# A3P Project: Melbourne Water Sediment Quality Assessment Program

## Temporal trends in sediment quality across Greater Melbourne from 2010 to 2021

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# Executive Summary

The Sediment Quality Monitoring Program (SQMP) was established in 2010 by Melbourne Water to monitor heavy metals and other pollutants in waterways across the Greater Melbourne Area and to support the management of Melbourne Water's assets, specifically rivers, estuaries, retarding basins and wetlands in the Port Phillip and Western Port catchments. The resulting data is used to identify significant trends in sediment quality and to identify sites that have been under long-term stress from aquatic pollution. Management actions can then be objectively prioritised to fulfil catchment and asset management objectives.

Sediment sampling in 2021 constituted the 14th monitoring event and provided spatio-temporal data on sediment quality across all 5 major Healthy Waterways Strategy catchments and 33 of the 69 Healthy Waterways Strategy sub-catchments. Overall sediment quality has generally remained consistent across the catchments from 2010 to 2021, with the exception of five sites. Sediment quality had significantly declined at the Platypus Wetlands, Lynbrook Estate Wetland and in the Yarra River near Dights Falls, whilst it had significantly improved at Shankland Wetland and Highlands Estate Wetland. Sediment quality was degraded in more urbanised areas in the lower reaches of catchments. Approximately a third of urban waterways monitored, and their respective sub-catchments, had moderately to highly toxic sediment including at the Southern Road Retarding Basin, Mordialloc Creek, Kananook Creek (Dandenong Catchment), Stony Creek, Moonee Ponds Creek (Maribyrnong Catchment), Kororoit Creek, Kororoit Creek Estuary (Werribee Catchment), Chinamans Creek (Western Port and Mornington Peninsula Catchment), Merri Creek, Leamington Street Wetland, Gardiners Creek and Darebin Creek (Yarra Catchment). Resident biota at these sites are therefore at risks of long-term exposure to stress. Such sites may present a considerable challenge for improvement where external influences beyond the control of management may be driving patterns in sediment quality.

Patterns in individual contaminants (zinc, copper and lead) were obscured by aggregated analysis of the mean probable effect concentration. Separate analysis of contaminants of interest provides useful information on the drivers of change within catchments and sub-catchments. Concentrations of zinc were greater in more urbanised areas of catchments compared to sites located in agricultural areas or in the upper reaches of catchments with fewer pressures from development. Lead concentrations are reducing at most sites.

This report provides an overview of the current state of sediment quality and identifies trends in aquatic pollution as predicted by heavy metal concentrations in sediments. On-going monitoring is essential to identify any changing patterns in pollutant inputs over time.

The monitoring program has shown that long-term monitoring of sediment is a cost-effective tool to assess pollution and ecological condition especially in urban catchments. Integrating sediment quality data into planning and adaptive resource management plans alongside other available data (e.g. water and ecological quality and land-use) provides a powerful tool in setting catchment priorities moving forward.

# 1. Introduction

The health of waterways, and the vegetation and wildlife they support, is essential to Melbourne's amenity, biodiversity and economic prosperity. The Healthy Waterways Strategy was co-designed in partnership between Melbourne Water, the State Government of Victoria and the public. It aims to protect and enhance Melbourne's waterways by prioritising investments while maximising outcomes to community and environmental values and increasing liveability. Melbourne Water is responsible for the implementation of the Healthy Waterways Strategy and to manage and protect over 8,400 km of waterways across Greater Melbourne for the safe and efficient provision of water resources.

Melbourne is a rapidly expanding city, and like most cities across the world, aquatic environments are under increasing threat due to poor water quality, loss of biological integrity and increased pollution. Sustainable management of urban landscapes, however, is complex and multiple, and often competing factors drive how these assets are valued and ultimately managed. Where investment is limited, adaptive management (whereby the outcomes of monitoring programs are continuously integrated into management strategies) is useful to help allocate management resources while maximising desired outcomes.

Constructed wetlands have been integrated into many urban areas as a cost-effective management solution to reduce flood risks and capture pollutants from stormwater before they can enter more sensitive downstream environments. Inevitably, sediment from these wetlands have a greater inherent likelihood of exceeding regulatory guidelines and the ecological thresholds of local wildlife (Snodgrass et al. 2008). Constructed wetlands may therefore become ecological traps with the potential to reduce the fitness of wildlife that frequent and inhabit these wetlands (Hale et al. 2018, Sievers et al. 2018, Hale et al. 2019, Zhang et al. 2020). Expensive corrective efforts may be necessary should these wetlands become polluted. It is therefore essential these habitats are managed effectively to avoid or limit potential impacts both at the site of the wetland and downstream.

Sediment quality monitoring is a cost-effective strategy for the long-term evaluation of catchments under pressure from urbanisation, diffuse and point source pollution and environmental change. Sediments are major sinks for hydrophobic toxicants such as heavy metals, hydrocarbons, pesticides and other particulate-bound inorganic and organic chemicals. These chemicals bind with particles and are deposited to the riverbed (Pitt 1995) where they can persist in sediments and become a long-term source of contamination to a waterway and threaten aquatic biota (Pettigrove and Hoffmann 2005). Sediments, therefore, provide a powerful assessment tool from which to assess long-term and catchment-wide pollution. Surficial sediments (the top 2- 10cm), are important for their ability to convey information about recent contaminant inputs. Long-term monitoring of surficial sediments provides a mechanism from which to predict short- to medium-term trends in pollution at a site and/or catchment scale.

The Sediment Quality Monitoring Program (SQMP) was established in 2010 by Melbourne Water to monitor sediment toxicant concentrations in waterways across 55 sites in the Greater Melbourne Area and support the management of Melbourne Water's assets, specifically rivers, estuaries, retarding basins and wetlands in the Port Phillip and Western Port catchments. Long-term and routine assessment of sediment toxicant concentrations across the Greater Melbourne Area will identify areas of concern for pollutants and will help prioritise additional or remedial on-ground actions. The SQMP provides a detailed temporal dataset that allows for catchment objectives and management actions to be evaluated and adapted to address changing challenges. The data helps to elucidate alternate ways for addressing and prioritising waterway quality objectives and allocate resources based on current knowledge of pollution and sediment quality. The identification of spatio-temporal trends is essential to the successful long-term management of key values and the fulfilment of catchment management objectives and the Healthy Waterways Strategy (Victoria State Government 2018). Where concerns over emerging contaminants have arisen, they have been integrated into the program.

This report focuses on the long-term ecological health of the five major Healthy Waterways Strategy catchments. An assessment is presented for each catchment, with consideration given to HWS sub-catchment management units that have at least one sediment quality site. The sediment quality of constructed wetlands monitored as part of the SQMP have also received additional focus to identify any potential adverse impacts associated with their inherent purpose and surrounding land use. This report follows on from a summary report of the results from the 2020 and 2021 SQMP sediment sampling and assessment.

## 1.1. Objectives

The objectives of this report were to:

- Identify long-term trends in the concentrations of contaminants in sediments, specifically heavy metals and total petroleum hydrocarbons.
- Assess the long-term health risks for resident biota of selected constructed wetlands and streams in urban and peri-urban areas as collection points for contaminants.
- Characterise the relationship between long-term trends in sediment quality and changes in the surrounding land use.

# 2. Methods

## 2.1. Study area

The Healthy Waterways Strategy focuses on 5 major catchments across the Greater Melbourne Area. These consist of the Dandenong, Maribyrnong, Werribee, Westernport and Mornington Peninsula, and Yarra catchments. The study area incorporates all 5 major catchments and consists of 55 sites, with 8 to 16 sites per catchment (Table 1, Figure 1). The 5 major catchments are subdivided into 69 sub-catchments that reflect the drainage of smaller creeks and tributaries into the larger river systems. Management efforts and investment throughout the study area is focused at the catchment and sub-catchment level.

Two or more sites were selected from each catchment for further detailed analysis, of which at least one from each catchment was a wetland. These sites were selected for focus to observe the impacts of increasing urbanisation.

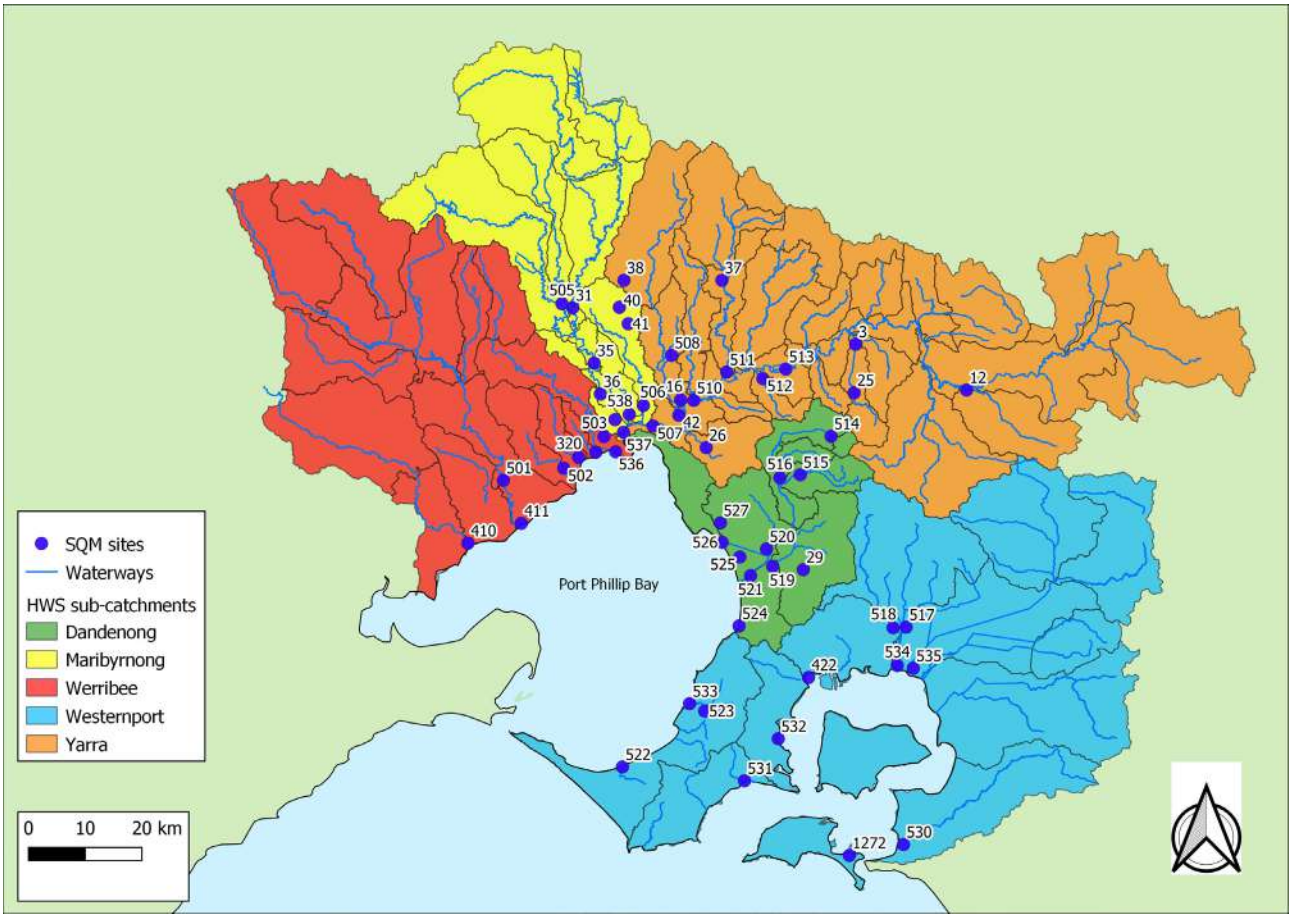


Figure 1. Sediment sampling sites across the Greater Melbourne Area. Details on study sites are provided in Table 1.

