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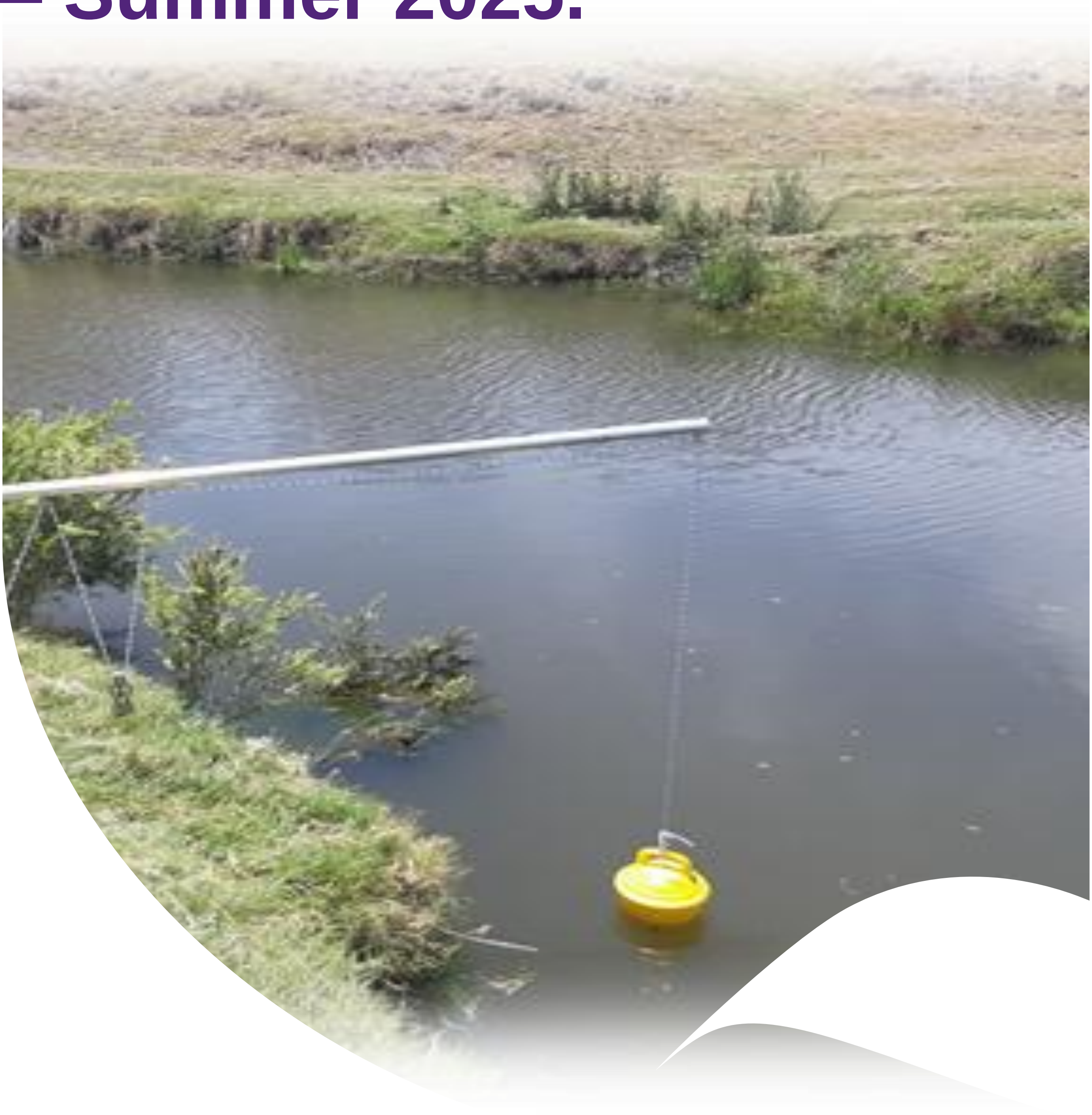
Catchment and Drinking Water Quality Micro Pollutant Monitoring program – Passive Sampling. Report 22 – Summer 2025.



Title

Catchment and Drinking Water Quality Micro Pollutant Monitoring program – Passive Sampling. Report 22 – Summer 2025.

Disclaimer

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THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Executive Summary

The *Catchment and Drinking Water Quality Micro Pollutant Monitoring Program* was launched in mid-2014 with the aim of improving the characterisation and understanding of the micro pollutant risk profile in source water reservoirs through bi-annual summer and winter sampling campaigns. The monitoring program, utilising passive samplers, was continued in reservoirs in South-East Queensland (SEQ) during the first quarter of 2025. Results presented provide a continued insight into the water quality of the target catchments and drinking water reservoirs. Samplers were deployed for approximately one month, and one set of samplers was deployed for seven days during a high rainfall event.

A wide range of polar and non-polar organic contaminants of interest were monitored using passive samplers, including herbicides, fungicides, insecticides, pharmaceuticals and personal care products (PPCPs), per- and poly-fluoroalkyl substances (PFAS), UV filters, organochlorine pesticides (OCPs), fire ant bait chemicals and polycyclic aromatic hydrocarbons (PAHs). Samples were analysed at the Queensland Alliance for Environmental Health Sciences (QAEHS), UQ by LC-QQQ MS/MS (polar compounds), LC-QToF MS/MS (polar compounds; suspect screening) and GC-HRMS (non-polar chemicals) using the latest analytical methods and established standard operating protocols (SOPs).

Chemical analyses of the passive sampler extracts reported 66 different chemicals including 19 OCPs, 11 PAHs, 33 polar pesticides and three PPCPs. OCPs were detected at 84% of sites, with Chlorpyrifos (84%) and p,p-DDD (32%) the most frequently reported. Total ∑OCP water concentrations across sites ranged between 0.035 – 5.13 ng L^{-1} where concentrations were reportable. PAHs were detected at 78% of sites, with Benzo[a]anthracene (38%) and Benzo[b,j,k]fluoranthene (76%) reported at the highest abundance across all sites. Total ∑PAH water concentrations across sites ranged between 0.001 – 1.24 ng L^{-1}. In total, 33 different polar pesticides were reported in 33 sites (89%), with Terbuthylazine desethyl (89%) and Metsulfuron methyl (84%) the most frequently detected. Total ∑polar pesticides ranged between 1.030 – 392 ng L^{-1}. Additionally, four PPCPs were detected across sites with highest detection frequencies observed for DEET (95%) and Carbamazepine (24%). Total estimated ∑PPCP water concentrations ranged between 3.22 – 73 ng L^{-1} across sites. Four PFAS were detected across 17 sites (43%), with PFBA the most frequently detected (24%). Total PFAS concentrations were low, with ΣPFAS concentrations from 4.25 ng L^{-1} to 10 ng L^{-1}.

Event passive samplers were deployed for seven days at Mt Crosby Westbank Offtake Tower. A total of 11 OCPs, one PAH, 15 polar pesticides and one PPCP were detected. ∑OCP estimated water concentration was 8.3 ng L^{-1}, and ∑polar pesticides estimated concentration was 73 ng L^{-1}. No PFAS were found above detection limits in the MPT event samplers.

Australian Drinking Water Guidelines (ADWG) as well as Australia and New Zealand guidelines for Fresh and Marine Water Quality values are available for some of these chemicals for comparison (ANZECC & ARMCANZ 2018). No chemicals were present at concentrations that exceeded the ADWG values. In the ecotoxicological setting, diazinon, metolachlor, tebuthiuron and chlorpyrifos were often above the thresholds set for 99% species protection, however there were no chemicals detected above the 95% protection level.

Introduction

As the bulk supplier of drinking water to Southeast Queensland, Seqwater maintains a Catchment and Drinking Water Quality Micro Pollutant Monitoring Program to ensure safe and reliable supply of the region's drinking water source reservoirs. The aim of this program is to identify and understand the presence of micro pollutants in the source water reservoirs as well as to recognise any spatial and temporal trends of micro pollutants. The first campaigns ran between 2014 and 2020 and an extension of the program has been introduced to extend the use of passive sampling technologies in the monitoring of source water reservoirs over a five-year period (2020 – 2025; summer and winter sampling campaigns). The recent campaign aims to continue to assess the risk from micro pollutants posed to drinking water quality as well as add to a longitudinal dataset to aid catchment management. Additional passive samplers may be deployed at sites when required during high rainfall or event periods.

The typically low-level concentrations of micro pollutants present in environmental waters raise analytical challenges as well as further challenges in obtaining appropriate and representative samples. Grab samples may not offer enough volume to allow sufficient concentration factors for the quantification of micro pollutants and may miss episodic contamination events, given they represent a single point in time. The use of passive sampling technologies has been introduced to complement and overcome some of these challenges, substantially improving chemical pollutant monitoring in liquid phases over the last two decades. Benefits of passive sampling tools include *in-situ* concentration of chemical pollutants, increased sensitivity, the provision of time-weighted average concentration estimates for chemicals over periods of ≥ 1 month, increased data resolution and risk profiling using a robust scientific methodology. Passive samplers designed to monitor non-polar (polydimethylsiloxane; PDMS) as well as polar (Empore™ Disk; ED) chemical pollutants have been chosen for deployment in this program.

The list of target chemicals for inclusion in the monitoring campaign was identified via a review of the Australian Drinking Water Guideline (ADWG) and Australian and New Zealand Environmental Conservation Council (ANZECC) lists of chemicals and parameters. The list was refined based on an assessment of their possible application in the catchment areas investigated and assessment from Australian Pesticides and Veterinary Medicines Authority (APVMA) registered products uses, as well as water solubility and guideline values. The target list is reviewed every six months to investigate the need for inclusion / exclusion of target analytes based on on-going risk assessment and detection frequency.

Methodology

Passive water samplers were deployed in periods between January and February 2025 at 39 SEQ reservoirs/waterways (Table 1), with an additional four sites where only MPT passive samplers were deployed. All passive samplers at sites 19 and 37, and MPTs at site 31, were found out of the water, but there was no re-deployment due to time constraints. One set of event passive samplers were deployed in Mt Crosby Westbank Offtake Tower in March for seven days during a period of high rainfall.

Deployments were for periods of 27 to 36 days in duration. Duplicate passive samplers were deployed at 11 randomly selected sites (Table 1, highlighted in green), with six of these extra passive samplers used as quality control site duplicates. The remaining five were spiked with native target analytes as part of QAEHS' routine quality control procedures.

The deployment of samplers was conducted in alignment with the "Drinking and Catchment Water Quality Micro Pollutant Passive Sampling Procedure" (January 2021). Table 1 below lists the deployment site locations, site numbers, site codes, deployment and retrieval dates and lengths of deployment periods, as well as the water velocity (cm s^{-1}) estimated at each site.

Table 1. Passive sampler deployment locations, dates, lengths of deployment period and water velocity measured at each site.

