In addition, it provides an approach that is able to be automated in software to select the most appropriate load estimation method. In this study, the extensive event monitoring data sets collected over five years in South East Queensland and the Great Barrier Reef catchments were used.

The project developed a framework for selecting the best loads estimate methods for total suspended solids, total nitrogen, total phosphorus, oxidised nitrogen, ammonium and dissolved inorganic phosphorus) based on the sampling regime (sample size and sample distribution) and location of the site (either within the Great Barrier Reef or the South East Queensland catchments). No single loads estimation method was found to have sufficient universal applicability, therefore two look-up tables were generated, one for the South East Queensland region and the other for the Great Barrier Reef region, that identified the best loads estimation method for each combination of sampling regime and parameter. There were strong similarities between the load estimation methods identified as the best for the South East Queensland and Great Barrier Reef regions.

The greatest error in load estimations occurred when sampling was not undertaken on the fall of the hydrograph. It is therefore recommended that samples, whenever practical, be collected across both the rise and fall of the hydrograph. Data analysis identified a relationship between sample regime and the error in loads estimation. It is therefore recommended that for South East Queensland catchments at least ten samples be collected over an event (with at least 50% on the fall). Such sampling can provide load estimates with an error of 20% or less. Further, it is recommended that for Great Barrier Reef catchments at least six samples be collected, with most on the fall, to reduce the error to approximately 20%. Increasing the sample size beyond these recommended minima, while maintaining an approximately even distribution of samples over the hydrograph, further decreases the error towards 10%.

The developed framework provides an evidence-based, robust and repeatable means of estimating loads that makes optimum use of the available data. The results of this project can be incorporated into loads estimation software packages such as Water Quality Analyser. This would automate the process and decrease the time involved in calculating loads, while using the best loads estimation method for the data available.

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List of abbreviations

CESE	Conference on Environmental Science and Engineering
DERM	Department of Environment and Resource Management
DIP	Dissolved inorganic phosphorous
GBR	Great Barrier Reef
GBRCLMP	Great Barrier Reef Catchment Loads Monitoring Program
IMACS	International Association for Mathematics and Computers in Simulation
km	Kilometers
ML	Megalitres
MODSIM	Modelling and Simulation
NH_4^+	Ammmonium
No.	Number
NO_X	Oxidised nitrogen
RMSE	Root mean squared error
SEQ	South East Queensland
SEQEM	South East Queensland Event Monitoring
t	Tonnes
TN	Total nitrogen
TP	Total phosphorous
TSS	Total suspended solids
WQA	Water Quality Analyser

1. Introduction

Catchment models have been used extensively in Queensland to make informed decisions about catchment management practices, predicting and regulating regional load exports, setting meaningful targets to reduce contaminant loads and evaluating the effectiveness of management actions (Neil and Yu 1996, Chiew and Scanlon 2002, Chiew et al. 2002, Neil et al. 2002, Beling 2004, BMT WBM 2004 a, b, c, d, Beling and McAlister 2005, NRM&W 2006, Waters 2006, ARUP 2009, Brodie et al. 2009, BMT WBM 2010, eWater CRC 2011). Given the reliance on catchment models to support these policies and plans it is important that the accuracy of these models be validated or reconciled with empirically-derived load estimates (Fox and Argent 2009). The Great Barrier Reef Catchments Loads Monitoring Program (GBRCLMP) and the South East Queensland Event Monitoring (SEQEM) program were established in 2005 and 2007 respectively, to monitor contaminant loads from rural diffuse sources in catchments flowing into the Great Barrier Reef Lagoon and Moreton Bay, respectively. These monitoring programs provide the information needed for validation and calibration of catchment models used to support the Reef Plan 2003 and 2009 and associated Reef Regulations 2009 (DPC 2009) and the South East Queensland Healthy Waterways Strategy 2007-2012 (SEQ Healthy Waterways Partnership 2007).

Empirically-derived load estimates must be based on robust, accurate and repeatable loads determination methods (Marsh 2011). Data required for load estimation are generally a flow value and a parameter concentration value. These are combined together with a specified time period to give a load estimate. If both flow and concentration could be measured continuously, a resultant load could be accurately computed (the only error would be due to the measurements themselves). While, in reality, flow can be measured continuously, concentrations are often measured from a sample of water at a discrete point in time. The accuracy of the resulting load estimate depends on how well the concentration samples are able to characterise what is, in reality, continuously varying in the waterway. The accuracy of this characterisation depends on the number and timing of the collection of samples, the variation of the actual concentrations and the mathematics of how the flow and concentration estimates are combined. There are numerous ways in which to calculate a load and the most accurate method depends on many factors. Identifying a method that may be used to most accurately estimate a load can require understanding of factors including rainfall (quantity, distribution, and intensity), antecedent moisture conditions, size and shape of the catchment, the underlying land use, topography, geology and soil type and the sample number and timing (Chiew and Scanlon 2002, McDowell and Sharpley 2002, Quilbe et al. 2006, Joo 2012). As a result, there is no single best approach for estimating sediment and nutrient loads consistently and accurately under all circumstances. Examples of comparative analysis of methods are presented in various studies (e.g. Richards and Holloway 1987, Ferguson 1987, Preston et al. 1989, Kronvang and Bruhn 1996, Webb et al. 1997, Horowitz 2003, Quilbe et al., 2006, Marsh and Waters 2009, and Joo 2012).

Where loads are required for all events and for each of the parameters typically measured—total suspended solids and nutrients— it is often not practical to undertake such detailed assessment. Given the high spatial, temporal, hydrological, geological and meteorological variability, there is no national, state or regional guidance on which method should be used to calculate loads.

As a result a range of methods have been applied for determining catchment loads in Queensland, ranging from linear interpolation (Packett 2007, Packett et al. 2009), regression methods (Kuhnert and Henderson 2010, Kroon et al. 2010), or a combination of methods (Brodie et al. 2009). However, depending on the method of analysis, there are commonly differences up to two orders of magnitude in calculated loads (Marsh 2011).

A report prepared for DERM (Marsh 2011) investigated techniques to select load estimation methods and to give recommendations for a decision support system for selecting an appropriate load estimation method and to report load error. The current report presents an analysis approach that can select the most appropriate load estimation method based on a combination of the total number of samples and the distribution of the samples over the event hydrograph. One of the major advantages of such an approach is that it could potentially be included (automated) in the Water Quality Analyser (WQA) software tool (eWater CRC 2012) or similar. This would provide a rapid means of automating the process of selecting a load estimation method that would provide reliable results.

In order to achieve this for data collected in South East Queensland (SEQ) and the Great Barrier Reef (GBR) it was necessary to revise the analyses performed by Marsh (2011) using the currently available event monitoring data in Queensland. The results from this analysis should be applied to the calculation of loads for catchments in the SEQ and GBR regions and provide initial guidance for other areas.

2. Methodology

Prior to adopting the approach recommended by Marsh (2011), feedback on the technique was obtained from a number of experts and subsequently the analysis methodology was further refined. A summary report (Marsh and Waters 2009) describing the problem and the proposed approach was presented to two expert workshops (18th World International Association for Mathematics and Computers in Simulation (IMACS)/Modelling and Simulation Society of Australia and New Zealand (MODSIM) Congress and the 2010 Conference on Environmental Science and Engineering (CESE). Outcomes of the workshops were outlined in the report by Marsh (2011).

The analysis approach is summarised below. Each step is described in detail within the summary reports (Marsh and Waters 2009, Marsh 2011) and the following sections (2.1 to 2.3).

1. Data collation
    a. identify high quality data sets.
2. Loads data generation
    a. infill the high quality data sets
    b. calculate the theoretical 'true' loads estimate
    c. identify sampling regimes to be examined
    d. identify load estimation methods to be used
    e. calculate loads for all combinations of sampling regime and loads estimation methods for each event.
3. Statistical analysis
    a. analyse loads data
    b. remove outlying data

c. repeat analyses for each parameter in each region
d. identify best loads estimation methods.

2.1 Data collation

Data sets from both the SEQEM program and GBRCLMP were reviewed to identify suitable event data sets to enable the generation of infilled concentration data sets. Data sets that were deemed suitable for this purpose were high flow events that had a minimum of ten samples over the hydrograph and a minimum of two samples on the rising portion of the hydrograph (Olley et al. in press). Each event data set contained concentration data for total suspended solids (TSS), total nitrogen (TN), total phosphorus (TP), oxidised nitrogen (NO_X), ammonium (NH_4^+) and dissolved inorganic phosphorus (DIP) (with exception of the Kilcoy, Comet and South Johnstone catchments where only total nutrients were available). At the beginning and end of each concentration data set, a single tie down value was used to define the start and end of each event. The tie down value used at each monitoring site was the median value of historical base flow concentrations for each parameter. Each event concentration data set was associated with a concurrent flow data set consisting of a total hourly discharge (m^3s^{-1}) obtained from the Queensland Government surface water database (Hydstra).

In total, 116 events were identified as being suitable for use in defining the best estimates of loads. Of these, 77 events sampled from 15 event monitoring sites in the SEQ region were deemed suitable, and 39 events sampled at 14 event monitoring sites in the GBR region were deemed suitable (Appendix A). Sites were located on many of the major rivers on the eastern coast of Queensland (Figure 1). Monitoring was undertaken at a diverse range of catchments including sites from the small Petrie Creek catchment (38 km^2) to the large Fitzroy River catchment (139 159 km^2). The size of the events (discharge) for a given site varied over a wide range (Appendix A). All data analyses were undertaken separately for the GBR and SEQ regions.

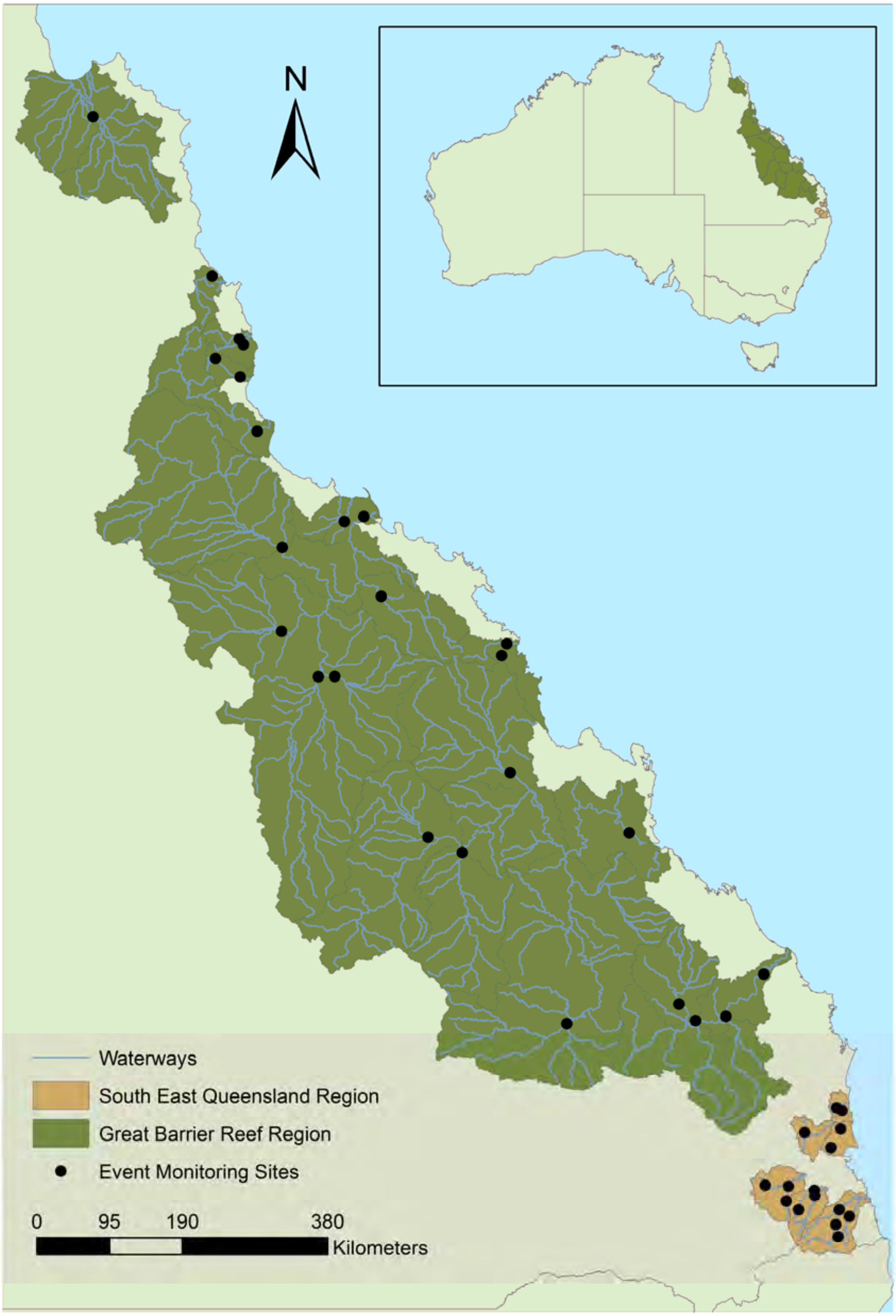

Figure 1 Event monitoring sites located in the Great Barrier Reef and South East Queensland regions.

2.2 Loads data generation

The concentration and flow data sets for each event were infilled using a linear process. This added 1500 concentration and flow values, at equal duration time-steps, into each of the selected 116 events. The linear interpolation loads estimation method (refer to method seven in Appendix B for details of the formula and source) was then applied to each complete infilled data set (presented in Appendix A) to generate the theoretical 'true load' for each event (Marsh 2011). The theoretical 'true load' is the best possible estimate of the load. The linear interpolation method was used to calculate the theoretical 'true load' as it has been shown to be the method that: is the least susceptible to inter-stream and inter-annual variation; has the lowest root mean squared error (RMSE); and the highest precision (Kronvang and Bruhn 1996; Letcher et. al. 1999) when there are sufficient data. The theoretical 'true load' was compared with load estimates determined with different combinations of sampling regime and load estimation method. Sampling regime refers to a combination of the total number of samples (sample size) and the number of samples collected on the rise and on the fall of the event hydrograph (sample distribution).