**Table 1. Sediment quality assessment sites across Greater Melbourne and their respective Healthy Waterways Strategy (HWS) catchments. Priority values and management for each one, along with priority levels are listed and sites highlighted blue are of focus in this report.**

| HWS Catchment | HWS Sub-Catchment | HWS Wetland or Estuary | Waterway Type | AQUEST SITE ID | Latitude | Longitude | HWS Priority Value and Management |
|---|---|---|---|---|---|---|---|
| **Dandenong** | Corhanwarrabul, Monbulk and Ferny Creeks | Corhanwarrabul Creek | Stream | 515 | -37.9049 | 145.2485 | Frogs (I) |
| | Dandenong Creek Lower | Dandenong Creek | Stream | 520 | -38.0312 | 145.184 | Birds (I); Amenity (M) |
| | | Edithvale South Wetland | Estuary | 525 | -38.1434 | 145.1197 | Birds (I); Amenity (I); Frogs (I) |
| | | Southern Road Retarding Basin | Wetland | 527 | -37.9789 | 145.0865 | None |
| | | Mordialloc Creek | Estuary | 526 | -38.0098 | 145.0889 | Birds (I); Amenity (I); Frogs (I) |
| | Dandenong Creek Middle | Dandenong Valley Treatment Wetlands | Wetland | 516 | -37.9091 | 145.2076 | Birds (I); Frogs (I); Vegetation (M) |
| | Dandenong Creek Upper | Dandenong Creek | Wetland | 514 | -37.8447 | 145.3118 | Amenity (M); Macros (I); Platypus (S) |
| | Eumemmerring Creek | Lynbrook Estate Wetland | Wetland | 29 | -38.0559 | 145.2511 | None |
| | | Eumemmerring Creek | Stream | 519 | -38.0416 | 145.1867 | Birds (I); Vegetation (M) |
| | Kananook Creek | Lake Legana | Wetland | 521 | -38.0637 | 145.1448 | Birds; Amenity |
| | | Kananook Creek | Wetland | 524 | -38.0338 | 145.124 | Amenity (M) |
| **Maribyrnong** | Deep Creek Lower | Deep Creek | Stream | 31 | -37.6319 | 144.8001 | Vegetation (M) |
| | Jacksons Creek | Jacksons Creek | Stream | 505 | -37.6251 | 144.7788 | Platypus (S) |
| | Maribyrnong River | Maribyrnong River | Stream | 35 | -37.7205 | 144.8404 | Amenity (I) |
| | | Maribyrnong River | Stream | 36 | -37.77 | 144.8514 | Amenity (I) |
| | | Maribyrnong River | Estuary | 538 | -37.8036 | 144.9084 | Amenity (I) |
| | Moonee Ponds Creek | Brodies Lakes | Wetland | 40 | -37.6329 | 144.8933 | Amenity A (M); Frogs C (I)] |
| | | Moonee Ponds Creek | Stream | 506 | -37.7898 | 144.9369 | Amenity A (M) |
| | | Shankland Wetland | Wetland | 41 | -37.6517 | 144.90913 | Amenity A (M); Frogs C (I)] |
| | Stony Creek | Stony Creek | Stream | 504 | -37.8153 | 144.8757 | None |
| **Werribee** | Cherry Creek | Cherry Lake | Wetland | 316 | -37.8623 | 144.8396 | Birds (I) |
| | Kororoit Creek Lower | Kororoit Creek | Stream | 503 | -37.8551 | 144.844 | Birds (I); Amenity (I) |

| HWS Catchment | HWS Sub-Catchment | HWS Wetland or Estuary | Waterway Type | AQUEST SITE ID | Latitude | Longitude | HWS Priority Value and Management |
|---|---|---|---|---|---|---|---|
| | | Kororoit Creek Estuary | Estuary | 536 | -37.8564 | 144.8532 | Birds (I); Amenity (I) |
| | Laverton Creek | Truganina Swamp | Wetland | 320 | -37.8697 | 144.8049 | Birds (I) |
| | Little River Lower | Little River Estuary | Estuary | 410 | -38.0019 | 144.5785 | Birds (I); Frogs (I); Vegetation (M); Fish (I) |
| | Skeleton Creek | Skeleton Creek | Estuary | 502 | -37.8867 | 144.7745 | Birds (I); Amenity (I) |
| | Werribee River Lower | Werribee River Estuary | Estuary | 411 | -37.9725 | 144.6867 | Amenity (I); Fish (I); Platypus (S) |
| | | Werribee River | Stream | 501 | -37.9034 | 144.6529 | Birds (I); Amenity (I); Vegetation (M); Fish (I) |
| **Westernport and Mornington Peninsula** | Bass River | Bass River Estuary | Estuary | 530 | -38.4955 | 145.44316 | Vegetation C (M) |
| | Cardinia, Toomuc, Deep and Ararat Creeks | Deep Creek | Stream | 517 | -38.1494 | 145.44873 | None |
| | | Cardinia Creek | Stream | 518 | -38.147 | 145.43232 | Vegetation V (M); Fish (M)] |
| | | Cardinia River Estuary | Estuary | 534 | -38.2109 | 145.43673 | Birds A (I); Vegetation A (I) |
| | Bunyip Lower | Bunyip River Estuary | Estuary | 535 | -38.2132 | 145.45844 | Birds A (I) |
| | French and Phillip Islands | Fishers Wetland | Wetland | 1272 | -38.5116 | 145.3414 | |
| | Mornington Peninsula North-Eastern Creeks | Watsons Creek Estuary | Estuary | 422 | -38.2273 | 145.25755 | Birds A (I) |
| | | Warrangine Creek Estuary | Estuary | 532 | -38.3239 | 145.19401 | None |
| | Mornington Peninsula South-Eastern Creeks | Merricks River Estuary | Estuary | 531 | -38.3894 | 145.12433 | Amenity C (M); Vegetation C (I) |
| | Mornington Peninsula Western Creeks | Chinamans Creek | Stream | 522 | -38.3633 | 144.87846 | Amenity C (M); Birds B (I) |
| | | Balcombe Creek | Stream | 523 | -38.2665 | 145.03367 | Amenity B (M); Birds D (I) [Frogs A (M) |
| | | Balcombe Creek Estuary | Estuary | 533 | -38.2653 | 145.01624 | Amenity B (M); Birds D (I) |
| **Yarra** | Darebin Creek | Darebin Creek | Stream | 510 | -37.7833 | 145.03807 | Vegetation C (I); Amenity A (M) |
| | Gardiners Creek | Gardiners Creek | Stream | 26 | -37.8588 | 145.06107 | Amenity A (M) |
| | Merri Creek Lower | Merri Creek | Stream | 16 | -37.7938 | 145.00274 | Amenity D (M); Vegetation C (I) |
| | | Leamington Street Wetland | Wetland | 508 | -37.711 | 144.99558 | [4.5km d/s Amenity D (M)] |
| | Merri Creek Upper | Highlands Estate Wetland | Wetland | 38 | -37.5902 | 144.90371 | Amenity C (I) |
| | Mullum Mullum Creek | Mullum Mullum Creek | Stream | 512 | -37.751 | 145.17726 | Vegetation D (I) |

| HWS Catchment | HWS Sub-Catchment | HWS Wetland or Estuary | Waterway Type | AQUEST SITE ID | Latitude | Longitude | HWS Priority Value and Management |
|---|---|---|---|---|---|---|---|
| | Olinda Creek | Olinda Creek | Stream | 3 | -37.6991 | 145.36433 | None |
| | | Platypus Wetlands | Wetland | 25 | -37.7762 | 145.35959 | Platypus C (S) |
| | Plenty River Lower | Plenty River | Stream | 511 | -37.7395 | 145.10522 | Amenity A (M); Vegetation C (I) |
| | | Stockland Development Wetland | Wetland | 37 | -37.5935 | 145.09926 | Amenity A (M); Frogs C (M); Vegetation B (I) |
| | Yarra River Lower | Yarra River | Stream | 42 | -37.7968 | 144.9998 | Amenity A (M); Vegetation C (I) |
| | | Yarra River | Estuary | 507 | -37.8228 | 144.9555 | Amenity A (I); Fish B (M) |
| | | Yarra River Estuary | Estuary | 537 | -37.8318 | 144.89594 | Amenity A (I); Fish B (M) |
| | | Yarra River | Stream | 513 | -37.7365 | 145.22377 | Amenity A (M); Vegetation A (M) |
| | Yarra River Upper (Rural) | Yarra River | Stream | 12 | -37.7748 | 145.58479 | Macros, Amenity, Vegetation |

## 2.2. Sediment quality guidelines and Threshold Effect Concentrations (TEC)/ Probable Effects Concentrations (PEC)

Heavy metal concentrations in sediments are often compared to the default guideline value (DGV) and the guideline value high (GV-high) to assess the ecological threat of pollutants entering urban waterways in Australia (Table 3). These guidelines are derived from empirical analyses of field and laboratory data in whole sediments and represent a concentration threshold above which adverse effects are possible (DGV) or probable (GV-high)(ANZECC 2000, Simpson et al. 2013, ANZG 2018). Trigger thresholds have become established as screening tools to highlight where further investigations of toxicity are needed (Long et al. 1995).

Mean probable effect concentration quotients (mPECq) are an effective tool for assessing the potential aggregate impact of contaminants when they occur in complex mixtures. As the mPECq increases so does the probability of toxicity (MacDonald et al. 2000, Long et al. 2005). Table 2 provides the likelihood of amphipod toxicity when exposed to sediments at varying mPECq ranges (*Hyalella azteca* 28- to 42-day tests in freshwater sediments from North America) (Ingersoll et al. 2001). Mean quotients were calculated and used to assess the toxicity of sediments occurring at sites.

**Table 2. The likelihood of amphipod toxicity when exposed to sediments with various mean probable effect concentration quotient (mPECq) ranges (*Hyalella azteca* 28- to 42-day tests in freshwater sediments from North America) (Ingersoll et al., 2001).**

| mPECq range | Probability | Classification |
|---|---|---|
| <0.1 | 10% | Low |
| 0.1-<0.5 | 17% | |
| 0.5-<1.0 | 56% | Moderate |
| 1-<5 | 97% | High |
| >5 | 100% | |

### 2.2.1. Heavy metals

The potential for overall sediment toxicity was estimated from mPECq derived from sediment concentrations of heavy metals at each site using consensus based sediment quality guidelines in freshwater ecosystems (MacDonald et al. 2000). Table 3 provides the PEC and theoretical effect concentration (TEC) for the assessed metals (MacDonald et al. 2000)

The mPECq values were computed using the equation:

$$\mathbf{mPECq = \sum(i/PECi)/n\ *}$$

*Where i = concentration of a metal, PECi is PEC for a specific metal and n = number of metals

The resulting mPECq values provide measures of metal contaminants at each site, and subsequently sediment toxicity, from which ecological health can be inferred and management actions prioritised.

Concentrations of analytes were routinely below the limit of reporting, where this occurred, half the detection limit value was used to calculate means, and subsequently, mPECq, in alignment with previous reporting. Substitution with half detection limits is commonly used and may lead to misrepresentations of data including under- and over-estimates of both the mean and standard deviation (Wood et al. 2012). However, where values below the limit of detection constitute a minor proportion of the data, substitution may be appropriate (US EPA 2000). With respect to the 2021 data, 35% of the dataset consisted of values below the limit of detection.

**Table 3. Consensus-based freshwater sediment quality guidelines. Probable effects concentrations (PEC) and threshold effect concentrations (TEC). LOR is the limit of reporting. Units are mg/kg (dry weight) (MacDonald et al. 2000).**

| Metal | Symbol | Threshold effect concentrations (TEC) | Probable effects Concentrations (PEC) | LOR |
|---|---|---|---|---|
| Antimony | Sb | - | - | 5 |
| Arsenic | As | 9.79 | 33 | 5 |
| Cadmium | Cd | 0.99 | 4.98 | 1 |
| Chromium | Cr | 43.4 | 111 | 2 |
| Copper | Cu | 31.6 | 149 | 5 |
| Lead | Pb | 35.8 | 128 | 5 |
| Mercury | Hg | 0.18 | 1.06 | 0.1 |
| Nickel | Ni | 22.7 | 48.6 | 2 |
| Silver | Ag | - | - | 2 |
| Zinc | Zn | 121 | 459 | 5 |

## 2.2.2. Hydrocarbons

A DGV of 280 mg/kg and a GV-high of 550 mg/kg has been proposed for Total Petroleum Hydrocarbons (TPH) (Simpson et al. 2013). These guidelines were based on analytical detection limits of TPH fractions as well as invertebrate ecotoxicological testing using sediment from polluted wetlands in Melbourne (Pettigrove and Hoffmann 2005) and from marine studies (Simpson et al. 2007, Verbruggen et al. 2008).

