# Surface water quality – chemical assessment

Assessment of surface water and sediment quality in the vicinity of power stations and coal ash repositories in Lake Macquarie, NSW

**Department of Climate Change,**
**Energy, the Environment and Water**

## Acknowledgement of Country

Department of Climate Change, Energy, the Environment and Water acknowledges the Traditional Custodians of the lands where we work and live.

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Report prepared by DCCEEW for the New South Wales Environmental Protection Authority (NSW EPA)

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# Executive summary

This report presents the findings of an assessment of surface water quality in Lake Macquarie (NSW, Australia) based on monthly sampling conducted between March 2022 and February 2023. Samples were collected from 29 sites and analysed for physicochemical indicators, nutrients, and metals/metalloids. The specific objectives of the study were to:

- Determine contaminant concentrations and distributions within surface water adjacent to the power stations and, more broadly, within the southern section of Lake Macquarie.
- Undertake a screening assessment of the measured contaminant concentrations within Lake Macquarie against Australian water quality guideline values to identify contaminants of potential concern (CoPC) to the health of ecological receptors within surface waters.

Overall, the water quality parameters assessed were generally within the recommended range of relevant default guideline values (ANZG, 2018; ANZECC/ARMCANZ, 2000; DCCEEW, 2024). The key findings were as follows:

- The physicochemical parameters of dissolved oxygen, pH, total suspended solids, and turbidity were all below (or within) guideline values for NSW estuaries except for a few localised exceedances.
- Temperature differences were observed across the lake with variations of as much as 5 to 10°C observed within a single sampling event. Elevated temperatures relative to other sites were observed within the receiving waters for the Eraring Power Station cooling water outlet and the Vales Point Power Station cooling water outlet.
- Median concentrations of total nitrogen and total phosphorus concentrations were below guideline values for NSW estuaries at all sites. Oxidised nitrogen, ammonia nitrogen, and dissolved phosphorus concentrations exceeded guideline values on several occasions around the foreshore areas in the southwest basin and Wyee Bay, while concentrations in the main body of the lake were below guideline values. Free reactive phosphorus concentrations usually exceeded guideline values across all sites sampled.
- The concentrations of eight metals (cadmium, chromium, lead, mercury, nickel, selenium, silver, and vanadium) were below the screening criteria for all surface water samples collected. Seven metals (aluminium, arsenic, cobalt, copper, manganese, molybdenum, and zinc) had at least one exceedance during the monitoring program. Arsenic, cobalt, and molybdenum concentrations were below the screening criteria on ≥99% of all occasions and were not considered contaminants of concern in surface waters. Aluminium, copper, manganese, and zinc exceeded the screening criteria at some sites, indicating potential concerns. However, concentrations were below the criteria on 96%, 78%, 99%, and 96% of all sampling occasions, respectively. Low concentrations of dissolved copper (<0.001 - 0.004 mg/L) exhibited a relatively even distribution across the lake. DOC was found at concentrations that would likely provide some amelioration of the adverse effects from the copper concentration range measured. Aluminium and zinc concentrations were similar between the northern and southern sections of the lake and appear to be related to freshwater inflows bringing these contaminants from the catchment (via Dora Creek and Wyee Creek within the southern section of the lake). A single site, located within Dora Creek, exceeded the screening criterion for manganese on a few occasions.
- Sampling was conducted during both dry and wet conditions and thus captured both background/ambient concentrations and occasions where concentrations were likely to be elevated following rain events. Consideration of rainfall patterns identified that the sampling

period was the wettest year on record within the preceding 10-year period. During the monitoring program, a single coal ash repository over-boarding event occurred at the Vales Point Power Station. Data from four samples collected during this event showed that the addition of over-boarded water to Wyee Creek had no significant adverse influence on metal/nutrient concentrations downstream of the discharge into Wyee Creek.

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# Glossary of acronyms and common terms

| **Acronyms** | |
|---|---|
| APHA | American Public Health Association |
| ALS | Australian Laboratory Services |
| ANZECC/ARMCANZ | Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand |
| ANZG | Australian and New Zealand Governments |
| BOM | Australian Bureau of Meteorology |
| DGV | Default guideline value |
| DOC | Dissolved organic carbon |
| DCCEEW | Department of Climate Change, Energy, the Environment and Water |
| DQO | Data quality objectives |
| EF | Environmental Forensics |
| FRP | Free reactive phosphorus |
| GV | Guideline value |
| ICP-OES | Inductively coupled plasma optical emission spectrometry |
| ICP-MS | Inductively coupled plasma mass spectrometry |
| LOR | Limit of reporting |
| NATA | National Association of Testing Authorities |
| NOx/NH-N | Oxidised nitrogen/ammonia nitrogen |
| NSW EPA | New South Wales Environment Protection Authority |
| PCA | Principal components analysis |
| PES | Polyethersulfone |
| QA/QC | Quality assurance and quality control |
| RPD | Relative percentage difference |
| SAQP | Sampling, Analysis and Quality Plan |
| S&I | Science and Insights |
| SWEL | Soil and Water Environmental Monitoring Laboratory |
| TN/TDN | Total nitrogen/Total dissolved nitrogen |
| TP/TDP | Total phosphorus/total dissolved phosphorus |
| TSS | Total suspended solids |
| US EPA | United States Environmental Protection Agency |

| **Definitions** | |
|---|---|
| Bioavailable /bioavailable fraction | Able to be taken up by an organism / a relative measure of the proportion of a chemical that an organism is exposed to through water, sediment, soil, suspended particles, organic carbon and/or food |
| Catchment | The area of land that rain lands in and drains into waterways |

| | |
|---|---|
| Container blank | Prepared in the laboratory to identify contamination coming from sampling equipment such as vials and filters |
| Contaminants/toxicants | Biological or chemical substances or entities, not normally present in a system, capable of producing an adverse effect in a biological system, seriously injuring structure or function |
| Dissolved contaminant | Operationally defined by what will pass through a 0.45 µm filter |
| Ecosystem | A community of plants, animals, bacteria and the interrelated chemical and physical environment |
| Field blank | Prepared in the field during a sampling event and submitted to the laboratory to identify contamination occurring during the collection and transport of the environmental samples |
| Guideline value | Measurable quantity (threshold) or condition of an indicator for a specific community value below or, for some stressors, above which we consider to be a low risk of unacceptable effects occurring |
| Organism | Any living animal or plant; anything capable of carrying on life processes |
| Percentile | Interval in a graphical distribution that represents a given percentage of the data points |
| Speciation | Measurement of different chemical forms or species of an element in a solution or solid |
| Total contaminant | Determined on an unfiltered sample, is a measure of both the particulate (insoluble) concentration and the dissolved (soluble) concentration of the contaminant |

| Units | |
|---|---|
| °C | Degree Celsius |
| km | Kilometre |
| GL | Gigalitre |
| m | Metre |
| min | Minute |
| mg/kg | Milligrams/Kilogram |
| mg/L | Milligrams/Litre |
| µg/L | Micrograms/Litre |
| pH | Potential Hydrogen |
| PSU | Practical salinity units |

# 1. Introduction

## 1.1 Project overview

The Science and Insights Division (S&I) of the New South Wales (NSW) Department of Climate Change, Energy, the Environment and Water (DCCEEW) was engaged by the NSW Environment Protection Authority (EPA) to undertake an independent assessment of surface water and sediment quality within the southern section of Lake Macquarie, NSW, Australia. The main purpose of this investigation was to obtain information to facilitate the EPA's contribution to the NSW Government's response to the recommendations in the NSW Parliamentary Inquiry's report into the costs of remediation of coal ash repositories (Parliament of NSW, 2021). The information gathered herein provides a present-day assessment of the contamination status of Lake Macquarie against which future changes, impacts, and/or mitigation and remediation activities can be assessed.

The scope of works outlined in the Sampling, Analysis, and Quality Plan (SAQP) (DPE, 2023) has been developed to (i) determine present-day concentrations of metals and metalloids (hereafter referred to as "metals" for simplicity) and nutrients to assess surface water quality, (ii) delineate the extent of metal contamination in sediments, and (iii) assess the potential risks to ecological receptors in the vicinity of the power stations, coal ash repositories, and more broadly within the southern section of Lake Macquarie. The project was broken up into a series of stages, as described in the SAQP (DPE, 2023).

The current report provides a screening level risk assessment and indication of surface water quality following 12 months of monthly sampling carried out within Lake Macquarie between March 2022 and February 2023.

## 1.2 Aims and objectives

The primary aim of this surface water quality investigation was to measure the current concentrations of metals and nutrients in surface waters within southern Lake Macquarie and assess the risk that they pose to ecological receptors.

The specific objectives to be addressed were to:

- Characterise contaminant concentrations and distributions within surface water adjacent to the power stations and, more broadly, within the southern section of Lake Macquarie.
- Conduct a screening assessment of the measured contaminant concentrations within Lake Macquarie against Australian water quality guideline values to identify contaminants of potential concern (CoPC) to the health of ecological receptors within surface waters.

## 1.3 Project location

Lake Macquarie (Awaba) is the largest coastal saltwater lake in the Southern Hemisphere. It is located in the Lower Hunter Region of NSW, Australia, approximately 90 km north of Sydney. The lake is described as a temperate, wave-dominated barrier estuary with a small tidal range (maximum tidal range of around 30 cm) and a permanent entrance connecting it to the Pacific Ocean at Swansea Channel. Shallow waters exist between Swansea and Wangi Wangi Point and allow for the lake to be operationally defined into northern and southern sections about this latitudinal axis.

Key geographical features of Lake Macquarie are summarised in Table 1. The lake's catchment area is about 604 km$^2$ (Roper et al., 2011) and receives an average total surface flow from the catchment of about 85 GL/year (DPIE, 2020). The largest sub-catchments discharging into the lake are Dora Creek and Wyee Creek in the southern section and Cockle Creek and Stony Creek in the northern section. The estuary hydrodynamic processes are primarily wind-driven circulation, catchment flows from rainfall and, in the southern section of the lake, the intake and discharge of cooling waters from the Eraring and Vales Point Power Stations.

Former and current heavy industry have largely been situated on the north, west and southern shores of the lake. In the northern section of the lake, the most significant industries have included a lead and zinc smelter, a fertiliser plant, a steel foundry, collieries, and wastewater treatment works (Batley, 1987). In the southern section of the lake, the most significant industries have included coal-fired power stations, coal washeries and wastewater treatment works (Batley, 1987). The Vales Point Power Station (established in 1963, currently operated by Delta Electricity), the Eraring Power Station (established in 1981, currently operated by Origin Energy), and the decommissioned Wangi Power Station (operated between 1956 and 1986) are the three coal-fired power stations that have been situated on the southern shores of Lake Macquarie.

**Table 1. Key geographical features of Lake Macquarie**

| Characteristics | Value | Reference |
|---|---|---|
| Average lake volume | 666 GL | DPIE, 2020 |
| Maximum depth | 13 m | DPIE, 2020 |
| Average depth | 8 m | DPIE, 2020 |
| Length of shoreline perimeter | 170 km | DPIE, 2020 |
| Total surface flows from catchment (estimate) | 85 GL/y | DPIE, 2020 |
| Estuary surface area | 113 $km^2$ | Roper et al., 2011 |
| Catchment surface area | 604 $km^2$ | Roper et al., 2011 |
| Annual rainfall (1975-2007) | 988 mm | Roper et al., 2011 |
| Annual evaporation (1975-2007) | 1516 mm | Roper et al., 2011 |
| Tidal flushing time | 249.9 days | Roper et al., 2011 |

# 2. Methods

## 2.1 Sample collection

The water quality monitoring program ran from March 2022 to February 2023 and included monthly sampling at up to 29 sites. Each month, sampling was spread over two days. Nine of the sampling events occurred on consecutive days and three occurred on consecutive weeks.

At each site, physicochemical parameters (including temperature, specific conductance (i.e., conductivity), dissolved oxygen (DO), pH, and turbidity) were recorded using a calibrated multi-parameter water quality probe (YSI EXO2 or ProDSS models) which was held below the surface (20–40 cm depth). The collection of surface water physicochemical indicators (including temperature, conductivity, DO, pH, turbidity, total suspended solids (TSS) and dissolved organic carbon (DOC)) was undertaken to provide useful contextual data to assist in interpreting results (e.g., the influence of physical and seasonal drivers on the lake's water quality). Descriptions of the water quality indicators are provided in Table 2.

To avoid cross-contamination, a new set of disposable, powder-free nitrile gloves was worn at each site and disposed of at the end of each site. All samples were collected in new, laboratory-prepared sample containers The containers were rinsed with the water intended for collection before the samples were taken. All samples were kept on ice within an insulated chest during sampling. Samples for nutrient analysis were frozen (<-20°C) as soon as feasible and on the same day of collection. All other samples (for metals, TSS and DOC analyses) were stored at 4°C until analysis.

Discrete samples for total metal analysis were collected into acid-washed containers from the surface (20-40 cm depth) using a sampling pole rinsed with site water. From this sample, a 60 mL syringe and 0.45 µm polyethersulfone (PES) syringe filter (Microscience - SF35PS045) were used to collect a subsample into a second acid-washed container for dissolved metal analysis. The syringe and filter were pre-rinsed with the sample. Both samples were acidified (pH <2) with nitric acid (Ultrapure, ARISTAR® ULTRA, VWR Chemicals BDH, England) upon return to the laboratory. Discrete water samples were collected directly into laboratory-prepared containers to minimise the potential for introducing contamination to the samples.

For boat-based sample collection, integrated water samples were collected from the surface to 1 m depth over a 2 min drift, pooling samples in a 10 L bucket to be used for collecting nutrient, TSS, and DOC subsamples. Subsamples from the bucket were first collected for nutrients using a 60 mL syringe and 0.45 µm PES syringe filter (Sartorius Minisart® – 16533K) to collect one 30 mL vial of unfiltered water, and two 30 mL vials of filtered water (for total, dissolved inorganic, and dissolved organic nutrients, respectively). Subsampling was then done for DOC using a 60 mL syringe and 0.45 µm PES syringe filter to collect one 50 mL amber vial, containing a few drops of sulfuric acid as a preservative. Lastly, a 2 L container was used to collect a sample for TSS, ensuring the bucket was agitated to resuspend any settled particles. Integrated water samples were collected to reduce the influence of small-scale variation of concentration at a site. For land-based sample collection, TSS samples were collected as discrete samples using the sampling pole. Subsamples for nutrients and DOC were collected in the manner described above but from the TSS container instead of a bucket.

A field duplicate water sample (for intra-laboratory analysis) was collected at a rate of 1 in 20 samples for the analysis of metals (total and dissolved), nutrients (total, dissolved inorganic, and dissolved organic), TSS, and DOC with sites selected at random before sampling commenced. A laboratory duplicate sample (for inter-laboratory analysis) was collected at every sample collection round and analysed for metals (total and dissolved) and nutrients (total, dissolved inorganic, and dissolved organic). A field blank was collected for each sample collection round for metals (total and dissolved) and on three sampling occasions for nutrients (total, dissolved inorganic, and dissolved organic). Further details on the quality assurance and quality control (QA/QC) measures implemented in the current study are provided in Appendix A – Data quality assessment.

**Table 2. Description of water quality indicators measured in situ**

| Water quality indicators | Description |
|---|---|
| Temperature | Temperature is a physical quantity that expresses quantitatively the perceptions of hotness or coldness. |
| Conductivity | Is a measure of the ability of water to conduct an electric current. This ability is directly related to the concentration of dissolved ions (usually salts) in the water. Provides an indication of freshwater or marine water. |
| Dissolved oxygen | Is a measure of the amount of oxygen dissolved in a water sample. Dissolved oxygen enters water via photosynthesis by aquatic biota and by the transfer of oxygen across the air-water interface. It is a necessary parameter for the survival of aquatic organisms. |
| pH | Is a measure of the acidity or alkalinity of a solution, with a range from 0 (most acidic) to 14 (most alkaline). Influences many chemical and biological processes. |
| Turbidity | Refers to the relative clarity of a water sample. It is a measure of the scattering and absorption of light by suspended particles in the water. This affects the amount of light available for photosynthesis. |

## 2.2 Chemical analyses

### 2.2.1 Physicochemical indicators

A summary of surface water analyses, laboratories, and methodologies are provided in Table 3.

*Total suspended solids*

TSS refers to the total mass of solid particles that are suspended in a water sample. It can be comprised of both inorganic and organic suspended solids and can be influenced by physical processes (e.g., rainfall, flocculation, dredging, shipping movements, wind, and tidal-driven resuspension) and biological processes (e.g., phytoplankton production, and organic enrichment). TSS analysis was performed by the DCCEEW Environmental Forensics (EF) Laboratory using in-house National Association of Testing Authorities (NATA) accredited methods based on American Public Health Association (APHA) Method 2540 D: *Total Suspended Solids Dried at 103–105°C*. In brief, the sample is filtered through a pre-weighed glass-fibre filter (pore size 1.2 mm). The residue retained on the filter is dried in an oven at 103–105°C until constant weight. The increase in weight of the filter represents the TSS.

*Dissolved organic carbon*

DOC was included in the analysis suite as it is an important local water quality variable that has the potential to reduce the bioavailability of some metals through complexation. DOC analysis was performed on filtered samples by the Australian Laboratory Services (ALS) using an in-house NATA-accredited method based on APHA method 5310 B: High-Temperature Combustion Method. In brief, samples were combusted at high temperature in the presence of an oxidative catalyst. The evolved carbon dioxide was quantified using an infrared detector.

### 2.2.2 Nutrients

Total nitrogen was measured in unfiltered samples (commonly referred to as TN) and total dissolved nitrogen was measured in paired filtered samples (commonly referred to as TDN). The amount of nitrogen present as oxidised nitrogen (the sum of nitrate and nitrite, also commonly referred to as NOx) and as total ammonia nitrogen (the sum of ammonia and ammonium, also commonly referred to as NH-N) was also measured in filtered samples. Oxidised nitrogen and ammonia are the reactive inorganic forms of nitrogen which are generally considered to be more bioavailable. Total phosphorus was measured in unfiltered samples (commonly referred to as TP) and in paired filtered samples (commonly referred to as TDP). The amount of phosphorus present as free reactive phosphorus was also measured in filtered samples. Free reactive phosphorus (commonly referred to as FRP) is the amount of simple inorganic phosphorus (such as orthophosphate) and is considered more bioavailable than other forms of phosphorus. Paired samples mean that the samples were collected in a single syringe draw and divided between the unfiltered and filtered sample containers.

Nutrient analyses were performed by the DCCEEW Soil and Water Environmental Monitoring Laboratory (SWEL) using in-house methods based on APHA Methods: 4500-$NO_{3\text{-}I}$: *Cadmium Reduction Method* (for nitrate), 4500-$NH_3$-H: *Phenate Method* (for ammonium-N), 4500-P-E: *Ascorbic acid method* (for FRP), and 4500-P-J: *Persulfate Digestion* (for TN, TP, TDN, and TDP). Sydney Water was utilised as a secondary laboratory for nutrient analysis as part of the inter-laboratory comparison for QA/QC procedures.

### 2.2.3 Metals

A general suite of metals of concern for marine environments were investigated as part of the current study and included aluminium (Al), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), silver (Ag), vanadium (V), and zinc (Zn). Additional metalloids of concern for marine environments investigated as part of the current study included boron (B), arsenic (As), and selenium (Se) which is sometimes referred to as a metalloid. The general suite of analysis was expanded to include barium (Ba), beryllium (Be), and thallium (Tl) for their known association with coal and coal-burning products.

Total metal concentrations were determined on the unfiltered samples while dissolved metal concentrations were determined on the filtered (<0.45 µm) samples. Total metal analysis refers to the measurement of all forms of a particular metal present in a water sample, including both particulate and dissolved forms. Total metals may include the measurement of forms of a metal that are unavailable for biological uptake because they are bound up in the mineral matrix of particles or adsorbed to solid particles. Total metals can be heavily influenced by environmental factors that affect the quantity of particulate matter suspended in the water column (such as inflows from the catchment following rainfall, tidal currents, wind and swell conditions). Dissolved metal analyses specifically target the measurement of the dissolved, colloidal, or soluble form of a particular metal present in a water sample. Dissolved metals may exist as free metal ions or small metal complexes that are typically more readily available for uptake by aquatic organisms and provide a better indication of the potential risks to aquatic ecosystems than the total metal concentration.

Total and dissolved metal analyses were performed by the EF Laboratory using in-house NATA-accredited methods based on the United States Environmental Protection Agency (US EPA) Method 200.8: *Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma-Mass Spectrometry* (ICP-MS) and APHA Method 3125: *Metals by ICP-MS*. In brief, samples were acidified at room temperature with concentrated nitric acid ($HNO_3$) to pH <2, then were diluted up to 10 times based on the dissolved solids content, estimated from the conductivity, and were analysed by ICP-MS. ALS was utilised as a secondary laboratory for metals analysis as part of the QA/QC procedures.

### *Mercury*

Mercury was determined by cold vapour atomic absorption spectrometry. Samples were triaged for mercury analysis and if mercury was not detected in the total-unfiltered sample it was not analysed for in the dissolved-filtered sample. Mercury analyses were performed by the EF Laboratory using in-house NATA-accredited methods based on USEPA Method 245.1: *Determination of Mercury in Water by Cold Vapour Atomic Absorption Spectrometry*. ALS was utilised as a secondary laboratory for mercury analysis as part of the QA/QC procedures.

### *Arsenic speciation*

Analysis of the speciated forms of arsenic was performed on samples collected from the final sample collection round for a subset of sites only that had regular measurements of dissolved arsenic above the limit of reporting (LOR) during the preceding 11 sampling rounds. Arsenic speciation was performed by Envirolab Services using an in-house NATA-accredited method. In brief, the speciated forms of arsenic were separated by high-performance liquid chromatography followed by ICP-MS analysis. The arsenic species determined were arsenobetaine, arsenious acid (As(III)), dimethylarsenic acid, monomethylarsonic acid, and arsenic acid (As(V)).

**Table 3. List of surface water analyses, laboratories, and methods**

| Parameter | Laboratory | Methods |
|---|---|---|
| Total suspended solids | EF | In-house method based on APHA Method 2540 D |
| Dissolved organic carbon | ALS | In-house method based on APHA Method 5310 B |
| Nutrients<br>(NOx-N, Ammonia-N, FRP, TN and TDN, TP and TDP)* | Primary: SWEL<br>Secondary: Sydney Water | Both laboratories used in-house methods based on APHA Methods: 4500-$NO_{3}$-I (for nitrate), 4500-$NH_3$-H (for ammonium-N), 4500-P-E (for FRP), and 4500-P-J (for TN, TP, TDN, and TDP). |
| Total recoverable metals<br>(Ag, Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Pb, Mn, Mo, Ni, Se, Tl, V, Zn and Hg) | Primary: EF<br>Secondary: ALS | Both laboratories used in-house methods based on US EPA Method 200.8 and APHA Method 3125. Subsamples for dissolved metals were filtered through a 0.45 µm PES syringe filter at the time of collection in the field. Both total and dissolved metal samples were acidified (pH <2) with nitric acid (Ultrapure) once samples were brought to the laboratory. |
| Dissolved metals<br>(Ag, Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Pb, Mn, Mo, Ni, Se, Tl, V, Zn and Hg) | Primary: EF<br>Secondary: ALS | |
| Total recoverable low-level mercury | Primary: EF<br>Secondary: ALS | US EPA Method 200.8 |
| Arsenic speciation | Envirolab Services | In-house NATA accredited method |

* NOx-N = nitrate + nitrite, FRP = free reactive phosphorus, TN = total nitrogen, TDN = total dissolved nitrogen, TP = total phosphorus, TDP = Total dissolved phosphorus

## 2.3 Rainfall

Rainfall data were obtained from the Australian Bureau of Meteorology (BOM) to provide information on the ambient conditions preceding each sampling event. Weather stations within the Lake Macquarie Catchment include Eraring (Payten St, 061376, 151.54°E, 33.08°S) and Swansea (Catherine St, 061377, 151.63°E, 33.09°S).

Daily rainfall at the Eraring and Swansea weather stations for the period of February 2022 to February 2023 are shown in Figure 1. Monthly and annual total rainfall records for the Eraring and Swansea weather stations for the last ten years (January 2013 to March 2023) are provided in Appendix B – Monthly rainfall summaries. Higher than-average rainfall occurred during the monitoring period:

- At the Eraring weather station, total rainfall during the months of March 2022 (380 mm) and July 2022 (370 mm) was greater than the 95th percentile of monthly data collected between January 2013 and March 2023. Six out of the 12 months sampled (March, April, May, July, September, and October) had above-average rainfall compared to the 10-year average.
- At the Swansea weather station, total rainfall during the month of July 2022 (350 mm) was greater than the 95th percentile of monthly data collected between January 2013 and March 2023. Six out of the 12 months sampled (February, March, April, May, July, and October) had above-average rainfall compared to the 10-year average.
- At both Eraring and Swansea, the 2022 annual rainfall total was the wettest year in the preceding 10-year period, with approximately 1700 mm falling.

Rainfall for each sampling day was also presented as the total rainfall (based on an average of the Eraring and Swansea weather stations data) in the seven days preceding the sampling event. Rainfall was described as falling into one of four categories:

- Dry conditions: <10 mm total rainfall in the previous seven days.
- Low rainfall: 10 to 20 mm total rainfall in the previous seven days.
- Moderate rainfall: 20 to 35 mm total rainfall in the previous seven days.
- High rainfall: >35 mm total rainfall in the previous seven days.

All rainfall categories were experienced over the duration of the 12-month monitoring program (Table 4).

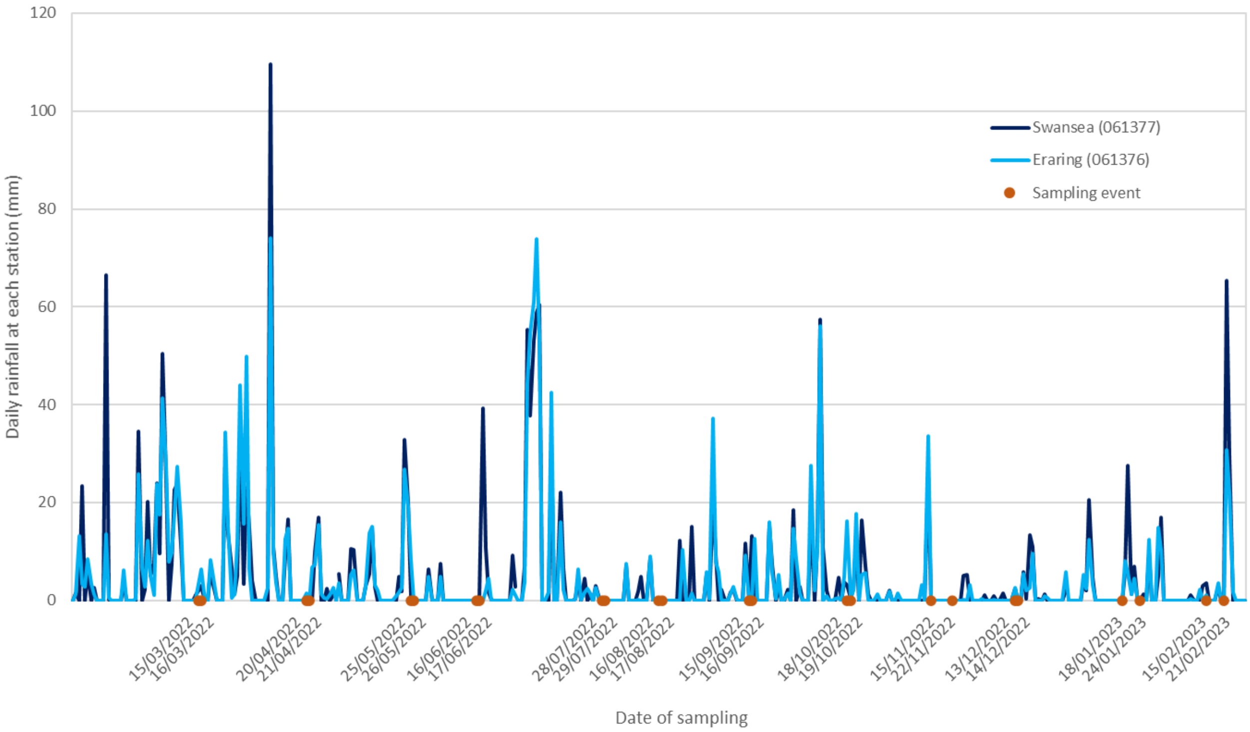


**Figure 1. Daily rainfall recorded at the Eraring (Station 061376) and Swansea (Station 061377) weather stations within the Lake Macquarie Catchment between February 2022 and February 2023. Data sourced from the Australian Bureau of Meteorology.**

**Table 4. Description of rainfall experienced in Lake Macquarie during the 12-month surface water quality monitoring program**

| Sampling period | Date of sampling | Total rainfall over the preceding 7 days (mm) | Description of rainfall |
|---|---|---|---|
| March 2022 | 15th/16th | 40/17 | High/low |
| April | 20th/21st | 27/16 | Moderate/low |
| May | 25th/26th | 55/60 | High |
| June | 16th/17th | 0/0 | Dry |
| July | 28th/29th | 8.5/8.4 | Dry |
| August | 16th/17th | 12/11 | Low |
| September | 15th/16th | 15/15 | Low |
| October | 18th/19th | 8.5/17 | Dry/low |
| November | 15th/22nd | 31/0 | High/Dry |
| December | 13th/14th | 1.2/3.2 | Dry |
| January 2023 | 18th/24th | 0/31 | Dry/High |
| February | 15th/21st | 3.3/7.0 | Dry |

## 2.4 Identifying key contaminants of potential concern

### 2.4.4 Physical and chemical stressors

Draft NSW Estuary Water Quality Guideline Values (NSW GVs) for physical and chemical stressors have been derived for NSW Estuaries (DCCEEW, 2024) based on the guidance provided in the ANZECC/ARMCANZ Water Quality Guidelines (ANZECC/ARMCANZ, 2000). The NSW GVs were derived from reference estuaries at the seaward end of low disturbance catchments and are based on 80th and/or 20th (if detrimental effects occur at low concentrations) percentile values for each indicator. The NSW GVs represent the expected values for each indicator in minimally disturbed systems and so can be used comparatively to indicate when an indicator is outside the expected range. NSW GVs are available for a range of physicochemical indicators, including organic and inorganic nutrients containing nitrogen and phosphorus. It is noted that Lake Macquarie has been categorised as a moderately disturbed, wave-dominated barrier estuary (Roper et al., 2011). The Lake Macquarie sampling sites were compared to the NSW GVs for ‘lakes’ (Table 5). It is acknowledged that the NSW GVs for lakes are intended to be used for lake basin waters rather than waters in bays or close to the shore, and this was considered during data interpretation. Default guideline values (DGVs) for moderately disturbed estuaries in south-east Australia are also available and presented in Table 5. ANZG (2018) recommends that where individual states or territories have developed their own regional guideline values, those values should be used in preference to the default values. However, since the NSW GVs are unpublished (i.e., draft values under review), both the NSW GVs and the default GVs are considered in this assessment.

Where NSW GVs or DGVs were not available, the water quality indicators were compared to the 80th percentile (or 20th percentile for stressors that cause adverse effects at low concentrations) of all data collected for the monitoring program (and/or to reference locations) to identify whether the concentration is considered elevated with respects to the surrounding environment.

Table 5. Screening criteria adopted for physical and chemical stressors for estuarine waters

| Physical and chemical stressors | NSW estuary water quality guideline values for lakes[a] | Default guideline values for physical and chemical stressors[b] |
|---|---|---|
| Total nitrogen | 750 µg N/L | 300 µg N/L |
| Total dissolved nitrogen | 670 µg N/L | - |
| Oxidised nitrogen (NOx) | 3 µg N/L | 15 µg N/L |
| Ammonia-N (NH-N, ammonia + ammonium) | 14 µg N/L | 15 µg N/L |
| Total phosphorus | 24 µg P/L | 30 µg P/L |
| Total dissolved phosphorus | 9 µg P/L | - |
| Free reactive phosphorus | 1 µg P/L | 5 µg P/L |
| Turbidity | 5.5 NTU | 0.5 – 10[c] |
| Dissolved oxygen | 93 – 115% | 80 – 110% |
| pH | 8.1 – 9.1 | 8.0 – 8.4 |

[a] NSW region-specific guideline values for estuarine lakes (DCCEEW, 2024)

[b] Default guideline values for moderately disturbed estuaries in southeast Australia have been applied as screening criteria unless otherwise specified (ANZECC/ARMCANZ, 2000).

[c] Estuarine and marine (ANZECC/ARMCANZ, 2000)

### 2.4.5 Water quality guidelines for toxicants

Measured total and dissolved metal concentrations of the surface waters were compared with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality where available (ANZG, 2018). ANZG (2018) provides DGVs, which represent estimates of the concentration of chemicals below which there is a low risk of significant adverse effects on the aquatic ecosystem, to assist in identifying where further investigation or consideration of potential risks may be required. Lake Macquarie is best described as a slightly to moderately disturbed system. Slightly to moderately disturbed systems are those 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. Where available, marine DGVs for slightly to moderately disturbed systems (95% species protection) were adopted, except for chemicals that may bioaccumulate, for which a higher level of protection is recommended. For cadmium and mercury, the marine DGVs for high conservation or ecological value systems (99% species protection) were adopted. The adopted screening criteria for the current investigation are provided in Table 6.

For toxicants where only a limited amount of toxicity data are available, ANZG (2018) may provide an indicative interim working level for screening purposes. These values are typically determined by applying an assessment factor to the lowest available toxicity data and are of low reliability. They are considered interim as they should be revised when more data becomes available.

- ANZG (2018) provides a low reliability indicative interim working level of 0.5 µg/L for aluminium for marine receiving environments. Golding et al. (2015) presented a revised water quality guideline value for aluminium in receiving marine environments of 24 µg/L total aluminium for 95% species protection. More recently, van Dam et al. (2018) and Markich (2021) presented additional chronic toxicity data for Australian tropical marine species and bivalves. The inclusion of the additional data has resulted in a draft DGV of 37 µg/L for the marine receiving environment and protects species from both dissolved and precipitated forms of aluminium (ANZG, 2024; G.E. Batley, personal communication). The draft DGV is significantly lower than aluminium's solubility limit in seawater, indicating that the total concentration consists mostly of dissolved aluminium at concentrations up to its solubility limit in seawater (approximately 500 µg/L) (ANZG, 2024). Therefore, a dissolved aluminium measurement (0.45 µm filtered) of an environmental sample should be appropriate for comparison with the DGVs (ANZG, 2024). Following the criteria detailed by Warne et al. (2018), the revised guideline value for aluminium has been categorised as very high reliability (ANZG, 2024).

- ANZG (2018) provides a low reliability indicative interim working level of 2.3 and 4.5 µg/L for arsenic(III) and arsenic(V), respectively, for marine receiving environments. Golding et al. (2022) presented a revised water quality guideline value for arsenic(V) in receiving marine environments of 12 µg/L for 95% species protection. For this study, dissolved arsenic has been screened against the indicative interim working level and the draft DGV of 12 µg As(V)/L for 95% species protection (G.E. Batley, personal communication).
- A revised guideline value of 6.1 µg/L for cobalt in marine waters has been proposed for 95% species protection, derived using the species sensitivity distribution method (G.E. Batley, personal communication). This study screened dissolved cobalt concentrations against the existing DGV of 1 µg/L and the draft DGV of 6.1 µg/L (G.E. Batley, personal communication).
- ANZG (2018) provides a low reliability indicative interim working level of 23 µg/L for molybdenum for marine receiving environments. van Dam et al. (2018) presented a revised water quality guideline value for molybdenum in marine receiving environments of 3.88 mg/L for 95% species protection. For this study, dissolved molybdenum concentrations have been screened against the indicative interim working level of 23 µg/L and the draft DGV of 5 mg/L for 95% species protection (G.E. Batley, personal communication).

A summary of the adopted screening criteria for the current investigation is provided in Table 6. For metals where no DGV or indicative interim working value are provided, the LOR was used as an initial screening criterion. If the LOR was exceeded, a judgement was made on whether the measured concentration was considered higher than the surrounding environment and other similar estuarine environments.

Contrary to TVs for physical and chemical stressors, DGVs for metals are based on actual biological-effects data, and so exceedance of a DGV indicates the potential for ecological harm. ANZG (2018), therefore, recommends that a more conservative approach to the comparison of toxicant-test data with DGVs is taken. Specifically, ANZG (2018) recommends that the 95th percentile of measured concentrations at the test site should be less than the relevant guideline value for the toxicant (i.e., further investigation is triggered if the 95th percentile concentrations at the test site exceed the relevant DGV for the toxicant). The 95th percentile represents the value below which 95% of the data points fall below. This approach is often adopted to ensure that a comparison against the DGVs is made against the upper range of metal concentrations in the dataset but that it is not overly influenced by outliers. In the current study, however, the 95th percentile concentration was based on 12 measurements per test site. It is noted that in some instances a single exceedance of the screening criteria can lead to the 95th percentile value exceeding the screening criteria, triggering further investigation. Dissolved metal concentrations (0.45 µm filtered) were compared to the DGVs in accordance with ANZG (2018).

### 2.4.6 Data and statistical analysis

Data are presented as summary descriptive statistics (50th percentile, 95th percentile and the maximum concentration), line plots and/or box plots to provide a visual assessment of key contaminants of potential concern. Line plots display the individual measured values for a variable for all sites and sampling occasions (March 2022 to February 2023). Box plots display important summary statistics, including the median (centre line), the inter-quartile range (25th and 75th percentiles), whiskers (highest and lowest concentrations excluding outliers) and outliers (identified by dots). Box plots were created in Primer-E V7. Where concentrations of nutrients or metals were below the LOR, values were substituted as half the LOR for calculations and data visualisations.

For all figures presented in Section 3 and Section 4, colour represents general location/grouping information about the sampling sites:

- Section 3: Dora Creek (yellow); sites within the southern section of the lake: southwest zone (green), southeast zone (blue), and south zone (lavender); sites within the northern section of the lake (pink).
- Section 4: Coal ash repository decant or seepage waters (orange); Whiteheads Lagoon (green); Crooked Creek and Wyee Creek (yellow); Mannering Bay (lavender).

**Table 6. Screening criteria adopted for dissolved metals and metalloids in estuarine surface waters**

| Metals and metalloids | Marine DGV, 95% species protection (µg/L)[a] | Reliability, published date |
|---|---|---|
| Chromium (CrIII) | 27 | Low, 2000 |
| Chromium (CrVI) | 4.4 | Very high, 2000 |
| Cobalt | 1.0 | High, 2000 |
| Copper | 1.3 | Very high, 2000 |
| Lead | 4.4 | Low, 2000 |
| Nickel | 70 | Very high, 2000 |
| Silver | 1.4 | Moderate, 2000 |
| Vanadium | 100 | Moderate, 2000 |
| Zinc | 8.0 | Very high, 2021 |
| | **Marine DGV, 99% species protection (µg/L)[ab]** | |
| Cadmium | 0.7 | Very high, 2000 |
| Mercury (inorganic) | 0.1 | Very high, 2000 |
| | **Indicative interim working level (µg/L)[ac]** | |
| Aluminium | 0.5 | Low reliability, 2000 |
| Arsenic (AsIII) | 2.3 | Low reliability, 2000 |
| Arsenic (AsV) | 4.5 | Low reliability, 2000 |
| Manganese | 80 | Low reliability, 2000 |
| Molybdenum | 23 | Low reliability, 2000 |
| Selenium (total: SeIV and SeVI) | 3 | Low reliability, 2000 |
| | **Third-party guideline value, 95% species protection (µg/L)[d]** | |
| Aluminium | 37 | High reliability, draft value |
| Arsenic (AsV) | 12 | Moderate reliability, draft value |
| Cobalt | 6.1 | Moderate reliability, draft value |
| Molybdenum | 5000 | Unknown reliability, draft value |

[a] ANZG, 2018

[b] To account for the bioaccumulating nature of these toxicants (Cd and Hg), it is recommended that the 99% species protection level DGV is used for slightly to moderately disturbed systems

[c] ANZG (2018) may provide an indicative interim working level for toxicants where only a limited amount of toxicity data is available. They are considered interim as they should be revised when more data becomes available. Where further data had been generated, proposed third party guideline values had also been presented and used for screening purposes.

[d] G.E. Batley, personal communication

# 3. Lake Macquarie surface water quality assessment

## 3.1 Sampling locations

Routine monitoring of water quality and ecological health indicators has been conducted by DCCEEW S&I within Lake Macquarie since 2011. Ten sites have been routinely monitored at the request of Lake Macquarie City Council, with a further three sites added to the southern section of the lake in 2017 at the request of Central Coast Council. The monitoring program includes measurement of physicochemical properties, chlorophyll-a, TSS, dissolved inorganic, dissolved organic and total nutrients (DPE, 2023b). The current study has included the monitoring of total and dissolved metals and dissolved organic carbon (DOC) which are not part of the routine DPE SEI monitoring program.

The aim of the current sampling program was to focus on determining water quality in the southern section of the lake. Nineteen sites were selected. This included eight of the long-standing monitoring sites routinely monitored by DPE SEI and eleven new sites selected as areas of interest with respect to the influence of the power stations and coal ash repositories on surface water quality. The surface water sampling locations for Lake Macquarie are provided in Figure 2. A description of each site and its grouping into zones/categories for reporting purposes are provided in Table 7. Four of these sites (E-In, E21, V-In, and V22) were accessible by land while the remaining 14 sites were accessed via boat.

A further ten sites were selected to monitor the presence of contaminants in the coal ash repositories, the return or seepage waters, and onsite surface waters that receive water flows from the site and/or emergency discharges from the Eraring and Vales Point Power Stations following wet weather. Further information on these sites is provided in Section 4.

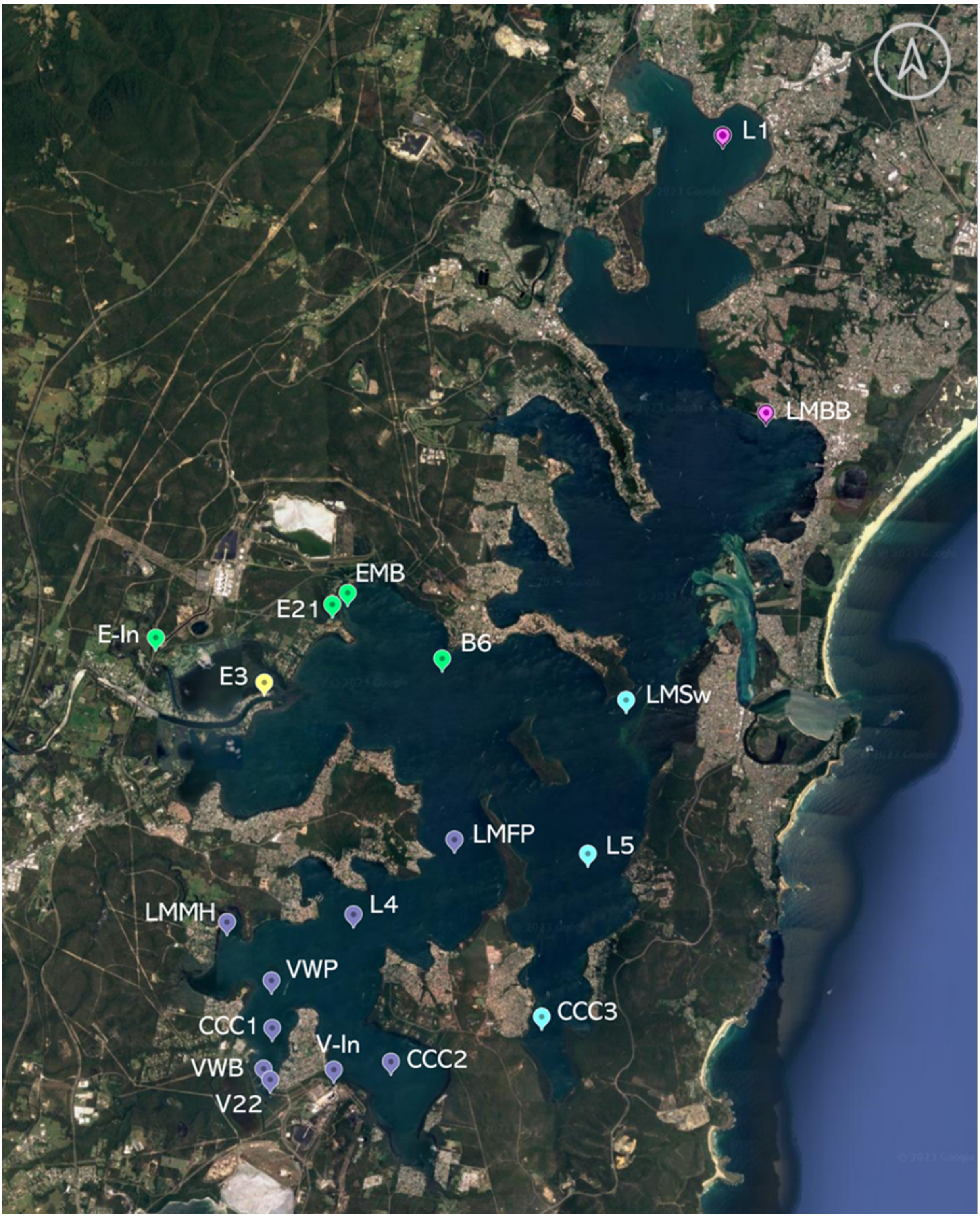


**Figure 2. Surface water sampling locations in Lake Macquarie. Icon colour represents general location/grouping information about the sampling sites: Dora Creek (yellow); sites within the southern section of the lake: southwest zone (green), southeast zone (blue), and south zone (lavender); sites within the northern section of the lake (pink).**

Table 7. Location and description of surface water sampling sites within Lake Macquarie

| Site name | Site location | Habitat type or description | Category for reporting | Latitude (°N)[a] | Longitude (°E)[a] |
|---|---|---|---|---|---|
| E3[b] | Dora Creek | Creek | Creek | -33.0840 | 151.5304 |
| E-In[c] | Eraring Power Station | Cooling water inlet canal | South-west zone | -33.0756 | 151.5050 |
| E21[c] | Eraring Power Station | Cooling water outlet canal | South-west zone | -33.0693 | 151.5452 |
| EMB | Myuna Bay | Bay | South-west zone | -33.0671 | 151.5487 |
| B6[b] | South-west basin | Lake Basin | South-west zone | -33.0832 | 151.5697 |
| LMSw | Swansea | Lake basin | South-east zone | -33.0876 | 151.6121 |
| L5[b] | Crangan Bay | Lake basin | South-east zone | -33.1169 | 151.6034 |
| CCC3[b] | Gwandalan | Lake basin | South-east zone | -33.1480 | 151.5929 |
| LMFP | Fishery Point | Lake basin | South zone | -33.1142 | 151.5730 |
| L4[b] | Bardens Bay | Lake basin | South zone | -33.1285 | 151.5500 |
| CCC2[b] | Chain Valley Bay | Bay | South zone | -33.1566 | 151.5585 |
| V-In[c] | Vales Point Power Station | Cooling water inlet canal | South zone | -33.1577 | 151.5440 |
| V22[c] | Vales Point Power Station | Cooling water outlet canal | South zone | -33.1600 | 151.5310 |
| VWB | Wyee Bay | Bay | South zone | -33.1579 | 151.5295 |
| CCC1[b] | Wyee Bay | Bay | South zone | -33.1501 | 151.5315 |
| VWP | Wyee Point | Lake basin | South zone | -33.1411 | 151.5313 |
| LMMH | Morisset | Bay | South zone | -33.1299 | 151.5212 |
| L1[b] | Speers Point | Lake basin | Northern zone | -32.9801 | 151.6339 |
| LMBB | Belmont Bay | Bay | Northern zone | -33.0330 | 151.6438 |

[a] Coordinates presented are based on the first sampling round and are representative as slight variations may have occurred over the monitoring program.

[b] Routine water quality monitoring sites used by DCCEEW S&I since 2011 (n=8). All other sites were newly selected for this investigation.

[c] Sampling locations accessible by land (n=4). All other sites were accessed by boat.

## 3.2 Results

All surface water quality physicochemical indicator, nutrient, and metal concentration data collected during the 12-month Lake Macquarie monitoring program are provided in the Supplementary Information.

### 3.2.1 Physicochemical indicators

Summary descriptive statistics for surface water quality indicators collected within Lake Macquarie are provided in Table 8. Box plots summarising the distribution of the measured values by site are provided below. Scatter plots showing the individual measurements by sampling date and comparison against rainfall data are provided in Appendix C – Temporal analysis of physicochemical indicator data.

#### *Temperature*

Temperature variations within the lake were observed across both space and time (Figure 3). During a single sampling event, the temperature difference between sites was as much as 5-10°C. Across the monitoring period, there was a seasonal temperature variation between summer and winter within a site of approximately 11-15°C (Figure A1). The 80th percentile value of temperature measurements collected at all sites throughout the monitoring program was 26°C. Sites with elevated surface water temperatures relative to other sites within the lake (median surface water temperatures > 26°C) included sites V22 (27°C), VWB (28°C), and CCC1 (27°C), which were located within the receiving waters for the Vales Point Power Station cooling water discharges.

#### *Conductivity*

A conductivity of approximately 47,000 µS/cm (50th percentile of all samples collected) was maintained for most sites (Figure 4). The 20th percentile value of conductivity measurements collected at all sites throughout the monitoring program was 42,000 µS/cm. The median conductivity was greater than 42,000 µS/cm at all sites except Site E3 (40,000 µS/cm), which is located within Dora Creek. The greatest reductions in conductivity were observed during the April, May, July, and October sampling events coinciding with large and sustained rainfall events and sites closest to where freshwater inflows enter the lake (e.g., Site E3) (Figure A2).

#### *Dissolved oxygen*

A DO concentration of approximately 100% was maintained for most sites (Figure 5). The median DO concentration was marginally lower than the NSW GV range for DO of 93-115% at Site E-In (91%) and higher than the NSW GV at Site E21 (140%). A DO range of 80 to 110% is generally considered to be satisfactory for estuarine ecosystems (ANZECC/ARMCANZ, 2000; ANZG, 2018). Site E21 is located within the Eraring Power Station cooling water outlet canal. The water here is fast-flowing and highly aerated, as evidenced by its foamy white appearance as it travels through the concrete canal (Figure 6).

#### *pH*

A pH of approximately 8.1 was maintained for most sites (Figure 7). The median pH was marginally lower than the NSW GV range of 8.1 to 9.1 at Sites E3, E-In, E21, V-In, V22, VWB, CCC1, VWP, and LMMH (pH was between 7.9 and 8.1). A pH range of 7.0 to 8.5 is generally considered to be satisfactory for estuarine ecosystems (ANZECC/ARMCANZ, 2000; ANZG, 2018).

#### *Total suspended solids*

TSS was quite variable over space and time but did not exceed 11 mg/L throughout the monitoring program (Figure 8, Figure A5). The 80th percentile value of TSS measurements collected throughout the monitoring program was 6 mg/L. The median TSS concentration was only marginally greater than this at Site E3 (Dora Creek, 7 mg/L).

### *Turbidity*

The median turbidity was lower than the NSW GV of 5.5 FNU at all sites except Site E21 (11.4 FNU), which recorded several peaks in turbidity (individual measurements up to 79 FNU) (Figure 9). A turbidity range of 0.5 to 10 FNU is generally considered to be satisfactory for estuarine ecosystems (ANZECC/ARMCANZ, 2000; ANZG, 2018). The elevated readings at Site E21 may be attributed to the presence of bubbles within the highly aerated water of the outlet canal (Figure 6), as the TSS measurements in both Sites E21 and E-In were comparable, indicating they have similar amounts of particulate matter (Figure 8) but Site E-In, the inlet canal, had much lower turbidity indicating greater clarity.

### *Dissolved organic carbon*

DOC concentrations were consistent across the lake; generally, around 3 mg/L (fluctuating between <1 and 7 mg/L, with a potential outlier of 25 mg/L for Site E-In) (Figure 10).

### *Overall*

Lake Macquarie is an estuarine environment, forming a transition zone between freshwater catchment inflows and the marine environment. As such, physical-chemical conditions can vary both temporally and spatially as a function of tidal influence and catchment rainfall. The physicochemical parameters of dissolved oxygen, pH, total suspended solids, and turbidity were all within relevant guideline values except for a few localised exceedances. Sustained elevated temperatures were, however, observed within the receiving waters for the Eraring Power Station cooling water outlet and the Vales Point Power Station cooling water outlet.

**Table 8. Descriptive statistics for surface water quality indicators collected within Lake Macquarie from March 2022 to February 2023 (n = ~228: 19 sites x 12 sampling time-points). Values below the limit of reporting (LOR) were substituted as half of the LOR for calculating summary statistics.**

| Parameter | Guideline value[a] | Minimum | 20th percentile | Median | 80th percentile | Maximum |
|---|---|---|---|---|---|---|
| Temperature (°C) | NA | 13 | 18 | 23 | 26 | 34 |
| Conductivity (µS/cm) | NA | 13,000 | 42,000 | 47,000 | 51,000 | 55,000 |
| Dissolved oxygen (%) | 93-115 | 63 | 95 | 100 | 108 | 144 |
| pH | 8.1-9.1 | 7.3 | 7.9 | 8.1 | 8.1 | 8.5 |
| Total suspended solids (mg/L) | NA | <3 | <3 | 4 | 6 | 11 |
| Turbidity (FNU) | 5.5[b] | 0.09 | 0.59 | 1.1 | 2.1 | 79 |
| Dissolved organic carbon (mg/L) | NA | <1 | 2 | 3 | 5 | 25 |

NA = Not available

[a] NSW Estuary Water Quality Guideline Values (GVs) for physical and chemical stressors for estuarine waters classified as lakes (DCCEEW, 2024).

[b] GV provided in NTU. Our measurement reported in FNU which is equivalent to NTU as methodology is consistent with ISO7027.

