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Executive summary

Elevated concentrations of agriculturally derived pollutants (suspended sediments, dissolved and particulate nutrients and pesticides) represent an ongoing threat to the health and resilience of freshwater and nearshore marine ecosystems along the Queensland coast. In 2003 the Reef Water Quality Protection Plan (Reef Plan) was released by the Queensland and Australian governments (subsequently revised in 2009 and 2013) with the long-term goal of ensuring the quality of water entering the reef from adjacent catchments has no long-term detrimental impact on the health and resilience of the Great Barrier Reef.

Catchment scale water quality monitoring initiated under Reef Plan has identified elevated concentration of priority pollutants in some catchments. The monitoring results since 2009 have included periods when the concentrations of some pesticides have exceeded ecosystem protection guideline concentrations in catchments with extensive sugar cane growing areas, including the Mackay Whitsunday region in central Queensland.

Significant investment has been made by the Queensland and Australian governments together with private businesses of the agricultural sector, to improve water quality draining from agricultural lands including the Mackay Whitsunday region. The sugar industry in Mackay Whitsunday region, and in particular the growers in Sandy Creek catchment, have acknowledged the need to collectively act in order to manage the off-farm losses of pesticides and nutrients to reduce the concentrations in local waterways that flow to the Great Barrier Reef.

The Sandy Creek Sub-catchment Water Quality Monitoring Project was initiated by growers and leading industry bodies in response to continued exceedance of water quality guidelines, with the aim of identifying where in the catchment problems exist, thereby enabling growers to make informed decisions to improve management practices and improve the health of Sandy Creek. Through the Sandy Creek Sub-catchment Water Quality Monitoring Project, local growers together with Mackay Area Productivity Services and Farmacist have monitored water quality at 13 sub-catchment sites in Sandy Creek. The results presented in this report highlight the magnitude and spatial extent of the challenge that the sugar industry faces in implementing effective strategies to reduce off-farm losses of priority pollutants.

The key findings of this project were:

- Sub-catchments in the north-west section of Sandy Creek including Ross Creek, Sandy Creek North Branch, and Draper Creek, together with the end-of-catchment monitoring site at the Bruce Highway had the highest $\text{mean}_{(BT)}$ concentration of more pesticides than all other sub-catchments.
- The concentration of diuron was very high in all monitored sub-catchments
    - 84 per cent of samples exceeded the ecosystem protection guideline trigger value for freshwater ecosystems (0.2 μgL^{-1});
    - 45 per cent of samples exceeded the irrigation residue limit (2 μgL^{-1});
    - The 95th percentile concentration of diuron in the monitored catchments was 17 to 85 times greater than the ecosystem protection guideline trigger value (excluding Cut Creek and Oaky Creek).
- Metolachlor, MCPA and atrazine were detected above current ecosystem protection guideline trigger value.
- Imidacloprid, imazapic, hexazinone, diuron, atrazine and 2,4-D were detected in greater than 75 per cent of all samples. Fluroxypyr, MCPA, isoxaflutole metabolite, metribuzin and metolachlor were detected in more than 50 percent of all samples.

- The median concentration of dissolved inorganic nitrogen and dissolved inorganic phosphorus exceeded the water quality objective for the protection of environmental values in most sub-catchments.
- The median concentration of oxidised nitrogen exceeded the water quality guideline concentration in all catchments, and the median concentration of ammonium nitrogen exceed the guideline concentration in all catchments except Cut Creek and Oaky Creek.

The aggregated data as presented in this report underscores the depth of the data resource obtained through this project. It is this resource that will be valuable in informing ongoing extension and management action by the sugar industry in the Sandy Creek catchment.

The Sandy Creek Sub-catchment Water Quality Monitoring Project was led by the sugar industry from concept development, project design, sample collection, interpretation of results, and planning of management actions to redress off-farm losses of pesticides. The leadership shown by the sugar industry and commitment of all participating growers underpins the successes of this project in advancing our understanding of the water quality in Sandy Creek.

This project is proudly funded by the Queensland Reef Water Quality Program from Department of Environment and Heritage Protection (EHP).

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1 Introduction

The Scientific Consensus Statement that underpins the Reef Water Quality Protection Plan (Brodie et al. 2013a and 2013b), together with the Mackay Whitsunday regional Water Quality Improvement Plan (Folkers et al. 2014), identify the high level of risk to the health and resilience of the Great Barrier Reef in the Mackay Whitsunday region due to high concentrations and loads of pesticides and nutrients. The sugar industry in Mackay Whitsunday region, and in particular the Sandy Creek catchment, have acknowledged the need to collectively act in order to manage the off-farm losses to reduce the concentrations of pesticides and nutrients in local waterways that flow to the Great Barrier Reef.

The need to mitigate the threat of pesticides and nutrients on the health and resilience of the Great Barrier Reef underpins the significant financial investment made by the Queensland and Commonwealth Governments, and the private businesses of the agricultural sector to improve water quality draining from agricultural lands. One of the key challenges facing all stakeholders is managing the balance between environmental protection and the economic security of the agricultural industries that are critical to regional communities throughout Queensland.

Water quality data obtained though current programs such as the Great Barrier Reef Catchment Loads Monitoring Program[1] have identified catchments in the Mackay Whitsunday region, including Sandy Creek, as having high and persistent concentrations of multiple pesticides. Some of these pesticides, such as diuron, exceed the 95 per cent ecosystem protection guideline concentration (ANZECC and ARMCANZ, 2000) for extended periods during each wet season.

There are four core areas in which the risk posed by pesticides to the health of the Great Barrier Reef may be mitigated:

1. Development or selection/use of pesticides that have low environmental toxicity (reduced toxicity);
2. Adoption of application techniques that require lower rates of application (resulting in reduced paddock/source load);
3. Use of pesticides and fertilisers that have a lower susceptibility to runoff, shorter half-life and great sorption to soils/organic carbon to reduce off-farm mobilisation into receiving aquatic environments (reduced environmental exposure);
4. Adoption of farm management practices which minimise off-farm losses.

The selection of pesticides of low environmental toxicity is constrained by the need to maintain efficacy of pesticides in the farm management system to ensure effective weed and pest management. Additional products have come to market over recent decades that have been identified as having lower toxicity to non-target species compared to some of the more traditional pesticides; noting, the toxicity of some alternative chemicals is not well understood and aquatic ecosystem protection guideline values do not exist. A transition to these alternate products is occurring; however, barriers to the adoption and use of these chemicals still exist (e.g. product

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[1] The Great Barrier Reef Catchment Loads Monitoring Program monitors long-term trends in water quality entering the Great Barrier Reef lagoon from priority catchments as part of the Paddock to Reef program. Monitoring is undertaken at 18 end-of-catchment and seven nested sub-catchment monitoring sites across 14 basins.

cost, access to equipment, confidence in the product). The presence of high levels of diuron in catchments of the Mackay Whitsunday region (Smith et al. 2012; Smith et al. 2017) highlights the continued requirement for market based support from chemical manufacturers and resellers to assist growers in this transition; this follows the diuron chemical review undertaken by the Australian Pesticide and Veterinary Medicine Authority in 2011–2012.

On-farm trials have been undertaken throughout Queensland, including in Sandy Creek catchment, demonstrating significant reduction in the amount of pesticides required to attain equivalent efficacy through changes in product choice and application technique (e.g. Filliols and Callow 2011; Masters et al. 2013; Rhode et al. 2013a). Significant ongoing investment is also being made by the Queensland Government in conjunction with leading industry groups through best management practice programs to increase the adoption of farm management practices that reduce the total pesticide load (e.g. use of fallow crops, green cane trash blankets, banded spraying, variable rate application) and risk of off-farm losses (e.g. risk assessment, controlled traffic, incorporation after application) (Trendell 2013; State of Queensland 2014a and 2014b).

In the Mackay Whitsunday region, the majority of the pesticide load entering local waterways is mobilised during periods of rainfall surface runoff, within the first three weeks after application (Rohde et al. 2013). Continued selection of products with low mobility and implementation of farm practices (e.g. banded spraying; irrigation strategy to incorporate nutrient and pesticide applications) that reduce the risk of mobilisation during rainfall, offers additional opportunity to reduce the environmental exposure as a result of off-farm mobilisation (Devlin et al. 2015). This involves using products with a lower rate of application, lower inherent susceptibility to movement in runoff, shorter half-life and greater sorption to soil/organic carbon (and lower toxicity).

The Sandy Creek catchment has characteristics that heighten the risk of pesticide toxicity in downstream aquatic ecosystems. Unlike the major river systems of the Wet Tropics region, a high proportion of the Sandy Creek catchment is dominated by sugar cane production systems, and does not have an extensive upstream catchment or a high annual rainfall to provide substantial dilution of the pesticide concentrations that enter the stream network. It is critical, therefore, that management of pesticides occurs at the farm level through appropriate product selection, minimum application to attain required efficacy, and application in a manner to reduce mobilisation and off-farm losses.

This report presents the pesticide and nutrient concentrations detected in water samples collected across 13 sites in the Sandy Creek catchment, between Novmeber 2015 and March 2016. The authors acknowledge the challenge of managing pesticide losses is great and multifaceted. Here we aim to address one principle question – where are they coming from? In doing so, we anticipate that the results presented in this report will aid farm management to address pesticide losses while also improving ecosystem health in the Sandy Creek catchment.

1.1 Background

In response to continued exceedance of ANZECC and ARMCANZ (2000) water quality guidelines, concerned growers approached leading industry representative bodies including Mackay Area Productivity Services, Farmacist and Sugar Research Australia to develop a project to identify sources of pesticides entering Sandy Creek. Influenced by local growers, the concept of the Sandy Creek Sub-catchment Water Quality Monitoring Project was formulated between these industry bodies and the larger Sugar Regional Working Group, whose membership includes Canegrowers Proserpine, Canegrowers Mackay/Plane, Department of Agriculture and Fisheries, Reef Catchments, Sugar Research Australia and Mackay Area Productivity Services. Together, members of the sugarcane industry and the Department of Science, Information Technology and Innovation petitioned the Department of Environment and Heritage Protection for funding to establish a targeted water quality monitoring project in the Sandy Creek catchment.

The Sandy Creek Sub-catchment Water Quality Monitoring Project was a unique project ultimately driven by local sugarcane growers and assisted by members of the sugarcane industry to identify where in the catchment problems exist, thereby enabling growers to make informed decisions to improve management practices and improve the health of Sandy Creek.

Ownership of the project was shared between Department of Science, Information Technology and Innovation, Mackay Area Productivity Services, Farmacist, Sugar Research Australia and local sugarcane growers. Both Mackay Area Productivity Services and Farmacist work closely with growers in the region and together, both organisations acted as the regional coordinators for the project.

1.2 Objectives

The objectives of the Sandy Creek Sub-catchment Water Quality Monitoring Project were to:

1. Identify sub-catchments producing high pesticide concentrations, contributing to exceedance in water quality guidelines;
2. Assess levels of nutrients entering Sandy Creek from selected sub-catchments;
3. Identify, if possible, those sub-catchments where management practice change could best effect a reduction in observed pesticide and nutrient concentrations entering Sandy Creek;
4. Engage with local growers to collect water quality samples creating awareness and ownership of the health of Sandy Creek.

This report presents aggregated data across all monitored events during the 2015–2016 wet season, and it is highlighted that the finer scale event based comparison of concentration differences or changes within events, provide an additionally valuable resource. The full dataset that underpins this report has been made available to the sugar industry in the Mackay Whitsunday region through Mackay Area Productivity Services and Farmacist.

2 Methods

2.1 Monitoring sites

Situated within the Plane Creek basin, the largest of the Mackay Whitsunday basins (approximately 2500 km^2), the Sandy Creek catchment covers an area of approximately 460 km^2 (Department of Science, Information Technology and Innovation 2016). Sandy Creek extends from the town of Mirani in the upper catchment, down to Eton at its centre before draining into the Great Barrier Reef Lagoon 12 km south of Mackay (Queensland).

Within the Sandy Creek catchment, 13 monitoring sites were selected to identify the main sub-catchments contributing to the high concentrations of pesticides and nutrients measured in Sandy Creek at Homebush as part of monitoring conducted by the Great Barrier Reef Catchment Loads Monitoring Program (Figure 2-1 and Table 2-1). All nested sub-catchment monitoring sites are located upstream of the end-of-catchment site, Sandy Creek at Bruce Highway. The majority of sites were located on large tributaries that feed into Sandy Creek; others were situated on the main channel of Sandy Creek downstream of those confluences. Linking sites between key sub-catchment tributaries and sites located on the main Sandy Creek channel, provided an opportunity to observe changes in pollutant concentrations as they move through the catchment.

Nested sites within the Draper Creek sub-catchment include De Moleyns Lagoon upstream of the DNRM Multi-farm site (see below for explanation) at Kinchant Dam Road, which is upstream of the Peak Downs Highway site. The individual sub-catchment sites, Sandy Creek North Branch, Sandy Creek South Branch and Cut Creek converge into the main channel of Sandy Creek at Eton site. The Ross Creek, Bagley Creek, Oaky Creek, Frenchmans Creek and BL Creek sites are located on individual sub-catchments that all converge into the main Sandy Creek channel at various locations upstream of the end-of-catchment site located at the Bruce Highway.

The Sandy Creek Sub-catchment Water Quality Monitoring Project also incorporated data collected from two existing water quality monitoring sites: the Department of Natural Resources and Mines (DNRM) Draper Creek Multi-farm site (Rohde et al. 2013); and the Great Barrier Reef Catchment Loads Monitoring Program site located near Homebush (Wallace et al. 2016). These sites were established under the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program[2] (Paddock to Reef program) and were advantageous in that the Sandy Creek Sub-catchment Water Quality Monitoring Project could utilise existing infrastructure and long-term datasets.

All sites included in the Sandy Creek Sub-catchment Water Quality Monitoring Project were monitored for pesticides, total and dissolved nutrients (phosphorus and nitrogen) using various sample collection methods that included manual sampling, rising stage samplers and automatic pump samplers (Table 2-1).

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[2] Paddock to Reef Integrated Monitoring, Modelling and Reporting Program is a collaboration involving governments, industry bodies, regional natural resource management bodies, landholders and research organisations. Information from this program is used to evaluate, prioritise and continuously improve the efficiency and effectiveness of on-ground Reef Plan actions.

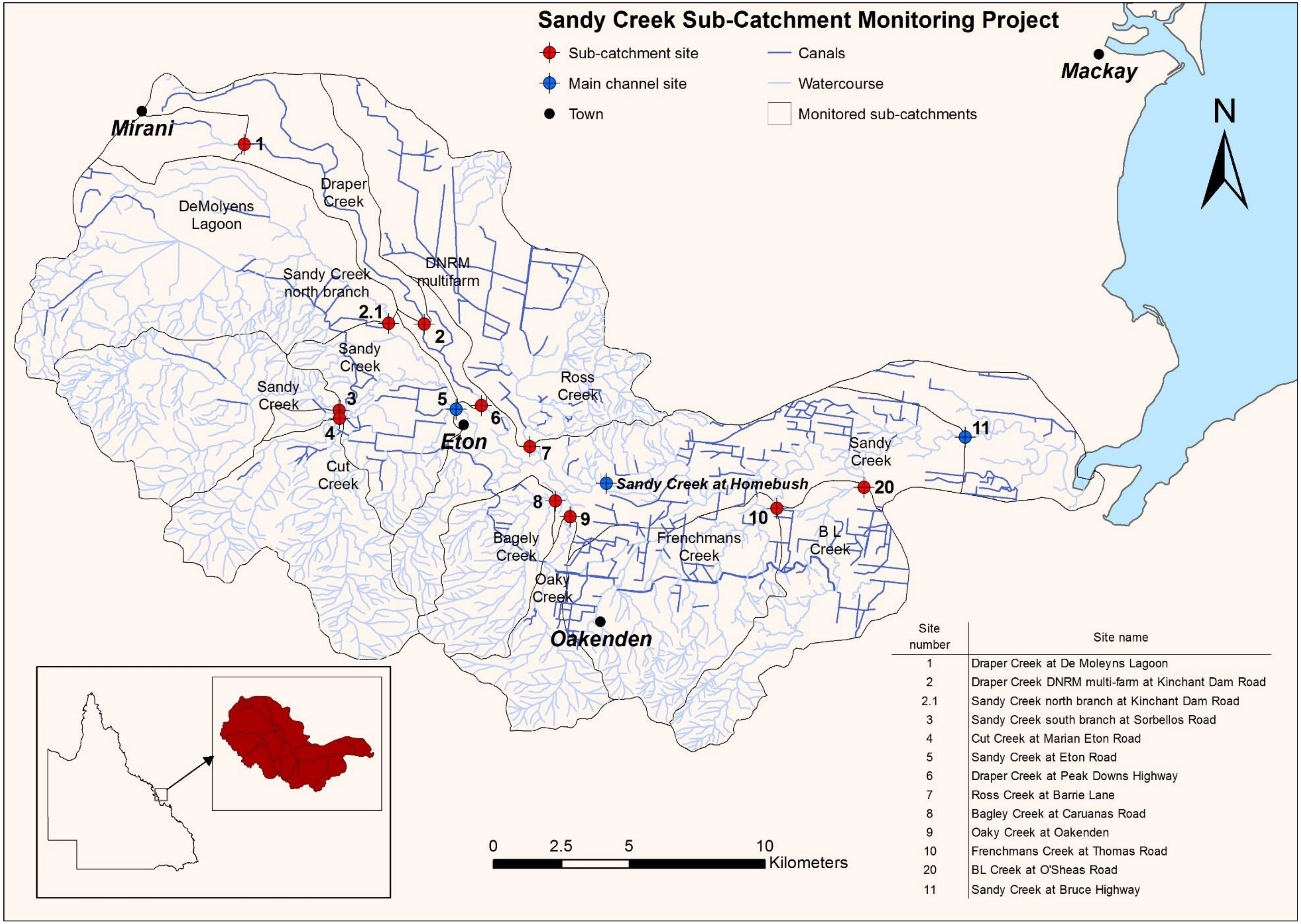

Figure 2-1 Locations of the Sandy Creek Sub-catchment Water Quality Monitoring Project monitoring sites October 2015 and April 2016.

Table 2-1 Summary information on sites monitored for the Sandy Creek Sub-catchment Monitoring Program. Sub-catchments are listed in order from the upper-catchment to lower-catchment.

Site Number	Sub-catchment	Site name	Latitude	Longitude	Sample collection method
2.1	Sandy Creek North Branch	Sandy Creek North Branch at Kinchant Dam Road	-21.2303	148.9503	Manual + rising stage sampler
3	Sandy Creek South Branch	Sandy Creek South Branch at Sorbellos Road	-21.2591	148.9339	Manual + rising stage sampler
4	Cut Creek	Cut Creek at Marian Eton Road	-21.2618	148.9340	Manual + rising stage sampler
5	Sandy Creek	Sandy Creek at Eton Road	-21.2588	148.9727	Manual + rising stage sampler
1	Draper Creek	Draper Creek at De Moleyns Lagoon	-21.1710	148.9025	Manual
2		Draper Creek DNRM Multi-farm at Kinchant Dam Road	-21.2305	148.9622	Refrigerated automatic sampler
6		Draper Creek at Peak Downs Highway	-21.2576	148.9812	Manual + rising stage sampler
7	Ross Creek	Ross Creek at Barrie Lane	-21.2712	148.9972	Manual + rising stage sampler
8	Bagley Creek	Bagley Creek at Caruanas Road	-21.2892	149.0057	Manual + rising stage sampler
9	Oaky Creek	Oaky Creek at Oakenden	-21.2944	149.0105	Manual
P2R	Sandy Creek	Sandy Creek at Homebush[1]	-21.2831	149.0228	Refrigerated automatic sampler
10	Frenchmans Creek	Frenchmans Creek at Thomas Road	-21.2916	149.0790	Manual + rising stage sampler
20	BL Creek	BL Creek at O'Sheas Road	-21.2857	149.0916	Manual + rising stage sampler
11	Sandy Creek	Sandy Creek at Bruce Highway	-21.2679	149.1415	Manual

[1] Great Barrier Reef Catchment Loads Monitoring Program site

2.2 Land use areas

For each monitored sub-catchment, the land use data were obtained from the Queensland Land Use Monitoring Program, which is part of the Australian Collaborative Land Use Mapping Program and sourced through the Queensland Government Information Service (Department of Science, Information Technology and Innovation, 2016). These data were aggregated into eight categories: conservation, forestry, grazing, horticulture, sugarcane, urban, water and other. Land use areas for sub-catchment site are presented in Table 2-2 and Figure 2-3.

Sugarcane is the single largest land use within the Sandy Creek catchment, accounting for approximately 50 per cent of the total catchment area. Other significant land uses include grazing (30 per cent), forestry (7 per cent) and land set aside for nature conservation (6 per cent).

As previously stated, the majority of sites were located on tributaries that feed into Sandy Creek; others were situated along the main channel of Sandy Creek downstream of those confluences. Land use areas for sites situated downstream of confluences include those calculated for upstream sites. Therefore, the end-of-catchment site, Sandy Creek at Bruce Highway, logically represents the largest land use area in all categories.

2.2.1 Sugarcane

Sub-catchments that contain large areas of sugarcane cultivation include Ross Creek (42 km^2; 68 per cent); Draper Creek at Peak Downs Highway (32 km^2; 89 per cent), which is dominated by contributions from the Draper Creek DNRM Multi-farm sub-catchment (28 km^2; 90 per cent); and Sandy Creek at Eton Road (59 km^2;35 per cent), including contributions from both the Sandy Creek North Branch (25 km^2; 37 per cent) and Sandy Creek South Branch (13 km^2;34 per cent) sub-catchments. Cut Creek (3.9 km^2; 10 per cent) and Oaky Creek (4.6 km^2; 29 per cent) sub-catchments contain the smallest land use areas for sugarcane.

Table 2-2 Sandy Creek sub-catchment site land use areas

Site name	Conservation		Forestry		Grazing		Horticulture		Sugar		Urban		Water		Other		Monitored Sub-catchment Area
	km²	%	km²	%	km²	%	km²	%	km²	%	km²	%	km²	%	km²	%	km²
Sandy Creek North Branch at Kinchant Dam Road	4.9	7.3	0.48	0.72	25	37	0.028	0.042	25	37	0.92	1.4	10	15	0.87	1.3	67
Sandy Creek South Branch at Sorbellos Road	1.2	3.2	12	32	11	29	0.14	0.37	13	34	0.15	0.40	0.090	0.24	0.043	0.11	38
Cut Creek at Marian Eton Road	1.6	4.1	11	28	22	56	0.028	0.072	3.9	10	0.093	0.24	0.0	0.0	0.035	0.090	39
Sandy Creek at Eton Road	8.3	4.9	24	14	64	38	0.20	0.12	59	35	1.7	1.0	11	6.5	0.97	0.57	170
Draper Creek at De Moleyns Lagoon	0.0	0.0	0.0	0.0	1.4	17	0.0	0.0	6.2	74	0.51	6.1	0.18	2.1	0.15	1.8	8.4
Draper Creek DNRM multi-farm at Kinchant Dam Road	0.029	0.094	0.0	0.0	1.8	5.8	0.0	0.0	28	90	1.1	3.5	0.32	1.0	0.18	0.58	31
Draper Creek at Peak Downs Highway	0.45	1.3	0.0	0.0	1.8	5.0	0.0	0.0	32	89	1.2	3.3	0.32	0.89	0.35	0.97	36
Ross Creek at Barrie Lane	2.2	3.5	0.0	0.0	16	26	0.0070	0.011	42	68	1.3	2.1	0.31	0.50	0.021	0.034	62
Bagley Creek at Caruanas Road	0.20	1.0	1.7	8.5	10	50	0.60	3.0	7.1	36	0.017	0.085	0.22	1.1	0.0	0.0	20
Oaky Creek at Oakenden	0.61	3.8	7.6	48	3.1	19	0.11	0.69	4.6	29	0.0	0.0	0.024	0.15	0.0078	0.049	16
Sandy Creek at Homebush	13	3.9	34	10	100	30	1.1	0.33	160	48	5.7	1.7	12	3.6	0.34	0.10	330
Frenchmans Creek at Thomas Road	5.6	14	0.14	0.34	14	34	0.052	0.13	19	46	1.3	3.2	0.41	1.0	0.0	0.0	41
BL Creek at O'Sheas Road	8.2	7.5	0.0	0.0	73	66	0.0	0.0	27	25	1.1	1.0	1.0	0.91	0.0	0.0	110
Sandy Creek at Bruce Highway	24	5.5	34	7.7	140	32	1.2	0.27	220	50	6.9	1.6	14	3.2	1.8	0.41	440

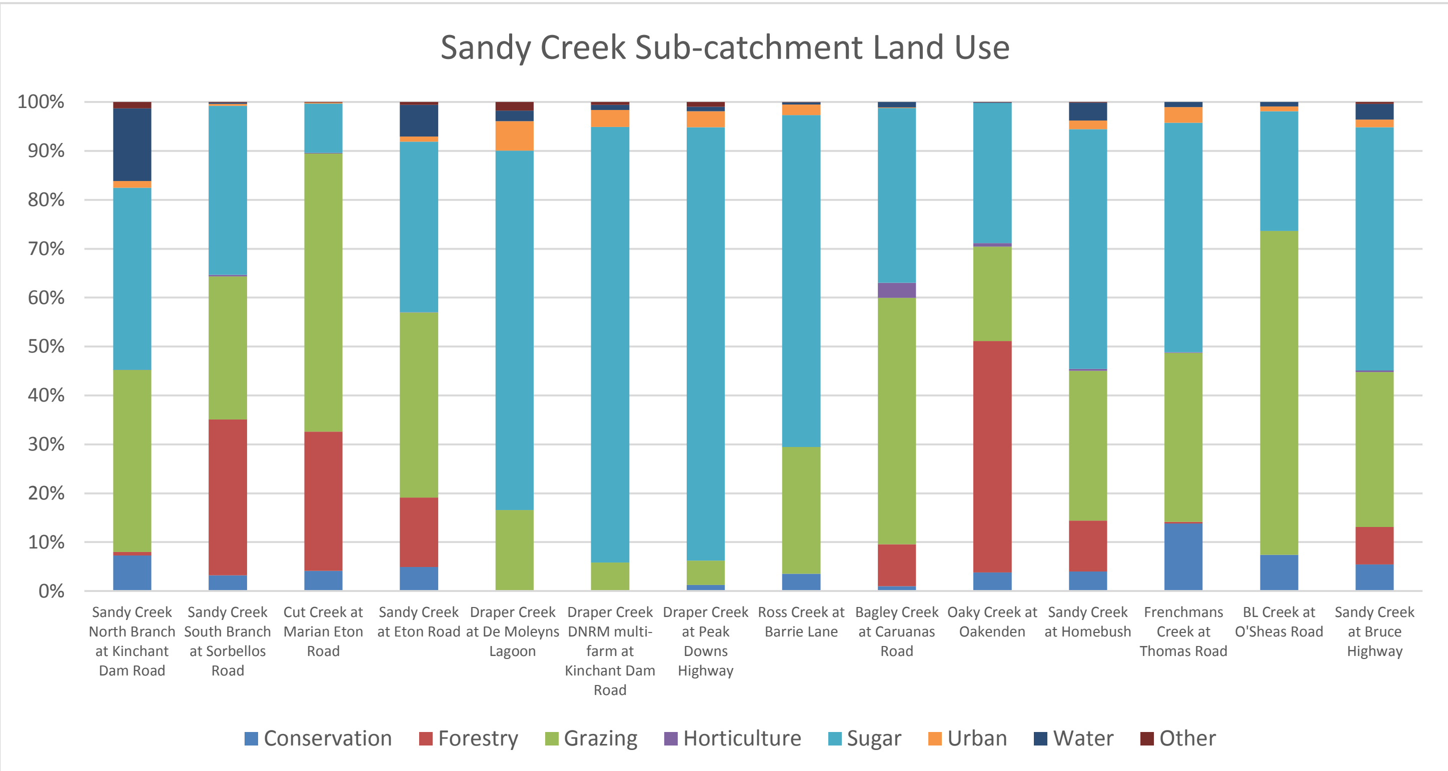

Figure 2-2 Sandy Creek sub-catchment land use as a relative proportion of all mapped land uses.

2.2.2 Grazing

Grazing is the next most prevalent land use within Sandy Creek catchment. Over half the grazing land use area is located in the BL Creek sub-catchment (73 km^2, 66 per cent) and a further 46 per cent upstream of Sandy Creek at Eton Road (64 km^2) which encompasses the nested sub-catchments of Sandy Creek North Branch (25 km^2, 37 per cent), Sandy Creek South Branch (11 km^2; 29 per cent) and Cut Creek (22 km^2; 56 per cent). Only small grazing areas are located in the upper Drapers Creek sub-catchment at De Moleyns Lagoon (1.4 km^2; 17 per cent) and Oaky Creek (3.1 km^2; 19 per cent) sub-catchments.

2.2.3 Forestry

Approximately 34 km^2 of Sandy Creek catchment is used for forestry production with the majority located on the range extending along the southern catchment boundary. The sub-catchments upstream of Sandy Creek South Branch (12 km^2, 32 per cent), Cut Creek (11 km^2; 28 per cent) and Oaky Creek (7.6 km^2; 48 per cent) have the highest proportion of area under forestry production. Draper Creek, Ross Creek and BL Creek sub-catchments do not contain any areas of forestry production.

2.2.4 Nature conservation

BL Creek (8.2 km^2; 7.5 per cent), Frenchmans Creek (5.6 km^2; 14 per cent) and Sandy Creek North Branch (4.9 km^2; 7.3 per cent) contain the largest areas set aside for nature conservation. The proportion of the sub-catchment area for nature conservation in Draper Creek at De Moleyns Lagoon, Draper Creek at Multi-farm and Bagley Creek are 1 per cent or less.

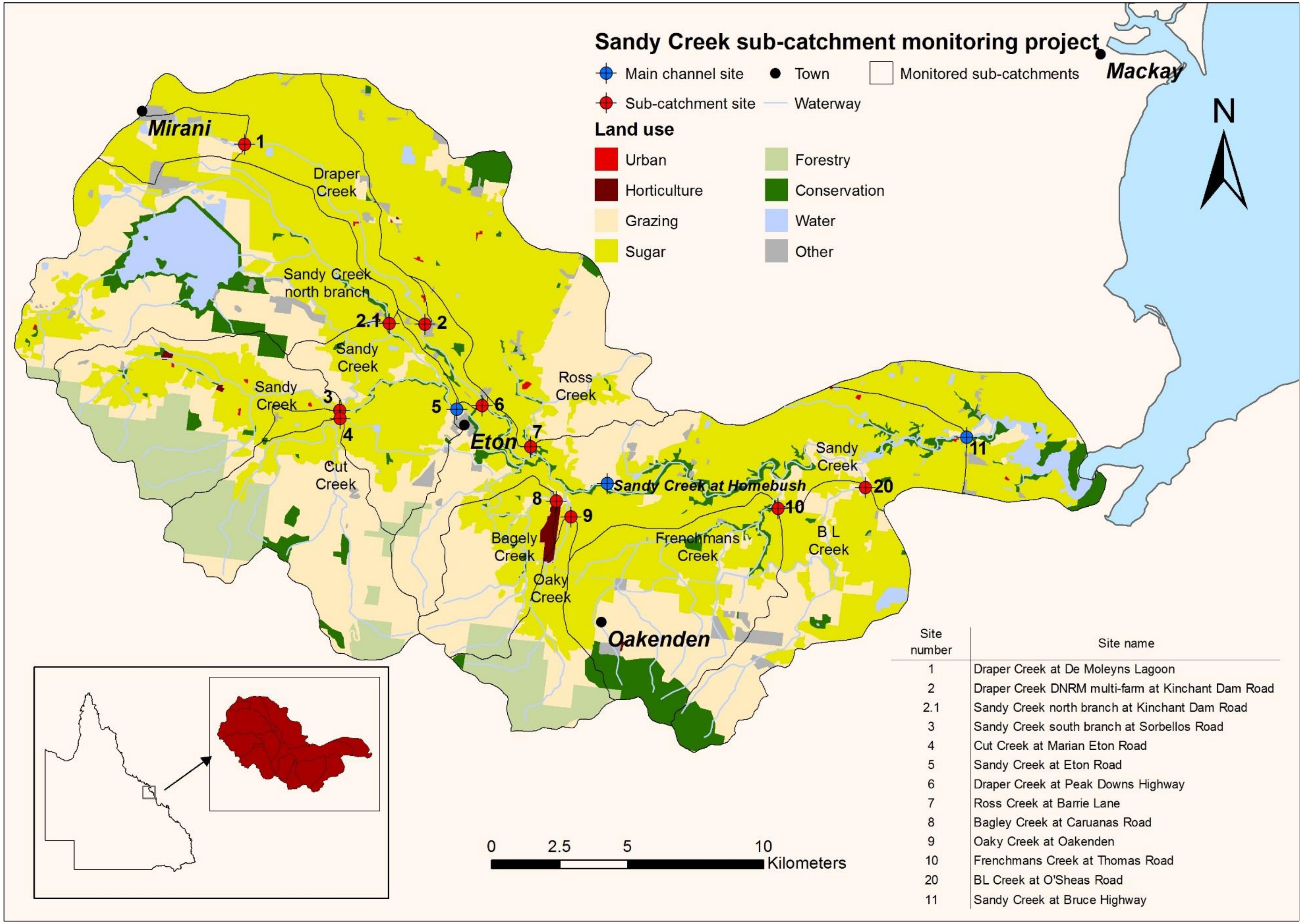

Figure 2-3 Sandy Creek catchment land use.

2.3 Rainfall

Daily rainfall grids (5 km^2) covering the Sandy Creek catchment area were obtained from the Queensland Government SILO database (<https://www.longpaddock.qld.gov.au/silo/>). These data were synthesised using a Geographical Information System (GIS) to create rainfall maps for each event in the Sandy Creek catchment during the monitoring period using the following steps:

1. Water level hydrographs (constructed from water depth logger data) were examined to identify the approximate rainfall period leading up to the rainfall runoff and daily rainfall grids surrounding these dates were examined;
2. A rainfall event period was determined by including days where greater than 10 mm of rain fell in consecutive 24 hour periods and during at least one of these periods, greater than 25 mm of rainfall was received anywhere within the Sandy creek catchment;
3. All daily rainfall grids within the identified event period were then summed, and a new 'total rain event grid' was created;
4. The new 'total rain event grid' was then contoured and classified into nine classifications <25 mm, 25-50 mm, 50-75 mm, 75-100 mm, 100-150 mm, 150-200 mm, 200-250 mm. 250-300 mm, >300 mm (to cover the smallest to largest rainfall totals);
5. For the total monitoring period rainfall map monthly rainfall grids from 1 November 2015 to 31 March 2016 were summed and a 'total monitoring period grid' was created, contoured and classified into six groups covering the minimum and maximum totals.

2.4 Stage height

Water depth loggers were installed at all sites (excluding the tidally influenced end-of-catchment site Sandy Creek at Bruce Highway) to measure the water level at monitoring sites over the term of the project. A single barometric logger was installed to correct the depth data measured at each monitored sub-catchment site.

A measurement of water level allowed an assessment of the timing of sample collection with respect to the stage (rise, peak and fall) of the hydrograph. Monitoring undertaken as part of the Great Barrier Reef Catchment Loads Monitoring Program has shown that the peak in concentration for most pesticides occurs during the rising stage of the hydrograph (Smith et al. 2012). Water level data was used to assess whether concentration data was biased towards periods of expected high concentrations (majority of samples collected during the rising stage) or lower concentration (majority of samples collected on the falling stage).

Water depth loggers were mounted inside electrical conduit, fixed in place with a star picket and securely attached to a tree (Figure 2-4). Depth loggers were installed in positions which provided protection during high flow conditions, and co-located with rising stage samplers. The height records obtained from the depth loggers were used to determine the date and time the rising stage samplers filled.

Water level data obtained from the Department of Natural Resources and Mines hydrographic gauging station located at Homebush were used as a surrogate for the water level at the Sandy Creek at Bruce Highway end-of-catchment monitoring site.

Figure 2-4 Water depth logger and rising stage samplers installed in Sandy Creek South Branch on the downstream side of a tree.

2.5 Water quality sampling

All water samples analysed for the Sandy Creek Sub-catchment Water Quality Monitoring Project were obtained following methods outlined in the Environmental Protection (Water) Policy Monitoring and Sampling Manual (EPP (Water)) (DEHP 2013b) and in accordance with field methods developed for the Great Barrier Reef Catchment Loads Monitoring Program as per the Water Quality and Investigations Quality Management System.

Water quality sampling for the Sandy Creek Sub-catchment Water Quality Monitoring Project targeted the early rainfall runoff events of the season (between November and February) as this is the period when the majority of pesticides and fertilisers are mobilised from cropping areas and enter local waterways (Smith et al. 2012; Agnew et al. 2011; Rhode et al. 2013; Dang et al. 2016).

Manual grab sample collection was undertaken by trained local sugarcane growers at 13 sub-catchment sites. Participating growers were instructed to commence sample collection when sufficient local rainfall had resulted in runoff leading to an increase (>0.5 m rise) in water depth in monitored waterways. Sample collection was to continue at an interval of three samples per day until the water level receded to near-base flow levels.

Each set of samples collected by the growers consisted of a pesticide sample bottle and total nutrient sample bottle. Samples were retrieved from each grower by regional coordinators within 24 hours of sample collection to ensure that filtration of the dissolved nutrient samples and preservation of all samples were done in accordance with standards defined in the Environmental Protection (Water) Policy Monitoring and Sampling Manual (EPP (Water)) (DEHP 2013b).

The Department of Science, Information Technology and Innovation project team retrieved and replaced all rising stage samplers and collected supplementary manual grab samples. Sample collection from automated sites was coordinated by Department of Natural Resources and Mines for the Draper Creek Multi-farm site and by Department of Science, Information Technology and Innovation for the Sandy Creek at Homebush site

2.5.1 Training

The Department of Science, Information Technology and Innovation project team developed a tailored competency based training package that was delivered to all participating growers and regional coordinators. The four hour training course comprised the following areas and competencies:

- background and objectives to the project;
- water sample collection by manual grab sampling;
- water sample filtration, preservation and transport;
- contamination controls.

The sampling process for the Sandy Creek Sub-catchment Water Quality Monitoring Project was designed to be simple and quick, thereby encouraging growers to continue to sample over multiple events. This was facilitated by tasking regional coordinators with the responsibility of sample filtration, preservation and transport, which also reduced the risk of sample contamination.

2.5.2 Sampling equipment

All participating growers were provided with pre-prepared sampling kits. The kits were stored in a plastic tote box to act as a barrier to potential contamination and contained all the equipment required to take a single grab sample, including individually packaged pairs of total nutrients and pesticide sample bottles each with two sets of vinyl gloves, a chain-of-custody form, pencil and laminated pictorial instructions as a quick reference to ensure samples were collected in accordance with approved methods. Sampling equipment provided in the kits was supplied by the Science Division Chemistry Centre and Queensland Health Forensic and Scientific Services. Growers were initially provided with two sampling tote boxes containing sufficient sampling kits to collect eight samples during each of the first two events. Additional sampling kits were subsequently provided to growers as required.

Participating growers were also supplied with an extendable sampling pole, ice boxes and ice bricks. The extendable sampling pole enabled growers to collect samples from a well-mixed, representative section of the stream. Ice boxes and ice bricks were supplied to growers to preserve water samples prior to further processing by the regional coordinators.

The regional coordinators were supplied with all equipment necessary to filter the dissolved nutrient samples from the total nutrient samples collected by growers (i.e. written and illustrated instruction, filters, syringes, gloves and dissolved nutrient sample bottles supplied by Science Division Chemistry Centre) and to courier all samples (pesticide and nutrient) overnight to Department of Science, Information Technology and Innovation offices in Brisbane (i.e. large eskies and ice bricks).

2.5.3 Rising stage samplers

Two rising stage samplers were installed at the majority of sites (see Figure 2-4 and Figure 2-5) with the exception of Drapers Creek at De Moleyns Lagoon, Oaky Creek and the tidally influenced end-of-catchment site Sandy Creek at the Bruce Highway. These equipment enable the collection of water samples for the analysis of pesticides during the early stages of rainfall runoff events within respective sub-catchments. Rising stage samplers represent an economical method of passive sample collection, reducing the risk of missed sampling due to rapid rises in water levels (i.e. storm driven runoff events) if growers were unavailable to manually collect samples.

All rising stage sampler inlet-tube and outlet tubes were fabricated by the Department of Science, Information Technology and Innovation at the EcoSciences Precinct, Brisbane. The inlet and outlet tubes were constructed from stainless steel tubing set in a nylon stopper (Figure 2-5). Suitable borosilicate amber glass bottles, capable of withstanding increased lateral hydrological pressure applied to the intake and exhaust tubes during high flow events, were acquired for this project. Bottles were subsequently provided to Queensland Health Forensic and Scientific Services to be prepared for pesticide sample collection as per internal procedures.

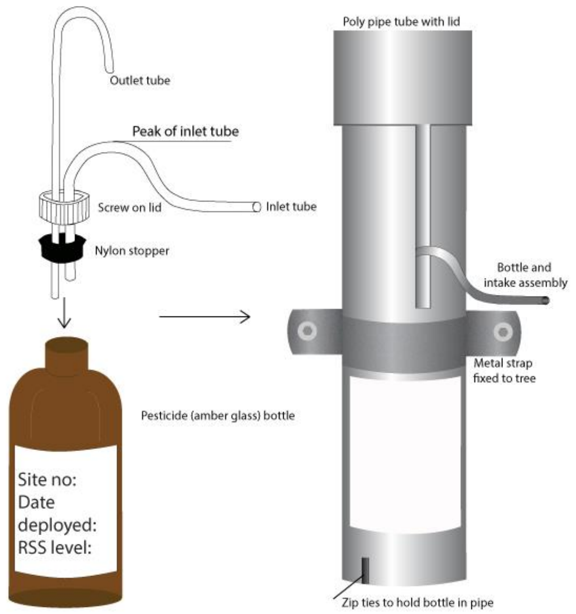

Figure 2-5 Rising stage sampler assembly.

Housing for the rising stage samplers was fabricated from PVC cylinders capped to reduce exposure to sunlight between the time of filling and retrieval of samples (Figure 2-5). The PVC housing also served to protect sample bottles against hydrological pressure and debris during high flow events. A single rising stage sample bottle was contained within each individual PVC housing to allow increased flexibility in deployment height of rising stage samplers.

Initially two rising stage sampler units were installed at predetermined flow heights at each selected monitoring site. A third rising stage sampler was installed at most sites in February 2016 to accommodate forecasts for high rainfall that were expected to result in substantially higher stream depths than the first two monitored runoff events.

To mitigate the risk of contamination of rising stage sampler bottles during periods of deployment, all bottles were replaced once per month and following each rainfall runoff event. The inlet and outlet tubes of rising stage samplers were also flushed with deionised water as part of the refurbishment procedure.

Field blanks were undertaken on rising stage sample bottles from a subset of sites across the study area. Field blanks were conducted on bottles following a four week deployment period during which no rainfall runoff events occurred.

2.5.4 Automatic pump sampler

Refrigerated automatic pump samplers were used to collect samples at two sites in the Sandy Creek catchment: Drapers Creek DNRM Multi-farm site located on Kinchant Dam Road; and the Great Barrier Reef Catchment Loads Monitoring Program site located on Sandy Creek at Homebush. Each site was equipped with two refrigerated automatic pump samplers, one configured for collecting nutrient samples (using 14 polypropylene collection bottles) and the other for pesticide samples (using 12 glass collection bottles). Samples were collected by staff of DNRM at the DNRM Multi-farm site and Reef Catchments NRM at the Homebush site in accordance with field methods developed for the Great Barrier Reef Catchment Loads Monitoring Program.

2.6 Sample analysis

2.6.1 Pesticides

Analysis of all samples for pesticides was undertaken by the Queensland Health Forensic and Scientific Services, Cooper Plains. The laboratory is accredited by the National Association of Testing Authorities (NATA, Australia).

Pesticide samples collected by participating growers were analysed using the liquid chromatography-mass spectrometry/mass spectrometry (LC-MS/MS) following a single-run, programmed direct injection method. Samples collected at the Drapers Creek DNRM Multi-farm site and the Sandy Creek at Homebush site were analysed using the same LC-MS/MS method following solid phase extraction.

The direct injection method was selected as the primary analytical method for this project as this method is capable of detecting a broader suite of chemicals compared to the alternative solid phase extraction method used as part of the Great Barrier Reef Catchment Loads Monitoring Program. As a result of the differences in the analytical method (see Appendix A for a comparison between the two methods), fewer chemicals were detected at both the Drapers Creek at DNRM Multi-farm site and Sandy Creek at Homebush site. It should also be noted that the limit of reporting differs for some chemicals between the direct injection and solid phase extraction methods (see Table 7-1in Appendix A).

2.6.2 Nutrients

Nutrient analyses of all samples were undertaken by the Science Division Chemistry Centre (Dutton Park, Queensland) according to Standard Methods 2540 D, 4500-NO_3 I, 4500-NH_3 H, 4500-N_{org} D and 4500-P G (APHA-AWWA-WEF 2005).

The Science Division Chemistry Centre (Dutton Park, Queensland) is accredited by the National Association of Testing Authorities (NATA, Australia).

2.7 Statistical analysis

2.7.1 Data substitution

Measured pesticide concentration data that were below the analytical limit of reporting were substituted based on the following rules:

1. If an analyte was detected above the analytical limit of reporting in one or more samples at the site, then all concentration values below the analytical limit of reporting (at the same site) were replaced with a value equal to half the limit of reporting;
2. If an analyte was not detected above the analytical limit of reporting in one or more samples at the site, then all concentration values below the analytical limit of reporting within the site were replaced with a value equal to 0.

2.7.2 Descriptive statistics

Descriptive statistics were undertaken using Microsoft Excel and SigmaPlot 12.5 software (Systat) packages. The descriptive statistics provided in this report include the number of samples collected, number of samples detected above the analytical limit of reporting, detection frequency, mean concentration, standard deviation, 95th percentile concentration and maximum concentration.

As the concentration data were highly skewed, the mean and standard deviation were calculated on log transformed data with only the back transformed mean (herein referred to as the mean$_{(BT)}$) presented in this report. All box plots and 95th percentiles were generated using non-transformed data. The detection frequencies for all pesticides were determined based on measured concentration values above the analytical limit of reporting.

The sub-catchment mean$_{(BT)}$ concentration data for each analyte were quartile ranked (<25th percentile; ≥25th<50th percentile; ≥50th<75th percentile; ≥75th percentile). These ranked categorical data are spatially represented on catchment maps in Section 3.2.2 to Section 3.3.5.

Due to differences in the sampling procedure at the Sandy Creek at Homebush site (i.e. a larger number of samples were collected and the timing of the collections were different compared to the other sites due to the requirements of the Great Barrier Reef Catchment Loads Monitoring Program), the Sandy Creek at Homebush concentration data were not included in the aggregated descriptive statistics. The sampling procedure at Sandy Creek at Homebush covered a larger range of hydrological conditions and different concentration dynamics that would ultimately bias the results towards these additional observations, which were not covered with the sampling at the other sites. As such, data obtained for the Sandy Creek Sub-catchment Water Quality Monitoring Project was analysed independent of Sandy Creek at Homebush concentration data.

Concentration data for samples collected during base flow conditions were not included in the calculation of descriptive statistics.

2.7.3 Comparison with water quality guidelines and water quality objectives

Aquatic Ecosystem Protection

The level of protection applied to the Sandy Creek catchment was based on a *slightly to moderately disturbed ecosystem* condition (ANZECC and ARMCANZ, 2000; DEHP, 2013). This is defined as:

> "ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. The biological communities remain in a healthy condition and ecosystem integrity is largely retained. Typically, freshwater systems would have slightly to moderately cleared catchments and/or reasonably intact riparian vegetation; marine systems would have largely intact habitats and associated biological communities. Slightly– moderately disturbed systems could include rural streams receiving runoff from land disturbed to varying degrees by grazing or pastoralism, or

marine ecosystems lying immediately adjacent to metropolitan areas" (ANZECC and ARMCANZ, 2000).

Pesticides

Default pesticide water quality guideline trigger values were sourced from ANZECC and ARMCANZ (2000). The recommendation of the water quality guidelines is to compare the 95th percentile concentration from a test site against the trigger value of the same indicator, water type and level of aquatic ecosystem protection. However, it is also noted that "because the proportion of values required to be less than the default trigger value is very high (95%), a single observation greater than the trigger value would be legitimate grounds for action in most cases, even early in a sampling program". Because in several sub-catchments the number of observations is small, this report has also compared maximums against guideline values.

Nutrients

Dissolved inorganic nitrogen and dissolved inorganic phosphorus water quality objectives for Sandy Creek were sourced from DEHP (2013). Water quality objectives for ammonium nitrogen and oxidised nitrogen were sourced from DERM (2009). According to DEHP (2013) and DERM (2009), the median water quality value (e.g. concentration) of a number (preferably five or more) of consecutive samples from the test site was compared against the water quality objectives of the same indicator, for freshwaters of *slightly to moderately disturbed* ecosystems under event (high flow) conditions.

To assess for potential toxic effects of ammonium nitrogen, the total ammonia trigger value was sourced from ANZECC and ARMCANZ (2000) and compared against the 95th percentile and maximum concentrations (as was done for pesticide trigger values).

3 Results and Discussion

3.1 Rainfall, events and sampling summary

During the 24 months preceding the commencement of the Sandy Creek Sub-catchment Water Quality Monitoring Project, rainfall over the catchment was below average to very much below average (Australian Bureau of Meteorology Product Code: IDCKAR5AQ0). Sandy creek catchment in November 2015 was very dry with few monitoring sites containing standing water. Over the monitoring period (November 2015 to March 2016), between 700 mm to over 900 mm of rainfall was received across Sandy Creek catchment. The higher rainfall totals were received across the northern and eastern sub-catchments of Drapers Creek, Ross Creek, Frenchmans Creek, BL Creek and upstream of the end of catchment site at the Bruce Highway (Figure 3-1).

During November and December 2015, the dry conditions persisted with storms a regular feature of the seven day forecasts. Most of these storms were isolated cells that moved across small areas of the catchment and resulted in low rainfall totals (Figure 3-2 and Figure 3-3). More complex weather systems were not observed until January 2016 during which consecutive periods of low rainfall totals (20 mm to 100 mm) (Figure 3-4 to Figure 3-6) resulted in small rainfall runoff events in most sub-catchments. In February and March, low pressure systems and troughs resulted in widespread rainfall across the entire catchment generating moderate flooding across all monitored sub-catchments (Figure 3-7 and Figure 3-8). Seven events were recorded in which water quality samples were collected (Table 3-1). These are described in more detail below.

Event 1

In early November 2015, SunWater dosed the irrigation channel network with acrolein (*pers. com. M. Sammut*) which is used in the control of macrophytes that reduce the efficiency of the water supply network. During November 2015, it is understood that treated water was released into the Sandy Creek catchment, the timing of which coincided with an isolated storm on 9 November 2016 (Figure 3-2). This flow event resulted in a small rise in water level sufficient to commence manual sample collection in Frenchmans Creek and trigger the automatic sampler at the Sandy Creek at Homebush site (Table 3-1).

Monitoring for acrolein did not form part of the objectives of the current project and was not part of the analytical suite of pesticides.

Event 2

Onshore airflow during mid- to late November produced isolated shower and storm activity across sections of the Sandy Creek catchment from 16 to 17 November 2015. This resulted in low rainfall totals (Figure 3-3) and very small runoff events in a few sub-catchments with a low number of water samples collected in Sandy Creek North Branch, Sandy Creek South Branch, Ross Creek and Sandy Creek at Homebush (Table 3-1). Small runoff events also occurred during this period in Sandy Creek at Eton and Frenchmans Creek, however, no samples were collected.

Event 3

A tropical low and broad trough that were present near the Gulf of Carpentaria at the start of January 2016 moved across the central Queensland coast on 4 January 2016, producing isolated storm activity. The storm cells moved across the monitored sub-catchments quickly, resulting in only low rainfall totals (Figure 3-4). Combined with dry antecedent conditions, the low rainfall resulted in small events in all catchments except Cut Creek and Oaky Creek. Samples were collected at all sites that received sufficient rainfall to generate runoff except at Draper Creek at Multi-farm (Table 3-1) where the amount of runoff was not sufficient to trigger the automatic sampler.

Overall the number of samples collected at the sub-catchment monitoring sites during Event 3 were low (1 to 8 samples) compared to the number of samples collected at the automated site at Sandy Creek at Homebush (19 samples) (Table 3-1). The low number of samples reflects the small magnitude and short duration of this event and the reduced sampling frequency undertaken at the manually sampled sites.

Event 4

An inland trough extending through central Queensland resulted in thunderstorm activity that persisted over the region from 9 to 10 January 2016, resulting in runoff events across all monitored sub-catchments, except Draper Creek at De Moleyns Lagoon, Cut Creek and Oaky Creek. The rainfall totals during this event were generally low (Figure 3-5) and responses in the hydrograph at all sites were quite rapid with a return to near base flow levels within one day.

During Event 4, the number of samples collected was generally similar to Event 3 (1 to 7 samples) (Table 3-1), reflecting the small magnitude and duration of this runoff event. During Event 4 11 samples were collected at the automated site at Sandy Creek at Homebush.

Event 5

An inland trough and ridge over central Queensland resulted in moderated rainfall across monitored sub-catchments on 17 January 2016 (Figure 3-6). Rainfall totals were sufficient to again produce sufficient runoff to generate flow events in all monitored sub-catchments excluding Draper Creek at De Moleyns Lagoon and Draper Creek at Multi-farm, and Cut Creek and Oaky Creek which remained dry.

Overall the number of samples collected during Event 5 were similar to the earlier events in January 2016 (range, 1 to 7 samples) with fewer samples collected at the automated site at Sandy Creek at Homebush (7 samples) than were collected during earlier events at this site (Table 3-1).

Event 6

A low pressure system near an inland trough generated heavy rainfall across the entire Sandy Creek catchment commencing on the 5 February 2016 and intensifying over the following days. Rainfall totals during this period were in the range 100 mm – 200 mm across all monitored sub-catchments (Figure 3-7). Sufficient rainfall was received across all monitored sub-catchments to generate runoff including Cut Creek and Oaky Creek which only commenced to flow during this event.

Water samples were collected at all sub-catchment monitoring sites during this runoff event. The numbers of samples collected at all sites were higher than preceding events (Table 3-1) which reflects the larger magnitude and longer duration of this event. The number of samples collected at the automated sampling sites at Draper Creek at Multi-farm and Sandy Creek at Homebush were generally two to three times greater than the number of samples collected at the manually sampled sites (Table 3-1). The higher number of samples at these sites was generally attained through higher frequency sampling during all stages of the hydrograph and continuation of sampling during the lower stage of the falling hydrograph, particularly at Sandy Creek at Homebush.

Event 7

Ex-tropical cyclone Winston passed close to the central Queensland coast in early March 2016, resulting in heavy rainfall across the catchment with rainfall totals ranging from 100 mm in sub-catchments on the southern side of Sandy Creek to over 300 mm in sections of Draper Creek, Ross Creek, BL Creek and lower Sandy Creek catchment near the mouth (Figure 3-8).

Due to the late occurrence of this event in the project (i.e. the project plan was to monitor the first three runoff events), water samples were not collected at all sites during this event (Table 3-1). Samples were collected where growers had spare sampling equipment unused from previous event sampling.

During Event 7, the number of samples collected at the automated sites at Draper Creek at DNRM Multi-farm and Sandy Creek at Homebush was high compared to each of the manually sampled sites. The higher frequency sample collection at these sites included the period of the falling hydrograph when the concentrations of many pesticides is likely to have been low (see Appendix B).

Table 3-1 Sampling summary for rainfall runoff events during which water samples were obtained from monitored sub-catchments. Numbers represent the number of samples collected.

Event Number	Event Period	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Ck.	Sandy Ck. Bruce Hwy
Event 1	9th – 10th Nov. 2015	No event	No event	No event	No event	No event	No event	No event	No event	No event	No event	12	4	No event	No event
Event 2	16th – 21st Nov. 2015	2	2	No event	Not sampled	No event	No event	No event	3	No event	No event	12	Not sampled	Not sampled	No event
Event 3	4th – 7th Jan. 2016	5	5	No event	8	2	Not sampled	1	8	5	No event	19	6	3	4
Event 4	8th – 12th Jan.2016	4	1	No event	3	No event	2	2	7	5	No event	11	7	2	3
Event 5	17th – 20th Jan. 2016	5	4	No event	3	No event	No event	1	5	5	No event	7	7	1	5
Event 6	5th – 12th Feb. 2016	7	11	9	9	3	20	8	9	8	6	22	7	7	8
Event 7	2nd – 10th Mar. 2016	6	4	7	2Ltd	Not sampled	20	2	6Ltd	6	4	26	4	3	Not sampled
Total		29	27	16	25	5	42	14	38	29	10	109	35	16	20

Note – not all sub-catchments received sufficient rainfall to generate runoff in all events particularly during the isolated storm driven runoff events early in the monitoring period (Event 1 and Event 2).

No event – indicates where no event has occurred in the sub-catchment during a period when an event has occurred elsewhere in the catchment.

Not sampled – indicates where an event occurred but no samples were collected.

Ltd – indicates only limited sampling was undertaken over the event and concentration data available may not reflect the change in concentration which may have been monitored if a greater number of samples were collected during the period of increased discharge.

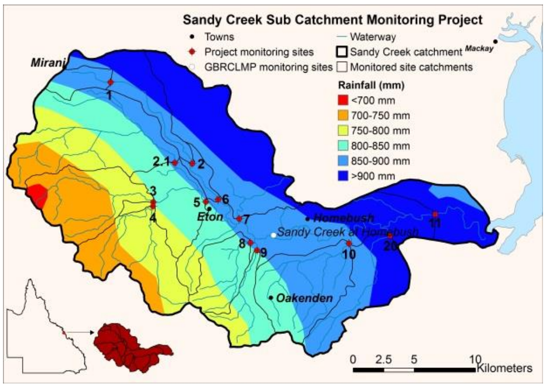

Figure 3-1 Total rainfall received over the monitoring period, 1 November 2015 to 31 March 2016.

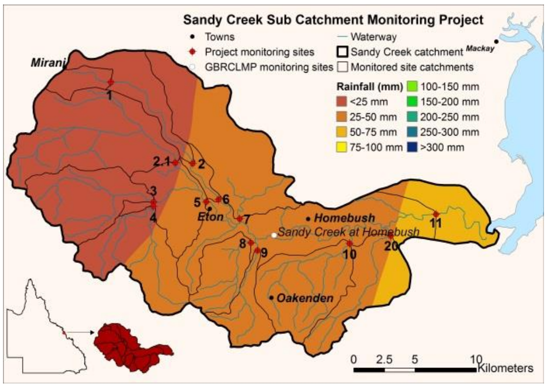

Figure 3-2 Rainfall received preceding and during Event 1 – 6 to 9 November 2015.

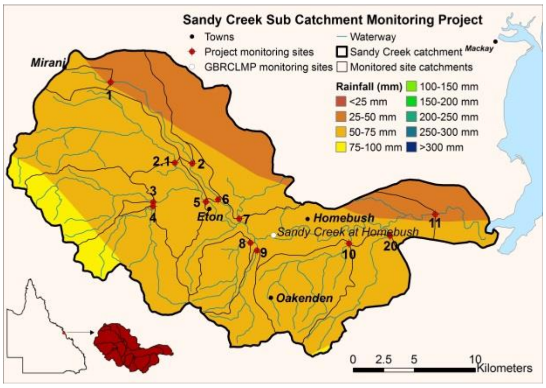

Figure 3-3 Rainfall received preceding and during Event 2 – 15 to 17 November 2015.

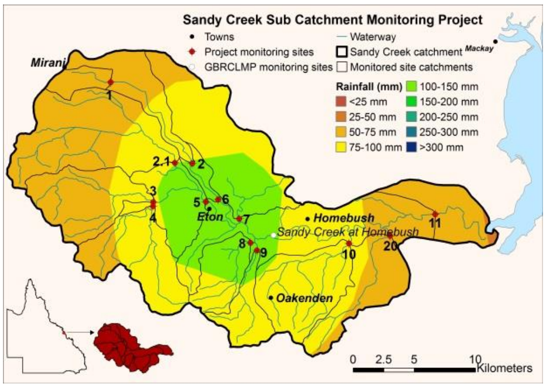

Figure 3-4 Rainfall received preceding and during Event 3 – 3 to 5 January 2016.

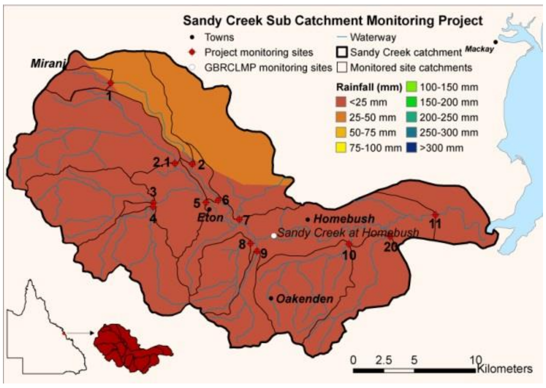

Figure 3-5 Rainfall received preceding and during Event 4 – 9 to 10 January 2016.

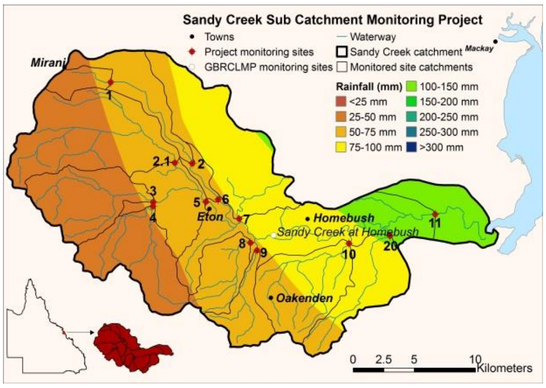

Figure 3-6 Rainfall received preceding and during Event 5 – 17 to 18 January 2016.

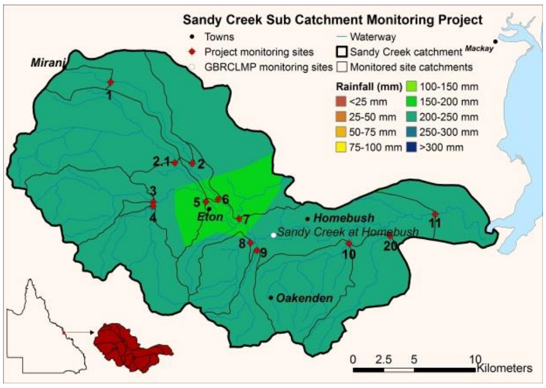

Figure 3-7 Rainfall received preceding and during Event 6 – 5 to 12 February 2016.

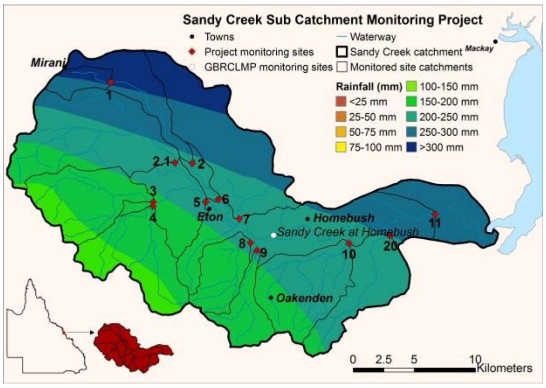

Figure 3-8 Rainfall received preceding and during Event 7 – 2 to 9 March 2016.

3.2 Pesticides

Section 3.2.1 presents an overview of the summary statistics of pesticide concentration data and exceedances of water quality guideline trigger values. Sections 3.2.2 to 3.2.14 provide more detailed information on each individual pesticide detected in more than 30 per cent of samples, in order from the pesticide with the highest to the lowest detection frequency. A summary of other pesticides detected in less than 30 per cent of samples is presented in Section 3.2.15. Plots of the pesticide concentrations and hydrographs are presented in Appendix B.

Review of the limitations relating to the data, as outlined in Section 4, should also be considered in relation to the pesticide concentration data presented in the following section.

In order to constrain the results within the objective of the current report, analytical results for samples collected during base flow conditions were not included in the descriptive statistics calculations and graphical presentation of data in the main report. This was done because very few of the monitored sites contained flowing water prior to the commencement of the first rainfall event of the season. The analytical results from base flow samples have been retained in the site specific hydrographs and plots of concentration data presented in Appendix B.

3.2.1 Overview of Pesticide Results

3.2.1.1 Pesticide concentrations and exceedances of water quality guideline trigger values

Overall, monitored sub-catchments in the north-west section of Sandy Creek catchment, including Ross Creek, Sandy Creek North Branch and Draper Creek, together with the end-of-catchment monitoring site at the Bruce Highway had higher $\text{mean}_{(BT)}$ concentrations of more pesticides than all other sub-catchments. All sub-catchments, however, ranked within the top three sub-catchments (i.e. the 25^{th} percentile of the $\text{mean}_{(BT)}$ concentrations of all sub-catchments) for one or more pesticides with the exception of BL Creek, Cut Creek and Oaky Creek which only commenced to flow in the large flow events later in the wet season.

The concentration of diuron was high in all monitored sub-catchments relative to the current ecosystem protection, low reliability[3], water quality guideline trigger value (0.2 μgL^{-1}; ANZECC and ARMCANZ, 2000), exceeding this level in 84 per cent of all samples (Table 3-3). The irrigation residue guideline for diuron (2 μgL^{-1}; ANZECC and ARMCANZ, 2000) was exceeded in 45 per cent of samples (Table 3-3). Three other pesticides were also detected at concentrations exceeding their respective water quality guideline trigger value (ANZECC and ARMCANZ 2000) – metolachlor was above the low reliability trigger value (0.02 μgL^{-1}) in 53 per cent of samples; atrazine was above the 95 per cent species protection trigger value (13 μgL^{-1}) in 4.2 per cent of samples; and MCPA was above the low reliability trigger value (1.4 μgL^{-1}) in 2.6 per cent of samples (Table 3-3). However, it needs to be emphasised that at the time of publication there were only water quality guideline trigger values for aquatic ecosystem protection for nine of the 26 pesticides detected above the analytical limit of reporting during this project (Table 3-2).

[3] Low reliability values are calculated using the assessment factor approach (ANZECC and ARMCANZ, 2000), therefore they do not correspond with a protection level (e.g. 95% species protection) and should only be used as an interim indicative working level.

Diuron has a high relative toxicity compared to many of the pesticides detected in Sandy Creek (Smith et al. 2015; Smith et al. 2017). The 95th percentile concentration of diuron in the monitored sub-catchments was 17 to 85 times above the low reliability ecosystem protection water quality guideline trigger value (0.2 μgL^{-1}) during the monitored runoff events (excluding Cut Creek and Oaky Creek).

The 95th percentile concentration of metolachlor during the monitored runoff events was also high. In all catchments, except Oaky Creek and Cut Creek, the 95th percentile concentrations in monitored sub-catchments were between 5.5 to 165 times above the low reliability ecosystem protection guideline trigger value(0.02 μgL^{-1}).

The 95th percentile concentration of atrazine during the monitored events exceeded the moderate reliability 95 per cent species protection trigger value in two catchments. These catchments were Draper Creek and Frenchmans Creek, where the 95th percentile concentrations were 1.6 times and 1.8 times above the ecosystem (95 per cent of species) protection trigger value (13 μgL^{-1}), respectively.

In many instances there were only small differences in the monitored mean$_{(BT)}$ concentrations between sub-catchments despite being ranked in different percentile categories (i.e. <25th percentile; ≥25th<50th percentile; ≥50th<75th percentile; ≥75th percentile). This included instances where trigger values were exceeded in some sub-catchments, but the sub-catchment was still ranked in the lower percentile category (for that pesticide). For example, the mean$_{(BT)}$ and 95th percentile concentrations of diuron were very high in all sub-catchments relative to the trigger value, however some sub-catchments may be perceived as being a low risk when reported as falling within the lower percentile categories. Therefore, the ranking of sub-catchments for pesticides as presented in this report, if viewed in isolation from the detailed descriptive statistics, may not convey the immediate need to address the present risk of high concentrations of some pesticides in sub-catchments of Sandy Creek.

3.2.1.2 Pesticide detection frequency

A total of 26 pesticides (excluding metabolites[4]) were detected at concentrations above the analytical limit of reporting across all sites during the monitored events (Table 3-3). The most frequently detected pesticides overall were, in order from highest to lowest, imidacloprid, imazapic, hexazinone, diuron, atrazine and 2,4-D which were detected in greater than 75 per cent of all samples. Fluroxypyr, MCPA, isoxaflutole metabolite, metribuzin and metolachlor were also detected in more than 50 percent of all samples.

Imidacloprid, imazapic, hexazinone, diuron and atrazine were the only chemicals detected in all monitored sub-catchments. 2,4-D, fluroxypyr and MCPA were detected in all monitored sub-catchments except Oaky Creek. Similarly, propazine-2-hydroxy[4] was detected in all sub-catchments except Draper Creek at De Moleyens Lagoon, Oaky Creek and Cut Creek, and metolachlor and metribuzin were detected in all sub-catchments except Oaky Creek and BL Creek.

Twenty pesticides (excluding metabolites) included in the analytical suite (Table 7-1, Appendix A) were not detected at any of the monitored sub-catchments. A large number of pesticides were also detected in very few sub-catchments, including tebuthiuron, which was only detected at Sandy

[4] Isoxaflutole is reported as *isoxaflutole metabolite* measured as diketonitrile (DKN) metabolite which is the active form of isoxaflutole; propazine-2-hydroxy is a metabolite of propazine which is not included in the analytical suite of pesticides.

Creek at Eton; clomazone which was only detected in Ross Creek; terbuthylazine which was only detected in Sandy Creek North-Branch; halosulfuron methyl which was only detected in Draper Creek; and triclopyr which was only detected at Bagley Creek and Frenchmans Creek.

It is important to note that not all pesticides detected in sub-catchments of Sandy Creek are used in sugarcane production systems. This reflects the presence of other industries (e.g. forestry, grazing, horticulture and cropping) in the Sandy Creek catchment for which use of these chemicals is permitted.

Table 3-2 Frequency of detection for all pesticides detected above the analytical limit of reporting and ecosystem protection water quality guidelines, (ANZECC and ARMCANZ 2000); based on aggregated concentration data (*n*=306 discrete samples) from all sites excluding Sandy Creek at Homebush.

Active ingredient	Proportion of samples above limit of reporting	Trigger value for 95% species protection in freshwater ecosystems	Proportion of sample concentrations above trigger value	Irrigation guideline	Proportion of sample concentrations above irrigation guideline
	(%)	(μg L^{-1})	(%)	(μg L^{-1})	(%)
Imidacloprid	99		-	-	-
Imazapic	98		-	-	-
Hexazinone	96	75*	0.0	-	-
Diuron	96	0.2*	84	2	45
Atrazine	89	13	4.2	-	-
2,4-D	84	280	0.0	-	-
Fluroxypyr	72		-	-	-
MCPA	65	1.4*	2.6	-	-
Isoxaflutole	62		-	-	-
Metribuzin	60		-	-	-
Metolachlor	53	0.02*	53	-	-
Ametryn	49		-	-	-
Imazethapyr	44	240*	0.0	-	-
Propazin-2-hydroxy	26		-	-	-
Simazine	14	3.2	0.0	-	-
Methoxyfenocide	8.8		-	-	-
Metsulfuron methyl	8.8	8*	0.0	-	-
Haloxyfop	8.2		-	-	-
Acifluorfen	1.6		-	-	-
Triclopyr	1.5		-	-	-
Flusilazole	1.3		-	-	-
Halosulfuron methyl	1.0		-	-	-
Prometryn	0.65		-	-	-
Terbuthylazine	0.35			-	
Tebuthiuron	0.33	2.2		-	
Clomazone	0.33			-	

- No guideline value for that combination of chemical and use of the water

£ Isoxaflutole metabolite measured as diketonitrile metabolite which is the active species of isoxaflutole

* Low reliability value, calculated using the assessment factor approach. Note that this value does not correspond with a protection level (e.g. 95% species protection) and should only be used as an interim indicative working level.

3.2.1.3 Detection frequency between sub-catchments

Bagley Creek (20 pesticides) had the highest overall number of pesticides detected above the analytical limit of reporting and the lowest number of pesticides detected was in Oaky Creek (six pesticides) (Table 3-3 and Table 3-4).

The number of pesticides detected was similar between Sandy Creek North-Branch and Sandy Creek South-Branch with 18 and 15 pesticides, respectively (Table 3-3 and Table 3-4). In Cut Creek, which only commenced to flow during the final two events, a total of 14 pesticides were detected above the analytical limit of reporting despite the potential dilutive effect of the high rainfall totals that contributed to the large magnitude of these events relative to the earlier runoff events of the season in other monitored sub-catchments. It is notable that the highest number of pesticides were detected in samples collected at the very first flush of the first event at Cut Creek, with as few as three pesticides detected in samples collected in the later period of the same event (Appendix B).

With the exception of metsulfuron methyl and flusilazole, all the chemicals detected in Sandy Creek North-Branch, Sandy Creek South-Branch and Cut Creek were also detected at the downstream main channel site, Sandy Creek at Eton (18 pesticides) (Table 3-3 and Table 3-4).

The number of pesticides detected in Draper Creek increased from 13 pesticides at De Moleyns Lagoon (downstream of Mirani) to 17 pesticides at the Multi-farm site and Peak Downs Highway site – all pesticides detected at the Multi-farm site were detected at Peak Downs Highway site (Table 3-3 and Table 3-4). A similar number of pesticides were also detected in Ross Creek (20 pesticides), which drains the Victoria Plains area.

A total of 20 pesticides were detected in Bagley Creek during five monitored events from 29 samples. By contrast, only six pesticides were detected in the ten samples collected from the adjacent sub-catchment, Oaky Creek, over two large events at the end of the season (Table 3-3 and Table 3-4).

A similar contrast in the number of pesticides detected between adjacent sub-catchments also occurred between Frenchmans Creek where 19 pesticides were detected over six monitored events, and BL Creek where only 10 pesticides were detected over five monitored events (Table 3-3 and Table 3-4).

At the end-of-catchment monitoring site, Sandy Creek at the Bruce Highway, 17 pesticides were detected during the monitored event periods. Metsulfuron methyl, prometryn, haloxyfop and acifluorfen were chemicals detected at three of the upstream sites that were not detected at the end-of-catchment site (Table 3-4).

Table 3-3 Frequency of detection for all pesticides detected above the analytical limit of reporting based on sub-catchment.

Site	n	Imidacloprid (%)	Imazapic (%)	Hexazinone (%)	Diuron (%)	Atrazine (%)	2,4-D (%)	Fluroxypyr (%)	MCPA (%)	Isoxaflutole metabolite (%)	Metribuzin (%)	Metolachlor (%)	Ametryn (%)	Imazethapyr (%)	Propazin-2-hydroxy (%)
Sandy Ck. North Branch	29	100	100	86	97	90	93	69	69	79	79	79	52	72	48
Sandy Ck. South Branch	27	100	100	100	100	100	85	70	19	96	85	41	0	0	7
Cut Ck.	16	88	94	69	50	13	38	38	13	88	38	13	6	0	0
Sandy Ck. Eton	25	100	100	100	100	100	88	88	100	100	88	56	56	68	36
Draper Ck. De Moleyns Lagoon	5	100	100	100	100	80	100	100	80	40	60	60	0	0	0
Draper Ck. Multi-farm	42	100	100	100	100	100	100	100	100	100	100	86	19	19	55
Draper Ck. Peak Downs Highway	14	100	93	100	100	93	93	100	100	64	64	50	36	29	14
Ross Ck.	38	100	100	100	100	100	100	100	92	95	76	92	89	82	42
Bagley Ck.	29	100	97	97	97	83	59	17	14	0	21	48	69	86	3
Oaky Ck.	10	100	70	80	90	70	0	0	0	0	0	0	50	0	0
Sandy Ck. Homebush	109	89	89	100	100	100	90	89	83	77	70	89	57	68	NA
Frenchmans Ck.	35	100	100	100	100	91	89	71	54	0	9	3	83	29	26
BL Creek	16	100	100	100	100	81	81	25	69	0	0	0	0	0	25
Sandy Ck. Bruce Hwy	20	100	100	100	100	100	100	100	95	95	95	85	100	100	25

Table 3-4 Frequency of detection for all pesticides detected above the analytical limit of reporting based on sub-catchment.

Site	n	Simazine (%)	Methoxy-fenocide (%)	Metsulfuron methyl (%)	Haloxyfop (%)	Acifluorfen (%)	Triclopyr (%)	Flusilazole (%)	Halosufuron methyl (%)	Prometryn (%)	Terbu-thylazine (%)	Tebuthiuron (%)	Clomazone (%)
Sandy Ck. North Branch	29	38	0	0	17	3	0	0	0	0	3	0	0
Sandy Ck. South Branch	27	19	0	4	7	0	0	0	0	0	0	0	0
Cut Ck.	16	0	0	19	0	0	0	6	0	0	0	0	0
Sandy Ck. Eton	25	12	0	0	20	8	0	0	0	0	0	4	0
Draper Ck. De Moleyns Lagoon	5	0	0	40	20	0	0	0	0	0	0	0	0
Draper Ck. Multi-farm	42	13	0	10	0	0	0	0	10	0	0	0	0
Draper Ck. Peak Downs Highway	14	29	0	14	0	0	0	0	7	0	0	0	0
Ross Ck.	38	11	0	18	8	0	0	3	0	3	0	0	2.6
Bagley Ck.	29	0	38	7	28	3	3	3	0	3	0	0	0
Oaky Ck.	10	0	0	0	0	0	0	0	0	0	0	0	0
Sandy Ck. Homebush	109	10	NA	17	7	6	17	NA	NA	3	0	0	0
Frenchmans Ck.	35	20	34	11	3	3	9	0	0	0	0	0	0
BL Creek	16	0	0	13	0	0	0	0	0	0	0	0	0
Sandy Ck. Bruce Hwy	20	5	20	0	0	0	0	5	0	0	0	0	0

NA – these pesticides are not detected by the solid phase extraction LC-MS/MS analytical method used for the analysis of samples collected from Sandy Creek at Homebush – see Table 7-1, Appendix A.

3.2.2 Imidacloprid

Guideline Note –

There are no current ecosystem protection or irrigation guidelines for imidacloprid.

The Queensland Department of Science, Information Technology and Innovation are currently reviewing international literature to derive a national ecosystem protection guideline for imidacloprid. The revised ecosystem protection guideline is scheduled for release in 2017.

The derivation of an irrigation residue guideline is not currently scheduled.

3.2.2.1 Detection frequency

Imidacloprid was among the most frequently detected pesticides, with an overall detection frequency of 99 per cent (Table 3-2). The concentration of imidacloprid was above the analytical limit of reporting (< 0.02 μgL^{-1}) in all samples collected at all sites except two samples in the Cut Creek sub-catchment, which were collected during the large runoff event in March (Table 3-5).

3.2.2.2 Distribution of concentrations

The highest detected concentrations of imidacloprid was 4.1 μgL^{-1}, measured at Sandy Creek South Branch during the first catchment wide event (Event 3) in early January 2016 (Table 3-5). The concentration of preceding samples collected at Sandy Creek South Branch during the same event were also relatively high (range, 0.74 μgL^{-1} to 3.2 μgL^{-1}). This result is not surprising given the occurrence of early events at this site in November and January and the good representivity of monitoring at this site. The main distribution of concentrations (≥ 50th<75th percentile) at this site were on par with a number of other sub-catchments further downstream (Figure 3-9). The maximum concentration of imidacloprid at the downstream main channel site, Sandy Creek at Eton (2.0 μgL^{-1}), also occurred during Event 3, and was likely to be predominantly influenced by the discharge from the Sandy Creek South Branch, given the low concentration distributions at the other two sites in the upper catchment; Sandy Creek North Branch and Cut Creek.

The maximum concentration of imidacloprid in all other monitored sub-catchments exceeded 1.0 μgL^{-1} except in Bagley Creek (0.59 μgL^{-1}), Draper Creek at Peak Downs Highway (0.96 μgL^{-1}), BL Creek (0.35 μgL^{-1}), and Cut (0.42 μgL^{-1}) and Oaky creeks (0.23 μgL^{-1}), which only commenced to flow during the large runoff event in February (Table 3-5).

In the Draper Creek sub-catchment, concentration distributions were highest in the nested upstream site, Draper Creek at De Moleyns Lagoon (maximum concentration = 1.80 μgL^{-1}; Table 3-5), whereas the Draper Creek at Multi-farm and Draper Creek at Peak Downs Highway sites were lower and comparable with each other (Figure 3-9). It should be noted that the data from the Draper Creek at De Moleyns Lagoon site is considered to have a low representivity of the conditions due to low coverage of the events (only five samples were collected; Table 3-1), but it is likely that the highest concentrations were detected from the first monitored event). The two downstream sites, Draper Creek at Multi-farm and Draper Creek at Peak Downs Highway, had much better representivity, along with the adjacent Ross Creek, and Cut Creek and Oaky Creek in the southern side of Sandy Creek catchment. The distribution of concentrations in Ross Creek were comparable to Draper Creek at Multi-farm and Draper Creek at Peak Downs Highway sites, whereas the concentration distributions at Cut Creek and Oaky Creek were much lower (Figure 3-9). Low concentrations at these latter two sites are not surprising given the first events occurred later in the wet season (February), allowing for longer periods for chemical breakdown in soil, the lower proportion of these sub-catchments used in the production of sugar cane (Table 2-2), and the high volumes of discharge during the monitored events generating higher dilution rates.