## 2.2.3. Pesticides

Bifenthrin, a synthetic pyrethroid insecticide, was broadly detected in sediment between 2015 and 2020 and is considered further here. Regulatory guidelines for the concentration of bifenthrin in sediments are not established. In lieu of this, amphipod toxicity (LC50) to bifenthrin (1.09 (±0.08) µg/gOC) was determined by Jeppe et al. (2017) and the detection frequency has been used to assess temporal trends.

## 2.3. Limitations

Heavy metals and hydrocarbon analyses were conducted on filtered sediments (<63 µm) to reduce inherent variability of grain size and organic carbon across sites and associated impacts to analytical techniques. Contaminant concentrations are typically standardized to <63 µm sediment fraction (i.e., silt and clay) (ANZECC 2000). These fine sediment particles (<63 µm) are commonly ingested by benthic biota (Tessier et al. 1984) and therefore may be of primary concern for ecotoxicological assessments. However, guidelines based on whole sediments may overestimate the ecological risk, primarily at sites where there is a greater quantity of coarse sand and smaller amounts of silt and clay as the degree of ecological exposure may be reduced. Further information is required to better understand the relationship between fine and whole sediment and contaminants.

## 2.4. Data analysis

Temporal trends in the mPEC of contaminants in sediment were identified using linear regressions in R-Studio V1.2.5042 (RStudio Team 2020). Linear regressions were also used to assess zinc, copper and lead concentrations in further detail at sites of interest. Zinc, copper and lead are of interest given their correlation to urbanisation.

Correlations between land use and contaminant concentration could not be quantitatively assessed as temporal land use GIS data was not accessible for the study area. Alternatively, changes in land use around sites was visually assessed using time lapse images available from Google Earth to determine any association or potential correlation.

The concentration of contaminants in sub-catchments has been visualised using the mapping software QGIS. Where multiple sites are present in one sub-catchment their values were averaged. Several sub-catchments are represented by a single site and thus may misrepresent trends and health across the whole sub-catchment.

# 3. Results

## 3.1. Yarra Catchment

Sediment quality has been routinely monitored from 16 sites in the Yarra Catchment since 2010. These sites provide information on 10 of the 25 sub-catchments which make up the Yarra Catchment. These include the: Darebin Creek, Gardiners Creek, Merri Creek Upper, Merri Creek Lower, Mullum Mullum Creek, Olinda Creek, Plenty River Lower, Yarra River Upper (Rural) and Yarra River Lower sub-catchments.

Sites in the Mullum Mullum Creek, Plenty River Lower, Darebin Creek, Merri Creek Lower and Gardiners Creek sub-catchments showed no significant changes in mPECq between 2010 and 2021 (Table 4). Mean PECq at site 42 (Yarra River Dights Falls) in the Yarra River Lower Sub-Catchment increased significantly over the monitoring period, largely driven by an increase in zinc (Figure 2). Overall toxicity of sediment at this site is considered high (Table 2) and may exceed the ecological threshold of some taxa.

Concentrations of zinc, copper and lead in sediment at four focal sites (sites 25 (Platypus Wetlands), 37 (Stockland Development Wetland), 38 (Highlands Estate Wetland) and 513 (Yarra River at Warrandyte)) in the Yarra Catchment were examined further to assess changes in sediment quality associated with surrounding land use changes (Table 5, Table 6, Table 7, Figure 2, Figure 3 and Figure 4). Copper decreased by half in the Highlands Estate Wetland located in the Merri Creek Upper Sub-catchment (site 38, p=0.037), and lead significantly decreased at the Stockland Development Wetland (site 37, Plenty River Lower Sub-catchment, p=0.011) and Highlands Estate Wetland (site 38, p=0.018). These sites have historically had low levels of heavy metal contamination.

In contrast, zinc significantly increased at the Platypus Wetlands in the Olinda Creek Sub-catchment (site 25, p=0.007) and occasionally exceeded the PEC for zinc (121 mg/kg). Sediment toxicity at the

Platypus Wetlands has significantly increased over the monitoring period (p=0.027) but has overall low levels of heavy metal contamination. Visual assessment of the surrounding land use showed no obvious change between 2010 and 2021.

## 3.2. Maribyrnong Catchment

Sediment quality is monitored at nine sites located in the Maribyrnong Catchment, and provides information on contamination across five management sub-catchments (Deep Creek Lower, Jacksons Creek, Maribyrnong River, Moonee Ponds Creek and Stony Creek sub-catchments).

No significant changes in sediment quality were detected in the Maribyrnong River, Jacksons Creek, Stony Creek or Deep Creek Lower sub-catchments. Whilst site 36, Maribyrnong River (Canning Street) in the Maribyrnong River Sub-catchment showed no significant trend in mPECq, data from this site suggests that sediment quality may be declining due to recent increases in zinc and copper.

Heavy metal contamination was further investigated at Brodies Lakes (site 40), Shankland Wetland (site 41) and Jacksons Creek (site 505).

Sediment quality at the Shankland Wetland (site 41) in the Moonee Ponds Creek Sub-catchment has marginally improved from earlier sampling years. This change has largely been driven by a substantial reduction in zinc and lead, and a marginal reduction in copper following 2019 (Table 5, Table 6, Table 7). Similarly, a reduction in lead was also observed at Jacksons Creek. No significant change in heavy metal concentrations was detected at Brodies Lakes despite an increase in residential development in the surrounding area (particularly following 2013).

## 3.3. Dandenong Catchment

The Dandenong Catchment is represented by 11 sites located across 6 sub-catchment management areas including Dandenong Creek: Lower, Middle and Upper, Kananook Creek, Eumemmerring Creek, and Corhanwarrabul, Monbulk and Ferny Creeks sub-catchments).

The Dandenong Creek Lower, Kananook Creek and Eumemmerring Creek sub-catchments were found to have sites with high overall sediment toxicity. A significant increase in the mPECq was detected in the Eumemmerring Creek Sub-catchment at the Lynbrook Estate Wetlands (site 29, p=0.034). Sites in the Eumemmerring Creek Sub-catchment (sites 29 (Lynbrook Estate Wetland) and 519 (Eumemmering Creek)) were given further attention. Zinc ($p<0.001$), copper (p=0.001) and lead (p=0.005) were all found to significantly increase at the Lynbrook Estate Wetlands (Table 5, Table 6, Table 7, Figure 2). In contrast, lead significantly decreased at Eumemmering Creek (site 519, p=0.063), but no other changes were detected. The Eumemmering Creek Sub-catchment was among the top five sub-catchments assessed with the greatest overall sediment toxicity.

No significant change in overall sediment toxicity (mPECq) was detected in any other sub-catchment in the Dandenong Catchment (Table 4).

## 3.4. Westernport and Mornington Peninsula Catchment

Twelve sediment quality monitoring sites are located in the Westernport and Mornington Peninsula Catchment and represent seven sub-catchments (the French and Phillip Islands, Bass River, Bunyip

Lower and Cardinia, Toomuc, Deep and Ararat creeks sub-catchments, and the Mornington Peninsula Western, North-eastern and South-eastern creeks).

No significant change in the overall toxicity of sediments was detected in the Westernport and Mornington Peninsula Catchment during the monitoring period (Table 4). However, additional analysis of sites located in the Mornington Peninsula Western Creeks (Chinamans Creek (site 522), Balcombe Creek (site 523) and Balcombe Creek Estuary (533)) show a significant decrease in lead at Chinamans and Balcombe creeks (p=0.005 and p=0.033, respectively) and a marginal decrease in zinc at Balcombe Creek Estuary (p=0.068) (Table 5, Table 6, Table 7). Sediment at both Balcombe Creek Estuary and Chinamans Creek remain moderately and highly toxic, respectively. The Mornington Peninsula Western Creeks Sub-catchment is the only management area of concern as sediment from all other sites were considered to be of low heavy metal toxicity. Visual assessment of land use satellite imagery shows no major changes in the surrounding land use during the monitoring period.

## 3.5. Werribee Catchment

Sediment quality in the Werribee Catchment is monitored at eight sites spread across six sub-catchment management units (Kororoit Creek Lower, Skeleton Creek, Werribee River Lower, Little River Lower, Laverton Creek and Cherry Creek sub-catchments).

Sediment in the Kororoit Creek Lower Sub-catchment was assessed to be highly toxic, while sediment in the Werribee River Lower, Laverton Creek and Cherry Creek sub-catchments was assessed as moderately toxic. Overall, sediment quality in the Werribee catchment is relatively poor, with no sites indicating any significant improvement in the mPECq throughout the study period (Table 4).

Trends in zinc, copper and lead were assessed in further detail from two focus sites: Truganina Swamp and Skeleton Creek. Zinc and lead significantly decreased in Skeleton Creek (p=0.0021, p=0.004) as did lead in Truganina Swamp (p=0.045) despite expansion of industrial areas nearby (Table 5, Table 6, Table 7).

## 3.6. Sediment quality in wetlands

Fifteen of the 55 SQMP sites are wetlands. Mean overall sediment toxicity and concentrations of zinc, copper and lead did not differ between wetlands and estuaries or wetlands and streams (t-test, >0.05) (Figure 7, Figure 8). Bifenthrin was detected significantly more in wetland sites compared to estuaries (t-test, p=0.03) but not streams (t-test, p>0.05) (Figure 6) and at much higher concentrations. Bifenthrin was routinely detected in 2020 from all habitat types above the LC50 for amphipods (1.09 (±0.08) µg/g OC) (Figure 10).

**Table 4. Mean PECq values for all 55 SQMP monitoring sites between 2010 and 2021. Mean PECq values for 2011, 2014, 2016 and 2018 were only calculated for sites of interest. Cells are highlighted to reflect likelihood of amphipod toxicity (Table 2) and to display temporal trends (green = low (<0.5), orange = moderate (0.5-<1), red = high (>1)).**

| Site code | HWS Sub-Catchment | Site | Priority | 2010 | 2011 | 2012 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | p | ↑↓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DANDENONG** | | | | | | | | | | | | | | | | |
| 527 | Dandenong Creek Lower | Southern Road Retarding Basin | High | 5.66 | | 5.96 | | 1.86 | | 0.12 | | 4.43 | 4.20 | | NS | - |
| 526 | | Mordialloc Creek | High | 1.78 | | 1.97 | | 0.63 | | 2.02 | | 2.00 | 1.84 | 1.99 | NS | - |
| 525 | | Edithvale South Wetland | High | 0.87 | | 0.48 | | 0.25 | | 0.81 | | | 0.56 | 0.38 | NS | - |
| 520 | | Dandenong Creek | High | 0.56 | | 0.74 | | 0.29 | | 0.21 | | 0.43 | 0.86 | 0.87 | NS | - |
| 516 | Dandenong Creek Middle | Dandenong Valley Wetland | High | 0.47 | | 0.57 | | 0.20 | | 0.15 | | 0.41 | 0.39 | 0.26 | NS | - |
| 514 | Dandenong Creek Upper | Dandenong Creek (Liverpool Rd) | High | 0.16 | | 0.19 | | 0.18 | | 0.11 | | 0.36 | 0.25 | 0.28 | NS | - |
| 524 | Kananook Creek | Kananook Creek | High | 1.68 | | 1.49 | | 0.61 | | 0.43 | | 1.79 | 1.33 | 1.30 | NS | - |
| 521 | | Lake Legana | High | 0.26 | | 0.49 | | 0.27 | | 0.85 | | 0.41 | 0.26 | 0.33 | NS | - |
| 29 | Eumemmerring Creek | Lynbrook Estate Wetland | High | 0.67 | 0.64 | 0.82 | 0.95 | 0.41 | 1.04 | 0.42 | 1.15 | 1.03 | 1.46 | 1.32 | 0.034 | ↑ |
| 519 | | Eumemmerring Creek | High | 1.09 | 0.99 | 1.12 | | 0.44 | 0.94 | 0.28 | 1.18 | 1.06 | 1.01 | 1.15 | NS | - |
| 515 | Corhanwarrabul, Monbulk and Ferny Creeks | Corhanwarrabul Creek | High | 0.34 | | 0.31 | | 0.23 | | 0.16 | | 0.49 | 0.31 | 0.38 | NS | - |
| **MARIBYRNONG** | | | | | | | | | | | | | | | | |
| 538 | Maribyrnong River | Maribyrnong River Estuary | High | 0.67 | | 0.67 | | 0.69 | | 0.56 | | 1.31 | 0.78 | 0.67 | NS | - |
| 36 | | Maribyrnong River (Canning Street) | Low | 0.45 | | 0.38 | | 0.32 | | 0.30 | | 0.78 | 0.50 | 0.59 | NS | - |
| 35 | | Maribyrnong River (Calder Highway) | High | 0.36 | | 0.50 | | 0.29 | | 0.30 | | 0.54 | 0.60 | 0.43 | NS | - |
| 506 | Moonee Ponds Creek | Moonee Ponds Creek | High | 2.06 | | 2.20 | | 0.81 | | 0.48 | | 1.59 | 1.96 | 1.86 | NS | - |
| 41 | | Shankland Wetland | High | 0.55 | 0.71 | 0.68 | 0.72 | 0.37 | 0.45 | 0.25 | 0.36 | 0.69 | 0.26 | 0.32 | 0.05 | ↓ |
| 40 | | Brodies Lakes | High | 0.27 | 0.38 | 0.30 | 0.31 | 0.23 | 0.25 | 0.11 | 0.29 | 0.49 | 0.32 | 0.35 | NS | - |
| 505 | Jacksons Creek | Jacksons Creek | High | 0.45 | 0.38 | 0.37 | | 0.23 | 0.40 | 0.93 | 0.37 | 0.39 | 0.42 | 0.41 | NS | - |