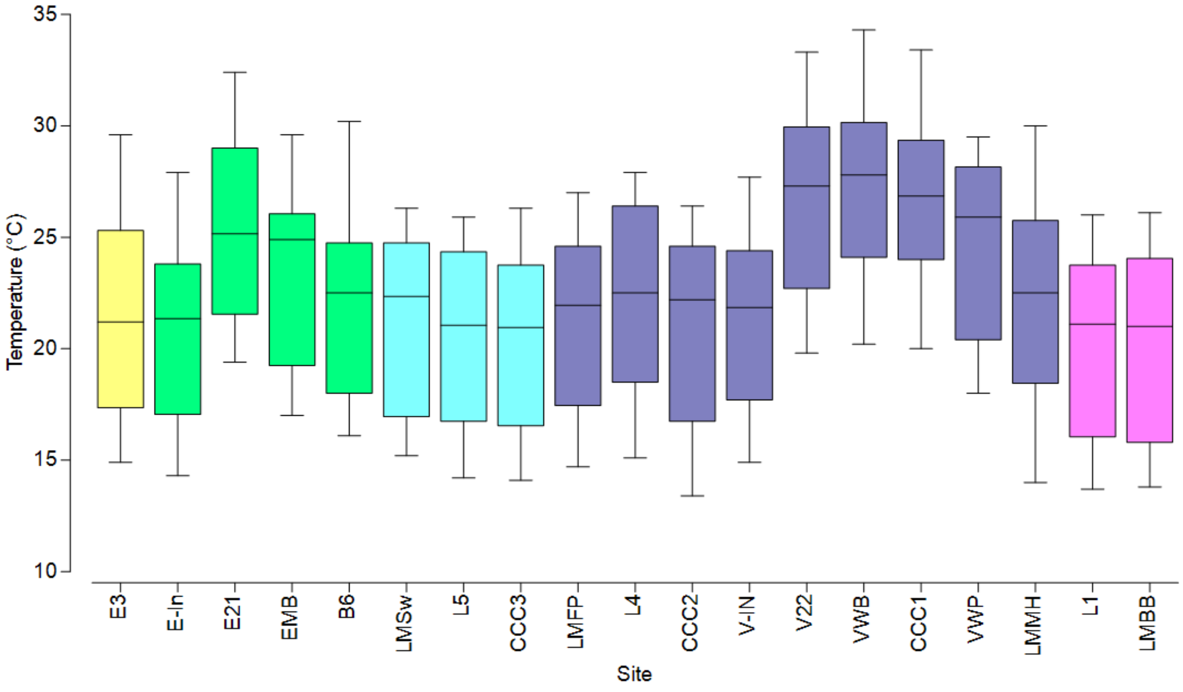


**Figure 3. Box plots of temperature (°C) in surface waters at 19 sites within Lake Macquarie throughout the monitoring program (March 2022 to February 2023, n=12)**

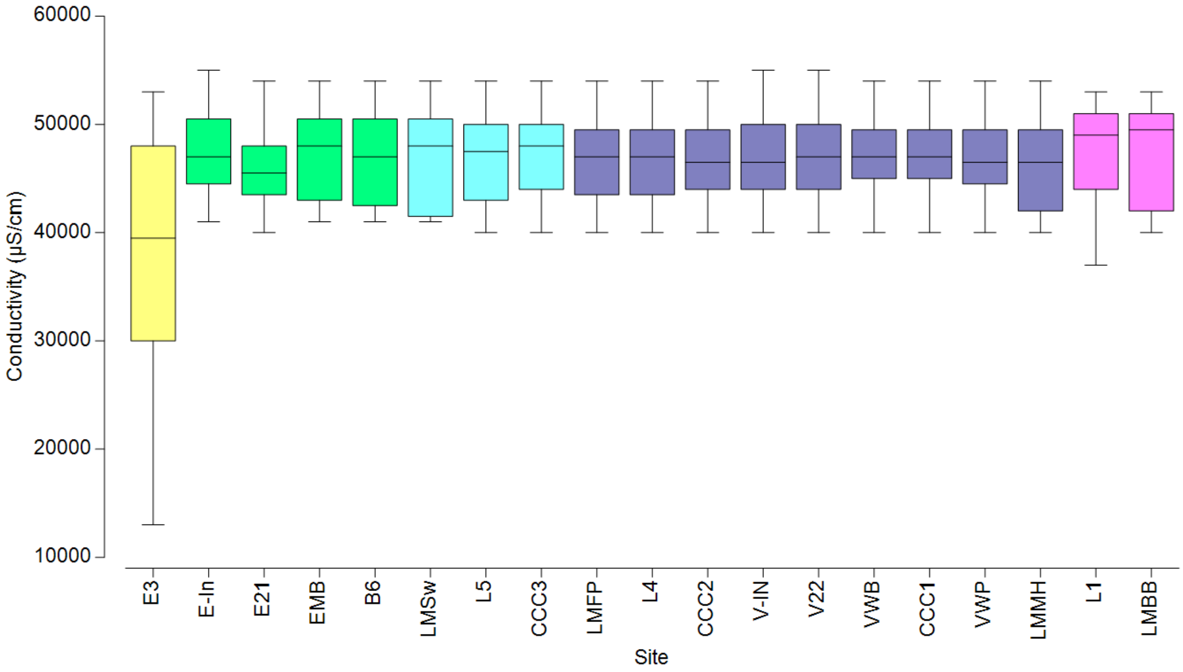


Figure 4. Box plots of conductivity (µS/cm) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12)

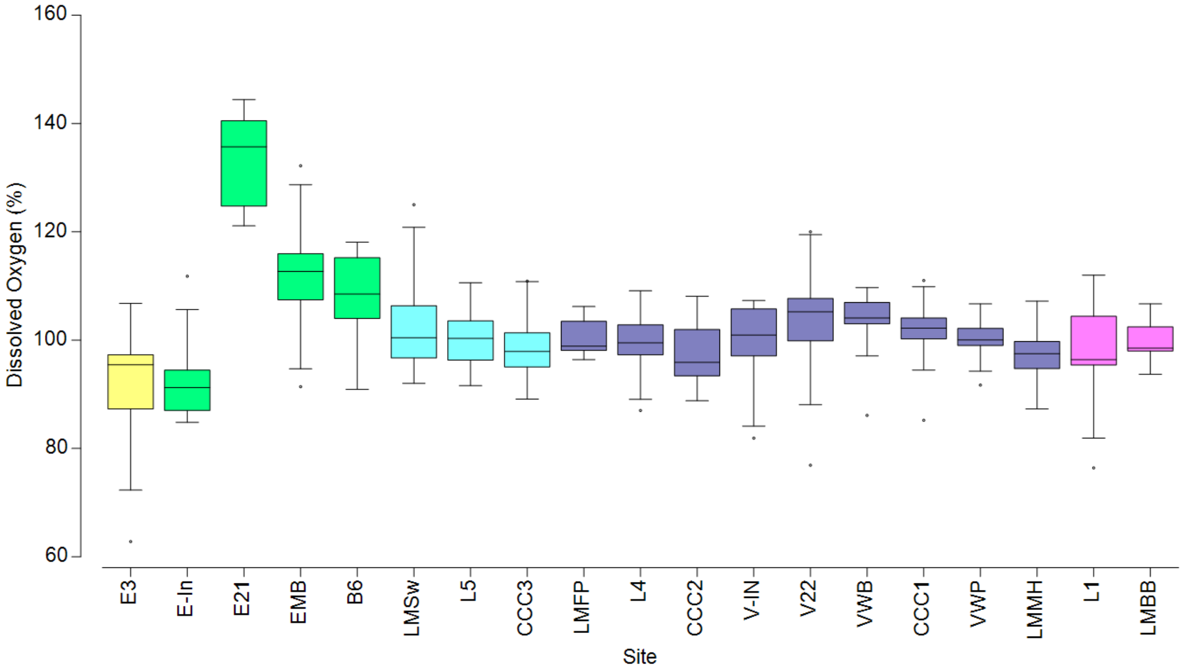


Figure 5. Box plots of dissolved oxygen (%) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12)

**Figure 6. Representative image of Site E21 which is located within the Eraring Power Station cooling water outlet canal**

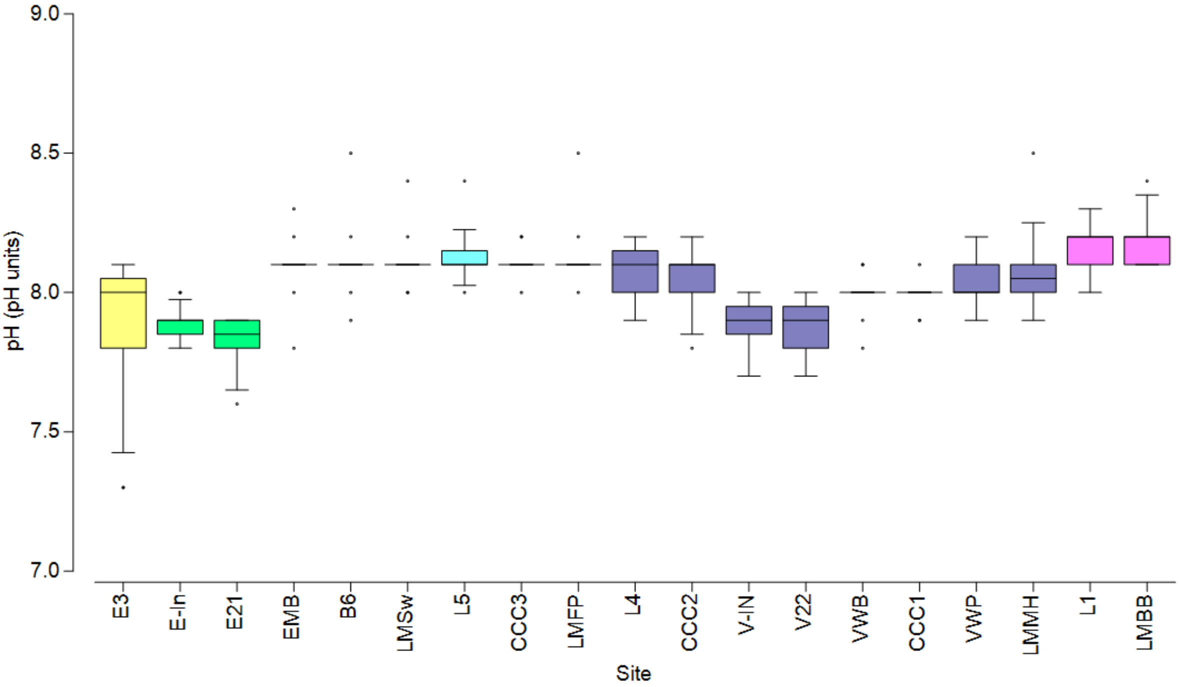


**Figure 7. Box plots of pH (pH units) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12)**

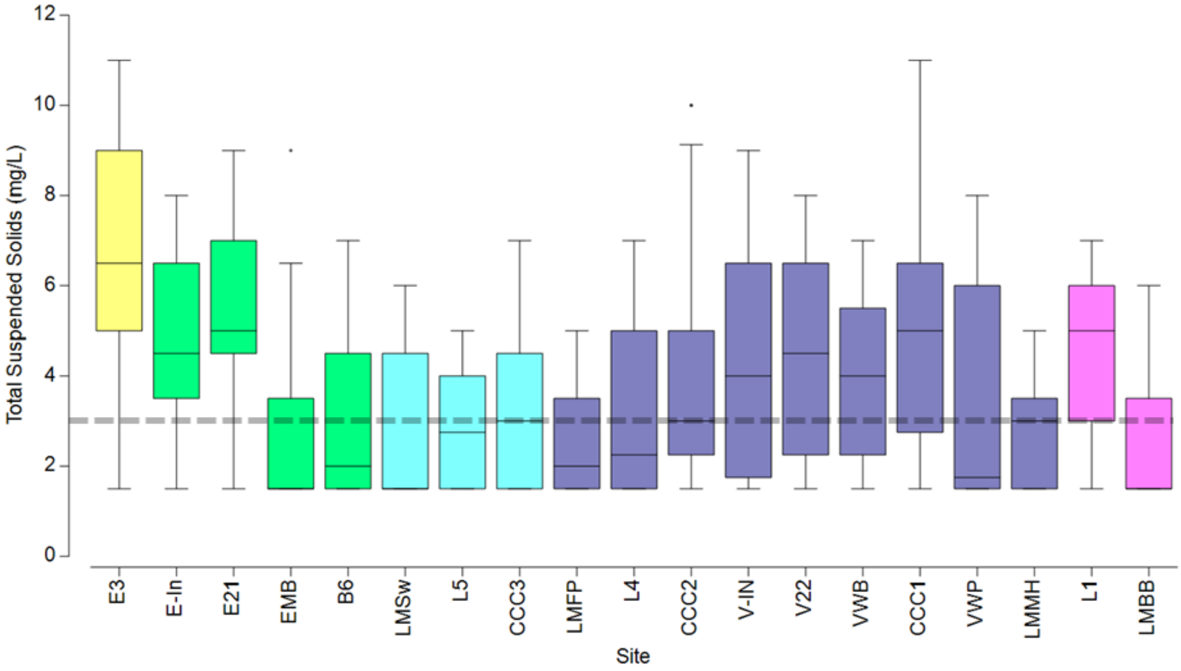


**Figure 8. Box plots of total suspended solids (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The horizontal grey dashed line indicates the limit of reporting (LOR, 3 mg/L). Values below the LOR were replaced with half the LOR to determine descriptive statistics.**

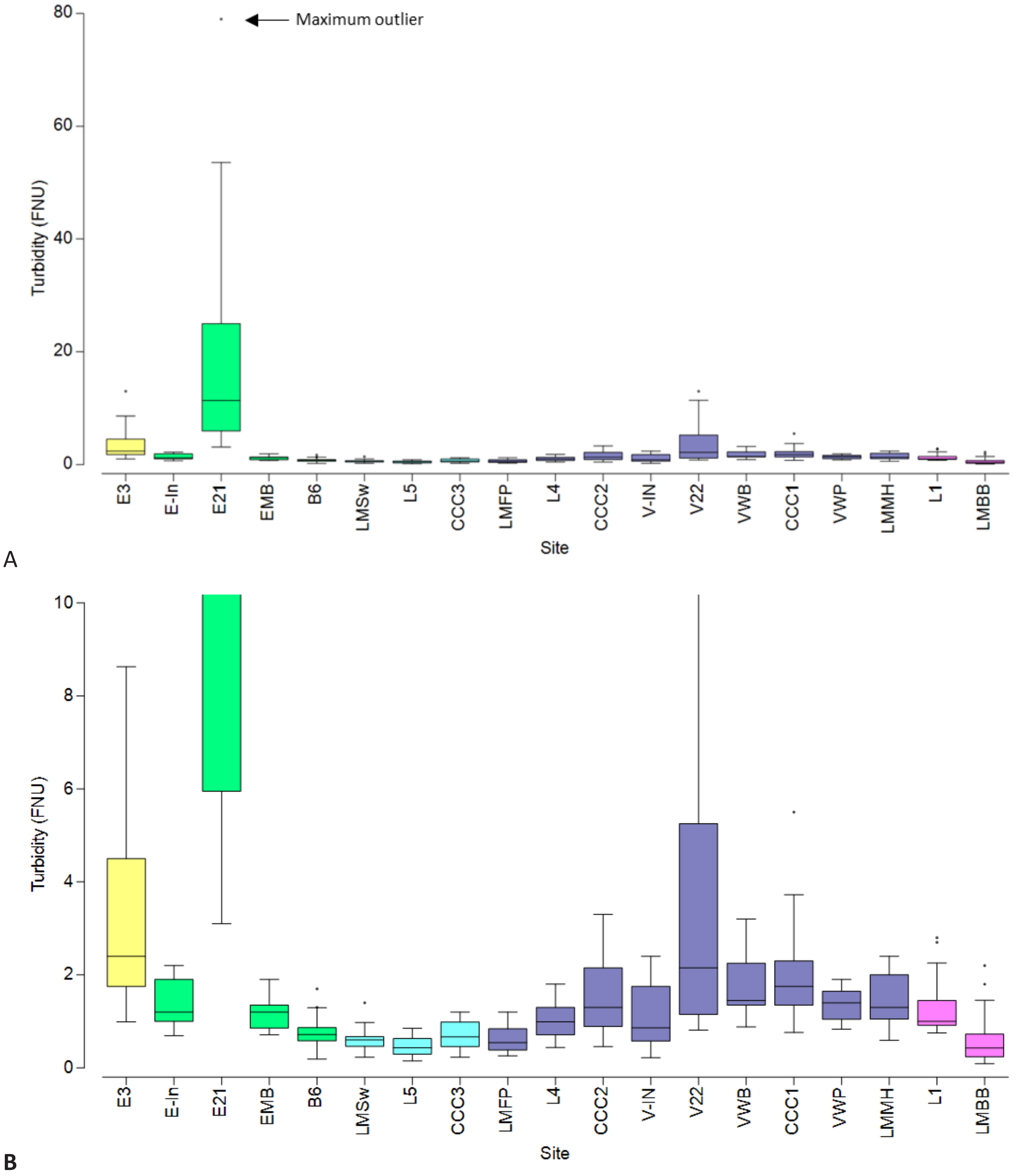


**Figure 9. Box plots of turbidity (FNU) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12): A) scale bar set to include all data points (including outliers); and B) refined scale bar set to discern differences at low concentrations.**

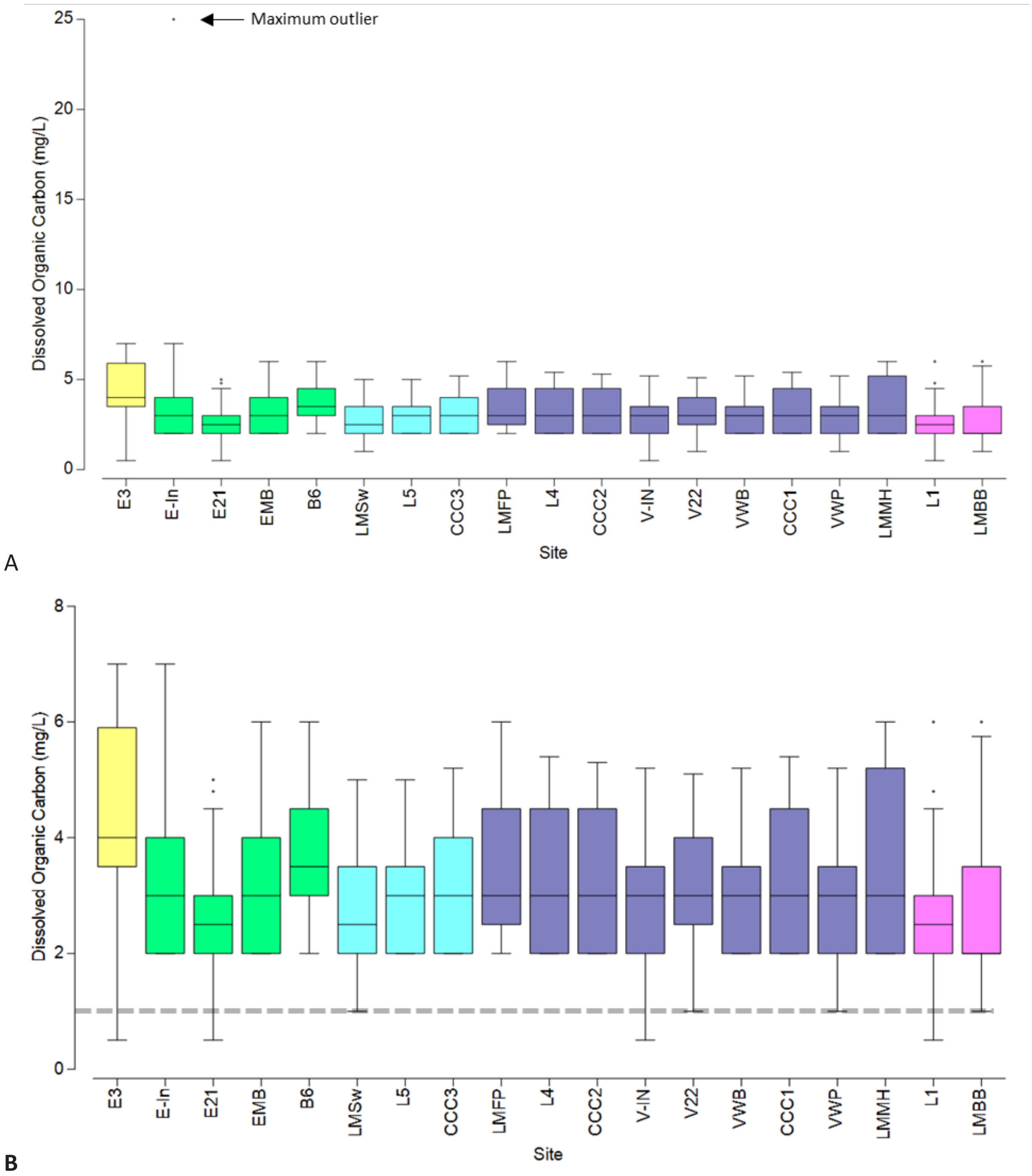


**Figure 10. Box plots of dissolved organic carbon (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12): A) scale bar set to include all data points (including outliers); and B) refined scale bar set to discern differences at low concentrations. The horizontal grey dashed line indicates the limit of reporting (LOR, 1 mg/L). Values below the LOR were replaced with half the LOR to determine descriptive statistics.**

### 3.2.2 Screening assessment – Nutrients

Summary descriptive statistics for surface water quality indicators collected within Lake Macquarie are provided in Table 9. Box plots summarising the distribution of the measured values by site are provided below. Scatter plots showing the individual nutrient concentration measurements by sampling date and comparison against rainfall data are provided in Appendix D – Temporal analysis of nutrient data.

*Nitrogen*

Note that the data quality assessment found an issue of nitrogen contamination associated with some of the sample containers (Appendix A – Data quality assessment). Therefore, while not all samples would have been affected, samples with concentrations of total nitrogen <0.2 mg/L, dissolved nitrogen <0.3 mg/L, oxidised nitrogen <0.09 mg/L, and ammonia-N <0.02 mg/L were treated as estimated concentrations.

A total nitrogen concentration of approximately 0.18 mg/L (50th percentile concentration of all samples collected) was generally maintained within Lake Macquarie surface waters throughout the monitoring program (Table 9, Figure 11). Individual median concentrations for each site were between 0.14 (LMBB) and 0.23 mg/L (E3). The median concentration of total nitrogen was below the NSW GV of 0.75 mg/L for all sites. Only a single exceedance of the NSW GV occurred, which was for Site V-In during the April sampling. The median concentration of total nitrogen was also below the more conservative DGV of 0.300 mg/L for all sites.

A dissolved nitrogen concentration of approximately 0.15 mg/L was maintained within Lake Macquarie surface waters throughout the monitoring program (Table 9, Figure 12). Individual median concentrations for each site were between 0.12 (LMBB) and 0.18 mg/L (E3). The median concentration of dissolved nitrogen was below the NSW GV of 0.67 mg/L at all sites. No single measurement exceeded the NSW GV. Dissolved nitrogen during the April sampling was elevated at Sites V-In (0.66 mg/L) and E21 (0.64 mg/L) but below the NSW GV.

Individual median oxidised nitrogen concentrations were between <0.001 (LMBB) and 0.011 mg/L (E21) (Figure 13). The median concentrations of oxidised nitrogen exceeded the NSW GV of 0.003 mg/L at six sites, including E3, E-In, E21, V22, VWB, and CCC1, but were below the DGV of 0.015 mg/L at all sites. Oxidised nitrogen and ammonia-N concentrations showed similar patterns across the lake. Individual median ammonia-N concentrations were between 0.003 (EMB, B6, LMSw, LMFP, L1, LMBB) and 0.023 mg/L (E21) (Figure 14). The median concentration of ammonia-N exceeded the NSW GV of 0.014 mg/L and the DGV of 0.015 mg/L at five sites, including E-In, E21, V22, VWB, and CCC1. Sites with median concentrations that exceeded the NSW GV for oxidised nitrogen and ammonia-N were in bays close to the receiving environments for the Dora Creek and Wyee Creek tributaries and the Power Station cooling water outlet canals (i.e., other sites within the lake had median concentrations below the NSW GVs).

*Phosphorus*

A total phosphorus concentration of approximately 0.016 mg/L (50th percentile of all samples collected) was maintained within Lake Macquarie surface waters throughout the monitoring program (Table 9, Figure 15). Individual median total phosphorus concentrations for each site were between 0.012 (LMBB) and 0.020 mg/L (CCC1 and VWP). The median concentration of total phosphorus was below the NSW GV of 0.024 mg/L and the DVG of 0.030 mg/L at all sites.

Individual median dissolved phosphorus concentrations for each site were between 0.007 (E3 and LMBB) and 0.014 mg/L (E21 and V22) (Figure 16). The median concentration of dissolved phosphorus exceeded the NSW GV of 0.009 mg/L at 10 sites (E-In, E21, EMB, CCC2, V-In, V22, VWB, CCC1, VWP, and LMMH).

Individual median free reactive phosphorus concentrations for each site were between 0.003 (E3, L5, CCC3, and LMBB) and 0.011 mg/L (E21) (Figure 17). The median concentration of dissolved phosphorus exceeded the NSW GV of 0.001 mg/L at all sites and the DGV of 0.005 mg/L at eight sites (E-In, E21, EMB, CCC2, V22, VWB, CCC1, and VWP). Peak concentrations of dissolved and free reactive phosphorus were observed during the May sampling event, following the highest rainfall total measured in the preceding seven days (55 - 60 mm). Lake basin Sites L5 and CCC3, northern lake reference site LMBB and Dora Creek Site E3 all had the lowest median free reactive phosphorus concentration (0.003 mg/L), while the site with the highest median concentration was the Eraring Cooling water outlet Site E21 (0.010 mg/L).

### *Overall*

Median concentrations of total nitrogen and total phosphorus concentrations were below NSW GVs at all sites.

Oxidised nitrogen, ammonia-N, and dissolved phosphorus concentrations exceeded the NSW GVs on several occasions around the foreshore areas in the southwest basin and Wyee Bay. The NSW GVs for lakes were derived for basin waters as opposed to bays or foreshore areas where catchment runoff is expected to be higher, which may explain these exceedances. Concentrations of these nutrients in the main body of the lake were below NSW GVs. Free reactive phosphorus concentrations usually exceeded NSW GVs across all sites sampled but only exceeded based on the DGV at eight sites, predominately around the foreshore areas in the southwest basin and Wyee Bay.

Cooling water from the Eraring and Vales Point Power Stations contained moderate concentrations of oxidised nitrogen and ammonia-N, which are bioavailable forms of nitrogen. Bioavailable nutrients are more readily utilised by algae and plants for growth and can lead to harmful algal blooms and sediment enrichment when in excess. Exceedance of the NSW GVs at these locations suggests further monitoring or management action may be required.

The nutrient results captured in this monitoring program are consistent with long-term nutrient monitoring studies for Lake Macquarie which have indicated that the lake is generally well-buffered against severe eutrophication (DPE, 2023b; DPIE 2020). Within the southern lake area, the areas at most risk of nutrient enrichment are most likely the receiving environments for the Dora Creek and Wyee Creek tributaries and the power station cooling waters (southwest basin and Wyee Bay). This is likely due to the poorer oceanic flushing rates due to distance from the open channel and the water circulation patterns resulting from the power station cooling water intake and outlet channels, which act to retain catchment and industry inputs in the southern region of the lake (DPE, 2023b; DPIE 2020).

**Table 9. Descriptive statistics for surface water sampling nutrients data collected within Lake Macquarie from March 2022 to February 2023 (n = ~288: 19 sites x 12 sampling time-points). All data are in mg/L. Values that exceed the NSW GV are indicated in bold purple font.**

| Analyte | NSW GV[a] | DGV[b] | Descriptive Statistics[c] | | | |
|---|---|---|---|---|---|---|
| | | | Minimum | 50th percentile | 80th percentile | Maximum |
| Total nitrogen | 0.750 | 0.300 | 0.1 | 0.18 | 0.24 | **2.4** |
| Dissolved nitrogen | 0.670 | - | 0.07 | 0.15 | 0.21 | 0.66 |
| Oxidised nitrogen (NOx) | 0.003 | 0.015 | <0.002 | 0.002 | **0.005** | **2.1** |
| Ammonia nitrogen (NH-N) | 0.014 | 0.015 | <0.001 | 0.005 | **0.017** | **0.068** |
| Total phosphorus | 0.024 | 0.030 | 0.009 | 0.016 | 0.020 | **0.040** |
| Dissolved phosphorus | 0.009 | - | <0.004 | **0.010** | **0.013** | **0.023** |
| Free reactive phosphorus | 0.001 | 0.005 | <0.001 | **0.005** | **0.008** | **0.022** |

[a] NSW region-specific guideline values (NSW GVs) for estuarine lakes (DCCEEW, 2024)

[b] Default guideline values (DGVs) for moderately disturbed estuaries in south-east Australia (ANZECC/ARMCANZ, 2000)

[c] Values below the limit of reporting (LOR) were substituted as half of the LOR for calculating summary statistics

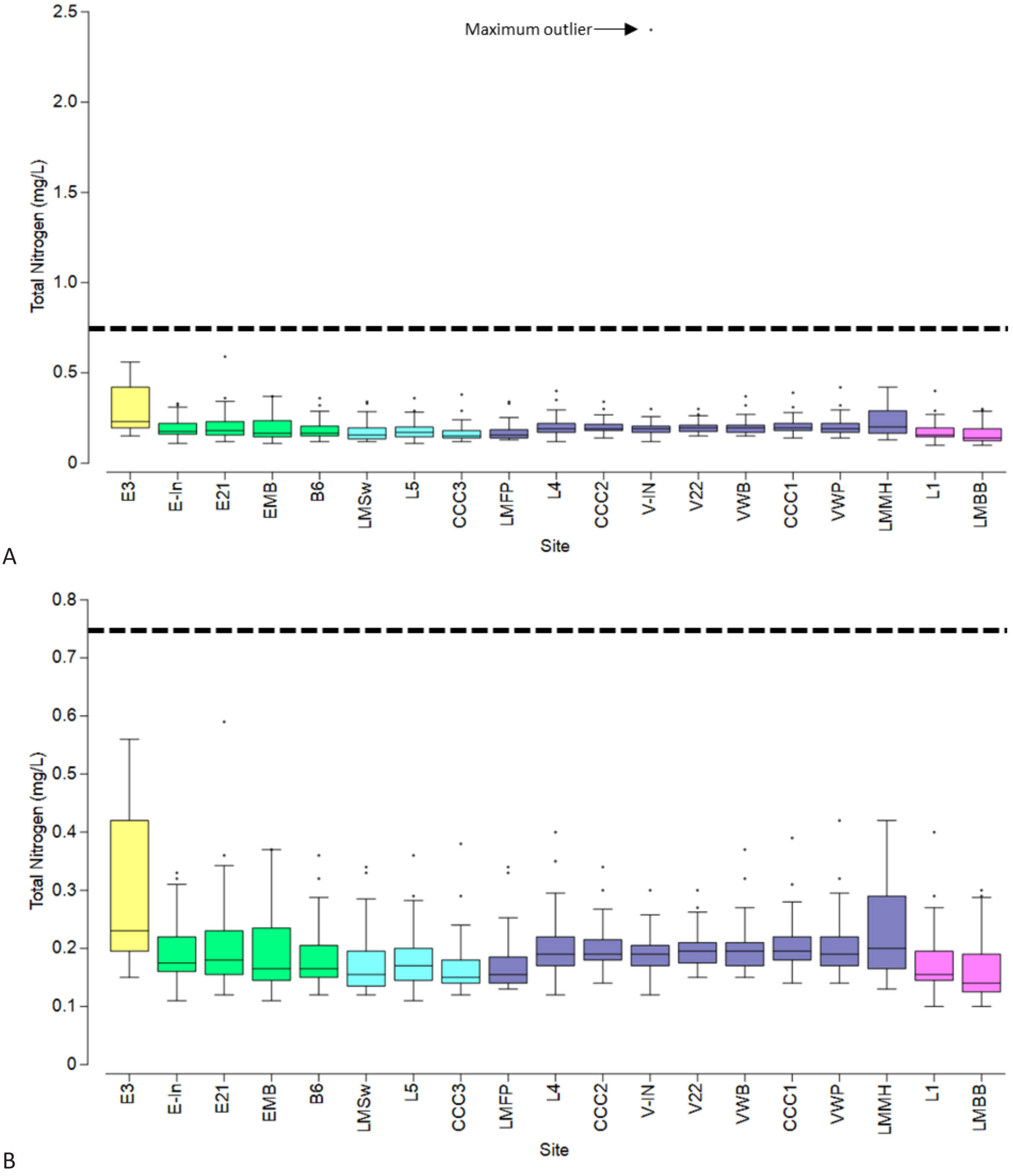


**Figure 11. Box plots of total nitrogen (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12): A) scale bar set to include all data points (including outliers); and B) refined scale bar set to discern differences at low concentrations. The horizontal black dashed line indicates the screening criterion concentration of 0.75 mg/L (DCCEEW, 2024). All values were greater than the limit of reporting of 0.02 mg/L.**

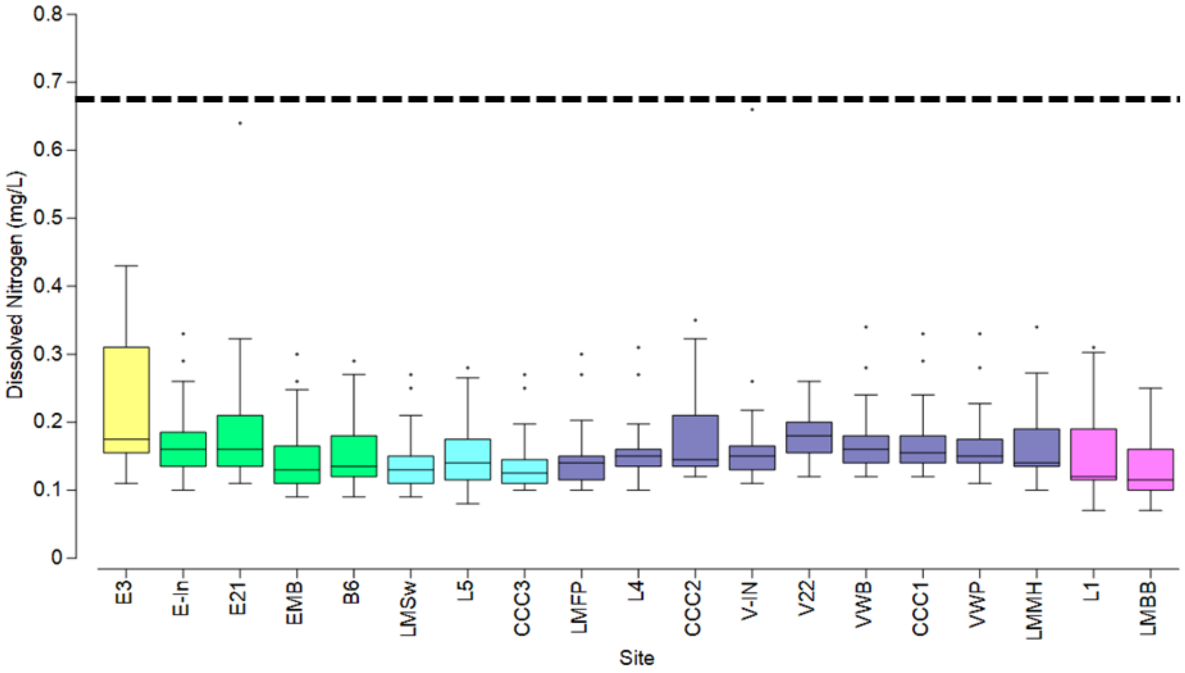


**Figure 12. Box plots of dissolved nitrogen (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023. The horizontal black dashed line indicates the screening criterion concentration of 0.67 mg/L (DCCEEW, 2024). All values were greater than the limit of reporting of 0.02 mg/L.**

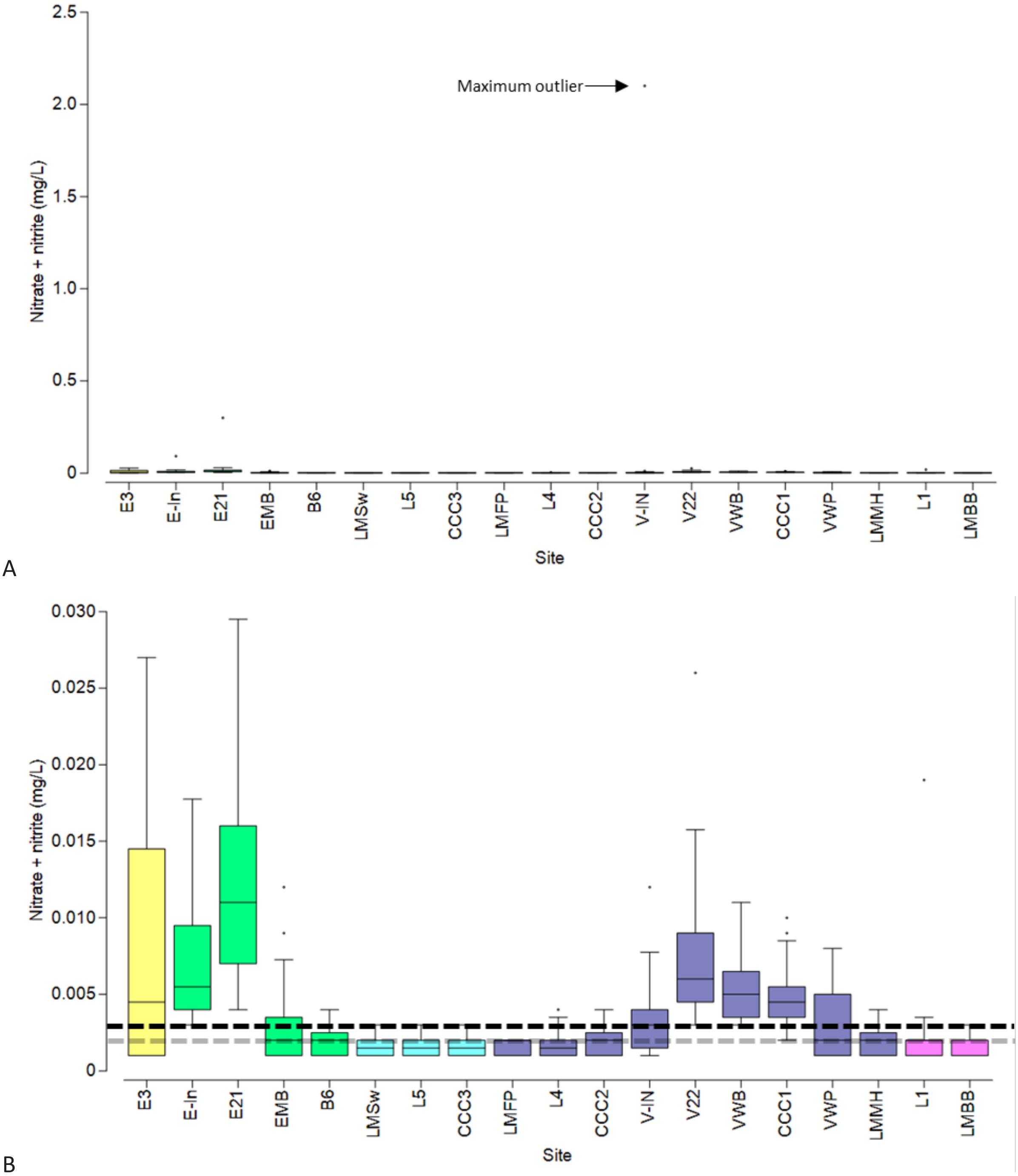


**Figure 13. Box plots of oxidised nitrogen (nitrate + nitrite) (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12): A) scale bar set to include all data points (including outliers); and B) refined scale bar set to discern differences at low concentrations. The horizontal black dashed line indicates the screening criterion concentration of 0.003 mg/L (DCCEEW, 2024). The horizontal grey dashed line indicates the limit of reporting (LOR, 0.002 mg/L); values below the LOR were replaced with half the LOR.**

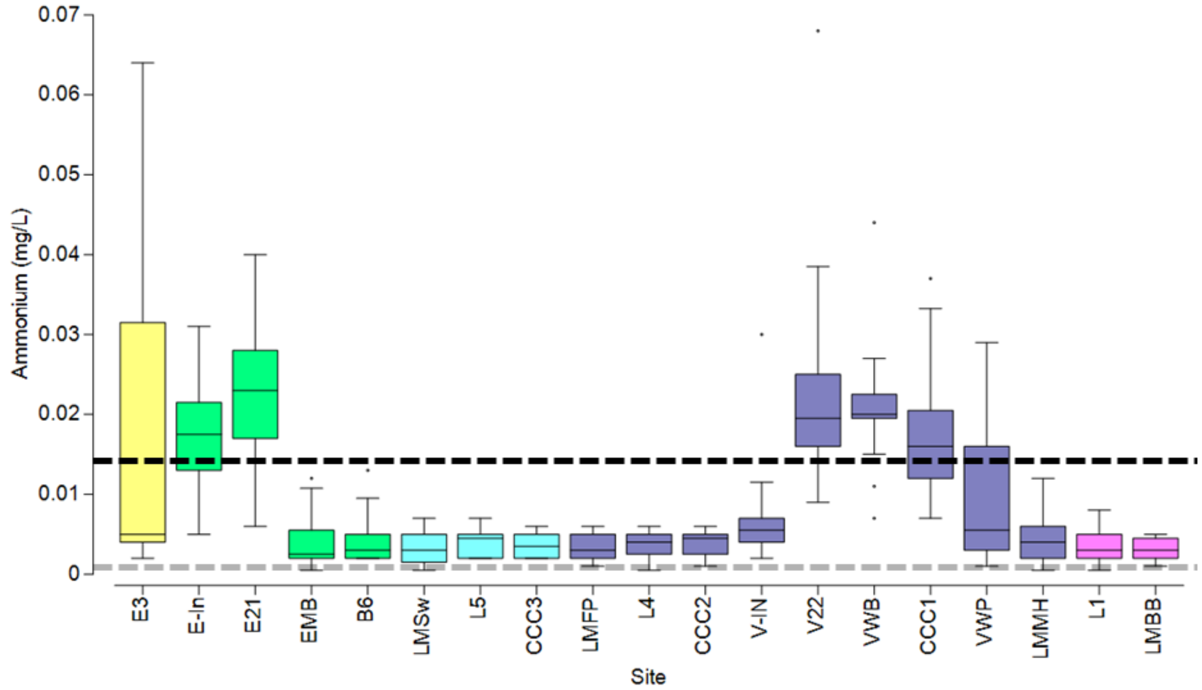


Figure 14. Box plots of ammonia-N (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The horizontal black dashed line indicates the screening criterion concentration of 0.014 mg/L (DCCEEW, 2024). The horizontal grey dashed line indicates the limit of reporting (LOR, 0.001 mg/L); values below the LOR were replaced with half the LOR.

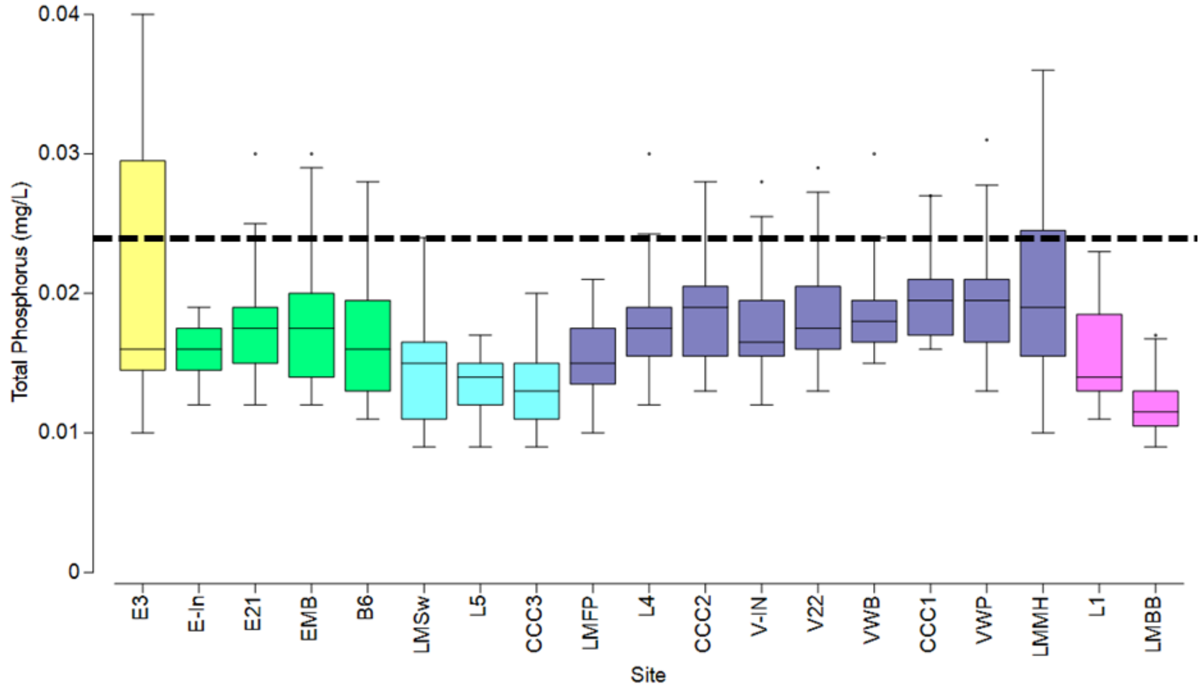


Figure 15. Box plots of total phosphorus (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The horizontal black dashed line indicates the screening criterion concentration of 0.024 mg/L (DCCEEW, 2024). All values were greater than the limit of reporting of 0.004 mg/L.

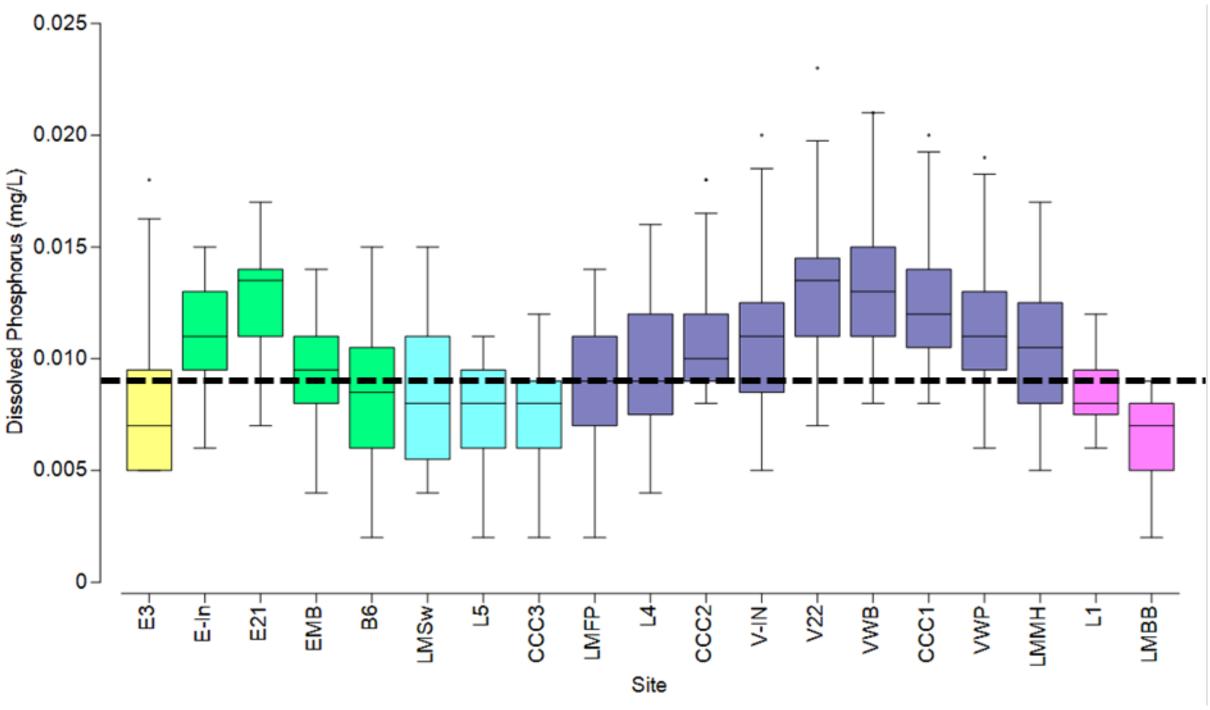


Figure 16. Box plots of dissolved phosphorus (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The horizontal black dashed line indicates the screening criterion concentration of 0.009 mg/L (DCCEEW, 2024). The limit of reporting (LOR) was 0.004 mg/L; values below the LOR were replaced with half the LOR.

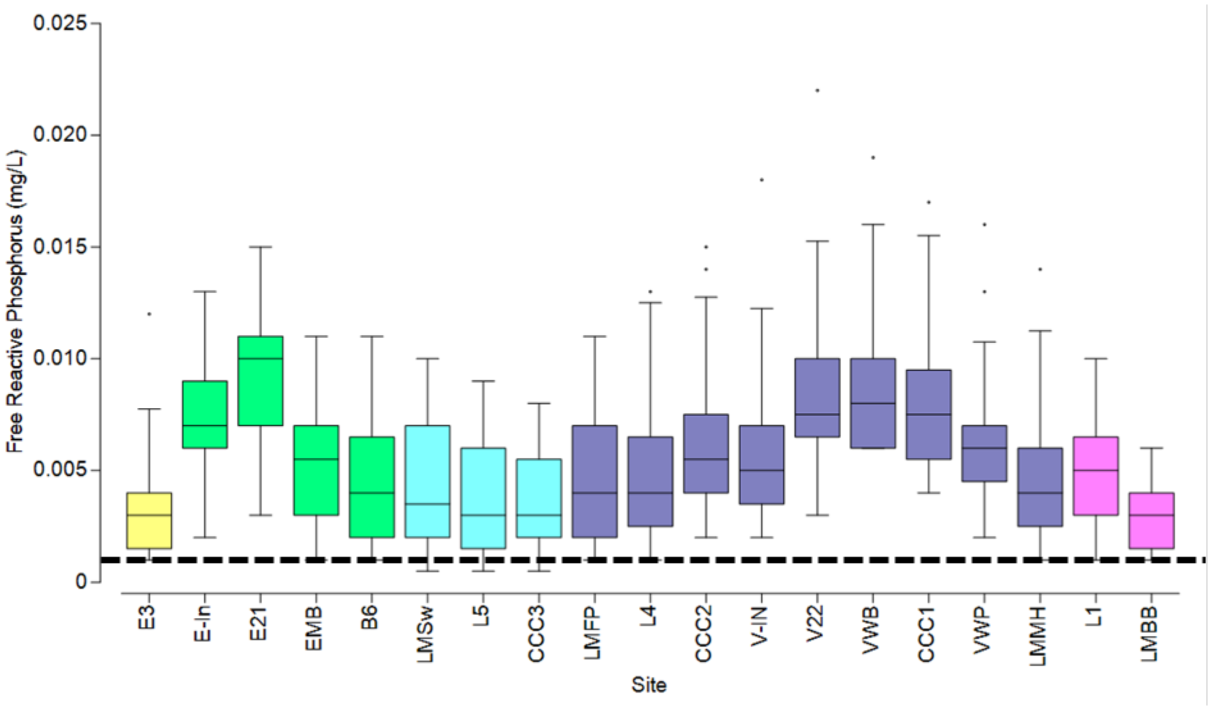


Figure 17. Box plots of free reactive phosphorus (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The horizontal black dashed line indicates the screening criterion concentration of 0.001 mg/L (DCCEEW, 2024). The limit of reporting (LOR) was 0.001 mg/L; values below the LOR were replaced with half the LOR.

### 3.2.3 Screening assessment – Metals

Summary descriptive statistics of total and dissolved metal concentrations collected across all lake sites during the 12-month monitoring program are compared against their respective screening criteria in Table 10. All measurements of silver, thallium and mercury were below the limits of reporting (LOR) and their respective screening criteria where available (ANZG, 2018). A further six metals (Cd, Cr, Pb, Ni, Se, and V) all had total and dissolved metal concentrations below their respective screening criteria and are therefore not considered contaminants of concern within surface waters of southern Lake Macquarie (ANZG, 2018; Buchman, 2008). Box plots of these metals (Cd, Cr, Pb, Ni, Se, and V) are provided in Appendix E – Additional metal box plots for completeness.

Seven metals (Al, As, Co, Cu, Mn, Mo, Zn) were identified as having at least one exceedance of their respective screening criteria based on dissolved metal concentrations measured during the monitoring program (ANZG, 2018). Box plots summarising the distribution of the measured values of these metals by site are provided below (Figure 18 to Figure 24). Scatter plots showing the individual metal concentration measurements by sampling date and comparison to rainfall data (for total Al and dissolved As, Co, Cu, Mn, Mo, and Zn) are provided in Appendix F – Temporal analysis of metal data.

The 95th percentile concentrations of dissolved arsenic, cobalt, and molybdenum at each of the sites within Lake Macquarie were all below their respective screening criteria, and therefore, these metals are not considered to be contaminants of potential concern within surface waters of southern Lake Macquarie. Arsenic, cobalt, and molybdenum concentrations were below the screening criteria on ≥99% of all sampling occasions (n=227).

- For dissolved arsenic, exceedance of screening criteria (0.0023 mg As/L) occurred at three sites (E-In, LMSw, CCC1) on a single sampling occasion each (Figure 19). The screening criterion for arsenic was set at the more conservative indicative interim working level for As(III) of 0.0023 mg/L as opposed to the indicative interim working level for As(V) of 0.0045 mg/L. No sites exceeded the indicative working level for As(V) (maximum dissolved arsenic concentration measured was 0.004 mg/L) or the draft AsV DGV of 0.012 mg/L. As an additional precautionary measure, arsenic speciation was carried out on a subset of samples and the results are provided in Appendix G – Arsenic speciation. Arsenic speciation showed that As(III) was not detected at any of the sites tested, suggesting the As(V) guideline value is appropriate to use. As(V) was below the guideline value (0.0045 mg/L) at all lake sites tested (E-In, E21, V-In, V22).
- For dissolved cobalt, exceedance of screening criteria (0.001 mg/L) occurred for a single site (E3) and timepoint (March 2022) (Figure 20). The concentration of cobalt measured in the total and dissolved fractions were 0.0013 and 0.0016 mg/L, respectively. No sites exceeded the draft cobalt DGV of 0.0061 mg/L. E3 demonstrated significant peaks in March and October and a slow reduction in total and dissolved cobalt concentrations over subsequent sampling rounds (Figure A26). E3 is a site within Dora Creek, which is the largest tributary with the largest catchment draining into Lake Macquarie.
- For dissolved molybdenum, exceedance of the screening criterion (0.023 mg/L) occurred for a single site (CCC1) and timepoint (June 2022) (Figure 23). The concentration of molybdenum measured in the total and dissolved fractions were 0.012 and 0.026 mg/L, respectively, indicating that the molybdenum exceedance is likely an erroneous result, due to contamination of the dissolved metal sample (Appendix A – Data quality assessment). No sites exceeded the draft molybdenum DGV of 5 mg/L.

The 95th percentile concentrations of dissolved aluminium, copper, manganese, and zinc, exceeded their respective screening criteria at one or more sites, identifying them as potential metals of concern within Lake Macquarie. However, concentrations were below the criteria on 96%, 78%, 99%, and 96% of all sampling occasions (n=227), respectively.

- The 95th percentile concentration of dissolved aluminium exceeded the screening criterion (draft DGV of 0.037 mg/L) at five sites (including E3, B6, L4, CCC1, and LMMH) (Figure 18). At these sites, exceedances occurred on four occasions at E3, three occasions at LMMH, and the rest on a single occasion. The highest concentrations of total aluminium were measured at Site E3 (maximum of 1.4 mg/L). Concentrations of dissolved aluminium in the lake (excluding E3) ranged from <0.01 to 0.06 mg/L and in the northern section of the lake from <0.01 to 0.03 mg/L. The lowest concentrations of total aluminium were observed in the southeast zone of the southern lake. Concentrations of total aluminium in the southern section of the lake (excluding E3) ranged from <0.01 to 0.16 mg/L and were relatively comparable to concentrations in the northern section (Sites L1 and LMBB) of the lake <0.01 to 0.14 mg/L.
- The 95th percentile concentration of dissolved copper exceeded the screening criterion (0.0013 mg/L) at 16 sites (including Sites E3, E21, EMB, B6, LMSw, LMFP, L4, CCC2, V22, VWB, VWP, LMMH, L1, and LMBB with a 95th percentile concentration of 0.002 mg/L and L5 and CCC1 with a 95th percentile concentration of 0.003 mg/L)(Figure 21). Concentrations of dissolved copper in the southern section of the lake ranged from <0.001 to 0.004 mg/L and were relatively comparable to concentrations in the northern section of the lake <0.001 to 0.002 mg/L. DOC was measured at each site and each sampling event. A revised default guideline value for copper in marine water, that can be adjusted for different DOC concentrations to produce a DOC-modified DGV has recently been proposed and is currently undergoing a peer review process (ANZG, 2023). The median DOC concentration for the lake sites across all time points was 3 mg/L (n=228). The corresponding proposed DOC-modified DGV for 3 mg DOC/L for 95% species protection is 0.0035 mg/L. All sites had a 95th percentile concentration of ≤0.003 mg/L.
- The 95th percentile concentration of dissolved manganese exceeded the screening (0.080 mg/L) criterion at only one site, Site E3 (Figure 22). E3 had dissolved manganese exceedances on three sampling occasions, with significant peaks in March and October and a slow reduction in total and dissolved concentrations over subsequent sampling rounds (similar to the pattern observed for dissolved cobalt) (Figure A28).
- The 95th percentile concentrations of dissolved zinc exceeded screening criterion (0.008 mg/L) at eight sites (including E3, E-In, V-In, V-22, VWB, VWP, L1 and LMBB) (Figure 24). Six of these sites (E3, E-In, V-In, V-22, VWB, VWP) exceeded the screening criterion on only one sampling occasion and at two of these sites (L1 and LMBB) on two sampling occasions. Concentrations of dissolved zinc in the southern section of the lake ranged from <0.003 to 0.024 mg/L and were relatively comparable to concentrations in the northern section of the lake <0.003 to 0.021 mg/L.

Metals without screening criteria included barium, boron, and iron. Box plots of these metals are provided in Appendix E – Additional metal box plots for completeness and briefly summarised below:

- The 95th percentile concentrations for total and dissolved barium were within the range of typical barium concentrations in marine waters of 0.004 to 0.02 mg/L (Haanes et al., 2023) for all sites except for E3, being slightly greater (0.044 and 0.047 mg/L, respectively).
- The 95th percentile concentrations for total and dissolved boron were within the range of typical boron concentrations in marine waters of 4.5 to 5.1 mg/L (ANZG, 2021) for all sites except at Site E3 (Dora Creek) which was slightly (but not significantly) lower (4.4 mg/L for both), likely due to freshwater inflows.

- The 95th percentile concentrations for total and dissolved iron were between 0.03 to 1.9 mg/L and <0.02 to 0.85 mg/L, respectively, with the highest concentrations being observed at E3.
- Freshwater inflows from Dora Creek are a significant source of barium (mostly dissolved) and iron (mostly particulate) to the lake.

### *Overall*

Overall, concentrations of metals in the southern section of the lake were below their respective screening criteria and/or were comparable to concentrations measured in the northern section of the lake. Concentrations of aluminium, barium, iron, manganese and zinc appear to be related to freshwater inflows bringing these contaminants from the catchment via the Dora Creek and Wyee Creek tributaries (see Section 4). Low concentrations of dissolved copper were relatively uniformly distributed across the lake. There are numerous potential sources of copper to the lake, which include the piping used in the cooling water system of the power stations and surface run-off from mixed land-use catchment (e.g., from urban inputs such as roofs and roads) (DPIE, 2020), as well as resupply from sediments which have acted as a sink for historical contamination (DCCEEW, 2024). In marine waters, copper is likely to complex with DOC thereby reducing its bioavailability and toxicity. DOC concentrations measured in Lake Macquarie during this monitoring program (median concentration for all sites and sampling time-points was 3 mg/L) would likely be protective of adverse effects from the copper concentrations measured in the lake.

**Table 10. Descriptive statistics for surface water metals data collected within Lake Macquarie from March 2022 to February 2023 (n = ~228: 19 sites x 12 sampling time-points). All values are in mg/L. Values below the limit of reporting (LOR) were substituted as half of the LOR for calculating summary statistics. ANZG marine default guideline values (DGVs) for 95% species protection have been applied as screening criteria unless otherwise indicated. Values that exceed the screening criteria are indicated in bold purple font.**

| Analyte | Screening criteria | Total metals | | | Dissolved metals | | |
|---|---|---|---|---|---|---|---|
| | | 50th percentile | 95th percentile | Maximum | 50th percentile | 95th percentile | Maximum |
| Ag | 0.0014 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Al | 0.037[a] | 0.03 | **0.09** | **1.4** | <0.01 | **0.04** | **0.11** |
| As | 0.0023[b] | 0.002 | 0.002 | **0.003** | 0.002 | 0.002 | **0.004** |
| Ba | NA | 0.010 | 0.016 | 0.045 | 0.010 | 0.016 | 0.051 |
| Be | NA | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| B | NA | 4.3 | 4.8 | 5.0 | 4.1 | 4.8 | 4.9 |
| Cd | 0.0007[c] | <0.0002 | 0.0003 | 0.0005 | <0.0002 | 0.0003 | 0.0004 |
| Cr | 0.0044 | <0.0005 | 0.0007 | 0.0013 | <0.0005 | 0.0010 | 0.0025 |
| Co | 0.001 | 0.0001 | 0.0002 | **0.0013** | <0.0001 | 0.0002 | **0.0016** |
| Cu | 0.0013 | 0.001 | **0.003** | **0.094** | 0.001 | **0.002** | **0.004** |
| Fe | NA | 0.04 | 0.20 | 2.1 | <0.02 | 0.03 | 1.0 |
| Pb | 0.0044 | <0.0005 | 0.0006 | 0.0024 | <0.0005 | <0.0005 | <0.0005 |
| Hg | 0.0001[c] | <0.00005 | <0.00005 | <0.00005 | NM | NM | NM |
| Mn | 0.080[b] | 0.010 | 0.033 | **0.19** | 0.005 | 0.027 | **0.22** |
| Mo | 0.023[b] | 0.012 | 0.016 | 0.020 | 0.012 | 0.017 | **0.026** |
| Ni | 0.070 | <0.001 | <0.001 | 0.01 | <0.001 | 0.001 | 0.007 |
| Se | 0.003[b] | <0.002 | <0.002 | 0.003 | <0.002 | <0.002 | 0.002 |
| Tl | NA | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| V | 0.100 | 0.0021 | 0.0039 | 0.0045 | 0.0020 | 0.0037 | 0.0059 |
| Zn | 0.0080 | <0.003 | **0.011** | **0.033** | <0.003 | 0.008 | **0.024** |

NA = Not available.