Site	Site Code	Date Deployed	Date Retrieved	Days Deployed	Flow Velocity (cm/s)	Comments
Event2 : Mt Crosby Westbank Offtake Tower	CMR-MBR-02-OFF-PS	5/03/2025	12/03/2025	7	24.2	
SEQ01 : Mary River @ Coles X ing	CMV-MRS-01-OFF-PS	14/01/2025	18/02/2025	35	5.9	
SEQ02 : Lake Macdonald Intake	CSX-LMD-01-OFF-PS	23/01/2025	26/02/2025	34	10.6	
SEQ04 : Mary River @ Kenilworth	CMV-MRS-40-RIV-PS	23/01/2025	19/02/2025	27	13.8	
SEQ05 : Poona Dam	CMR-POD-01-OFF-PS	21/01/2025	18/02/2025	28	4.2	
SEQ06 : South Maroochy Intake Weir	CMR-SOR-25-OFF-PS	21/01/2025	18/02/2025	28	3.9	
SEQ07 : Yabba Creek @ Jimna	CMV-YAC-01-OFF-PS	23/01/2025	19/02/2025	27	3.8	
SEQ08 : Baroon Pocket Dam	CBT-BPD-15-OFF-PS	30/01/2025	27/02/2025	28	8.1	
SEQ09 : Ewen Maddock	CML-EMD-01-OFF-PS	4/02/2025	5/03/2025	29	7.6	
SEQ10 : Kilcoy WTP offtake	CST-SOD-90-OFF-PS	9/01/2025	10/02/2025	32	9	
SEQ11 : Kirkleagh	CST-SOD-71-OFF-PS	9/01/2025	10/02/2025	32	11.1	
SEQ12 : Somerset Dam Wall	CST-SOD-01-OFF-PS	9/01/2025	10/02/2025	32	7.5	
SEQ13 : Wivenhoe Dam @ Esk	CUB-WID-90-OFF-PS	7/01/2025	4/02/2025	28	10.8	
SEQ14 : Wivenhoe Dam Wall	CUB-WID-01-OFF-PS	7/01/2025	4/02/2025	28	16	
SEQ15 : Lockyer Creek @ Lake Clarendon Way	CCK-LOC-50-RIV-PS	8/01/2025	5/02/2025	28	5.6	
SEQ16 : Lockyer Creek @ OReillys	CCK-LOC-11-RIV-PS	9/01/2025	6/02/2025	28	5.3	

SEQ17 : Lowood Intake	**CMB-MBR-80-OFF-PS**	**9/01/2025**	**6/02/2025**	**28**	**10.4**	
SEQ18 : Mt Crosby Westbank Offtake Tower	**CMB-MBR-02-OFF-PS**	**9/01/2025**	**14/02/2025**	**36**	**10.9**	
SEQ19 : North Pine River @ Dayboro Well	**CPV-NPR-70-OFF-PS**	**NA**	**NA**	**NA**	**NA**	Samplers found out of water. No re-deployment
SEQ20 : North Pine VPS	**CPV-NOD-10-OFF-PS**	**21/01/2025**	**18/02/2025**	**28**	**6.3**	
SEQ21 : Lake Kurwongbah	**CPV-LAK-01-OFF-PS**	**22/01/2025**	**19/02/2025**	**28**	**7.1**	
SEQ23 : Herring Lagoon	**CNS-HLA-01-OFF-PS**	**21/01/2025**	**18/02/2025**	**28**	**4.7**	
SEQ24 : Leslie Harrison Dam	**CRL-LHD-05-VPS-PS**	**24/01/2025**	**25/02/2025**	**32**	**5.9**	
SEQ25 : Wyaralong Dam Wall	**CLR-WYD-01-REC-PS**	**9/01/2025**	**6/02/2025**	**28**	**6.9**	
SEQ26 : Reynolds Creek @ Boonah	**CWV-REY-20-OFF-PS**	**23/01/2025**	**20/02/2025**	**28**	**5.3**	
SEQ27 : Moogerah Dam	**CWV-MOD-02-OFF-PS**	**23/01/2025**	**20/02/2025**	**28**	**12.6**	
SEQ28 : Logan River @ Kooralbyn Offtake	**CLR-LOG-60-OFF-PS**	**8/01/2025**	**5/02/2025**	**28**	**14.6**	
SEQ29 : Maroon Dam Wall	**CLR-MAD-04-OFF-PS**	**4/02/2025**	**5/03/2025**	**29**	**16.5**	
SEQ30 : Logan River @ Helen St	**CLR-LOG-30-OFF-PS**	**8/01/2025**	**5/02/2025**	**28**	**29.7**	
SEQ31 : Rathdowney Weir	**CLR-LOG-80-OFF-PS**	**8/01/2025**	**5/02/2025**	**28**	**20.2**	MPT sampler found out of water
SEQ32 : Canungra Creek @ Offtake	**CLR-CAC-01-OFF-PS**	**20/01/2025**	**17/02/2025**	**28**	**10.1**	
SEQ33 : Little Nerang Dam	**CNR-LND-01-OFF-PS**	**29/01/2025**	**26/02/2025**	**28**	**6.1**	
SEQ34 : Hinze Upper Intake	**CNR-HID-20-OFF-PS**	**30/01/2025**	**27/02/2025**	**28**	**6.9**	
SEQ35 : Hinze Lower Intake	**CNR-HID-01-OFF-PS**	**30/01/2025**	**27/02/2025**	**28**	**8.6**	
SEQ36 : Fernvale STP @ Savages Crossing	**CMB-MBR-60-RIV-PS**	**9/01/2025**	**6/02/2025**	**28**	**21.2**	
SEQ 37 : Logan River @ Cedar Grove	**CLR-LOG-12-RIV-PS**	**NA**	**NA**	**NA**	**NA**	Samplers found out of water. No re-deployment
SEQ38 : Wappa Dam	**CMR-WAD-01-OFF-PS**	**21/01/2025**	**18/02/2025**	**28**	**4.5**	
SEQ39 : Cooloolabin Dam	**CMR-COD-01-OFF-PS**	**7/01/2025**	**4/02/2025**	**28**	**4.9**	
SEQ40 : Wivenhoe Dam @ Logans Inlet PRW	**CUB-WID-59-PRW-PS**	**7/01/2025**	**4/02/2025**	**28**	**16.9**	
SEQ41 : LHD at Priest Gully and Stockyard Ck Confluence	**CRL-LHD-48-LAK-PS**	**24/01/2025**	**25/02/2025**	**32**	**NA**	MPT only site
SEQ42 : LHD at Upper Tingalpa Ck Arm (50m US Bridge)	**CRL-LHD-25-LAK-PS**	**29/01/2025**	**26/02/2025**	**28**	**NA**	MPT only site
SEQ43 : Enoggera Reservoir	**CLB-END-01-OFF-PS**	**14/01/2025**	**13/02/2025**	**30**	**6.5**	

SEQ44 : Mt Crosby Eastbank Offtake Tower	**CMB-MBR-01-OFF-PS**	**9/01/2025**	**14/02/2025**	**36**	**NA**	MPT only site
SEQ45 : Ewen Maddock @ Addlington Ck Arm	**CML-EMD-30-LAK-PS**	**4/02/2025**	**5/03/2025**	**29**	**NA**	MPT only site

Note:- Flow velocity of 3.4 cm s^{-1} was used where the calculated flow velocity was smaller than 3.4 cm s^{-1}
Sites with replicate samplers deployed for QA/QC purposes are highlighted in green.

Passive sampler preparation and extraction

In this campaign, three types of passive samplers were deployed. Empore Disk™ (3M; ED) samplers were deployed to detect and quantify the presence of polar organic pollutants such as herbicides, pharmaceuticals and personal care products (PPCPs) (Figure 1). Polydimethylsiloxane (PDMS) strips in stainless steel cages (Figure 2) were deployed to quantify the presence of more hydrophobic organic pollutants (non-polar chemicals) such as certain organochlorine pesticides (OCPs) and polycyclic aromatic hydrocarbons (PAHs). Microporous polyethylene tubes (MPT) were deployed to detect and quantify the presence of per- and polyfluoroalkyl substances (PFAS) (Figure 3). Passive flow monitors (PFMs) were co-deployed in duplicate with the passive samplers at each site to estimate the water flow conditions during the deployment period. ED and PDMS passive samplers and PFMs were all prepared and extracted according to previously published procedures and methods described in Kaserzon *et al.* (2017). MPT samplers were prepared and extracted according to Kaserzon *et al.* (2019) and Mackie *et al.* (2024).

Figure 1. Preparation of an Empore Disk passive sampler.

Figure 2. Preparation of a PDMS passive sampler in a stainless steel cage.

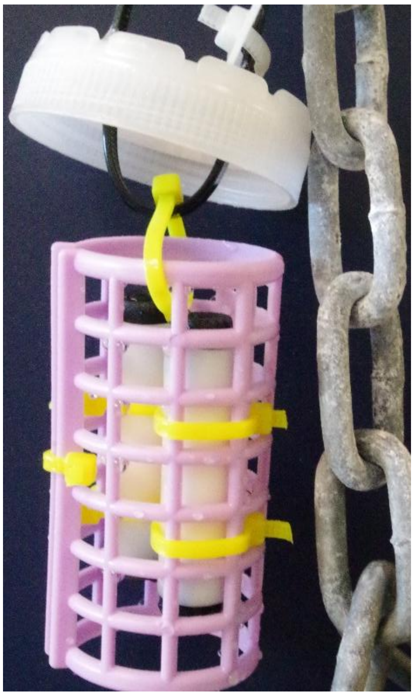

Figure 3. Microporous Polyethylene Tube (MPT) passive samplers for monitoring of PFAS in mesh enclosure

Analytical methods

Chemical analysis was performed at QAEHS using established standard operating procedures (SOPs). ED and MPT extracts were analysed by LC-QQQ MS/MS for PFAS, polar herbicides and PPCPs (112 chemicals) as well as on LC-QToF MS/MS with detect/non-detect screening conducted for an additional >45 chemicals. PDMS extracts were analysed for non-polar chemicals comprising of 30 OCPs, 16 PAHs, 2 UV filters and 3 other Herbicide/Pesticide compounds via GC-HRMS (Appendix 1). The analytical methods for PFAS, herbicides and PPCPs (LC-QQQ MS/MS), OCPs and PAHs (GC-HRMS), and suspect screening of herbicides and PPCPs (LC-QToF MS/MS) are detailed in previously published reports (Kaserzon *et al.* 2017; Kaserzon *et al.* 2019, Mackie *et al.* 2024) and in *Quality Protocol: Contract 03944 Micro-Pollutant and Passive Sampler Monitoring program*.

Data modelling and reporting of results

Data were modelled and reported according to previously published procedures and methods described in Kaserzon *et al.* (2017).

Quality control and assurance (QC/QA) procedures

Quality control was carried out in accordance with Quality Protocol: Contract 03944 Micro-Pollutant and Passive Sampler Monitoring program.

Results

Passive flow monitors (PFM) results

Two passive flow monitors (PFMs) were deployed at each site to allow for flow rate calculations. Under very low flow conditions the change in mass loss rates from the PFM are too small to provide a reliable measure of flow, and therefore cannot accurately provide flow data for the chemical sampling rate (R_s) calculation (i.e. below a threshold flow of 3.40 cm s^{-1} or PFM loss rate equal to 0.58 g d^{-1}; O'Brien *et al.* 2009; 2011b). Therefore, to remain within the accurate mathematical modelling range for PFM-based flow velocity prediction, a minimum flow rate of 3.40 cm s^{-1} was applied for the sites showing flow below this threshold and the minimum atrazine equivalence R_s. This may result in a slight over-estimation of R_s and under-estimation of water concentration estimates (C_w), though we do not expect this to be significant (Kaserzon *et al.* 2014; O'Brien *et al.* 2011b). Average flow velocities estimated from PFMs over the deployment period ranged from between 3.8 cm s^{-1} (SEQ07: Yabba Ck @ Jimna) to 29.7 cm s^{-1} (SEQ30 : Logan River @ Helen St) (Figure 4).