A total of 250 sampling regimes were used in this project. The sample sizes used ranged from three to 30. For each sample size, all combinations of sample distribution (i.e., the number of samples from the rise and fall of the hydrograph) were used, up to a maximum of 15 on the rise and/or the fall (refer to Appendix C). Each sampling regime was replicated 50 times using a Monte-Carlo approach.

Thirty-four alternative loads estimation methods (identified in Marsh 2011 and Appendix B) were applied to the 50 replicates of each of the 250 sampling regimes to estimate loads. Of the load estimation methods, ten were averaging, 14 were ratio and ten were regression type methods. The outputs were then analysed to determine the effect of sample regime on loads estimation accuracy. Some load estimation methods were successfully applied in only a few cases due to either a poor correlation between concentration and flow or an inability to calculate a loads estimate and were subsequently not presented in the results tables (Note in Appendix B).

2.3 Statistical methods

In order to test the performance of each combination of load estimation methods and sampling regime, the RMSE was determined (Preston et al. 1989, Kronvang and Bruhn 1996, Marsh 2011). The RMSE consists of a measure of the variance and the bias of the estimated load. A low RMSE value indicates an accurate (low bias) and consistent (low variance) load estimate. In addition, the estimate of error is the mean deviation (deviation is determined as 1.96 times the standard deviation of the calculated load from the theoretical load estimate for 50 replicate samples) and is represented as a percentage deviation from the theoretical load estimate. In summarising the results, only the combinations of load estimation method and sampling regime that had a success rate of > 80% were included. That is, combinations that failed to provide a load estimate or that predicted unreasonably high loads (i.e. estimated load >1000% of theoretical load) in > 20% of events for the SEQ and GBR catchments were removed from further analysis.

3. Results and discussion

3.1 Theoretical 'true load' estimate

Summary information of the characteristics of the events selected to estimate the theoretical ‘true loads’ are provided in Appendix A. The information presented includes the sample size and sample distribution, and the resultant theoretical loads. The total discharge (ML) and surface area (km^2) of each catchment for each event are also shown in Appendix A to provide an indication of the loads relative to the total discharge and catchment area.

3.2 Effect of sampling regime on root mean squared error associated with load estimates

The effect of sample size and sample distribution on the mean (and 25th and 75th percentiles) of the lowest RMSE values across events with three to seven samples (i.e. the most frequently occurring sample size) are presented in Figure 2 and Figure 3 for TSS in SEQ and GBR sites, respectively, and in Appendix D and Appendix E for all other parameters.

The mean of the lowest RMSE values across all 77 SEQ events (Figure 2) varied from 21-41% of the theoretical load estimate for TSS, and between 12-24% for TN, 16-34% for TP, 15-33% for NO_X, 16-39% for NH_4^+ and 12-42% for DIP (Appendix D). The mean RMSE value and the inter-event variability (indicated by the 75th and 25th percentile bars in Figure 2 and Appendix D) for events with the same sample size varied according to the sample distribution. The mean RMSE value and the inter-event variability were generally lowest when there were samples that covered both the rise and the fall of the hydrograph. The highest mean RMSE values and inter-event variability generally occurred when there were no samples taken on either the rise or fall of the hydrograph. These results support the findings from Marsh & Waters (2009) and Marsh (2011).

Sample regimes for events containing three to seven samples exerted the same effect on the mean of the lowest RMSE values for GBR sites as for SEQ sites (compare Figure 2 and Figure 3). The mean of the best RMSE values across all 39 GBR events varied from 21-43% of the theoretical load estimate for TSS (Figure 3), and between 8-18% for TN, 15-34% for TP, 10-20% for NO_X, 13-24% for NH_4^+ and 11-26% for DIP (Appendix D). As with the SEQ sites, the mean of the best RMSE values decreased with increasing sample size. Again, the mean RMSE value and the inter-event variability (indicated by the 75th and 25th percentile bars in Figure 3 and Appendix D) for events with the same sample size were lowest when samples were spread across the hydrograph and were largest when samples were not collected on either the rise or the fall.

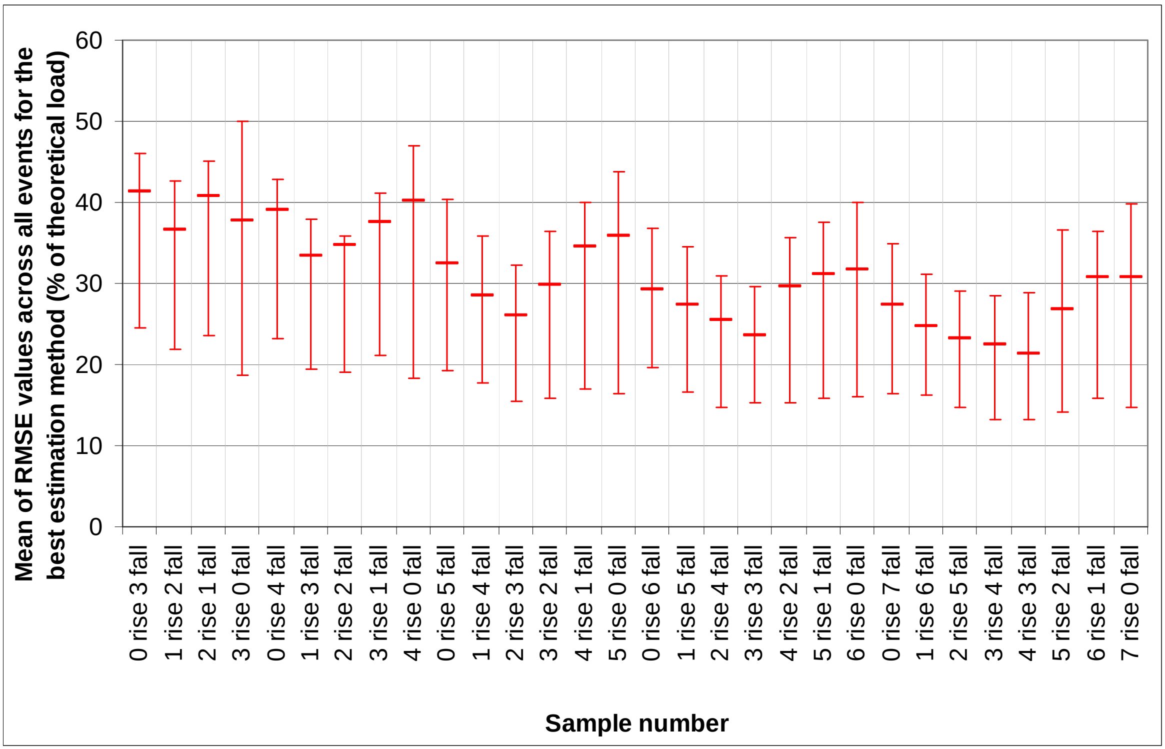

Figure 2 Effect of sample regime for events that have a sample size of three to seven, on the mean root mean square error (mean RMSE) values of the best loads estimation method (error bars show 75th and 25th percentile range) for total suspended solids in South East Queensland catchments.

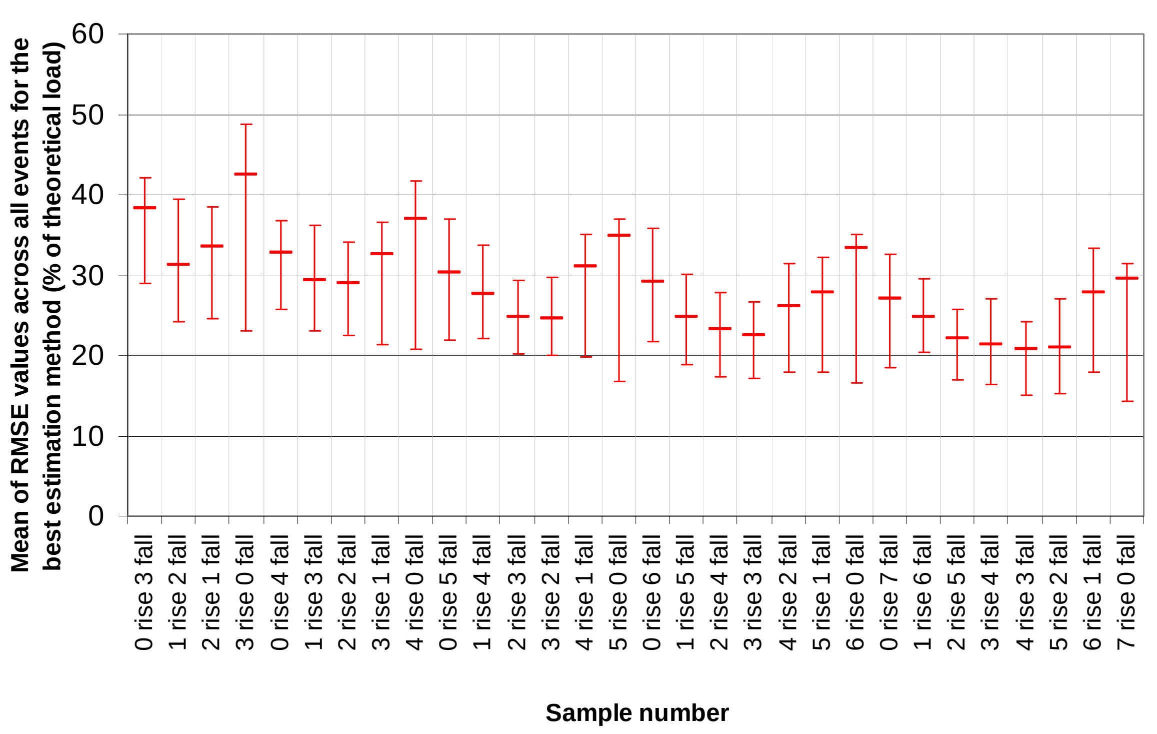

Figure 3 Effect of sample regime for events that have a sample size of three to seven, on the mean root mean square error (mean RMSE) values of the best loads estimation method (error bars show 75th and 25th percentile range) for total suspended solids in Great Barrier Reef catchments.

The same plots as Figure 2 and Figure 3, but for all sampling regimes examined up to a maximum sample size of 30 are presented in Figure 4 and Figure 5 respectively. Equivalent figures for TN, TP, NO_X, NH_4^+ and DIP are presented in Appendix E.

The overall relationships for SEQ and GBR catchments are both asymptotic (i.e. the mean RMSE values decrease approaching but never reaching zero, as sample size increases) in accordance with the results reported in Marsh (2011). However, in these plots it was only possible to indicate on the 'x' axis the sample size and not the sample distribution. These data are presented and are responsible for the characteristic "U" shape for each sample size. The variability of the mean RMSE decreases steadily with increasing sample size in each event (Figure 4 and Figure 5 and Appendix E). The variability of the mean RMSE become less pronounced once the sample number exceeds 18, which is the point at which all the sampling regimes examined, included at least three samples on the rise and at least three or more samples on the fall. Therefore, increasing an event sample size to more than 18 samples will not significantly reduce the variation of the mean RMSE (thus, only sample numbers up to and including 18 are included in the results table in Appendix E).

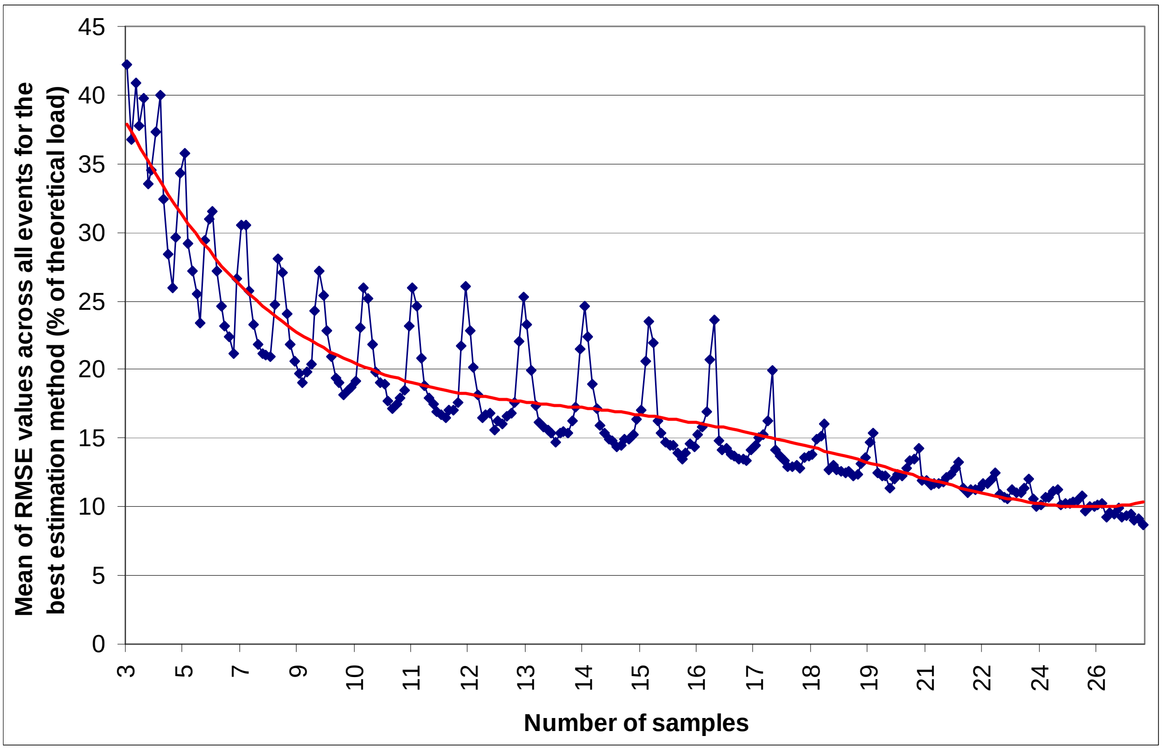

Figure 4 Effect of sample regime for events that contain 3-30 samples, on the mean root mean square error (mean RMSE) values of the best loads estimation method for total suspended solids in South East Queensland catchments. Points denote the mean RMSE for all events and samling regimes, the red line denotes the polynomial trend line.