NM = Not measured

[a] Proposed third-party guideline value.

[b] Indicative interim working level

[c] To account for the bioaccumulating nature of this toxicant, it is recommended that the 99% species protection level DGV is used for slightly to moderately disturbed systems.

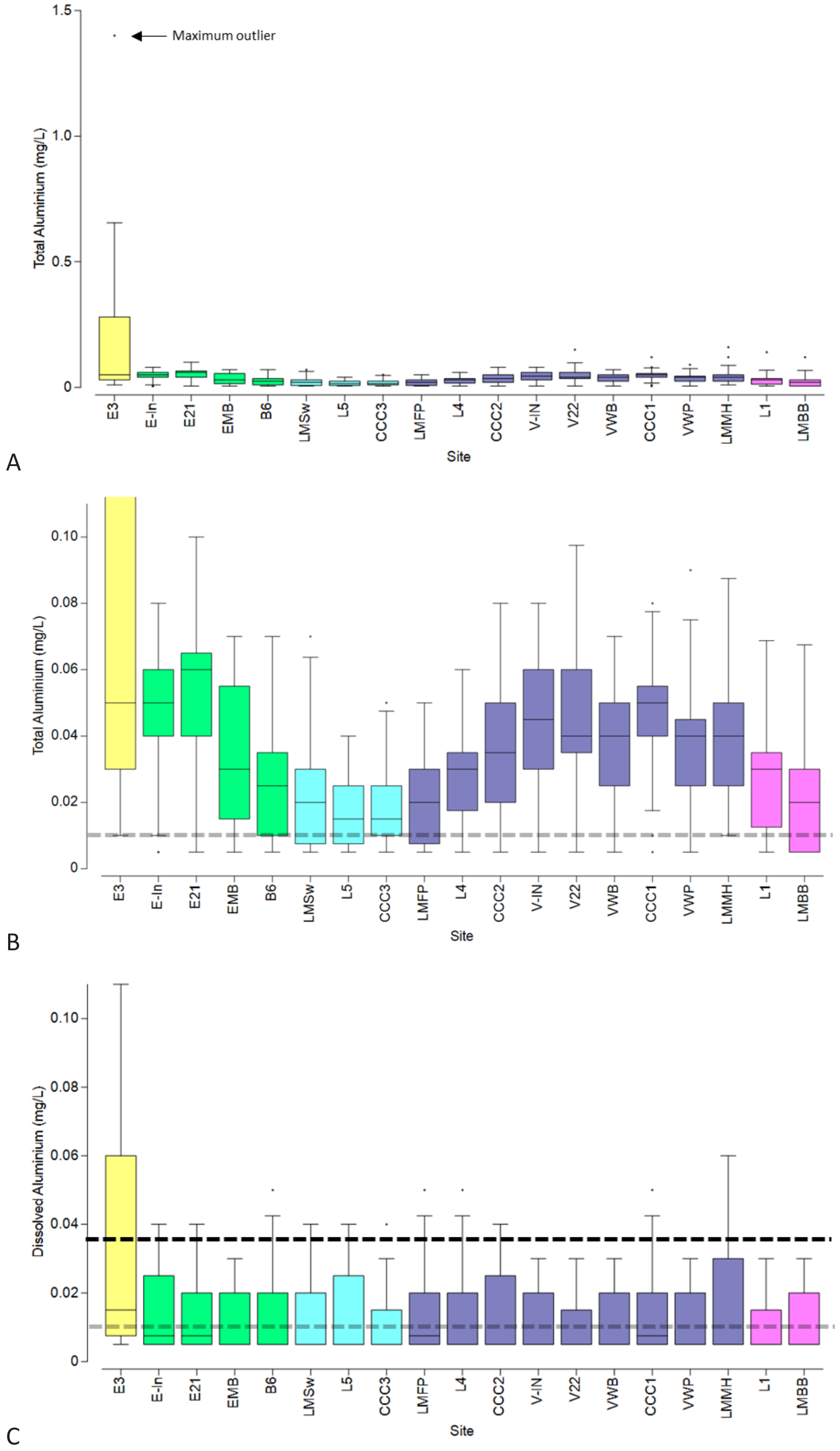


**Figure 18. Box plots of aluminium concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023: A) total aluminium with scale bar set to include all data points (including outliers); B) total aluminium with refined scale bar set to discern differences at low concentrations; C) dissolved (<0.45 µm filtered) aluminium. The horizontal black dashed line (in Figure C) indicates the screening criterion concentration, 0.037 mg/L (ANZG, 2024; G.E. Batley, personal communication). The horizontal grey dashed line indicates the limit of reporting (LOR, 0.01 mg Al/L); values below the LOR were replaced with half the LOR.**

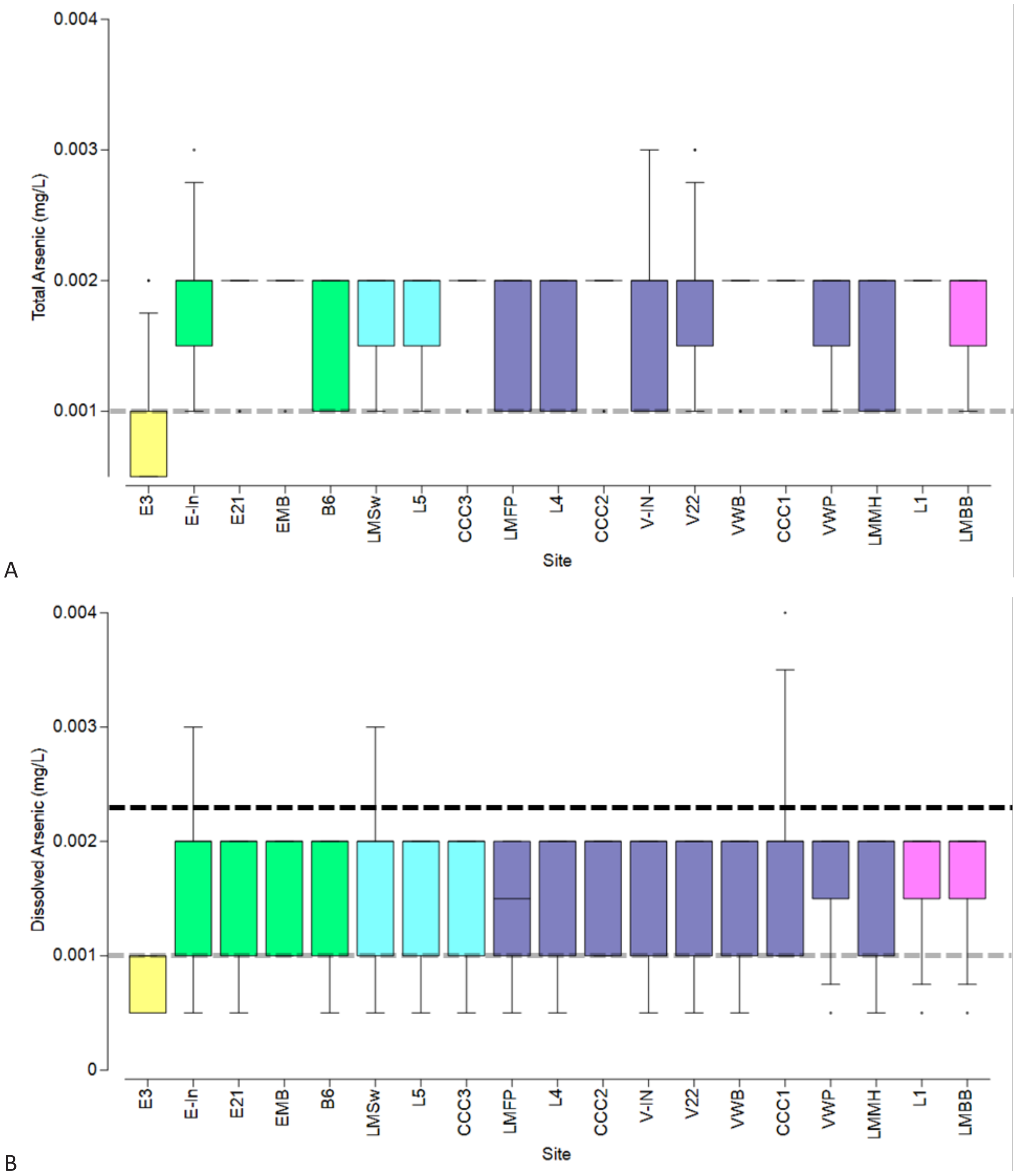
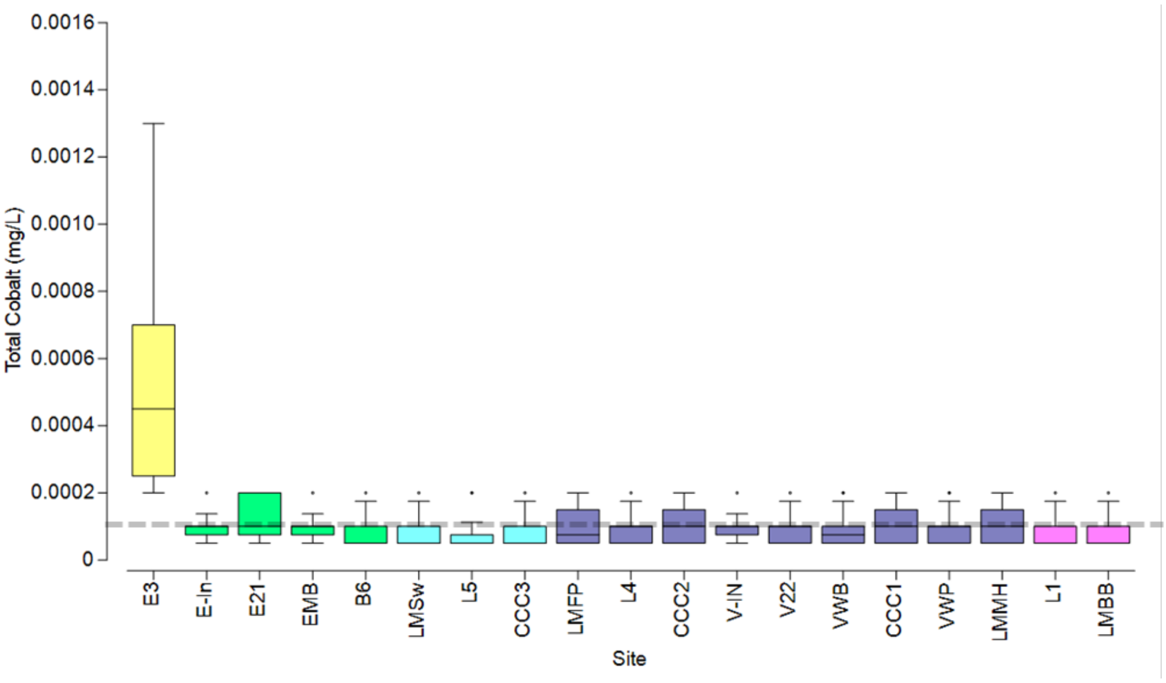


**Figure 19. Box plots of arsenic concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023: A) total arsenic; B) dissolved (<0.45 µm filtered) arsenic. The horizontal black dashed line (in Figure B) indicates the screening criterion concentration, 0.0023 mg/L (ANZG, 2018). The horizontal grey dashed line indicates the limit of reporting (LOR, 0.001 mg As/L); values below the LOR were replaced with half the LOR.**



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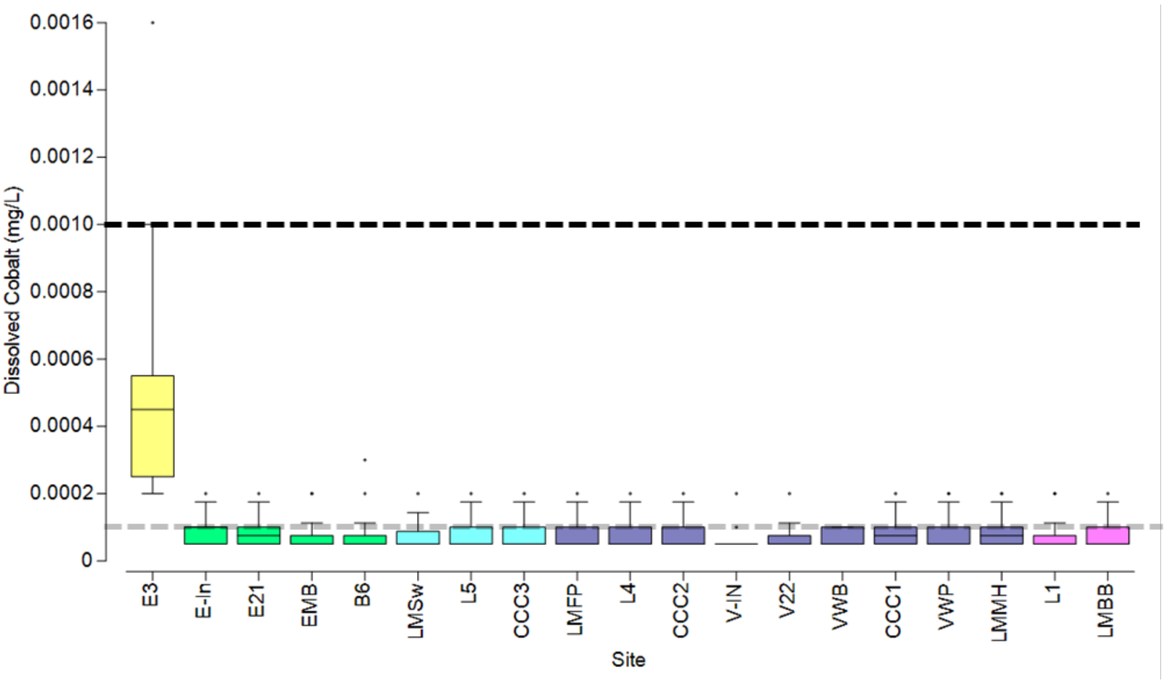


B

**Figure 20. Box plots of cobalt concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023: A) total cobalt; B) dissolved (<0.45 µm filtered) cobalt. The horizontal black dashed line (in Figure B) indicates the screening criterion concentration, 0.001 mg/L (ANZG, 2018). The horizontal grey dashed line indicates the limit of reporting (LOR, 0.0001 mg Co/L); values below the LOR were replaced with half the LOR.**

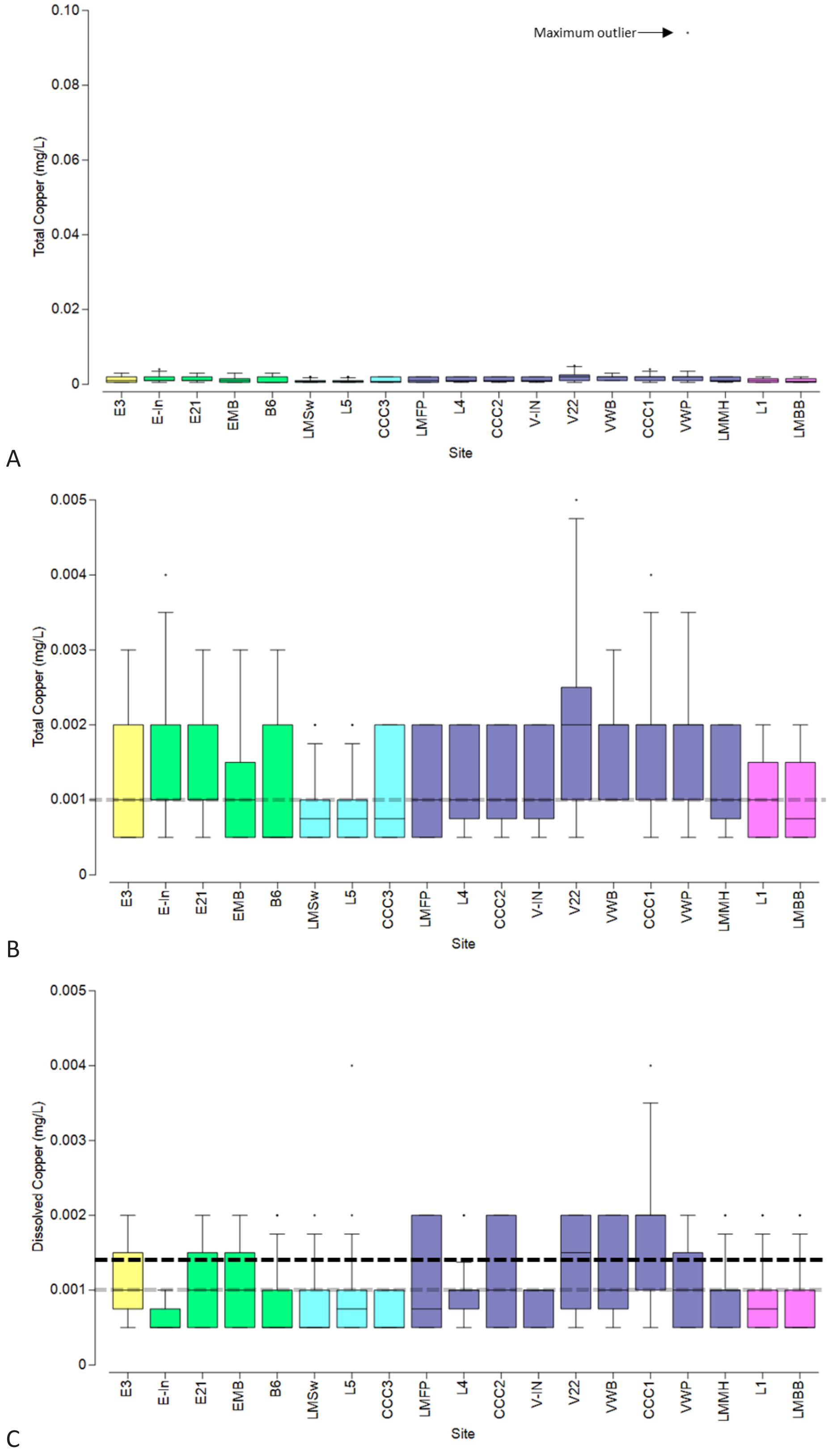


**Figure 21. Box plots of copper concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023: A) total copper with scale bar set to include all data points (including outliers); B) total copper with refined scale bar set to discern differences at low concentrations; C) dissolved (<0.45 µm filtered) copper. The horizontal black dashed line (in Figure C) indicates the screening criterion concentration, 0.0013 mg/L (ANZG, 2018). The horizontal grey dashed line indicates the limit of reporting (LOR, 0.001 mg Cu/L); values below the LOR were replaced with half the LOR.**

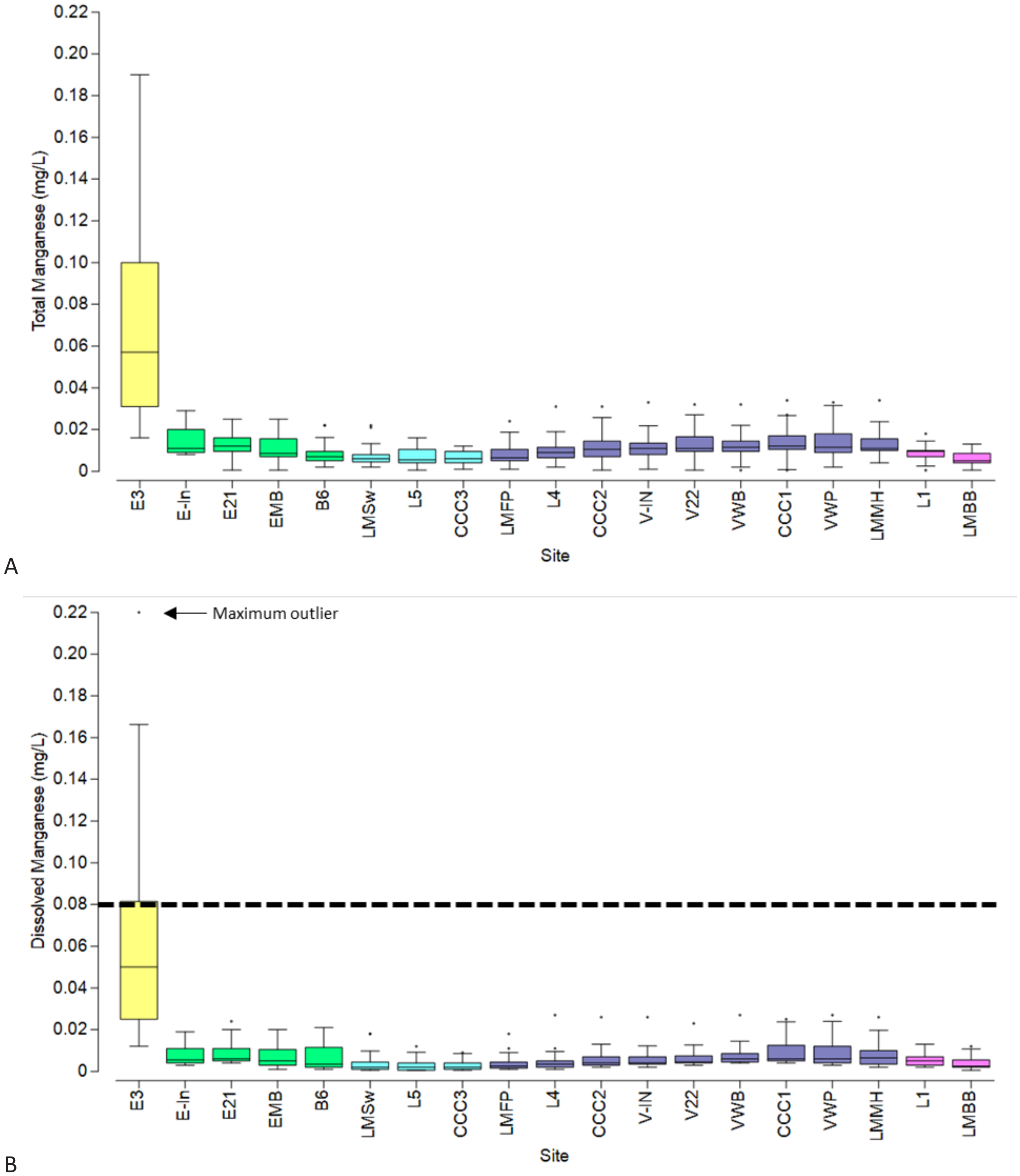
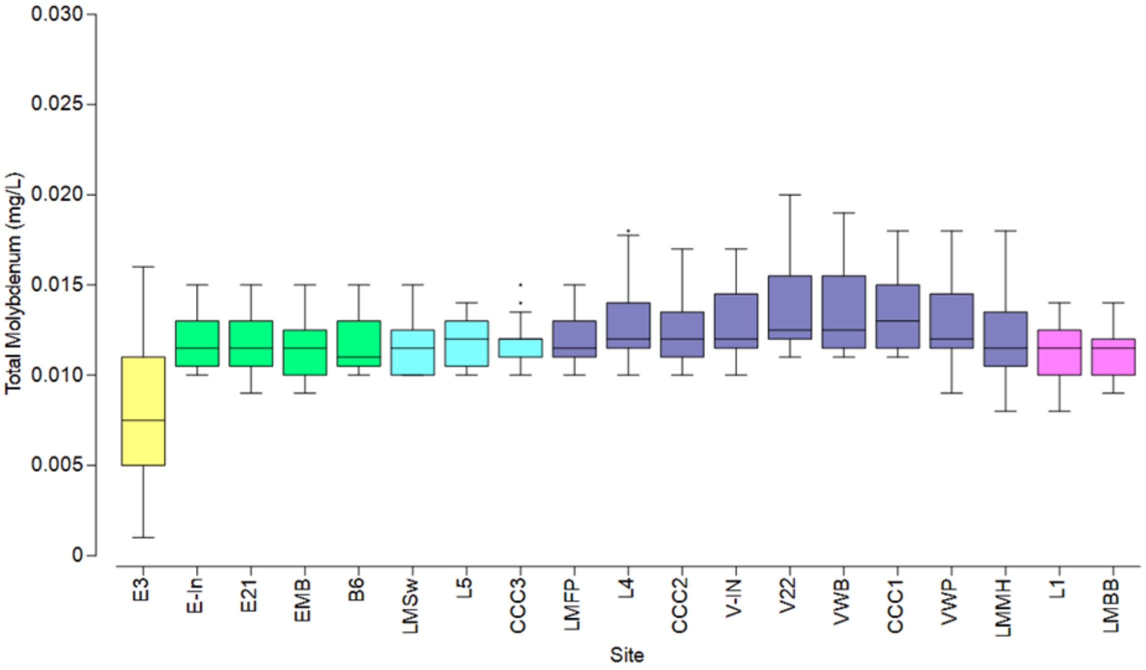


**Figure 22. Box plots of manganese concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023: A) total manganese; B) dissolved (<0.45 µm filtered) manganese. The horizontal black dashed line (in Figure B) indicates the screening criterion concentration, 0.080 mg/L (ANZG, 2018). The limit of reporting (LOR) was 0.001 mg Mn/L; values below the LOR were replaced with half the LOR.**



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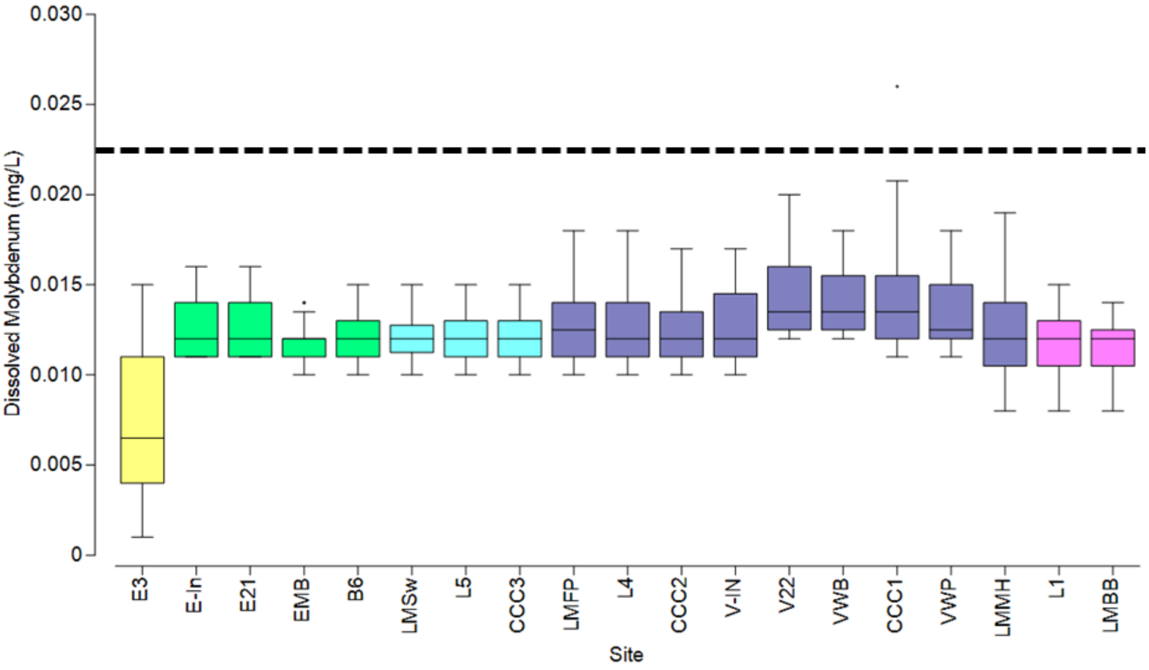


B

**Figure 23. Box plots of molybdenum concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023: A) total molybdenum; B) dissolved (<0.45 µm filtered) molybdenum. The horizontal black dashed line (in Figure B) indicates the screening criterion concentration, 0.023 mg/L (ANZG, 2018). All values were greater than the limit of reporting (LOR) of 0.001 mg Mo/L.**

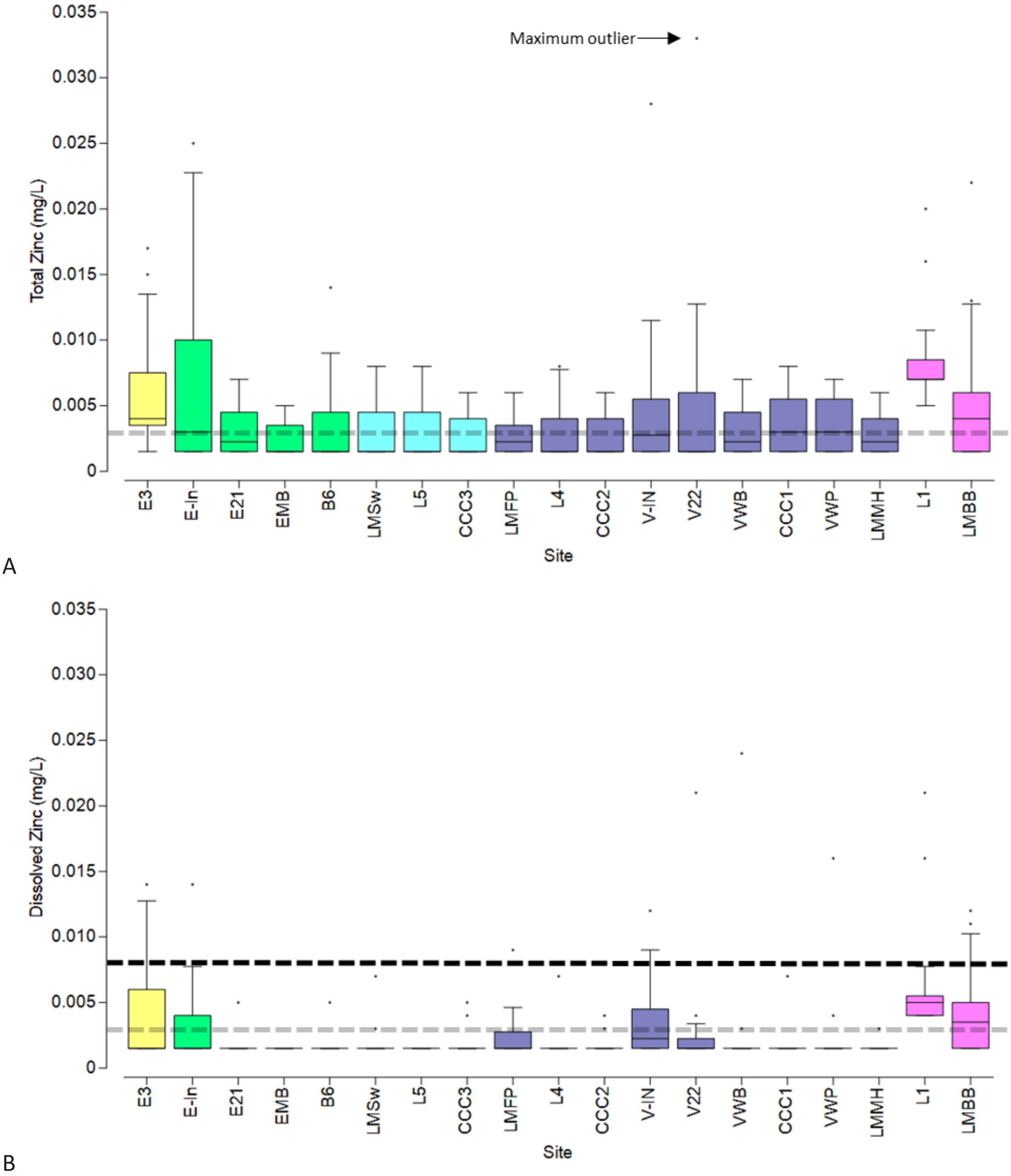


**Figure 24. Box plots of zinc concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023: A) total zinc; B) dissolved (<0.45 µm filtered) zinc. The horizontal black dashed line (in Figure B) indicates the screening criterion concentration, 0.0080 mg/L (ANZG, 2018). The limit of reporting (LOR) was 0.003 mg Zn/L; values below the LOR were replaced with half the LOR.**

## 3.3 Summary of water quality within the southern lake basin

Principal components analysis (PCA) was used to explore the differences in key water quality parameters (temperature, TSS, oxidised nitrogen, ammonia-N, total Al, and dissolved As, Co, Cu, Mn, Mo, and Zn) among the 19 sites (Figure 25). The first PCA axis explained 25.5% of the variation across sites, where increasing dissolved cobalt and manganese and decreasing dissolved molybdenum were the main variables separating the sites. The second PCA axis explained 19.5% of the variation across sites, where increasing temperature, ammonia-N, and free reactive phosphorus were the main variables separating the sites. The PCA shows that most of the sites are similar, indicated by the clustering of data points in the bottom left of the graph. Sites showing differences to northern lake sites (L1 and LMBB) are mainly Site E3, which had greater dissolved metals, including cobalt and manganese, and Sites E21, VWB, CCC1, and V22, which had greater temperature and ammonia-N. The Site E3 data points were quite dispersed, indicating more variability in water quality between the respective replicates through the monitoring program, likely to be linked to the varying influence of catchment runoff on water quality in Dora Creek.

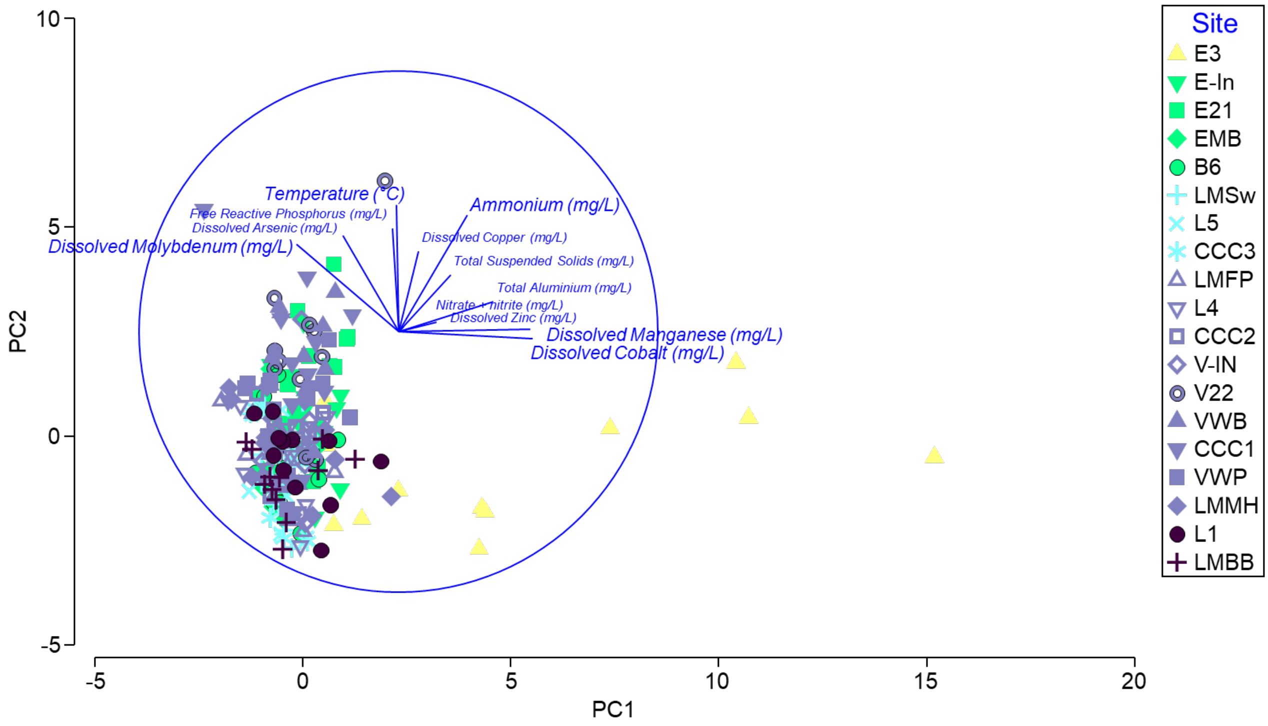


**Figure 25. Principal components analysis of key water quality parameters collected from 19 sites with Lake Macquarie from March 2022 to February 2023. Icon colour represents general location/grouping information about the sampling sites: Dora Creek (yellow); sites within the southern section of the lake: southwest zone (green), southeast zone (blue), and south zone (lavender); sites within the northern section of the lake (plum).**

# 4. Eraring and Vales Point surface water monitoring

## 4.1 Sampling locations

Alongside the monitoring of water quality within the southern section of Lake Macquarie (Section 3), a complementary surface water monitoring program was conducted to characterise the concentrations of nutrients and metals in the coal ash repositories decant/return water and seepage waters, as well as onsite surface waters that may receive water flows from the site and/or emergency discharges from the Eraring and Vales Point Power Stations following wet weather. Ten sites were selected (Figure 26), and a description of each site and its grouping into zones/categories for reporting purposes is provided in Table 11. All ten sites were accessible by land.

An additional sample collection event occurred on the 1st of April 2022 at a subset of the sites within Vales Point Power Station (V25, V25U, V25D and VWC) after it was reported that their ash repository had reached maximum water storage capacity and emergency discharge was occurring to Lake Macquarie via Wyee Creek. Emergency discharges to the lake are rare but are more common in wetter years. No emergency discharge by Eraring Power Station occurred during the monitoring period.

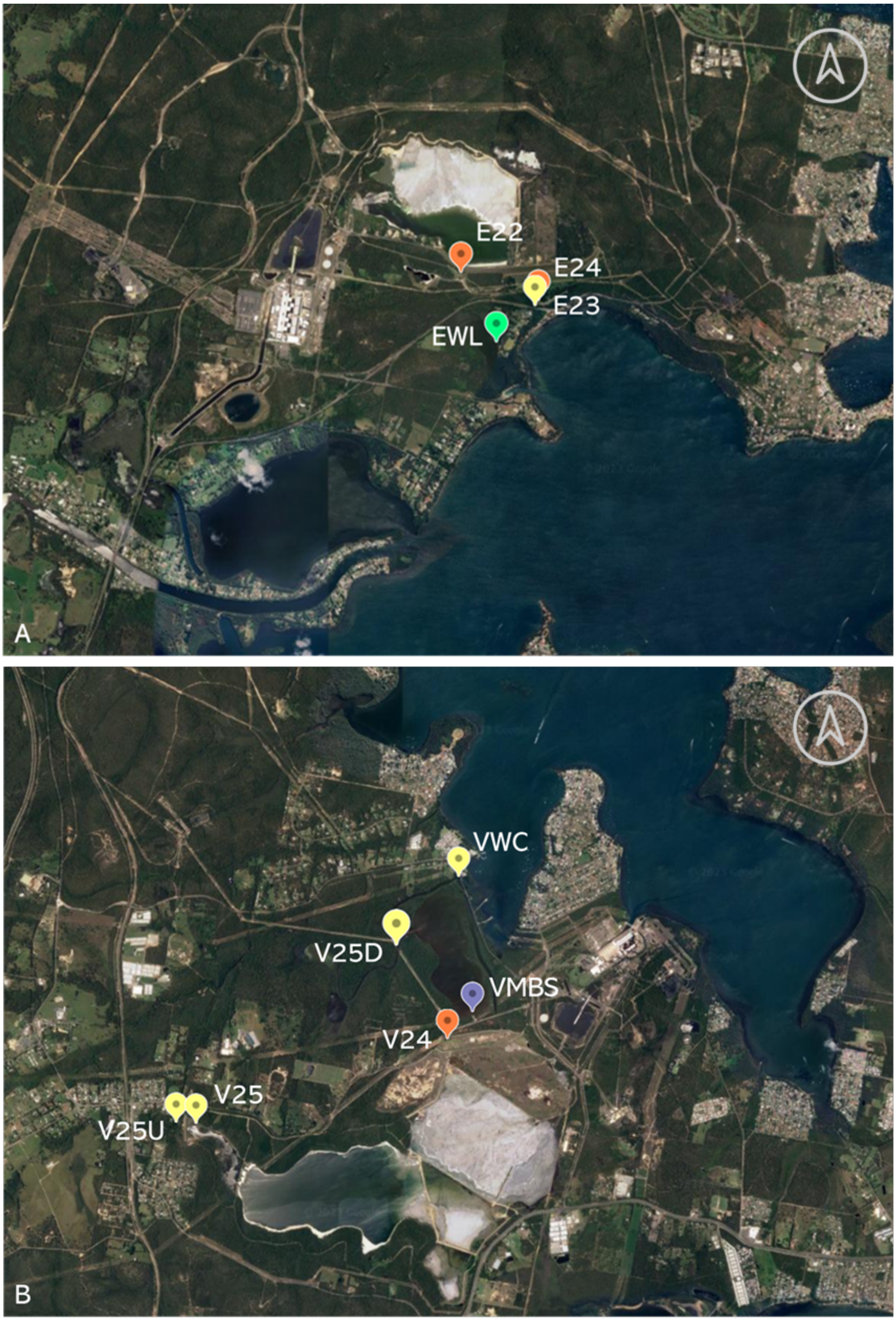


**Figure 26. Surface water sampling locations at Eraring (A) and Vales Point Power Stations (B). Icon colour represents general location/grouping information about the sampling sites: Crooked Creek (A) and Wyee Creek (B) (yellow); coal ash repository water (orange), sites within the southern section of the lake: southwest zone (green) and south zone (lavender).**

**Table 11. Location and description of surface water sampling sites at Eraring and Vales Point Power Stations**

| Site name | Site location | Description | Zone designation | Latitude (°N)[a] | Longitude (°E)[a] |
|---|---|---|---|---|---|
| E22 | Eraring Power Station | Coal ash repository decant/return water | Coal ash repository water | -33.0583 | 151.5395 |
| E24 | Eraring Power Station | Toe drain - storage pond that collects seepage water from coal ash | Coal ash repository water | -33.0609 | 151.5482 |
| E23 | Crooked Creek | Crooked Creek - can receive emergency overflow from the toe drain during high rainfall events | Creek | -33.0614 | 151.5478 |
| EWL | Whiteheads Lagoon | Whiteheads Lagoon – can receive surface water flows | South-west zone | -33.0648 | 151.5435 |
| V25 | Vales Point Power Station | Coal ash repository decant/return water<br>Water from the coal ash repository is recycled through the ash system, and surplus water is discharged under controlled conditions to the outlet canal. When required, overflows during extreme rainfall events from the coal ash repository can be discharged to the Wyee Creek diversion channel. | Coal ash repository water | -33.1779 | 151.4948 |
| V25U | Wyee Creek | Wyee Creek, upstream of coal ash repository emergency overflow | Creek | -33.1778 | 151.4925 |
| V25D | Wyee Creek | Wyee Creek downstream of coal ash repository emergency overflow | Creek | -33.1607 | 151.5180 |
| VWC | Wyee Creek | Wyee Creek, further downstream, just before where the creek enters the lake | Creek | -33.1540 | 151.5252 |
| V24 | Vales Point Power Station | Seepage water from the rehabilitated coal ash repository is captured and returned to the coal ash repository.<br>Surface water infiltrating the coal ash repository is recirculated (as groundwater) through the coal ash repository by the pumping of groundwater from behind the northern coal ash repository wall adjacent to Mannering Bay | Coal ash repository water | -33.1697 | 151.5239 |
| VMBS | Mannering Bay | Mannering Bay South | South zone | -33.1671 | 151.5268 |

[a] The coordinates presented are based on the first sampling round and are representative as slight variations may have occurred during the monitoring program.

## 4.2 Results

All surface water quality physicochemical indicators, nutrient, and metal concentration data collected during the 12-month Eraring and Vales Point Power Stations monitoring program are provided in the Supplementary Information.

### 4.2.1 Physicochemical indicators

#### *Temperature*

Median temperatures across the sites were between 18 (V25U) and 25°C (VWC) (Figure 27). The minimum and maximum median temperatures were both collected from Wyee Creek indicating a roughly 7°C difference between the upstream freshwater site (V25U) and the downstream estuarine site where the creek meets the lake (VWC). Site VWC is tidal where water temperature is influenced by the inflow of warm waters from Wyee Bay into lower Wyee Creek.

#### *Conductivity*

Median conductivity concentrations varied widely between sites (Figure 28). Freshwater sites included Crooked Creek (Site E23: 1,100 µS/cm) and upstream Wyee Creek (Site V25U: 625 µS/cm). Downstream Wyee Creek sites were tidal and experienced the greatest variation in conductivity throughout the monitoring program. The minimum and maximum values measured at Site V25D were 2,600 – 52,000 µS/cm, and at Site VWC were 5,600 – 55,000 µS/cm. Conductivity was typically brackish to saline in the coal ash repositories and return waters with median values of 5,200 (E22), 17,000 (E24), 9,600 (V25), and 33,000 µS/cm (V24). Conductivity was saline in Whiteheads Lagoon (46,000 µS/cm, median at EWL) and Mannering Bay (43,000 µS/cm, median at VMBS).

#### *Dissolved oxygen*

Median dissolved oxygen levels were between 40 (E23) and 107% (VMBS) (Figure 29). The lowest dissolved oxygen concentrations were observed in Crooked Creek (E23) and upstream Wyee Creek (V25U). Both creeks were characterised by low water flow except after rainfall.

#### *pH*

Median pH values varied widely between sites (Figure 30). Generally lower pH values were observed in Crooked Creek (6.4 at E23) and Wyee Creek (7.2, 7.1, and 7.7 at V25U, V25D and VWC, respectively). At both Eraring and Vales Point Power Stations, the median pH was higher in the coal ash repository decant/return waters (8.4 at E22 and 9.2 at V25, respectively) compared to the coal ash repository seepage/return water (6.8 at E24 and 8.1 at V24, respectively). The median pH at EWL (7.8) and VMBS (7.7) were slightly lower than the median pH value observed for all lake sites during the monitoring period (8.1) (Section 3.2.1).

#### *Total suspended solids*

Figure 31 shows the total suspended solid concentrations for sampling sites at Eraring and Vales Point Power Stations. Median TSS concentrations were generally greater in the coal ash repository decant or seepage waters (7, 11, and 5 mg/L at Sites E22, E23, and V25, respectively), creek sites (11, 9, and 9 mg/L at Sites E23, V25U, V25D, respectively), and local receiving waters (10 mg/L at EWL and 28 mg/L at VMBS) compared to the lake sites (median TSS of 4 mg/L). Site V24 (2 mg/L) was the only exception where the median TSS concentration was below that of the lake sites.

#### *Turbidity*

Figure 32 shows the turbidity measurements for sampling sites at Eraring and Vales Point Power Stations. Median turbidity measurements were greater in the coal ash repository decant or seepage waters (6.4, 19, 1.9, and 3.7 FNU at Sites E22, E23, V25, and V24 respectively), in the creek sites (57, 17, and 9.5 FNU at Sites E23, V25U, V25D, respectively) and the local receiving waters (6.6 FNU at EWL and 11 FNU at VMBS) compared to the lake sites (median turbidity of 1.1 FNU).

#### *Dissolved organic carbon*

Figure 33 shows the DOC concentrations for sampling sites at Eraring and Vales Point Power Stations for Sites E22, E24, EWL, V25, V24, VWC, and VMBS, dissolved organic carbon concentrations (median DOC <5 mg/L) were generally similar to those observed within the lake (median DOC of 3 mg/L). Median DOC concentrations were substantially greater at the creek sites (12, 10 and 7 mg/L at Sites E23, V25U and V25D, respectively).

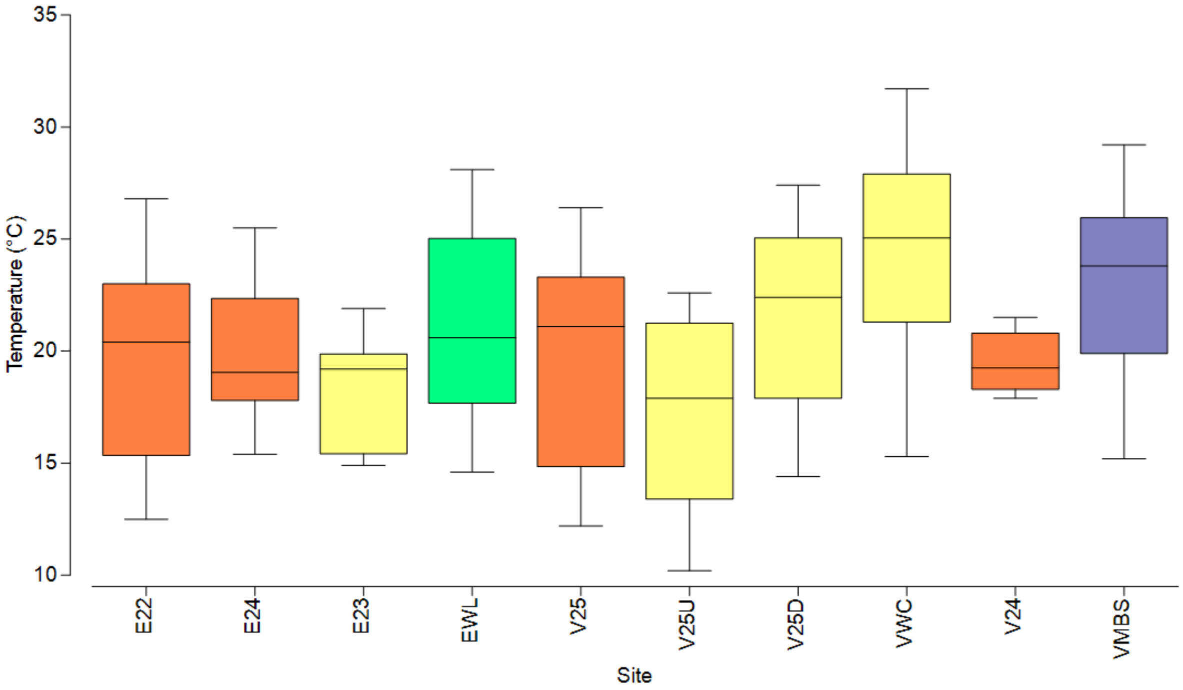


Figure 27. Box plots of temperature (°C) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12; EWL n=11; E23 n=5)

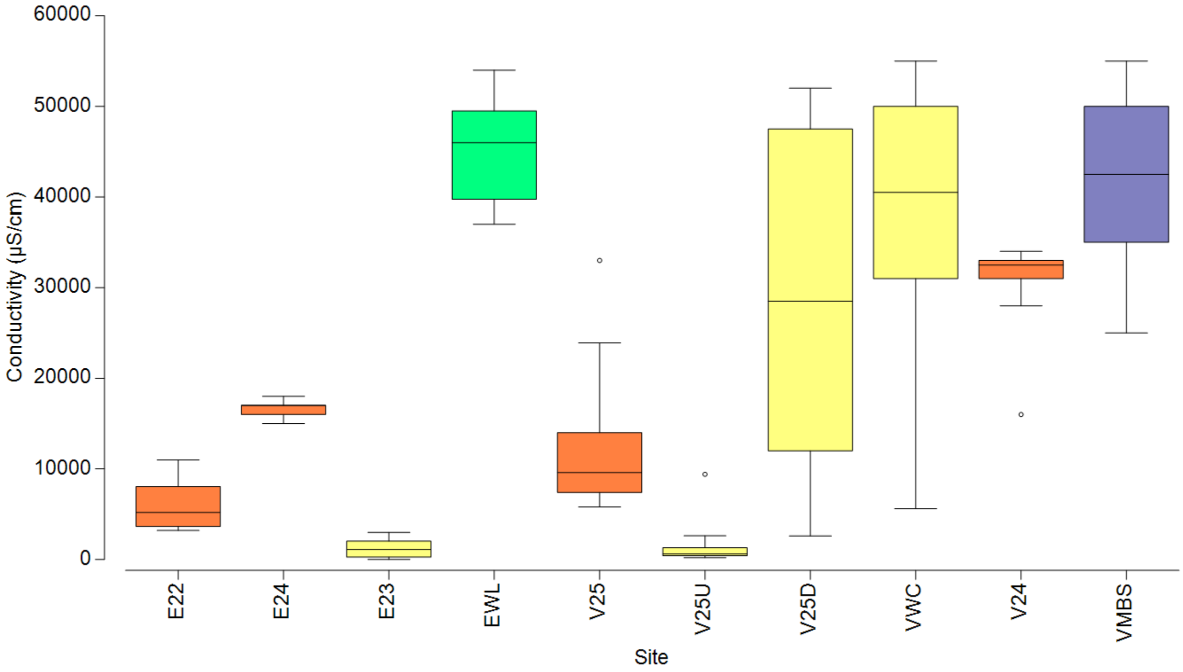


Figure 28. Box plots of conductivity (µS/cm) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12; EWL n=11; E23 n=5)

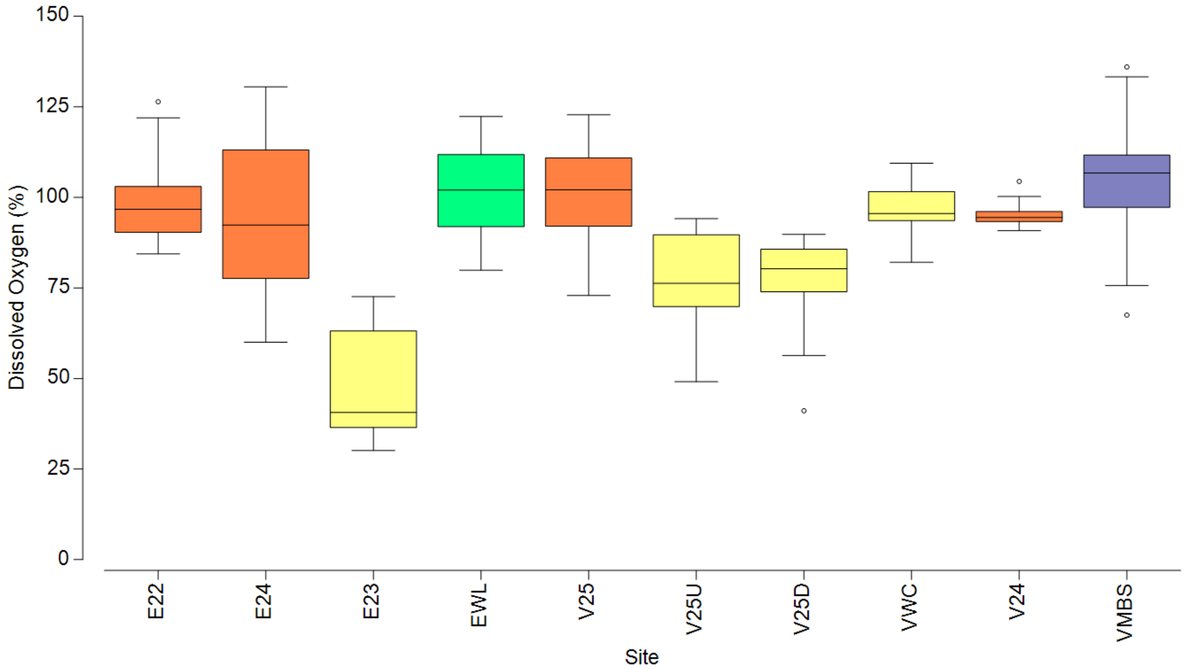


**Figure 29. Box plots of dissolved oxygen (%) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12; EWL n=11; E23 n=5)**

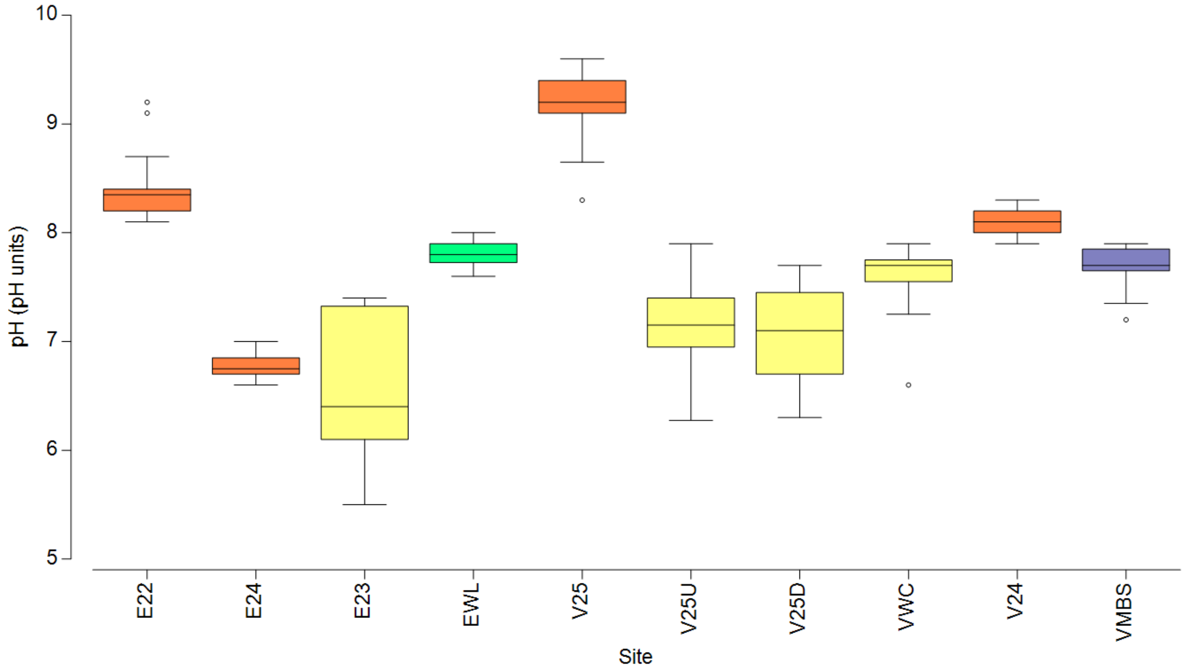


**Figure 30. Box plots of pH (pH units) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12; EWL n=11; E23 n=5)**

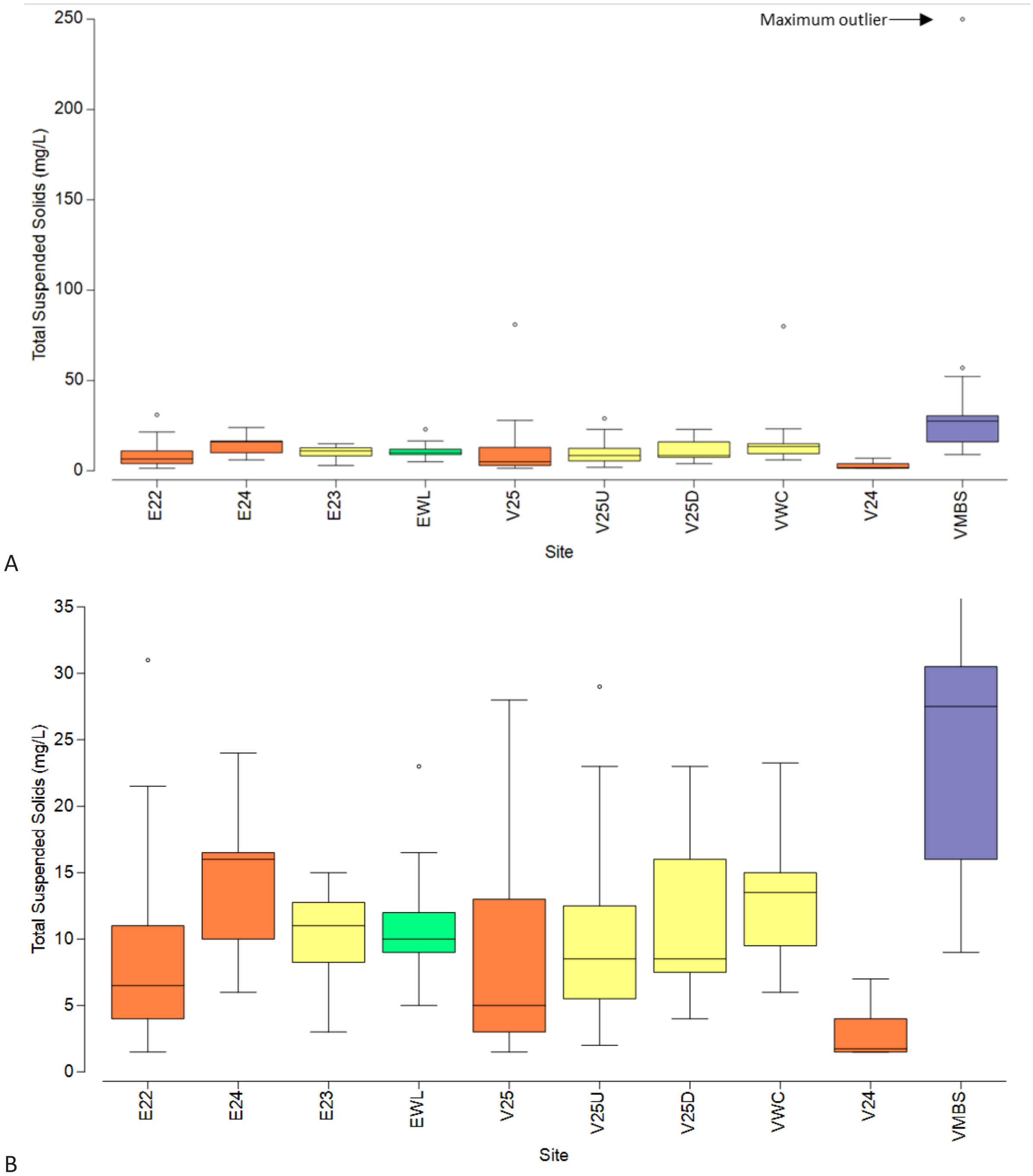


**Figure 31. Box plots of total suspended solids (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12; EWL n=11; E23 n=5): A) scale bar set to include all data points (including outliers); and B) refined scale bar set to discern differences at low concentrations**