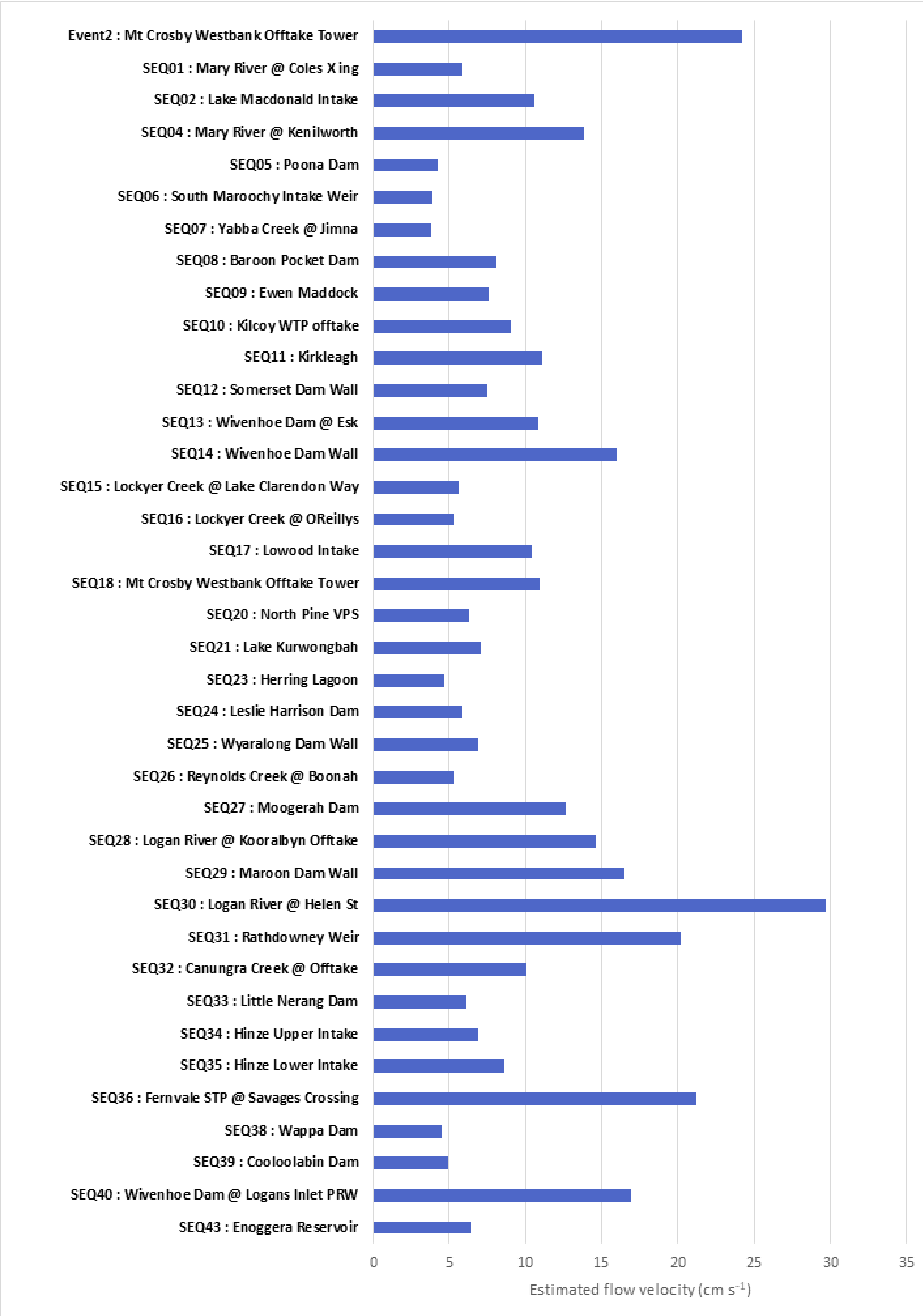

Figure 4. Passive flow monitor (PFM) based water flow velocity estimations (cm s^{-1}) at the deployment sites (n=37).

Note: A minimum flow velocity of 3.4 cm s^{-1} is used to assess flow velocity using Passive Flow Monitors (PFMs).

Chemical analysis results

A summary of the number of chemicals quantified at the sampling sites, the percent detection of each chemical and mass accumulation (ng sampler^{-1}) is presented in Tables 2 and 3 below. Table 2 summarises the non-polar chemicals detected via PDMS (OCPs, UV filters and PAHs). A total of 19 OCPs and 11 PAHs were accumulated in samplers with percent detection at sampling sites ranging from 3% – 84% for OCPs and 3% – 76% for PAHs. Table 3 summarises the polar chemicals quantified via ED (pesticides and PPCPs). A total of 33 pesticides (predominantly herbicides) and 4 PPCPs accumulated in samplers with percent detection at sampling sites ranging from 3% - 89% for pesticides and 3% - 95% for PPCPs. PFAS chemicals were detected at 17 sites with percent detection at sampling sites ranging from 2% - 24% (Table 4).

Table 2. Summary of the number of chemicals accumulated in PDMS passive samplers, percentage of detection at the sites and the range of mass accumulated over the deployment periods (ng PDMS^{-1}).

Analyte	Number of sites detected	% Detection	Min reported (ng/PDMS)	Max reported (ng/PDMS)
		OCP		
Aldrin	1	3%	1.08	1.08
Azinphos methyl	0	0%	<LOR	<LOR
Bifenthrin	4	11%	7.82	16.30
Chlorpyrifos	31	84%	2.63	311
cis-Chlordane	2	5%	12.7	12.9
Cypermethrin	1	3%	3.00	3.00
Dacthal	5	14%	20.10	52
Deltamethrin	0	0%	<LOR	<LOR
Dieldrin	9	24%	11.20	88.1
Endosulfan sulfate	4	11%	1.17	1.75
Endrin	1	3%	1.27	1.27
Endrin ketone	0	0%	<LOR	<LOR
HCB	1	3%	3.89	3.89
Heptachlor	0	0%	<LOR	<LOR
Heptachlor epoxide a	0	0%	<LOR	<LOR
Heptachlor epoxide b	6	16%	1.50	17.2
Methoprene	0	0%	<LOR	<LOR
Methoxychlor	0	0%	<LOR	<LOR
Mirex	0	0%	<LOR	<LOR
o,p-DDD	3	8%	1.82	3.05
o,p-DDE	0	0%	<LOR	<LOR
o,p-DDT	0	0%	<LOR	<LOR
p,p-DDD	12	32%	1.22	7.25
p,p-DDE	11	30%	2.02	56.2
p,p-DDT	5	14%	2.65	4.47
Pendimethalin	6	16%	13.4	72
Permethrin	5	14%	1.66	3.97
Pyriproxyfen	1	3%	10.8	10.8
trans-Chlordane	1	3%	24.60	24.6
UV327	0	0%	<LOR	<LOR

UV328	0	0%	<LOR	<LOR
α-Endosulfan	0	0%	<LOR	<LOR
α-HCH	0	0%	<LOR	<LOR
β-endosulfan	0	0%	<LOR	<LOR
β-HCH	0	0%	<LOR	<LOR
γ-HCH (Lindane)	0	0%	<LOR	<LOR
PAH				
Acenaphthene	0	0%	<LOR	<LOR
Acenaphthylene	2	5%	5.25	7.61
Anthracene	4	11%	9.27	25.1
Benzo[a]anthracene	14	38%	1.38	11.8
Benzo[a]pyrene	3	8%	1.98	3.22
Benzo[b,j,k]fluoranthene	28	76%	0.527	5.68
Benzo[e]pyrene	2	5%	201	317
Benzo[g,h,i]perylene	5	14%	1.56	5.02
Chrysene/Triphenylene	8	22%	3.48	20.5
Dibenz[a,h]anthracene	0	0%	<LOR	<LOR
Fluoranthene	4	11%	97.3	166
Fluorene	0	0%	<LOR	<LOR
Indeno[1,2,3-c,d]pyrene	4	11%	1.92	3.11
Naphthalene	0	0%	<LOR	<LOR
Phenanthrene	0	0%	<LOR	<LOR
Pyrene	1	3%	94.2	94.2

Table 3. Summary of the number of chemicals accumulated in ED passive samplers, percentage of detection at the sites and the range of mass accumulated over the deployment periods (ng ED^{-1}).

Analyte	Number of sites detected	% Detection	Min reported (ng/ED)	Max reported (ng/ED)
Herbicides and Pesticides				
2,4,5-T	0	0%	<LOR	<LOR
2,4-D	6	16%	5.27	43.8
3,4 Dichloroaniline	0	0%	<LOR	<LOR
Ametryn	0	0%	<LOR	<LOR
Ametryn hydroxy	6	16%	1.04	2.73
Aminocarb	0	0%	<LOR	<LOR
Atrazine	28	76%	1.10	175
Atrazine desethyl	17	46%	1.48	12.3
Atrazine desisopropyl	18	49%	1.05	6.95
Bendiocarb	0	0%	<LOR	<LOR
Bromacil	1	3%	35.84	35.84
Bromoxynil	0	0%	<LOR	<LOR
Carbaryl	1	3%	4.60	4.60
Carbendazim	9	24%	2.39	21.7
DCPMU	1	3%	0.510	0.510

DCPU	0	0%	<LOR	<LOR
Diazinon	24	65%	0.180	4.950
Difenoconazole	0	0%	<LOR	<LOR
Diketonitrile	5	14%	0.100	0.160
Diuron	22	59%	0.600	44.4
Fenuron	0	0%	<LOR	<LOR
Fipronil	10	27%	0.680	11.56
Fluazifop	6	16%	0.530	3.52
Fluometuron	0	0%	<LOR	<LOR
Fluroxypyr	0	0%	<LOR	<LOR
Haloxyfop	12	32%	1.21	23.28
Hexazinone	13	35%	1.69	4.45
Imazapyr	0	0%	<LOR	<LOR
Imazethapyr	0	0%	<LOR	<LOR
Imidacloprid	16	43%	1.70	19.7
Malathion	0	0%	<LOR	<LOR
MCPA	2	5%	8.38	8.75
Metalaxyl	15	41%	0.140	4.71
Methidathion	0	0%	<LOR	<LOR
Methomyl	5	14%	1.57	20.7
Metolachlor (S+R)	24	65%	1.33	291
Metolcarb	0	0%	<LOR	<LOR
Metribuzin	2	5%	2.00	3.11
Metsulfuron methyl	31	84%	1.63	104.7
Mexacarbate	0	0%	<LOR	<LOR
Oryzalin	0	0%	<LOR	<LOR
Picloram	0	0%	<LOR	<LOR
Promecarb	0	0%	<LOR	<LOR
Prometryn	2	5%	1.23	4.29
Propachlor	0	0%	<LOR	<LOR
Propazine	2	5%	1.19	1.27
Propiconazole	6	16%	1.05	3.78
Propoxur	0	0%	<LOR	<LOR
Simazine	15	41%	1.21	8.5
Simazine hydroxy	0	0%	<LOR	<LOR
Tebuconazole	9	24%	1.08	3.20
Tebuthiuron	22	59%	1.03	56
Terbuthylazine	22	59%	1.25	23.14
Terbuthylazine desethyl	33	89%	1.09	20.0
Thiamethoxam	6	16%	1.260	15.28
Triclopyr	13	35%	5.45	191.4
Pharmaceuticals and personal care products (PPCPs)				
Acesulfame	0	0%	<LOR	<LOR
Atenolol	0	0%	<LOR	<LOR

