Using revolutionary real-time analyser technology to inform best practice environmental river management in Tasmania

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Derwent Estuary
Program

The Derwent Estuary Program (DEP) is a regional partnership between local governments, the Tasmanian State Government, businesses, scientists, and community-based groups to share science for the benefit of our estuary. The DEP was established in 1999 and has been nationally recognised for excellence in coordinating initiatives to reduce water pollution, conserve habitats and species, monitor river health and promote greater use and enjoyment of the foreshore.

Our major sponsors include Brighton, Clarence, Derwent Valley, Glenorchy, Hobart and Kingborough councils, the Tasmanian State Government, TasWater, Tasmanian Ports Corporation, Boyer Paper Mill, Nyrstar Hobart Smelter, Hydro Tasmania, NRM South and EPA Tasmania.

We thank The Ian Potter Foundation, EPA Tasmania, Meadowbank Tasmania, Hydro Tasmania and TasWater for financial contributions to this project.

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Executive Summary

Nutrient pollution in waterways remains one of the most significant and costly environmental challenges globally. Traditional water quality monitoring approaches–relying on infrequent, manual sample collection and laboratory analysis–often fail to capture short-term fluctuations in nutrient concentrations and can result in delayed or ineffective management decisions (Cappell *et al.*, 2017; Elfferich *et al.*, 2024).

To address these limitations, the Derwent Estuary Program (DEP), in collaboration with key partners and supported by The Ian Potter Foundation, initiated a trial of real-time nutrient monitoring using Eco Detection's Ion-Q® analyser technology. Over a three-year period (2021–2024), seven real-time nutrient analysers were deployed across the River Derwent catchment, encompassing pristine forested rivers, agricultural landscapes, and industrial outfalls. These analysers provided high-frequency, in-situ measurements of key dissolved nutrients, including nitrate, nitrite, and phosphate. The study demonstrated that real-time data offer unparalleled insight into nutrient dynamics, revealing distinct seasonal patterns (e.g., winter nitrate flushing), identifying nutrient pulses from point sources, and enhancing our ability to estimate annual dissolved nutrient loads.

Validation against laboratory results confirmed that nitrate measurements were generally accurate at lower concentrations, although discrepancies increased at higher levels. Phosphate measurements were often below the current detection limits, especially in riverine environments, highlighting the need for improved sensitivity in future deployments.

Despite not capturing total nutrient loads (e.g., particulate or organic nitrogen), the analysers provided valuable dissolved nutrient load estimates. These were particularly useful in understanding nutrient transport processes and informing adaptive management. For example, dissolved nutrient export rates varied widely across the catchment–from 0.015 kg/ha/year in the Ouse River to 3.15 kg/ha/year in the Tyenna River–reflecting differences in land use, hydrology, and discharge sources.

While the technology shows great promise, two key challenges remain: (1) the need for lower detection limits for phosphate and ammonium to meet scientific and regulatory requirements, and (2) the lack of a current accreditation pathway for compliance use. Addressing these challenges, alongside ongoing collaboration with regulators and stakeholders, will help unlock broader adoption.

As of 2025, the Ion-Q® analysers continue to be used at key river and industry sites across Tasmania. A new high-resolution monitoring station near Hobart's Bryn Estyn drinking water facility is also being established to improve end-of-catchment load estimates.

This project represents a major step forward in catchment-scale nutrient monitoring and management in Tasmania. The success of this trial provides a model for how real-time technologies can be integrated into water quality programs to enable faster and more effective environmental decision-making.

Introduction

Nutrient pollution is one of the most widespread, costly, and persistent environmental challenges globally. Efforts to manage nutrient inputs have been limited by traditional monitoring approaches, which are often slow, labour-intensive, and costly (Elfferich et al., 2024). The conventional 'grab-to-lab' method—relying on infrequent manual sampling, transport, and laboratory analysis—provides only a limited snapshot of water quality conditions, often failing to capture the temporal variability necessary for informed, real-time decision-making (Elfferich et al., 2024).

In September 2021, the Derwent Estuary Program (DEP) embarked on a new water quality monitoring program 'Using revolutionary real-time analyser technology to inform best practice environmental river management in Tasmania', funded by DEP's stakeholders (Hydro Tasmania, TasWater, the Environmental Protection Agency, Meadowbank Vineyard) and The Ian Potter Foundation.

The total project cost $818,000 (cash and in-kind) over three years (2021-2024) and aimed to use novel in-situ real-time analyser technology to revolutionise catchment water quality monitoring in Tasmania. Current water quality monitoring programs in the State are sparse, driven by individual industries/organisations, costly, and at a low frequency that does not capture incidents, variable pollutant sources, rainfall-runoff events and biogeochemical in-stream processes. The funds were used to purchase six Eco Detection real-time water quality monitoring systems to measure nitrate, nitrite, phosphate, chloride, carbonate, sulphate and fluoride, as well as other key analytes and parameters. The technology was developed by the University of Tasmania and is now commercialised by Melbourne-based company Eco Detection as the 'Ion-Q®' system, with the goal to provide robust, autonomous and low cost systems that provides data in real-time allowing fast and better informed decisions regarding industry operations and waterway management. Unlike other water quality sensors, the unique Eco Detection system is based on capillary electrophoresis (CE) and simultaneously measures an unprecedented number of analytes, providing comprehensive, robust, autonomous and low-cost systems. With analytical results sent via telemetry, generating data in real time enables decision making for industry operations and waterway management based on accurate and current knowledge.

In this trial, prototype-Ion-Q® systems were deployed. The results from this study have resulted in improvements that led to the release of a new improved version of this system by Eco Detection called Ion-Q®.

In May 2022, all six Eco Detection units were deployed in the field in the River Derwent catchment, which provides 60% of Hobart's drinking water. An additional unit was donated by UTAS, completing a network of seven Eco Detection units. The catchment has a history of land use change, diverse diffuse and point sources of nutrients and is home to a variety of water-dependent industries. This is the first water quality monitoring network on a catchment scale using this innovative technology. With the infrastructure in place in the River Derwent catchment and data being streamed to a data platform called eagle.io (7 systems, 1-4 measurements a day, 6 analytes, 5 external sensor measurements, totalling a minimum of 9,240 data points per month), this provides an unprecedented dimension of data availability compared to the typical 'grab-to-lab' approach (77 data points per month). The data allows us to calculate dissolved nutrient budgets for the catchment, allowing us to prioritise catchment management actions and help individual point source industries such as fish hatcheries and sewage treatment plants (STPs) to evaluate their nutrient discharges, with the aim of improving discharge levels.

Sampling sites

Sites were selected based on previous water quality monitoring in the catchment and end of sub-catchments were chosen to provide the opportunity to compare to previous nutrient catchment loads (
Table 1). Initially, it proved difficult to find suitable sites that are secure (private land), have access to power or good solar orientation, not flood prone but good river access, free from livestock, suitable ground cover and geology (for ground screw/mounting options). The project aimed to test benefits and limitations of this novel technology in a wide range of different environments and nutrient concentrations, so both river sites and outfall sites were chosen (Figure 1c). Initially, the five river sites include Florentine, Tyenna, Ouse and Clyde rivers, and the River Derwent below Meadowbank dam, and two industry outfalls were chosen (Boyer Paper Mill, TasWater Turriff Lodge STP) (1b). Some units were moved in 2023 and 2024 to accommodate new trials with new stakeholders (see table 1). Over the project duration, a total of eleven sites were tested using Eco Detection systems. Industry data is not included in the discussion below. The site Derwent below Meadowbank dam is located below the 'upper Derwent catchment' but is not representative of the entire Derwent catchment ('upper' and 'lower' Derwent catchments combined). Ultimately, a monitoring site upstream of 'Bryn Estyn', Hobart's Drinking Water Treatment Plant, would best represent end-of-catchment loads, as previously sampled in monthly grab sampling programs. A new monitoring site was installed in February 2025, as a combination of a real time flow gauge with a real time Eco Detection water quality analyser (this data is not included in the present study).

Table 1: List of sites and installation dates for Eco Detection units.

Eco Detection unit	Site name	Installation period	Coordinates (GDA94 Lat/Lon)
S/N 126	Outfall - Turriff Lodge STP, New Norfolk, TasWater	21/12/2021-15/09/2023	Available upon request
S/N 136	Outfall – Norske Skog Boyer (NSB)	24/2/2022-08/2024	Available upon request
S/N 135	River - Derwent below Meadowbank dam, private land	23/2/2022 - current	Available upon request
S/N 139	River - Florentine	18/5/2022 – 07/2024	Available upon request

S/N 140	River – Clyde below Hamilton, private land	19/5/2022 - current	Available upon request
S/N 137	River – Ouse below Ouse township, private land	20/5/2022 - current	Available upon request
UTAS/Sense-T device	River – Tyenna, private land	08/2021-08/2023; 08/2023 - current	Available upon request

Figure 1a: Installation examples of Eco Detection units. Left: Ouse, device mounted on a pole with solar power. Right: Derwent below Meadowbank dam, device mounted with ground screw and pole, access to mains power, and antenna.

Figure 1b: Installation examples of Eco Detection units. Left: Norske Skog, device on frame, access to mains power. Right: Sewage treatment plant outfall, TasWater, Turriff Lodge (New Norfolk), device mounted to railing with access to mains power.

Figure 1c: Site locations as of May 2022. Please note some sites have changed to accommodate trial at new sites.

Analyser validation

For the first twelve months following installation, a monthly grab sampling program was conducted to allow for comparison of Eco Detection analyser data to traditional laboratory analysis at Analytical Services Tasmania (AST). The real time nutrient measurements from river sites were in good agreement with the laboratory results, at least for nitrate as shown in

Figure 2a. It is noteworthy to highlight that there was increased error in measurements as nitrate increased above 0.6 mg/L. When comparing to phosphate there was good agreement at lower phosphate concentrations, however there was increased uncertainty as phosphorus increased above 2mg/L (Figure 3b). It is important to note that the data forming figure 3b is from industrial sites as phosphate levels were below detection limits for most river sites. To further explore the differences between real time analyser and laboratory data a Bland-Altman plot was produced (Figure 4). As can be seen from Bland Altman figure for nitrate there is good agreement and low bias at lower nitrate concentrations (i.e., below 1mg/L). However there is some increase in the difference between the methods as mg/L increases beyond 1mg/L.

No comparison could be made for phosphate in the river systems given that phosphate results from Eco Detection units were predominantly under the current level of reporting (LoR) for both lab and field data, (Table 2, & Figure 5), highlighting the need for improved phosphate detection. Some comparisons of phosphate were possible from data from Turriff lodge and Boyer outfall sites and is presented in figure 3b. There was increased error as phosphate concentrations increased. One hypothesis to explain this is that the nature of effluent (fast conversion between nitrogen species) and/or the lag time between sampling and laboratory analysis may cause the discrepancies. An alternative hypothesis is other solutes and physiochemistry conditions are interfering with the Ion Q system. Problems with high chloride contents affecting nitrite and nitrate analysis were also encountered at one industry site, however, were resolved by refinement of the CE system by Eco Detection. Future work is needed to 1) address the need for low level nutrient measurements below current LoR, 2) identify the causes for discrepancies at industry outfalls between laboratory and analyser results, and 3) develop a chloride removal sample preparation step for high EC waters, including seawater. Eco detection has recently made improvements to the algorithm that detects phosphate peaks.

