Bio2Lab
Environmental Intelligence

Pollution profiling of Upper Dandenong catchments to inform stormwater education strategies and policy

A science driven stormwater education project

Client: First Friends of Dandenong Creek

LORD MAYOR'S CHARITABLE FOUNDATION

Prepared by
Bio2Lab Pty Ltd

Version 1.3
Phase 1 monitoring: Interim data summary report

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A summary of results can be found on Bio2Lab's Interactive Dashboard here

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Scope of this report

This report provides an interim data summary of results from Phase One. The final report (to be completed after the Phase Two of the monitoring program) will include recommendations, pollution reduction and education strategies, and a pollution investigation template that other community groups and local governments can use as a guide for similar programs.

Acknowledgements

We wish to thank First Friends of Dandenong Creek for supporting this important project and securing funding from the Lord Mayor's Charitable Foundation, and the Knox Environment Society for assistance in managing the project. Special thanks to Anthony Bigelow for his persistence in bringing this project together.

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Summary

The aim of this survey is to identify and prioritise pollution sources in Dandenong Creek above Heatherdale Creek, and work with both relevant catchment managers and the community towards a strategy to prevent pollution events from impacting the ecological condition of the creek any further. This survey aims to provide a model work-flow for other groups to follow to improve the condition of urban waterways by identifying and reducing pollution sources.

All sites below the Upper Dandenong Creek failed environmental quality objectives for sediment. The contaminants of most concern generally were zinc and oils, while specific sites had problems with silver, arsenic, bifenthrin and permethrin. Sediment quality was very poor at Old Joes Creek, Bungalook Creek and Heatherdale Creek, with metal, oil, or insecticide concentrations at these sites likely to be toxic to aquatic biota. Although Middle Dandenong Creek failed only a single environmental objective (Total Petroleum Hydrocarbons), there was evidence that silver pollution originating upstream at Old Joes Creek is already impacting the ecological condition of this site only months after completion of the restoration works. Passive samplers showed runoff from all catchments below Upper Dandenong creek was polluted. The most heavily polluted runoff was from Old Joes and Tarralla Creeks, followed by Heatherdale and Bungalook Creeks.

The recent update of the State Environmental Protection Policy for Waters of Victoria (SEPP WoV), including sediment quality guidelines is timely. For the first time in Victoria, sediment pollution can be assessed against legal environmental objectives, which should prompt investigation into the impacts of stormwater pollution on the health of Dandenong Creek, and drive more detailed monitoring to identify and control pollution sources.

To manage stormwater, the water industry primarily relies on stormwater treatment such as constructed wetlands and rain gardens to capture contaminants before they reach receiving environments. However, these strategies merely manage pollution generated from human activities and do little to reduce or stop the generation of pollutants in urban catchments.

The most effective way to reduce the ecological impact of pollution on urban waterways is to stop pollution at the source. An effective way to achieve this is through education and enforcement programs: education to increase awareness and encourage good management practices, and enforcement to discourage poor management practices. Stormwater education programs not only increase community knowledge of the sources and impacts of stormwater pollution, but can be part of the solution to reduce stormwater impacts on local aquatic environments through encouraging behavioural change.

The aim of this interim report is to raise community and business awareness of the impact of stormwater runoff on local waterways. Identifying priority sources of pollution will help local government, EPA, Melbourne Water, and the community better target education and enforcement campaigns. Collaboration between all these stakeholders is critical to improve the condition of our urban waterways by reducing water pollution.

Introduction

Dandenong Creek is a large urban creek flowing 55 km from the foothills of Mt Dandenong to the Patterson River. Water quality monitoring conducted across the Dandenong catchment by EPA Victoria show that 97% of waterways in the catchment are under severe ecological stress, primarily driven by high heavy metal and nutrient pollution (Yarra and Bay Report Card). Over the last century, catchment urbanisation and channel modification have led to a dramatic decline in the health of the creek: replacement of natural waterways with concrete channels and pipes to reduce flooding; pollution from industrial stormwater; and absence of both in-stream and stream-side vegetation has led to loss of macroinvertebrate communities, platypus and native fish (Kellar *et al* 2014).

A study by Marshall *et al* (2010) showed that pollution was implicated in poor macroinvertebrate community structure in the urban areas of the Upper Dandenong Creek Catchment, before showing some recovery in the urban areas in the Lower Dandenong Creek Catchment. In 2014, a major study into the likely impacts on the ecological health of Dandenong Creek concluded that a combination of metals and pesticides was likely causing ecological impairment of the creek; with several point sources of both metals and pesticides identified, including Old Joes Creek and Bungalook Creek (Kellar *et al* 2014). According to long term EPA assessment data, waterways in the catchment have been under severe stress since at least 2000, which has been attributed to increased urbanisation and highly polluted runoff from industrial areas (Yarra and Bay Report Card).

For the first time, the recently amended State Environmental Protection Policy for Waters of Victoria (SEPP WoV) includes environmental quality objectives for aquatic sediments, which were not included in previous versions of the policy. Briefly, it is recommended that if pollutant concentrations exceed default guideline values (Simpson *et al.* 2013), the risk to the local aquatic environment should be assessed further using multiple lines of evidence. (See Table 11 in the SEPP for more information on the different approaches). Pollutants exceeding the high guideline are more likely to be toxic to benthic fauna such as insect larvae, crustaceans, worms and snails. As sediments become more toxic, fewer species can survive, which can undermine aquatic food-webs; affecting populations of platypus, fish, birds, frogs and turtles which depend on these animals for food. Persistent pollutants such as heavy metals can also enter the food chain, which can have long term impacts on wildlife.

