Department of Science, Information Technology, Innovation and the Arts

Risk Assessment and Catchment Prioritisation for Suspended Solids, Nutrients and Pesticides in the Mackay Whitsunday Region and Recommendations for Future Water Quality Monitoring

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Prepared by

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Executive summary

The Mackay Whitsunday region in central Queensland extends along the eastern coast north of Clairview to south of Bowen and includes the Whitsunday Islands of the Great Barrier Reef (GBR). The region covers over 800,000 hectares and is diverse in ecosystems. The major land uses in the region are grazing and sugar cane farming, followed by horticulture and urban development. In 2008, the Mackay Whitsunday Water Quality Improvement Plan (WQIP) was released, summarising the 2007 water quality, water quality objectives for 2050, and water quality targets for 2014 for both ambient and event conditions. The overall aim of the targets and WQOs was to improve water quality and ecological health of regional waterways, estuaries and relevant areas of the GBR.

This report performed target and risk assessments of total suspended solids (TSS), nutrients, and pesticides in waterways within the Mackay Whitsunday region. This report identifies if concentrations of TSS, nutrients and pesticides have changed over time within the region, whether current targets are appropriate to provide adequate protection of the waterways and if risks posed by pesticides have changed over time. Additionally, this report incorporates the development of new ecotoxicity thresholds for the priority PSII herbicides, consistent with the recommended rules for deriving the current Australian and New Zealand water quality guideline trigger values.

New ecotoxicity thresholds were derived for the pesticides ametryn, atrazine, diuron, hexazinone, and tebuthiuron. With regard to the 95% species protection levels, the ecotoxicity thresholds proposed are approximately half the current Australian and New Zealand water quality guideline trigger value for atrazine, slightly higher for diuron, significantly lower for hexazinone and significantly higher for tebuthiuron. Based on the data used to derive the new ecotoxicity thresholds, the toxic effects of pesticide mixtures were also calculated using the multisubstance potentially affected fraction (ms-PAF) method.

Of the 24 water quality sites in the Mackay Whitsunday region, 13 sites had good data availability for the assessment of TSS and nutrients under ambient conditions. For the majority of these sites, data were only available for one year (2007–2008) after the WQIP targets were set in 2007. Only two sites had good data availability for TSS and nutrients under event conditions. For pesticide sampling, 13 out of the 24 sites had good data availability under ambient conditions and only two sites had good data availability for event conditions. Concentrations of TSS, nutrients and pesticides sampled from July 2007 onwards, were compared to the 2014 targets; however, for all sites except Pioneer River and Sandy Creek, ambient and event data have not been collected since 2009. It is highly recommended that further data are collected to assess the current status of TSS, nutrient, and pesticide concentrations relative to the 2014 targets.

Few changes occurred over the sampling period (2004–2013) in TSS concentrations, however in Sandy Creek where more data were available, there was a decrease in ambient concentrations. Only one site had an increase in event TSS concentrations over the sampling period. The highest ambient TSS concentration occurred in Myrtle Creek (150 mg/L). The highest event TSS concentration occurred in Airlie Creek (2665 mg/L). Based on the data available, it is recommended that monitoring for TSS is resumed at Airlie Creek, Myrtle Creek, and Waite Creek as a first priority based on the TSS concentrations detected at these sites.

The nutrient concentrations show varied results in a number of waterways in both ambient and event conditions. Particulate Nitrogen (PN) concentrations changed over time (increased) for event

conditions in Plane Creek. Event Particulate Phosphorus (PP) concentrations increased over time in Myrtle Creek and Plane Creek. No waterways had a decrease in event or ambient PN or PP concentrations over the sampling period. Ambient dissolved inorganic nitrogen (DIN) concentrations increased at seven of the sampling sites. Sandy Creek had a decrease in event DIN concentrations, while in Gregory River, event concentrations increased. Increases in ambient FRP were seen in Upper Andromache River and Basin Creek. Sandy Creek had decreases in both ambient and event FRP over the sampling period. Based on the data available, it is recommended that monitoring for nutrients is resumed at Bakers Creek, Mackay City, Sandy Creek, and Waite Creek as a first priority based on the nutrient concentrations detected at these sites.

Regarding individual pesticide concentrations in the sampled waterways, no sites showed trends in ambient or event ametryn concentrations over time. Changes in atrazine concentrations were seen in four waterways, three of which had increases over time in event atrazine concentrations. A decrease in atrazine concentrations was seen in Sandy Creek. Diuron concentrations changed over time only in Sandy Creek, which was one of the two waterways that had more data available than the other waterways. Diuron concentrations for both ambient and event samples decreased in Sandy Creek. There were only two waterways in which hexazinone concentrations changed over time. These were Sandy Creek (decrease in ambient and event concentrations), and Andromache River (increase in event concentrations). Two waterways had an increase in event tebuthiuron concentrations over the sampling period, while no waterways had a decrease in tebuthiuron over time.

It appears that few changes have occurred in the mixtures of pesticides (demonstrated in ms-PAF results) over the sampling period in the Mackay Whitsunday region in both ambient and event conditions. However, the two sites in which changes in ms-PAF results were seen, Sandy Creek and Pioneer River, are the only sites with extended monitoring (beyond 2009). In Pioneer River the ms-PAF results for ambient conditions decreased over the sampling period. In Sandy Creek the ms-PAF results decreased under both the ambient and event conditions over the sampling period. The ms-PAF results for a number of waterways under ambient conditions indicate adequate protection was provided, but under event conditions, the protection for species was not adequate. Based on the data available, it is recommended that monitoring for pesticides is resumed at Bakers Creek, Carmila Creek, Gregory River, Myrtle Creek, O'Connell River, Pioneer River, Plane Creek, Rocky Dam Creek and Sandy Creek as a first priority based on the individual pesticide concentrations and pesticide mixtures detected at these sites.

Contents

List of tables

List of figures

1 Introduction

1.1 General

The Mackay Whitsunday region in central Queensland extends along the eastern coast north of Clairview to south of Bowen and includes the Whitsunday Islands of the Great Barrier Reef (GBR). The region covers over 800,000 hectares (ha) and is bounded by the Connors-Clarke ranges to the west, and the Coral Sea to the east (Drewry et al. 2008). The region is diverse in ecosystems, including soft coral communities, wetlands, riparian vegetation, mangroves, seagrass and fish habitats, forested mountain ranges, and areas of national parks and conservation (Drewry et al. 2008).

Land uses in the region in 2008 were estimated to be dominated by grazing and forestry (approximately 56 per cent of the region's surface area), national parks and reserves (17 per cent) and sugar cane farming (approximately 19 per cent), followed by wetlands (6 per cent), dams and reservoirs (1 per cent), urban development (1 per cent), and horticulture (less than 1 per cent) (Drewry et al. 2008). More recently, the land use estimates relative to farming practice were reported as 69 per cent grazing, 31 per cent cane farming, and 1 per cent horticulture (State of Queensland 2014). As a result of these land uses, the key water quality pollutants of concern are dissolved and particulate forms of nitrogen and phosphorus, suspended sediment, and pesticides. In 2008 it was reported that increased amounts of sediment, nutrients, and herbicides were entering the freshwater ecosystems, and subsequently, the marine ecosystems of the GBR lagoon (Drewry et al. 2008). At this time, cane farming practices were estimated to account for approximately 50 per cent of the particulate nitrogen load, 77 per cent of the dissolved inorganic nitrogen load, and 29 per cent of the total suspended sediment load in the region (Drewry et al. 2008).

The herbicides of concern are photosystem II (PSII) inhibiting, which act on the target organisms (weeds) by inhibiting photosynthesis, and subsequently their growth. When the PSII herbicides enter a waterway, they act in the same manner on non-target aquatic photosynthetic organisms such as, seagrass and other aquatic plants, and algae (including coral symbionts). The PSII herbicides of interest in this report are the five priority PSII herbicides of the Reef Water Quality Protection Plans of 2009 and 2013 (State of Queensland and Commonwealth of Australia 2009 and 2013): ametryn, atrazine, diuron, hexazinone, and tebuthiuron.

1.2 Mackay Whitsunday Water Quality Improvement Plan 2008

In 2008, the Mackay Whitsunday Water Quality Improvement Plan (WQIP) (Drewry et al. 2008) was released. It summarised the then current condition of water quality across the region (as of 2007), and proposed water quality targets for 2014 and water quality objectives (WQOs) for 2050. Water quality targets and WQOs were proposed for both ambient and event conditions. The overall aim of the targets and WQOs was to improve water quality and ecological health of regional waterways, estuaries and relevant areas of the GBR. The WQIP also provided recommendations for improved management practices to reduce loads of contaminants in the waterways.

For the purposes of assessment and focusing improvement measures, the Mackay Whitsunday region was broken into 33 catchment management areas (CMAs) in the WQIP (Drewry et al. 2008). For each CMA the per cent of land under cane farming, grazing and other land uses was defined. The ambient (low flow) condition concentrations for total suspended solids (TSS), nutrients and pesticides were determined using the 50th percentile of existing sampling results in local waterways. End of catchment event mean concentrations (EMCs) were estimated by adjusting SedNet- and Annex-based modelling with existing event-based monitored water quality (Drewry et al. 2008). The 2014 targets were set based on a realistic expected adoption rate of new management practices, and likely resulting reductions in TSS, nutrients, and pesticide loads. Predictions in the WQIP (Drewry et al. 2008) estimated that a 65 per cent adoption of nutrient and pesticide management in sugar cane farming and horticulture would result in a 27 per cent reduction in dissolved inorganic nitrogen concentrations and a 25 per cent reduction in herbicide concentrations by 2014. Similarly, it was estimated that adoption of improved soil management practices by 30 per cent of grazing land and 50 per cent of cane farming and horticulture would reduce particulate phosphorus levels by 23 per cent by 2014. WQOs for each management area were developed and presented in the WQIP with the purpose to protect human uses and aquatic ecosystem values identified by the community (Drewry et al. 2008). High Ecological Value (HEV) areas (such as national parks, conservation reserves or undeveloped inaccessible locations) were identified and used as reference catchments to determine WQOs. As the WQOs for HEV areas and disturbed/developed areas are based on locally collected water quality samples, in many cases they are more stringent than state or national water quality guidelines.

To provide a picture of the quality of water in the Mackay Whitsunday region the WQIP (Drewry et al. 2008) compared the then current conditions to the WQOs. The per cent of management areas above the ambient and event WQOs in 2007 is shown in Table 1.

Table 1 Per cent of management areas where the 2007 water quality parameters exceeded the ambient and event water quality objectives (WQO). Source: Drewry et al. 2008.

Parameter	Per cent of management areas above ambient WQO	Per cent of management areas above event WQO
Dissolved inorganic nitrogen	27	79
Particulate nitrogen	6	45
Filterable reactive phosphorus	21	82
Particulate phosphorus	36	45
Total suspended solids	6	9

Following the release of the WQIP (Drewry et al. 2008), there was a coordinated effort between Reef Catchments and local land owners to change land management practices. Such changes included installation and use of new machinery and equipment, different fertiliser applications, and installation of off-stream watering and riparian fencing.

As of 2013, it is estimated that between 2009 and June 2013, the total nitrogen load leaving the Mackay Whitsunday region was reduced by 17 per cent, the DIN load was reduced by 24 per cent and the suspended sediment load by 9 per cent (State of Queensland 2014). Additionally, it was estimated that the PSII pesticide load was reduced by 42 per cent over this same time period (State of Queensland 2014).

1.3 Purpose of this Report

The purpose of this report is to perform impact and risk assessments of TSS, nutrients, and pesticides in waterways within the Mackay Whitsunday region based on the available data (i.e. up to 2013 for Pioneer River and Sandy Creek). The report assesses the available data to determine which analyses can be undertaken and then identifies if the risks posed by TSS, nutrients and pesticides have changed over time within the region. For sites where recent data is available (July 2007 onwards), the report assesses whether the predicted reductions (outlined in Drewry et al. 2008) have occurred. The report also assesses whether the current WQIP targets are appropriate to provide adequate protection of the waterways and associated ecosystems. This report also identifies priority catchments, contaminants, and potential indicator species that should be the focus for future management and monitoring efforts.

The results of the assessment will be used to develop new water quality objectives and targets and management practices in the updated Mackay Whitsunday WQIP to be released in 2014. Additionally, this report also incorporates the development of new ecotoxicity thresholds for the priority PSII herbicides.

2 Methods

2.1 Data quality and coverage assessment

Water quality data for TSS, nutrients, and pesticides were obtained from monitoring programs conducted by Reef Catchments and the Queensland Government. A summary of the available information is provided, below (Table **2**). The Reef Catchments data have been split into two time periods: July 2004–June 2007 (this data was used for the development of the WQIP targets), and July 2007–June 2008 (this data was collected subsequent to the development of the targets).

Table 2 Summary of the data used in the current project.

Data source	Years data are available for	No. of water quality sites	
		Ambient data	**Event Data**
Reef Catchments	July 2004–June 2007	13	22
	July 2007–June 2008	13	1 (O'Connell 2)
Queensland Government	July 2009–June 2013	2 (Sandy Creek, Pioneer River)	2 (Sandy Creek, Pioneer River)

The quality of data was determined by the number of samples available for each combination of parameters and site, under both ambient and event conditions. Less than five samples for a site was classed to be of poor quality; five to nine samples classed as moderate quality; and ten or more samples as good data quality.

Differentiation between ambient and event samples that was used for all sites except Pioneer River and Sandy Creek, was based on Reef Catchments data (monthly ambient samples or event driven samples) (Drewry et al. 2008). Differentiation between ambient and event samples for Pioneer River and Sandy Creek was based on flow. A sample was defined as being an event sample if:

- the daily discharge was above the 80th percentile daily discharge for the period 2004–2014, or
- the discharge for the previous seven days was higher than the seven day 80th percentile for the period 2004–2014, or
- the discharge for the previous 14 days was higher than the 14 day 80th percentile for the period 2004–2014.

All other samples were classified as ambient samples. Further information on the calculation and assessment of event concentrations can be found in Section 2.4.

Flow data were obtained from the Queensland Government electronic data management system (Hydstra) for the years in which sampling was conducted and was used to create hydrographs for each waterway. Sampled events were plotted on flow hydrographs to ensure data coverage was adequate (Appendix B).

2.2 Collation of water quality guideline values and water quality objectives

The 2014 targets for the Mackay Whitsunday region were obtained from Drewry et al. 2008.

Nutrient and TSS guidelines are presented in three documents: the *Environmental Protection (Water) Policy 2009: Pioneer River and Plane Creek Basins Environmental Values and Water Quality Objectives* (DEHP 2013a); *Environmental Protection (Water) Policy 2009: Proserpine River, Whitsunday Island and O'Connell River Basins Environmental Values and Water Quality Objectives* (DEHP 2013 b); and the Queensland Water Quality Guidelines (DEHP 2009). All of these guidelines were derived from data presented in Drewry et al. (2008). The targets presented in Drewry et al. (2008) for each CMA have been used in this report.

Drewry et al. (2008) also provides pesticide targets for each CMA. These are specific to each CMA and are generally more stringent than the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000). As part of this report, new ecotoxicity thresholds for five pesticides were derived (see Section 2.3). In this report measured pesticide concentrations were compared to the 2014 pesticide targets (Drewry et al. 2008).

2.3 Derivation of new ecotoxicity thresholds

Toxicity data records were sourced from various sources, including the United States Environmental Protection Agency (USEPA) ECOTOX database, peer-reviewed scientific journals, and a commissioned laboratory study. The quality of all data was assessed using the data quality scoring method described in Hobbs et al. (2005). This method asks a series of approximately 20 questions to determine the scientific quality (high, acceptable or unacceptable quality) of the methods used to derive the toxicity data. The toxicity data that were of high or acceptable quality were entered into an Access™ database. All data in the database were checked back to the original publications to ensure the accuracy of the data. The definitions used to determine whether the ecotoxicity data were acute or chronic were those proposed in the current revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Batley et al. in review; Warne et al. in review).

The quality assured data for each pesticide (ametryn, atrazine, diuron, hexazinone, and tebuthiuron) were exported into a separate Microsoft Excel™ spreadsheet. Only toxicity data for phototrophic species (species that photosynthesise) were used to derive the ecotoxicity thresholds as these are the target organisms of, and most susceptible organisms to, PSII herbicides. Toxicity data based on measuring impacts on photosynthesis were not included, consistent with the recommended rules for deriving the current Australian and New Zealand water quality guideline trigger values (ANZECC and ARMCANZ 2000) and the proposed revision of the Guidelines for Fresh and Marine Water Quality (Batley et al. in review; Warne et al. in review).

For each pesticide the data were organised into species, and the following steps were performed (following the methodology presented in Warne et al. in review):

1. Toxicity data were grouped by media type (freshwater, estuarine, marine), duration of exposure, and the biological effect tested;
2. Chronic toxic concentrations were converted, if required, to provide an estimate of the highest concentration that caused no significant effect to the population (NOEC) or the highest concentration that caused an effect to 10–20 per cent of the population (EC10–20) (in µg/L);
3. Acute toxic concentrations were converted, if required, to provide an estimate of the chronic NOEC/EC10–20 value (in µg/L);
4. Where multiple toxicity data were available for the same effect, test and duration, the geometric mean of the results was calculated;
5. The minimum concentration for each species across all tests was selected. This became the value that represented the sensitivity of the species (in µg/L); and
6. All calculations and results were checked independently by two scientists.

The single species values for each pesticide were graphed on a distribution curve and reviewed to determine if the distributions were uni- or multi-modal (ANZECC and ARMCANZ 2000; Batley et al. in review; Warne et al. in review).

If the data for a chemical was uni-modal, the values for each species were entered into BurrliOz v2.0 to obtain the species sensitivity distribution (SSD) and concentrations that should theoretically protect 99 per cent, 95 per cent, 90 per cent and 80 per cent of species (i.e., the PC99, PC95, PC90 and PC80, respectively), for each pesticide. The minimum toxicity data required to run BurrliOz are for five species that belong to at least four different phyla (ANZECC and ARMCANZ 2000; Batley et al. in review; Warne et al. in review).

We believe that these ecotoxicity thresholds are more appropriate than the existing Australian and New Zealand trigger values as they are based on more current data. Therefore, the WQIP pesticide targets (Drewry et al. 2008) were compared to the ecotoxicity thresholds to determine if the targets provided environmental protection consistent with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000).

2.4 Prioritisation of catchments for further monitoring

Assessments were conducted by comparing ambient and event sampling results for each site (July 2007-June 2013) with the appropriate 2014 ambient and event targets (Drewry et al. 2008). The July 2004–June 2007 data were not compared to the 2014 targets as they had been used to develop the targets (Drewry et al. 2008). Comparisons were made for the following parameters:

- Total Suspended Solids (TSS)
- Nutrients:
    - Particulate Nitrogen (PN)
    - Dissolved Inorganic Nitrogen (DIN)
    - Particulate Phosphorus (PP)
    - Filter Reactive Phosphorus (FRP)
- Pesticides:
    - Ametryn
    - Atrazine

- Diuron
- Hexazinone
- Tebuthiuron.

Event sampling subsequent to the development of the 2014 targets was only conducted in three sites (Sandy Creek, O'Connell River, and Pioneer River). For the purposes of this report, the following steps were taken to analyse the parameters of interest at each site:

- Each event was determined for each year from July 2007
- The median of each parameter for each event was calculated
- The medians for each parameter were compared to each other over the period for which data were available, to determine if there were any changes over time.

A minimum of three samples were used to generate event median concentration. Events in which less than three samples existed were not included in the analysis.

Event concentrations shown in this report for all other sites (excluding Pioneer River, Sandy Creek, and O'Connell River) and years are individual sample concentrations. Multiple event samples taken over one day were averaged to provide one value for each event day.

All sampling results were separated into ambient or event sampling and (with the exception of the event concentration data from Sandy Creek, Pioneer River, and O'Connell River which is discussed above) entered into Microsoft Excel™. Conditional formatting was used to identify the sample results above the relevant 2014 target (Drewry et al. 2008) for each parameter at that site. The number of results exceeding the target was then calculated as a percentage of all samples taken at the site for that year.

To understand if there were any temporal trends (an increase or decrease over time) in concentrations at each site, all available sampling results were analysed using linear regression analysis in Microsoft Excel™. Linear regression analysis was carried out between each concentration parameter and time for each sampling site if there were five or more data points. A p-value of 0.05 or less was deemed to indicate a significant trend. The p values and R^2 values have been quoted in the results section of this report. Appendix C includes the full regression results.

All assessment results tables were colour coded to indicate the data availability - red indicates poor data availability (0–4 samples); amber indicates moderate data availability (5–9 samples); and green indicates good data availability (≥ 10 samples) (see Section 3.1).

From the concentration assessment results, catchments which recorded the highest concentrations (for each parameter) have been identified as priority focus areas. These priority areas have been further split into primary and secondary focus areas, depending on the access to funding (i.e. in the instance that funding is limited, the primary priority sites should be the initial focus for improvement).

2.5 Multisubstance potentially affected fraction (ms-PAF)

Multisubstance potentially affected fraction (ms-PAF) provides a more comprehensive assessment of the potential ecological impacts of pesticides as it analyses the effect of the mixture of pesticides (i.e. when the pesticides occur at the same time) which have the same mode of action (i.e. the pesticides which exert their toxicity at the same target by the same means). PSII herbicides all have the same mode of action and therefore mixtures of these herbicides can be predicted using the ms-PAF method.

To enable the calculation of ms-PAF values, concentrations recorded as being below the level of reporting (< LOR) were modified. For the Reef Catchments' data if no other pesticides were detected above the LOR in the sample, all "< LOR" values were replaced with "0". If other pesticides were detected in the same sample, "< LOR" values were replaced with "0.005", i.e. half the LOR (0.01 µg/L). Data obtained from the Queensland Government was treated differently as the sampling design was different. When pesticide concentrations in a sample were below the LOR, but were detected in other samples in the same event, they were replaced by half the LOR. Where a pesticide was not detected in an event, the concentrations of that pesticide for all samples reported as < LOR were adjusted to 0 µg/L (Turner et al. 2012, 2013; Wallace et al. in prep).

The ms-PAF was calculated using the method of Traas et al. (2002) using the following steps:

1. The individual sample concentrations for each herbicide were converted to Hazard Units (HU) by normalizing the concentration for each herbicide. The following equation was used to convert to HUs:

$$HU_i^j = \frac{NOEC_i^j}{median\ NOEC_i}$$

   where *j* is an individual species, *i* is an individual herbicide, $NOEC_i^j$ is the NOEC/EC10–20 of species *j* for herbicide *i*, and $median\ NOEC_i$ is the median NOEC/EC10–20 of all species for herbicide *i*;
2. The mixture HU for each sample was calculated as the sum of the individual pesticide HUs in that sample;
3. A SSD for each of the five PSII herbicides was derived by fitting a logistic distribution to the calculated HUs;
4. A representative SSD for mixtures of PSII herbicides was then calculated. This was done by calculating the slope (β) of the SSDs of each herbicide and then calculating an average β based on the PSII herbicides present in the mixture. The average β was calculated on a sample by sample basis, based on the PSII herbicides present in each sample (e.g. if only three herbicides were detected in the sample, the average β was calculated from only those three herbicides present in the sample, not all five); and;
5. The percent of species affected was then calculated based on the concentrations of the pesticides in each sample using the concentration addition methodology in Traas et al. (2002), i.e. a percent of species affected was estimated for each sample, and a daily average was calculated where appropriate (refer to Section 2.1).

For the hazard assessment, the ms-PAF results were assessed against a 95 per cent species protection level (PC95). That is, a ms-PAF result greater than 5 per cent indicates that more than 5 per cent of species will potentially be impacted by the mixture of PSII herbicides. For HEV sites the PC99 value was used to assess hazards.

2.6 Risk assessment

Results of the ms-PAF analysis were used to quantify ecological risk associated with mixtures of PSII herbicides to aquatic species. The ms-PAF results were grouped to determine the number of days in which differing levels of risk were reached for each waterway. Table 3 shows the risk classifications used (adapted from Lewis et al. 2013).

Table 3 ms-PAF based risk classifications for exposure to photosystem II inhibiting herbicide mixtures, and the per cent of phototrophs that would potentially experience a toxic effect (adapted from Lewis et al. 2013).

Risk classification	Per cent phototrophic species to experience minor effects (NOEC, <EC50)
Very High	>70
High	40–70
Medium	5–40
Low	0–5

2.7 Probabilistic ecological risk assessment

A probabilistic ecological risk assessment (PERA) approach was employed to determine the probability in which a per cent of species was likely to be affected during event or ambient conditions for Sandy Creek and Pioneer River. This was only conducted for Sandy Creek and Pioneer River as these were the only sites with sufficient data available. The PERA is normally calculated with joint probability curves by combining the exposure concentration distribution of a chemical (i.e. the cumulative distribution of the concentrations of a chemical detected during a defined sampling period) with the SSD of that chemical (Aldenberg et al. 2002). The method used here expands on this by incorporating the ms-PAF methodology into the PERA model (Carriger and Rand 2008; Schuler and Rand 2008) to account for the probability of the per cent of species affected by the pesticide mixtures.

For each sample, the ms-PAF was calculated, and the sample was classified as to whether it was collected during event or ambient conditions (see Section 2.1). The ms-PAF values were then fitted to an inverse cumulative log-normal distribution and used to estimate the cumulative exposure frequency (days) by multiplying the probability of detection by the total number of days under event or ambient conditions. Based on the risk categories in Table 3, the number of days (under both ambient and event conditions) which fell into each risk category were calculated.

2.8 Selection of indicator species for biomonitoring

Potential methods for biomonitoring were reviewed for their suitability for the Mackay Whitsunday region.

3 Results

3.1 Data quality and coverage assessment

Of the 24 water quality sites included in the WQIP (Drewry et al. 2008) 13 sites had good data availability (ten or more sampling events) for TSS and nutrients under ambient conditions, from July 2007 (when the 2014 targets were established) onward (Table 4). For the majority of these sites there was only one year of good data availability. Only Sandy Creek and Pioneer River had good data availability for TSS and nutrients under event conditions, for one year. Eleven sites had poor or moderate data availability for TSS and nutrients under both ambient and event conditions (Table 4).

For pesticide sampling, 13 out of the 24 sites had good data availability under ambient conditions and for many of these sites, data was only available for one year after July 2007 (Table 5). Only Pioneer River and Sandy Creek had good data availability for pesticides under event conditions, for only one year. Eleven of 24 sites have only poor or moderate data availability for all pesticide sampling (both ambient and event).

Refer to Appendix A for a full list of the sampling sites, including latitude and longitudes, and differentiation of sites within the same waterways.

For sites with flow data available, hydrographs showing discharge and sampling data (both ambient and event conditions) are located at Appendix B.

The data availability for each parameter and each site (Table 4 and Table 5) limited the type of assessment that could be conducted, as shown in Table 6. Linear time trend assessments for TSS, nutrients, and pesticides ambient sampling results could be conducted for 13 of the 24 sites. TSS was the only event sampling parameter that could be assessed for Airlie Creek. Risk assessments for pesticide could be conducted for 12 sites under ambient conditions, but only for three sites under event conditions. A probabilistic ecological risk assessment (PERA) could only be performed for the Pioneer River and Sandy Creek.

Table 4 Quality of total suspended solids and nutrient water quality data from 2007–2013, based on number of samples. A = ambient, E = event. Red indicates poor data availability (0–4 samples), amber indicates moderate data availability (5–9 samples), green indicates good data availability (≥ 10 samples). The numbers in the event columns are the number of event days sampled.

Site	Year											
	2007–2008		2008–2009		2009–2010		2010–2011		2011–2012		2012–2013	
	A	E	A	E	A	E	A	E	A	E	A	E
Airlie Creek	0	0	0	0	0	0	0	0	0	0	0	0
Andromache River	0	0	0	0	0	0	0	0	0	0	0	0
Upper Andromache River	12	0	0	0	0	0	0	0	0	0	0	0
Bakers Creek	11	0	0	0	0	0	0	0	0	0	0	0
Basin Creek	12	0	0	0	0	0	0	0	0	0	0	0
Blacks Creek	0	0	0	0	0	0	0	0	0	0	0	0
Carmila Creek	12	0	0	0	0	0	0	0	0	0	0	0
Finch Hatton Creek	12	0	0	0	0	0	0	0	0	0	0	0
Gregory River	0	0	0	0	0	0	0	0	0	0	0	0
Impulse Creek	12	0	0	0	0	0	0	0	0	0	0	0
Mackay 1	0	0	0	0	0	0	0	0	0	0	0	0
Mackay 2	0	0	0	0	0	0	0	0	0	0	0	0
Myrtle Creek	12	0	0	0	0	0	0	0	0	0	0	0
O'Connell River 1	12	0	0	0	0	0	0	0	0	0	0	0
O'Connell River 2	0	2	0	0	0	0	0	0	0	0	0	0
Pioneer River	12	1	0	0	9	2	3	18	4	4	6	6
Plane Creek	11	0	0	0	0	0	0	0	0	0	0	0
Proserpine 1	0	0	0	0	0	0	0	0	0	0	0	0
Proserpine 2	0	0	0	0	0	0	0	0	0	0	0	0
Rocky Dam Creek	10	0	0	0	0	0	0	0	0	0	0	0
Sandy Creek	10	0	0	0	5	5	4	14	3	3	8	2
Sarina – Urban	0	0	0	0	0	0	0	0	0	0	0	0
St Helens Creek	12	0	0	0	0	0	0	0	0	0	0	0
Waite Creek	0	0	0	0	0	0	0	0	0	0	0	0

Table 5 Quality of pesticide water quality data from 2007–2013, based on number of samples. A = ambient, E = event. Red indicates poor data availability (0–4 samples), amber indicates moderate data availability (5–9 samples), green indicates good data availability (≥ 10 samples). The numbers in the event columns are the number of event days sampled.

Site	Year											
	2007–2008		2008–2009		2009–2010		2010–2011		2011–2012		2012–2013	
	A	E	A	E	A	E	A	E	A	E	A	E
Airlie Creek	0	0	0	0	0	0	0	0	0	0	0	0
Andromache River	0	0	0	0	0	0	0	0	0	0	0	0
Upper Andromache River	12	0	0	0	0	0	0	0	0	0	0	0
Bakers Creek	11	0	0	0	0	0	0	0	0	0	0	0
Basin Creek	12	0	0	0	0	0	0	0	0	0	0	0
Blacks Creek	0	0	0	0	0	0	0	0	0	0	0	0
Carmila Creek	12	0	0	0	0	0	0	0	0	0	0	0
Finch Hatton Creek	12	0	0	0	0	0	0	0	0	0	0	0
Gregory River	0	0	0	0	0	0	0	0	0	0	0	0
Impulse Creek	13	0	0	0	0	0	0	0	0	0	0	0
Mackay 1	0	0	0	0	0	0	0	0	0	0	0	0
Mackay 2	0	0	0	0	0	0	0	0	0	0	0	0
Myrtle Creek	12	0	0	0	0	0	0	0	0	0	0	0
O'Connell River 1	12	0	0	0	0	0	0	0	0	0	0	0
O'Connell River 2	0	2	0	0	0	0	0	0	0	0	0	0
Pioneer River	10	2	0	0	1	2	7	17	4	4	6	6
Plane Creek	11	0	0	0	0	0	0	0	0	0	0	0
Proserpine 1	0	0	0	0	0	0	0	0	0	0	0	0
Proserpine 2	0	0	0	0	0	0	0	0	0	0	0	0
Rocky Dam Creek	10	0	0	0	0	0	0	0	0	0	0	0
Sandy Creek	10	0	0	0	5	5	4	12	3	2	8	1
Sarina – Urban	0	0	0	0	0	0	0	0	0	0	0	0
St Helens Creek	12	0	0	0	0	0	0	0	0	0	0	0
Waite Creek	0	0	0	0	0	0	0	0	0	0	0	0

Table 6 Types of assessments that could be conducted for nutrients (N), total suspended solids (TSS), and pesticides (P) according to data availability. Linear time trend assessment can be performed on any number of samples, risk assessment requires a minimum of ten samples. Event = number of event days (not individual event samples). The CMA for each site is also shown. Asterisks (*) indicate HEV sites.

Site	Catchment Management Area (CMA)	Ambient		Event	
		Type of assessment			
		Temporal	Risk	Temporal	Risk
Airlie Creek	Whitsunday Coast	-	-	TSS	-
Andromache River	Andromache River	-	-	N, TSS, P	-
Upper Andromache River *	Andromache River	N, TSS, P	P	N, TSS, P	-
Bakers Creek	Bakers Creek	N, TSS, P	P	-	-
Basin Creek*	Gillinbin Creek	N, TSS, P	P	N, TSS, P	-
Blacks Creek	Blacks Creek	-	-	N, TSS, P	-
Carmila Creek	Carmila Creek	N, TSS, P	P	N, TSS, P	-
Finch Hatton Creek*	Upper Cattle Creek	N, TSS, P	P	N, TSS, P	-
Gregory River	Gregory River	-	-	N, TSS, P	-
Impulse Creek*	Repulse Creek	N, TSS, P	P	N, TSS, P	-
Mackay 1	Mackay City	-	-	N, TSS, P	-
Mackay 2	Mackay City	-	-	N, TSS, P	-
Myrtle Creek	Myrtle Creek	N, TSS, P	P	N, TSS, P	P
O'Connell River 1	O'Connell River	N, TSS, P	P	N, TSS, P	-
O'Connell River 2	O'Connell River	-	-	N, TSS, P	-
Pioneer River	Pioneer River	N, TSS, P	P	N, TSS, P	P
Plane Creek	Plane Creek	N, TSS, P	P	N, TSS, P	-
Proserpine 1	Proserpine River	-	-	N, TSS, P	-
Proserpine 2	Proserpine River	-	-	N, TSS, P	-
Rocky Dam Creek	Rocky Dam Creek	N, TSS, P	P	N, TSS, P	-
Sandy Creek	Sandy Creek	N, TSS, P	-	N, TSS, P	P
Sarina - Urban	Plane Creek	-	-	N, TSS, P	-
St Helens Creek*	St Helens Creek	N, TSS, P	P	N, TSS, P	-
Waite Creek	Whitsunday Coast	-	-	N, TSS, P	-

3.2 Collated trigger values and new ecotoxicity thresholds

3.2.1 Suspended solids and nutrient trigger values and targets

The WQIP (Drewry et al. 2008) identifies the TSS and nutrient targets for both ambient and event conditions for each of the 33 CMAs. The targets for the sites analysed in this report are shown below in Table 7.

Table 7 Mackay Whitsunday 2014 ambient and event targets for total suspended solids (mg/L) and nutrients (µg/L) by Catchment Management Area.

Attribute	Catchment Management Area																	
	Gregory River	Whitsunday Coast	Repulse Creek	Myrtle Creek	Proserpine River	Andromache River	O'Connell River	St Helens Creek	Mackay City	Pioneer River	Upper Cattle Creek	Blacks Creek	Bakers Creek	Sandy Creek	Plane Creek	Rocky Dam Creek	Gillinbin Creek	Carmila Creek
TSS Ambient	2	2	2	5	5	1	2	4	5	5	3	2	4	5	3	4	2	3
TSS Event	42	8	8	40	194	217	158	45	39	198	43	183	57	71	200	120	66	39
PN Ambient	43	16	16	112	210	39	43	142[#]	110	102	78	58	150	110	101	142	58	78
PN Event	254	261	261	324	406	331	314	121[#]	198	436	118	440	342	265	178	295	152	256
DIN Ambient	45	20	20	77	175	18	45	10	107	8	8	9	456	107	8	10	9	8
DIN Event	387	256	256	414	300	295	300	266	420	268	266	317	460	353	368	422	42	465
PP Ambient	6	10	10	41	60	9	6	20	20	20	10	12	28	20	18	20	12	10
PP Event	57	31	31	117	81	175	108	33	51	195	53	136	98	101	61	72	37	53
FRP Ambient	6	10	10	25	95[#]	22[#]	6	6	25	5	5	2	27	25	8	6	2	5
FRP Event	54	27	27	193	45[#]	0[#]	37	23	377	40	30	50	163	137	59	33	3	27

[#]indicates a more stringent event target than ambient

3.2.2 Pesticide ecotoxicity thresholds

New ecotoxicity thresholds were derived for ametryn, atrazine, diuron, hexazinone, and tebuthiuron as part of this report (Table 8). These ecotoxicity thresholds differ from the current Australian and New Zealand trigger values (ANZECC and ARMCANZ 2000) as they were derived using the revised method for calculating trigger values (Warne et al. in review) and more recent toxicity data. In terms of the 95 per cent protection levels (Table 8), the ecotoxicity thresholds proposed are approximately half the current trigger values for atrazine, slightly higher for diuron, significantly lower for hexazinone and significantly higher for tebuthiuron (Table 8). There is no current trigger value for ametryn. The previous trigger values for hexazinone were classed as low reliability (based on the number of phyla and species used to generate the trigger value – refer to Warne 2001), whereas the ecotoxicity threshold has a moderate reliability (Table 9). The proposed ecotoxicity thresholds for ametryn, atrazine and diuron are all classed as high reliability (as defined by Warne et al. in review) (Table 9).

Table 8 Proposed pesticide ecotoxicity thresholds (concentrations in µg/L) for freshwater phototrophic species compared to the current Australian and New Zealand water quality guideline trigger values (ANZECC and ARMCANZ 2000).

		Level of protection (per cent of species protected)		
Pesticide	**Guideline**	**99**	**95**	**90**
Ametryn	Ecotoxicity threshold	0.02	0.1	0.3
	Australian and NZ trigger value	N/A	N/A	N/A
Atrazine	Ecotoxicity threshold	3.7	6	8.1
	Australian and NZ trigger value	0.7	13	45
Diuron	Ecotoxicity threshold	0.2	0.3	0.4
	Australian and NZ trigger value	0.2	0.2	0.2
Hexazinone	Ecotoxicity threshold	0.2	0.7	1.3
	Australian and NZ trigger value	75	75	75
Tebuthiuron	Ecotoxicity threshold	4.3	8.8	12.0
	Australian and NZ trigger value	0.02	2.2	20

N/A = not applicable

Table 9 Number of species and phyla used to derive proposed ecotoxicity thresholds, the fit of the distribution to the toxicity data and the resulting reliability (following the method of Warne et al. in review).

Pesticide	Media	No. Phyla	No. Species	Reliability
Ametryn	Freshwater and Marine	4	10	High
Atrazine	Freshwater	4	16	Very High
	Estuarine	5	8	High
	Marine	4	11	High
Diuron	Freshwater (and Estuarine)	4	14	High
	Marine (and Estuarine)	7	14	Moderate
Hexazinone	Freshwater	4	5	Moderate
	Marine (Freshwater and Marine)	4	8	High
Tebuthiuron	Freshwater and Marine	4	5	Low

The proposed ecotoxicity thresholds were compared to the 2014 ambient and event targets (Drewry et al. 2008) for each of the CMAs relevant to this report. For the majority of the CMAs, the existing 2014 targets were below the proposed ecotoxicity thresholds for protection of 95 per cent of the species because they were set to less than the detection limit (0.01 µg/L in 2007) (Table 10). The event targets for diuron were frequently above the 95 per cent protection ecotoxicity threshold with the highest event target being 1.5 µg/L, compared to the ecotoxicity threshold of 0.3 µg/L. All ambient targets for diuron are below the ecotoxicity threshold. In Myrtle Creek, the event target for ametryn is just above the 95 per cent protection threshold (Table 10). In summary, apart from diuron, the WQIP pesticide targets for CMAs appear to be providing sufficient ecosystem protection for exposure to individual pesticides. It does not necessarily mean that the targets provide sufficient protection from mixtures of pesticides. This issue will be addressed later in the report. It should be noted that high ecological value sites (e.g., Andromache Upper) should have targets that meet the 99 per cent protection ecotoxicity threshold.

In both Proserpine River and St Helens Creek CMAs, the event target for ametryn is more stringent than the ambient target. This indicates that at least the event target needs to be reassessed, which will require further sampling.

Table 10 Proposed pesticide ecotoxicity thresholds (µg/L) for freshwater phototrophic species and the 2014 ambient (A) and event (E) targets for the Mackay Whitsunday region (Drewry et al. 2008). Amber shading indicates a target that is above the 95% protection ecotoxicity threshold. The level of reporting (LOR) for pesticide sampling is 0.01 µg/L.

Pesticide	Ecotoxicity thresholds for different % species protected (µg/L)		Condition	2014 Targets (µg/L)																	
	PC99	PC95		Gregory River	Whitsunday Coast	Repulse Creek	Myrtle Creek	Proserpine River	Andromache River	O'Connell River	St Helens Creek	Mackay City	Pioneer River	Upper Cattle Creek	Blacks Creek	Bakers Creek	Sandy Creek	Plane Creek	Rocky Dam Creek	Gillinbin Creek	Carmila Creek
Ametryn	0.02	0.1	A	<LOR	<LOR	<LOR	0.04	0.04[#]	<LOR	<LOR	0.02[#]	0.02	<LOR	<LOR	<LOR	0.01	0.02	<LOR	0.02	<LOR	<LOR
			E	<LOR	<LOR	<LOR	0.12	<LOR[#]	<LOR	<LOR	<LOR[#]	0.08	0.03	<LOR	<LOR	0.08	0.02	<LOR	0.04	<LOR	<LOR
Atrazine	3.7	6	A	<LOR	<LOR	<LOR	0.11	0.11	<LOR	<LOR	<LOR	0.09	0.02	<LOR	<LOR	0.17	0.09	<LOR	<LOR	<LOR	<LOR
			E	0.06	<LOR	<LOR	0.94	0.26	0.02	0.06	0.04	0.75	0.43	0.14	<LOR	0.83	0.4	0.17	0.27	0.02	0.04
Diuron	0.2	0.3	A	<LOR	<LOR	<LOR	0.11	0.11	<LOR	<LOR	0.07	0.19	0.02	<LOR	<LOR	0.11	0.19	0.01	0.07	<LOR	<LOR
			E	0.31	<LOR	<LOR	1.5	1.02	<LOR	0.28	0.46	1.25	0.75	0.43	0.06	1.38	0.75	0.51	0.75	0.05	0.46
Hexazinone	0.2	0.7	A	<LOR	<LOR	<LOR	0.08	0.08	<LOR	<LOR	0.13	0.2	0.02	0.01	<LOR	0.14	0.2	0.04	0.13	<LOR	0.01
			E	0.04	<LOR	<LOR	0.49	0.19	<LOR	0.04	0.23	0.51	0.19	0.16	0.03	0.56	0.41	0.14	0.55	<LOR	0.23
Tebuthiuron	4.3	8.8	A	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
			E	<LOR	<LOR	<LOR	<LOR	0.43	<LOR	0.16	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR

[#]indicates a more stringent event target than ambient target

3.3 TSS and nutrients

No ambient sampling was conducted in Airlie Creek, Andromache River, Blacks Creek, Gregory River, Mackay City, O'Connell 1, Proserpine River and Sarina in any year. No event sampling was conducted for Bakers Creek and no event nutrient sampling was conducted for Airlie Creek, in any year.

3.3.1 Airlie Creek

No ambient sampling was conducted for Airlie Creek in any year, thus the following results are based on event conditions from 2004–2007.

3.3.1.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Event sampling TSS concentrations in Airlie Creek from 2004–2007 had high variability with no linear temporal trend ($p = 1.00$) (Figure 1). The concentrations recorded in event conditions were up to 2665 mg/L, which was approximately 300-times greater than the event target of 8 mg/L, with the highest concentrations occurring during the wet season.

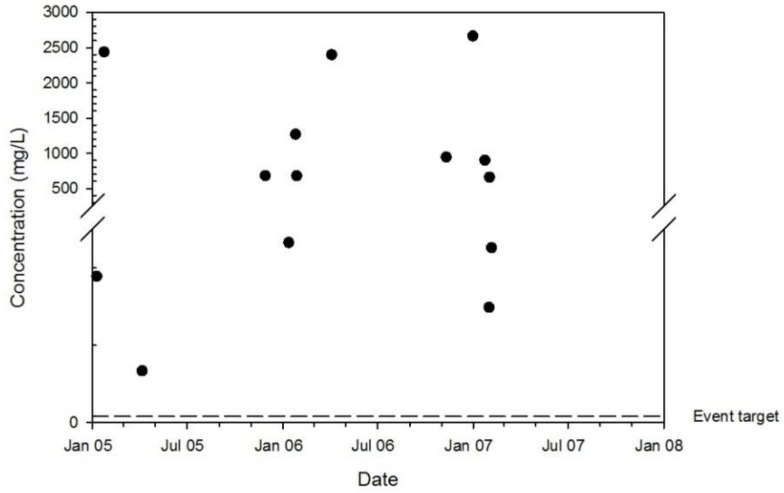

Figure 1 Temporal variation in total suspended solids (TSS) concentrations during event conditions at Airlie Creek from 2004–2007. The dashed line indicates the 2014 event TSS target for the Whitsunday Coast Catchment Management Area.

Frequency of target exceedances

No sampling was conducted in Airlie Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets can be undertaken. All TSS concentrations during events at Airlie Creek exceeded the 2014 event target for Airlie Creek (Table 11); i.e. three samples in 2004–2005, five samples in 2005–2006 and six samples in 2006–2007.

Table 11 Percent of exceedances of the 2014 Total Suspended Solids targets for Airlie Creek from 2004–2007.

Year	Per cent exceedances (total no. samples)	
	Ambient	Event
2004–2005	-	100 (3)
2005–2006	-	100 (5)
2006–2007	-	100 (6)
2007–2008	-	-

3.3.1.2 Nutrients

No nutrient sampling was conducted for Airlie Creek in any year.

3.3.1.3 Upper Andromache and Andromache River

The results for both the Andromache River and Upper Andromache River sites from 2004–2009 are presented below. No ambient sampling was conducted for Andromache River, however the Upper Andromache site had ambient and event samples.

3.3.1.4 TSS

Temporal variation in TSS and comparison to 2014 targets

Ambient sampling in Upper Andromache River from 2006–2008 showed concentrations of TSS remained relatively constant, with the exception of two very high concentrations recorded in early 2008. There was no linear temporal trend ($p = 0.28$) in ambient TSS concentrations (Figure 2). The concentrations recorded in ambient conditions were up to 130 mg/L, which was well above the ambient target of 1 mg/L. The event sampling in Andromache River was limited to only a few samples in 2005, therefore linear regression could not be performed. Any trends in the data are likely to be seasonal trends, with no linear temporal trend ($p = 0.25$). The Upper Andromache event sampling results from 2004–2007 were fairly sparse (five event days) and scattered with no linear temporal trend ($p = 0.99$) (Figure 2). Only one sample had a TSS concentration above the event target of 217 mg/L.

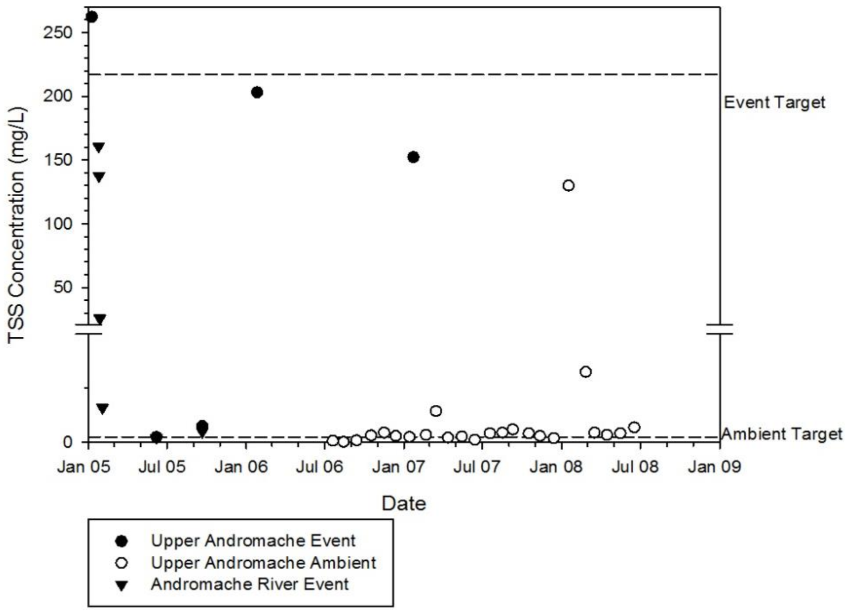

Figure 2 Temporal variation in total suspended solids (TSS) concentrations during ambient and event conditions at Andromache River and Upper Andromache River from 2004–2009. Dashed lines indicate the 2014 ambient and event TSS targets for the Andromache River Catchment Management Area. Each gradation on the y-axis is 10 mg/L.

Frequency of target exceedance

No event sampling was conducted for Andromache River (at either location) subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of TSS concentration exceedances against the targets can be undertaken. Ambient concentrations of TSS at Upper Andromache River were taken in one year subsequent to 2006–2007. In 2007–2008, 92 per cent of the 12 samples taken exceeded the TSS ambient target for the Andromache River CMA.

3.3.1.5 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Ambient concentrations of PN at Upper Andromache River varied from 2006–2008 with no temporal trend ($p = 0.47$) and one high value (460 µg/L) (Figure **3**). Approximately half of the samples were greater than the ambient target of 39 µg/L. The event sampling at both Andromache River and Upper Andromache River was limited to only a few samples. Due to the limited period of time over which samples were taken at Andromache River, no linear regression can be performed. Event concentrations at Andromache River were limited to less than a year, therefore no linear regression could be conducted. There were only five event samples taken from Upper Andromache River, with no linear temporal trend ($p = 0.99$). Similarly, there was no linear trend at Andromache River ($p = 0.19$).

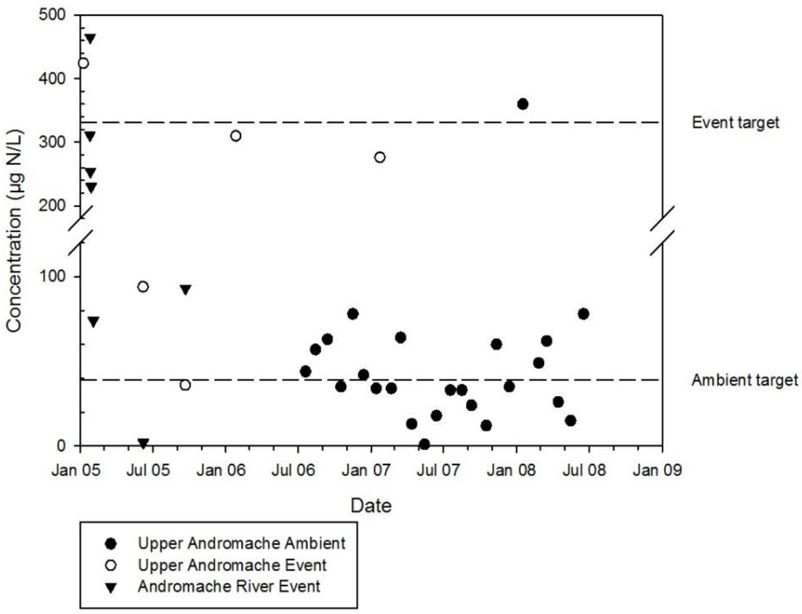

Figure 3 Temporal variation in particulate nitrogen (PN) concentrations during ambient and event conditions at Andromache River and Upper Andromache River from 2004–2009. Dashed lines indicate the 2014 ambient and event PN targets for the Andromache River Catchment Management Area.

Ambient concentrations of DIN at Upper Andromache River from 2006–2008 increased over time ($p = 0.009$; $R^2 = 0.27$); however, the low R^2 value suggests there are other factors also influencing the results (Figure 4). The majority of ambient DIN concentrations were above the ambient target (18 µg/L). Event sampling in the Upper Andromache River showed varied concentrations from 10–350 µg/L (exceeding the event target; 295 µg/L) with no linear temporal trends ($p = 0.78$); however the data was limited to only a few samples (Figure 4). Sampling at Andromache River covered less than a year so it was not possible to perform a linear regression on the data. There was no linear temporal trend in event DIN concentrations at the Andromache River site ($p = 0.12$).

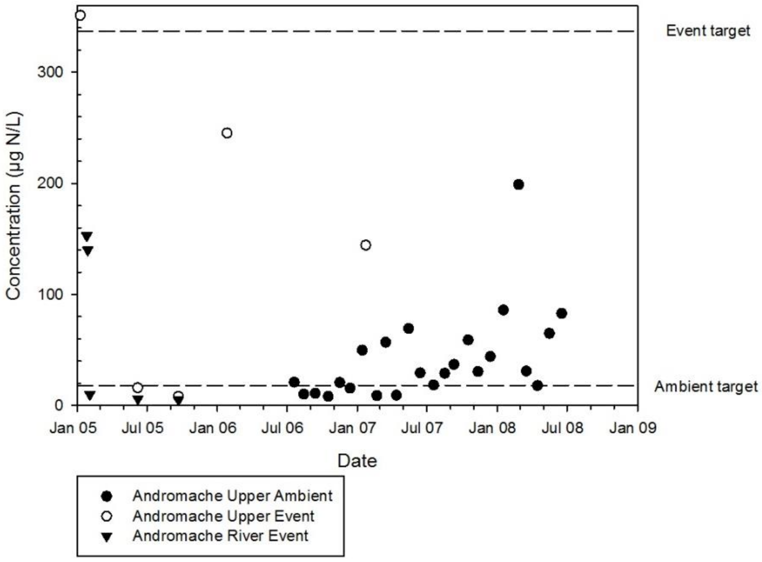

Figure 4 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient and event conditions at Andromache River and Upper Andromache River from 2004–2009. Dashed lines indicate the 2014 ambient and event DIN targets for the Andromache River Catchment Management Area.

Ambient concentrations of PP at Upper Andromache River in 2006–2008 fluctuated around the ambient target (9 µg/L) with only one higher value recorded in 2006 (166 µg/L) and there was no linear temporal trend ($p = 0.98$) (Figure 5). The majority of ambient results were below the ambient target, but there were a number above the target. Event sampling in the Upper Andromache River showed varied concentrations from 10–170 µg/L, however all results were below the event target (175 µg/L) (Figure 5). The event sampling in both Andromache River and Upper Andromache River was limited to only a few samples. No significant linear regressions were found at Upper Andromache River ($p = 0.90$) or Andromache River ($p = 0.25$). Sampling at Andromache River covered less than a year so it was not possible to perform a linear regression on the data.

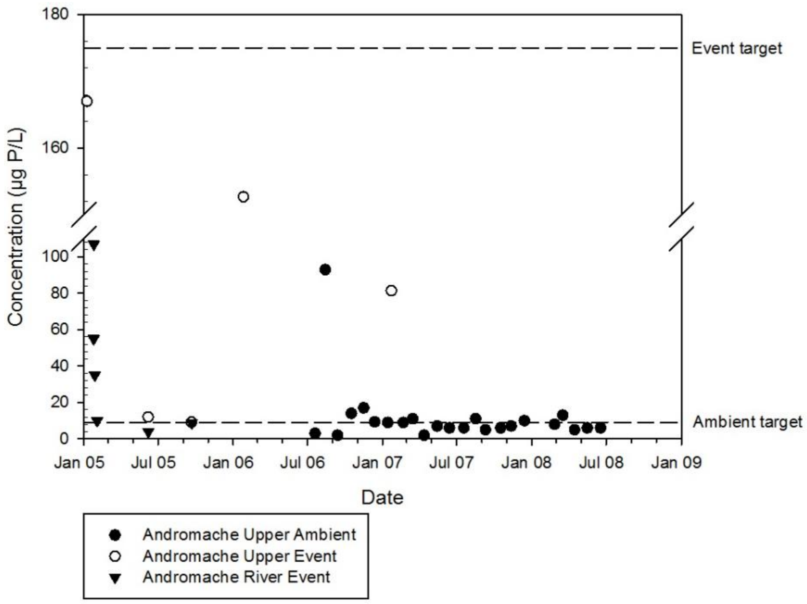

Figure 5 Temporal variation in particulate phosphorus (PP) concentrations during ambient and event conditions at Andromache River and Upper Andromache River from 2004–2009. Dashed lines indicate the 2014 ambient and event PP targets for the Andromache River Catchment Management Area.

Ambient concentrations of FRP at Upper Andromache River increased from 2006–2008 ($p = 0.025$; $R^2 = 0.21$); however, the low R^2 value suggested there were other factors also influencing the results. More than half of the results were above the ambient target (22 µg/L) (Figure 6). The event target for FRP in the Andromache CMA was 0 µg/L, which was below the ambient target. All event samples in both the Upper Andromache River and Andromache River sites were above the event target (Figure 6). Event sampling in the Upper Andromache River showed varied FRP concentrations from 22–213 µg/L, with no linear temporal trend ($p = 0.57$). Event FRP concentrations at Andromache River decreased over time however as sampling covered less than a year, it was not possible to perform a linear regression on the data.

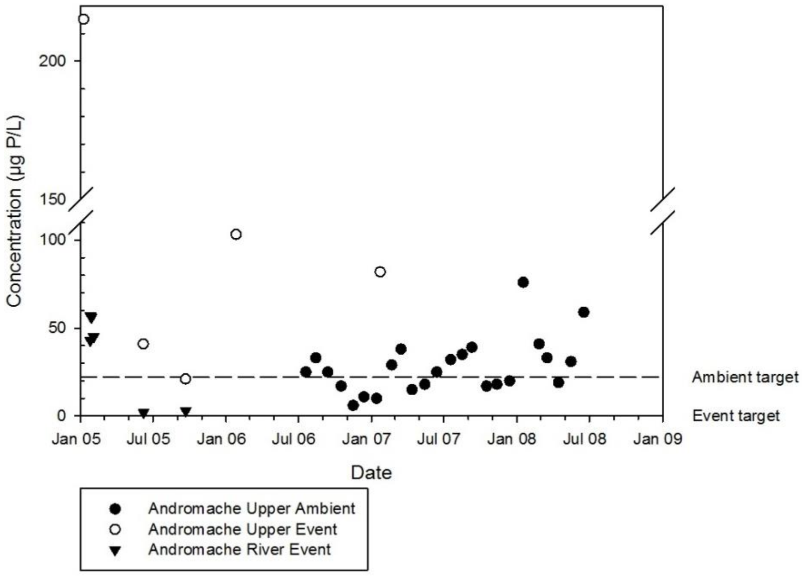

Figure 6 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient and event conditions at Andromache River and Upper Andromache River from 2004–2009. Dashed lines indicate the 2014 ambient and event FRP targets for the Andromache River Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted for Andromache River (at either location) subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of nutrient concentration exceedances against the targets can be undertaken.

Ambient sampling of nutrients at Upper Andromache River was undertaken for one year subsequent to 2006–2007, with a total of 12 ambient samples taken in 2007–2008. The following results refer to these sampling results. Of the ambient samples taken, 42 per cent of samples exceeded the PN target, 92 per cent exceeded the DIN target, 33 per cent of samples exceeded the PP target, and 67 per cent of samples exceeded the FRP target.

3.3.2 Bakers Creek

No event sampling was conducted for Bakers Creek, thus, the following results are based on ambient conditions from 2006–2008.

3.3.2.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Ambient sampling in Bakers Creek from 2006–2008 showed concentrations of TSS varied between 0 and 17 mg/L, with no linear temporal trend in ambient TSS concentrations ($p = 0.60$) (Figure 7). The highest concentrations recorded (12–17 mg/L) occurred in mid-2007 and were up to four-times higher than the ambient target of 4 mg/L.

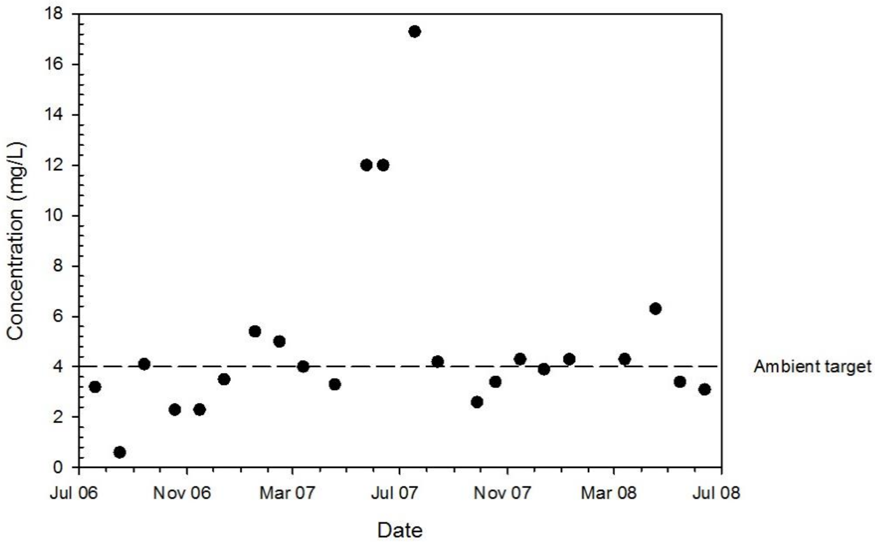

Figure 7 Temporal variation in total suspended solids (TSS) concentrations during ambient conditions at Bakers Creek from 2006–2008. The dashed line indicates the 2014 ambient TSS target for the Bakers Creek Catchment Management Area.

Frequency of target exceedances

The ambient concentrations of TSS in Bakers Creek exceeded the ambient target in 55 per cent of the 11 samples taken in 2007–2008.

3.3.2.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Ambient concentrations of PN at Bakers Creek were both above and below the 2014 ambient PN target concentration (150 µg/L) from 2006–2008 (Figure 8). The majority of the samples were greater than the ambient target and two very high concentrations were detected in December 2006 (1180 µg/L) and June 2007 (1513 µg/L) (Figure 8). There was no linear temporal trend in ambient PN over the two years ($p = 0.65$). The concentrations ranged from < LOR to a highest concentration of 1513 µg/L, approximately 10-times higher than the ambient target.

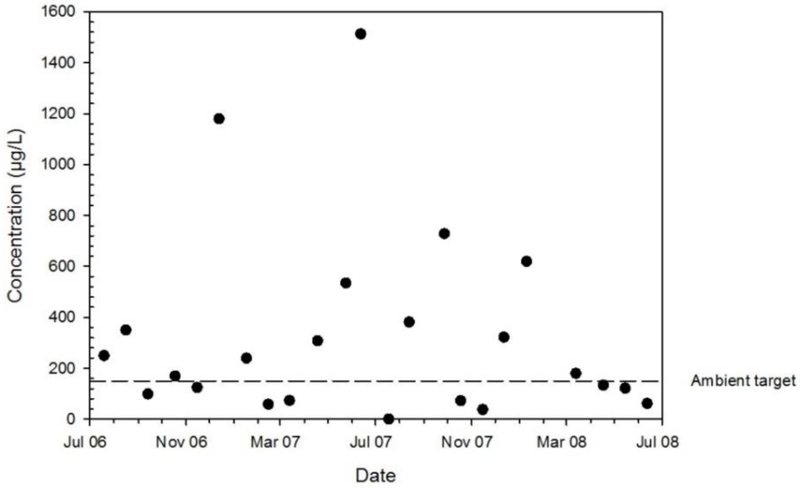

Figure 8 Temporal variation in particulate nitrogen (PN) concentrations during ambient conditions at Bakers Creek from 2006–2008. The dashed line indicates the 2014 ambient PN target for the Bakers Creek Catchment Management Area.

Ambient concentrations of DIN at Bakers Creek were scattered during 2006–2008 with no linear temporal trend ($p = 0.18$) (Figure 9). The majority of the samples were greater than the ambient target (456 µg/L). The concentrations ranged from 340 to 3050 µg/L, approximately seven-times higher than the ambient target.

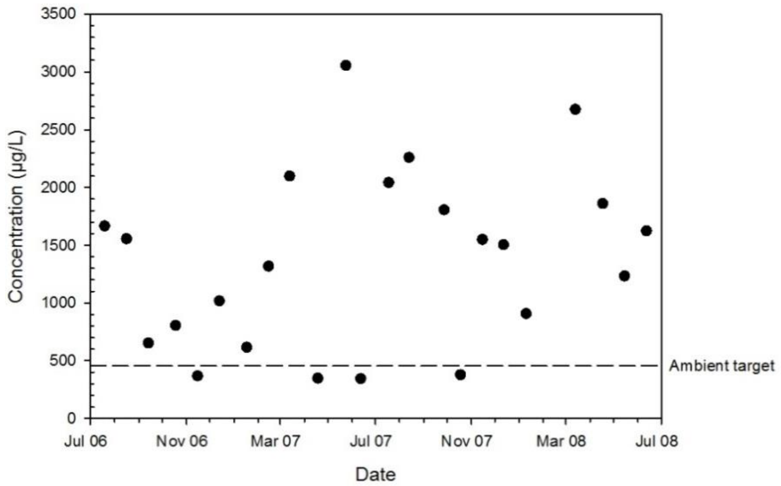

Figure 9 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient conditions at Bakers Creek from 2006–2008. The dashed line indicates the 2014 ambient DIN target for the Bakers Creek Catchment Management Area.

Ambient concentrations of PP at Bakers Creek ranged from < LOR to 159 µg/L from 2006–2008 with only one very high concentration (540 µg/L) (Figure 10). There was no linear temporal trend in ambient PP over the two years ($p = 0.17$). The majority of the samples were greater than the ambient target (28 µg/L), with the maximum concentration approximately 20-times higher than the ambient target.

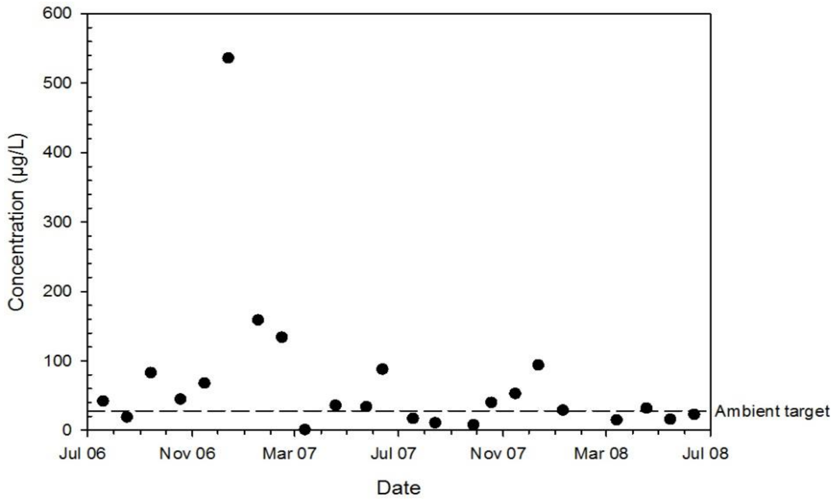

Figure 10 Temporal variation in particulate phosphorus (PP) concentrations during ambient conditions at Bakers Creek from 2006–2008. The dashed line indicates the 2014 ambient PP target for the Bakers Creek Catchment Management Area.

Ambient concentrations of FRP at Bakers Creek were fairly consistent between < LOR and 95 µg/L from 2006–2008 with three higher concentrations (200, 236, and 346 µg/L) (Figure 11). There was no linear temporal trend in ambient FRP over the two years ($p = 0.35$). The majority of the samples were greater than the ambient target (27 µg/L). The concentrations ranged from 12–346 µg/L, approximately 13-times higher than the ambient target.

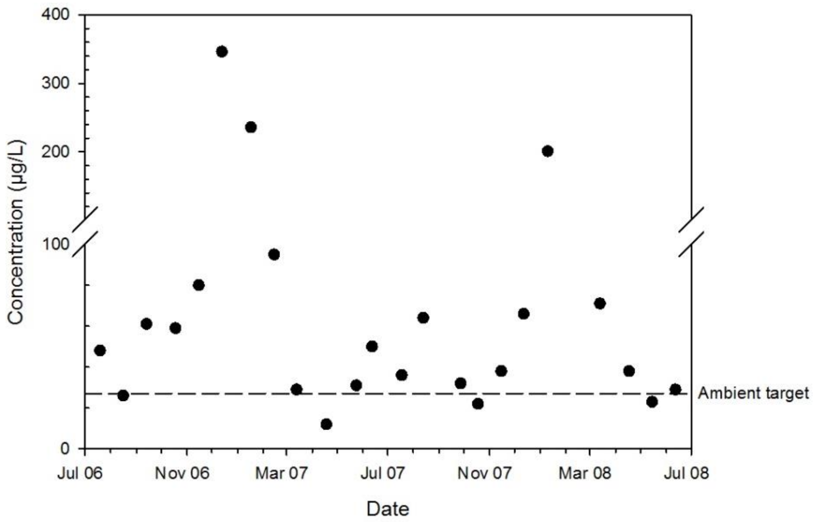

Figure 11 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient conditions at Bakers Creek from 2006–2008. The dashed line indicates the 2014 ambient FRP target for the Bakers Creek Catchment Management Area.

Frequency of target exceedances

Ambient concentrations of PN in Bakers Creek exceeded the 2014 target in 45 per cent of the 11 samples in 2007–2008. The DIN target was exceeded in 91 per cent of the samples. The PP target was exceeded in 45 per cent of the samples, and the FRP target was exceeded in 82 per cent of the samples.

3.3.3 Basin Creek

3.3.3.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Ambient sampling in Basin Creek from 2006–2008 showed concentrations of TSS varied from approximately 0–50 mg/L with no linear temporal trend ($p = 0.29$) (Figure 12). The highest ambient concentration recorded (50 mg/L) occurred in the wet season of 2006–2007, and was 25-times greater than the target of 2 mg/L. While the concentrations of event TSS in early 2007 were higher than previous years, the event sampling in Basin Creek did not show any linear temporal trend ($p = 0.21$) (Figure 12). All high concentrations occurred during the wet seasons, and nearly half of them above the event target of 66 mg/L.

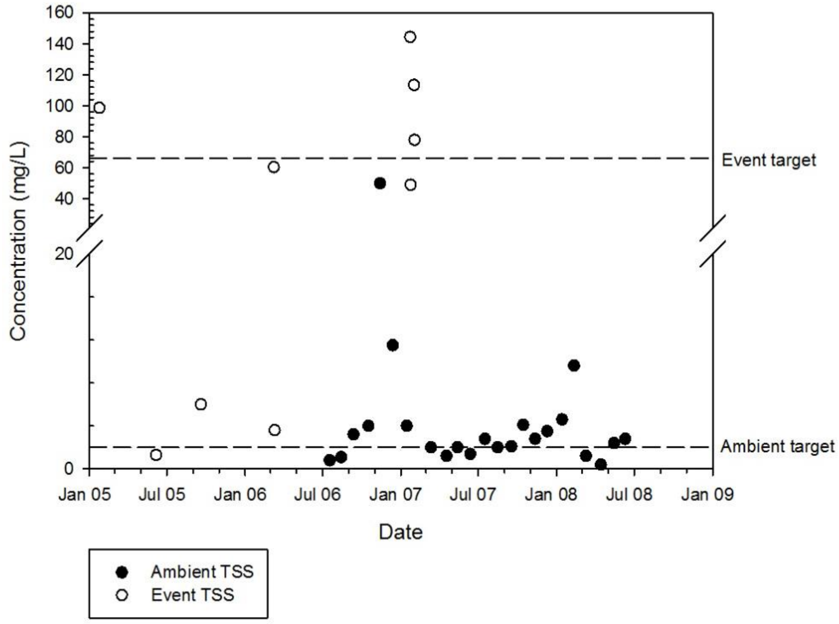

Figure 12 Temporal variation in total suspended solids (TSS) concentrations during ambient and event conditions at Basin Creek from 2004–2009. Dashed lines indicate the 2014 ambient and event TSS targets for the Gillinbin Creek Catchment Management Area.

Frequency of target exceedances

The ambient concentrations of TSS in Basin Creek exceeded the ambient target in 75 per cent of the 12 samples taken in 2007–2008. No event sampling was undertaken subsequent to the establishment of the targets.

3.3.3.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Ambient concentrations of PN in Basin Creek varied between < LOR and 160 µg/L in the period 2006–2008 with no linear temporal trend ($p = 0.93$) (Figure 13). There was one high concentration (440 µg/L), which was approximately seven-times greater than the ambient target (58 µg/L). The majority of the samples were at or greater than the ambient target. There was no linear temporal trend in the event PN concentrations in Basin Creek (p = 0.83). The concentrations ranged from < LOR to 270 µg/L, with almost half of the concentrations occurring above the event target.

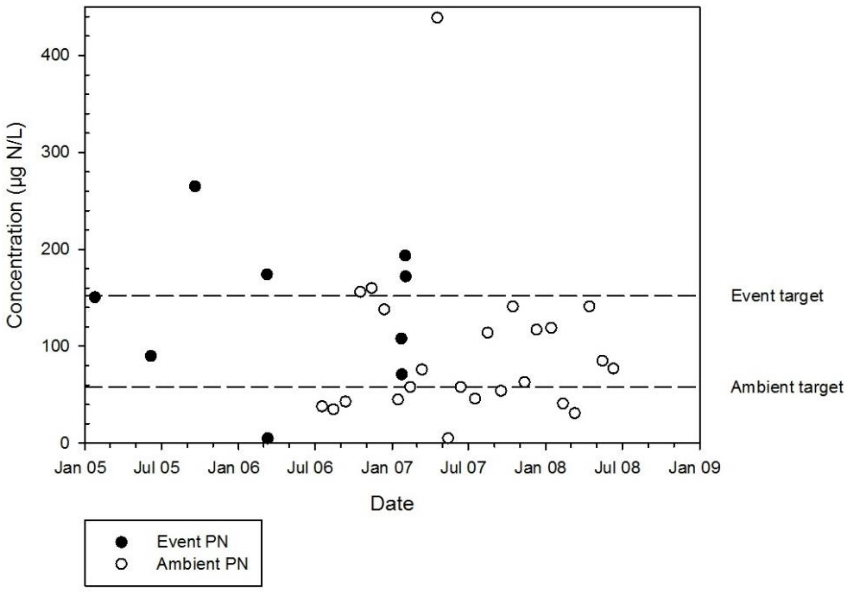

Figure 13 Temporal variation in particulate nitrogen (PN) concentrations during ambient and event conditions at Basin Creek from 2004–2009. Dashed lines indicate the 2014 ambient and event PN targets for the Gillinbin Creek Catchment Management Area.

Ambient concentrations of DIN in Basin Creek from 2006–2008 were scattered between < LOR and 55 µg/L (Figure 14). There was an increase in concentrations over time, however the low R^2 value suggested there were other factors also influencing the results ($p = 0.001$; $R^2 = 0.38$). The majority of ambient DIN concentrations were above the ambient target (9 µg/L). Event sampling in Basin Creek showed varied concentrations from 5–75 µg/L (exceeding the event target of 42 µg/L), with no linear temporal trend ($p = 0.51$).

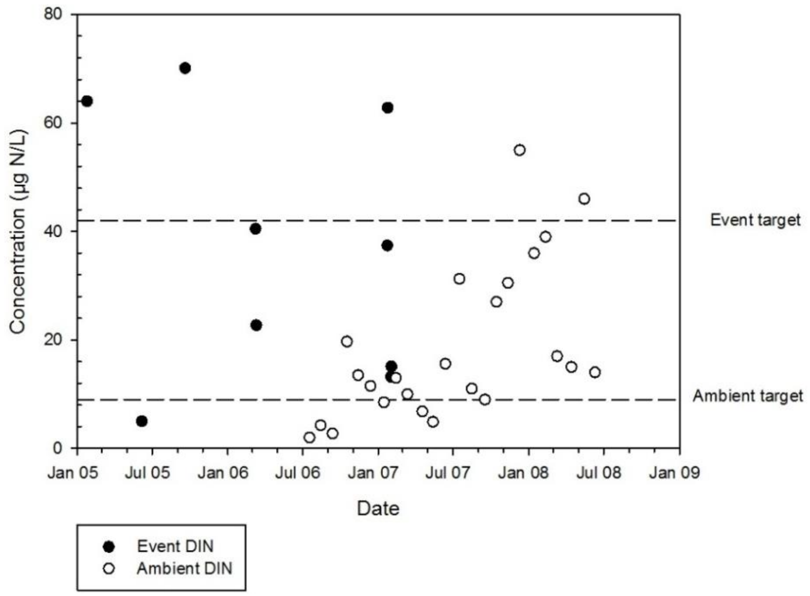

Figure 14 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient and event conditions at Basin Creek from 2004–2009. Dashed lines indicate the 2014 ambient and event DIN targets for the Gillinbin Creek Catchment Management Area.

Ambient concentrations of PP in Basin Creek were reasonably consistent around the ambient target in 2006–2008, with no linear temporal trend ($p = 0.37$) (Figure 15). The concentrations ranged from < LOR to 32 µg/L (three-times greater than the target). The majority of ambient results were at or below the target. The highest concentrations for both ambient and event PP occurred in the wet seasons. Event sampling showed varied concentrations, from 9–59 µg/L, with some results above the event target (37 µg/L). The event PP concentrations were scattered and did not show any linear temporal trend ($p = 0.58$).

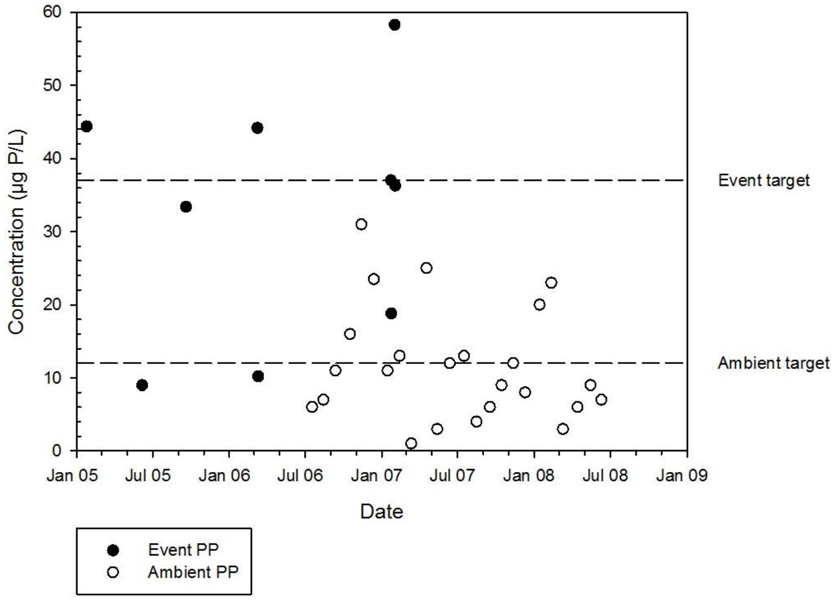

Figure 15 Temporal variation in particulate phosphorus (PP) concentrations during ambient and event conditions at Basin Creek from 2004–2009. Dashed lines indicate the 2014 ambient and event PP targets for the Gillinbin Creek Catchment Management Area.

Ambient concentrations of FRP in Basin Creek increased from 2006–2008 ($p = 0.016$; $R^2 = 0.24$), with more than half of the results being above the ambient target (2 µg/L) (Figure 16). Even though there was a linear increase in FRP concentrations over time, the low R^2 value suggests there are other factors also influencing the results. The highest ambient concentration recorded was 17 µg/L, which was eight-times greater than the ambient target. More than half of the event samples were higher than the event target (3 µg/L), with a highest concentration of 7 µg/L. There was no linear temporal trend in event concentrations in Basin Creek ($p = 0.58$).