The distribution of concentrations at the Sandy Creek Homebush site is lower than the other two sites in the main channel sites, Sandy Creek at Eton and Sandy Creek at Bruce Highway, for which the data had a low and moderate representivity of the conditions (respectively). The lower concentrations at Sandy Creek at Homebush is likely due to the intensive sampling with the automatic water sampler collecting more samples during periods of lower flow conditions, compared to other sites, which generally have lower concentrations. It is possible that the maximum concentrations at Sandy Creek at Eton were in fact higher than what was detected as the first event of the wet season was missed at this site, although concentrations were highest upstream at Sandy Creek South Branch in Event 3 which was also monitored at Sandy Creek at Eton. The concentration distribution at Frenchmans Creek was comparable to other sub-catchments and lower for BL Creek. The representivity of the data at both these sites were considered to be good and moderate, respectively.

3.2.2.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. Although there is no current water quality guideline trigger values for imidacloprid, future guideline values should be compared against the following results.

The highest 95th percentile concentrations of imidacloprid were in Sandy Creek South Branch (3.2 μgL^{-1}), Sandy Creek at Eton (1.8 μgL^{-1}), Draper Creek at De Moleyns Lagoon (1.8 μgL^{-1}) and Sandy Creek at Bruce Highway (1.3 μgL^{-1}) (Table 3-5).

The 95th percentile concentrations were marginally lower at Frenchmans Creek (1.0 μgL^{-1}), Sandy Creek at Homebush (0.99 μgL^{-1}) and Draper Creek at Multi-farm and Peak Downs Highway (0.95 μgL^{-1} and 0.96 μgL^{-1} respectively) (Table 3-5).

The lowest 95th percentile concentration of imidacloprid was detected in BL Creek (0.17 μgL^{-1}), which was less than both Cut Creek (0.38 μgL^{-1}) and Oaky Creek (0.19 μgL^{-1}), both of which only commenced to flow during the large rainfall runoff events in February (Table 3-5).

3.2.2.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their mean$_{(BT)}$ concentration were, from highest to lowest: the upper nested sub-catchment site Draper Creek at De Moleyns Lagoon, Site 1 (mean$_{(BT)}$ = 0.94 μgL^{-1}); Sandy Creek South Branch, Site 3 (mean$_{(BT)}$ = 0.67 μgL^{-1}); the nested sub-catchment site Draper Creek at Multi-farm, Site 2 (mean$_{(BT)}$ = 0.54 μgL^{-1}); and, Sandy Creek at Eton, Site 5 (mean$_{(BT)}$ = 0.52 μgL^{-1}) (Table 3-5 and Figure 3-10). The next highest ranked sub-catchments (≥ 50th<75th percentile), from highest to lowest, mean$_{(BT)}$ imidacloprid concentrations: Sandy Creek at Bruce Highway, Site 11 (mean$_{(BT)}$ = 0.49 μgL^{-1}); Ross Creek, Site 7 (mean$_{(BT)}$ = 0.48 μgL^{-1}); and, Draper Creek at Peak Downs Highway, Site 6 (mean$_{(BT)}$ = 0.46 μgL^{-1}), with the latter two sites located in the north-west section of Sandy Creek catchment. The third grouping of sub-catchments ranked in the ≥25th<50th percentile category are on the southern side and upper reaches of the Sandy Creek catchment. These sites included, from highest to lowest mean$_{(BT)}$ imidacloprid concentrations: Frenchmans Creek, Site 10 (mean$_{(BT)}$ = 0.33 μgL^{-1}); Sandy Creek North Branch, Site 2.1 (mean$_{(BT)}$ = 0.19 μgL^{-1}); and, Bagley Creek, Site 8 (mean$_{(BT)}$ = 0.18 μgL^{-1}). The lowest ranked group of sub-catchments based on the mean$_{(BT)}$ imidacloprid concentrations were also on the southern side of Sandy Creek catchment and included, from highest to lowest: BL Creek, Site 20 ($mean_{(BT)}$ = 0.085 µgL^{-1}); Oaky Creek, Site 9 ($mean_{(BT)}$ = 0.072 µgL^{-1}); and, Cut Creek, Site 4 ($mean_{(BT)}$ = 0.057 µgL^{-1}).

It is important to note, only five samples were collected at De Moleyns Lagoon, with all samples collected during Event 3 and Event 6. Despite the low number of samples at this site, the $mean_{(BT)}$ concentration of imidacloprid was relative to the other two Draper Creek sites.

In the upper Sandy Creek catchment, the high concentrations in the Sandy Creek South Branch was likely contributing to the high $mean_{(BT)}$ concentration observed downstream at Sandy Creek at Eton (0.52 µgL^{-1}). In contrast, the concentrations in Sandy Creek North Branch were comparatively low, and very low in Cut Creek, which both flow into the Sandy Creek at Eton site.

The low $mean_{(BT)}$ concentration of imidacloprid in BL Creek warrants further investigation as initial consultation with participating growers indicated this may be due to low adoption rates of chemical-based cane grub control rather than a low incidence of cane grub or good farm practice leading to reduced imidacloprid losses. It is noted, however, that BL Creek does have a lower proportion of the catchment under cane (25 per cent) compared to most other monitored sub-catchments. Review of the box plot supports the low distribution of imidacloprid concentration data in the BL Creek sub-catchment and this distribution is not an artefact of the sampling undertaken in this sub-catchment (Figure 3-9).

The $mean_{(BT)}$ concentration of imidacloprid at the end-of-catchment site at Bruce Highway (0.49 µgL^{-1}) was less than the upstream monitoring site, Sandy Creek at Eton (0.52 µgL^{-1}), which differs from the general trend observed for the other pesticides (see Section 3.2.3 to Section 3.2.14) which typically had higher concentrations at the end-of-catchment site. The difference in the $mean_{(BT)}$ concentration between the Sandy Creek at Homebush site (0.20 µgL^{-1}) and Sandy Creek at Bruce Highway (0.49 µgL^{-1}) is likely due to the continuation of sample collection at the Sandy Creek at Homebush site for a longer period over the falling hydrograph, during which the concentration of pesticides are generally lower. Notably, the box plots (Figure 3-9) for the main channel sites indicate higher dissimilarity in the distribution of imidacloprid concentration data than observed in many of the other frequently detected pesticides (reported in the following sections).

Table 3-5 Summary statistics for water quality samples analysed for imidacloprid.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections >LOR	29	27	14	25	5	42	14	38	29	10	97	35	16	20
Detection Freq. (%)	100	100	88	100	100	100	100	100	100	100	89	100	100	100
Mean$_{(BT)}$	0.19	0.67	0.057	0.52	0.94	0.54	0.46	0.48	0.18	0.072	0.20	0.33	0.085	0.49
Std. Dev.	0.34	0.39	0.54	0.40	0.35	0.20	0.33	0.26	0.38	0.23	0.62	0.35	0.21	0.25
Median	0.17	0.51	0.04	0.59	1.2	0.57	0.62	0.52	0.23	0.065	0.26	0.35	0.075	0.43
95th Percentile	0.69	3.2	0.38	1.8	1.8	0.95	0.96	1.1	0.50	0.19	0.99	1.0	0.17	1.3
Max. Conc.	1.5	4.1	0.42	2.0	1.8	1.1	0.96	1.7	0.59	0.23	1.2	1.3	0.35	1.3

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency (%)** – the proportion of samples collected at a site which the concentration of imidacloprid was above the analytical limit of reporting.

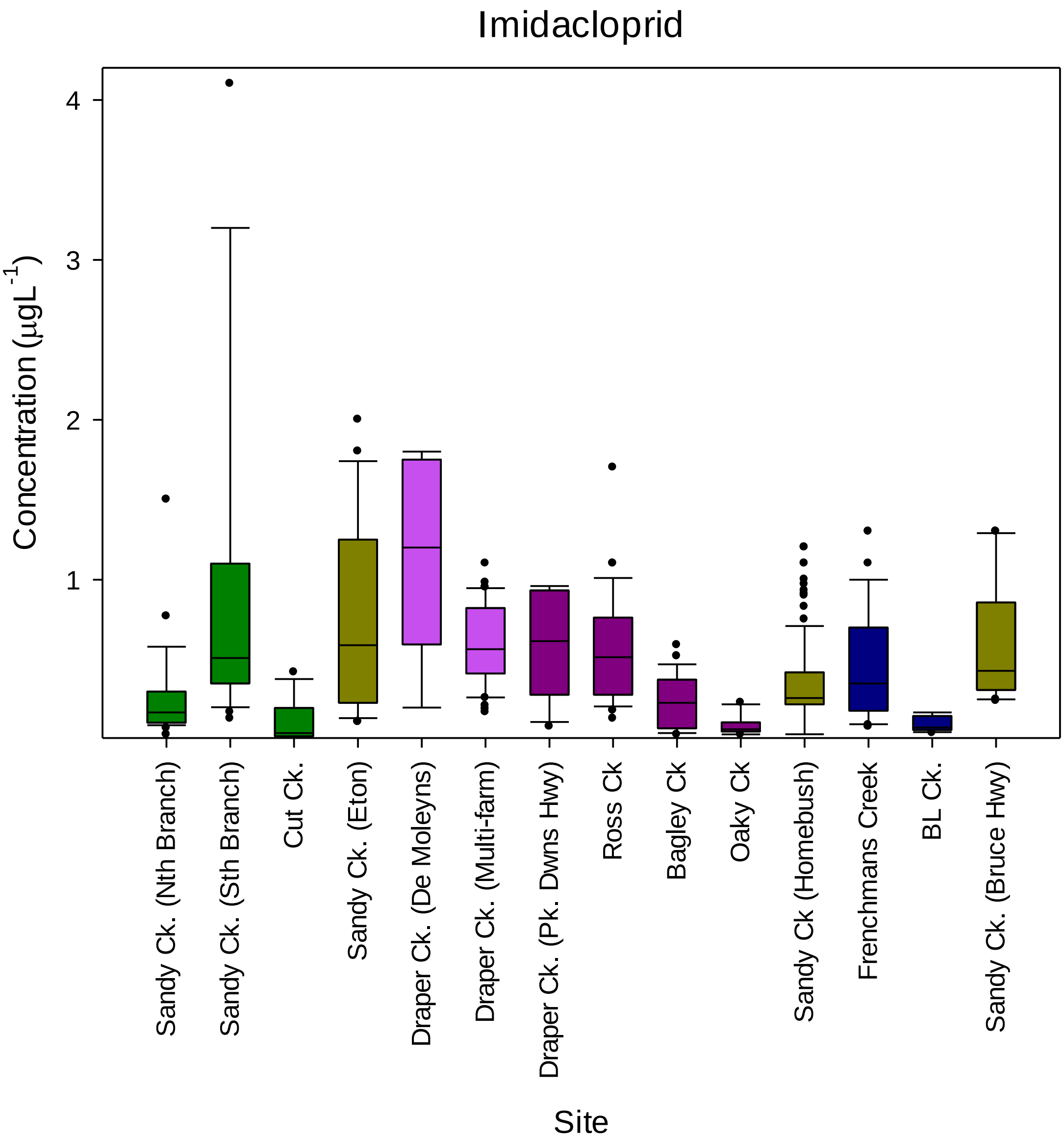

Figure 3-9 Box plot of measured concentrations of imidacloprid at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles, solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

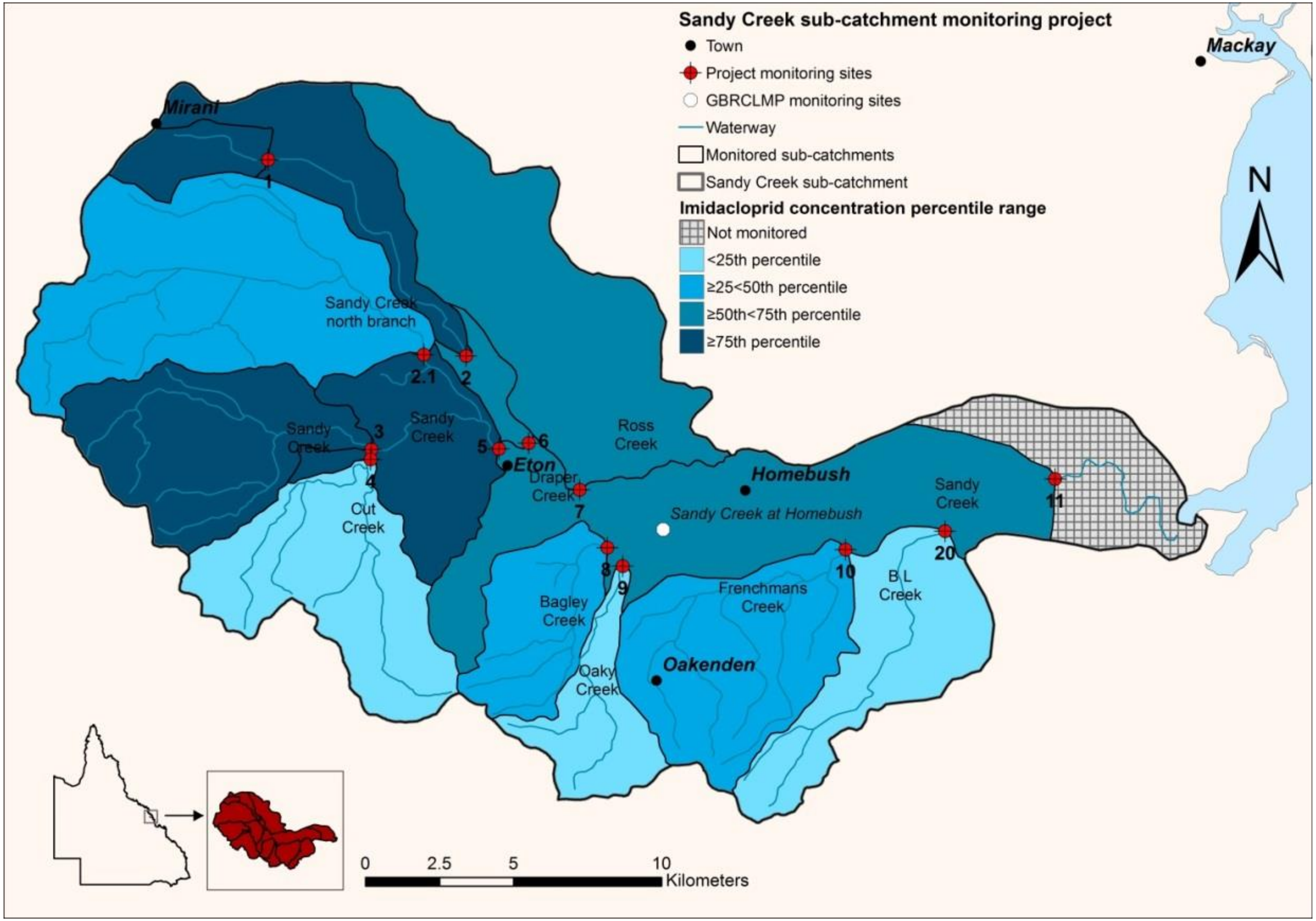

Figure 3-10 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of imidacloprid in water samples collected at each sub-catchment during the monitored events. See Table 3-5 for reference of site name to site number.

3.2.3 Imazapic

Guideline Note –

There are no current ecosystem protection or irrigation guidelines for imazapic.

The Queensland Department of Science, Information Technology and Innovation are currently reviewing international literature to derive a national ecosystem protection guideline for imazapic. The revised ecosystem protection guideline is scheduled for release in 2017.

The derivation of an irrigation residue guideline is not currently scheduled.

3.2.3.1 Detection frequency

Imazapic was one of the most frequently detected pesticides across all monitored sub-catchments with an overall detection frequency above the analytical limit of reporting of 98 per cent (Table 3-2). The detection frequency was only below 100 per cent in Bagley Creek (97 per cent), Cut Creek (94 per cent), Draper Creek (Peak Downs Highway, 93 per cent) and Oaky Creek (70 per cent) (Table 3-6).

3.2.3.2 Distribution of concentrations

The pattern of concentration distributions across sub-catchments for imazapic was different to imidacloprid, which may indicate a difference in usage patterns of certain pesticides between sub-catchments, or interactions between localised environmental conditions (e.g. soil type) and the physico-chemical characteristics of the pesticides (Figure 3-11). The highest maximum concentrations of imazapic were monitored in Ross Creek (2.5 μgL^{-1}), Draper Creek at De Moleyns Lagoon, 2.1 μgL^{-1}), Sandy Creek North Branch (1.9 μgL^{-1}) and Sandy Creek South Branch (1.6 μgL^{-1}) (Table 3-6). The maximum concentration in all other sub-catchments was less than 1.5 μgL^{-1} with the lowest maximum concentration monitored in Oaky Creek (0.02 μgL^{-1}), which only commenced to flow in the large runoff event in February 2016.

The highest concentration distributions were at Draper Creek at De Moleyns Lagoon, Ross Creek, Sandy Creek at North Branch and Sandy Creek at Eton, however, the data from the Sandy Creek at Eton and Draper Creek at De Moleyns Lagoon sites have low representivity of the true conditions and should be judged with caution. Concentration distributions were more comparable for Sandy Creek at South Branch, Draper Creek at Multi-farm and Draper Creek at Peak Downs Highway, Sandy Creek at Homebush and Sandy Creek at Bruce Highway, Frenchmans Creek and BL Creek. The data for each of these catchments has a moderate to good representivity of the conditions, therefore we have confidence in these trends, except for the Sandy Creek at Homebush which is likely to have a lower distribution than the other sub-catchments due to the automatic sampling regime at this site. Cut Creek, Bagley Creek and Oaky Creek all had low concentration distributions (similar to imidacloprid trends) with good representivity of the data, which confirms these results.

3.2.3.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. Although there is no current water quality guideline trigger values for imazapic, future guideline values should be compared against the following results.

The highest 95th percentile concentrations were monitored in Draper Creek (De Moleyns Lagoon, 1.8 μgL^{-1}), Ross Creek (1.8 μgL^{-1}) and Sandy Creek North Branch (1.7 μgL^{-1}) (Table 3-6).

The high 95th percentile concentration for the main channel site at Eton (1.3 μgL^{-1}) reflects the high 95th percentile concentration of the upstream North Branch site, as the 95th percentile concentration in Sandy Creek South Branch (0.61 μgL^{-1}) and Cut Creek (0.060 μgL^{-1}) were comparatively low (Table 3-6).

The 95th percentile concentration in all other sub-catchments were 0.91 μgL^{-1} or less, with the lowest 95th percentile concentration monitored in Bagley Creek (0.25 μgL^{-1}) (excluding Oaky Creek (0.020 μgL^{-1} and Cut Creek 0.06 μgL^{-1}), which only commenced to flow during the large rainfall event in February) (Table 3-6).

3.2.3.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking, based on their mean$_{(BT)}$ concentration, occurred in the north-west section of the catchment and included, from highest to lowest: the upper nested sub-catchment site Draper Creek at De Moleyns Lagoon, Site 1 (mean$_{(BT)}$ = 0.68 μgL^{-1}); Sandy Creek North Branch, Site 2.1 (mean$_{(BT)}$ = 0.64 μgL^{-1}); Ross Creek, Site 7 (mean$_{(BT)}$ = 0.54 μgL^{-1}); and, Sandy Creek at Eton, Site 5 (mean$_{(BT)}$ = 0.40 μgL^{-1}) (Figure 3-12).

The next highest ranked sub-catchments (≥ 50th<75th percentile) were: Sandy Creek at Bruce Highway, Site 11 (mean$_{(BT)}$ = 0.37 μgL^{-1}) and Frenchmans Creek, Site 10 (mean$_{(BT)}$ = 0.29 μgL^{-1}); and, the nested sub-catchment site Draper Creek at Multi-farm, Site 2 (mean$_{(BT)}$ = 0.25 μgL^{-1}) (Table 3-6 and Figure 3-12).

The third grouping of sub-catchments ranked in the ≥25th<50th percentile category were, from highest to lowest: Sandy Creek South Branch, Site 3 (mean$_{(BT)}$ = 0.24 μgL^{-1}); BL Creek, Site 20 (mean$_{(BT)}$ = 0.18 μgL^{-1}); Draper Creek at Peak Downs Highway, Site 6 (mean$_{(BT)}$ = 0.14 μgL^{-1}).

The lowest ranked group of sub-catchments based on the mean$_{(BT)}$ imazapic concentrations lay on the southern side of the Sandy Creek catchment and included, from highest to lowest: Bagley Creek, Site 8 (0.050 μgL^{-1}); Cut Creek, Site 4 (0.019 μgL^{-1}); and, Oaky Creek, Site 9 (0.0093 μgL^{-1}).

The mean$_{(BT)}$ concentrations of imazapic were similar between the main channel monitoring sites at Sandy Creek at Eton and Sandy Creek at Bruce Highway, which differs from the general trend observed for other commonly detected pesticides where the concentration was higher at the end-of-catchment site relative to the upstream sites (reported in the following sections). The mean$_{(BT)}$ at Sandy Creek at Homebush (0.16 μgL^{-1}) was low compared to the other main channel sites owing to the higher number of samples collected at this site during periods reduced discharge and low concentration.

Amongst the upper sub-catchments, the mean$_{(BT)}$ concentration in Sandy Creek North Branch was substantially higher than in the South Branch and Cut Creek. Review of the box plots for these sites indicates Sandy Creek North Branch as the dominant sub-catchment contributing to the higher overall concentration distribution of imazapic at the downstream main channel site at Eton (Figure 3-11).

Despite similarities in the upper and lower quartile concentrations of the neighbouring Frenchmans and BL creeks (Figure 3-11), there were substantial differences in the mean$_{(BT)}$ (0.29 μgL^{-1} and 0.18 μgL^{-1}, respectively) and median (0.38 μgL^{-1} and 0.14 μgL^{-1}, respectively) concentrations between these sites (Table 3-6). The concentration data in Frenchmans Creek was strongly negatively skewed which was in contrast to the more positively skewed data in BL Creek.

Within the Draper Creek sub-catchment, the $mean_{(BT)}$ concentration of imazapic was high at De Moleyns Lagoon relative to the downstream sites at Multi-farm and Peak Downs Highway, where concentrations are low relative to the proportion of sugar cane. It should be noted that only five samples representing two events were collected at the Draper Creek at De Moleyns Lagoon. Although these samples may overestimate the $mean_{(BT)}$ concentration of imazapic, where the timing of sample collection coincided with the period of local runoff, the discrete concentration points indicate that this area may potentially be a significant source of the imazapic concentrations observed in the downstream monitoring sites, i.e. Sandy Creek at Homebush and Sandy Creek at Bruce Highway.

Bagley Creek had amongst the lowest $mean_{(BT)}$ concentration of imazapic of all monitored sub-catchments, only higher than Cut Creek (0.019 μgL^{-1}) and Oaky Creek (0.0093 μgL^{-1}), both of which only commenced to flow in the large rainfall driven runoff event in February.

Table 3-6 Summary statistics for water quality samples analysed for imazapic.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	29	27	15	25	5	42	13	38	28	7	97	35	16	20
Detection Freq. (%)	100	100	94	100	100	100	93	100	97	70	89	100	100	100
Mean$_{(BT)}$	0.64	0.24	0.019	0.40	0.68	0.25	0.14	0.54	0.050	0.0093	0.16	0.29	0.18	0.37
Std. Dev.	0.37	0.32	0.34	0.39	0.26	0.26	0.64	0.37	0.45	0.21	0.64	0.34	0.31	0.26
Median	0.78	0.20	0.020	0.41	0.61	0.22	0.215	0.50	0.06	0.01	0.18	0.38	0.14	0.43
95th Percentile	1.7	0.61	0.060	1.3	1.8	0.69	0.68	1.8	0.25	0.020	0.89	0.73	0.45	0.91
Max. Conc.	1.90	1.60	0.09	1.50	2.10	0.71	0.69	2.50	0.26	0.02	0.95	1.20	0.48	1.00

n – number of samples analysed; **LOR** – number of samples where the concentration was below the analytical limit of reporting; **Detection Frequency (%)** – the proportion of samples collected at a site which the concentration of imazapic was above the analytical limit of reporting.

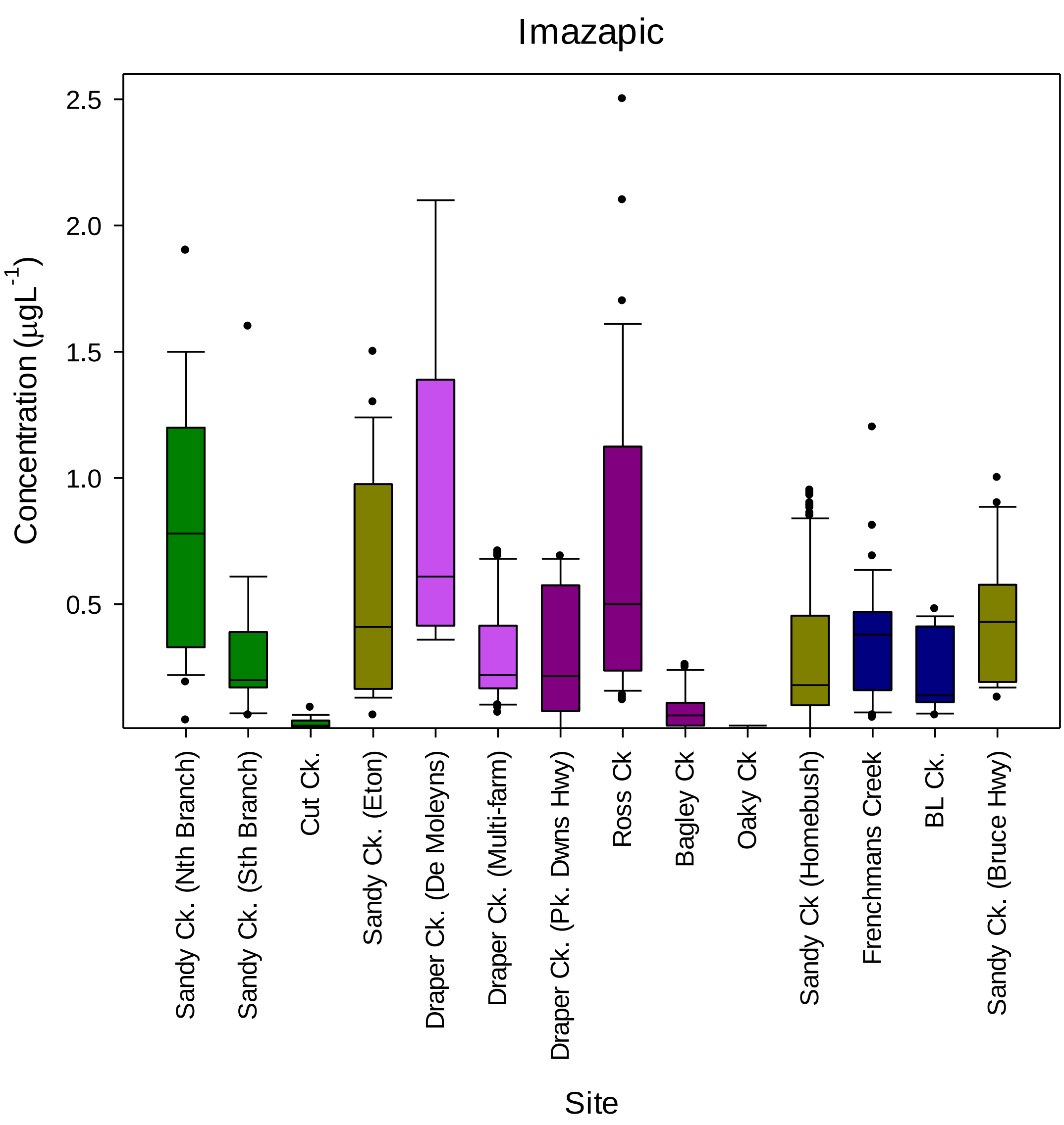

Figure 3-11 Box plot of measured concentration of imazapic at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles and solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

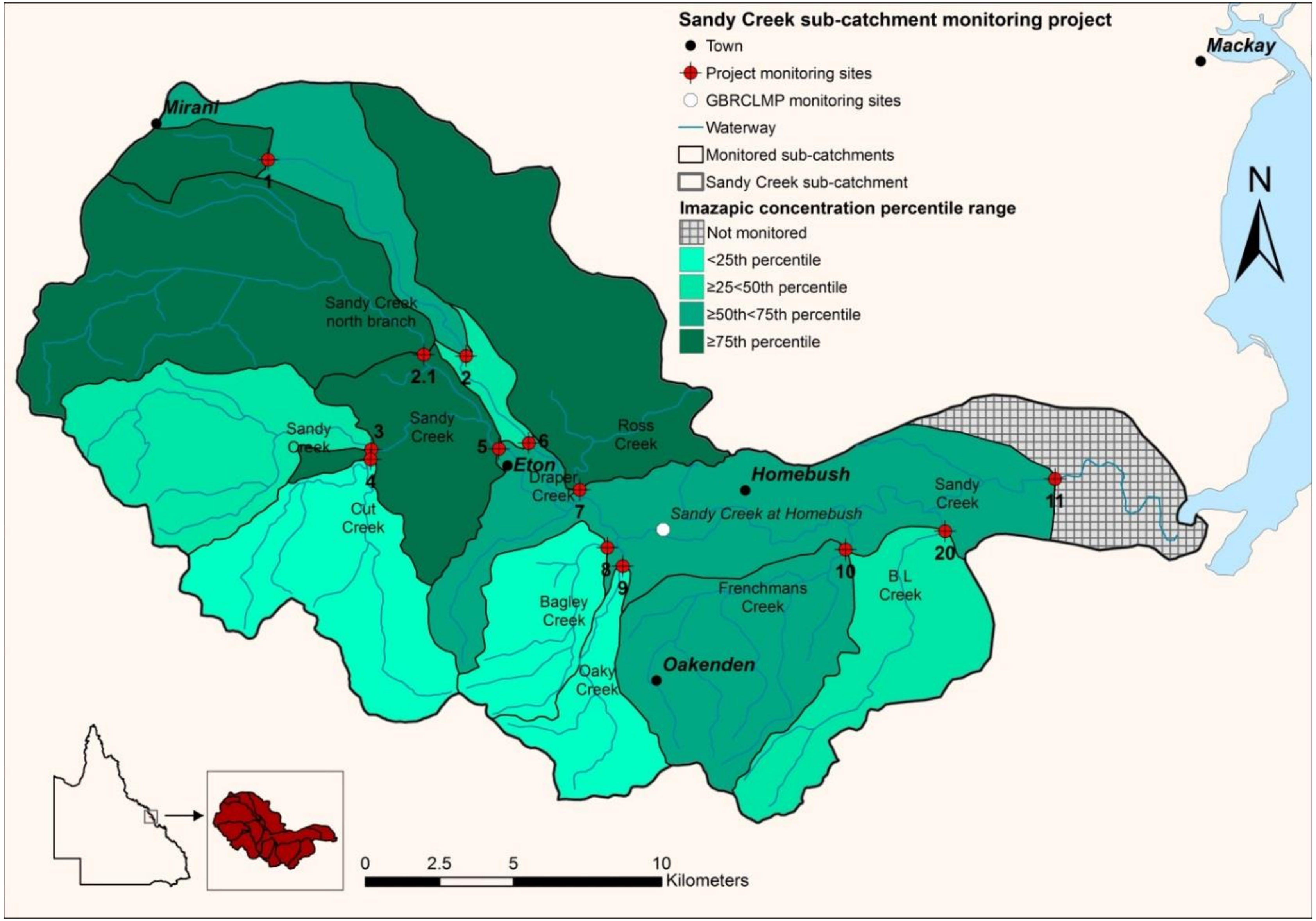

Figure 3-12 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of imazapic in water samples collected at each sub-catchment during the monitored events. See Table 3-6 for reference of site name to site number.

3.2.4 Hexazinone

Guideline Note *–*

The current ecosystem protection guideline trigger value (ANZECC and ARMCANZ 2000) for hexazinone in freshwater ecosystems is:

- *A low reliability trigger value of 75 μgL^{-1}, calculated using the assessment factor method. This value does not correspond with a protection level (e.g. 95 per cent species protection) and should only be used as an interim indicative working level. The Queensland Department of Science, Information Technology and Innovation are currently reviewing international literature to revise the national ecosystem protection guideline for hexazinone. The revised ecosystem protection guideline is scheduled for release in 2017.*

There is no current residue limit for hexazinone in irrigation water. The derivation of an irrigation guideline is not currently scheduled.

3.2.4.1 Detection frequency

Hexazinone was detected in all monitored sub-catchments and in all events, with an overall detection frequency above the analytical limit of reporting (<0.01 μgL^{-1}) of 96 per cent (Table 3-2). Hexazinone was detected in 100 per cent of samples at 10 of the 14 monitored sites.

Hexazinone is co-formulated with diuron in products used in sugarcane production systems. The co-formulation of these chemicals accounts for the similarly high detection frequency.

3.2.4.2 Distribution of concentrations

The highest concentration of hexazinone was detected at Sandy Creek at Homebush (7.3 μgL^{-1}) which was detected in the first sample of the first storm driven rainfall runoff event of the monitoring period in mid-November 2015 (Event 2). The concentrations of hexazinone in subsequent samples during this event were in the range 0.25 to 1.0 μgL^{-1} (Appendix B).

The maximum detected concentration of hexazinone at all other sites were within the range, 1.3 μgL^{-1} to 3.8 μgL^{-1}, excluding Cut Creek and Oaky Creek where the maximum concentration of hexazinone (0.18 μgL^{-1} and 0.070 μgL^{-1}, respectively) was low due to the later occurrence and large magnitude of the first runoff event in these monitored sub-catchments. Amongst these sites, higher maximum concentrations were monitored at Draper Creek at Multi-farm (3.8 μgL^{-1}) and Draper Creek at Peak Downs Highway (3.2 μgL^{-1}), and Ross Creek (3.0 μgL^{-1}) (Table 3-7).

The pattern of concentration distributions of hexazinone between sub-catchments varied from those of imidacloprid and imazapic which may indicate a difference in usage of certain pesticides between sub-catchments, or interactions between localised environmental conditions (e.g. soil type) and the physico-chemical characteristics of the pesticides (Figure 3-13). The highest distributions were principally in the Draper Creek catchment, Peak Downs Highway, and Ross Creek, which have good data representivity. All other catchments, apart from Cut Creek and Oaky Creek, have comparable distributions. Similar to other pesticides, the low concentration distributions at Cut Creek and Oaky Creek is likely to be due to the late occurrence of the first events and the magnitude of discharge in these events.

3.2.4.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. The current water quality guideline trigger values for hexazinone is 75 μgL^{-1}, which was not exceeded in any samples. The maximum concentrations at all sites were also well below the hexazinone trigger value. Future review of these guideline values should be compared against the following results.

The highest 95th percentile concentrations of hexazinone were monitored in Draper Creek at Peak Downs Highway (2.9 μgL^{-1}) and Ross Creek (2.6 μgL^{-1}) (Table 3-7). Within the Draper Creek sub-catchment, the increase in the 95th percentile concentration between Draper Creek at Multi-farm (1.2 μgL^{-1}) and the downstream site, Draper Creek at Peak Downs Highway (2.9 μgL^{-1}), is notable as these two sites are in close proximity and the reverse pattern was recorded for the maximum concentrations. This difference is possibly due to the difference in sample numbers with a higher number of samples collected at the Draper Creek at Multi-farm site (n=42) compared with the number of samples collected at the Draper Creek at Peak Downs Highway (n=14) site.

The 95th percentile concentration was similar between Sandy Creek North Branch (1.8 μgL^{-1}) and Sandy Creek South Branch (1.9 μgL^{-1}), which were both higher than the downstream main channel site Sandy Creek at Eton where the 95th percentile concentration was 1.2 μgL^{-1} (Table 3-7).

The 95th percentile concentration in Bagley Creek was 1.2 μgL^{-1},which was similar to Frenchmans Creek (1.8 μgL^{-1}) and BL Creek (1.7 μgL^{-1}) (Table 3-7).

The 95th percentile concentration of hexazinone marginally increased in a downstream direction between the three main channel sites, Sandy Creek at Eton (1.2 μgL^{-1}), Sandy Creek at Homebush (1.3 μgL^{-1}) and Sandy Creek at Bruce Highway (1.9 μgL^{-1}) (Table 3-7).

3.2.4.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their $mean_{(BT)}$ concentration are located on the northern side of the catchment and included, from highest to lowest: Sandy Creek at Bruce Highway, Site 11 (0.82 µgL-1); Ross Creek, Site 7 (0.72 μgL^{-1}); Draper Creek at De Moleyns Lagoon, Site 1 (0.62 μgL^{-1}); and Draper Creek at Multi-farm, Site 2 (0.59 μgL^{-1}) (Figure 3-14).

The next highest ranked sub-catchments (≥ 50th<75th percentile) based on their $mean_{(BT)}$ concentration included, from highest to lowest: Frenchmans Creek, Site 10 (0.58 μgL^{-1}); Draper Creek at Peak Downs Highway, Site 6 (0.54 μgL^{-1}); and, Sandy Creek at Eton (0.44 μgL^{-1}) (Figure 3-14).

The third grouping of sub-catchments ranked in the ≥25th<50th percentile category, included, from highest to lowest $mean_{(BT)}$ hexazinone concentrations: BL Creek, Site 20 (0.32 μgL^{-1}); Sandy Creek South Branch, Site 3 (0.31 μgL^{-1}); and, Sandy Creek North Branch, Site 2.1 (0.28 μgL^{-1}) (Figure 3-14).

The lowest ranked group of sub-catchments based on the $mean_{(BT)}$ hexazinone concentrations were located on the southern side of the catchment and included, from highest to lowest: Bagley Creek, Site 8 (0.27 μgL^{-1}); Cut Creek, Site 4 (0.023 μgL^{-1}); and, Oaky Creek, Site 9 (0.018 μgL^{-1}) (Figure 3-14).

The $mean_{(BT)}$ concentration of hexazinone was similar between the upper sub-catchment of Sandy Creek North Branch and Sandy Creek South Branch however the concentration data from the North Branch site were much more widely distributed (Figure 3-13). The maximum concentration and 90th percentiles were similar between these sites; however, the median concentration in the Sandy Creek North Branch sub-catchment was notably higher (0.58 μgL^{-1}) compared to the Sandy Creek South Branch (0.45 μgL^{-1}) sub-catchment. Both the $mean_{(BT)}$ and median concentration of hexazinone at the downstream site, Sandy Creek at Eton (0.44 μgL^{-1} and 0.63 μgL^{-1}, respectively), were higher than both upstream sites. The distribution of the concentration data at the main channel site Sandy Creek at Eton, however, more closely matched the combined distribution of the two upstream sites (Figure 3-13).

The $mean_{(BT)}$ concentration between the main channel sites followed a similar trend to diuron (Section 3.2.5), with the highest $mean_{(BT)}$ concentration observed at the Sandy Creek at Bruce Highway end-of-catchment monitoring site and lowest $mean_{(BT)}$ concentration at the Sandy Creek at Homebush monitoring site. As for diuron, the lower $mean_{(BT)}$ and lower overall distribution of the hexazinone concentration data for the Sandy Creek at Homebush site (Figure 3-13) is explained by the high number of samples collected at this site including during periods of low concentration (e.g. falling hydrograph). The high $mean_{(BT)}$ concentration at the Sandy Creek at Bruce Highway site is supported by review of the box plot, which indicates a higher distribution of the concentration data at this site compared to all other monitored sub-catchments (Figure 3-13).

The $mean_{(BT)}$ concentration of hexazinone was similar between Bagley Creek and BL Creek which was similar to the trend in diuron concentration data presented below (Section 3.2.5). The $mean_{(BT)}$ concentration in the adjacent Frenchmans Creek, however, was comparatively high (as it contains considerably greater proportion of land under sugar cane). Review of the box plots indicates that while there is general similarity in overall distribution of the data as indicated by the upper-quartile and 90^{th} percentile whisker, the concentration data in BL Creek is strongly negatively skewed with a much lower median value (0.23 μgL^{-1}) than both Frenchmans Creek (0.76 μgL^{-1}) and Bagley Creek (0.58 μgL^{-1}) (Figure 3-13).

The $mean_{(BT)}$ concentration of hexazinone in Draper Creek sub-catchment was generally consistent between all three sites with any differences likely due to the variation in sample numbers at each site. The tighter distribution of data for the Draper Creek at Multi-farm site, as reflected in the box plot (Figure 3-13), is likely due to the higher number of data points for this site compared to the Draper Creek at De Moleyns Lagoon and Draper Creek at Peak Downs Highway sites.

The $mean_{(BT)}$ concentration of hexazinone in Cut Creek was similar to Oaky Creek and expectedly low due to the magnitude of the rainfall events that precipitated both monitored events in these sub-catchments and the low proportion of land used for sugar cane production.

Table 3-7 Summary statistics for water quality samples analysed for hexazinone.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	25	27	11	25	5	42	14	38	28	8	109	35	16	20
Detection Freq. (%)	86	100	69	100	100	100	100	100	97	80	100	100	100	100
Mean(BT)	0.28	0.31	0.023	0.44	0.62	0.59	0.54	0.72	0.27	0.018	0.27	0.58	0.32	0.82
Std. Dev.	0.86	0.52	0.58	0.38	0.35	0.29	0.59	0.46	0.64	0.35	0.54	0.40	0.48	0.29
Median	0.58	0.45	0.020	0.63	0.85	0.57	0.80	0.96	0.58	0.020	0.39	0.76	0.23	1.0
95th Percentile	1.8	1.9	0.14	1.2	1.5	1.2	2.9	2.6	1.2	0.057	1.3	1.8	1.7	1.9
Max. Conc.	1.9	2.2	0.18	1.3	1.5	3.8	3.2	3.0	1.4	0.07	7.3	2.0	1.9	2.3

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of hexazinone was above the analytical limit of reporting.

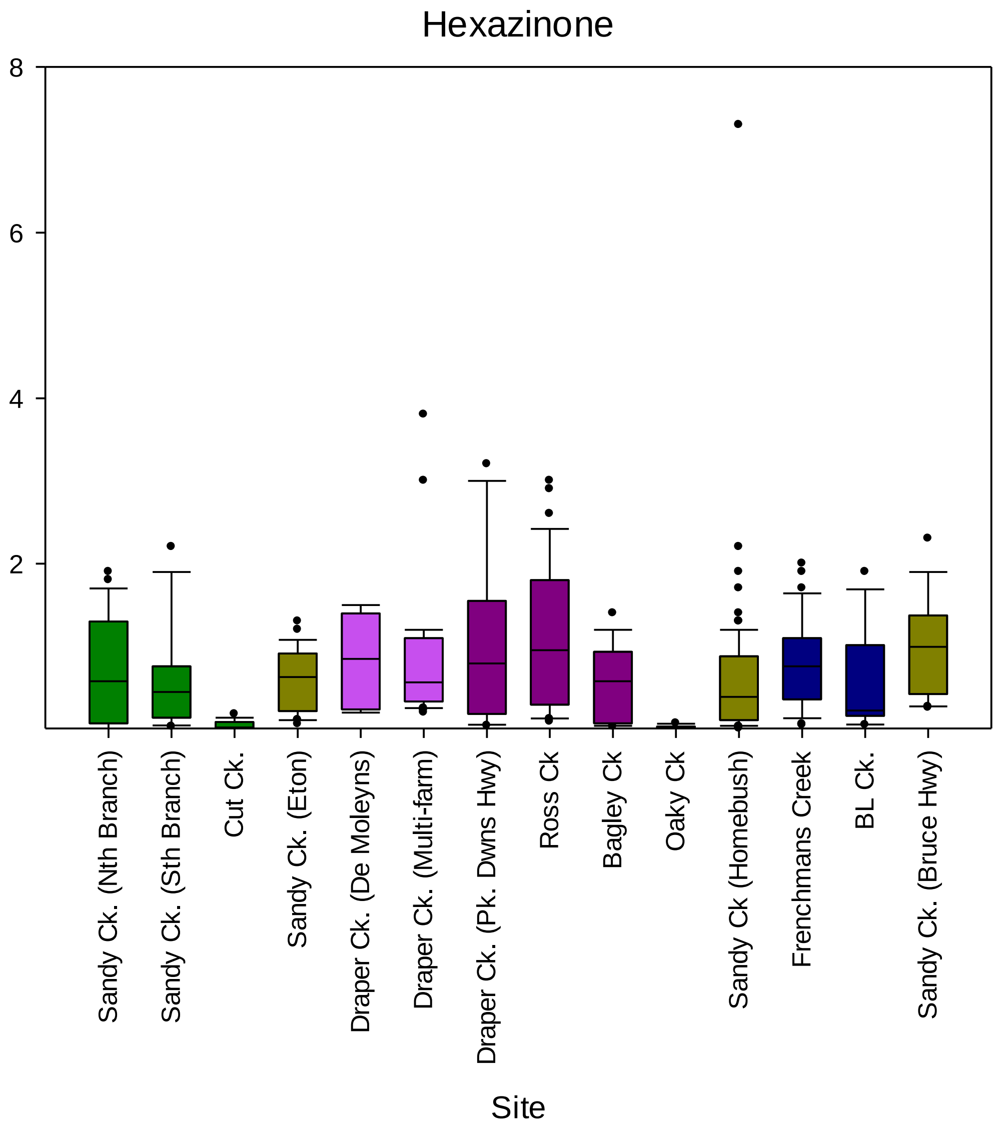

Figure 3-13 Box plot of measured concentration of hexazinone at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles and solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

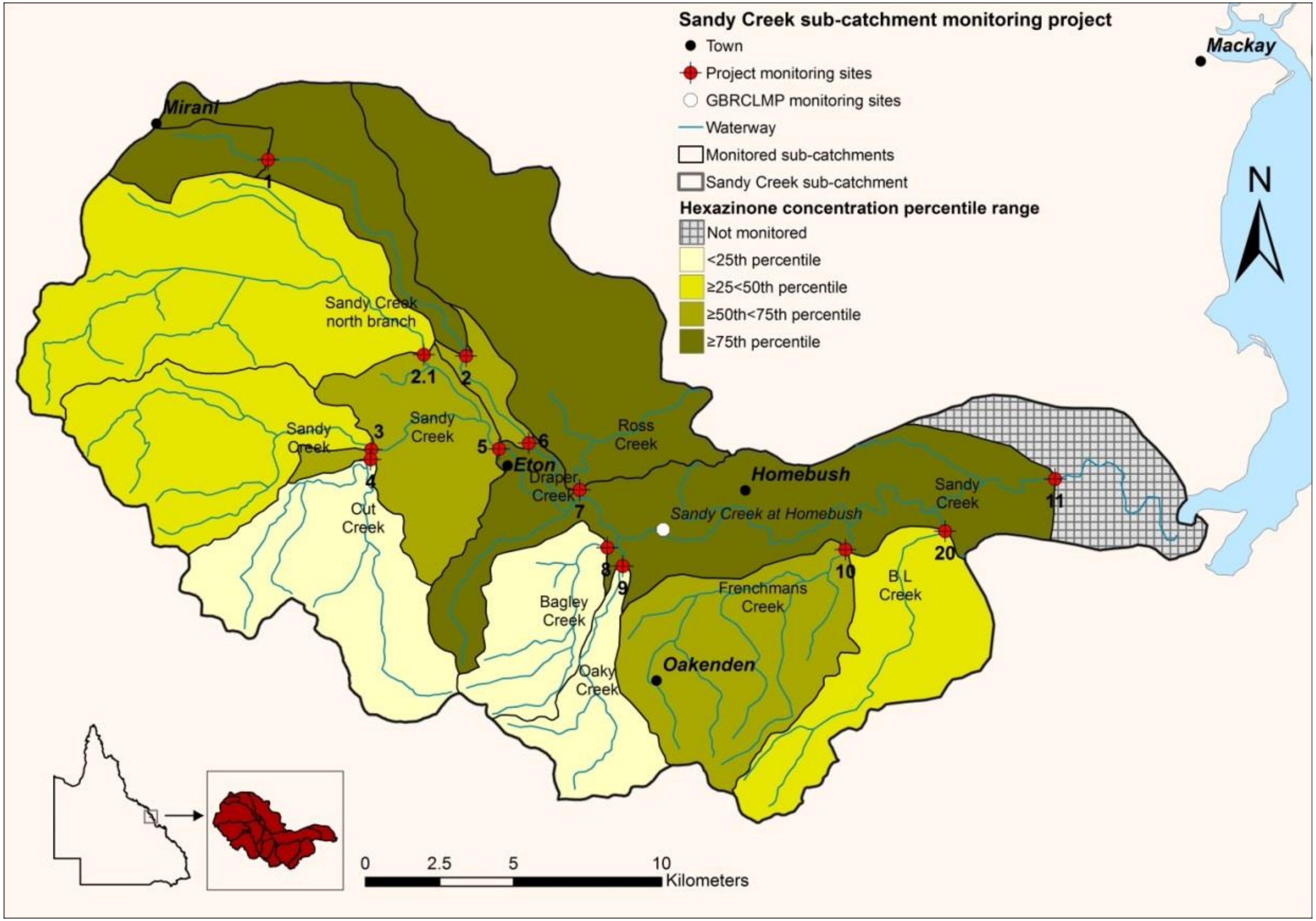

Figure 3-14 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of hexazinone in water samples collected at each sub-catchment during the monitored events. See Table 3-7 for reference of site name to site number.

3.2.5 Diuron

Guideline Note –

The current ecosystem protection guideline trigger value (ANZECC and ARMCANZ 2000) for diuron in freshwater ecosystems is:

- *A low reliability trigger value of 0.2 µgL^{-1}, calculated using the assessment factor method. This value does not correspond with a protection level (e.g. 95 per cent species protection) and should only be used as an interim indicative working level.*

The Queensland Department of Science, Information Technology and Innovation are currently reviewing international literature to revise the national ecosystem protection guideline for diuron. The revised ecosystem protection guideline is scheduled for release in 2017.

The diuron residue limit in irrigation water is 2 µgL^{-1}. *No revision of existing irrigation guidelines is currently scheduled.*

3.2.5.1 Detection frequency

Diuron was detected in all monitored sub-catchments and in all events, with an overall detection frequency above the analytical limit of reporting (0.02 µgL^{-1}) of 96 per cent (Table 3-2) – Cut Creek, Bagley Creek and Oaky Creek were the only monitored sub-catchments where the concentrations of diuron were detected at levels below the analytical limit of reporting (Table 3-8). Of the 318 samples collected across the monitored sub-catchment sites, diuron was detected above the low reliability trigger value in 85 per cent of samples and above the irrigation guideline in 46 per cent of samples (Table 3-2).

3.2.5.2 Distribution of concentrations

The highest observed concentrations of diuron were generally associated with the small storm driven runoff events early in the wet season. Across all sub-catchments, the highest monitored concentration of diuron was in Sandy Creek South Branch (26 µgL^{-1}) which occurred following an isolated storm in November 2015 (Table 3-8). Similarly high concentrations were also detected during a small first flush event in Draper Creek during early January 2016, with the maximum concentrations recorded at Draper Creek at Multi-farm (25 µgL^{-1}) and Draper Creek at Peak Downs Highway (18 µgL^{-1}), respectively. Among all other sub-catchments (excluding Cut Creek and Oaky Creek), the maximum concentrations were in the range of 4.8 µgL^{-1} to 13 µgL^{-1} (Table 3-8). In Cut Creek and Oaky Creek, the maximum monitored concentrations were 0.20 µgL^{-1} and 0.40 µgL^{-1}, respectively (Table 3-8). However, these were associated with large rainfall events coinciding with their first flush for the season in February. The dilutive effect of high rainfall runoff during this event resulted in comparatively low maximum monitored concentrations.

At the automated Sandy Creek at Homebush site, similarly high concentrations (maximum, 19 µgL^{-1}) were detected during the second monitored event of the season (the first monitored event was due to an irrigation water release). It is important to note, the sample which contained the highest concentration, was the first sample collected during the first rainfall runoff event of the wet season when the discharge was less than 2 m^{3}s^{-1}. As part of the Great Barrier Reef Catchment Loads Monitoring Program, samples have not previously been collected during periods of such low discharge as the trigger height to commence sampling is generally set at a higher level. Concentrations of diuron in this range are not unexpected during the early stage of the first runoff event of the year when local runoff is the dominant source of water in the system. Subsequent samples collected during this event, support previous observations that there is rapid decrease in the concentration of pesticides such as diuron at this site, as runoff from the broader catchment area reaches the Sandy Creek at Homebush monitoring location (see Appendix B).

The pattern of the concentration distributions across sub-catchments of diuron were somewhat similar to hexazinone, which is not surprising given that hexazinone and diuron are applied together (Figure 3-13 and Figure 3-15). Differences that were observed are therefore more likely to be due to interactions between localised environmental conditions (e.g. soil type) and the physico-chemical characteristics of the pesticides.

3.2.5.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. The current water quality guideline trigger value for diuron is 0.2 μgL^{-1}, and the irrigation guideline is 2.0 μgL^{-1}.The 95th percentile concentration exceeded both guidelines at Draper Creek at Peak Downs Highway (17 μgL^{-1}), Sandy Creek at South Branch (15 μgL^{-1}), Ross Creek (9.6 μgL^{-1}), Frenchmans Creek (8.5 μgL^{-1}), Sandy Creek North Branch (6.8 μgL^{-1}), Sandy Creek at Bruce Highway (6.6 μgL^{-1}), Sandy Creek at Eton (6.3 μg^{-1}), Sandy Creek at Homebush (6.0 μgL^{-1}), BL Creek (4.4 μgL^{-1}), Bagley Creek (3.6 μgL^{-1}), Draper Creek at De Moleyns Lagoon (3.4 μgL^{-1}) and Draper Creek at Multi-farm (4.9 μgL^{-1}) (Table 3-8).

In the Draper Creek sub-catchment the 95th percentile concentration was similarly high at Draper Creek at De Moleyns Lagoon (3.4 μgL^{-1}) and Draper Creek at Multi-farm (4.9 μgL^{-1}). The very high 95th percentile concentration at Draper Creek at Peak Downs Highway was due to two samples in Event 4 (17 μgL^{-1} and 18 μgL^{-1}) (Figure 7-49, Appendix B). Although similarly high concentrations were also monitored at Sandy Creek at Peak Downs Highway, the substantially higher number of samples collected at the Draper Creek at Multi-farm site, including periods of low concentration, resulted in a lower calculated 95th percentile based on the data available.

The 95th percentile concentration in Oaky Creek (0.32 μgL^{-1}) and the maximum concentration in Cut Creek (0.2 μgL^{-1}), exceeded (or met) the ecosystem protection trigger value but not the irrigation guideline. Both of these systems only commenced to flow following the significant rainfall runoff event in February and monitored in a similarly large event in March. As a result of the dilutive effect of the large amount of runoff during these events, the monitored concentrations of diuron were low. Additional monitoring of these catchments is warranted to allow comparison of these sub-catchments over multiple and varied seasonal rainfall conditions.

3.2.5.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their mean$_{(BT)}$ concentration were all located on the northern side of Sandy Creek catchment and included, from highest to lowest: Sandy Creek at Bruce Highway, Site 11 (2.7 μgL^{-1}); Draper Creek at Peak Downs Highway, Site 6 (2.6 μgL^{-1}); Ross Creek, Site 7 (2.2 μgL^{-1}); and, Draper Creek Multi-farm (2 μgL^{-1}) (Figure 3-16).

The next highest ranked sub-catchments (≥ 50th<75th percentile) included, from the highest to lowest mean$_{(BT)}$ diuron concentrations: Sandy Creek at Eton, Site 5 (1.8 μgL^{-1}); Draper Creek at De Moleyns Lagoon, Site 1 (1.6 μgL^{-1}); and, Frenchmans Creek, Site 10 (1.5 μgL^{-1}) (Figure 3-16).

The third grouping of sub-catchments, ranked in the ≥25th<50th percentile category, included, from highest to lowest mean$_{(BT)}$ diuron concentrations: Sandy Creek South Branch, Site 3 (1.4 μgL^{-1}); Sandy Creek North Branch, Site 2.1 (1.3 μgL^{-1}); and, BL Creek, Site 20 (0.86 μgL^{-1}) (Figure 3-16).

The lowest ranked group of sub-catchments based on the $mean_{(BT)}$ diuron concentrations lay on the southern side of the catchment and included, from highest to lowest: Bagley Creek, Site 8 (0.60 μgL^{-1}); Oaky Creek, Site 9 (0.083 μgL^{-1}); and, Cut Creek, Site 4 (0.035 μgL^{-1}) (Figure 3-16).

The similarities in diuron $mean_{(BT)}$ concentrations in the Draper Creek and Ross Creek sub-catchments may be due to the similarly high proportions of land under sugar cane production and are likely to have similar soil types and topology across much of the land area supporting sugar cane production. Review of the box plots for these sites indicates that the concentration data in Ross Creek was more broadly distributed than both Draper Creek and Sandy Creek at Bruce Highway (Figure 3-15). The distribution of the concentration data in Ross Creek sub-catchment was similar to Frenchmans Creek on all measures including the maximum, median and 20^{th} and 80^{th} percentiles.

In the upper Sandy Creek sub-catchments, the $mean_{(BT)}$ concentration of diuron was similar in both the Sandy Creek South Branch and Sandy Creek North Branch. Review of the box plot (Figure 3-15) indicates the concentration data at Sandy Creek North Branch are centrally distributed around the median (3.1 μgL^{-1}) with a few outliers and low maximum concentration compared to Sandy Creek South Branch. Sandy Creek South Branch had a notably lower median concentration (1.5 μgL^{-1}) though high maximum concentrations resultant from the early storm driven runoff event in December. The $mean_{(BT)}$ concentration at the main channel site at Sandy Creek at Eton was consistent with monitored results from the primary upstream sites (South Branch and North Branch) with the distribution of concentration data reflecting more closely to Sandy Creek North Branch.

The $mean_{(BT)}$ concentration of diuron at Cut Creek was exceptionally low as this sub-catchment only commenced to flow following the significant rainfall in early February, which, as indicated above, is likely to have had a dilutive effect on monitored concentrations. Compared to other monitored sub-catchments, the small area of sugar cane production upstream of this site, which represents only 10 per cent of the sub-catchment area (Table 2-2), would also contribute to the comparably low $mean_{(BT)}$ concentration of diuron in the Cut Creek sub-catchment.

In the Draper Creek sub-catchment, the $mean_{(BT)}$ concentration of diuron increased in a downstream direction. This trend is also reflected in the overall distribution of the concentration data as presented in the box plots; the median concentration and upper-quartile increasing between each site in a downstream direction (Figure 3-15). The $mean_{(BT)}$ concentration of diuron at the Draper Creek at Multi-farm site remained high despite 40 of 42 samples being collected during the two large magnitude events. The sustained elevated concentration of diuron at the monitoring sites in the lower Draper Creek catchment (Multi-farm and Peak Downs Highway), including the large events in February and March, indicate a large source load of diuron relative to the total sub-catchment area of Draper Creek. Draper Creek has the highest proportion of the sub-catchment area under sugar cane of all monitored sub-catchments. Further analysis of the loads of diuron is warranted should flow data become available to the Sandy Creek Sub-catchment Water Quality Monitoring Project in the future. The results from Draper Creek and Sandy Creek at Bruce Highway indicate that within the Sandy Creek catchment, the $mean_{(BT)}$ concentration of diuron increases as a function of area of land used for the production of sugar cane; i.e. sites lower in the catchment (or sub-catchment in the case of Draper Creek) will be exposed to high $mean_{(BT)}$ concentrations of diuron.

Bagley Creek sub-catchment on the southern side of Sandy Creek catchment had the lowest monitored $mean_{(BT)}$ concentration of diuron of all sub-catchments, and lowest overall distribution of concentration data (excluding Cut Creek and Oaky Creek). The median and maximum concentrations of diuron in Bagley Creek (0.93 μgL^{-1} and 4.8 μgL^{-1}, respectively) were similar to BL Creek (0.88 μgL^{-1} and 4.8 μgL^{-1}, respectively). Bagley Creek received a moderate rainfall runoff event earlier in the season (Event 3), which preceded similar magnitude events in all other sub-catchments. Consultation with participating growers indicated that much of the rain associated with this event fell in the forested hill country as opposed to the cane growing areas on the lower slopes. It may therefore be considered that the low $mean_{(BT)}$ concentration and overall distribution of concentration data in this sub-catchment is a function of the comparatively small area of sugar cane production upstream of this monitoring site – second smallest area of cane production behind Draper Creek at De Moleyns Lagoon (excluding Cut Creek and Oaky Creek). Bagley Creek, in comparison to Draper Creek upstream of De Moleyns Lagoon, has a proportionally much larger area of land upstream that is not used for sugar cane production. This is likely to provide a dilutive function to the monitored concentration of diuron at the Bagley Creek sub-catchment monitoring site.

The $mean_{(BT)}$ concentration of diuron and the overall distribution of concentration data from Frenchmans Creek as presented in the box plot (Figure 3-15) was high, similar to reported concentrations for Ross Creek. The $mean_{(BT)}$, 95^{th} percentile and median concentration of diuron in Frenchmans Creek were approximately double the same metrics in neighbouring BL Creek. It is important to note that the first flush event in BL Creek was not monitored as part of this project and the concentration of diuron in the unmonitored event is not known.

In the Oaky Creek sub-catchment, only a few samples were collected as this system only commenced to flow during the two major events at the end of the season. The large magnitude of these events is likely to have had a dilutive effect on the measured concentrations relative to other sub-catchments. The $mean_{(BT)}$ concentration of diuron at Oaky Creek was consequently very low, similar to what has been observed for other pesticides reported here.

At the automated monitoring site at Homebush, the $mean_{(BT)}$ concentration ,0.78 μgL^{-1}, was less than both the main channel sites at Eton and Bruce Highway. The overall distribution of concentration data at the Homebush site was also lower than the upstream main channel site at Eton and downstream main channel site at Bruce Highway. This difference in the distribution of the data is likely a function of the large number of samples collected during periods of reduced concentration (i.e. falling hydrograph) at the Homebush sites compared to the Eton and Bruce Highway sites. There is, however, a pronounced similarity in the distribution of data between the Eton and Bruce Highway sites despite the difference in area upstream of these sites. This may reflect the general similarity in the proportion of area of each sub-catchment used in the production of sugar cane within the broader Sandy Creek catchment.

Table 3-8 Summary statistics for water quality samples analysed for diuron.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	28	27	8	25	5	42	14	38	28	9	109	35	16	20
Detection Freq. (%)	97	100	50	100	100	100	100	100	97	90	100	100	100	100
Mean$_{(BT)}$	1.3	1.4	0.035	1.8	1.6	2.0	2.6	2.2	0.60	0.083	0.78	1.5	0.86	2.7
Std. Dev.	0.86	0.72	0.55	0.51	0.25	0.40	0.49	0.53	0.62	0.45	0.69	0.66	0.51	0.32
Median	3.1	1.5	0.040	3.2	1.4	2.3	3.1	2.4	0.93	0.11	0.74	1.9	0.88	3.8
95th Percentile	6.8	15	0.16	6.3	3.4	4.9	17	9.6	3.6	0.32	6.0	8.5	4.4	6.6
Max. Conc.	6.9	26	0.20	13	3.6	25	18	9.6	4.80	0.40	19	8.7	4.8	6.7

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency (%)** – the proportion of samples collected at a site which the concentration of diuron was above the analytical limit of reporting.

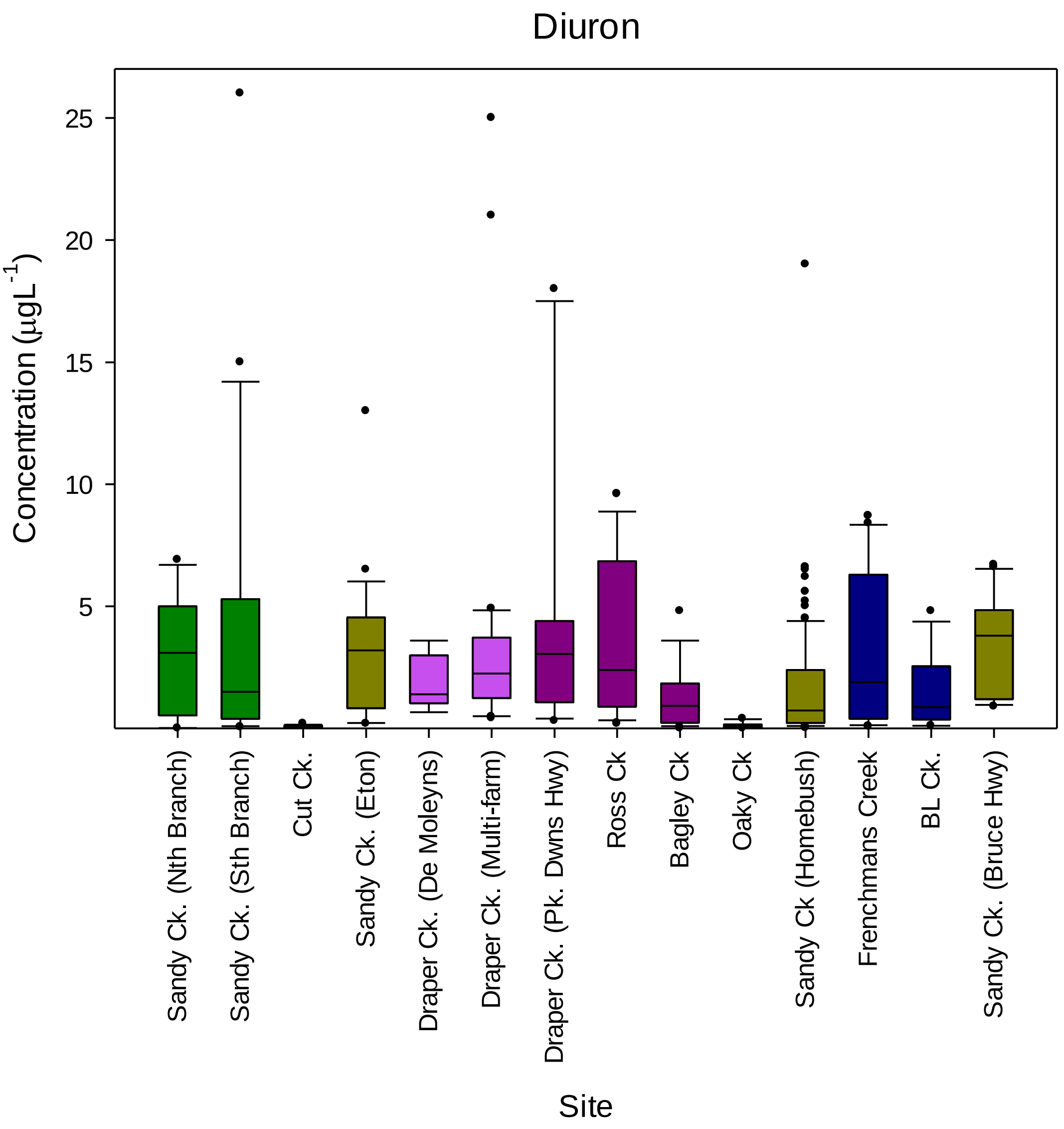

Figure 3-15 Box plot of measured concentration of diuron at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles, solids dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

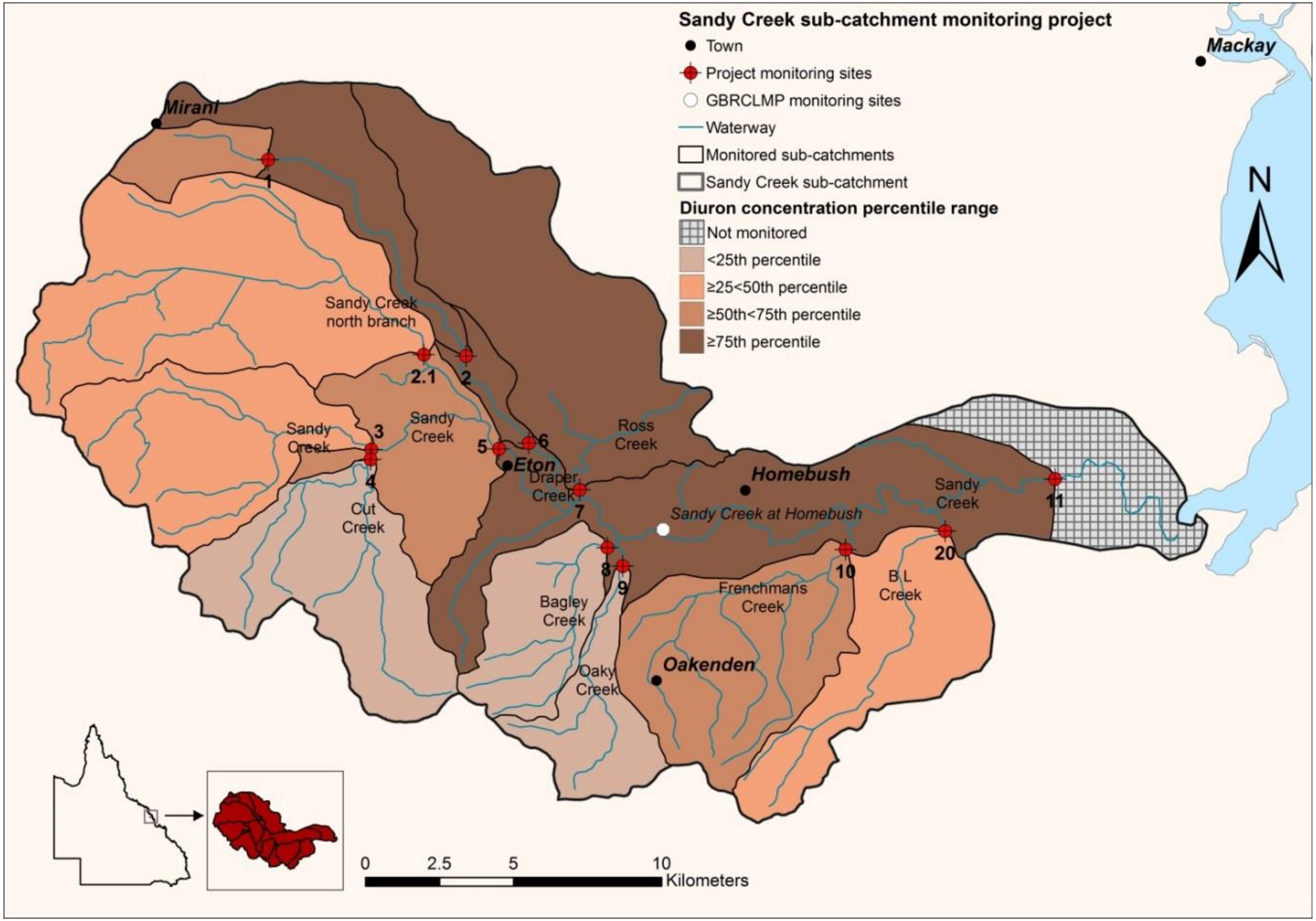

Figure 3-16 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of diuron in water samples collected at each sub-catchment during the monitored events. See Table 3-8 for reference of site name to site number.

3.2.6 Atrazine

***Guideline Note** –*

The current ecosystem protection guideline trigger values (ANZECC and ARMCANZ 2000) for atrazine in freshwater ecosystems are:

- *guideline for the protection of high ecological value ecosystems - 99 per cent species protection – 0.7 µgL^{-1};*
- *guideline for the protection of slightly-to-moderately disturbed ecosystems - 95 per cent species protection – 13 µgL^{-1}*
- *guideline for the protection of highly disturbed ecosystems*
    - *90 per cent species protection – 45 µgL^{-1}*
    - *80 per cent species protection – 150 µgL^{-1}*

The Queensland Department of Science, Information Technology and Innovation are currently reviewing international literature to revise the national ecosystem protection guideline for atrazine. The revised ecosystem protection guideline is scheduled for release in 2017.

There is no current irrigation residue guideline for atrazine. The derivation of an irrigation guideline is not currently scheduled.

3.2.6.1 Detection frequency and maximum concentrations

Atrazine was detected above the analytical limit of reporting (<0.07 µgL^{-1}) in 89 per cent of samples collected across all monitored sub-catchments (Table 3-2). In 33 samples the concentration of atrazine was below the analytical limit of reporting with all of these samples collected during the large rainfall runoff events of February and March – half of the samples below the limit of reporting were collected in the Cut Creek and Oaky Creek sub-catchments.

3.2.6.2 Distribution of concentrations

The highest concentrations of atrazine were monitored at the nested monitoring sites in Draper Creek (Multi-farm, 28 µgL^{-1}; Peak Downs Highway, 26 µgL^{-1}) (Table 3-9). The corresponding samples at each site were collected during the initial commencement of flow at these sites in mid-January (Event 4) (Figure 7-58 and Figure 7-63, Appendix B). The maximum concentration in Frenchmans Creek sub-catchment was also 25 µgL^{-1}, with a similarly high concentration monitored in the Sandy Creek North Branch sub-catchment (20 µgL^{-1}) (Table 3-9).

The maximum monitored concentration of atrazine in the Ross Creek sub-catchment was 13 µgL^{-1}, and similar among the main channel sites at Sandy Creek at Eton, Sandy Creek at Homebush and Sandy Creek at Bruce Highway (range, 8.4 to 10 µgL^{-1}) (Table 3-9). The maximum concentration of atrazine in the Sandy Creek South Branch sub-catchment (6.5 µgL^{-1}), BL Creek (4.2 µgL^{-1}) and Bagley Creek (3.1 µgL^{-1}) were the lowest of all monitored sub-catchments (excluding Cut Creek (0.50 µgL^{-1}) and Oaky Creek (0.16 µgL^{-1}), which only commenced to flow during the large runoff event in February) (Table 3-9).

Differences in the general distribution (25th – 75th percentile) of concentrations was also noted for atrazine, compared to previously discussed pesticides (Figure 3-17). The Draper Creek sub-catchment sites had comparatively lower distributions, whereas Frenchmans Creek, Sandy Creek at Bruce Highway, Ross Creek, Sandy Creek at Eton and Sandy Creek North Branch stood out as having the higher distributions of atrazine. As with the other pesticides, Cut Creek, Bagley Creek, Oaky Creek and BL Creek all had low concentration distributions (Figure 3-17).

3.2.6.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. The current water quality guideline trigger value for atrazine is 13 μgL^{-1} (95% species protection), which was exceeded by the 95th percentile concentration in the Draper Creek (Peak Downs Highway, 24 μgL^{-1}) and Frenchmans Creek (21 μgL^{-1}) sub-catchments (Table 3-9). The 95th percentile concentration did not exceed the trigger value at any other site; however, the maximum concentration did exceed (or met) the trigger value at Sandy Creek North Branch (20 μgL^{-1}), Draper Creek at Multi-farm (28 μgL^{-1}) and Ross Creek (13 μgL^{-1}) (Table 3-9).

The 95th percentile concentration was similar between the main channel sites at Sandy Creek at Eton (9.1 μgL^{-1}) and Sandy Creek at Bruce Highway (8.2 μgL^{-1}) (Table 3-9). The 95th percentile concentration at the automated site at Sandy Creek at Homebush (5.4 μgL^{-1}) was lower, due the very large number of samples collected at this site relative to the other two main channel sites (Table 3-9).

In the Draper Creek sub-catchment, the 95th percentile concentration increased between sites in a downstream direction from 2.1 μgL^{-1} at Draper Creek at De Moleyns Lagoon, 5.1 μgL^{-1} at Draper Creek at Multi-farm, and 24 μgL^{-1} at Draper Creek at Peak Downs Highway (Table 3-9). The very high 95th percentile concentration at the Draper Creek at Peak Downs Highway site compared to the Draper Creek at Multi-farm site, occurred due to the few high concentrations in samples collected at the Draper Creek at Peak Downs Highway site during the first flush event and the lower overall number of samples collected biasing this statistic at this site upward.

The 95th percentile concentrations in Ross Creek and BL Creek were 7.5 μgL^{-1} and 3.9 μgL^{-1}, respectively, and expectedly low in both Cut Creek (0.42 μgL^{-1}) and Oaky Creek (0.16 μgL^{-1}) (Table 3-9).

3.2.6.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their $mean_{(BT)}$ atrazine concentration were principally in the lower reaches of the Sandy Creek catchment with one exception (Sandy Creek North Branch). These sub-catchments included, from highest to lowest: Sandy Creek Bruce Highway, Site 11 (2.8 μgL^{-1}); Ross Creek, Site 7 (1.9 μgL^{-1}); Sandy Creek North Branch, Site 2.1, (1.5 μgL^{-1}); and, Frenchmans Creek, Site 10 (1.5 μgL^{-1}) (Figure 3-18).

The next highest ranked sub-catchments (≥ 50th<75th percentile) were nested within the sub-catchments in the highest grouping and included, from the highest to lowest $mean_{(BT)}$ atrazine concentration: Sandy Creek at Eton, Site 5 (1.4 μgL^{-1}); Draper Creek at Peak Downs Highway, Site 6 (1.0 μgL^{-1}); and Draper Creek at Multi-farm, Site 2 (0.74 μgL^{-1}) (Figure 3-18).

The third grouping of sub-catchments ranked in the ≥25th<50th percentile category included, from highest to lowest $mean_{(BT)}$ atrazine concentrations: Sandy Creek South Branch, Site 3 (0.61 μgL^{-1}); BL Creek, Site 20 (0.43 μgL^{-1}); and, Draper Creek at De Moleyns Lagoon, Site 1 (0.26 μgL^{-1}) (Figure 3-18).

The lowest ranked group of sub-catchments based on the $mean_{(BT)}$ atrazine concentrations lay on the southern side of the catchment and included, from highest to lowest: Bagley Creek, Site 8 (0.24 μgL^{-1}); Oaky Creek, Site 9 (0.078 μgL^{-1}); and, Cut Creek, Site 4 (0.048 μgL^{-1}) (Figure 3-18).

The $mean_{(BT)}$ concentration of atrazine at the end-of-catchment site, Sandy Creek at Bruce Highway, was high compared to the automated monitoring site Sandy Creek at Homebush where the $mean_{(BT)}$ concentration of atrazine was 0.66 μgL^{-1}. The $mean_{(BT)}$ concentration of atrazine at Sandy Creek at Eton was 1.4 μgL^{-1} – approximately half the $mean_{(BT)}$ concentration at the end-of-catchment site, which is consistent with the results for both diuron and hexazinone. Review of the box plots supports the higher distribution of the concentration data at the Bruce Highway site, in particular the median concentration (4.6 μgL^{-1}), which was very high relative to all monitored sub-catchment sites. The low $mean_{(BT)}$ concentration at the automated Homebush site compared to the end-of-catchment site, is likely due to the higher number of samples collected at the Homebush site during the falling stage of the hydrograph of each monitored event when the concentration of atrazine was lower. By contrast, samples at the other two sites were collected primarily during periods of high discharge and correspondingly elevated concentrations. It is also important to note that no samples were collected at the Bruce Highway site during the last event when concentrations were generally low in all monitored upstream sub-catchments.

The $mean_{(BT)}$ concentration of atrazine at Sandy Creek at Eton appears to have been influenced by the North Branch sub-catchment, which had a notably higher $mean_{(BT)}$ concentration of atrazine compared to Sandy Creek South Branch. The distribution of the concentration data at Sandy Creek at Eton more closely resembles the distribution of data from the North Branch, with similar median, and upper and lower quartile concentrations (Figure 3-17).

In Draper Creek, the $mean_{(BT)}$ concentration increased between the monitored sites in a downstream direction from Draper Creek at De Moleyns Lagoon, at Draper Creek at Multi-farm and Draper Creek at Peak Downs Highway, respectively. The distribution of the concentration data as presented in the box plots (Figure 3-17) shows the low median concentration at Draper Creek at De Moleyns lagoon is likely an artefact of there being few samples collected from only two events, and the upper-quartile at Draper Creek at Peak Downs Highway is likely influenced by the outlying concentration data monitored during the first flush event. The median concentrations were similar between the Draper Creek at Multi-farm and Draper Creek at Peak Downs Highway sites (0.85 μgL^{-1} and 0.83 μgL^{-1}, respectively).

The $mean_{(BT)}$ concentration of atrazine in Ross Creek, which drains the Victoria Plains area, was high compared to the adjacent Draper Creek sub-catchment and very high compared to Bagley Creek on the southern side of the Sandy Creek catchment. In Frenchmans Creek the concentration data was highly variable, which is possibly due to the number of samples with higher concentrations (i.e. >5.0 μgL^{-1}) during the early events of the monitoring period. The $mean_{(BT)}$ atrazine concentration in Frenchmans Creek was high compared to the adjacent BL Creek. The distribution of atrazine concentration data in Ross Creek and Frenchmans Creek were among the highest of all monitoring sub-catchments (Figure 3-17). BL Creek, by contrast, had among the lowest distributions of concentration data, similar to Sandy Creek South Branch.

The $mean_{(BT)}$ concentrations of atrazine in Cut Creek and Oaky Creek were expectedly low as only two events were received in these catchments during the monitoring year, both of which resulted in large runoff events. This had a subsequent dilutive effect on the monitored concentration of atrazine at these sites.

The strong negative skewness in the measured concentration data at Sandy Creek at Bruce Highway is a notable feature of the box plots (Figure 3-17). This may be an artefact of sample collection ceasing much earlier in monitored runoff periods than monitored upstream sub-catchments, particularly the main channel site at Sandy Creek at Homebush. Sampling was generally terminated at the Sandy Creek at Bruce Highway site earlier than upstream sites due to concern for the potential influence of dilution resulting from tidal mixing at this site. Subsequently, fewer samples were collected during lower stages of the falling hydrograph when concentrations are typically lower than during higher flow periods. Confounding this is that no samples were collected at the end-of-catchment site during the final runoff event. Subsequently, the median concentration of atrazine at this site reflects a concentration point during Event 4 when the concentration of most analytes was among the highest concentrations observed at this site.