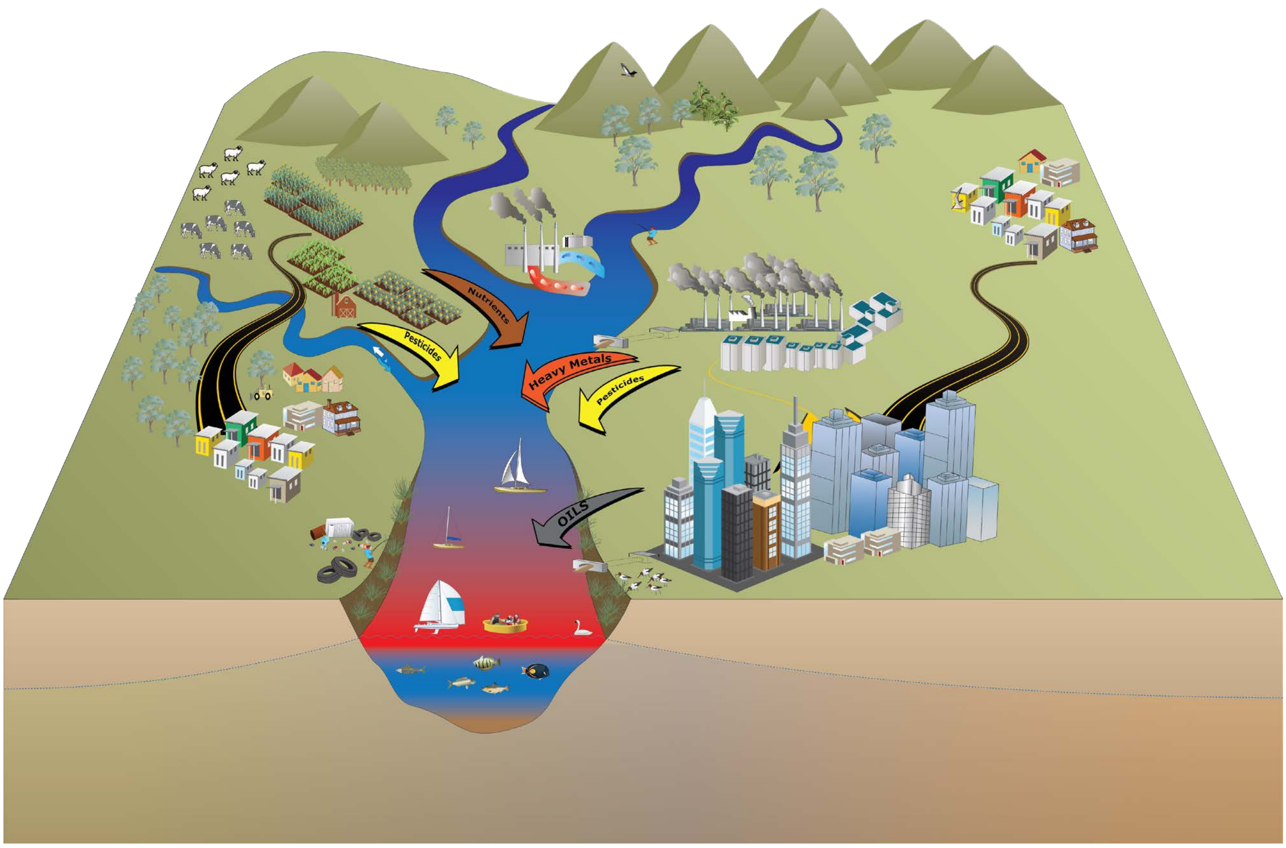
With expansion of urban landscapes, maintaining the ecological condition of waterways becomes increasingly difficult: biological degradation can be caused by both changed hydrology due to runoff from impervious surfaces, and by toxicity due to stormwater pollution. Trace metals, pesticides and hydrocarbons can all enter aquatic environments via stormwater runoff Marshall *et al* 2016; Sharley *et al* 2017), and accumulate within local sediments (Sharley *et al* 2016), leading to degradation of aquatic communities. Reducing pollution inputs to urban aquatic ecosystems is a key challenge facing water managers as urban landscapes expand. If waterway management strategies are to be effective, it is vital to identify priority stressors, their sources, and impacts on aquatic systems (See conceptual diagram below).

In response to public concern over continued pollution events, the First Friends of Dandenong Creek commissioned Bio2Lab to determine contaminants and catchments of concern. The aim of this survey is therefore to identify and prioritise sources of contaminants in Dandenong Creek above Heatherdale Creek, and work with both relevant catchment managers and the community towards a strategy to reduce the impact of pollution on the ecological condition of the creek. This project - once completed - will provide a model work-flow for other groups to follow to improve the ecology and amenity of urban waterways by identifying and reducing pollution sources.

Project scope

This investigation consists of a catchment pollution profiling program to:

- Identify contaminants and catchments of concern,
- Establish a pollution baseline to be used to measure improvement in creek health,
- Provide a scientifically rigorous assessment tool for ongoing education and awareness programs, and
- Provide a template for future investigations.



Conceptual diagram illustrating major human activities that contribute to pollution of urban waterways

Brief Methods

Bio2Lab conducted both passive sampling and sediment quality surveys across five major catchments (Table 1, Figures 1 and 2):

Table 1 Site information

Catchment	Major land-use
1. Heatherdale Creek	Residential and industrial
2. Tarralla Creek	Mix of residential, commercial and industrial
3. Bungalook Creek	Commercial and industrial
4. Old Joes Creek	Mostly industrial, some commercial
5. Upper Dandenong Creek	Mostly forested with some rural

Samples were also collected from Dandenong Creek just downstream of Bungalook Creek (Middle Dandenong Creek) to assess sediment quality following restoration of this section of Dandenong Creek.

Sediment quality assessment

Bio2lab collected surface sediments using standard methods (Sharp and Sharley 2012), and had them analysed for persistent contaminants commonly found in Melbourne stormwater, including: heavy metals (arsenic, cadmium, copper, chromium, nickel, lead, zinc), oils (as total petroleum hydrocarbons or TPH) and insecticides (synthetic pyrethroids) (Table 2). Contaminant concentrations were compared with the SEPP WoV, National Sediment Quality Guidelines (Simpson *et al* 2013) or published ecotoxicology literature. For the first time, the SEPP now includes environmental quality objectives for aquatic sediments, which has been lacking in the past. Results were compared to the Default Guideline Value (DGV) and the Guideline Value High (GV-H). Contaminants in urban stream sediments should not exceed the DGV, while GV-H is the upper limit above which direct toxicity to aquatic biota becomes likely. All chemical analysis was performed by consulting laboratories accredited by the National Association of Testing Laboratories Australia (NATA). We also combined individual contaminant concentrations into a mean sediment quality index (Figure 4) to facilitate interpretation and communication of sediment quality data to both catchment managers and the wider community (Figures 3 and 4) (Caeiro *et al* 2005).

Pollution profiling

Bio2Lab deployed passive samplers at major drain outlets or tributaries three times over a six week period between 21st August and 3rd October 2018 (See Appendix 1 for an explanation of how passive sampling works). After each fortnightly sampling event, media from the sampler was processed and analysed for common persistent contaminants (Table 2). We converted contaminant concentrations into a simple colour-coded scale for ease of interpretation, with colour ratings for each pollutant based on concentrations detected (Figure 6). We also combined average contaminant concentrations into a colour-coded index to visually colour catchments according to the pollution index. A web-based education tool summarises the results from both the sediment and passive sampling surveys.

Table 2 List of common pollutants tested for in sediment and passive samplers, their common uses and summary of ecological impact.

Pollutant	Sampling type P = passive sampling S= Sediment	Use and common sources	Potential impact on aquatic biota.
Metals			
Arsenic	P and S	Industrial processes, E-waste, wood preservatives and pesticides	Heavy metals vary significantly in their toxicity to aquatic biota. Of the metals tested here, silver generally has the highest relative toxicity, while zinc has the lowest. Toxicity can not only directly increase mortality of exposed animals, but also lead to sub-lethal effects, such as decreased growth, pollution induced morphological deformities and lesions, as well as changes in fertility rates. Because metals persist within sediments, changes can occur at both the population and community level which can lead to loss of sensitive species and reduced biodiversity. As heavy metals generally persist within the environment and are not readily broken down, they can also enter food-chains which can have long-term impacts on wildlife including many fish species, platypus, turtles and birds. Toxicity responses to individual contaminants is complex and can vary considerably within and between animal groups. Pollutants also often have synergistic effects meaning toxicity can often increase in the presence of other pollutants (MacDonald 2000).
Cadmium	P and S	Rechargeable batteries, E-waste, manufacturing, fertilisers	
Copper	P and S	Metal processing, electrical equipment and wires, construction and vehicle brake systems, anti-fouling product, insecticides and fungicides	
Chromium	P and S	Electroplating, leather processing and other industrial processes	
Lead	P and S	Car batteries, pigments and industrial processes - previous widespread use in petroleum products have been phased out	
Nickel	P and S	Electroplating, batteries, and other industrial processes	
Silver	P and S	Metal finishing processes, photography, x-ray waste, dental amalgams, while silver nanoparticles and increasingly used in clothing and personal care products	
Zinc	P and S	Wide spread use in galvanising, casting, paints, tyres, brakes, batteries, lubricants, cosmetics, textiles and industrial processes	
Total Petroleum Hydrocarbons			
Oils	P and S	Lubricants, petroleum products, hydraulic fluid, solvents and cleaning products	Physical smothering, reduction in oxygen level. Toxicity is moderate although variation among species is considerable
Insecticides (synthetic pyrethroids)			
Bifenthrin	S	Garden pest control, Domestic and commercial barrier sprays, termite treatment, agriculture	Synthetic pyrethroids are potent neurotoxins which act on the nervous system of insects, quickly causing paralysis and death (Narahashi 1971). Like metals, synthetic pyrethroids can vary in their toxicity, but the majority of them are very toxic to birds, most aquatic insects, crustaceans, fish, honeybees and worms. All pyrethroids can bioaccumulate to some degree, and have long-term impacts on wildlife[1].
Cyhalothrin	S	Garden pest control, seed treatment,	
Cypermethrin	S	Agriculture and ectoparasiste control and domestic pest control for pets	
Deltamethrin	S	Domestic pest control, tick control in animals, garden pest control, golf course pest control	
Fenvalerate	S	Insect controls for food and fabric manufacturing premises, and domestic and commercial animal protection	
Permethrin	S	Mosquito nets, textile industry, clothing spray, agriculture, parasites, timber treatment,	