Table 2: Limits of Reporting (LoR) comparison between the lab (AST) and in-situ analyser (Eco Detection).

Analyte	AST LoR (mg/L)	Eco Detection LoR (mg/L)
Nitrite NO2-N	0.002 ±10%	0.03 ±10%
Nitrate NO3-N	0.002 ±15%	0.03 ±10%
Phosphate PO4-P	0.003 ±20%	0.1 (0.01) ±10%
Ammonium NH4-N	0.005 (NH3-N) ±15%	0.2 ±10%

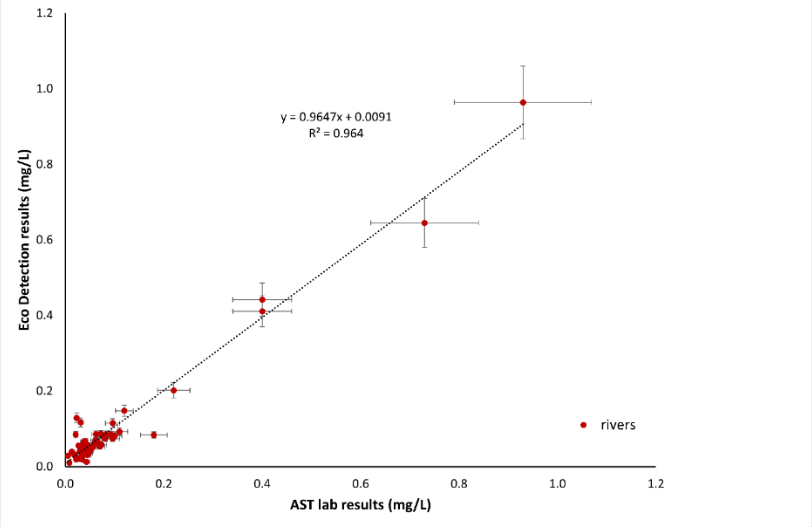

Figure 2a: Comparison of nitrate-N data from Eco Detection units to AST lab results for all river sites.

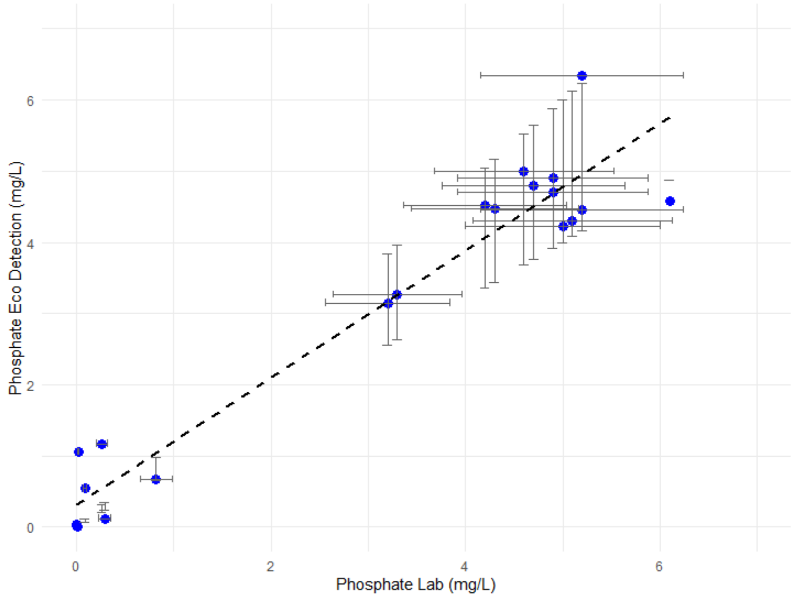

Figure 3b: Comparison of phosphate data from Eco Detection units to lab (AST) data. Note that this data is from industrial sites and not river sites.

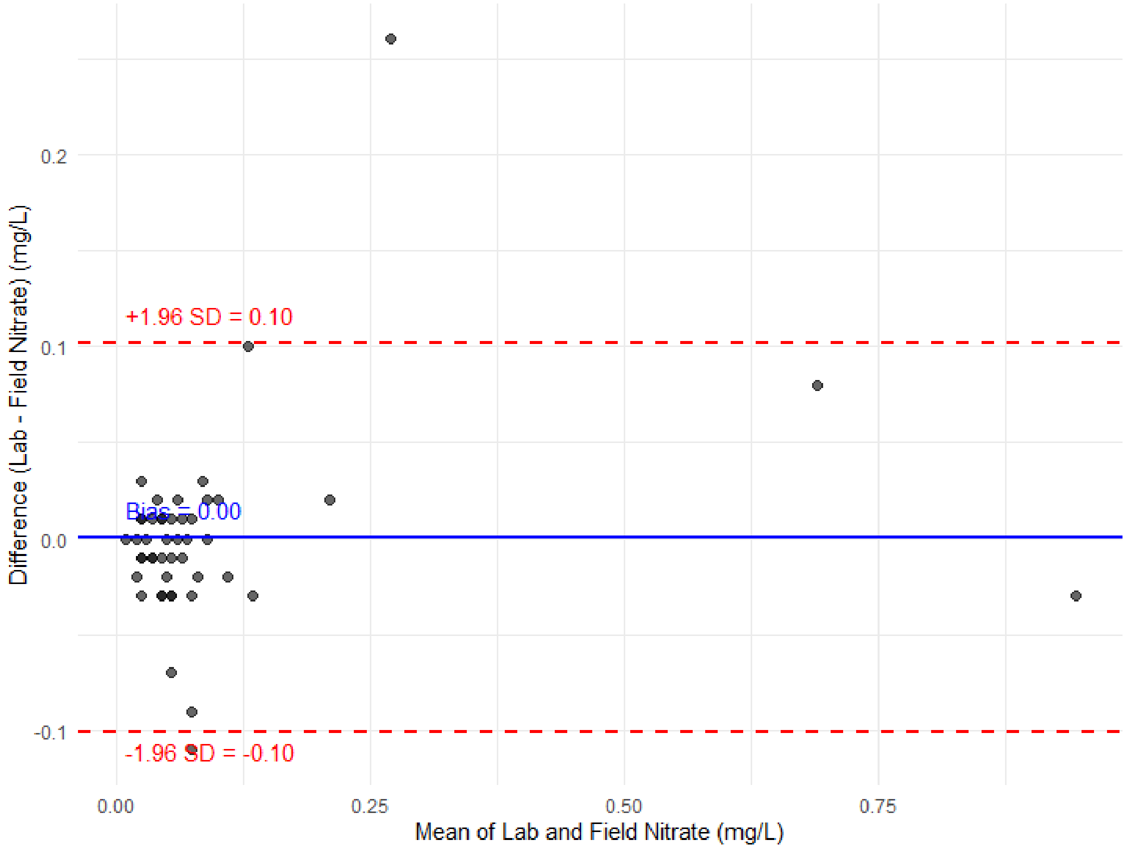

Figure 4. Bland-Altman plot of field analsyer v's lab Nitrate data. This data comparison is for the river data only. The blue line indicates the zone where there is zero difference between methods.

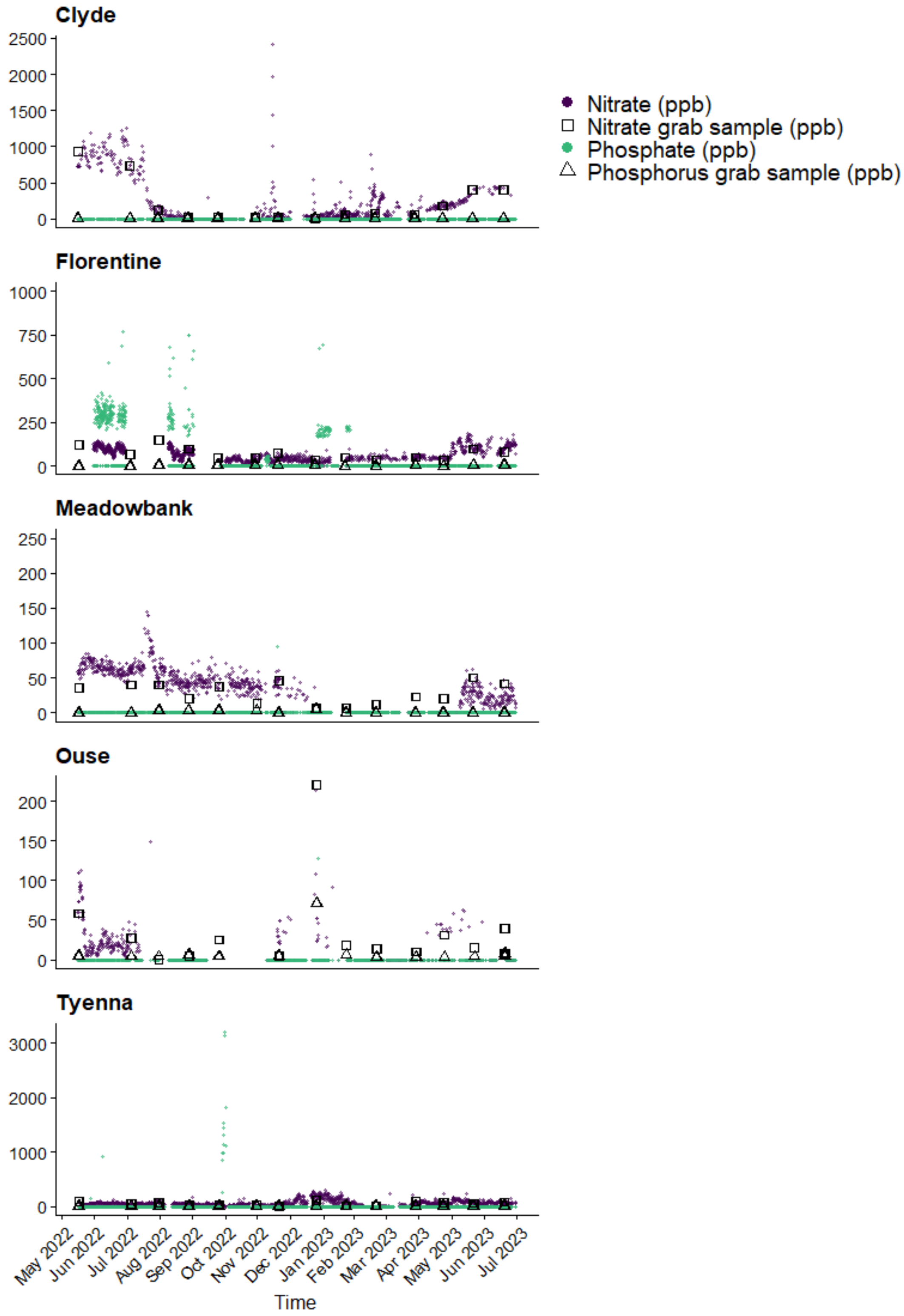

Figure 5: Comparison of Eco Detection data for nitrate (purple) and phosphate (green) in comparison to results from monthly grab sampling at the same sites.