Atorvastatin	0	0%	<LOR	<LOR
Caffeine	0	0%	<LOR	<LOR
Carbamazepine	9	24%	1.28	4.90
Codeine	0	0%	<LOR	<LOR
DEET	35	95%	10.36	162
Diclofenac	0	0%	<LOR0	<LOR0
Gabapentin	0	0%	<LOR	<LOR
Hydrochlorothiazide	0	0%	<LOR	<LOR
Iopromide	0	0%	<LOR	<LOR
Naproxen	0	0%	<LOR	<LOR
Oxazepam	0	0%	<LOR	<LOR
Paracetamol	0	0%	<LOR	<LOR
Paraxanthine	0	0%	<LOR	<LOR
Salicylic acid	0	0%	<LOR	<LOR
Sulfadiazine	1	3%	0.640	0.640
Sulfamethoxazole	1	3%	0.130	0.130
Tadalafil	0	0%	<LOR	<LOR
Temazepam	0	0%	<LOR	<LOR
Verapamil	0	0%	<LOR	<LOR

Table 4. Summary of the number of chemicals accumulated in MPT passive samplers, percentage of detection at the sites and the range of mass accumulated over the deployment periods (ng MPT^{-1}).

Analyte	Number of sites detected	% Detection	Min reported (ng/MPT)	Max reported (ng/MPT)
4:2 FTS	0	0%	<LOR	<LOR
5:3 FTCA	0	0%	<LOR	<LOR
6:2 FTAB	1	2%	1.08	1.08
6:2 FTCA	0	0%	<LOR	<LOR
6:2 FTS	0	0%	<LOR	<LOR
8:2 FTCA	0	0%	<LOR	<LOR
8:2 FTS	0	0%	<LOR	<LOR
8Cl-PFOS	0	0%	<LOR	<LOR
9Cl-F53B	0	0%	<LOR	<LOR
ADONA	6	15%	1.18	3.45
FBSA	0	0%	<LOR	<LOR
FHxSA	0	0%	<LOR	<LOR
FOSA	0	0%	<LOR	<LOR
GenX	0	0%	<LOR	<LOR
N-EtFOSAA	0	0%	<LOR	<LOR
N-MeFOSAA	0	0%	<LOR	<LOR
PFBA	10	24%	1.33	3.57
PFBS	0	0%	<LOR	<LOR
PFDA	0	0%	<LOR	<LOR
PFDoDA	0	0%	<LOR	<LOR

PFECHS	**0**	**0%**	**<LOR**	**<LOR**
PFHpA	**0**	**0%**	**<LOR**	**<LOR**
PFHpS	**0**	**0%**	**<LOR**	**<LOR**
PFHxA	**0**	**0%**	**<LOR**	**<LOR**
PFHxS Total	**0**	**0%**	**<LOR**	**<LOR**
PFNA	**0**	**0%**	**<LOR**	**<LOR**
PFOA Total	**0**	**0%**	**<LOR**	**<LOR**
PFOPA	**0**	**0%**	**<LOR**	**<LOR**
PFOS Total	**3**	**7%**	**1.2**	**1.36**
PFPeA	**0**	**0%**	**<LOR**	**<LOR**
PFPeS	**0**	**0%**	**<LOR**	**<LOR**
PFPrS	**0**	**0%**	**<LOR**	**<LOR**
PFUnDA	**0**	**0%**	**<LOR**	**<LOR**

Organochlorine pesticides (OCPs)

In total, 19 OCPs were accumulated in PDMS samplers over the deployment period across 33 of the 37 sites (Table 2, Figure 5, Appendix 1), with the amount of ∑OCPs accumulated ranging from below reporting limits (SEQ25 - Wyaralong Dam Wall; SEQ07 - Yabba Creek @ Jimna; SEQ39 - Cooloolabin Dam; SEQ05 - Poona Dam; SEQ43 - Enoggera Reservoir; SEQ23 - Herring Lagoon) to 455 ng $PDMS^{-1}$ (SEQ15 - Lockyer Creek @ Lake Clarendon Way). The event sampling data are discussed below.

Figure 5. Total mass of 19 ΣOCPs (ng PDMS^{-1}) accumulated in PDMS passive samplers at each site.

Discounting the sites below reporting limits, the conversion of ∑OCP masses accumulated in passive samplers to time-weighted average water concentrations revealed an estimated water concentration range of 0.035 to 5.13 ng L^{-1} (SEQ04 - Mary River @ Kenilworth and SEQ15 - Lockyer Creek @ Lake Clarendon Way, respectively; Figure 6). The event sampling data are discussed below.

Figure 6. Total estimated water concentrations (ng L^{-1}) of 19 ΣOCPs at each site derived from PDMS passive samplers.

Polycyclic aromatic hydrocarbons (PAHs)

In total, 11 PAHs were accumulated in PDMS samplers over the deployment period (Table 2, Figure 7, Appendix 1), with the amount of ∑PAHs accumulated ranging from below reporting limits (SEQ43 - Enoggera Reservoir; SEQ38 - Wappa Dam; SEQ27 - Moogerah Dam; SEQ35 - Hinze Lower Intake; SEQ07 - Yabba Creek @ Jimna; SEQ39 - Cooloolabin Dam; SEQ06 - South Maroochy Intake Weir; SEQ05 - Poona Dam) to 335 ng PDMS^{-1} (SEQ24 - Leslie Harrison Dam).

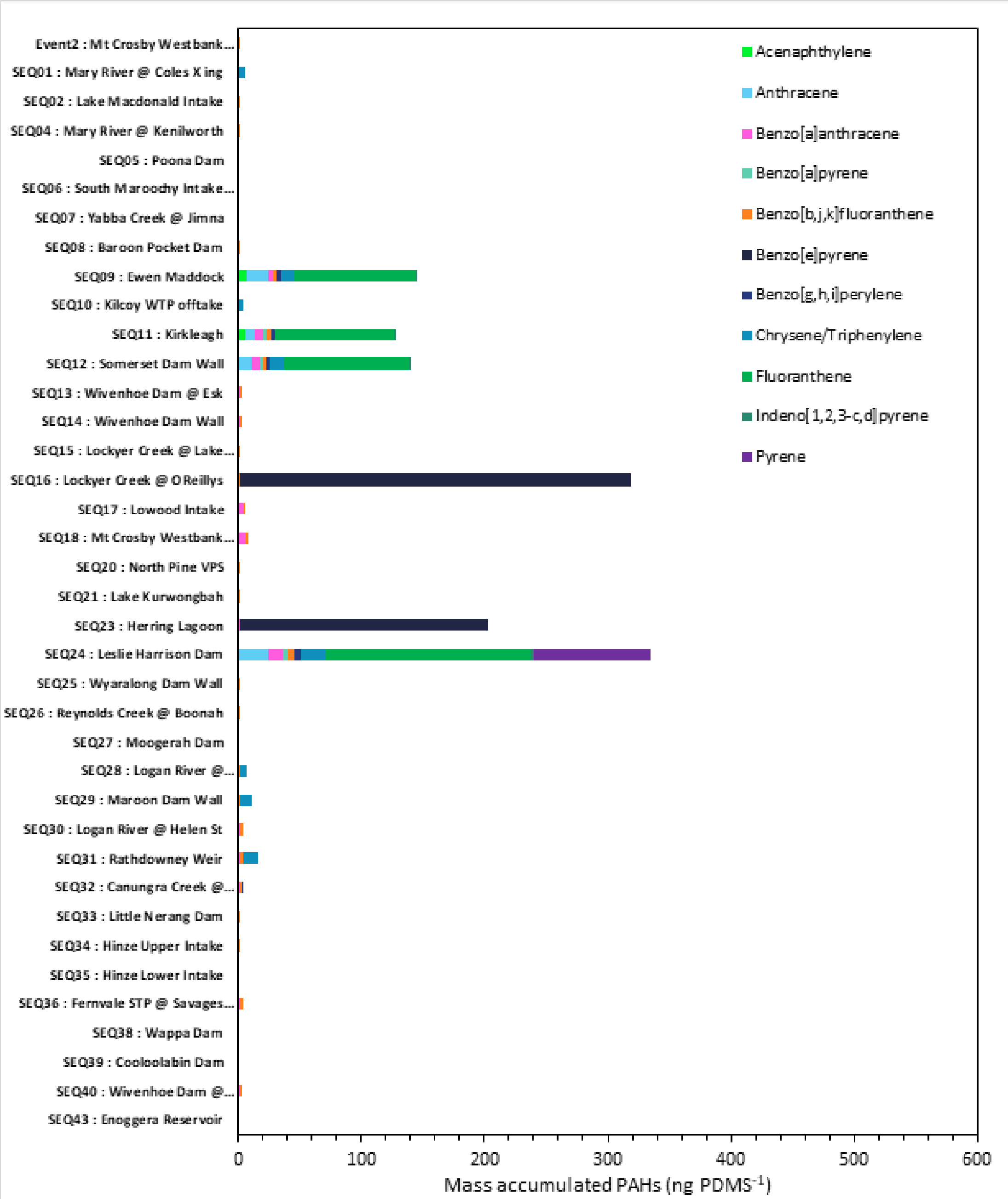

Figure 7. Total mass of 11 ΣPAHs (ng $PDMS^{-1}$) accumulated in PDMS passive samplers at each site.

Discounting the sites below reporting limits, the conversion of ∑PAH masses accumulated in passive samplers to time-weighted average water concentrations revealed an estimated water concentration range of 0.001 to 1.24 ng L^{-1} (SEQ04 - Mary River @ Kenilworth and SEQ24 - Leslie Harrison Dam, respectively; Figure 8).