1 - see the Pesticide properties database at https://sitem.herts.ac.uk/aeru/ppdb/en/index.htm

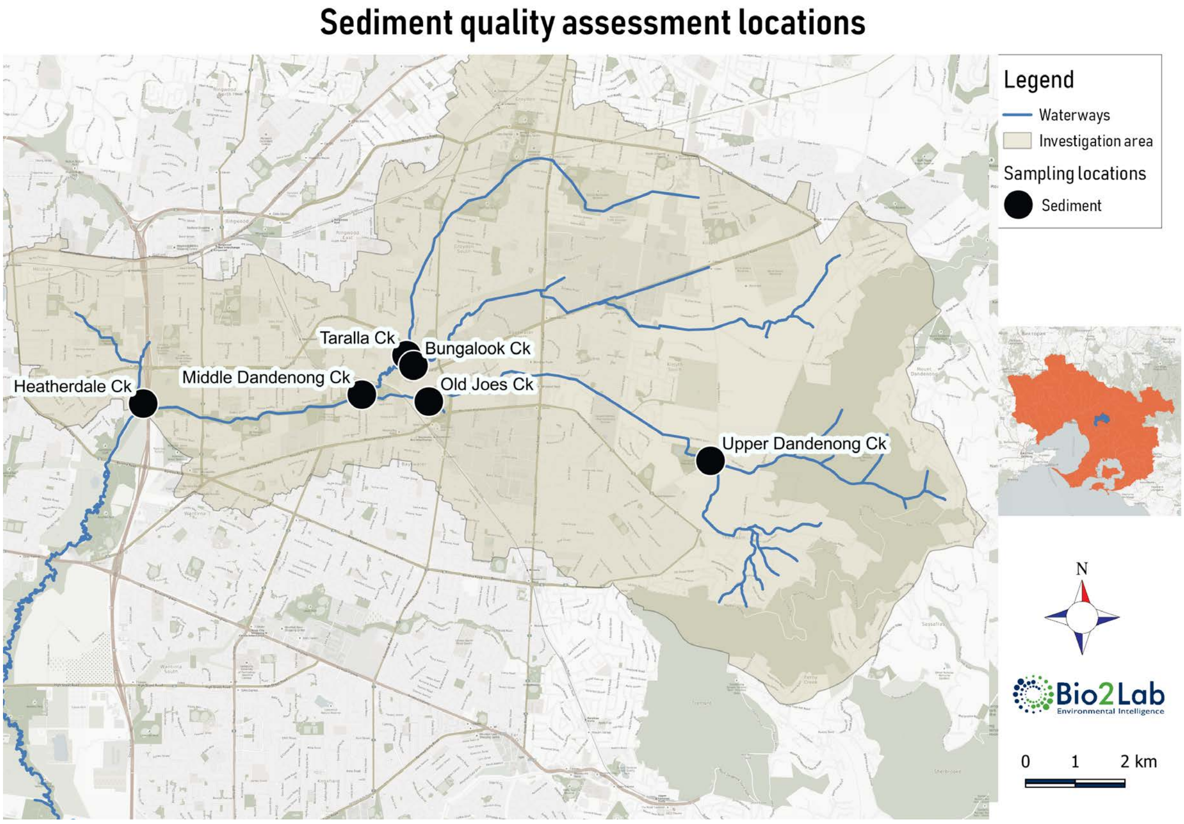


Figure 1 Sediment quality assessment sites

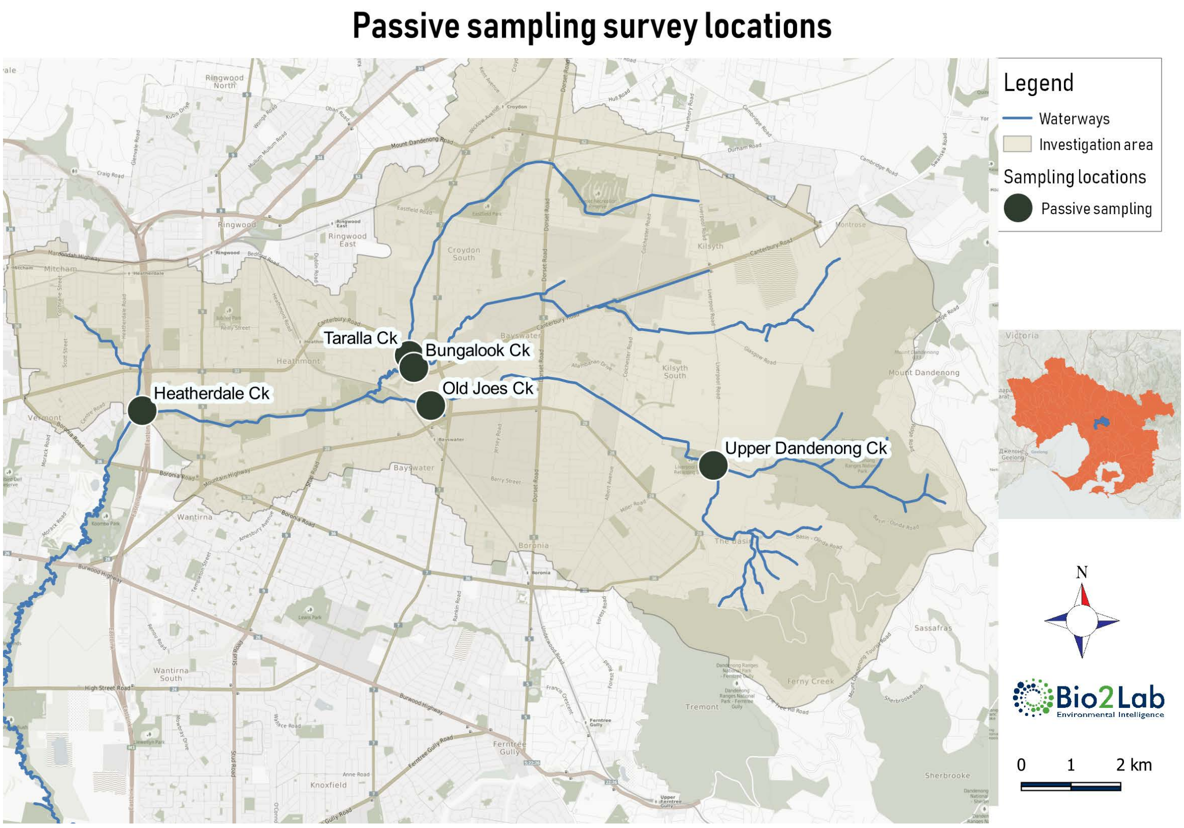


Figure 2 Passive sampling sites

Results and Discussion
Sediment quality

Bio2Lab collected sediment from six locations throughout the study area (Figure 1). The Upper Dandenong Creek was the only site to meet the environmental quality objectives required by the State Environment Protection Policy. Every site downstream of this point failed at least one objective, and most failed multiple objectives by a large margin (Figure 3). Sediment ecological risk - based on metals and hydrocarbons in sediments - was very high at Old Joes Creek and Heatherdale Creek, with metal and oil concentrations at both these sites likely to be toxic to aquatic biota.