External Sensors

The integration of external sensors for dissolved oxygen (DO), turbidity, pH, temperature, and electrical conductivity (EC) presented several challenges due to their continuous submersion in the water. It is important to clarify that these external sensors were supplied by a third party and are not components of the Eco Detection analyser system. At several locations, sensor performance was compromised by biofouling, sediment accumulation, and activity from macroinvertebrates. Without a consistent and rigorous cleaning schedule, it was difficult to discern whether observed peaks–particularly in turbidity–were the result of actual environmental events, local disturbances, or sensor artefacts. Turbidity and DO sensors were especially sensitive to such interference. In contrast, EC remained a reliable indicator of surface runoff, and temperature data appeared robust.

To improve data quality and reliability, further work is recommended to:

1. Position external sensors in surface waters (e.g., on buoys) while maintaining easy access for cleaning from the shore.
2. Establish methods for ongoing calibration without requiring sensor replacement.
3. Consider installing cameras to visually confirm site conditions during anomalous readings.

Additionally, it is important to note that the proportion of nitrate plus nitrite relative to total nitrogen load can vary depending on physicochemical factors such as dissolved oxygen. This underscores the value of combining Eco Detection nutrient data with supporting physicochemical datasets to fully understand nutrient dynamics and transport processes.

River results to date

Nutrient Monitoring Overview

Data from all seven Eco Detection units are automatically transmitted to the cloud and displayed via the eagle.io dashboard. Due to limited analytical tools within eagle.io, data was downloaded and analysed using R programming language. The figures below summarise all available data from each river site, covering the period from installation to October 2023. Historical water quality monitoring (grab sampling) was also conducted monthly between September 2015 and September 2017 for the Clyde, Ouse, Tyenna, Florentine, and the Derwent below Meadowbank Dam (Proemse et al., 2018).

Clyde River

The Clyde catchment is dominated by grazing agriculture and is highly susceptible to rainfall-runoff events due to limited vegetation cover. The EPA's Default Guideline Value (DGV) for nitrate in the Clyde catchment is 5 ppb. The 80th percentile of the nitrate data for the Clyde is 288 ppb.

Winter nitrate concentrations are typically elevated, likely due to increased runoff and soil saturation. In Tasmanian rivers, winter is often associated with two processes: (1) reduced nutrient uptake by algae due to lower light and temperature, and (2) increased nitrate flushing as wet soils leach nitrogen (Proemse *et al.*, 2022). This results in a wave like seasonal pattern of nitrate concentrations, which may not align directly with flow events. The in-situ analyser confirmed these trends (Figure 6a), with nitrate peaks reaching ~1 mg/L NO_3-N, compared to a historical maximum of 0.7 mg/L. Notably, flow releases from Lake Crescent dilute nitrate concentrations during spring, lowering them until the following winter. Phosphate concentrations remained consistently below the limit of reporting (LoR).

Ouse River

Like the Clyde, the Ouse catchment is agriculturally dominated and exhibits similar sensitivity to rainfall-runoff. The EPA's Default Guideline Value (DGV) for nitrate in the Ouse catchment is 2 ppb. The 80th percentile of the nitrate data for the Ouse is 17 ppb.

Nitrate peaks were observed between May and July, with occasional pulses in December–January (Figure 7b). Phosphate remained below detection limits throughout the study. Overall, dissolved nutrient concentrations were low (Figure 7a), and previous data suggest nitrogen in the Ouse is primarily in particulate or organic form (DEP, 2018).

Florentine River

The Florentine catchment comprises forestry and National Park land. Nitrate levels were consistently low but still above the DGV for the region (~100 ppb or 0.1 mg/L), with occasional peaks up to 1500 ppb (1.5 mg/L) (Figure 8a). The EPA's Default Guideline Value (DGV) for nitrate in the Florentine catchment is 2 ppb. The 80th percentile of the nitrate data for the Florentine is 104 ppb. Phosphate peaks (~350 ppb or 0.35mg/L) occurred in June, July, August, and January, with a maximum of ~750 ppb or 0.75 mg/L (Figure 8c). These trends align with previous monitoring, confirming low nutrient concentrations typical of a forested catchment.

Tyenna River

The Tyenna catchment includes forestry, protected areas, and point source discharges from two hatcheries and a sewage treatment plant. The EPA's Default Guideline Value (DGV) for nitrate in the Tyenna catchment is 35 ppb. The 80th percentile of the nitrate data for the Tyenna is 100 ppb. Nitrate levels were typically above the

DGV (~100 ppb or 0.1 mg/L), with notable peaks in January–February reaching 550 ppb or 0.55 mg/L. Phosphate was generally below detection limits, except for a significant peak (~3000 ppb) in October. The analyser was relocated in August 2023 from Westerway to the lower Tyenna to better capture end-of-catchment loads. Data from Westerway (Figure 9a) show summer nutrient enrichment, likely from point sources, contrasting with typical seasonal patterns where uptake by algae limits nutrients in summer. This trend supports the influence of anthropogenic discharges during low flow conditions. To put this in context the EPA default guideline values for Nitrate in the Lower Derwent Catchment are 0.09 mg/L

Derwent River (Below Meadowbank Dam)

The EPA's Default Guideline Value (DGV) for nitrate in the Derwent River catchment is 2 ppb. The 80th percentile of the nitrate data for the River Derwent is 57 ppb. At the Derwent below Meadowbank Dam site, nitrate concentrations remained above DGV values (~100 ppb or 0.1mg/L) year-round, with a modest rise to ~0.1 mg/L NO_3-N in winter (Figure 10a). Phosphate levels were mostly undetectable except for peaks of ~300–500 ppb between January and March (Figure 10c), suggesting occasional inputs potentially linked to upstream land use or minor releases.

Overall river nutrient processes

In Tasmanian rivers, winter is typically associated with two key processes affecting nutrient dynamics: (1) reduced nutrient uptake by algae due to lower solar radiation, shorter photoperiods, and cooler water temperatures, and (2) increased nitrate flushing as catchment soils become saturated and subsurface flow pathways mobilise nitrogen from accumulated organic matter and fertiliser residues. This combination results in a sinusoidal seasonal pattern of nitrate concentrations, with winter peaks and summer troughs.

Importantly, these nitrate patterns often do not closely align with surface flow events, as much of the nitrogen is transported via slow-moving subsurface pathways (e.g. through groundwater or tile drainage, which is a type of subsurface drainage system), rather than rapid surface runoff. This is particularly true in temperate and semi-permeable catchments like those in Tasmania, where flashy storm-driven runoff is less dominant than in some agricultural landscapes overseas.

Similar seasonal dynamics have been observed in temperate river systems worldwide, including the UK, northern Europe, and the northeastern USA. For example, in the Thames and Seine catchments, nitrate concentrations peak in late winter to early spring due to post-fertilisation leaching and low biological uptake, while summer concentrations drop due to plant and algal assimilation. In contrast, phosphorus tends to be more event-driven, often spiking in response to high-flow events that mobilise particulate-bound P from soil and streambanks.

In Tasmania, phosphorus tends to remain at or below detection limits in many rivers, unless disturbed by point sources (e.g. hatcheries, STPs) or intensive land use, which contrasts with nitrate's more diffuse, seasonal signal.

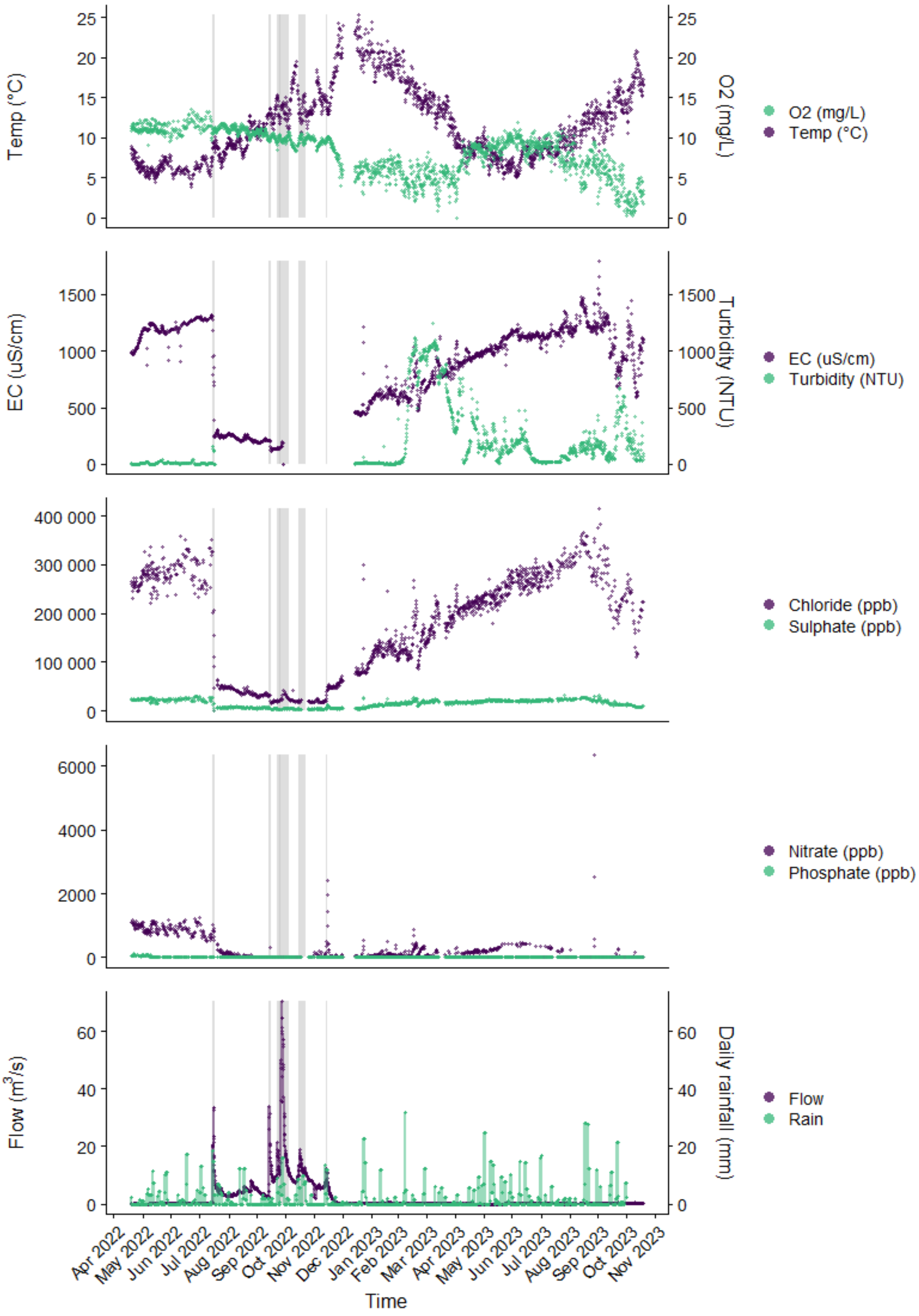

Figure 6a: In-situ analyser results for the River Clyde. The grey bars indicated the top 5% of flow.