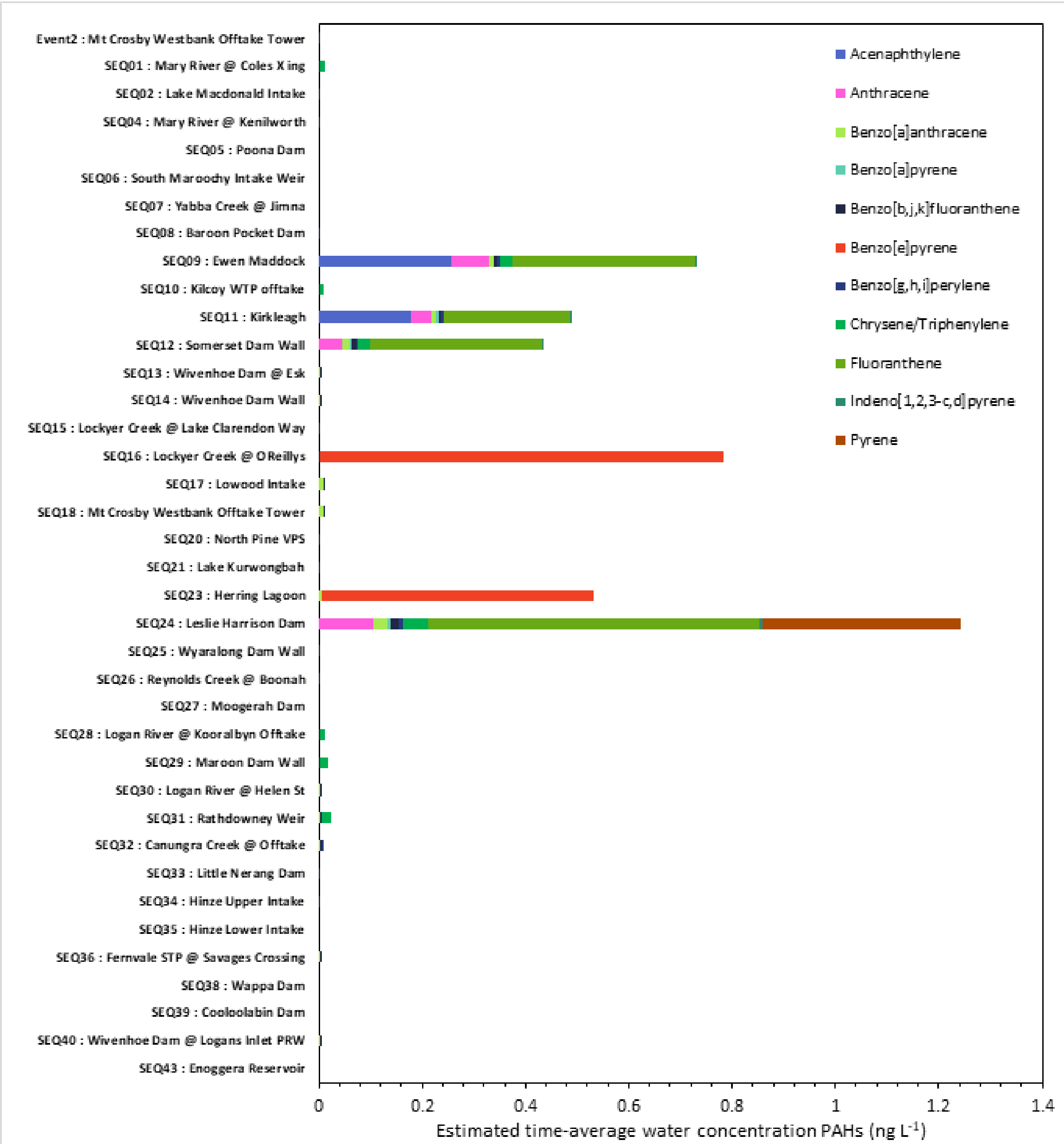

Figure 8. Total estimated water concentrations (ng L^{-1}) of 11 ΣPAHs at each site derived from PDMS passive samplers.

Per- and Polyfluoroalkyl substances (PFAS)

Four PFAS were detected above the LOQ in the MPT samplers (Table 4, Figure 9, Appendix 1). Discounting the sites with all PFAS below reporting limits, the ∑PFAS accumulated ranged from 1.08 ng MPT^{-1} (SEQ14 - Wivenhoe Dam Wall) to 3.64 ng MPT^{-1} (SEQ41 - LHD at Priest Gully and Stockyard Ck Confluence).

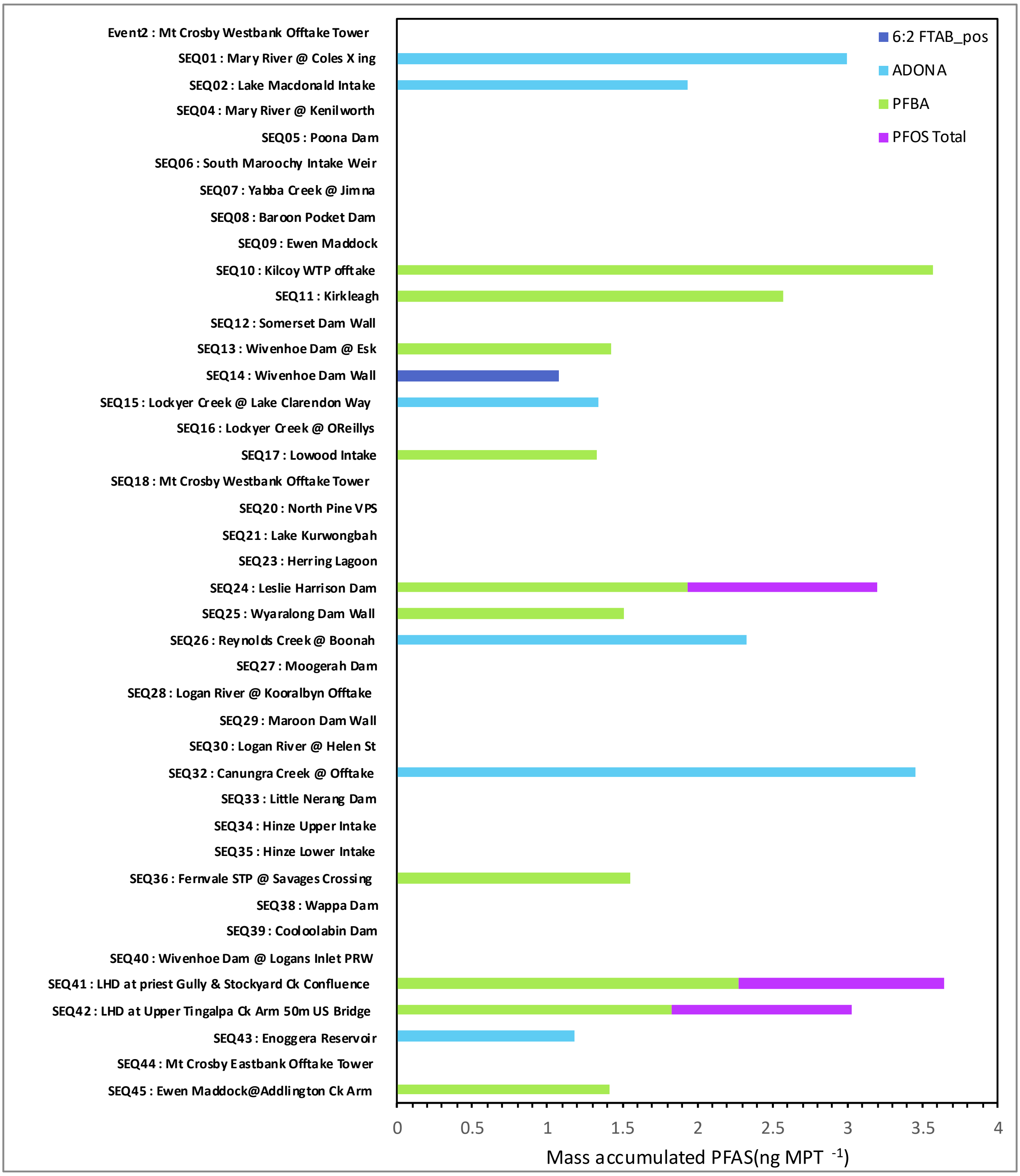

Figure 9. Total mass of 4 ΣPFAS (ng MPT^{-1}) accumulated in MPT passive samplers at each site.

Water concentrations were estimated for the PFAS accumulated where sampling rates have been previously calibrated. Two PFAS, PFBA and PFOS, could be converted to estimated water concentrations (Figure 10). These ΣPFAS concentrations ranged from 4.25 ng L^{-1} (SEQ17 – Lowood Intake) to 10 ng L-1 (SEQ10 - Kilcoy WTP offtake)

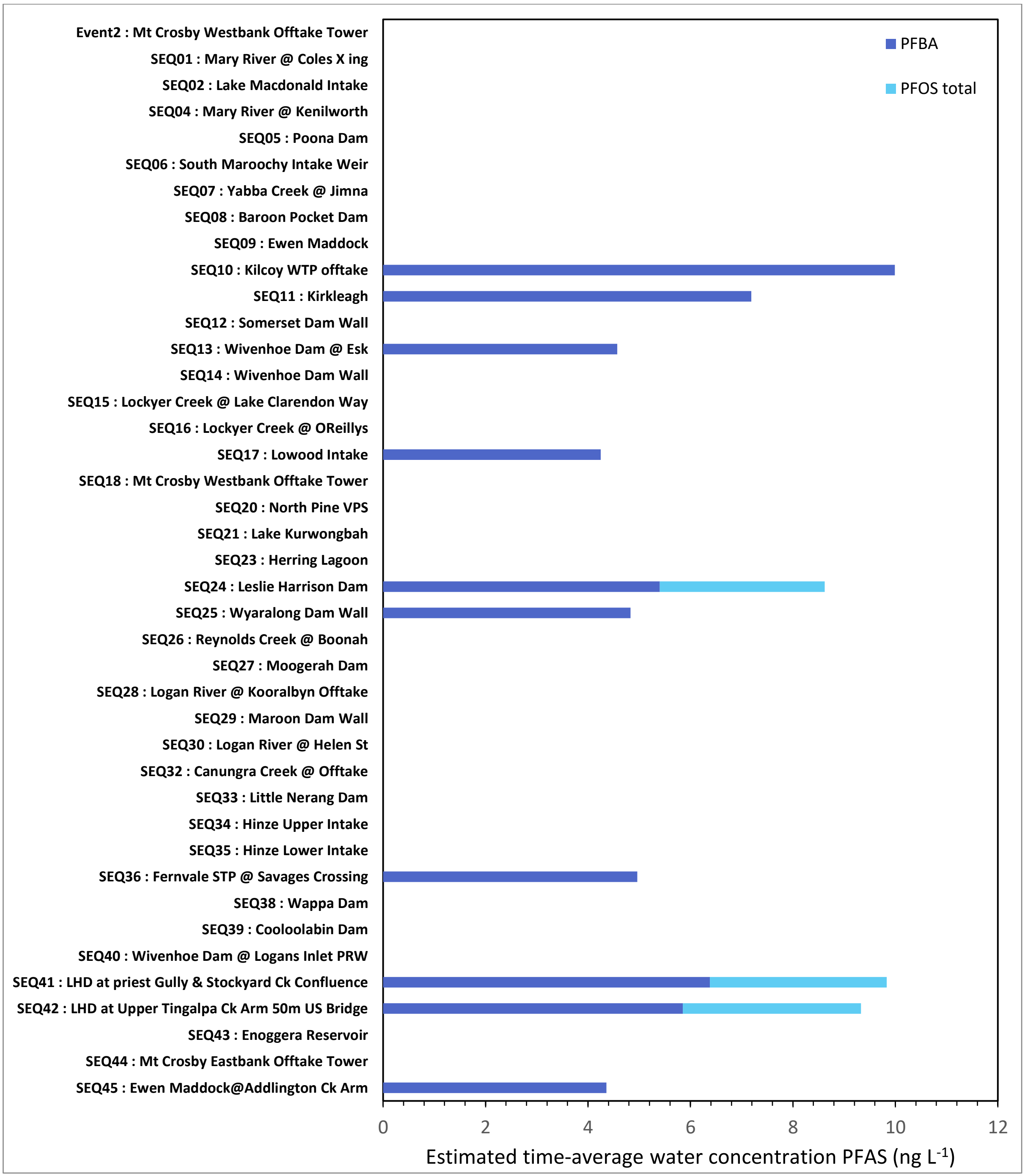

Figure 10. Total estimated water concentrations (ng L^{-1}) of 2 ΣPFAS at each site derived from MPT passive samplers.