Table 3-9 Summary statistics for water quality samples analysed for atrazine.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	26	27	2	25	4	42	13	38	24	7	109	32	13	20
Detection Freq. (%)	90	100	13	100	80	100	93	100	83	70	100	91	81	100
Mean$_{(BT)}$	1.5	0.61	0.048	1.4	0.26	0.74	1.0	1.9	0.24	0.078	0.66	1.5	0.43	2.8
Std. Dev.	0.77	0.48	0.36	0.59	0.74	0.64	0.80	0.46	0.61	0.24	0.67	0.88	0.69	0.39
95th Percentile	12	2.9	0.42	9.1	2.1	5.1	24	7.5	2.7	0.16	5.4	21	3.9	8.2
Median	2.5	0.52	0.035	2.4	0.10	0.85	0.83	2.1	0.16	0.095	0.66	1.5	0.41	4.6
Max. Conc.	20	6.5	0.50	10	2.1	28	26	13	3.1	0.16	8.4	25	4.2	9.5

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of ametryn was above the analytical limit of reporting.

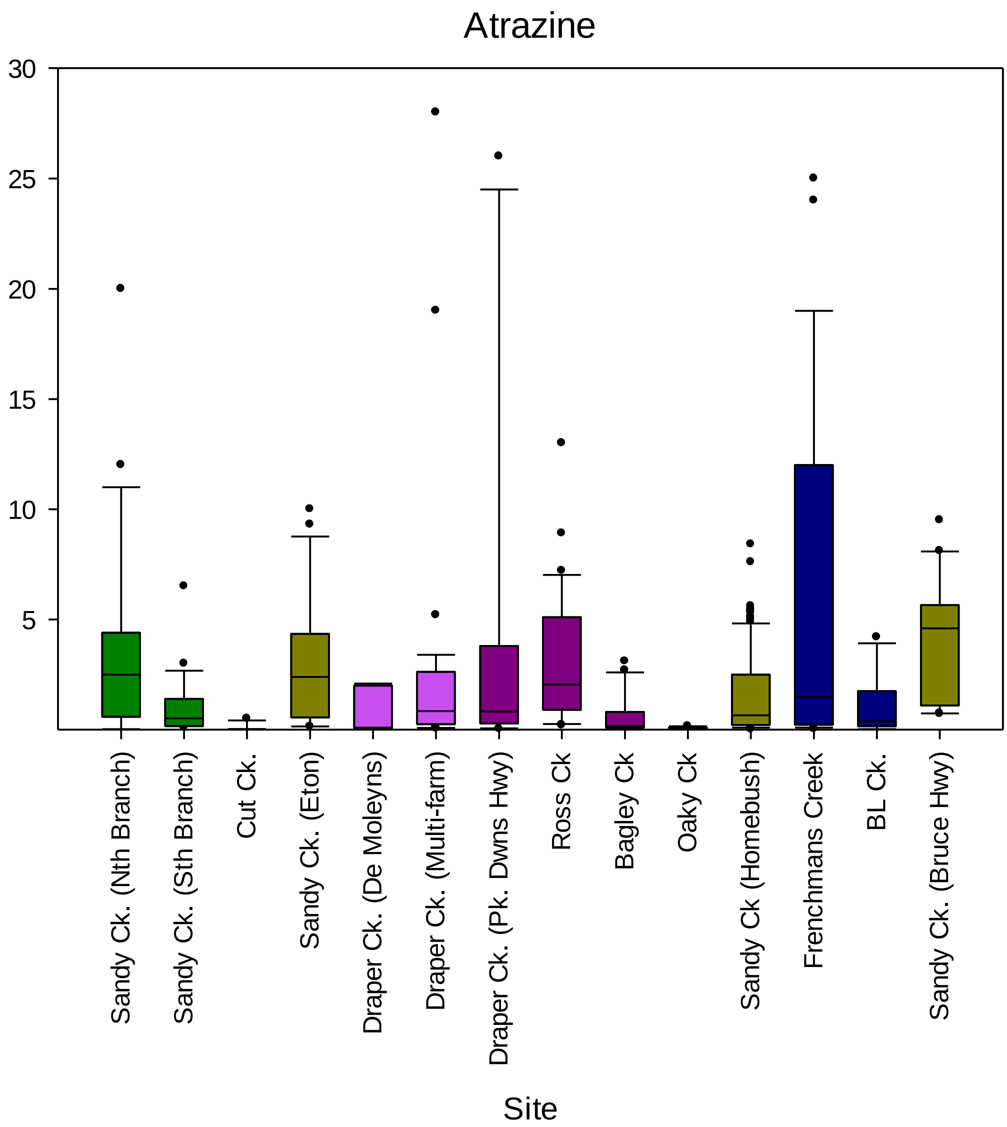

Figure 3-17 Box plot of measured concentration of atrazine at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles and solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

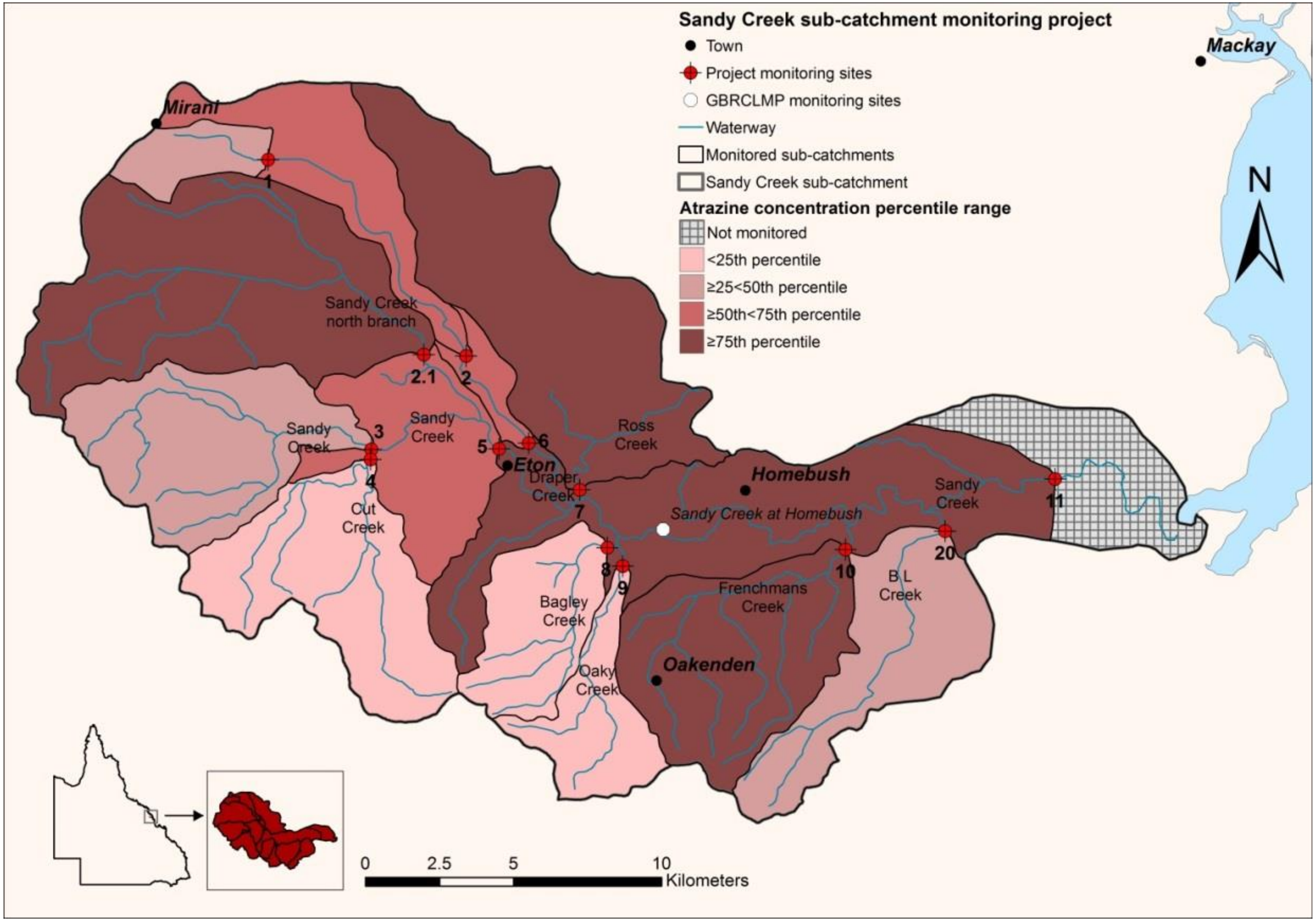

Figure 3-18 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of atrazine in water samples collected at each sub-catchment during the monitored events. See Table 3-9 for reference of site name to site number.

3.2.7 2,4-D

Guideline Note *–*

The current ecosystem protection guideline trigger values (ANZECC and ARMCANZ 2000) for 2,4-D in freshwater ecosystems are:

- *guideline for the protection of high ecological value ecosystems - 99 per cent species protection – 140 µgL^{-1};*
- *guideline for the protection of slightly-to-moderately disturbed ecosystems – 95 per cent species protection – 280 µgL^{-1}*
- *guideline for the protection of highly disturbed ecosystems*
    - *90 per cent ecosystem protection – 450 µgL^{-1}*
    - *80 per cent ecosystem protection – 830 µgL^{-1}*

The Queensland Department of Science, Information Technology and Innovation are currently reviewing international literature to revise the national ecosystem protection guideline for atrazine. The revised ecosystem protection guideline is scheduled for release in 2017.

There is no current irrigation residue guideline for 2,4-D. The revision of the irrigation residue guideline is not currently scheduled.

3.2.7.1 Detection frequency

2,4-D was among the most commonly detected pesticides with an overall detection frequency above the analytical limit of reporting (<0.05 µgL^{-1}) of 84 per cent (Table 3-2). 2,4-D was detected in all samples collected at the end-of-catchment site at Sandy Creek at Bruce Highway, Ross Creek and in Draper Creek at De Moleyns Lagoon and Multi-farm.

The detection frequency in all remaining catchments was above 80 per cent, except in Bagley Creek (59 per cent), Cut Creek (38 per cent) and Oaky Creek (0 per cent) – the latter two sites only commenced to flow during the large rainfall runoff event in February 2016 and the detection frequency in each of these catchments was expectedly low.

3.2.7.2 Distribution of concentrations

The highest concentration of 2,4-D was monitored in Sandy Creek South Branch (41 µgL^{-1}), which was very high relative to all other sub-catchments including Sandy Creek North Branch (11 µgL^{-1}) and the downstream monitoring site on the main channel Sandy Creek at Eton (15 µgL^{-1}) (Table 3-10). These sites together had the highest maximum concentration of 2,4-D of all monitored sub-catchments.

The maximum concentration of 2,4-D in all other sites was in the range 4.7 µgL^{-1} to 9.0 µgL^{-1}, except in BL Creek (0.71 µgL^{-1}) and Cut Creek (0.75 µgL^{-1}) (Table 3-10).

The pattern between sub-catchments of the general concentration distributions (25th – 75th percentile) for 2,4-D were very similar to imazapic (Figure 3-19). The higher general distributions were detected at Draper Creek at De Moleyns Lagoon, Sandy Creek at North Branch and Sandy Creek at Eton, although the quality of data representivity is low for two of these sites, Sandy Creek at Eton and Draper Creek at De Moleyns Lagoon, and should be judged with caution. As in previous cases, Cut, Bagley, Oaky and BL creeks all had low concentration distributions.

3.2.7.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. The current water quality guideline trigger values for 2,4-D is 280 μgL^{-1} (95% species protection), which was not exceeded in any samples. Future review of these guideline values should be compared against the following results.

The highest 95th percentile concentrations were amongst the upper catchment sites at Sandy Creek South Branch (26 μgL^{-1}), Sandy Creek North Branch (9.3 μgL^{-1}) and the main channel site Sandy Creek at Eton (6.8 μgL^{-1}) (Table 3-10).

The 95th percentile concentration was similar between Draper Creek (Peak Downs Highway, 3.7 μgL^{-1}) and Ross Creek (3.5 μgL^{-1}) and between Bagley Creek (4.4 μgL^{-1}) and Frenchmans Creek (4.7 μgL^{-1}). The 95th percentile concentrations of 2,4-D in both BL Creek (0.69 μgL^{-1}) and Cut Creek (0.53 μgL^{-1}) were low (Table 3-10).

3.2.7.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their $mean_{(BT)}$ concentration were all located in the north-west section of Sandy Creek catchment. These sub-catchments included, from highest to lowest: Draper Creek at De Moleyns Lagoon, Site 1 (2.1 μgL^{-1}); Ross Creek, Site 7 (1.1 μgL^{-1}); Sandy Creek North Branch, Site 2.1 (0.96 μgL^{-1}); and, Draper Creek Multi-farm, Site 2 (0.88 μgL^{-1}) (Figure 3-20).

The next highest ranked sub-catchments (≥ 50th <75th percentile) included, from highest to lowest: Sandy Creek at Bruce Highway, Site 11 (0.81 μgL^{-1}); Sandy Creek at Eton, Site 5 (0.66 μgL^{-1}); and, Draper Creek at Peak Downs Highway, Site 6 (0.65 μgL^{-1}) (Figure 3-20). The latter two sub-catchment monitoring sites are adjacent to the sub-catchment sites in the highest category of percentile ranked $mean_{(BT)}$ concentration.

The third grouping of sub-catchments ranked in the ≥25th <50th percentile category and included, from highest to lowest $mean_{(BT)}$ 2,4-D concentrations: Frenchmans Creek, Site 10 (0.51 μgL^{-1}); Sandy Creek South Branch, Site 3 (0.43 μgL^{-1}); and, BL Creek, Site 20 (0.16 μgL^{-1}) (Figure 3-20).

The lowest ranked group of sub-catchments based on the $mean_{(BT)}$ 2,4-D concentrations were all located on the southern side of the Sandy Creek catchment and included, from highest to lowest: Bagley Creek, Site 8 (0.13 μgL^{-1}); Cut Creek, Site 4 (0.066 μgL^{-1}); and, Oaky Creek in which there were no detections above the analytical limit of reporting (Figure 3-20).

The $mean_{(BT)}$ concentration of 2,4-D was much higher in the upper nested Draper Creek sub-catchment site De Moleyns Lagoon compared to the two downstream sites Draper Creek at Multi-farm and Draper Creek at Peak Downs Highway. This result may be due to an artefact of the low number of samples collected over two flow events at the Draper Creek at De Moleyns site.

The $mean_{(BT)}$ concentration in Sandy Creek North Branch was more than double the $mean_{(BT)}$ concentration of 2,4-D in Sandy Creek South Branch despite two samples in South Branch being higher than 30 μgL^{-1}. At the downstream monitoring site at Sandy Creek at Eton, the $mean_{(BT)}$ concentration was approximately half the $mean_{(BT)}$ concentration of the upstream sites, excluding Cut Creek, where the $mean_{(BT)}$ concentration of 2,4-D was low. Review of the box plots strongly indicates the higher distribution of concentration data in Sandy Creek North Branch than all other monitored sites (excluding Draper Creek at De Moleyns Lagoon) and very high compared to the Sandy Creek North Branch and Sandy Creek at Eton sites, despite the high outlying concentrations at the Sandy Creek South Branch site (Figure 3-19).

The $mean_{(BT)}$ concentration in Frenchmans Creek was high compared to the adjacent BL Creek and Bagley Creek. The box plots show that the concentration data in Frenchmans Creek are more highly distributed than indicated in the $mean_{(BT)}$ alone, which may be due to a wide upper quartile in this positively skewed dataset compared to other sub-catchments with a more central distribution (Figure 3-19).

Amongst the main channel sites the $mean_{(BT)}$ concentration increased between the upper-catchment site Sandy Creek at Eton and the end-of-catchment site at Bruce Highway. The $mean_{(BT)}$ concentration at Homebush, however, was low, which is due to the very large number of samples that were collected at this automated site including during periods of the falling hydrograph when the concentration of most pesticide is low.

Table 3-10 Summary statistics for water quality samples analysed for 2,4-D.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	27	23	6	22	5	42	13	38	17	0	98	31	13	20
Detection Freq. (%)	93	85	38	88	100	100	93	100	59	0	90	89	81	100
Mean(BT)	0.96	0.43	0.066	0.66	2.1	0.88	0.65	1.1	0.13	NC	0.29	0.51	0.16	0.81
Std. Dev.	0.76	0.90	0.55	0.79	0.35	0.33	0.55	0.41	0.80	NC	0.76	0.73	0.51	0.41
Median	1.4	0.28	0.025	0.54	2.5	1.0	0.77	1.40	0.060	NC	0.40	0.67	0.20	0.75
95th Percentile	9.3	26	0.53	6.8	5.0	2.5	3.7	3.5	4.4	NC	1.6	4.7	0.69	4.4
Max. Conc.	11	41	0.750	15	5.5	7.0	6.30	6.9	7.7	NC	9.0	5.2	0.71	4.7

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency (%)** – the proportion of samples collected at a site which the concentration of 2,4-D was above the analytical limit of reporting. **NC** – not calculated – the concentration of 2,4-D was below the analytical limit of reporting in all samples collected at the site during the monitoring period and descriptive statistics were not calculated.

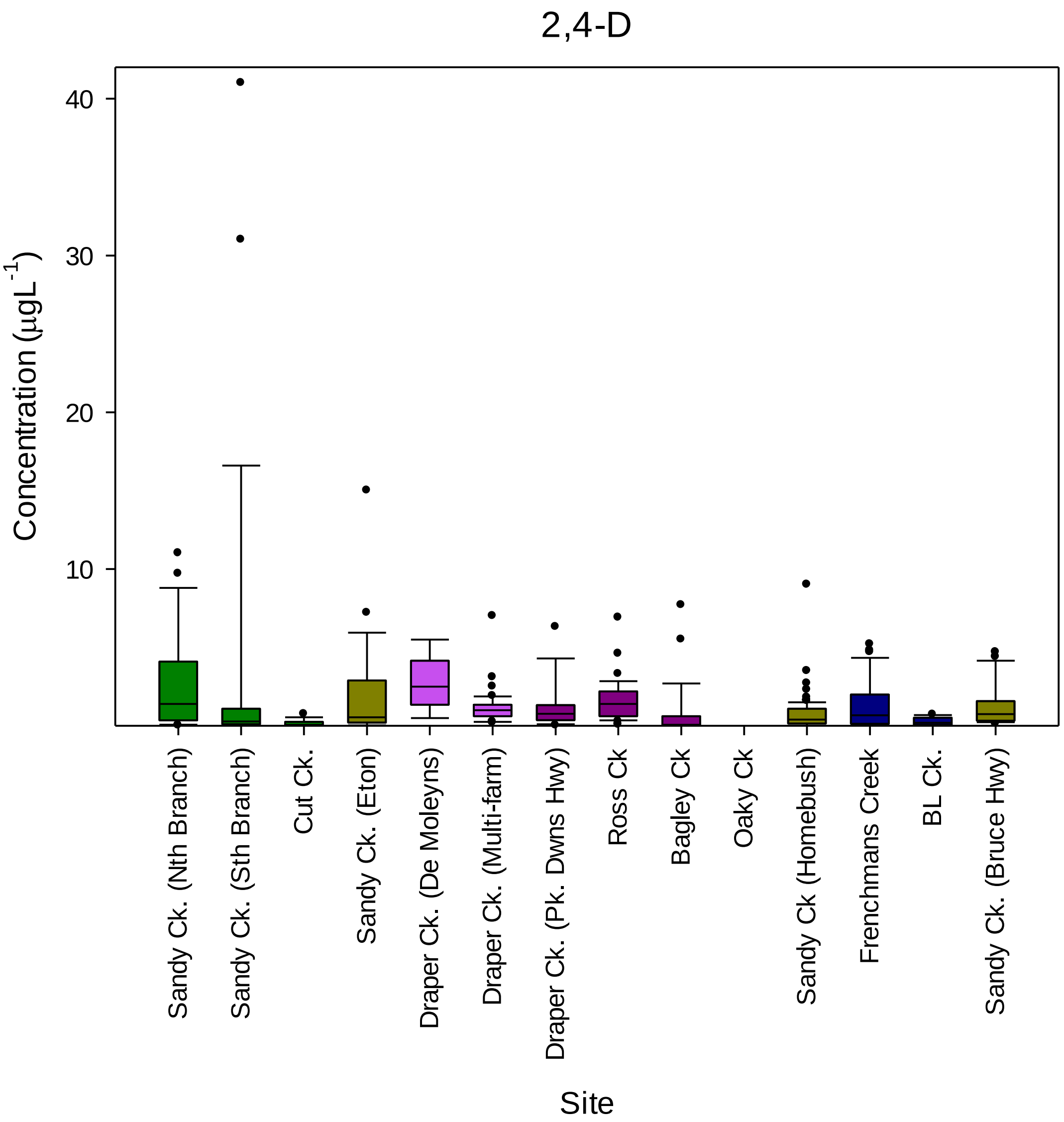

Figure 3-19 Box plot of measured concentration of 2,4-D at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles, solids dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

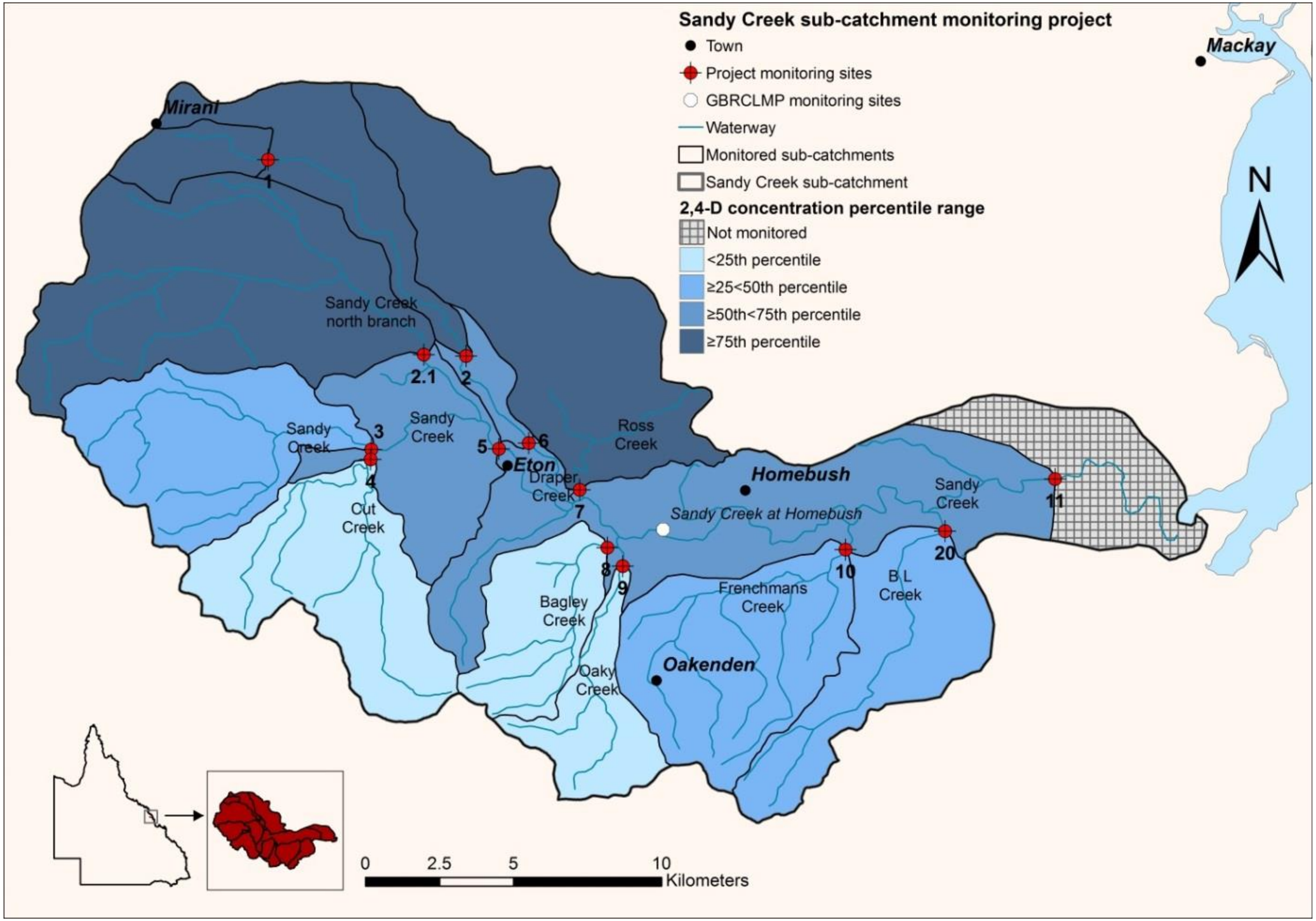

Figure 3-20 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of 2,4-D in water samples collected at each sub-catchment during the monitored events. See Table 3-10 for reference of site name to site number.

3.2.8 Fluroxypyr

Guideline Note –

There are no current ecosystem protection or irrigation guidelines for fluroxypyr.

The Queensland Department of Science, Information Technology and Innovation are currently reviewing international literature to derive a national ecosystem protection guideline for fluroxypyr. The revised ecosystem protection guideline is scheduled for release in 2017.

The derivation of an irrigation residue guideline is not currently scheduled.

3.2.8.1 Detection frequency

Fluroxypyr was one of the more commonly detected pesticides across the monitored sub-catchments in Sandy Creek with an overall detection frequency above the analytical limit of reporting (<0.07 μgL^{-1}) of 72 per cent (Table 3-2).

Fluroxypyr was detected in all samples collected in Draper Creek, Ross Creek and at the end-of-catchment monitoring site at Bruce Highway. The frequency of detection in all other catchments was generally high except BL Creek and Bagley Creek, which had the lowest rates of detection.

Fluroxypyr was not detected in Oaky Creek, which did not commence to flow until the large runoff event in February. Cut Creek by contrast had a detection frequency of 38 per cent (Table 3-11).

3.2.8.2 Distribution of concentrations

The highest concentration of fluroxypyr was monitored in Draper Creek at Peak Downs Highway (9.1 μgL^{-1}). The maximum concentration of fluroxypyr at other Draper Creek sites was also high; De Moleyns Lagoon (2.1 μgL^{-1}) and Multi-farm (2.6 μgL^{-1}) (Table 3-11).

The maximum concentration at Draper Creek at Peak Downs Highway was approximately six times higher than the maximum concentration monitored in Sandy Creek South Branch (1.6 μgL^{-1}) and Ross Creek (1.4 μgL^{-1}) which had the highest concentrations outside of the Draper Creek catchment (Table 3-11).

The maximum concentration of fluroxypyr decreased between the main channel sites in a downstream direction from 1.7 μgL^{-1} at Sandy Creek at Eton, 1.5 μgL^{-1} at Sandy Creek at Homebush and 0.51 μgL^{-1} at Sandy Creek at Bruce Highway (Table 3-11).

The general concentration distributions (25th – 75th percentile) of fluroxypyr was highest in the Draper Creek sub-catchment sites and neighbouring Ross Creek. All other sub-catchments had comparable concentration distributions, excluding Cut Creek, Sandy Creek at Eton, Bagley Creek, Oaky Creek and BL Creek, which were all low.

3.2.8.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. Although there is no current water quality guideline trigger values for fluroxypyr, future guideline values should be compared against the following results.

The 95th percentile concentration was very high at the monitored sites in Draper Creek sub-catchment (range, 1.6 μgL^{-1} to 5.0 μgL^{-1}) compared to all other sub-catchments (Table 3-11).

In Sandy Creek South Branch (1.4 μgL^{-1}) and Ross Creek (1.3 μgL^{-1}), the 95th percentile concentrations were high compared to most sub-catchments with Frenchmans Creek, Bagley Creek, Sandy Creek North Branch and BL Creek all in the range, 0.14 μgL^{-1} to 0.75 μgL^{-1} (Table 3-11).

The 95th percentile concentration of fluroxypyr was similar between all main channel sites (range, 0.46 μgL^{-1} to 0.53 μgL^{-1}) (Table 3-11).

3.2.8.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their $mean_{(BT)}$ concentration were all located in the north-west section of Sandy Creek catchment. These sub-catchments included, from highest to lowest: Draper Creek at Peak Downs Highway, Site 6 (1.0 μgL^{-1}); Draper Creek at De Moleyns Lagoon, Site 1 (0.53 μgL^{-1}); Draper Creek at Multi-farm, Site 2.1 (0.42 μgL^{-1}); and Ross Creek, Site 7 (0.39 μgL^{-1}) (Figure 3-22).

The next highest ranked sub-catchments (≥ 50th <75th percentile) included, from highest to lowest: Sandy Creek at Bruce Highway, Site 11 (0.31 μgL^{-1}); Sandy Creek North Branch, Site 2.1 (0.18 μgL^{-1}); and, Sandy Creek South Branch, Site 3 (0.18 μgL^{-1}) (Figure 3-22).

The third grouping of sub-catchments ranked in the ≥25th <50th percentile category included, from highest to lowest $mean_{(BT)}$ fluroxypyr concentrations: Frenchmans Creek, Site 10 (0.16 μgL^{-1}); Sandy Creek at Eton, Site 5 (0.15 μgL^{-1}); and, Cut Creek, Site 4 (0.058 μgL^{-1}) (Figure 3-22).

The lowest ranked group of sub-catchments based on the $mean_{(BT)}$ fluroxypyr concentrations were located on the southern side of the catchment and included, from highest to lowest: BL Creek, Site 20 (0.052 μgL^{-1}); Bagley Creek, Site 8 (0.049 μgL^{-1}); and, Oaky Creek in which there were no detections above the analytical limit of reporting (Figure 3-22).

Review of the monitored concentration data for fluroxypyr at all sites in Draper Creek, strongly indicate substantial loss of this pesticide at multiple locations throughout this catchment. The high concentrations of fluroxypyr were detected at the commencement of flow in early January and persisted through to the large flow event in February when the concentrations of most other chemicals had reduced due to the dilutive effect of high runoff volumes in the respective sub-catchments.

The $mean_{(BT)}$ concentration of fluroxypyr in Draper Creek catchment generally increased in a downstream direction between Draper Creek at De Moleyns Lagoon and Draper Creek at Peak Downs Highway. The lower $mean_{(BT)}$ concentration at Draper Creek at Multi-farm is likely to be due to a high number of samples being collected during the final event when the concentrations of fluroxypyr were lower. No samples were collected at either Draper Creek at De Moleyns Lagoon or Draper Creek at Peak Downs Highway during Event 7.

The $mean_{(BT)}$ concentration of fluroxypyr was also comparatively high in Ross Creek. Review of the box plot supports the higher overall distribution of the concentration data at Ross Creek relative to other monitored sub-catchments, excluding Draper Creek (Figure 3-21).

The $mean_{(BT)}$ concentration of fluroxypyr at the main channel site Sandy Creek at Eton corresponds well to the monitored results from the upstream monitored sub-catchments, Sandy Creek South Branch and Sandy Creek North Branch. This suggests little additional input of fluroxypyr from areas downstream of these two sites. The box plot for the Sandy Creek at Eton site indicates a much finer distribution of concentration data, possibly reflecting the similarity in the concentration of fluroxypyr coming from the both upstream sub-catchments (Figure 3-21).

The higher $mean_{(BT)}$ concentration of fluroxypyr at the end-of-catchment monitoring site at Bruce Highway compared to the upstream sites may indicate influence of an input downstream of the main channel site at Homebush where the $mean_{(BT)}$ concentration was 0.14 μgL^{-1}. Review of the hydrograph suggests this input may have been from Frenchmans Creek given the higher distribution of concentration data in the sub-catchment compared to Sandy Creek at Homebush and BL Creek (Figure 3-21).

Table 3-11 Summary statistics for water quality samples analysed for fluroxypyr.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	20	19	6	22	5	40	14	38	5	0	97	25	4	20
Detection Freq. (%)	69	70	38	88	100	100	100	100	17	0	89	71	25	100
Mean$_{(BT)}$	0.18	0.18	0.058	0.15	0.53	0.42	1.0	0.39	0.049	**NC**	0.14	0.16	0.052	0.31
Std. Dev.	0.52	0.55	0.27	0.39	0.41	0.38	0.43	0.36	0.33	**NC**	0.63	0.49	0.24	0.16
95th Percentile	0.69	1.4	0.15	0.46	1.9	1.6	5.0	1.3	0.30	**NC**	0.53	0.75	0.14	0.50
Median	0.31	0.24	0.04	0.14	0.28	0.34	0.92	0.47	0.040	**NC**	0.21	0.17	0.04	0.32
Max. Conc.	0.82	1.6	0.17	1.7	2.1	2.6	9.1	1.4	0.50	**NC**	1.5	0.86	0.15	0.51

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency (%)** – the proportion of samples collected at a site which the concentration of fluroxypyr was above the analytical limit of reporting. **NC** – not calculated – the concentration of ametryn was below the analytical limit of reporting in all samples collected at the site during the monitoring period and descriptive statistics were not calculated.

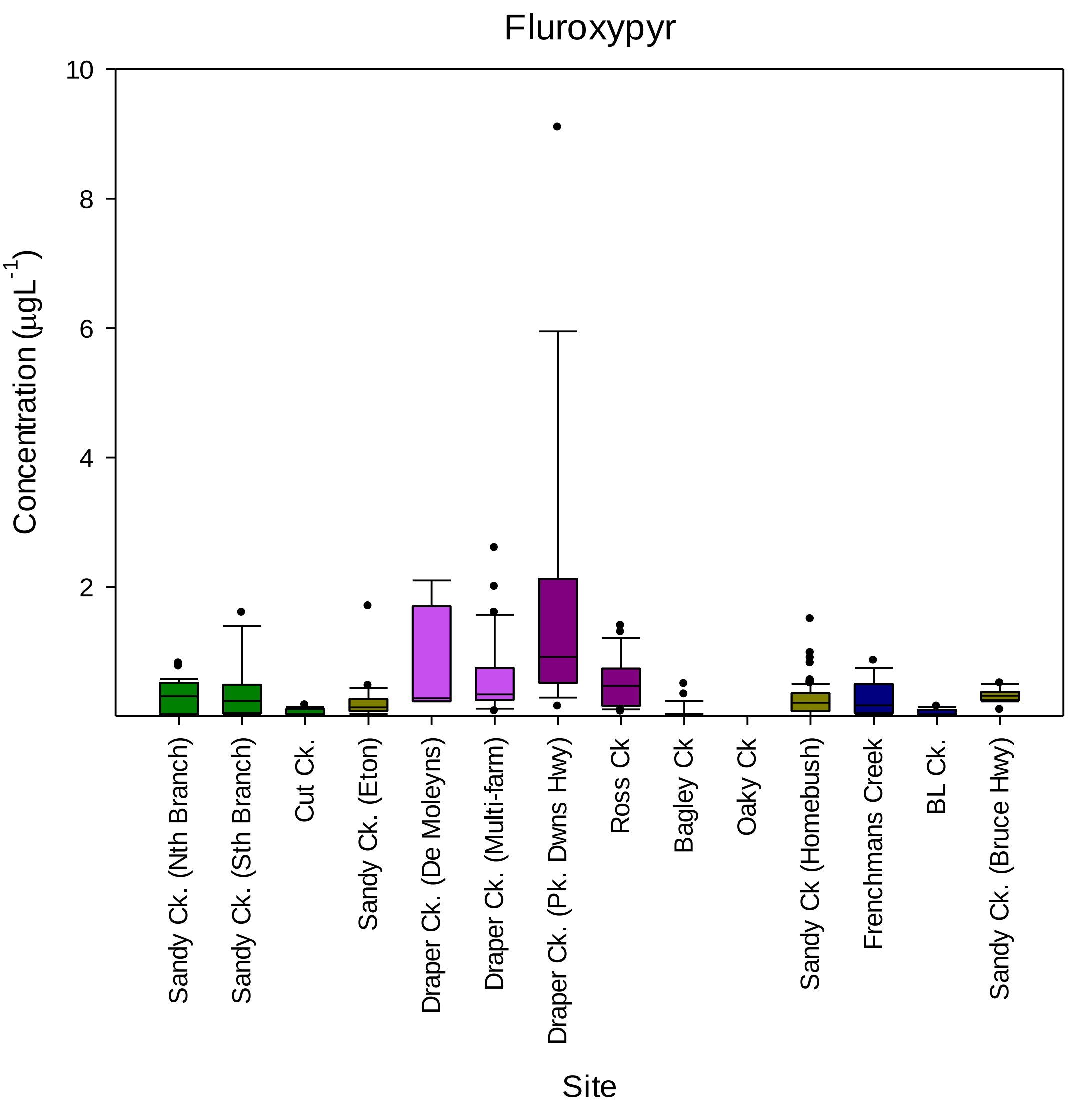

Figure 3-21 Box plot of measured concentration of fluroxypyr at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles and solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

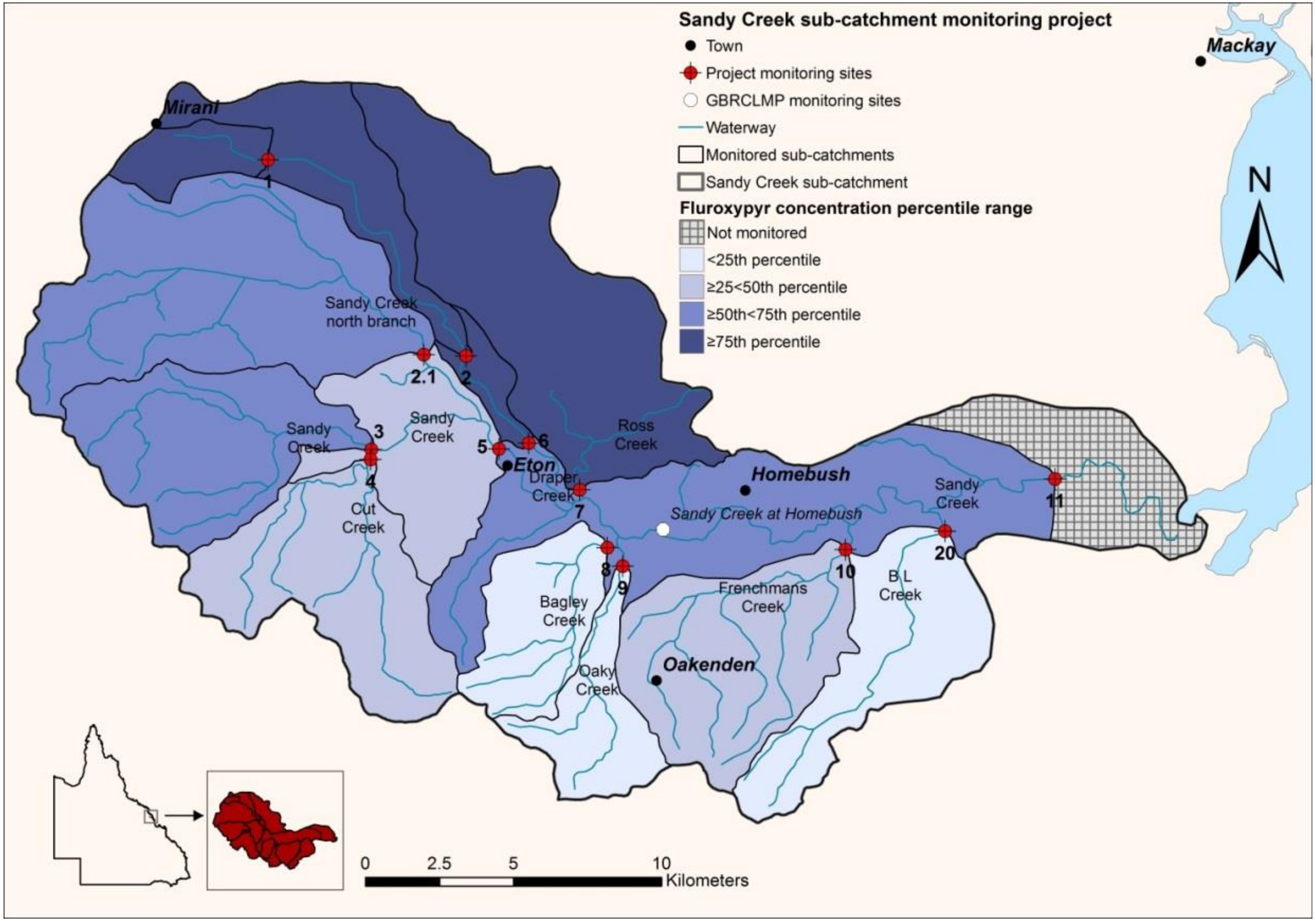

Figure 3-22 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of fluroxypyr in water samples collected at each sub-catchment during the monitored events. See Table 3-11 for reference of site name to site number.

3.2.9 MCPA

Guideline Note –

The current ecosystem protection guideline trigger value (ANZECC and ARMCANZ 2000) for MCPA in freshwater ecosystems is:

- *A low reliability trigger value of 1.4 µgL^{-1}, calculated using the assessment factor method. This value does not correspond with a protection level (e.g. 95% species protection) and should only be used as an interim indicative working level.*

Work is currently being undertaken by the Queensland Government to revise the national ecosystem protection guideline for MCPA which is scheduled for release in 2017.

The derivation of an irrigation residue guideline is not currently scheduled.

3.2.9.1 Detection frequency

MCPA was detected above the analytical limit of reporting (<0.02 µgL^{-1}) in 65 per cent of samples collected across all monitored sub-catchments (Table 3-2). The detection frequency of MCPA was high in Sandy Creek North Branch (69 per cent), Draper Creek (range, 80 to 100 per cent), Ross Creek (92 per cent) and among all main channel sites (range, 83 to 100 per cent) (Table 3-12).

The detection frequency was also comparatively moderate in BL Creek (69 per cent) and Frenchmans Creek (54 per cent) and low in Sandy Creek South Branch (19 per cent) and Cut Creek (13 per cent) (Table 3-12).

MCPA was not detected in Oaky Creek (Table 3-12).

3.2.9.2 Distribution of concentrations

The highest concentration of MCPA was monitored in Draper Creek (Peak Downs Highway, 2.2 µgL^{-1}, Multi-farm, 2.0 µgL^{-1}) with similarly high maximum concentrations also monitored at the main channel sites at Sandy Creek at Eton (1.9 µgL^{-1}) and Sandy Creek at Homebush (2.0 µgL^{-1}) (Table 3-12).

In the upper Sandy Creek catchment, the maximum concentration of MCPA in Sandy Creek North Branch (0.70 µgL^{-1}), Sandy Creek South Branch (0.46 µgL^{-1}) and Cut Creek (0.040 µgL^{-1}) were low compared to the downstream main channel site at Sandy Creek at Eton (1.90 µgL^{-1}), indicating possible additional source of MCPA between Sandy Creek at Eton and the upstream monitoring sites (Table 3-12).

The low maximum concentration of MCPA in Draper Creek at De Moleyns Lagoon relative to the downstream sites on Draper Creek, indicate the source of MCPA in this sub-catchment is downstream of De Moleyns lagoon.

The maximum concentration of MCPA in Ross Creek was 1.4 µgL^{-1} and low in Bagley Creek (0.44 µgL^{-1}), BL Creek (0.21 µgL^{-1}) and Frenchmans Creek (0.16 µgL^{-1}). MCPA was not detected in Oaky Creek in either of the two monitored events at this site (Table 3-12).

The maximum concentration of MCPA the end-of-catchment site, Sandy Creek at Bruce Highway (0.66 µgL^{-1}) was low compared to each of the upstream main channel sites (Table 3-12).

The general concentration distributions (25th – 75th percentile) follow a similar pattern to the maximum concentrations, and show that there is high variability in MCPA concentrations between sub-catchment sites (Figure 3-23). The highest distributions were the downstream sites of Drapers Creek, Multi-farm and Peak Downs Highway. Sandy Creek at Eton also had a higher distribution than many other sites, although the representivity of data at this site is considered low, and Sandy Creek at Homebush would likely have a higher distribution, similar to Eton, if the sampling regimes were similar. Sandy Creek at North Branch, Ross Creek and Sandy Creek at Bruce Highway were comparable in their concentration distributions. All other sites had low concentration distributions or a large number of samples with concentrations below the analytical limit of reporting.

3.2.9.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. The current water quality guideline trigger values for MCPA (1.4 µgL^{-1}) was exceeded (or met) by the 95th percentile concentration at Draper Creek Peak at Downs Highway (2.0 µgL^{-1}) and Draper Creek at Multi-farm (1.7 µgL^{-1}), and the maximum concentration at Sandy Creek at Eton (1.9 µgL^{-1}) and Ross Creek (1.4 µgL^{-1}) (Table 3-12).

The high 95th percentile concentration of MCPA at Sandy Creek at Eton was not corroborated by monitoring data from either of the upstream monitoring sites, Sandy Creek North Branch (0.27 µgL^{-1}) or Sandy Creek South Branch (0.17 µgL^{-1}), which indicates a local input source between these monitoring sites is likely to have contributed to the high concentrations monitored at Sandy Creek at Eton during Event 3 (Table 3-12).

The 95th percentile concentration of MCPA decreased between the main channel sites in a downstream direction from a high of 1.2 µgL^{-1} at Sandy Creek at Eton, 0.50 µgL^{-1} at Sandy Creek at Homebush and 0.31 µgL^{-1} at the end-of-catchment monitoring site Sandy Creek at Bruce Highway (Table 3-12). These results indicate the progressive dilution of MCPA as this body of water moved through the mid- and lower-sections of the Sandy Creek catchment.

The 95th percentile concentration in Ross Creek was 0.37 µgL^{-1} and comparatively low in BL Creek (0.13 µgL^{-1}) and Frenchmans Creek (0.10 µgL^{-1}). As stated above, MCPA was not detected in Oaky Creek (Table 3-12).

3.2.9.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their mean$_{(BT)}$ MCPA concentration were, from highest to lowest: Draper Creek at Peak Downs Highway, Site 6 (0.35 µgL^{-1}); Draper Creek at Multi-farm, Site 2 (0.19 µgL^{-1}); Sandy Creek at Eton (0.16 µgL^{-1}); and Sandy Creek at Bruce Highway, Site 11 (0.10 µgL^{-1}) (Figure 3-24).

The next highest ranked sub-catchments (≥50th<75th percentile) included, from highest to lowest: Ross Creek, Site 7 (0.077 µgL^{-1}); Sandy Creek North Branch, Site 2.1 (0.052 µgL^{-1}); and BL Creek, Site 20 (0.028 µgL^{-1}) (Figure 3-24).

The third grouping of sub-catchments ranked in the ≥25th <50th percentile category included, from highest to lowest mean$_{(BT)}$ MCPA concentrations: Draper Creek at De Moleyns Lagoon, Site 1 (0.023 µgL^{-1}); Frenchmans Creek, Site 10 (0.022 µgL^{-1}); and, Sandy Creek South Branch, Site 3 (0.016 µgL^{-1}) (Figure 3-24).

The lowest ranked group of sub-catchments based on the mean$_{(BT)}$ MCPA concentrations were located on the southern side of the catchment and included, from highest to lowest: Bagley Creek, Site 8 (0.013 µgL^{-1}); Cut Creek (0.012 µgL^{-1}); and, Oaky Creek for which there were no detections above the analytical limit of reporting (Figure 3-24).

The sharp peak in concentration and rapid dissipation of MCPA at the Sandy Creek at Eton site potentially indicates recent application prior to Event 3 (Figure 7-104, Appendix B). The $mean_{(BT)}$ concentration of MCPA at Sandy Creek at Eton was high compared to the upstream monitored sub-catchments of Sandy Creek North Branch, Sandy Creek South Branch and Cut Creek. Review of the box plots indicates the higher distribution of MCPA concentration data at Sandy Creek at Homebush compared to the upstream sites (Figure 3-23). In Sandy Creek catchment, MCPA is applied to control vine weeds in large cane and the rate applied would rarely be at the maximum permitted rate (*pers. comm. J. Agnew. 2/12/16*). Further consultation with local industry is warranted to identify links between the recorded concentration data and application in the period immediately prior to Event 3 in this small section of the Sandy Creek catchment, and to communicate the risk of loss of MCPA as a result of storm driven rainfall runoff events at the onset of the wet season.

The high $mean_{(BT)}$ concentration of MCPA in Draper Creek measured at both the Multi-farm and Peak Downs Highway sites indicate a moderate load source of MCPA in this sub-catchment relative to other monitored sub-catchments. The box plots clearly support the high distribution of the MCPA concentration data at the lower Draper Creek sub-catchment monitoring sites relative to all other monitored sub-catchments (Figure 3-23). Further communication with local growers in this area is recommended to ensure the risk of MCPA mobilising during rainfall runoff events is understood and management options identified.

The $mean_{(BT)}$ concentration of MCPA in Ross Creek was similar to the Sandy Creek main channel sites at Homebush (0.055 μgL^{-1}) and Bruce Highway, which were both substantially lower than the upstream main channel site at Eton. Review of the box plots indicate the large number of concentration data monitored at the Homebush site above 0.50 μgL^{-1} (Figure 3-23). Due to the high number of samples collected at this site, including during periods of very low concentration, these concentration did not reflect strongly in the descriptive statistic. Review of the hydrograph plots shows high concentrations above 0.50 μgL^{-1} occurred during both the earlier Event 2 in November 2015 and Event 3 in January 2016 (Figure 7-109, Appendix B).

Table 3-12 Summary statistics for water quality samples analysed for MCPA.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	20	5	2	25	4	42	14	35	4	0	91	19	11	19
Detection Freq. (%)	69	19	13	100	80	100	100	92	14	0	83	54	69	95
Mean$_{(BT)}$	0.052	*0.016*	*0.012*	0.16	0.023	0.19	0.35	0.077	*0.013*	**NC**	0.055	0.022	0.028	0.10
Std. Dev.	0.56	*0.45*	0.18	0.53	0.29	0.54	0.52	0.46	*0.38*	**NC**	0.61	0.37	0.40	0.38
Median	0.07	*0.01*	*0.01*	0.16	0.02	0.15	0.31	0.08	*0.01*	**NC**	0.07	0.02	0.03	0.09
95th Percentile	0.27	0.17	0.033	1.2	0.068	1.7	2.0	0.37	0.13	**NC**	0.50	0.10	0.13	0.31
Max. Conc.	0.70	0.46	0.04	1.9	0.08	2.0	2.2	1.4	0.44	**NC**	1.0	0.16	0.21	0.66

n – number of samples analysed; **LOR** –limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of MCPA was above the analytical limit of reporting. **Text in italics** indicates values below the analytical limit of reporting. **NC** – not calculated – the concentration of MCPA was below the analytical limit of reporting in all samples collected at the site during the monitoring period and descriptive statistics were not calculated.

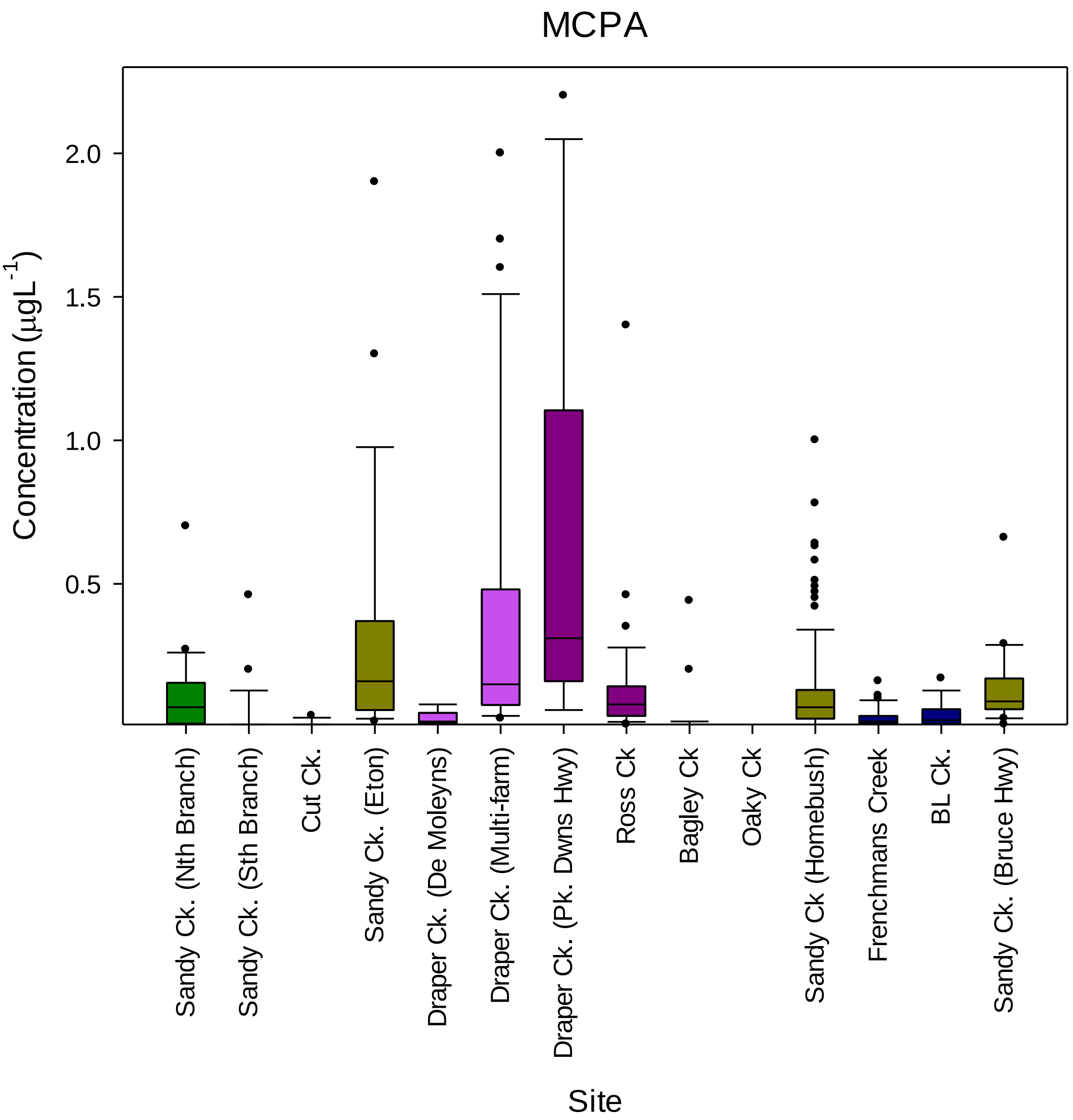

Figure 3-23 Box plot of measured concentration of MCPA at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles and solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

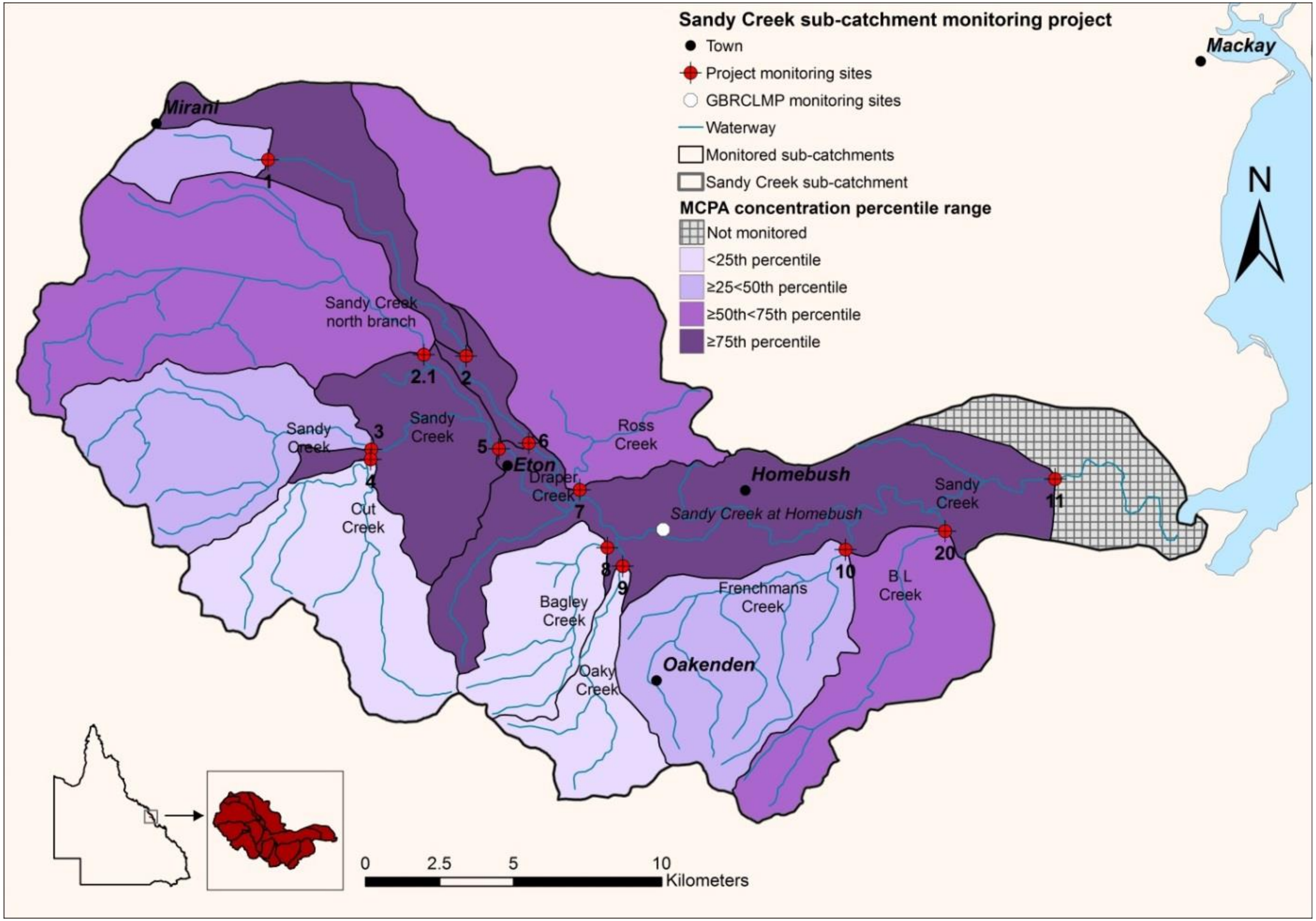

Figure 3-24 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of MCPA in water samples collected at each sub-catchment during the monitored events. See Table 3-12 for reference of site name to site number.

3.2.10 Isoxaflutole metabolite

Queensland Health Forensic Scientific Services only report the concentration of isoxaflutole metabolite, diketonitrile, as the active species of isoxaflutole.

Guideline Note *–*

There are no current ecosystem protection or irrigation guidelines for isoxaflutole metabolites.

The Queensland Department of Science, Information Technology and Innovation are currently reviewing international literature to derive a national ecosystem protection guideline for isoxaflutole. The revised ecosystem protection guideline is scheduled for release in 2017.

The derivation of an irrigation residue guideline is not currently scheduled.

3.2.10.1 Detection frequency

Isoxaflutole metabolites were detected above the analytical limit of reporting (<0.01 μgL^{-1}) in 62 per cent of all samples collected at sites monitored as part of the Sandy Creek Sub-catchment Water Quality Monitoring Project (Table 3-2).

In the upper Sandy Creek sub-catchments, the detection frequency was high in Sandy Creek North Branch (79 per cent), Sandy Creek South Branch (96 per cent) and Cut Creek (88 per cent). The subsequent detection frequency of isoxaflutole metabolites at the main channel site at Sandy Creek at Eton downstream from these sites was 100 per cent (Table 3-13).

In the Draper Creek sub-catchment the detection frequency differed between sites, ranging from 40 per cent at Draper Creek at De Moleyns Lagoon, 100 per cent at Draper Creek at Multi-farm and 64 per cent at Draper Creek at Peak Downs Highway (Table 3-13). The lower detection frequency at Draper Creek at Peak Downs Highway compared to Draper Creek at Multi-farm requires further investigation, although it may be due to differences in the recovery rates obtained by the direct injection solid phase extraction LC-MS/MS analytical methods, which were used to analyse samples from these sites, respectively. The detection frequency was also high in Ross Creek (95 per cent) which is adjacent to Draper Creek sub-catchment (Table 3-13).

Isoxaflutole metabolites were not detected above the analytical limit of reporting in Oaky Creek, Frenchmans Creek and BL Creek sub-catchments (Table 3-13).

3.2.10.2 Distribution of concentrations

The highest concentration of isoxaflutole metabolites was monitored at Sandy Creek at Eton (1.9 μgL^{-1}) which was substantially higher than the maximum concentration monitored at all other sites including Sandy Creek North Branch (0.18 μgL^{-1}), Sandy Creek South Branch (0.45 μgL^{-1}) and Cut Creek (0.24 μgL^{-1}) (Table 3-13) which are located upstream of the Sandy Creek at Eton site.

In Draper Creek the maximum concentration of isoxaflutole metabolites was low (range, 0.010 μgL^{-1} to 0.080 μgL^{-1}), and below the analytical limit of reporting in all samples collected at Bagley Creek, Oaky Creek, Frenchmans Creek and BL Creek (Table 3-13).

The pattern between sub-catchments of the general distribution of concentrations (25th – 75th percentile) of isoxaflutole metabolites was unique compared to the other pesticides previously discussed here (Figure 3-25). It is clear that the principle sources of isoxaflutole metabolites in the main channel were from the upper catchment above the Sandy Creek at Eton site and Ross Creek. The only other source, but at a much lower level, was Draper Creek (Table 3-13).

3.2.10.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. Although there is no current water quality guideline trigger values for isoxaflutole metabolite, future guideline values should be compared against the following results.

The highest 95th percentile concentration was monitored at the main channel site at Sandy Creek at Eton (0.72 µgL^{1}), which was very high relative to all other monitored sub-catchments, including the upstream monitoring sites at Sandy Creek North Branch (0.15 µgL^{-1}), Sandy Creek South Branch (0.19 µgL^{-1}) and Cut Creek (0.23 µgL^{-1}), and high compared to all other monitored sub-catchments (Table 3-13).

The 95th percentile concentrations were similar between Ross Creek (0.24 µgL^{-1}) and Sandy Creek at Homebush (0.25 µgL^{-1}), which were both high compared to the end-of-catchment monitoring site at Sandy Creek at Bruce Highway (0.16 µgL^{-1}). In the Draper Creek sub-catchment, the 95th percentile concentration was low amongst all sites (range, 0.010 µgL^{-1} to 0.079 µgL^{-1}) (Table 3-13).

3.2.10.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their mean$_{(BT)}$ concentration were, from highest to lowest: Sandy Creek at Eton, Site 5 (0.10 µgL^{-1}); Sandy Creek South Branch, Site 3 (0.061 µgL^{-1}); Ross Creek, Site 7 (0.044 µgL^{-1}); and Sandy Creek at Bruce Highway, Site 11 (0.041 µgL^{-1}) (Figure 3-25).

The next highest ranked sub-catchments (≥50th <75th percentile) included, from highest to lowest: Draper Creek at Multi-farm, Site 2 (0.029 µgL^{-1}); Sandy Creek North Branch, Site 2.1 (0.028 µgL^{-1}); Cut Creek, Site 4 (0.022 µgL^{-1} (Figure 3-25).

The third grouping of sub-catchments ranked in the ≥25th <50th percentile category included, from highest to lowest mean$_{(BT)}$ isoxaflutole metabolite concentrations: Draper Creek at Peak Downs Highway, Site 6 (0.014 µgL^{-1}); and Draper Creek at De Moleyns Lagoon, Site 1 (0.0066 µgL^{-1}) (Figure 3-25).

The lowest ranked group of sub-catchments included Bagley Creek, Oaky Creek, Frenchmans Creek and BL Creek – isoxaflutole metabolites were not detected above the analytical limit of reporting in any of the samples collected from these sub-catchment monitoring sites (Table 3-13).

The mean$_{(BT)}$ concentration of isoxaflutole metabolites at the main channel site at Sandy Creek at Eton (0.10 µgL^{-1}) was substantially higher than at all other monitored sub-catchments, including the monitored upstream sub-catchments, Sandy Creek North Branch (0.028 µgL^{-1}), Sandy Creek South Branch (0.061 µgL^{-1}) and Cut Creek (0.022 µgL^{-1}) (Table 3-13). Review of the box plots indicates the higher distribution of concentration data at Sandy Creek at Eton compared to all other sites (Figure 3-25). This difference was due to the comparatively high concentration of isoxaflutole metabolites at the Sandy Creek at Eton site during Event 3 and Event 4, which resulted in a wide spread of the positively skewed data. Although the median concentrations of isoxaflutole metabolites were similar between Sandy Creek at Eton (0.080 µgL^{-1}) and Sandy Creek South Branch (0.070 µgL^{-1}), the overall difference in the distribution of the data between these sites indicates that an additional source of isoxaflutole metabolites was likely to have existed between Sandy Creek at Eton and the upstream monitoring sites during the period of monitoring.

The mean$_{(BT)}$ concentration of isoxaflutole metabolites differed between the automated monitoring site at Sandy Creek at Homebush (0.033 µgL^{-1}) and the end-of-catchment monitoring site at Sandy Creek at Bruce Highway (0.41 µgL^{-1}) (Table 3-13). This difference, however, is likely due to the concentration of isoxaflutole metabolites being below the analytical limit of reporting in a much larger number of samples at the Sandy Creek at Homebush site (*n*=25) than at the Sandy Creek at Bruce Highway site (*n*=1) as a result of the sampling undertaken. The substitution of concentration values below the analytical limit of reporting with a value equal to half the limit of reporting reduced the lower quartile of concentration data at the Sandy Creek at Homebush site relative to the Sandy Creek at Bruce Highway site as indicated in the box plots (Figure 3-25). The box plots also show the very high concentrations that were monitored at the Sandy Creek at Homebush site. Based on the box plots it appears that the high concentrations are more likely to have originated from upstream of Sandy Creek at Eton than from Ross Creek, which also had a moderately high distribution of concentration data relative to other sub-catchments.

The $mean_{(BT)}$ concentration of isoxaflutole metabolites in Ross Creek sub-catchment was 0.044 μgL^{-1}, which was high compared to the $mean_{(BT)}$ concentration in the adjacent Draper Creek sub-catchment (Draper Creek at Multi-farm, 0.029 $\mu gL^{-}1$; Draper Creek at Peak Downs Highway, 0.014 μgL^{-1}) – the $mean_{(BT)}$ concentration at Draper Creek at De Moleyns Lagoon was below the analytical limit of reporting. (Table 3-13)

Isoxaflutole metabolites were not detected in Bagley Creek, Oaky Creek, Frenchmans Creek or BL Creek (Table 3-13), possibly indicating this pesticide is not used in these sub-catchments or not used in the recent period prior to the Sandy Creek Sub-catchment Water Quality Monitoring Project.

Table 3-13 Summary statistics for water quality samples analysed for isoxaflutole metabolite.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	22	14	38	29	10	109	35	16	20
Detections. >LOR	23	26	14	25	2	22	9	36	0	0	84	0	0	19
Detection Freq. (%)	79	96	88	100	40	100	64	95	0	0	77	0	0	95
Mean$_{(BT)}$	0.028	0.061	0.022	0.10	*0.0066*	0.029	0.014	0.044	**NC**	**NC**	0.033	**NC**	**NC**	0.041
Std. Dev.	0.48	0.41	0.51	0.52	*0.15*	1.2	0.36	0.48	**NC**	**NC**	0.59	**NC**	**NC**	0.39
Median	0.03	0.07	0.015	0.08	5.00	0.025	0.02	0.04	**NC**	**NC**	0.03	**NC**	**NC**	0.04
95th Percentile	0.15	0.19	0.23	0.72	0.010	0.079	0.047	0.24	**NC**	**NC**	0.25	**NC**	**NC**	0.16
Max. Conc.	0.18	0.45	0.24	1.9	0.01	0.08	0.06	0.37	**NC**	**NC**	0.52	**NC**	**NC**	0.22

n – number of samples analysed; **LOR** –limit of reporting; **Detection Frequency (%)** – the proportion of samples collected at a site which the concentration of isoxaflutole metabolite was above the analytical limit of reporting. **Text in italics** indicates values below the analytical limit of reporting. **NC** – not calculated – the concentration of isoxaflutole metabolite was below the analytical limit of reporting in all samples collected at the site during the monitoring period and descriptive statistics were not calculated.

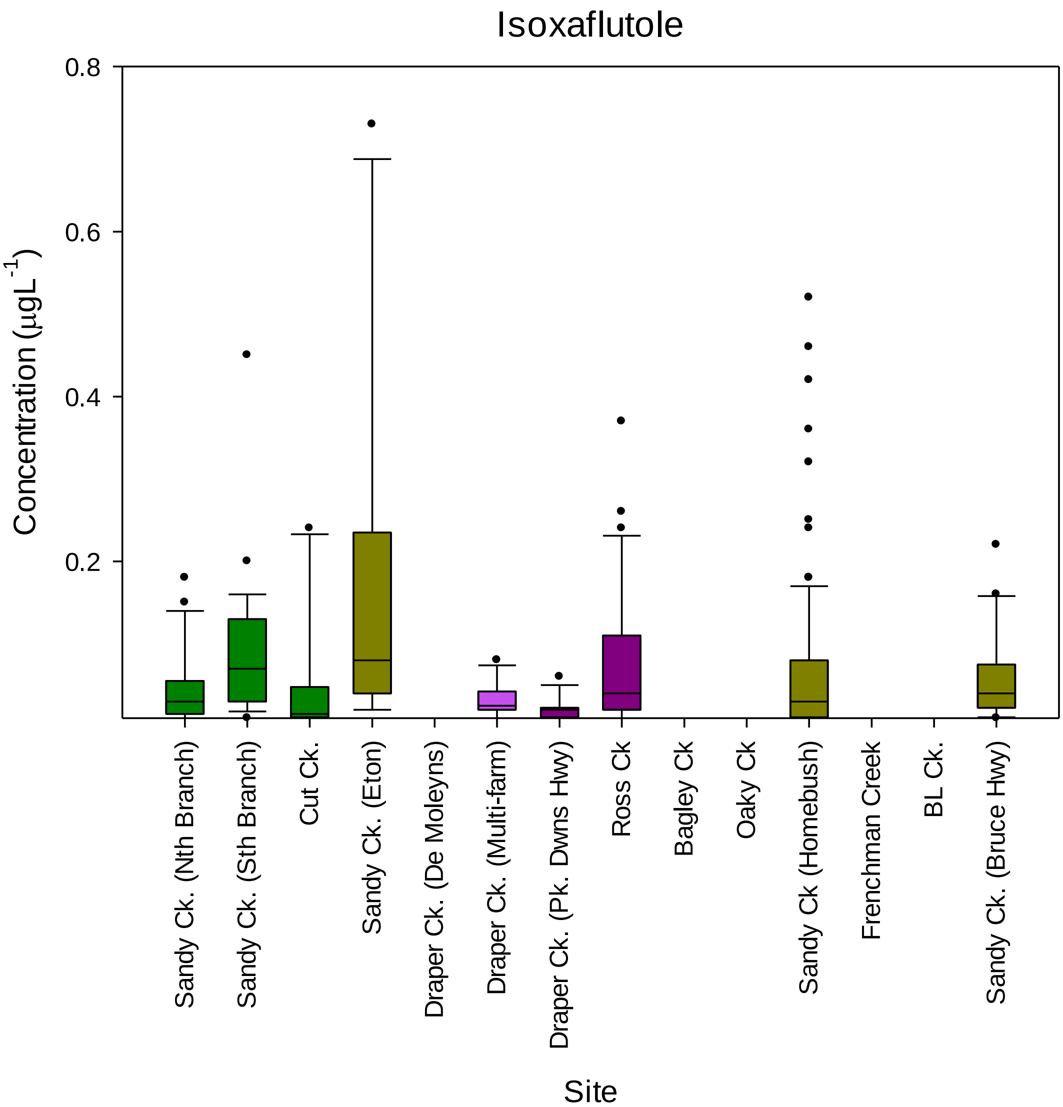

Figure 3-25 Box plot of measured concentration of isoxaflutole metabolites at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles and solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

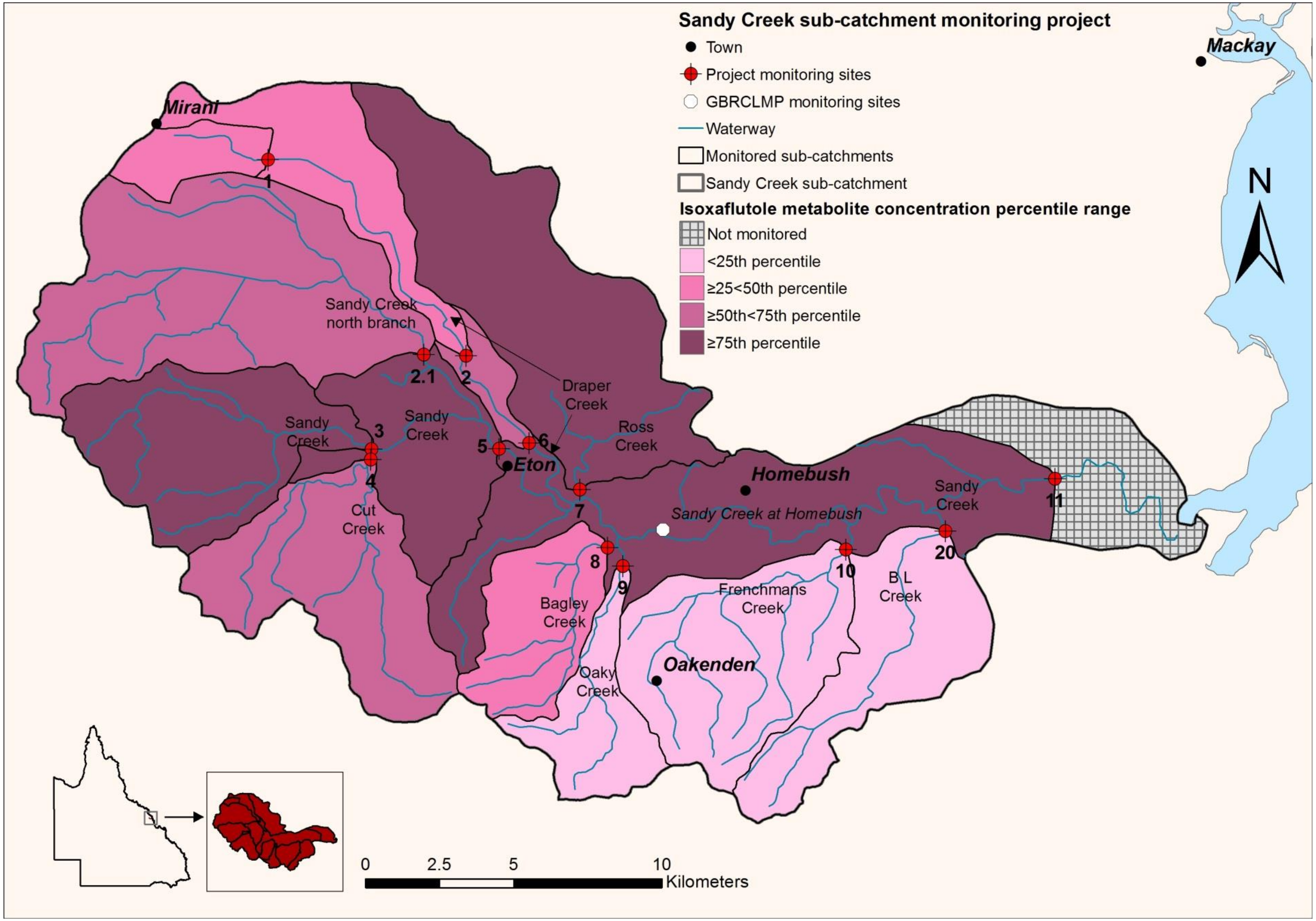

Figure 3-26 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of isoxaflutole metabolites in water samples collected at each sub-catchment during the monitored events. See Table 3-13 for reference of site name to site number.

3.2.11 Metribuzin

Guideline Note –

There are no current ecosystem protection or irrigation guidelines for metribuzin.

The Queensland Department of Science, Information Technology and Innovation are currently reviewing international literature to derive a national ecosystem protection guideline for imidacloprid. The revised ecosystem protection guideline is scheduled for release in 2017.

The derivation of an irrigation residue guideline is not currently scheduled.

3.2.11.1 Detection frequency

Metribuzin was detected above the analytical limit of reporting (<0.02 μgL^{-1}) in 60 per cent of all samples collected as part of the Sandy Creek Sub-catchment Water Quality Monitoring Project (Table 3-2).

In the Sandy Creek North Branch (79 per cent) and Sandy Creek South Branch (85 per cent) sub-catchments, the detection frequency of metribuzin was high and this was reflected in the downstream main channel site at Sandy Creek at Eton (88 per cent) where the detection frequency was also high (Table 3-14).

The detection frequency at the end-of-catchment site, Sandy Creek at Bruce Highway (95 per cent) was higher than the automated site at Sandy Creek at Homebush (Table 3-14) which is due to the continued collection of samples at the Sandy Creek at Homebush site during the later stages of the falling hydrograph. During the falling stage, the concentration of many pesticides are generally low compared to the rising stage and periods of peak discharge.

The detection frequency in the Draper Creek sub-catchment ranged from 60 per cent at Draper Creek at De Moleyns Lagoon to 100 per cent at the Draper Creek at Multi-farm site. The detection frequency was also similar in the adjacent Ross Creek sub-catchment (76 per cent), and low in Bagley Creek (21 per cent) and Frenchmans Creek (9 per cent) (Table 3-14).

Metribuzin was not detected above the analytical limit of reporting in BL Creek or Oaky Creek (Table 3-14).

3.2.11.2 Distribution of Concentrations

Very high concentrations of metribuzin were monitored at all main channel sites following the intense rainfall on 4th January 2016: Sandy Creek at Eton (11 μgL^{-1}), Sandy Creek at Homebush (4.5 μgL^{-1}) and Sandy Creek at Bruce Highway (3.8 μgL^{-1}). Consultation with participating growers of the Sandy Creek Sub-catchment Water Quality Monitoring Project, indicated that a local grower upstream of Sandy Creek at Eton had applied metribuzin immediately prior to this event as the forecast rainfall had been low. The application was made on a day of forecast rainfall of 5mm to 15 mm – similar forecasts had been issued over the preceding weeks without any local rainfall in the Sandy Creek catchment.

On the 4th January, following application of metribuzin by the identified grower, an isolated storm resulted in approximately 70 mm of rain at the property. The grower highlighted that it was very unlikely that any other local growers had applied metribuzin at this period, and the elevated concentration of metribuzin monitored at all main channel sites downstream originated from the single application on this one property (Figure 3-27).

The property from which the metribuzin was likely lost, is part of one of the most progressive farming operations in the district, having been early adopters of advanced farming practices to reduce off-farm loss of pesticides and transitioned to alternative pesticides ahead of the their peers. This case highlighted very strongly within the participating growers, that storm events at the onset of the wet season represent a very high risk both to farming operations with respect to financial loss and the potential reduced efficacy of chemical application but also the risk to water quality downstream.

The maximum detected concentration of metribuzin in all other sub-catchments was in the range, 0.04 μgL^{-1} to 0.81 μgL^{-1} (Table 3-14).

3.2.11.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. Although there is no current water quality guideline trigger values for metribuzin, future guideline values should be compared against the following results.

The 95th percentile concentration of metribuzin was high at all main channel sites, with the 95th percentile concentration decreasing in a downstream direction from Sandy Creek at Eton (6.5 μgL^{-1}), Sandy Creek at Homebush (2.0 μgL^{-1}) and Sandy Creek at Bruce Highway (1.2 μgL^{-1}) (Table 3-14). Among all other sub-catchments, the 95th percentile concentrations of metribuzin were comparatively low (range, 0.026 μgL^{-1} to 0.75 μgL^{-1}) (Table 3-14).

3.2.11.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their $mean_{(BT)}$ metribuzin concentration were, from highest to lowest: Sandy Creek at Eton, Site 5 (0.67 μgL^{-1}); Sandy Creek at Bruce Highway, Site 11 (0.20 μgL^{-1}); Draper Creek at De Moleyns Lagoon, Site 1 (0.11 μgL^{-1}); and, Sandy Creek South Branch, Site 3 (0.082 μgL^{-1}) (Figure 3-28).

The next highest ranked sub-catchments (≥50th <75th percentile) were located in the north-west section of the Sandy Creek catchment and included, from highest to lowest: Ross Creek, Site 7 (0.071 μgL^{-1}); Sandy Creek North Branch, Site 2.1 (0.067 μgL^{-1}); and Draper Creek Multi-farm, Site 2 (0.063 μgL^{-1}) (Figure 3-28).

The third grouping of sub-catchments ranked in the ≥25th <50th percentile category included, from highest to lowest $mean_{(BT)}$ metribuzin concentrations: Draper Creek at Peak Downs Highway, Site 6 (0.038 μgL^{-1}); Cut Creek, Site 4 (0.019 μgL^{-1}); and Bagley Creek, Site 8 (0.015 μgL^{-1}) (Figure 3-28).

The lowest ranked group of sub-catchments based on the $mean_{(BT)}$ metribuzin concentrations were located in the south-eastern section of the catchment and included, from highest to lowest: Frenchmans Creek, Site 10 (0.011 μgL^{-1}); and Oaky Creek and BL creeks for which there were no detections above the analytical limit of reporting (Figure 3-28).