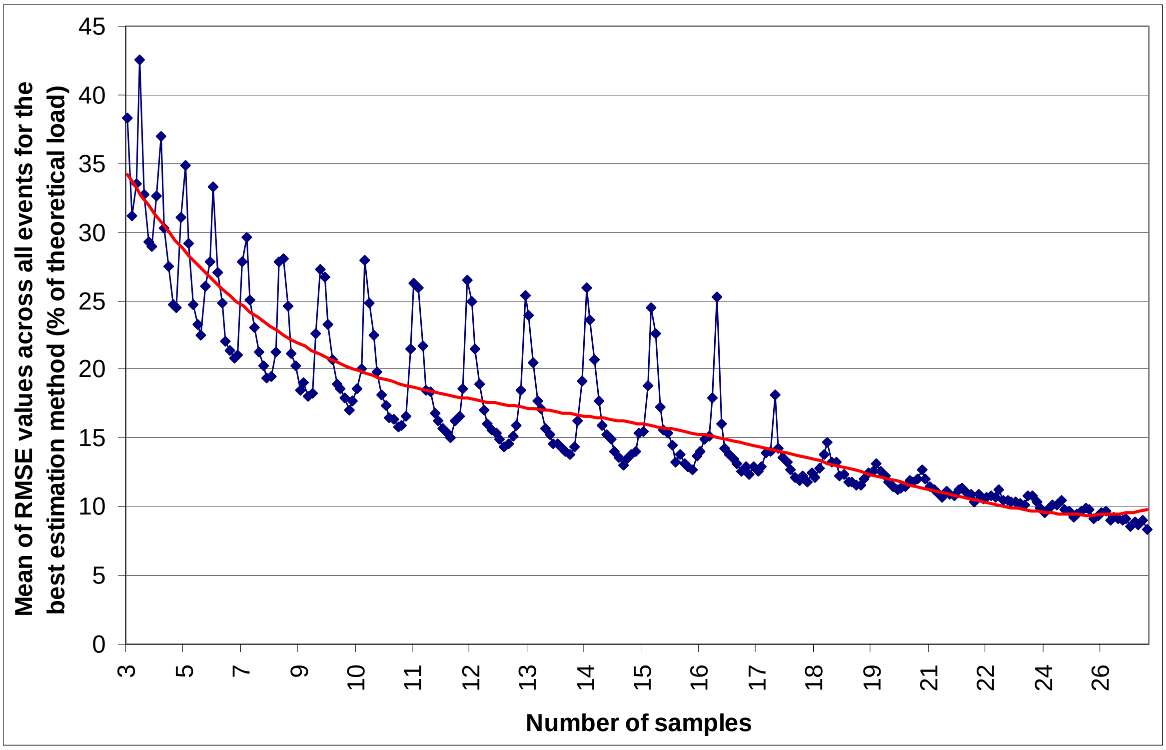

Figure 5 Effect of sample regime for events that contain 3-30 samples, on the mean root mean square error (mean RMSE) values of the best loads estimation method for total suspended solids in Great Barrier Reef catchments. Points denote the mean RMSE for all events and samling regimes, the red line denotes the polynomial trend line.

3.3 Loads estimation methods recommended for SEQ and GBR catchments

Table 1 presents a summary of the best loads estimation methods for each parameter in each region when events have been sampled poorly ($n \leq 7$) or well ($n > 7$). This table indicates the best loads estimation methods based on the sample size and doesn't consider sample distribution. While this may be applicable in some circumstances it is clear that no single load estimation method was the best for any combination of load parameter and sample size more than 60% of the time (Table 1). It is therefore recommended that the look-up tables in Appendix C be used to determine the loads estimation method for any particular event (based on region, parameter and sampling regime). It is interesting to note that the best loads estimation method was the same for the SEQ and GBR catchments in six of the 12 combinations of loads parameter and sample size. In another three combinations the best loads estimation method in one region was the second best in the other region. Thus there are similarities between the two regions regarding what is considered the most appropriate loads estimation methods.

When there are at least ten samples collected over an event in the SEQ region the error between loads estimates calculated by the best method and the theoretical load estimate reduced to 20% or less at least once for all parameters (Appendix C). In the GBR region, the error reduces to approximately 20% for all parameters when the sample size of an event was greater than six samples with most samples collected on the fall (Appendix C). These sample regimes are the minimum recommended for all future event-based monitoring in SEQ and GBR catchments. Increasing the sample size beyond these recommended minima, while maintaining an approximately even distribution over the hydrograph, further decreases the error towards 10%.

3.4 Incorporation of results into a software tool

Water Quality Analyser (WQA) (eWater 2012) is a software tool that brings together a collection of tools, databases, a knowledge base, electronic documents and a decision support system in order to analyse and collate water quality data. As part of WQA, the Loads Tool presents a variety of methods for estimating pollutant loads in streams and a decision support system for selecting the most appropriate loads estimation method. The current version of the Loads Tool (WQA v2.1.2.4) contains decision support for selecting a method for long-term estimation of loads (e.g. annual loads). The Loads Tool will be updated to incorporate the look-up tables of the best loads estimation methods developed by this report (Appendix C), to permit the automated choice of the most appropriate loads estimation methods for a range of sampling regimes over events.

The Loads Tool will interrogate the input concentration and flow data, then select the hierarchy of most appropriate load estimation methods (lowest to highest estimated confidence interval for that sampling method). The tool will then apply the loads estimation methods in order of priority (in the event that one of the more preferred methods cannot be applied to a particular dataset). In addition to the selection of the most appropriate loads estimation method, provision will be made for the Loads Tool to conduct more detailed analysis including position in the catchment and event size. This provision can be provided in the software by a hierarchy of look-up tables.

The updating of the Loads Tool is currently underway, and the updated version with the automated selection of methods in order of hierarchy will be available for download from the eWater website (http://www.ewater.com.au/products/ewater-toolkit/eco-tools/water-quality-analyser/) after review and approvals.

Table 1 A summary of the best load estimation methods for each combination of load parameter and sample size (≤ 7 or > 7 data—up to 18 samples) for South East Queensland and Great Barrier Reef catchments. In parenthesis is the percentage of sampling regimes for which each load estimation method is the best[*].

Parameter	Sample size	Load estimation methods and number of times they were the best method (in parentheses)	
		South East Queensland	Great Barrier Reef
TSS	≤ 7 (no. of sample regimes =30)[#]	Mean flow x mean concentration (where all flow data are used) (30%) Flow weighted concentration combined with mean discharge for the period (23%) Tins modified ratio: stratified by peak flow (20%)	Mean flow x mean concentration (where all flow data are used) (60% Tins modified ratio: stratified by peak flow (20%)
	> 7 (no. of sample regimes =142)[#]	Inter-sample mean concentration x flow (35%) Tins modified ratio: stratified by peak flow (35%)	Tins modified ratio: stratified by peak flow (31%) Inter-sample mean concentration x flow (20%)
TN	≤ 7	Mean flow x mean concentration (where all flow data are used) (50%)	Mean flow x mean concentration (where all flow data are used) (40%) Tins modified ratio: stratified by peak flow (20%)
	> 7	Inter-sample mean concentration x flow (55%)	Tins modified ratio: stratified by peak flow (40%)
TP	≤ 7	Mean flow x mean concentration (where all flow data are used) (50%)	Mean flow x mean concentration (where all flow data are used) (53%)
	> 7	Inter-sample mean concentration x flow (58%)	Inter-sample mean concentration x flow (31%) Tins modified ratio: stratified by peak flow (28%)
NOx	≤ 7	Time stratified average load where N is total number of time steps and n is flow strata defined as before or after the peak flow (flow stratified sampling) (37%)	Time stratified average load where N is total number of time steps and n is flow strata defined as before or after the peak flow (flow stratified sampling) (43%) Flow weighted concentration combined with mean discharge for the period (23%)
	> 7	Inter-sample mean concentration x flow (23%)	Linear interpolation of concentration (35%)

Parameter	Sample size	Load estimation methods and number of times they were the best method (in parentheses)	
		South East Queensland	Great Barrier Reef
NH_4^+	≤ 7	Time stratified average load where N is total number of time steps and n is flow strata defined as before or after the peak flow (flow stratified sampling) (50%)	Flow weighted concentration combined with mean discharge for the period (47%) Time stratified average load where N is total number of time steps and n is flow strata defined as before or after the peak flow (flow stratified sampling) (40%)
	> 7	Tins modified ratio: stratified by peak flow (30%) Simple Ratio (27%) Time stratified average load where N is total number of time steps and n is flow strata defined as before or after the peak flow (flow stratified sampling) (23%)	Flow weighted concentration combined with mean discharge for the period (27%) Concentration Power Curve Fitting (20%)
DIP	≤ 7	Mean flow x mean concentration (where all flow data are used) (53%)	Mean flow x mean concentration (where all flow data are used) (40%) Flow weighted concentration combined with mean discharge for the period (20%)
	> 7	Tins modified ratio: stratified by peak flow (40%) Inter-sample mean concentration x flow (28%)	Inter-sample mean concentration x flow (22%)

[*] All methods that are the best at least 20% of the time are included. # These apply to all the load parameters.

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Appendix A

Summary characteristics of events and theoretical ('true load') loads estimates for each parameter

Table 2 Theoretical 'true load' for each parameter for each suitable event selected from South East Queensland sites. Total discharge and total number of samples per event are also presented.

Catchment	Site Gauging station No.	Year	Total No. samples (rise, fall)	Event discharge (ML)	Catchment area (km^2)	Event load TSS (t)	Event load TN (t)	Event load TP (t)	Event load NO$_X$ (t)	Event load NH$_4^+$ (t)	Event load DIP (t)
Maroochy	Eudlo Creek @ Kiel's Mountain 141008A	Jan-08	32 (21, 11)	2,960	62	123	2.53	0.28	0.10	0.08	0.03
		Feb-08	18 (9, 9)	3,825	62	232	3.49	0.36	0.25	0.15	0.03
		Jun-08	19 (4, 15)	8,404	62	369	6.46	0.91	1.27	0.14	0.08
		Apr-09	22 (17, 5)	14,462	62	1,409	9.46	0.92	0.84	0.28	0.09
		May-09	11 (5, 6)	4,832	62	359	2.70	0.30	0.37	0.12	0.04
		Feb-10	11 (7, 4)	2,124	62	120	1.84	0.25	0.17	0.06	0.03
	Petrie Creek @ Warana Bridge 141003C	Feb-08	23 (8, 15)	9,609	38	808	4.21	0.93	0.37	0.09	0.16
		Jun-08	15 (4, 11)	32,788	38	4,057	19.14	5.15	2.62	0.68	0.19
		Feb Mar-10	14 (6, 8)	10,044	38	1,317	5.86	1.75	0.88	0.05	0.22
Pumicestone	Coochin Creek @ Mawson's Road 141010A	Feb-07	30 (9, 21)	212	55	15	0.45	0.04	3.59	0.03	0.01
		Mar-07	15 (3, 12)	599	55	7	0.34	0.02	0.18	0.01	0.003
		Jun-07	23 (10, 13)	983	55	79	0.90	0.08	0.46	0.03	0.02
		Aug-07	38 (17, 21)	4,398	55	349	6.57	0.57	3.59	0.26	0.21

Catchment	Site Gauging station No.	Year	Total No. samples (rise, fall)	Event discharge (ML)	Catchment area (km^2)	Event load TSS (t)	Event load TN (t)	Event load TP (t)	Event load NO$_X$ (t)	Event load NH$_4^+$ (t)	Event load DIP (t)
Pumicestone	Coochin Creek @ Mawson's Road 141010A	Jan-08	14 (5, 9)	2,150	55	50	3.50	0.39	1.80	0.13	0.03
		Apr-09	22 (7, 15)	5,972	55	703	7.13	0.55	2.85	0.22	0.08
		May-09	19 (13, 6)	14,209	55	2,409	19.53	2.30	8.23	0.48	0.32
Caboolture	Caboolture River @ Upper Caboolture 142001A	Aug-07	49 (17, 32)	2,496	94	259	3.07	0.24	0.75	0.05	0.07
		Jan-08	17 (3, 14)	3,018	94	557	5.63	0.71	0.29	0.11	0.07
		Feb-09	10 (4, 6)	3,658	94	175	6.10	3.41	1.45	0.28	1.91
		May-09	12 (7, 5)	23,458	94	8,652	28.63	4.58	3.35	0.54	0.57
Albert	Albert River @ Bromfleet 145102B	Jan-08	21 (12, 19)	75,134	544	752	6.87	1.52	1.49	0.33	0.55
		Nov-08	15 (8, 7)	7,121	544	2,126	12.41	4.90	1.20	0.15	1.43
		Dec-08	11 (7, 4)	1,120	544	267	0.98	0.52	0.05	0.02	0.10
		Apr-09	24 (17, 7)	7,514	544	1,536	6.66	2.36	1.14	0.19	0.76
		May-09	26 (15, 11)	55,341	544	593	16.30	6.99	2.31	0.30	4.09
Logan	Logan River @ Bromelton Weir 145025A	Aug-07	39 (3, 36)	1,561	1,297	86	3.69	0.19	1.36	1.18	0.09
		Oct-07	39 (23, 16)	8,059	1,297	15,670	25.00	5.13	3.38	2.63	0.28
		Dec-07	20 (12, 8)	4,751	1,297	4,007	11.05	2.46	0.47	1.41	0.16
		Feb-08	31 (18, 13)	21,217	1,297	10,120	37.55	9.69	2.80	1.29	1.32
		Nov-08	15 (7, 6)	6,747	1,297	1,934	12.67	2.78	2.40	2.09	1.06
	Logan River @ Yarrahappini 145014A	Oct-07	25 (11, 14)	16,836	2,416	26,801	35.57	7.69	5.76	2.13	0.88
		Feb-08	31 (18, 13)	46,148	2,416	17,164	82.10	20.69	4.08	1.69	4.68
		Dec-08	13 (7, 6)	10,079	2,416	12,288	23.38	7.77	0.59	0.28	0.42