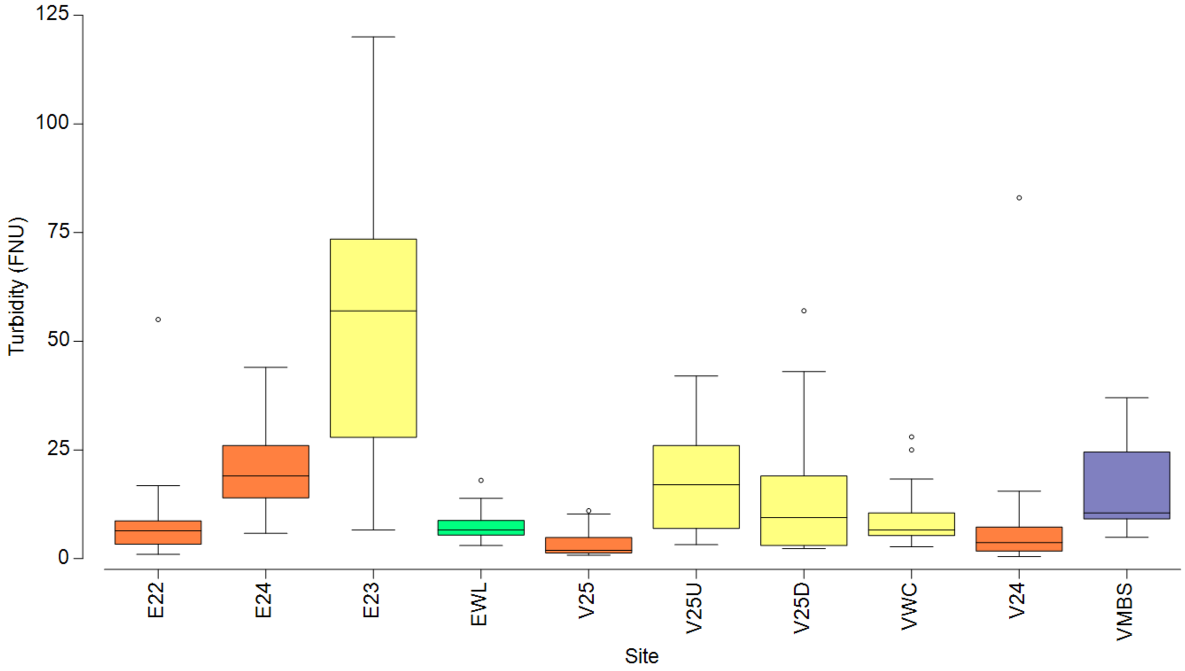


Figure 32. Box plots of turbidity (FNU) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12; EWL n=11; E23 n=5)

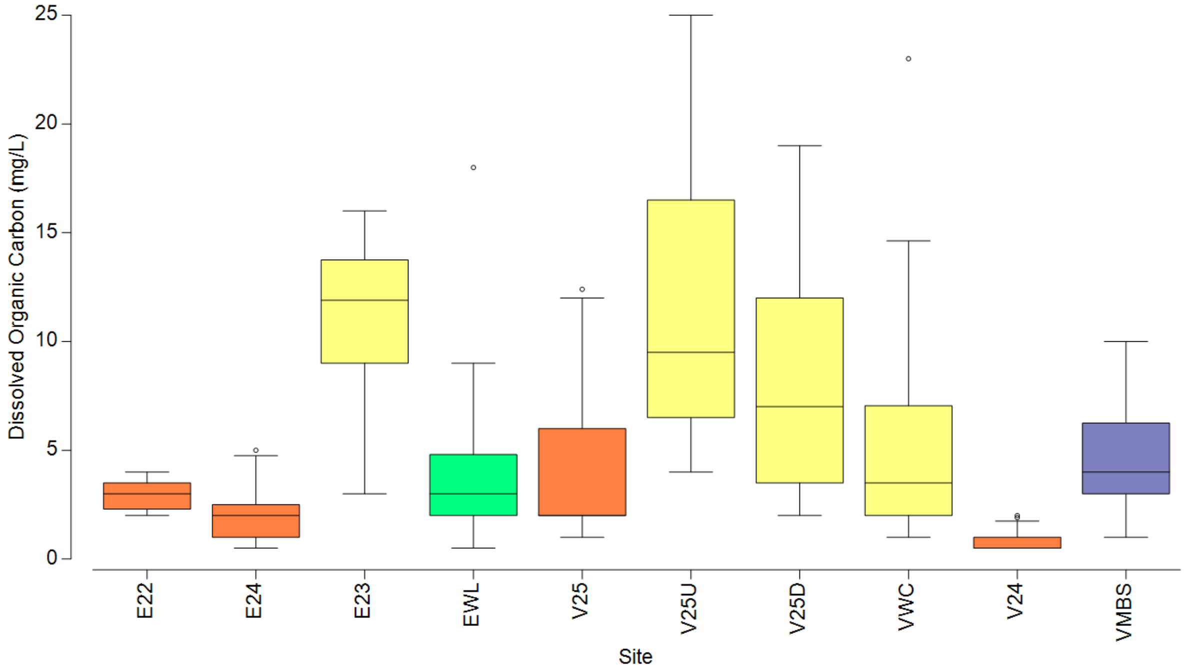


Figure 33. Box plots of dissolved organic carbon (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12; EWL n=11; E23 n=5)

### 4.2.2 Nutrients

*Nitrogen*

Note that the data quality assessment found nitrogen contamination associated with some of the sample containers (Appendix A – Data quality assessment). Therefore, while not all samples were affected, samples with concentrations of total nitrogen <0.2 mg/L, dissolved nitrogen <0.3 mg/L, oxidised nitrogen <0.09 mg/L, and ammonia-N <0.02 mg/L were treated as estimated concentrations.

Figure 34 shows the total nitrogen concentrations for sampling sites at Eraring and Vales Point Power Stations. The total and dissolved nitrogen concentrations were much greater in the coal ash repository water at Eraring (E22 and E24) and Vales Point Power Stations (V24) compared to the creek waters. The dissolved nitrogen concentrations were highly comparable to the total nitrogen concentrations for each respective site (the average proportion of dissolved nitrogen to total nitrogen across all samples was 80%, n=112), indicating that nitrogen in the samples was predominantly in the dissolved form (Figure 34 and Figure 35). Dissolved nitrogen was predominately present as oxidised nitrogen (nitrate + nitrite) at Site E22 (average proportion of oxidised nitrogen to dissolved nitrogen 82%, n=12; Figure 36) whereas at Sites E24 and V24 dissolved nitrogen was predominately present as ammonia-N (average proportion of ammonia-N to dissolved nitrogen 97 and 86% (n=12), respectively; Figure 37). The remaining sites had generally equal concentrations of oxidised nitrogen and ammonia-N (Figure 36 and Figure 37).

Nitrogen (total, dissolved, nitrate + nitrite, and ammonia-N) concentrations in Wyee Creek decreased from upstream to downstream (median concentrations at V25U > V25D > VWC) and were generally greater than concentrations measured within Wyee Bay.

The coal ash repository waters (discharged via the cooling water outlet canal when excess volumes are present on site under controlled conditions; Sites V22 and E21) and catchment runoff from Dora Creek and Wyee Creek are both potential sources of nitrogen to the lake.

*Phosphorus*

Figure 38 shows the total phosphorus concentrations for sampling sites at Eraring and Vales Point Power Stations. Total phosphorus was greatest within the Eraring coal ash repository water (Site E22) and the toe drain/seepage water storage pond (E24). At Site E22, the dissolved phosphorus concentrations (Figure 39) and the free reactive phosphorus concentrations (Figure 40) were highly comparable, indicating phosphorus was predominately present as inorganic phosphorus (such as orthophosphate). Dissolved phosphorus and free reactive phosphorus were both relatively low at Site E24, indicating the phosphorus was predominately present in the particulate form. Particulate phosphorus can be made up of living or dead phytoplankton, precipitates of phosphorus, or phosphorus adsorbed to suspended particulate matter such as clays and detritus.

The remaining sites (E23, EWL, V25, V25U, V25D, VWC, V24, and VMBS) had comparatively low concentrations of total, dissolved, and free reactive phosphorus which were similar to concentrations observed within the lake.

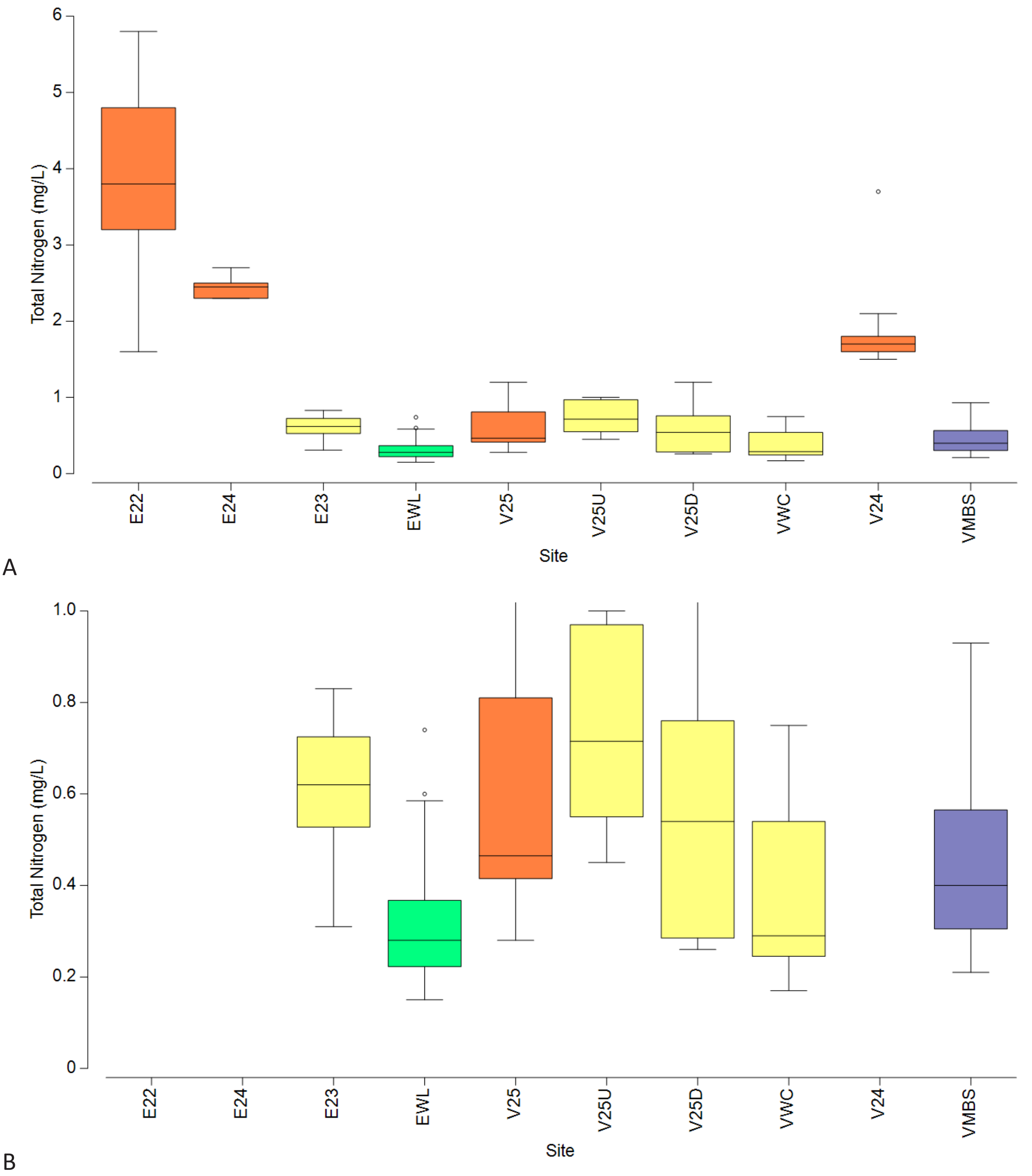


**Figure 34. Box plots of total nitrogen (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) scale bar set to include all data points; and B) refined scale bar set to discern differences at low concentrations. All values were greater than the limit of reporting (LOR) for total nitrogen of 0.02 mg/L. The 50th percentile concentration for total nitrogen measured across all lake sites through the monitoring program was 0.18 mg/L.**

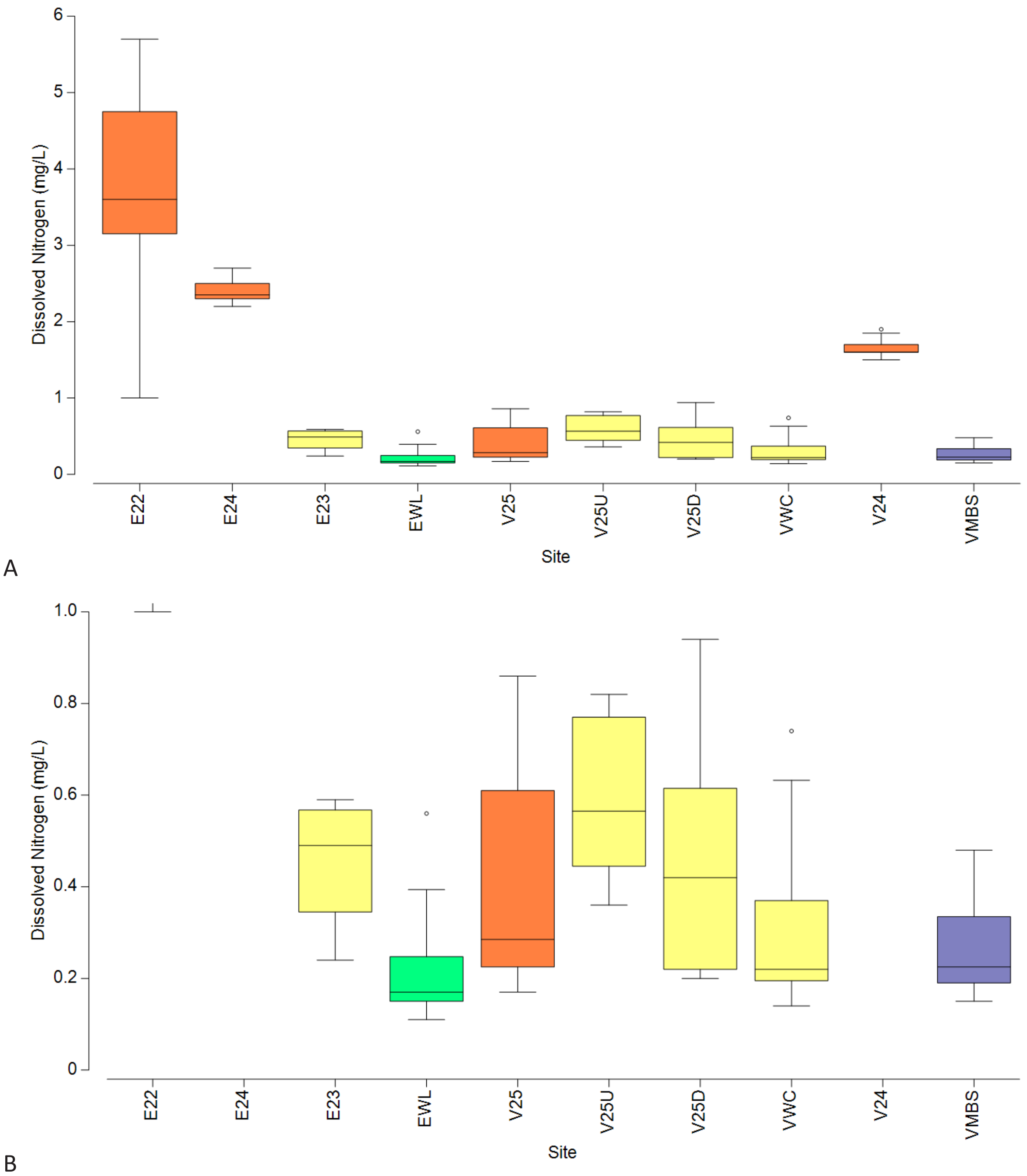


**Figure 35. Box plots of dissolved nitrogen (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) scale bar set to include all data points; and B) refined scale bar set to discern differences at low concentrations. All values were greater than the limit of reporting (LOR) for dissolved nitrogen of 0.02 mg/L. The 50th percentile concentration for dissolved nitrogen measured across all lake sites through the monitoring program was 0.15 mg/L.**

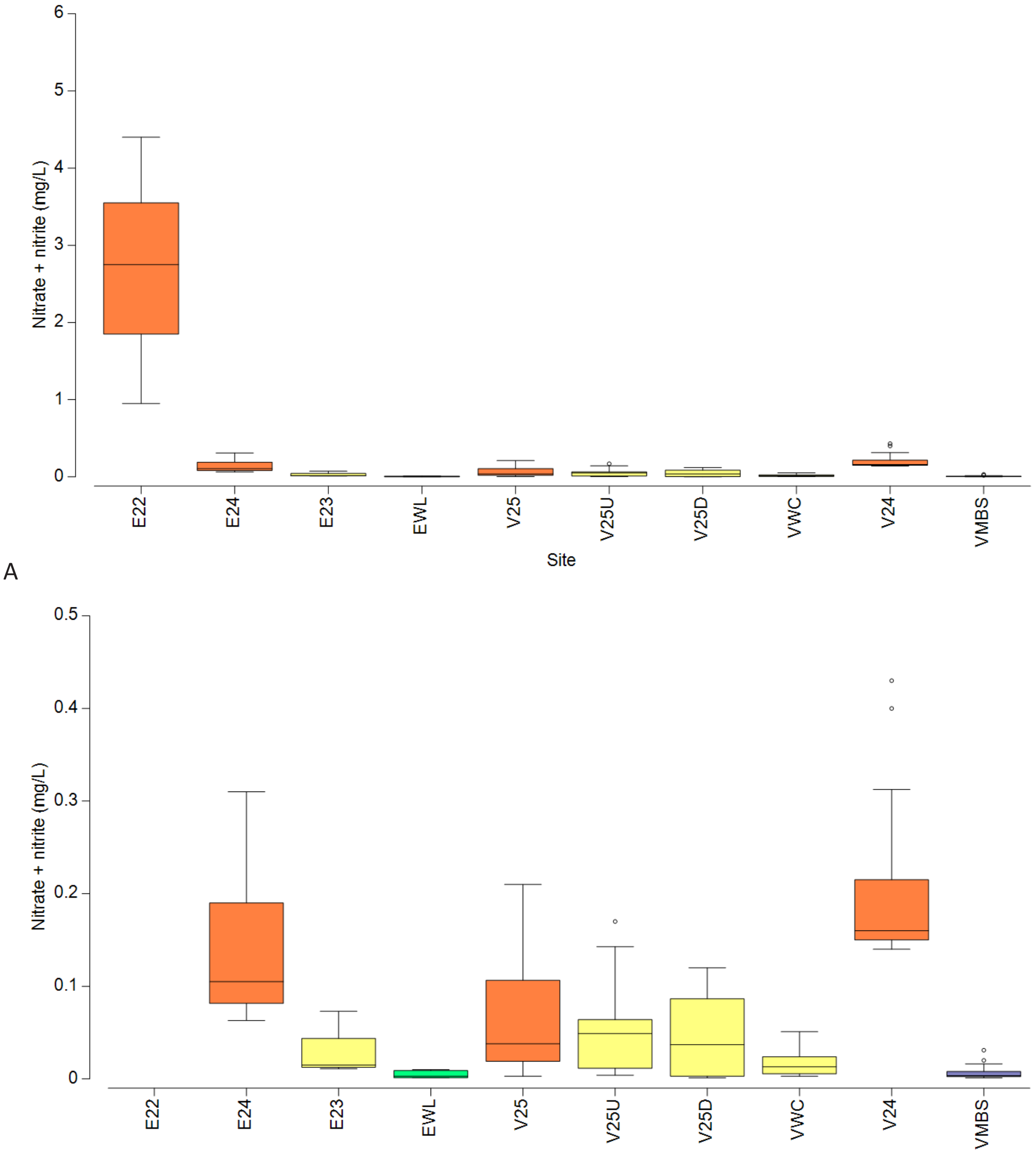


**Figure 36. Box plots of oxidised nitrogen (nitrate + nitrite) (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) scale bar set to include all data points; and B) refined scale bar set to discern differences at low concentrations. The limit of reporting (LOR) was 0.002 mg/L; values below the LOR were replaced with half the LOR. The 50th percentile concentration for oxidised nitrogen measured across all lake sites through the monitoring program was 0.002 mg/L.**

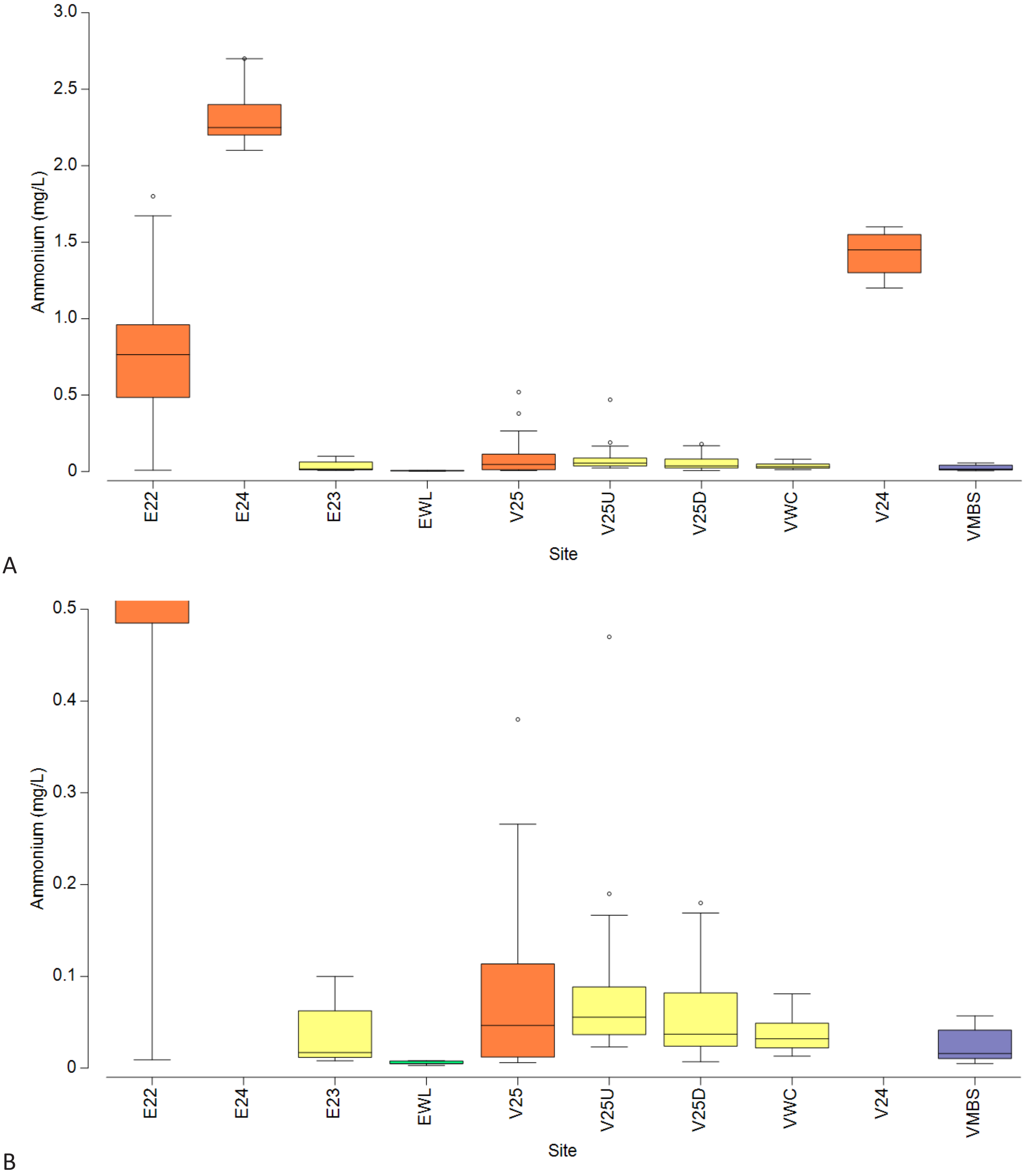


**Figure 37. Box plots of ammonia-N (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) scale bar set to include all data points; and B) refined scale bar set to discern differences at low concentrations. All values were greater than the limit of reporting (LOR) for ammonia-N of 0.001 mg/L. The 50th percentile concentration for ammonia-N measured across all lake sites through the monitoring program was 0.005 mg/L.**

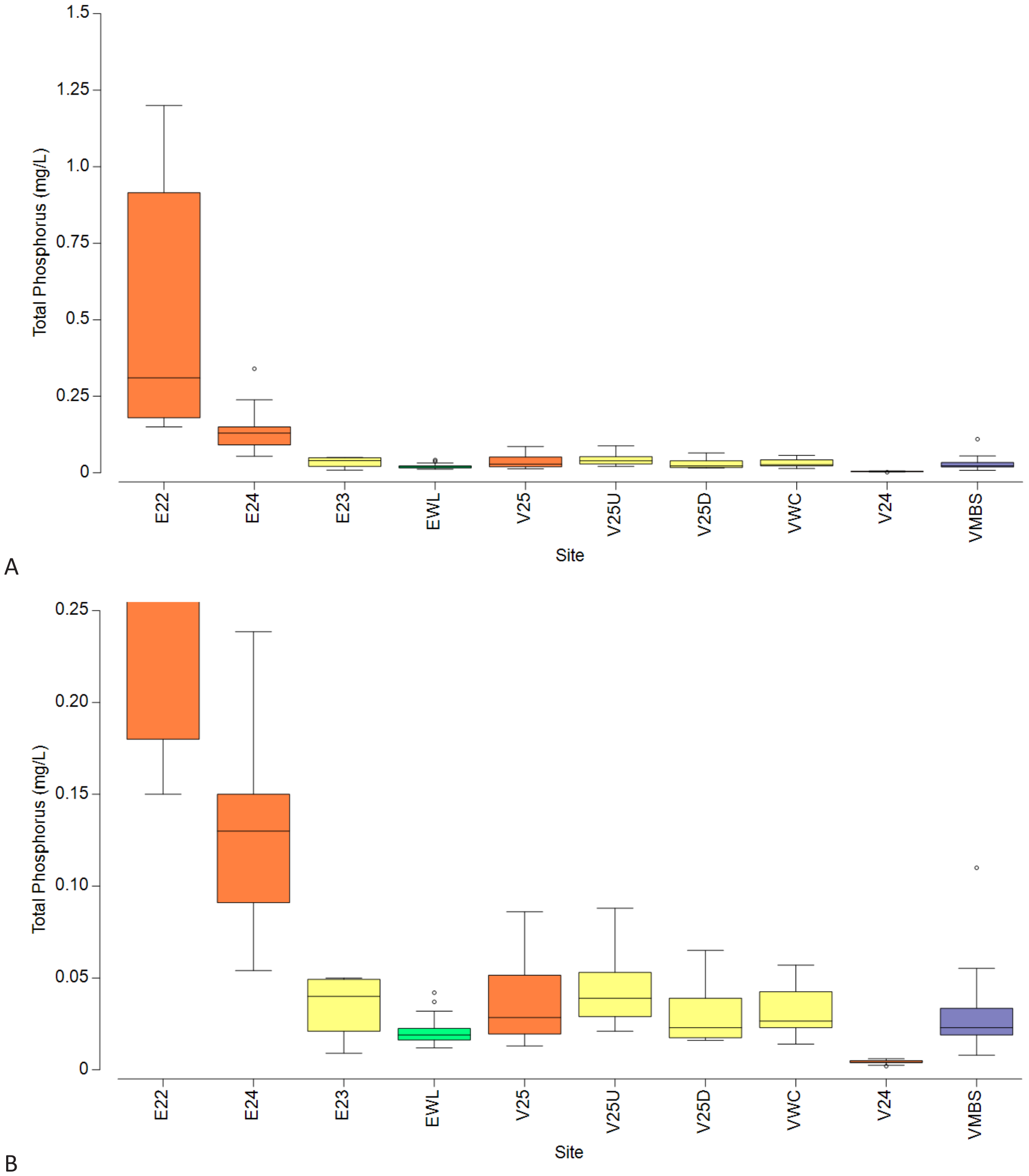


**Figure 38. Box plots of total phosphorus (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) scale bar set to include all data points; and B) refined scale bar set to discern differences at low concentrations. The limit of reporting (LOR) was 0.004 mg/L; values below the LOR were replaced with half the LOR. The 50th percentile concentration for total phosphorus measured across all lake sites through the monitoring program was 0.016 mg/L.**

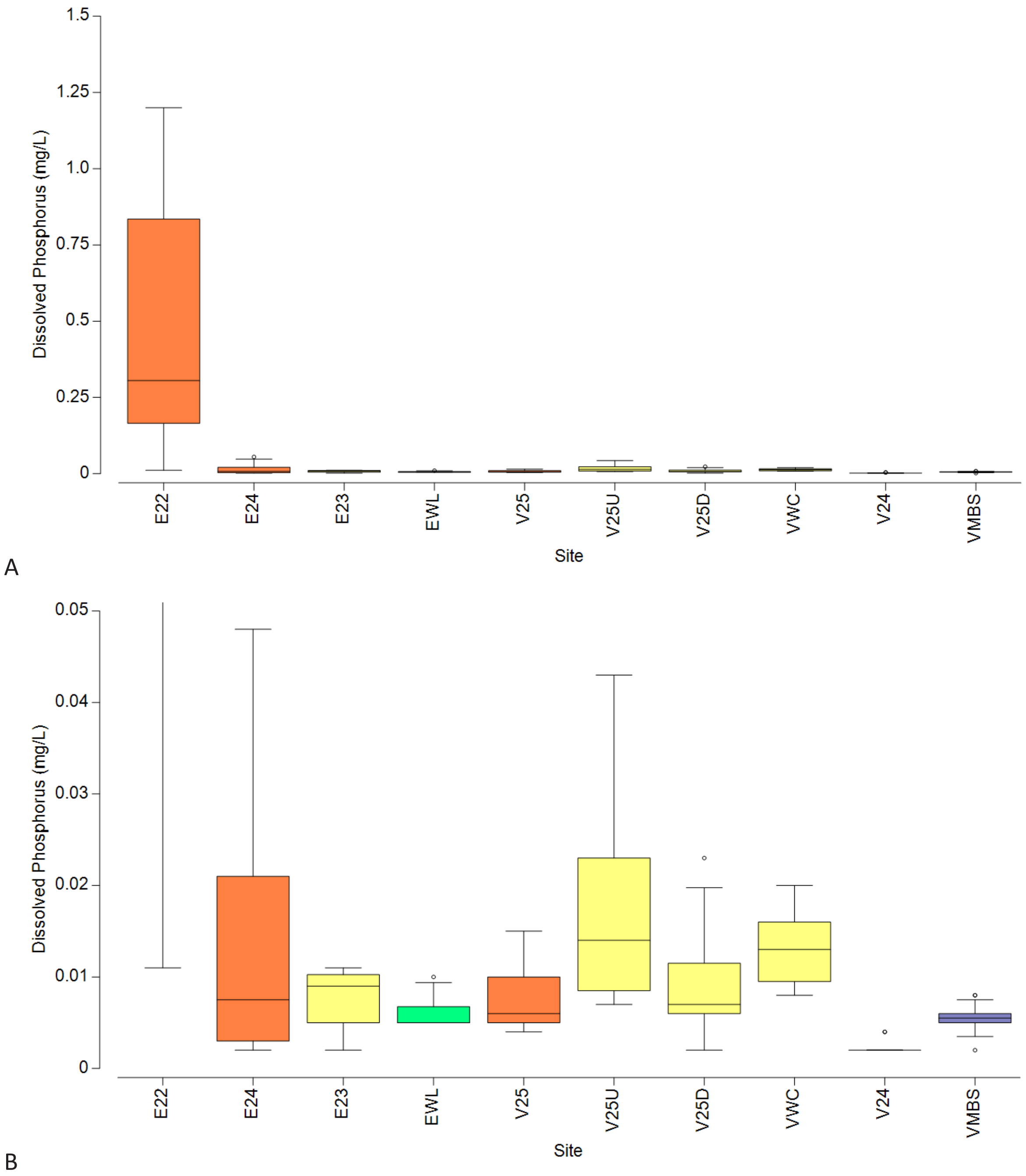


**Figure 39. Box plots of dissolved phosphorus (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) scale bar set to include all data points; and B) refined scale bar set to discern differences at low concentrations. The limit of reporting (LOR) was 0.004 mg/L; values below the LOR were replaced with half the LOR. The 50th percentile concentration for dissolved phosphorus measured across all lake sites through the monitoring program was 0.010 mg/L.**

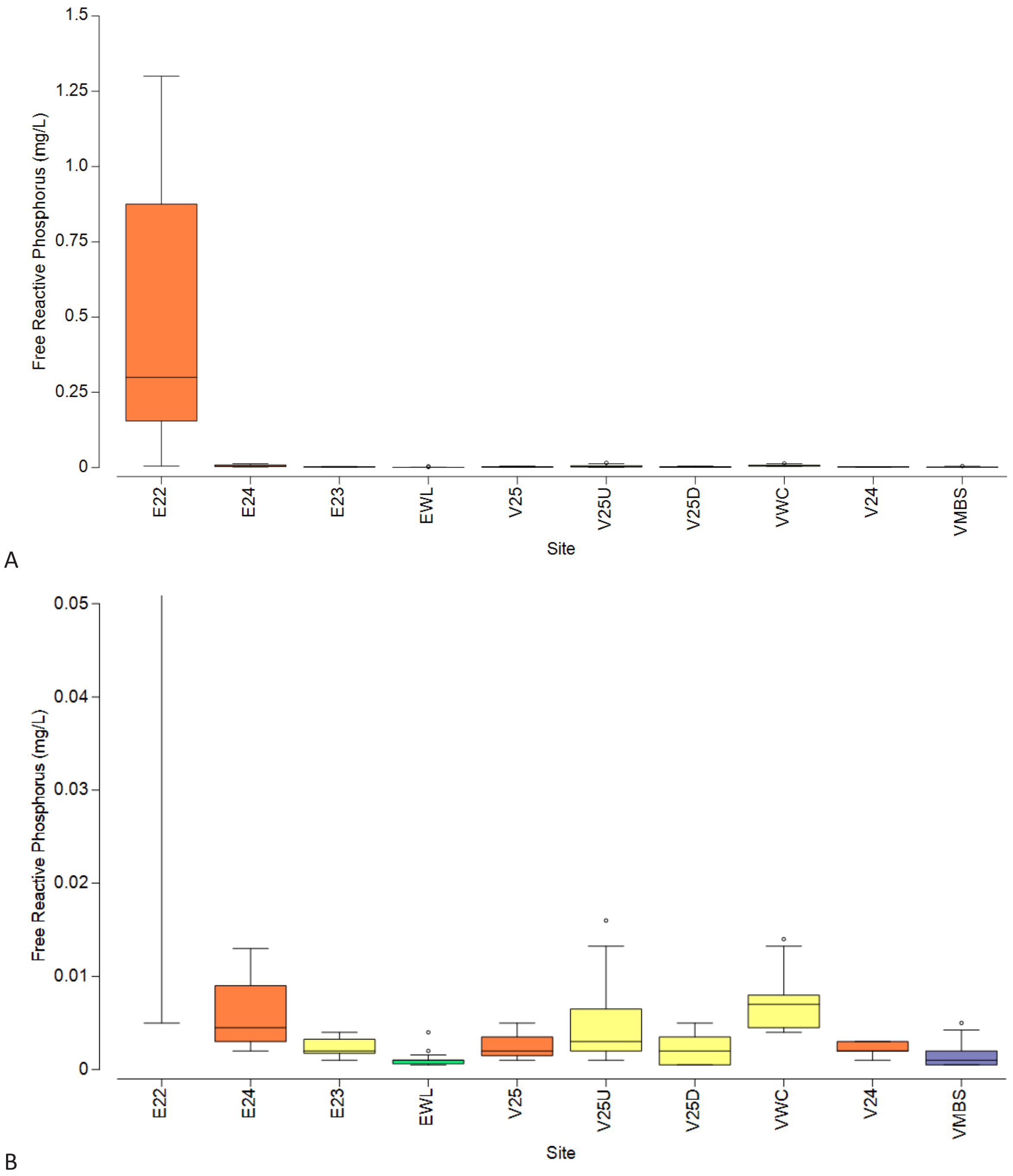


**Figure 40. Box plots of free reactive phosphorus (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) scale bar set to include all data points; and B) refined scale bar set to discern differences at low concentrations. The limit of reporting (LOR) was 0.001 mg/L; values below the LOR were replaced with half the LOR. The 50th percentile concentration for free reactive phosphorus measured across all lake sites through the monitoring program was 0.005 mg/L.**

### 4.2.3 Metals

Box plots summarising the distribution of the measured metal concentrations by site are provided below (Figure 41 to Figure 57). Mercury, silver and thallium are not presented as their concentrations were below the LOR for all samples.

The main metals present in the surface waters within the vicinity of Eraring Power Station were as follows:

- Ash repository decant/return water (E22) and/or seepage water (E24) – arsenic, barium, boron, cadmium, chromium, copper, iron, manganese, molybdenum, nickel, selenium, and vanadium.
- Crooked Creek (E23) – aluminium, cobalt, iron, lead, manganese, nickel, and zinc.
- Whiteheads Lagoon (EWL) – aluminium.

The main metals present in surface waters within the vicinity of Vales Point Power Station were:

- Ash repository decant/return water (V25) and/or seepage water (V24) – arsenic, barium, boron, cadmium, chromium, manganese, molybdenum, selenium, and vanadium.
- Wyee Creek (V25U, V25D, and VWC) – aluminium, cobalt, iron, lead, manganese, nickel, and zinc.
- Mannering Bay (VMBS) – aluminium, cobalt, lead, and manganese.

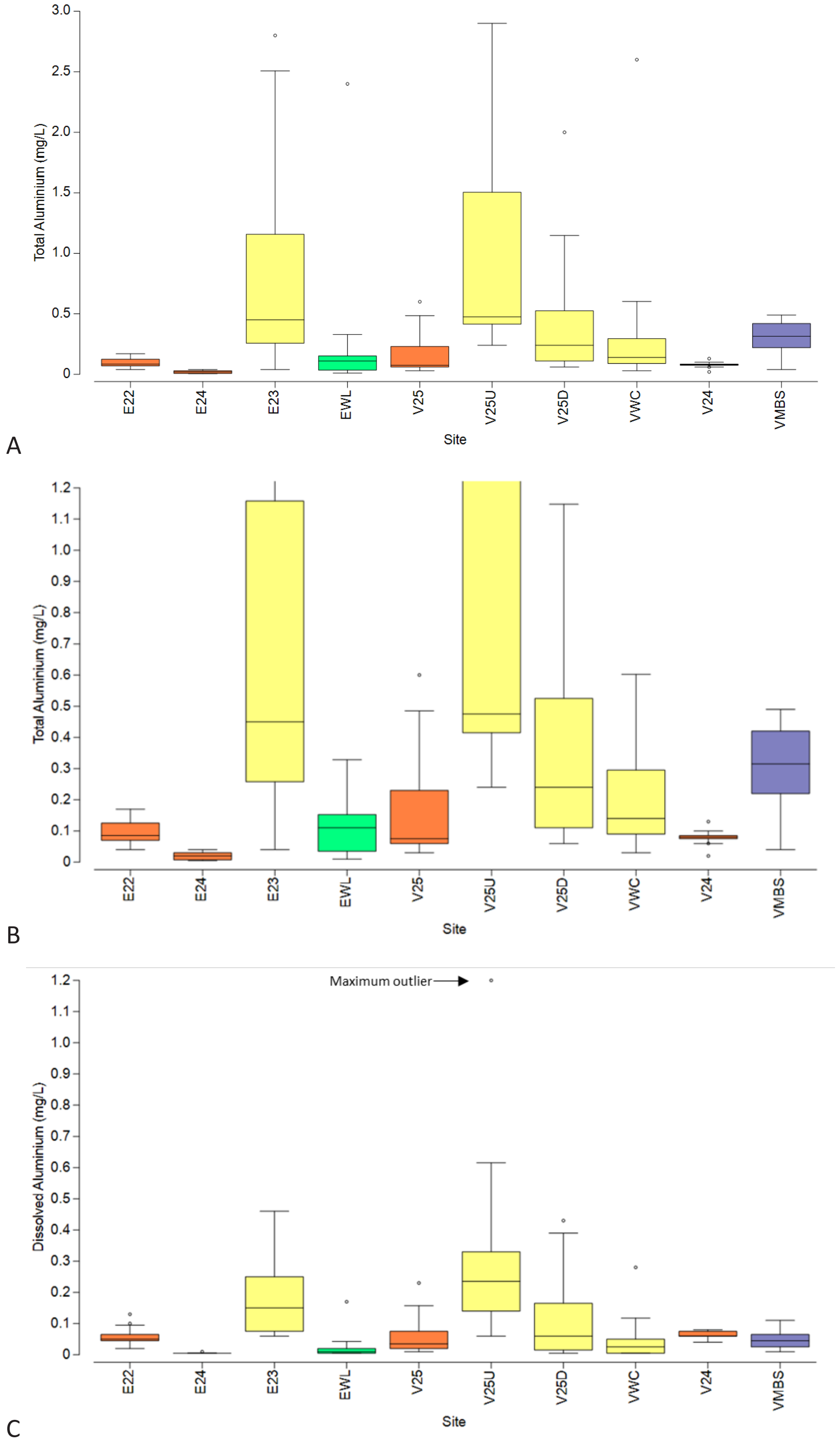


**Figure 41. Box plots of aluminium concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total aluminium scale bar set to include all data points; B) total aluminium with refined scale bar set to discern differences at low concentrations; C) dissolved (<0.45 µm) aluminium. The limit of reporting (LOR) was 0.01 mg Al/L; values below the LOR were replaced with half the LOR. The 95th percentile concentration for total and dissolved aluminium measured across all lake sites through the monitoring program were 0.09 and 0.04 mg/L, respectively.**

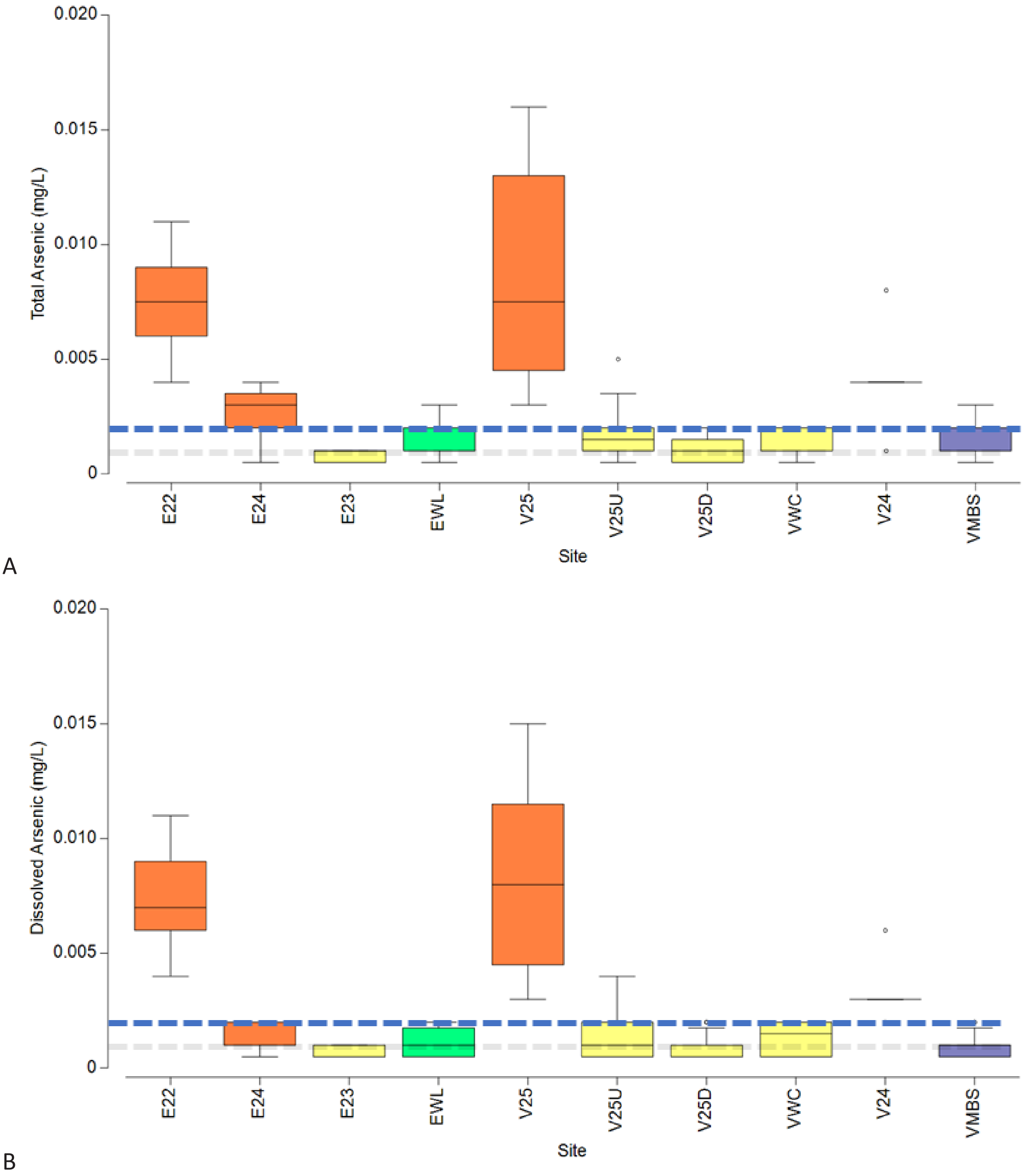
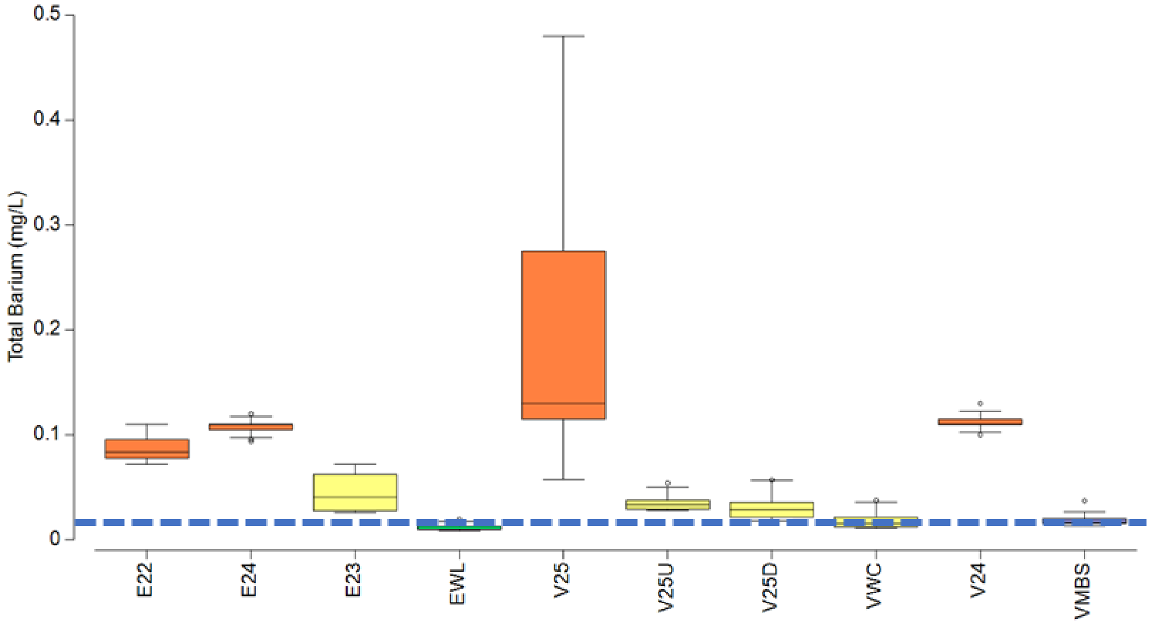
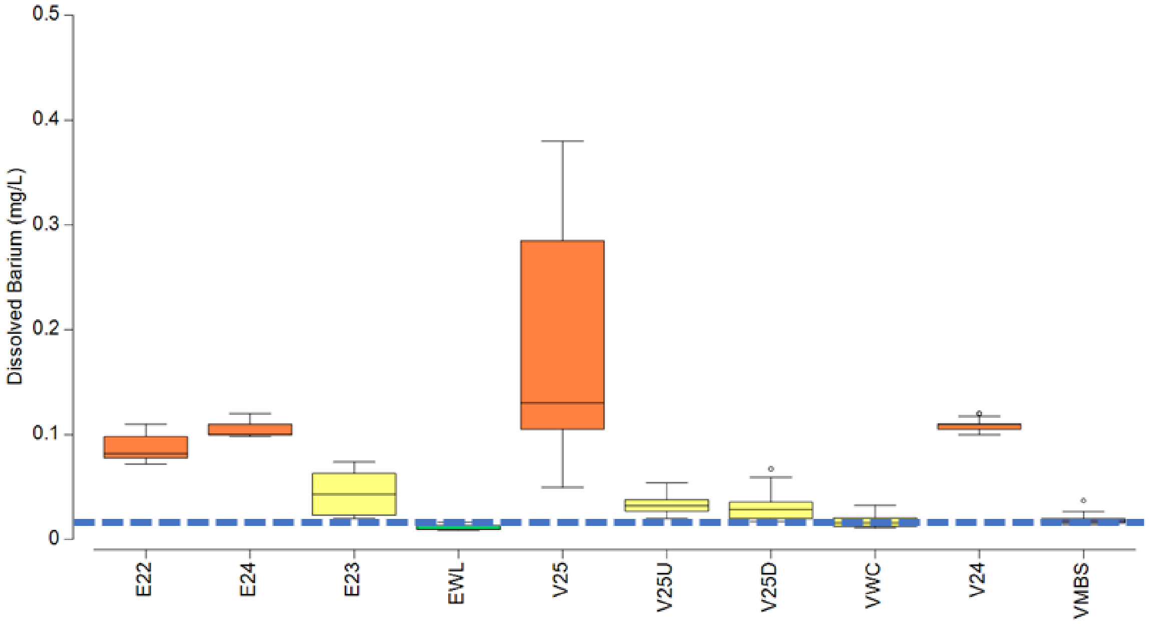


**Figure 42. Box plots of arsenic concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total arsenic; B) dissolved (<0.45 µm) arsenic. The horizontal grey dashed line indicates the limit of reporting (LOR, 0.001 mg As/L); values below the LOR were replaced with half the LOR. The horizontal blue dashed line indicates the 95th percentile concentration for arsenic measured across all lake sites through the monitoring program.**



A



B

**Figure 43. Box plots of barium concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total barium; B) dissolved (<0.45 µm) barium. All values were greater than the limit of reporting for barium. The horizontal blue dashed line indicates the 95th percentile concentration for barium measured across all lake sites through the monitoring program.**