As outlined above, consultation with participating growers identified the high concentrations monitored at Sandy Creek at Eton were attributable to an upstream property where metribuzin was applied in the period immediately prior to Event 3. The pulse of metribuzin from this property was detected at all three main channel sites during this event, reaching Sandy Creek at Homebush 12 hours after Sandy Creek at Eton and taking three days to reach the Sandy Creek at Bruce Highway monitoring site. It is worth emphasising that although the local rainfall totals were high on the affected property, the storm cell was small and generally resulted in low rainfall totals across much of the Sandy Creek catchment.

The $mean_{(BT)}$ concentration of metribuzin at the main channel sites decreased in a downstream direction: Sandy Creek at Eton (0.67 μgL^{-1}), Sandy Creek at Homebush (0.051 μgL^{-1}), Sandy Creek at Bruce Highway (0.20 μgL^{-1}) (Table 3-14), with the lower $mean_{(BT)}$ concentration at Sandy Creek at Homebush due to the high number of samples collected at this site including during extended periods of the falling hydrograph when the concentration of many pesticides is low compared to the rising hydrograph or period of peak discharge. The box plot displays the dissimilarity of the main channel sites from all other monitored sub-catchment sites (Figure 3-25).

In the upper Sandy Creek catchment, the $mean_{(BT)}$ concentration of metribuzin was similar between the Sandy Creek North Branch and Sandy Creek South Branch sub-catchments (Table 3-14).

The $mean_{(BT)}$ concentration of metribuzin in Draper Creek increased between Draper Creek at De Moleyns Lagoon and Draper Creek Peak Downs Highway. The $mean_{(BT)}$ concentration in Ross Creek was similar to the adjacent Draper Creek (Table 3-14). And, in Bagley Creek and Frenchmans Creek the concentration of metribuzin was low (Table 3-14).

Table 3-14 Summary statistics for water quality samples analysed for metribuzin.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	23	23	6	22	3	40	9	29	6	0	76	3	0	19
Detection Freq. (%)	79	85	38	88	60	100	64	76	21	0	70	9	0	95
Mean$_{(BT)}$	0.067	0.082	0.019	0.67	0.11	0.063	0.038	0.071	0.015	**NC**	0.051	0.011	**NC**	0.20
Std. Dev.	0.55	0.50	0.39	0.92	0.86	0.37	0.49	0.60	0.39	**NC**	0.90	0.15	**NC**	0.52
Median	0.08	0.11	0.01	1.7	0.38	0.075	0.05	0.085	0.010	**NC**	0.03	0.01	**NC**	0.15
95th Percentile	0.40	0.34	0.12	6.5	0.75	0.19	0.14	0.53	0.11	**NC**	2.0	0.026	**NC**	1.2
Max. Conc. (µgL^{-1})	0.43	0.40	0.16	11	0.81	0.21	0.15	0.59	0.23	**NC**	4.5	0.04	**NC**	3.8

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency (%)** – the proportion of samples collected at a site which the concentration of metribuzin was above the analytical limit of reporting. **NC** – not calculated – the concentration of metribuzin was below the analytical limit of reporting in all samples collected at the site during the monitoring period and descriptive statistics were not calculated.

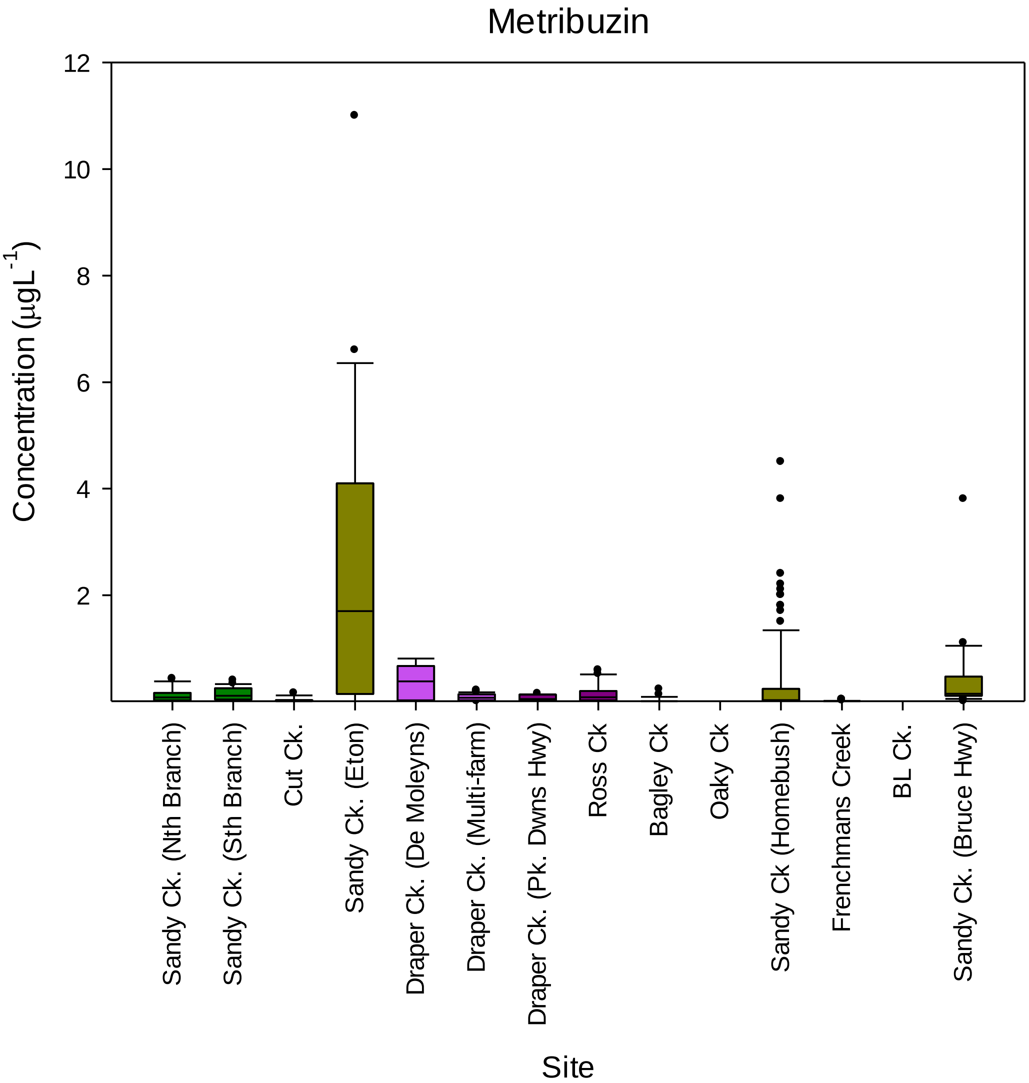

Figure 3-27 Box plot of measured concentrations of metribuzin at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles, solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

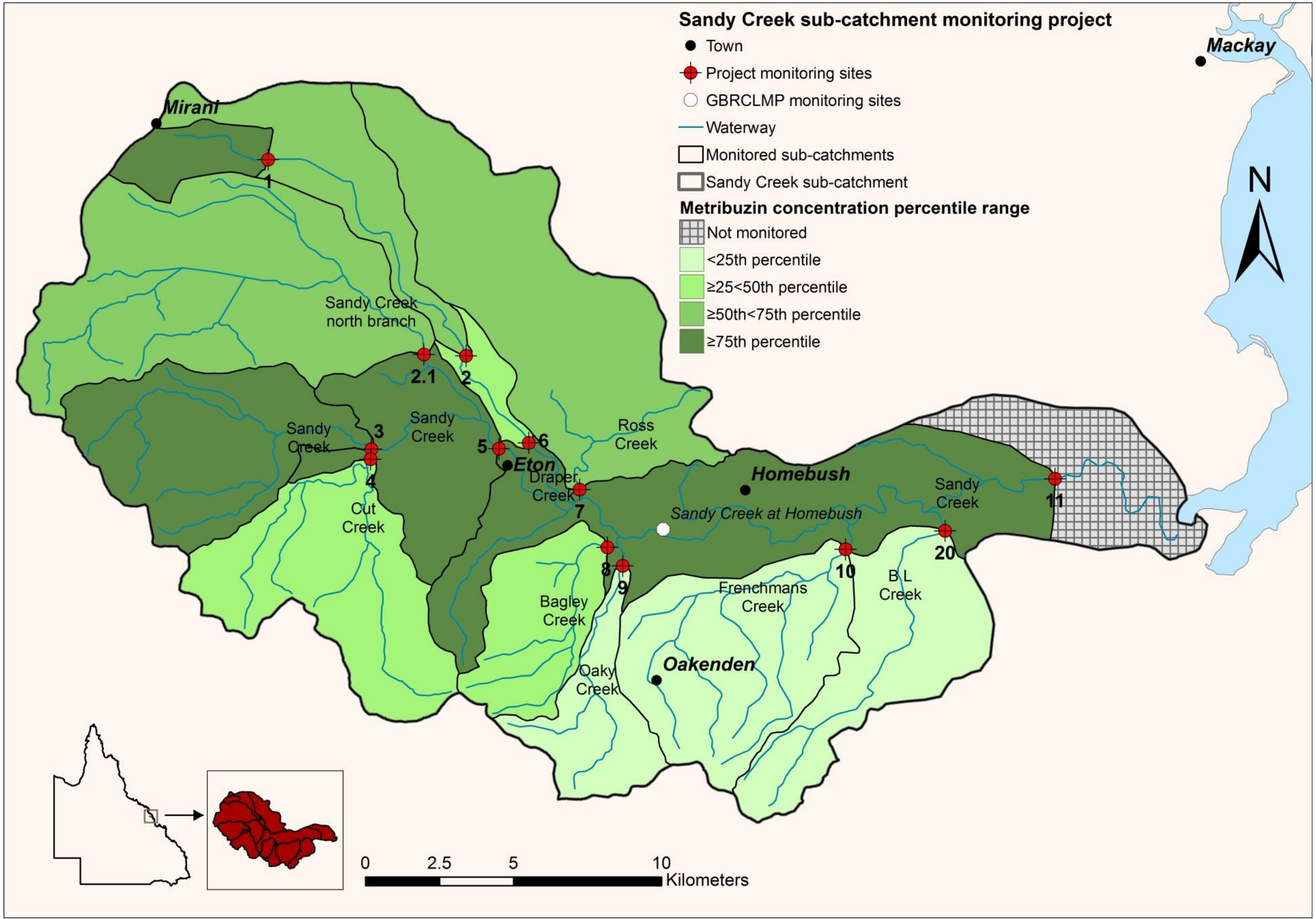

Figure 3-28 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of metribuzin in water samples collected at each sub-catchment during the monitored events. See Table 3-14 for reference of site name to site number.

3.2.12 Metolachlor

Guideline Note –

The current ecosystem protection guideline trigger value (ANZECC and ARMCANZ 2000) for metolachlor in freshwater ecosystems is:

- *A low reliability trigger value of 0.02 µgL^{-1}, calculated using the assessment factor method. This value does not correspond with a protection level (e.g. 95% species protection) and should only be used as an interim indicative working level.*

Work is currently being undertaken by the Queensland Government to revise the national ecosystem protection guideline for metolachlor which is scheduled for release in 2017.

3.2.12.1 Detection frequency

Metolachlor was detected above the analytical limit of reporting (<0.01 µgL^{-1}) in 53 per cent of all samples collected across all monitored sub-catchments (Table 3-2). The detection frequency of metolachlor was above 50 per cent at eight sites with the highest detection frequencies occurring in Ross Creek (92 per cent), Draper Creek (Multi-farm, 86 per cent) and Sandy Creek North Branch (79 per cent). The detection frequency at all main channel sites was high (range, 85 to 89 per cent) (Table 3-15).

It is notable the metolachlor was not detected in BL Creek and only detected in a single sample at Frenchmans Creek during the first event. Metolachlor was also below the analytical limit of reporting in all samples collected at Oaky Creek and in all but two samples collected at Cut Creek (Table 3-15). These latter two sites only commenced to flow during the two large events of February and March and the observed concentration of most pesticides in these catchments was near to the analytical limit of reporting.

3.2.12.2 Distribution of concentrations

The highest monitored concentrations of metolachlor were within the upper Sandy Creek sub-catchment sites of Sandy Creek at North Branch (27 µgL^{-1}) and Sandy Creek at South Branch (4.1 µgL^{-1}) which are both likely to have contributed to the comparatively high maximum concentration at the downstream site on the main channel at Eton (6.4 µgL^{-1}) (Table 3-15).

The maximum concentration at all other sites was comparatively low, with only Ross (1.6 µgL^{-1}) and the main channel sites at Sandy Creek at Homebush (1.3 µgL^{-1}) and Sandy Creek at Bruce Highway (1.1 µgL^{-1}) exceeding 1.0 µgL^{-1} (Table 3-15).

The pattern between sub-catchments of the general distribution of concentrations (25th – 75th percentile) of metolachlor was somewhat similar to isoxaflutole metabolite in that the principle sources of isoxaflutole metabolite in the main channel were from the upper catchment above the Sandy Creek at Eton site and Ross Creek site (Figure 3-29). The only other sources, but at a much lower level, were Draper Creek, Bagley Creek and Frenchmans Creek.

3.2.12.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. The current water quality guideline trigger values for metolachlor is 0.02 µgL^{-1}, which was exceeded by the 95th percentile concentration at all sites.

The 95th percentile concentrations were high in Sandy Creek North Branch (3.3 μgL^{-1}) and the downstream main channel site at Sandy Creek at Eton (1.6 μgL^{-1}). The 95th percentile concentration was also high in Ross Creek (1.3 μgL^{-1}) and the lower main channel sites at Sandy Creek at Homebush (0.99 μgL^{-1}) and Sandy Creek at Bruce Highway (1.0 μgL^{-1}) (Table 3-15).

In Sandy Creek South Branch (0.60 μgL^{-1}) and Cut Creek (0.11 μgL^{-1}), the 95th percentile concentrations were relatively low compared to Sandy Creek North Branch and the downstream site, Sandy Creek at Eton (Table 3-15).

The 95th percentile concentration was similar amongst all sites in Draper Creek sub-catchment (range, 0.16 μgL^{-1} to 0.19 μgL^{-1}), which was notably low compared to the adjacent Ross Creek (1.3 μgL^{-1}) sub-catchment (Table 3-15).

The 95th percentile concentration of metolachlor in Bagley Creek was 0.56 μgL^{-1}. Metolachlor was not detected above the analytical limit of reporting in Oaky Creek or BL Creek and only detected in one sample collected in Frenchmans Creek where the 95th percentile was below the analytical limit of reporting (Table 3-15).

3.2.12.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their mean$_{(BT)}$ concentration were, from highest to lowest: Ross Creek, Site 7 (0.29 μgL^{-1}); Sandy Creek at Bruce Highway, Site 11 (0.18 μgL^{-1}); Sandy Creek North Branch, Site 2.1 (0.15 μgL^{-1}); and, Sandy Creek at Eton, Site 5 (0.14 μgL^{-1}) (Figure 3-30).

The next highest ranked sub-catchments (≥50th <75th percentile) included, from highest to lowest: Bagley Creek, Site 8 (0.084 μgL^{-1}); Draper Creek at De Moleyns Lagoon, Site 1 (0.078 μgL^{-1}); Sandy Creek South Branch, Site 3 (0.072 μgL^{-1}) (Figure 3-30).

The third grouping of sub-catchments ranked in the ≥25th <50th percentile category included, from highest to lowest mean$_{(BT)}$ metolachlor concentrations: Draper Creek at Multi-farm, Site 2 (0.072 μgL^{-1}); Draper Creek at Peak Downs Highway, Site 6 (0.070 μgL^{-1}); and Cut Creek, Site 4 (0.041 μgL^{-1}) (Figure 3-30). It is noted that the mean$_{(BT)}$ metolachlor concentration at Sandy Creek South Branch and Draper Creek at Multi-farm was 0.072 μgL^{-1} – the categorical separation of these sites was based on unrounded mean$_{(BT)}$ concentration data.

The lowest ranked group of sub-catchments based on the mean$_{(BT)}$ metolachlor concentrations were located in the southern section of the catchment and included, from highest to lowest: Frenchmans Creek, Site 10 (0.036 μgL^{-1}); and Oaky and BL creeks for which there were no detections of metolachlor above the analytical limit of reporting (Figure 3-30).

The mean$_{(BT)}$ concentration of metolachlor in Ross Creek was very high compared to all other monitored sub-catchments including four times higher than the adjacent Draper Creek sub-catchment (Peak Downs Highway, 0.070 μgL^{-1}) (Table 3-15) – for many of the frequently detected chemicals the mean$_{(BT)}$ concentrations were similar in these two sites. Review of the box plots supports Ross Creek as the sub-catchment with the most highly distributed concentration data (Figure 3-29). The median concentration of metolachlor in the Ross Creek sub-catchment was more than twice the median concentration monitored in all other sub-catchments (Table 3-15), which differs from the observed pattern of concentration for other pesticides. The higher concentration distribution of metolachlor in Ross Creek is due to the sustained elevated concentrations during Event 3 to Event 5, with a very high detection frequency above the analytical limit of reporting compared to other monitored sub-catchment (Table 3-15).

The $mean_{(BT)}$ concentration was similarly high between the Sandy Creek main channel sites, Sandy Creek at Eton, Sandy Creek at Homebush and Sandy Creek at Bruce Highway, which is supported by review of the box plots, which also show similarity in the concentration distribution between these sites (Table 3-15 and Figure 3-29).

Within the upper sub-catchment sites, Sandy Creek North Branch appears to have had a large contribution to detections at the main channel site, Sandy Creek at Eton, compared to Sandy Creek South Branch, which had a much lower $mean_{(BT)}$ concentration. The high proportion of samples below the analytical limit of reporting negatively skewed the data in Sandy Creek South Branch resulting in $mean_{(BT)}$ and median concentrations below the analytical limit of reporting (Table 3-15). This result is supported by review of the box plot; however, the higher distribution of the concentrations at Sandy Creek at Eton compared to the Sandy Creek North Branch sub-catchment may indicate an additional input source of metolachlor between these monitoring sites or sampling bias at the Sandy Creek at Eton site towards periods of higher concentrations (Figure 3-29).

The $mean_{(BT)}$ concentration was similar between all sites in the Draper Creek sub-catchment (Table 3-15). The distribution of metolachlor concentration data was generally similar between sites in Draper Creek, taking into account the low number of samples at the Draper Creek at De Moleyns Lagoon site in the upper catchment and high total number of samples collected at the Draper Creek at Multi-farm site. The maximum monitored concentration of metolachlor was similar amongst these sites (Table 3-15).

The $mean_{(BT)}$ concentration of metolachlor in Bagley Creek on the southern side of the Sandy Creek catchment was similar to Draper Creek, although the overall distribution of the concentration data was influenced by higher maximum concentrations in Bagley Creek (Table 3-15).

Metolachlor was only detected in a single sample at Frenchmans Creek, which is notable given the frequency of detection and concentration range of other pesticides in this sub-catchment. Metolachlor was not detected in the adjacent BL Creek sub-catchment (Table 3-15). This result may suggest very low usage of metolachlor in this area of the Sandy Creek sub-catchment or differences in soil type or method and timing of application.

Table 3-15 Summary statistics for water quality samples analysed for metolachlor.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	23	11	2	14	3	36	7	35	14	0	97	1	0	17
Detection Freq. (%)	79	41	13	56	60	86	50	92	48	0	89	3	0	85
Mean(BT)	0.15	0.072	0.041	0.14	0.078	0.072	0.070	0.29	0.084	**NC**	0.11	0.036	**NC**	0.18
Std. Dev.	0.64	0.50	0.18	0.63	0.30	0.20	0.31	0.51	0.43	**NC**	0.67	0.11	**NC**	0.48
Median	0.13	0.035	0.035	0.16	0.10	0.07	0.068	0.34	0.035	**NC**	0.11	0.035	**NC**	0.15
95^{th} Percentile	3.3	0.60	0.11	1.6	0.18	0.16	0.19	1.32	0.56	**NC**	0.99	0.04	**NC**	1.0
Max. Conc.	27	4.1	0.14	6.4	0.20	0.18	0.27	1.6	0.62	**NC**	1.3	0.15	**NC**	1.1

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency (%)** – the proportion of samples collected at a site which the concentration of metolachlor was above the analytical limit of reporting; **NC** – not calculated – the concentration of metolachlor was below the analytical limit of reporting in all samples collected at the site during the monitoring period and descriptive statistics were not calculated.

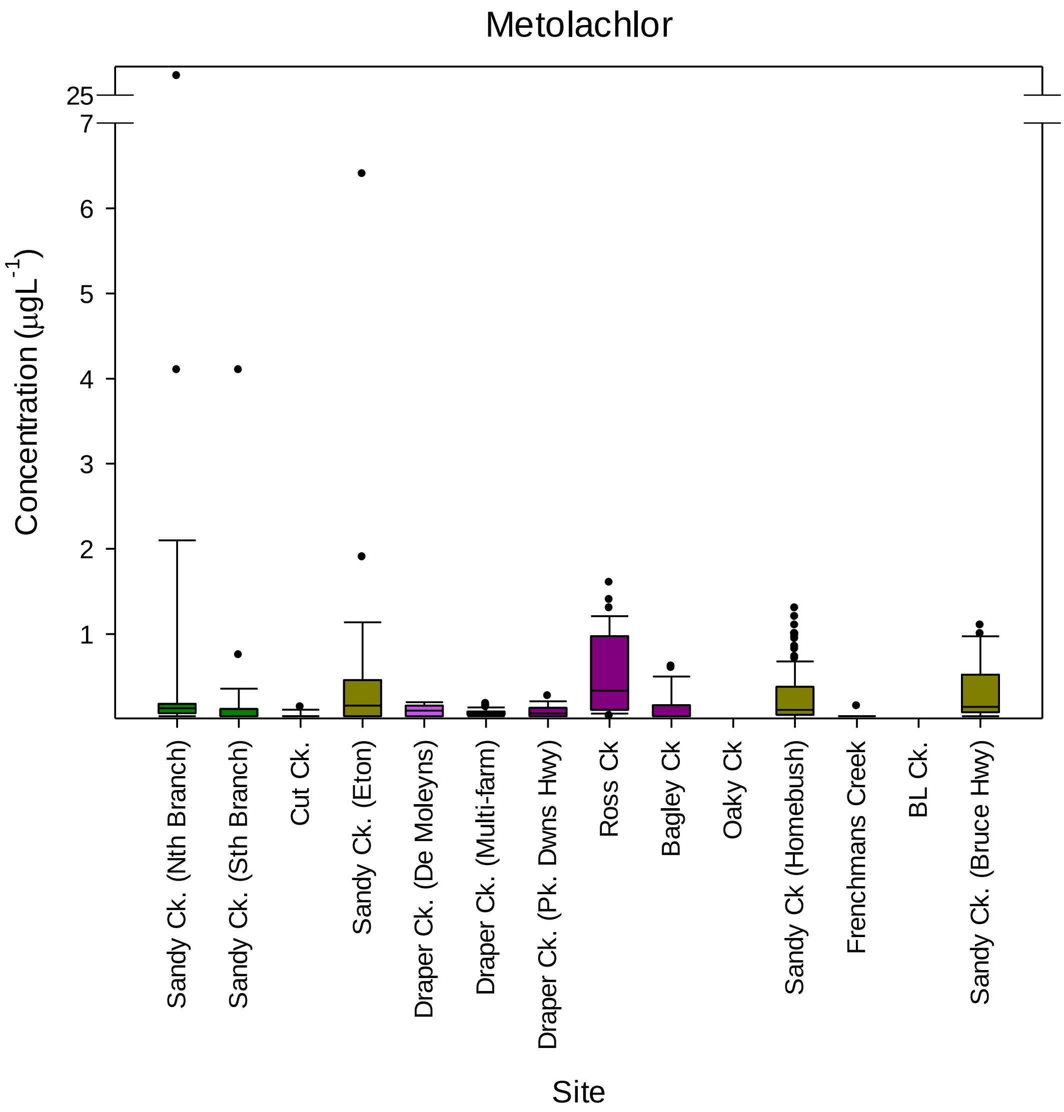

Figure 3-29 Box plot of measured concentration of metolachlor at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles and solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

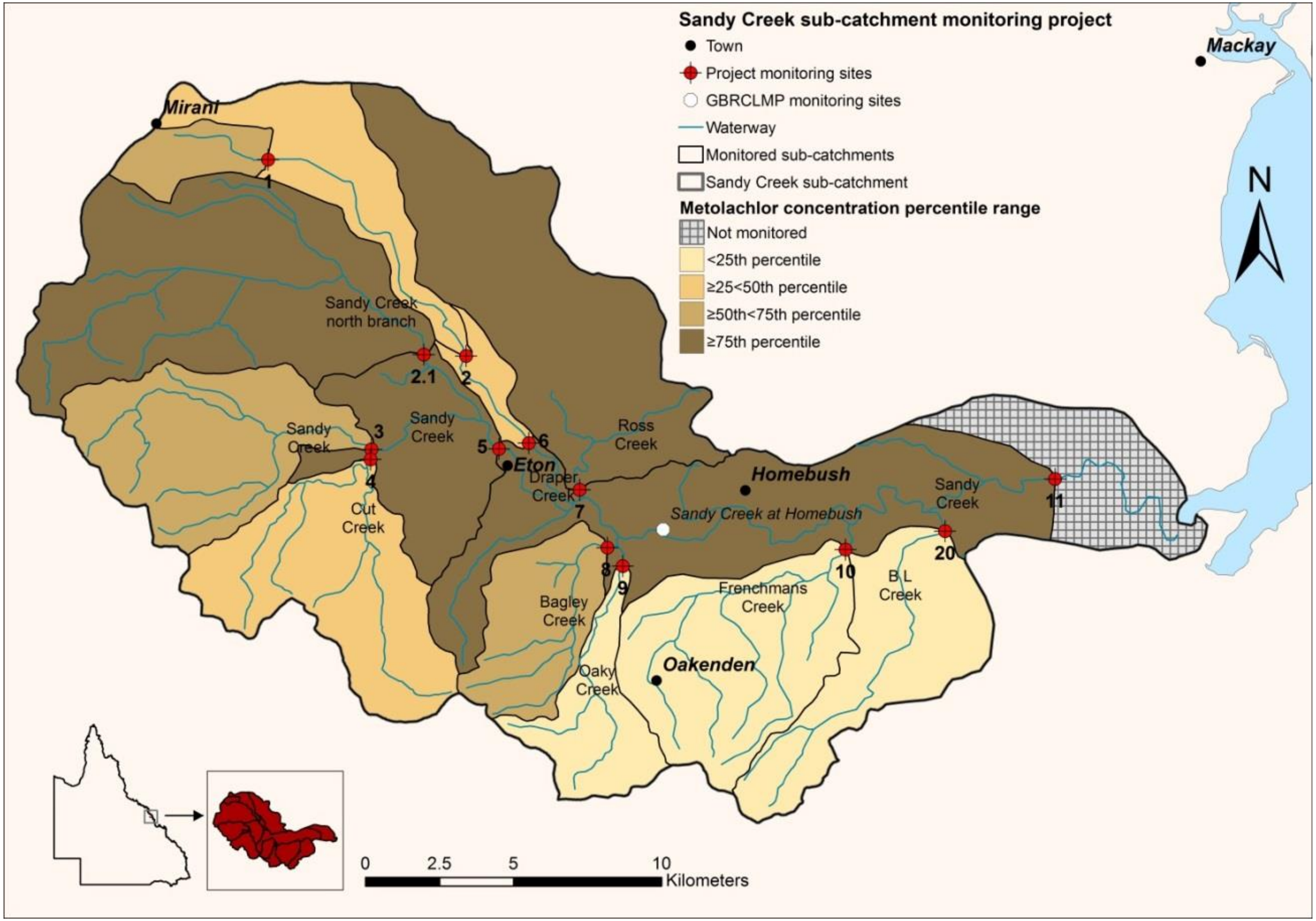

Figure 3-30 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of metolachlor in water samples collected at each sub-catchment during the monitored events. See Table 3-15 for reference of site name to site number.

3.2.13 Ametryn

Guideline Note –

There are no current ecosystem protection or irrigation guidelines for ametryn.

The Queensland Department of Science, Information Technology and Innovation are currently reviewing international literature to derive a national ecosystem protection guideline for ametryn. The revised ecosystem protection guideline is scheduled for release in 2017.

The derivation of an irrigation residue guideline is not currently scheduled.

3.2.13.1 Detection frequency

Ametryn was detected above the analytical limit of reporting (<0.01 μgL^{-1}) in 49 per cent of samples collected across all sites (Table 3-2). The highest frequency of detection was observed at the end-of-catchment monitoring site at Bruce Highway (100 per cent), which was approximately twice the detection frequency at the automated site at Homebush (57 per cent) (Table 3-16) and is likely due to the continuation of sample collection during periods of expectedly lower concentrations (i.e. falling hydrograph) at the Sandy Creek at Homebush site.

The detection frequency of ametryn was similar between Ross Creek (89 per cent) where ametryn was detected in all monitored events, and Frenchmans Creek (83 per cent) (Table 3-16) where ametryn was detected in all events except Event 7. Bagley Creek also had a comparatively high overall frequency of detection (69 per cent) with monitored concentrations above the analytical limit of reporting in all monitored events.

In the Sandy Creek North Branch (52 per cent) sub-catchment and main channel monitoring site, Sandy Creek at Eton (56 per cent), ametryn was detected above the analytical limit of reporting in all monitored events except Event 7, during which the concentration in all samples at both sites were less than 0.01 μgL^{-1} (Table 3-16). Ametryn was not detected above the analytical limit of reporting in Sandy Creek South Branch and only detected above the analytical limit of reporting at Cut Creek in the first sample collected during the commencement to flow in Event 6. The concentration of ametryn in all other samples collected at Cut Creek was less than 0.01 μgL^{-1}.

Ametryn was detected in 50 per cent of samples collected in the Oaky Creek sub-catchment (Table 3-16), with the concentration below the analytical limiting of reporting in all samples collected during Event 7.

In all other sub-catchments the detection frequency was less than 50 per cent, with the lowest detection frequency occurring in Cut Creek (6 per cent) and below the analytical limit of reporting in all samples collected in BL Creek, Draper Creek at De Moleyns Lagoon and Sandy Creek South Branch sub-catchments (Table 3-16).

3.2.13.2 Distribution of concentrations

The highest monitored concentration of ametryn across all sites, 4.2 μgL^{-1}, was monitored at the main channel site located at Sandy Creek at Homebush (Table 3-16). This high concentration was observed in the first sample collected during Event 2.The highest concentration of ametryn in Ross Creek (1.4 μgL^{-1}) also occurred during this same event. As few sites received sufficient rainfall during this period to generate runoff, this result may indicate Ross Creek as the source of ametryn that contributed to the high monitored concentrations at the Sandy Creek at Homebush site (Figure 3-31).

The maximum concentration among the remaining sub-catchment sites was comparatively moderate between Bagley Creek (0.60 μgL^{-1}), Sandy Creek at Bruce Highway (0.53 μgL^{-1}) and Frenchmans Creek (0.32 μgL^{-1}), and low in all other sub-catchments where ametryn was detected above the analytical limit of reporting (Table 3-16).

The pattern between sub-catchments of the general distribution of concentrations (25th – 75th percentile) of ametryn mirrored the patterns of the maximum concentrations (Figure 3-31).

3.2.13.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. Although there is no current water quality guideline trigger values for ametryn, future guideline values should be compared against the following results.

The highest 95th percentile concentration was in Ross Creek (0.36 μgL^{-1}), which was driven by elevated concentrations in Event 2 to Event 4. The peaks in concentration in Ross Creek between events closely match the timing in the rise of concentration at both the Sandy Creek at Homebush and Sandy Creek at Bruce Highway sites where the 95th percentile concentrations were, 0.33 μgL^{-1} and 0.23 μgL^{-1}, respectively (Table 3-16).

The 95th percentile concentration at all other sites was less than or equal to 0.11 μgL^{-1} (Table 3-16). It is notable though that the 95th percentile concentration and detection frequency of ametryn is higher at the Sandy Creek at Eton site than each of the upstream tributaries, indicating a possible source between these respective sites.

3.2.13.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their mean$_{(BT)}$ concentration were located throughout the Sandy Creek sub-catchment and included, from highest to lowest: Sandy Creek at Bruce Highway, Site 11 (0.055 μgL^{-1}); Ross Creek, Site 7 (0.047 μgL^{-1}); Frenchmans Creek, Site 10 (0.025 μgL^{-1}); and, Bagley Creek, Site 8 (0.020 μgL^{-1}) (Figure 3-32).

The next highest ranked sub-catchments (≥50th<75th percentile) occurred principally in the upper catchment with one exception (Oaky Creek) and included, from highest to lowest: Sandy Creek at Eton, Site 5 (0.017 μgL^{-1}); Sandy Creek North Branch, Site 2.1 (0.013 μgL^{-1}); and Oaky Creek, Site 9 (0.0091 μgL^{-1}) (Figure 3-32).

The third grouping of sub-catchments ranked in the ≥25th<50th percentile category included, from highest to lowest mean$_{(BT)}$ ametryn concentrations: Draper Creek at Peak Downs Highway, Site 6 (0.0088 μgL^{-1}); Draper Creek at Multi-farm, Site 2 (0.0065 μgL^{-1}); and, Cut Creek, Site 4 (0.0052 μgL^{-1}) (Figure 3-32).

The lowest ranked group of sub-catchments based on the mean$_{(BT)}$ ametryn concentrations were, from highest to lowest: Sandy Creek South Branch, Site 3, Draper Creek at De Moleyns Lagoon, Site 1, and BL Creek, Site 20, for which no concentrations were detected above the analytical limit of reporting (Figure 3-32).

The highest mean$_{(BT)}$ concentrations of ametryn were monitored at the end-of-catchment site at Sandy Creek at Bruce Highway (0.055 μgL^{-1}) and in Ross Creek (0.047 μgL^{-1}) (Table 3-16). The mean$_{(BT)}$ concentration of ametryn was similar between Frenchmans Creek (0.025 μgL^{-1}) and Bagley Creek (0.020 μgL^{-1}) and the main channel sites at Sandy Creek at Homebush (0.019 μgL^{-1}) and Sandy Creek at Eton (0.017 μgL^{-1}).

Review of the box plots for the Sandy Creek at Bruce Highway and Ross Creek sites, supports the higher overall distribution of concentration data within these monitored sub-catchments relative to other monitored sub-catchments (Figure 3-32).

The $mean_{(BT)}$ concentration of ametryn in the Sandy Creek North Branch sub-catchment (0.013 μgL^{-1}) was notably less than the downstream site of Sandy Creek at Eton – ametryn was not detected in Sandy Creek South Branch and the $mean_{(BT)}$ concentration of ametryn in the Cut Creek sub-catchment was below the analytical limit of reporting (Table 3-16). This result, combined with review of the distribution of the concentration data presented in the box plot (Figure 3-31) further supports an input source of ametryn between the Sandy Creek at Eton monitoring site and nested upstream monitoring sites.

The $mean_{(BT)}$ concentration of ametryn in Cut Creek, Draper Creek (Multi-farm and Peak Downs Highway) and Oaky Creek were all below the analytical limit of reporting (Table 3-16).

Table 3-16 Summary statistics for water quality samples analysed for ametryn.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	15	0	1	14	0	8	5	34	20	5	62	29	0	20
Detection Freq. (%)	52	0	6	56	0	19	36	89	69	50	57	83	0	100
Mean$_{(BT)}$	0.013	NC	*0.0052*	0.017	NC	*0.0065*	*0.0088*	0.047	0.020	*0.0091*	0.019	0.025	NC	0.055
Std. Dev.	0.40	NC	0.07	0.51	NC	0.25	0.36	0.55	0.53	0.32	0.68	0.45	NC	0.36
Median	0.01	NC	*0.005*	0.03	NC	*0.005*	*0.005*	0.045	0.03	*0.008*	0.01	0.03	NC	0.055
95th Percentile	0.04	NC	0.01	0.09	NC	0.02	0.04	0.36	0.11	0.04	0.33	0.11	NC	0.23
Max. Conc.	0.04	NC	0.01	0.13	NC	0.04	0.05	1.40	0.60	0.04	4.20	0.32	NC	0.53

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency (%)** – the proportion of samples collected at a site which the concentration of ametryn was above the analytical limit of reporting. **Text in italics** indicates values below the analytical limit of reporting. **NC** – not calculated – the concentration of ametryn was below the analytical limit of reporting in all samples collected at the site during the monitoring period and descriptive statistics were not calculated.

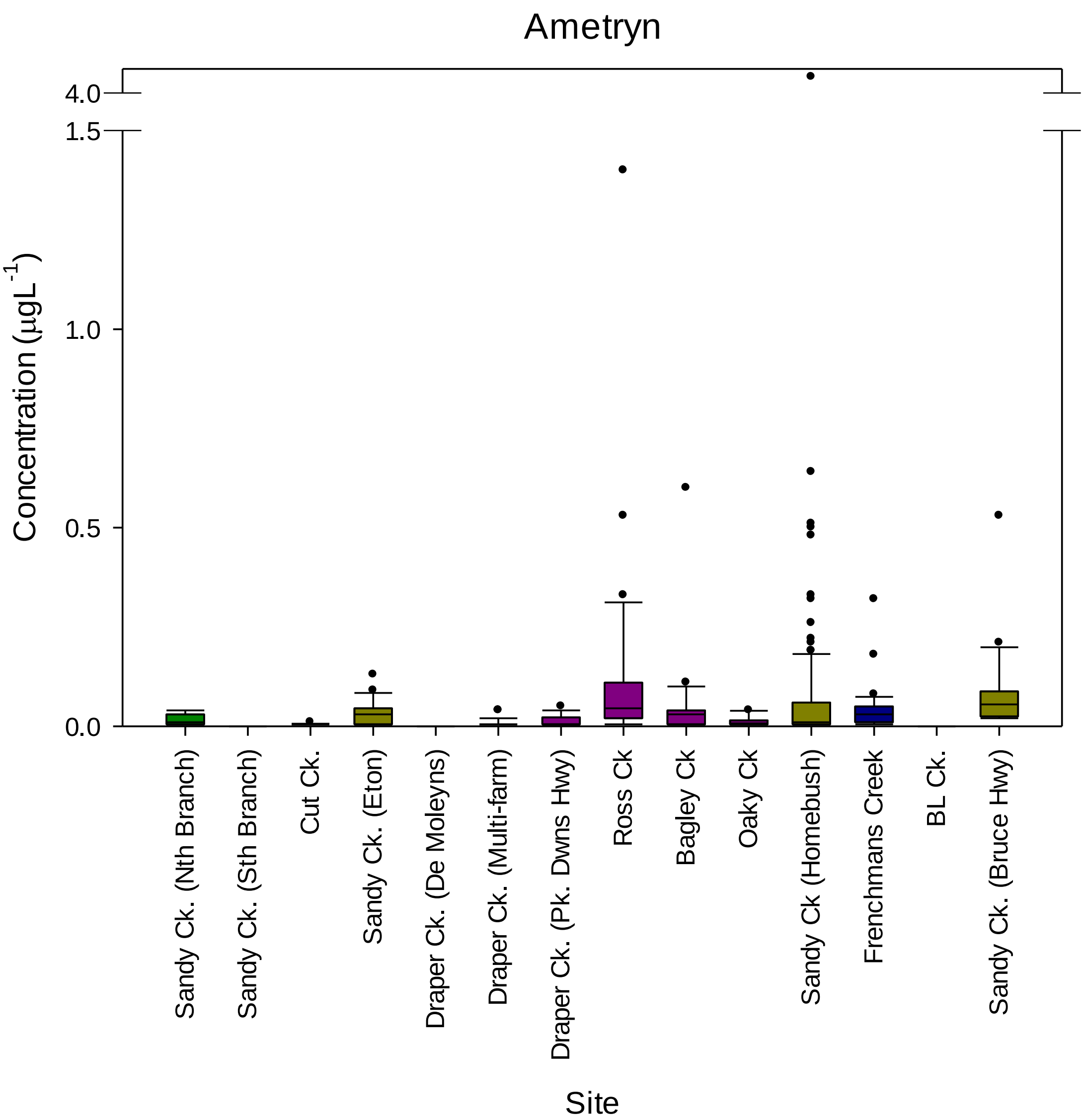

Figure 3-31 Box plot of measured concentration of ametryn at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles, solids dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

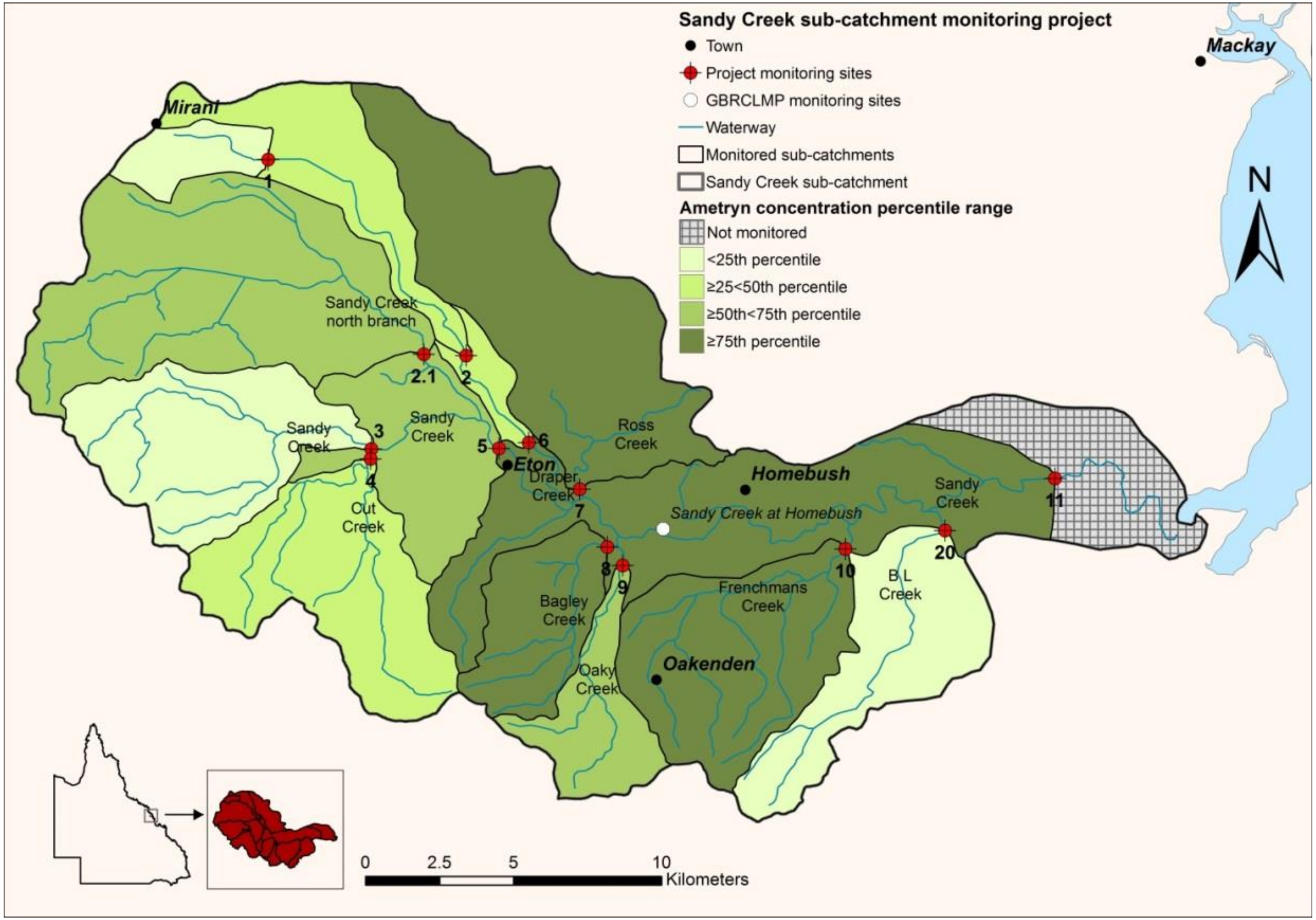

Figure 3-32 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of ametryn in water samples collected at each sub-catchment during the monitored events. See Table 3-16 for reference of site name to site number.

3.2.14 Imazethapyr

Guideline Note –

There are no current ecosystem protection or irrigation guidelines for imazethapyr.

The Queensland Department of Science, Information Technology and Innovation are currently reviewing international literature to derive a national ecosystem protection guideline for imazethapyr. The revised ecosystem protection guideline is scheduled for release in 2017.

The derivation of an irrigation residue guideline is not currently scheduled.

3.2.14.1 Detection frequency

Imazethapyr was detected above the analytical limit of reporting in 44 per cent of all samples collected as part of the Sandy Creek Sub-catchment Water Quality Monitoring Project (Table 3-2). Imazethapyr was, however, only detected in comparatively few sub-catchments relative to other pesticides with similar detection frequencies (Table 3-3 and Table 3-4).

Imazethapyr was detected in Sandy Creek North Branch (72 per cent) and at the downstream main channel site Sandy Creek at Eton (68 per cent). However, imazethapyr was not detected in either Sandy Creek South Branch or Cut Creek (Table 3-17).

The frequency of detection was high in Ross Creek (82 per cent) and Bagley Creek (86 per cent), and in at the main channel sites at Sandy Creek at Homebush (68 per cent) and Sandy Creek at Bruce Highway (100 per cent) (Table 3-17).

In the Draper Creek sub-catchment, imazethapyr had a low detection frequency at the lower sub-catchment sites (Multi-farm, 19 per cent; Peak Downs Highway, 29 per cent), and was not detected in at De Moleyns Lagoon (Table 3-17).

3.2.14.2 Distribution of concentrations

The highest concentrations of imazethapyr were monitored in Sandy Creek North Branch (2.1 μgL^{-1}) and Bagley Creek (1.7 μgL^{-1}) (Table 3-17). In the Bagley Creek sub-catchment, there was a much higher distribution of concentrations than all other sub-catchments (Figure 3-33) with the higher concentrations detected during Event 3 to Event 5 in January 2016 (Figure 7-177, Appendix B). Higher concentrations in Sandy Creek North Branch were detected only during Event 5 (Figure 7-171, Appendix B).

The maximum concentration of imazethapyr at Sandy Creek at Eton was (1.4 μgL^{-1}) (Table 3-17). The timing of the maximum concentration at this site on 18 January at 16:20, aligns with the time at which the maximum concentration was monitored at the upstream Sandy Creek at North Branch site, i.e. 18 January at 15:35 (Figure 7-171, Appendix B.

Despite the relatively high concentrations upstream of Sandy Creek at Homebush, the concentration distribution at this site was relatively low, as was the concentration distribution at Sandy Creek at Bruce Highway (Figure 3-33).

General concentration distributions were low in Ross Creek and Frenchmans Creek, with correspondingly low maximum concentrations (0.53 μgL^{-1} in Ross Creek and 0.27 μgL^{-1} in Frenchmans Creek), and low in all other monitoring sites (Table 3-17).

3.2.14.3 95th percentile concentration and trigger value exceedances

The 95th percentile concentration is generally used for hazard assessments when comparing against water quality guideline values, if available. Although there is no current water quality guideline trigger values for imazethapyr, future guideline values should be compared against the following results.

The 95th percentile concentration was very high in Bagley Creek (1.7 μgL^{-1}) and Sandy Creek North Branch (1.2 μgL^{-1}) relative to all other sub-catchments (Table 3-17).

The 95th percentile concentration at Sandy Creek at Eton (0.69 μgL^{-1}) corresponds to the high concentrations monitored at the upstream Sandy Creek North Branch site. In all other monitored sub-catchments where imazethapyr was detected above the analytical limit of reporting, the 95th percentile concentrations were comparatively low (range, 0.067 μgL^{-1} to 0.25 μgL^{-1}) (Table 3-17).

3.2.14.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their $mean_{(BT)}$ concentration were, from highest to lowest: Bagley Creek, Site 8 (0.10 μgL^{-1}); Sandy Creek at Eton, Site 5 (0.047 μgL^{-1}); Sandy Creek at Bruce Highway, Site 11 (0.40 μgL^{-1}); and, Ross Creek, Site 7 (0.037 μgL^{-1}).

The next highest ranked sub-catchments (≥50th <75th percentile) included, from highest to lowest: Sandy Creek North Branch, Site 2.1 (0.033 μgL^{-1}); Sandy Creek at Homebush (0.018 μgL^{-1}); and, Frenchmans Creek, Site 10 (0.0093 μgL^{-1}).

The third grouping of sub-catchments ranked in the ≥25th <50th percentile category were in the Draper Creek sub-catchment: Draper Creek at Peak Downs Highway, Site 6 (0.0091 μgL^{-1}); and, Draper Creek at Multi-farm, Site 2 (0.0078 μgL^{-1}).

The lowest ranked group of sub-catchments based on the $mean_{(BT)}$ imazethapyr concentrations were sub-catchment sites where imazethapyr was not detected above the analytical limit of reporting. These sub-catchment monitoring sites were: Sandy Creek South Branch, Cut Creek, Draper Creek at De Moleyns Lagoon, Oaky Creek, and BL Creek.

The $mean_{(BT)}$ concentration of imazethapyr was low at all sub-catchments where this pesticide was detected above the analytical limit of reporting. The highest $mean_{(BT)}$ concentration of imazethapyr was monitored in Bagley Creek (0.10 μgL^{-1}), which was double the $mean_{(BT)}$ concentration at Sandy Creek at Eton (0.047 μgL^{-1}) (Table 3-17).

It is important to note that although the $mean_{(BT)}$ concentration of imazethapyr at Sandy Creek at Eton (0.047 μgL^{-1}) is higher than Sandy Creek at North Branch (0.033 μgL^{-1}) (Table 3-17) and the percentile rank as presented in Figure 3-34 is higher, a large proportion of the imazethapyr monitored at the Sandy Creek at Eton site is likely to have come from the Sandy Creek North Branch sub-catchment.

The $mean_{(BT)}$ concentration of imazethapyr was similar between the main channel sites Sandy Creek at Eton (0.047 μgL^{-1}) and Sandy Creek at Bruce Highway (0.040 μgL^{-1}), and slightly lower at Homebush (0.018 μgL^{-1}) (Table 3-17) which may be attributed to the collection of a large number of samples during the lower section of the falling hydrograph when concentration of most pesticides was low compared to the rising hydrograph and periods of peak discharge.

The $mean_{(BT)}$ concentration of imazethapyr in all other sub-catchments was low (range, 0.0078 μgL^{-1} to 0.037 μgL^{-1}) (Table 3-17).

Table 3-17 Summary statistics for water quality samples analysed for imazethapyr.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	21	0	0	17	0	8	4	31	25	0	74	10	0	20
Detection Freq. (%)	72	0	0	68	0	19	29	82	86	0	68	29	0	100
Mean$_{(BT)}$	0.033	**NC**	**NC**	0.047	**NC**	*0.0078*	*0.0091*	0.037	0.10	**NC**	0.018	*0.0093*	**NC**	0.040
Std. Dev.	0.76	**NC**	**NC**	0.74	**NC**	*0.41*	*0.43*	0.54	0.87	**NC**	0.47	*0.49*	**NC**	0.16
Median	0.03	**NC**	**NC**	0.04	**NC**	0.005	0.005	0.05	0.06	**NC**	0.02	0.005	**NC**	0.04
95th Percentile	1.2	**NC**	**NC**	0.69	**NC**	0.079	0.067	0.25	1.7	**NC**	0.10	0.11	**NC**	0.071
Max. Conc.	2.1	**NC**	**NC**	1.4	**NC**	0.13	0.08	0.53	1.7	**NC**	0.33	0.27	**NC**	0.08

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of imazethapyr was above the analytical limit of reporting. **Text in italics** indicates values below the analytical limit of reporting. **NC** – not calculated – the concentration of imazethapyr was below the analytical limit of reporting in all samples collected at the site during the monitoring period.

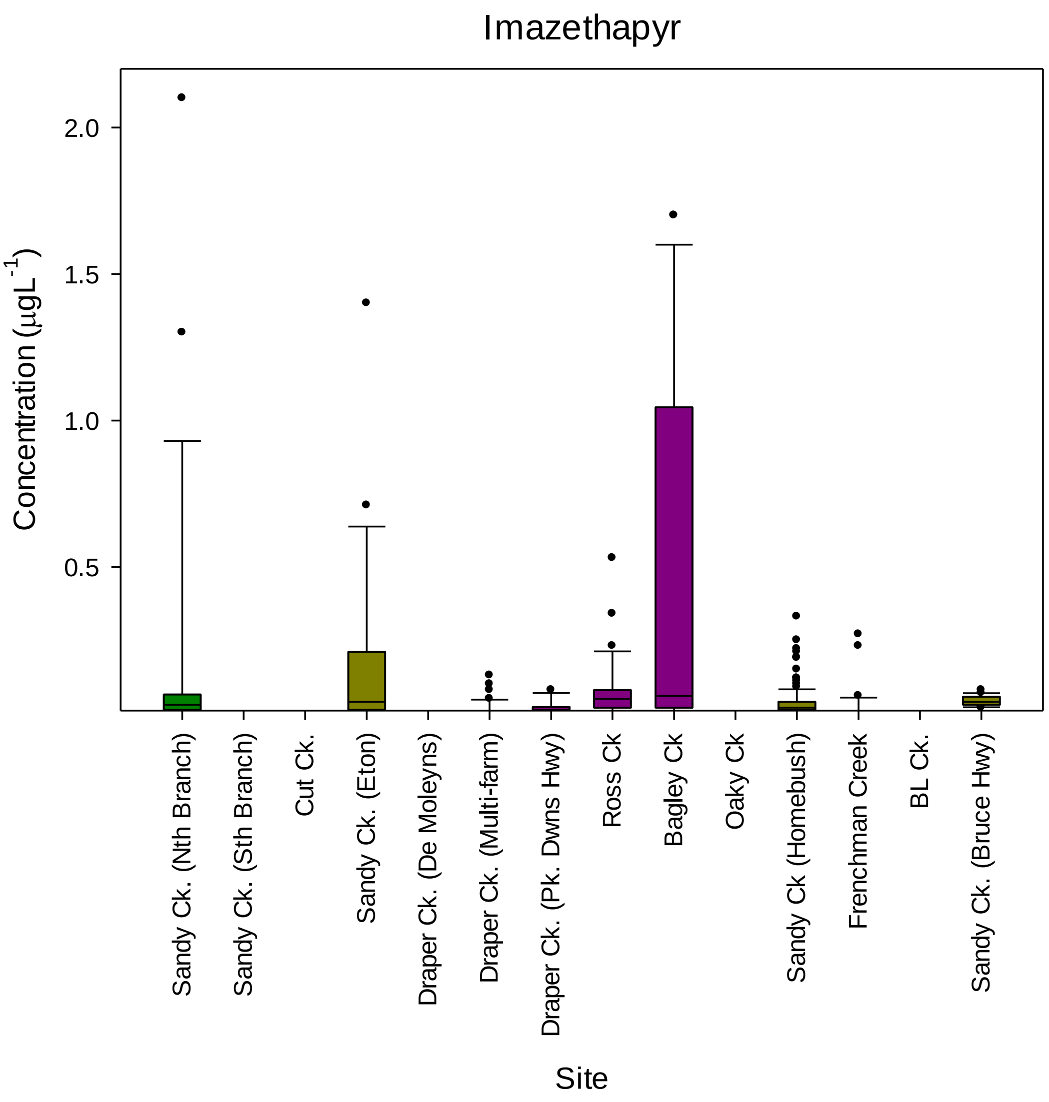

Figure 3-33 Box plot of measured concentration of imazethapyr at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles and solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

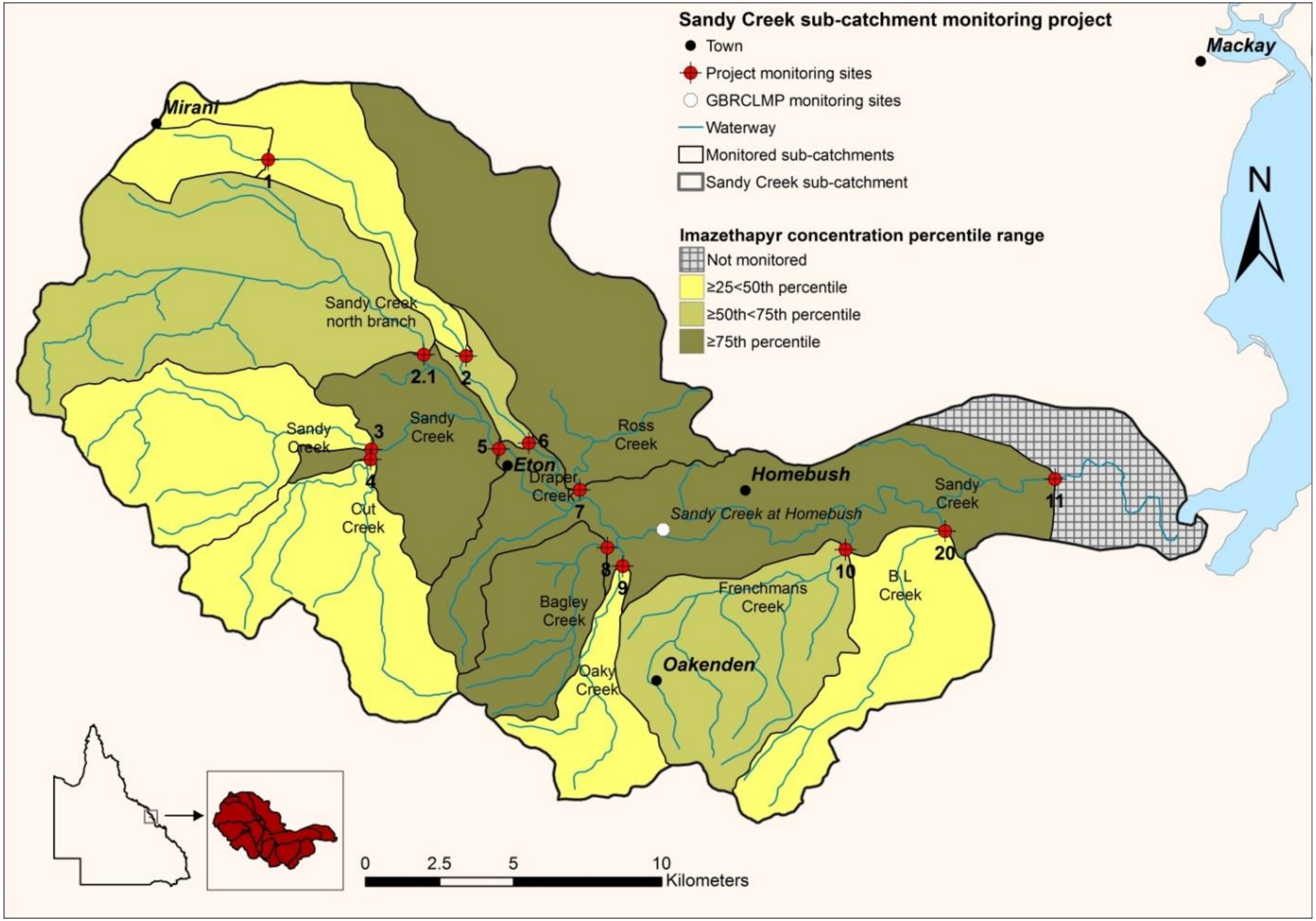

Figure 3-34 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of imazethapyr in water samples collected at each sub-catchment during the monitored events. See Table 3-17 for reference of site name to site number.

3.2.15 Other Pesticides

A total of 39 pesticides including metabolites were detected at sites monitored by the Sandy Creek Sub-catchment Water Quality Monitoring Project. Additional pesticides known to be used in the monitored area (e.g. glyphosate, pendimethalin, paraquat) were not included in the analytical suite of pesticides detected by the laboratory's Direct Inject or solid phase extraction LC-MS/MS method used during the Sandy Creek Sub-catchment Water Quality Monitoring Project. The total number of pesticides present in runoff is therefore likely to be higher than reported here. It is important to note, however, that not all pesticides detected in sub-catchments of Sandy Creek are used in sugarcane production systems. This reflects the presence of other industries in the Sandy Creek catchment for which use of these chemicals is permitted (e.g. forestry, grazing, horticulture and cropping).

3.2.15.1 Guideline note

Of the additional pesticides detected as part of the Sandy Creek Sub-catchment Water Quality Monitoring Project, there are only current ecosystem protection trigger values for simazine, metsulfuron-methyl and tebuthiuron. None of these trigger values were exceeded in any samples collected at the monitored sub-catchment sites. Additional projects are currently being undertaken by the Queensland Department of Science, Information Technology and Innovation to derive guidelines for some of the additional pesticides detected during this project. It is anticipated that when these guideline values becomes available a review of the concentrations detected during this project will be undertaken.

3.2.15.2 Detection frequency and concentration results

Thirteen additional pesticides were detected at sub-catchments monitored by the Sandy Creek Sub-catchment Water Quality Monitoring Project. The overall detection frequency for each of these pesticides was below 30 per cent (excluding Sandy Creek at Home bush). Although no detailed description of these data are provided in this report, it is important to note that within this group of pesticides, there are specific chemicals which are used within the sugar industry and further review by the sugar industry is warranted.

Propazin-2-hydroxy was detected above the analytical limit of reporting at 10 sub-catchment sites and had an overall detection frequency of 26 per cent (Table 3-18). The highest concentration of propazin-2-hydroxy was monitored at Draper Creek Multi-farm (0.04 μgL^{-1}). The maximum concentration in all other sub-catchments was near the analytical limit of reporting (0.01 μgL^{-1}).

Simazine was detected at eight sub-catchment monitoring sites with an overall detection frequency of 14 per cent (Table 3-19) (excluding Sandy Creek at Homebush). At Sandy Creek North Branch, the monitored concentration of simazine peaked during Event 5 (0.23 μgL^{-1}) with only low concentrations (maximum, 0.02 μgL^{-1}) detected during Event 3 and Event 4 over the preceding weeks, which may indicate local application of this pesticide in the period immediately prior to this event.

Methoxyfenocide was only detected in Bagley Creek and Frenchmans Creek, and the downstream end-of-catchment site at Bruce Highway with a detection frequency in each sub-catchment of 38 per cent, 34 per cent and 20 per cent, respectively (Table 3-20). The maximum concentration of methoxyfenocide, however, was high in Bagley Creek during Event 4 to Event 6 (maximum, 0.42 μgL^{-1}) which may be linked to the horticultural production in this sub-catchment.

Metsulfuron-methyl was detected in nine sub-catchments with an overall detection frequency of 8.8 per cent (excluding Sandy Creek at Homebush). The highest rates of detection were in Draper

Creek, Ross Creek and Cut Creek with similar detection frequency monitored at the main channel site, Sandy Creek at Homebush (Table 3-21). Metsulfuron methyl was not detected at the end-of-catchment site at Bruce Highway. The highest concentrations of metsulfuron-methyl were in Frenchmans Creek (0.16 μgL^{-1}) and Bagley Creek (0.15 μgL^{-1}), with concentrations in the remaining sub-catchments where metsulfuron-methyl was detected, between 0.02 μgL^{-1} and 0.11 μgL^{-1}.

Haloxyfop was detected in seven sub-catchments, with an overall detection frequency of 8.2 per cent (Table 3-22) (excluding Sandy Creek at Homebush). The maximum concentration of haloxyfop (0.05 μgL^{-1}) was near to the analytical limit of reporting. Acifluorfen was detected in four sub-catchments (Table 3-23) with the maximum concentration in all sub-catchments near the analytical limit of reporting (range, 0.02 μgL^{-1} to 0.05 μgL^{-1}).

Acifluorfen was detected in five sub-catchments, with an overall detection frequency of 1.6 per cent (Table 3-22) (excluding Sandy Creek at Homebush). The maximum detected concentration of acifluorfen (0.05 μgL^{-1}) was at Sandy Creek at Eton during Event 6.

Triclopyr was only detected in four samples from Bagley Creek and Frenchmans Creek (Table 3-23) with the maximum concentration in each sub-catchment being 0.29 μgL^{-1} and 0.11 μgL^{-1} respectively.

Flusilazole was detected at four sub-catchment monitoring sites: Cut Creek, Ross Creek, Bagley Creek and Sandy Creek at Bruce Highway (Table 3-25). The maximum concentration of flusilazole in all sub-catchments was 0.02 μgL^{-}1 (analytical limit of reporting, <0.01 μgL^{-1}).

Halosulfuron methyl was only detected above the analytical limit of reporting in three samples collected in the Draper Creek catchment (Table 3-26). The concentration of halosulfuron methyl in these samples was 0.02 μgL^{-1}.

Prometryn was only detected in two samples collected from Ross Creek and Bagley Creek with the concentration in both samples being near the analytical limit of reporting (Table 3-27).

Three pesticides were only detected above the analytical limit of reporting in a single sample: terbuthylazine (Sandy Creek North Branch, 0.02 μgL^{-1}) (Table 3-28); tebuthiuron (Sandy Creek at Eton, 0.05 μgL^{-1}) (Table 3-29), and clomazone (Ross Creek, 0.03 μgL^{-1}) (Table 3-30). The maximum concentration of each of these pesticides were near to the analytical limit of reporting.

Table 3-18 Summary statistics for water quality samples analysed for propazine-2-hydroxy.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	14	2	0	9	0	11	2	16	1	0	NA	9	4	5
Detection Freq. (%)	48	7	0	36	0	55	14	42	3	0	NA	26	25	25

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of propazine-2-hydroxy was above the analytical limit of reporting; NA – Not analysed – this pesticide is not part of the suite of pesticides detected using the solid phase extraction analytical.

Table 3-19 Summary statistics for water quality samples analysed for simazine.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	11	5	0	3	0	5	4	4	0	0	11	7	0	1
Detection Freq. (%)	38	19	0	12	0	13	29	11	0	0	10	20	0	5

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of simazine was above the analytical limit of reporting.

Table 3-20 Summary statistics for water quality samples analysed for methoxyfenocide.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	0	0	0	0	0	0	0	0	11	0	0	12	0	4
Detection Freq. (%)	0	0	0	0	0	0	0	0	38	0	NA	34	0	20

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of methoxyfenocide was above the analytical limit of reporting; NA – Not analysed – this pesticide is not part of the suite of pesticides detected using the solid phase extraction analytical.

Table 3-21 Summary statistics for water quality samples analysed for metsulfuron methyl.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	0	1	3	0	2	4	2	7	2	0	18	4	2	0
Detection Freq. (%)	0	3.7	19	0	40	9.5	14	18	6.9	0	17	11	13	0

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of metsulfuron methyl was above the analytical limit of reporting.

Table 3-22 Summary statistics for water quality samples analysed for haloxyfop.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	**2.1**	**3**	**4**	**5**	**1**	**2**	**6**	**7**	**8**	**9**	**-**	**10**	**20**	**11**
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	5	2	0	5	1	0	0	3	8	0	8	1	0	0
Detection Freq. (%)	17	7.4	0	20	20	0	0	7.9	28	0	7.3	2.9	0	0

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of haloxyfop was above the analytical limit of reporting.

Table 3-23 Summary statistics for water quality samples analysed for acifluorfen.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	1	0	0	2	0	0	0	0	1	0	7	1	0	0
Detection Freq. (%)	3.4	0	0	8.0	0	0	0	0	3.4	0	6.4	2.9	0	0

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of acifluorfen was above the analytical limit of reporting.

Table 3-24 Summary statistics for water quality samples analysed for triclopyr.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	0	0	0	0	0	0	0	0	1	0	18	3	0	0
Detection Freq. (%)	0	0	0	0	0	0	0	0	3.4	0	17	8.6	0	0

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of triclopyr was above the analytical limit of reporting.

Table 3-25 Summary statistics for water quality samples analysed for flusilazole.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	0	0	1	0	0	0	0	1	1	0	0	0	0	1
Detection Freq. (%)	0	0	6.3	0	0	0	0	2.6	3.4	0	NA	0	0	5.0

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of flusilazole was above the analytical limit of reporting; NA – Not analysed – this pesticide is not part of the suite of pesticides detected using the solid phase extraction analytical.

Table 3-26 Summary statistics for water quality samples analysed for halosulfuron methyl.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	0	0	0	0	0	2	1	0	0	0	0	0	0	0
Detection Freq. (%)	0	0	0	0	0	4.7	7.1	0	0	0	NA	0	0	0

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of halosulfuron methyl was above the analytical limit of reporting; NA – Not analysed – this pesticide is not part of the suite of pesticides detected using the solid phase extraction analytical.

Table 3-27 Summary statistics for water quality samples analysed for prometryn.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	0	0	0	0	0	0	0	1	1	0	3	0	0	0
Detection Freq. (%)	0	0	0	0	0	0	0	2.6	3.4	0	2.8	0	0	0

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of prometryn was above the analytical limit of reporting.

Table 3-28 Summary statistics for water quality samples analysed for terbuthylazine.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Detection Freq. (%)	3.4	0	0	0	0	0	0	0	0	0	0	0	0	0

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of terbuthylazine was above the analytical limit of reporting.

Table 3-29 Summary statistics for water quality samples analysed for tebuthiuron.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Detection Freq. (%)	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of tebuthiuron was above the analytical limit of reporting.

Table 3-30 Summary statistics for water quality samples analysed for clomazone.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	29	27	16	25	5	42	14	38	29	10	109	35	16	20
Detections. >LOR	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Detection Freq. (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0

n – number of samples analysed; **LOR** – limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of clomazone was above the analytical limit of reporting.

3.2.16 Pesticide summary

3.2.16.1 Storm driven events are high risk periods

Rainfall runoff is a primary mechanism for the mobilisation of pesticides leading to off-farm losses to local waterways (Smith et al. 2009; Agnew et al. 2011; Rhode et al. 2013). The results of this project have shown that the highest concentrations of most pesticides occurred during the storm driven rainfall runoff events early in the wet season. Storm driven rainfall runoff events represent a high risk period because the intensity of the rainfall received during these short-term events are potentially more likely to result in runoff than equivalent rainfall totals received over a longer period, which may result in higher rates of infiltration and retention of pesticides in the soil profile.

Storm driven rainfall runoff events generally occur earlier in the wet season, closer in time, to the period when some pesticides are being applied to plant cane and ratoon crops following annual harvest (Lewis et al. 2009). Rainfall runoff trials have demonstrated that the shorter the time interval between the application of pesticides and rainfall, the higher concentration of some pesticides in runoff (Silburn et al. 2013; Rhode et al. 2013). This is a function of multiple factors including reduced period for incorporation of pesticides into the soil through irrigation; reduced period for uptake of pesticides by plants; and reduced period for the degradation of the pesticides (Devlin et al. 2015).

Storm driven rainfall runoff events generally result in lower overall runoff volumes entering the local waterways compared to sustained rainfall events over multiple days. This may result in high concentrations of many pesticides entering the waterways, which may persist for longer durations than during periods of high discharge volumes that provide greater dilution of the pesticide load. The concentration and hydrograph plots presented in Appendix B demonstrate that the peak in concentration of many pesticides occurred during the storm driven runoff events in January 2016 (e.g. diuron, Figure 7-43 to Figure 7-56). Anomalies to this trend were observed in some catchments with the peak in concentration for some pesticides occurring in the larger event in February 2016. An example of this, is the maximum monitored concentration of atrazine in Sandy Creek South Branch (Figure 7-60) that occurred in February 2016, possibly reflecting an application in the period between the small storms driven events in January 2016 and the larger rainfall event of February 2016.

3.2.16.2 Concentration dissipation during the wet season

Concentration dissipation was observed in all monitored sub-catchments over the wet season, with low concentrations of all pesticides observed during the monitored runoff events in February and March 2016. Concentration dissipation is a function of multiple loss pathways including surface water runoff mobilisation of pesticides from paddocks into the waterways; incorporation of pesticides into the soil profile through irrigation limiting mobilisation; uptake by plants, and degradation of the active ingredient (e.g. photodegradation). As these factors vary considerably, spatially and temporarily, monitoring undertaken as part of the Sandy Creek Sub-catchment Water Quality Monitoring Program aimed to monitor all sub-catchments for three events to observe concentration dissipation, i.e. a reduction over time in the risk of pesticides to aquatic ecosystems. Concentration dissipation in many catchments was observed during the rainfall events in January 2016, with significant further reductions in the monitored concentrations in all sub-catchments in February and March 2016 (see Appendix B).

3.2.16.3 Concentration trends and ecological risk

Through the Sandy Creek Sub-catchment Water Quality Monitoring Project a substantial water quality data resource was acquired to assist the sugar industry in the Sandy Creek catchment to identify differences in the water quality between sub-catchments. With this information the sugar industry has the opportunity to enhance existing strategies and on ground management activities to reduce the rate of off-farm losses of pesticides.

The data presented here indicates that pesticides were widespread throughout the catchment, with some sub-catchments exhibiting higher numbers of pesticides, higher frequencies of detection and higher concentrations. In total, 26 different pesticides were detected with five of these detected at every monitoring site; imidacloprid, imazapic, hexazinone, diuron and atrazine. These five pesticides were also detected in the highest frequency across the whole catchment. Ross Creek and Bagley Creek sub-catchments had the highest number of recorded pesticides (20), followed by Sandy Creek at Homebush and Frenchmans Creek (19), Sandy Creek at North Branch and Sandy Creek at Eton (18), Draper Creek at Multi-farm and Peak Downs Highway, and Sandy Creek at Bruce Highway (17).

Sub-catchments in the north-west section of Sandy Creek (Ross Creek, Sandy Creek North Branch, Draper Creek) and the lower catchment monitoring site Sandy Creek at the Bruce Highway, had higher $mean_{(BT)}$ concentrations of more pesticides than other monitored sites in the Sandy Creek catchment. These observations most likely resulted from the larger area and higher proportion of intensive cropping land use, the total rainfall/runoff and timing of rainfall/runoff events, and land management practices in each sub-catchment.

The patterns of concentration distributions observed across sub-catchments varied between pesticides, indicating that the interaction between a pesticide’s physico-chemical characteristics (e.g. Log K_{ow}) and the local environmental conditions (e.g. soil type, rainfall), land use type, and/or application practices, are the most likely factors contributing to those differences.

Concentrations were found to exceed the ANZECC and ARMCANZ (2000) water quality guideline trigger values for a number of pesticides (where trigger values were available). As outlined for each of the pesticides discussed in Section 3.2.2 to 3.2.15, many of the existing ecosystem protection guideline values presented in this report are currently under review, and guidelines are being derived for additional pesticides for which no current guideline values are available (King et al. in prep). It is expected that the completion of this work will significantly advance our understanding of the threat of pesticides to the freshwater aquatic ecosystems including Sandy Creek.

Given the number of pesticides detected and the magnitude of trigger value exceedances, it is reasonable to suggest that there is a current ecological risk to the fresh and estuarine ecosystems of the Sandy Creek catchment from a variety of pesticides. On a spatial scale, this risk starts in the upper sub-catchments and continues downstream along the main channel until at least the Sandy Creek at Bruce Highway site, and is likely to continue beyond that site. DSITI are also developing a risk assessment tool that will allow the quantification of the ecological risk associated with mixtures of pesticides when the concentrations and exposure periods are known. This tool has recently been used to report the ecological risk of mixtures of photosystem II herbicides in the Wet Tropics (Hunt 2016).

3.2.16.4 Sampling Bias

The Sandy Creek Sub-catchment Water Quality Monitoring Project aimed to collect up to eight samples at each site during the first three rainfall runoff events. In many cases, a substantially greater number of samples were collected, because either (a) samples were collected during more than three runoff events and/or (b) sampling was sustained during the falling stage as the creeks returned to base flow dominated systems. However, because of the differences in rainfall and hydrological response between sub-catchments, samples were collected at varying stages of the rise, peak and fall of the hydrograph between sites. Consequently, comparing the descriptive statistics as presented in the report in isolation, overlooks the potential impact of sampling bias that exists between sites and within sites between events. This was particularly notable in the lower $mean_{(BT)}$ concentrations of many pesticides reported for the Sandy Creek at Homebush monitoring site. This occurred because a large number of samples were collected at this site during periods of reduced discharge during the falling stage of the hydrograph when the concentration of many pesticides were low. By contrast, sample collection at the end-of-catchment site, Sandy Creek at Bruce Highway, was only undertaken during the period of highest discharge; sampling ceased once flow at this site became tidally dominated. This resulted in the majority of samples being collected at this site during periods of elevated concentration. Sampling bias at Sandy Creek at Bruce Highway was compounded further because no samples were collected at this site during the last event when the concentration for all pesticides at all sites were low compared to the earlier events of the season.

Other sites where sampling bias is apparent, include the Draper Creek at Multi-farm site, which was equipped with an automatic sampler. Similar to Sandy Creek at Homebush, a very high number of samples were collected at this site including during periods of reduced discharge. The only way to overcome this issue is to report flow weighted event mean concentrations for all sampling sites; however, measured flow data are only available for the Draper Creek at Multi-farm and Sandy Creek at Homebush sites.

More detailed analysis of the concentration data are proposed that will investigate further the relationship between the measured concentration data and the factors listed above. These analyses are partially contingent on the availability of additional supporting datasets including sub-catchment discharge data, chemical usage data, and availability of a revised and broader suite of water quality guidelines.

3.2.16.5 Chemical usage data

It is well understood that elevated concentrations of pesticides in runoff from sugarcane production areas are believed to pose an ecological risk to the health of freshwater and estuarine ecosystems and the nearshore marine environment of the Great Barrier Reef lagoon (Brodie et al. 2013c). A significant ongoing constraint to the effective management of pesticides in surface water runoff is the difficulty in acquiring current pesticide usage data. Presently, there is no comprehensive data acquisition and reporting mechanism that could provide information on which chemicals are being used and where, the timing of application, and application rates.

The water quality results obtained through the Sandy Creek Sub-catchment Water Quality Monitoring Project highlight large differences in the concentration of pesticides within sub-catchments between events, and between sub-catchments during the same events. In the absence of chemical use data, it is not possible to analyse these data to determine the principle reason for the off-farms losses that were observed.

Projects such as the Sandy Creek Sub-catchment Water Quality Monitoring Project highlight the urgent need for consistent reporting of chemical use data and the provision of these data to leading industry bodies and government agencies to enable the identification of regions or catchments where the monitored rates of off-farm losses are high. With these data growers and industry bodies would be able to develop targeted strategies to enhance adoption of farm management practices that reduce off-farm losses to facilitate further improvement in water quality in areas such as Sandy Creek.

Accurate chemical usage data is also a critical input into paddock scale and catchment scale models that are used to calculate the mass loads of pesticides derived annually from sugarcane production systems. Modelling approaches are a valuable resource available to the sugar industry to guide development and implementation of management strategies to reduce pesticide losses, thereby improving efficacy of pesticide applications, increase farm productivity, and at the same time achieve the land and water conservation targets stipulated within regional Water Quality Improvement Plans and the State environmental protection policies.

3.3 Nutrients

3.3.1 Nutrients overview

Dissolved inorganic nitrogen has been identified in both the Scientific Consensus Statement (Brodie et al. 2013) and the Mackay Whitsunday Water Quality Improvement Plan (Folkers et al. 2014) as a high risk pollutant in the Mackay Whitsunday region. The load per unit area of dissolved inorganic nitrogen, oxidised nitrogen and dissolved inorganic phosphorus in Sandy Creek is very high relative to other monitored catchments in the Mackay Whitsunday region and high relative to many coastal catchments that discharge to the Great Barrier Reef (Wallace et al. 2016).

The collection of water samples for the analysis of nutrients was undertaken in parallel with the manual collection of samples for analysis of pesticides. This was done to increase the spatial resolution of nutrient concentration data available for the Sandy Creek catchment. The data resource obtained through the Sandy Creek Sub-catchment Water Quality Monitoring Project provides an additional tool to guide management actions to reduce fertiliser losses from sugar cane production systems.

The results presented below identify some notable differences between sub-catchments and strong similarities in many other instances. Overall, catchments in the north-west section of the catchment, including Sandy Creek North Branch, Draper Creek and Ross Creek had higher overall $mean_{(BT)}$ concentrations of ammonium nitrogen, oxidised nitrogen and dissolved inorganic phosphorus. Of particular note, was Oaky Creek (0.79 mgL^{-1}), which had amongst the highest $mean_{(BT)}$ concentrations of dissolved inorganic nitrogen which was driven by high concentrations of oxidised nitrogen. This result is in contrast to the low concentrations of pesticides monitored in this sub-catchment.

The median concentration of dissolved inorganic nitrogen exceeded the water quality objective for the protection of aquatic environmental values (DEHP 2013) in freshwater aquatic ecosystems of Sandy Creek at all sub-catchment monitoring sites except Draper Creek at De Moleyens Lagoon, Draper Creek at Multi-farm and Balgey Creek.

The median concentration of oxidised nitrogen exceeded the regional water quality guidelines for Central Coast Queensland (DERM 2009) in all catchments, and for ammonium nitrogen, in all monitored sub-catchments, except Cut Creek and Oaky Creek.

The median concentration of dissolved inorganic phosphorus exceeded the water quality objective for the protection of aquatic environmental values (DEHP 2013) in freshwater aquatic ecosystems of Sandy Creek in all catchments, except Cut Creek and Bagley Creek.

Review of the limitations relating to the data, as outlined in Section 4, should also be considered in relation to the nutrient concentration data presented in the following section.

3.3.2 Dissolved Inorganic Nitrogen

Guideline Note –

The current water quality objective for the protection of aquatic environmental values (DEHP 2013) in freshwater aquatic ecosystems of Sandy Creek for dissolved inorganic nitrogen are:

- *Moderately disturbed end-of-system (high flows)* **–** *< 0.3 mgL^{-1}*

3.3.2.1 Detection frequency

Dissolved inorganic nitrogen was detected above the analytical limit of reporting in all samples collected from all sub-catchments (Table 3-31).