Catchment	Site Gauging station No.	Year	Total No. samples (rise, fall)	Event discharge (ML)	Catchment area (km^2)	Event load TSS (t)	Event load TN (t)	Event load TP (t)	Event load NO_X (t)	Event load NH_4^+ (t)	Event load DIP (t)
Logan	Logan River @ Yarrahappini 145014A	Feb-10	17 (6, 11)	22,901	2,416	15,966	50.82	16.65	0.88	0.34	1.77
		Oct-10	15 (10, 5)	26,566	2,416	46,903	266.32	141.48	3.43	0.85	3.09
		Dec-10	17 (11, 6)	205,948	2,416	107,740	416.24	148.07	5.52	6.92	13.90
	Christmas Creek @ Tramway Lane 145025A	Oct-10	15 (12, 3)	5,972	166	1,055	11.61	5.30	0.90	0.13	0.43
Bremer	Bremer River @ Adam's Bridge 143110A	Oct-10	16 (4, 12)	2,508	125	914	5.38	2.69	0.70	0.07	1.43
	Bremer River @ Walloon 143107A	Nov-07	13 (8, 5)	1,903	622	833	3.36	1.44	0.91	0.06	0.89
		Dec-07	24 (6, 18)	3,644	622	811	7.21	2.49	0.46	0.14	1.27
		Feb-08	27 (5, 22)	30,098	622	5,530	46.41	13.05	1.20	0.85	7.61
		Jan-09	15 (5, 10)	6,045	622	367	9.85	3.09	0.17	0.15	1.77
		May-09	11 (4, 7)	47,467	622	9,637	61.19	19.60	7.15	1.29	12.21
		Oct-10	14 (8, 6)	24,384	622	3,129	46.73	16.23	3.58	0.60	8.17
		Dec-10	10 (4, 6)	17,613	622	1,870	27.76	10.34	0.32	0.24	5.07
		Dec-10	16 (6, 10)	83,493	622	11,938	139.23	60.11	1.73	1.67	18.79
		Jan-11	13 (5, 8)	27,415	622	3,622	60.21	20.30	1.90	1.02	8.68
	Warrill Creek @ Amberley 143108A	Jan-08	12 (4, 8)	14,471	914	3,576	27.15	10.76	1.53	0.80	3.72
		Feb-08	34 (13, 21)	47,667	914	10,690	74.95	29.30	3.34	1.01	13.47
		Nov-08	23 (7, 16)	24,720	914	7,437	47.41	17.94	3.28	0.78	7.01

Catchment	Site Gauging station No.	Year	Total No. samples (rise, fall)	Event discharge (ML)	Catchment area (km^2)	Event load TSS (t)	Event load TN (t)	Event load TP (t)	Event load NO_X (t)	Event load NH_4^+ (t)	Event load DIP (t)
Bremer	Warrill Creek @ Amberley 143108A	May-09	13 (4, 9)	39,029	914	8,911	49.97	17.82	7.97	1.81	9.48
		Feb-10	11 (6, 5)	16,346	914	2,940	21.78	9.83	1.98	0.29	3.46
Lockyer	Lockyer Creek @ Helidon no. 3 143203C	Nov-08	22 (12, 10)	6,835	357	13,293	90.27	14.22	3.16	0.28	0.38
		Mar-10	13 (5, 8)	5,324	357	3,068	21.30	2.99	1.75	0.12	0.41
		Dec-10	11 (6, 5)	26,998	357	66,122	492.06	93.13	2.99	0.73	1.49
	Laidley Creek @ Mulgowie 143209B	Jan-08	14 (3, 11)	1,418	167	782	3.40	1.97	0.38	0.11	0.39
		May-09	20 (6, 14)	6,818	167	4,210	13.23	7.47	3.65	0.31	2.05
		Feb-10	11 (4, 7)	3,501	167	856	5.13	2.88	0.62	0.04	0.77
		Mar-10	12 (6, 6)	1,936	167	227	2.65	1.14	0.70	0.03	0.43
	Laidley Creek @ Warrego Highway 143229A	Nov-07	20 (11, 9)	1,788	450	745	3.72	2.07	1.14	0.09	1.15
		Jan-08	15 (4, 11)	593	450	132	1.26	0.57	0.17	0.04	0.24
		Feb-08	35 (15, 20)	7,517	450	46,393	14.08	8.30	1.38	0.62	3.53
		May-09	17 (10, 7)	6,251	450	2,790	13.34	5.98	2.32	1.65	1.93
		Nov-09	10 (4, 6)	58	450	18	0.11	0.05	0.004	0.002	0.01
	Laidley Creek @ Warrego Highway 143229A	Feb-10	14 (6, 8)	335	450	248	0.88	0.57	0.06	0.01	0.07
		Feb-10	10 (6, 4)	711	450	554	1.94	1.27	0.18	0.01	0.19
		Oct-10	10 (7, 3)	3,681	450	27,176	16.52	9.19	1.81	0.96	1.97
Stanley	Kilcoy Creek @ ds Kilcoy weir - 143312A	Aug-07	20 (17, 3)	5,006	131	411	9.84	0.97	no data	no data	no data
		Sep-07	51 (31, 20)	2,655	131	85	2.55	0.31	no data	no data	no data

Catchment	Site Gauging station No.	Year	Total No. samples (rise, fall)	Event discharge (ML)	Catchment area (km^2)	Event load TSS (t)	Event load TN (t)	Event load TP (t)	Event load NO_X (t)	Event load NH_4^+ (t)	Event load DIP (t)
Stanley	Kilcoy Creek @ ds Kilcoy weir - 143312A	Feb-08	44 (20, 24)	5,303	131	1,272	8.07	1.27	no data	no data	no data
		Feb-08	55 (40, 15)	2,492	131	80	2.42	0.26	no data	no data	no data
		Jun-08	18 (5, 13)	2,259	131	423	2.95	0.37	no data	no data	no data
		Jul-08	36 (16, 20)	2,113	131	69	1.67	0.16	no data	no data	no data
		Sep-08	17 (5, 12)	497	131	13	0.44	0.07	no data	no data	no data
		Feb-09	39 (8, 31)	520	131	39	0.55	0.08	no data	no data	no data
		Apr-09	64 (32, 32)	5,219	131	110	1.26	0.16	no data	no data	no data
		May-09	29 (11, 18)	2,593	131	145	2.51	0.42	no data	no data	no data

Great Barrier Reef

Table 3 Theoretical 'true load' for each parameter for each suitable event selected from Great Barrier Reef sites. Total discharge and total number of samples per event are also presented.

Catchment	Site Gauging station No.	Year	Total No. samples (rise, fall)	Event discharge (ML)	Catchment area (km^2)	Event load TSS (t)	Event load TN (t)	Event load TP (t)	Event load NO_X (t)	Event load NH_4^+ (t)	Event load DIP (t)
Normanby	Normanby River @ Kalpowar Crossing 105107A	Feb-07	23 (16, 7)	1,246,857	12,934	42,176	523.56	59.95	21.94	14.75	16.96
		Feb-08	20 (14, 6)	3,300,715	12,934	188,418	1557	143.27	29.61	40.23	26.99
		Feb-09	11 (4, 7)	1,037,596	12,934	47,853	491.83	46.09	24.26	12.81	8.65
Barron	Barron River @ Myola 110001D	Dec-07	13 (14, 9)	3,475	1,945	339	2.75	0.31	0.35	0.06	0.04
		Jan-08	27 (17, 10)	160,057	1,945	35,614	176.27	21.71	9.05	0.88	1.19
		Feb-08	59 (52, 7)	287,295	1,945	58,944	262.78	51.58	11.60	2.16	5.56
		Jan-09	30 (5, 25)	76,275	1,945	31,896	62.56	8.82	2.85	0.70	0.43
	Barron River @ Picnic Crossing 110003A	Jan-07	25 (21, 4)	2,614	228	150	2.08	0.41	0.51	0.06	0.04
		Feb-07	15 (5, 10)	13,658	228	976	11.95	2.46	2.41	0.36	0.18
		Feb-07	14 (10, 4)	2,888	228	117	1.98	0.37	0.48	0.06	0.04
		Jan-08	53 (26, 27)	9,632	228	0.81	0.01	0.002	0.0014	0.0003	0.0001
		Feb-08	59 (36, 25)	32,130	228	2,348	24.01	4.68	4.21	0.65	0.58
		Mar-08	17 (5, 12)	43,806	228	5,605	30.35	7.96	7.82	0.74	0.66
		Jan-09	27 (14, 13)	6,980	228	442	4.97	1.17	0.76	0.13	0.19
		Feb-09	25 (8, 17)	7,398	228	673	6.17	1.62	0.90	0.11	0.09
		Feb-09	25 (14, 11)	29,901	228	1,890	18.24	4.17	3.42	0.35	0.73

Catchment	Site Gauging station No.	Year	Total No. samples (rise, fall)	Event discharge (ML)	Catchment area (km^2)	Event load TSS (t)	Event load TN (t)	Event load TP (t)	Event load NO_X (t)	Event load NH_4^+ (t)	Event load DIP (t)
Johnstone /Tully	North Johnstone River @ Tung Oil 112004A	Feb-07	10 (4, 6)	256,769	925	5,403	74.27	10.75	39.52	1.13	2.34
	South Johnstone River @ Upstream Central 112101B	Mar-08	13 (5, 8)	29,158	400	41	34.14	35.85	5.05	0.34	0.46
		Mar-08	25 (8, 17)	112,359	400	53	29.94	43.07	21.60	0.73	1.29
		Jan-09	11 (7, 4)	31,925	400	3,403	11.65	no data	3.73	0.32	0.49
		Feb-09	19 (10, 9)	170,977	400	64,472	265.70	84.07	23.82	1.79	1.55
	Tully River @ Euramo 113006A	Feb-08	13 (6, 7)	583,013	1,450	19,872	232.87	15.17	103.46	3.26	4.30
		Jan-09	22 (11, 11)	390,575	1,450	15,316	196.00	17.40	68.01	3.23	4.56
		Jan-09	52 (19, 33)	1,197,520	1,450	54,005	527.56	65.13	156.05	9.92	8.91
		Mar-09	20 (6, 14)	275,636	1,450	8,252	108.19	9.05	45.13	1.91	1.37
		Apr-09	21 (10, 11)	359,561	1,450	12,145	142.54	13.79	59.43	2.56	2.36
Herbert	Herbert River@ Ingham 116001F	Feb-07	10 (5, 5)	1,499,053	8,581	118,660	625.22	70.51	86.59	7.26	14.17
Burdekin	Burdekin River @ Home Hill 120001A	Jan-08	17 (6, 11)	7,000,777	129,760	2,923,132	7346.89	1839.1	750.27	44.30	167.08
		Jan-09	10 (4, 6)	1,879,248	129,760	54,5915	1086.88	290.48	123.14	40.16	42.30
		Jan-10	28 (13, 15)	20,137,086	129,760	6,950,171	16554.3	4883.3	838.01	642.69	475.19
Burdekin	Cape River @ Taemas 120302B	Dec-07	11 (7, 4)	75,952	16,074	23,665	65.72	11.85	0.94	0.39	0.38

Catchment	Site Gauging station No.	Year	Total No. samples (rise, fall)	Event discharge (ML)	Catchment area (km^2)	Event load TSS (t)	Event load TN (t)	Event load TP (t)	Event load NO$_X$ (t)	Event load NH$_4^+$ (t)	Event load DIP (t)
Burdekin	Suttor River @ Bowen Development Road 120310A	Jan-08	10 (4, 6)	316,547	10,758	118,827	348.90	87.03	10.92	7.38	10.82
Fitzroy	Fitzroy River @ Rockhampton 1300000	Feb-07	29 (16, 23)	569,079	139,159	70,210	828.26	272.87	130.54	37.06	23.32
		Jan-08	15 (7, 8)	5,700,293	139,159	3,065,798	8616.22	3431.1	779.42	151.59	440.94
		Feb-08	13 (7, 6)	5,399,360	139,159	1,537,807	5713.64	1893.1	610.88	65.34	503.83
		Feb-09	10 (6, 4)	1,177,466	139,159	260,968	1128.28	380.02	174.68	11.31	120.40
	Comet River @ Comet Weir 130504B	Jan-07	11 (8, 3)	40,447	16,457	45,950	81.51	44.02	no data	no data	no data
Burnett	Burnett River @ Mt Lawless 136002D	Oct-07	14 (4, 10)	6,241	29,395	2,145	8.46	1.63	0.75	0.26	0.33
	Burnett River @ Jones Weir TW 136094A	Feb-08	17 (9, 9)	4,769	21,700	1,419	6.40	1.13	0.79	0.25	0.20

Appendix B

Loads estimation methods (from Marsh 2011)

Table 4 Loads estimation methods and their source.