Pesticides

Over the deployment period, 33 polar pesticides (including herbicides, fungicides and insecticides) accumulated in ED passive samplers (Table 3, Figure 11, Appendix 1). The ∑polar pesticides accumulated ranged from below reporting limits (SEQ32 - Canungra Creek @ Offtake; SEQ23 - Herring Lagoon; SEQ39 - Cooloolabin Dam; SEQ07 - Yabba Creek @ Jimna; SEQ39 – Cooloolabin Dam) to 963 ng ED^{-1} (SEQ15 - Lockyer Creek @ Lake Clarendon Way).

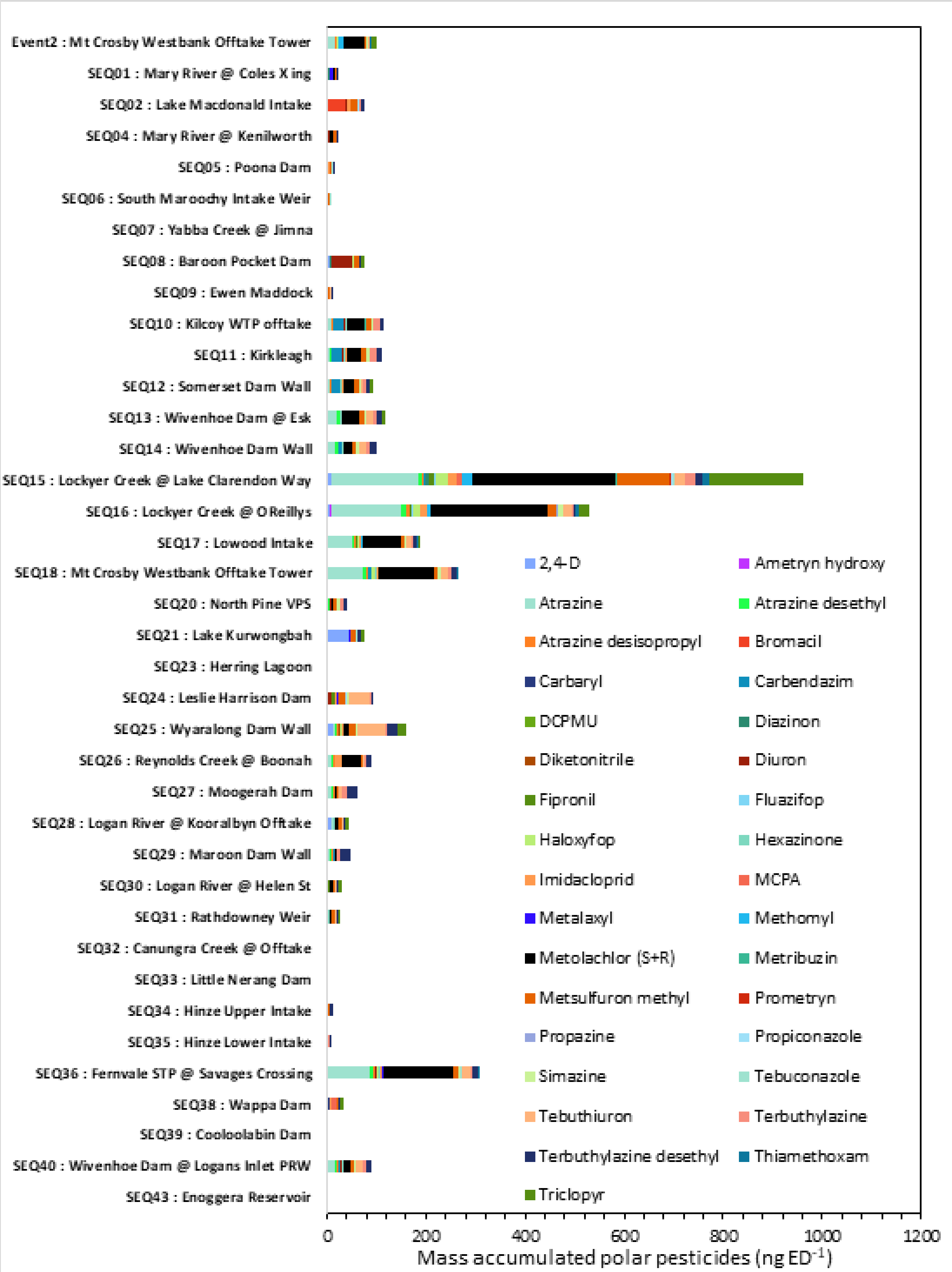

Figure 11. Total mass of 33 Σpolar pesticides (ng ED^{-1}) accumulated in ED passive samplers at each site.

Water concentrations were estimated for the polar pesticides accumulated where sampling rates have been previously calibrated. From the 33 chemicals reported, 17 were converted to time-weighted average water ∑concentrations. Discounting the sites below reporting limits, these water concentrations ranged between 1.030 and 392 ng L^{-1} (SEQ35 - Hinze Lower Intake and SEQ15 - Lockyer Creek @ Lake Clarendon Way, respectively; Figure 12).

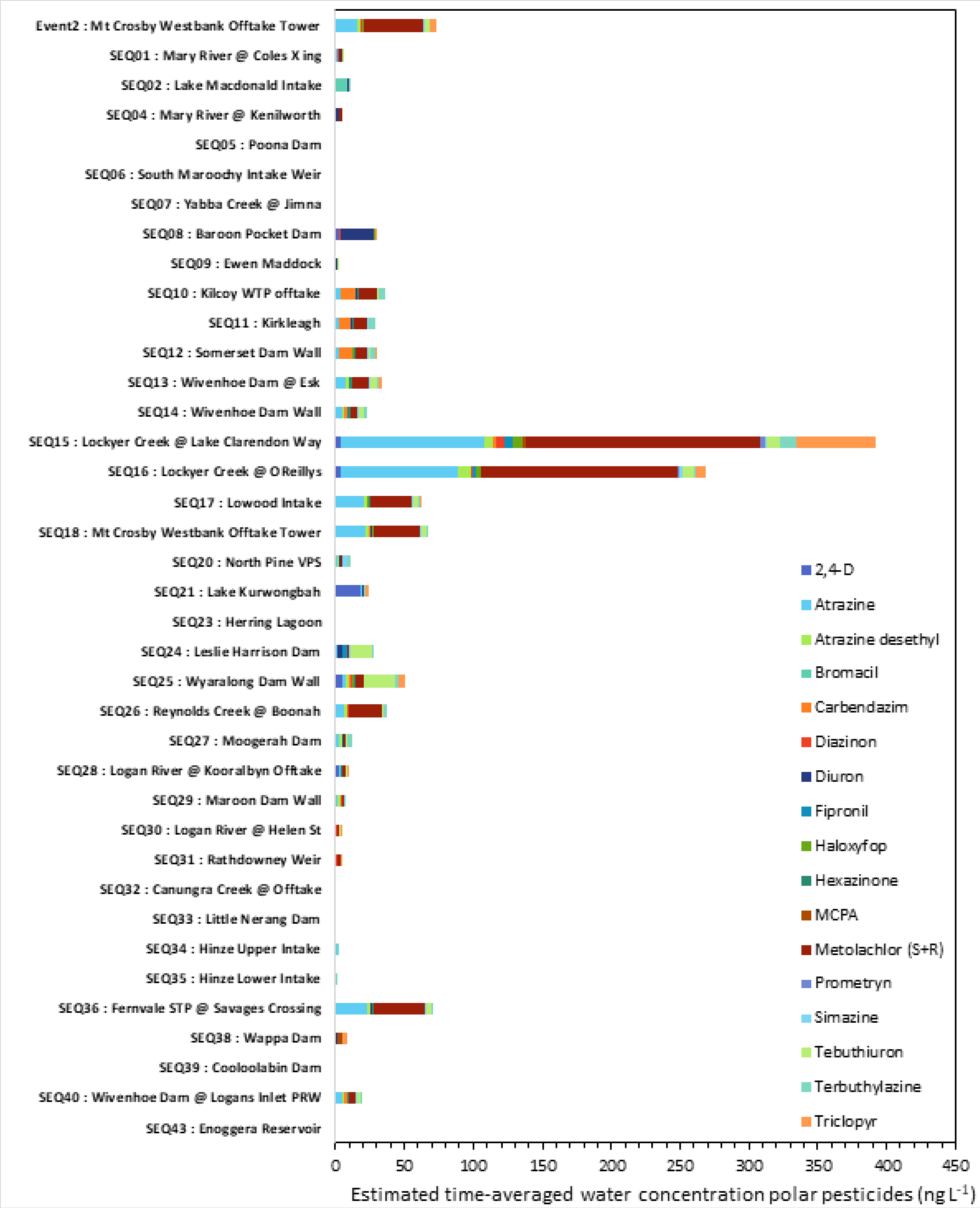

Figure 12. Total estimated water concentrations (ng L^{-1}) of 17 Σpolar pesticides at each site derived from ED passive samplers.

Pharmaceuticals and personal care products (PPCPs)

In total, 4 PPCPs were reported (Table 3, Figure 13, Appendix 1) with the average amount of ΣPPCPs accumulated during the routine monitoring campaign ranging from 10.36 ng ED^{-1} (SEQ38 - Wappa Dam) to 167 ng ED^{-1} (SEQ15 - Lockyer Creek @ Lake Clarendon Way).