3.3.2.2 Distribution of concentrations

The highest concentration of dissolved inorganic nitrogen was monitored in BL Creek (7.7 mgL^{-1}) with comparatively high concentrations also monitored in Sandy Creek at Eton (6.0 mgL^{-1}), Ross Creek (5.3 mgL^{-1}) and Draper Creek at De Moleyns Lagoon (4.7 mgL^{-1}) (Table 3-31). The maximum concentrations of dissolved inorganic nitrogen in all other sub-catchments were in the range 0.46 mgL^{-1} monitored at Bagley Creek to 3.8 mgL^{-1} at Sandy Creek North Branch.

The pattern between sub-catchments of the general concentration distributions (25th – 75th percentile) for dissolved inorganic nitrogen indicate higher distributions were detected in Sandy Creek South Branch, Ross Creek and Oaky Creek which are likely to have influenced the concentration distributions at the main channel sites more than other monitored sub-catchments (Figure 3-35). The concentration distribution of dissolved inorganic nitrogen, is expectedly similar to the general concentration distributions for oxidised nitrogen.

3.3.2.3 Median concentrations and exceedance of the water quality objectives

The median concentration exceeded the water quality objective value at Sandy Creek at Eton (0.94 mgL^{-1}), Oaky Creek (0.85 mgL^{-1}), Sandy Creek South Branch (0.72 mgL^{-1}), Cut Creek (0.62 mgL^{-1}), Sandy Creek North Branch (0.59 mgL^{-1}), Sandy Creek Bruce Highway (0.57 mgL^{-1}), BL Creek (0.55 mgL^{-1}), Ross Creek (0.52 mgL^{-1}), Frenchmans Creek (0.46 mgL^{-1}), Draper Creek at Peak Downs Highway (0.37 mgL^{-1}) and Sandy Creek at Homebush (0.37 mgL^{-1}). The water quality objective was not exceeded by the median concentrations at Draper Creek at Multi-farm and De Moleyns Lagoon (0.29 and 0.18 mgL^{-1}, respectively) and Bagley Creek (0.18 mgL^{-1}) (Table 3-31).

3.3.2.4 Mean concentration

The four sub-catchments that fell within the ≥75th percentile ranking based on their mean$_{(BT)}$ dissolved inorganic nitrogen concentration were principally on the southern section of Sandy Creek catchment. These sub-catchments included, from highest to lowest: Sandy Creek at Bruce Highway, Site 11 (0.90 mgL^{-1}); Oaky Creek, Site 9 (0.79 mgL^{-1}); Sandy Creek at Eton, Site 5 (0.59 mgL^{-1}); and, Sandy Creek South Branch, Site 3 (0.54 mgL^{-1}) (Figure 3-36).

The next highest ranked sub-catchments (≥50th<75th percentile) included, from highest to lowest: Ross Creek, Site 7 (0.48 mgL^{-1}); Frenchmans Creek, Site 10 (0.47 mgL^{-1}); and, BL Creek, Site 20 (0.37 mgL^{-1}).

The third grouping of sub-catchments ranked in the ≥25th<50th percentile category included, from highest to lowest mean$_{(BT)}$ dissolved inorganic nitrogen concentrations: Draper Creek at De Moleyens Lagoon, Site 1 (0.37 mgL^{-1}); Cut Creek, Site 4 (0.36 mgL^{-1}); and Draper Creek at Peak Downs Highway, Site 6 (0.30 mgL^{-1}) (Figure 3-36).

The lowest ranked group of sub-catchments based on the $mean_{(BT)}$ dissolved inorganic nitrogen concentrations were, from highest to lowest: Sandy Creek North Branch, Site 2.1 (0.29 mgL^{-1}); Draper Creek at Multi-farm, Site 2 (0.28 mgL^{-1}); and Bagley Creek, Site 8 (0.15 mgL^{-1}) (Figure 3-36).

The high $mean_{(BT)}$ concentration of dissolved inorganic nitrogen in Oaky Creek is most notable as this is in contrast to the low concentration of all detected pesticides in this sub-catchment, which only commenced to flow during the larger rainfall runoff events in February and March.

In the upper Sandy Creek sub-catchments, the $mean_{(BT)}$ concentration of dissolved inorganic nitrogen was similar between Sandy Creek South Branch (0.54 mgL^{-1}) and Sandy Creek at Eton (0.59 mgL^{-1}). By contrast the $mean_{(BT)}$ concentration of dissolved inorganic nitrogen in Sandy Creek North Branch (0.29 mgL^{-1}) and Cut Creek (0.36 mgL^{-1}) were moderate (Table 3-31). The difference between these sub-catchments is supported by review of the box plot (Figure 3-35) which shows a higher overall distribution of the concentration data from Sandy Creek South Branch compared to both Sandy Creek North Branch and Cut Creek. There is strong similarity in the distribution of the concentration data between Sandy Creek South Branch and the downstream main channel site, Sandy Creek at Eton (Figure 3-35).

The $mean_{(BT)}$ concentration of dissolved inorganic nitrogen in Draper Creek (range, 0.28 mgL^{-1} to 0.37 mgL^{-1}) was similar to the adjacent Sandy Creek North Branch (0.29 mgL^{-1}) though less than Ross Creek (0.48 mgL^{-1}) which drains the Victoria Plains area on the eastern side of Draper Creek (Table 3-31).

Amongst the southern sub-catchments, the $mean_{(BT)}$ concentration of dissolved inorganic nitrogen was low in Bagley Creek (0.15 mgL^{-1}) compared to all other sub-catchments including the adjacent Oaky Creek (0.79 mgL^{-1}), Frenchmans Creek (0.47 mgL^{-1}) and BL Creek (0.37 mgL^{-1}) (Table 3-31).

Table 3-31 Summary statistics for water quality samples analysed for dissolved inorganic nitrogen. All concentrations are reported in mgL^{-1}.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	7	41	11	26	20	23	13	16	22	10	116	27	12	20
Detections. >LOR	7	41	11	26	20	23	13	16	22	10	116	27	12	20
Detection Freq. (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Mean$_{(BT)}$	0.29	0.54	0.36	0.59	0.37	0.28	0.30	0.48	0.15	0.79	0.44	0.47	0.37	0.90
Std. Dev.	0.68	0.57	0.34	0.61	0.86	0.63	0.64	0.68	0.33	0.25	0.56	0.41	0.58	0.35
Median	0.59	0.72	0.62	0.94	0.18	0.29	0.37	0.52	0.18	0.85	0.37	0.46	0.55	0.57
95th Percentile	2.3	3.5	0.74	4.7	4.5	1.8	1.8	4.6	0.44	1.55	3.0	2.4	4.2	3.4
Max. Conc.	3.8	3.7	0.820	6.0	4.7	2.0	2.1	5.3	0.46	1.5	4.7	2.5	7.7	3.8

n – number of samples analysed; **>LOR** – number of samples where the concentration was below the analytical limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of dissolved inorganic nitrogen was above the analytical limit of reporting.

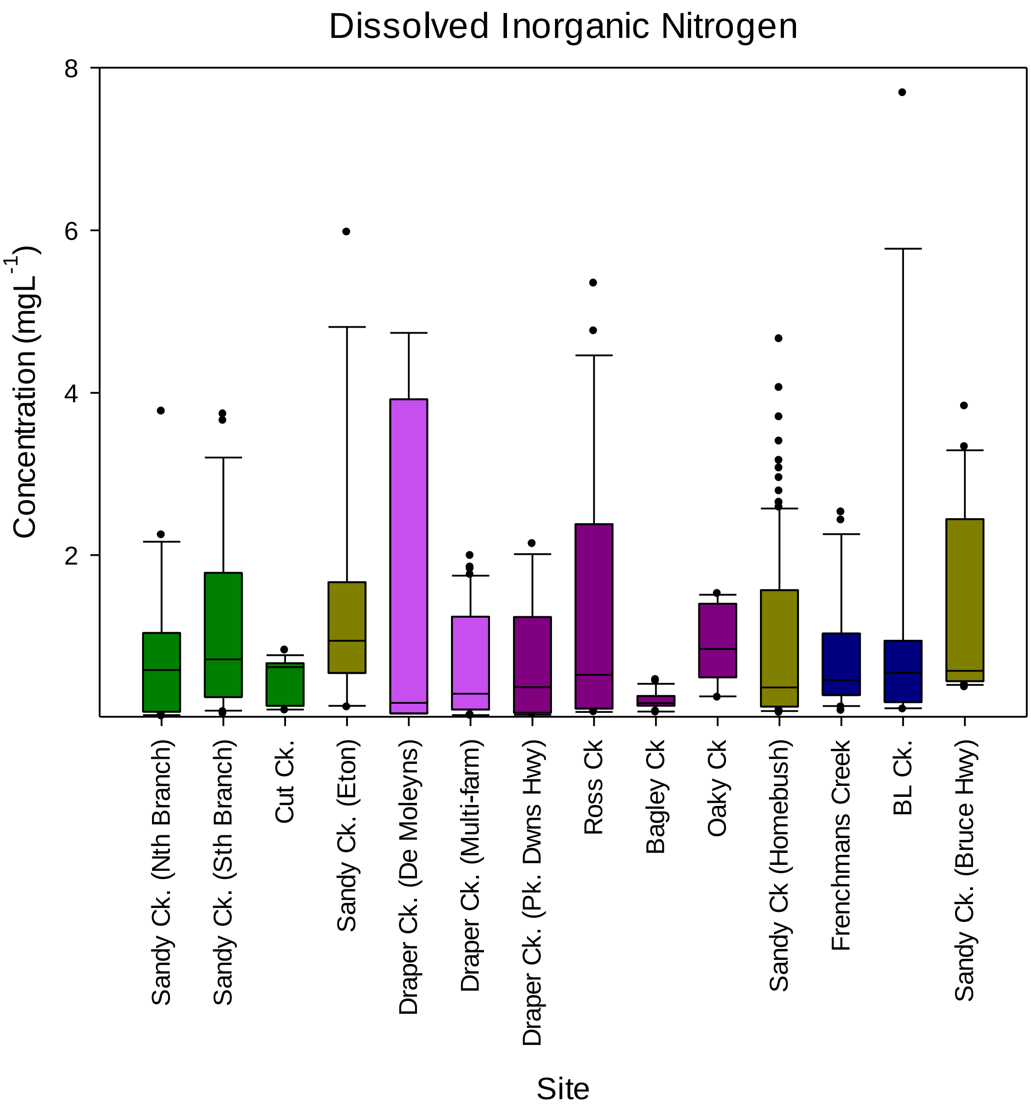

Figure 3-35 Box plot of measured concentration of dissolved inorganic nitrogen at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles, solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

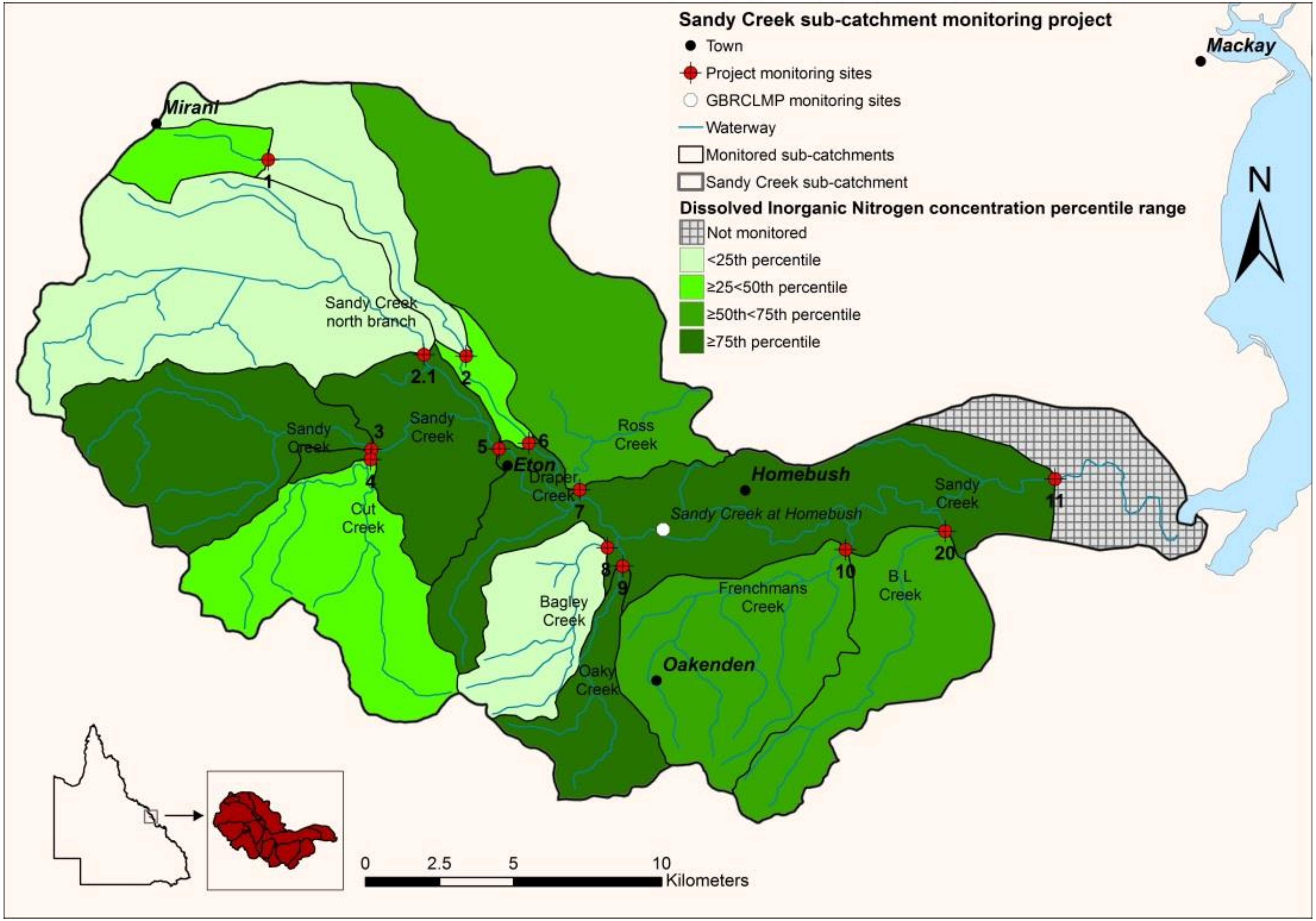

Figure 3-36 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of dissolved inorganic nitrogen in water samples collected at each sub-catchment during the monitored events.

3.3.3 Ammonium nitrogen

Guideline Note –

There are no current scheduled water quality objectives for oxidised nitrogen under event flow conditions as there are for DIN (DEHP 2013). However, there are regional water quality guidelines for Central Coast Queensland (DERM 2009).

- *For slightly to moderately disturbed lowland streams in Central Coast Queensland – 0.02 mgL^{-1}*
- *For slightly to moderately upper estuaries in Central Coast Queensland – 0.03 mgL^{-1}*

There is also a current ANZECC and ARMCANZ (2000) toxicity trigger value for total ammonia. The current default trigger value for ammonium is 0.84 mgL^{-1}:

- *Based on the guideline value for total ammonia of 0.9 mgL^{-1} at pH 8.0 and 20 degrees Celsius, the percentage of unionised ammonia at pH8.0 at 27.5 degrees Celsius is 6.36 per cent. Ionised ammonia measured as ammonium nitrogen (NH_4^+-N) is 93.6 per cent of 0.90 mgL^{-1}.*

3.3.3.1 Detection frequency

Ammonium nitrogen was detected above the analytical limit of reporting in all samples collected from all sub-catchments.

3.3.3.2 Distribution of concentrations

The highest concentration of ammonium nitrogen was monitored in Ross Creek (1.6 mgL^{-1}), which was approximately twice the maximum concentration monitored in Draper Creek at Multi-farm (0.88 mgL^{-1})and Sandy Creek at Homebush (0.68 mgL^{-1}). The maximum concentration in all other catchments ranged from 0.26 mgL^{-1} in Sandy Creek North Branch and Sandy Creek at Bruce Highway, to 0.058 mgL^{-1} in BL Creek, excluding Cut Creek and Oaky Creek. The maximum concentration of ammonium nitrogen in Cut Creek (0.026 mgL^{-1}) and Oaky Creek (0.011 mgL^{-1}) was very low compared to all other catchments (Table 3-32).

The pattern between sub-catchments of the general concentration distributions (25th – 75th percentile) for ammonium nitrogen differed from dissolved inorganic nitrogen and oxidised nitrogen (Section 3.3.4.2). Ross Creek and Sandy Creek North Branch had high concentration distributions compared to all other monitored sub-catchments. The contribution of these two sub-catchments is likely driving the high distribution of concentration for each of the main channel sites. The concentration distribution of all other sub-catchments were comparatively low (Figure 3-37).

3.3.3.3 Median concentrations and exceedance of the water quality objectives

The median concentration exceeded the water quality guideline value (for lowland streams) at Sandy Creek at Eton (0.11 mgL^{-1}), Ross Creek (0.081 mgL^{-1}), Sandy Creek North Branch (0.063 mgL^{-1}), Draper Creek at De Moleyns Lagoon (0.036 mgL^{-1}), Sandy Creek at Homebush (0.032 mgL^{-1}), Draper Creek at Multi-farm (0.029 mgL^{-1}), Sandy Creek South Branch (0.028 mgL^{-1}), Frenchmans Creek (0.025 mgL^{-1}), Draper Creek at Peak Downs Highway (0.024 mgL^{-1}), BL Creek (0.024 mgL^{-1}), Bagley Creek (0.022 mgL^{-1}). The median concentration at Sandy Creek at Bruce Highway (0.57 mgL^{-1}) exceeded the water quality objective for upper estuaries. The water quality objective was not exceeded by the median concentrations at Cut Creek (0.015 mgL^{-1}) and Oaky Creek (0.0085 mgL^{-1}) (Table 3-31).

3.3.3.4 95th percentile concentration and trigger value exceedances

The ammonia trigger value was only exceed in one instance by the maximum concentration at Ross Creek (1.6 mgL^{-1}).

The 95th percentile concentration was high in Ross Creek (0.56 mgL^{-1}) compared to all other monitored sub-catchment (Table 3-32). The 95th percentile concentration was similar between all three sites on Sandy Creek main channel – Sandy Creek at Eton (0.23 mgL^{-1}), Sandy Creek at Homebush (0.31 mgL^{-1}), and Sandy Creek at Bruce Highway (0.25 mgL^{-1}) – with a similar 95th percentile concentration also monitored at Sandy Creek North Branch (0.26 mgL^{-1}). The 95th percentile concentration in all other sub-catchment was in the range 0.17 mgL^{-1} to 0.047 mgL^{-1}, excluding Cut Creek (0.023 mgL^{-1}) and Oaky Creek (0.011 mgL^{-1}) where the concentration was low (Table 3-32).

3.3.3.5 Mean concentration

The four sub-catchments within the ≥75th percentile ranking based on their $mean_{(BT)}$ dissolved inorganic nitrogen concentration included, from highest to lowest: Ross Creek, Site 7 (0.091 mgL^{-1}); Sandy Creek at Bruce Highway, Site 11 (0.082 mgL^{-1}); Sandy Creek North Branch, Site 2.1 (0.076 mgL^{-1}); and, Sandy Creek at Eton, Site 5 (0.070 mgL^{-1}) (Figure 3-37).

The next highest ranked sub-catchments (≥50th<75th percentile) included, from highest to lowest: Draper Creek at De Moleyns Lagoon, Site 1 (0.045 mgL^{-1}); Frenchmans Creek, Site 10 (0.035 mgL^{-1}); and, Draper Creek at Multi-farm, Site 2 (0.032 mgL^{-1}) (Figure 3-37).

The third grouping of sub-catchments ranked in the ≥25th<50th percentile category included, from highest to lowest $mean_{(BT)}$ dissolved inorganic nitrogen concentrations: Draper Creek at Peak Downs Highway, Site 6 (0.030 mgL^{-1}); Sandy Creek South Branch, Site 3 (0.025 mgL^{-1}); and, BL Creek, Site 20 (0.023 mgL^{-1}) (Figure 3-36Figure 3-32).

The lowest ranked group of sub-catchments based on the $mean_{(BT)}$ ammonium nitrogen concentrations were, from highest to lowest: Bagley Creek, Site 8 (0.020 mgL^{-1}); Cut Creek, Site 4 (0.016 mgL^{-1}); and, Oaky Creek, Site 9 (0.0081 mgL^{-1}) (Figure 3-36Figure 3-32).

The influence of the high $mean_{(BT)}$ concentration from Sandy Creek South Branch, compared to Sandy Creek North Branch (0.076 mgL^{-1}) and Cut Creek (0.016 mgL^{-1}), is reflected in the similarly high $mean_{(BT)}$ concentration of ammonium nitrogen monitored at Sandy Creek at Eton (0.070 mgL^{-1}).

The $mean_{(BT)}$ concentration of ammonium nitrogen was similar between all monitored sites in Draper Creek (range, 0.045 mgL^{-1} to 0.030 mgL^{-1}), which were low compared to the concentration in the adjacent Sandy Creek North Branch and Ross Creek.

Among the sub-catchments on the southern side of Sandy Creek, the $mean_{(BT)}$ concentration of ammonium nitrogen was generally low, ranging from 0.035 mgL^{-1} in Frenchmans Creek, 0.023 mgL^{-1} in BL Creek to 0.020 mgL^{-1} in Bagley Creek. In Oaky Creek, the $mean_{(BT)}$ of ammonium nitrogen was low (0.0081 mgL^{-1}).

The $mean_{(BT)}$ concentration of ammonium nitrogen remained high at all the main channel sites, with the concentration at the end-of-catchment site, Sandy Creek at Bruce Highway (0.082 mgL^{-1}) being among the highest of all monitored sites.

Table 3-32 Summary statistics for water quality samples analysed for ammonium nitrogen. All concentrations are reported in mgL-1.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	7	41	11	26	20	23	13	16	22	10	116	27	12	20
Detections. >LOR	7	41	11	26	20	23	13	16	22	10	116	27	12	20
Detection Freq. (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100
$Mean_{(BT)}$	0.076	0.025	0.016	0.070	0.045	0.032	0.030	0.091	0.020	0.0081	0.047	0.035	0.023	0.082
Std. Dev.	0.39	0.20	0.12	0.40	0.21	0.29	0.28	0.50	0.26	0.084	0.46	0.33	0.20	0.29
Median	0.073	0.028	0.015	0.11	0.036	0.029	0.024	0.081	0.022	0.0085	0.032	0.025	0.024	0.063
95^{th} Percentile	0.26	0.051	0.023	0.23	0.089	0.074	0.12	0.56	0.047	0.011	0.31	0.17	0.060	0.25
Max. Conc.	0.26	0.070	0.026	0.25	0.090	0.88	0.16	1.6	0.058	0.011	0.68	0.18	0.065	0.26

n – number of samples analysed; **>LOR** – number of samples where the concentration was below the analytical limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of ammonium nitrogen was above the analytical limit of reporting.

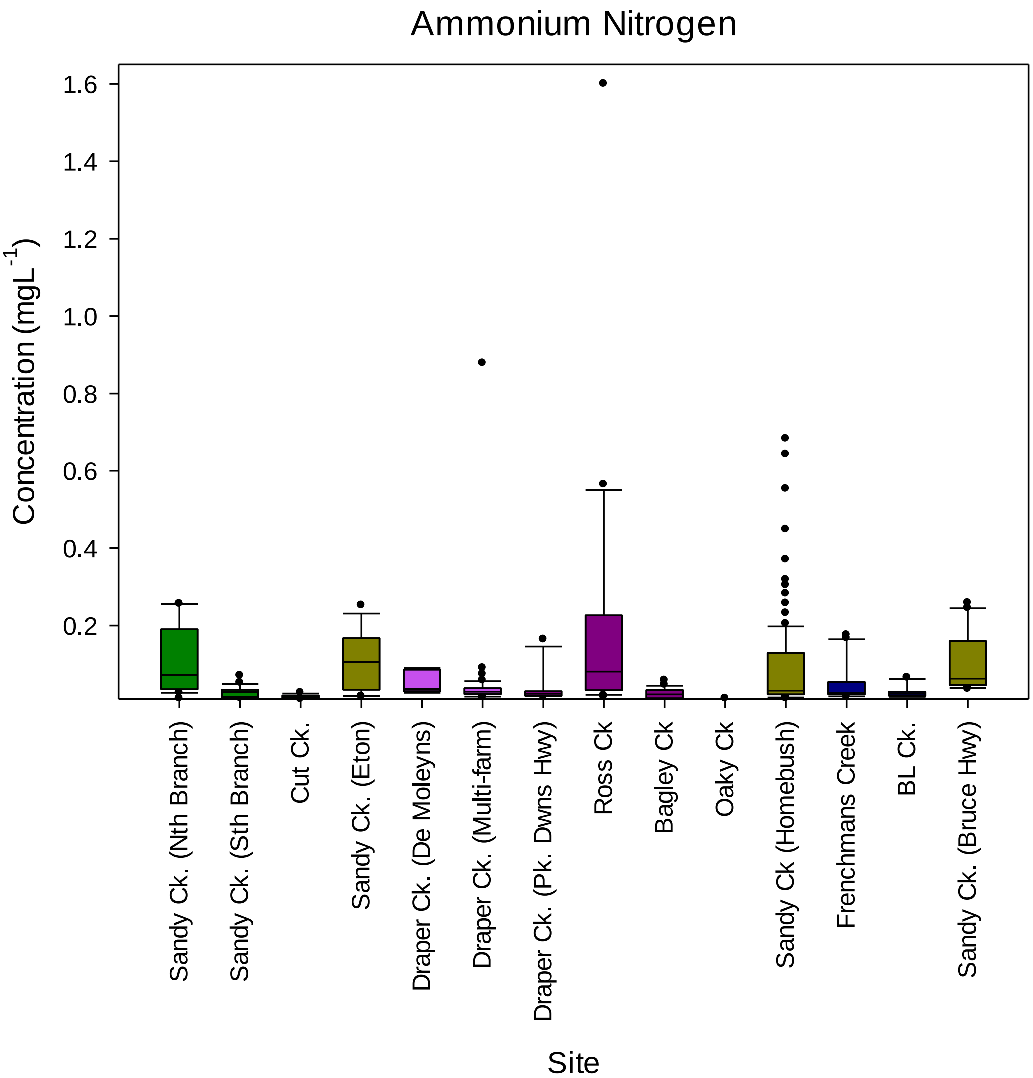

Figure 3-37 Box plot of measured concentration of ammonium nitrogen at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the 90th and 10th percentiles, solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

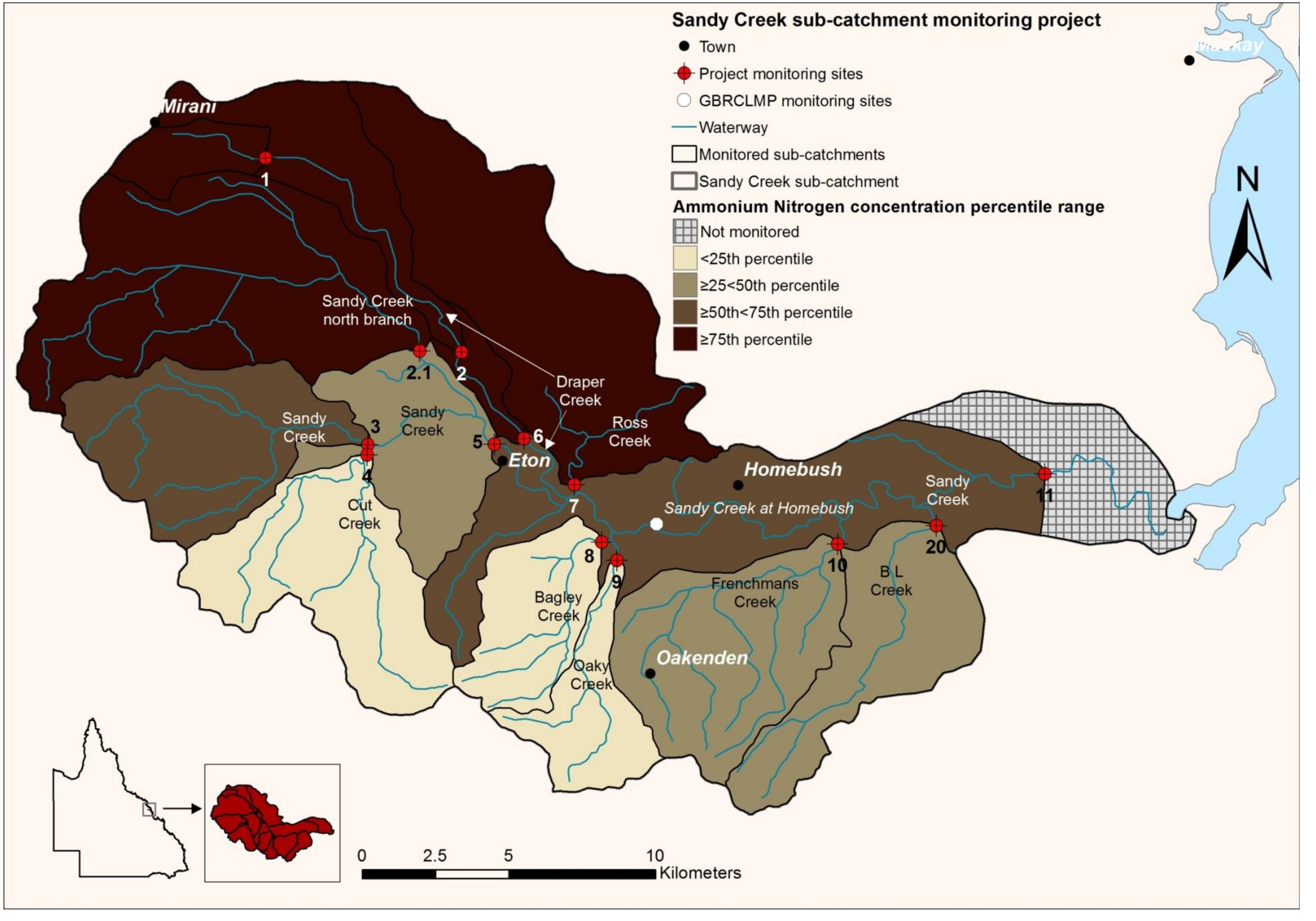

Figure 3-38 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of ammonium nitrogen in water samples collected at each sub-catchment during the monitored events.

3.3.4 Oxidised nitrogen

Guideline Note –

There are no current scheduled water quality objectives for oxidised nitrogen under event flow conditions as there are for DIN (DEHP 2013). However, there are regional water quality guidelines for Central Coast Queensland (DERM 2009).

- *For slightly to moderately disturbed lowland streams in Central Coast Queensland – 0.06 mgL-1*
- *For slightly to moderately disturbed upper estuaries in Central Coast Queensland – 0.015 mgL^{-1}*

3.3.4.1 Detection frequency

Oxidised nitrogen was detected above the analytical limit of reporting in all samples collected from all sub-catchments (Table 3-33).

3.3.4.2 Distribution of concentrations

The pattern of the general concentration distributions (25th – 75th percentile) for oxidised nitrogen was expectedly similar to dissolved inorganic nitrogen (Section 3.3.2.2) – dissolved inorganic nitrogen is the sum of oxidised nitrogen and ammonium nitrogen. Sandy Creek South Branch, Ross Creek and Oaky Creek had high concentration distributions compared to all other monitored sub-catchments. The input from Sandy Creek North Branch likely contributed to the higher concentration distribution detected at Sandy Creek at Eton. The concentration distribution was also comparatively high at Sandy Creek at Bruce Highway. The general concentration distribution in Sandy Creek North Branch, Cut Creek and Bagley Creek were low (Figure 3-39).

The highest concentrations of oxidised nitrogen was monitored in BL Creek (7.6 mgL^{-1}), Sandy Creek at Eton (5.8 mgL^{-1}), Ross Creek (5.2 mgL^{-1}), Draper Creek at De Moleyns Lagoon (4.7 mgL^{-1}) and Sandy Creek at Homebush (4.5 mgL^{-1}). There was no consistent trend in the timing of when these maximum concentrations were observed with these results occurring between Event 2 and Event 6 depending on sub-catchment (Appendix C). The maximum concentrations in all other catchments was below 4.0 mgL^{-1}. Bagley Creek (0.45 mgL^{-1}) and Cut Creek (0.81 mgL^{-1}) had the lowest monitored maximum concentrations of all sub-catchments.

3.3.4.3 Median concentrations and exceedance of the water quality objectives

The median concentration exceeded the water quality objectives for lowland streams at all sites. The median values were, from highest to lowest: Oaky Creek (0.84mgL^{-1}), Sandy Creek at Eton (0.81 mgL^{-1}), Sandy Creek South Branch (0.69 mgL^{-1}), Cut Creek (0.61 mgL^{-1}), BL Creek (0.53 mgL^{-1}), Frenchmans Creek (0.44 mgL^{-1}), Ross Creek (0.41 mgL^{-1}), Sandy Creek North Branch (0.37 mgL^{-1}), Draper Creek at Peak Downs Highway (0.35 mgL^{-1}) and Sandy Creek at Homebush (0.3 mgL^{-1}), Draper Creek at Multi-farm (0.25 mgL^{-1}), Bagley Creek (0.16 mgL^{-1}) and Draper Creek at De Moleyns Lagoon (0.15 mgL^{-1}). The median concentration at the estuarine site, Sandy Creek at Bruce Highway (0.57 mgL^{-1}), exceeded the water quality objective value for estuaries (Table 3-33).

3.3.4.4 Mean concentration

The four sub-catchments within the ≥75th percentile ranking based on their mean$_{(BT)}$ oxidised nitrogen concentrations were, from highest to lowest: Sandy Creek Bruce Highway, Site 11

(0.80 mgL^{-1}); Oaky Creek, Site 9 (0.78 mgL^{-1}); Sandy Creek South Branch, Site 3, (0.47 mgL^{-1}); and, Frenchmans Creek, Site 10 (0.43 mgL^{-1}) (Figure 3-40).

The next highest ranked sub-catchments (≥ 50^{th}<75^{th} percentile) included, from highest to lowest: Sandy Creek at Eton, Site 5 (0.39 mgL^{-1}); Ross Creek, Site 7 (0.34 mgL^{-1}); and, BL Creek, Site 20 (0.33 mgL^{-1}) (Figure 3-40).

The third grouping of sub-catchments ranked in the ≥25^{th}<50^{th} percentile category included, from highest to lowest $mean_{(BT)}$ oxidised nitrogen concentrations: Cut Creek, Site 4 (0.33 mgL^{-1}); Draper Creek at De Moleyns Lagoon, Site 1 (0.23 mgL^{-1}); and, Draper Creek at Peak Downs Highway, Site 6 (0.22 mgL^{-1}) (Figure 3-40). BL Creek and Cut Creek were assigned different categorical rankings based on unrounded $mean_{(BT)}$ concentrations.

The lowest ranked group of sub-catchments based on the $mean_{(BT)}$ oxidised nitrogen concentrations were, from highest to lowest: Draper Creek at Multi-farm, Site 2 (0.19 mgL^{-1}); Sandy Creek North Branch, Site 2.1 (0.12 mgL^{-1}); and, Bagley Creek, Site 8 (0.12 mgL^{-1}) (Figure 3-40).

The high $mean_{(BT)}$ concentration of oxidised nitrogen at the end-of-catchment site, Sandy Creek at Bruce Highway (0.80 mgL^{-1}), is notable as it is particularly high relative to both the upstream monitoring site at Sandy Creek at Homebush (0.38 mgL^{-1}) and Sandy Creek at Eton (0.39 mgL^{-1}). The box plot (Figure 3-39) shows the distribution of the concentration data at the Sandy Creek at Bruce Highway is strongly positively skewed with many of the higher monitored concentration occurring during Event 3 and Event 4 (Figure 7-237, Appendix C) when the maximum concentrations of oxidised nitrogen was monitored in many of the sub-catchments. On the other hand, the high $mean_{(BT)}$ concentration at Oaky Creek is also notable because this sub-catchment generally had low concentration of most pesticides and the lowest $mean_{(BT)}$ of ammonium nitrogen of all monitored sub-catchments. The $mean_{(BT)}$ concentration of Sandy Creek at Bruce Highway and Oaky Creek was approximately two to four times higher than all other monitored sub-catchments (Table 3-33).

Among the upper- Sandy Creek sub-catchments, the $mean_{(BT)}$ concentration of oxidised nitrogen in Sandy Creek South Branch (0.47 mgL^{-1}) and Cut Creek (0.33 mgL^{-1}) was notably higher than Sandy Creek North Branch (0.12 mgL^{-1}).

Within the Draper Creek sub-catchment, the $mean_{(BT)}$ concentration of oxidised nitrogen was similar between all sites (range, 0.19 mgL^{-1} to 0.23 mgL^{-1}) and were lower than the adjacent Ross Creek sub-catchment (0.34 mgL^{-1}). The $mean_{(BT)}$ concentration of oxidised nitrogen differed between sub-catchments on the southern side of Sandy Creek catchment, with the previously discussed high concentrations in Oaky Creek, and lesser concentrations in Frenchmans Creek (0.43 mgL^{-1}), BL Creek (0.33 mgL^{-1}) and Bagley Creek (0.12 mgL^{-1}), which had the equal lowest $mean_{(BT)}$ concentration of oxidised nitrogen of all monitored sub-catchments.

Table 3-33 Summary statistics for water quality samples analysed for oxidised nitrogen. All concentrations are reported in mgL^{-1}.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	7	41	11	26	20	23	13	16	22	10	116	27	12	20
Detections. >LOR	7	41	11	26	20	23	13	16	22	10	116	27	12	20
Detection Freq. (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100
$Mean_{(BT)}$	0.12	0.47	0.33	0.39	0.23	0.19	0.22	0.34	0.12	0.78	0.38	0.43	0.33	0.80
Std. Dev.	1.1	0.65	0.37	0.87	1.1	0.83	0.80	0.77	0.44	0.25	0.58	0.44	0.63	0.37
Median	0.37	0.69	0.61	0.81	0.15	0.25	0.35	0.41	0.16	0.84	0.30	0.44	0.53	0.53
95^{th} Percentile	2.1	3.5	0.72	4.6	4.4	1.7	1.7	4.1	0.38	1.5	2.8	2.2	4.1	3.1
Max. Conc.	3.7	3.7	0.81	5.8	4.7	1.8	2.0	5.2	0.45	1.5	4.5	2.4	7.6	3.6

n – number of samples analysed; **>LOR** – number of samples where the concentration was below the analytical limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of oxidised nitrogen was above the analytical limit of reporting.

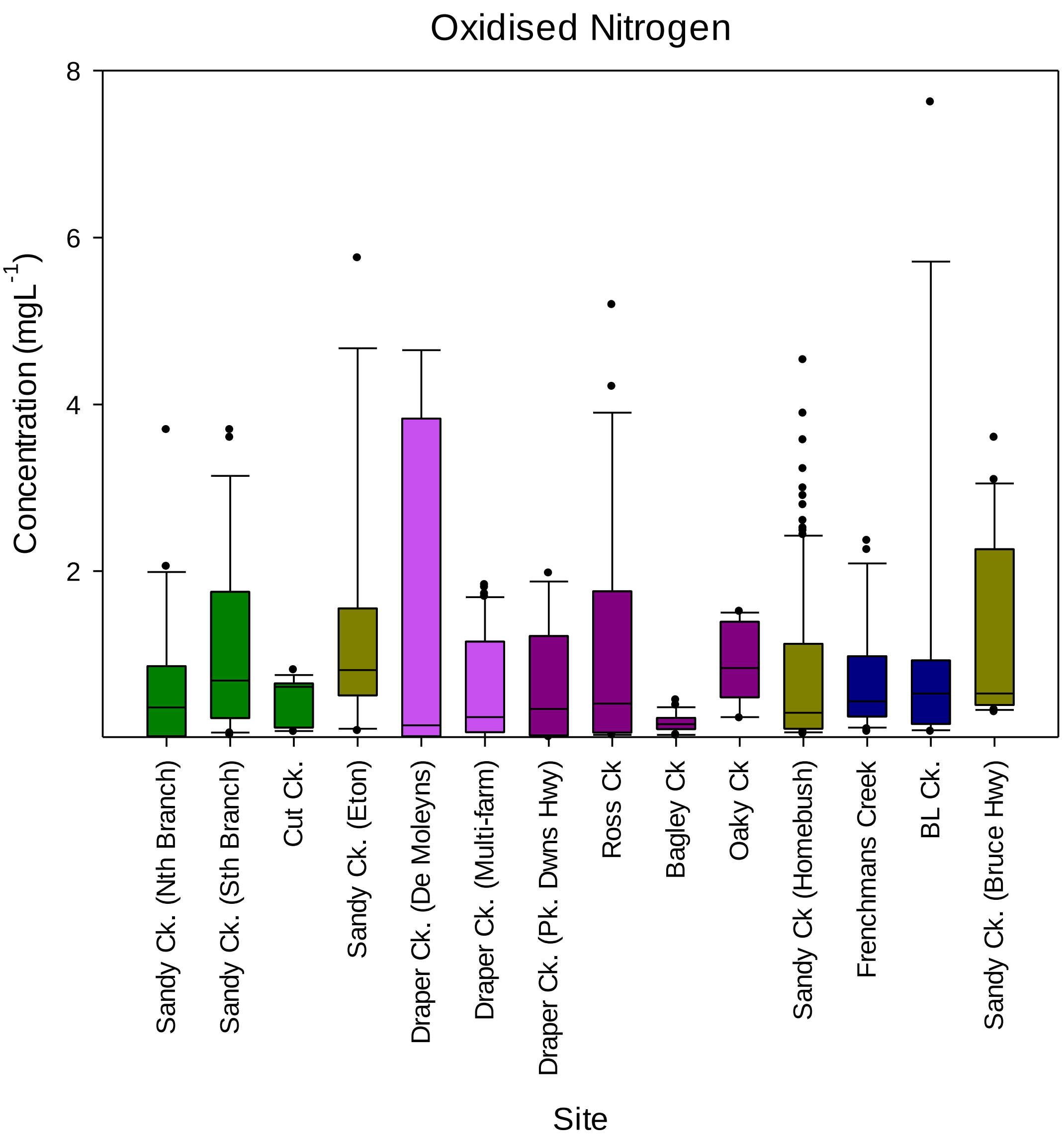

Figure 3-39 Box plot of measured concentration of oxidised nitrogen at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75^{th} percentile, whiskers indicate the 90^{th} and 10^{th} percentiles, solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

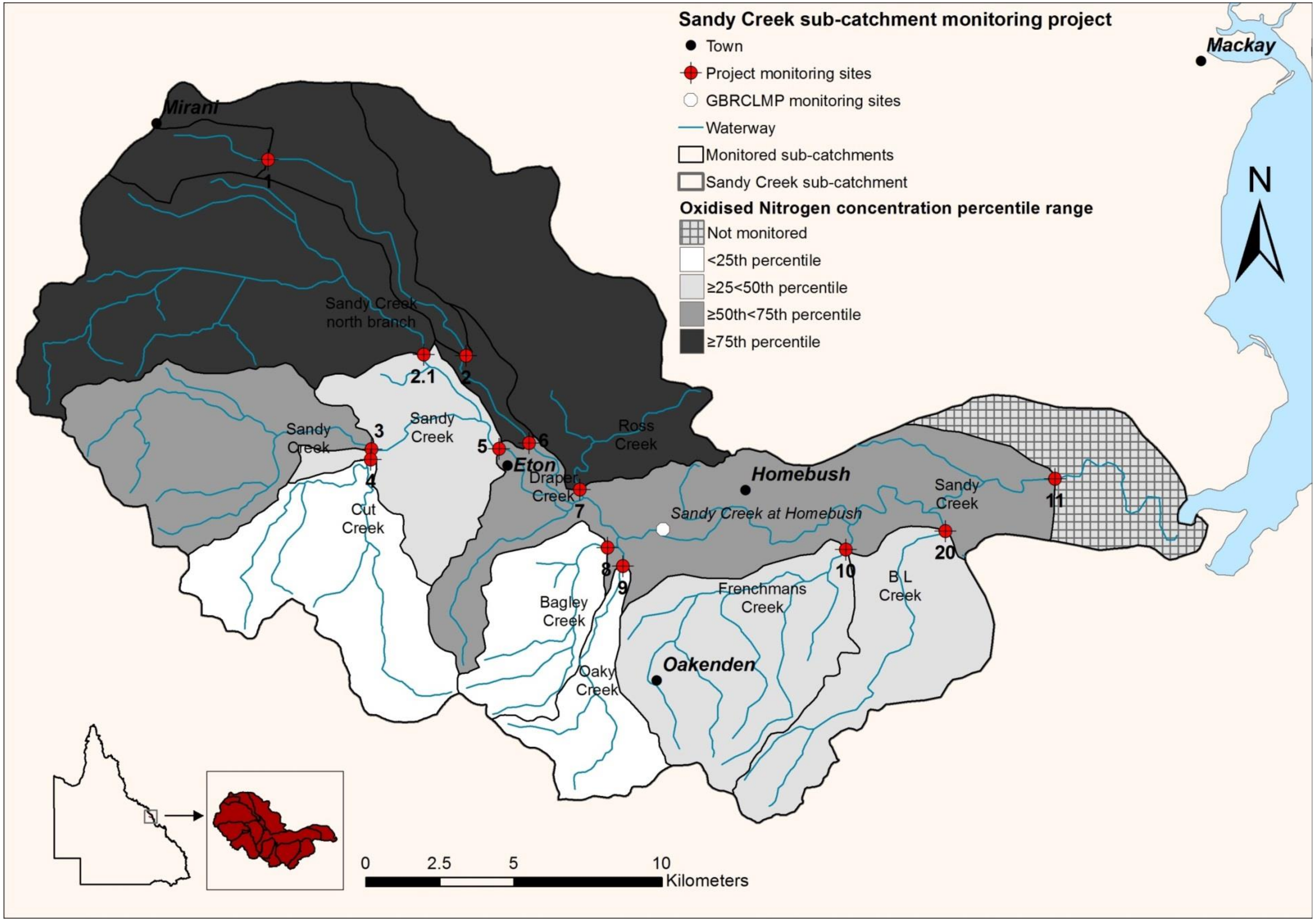

Figure 3-40 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of oxidised nitrogen in water samples collected at each sub-catchment during the monitored events.

3.3.5 Dissolved Inorganic Phosphorus

Guideline Note –

The current water quality objective for the protection of aquatic environmental values (DEHP 2013) in freshwater aquatic ecosystems of Sandy Creek for dissolved inorganic phosphorus are:

- *Moderately disturbed end-of-system (high flows)* – *< 0.03 mgL^{-1}*

3.3.5.1 Detection frequency

Dissolved inorganic phosphorus was detected above the analytical limit of reporting in all samples collected from all sub-catchments.

3.3.5.2 Distribution of concentrations

The highest concentrations of dissolved inorganic phosphorus were monitored in Draper Creek (De Moleyns Lagoon (0.85 mgL^{-1}) and Peak Downs Highway (0.74 mgL^{-1}), and Sandy Creek North Branch (0.81 mgL^{-1}). The maximum concentration in all other sub-catchments was in the range 0.48 mgL^{-1} to 0.065 mgL^{-1}.

The pattern between sub-catchments of the general distribution of concentrations (25th – 75th percentile) of dissolved inorganic phosphorus was somewhat dissimilar to the reported nitrogen results in Section 3.3.2 to 3.3.4. The sub-catchments in the north-west section of the catchment had generally higher distributions of concentration than all other sub-catchments (Figure 3-41), These catchments include Sandy Creek North Branch, Draper Creek and Ross Creek. Further consultation with the local sugar industry is required to determine whether this may be related to the proximity of these sub-catchment to the Mackay Mill and potentially higher usage of mill mud.

3.3.5.3 Median concentrations and exceedance of the water quality objectives

The median concentration exceeded the water quality objective value at Draper Creek at Peak Downs Highway (0.33 mgL^{-1}), Draper Creek at De Moleyns Lagoon (0.30 mgL^{-1}), Draper Creek at Multi-farm (0.29 mgL^{-1}), Ross Creek (0.28 mgL^{-1}), Sandy Creek North Branch (0.25 mgL^{-1}), Sandy Creek South Branch (0.19 mgL^{-1}), Sandy Creek at Homebush (0.19 mgL^{-1}), Sandy Creek Bruce Highway (0.18 mgL^{-1}), Sandy Creek at Eton (0.17 mgL^{-1}), Frenchmans Creek (0.15 mgL^{-1}), BL Creek (0.077 mgL^{-1}) and Oaky Creek (0.073 mgL^{-1}). The water quality objective was not exceeded by the median concentrations at Cut Creek (0.029 mgL^{-1}) and Bagley Creek (0.024 mgL^{-1}) (Table 3-34).

3.3.5.4 Mean concentration

The four sub-catchments within the ≥75th percentile ranking based on their mean$_{(BT)}$ dissolved inorganic phosphorus concentrations were, from highest to lowest: Draper Creek at Peak Downs Highway, Site 6 (0.35 mgL^{-1}); Draper Creek at De Moleyns Lagoon, Site 1 (0.33 mgL^{-1}); Draper Creek at Multi-farm, Site 2 (0.29 mgL^{-1}); and, Sandy Creek North Branch, Site 2.1 (0.27 mgL^{-1}) (Figure 3-42).

The next highest ranked sub-catchments (≥50th <75th percentile) included, from highest to lowest: Ross Creek, Site 7 (0.26 mgL^{-1}); Sandy Creek at Bruce Highway, Site 11 (0.16 mgL^{-1}); and, Sandy Creek South Branch, Site 3 (0.16 mgL^{-1}) (Figure 3-42).

The third grouping of sub-catchments ranked in the ≥25th<50th percentile category included, from highest to lowest mean$_{(BT)}$ dissolved inorganic phosphorus concentrations: Sandy Creek at Eton, Site 5 (0.14 mgL^{-1}); Frenchmans Creek, Site 10 (0.13 mgL^{-1}); and, Oaky Creek, Site 9 (0.071 mgL^{-1}) (Figure 3-42).

The lowest ranked group of sub-catchments based on the $mean_{(BT)}$ dissolved inorganic phosphorus concentrations were, from highest to lowest: Figure 3-32BL Creek, Site 20 (0.061 mgL^{-1}); Cut Creek, Site 4 (0.030 mgL^{-1}); and, Bagley Creek, Site 8 (0.028 mgL^{-1}) (Figure 3-42).

The $mean_{(BT)}$ concentrations of dissolved inorganic phosphorus were similar at all monitoring sites on the Sandy Creek main channel: Sandy Creek at Eton (0.14 mgL^{-1}), Sandy Creek at Homebush (0.15 mgL^{-1}) and Sandy Creek at Bruce Highway (0.16 mgL^{-1}).

Among the upper-Sandy Creek sub-catchments, the $mean_{(BT)}$ in Sandy Creek South Branch (0.16 mgL^{-1}) was similar to the downstream main channel site, Sandy Creek at Eton (0.14 mgL^{-1}) – with the $mean_{(BT)}$ concentration at these sites approximately half the concentration in Sandy Creek North Branch (0.27 mgL^{-1}). The $mean_{(BT)}$ concentration in Cut Creek was expectedly low (0.030 mgL^{-1}) as this sub-catchment only commenced to flow during the large flow events in February and March and has a small proportion of the catchment area under cane relative to other monitored sub-catchments.

The sub-catchments draining the southern side of Sandy Creek catchment all had monitored $mean_{(BT)}$ concentrations of dissolved inorganic phosphorus concentrations that were much lower than the sub-catchment on the northern side of the catchment.

Table 3-34 Summary statistics for water quality samples analysed for dissolved inorganic phosphorus. All concentrations are reported in mgL^{-1}.

Site	Sandy Ck. North Branch	Sandy Ck. South Branch	Cut Ck.	Sandy Ck. Eton	Draper Ck. De Moleyns Lagoon	Draper Ck. Multi-farm	Draper Ck. Peak Downs Highway	Ross Ck.	Bagley Ck.	Oaky Ck.	Sandy Ck. Homebush	Frenchmans Ck.	BL Creek	Sandy Ck. Bruce Hwy
Site Number	2.1	3	4	5	1	2	6	7	8	9	-	10	20	11
n	7	41	11	26	20	23	13	16	22	10	116	27	12	20
Detections. >LOR	7	41	11	26	20	23	13	16	22	10	116	27	12	20
Detection Freq. (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Mean$_{(BT)}$	0.27	0.16	0.030	0.14	0.33	0.29	0.35	0.26	0.028	0.071	0.15	0.13	0.061	0.16
Std. Dev.	0.16	0.16	0.20	0.29	0.19	0.079	0.11	0.20	0.54	0.14	0.32	0.30	0.33	0.14
Median	0.25	0.19	0.029	0.17	0.30	0.29	0.33	0.28	0.024	0.073	0.19	0.15	0.077	0.18
95th Percentile	0.44	0.25	0.061	0.24	0.70	0.39	0.55	0.45	0.17	0.12	0.34	0.40	0.23	0.23
Max. Conc.	0.81	0.27	0.065	0.24	0.85	0.44	0.74	0.48	0.23	0.14	0.39	0.45	0.30	0.24

n – number of samples analysed; **>LOR** – number of samples where the concentration was below the analytical limit of reporting; **Detection Frequency** – the proportion of samples collected at a site which the concentration of dissolved inorganic phosphorus was above the analytical limit of reporting.

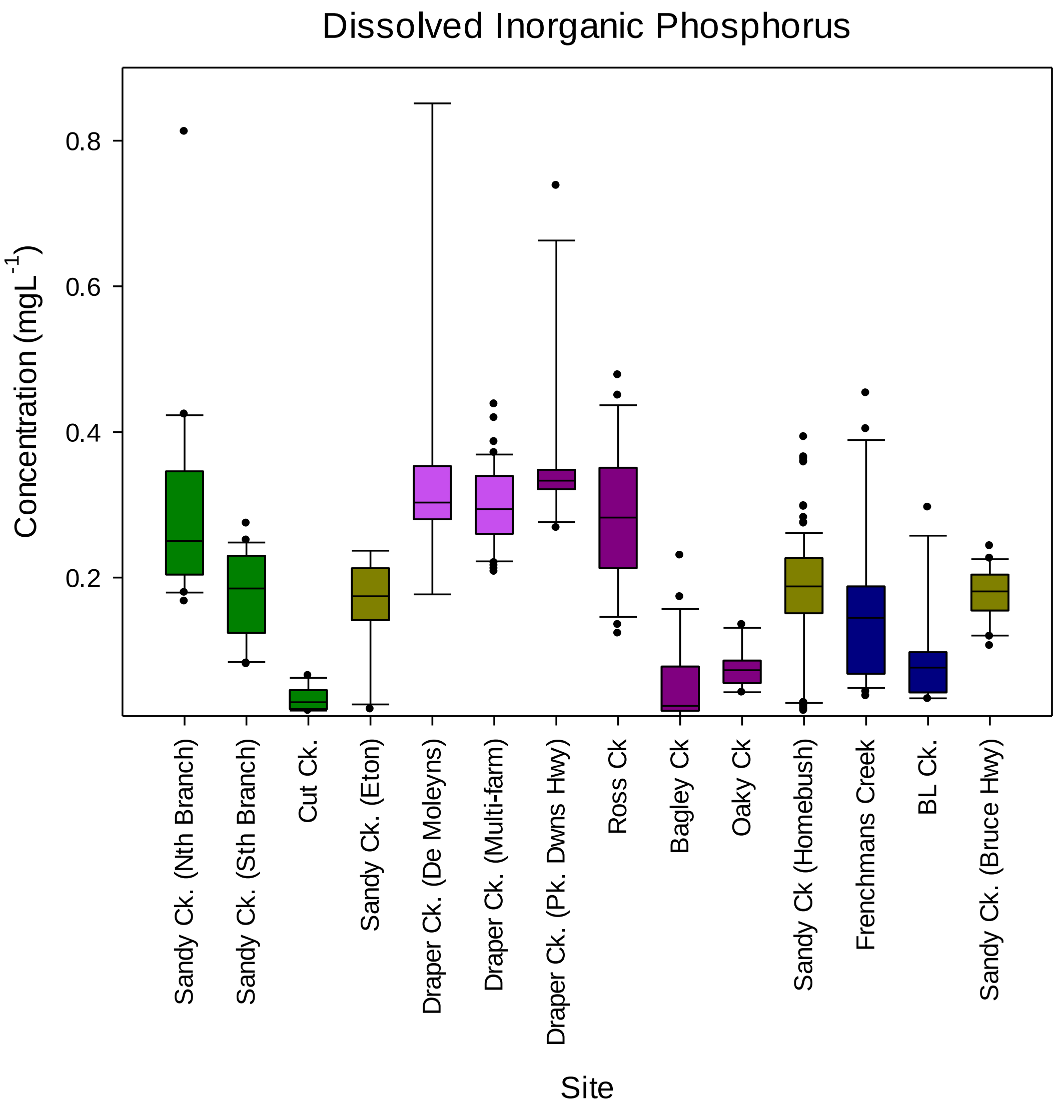

Figure 3-41 Box plot of measured concentration of dissolved inorganic phosphorus at monitoring sites in the Sandy Creek catchment. Lower boundary of the box is the 25th percentile, horizontal solid line is the median, upper boundary of the box is the 75th percentile, whiskers indicate the upper 90th and 10th percentiles, solid dots are outlying concentrations. Sites are presented from the upper catchment (left) to lower catchment (right). Gold = main channel sites; Green = upstream of main channel site Sandy Creek at Eton; light purple = nested sub-catchment sites in Draper Creek; dark purple = sub-catchments draining into the main channel upstream of Sandy Creek at Homebush; blue = sub-catchments draining into the main channel upstream of Sandy Creek at Bruce Highway.

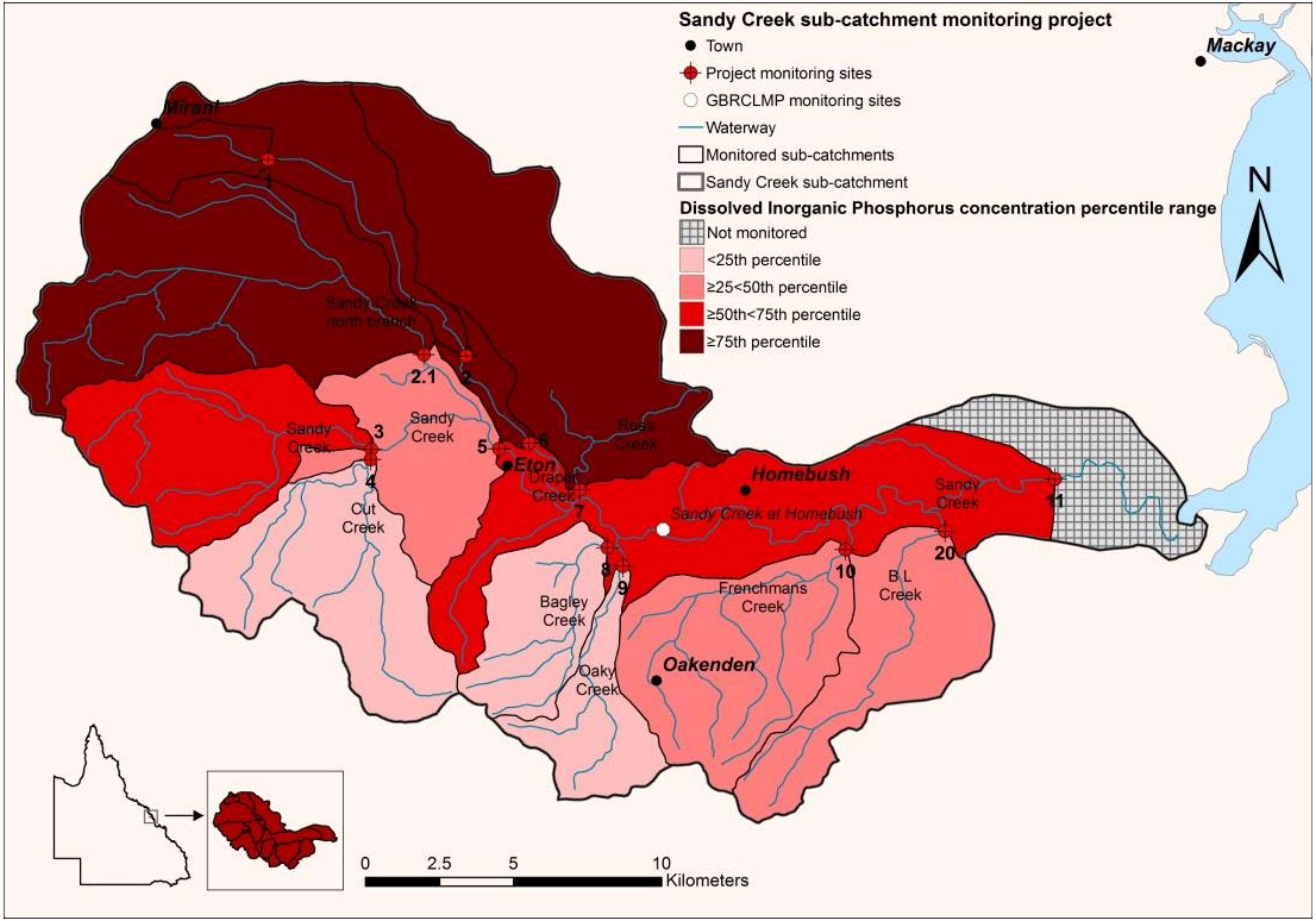

Figure 3-42 Map displaying the sub-catchment area upstream of each monitoring site. Sub-catchments are shaded to represent the percentile rank of the mean$_{(BT)}$ concentration of dissolved inorganic phosphorus in water samples collected at each sub-catchment during the monitored events.

4 Limitations and recommendations

In all monitoring programs there are inherent limitations in the data that must be considered prior to making any conclusive determinations or deciding on a course of action. Some of the key limitations to the data presented in this report are outlined below. These should be considered within the objectives of the Sandy Creek Sub-catchment Water Quality Monitoring Project and the objectives of the further use or application of these data.

Water quality sampling

The number of samples collected, and the number of events monitored were not consistent across all sub-catchments. Due to the temporal variability in concentrations of pesticides and nutrients in surface water runoff, inconsistencies in the sampling regime could lead to erroneous conclusions if these differences are not taken into consideration when interpreting the results. For this reason, it should be noted that:

- the individual results represent the concentrations of pesticides and nutrients at discrete points in time, and the timing of the sample collection in relation to the hydrograph (presented in Appendix B and Appendix C) should be considered when interpreting the data;
- the absence of samples during early events means that the sampling program may have missed periods of elevated concentrations, and therefore, the descriptive statistics may be biased toward a lower overall distribution of concentration data. Similarly, if events later in the wet season were not sampled or under-sampled, the descriptive statistics may represent a higher overall distribution of concentration data;
- the collection of samples over the full hydrograph, including the lower stages of the falling hydrograph, are likely to result in a lower overall distribution of concentration data (e.g. Sandy Creek at Homebush) compared to sites or events where sample collection was limited to the rise and peak of the hydrograph (when concentrations are generally higher).

The measurement or modelling of discharge at all monitored sites would allow for inclusion of discharge as a function in statistical analysis of the data, possibly reducing some of the potential bias resulting from differences in sampling coverage between sub-catchments and events.

Discharge data

The calculation of discharge for each sub-catchment was outside the scope of the current project. Although depth loggers were installed at the sub-catchment monitoring sites, no flow gaugings were undertaken to develop a hydrological rating curve for each site. Subsequently, no discharge data are currently available for any of the sub-catchment monitoring sites, with the exception of Sandy Creek at Homebush which is monitored as part of the Great Barrier Reef Catchment Loads Monitoring Program, and Draper Creek at Multi-farm which has an existing rating curve developed as part of earlier research programs (Rhode et al. 2013).

In the absence of discharge data, the back transform of the log mean concentration has been presented in this report. The availability of either monitored or modelled discharge data would permit the calculation of the flow weighted mean, which provides a more robust calculation of the mean concentration. One approach that would estimate discharge for the monitoring sites is through hydrological modelling of the rainfall-runoff. A consultant has been engaged to run a hydrological model across the Sandy Creek catchment. The availability of modelled discharge data for each monitoring site will enable further analysis of the measured concentration data that will complement the data presented in this report. These additional analyses of the concentration data may include:

- Analysis of the relative contribution of discharge from each sub-catchment;
- Calculation of the mass loads of each pesticide and monitored nutrients transported past the monitoring sites;
- Calculation of the flow weighted event mean concentration enabling a more robust comparison between sub-catchments and events – calculation of the flow weighted mean concentration of each pesticide and the monitored nutrients will reduce the bias that occurs in the calculation of the arithmetic mean;
- Analysis of the relationship between pesticide and nutrient concentrations/loads and land use area;

Laboratory analyses

The laboratory methods used to analyse the water samples are not capable of detecting all pesticides, and as such, some chemicals that may be present in Sandy Creek are not presented in this report. Since completion of monitoring during the 2015 – 2016 wet season, Queensland Health Forensic Scientific Services have increased the number of pesticides reported in the direct injection analytical suite and reduced the analytical limit of reporting for some pesticides. Future monitoring of water quality in Sandy Creek will benefit from these advances.

Chemical usage data

One key area that is not discussed in this report, is the differences in the monitored concentrations and frequency of detection between pesticides as a function of the mobilisation of pesticides from the point of application to the waterways. Further analysis of these differences would be enhanced by the provision of current pesticide use data across all sub-catchments. This information would greatly enhance the understanding of differences in the rates of loss between sub-catchments and improve advice provided to local growers with respect to product choice and management practice.

Fertiliser usage data

The provision of management practice data relating to fertiliser usage would greatly assist in understanding the differences in the monitored concentration data presented in this report. This information would be greatly beneficial to understanding the relationship between application rates and loss pathways, which together would assist in the implementation of appropriate and effective management strategies to reduce off-farm losses.

Toxicity

The toxicity of mixtures of pesticides to which aquatic ecosystems are exposed in Sandy Creek has not been addressed in the current report. The Department of Science, Information Technology and Innovations are currently deriving water quality guidelines for many of the pesticides detected in Sandy Creek. Once these guidelines are finalised in 2017, a reanalysis of the concentration data including the combined toxicity of multiple pesticides is recommended.

5 Conclusions

The local sugar industry in the Sandy Creek catchment is determined to reduce off-farm losses of pesticides and nutrients to ensure the long-term sustainability of their industry and the local environment. The Sandy Creek Sub-catchment Water Quality Monitoring Project was initiated by Mackay Area Productivity Services, Farmacist and Sugar Research Australia in collaboration with participating growers with the aim of identifying areas of the sub-catchment where off-farm losses of pesticides and nutrients contribute to the exceedance of the water quality guidelines.

The commitment of all participating members of the project has been overwhelming. The Sandy Creek Sub-catchment Water Quality Monitoring Project was led by the sugar industry from concept development, project design, sample collection, interpretation of results, and planning of management actions to address off-farms losses of pesticides. The leadership shown by the sugar industry and the success of this project in advancing our understanding of the water quality in Sandy Creek, was acknowledged by the former Queensland Chief Scientist, Dr Geoff Garrett, who met with the project team in February 2016.

The key outcomes of the Sandy Creek Sub-catchment Water Quality Monitoring Project are:

- Water quality was monitored at 13 sites over multiple rainfall runoff events during the 2015–2016 wet season.
- Approximately 300 samples were analysed for pesticides and 250 samples analysed for nutrients. The results of an additional 109 samples that were collected at the existing automated sampling site, Sandy Creek at Homebush, are also presented in this report.
- Imidacloprid, imazapic, hexazinone, diuron, atrazine and 2,4-D were detected in greater than 75 per cent of all samples. Fluroxypyr, MCPA, isoxaflutole metabolite, metribuzin and metolachlor were detected in more than 50 per cent of all samples.
- The total number of pesticides detected was similar among many of the monitored sub-catchments. Bagley Creek (20 pesticides) had the highest overall number of pesticides detected and BL Creek (10 pesticides) had the lowest number of pesticides detected.
- Monitored sub-catchments in the north-west section of Sandy Creek including Ross Creek, Sandy Creek North Branch, and Draper Creek, together with the end-of-catchment monitoring site at the Bruce Highway had the highest $\text{mean}_{(BT)}$ concentrations of more pesticides than all other sub-catchments.
- The concentration of diuron was very high in all monitored sub-catchments – 84 per cent of samples exceeded the low reliability ecosystem protection guideline trigger value (0.2 μgL^{-1}) and 45 per cent of samples exceeded the irrigation residue guideline (2 μgL^{-1}). The monitored 95th percentile concentration of diuron was 17 to 85 times above the ecosystem protection guideline trigger value in all monitored sub-catchments except Cut Creek and Oaky Creek.
- Metolachlor was detected above the low reliability ecosystem protection guideline trigger value (0.02 μgL^{-1}) in 53 per cent of samples. The 95th percentile concentration of metolachlor in the monitored sub-catchments was 5.5 to 165 times above the low reliability ecosystem protection guideline.
- Atrazine was detected above the ecosystem protection (95% of species) guideline trigger value (13 μgL^{-1}) in 4.2 per cent of samples.
- MCPA was detected above the low reliability ecosystem protection guideline trigger value (1.4 μgL^{-1}) in 2.6 per cent of samples.

- Storm driven rainfall runoff events early in the wet season generally resulted in the highest monitored concentrations of many pesticides.
- Application of pesticides during the wet season resulted in subsequent peaks in the monitored concentration of pesticides; in some instances exceeding the maximum observed concentration during early events.
- The substantial data resource gained through the intensive monitoring undertaken will enable targeted extension activities in areas identified as producing high concentrations of priority pesticides.

In December 2016, the Department of Environment and Heritage Protection committed ongoing funding to assist the sugar industry to improve water quality flowing from Sandy Creek to the Great Barrier Reef. The extension in funding will enable this project to:

1. Monitor sub-catchment water quality to link farm practice to in-stream water quality and direct extension activities to sub-catchments where water quality exceeds guidelines;
2. Provide targeted extension services to reduce off-farm losses of pesticides and nutrients through adoption of specific management practices;
3. Identify management practice change barriers and develop strategies to overcome these through novel social approaches.

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7 Appendices

Appendix A Comparison of solid phase extraction and direct injection analytical methods for pesticides.

7.1.1.1 Sensitivity

When comparing solid phase extraction (high limit of reporting) and Direct Injection, neither method is necessarily more sensitive than the other when analysing for pesticides in surface water samples. As the methods are carried out differently, slight detection differences between the two methods are evident.

The solid phase extraction method uses a small extraction cartridge by which liquid passes through to separate compounds in the mixture according to their physical and chemical properties (Sigma-Aldrich 2016). Laboratories use solids phase extraction prior to analysis to pre-concentrate and purify samples by removing some interference (Hernandez et al. 2001). This allows for a cleaner extract containing the analytes of interest. The extraction is often referred to as a ‘clean-up’ step.

The Direct Injection method differs from the solids phase extraction method as it has no ‘clean-up’ or enrichment step. Instead, the aqueous sample is directly injected into the LC-MS/MS for analysis. This means that the sample can be up to a thousand-fold more dilute when entering the LC-MS/MS compared to when using the solid phase extraction (high limit of reporting) method, allowing less of the compound of interest onto the detector. To compensate for this, the injection volume into the LC-MS/MS can be increased. At Queensland Health Forensic Scientific Services, the laboratory increases the direct injection volume by approximately 25× the usual solid phase extraction (high limit of reporting) injection volume for aqueous samples.

7.1.1.2 Recovery

When using the solid phase extraction method, some compounds are not well extracted from the water sample, which means they will not be detected in the analysis. In these cases, the direct injection method is advantageous as it allows all of the compound of interest within the sample to touch the detector. Therefore the direct injection method is a great alternative to increase detection frequency and accuracy of compounds that are normally lost via the solid phase extraction method.

An example of this is when testing for chlorpyrifos, as only <10% of the compound survives the solid phase extraction procedure. It is therefore not normally detected or reported via the solid phase extraction method. However, good recoveries of chlorpyrifos are reported when using the Direct Injection method with a good limit of reporting. Evidently, the Direct Injection method can be useful in obtaining a more thorough analysis of pesticide residue in surface water samples.

7.1.1.3 Limit of reporting

The current limits of reporting of the solid phase extraction (high limit of reporting) method are generally lower than the Direct Injection method (see Table 7-1). When comparing limits of reporting between methods, the Direct Injection method reports limits of reporting are up to 10× higher than the respective solid phase extraction (high) limits of reporting for that same analyte.

Only 6 out of 68 analytes have a lower limit of reporting when using the Direct Injection method in comparison to the solid phase extraction (high limit of reporting) method. These include

3,4-Dichloroaniline, Flusilazole, N-Demethyl Acetamiprid, Propazin-2-hydroxy, Total Acetamiprid and Total Diuron.

Two out of 28 analytes are not detected using the Direct Injection method in comparison to the solid phase extraction (high limit of reporting) method. These include Total Imazapic and Imazapic metabolites. In contrast, 13 out of 68 analytes are not detected using the solid phase extraction (high limit of reporting) method in comparison to the Direct Injection method. These include Atrazine-2-hydroxy, Chlorpyrifos, Chlorpyrifos oxon, DCPMU, DCPU, Diazinon, Fipronil, Fipronil sulfide, Fipronil sulfone, Halosulfuron methyl, Metolachlor-OXA, Total Fipronil and Trinexapac (acid). Although it has higher overall limits of reporting than the solid phase extraction (high limit of reporting) method, the Direct Injection method is advantageous in detecting a larger number of analytes.

It is unfavourable that the most commonly detected compounds such as atrazine, diuron and imidacloprid have higher limits of reporting using the Direct Injection method (Table 7-1). To investigate this, the Queensland Health Forensic Scientific Services laboratory has ensured validation studies will be carried out to decrease limits of reporting for all analytes including these; however it won’t be revisited until February, 2017. When this occurs, Queensland Health Forensic Scientific Services has also advised that more analytes will be added to the direct injection suite, which will be beneficial to monitoring of runoff from agricultural areas.

Table 7-1 Analytes detected and their limits of reporting using Solid Phase Extraction (SPE) and Direct Injection.

Compound	SPE – KWHSPH	Direct Injection –
2,4-D (high)	0.01	0.05
2,4-DB (high)	0.01	0.05
3,4-Dichloroaniline (high)	0.05	0.02
Acetamiprid (High)	0.01	0.01
Acifluorfen (high)	0.01	0.02
Ametryn (high)	0.01	0.01
Atrazine (high)	0.01	0.07
Atrazine, 2-hydroxy	Not in suite	0.07
Bromacil (high)	0.01	0.02
Chlorpyrifos	Not in suite	0.02
Chlorpyrifos oxon	Not in suite	0.01
Clomazone (high)	0.01	0.01
Clothianidin (high)	0.01	0.02
Cyanazine (high)	0.01	0.01
DCPMU	Not in suite	0.02
DCPU	Not in suite	0.02
Desethyl Atrazine (high)	0.01	0.02
Desisopropyl Atrazine (high)	0.01	0.02
Diazinon	Not in suite	0.01
Diuron (high)	0.01	0.02
Ethametsulfuron methyl (high)	0.01	0.01
Fipronil	Not in suite	0.01
Fipronil sulphide	Not in suite	0.01
Fipronil sulfone	Not in suite	0.02
Fluometuron (high)	0.01	0.01
Fluroxypyr (high)	0.01	0.07
Flusilazole (high)	0.02	0.01
Halosulfuron methyl	Not in suite	0.01
Haloxyfop (acid)(high)	0.01	0.02
Hexazinone (high)	0.01	0.01
Imazapic (High)	0.01	0.01
Imazapic Metabolites (High)	0.02	Not in suite
Imazapyr (High)	0.01	0.01
Imazethapyr (high)	0.01	0.01
Imidacloprid (high)	0.01	0.02
Imidacloprid metabolites (high)	0.01	0.02
MCPA (high)	0.01	0.02
MCPB (high)	0.01	0.2
Mecoprop (high)	0.01	0.02
Mesosulfuron methyl (high)	0.01	0.02
Methoxyfenozide (High)	0.01	0.01
Metolachlor (high)	0.01	0.07
Metolachlor-OXA	Not in suite	0.2
Metribuzin (high)	0.01	0.02
Metsulfuron methyl (high)	0.01	0.02
Napropamide (high)	0.01	0.01
N-Demethyl Acetamiprid (High)	0.02	0.01
Prometryn (high)	0.01	0.01
Propachlor (high)	0.01	0.02
Propazin-2-hydroxy (high)	0.02	0.01
Sethoxydim (including Clethodim) (high)	0.02	0.02
Simazine (high)	0.01	0.02
Sulfosulfuron (high)	0.01	0.07
Tebuthiuron (high)	0.01	0.02
Terbuthylazine (high)	0.01	0.01
Terbuthylazine desethyl (high)	0.01	0.01
Terbutryn (high)	0.02	0.01
Thiacloprid (High)	0.01	0.01
Thiamethoxam (high)	0.01	0.02
Total Acetamiprid (High)	0.03	0.02
Total Diuron (high)	0.1	0.06
Total Fipronil	Not in suite	0.04
Total Imazapic (high)	0.05	Not in suite
Total Imidacloprid (high)	0.03	0.04
Total Isoxaflutole (high)	0.01	0.01
Triclopyr (high)	0.01	0.1
Trifloxysulfuron (high)	0.01	0.05
Trinexapac (acid)	Not in suite	0.05

Appendix B Hydrograph and pesticide concentration plots

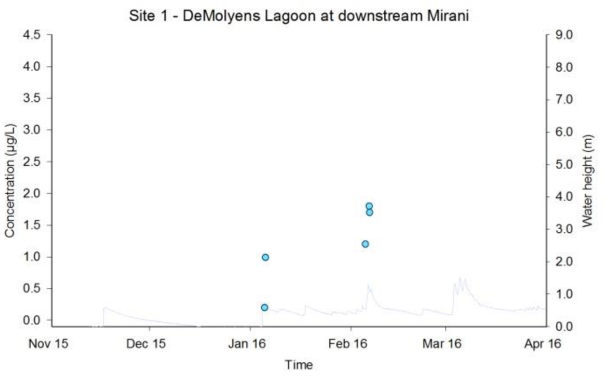

Figure 7-1 Hydrographic plot of water level and concentration (µgL^{-1}) of imidacloprid in Draper Creek at De Moleyns Lagoon.

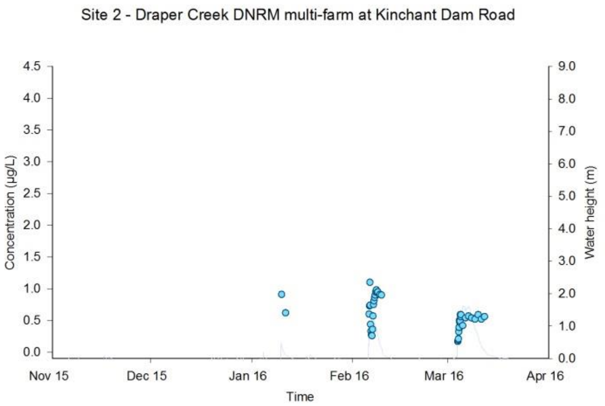

Figure 7-2 Hydrographic plot of water level and concentration (µgL^{-1}) of imidacloprid in Draper Creek at Multi-farm.

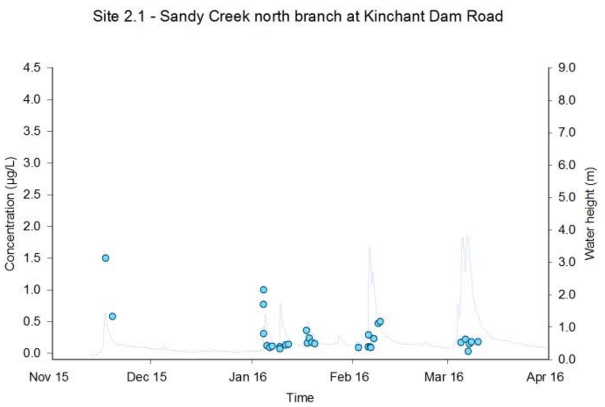

Figure 7-3 Hydrographic plot of water level and concentration (µgL^{-1}) of imidacloprid in Sandy Creek North Branch.

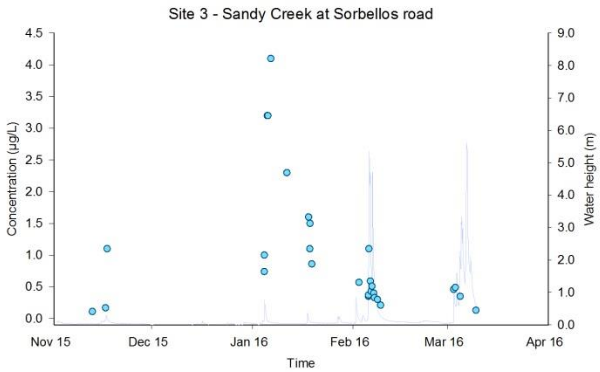

Figure 7-4 Hydrographic plot of water level and concentration (µgL^{-1}) of imidacloprid in Sandy Creek South Branch.