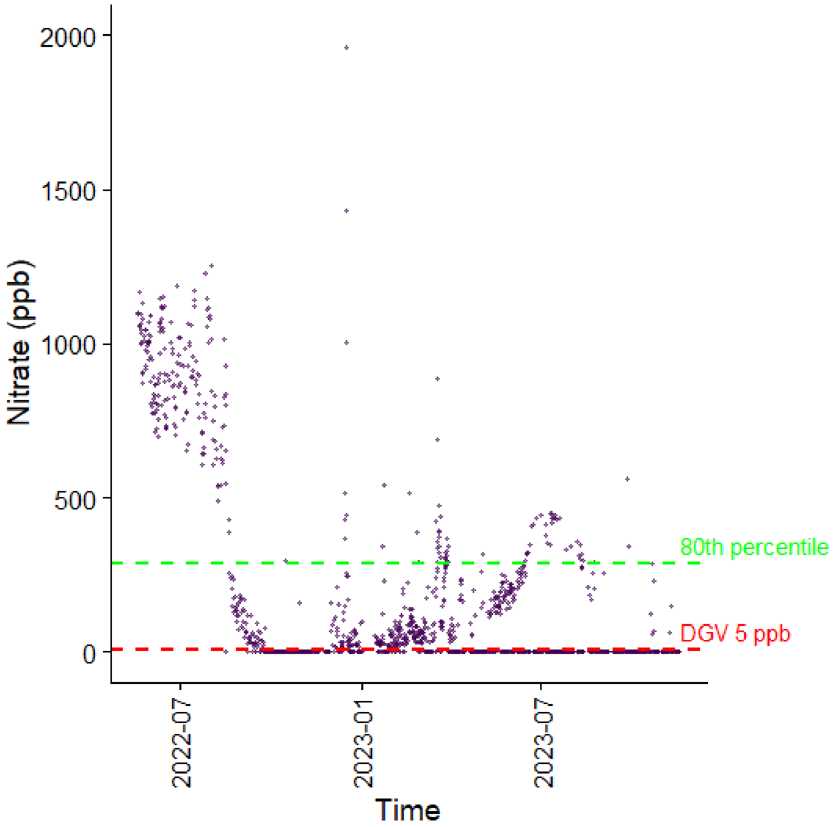

Figure 6b: Nitrate levels in the Clyde River. The red dashed line is the Default Guideline Value (DGV) which is 5 ppb and the 80th percentile for the data is 288 ppb and is the green dashed line. Note that this is a higher resolution version of figure 6a.

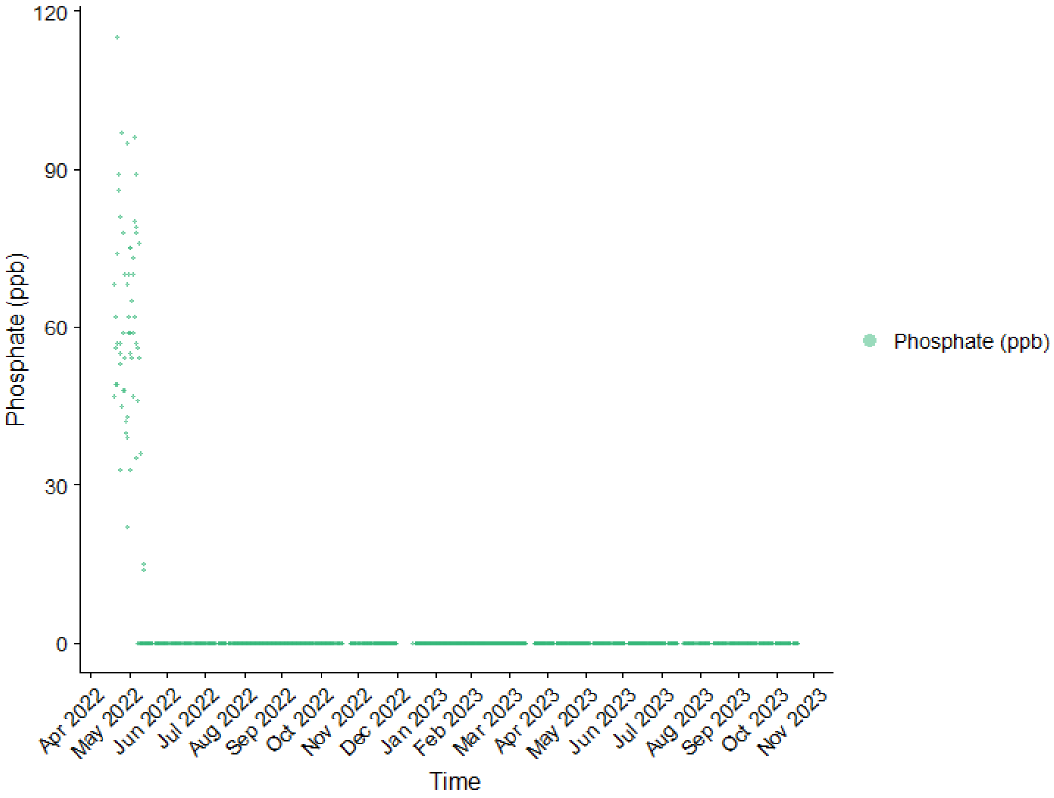

Figure 6c:Phosphate levels in the Clyde River. Note that this is a higher resolution version of figure 6a.

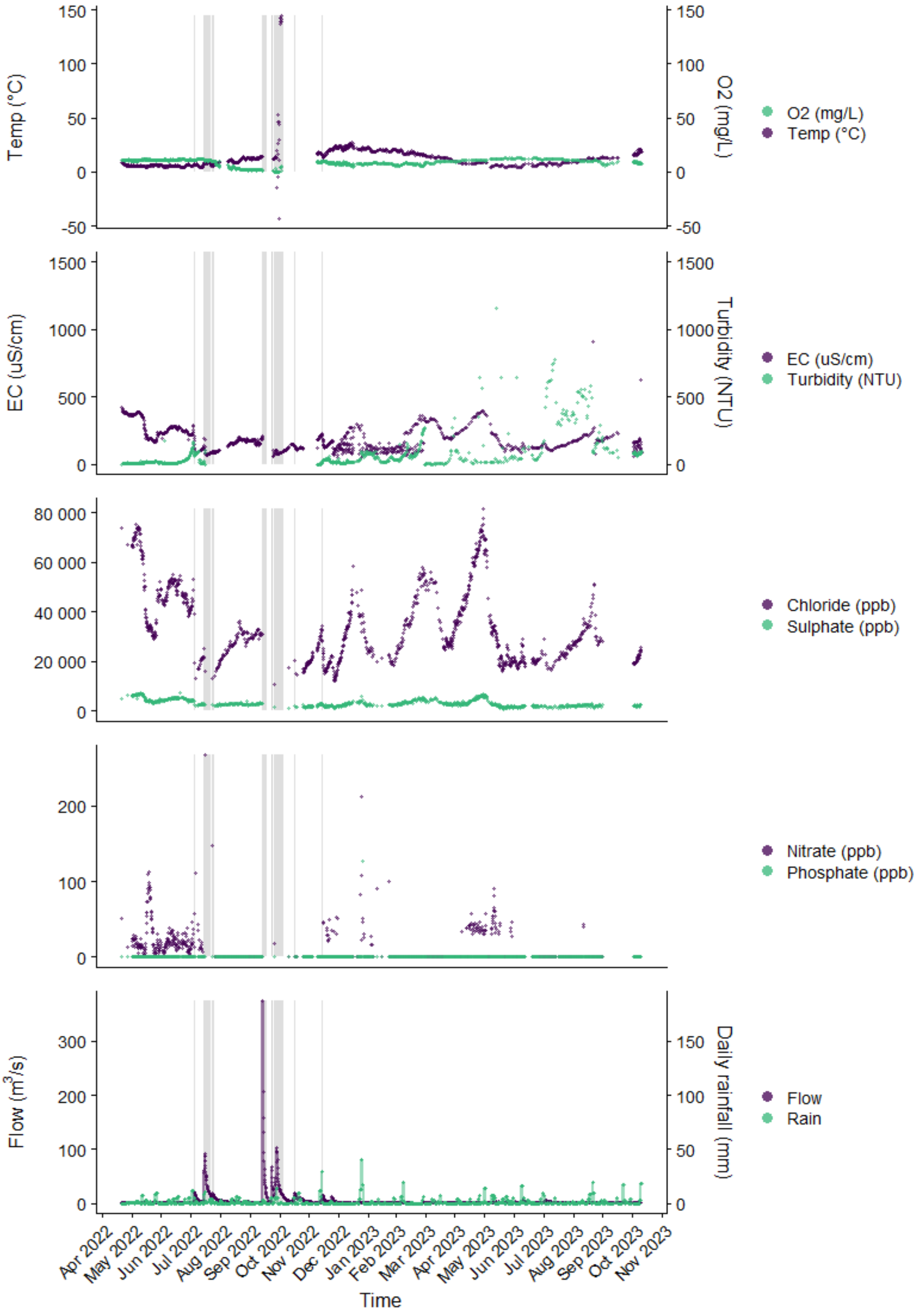

Figure 7a: In-situ analyser results for the River Ouse. Grey bars indicate the top 5% of flow.

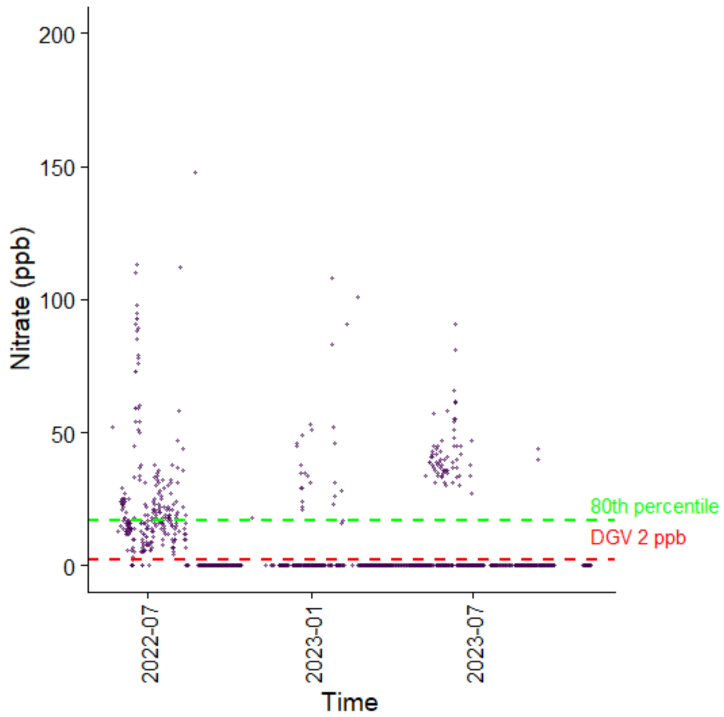

Figure 7b: Nitrate levels in the Ouse River. The red dashed line is the Default Guideline Value from the EPA. The green dashed line is the 80th percentile of the data which was 17 ppb. Note this is a higher resolution version of figure 7a.