Method	Formula	Description	Source
	Averaging		
1	$k\sum_{i-1}^{n}\frac{c_i}{n}\sum_{i-1}^{n}\frac{q_i}{n}=k\overline{c}\overline{q}$	Mean flow x mean concentration (where only flow at concentration sampling times are used)	Walling and Webb 1981, Littlewood 1995
2	$k\sum_{i-1}^{n}\frac{c_i}{n}\sum_{i-1}^{n}\frac{q_i}{n}=k\overline{c}\overline{q}$	Mean flow x mean concentration (where all flow data are used)	Marsh 2011
3	$k\sum_{i-1}^{n}\frac{c_i q_i}{n}$	Traditional	Littlewood 1995, Walling and Webb 1981
4	$k\frac{\sum_{i-1}^{n}c_i q_i}{\sum_{i-1}^{n}q_i}\overline{q}$	Flow weighted concentration combined with mean discharge for the period.	Walling and Webb 1981
5	$\sum_{i-1}^{n}\frac{c_i+c_{i+1}}{2}q_i$	Inter-sample mean concentration times flow	Letcher et al. 1999
6	$\sum_{i-1}^{n}\frac{c_i+c_{i+1}}{2}\overline{q}_{<i+1}$	Inter-sample mean concentration times mean flow between concentration samples	Coats et al. 2007
7	$\sum_{i=0}^{n+1}\sum_{t_i<t\le t_{i+1}}^{i}q_t\frac{c_{tj}\left(t_{j+1}-t\right)+c_{tj+1}\left(t-t_j\right)}{t_{j+1}-t_j}$	Linear interpolation of concentration	Kronvang and Bruhn 1996
8	$k\sum_{i-1}^{n}c_i\overline{q_{pi}}$ Where pi denotes the period between samples	Average between sample flow; Sum of the products of sampled concentration and mean discharge for individual intervals	Walling and Webb 1981
9	$\sum_{j=1}^{2}\frac{N_j}{n_j}\left[\sum_{i=1}^{n_j}q_{ij}c_{ij}\right]$	Flow stratified average load where N is total number of time steps and n is flow strata defined as baseflow (<mean flow) or flood flow >mean flow) (flow stratified sampling)	Preston et al. 1989 in Letcher et al. 1999
10	$\sum_{j=1}^{2}\frac{N_j}{n_j}\left[\sum_{i=1}^{n_j}q_{ij}c_{ij}\right]$	Time stratified average load where N is total number of time steps and n is flow strata defined as before or after the peak flow (flow stratified sampling)	Marsh 2011

Method	Formula	Description	Source
	Ratio		
11	$\frac{\bar{l}}{\bar{q}}Q$	Simple Ratio; Using only concurrent flow and concentration data	Letcher et al. 1999
12	$\frac{\bar{l}}{\bar{q}}Q$	Simple Ratio; Using all flow data	Many authors
13	$\sum_{j=1}^{2}\left[\frac{\bar{l}_j}{\bar{q}_j}Q_j\right]$	Time Stratified Simple Ratio; stratified by peak flow. Using all flow data Determine load for rise and then for fall and combine	Marsh 2011
14	$Q\left(\frac{\bar{l}}{\bar{q}}\right)\left[\frac{1+\frac{S_{lq}}{n\bar{l}\bar{q}}}{1+\frac{S_{q^2}}{n\bar{q}^2}}\right]$	Beale Ratio	Beale 1962 described in Quilbe et al. 2006
15	$\sum_{j=1}^{2}\left\{Q\left(\frac{\bar{l}}{\bar{q}}\right)\left[\frac{1+\frac{S_{lq}}{n\bar{l}\bar{q}}}{1+\frac{S_{q^2}}{n\bar{q}^2}}\right]\right\}_j$	Beale Ratio: stratified by peak flow Determine load for rise and then for fall and combine	Marsh 2011
16	$Q\left(2R-0.5\left(R_1+R_2\right)\right)$	Quenouille Ratio (stratified): R = estimated ratio of the population $\frac{\bar{l}}{\bar{q}}$, and R1 is R applied to the first half of the concentration samples and R2 is R applied to the second half of the concentration samples. $\bar{q}$ is determined using only those flow values which are concurrent with concentration values	Quenouille 1956 described in Durbin 1959
17	$Q\left(2R-0.5\left(R_1+R_2\right)\right)$	Quenouille Ratio (stratified using – all data): R = estimated ratio of the population $\frac{\bar{l}}{\bar{q}}$, and R1 is R applied to the first half of the concentration samples and R2 is R applied to the second half of the concentration samples. $\bar{q}$ is determined using all flow values not just those concurrent with concentration values	Marsh 2011

Method	Formula	Description	Source
18	$Q\left(2R-0.5\left(R_1+R_2\right)\right)$	Quenouille Ratio – (time stratified by flow peak using): R = estimated ratio of the population $\frac{\bar{l}}{\bar{q}}$, and R1 is R applied prior to the peak flow and R_2 is R applied after the peak flow. $\bar{q}$ is determined using all flow values	Marsh 2011
19	$\hat{R}\left[\frac{1+\left(\frac{1}{n}-\frac{1}{N}\right)\left(\frac{S_{lq}}{\bar{l}\bar{q}}\right)}{1+\left(\frac{1}{n}-\frac{1}{N}\right)\left(\frac{S_{q^2}}{\bar{q}^2}\right)}\right]$	Tins Modified Ratio	Tin 1965
20	$\sum_{j=1}^{2}\left\{\hat{R}\left[\frac{1+\left(\frac{1}{n}-\frac{1}{N}\right)\left(\frac{S_{lq}}{\bar{l}\bar{q}}\right)}{1+\left(\frac{1}{n}-\frac{1}{N}\right)\left(\frac{S_{q^2}}{\bar{q}^2}\right)}\right]\right\}_j$	Tins Modified Ratio:stratified by peak flow Determine load for rise and then for fall and combine	Marsh 2011
21	$Q\left(R+\frac{n}{n-1}\left(\bar{l}-R\bar{q}\right)\right)$	Goodman and Hartley Ratio	Rao 1969
22	$\sum_{j=1}^{2}\left\{Q\left(R+\frac{n}{n-1}\left(\bar{l}-R\bar{q}\right)\right)\right\}_j$	Goodman and Hartley Ratio: stratified by peak flow Determine load for rise and then for fall and combine	Marsh 2011
23	$\left(\frac{\bar{y}}{\bar{x}}Q+\frac{1}{n-1}\left(\bar{l}-R\bar{q}\right)\right)$	Hartley Ratio	Rao 1969
24	$\sum_{j=1}^{2}\left\{\frac{\bar{y}}{\bar{x}}Q+\frac{1}{n-1}\left(\bar{l}-R\bar{q}\right)\right\}_j$	Hartley Ratio: stratified by peak flow Determine load for rise and then for fall and combine	Marsh 2011
	Regression		
25	$k\sum_{i-1}^{n}\frac{c_i q_i}{n}$ where $c_i = a q_i^b$	Concentration Power Curve Fitting	Many authors
26*	$\sum_{j=1}^{2}\left\{k\sum_{i-1}^{n}\frac{c_i q_i}{n}\right\}_j$ where $c_i = a q_i^b$	Concentration Power Curve Fitting: stratified by peak flow Determine load for rise and then for fall and combine	Marsh 2011

Method	Formula	Description	Source
27	$\sum_{j=1}^{2}\left\{\left(k\sum_{i-1}^{n}\frac{c_i q_i}{n}\right)CF\right\}_j$ where $c_i = a q_i^{b}$ $CF = \exp(2.651 s_c^2)$	Concentration Power Curve Fitting with Ferguson correction	Ferguson 1987
28*	$\sum_{j=1}^{2}\left\{\left(k\sum_{i-1}^{n}\frac{c_i q_i}{n}\right)CF\right\}_j$ where $c_i = a q_i^{b}$ $CF = \exp(2.651 s_c^2)$	Concentration Power Curve Fitting with Ferguson correction: stratified by peak flow Determine load for rise and then for fall and combine	Marsh 2011
29	$k\sum_{i-1}^{n}\frac{c_i q_i}{n}$ where $c_i = a + b q_i$ Where a and b are fitting coefficients	Concentration Linear Regression	Henriksen et al. 1985 in Kronvang and Bruhn 1996
30*	$\sum_{j=1}^{2}\left\{k\sum_{i-1}^{n}\frac{c_i q_i}{n}\right\}_j$ where $c_i = a + b q_i$ Where a and b are fitting coefficients	Concentration Linear Regression: stratified by peak flow Determine load for rise and then for fall and combine	Marsh 2011
31	$k\sum_{i-1}^{n}\frac{c_i q_i}{n}$ where $c_i = \exp(a + b q_i)\exp\left(\frac{s_c^2}{2}\right)$ where a and b are fitting coefficients and s^2 is the variance of concentration values	Power Regression Curve Fitting	Ferguson 1985
32*	$\sum_{j=1}^{2}\left\{k\sum_{i-1}^{n}\frac{c_i q_i}{n}\right\}_j$ where $c_i = \exp(a + b q_i)\exp\left(\frac{s_c^2}{2}\right)$ Where a and b are fitting coefficients and s^2 is the variance of concentration values	Power Regression Curve Fitting: stratified by peak flow Determine load for rise and then for fall and combine	Marsh 2011

Method	Formula	Description	Source
33	$k\sum_{i-1}^{n}\frac{c_i q_i}{n}$ where $c_i = \exp(a + bq_i)\exp\left(\frac{s_c^2}{2}\right)$ where a and b are fitting coefficients and s^2 is the variance of concentration values	Power Regression Curve Fitting	Ferguson 1985 in Kronvang and Bruhn 1996
34*	$\sum_{j=1}^{2}\left\{k\sum_{i-1}^{n}\frac{c_i q_i}{n}\right\}_j$ where $c_i = \exp(a + bq_i)\exp\left(\frac{s_c^2}{2}\right)$ where a and b are fitting coefficients and s^2 is the variance of concentration values	Power Regression Curve Fitting: stratified by peak flow Determine load for rise and then for fall and combine	Marsh 2011

* Loads estimation methods that were not successfully applied due to poor correlation between concentration and discharge values and an inability to return a loads estimate.

Appendix C

Best load estimation methods for each combination of loads parameter and sample regime

South East Queensland

Table 5 The best loads estimation method for each sampling regime and % deviation of this methods load estimate from the theoretical load for South East Queensland catchments. Load estimates within 20% of theoretical load estimate are shaded light grey, between 21-50% of the theoretical load estimate are shaded dark grey, between 51-100% of the theoretical load estimate are black.

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium nitrogen as N		Dissolved inorganic phosphorus	
Total No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
3	0	3	2	31	16	28	11	29	16	30	16	27	2	66
3	1	2	NONE	NONE	2	26	2	25	11	33	2	48	2	20
3	2	1	2	41	2	30	2	28	4	51	14	41	2	30
3	3	0	2	62	4	35	2	44	4	75	4	73	2	46
4	0	4	14	26	8	22	19	27	19	23	16	26	8	56
4	1	3	4	27	2	26	11	25	23	21	11	26	6	33
4	2	2	2	33	2	26	2	26	11	34	23	31	2	21
4	3	1	4	47	2	30	2	31	16	47	14	44	2	33
4	4	0	4	63	2	33	2	42	4	70	16	63	2	46
5	0	5	11	26	8	22	8	18	10	21	8	25	7	26
5	1	4	4	27	11	23	5	21	10	24	14	23	10	21
5	2	3	20	23	20	23	20	24	10	25	16	31	20	16
5	3	2	2	39	2	28	2	27	10	31	10	27	2	24
5	4	1	2	45	2	30	2	34	23	50	10	34	2	33

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium nitrogen as N		Dissolved inorganic phosphorus	
Total No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
5	5	0	4	67	2	35	2	40	4	68	19	73	2	45
6	0	6	19	24	8	22	8	20	10	24	8	23	10	22
6	1	5	5	26	11	23	6	22	16	21	10	21	10	21
6	2	4	20	25	20	22	5	22	10	25	10	22	20	17
6	3	3	20	24	20	23	24	24	24	22	10	25	24	17
6	4	2	2	41	2	28	2	29	10	32	10	31	2	26
6	5	1	4	50	2	30	2	35	10	45	10	38	2	35
6	6	0	4	72	2	34	2	42	10	57	10	44	2	49
7	0	7	14	25	10	20	8	21	10	23	10	22	10	21
7	1	6	11	24	6	21	5	21	10	22	10	21	10	22
7	2	5	20	23	25	20	5	19	15	23	10	25	20	20
7	3	4	20	22	5	20	5	21	15	22	10	24	20	14
7	4	3	20	23	20	20	20	23	24	23	20	27	20	17
7	5	2	5	42	2	29	2	31	16	38	10	32	2	28
7	6	1	2	57	2	29	2	35	25	46	10	38	2	41
7	7	0	2	72	2	33	2	41	4	65	10	47	2	47
8	0	8	23	26	8	21	8	20	10	24	10	22	10	23
8	1	7	8	24	5	21	5	18	16	19	11	21	6	20
8	2	6	20	23	5	18	5	15	23	21	11	21	20	16
8	3	5	20	22	5	17	5	20	15	20	11	23	20	15
8	4	4	20	22	5	20	5	19	15	22	20	23	20	15
8	5	3	20	22	25	20	5	23	24	22	24	24	20	18
8	6	2	33	47	33	25	2	32	16	40	10	35	2	31
8	7	1	2	59	2	31	2	36	25	47	10	39	2	38