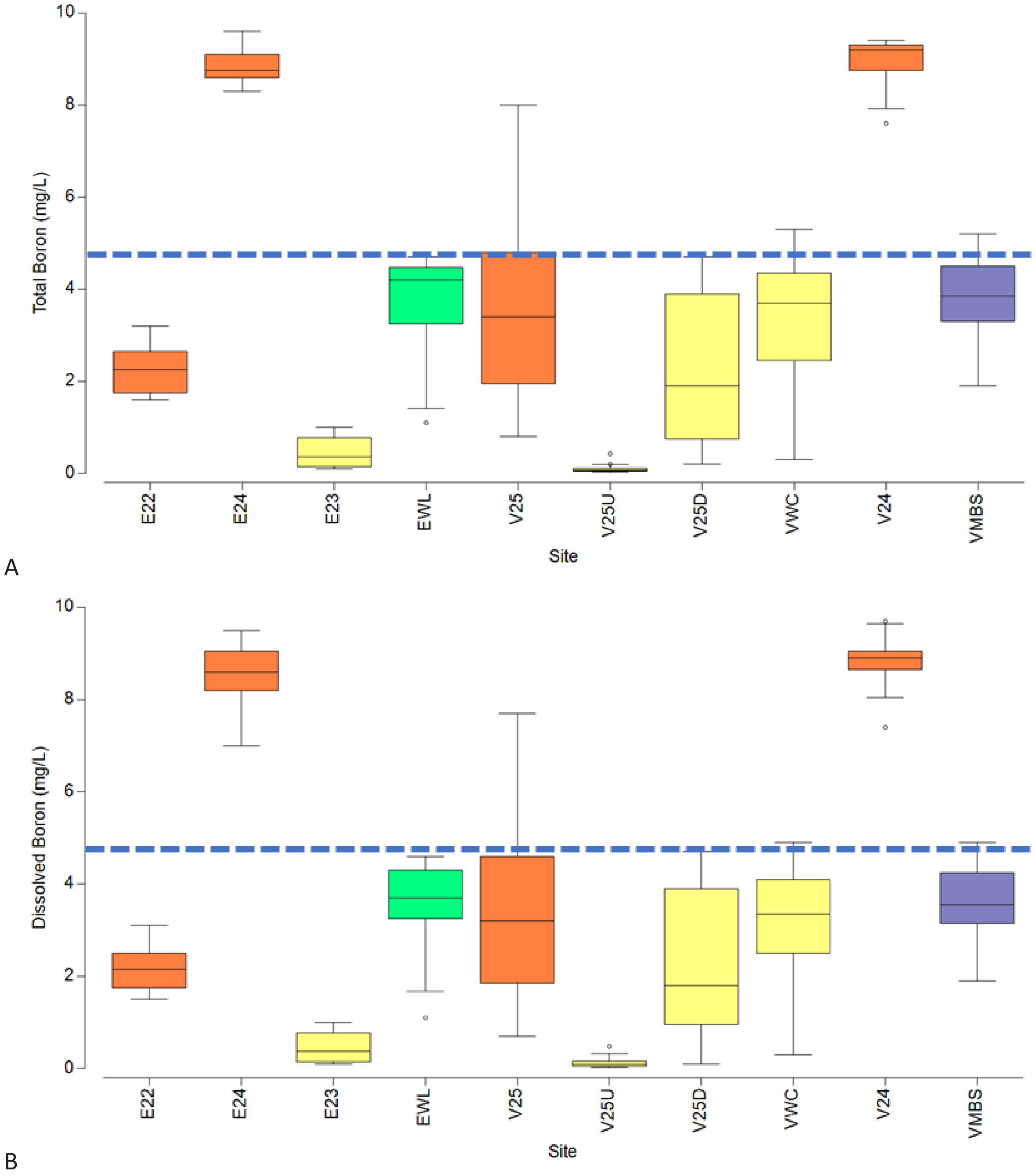
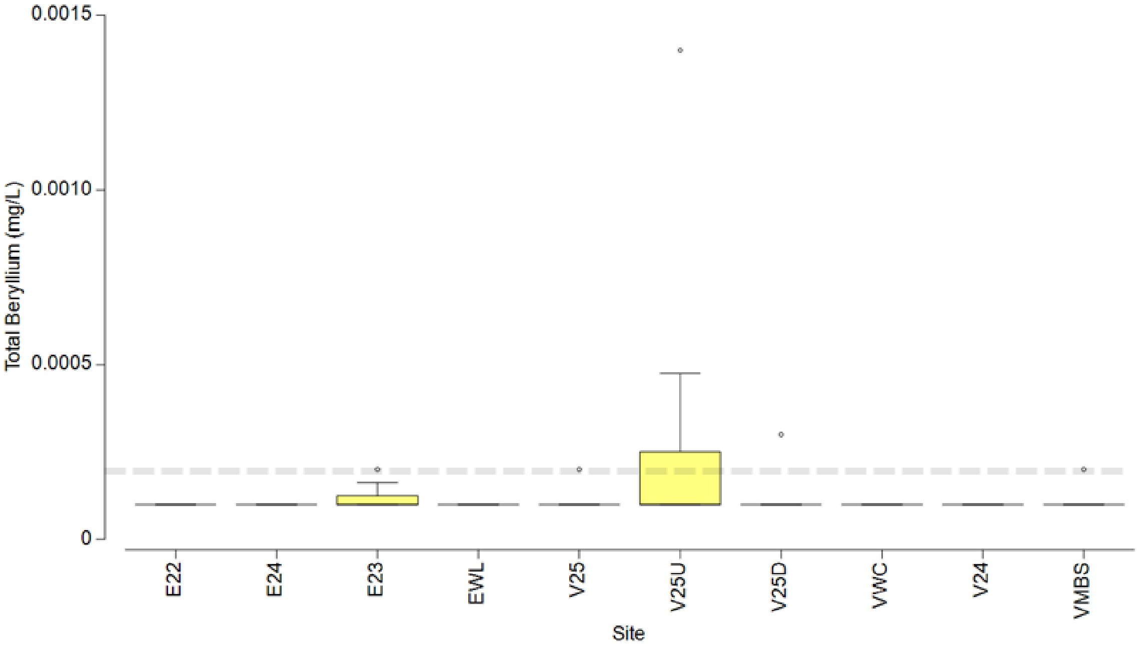
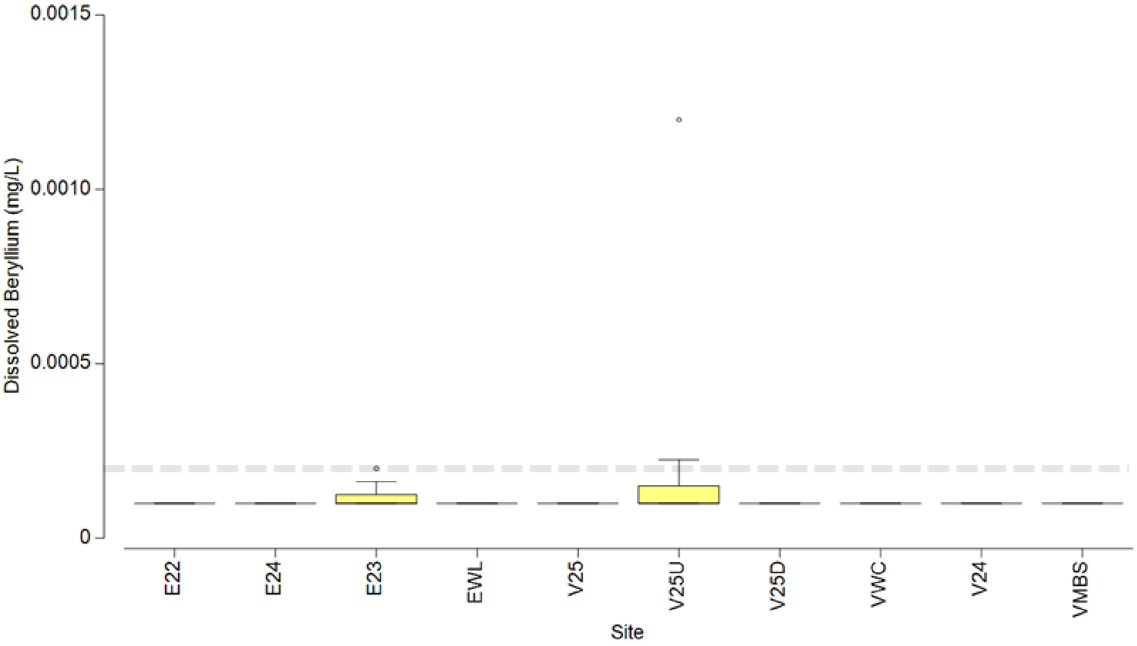


**Figure 44. Box plots of boron concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total boron; B) dissolved (<0.45 µm) boron. All values were greater than the limit of reporting for boron. The horizontal blue dashed line indicates the 95th percentile concentration for boron measured across all lake sites through the monitoring program.**

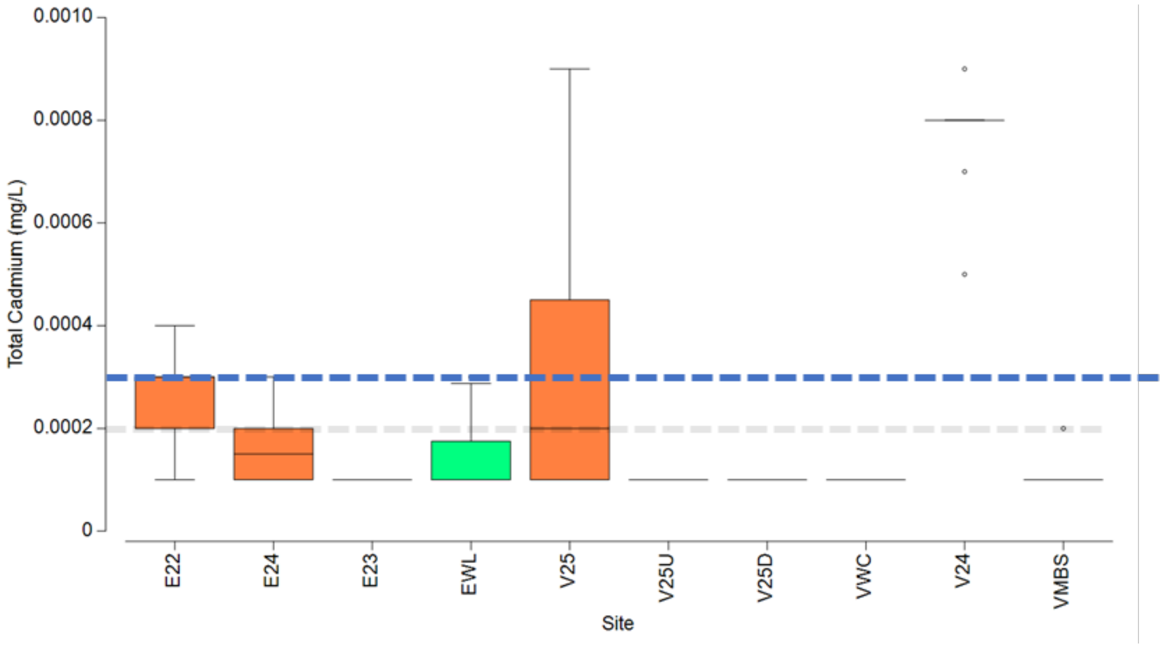


A

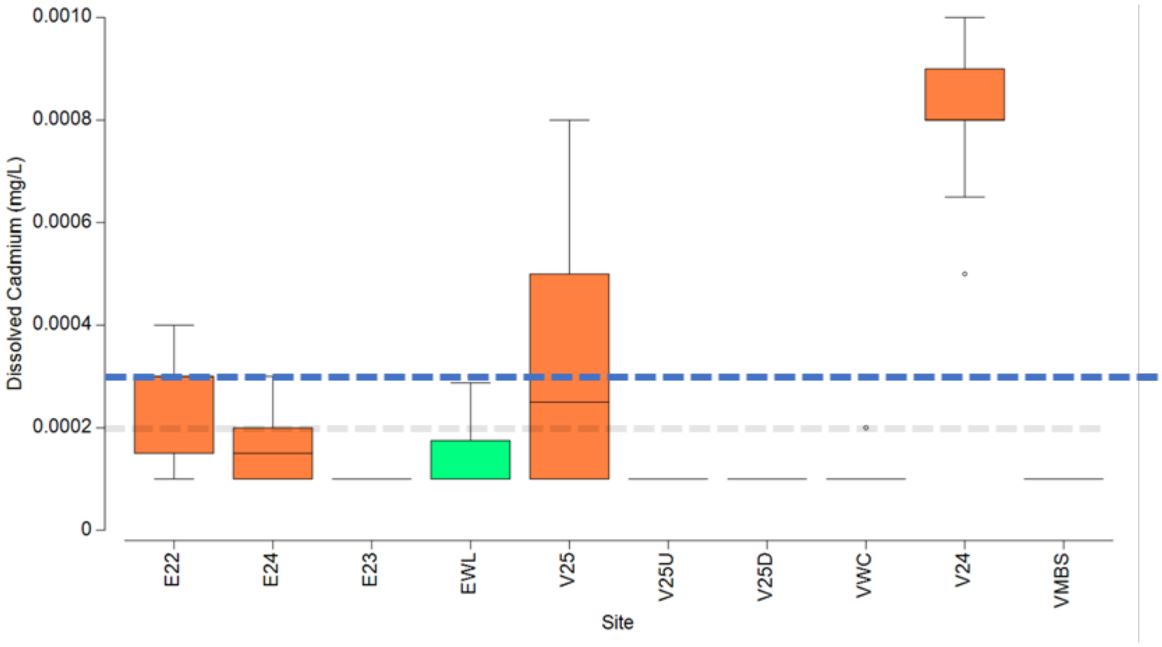


B

**Figure 45. Box plots of beryllium concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total beryllium; B) dissolved (<0.45 µm) beryllium. The horizontal grey dashed line indicates the limit of reporting (LOR, 0.0002 mg Be/L); values below the LOR were replaced with half the LOR. The 95th percentile concentration for total and dissolved beryllium measured across all lake sites through the monitoring program was <LOR.**

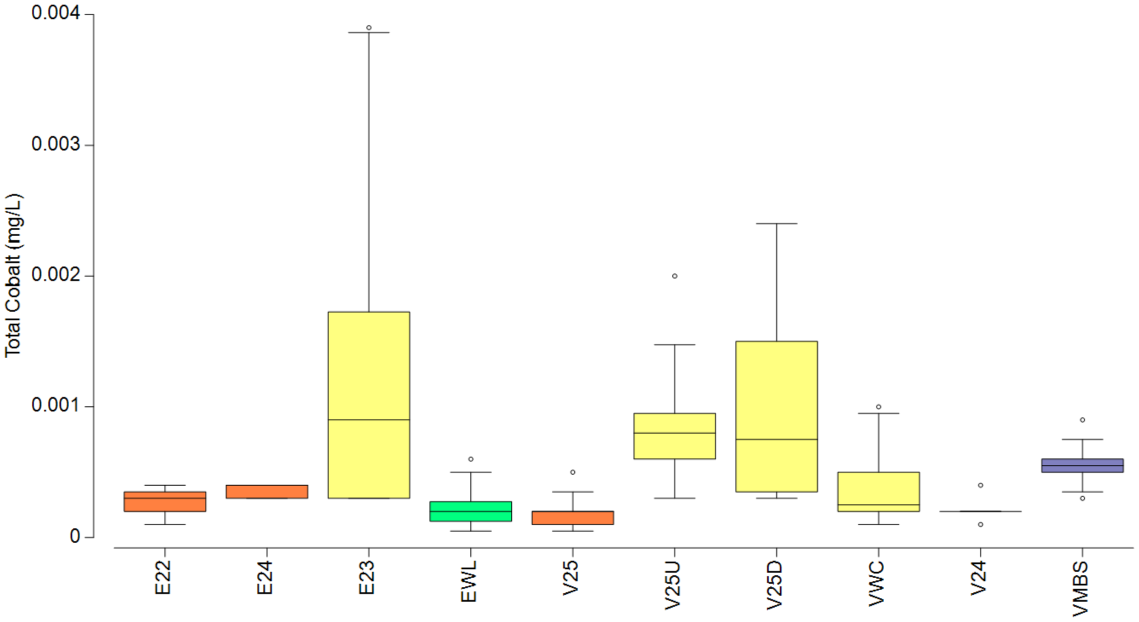


A

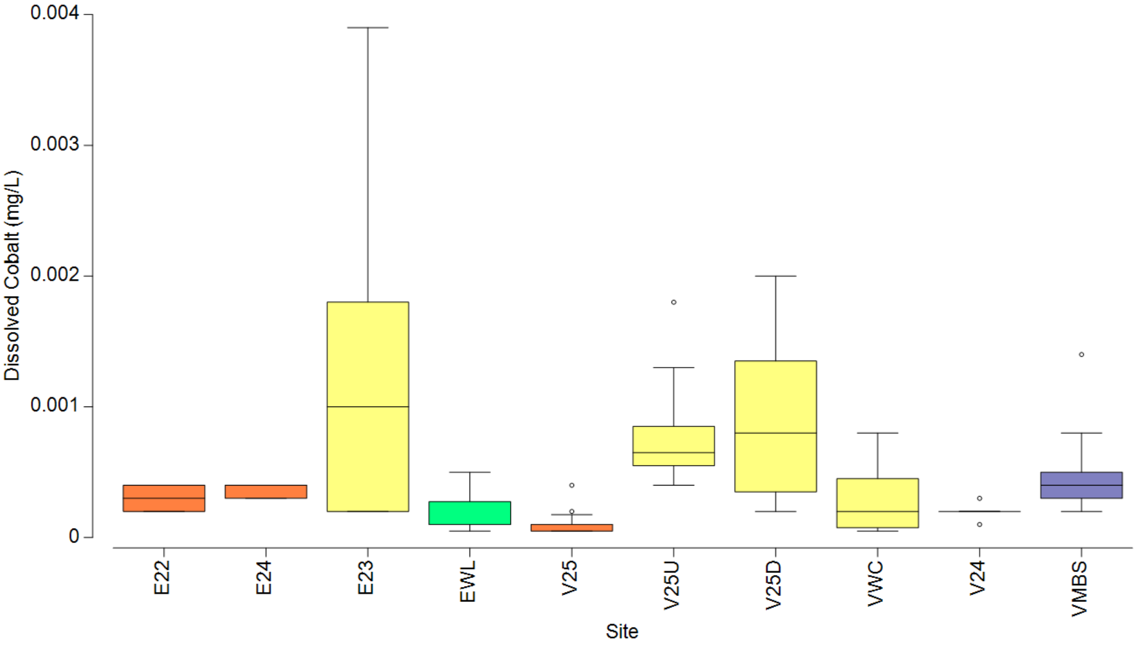


B

**Figure 46. Box plots of cadmium concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total cadmium; B) dissolved (<0.45 µm) cadmium. The horizontal grey dashed line indicates the limit of reporting (LOR, 0.0002 mg Cd/L); values below the LOR were replaced with half the LOR. The horizontal blue dashed line indicates the 95th percentile concentration for cadmium measured across all lake sites through the monitoring program.**

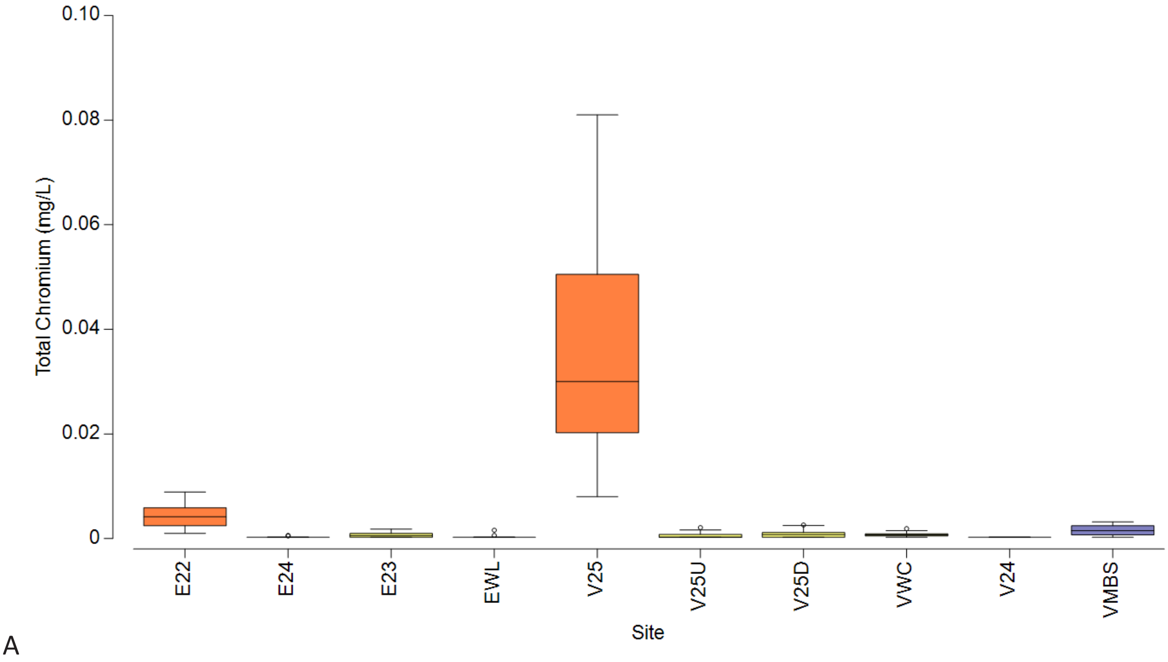


A



B

**Figure 47. Box plots of cobalt concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total cobalt; B) dissolved (<0.45 µm) cobalt. The limit of reporting (LOR) was 0.0001 mg Co/L; values below the LOR were replaced with half the LOR. The 95th percentile concentration for total and dissolved cobalt measured across all lake sites through the monitoring program was 0.0002 mg/L.**



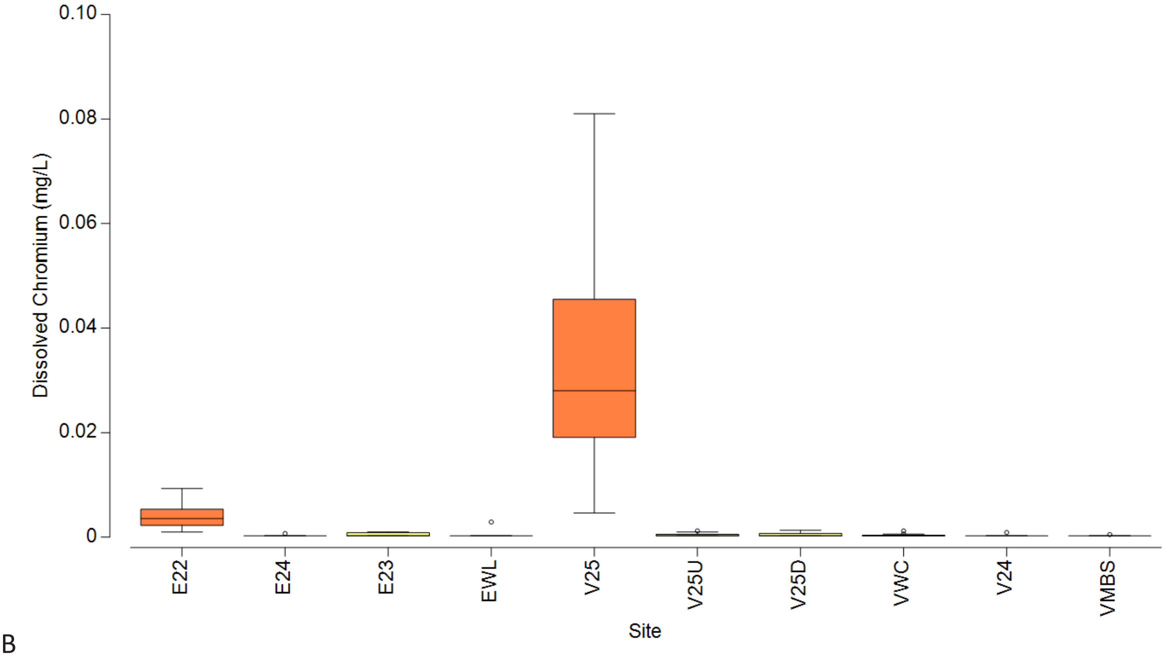
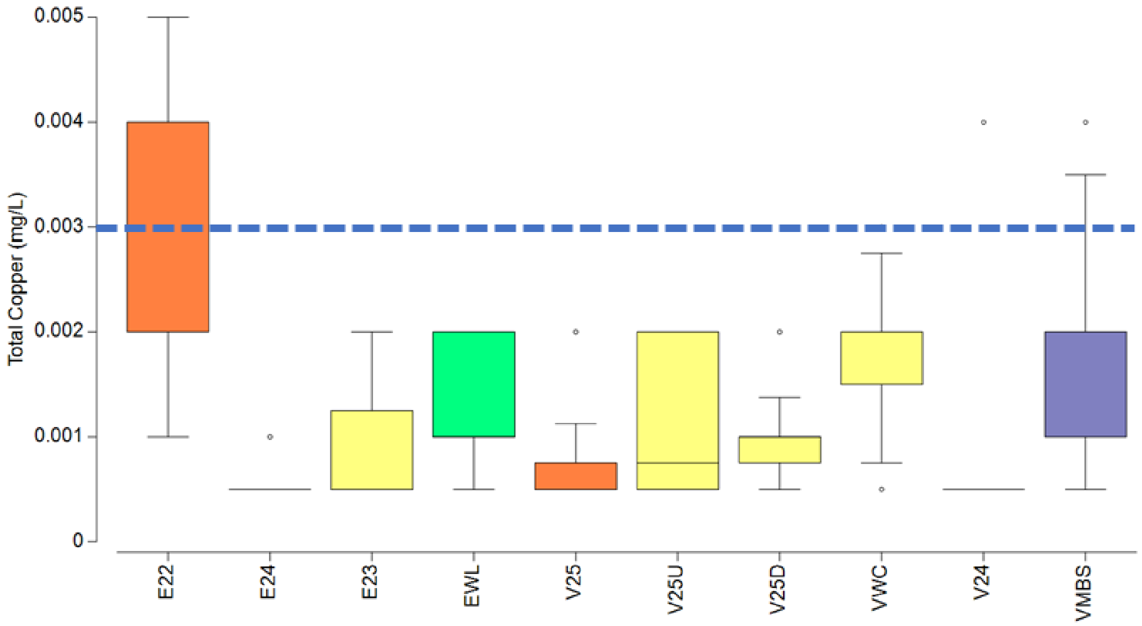
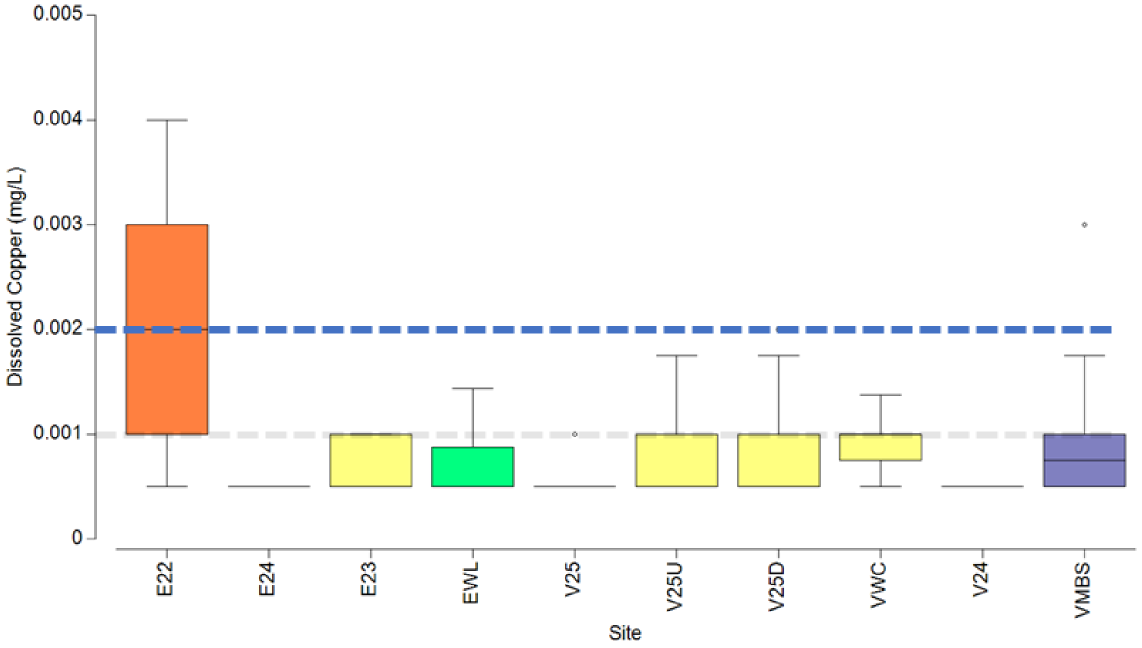


**Figure 48. Box plots of chromium concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total chromium; B) dissolved (<0.45 µm) chromium. The limit of reporting (LOR) was 0.0005 mg Cr/L; values below the LOR were replaced with half the LOR. The 95th percentile concentration for total and dissolved chromium measured across all lake sites through the monitoring program were 0.0007 and 0.0010 mg/L, respectively.**



A



B

**Figure 49. Box plots of copper concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total copper; B) dissolved (<0.45 µm) copper. The horizontal grey dashed line indicates the limit of reporting (LOR, 0.001 mg Cu/L); values below the LOR were replaced with half the LOR. The horizontal blue dashed line indicates the 95th percentile concentration for copper measured across all lake sites through the monitoring program.**

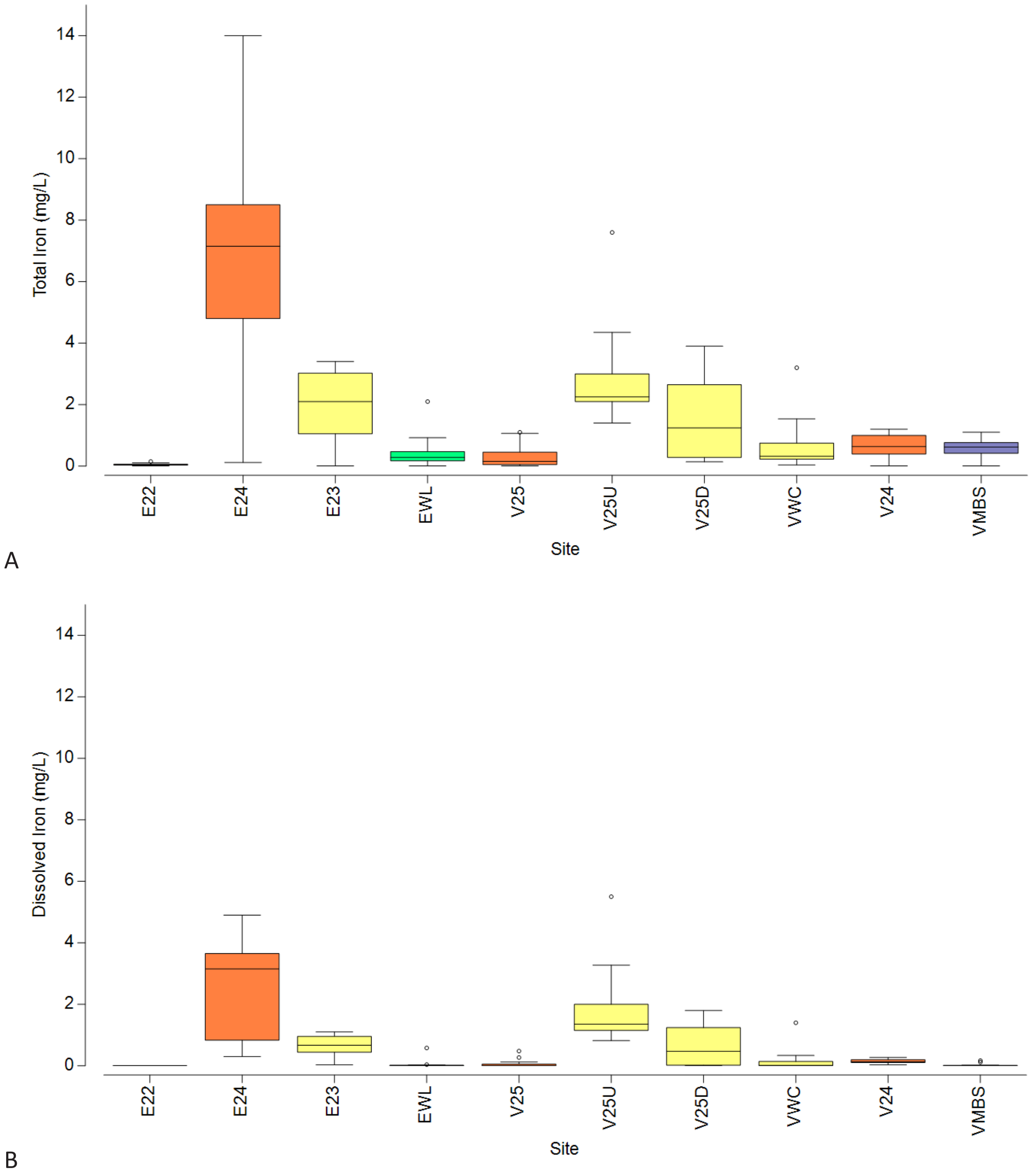
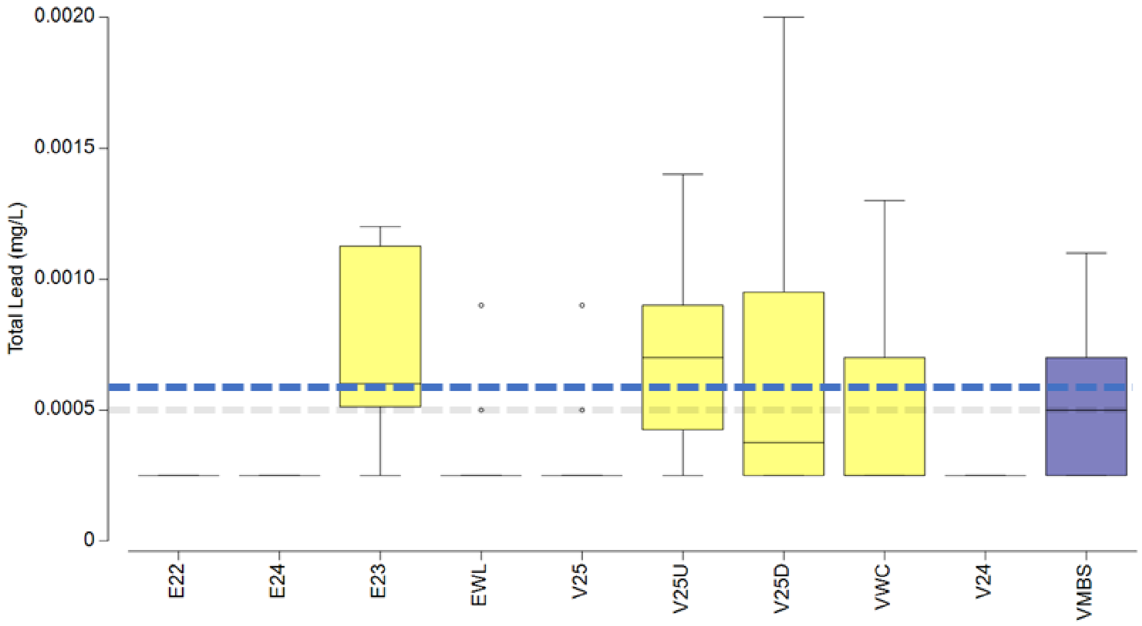
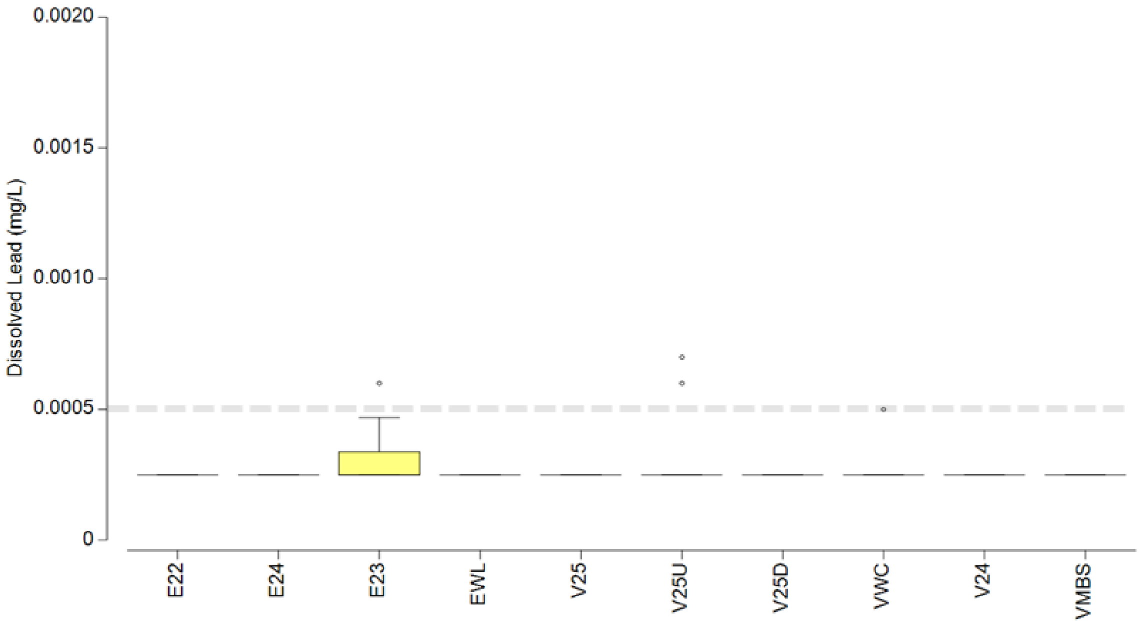


**Figure 50. Box plots of iron concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total iron; B) dissolved (<0.45 µm) iron. The limit of reporting (LOR) was 0.02 mg Fe/L; values below the LOR were replaced with half the LOR. The 95th percentile concentration for total and dissolved iron measured across all lake sites through the monitoring program were 0.20 and 0.03 mg/L, respectively.**



A



B

**Figure 51. Box plots of lead concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total lead; B) dissolved (<0.45 µm) lead. The horizontal grey dashed line indicates the limit of reporting (LOR, 0.0005 mg Pb/L); values below the LOR were replaced with half the LOR. The horizontal blue dashed line indicates the 95th percentile concentration for lead measured across all lake sites through the monitoring program (dissolved lead was <LOR).**

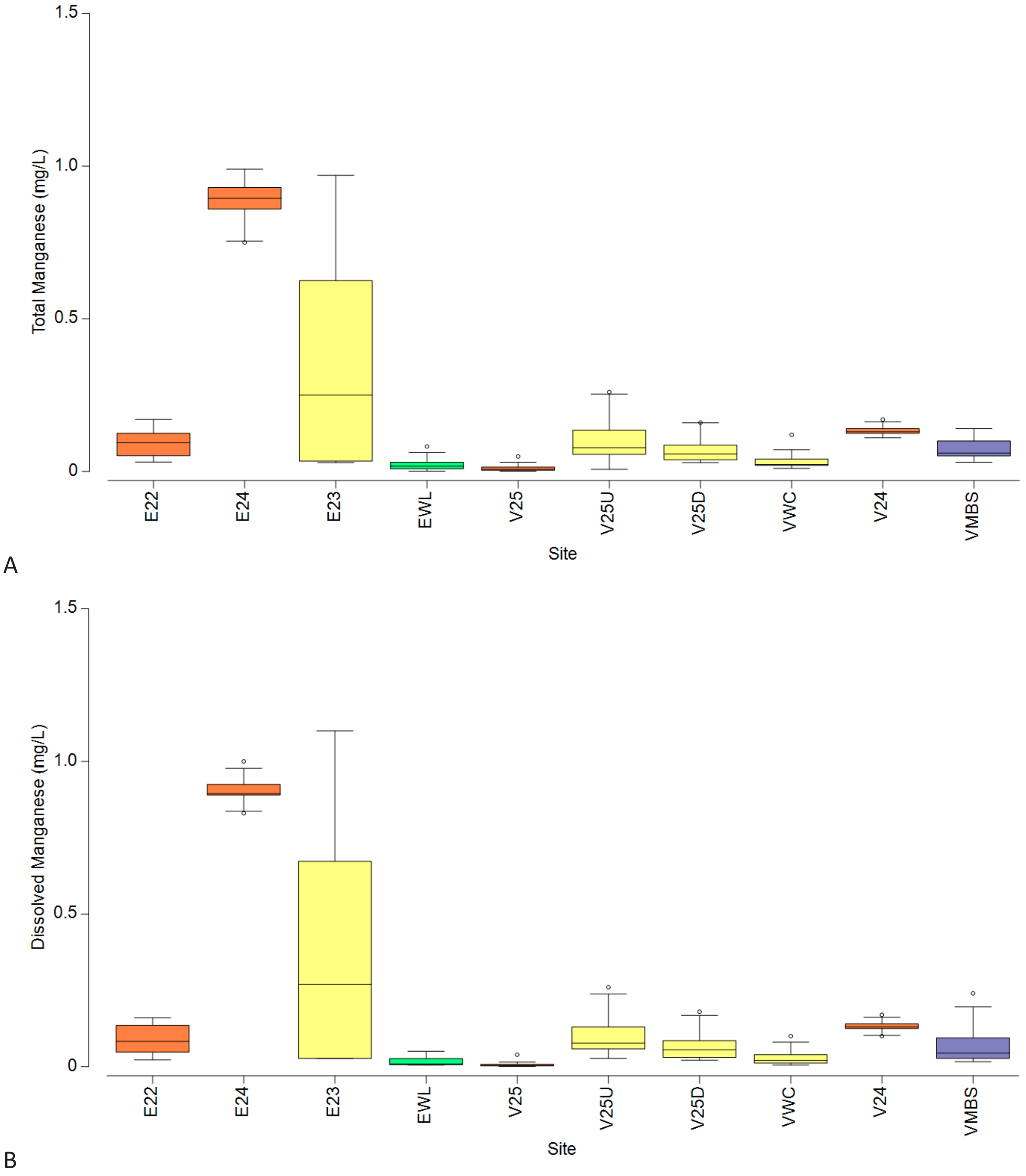


**Figure 52. Box plots of manganese concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total manganese; B) dissolved (<0.45 µm) manganese. The limit of reporting (LOR) was 0.001 mg Mn/L; values below the LOR were replaced with half the LOR. The 95th percentile concentration for total and dissolved manganese measured across all lake sites through the monitoring program were 0.033 and 0.027 mg/L, respectively.**

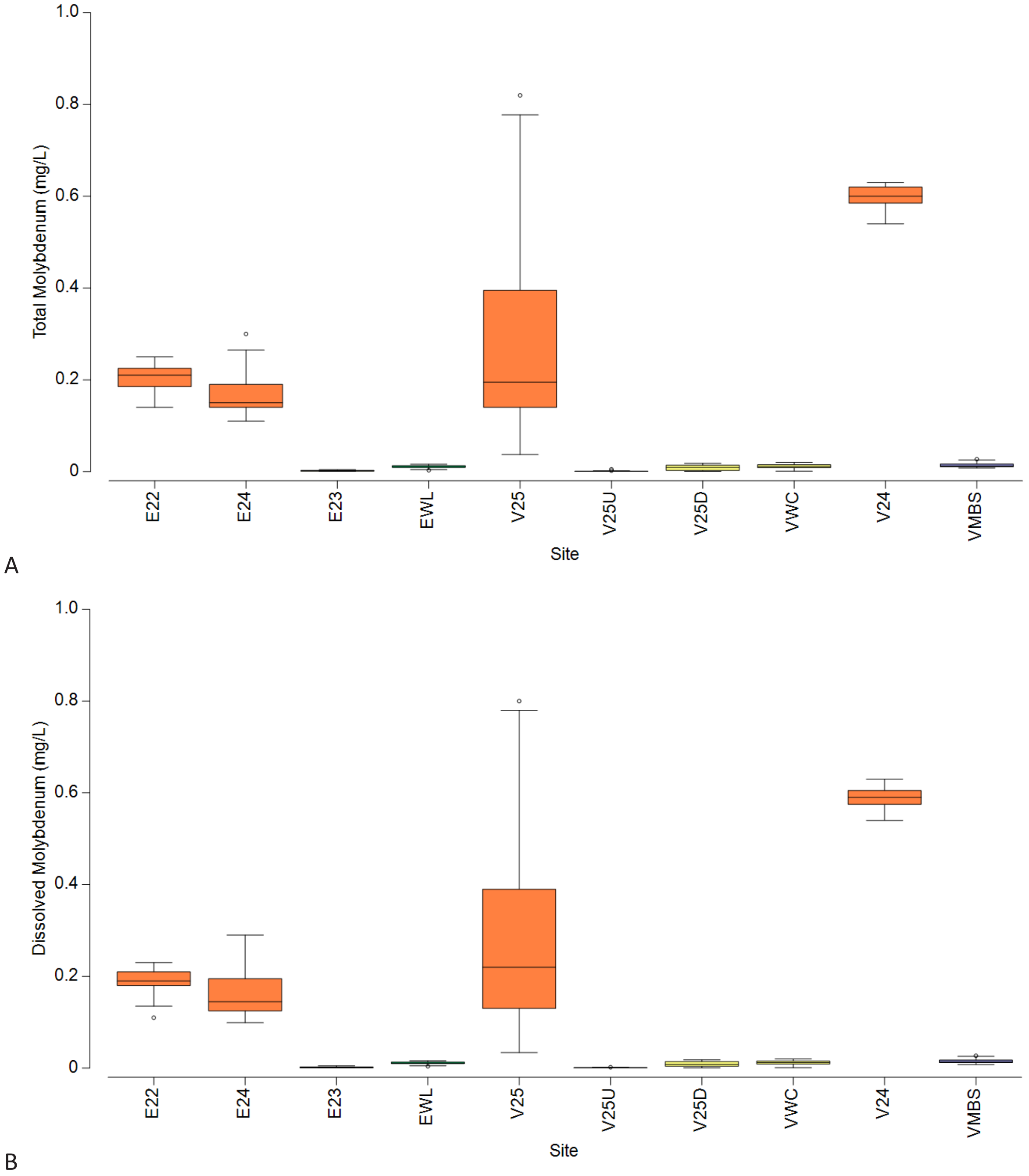


**Figure 53. Box plots of molybdenum concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total molybdenum; B) dissolved (<0.45 µm) molybdenum. The limit of reporting (LOR) was 0.001 mg Mo/L; values below the LOR were replaced with half the LOR. The 95th percentile concentration for total and dissolved molybdenum measured across all lake sites through the monitoring program were 0.016 and 0.017 mg/L, respectively.**

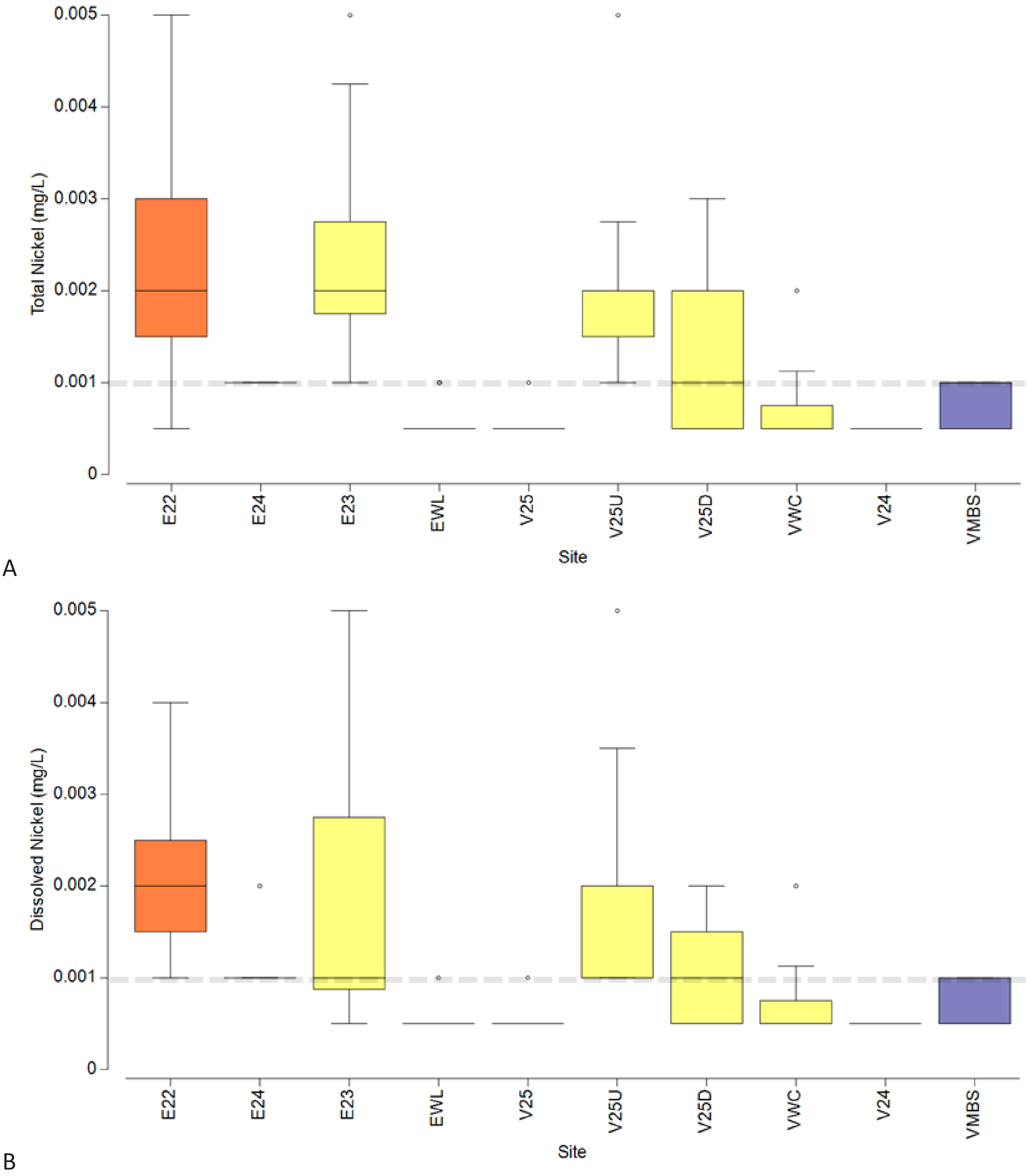


**Figure 54. Box plots of nickel concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total nickel; B) dissolved (<0.45 µm) nickel. The horizontal grey dashed line indicates the limit of reporting (LOR, 0.001 mg Ni/L); values below the LOR were replaced with half the LOR. The 95th percentile concentration for total and dissolved nickel measured across all lake sites through the monitoring program was ≤LOR.**

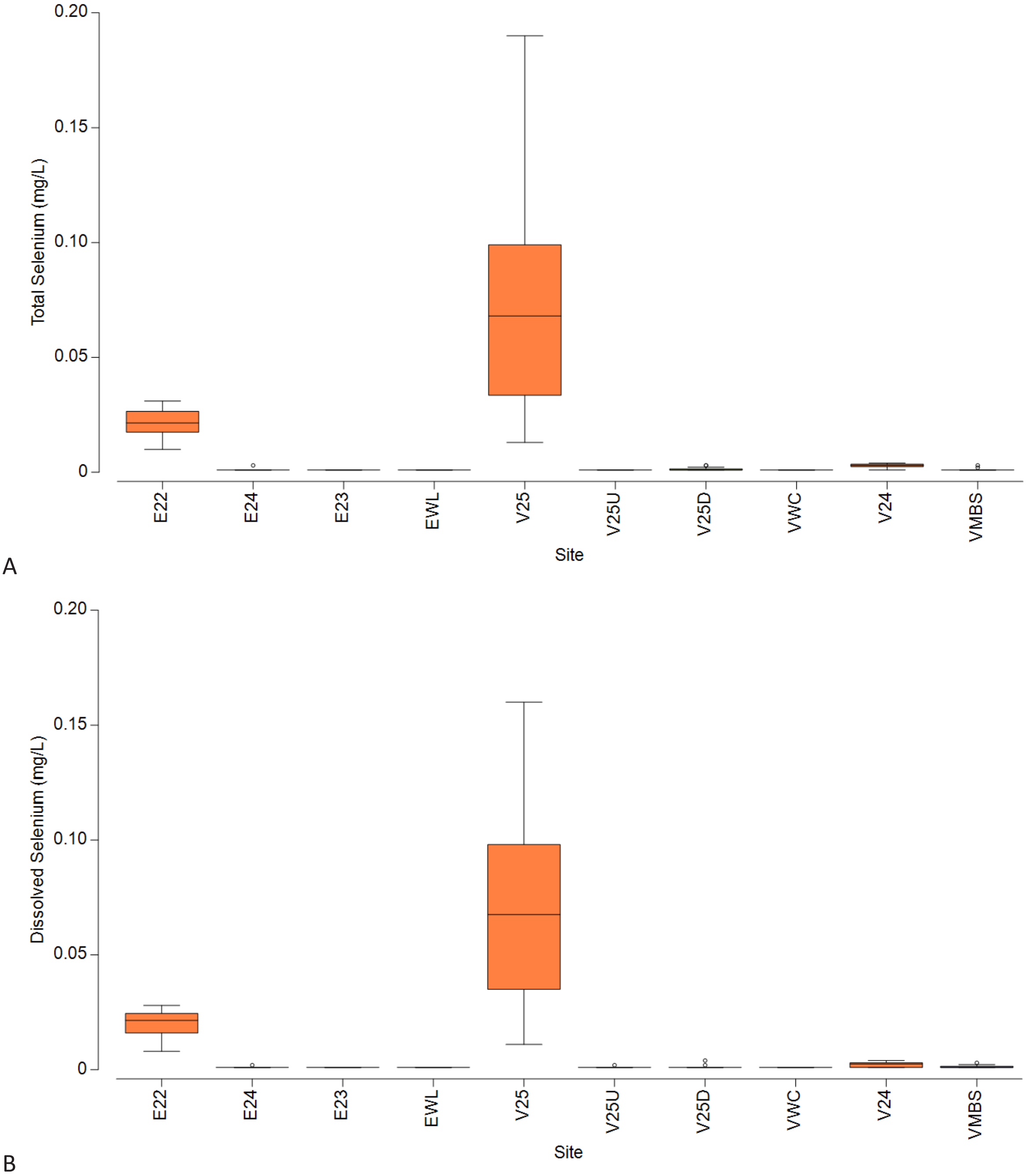


**Figure 55. Box plots of selenium concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total selenium; B) dissolved (<0.45 µm) selenium. The limit of reporting (LOR) was 0.002 mg Se/L; values below the LOR were replaced with half the LOR. The 95th percentile concentration for total and dissolved nickel measured across all lake sites through the monitoring program was <LOR.**

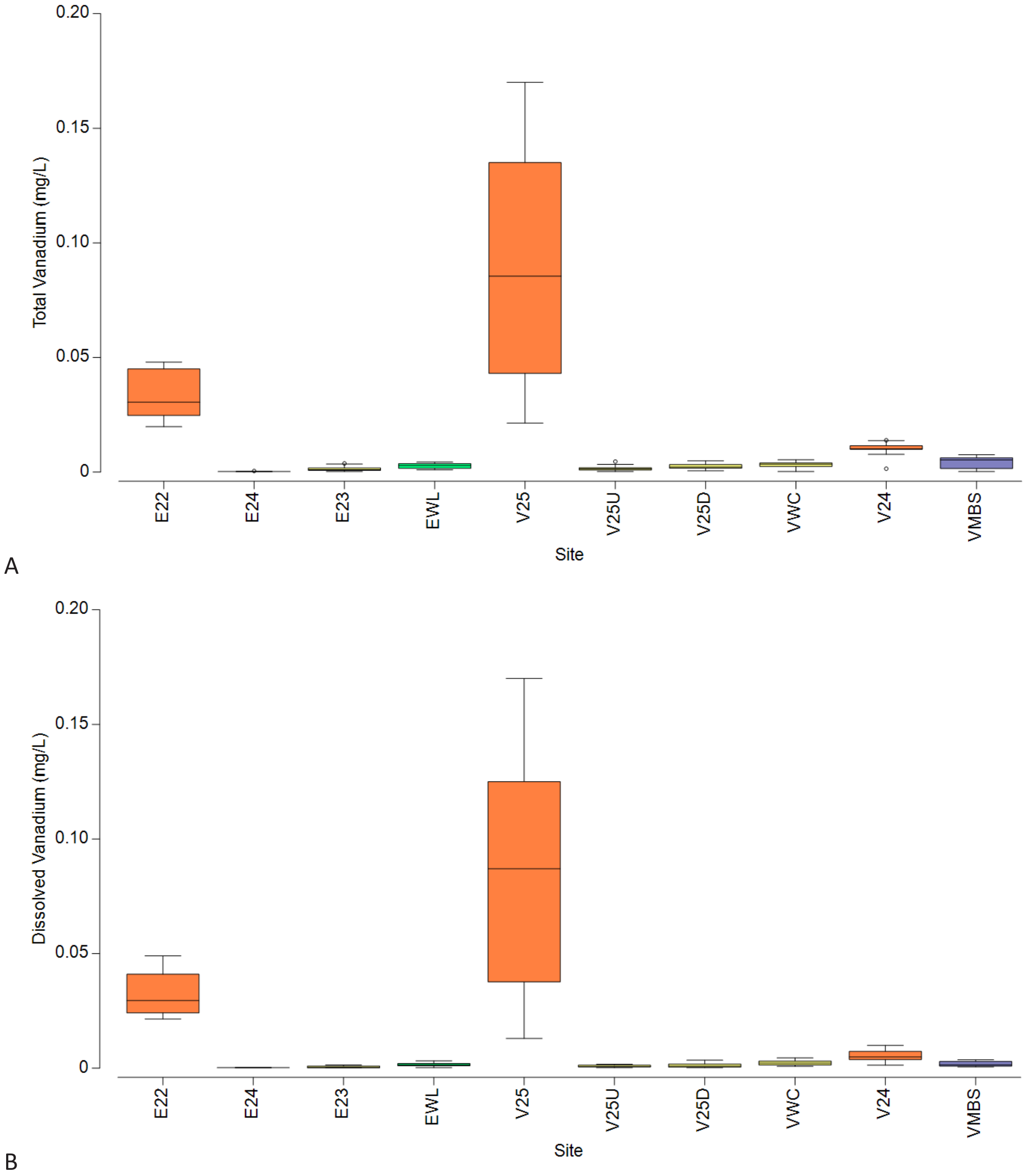
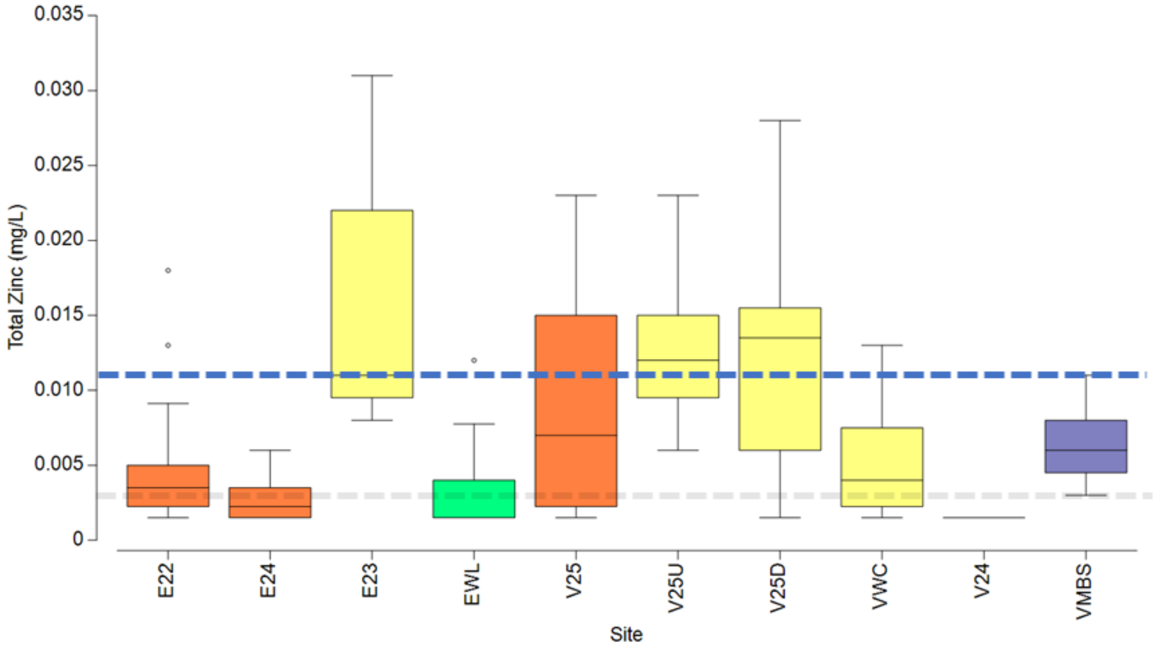
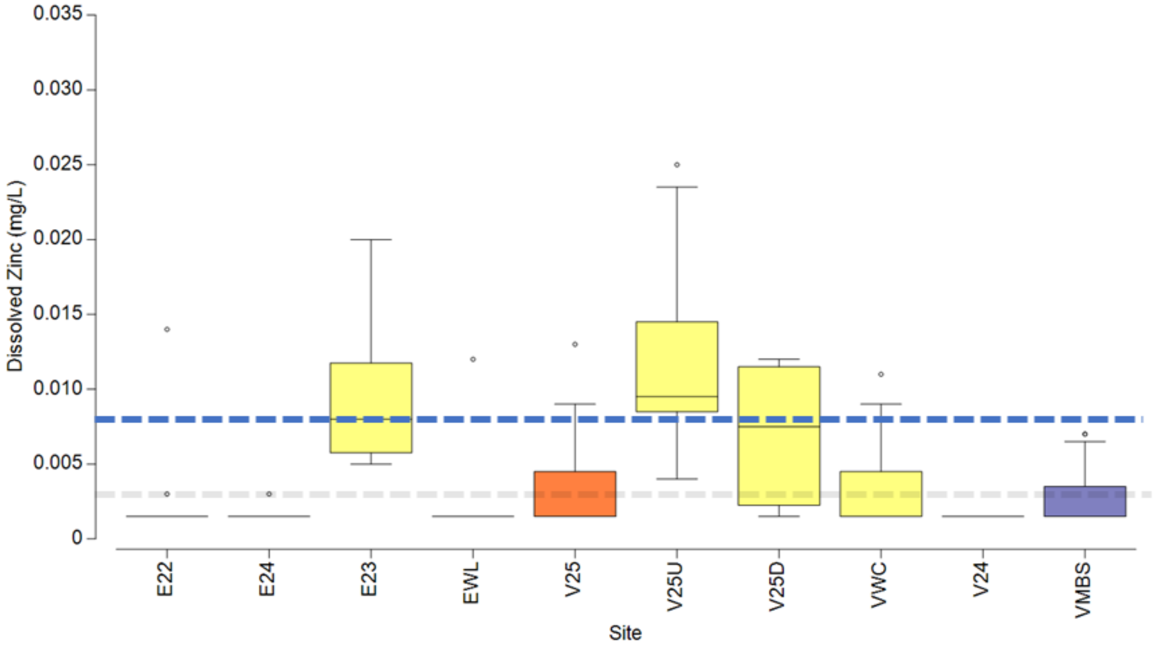


**Figure 56. Box plots of vanadium concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total vanadium; B) dissolved (<0.45 µm) vanadium. The limit of reporting (LOR) was 0.0005 mg V/L; values below the LOR were replaced with half the LOR. The 95th percentile concentration for total and dissolved nickel measured across all lake sites through the monitoring program was <LOR. The 95th percentile concentration for total and dissolved vanadium measured across all lake sites through the monitoring program were 0.0039 and 0.0037 mg/L, respectively.**



A



B

**Figure 57. Box plots of zinc concentrations (mg/L) in surface waters at 10 sites within the vicinity of the Eraring and Vales Point Power Stations from March 2022 to February 2023 (n=12): A) total zinc; B) dissolved (<0.45 µm) zinc. The horizontal blue dashed line indicates the 95th percentile concentration for zinc measured across all lake sites through the monitoring program. The horizontal grey dashed line indicates the limit of reporting (LOR, 0.003 mg Zn/L); values below the LOR were replaced with half the LOR.**

### 4.2.4 Vales Point emergency discharge

Concentrations of physicochemical indicators, nutrients, and metals determined during the Vales Point wet weather emergency discharge event sampling are in Appendix H – Vales Point wet-weather event sampling box plots. The following observations were collected from the single wet weather coal ash repository over-boarding event that occurred during the monitoring program:

- Conductivity and pH were lower in the coal ash repository and Wyee Creek compared to the range of measurements collected throughout the monitoring program.
- TSS in Wyee Creek at the time of sampling was on the higher end of the range of measurements collected through the monitoring program. TSS in the coal ash repository (V25) was within the range of measurements collected through the monitoring program. TSS was greater in the Wyee Creek upstream sample compared to the coal ash repository.
- DOC was elevated in the coal ash repository and Wyee Creek compared to the measurements collected throughout the monitoring program.
- Total nitrogen and oxidised nitrogen within Wyee Creek were on the higher end of measurements recorded throughout the monitoring program. The highest concentrations were measured in the Wyee Creek upstream sample (V25U).
- Oxidised nitrogen and ammonia-N concentrations measured during the event sampling were within the middle range of measurements recorded throughout the monitoring program and relatively consistent across the sampling sites.
- Total phosphorus, dissolved phosphorus and free reactive phosphorus concentrations measured during the event sampling were all on the higher end of measurements recorded throughout the monitoring program. The highest concentrations were measured in the Wyee Creek upstream sample (V25U).
- Total and dissolved aluminium, cobalt, lead, nickel, and zinc concentrations were elevated within Wyee Creek (V25U, V25D and VWC) compared to the measurements collected throughout the monitoring program (Figure A39, Figure A44, Figure A47, Figure A50, and Figure A52). The concentrations of these metals within the ash repository decant/return water (V25) were lower compared to those measured at the upstream Wyee Creek site.
- Total and dissolved arsenic, barium, molybdenum, and vanadium in Wyee Creek were generally within the range of measurements recorded throughout the monitoring program (Figure A40, Figure A41, Figure A49, and Figure A51). The concentrations of these metals were substantially more dilute in the ash repository decant/return water (V25) during the event sample collection compared to the measurements collected during the monitoring program.
- Total and dissolved selenium in the coal ash repository (V25) (0.016 and 0.015 mg/L, respectively) were on the lower end of measurements recorded throughout the monitoring program and were below the detection limit (<0.002 mg/L) within Wyee Creek (V25U, V25D and VWC).
- Very low concentrations of total and dissolved chromium and cobalt were generally observed in the ash repository decant/return water (V25) and Wyee Creek (V25U, V25D and VWC) and marginal increases were observed during the wet weather event sampling (Figure A43 and Figure A44).
- Total and dissolved iron and manganese were all slightly elevated in the ash repository decant/return water (V25) during the event sample collection, compared to the measurements collected during the monitoring program (Figure A46 and Figure A48). These

concentrations were similar to those observed in the upstream Wyee Creek sample and lower than the concentrations usually observed during the monitoring program (except for dissolved iron, which was within the range usually observed.