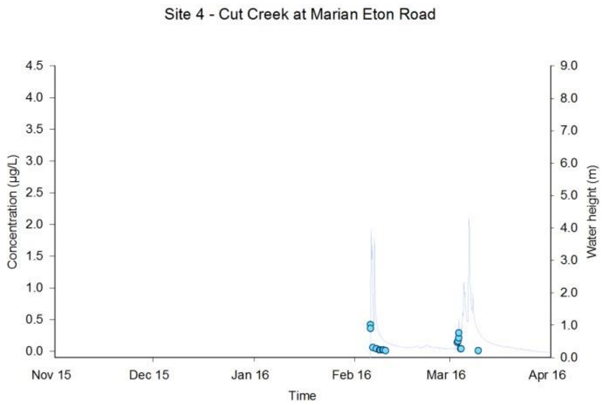

Figure 7-5 Hydrographic plot of water level and concentration (µgL^{-1}) of imidacloprid in Cut Creek.

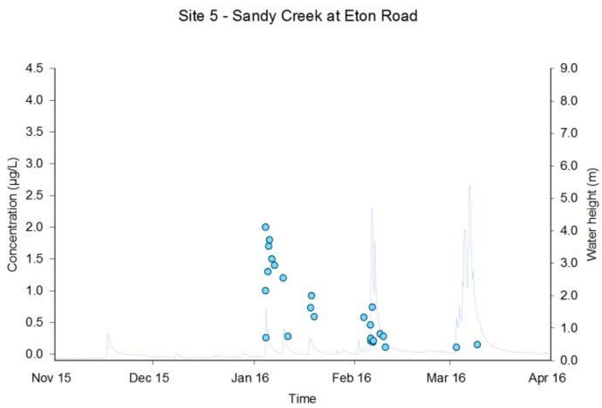

Figure 7-6 Hydrographic plot of water level and concentration (µgL^{-1}) of imidacloprid in Sandy Creek at Eton.

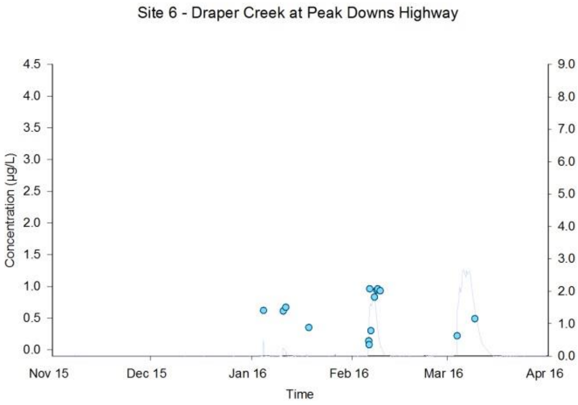

Figure 7-7 Hydrographic plot of water level and concentration (μgL^{-1}) of imidacloprid in Draper Creek at Peak Downs Highway.

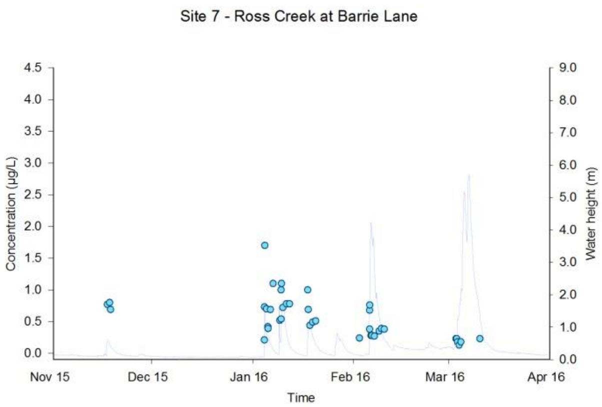

Figure 7-8 Hydrographic plot of water level and concentration (μgL^{-1}) of imidacloprid in Ross Creek at Barrie Lane.

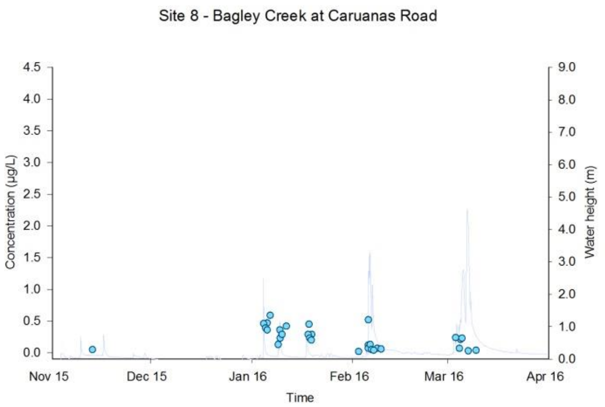

Figure 7-9 Hydrographic plot of water level and concentration (μgL^{-1}) of imidacloprid in Bagley Creek.

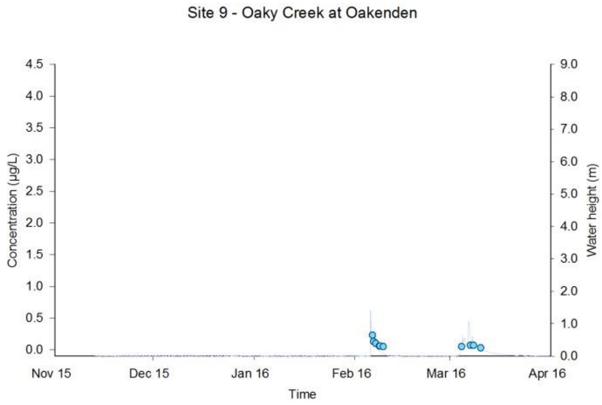

Figure 7-10 Hydrographic plot of water level and concentration (μgL^{-1}) of imidacloprid in Oaky Creek.

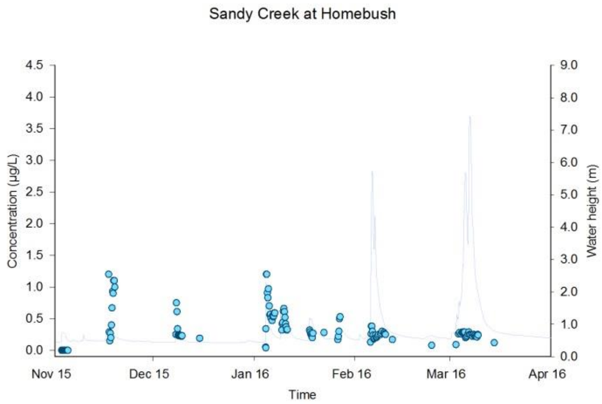

Figure 7-11 Hydrographic plot of water level and concentration (μgL^{-1}) of imidacloprid in Sandy Creek at Homebush.

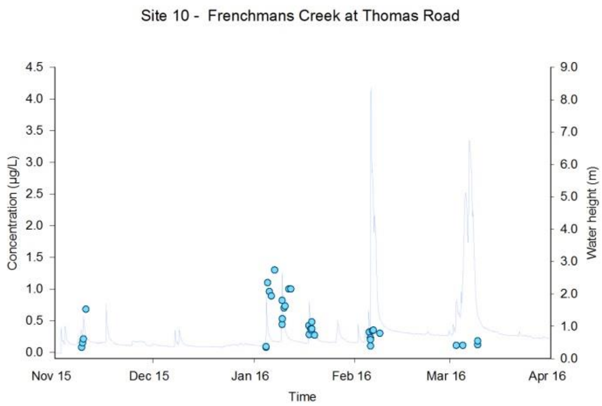

Figure 7-12 Hydrographic plot of water level and concentration (μgL^{-1}) of imidacloprid in Frenchmans Creek.

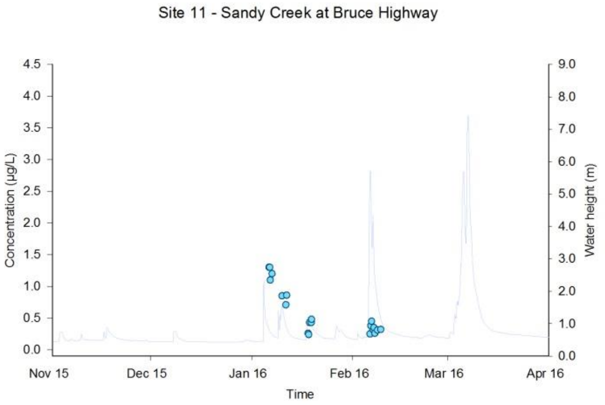

Figure 7-13 Hydrographic plot of water level and concentration (µgL^{-1}) of imidacloprid in Sandy Creek at Bruce Highway.

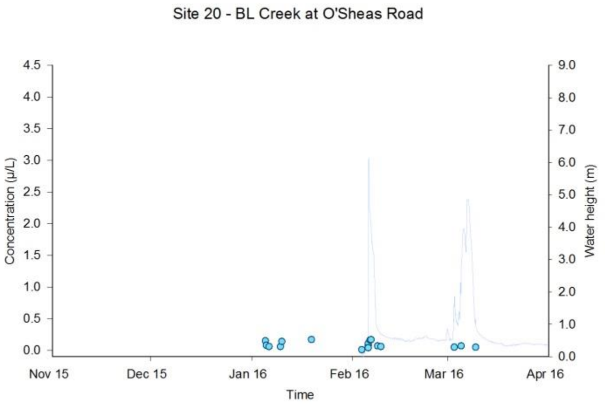

Figure 7-14 Hydrographic plot of water level and concentration (µgL^{-1}) of imidacloprid in BL Creek.

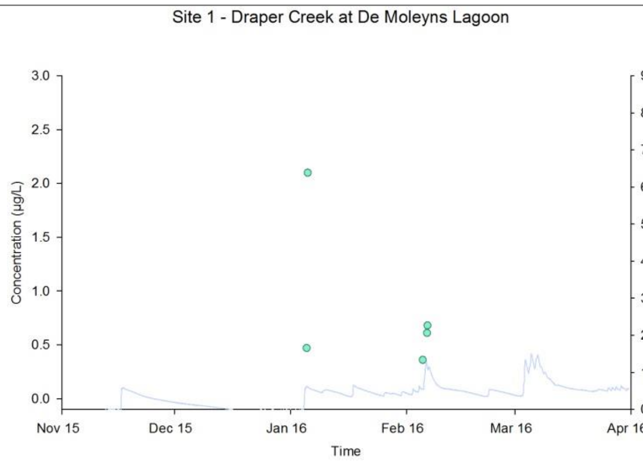

Figure 7-15 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Draper Creek at De Moleyns Lagoon.

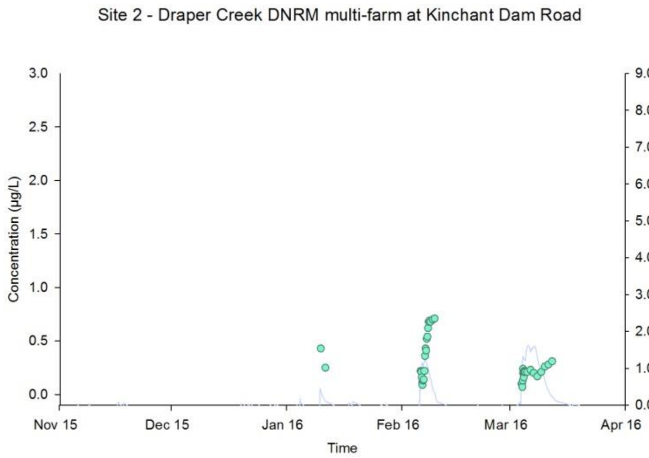

Figure 7-16 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Draper Creek at Multi-farm.

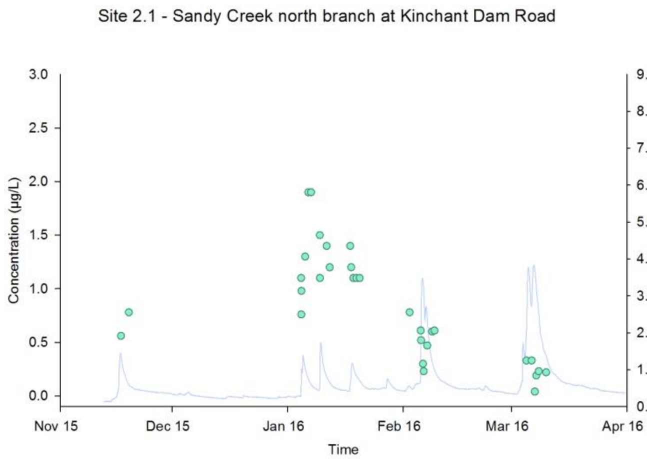

Figure 7-17 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Sandy Creek North Branch.

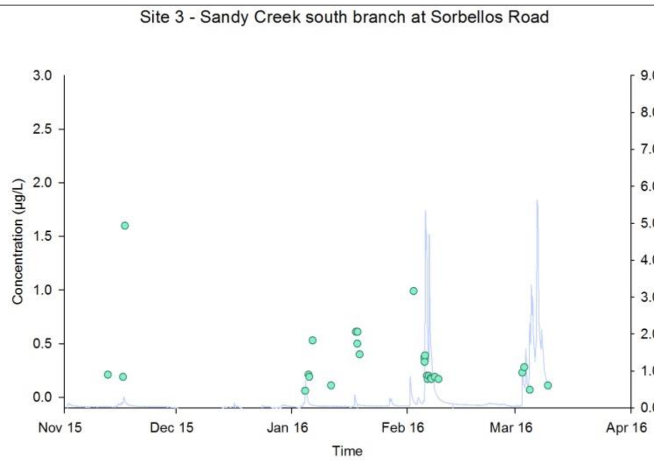

Figure 7-18 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Sandy Creek South Branch.

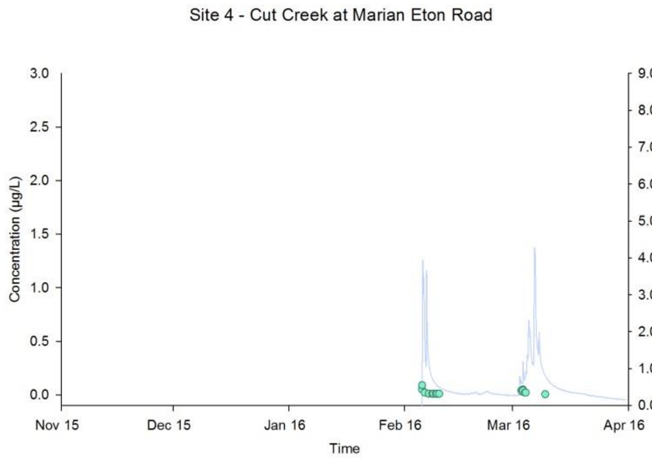

Figure 7-19 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Cut Creek.

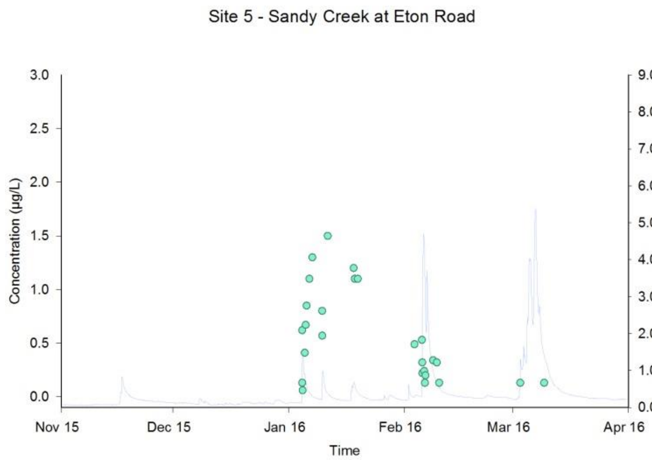

Figure 7-20 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Sandy Creek at Eton.

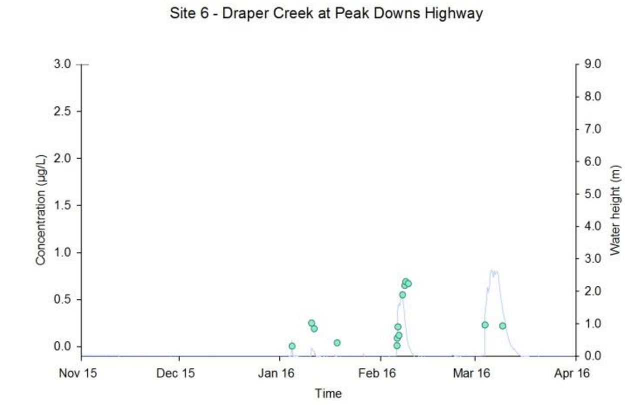

Figure 7-21 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Draper Creek at Peak Downs Highway.

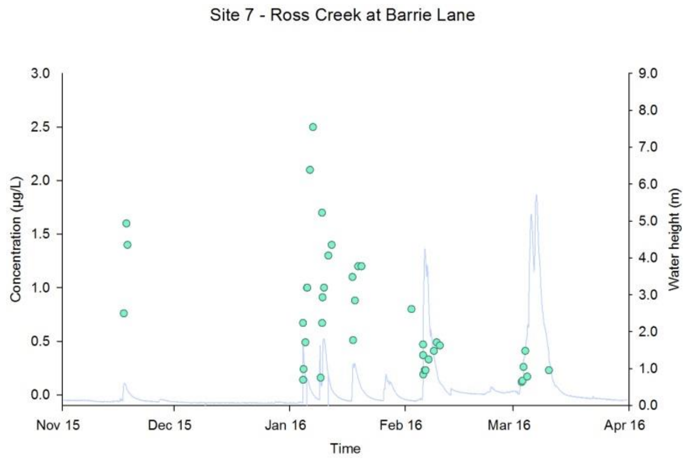

Figure 7-22 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Ross Creek at Barrie Lane.

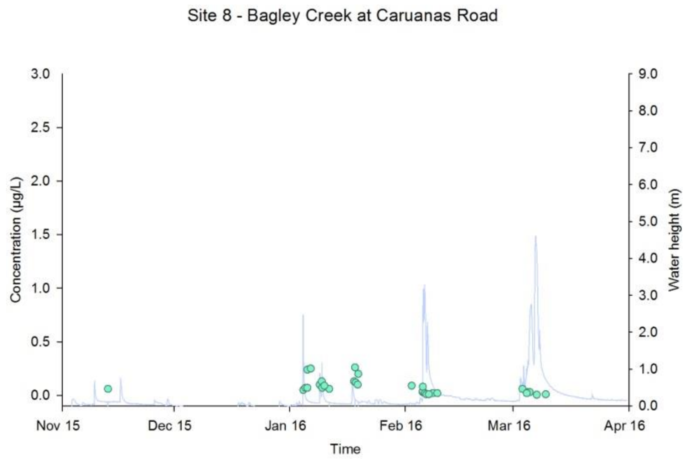

Figure 7-23 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Bagley Creek.

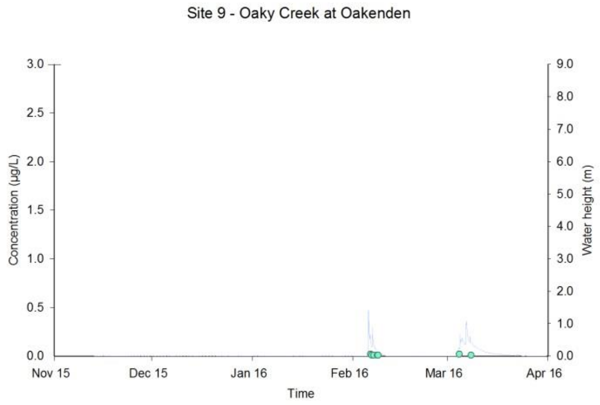

Figure 7-24 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Oaky Creek.

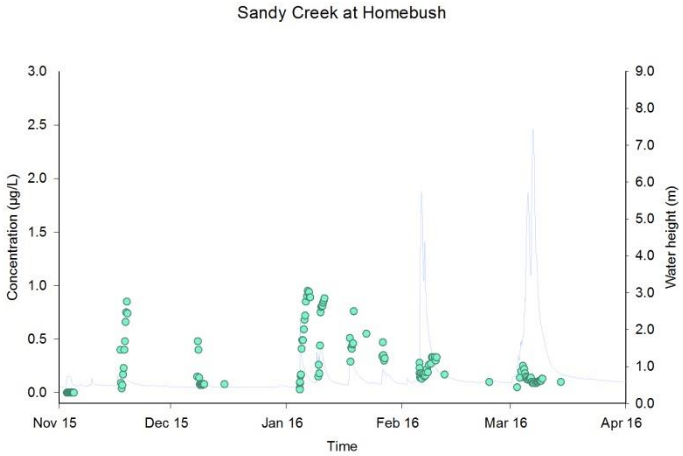

Figure 7-25 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Sandy Creek at Homebush.

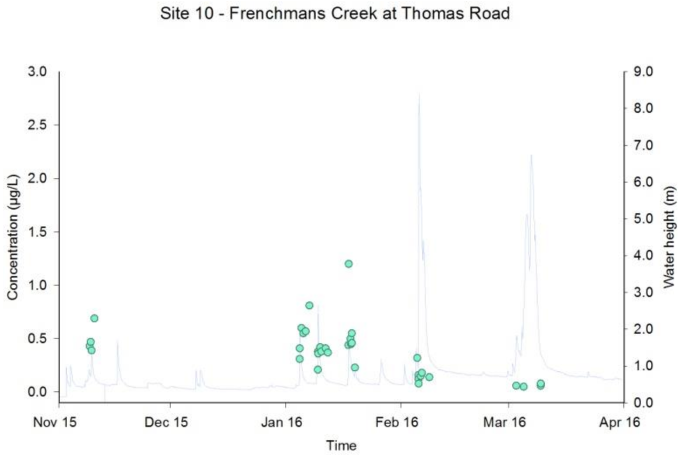

Figure 7-26 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Frenchmans Creek.

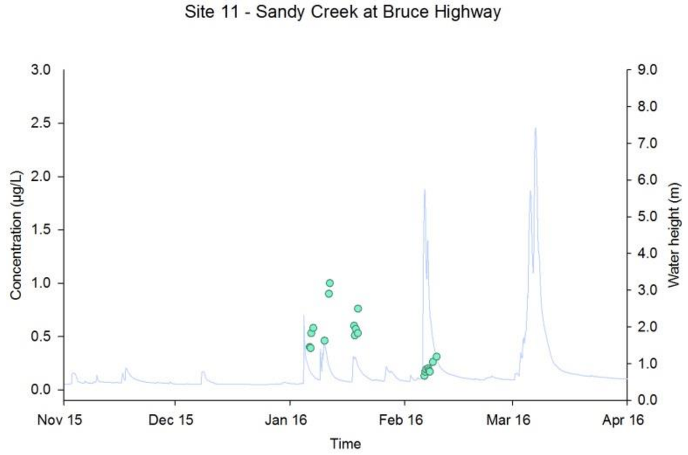

Figure 7-27 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in Sandy Creek at Bruce Highway.

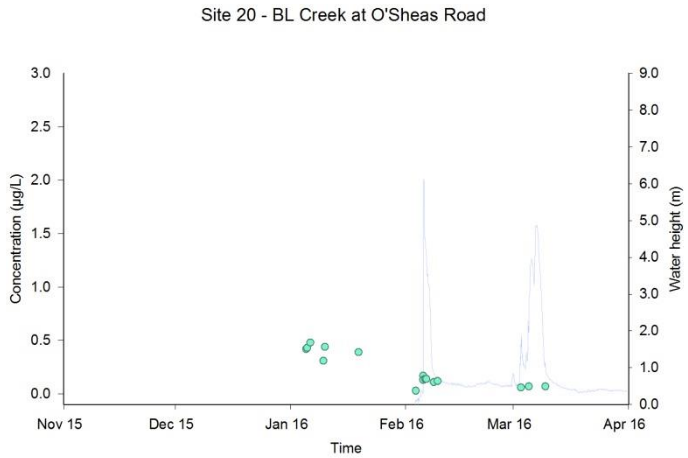

Figure 7-28 Hydrographic plot of water level and concentration (µgL^{-1}) of imazapic in BL Creek.

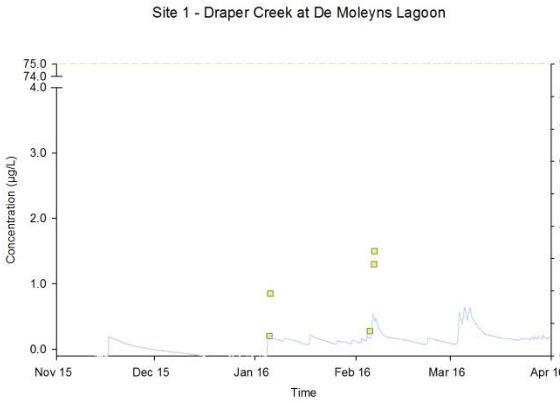

Figure 7-29 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Draper Creek at De Moleyns Lagoon.

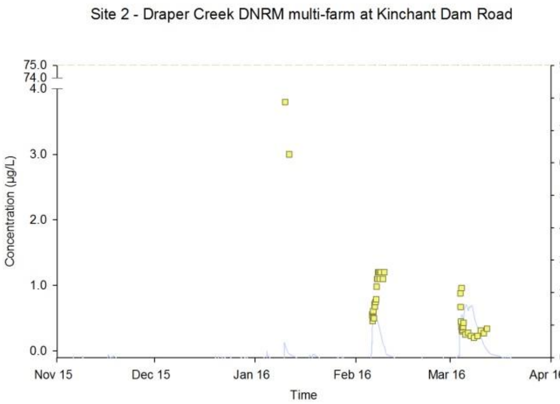

Figure 7-30 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Draper Creek at Multi-farm.

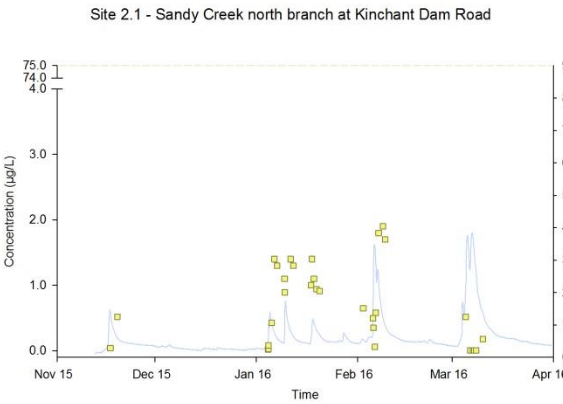

Figure 7-31 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Sandy Creek North Branch.

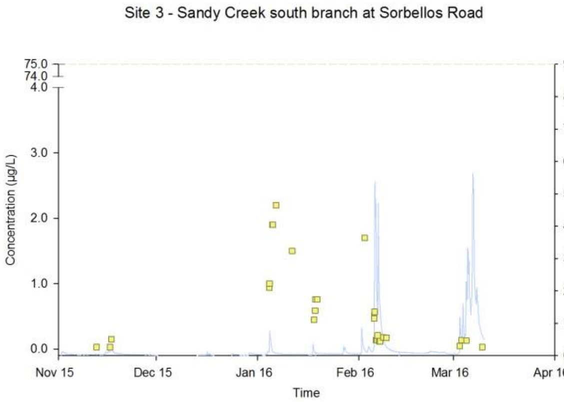

Figure 7-32 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Sandy Creek South Branch.

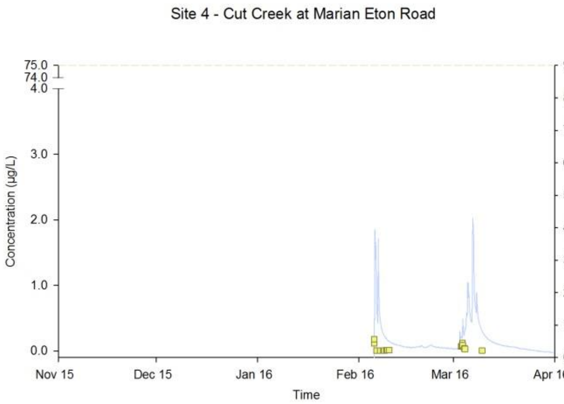

Figure 7-33 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Cut Creek.

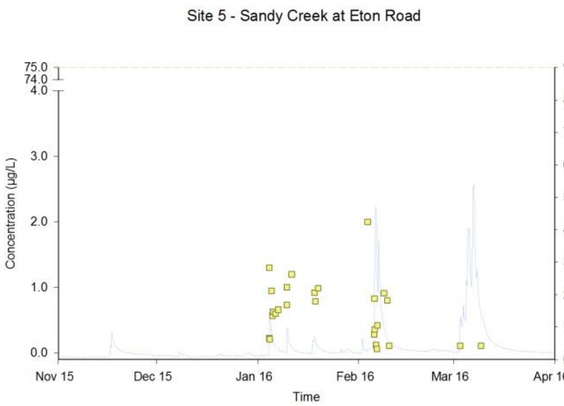

Figure 7-34 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Sandy Creek at Eton.

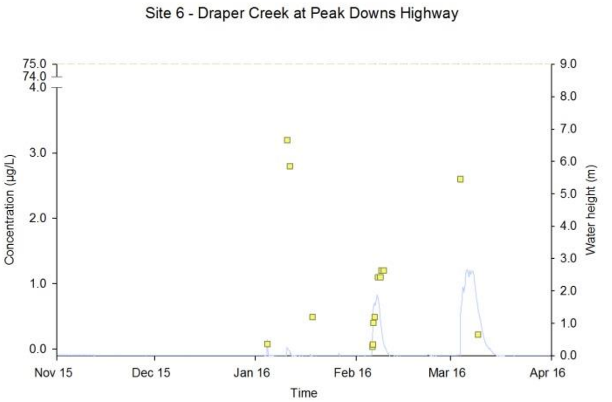

Figure 7-35 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Draper Creek at Peak Downs Highway.

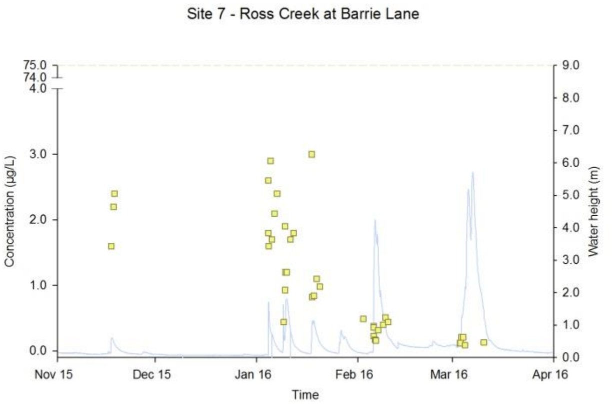

Figure 7-36 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Ross Creek at Barrie Lane.

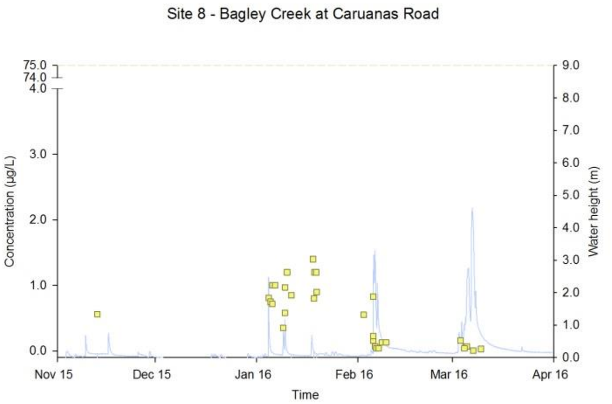

Figure 7-37 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Bagley Creek.

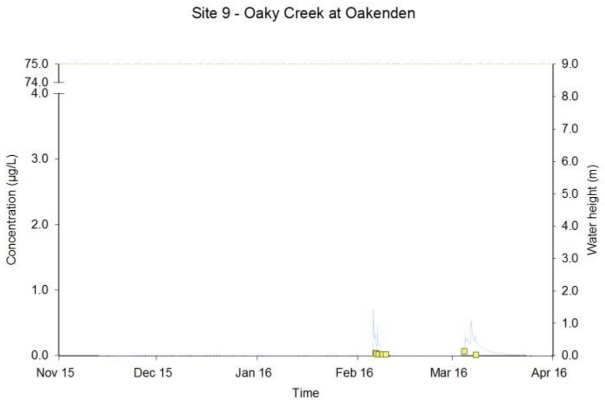

Figure 7-38 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Oaky Creek.

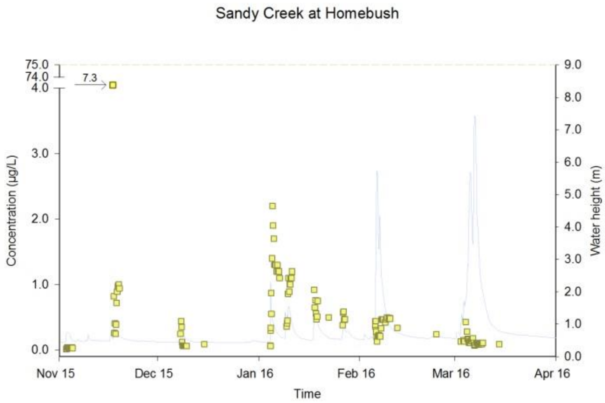

Figure 7-39 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Sandy Creek at Homebush.

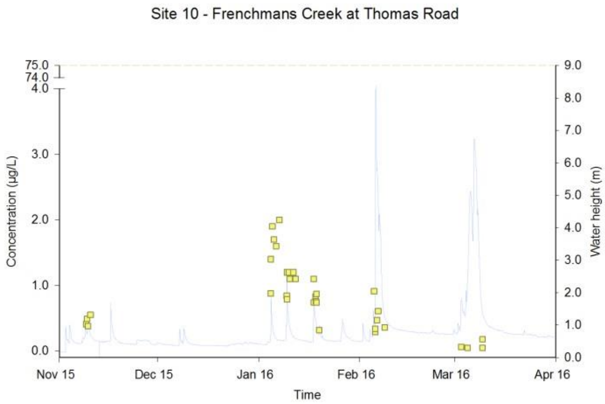

Figure 7-40 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Frenchmans Creek.

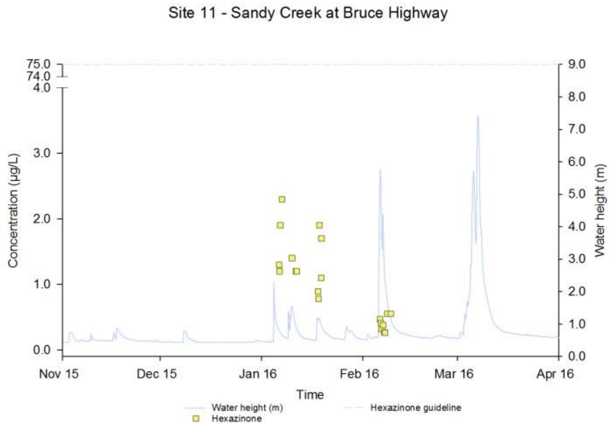

Figure 7-41 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in Sandy Creek at Bruce Highway.

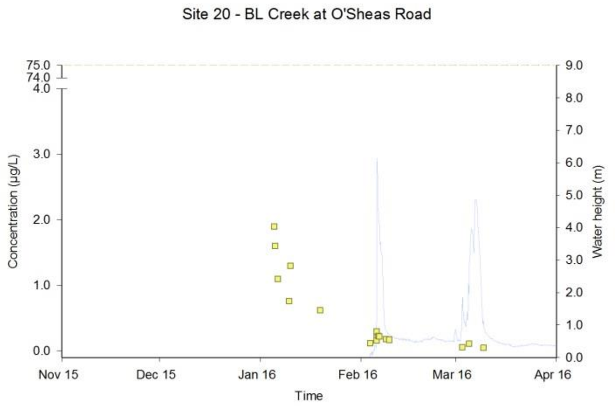

Figure 7-42 Hydrographic plot of water level and concentration (µgL^{-1}) of hexazinone in BL Creek.

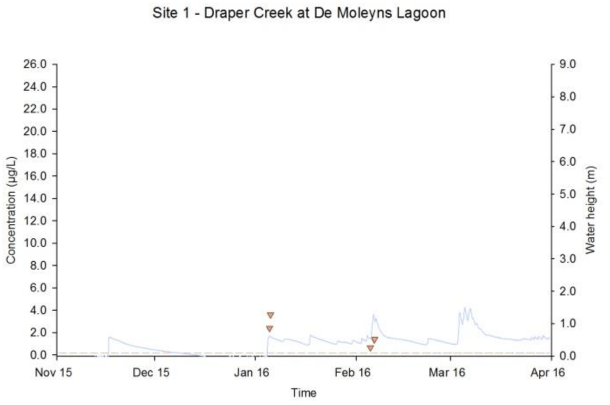

Figure 7-43 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Draper Creek at De Moleyns Lagoon.

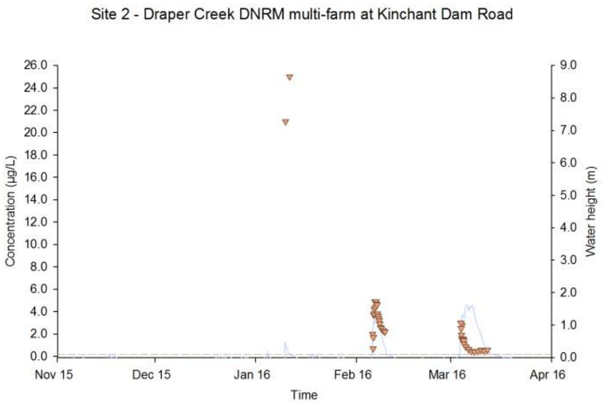

Figure 7-44 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Draper Creek at Multi-farm.

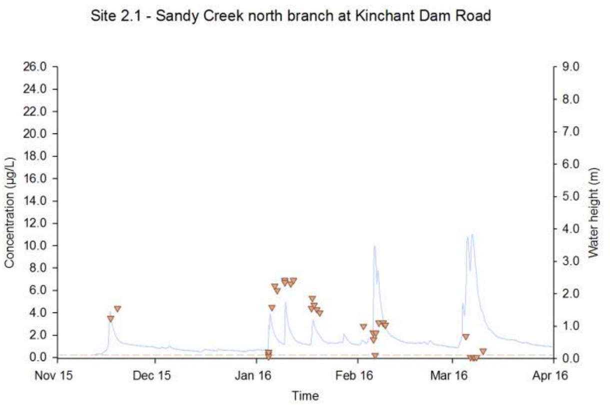

Figure 7-45 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Sandy Creek North Branch.

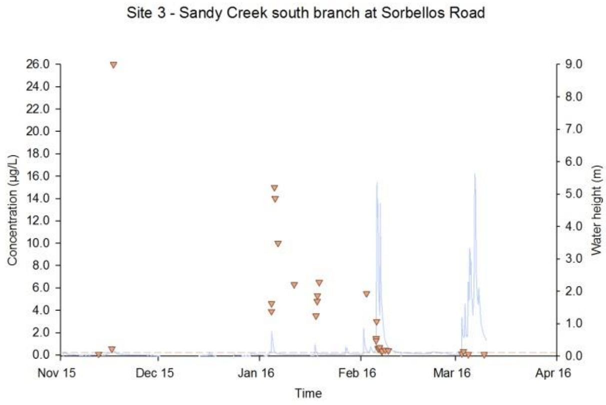

Figure 7-46 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Sandy Creek South Branch.

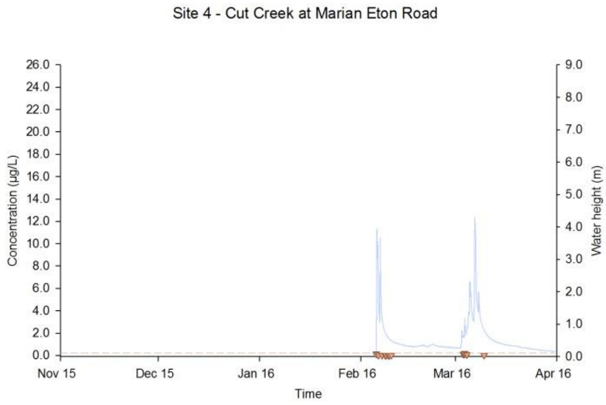

Figure 7-47 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Cut Creek.

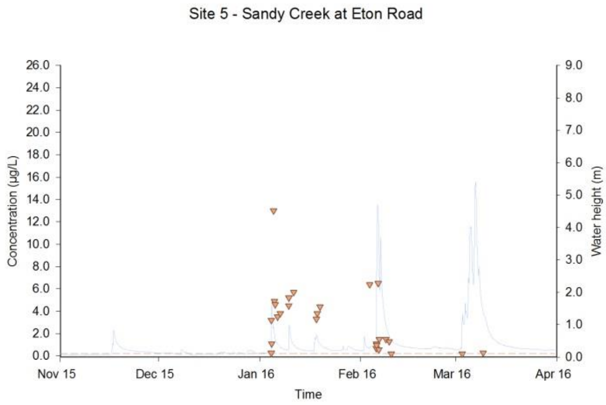

Figure 7-48 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Sandy Creek at Eton.

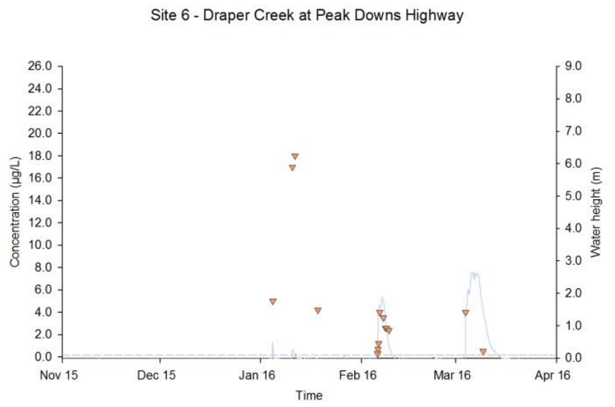

Figure 7-49 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Draper Creek at Peak Downs Highway.

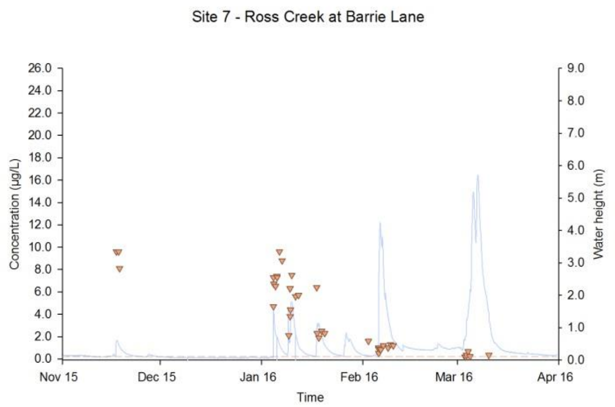

Figure 7-50 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Ross Creek at Barrie Lane.

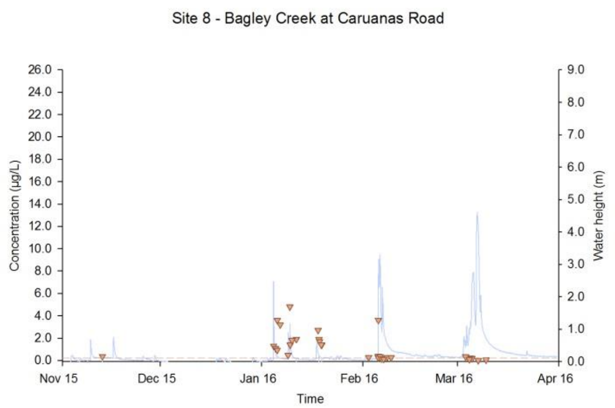

Figure 7-51 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Bagley Creek.

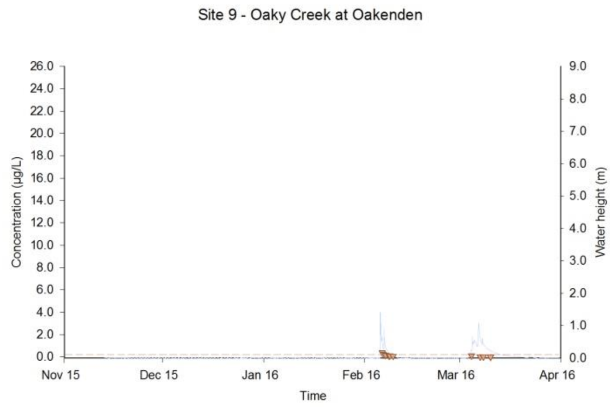

Figure 7-52 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Oaky Creek.

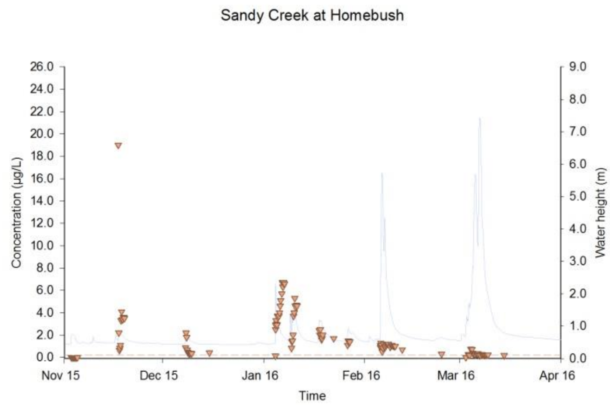

Figure 7-53 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Sandy Creek at Homebush.

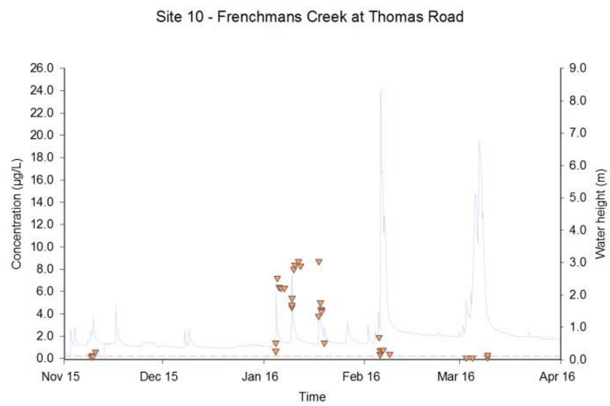

Figure 7-54 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Frenchmans Creek.

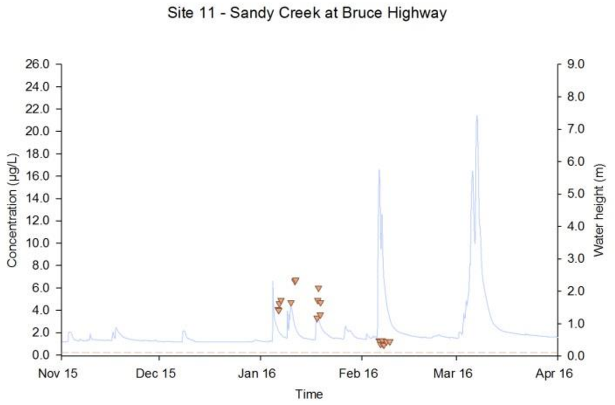

Figure 7-55 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in Sandy Creek at Bruce Highway.

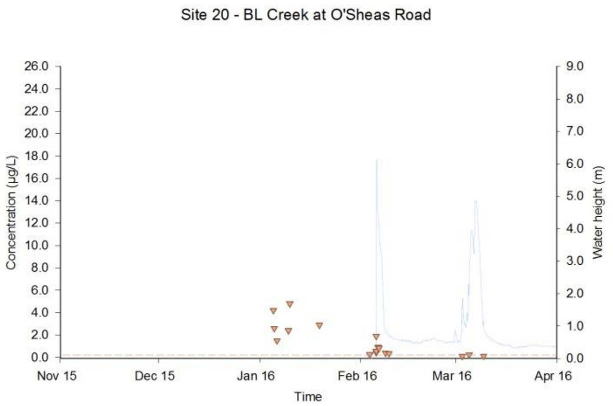

Figure 7-56 Hydrographic plot of water level and concentration (µgL^{-1}) of diuron in BL Creek.

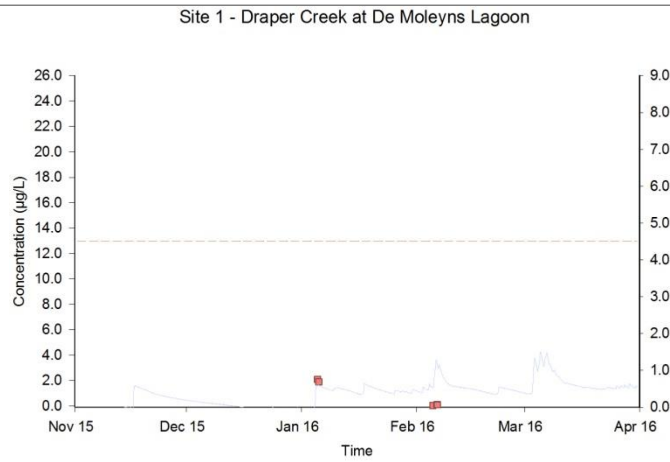

Figure 7-57 Hydrographic plot of water level and concentration (μgL^{-1}) of atrazine in Draper Creek at De Moleyns Lagoon.

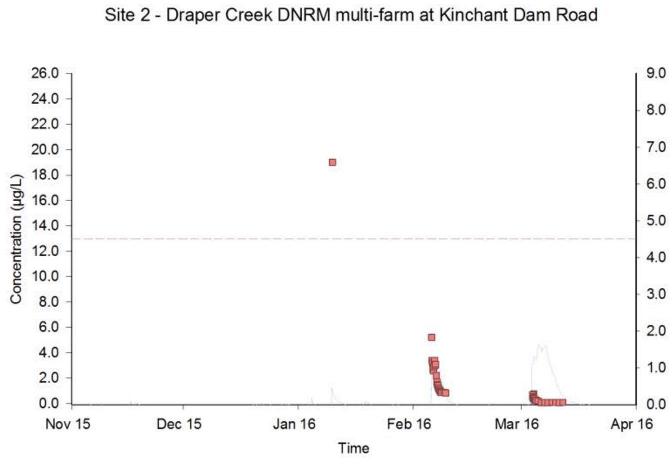

Figure 7-58 Hydrographic plot of water level and concentration (μgL^{-1}) of atrazine in Draper Creek at Multi-farm.

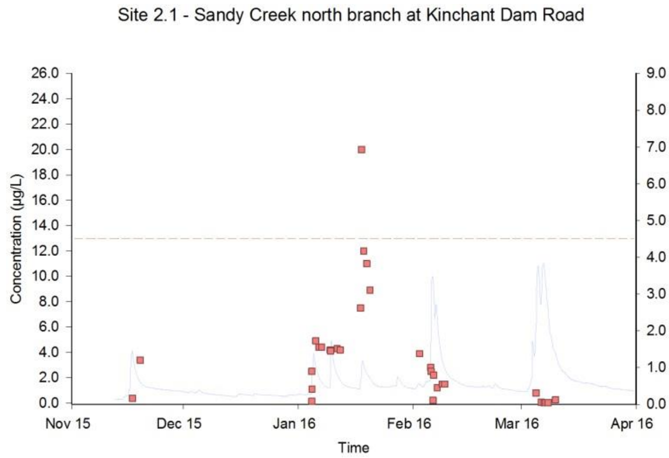

Figure 7-59 Hydrographic plot of water level and concentration (μgL^{-1}) of atrazine in Sandy Creek North Branch.

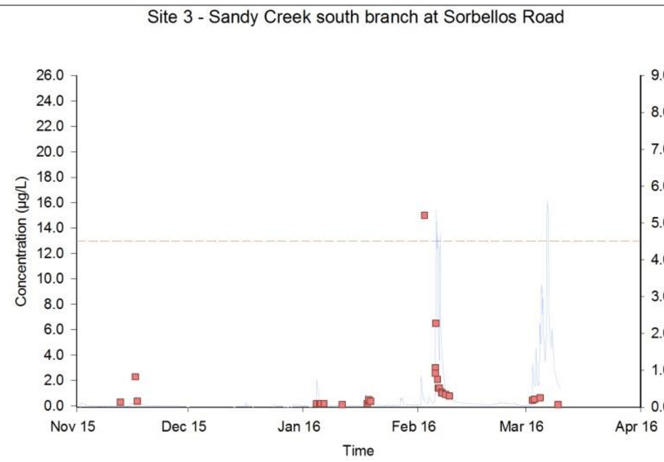

Figure 7-60 Hydrographic plot of water level and concentration (μgL^{-1}) of atrazine in Sandy Creek South Branch.

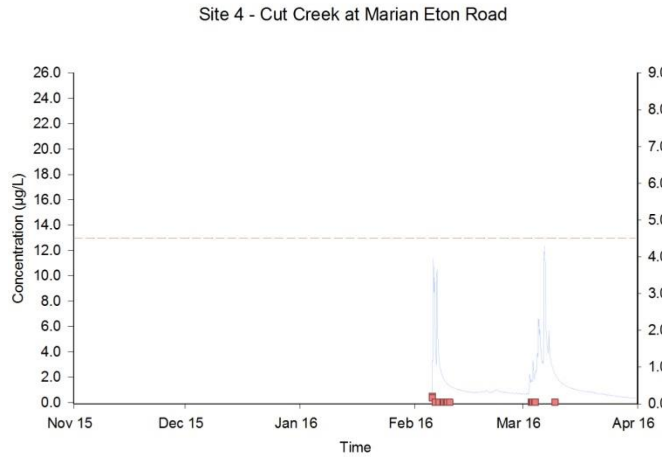

Figure 7-61 Hydrographic plot of water level and concentration (μgL^{-1}) of atrazine in Cut Creek.

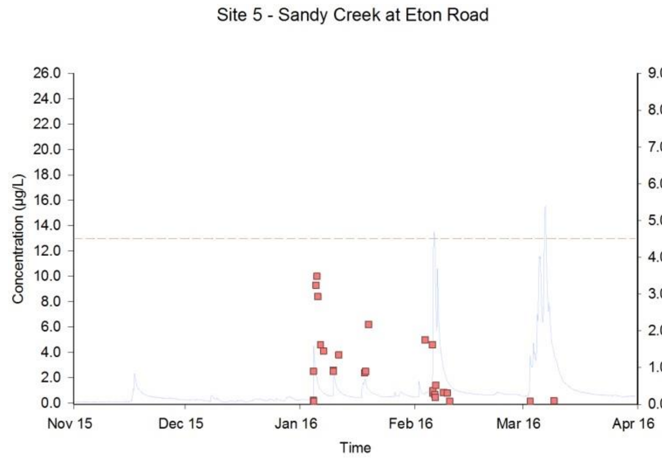

Figure 7-62 Hydrographic plot of water level and concentration (μgL^{-1}) of atrazine in Sandy Creek at Eton.

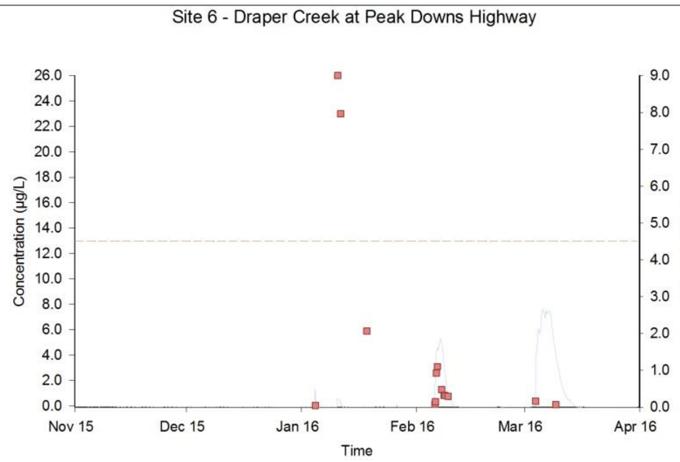

Figure 7-63 Hydrographic plot of water level and concentration (µgL^{-1}) of atrazine in Draper Creek at Peak Downs Highway.

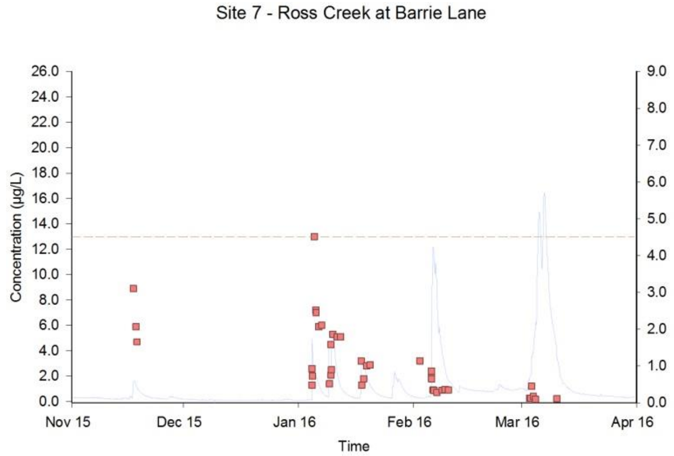

Figure 7-64 Hydrographic plot of water level and concentration (µgL^{-1}) of atrazine in Ross Creek at Barrie Lane.

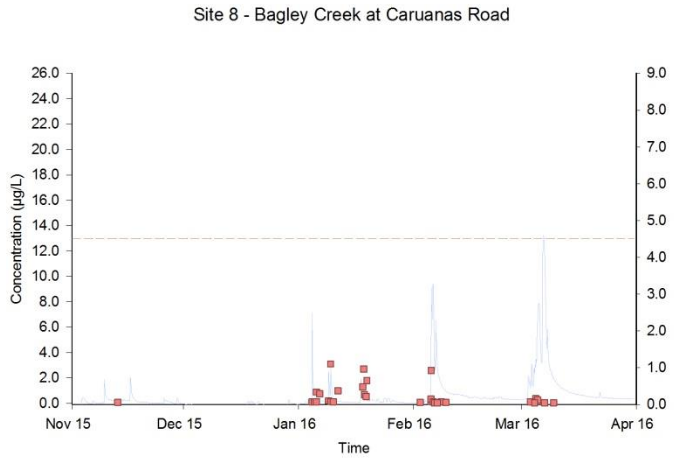

Figure 7-65 Hydrographic plot of water level and concentration (µgL^{-1}) of atrazine in Bagley Creek.

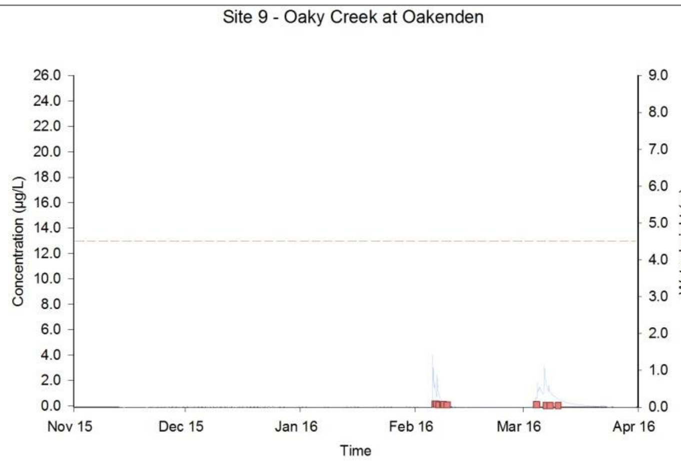

Figure 7-66 Hydrographic plot of water level and concentration (µgL^{-1}) of atrazine in Oaky Creek.

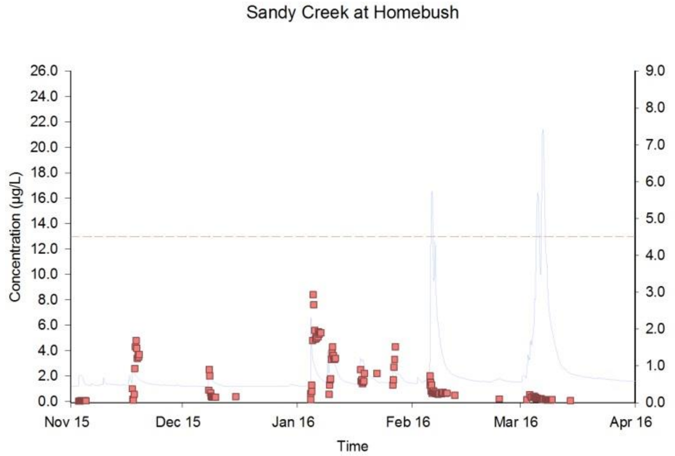

Figure 7-67 Hydrographic plot of water level and concentration (µgL^{-1}) of atrazine in Sandy Creek at Homebush.

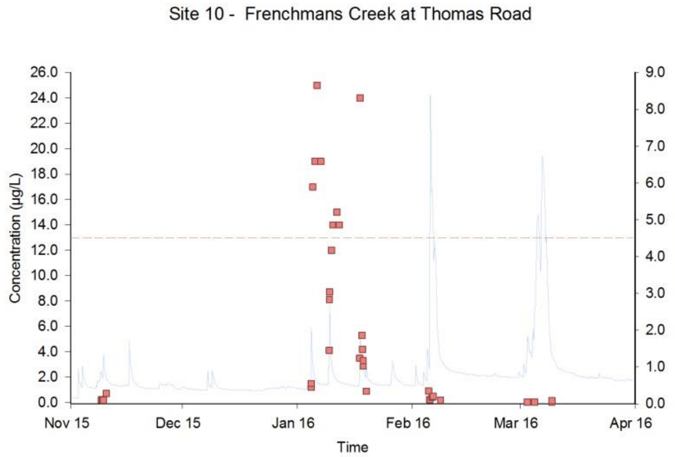

Figure 7-68 Hydrographic plot of water level and concentration (µgL^{-1}) of atrazine in Frenchmans Creek.

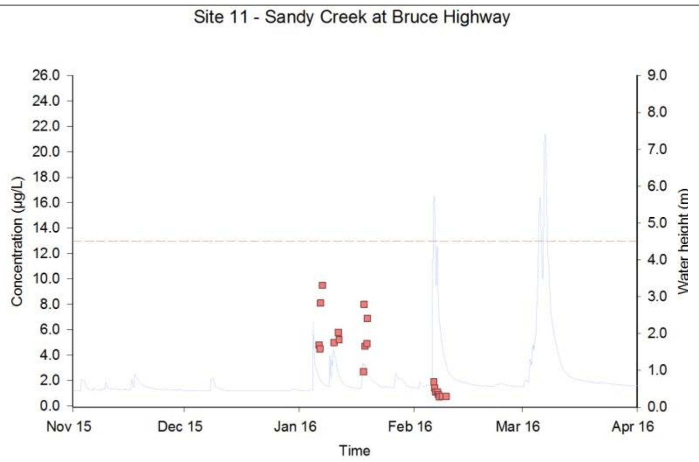

Figure 7-69 Hydrographic plot of water level and concentration (µgL^{-1}) of atrazine in Sandy Creek at Bruce Highway.

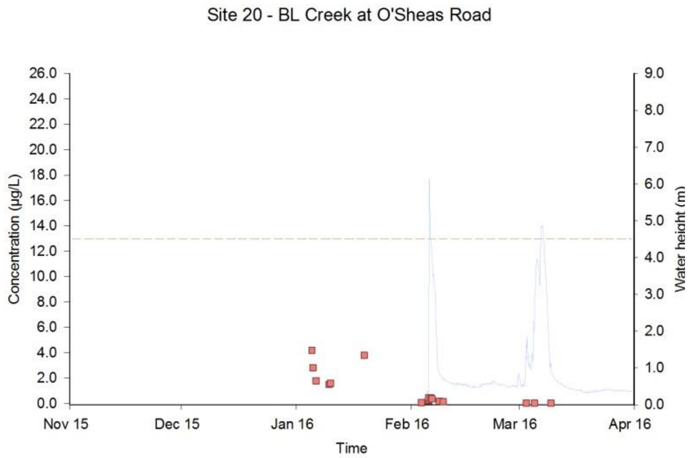

Figure 7-70 Hydrographic plot of water level and concentration (µgL^{-1}) of atrazine in BL Creek.

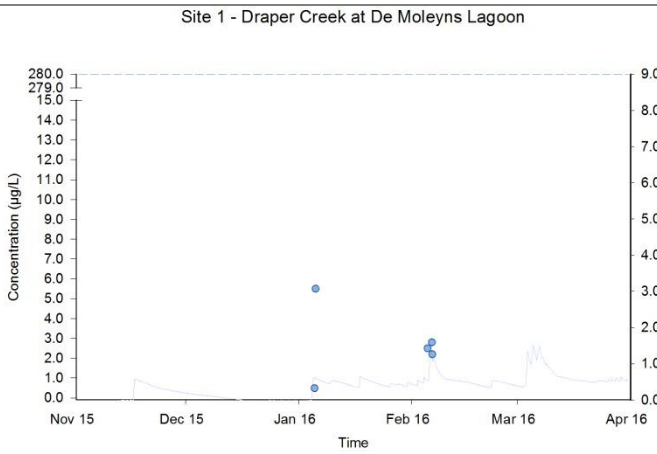

Figure 7-71 Hydrographic plot of water level and concentration (µgL-1) of 2,4-D in Draper Creek at De Moleyns Lagoon.

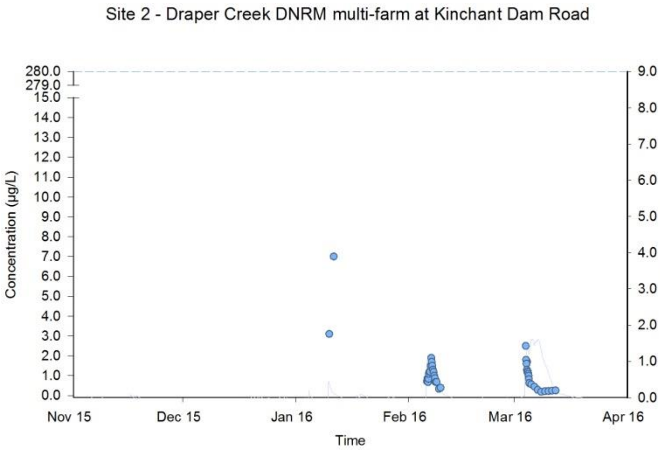

Figure 7-72 Hydrographic plot of water level and concentration (µgL-1) of 2,4-D in Draper Creek at Multi-farm.

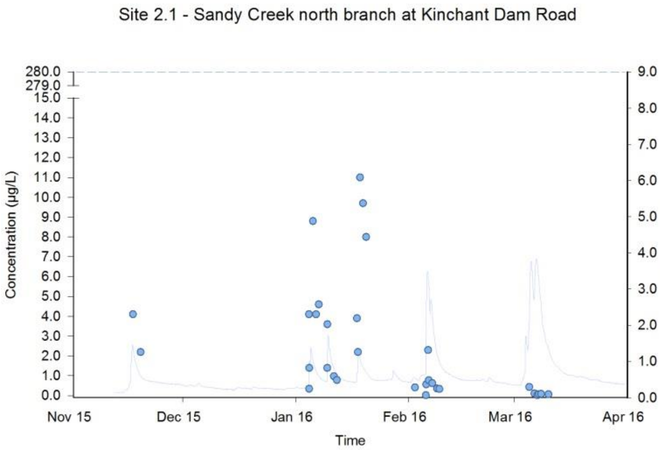

Figure 7-73 Hydrographic plot of water level and concentration (µgL-1) of 2,4-D in Sandy Creek North Branch.

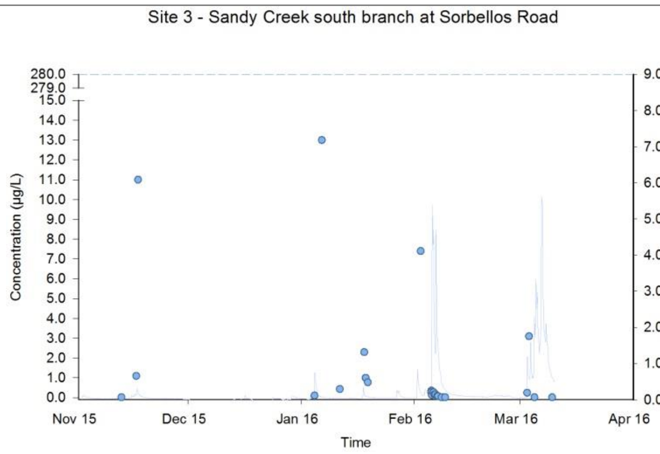

Figure 7-74 Hydrographic plot of water level and concentration (µgL-1) of 2,4-D in Sandy Creek South Branch.

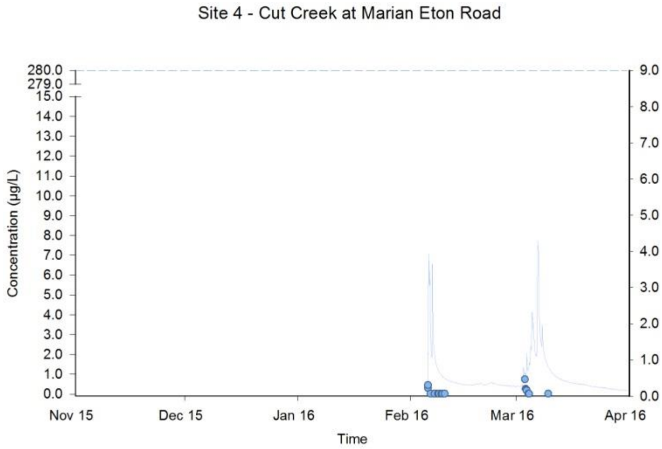

Figure 7-75 Hydrographic plot of water level and concentration (µgL-1) of 2,4-D in Cut Creek.

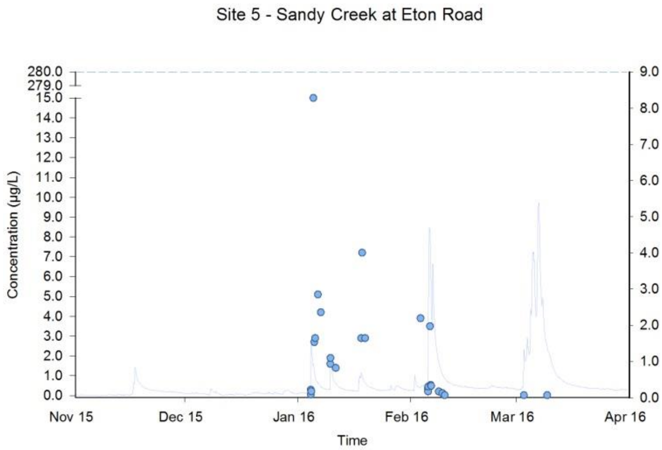

Figure 7-76 Hydrographic plot of water level and concentration (µgL-1) of 2,4-D in Sandy Creek at Eton.

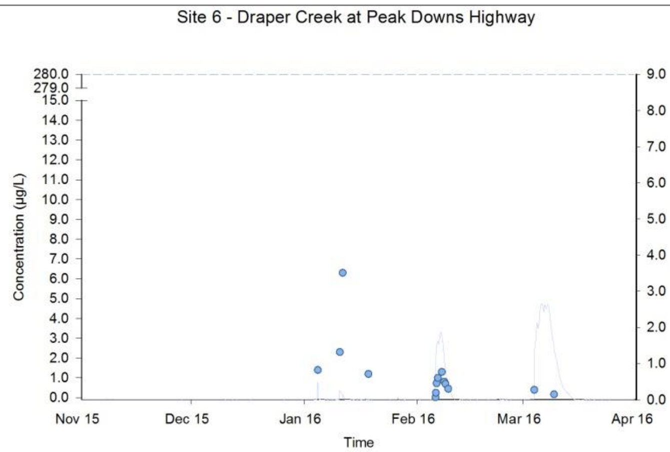

Figure 7-77 Hydrographic plot of water level and concentration (µgL^{-1}) of 2,4-D in Draper Creek at Peak Downs Highway.

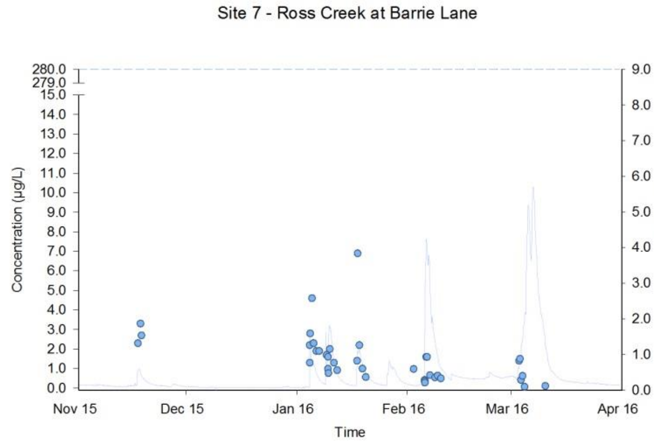

Figure 7-78 Hydrographic plot of water level and concentration (µgL^{-1}) of 2,4-D in Ross Creek at Barrie Lane.

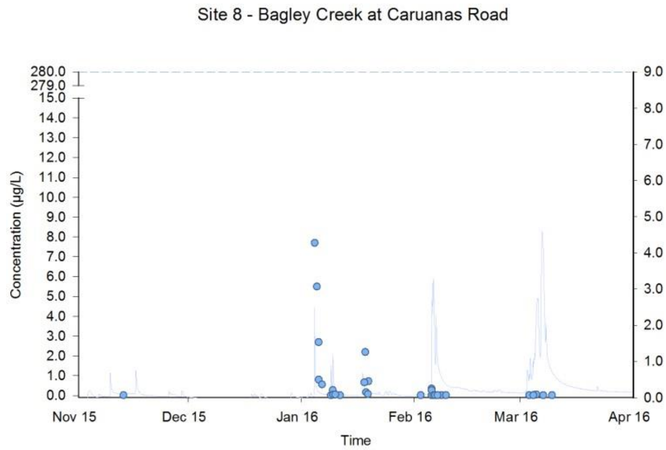

Figure 7-79 Hydrographic plot of water level and concentration (µgL^{-1}) of 2,4-D in Bagley Creek.

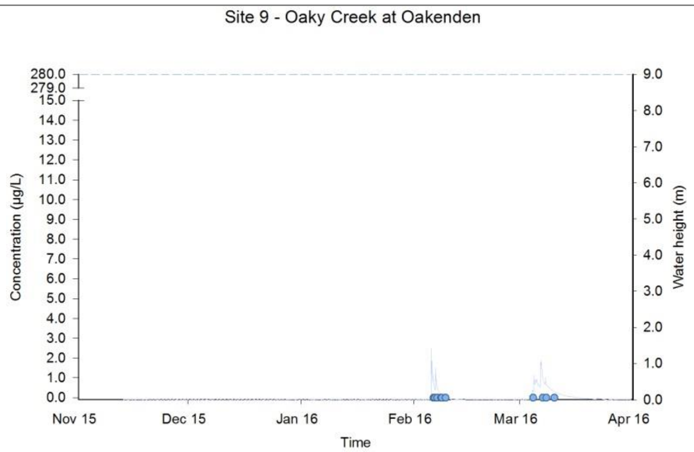

Figure 7-80 Hydrographic plot of water level and concentration (µgL^{-1}) of 2,4-D in Oaky Creek.

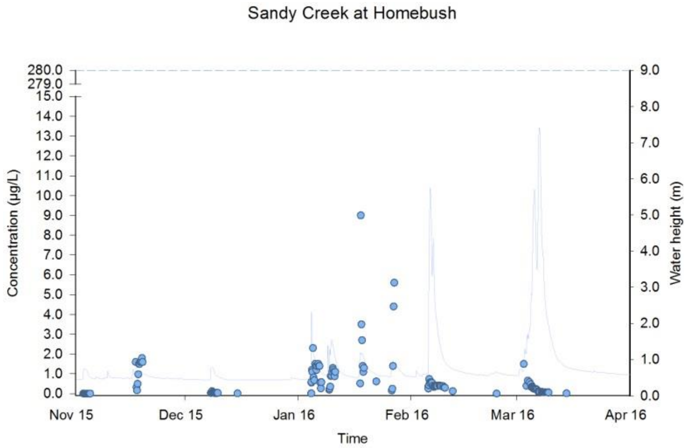

Figure 7-81 Hydrographic plot of water level and concentration (µgL^{-1}) of 2,4-D in Sandy Creek at Homebush.

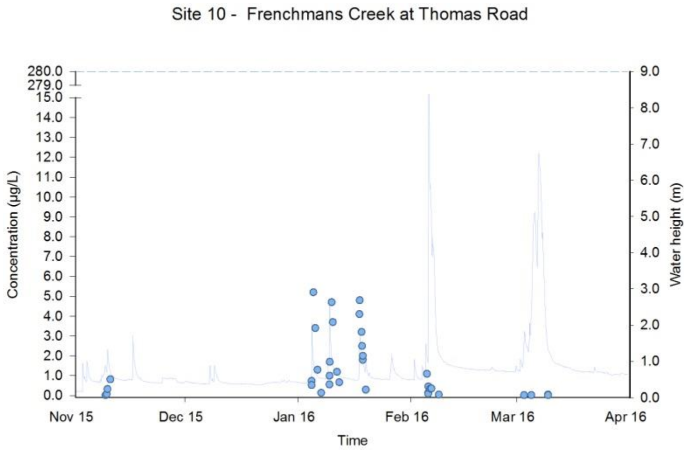

Figure 7-82 Hydrographic plot of water level and concentration (µgL^{-1}) of 2,4-D in Frenchmans Creek.

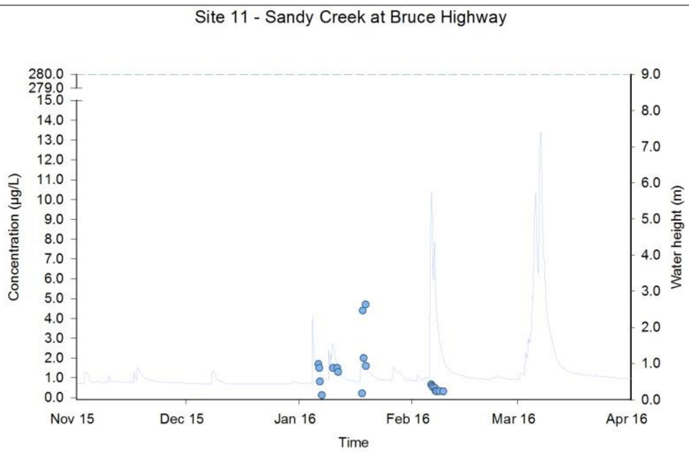

Figure 7-83 Hydrographic plot of water level and concentration (µgL^{-1}) of 2,4-D in Sandy Creek at Bruce Highway.

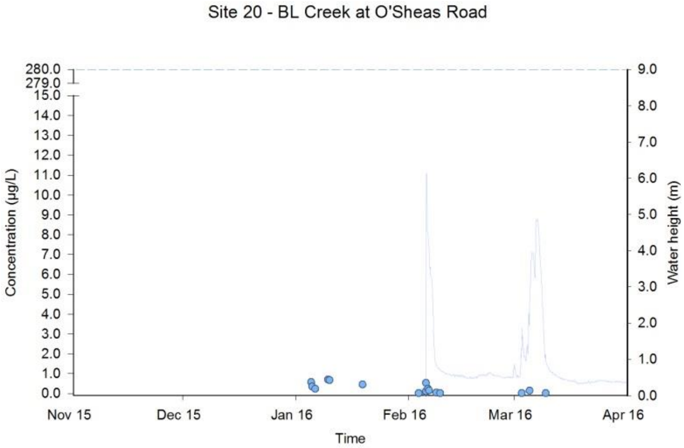

Figure 7-84 Hydrographic plot of water level and concentration (µgL^{-1}) of 2,4-D in BL Creek.

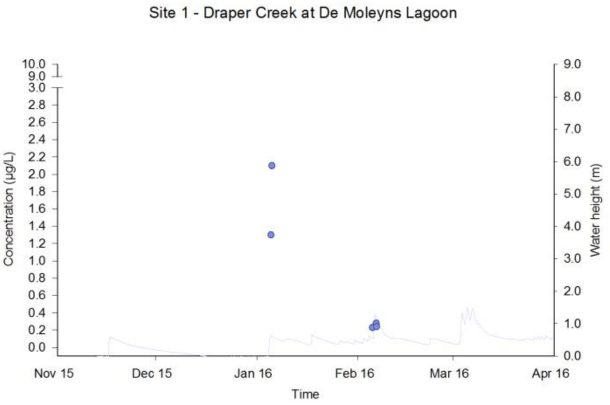

Figure 7-85 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Draper Creek at De Moleyns Lagoon.

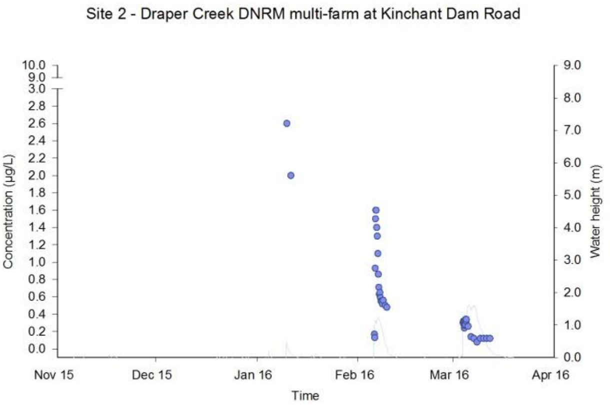

Figure 7-86 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Draper Creek at Multi-farm.

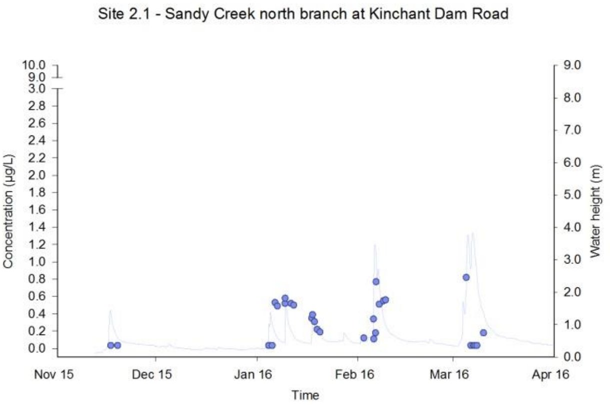

Figure 7-87 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Sandy Creek North Branch.