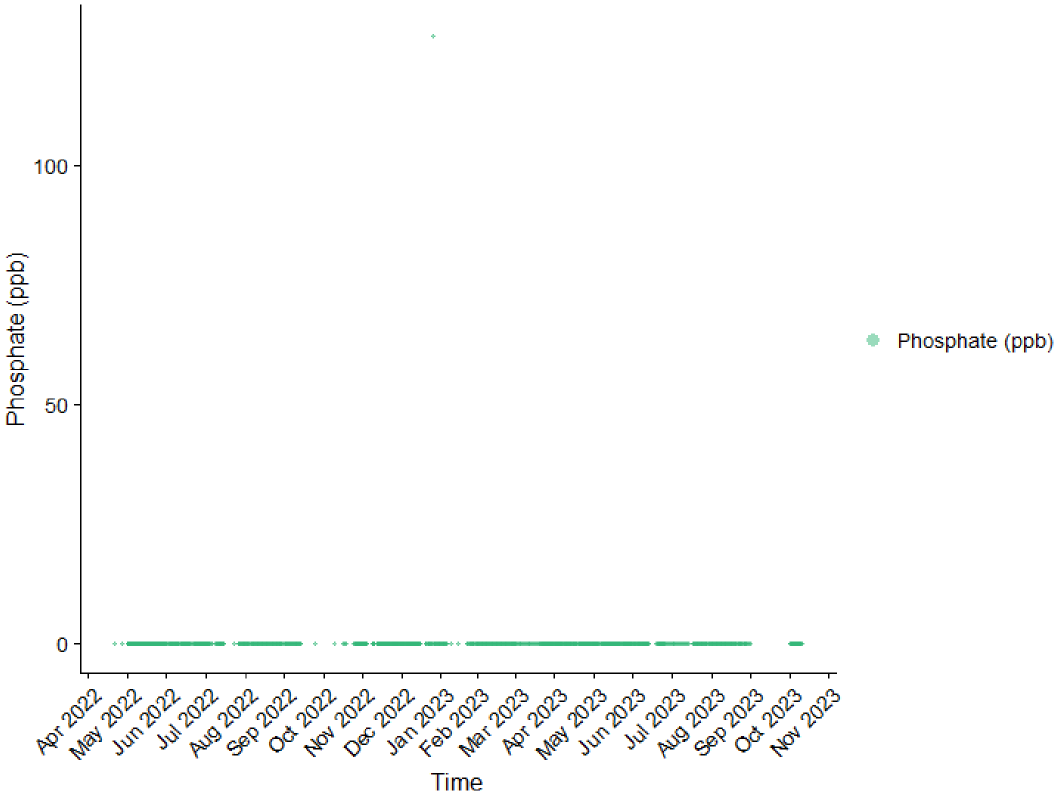

Figure 7c. Phosphate levels in the Ouse River. Note this is a higher resolution version of figure 7a.

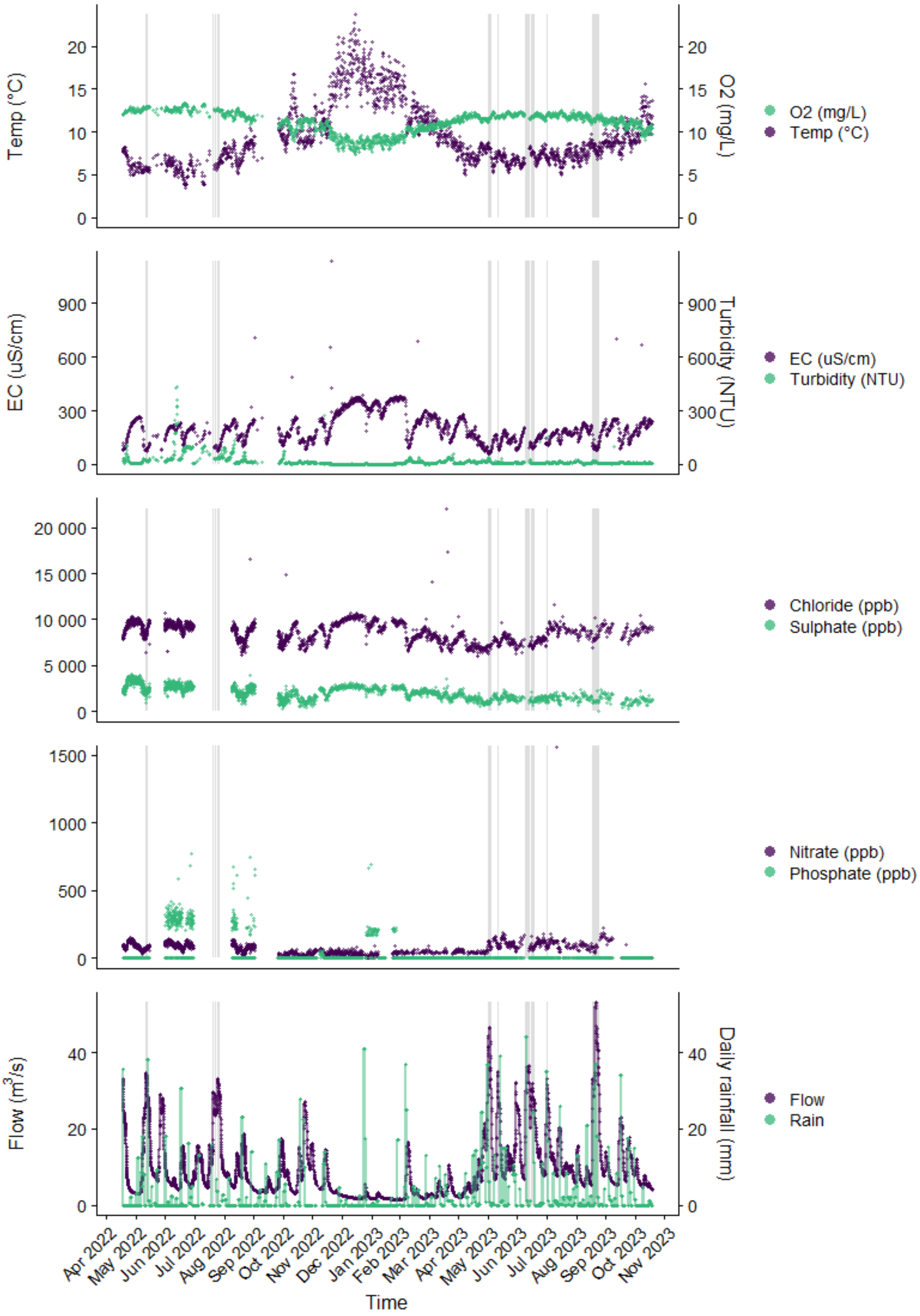

Figure 8a: In-situ analyser results for the Florentine River. Grey bars indicate the top 5% of flow.

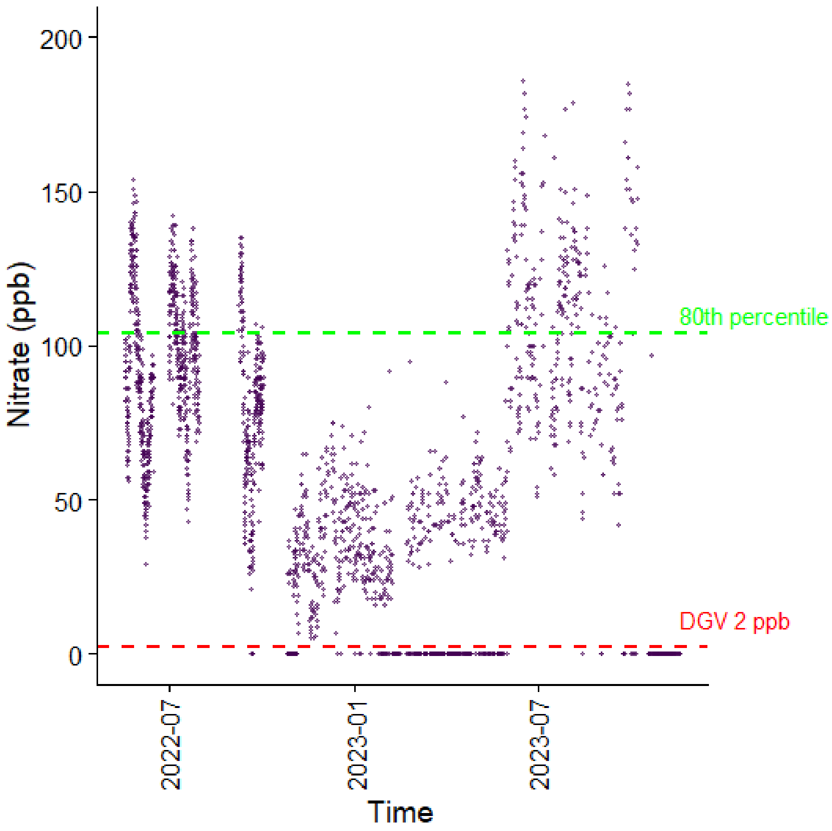

Figure 8b: Nitrate levels in the Florentine River. Red dashed line is the Default Guideline Value (DGV) from the EPA. Green dashed line is the 80th percentile of the data which is 104 ppb. Note that this is a higher resolution version of figure 8a.

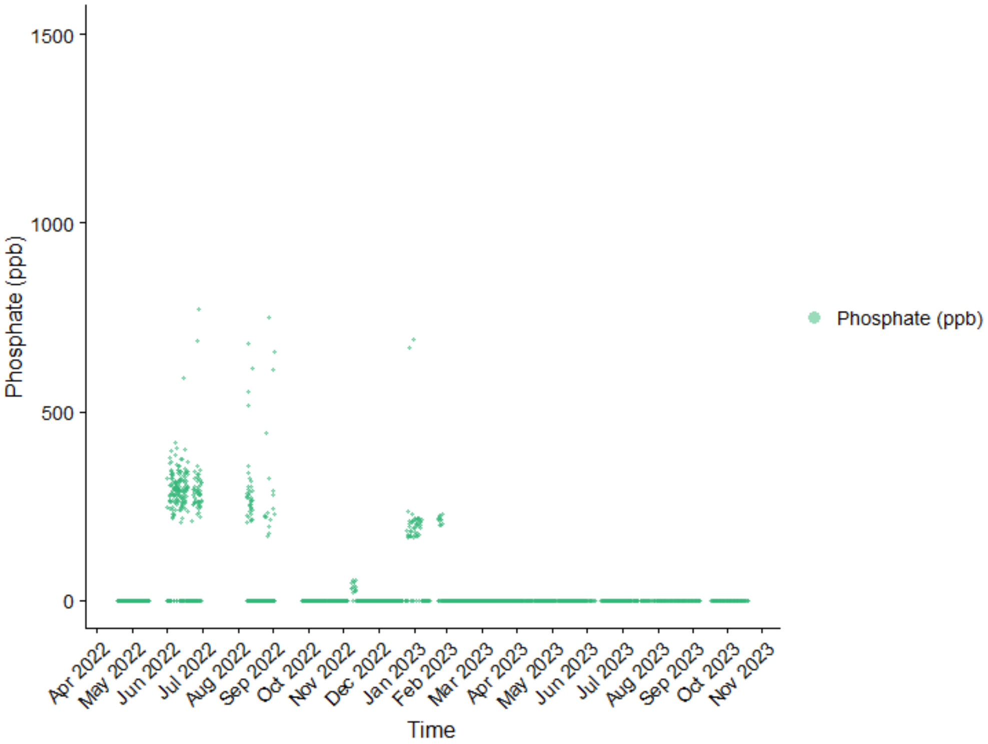

Figure 8c: Phosphate levels in the Florentine River. Note this is a higher resolution version of figure 8a.