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium nitrogen as N		Dissolved inorganic phosphorus	
Total No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
8	8	0	4	68	2	34	2	40	4	64	10	47	2	47
9	0	9	14	26	10	19	8	20	10	24	8	22	10	23
9	1	8	11	24	5	20	6	18	10	21	10	21	6	21
9	2	7	20	22	7	17	5	15	10	22	11	20	5	17
9	3	6	20	22	5	16	5	16	15	19	11	23	20	15
9	4	5	20	22	5	17	5	18	15	19	20	20	20	16
9	5	4	20	23	5	20	5	23	15	19	24	23	20	16
9	6	3	20	22	20	21	5	23	15	27	24	23	20	16
9	7	2	25	43	33	29	2	32	16	45	10	35	2	32
9	8	1	25	60	2	30	2	36	25	46	10	42	2	42
9	9	0	4	72	2	33	2	40	4	66	10	46	2	44
10	0	10	8	26	8	22	8	19	10	23	8	24	10	22
10	1	9	5	23	11	19	6	18	16	19	10	22	6	20
10	2	8	20	21	5	16	5	17	16	19	11	20	24	16
10	3	7	5	19	5	13	5	12	15	17	11	21	5	15
10	4	6	20	21	5	15	7	15	15	19	11	23	20	15
10	5	5	20	20	5	19	5	18	15	17	20	24	20	14
10	6	4	20	22	5	18	20	21	15	24	20	21	20	15
10	7	3	20	22	20	20	20	21	15	25	20	25	20	17
10	8	2	25	45	2	29	25	32	16	44	10	36	2	34
10	9	1	25	59	33	30	2	37	25	47	10	45	2	40
10	10	0	2	70	2	32	2	40	25	55	10	47	2	45
11	0	11	10	25	11	21	8	21	10	22	16	24	10	24
11	1	10	5	23	6	19	6	17	10	22	11	22	6	21

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium nitrogen as N		Dissolved inorganic phosphorus	
Total No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
11	2	9	11	24	5	14	5	14	16	18	11	20	20	14
11	3	8	5	21	5	13	5	16	7	19	11	20	5	12
11	4	7	20	21	5	12	5	16	5	19	11	22	20	14
11	5	6	20	20	5	15	5	16	15	17	11	20	20	15
11	6	5	20	20	5	16	7	17	15	20	15	23	20	14
11	7	4	20	19	20	19	5	21	24	22	20	20	20	15
11	8	3	20	21	20	20	20	20	15	27	20	25	20	16
11	9	2	5	47	2	28	25	31	25	40	10	41	2	35
11	10	1	2	62	2	32	2	38	25	47	10	53	2	39
11	11	0	29	51	2	33	2	40	4	65	10	60	2	47
12	0	12	14	27	11	20	8	20	10	23	10	22	10	21
12	1	11	6	22	11	17	8	20	10	21	11	22	6	20
12	2	10	5	19	5	16	5	15	16	19	11	18	20	13
12	3	9	5	19	5	12	5	15	7	18	11	21	20	14
12	4	8	20	20	5	11	5	13	7	18	11	19	5	16
12	5	7	20	20	5	15	5	15	15	16	11	22	5	12
12	6	6	20	19	5	13	5	17	15	18	20	21	20	14
12	7	5	20	20	20	17	5	18	7	20	20	24	20	14
12	8	4	20	21	20	20	5	18	15	22	20	22	20	16
12	9	3	20	21	20	21	20	19	24	26	20	24	20	15
12	10	2	5	48	33	28	2	34	25	40	10	38	2	36
12	11	1	2	63	2	31	2	37	25	50	10	44	2	41
12	12	0	29	51	2	33	2	41	25	62	10	57	2	46
13	0	13	8	25	11	20	8	20	10	20	8	23	10	23

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium nitrogen as N		Dissolved inorganic phosphorus	
Total No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
13	1	12	7	21	11	17	6	18	10	20	11	21	6	20
13	2	11	5	20	5	14	5	16	7	18	11	19	20	14
13	3	10	20	21	5	13	5	14	7	16	11	17	5	13
13	4	9	5	17	5	11	5	14	7	18	11	18	5	13
13	5	8	20	19	5	12	5	15	5	16	11	20	5	14
13	6	7	5	19	5	12	5	13	7	15	20	21	20	13
13	7	6	24	20	5	13	20	20	5	20	20	21	20	13
13	8	5	20	20	5	16	5	17	15	20	20	21	20	13
13	9	4	20	20	5	18	5	20	24	22	20	20	20	16
13	10	3	20	21	20	19	20	20	20	21	20	26	20	15
13	11	2	5	49	33	27	2	34	25	39	5	45	2	36
13	12	1	2	61	33	28	2	37	25	45	10	54	2	40
13	13	0	29	60	2	33	2	40	25	56	10	53	2	46
14	0	14	14	25	27	19	8	21	10	21	10	23	10	21
14	1	13	11	21	11	18	8	18	10	19	14	21	10	20
14	2	12	5	20	5	16	5	16	10	18	11	18	20	16
14	3	11	7	19	5	13	5	13	7	17	11	18	20	13
14	4	10	7	18	5	11	5	10	7	14	11	17	20	13
14	5	9	5	17	5	10	5	16	5	15	11	18	5	12
14	6	8	5	17	5	11	5	11	5	15	20	20	20	11
14	7	7	5	18	5	12	5	14	5	15	15	20	5	12
14	8	6	20	19	5	13	5	15	5	18	20	20	20	14
14	9	5	20	20	5	15	5	18	5	22	20	22	20	15
14	10	4	20	20	5	20	20	21	15	22	20	21	20	14

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium nitrogen as N		Dissolved inorganic phosphorus	
Total No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
14	11	3	20	22	20	20	20	22	24	23	20	19	20	17
14	12	2	5	49	33	27	33	33	25	42	5	42	2	36
14	13	1	2	64	33	31	2	38	25	48	10	48	2	41
14	14	0	29	48	33	33	29	37	25	57	10	58	2	46
15	0	15	3	25	11	20	11	21	10	21	10	23	10	24
15	1	14	5	21	11	17	11	19	10	20	11	21	10	18
15	2	13	5	18	5	14	5	15	15	17	11	19	5	16
15	3	12	5	20	5	12	5	16	7	15	11	17	20	13
15	4	11	5	18	5	15	5	13	7	14	11	17	5	12
15	5	10	7	17	5	11	5	11	7	16	20	21	5	11
15	6	9	5	18	5	11	5	13	7	15	15	20	20	12
15	7	8	5	17	5	11	5	11	5	16	20	18	5	11
15	8	7	5	18	5	11	5	13	5	18	20	18	5	12
15	9	6	5	19	5	11	5	14	5	20	20	18	20	15
15	10	5	20	20	5	15	5	16	7	20	20	20	20	15
15	11	4	20	20	20	19	5	18	24	20	20	19	20	15
15	12	3	20	21	20	21	20	22	15	28	20	24	20	17
15	13	2	5	53	33	27	33	34	25	41	10	50	2	36
15	14	1	2	64	33	28	2	39	25	44	10	54	2	41
15	15	0	29	48	2	33	2	41	25	60	29	36	2	45
16	1	15	23	21	11	17	6	17	10	20	10	20	10	18
16	2	14	5	20	5	15	5	17	15	16	11	19	5	14
16	3	13	5	18	7	12	5	14	7	16	11	17	5	14
16	4	12	5	18	5	10	5	12	7	14	7	20	5	13

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium nitrogen as N		Dissolved inorganic phosphorus	
Total No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
16	5	11	7	18	5	10	5	12	7	13	10	19	5	11
16	6	10	5	16	5	11	5	13	5	14	15	19	5	11
16	7	9	5	15	5	9	5	11	5	14	20	17	5	11
16	8	8	5	15	5	10	5	11	5	15	5	19	5	10
16	9	7	5	15	5	11	5	13	5	15	20	19	5	12
16	10	6	20	18	5	12	5	13	5	20	7	19	20	13
16	11	5	5	19	5	15	5	16	5	20	20	17	20	14
16	12	4	20	21	20	18	5	20	24	23	20	23	20	15
16	13	3	20	20	24	21	20	20	24	24	24	25	20	16
16	14	2	5	50	33	28	2	35	25	39	10	48	2	37
16	15	1	25	61	33	30	2	37	19	58	10	55	2	40
17	2	15	7	18	11	15	5	14	10	16	11	19	20	15
17	3	14	7	18	5	11	5	16	7	15	11	17	7	11
17	4	13	5	17	5	10	5	11	7	12	19	18	5	10
17	5	12	5	15	5	11	5	15	5	13	11	16	5	10
17	6	11	5	15	5	9	5	12	5	13	7	18	5	11
17	7	10	5	16	5	9	5	11	7	11	5	18	5	10
17	8	9	5	14	5	9	5	13	5	12	5	15	5	10
17	9	8	5	15	5	10	5	11	5	16	20	17	5	12
17	10	7	5	15	5	11	5	13	5	16	20	19	20	13
17	11	6	20	18	5	13	5	13	5	18	20	19	20	13
17	12	5	20	20	5	14	5	13	5	22	20	22	20	14
17	13	4	20	20	20	18	20	20	5	23	20	19	20	15
17	14	3	20	21	20	20	20	21	24	22	20	23	20	16

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium nitrogen as N		Dissolved inorganic phosphorus	
Total No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
17	15	2	5	48	33	29	2	35	25	41	10	46	5	36
18	3	15	20	18	7	12	5	13	7	16	11	18	5	12
18	4	14	5	17	5	10	7	12	7	13	11	20	5	10
18	5	13	5	17	5	10	5	17	7	13	11	17	5	11
18	6	12	5	13	5	8	5	11	5	13	7	18	5	10
18	7	11	5	16	5	10	5	11	5	12	20	17	5	9
18	8	10	7	14	5	9	5	12	5	12	7	16	5	9
18	9	9	5	14	5	10	5	11	5	13	20	19	5	10
18	10	8	5	14	5	10	5	11	5	16	5	18	5	11
18	11	7	5	18	5	11	5	12	5	15	6	18	5	11
18	12	6	20	18	5	12	5	13	5	20	5	20	5	12
18	13	5	20	19	5	16	5	16	6	22	20	20	20	13
18	14	4	20	20	20	19	5	18	24	17	20	21	20	14
18	15	3	20	20	20	19	20	20	24	28	20	24	20	14

Great Barrier Reef

Table 6 The best loads estimation method for each sampling regime and % deviation of this methods load estimate from the theoretical load for Great Barrier Reef catchments. Load estimates within 20% of the theoretical load estimate are shaded light grey, between 21-50% of the theoretical load estimate are shaded dark grey, while those between 51-100% of the theoretical load estimate or none are black.

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium		Dissolved inorganic phosphorus	
No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
3	0	3	2	24	23	21	16	21	10	16	4	22	4	27
3	1	2	2	21	2	18	2	18	10	16	16	23	10	19
3	2	1	2	41	2	18	2	28	10	19	10	17	2	29
3	3	0	2	75	2	27	2	60	10	20	10	22	2	40
4	0	4	4	22	14	19	23	20	10	21	10	15	4	29
4	1	3	2	22	11	16	2	18	23	18	10	13	10	20
4	2	2	2	31	2	16	2	22	10	19	10	18	2	24
4	3	1	2	49	2	20	2	41	10	22	10	19	2	31
4	4	0	2	68	2	26	2	52	10	20	10	22	2	40
5	0	5	5	20	14	18	14	20	4	20	10	19	4	28
5	1	4	2	23	11	16	6	16	4	17	10	19	10	25
5	2	3	20	20	20	14	20	16	4	19	10	22	6	22
5	3	2	2	37	2	19	2	27	10	23	4	18	2	25
5	4	1	2	56	2	22	2	42	10	22	4	19	2	33
5	5	0	2	74	2	26	2	55	10	23	4	22	2	40
6	0	6	8	21	14	16	14	19	4	18	3	19	4	23
6	1	5	1	20	11	14	6	13	16	18	3	18	4	20
6	2	4	20	21	20	13	6	14	16	19	10	18	20	21
6	3	3	20	20	20	13	20	15	20	14	4	17	20	21
6	4	2	2	44	2	18	2	32	10	19	4	17	25	27

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium		Dissolved inorganic phosphorus	
No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
6	5	1	2	56	27	21	2	42	33	19	4	18	25	29
6	6	0	2	69	2	26	2	52	25	18	4	22	2	38
7	0	7	8	20	25	15	23	19	4	20	3	18	4	25
7	1	6	4	22	11	13	6	15	4	16	10	19	4	23
7	2	5	20	20	20	13	20	15	4	16	4	16	20	20
7	3	4	20	17	20	12	20	14	20	15	4	15	20	20
7	4	3	20	22	20	12	20	17	20	14	4	16	20	20
7	5	2	2	48	27	17	2	34	10	20	4	18	2	30
7	6	1	2	58	27	20	2	45	25	19	4	18	2	35
7	7	0	2	69	2	28	2	52	25	26	4	20	2	40
8	0	8	25	21	14	16	14	19	11	18	4	20	4	25
8	1	7	25	21	11	12	6	13	4	18	10	20	4	19
8	2	6	6	18	20	12	6	13	4	16	4	18	20	17
8	3	5	20	20	20	11	5	15	20	15	4	14	6	15
8	4	4	20	19	20	12	20	15	7	16	4	14	20	18
8	5	3	20	17	20	12	20	18	25	16	4	15	20	19
8	6	2	25	46	25	20	25	36	25	18	4	17	2	30
8	7	1	2	58	27	21	2	44	33	20	4	19	25	33
8	8	0	2	68	2	27	2	52	10	22	4	22	2	38
9	0	9	8	19	14	15	14	20	4	18	3	20	4	23
9	1	8	4	21	11	13	6	15	4	13	4	17	4	19
9	2	7	5	19	20	12	5	13	4	13	4	18	20	16
9	3	6	20	18	5	11	20	13	4	14	16	18	5	15
9	4	5	20	19	20	10	20	14	7	14	5	17	6	13