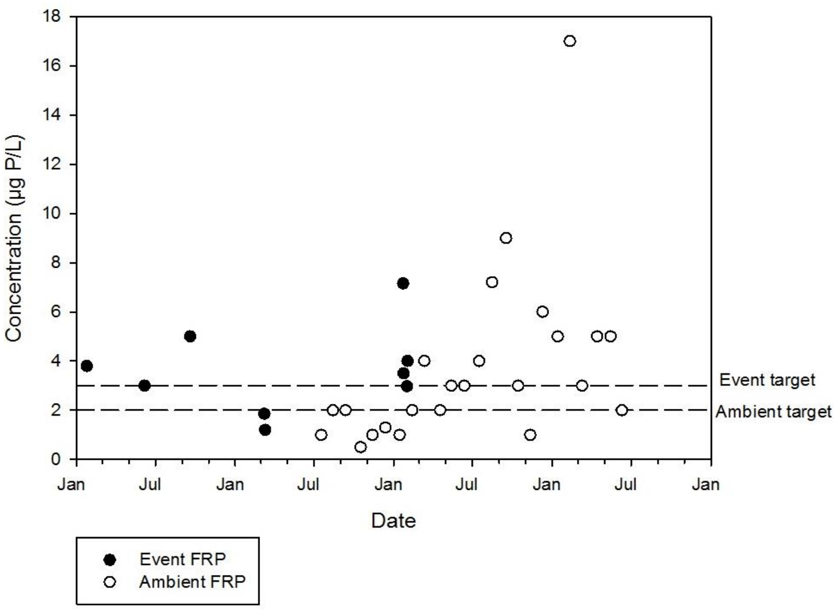

Figure 16 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient and event conditions at Basin Creek from 2004–2009. Dashed lines indicate the 2014 ambient and event FRP targets for the Gillinbin Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted for Basin Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of nutrient concentration exceedances against the targets can be undertaken.

Ambient sampling of nutrients in Basin Creek was undertaken for one year subsequent to 2006–2007, with a total of 12 ambient samples taken in 2007–2008. Of these ambient samples, 67 per cent exceeded the target for PN. Concentrations of DIN exceeded the target in 92 per cent of samples. The PP target was exceeded in 25 per cent of the samples, and 83 per cent of the samples exceeded the FRP target.

3.3.4 Blacks Creek

No ambient sampling was conducted for Blacks Creek, thus, the following results are based on event conditions from 2004–2007.

3.3.4.1 TSS

Temporal variation in TSS and comparison to 2014 targets

The event TSS sampling in Blacks Creek was limited to only four samples (Figure 17), so it was not possible to assess any temporal trend. The two sampling periods with data available (both within the wet season), show similar results, with one concentration approximately 30–45 mg/L, and one at 530 or 630 mg/L (approximately three-times the event target; 183 mg/L) (Figure 17).

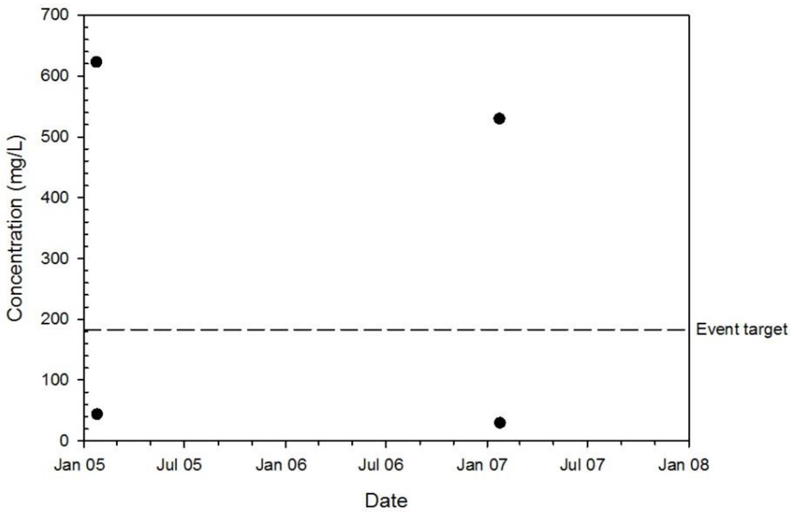

Figure 17 Temporal variation in total suspended solids (TSS) concentrations during event conditions at Blacks Creek from 2004–2007. The dashed line indicates the 2014 event TSS target for the Blacks Creek Catchment Management Area.

Frequency of target exceedances

No TSS sampling was conducted in Blacks Creek after the 2014 targets were established, therefore there has been no assessment of exceedances performed. The event concentrations of TSS in Blacks Creek exceeded the target in one sample (50 per cent) in each year (Table 12).

Table 12 Per cent of exceedances of the 2014 total suspended solids event target for Blacks Creek for 2004–2005 and 2006–2007.

Year	Per cent exceedances (total no. samples)	
	Ambient	Event
2004–2005	-	50 (2)
2005–2006	-	-
2006–2007	-	50 (2)
2007–2008	-	-

3.3.4.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

The event sampling for Blacks Creek was limited to only a few samples within the wet season. Event concentrations of PN and DIN had a similar pattern in both events sampled. Highest PN concentrations were approximately 800 µg/L (2004–2005) and 1900 µg/L (2006–2007), which were above the event target of 440 µg/L (Figure 18). The highest concentration of DIN was 430 µg/L, above the event target of 317 µg/L (Figure 18).

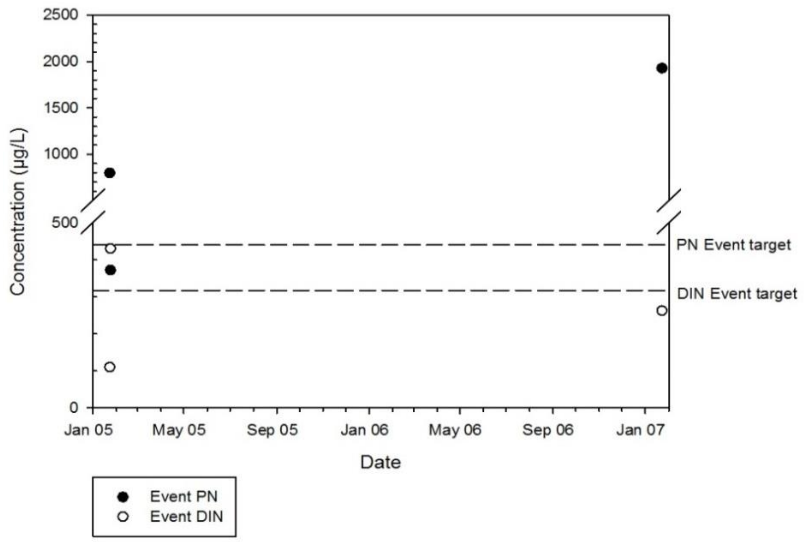

Figure 18 Temporal variation in particulate nitrogen (PN) and dissolved inorganic nitrogen (DIN) concentrations during event conditions at Blacks Creek from 2004–2007. Dashed lines indicate the 2014 event PN and DIN targets for the Blacks Creek Catchment Management Area.

The event sampling for Blacks Creek was limited to only a few samples. Event concentrations of PP and FRP showed a similar pattern in both events sampled. Highest PP concentrations were around 490 µg/L for both years, more than three-times the event target of 136 µg/L (Figure 19). The highest concentration of FRP was 160 µg/L, three-times the event target of 50 µg/L (Figure 19).

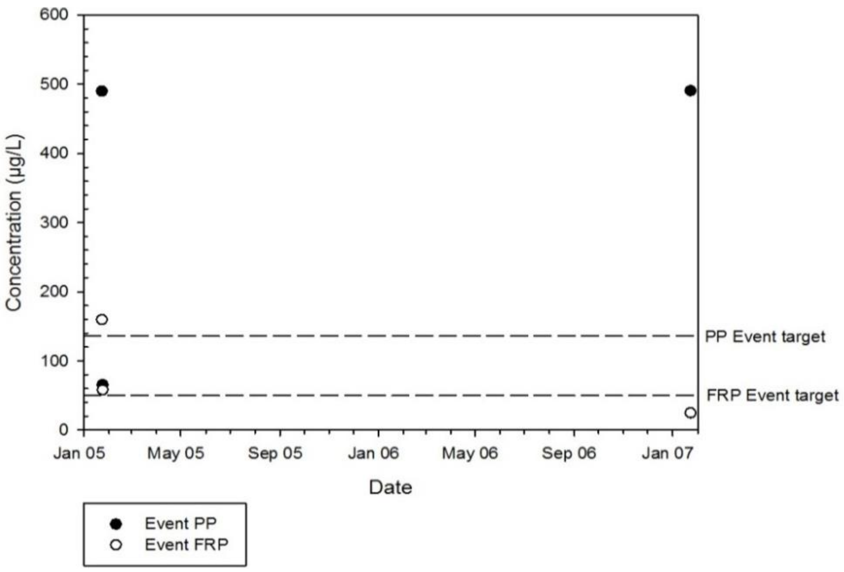

Figure 19 Temporal variation in particulate phosphorus (PP) and filterable reactive phosphorus (FRP) concentrations during event conditions at Blacks Creek from 2004–2007. Dashed lines indicate the 2014 event PP and FRP targets for the Blacks Creek Catchment Management Area.

Frequency of target exceedances

No nutrient sampling was conducted after the 2014 targets were established; therefore there has been no assessment of exceedances performed.

Event concentrations of PN in Blacks Creek exceeded the target in one sample each year, equating to 50 per cent in 2004–2005, and 100 per cent in 2006–2007 (Table 13).

Event concentrations of DIN and PP exceeded the targets in one sample each in 2004–2005 (50 per cent) (Table 13). Event concentrations of PP exceeded the target in one sample (100 per cent) in 2006–2007 (Table 13).

Event concentrations of FRP exceeded the target in two samples (100 per cent) in 2004–2005 (100 per cent) (Table 13).

Table 13 Per cent of exceedances of the 2014 nutrient event targets for Blacks Creek from 2004–2008.

Year	Per cent exceedances (total no. samples)							
	PN		DIN		PP		FRP	
	Ambient	Event	Ambient	Event	Ambient	Event	Ambient	Event
2004–2005	-	50 (2)	-	50 (2)	-	50 (2)	-	100 (2)
2005–2006	-	-	-	-	-	-	-	-
2006–2007	-	100 (1)	-	0 (1)	-	100 (1)	-	0 (1)
2007–2008	-	-	-	-	-	-	-	-

3.3.5 Carmila Creek

3.3.5.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Ambient concentrations of TSS in Carmila Creek from 2006–2008 remained relatively constant around the ambient target, with four slightly higher concentrations across the period (Figure 20). There was no linear trend in ambient TSS concentrations ($p = 0.83$). The concentrations recorded in ambient conditions were up to 26 mg/L, above the ambient target of 3 mg/L. The highest ambient TSS concentrations occurred during the wet seasons. While the event concentrations of TSS event sampling in Carmila Creek appeared to increase in the 2006–2007 year, there was not any linear temporal trend ($p = 0.12$), with results scattered between 3 mg/L and 88 mg/L (Figure 20). Three event concentrations in 2006 and 2007 were above the event target of 39 mg/L.

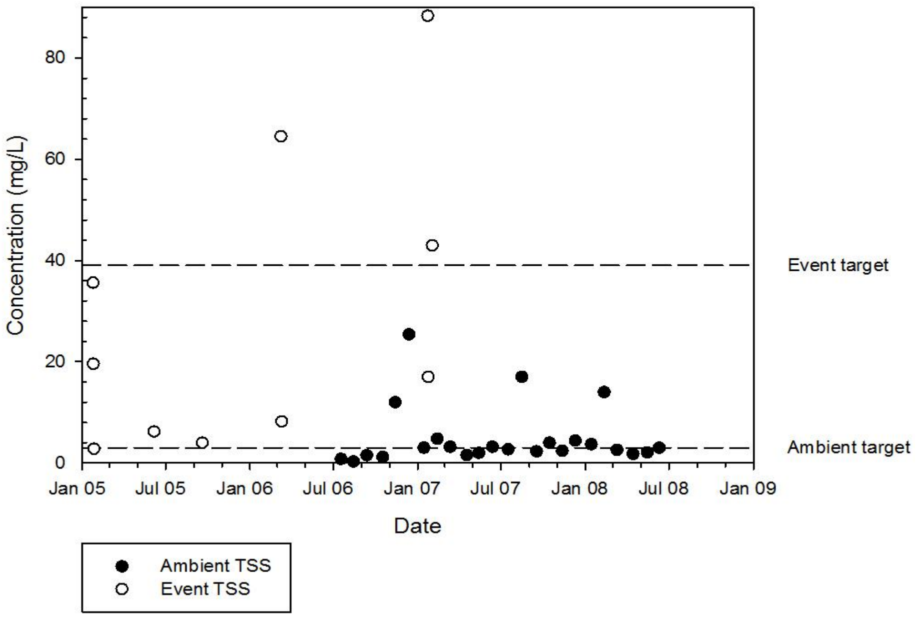

Figure 20 Temporal variation in total suspended solids (TSS) concentrations during ambient and event conditions at Carmila Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event TSS targets for the Carmila Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted for Carmila Creek subsequent to 2006–2007, therefore no assessment of event concentration exceedances against the targets can be undertaken. Ambient sampling of nutrients at Carmila Creek was undertaken for one year subsequent to 2006–2007. Of the 12 ambient samples taken in 2007–2008, 42 per cent exceeded the target.

3.3.5.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

The majority of ambient PN concentrations in Carmila Creek varied from 20–250 µg/L from 2006–2008 with two higher concentrations (340 and 380 µg/L) (Figure 21). Approximately half of the concentrations were greater than the ambient target of 78 µg/L. There was no linear temporal trend over the two years ($p = 0.64$). The highest ambient concentration (380 µg/L) was five-times greater than the ambient target. The event sampling concentrations were scattered between 20–560 µg/L (Figure 21) with no linear temporal trend ($p = 0.49$). The highest event concentration (560 µg/L) was two-times greater than the event target.

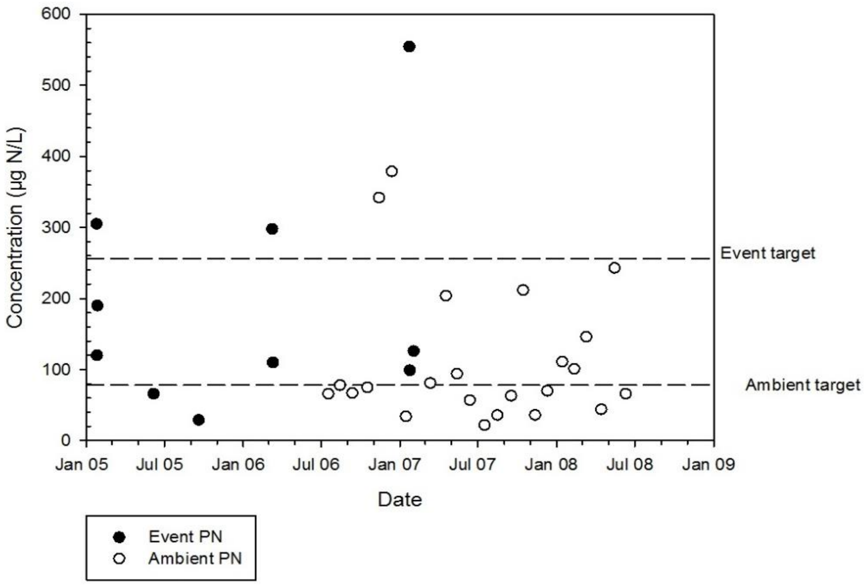

Figure 21 Temporal variation in particulate nitrogen (PN) concentrations during ambient and event conditions at Carmila Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PN targets for the Carmila Creek Catchment Management Area.

The majority of the ambient concentrations of DIN in Carmila Creek in 2006–2007 were consistently around the ambient target (8 µg/L); however, the majority of concentrations in 2007–2008 were above the ambient target (Figure 22). There were five samples between 100 and 200 µg/L, and one very high concentration (700 µg/L) during the 2007 wet season (Figure 22). There was no linear temporal trend in ambient DIN concentrations ($p = 0.82$). Event sampling showed varied concentrations up to 1850 µg/L, with approximately half of the event concentrations above the event target (465 µg/L) (Figure 22). While the highest event concentration occurred in January 2005 and there was a subsequent decrease in concentrations, there was no linear temporal trend ($p = 0.21$). The highest event concentration occurred in early 2005, while concentrations from 2006 and 2007 were much lower.

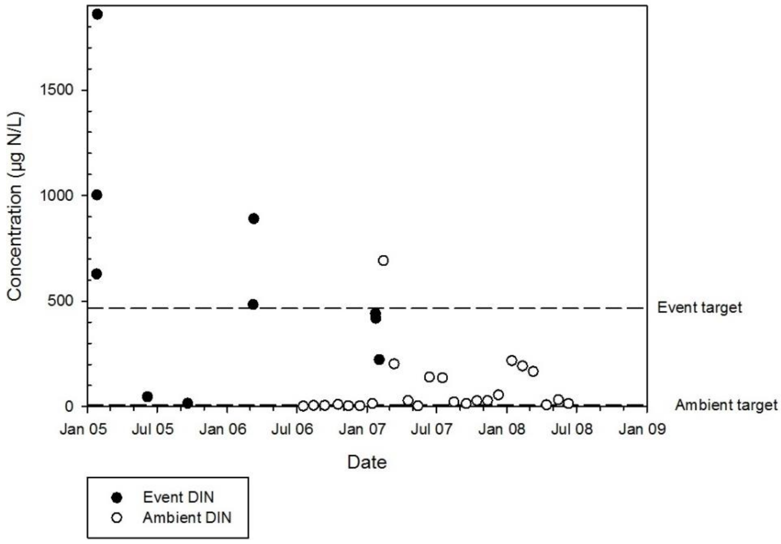

Figure 22 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient and event conditions at Carmila Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event DIN targets for the Carmila Creek Catchment Management Area.

Ambient PP concentrations in Carmila Creek from 2006–2008 were evenly spread around the ambient target with two higher values (53 and 74 µg/L) (Figure 23). Approximately half of the ambient results were below, or at, the ambient target (10 µg/L). The highest ambient concentration during the monitored wet seasons was 76 µg/L. There was no linear temporal trend in ambient PP over this period ($p = 0.37$). Event sampling showed varied concentrations with the majority occurring between 14 and 64 µg/L (Figure 23). While the peak concentrations appeared to increase over time, there was no linear temporal trend for the sampling period ($p = 0.14$). The highest concentration was 110 µg/L, which was above the event target (53 µg/L).

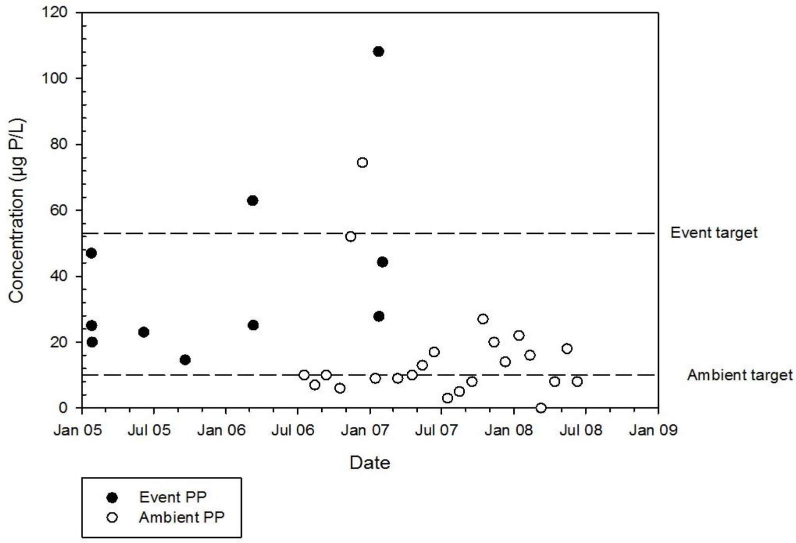

Figure 23 Temporal variation in particulate phosphorus (PP) concentrations during ambient and event conditions at Carmila Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PP targets for the Carmila Creek Catchment Management Area.

Ambient concentrations of FRP in Carmila Creek were ranged from < LOR–14 µg/L from 2006–2008 (Figure 24). It appeared there may have been an increase in FRP from July 2006 to late 2007, before decreasing; however, there was no linear temporal trend ($p = 0.12$). There was one higher concentration (24 µg/L) in early 2008. Approximately half of the concentrations were at or below the ambient target (5 µg/L). The event concentrations were varied with no linear temporal trend ($p = 0.44$) (Figure 24). The majority of event samples were above the event target (27 µg/L). Event sampling shows FRP concentrations of 3–42 µg/L, with no temporal trend.

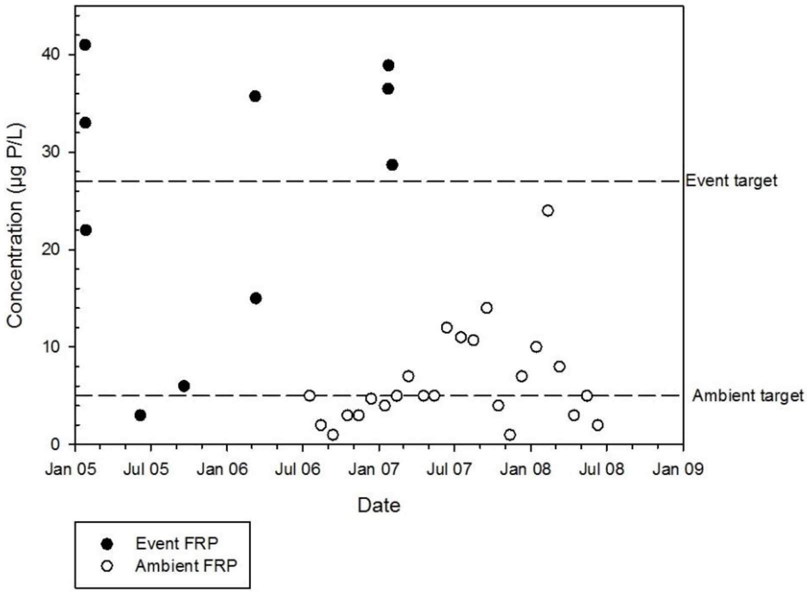

Figure 24 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient and event conditions at Carmila Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event FRP targets for the Carmila Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted for Carmila Creek subsequent to 2006–2007, therefore no assessment of concentration exceedances against the targets can be undertaken. Ambient sampling of nutrients was undertaken for one year subsequent to 2006–2007, with a total of 12 ambient samples taken in 2007–2008. Of the samples taken, 42 per cent exceeded the PN target, 92 per cent exceeded the DIN target, while 33 per cent of samples exceeded the PP target and 67 per cent exceeded the FRP target.

3.3.6 Finch Hatton Creek

3.3.6.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Ambient sampling in Finch Hatton Creek from 2006–2008 showed concentrations of TSS spread between < LOR and 120 mg/L, with the data appearing to increase in variability over time (Figure 25). Although ambient TSS concentrations appeared to increase over time, there was no temporal trend ($p = 0.12$). The majority of ambient concentrations were below the target (3 mg/L). The highest ambient concentration (120 mg/L) was 40-times higher than the target. The event TSS sampling occurred prior to the ambient sampling from 2004–2007. Concentrations ranged from < LOR–210 mg/L, with no linear trend over time ($p = 0.26$). The majority of the event concentrations were below 5 mg/L, with four concentrations between 60 and 80 mg/L, all above the event target (43 mg/L) (Figure 25).

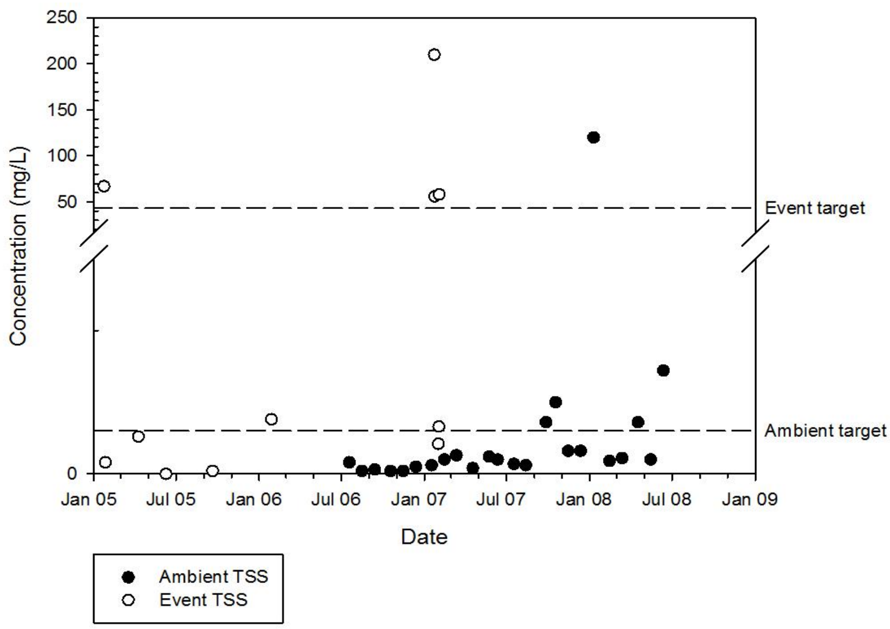

Figure 25 Temporal variation in total suspended solids (TSS) concentrations during ambient and event conditions at Finch Hatton Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event TSS targets for the Upper Cattle Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted in Finch Hatton Creek subsequent to 2006–2007, however one year of ambient sampling (12 samples) was undertaken in 2007–2008, in which 42 per cent of the samples exceeded the ambient TSS target.

3.3.6.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Ambient concentrations of PN in Finch Hatton Creek from 2006–2008 showed concentrations to vary between < LOR and 460 µg/L, with an increase in variability over time (Figure 26). There was no linear temporal trend in ambient PN concentrations ($p = 0.20$).

The majority of ambient concentrations were below the ambient PN target (78 µg/L). The highest ambient concentration (460 µg/L) was six-times higher than the target. Event sampling for nutrients took place from 2004–2006. The event PN concentrations ranged from < LOR–480 µg/L (Figure 26), with the highest concentration occurring in early 2005. Due to sampling data being limited to six samples covering only one year, linear regression was not performed on the data. All but one concentration was below the event target (118 µg/L).

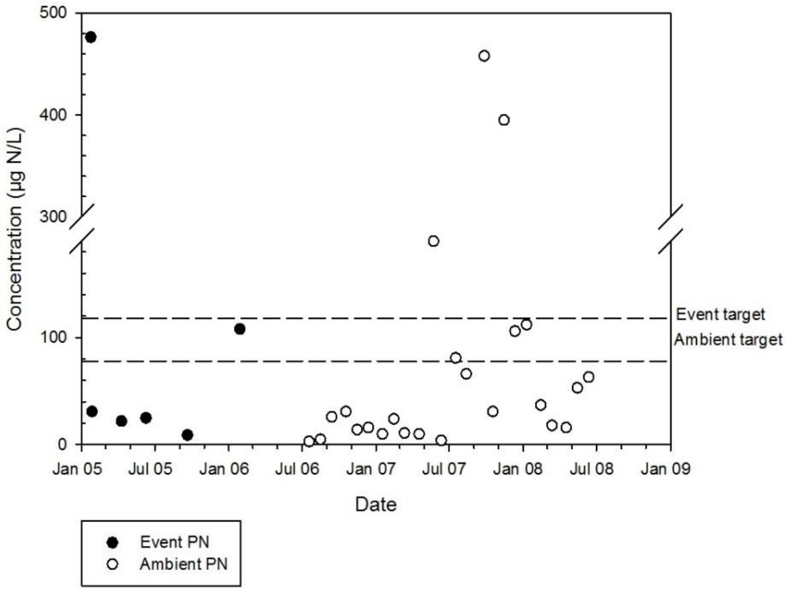

Figure 26 Temporal variation in particulate nitrogen (PN) concentrations during ambient and event conditions at Finch Hatton Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PN targets for the Upper Cattle Creek Catchment Management Area.

Ambient concentrations of DIN in Finch Hatton Creek showed concentrations to increase from 2006–2008 ($p = 0.017$; $R^2 = 0.232$), however the low R^2 value suggested there were other factors also influencing the results (Figure 27). The majority of ambient concentrations were above the target (8 µg/L), with the highest ambient concentration (130 µg/L) being 16-times higher than the target. The event DIN concentrations ranged from 8–110 µg/L, with all concentrations well below the event target (266 µg/L). Due to sampling data being limited to six samples covering only one year, linear regression was not performed on the data. The highest concentration occurred in January 2005 and the concentrations after this were lower.

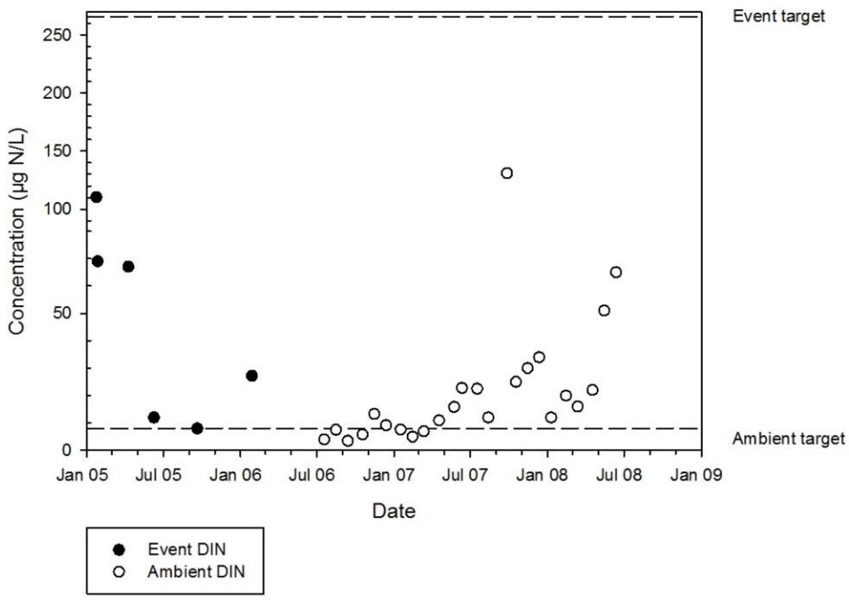

Figure 27 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient and event conditions at Finch Hatton Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event DIN targets for the Upper Cattle Creek Catchment Management Area.

Ambient concentrations of PP in Finch Hatton Creek showed an increase in variability from 2006–2008 (Figure 28). There was no linear temporal trend in the ambient PP concentrations ($p = 0.51$). The majority of the concentrations were below the ambient target (10 µg/L). The highest ambient concentration (42 µg/L) was four-times higher than the target. Event concentrations ranged from 2–58 µg/L. Only one value was above the event target (53 µg/L). The event sampling was limited to only six samples across one year so no linear regression was performed; however, the concentrations were much lower than the concentration measured in early 2005.

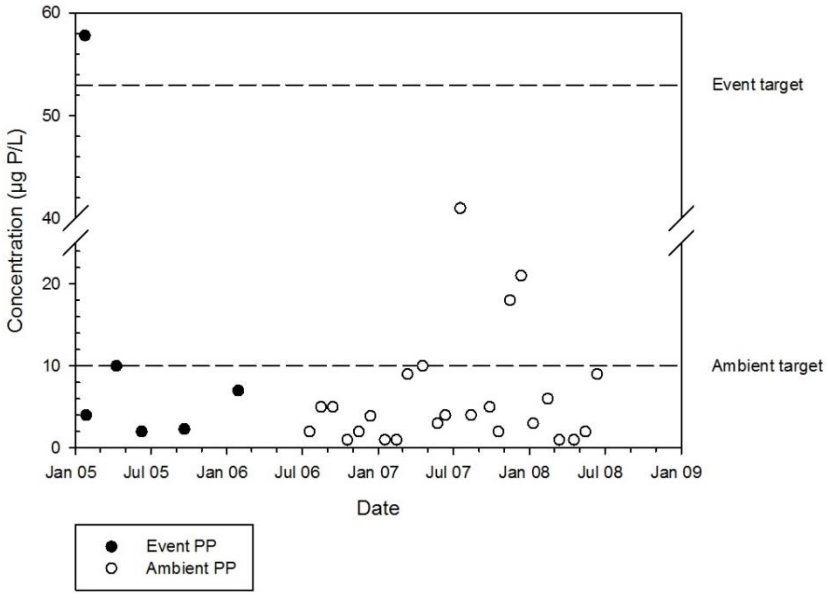

Figure 28 Temporal variation in particulate phosphorus (PP) concentrations during ambient and event conditions at Finch Hatton Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PP targets for the Upper Cattle Creek Catchment Management Area.

Ambient concentrations of FRP in Finch Hatton Creek were ranged from < LOR–13 µg/L, from 2006–2008 (Figure 29), with one higher value (25 µg/L) and no linear temporal trend ($p = 0.51$). Approximately half of the ambient concentrations were below the target of 5 µg/L. The highest ambient concentration (25 µg/L) was five-times higher than the target. The event concentrations ranged from 1–10 µg/L, with all samples well below the event target (30 µg/L). There was a decrease in event FRP concentrations over time; however, the sampling was limited to only six samples over one year, so linear regression could not be performed.

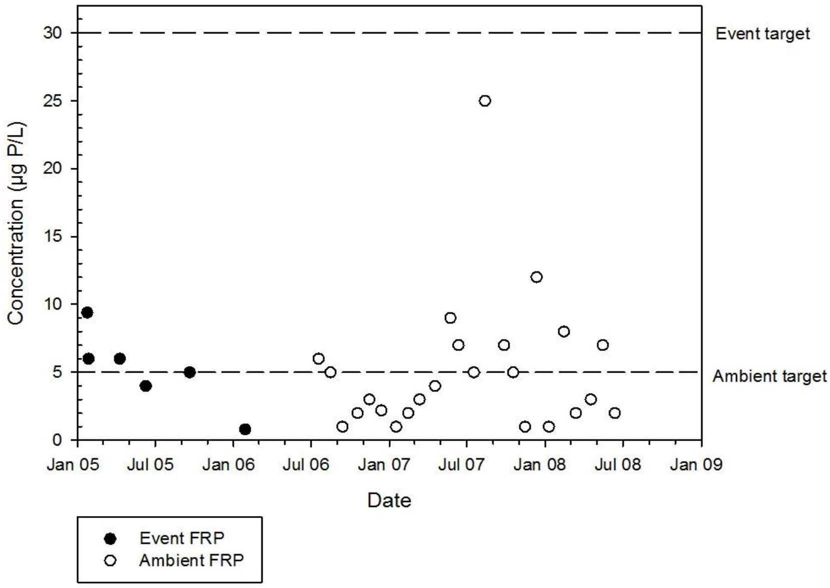

Figure 29 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient and event conditions at Finch Hatton Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event FRP targets for the Upper Cattle Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted in Finch Hatton Creek subsequent to 2006–2007; however, one year of ambient sampling (12 samples) was undertaken in 2007–2008. The following results are based on the ambient 2007–2008 concentrations. Ambient concentrations of PN in Finch Hatton Creek exceeded the target in 42 per cent of the samples, while the DIN target was exceeded in 100 per cent of the samples. Ambient concentrations of PP exceeded the target in 25 per cent of the samples, and exceeded the FRP target in 42 per cent of the samples.

3.3.7 Gregory River

No ambient sampling was conducted for Gregory River, thus, the following results are based on event conditions from 2004–2007.

3.3.7.1 TSS

Temporal variation in TSS and comparison to 2014 targets

The event sampling in Gregory River showed concentrations to be scattered across the events, with no linear temporal trend ($p = 0.72$) (Figure 30). The concentrations recorded were up to 74 mg/L, which was above the event target of 42 mg/L, with the highest concentrations occurring during the wet season, indicating seasonal trends.

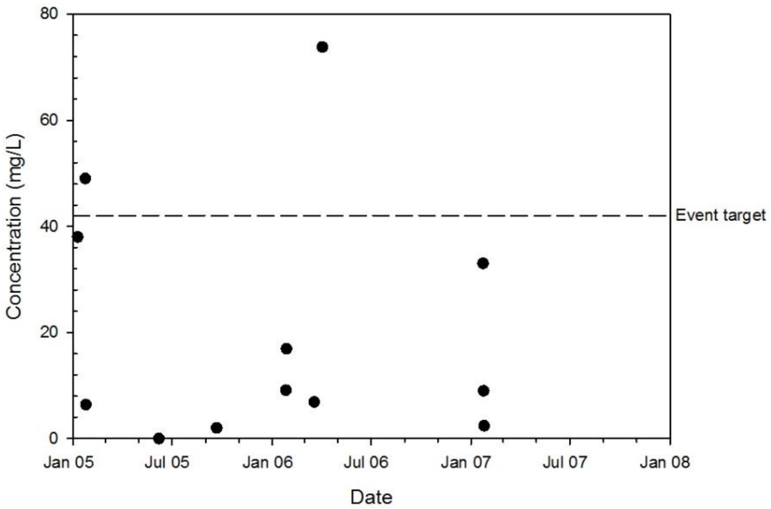

Figure 30 Temporal variation in total suspended solids (TSS) concentrations during event conditions at Gregory River from 2004–2007. The dashed line indicates the 2014 event TSS target for the Gregory River Catchment Management Area.

Frequency of target exceedances

No sampling was conducted for Gregory River subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets can be undertaken.

3.3.7.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Event concentrations of PN at Gregory River from 2006–2008 were scattered between 15 and 380 µg/L with no linear temporal trend ($p = 0.12$) (Figure 31). The majority of concentrations were above the event target (254 µg/L), with the highest concentrations occurring in the early part of each year, indicating seasonal trends.

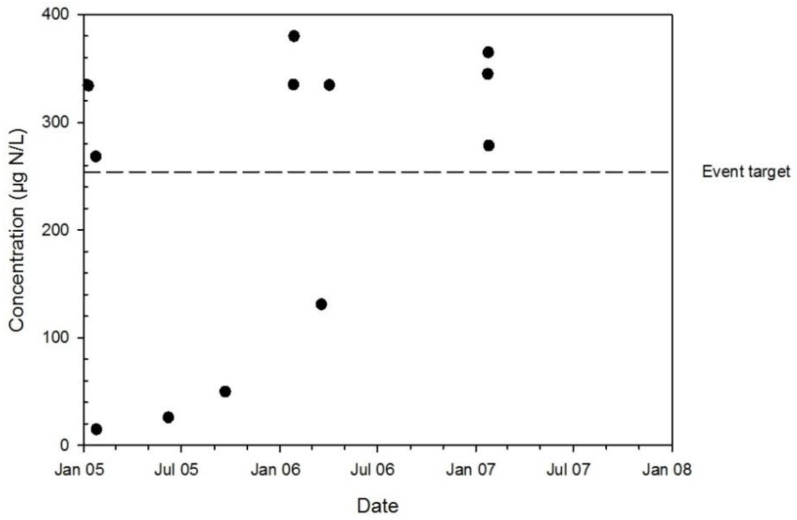

Figure 31 Temporal variation in particulate nitrogen (PN) concentrations during event conditions at Gregory River from 2004–2007. The dashed line indicates the 2014 event PN target for the Gregory River Catchment Management Area.

Event concentrations of DIN at Gregory River from 2006–2008 were scattered between < LOR and 1300 µg/L, with an increase over time ($p = 0.037$; $R^2 = 0.368$), however the low R^2 value indicates there are other factors also influencing the results (Figure 32). The majority of concentrations were above the event target (387 µg/L). The lowest concentration was < LOR and the highest was approximately 1300 µg/L (three-times greater than the target). The highest concentrations occurred at the start of each year, indicating that seasonal trends may have occurred.

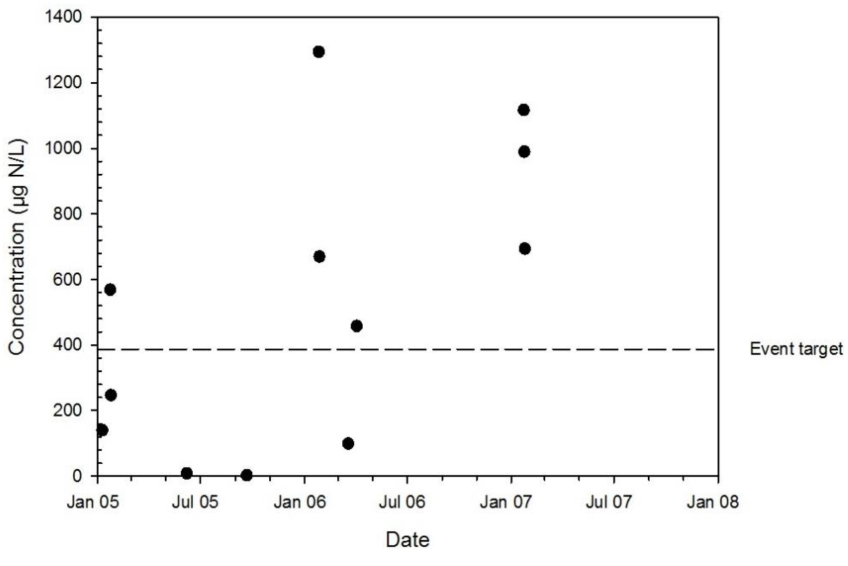

Figure 32 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during event conditions at Gregory River from 2004–2007. The dashed line indicates the 2014 event DIN target for the Gregory River Catchment Management Area.

Event concentrations of PP at Gregory River were scattered from 2006–2008 with no linear temporal trend ($p = 0.96$) (Figure 33). The majority of concentrations were below the event target (57 µg/L). The concentrations ranged from 6–95 µg/L, with the highest concentrations occurring at the beginning of each year, during the wet season.

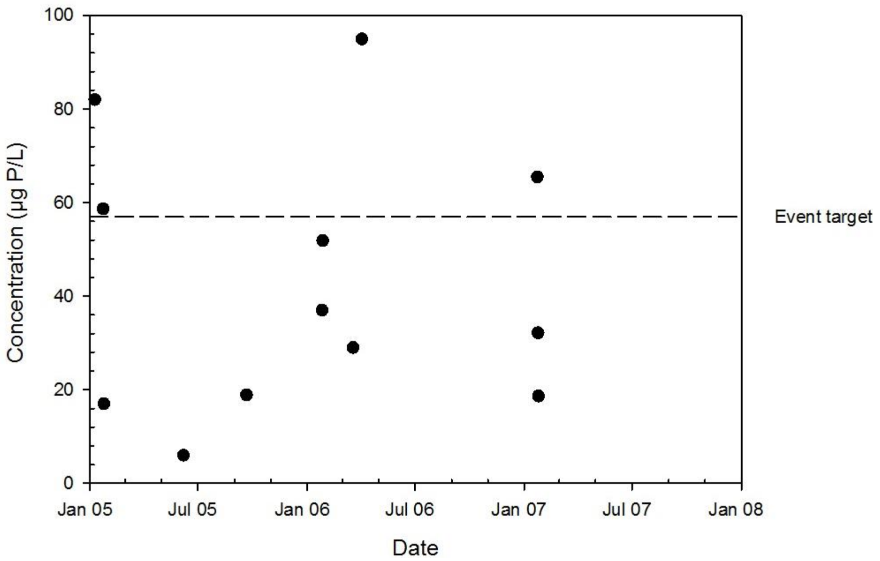

Figure 33 Temporal variation in particulate phosphorus (PP) concentrations during event conditions at Gregory River from 2004–2007. The dashed line indicates the 2014 event PP target for the Gregory River Catchment Management Area.

Event concentrations of FRP at Gregory River from 2006–2008 were scattered between < LOR and 112 µg/L with no linear temporal trend (p = 0.97) (Figure 34). Approximately half of the concentrations were below the event target (54 µg/L). The highest concentration (112 µg/L) was two times greater than the target. All of the highest concentrations occurred during the wet seasons, indicating seasonal trends.

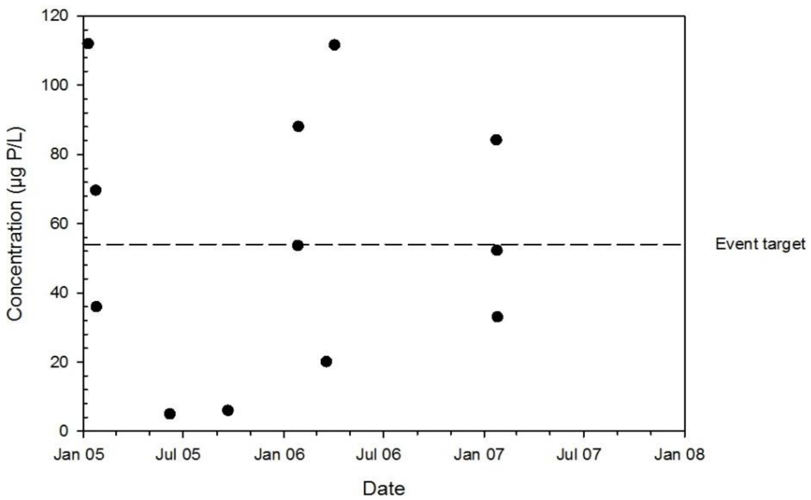

Figure 34 Temporal variation in filterable reactive phosphorus (FRP) concentrations during event conditions at Gregory River from 2004–2007. The dashed line indicates the 2014 event FRP target for the Gregory River Catchment Management Area.

Frequency of target exceedances

No sampling was conducted for Gregory River subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets can be undertaken.

3.3.8 Impulse Creek

3.3.8.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Impulse Creek sampling from 2006–2008 showed ambient concentrations of TSS spread from < LOR to 4.4 mg/L (Figure 35). There was no linear temporal trend in ambient TSS concentrations ($p = 0.89$). The majority of concentrations recorded in ambient conditions were at or below the ambient target of 2 mg/L. Event sampling in Impulse Creek was limited to seven samples over one year, so linear regression could not be performed. The highest event TSS concentration (43 mg/L) was in early 2005, and well above the event target of 8 mg/L (Figure 35). All other event concentrations were below the event target, with the second peak in early 2006.

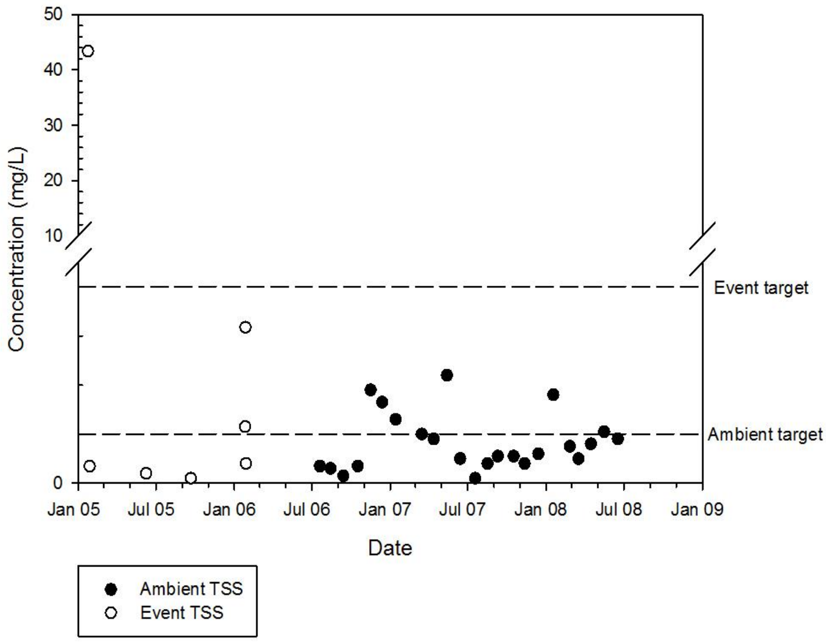

Figure 35 Temporal variation in total suspended solids (TSS) concentrations during ambient and event conditions at Impulse Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event TSS targets for the Repulse Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted in Impulse Creek subsequent to 2006–2007; however, one year of ambient sampling (12 samples) was undertaken in 2007–2008, in which 17 per cent of the samples exceeded the ambient TSS target.

3.3.8.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Impulse Creek ambient concentrations of PN from 2006–2008 were spread between < LOR and 80 µg/L with no temporal trend ($p = 0.40$) (Figure 36). The majority of the concentrations were greater than the ambient target (16 µg/L). The event sampling in Impulse Creek was limited to seven samples over a one year period, so linear regression was not performed. The majority of event concentrations at Impulse Creek ranged from 10–200 µg/L with only one concentration (580 µg/L) above the target (261 µg/L). This concentration was measured in January 2005.

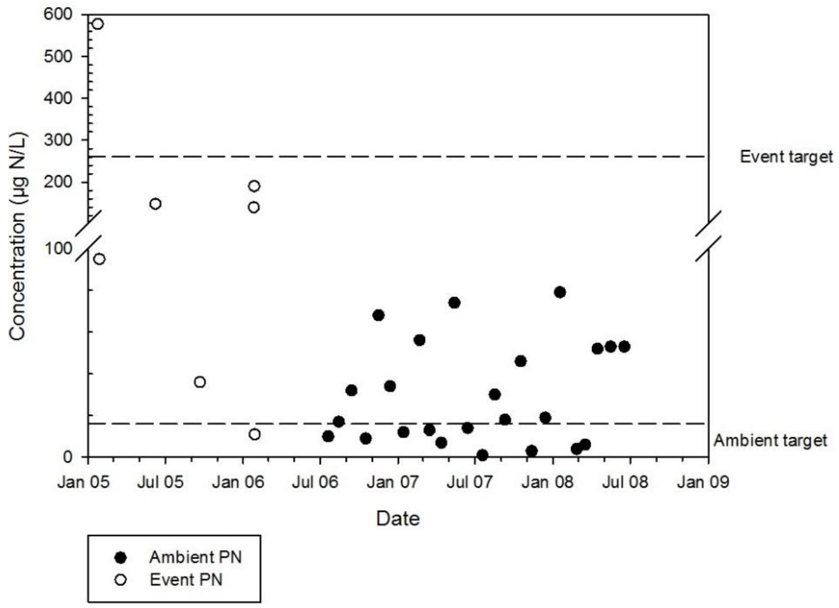

Figure 36 Temporal variation in particulate nitrogen (PN) concentrations during ambient and event conditions at Impulse Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PN targets for the Repulse Creek Catchment Management Area.

Ambient concentrations of DIN in Impulse Creek were scattered, and increased from 2006–2008 ($p = 0.001$; $R^2 = 0.399$); however, the low R^2 value suggests there are other factors also influencing the results (Figure 37). The majority of ambient concentrations were greater than the ambient target (20 µg/L). The highest ambient concentration was approximately 100 µg/L. Event sampling in Impulse Creek was limited to seven samples over a period of one year, so linear regression was not performed. Event concentrations at Impulse Creek ranged from 30–800 µg/L (three-times greater than the event target of 256 µg/L), with peaks occurring at the start of 2005 and 2006.

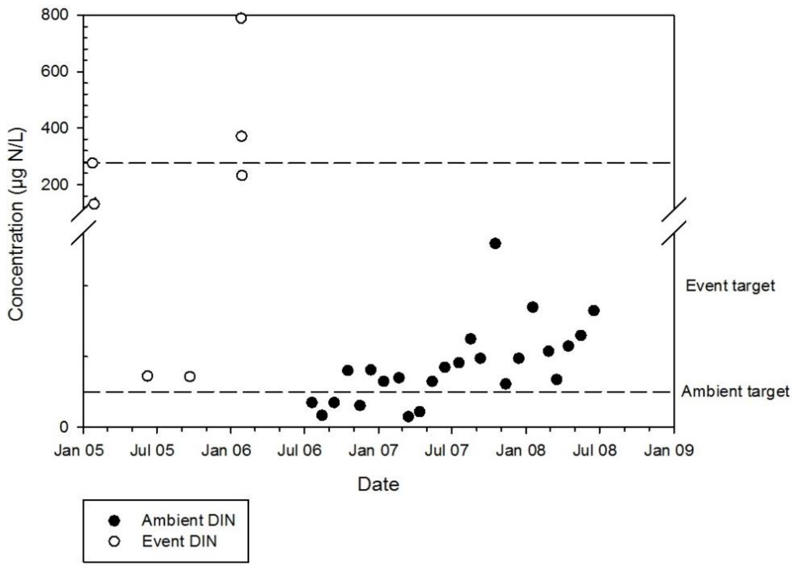

Figure 37 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient and event conditions at Impulse Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event DIN targets for the Repulse Creek Catchment Management Area.

Ambient concentrations of PP in Impulse Creek were scattered from 2006–2008, with no linear temporal trend ($p = 0.44$) (Figure 38). The majority of the concentrations were below the ambient target (10 µg/L). The highest ambient concentration was approximately 50 µg/L (five-times greater than the target) and occurred in the wet season. Event sampling in Impulse Creek was limited to seven samples, over one year, so no linear regression was performed on the data. Event concentrations at Impulse Creek ranged from < LOR–89 µg/L, with the highest concentration occurring in January 2005. This was the only concentration above the event target for PP of 31 µg/L. All other concentrations were below the event target, and the second peak was in January 2006.

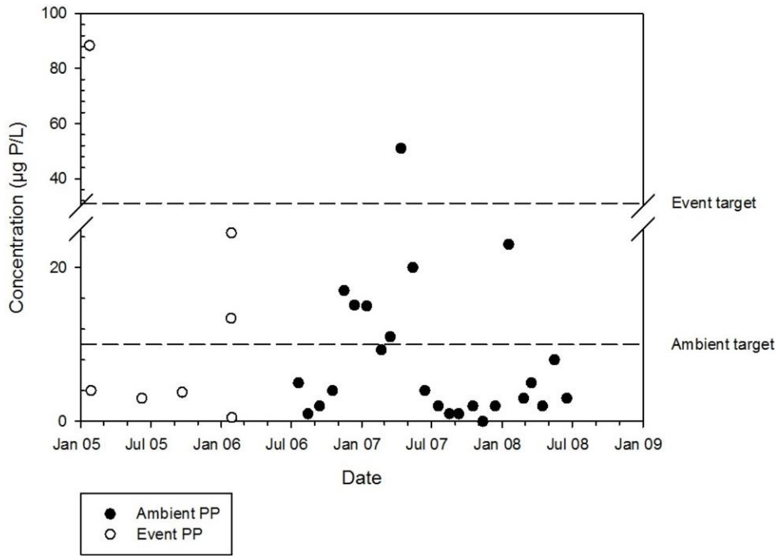

Figure 38 Temporal variation in particulate phosphorus (PP) concentrations during ambient and event conditions at Impulse Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PP targets for the Repulse Creek Catchment Management Area.

Ambient concentrations of FRP in Impulse Creek from 2006–2008 were scattered, with no linear temporal trend (p = 0.38) (Figure 39). Half of the ambient concentrations were at or below the ambient target (10 µg/L). The highest ambient concentration was approximately 19 µg/L. Event sampling in Impulse Creek was limited to seven samples across one year, so no linear regression was performed. Event concentrations at Impulse Creek ranged from 8–38 µg/L, with the highest concentration in January 2005, and the next highest concentration in January 2006. The majority of event concentrations were below the event target (27 µg/L).

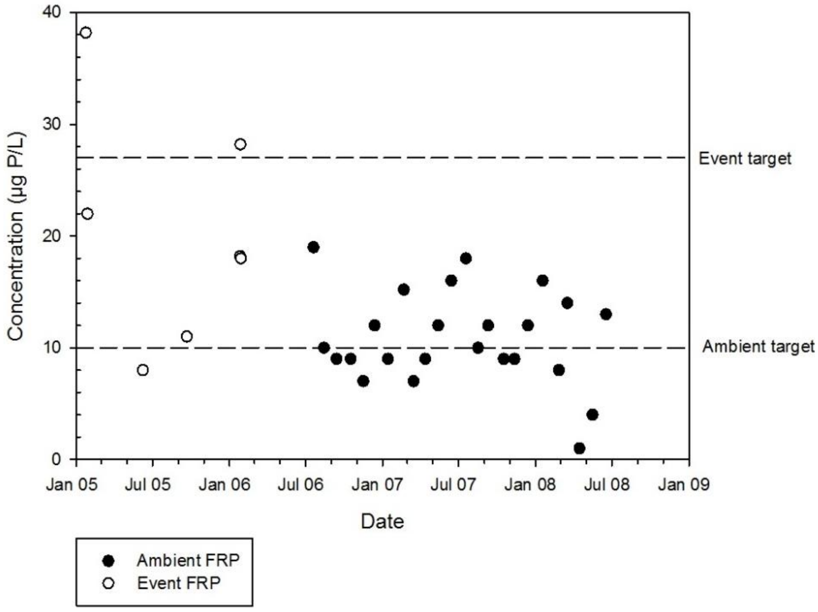

Figure 39 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient and event conditions at Impulse Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event FRP targets for the Repulse Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted in Impulse Creek subsequent to 2006–2007, however one year of ambient sampling (12 samples) was undertaken in 2007–2008. Ambient concentrations of PN exceeded the target in 67 per cent of the samples taken, and exceeded the DIN target in 100 per cent of the samples. The PP target was exceeded in 8 per cent of samples and the FRP target exceeded in 50 per cent of samples.

3.3.9 Mackay City

No ambient sampling for Mackay City was conducted, thus, the following results are based on event conditions from 2004–2007 for the two sites, Mackay 1 and 2. Linear regression could not be performed on the results from Mackay 2 samples, therefore all p-values below refer to the Mackay 1 site only.

3.3.9.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Event sampling in Mackay City from 2004–2007 showed concentrations of TSS varied at both sites (Figure 40). Concentrations were low in early 2005, and then increased in mid-2005, to a peak in January 2006, and then decreased. There was no linear temporal trend in the Mackay 1 concentrations ($p = 0.33$) (Figure 40). The concentrations recorded were up to 192 mg/L, which was five-times greater than the event target of 39 mg/L.

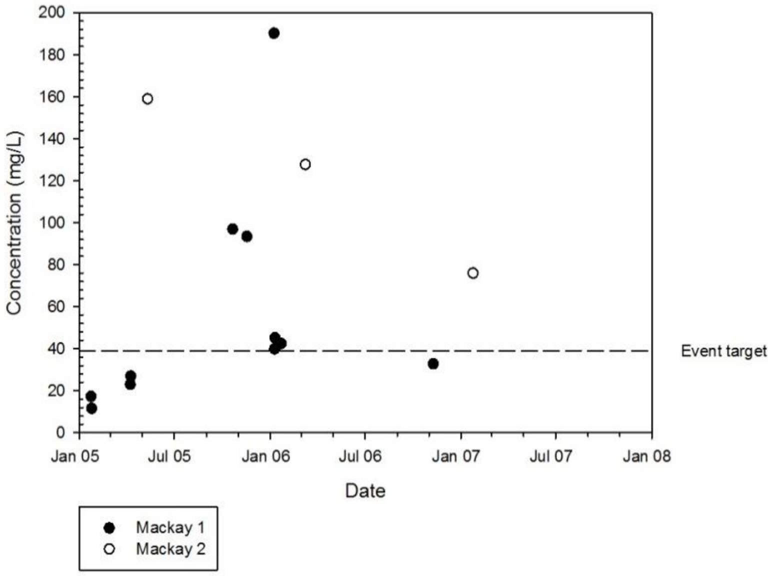

Figure 40 Temporal variation in total suspended solids (TSS) concentrations during event conditions at Mackay 1 and 2 from 2004–2007. The dashed line indicates the 2014 event TSS target for the Mackay City Catchment Management Area.

Frequency of target exceedances

No sampling was conducted for Mackay City (at either site) subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets can be undertaken.

3.3.9.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Event concentrations of PN at the Mackay City sites from 2004–2006 were scattered between 40–530 µg/L with one higher value (1520 µg/L) in January 2006 (Figure 41). The majority of the concentrations were above the event target. While there appeared to be an increase in concentrations, there was no linear temporal trend at the Mackay 1 site ($p = 0.18$). The highest concentration was 1520 µg/L, compared to the target of 198 µg/L.

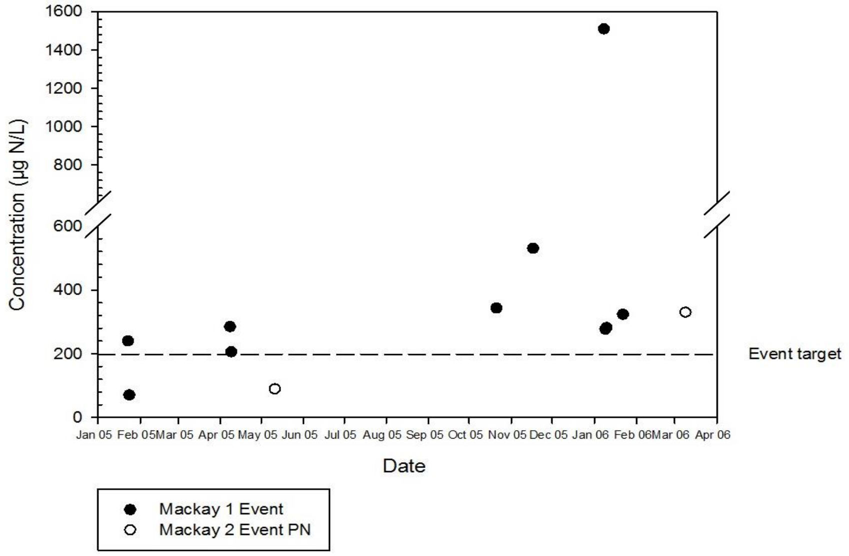

Figure 41 Temporal variation in particulate nitrogen (PN) concentrations during event conditions at Mackay 1 and 2 from 2004–2006. The dashed line indicates the 2014 event PN target for the Mackay City Catchment Management Area.

Event concentrations of DIN at the Mackay City sites from 2004–2006 were scattered, with one higher value (1160 µg/L) in October 2005 (Figure 42). The majority of the concentrations were below the event target, and there was no linear trend over time at the Mackay 1 site ($p = 0.28$). The highest concentration was 1160 µg/L, compared to the event DIN target of 420 µg/L.

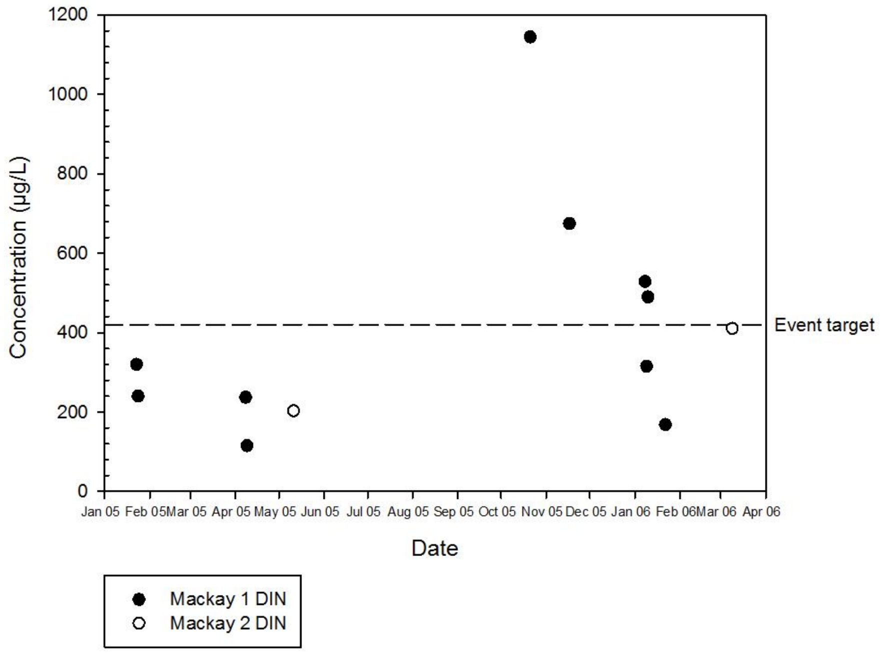

Figure 42 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during event conditions at Mackay 1 and 2 from 2004–2006. The dashed line indicates the 2014 event DIN target for the Mackay City Catchment Management Area.

The majority of event PP concentrations at the Mackay City sites from 2004–2006 were scattered between 30–160 µg/L, with one higher value (560 µg/L) in January 2006 (Figure 43). The majority of the concentrations were above the event target. There appeared to be an increase in the concentrations over time, however there was no significant linear trend at the Mackay 1 site ($p = 0.16$). The highest concentration (560 µg/L) was ten-times greater than the event target of 51 µg/L.

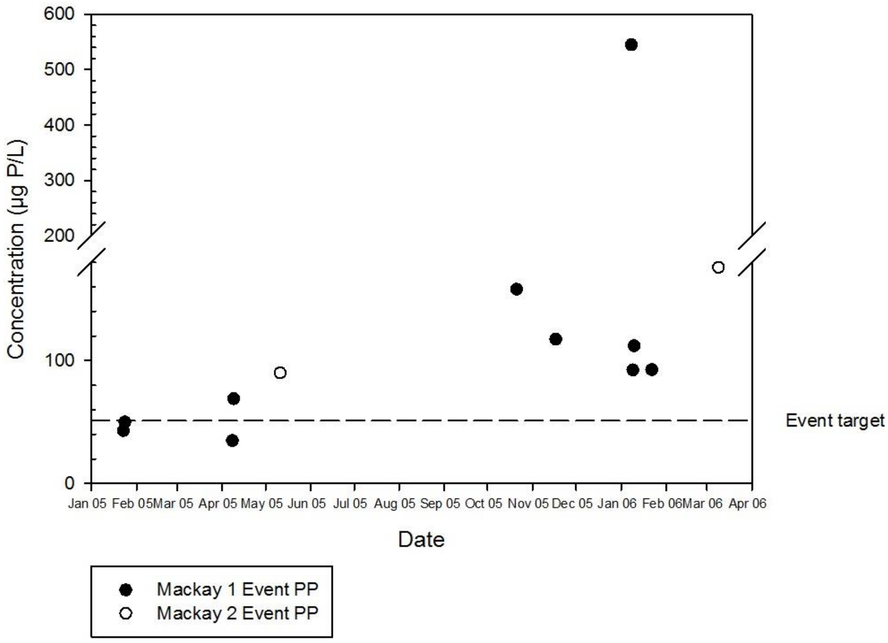

Figure 43 Temporal variation in particulate phosphorus (PP) concentrations during event conditions at Mackay 1 and 2 from 2004–2006. The dashed line indicates the 2014 event PP target for the Mackay City Catchment Management Area.

Event concentrations of FRP at the Mackay City sites from 2004–2006 were scattered between 40–400 µg/L, with one higher concentration (590 µg/L) in October 2005 (Figure 44). The majority of the concentrations were below the event target of 377 µg/L. The FRP concentrations recorded at Mackay 1 showed no linear temporal trend ($p = 0.51$). The highest concentration (590 µg/L) was higher than the FRP event target of 377 µg/L.

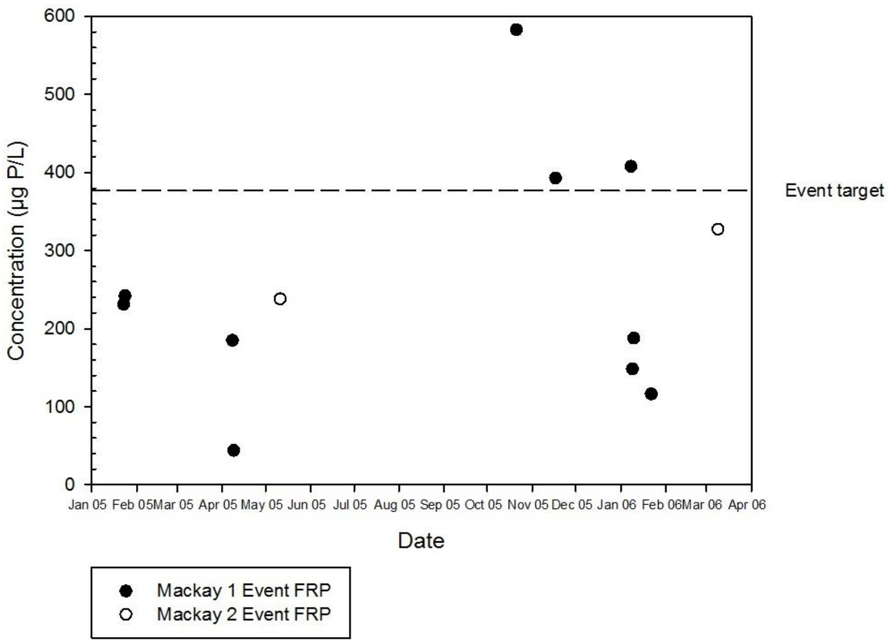

Figure 44 Temporal variation in filterable reactive phosphorus (FRP) concentrations during event conditions at Mackay 1 and 2 from 2004–2006. The dashed line indicates the 2014 event FRP target for the Mackay City Catchment Management Area.

Frequency of target exceedances

No sampling was conducted for Mackay City (at either site) subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets can be undertaken.

3.3.10 Myrtle Creek

3.3.10.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Ambient sampling in Myrtle Creek from 2006–2008 showed concentrations of TSS to be fairly consistent apart from one higher value (Figure 45). There was no linear temporal trend over the sampling period ($p = 0.37$). The ambient TSS values ranged from 1.4–150 mg/L, with the largest value being 30-times greater than the target (5 mg/L). Approximately half of the ambient TSS concentration samples were at or below the ambient target. The majority of event sampling results from 2004–2007 ranged from < LOR–40 mg/L (Figure 45), with the three highest concentrations falling between 110 and 184 mg/L (occurring in January 2005, January 2006, and January 2007). While it appeared there may have been an increase in event TSS concentrations over time, there was no linear temporal trend ($p = 0.27$). The highest concentration (184 mg/L) was nearly five-times greater than the event target of 40 mg/L.

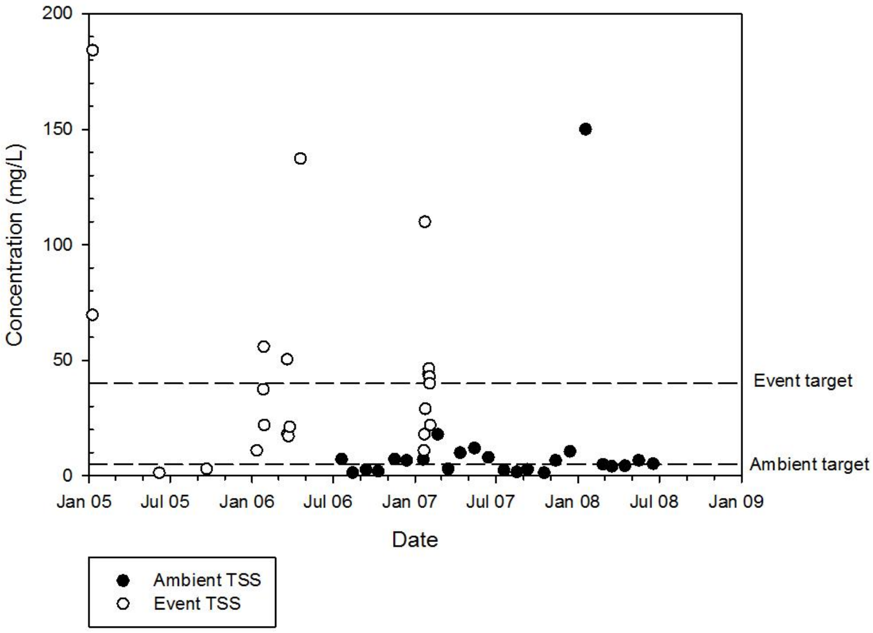

Figure 45 Temporal variation in total suspended solids (TSS) concentrations during ambient and event conditions at Myrtle Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event TSS targets for the Myrtle Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted in Myrtle Creek subsequent to 2006–2007; however, one year of ambient sampling (12 samples) was undertaken in 2007–2008, in which 42 per cent of the samples exceeded the ambient TSS target.

3.3.10.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Ambient concentrations of PN in Myrtle Creek from 2006–2008 varied between < LOR and 320 µg/L with two higher values (600 and 720 µg/L) (Figure 46). Approximately half of the samples were below the ambient target of 112 µg/L. There was no temporal trend in ambient PN over the two years ($p = 0.40$). The highest ambient concentration was approximately 720 µg/L, six-times greater than the ambient target. Event concentrations of PN in Myrtle Creek were scattered with no linear temporal trend over the period ($p = 0.21$) (Figure 46). The highest concentrations occurred in the beginning of each sampled year, indicating some seasonal trends. Approximately half of the event concentrations were below the event target of 324 µg/L. The highest event PN concentration was approximately 1210 µg/L, three-times greater than the event target.

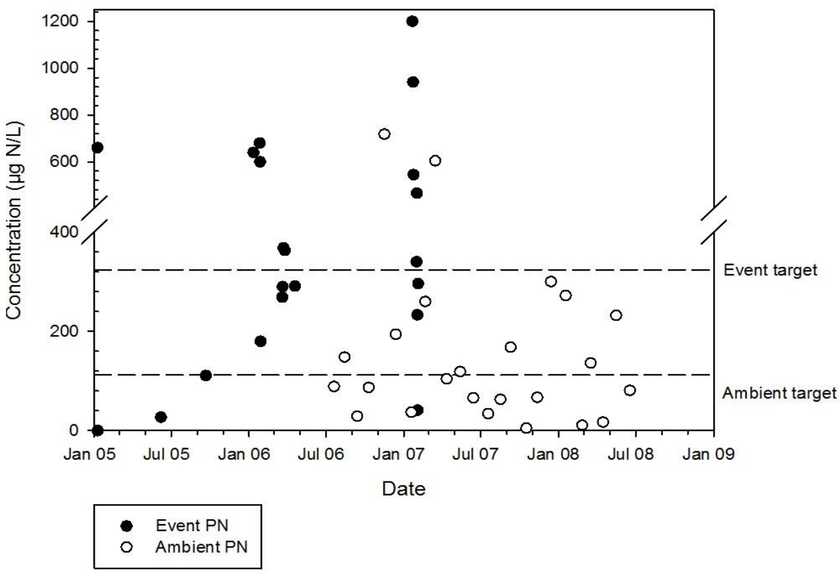

Figure 46 Temporal variation in particulate nitrogen (PN) concentrations during ambient and event conditions at Myrtle Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PN targets for the Myrtle Creek Catchment Management Area.

Ambient concentrations of DIN in Myrtle Creek varied between < LOR and 1000 µg/L from 2006–2008, with an increase over time ($p = 0.016$; $R^2 = 0.2359$); however, the low R^2 value suggested there were other factors also influencing the results (Figure 47). The majority of the concentrations were above the ambient target of 77 µg/L. The highest ambient concentration was approximately 1040 µg/L, 13-times greater than the ambient target. Event concentrations of DIN in Myrtle Creek were scattered from 2004–2007 with no temporal trend ($p = 0.92$) (Figure 47). The highest concentrations occurred in the beginning of each sampled year, indicating seasonal trends. Approximately half of the samples were below the event target of 414 µg/L. The highest event DIN concentration was approximately 6080 µg/L, 14-times greater than the event target.

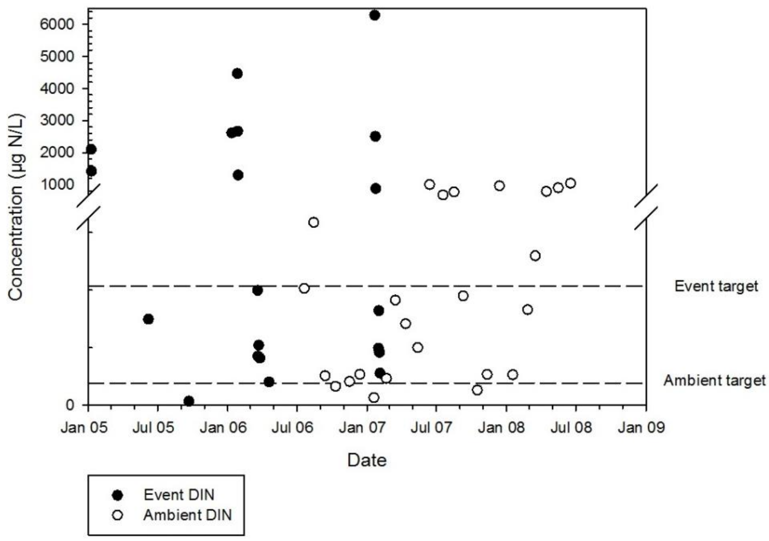

Figure 47 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient and event conditions at Myrtle Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event DIN targets for the Myrtle Creek Catchment Management Area.

The majority of ambient concentrations of PP in Myrtle Creek ranged between < LOR and 60 µg/L from 2006–2008 (Figure 48). There were five ambient concentrations between 200 and 330 µg/L. There was no linear temporal trend in ambient concentrations ($p = 0.80$). The majority of the concentrations were above the ambient target of 41 µg/L. Event concentrations of PP in Myrtle Creek were scattered from 2004–2007 with an increase over time ($p = 0.026$; $R^2 = 0.235$); however, the low R^2 value suggested there were other factors also influencing the results (Figure 48). Approximately half of the samples were at or below the event target of 117 µg/L. The highest event PP concentration (330 µg/L) was double the event target, with the higher concentrations occurring at the start of each year, during the wet season.

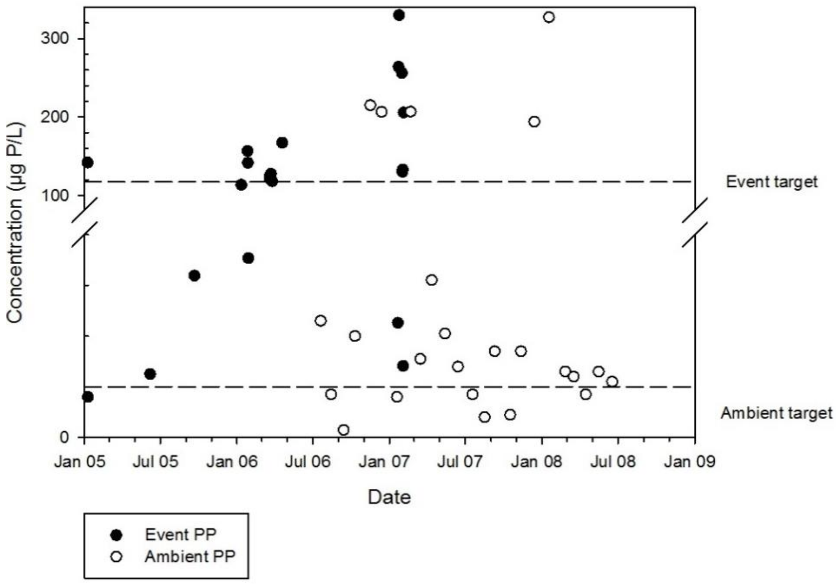

Figure 48 Temporal variation in particulate phosphorus (PP) concentrations during ambient and event conditions at Myrtle Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PP targets for the Myrtle Creek Catchment Management Area.

Ambient concentrations of FRP in Myrtle Creek varied between < LOR and 140 µg/L from 2006–2008, with one higher value (540 µg/L) in December 2007 (Figure 49). Approximately half of the concentrations were below the ambient target of 25 µg/L. The highest concentration was 530 µg/L, 21-times greater than the ambient target. There was no linear temporal trend ($p = 0.67$). Event concentrations of FRP in Myrtle Creek were scattered from 2004–2007 with no linear temporal trend across the sampling period ($p = 0.61$). The majority of the concentrations were above the event target (193 µg/L) (Figure 49). The highest event FRP concentration was approximately 550 µg/L, which was nearly three-times greater than the event target. The peak concentrations occurred at the start of each year, during the wet season.