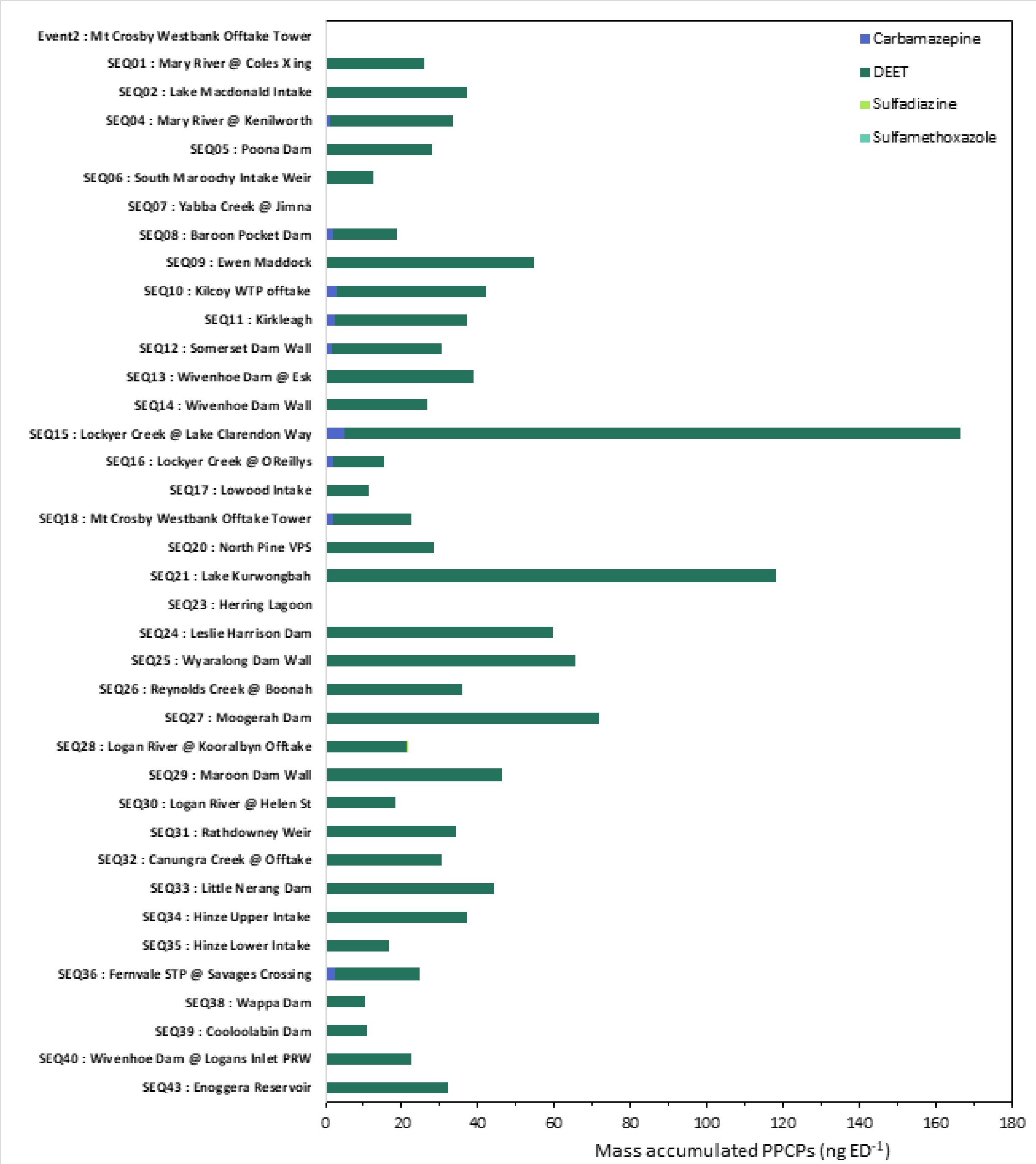

Figure 13. Total mass of 4 ΣPPCPs (ng ED^{-1}) accumulated in ED passive samplers at each site.

Of the 4 reported PPCPs, 3 were converted into estimated time-weighted average water concentrations. Discounting the sites below reporting limits and the event sampler, these ∑PPCP water concentrations ranged between 3.22 and 73 ng L^{-1} (sites SEQ17 - Lowood Intake and SEQ15 - Lockyer Creek @ Lake Clarendon Way, respectively; Figure 14).

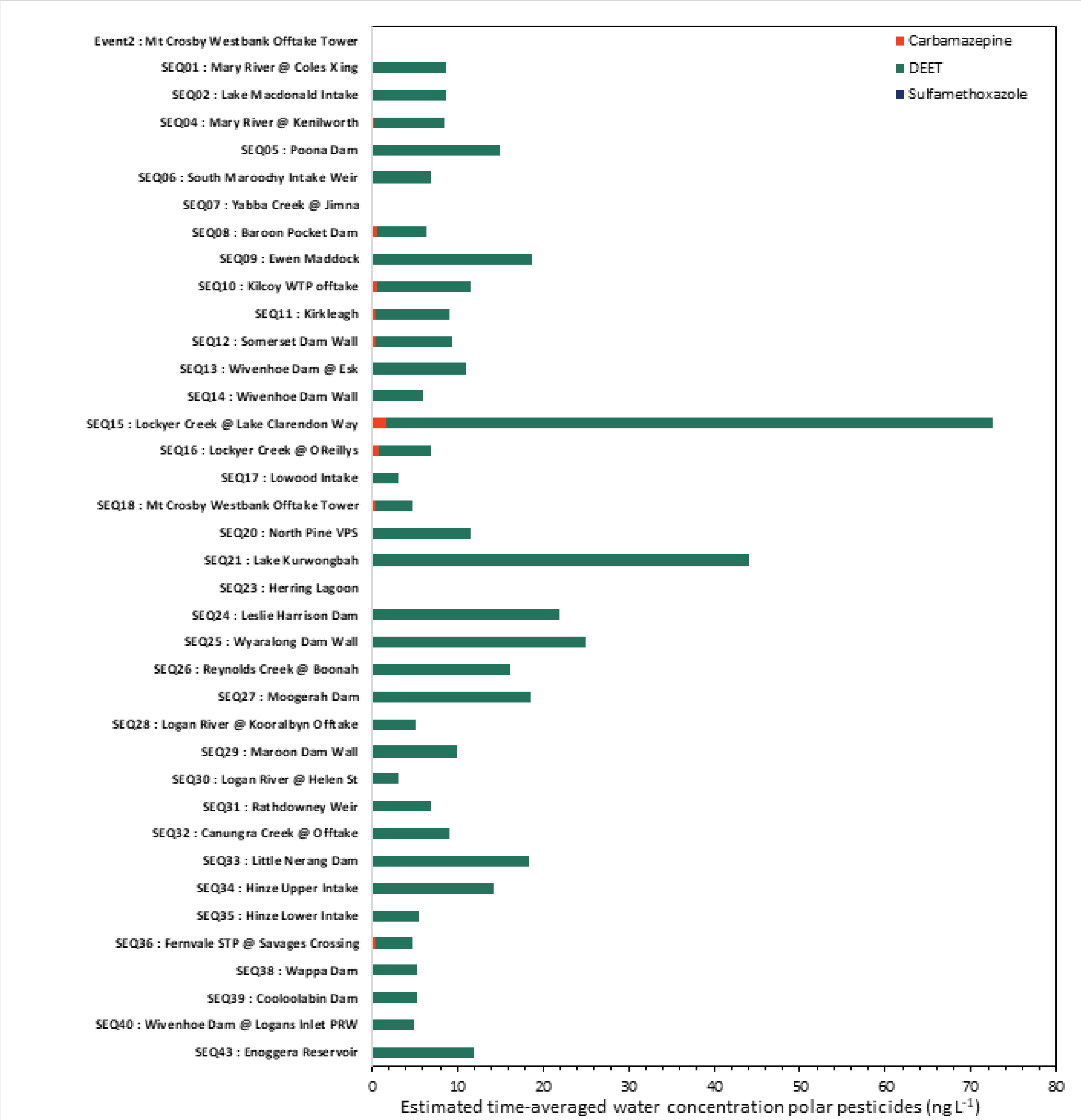

Figure 14. Total estimated water concentrations (ng L^{-1}) of 3 ΣPPCPs derived from ED passive samplers.

Event samples

Eleven OCPs (∑OCPs 515 ng $PDMS^{-1}$; 8.3 ng L^{-1}) and one PAH (Benzo[b,j,k]fluoranthene, 0.73 ng $PDMS^{-1}$; 0.004 ng L^{-1}) were detected in PDMS (Figure 5 toFigure 8). Fifteen polar pesticides (∑polar pesticides 100 ng ED^{-1}; 73 ng L^{-1}) and one PPCP (sulfamethoxazole, 0.13 ng ED^{-1}; 0.18 ng L^{-1}) were detected in ED samplers (Figure 11 Figure 14). No PFAS were found above detection limits in the MPT event samplers.

Analysis of non-target polar chemicals

Along with the target list of polar chemicals identified for investigation, screening was performed for additional herbicides and PPCP chemicals that have the potential to transport to waterways to investigate their presence in the water systems. This screening revealed tentative detection of 6 compounds (Table 5). The suspect screening provides tentative identification of the presence / absence of these chemicals. It is noted that to fully confirm the identification and quantification of these analytes, the use of appropriate chemical standards would be necessary. Tentative identifications are considered when the suspect spectra met strict criteria (strong signal/noise of >3, peak height >5x height of largest blank, reverse dot product score >0.85, matched peaks with library spectra >0.8) and m/z similarity greater than 0.98.

Table 5. List of tentatively identified non-target chemicals in EDs, and the sites in which they were detected.

Chemical Name	Description	Sites with tentative detects
Aminocarb	Carbamate pesticide	SEQ14 : Wivenhoe Dam Wall
		SEQ27 : Moogerah Dam
		SEQ36 : Fernvale STP @ Savages Crossing
		SEQ40 : Wivenhoe Dam @ Logans Inlet PRW
Quetiapine	Antipsychotic drug	SEQ02 : Lake Macdonald Intake
		SEQ04 : Mary River @ Kenilworth
		SEQ07 : Yabba Creek @ Jimna
		SEQ08 : Baroon Pocket Dam
		SEQ10 : Kilcoy WTP offtake
		SEQ11 : Kirkleagh
		SEQ12 : Somerset Dam Wall
		SEQ13 : Wivenhoe Dam @ Esk
		SEQ15 : Lockyer Creek @ Lake Clarendon Way
		SEQ18 : Mt Crosby Westbank Offtake Tower
		SEQ20 : North Pine VPS
		SEQ21 : Lake Kurwongbah
		SEQ24 : Leslie Harrison Dam
		SEQ25 : Wyaralong Dam Wall
		SEQ27 : Moogerah Dam
		SEQ30 : Logan River @ Helen St
		SEQ39 : Cooloolabin Dam
		SEQ40 : Wivenhoe Dam @ Logans Inlet PRW
		SEQ43 : Enoggera Reservoir
Norbuprenorphine	Major metabolite of the opioid buprenorphine	SEQ23 : Herring Lagoon
Azoxystrobin acid	Metabolite of the fungicide azoxystrobin	Event2 : Mt Crosby Westbank Offtake Tower
		SEQ05 : Poona Dam
		SEQ06 : South Maroochy Intake Weir
		SEQ15 : Lockyer Creek @ Lake Clarendon Way
		SEQ16 : Lockyer Creek @ OReillys
		SEQ17 : Lowood Intake
		SEQ18 : Mt Crosby Westbank Offtake Tower
		SEQ24 : Leslie Harrison Dam
		SEQ36 : Fernvale STP @ Savages Crossing

		SEQ38 : Wappa Dam
EDDP (2-ethylidene-1,5-dimethyl-3,3-diphenylpyrrolidine)	Major metabolite of methadone	SEQ02 : Lake Macdonald Intake
		SEQ08 : Baroon Pocket Dam
		SEQ09 : Ewen Maddock
		SEQ10 : Kilcoy WTP offtake
		SEQ12 : Somerset Dam Wall
		SEQ13 : Wivenhoe Dam @ Esk
		SEQ18 : Mt Crosby Westbank Offtake Tower
		SEQ20 : North Pine VPS
		SEQ25 : Wyaralong Dam Wall
		SEQ27 : Moogerah Dam
		SEQ29 : Maroon Dam Wall
		SEQ36 : Fernvale STP @ Savages Crossing
		SEQ40 : Wivenhoe Dam @ Logans Inlet PRW
Methadone	Synthetic opioid used to treat chronic pain and opioid dependence	SEQ02 : Lake Macdonald Intake
		SEQ09 : Ewen Maddock
		SEQ10 : Kilcoy WTP offtake
		SEQ16 : Lockyer Creek @ OReillys
		SEQ18 : Mt Crosby Westbank Offtake Tower
		SEQ27 : Moogerah Dam
		SEQ34 : Hinze Upper Intake
		SEQ35 : Hinze Lower Intake
		SEQ36 : Fernvale STP @ Savages Crossing
		SEQ40 : Wivenhoe Dam @ Logans Inlet PRW

Comparison to water quality guideline values

A selection of water guideline values and species protection values are provided in Table 6. No compounds with an available Australian drinking water guideline (ADWG) value were reported with estimated average concentrations above the ADWG value. This analysis is somewhat limited in that not all reported compounds were able to be converted to a water concentration, and not all compounds have guideline values available. However, given the levels observed, and the comparisons that were able to be made, we believe it is unlikely there would be any further exceedances attributed to any of the compounds reported as mass per sampler.