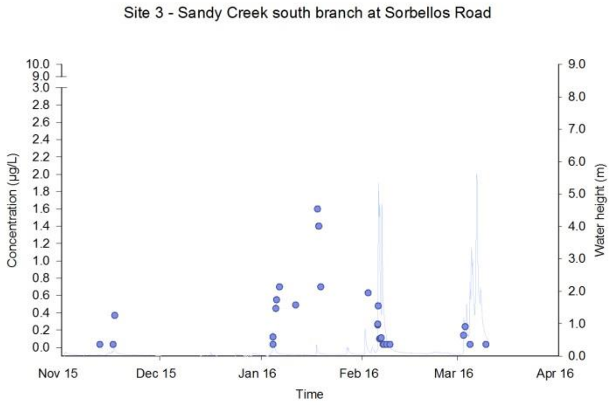

Figure 7-88 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Sandy Creek South Branch.

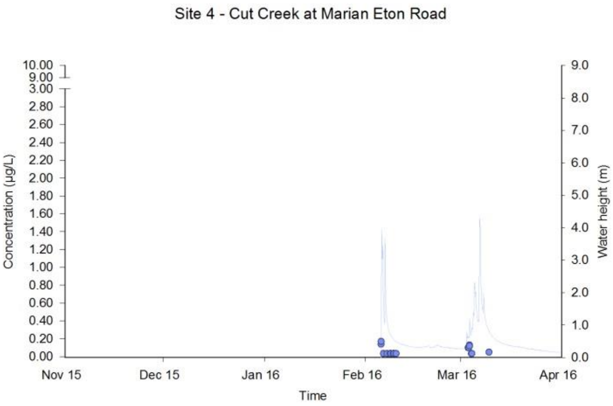

Figure 7-89 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Cut Creek.

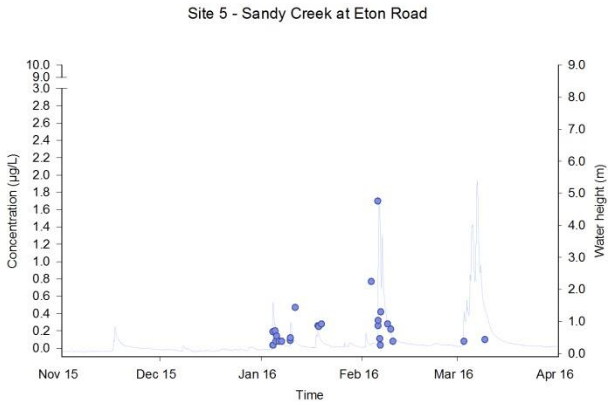

Figure 7-90 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Sandy Creek at Eton.

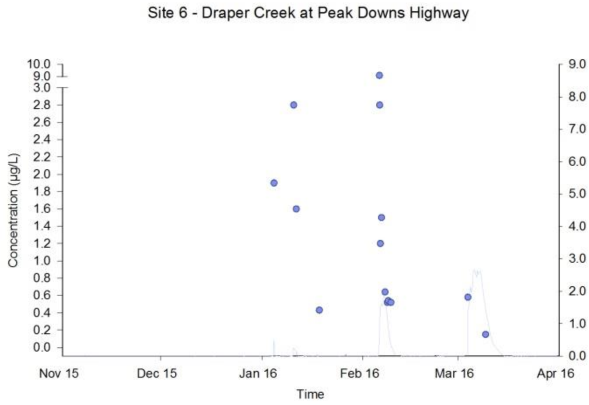

Figure 7-91 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Draper Creek at Peak Downs Highway.

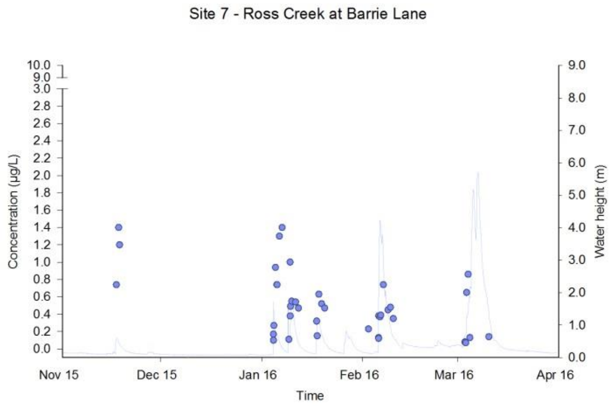

Figure 7-92 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Ross Creek at Barrie Lane.

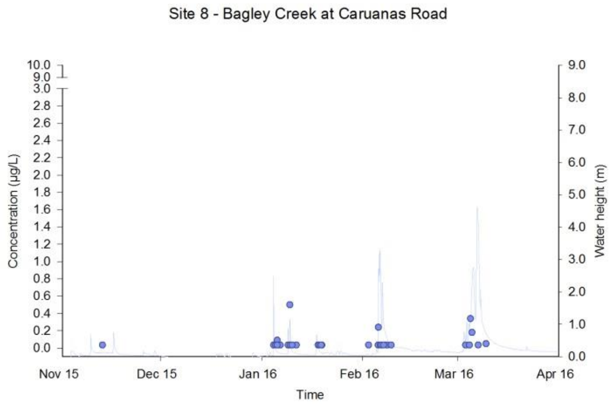

Figure 7-93 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Bagley Creek.

Figure 7-94 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Oaky Creek.

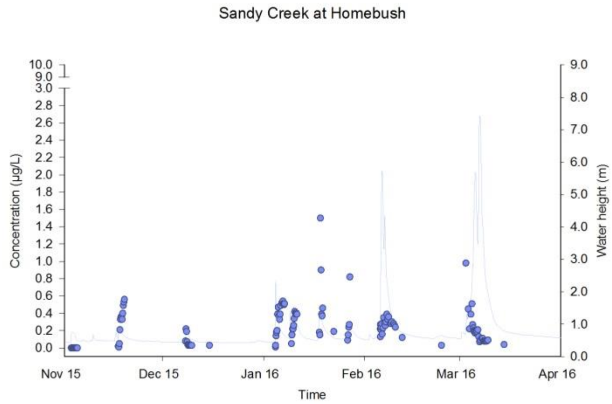

Figure 7-95 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Sandy Creek at Homebush.

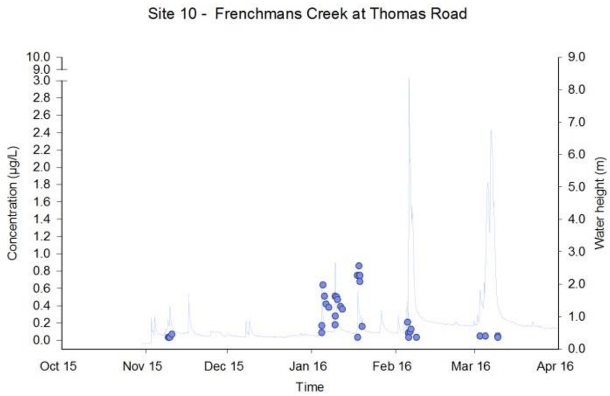

Figure 7-96 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Frenchmans Creek.

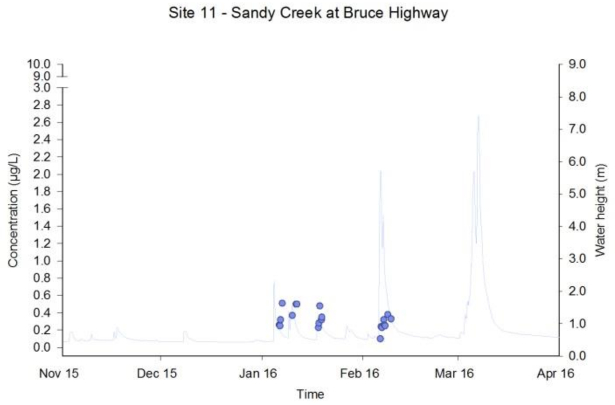

Figure 7-97 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in Sandy Creek at Bruce Highway.

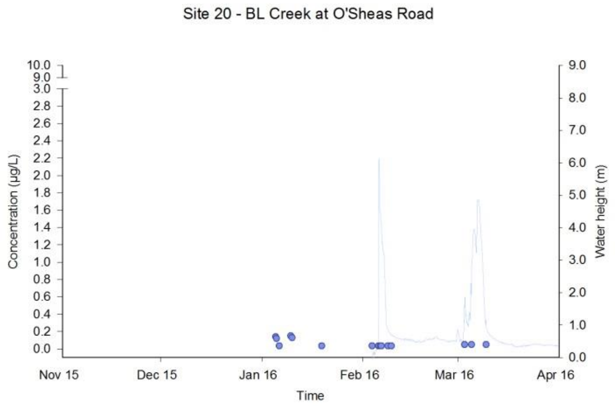

Figure 7-98 Hydrographic plot of water level and concentration (µgL^{-1}) of fluroxypyr in BL Creek.

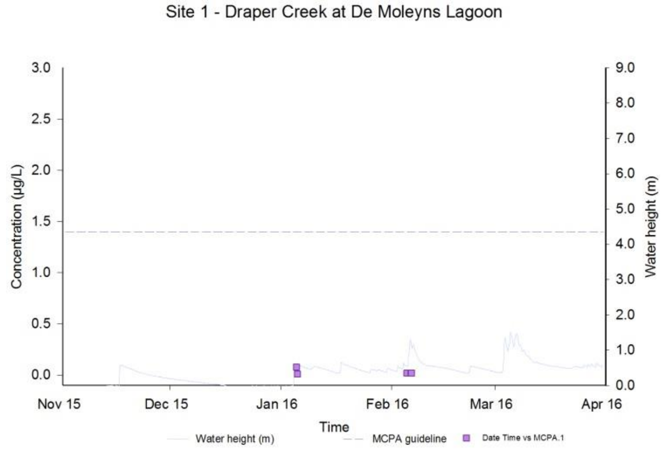

Figure 7-99 Hydrographic plot of water level and concentration (µgL-1) of MCPA in Draper Creek at De Moleyns Lagoon.

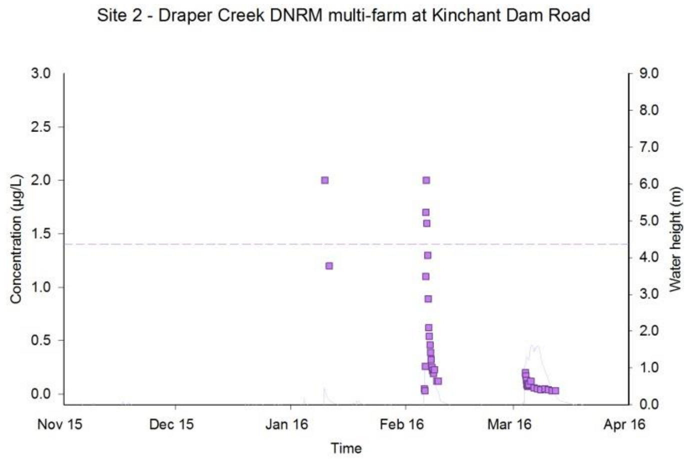

Figure 7-100 Hydrographic plot of water level and concentration (µgL-1) of MCPA in Draper Creek at Multi-farm.

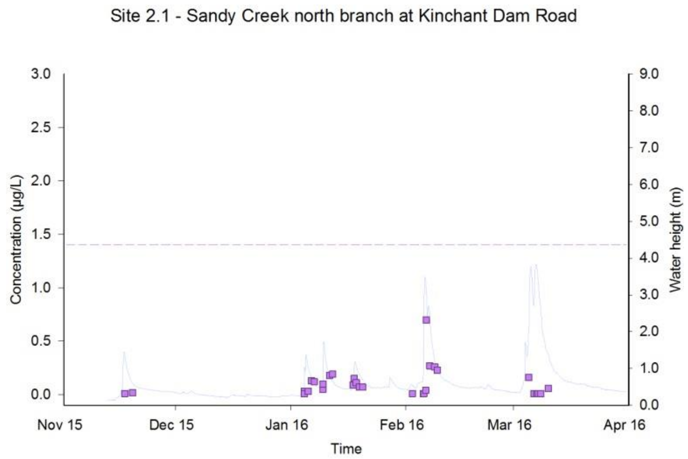

Figure 7-101 Hydrographic plot of water level and concentration (µgL-1) of MCPA in Sandy Creek North Branch.

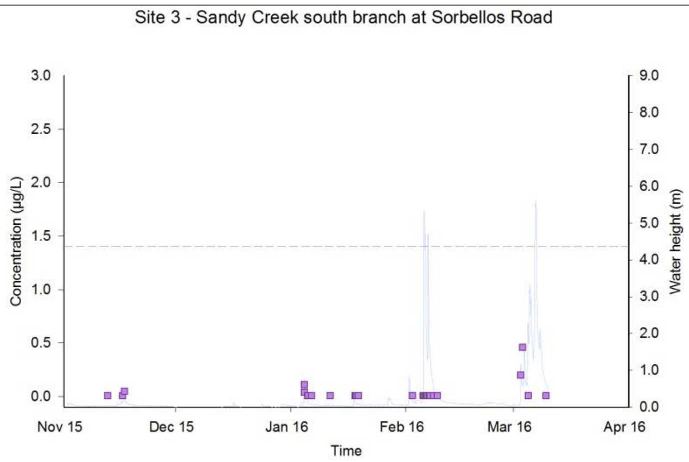

Figure 7-102 Hydrographic plot of water level and concentration (µgL-1) of MCPA in Sandy Creek South Branch.

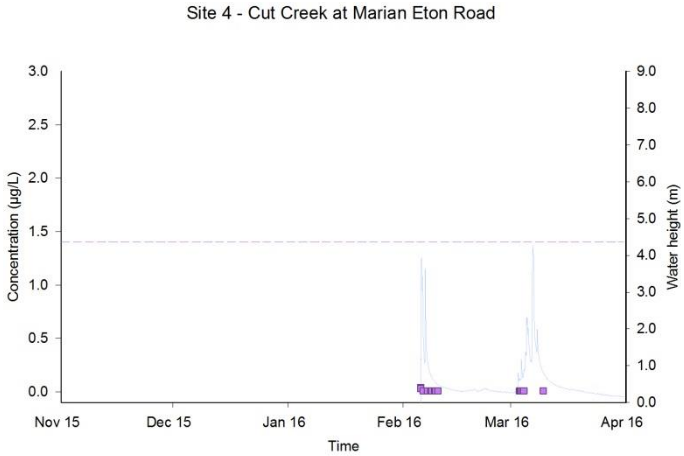

Figure 7-103 Hydrographic plot of water level and concentration (µgL-1) of MCPA in Cut Creek.

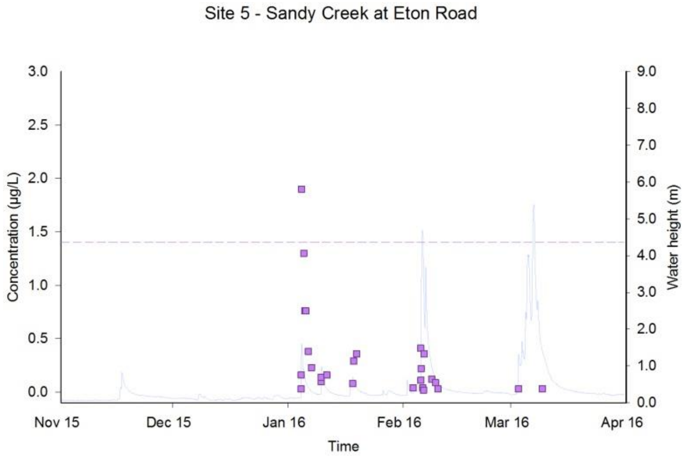

Figure 7-104 Hydrographic plot of water level and concentration (µgL-1) of MCPA in Sandy Creek at Eton.

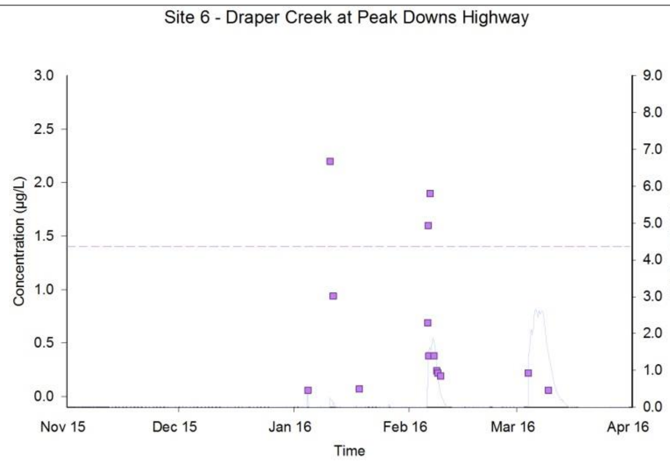

Figure 7-105 Hydrographic plot of water level and concentration (µgL^{-1}) of MCPA in Draper Creek at Peak Downs Highway.

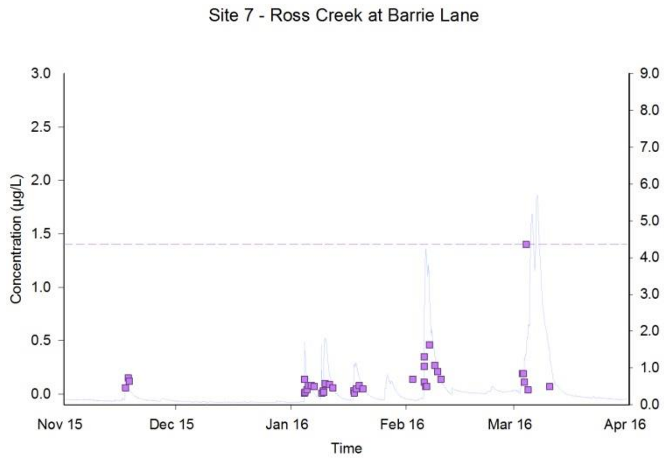

Figure 7-106 Hydrographic plot of water level and concentration (µgL^{-1}) of MCPA in Ross Creek at Barrie Lane.

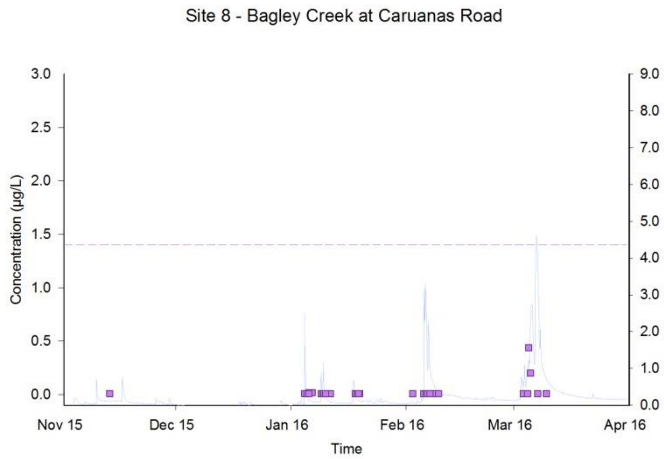

Figure 7-107 Hydrographic plot of water level and concentration (µgL^{-1}) of MCPA in Bagley Creek.

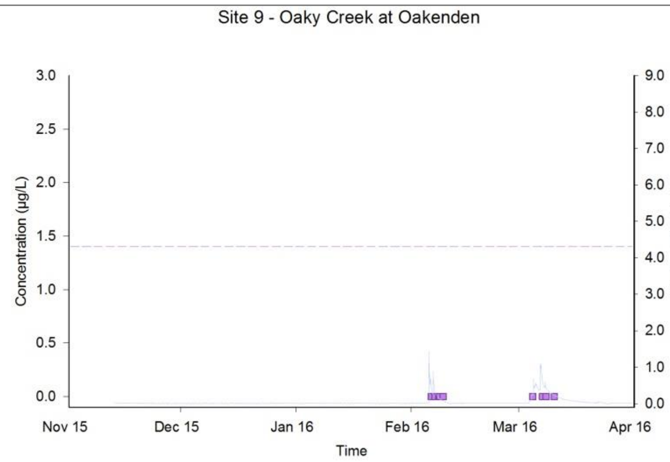

Figure 7-108 Hydrographic plot of water level and concentration (µgL^{-1}) of MCPA in Oaky Creek.

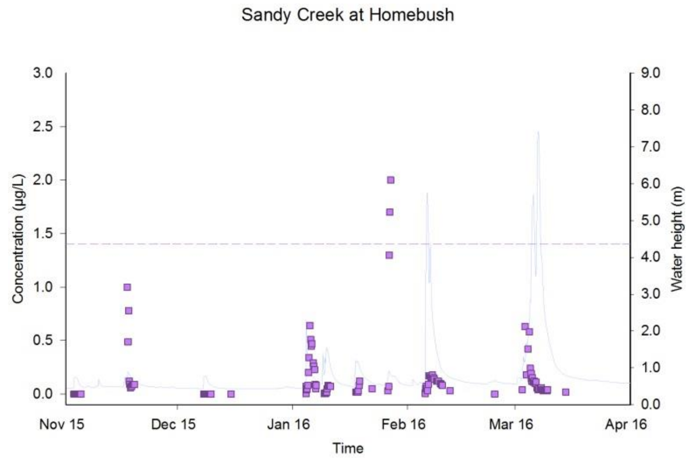

Figure 7-109 Hydrographic plot of water level and concentration (µgL^{-1}) of MCPA in Sandy Creek at Homebush.

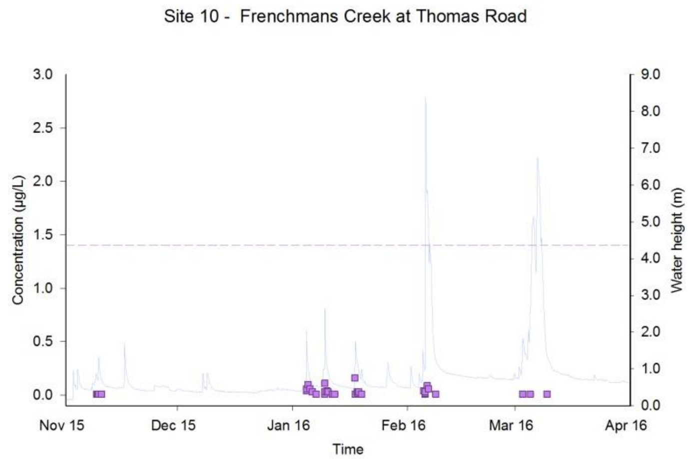

Figure 7-110 Hydrographic plot of water level and concentration (µgL^{-1}) of MCPA in Frenchmans Creek.

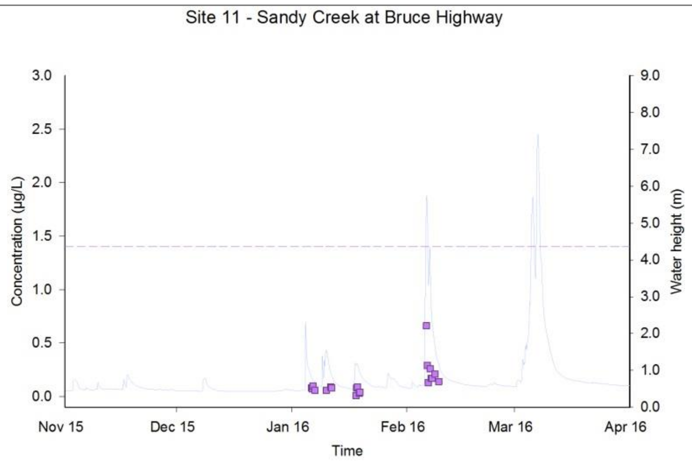

Figure 7-111 Hydrographic plot of water level and concentration (µgL^{-1}) of MCPA in Sandy Creek at Bruce Highway.

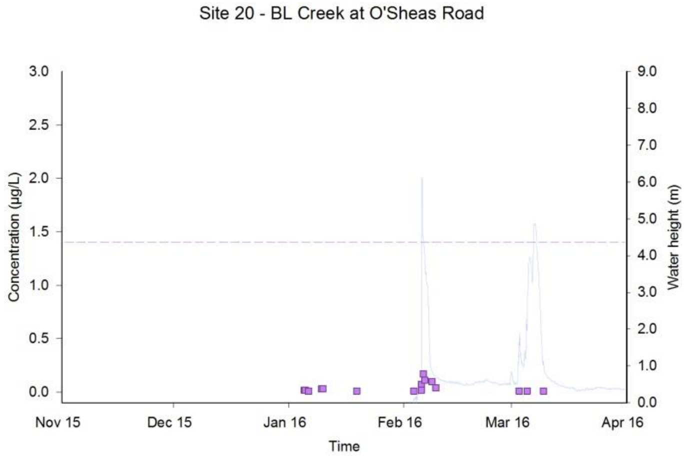

Figure 7-112 Hydrographic plot of water level and concentration (µgL^{-1}) of MCPA in BL Creek.

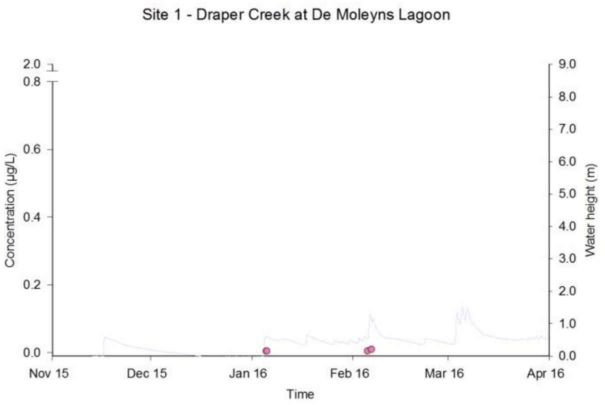

Figure 7-113 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Draper Creek at De Moleyns Lagoon.

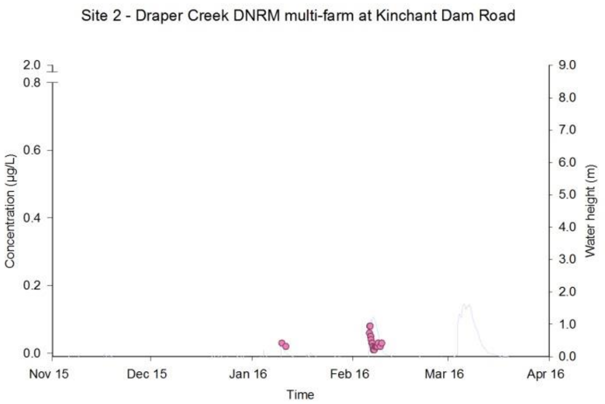

Figure 7-114 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Draper Creek at Multi-farm.

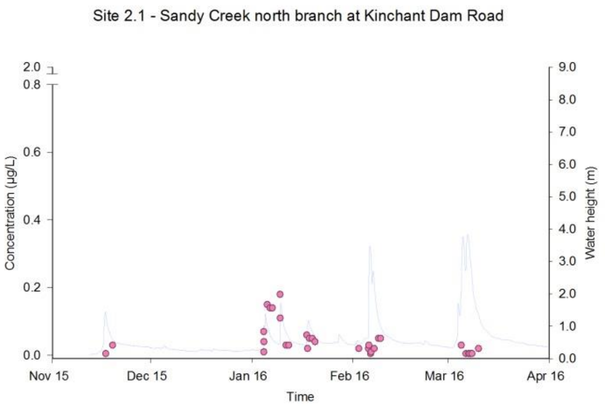

Figure 7-115 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Sandy Creek North Branch.

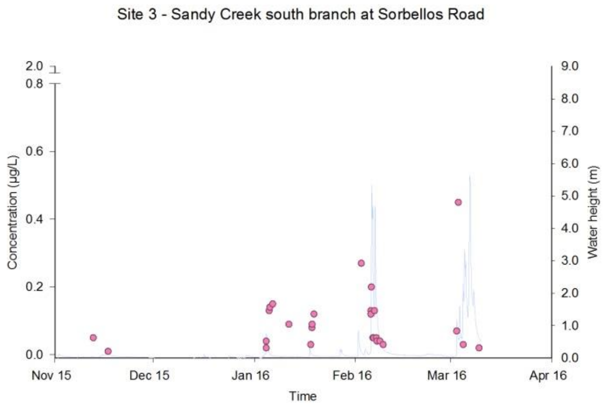

Figure 7-116 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Sandy Creek South Branch.

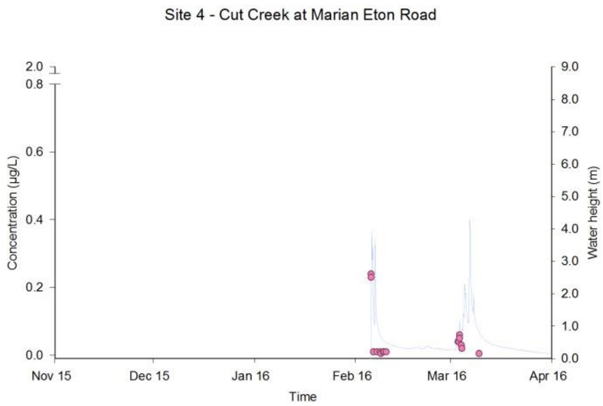

Figure 7-117 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Cut Creek.

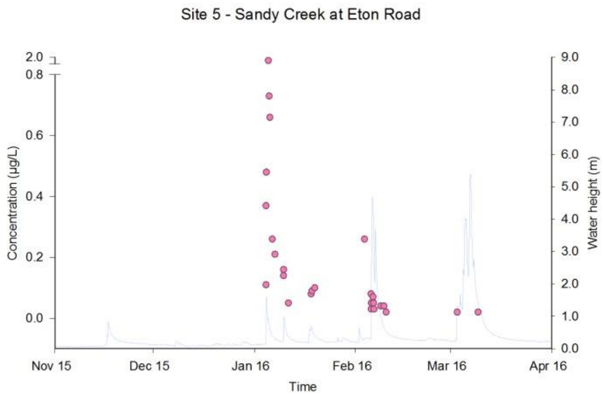

Figure 7-118 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Sandy Creek at Eton.

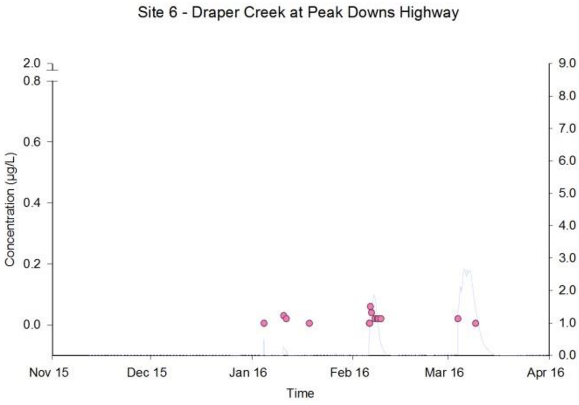

Figure 7-119 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Draper Creek at Peak Downs Highway.

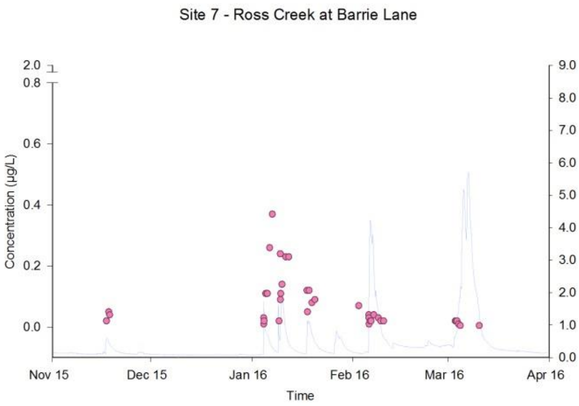

Figure 7-120 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Ross Creek at Barrie Lane.

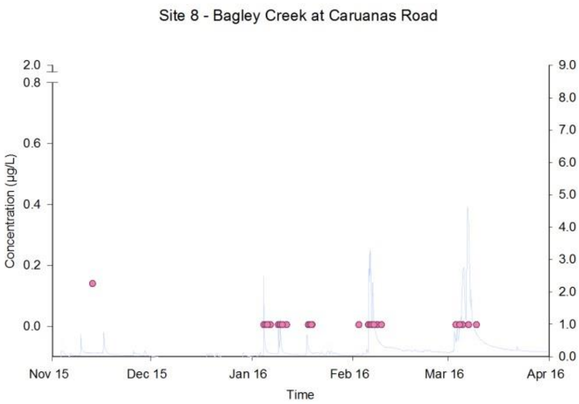

Figure 7-121 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Bagley Creek.

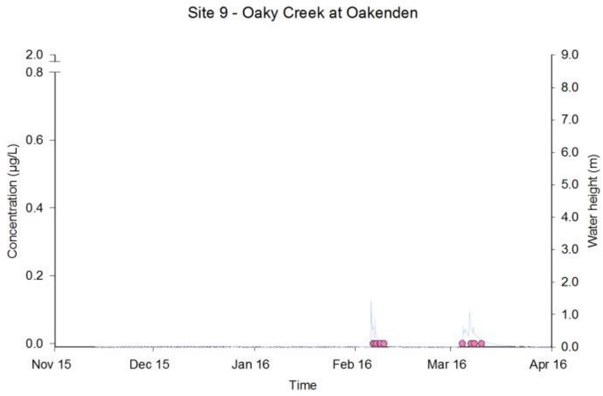

Figure 7-122 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Oaky Creek.

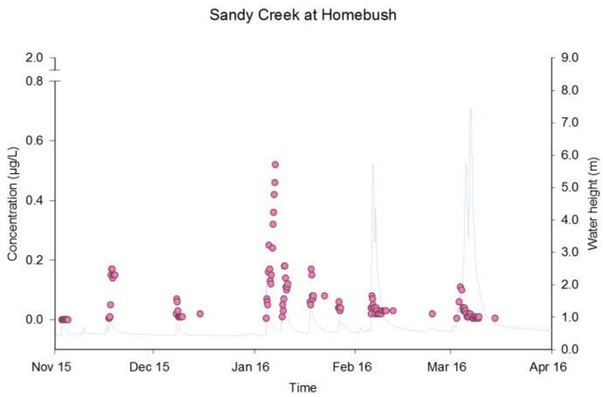

Figure 7-123 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Sandy Creek at Homebush.

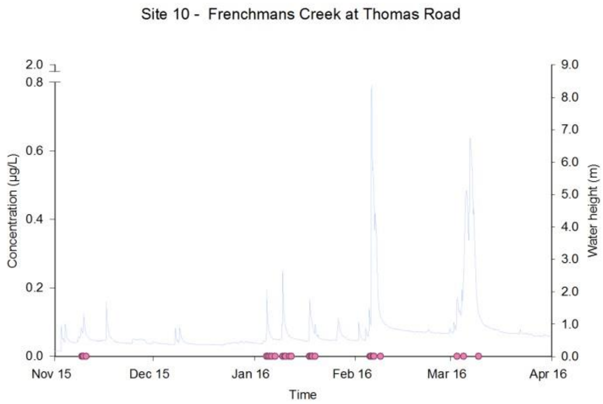

Figure 7-124 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Frenchmans Creek.

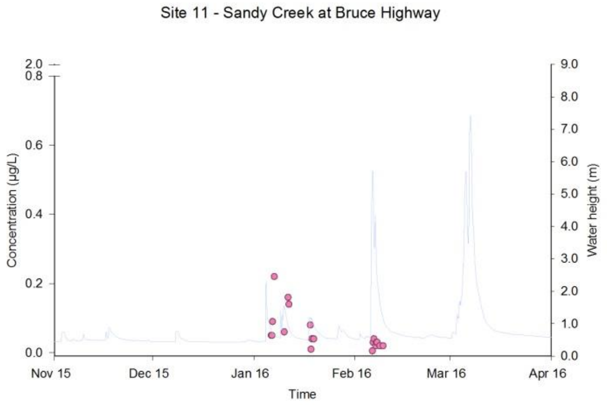

Figure 7-125 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in Sandy Creek at Bruce Highway.

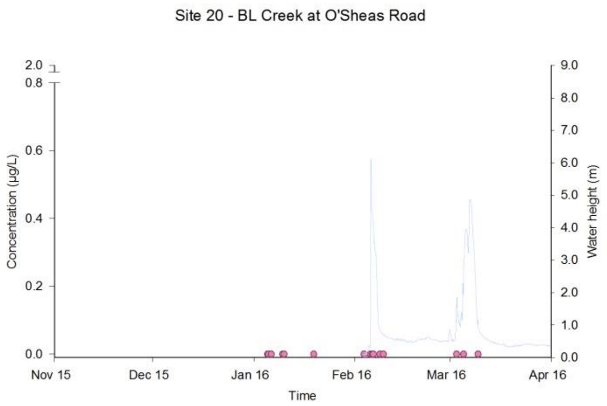

Figure 7-126 Hydrographic plot of water level and concentration (µgL^{-1}) of isoxaflutole metabolite (DKN) in BL Creek.

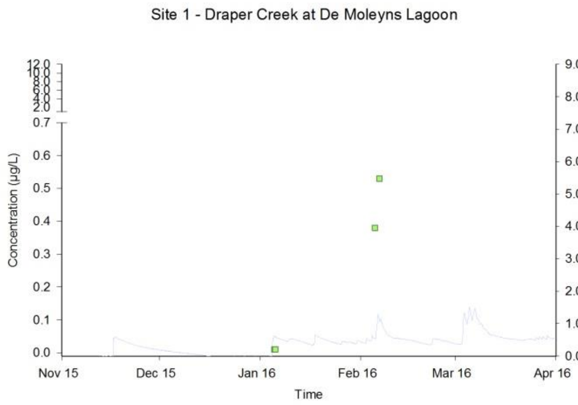

Figure 7-127 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Draper Creek at De Moleyns Lagoon.

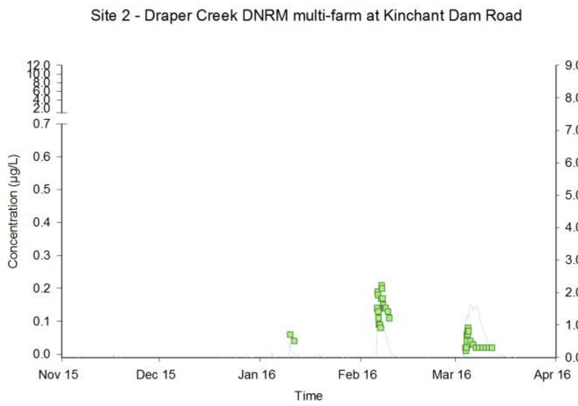

Figure 7-128 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Draper Creek at Multi-farm.

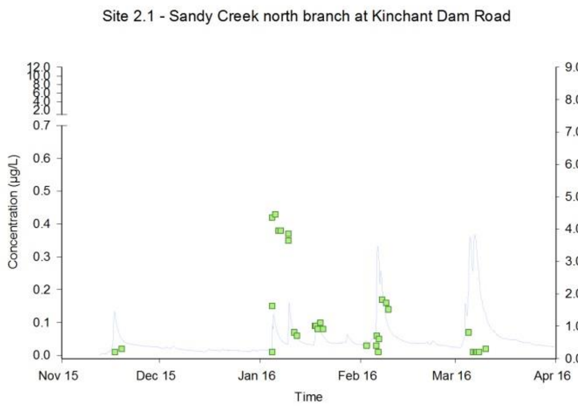

Figure 7-129 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Sandy Creek North Branch.

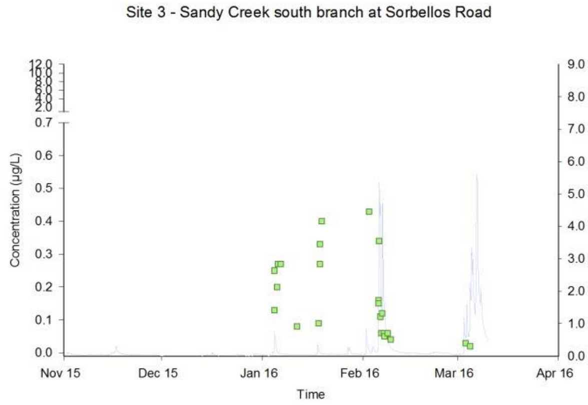

Figure 7-130 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Sandy Creek South Branch.

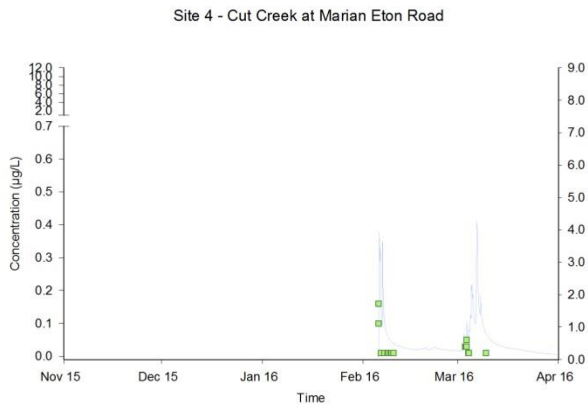

Figure 7-131 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Cut Creek.

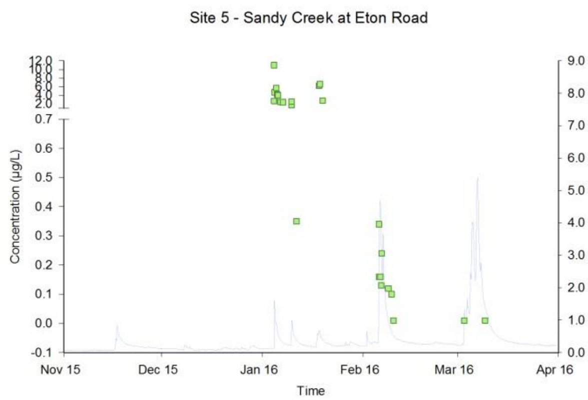

Figure 7-132 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Sandy Creek at Eton.

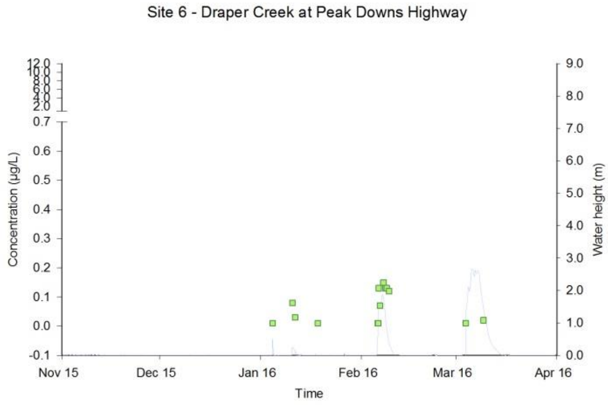

Figure 7-133 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Draper Creek at Peak Downs Highway.

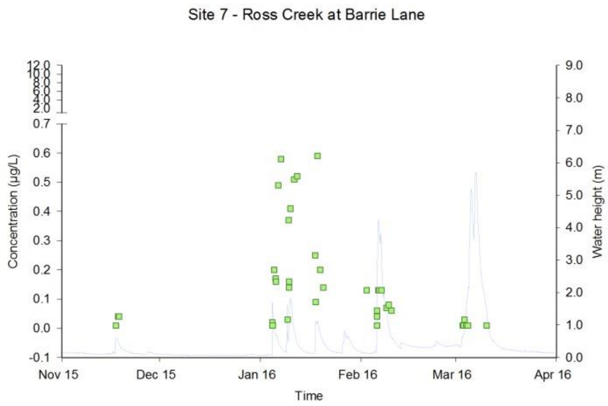

Figure 7-134 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Ross Creek at Barrie Lane.

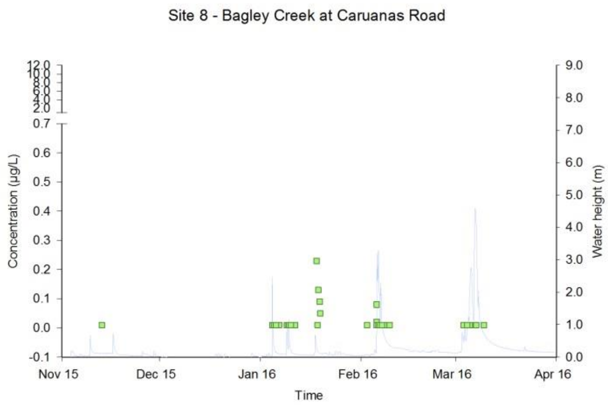

Figure 7-135 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Bagley Creek.

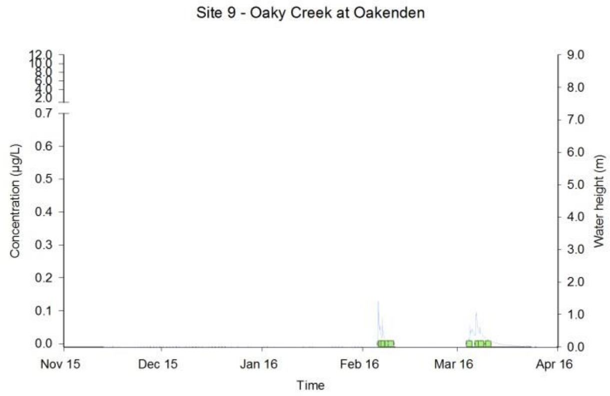

Figure 7-136 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Oaky Creek.

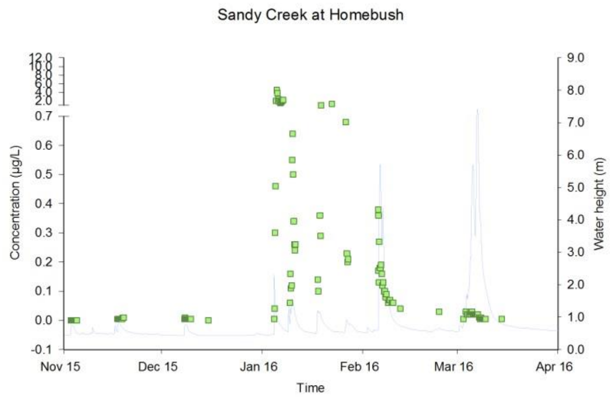

Figure 7-137 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Sandy Creek at Homebush.

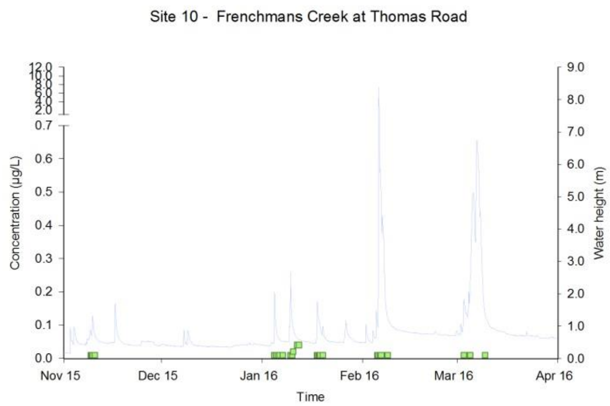

Figure 7-138 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Frenchmans Creek.

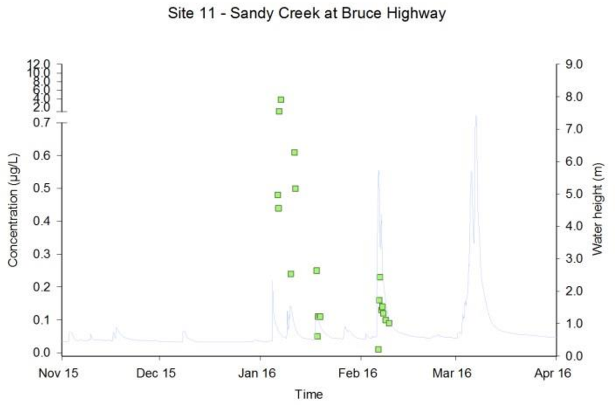

Figure 7-139 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in Sandy Creek at Bruce Highway.

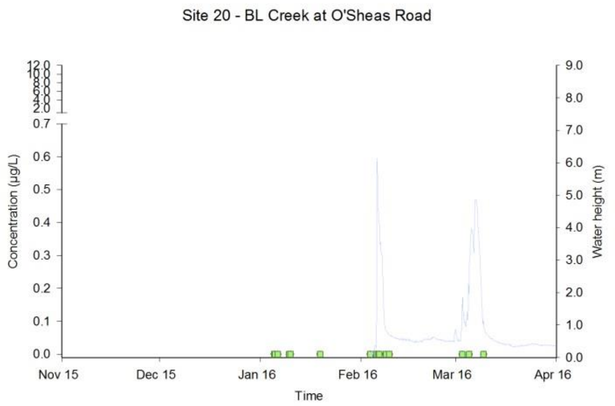

Figure 7-140 Hydrographic plot of water level and concentration (µgL^{-1}) of metribuzin in BL Creek.

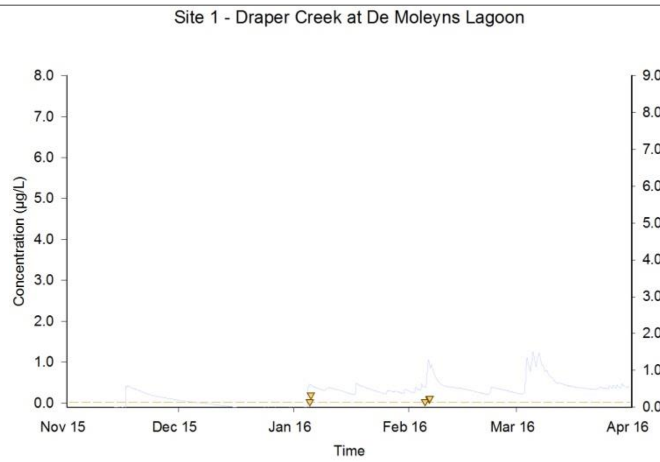

Figure 7-141 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Draper Creek at De Moleyns Lagoon.

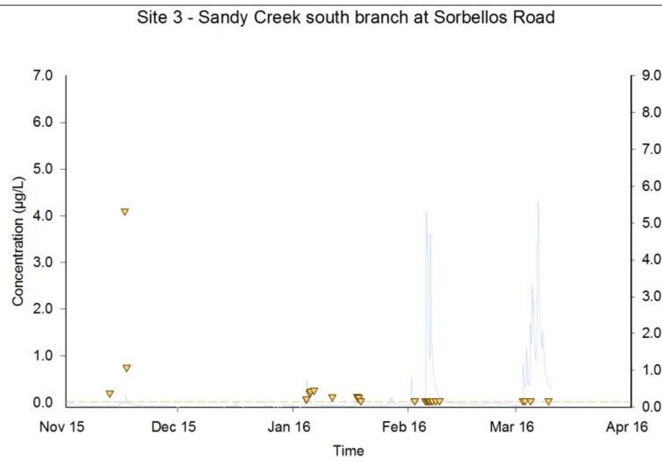

Figure 7-144 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Sandy Creek South Branch.

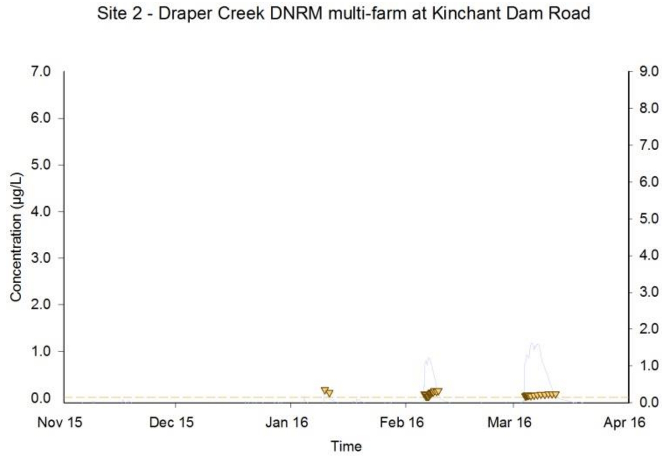

Figure 7-142 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Draper Creek at Multi-farm.

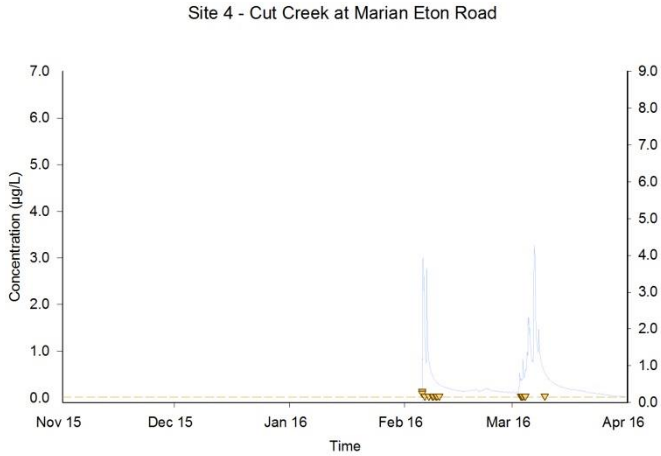

Figure 7-145 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Cut Creek.

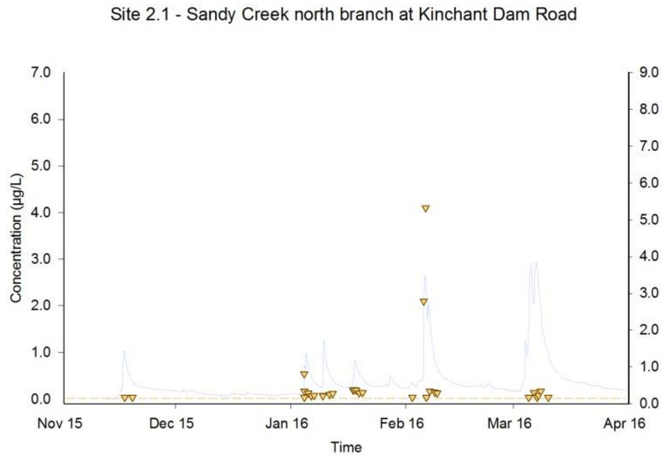

Figure 7-143 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Sandy Creek North Branch.

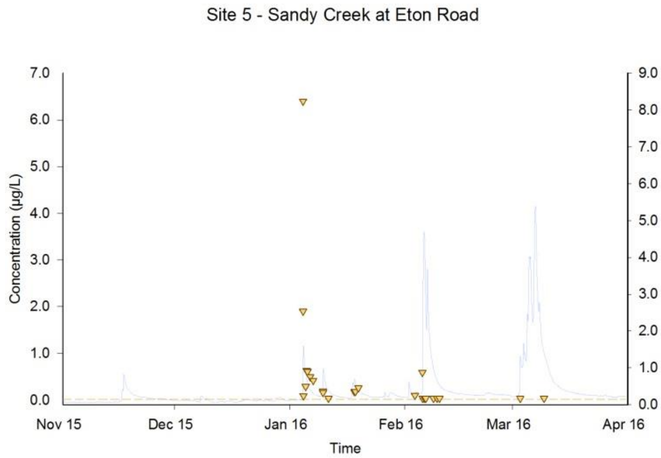

Figure 7-146 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Sandy Creek at Eton.

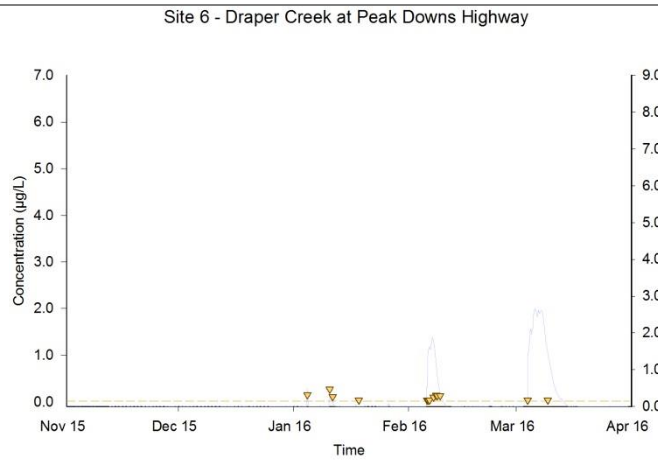

Figure 7-147 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Draper Creek at Peak Downs Highway.

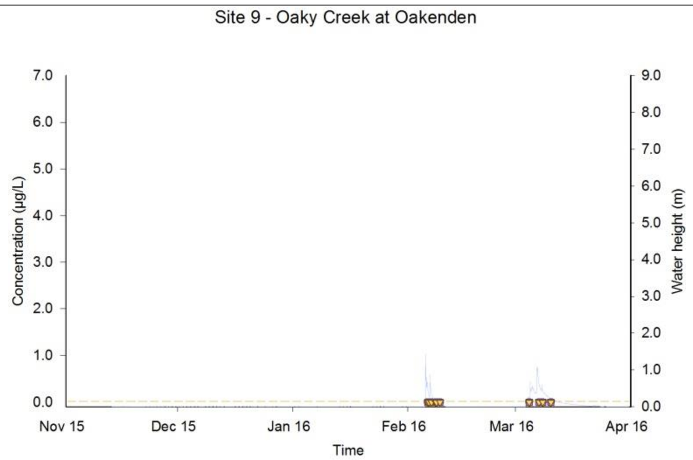

Figure 7-150 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Oaky Creek.

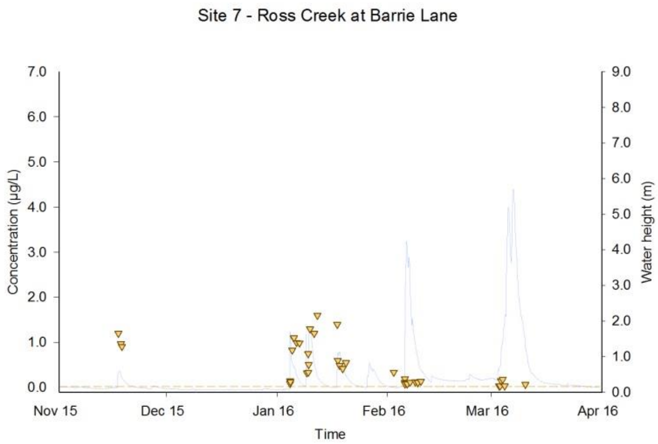

Figure 7-148 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Ross Creek at Barrie Lane.

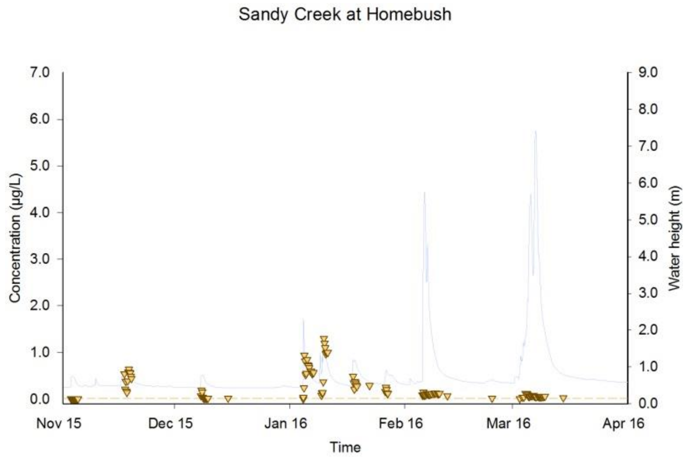

Figure 7-151 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Sandy Creek at Homebush.

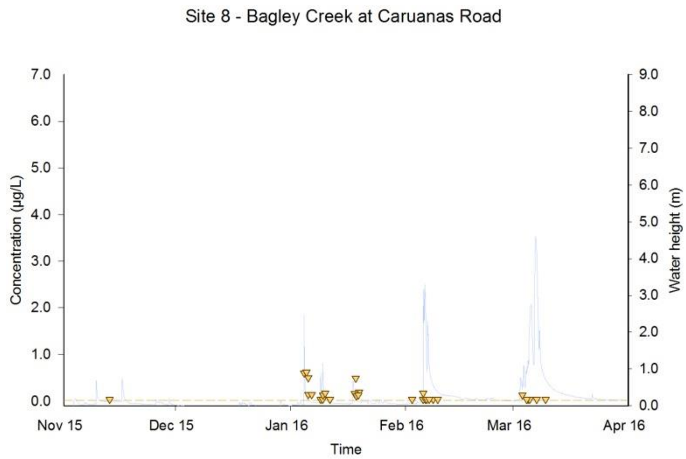

Figure 7-149 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Bagley Creek.

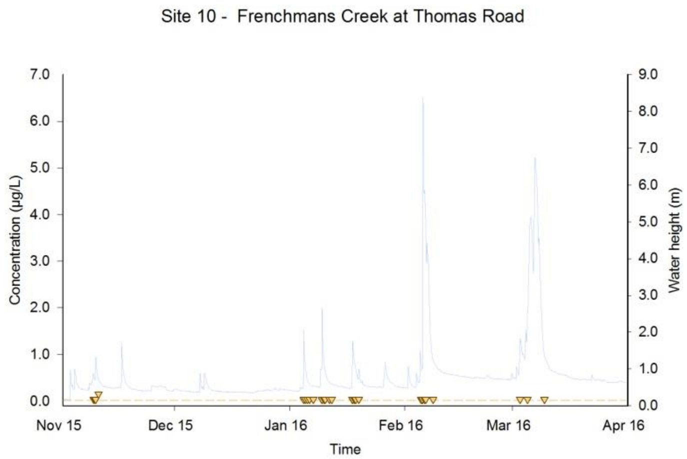

Figure 7-152 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Frenchmans Creek.

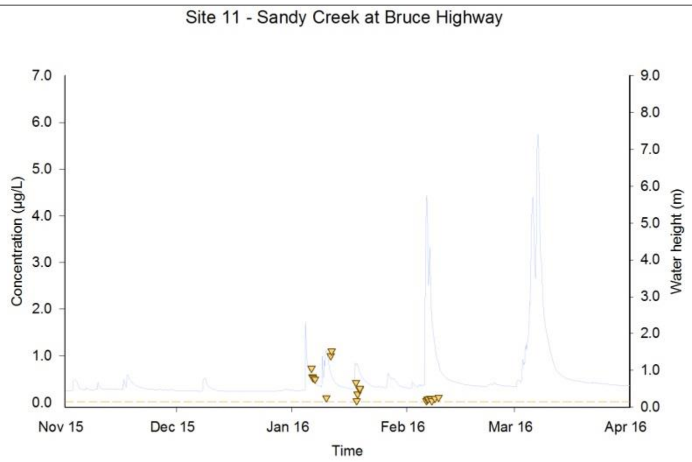

Figure 7-153 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in Sandy Creek at Bruce Highway.

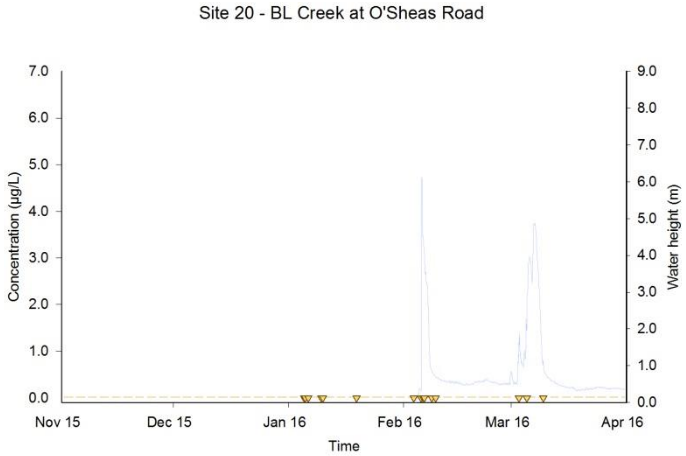

Figure 7-154 Hydrographic plot of water level and concentration (µgL^{-1}) of metolachlor in BL Creek.

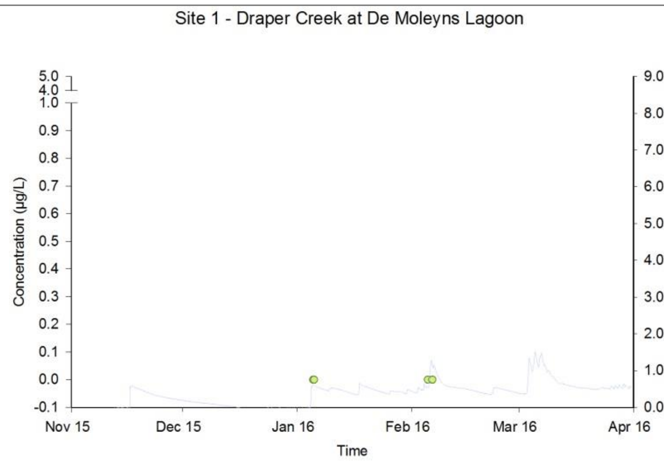

Figure 7-155 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Draper Creek at De Moleyns Lagoon.

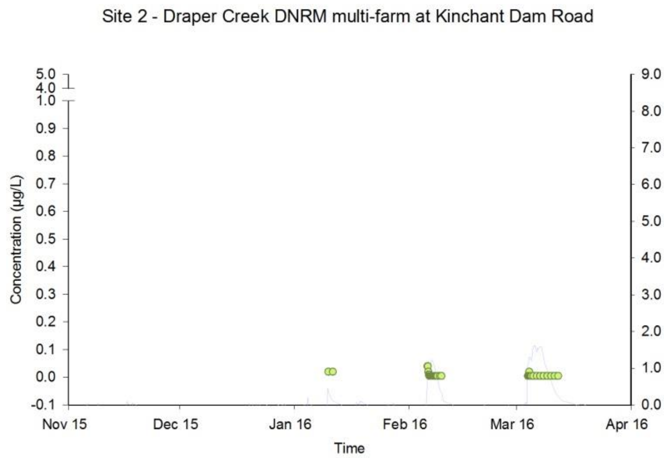

Figure 7-156 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Draper Creek at Multi-farm.

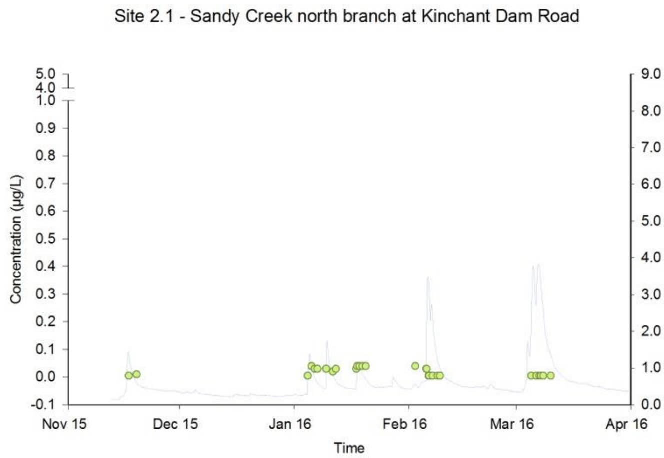

Figure 7-157 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Sandy Creek North Branch.

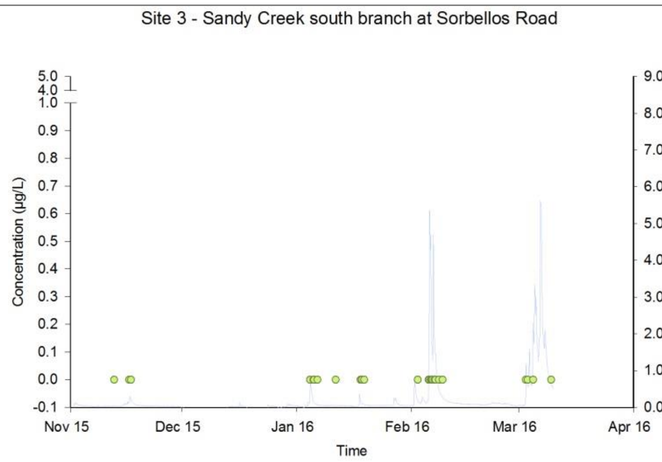

Figure 7-158 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Sandy Creek South Branch.

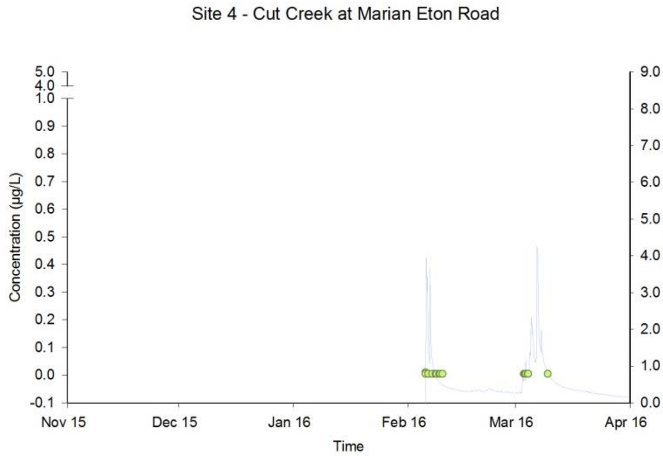

Figure 7-159 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Cut Creek.

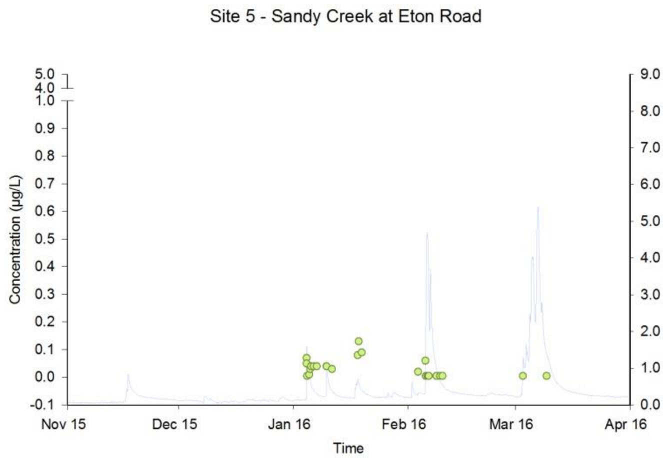

Figure 7-160 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Sandy Creek at Eton.

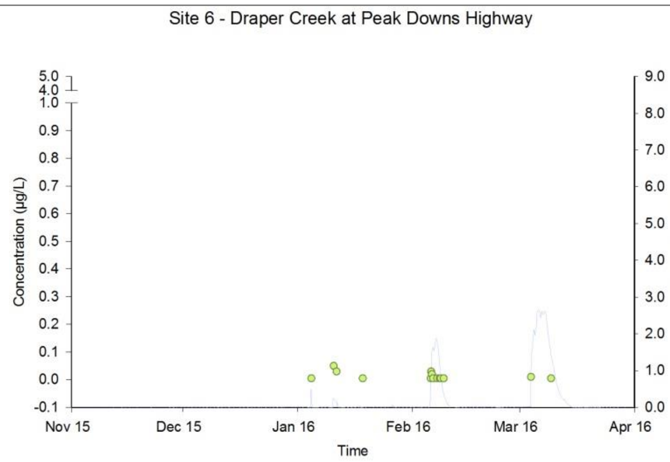

Figure 7-161 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Draper Creek at Peak Downs Highway.

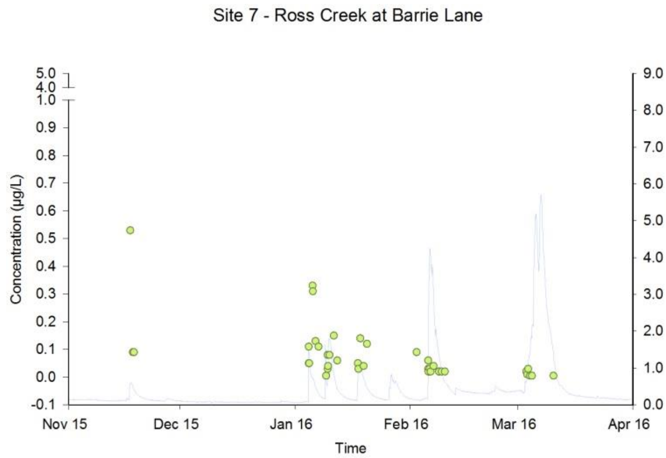

Figure 7-162 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Ross Creek at Barrie Lane.

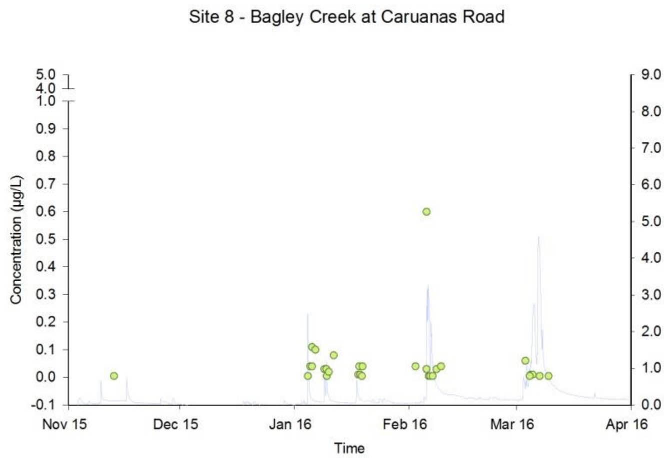

Figure 7-163 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Bagley Creek.

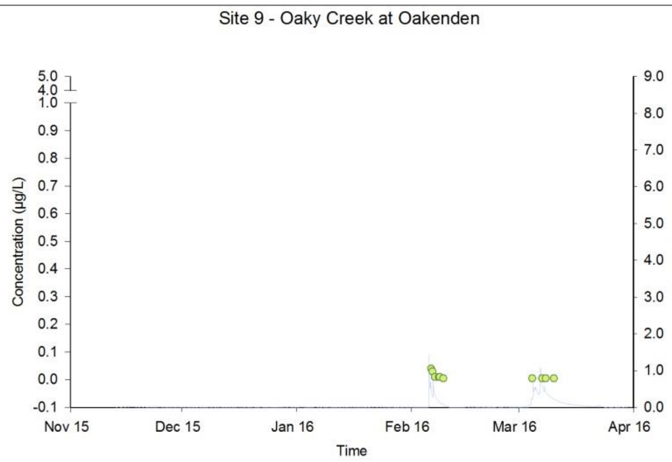

Figure 7-164 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Oaky Creek.

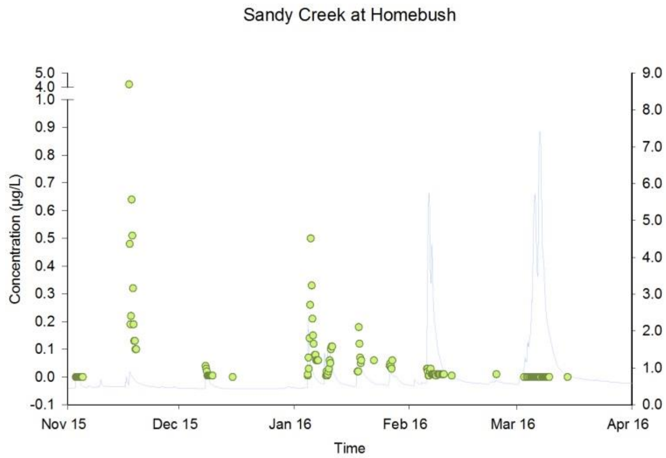

Figure 7-165 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Sandy Creek at Homebush.

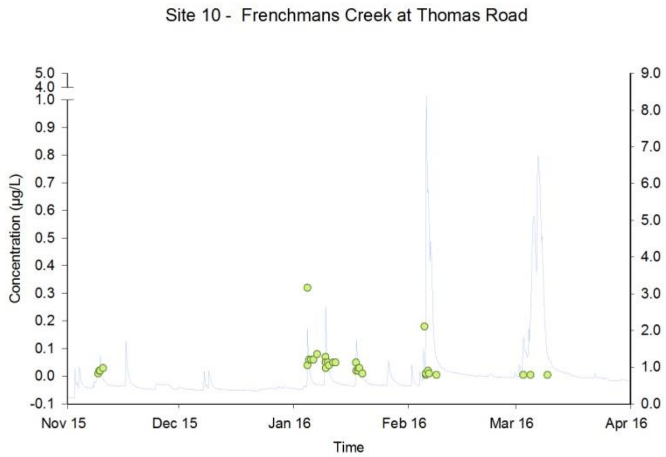

Figure 7-166 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Frenchmans Creek.

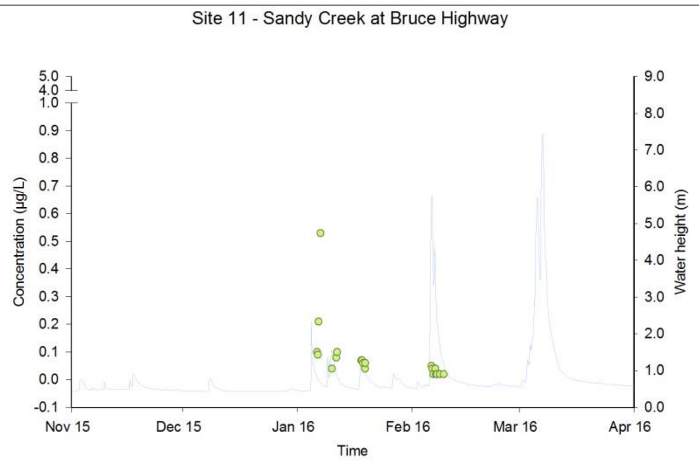

Figure 7-167 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in Sandy Creek at Bruce Highway.

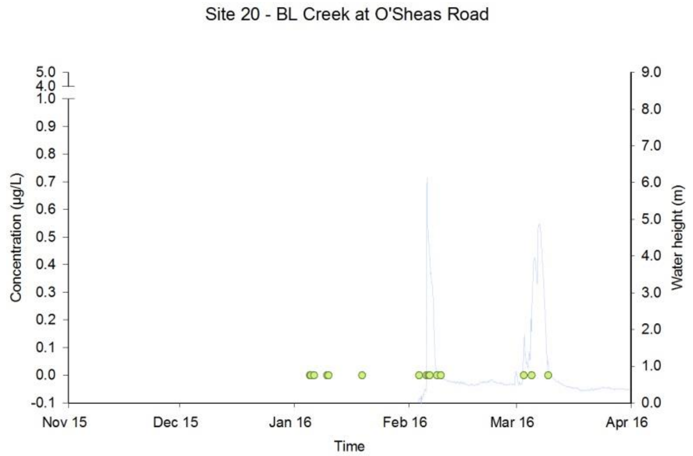

Figure 7-168 Hydrographic plot of water level and concentration (µgL^{-1}) of ametryn in BL Creek.

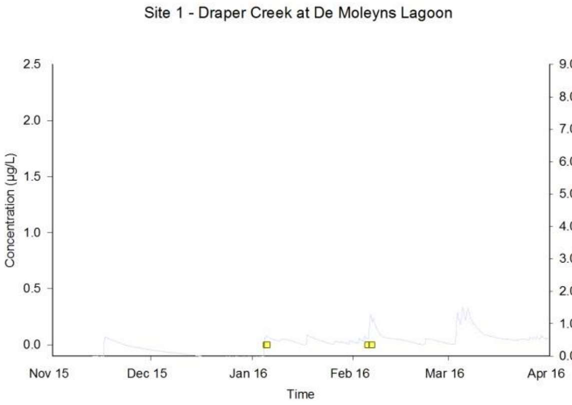

Figure 7-169 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Draper Creek at De Moleyns Lagoon.

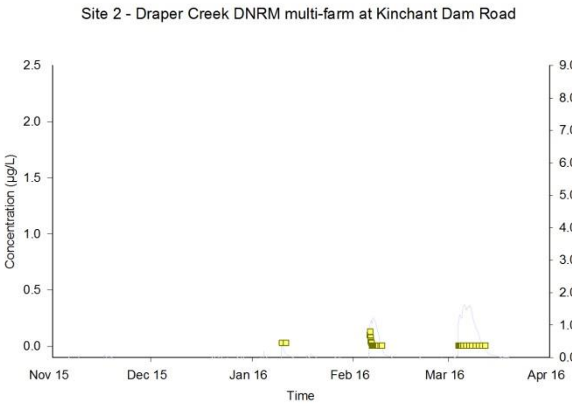

Figure 7-170 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Draper Creek at Multi-farm.

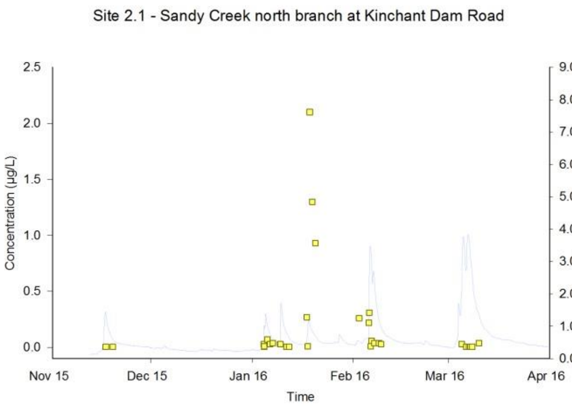

Figure 7-171 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Sandy Creek North Branch.

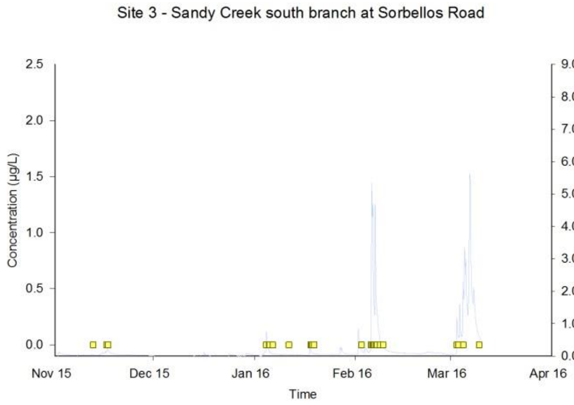

Figure 7-172 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Sandy Creek South Branch.