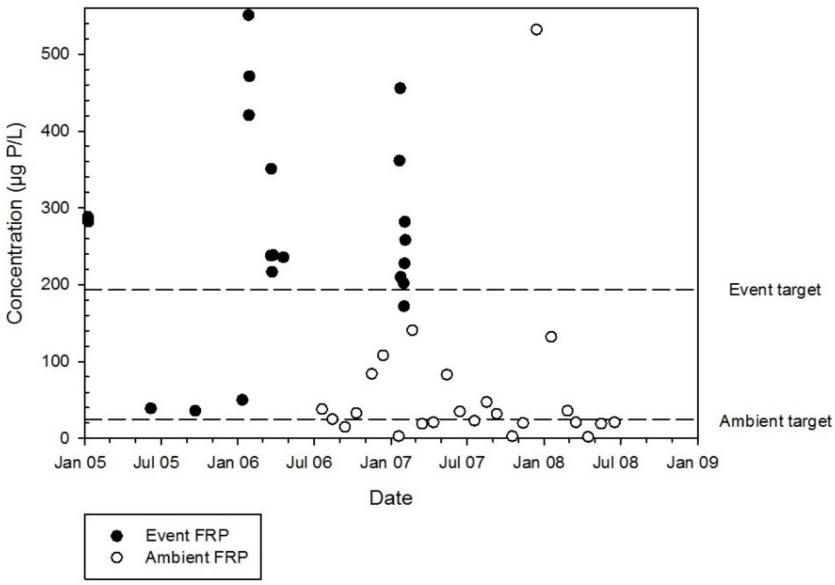

Figure 49 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient and event conditions at Myrtle Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event FRP targets for the Myrtle Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted for Myrtle Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets was undertaken. Ambient sampling of nutrients was undertaken for one year subsequent to 2006–2007, with a total of 12 ambient samples taken in 2007–2008. The PN target was exceeded in 42 per cent of the samples, and the DIN target was exceeded in 92 per cent. The ambient concentrations of PP exceeded the target in 67 per cent of the samples and exceeded the FRP target in 42 per cent of the samples.

3.3.11 O'Connell River

The results for both O'Connell 1 and O'Connell 2 sites from 2004–2008 are presented below. No ambient sampling was conducted for O'Connell 2. The O'Connell 1 site had ambient and event samples taken.

3.3.11.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Ambient sampling at O'Connell 1 from 2006–2008 showed the majority of TSS concentrations were scattered between < LOR and 5 mg/L (Figure 50). There were three values at 7, 8, and 12 mg/L, and two higher concentrations at 62 and 95 mg/L. There was no linear temporal trend in ambient TSS concentrations ($p = 0.17$). Approximately half of the concentrations recorded in ambient conditions were above the ambient target of 2 mg/L.

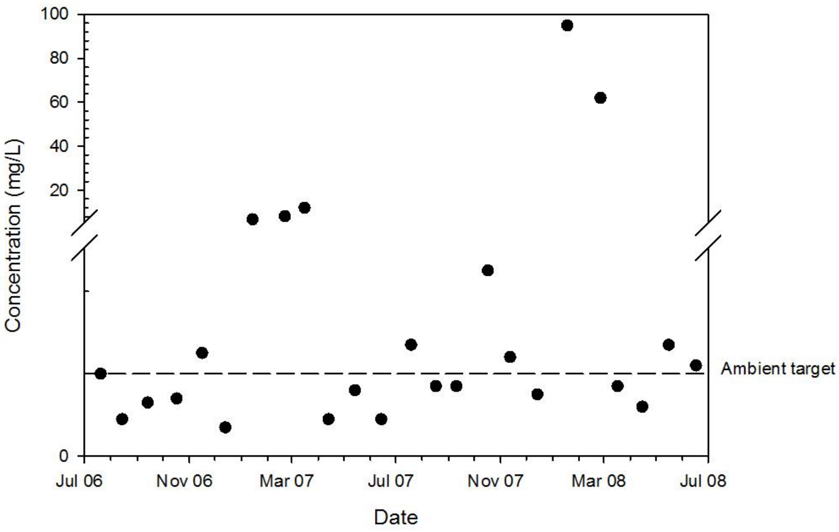

Figure 50 Temporal variation in total suspended solids (TSS) concentrations during ambient conditions at O'Connell River from 2004–2008. The dashed line indicates the 2014 ambient TSS target for the O'Connell River Catchment Management Area.

The event sampling in O'Connell River occurred from 2004–2007 at O'Connell 1 and 2004–2008 at O'Connell 2 (Figure 51). For both sites the median TSS concentrations were scattered from 8–324 mg/L, with the majority of values being between 8 and 169 mg/L. The highest values occurred in January 2006 (324 mg/L) and January 2005 (260 mg/L). There was no linear temporal trend at either site (O'Connell 1: 0.77; O'Connell 2: p = 0.58).

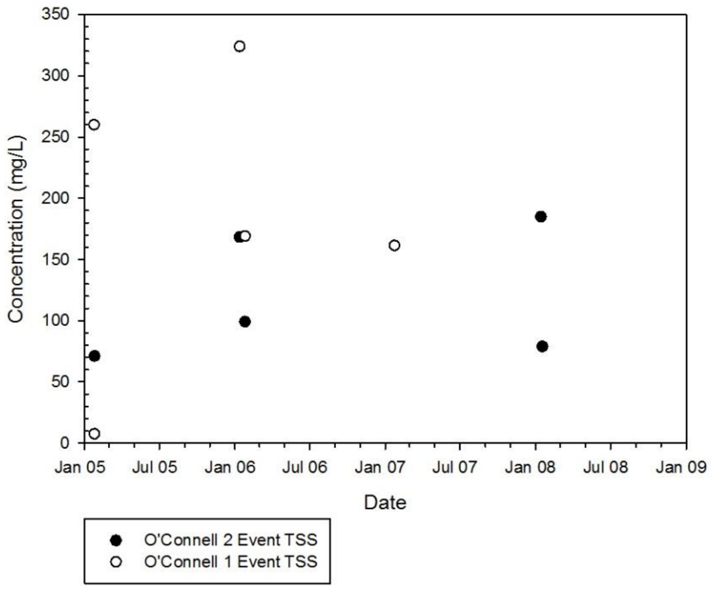

Figure 51 Temporal variation in median total suspended solids (TSS) concentrations during event conditions at O'Connell River from 2004–2008.

Frequency of target exceedances

Ambient sampling of TSS at O'Connell River was undertaken for one year subsequent to 2006–2007, with a total of 12 ambient samples taken in 2007–2008. Of the ambient TSS concentrations, 58 per cent exceeded the target.

3.3.11.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

The majority of ambient concentrations of PN at O'Connell River were spread between 4 and 91 µg/L from 2006–2008, with three values between 100 and 200 µg/L (Figure 52). Although the bulk of the concentrations appeared to increase over time, there was no linear temporal trend (p = 0.65). Approximately half of the samples were greater than the ambient target of 43 µg/L. The highest ambient concentration was 201 µg/L, five-times higher than the ambient target.

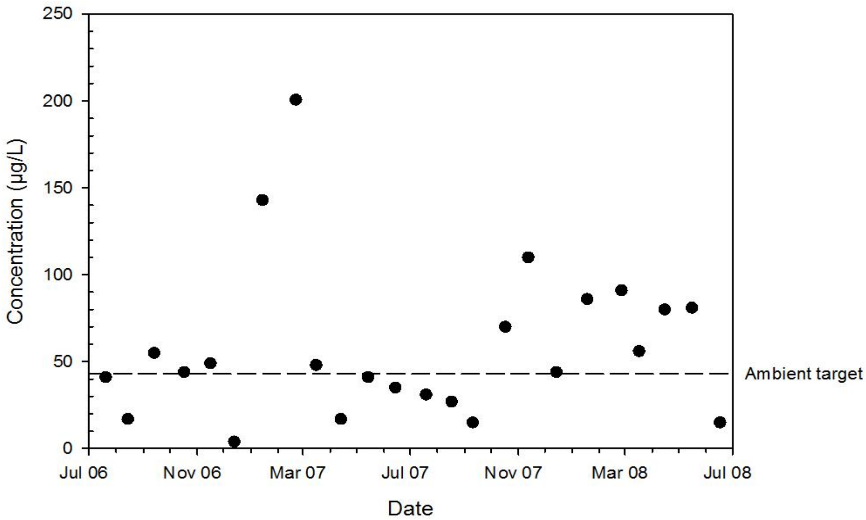

Figure 52 Temporal variation in particulate nitrogen (PN) concentrations during ambient conditions at O'Connell River from 2004–2008. The dashed line indicates the 2014 ambient PN target for the O'Connell River Catchment Management Area.

The event median PN concentrations from both sites were scattered, from 103–532 µg/L (Figure 53). The highest median concentrations occurred during events in January 2005 (532 µg/L), January 2007 (396 µg/L), and January 2006 (390 µg/L). There was no linear temporal trend at either site over the sampling period (O'Connell 1: p = 0.90; O'Connell 2: p = 0.47).

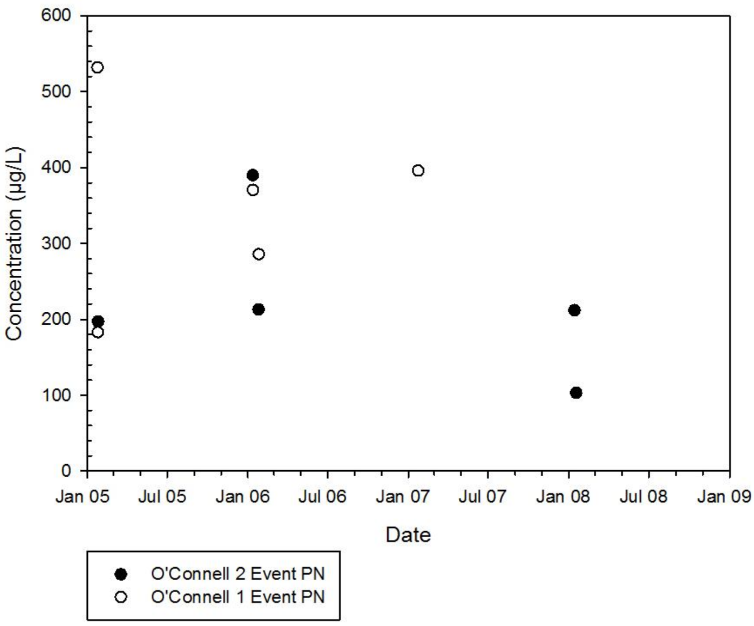

Figure 53 Temporal variation in particulate nitrogen (PN) median concentrations during event conditions at O'Connell River from 2004–2008.

Ambient concentrations of DIN at O'Connell River varied from 18–188 µg/L from 2006–2008 with no linear temporal trend ($p = 0.53$) (Figure 54). The majority of concentrations were greater than the ambient target of 45 µg/L. The highest ambient concentration (188 µg/L) was four-times higher than the ambient target, and occurred during the wet season in February 2008.

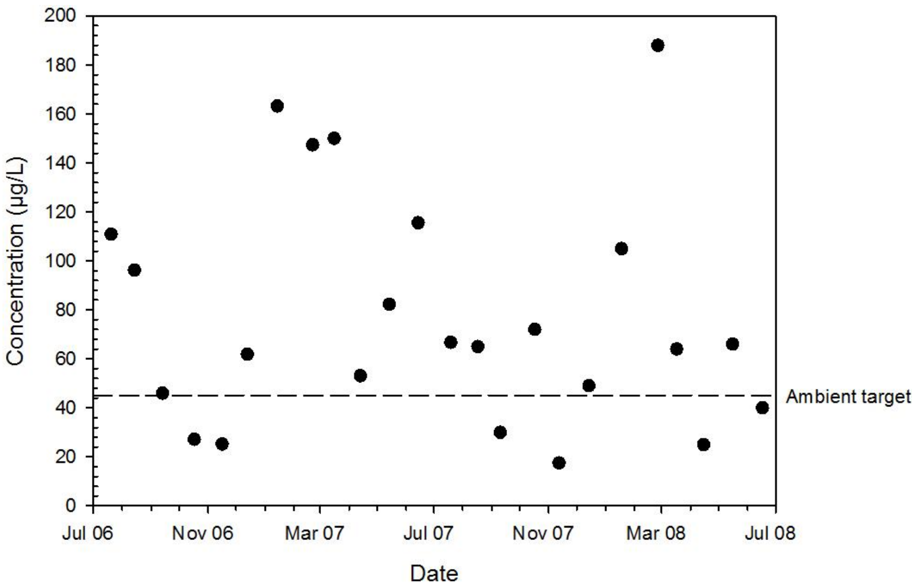

Figure 54 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient conditions at O'Connell River from 2004–2008. The dashed line indicates the 2014 ambient DIN target for the O'Connell River Catchment Management Area.

The event DIN median concentrations from both sites were scattered, with concentrations peaking at the start of each year, during the wet season (Figure 55). The majority of the median concentrations ranged from 123–461 µg/L. The two highest values occurred in

January 2006 (944 and 933 µg/L). Results from the O'Connell River did not show any linear temporal trend (O'Connell 1: p = 0.75; O'Connell 2: p = 0.55).

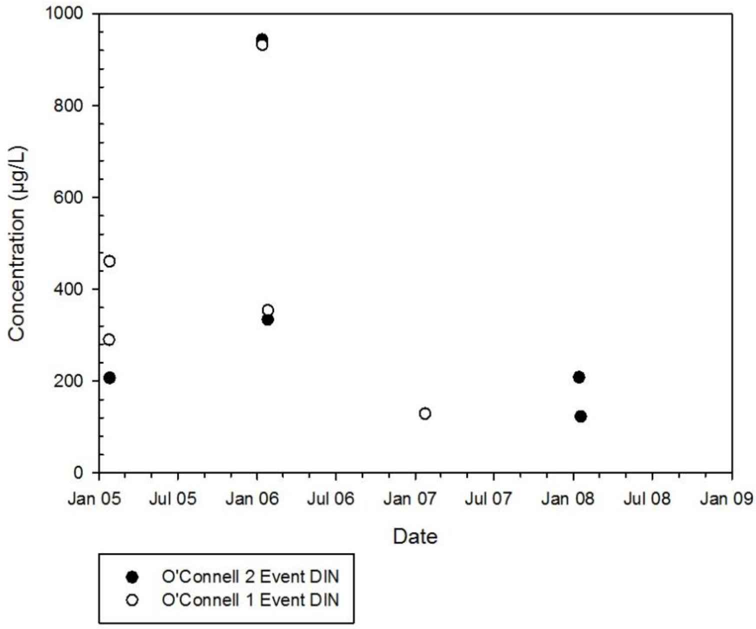

Figure 55 Temporal variation in dissolved inorganic nitrogen (DIN) median concentrations during event conditions at O'Connell River from 2004–2008.

Ambient concentrations of PP at O'Connell River were spread between < LOR and 25 µg/L from 2006–2008 with one higher value (56 µg/L) and no temporal trend (p = 0.3) (Figure 56). Approximately half of the concentrations were below the ambient target of 6 µg/L. The highest ambient concentration (56 µg/L) occurred in January 2008, and was nine-times higher than the ambient target.

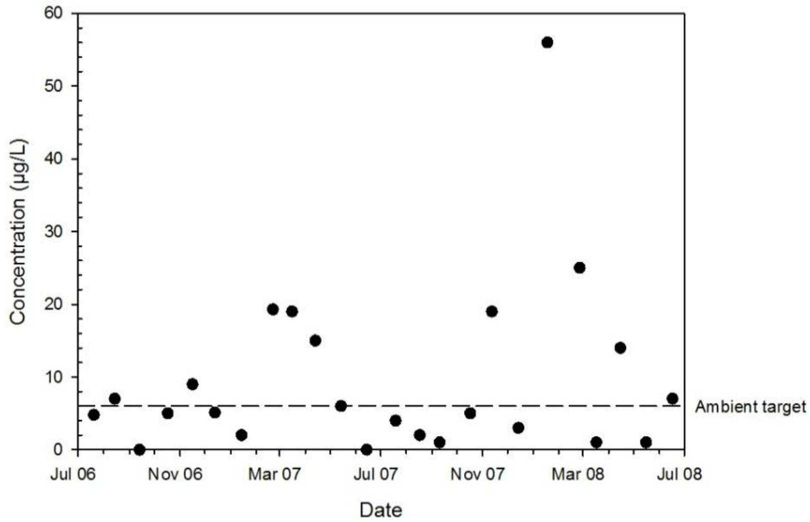

Figure 56 Temporal variation in particulate phosphorus (PP) concentrations during ambient conditions at O'Connell River from 2004–2008. The dashed line indicates the 2014 ambient PP target for the O'Connell River Catchment Management Area.

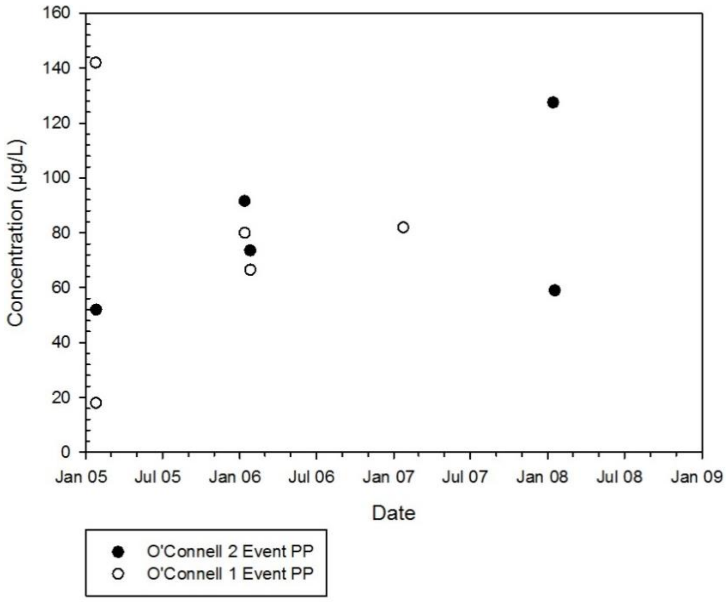

Figure 57 Temporal variation in particulate phosphorus (PP) median concentrations during event conditions at O'Connell River from 2004–2008.

Ambient concentrations of FRP at O'Connell River were largely spread between 1 and 35 µg/L from 2006–2008 (Figure 58). One higher value (86 µg/L) occurred in January 2007, during the wet season. While overall, the concentrations appeared to increase over time, there was no linear temporal trend across the sampling period (p = 0.81). Results from mid- to late 2006 and early to mid-2008 ambient FRP concentrations showed decreases. Approximately half of the concentrations were below the ambient target of 6 µg/L. The highest ambient concentration (86 µg/L) was 14-times higher than the ambient target.

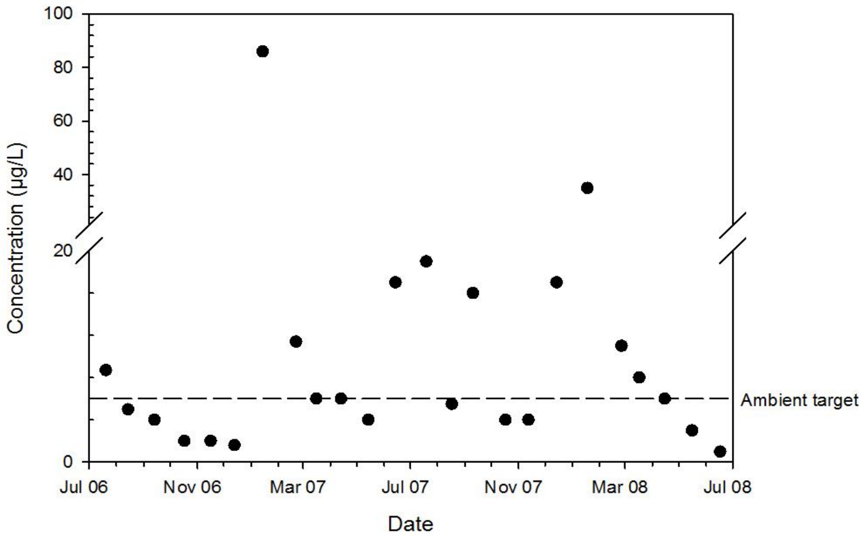

Figure 58 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient conditions at O'Connell River from 2004–2008. The dashed line indicates the 2014 ambient FRP target for the O'Connell River Catchment Management Area.

The median concentrations of event FRP from both sites were scattered between 22 and 42 µg/L, with one median concentration of 60 µg/L occurring in January 2006 (Figure 59).

There was no linear temporal trend at either site (O'Connell 1: $p = 0.66$; O'Connell 2: $p = 0.27$).

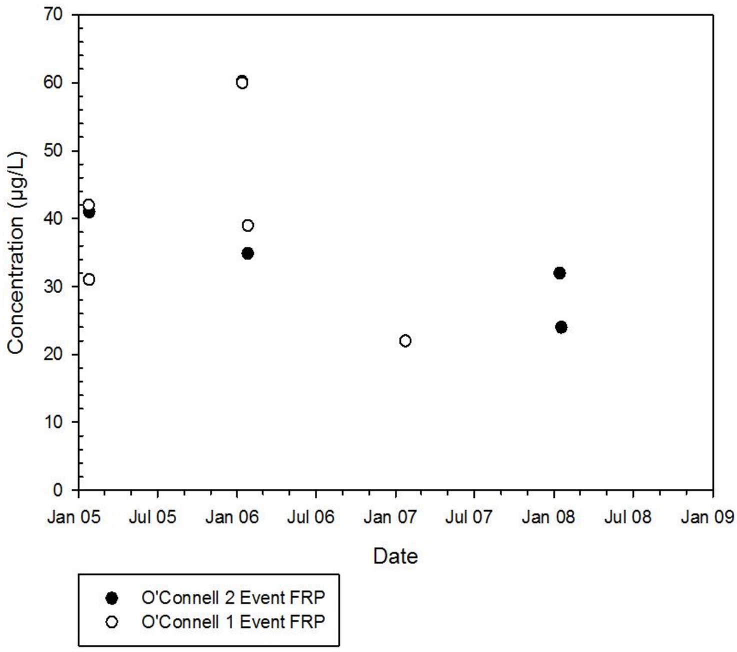

Figure 59 Temporal variation in filterable reactive phosphorus (FRP) median concentrations during event conditions at O'Connell River from 2004–2008.

Frequency of target exceedances

Sampling of nutrients at O'Connell River was undertaken for one year subsequent to 2006–2007, with a total of 12 ambient samples taken in 2007–2008. Concentrations of PN and DIN exceeded the respective ambient targets in 67 per cent of samples. The ambient PP target was exceeded in 42 per cent of samples, while the ambient target for FRP was exceeded in 50 per cent of samples.

3.3.12 Pioneer River

3.3.12.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Ambient sampling in Pioneer River from 2006–2013 showed concentrations of TSS remained relatively scattered, with no temporal trend ($p = 0.08$) (Figure 60). The concentrations recorded in ambient conditions were up to 28 mg/L, which was nearly six-times the ambient target of 5 mg/L. Approximately half of the ambient concentrations were below the ambient target.

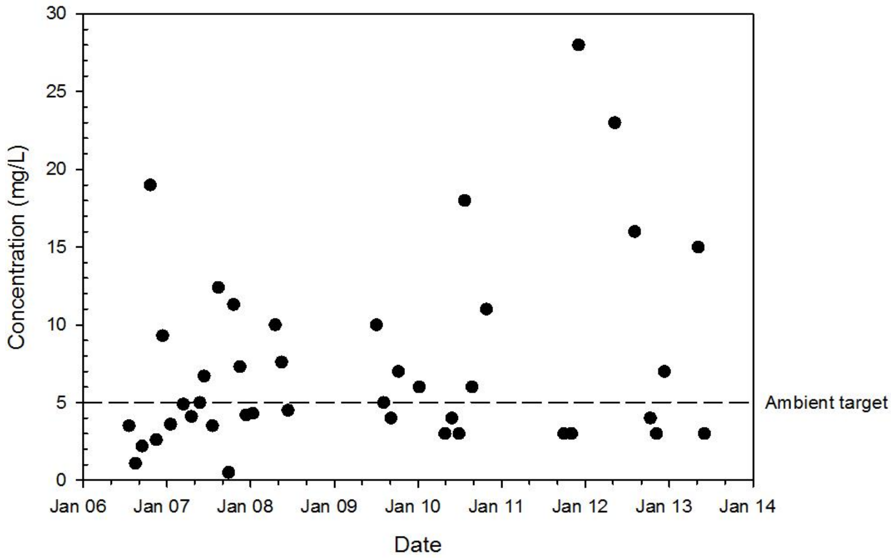

Figure 60 Temporal variation in total suspended solids (TSS) concentrations during ambient conditions at Pioneer River from 2006–2013. The dashed line indicates the 2014 ambient TSS target for the Pioneer River Catchment Management Area.

The TSS event sampling in Pioneer River from 2004–2013 was scattered and covered many events, with no temporal trend over the sampling period ($p = 0.82$) (Figure 61). The highest median concentrations occurred at the start of every year, with the highest at 263 mg/L from January 2011.

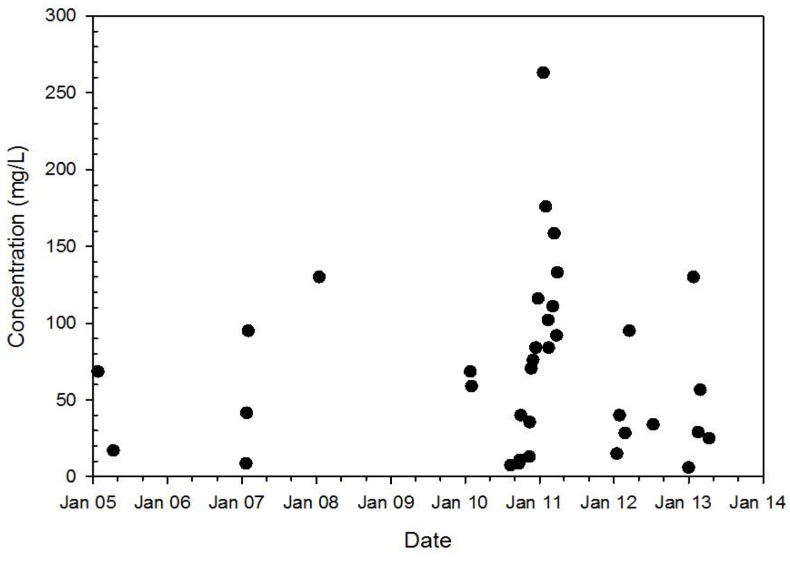

Figure 61 Temporal variation in median total suspended solids (TSS) concentrations during event conditions at Pioneer River from 2004–2013.

Frequency of target exceedances

The ambient concentrations of TSS in the Pioneer River exceeded the ambient target (in all of the sampled years), with exceedances ranging from 38–100 per cent (Table 14).

Table 14 Per cent of exceedances of the 2014 TSS ambient target for Pioneer River from 2007–2013. Red indicates poor data availability (0–4 samples), amber indicates moderate data availability (5–9 samples), green indicates good data availability (≥ 10 samples).

Year	Per cent exceedances (total no. samples)
	Ambient
2007–2008	50 (10)
2008–2009	-
2009–2010	38 (8)
2010–2011	100 (3)
2011–2012	50 (4)
2012–2013	50 (6)

3.3.12.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Ambient concentrations of PN at Pioneer River were scattered between < LOR and 500 µg/L from 2006–2013 with one higher value (2000 µg/L in January 2007) (Figure 62). Concentrations increased over time from late 2006 to mid-2008, and then again from January 2010 to January 2011; however, over the entire period there was no linear trend in ambient PN ($p = 0.54$). Approximately half of the samples were greater than the ambient target (102 µg/L). The highest ambient PN concentration (2000 µg/L) was 20-times greater than the ambient target.

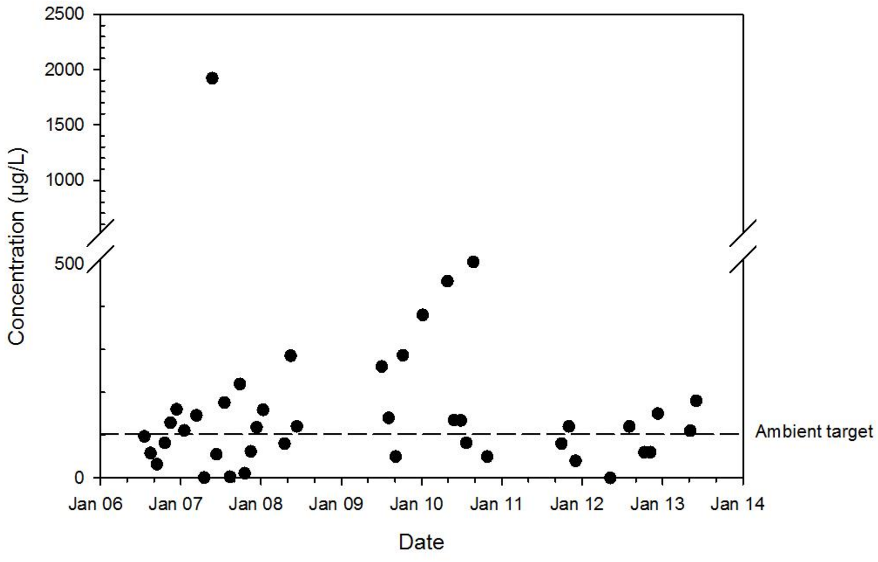

Figure 62 Temporal variation in particulate nitrogen (PN) concentrations during ambient conditions at Pioneer River from 2006–2013. The dashed line indicates the 2014 ambient PN target for the Pioneer River Catchment Management Area.

The event PN concentrations were scattered from 2004–2013 (Figure 63). The highest concentration recorded was 820 µg/L. There appeared to be an increase in the median concentrations over time, however there was not a significant linear trend (p = 0.068). The majority of the concentration peaks were at the start of the year, during the wet season.

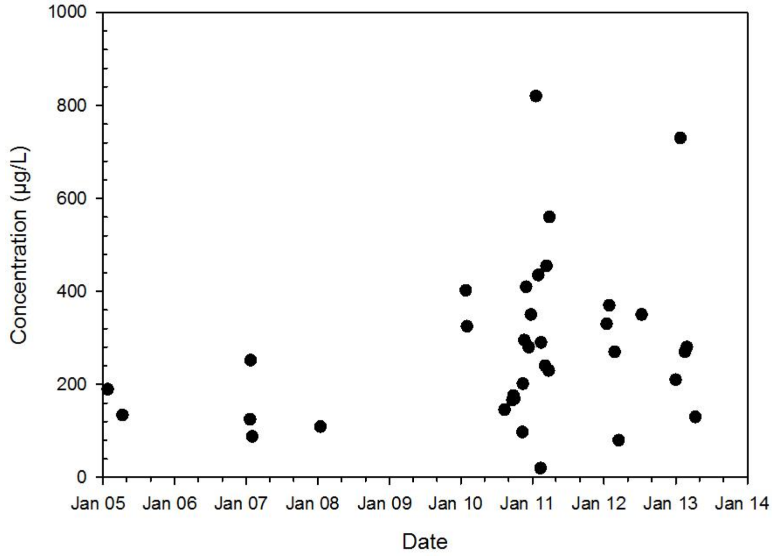

Figure 63 Temporal variation in median particulate nitrogen (PN) concentrations during event conditions at Pioneer River from 2004–2013.

Ambient concentrations of DIN at Pioneer River from 2006–2013 varied from < LOR to 400 µg/L with two higher values (1200 and 1400 µg/L) (Figure 64). The two higher values occurred in January 2010 and August 2010. The vast majority of concentrations were greater than the ambient target of 8 µg/L. There was no trend in ambient DIN over the sampling period (p = 0.49). The highest concentration for ambient DIN (just below 1400 µg/L) was 175-times greater than the ambient target.

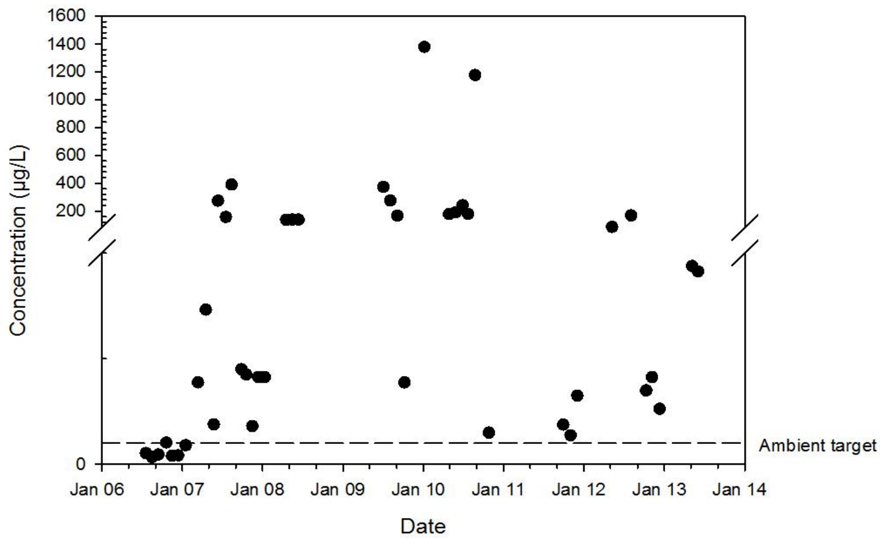

Figure 64 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient conditions at Pioneer River from 2006–2013. The dashed line indicates the 2014 ambient DIN target for the Pioneer River Catchment Management Area.

Event DIN median concentrations were scattered between 98 and 714 µg/L and covered many events from 2004–2013 (Figure 65), with no linear temporal trend over the sampling period (p = 0.23). The highest median concentration was 714 µg/L, which occurred during an event in September 2009, followed by 588 µg/L in December 2012.

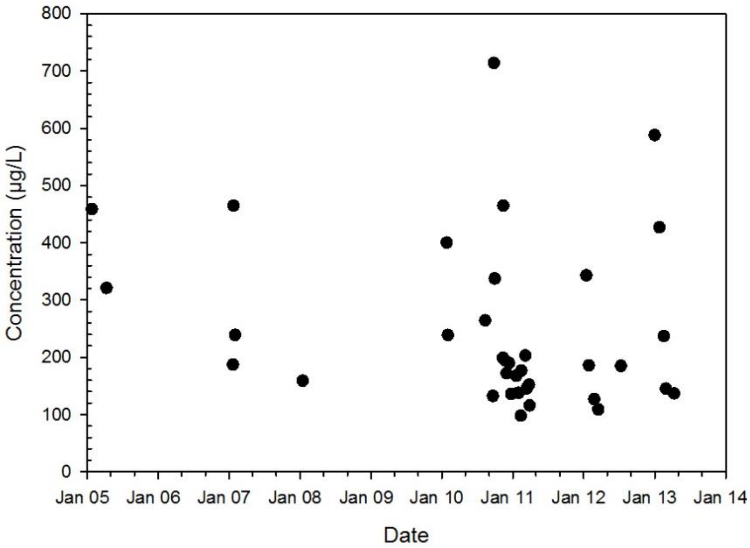

Figure 65 Temporal variation in median dissolved inorganic nitrogen concentrations during event conditions at Pioneer River from 2004–2013.

Ambient concentrations of PP at Pioneer River were fairly consistent from 2006–2013 with one higher value (169 µg/L) and no temporal trend (p = 0.86) (Figure 66). Approximately half of the concentrations were greater than the ambient target of 20 µg/L. The majority of the concentrations were between 0 and 52 µg/L, with the higher value (169 µg/L) being eight-times greater than the target.

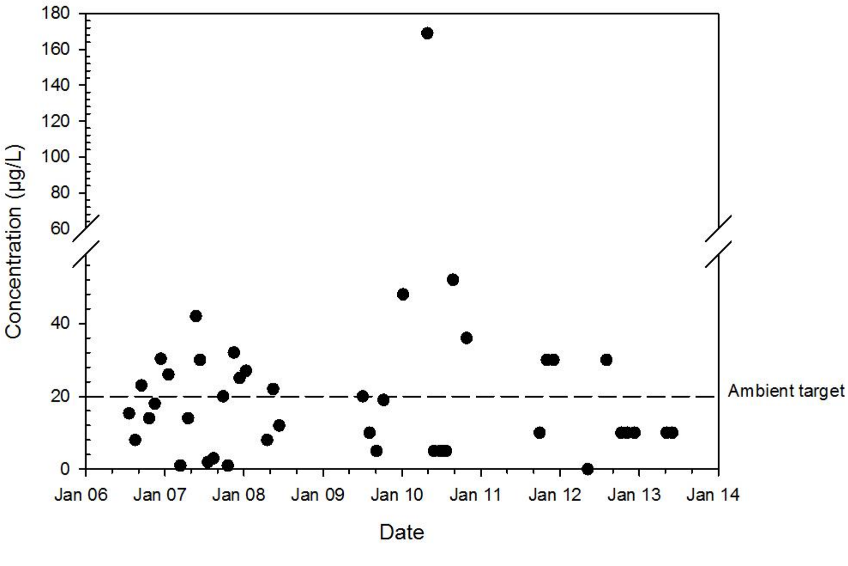

Figure 66 Temporal variation in particulate phosphorus (PP) concentrations during ambient conditions at Pioneer River from 2006–2013. The dashed line indicates the 2014 ambient PP target for the Pioneer River Catchment Management Area.

The median concentrations of event PP sampling were scattered and covered many events from 2004–2013, with no linear temporal trend (p = 0.41) (Figure 67). Other than one high value, the median concentrations were between 0 and 180 µg/L. The highest recorded value was 310 µg/L, from an event in January 2011.

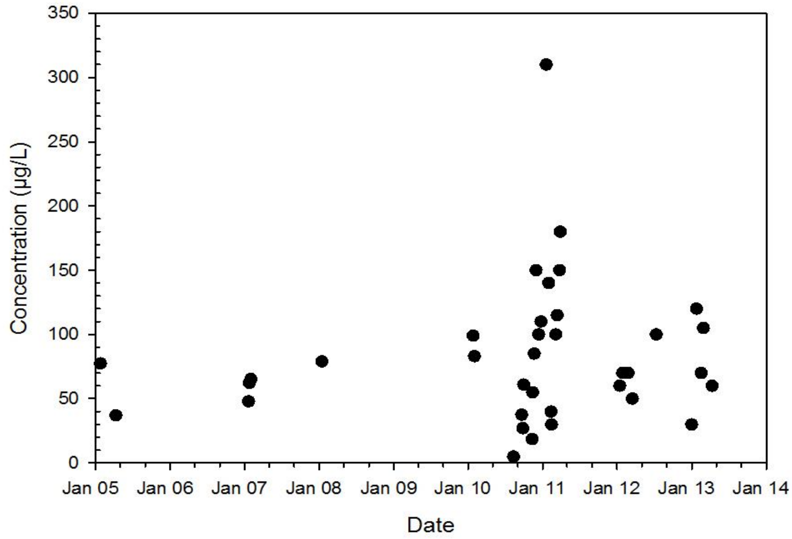

Figure 67 Temporal variation in median particulate phosphorus (PP) concentrations during event conditions at Pioneer River from 2004–2013.

The majority of the ambient concentrations of FRP at Pioneer River were spread between the < LOR and 14 µg/L from 2006–2013 (Figure 68). There were four higher concentrations; the highest was 40 µg/L in January 2010, followed by 33 µg/L in August 2010, 25 µg/L in June 2007, and 20 µg/L in September 2007. Approximately half of the concentrations were greater than the ambient target of 5 µg/L. The highest concentration (40 µg/L) was eight-times greater than the target. There was no temporal trend in ambient FRP (p = 0.23).

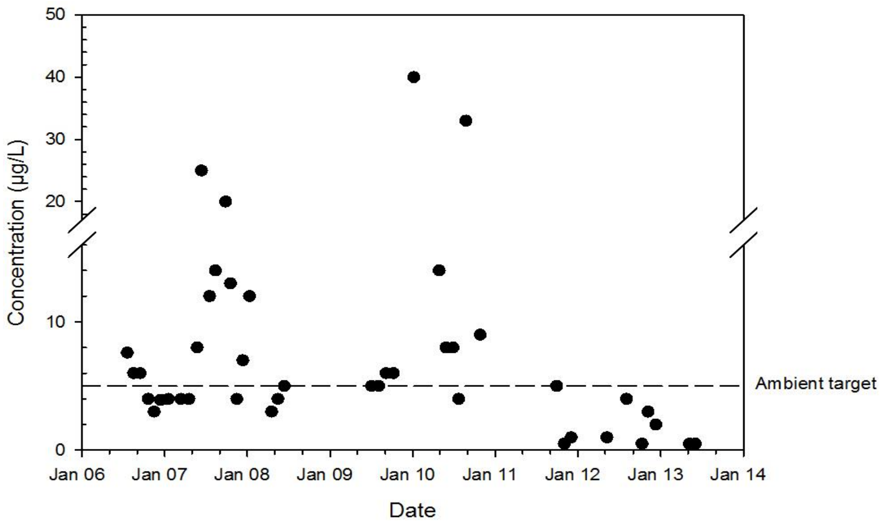

Figure 68 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient conditions at Pioneer River from 2006–2013. The dashed line indicates the 2014 ambient PP target for the Pioneer River Catchment Management Area.

Event FRP median concentrations were scattered and covered many events from 2005–2013 (Figure 69). The median concentrations ranged from 5–75 µg/L. High values occurred over all the sampling period and there was no linear temporal trend in the results ($p = 0.14$).

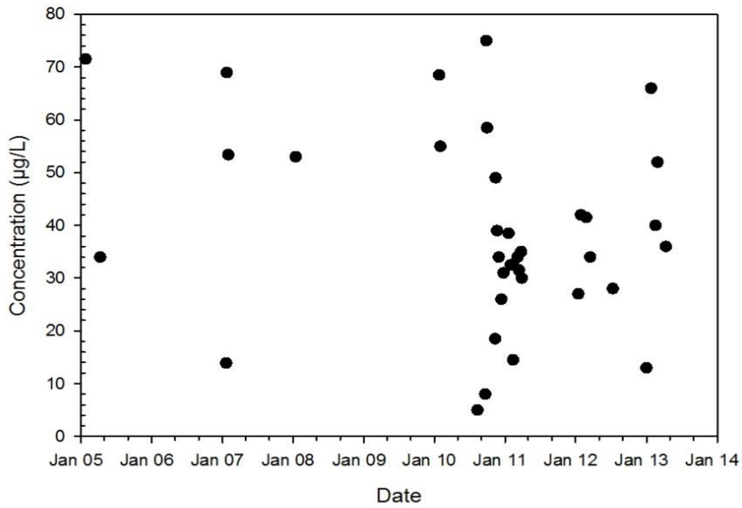

Figure 69 Temporal variation in median filterable reactive phosphorus (FRP) concentrations during event conditions at Pioneer River from 2004–2013.

Frequency of target exceedances

In every sampled year, ambient concentrations of PN in the Pioneer River exceeded the target, ranging from 25–88 per cent exceedances (Table 15). Ambient concentrations of DIN exceeded the target in 100 per cent of samples (Table 15). In all years sampled, ambient concentrations of PP exceeded the target, ranging from 17 per cent exceedances to 67 per cent (Table 15). Ambient concentrations of FRP in the Pioneer River exceeded the target in three of the sampled years (ranging from 60–75 per cent exceedances, but no samples exceeded the target in 2011–2012 or 2012–2013 (Table 15).

Table 15 Per cent of exceedances of the 2014 nutrient targets for Pioneer River from 2007–2013. Red indicates poor data availability (0–4 samples), amber indicates moderate data availability (5–9 samples), green indicates good data availability (≥ 10 samples).

Year	Per cent exceedances in ambient sampling (total number of samples)			
	PN	DIN	PP	FRP
2007–2008	60 (10)	100 (10)	40 (10)	60 (10)
2008–2009	-	-	-	-
2009–2010	88 (8)	100 (8)	25 (8)	75 (8)
2010–2011	33 (3)	100 (3)	67 (3)	67 (3)
2011–2012	25 (4)	100 (4)	50 (4)	0 (4)
2012–2013	67 (6)	100 (6)	17 (6)	0 (6)

3.3.13 Plane Creek

3.3.13.1 TSS

Temporal variation in TSS and comparison to 2014 targets

TSS ambient sampling in Plane Creek from 2006–2008 varied between 0.4 and 45 mg/L (Figure 70). The ambient concentrations appeared to increase, however there was no linear temporal trend ($p = 0.16$). The majority of ambient concentrations were above the target (3 mg/L). Event sampling concentrations from 2004–2007 showed an increase over time ($p = 0.03$; $R^2 = 0.350$), however the low R^2 value suggested there were other factors also influencing the results (Figure 70). All event concentrations were below the event target of 200 mg/L. The highest concentration was approximately 140 mg/L.

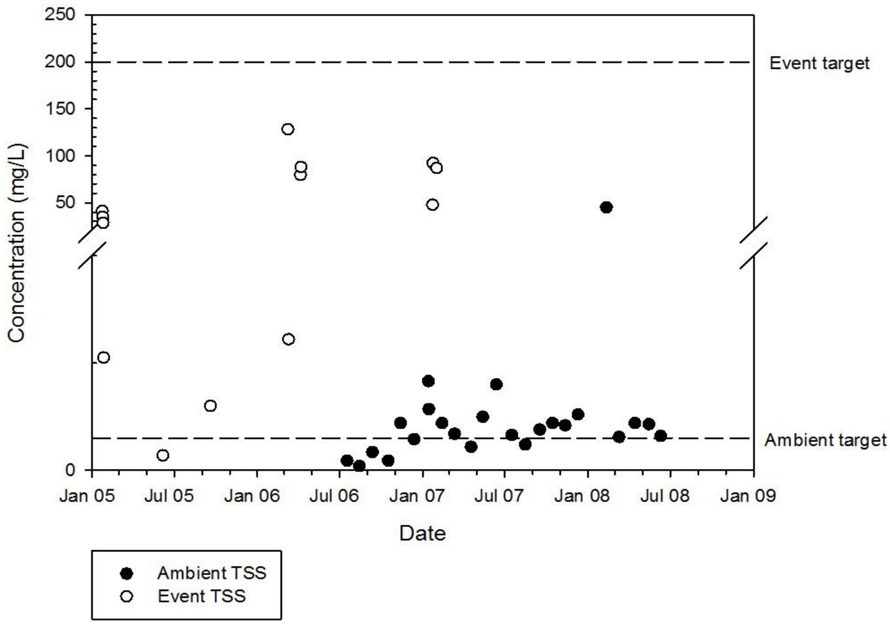

Figure 70 Temporal variation in total suspended solids (TSS) concentrations during ambient and event conditions at Plane Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event TSS targets for the Plane Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted in Plane Creek subsequent to 2006–2007, however one year of ambient sampling (11 samples) was undertaken in 2007–2008, in which 91 per cent of the samples exceeded the ambient TSS target.

3.3.13.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Ambient concentrations of PN in Plane Creek were scattered from 2006–2008 with no linear temporal trend ($p = 0.89$) (Figure 71). Approximately half of the samples were below the ambient target (101 µg/L). The highest ambient concentration was approximately 360 µg/L, three-times greater than the ambient target. Event sampling in Plane Creek occurred from 2004–2007, with an increase in concentrations over time ($p = 0.000$; $R^2 = 0.723$) (Figure 71).

The majority of concentrations were below the event target of 178 µg/L. The highest PN event concentration was 630 µg/L, three-times greater than the event target.

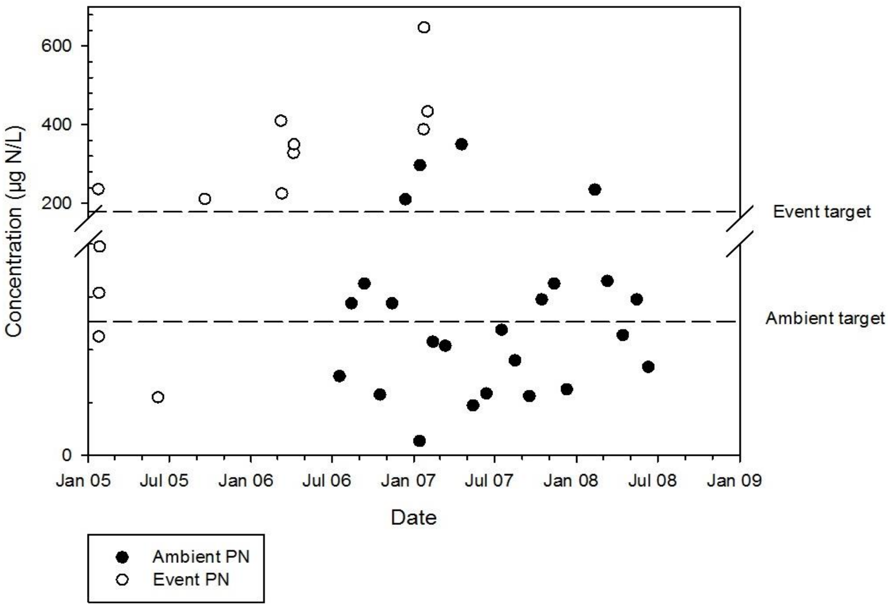

Figure 71 Temporal variation in particulate nitrogen (PN) concentrations during ambient and event conditions at Plane Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PN targets for the Plane Creek Catchment Management Area.

Ambient concentrations of DIN in Plane Creek varied from < LOR to 400 µg/L from 2006–2008 with no linear temporal trend ($p = 0.9$) (Figure 72). Most of the concentrations were above the ambient target (8 µg/L). In 2006 the ambient concentrations were much lower than concentrations in the following years. The highest ambient concentration (400 µg/L) was approximately 50-times the ambient target. The event DIN concentrations in Plane Creek were also scattered (Figure 72), with no linear temporal trend from 2004–2007 ($p = 0.87$). Half of the concentrations were below the event target (68 µg/L), with the majority of the concentrations occurring between 100 and 500 µg/L. The highest event concentrations occurred in the first half of each year, with a peak concentration of 570 µg/L.

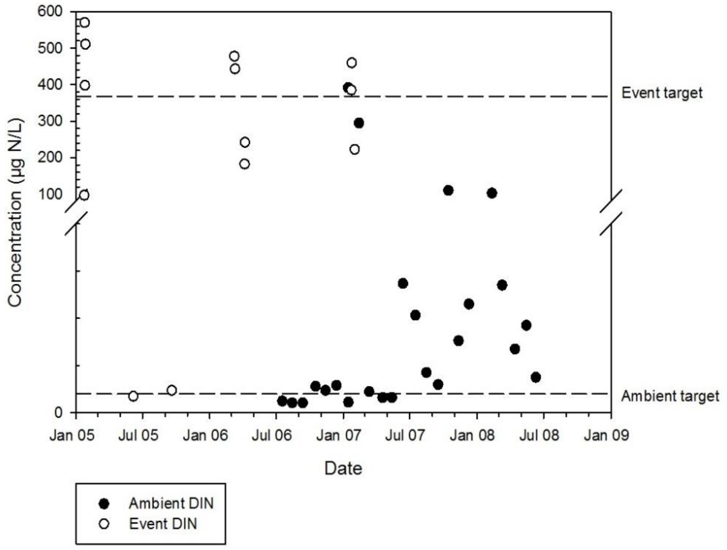

Figure 72 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient and event conditions at Plane Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event DIN targets for the Plane Creek Catchment Management Area.

Ambient concentrations of PP in Plane Creek were spread around the ambient target (18 µg/L) from 2006–2008, with two higher values (61 and 90 µg/L), and no linear temporal trend ($p = 0.72$) (Figure 73). Approximately half of the concentrations were above the ambient target. The event PP sample concentrations in Plane Creek were scattered, with an increase in concentrations over time ($p = 0.037$; $R^2 = 0.340$); however, the low R^2 value suggested there were other factors also influencing the results (Figure 73). The majority of the concentrations were above the event target of 61 µg/L. The highest event concentration was 270 µg/L, four-times greater than the target. The highest concentrations occurred in the first half of each year (during the wet season), increasing from January 2005 to January 2006, before decreasing in January 2007.

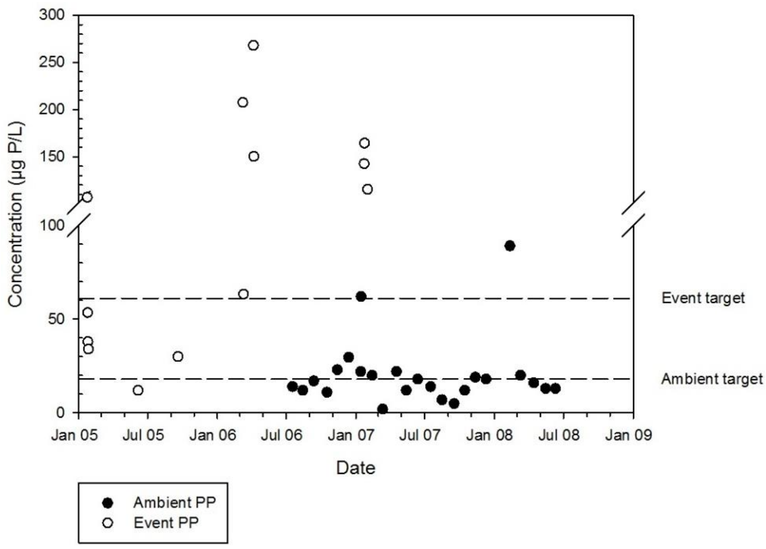

Figure 73 Temporal variation in particulate phosphorus (PP) concentrations during ambient and event conditions at Plane Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PP targets for the Plane Creek Catchment Management Area.

Ambient concentrations of FRP in Plane Creek from 2006–2008 were fairly consistent (between < LOR and 24 µg/L), with two higher values (44 and 70 µg/L), and no temporal trend ($p = 0.61$) (Figure 74). Approximately half of the concentrations were at or below the ambient target of 8 µg/L. The highest concentration (67 µg/L) was nearly nine-times greater than the ambient target. The event FRP concentrations in Plane Creek were scattered (Figure 74), with no linear temporal trend across the sampling period ($p = 0.13$). The majority of concentrations were above the event target of 59 µg/L, with the highest concentrations occurring in the wet season. The highest event concentration recorded was 156 µg/L.

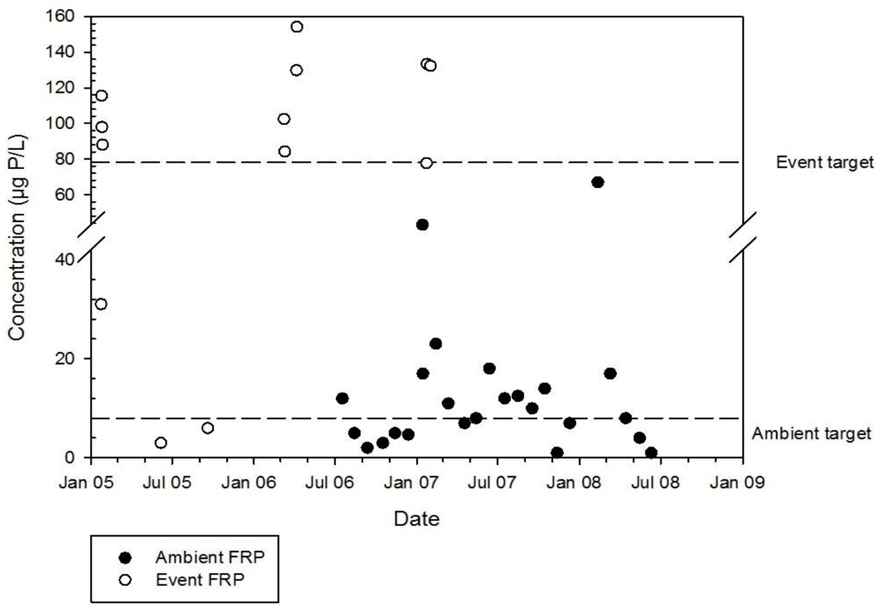

Figure 74 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient and event conditions at Plane Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event FRP targets for the Plane Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted in Plane Creek subsequent to 2006–2007, however one year of ambient nutrient sampling (11 samples) was undertaken in 2007–2008. Ambient concentrations in Plane Creek exceeded the PN target in 45 per cent of the samples and the DIN target in 100 per cent of samples. The PP target was exceeded in 27 per cent of samples and the FRP target was exceeded in 55 per cent of samples.

3.3.14 Proserpine River

No ambient sampling was conducted for Proserpine River, thus the following results are based on event conditions from 2004–2006. Due to the limited sampling, no linear regressions were performed.

3.3.14.1 TSS

Temporal variation in TSS and comparison to 2014 targets

The event sampling in Proserpine River was limited to seven samples across two sites over a 15-month period so it was not possible to discern any temporal trend (Figure 75). The concentrations ranged from below 5–45 mg/L. All concentrations were well below the event target of 194 mg/L. There was no obvious difference between the two sampling sites.

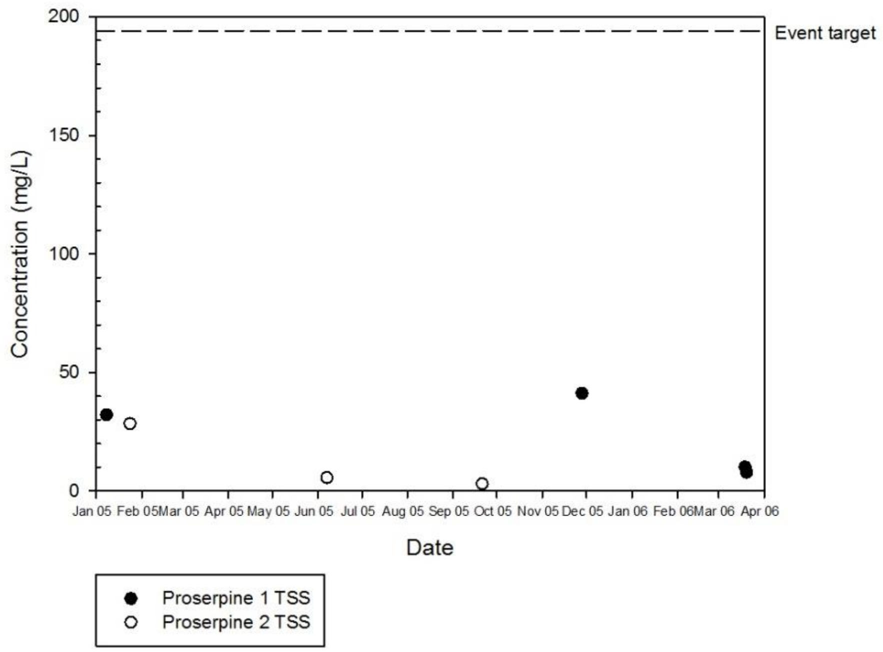

Figure 75 Temporal variation in total suspended solids (TSS) concentrations during event conditions at Proserpine River from 2004–2006. The dashed line indicates the 2014 event TSS target for the Proserpine River Catchment Management Area.

Frequency of target exceedances

No sampling was conducted for Proserpine River subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets can be undertaken.

3.3.14.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Event concentrations of PN in the Proserpine River in 2004–2006 were spread between 130 and 310 µg/L (Figure 76). All concentrations were below the event target of 406 µg/L. The spread of concentrations and low number of samples did not allow for any temporal trend to be discerned over the period. There was no obvious difference between the two sampling sites.

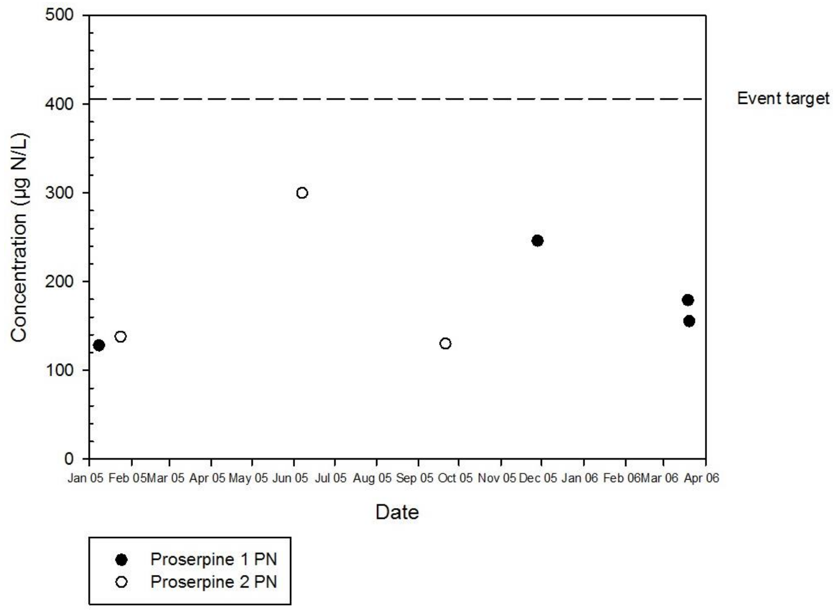

Figure 76 Temporal variation in particulate nitrogen (PN) concentrations during event conditions at Proserpine River from 2004–2006. The dashed line indicates the 2014 event PN target for the Proserpine River Catchment Management Area.

Event concentrations of DIN in the Proserpine River were varied in 2004–2006, with concentrations ranging from < LOR–4020 µg/L (Figure 77). Half of the concentrations were above the event target (300 µg/L), with the highest concentration (4020 µg/L) being 13-times greater than the target. The highest values (4000 and 2000 µg/L) occurred at Proserpine 2 in mid- and late 2005; all other concentrations were below 500 µg/L. However, due to the low number of samples it was not possible to detect any clear temporal trend.

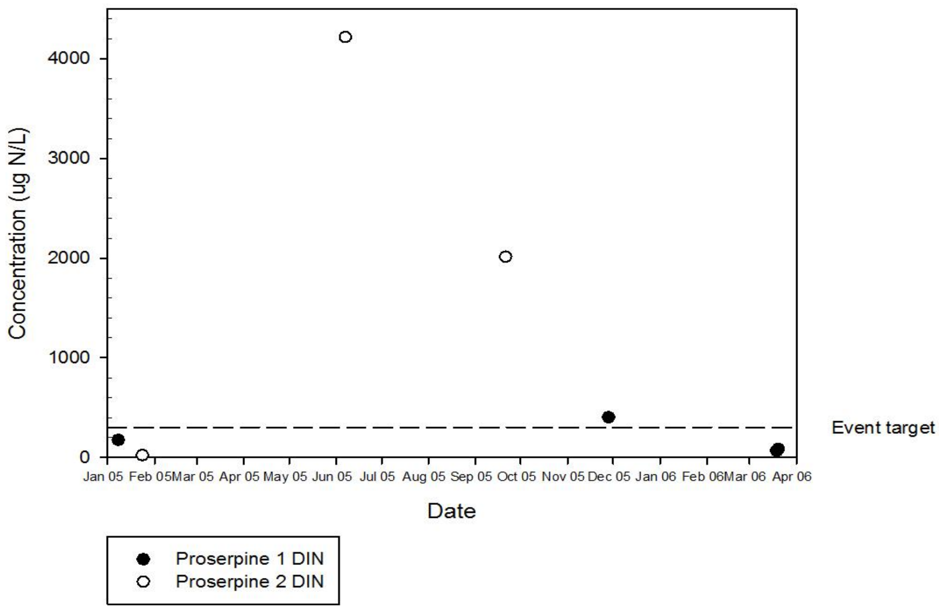

Figure 77 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during event conditions at Proserpine River from 2004–2006. The dashed line indicates the 2014 event DIN target for the Proserpine River Catchment Management Area.

Event concentrations of PP were fairly variable in 2004–2006, with one higher value (180 µg/L) in mid-2005 (Figure 78). The majority of concentrations ranged from 20–65 µg/L (all below the event target of 81 µg/L), with one (180 µg/L) concentration above the event target. There may be a slight decrease in PP over the sampling period, however, the limited sample numbers made it difficult to detect a temporal trend. There was no obvious difference between the two sampling sites.

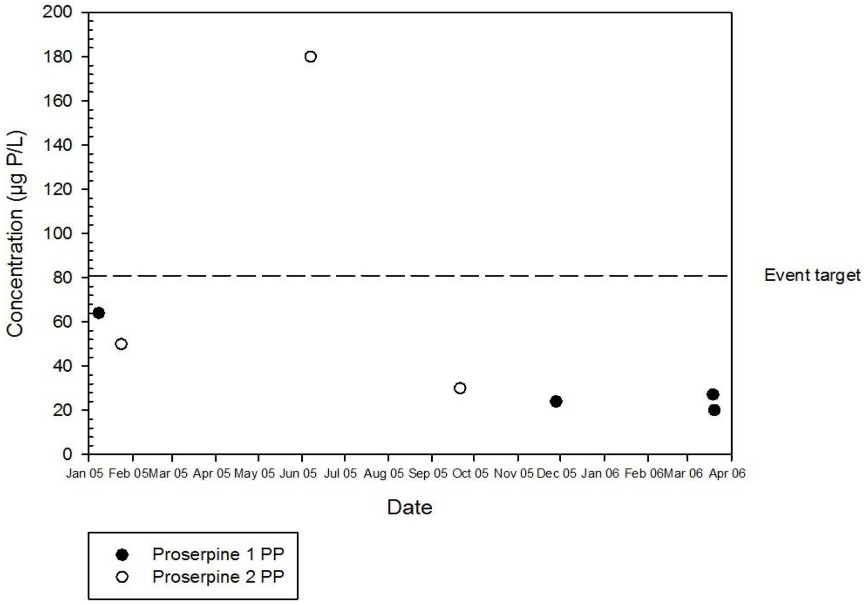

Figure 78 Temporal variation in particulate phosphorus (PP) concentrations during event conditions at Proserpine River from 2004–2006. The dashed line indicates the 2014 event PP target for the Proserpine River Catchment Management Area.

Event concentrations of FRP were variable in 2004–2006, with one higher value (1220 µg/L) in late 2005, and no temporal trend ($p = 0.2$) (Figure 79). The majority of concentrations ranged from 50–500 µg/L. All concentrations were above the event target of 45 µg/L, however it should be noted that the event FRP target for Proserpine River CMA (45 µg/L) was lower than the ambient target (95 µg/L). There was no obvious difference between the two sampling sites.

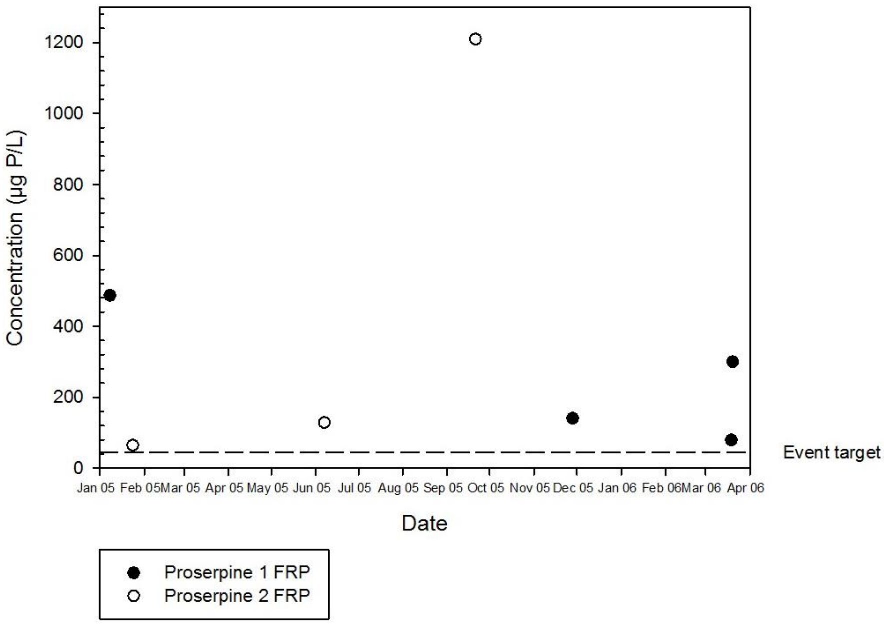

Figure 79 Temporal variation in filterable reactive phosphorus (FRP) concentrations during event conditions at Proserpine River from 2004–2006. The dashed line indicates the 2014 event FRP target for the Proserpine River Catchment Management Area.

Frequency of target exceedances

No sampling was conducted for Proserpine River subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets can be undertaken.

3.3.15 Rocky Dam Creek

3.3.15.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Ambient sampling in Rocky Dam Creek from 2006–2008 showed TSS concentrations remained relatively constant, with the exception of one higher value (37 mg/L) in early 2008 (Figure 80). Concentrations appeared to increase slightly over time, however there was no linear temporal trend ($p = 0.11$). Half of the samples were at or below the ambient target of 4 mg/L. The highest ambient concentration was 45 mg/L, 11-times greater than the ambient target. Event concentrations in Rocky Dam Creek were scattered across the sampling period with no linear temporal trend ($p = 0.53$) (Figure 80). Approximately half of the samples were above the event target of 120 mg/L. The highest concentration recorded was 270 mg/L. In each year sampled, the highest concentrations were detected early the year.

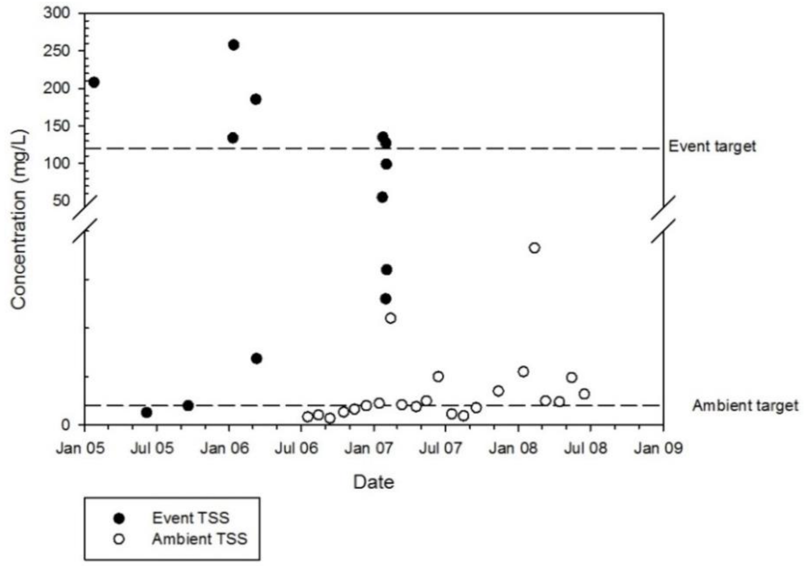

Figure 80 Temporal variation in total suspended solids (TSS) concentrations during ambient and event conditions at Rocky Dam Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event TSS targets for the Rocky Dam Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted in Rocky Dam Creek subsequent to 2006–2007, however one year of ambient sampling (10 samples) was undertaken in 2007–2008, in which 70 per cent of the samples exceeded the ambient TSS target.

3.3.15.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Ambient concentrations of PN at Rocky Dam Creek were scattered from 2006–2008, with no change in concentrations over the sampling period ($p = 0.07$) (Figure 81). The majority of concentrations were above the ambient target of 142 µg/L, with the highest at 371 µg/L. The event sampling concentrations were scattered, with no linear temporal trend ($p = 0.81$) (Figure 81). Half of the concentrations were below the event target (295 µg/L). The highest event concentration (just over 800 µg/L) occurred in January 2006, approximately two-times greater than the event target.

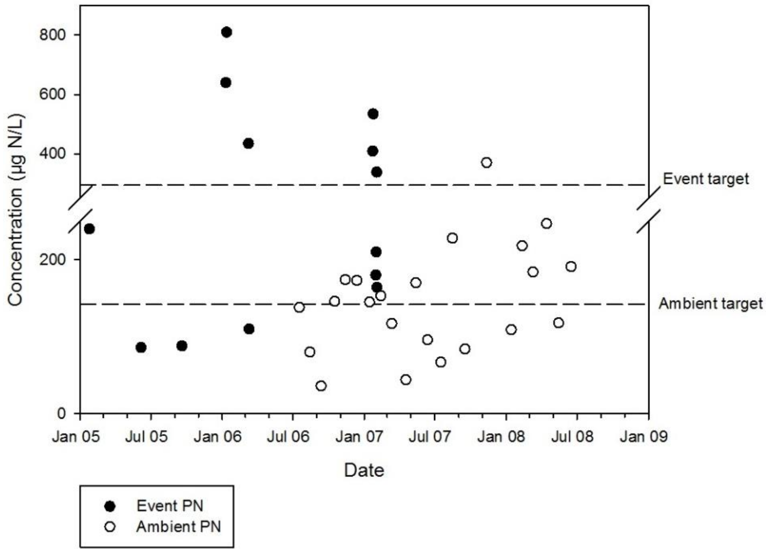

Figure 81 Temporal variation in particulate nitrogen (PN) concentrations during ambient and event conditions at Rocky Dam Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PN targets for the Rocky Dam Creek Catchment Management Area.

Ambient concentrations of DIN at Rocky Dam Creek varied from < LOR–400 µg/L from 2006–2008 (Figure 82). The majority of concentrations were above the ambient target of 10 µg/L. The highest concentration was approximately 358 µg/L, 35-times greater than the target. Ambient concentrations in 2006 were much lower than those in 2007 and 2008, however there was no linear temporal trend (p = 0.24). Event concentrations of DIN were scattered (Figure 82). The highest concentrations were recorded at the start of each year; however, there was no linear temporal trend (p = 0.94). The majority of concentrations were above the event target (422 µg/L). The highest event concentration was 2200 µg/L, approximately five-times greater than the event target.

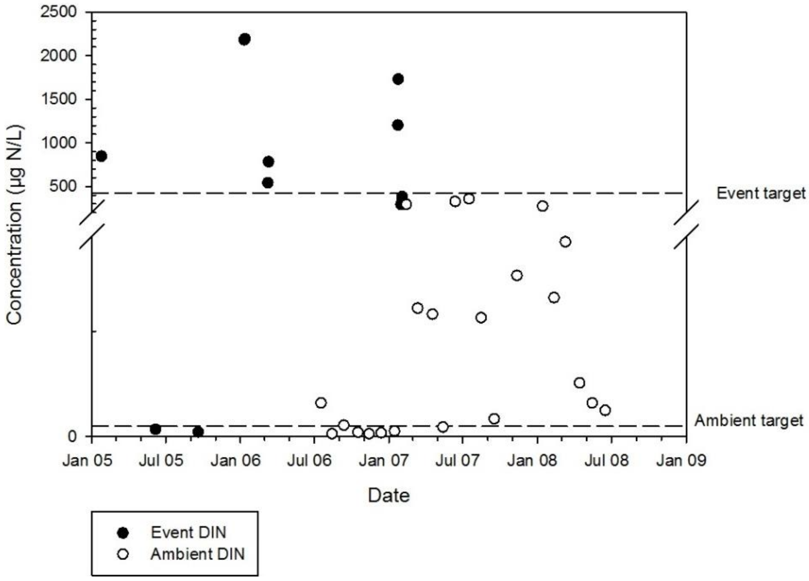

Figure 82 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient and event conditions at Rocky Dam Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event DIN targets for the Rocky Dam Creek Catchment Management Area.

Ambient concentrations of PP at Rocky Dam Creek were fairly scattered from 2006–2008, with no linear temporal trend (p = 0.38) (Figure 83). Concentrations were highest from January 2007 through to July 2008. The majority of concentrations were above the ambient target of 20 µg/L, with the highest around 72 µg/L. The PP event sampling concentrations were also scattered, with no temporal trend (p = 0.63) (Figure 83). The peak concentrations occurred in the early part of every sampled year. The majority of concentrations were below the event target (72 µg/L). The highest event concentration was 245 µg/L, approximately three-times greater than the event target, and it occurred in January 2006.

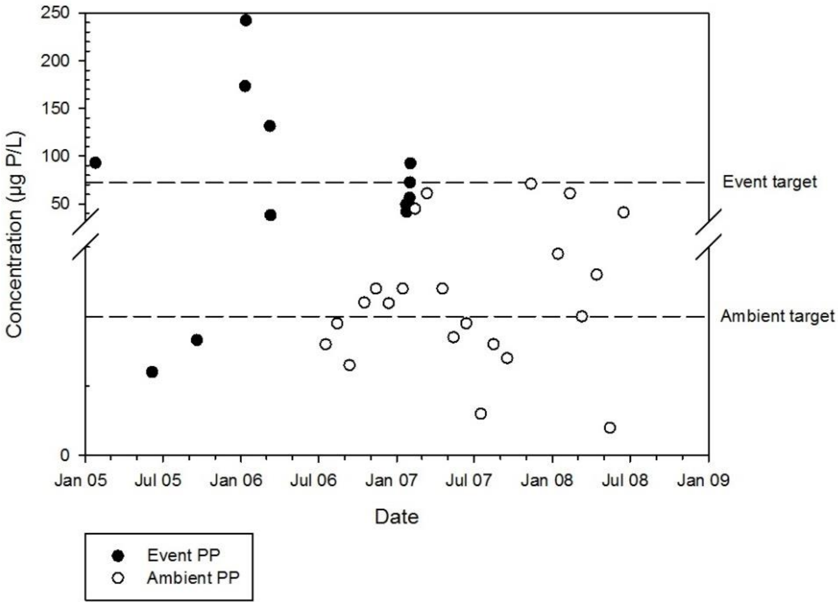

Figure 83 Temporal variation in particulate phosphorus (PP) concentrations during ambient and event conditions at Rocky Dam Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PP targets for the Rocky Dam Creek Catchment Management Area.

Ambient concentrations of FRP at Rocky Dam Creek were scattered and ranged from 2–40 µg/L in the period of 2006–2008 (Figure 84). There appeared to be an increase over time, however, there was no linear temporal trend (p = 0.37). The majority of concentrations were at or above the ambient target of 6 µg/L. The highest concentration was 40 µg/L, and occurred in early 2008. The FRP event sampling concentrations were scattered in the wet seasons, with no temporal trend (p = 0.93) (Figure 84). The peak concentrations occurred in the early part of every sampled year. The majority of concentrations were at or above the event target (33 µg/L). The highest event concentration was 150 µg/L, approximately five-times greater than the event target.

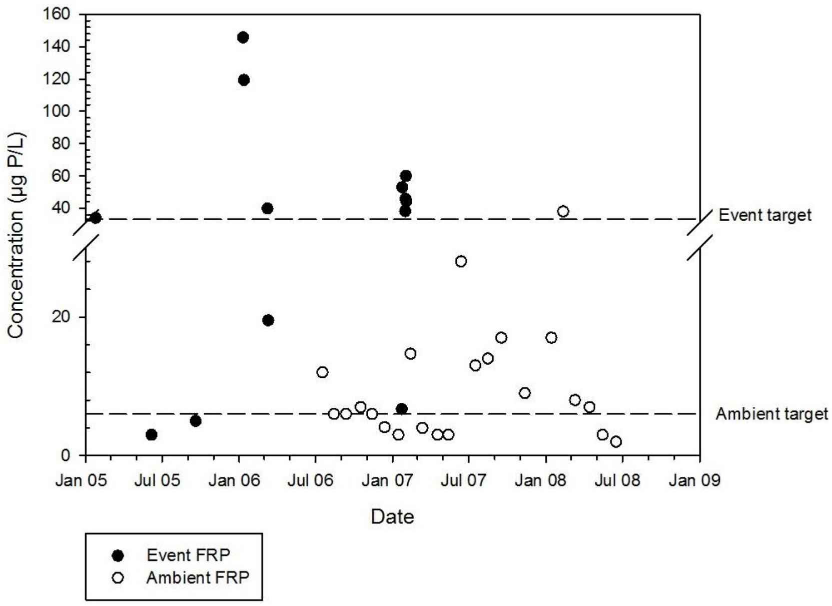

Figure 84 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient and event conditions at Rocky Dam Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event FRP targets for the Rocky Dam Creek Catchment Management Area.

Frequency of target exceedances

No event nutrient sampling was conducted for Rocky Dam Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established); therefore, no assessment of event concentration exceedances against the targets can be undertaken. Ambient sampling of nutrients at Rocky Dam Creek was undertaken for one year subsequent to 2006–2007, with a total of 10 ambient samples taken in 2007–2008. Ambient concentrations exceeded the PN target in 60 per cent of samples, and exceeded the DIN target in 100 per cent of samples. The PP target was exceeded in 50 per cent of samples and the FRP target was exceeded in 80 per cent of samples.