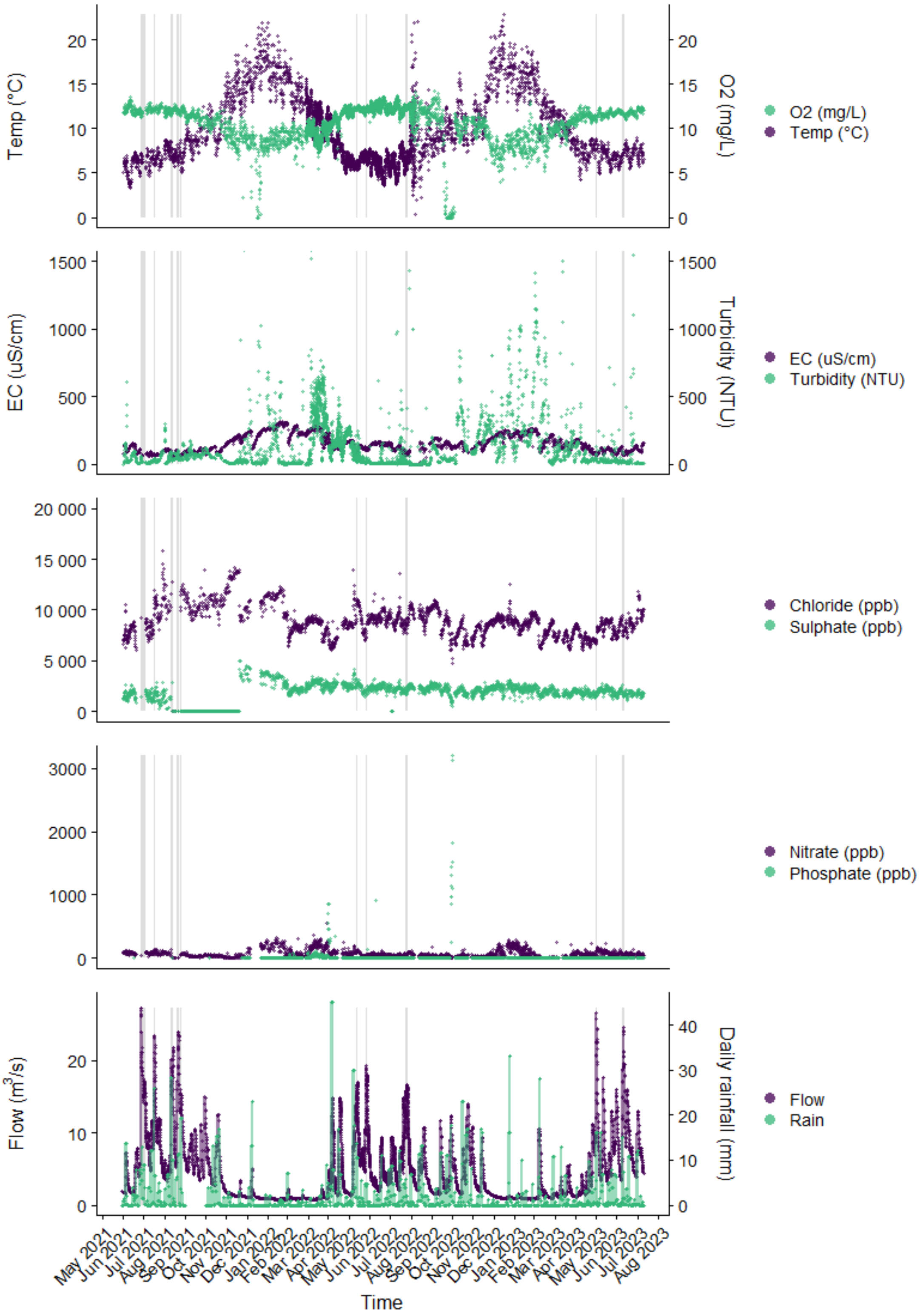

Figure 9a: In-situ analyser results for the Tyenna River. Grey bars indicate the top 5% of flow.

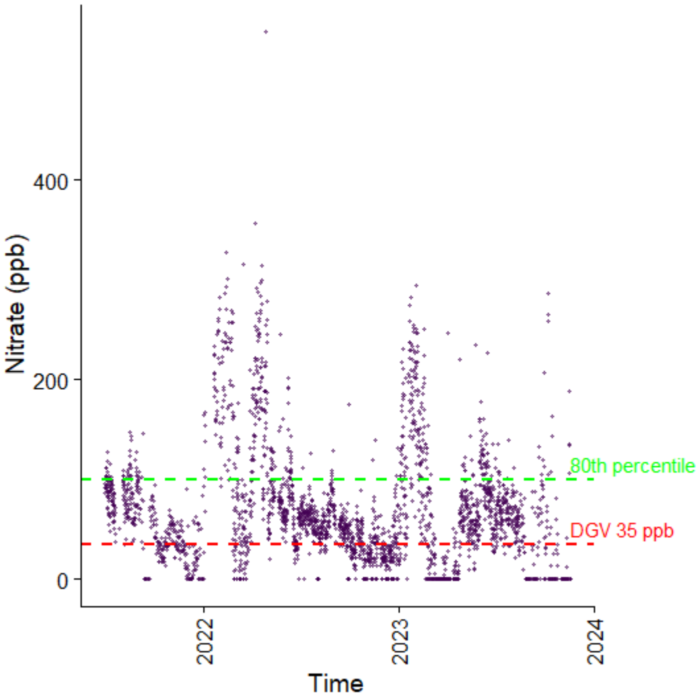

Figure 9b: Nitrate levels in the Tyenna River. Red dashed line is the Default Guideline Value from the EPA. Note this is a higher resolution version of figure 9a.

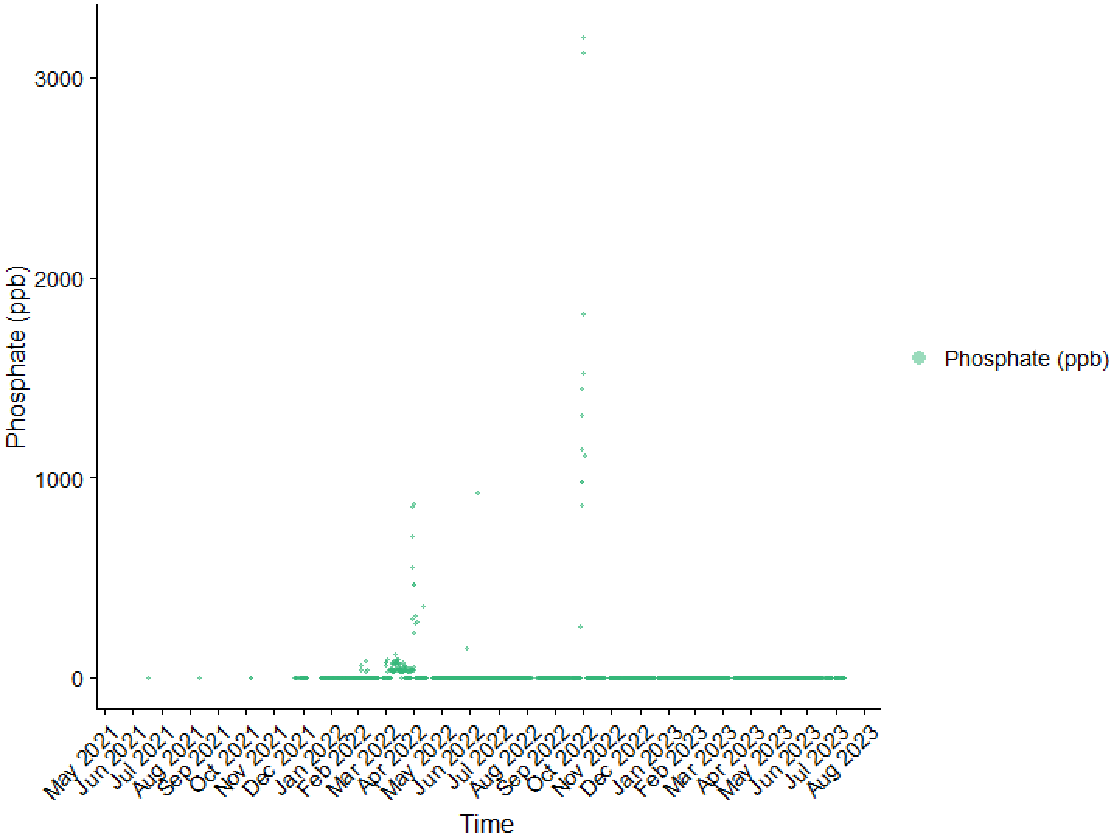

Figure 9c:Phosphate levels in the Tyenna River. Note this is a higher resolution version of figure 9a.