# 5. Conclusion

The key findings of the surface water quality assessment of southern Lake Macquarie were as follows:

- The physicochemical parameters of dissolved oxygen, pH, TSS, and turbidity were all within relevant guideline values except for a few localised exceedances.
- Temperature differences were observed across the lake with variations of as much as 5 to 10°C observed within a single sampling event. Elevated temperatures relative to other sites were observed within the receiving waters for the Eraring Power Station cooling water outlet and the Vales Point Power Station cooling water outlet.
- Median concentrations of total nitrogen and total phosphorus were below NSW GVs at all sites. Oxidised nitrogen, ammonia-N, and dissolved phosphorus concentrations exceeded guideline values on several occasions around the foreshore areas in the southwest basin and Wyee Bay, while concentrations in the main body of the lake were below guideline values. Free reactive phosphorus concentrations usually exceeded guideline values across all sites sampled.
- The concentrations of eight metals (cadmium, chromium, lead, mercury, nickel, selenium, silver, and vanadium) were below the screening criteria for all surface water samples collected. Seven metals (aluminium, arsenic, cobalt, copper, manganese, molybdenum, and zinc) had at least one exceedance during the monitoring program. Arsenic, cobalt, and molybdenum concentrations were below the screening criteria on ≥99% of all occasions and were not considered contaminants of concern in surface waters. Aluminium, copper, manganese, and zinc exceeded the screening criteria at some sites, indicating potential concerns. However, concentrations were below the criteria on 96%, 78%, 99%, and 96% of all sampling occasions, respectively. Low concentrations of dissolved copper (<0.001 - 0.004 mg/L) exhibited a relatively even distribution across the lake. DOC was found at concentrations that would likely provide some amelioration of the adverse effects from the copper concentration range measured. Aluminium and zinc concentrations were similar between the northern and southern sections of the lake and appear to be related to freshwater inflows bringing these contaminants from the catchment (via Dora Creek and Wyee Creek within the southern section of the lake). A single site, located within Dora Creek, exceeded the screening criterion for manganese on a few occasions.

Overall, the concentrations of contaminants in the lake reported here represent a low risk of adverse effects to aquatic organisms. Areas with more regular guideline exceedances were mostly constrained to the southwest basin and Wyee Bay, the receiving environments for Dora Creek and Wyee Creek, respectively, which drain mixed land-use catchments. The southwest basin and Wyee Bay also receive power station cooling waters and licenced discharges. Restricted oceanic flushing of the southwest and southern regions of Lake Macquarie, due to distance from the open channel at Swansea, is one factor likely contributing to more exceedances of guideline values in these areas. Another potential factor is the water circulation patterns in southern Lake Macquarie resulting from the power stations use of lake water from Bonnells Bay and Chain Valley Bay and the subsequent discharge of cooling water to Myuna Bay (~7000 ML/day) and Wyee Bay (~4000 ML/day).

Notable contaminants in the various source waters are summarised below:

- TSS and turbidity were generally elevated within all source waters to the lake (coal ash repository decant or seepage waters and all creek sites) relative to concentrations observed within the lake basin.

- The Eraring and Vales Point coal ash repository/return waters and catchment runoff from mixed land uses via Dora Creek, Crooked Creek, and Wyee Creek all appear to be potential sources of nitrogen (total, dissolved, and oxidised forms) to the lake and total phosphorus to the lake.
- With respect to source water in the south-west basin, Dora Creek generally had lower concentrations of dissolved and free reactive phosphorus compared to the concentrations measured within the lake while the Eraring coal ash repository/ return waters had highly elevated concentrations of dissolved and free reactive phosphorus.
- With respect to source water around Wyee Bay, concentrations of phosphorus were usually slightly elevated in the Wyee Creek upstream sample relative to the Vales Point coal ash repository/return waters, and this was further demonstrated during the Vales Point wet-weather event sampling.
- Coal ash repository/return waters were characterised by elevated concentrations of arsenic, barium, boron, cadmium, chromium, manganese, molybdenum, selenium, and vanadium at both power stations. Copper, iron (in the seepage water), and nickel were also elevated at Eraring Power Station.
- Surface waters receiving catchment run-off (such as Wyee Creek, Dora Creek and Crooked Creek) were characterised by elevated aluminium, cobalt, iron, lead, manganese, nickel, and zinc.

Sampling was conducted during both dry and wet conditions and thus has captured both background/ambient concentrations as well as when concentrations were likely to be elevated following rain events. Consideration of rainfall patterns identified that the sampling period was the wettest year on record within the preceding 10-year period. Data were also captured during a coal ash repository over-boarding event at Vales Point Power Station and showed that the addition of over-boarded water to Wyee Creek had no significant adverse influence on metal/nutrient concentrations downstream of the discharge into Wyee Creek.

The water quality data collected during this program form a baseline against which future developments in the southern region of the lake can be assessed. This report is a companion to a comprehensive investigation of surface sediment quality within the southern section of Lake Macquarie. The surface sediment quality investigation includes multiple lines of investigation including sediment chemistry, toxicity, and benthic ecology. Following on from these investigations of surface water and sediment quality, an additional study is being implemented to investigate the concentration of metals within freshly deposited sediments. A final synthesis report will be prepared which will consider all lines of evidence investigated as part of the assessment of surface water and sediment quality within the southern section of Lake Macquarie.

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# 7. Appendices

## Appendix A – Data quality assessment

### Quality assurance and quality control measures

QA procedures were established for this project to maximise sample integrity and included the use of:

- standard operating procedures for water sampling and analyses.
- a new pair of disposable nitrile gloves for each sampling location.
- laboratory-supplied sampling containers and storage procedures appropriate for each analysis type.

QC procedures were established to check the success of QA and are used to classify the validity of the laboratory data.

Laboratory QC included the use of laboratory reagent or preparation blanks, spike blanks, certified reference materials, laboratory duplicates, and matrix spikes, which had to comply with the laboratory's established criteria of acceptance for reporting.

Field QC included the collection of:

- A field blank for every surface water sample collection round, analysed for total and dissolved metals.
- During the investigation a field blank was added to three surface water sample collection rounds and analysed for nutrients (total, dissolved inorganic, and dissolved organic). Six container blanks were also prepared and analysed for nutrients to investigate a suspected contamination issue.
- One field duplicate sample (for intra-laboratory analysis) for every twenty primary samples.
- One laboratory duplicate sample (for inter-laboratory analysis) for every sample collection round.

#### *Data quality indicators for field blanks*

The field blank was used to assess the potential for contamination of samples during the collection and transport of the environmental samples. The container blank was used to assess the potential for contamination coming from sampling equipment such as vials and filters. The data quality indicator (DQI) for the field blank was no detections above the LOR. Where an analyte was detected in the blank sample (concentration was greater than the LOR), the occurrence was noted and investigated to identify any sources of reporting errors or contamination sources. Where a significant contamination issue in the blank was identified for an analyte, the following approach was applied:

- If the sample concentration was ≥10 times the maximum blank concentration the impact of the blank contamination is considered negligible – no action taken.
- If the sample concentration was <10 times the maximum blank concentration – the result was reported as an estimated quantity (due to contamination the result may be biased to be high).

### *Data quality indicators for field and laboratory duplicates*

The location for the collection of the field and laboratory duplicate samples was chosen at random before commencing the sampling event. The duplicate samples were labelled to conceal their relationships to the primary sample. The field duplicate was used to identify variations in analyte concentrations between samples collected from the same sampling point. The laboratory duplicate was used to assess laboratory performance and to classify the validity of the laboratory data. The data quality indicator (DQI) was for the primary and duplicated samples to be within the specified relative percentage difference (RPD) for the method (typically 30%). RPD is calculated as follows:

$$\mathrm{RPD}\ (\%) = \frac{(\text{difference between sample duplicates})}{(\text{average of sample duplicates})}\ \mathrm{X}\ 100$$

Low levels of contaminants can exaggerate the RPD, and this will be taken into consideration using the following approach. Duplicate results with a RPD greater than 30% were considered acceptable if the detected values were within 10 times the LOR for metals (LORs 0.00005 – 0.02 mg/L) and nutrients (LORs 0.001 – 0.02 mg/L) or 2 times the LOR for TSS (LOR 3 mg/L) and DOC (LOR 1 mg/L).

## Data quality

### *Assessment of field QA/QC*

Surface water was collected from 29 sites on 12 sampling occasions. Field sampling QC analytical results are provided in Table A1, Table A2, and Table A3 and are summarised below:

- Twelve field blank samples were analysed for the suite of total metals (Ag, Al, As, Ba, Be, B, Cd, Cr, Co, Cu, Pb, Mn, Mo, Ni, Pb, Se, Tl, V, Zn, and Hg) and all but barium and zinc met the DQI (Table A1). Total barium and total zinc were detected in the field blank on a single occasion each and were considered low-level contamination (detected values were within 2 times their respective LORs). No significant source of total barium or total zinc contamination was identified. The analytical data are considered acceptably reliable for the purpose of the investigation.
- Eleven field blank samples were analysed for the suite of dissolved metals (Ag, Al, As, Ba, Be, B, Cd, Cr, Co, Cu, Pb, Mn, Mo, Ni, Pb, Se, Tl, V, and Zn) and all met the DQI (Table A1).
- Three field blank and six container blank samples were analysed for nitrogen (total, dissolved inorganic, and dissolved organic) and the DQI was not met (Table A1). A significant source of nitrogen contamination was identified as coming from some of the sample containers. As a result, all samples with detected concentrations less than 10 times the maximum blank concentration were reported as an estimated quantity (due to contamination, the result may be biased to be high). Where the detected concentrations were ≥10 times the maximum blank concentration the analytical data were considered acceptably reliable for the purpose of the investigation.
- Three field blank and six container blank samples were analysed for phosphorus (total, dissolved inorganic, and dissolved organic) and all but free reactive phosphorus met the DQI (Table A1). Free reactive phosphorus was detected in the field blank on a single occasion and was considered low-level contamination (the detected value was equal to the LOR). No significant source of phosphorus contamination was identified. The analytical data were considered acceptably reliable for the purpose of the investigation.

- Twenty-three field duplicate samples were collected and analysed for the suite of total and dissolved metals (Ag, Al, As, Ba, Be, B, Cd, Cr, Co, Cu, Pb, Mn, Mo, Ni, Pb, Se, Tl, V, and Zn) and total mercury. All duplicates met the DQI except for manganese and molybdenum (Table A2). Sample heterogeneity was identified in 9% (n=2) of duplicate samples for total manganese as well as total and dissolved molybdenum. The differences observed for manganese and molybdenum are most likely attributed to random sample heterogeneity. The analytical data were considered acceptably reliable for the purpose of the investigation.
- Twenty-three field duplicate samples were collected and analysed for the suite of total and dissolved nutrient analyses (total nitrogen, dissolved nitrogen, oxidised nitrogen, ammonia-N, total phosphorus, dissolved phosphorus, and free reactive phosphorus) and TSS. All duplicates for free reactive phosphorus met the DQI (Table A3). For the remaining analyses, at least one duplicate did not meet the DQI (Table A3). Sample heterogeneity was identified in 9% (n=2) of duplicate samples for total nitrogen and dissolved nitrogen, and 4% (n=1) of duplicate samples for oxidised nitrogen, ammonia-N, total phosphorus, dissolved phosphorus, and TSS. Twenty-two field duplicates were collected and analysed for DOC. For DOC, 5% (n=1) of duplicates did not meet the DQI. In all cases, the issue does not appear to be systemic and is likely attributable to random sampling heterogeneity. Given the small incidence, the analytical data were acceptably reliable for the purpose of the investigation.

**Table A1. Evaluation of field blanks for metal and nutrient analyses**

| Analyte | LOR (mg/L) | No. of samples | Number of detects | Range of detects (min-max) | Result from data quality investigation |
|---|---|---|---|---|---|
| Total barium | 0.0005 | 12 | 1 | 0.0010 | A single detection of total barium and total zinc was noted for the field blank samples. Both values were within 2 times their respective LOR. No significant source of total barium or total zinc contamination was identified. No action taken. |
| Total zinc | 0.003 | 12 | 1 | 0.006 | |
| Total Ag, Al, As, Be, B, Cd, Cr, Co, Cu, Pb, Mn, Mo, Ni, Pb, Se, Tl, V, Hg | Various | 12 | Not detected above LOR | NA | No contamination was identified. |
| Dissolved Ag, Al, As, Ba, Be, B, Cd, Cr, Co, Cu, Pb, Mn, Mo, Ni, Pb, Se, Tl, V, Zn | Various | 11 | Not detected above LOR | NA | |
| Total nitrogen | 0.02 | 9 | 1 | 0.02 | A significant source of nitrogen contamination was identified as coming from some of the sample containers. For samples with concentration <10 times the maximum blank concentration – the result was reported as an estimated quantity (due to contamination the result may be biased to be high). |
| Dissolved nitrogen | 0.02 | 9 | 4 | 0.02 – 0.03 | |
| Oxidised nitrogen | 0.002 | 9 | 5 | 0.002 – 0.009 | |
| Ammonia-N | 0.001 | 9 | 5 | 0.001 – 0.002 | |
| Total phosphorus | 0.004 | 9 | Not detected above LOR | NA | Free reactive phosphorus was present on two occasions in the field blank sample. Both values were equal to the LOR. No significant source of phosphorus contamination was identified. No action was taken. |
| Dissolved phosphorus | 0.004 | 9 | Not detected above LOR | NA | |
| Free reactive phosphorus | 0.001 | 9 | 2 | 0.001 | |

LOR = Limit of reporting

**Table A2. Evaluation of field duplicate samples for total and dissolved metal analyses (n=23[a] duplicates)**

| Analyte | LOR (mg/L) | Median % RDP[a] | Max % RDP[a] | Samples that exceeded the DQI and the results of at least one of the samples were greater than 10 times the LO<br>Date, site collected, primary sample & duplicate sample (mg/L) | Result from data quality investigation |
|---|---|---|---|---|---|
| Total Ag, Be, Pb, Tl and Hg | Various | NA | NA | NA – All values below the LOR | The analytical data are acceptably reliable for the purpose of the investigation. |
| Total Al, As, Ba, B, Cd, Cr, Co, Cu, Fe, Ni, Se, V, Zn | Various | Various | ≤30 | NA – All values below the DQI | The analytical data are acceptably reliable for the purpose of the investigation. |
| Dissolved Ag, Be, Pb, Tl | Various | NA | NA | NA – All values below the LOR | The analytical data are acceptably reliable for the purpose of the investigation. |
| Dissolved Al, As, Ba, B, Cd, Cr, Co, Cu, Fe, Mn, Ni, Se, V, Zn | Various | Various | ≤30 | NA – All values below the DQI | The analytical data are acceptably reliable for the purpose of the investigation. |
| Total Mn | 0.001 | 8% | 76% | 20/04/2022, E3, 0.12 & 0.088<br>16/09/2022, E22, 0.12 & 0.054 | Sample heterogeneity was identified in 9% of duplicate samples for total manganese. No differences were observed in the corresponding dissolved manganese samples. The difference is most likely attributable to random sampling heterogeneity. The analytical data are acceptably reliable for the purpose of the investigation. |
| Total Mo | 0.001 | 3% | 100% | 16/06/2022, LMMH, 0.011 & 0.022<br>29/07/2022, E21, 0.011 & 0.033 | Sample heterogeneity was identified in 9% of duplicate samples for total and dissolved molybdenum. The total and dissolved molybdenum concentrations were consistent |

| Analyte | LOR (mg/L) | Median % RDP[a] | Max % RDP[a] | Samples that exceeded the DQI and the results of at least one of the samples were greater than 10 times the LO<br>Date, site collected, primary sample & duplicate sample (mg/L) | Result from data quality investigation |
|---|---|---|---|---|---|
| Dissolved Mo | 0.001 | 8% | 83% | 16/06/2022, LMMH, 0.012 & 0.02<br>29/07/2022, E21, 0.012 & 0.029 | between corresponding samples. The difference is most likely attributable to random sampling heterogeneity. The analytical data are acceptably reliable for the purpose of the investigation. |

DQI = data quality indicator (30% relative percentage difference, RPD), LOR = Limit of reporting, NC = Not calculable,

[a] Two duplicates were to be collected per sampling event, with 12 sampling events scheduled. One duplicate sample missed during sampling round 12.

**Table A3. Evaluation of field duplicate samples for total and dissolved nutrient analyses (n=23[a] duplicates)**

| Analyte | LOR (mg/L) | Median[b] % RDP | Max[b] % RDP | Samples that exceeded the DQI (30% RPD)<br>Date, site collected, primary sample, duplicate sample (mg/L) | Result data quality investigation |
|---|---|---|---|---|---|
| Total nitrogen | 0.02 | 6% | 40% | 20/04/2022, E3, 0.56 & 0.4<br>13/12/2022, CCC3, 0.14 & 0.21 | Sample heterogeneity was identified in 9% of duplicate samples for total and dissolved nitrogen. Total and dissolved nitrogen concentrations were generally >10 the LOR. The issue does not appear to be systemic and is likely attributable to random sampling heterogeneity. The analytical data are acceptably reliable for the purpose of the investigation. |
| Dissolved nitrogen | 0.02 | 6% | 55% | 20/04/2022, E3, 0.43 & 0.31<br>15/09/2022, L1, 0.21 & 0.12 | |
| Oxidised nitrogen | 0.002 | 0% | 80% | 25/05/2022, V-In, 0.012 & 0.022 | Sample heterogeneity was identified in 4% of duplicate samples for oxidised nitrogen and ammonia-N. Oxidised nitrogen and ammonia-N concentrations were generally >10 times the LOR. The issue does not appear to be systemic and is likely attributable to random sampling heterogeneity. The analytical data are acceptably reliable for the purpose of the investigation. |
| Ammonia-N | 0.001 | 8% | 154% | 15/02/2023, CCC1, 0.022 & 0.17 | |
| Total phosphorus | 0.004 | 5% | 32% | 16/09/2022, E22, 0.32 & 0.44 | Sample heterogeneity was identified in 4% of duplicate samples for total and dissolved phosphorus. The total and dissolved phosphorus concentrations were consistent between the corresponding samples. The difference is most likely attributable to random sampling heterogeneity. The analytical data are acceptably reliable for the purpose of the investigation. |
| Dissolved phosphorus | 0.004 | 7% | 55% | 16/09/2022, E22, 0.32 & 0.46 | |
| Free reactive phosphorus | 0.001 | 0% | 29% | NA | The analytical data is acceptably reliable for the purpose of the investigation. |
| Total suspended solids | 3 | 18% | 50% | 19/10/2022, V25, <3 & 9 | Sample heterogeneity was identified in 4% of duplicate samples for total suspended solids. The difference is potentially attributable to random sampling or analysis error. The issue does not appear to be systemic and is likely attributable to random sampling heterogeneity. The analytical data are acceptably reliable for the purpose of the investigation. |

| Analyte | LOR (mg/L) | Median[b] % RDP | Max[b] % RDP | Samples that exceeded the DQI (30% RPD)<br>Date, site collected, primary sample, duplicate sample (mg/L) | Result data quality investigation |
|---|---|---|---|---|---|
| Dissolved organic carbon | 1 | 0%[c] | 40%[c] | 15/11/2022, B6, 3 & 2 | Sample heterogeneity was identified in 5% of duplicate samples for dissolved organic carbon. The issue does not appear to be systemic and is likely attributable to random sampling heterogeneity. The analytical data are acceptably reliable for the purpose of the investigation. |

LOR = Limit of reporting

[a] Two duplicates were to be collected per sampling event, with 12 sampling events scheduled. One duplicate sample was missed during sampling round 12.

[b] Median/maximum value excludes results where one or both values were less than the limit of reporting.

[c] Two duplicate samples were missed during sampling round 12 (n=22 duplicates).

# Appendix B – Monthly rainfall summaries

**Table A4. Monthly rainfall (mm) at Eraring Station (Payten St, station no. 061376, 151.54°E, 33.08°S) for the period of January 2013 to March 2023. Monthly rainfall within the 95th (*highlighted dark pink*) and 50th (*highlighted light pink*) percentile of the dataset.**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | 206.0 | 188.4 | 149.2 | 121.0 | 63.6 | 98.6 | 15.2 | 14.2 | 21.8 | 41.6 | 294.8 | 26.8 | 1241 |
| 2014 | 14.8 | 301.6 | 96.8 | 127.0 | 51.0 | 64.4 | 15.6 | 154.6 | 47.0 | 54.8 | 31.4 | 121.0 | 1080 |
| 2015 | 242.0 | 70.0 | 99.2 | 412.2 | 138.0 | 69.2 | 10.0 | 20.2 | 86.8 | 58.6 | 107.2 | 103.8 | 1417 |
| 2016 | 322.0 | 21.6 | 62.2 | 27.8 | 9.4 | 210.0 | 57.2 | 68.6 | 59.0 | 57.2 | 40.6 | 65.8 | 1001 |
| 2017 | 72.4 | 108.8 | 256.8 | 80.6 | 18.6 | 121.2 | 2.2 | 9.4 | 12.4 | 126.4 | 59.2 | 60.0 | 928 |
| 2018 | 16.6 | 155.2 | 74.6 | 48.6 | 13.4 | 207.4 | 0.2 | 34.8 | 74.2 | 193.0 | 86.8 | 60.2 | 965 |
| 2019 | 53.8 | 94.2 | 159.6 | 46.8 | 14.2 | 127.4 | 45.2 | 140.4 | 97.0 | 23.6 | 27.0 | 2.4 | 832 |
| 2020 | 39.0 | 283.2 | 158.6 | 61.0 | 75.4 | 72.8 | 234.2 | 45.0 | 26.6 | 150.0 | 40.0 | 206.0 | 1392 |
| 2021 | 86.2 | 163.0 | 483.0 | 35.8 | 26.0 | 47.2 | 31.4 | 69.6 | 43.4 | 65.6 | 196.0 | 78.4 | 1326 |
| 2022 | 128.6 | 107.8 | 384.4 | 160.4 | 115.8 | 14.4 | 368.6 | 28.6 | 126.8 | 162.0 | 43.4 | 30.0 | 1671 |
| 2023 | 81.2 | 61.4 | 115.8 | | | | | | | | | | |

**Table A5. Monthly rainfall (mm) at Swansea Station (Catherine St, station no. 061377, 151.63°E, 33.09°S for the period of January 2013 to March 2023. Monthly rainfall within the 95th (*highlighted dark pink*) and 50th (*highlighted light pink*) percentile of the dataset.**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | 218.4 | 197 | 183.8 | 141.2 | 95 | 170.6 | 50.2 | 18.8 | 24.4 | 32.4 | 340.4 | 21 | 1493 |
| 2014 | 14.8 | 316.2 | 65 | 153 | 75 | 158.8 | 20.4 | 194.2 | 53.8 | 52.8 | 16.6 | 131.4 | 1252 |
| 2015 | 244.4 | 59.2 | 77.8 | 358 | 170.4 | 95.4 | 24.6 | 29.4 | 106.4 | 68.6 | 105.2 | 117.2 | 1457 |
| 2016 | 398.2 | 27.4 | 83.4 | 35 | 17 | 233 | 72.8 | 92 | 60.4 | 83.4 | 44.4 | 67.6 | 1215 |
| 2017 | 68 | 101.2 | 288.6 | 100.6 | 30.6 | 210.4 | 14.6 | 10.8 | 13.2 | 131.8 | 73.6 | 33 | 1076 |
| 2018 | 13.8 | 111 | 60 | 45 | 22.8 | 299.8 | 2.6 | 9.4 | 65.6 | 220.4 | 76.2 | 81.2 | 1008 |
| 2019 | 26.4 | 45 | 138.6 | 51.4 | 19 | 185.8 | 35.6 | 200 | 115.2 | 47.4 | 33 | 4.2 | 902 |
| 2020 | 19.8 | 306.6 | 151.6 | 57.2 | 137.4 | 82.2 | 316.2 | 46.2 | 28.8 | 118.2 | 49.2 | 216.6 | 1530 |
| 2021 | 108.8 | 169.2 | 394.4 | 53.4 | 27 | 81 | 28.6 | 57 | 75 | 62.8 | 112.6 | 30.4 | 1200 |
| 2022 | 107.4 | 173.4 | 305.6 | 200.4 | 118.8 | 71.4 | 346 | 49.6 | 112.4 | 153.8 | 38.2 | 39.8 | 1716 |
| 2023 | 106.2 | 105.4 | 158 |  |  |  |  |  |  |  |  |  |  |

# Appendix C – Temporal analysis of physicochemical indicator data

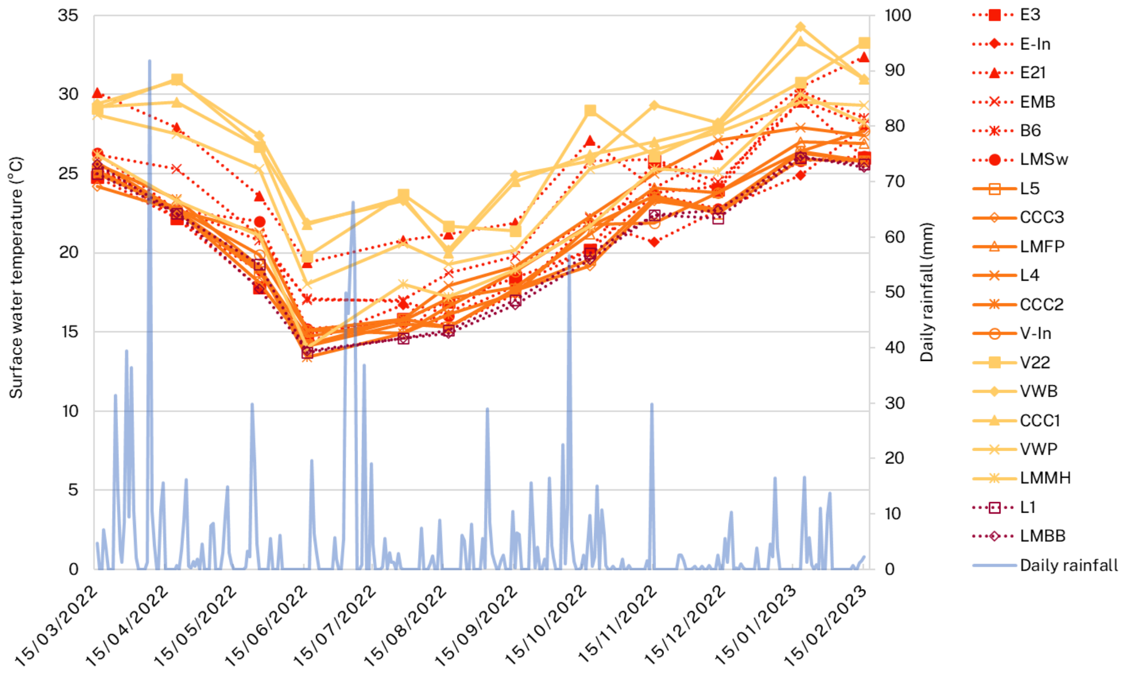


**Figure A1. Plots of surface water temperature (°C) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12)**

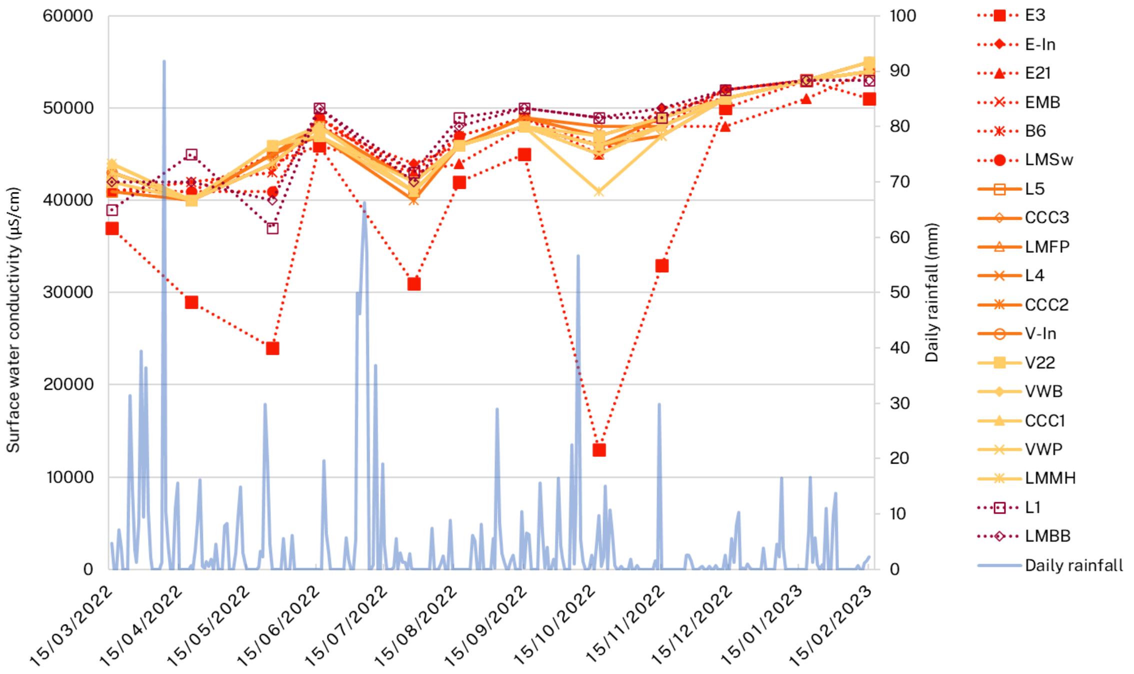


**Figure A2. Plots of surface water conductivity (µS/cm) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12)**

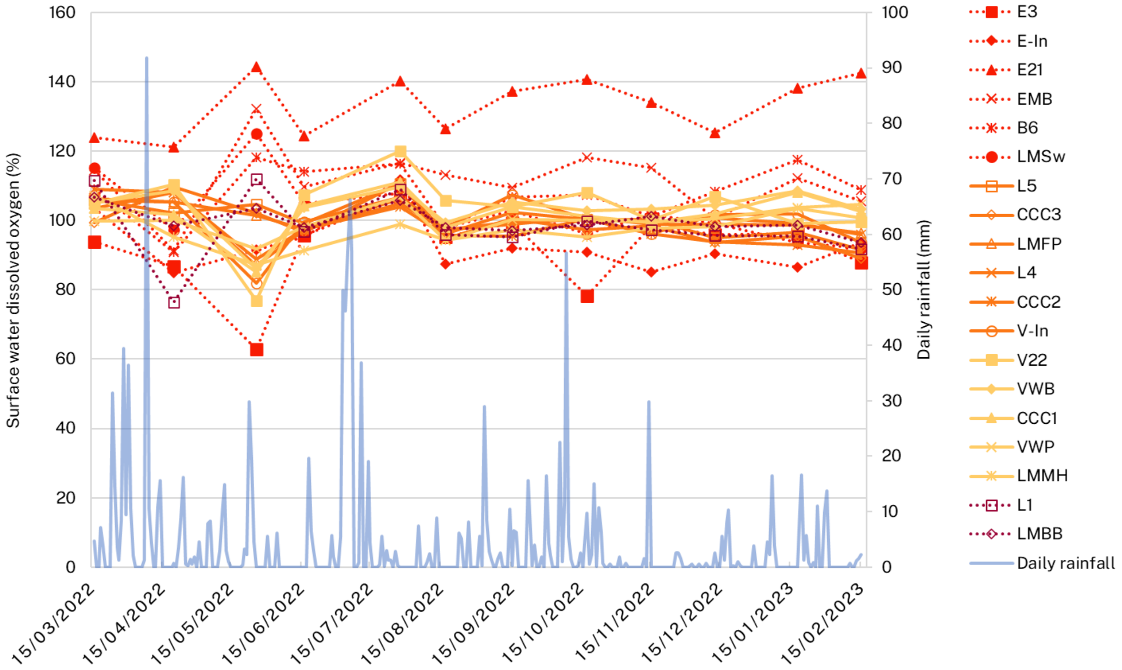


Figure A3. Plots of surface water dissolved oxygen (%) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12)

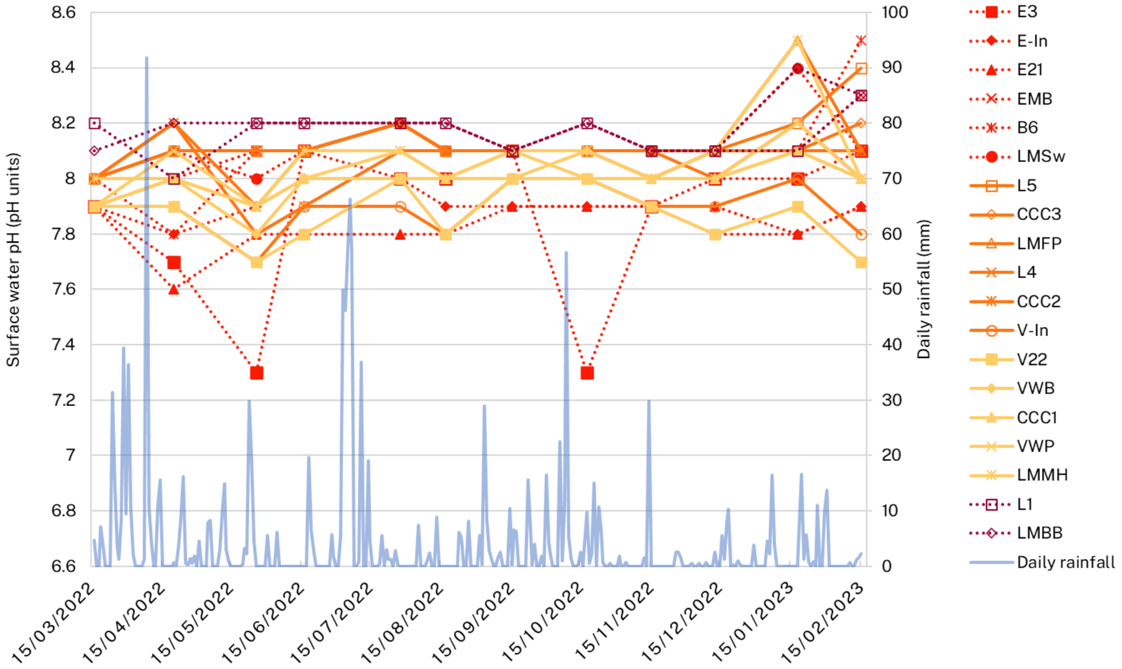


Figure A4. Plots of surface water pH (pH units) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12)

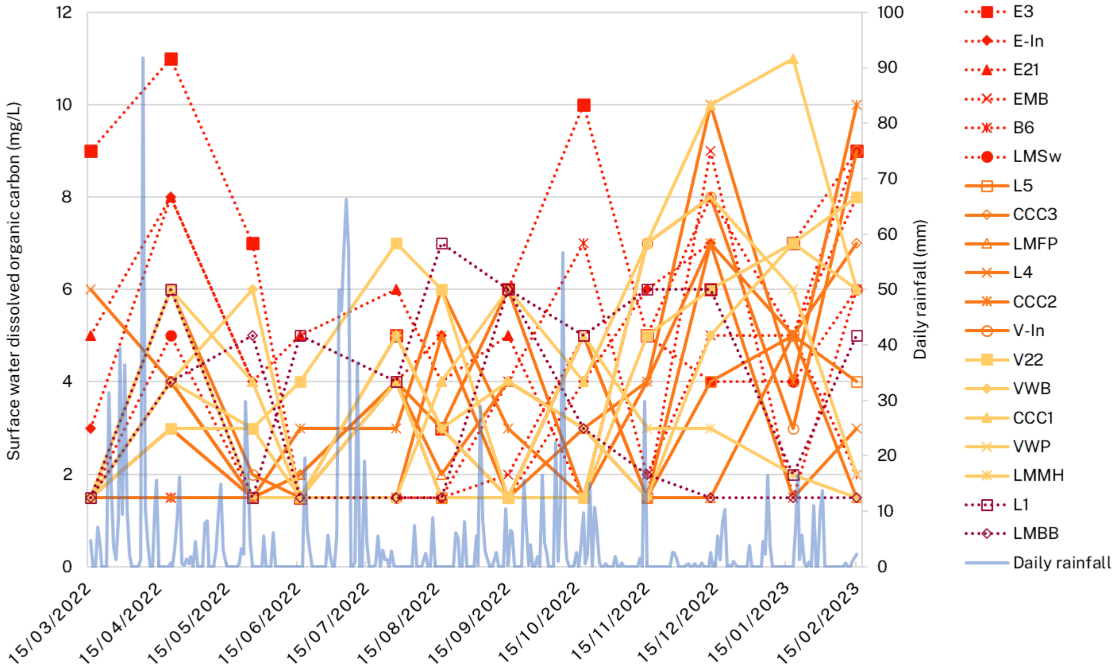


**Figure A5. Total suspended solids (mg/L) at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). Limit of reporting (LOR) was 3 mg/L, values below the LOR were replaced with half the LOR.**

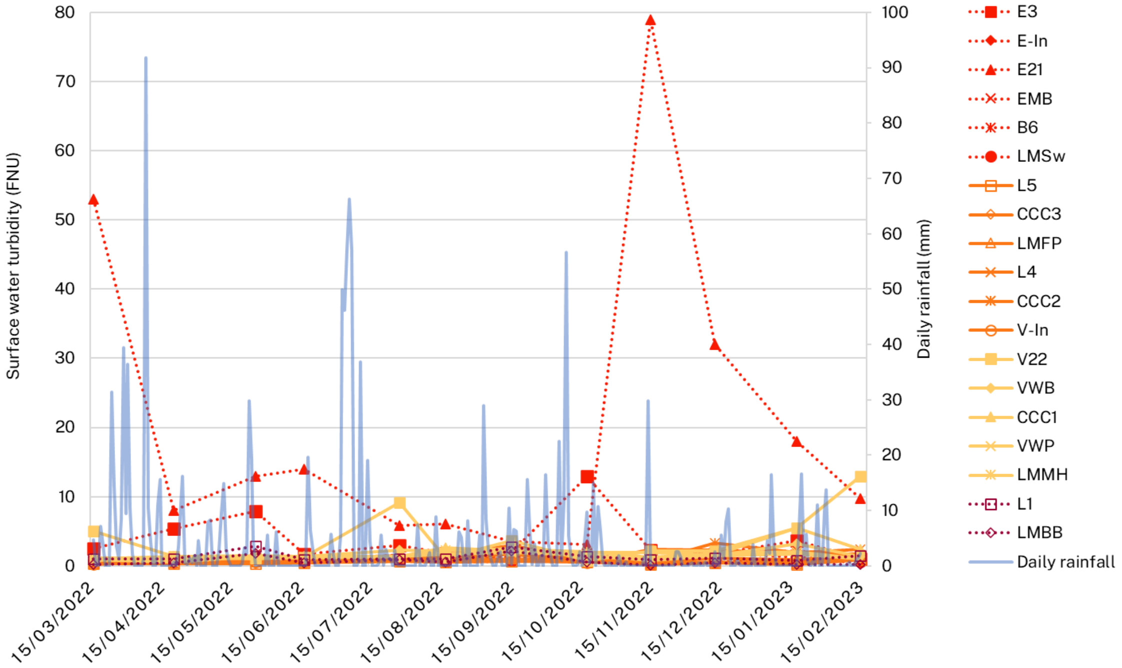


**Figure A6. Plots of surface water turbidity (FNU) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12)**

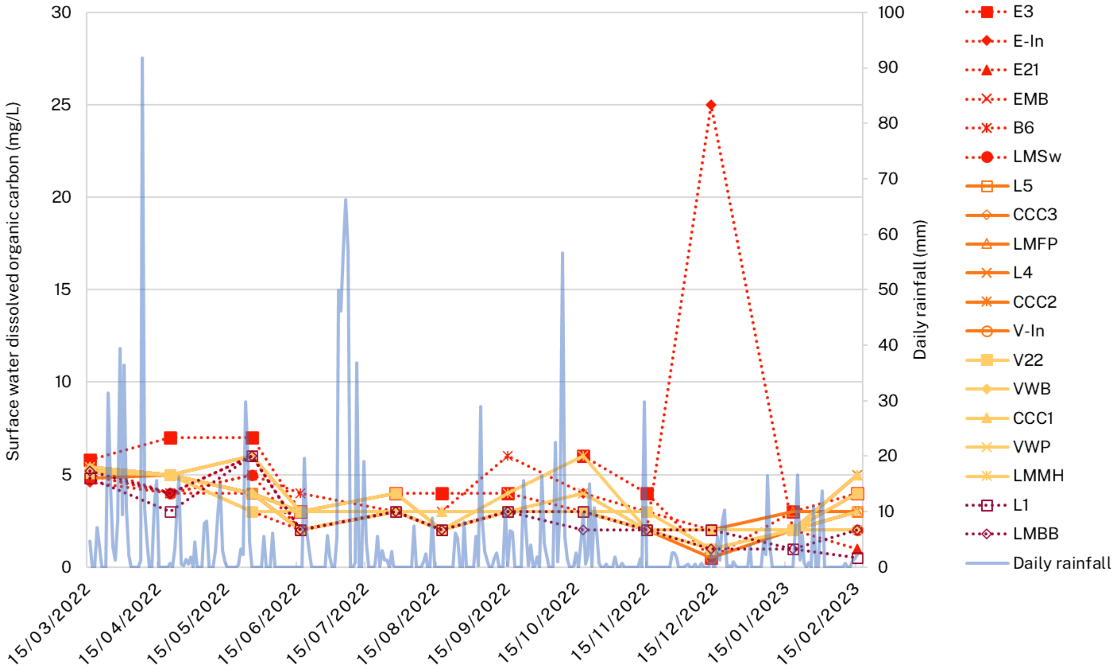


**Figure A7. Plots of surface water dissolved organic carbon (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). Limit of reporting (LOR) was 1 mg/L, values below the LOR were replaced with half the LOR.**

# Appendix D – Temporal analysis of nutrient data

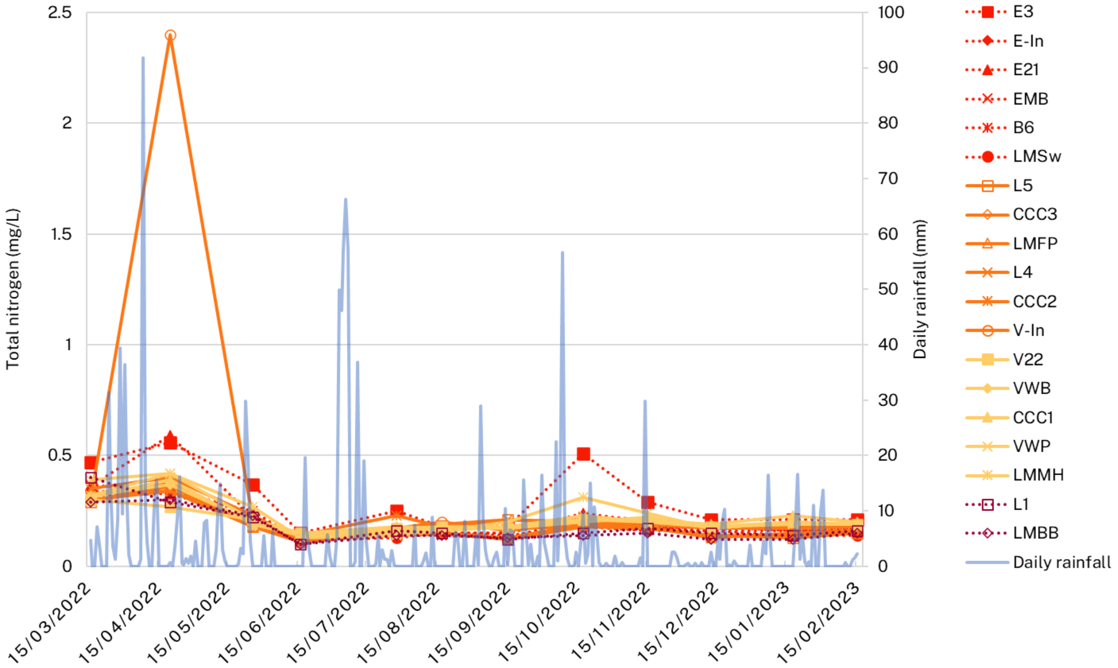


**Figure A8. Plots of total nitrogen (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). All values were greater than the limit of reporting of 0.02 mg/L.**

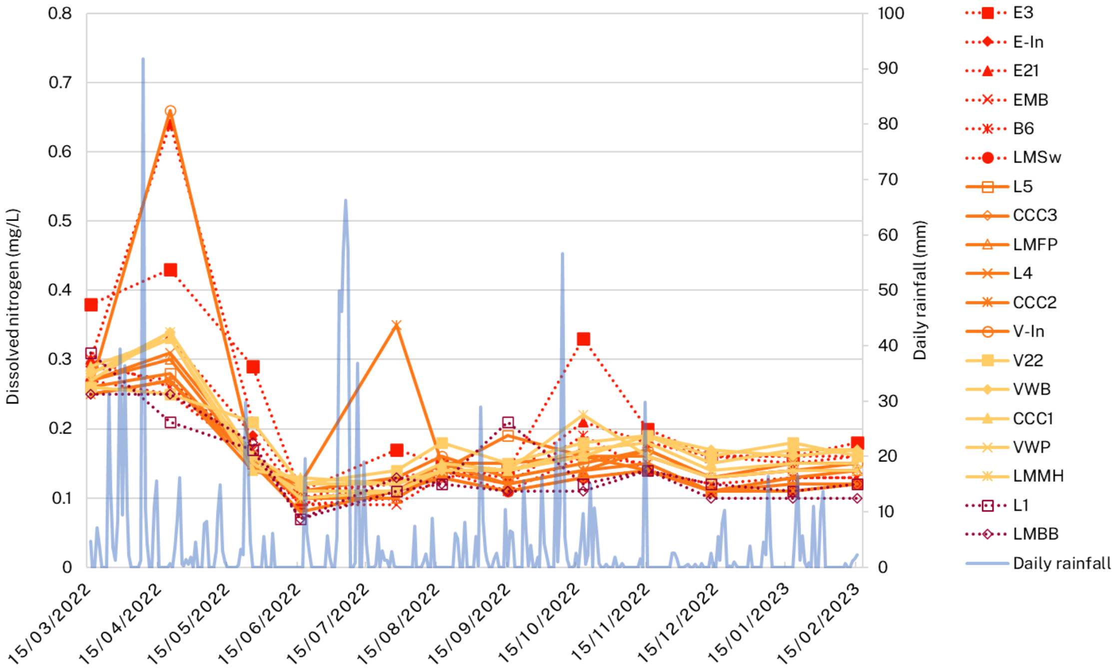


**Figure A9. Plots of dissolved nitrogen (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). All values were greater than the limit of reporting of 0.02 mg/L.**

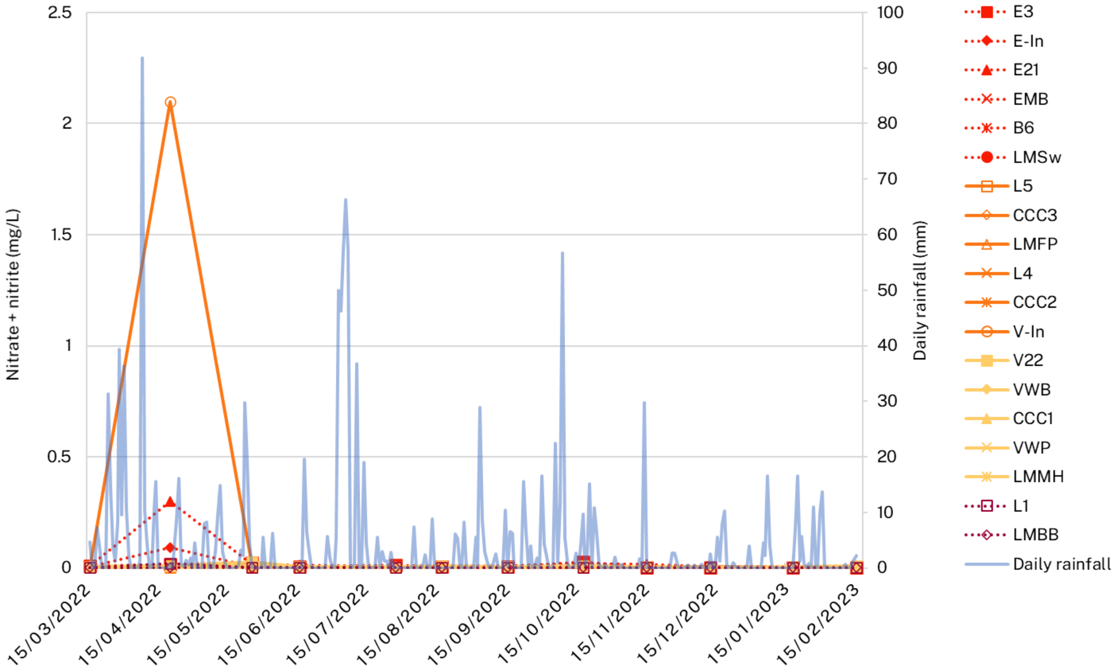


Figure A10. Plots of oxidised nitrogen (nitrate + nitrite) (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The limit of reporting (LOR) was 0.002 mg/L; values below the LOR were replaced with half the LOR.

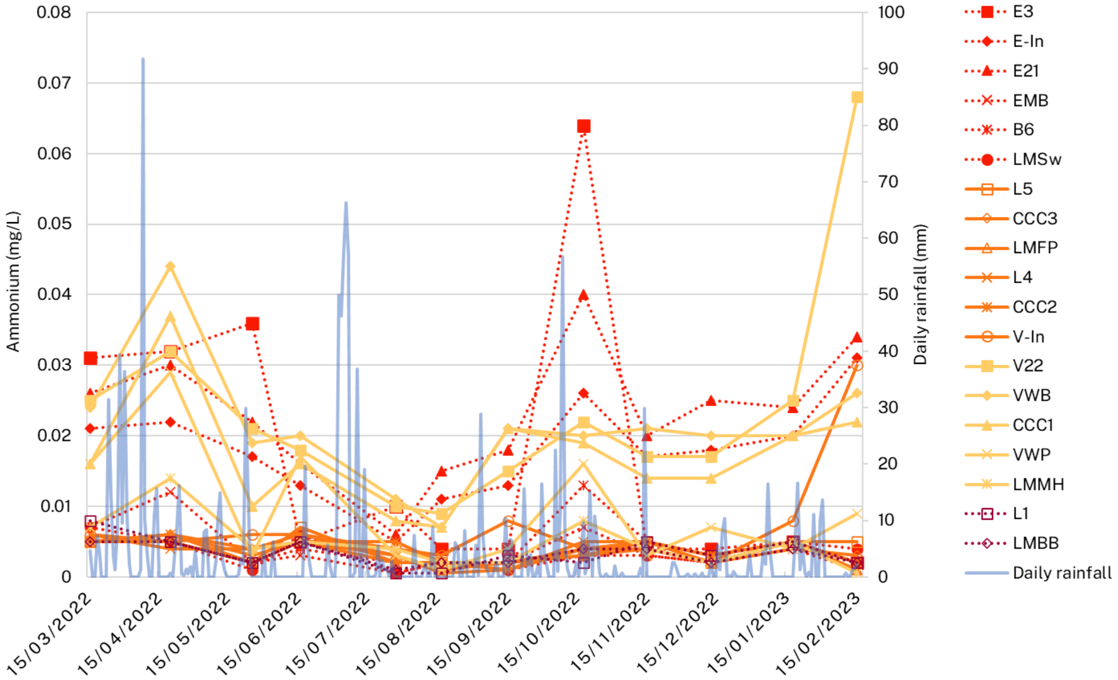


Figure A11. Plots of ammonia-N (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The limit of reporting (LOR) was 0.001 mg/L; values below the LOR were replaced with half the LOR.

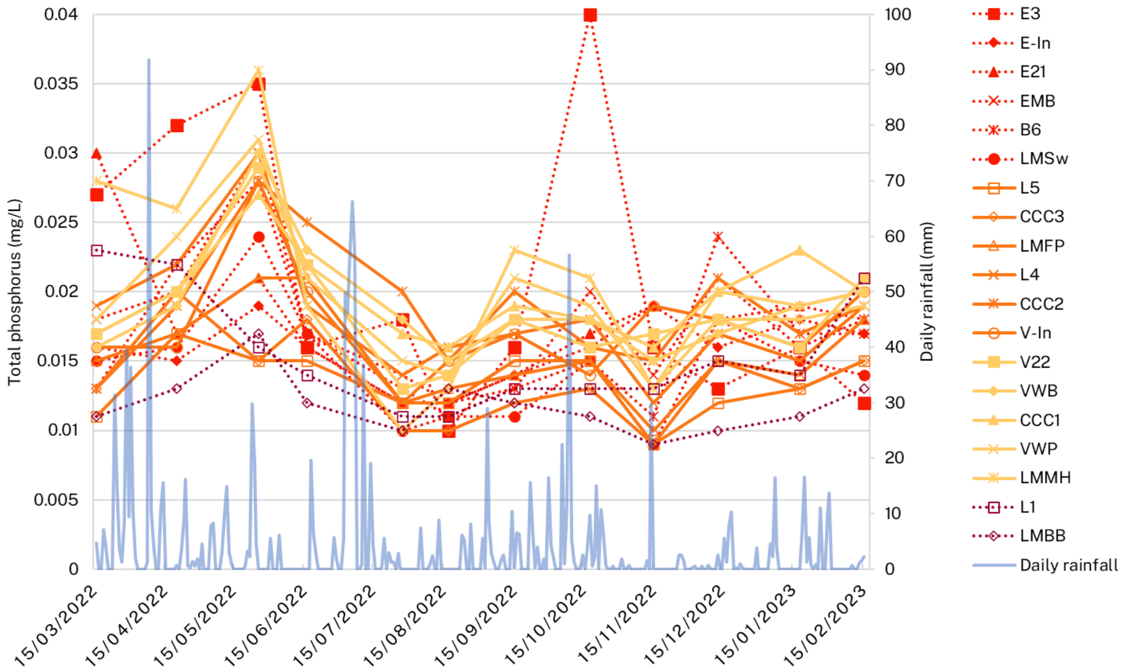


Figure A12. Plots of total phosphorus (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). All values were greater than the limit of reporting of 0.004 mg/L.