3.3.16 Sandy Creek

3.3.16.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Ambient concentrations of TSS in Sandy Creek from 2006–2013 remained relatively constant, with a decreasing trend over time ($p = 0.002$; $R^2 = 0.224$); however, the low R^2 value suggested there were other factors also influencing the results (Figure 85). The concentrations recorded in ambient conditions were up to 11 mg/L, which was two-times greater than the ambient target of 5 mg/L. The majority of the ambient concentrations were below the ambient target.

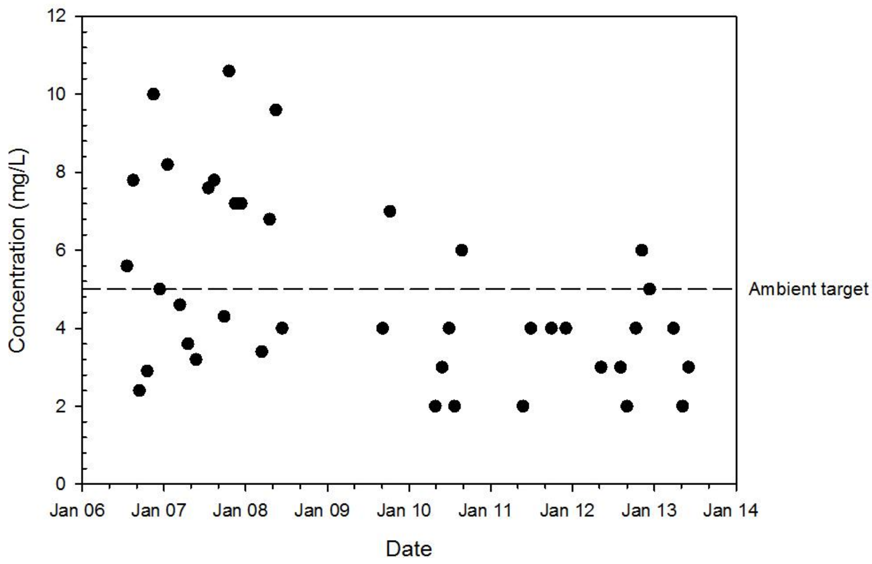

Figure 85 Temporal variation in total suspended solids (TSS) concentrations during ambient conditions at Sandy Creek from 2005–2013. The dashed line indicates the 2014 ambient TSS targets for the Sandy Creek Catchment Management Area.

The median concentrations from TSS event sampling in Sandy Creek from 2004–2013 were scattered and covered many events (Figure 86). There was no linear temporal trend across the sampling period (p = 0.97). The majority of the median TSS concentration values were between 19 and 104 mg/L, with two higher values at 185 and 191 mg/L in February and March 2012.

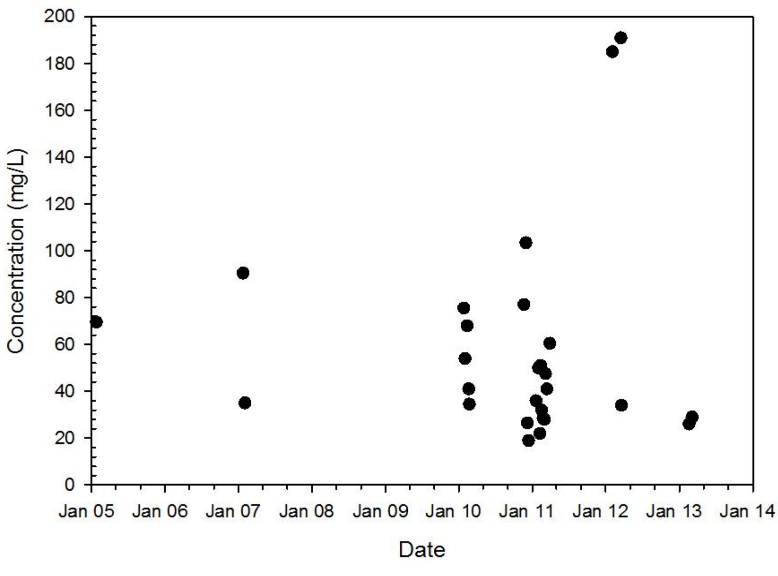

Figure 86 Temporal variation in median total suspended solids (TSS) concentrations during event conditions at Sandy Creek from 2005 –2013.

Frequency of target exceedances

The ambient concentrations of TSS in Sandy Creek frequently exceeded the ambient target (in four of the six sampled years) (Table 16), with exceedances occurring in 13–70 per cent of samples taken.

Table 16 Per cent of exceedances of the 2014 TSS ambient targets for Sandy Creek from 2007–2013. Red indicates poor data availability (0–4 samples), amber indicates moderate data availability (5–9 samples), green indicates good data availability (≥ 10 samples).

Year	Per cent exceedances (total no. samples) – under ambient conditions
2007–2008	70 (10)
2008–2009	-
2009–2010	20 (5)
2010–2011	25 (4)
2011–2012	0 (3)
2012–2013	13 (8)

3.3.16.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Ambient concentrations of PN at Sandy Creek from 2005–2013 varied from < LOR–1752 µg/L with no temporal trend (p = 0.36) (Figure 87). The majority of the concentrations were below 460 µg/L, with two higher values (1752 and 1115 µg/L). Approximately half of the samples were below the ambient target of 110 µg/L. Between 2006 and 2008 the peak ambient concentrations were higher than those between 2010 and 2013. The highest ambient PN concentration (1750 µg/L) was 16-times higher than the ambient target.

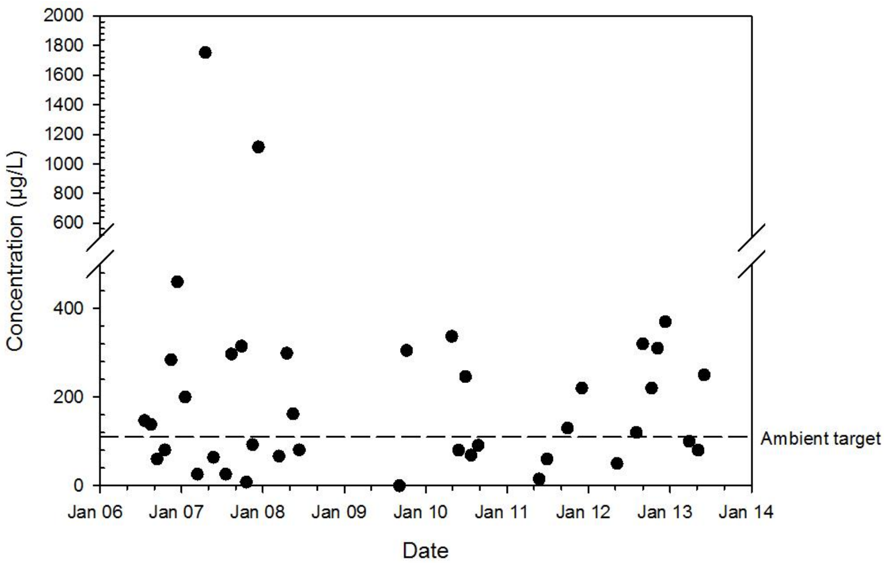

Figure 87 Temporal variation in particulate nitrogen (PN) concentrations during ambient conditions at Sandy Creek from 2004–2013. The dashed line indicates the 2014 ambient PN target for the Sandy Creek Catchment Management Area.

The event sampling showed median PN concentrations were scattered across multiple events, with no temporal trend (p = 0.77) (Figure 88). All but two of the median concentration values were at or below 500 µg/L. The two higher values were 895 µg/L in January 2007, and 1000 µg/L in February 2012.

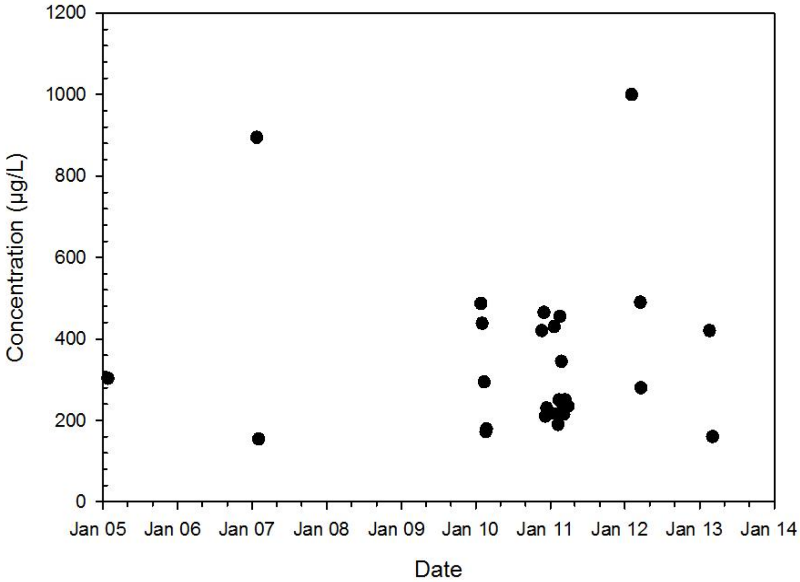

Figure 88 Temporal variation in median particulate nitrogen (PN) concentrations during event conditions at Sandy Creek from 2004–2013.

Ambient concentrations of DIN at Sandy Creek were highly scattered between 4 and 1851 µg/L from 2005–2013, with an increase in DIN over time ($p = 0.001$; $R^2 = 0.238$); however, the low R^2 value suggests there are other factors also influencing the results (Figure 89). The majority of concentrations were greater than the ambient target (107 µg/L). The highest concentration for ambient DIN was 1851 µg/L (17-times greater than the ambient target); however, there were 12 other instances where the ambient concentration of DIN was above 1000 µg/L.

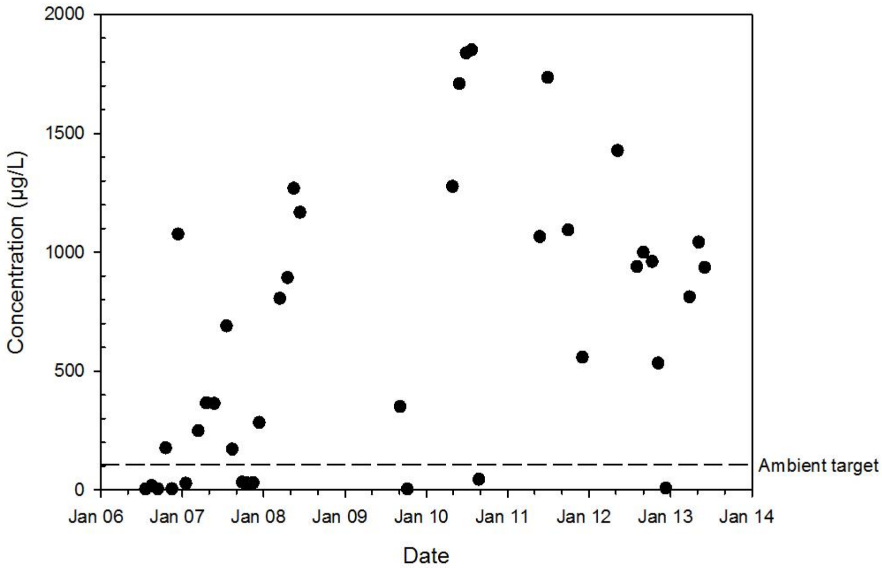

Figure 89 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient conditions at Sandy Creek from 2005–2013. The dashed line indicates the 2014 ambient DIN target for the Sandy Creek Catchment Management Area.

The event DIN sampling was scattered and covered many events (Figure 90). There was a decrease in median event concentrations over time ($p = 0.000$; $R^2 = 0.575$). The two highest median concentrations were 1081 and 1041 µg/L, which occurred in January 2005, and January 2007, respectively. The remaining values were all between 41 and 202 µg/L, with one at 337 µg/L and one at 302 µg/L.

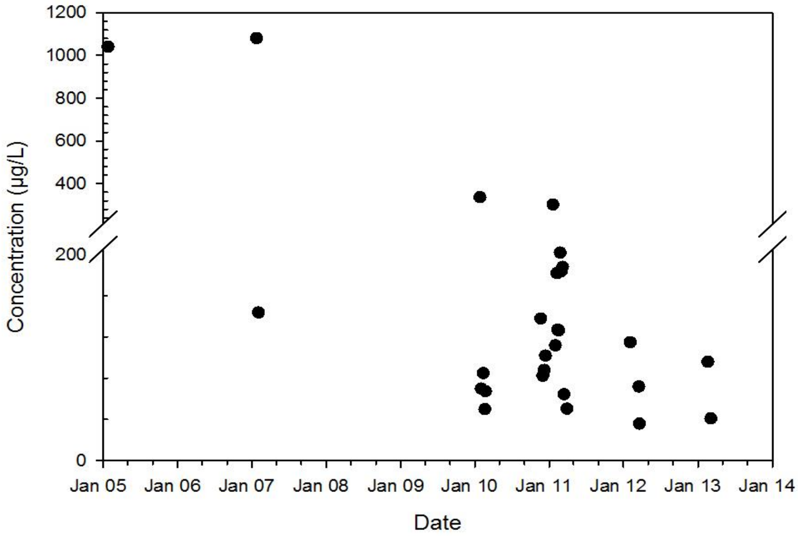

Figure 90 Temporal variation in median dissolved inorganic nitrogen (DIN) concentrations during event conditions at Sandy Creek from 2004–2013.

Ambient concentrations of PP at Sandy Creek were scattered from 2005–2013 with the majority occurring below 100 µg/L (Figure 91). Three concentrations between 150 and 220 µg/L occurred in October 2006, December 2012, and April 2010. There was no temporal trend in ambient PP concentrations over the sampling period (p = 0.43). Approximately half of the concentrations were greater than the ambient target of 20 µg/L.

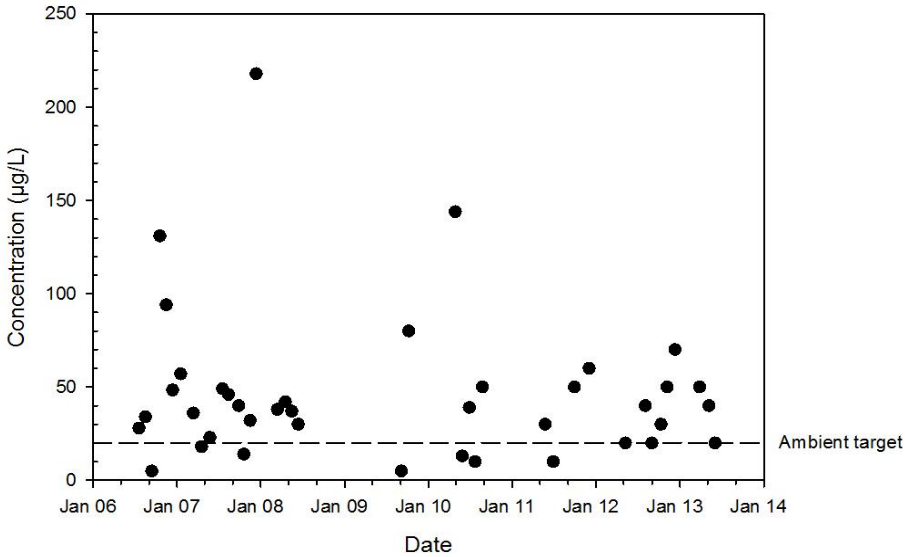

Figure 91 Temporal variation in particulate phosphorus (PP) concentrations during ambient conditions at Sandy Creek from 2004–2013. The dashed line indicates the 2014 ambient PP target for the Sandy Creek Catchment Management Area.

The median event PP concentrations were scattered and covered many events, with no linear temporal trend over the sampling period ($p = 0.35$) (Figure 92). The median concentrations ranged from 10–228 µg/L. The majority of the values were between 50 and 200 µg/L.

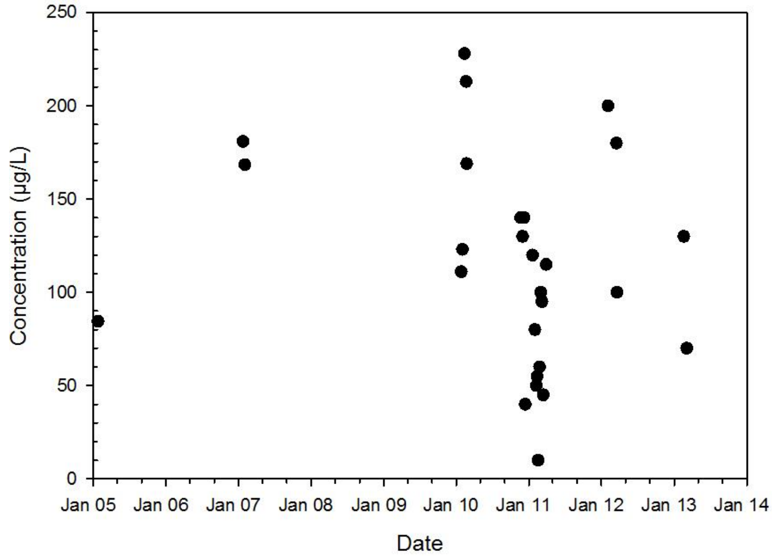

Figure 92 Temporal variation in median particulate phosphorus (PP) concentrations during event conditions at Sandy Creek from 2004–2013.

Ambient concentrations of FRP at Sandy Creek were fairly consistent from 2005–2013 with a decrease over time ($p = 0.002$; $R^2 = 0.226$); however, the low R^2 value suggests there are other factors also influencing the results (Figure 93). Approximately half of the concentrations were greater than the ambient target of 25 µg/L, with most concentrations between 7 and 51 µg/L. There were five higher values, which were 135, 193, 201, 230, and 232 µg/L. The highest four concentrations occurred in between October 2006 and January 2007, and the next highest concentration was in December 2007.

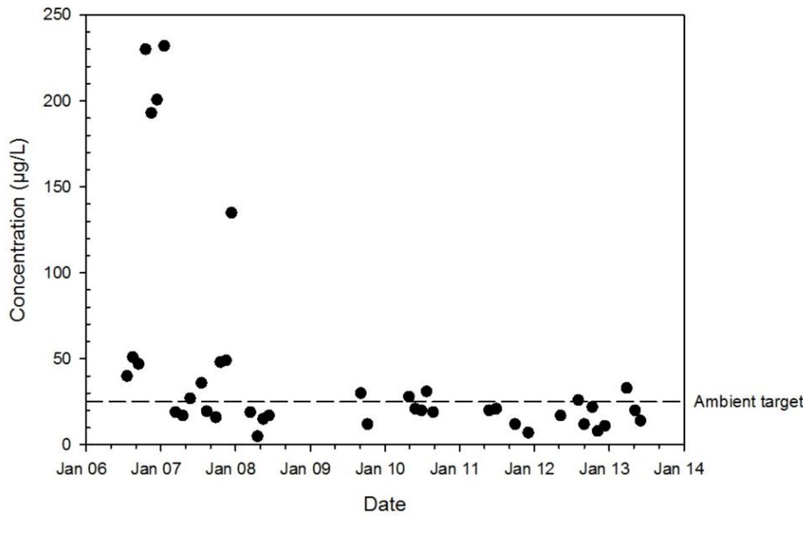

Figure 93 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient conditions at Sandy Creek from 2004–2013. The dashed line indicates the 2014 ambient FRP target for the Sandy Creek Catchment Management Area.

The event FRP median concentrations were scattered and covered many events, with a decrease over time ($p = 0.000$; $R^2 = 0.487$) (Figure 94). The highest concentrations were 228 and 232 µg/L, which occurred in January 2007 and January 2005, respectively. Concentrations were much lower in early 2011 before increasing again.

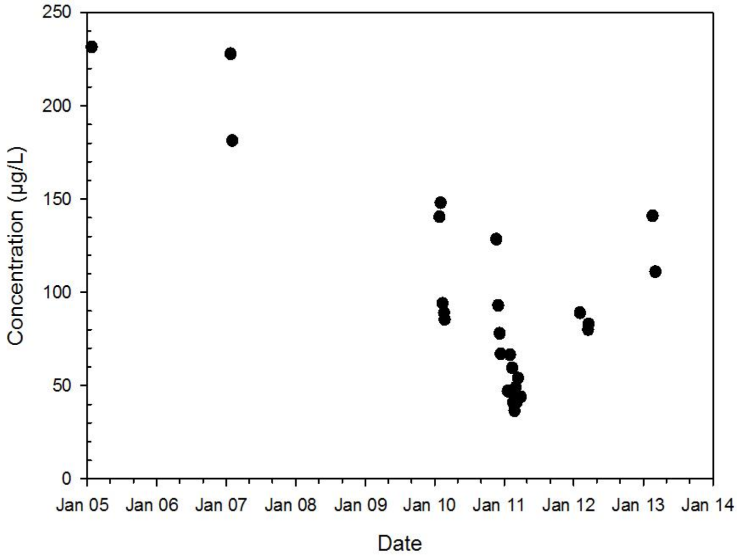

Figure 94 Temporal variation in median filterable reactive phosphorus (FRP) concentrations during event conditions at Sandy Creek from 2004–2013.

Frequency of target exceedances

Ambient concentrations in Sandy Creek exceeded the ambient PN target in four out of five sampled years, with exceedances ranging from 50–75 per cent (Table 17). All sampled years had samples which exceeded the DIN ambient target, ranging from 70–100 per cent exceedance (Table 17). Ambient concentrations of PP exceeded the target in all years, ranging from 50–90 per cent (Table 17). Ambient concentrations in Sandy Creek exceeded the FRP target in four out of the five sampled years, with exceedances ranging from 25–40 per cent (Table 17).

Table 17 Per cent of exceedances of the 2014 nutrient ambient targets for Sandy Creek from 2007–2013. Red indicates poor data availability (0–4 samples), amber indicates moderate data availability (5–9 samples), green indicates good data availability (≥ 10 samples).

Year	Per cent exceedances (total no. samples) of ambient samples			
	PN	DIN	PP	FRP
2007–2008	50 (10)	70 (10)	90 (10)	40 (10)
2008–2009	-	-	-	-
2009–2010	60 (5)	80 (5)	60 (5)	40 (5)
2010–2011	0 (4)	75 (4)	50 (4)	25 (4)
2011–2012	67 (3)	100 (3)	67 (3)	0 (3)
2012–2013	75 (8)	88 (8)	75 (8)	25 (8)

3.3.17 Sarina

There was no ambient sampling conducted for Sarina, thus, the following results are based on event conditions from 2006–2007.

3.3.17.1 TSS

Temporal variation in TSS and comparison to 2014 targets

The event sampling at Sarina was limited to seven samples, in two distinct periods, over one year (Figure 95). Due to lack of data over multiple years, linear regression was not performed. All the concentrations were below the event target of 200 mg/L. The highest concentration (141 mg/L) occurred in early 2006. The concentrations that occurred in early 2007 were much lower (below 30 mg/L) than those in early 2006.

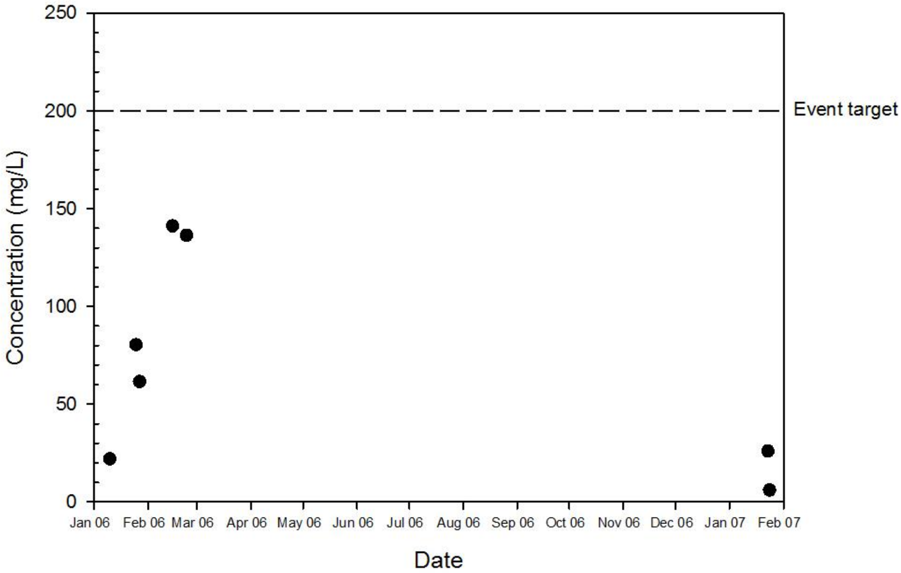

Figure 95 Temporal variation in total suspended solids (TSS) concentrations during event conditions at Sarina from 2004–2007. The dashed line indicates the 2014 event TSS target for the Plane Creek Catchment Management Area.

Frequency of target exceedances

No sampling was conducted at Sarina subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets can be undertaken.

3.3.17.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

The event PN sampling at Sarina was limited to six samples, over two distinct periods (Figure 96). Due to lack of data over multiple years, linear regression was not performed. The highest concentration recorded was 498 µg/L, compared to the target of 178 µg/L. The majority of the concentrations were above the PN event target. The concentrations in early 2006 were much higher than those recorded in early 2007.

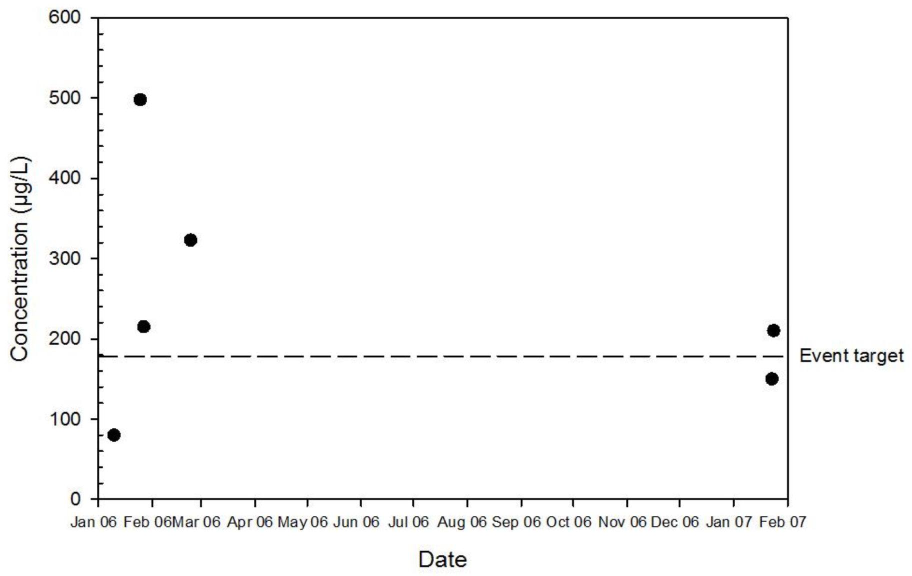

Figure 96 Temporal variation in particulate nitrogen (PN) concentrations during event conditions at Sarina from 2004–2007. The dashed line indicates the 2014 event PN target for the Plane Creek Catchment Management Area.

The event DIN sampling at Sarina was limited to seven samples, over two distinct periods (Figure 97). Due to data being available for only one year, no linear regression was performed. The highest concentration recorded was 359 µg/L. All concentrations were below the DIN event target (368 µg/L).

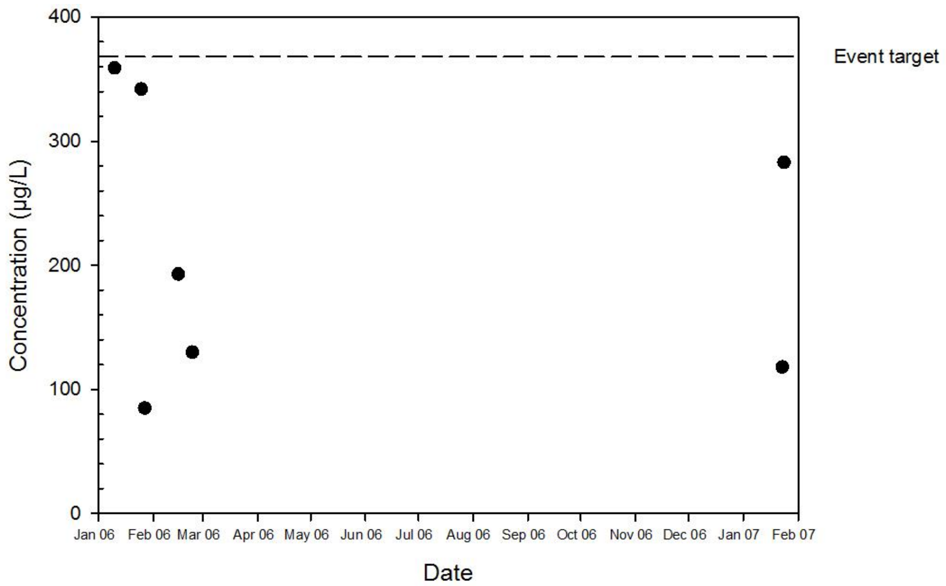

Figure 97 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during event conditions at Sarina from 2004–2007. The dashed line indicates the 2014 event DIN target for the Plane Creek Catchment Management Area.

The event sampling at Sarina was limited to six samples, over two distinct periods (Figure 98). The concentrations in early 2006 were much higher than those in early 2007; however, due to data being only available for a year, it was not possible to perform linear regression.

The highest concentration recorded was approximately 200 µg/L, compared to the target of 61 µg/L. The majority of the concentrations were above the PP event target.

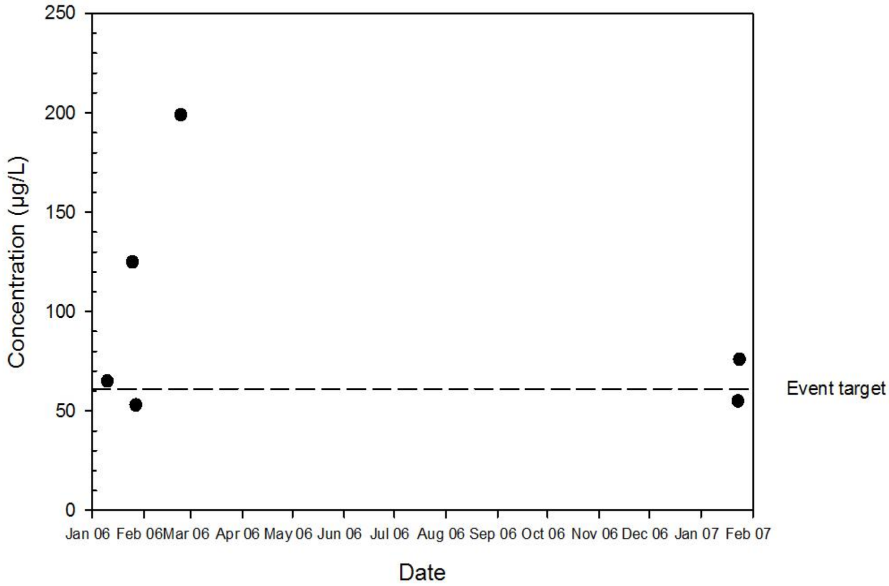

Figure 98 Temporal variation in particulate phosphorus (PP) concentrations during event conditions at Sarina from 2004–2007. The dashed line indicates the 2014 event PP target for the Plane Creek Catchment Management Area.

The event sampling at Sarina was limited to seven samples, over two distinct periods (Figure 99). Due to a lack of sampling data, no linear regression was performed. The highest concentration recorded was 338 µg/L, compared to the target of 59 µg/L. All but one concentration, were above the FRP event target.

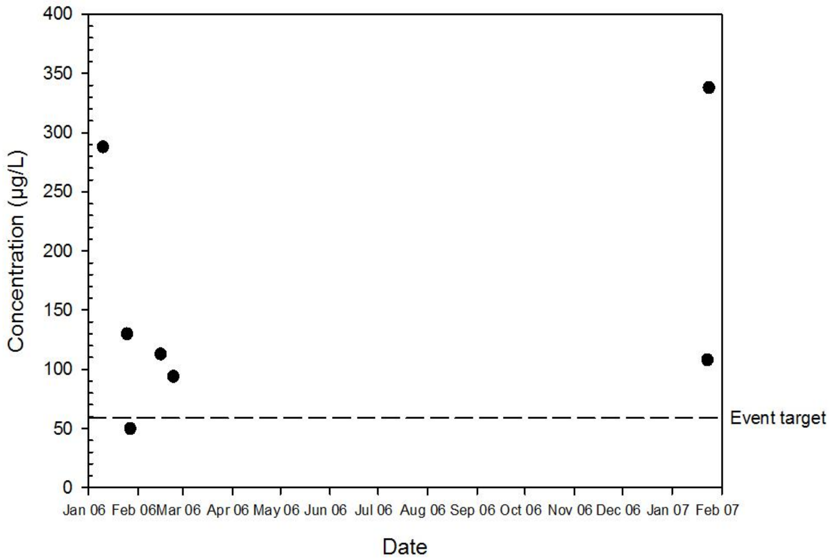

Figure 99 Temporal variation in filterable reactive phosphorus (FRP) concentrations during event conditions at Sarina from 2004–2007. The dashed line indicates the 2014 event FRP target for the Plane Creek Catchment Management Area.

Frequency of target exceedances

No sampling was conducted at Sarina subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets can be undertaken.

3.3.18 St Helens Creek

3.3.18.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Ambient sampling in St Helens Creek from 2006–2008 showed concentrations of TSS to vary between 0–5.2 mg/L (Figure 100). There was an increase in ambient TSS concentrations over the sampling period ($p = 0.017$, $R^2 = 0.23$); however, the low R^2 value suggests that other factors are likely to be influencing the results. The event sampling in St Helens Creek was limited to three samples in early 2005, three from mid-2005 to mid-2006, and five in early 2007. There was no linear temporal trend in event concentrations ($p = 0.28$) (Figure 100), although the concentrations in January 2007 are dramatically higher than those in previous years. The majority of concentrations were below the event target of 45 mg/L. The highest event concentration was approximately 500 mg/L.

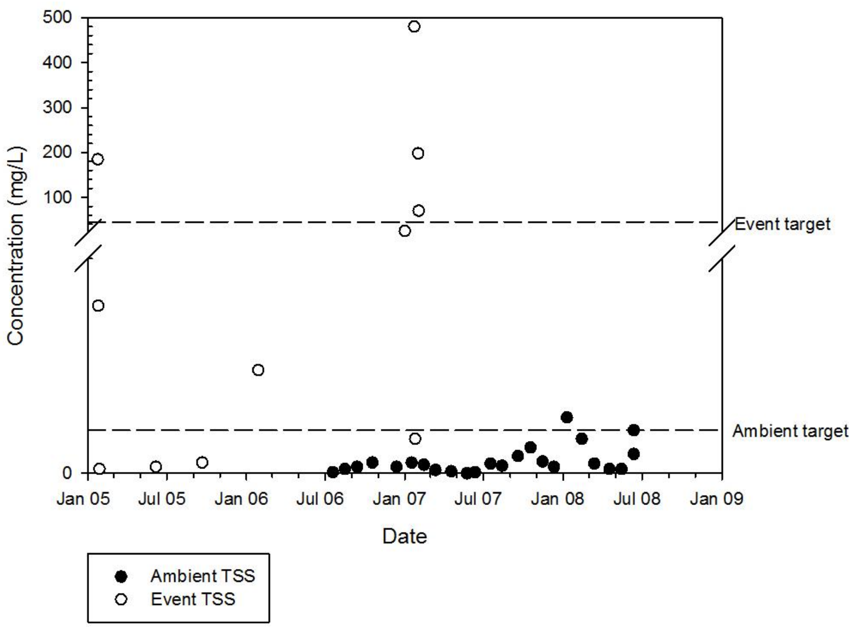

Figure 100 Temporal variation in total suspended solids (TSS) concentrations during ambient and event conditions at St Helens Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event TSS targets for the St Helens Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted in St Helens Creek subsequent to 2006–2007, however one year of ambient sampling (12 samples) was undertaken in 2007–2008, in which 8 per cent of the samples exceeded the ambient TSS target.

3.3.18.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Ambient concentrations of PN in St Helens Creek were spread between < LOR and 140 µg/L from 2006–2008 with one higher value (1467 µg/L) in mid-2007 and no temporal trend ($p = 0.83$) (Figure 101). All concentrations except the higher value were below the ambient target. The higher value (1467 µg/L) was ten-times greater than the target. The event concentrations were scattered across the sampling period with no temporal trend in event concentrations ($p = 0.72$) (Figure 101). The majority of concentrations were below the event target (121 µg/L), with the highest event concentration at 434 µg/L. The highest event concentrations of PN occurred in the beginning of each year, suggesting seasonal trends. The event target for PN at St Helens Creek was more stringent than the ambient target.

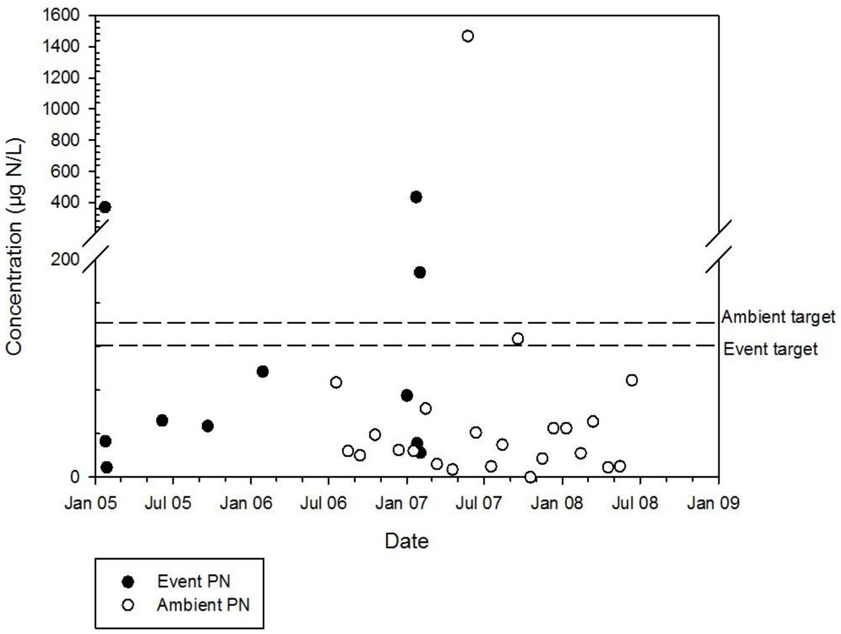

Figure 101 Temporal variation in particulate nitrogen (PN) concentrations during ambient and event conditions at St Helens Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PN targets for the St Helens Creek Catchment Management Area.

Ambient concentrations of DIN from 2006–2008 showed an increase over time ($p = 0.004$; $R^2 = 0.337$) (Figure 102). The low R^2 value suggests there are other factors also influencing the results. The majority of concentrations were above the ambient target (10 µg/L). The highest ambient concentration recorded (117 µg/L) was 11-times greater than the target. The event concentrations were scattered across the sampling period (Figure 102). Although the peak concentrations decreased over time from early 2005 to early 2007, there was no linear temporal trend ($p = 0.44$). The majority of event DIN concentrations were above the event target (266 µg/L). The highest event concentration was approximately 400 µg/L.

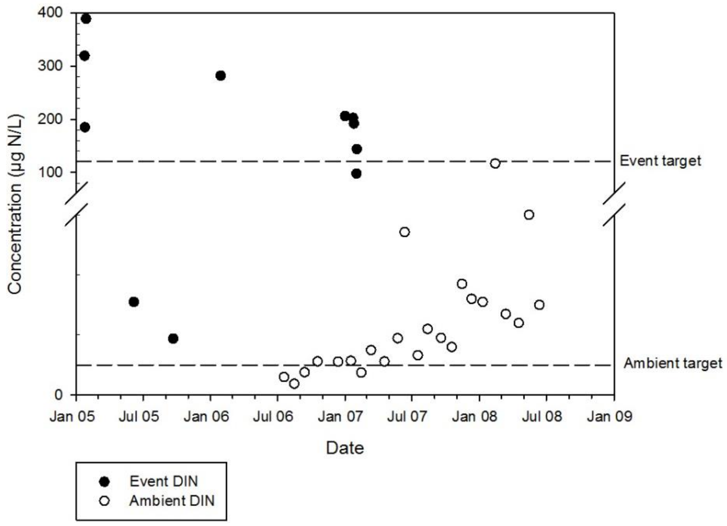

Figure 102 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during ambient and event conditions at St Helens Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event DIN targets for the St Helens Creek Catchment Management Area.

Ambient concentrations of PP from 2006–2008 were consistent, with one higher value (180 µg/L) in mid-2007 (Figure 103). The highest concentration recorded (180 µg/L) was nine-times greater than the ambient target of 20 µg/L, however all other concentrations recorded were below the target. There was no temporal trend ($p = 0.8$) in ambient PP concentrations. The event concentrations were scattered across the sampling period. The concentrations were higher at the start of each year, and were higher in 2007 and then 2005; however, there was no linear temporal trend ($p = 0.25$) (Figure 103). The majority of concentrations were below the event target (33 µg/L). The highest event concentration was approximately 380 µg/L, ten-times greater than the target.

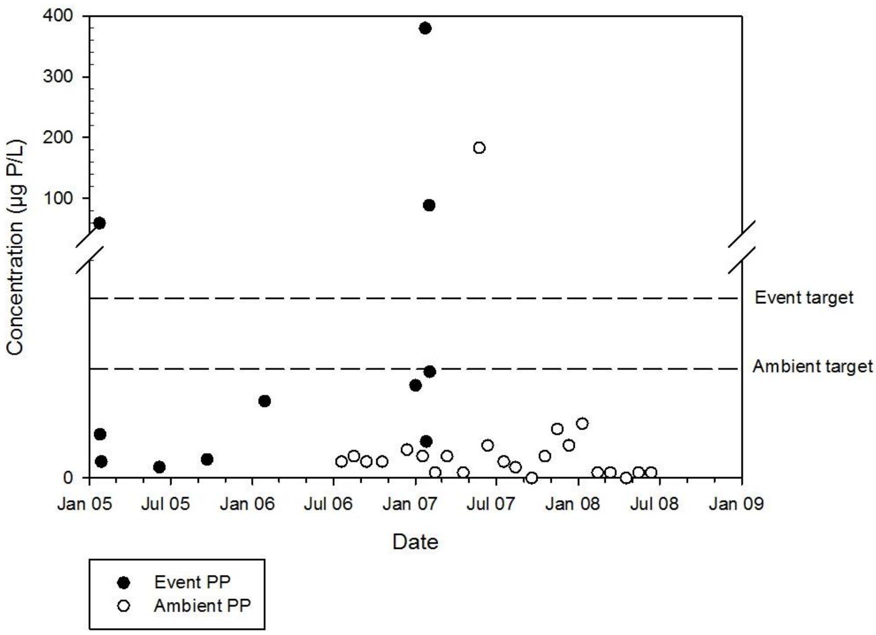

Figure 103 Temporal variation in particulate phosphorus (PP) concentrations during ambient and event conditions at St Helens Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event PP targets for the St Helens Creek Catchment Management Area.

Ambient concentrations of FRP from 2006–2008 were spread between 3 and 23 µg/L (Figure 104), with no temporal trend ($p = 0.22$). The majority of concentrations were above the ambient target (6 µg/L). The highest ambient concentration was 23 µg/L and occurred in early 2008. Event concentrations varied between 4 and 30 µg/L, across the sampling period, with no temporal trend ($p = 0.1$) (Figure 104). The highest concentration was recorded in January 2007, and this was higher than the other wet season concentrations. Only one concentration was above the event target (23 µg/L).

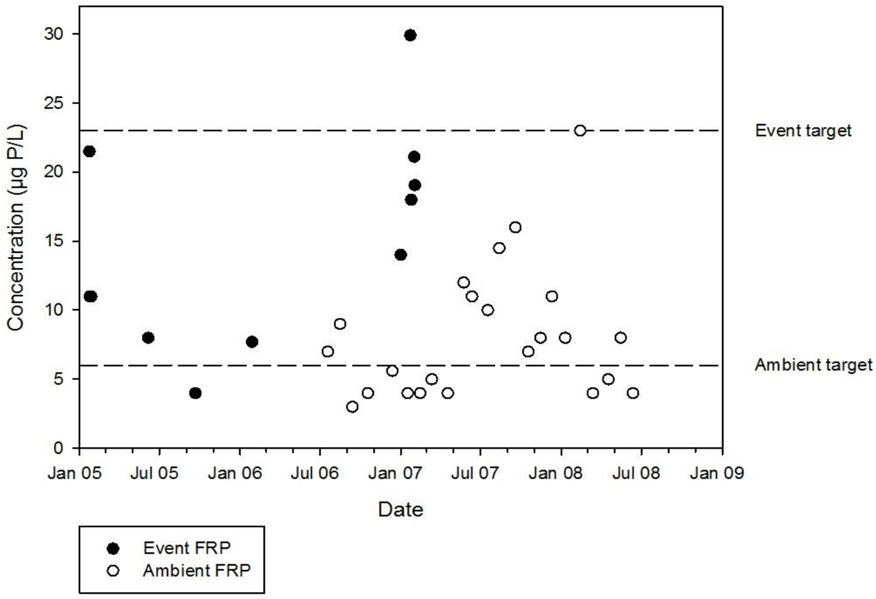

Figure 104 Temporal variation in filterable reactive phosphorus (FRP) concentrations during ambient and event conditions at St Helens Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event FRP targets for the St Helens Creek Catchment Management Area.

Frequency of target exceedances

No event sampling was conducted in St Helens Creek subsequent to 2006–2007, however one year of ambient sampling (12 samples) was undertaken in 2007–2008. Ambient concentrations of PN and PP in St Helens Creek did not exceed the target in 2007–2008. Ambient concentrations of DIN exceeded the target in 100 per cent of samples, and the FRP target was exceeded in 75 per cent of the samples.

3.3.19 Waite Creek

No ambient sampling was conducted for Waite Creek, thus, the following results are based on event conditions from 2004–2006.

3.3.19.1 TSS

Temporal variation in TSS and comparison to 2014 targets

Event TSS concentrations in Waite Creek in 2004 and 2006 increased over time; however, the number of samples was limited so linear regression was not performed (Figure 105). All concentrations were above the event target of 8 mg/L. The highest concentration

(2100 mg/L) was 262-times greater than the event target. Event TSS concentrations were much higher in the 2005–2006 wet season, then the 2004–2005 wet season.

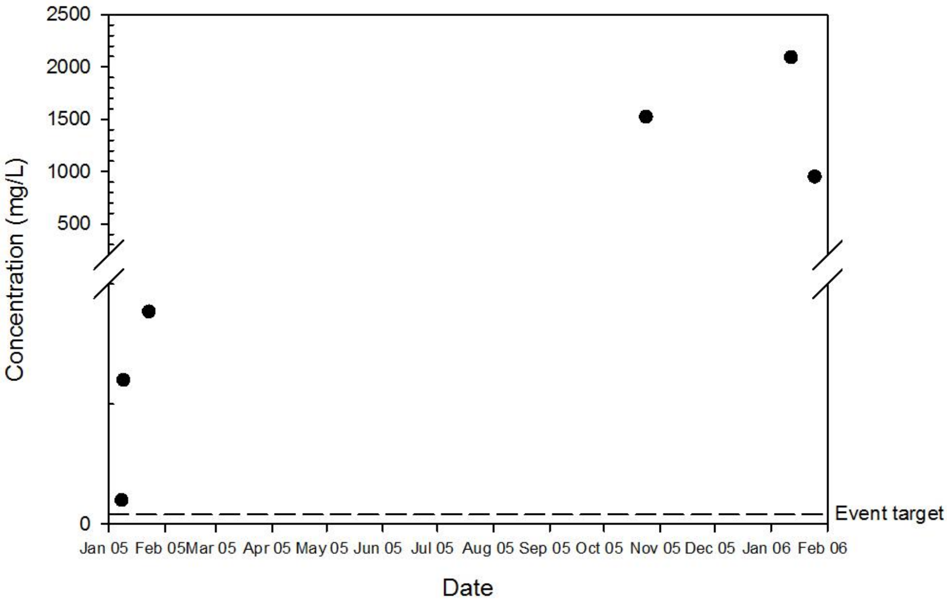

Figure 105 Temporal variation in total suspended solids (TSS) concentrations during event conditions at Waite Creek from 2004–2006. The dashed line indicates the 2014 event TSS target for the Whitsunday Coast Catchment Management Area.

Frequency of target exceedances

No sampling was conducted for Waite Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established); therefore, no assessment of concentration exceedances against the targets can be undertaken.

3.3.19.2 Nutrients

Temporal variation in nutrients and comparison to 2014 targets

Event concentrations of PN in Waite Creek were scattered (Figure 106). Due to the limited number of samples, and only occurring over a one-year period, no linear regression was performed. All but one concentration, were above the event target for PN. The highest concentration was approximately 1200 µg/L, four-times greater than the target, and occurred in early 2006.

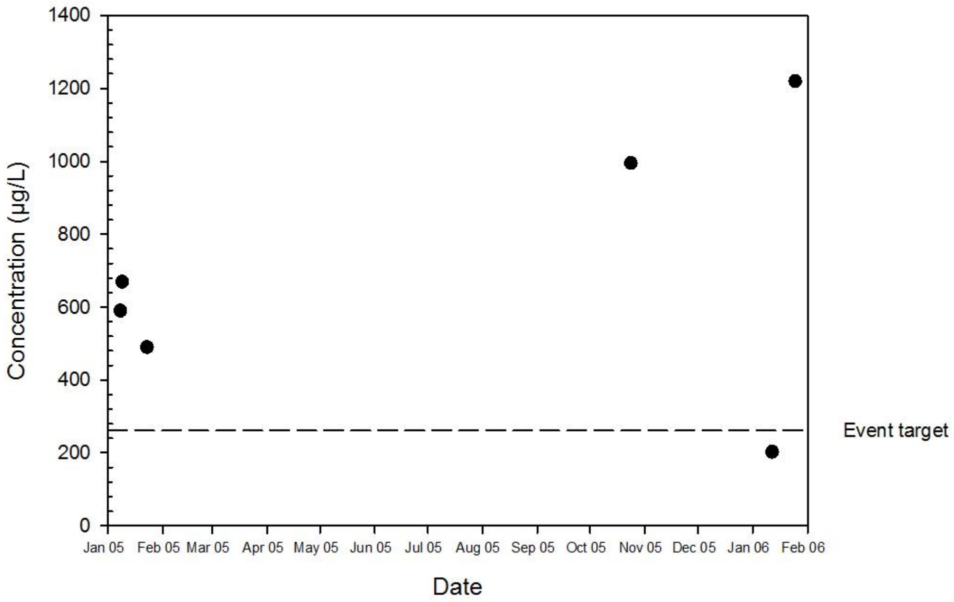

Figure 106 Temporal variation in particulate nitrogen (PN) concentrations during event conditions at Waite Creek from 2004–2006. The dashed line indicates the 2014 event PN target for the Whitsunday Coast Catchment Management Area.

Event concentrations of DIN in Waite Creek varied between 295 and 1850 µg/L (Figure 107). Due to the limited number of samples taken over only one year, no linear regression was performed. All samples were above the event target. The highest concentration occurred in early 2005 and was 1850 µg/L, which was seven-times greater than the target of 256 µg/L.

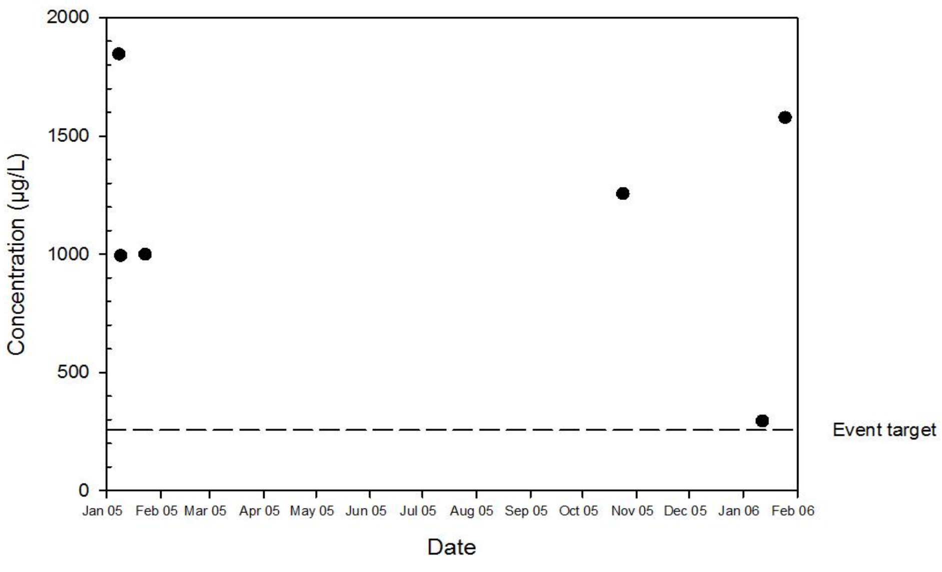

Figure 107 Temporal variation in dissolved inorganic nitrogen (DIN) concentrations during event conditions at Waite Creek from 2004–2006. Dashed line indicates the 2014 event DIN target for the Whitsunday Coast Catchment Management Area.

Event concentrations of PP varied greatly between the two sampling years (Figure 108). The concentrations were much higher in 2005–2006 compared to those in 2004–2005; however, due to the limited sampling period and number of samples taken, linear regression was not performed. All samples were above the event target of 31 µg/L. The highest concentration (550 µg/L) was 17-times greater than the target.

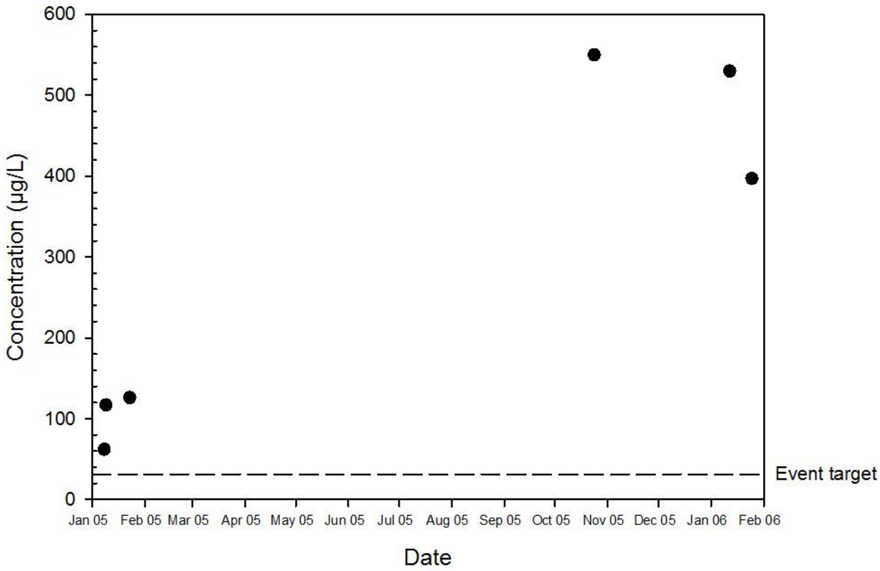

Figure 108 Temporal variation in particulate phosphorus (PP) concentrations during event conditions at Waite Creek from 2004–2006. The dashed line indicates the 2014 event PP target for the Whitsunday Coast Catchment Management Area.

Event concentrations of FRP ranged from 7–283 µg/L across the sampling period (Figure 109). Due to the limited data, linear regression was not performed; however, there does not appear to be any trends. All but one sample, were above the event target of 27 µg/L. The highest concentration was 283 µg/L, which was ten-times greater than the target.

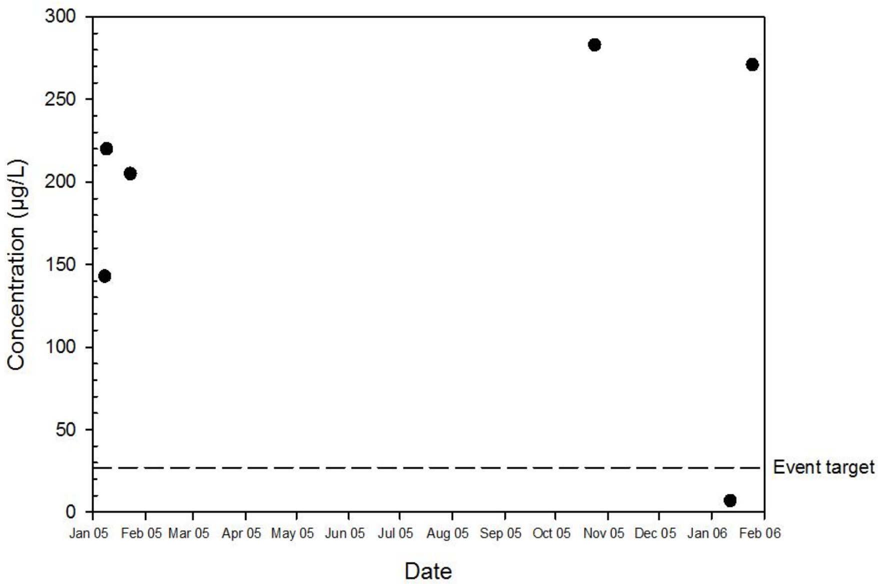

Figure 109 Temporal variation in filterable reactive phosphorus (FRP) concentrations during event conditions at Waite Creek from 2004–2006. The dashed line indicates the 2014 event FRP target for the Whitsunday Coast Catchment Management Area.

Frequency of target exceedances

No sampling was conducted for Waite Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established); therefore, no assessment of concentration exceedances against the targets can be undertaken.

3.4 Pesticides

No pesticide sampling was conducted in Airlie Creek. No ambient pesticide sampling was conducted in Blacks Creek, Gregory River, Mackay City, O'Connell 2, Proserpine River, Rocky Dam Creek and Sarina, in any year. No event pesticide sampling was conducted in Bakers Creek and St Helens Creek, in any year.

3.4.1 Upper Andromache and Andromache River

The results for both the Andromache and Upper Andromache River sites from 2004–2009 are presented below. No ambient sampling was conducted for Andromache River, however the Upper Andromache site had ambient and event samples taken.

3.4.1.1 Temporal variation in pesticides and comparison to trigger values and targets

All concentrations of ametryn sampled from Andromache River (Andromache River and Upper Andromache River sites) for both ambient and event conditions were < LOR (the ambient and event targets), and therefore, have not been graphed.

The majority of ambient and event concentrations of atrazine in Andromache River were ≤ LOR (0.01 µg/L) (Figure 110). There was no linear temporal trend in ambient atrazine concentrations at Upper Andromache River ($p = 0.45$). There was a slight increase over time in the Andromache River event concentrations ($p = 0.030$; $R^2 = 0.729$); however, this was based on only a few samples in one year of sampling. The event atrazine concentrations at Upper Andromache River did not show a linear temporal trend ($p = 0.28$). There were only two samples > LOR, one ambient and one event sample in Upper Andromache River (one in early 2005 and one in early 2008). These concentrations were both above their respective target concentrations of 0.01 µg/L and 0.02 µg/L, respectively.

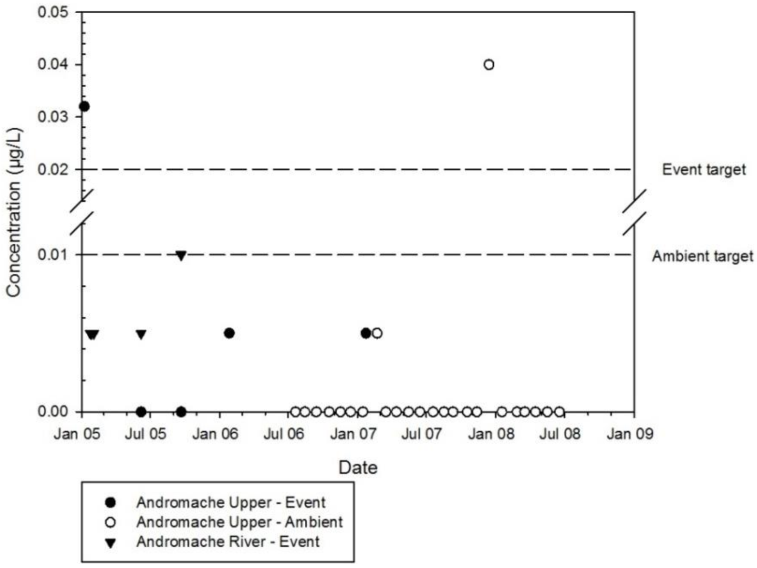

Figure 110 Temporal variation in atrazine concentrations during ambient and event conditions at Upper Andromache River and Andromache River from 2004–2008. Dashed lines indicate the 2014 ambient and event atrazine targets for the Andromache River Catchment Management Area.

The majority of ambient and event concentrations of diuron in Andromache River were at or below the 2014 ambient and event target (0.01 µg/L) (Figure 111). The three highest concentrations were all event concentrations recorded at the Andromache River site. The highest concentration was 0.06 µg/L, however this was still well below the PC95 ecotoxicity threshold for diuron (0.3 µg/L). There was no temporal linear trend for event concentrations at Andromache River ($p = 0.079$).

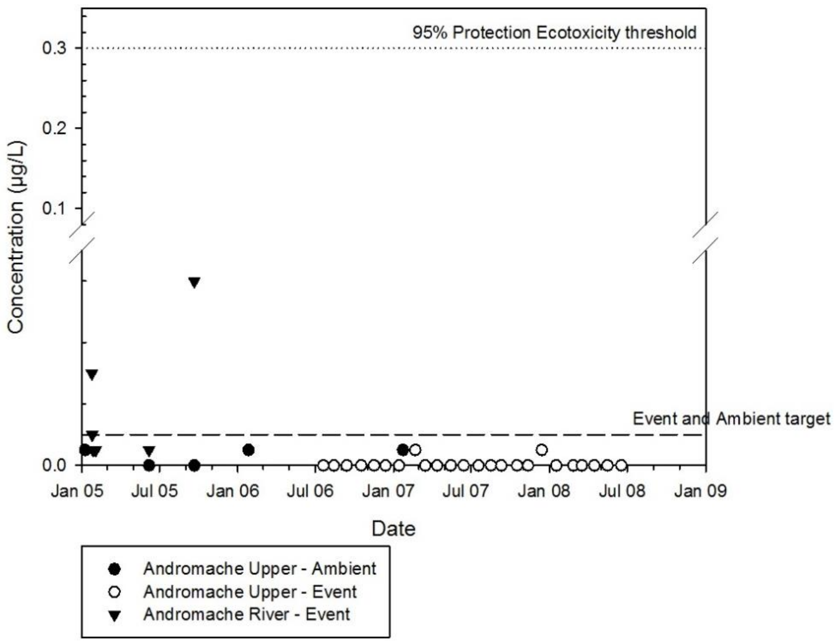

Figure 111 Temporal variation in diuron concentrations during ambient and event conditions at Upper Andromache River and Andromache River from 2004–2008. The dashed line indicates the 2014 ambient and event diuron target for the Andromache River Catchment Management Area. The dotted line indicates the PC95 ecotoxicity threshold for diuron.

The majority of ambient and event concentrations of hexazinone in Andromache River were at or below the 2014 ambient and event target (0.01 µg/L) (Figure 112). The two highest concentrations were event concentrations, one at each site. The highest concentration (0.12 µg/L) was well below the PC95 ecotoxicity threshold for hexazinone (0.7 µg/L). There was no linear temporal trend in event hexazinone concentrations at Upper Andromache River ($p = 0.31$). The Andromache River event concentrations increased over time ($p = 0.030$; $R^2 = 0.729$); however, this was based on only a few samples in one year of sampling. It therefore, cannot be taken as evidence of increasing hexazinone concentrations over time.

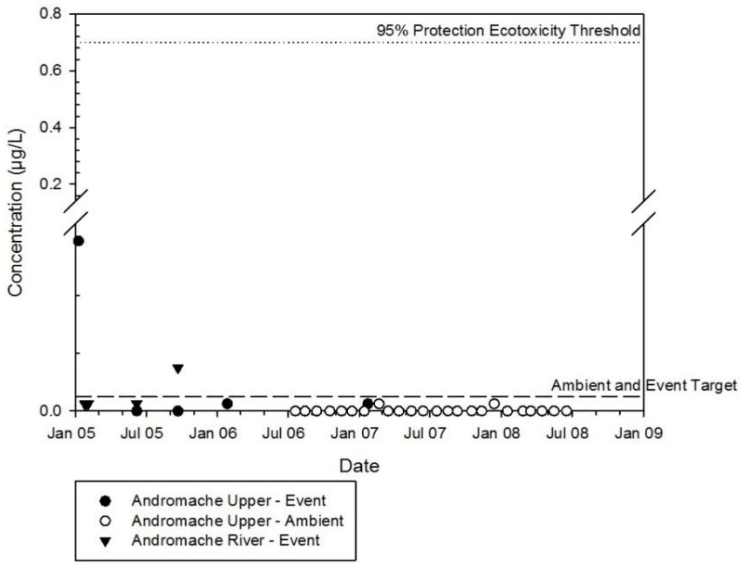

Figure 112 Temporal variation in hexazinone concentrations during ambient and event conditions at Upper Andromache River and Andromache River from 2004–2008. The dashed line indicates the 2014 ambient and event hexazinone target for the Andromache River Catchment Management Area. The dotted line indicates the PC95 ecotoxicity threshold for hexazinone.

All but one of the ambient concentrations of tebuthiuron were at or below the ambient target (0.01 µg/L) (Figure 113), while the majority of event concentrations were above the event target (0.01 µg/L). The ambient concentration above the target, was 0.02 µg/L. All event tebuthiuron concentrations ranged from < LOR–0.48 µg/L. The event results at Upper Andromache River increased over time ($p = 0.037$; $R^2 = 0.813$) but this is based on a limited number of samples over only two years. There was no temporal trend in the event concentrations at the Andromache River site ($p = 0.093$). All concentrations recorded were well below the PC95 ecotoxicity threshold for tebuthiuron (8.8 µg/L).

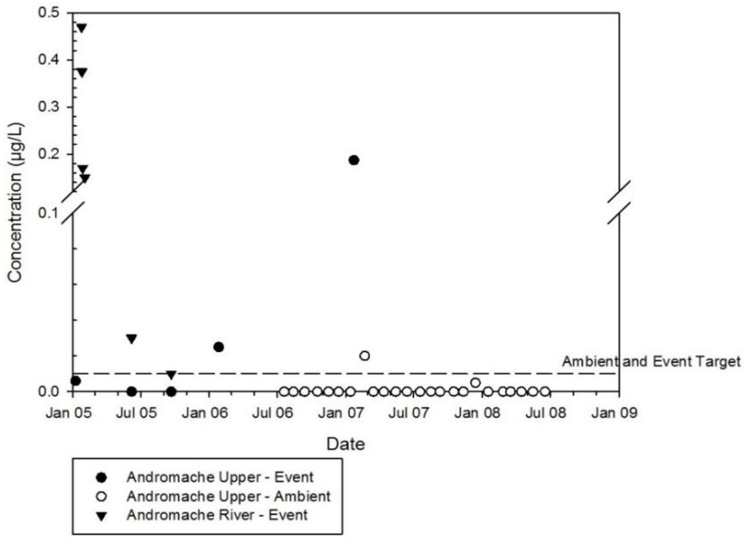

Figure 113 Temporal variation in tebuthiuron concentrations during ambient and event conditions at Upper Andromache River and Andromache River from 2004–2008. The dashed line indicates the 2014 ambient and event tebuthiuron targets for the Andromache River Catchment Management Area.

3.4.1.2 Frequency of trigger value and target exceedances

No event pesticide sampling was conducted for Andromache River subsequent to 2006–2007 (i.e. when the 2014 targets were established); therefore, no assessment of concentration exceedances against the targets was undertaken. Ambient sampling of pesticides was undertaken at Upper Andromache River for one year subsequent to 2006–2007, with a total of 12 ambient samples collected in 2007–2008. Ambient concentrations of ametryn, diuron, hexazinone and tebuthiuron did not exceed the targets in any samples taken. One sample (8 per cent) exceeded the atrazine target.

3.4.2 Bakers Creek

No event pesticide sampling was conducted in Bakers Creek, thus, the following results are based on ambient conditions from 2006–2008.

3.4.2.1 Temporal variation in pesticides and comparison to trigger values and targets

The majority of ambient concentrations of ametryn in Bakers Creek were at or below the ambient target (0.01 µg/L) (Figure 114). Four concentrations (between 0.02 and 0.06 µg/L) were recorded above the LOR. There was no linear temporal trend in ambient concentrations ($p = 0.66$). The three highest concentrations occurred at the start of the year (during the wet season). The highest concentration (0.06 µg/L) was six-times greater than the target. All concentrations were below the PC95 ecotoxicity threshold for ametryn (0.1 µg/L).

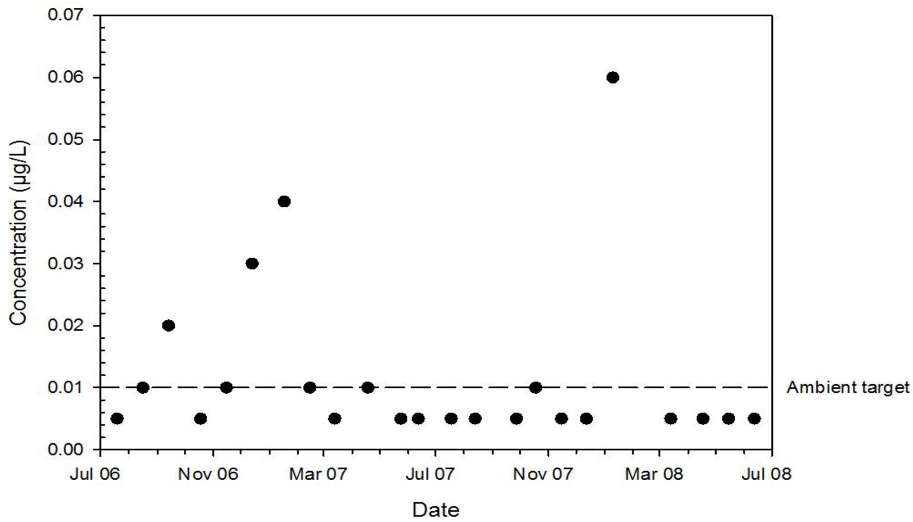

Figure 114 Temporal variation in ametryn concentrations during ambient conditions at Bakers Creek from 2006–2008. The dashed line indicates the 2014 ambient ametryn target for the Bakers Creek Catchment Management Area.

The ambient concentrations of atrazine in Bakers Creek varied over the sampling period with the recent years generally having lower concentrations, though there was no temporal trend (p = 0.29) (Figure 115). Approximately half of the concentrations were below the target (0.17 µg/L). The highest concentration (14 µg/L) was 82-times greater than the ambient target, and was also well above the event target for this CMA (0.83 µg/L). This concentration occurred during the wet season. All concentrations were well below the PC95 ecotoxicity threshold for atrazine (6 µg/L).

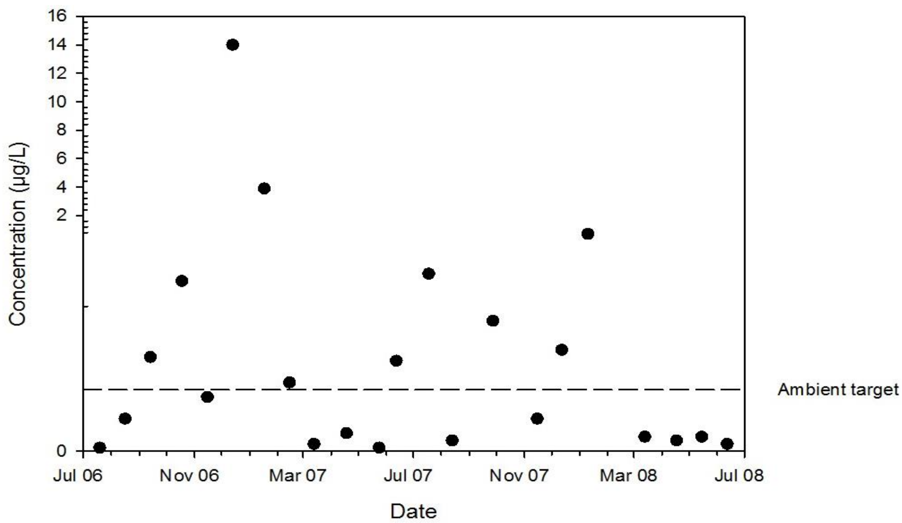

Figure 115 Temporal variation in atrazine concentrations during ambient conditions at Bakers Creek from 2006–2008. The dashed line indicates the 2014 ambient atrazine target for the Bakers Creek Catchment Management Area.

The ambient concentrations of diuron in Bakers Creek were between < LOR and 14 µg/L with no linear temporal trend (p = 0.34) (Figure 116). The highest peaks occurred in the wet seasons, in early 2007 and early 2008. Approximately half of the concentrations were at or below the ambient target (0.11 µg/L) (Figure 116). The highest concentration of 14 µg/L was

127-times greater than the ambient target. This was also well above the event target for this CMA (1.38 µg/L), and above the PC95 ecotoxicity threshold for diuron (0.3 µg/L).

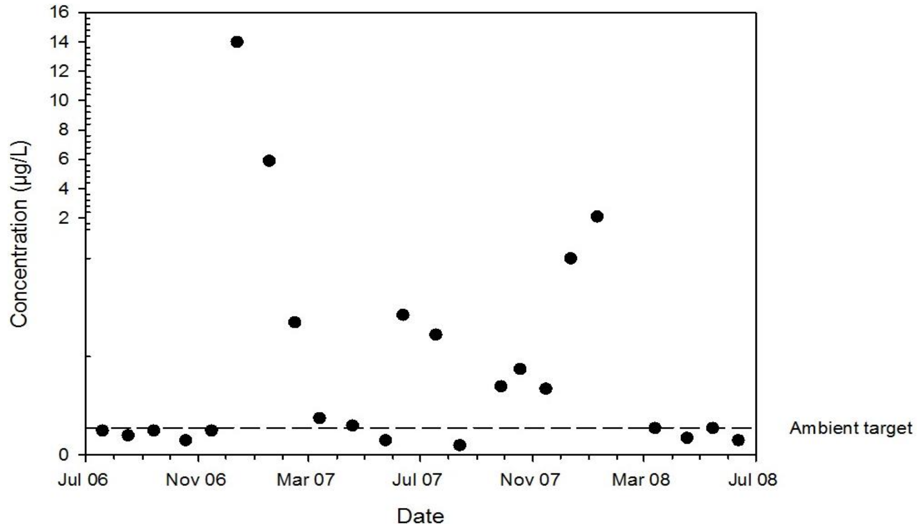

Figure 116 Temporal variation in diuron concentrations during ambient conditions at Bakers Creek from 2006–2008. The dashed line indicates the 2014 ambient diuron target for the Bakers Creek Catchment Management Area.

The majority of ambient concentrations of hexazinone in Bakers Creek were predominantly between < LOR and 0.22 µg/L, with five values occurring between 0.25 and 4.4 µg/L (Figure 117). There was no linear temporal trend ($p = 0.28$) in hexazinone concentrations. The highest peaks occurred during the wet seasons in early 2007 and early 2008. The majority of the concentrations were at or below the ambient target (0.14 µg/L). The highest concentration (4.4 µg/L) was 31-times greater than the ambient target; above the event target for this CMA (0.56 µg/L); and above the PC95 ecotoxicity threshold for hexazinone (0.7 µg/L).

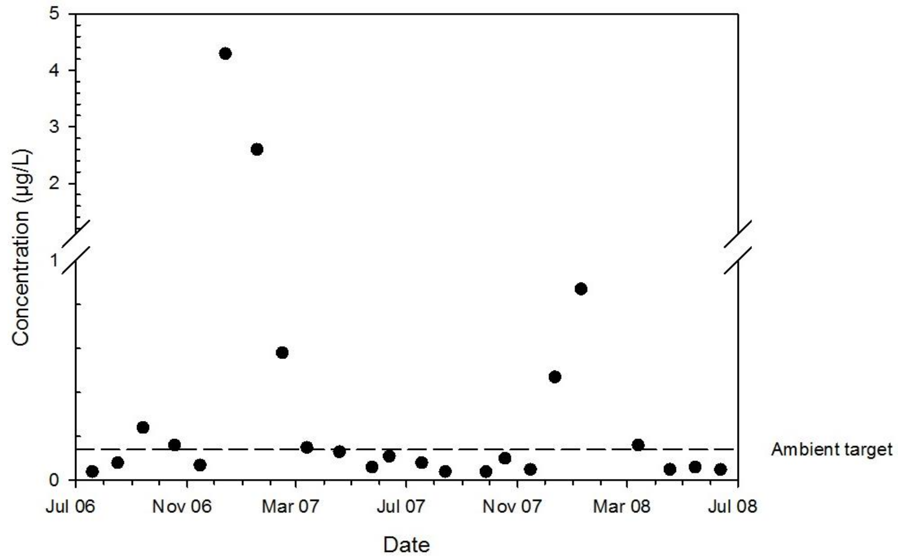

Figure 117 Temporal variation in hexazinone concentrations during ambient conditions at Bakers Creek from 2006–2008. The dashed line indicates the 2014 ambient hexazinone target for the Bakers Creek Catchment Management Area.

The ambient concentrations of tebuthiuron were below the target (0.01 µg/L) for 22 out of 23 of the samples (data not shown). One concentration above the target (0.04 µg/L) occurred in November 2006; however, it was well below the PC95 ecotoxicity threshold for tebuthiuron (8.8 µg/L). There was no temporal trend over time (p = 0.31).

3.4.2.2 Frequency of trigger value and target exceedances

No event sampling of pesticides was conducted for Bakers Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established); therefore, no assessment of exceedances against the targets can be undertaken. Ambient sampling of pesticides at Bakers Creek was undertaken for one year subsequent to 2006–2007, with a total of 11 ambient samples taken in 2007–2008. The ametryn target was exceeded in 9 per cent of samples. The atrazine concentrations exceeded the target in 45 per cent of samples. Diuron concentrations exceeded the target in 55 per cent of samples. The hexazinone target was exceeded in 27 per cent of samples, and the tebuthiuron target was not exceeded in any sample.

3.4.3 Basin Creek

3.4.3.1 Temporal variation in pesticides and comparison to trigger values and targets

All ambient and event concentrations for ametryn, hexazinone and tebuthiuron were < LOR.

The majority of ambient concentrations of atrazine in Basin Creek were at or below the ambient target (0.01 µg/L) (Figure 118). There were no linear temporal trends in either the ambient (p = 0.15) or event (p = 0.082) concentrations. There were two ambient concentrations above the target (both 0.02 µg/L); both concentrations occurred in early 2008. The majority of event concentrations of atrazine exceeded the event target (0.02 µg/L). Event concentrations were much higher in early 2007 (0.185 µg/L) compared to preceding years (a maximum of 0.04 µg/L); however, this was not a significant trend. The 2007 event concentrations were both above the event target. All concentrations were well below the PC95 ecotoxicity threshold for atrazine of 6 µg/L.