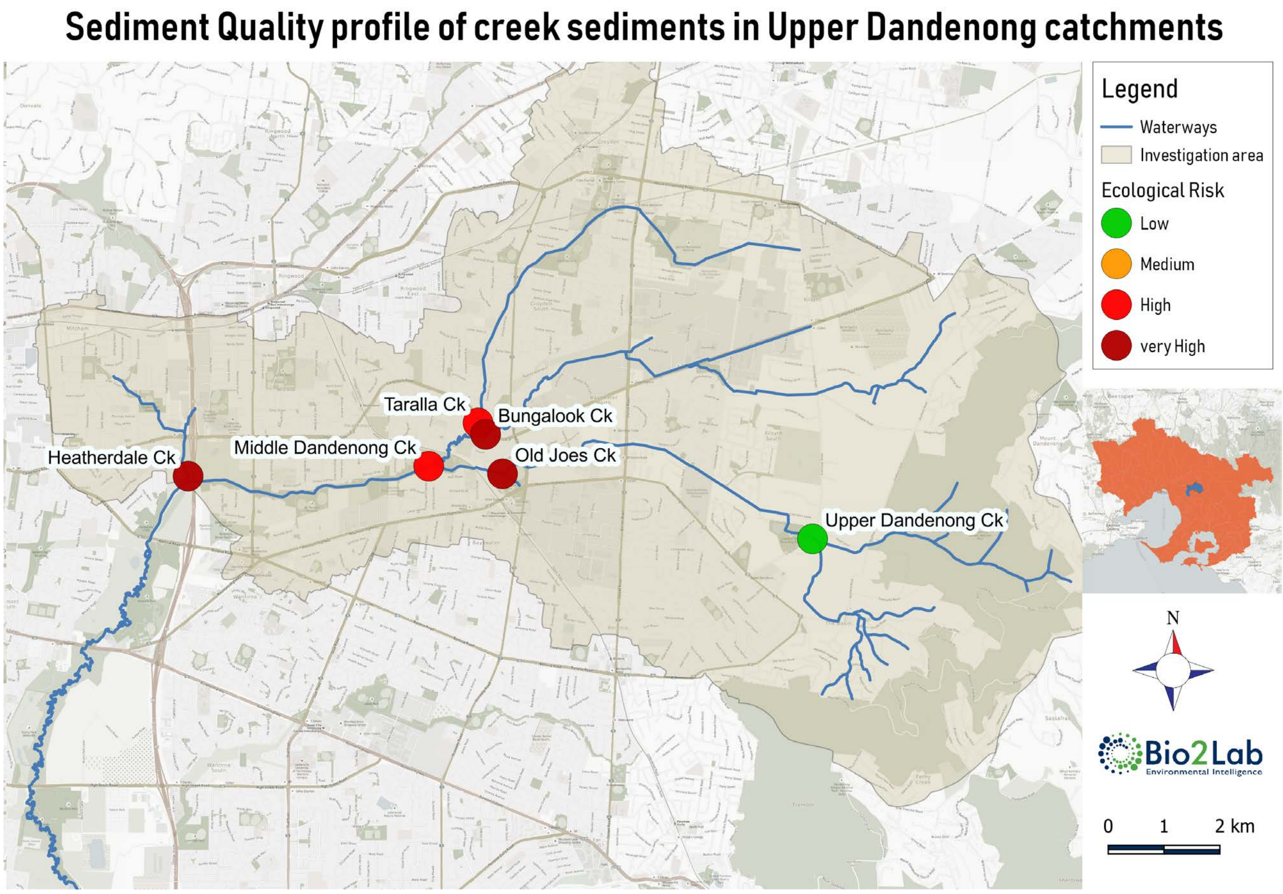
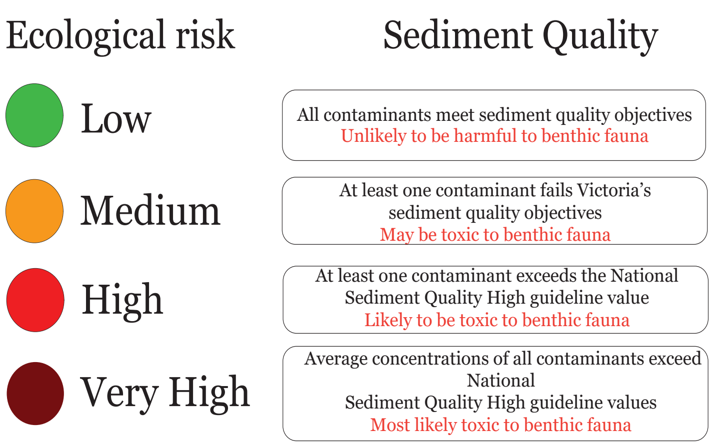


Figure 3 Sediment quality profiles at the six sampling locations



Benthic fauna are small aquatic animals that live in or on the sediment, such as insect larvae, crustaceans, worms and snails. They are an important food source for platypus, fish, birds, frogs and turtles and help recycle nutrients in aquatic ecosystems. Increases in sediment toxicity can decrease biodiversity and impact aquatic food webs. Persistant pollutants such as heavy metals can also enter food chains which can have long term impacts on wildlife.

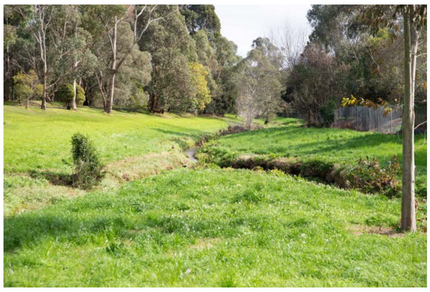
Sediment quality objectives are set in Victoria's State Environmental Protection Policy

Figure 4 Sediment quality profile information derived from standard sediment quality assessments

While ecological risk was merely high at Bungalook, Taralla and Middle Dandenong Creeks (Figure 3), these sites all failed environmental quality objectives for numerous contaminants (Figures 5). Very high levels of both zinc and oils were found throughout the urbanised sections of the catchment (Figures 5). These are both common urban pollutants and are expected to be associated with urban catchments, but such high concentrations suggest more serious pollution problems than simply runoff from impervious surfaces. Silver was also found at moderate to high levels in sediments from Middle Dandenong and Old Joes Creek respectively (Figure 5). Unlike zinc and oils, silver is rarely found in urban runoff, suggesting distinct point sources in the Old Joes and Heatherdale catchments. Sediments from Old Joes, Bungalook and Heatherdale Creeks all had high levels of copper, lead and nickel, with high levels of arsenic also found in sediments from Heatherdale Creek (Figure 5).

The recent stream restoration of Middle Dandenong Creek has apparently improved not only the physical habitat and visual amenity, but also the sediment quality. Although it failed to meet the SEPP environmental objectives for oils and silver, it was the only site in the urban area to meet SEPP objectives for all other metals. We attribute the better sediment quality here to the comparatively short exposure to upstream pollution inputs, although this is unlikely to last as sediments start to accumulate pollutants from upstream. For instance, silver at failed to meet Victoria's sediment quality objective; evidence that silver contamination originating upstream at Old Joes Creek is already impacting the ecological condition of Middle Dandenong Creek, only months after completion of the restoration works.