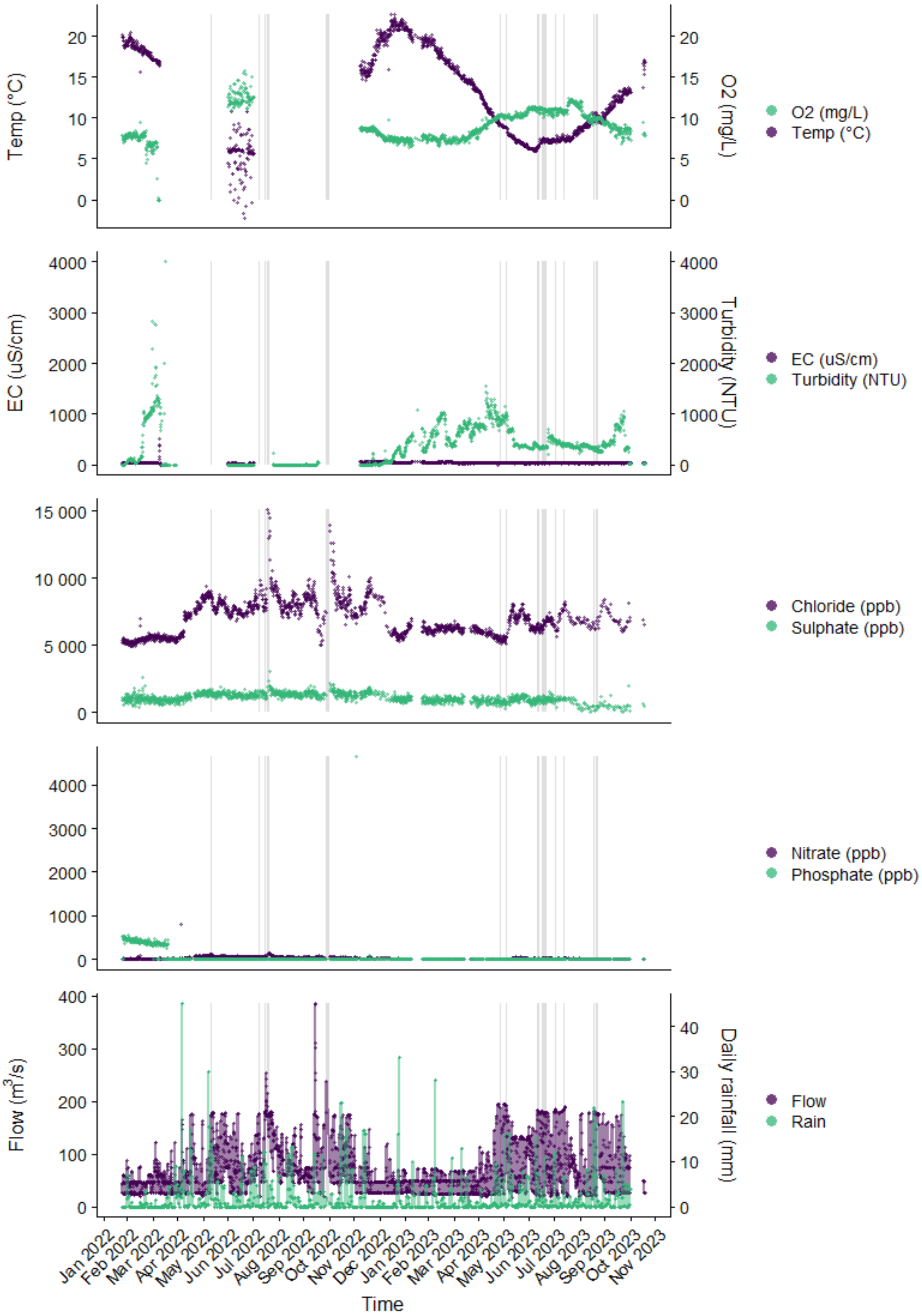

Figure 10a: In-situ analyser results for the River Derwent below Meadowbank Dam. Grey bars indicate the top 5% of flow.

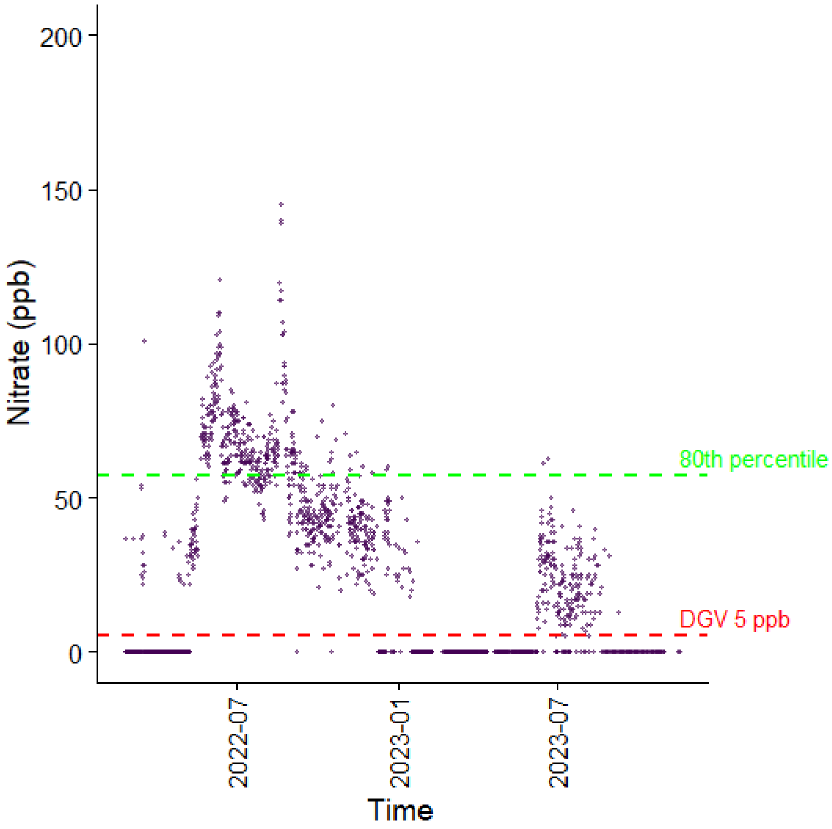

Figure 10b: Nitrate levels at River Derwent below Meadowbank Dam. Red dashed line is the EPA's Default Guideline Value (DGV). The green dashed line is the 80th percentile of the nitrate data which is 57 ppb. Note this is a higher resolution version of figure 10a.

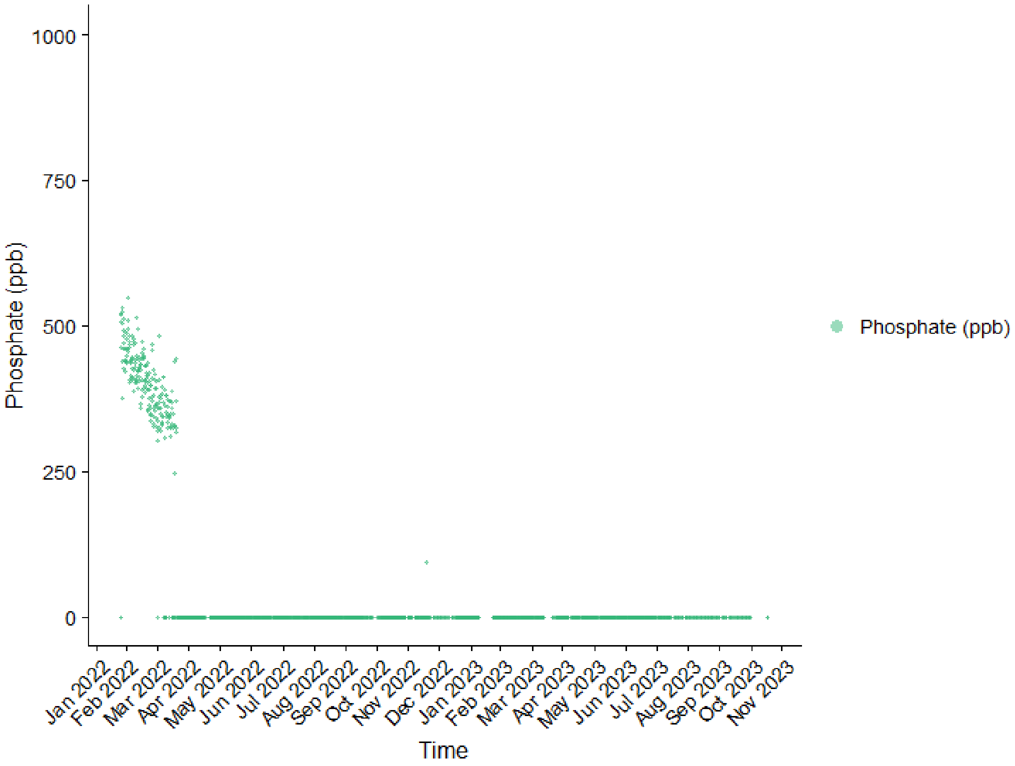

Figure 10c: Phosphate levels at River Derwent below Meadowbank Dam. Note this is a higher resolution version of figure 10a.

Nutrient Loads

In downstream receiving environments such as lakes, estuaries, and nearshore coastal waters, nutrient loads—commonly expressed as total nitrogen (TN) and total phosphorus (TP) in mass per year—are more ecologically meaningful than concentrations alone. These values are often normalised to catchment size (e.g. kg/ha/year) to assess nutrient export efficiency and compare across regions. While in-situ sensors such as the Eco Detection analysers provide high-frequency measurements of dissolved nutrient species (e.g. nitrate + nitrite and phosphate), these represent only a fraction of the total nutrient load, as they exclude particulate and organic forms.

In this study, we aim to extend the value of the Eco Detection data by presenting a novel parameter (Annual nutrient loads): which are similar to mass load estimates except they are based solely on dissolved nutrient concentrations, referred to below as "Annual nutrient loads". This approach allows for a more dynamic assessment of nutrient transport in near-real time, leveraging the temporal resolution of sensor data. However, we also acknowledge the limitations of this method, particularly that it captures only part of the nutrient budget. These limitations are discussed further below.

In Tasmanian rivers, nitrate + nitrite ($NO_3^- + NO_2^-$) typically account for only 10–20% of total nitrogen, with the remaining majority consisting of organic or particulate-bound nitrogen. Similarly, phosphate measured by sensors generally reflects dissolved reactive phosphorus (DRP), which can make up only a small fraction of total phosphorus, particularly during high-flow conditions that mobilise sediment-bound phosphorus.

As such, while real-time dissolved nutrient data are extremely valuable for detecting short-term variability and seasonal patterns, they should be interpreted within the broader context of total nutrient loads. This distinction is especially important in Tasmanian catchments, where nutrient form and transport mechanisms are closely linked to land use and seasonal hydrology. For example, winter nitrate peaks in agricultural catchments like the Clyde and Ouse are typically associated with soil flushing, while phosphorus is often tied to erosion events and sediment transport during heavy rainfall.

For each river site, four different estimates of annual nutrient loads (for nitrate + nitrite, and phosphate) were calculated. These estimates are:

1) Annual nutrient loads for 2023-2024, based on in-situ analyser measurements of nutrient concentrations and using instantaneous flow measurements
2) Annual nutrient loads for 2022-2023, based on in-situ analyser measurements of nutrient concentrations and using instantaneous flow measurements
3) Annual nutrient loads for 2022-2023, based on grab samples of nutrient concentrations and using instantaneous flow measurements
4) Annual nutrient loads for 2022-2023, based on grab samples of nutrient concentrations and using the monthly flow volume for the month in which each given sample was taken. The monthly flow volume is calculated using the average daily flow rate for the month.
5) Annual nutrient loads for 2015-2016 and 2016-2017, based on grab samples of nutrient concentrations and using instantaneous flow measurements (Proemse et al., 2018);(Proemse *et al.*, 2022)

Flow data was obtained from NRE and Hydro Tas sites as described in Proemse et al., (2022). Nutrient load results are shown in tables below. For any data series containing values below the LoR, the LoR was used, therefore providing a 'worst case' scenario. If a data series contained values only below the LoR, no estimate is given.