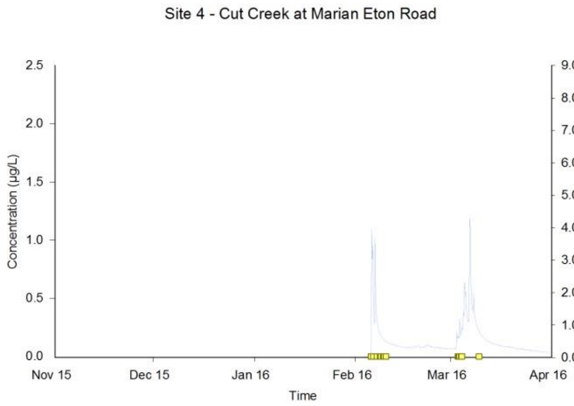

Figure 7-173 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Cut Creek.

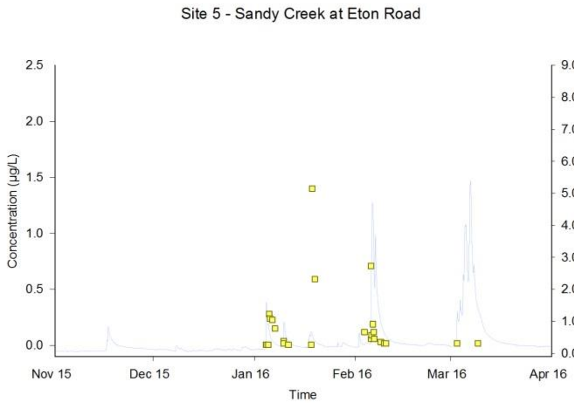

Figure 7-174 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Sandy Creek at Eton.

Figure 7-175 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Draper Creek at Peak Downs Highway.

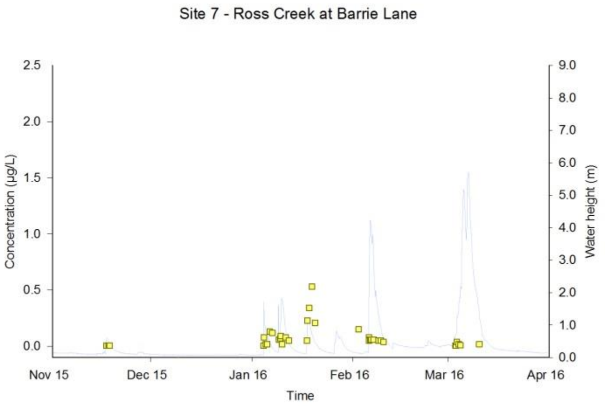

Figure 7-176 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Ross Creek at Barrie Lane.

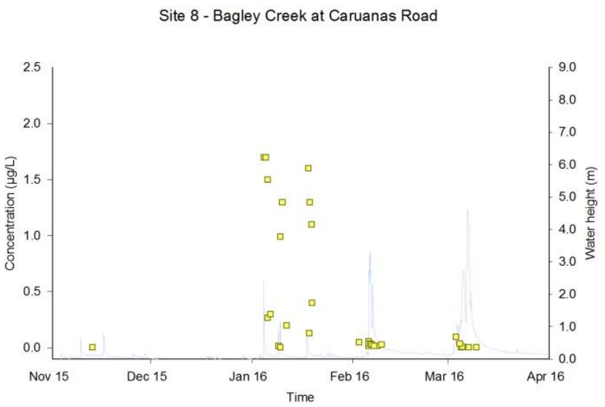

Figure 7-177 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Bagley Creek.

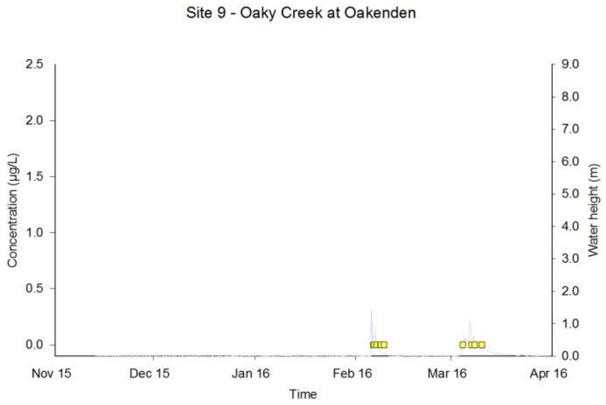

Figure 7-178 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Oaky Creek.

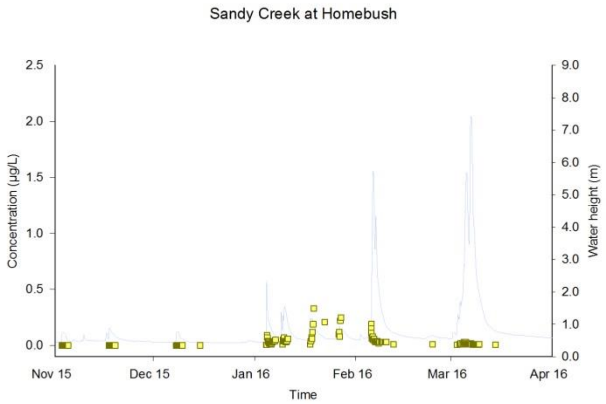

Figure 7-179 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Sandy Creek at Homebush.

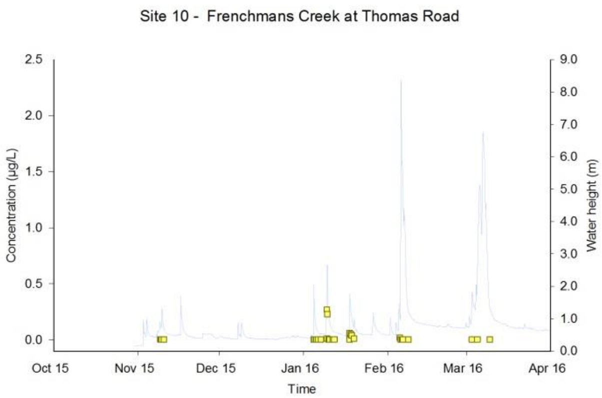

Figure 7-180 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Frenchmans Creek.

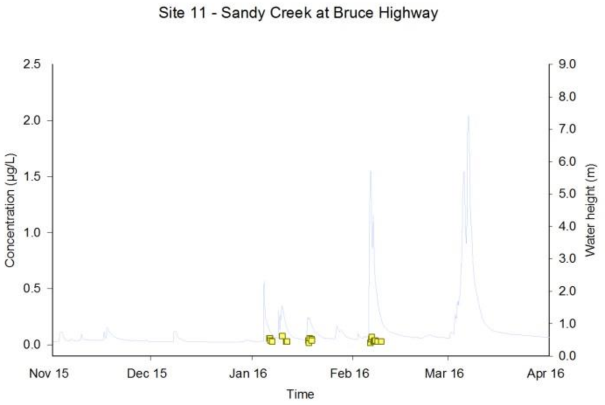

Figure 7-181 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Sandy Creek at Bruce Highway.

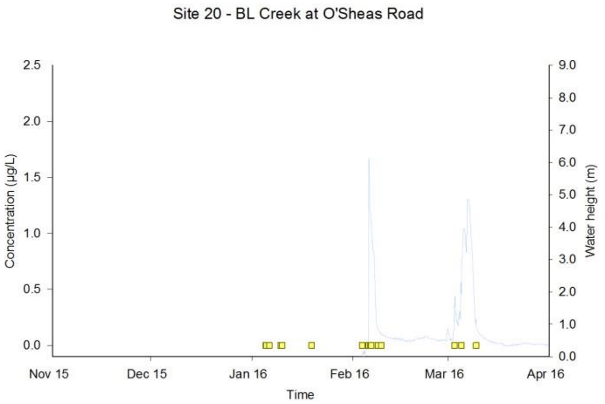

Figure 7-182 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in BL Creek.

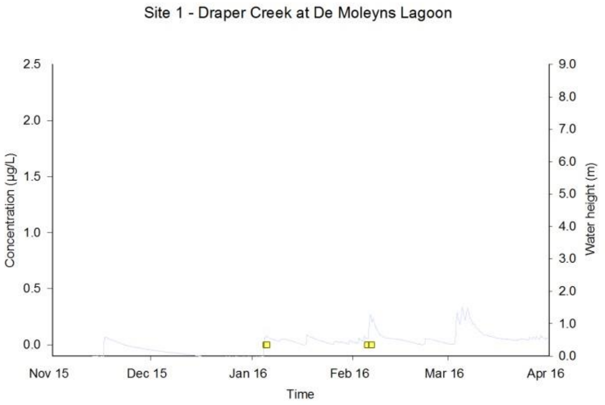

Figure 7-183 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Draper Creek at De Moleyns Lagoon.

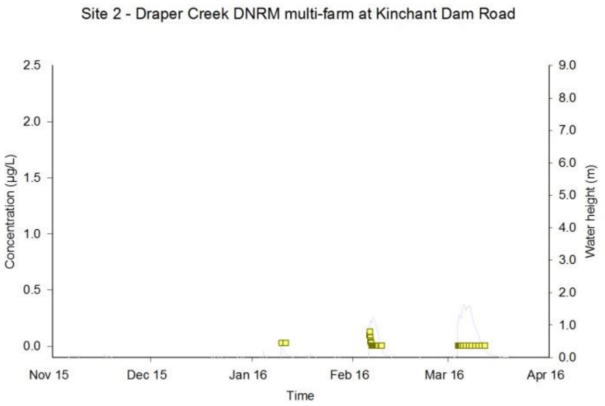

Figure 7-184 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Draper Creek at Multi-farm.

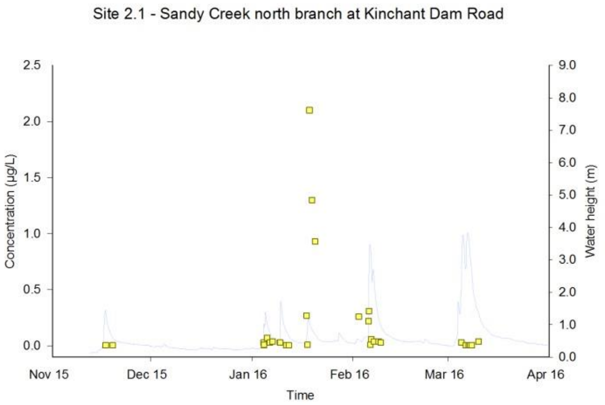

Figure 7-185 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Sandy Creek North Branch.

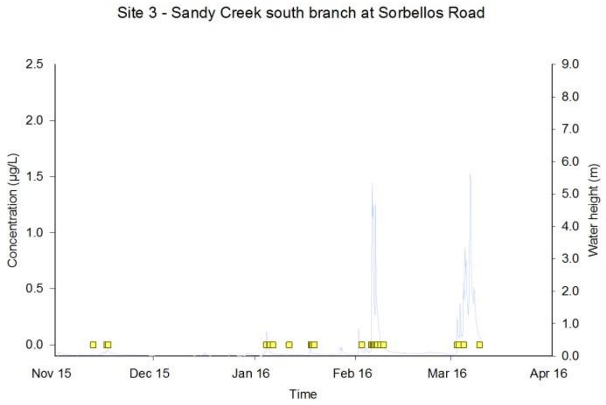

Figure 7-186 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Sandy Creek South Branch.

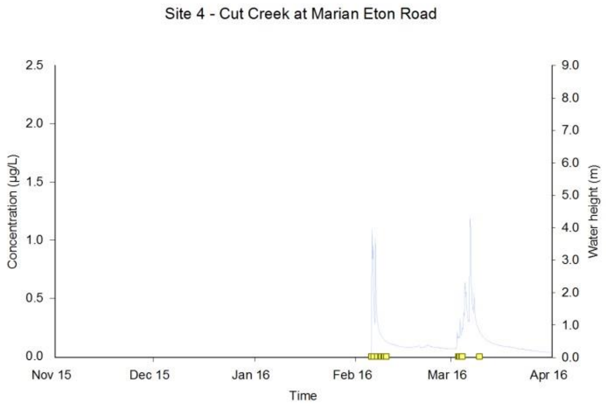

Figure 7-187 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Cut Creek.

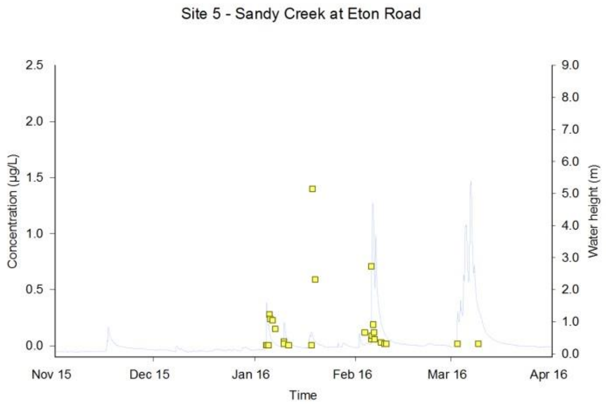

Figure 7-188 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Sandy Creek at Eton.

Figure 7-189 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Draper Creek at Peak Downs Highway.

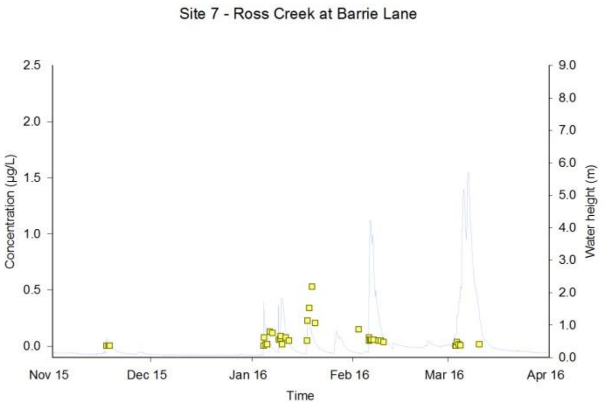

Figure 7-190 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Ross Creek at Barrie Lane.

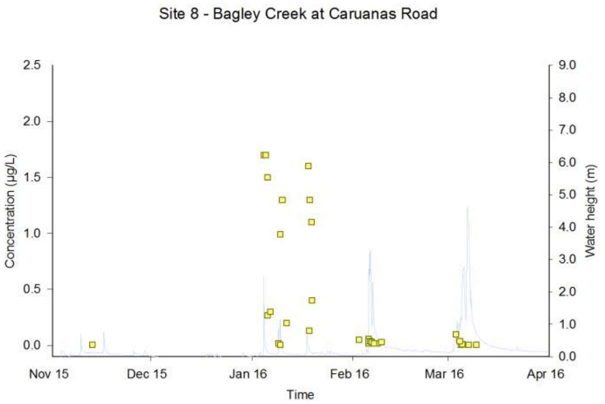

Figure 7-191 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Bagley Creek.

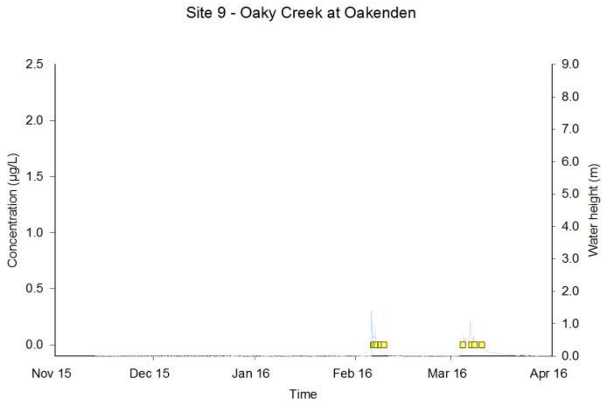

Figure 7-192 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Oaky Creek.

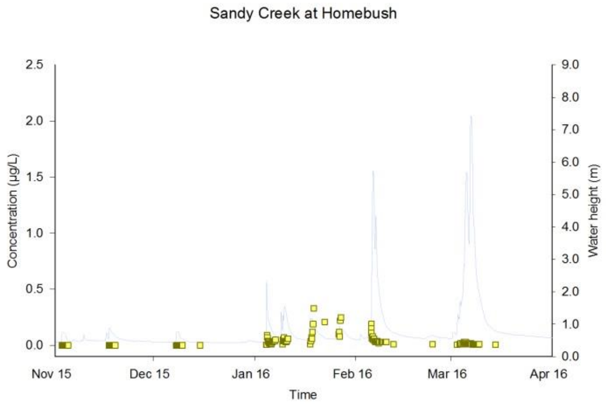

Figure 7-193 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Sandy Creek at Homebush.

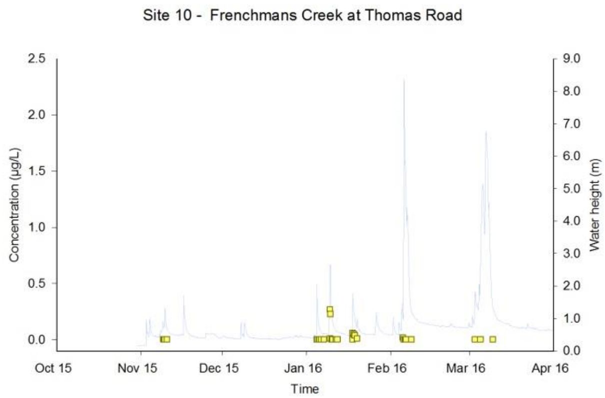

Figure 7-194 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in Frenchmans Creek.

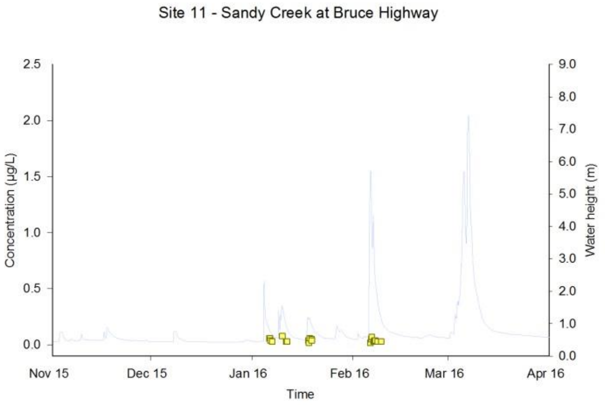

Figure 7-195 Hydrographic plot of water level and concentration (µgL-1) of imazethapyr in Sandy Creek at Bruce Highway.

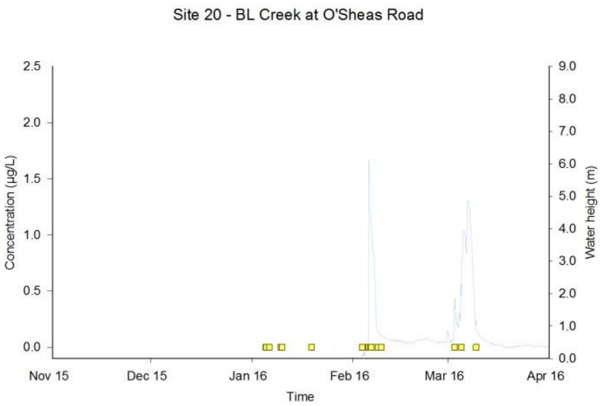

Figure 7-196 Hydrographic plot of water level and concentration (µgL^{-1}) of imazethapyr in BL Creek.

Appendix C Hydrograph and nutrient concentration plots

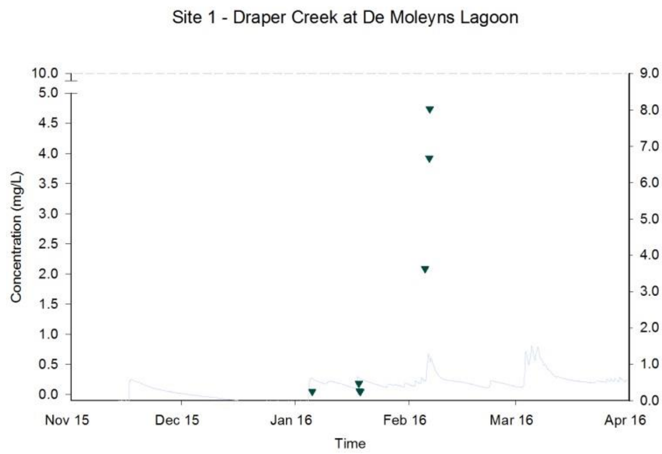

Figure 7-197 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Draper Creek at De Moleyns Lagoon.

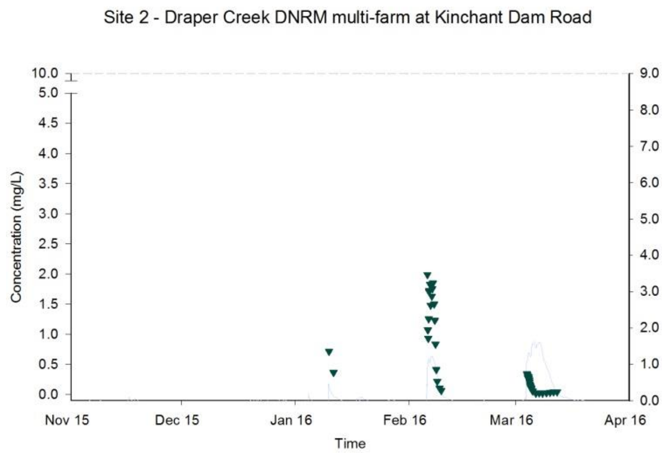

Figure 7-198 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Draper Creek at Multi-farm.

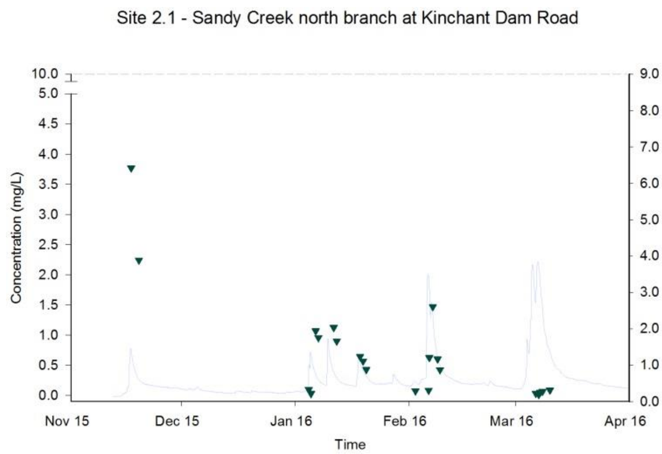

Figure 7-199 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Sandy Creek North Branch.

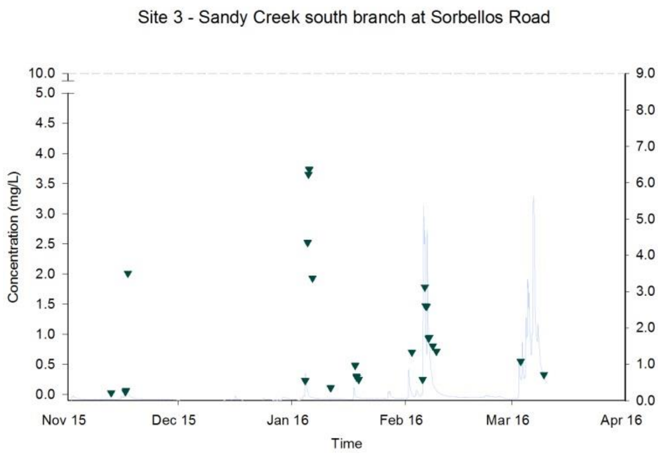

Figure 7-200 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Sandy Creek South Branch.

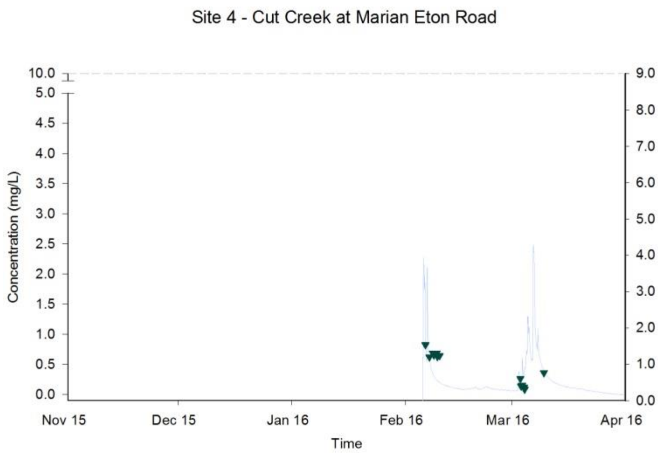

Figure 7-201 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Cut Creek.

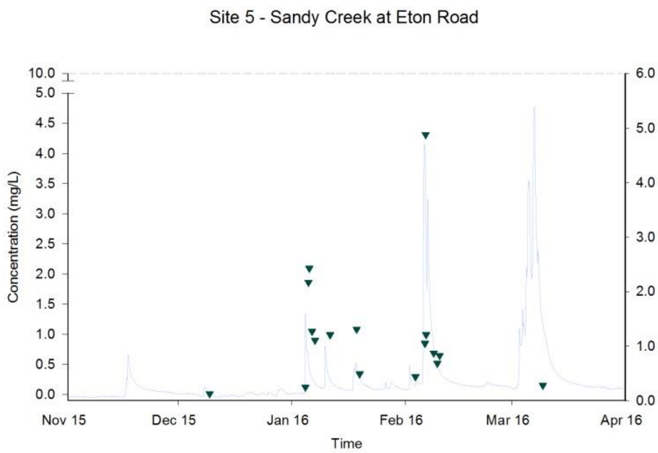

Figure 7-202 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Sandy Creek at Eton.

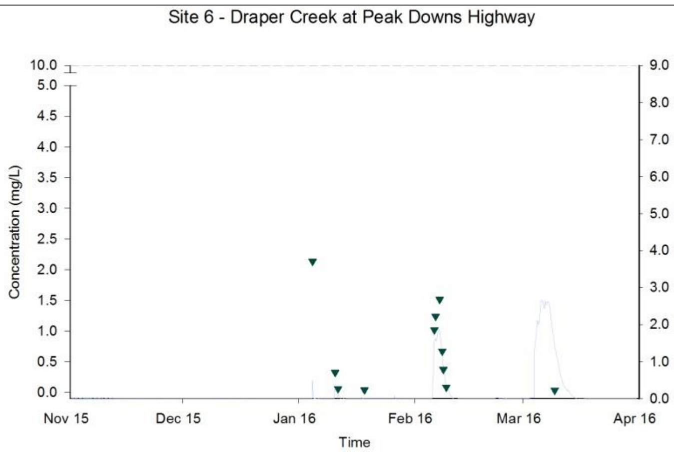

Figure 7-203 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Draper Creek at Peak Downs Highway.

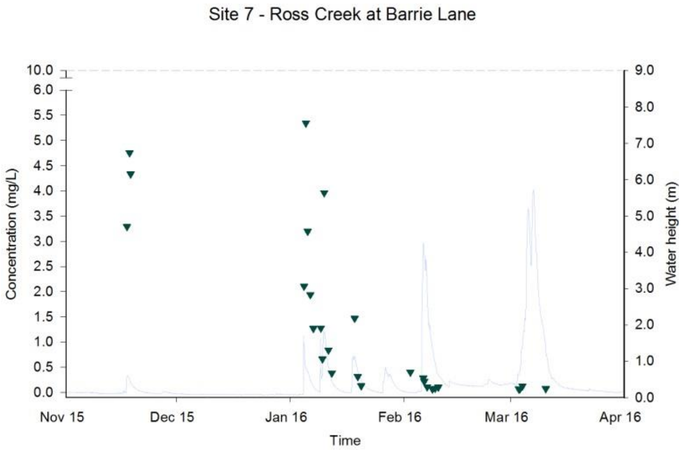

Figure 7-204 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Ross Creek at Barrie Lane.

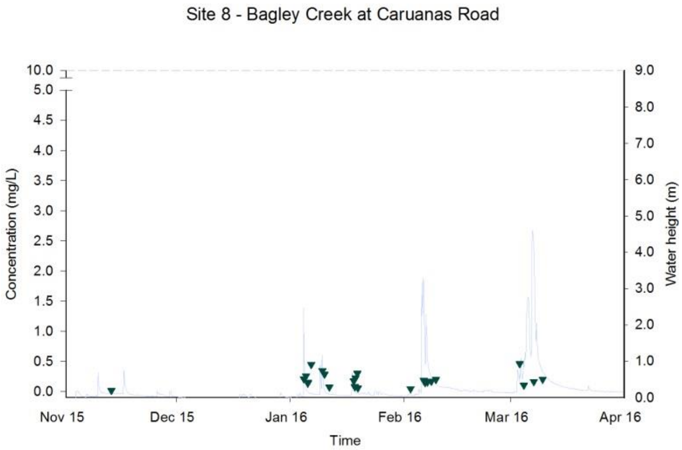

Figure 7-205 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Bagley Creek.

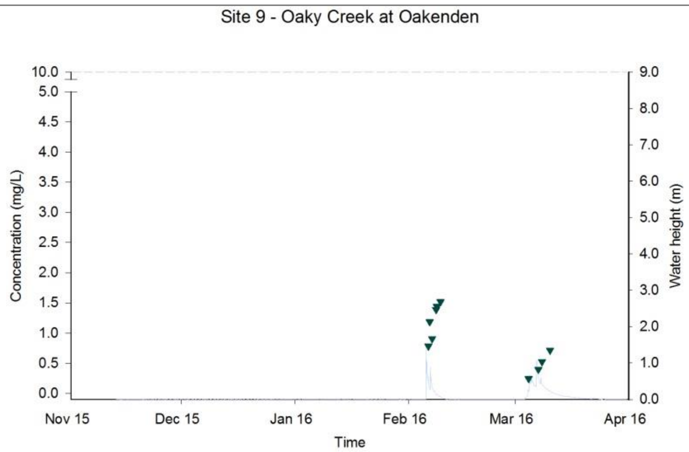

Figure 7-206 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Oaky Creek.

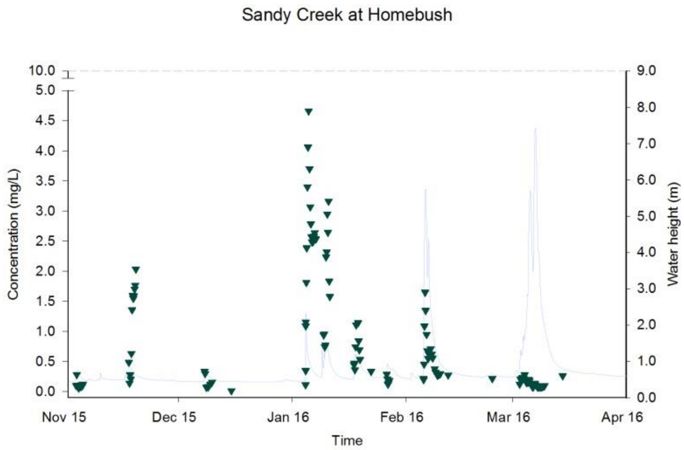

Figure 7-207 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Sandy Creek at Homebush.

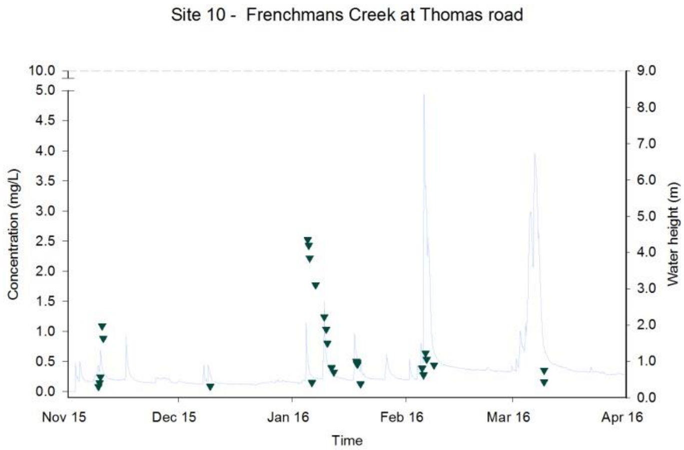

Figure 7-208 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Frenchmans Creek.

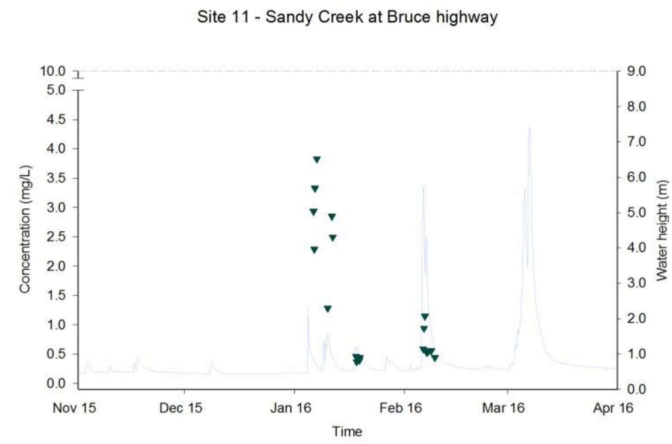

Figure 7-209 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in Sandy Creek at Bruce Highway.

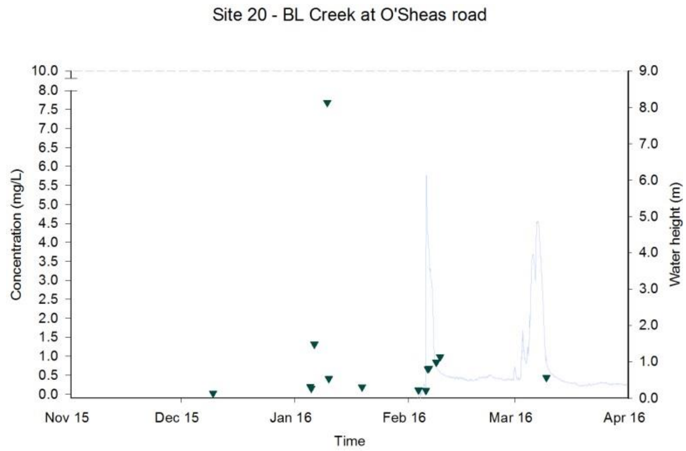

Figure 7-210 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic nitrogen in BL Creek.

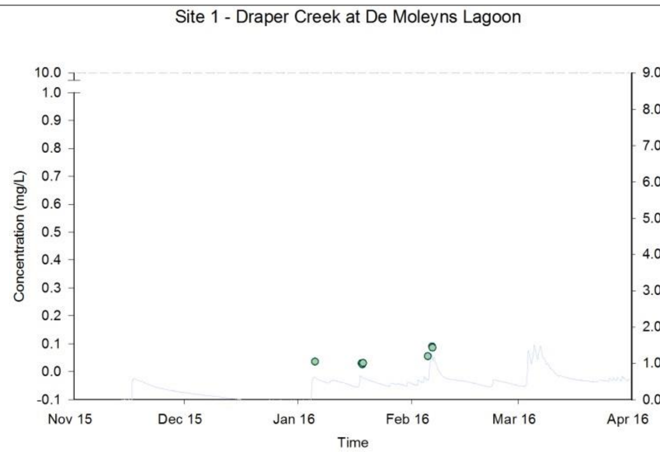

Figure 7-211 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Draper Creek at De Moleyns Lagoon.

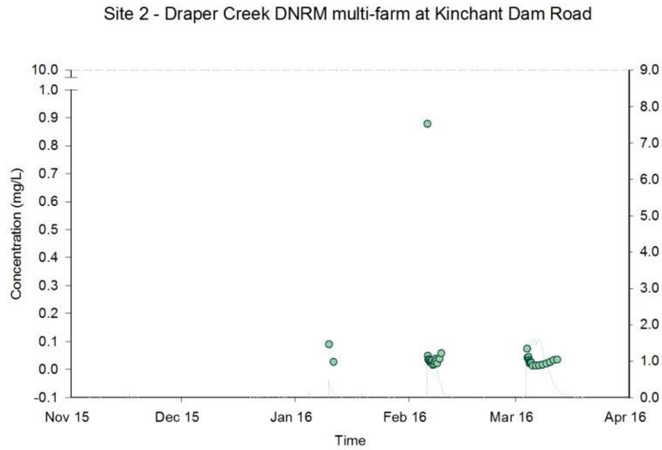

Figure 7-212 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Draper Creek at Multi-farm.

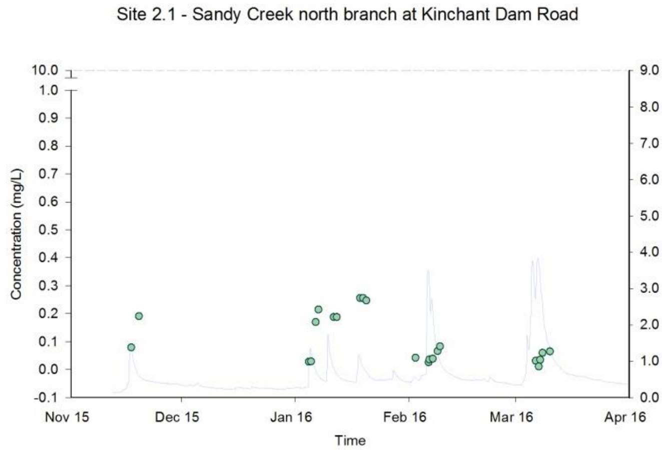

Figure 7-213 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Sandy Creek North Branch.

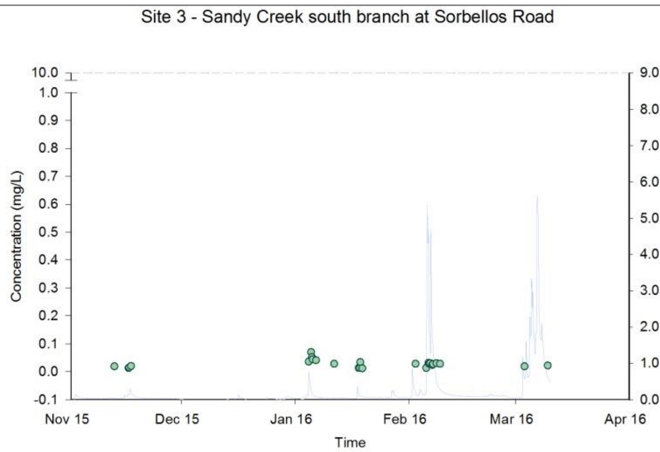

Figure 7-214 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Sandy Creek South Branch.

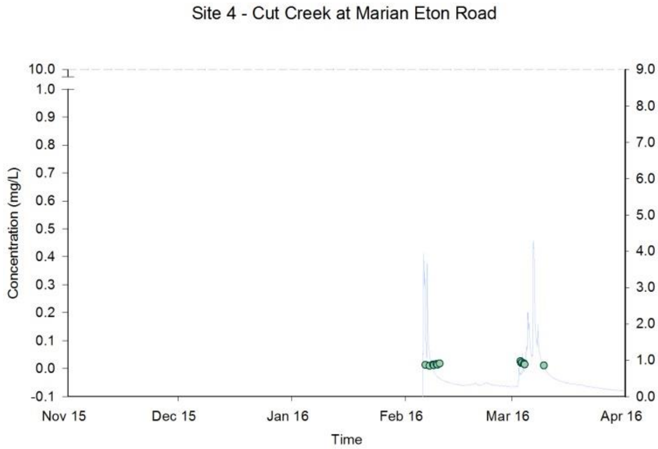

Figure 7-215 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Cut Creek.

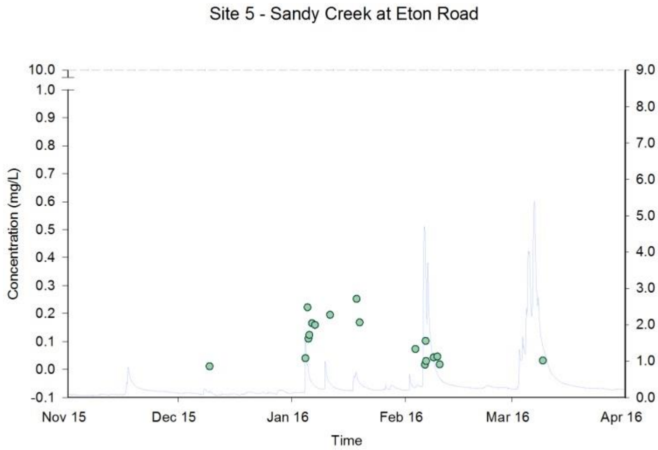

Figure 7-216 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Sandy Creek at Eton.

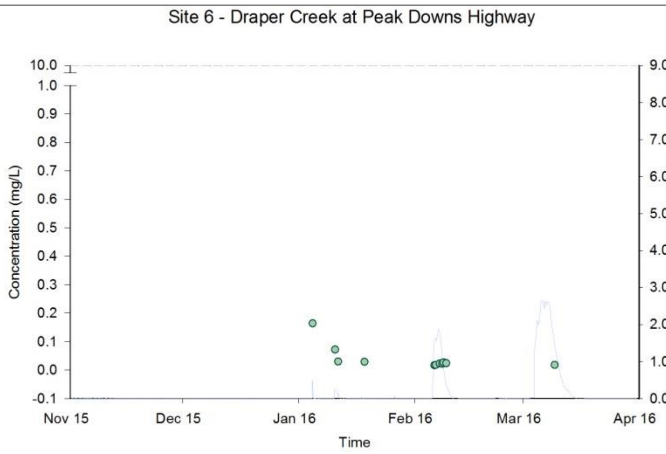

Figure 7-217 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Draper Creek at Peak Downs Highway.

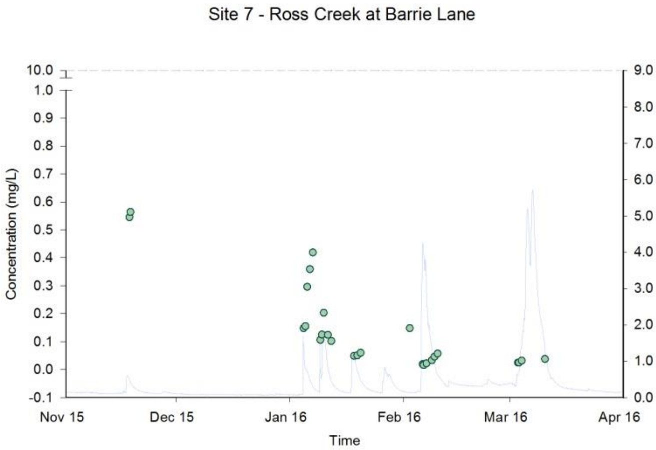

Figure 7-218 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Ross Creek at Barrie Lane.

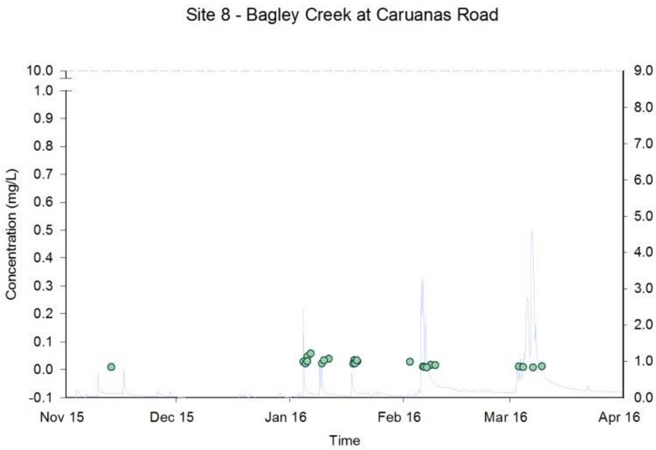

Figure 7-219 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Bagley Creek.

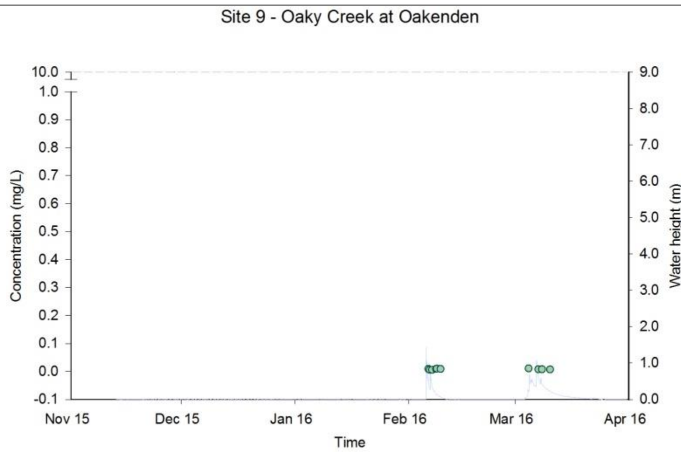

Figure 7-220 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Oaky Creek.

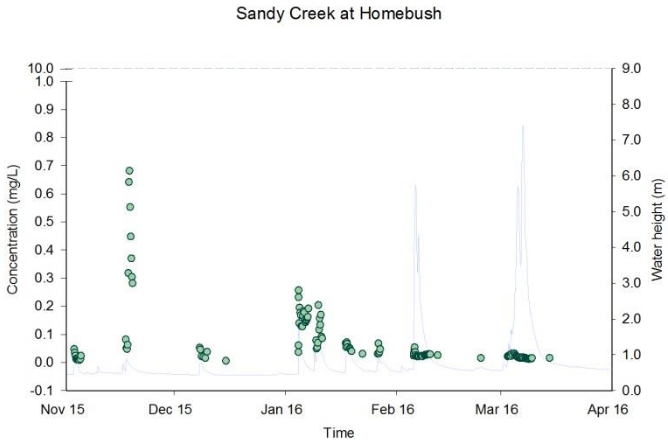

Figure 7-221 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Sandy Creek at Homebush.

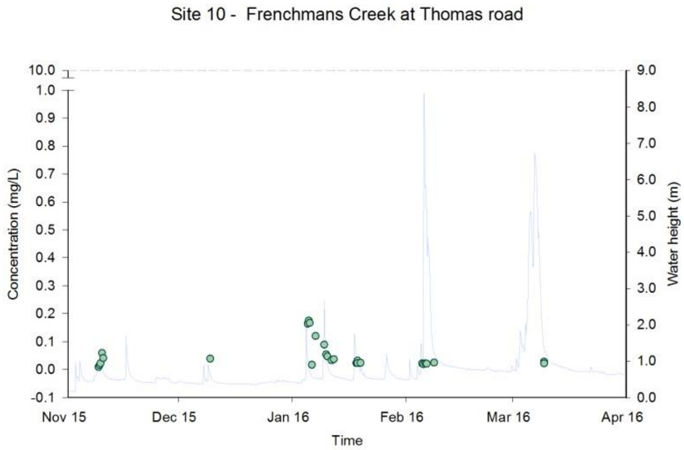

Figure 7-222 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Frenchmans Creek.

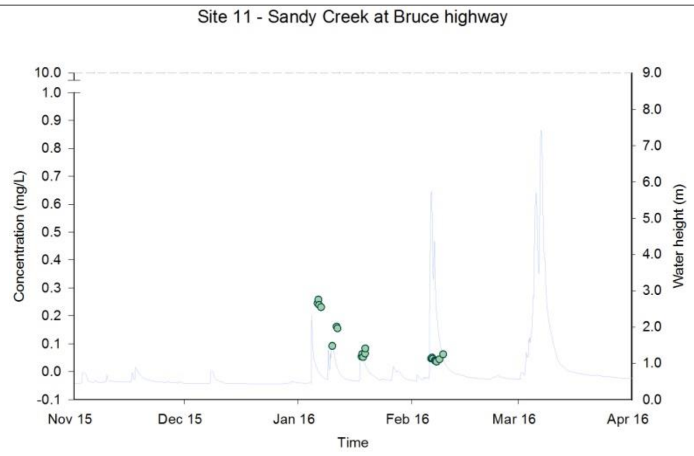

Figure 7-223 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in Sandy Creek at Bruce Highway.

Figure 7-224 Hydrographic plot of water level and concentration (mgL^{-1}) of ammonium nitrogen in BL Creek.

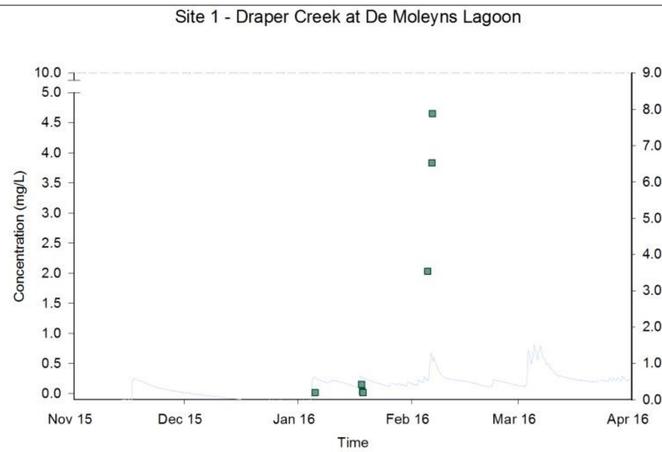

Figure 7-225 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Draper Creek at De Moleyns Lagoon.

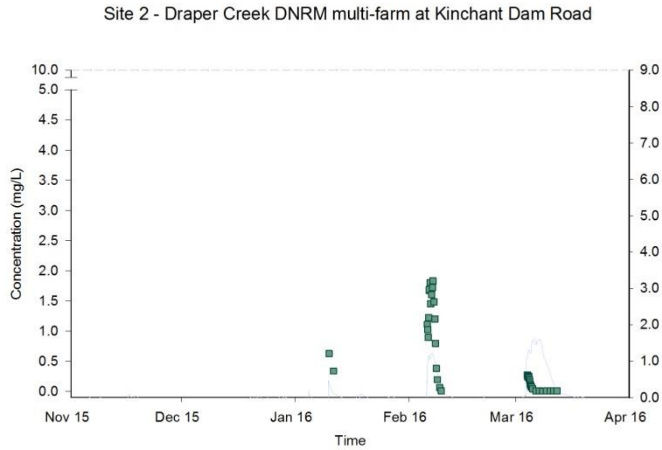

Figure 7-226 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Draper Creek at Multi-farm.

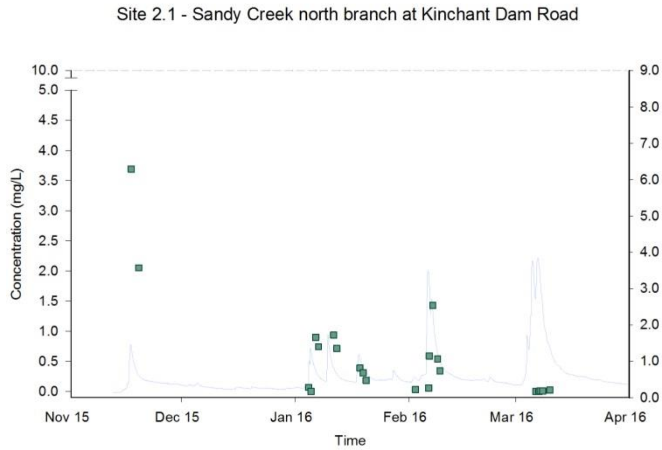

Figure 7-227 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Sandy Creek North Branch.

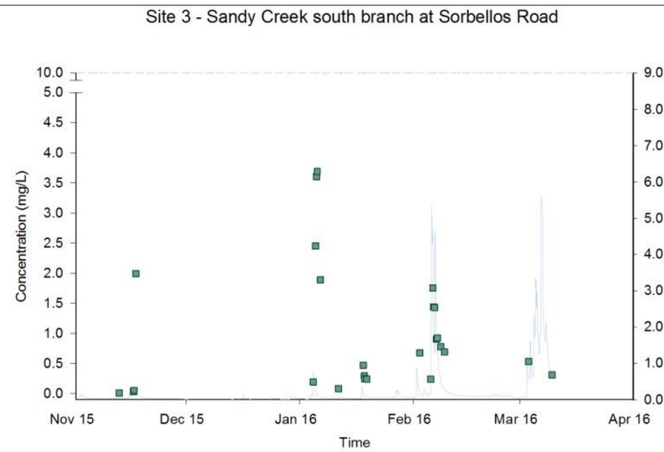

Figure 7-228 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Sandy Creek South Branch.

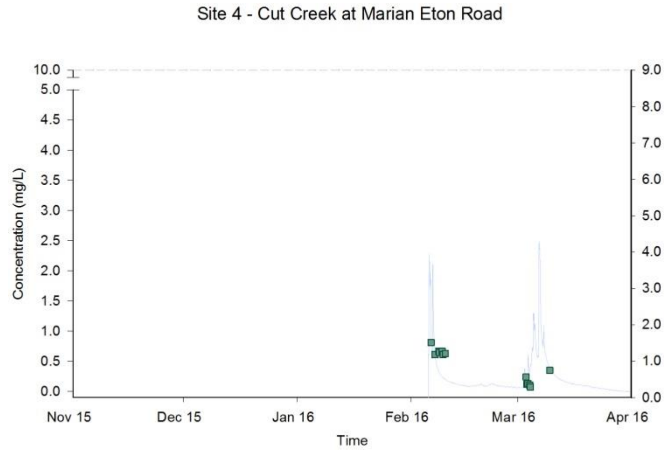

Figure 7-229 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Cut Creek.

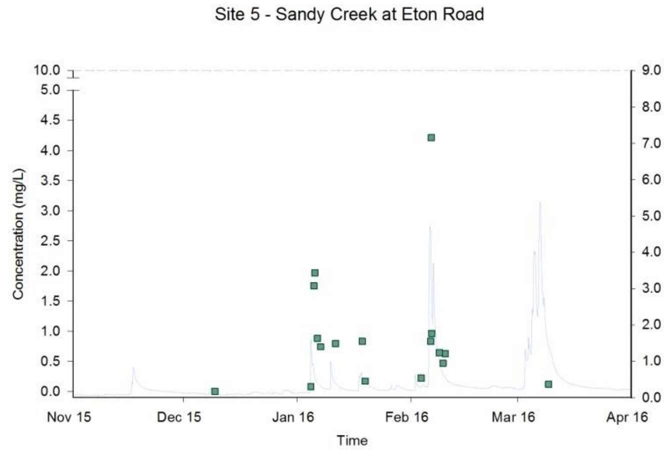

Figure 7-230 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Sandy Creek at Eton.

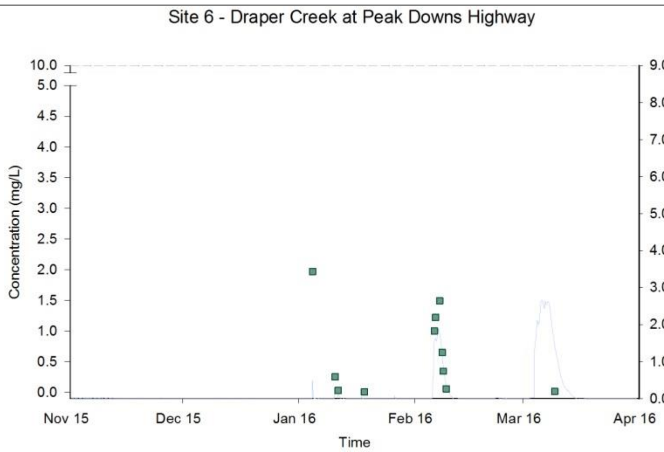

Figure 7-231 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Draper Creek at Peak Downs Highway.

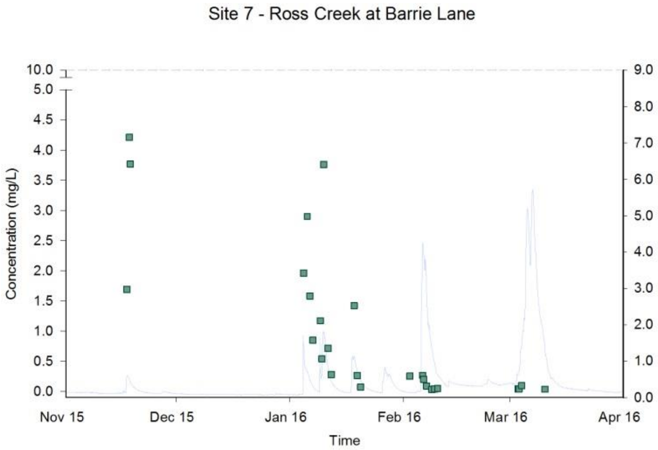

Figure 7-232 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Ross Creek at Barrie Lane.

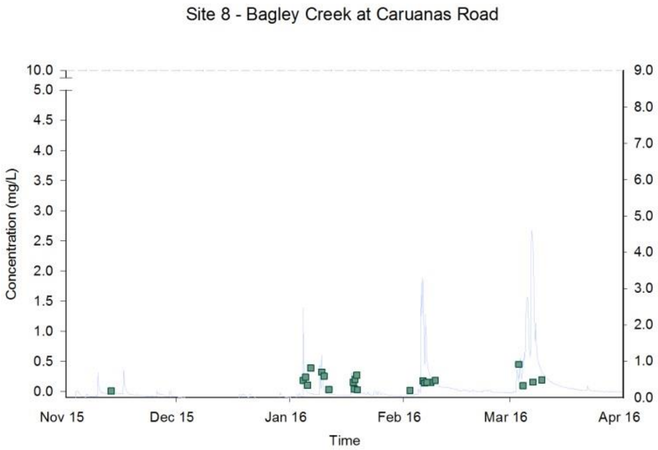

Figure 7-233 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Bagley Creek.

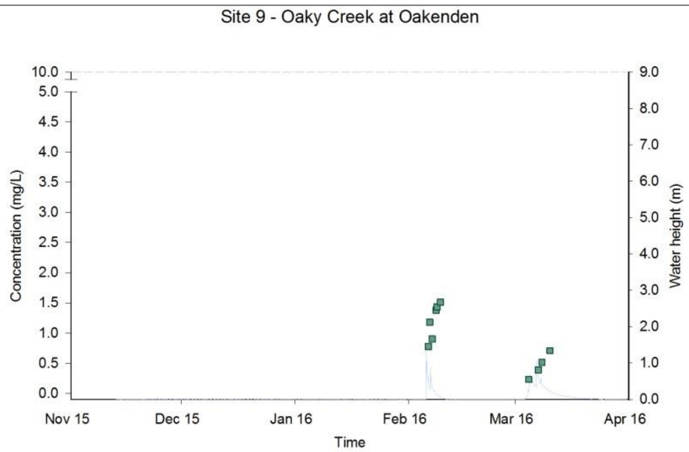

Figure 7-234 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Oaky Creek.

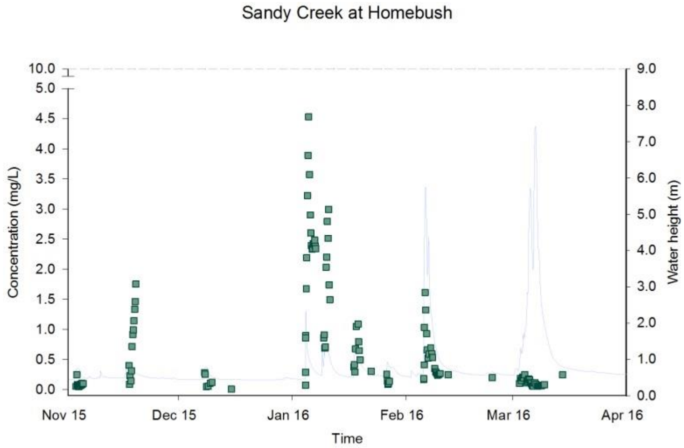

Figure 7-235 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Sandy Creek at Homebush.

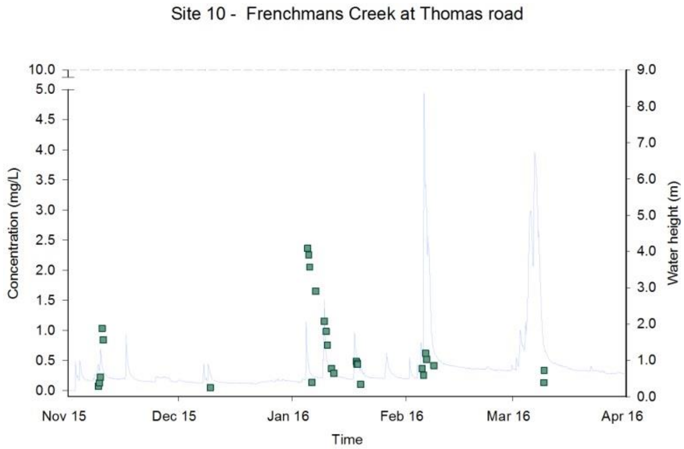

Figure 7-236 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Frenchmans Creek.

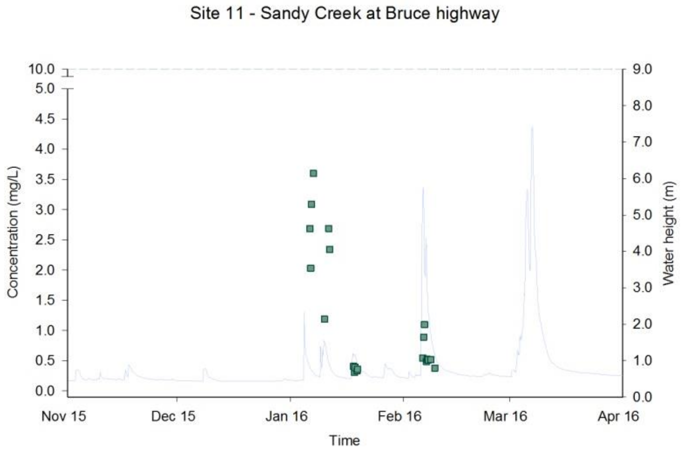

Figure 7-237 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in Sandy Creek at Bruce Highway.

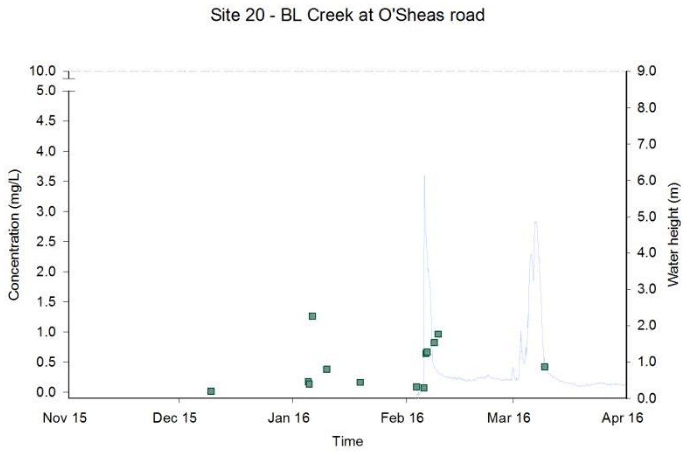

Figure 7-238 Hydrographic plot of water level and concentration (mgL^{-1}) of oxidised nitrogen in BL Creek.

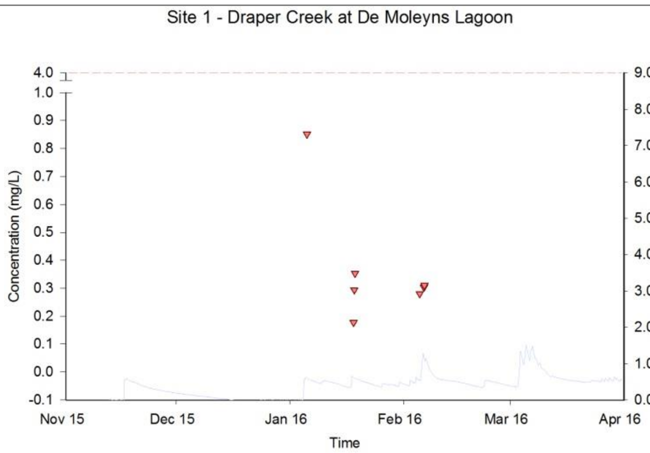

Figure 7-239 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Draper Creek at De Moleyns Lagoon.

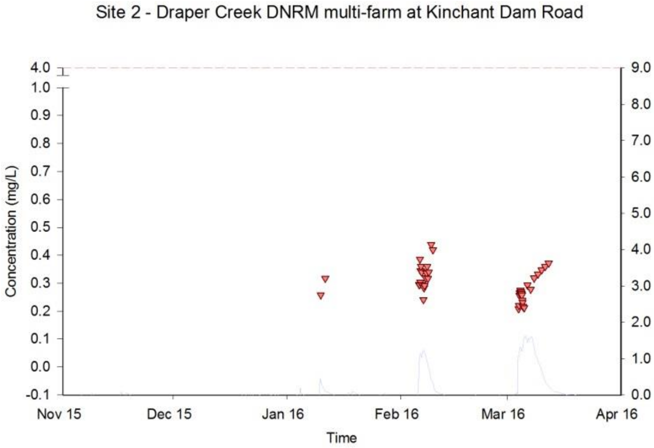

Figure 7-240 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Draper Creek at Multi-farm.

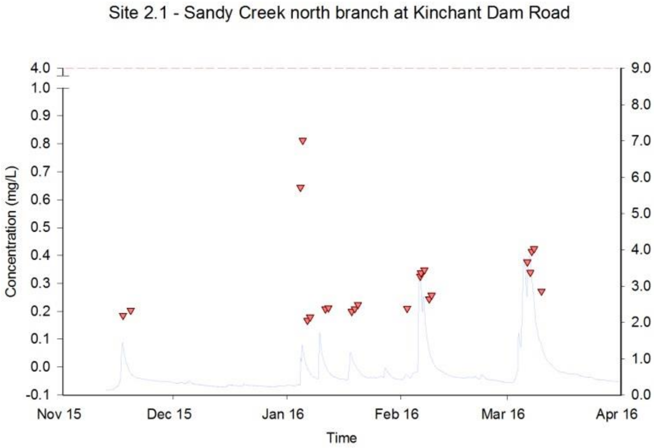

Figure 7-241 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Sandy Creek North Branch.

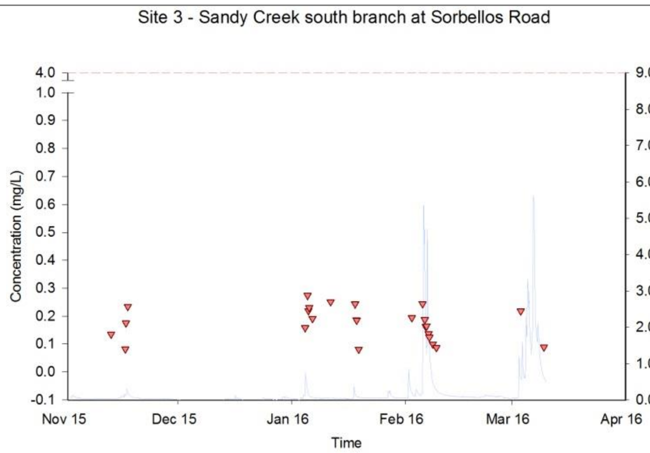

Figure 7-242 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Sandy Creek South Branch.

Figure 7-243 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Cut Creek.

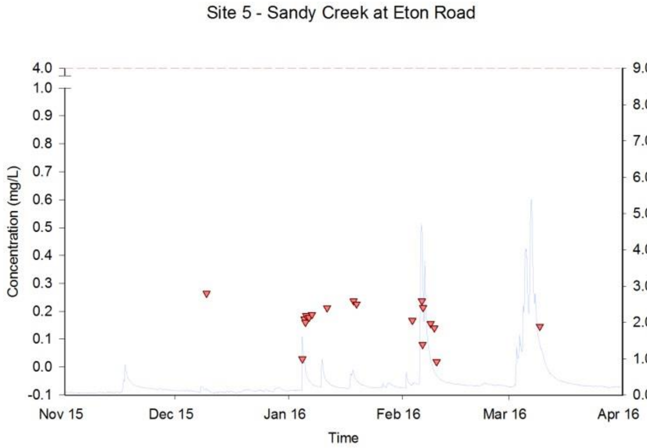

Figure 7-244 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Sandy Creek at Eton.

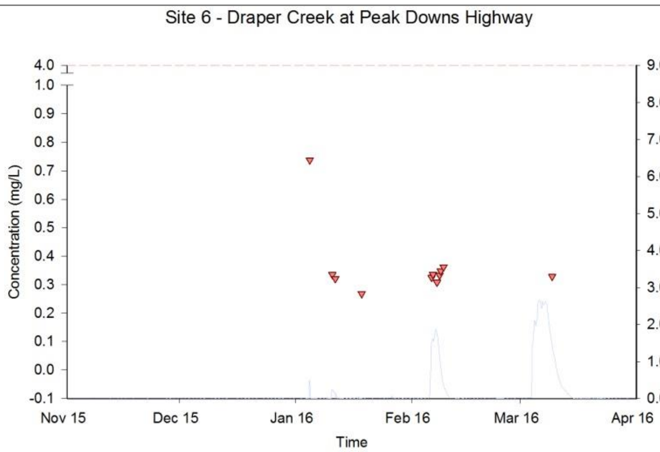

Figure 7-245 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Draper Creek at Peak Downs Highway.

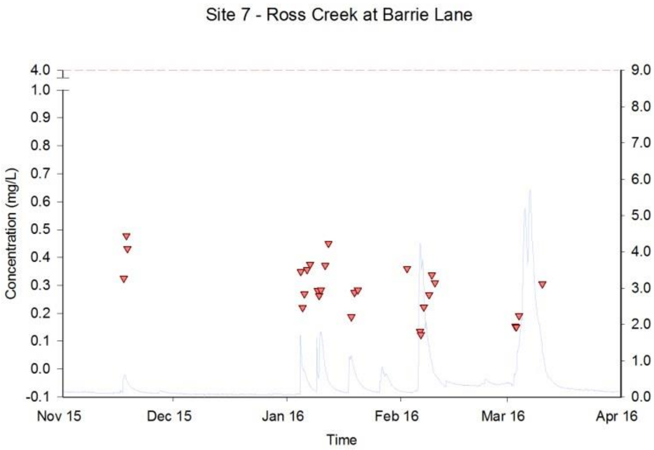

Figure 7-246 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Ross Creek at Barrie Lane.

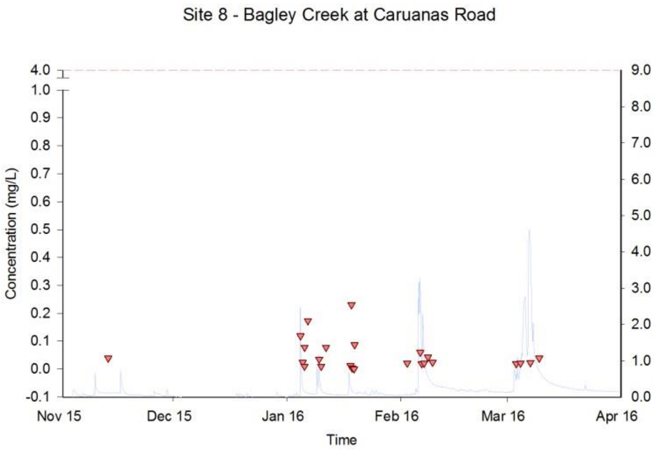

Figure 7-247 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Bagley Creek.

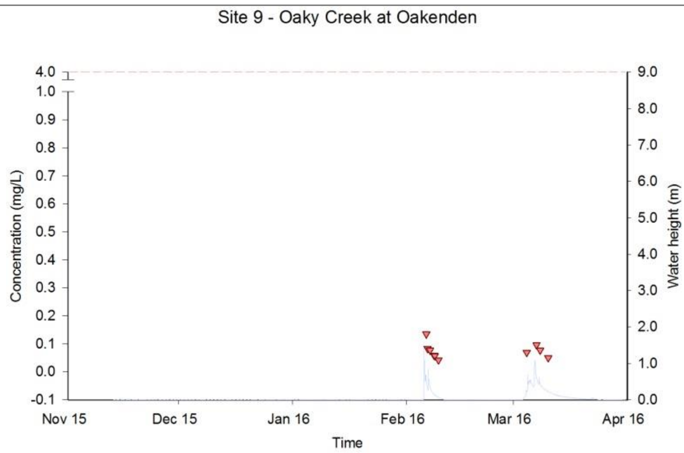

Figure 7-248 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Oaky Creek.

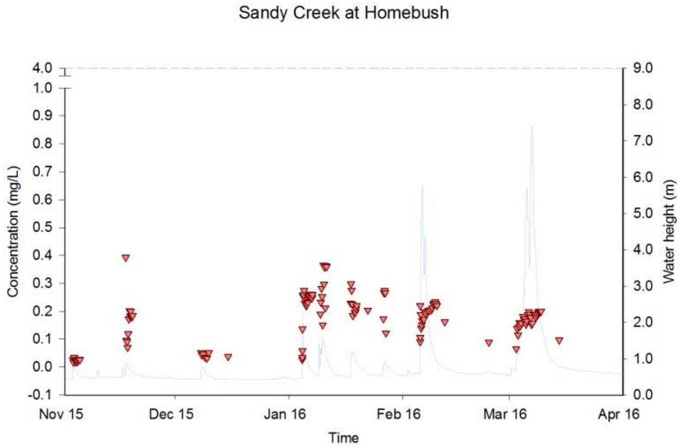

Figure 7-249 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Sandy Creek at Homebush.

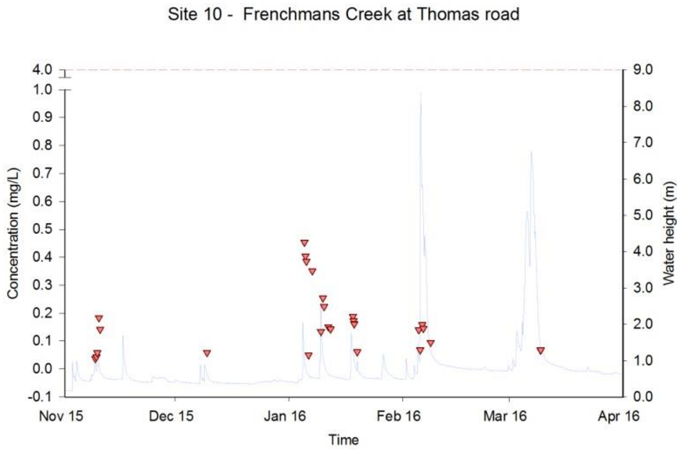

Figure 7-250 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Frenchmans Creek.

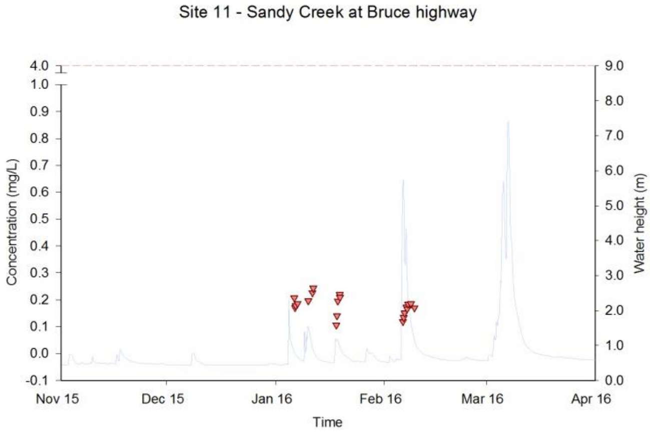

Figure 7-251 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in Sandy Creek at Bruce Highway.

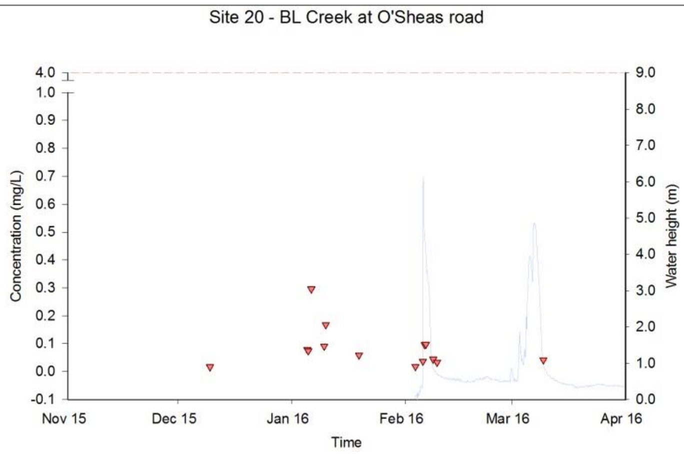

Figure 7-252 Hydrographic plot of water level and concentration (mgL^{-1}) of dissolved inorganic phosphorus in BL Creek.

Appendix D Mode of action and octanol-water partition coefficient

Table 7-2 presents the mode of action and octanol-water partition coefficient for selected pesticides that were detected in sub-catchments monitored as part of the Sandy Creek Sub-catchment Water Quality Monitoring Project.

Table 7-2 The mode of action and octanol-water partition coefficient of selected pesticides

Mode of Action	Pesticide	Log KoW	Log KoC	Type
Priority PSII Herbicides				
PSII Herbicides	Ametryn	2.63 @ pH 7, temperature of 20°C[1] 2.63 @ pH 7, temperature of 20°C[2]	2.49[2]	**Herbicide**
	Atrazine	2.7 @ pH 7, temperature of 20°C[1] 2.7 @ pH 7, temperature of 20°C[2]	2[2]	
	Diuron	2.87 @ pH 7, temperature of 20°C[1] 2.87 @ pH 7, temperature of 20°C[2]	2.91[2]	
	Hexazinone	1.17 @ pH 7, temperature of 20°C[1] 1.17 @ pH 7, temperature of 20°C[2]	1.73[2]	
	Tebuthiuron	1.79 @ pH 7, temperature of 20°C[1] 1.79 @ pH 7, temperature of 20°C[2]	1.9[2]	
Alternate Pesticides				
Amino acid inhibitor	Imazapic	0.393 @ pH 4, 5, 6 (buffer), temperature of 25°C[1] 2.47 @ pH 7, temperature of 20°C[2]	2.14[2]	**Herbicide**
	Imazapyr	0.11 @ pH not stated, temperature of 22°C[1] 0.11 @ pH 7, temperature of 20°C[2]	Not stated	
	Imazethapyr	1.04 @ pH 5, 1.49 @ pH 7, 1.20 @ pH 9, temperature of 25°C[1] 1.49 @ pH 7, temperature at 20°C[2]	2.18[2]	
	Metsulfuron-methyl	-1.87 @ pH 7, temperature of 20°C[1] -1.87 @ pH 7, temperature of 20°C[2]	Not stated	
Auxin growth regulators	2,4-D	2.58-2.83 @ pH 1, 0.04-0.33 @ pH 5, -0.75 @ pH 7, temperature not stated[1] -0.82 @ pH 7, temperature of 20°C[2]	1.59[2]	
	Fluroxypyr	-1.24[a] @ pH not stated, temperature not stated[1] 0.04 @ pH 7, temperature of 20°C[2]	Not stated	
	MCPA	2.75 @ pH 1, 0.59 @ pH 5, -0.71 @ pH 7, temperature of 25°C[1] -0.81 @ pH 7, temperature of 20°C[2]	Not stated	
	Triclopyr	0.42 @ pH 5, -0.45 @ pH 7, -0.96 @ pH 9, temperature not stated[1] 4.62 @ pH 7, temperature of 20°C[2]	1.43[2]	
Cell membrane disruptor	Acifluorfen	1.19 @ pH 5, temperature of 25°C[1] 1.18 @ pH 7, temperature of 20°C[2]	2.05[2]	
Inhibitor of enzyme EPSP synthase	Glyphosate	<-3.2 @ pH 5-9, temperature of 20°C[1] -3.2 @ pH 7, temperature of 20°c[2]	3.15[2]	
Inhibitor of meristematic tissue growth	Haloxyfop	Not stated	1.88[2]	
Inhibitor of carotenoid biosynthesis	Isoxaflutole	2.34 @ pH 5.5, temperature of 20°C[1] 2.34 @ pH 7, temperature of 20°C[2]	2.16[2]	
PSII inhibitors	Bromacil	1.88 @ pH 5, temperature not stated[1] 1.88 @ pH 7, temperature of 20°C[2]	1.5[2]	
	Metribuzin	1.6 @ pH 5.6, temperature of 20°C[1] 1.65 @ pH 7, temperature of 20°C[2]	Not stated	
	Prometryn	3.1 @ pH not stated, temperature of 25°C (unionised)[1] 3.34 @ pH 7, temperature of 20°C[2]	2.6[2]	
	Propazine-2-hydroxy	2.51 @ pH 7, temperature of 20°C[3]	0[3]	
	Simazine	2.1 @ pH not stated, temperature of 25°C (unionised)[1] 2.3 @ pH 7, temperature of 20°C[2]	2.11[2]	
	Terbuthy-lazine	3.4 @ pH not stated, temperature of 25°C[1] 3.4 @ pH 7, temperature of 20°C[2]	Not stated	

Mode of Action	Pesticide	Log KoW	Log KoC	Type
Inhibitor of long-chain fatty acids	Metolachlor	2.9 @ pH not stated, temperature of 25ºC[1] 3.4 @ pH 7, temperature of 20ºC[2]	2.08[2]	
Nicotinic acetylcholine receptor (nAChR) competitive modulators (neonicotinoid)	Clothianidin	0.7 @ pH not stated, temperature of 25ºC[1] 0.905 @ pH 7, temperature of 20ºC[2]	2.09[2]	
	Imidacloprid	0.57 @ pH not stated, temperature of 21ºC[1] 0.57 @ pH 7, temperature of 20ºC[2]	Not stated	

[1] BCPC (British Crop Production Council) (2012). A world compendium. The Pesticide Manual. Sixteenth Edition. MacBean (Ed), BCPC, Alton, United Kingdom.

[2] University of Hertfordshire (2013). The Pesticide Properties DataBase (PPDB) developed by the Agriculture & Environment Research Unit (AERU), University of Hertfordshire, 2006–2013. Available from: http://sitem.herts.ac.uk/aeru/ppdb/en/>, Accessed: August, 2016.

[3] International Union of Pure and Applied Chemistry (IUPAC) (2015). The Pesticide Properties DataBase (PPDB) developed by the Agriculture & Environment Research Unit (AERU), University of Hertfordshire, 2006–2013. Available from: http://sitem.herts.ac.uk/aeru/iupac/Reports/925.htm, Accessed August 2016.