| Site code | HWS Sub-Catchment | Site | Priority | 2010 | 2011 | 2012 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | p | ↑↓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 504 | Stony Creek | Stony Creek | High | 2.24 |  | 2.38 |  | 0.92 |  | 0.23 |  | 2.41 | 2.93 | 2.38 | NS | - |
| 31 | Deep Creek Lower | Deep Creek (Trap Street) | High | 0.31 |  | 0.30 |  | 0.23 |  | 0.52 |  | 0.71 | 0.33 | 0.44 | NS | - |
| **WERRIBEE** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 536 | Kororoit Creek Lower | Kororoit Creek Estuary | High | 1.15 |  | 1.43 |  | 0.68 |  | 0.64 |  | 2.51 | 1.25 | 1.27 | NS | - |
| 503 |  | Kororoit Creek | Low | 0.90 |  | 1.29 |  | 0.67 |  | 1.05 |  | 2.66 | 1.29 | 1.13 | NS | - |
| 502 | Skeleton Creek | Skeleton Creek | High | 0.62 | 0.62 | 0.59 |  | 0.26 | 0.50 | 0.70 | 0.51 | 0.60 | 0.52 | 0.44 | NS | - |
| 501 | Werribee River Lower | Werribee River | High | 0.92 |  | 1.48 |  | 0.59 |  | 0.34 |  | 0.82 | 0.95 | 0.56 | NS | - |
| 411 |  | Werribee River Estuary | High | 0.37 |  | 0.36 |  | 0.21 |  | 0.29 |  | 0.62 | 0.44 | 0.40 | NS | - |
| 410 | Little River Lower | Little River Estuary | High | 0.34 |  | 0.40 |  | 0.28 |  | 0.30 |  | 0.90 | 0.51 | 0.42 | NS | - |
| 320 | Laverton Creek | Truganina Swamp | High | 0.55 | 0.59 | 0.72 | 0.72 | 0.39 | 0.62 | 0.37 | 0.56 | 0.50 | 0.68 | 0.58 | NS | - |
| 316 | Cherry Creek | Cherry Lake | High | 0.71 |  | 0.95 |  | 0.51 |  | 0.70 |  | 1.10 | 0.84 | 0.91 | NS | - |
| **WESTERNPORT AND MORNINGTON PENINSULA** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1272 | French and Phillip Islands | Fisher's Wetland |  | 0.32 |  |  |  |  |  | 0.27 |  | 0.41 | 0.27 | 0.39 | NS | - |
| 535 | Bunyip Lower | Bunyip River Estuary | High | 0.23 |  | 0.19 |  | 0.19 |  | 0.19 |  | 0.38 | 0.26 | 0.23 | NS | - |
| 422 | Mornington Peninsula North-Eastern Creeks | Watson's Creek Estuary | High | 0.26 |  | 0.26 |  | 0.27 |  | 0.41 |  | 0.36 | 0.29 | 0.27 | NS | - |
| 532 |  | Warrangine Creek Estuary | High |  |  | 0.28 |  | 0.23 |  | 0.27 |  | 0.42 | 0.37 | 0.29 | NS | - |
| 531 | Mornington Peninsula South-Eastern Creeks | Merricks River Estuary | High | 0.22 |  | 0.19 |  | 0.16 |  | 0.17 |  | 0.26 | 0.21 | 0.19 | NS | - |
| 533 | Mornington Peninsula Western Creeks | Balcombe Creek Estuary | High | 0.62 | 0.89 | 0.60 |  | 0.32 | 0.61 | 0.35 | 0.60 | 0.86 | 0.56 | 0.57 | NS | - |
| 523 |  | Balcombe Creek | High | 0.51 | 0.46 | 0.35 |  | 0.26 | 0.51 | 1.09 | 0.50 | 0.56 | 0.42 | 0.43 | NS | - |
| 522 |  | Chinaman Creek | High | 2.11 | 2.69 | 1.97 |  | 0.68 | 2.07 | 0.29 | 1.67 | 1.48 | 1.92 | 1.96 | NS | - |
| 530 | Bass River | Bass River Estuary | High | 0.15 |  | 0.14 |  | 0.12 |  | 0.12 |  | 0.29 | 0.18 | 0.14 | NS | - |
| 518 | Cardinia, Toomuc, Deep and Ararat Creeks | Cardinia Creek | Low | 0.17 |  | 0.17 |  | 0.13 |  | 0.45 |  | 0.34 | 0.19 | 0.17 | NS | - |
| 517 |  | Deep Creek (Ballarto Rd) | High | 0.23 |  | 0.21 |  | 0.16 |  | 0.10 |  | 0.43 | 0.29 | 0.23 | NS | - |
| 534 |  | Cardinia River Estuary | High | 0.21 |  | 0.26 |  | 0.20 |  | 0.23 |  | 0.43 | 0.29 | 0.25 | NS | - |
| **YARRA** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 12 | Yarra River Upper (Rural) | Yarra River (Don Rd) | High | 0.25 |  | 0.21 |  | 0.17 |  | 0.15 |  | 0.23 | 0.22 | 0.24 | NS | - |

| Site code | HWS Sub-Catchment | Site | Priority | 2010 | 2011 | 2012 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | p | ↑↓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 537 | Yarra River Lower | Yarra River Estuary | High | 0.71 |  | 0.78 |  | 0.68 |  | 0.70 |  | 1.43 | 0.89 | 0.81 | NS | - |
| 513 |  | Yarra River (Warrandyte) | Low | 0.50 | 0.35 | 0.36 |  | 0.16 | 0.46 | 0.18 | 0.48 | 0.38 | 0.28 | 0.49 | NS | - |
| 507 |  | Yarra River (Spencer St) | High | 1.01 |  | 0.59 |  | 0.36 |  | 0.95 |  | 1.27 | 0.90 | 0.66 | NS | - |
| 42 |  | Yarra River D/S Dights Falls | Low |  |  |  |  | 0.54 |  | 0.37 |  | 1.04 |  | 1.14 | 0.021 | ↑ |
| 512 | Mullum Mullum Creek | Mullum Mullum Ck. | High | 0.21 |  | 0.26 |  | 0.22 |  | 0.22 |  | 0.35 | 0.20 | 0.28 | NS | - |
| 511 | Plenty River Lower | Plenty River | High | 0.41 |  | 0.33 |  | 0.24 |  | 0.16 |  | 0.52 | 0.37 | 0.46 | NS | - |
| 37 |  | Stockland Development Wetland | High | 0.16 | 0.20 | 0.19 | 0.23 | 0.18 |  | 0.26 | 0.20 | 0.33 | 0.20 | 0.23 | NS | - |
| 510 | Darebin Creek | Darebin Ck. | High | 1.88 |  | 1.59 |  | 0.65 |  | 0.26 |  | 1.32 | 0.99 | 1.33 | NS | - |
| 508 | Merri Creek Lower | Leamington St Wetland | High | 1.63 |  | 2.88 |  | 0.73 |  | 0.60 |  | 1.23 | 2.45 | 2.59 | NS | - |
| 16 |  | Merri Creek | High | 2.30 | 2.71 | 2.53 |  | 1.11 | 2.37 | 1.33 | 2.14 | 1.92 | 2.02 | 2.28 | NS | - |
| 38 | Merri Creek Upper | Highlands Estate Wetland | High | 0.20 | 0.33 | 0.25 | 0.15 | 0.13 | 0.23 | 0.18 | 0.12 | 0.25 | 0.15 | 0.13 | 0.094 | ↓ |
| 26 | Gardiners Creek | Gardiners Creek | High | 1.04 | 1.14 | 1.52 |  | 0.50 | 1.19 | 0.18 | 1.12 | 0.96 | 1.26 | 1.37 | NS | - |
| 25 | Olinda Creek | Platypus Wetlands | High | 0.19 | 0.21 | 0.18 | 0.24 | 0.17 | 0.22 | 0.23 | 0.28 | 0.39 | 0.29 | 0.25 | 0.027 | ↑ |
| 3 |  | Olinda Creek | High | 0.24 |  | 0.21 |  | 0.19 |  | 0.17 |  | 0.42 | 0.29 | 0.29 | NS | - |

**Table 5. Concentration of zinc (mg/kg) at focal sites between 2010 and 2021. The PEC for zinc is 121 mg/kg, cells shaded green are >50% of the PEC, orange cells are 50-100% of the PEC, and red cells are greater than the PEC.**

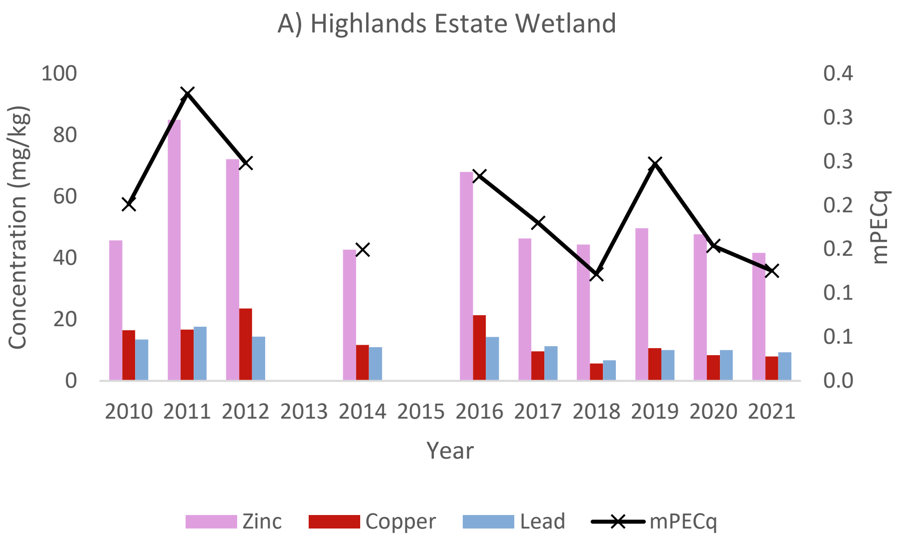
| Site code | HWS Sub-Catchment | Site | 2010 | 2011 | 2012 | 2014 | 2015 | 2016 | 2018 | 2019 | 2020 | 2021 | P | ↑↓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DANDENONG** | | | | | | | | | | | | | | |
| 29 | Eumemmerring Creek | Lynbrook Estate Wetland | 410.67 | 393.00 | 505.78 | 624.67 | | 705.33 | 831.67 | 881.30 | 993.00 | 945.00 | <0.001 | ↑ |
| 519 | | Eumemmerring Creek | 731.73 | 612.00 | 730.42 | | 696.25 | 611.67 | 813.67 | 711.30 | 594.00 | 730.00 | NS | - |
| **MARIBYRNONG** | | | | | | | | | | | | | | |
| 40 | Moonee Ponds Creek | Brodies Lakes | 76.67 | 97.33 | 76.78 | 89.67 | | 79.00 | 83.33 | 84.00 | 95.67 | 97.00 | NS | - |
| 41 | | Shankland Wetland | 299.00 | 410.33 | 381.00 | 393.33 | | 206.67 | 162.67 | 309.00 | 44.67 | 83.00 | 0.01 | ↓ |
| 505 | Jacksons Creek | Jacksons Creek | 188.44 | 118.33 | 129.78 | | 139.33 | 165.33 | 153.67 | 118.00 | 168.00 | 172.67 | NS | - |
| **WERRIBEE** | | | | | | | | | | | | | | |
| 320 | Laverton Creek | Truganina Swamp | 261.33 | 297.88 | 369.17 | 376.33 | | 307.33 | 271.00 | 189.00 | 358.33 | 303.33 | NS | - |
| 502 | Skeleton Creek | Skeleton Creek | 332.67 | 330.67 | 287.78 | | 199.00 | 242.67 | 240.00 | 217.70 | 229.67 | 172.67 | 0.0021 | ↓ |
| **WESTERN PORT AND MORNINGTON PENINSULA** | | | | | | | | | | | | | | |
| 522 | Mornington Peninsula Western Creeks | Chinaman Creek | 1501.25 | 1945.00 | 1378.33 | | | 1470.00 | 1150.00 | 1330.00 | 1353.33 | 1420.00 | NS | - |
| 523 | | Balcombe Creek | 253.22 | 222.00 | 166.00 | | | 288.33 | 288.33 | 263.30 | 230.00 | 229.33 | NS | - |
| 533 | | Balcombe Creek Estuary | 324.22 | 391.00 | 273.83 | | 228.33 | 315.00 | 269.33 | 264.30 | 221.00 | 273.33 | 0.068 | ↓ |
| **YARRA** | | | | | | | | | | | | | | |
| 25 | Olinda Creek | Platypus Wetlands | 81.67 | 85.83 | 68.33 | 97.00 | | 88.33 | 129.67 | 129.00 | 136.00 | 108.00 | 0.007 | ↑ |
| 37 | Plenty River Lower | Stockland Development Wetland | 30.00 | 40.00 | 43.11 | 57.33 | | 80.00 | 50.33 | 51.70 | 48.00 | 67.67 | NS | - |
| 38 | Merri Creek Upper | Highlands Estate Wetland | 45.78 | 85.00 | 72.22 | 42.67 | | 68.00 | 44.33 | 49.70 | 47.67 | 41.67 | NS | - |
| 513 | Yarra River Lower | Yarra River (Warrandyte) | 156.00 | 67.17 | 94.67 | | 90.00 | 109.33 | 107.00 | 112.00 | 91.00 | 103.33 | NS | - |