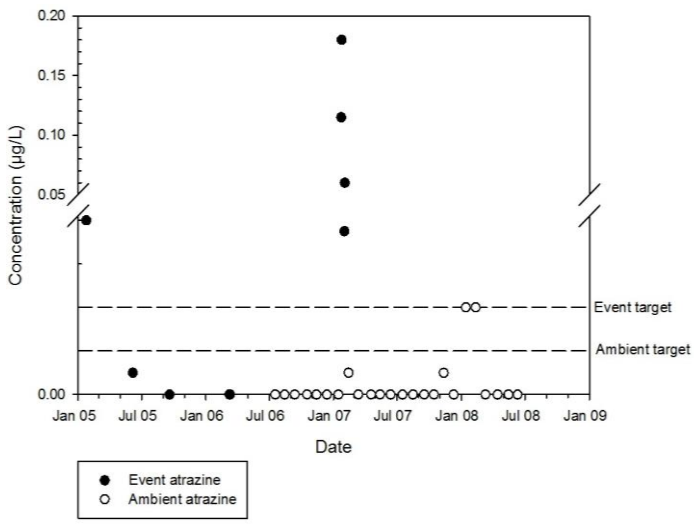

Figure 118 Temporal variation in atrazine concentrations during ambient and event conditions at Basin Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event atrazine targets for the Gillinbin Creek Catchment Management Area.

The majority of ambient diuron concentrations in Basin Creek were at or below the ambient target (0.01 µg/L) (Figure 119). One ambient concentration occurred above the target (0.02 µg/L) in early 2007. All ambient concentrations were below the PC95 ecotoxicity threshold for diuron (0.3 µg/L). The majority of event concentrations of diuron exceeded the event target (0.05 µg/L). The event concentrations were much higher in early 2007 (0.46 µg/L) compared to early 2005 (0.12 µg/L). The highest concentration was above the PC95 ecotoxicity threshold for diuron (0.3 µg/L). There was no linear temporal trend in either the ambient (p = 0.68) or event concentrations (p = 0.076).

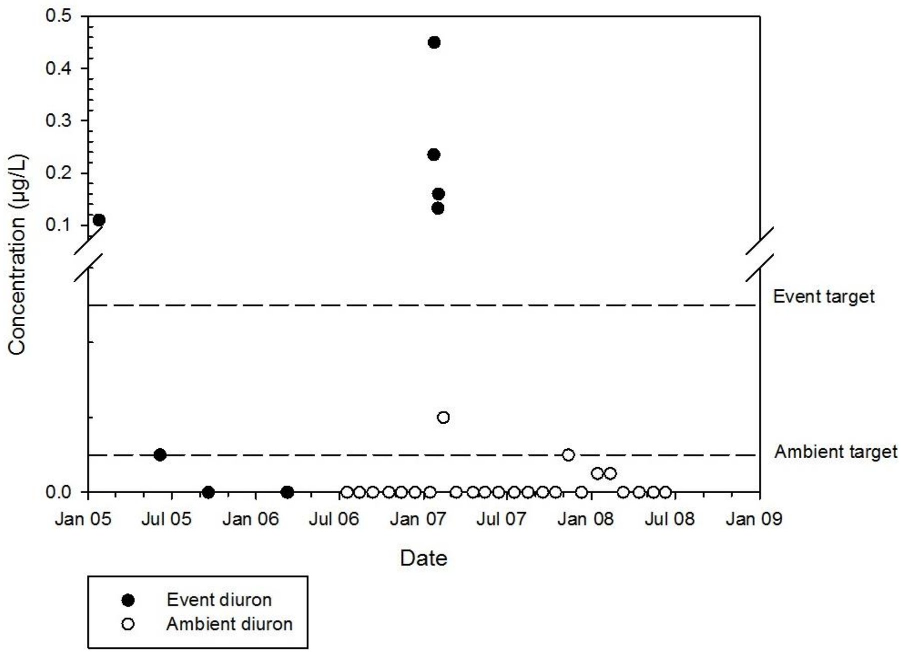

Figure 119 Temporal variation in diuron concentrations during ambient and event conditions at Basin Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event diuron targets for the Gillinbin Creek Catchment Management Area.

3.4.3.2 Frequency of trigger value and target exceedances

No event pesticide sampling was conducted for Basin Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established); therefore, no assessment of event concentration exceedances against the targets was undertaken. Ambient sampling of pesticides was undertaken in Basin Creek for one year subsequent to 2006–2007, with a total of 12 ambient samples taken in 2007–2008. Ambient concentrations of ametryn, hexazinone, and tebuthiuron did not exceed the targets in any samples taken. The concentrations of atrazine exceeded the target in 17 per cent of samples taken, and 8 per cent of the samples exceeded the diuron target.

3.4.4 Blacks Creek

No ambient pesticide sampling was undertaken at Blacks Creek, thus, the following results are based on event conditions from 2004–2007.

3.4.4.1 Temporal variation in pesticides and comparison to trigger values and targets

All event concentrations of ametryn, atrazine and tebuthiuron were ≤LOR (0.01 µg/L). As the sampling for Blacks Creek was limited to only three samples, it was not possible to discern any temporal trend in concentrations of diuron (Figure 120). Two concentrations were below the event target (0.06 µg/L), and one was above. The highest concentration (0.18 µg/L) occurred in January 2007. This concentration was three-times greater than the target, however it was below the PC95 ecotoxicity threshold for diuron (0.3 µg/L).

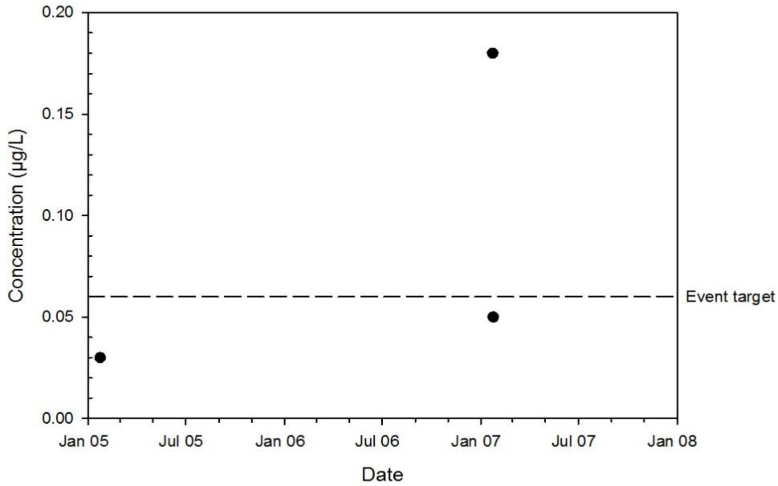

Figure 120 Temporal variation in diuron concentrations during event conditions at Blacks Creek from 2004–2007. The dashed line indicates the 2014 event diuron target for the Blacks Creek Catchment Management Area.

As the sampling for Blacks Creek was limited to only three samples, it was not possible to discern any linear temporal trend in hexazinone concentrations (Figure 121). Two concentrations were above the event target (0.03 µg/L), and one was below. The highest concentration of hexazinone (0.22 µg/L) occurred in early 2005, and was seven-times greater than the target, however it was below the hexazinone PC95 ecotoxicity threshold (0.7 µg/L).

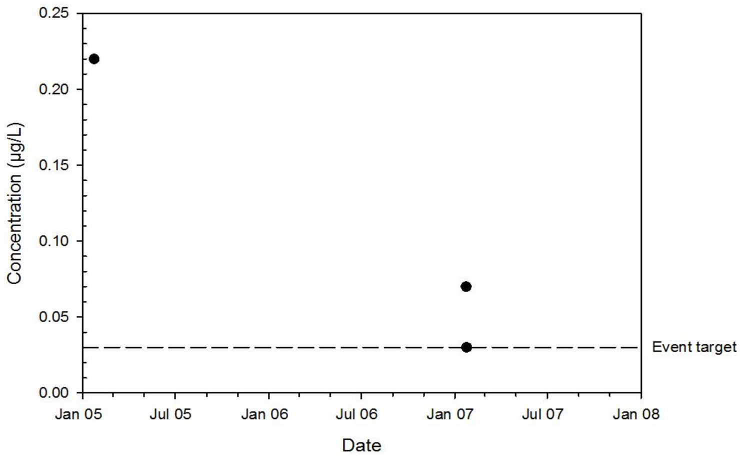

Figure 121 Temporal variation in hexazinone concentrations during event conditions at Blacks Creek from 2004–2007. The dashed line indicates the 2014 event hexazinone target for the Blacks Creek Catchment Management Area.

3.4.4.2 Frequency of trigger value and target exceedances

No pesticide sampling was conducted for Blacks Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established); therefore, no assessment of concentration exceedances against the targets can be undertaken.

3.4.5 Carmila Creek

3.4.5.1 Temporal variation in pesticides and comparison to trigger values and targets

All event concentrations for ametryn (data not shown) were below the target (0.01 µg/L). One ambient concentration of ametryn was recorded above the target, with a concentration of 0.3 µg/L.

All ambient and event concentrations for tebuthiuron (data not shown) were below the target (0.01 µg/L).

Ambient concentrations of atrazine at Carmila Creek were fairly consistent from 2006–2008, with no linear temporal trend ($p = 0.76$) (Figure 122). There was one higher value (0.12 µg/L) in early 2008. The majority of ambient concentrations of atrazine were below the ambient target (0.01 µg/L). The highest ambient concentration (0.12 µg/L) was 12-times greater than the ambient target. The event concentrations appeared to increase over time; however, there was no linear temporal trend ($p = 0.07$) (Figure 122). The majority of event concentrations were at or below the target of 0.04 µg/L. The highest event concentration was 0.084 µg/L, which was two-times greater than the event target. All concentrations were below the PC95 ecotoxicity threshold for atrazine (6 µg/L).

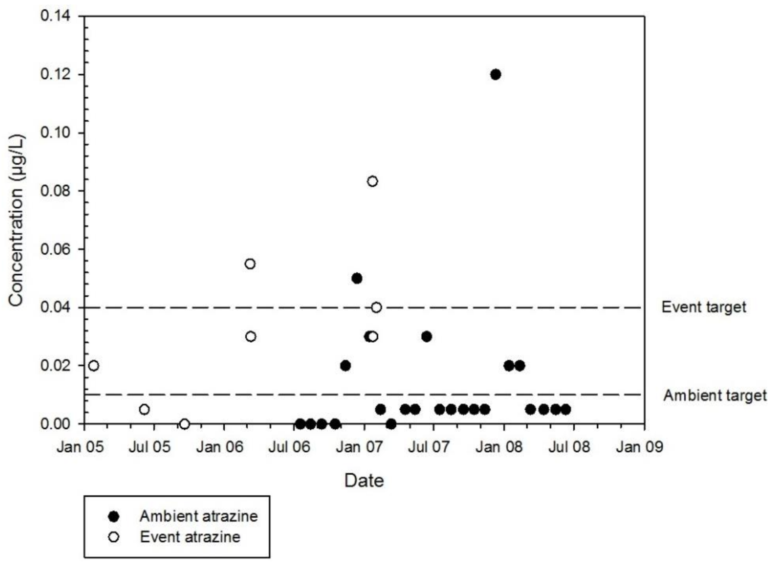

Figure 122 Temporal variation in atrazine concentrations during ambient and event conditions at Carmila Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event atrazine targets for the Carmila Creek Catchment Management Area.

Ambient and event concentrations of diuron at Carmila Creek were scattered from 2004–2008 (Figure 123). There was no linear temporal trend in ambient concentrations ($p = 0.48$) or event concentrations ($p = 0.08$). The majority of the ambient concentrations were at or below the target (0.01 µg/L). The highest ambient concentration was 1.0 µg/L, 100-times greater than the ambient target. All but one of the event concentrations were below the target (0.46 µg/L) (Figure 123). The highest event concentration was 1.0 µg/L, which was twice the target. A limited number of ambient and event concentrations occurred above the PC95 ecotoxicity threshold for diuron (0.3 µg/L).

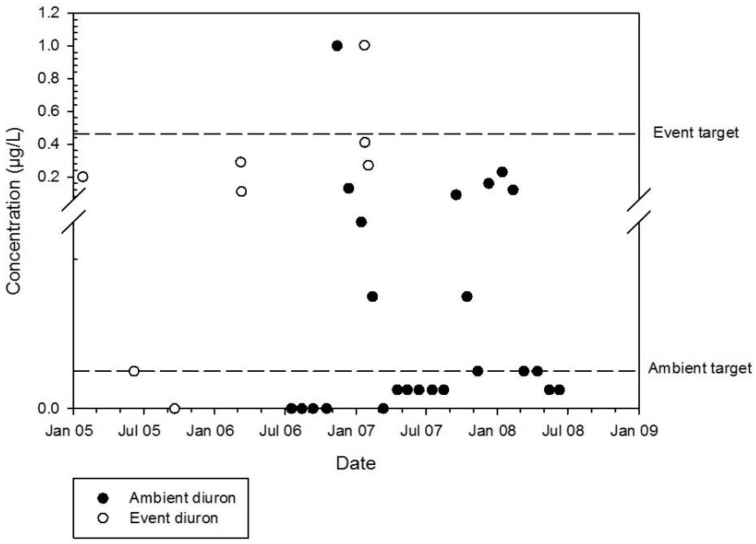

Figure 123 Temporal variation in diuron concentrations during ambient and event conditions at Carmila Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event diuron targets for the Carmila Creek Catchment Management Area.

Ambient concentrations of hexazinone at Carmila Creek from 2004–2008 were scattered, with no linear temporal trend ($p = 0.88$) (Figure 124). The majority of the concentrations were above the ambient target (0.01 µg/L). The highest ambient concentration (0.46 µg/L) was 46-times greater than the ambient target. Event concentrations of hexazinone at Carmila Creek were also scattered from 2004–2007, with no linear temporal trend ($p = 0.071$) (Figure 124). The majority of event concentrations were below the event target (0.23 µg/L). The highest event concentration (0.58 µg/L) was two-times greater than the event target. All ambient and event concentrations were below the PC95 ecotoxicity threshold for hexazinone (0.7 µg/L).

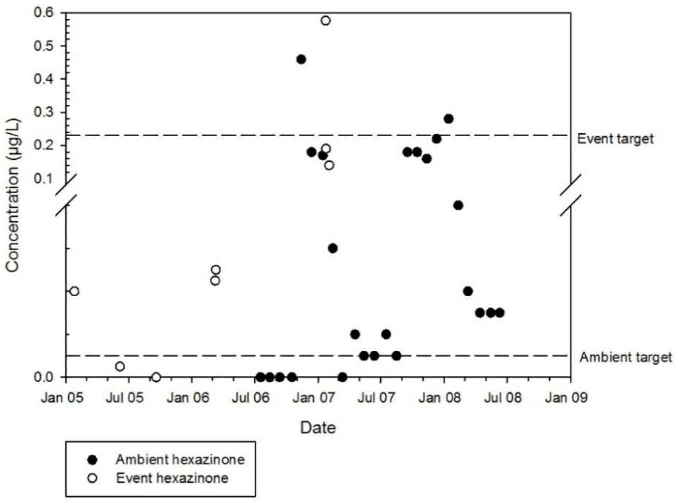

Figure 124 Temporal variation in hexazinone concentrations during ambient and event conditions at Carmila Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event hexazinone targets for the Carmila Creek Catchment Management Area.

3.4.5.2 Frequency of trigger value and target exceedances

No event pesticide sampling was conducted for Carmila Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established); therefore, no assessment of exceedances against the event targets can be undertaken. Ambient sampling of pesticides was undertaken in Carmila Creek for one year subsequent to 2006–2007, with a total of 12 ambient samples taken in 2007–2008. Ambient concentrations of ametryn and tebuthiuron did not exceed the targets in any samples taken. The concentrations of atrazine exceeded the target in 25 per cent of samples, diuron concentrations exceeded the target in 42 per cent of samples, and 92 per cent of the samples exceeded the hexazinone target.

3.4.6 Finch Hatton Creek

3.4.6.1 Temporal variation in pesticides and comparison to trigger values and targets

All ambient or event concentrations of all pesticides were 0.01 µg/L or below at Finch Hatton Creek, therefore the results have not been graphed.

One ambient sample had an atrazine concentration of 0.01 µg/L; therefore, exceeding the ambient target of < LOR. This concentration occurred in January 2007, during the wet season. The PC95 and PC99 ecotoxicity thresholds for atrazine are 6 µg/L and 3.7 µg/L, respectively, so the atrazine concentrations in Finch Hatton were well below both of these thresholds.

3.4.6.2 Frequency of trigger value and target exceedances

No event pesticide sampling was conducted for Finch Hatton Creek subsequent to 2006–2007, therefore no assessment of exceedances against the event targets can be undertaken. Ambient sampling of pesticides was undertaken in Finch Hatton Creek in 2007–2008, with a total of 12 samples taken; however, no pesticide concentrations exceeded the targets in any sample.

3.4.7 Gregory River

No ambient pesticide sampling was undertaken at Gregory River, thus, the following results are based on event conditions from 2004–2007.

3.4.7.1 Temporal variation in pesticides and comparison to trigger values and targets

All event concentrations of ametryn and tebuthiuron recorded at Gregory River were below the LOR, and therefore have not been graphed.

Event concentrations of atrazine at Gregory River were fairly consistent from 2005–2007, apart from one markedly higher value (Figure 125). There was no linear temporal trend ($p = 0.44$). The highest value occurred in early 2005, with a concentration of 4.2 µg/L. The majority of atrazine concentrations were above the event target of 0.06 µg/L. The highest value (4.2 µg/L) was 70-times greater than the target, however it was still below the PC95 ecotoxicity threshold for atrazine (6 µg/L).

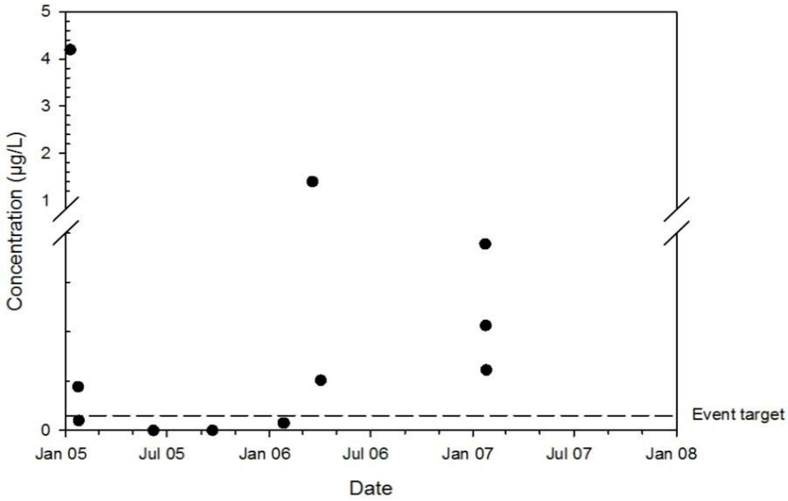

Figure 125 Temporal variation in atrazine concentrations during event conditions at Gregory River from 2004–2007. The dashed line indicates the 2014 event atrazine target for the Gregory River Catchment Management Area.

The majority of event concentrations of diuron at Gregory River varied from < LOR to 1.5 µg/L, with one markedly higher value (6.5 µg/L) and there was no linear temporal trend over the sampling period (p = 0.41) (Figure 126). The highest value occurred in early 2005, after which the concentrations decreased in mid-2005, and slowly increased into early 2007. The majority of diuron concentrations were above the event target (0.31 µg/L). The highest value had a concentration of 6.5 µg/L, 20-times greater than the target. The PC95 ecotoxicity threshold for diuron was 0.3 µg/L. This was exceeded by the event target and the majority of the sampled concentrations.

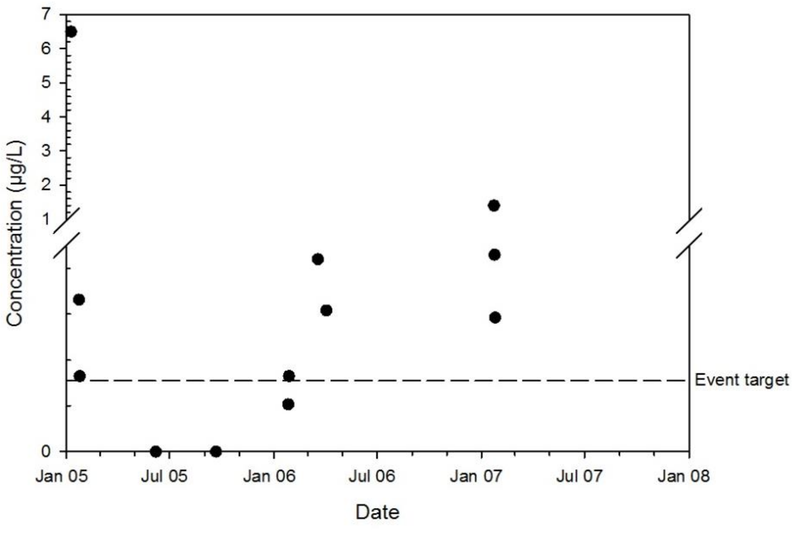

Figure 126 Temporal variation in diuron concentrations during event conditions at Gregory River from 2004–2007. The dashed line indicates the 2014 event diuron target for the Gregory River Catchment Management Area.

The majority of event concentrations of hexazinone at Gregory River varied from < LOR–0.2 µg/L, with no linear temporal trend over time (p = 0.98) (Figure 127). Event concentrations were higher in early 2005, before decreasing in mid-2005, and increasing into early 2007. The majority of hexazinone concentrations were above the event target (0.04 µg/L). There was one markedly higher value (0.45 µg/L) which occurred in early 2005, with a concentration 11-times greater than the target. All hexazinone concentrations were below the PC95 ecotoxicity threshold (0.7 µg/L).

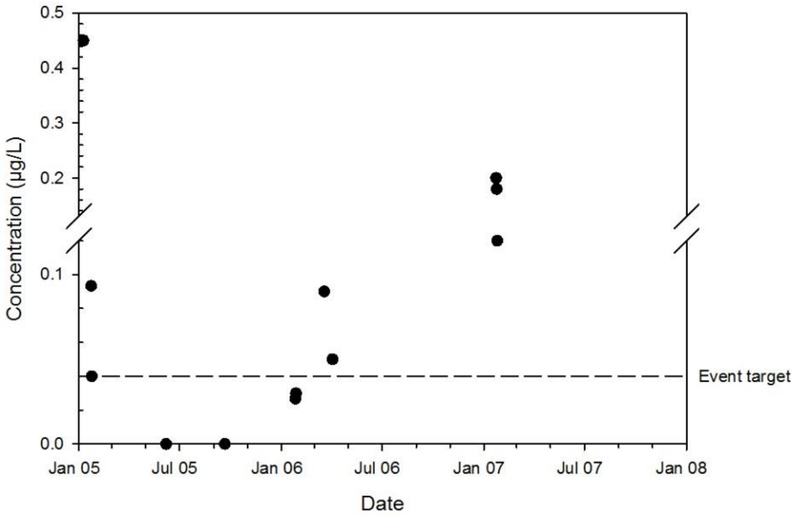

Figure 127 Temporal variation in hexazinone concentrations during event conditions at Gregory River from 2004–2007. The dashed line indicates the 2014 event hexazinone target for the Gregory River Catchment Management Area.

3.4.7.2 Frequency of trigger value and target exceedances

No pesticide sampling was conducted for Gregory River subsequent to 2006–2007, therefore no assessment of exceedances against the event targets can be undertaken.Impulse Creek

3.4.7.3 Temporal variation in pesticides and comparison to trigger values and targets

All ambient concentrations and the majority of event concentrations for all pesticides in Impulse Creek were < LOR and hence were not graphed.

In samples from 14/05/2006 both ametryn (0.03 µg/L) and atrazine (0.02 µg/L) were detected. Additionally, in one event sample from 13/12/2006 (during the wet season) diuron was detected, at a concentration of 0.01 µg/L. All samples excluding these three concentrations, were below the 2014 ambient and event target of < LOR.

3.4.7.4 Frequency of trigger value and target exceedances

No event pesticide sampling was conducted in Impulse Creek subsequent to 2006–2007, therefore no assessment of exceedances against the event targets can be undertaken. Ambient sampling of pesticides was undertaken in Impulse Creek in 2007–2008, with a total of 12 samples taken; however, no pesticide concentrations exceeded the targets in any sample.

3.4.8 Mackay City

No ambient sampling for pesticides was conducted at either of the Mackay sampling locations, thus, the following results are based on event conditions from 2004–2007.

3.4.8.1 Temporal variation in pesticides and comparison to trigger values and targets

Pesticide concentrations were all below the LOR in event samples from the Mackay 2 site. At the Mackay 1 site, there were no event concentrations of ametryn, atrazine or tebuthiuron higher than the LOR. These results have, therefore, not been graphed.

One hexazinone concentration was above 0.01 µg/L, this was from 09/01/2006 (0.03 µg/L). This concentration was below the event target of 0.51 µg/L and the PC95 ecotoxicity threshold for hexazinone (0.7 µg/L). There was no linear temporal trend in event hexazinone over the period (p = 0.68) and these results have not been graphed.

Diuron was detected in event samples from nine days, with the highest concentration being 0.38 µg/L (Figure 128). All concentrations were below the diuron event target for the Mackay City Catchment Management Area (1.25 µg/L). The PC95 ecotoxicity threshold for diuron (0.3 µg/L) was exceeded once. There was no linear temporal trend in event diuron concentrations over the period (p = 0.76).

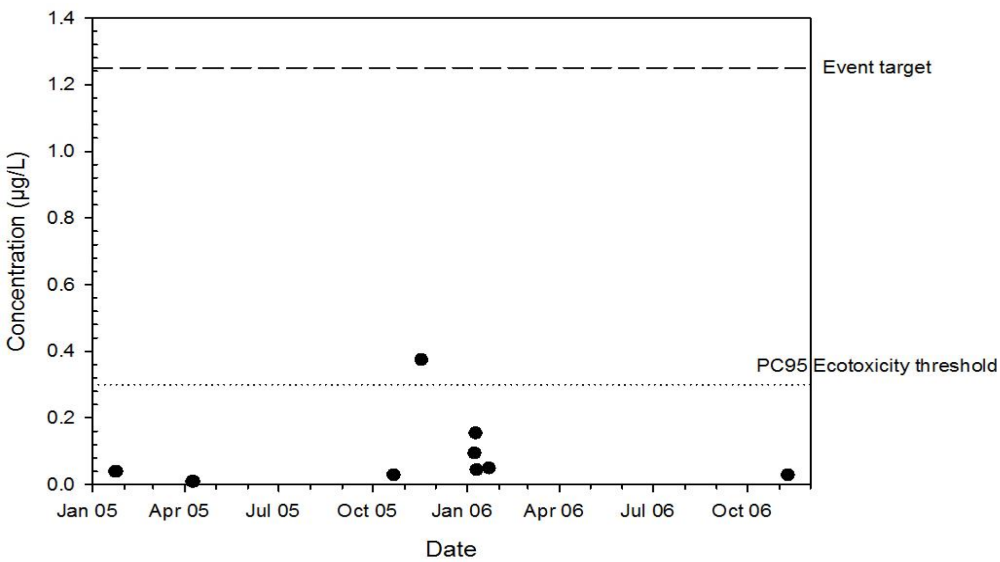

Figure 128 Temporal variation in diuron concentrations during event conditions at Mackay 1 from 2004–2007. The dashed line indicates the 2014 event diuron target for the Mackay City Catchment Management Area. The dotted line indicates the PC95 ecotoxicity threshold for diuron.

3.4.8.2 Frequency of trigger value and target exceedances

No pesticide sampling was conducted at Mackay City (for either site) subsequent to 2006–2007, therefore no assessment of exceedances against the event targets can be undertaken.

3.4.9 Myrtle Creek

3.4.9.1 Temporal variation in pesticides and comparison to trigger values and targets

No ambient or event concentrations of tebuthiuron at Myrtle Creek were detected above the LOR, and therefore, they have not been graphed.

The majority of ambient concentrations of ametryn at Myrtle Creek were consistent from 2006–2008, with no linear temporal trend ($p = 0.69$) (Figure 129). There were two considerably higher values, one in early 2007 (0.5 µg/L) and one in early 2008 (0.9 µg/L). The majority of the ambient concentrations were at or below the target (0.04 µg/L). The highest ambient concentration (0.9 µg/L) was 22-times greater than the ambient target.

Event concentrations of ametryn at Myrtle Creek were variable and covered three events from 2005–2007. There was no linear temporal trend ($p = 0.88$) (Figure 129). Approximately half of the ametryn event concentrations were at or below the event target (0.12 µg/L). The highest event concentration (2.7 µg/L) was 22-times greater than the event target. Many concentrations for both ambient and event concentrations were above the PC95 ecotoxicity threshold (0.1 µg/L).

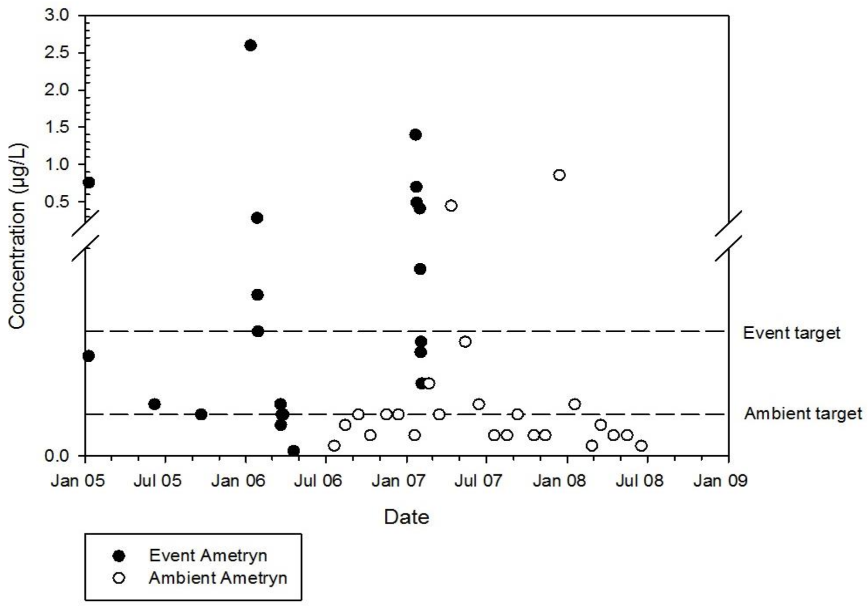

Figure 129 Temporal variation in ametryn concentrations during ambient and event conditions at Myrtle Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event ametryn targets for the Myrtle Creek Catchment Management Area.

The majority of ambient concentrations of atrazine at Myrtle Creek were scattered between < LOR and 0.4 µg/L from 2006–2008, with two higher values (one in early 2007, 1.1 µg/L and one in early 2008, 8.4 µg/L) (Figure 130). There was no linear temporal trend over the sampling period ($p = 0.54$). The majority of the ambient concentrations were at or below the target (0.11 µg/L). The highest ambient concentration (8.4 µg/L) was 76-times greater than the ambient target.

Event concentrations of atrazine at Myrtle Creek covered three events from 2004 to 2007 and were quite variable. There was no linear temporal trend ($p = 0.92$) (Figure 130). The majority of the atrazine event concentrations were at or below the event target (0.94 µg/L). The highest event concentration (5.2 µg/L) was five-times greater than the event target, but below the PC95 ecotoxicity threshold (6 µg/L). All concentrations (both ambient and event) were below the PC95 ecotoxicity threshold.

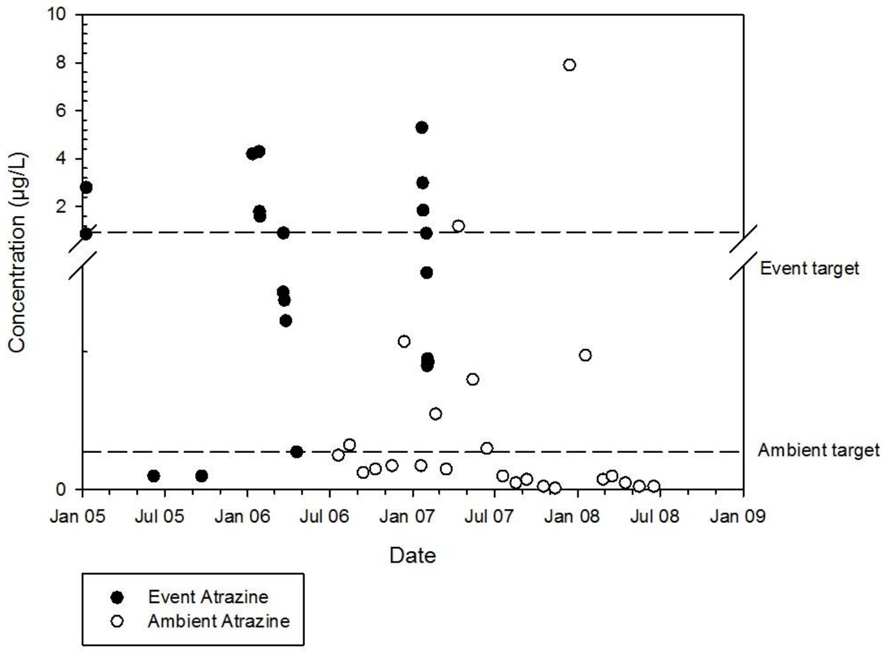

Figure 130 Temporal variation in atrazine concentrations during ambient and event conditions at Myrtle Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event atrazine targets for the Myrtle Creek Catchment Management Area.

Ambient concentrations of diuron in Myrtle Creek were highly variable from 2006–2008 lying between < LOR and approximately 12 µg/L, with no linear temporal trend ($p = 0.36$) (Figure 131). Approximately half of the ambient concentrations were below the ambient target (0.11 µg/L), with the highest concentration (12 µg/L) was 109-times greater than the target and 40-times greater the PC95 ecotoxicity threshold for diuron (0.3 µg/L).

The event concentrations of diuron covered three events from 2004–2007 and were quite variable ranging from <0.1 to 19 µg/L (Figure 131). There was no linear temporal trend ($p = 0.54$). The majority of the diuron event concentrations were above the event target (1.5 µg/L). The highest event concentration (19 µg/L) was 12-times greater than the event target, and 63-times greater than the PC95 ecotoxicity threshold.

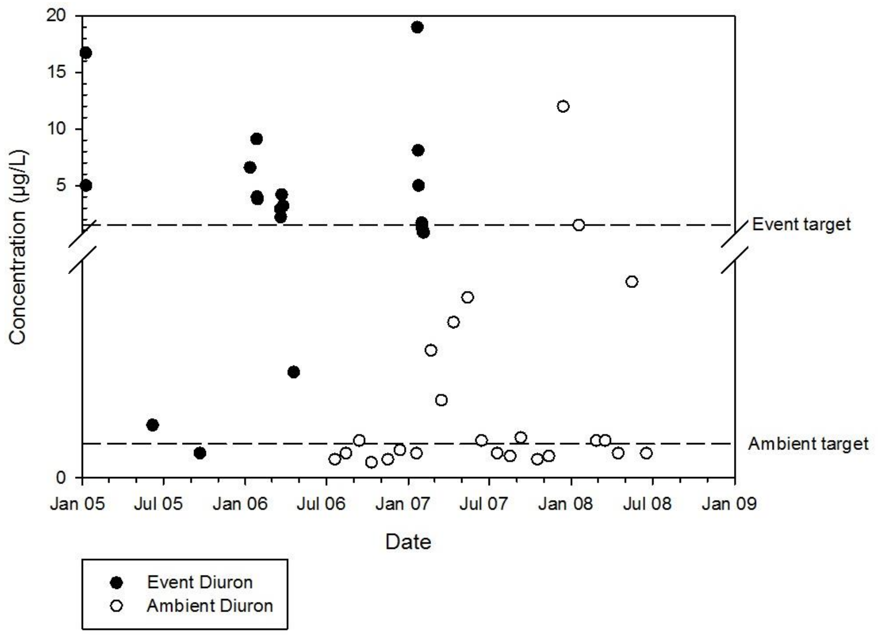

Figure 131 Temporal variation in diuron concentrations during ambient and event conditions at Myrtle Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event diuron targets for the Myrtle Creek Catchment Management Area.

Ambient concentrations of hexazinone at Myrtle Creek were fairly consistent from 2006–2008, with no linear temporal trend (p = 0.47) (Figure 132). There was one markedly higher value in early 2008 (4 µg/L) which was 50-times greater than the ambient target (0.08 µg/L), and five-times greater than the PC95 ecotoxicity threshold for hexazinone (0.7 µg/L). The majority of the ambient concentrations were at or below the target.

The event concentrations of hexazinone at Myrtle Creek covered three events from 2004–2007 and were fairly variable and (Figure 132). There was no linear temporal trend (p = 0.18). Approximately half of the hexazinone event concentrations were at or below the event target (0.49 µg/L). The highest event concentration was approximately 7.4 µg/L, which was 15-times greater than the event target and 11-times greater than the PC95 ecotoxicity threshold.

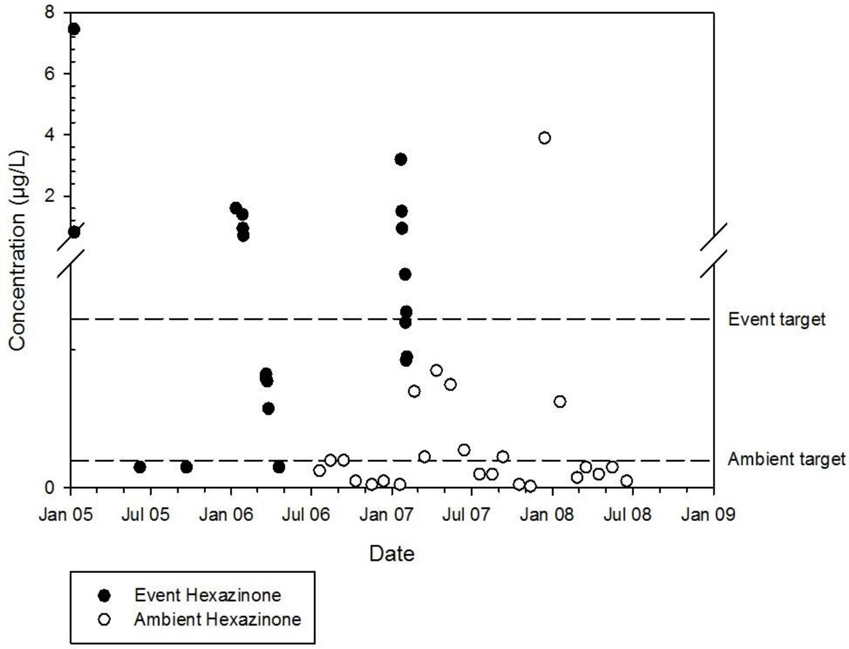

Figure 132 Temporal variation in hexazinone concentrations during ambient and event conditions at Myrtle Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event hexazinone targets for the Myrtle Creek Catchment Management Area.

3.4.9.2 Frequency of trigger value and target exceedances

No event pesticide sampling was conducted for Myrtle Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of exceedances against the event targets was undertaken. Ambient sampling of pesticides was for one year subsequent to 2006–2007, with a total of 12 ambient samples taken in 2007–2008. Ambient concentrations of ametryn and atrazine exceeded the target in 17 per cent of samples taken, diuron concentrations exceeded the target in 50 per cent of samples, and 25 per cent of the samples exceeded the hexazinone target. Tebuthiuron concentrations did not exceed the target in any samples.

3.4.10 O'Connell River

The results for both O'Connell 1 and O'Connell 2 sites from 2004–2008 are presented below. No ambient sampling was conducted for O'Connell 2. The O'Connell 1 site had ambient and event samples taken.

3.4.10.1 Temporal variation in pesticides and comparison to trigger values and targets

All ambient and event concentrations of ametryn sampled from O'Connell River (at both sites), were below the LOR, and therefore have not been graphed.

The majority of the ambient concentrations of atrazine in O'Connell River were below the ambient target (0.01 µg/L), with peak concentrations in September 2007 (0.14 µg/L), December 2007 (0.55 µg/L), and January 2008 (0.13 µg/L) (Figure 133). There was no temporal trend in ambient atrazine concentrations ($p = 0.32$). The highest concentration recorded was 0.55 µg/L, 55-times greater than the target. All ambient concentrations were well below the PC95 ecotoxicity threshold for atrazine (6 µg/L).

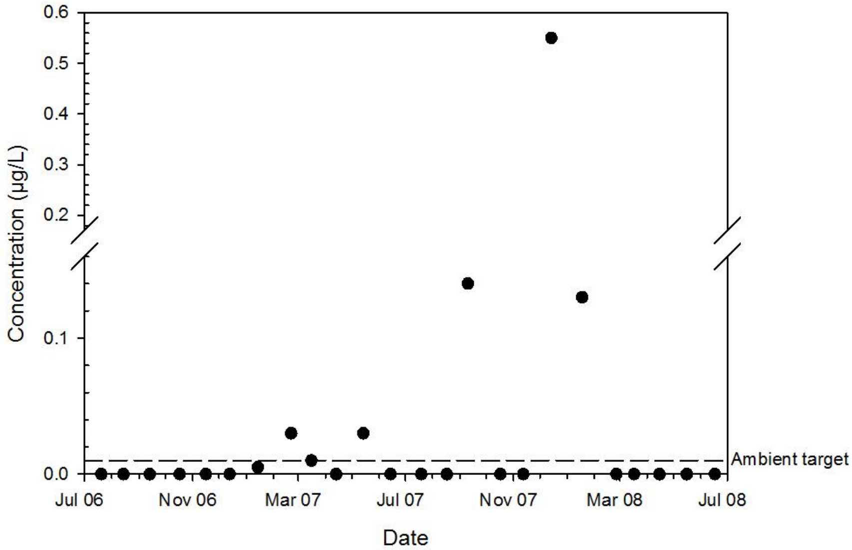

Figure 133 Temporal variation in atrazine concentrations during ambient conditions at O'Connell River from 2004–2008. The dashed line indicates the 2014 ambient atrazine target for the O'Connell River Catchment Management Area.

Median event concentrations of atrazine in O'Connell River were scattered between < LOR and 0.7 µg/L over the sampling period (Figure 134). The results from O'Connell 1 showed an increase in concentrations over time ($p = 0.042$; $R^2 = 0.796$). There was no linear temporal trend in median event concentrations at the O'Connell 2 site ($p = 0.71$) which were low in early 2005, much higher in early 2006 and then lower in early 2008. All median event concentrations were well below the PC95 ecotoxicity threshold for atrazine (6 µg/L).

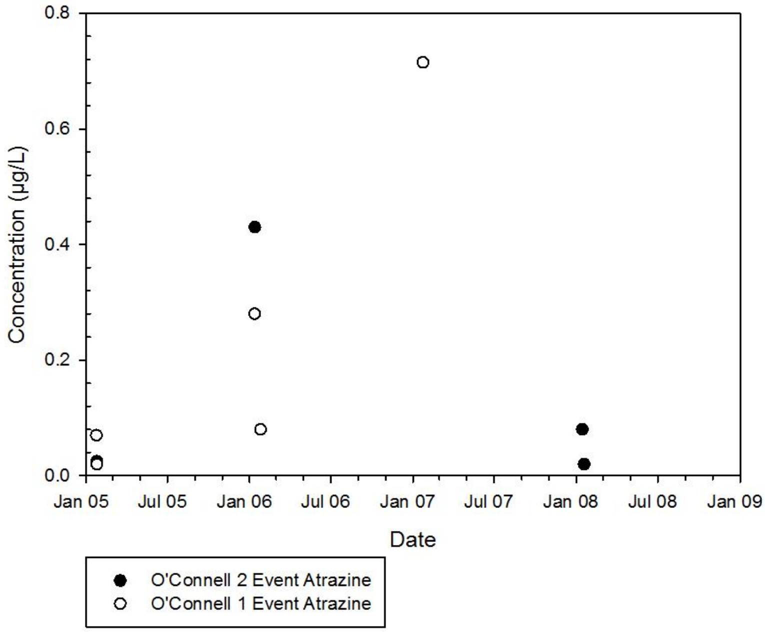

Figure 134 Temporal variation in median atrazine concentrations during event conditions at O'Connell River from 2004–2008. The PC95 ecotoxicity threshold for atrazine has not been plotted as it is 6 mg/L.

The majority of the ambient concentrations of diuron in O'Connell River were below the ambient target (0.01 µg/L), with peak concentrations in December 2007 and January 2008 (Figure 135). These two concentrations were much higher than the previous peak in March 2007 of 0.09 µg/L. There was no linear temporal trend in ambient concentrations ($p = 0.31$). The highest concentration recorded (0.32 µg/L) was 32-times greater than the target. Only one ambient concentration was above the PC95 ecotoxicity threshold for diuron (0.3 µg/L), and two were above the current Australian and New Zealand guideline PC95 value (0.2 µg/L).

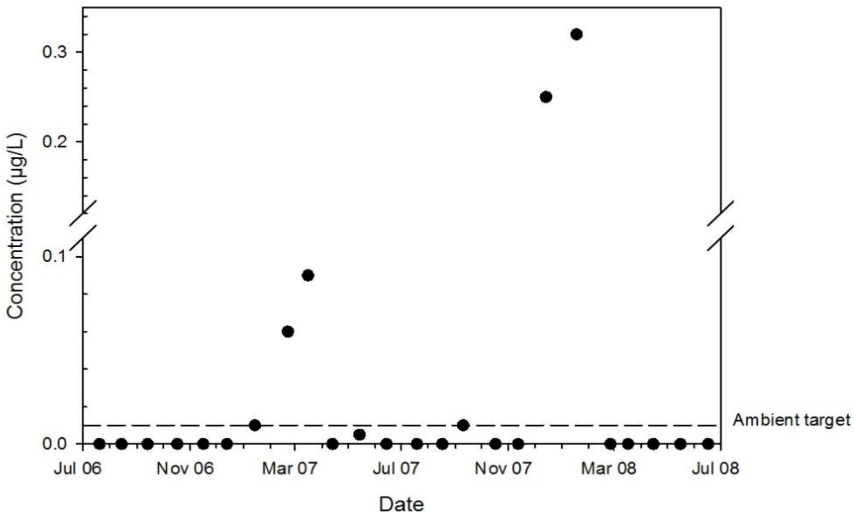

Figure 135 Temporal variation in diuron concentrations during ambient conditions at O'Connell River from 2004–2008. The dashed line indicates the 2014 ambient diuron target for the O'Connell River Catchment Management Area.

Median event concentrations of diuron in the O'Connell River varied over the sampling period (Figure 135). There was no linear temporal trend at O'Connell 1 ($p = 0.31$) or O'Connell 2 ($p = 0.66$); however, the peaks did increase from January 2005 to January 2006, and then decreased from January 2006–January 2008. The highest event concentration recorded was 2.0 µg/L. The majority of median concentrations were above the PC95 ecotoxicity threshold (0.3 µg/L) and the current Australian and New Zealand guideline PC95 value (0.2 µg/L).

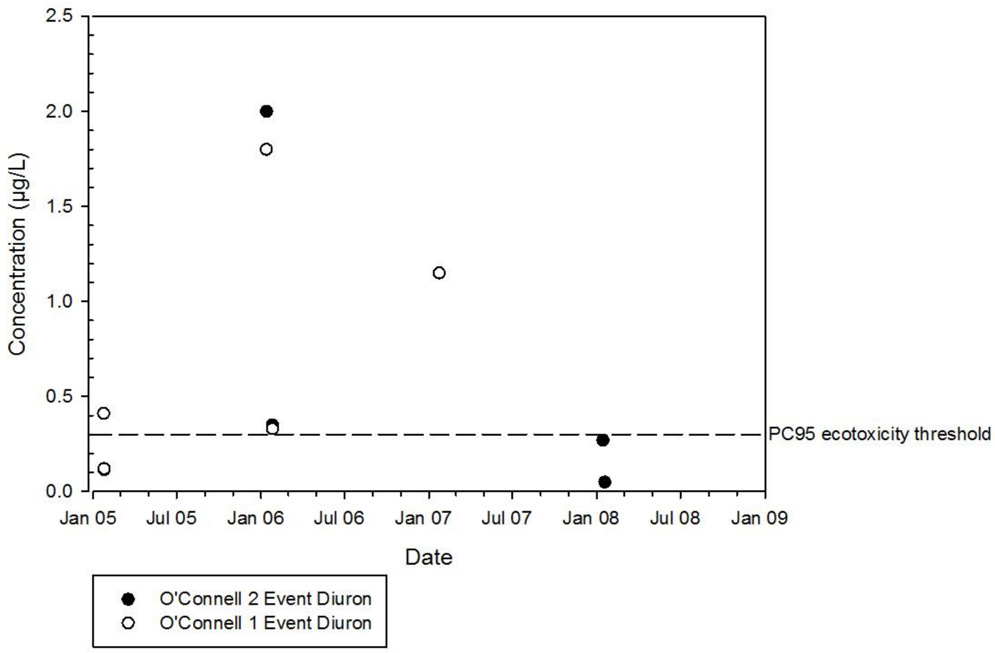

Figure 136 Temporal variation in median diuron concentrations during event conditions at O'Connell River from 2004–2008. The dashed line indicates the PC95 ecotoxicity threshold for diuron.

The majority of the ambient concentrations of hexazinone in O'Connell River were below the ambient target (0.01 µg/L), except on four occasions (Figure 137). While the higher values appeared to increase over time, there was no linear temporal trend across the sampling period (p = 0.43). The highest ambient concentration (0.5 µg/L) was 50-times greater than the target.

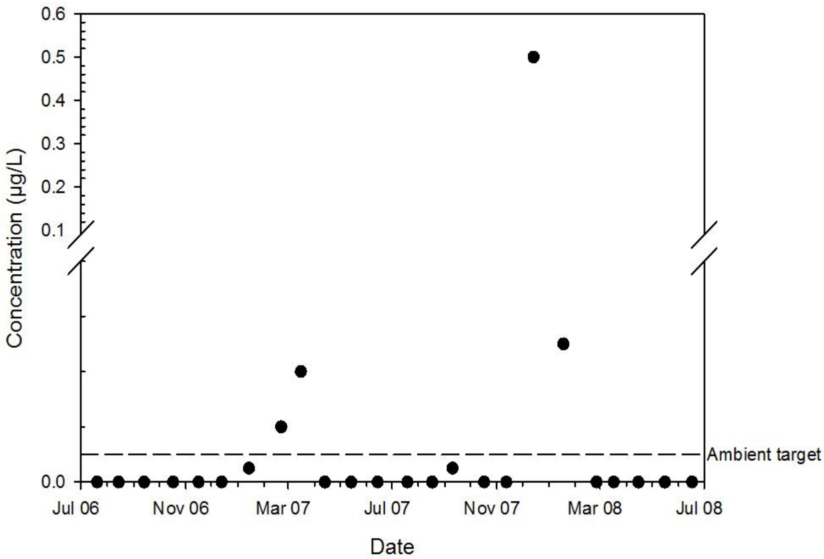

Figure 137 Temporal variation in hexazinone concentrations during ambient conditions at O'Connell River from 2004–2008. The dashed line indicates the 2014 ambient hexazinone target for the O'Connell River Catchment Management Area.

The median hexazinone event concentrations in the O'Connell River showed no linear temporal trend at O'Connell 1 (p = 0.63) or O'Connell 2 (p = 0.71) (Figure 138). The highest event concentrations recorded were 0.29 and 0.28 µg/L. These concentrations were both recorded on the same day (12/01/2006), but at the two different sites. All median event concentrations were below the PC95 ecotoxicity threshold for hexazinone of 0.7 µg/L.

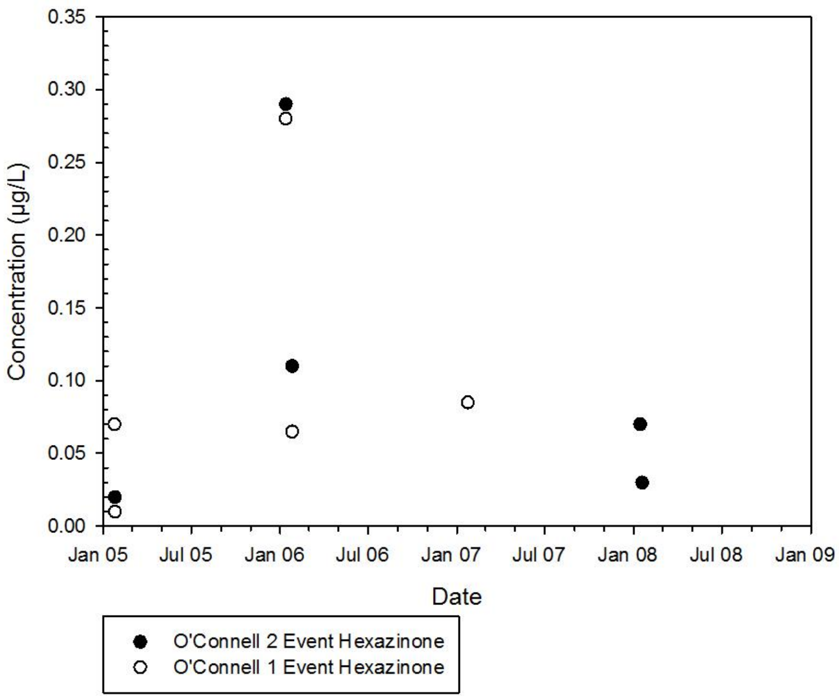

Figure 138 Temporal variation in median hexazinone concentrations during event conditions at O'Connell River from 2004–2008. The PC95 ecotoxicity threshold for hexazinone has not been plotted as it is 0.7 µg/L.

The ambient sampling did not detect any concentrations of tebuthiuron > LOR, therefore these data were not graphed.

The median event concentrations of tebuthiuron in O'Connell River were scattered over the sampling period (Figure 139). No linear temporal trend was seen at either site (O'Connell 1: p = 0.34; O'Connell 2: p = 0.35). The peak median concentration in 2006 (0.91 µg/L) was higher than the peaks in 2005 (0.51 µg/L), 2007 (0.005 µg/L), and 2008 (0.03 µg/L). All concentrations were well below the PC95 ecotoxicity threshold for tebuthiuron (8.8 µg/L).

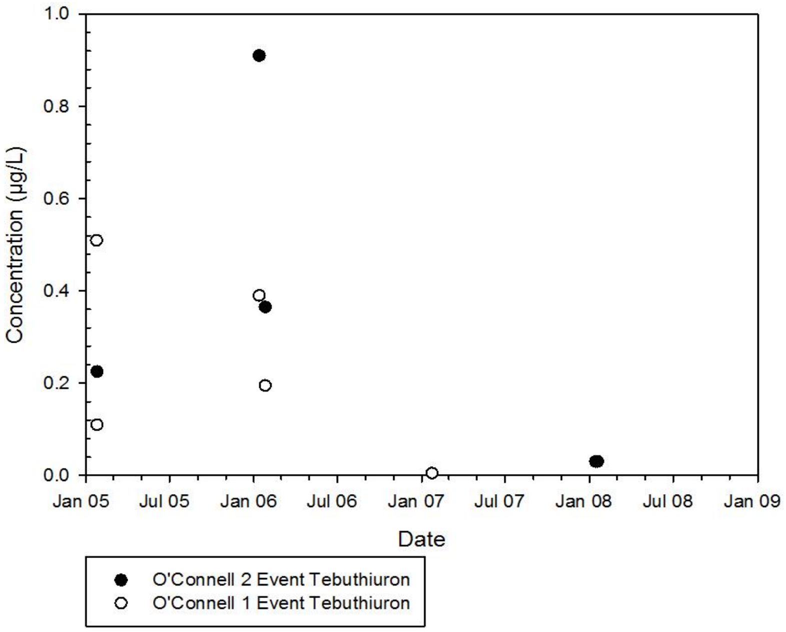

Figure 139 Temporal variation in median tebuthiuron concentrations during event conditions at O'Connell River from 2004–2008. The PC95 ecotoxicity threshold for tebuthiuron has not been plotted as it is 8.8 µg/L.

3.4.10.2 Frequency of trigger value and target exceedances

Ambient and event sampling of pesticides was undertaken at O'Connell River for one year subsequent to 2006–2007. The number of event samples was limited to three and therefore the per cent of samples that exceeded the event target was not determined. In 2007–2008, 12 ambient samples were taken at the O'Connell 1 site. The ametryn targets were not exceeded in any ambient sample (Table 18). Concentrations of atrazine exceeded the targets in 25 per cent of the ambient samples (Table 18). Concentrations of diuron exceeded the targets in 25 per cent of the ambient samples (Table 18). Concentrations of hexazinone exceeded the targets in 17 per cent of the ambient samples (Table 18). Concentrations of tebuthiuron did not exceed the ambient target in any sample taken (Table 18).

Table 18 Per cent of exceedances of the 2014 ambient (O'Connell 1) pesticide targets for O'Connell River for 2007–2008.

	Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron
Per cent exceedances (total no. samples) in ambient samples	0 (12)	25 (12)	25 (12)	17 (12)	0 (12)

3.4.11 Pioneer River

3.4.11.1 Temporal variation in pesticides and comparison to trigger values and targets

The ambient concentrations of ametryn in Pioneer River were consistent across the sampling period (at 0 or 0.005 µg/L), with only one concentration above the ambient target

0.01 µg/L) (Figure 140). This concentration was recorded in January 2008 (0.02 µg/L), but the concentration was still well below the ecotoxicity threshold PC95 level (0.1 µg/L). There was no linear temporal trend in ambient concentrations across the sampling period ($p = 0.77$).

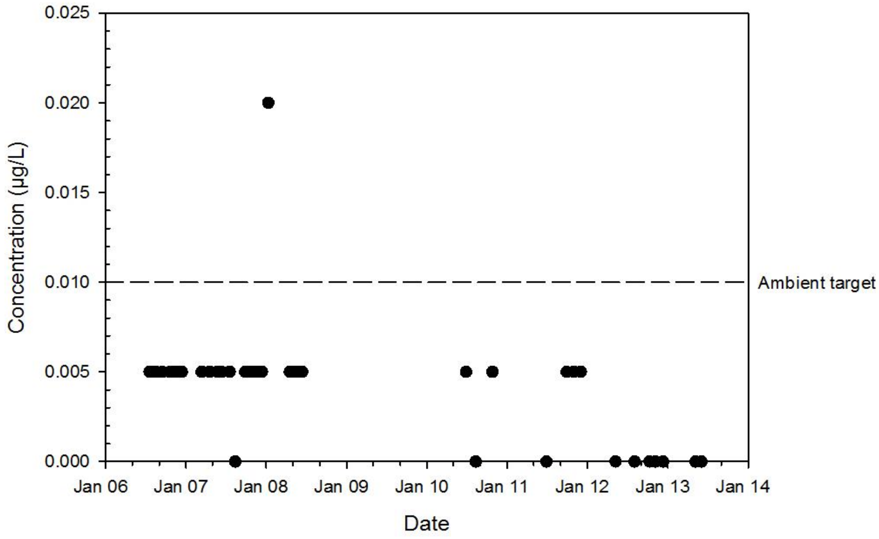

Figure 140 Temporal variation in ametryn concentrations during ambient conditions at Pioneer River from 2006–2013. The dashed line indicates the 2014 ambient ametryn target for the Pioneer River Catchment Management Area.

Event concentrations of ametryn were varied and covered multiple events (Figure 141), with no linear temporal trend ($p = 0.63$). The highest median concentration occurred in January 2010 (0.18 µg/L). All other median concentrations were equal to or below the PC95 ecotoxicity threshold level of 0.1 µg/L.

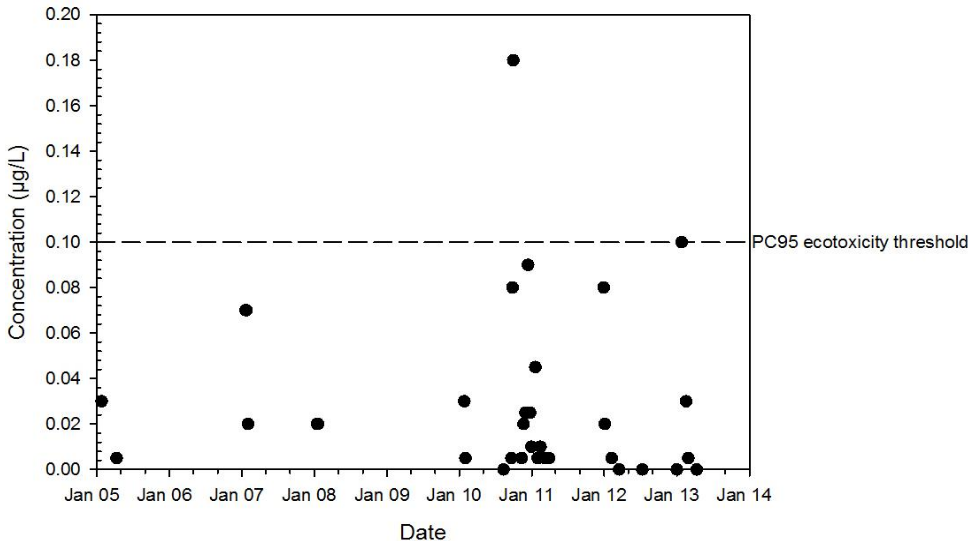

Figure 141 Temporal variation in median ametryn concentrations during event conditions at Pioneer River from 2004–2008. The dashed line indicates the PC95 ecotoxicity threshold for ametryn.

The ambient concentrations of atrazine in the Pioneer River were consistent, with peaks in January 2007, late 2010 and late 2011 (Figure 142). These concentration peaks occurred within the wet season, so may have been associated with event conditions. The majority of the ambient concentrations of atrazine were at or below the ambient target (0.02 µg/L). There was no linear temporal trend in ambient atrazine concentrations (p = 0.90). All median ambient concentrations were below the ecotoxicity threshold PC95 level of 6 µg/L.

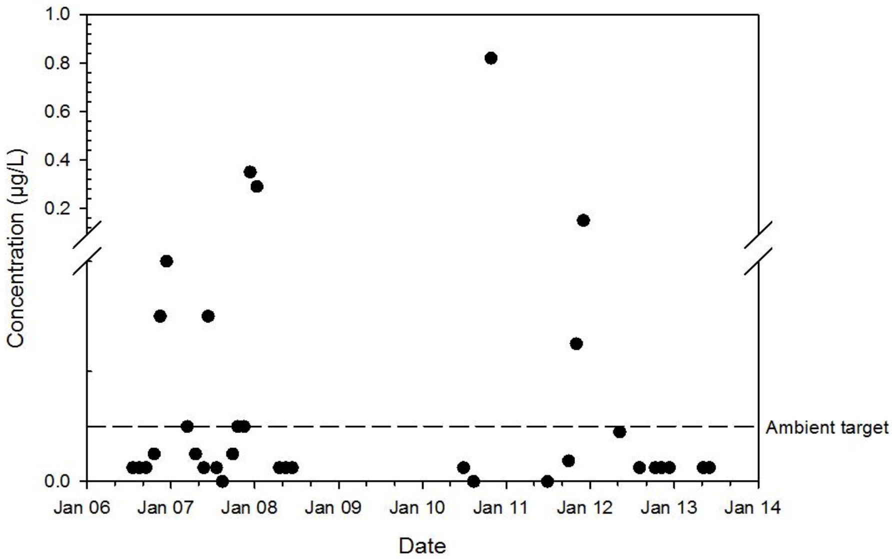

Figure 142 Temporal variation in atrazine concentrations during ambient conditions at Pioneer River from 2006–2013. The dashed line indicates the 2014 ambient atrazine target for the Pioneer River Catchment Management Area.

Median event concentrations of atrazine were scattered and covered multiple events (Figure 143). There was no linear temporal trend (p = 0.23) across the sampling period. All median event concentrations were below the ecotoxicity threshold PC95 level of 6 µg/L. The highest median concentration occurred in January 2007 (2 µg/L), followed by 1.4 µg/L in both December 2011 and January 2013, and 1.2 µg/L in January 2007.

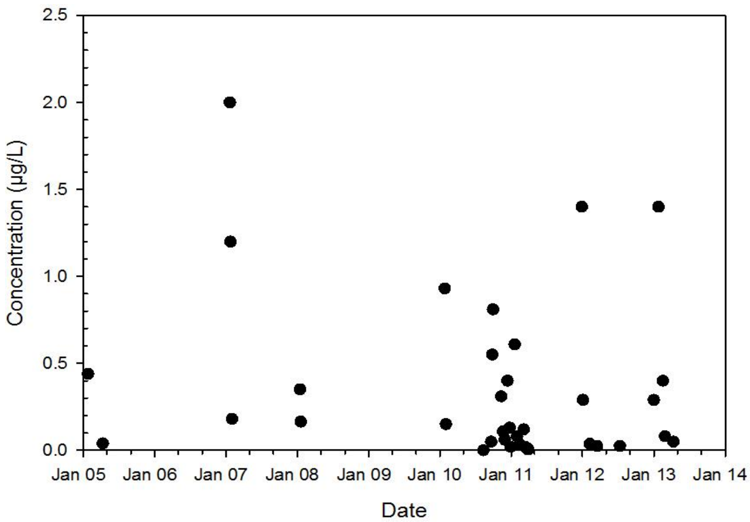

Figure 143 Temporal variation in median atrazine concentrations during event conditions at Pioneer River from 2004–2008. The PC95 ecotoxicity threshold for atrazine has not been plotted as it is 6 µg/L.

The ambient concentrations of diuron in the Pioneer River varied during the sampling period, with no linear temporal trend (p = 0.84) (Figure 144). During the 2006–2008 sampling period the concentrations varied between < LOR and 0.28 µg/L, with approximately half of the concentrations at or below the ambient target (0.02 µg/L). In the 2010–2013 sampling period the majority of the ambient diuron concentrations were below the ambient target, with only two concentrations being higher than the ambient target. The highest concentration was 0.7 µg/L, occurred in the wet season, and was also above the PC95 ecotoxicity threshold for diuron (0.3 µg/L).

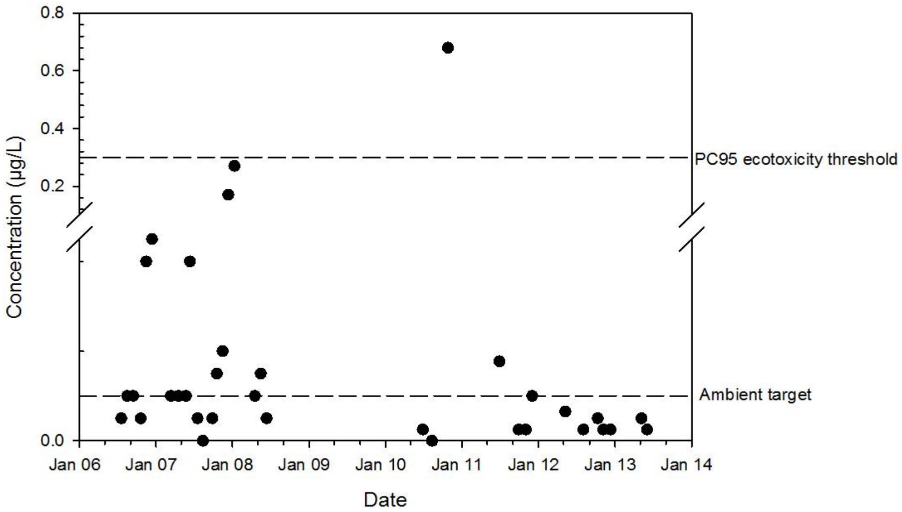

Figure 144 Temporal variation in diuron concentrations during ambient conditions at Pioneer River from 2006–2013. The dashed lines indicate the 2014 ambient diuron target for the Pioneer River Catchment Management Area and the PC95 ecotoxicity threshold.

Median event concentrations of diuron were scattered and did not show any linear temporal trend over the sampling period (p = 0.06) (Figure 145). The event concentrations peaked in the wet season of most years, ranging from 1.5 to 2.2 µg/L. The majority of diuron event concentrations were above the ecotoxicity threshold PC95 level for diuron of 0.3 µg/L. In the 2010–2013 sampling period there were many median concentrations recorded below the toxicity threshold, compared to the 2005–2008 period; however, this could be the result of a larger sampling effort during 2010–2013.

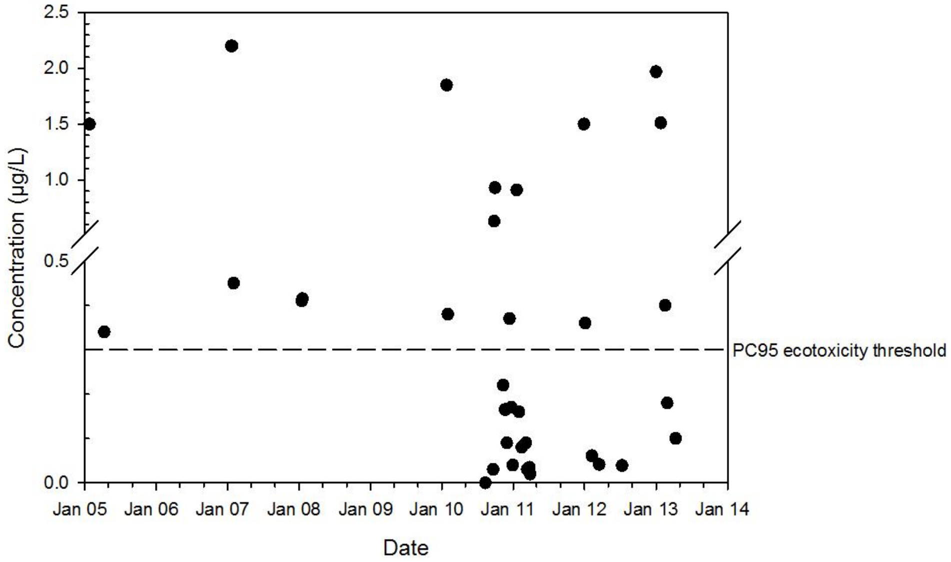

Figure 145 Temporal variation in median diuron concentrations during event conditions at Pioneer River from 2004–2008. The dashed line indicates the PC95 ecotoxicity threshold for diuron.

The ambient concentrations of hexazinone in the Pioneer River were largely consistent across the sampling period with the great majority of results being ≤LOR (0.01 µg/L), which was also the ambient target (Figure 146). There was no linear temporal trend across the sampling period ($p = 0.98$). Two markedly higher concentrations were recorded (0.07 and 0.23 µg/L); however, both of these occurred during the wet season and could therefore be from events. All ambient concentrations were below the hexazinone ecotoxicity threshold PC95 level of 0.7 µg/L.

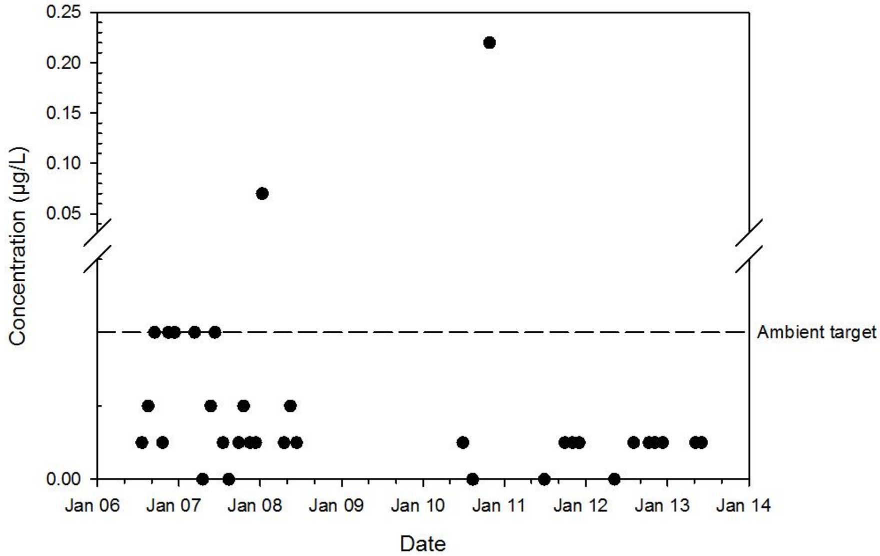

Figure 146 Temporal variation in median hexazinone concentrations during ambient conditions at Pioneer River from 2006–2013. The dashed line indicates the 2014 ambient hexazinone target for the Pioneer River Catchment Management Area.

The median event concentrations of hexazinone varied across sampled events (Figure 147). The event concentrations peaked in January 2007 (0.77 µg/L), before decreasing in subsequent years; however, there was no linear temporal trend over the entire sampling period ($p = 0.052$). All but one of the event median concentrations were below ecotoxicity threshold PC95 level of 0.7 µg/L.

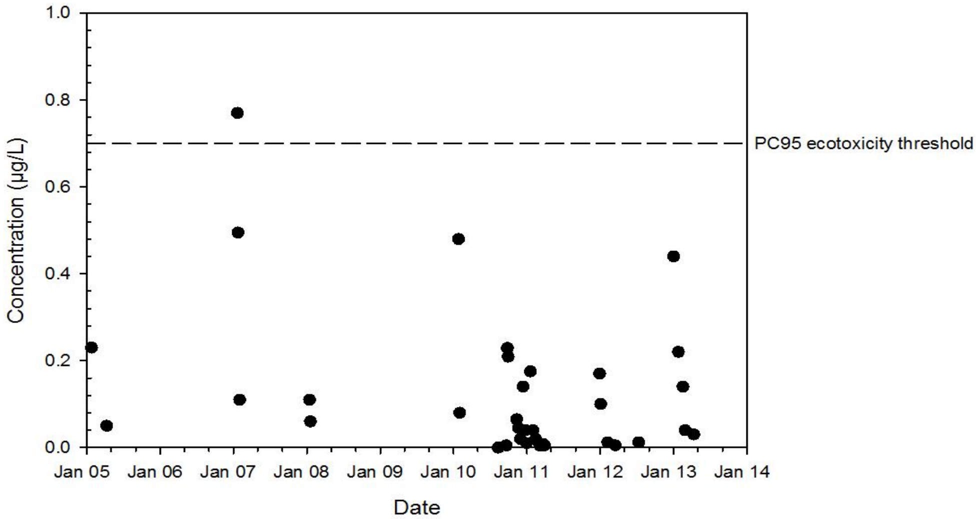

Figure 147 Temporal variation in median hexazinone concentrations during event conditions at Pioneer River from 2004–2008. The dashed line indicates the PC95 ecotoxicity threshold for hexazinone.

There were no ambient concentrations of tebuthiuron above the LOR in any year sampled, therefore this has not been graphed.

The median event concentrations of tebuthiuron were all < LOR between 2004 and 2008, and 2011 and 2012 (Figure 148). The only year in which event concentrations were recorded above the LOR was in 2012–2013, when the median concentrations peaked in January 2013 at 0.1 µg/L. There was an increase in tebuthiuron over time ($p = 0.036$; $R^2 = 0.261$), however the low R^2 value indicates that other factors are also influencing the results. Additionally, there was a gap in the sampling for approximately three years. All of the median event concentrations recorded were well below the ecotoxicity threshold PC95 level for tebuthiuron (8.8 µg/L).

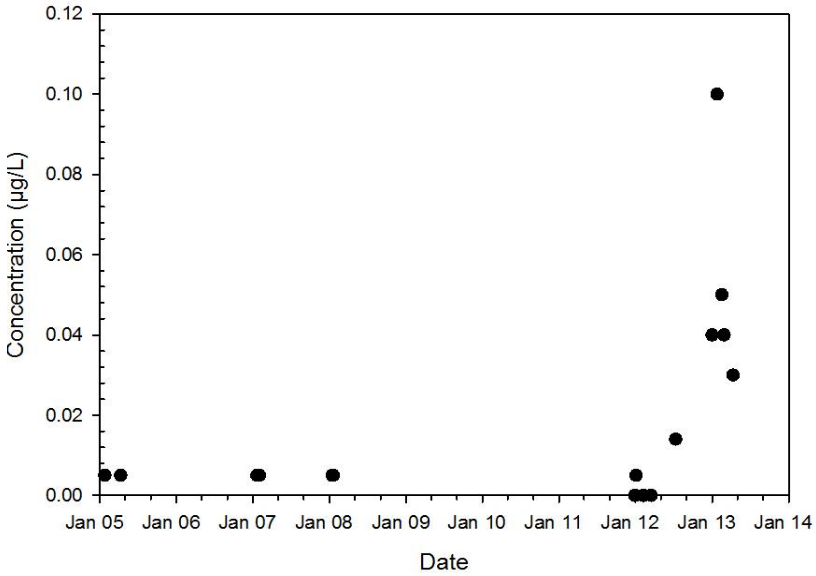

Figure 148 Temporal variation in median tebuthiuron concentrations during event conditions at Pioneer River from 2004–2013. The PC95 ecotoxicity threshold for tebuthiuron (8.8 µg/L) has not been plotted on this graph.

3.4.11.2 Frequency of trigger value and target exceedances

Ambient concentrations of ametryn in the Pioneer River exceeded the target in one out of five years, with an exceedance of 10 per cent (Table 19). Ambient concentrations of atrazine exceeded the target in three out of the five sampled years, with exceedances ranging from 20 to 50 per cent (Table 19). Ambient concentrations of diuron and hexazinone exceeded the target in two out of the five years (2007–2008 and 2010–2011), with 50 and 67 per cent exceedance for diuron and 10 and 33 per cent exceedances for hexazinone (Table 19). Ambient concentrations of tebuthiuron were sampled in three years and did not exceed the target in any of these years (Table 19).

Table 19 Per cent of exceedances of the 2014 ambient pesticide targets for Pioneer River for 2007–2013. Red indicates poor data availability (0–4 samples), amber indicates moderate data availability (5–9 samples), green indicates good data availability (≥ 10 samples).

Year	Per cent exceedances (total no. samples) of ambient samples				
	Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron
2007-2008	10 (10)	20 (10)	50 (10)	10 (10)	0 (10)
2008-2009	-	-	-	-	-
2009-2010	0 (1)	0 (1)	0 (1)	0 (1)	-
2010-2011	0 (3)	33 (3)	67 (3)	33 (3)	-
2011-2012	0 (4)	50 (4)	0 (4)	0 (4)	0 (4)
2012-2013	0 (6)	0 (6)	0 (6)	0 (6)	0 (6)

3.4.12 Plane Creek

3.4.12.1 Temporal variation in pesticides and comparison to trigger values and targets

All ambient and event concentrations of tebuthiuron sampled at Plane Creek were at or below the LOR (0.01 µg/L) and therefore have not been graphed.

There was one ambient ametryn concentration of 0.03 µg/L recorded in the sample from 14/05/2007. This concentration was above the ambient target of < LOR; however, it was below the PC95 ecotoxicity threshold (0.1 µg/L). All other ametryn concentrations for ambient and event conditions were 0.01 µg/L or below, therefore ametryn concentrations have not been graphed.

The ambient concentrations of atrazine in Plane Creek were fairly consistent, with no linear temporal trend ($p = 0.45$), and only two higher values (Figure 149). The majority of the ambient concentrations were below the ambient target (0.01 µg/L). The highest value occurred in early 2007, had a concentration of 2.2 µg/L and was 220-times greater than the ambient target.

The event concentrations of atrazine were fairly variable, and increased over time ($p = 0.041$; $R^2 = 0.25$), however the low R^2 value indicates that other factors are also influencing the result (Figure 149). The event concentrations peaked in early 2005, early 2006, with the highest event peak in early 2007. The majority of the concentrations were below the event target. The highest event concentration recorded was 1.2 µg/L, which was seven-times greater than the event target of 0.17 µg/L. All atrazine concentrations (both ambient and event) were well below the PC95 ecotoxicity threshold of 6 µg/L.