Exceedances for eco-toxicological guidelines were observed in the estimated time-averaged water concentrations for diazinon, metolachlor, tebuthiuron and chlorpyrifos. ANZECC & ARMCANZ have set diazinon freshwater guideline values of 0.03 and 10 ng L^{-1} for 99% and 95% species protection levels, respectively. There were no sites with any detections in excess of the 95% species protection guideline for any chemical. Furthermore, totals of 27, 14, 1 and 33 sites exceeded the 99% species protection guidelines for diazinon, metolachlor, tebuthiuron and chlorpyrifos, respectively (Table 6).

Table 6. Threshold chemical guidelines for Australian Drinking Water and Freshwater Aquatic Ecosystems. Values highlighted in yellow exceed the 99% species protection guideline.

Australian Drinking Water Guidelines 6 (2011) Version 3.6 Updated December 2024		ANZECC & ARMCANZ (2021) Trigger values for freshwater		This campaign
Herbicides & Insecticides	Guideline value (ng L-1)	99% species protection value (ng L-1)	95% species protection value (ng L-1)	Highest Reported Value (ng L-1)
Atrazine	20000	700	13000	104
Ametryn	70000	N/A	N/A	N/A
Bromacil	400000	N/A	N/A	7.85
Bromoxynil	10000	N/A	N/A	N/A
Carbaryl	30000	N/A	N/A	N/A
Carbendazim	90000	N/A	N/A	9.86
Cypermethrin	200000	N/A	N/A	N/A
Diazinon	4000	0.03	10	5.88
Diuron	20000	N/A	N/A	24.7
Fipronil	700	N/A	N/A	6.01
Fluometuron	70000	N/A	N/A	N/A
Haloxyfop	1000	N/A	N/A	7.18
Hexazinone	400000	N/A	N/A	1.38
Imazapyr	9000000	N/A	N/A	N/A
MCPA	40000	N/A	N/A	3.70
Malathion	70000	2	50	N/A
Methomyl	20000	N/A	N/A	N/A
Metolachlor (S+R)	300000	8.4	460	170
Metribuzin	70000	N/A	N/A	N/A
Metsulfuron methyl	40000	3.7	18	N/A
Oryzalin	400000	N/A	N/A	N/A
Pendimethalin	400000	N/A	N/A	N/A
Picloram	300000	N/A	N/A	N/A
Propachlor	70000	N/A	N/A	N/A
Propazine	50000	N/A	N/A	N/A
Propiconazole	100000	N/A	N/A	N/A
Simazine	20000	200	3200	3.30
Tebuthiuron	N/A	20	2200	22.3
Terbuthylazine	10000	N/A	N/A	12.7
Triclopyr	20000	N/A	N/A	57.4
2,4-D	30000	140000	280000	18.6
2,4,5-T	100000	3000	36000	N/A
3,4-Dichloroaniline	N/A	1300	3000	N/A
OCPs				
Azinphos methyl	30000	10	20	N/A
Chlordane	2000	30	80	N/A
Chlorpyrifos	10000	0.04	10	4.19
Cypermethrin	200000	N/A	N/A	0.007
DDT	9000	6	10	0.175
Dieldrin	300	N/A	N/A	0.168
Aldrin	300	N/A	N/A	0.0
Endosulfan	20000	30	200	0.232
Endrin	N/A	10	20	0.190
Heptachlor	300	10	90	N/A
γ-HCH (Lindane)	10000	70	200	N/A
Methoxychlor	300000	N/A	N/A	N/A
PAHs				
Anthracene	N/A	10	400	0.107

Benzo[a]pyrene	10	N/A	N/A	0.007
Fluoranthene	N/A	1000	1400	0.641
Naphthalene	N/A	2500	16000	N/A
Phenanthrene	N/A	600	2000	N/A
PFAS				
Sum of PFOS and PFHxS	70	N/A	N/A	3.48
PFOA	560	N/A	N/A	N/A

Discussion

OCPs were first introduced into Australia in the mid-1940s and were applied in many commercial products in different forms (such as powders and liquids). At one time up to 150 commercial products containing OCPs may have been registered in Australia. This followed a period of widespread use until the 1970s when recognition of risks related to OCPs resulted in reduced use and their ultimate ban in the 1980s. Since then, human biomonitoring studies in blood and breastmilk have showed the substantial decline of these chemicals from the early 1980s to the 1990s after which levels appear to plateau (Toms *et al.* 2012). Although OCPs were reported at 31 sites (84%), the concentrations were low (total ∑OCPs <5.13 ng L^{-1}). Compounds still in use such as chlorpyrifos were reported at higher concentrations, consistent with ongoing inputs to the environment. Chlorpyrifos was introduced in 1965 and has been included in many products and formulations aimed at agricultural, urban, commercial and residential uses. Although regulation measures have been put in place in Australia (APVMA 2011b) the chemical has not been strictly banned. A search of the APVMA PUBCRIS database reveals 67 currently registered or approved products containing chlorpyrifos. A continued review of chlorpyrifos is warranted to estimate any future risk. Chlorpyrifos was the most frequently detected OCP, reported at 31 sites (84% of sites) and p,p-DDD was the second most frequent at 12 sites (32% of sites). DDD (Dichlorodiphenyldichloroethane) is a metabolite of the pesticide DDT (Dichlorodiphenyltrichloroethane). DDT is listed under Annex B of the Stockholm Convention (Stockholm Convention Secretariat, 2023). While its use is banned in many countries, it is still used in some cases as a mosquito treatment to control malaria.

PAHs are ubiquitous in the environment and are introduced via anthropogenic sources primarily as a result of incomplete combustion as well as via natural sources (i.e. forest fires and the transformation of biogenic precursors) (Nguyen *et al.* 2014). Several PAHs have been included as chemicals of concern under the Stockholm Convention on Persistent Organic Pollutants (2011) due to their toxic and carcinogenic properties. They enter aquatic systems via storm water runoff from urban and industrial areas, roads and spills as well as via recreational activities such as boating. PAHs can undergo long-range atmospheric transport and deposition and are distributed in waterways during intense rainfall and flooding (Nguyen *et al.* 2014). The hydrophobic nature of PAHs typically results in low concentrations in water as they generally associate with particulate matter and sediment. Reportable concentrations of PAHs were detected at 29 sites (78% detection frequency). Benzo[b,j,k]fluoranthene was the most frequently detected PAH (76% detection frequency) although this was at low levels, with a maximum concentration of 0.013 ng L^{-1} at site SEQ24 - Leslie Harrison Dam.

Polar pesticides (herbicides, insecticides and fungicides) were reported at 33 sites. The two most frequently reported pesticides were Terbuthylazine desethyl (detected at 33 sites; 89%) and Metsulfuron methyl (detected at 31 sites; 84%). Terbuthylazine desethyl is a breakdown product of terbuthylazine, which is both used in sugarcane and other farming crops as a broad spectrum pre- and early post-emergent control for various grass and broadleaf weeds. Triazine herbicides such as atrazine, simazine, terbuthylazine, hexazinone and degradation products such as terbuthylazine desethyl, atrazine desisopropyl and atrazine desethyl can remain in soils for several months and can migrate from soil to groundwater or transport to waterways via runoff and flooding events. Atrazine and metsulfuron methyl have been widely used in

Australia and are registered for 1600 uses including weed control in orchards and various crops (APVMA 2011a; ANZECC & ARMCANZ 2018). They can be used in conjunction with diuron and hexazinone, two herbicides also frequently observed.

Pharmaceuticals and personal care products have emerged as a major group of environmental contaminants over the past decades. Some polar organic chemicals persist through wastewater treatment processes resulting in their continuous release into the aquatic environment (Kaserzon *et al.* 2014). The most frequently reported PPCP was DEET (found at 95% of sites) which can often be attributed to background contamination due to requirements of field staff to use insect repellent products in the field which contain DEET. The second most frequently reported PPCP was Carbamazepine (detected at 24% of sites). Carbamazepine is an antiepileptic drug that has been detected in wastewater, surface waters and drinking water (Donner *et al.* 2013). UV treatment of carbamazepine may produce degradation products with ecotoxic effects (Donner *et al.* 2013). The contribution of pharmaceuticals and personal care products can be an indicator of systems which are used for human recreational activities, or that receive some degree of treated effluent.

Per- and polyfluoroalkyl substances (PFAS) have been in use since the 1950s as components of Aqueous Film-forming Foams (AFFF) in firefighting products as well as in a wide range of consumer products such as non-stick pans, textiles and fabrics, food packaging materials, finishing products and personal use products (Xiao *et al.* 2017, Dewapriya *et al.* 2023). Their use in a wide variety of products, as well as their persistence in the environment has led to concerns about their presence in waterways, although PFAS are not manufactured in Australia (Ackerman Grunfeld *et al.*, 2024). Perfluorobutanoic acid (PFBA) was most frequently detected, found at 10 sites, albeit at low concentrations (<10 ng L^{-1}). Of the three regulated PFAS in the ADWG (PFOA, PFOS and PFHxS), only PFOS was detected at a maximum of 3.48 ng L^{-1}, well below the guideline value of 70 ng L^{-1}.

Future recommendations

- Recommendations for future work that build upon the findings in the current report.
- Continue temporal/ seasonal and spatial comparisons to investigate long term trends between sites and seasons.

- Review target compound lists to see if those frequently non-detected are better replaced with other targets.

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Appendix 1

See enclosed excel file ‘250507_S25_Client_Report_combined.xlsx’

Reporting sheet listing all micro pollutants investigated, levels accumulated in PDMS, ED and MPT passive samplers (ng $sampler^{-1}$) and estimated average water concentrations over the deployment periods (ng L^{-1}).

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