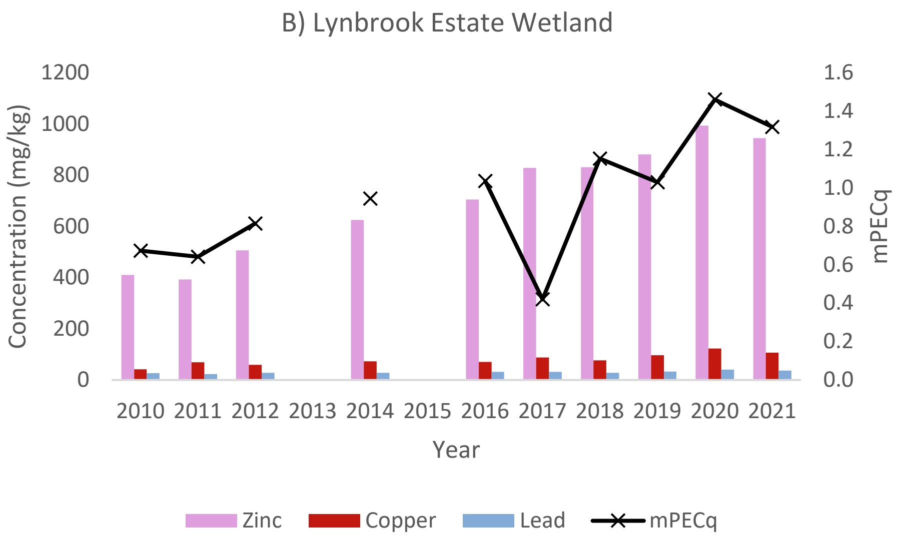
**Table 6. Concentration of copper (mg/kg) at focal sites between 2010 and 2021. The PEC for copper is 149 mg/kg, cells shaded green are >50% of the PEC, orange cells are 50-100% of the PEC, and red cells are greater than the PEC.**

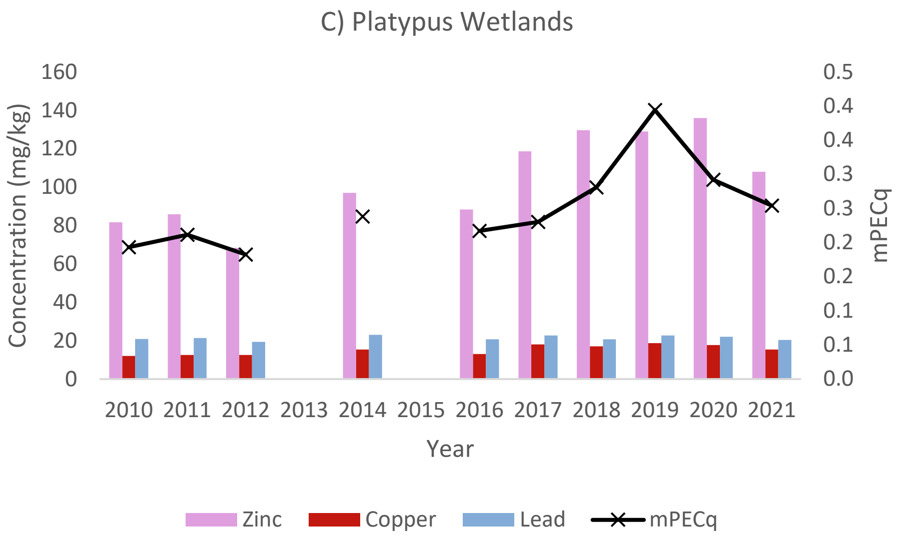
| Site code | HWS Sub-Catchment | Site | 2010 | 2011 | 2012 | 2014 | 2015 | 2016 | 2018 | 2019 | 2020 | 2021 | p | ↑↓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DANDENONG** | | | | | | | | | | | | | | |
| 29 | Eumemmerring Creek | Lynbrook Estate Wetland | 41.33 | 68.67 | 59.22 | 73.33 | | 70.33 | 76.67 | 96.70 | 123.33 | 106.67 | 0.001 | ↑ |
| 519 | | Eumemmerring Creek | 71.45 | | 102.58 | | 76.50 | 69.67 | 88.00 | 91.30 | 94.00 | 109.67 | NS | - |
| **MARYBYRNONG** | | | | | | | | | | | | | | |
| 40 | Moonee Ponds Creek | Brodies Lakes | 23.44 | 28.33 | 20.22 | 23.00 | | 19.67 | 19.33 | 24.00 | 24.33 | 25.00 | NS | - |
| 41 | | Shankland Wetland | 42.78 | 29.67 | 47.89 | 47.67 | | 31.00 | 23.33 | 39.70 | 16.00 | 22.00 | 0.054 | ↓ |
| 505 | Jacksons Creek | Jacksons Creek | 41.33 | | 27.67 | | 24.00 | 32.00 | 30.33 | 22.70 | 30.00 | 32.67 | NS | - |
| **WERRIBEE** | | | | | | | | | | | | | | |
| 320 | Laverton Creek | Truganina Swamp | 38.89 | | 53.67 | 53.00 | | 45.00 | 36.33 | 29.00 | 51.67 | 42.00 | NS | - |
| 502 | Skeleton Creek | Skeleton Creek | 42.78 | | 41.67 | | 28.00 | 30.67 | 41.00 | 37.00 | 51.67 | 39.33 | NS | - |
| **WESTERN PORT AND MORNINGTON PENINSULA** | | | | | | | | | | | | | | |
| 522 | Mornington Peninsula Western Creeks | Chinaman Creek | 97.88 | | 96.50 | | | 87.00 | 89.00 | 88.70 | 97.67 | 99.67 | NS | - |
| 523 | | Balcombe Creek | 29.56 | 112.00 | 25.17 | | | 29.33 | 31.67 | 31.30 | 27.00 | 29.00 | NS | - |
| 533 | | Balcombe Creek Estuary | 48.89 | | 49.50 | | 39.00 | 53.00 | 56.00 | 50.30 | 52.33 | 58.00 | NS | - |
| **YARRA** | | | | | | | | | | | | | | |
| 25 | Olinda Creek | Platypus Wetlands | 12.11 | 125.67 | 12.50 | 15.33 | | 13.00 | 17.00 | 18.70 | 17.67 | 15.33 | NS | - |
| 37 | Plenty River Lower | Stockland Development Wetland | 12.78 | | 14.22 | 16.67 | | 19.00 | 13.00 | 13.30 | 11.67 | 16.33 | NS | - |
| 38 | Merri Creek Upper | Highlands Estate Wetland | 16.44 | 16.67 | 23.56 | 11.67 | | 21.33 | 5.67 | 10.70 | 8.33 | 8.00 | 0.037 | ↓ |
| 513 | Yarra River Lower | Yarra River (Warrandyte) | 16.83 | | 11.33 | | 11.67 | 15.00 | 15.67 | 15.30 | 12.00 | 13.67 | NS | - |

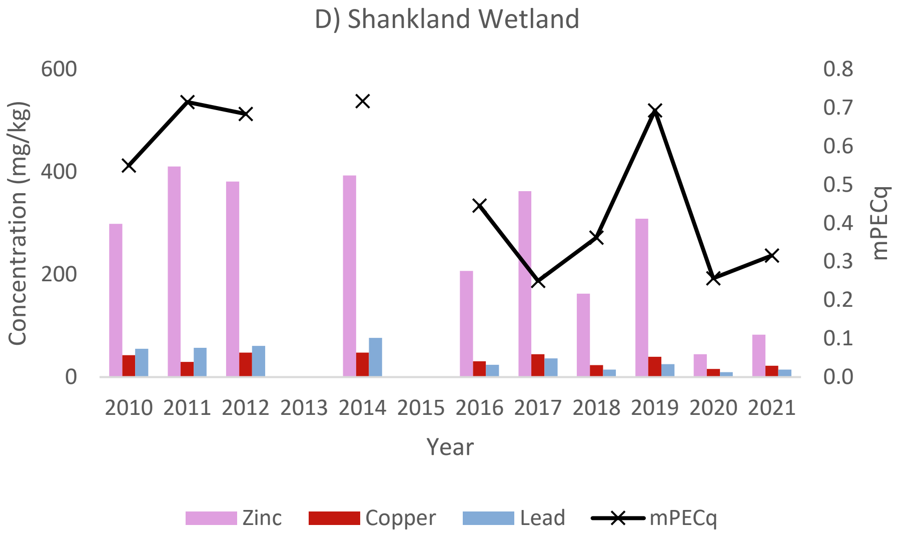
**Table 7. Concentration of lead (mg/kg) at focal sites between 2010 and 2021. The PEC for lead is 128 mg/kg, cells shaded green are >50% of the PEC, orange cells are 50-100% of the PEC, and red cells are greater than the PEC.**