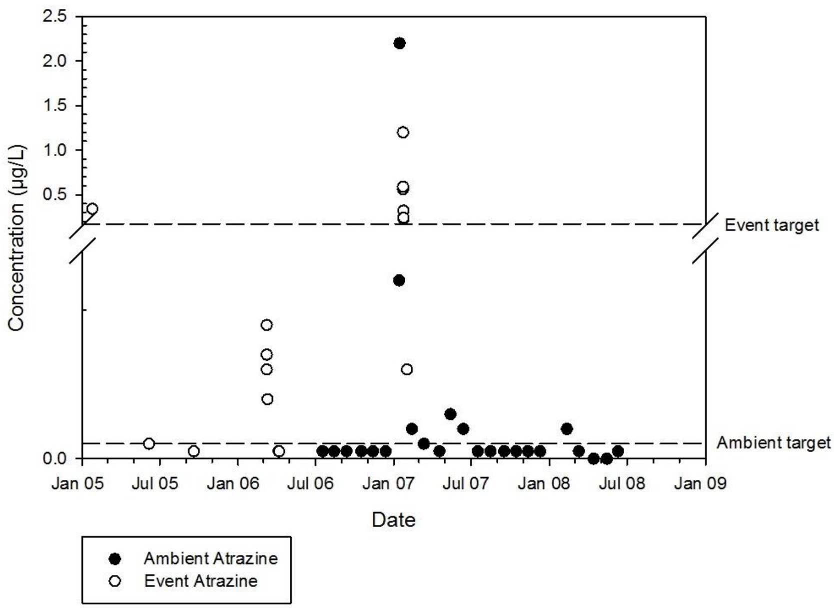

Figure 149 Temporal variation in atrazine concentrations during ambient and event conditions at Plane Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event atrazine targets for the Plane Creek Catchment Management Area.

The ambient concentrations of diuron in Plane Creek were fairly consistent, apart from one markedly higher value and there was no temporal trend ($p = 0.46$) (Figure 150). The majority of the ambient concentrations of diuron in Plane Creek were at or below the ambient target (< 0.01 µg/L). The higher value occurred in early 2007 and had a concentration of 1.6 µg/L, which was 160-times greater than the ambient target of 0.01 µg/L, and approximately five-times greater than the PC95 ecotoxicity threshold for diuron (0.3 µg/L).

The event concentrations of diuron were quite variable with no linear temporal trend ($p = 0.54$) (Figure 150). There was a peak in early 2005, followed by a decrease in early

2006, and another increase in early 2007. The majority of the event concentrations of diuron were below the event target (0.51 µg/L). The highest event concentration recorded was 1.3 µg/L that was four-times greater than the PC95 ecotoxicity threshold for diuron.

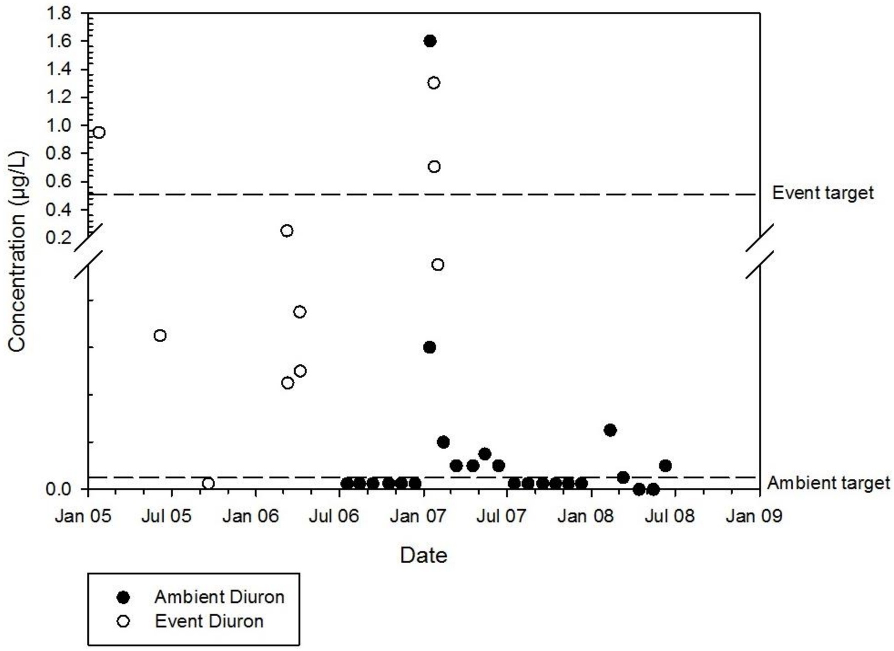

Figure 150 Temporal variation in diuron concentrations during ambient and event conditions at Plane Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event diuron targets for the Plane Creek Catchment Management Area.

The ambient concentrations of hexazinone in Plane Creek were fairly consistent, apart from one markedly higher value and there was no linear temporal trend ($p = 0.36$) (Figure 151). The majority of the ambient concentrations of hexazinone were at or below the ambient target (0.04 µg/L). The highest ambient value occurred in early 2007 and had a concentration of 1.2 µg/L, which was 30-times greater than the ambient target, and above the PC95 ecotoxicity threshold for hexazinone (0.7 µg/L).

The event concentrations of hexazinone were fairly consistent, with no linear temporal trend ($p = 0.93$) (Figure 151). There was a peak in mid-2005, followed by another peak in early 2007. Half of the concentrations were below the event target (0.14 µg/L). The highest event concentration recorded was 0.64 µg/L, four-times greater than the event target. All event concentrations were below the PC95 ecotoxicity threshold for hexazinone.

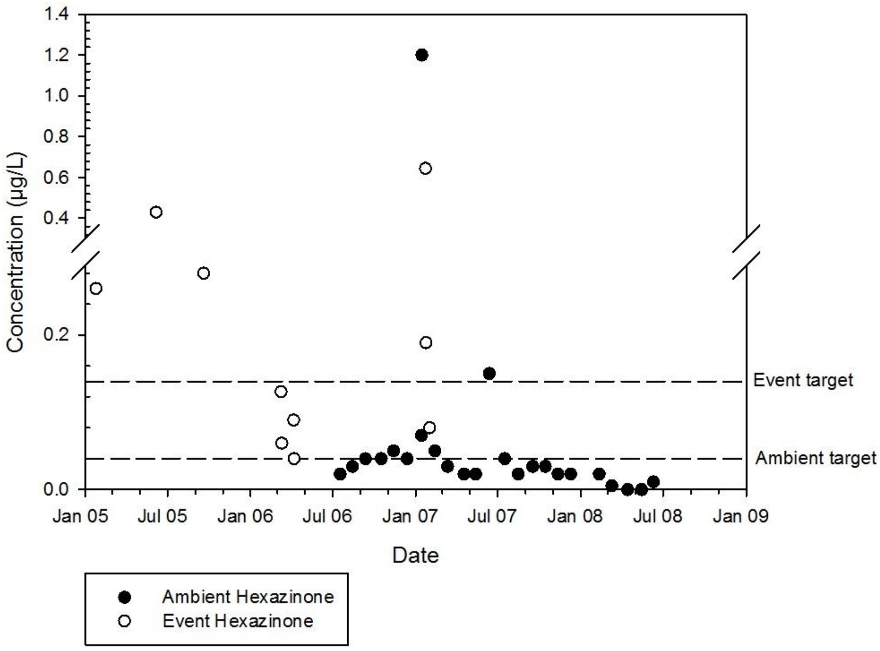

Figure 151 Temporal variation in hexazinone concentrations during ambient and event conditions at Plane Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event hexazinone targets for the Plane Creek Catchment Management Area.

3.4.12.2 Frequency of trigger value and target exceedances

No event pesticide sampling was conducted in Plane Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of exceedances against event targets was undertaken. Ambient sampling of pesticides was carried out for one year subsequent to 2006–2007, with a total of 11 ambient samples taken in 2007–2008. Ambient concentrations of ametryn, hexazinone, and tebuthiuron did not exceed the target in any samples taken. The atrazine target was exceeded in 9 per cent of samples and the diuron target was exceeded in 27 per cent of samples.

3.4.13 Proserpine River

No ambient sampling was conducted at Proserpine River, at either site; thus, the following results are based on event conditions from 2004–2006.

3.4.14 Temporal variation in pesticides and comparison to trigger values and targets

All event concentrations of ametryn and tebuthiuron sampled at Proserpine River were at, or below the LOR (0.01 µg/L) and therefore were not graphed.

There was one event hexazinone concentration of 0.04 µg/L recorded in the sample from 24/01/2005. This concentration was below the event target of 0.19 µg/L, and below the PC95 ecotoxicity threshold (0.7 µg/L) for hexazinone. All other hexazinone concentrations were ≤ 0.01 µg/L and therefore were not graphed.

All event atrazine concentrations in the Proserpine River were below the event target (0.26 µg/L) (Figure 152). As there were only four samples from Proserpine 1 and three samples from Proserpine 2, it was not possible to find any linear temporal trends. The highest concentration was 0.1 µg/L. All concentrations of atrazine were well below the PC95 ecotoxicity threshold for atrazine (6 µg/L).

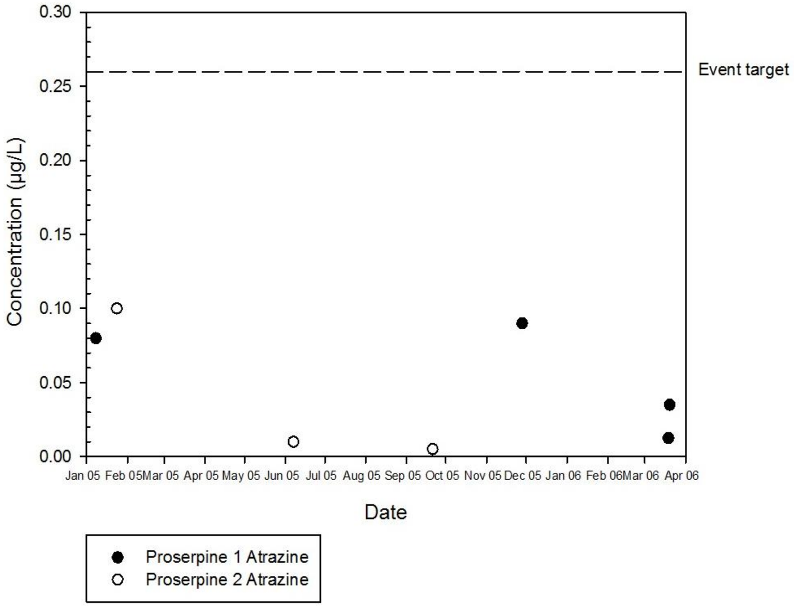

Figure 152 Temporal variation in atrazine concentrations during event conditions at Proserpine River from 2004–2006. The dashed line indicates the 2014 event atrazine target for the Proserpine River Catchment Management Area.

All event concentrations of diuron in the Proserpine River were below the event target (1.02 µg/L) (Figure 153). As there were only four samples from Proserpine 1 and three samples from Proserpine 2, linear temporal trends were not determined. The highest concentration occurred in early 2005, with a value just under 0.4 µg/L. This sample had the only concentration above the diuron PC95 ecotoxicity threshold of 0.3 µg/L.

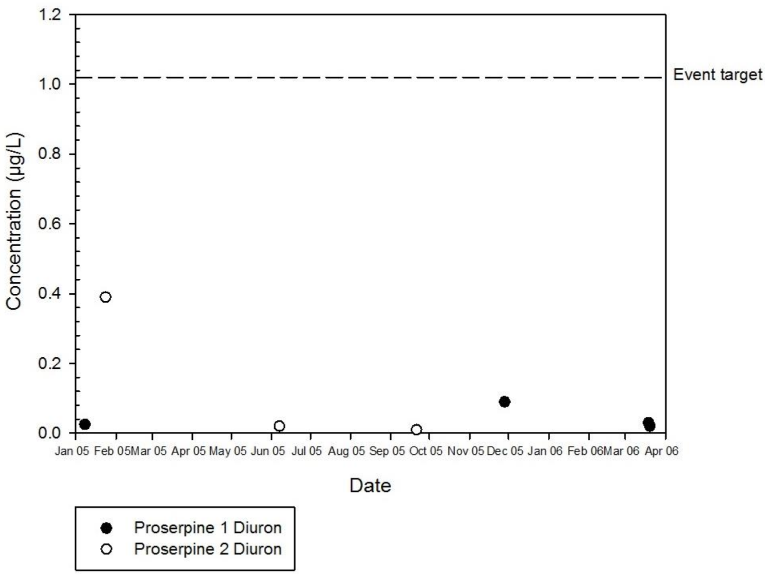

Figure 153 Temporal variation in diuron concentrations during event conditions at Proserpine River from 2004–2006. The dashed line indicates the 2014 event diuron target for the Proserpine River Catchment Management Area.

3.4.14.1 Frequency of trigger value and target exceedances

No sampling was conducted in Proserpine River (at either site) subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets can be undertaken.

3.4.15 Rocky Dam Creek

3.4.15.1 Temporal variation in pesticides and comparison to trigger values and targets

There was one event tebuthiuron concentration of 0.01 µg/L recorded in the sample taken on 12/01/2006. This concentration was above the event target of < LOR, however it was well below the PC95 ecotoxicity threshold (8.8 µg/L) for tebuthiuron. All other tebuthiuron concentrations were < LOR, therefore have not been graphed.

The ambient concentrations of ametryn in Rocky Dam Creek were fairly consistent, with a peak in early 2007 (Figure 154). There was no linear temporal trend in ambient concentrations ($p = 0.65$). The majority of the ambient concentrations were at or below the ambient target (0.02 µg/L). The two highest concentrations were around 0.16 µg/L, which was eight-times greater than the ambient target, and above the PC95 ecotoxicity threshold for ametryn (0.1 µg/L).

The event concentrations of ametryn were scattered, with no linear temporal trends ($p = 0.82$) across the sampling period (Figure 154). There was one higher value in early 2006, with a concentration of 1.4 µg/L. This concentration was 35-times greater than the event target and 14-times the PC95 ecotoxicity threshold. Half of the event concentrations were above the event target.

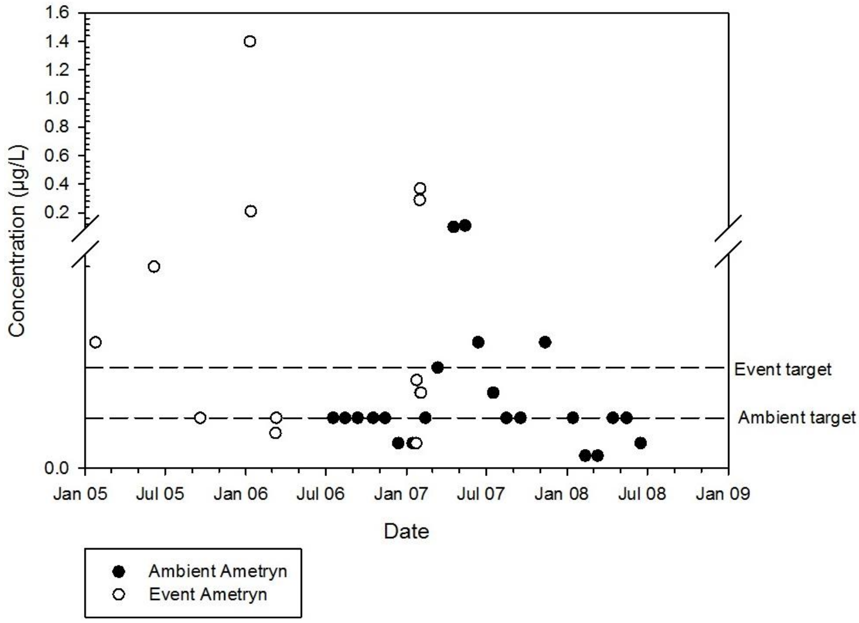

Figure 154 Temporal variation in ametryn concentrations during ambient and event conditions at Rocky Dam Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event ametryn targets for the Rocky Dam Creek Catchment Management Area.

The ambient concentrations of atrazine in Rocky Dam Creek were fairly consistent, with only one markedly higher value in early 2008 (Figure 155). There was no linear temporal trend across the sampling period (p = 0.37). The majority of the ambient concentrations were at or below the ambient target (< LOR). The highest value occurred at the end of 2007, with a concentration of 1.2 µg/L, 120-times greater than the ambient target.

Event concentrations of atrazine were varied, with no linear temporal trend (p = 0.82) (Figure 155). The peak in early 2005 was approximately 0.2 µg/L, while the peak in early 2006 was around 1.7 µg/L, followed by a peak of 0.9 µg/L in early 2007. The highest peak was six-times greater than the event target of 0.27 µg/L. No ambient or event atrazine concentrations were above the PC95 ecotoxicity threshold for atrazine of 6 µg/L.

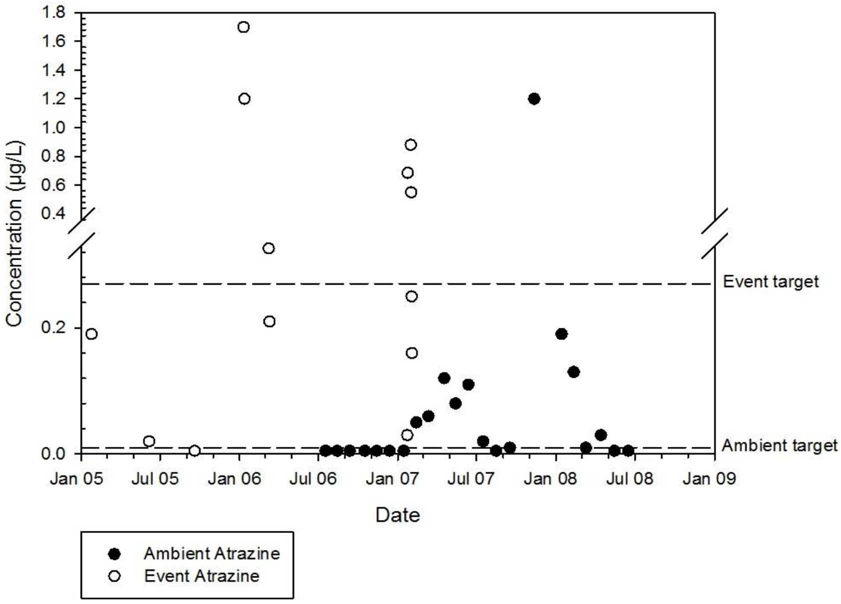

Figure 155 Temporal variation in atrazine concentrations during ambient and event conditions at Rocky Dam Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event atrazine targets for the Rocky Dam Creek Catchment Management Area.

The ambient concentrations of diuron in Rocky Dam Creek were fairly consistent between < LOR and 0.5 µg/L, with two peaks and two higher values (Figure 156). There was no linear temporal trend (p = 0.48). The concentration peaks occurred in early and late 2007. The highest concentration was 30 µg/L, which was 428-times the ambient target of 0.01 µg/L, and 100-times the diuron PC95 ecotoxicity threshold (0.3 µg/L). The majority of the ambient concentrations were at or below the ambient target.

Event concentrations of diuron were scattered across a few events, with no linear temporal trend (p = 0.64) (Figure 156). The peak in early 2005 was approximately 2 µg/L, while the peak in early 2006 was around 23 µg/L, followed by a peak of 5 µg/L in early 2007. The highest concentration was 30-times greater than the event target of 0.75 µg/L, and 76-times greater than the PC95 ecotoxicity threshold. Two-thirds of the event concentrations were above the event target.

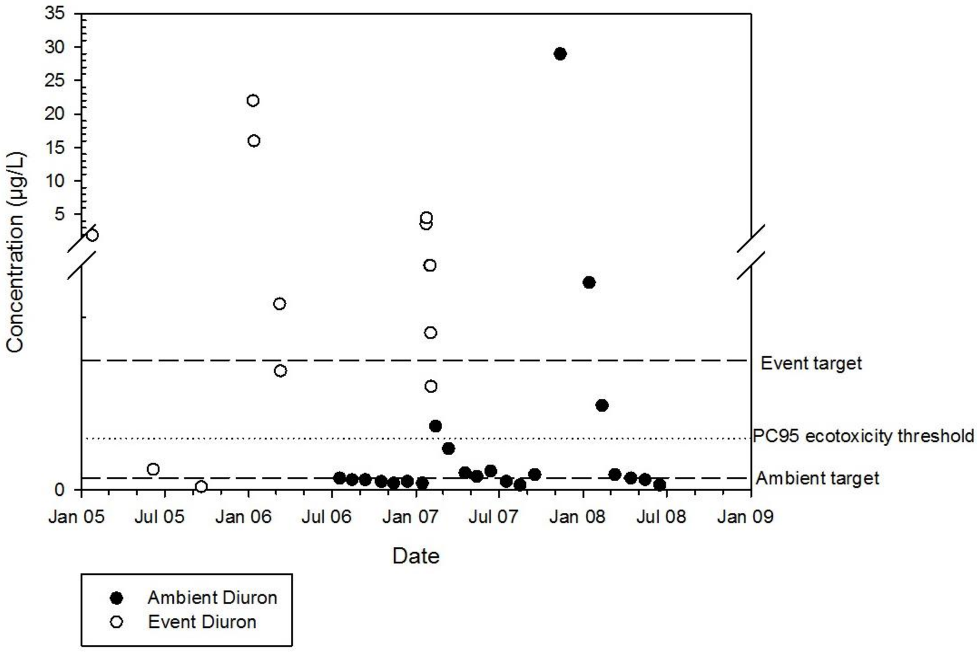

Figure 156 Temporal variation in diuron concentrations during ambient and event conditions at Rocky Dam Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event diuron targets for the Rocky Dam Creek Catchment Management Area. The dotted line indicates the PC95 ecotoxicity threshold for diuron.

The ambient concentrations of hexazinone in Rocky Dam Creek were fairly consistent, with one peak, which included one higher value (Figure 157). There was no linear temporal trend during the sampling period ($p = 0.49$). The majority of the ambient concentrations were at or below the ambient target. The concentration peak occurred in late 2007–early 2008. The highest concentration was 21 µg/L that was 161-times greater than the ambient target of 0.13 µg/L and 30-times greater than the hexazinone PC95 ecotoxicity threshold (0.7 µg/L).

Event concentrations of hexazinone were scattered across a few events, with no linear temporal trend ($p = 0.85$) (Figure 157). The majority of event concentrations of hexazinone were above the event target (0.55 µg/L). The highest concentration peak was in early 2006 (5 µg/L) with the following highest peak in early 2008, with a concentration of 3 µg/L. The concentration of 5 µg/L was nine-times greater than the event target, and seven-times greater than the PC95 ecotoxicity threshold.

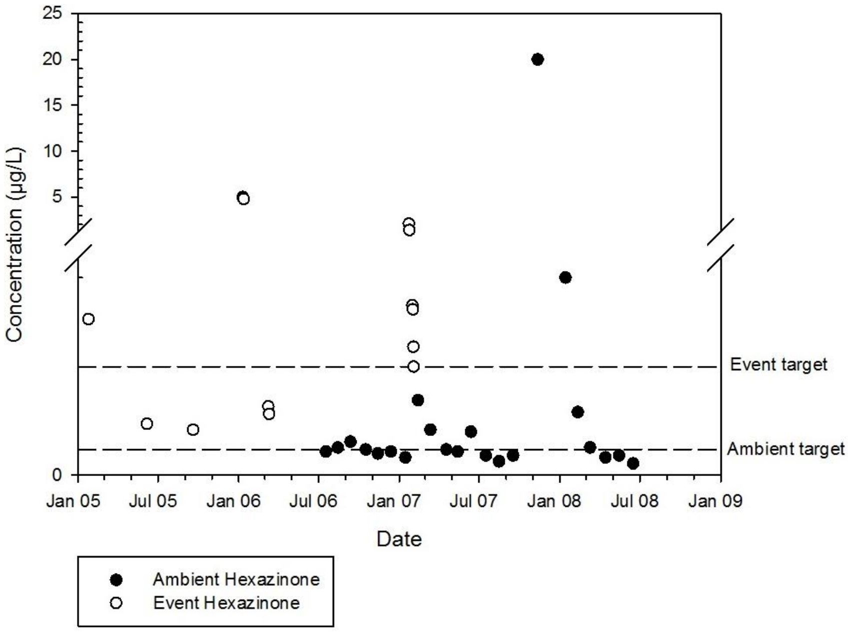

Figure 157 Temporal variation in hexazinone concentrations during ambient and event conditions at Rocky Dam Creek from 2004–2008. Dashed lines indicate the 2014 ambient and event hexazinone targets for the Rocky Dam Creek Catchment Management Area.

3.4.15.2 Frequency of trigger value and target exceedances

No event pesticide sampling was conducted in Rocky Dam Creek subsequent to 2006–2007, therefore no assessment of exceedances against event targets was undertaken. Ambient sampling of pesticides was carried out for one year subsequent to 2006–2007, with a total of 10 ambient samples taken in 2007–2008. Ambient concentrations of ametryn exceeded the target in 20 per cent of samples, and ambient atrazine concentrations exceeded the target in 70 per cent of samples. Diuron concentrations exceeded the target in 50 per cent of samples, and the hexazinone target was exceeded in 40 per cent of ambient samples. The concentrations of tebuthiuron did not exceed the target in any sample taken.

3.4.16 Sandy Creek

3.4.17 Temporal variation in pesticides and comparison to trigger values and targets

The ambient concentrations of ametryn in Sandy Creek ranged between 0 and 0.44 µg/L, with no linear temporal trend ($p = 0.27$) (Figure 158). The majority of the concentrations were at or below the ambient target. The ambient concentration peaks were 0.05 µg/L in early 2007 and 0.44 µg/L in early 2008. The highest concentration of 0.44 µg/L was 22-times greater than the ambient target of 0.02 µg/L, and approximately four-times greater than the PC95 ecotoxicity threshold of 0.1 µg/L. Since 2009, there were no ametryn concentrations above 0.02 µg/L.

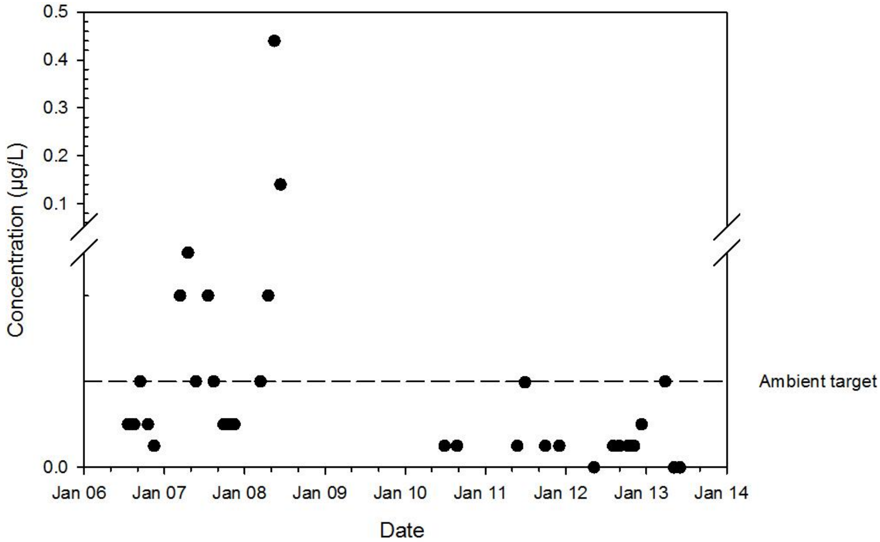

Figure 158 Temporal variation in ametryn concentrations during ambient conditions at Sandy Creek from 2006–2013. The dashed line indicates the 2014 ambient ametryn target for the Sandy Creek Catchment Management Area.

Median event concentrations of ametryn were scattered, with no linear temporal trend ($p = 0.97$) (Figure 159). The highest median concentration occurred in late 2010 (0.5 µg/L) with the second highest peak (0.095 µg/L) in January 2010. The ecotoxicity PC95 level for ametryn is 0.1 µg/L, and only one event median concentration was above this, although several approached this value.

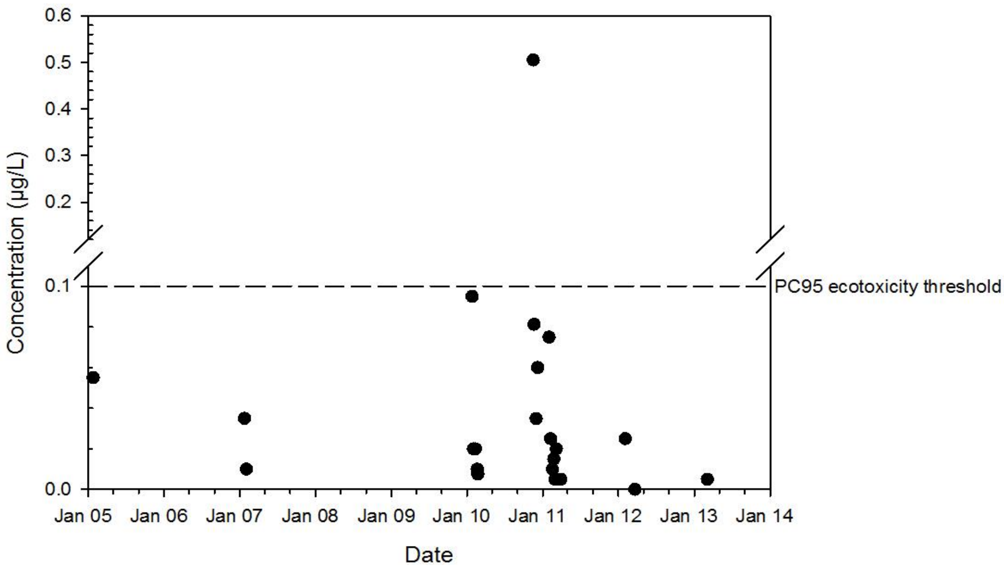

Figure 159 Temporal variation in ametryn concentrations during event conditions at Sandy Creek from July 2004–2013. The dashed line indicates the PC95 ecotoxicity threshold for ametryn.

The ambient concentrations of atrazine in Sandy Creek decreased over time ($p = 0.047$; $R^2 = 0.125$), however the low R^2 value indicates that other factors are influencing the results (Figure 160). The vast majority of the ambient concentrations were at or below the ambient target of 0.09 µg/L, with only three concentrations being higher than this target. The highest ambient concentration was 0.36 µg/L, four-times greater than the ambient target. Since 2009, there were no atrazine concentrations above the ambient target.

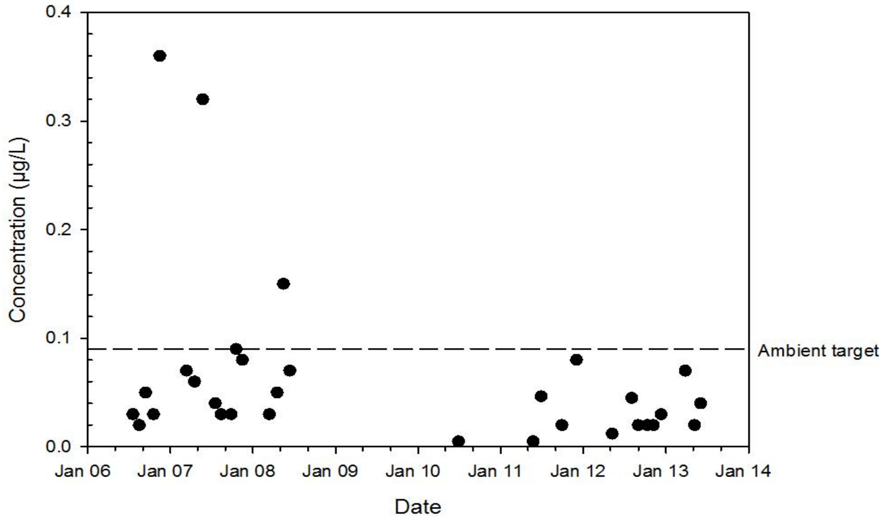

Figure 160 Temporal variation in atrazine concentrations during ambient conditions at Sandy Creek from 2006–2013. The dashed line indicates the 2014 ambient atrazine target for the Sandy Creek Catchment Management Area.

Median event concentrations of atrazine were scattered across multiple events and ranged between 0.02 and 2.0 µg/L, with no linear temporal trend ($p = 0.056$) (Figure 161). The highest concentrations peak occurred in early 2007 (1.7 µg/L), early 2010 (2.0 µg/L), and late 2010 (1.65 µg/L). All of the median concentrations were below the ecotoxicity threshold PC95 for atrazine (6 µg/L).

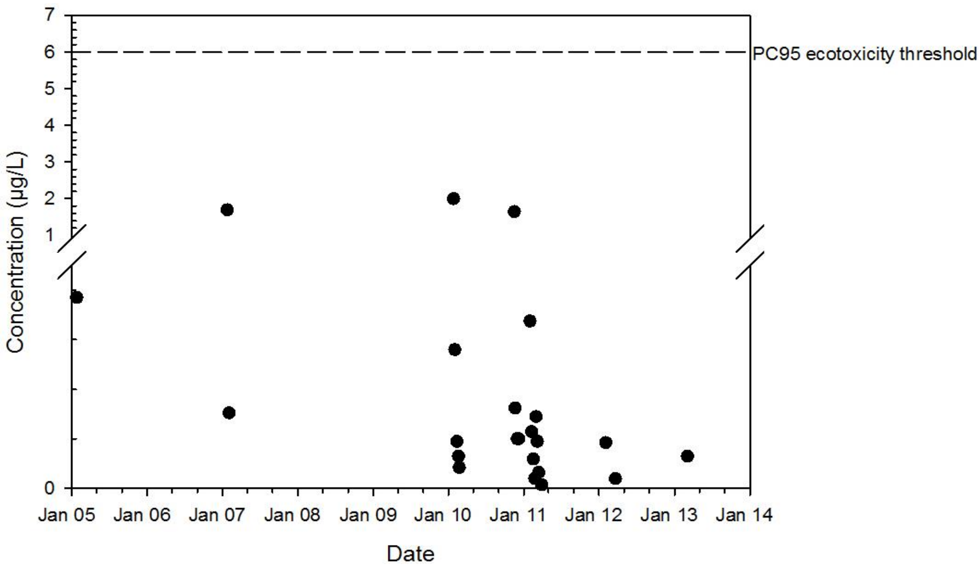

Figure 161 Temporal variation in median atrazine concentrations during event conditions at Sandy Creek from 2004–2013. The dashed line indicates the PC95 ecotoxicity threshold for atrazine.

The vast majority of ambient concentrations for diuron in Sandy Creek occurred below the ambient target of 0.19 µg/L, with a peak in early 2007 (Figure 162). There was a linear decrease in concentrations ($p = 0.004$; $R^2 = 0.245$); however, the low R^2 value indicates that other factors also influenced the results. Only two ambient concentrations were higher than the ambient target. The highest ambient concentration was 0.34 µg/L. All ambient diuron concentrations, except the highest value, were below the ecotoxicity threshold.

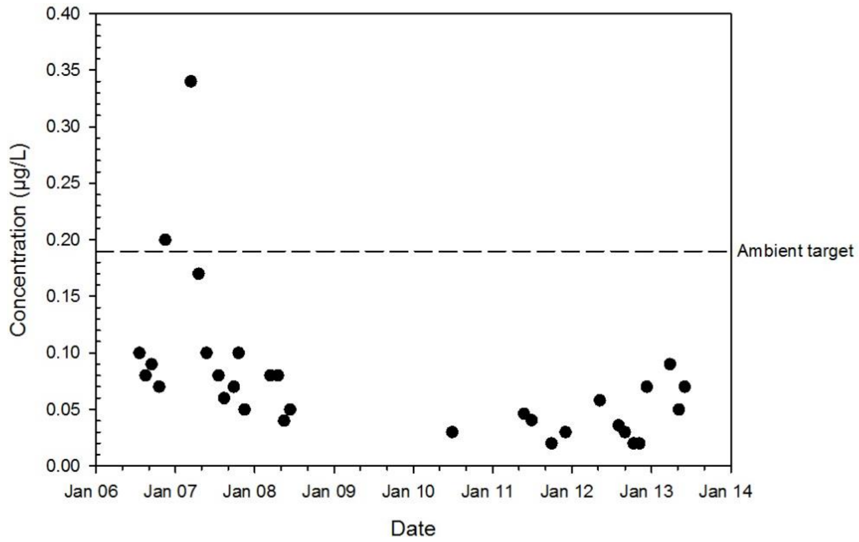

Figure 162 Temporal variation in diuron concentrations during ambient conditions at Sandy Creek from 2006–2013. The dashed line indicates the 2014 ambient diuron target for the Sandy Creek Catchment Management Area.

Median event concentrations of diuron were scattered, with a linear decrease over time ($p = 0.002$; $R^2 = 0.378$), however the low R^2 value indicates that there are other factors also influencing the results (Figure 163). The highest concentration occurred in early 2007 (5.7 µg/L), and peaks also occurred in January 2005 (3.1 µg/L), January 2010 (4.2 µg/L) andJanuary 2011 (2.2 µg/L). More than half the median event concentrations exceeded the ecotoxicity threshold PC95 for diuron of 0.3 µg/L and the current Australian and New Zealand Guideline Value of 0.2 µg/L.

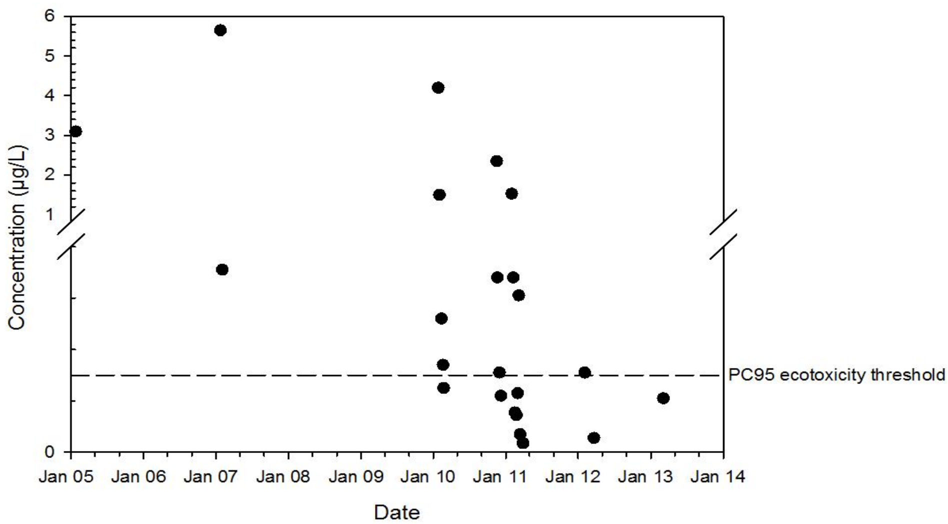

Figure 163 Temporal variation in diuron concentrations during event conditions at Sandy Creek from July 2007–2013. The dashed line indicates the PC95 ecotoxicity threshold for diuron.

The ambient concentrations of hexazinone in Sandy Creek peaked in early 2007 and then decreased linearly over time ($p = 0.000$; $R2 = 0.51$) (Figure 164). The range of concentrations from 2006–2008 was greater than the spread from 2010–2013. The concentrations in the second sampling period were much lower than those in the first. Only one concentration (0.35 µg/L) over the entire sampling period was above the ambient target of 0.2 µg/L. The PC95 ecotoxicity threshold for hexazinone is 0.7 µg/L; none of the ambient concentrations were above this.

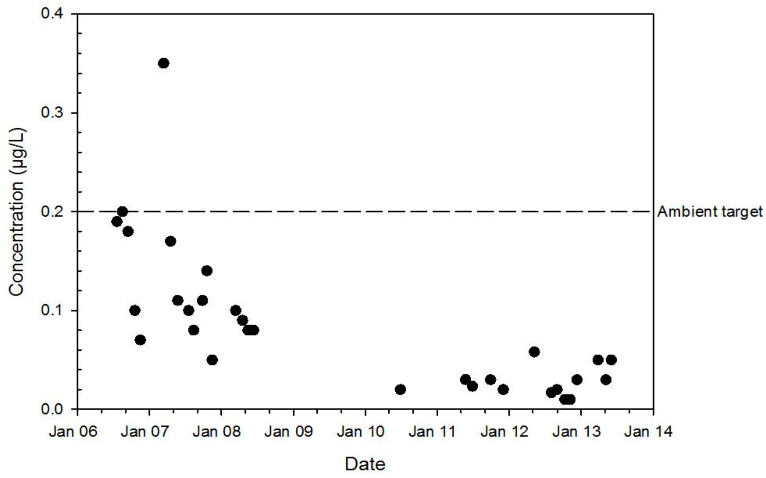

Figure 164 Temporal variation in hexazinone concentrations during ambient conditions at Sandy Creek from 2006–2013. The dashed line indicates the 2014 ambient hexazinone target for the Sandy Creek Catchment Management Area.

Median event concentrations of hexazinone were fairly scattered across multiple events, and decreased linearly over time ($p = 0.017$; $R^2 = 0.242$); however, the low R^2 value indicates that there are other factors also influencing the results (Figure 165). The highest median concentration of 1.8 µg/L occurred in early 2007, followed by a peak of 1.7 µg/L in early 2010. Three of the event median concentrations were above the ecotoxicity threshold PC95 for hexazinone (0.7 µg/L).

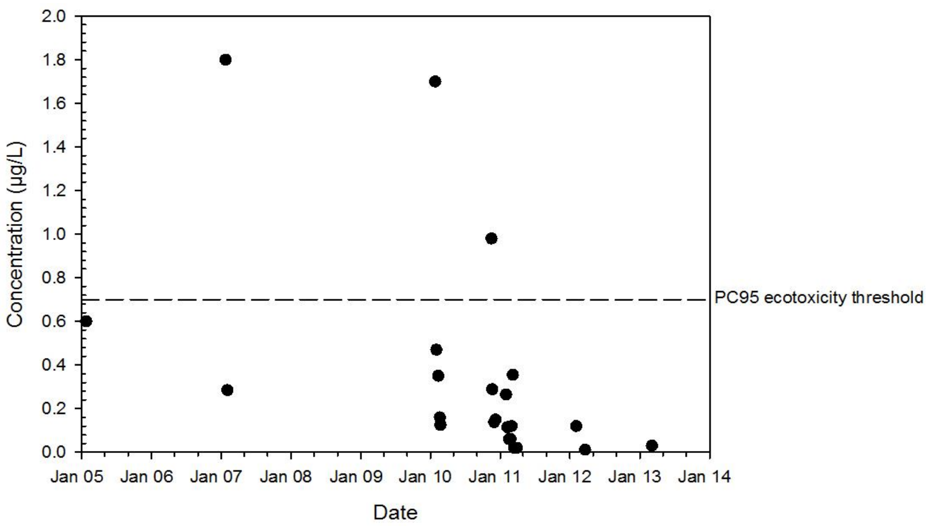

Figure 165 Temporal variation in hexazinone concentrations during event conditions at Sandy Creek from July 2007–2013. The dashed line indicates the PC95 ecotoxicity threshold for hexazinone.

The ambient concentrations of tebuthiuron in Sandy Creek were sampled from mid-2006 to mid-2008, and peaked in late 2006 (0.04 µg/L) (Figure 166). The vast majority of concentrations were below the target of 0.01 µg/L, with only two values above the target. There was no linear temporal trend over the sampling period ($p = 0.08$). All recorded ambient concentrations were well below the ecotoxicity threshold PC95 of 8.8 µg/L.

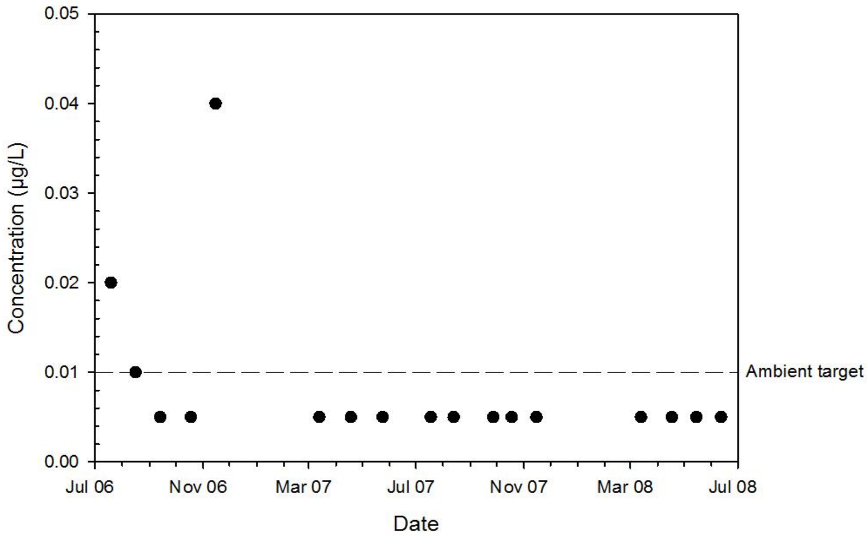

Figure 166 Temporal variation in tebuthiuron concentrations during ambient conditions at Sandy Creek from 2004–2013. The dashed line indicates the ambient target for the Sandy Creek Catchment Management Area.

Tebuthiuron sampling under event conditions was limited, but from the six median concentrations recorded, three were 0.005 µg/L and three were 0 µg/L (Figure 167). These values are all below the LOR, and therefore, linear regression was not performed. All values were well below the ecotoxicity threshold PC95 for tebuthiuron of 8.8 µg/L.

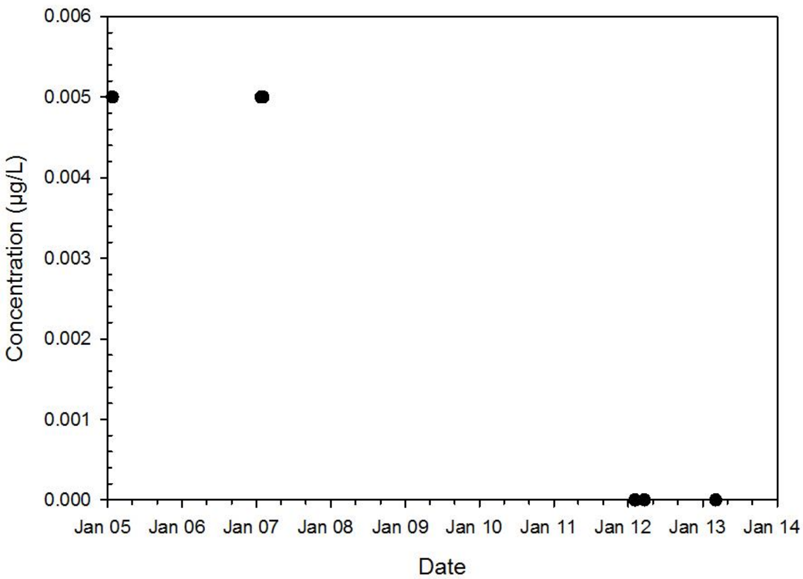

Figure 167 Temporal variation in tebuthiuron concentrations during event conditions at Sandy Creek from July 2007–2013.

3.4.17.1 Frequency of trigger value and target exceedances

Ambient concentrations of ametryn in Sandy Creek exceeded the target in one out of five sampled years, with an exceedance of 44 per cent (Table 20). Ambient concentrations of atrazine also exceeded the target in one year, with an exceedance of 11 per cent (Table 20). All ambient concentrations of diuron, hexazinone and tebuthiuron were below the relevant 2014 targets (Table 20).

Table 20 Per cent of exceedances of the 2014 ambient pesticide targets for Sandy Creek for 2007–2013. Red indicates poor data availability (0–4 samples), amber indicates moderate data availability (5–9 samples), green indicates good data availability (≥ 10 samples).

Year	Per cent exceedances (total no. samples) of ambient samples				
	Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron
2007–2008	44(9)	11 (9)	0 (9)	0 (9)	0 (9)
2008–2009	-	-	-	-	-
2009–2010	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
2010–2011	0 (3)	0 (3)	0 (3)	0 (3)	0 (3)
2011–2012	0 (3)	0 (3)	0 (3)	0 (3)	0 (3)
2012–2013	0 (8)	0 (8)	0 (8)	0 (8)	0 (8)

3.4.18 Sarina

There was no ambient pesticide sampling conducted for Sarina, thus, the following results are based on event conditions from 2004–2007.

3.4.18.1 Temporal variation in pesticides and comparison to trigger values and targets

All event concentrations of ametryn and tebuthiuron sampled at Sarina were at, or below, the LOR (0.01 µg/L) and have not been graphed.

The event concentrations of atrazine at Sarina only covered a one year period so no linear regression was performed. The peaks in early 2006 and 2007 were of similar concentrations (around 0.02 µg/L) (Figure 168). This peak concentration was below the event target for atrazine of 0.17 µg/L and the PC95 ecotoxicity threshold of 6 µg/L. All atrazine event concentrations were well below the event target.

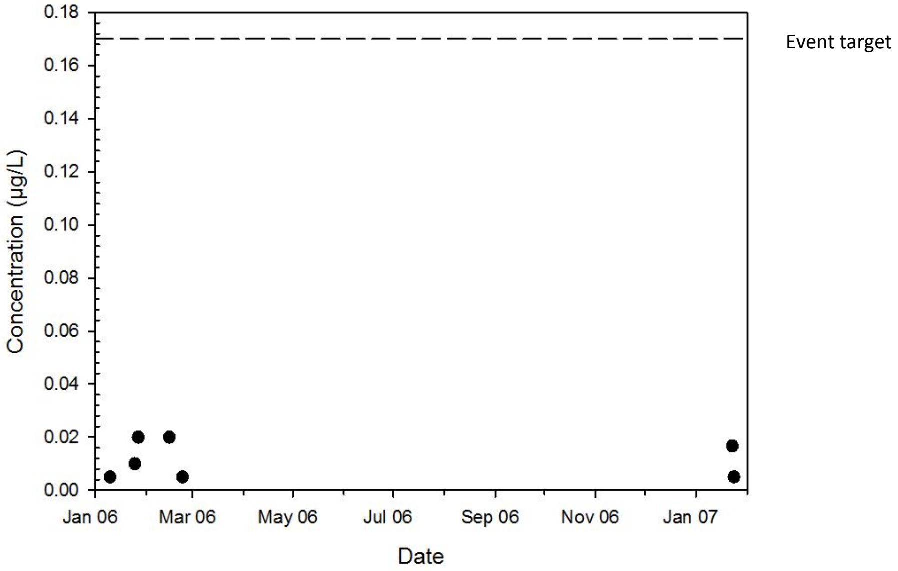

Figure 168 Temporal variation in atrazine concentrations during event conditions at Sarina from 2005–2007. The dashed line indicates the 2014 event atrazine target for the Plane Creek Catchment Management Area.

The event concentrations of diuron at Sarina only covered a one year period so no linear regression was performed (Figure 169). The two peaks (in early 2006 and 2007) were of similar concentrations. All event concentrations were below the event target of 0.51 µg/L. One event concentration was above the PC95 ecotoxicity threshold for diuron (0.3 µg/L), and two concentrations were above current Australian and New Zealand guideline PC95 value (0.2 µg/L).

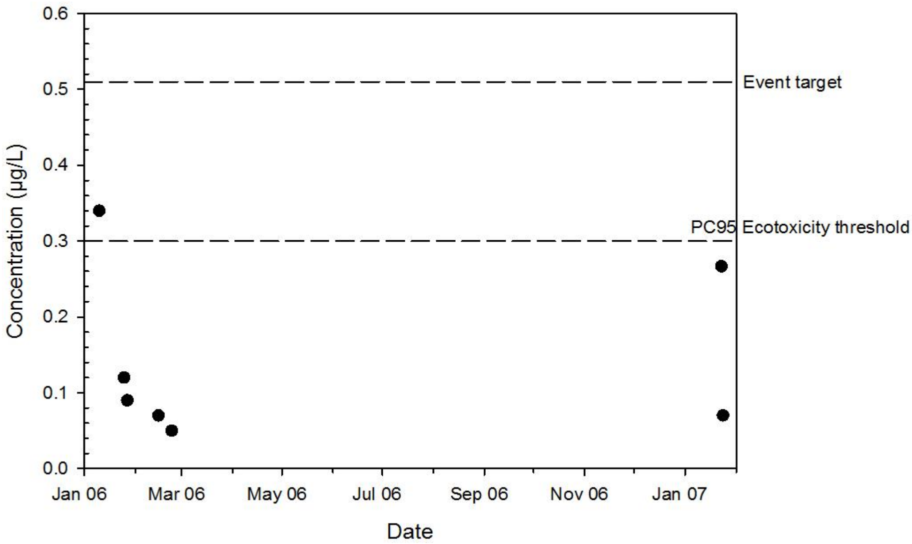

Figure 169 Temporal variation in diuron concentrations during event conditions at Sarina from 2005–2007. The dashed lines indicate the 2014 event diuron target for the Plane Creek Catchment Management Area and the PC95 ecotoxicity threshold.

Concentrations of hexazinone were scattered across the one-year sampling period so no linear regression was performed (Figure 170). The concentration in early 2006 peaked at 0.16 µg/L, which was much higher than the peak in early 2007 of 0.01 µg/L, although there was minimal sampling in the latter period. Only one concentration was above the event target of 0.14 µg/L, but this concentration was well below the hexazinone PC95 ecotoxicity threshold of 0.7 µg/L.

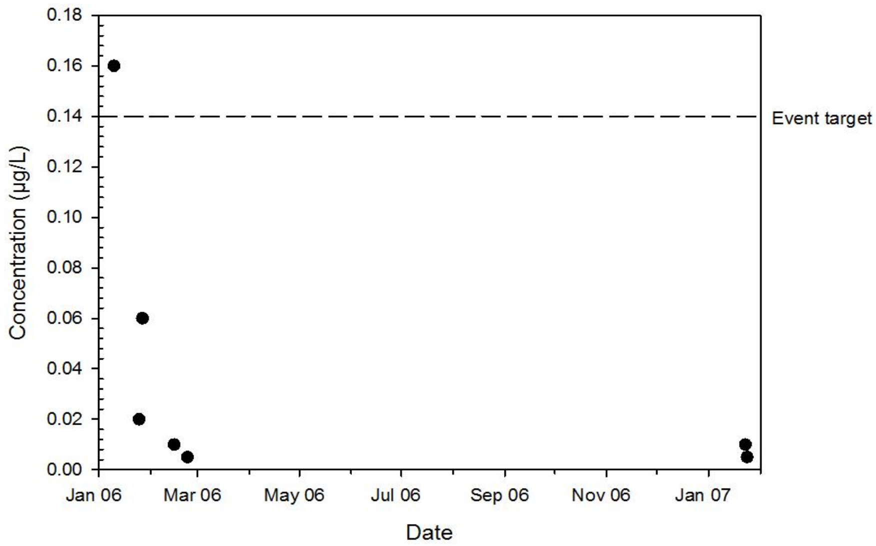

Figure 170 Temporal variation in hexazinone concentrations during event conditions at Sarina from 2005–2007. The dashed line indicates the 2014 event hexazinone target for the Plane Creek Catchment Management Area.

3.4.18.2 Frequency of trigger value and target exceedances

No sampling was conducted at Sarina subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets was undertaken.

3.4.19 St Helens Creek

No event sampling was conducted in St Helens Creek subsequent to 2006–2007, however one year of ambient sampling (12 samples) was undertaken in 2007–2008, in which no samples exceeded any of the pesticide targets and ecotoxicity thresholds.

3.4.20 Waite Creek

No pesticide sampling was conducted for Waite Creek subsequent to 2006–2007 (i.e. when the 2014 targets were established), therefore no assessment of concentration exceedances against the targets was undertaken.

3.5 Mixtures of Pesticides

3.5.1 Temporal variation in the measured level of protection being provided and comparison to adequate levels of protection and targets

3.5.1.1 Upper Andromache and Andromache River

The Upper Andromache River is a HEV site whereas the Andromache River site situated lower in the catchment is not. Therefore data collected from the Upper Andromache was compared to the ms-PAF target 1, which was derived to protect HEV systems (i.e., 99 per cent of phototrophic species), and the Andromache River data was compared to the ms-PAF target 5 which aims to protect 95 per cent of phototrophic species.

Ambient ms-PAF results were consistent in the Upper Andromache River, with no linear temporal trend (p = 0.85) (Figure 171). All ambient mixtures of pesticides in Upper Andromache River were well below the ms-PAF target for HEV sites of < 1 per cent of phototrophic species, indicating that adequate protection is provided under ambient conditions.

The event sampling in both Andromache River sites was limited, but there were no linear temporal trends at Upper Andromache River (p = 0.72) or Andromache River (p = 0.40). One of the event samples in Upper Andromache River was just above the ms-PAF target 1, with a ms-PAF value of 1.04 per cent. All other event samples for the Upper Andromache River were below the target, indicating that for the majority of the time adequate protection is provided under event conditions. The ms-PAF results tended to be higher in samples collected during events at the Andromache River site compared to the Upper Andromache River site, which was expected, as the Upper Andromache site is an HEV site, and the Andromache River site is downstream of the HEV site. Approximately 80 per cent of the land within this CMA is used for grazing (Drewry et al. 2008). All event ms-PAF values for the Andromache River were below the ms-PAF target 5 of 5 per cent of phototrophic species, indicating that adequate protection is provided under event conditions.

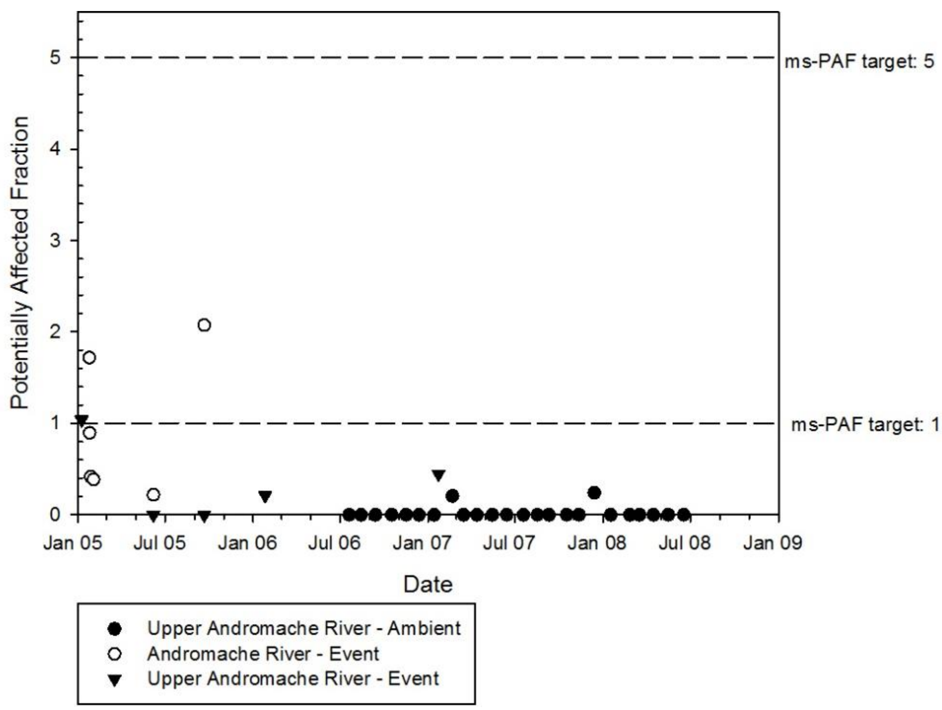

Figure 171 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient and event conditions at Upper Andromache River and Andromache River from 2004–2008. Dashed lines indicate the PC95 (ms-PAF target 5) and PC99 (ms-PAF target 1) ms-PAF targets for the normal sites and HEV sites, respectively.

3.5.1.2 Bakers Creek

Bakers Creek is not a HEV site and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. Ambient ms-PAF results in Bakers Creek were quite variable, with no linear temporal trend apparent ($p = 0.60$) (Figure 172). Of the 23 samples taken, 12 had ms-PAF values higher than the ms-PAF target 5. The highest ms-PAF result indicated that up to 94 per cent of phototrophic species may have been adversely affected. The majority of ms-PAF values were above the ms-PAF target of 5 at this site, indicating that in many instances, adequate protection to phototrophic species was not provided when mixtures were considered.

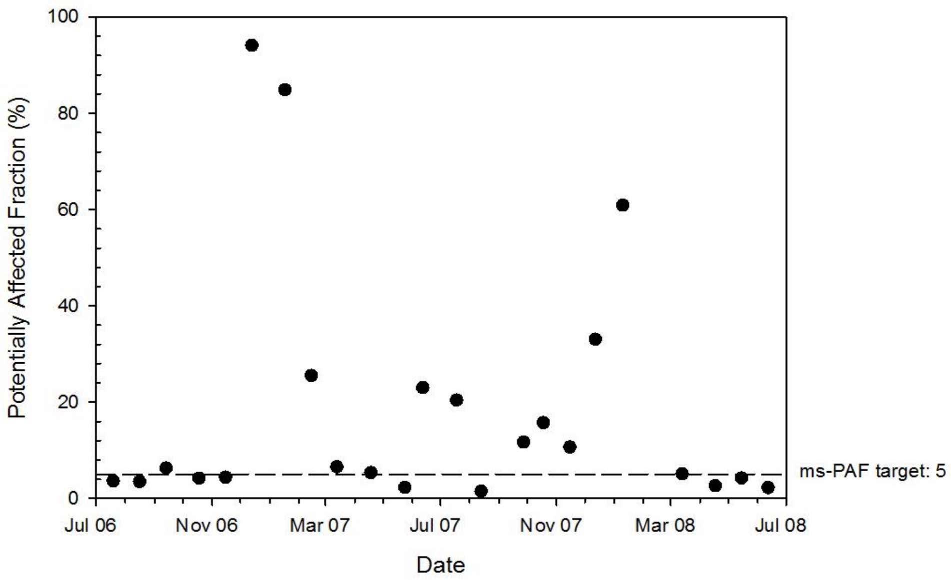

Figure 172 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient conditions at Bakers Creek from 2006–2008. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for this site.

3.5.1.3 Basin Creek

Basin Creek is an HEV site and therefore the ms-PAF target 1 that aims to protect 99 per cent of phototrophic species is the relevant target. Ambient ms-PAF results in Basin Creek were consistent, with no linear temporal trend over the sampling period ($p = 0.73$) (Figure 173). All ambient ms-PAF values were below the target for a HEV site, and therefore adequate protection to phototrophic species was provided under ambient conditions. The event sampling in Basin Creek was limited, and no linear temporal trend was apparent ($p = 0.079$). Only one of the six event samples had a ms-PAF below the target (Figure 173), indicating that in the majority of event conditions adequate protection was not provided to phototrophic species in Basin Creek. The highest ms-PAF value calculated indicated that up to 17 per cent of the phototrophic species were potentially affected by the mixture of pesticides during that event.

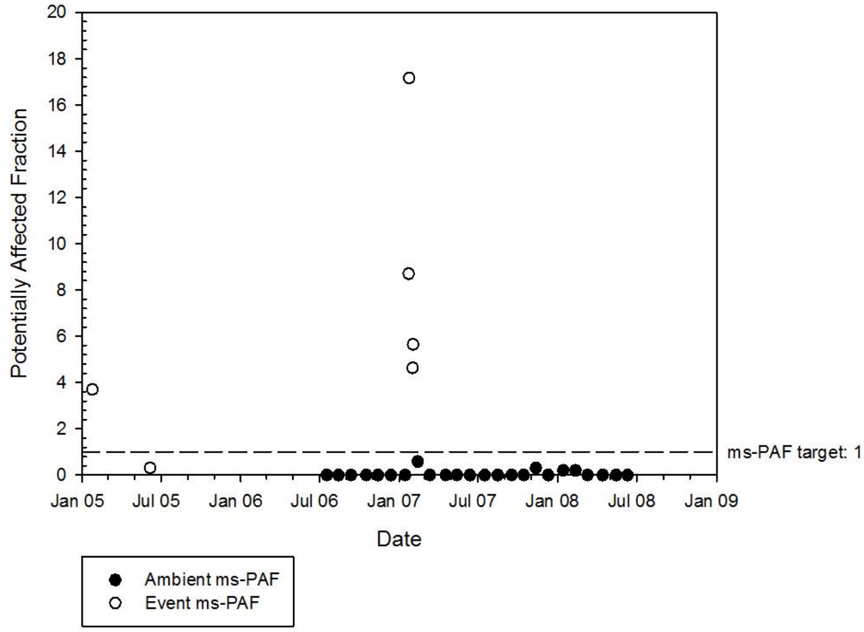

Figure 173 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient and event conditions at Basin Creek from 2004–2008. The dashed line indicates the PC99 ms-PAF target (ms-PAF target 1) for the site.

3.5.1.4 Blacks Creek

Blacks Creek is not a HEV site and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. Event ms-PAF results in Blacks Creek were limited to only three samples, so it was not possible to discern any linear temporal trend (Figure 174). Two of the three ms-PAF values were below the target, and one was above, at 7.1 per cent, indicating that in two out of three samples, adequate protection to phototrophic species was provided. This result should be interpreted cautiously given the limited number of samples for Blacks Creek.

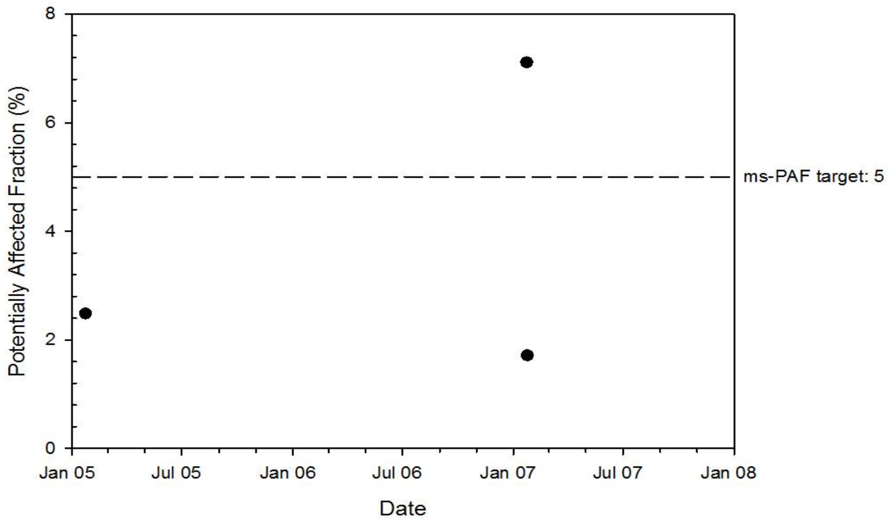

Figure 174 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during event conditions at Blacks Creek from 2004–2007. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for the site.

3.5.1.5 Carmila Creek

Carmila Creek is not a HEV site and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. Ambient ms-PAF results for Carmila Creek were fairly consistent, with no linear temporal trend ($p = 0.57$) over the sampling period (Figure 175). The highest ambient ms-PAF value occurred in late 2006, with a value of 38 per cent. The vast majority of the ambient ms-PAF values were below the target for Carmila Creek, indicating that generally adequate protection was provided to phototrophic species under ambient conditions. The event sampling showed no linear temporal trend in ms-PAF values ($p = 0.11$); however, there were limited samples available (Figure 175). The majority of event samples were above the ms-PAF target indicating that during event conditions, the mixtures of pesticides generally did not allow for adequate protection of phototrophic species. The highest event ms-PAF value occurred in early 2007, and was 38 per cent.

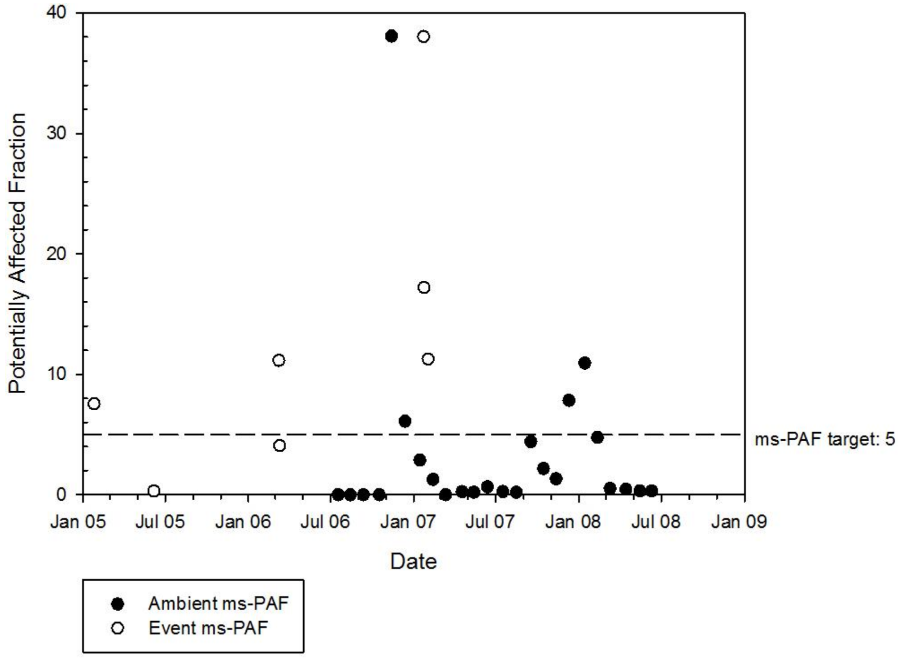

Figure 175 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient and event conditions at Carmila Creek from 2004–2008. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for the site.

3.5.1.6 Finch Hatton Creek

Finch Hatton Creek is a HEV site and therefore the ms-PAF target 1 that aims to protect 99 per cent of phototrophic species is the relevant target. The vast majority of the ms-PAF results for both ambient (21 out of 22 samples) and event (all four samples) conditions in Finch Hatton Creek had ms-PAF values of 0 per cent (Figure 176). All ms-PAF results for both ambient and event mixtures of pesticides in Finch Hatton Creek were below the HEV site ms-PAF target 1, indicating that under the vast majority of flow conditions, adequate protection to phototrophic species was provided at this site.

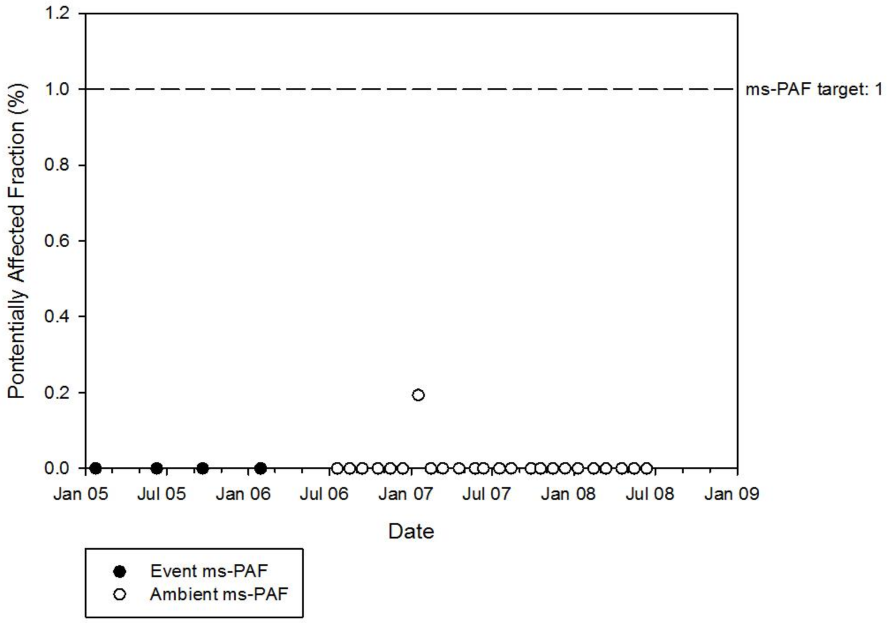

Figure 176 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient and event conditions at Finch Hatton Creek from 2004–2008. The dashed line indicates the PC99 ms-PAF target (ms-PAF target 1) for this site.

3.5.1.7 Gregory River

Gregory River is not a HEV site and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. Event ms-PAF results for Gregory River did not show any linear temporal trends ($p = 0.98$) over the monitoring period (Figure 177). The highest ms-PAF value occurred in early 2005 and indicated 84 per cent of phototrophic species experienced adverse effects at that time. The peak ms-PAF values subsequent to this were considerably lower (31 per cent and 46 per cent); however, they were still well above the ms-PAF target. This indicates that for the majority of time under event conditions inadequate protection is provided to phototrophic species within Gregory River, based on mixtures of pesticides.

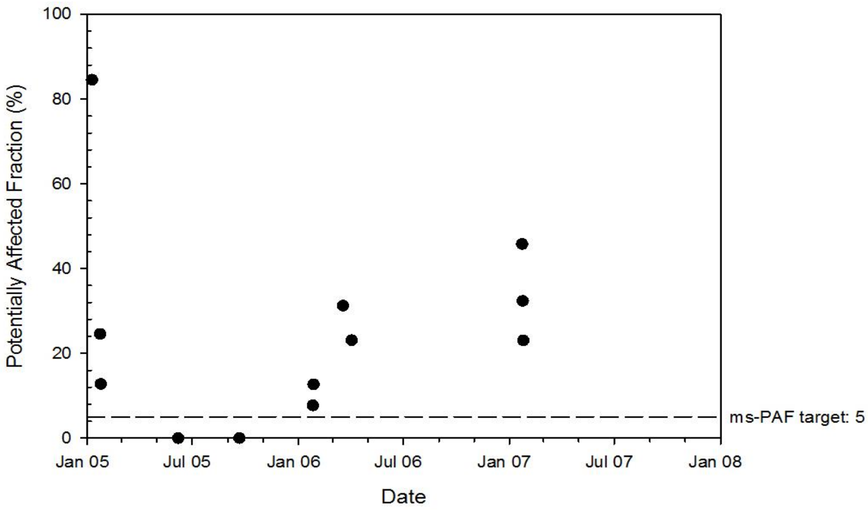

Figure 177 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during event conditions at Gregory River from 2004–2007. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for this site.

3.5.1.8 Impulse Creek

Impulse Creek is a HEV site and therefore the ms-PAF target 1 that aims to protect 99 per cent of phototrophic species is the relevant target. Of the 24 ambient ms-PAF results in Impulse Creek, all but two ms-PAF values were 0 per cent, and these two values indicated that only 0.31 per cent and 0.61 per cent of phototrophic species were affected (Figure 178). These values were below the target for an HEV site of 1 per cent. There were only four event samples available for Impulse Creek, and all ms-PAF results were 0 per cent. All ms-PAF results for both ambient and event mixtures of pesticides in Impulse Creek were below the appropriate ms-PAF targets, indicating that under both flow conditions, adequate protection to phototrophic species was provided.

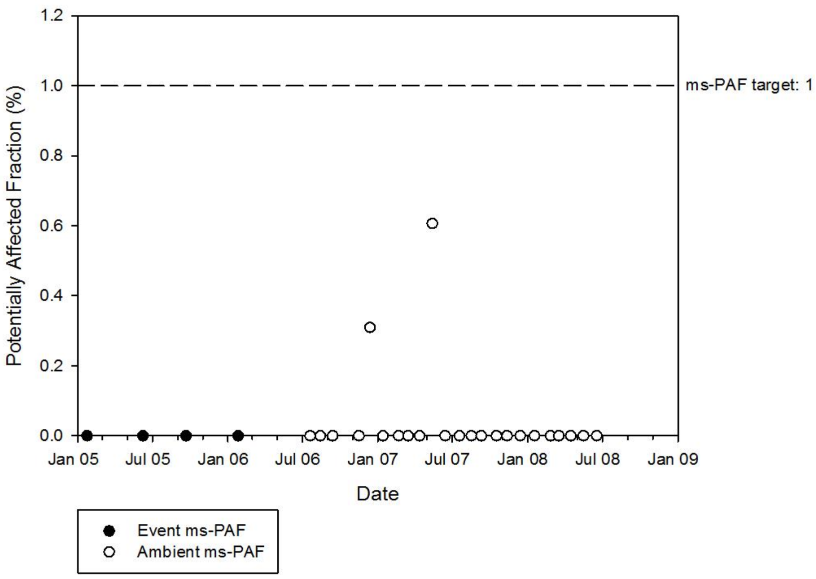

Figure 178 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient and event conditions at Impulse Creek from 2004–2008. The dashed line indicates the PC99 ms-PAF target (ms-PAF target 1) for this site.

3.5.1.9 Mackay City

The Mackay City sites are not HEV sites and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. There was no linear temporal trend at either the Mackay 1 (p = 0.70) or Mackay 2 (p = 0.20) sites (Figure 181). The highest ms-PAF value at the Mackay 1 site was in late 2005, and indicated that 14 per cent of phototrophic species were potentially affected. The only other ms-PAF value above the ms-PAF target of 5 was approximately 5.5 per cent. All other ms-PAF results were below the target, indicating that under the majority of event conditions adequate protection of phototrophic species was provided at these sites.

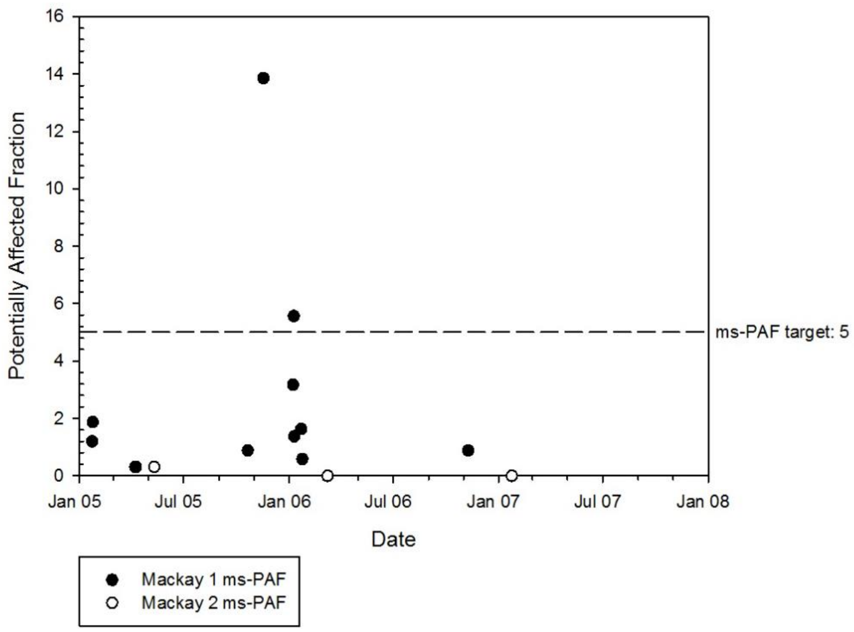

Figure 179 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during event conditions at Mackay 1 and Mackay 2 from 2004–2007. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for this site.

3.5.1.10 Myrtle Creek

Myrtle Creek is not a HEV site and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. Ambient ms-PAF results from Myrtle Creek were highly variable (from approximately 0 to 94 per cent over the sampling period), with no linear temporal trend (p = 0.27) (Figure 180). The highest ambient ms-PAF value occurred in late 2007, with a value of 94 per cent, indicating that only 6 per cent of the phototrophic species were potentially protected at that time. The majority of the ambient ms-PAF values were at or below the target; however, there were six ms-PAF results higher than 20 per cent. This indicates that generally adequate protection to phototrophic species is provided under ambient conditions, but sometimes inadequate protection is provided. The ms-PAF event results were highly variable across the sampling period with no linear temporal trends (p = 0.86) (Figure 180). The highest event ms-PAF value showed that 96 per cent of phototrophic species were potentially affected by the mixture of pesticides. In the majority of time under event conditions, inadequate protection to phototrophic species was provided.