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium		Dissolved inorganic phosphorus	
No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
9	5	4	20	20	20	10	20	15	7	16	16	17	6	16
9	6	3	20	17	20	12	20	18	20	13	25	17	20	18
9	7	2	25	49	27	18	25	35	25	18	4	16	25	28
9	8	1	2	60	27	21	25	46	33	20	14	19	2	35
9	9	0	2	67	2	27	2	55	25	22	19	23	2	39
10	0	10	8	21	14	15	14	18	14	17	19	20	4	23
10	1	9	4	19	11	12	5	14	11	16	8	18	4	18
10	2	8	6	18	5	11	5	11	11	13	4	18	25	16
10	3	7	5	18	6	10	5	11	7	14	4	17	20	15
10	4	6	20	20	6	10	5	12	4	13	20	17	6	14
10	5	5	20	19	20	10	20	14	7	12	33	17	6	12
10	6	4	20	21	20	11	20	16	25	13	4	14	20	18
10	7	3	20	21	20	12	20	15	4	19	25	16	20	19
10	8	2	25	51	27	18	25	35	25	17	25	15	25	27
10	9	1	25	60	27	23	2	48	25	17	4	19	25	34
10	10	0	2	69	2	26	2	55	33	21	2	38	2	39
11	0	11	14	22	19	15	14	19	11	15	10	21	4	23
11	1	10	4	19	14	13	11	15	11	15	3	19	4	20
11	2	9	5	18	11	10	5	12	4	11	10	16	4	16
11	3	8	5	15	5	9	5	10	7	12	4	17	6	14
11	4	7	5	17	5	9	5	11	7	12	4	14	6	12
11	5	6	20	17	20	10	20	11	6	13	4	13	5	14
11	6	5	20	16	20	10	20	13	7	12	4	14	6	14
11	7	4	20	20	20	11	20	14	25	13	33	17	5	16

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium		Dissolved inorganic phosphorus	
No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
11	8	3	20	17	20	11	20	18	20	13	25	16	20	20
11	9	2	25	49	27	21	25	37	4	20	25	16	25	28
11	10	1	25	59	27	21	25	47	33	15	25	29	27	35
11	11	0	2	69	2	26	2	54	25	22	2	34	2	39
12	0	12	14	21	19	14	19	19	11	18	4	19	4	21
12	1	11	4	19	14	12	6	14	11	14	4	19	4	20
12	2	10	5	16	11	11	5	10	11	13	4	17	4	18
12	3	9	5	16	20	10	6	9	11	12	7	17	6	14
12	4	8	6	17	20	9	5	10	7	12	16	17	5	13
12	5	7	24	16	6	9	5	12	7	10	31	13	5	13
12	6	6	20	20	20	10	20	12	7	12	27	15	5	12
12	7	5	20	19	20	10	20	13	7	13	31	14	5	11
12	8	4	20	21	20	11	20	14	25	14	20	18	6	15
12	9	3	20	20	20	12	20	18	20	12	25	17	20	19
12	10	2	25	50	27	19	25	38	27	15	25	17	25	30
12	11	1	2	61	27	22	25	47	27	17	19	20	2	36
12	12	0	2	71	2	26	2	55	25	20	14	22	2	40
13	0	13	19	21	14	15	19	18	11	15	19	19	4	23
13	1	12	4	19	19	11	14	14	11	13	4	17	4	19
13	2	11	6	16	25	9	5	10	4	14	4	18	4	17
13	3	10	5	14	20	9	5	9	7	13	4	15	20	14
13	4	9	5	15	5	8	5	9	7	10	5	14	6	12
13	5	8	24	17	5	8	5	10	7	10	31	15	6	11
13	6	7	20	18	20	8	24	11	7	10	33	17	5	12

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium		Dissolved inorganic phosphorus	
No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
13	7	6	20	19	20	10	20	13	25	12	5	14	5	12
13	8	5	20	18	20	10	20	16	25	12	16	16	5	15
13	9	4	20	19	20	11	20	14	25	14	25	18	6	15
13	10	3	20	18	20	12	20	18	20	14	4	17	20	19
13	11	2	25	50	27	21	25	41	27	15	25	17	27	30
13	12	1	25	60	27	22	25	46	27	19	25	25	27	33
13	13	0	2	70	2	26	2	55	25	19	2	35	2	40
14	0	14	14	21	19	14	14	18	11	15	8	19	4	22
14	1	13	4	19	14	12	6	15	11	14	4	17	4	19
14	2	12	5	16	11	11	7	12	11	12	4	17	25	16
14	3	11	5	16	5	9	5	11	7	12	4	15	25	14
14	4	10	6	15	6	7	5	8	7	10	27	14	6	13
14	5	9	24	16	5	7	5	9	7	10	27	13	25	13
14	6	8	24	16	6	7	5	11	7	10	5	17	6	9
14	7	7	5	19	6	9	24	14	7	9	27	13	6	12
14	8	6	20	14	20	9	20	12	20	11	27	13	6	12
14	9	5	20	18	20	10	20	13	7	12	16	14	5	12
14	10	4	20	15	20	10	20	15	25	14	25	17	5	18
14	11	3	20	17	20	11	20	16	20	13	25	15	20	19
14	12	2	25	56	27	21	25	39	25	17	25	18	25	32
14	13	1	25	61	27	21	25	48	33	16	25	32	27	36
14	14	0	2	71	2	27	2	55	25	20	25	23	2	39
15	0	15	19	22	25	14	14	18	11	15	19	20	4	22
15	1	14	4	19	14	11	6	15	11	13	4	18	4	20

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium		Dissolved inorganic phosphorus	
No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
15	2	13	4	17	14	10	5	12	11	14	4	17	25	16
15	3	12	5	14	20	9	5	10	11	12	27	15	20	14
15	4	11	5	14	6	7	5	9	7	10	7	14	6	10
15	5	10	6	13	5	7	5	9	7	9	27	14	6	10
15	6	9	5	13	6	8	5	9	7	9	5	12	6	11
15	7	8	24	15	20	8	5	10	7	9	27	13	5	9
15	8	7	24	16	20	9	24	11	7	10	27	14	5	10
15	9	6	20	19	20	9	20	12	7	11	33	14	6	11
15	10	5	20	18	20	10	20	15	25	13	20	15	5	13
15	11	4	20	22	20	11	20	16	20	12	25	14	5	16
15	12	3	20	17	20	12	20	15	20	14	31	14	20	19
15	13	2	25	54	2	22	25	41	4	22	25	20	27	30
15	14	1	25	62	27	21	25	48	33	17	25	29	25	34
15	15	0	2	71	2	26	2	55	25	19	25	26	2	39
16	1	15	4	19	19	11	6	15	11	14	4	17	4	19
16	2	14	5	17	14	9	5	12	11	12	4	17	20	15
16	3	13	5	15	20	9	7	8	7	12	4	16	25	15
16	4	12	5	12	5	7	5	8	7	9	4	14	6	11
16	5	11	5	14	5	7	5	8	7	8	27	14	5	12
16	6	10	24	15	6	6	5	8	7	9	5	12	33	12
16	7	9	24	15	6	7	5	9	6	8	6	10	6	9
16	8	8	24	16	20	8	5	10	7	9	5	14	6	10
16	9	7	20	16	20	9	24	12	6	9	16	14	5	9
16	10	6	24	19	20	9	24	11	7	11	33	14	5	11

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium		Dissolved inorganic phosphorus	
No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
16	11	5	20	21	20	11	20	12	25	13	33	15	5	12
16	12	4	20	16	20	11	20	14	25	14	25	16	5	15
16	13	3	20	19	20	14	20	18	25	15	25	16	20	18
16	14	2	25	55	27	19	25	42	25	19	25	22	27	30
16	15	1	25	64	27	21	25	48	27	16	25	26	25	35
17	2	15	5	17	14	10	7	13	11	12	8	16	4	17
17	3	14	5	16	20	9	7	8	11	11	4	16	20	14
17	4	13	5	14	5	6	5	9	7	9	4	13	20	13
17	5	12	5	13	5	6	5	7	7	8	20	13	7	11
17	6	11	6	13	6	7	5	8	7	8	7	13	7	12
17	7	10	24	13	6	7	5	10	7	8	27	13	5	11
17	8	9	5	15	5	7	5	9	6	8	5	10	5	9
17	9	8	24	16	6	8	20	9	7	9	31	12	5	9
17	10	7	24	17	20	8	24	12	7	9	33	15	5	10
17	11	6	20	17	20	9	24	13	6	10	33	14	6	11
17	12	5	20	18	20	10	20	12	7	12	20	15	5	13
17	13	4	20	15	20	12	20	14	27	12	25	15	5	16
17	14	3	20	18	20	11	20	20	20	14	25	17	20	20
17	15	2	25	56	27	20	25	42	4	20	25	18	27	30
18	3	15	5	15	20	9	7	10	11	12	4	16	20	13
18	4	14	5	14	5	7	5	7	7	9	4	14	6	11
18	5	13	5	13	5	6	5	8	7	8	5	14	7	11
18	6	12	24	13	6	6	5	8	7	8	5	13	33	11
18	7	11	5	13	6	6	5	9	7	8	5	12	5	9

Sample regime			Total suspended solids		Total nitrogen		Total phosphorus		Oxidised nitrogen		Ammonium		Dissolved inorganic phosphorus	
No. of samples	No. of samples on the rise	No. of samples on the fall	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load	Method No.	% deviation from theoretical load
18	8	10	24	13	5	6	5	9	7	8	5	12	7	11
18	9	9	24	14	6	7	5	10	7	7	5	11	5	8
18	10	8	24	16	24	8	5	11	7	8	5	11	20	11
18	11	7	24	15	20	9	24	11	7	9	5	12	5	10
18	12	6	20	17	20	9	20	14	25	12	5	14	5	11
18	13	5	20	17	20	10	20	13	25	13	33	15	20	14
18	14	4	20	16	20	10	20	14	20	12	25	15	20	18
18	15	3	20	18	20	12	20	16	25	16	25	16	20	20

Appendix D

Effect of sample regime on the root mean square error values for events with three to seven samples

South East Queensland

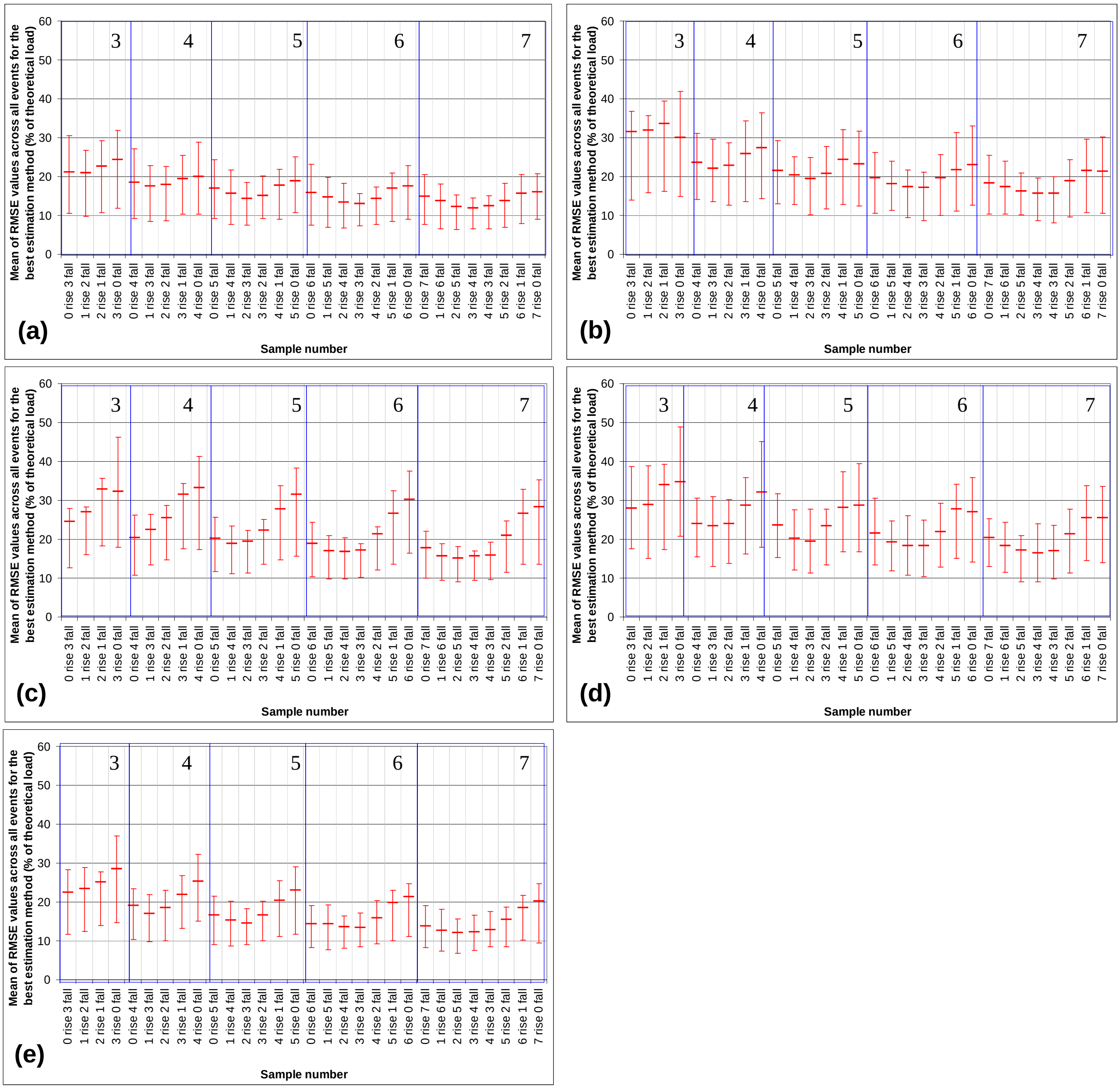

Figure 6 Effect of sample regime ([sample size - the number at the top of each segment in the graphs] and [sample distribution - the number of samples collected on the rise and fall of the hydrograph]) on mean root mean square error (Mean RMSE) values (error bars show 75th and 25th percentile range) for events in South East Queensland catchments for a) Total nitrogen; b) Total phosphorus; c) Oxidised nitrogen; d) Ammonium; and e) Dissolved inorganic phosphorus. The corresponding figure for total suspended solids is located in the text (Figure 2 in Section 3.2).