| Site code | HWS Sub-Catchment | Site | 2010 | 2011 | 2012 | 2014 | 2015 | 2016 | 2018 | 2019 | 2020 | 2021 | p | ↑↓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DANDENONG** | | | | | | | | | | | | | | |
| 29 | Eumemmerring Creek | Lynbrook Estate Wetland | 26.78 | 23.00 | 28.44 | 28.33 | | 31.33 | 28.33 | 32.70 | 40.00 | 36.33 | 0.005 | ↑ |
| 519 | | Eumemmerring Creek | 70.00 | 64.75 | 76.08 | | 73.75 | 53.33 | 71.00 | 52.00 | 55.33 | 55.33 | 0.063 | ↓ |
| **MARYBYRNONG** | | | | | | | | | | | | | | |
| 40 | Moonee Ponds Creek | Brodies Lakes | 11.89 | 14.33 | 12.00 | 12.67 | | 11.33 | 10.33 | 10.30 | 12.67 | 11.67 | NS | - |
| 41 | | Shankland Wetland | 55.11 | 57.33 | 61.00 | 76.33 | | 24.00 | 14.67 | 25.30 | 9.67 | 14.33 | 0.004 | ↓ |
| 505 | Jacksons Creek | Jacksons Creek | 30.11 | 27.00 | 30.11 | | 29.00 | 25.67 | 20.00 | 15.00 | 26.33 | 20.00 | 0.026 | ↓ |
| **WERRIBEE** | | | | | | | | | | | | | | |
| 320 | Laverton Creek | Truganina Swamp | 49.22 | 38.25 | 48.00 | 51.33 | | 42.33 | 29.33 | 21.70 | 40.33 | 31.33 | 0.045 | ↓ |
| 502 | Skeleton Creek | Skeleton Creek | 47.00 | 39.00 | 44.22 | | 31.00 | 35.33 | 32.67 | 30.00 | 32.67 | 26.33 | 0.001 | ↓ |
| **WESTERN PORT and MORNINGTON** | | | | | | | | | | | | | | |
| 522 | Mornington Peninsula Western Creeks | Chinaman Creek | 118.25 | 128.33 | 114.33 | | | 96.33 | 92.00 | 105.00 | 96.67 | 75.33 | 0.005 | ↓ |
| 523 | | Balcombe Creek | 44.22 | 47.50 | 43.33 | | | 38.67 | 36.33 | 42.30 | 34.00 | 40.00 | 0.033 | ↓ |
| 533 | | Balcombe Creek Estuary | 61.56 | 169.00 | 110.67 | | 93.00 | 48.67 | 86.00 | 93.70 | 96.67 | 51.33 | NS | - |
| **YARRA** | | | | | | | | | | | | | | |
| 25 | Olinda Creek | Platypus Wetlands | 20.89 | 21.33 | 19.33 | 23.00 | | 20.67 | 20.67 | 22.70 | 22.00 | 20.33 | NS | - |
| 37 | Plenty River Lower | Stockland Development Wetland | 12.44 | 15.00 | 12.56 | 13.33 | | 12.00 | 9.67 | 11.00 | 9.33 | 11.00 | 0.011 | ↓ |
| 38 | Merri Creek Upper | Highlands Estate Wetland | 13.44 | 17.67 | 14.44 | 11.00 | | 14.33 | 6.67 | 10.00 | 10.00 | 9.33 | 0.018 | ↓ |
| 513 | Yarra River Lower | Yarra River (Warrandyte) | 22.17 | 13.83 | 17.50 | | 17.00 | 21.67 | 21.67 | 19.00 | 15.67 | 20.00 | NS | - |


A) Highlands Estate Wetland


B) Lynbrook Estate Wetland


C) Platypus Wetlands



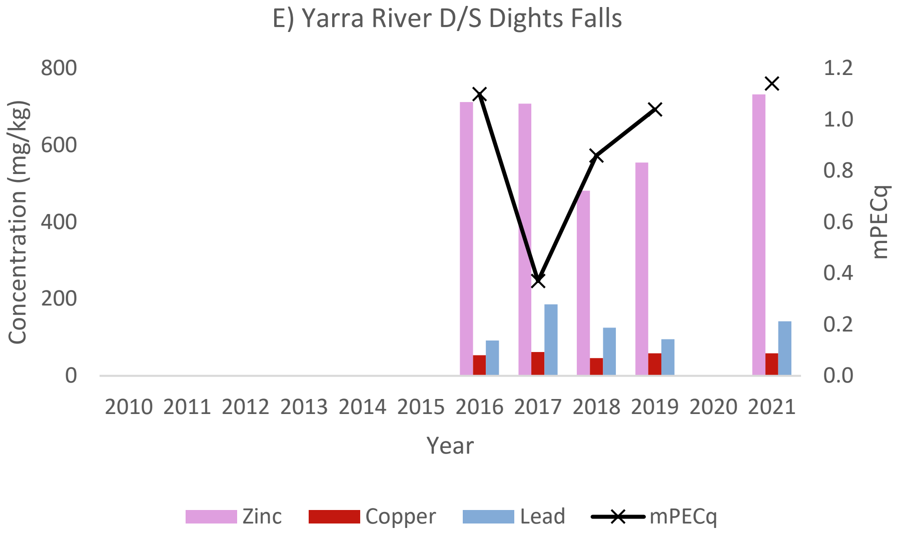
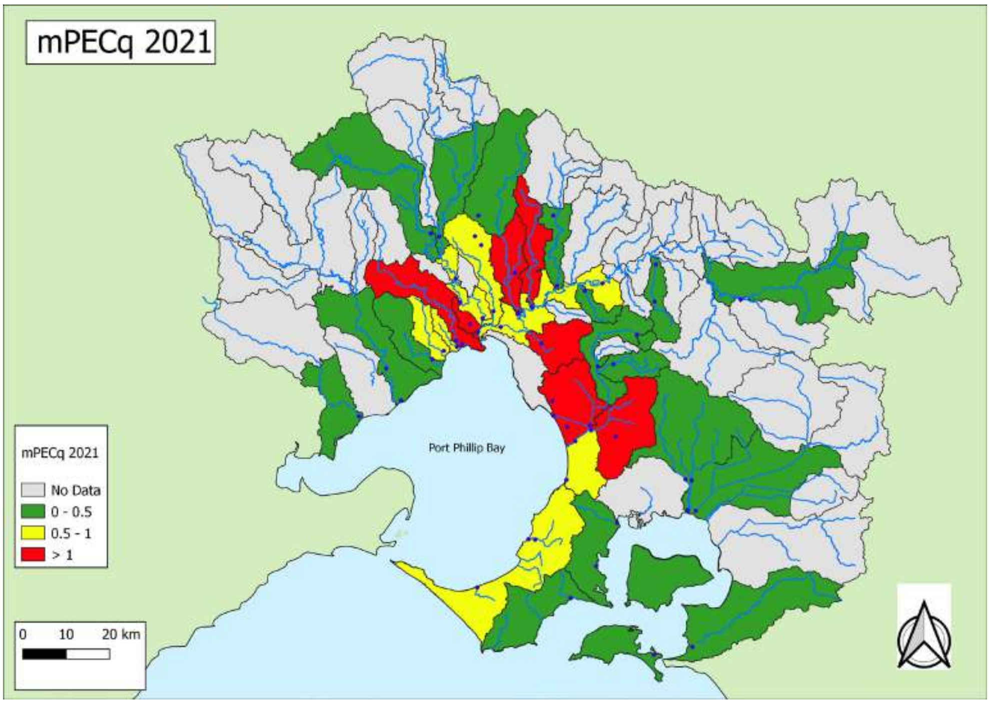


**Figure 2. Temporal trends in overall sediment toxicity (mPECq) at sites where a significant trend was identified (A) Highland Estate Wetland, B) Lynbrook Estate Wetland, C) Platypus Wetlands, D) Shankland Wetland, and E) Yarra River downstream of Dights Falls) and their respective concentrations of zinc, copper and lead. Site 42, Yarra River downstream of Dights Falls, was added to the sediment quality monitoring program in 2016 and could not be sampled in 2020 due to flow conditions. Sites were not sampled in 2013, and only select sites were sampled in 2014 and 2015.**

A)



B)

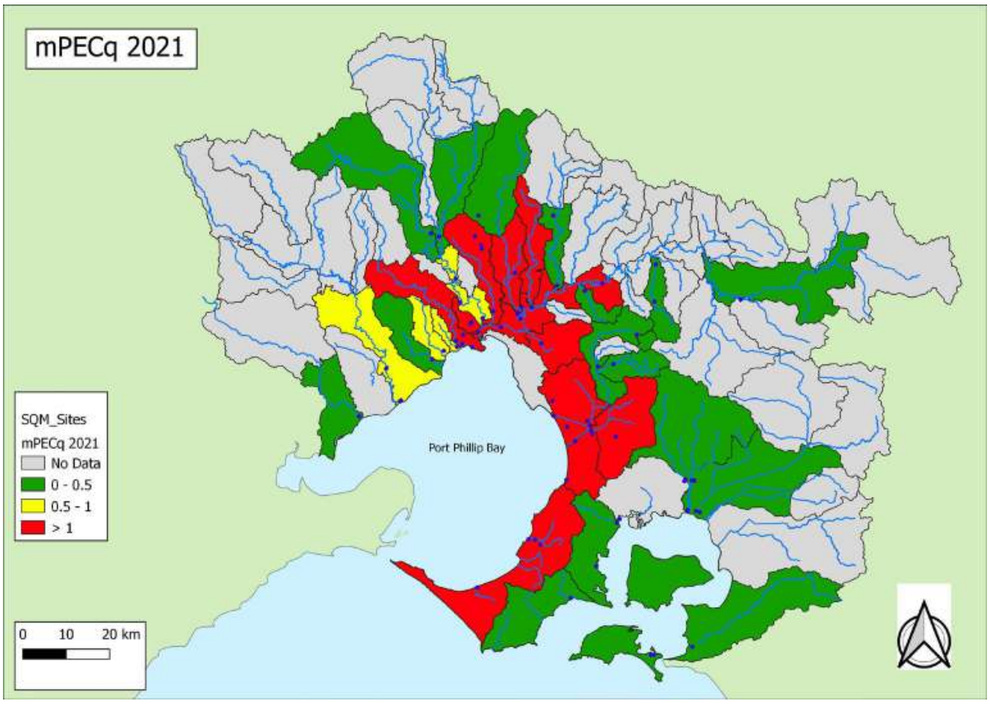
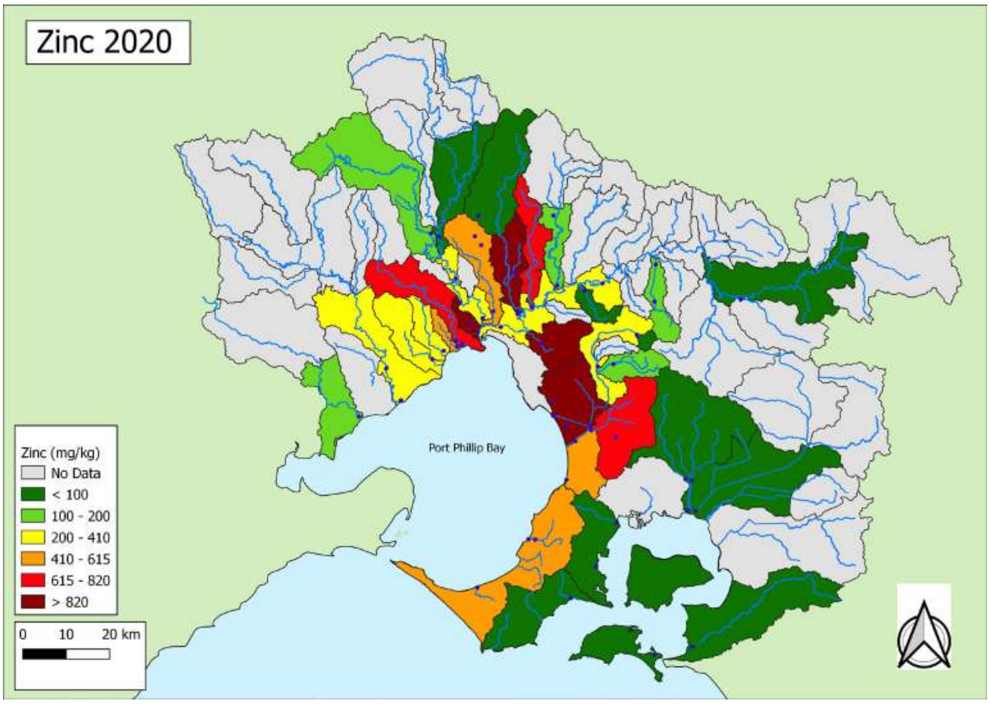


**Figure 3. mPECq in Sub-catchments with at least one site in 2021. Where there are multiple sites in a sub-catchment, A) shows the average, B) shows the maximum reported. Green indicates sub-catchments with low overall sediment toxicity, yellow indicates moderate toxicity and red indicates sub-catchments with high sediment toxicity.**