In addition to heavy metals and oils, a number of common synthetic pyrethroids were also analysed (Table 2). The use of synthetic pyrethroids for pest control has risen dramatically over the past decade as they replaced older insecticides such as dieldrin and chlorpyrifos. Although this family of chemicals tend to be less toxic to humans, they are often very toxic to aquatic biota, especially when compared to heavy metals and oils (Table 2). We used toxicity ratings derived from published data (Jeppe *et al* 2017; Amweg *et al* 2005) to assess the toxicity of sediments due to synthetic pyrethroids. Old Joes Creek and Bungalook Creek had very high levels of bifenthrin and permethrin respectively (Figure 5), suggesting aquatic biota in these sediments would have limited growth and poor survival. Permethrin contamination has been a serious environmental problem for Bungalook creek for many years (Kellar *et al* 2014), and these results suggest there are still major sources of this highly toxic insecticide in the catchment. Interestingly, bifenthrin concentrations in Old Joes Creek seemed to have increased significantly since 2014 (Kellar *et al* 2014), suggesting new sources of bifenthrin are appearing in the catchment. Trace levels of bifenthrin and permethrin were detected at all sites, but were below the limit of quantification. Unfortunately, the urban area of Dandenong Creek has been in poor condition for many years, and these results are consistent with previous catchment surveys which have found sediment from the urban stretches of Dandenong Creek is toxic to both wild (Marshall *et al* 2010) and laboratory-cultured (Kellar *et al* 2014) invertebrates.

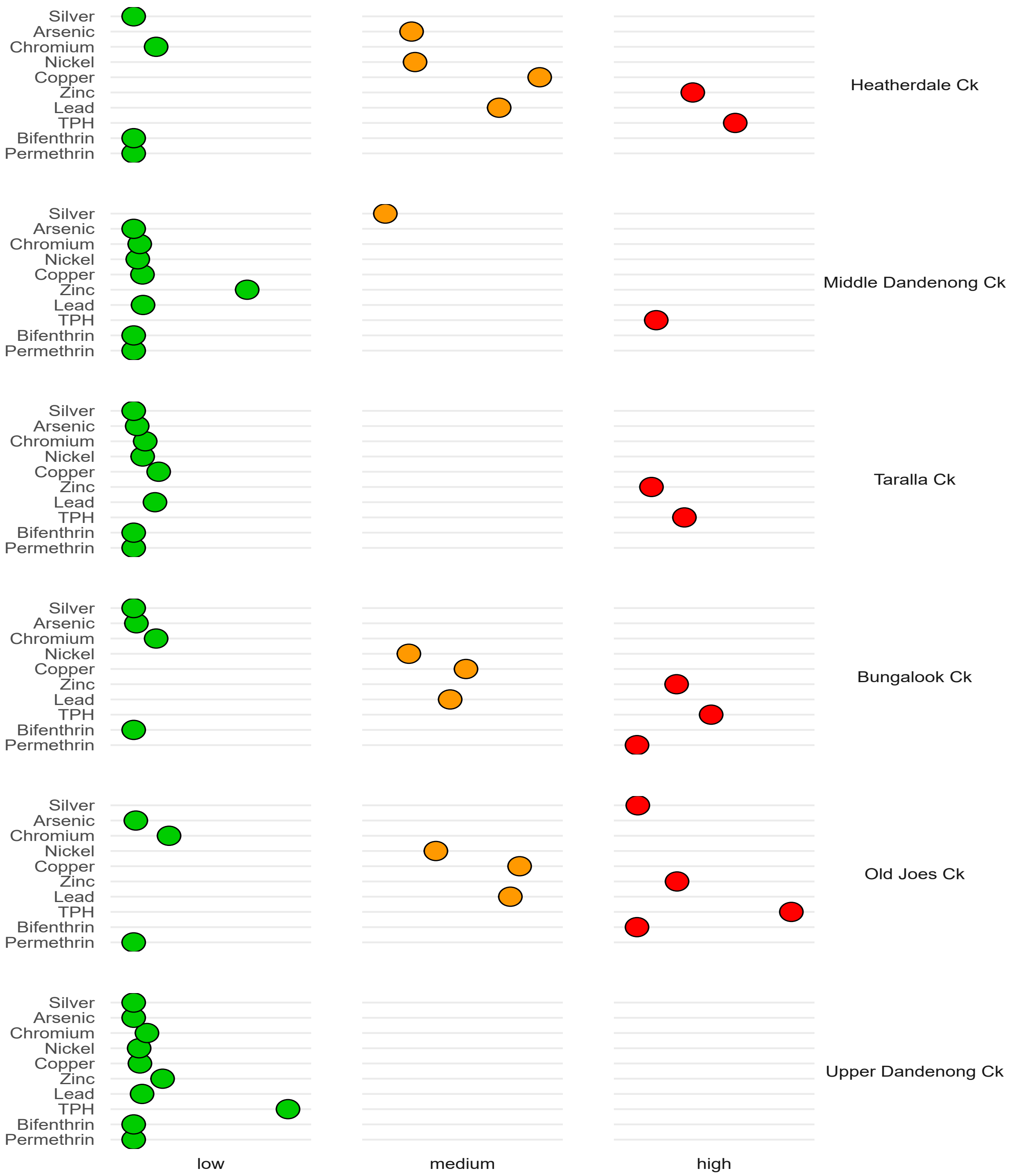
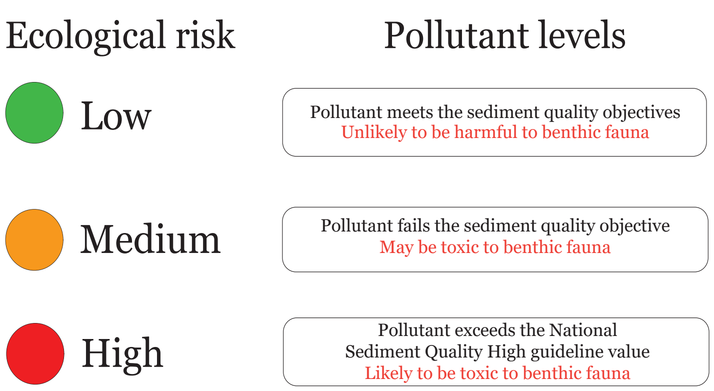


Figure 5 Plot showing silver, arsenic Bifenthrin, Permethrin, Copper, TPH, Zinc, Chromium, Lead and Nickel levels in sediments from the six survey locations. See Figure 6 below for information on circle colours.



If pollutants fail the sediment quality objectives, this should trigger further investigations such as weight evidence approaches (See table 11 in the State Environmental Protection Policy).

Pollutants exceeding the High guideline are more likely to be toxic to benthic fauna such as insect larvae, crustaceans, worms and snails. As sediments become more toxic, fewer species can survive. This can undermine aquatic foodwebs, affecting populations of platypus, fish, birds, frogs and turtles.

Persistent pollutants such as heavy metals can also enter food chains which can have long term impacts on wildlife.

Figure 6 Guidance on interpretation of the ecological risk categories

Stormwater Pollution Profiling

Stormwater pollutant profiles were developed using passive samplers to collect a time-integrated assessment of pollution entering the Dandenong Creek from each of five major tributaries. The only catchment with background levels of contamination was Upper Dandenong Creek (Figure 8 and 9).