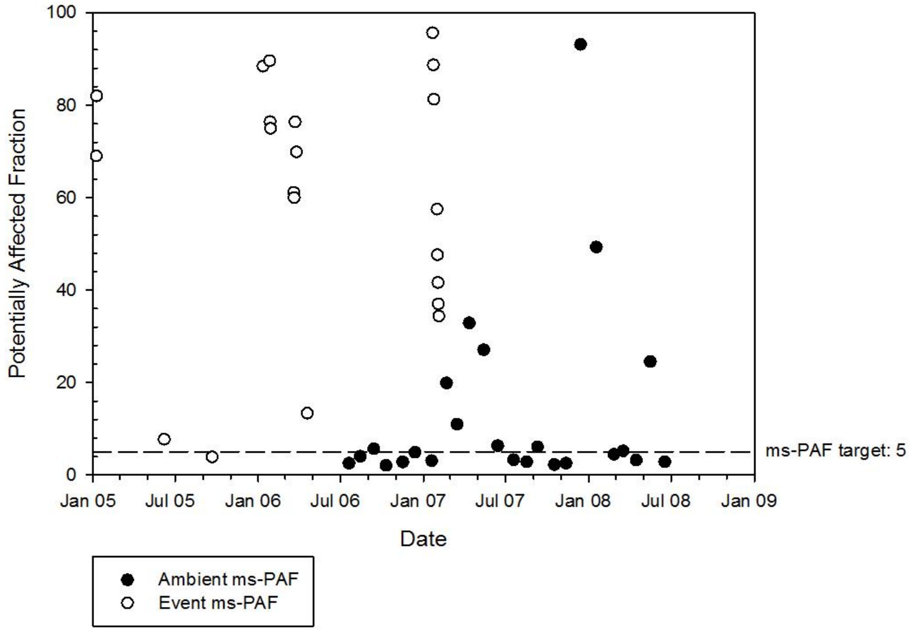

Figure 180 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient and event conditions at Myrtle Creek from 2004–2008. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for the site.

3.5.1.11 O'Connell River

The O'Connell River sites are not HEV sites and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. Ambient ms-PAF results were largely consistent for the O'Connell 1 site and did not show any linear temporal trend ($p = 0.29$) (Figure 181). Two ambient ms-PAF results in late 2007/early 2008 exceeded the ms-PAF target of 5, with values of 11 and 13 per cent, respectively. Event sampling results in both sites varied, with peak values ranging from 36 to 58 per cent (Figure 181). There were no linear temporal trends in event ms-PAF values for O'Connell 1 ($p = 0.08$) or O'Connell 2 ($p = 0.71$). The ms-PAF event values were highest in early 2006, and decreased toward early 2008, but the limited sampling could be misleading. The majority of ms-PAF event values were larger than the ms-PAF target value, indicating that adequate protection of phototrophic species was typically not provided.

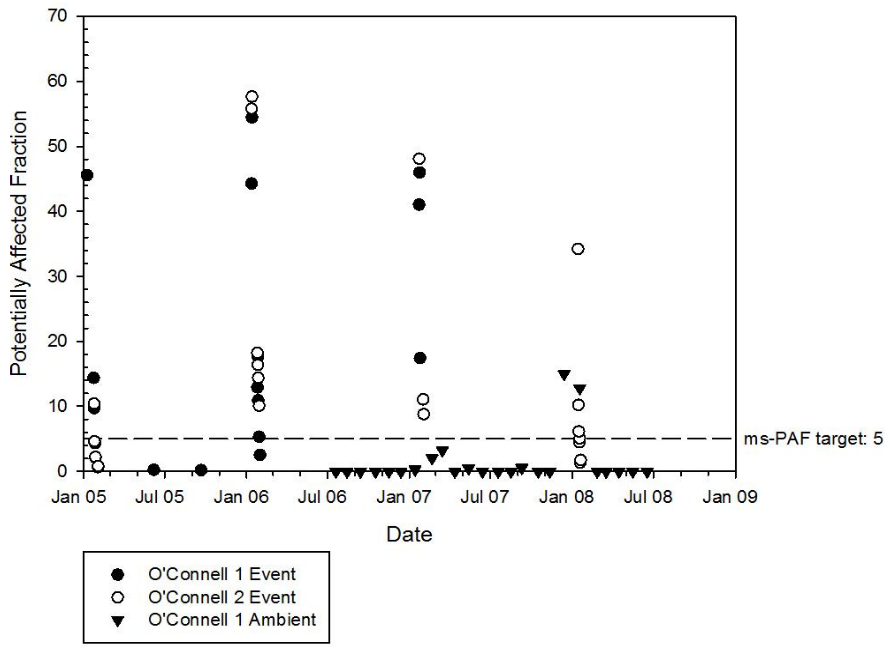

Figure 181 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient and event conditions at O'Connell River from 2004–2008. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for this site.

3.5.1.12 Pioneer River

The Pioneer River is not a HEV site and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. Ambient ms-PAF results for the Pioneer River were consistent and did not show any linear temporal trends ($p = 0.97$) (Figure 182). There were values that exceeded the ms-PAF target of 5, with the highest ms-PAF value being 30 per cent, however the timing of all three of these values appeared to be within events. All other ambient ms-PAF values were below the ms-PAF target for the Pioneer River. Thus, under the vast majority of ambient conditions adequate protection is provided to phototrophic species in the Pioneer River.

The event sampling from Pioneer River showed a slight linear decrease over time ($p = 0.000$; $R^2 = 0.059$); however, the low R^2 value indicates that there are other factors (rather than just time) also influencing the ms-PAF results (Figure 182). The majority of the event ms-PAF results in Pioneer River were above the ms-PAF target of 5, with a high number of results over an ms-PAF of 20, and multiple over 60. The highest ms-PAF event value was approximately 77 per cent, which is well above the ms-PAF target. These event results indicate that generally inadequate protection is provided to phototrophic species under event conditions in the Pioneer River and the degree of protection can be quite low.

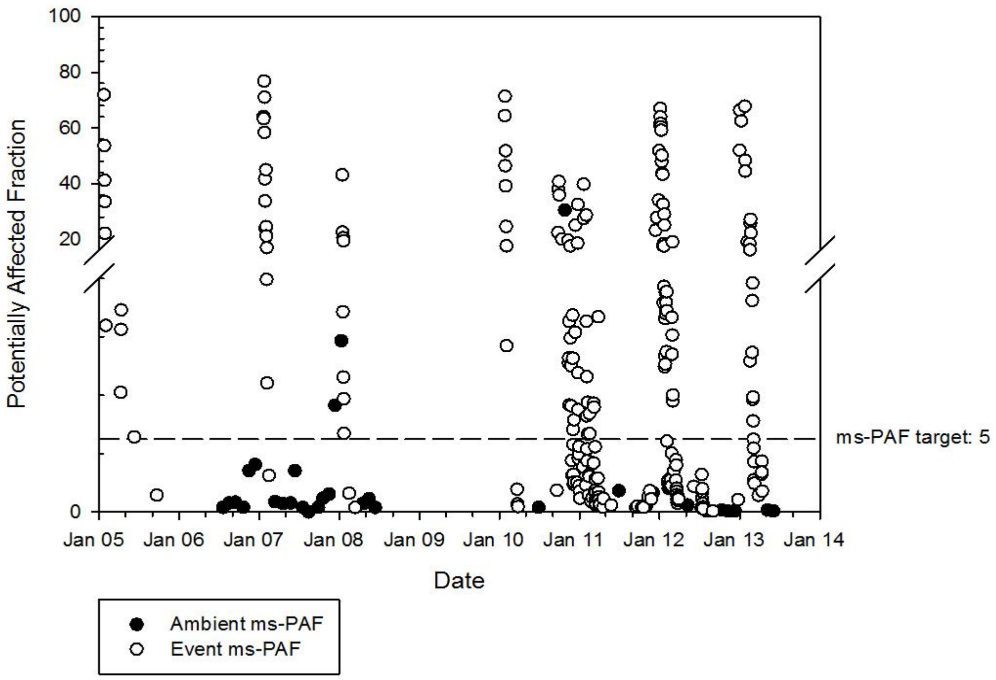

Figure 182 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient and event conditions at Pioneer River from 2004–2013. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for this site.

3.5.1.13 Plane Creek

Plane Creek is not a HEV site and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. Ambient ms-PAF results were consistent for Plane Creek, with one notable exception, and did not show any linear temporal trend ($p = 0.44$) (Figure 183). One ambient value exceeded the ms-PAF target of 5 (57 per cent). All ambient results except this value were at or below the ms-PAF target for Plane Creek indicating that under the vast majority of ambient conditions adequate protection of phototrophic species is provided in Plane Creek. The event ms-PAF results from Plane Creek were variable, with no linear temporal trend ($p = 0.61$) (Figure 183). The ms-PAF event values were highest in early 2005 (36 per cent), and early 2007 (45 per cent). The majority of event samples were above the ms-PAF target, indicating that during event conditions inadequate protection was provided to phototrophic species in Plane Creek.

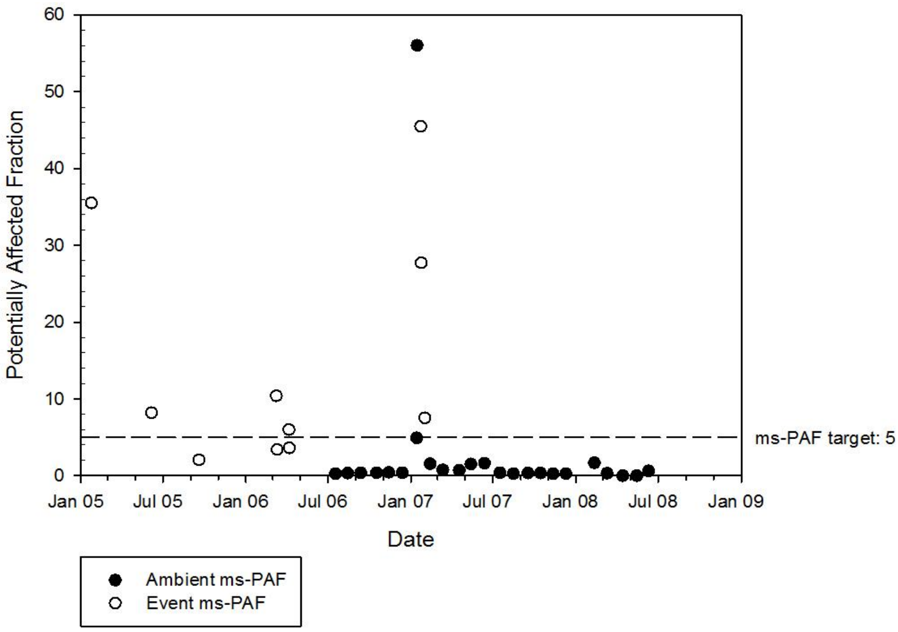

Figure 183 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient and event conditions at Plane Creek from 2004–2008. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for this site.

3.5.1.14 Proserpine River

The Proserpine River sites are not HEV sites and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. Both Proserpine River sites had very limited number of samples and ms-PAF values. Event ms-PAF results were consistent in Proserpine 1 and did not show any linear temporal trend ($p = 0.93$) (Figure 184). There were not enough data points from Proserpine 2 to discern any linear trends. There was one elevated ms-PAF value in early 2005 (approximately 15 per cent), but all other samples had ms-PAF values below the target of 5. The sampling in both sites was limited with no discernible difference between the sites. Based on the limited sampling it appears that under the majority of event conditions adequate protection to phototrophic species is provided in Proserpine River.

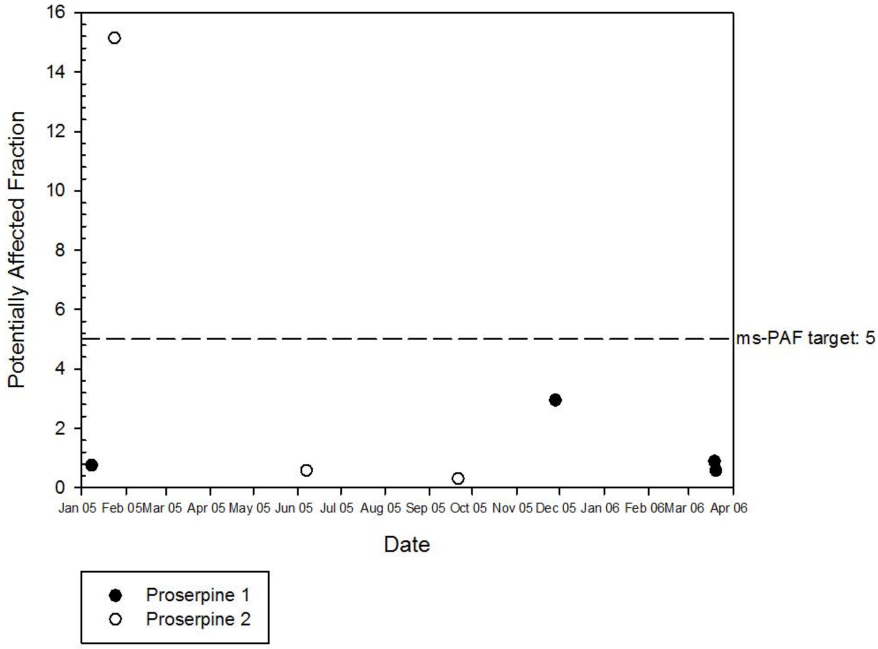

Figure 184 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during event conditions at Proserpine River from 2004–2006. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for this site.

3.5.1.15 Rocky Dam Creek

Rocky Dam Creek is not a HEV site and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. The ambient ms-PAF results for Rocky Dam Creek were largely consistent and did not show any linear temporal trend ($p = 0.28$) (Figure 185). There were a number of elevated ambient ms-PAF values calculated, however the ms-PAF values from 14 January 2008 and 11 February 2008 (Figure 185), align with an event (refer to hydrograph for Rocky Dam Creek in Appendix B). The majority of ambient ms-PAF values were below the ms-PAF target of 5, indicating that generally adequate protection is provided to phototrophic species in Rocky Dam Creek under ambient conditions. The results from event sampling at Rocky Dam Creek had no linear temporal trend ($p = 0.55$) (Figure 185). The ms-PAF event values were highest in early 2006 with a value of approximately 96 per cent. The majority of event ms-PAF values were above the target of 5, indicating that adequate protection was not being provided during events and the degree of protection was in some cases very low.

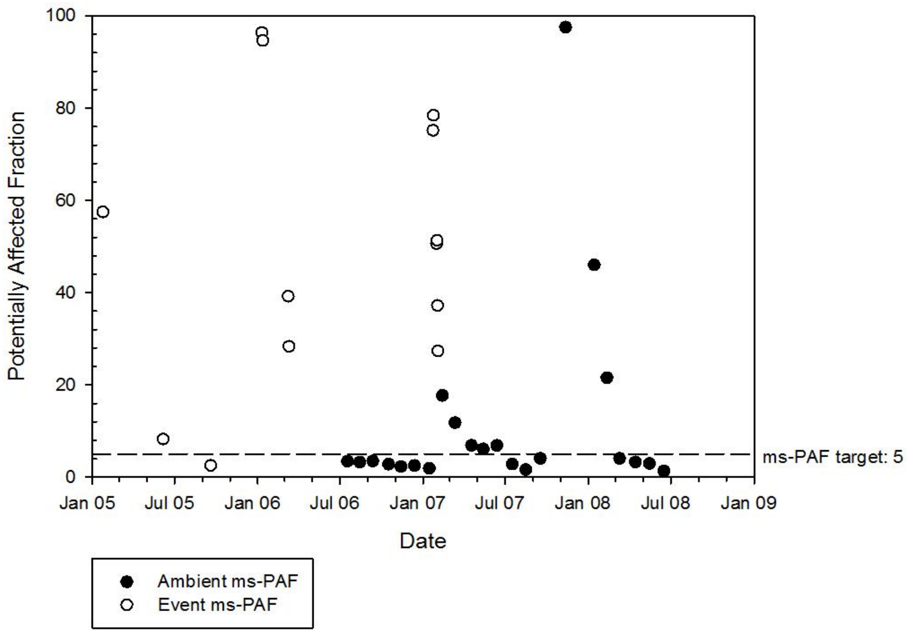

Figure 185 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient and event conditions at Rocky Dam Creek from 2004–2008. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for this site.

3.5.1.16 Sandy Creek

Sandy Creek is not a HEV site and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. Ambient ms-PAF results for Sandy Creek decreased between the 2006–2008 and 2010–2013 sampling periods ($p = 0.002$; $R^2 = 0.267$); however, the low R^2 values indicate that there are other factors (in addition to time) also influencing the variation in ms-PAF results (Figure 186). The majority of the ambient ms-PAF values in Sandy Creek were below the ms-PAF target , indicating that during ambient conditions adequate protection was generally provided.

The event sampling from Sandy Creek also showed a linear decrease in ms-PAF values ($p = 0.000$; $R^2 = 0.147$); however, the low R^2 values again indicated that there were other factors also influencing the ms-PAF values (Figure 186). The highest ms-PAF event value was approximately 89 per cent, which was well above the ms-PAF target of 5,. The majority of the event ms-PAF results in Sandy Creek were above the ms-PAF target of 5, with a high number of results over an ms-PAF of 20, and multiple over 60. This indicates that during events inadequate and a low degree of protection to phototrophich species is mainly provided in Sandy Creek.

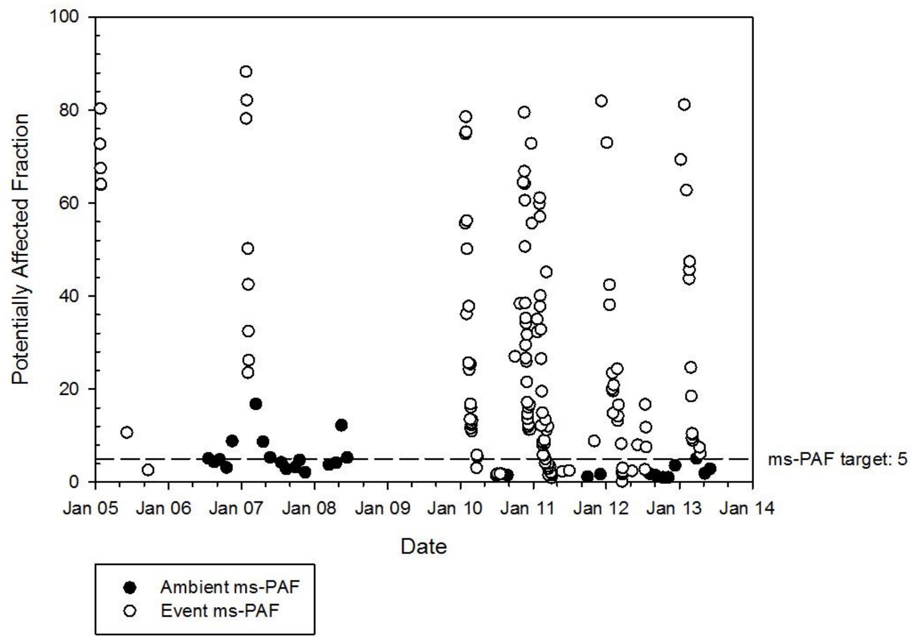

Figure 186 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient and event conditions at Sandy Creek from 2004–2013. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for this site.

3.5.1.17 Sarina

Sarina is not a HEV site and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. Event ms-PAF results at Sarina (in Plane Creek) were limited (five values in early 2006 and two values in early 2007), and did not show any linear temporal trend (p = 0.94) over the monitoring period (Figure 187). The highest ms-PAF value occurred in early 2006 and indicated 14 per cent of phototrophic species were potentially affected at that time. The majority of event ms-PAF values at Sarina were below the ms-PAF target of 5, indicating that adequate protection was generally provided at Sarina under event conditions.

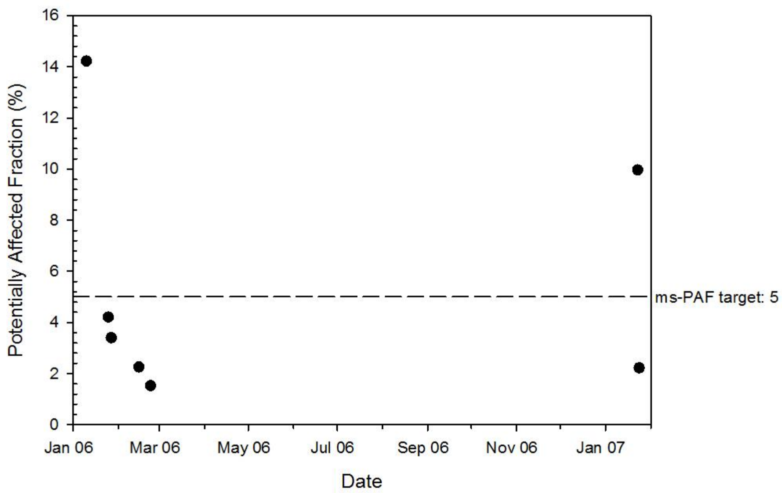

Figure 187 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during event conditions at Sarina from 2004–2008. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for this site.

3.5.1.18 St Helens Creek

St Helens Creek is a HEV site and therefore the ms-PAF target 1 that aims to protect 99 per cent of phototrophic species is the relevant target. All 23 ambient and nine event samples for St Helens Creek had ms-PAF results of 0 per cent (Figure 188) and as such were the ms-PAF target. This indicated that under both flow conditions, adequate protection to phototrophic species was always provided.

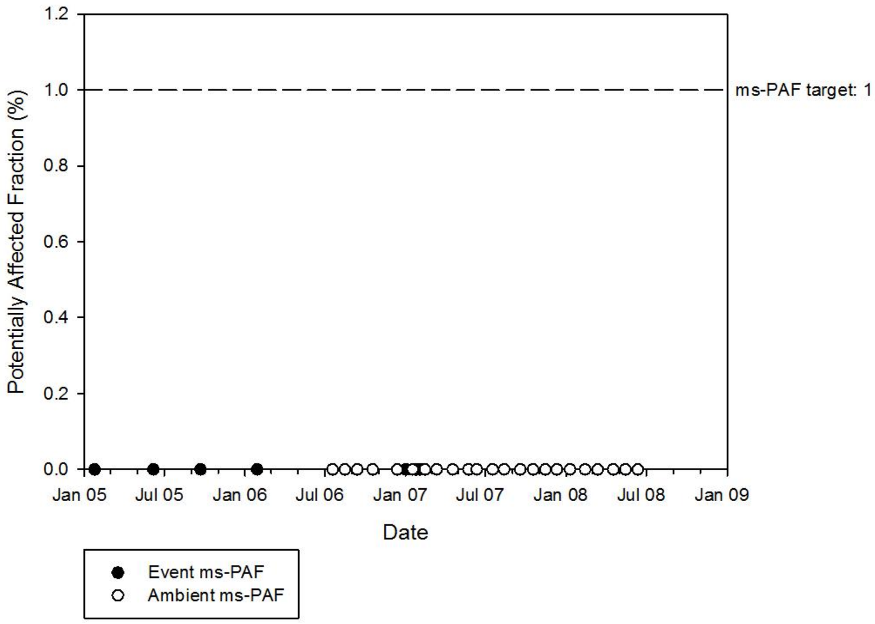

Figure 188 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during ambient and event conditions at St Helens Creek from 2004–2008. The dashed line indicates the PC99 ms-PAF target (ms-PAF target 1) for this site.

3.5.1.19 Waite Creek

Waite Creek is not a HEV site and therefore the ms-PAF target 5 that aims to protect 95 per cent of phototrophic species is the relevant target. Of the six event samples for Waite Creek, all samples but one, had a ms-PAF value of 0 per cent (Figure 189). The remaining sample had an ms-PAF value of 0.19 per cent. All event ms-PAF results for mixtures of pesticides in Waite Creek were below the ms-PAF target of 5, indicating that under event conditions, adequate protection was provided to phototrophic species.

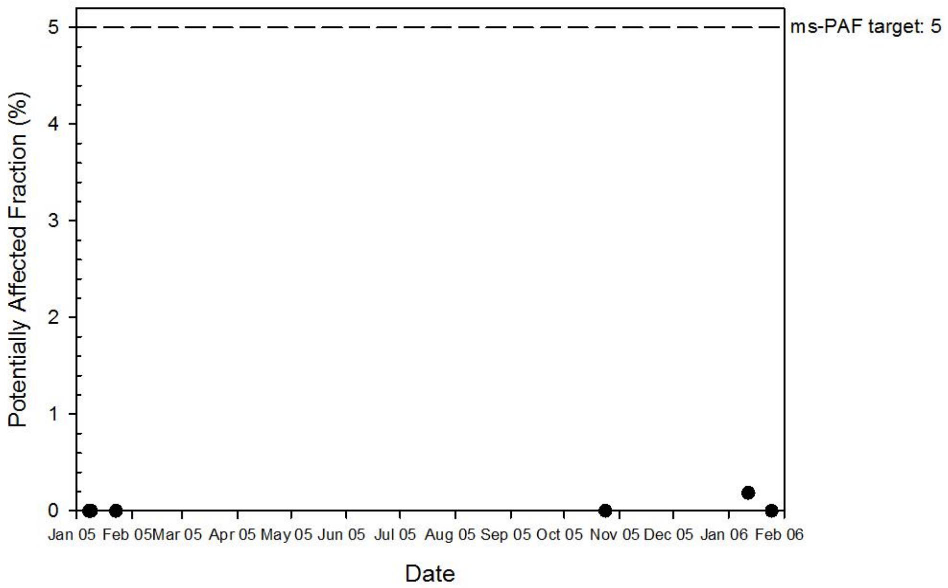

Figure 189 Temporal variation in multisubstance-potentially affected fraction (ms-PAF) results during event conditions at Waite Creek from 2004–2006. The dashed line indicates the PC95 ms-PAF target (ms-PAF target 5) for this site.

3.5.2 Risk assessment

3.5.2.1 Ambient conditions

Mixtures of pesticides were below the ms-PAF value that was calculated to protect 99 per cent of species in the five HEV sites (Upper Andromache River, Basin Creek, Finch Hatton Creek, Impulse Creek, and St Helens Creek), during ambient conditions (Table 21,Table 22).

In Bakers Creek, ambient concentrations of pesticide mixtures provided insufficient protection of species at the PC95 level (Table 21). In 2006–2007, 58 per cent of samples had ms-PAF values that exceeded the target value, and 64 per cent exceeded the target value in 2007–2008. In 2006–2007, 17 per cent of the samples were in the very high risk category; that is 70 per cent or more of phototrophic species were potentially affected in 17 per cent of the samples. In this same year, 42 per cent of samples posed a medium risk (5–40 per cent of phototrophic species were potentially affected). In 2007–2008, 55 per cent of samples were in the medium risk category (i.e., 5–40 per cent of phototrophic species potentially affected).

In Carmila Creek, ambient concentrations of pesticide mixtures provided insufficient protection of phototrophic species at the PC95 level, exceeding the ms-PAF target of 5 (Table 21). In both years, 83 per cent of samples were below target values and hence in the low risk category, but 17 per cent of the samples were in the medium risk category (i.e., 5–40 per cent of phototrophic species were potentially affected).

In Myrtle Creek, ambient concentrations of pesticide mixtures provided insufficient protection of phototrophic species at the PC95 level (Table 21). Only 50 per cent of the samples from 2006–2007 and 58 per cent from 2007–2008 were below the ms-PAF target of 5. In 2006–2007, 50 per cent of samples were in the medium risk category. In 2007–2008, 25 per cent of samples were in the medium risk category and 8 per cent of the samples were in both the high and very high risk categories.

At the O'Connell River 1 site, ambient concentrations of mixtures of pesticides were below target values in 2006–2007 (Table 21). In 2007–2008, 83 per cent of samples were in the low risk category while the remaining 17 per cent of samples were in the medium risk category.

In the Pioneer River, ambient concentrations of mixtures of pesticides were below the ms-PAF of 5 target value in 2006–2007 (Table 21). In 2007–2008, 80 per cent of samples were in the low risk category with the remaining 20 per cent of samples in the medium risk category. For all subsequent years, the number of samples limited the reliability of the risk assessments results.

In 2006–2007, 8 per cent of the ambient samples collected in Plane Creek, were in the high risk category (Table 21), with the remaining 92 per cent of samples being below the target value. In 2007-2008 all the samples were classed as low risk.

In Rocky Dam Creek, 58 and 42 per cent of the ambient samples were in the low and medium risk categories, respectively in 2006–2007. In 2007–2008, 10 per cent of the ambient samples fell into each of the medium, high and very high risk categories with the remainder being low risk (Table 21).

Table 21 Per cent of ambient samples occurring within each multisbustance-potentially affected fraction (ms-PAF) risk classification range. Red indicates poor data availability (0–4 samples), amber indicates moderate data availability (5–9 samples), green indicates good data availability (≥ 10 samples) as indicated in Table 5.

		ms-PAF results			
		Risk classification (percentage species affected)			
Waterway	Year (no. of samples)	Low risk (0–5% species affected)	Medium risk (5–40% species affected)	High risk (40–70% species affected)	Very high risk (≥ 70% species affected)
Upper Andromache River	2006–2007 (12)	100	0	0	0
	2007–2008 (12)	100	0	0	0
Bakers Creek	2006–2007 (12)	42	42	0	17
	2007–2008 (11)	36	55	9	0
Basin Creek	2006–2007 (12)	100	0	0	0
	2007–2008 (12)	100	0	0	0
Carmila Creek	2006–2007 (12)	83	17	0	0
	2007–2008 (12)	83	17	0	0
Finch Hatton Creek	2006–2007 (12)	100	0	0	0
	2007–2008 (12)	100	0	0	0
Impulse Creek	2006–2007 (12)	100	0	0	0
	2007–2008 (12)	100	0	0	0
Myrtle Creek	2006–2007 (12)	50	50	0	0
	2007–2008 (12)	58	25	8	8
O'Connell River 1	2006–2007 (12)	100	0	0	0
	2007–2008 (12)	83	17	0	0
Pioneer River	2006–2007 (10)	100	0	0	0
	2007–2008 (10)	80	20	0	0
	2008–2009 (0)	-	-	-	-
	2009–2010 (1)	100	0	0	0
	2010–2011 (2)	50	50	0	0
	2011–2012 (4)	100	0	0	0
	2012–2013 (6)	100	0	0	0
Plane Creek	2006–2007 (13)	92	0	8	0
	2007–2008 (9)	100	0	0	0
Rocky Dam Creek	2006–2007 (12)	58	42	0	0
	2007–2008 (10)	70	10	10	10
St Helens Creek	2006–2007 (11)	100	0	0	0
	2007–2008 (12)	100	0	0	0

Table 22 Per cent of ambient samples for the five High Ecological Value (HEV) sites that indicate 0–1% and 1–5% of species would be adversely affected according to multisubstance-potentially affected fraction (ms-PAF) results. Green shading indicates good data availability (≥ 10 samples).

		ms-PAF result Risk classification range	
Waterway	**Year (no. of samples)**	**0–1% species affected**	**1–5% species affected**
Upper Andromache River	2006–2007 (12)	**100**	**0**
	2007–2008 (12)	**100**	**0**
Basin Creek	2006–2007 (12)	**100**	**0**
	2007–2008 (12)	**100**	**0**
Finch Hatton Creek	2006–2007 (12)	**100**	**0**
	2007–2008 (12)	**100**	**0**
Impulse Creek	2006–2007 (12)	**100**	**0**
	2007–2008 (12)	**100**	**0**
St Helens Creek	2006–2007 (11)	**100**	**0**
	2007–2008 (12)	**100**	**0**

3.5.2.2 Event conditions

Event concentrations of pesticide mixtures provided insufficient protection (ms-PAF target of 5) in Myrtle Creek (Table 23), with no more than 10 per cent of event samples being below target values in any of the three years sampled (Table 23).

Samples collected in the Pioneer River generally exceeded target values (Table 23). In 2004–2005 no samples were below the ms-PAF target of 5. The number of event samples that were below ms-PAF target 5 value increased from 2005–2006, with 7 per cent in 2006–2007, 20 per cent in 2007–2008, 27 per cent in 2009–2010, 52 per cent in 2010–2011, 50 per cent in 2011–2012, and 54 per cent in 2012–2013. In most years, the Pioneer River showed the majority of samples posed a medium risk to species affected by pesticide mixtures (ranging from 30–70 per cent of samples). In 2004–2005, 2006–2007, and 2009–2010 there were samples which fell within the very high risk category.

Event samples collected from Sandy Creek generally exceeded targets in all years in which sufficient data was collected (Table 23). In 2009–2010, 4 per cent of samples were below the target value, 26 per cent in 2010–2011, 27 per cent in 2011–2012, and 6 per cent in 2012–2013. The majority of samples from Sandy Creek fell within the medium risk category, with significant numbers also falling in the high and very high risk categories (Table 23).

Table 23 Per cent of event multisubstance-potentially affected fraction (ms-PAF) results occurring within each risk classification range. Red indicates poor data availability (0–4 samples), amber indicates moderate data availability (5–9 samples), green indicates good data availability (≥ 10 samples) as indicated in Table 5.

		ms-PAF result			
		Risk classification range			
Waterway	Year (no. of samples)	Low risk (0–5% species affected)	Medium risk (5–40% species affected)	High risk (40–70% species affected)	Very high risk (≥ 70% species affected)
Myrtle Creek	2004–2005 (3)	0	33	33	33
	2005–2006 (10)	10	10	30	50
	2006–2007 (8)	0	25	38	38
Pioneer River	2004–2005 (10)	0	70	20	10
	2005–2006 (1)	100	0	0	0
	2006–2007 (15)	7	47	33	13
	2007–2008 (10)	20	70	10	0
	2008–2009 (0)	-	-	-	-
	2009–2010 (11)	27	30	27	9
	2010–2011 (81)	52	47	1	0
	2011–2012 (84)	50	33	17	0
	2012–2013 (41)	54	32	15	0
Sandy Creek	2004–2005 (6)	0	17	50	33
	2005–2006 (1)	100	0	0	0
	2006–2007 (8)	0	38	25	38
	2007–2008 (1)	100	0	0	0
	2008–2009 (0)	-	-	-	-
	2009–2010 (24)	4	67	13	17
	2010–2011 (68)	26	54	16	3
	2011–2012 (22)	27	59	5	9
	2012–2013 (18)	6	61	28	6

3.6 Assessment of the level of protection provided by the water quality targets

3.6.1 Assessment for individual pesticides

The ecotoxicity thresholds derived as part of this project differ from the Australian and New Zealand Water Quality Guidelines (ANZECC and ARCANZ 2000), as discussed in Section 3.2.2, and shown in Figure 190.

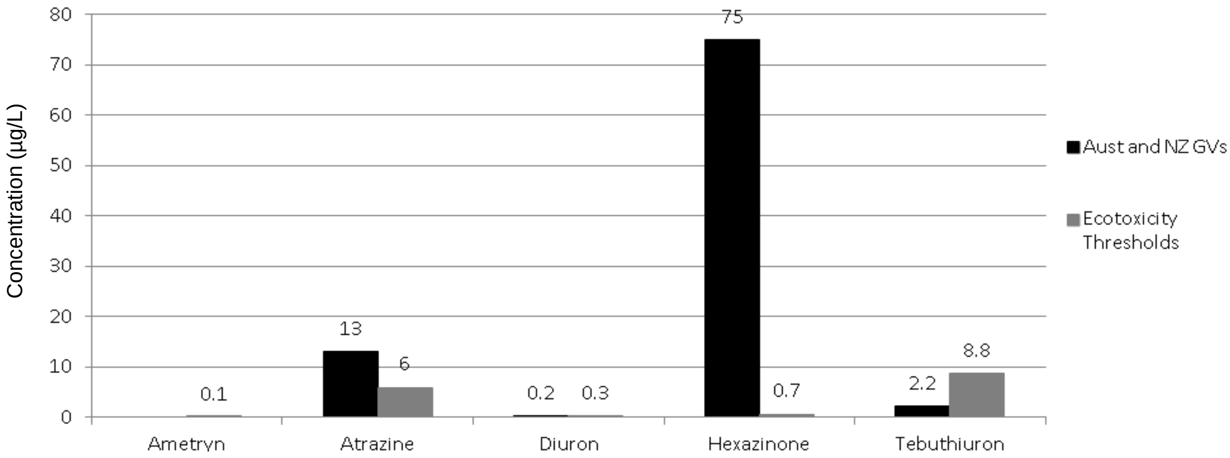

Figure 190 Comparison of Australia and New Zealand Guideline Values and the new ecotoxicity thresholds.

The pesticide targets set for the majority of CMAs within the Mackay Whitsunday WQIP (both ambient and event) are more stringent than the ecotoxicity thresholds, and therefore based on individual pesticides, should provide adequate protection to aquatic species. However, the diuron event pesticide 2014 targets for Gregory River, Myrtle Creek, Proserpine River, St Helens Creek, Mackay City, Pioneer River, and Upper Cattle, Bakers, Sandy, Plane, Rocky Dam, and Carmila creeks are all above both the Australian and New Zealand guideline values, and above the proposed ecotoxicity threshold. It is likely that these event targets are not providing adequate protection for phototrophic species.

The ametryn event 2014 target for Myrtle Creek is set at 0.12 µg/L, which is just above the PC95 ecotoxicity threshold of 0.1 µg/L. It is therefore likely that this event target is not providing adequate protection for aquatic phototrophic species.

The pesticide targets (both ambient and event) for HEV sites (i.e., Upper Andromache River, Basin Creek, Finch Hatton Creek, Impulse Creek, and St Helens Creek) should be aligned with the PC99 ecotoxicity thresholds to ensure adequate protection for these sites. The majority of the 2014 pesticide targets for these HEV sites (and associated CMAs) meet the PC99 ecotoxicity threshold (Table 24). The 2014 event targets for diuron and hexazinone for St Helens Creek are above the PC99 protection level (Table 24), as well as the diuron event target for Finch Hatton Creek. These pesticide event targets are unlikely to be providing adequate protection.

Table 24 Pesticide ecotoxicity thresholds (µg/L) for freshwater phototrophic species and the 2014 ambient and event targets for the Mackay Whitsunday high ecological value (HEV) sites (Drewry et al. 2008). "A" refers to the ambient 2014 target and "E" to the 2014 event target. Amber shading indicates a target that is above the 99% protection ecotoxicity threshold. The level of reporting (LOR) for pesticide sampling is 0.01 µg/L.

	Ecotoxicity thresholds			Pesticide targets for various sites (CMA) in the Mackay Whitsunday region (µg/L)				
Pesticide	**PC99 (µg/L)**	**PC95 (µg/L)**	**Condition**	**Impulse Creek (Repulse Creek)**	**Upper Andromache River (Andromache River)**	**St Helens Creek (St Helens Creek)**	**Finch Hatton Creek (Upper Cattle Creek)**	**Basin Creek (Gillinbin Creek)**
Ametryn	**0.02**	**0.1**	**A**	<LOR	<LOR	0.02#	<LOR	<LOR
			E	<LOR	<LOR	<LOR#	<LOR	<LOR
Atrazine	**3.7**	**6**	**A**	<LOR	<LOR	<LOR	<LOR	<LOR
			E	<LOR	0.02	0.04	0.14	0.02
Diuron	**0.2**	**0.3**	**A**	<LOR	<LOR	0.07	<LOR	<LOR
			E	<LOR	<LOR	0.46	0.43	0.05
Hexazinone	**0.2**	**0.7**	**A**	<LOR	<LOR	0.13	0.01	<LOR
			E	<LOR	<LOR	0.23	0.16	<LOR
Tebuthiuron	**4.3**	**8.8**	**A**	<LOR	<LOR	<LOR	<LOR	<LOR
			E	<LOR	<LOR	<LOR	<LOR	<LOR

#indicates a more stringent event target than ambient target

3.6.2 **Assessment for mixtures of pesticides**

The individual pesticide 2014 targets for each CMA may not be providing adequate protection to aquatic species when mixtures of pesticides are present in the waterways. The ms-PAF values for mixtures in seven waterways are above both the PC95 and PC99 protection levels (Figure 191).

If the current Australian and New Zealand guidelines (ANZECC and ARMCANZ 2000) were met for all five PSII herbicides, the ms-PAF analysis indicates that approximately 96 per cent of phototrophic species would be affected (Figure 191). Similarly, if the ecotoxicity thresholds were met for the five PSII herbicides at the same time, 44 per cent of phototrophic species may be affected by the mixture.

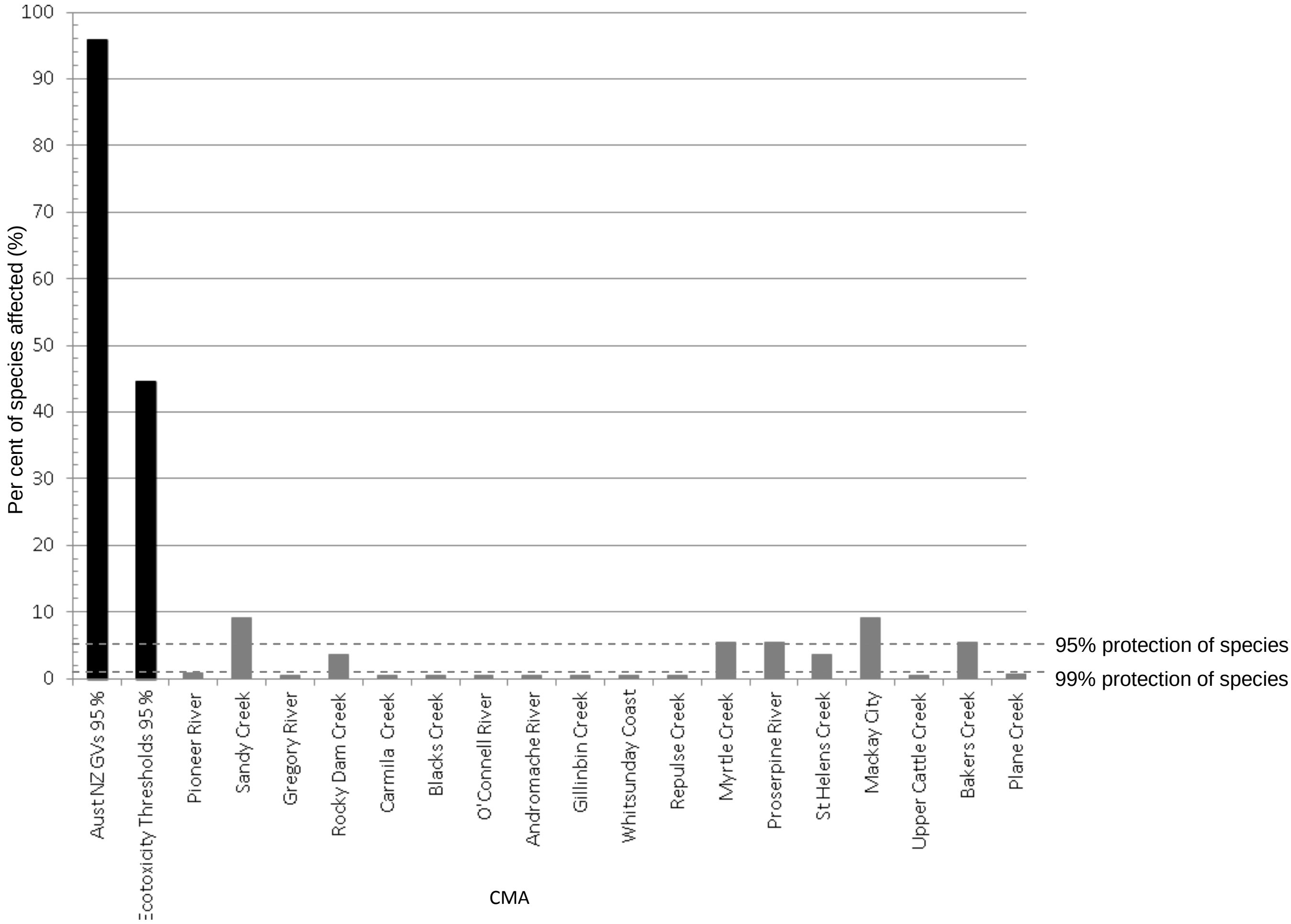

Figure 191 The percentage of species that would be affected according to the multisubstance-potentially affected fraction (ms-PAF) method, when the ambient targets for all five PSII herbicides were equaled at each catchment management area (CMA) compared to the 2014 pesticide ambient targets (e.g. 95% and 99%). The percentage of species that would be affected when the Australian and New Zealand Guideline Values and new ecotoxicity thresholds were met are also shown.

All the CMAs that did not contain HEV sites (i.e., Whitsunday Coast, Andromache River, Bakers Creek, Blacks Creek, Carmilla Creek, Gregory River, Mackay City, Myrtle Creek, O'Connell River, Pioneer River, Plane Creek, Proserpine River, Rocky Dam Creek and Sandy Creek) should not permit more than 5 per cent of species to experience toxic effects. The ms-PAF results for ambient conditions indicate that between 5 and 8 per cent of phototrophic species were potentially affected at Sandy Creek, Mackay City, Myrtle Creek, Proserpine River and Bakers Creek CMAs (Figure 192). The target and ms-PAF results are not identical – the former refers to the per cent of all species in the ecosystem being considered, while the latter only refers to percent of phototrophic species. Nonentheless given, phototrophic species are at the bottom of essentially all aquatic foodwebs and reductions in algal mass affect herbivores and subsequently carnivores, having more than 5 per cent of phototrophic species affected was considered to indicate inadequate protection. The remaining CMAs that did not contain HEV sites all provided adequate protection (i.e., < 5 per cent phototrophic species potentially affected) (Figure 192).

All the CMAs CMAs that contain HEV sites (Andromache River, Gillibin Creek, Upper Cattle Creek, Repulse Creek and St Helens Creek) should not permit more than 1 per cent of species to experience toxic effects. The ms-PAF results for ambient conditions indicate that this target was met in all cases, except for St Helens Creek where 3.6 per cent of phototrophic species were potentially affected (Figure 192).

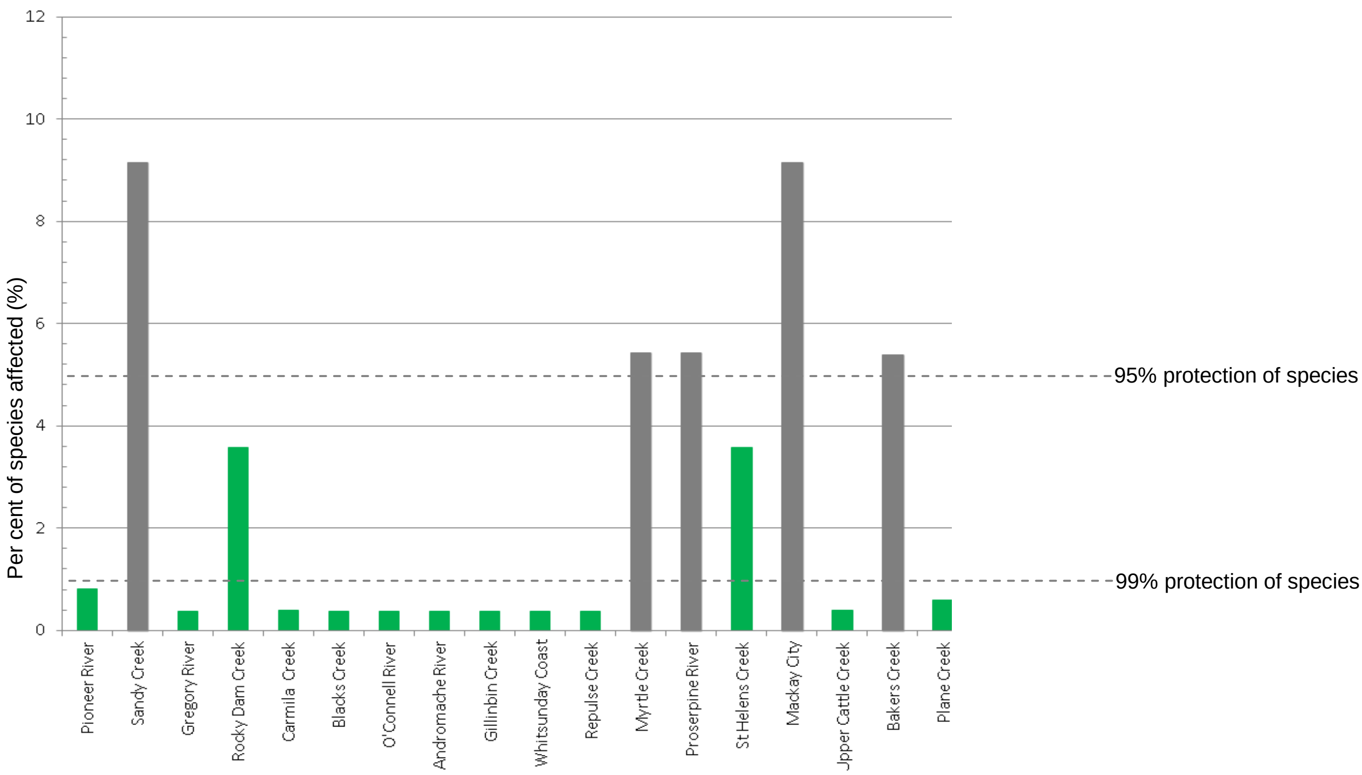

Figure 192 The percentage of species that would be affected, calculated using the multisubstance-potentially affected fraction (ms-PAF) method, when the ambient targets for all five PSII herbicides were equaled at each catchment management area (CMA) compared to the 2014 pesticide ambient targets (e.g. 95% and 99%). Green shading indicates the CMAs where targets are providing adequate protection.

Overall, the ambient individual pesticide concentration targets provide adequate protection to species in 66.66 per cent of the CMAs, and inadequate protection of species in 33.33 per cent.

When the concentrations of each of the five PSII herbicides equalled the CMA event pesticide 2014 targets, only in five CMAs was the appropriate level of protection provided – Blacks Creek, Andromache River, Gillibin Creek, Repulse Creek, Whitsunday Coast (Figure 193). The remaining CMAs potentially had 14–54 per cent of phototrophic species experiencing adverse toxic effects. The level of protection provided was particularly poor for St Helens Creek and Upper Cattle Creek where between 16–19 per cent of phototrophic species were potentially affected but only 1 per cent should be affected as these CMAs contain HEV sites.

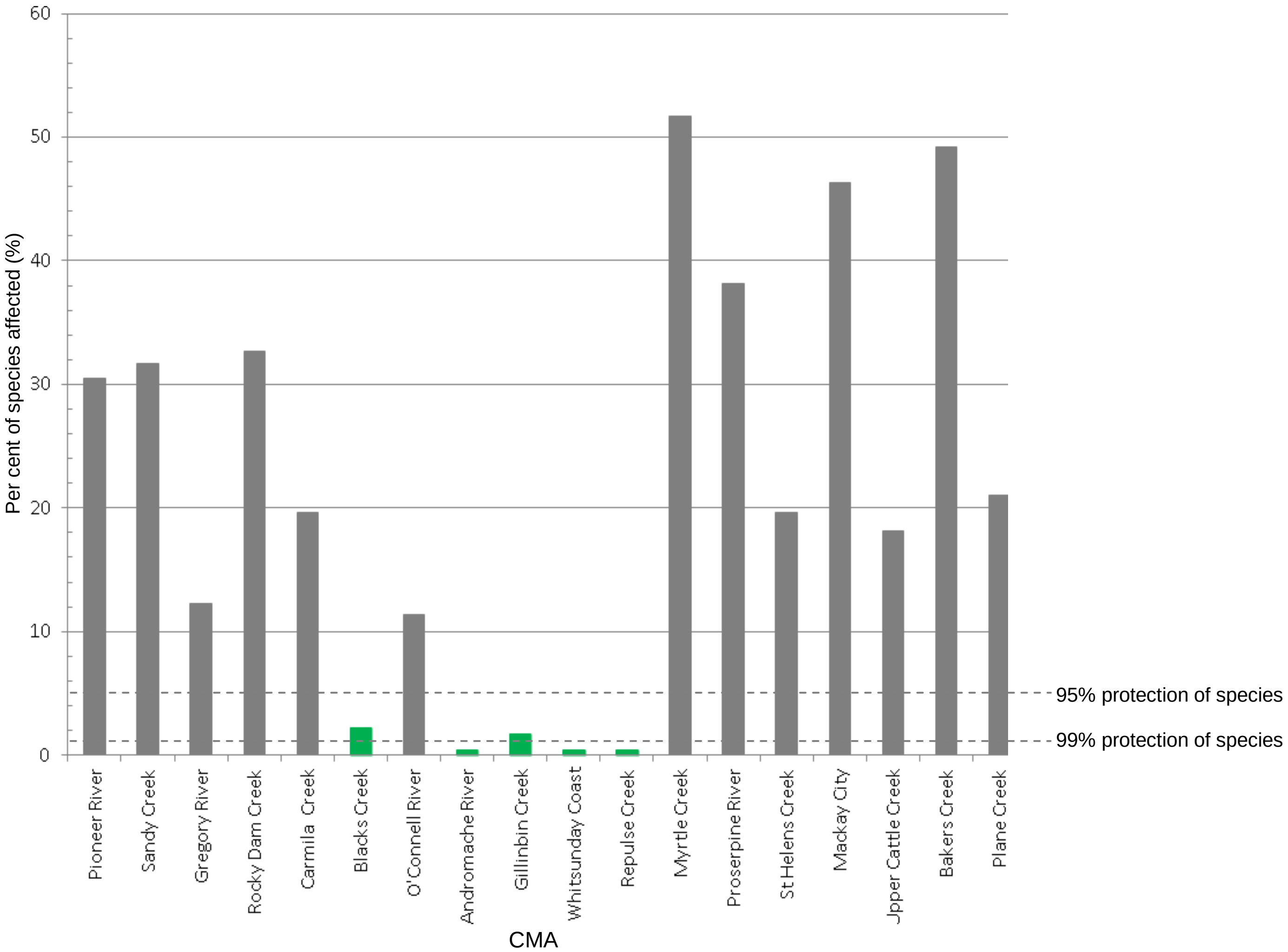

Figure 193 The percentage of species that would be affected, calculated using the multisubstance-potentially affected fraction (ms-PAF) method, when the event targets for all five PSII herbicides were equaled at each catchment management area (CMA) compared to the 2014 pesticide event targets (e.g. 95% and 99%). Green shading indicates CMAs where the targets provide adequate protection.

Overall, the event individual pesticide concentration targets provide adequate protection in only 28 per cent of CMAs, and inadequate protection in 72 per cent. It should be noted, however, that these results assume all five PSII herbicides are each at their 2014 target concentration at the same time.

3.7 Probabilistic ecological risk assessment for pesticide mixtures in Sandy Creek

The data available for ambient pesticide concentrations in Sandy Creek were not sufficient to undertake the PERA, therefore only event pesticide concentrations were analysed.

3.7.1 Risk assessment for each year

Based on the methodology set out in Section 2.1 to define ambient and event days, the total number of ambient and event days that occurred in Sandy Creek each year were calculated (Table 25). The most event days occurred in the 2010–2011 year (191 days), which was expected as this was a known wet year. The lowest number of event days occurred in 2005–2006 (ten days), followed by 2004–2005 (26 days).

Table 25 Number of ambient and event days in each year from 2004 onwards used in the probabilistic ecological risk assessment.

Year	No. ambient days	No. event days
2004–2005	339	26
2005–2006	355	10
2006–2007	282	83
2007–2008	273	93
2008–2009	257	108
2009–2010	262	103
2010–2011	174	191
2011–2012	249	117
2012–2013	258	107

The PERA of pesticide mixtures of event days occurring in Sandy Creek showed that in each of the four years analysed, risk category occurred, including up to 43/191 event days in 2010–2011 in the very high risk category (Table 26). The year in which the lowest number of days were classed as low risk was 2009–2010, when 9/103 (9 per cent) of event days occurred in this category. The year in which the highest number of days were classified as low risk was 2010–2011, when 24/191 (approximately 13 per cent) of days occurred in this category. The number of event days occurring within the low risk category, across all years is very small, indicating that for the majority of the event days in Sandy Creek, adequate protection did not occur.

Table 26 Number of event days predicted to occur within each risk category.

Year	No. of days predicted to occur in each risk category			
	Low risk (0–5% species affected)	Medium risk (5–40% species affected)	High risk (40–70% species affected)	Very high risk (≥ 70% species affected)
2009–2010	9	67	14	12
2010–2011	24	98	26	43
2011–2012	16	81	12	7
2012–2013	11	75	13	8

3.7.2 Temporal comparison of risk

The number of days occurring within each risk category in Sandy Creek did not differ sufficiently over the sampling period to show any temporal trends (Figure 194). There were the most event days in 2010–2011; this year also had the most number of days falling within the high (40–70 per cent species affected) and very high (≥ 70 per cent of species affected) risk categories. The other three years had fairly consistent numbers of days within each risk category. Determining the relative risk across years is done by comparing the distribution of days in each risk category. Years with more days in the lower risk categories pose a lower risk than years where there are more days in the middle or higher risk categories. Thus overall, the 2011–2012 and 2012–2013 years posed the lowest risk, followed closely by the 2009–2010 year as it had 50 per cent more very high risk days. The 2010–2011 year posed the greatest risk as it has a far larger number of days in the high and very high risk categories (Figure 194).

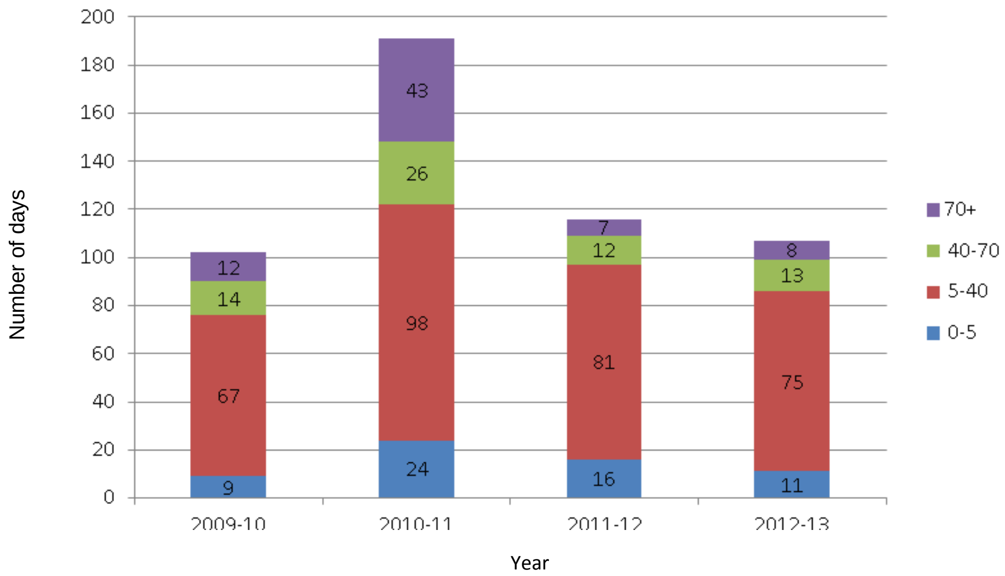

Figure 194 Comparison of number of event days (the value inside the bar graphs) that belong to each risk category for Sandy Creek from 2009–2013.

The percentages of event days within each category were most similar between 2011–2012 and 2012–2013 (Figure 195). Overall, only 9–14 per cent of event days fall into the low risk category each year. Thus, between 86 and 91 per cent of the event days pose a level of risk to the aquatic ecosystems, which does not provide adequate protection in Sandy Creek over the four years between 2009–2010 and 2012–2013.

Figure 195 Comparison of percentage of event days (the value inside the bar graphs) that belong to each risk category for Sandy Creek from 2009–2013.

3.8 Probabilistic ecological risk assessment for pesticide mixtures in Pioneer River

There was sufficient ambient and event pesticide concentration data to permit the PERA to be conducted for both sets of flow conditions.

3.8.1 Risk assessment for each year of ambient conditions

The total number of ambient and event days that occurred in the Pioneer River each year were calculated (Table 27). The most event days occurred in 2010–2011, which was to be expected as this was a known wet year. The lowest number of event days occurred in 2006–2007 (67 days), followed by 2008–2009 (68 days).

Table 27 Number of ambient and event days in each year from 2006 onwards used in the probabilistic ecological risk assessment.

Year	No. ambient days	No. event days
2006–2007	298	67
2007–2008	292	74
2008–2009	297	68
2009–2010	287	78
2010–2011	175	191
2011–2012	285	81
2012–2013	260	105

The results of the PERA of pesticide mixtures for ambient days in the Pioneer River showed that neither year analysed had any days which were classed as very high risk (≥ 70 per cent of species affected), and only one day in 2007–2008 that was classed as a high risk (40–

70 per cent of species affected) category (Table 28). In both years, the majority of ambient days were classed as low risk, and for the majority of days there was adequate protection from mixtures of pesticides under ambient conditions.

Table 28 Number of ambient days predicted to occur within each risk category.

Year	No. of days predicted to occur in each risk category			
	Low risk (0–5% species affected)	Medium risk (5–40% species affected)	High risk (40–70% species affected)	Very high risk (≥ 70% species affected)
2006–2007	291	7	0	0
2007–2008	256	35	1	0

3.8.2 Temporal comparison of risk under ambient conditions

The number of ambient days within each risk category in Pioneer River differed between the years sampled, but due to only having data for two years, it was not possible to discern any linear temporal trends (Figure 196). There were more ambient days in 2006–2007; though 2007–2008 had the most number of days falling within categories that did not provide adequate protection (risk categories where > 5 per cent of species would be affected).

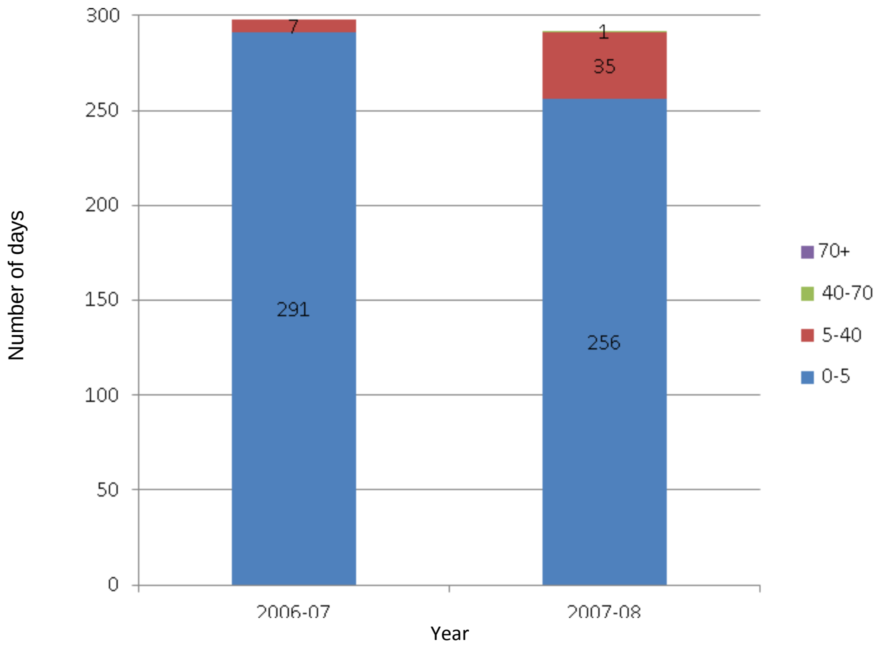

Figure 196 Comparison of number of ambient days (the value inside the bar graphs) that belong to each risk category for the Pioneer River from 2006–2008.

The percentages within each risk category in 2006–2007 were closer to achieving the target of less than 5 per cent of species affected, with only 2 per cent of ambient samples occurring in the medium risk (5–40 per cent of species being affected) category (Figure 197). 2007–2008 had 12 per cent of ambient days in the medium risk category, and a nominal per cent (below 1 per cent) of ambient samples within the high risk category. Overall the results from Pioneer River indicated that in the two sampled years, the ambient conditions were close to providing adequate protection.

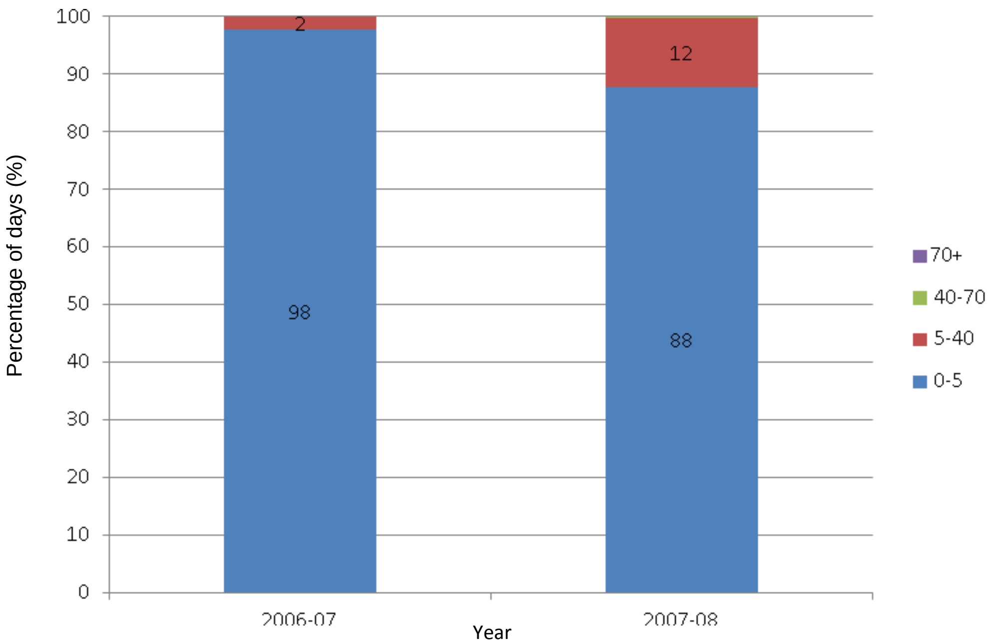

Figure 197 Comparison of percentage of event days (the value inside the bar graphs) that belong to each risk category for the Pioneer River from 2006–2008.

3.8.3 Risk assessment for each year of event conditions

The PERA of pesticide mixtures in event days occurring in the Pioneer River, showed that in each of the five years analysed, there were a number of days that belonged to each risk category, including up to 14/78 (18 per cent) event days in 2009–2010 in the very high risk category (Table 29). The year in which the lowest number of days fell within the low risk category was 2006–2007, when 0/67 (0 per cent) of event days occurred in this category. The year in which the highest number of days were classified as low risk was 2010–2011, when 105/191 (55 per cent) of days fell into this category. The number of event days occurring within the low risk category, across all years varied, but for most event days in the Pioneer River, adequate protection did not occur.

Table 29 Number of event days predicted to occur within each risk category.

Year	No. of days predicted to occur in each risk category			
	Low risk (0–5% species affected)	Medium risk (5–40% species affected)	High risk (40–70% species affected)	Very high risk (≥ 70% species affected)
2006–2007	0	29	28	10
2007–2008	28	36	5	5
2009–2010	26	32	7	14
2010–2011	105	78	5	3
2011–2012	37	35	4	4
2012–2013	54	39	5	7

3.8.4 Temporal comparison of risk under event conditions

The number of event days occurring under each risk category in the Pioneer River differed between the years sampled, and did not show any clear temporal trends, except an increase in the number of low risk days (Figure 198). The most event days occurred in 2010–2011; this year also showed a high number of days occurring in the low risk and medium risk categories. The number of days occurring within the high and very high risk categories varied across the years.

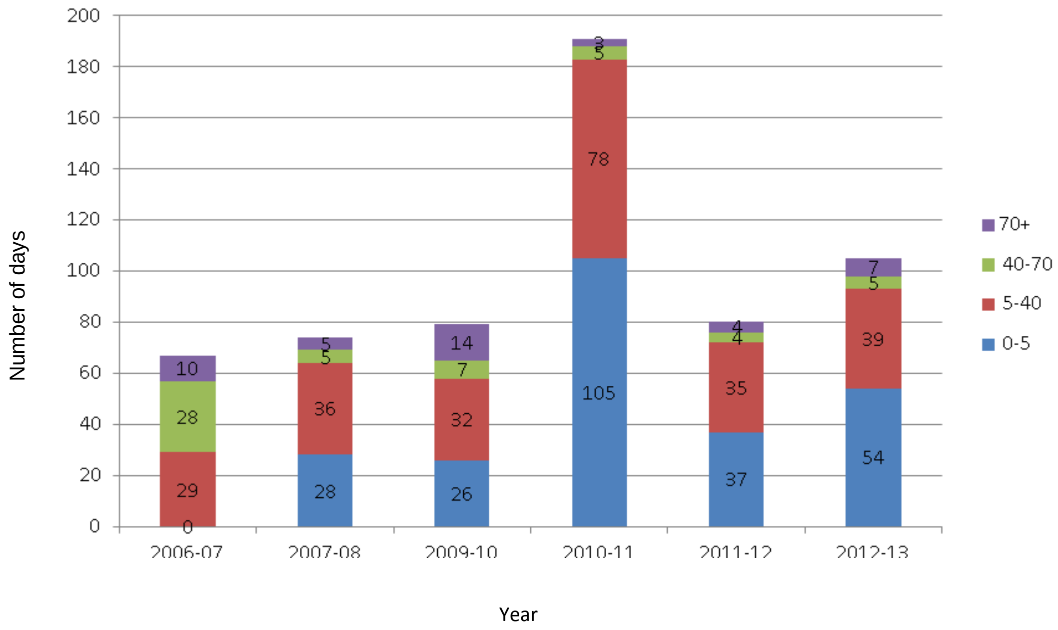

Figure 198 Comparison of Pioneer River event days from 2006–2013 within each risk category.

Across all years, the percentage of event days that occurred within the low risk category (ranged from 0 to 55 per cent of days) indicated that in Pioneer River adequate protection did not occur under event conditions (Figure 199). In 2006–2007 there were no event days that provided adequate protection from mixtures of pesticides. The percentage of event days that fell in the medium risk category was fairly consistent between years (37–49 per cent). For all years except 2010–2011, the majority of event days occurred in the moderate, high, or very high risk category, indicating that in the majority of event conditions, adequate protection was not provided.

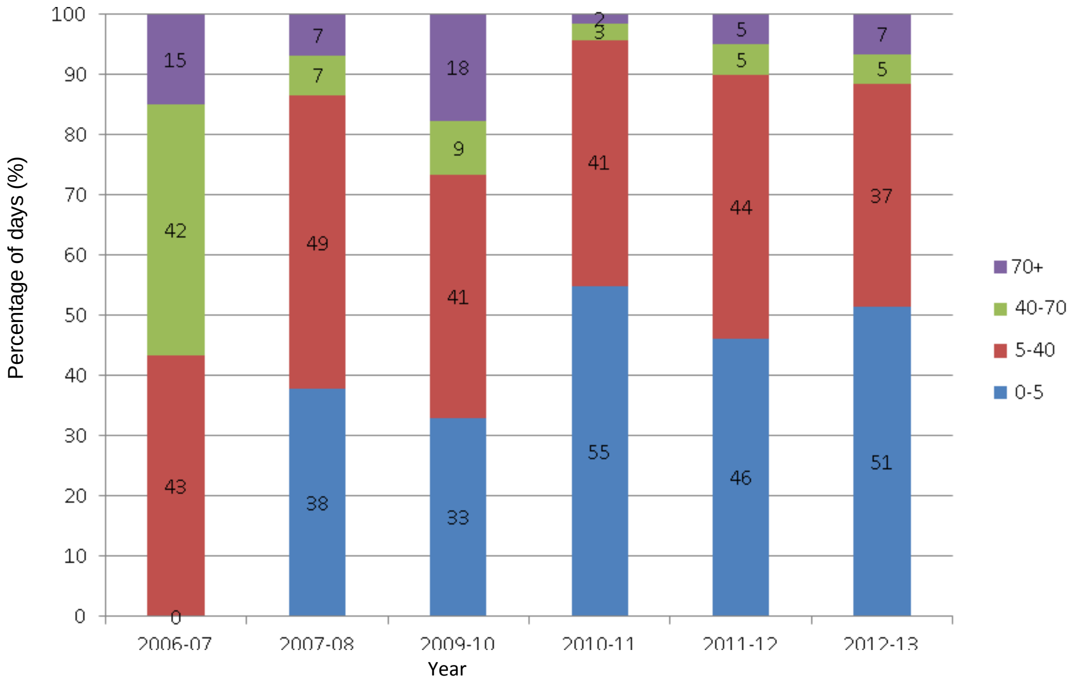

Figure 199 Comparison of Pioneer River event days as percentage from 2006–2013 within each risk category.

3.9 Selection of potential indicator species

Biological monitoring can be used alongside water quality data in order to assess the overall health of an aquatic community, and assess overall impacts of contaminants and stressors.

Rapids bioassessments using macroinvertebrates are commonly used to assess overall ecosystem health. Water quality guidelines using macroinvertebrates indices have been set for the Mackay Whitsunday region (Negus et al. 2013). The indices used are SIGNAL 2[1], PET[2] richness, taxa richness, % sensitive species and % tolerant taxa and were developed from reference site data. These indices are used to assess overall health from a combination of biological stressors including climatic conditions, physico-chemical properties, invasive species and pollutants.

More specific biological monitoring systems have recently been developed that assess impacts from pesticides. Kefford et al (2014) have modified an existing stream macroinvertebrate-based SPEcies At Risk from pesticides ($SPEAR_{pesticides}$) index that was developed and been applied successfully in temperate-sub-arctic climates (i.e. Europe). They have adapted the $SPEAR_{pesticide}$ index to a $SPEAR_{herbicides}$ for tropical north Queensland using diatoms found there. The method appears to respond only to pesticide impacts (Kefford et al 2014). As diatoms appear to recover fairly quickly to disturbance it is recommended that the data collection is undertaken at the end of the wet season.

[1] SIGNAL 2 index refers to the Stream Invertebrate Grade Number – Average Level. It was developed by Chessman (2003) and is calculated by grading each macroinvertebrate family by its tolerance to pollution.

[2] PET (Plecoptera (stoneflies), Ephemeroptera (mayflies) and Trichoptera (caddisflies)) taxa richness are used as these families are considered to be sensitive to pollution.

Another potential biomonitoring approach is the rapidly developing science of 'omics' including genomics, proteomics, metagenomics. These methods use micro-arrays and genetic sequencing methods to determine the types of genes, proteins and metabolites that are present in environmental samples. Recently (Chariton et al. 2010; Stephenson et al. 2014) have developed new techniques which can identify "all" (Chariton et al. 2014) types of organisms (both prokaryotes and eukaryotes) living in water and sediment samples with sufficient resolution to distinguish between "marginal reference sites and impacted sites" (Chariton et al. 2014). This technique has successfully been applied to five estuaries in South East Queensland (Stephenson et al. 2014). An advantage of this approach is that the resulting data can be analysed using multivariate statistical methods to determine if various stressors are responsible for the observed differences in biota between sites (Chariton et al. 2010; Stephenson et al. 2014). Other advantages of this approach are that it is far faster and cheaper than the traditional macro-invertebrate collection and identification methods that identify "a minute fraction of a system's true diversity" (Stephenson et al. 2014). The suitability of this approach to aquatic and sediment ecosystems of tropical Queensland will be investigated in 2014-2015 and later years through a collaboration between the Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP) and CSIRO Oceans and Atmosphere.

Multiple stressors are likely to be affecting the ecosystems in the Mackay-Whitsunday region – it is therefore unlikely that a single species or type of organism is going to successfully monitor ecosystem health. For example, the SPEAR work done by Kefford et al (2014) is most likely to only be sensitive to changes in land management practices that modify concentrations of herbicides. Rather, a broader approach which can identify many different taxa is most likely to be successful. If any method apart from the already established macro-invertebrate water quality guidelines and indices was used for biomonitoring purposes a research program should be undertaken to fully assess their suitability in the Mackay-Whitsunday area.

4 Conclusions and recommendations

4.1 TSS concentrations in the Mackay Whitsunday waterways

The TSS concentration results show that in the majority of the Mackay Whitsunday region sampling locations, few discernible changes have occurred over the sampling period in both ambient and event conditions (Table 30). Event TSS concentrations increased from 2004–2008 in Plane Creek and ambient TSS concentrations increased in St Helens Creek. Sandy Creek was the only waterway to show a decrease in TSS concentrations and this only applied to ambient conditions.

Table 30 Summary of temporal trends in ambient and event TSS concentration for each waterway.

Sampling site	Temporal Trend	
	Ambient (2006-08)	Event (2004-08)
Airlie Creek	No trend observed	
Andromache River	No trend observed	
Upper Andromache River	No trend observed	
Bakers Creek	No trend observed	
Basin Creek	No trend observed	
Blacks Creek	Insufficient number of samples	
Carmila Creek	No trend observed	
Finch Hatton Creek	No trend observed	
Gregory River	Not sampled	
Impulse Creek	No trend observed	
Mackay 1	No trend observed	
Mackay 2	Insufficient number of samples	
Myrtle Creek	No trend observed	
O'Connell River 1	No trend observed	
O'Connell River 2	No trend observed	
Pioneer River*	No trend observed	
Plane Creek	No trend observed	Increase
Proserpine 1	Insufficient number of samples	
Proserpine 2	Insufficient number of samples	
Rocky Dam Creek	No trend observed	
Sandy Creek*	Decrease	No trend observed
Sarina	Insufficient number of samples	
St Helens Creek	Increase	No trend observed
Waite Creek	Insufficient number of samples	

*Sampling in Pioneer River and Sandy Creek covered from 2004–2013

Sampling results indicate that most HEV sites have adequate ambient and event TSS concentrations. The majority of ambient TSS concentrations in Upper Andromache, Impulse and St Helens Creeks were below 10 mg/L. Event concentrations varied, with the highest event concentration seen in St Helens Creek (500 mg/L), followed by Upper Andromache Creek (260 mg/L), Finch Hatton Creek (220 mg/L), Basin Creek (150 mg/L) and lastly, Impulse Creek (44 mg/L). One event concentration in Upper Andromache was above the target of 217 mg/L, however, this target has been set much higher than the other HEV site targets, which range from 8–66 mg/L. Event concentrations in St Helens, Finch Hatton, and Basin creeks all were above the relevant event targets.

The ambient and event targets for the CMAs which contain HEV sites ed have been set for the entire CMA, not specifically for the HEVs. The majority of TSS concentrations from the HEV sites would be expected to be well below those set for the entire CMA, due to their near natural state and low level of disturbance. In Upper Andromache River, the majority of both ambient and event concentrations were below the targets. For Impulse, Basin, Finch Hatton and St Helens Creeks the ambient concentrations are above the ambient targets, but the majority of the event concentrations were below the event targets.

The majority of the recorded ambient TSS concentrations were 45 mg/L or below, with the exception of Myrtle Creek, which recorded up to 150 mg/L. The Myrtle Creek CMA is approximately 32 per cent crop land and 23 per cent grazing land (Drewry et al. 2008). The next highest ambient TSS concentrations were recorded in Plane Creek (up to 45 mg/L), which has approximately 21 per cent crop land and 65 per cent grazing land (Drewry et al. 2008). Rocky Dam Creek, Pioneer River, and Carmila Creek recorded the next highest ambient TSS concentration with 37, 28, and 26 mg/L respectively. Sites such as Bakers and Sandy creeks recorded all ambient TSS concentrations below 20 mg/L.

Event TSS concentrations were high in Airlie Creek and Waite Creek (2665 mg/L and 2100 mg/L, respectively). Both Airlie and Waite creeks are within the Whitsunday Coast CMA which was estimated to have 1 per cent crop land and 11 per cent grazing land (Drewry et al. 2008). Blacks Creek and O'Connell River recorded high concentrations of event TSS (623 mg/L and 324 mg/L, respectively). Pioneer River and Rocky Dam Creek recorded event TSS concentrations up to 263 and 270 mg/L, respectively. All other event TSS concentrations recorded were below 200 mg/L.

The TSS targets for event conditions varied greatly between CMAs. Ambient TSS targets varied from 2 –5 mg/L, however the event targets ranged from 8–217 mg/L (in the Andromache River CMA).