Great Barrier Reef

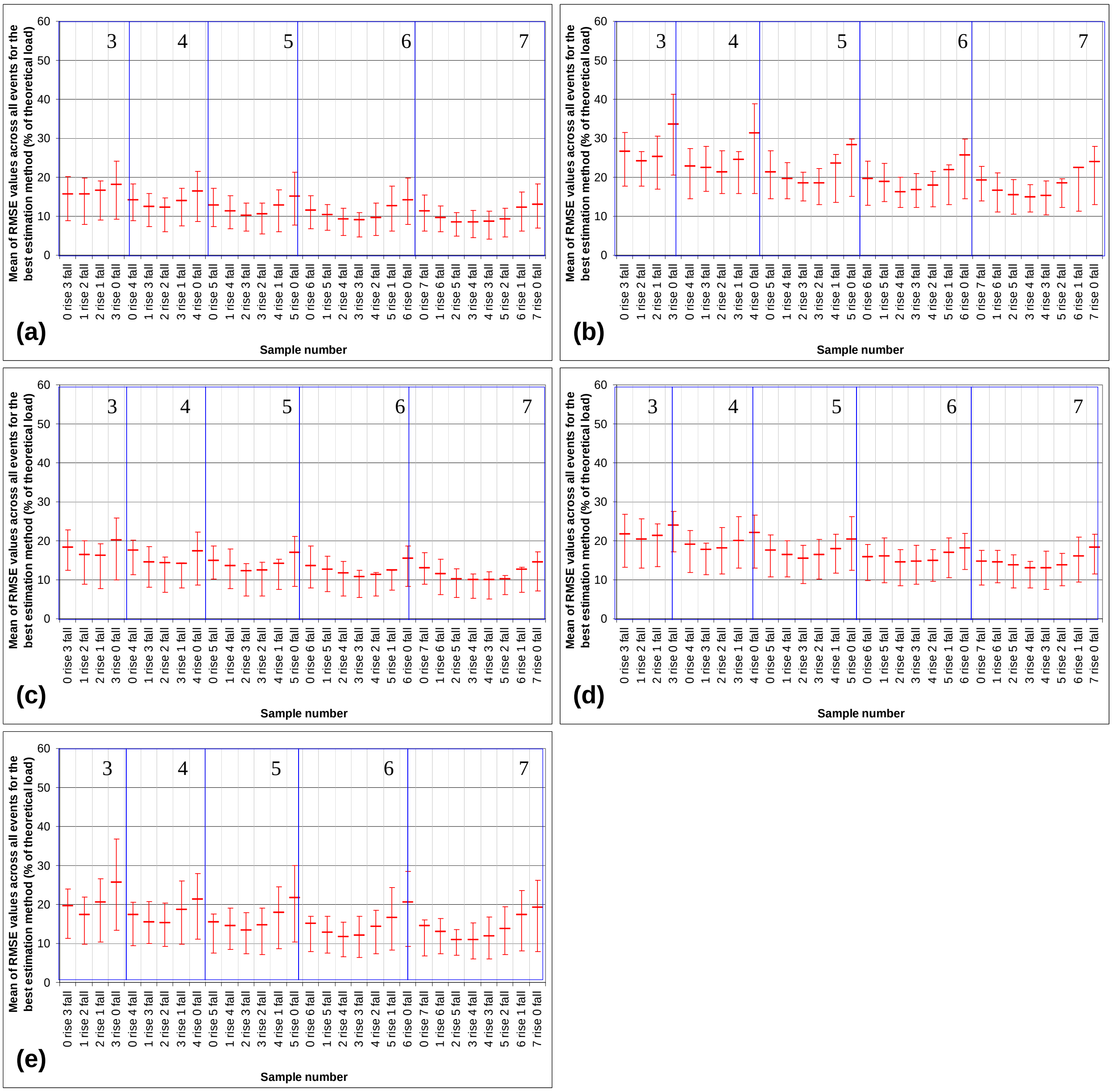

Figure 7 Effect of sample regime ([sample size - the number at the top of each segment in the graphs] and [sample distribution - the number of samples collected on the rise and fall of the hydrograph]) on mean root mean square error (Mean RMSE) values (error bars show 75th and 25th percentile range) for events in Great Barrier Reef catchments for a) Total nitrogen; b) Total phosphorus; c) Oxidised nitrogen; d) Ammonium; and e) Dissolved inorganic phosphorus. The corresponding figure for total suspended solids is located in the text (Figure 3 in Section 3.2).

Appendix E

Effect of sample regime on the root mean square error values for events with three to thirty samples

South East Queensland

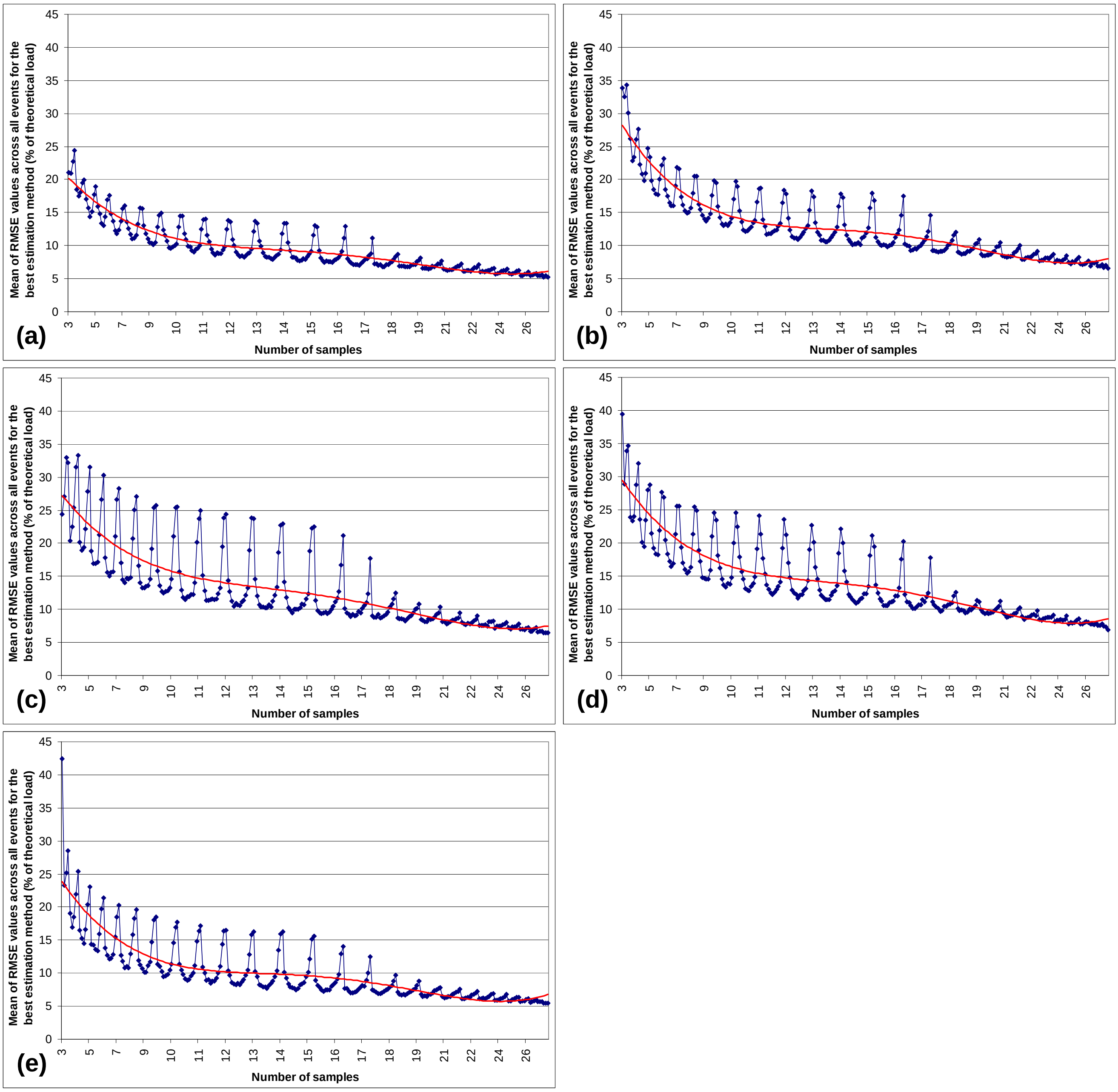

Figure 8 Effect of sample regime ([sample size - the number at the top of each segment in the graphs] and [sample distribution - the number of samples collected on the rise and fall of the hydrograph]) on mean root mean square error (Mean RMSE) values (error bars show 75th and 25th percentile range) for events in South East Queensland catchments for a) Total nitrogen; b) Total phosphorus; c) Oxidised nitrogen; d) Ammonium; and e) Dissolved inorganic phosphorus. The corresponding figure for total suspended solids is located in the text (Figure 4 in Section 3.2).

Great Barrier Reef

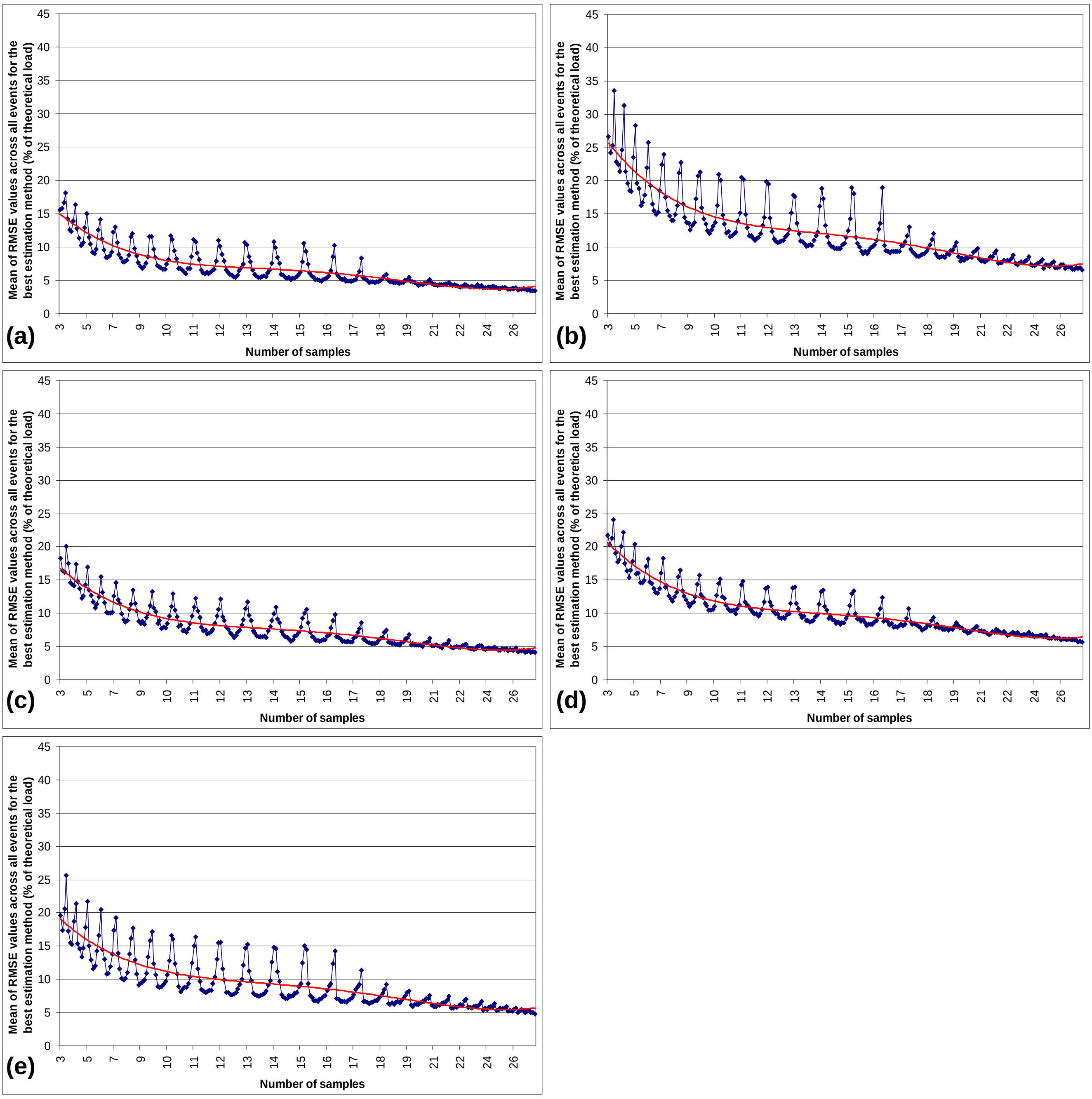

Figure 9 Effect of sample regime ([sample size - the number at the top of each segment in the graphs] and [sample distribution - the number of samples collected on the rise and fall of the hydrograph]) on mean root mean square error (Mean RMSE) values (error bars show 75th and 25th percentile range) for events in Great Barrier Reef catchments for a) Total nitrogen; b) Total phosphorus; c) Oxidised nitrogen; d) Ammonium; and e) Dissolved inorganic phosphorus. The corresponding figure for total suspended solids is located in the text (Figure 5 in Section 3.2).