Runoff from all catchments in the urban reaches of Dandenong Creek was at least moderately polluted with oils and metals. Runoff from Old Joes Creek was consistently heavily polluted with silver, arsenic, cadmium, copper and zinc and chromium, and very heavily polluted with lead, nickel and hydrocarbons (Figure 10 and 11). It's worth emphasising that cadmium and silver contamination were completely isolated to runoff from the Old Joes Creek catchment, occurring nowhere else. Arsenic was the major driver of pollution in runoff from Heatherdale and Taralla Creek catchments. Apart from Old Joes Creek, all other pollutants tended to occur at moderate levels in stormwater runoff (Figure 10 and 11).

When considering the variation in pollution level between sampling events, there is evidence for sporadic discharges in the Old Joes Creek catchment (Figure 12). Arsenic, lead, nickel and hydrocarbons all spiked during different sampling events, suggesting possible dumping events may have occurred, although there was little evidence contaminants were from the same source as spikes occurred in different weeks. Interestingly, a very large spike in arsenic occurred in the final week at Tarralla Creek, also suggesting a dumping event is likely to have occurred, although it is unclear where it would be coming from (Figure 12).

Figure 7 Sediment collection in Bungalook Creek

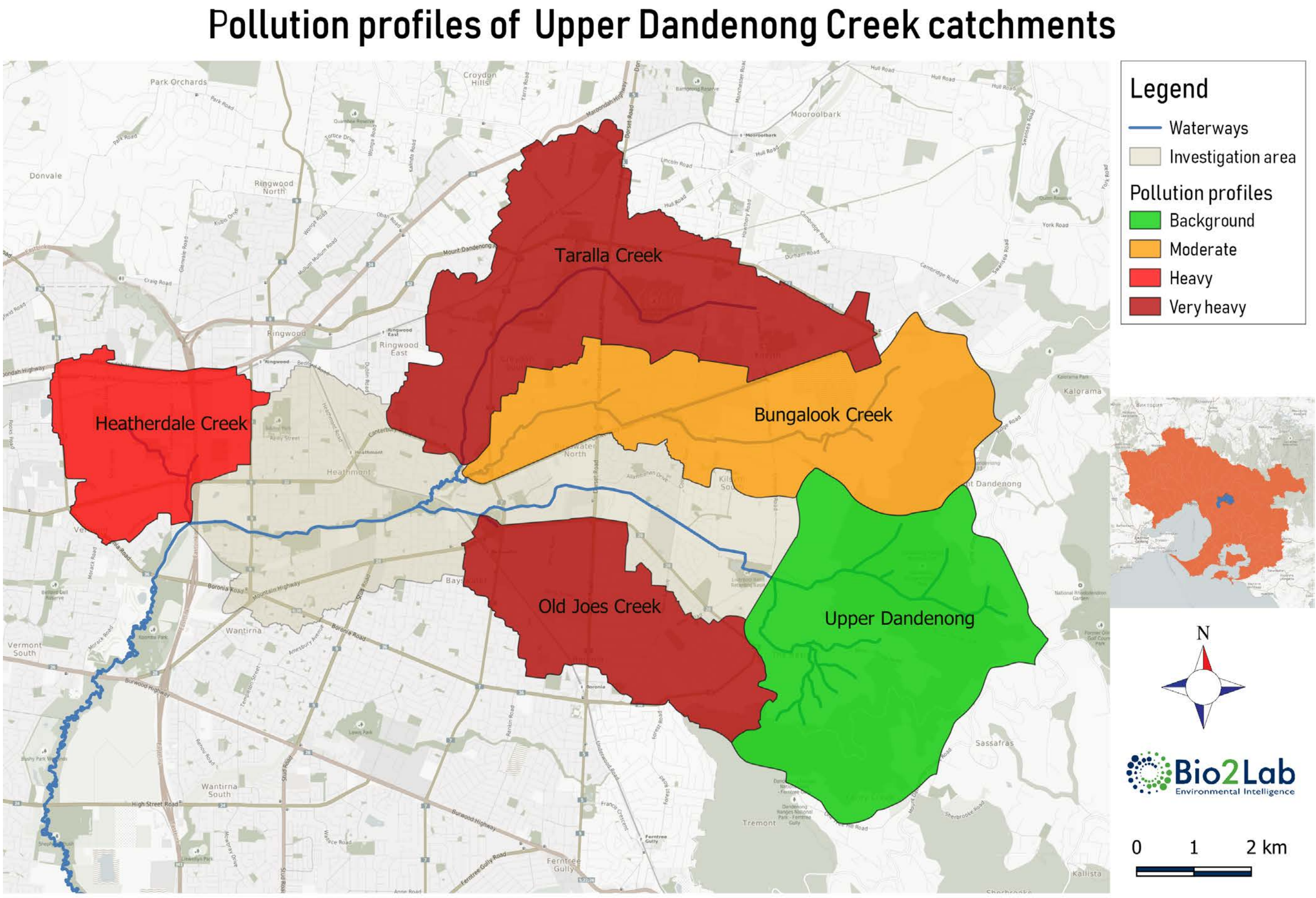


Figure 8 Catchment specific pollution profiles based on average contaminant concentrations over the three sampling events.