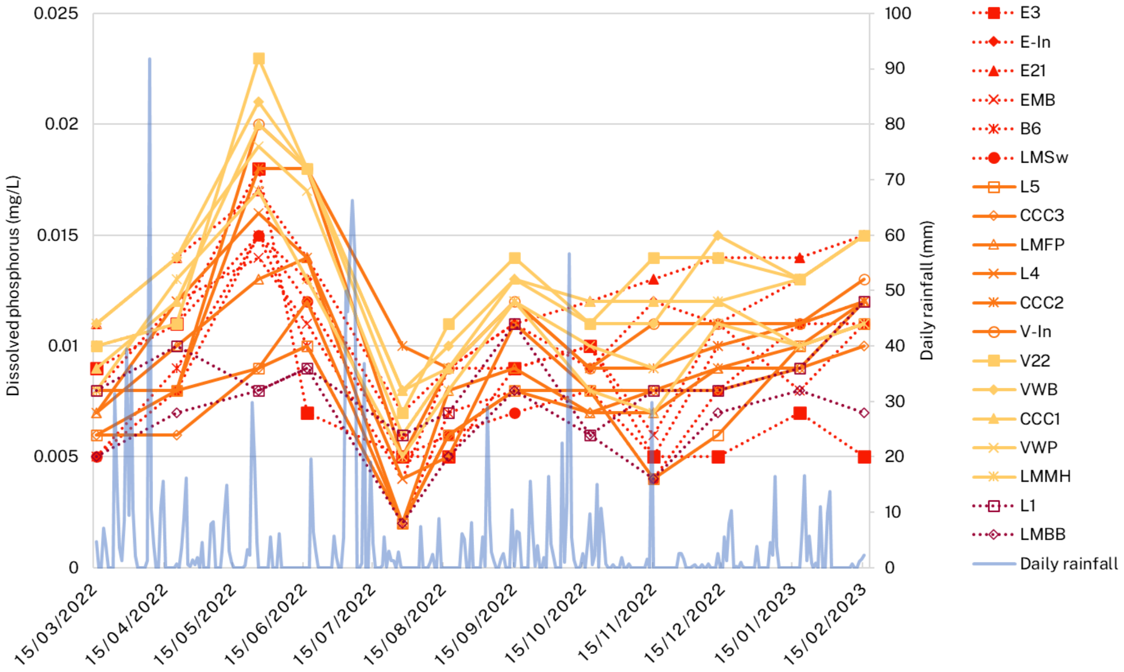


Figure A13. Plots of dissolved phosphorus (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The limit of reporting (LOR) was 0.004 mg/L; values below the LOR were replaced with half the LOR.

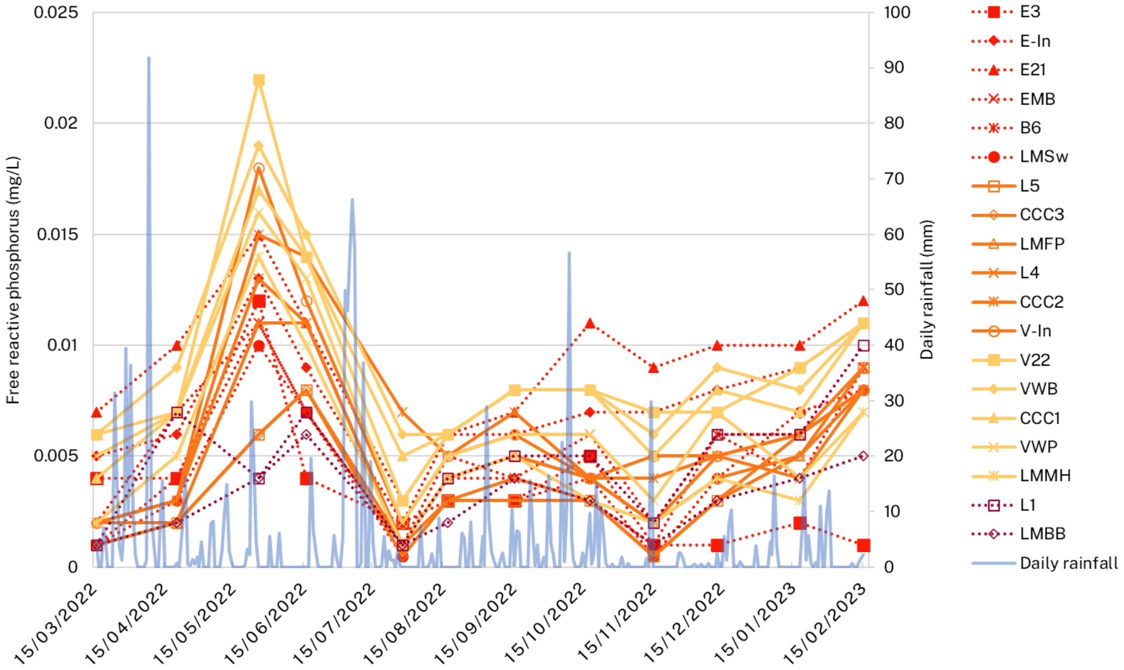


**Figure A14. Plots of free reactive phosphorus (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The limit of reporting (LOR) was 0.001 mg/L; values below the LOR were replaced with half the LOR.**

# Appendix E – Additional metal box plots

**Key for figures below**: Icon colour represents general location/grouping information about the sampling sites: Dora Creek (yellow); sites within the southern section of the lake: southwest zone (green), southeast zone (blue), and south zone (lavender); sites within the northern section of the lake (pink).

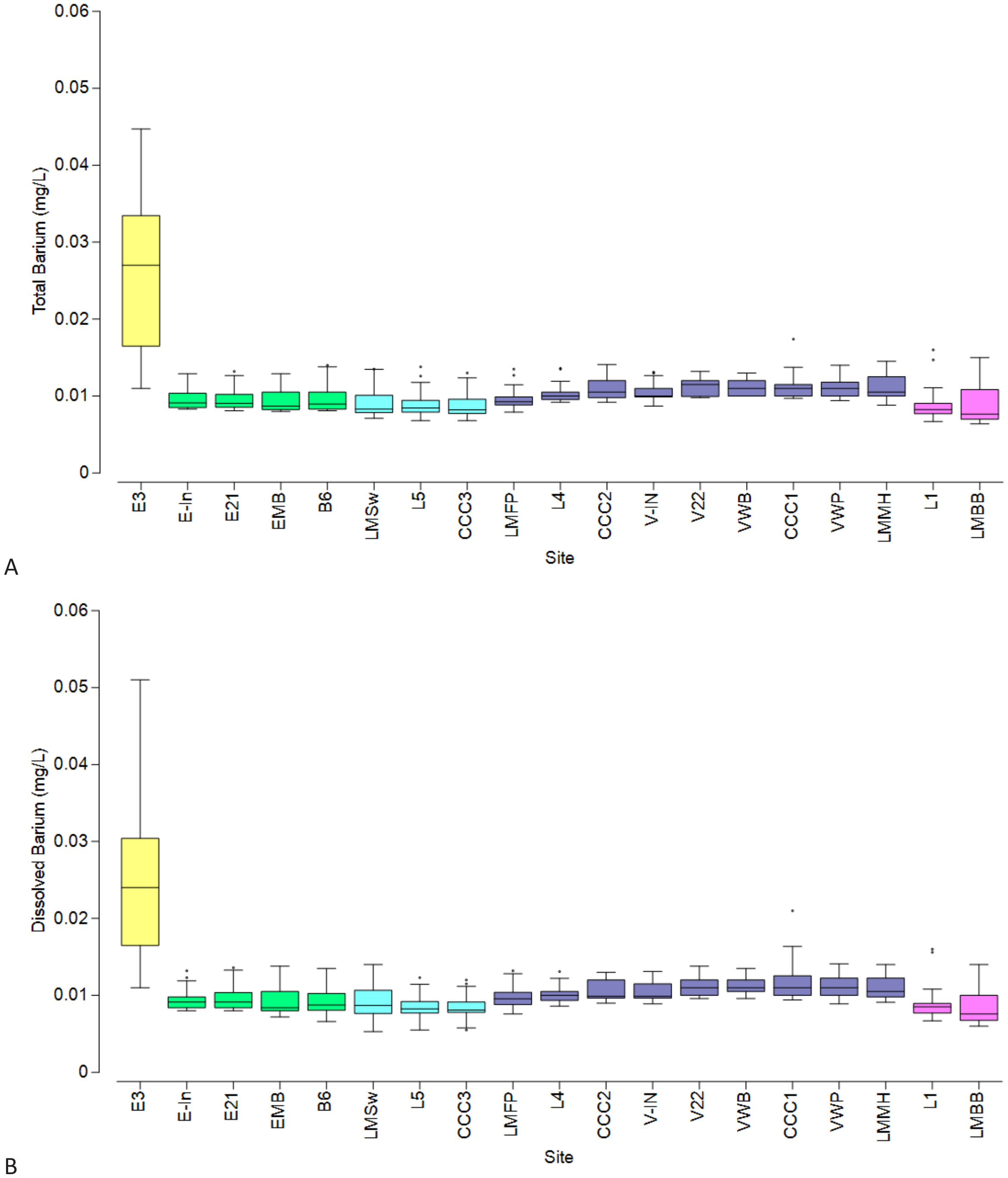


**Figure A15. Box plots of barium concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12): A) total barium; B) dissolved (<0.45 µm filtered) barium. All values were greater than the limit of reporting for barium.**

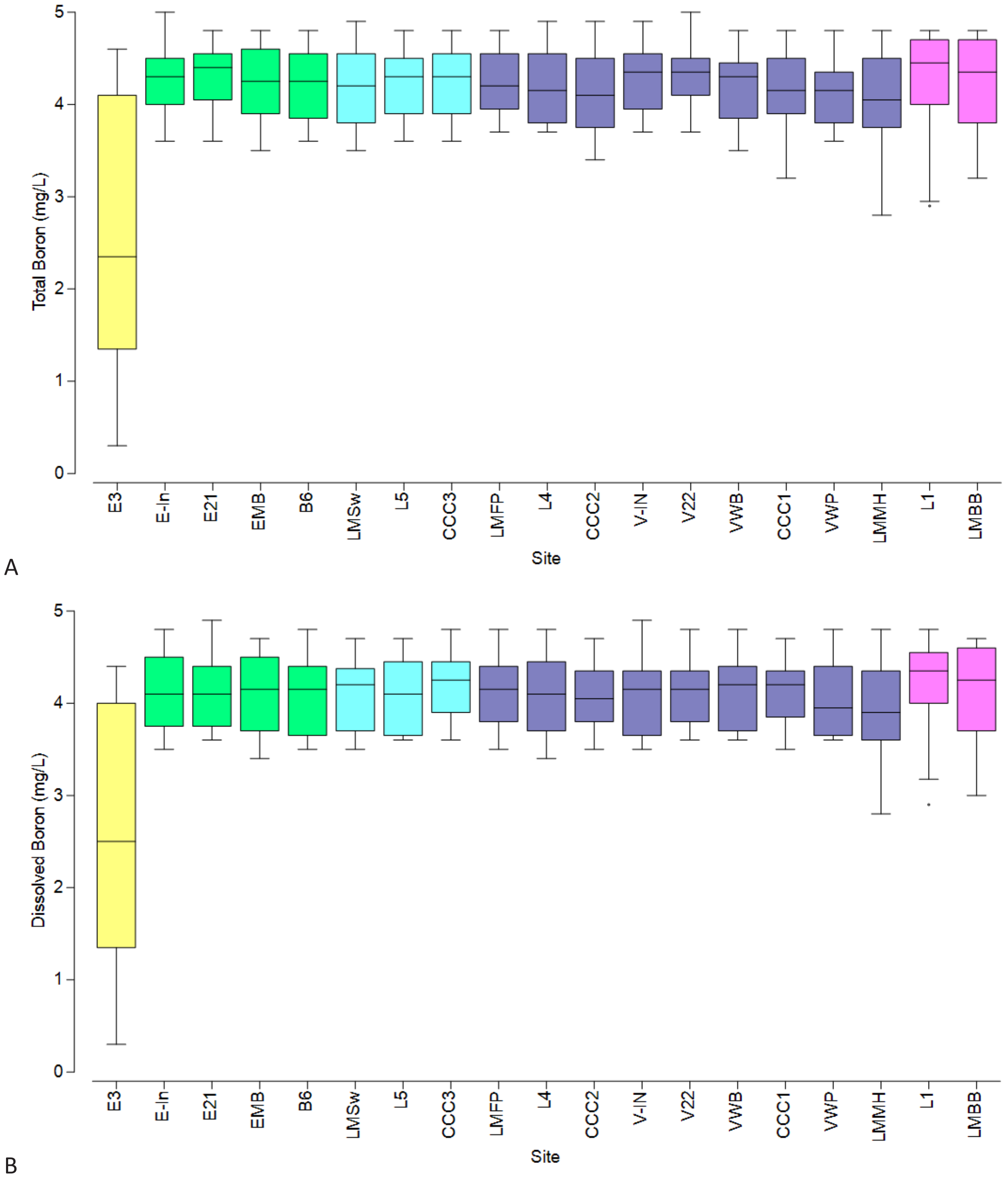


**Figure A16. Box plots of boron concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12): A) total boron; B) dissolved (<0.45 µm filtered) boron. All values were greater than the limit of reporting for boron.**

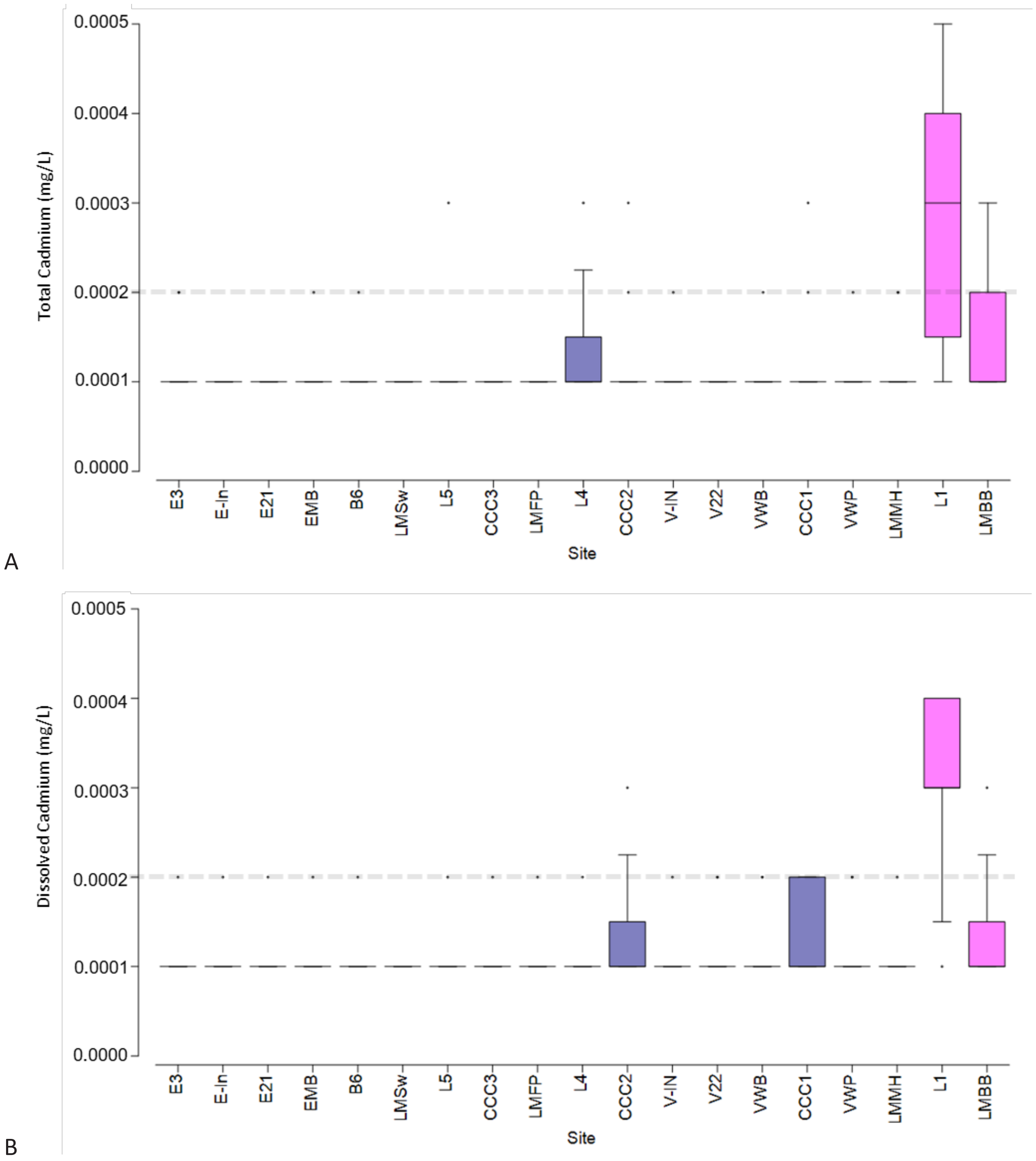
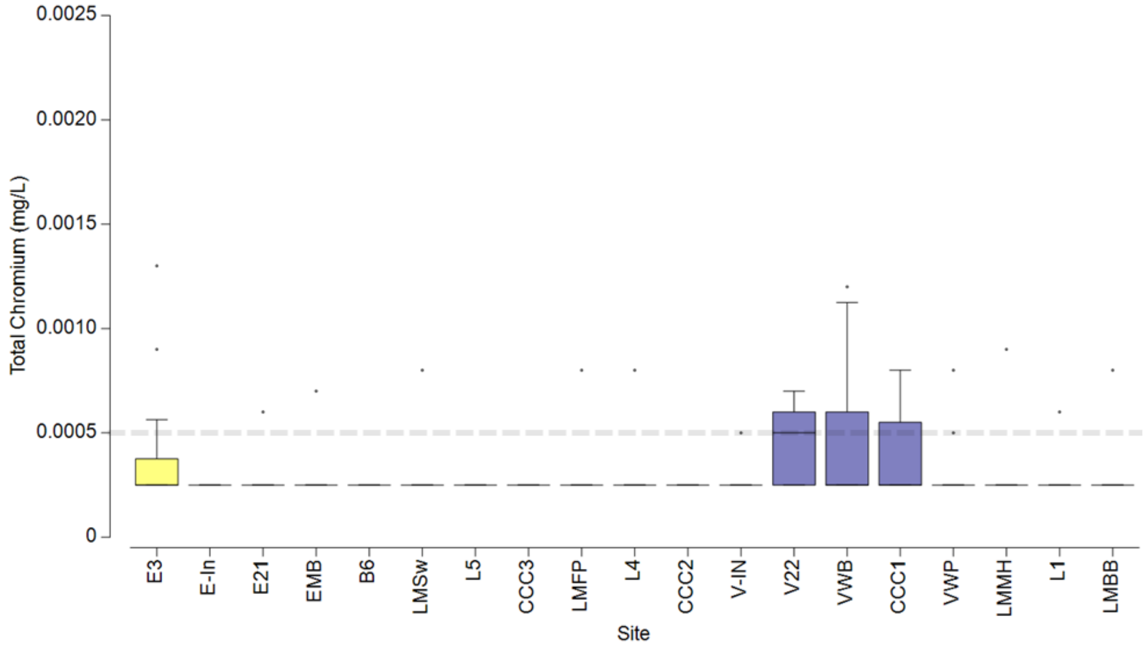
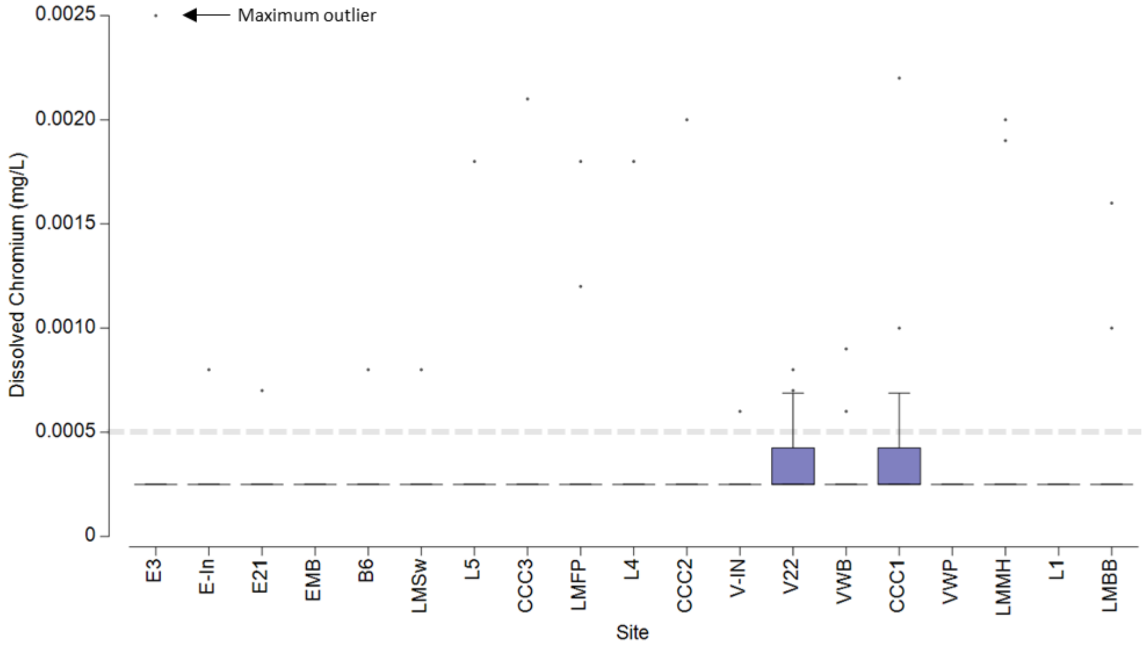


**Figure A17. Box plots of cadmium concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12): A) total cadmium; B) dissolved (<0.45 µm filtered) cadmium. All values were below the screening criteria concentration, 0.0007 mg Cd/L (ANZG, 2018). The horizontal grey dashed line indicates the limit of reporting (LOR, 0.0002 mg Cd/L); values below the LOR were replaced with half the LOR.**

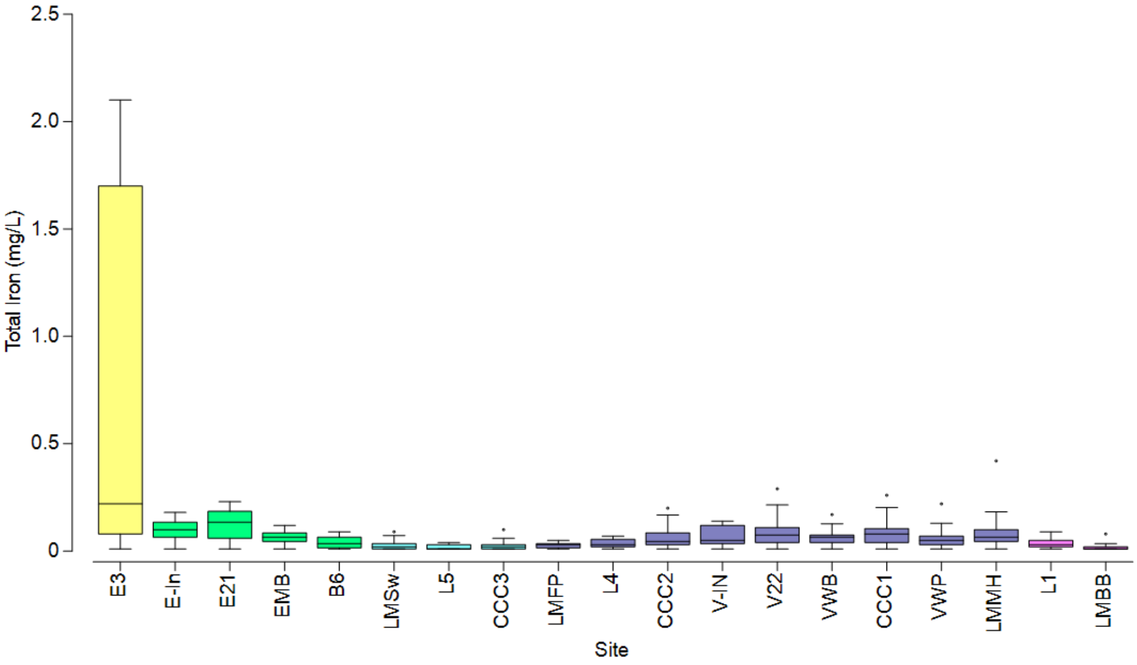


A

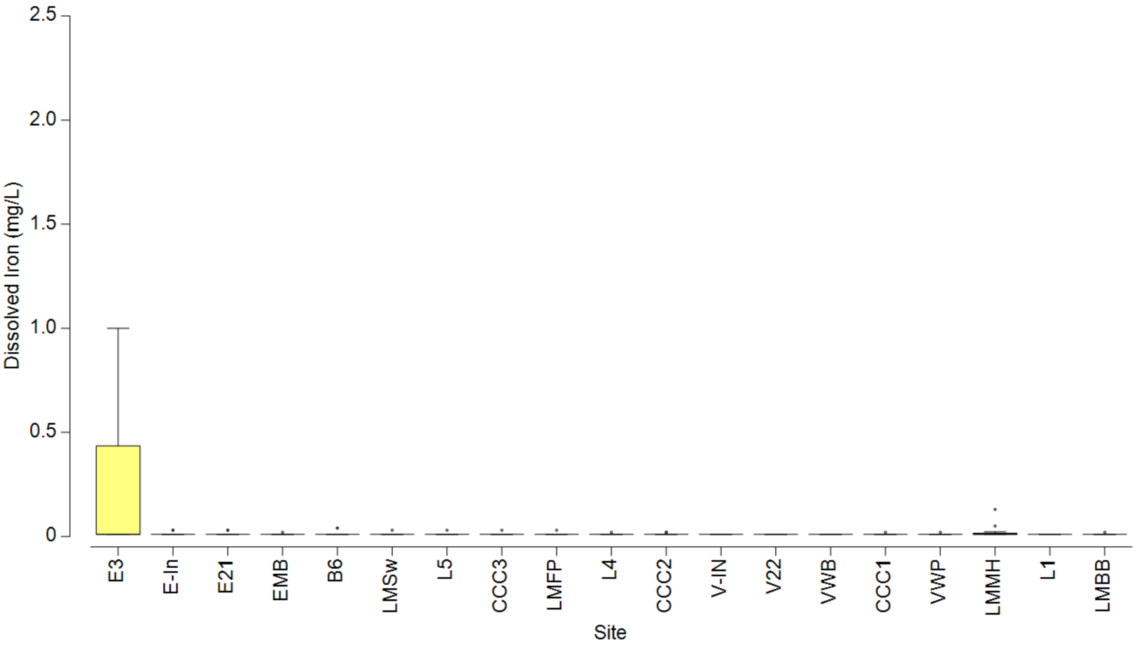


B

**Figure A18. Box plots of chromium concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12): A) total chromium; B) dissolved (<0.45 µm filtered) chromium. All values were below the screening criteria concentration, 0.0044 mg Cr/L (ANZG, 2018). The horizontal grey dashed line indicates the limit of reporting (LOR, 0.0005 mg Cr/L); values below the LOR were replaced with half the LOR.**



A



B

**Figure A19. Box plots of iron concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12): A) total iron; B) dissolved (<0.45 µm filtered) iron. The limit of reporting (LOR) was 0.02 mg Co/L; values below the LOR were replaced with half the LOR.**

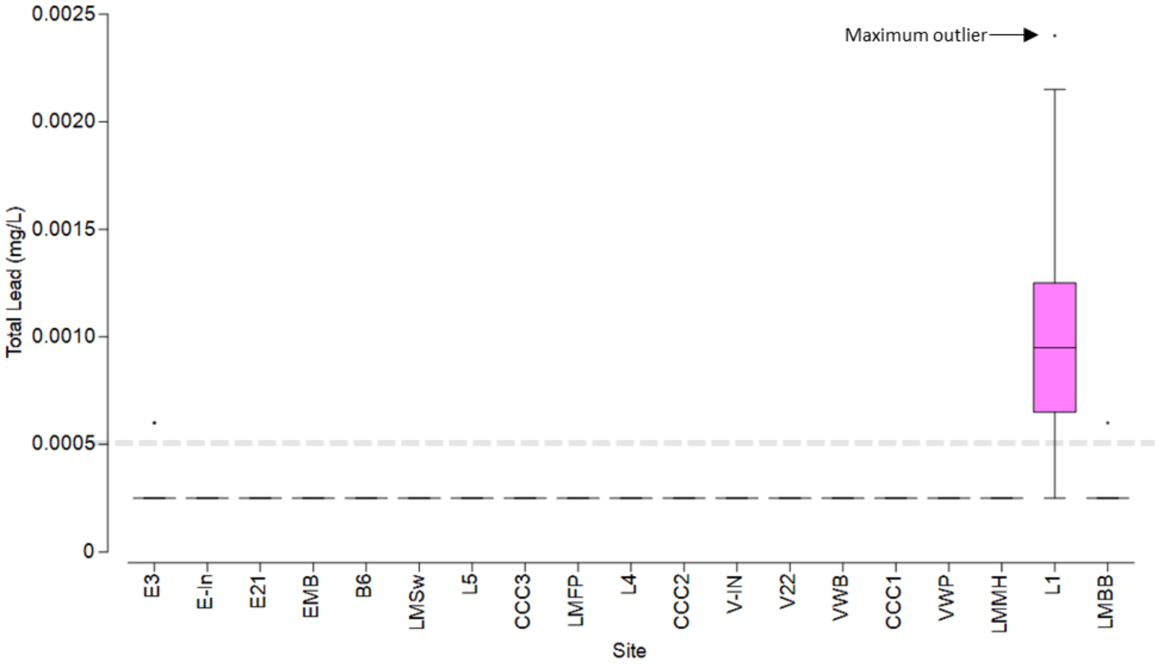


**Figure A20. Box plots of total lead concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). All values were below the screening criteria concentration, 0.0044 mg Pb/L (ANZG, 2018). The horizontal grey dashed line indicates the limit of reporting (LOR, 0.0005 mg Pb/L); values less than the LOR were substituted as half the LOR. Dissolved (<0.45 µm filtered) lead was below the LOR for all samples.**

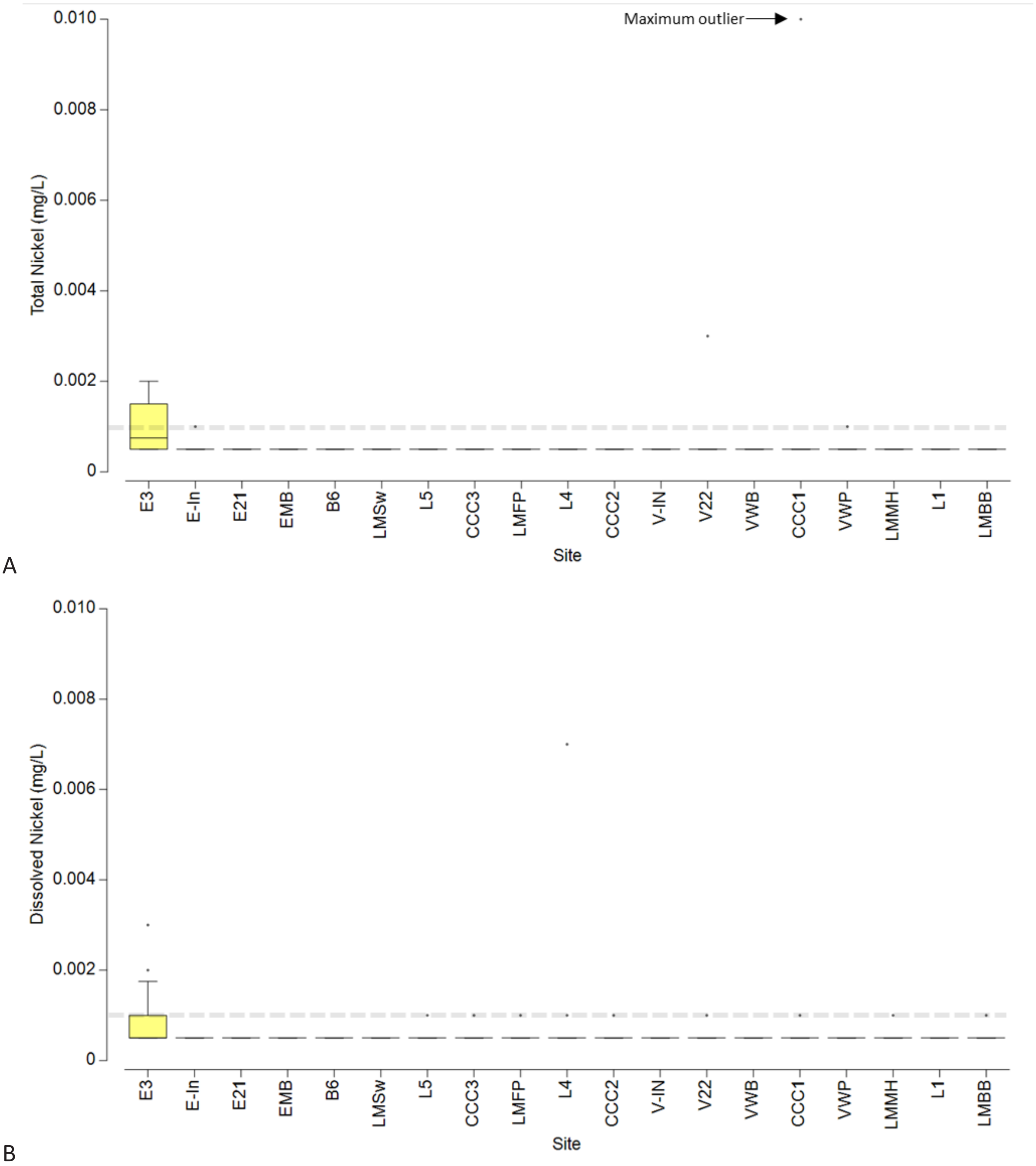


**Figure A21. Box plots of nickel concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12): A) total nickel; B) dissolved (<0.45 µm filtered) nickel. All values were below the screening criteria concentration, 0.070 mg Ni/L (ANZG, 2018). The horizontal grey dashed line indicates the limit of reporting (LOR, 0.001 mg Ni/L); values below the LOR were replaced with half the LOR.**

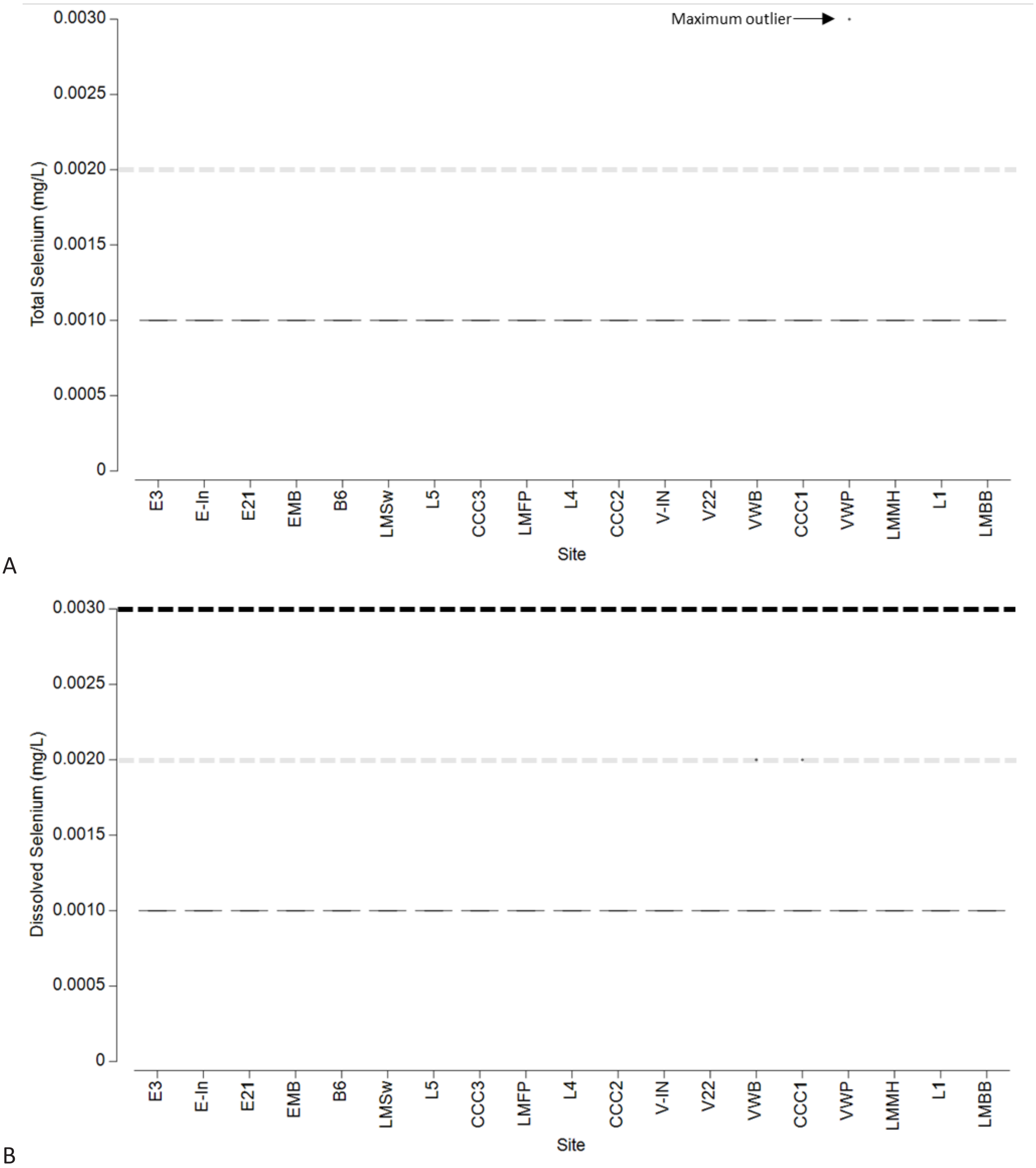
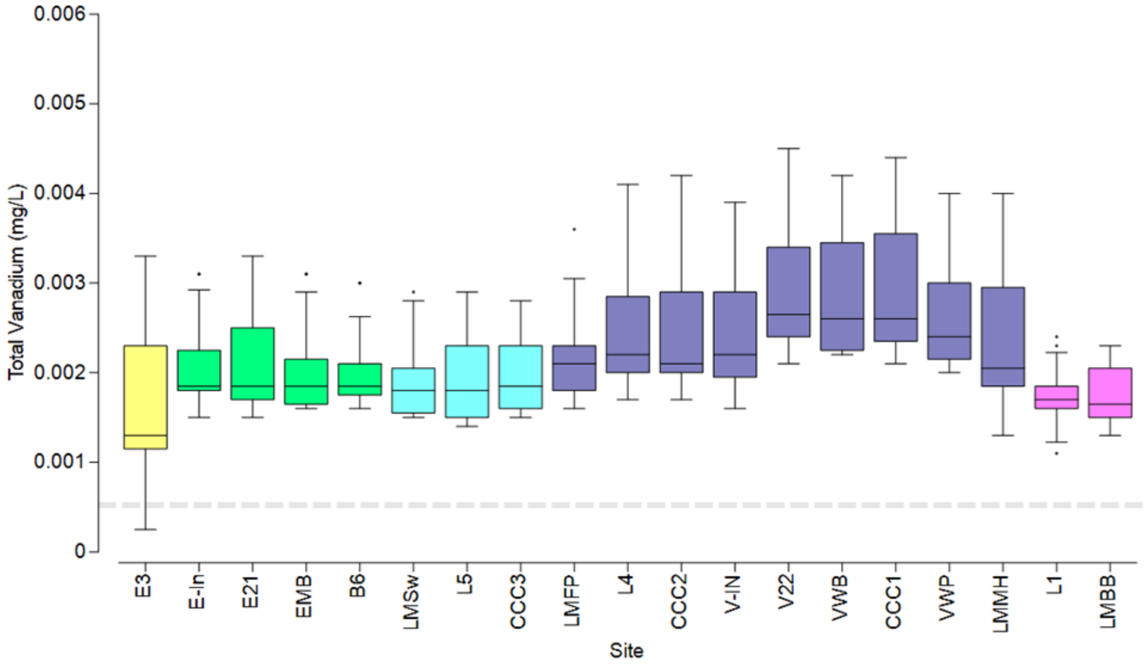
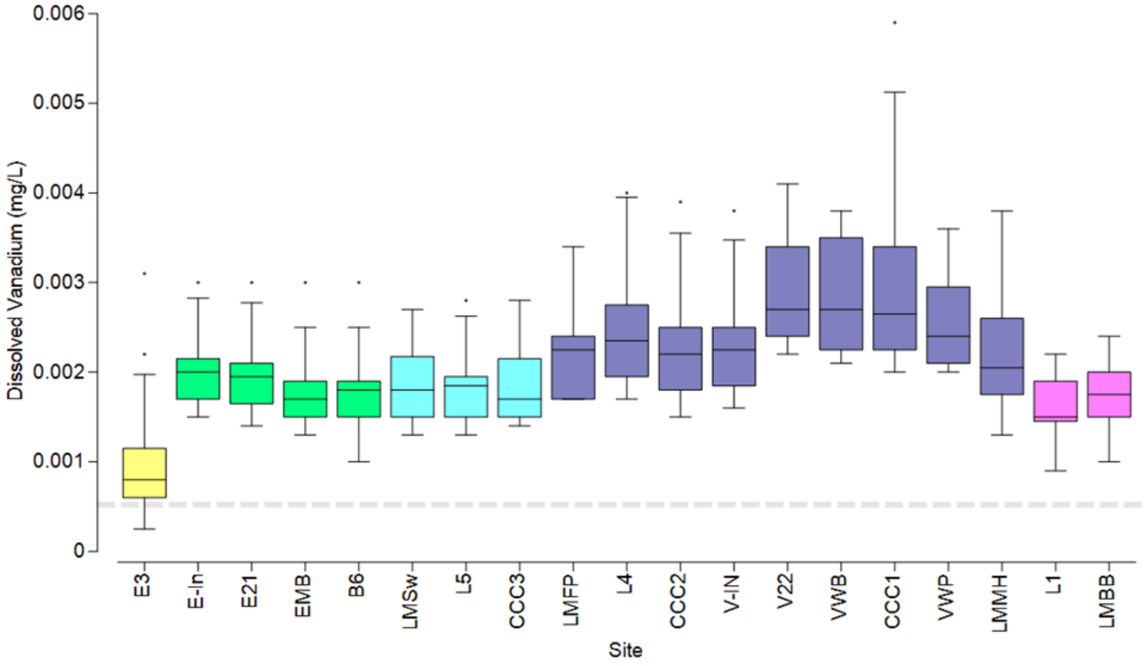


**Figure A22. Box plots of selenium concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12): A) total selenium; B) dissolved (<0.45 µm filtered) selenium. The horizontal black dashed line (in Figure B) indicates the screening criteria concentration, 0.003 mg/L (ANZG, 2018). The horizontal grey dashed line indicates the limit of reporting (LOR, 0.002 mg Se/L); values below the LOR were replaced with half the LOR.**



A



B

**Figure A23. Box plots of vanadium concentrations (mg/L) in surface waters at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12): A) total vanadium; B) dissolved (<0.45 µm filtered) vanadium. All values were below the screening criteria concentration, 0.100 mg V/L (ANZG, 2018). The horizontal grey dashed line indicates the limit of reporting (LOR, 0.0005 mg V/L); values below the LOR were replaced with half the LOR.**

# Appendix F – Temporal analysis of metal data

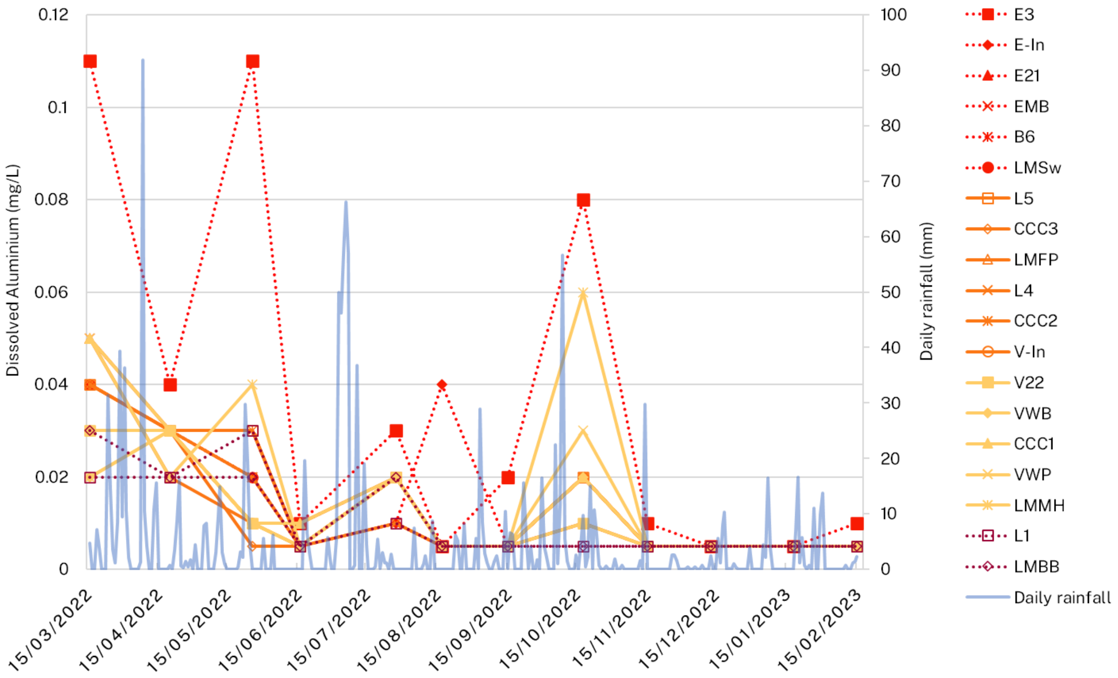


**Figure A24. Plots of dissolved aluminium (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The limit of reporting (LOR) was 0.01 mg/L; values below the LOR were replaced with half the LOR.**

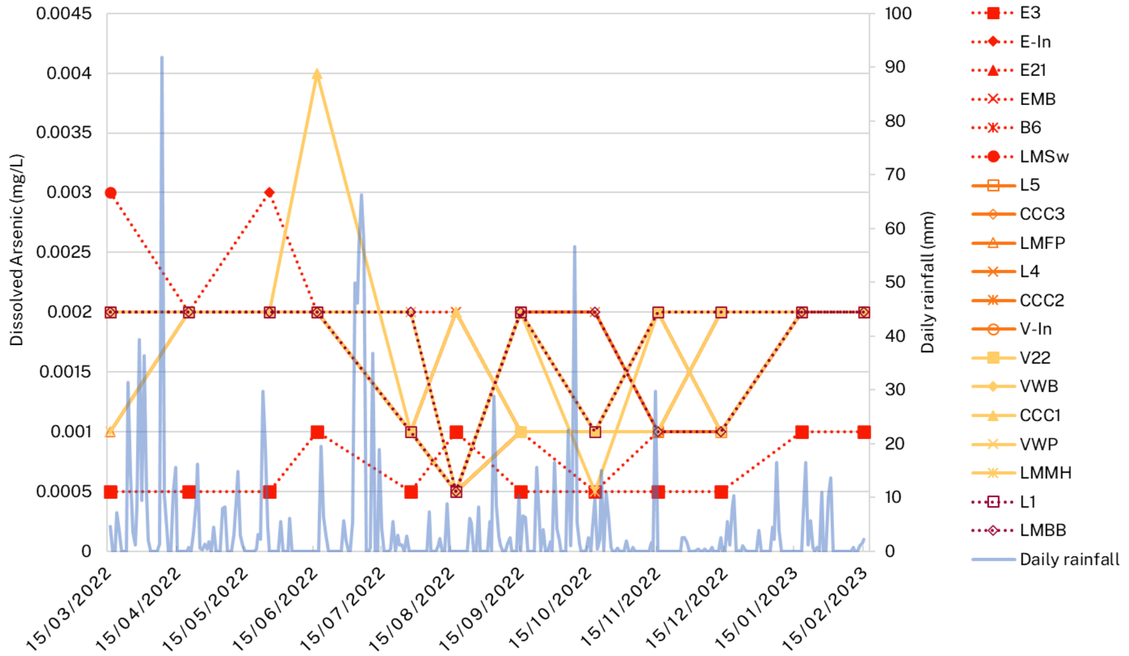


**Figure A25. Plots of dissolved arsenic (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The limit of reporting (LOR) was 0.001 mg/L; values below the LOR were replaced with half the LOR.**

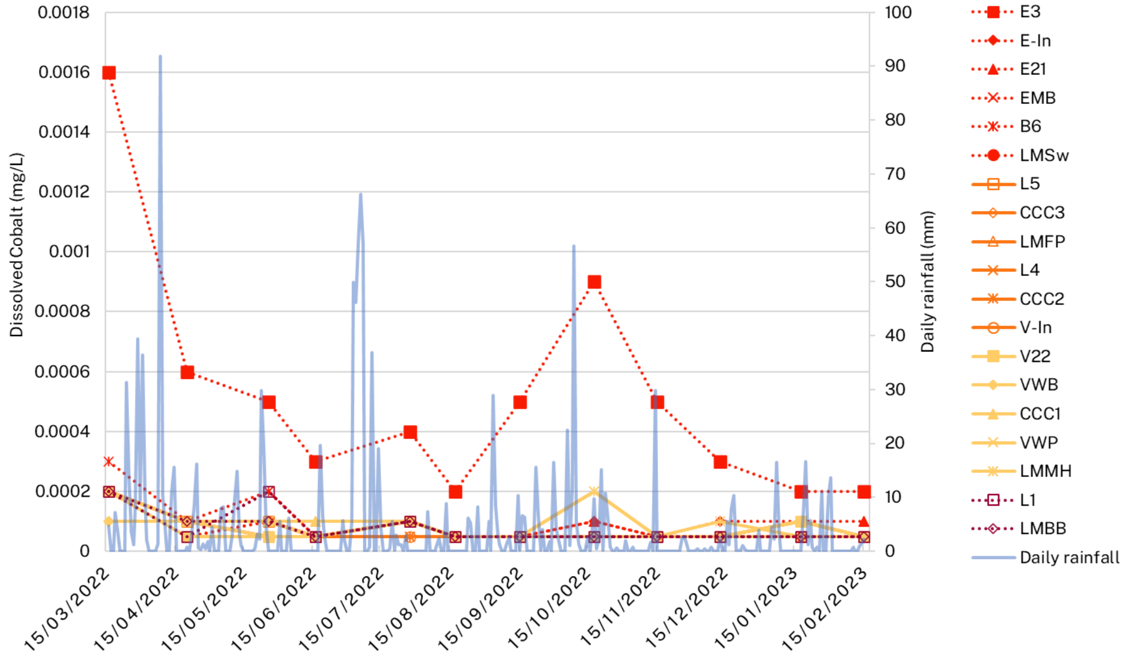


**Figure A26. Plots of dissolved cobalt (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The limit of reporting (LOR) was 0.0001 mg/L; values below the LOR were replaced with half the LOR.**

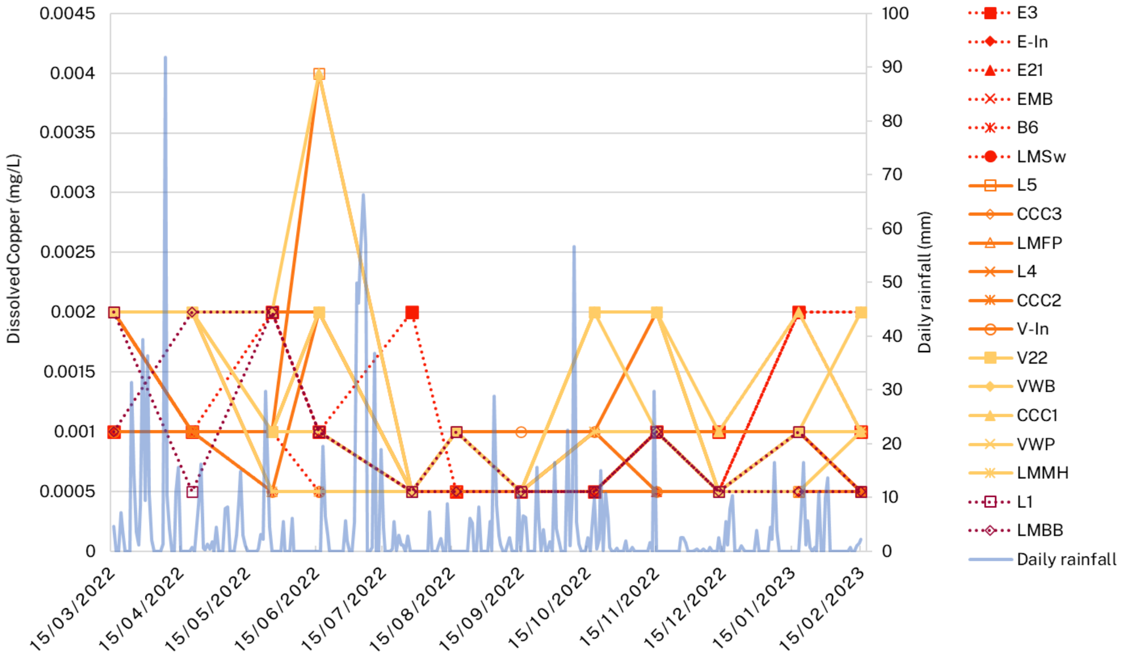


Figure A27. Plots of dissolved copper (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The limit of reporting (LOR) was 0.001 mg/L; values below the LOR were replaced with half the LOR.

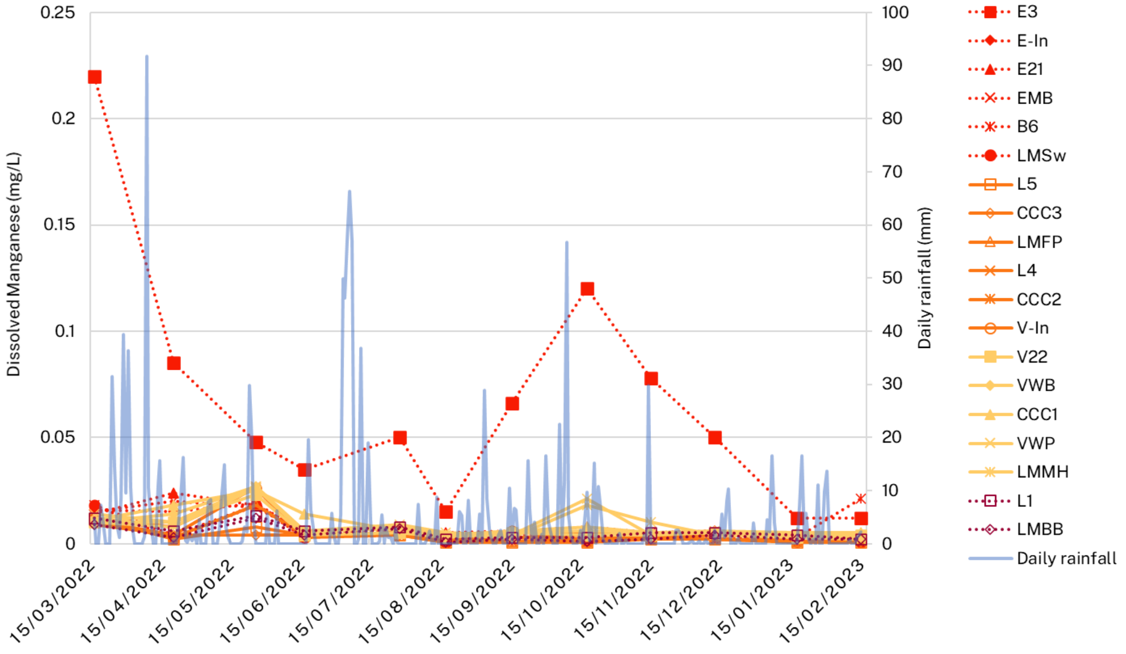


Figure A28. Plots of dissolved manganese (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The limit of reporting (LOR) was 0.001 mg/L; values below the LOR were replaced with half the LOR.