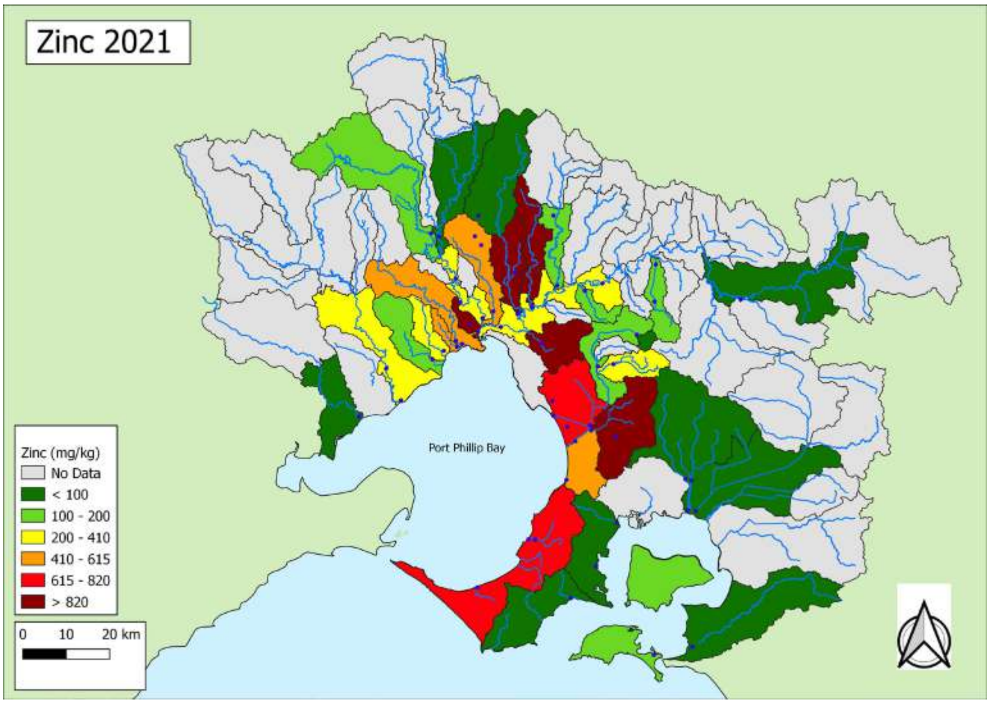


**Figure 4. Mean concentration of zinc in 2020 and 2021 in Sub-catchments with at least one site. Concentrations have been averaged where there are multiple sites within a Sub-catchment. Zinc PEC = 459 mg/kg (MacDonald et al. 2000); DGV = 200 mg/kg, GV-High = 410 mg/kg (ANZG, 2018).**

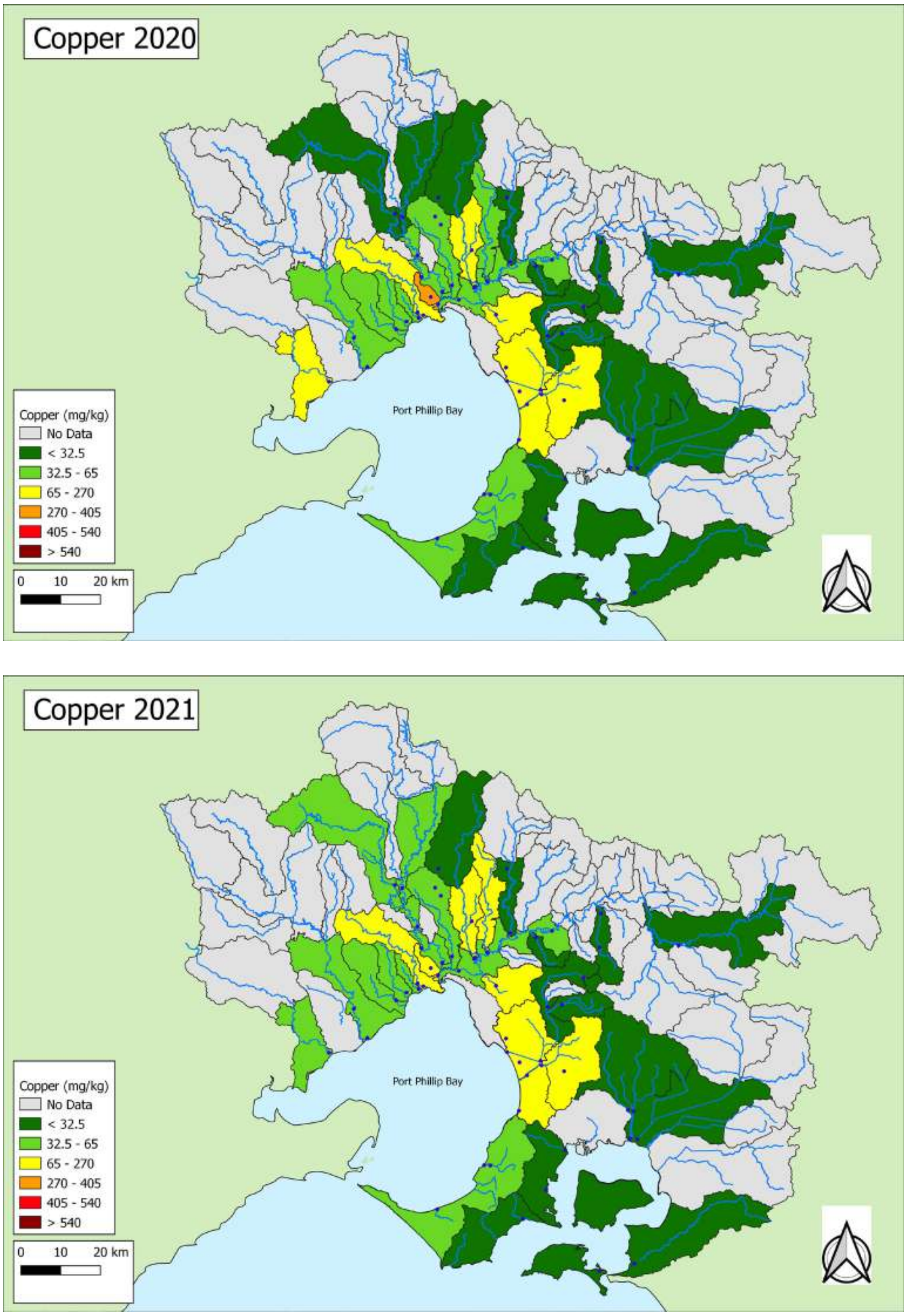


**Figure 5. Mean concentration of copper in 2020 and 2021 in Sub-catchments with at least one site. Concentrations have been averaged where there are multiple sites within a Sub-catchment. Copper PEC = 149 mg/kg (MacDonald et al. 2000); DGV = 65 mg/kg, GV-High = 270 mg/kg (ANZG, 2018).**

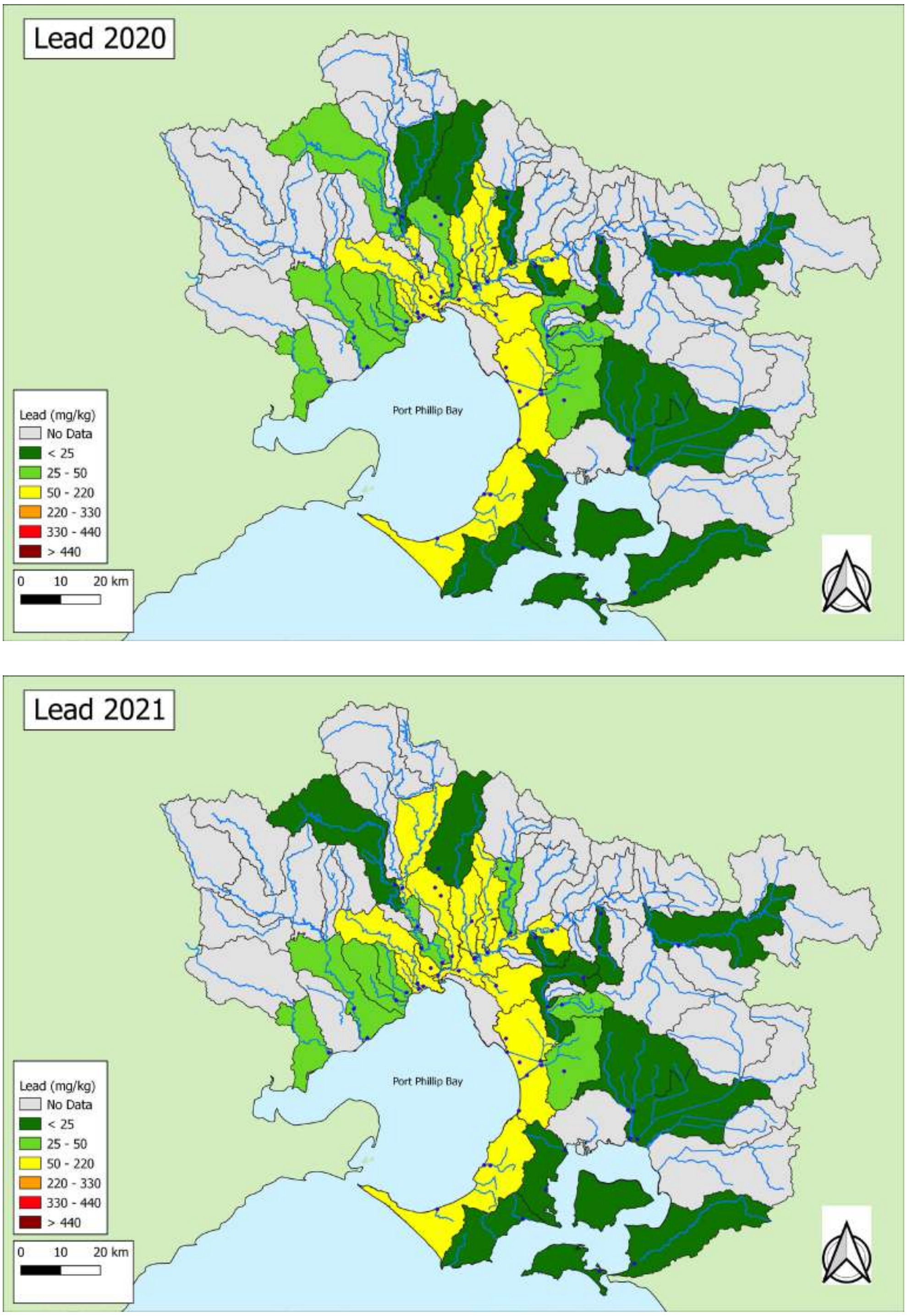


**Figure 6. Mean concentration of lead in 2020 and 2021 in Sub-catchments with at least one site. Concentrations have been averaged where there are multiple sites within a Sub-catchment. Lead PEC = 128 mg/kg (MacDonald et al. 2000); DGV = 50 mg/kg, GV-High = 220 mg/kg (ANZG, 2018).**

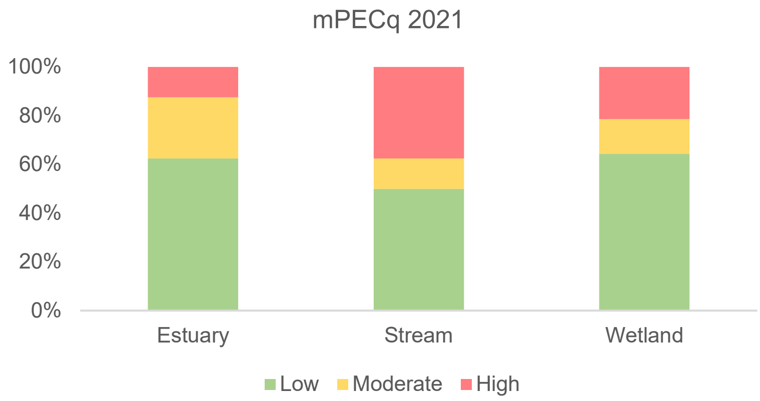


**Figure 7. Overall toxicity of sediment in different aquatic environments.**

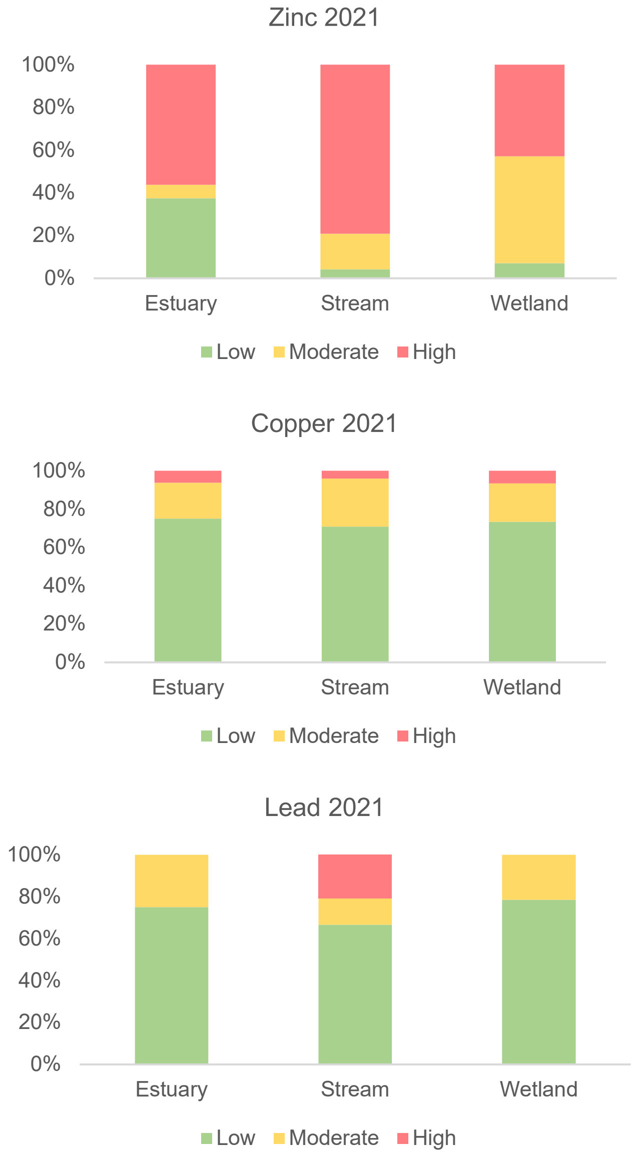


**Figure 8. Relative frequency of low, moderate and high concentrations of zinc, copper and lead found in sediments in 2021 in different aquatic habitats.**