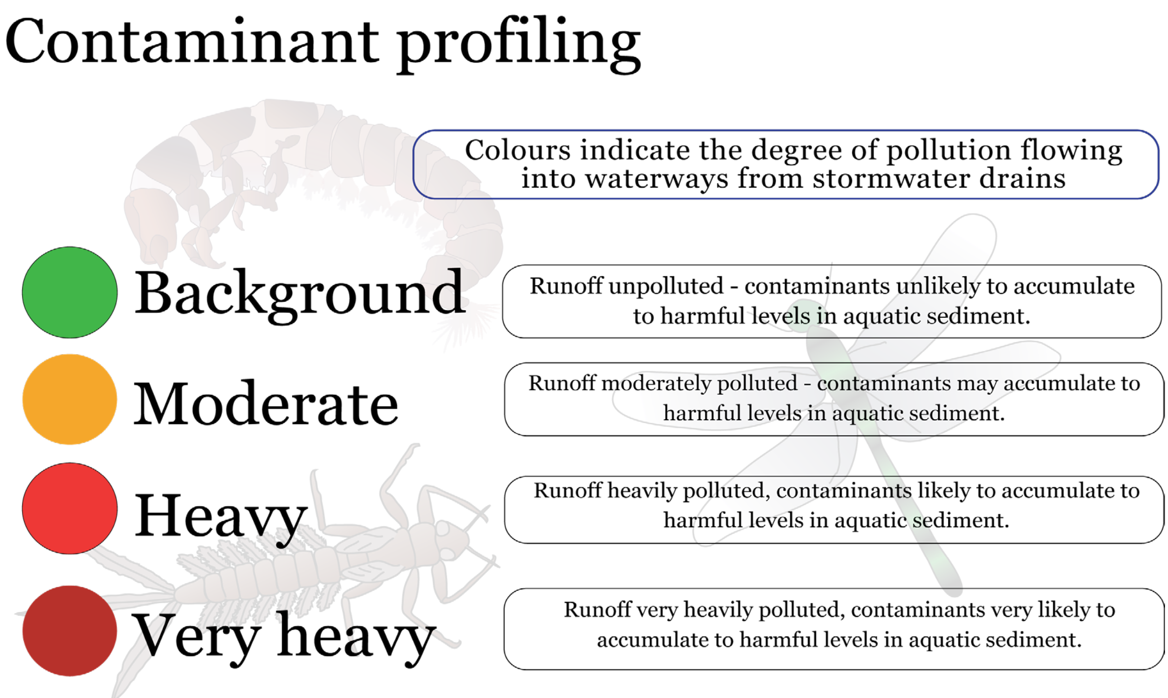


Figure 9 Contaminant profiling information derived from passive sampling data

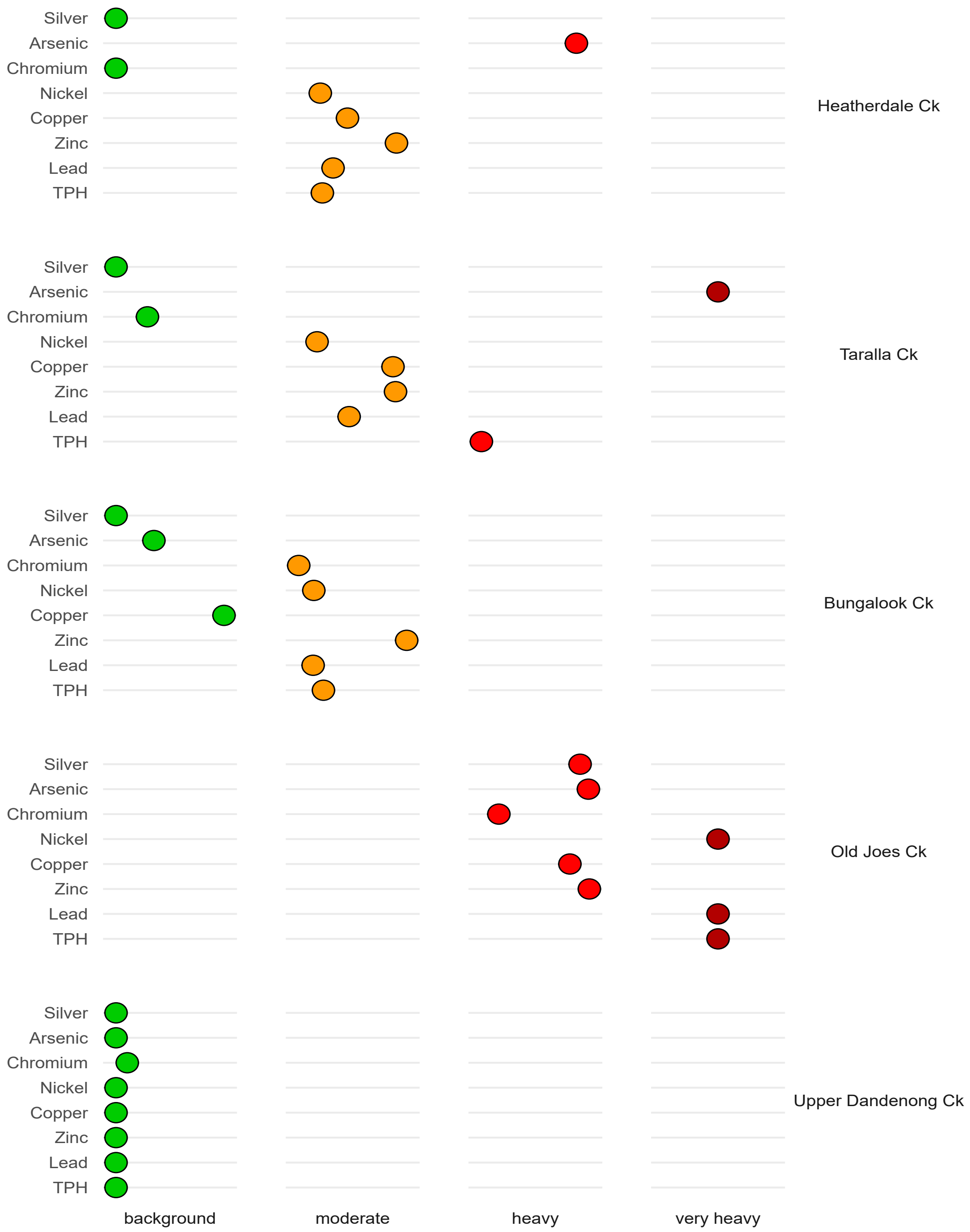


Figure 10 Average heavy metal and oil levels in passive sampler media. See Figure below for more information on the different levels of contamination