Summary tables by site

Table 3a. Clyde summary table

Estimate Method	Nitrate + Nitrite (kg/yr)	Phosphate (kg/yr)	Nitrate + Nitrite (Kg/ha/yr)	Total Nitrogen (Kg/year)	Total Phosphate (Kg/year)
Analyser samples, instantaneous load. 2023-2024	2243*	ID	0.02		
Analyser samples, instantaneous load. 2022-2023	7224	ID	0.065		
Grab samples, instantaneous load. 2022-2023	3289	559	0.029	26249	1660
Grab samples/monthly flow volume. 2022-2023	10273	669	0.092		
Grab samples, instantaneous load. 2015-2016	8226	335	0.074		
Grab samples, instantaneous load. 2016-2017	6346	488	0.057		

ID – insufficient data, * Analysis contained 14 days of missing data and a high proportion of zeros in the dataset

Table 3b. Florentine summary table

Estimate Method	Nitrate + Nitrite (kg)	Phosphate (kg)	Nitrate + Nitrite (kg/ha/yr)	Total Nitrogen (kg/year)	Total Phosphate (kg/year)
Analyser samples, instantaneous load. 2023-2024	ID	ID	ID		
Analyser samples, instantaneous load. 2022-2023	10263	1307	0.23		
Grab samples, instantaneous load. 2022-2023	16910	937	0.38	30019	1141 a
Grab samples/monthly flow volume. 2022-2023	18110	973	0.407		
Grab samples, instantaneous load. 2015-2016	22520	1296	0.506		
Grab samples, instantaneous load. 2016-2017	18528	1307	0.23		

ID – insufficient data, a-10 samples below detection limit

Table 3c. River Derwent below Meadowbank summary table

Estimate Method	Nitrate + Nitrite (kg)	Phosphate (kg)	Total Nitrogen (kg/year)	Total Phosphate (kg/year)
Analyser samples, instantaneous load 2023-2024	4990*	ID		
Analyser samples, instantaneous load. 2022-2023	61617	4394		
Grab samples, instantaneous load. 2022-2023	52340	6226	196071	10182
Grab samples/monthly flow volume. 2022-2023	72183	7551		
Grab samples, instantaneous load. 2015-2016	120473	10315	758291	31255
Grab samples, instantaneous load. 2016-2017	72344	10200	631474	30547

ID – insufficient data, * Analysis contained 56 days of missing data and a high proportion of zeros in the dataset

Table 3d. Ouse summary table

Estimate Method	Nitrate + Nitrite (kg)	Phosphate (kg)	Nitrate + Nitrite (kg/ha/yr)	Total Nitrogen (kg/year)	Total Phosphate (Kg/year)
Analyser samples, instantaneous load 2023-2024	ID*	ID*			
Analyser samples, instantanteous load. 2022-2023	2665	ID	0.015		
Grab samples, instantaneous load. 2022-2023	3084	730	0.017	23199	1235
Grab samples/monthly flow volume. 2022-2023	3151	958	0.018		
Grab samples, instantaneous load. 2015-2016	16244	869	0.093		
Grab samples, instantaneous load. 2016-2017	9093	972	0.052		

ID – Insufficient data, * Analysis contained 12 days of missing data and a high proportion of zeros in the dataset

Table 3e. Tyenna summary table

Estimate Method	Nitrate + Nitrite (kg)	Phosphate (kg)	Nitrate + Nitrite (kg/ha/yr)	Total Nitrogen (kg/year)	Total Phosphate (Kg/Year)
Analyser samples, instantaneous load. 2023-2024	3243*	124*	0.827		
Analyser samples, instantaneous load. 2022-2023	7127	4081	1.818		
Grab samples, instantaneous load. 2022-2023	6197	763	1.580	14867	899
Grab samples/monthly flow volume. 2022-2023	7964	881	2.031		
Grab samples, instantaneous load. 2015-2016	12352	1122	3.15		
Grab samples, instantaneous load. 2016-2017	8364	870	2.13		

* Analysis contained 15 days of missing data and a high proportion of zeros in the dataset

Annual nutrient load discussion

During the study period (2016 to 2024), annual nutrient loads across the catchments ranged from 2,243 to 120,473 kg/year, with the highest loads recorded at Meadowbank and the lowest at the Clyde River. When normalised by catchment area, the Tyenna River exhibited the highest export rate at 3.15 kg/ha/year in 2015/2016, while the Ouse River had the lowest at 0.015 kg/ha/year. Comparisons to other catchment regions is made difficult due to the lack of data in the same format of dissolved nutrients in annual nutrients loads. Comparing to the regions with TN and TP, typically TN export rates in heavily farmed catchments in southeast Australia can range from 5–10 kg/ha/year, while undisturbed forested catchments often export less than 0.1 kg/ha/year (Bartley et al., 2012). Annual phosphate loads ranged 4 to 7.5 tonnes per year.

Limitations – Mass load budgets for total nutrient v's total dissolved nutrients

Traditionally, nutrient data in river systems is reported as annual mass loads, expressed in kilograms per year (kg/yr) of total nitrogen (TN) or total phosphorus (TP) (Proemse et al., 2018). To account for differences in catchment size, these values are often normalised by the catchment area, resulting in units of kg/ha/yr. However, the current use of real-time nutrient analysers is limited to measuring only dissolved inorganic nitrogen in the form of nitrite + nitrate, and does not capture total nitrogen or total phosphorus concentrations. Nitrite + nitrate accounts for approximately 12 - 56% of the total nitrogen in river systems, highlighting a substantial gap in representing the full nitrogen load. The proportion of nitrogen present as nitrite + nitrate is typically highest in well-oxygenated rivers within agricultural catchments, or in systems where nitrification dominates and denitrification is minimal (Xingchen et al., 2024). In contrast, lower proportions are expected in river systems with high levels of organic nitrogen, anaerobic conditions, or enhanced denitrification (Dong et al., 2021).

The current study presents mass load estimates based solely on dissolved nutrient concentrations (i.e., nitrate + nitrite). It is important to note that, at the time of publication, few river systems have published load data based exclusively on dissolved nutrients, limiting opportunities for inter-catchment comparison. Broader adoption of real-time analyser technology is likely to improve this situation by enabling more consistent and comparable datasets across river systems.

Strengths – detection of dissolved nutrient pulses in river systems.

The capacity to measure real time pulses of dissolved nutrients is a major advantage of the Ion Q system. The Ion Q system demonstrates its value in situations where it may be necessary to monitor an outfall where the dissolved v's total nitrogen relationship is well understood. Additionally if a spike in dissolved nutrients is detected it is a valuable early warning sign that total nutrients may also be increasing.

Next steps

This suite of data has provided invaluable insights into instrument performance and end-users' needs, which have led to improvements in the Ion-Q® released to market in 2023. Examples of improvements include reduction of chloride interference on nitrate measurements and material changes in filtration paper. Furthermore, substantial stakeholder engagement during the trial has identified two key barriers that currently impede industry uptake and two opportunities that capitalise on the capabilities of this technology.

Barrier 1: Detection limits and ranges of parameters. A major market advantage of the real-time analyser technology using CE is the simultaneous detection of nitrate, nitrite, ammonium and phosphate, covering all key nutrients at the same time. The limits of detection are currently 30 ppb for nitrite and nitrate, 200 ppb for ammonium and 100 ppb for phosphate. While nitrogen limits are sufficient for a large range of industry applications, some end-users require phosphate concentrations in the 5-100 ppb range, which has previously not been detectable. This has now been achieved in laboratory experiments but not yet demonstrated to end-users. It is worth noting that for broadscale riverine sampling it is expected that limits of reporting be 1 ppb for DRP, 2ppb for NH4-N as well as measuring TN and TP.

Barrier 2: Accreditation of analysers. The current default data quality requirement for compliance monitoring by EPAs in Australia is NATA (National Association of Testing Authorities). Given the application of Eco Detection's novel technology outside of a conventional laboratory environment, there is no clearly identified pathway for the Eco Detection units to become NATA-accredited. Therefore, data generated by the Ion-Q® cannot currently replace environmental compliance grab-to-lab protocols, providing no monitoring cost benefit to industry end-users.

Opportunity 1: Improved accuracy and appropriateness of guidelines. The National Water Quality Management Strategy (NWQMS) and Water Quality Australia encourage and provide frameworks for developing locally-appropriate guideline values for nutrients and other pollutants. These opportunities are rarely exploited because of the high costs of grab-to-lab sampling programs, resulting in inefficient, infrequent (e.g., monthly) sampling and adoption of default guideline values (DGVs) which may not be locally appropriate. Access to high-frequency lab-quality real-time data now constitutes an unprecedented level of data availability, which will help understand the severity of data aliasing (data contamination by sampling too infrequently) in water quality monitoring, inform setting of catchment specific DGVs, and determine ideal sampling rates for a range of different monitoring purposes.

Opportunity 2: Diagnosis of sources, sinks and remediation. Catchment managers need to identify sources, sinks and potential restoration and infrastructure investments for nutrient offsetting, but are hampered from doing so because of the poverty of high frequency nutrient data from diffuse sources and sinks specific to land uses. Unprecedented availability of high-frequency lab-quality data opens opportunities for industries to undertake innovative projects like those recently announced by DEP stakeholder TasWater. TasWater's

Corporate Strategy (2024) aspires to significant reductions in nutrient discharge of sewage treatment plants to waterways. TasWater is therefore investigating a range of infrastructure upgrades as well as nutrient offsetting opportunities. Nutrient offsetting is a mechanism by which point source pollution may be offset by diffuse source nutrient reductions and/or nutrient load reductions from other point sources. While such frameworks currently do not exist in Tasmania, it has been highlighted in other states and globally that nutrient offsetting requires knowledge of accurate nutrient loads which can only be achieved with high frequency nutrient monitoring (Lu *et al.*, 2023).

Analyser use going forward

The rivers Clyde, Ouse and Tyenna, will be monitored by the Derwent Catchment Project using Eco Detection's real-time analyser technology. A new monitoring site at the end of the River Derwent catchment will be installed in February 2025. This new site is situated just upstream (7 km) of Bryn Estyn, Hobart's Drinking Water Treatment Plant, and will be comprised of a real time high frequency flow gauge and a real time high frequency Eco Detection water quality analyser. This site is fundamental for understanding pollutant loads into the upper estuary, as well as inform environmental flow requirements to the Derwent Estuary.

Industry partner TasWater has adopted the technology and already deployed three newly acquired analyser units across the State.

Conclusions

The deployment of real-time nutrient analysers has provided an unprecedented opportunity to investigate nutrient dynamics across the Derwent Catchment. These instruments offer clear advantages, particularly in detecting short-term spikes in nutrient concentrations within rivers. However, their current limitations include relatively high detection limits and the inability to measure total nutrient loads, such as total nitrogen and total phosphorus. As the technology is further adopted their value will increase as there will be more dissolved nutrient datasets to compare to.

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