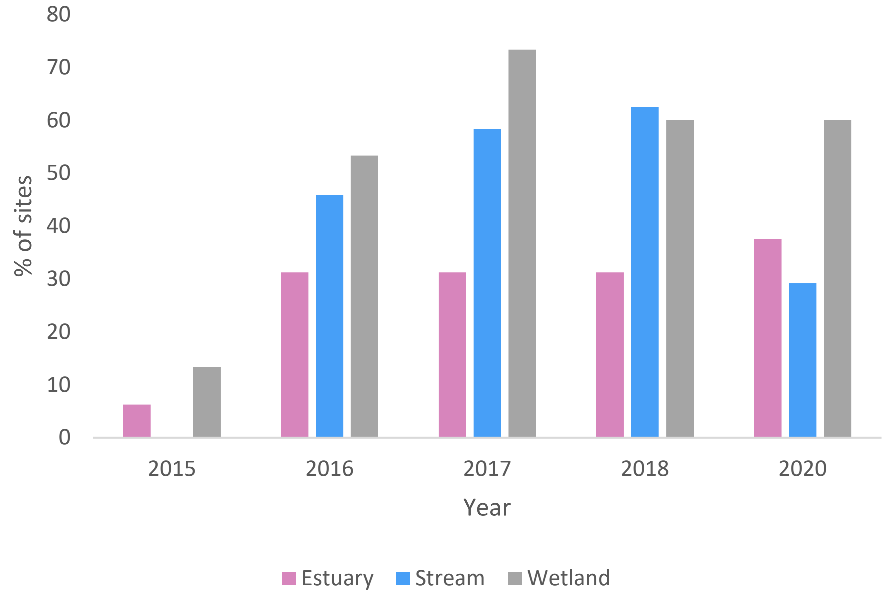


**Figure 9. Proportion of bifenthrin detections in different aquatic environments between 2015 and 2020. Detection frequency was generally greatest in wetlands. Pesticides were not analysed in 2019 or 2021.**

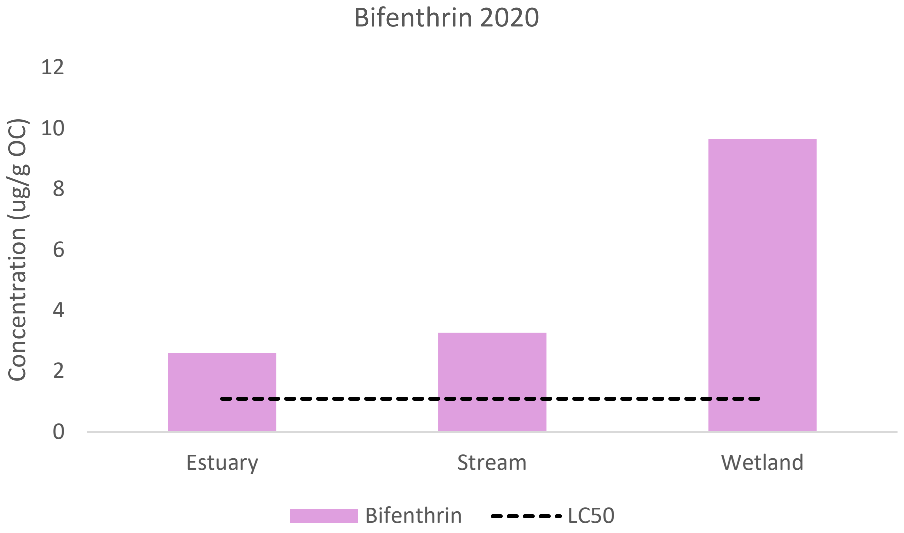


**Figure 10. Mean concentration of bifenthrin in different habitat types in the Greater Melbourne Area in 2020. Amphipod toxicity (LC50) accepted in this report is 1.09 (±0.08) µg/gOC (Jeppe et al. 2017).**

# 4. Discussion

The SQMP provides spatio-temporal monitoring data on the quality of sediment at 55 sites across all 5 major HWS catchments and 33 of the 69 HWS sub-catchments. This data provides information on the historic, current and probable future state of waterways across Melbourne and is essential to the successful long-term management of key values and fulfilment of catchment management objectives. The data was used to identify significant trends in sediment quality and to identify sites that have been under long-term stress from aquatic pollution which may benefit from additional management actions to meet catchment objectives. Overall sediment quality was degraded in more urbanised areas in the lower reaches of catchments as is consistent with previous reporting.

Significant change in overall sediment toxicity was detected at five monitoring sites, including one urban stream and four wetland sites (Highland Estate Wetland, Lynbrook Estate Wetland, Platypus Wetlands, Shankland Wetland, and Yarra River downstream of Dights Falls). Sediment quality at the Highlands Estate Wetland (Merri Creek Upper Sub-catchment) and Shankland Wetland (Moonee Ponds Creek Sub-catchment) improved significantly between 2010 and 2021. Shankland Wetland had been identified in previous reports as a site of potential concern (Sharp and Sharley 2017). This site was desilted in February 2020 which may explain the reduction in mPECq from 2019. In addition, a series of constructed wetlands have been developed further upstream which may be capturing sediment bound contaminants before they can enter Shankland Wetland. Similar reductions in sediment contamination following desilting may be observed at sites not monitored here. Desilting records should be cross referenced with mPECq values to understand how this practice is supporting the sediment management and rectification programs.

Conversely, at the Platypus Wetlands, Lynbrook Estate Wetland, and in the Yarra River near Dights Falls sediment quality has significantly declined since the inception of the SQMP. Although overall sediment quality has significantly declined at the Platypus Wetlands, toxicity remains relatively low and is below the ecological threshold for concern. Zinc is the primary factor driving the upward trend. No change in the surrounding land use was visually identifiable over the study period. However, changes in land use from commercial or residential to industrial may not be immediately identifiable from a rapid visual assessment. Maintaining the quality of sediment at Platypus Wetland is essential to preserve habitat suitability for healthy waterway values (i.e., platypus) present.

Monitoring of sediment at both the Lynbrook Estate Wetland and in the Yarra River near Dights Falls indicate increasing long-term ecological stress. Sediment at these sites is moderately to highly toxic. The decline of sediment quality at these sites presents a challenge for the fulfilment of performance objectives for the Yarra and Dandenong catchments. Upstream interventions may help to alleviate some of the ecological pressures resulting from degraded sediment quality. As the monitoring site is located just downstream of the Merri Creek confluence into the Yarra River it may be prudent to investigate where the greatest pressures are flowing from.

Most sites showed no change in sediment quality between 2010 and 2021. Approximately a third of urban waterways monitored, and their respective sub-catchments, had moderately to highly toxic sediment and are experiencing long term stress (e.g., Merri Creek, Kororoit Creek Estuary, Eumemmerring Creek, Mordialloc Creek). At these sites, the health of local flora and fauna communities may be affected, and the associated recreational value of the surrounding area may be reduced. Instream sediment quality of the most affected sites may be improved long-term by management of the upstream environment, such as maintaining healthy wetland environments. These actions may help to improve the overall sediment quality of the catchment.

Patterns in mean sediment toxicity may be obscured by mPECq calculations. An increase in one contaminant may be negated by a decrease in another. This may disguise changes in contaminants of concern or of interest to management and industry. When zinc, copper and lead concentrations were isolated and analysed for focal sites, significant trends were identified at a considerably larger proportion of sites. Skeleton Creek and Balcombe Creek Estuary showed no significant change in mPECq, despite zinc significantly reducing over the study period. Similarly lead decreased at seven focal sites which showed no change in mPECq (Eumemmerring Creek, Shankland Wetland, Jacksons Creek, Truganina Swamp, Skeleton Creek, Chinamans Creek, Balcombe Creek, Stockland Development Wetland, Highlands Estate Wetland). Individual contaminants should continue to be reviewed to avoid overlooking potentially important changes.

Land use is an important determinant of aquatic pollution (Foley et al. 2005, Kellar et al. 2014, Sharley et al. 2017). Increasing pressure from rapid urban development and broad scale agriculture across all 5 major catchments present a potential risk for adverse impacts to waterways and aquatic ecosystems.

High concentrations of zinc were detected broadly across the Greater Melbourne Area but were greatest in more urbanised areas of catchments compared to sites located in agricultural areas or in the upper reaches of the catchments with fewer pressures from development. However, even sediment from sites located in peri-urban areas or on the outskirts of urban areas had highly toxic concentrations of zinc. Stormwaters discharged from catchments with industrial activity are more likely to have higher concentrations of heavy metals, hydrocarbons and other pollutants, compared to other land use types (Kellar et al. 2014). Zinc, copper and cadmium are particularly pervasive in sediments of industrial catchments, while the concentration of lead is better explained by commercial activities and the age of the catchment (Sharley et al. 2017).

Heavy metal concentrations and overall sediment toxicity in wetlands sampled in 2021 was comparable to estuaries and streams. In contrast, the synthetic pyrethroid insecticide, bifenthrin was detected significantly more frequently in wetland habitats compared to estuaries (but not streams), and generally at higher mean concentrations. Land use characteristics are an important factor contributing to the quality of sediment in wetlands. Differences in the detection of bifenthrin between wetlands and estuaries likely reflect differences in the surrounding land use (and associated proximity to point sources) rather than factors associated with the habitat type. Bifenthrin is used for insect control in agriculture, turf and timber such as that used in new housing developments (Pettigrove and MacMahon 2019). Concentrations of bifenthrin found throughout the study area routinely exceeded ecological thresholds but were greatest in wetlands relative to streams and estuaries. Persistent elevated concentrations of bifenthrin could alter macroinvertebrate communities and have cascading impacts to higher life (e.g. birds) that utilise wetlands. Sediment quality at some urban wetlands, however, has been particularly poor since the start of the SQMP, such as at Leamington Street Wetland and the Lynbrook Estate Wetland. These sites present a considerable challenge for management. It is therefore essential these habitats are managed effectively to avoid or limit potential impacts.

Overall, sediment quality has generally remained consistent across catchments, however long-term trends in zinc are more variable between sites and lead is reducing at most sites. Overall, mean sediment toxicity from 2010 to 2021 exceeded the high threshold at the Southern Road Retarding Basin, Mordialloc Creek, Kananook Creek (Dandenong Catchment), Stony Creek, Moonee Ponds Creek (Maribyrnong Catchment), Kororoit Creek, Kororoit Creek Estuary (Werribee Catchment), Chinamans Creek (Western Port and Mornington Peninsula Catchment), Merri Creek, Leamington Street Wetland, Gardiners Creek, Darebin Creek (Yarra Catchment). Many of these sites have previously been identified by the SQMP as of concern and should be of priority to management to limit the impacts of long-term heavy metal contamination. The outcomes of this monitoring program can be integrated to optimise planning and the allocation of resources to better preserve and manage waterway assets. Identification of the source of pollutants at the catchment and sub-catchment scale (including those investigated as part of the Aquatic Pollution Prevention Partnership), upstream interventions, desilting, improvement in stormwater runoff and other remediation practices may help to improve sediment quality and to fulfill catchment objectives.

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