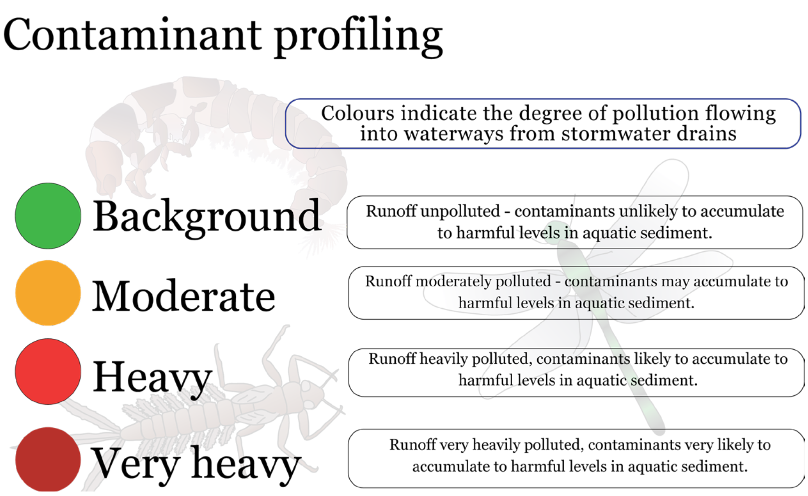


Figure 11 Contaminant profiling information derived from passive sampling data

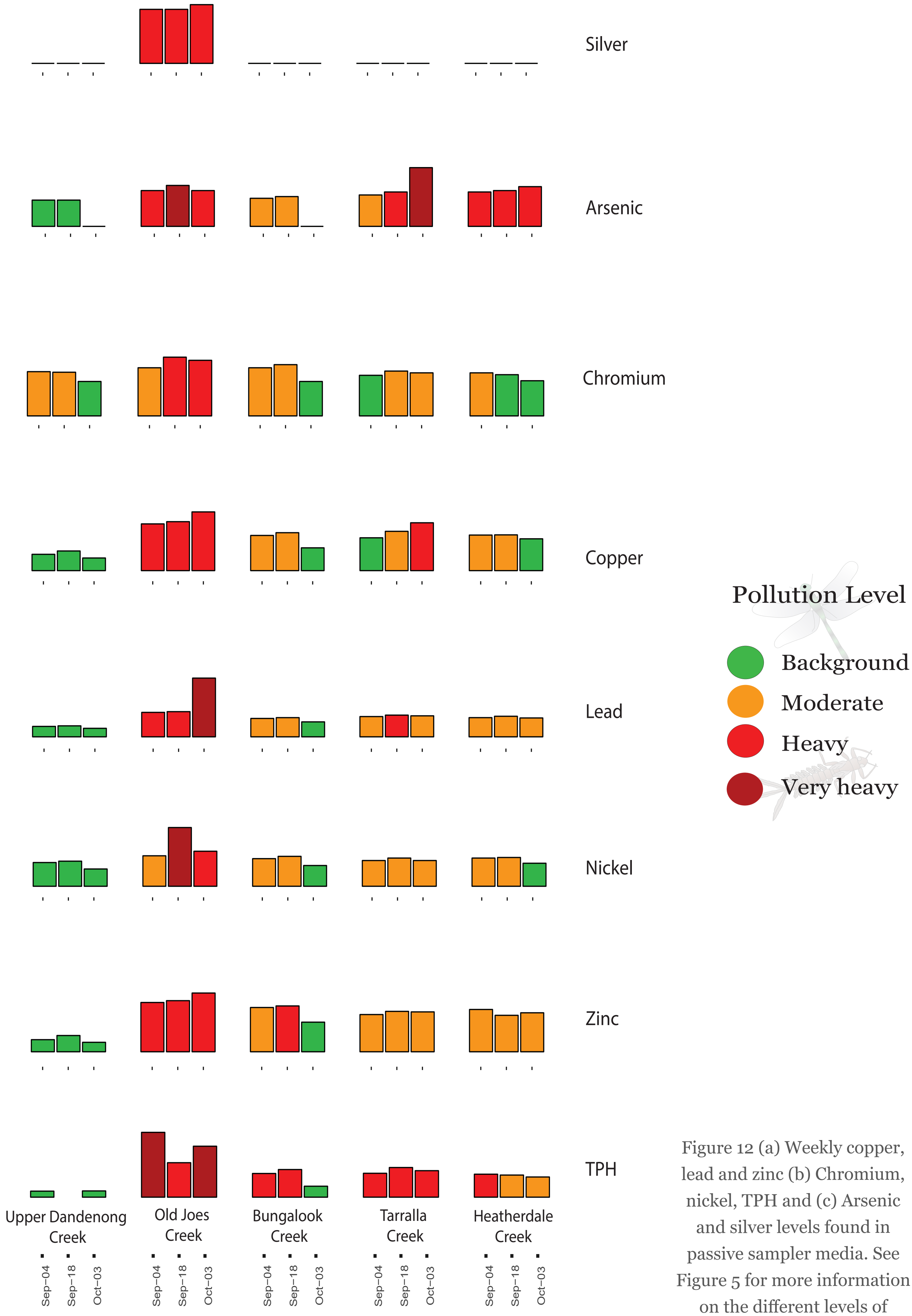


Figure 12 (a) Weekly copper, lead and zinc (b) Chromium, nickel, TPH and (c) Arsenic and silver levels found in passive sampler media. See Figure 5 for more information on the different levels of contamination

Community Education and Awareness

The pollutant profile of stormwater is determined largely by land use within the catchment. Every day activities such as driving, washing cars, painting, and applying pesticides to gardens and buildings all contribute to stormwater pollution. Stormwater runoff from industrial areas can contribute enormous amounts of pollution to waterways due to the scale of manufacturing and industrial processes. To manage stormwater, the water industry primarily relies on treatment by constructed wetlands and rain gardens to capture contaminants before they reach receiving environments. However, these strategies merely manage pollution generated from human activities and do nothing to stop the generation of pollutants in urban catchments.

The best way to reduce the ecological impact of pollution on urban waterways is to stop pollution at the source (SEPP WoV, section 34.4.a.i). An effective way to achieve this is through education and awareness programs guided by contaminant profiling surveys such as this one. Stormwater education programs not only increase community knowledge of the sources and impacts of stormwater pollution, but can be part of the solution to reduce stormwater impacts on local aquatic environments through encouraging behavioural change. Coupling education with enforcement from environmental regulatory authorities and councils is likely to be even more effective in preventing pollutants from entering stormwater (Sharley and Sharp 2016).

The aim of this interim report is to raise community and business awareness of the impact of stormwater runoff on local waterways. Identifying priority sources of pollution will help local government, EPA Victoria, Melbourne Water, and the community better target education and enforcement campaigns. Collaboration between all these stakeholders is critical to improve the condition of our urban waterways by reducing water pollution.

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Appendix 1 Continuous Water Quality Monitoring Using Passive Sampling Technology

It is difficult to characterise stormwater quality using traditional water sampling techniques such as grab sampling. Water levels can be very low during dry weather, making it impossible to collect a water sample, but very high during rain events, making sample collection difficult and dangerous. Because contaminants tend to enter the stormwater system in pulses, concentrations can vary significantly over short time scales. Under these conditions, logistically it becomes cost prohibitive to implement a grab sampling program to detect pulse pollution events.

To overcome these issues, passive sampling technology specifically designed to capture contaminants from stormwater pipes across predetermined time periods can be used. Passive samplers are devices that are deployed into stormwater drains where they remain until they are collected. The samplers accumulate contaminants continuously, providing a time-weighted average concentration for that period. This approach is ideal for detecting pulse pollution events that would likely be missed using grab sampling (Figure 1). Passive sampling not only significantly reduces sampling effort and monitoring costs, but can be used to identify and characterise numerous hydrophobic contaminants including pesticides, heavy metals and oils.

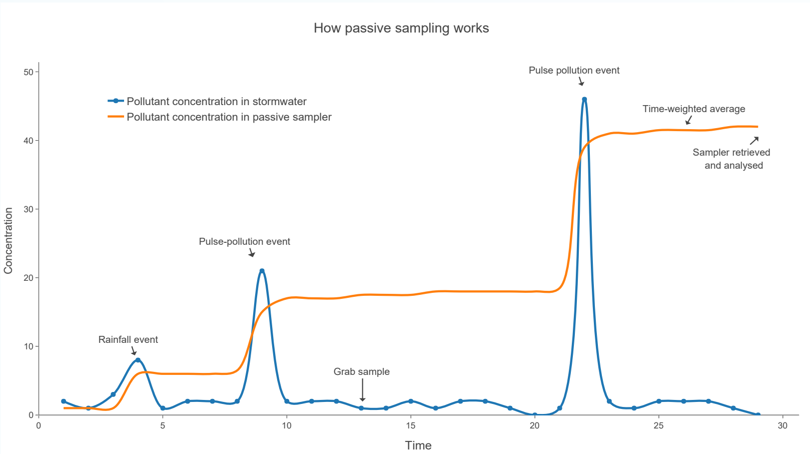
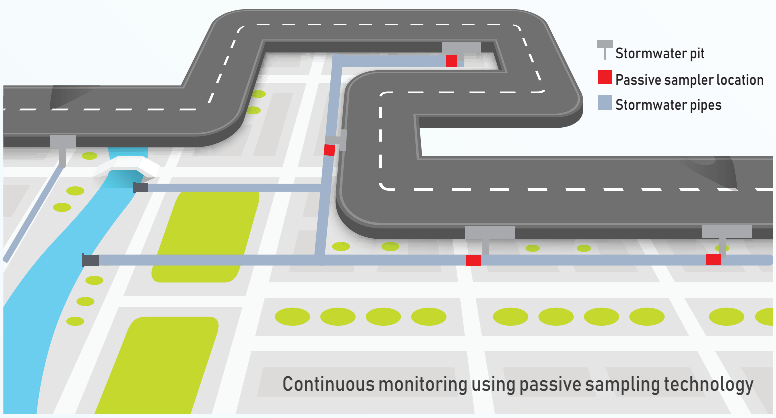


Figure A1 Plot showing how passive samplers accumulate pollutants over time providing a time-weighted average

Cost-effective

Deployment of one passive sampler can continuously monitor stormwater for an extended periods of time, reducing sampling effort significantly. Providing a time-weighted average, passive sampling can detect and account for pulse pollution events which would be very unlikely if a grab sampling program was employed to characterise stormwater quality.

Simultaneous water quality monitoring across stormwater networks



Simultaneous

A major advantage of using passive samplers to characterise stormwater quality is the ability to deploy numerous samplers simultaneously across a stormwater catchment. By carefully designing the survey to target major drainage junctions, high risk catchments can be isolated. Networked passive sampling programs prioritise areas within a catchment that are generating large amounts of contaminants. This provides stormwater managers with targeted areas to undertake compliance and education programs, or more intensive monitoring to track pollution sources to individual premises.

Supporting better decision making

Samplers are simple to use, cost-effective and require no power, so can be deployed anywhere

Company Directors

Dr David Sharley
Tel: 0407011074

Mr Steve Marshall
Tel: 0425884840

Suite B127 Melbourne Innovation Centre,
61 Civic Drive, Greensborough, Vic, 3088

E: info@bio2lab.com
W: www.bio2lab.com
ABN: 29 619 164 797

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