4.2 Nutrient concentrations in Mackay Whitsunday waterways

Nutrient concentrations showed varied results in a number of waterways in the Mackay Whitsunday region in both ambient and event conditions (Table **31**). Results from seven (Bakers Creek, Carmila Creek, Mackay 1, O'Connell 1 and 2, Rocky Dam Creek, and Sarina) of the twenty sampling sites that had sufficient data showed no discernible change over the sampling period in either ambient or event concentrations for any of the four nutrients analysed.

The only waterway in which a temporal change in PN was observed was in Plane Creek, with an increase in event concentrations (Table 31). In two waterways (Myrtle Creek and Plane Creek) event concentrations of PP also increased over the sampling period (Table 31). No waterways showed a decrease in event or ambient PN or PP concentrations over the sampling period.

Table 31 Summary of temporal trends in ambient and event concentrations of nutrients for each waterway.

Sampling site	Nutrient	Temporal Trends	
		Ambient	Event
Airlie Creek	All nutrients	No nutrient sampling data	
Andromache River	All nutrients	Insufficient number of samples	
Upper Andromache River	PN	No trend observed	
	DIN	Increase	No trend observed
	PP	No trend observed	
	FRP	Increase	No trend observed
Bakers Creek	All nutrients	No trends observed	
Basin Creek	PN	No trend observed	
	DIN	Increase	No trend observed
	PP	No trend observed	
	FRP	Increase	No trend observed
Blacks Creek	All nutrients	Insufficient number of samples	
Carmila Creek	All nutrients	No trends observed	
Finch Hatton Creek	PN	No trend observed	Insufficient number of samples
	DIN	Increase	
	PP	No trend observed	
	FRP	No trend observed	
Gregory River	PN	No trend observed	
	DIN	No trend observed	Increase
	PP	No trend observed	
	FRP	No trend observed	
Impulse Creek	PN	No trend observed	Insufficient number of samples
	DIN	Increase	
	PP	No trend observed	
	FRP	No trend observed	
Mackay 1	All nutrients	No trends observed	
Mackay 2	All nutrients	Insufficient number of samples	
Myrtle Creek	PN	No trend observed	
	DIN	Increase	No trend observed
	PP	No trend observed	Increase
	FRP	No trend observed	
O'Connell 1	All nutrients	No trend observed	
O'Connell 2	All nutrients	No trend observed	
Pioneer River*	PN	No trend observed	
Plane Creek	PN	No trend observed	Increase
	DIN	No trend observed	
	PP	No trend observed	Increase
	FRP	No trend observed	
Proserpine 1	All nutrients	Insufficient number of samples	
Proserpine 2	All nutrients	Insufficient number of samples	
Rocky Dam Creek	All nutrients	No trend observed	
Sandy Creek*	PN	No trend observed	
	DIN	Increase	Decrease
	PP	No trend observed	
	FRP	Decrease	Decrease
Sarina	All nutrients	Insufficient number of samples	
St Helens Creek	PN	No trend observed	
	DIN	Increase	No trend observed
	PP	No trend observed	
	FRP	No trend observed	
Waite Creek	All nutrients	Insufficient number of samples	

*Sampling in Pioneer River and Sandy Creek covered from 2004–2013

The temporal trends seen in the concentration of DIN over the sampling period varied greatly. Ambient DIN concentrations increased at seven of the sampling sites (Table 31). Interestingly, all five HEV sites showed an increase in DIN over the sampling period. Only one site which had an increase in ambient DIN levels also had a change in the event DIN levels. This occurred at Sandy Creek where there was a decrease in event DIN concentrations. Gregory River had an increase in event DIN concentrations.

Increases in ambient FRP were seen in both Upper Andromache River and Basin Creek. Sandy Creek, however, showed decreases in both ambient and event FRP over the sampling period.

The nutrients which consistently recorded high concentrations were PN (14 of the 18 sites) and DIN (13 of the 18 sites), followed by FRP and PP. The majority of the CMAs and water quality monitoring sites had high levels of nutrients. Only a few sites (Upper Andromache River, Basin Creek, and Finch Hatton Creek) appeared to not have any issues with high nutrient concentrations.

The majority of nutrient concentrations from sites within the HEV areas of Upper Andromache River, Basin Creek, and Finch Hatton Creek were low. This result was expected due to limited land disturbance in the HEV areas. In Upper Andromache River, Basin Creek, and Finch Hatton Creek PN concentrations were the highest of the nutrients sampled. Concentrations of DIN were highest in Finch Hatton, compared to the other HEV sites. Concentrations of FRP and PP were largely similar between the three HEV sites. Compared to the other HEV sites, St Helens Creek recorded higher concentrations of nutrients, specifically DIN (up to 400 µg/L during event), PP (380 µg/L during an event), and PN (1500 µg/L under ambient conditions). Similarly, Impulse Creek also had high levels of DIN (up to 800 µg/L in ambient conditions) and PN (up to 600 µg/L in event conditions).

As there was no recent sampling conducted in the HEV sites, it was not possible to assess any changes over time of the nutrient concentrations.

For most of the HEV sites, approximately half of the ambient and event concentrations were below the ambient target. This was expected as the original targets were derived from the available data. The event target for FRP in Andromache River CMA was unusual as it is more stringent than the ambient FRP target.

The majority of sites showed high concentrations of many of the nutrients analysed. The two nutrients with the most frequently high concentrations were PN and DIN. Five waterways, Bakers Creek, Waite Creek, Pioneer River, Mackay, and O'Connell River had very high concentrations recorded of all four nutrients, relative to the other waterways. Other than Waite Creek, these waterways all exist within CMAs with a high proportion of land use under cropping or grazing. It was estimated that 61 per cent of land use in the Bakers Creek CMA was crop land and 26 per cent grazing land. The Pioneer River CMA was approximately 50 per cent crop land and 28 per cent grazing land, while the O'Connell River CMA was approximately 11 per cent crop land and 76 per cent grazing. Land uses within the Mackay City CMA were estimated to be 37 per cent of crop land, 9 per cent of grazing and 26 per cent of urban use (Drewry et al. 2008).

High levels of PN (especially during events) were recorded in many waterways, including Carmila Creek, Gregory River, Plane Creek, and Rocky Dam Creek. Many waterways recorded maximum event concentrations of PN above 1000 µg/L, including: Blacks Creek (1930 µg/L), Sandy Creek (1050 µg/L), Mackay (1520 µg/L), Bakers Creek (1513 µg/L), Myrtle Creek and Waite Creek (1220 µg/L).

The highest concentration of DIN was observed during an event in early 2007 in Myrtle Creek, with a concentration of 6080 µg/L. Other high concentrations of DIN included: Proserpine River (4000 µg/L), Bakers Creek (3056 µg/L), Rocky Dam Creek (2200 µg/L), Waite Creek (1850 µg/L), Gregory River (1300 µg/L), Mackay (1160 µg/L), Carmila Creek (1000 µg/L), Sandy Creek (1081 µg/L), and O'Connell River (944 µg/L).

Concentrations of PP were highest at Mackay, Bakers Creek, and Waite Creek, with all three sites recording PP concentrations between 500 and 600 µg/L. The highest concentrations of FRP were recorded within CMAs with a high level of land use under cropping, grazing, and urban. The Proserpine River site recorded the highest concentration of FRP (1200 µg/L). The Proserpine River CMA was approximately 34 per cent crop land and 47 per cent grazing land (Drewry et al. 2008). Mackay and Myrtle Creek recorded 590 and 550 µg/L, respectively. Land use in Myrtle Creek was approximately 32 per cent crop land, and 23 per cent grazing land (Drewry et al. 2008). Other sampling sites which recorded high levels of FRP included Bakers Creek, Gregory River, Plane Creek, Sandy Creek, Sarina, and Waite Creek.

4.3 Pesticide concentrations in the Mackay Whitsunday waterways

4.3.1 Individual pesticides

The pesticide concentrations showed varied results in a number of waterways in the Mackay Whitsunday region in both ambient and event conditions (Table **32**). Results from 15 of the 21 sites in which pesticide samples were collected indicated that there was no significant linear change in concentration over the sampling period in either ambient or event concentrations for any of the five pesticides analysed.

Of the six sites in which a temporal change did occur, there were no significant changes in ametryn concentrations over time, for either ambient or event conditions (Table 32). Changes in atrazine concentrations were seen in four waterways (Table 32). Andromache River, O'Connell 1, and Plane Creek all had increases over time of event atrazine concentrations; none of these sites had any changes in ambient atrazine concentrations. The only decrease in atrazine concentrations was in ambient atrazine concentrations in Sandy Creek.

Sandy Creek was the only waterway in which diuron concentrations changed over time (Table 32). However, Sandy Creek and Pioneer River had more data available than the other waterways (from 2004–2013, rather than 2004–2009). Ambient and event diuron concentrations decreased in Sandy Creek.

There were only two waterways in which hexazinone concentrations changed over time - Sandy Creek and Andromache River (Table 32). In Sandy Creek, ambient and event hexazinone concentrations decreased. Results in Andromache River showed an increase over the sampling period for event hexazinone concentrations.

Two sites, Upper Andromache River and Pioneer River, showed event tebuthiuron concentrations increased over the sampling period (Table 32). No waterway sampling results showed a decrease in tebuthiuron over time.

Table 32 Summary of temporal trends in ambient and event concentrations of pesticides for each waterway.

Sampling site	Pesticide	Temporal Trends	
		Ambient (2006-08)	Event (2004-08)
Upper Andromache River	Ametryn	No trend observed	
	Atrazine	No trend observed	
	Diuron	No trend observed	
	Hexazinone	No trend observed	
	Tebuthiuron	No trend observed	Increase
Andromache River	Ametryn	No trend observed	
	Atrazine	No trend observed	Increase
	Diuron	No trend observed	
	Hexazinone	No trend observed	Increase
	Tebuthiuron	No trend observed	
Bakers Creek	All pesticides	No trend observed	
Basin Creek	All pesticides	No trend observed	
Blacks Creek	All pesticides	No trend observed	
Carmila Creek	All pesticides	No trend observed	
Finch Hatton Creek	All pesticides	No trend observed	
Gregory River	All pesticides	No trend observed	
Impulse Creek	All pesticides	No trend observed	
Mackay	All pesticides	No trend observed	
Myrtle Creek	All pesticides	No trend observed	
O'Connell 1	Ametryn	No trend observed	
	Atrazine	No trend observed	Increase
	Diuron	No trend observed	
	Hexazinone	No trend observed	
	Tebuthiuron	No trend observed	
O'Connell 2	All pesticides	No trend observed	
Pioneer River*	Ametryn	No trend observed	
	Atrazine	No trend observed	
	Diuron	No trend observed	
	Hexazinone	No trend observed	
	Tebuthiuron	No trend observed	Increase
Plane Creek	Ametryn	No trend observed	
	Atrazine	No trend observed	Increase
	Diuron	No trend observed	
	Hexazinone	No trend observed	
	Tebuthiuron	No trend observed	
Proserpine River	All pesticides	No trend observed	
Rocky Dam Creek	All pesticides	No trend observed	
Sandy Creek*	Ametryn	No trend observed	
	Atrazine	Decrease	No trend observed
	Diuron	Decrease	Decrease
	Hexazinone	Decrease	Decrease
	Tebuthiuron	No trend observed	
Sarina	All pesticides	No trend observed	
St Helens Creek	All pesticides	No trend observed	
Waite Creek	All pesticides	No trend observed	

*Sampling in Pioneer River and Sandy Creek covered from 2004–2013

The recorded concentrations of individual pesticides from the water quality sampling showed most pesticides to be detected at a number of sites, and some concentrations to be extremely high relative to the ecotoxicity thresholds. The highest concentrations appeared to be in response to events, and occurred frequently at the beginning of each year. Atrazine, diuron and hexazinone were detected at most sites.

The sampling results from the HEV sites had limited detections of pesticides, which was expected as these sites should have limited land disturbance. All detections in HEV sites were below the PC95 ecotoxicity thresholds relevant to each pesticide. No samples from St Helens Creek had pesticide concentrations above the LOR (0.01 µg/L). One sample from Finch Hatton Creek and many samples from Basin Creek had very low concentrations of atrazine, all below the PC99 for atrazine. Upper Andromache River had two samples with atrazine and diuron, and one sample each with hexazinone and tebuthiuron. All pesticide concentrations detected in Upper Andromache River were below the relevant PC99 concentrations. There were no pesticides detected in any ambient samples from Impulse Creek, but ametryn, atrazine and diuron were each detected in one event sample. The concentrations of diuron and atrazine were below the PC99 levels, however the recorded concentration of ametryn was 0.03 µg/L, and the PC99 for ametryn is 0.02 µg/L. Additionally, Waite Creek in the Whitsunday Coast CMA had no pesticides detected above 0.01 µg/L in any samples.

Many of the remaining sites samples did not have ametryn concentrations above 0.01 µg/L in either ambient or event conditions (Andromache River, Blacks Creek, Gregory River, Mackay, O'Connell River, Proserpine River, and Sarina). Bakers Creek and Plane Creek had a few samples with ametryn, all of low concentrations (the highest concentration was 0.06 µg/L, which is below the PC95 ecotoxicity threshold of 0.1 µg/L). The Camila Creek site had only one ambient sample with ametryn (a concentration of 0.3 µg/L, three times the PC95 ecotoxicity threshold). The Pioneer River, Sandy Creek, Rocky Dam Creek, and Myrtle Creek sites had many samples with ametryn (both ambient and event samples) with concentrations up to 0.18, 0.5, 1.4 and 2.7 µg/L, respectively. These concentrations were all well above the PC95 ecotoxicity threshold and occurred in different years for the different waterways.

Atrazine was detected in samples from the majority of sites. The PC95 ecotoxicity threshold for atrazine is 6 µg/L, and some concentrations above this threshold were recorded. There were no detections of atrazine above 0.01 µg/L in any samples from either Blacks Creek or at Mackay. Sarina had a few samples with atrazine detected, the highest concentration being 0.02 µg/L. Carmila Creek, Gregory River, O'Connell River, Pioneer River, Plane Creek, Proserpine River, Sandy Creek, and Rocky Dam Creek all had many samples with atrazine detected, especially during events, but all concentrations were below the PC95 ecotoxicity threshold (maximum concentrations range from 0.1 µg/L in Proserpine River to 6 µg/L in Gregory River). Atrazine was detected in many samples from Bakers Creek and Myrtle Creek, to concentrations above the PC95 ecotoxicity threshold (14 and 8.4 µg/L, respectively).

High concentrations of diuron were consistently recorded in samples from many waterways. Many of the CMA targets for diuron were well above the ecotoxicity threshold for PC95 (0.3 µg/L) and the Australian and New Zealand trigger value (0.02 µg/L), with targets up to 1.5 µg/L. Andromache River had one sample with a low concentration of diuron detected (0.06 µg/L). Blacks Creek had three samples with diuron, with a maximum concentration of 0.18 µg/L. All samples from Sarina had diuron detected, with the highest concentration being 0.34 µg/L. Mackay had many samples with diuron detected; the highest concentration was 0.38 µg/L. Carmila Creek and Plane Creek had many samples with diuron detected, particularly during events. The highest concentrations recorded in these waterways were 1.0 and 1.3 µg/L, respectively. Many samples from these sites had concentrations above the PC95 ecotoxicity threshold, and therefore also above the current Australian and New Zealand water quality guideline trigger value. In Plane Creek, the highest concentration of diuron occurred in early 2007 and remained low until 2008.

In O'Connell River, Pioneer River, Sandy Creek, and Gregory River, diuron was detected in many of the samples. Concentrations reached up to 2, 2.2, 5.7, and 6.5 µg/L respectively, which are all well above the ecotoxicity threshold and the Australian and New Zealand water quality guideline trigger value. The majority of the concentration peaks occurred in early 2007. Bakers Creek, Myrtle Creek, and Rocky Dam Creek had the highest concentrations of diuron found, with concentrations to 14, 19, and 30 µg/L, respectively.

Hexazinone was detected at most sampling locations in the Mackay Whitsunday area, however in approximately half of the sites, the highest concentrations recorded were below the ecotoxicity threshold of 0.7 µg/L. Both Mackay and Proserpine River sites had only one sample in which hexazinone was detected (0.03 and 0.04 µg/L, respectively). Sarina and Blacks Creek had only a few samples in which hexazinone was detected, with the maximum event concentration at Sarina being 0.16 µg/L and an ambient maximum concentration of 0.22 µg/L at Blacks creek. Hexazinone was detected in many samples from Gregory River, O'Connell River, and Carmila Creek with concentrations up to 0.45, 0.5 and 0.58 µg/L, respectively. These were all below the PC95 ecotoxicity threshold for hexazinone. Many ambient and event samples from Pioneer River, Plane Creek, and Sandy Creek had hexazinone concentrations above the ecotoxicity threshold. Concentrations were up to 0.8 and 1.2 µg/L for Pioneer River and Plane Creek, respectively. The highest concentration recorded in Sandy Creek was 1.8 µg/L. The highest concentrations of hexazinone in Plane and Sandy creeks occurred in early 2007. As was for diuron, Bakers Creek, Myrtle Creek and Rocky Dam Creek had high levels of hexazinone recorded. Bakers Creek ambient concentrations were up to 4.4 µg/L, Myrtle Creek had concentrations up to 7.4 µg/L, and Rocky Dam Creek had a highest concentration of 21 µg/L which occurred in early 2008.

Of the five PSII herbicides analysed in this report, tebuthiuron was the least detected pesticide in the samples analysed. Tebuthiuron was not detected above 0.01 µg/L in any samples from Blacks Creek, Carmila Creek, Gregory River, Mackay, Myrtle Creek, Plane Creek, Proserpine River, Rocky Dam Creek, Waite Creek or Sarina. Tebuthiuron is most commonly used on grazing land, however a number of the sites within CMAs with a high proportion of grazing land (i.e. Blacks Creek CMA is approximately 89 per cent grazing, Carmila Creek is approximately 75 per cent grazing (Drewry et al. 2008) did not detect any tebuthiuron in the water quality samples taken. In Bakers Creek, Pioneer River, Sandy Creek, Andromache River, and O'Connell River there were some detections of tebuthiuron, however these were all very low concentrations. These CMAs have approximately 26, 28, 40, 80 and 76 per cent of the land use under grazing, respectively (Drewry et al. 2008). The peak concentrations of tebuthiuron recorded at these sites occurred at different times. The PC95 ecotoxicity threshold for tebuthiuron is 8.8 µg/L and no concentrations of tebuthiuron were recorded above this level.

4.3.2 Mixtures of pesticides

The ms-PAF results show that in the majority of Mackay Whitsunday region sampling locations, few changes have occurred in the mixture of pesticides over the sampling period in both ambient and event conditions (Table 33). However, the two sites in which changes in ms-PAF were seen were Sandy Creek and Pioneer River, which are the only sites with extended monitoring (beyond 2009). In Pioneer River the ms-PAF results for ambient conditions decreased over the sampling period. In Sandy Creek the ms-PAF results decreased under both the ambient and event conditions over the sampling period. The decreases in ms-PAF results were also significant when they were only performed on the 2009–2013 data, thereby indicating the result is not a by-product of greater sampling coverage.

Table 33 Summary of temporal trends in ambient and event ms-PAF results for each waterway.

Sampling site	Temporal trends	
	Ambient (2006–2008)	Event (2004–2008)
Upper Andromache River	No trend observed	
Andromache River	No trend observed	
Bakers Creek	No trend observed	
Basin Creek	No trend observed	
Blacks Creek	No trend observed	
Carmila Creek	No trend observed	
Finch Hatton Creek	No trend observed	
Gregory River	No trend observed	
Impulse Creek	No trend observed	
Mackay	No trend observed	
Myrtle Creek	No trend observed	
O'Connell River	No trend observed	
Pioneer River	Decrease	No trend observed
Plane Creek	No trend observed	
Proserpine River	No trend observed	
Rocky Dam Creek	No trend observed	
Sandy Creek	Decrease	Decrease
Sarina	No trend observed	
St Helens Creek	No trend observed	
Waite Creek	No trend observed	

The ms-PAF results showed that in the majority of the waterways sampled, adequate protection for species from mixtures of pesticides did not occur. In many cases the ambient results for the potentially affected fraction of species were below, or close to, 5 per cent of species, however, in most waterways the event levels of potentially affected fraction of species were well above the 5 per cent (PC95) target, and in some cases nearly 100 per cent of phototrophic species were estimated to be affected. The ms-PAF values were highest at the start of each year, and in most waterways the highest ms-PAF recorded occurred in early 2007.

HEV sites (Upper Andromache River, Finch Hatton Creek, Impulse Creek and St Helens Creek) did not record an ambient or event ms-PAF value above 1 per cent, therefore the species at these HEV sites were being adequately protected in reference to the PC99 protection level. All ambient ms-PAF values at Basin Creek were below 1 per cent, however event ms-PAF values in early 2005 reached just below 4 per cent and in early 2007 reached 17 per cent, therefore not meeting the PC99 protection level required at HEV sites.

With the exception of the HEV sites, only one creek had ms-PAF results that met the target for adequate protection of species. All ambient and event ms-PAF results for Waite Creek were below the target of a 5 per cent potentially affected fraction. Blacks Creek had the next lowest ms-PAF results with the highest result showing 7 per cent of species were affected during an event. The majority of ms-PAF results for Mackay, Sarina, and Proserpine River were below 5 per cent of affected species for event samples, with a few instances of event ms-PAF results reaching 14 or 15 per cent.

The ms-PAF results for a number of waterways showed that under ambient conditions, adequate protection was provided, but under event conditions, the protection for species was not adequate. At Plane Creek the majority of samples not associated with an event had a maximum of 5 per cent of species affected; therefore under ambient conditions the species in Plane Creek were adequately protected. In early 2005 ms-PAF results peaked at 36 per cent, and in early 2007 at 57 per cent, while the majority of the event results were below 10 per cent. Ambient ms-PAF results from Pioneer River, Sandy Creek, and O'Connell River were mostly below the 5 per cent ms-PAF target, but event results were frequently above 70 per cent in the Pioneer River, above 80 per cent in Sandy Creek, and up to 60 per cent in O'Connell River.

Results from Carmila Creek showed the majority of ambient and event samples to have ms-PAF results between 0 and 20 per cent, with the maximum ms-PAF value of 38 per cent. Species in Carmila Creek were not adequately protected to the PC95 protection level. In Gregory River the highest recorded event ms-PAF value was 84 per cent in early 2005, with the majority of event ms-PAFs being below 50 per cent. Bakers Creek ms-PAF values reached 94, 84, and 61 per cent in late 2006, early 2007 and early 2008, with the majority of other values below 35 per cent.

Out of all the sampled waterways, the highest ms-PAF values were from Myrtle Creek and Rocky Dam Creek, both of which had up to 96 per cent of species affected in events. For both creeks the ms-PAF values frequently got to this level, specifically in early 2006, early 2007, and early 2008.

The risk assessment of ms-PAF results showed that only the five HEV sites provided adequate protection during ambient conditions. Three out of the 12 sites assessed (Bakers Creek, Myrtle Creek, and Rocky Dam Creek) had ambient days occurring in the very high risk category where 70 per cent or more of species were affected. Four out of the 12 sites (Bakers Creek, Myrtle Creek, Plane Creek, and Rocky Dam Creek) had days occurring within the high risk category (40–70 per cent of species affected), and 7 of the 12 sites had days within the medium risk category (5–40 per cent of species affected). For the three sites that the risk assessment of event ms-PAF results could be performed on (Myrtle Creek, Pioneer River, and Sandy Creek), all sites had days occurring in every risk category. The results for these three sites indicated inadequate protection of species in ambient and event conditions regarding mixtures of pesticides.

The probabilistic ecological risk assessment conducted for Sandy Creek and Pioneer River showed that in 2006–2007, 98 per cent of ambient days in the Pioneer River had adequate protection for the species and 88 per cent of ambient days had adequate protection in 2007–08. Pioneer River had the highest proportion of days in the very high risk category in 2009–10 with 18 per cent of event days affecting 70 per cent or more of species. The percentage of event days in which adequate protection was provided in each year varied between 0 and 55 per cent. Sandy Creek had the largest proportion of event days in the very high risk category in 2010–11 (23 per cent of event days), and only 9–14 per cent of event days in which adequate protection was provided in each year.

4.4 Do the water quality targets provide sufficient protection?

4.4.1 TSS

In a number of cases the TSS targets were exceeded. The ambient TSS targets ranged from 1 to 5 mg/L, and the event TSS targets ranged from 8 to 217 mg/L (Andromache River CMA). The TSS targets were developed using a combination of modelling and sampling of local sites, rather than using an ecological indicator to identify the TSS concentration levels that are likely to protect or affect aquatic species. The latter, in addition to the lack of monitoring data beyond 2008 for most sites, makes it difficult to determine whether or not the existing targets are providing adequate protection.

The TSS guidelines presented in the Queensland Water Quality Guidelines (EHP 2009) and the EPP (water) policies for Pioneer River and Plane Creek Basins (EHP 2013a), and Proserpine River, Whitsunday Island and O’Connell River Basins (EHP 2013b) were all derived from the targets in Drewry et al. (2008), as such they are the most relevant and localised targets available.

HEV sites should have a separate TSS target from disturbed sites within the same CMA as they require higher ecological protection and therefore should have lower targets to maintain that protection.

4.4.2 Nutrients

The nutrient targets were developed using a combination of modelling and sampling of local sites, rather than using an ecological indicator to identify the concentration of each nutrient that is likely to protect or affect aquatic species. The latter, in addition to the lack of monitoring data beyond 2008 for most sites, makes it difficult to determine whether or not the existing targets are providing adequate protection. In a number of cases the existing targets were being exceeded, therefore the waterways were not being adequately protected.

The PN targets ranged from 16–210 µg/L (Proserpine River CMA) for ambient and from 118–440 µg/L (Blacks Creek CMA) for event. The ambient DIN targets ranged from 8–456 µg/L (Bakers Creek CMA) and from 42–465 µg/L (Carmila Creek CMA) for event targets. The PP targets ranged from 6–60 µg/L (Proserpine River CMA) for ambient conditions and from 31–195 µg/L (Pioneer River CMA) for events. The ambient FRP targets ranged from 2–95 µg/L (Proserpine River CMA), and the event targets ranged from < LOR–377 µg/L (Mackay City CMA).

Nutrient Queensland Water Quality Guidelines (EHP 2009) and the EPP (water) policies for Pioneer River and Plane Creek Basins (EHP 2013a), and Proserpine River, Whitsunday Island and O'Connell River Basins (EHP 2013b) were all derived from the targets in Drewry et al. (2008) and as such they are the most relevant and localised targets available.

HEV sites should have separate nutrient targets from disturbed sites within the same CMA as they require higher ecological protection and therefore should have lower targets to maintain that protection.

4.4.3 Pesticides

4.4.3.1 Individual pesticides

The existing 2014 pesticide targets were below the PC95 ecotoxicity thresholds for the majority of the Mackay Whitsunday CMAs. All ambient targets for diuron are below the ecotoxicity threshold, but many of the CMAs' diuron event targets were above the ecotoxicity threshold and therefore would not be providing adequate protection and should be amended. The ametryn event target in Myrtle Creek is not providing adequate protection based on the ecotoxicity threshold. At the HEV sites the PC99 ecotoxicity threshold should be achieved, therefore the event diuron and hexazinone targets for the St Helens Creek CMA are not appropriate for the HEV site in this CMA. Similarly, the event target for diuron in the Upper Cattle Creek CMA is not appropriate for the Finch Hatton Creek HEV site.

For all other waterways and pesticides, the CMA pesticide targets appeared to be providing sufficient ecosystem protection for exposure to individual pesticides.

4.4.3.2 Mixtures of pesticides

To examine whether the targets set for the individual pesticides would provide adequate protection when the pesticides were present together as a mixture, the ms-PAF was calculated for each site from the 2014 target concentrations. The targets set for ambient conditions in each CMA (Drewry et al. 2008) are providing adequate protection to species (i.e. ms-PAF < 5 per cent) from mixtures of pesticides in 13 of the 18 CMAs (72 per cent). Under event conditions, in the majority (72 per cent) of CMAs, the individual pesticide targets are not providing adequate protection, i.e. ms-PAF ≥ 5 per cent. Only 28 per cent of sites have event targets which will protect 95 per cent of the species.

Every HEV site should be providing protection for 99 per cent of the species, therefore have a ms-PAF< 1 per cent. Under ambient conditions, if each HEV site met the individual pesticide 2014 targets, all but St Helens Creek would provide adequate protection to 99 per cent of species. However, under event conditions, if the HEV sites met the event targets of the individual pesticides, only Upper Andromache River and Impulse Creek HEV sites would be adequately protecting the species based on the ms-PAF. The Basin Creek, Finch Hatton Creek, and St Helens Creek sites were not providing adequate protection (i.e. not protecting 99 per cent of the species).

4.5 Recommendations

Water quality monitoring by Reef Catchments for TSS, nutrients and pesticides was discontinued in the Mackay Whitsunday region in 2008 (ambient sampling) and 2009 (event sampling). However, data were collected at Pioneer River and Sandy Creek subsequent to this by the Queensland Government – the Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP). It is understood that from 2009, best management land use practices have been implemented on farms in the Mackay Whitsundays region to reduce the loads of TSS, nutrients and pesticides in catchments. Monitoring at Sandy Creek and Pioneer River since 2009 by GBRCLMP has demonstrated that both increases and decreases in concentrations of pollutants have occurred over the sampling period of 2004–2013. While temporal trends (increases or decreases in concentrations over time) were observed at a number of sites in the sampling period of 2004–2009, there are no data to indicate what the current conditions of these waterways are since the implementation of the new land use practices as no data are available. Therefore, it is recommended that monitoring resumes in 2014–2015, with a particular focus on those sites where TSS, nutrients and/or pesticides posed an ecological risk to the waterways.

Sites were classified as being high or low priority based on the concentrations of pollutants measured during the sampling period. Sites of highest priority for continued monitoring are reported below based on the TSS, nutrient, and pesticide assessments and pesticide risk assessments. High priority sites that were initially identified were split into primary and secondary sites for TSS and pesticides. The primary sites were those with highest concentrations of pollutants detected, and if funding is limited, these should be targeted initially. It is recommended that both ambient and event monitoring should be undertaken with good sample coverage.

TSS

The sites recommended for further monitoring of TSS were classified based on the TSS assessment (Table 34). Sites classified as primary and secondary are priority sites for focused ambient and event monitoring, all other sites are considered a lower priority.

Table 34 Priority sites for further monitoring of TSS in the Mackay Whitsundays region.

Primary sites	Secondary sites
Airlie Creek	Blacks Creek
Myrtle Creek	O'Connell River
Waite Creek	Pioneer River
	Rocky Dam Creek

Nutrients

Site priority for further monitoring of nutrients was classified based on the nutrient assessment of at least one out of the four nutrients analysed (Table 35). Sites classified as primary and secondary are priority sites for focused ambient and event monitoring, all other sites are considered a lower priority.

Table 35 Priority sites for further monitoring of nutrients in the Mackay Whitsundays region.

Primary sites	Secondary sites
Bakers Creek Mackay City Sandy Creek Waite Creek	Blacks Creek Carmila Creek Gregory River Myrtle Creek O'Connell River
	Plane Creek Proserpine River Rocky Dam Creek

Pesticides

The sites recommended for further monitoring of pesticides were classified based on the assessments of individual pesticides (Table 36) and mixtures of pesticides (Table 37). Sites classified as primary and secondary are priority sites for focused ambient and event monitoring, all other sites are considered a lower priority.

Table 36 Priority sites for further monitoring of pesticides in the Mackay Whitsundays region based on the risk assessments of individual pesticides.

Primary sites	Secondary sites
Bakers Creek	Blacks Creek
Carmila Creek	Mackay City
Gregory River	Proserpine River
Myrtle Creek	Sarina
O'Connell River	
Pioneer River	
Plane Creek	
Rocky Dam Creek	
Sandy Creek	

Table 37 Priority sites for further monitoring of pesticides in the Mackay Whitsundays region based on the risk assessments of mixtures of pesticides.

Primary sites	Secondary sites
Bakers Creek	Mackay City
Carmila Creek	Plane Creek
Gregory River	Proserpine River
Myrtle Creek	Sarina
O'Connell River	
Pioneer River	
Rocky Dam Creek	
Sandy Creek	

Targets

It is recommended that ambient and event monitoring resumes in 2014–2015 to determine whether the 2014 targets developed in 2008 are relevant to the current conditions in the region, and in each CMA. Additionally, the TSS and nutrient 2014 targets should be assessed against the results from TSS and nutrient sampling at reference sites (as per the criteria described in Queensland Water Quality Guidelines (EHP 2009) to determine whether the targets are providing ecological protection.

Furthermore, where the event target is more stringent than the ambient target (e.g., FRP in Andromache River CMA and Proserpine River CMA; and PN in St Helens Creek CMA) these targets should be amended following further sampling.

With regard to pesticides, it is also recommended that ambient and event monitoring resumes in 2014–2015 to determine whether the 2014 targets are still relevant. Those CMA pesticide targets that have a higher concentration than the new ecotoxicity thresholds should be lowered to reflect the new threshold concentrations –subject to these thresholds being adopted as Australian and New Zealand Guideline Values. The diuron event target should be amended to reflect the PC95 ecotoxicity threshold (0.3 µg/L) for the following CMAs: Gregory River, Myrtle Creek, Proserpine River, St Helens Creek, Mackay City, Pioneer River, Upper Cattle Creek, Bakers Creek, Sandy Creek, Plane Creek, Rocky Dam Creek, and Carmila Creek. The event target for ametryn in Myrtle Creek should be amended to reflect the PC95 ecotoxicity threshold (0.1 µg/L). The PC99 ecotoxicity thresholds should be used for any HEV sites. Therefore, the event diuron target for the Finch Hatton Creek HEV site should be amended to reflect the PC99 (0.2 µg/L); and the event diuron and hexazinone targets for the St Helens Creek CMA should be amended (0.2 µg/L for both pesticides).

Biomonitoring

It would be highly advantageous to include biological monitoring along with traditional water quality monitoring in the waterways of the Mackay Whitsunday region. Due to the multiple stressors affecting these waterways it is not possible to identify a single species or even type of organism for biomonitoring. The SPeAR method shows considerable promise as a biomonitoring method for the deleterious effects of herbicides. Other broader approaches such as the traditional macro-invertebrate collection and identification methods (Negus et al. 2013) definitely have a potential role but these methods are typically fairly expensive, slow, costly and ignore many groups of organisms. New 'omics' based methods such as metabarcoding show considerable promise as they can identify 'all' taxa present in environmental samples. At this point only the traditional macroinvertebrate and SPeAR methods are ready for use but both have limitations. If any 'omics' method is to be used it would require further testing to determine its suitability for the Mackay Whitsunday region.

5 References

Aldenberg T, Jaworska J, Traas T. 2002. The potentially affected fraction as a measure of ecological risk. In: *Species Sensitivity Distributions in Ecotoxicology*, Ed. Posthuma L, Suter G, and Traas T. CRC Press 2002.

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC and ARMCANZ). 2000. National water quality management strategy, Australian and New Zealand Guidelines for fresh and marine water quality. ANZECC and ARMCANZ, Canberra, Australia.

Batley G, Chapman J, Fox D, Hickey C, Stauber J, van Dam R, and Warne M St J. *In review*. Revision of the Method for Deriving Water Quality Guideline Trigger Values for Toxicants. A Water for a Healthy Country Flagship Report. Prepared for the Department of Sustainability, Environment, Water, Population and Communities. 48p.

Carriger JF, & Rand GM. 2008. Aquatic risk assessment of pesticides in surface waters in and adjacent to the Everglades and Biscayne National Parks: I. Hazard assessment and problem formulation. *Ecotoxicology*, 17(7), 660–679.

Chariton AA, Court LN, Hartley DM, Colloff MJ and Hardy CM. 2010. Ecological assessment of estuarine sediment by pyrosequencing eukaryotic ribosomal DNA. *Frontiers in Ecology and the Environment*, 8 (5), 233–238.

Chessman B. 2003. SIGNAL 2 – A Scoring System for Macro-invertebrate ('Water Bugs') in Australian Rivers, Monitoring River Heath Initiative Technical Report no 31. Commonwealth of Australia, Canberra.

Department of Environment and Heritage Protection. 2009. Queensland Water Quality Guidelines, Version 3, ISBN 978-0-9806986-0-2.

Department of Environment and Heritage Protection. 2013a. Environmental Protection (Water) Policy 2009: Pioneer River and Plane Creek Basins Environmental Values and Water Quality Objectives. Brisbane.

Department of Environment and Heritage Protection. 2013b. Environmental Protection (Water) Policy 2009: Proserpine River, Whitsunday Island and O'Connell River Basins Environmental Values and Water Quality Objectives. Brisbane.

Drewry J, Higham W, Mitchell C. 2008. Water Quality Improvement Plan: Final report for Mackay Whitsunday region. Mackay Whitsunday Natural Resource Management Group.

Hobbs D, Warne M St J, Markich S. 2005. Evaluation of criteria used to assess the quality of aquatic toxicity data. *Integrated Environmental Assessment and Management* 1, 174–180.

Joo M, Raymond M, McNeil V, Huggins R, Turner R, Choy S. 2012. Estimates of sediment and nutrient loads in 10 major catchments draining to the Great Barrier Reef during 2006-2009. Marine Pollution Bulletin, 65 (4-9): 150–166.

Kefford, B.J., Wood, R.J., Mitrovic, S. and von der Ohe, P. (2014) Biomonitoring effects of pesticides in rivers draining on to the Great Barrier Reef. Final report for project number RRRD058: A novel biological method of monitoring herbicides. Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (109pp.).ISBN: 978-1-925088-18-2

Lewis S, Smith R, O'Brien D, Warne M St J, Negri A, Petus C, da Silva E, Zeh D, Turner R, Davis A, Mueller J, Brodie J. 2013. Chapter 4: Assessing the risk of additive pesticide exposure in Great Barrier Reef ecosystems. In: *Assessment of the relative risk of water quality to ecosystems of the Great Barrier Reef: Supporting Studies*. A report to the Department of the Environment and Heritage Protection, Queensland Government, Brisbane. TropWATER Report 13/30, Townsville, Australia.

Negus P., Steward, A., and Blessing J. (2013). Macroinvertebrate water quality guidelines: Townsville and Mackay-Whitsunday regions. Water Planning Ecology Group, Science Delivery Division. DSITIA, The State of Queensland.

Queensland Government. 2009. Environmental Protection (Water) Policy 2009. Brisbane.

Schuler LJ, & Rand GM. 2008. Aquatic risk assessment of herbicides in freshwater ecosystems of south Florida. *Archives of environmental contamination and toxicology*, 54(4), 571–583.

Smith R, Warne M St J, Delaney K, Turner R, Seery C, Pradella N, Vardy S, Rogers B, Arango C, Edge K, Julli M. *In prep*. Proposed guideline values for six priority pesticides of the Great Barrier Reef and its adjacent catchments.

State of Queensland and Commonwealth of Australia. 2009. Reef Water Quality Protection Plan: For catchments adjacent to the Great Barrier Reef World Heritage Area, Queensland Department of Premier and Cabinet, Brisbane.

State of Queensland and Commonwealth of Australia. 2013. Reef Water Quality Protection Plan: For catchments adjacent to the Great Barrier Reef World Heritage Area, Queensland Department of Premier and Cabinet, Brisbane.

State of Queensland. 2014. Great Barrier Reef Report Card 2012 and 2013: Reef Water Quality Protection Plan, Reef Water Quality Protection Plan Secretariat, Brisbane.

Stephenson S, Chariton AA, Steven A and Carlin G. (2014). Metabarcoding of benthic communities from five South East Queensland estuaries. Oral presentation to SETAC Australasia and Asia-Pacific Conference, 14–17 September, Adelaide, Australia. Conference Proceedings. Available from: http://www.setac2014.com.au/program.html.

Traas T, van de Meent D, Posthuma L, Hamers T, Kater B, de Zwart D, Aldenberg T. 2002. The potentially affected fraction as a measure of ecological risk. In: *Species Sensitivity Distributions in Ecotoxicology*, Ed. Posthuma L, Suter G, and Traas T. CRC Press 200.

Turner R, Huggins R, Wallace R, Smith R, Vardy S, Warne M St J. 2012. Sediment, nutrient and pesticide loads: Great Barrier Reef catchment loads monitoring 2009-2010. Department of Science, Information Technology, Innovation and the Arts, Brisbane.

Turner R, Huggins R, Wallace R, Smith R, Warne M St J. 2013. Total suspended solids, nutrient and pesticide loads (2010-2011) for rivers that discharge to the Great Barrier Reef. Department of Science, Information Technology, Innovation and the Arts, Brisbane.

Wallace R, Huggins R, Smith R, Turner R, Warne M St J. 2014. Total suspended solids, nutrient and pesticide loads (2011–2012) for rivers that discharge to the Great Barrier Reef – Great Barrier Reef Catchment Loads Monitoring Program 2011–2012. Department of Science, Information Technology, Innovation and the Arts, Brisbane.

Warne M St J, Batley G, van Dam R, Chapman J, Fox D, Hickey C, Stauber J, *In review*. A Revised Framework for Deriving Australian and New Zealand Water Quality Guidelines for Toxicants. Prepared for the Department of Sustainability, Environment, Water, Population and Communities. 52p.

Appendix A Locations of sampling sites

Sampling Site	Basin	Gauging Station	Coordinates
Airlie Creek	Proserpine River	1220047	20 16.233 S 148 34.017 E
Upper Andromache River	O'Connell River	124003A	20 34.733 S 148 28.283 E
Andromache River	O'Connell River	1240055	20 35.767 S 148 34.550 E
Bakers Creek	Plane Creek	1260052	
Basin Creek	Plane Creek	1260003	21 45.133 S 149 22.100 E
Blacks Creek	Pioneer River	125005A	21 19.783 S 149 49.883 E
Carmila Creek	Plane Creek	126003A	21 53.933 S 149 23.900 E
Finch Hatton Creek	Pioneer River	1250043	21 05.317 S 149 38.017 E
Gregory River	Proserpine River	122004A	20 18.050 S 148 32.850 E
Impulse Creek	Proserpine River	1220041	20 21.183 S 148 43.583 E
Mackay 1	Pioneer River	1250044	21 08.833 S 149 11.150 E
Mackay 2	Pioneer River	1240064	21 04.434 S 149 09.276 E
Myrtle Creek	Proserpine River	1220035, A, B	20 20.117 S 148 32.383 E
O'Connell River 1	O'Connell River	124001A 124001B	20 37.683 S 148 34.450 E 20 39.223 S 148 34.331 E
O'Connell River 2	O'Connell River	1240062	20 33.983 S 148 36.700 E
Pioneer River	Pioneer River	125013A	21 08.650 S 149 04.517 E
Plane Creek	Plane Creek	126002A	21 25.667 S 149 13.667 E
Proserpine River 1	Proserpine River	1220046	20 24.617 S 148 34.883 E
Proserpine River 2	Proserpine River	122005A	20 23.500 S 148 35.900 E
Rocky Dam Creek	Plane Creek	1260033 126007A	21 38.267 S 149 20.633 E 21 39.559 S 149 18.542 E
Sandy Creek	Plane Creek	126001A	21 16.983 S 149 01.367 E
Sarina	Plane	1260034	21 25.279 S 149 13.143 E
St Helens Creek	O'Connell River	1240061	20 58.467 S 148 41.250 E
Waite Creek	Proserpine River	1220045	20 17.283 S 148 40.683 E

Appendix B Hydrographs

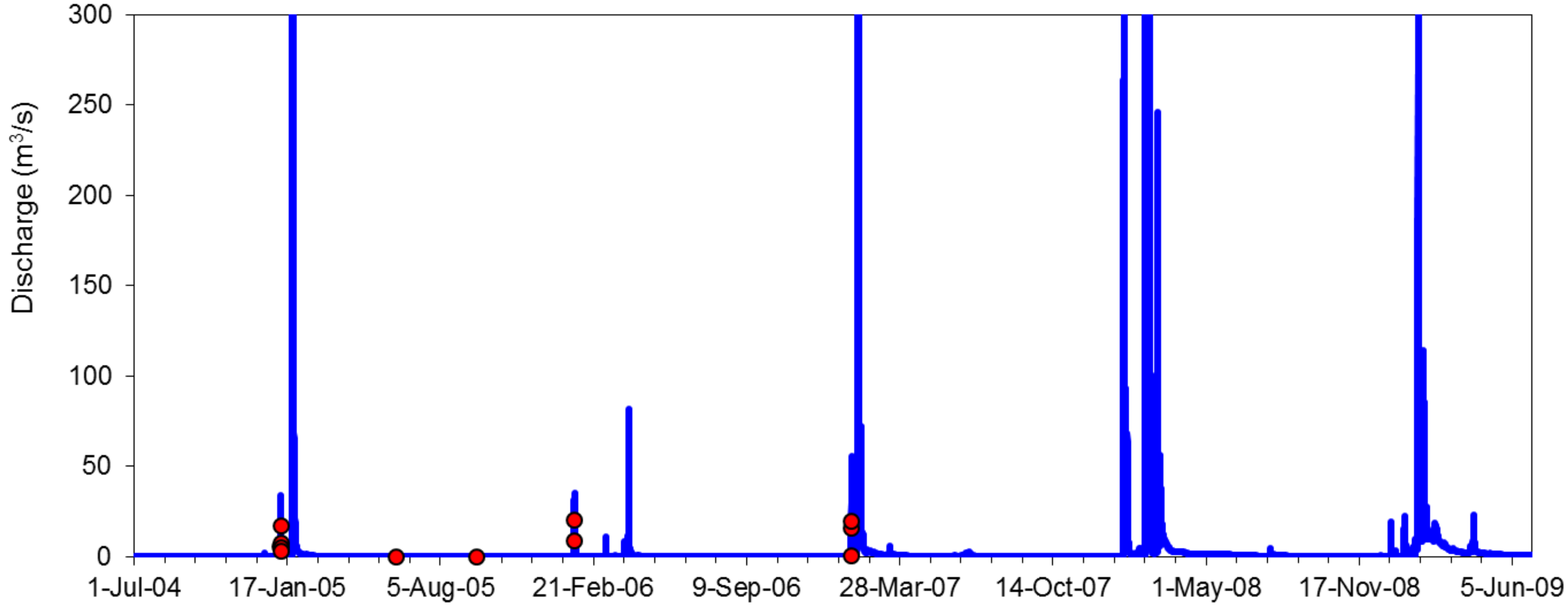

Figure B1 Hydrograph of discharge (in m^3/s) for Upper Andromache River, with event sampling plotted (red circles) against discharge level for the period of January 2005-April 2007.

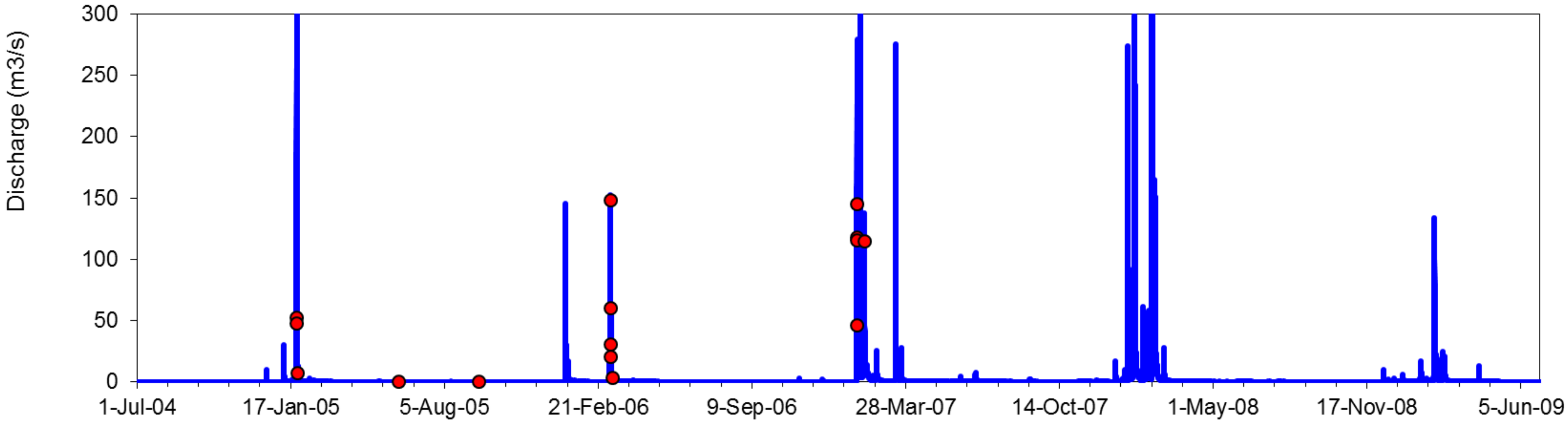

Figure B2 Hydrograph of discharge (in m^3/s) for Carmila Creek, with event sampling plotted (red circles) against discharge level for the period of January 2005- April 2007.

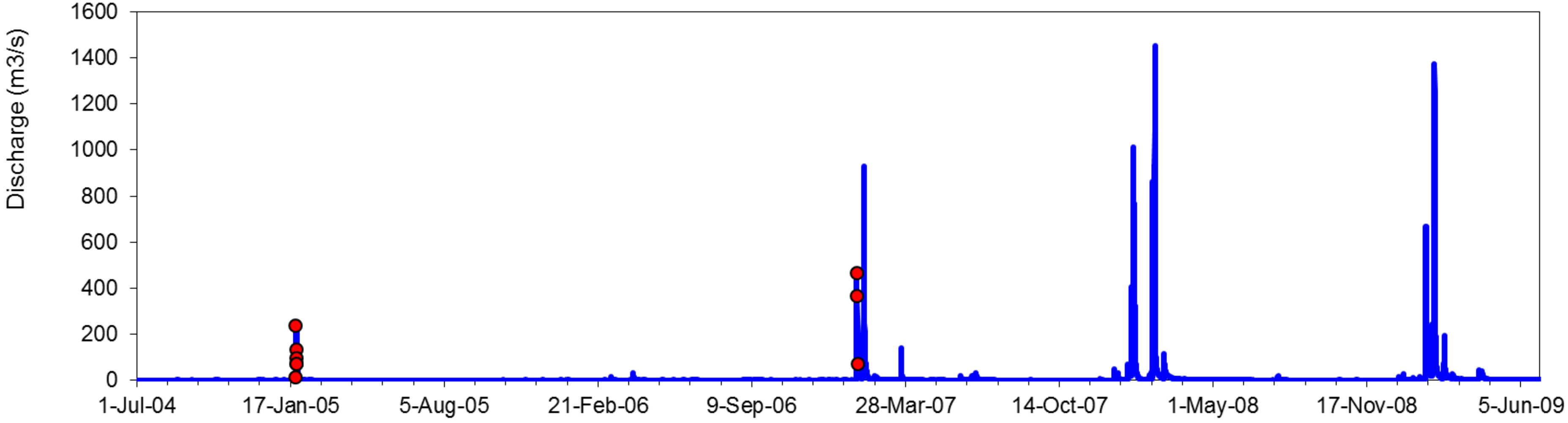

Figure B3 Hydrograph of discharge (in m^3/s) for Blacks Creek, with event sampling plotted (red circles) against discharge level for the period of January 2005- April 2007.

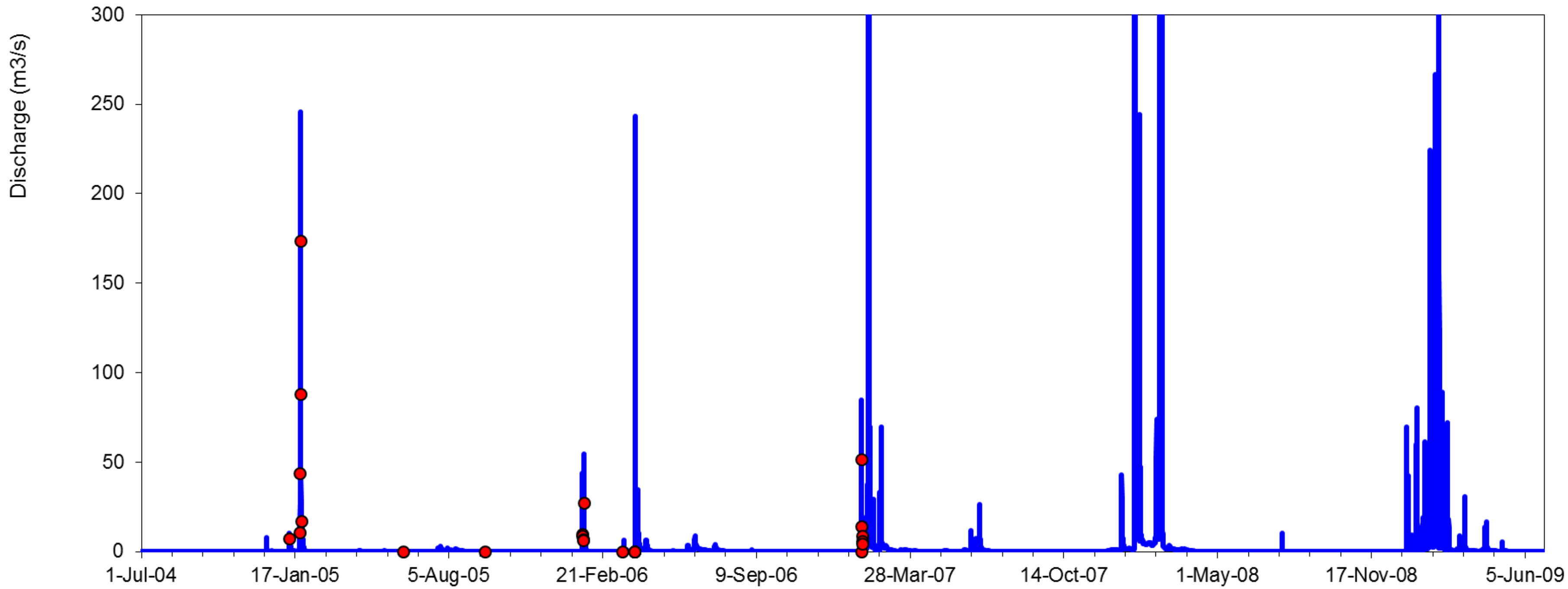

Figure B4 Hydrograph of discharge (in m^3/s) for Gregory River, with event sampling plotted (red circles) against discharge level for the period of January 2005- April 2007.

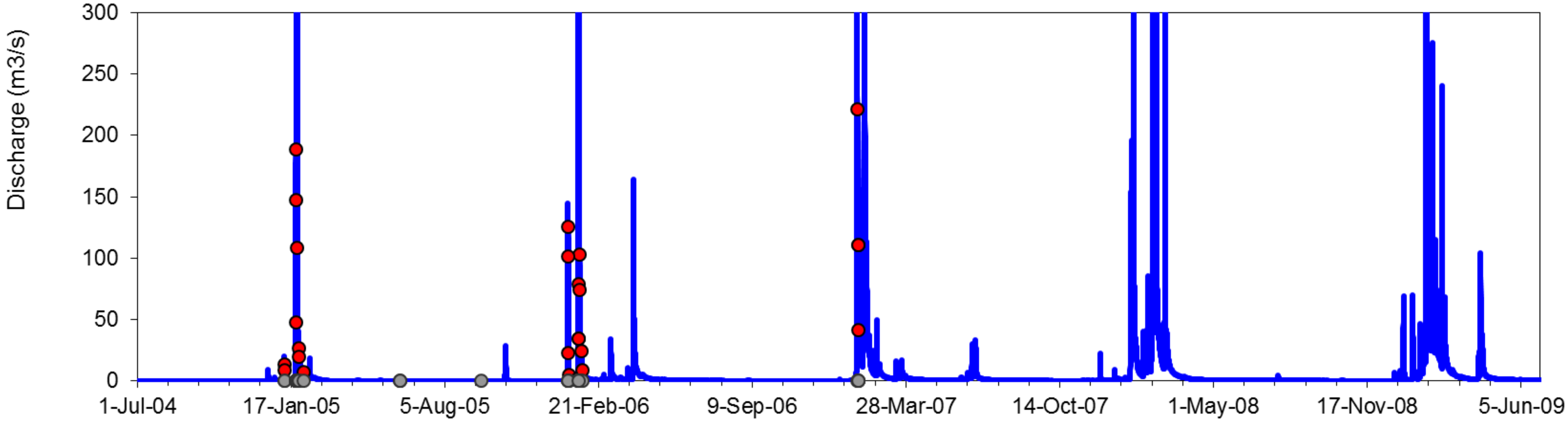

Figure B5 Hydrograph of discharge (in m^3/s) for O'Connell River, with event sampling (red circles) and ambient sampling (grey circles) plotted against discharge level for the period of January 2005- April 2007.

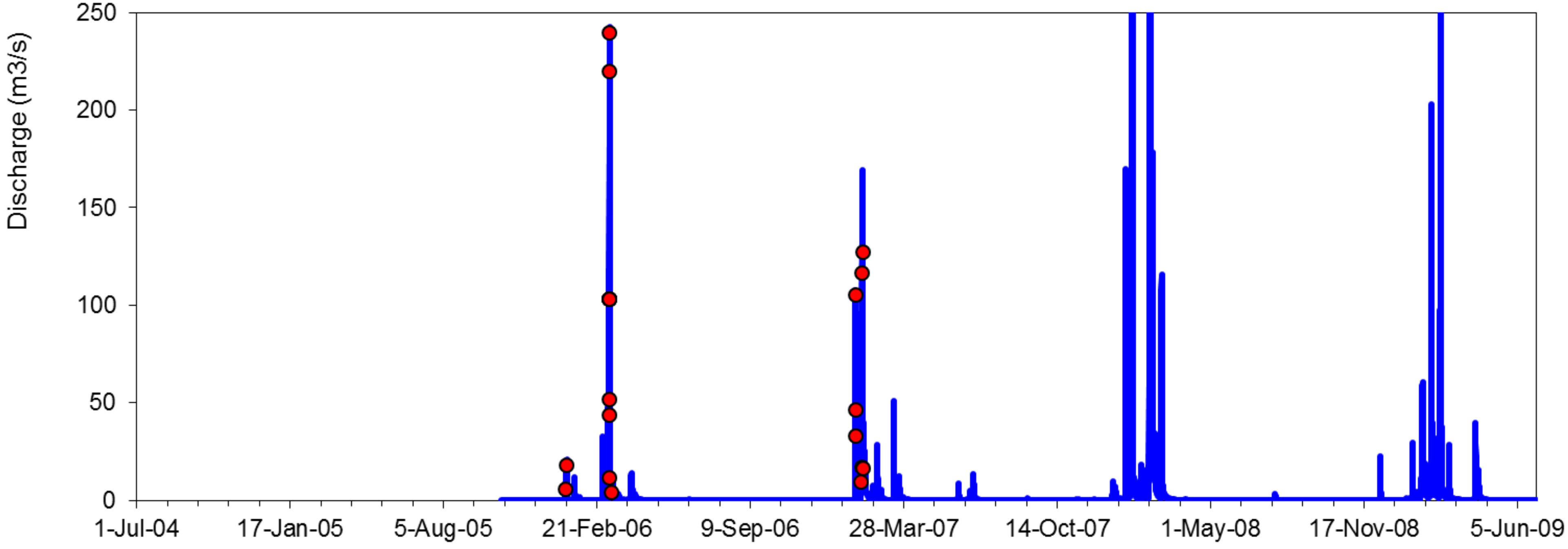

Figure B6 Hydrograph of discharge (in m^3/s) for Rocky Dam Creek, with event sampling (red circles) and ambient sampling (grey circles) plotted against discharge level for the period of February 2006- April 2007.

Appendix C Regression results table

Site	Parameter	Ambient/Event	No. of observations	p value	Slope	R2
Bakers Creek	TSS	Ambient	23	0.595	6.621	0.014
	PN	Ambient	23	0.647	-0.178	0.010
	DIN	Ambient	23	0.183	1.028	0.083
	PP	Ambient	23	0.166	-0.153	0.089
	FRP	Ambient	23	0.349	-0.077	0.042
St Helens Creek	TSS	Event	11	0.281	0.159	0.127
	TSS	Ambient	24	0.017	81.443	0.234
	PN	Event	11	0.721	0.053	0.015
	PN	Ambient	23	0.829	-0.067	0.002
	DIN	Event	11	0.442	-0.089	0.067
	DIN	Ambient	23	0.004	0.067	0.337
	PP	Event	11	0.254	0.125	0.142
	PP	Ambient	23	0.797	0.003	-0.010
	FRP	Event	11	0.096	0.012	0.278
	FRP	Ambient	23	0.221	0.006	0.070
Basin Creek	TSS	Event	9	0.208	0.083	0.22
	TSS	Ambient	23	0.290	-4.954	0.05
	PN	Event	9	0.831	-0.022	0.01
	PN	Ambient	24	0.925	-0.008	0.00
	DIN	Event	9	0.509	-0.021	0.06
	DIN	Ambient	24	0.001	0.041	0.38
	PP	Event	9	0.580	0.012	0.05
	PP	Ambient	24	0.366	-0.007	0.04
	FRP	Event	9	0.580	0.001	0.05
	FRP	Ambient	24	0.016	0.008	0.24
Carmila Creek	TSS	Event	10	0.124	0.048	0.270
	TSS	Ambient	24	0.832	-0.001	0.002
	PN	Event	10	0.490	0.125	0.062
	PN	Ambient	24	0.637	-0.047	0.011
	DIN	Event	10	0.207	-0.768	0.190
	DIN	Ambient	24	0.822	0.034	0.002
	PP	Event	10	0.140	0.045	0.251
	PP	Ambient	24	0.373	-0.015	0.038
	FRP	Event	10	0.436	0.012	0.077
	FRP	Ambient	24	0.124	0.008	0.104
Finch Hatton	TSS	Event	11	0.262	0.072	0.137
	TSS	Ambient	24	0.120	0.208	0.106
	PN	Ambient	24	0.197	0.149	0.074
	DIN	Ambient	24	0.017	0.062	0.232
	PP	Ambient	24	0.514	0.006	0.020
	FRP	Ambient	24	0.512	5.877	0.020
Gregory	PN	Event	12	0.121	0.236	0.223
	DIN	Event	12	0.037	0.948	0.368
	PP	Event	12	0.960	-0.002	0.000
	FRP	Event	12	0.968	0.002	0.000
	TSS	Event	7	0.258	-0.047	0.246
	TSS	Ambient	23	0.890	5.703	0.001

Rocky Dam	DIN	Event	13	0.944	-0.063	0.000
	DIN	Ambient	22	0.243	0.137	0.068
	PP	Event	13	0.627	-0.037	0.022
	PP	Ambient	22	0.381	0.016	0.039
	FRP	Event	13	0.930	0.004	0.001
	FRP	Ambient	22	0.367	0.008	0.041
Pioneer	TSS	Event	184	0.549	-0.008	0.002
	TSS	Ambient	42	0.081	0.002	0.074
	PN	Event	222	0.806	0.014	0.000
	PN	Ambient	42	0.542	-0.036	0.009
	DIN	Event	222	0.002	-0.050	0.043
	DIN	Ambient	42	0.493	0.037	0.012
	PP	Event	222	0.815	-0.004	0.000
	PP	Ambient	42	0.861	0.001	0.001
	FRP	Event	222	0.000	-0.007	0.069
	FRP	Ambient	42	0.231	-0.002	0.036
Plane	TSS	Event	13	0.033	0.083	0.350
	TSS	Ambient	24	0.351	-0.185	0.040
	PN	Event	13	0.000	0.492	0.723
	PN	Ambient	24	0.892	-0.011	0.001
	DIN	Event	13	0.867	0.034	0.003
	DIN	Ambient	24	0.897	-0.012	0.001
	PP	Event	13	0.037	0.157	0.340
	PP	Ambient	24	0.724	0.007	0.006
	FRP	Event	13	0.127	0.075	0.199
	FRP	Ambient	24	0.607	0.008	0.012
Upper Andromache River	TSS	Event	5	0.986656	0.004385	0.00011
	TSS	Ambient	24	0.281608	0.027884	0.052474
	PN	Event	5	0.985298	-0.00654	0.000133
	PN	Ambient	24	0.471892	0.049095	0.023777
	DIN	Event	5	0.781459	-0.09035	0.029757
	DIN	Ambient	24	0.009184	0.098911	0.270492
	PP	Event	5	0.903531	-0.02012	0.005752
	PP	Ambient	24	0.975199	-0.00102	4.49E-05
	FRP	Event	5	0.567861	-0.093	0.120037
	FRP	Ambient	24	0.024949	0.033208	0.208372
Andromache River	TSS	Event	6	0.249239	-0.40817	0.312048
	PN	Event	6	0.188969	-0.88213	0.384663
	DIN	Event	6	0.120455	-0.54166	0.491919
	PP	Event	6	0.245929	-0.22081	0.315651
	FRP	Event	6	0.010203	-0.23022	0.8397
Airlie Creek	TSS	Event	14	0.999812	-0.00022	4.82E-09
Andromache River	TSS	Ambient	23	0.908421	0.13532	0.000645
	PN	Ambient	23	0.646618	-0.17798	0.010198
	DIN	Ambient	23	0.183053	1.028415	0.082801
	PP	Ambient	23	0.166206	-0.15318	0.089224
	FRP	Ambient	23	0.349213	-0.07691	0.041831
Sarina	TSS	Event	7	0.16964	-0.18287	0.339716
	PN	Event	6	0.542132	-0.24977	0.09969
	DIN	Event	7	0.765737	-0.08965	0.019416

Impulse	PN	Ambient	24	0.397	0.021	0.033
	DIN	Ambient	24	0.001	0.066	0.399
	PP	Ambient	24	0.445	-0.008	0.027
	FRP	Ambient	24	0.382	-0.004	0.035
Mackay 1	TSS	Event	11	0.3295	0.0858	0.1056
	PN	Event	10	0.1806	1.1942	0.2119
	DIN	Event	10	0.2836	0.7421	0.1418
	PP	Event	10	0.1609	0.4620	0.2299
	FRP	Event	10	0.5145	0.2431	0.0549
Myrtle	TSS	Event	22	0.2699	-0.0444	0.0605
	TSS	Ambient	24	0.3726	1.3866	0.0363
	PN	Event	21	0.2075	0.3479	0.0823
	PN	Ambient	24	0.4012	-0.1472	0.0322
	DIN	Event	21	0.9162	-0.1628	0.0006
	DIN	Ambient	24	0.0161	0.7760	0.2359
	PP	Event	21	0.0259	0.1571	0.2350
	PP	Ambient	24	0.8001	-0.0223	0.0030
	FRP	Event	21	0.6124	0.0641	0.0138
	FRP	Ambient	24	0.6749	0.0449	0.0081
O'Connell 1	TSS	Event	18	0.244	0.121	0.084
	TSS	Ambient	24	0.173	2.808	0.083
	PN	Event	17	0.022	0.670	0.302
	PN	Ambient	24	0.653	0.020	0.009
	DIN	Event	17	0.800	-0.080	0.004
	DIN	Ambient	24	0.531	-0.030	0.018
	PP	Event	17	0.032	0.175	0.272
	PP	Ambient	24	0.298	0.013	0.049
	FRP	Event	17	0.998	0.000	0.000
	FRP	Ambient	24	0.813	-0.004	0.003
O'Connell 2	TSS	Event	20	0.302	0.088	0.076
	PN	Event	20	0.891	0.025	0.001
	DIN	Event	20	0.265	-0.169	0.068
	PP	Event	20	0.332	0.059	0.052
	FRP	Event	20	0.872	-0.003	0.001
St Helens	TSS	Event	11	0.281	0.159	0.127
	TSS	Ambient	23	0.966	0.014	0.000
	PN	Event	11	0.721	0.053	0.015
	PN	Ambient	23	0.829	-0.067	0.002
	DIN	Event	11	0.442	-0.089	0.067
	DIN	Ambient	23	0.004	0.067	0.337
	PP	Event	11	0.254	0.125	0.142
	PP	Ambient	23	0.797	-0.010	0.003
	FRP	Event	11	0.096	0.012	0.278
	FRP	Ambient	23	0.221	0.006	0.070
Sandy	TSS	Event	143	0.049	-0.016	0.027
	TSS	Ambient	40	0.002	-0.001	0.224
	PN	Event	143	0.212	-0.042	0.011
	PN	Ambient	40	0.361	-0.054	0.022
	DIN	Event	143	0.000	-0.160	0.118
	DIN	Ambient	40	0.001	0.331	0.238

	PP	Event	143	0.013	-0.023	0.043
	PP	Ambient	40	0.425	-0.006	0.017
	FRP	Event	143	0.000	-0.042	0.180
	FRP	Ambient	40	0.002	-0.034	0.226
Rocky Dam	TSS	Event	13	0.528	-0.061	0.037
	TSS	Ambient	22	0.112	0.013	0.121
	PN	Event	13	0.808	0.064	0.006
	PN	Ambient	22	0.072	0.135	0.153
	DIN	Event	13	0.944	-0.063	0.000
	DIN	Ambient	22	0.243	0.137	0.068
	PP	Event	13	0.627	-0.037	0.022
	PP	Ambient	22	0.381	0.016	0.039
	FRP	Event	13	0.930	0.004	0.001
	FRP	Ambient	22	0.367	0.008	0.041
Pioneer	TSS	Event	184	0.549	-0.008	0.002
	TSS	Ambient	42	0.081	0.002	0.074
	PN	Event	222	0.806	0.014	0.000
	PN	Ambient	42	0.542	-0.036	0.009
	DIN	Event	222	0.002	-0.050	0.043
	DIN	Ambient	42	0.493	0.037	0.012
	PP	Event	222	0.815	-0.004	0.000
	PP	Ambient	42	0.861	0.001	0.001
	FRP	Event	222	0.000	-0.007	0.069
	FRP	Ambient	42	0.231	-0.002	0.036
Plane	TSS	Event	13	0.033	0.083	0.350
	TSS	Ambient	24	0.159	7.305	0.088
	PN	Event	13	0.000	0.492	0.723
	PN	Ambient	24	0.892	-0.011	0.001
	DIN	Event	13	0.867	0.034	0.003
	DIN	Ambient	24	0.897	-0.012	0.001
	PP	Event	13	0.037	0.157	0.340
	PP	Ambient	24	0.724	0.007	0.006
	FRP	Event	13	0.127	0.075	0.199
	FRP	Ambient	24	0.607	0.008	0.012
Upper Andromache River	TSS	Event	5	0.9866559	0.00438533	0.00010984
	TSS	Ambient	24	0.2816078	0.02788358	0.05247449
	PN	Event	5	0.985298	-0.0065368	0.00013334
	PN	Ambient	24	0.4718917	0.049095	0.02377691
	DIN	Event	5	0.7814592	-0.0903494	0.02975656
	DIN	Ambient	24	0.0091837	0.09891139	0.270492
	PP	Event	5	0.9035314	-0.0201229	0.00575155
	PP	Ambient	24	0.9751994	-0.0010211	4.4939E-05
	FRP	Event	5	0.5678608	-0.0929955	0.12003676
	FRP	Ambient	24	0.0249495	0.03320837	0.20837176
Airlie Creek	TSS	Event	14	0.999812	-0.0002219	4.8242E-09
Andromache River	TSS	Ambient	23	0.9084209	0.13532036	0.00064506
	PN	Ambient	23	0.646618	-0.177981	0.01019759
	DIN	Ambient	23	0.1830531	1.0284149	0.08280064
	PP	Ambient	23	0.1662065	-0.1531815	0.08922413
	FRP	Ambient	23	0.349213	-0.0769104	0.04183059

Site	Pesticide	Ambient/ Event	No. of observations	p value	Slope	R2
Upper Andromache River	Atrazine	Event	5	0.2774	-2.6E-05	0.3687
	Atrazine	Ambient	24	0.445784	5.41E-06	0.026669
	Hexazinone	Event	5	0.309889	-0.00011	0.331315
	Tebuthiuron	Event	5	0.036568	0.000253	0.812666
	Tebuthiuron	Ambient	24	0.548037	-1.8E-06	0.016639
Andromache River	Atrazine	Event	6	0.030443	1.73E-05	0.729209
	Hexazinone	Event	6	0.030443	8.66E-05	0.729209
	Diuron	Event	6	0.079496	0.000152	0.490954
	Tebuthiuron	Event	6	0.092686	-0.00136	0.547438
Bakers Creek	Ametryn	Ambient	23	0.659673	-6.3E-06	0.009412
	Atrazine	Ambient	23	0.288092	-0.0032	0.053541
	Diuron	Ambient	23	0.33887	-0.003	0.043622
	Hexazinone	Ambient	23	0.280908	-0.0011	0.055116
	Tebuthiuron	Ambient	23	0.30681	-7.6E-06	0.049649
Basin Creek	Atrazine	Event	9	0.082786	0.000127	0.368901
	Atrazine	Ambient	24	0.146924	6.03E-06	0.09318
	Diuron	Event	9	0.076442	0.000315	0.381255
	Diuron	Ambient	24	0.684805	-1.3E-06	0.007632
Carmila Creek	Atrazine	Event	8	0.074852	6.18E-05	0.435723
	Atrazine	Ambient	24	0.756804	7.81E-06	0.004449
	Diuron	Event	8	0.080893	0.000724	0.422764
	Diuron	Ambient	24	0.476564	-0.00015	0.023285
	Hexazinone	Event	8	0.071299	0.000441	0.443729
	Hexazinone	Ambient	24	0.878655	1.77E-05	0.001083
Myrtle Creek	Ametryn	Event	21	0.881028	8.53E-05	0.00121
	Ametryn	Ambient	24	0.685998	7.53E-05	0.007571
	Atrazine	Event	21	0.915156	0.000154	0.000613
	Atrazine	Ambient	24	0.538375	0.00098	0.017448
	Diuron	Event	21	0.535471	-0.00292	0.020534
	Diuron	Ambient	24	0.363046	0.00218	0.037737
	Hexazinone	Event	21	0.183432	-0.00197	0.091171
	Hexazinone	Ambient	24	0.474595	0.000557	0.023492
O'Connell 1	Atrazine	Event	18	0.040884	0.000549	0.236159
	Atrazine	Ambient	24	0.323091	0.000112	0.044382
	Diuron	Event	18	0.102014	0.000945	0.158301
	Diuron	Ambient	24	0.306857	8.11E-05	0.047388
	Hexazinone	Event	18	0.097886	0.000143	0.161865
	Hexazinone	Ambient	24	0.426742	7.95E-05	0.028943
	Tebuthiuron	Event	18	0.13628	-0.00025	0.1333
O'Connell 2	Atrazine	Event	20	0.893828	1.79E-05	0.001017
	Diuron	Event	20	0.697871	-0.00013	0.008571
	Hexazinone	Event	20	0.852721	-1E-05	0.001967
	Tebuthiuron	Event	20	0.019414	-0.00036	0.267918
Plane Creek	Atrazine	Event	17	0.040981	0.00081	0.249973
	Atrazine	Ambient	24	0.454654	-0.00034	0.025658
	Diuron	Event	10	0.544554	0.000378	0.047661
	Diuron	Ambient	24	0.46138	-0.00024	0.024911

	Hexazinone	Event	10	0.933363	-2.3E-05	0.00093
	Hexazinone	Ambient	24	0.357121	-0.00022	0.038661
Roacky Dam Creek	Ametryn	Event	13	0.824075	-9.8E-05	0.00469
	Ametryn	Ambient	22	0.64637	-1.3E-05	0.010733
	Atrazine	Event	13	0.8246	0.000133	0.004662
	Atrazine	Ambient	22	0.372269	0.000229	0.039986
	Diuron	Event	13	0.635888	-0.00374	0.021097
	Diuron	Ambient	22	0.476517	0.004473	0.025646
	Hexazinone	Event	13	0.852549	-0.00035	0.003281
	Hexazinone	Ambient	22	0.486002	0.003009	0.024574
Sandy Creek	Ametryn	Event	180	0.816707	4.05E-06	0.000303
	Ametryn	Ambient	32	0.269918	-1.7E-05	0.040412
	Atrazine	Event	180	0.616952	-5.9E-05	0.001408
	Atrazine	Ambient	32	0.046994	-3E-05	0.125152
	Diuron	Event	180	1.86E-08	-0.00095	0.163231
	Diuron	Ambient	32	0.003951	-3.3E-05	0.245285
	Hexazinone	Event	180	3.61E-07	-0.0003	0.135722
	Hexazinone	Ambient	32	4.18E-06	-5.7E-05	0.511859
	Tebuthiuron	Event	180	0.334239	8.41E-08	0.005239
	Tebuthiuron	Ambient	32	0.084135	-2.2E-06	0.096153
Pioneer River	Ametryn	Event	252	0.470229	-3E-06	0.002088
	Ametryn	Ambient	34	0.769737	-1.6E-07	0.002716
	Atrazine	Event	252	0.148744	-7.5E-05	0.008322
	Atrazine	Ambient	34	0.895084	4.11E-06	0.000552
	Diuron	Event	252	7.96E-05	-0.00025	0.060489
	Diuron	Ambient	34	0.843122	-4.9E-06	0.001242
	Hexazinone	Event	252	0.000207	-6E-05	0.053674
	Hexazinone	Ambient	34	0.98326	1.6E-07	1.4E-05
	Tebuthiuron	Event	252	7.74E-06	7.98E-06	0.077036
Mackay 1	Atrazine	Event	18	0.154833	4.69E-06	0.122314
	Diuron	Event	18	0.760159	7.94E-05	0.005991
	Hexazinone	Event	18	0.687237	3.77E-06	0.010397
Gregory River	Atrazine	Event	12	0.44363	-0.00103	0.059811
	Diuron	Event	12	0.406869	-0.00165	0.06974
	Hexazinone	Event	12	0.982111	-3.2E-06	5.28E-05
Sarina	Atrazine	Event	7	0.882472	-2.8E-06	0.004816
	Diuron	Event	7	0.851209	5.71E-05	0.007741
	Hexazinone	Event	7	0.328443	-0.00014	0.18987

Sites with insufficient data to perform linear regression: Proserpine 1 and Proserpine 2, Mackay 2

ms-PAF results

Site	Ambient/ Event	No. of observations	p value	Slope	R2
Upper Andromache River	Event	**5**	0.72308747	-0.00034	0.048073
	Ambient	24	0.8494921	1.2E-05	0.001673
Andromache River	Event	6	0.40439339	0.003242	0.178209
Bakers Creek	Ambient	23	0.60203428	-0.01406	0.013173
Basin Creek	Event	9	0.07879162	0.012024	0.376584
	Ambient	24	0.73179323	4.82E-05	0.005447
Carmila Creek	Event	7	0.1144512	0.0267	0.421725
	Ambient	24	0.56516211	-0.00456	0.015266
Myrtle Creek	Event	21	0.86345783	0.004428	0.001597
	Ambient	24	0.26919125	0.022673	0.055182
O'Connell 1	Event	18	0.08256957	0.030366	0.176526
	Ambient	24	0.28975897	0.004099	0.050774
O'Connell 2	Event	20	0.70974761	-0.00374	0.007881
Plane Creek	Event	10	0.61387183	0.011059	0.033296
	Ambient	24	0.4394482	-0.00882	0.027409
Rocky Dam Creek	Event	13	0.54638095	0.020964	0.034016
	Ambient	22	0.27902396	0.02375	0.058298
Sandy Creek	Event		6.5328E-07	-0.01437	0.147127
	Ambient	32	0.00245598	-0.00189	0.267119
Pioneer River	Event	252	9.5755E-05	-0.00649	0.059173
	Ambient	33	0.96908049	-4.4E-05	4.93E-05
Mackay 1	Event	12	0.69633442	0.002508	0.015882
Gregory River	Event	12	0.98259844	0.000579	5E-05
Sarina	Event	7	0.93731615	0.00102	0.001365

Sites with insufficient data to perform linear regression: Proserpine 1 and Proserpine 2, Mackay 2