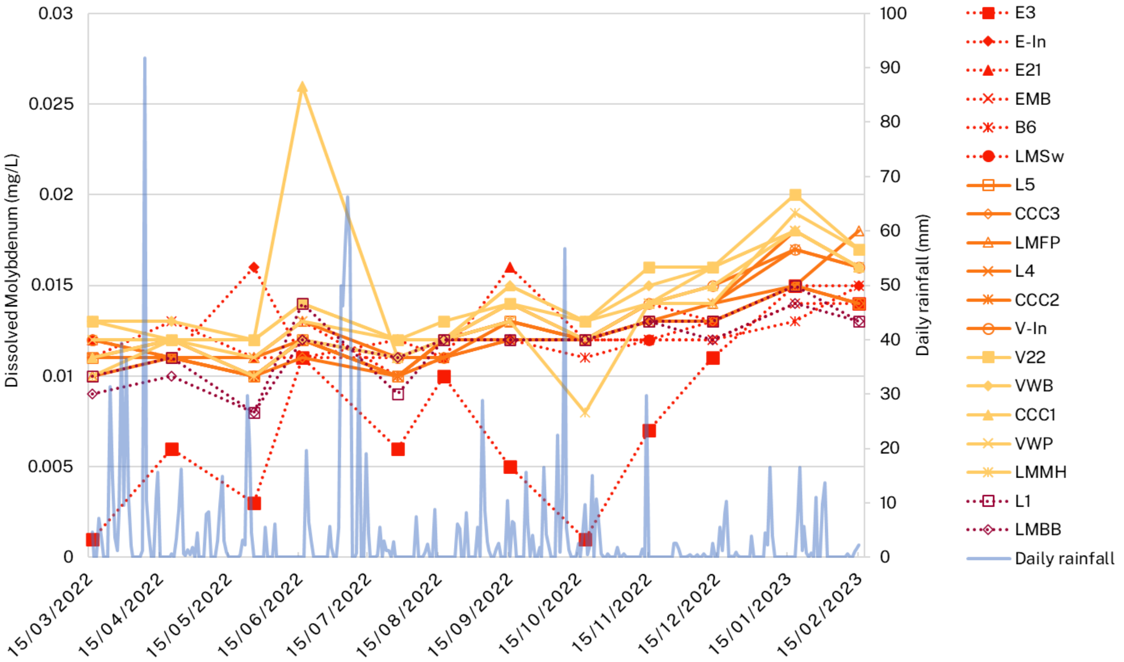


**Figure A29. Plots of dissolved molybdenum (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The limit of reporting (LOR) was 0.001 mg/L; values below the LOR were replaced with half the LOR.**

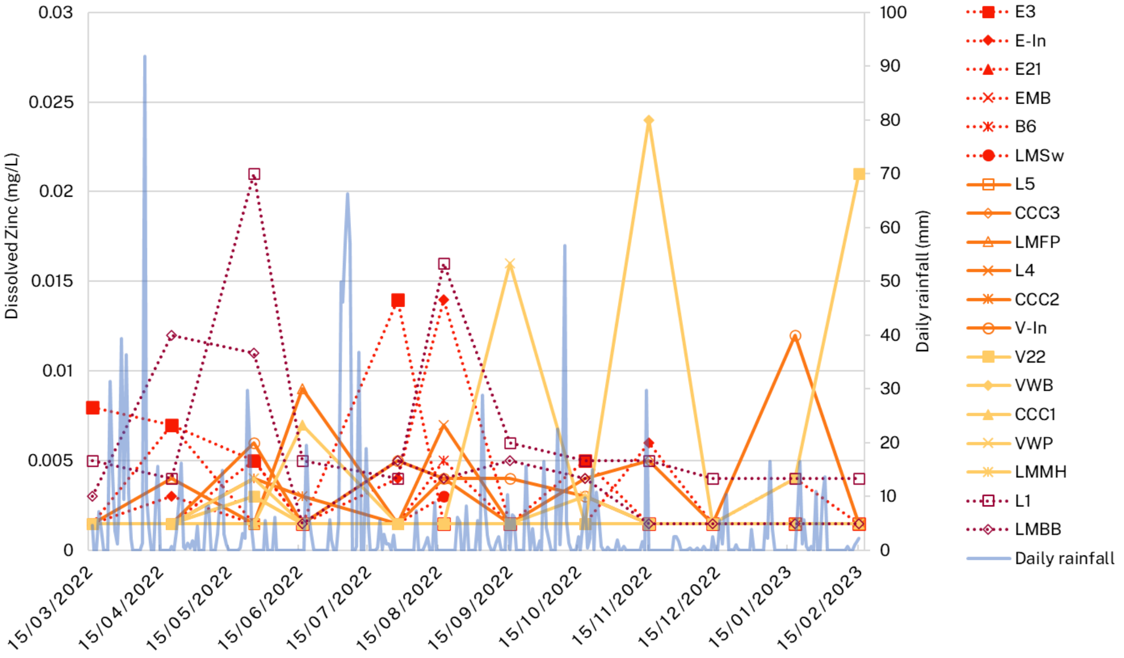


**Figure A30. Plots of dissolved zinc (mg/L) and daily rainfall at 19 sites within Lake Macquarie from March 2022 to February 2023 (n=12). The limit of reporting (LOR) was 0.003 mg/L; values below the LOR were replaced with half the LOR.**

# Appendix G – Arsenic speciation

The toxicity of arsenic depends on its speciation (oxidation state). In general, inorganic forms of arsenic are considered more toxic than organic forms. For all lake sites (Section 3), the 95th percentile concentrations of dissolved arsenic were below the indicative interim working level for As(III) of 0.0023 mg/L (ANZG, 2018) and the proposed third-party guideline value of 0.012 mg/L (Golding et al., 2022) and therefore arsenic is not considered to be a contaminant of potential concern within surface waters of southern Lake Macquarie.

Throughout the monitoring program, however, a single (marginal) exceedance of the screening criterion occurred at three sites (E-In, LMSw, CCC1), so during the final sampling round arsenic speciation was carried out on a subset of the samples to investigate the form of arsenic present as an additional line of evidence. In the samples tested, no arsenic was present above the LOR at lake sites E-In and E21. Arsenic was found in the form of As(V) at lake Site V22 and Land Sites E22 and V24. The forms As(V) and arsenobetaine were found at lake Site V-In and the forms As(V) and dimethylarsenic at V25. As(III) was not detected at any of the sites tested and As(V) was below the guideline value (0.0045 mg/L) at all lake sites tested (E-In, E21, V-In, V22).

**Table 12. Arsenic speciation at selected sites near Values Point Power Station (NSW) sampled on the 1st of April 2022. All values are in mg/L. Values greater than the limit of reporting are indicated in bold, and values that exceed the screening criteria are indicated in bold purple font.**

| Arsenic species | E-In | E21 | E22 | V-In | V22 | V24 | V25 | Blank |
|---|---|---|---|---|---|---|---|---|
| Arsenobetaine | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 |
| Arsenious Acid, As(III)[a] | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Dimethylarsenic Acid | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.003 | <0.001 |
| Monomethylarsonic Acid | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Arsenic Acid, As(V)[b] | <0.001 | <0.001 | 0.006 | 0.003 | 0.003 | 0.003 | 0.009 | <0.001 |

[a] Indicative interim working level for As(III) is 0.0023 mg/L (ANZG, 2018).

[b] Indicative interim working level for As(V) is 0.0045 mg/L (ANZG, 2018).

# Appendix H – Vales Point wet-weather event sampling box plots

**Key for figures below**: Coal ash repository (Site V25) and Wyee Creek (upstream to downstream Sites: V25U, V25D, and VWC).

## Physicochemical indicators

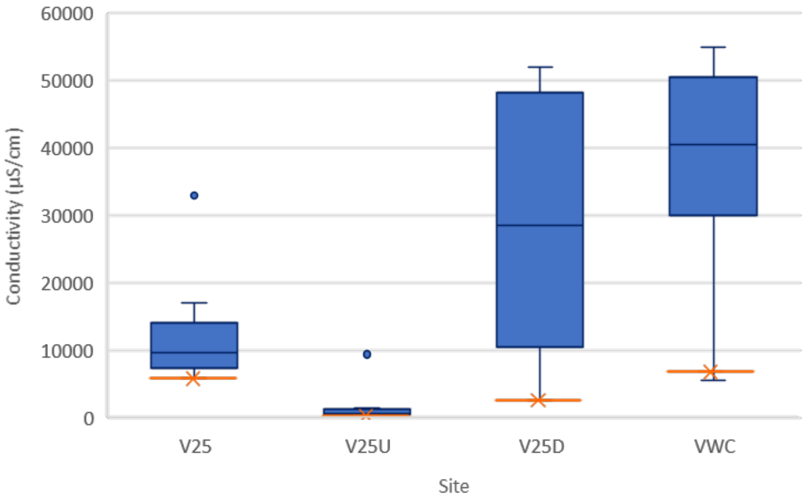


**Figure A31. Box plots (in blue) of conductivity (µS/cm) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

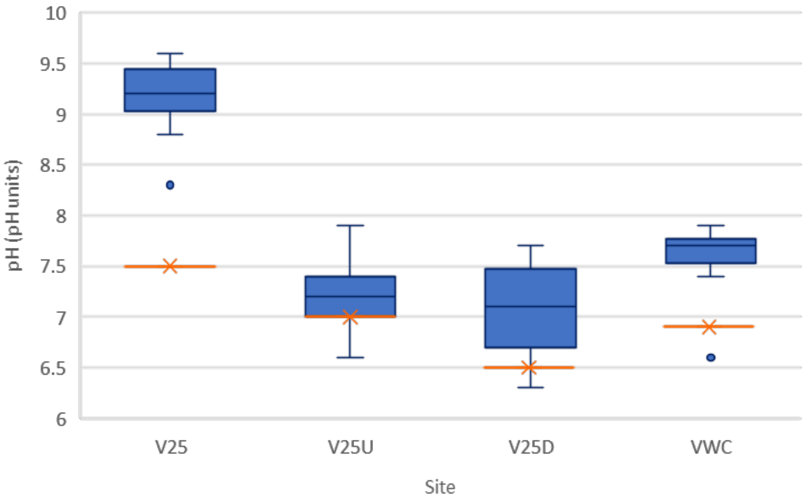


**Figure A32. Box plots (in blue) of pH (pH units) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

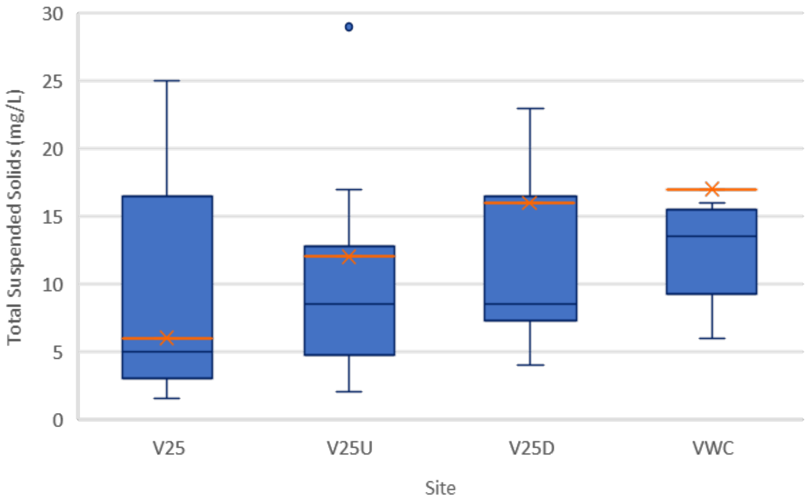


**Figure A33. Box plots (in blue) of total suspended solids (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

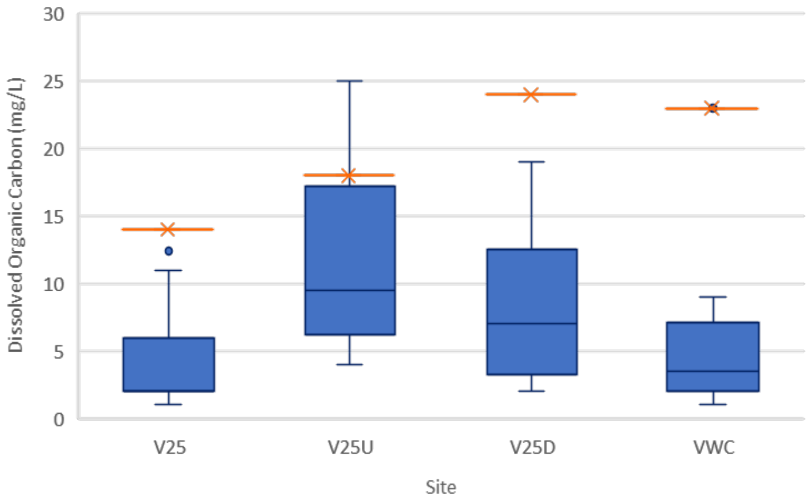
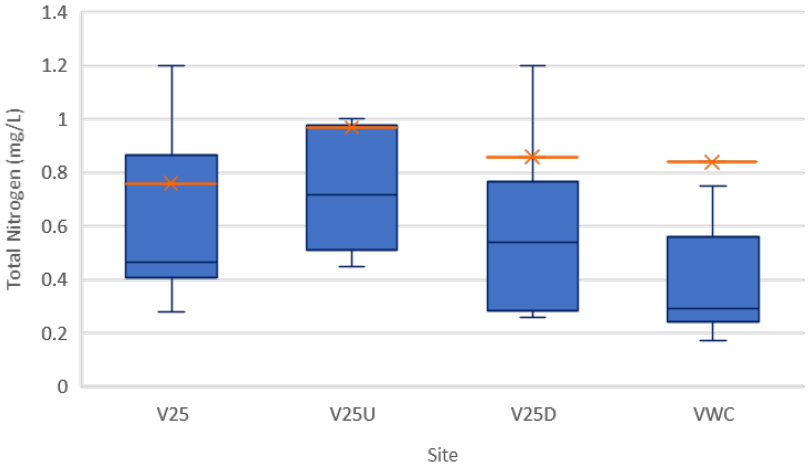
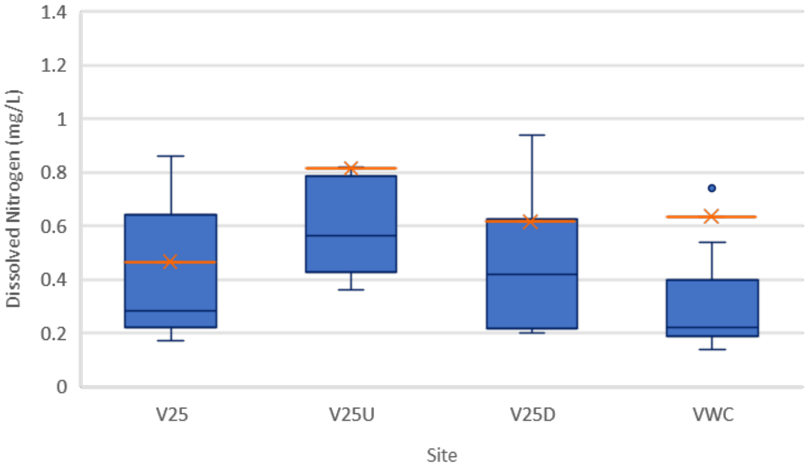


**Figure A34. Box plots (in blue) of dissolved organic carbon (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

## Nutrients



A



B

**Figure A35. Box plots (in blue) of the total nitrogen (A) and dissolved nitrogen (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

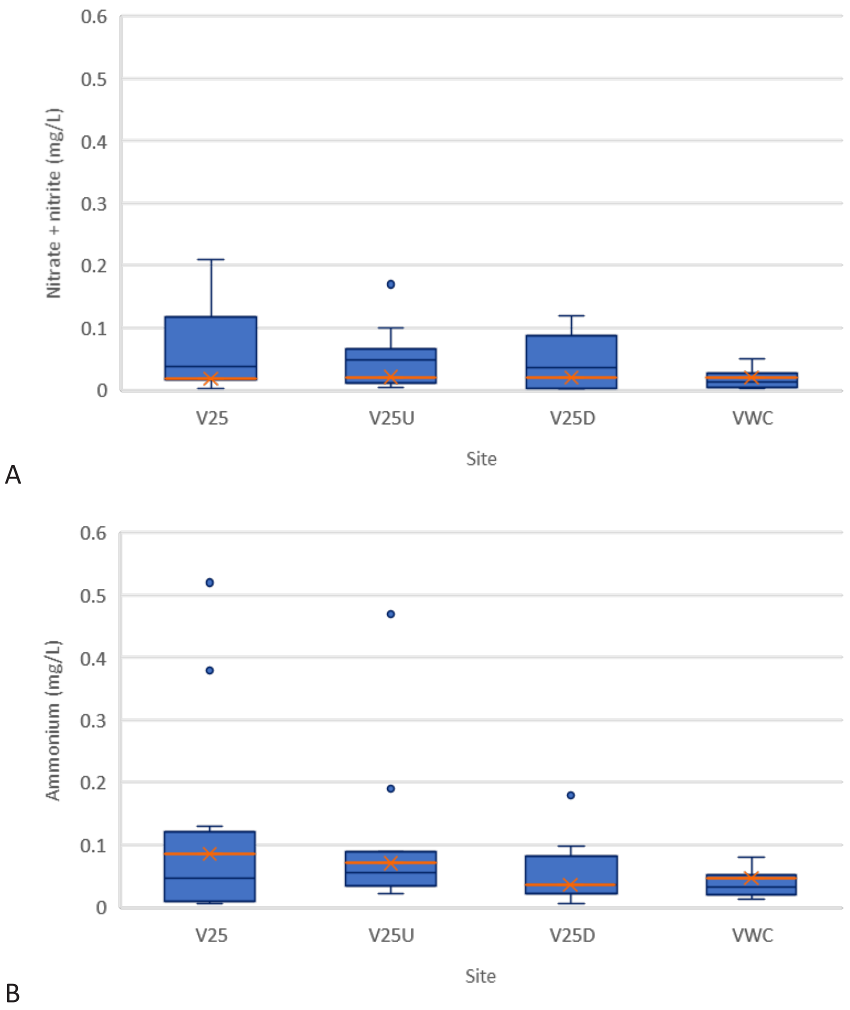
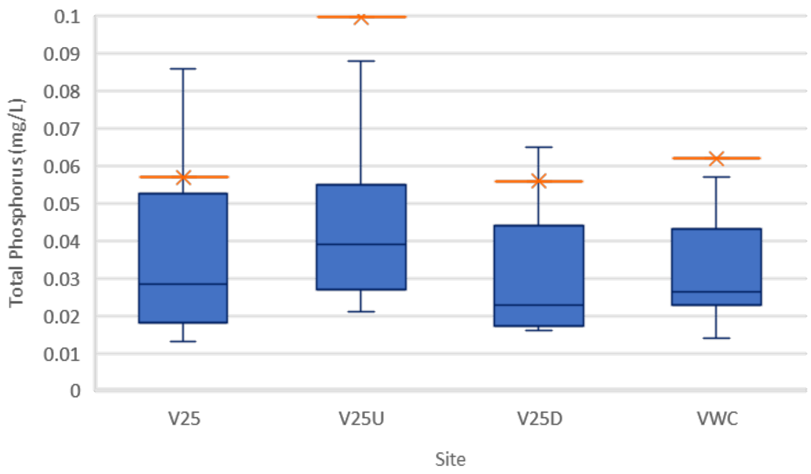
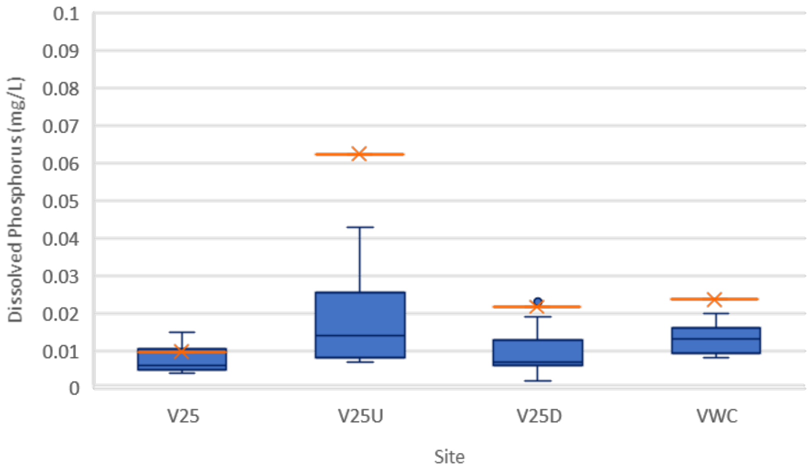


**Figure A36. Box plots (in blue) of the oxidised nitrogen (nitrate + nitrite) (A) and ammonia-N (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**



A



B

**Figure A37. Box plots (in blue) of the total phosphorus (A) and dissolved phosphorus (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

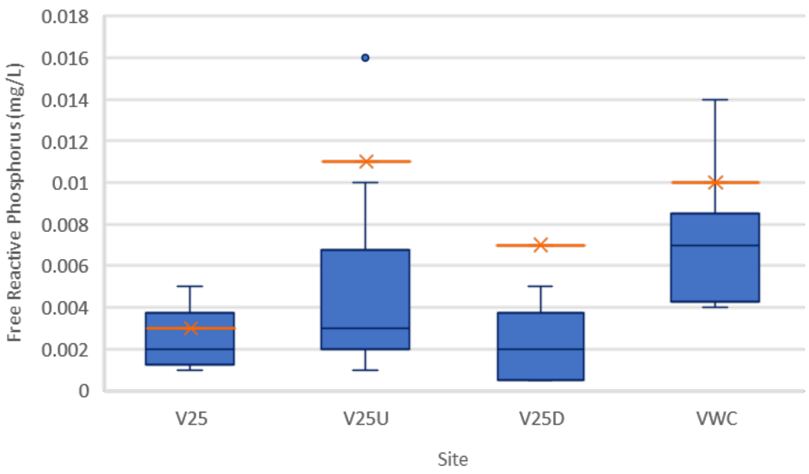


**Figure A38. Box plots (in blue) of the free reactive phosphorus (mg/L) concentrations in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars ( x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

## Metals

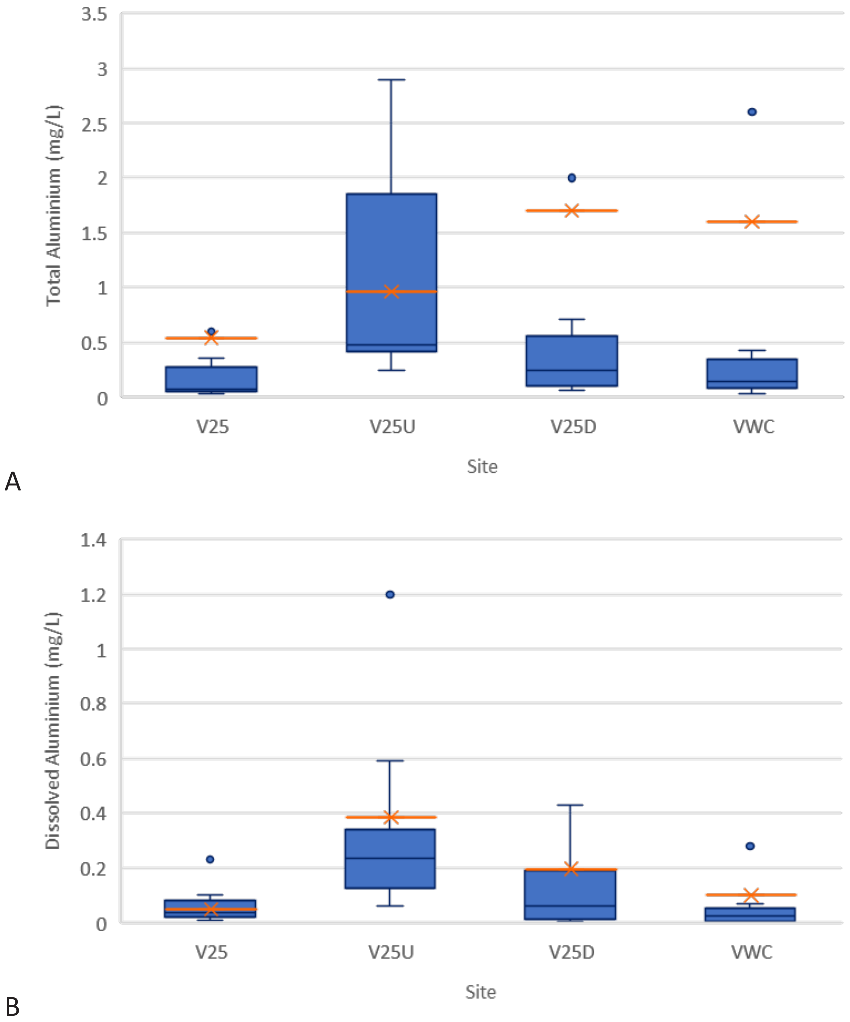


**Figure A39. Box plots (in blue) of total aluminium (A) and dissolved (<0.45 µm) aluminium (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

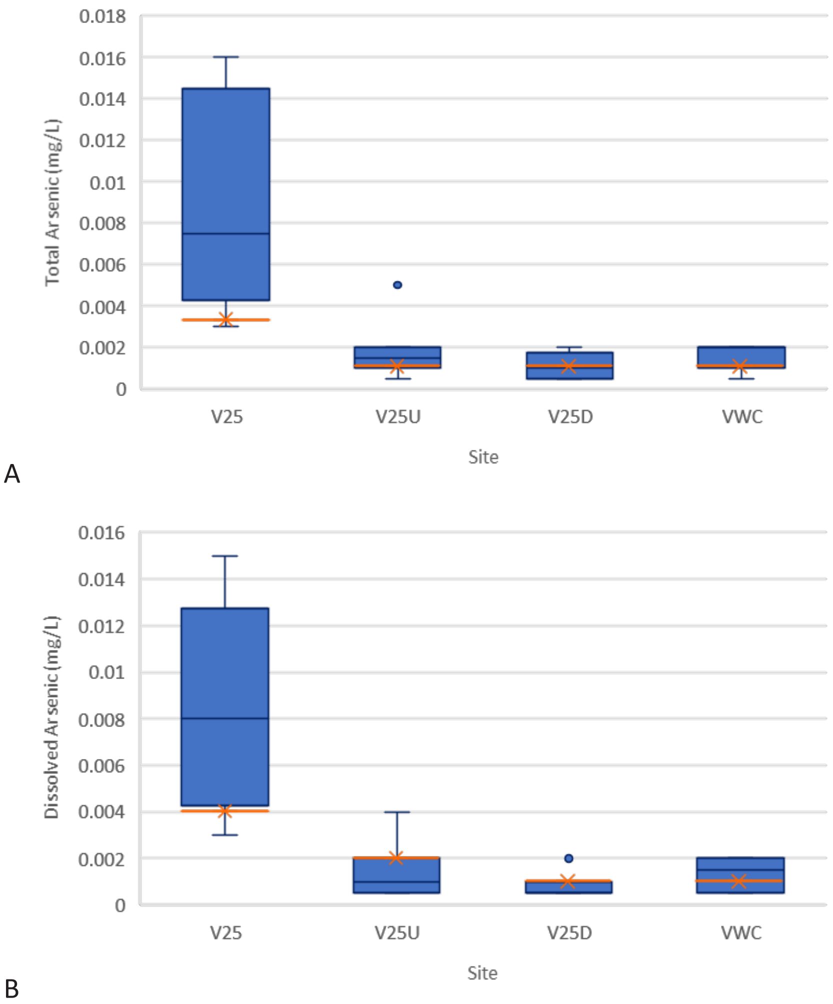


**Figure A40. Box plots (in blue) of total arsenic (A) and dissolved (<0.45 µm) arsenic (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

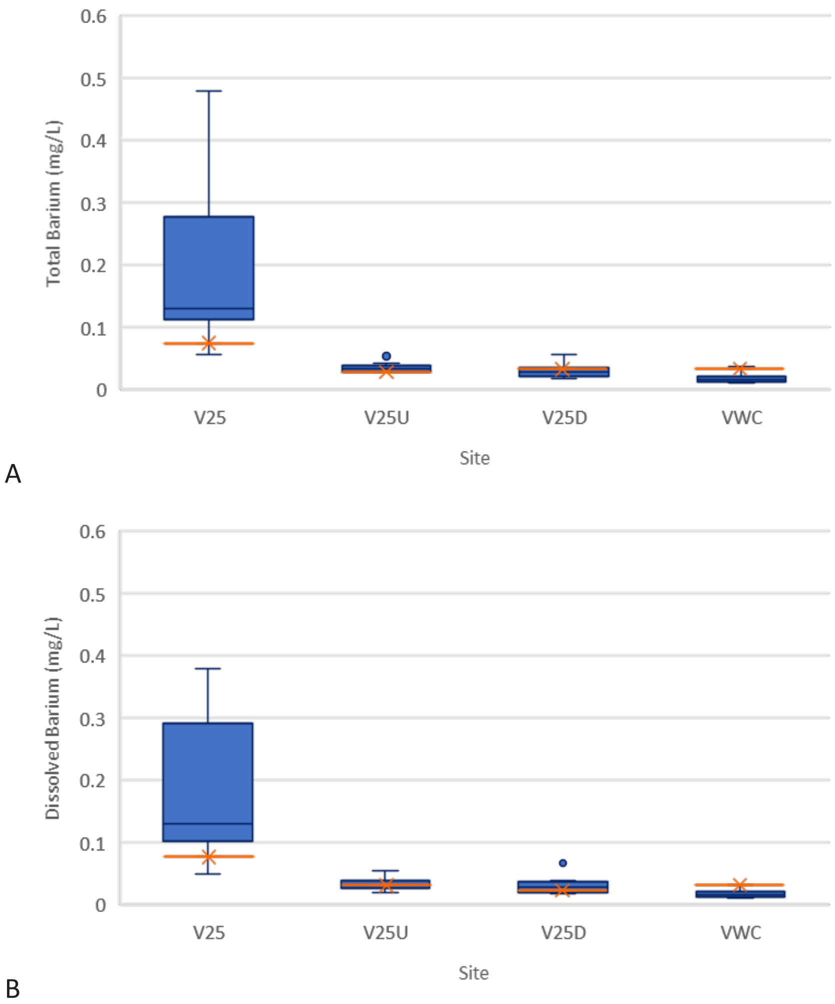


**Figure A41. Box plots (in blue) of total barium (A) and dissolved (<0.45 µm) barium (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

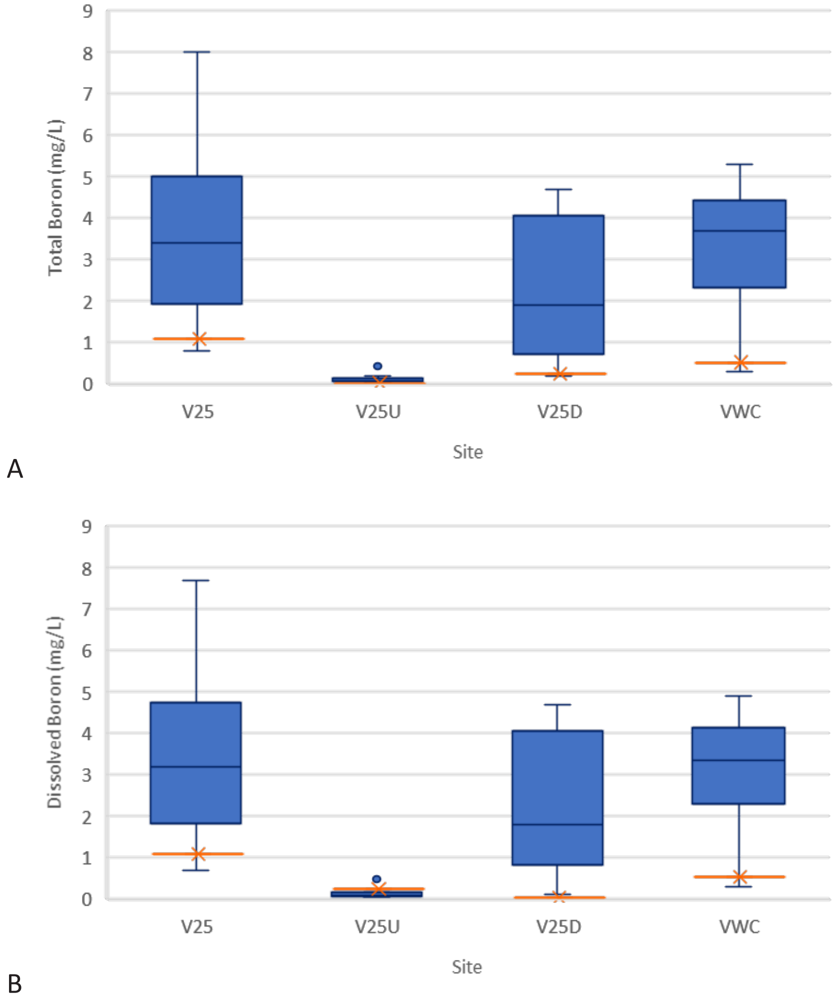
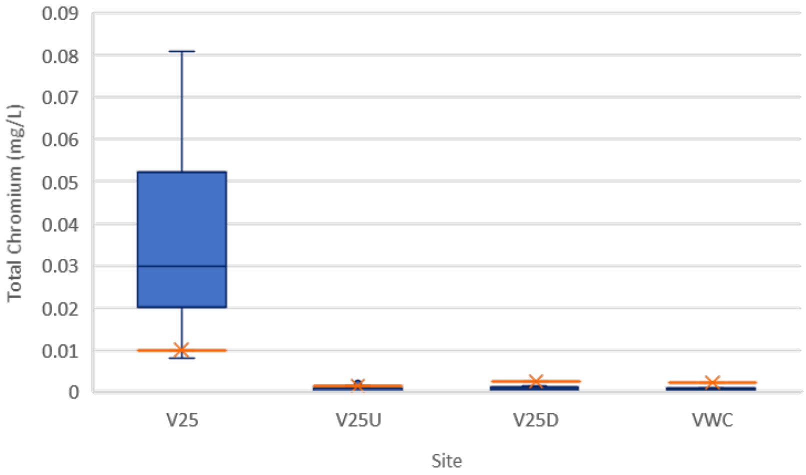


**Figure A42. Box plots (in blue) of total boron (A) and dissolved (<0.45 µm) boron (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**



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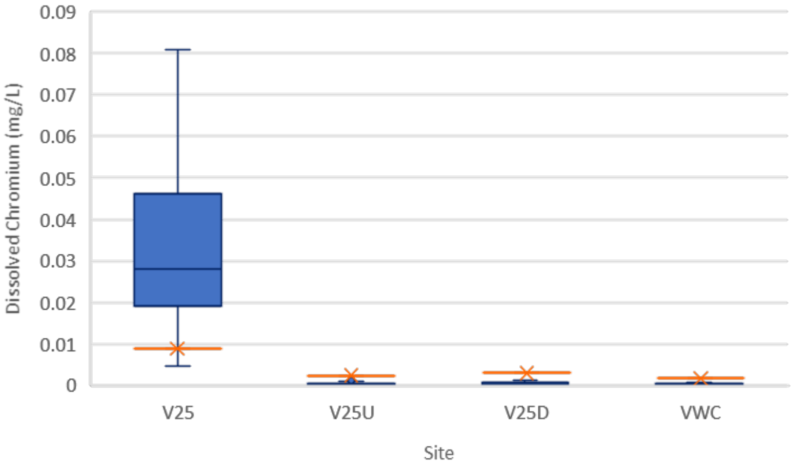
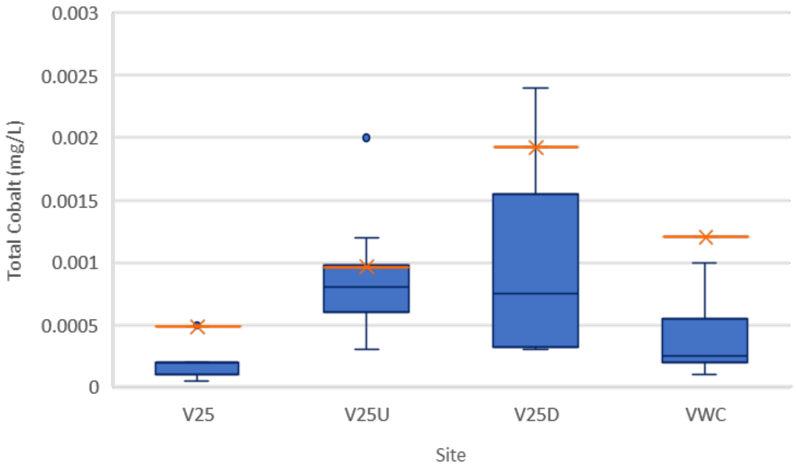
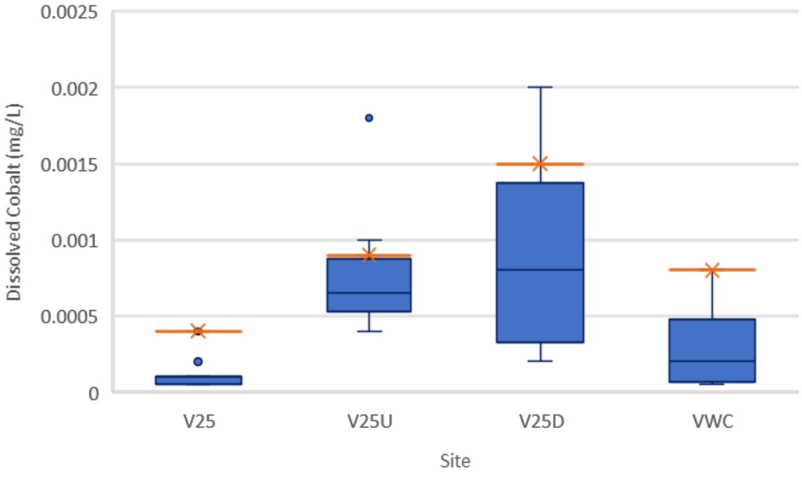


B

**Figure A43. Box plots (in blue) of total chromium (A) and dissolved (<0.45 µm) chromium (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

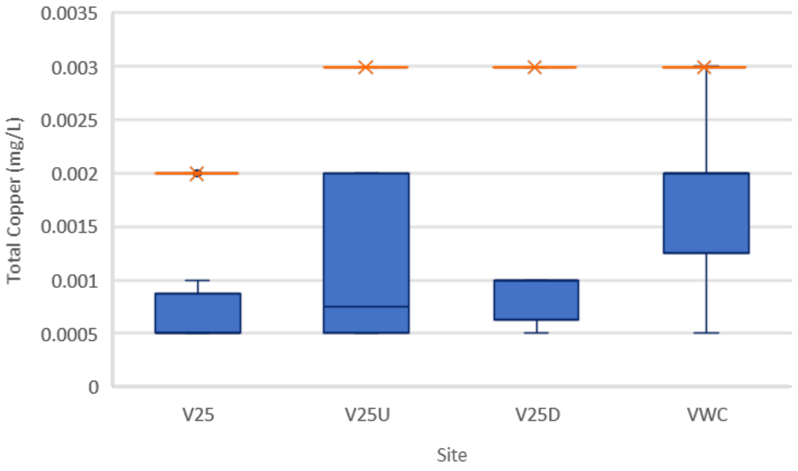


**A**

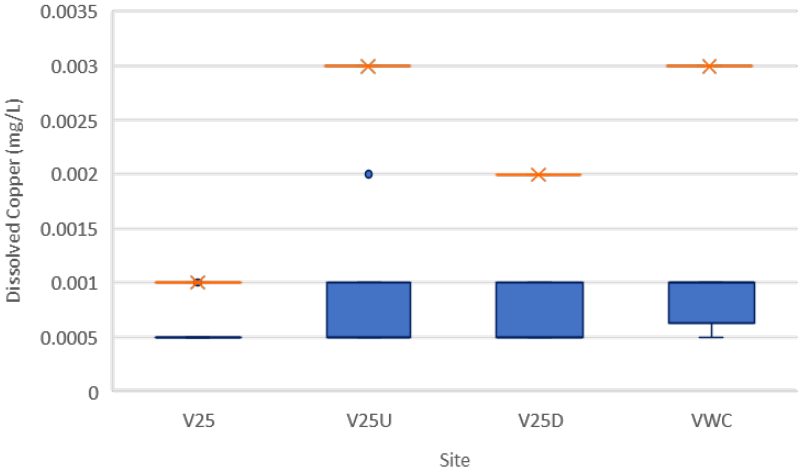


**B**

**Figure A44. Box plots (in blue) of total cobalt (A) and dissolved (<0.45 µm) cobalt (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet weather-emergency discharge event.**



A



B

**Figure A45. Box plots (in blue) of total copper (A) and dissolved (<0.45 µm) copper (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

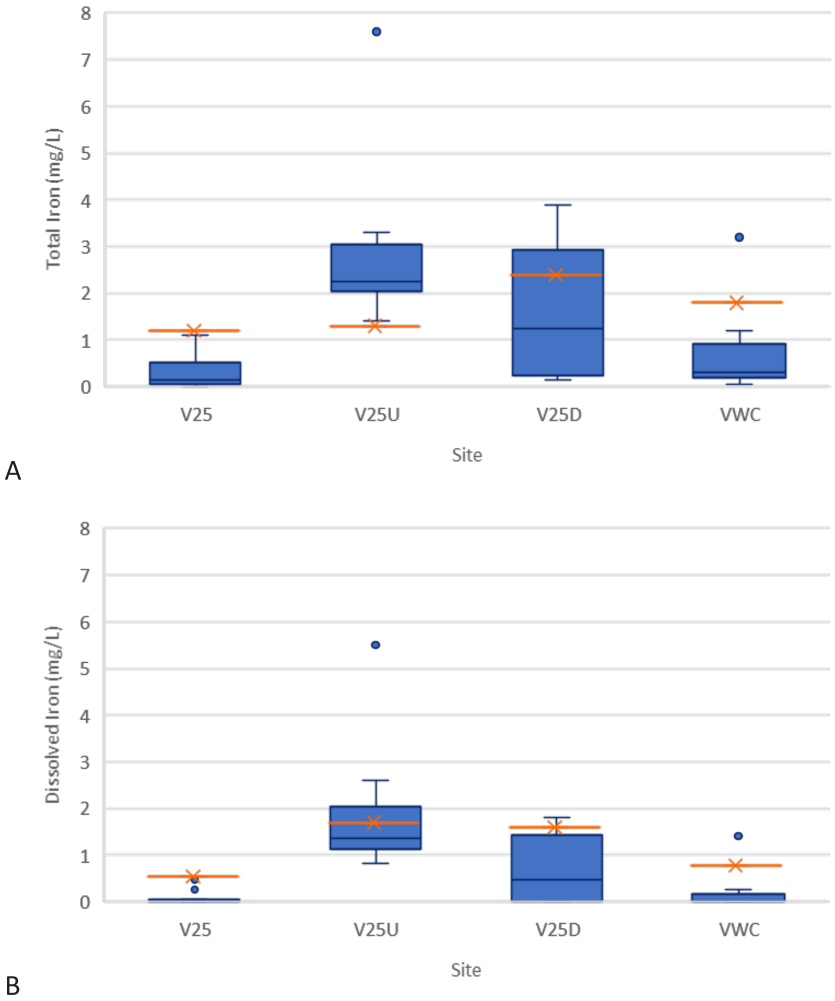


**Figure A46. Box plots (in blue) of total iron (A) and dissolved (<0.45 µm) iron (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

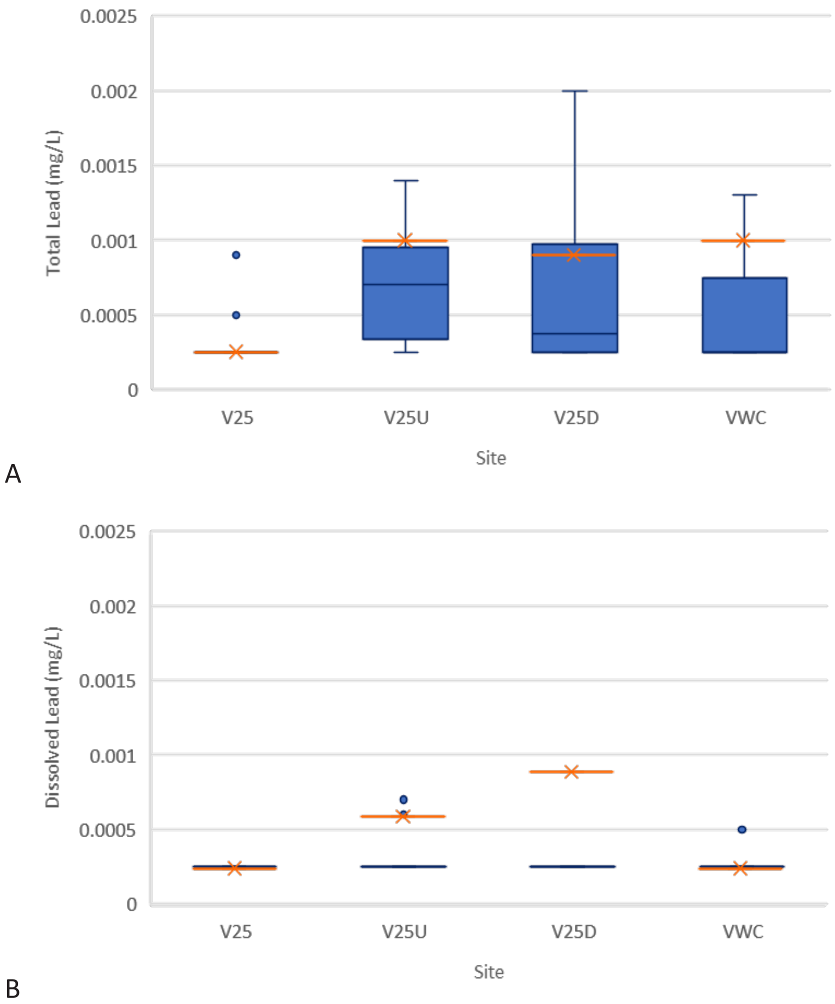
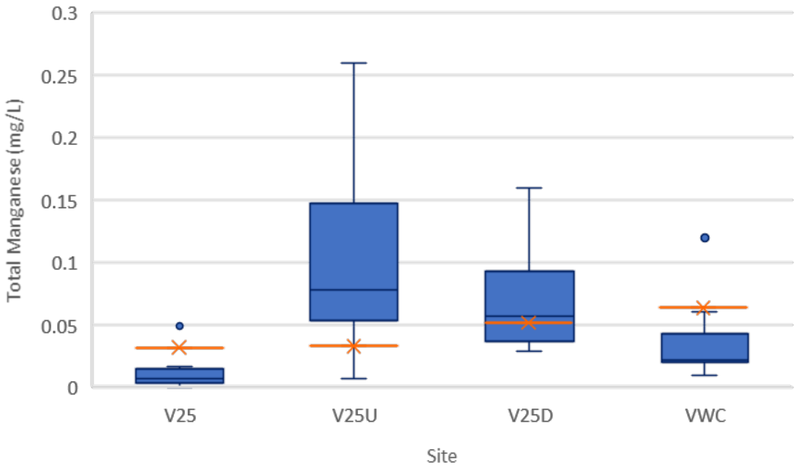
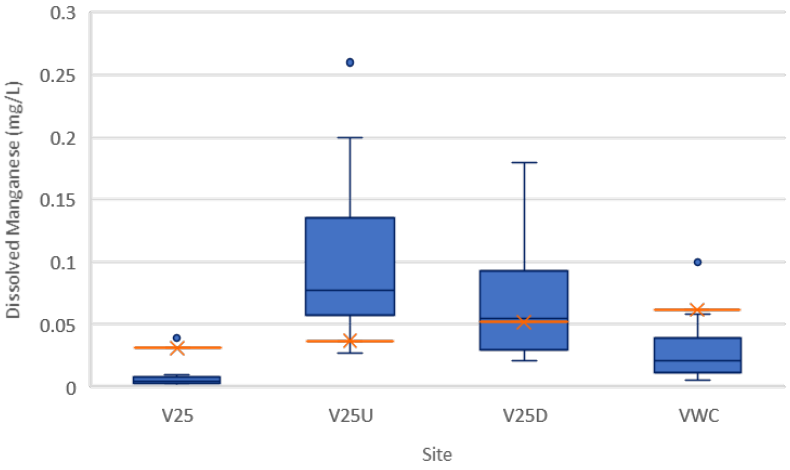


**Figure A47. Box plots (in blue) of total lead (A) and dissolved (<0.45 µm) lead (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

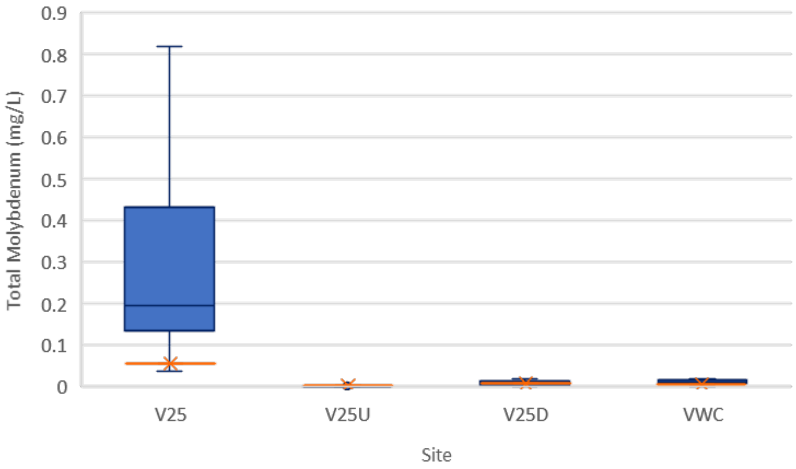


A

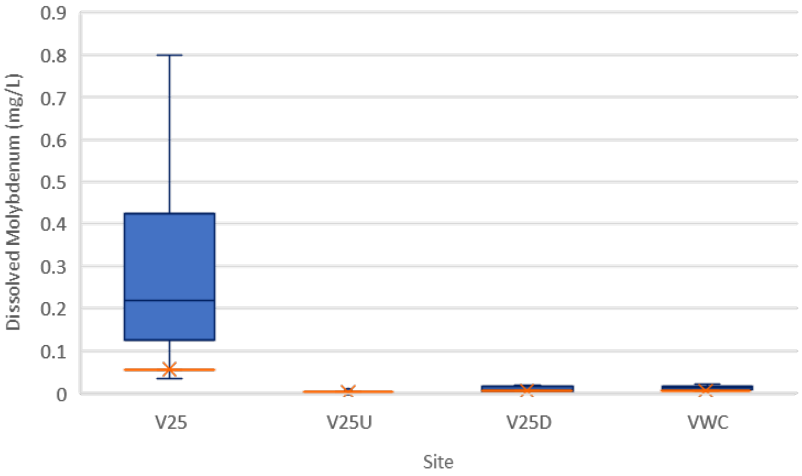


B

**Figure A48. Box plots (in blue) of total manganese (A) and dissolved (<0.45 µm) manganese (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

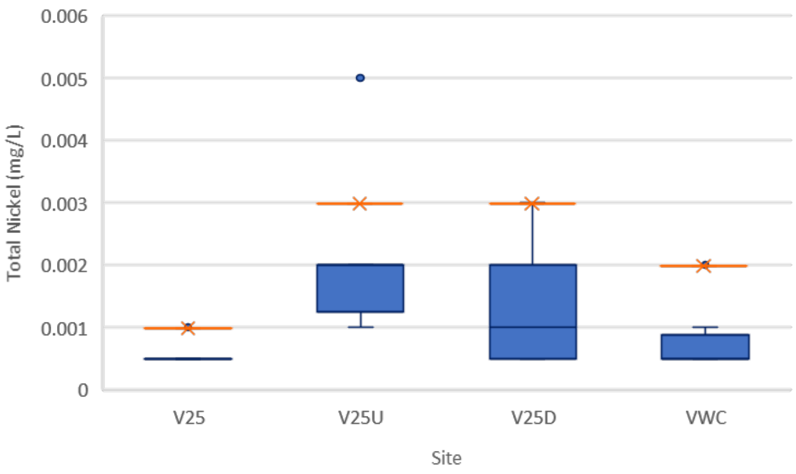


A

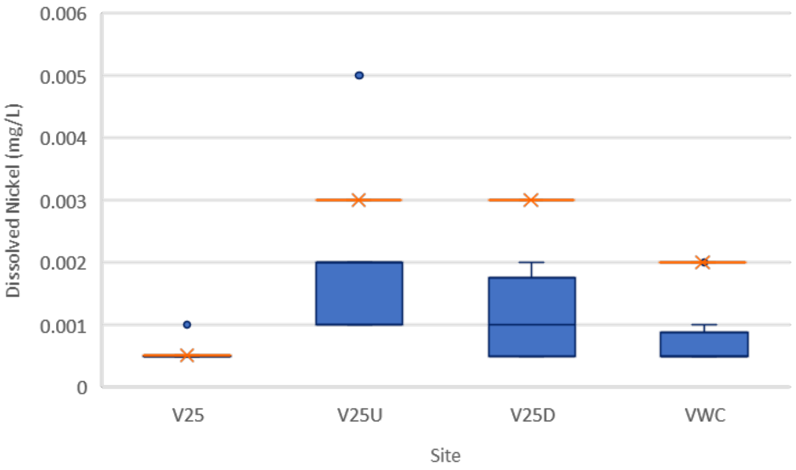


B

**Figure A49. Box plots (in blue) of total molybdenum (A) and dissolved (<0.45 µm) molybdenum (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

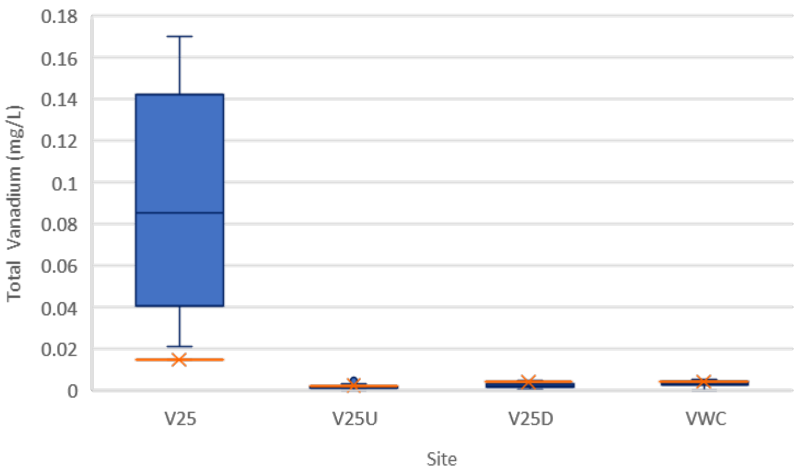


A

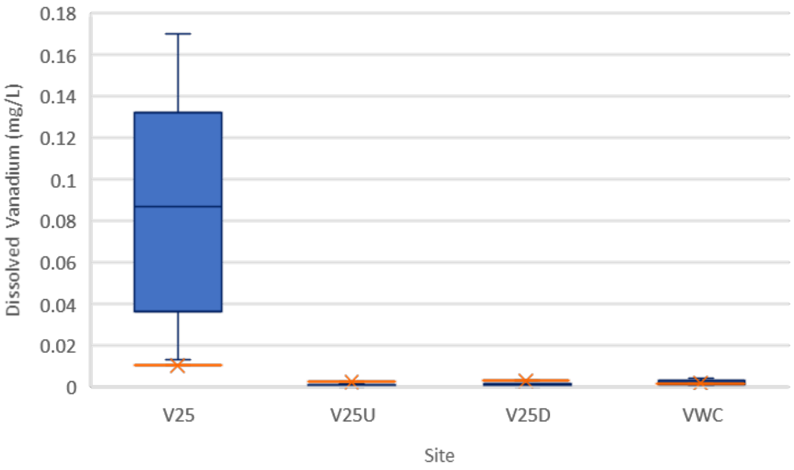


B

**Figure A50. Box plots (in blue) of total nickel (A) and dissolved (<0.45 µm) nickel (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**



A



B

**Figure A51. Box plots (in blue) of total vanadium (A) and dissolved (<0.45 µm) vanadium (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

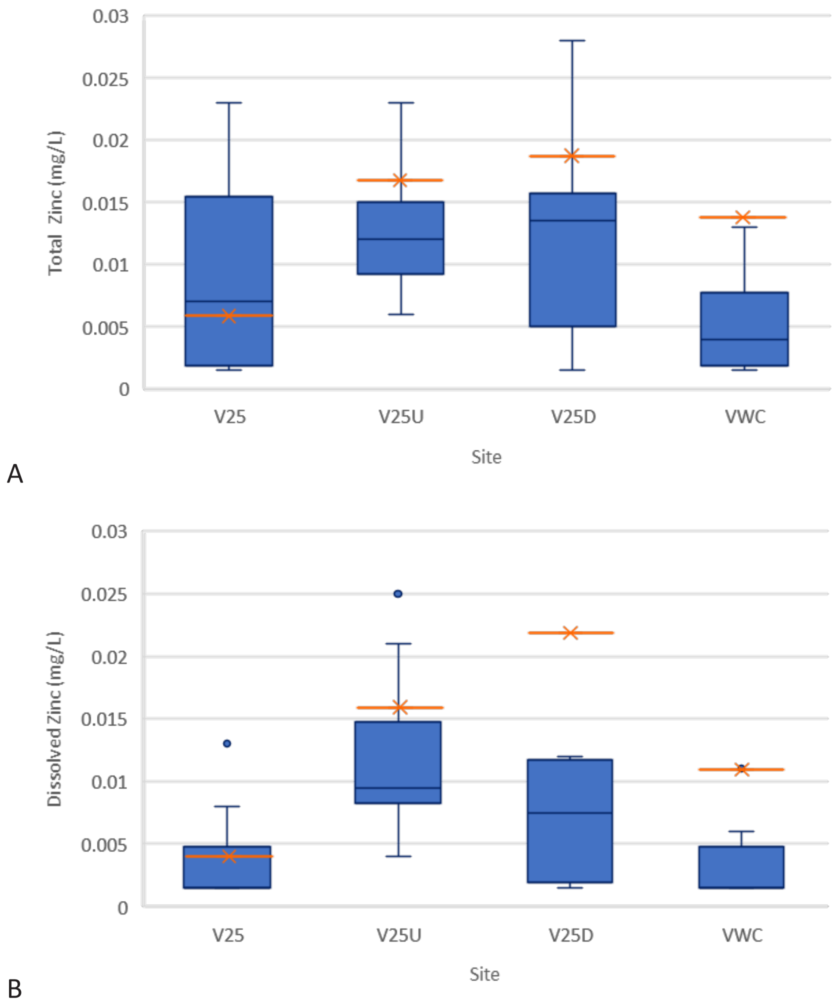


**Figure A52. Box plots (in blue) of total zinc (A) and dissolved (<0.45 µm) zinc (B) concentrations (mg/L) in surface water at 4 sites within the vicinity of Vales Point Power Station from March 2022 to February 2023. The orange bars (—x—) indicate the concentration measured during the Vales Point Power Station wet-weather emergency discharge event.**

# 8. Acknowledgements

This report was prepared by Dr Megan Gillmore (Environment Protection Science (EPS), DCCEEW), with valuable guidance provided by Christopher Doyle (EPS), Dr Mano Veeragathipillai (EPS), Matthew Thompson-Liang (EPS), Dr Yarong Li (EPS), Dr Rebecca Swanson (Water, Wetlands and Coastal Science (WWCS), DCCEEW), and Dr Jaimie Potts (WWCS) throughout the project. Special thanks to external peer reviewers Dr Graeme Batley (CSIRO Environment) and Dr Bill Maher (University of Canberra) for their expertise which has significantly enhanced the project. We also thank the scientists from WWCS and EPS, who have contributed to sample collection, sample analysis, and data verification for this project.