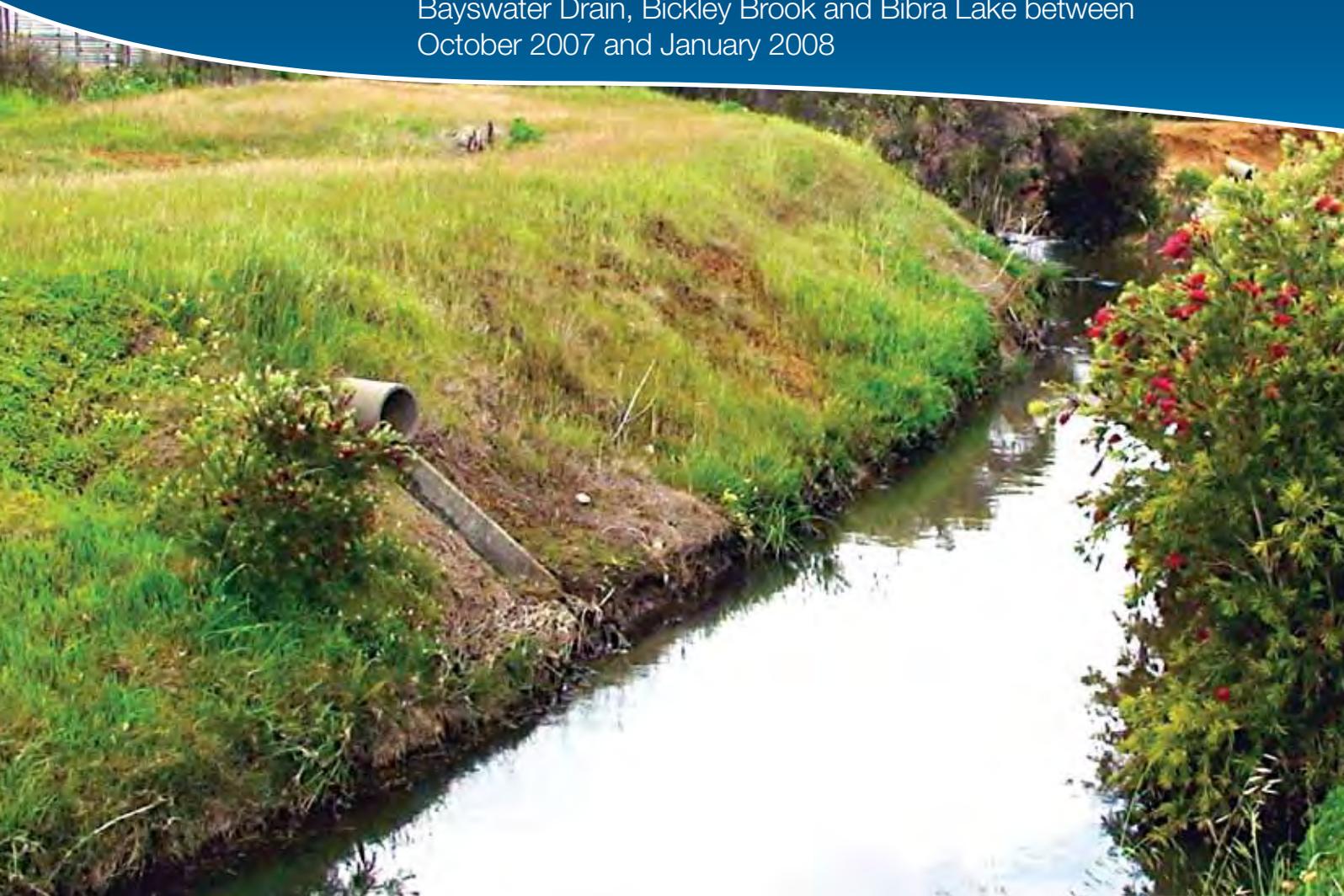




Government of **Western Australia**
Department of **Water**

A snapshot of contaminants in drains of Perth's industrial areas

Industrial contaminants in stormwater of Herdsman Lake,
Bayswater Drain, Bickley Brook and Bibra Lake between
October 2007 and January 2008



Looking after all our water needs

Water Science
technical series

Report no. WST 12
April 2009

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April 2009

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ISSN 1836-2869 (print)

ISSN 1836-2877 (online)

ISBN 978-1-921637-10-0 (print)

ISBN 978-1-921637-11-7 (online)

Acknowledgements



This project was funded by the Australian Government through the Perth Region NRM (formerly the Swan Catchment Council).

This report was prepared by George Foulsham with assistance from a number of staff in the Water Science Branch of the Department of Water. Sarah Evans provided support in the field with all the water and sediment collection. Helen Nice assisted in the project planning stages. Special thanks to Scott Favacho (Perth Region NRM), Carmelo Gumina (Perth Region NRM), Ana Terrazas (South East Regional Centre for Urban Landcare) and Nicole Roach (formerly North Metropolitan Catchment Group) for assistance with project planning.

Recommended reference

The recommended reference for this publication is:

Foulsham, G 2009, *A snapshot of contaminants in drains of Perth's industrial areas*, Water Science technical series report No.12, Department of Water, Western Australia.

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Summary

Surface water and sediment were sampled in a snapshot study at six sites in four industrial drains in the Perth area for a range of contaminants. All four drains, namely Herdsman Lake, Bayswater, Bibra Lake and Bickley Brook were contaminated to some degree by compounds from various industrial activities and other anthropogenic sources. The extent and type of contamination varied between sites and also varied over the three sampling periods.

Contaminants that were detected either in sediments or water include:

- hormones, in particular the synthetic hormone ethinylestradiol
- polychlorinated biphenyls (PCBs)
- metals, including aluminium, arsenic, lead, chromium, copper, nickel and zinc
- polycyclic aromatic hydrocarbons (PAHs)
- total petroleum hydrocarbons (TPHs)
- surfactants, both anionic and non-ionic forms
- phenolic compounds, in particular phenol and creosol
- nutrients: primarily total oxidised nitrogen, organic nitrogen and particulate phosphorus.

Herdsman Lake was identified as the site with the highest level of contaminants of the four locations with PCBs, ethinylestradiol, and a range of other contaminants detected. PCBs are highly persistent in the environment, have a high potential for accumulation in aquatic organisms, and have been banned for use in Australia. Ethinylestradiol is the active ingredient used in the birth control pill and in hormone replacement therapy. The most likely pathway for it entering surface water is in sewage from septic tanks or leaking sewerage systems.

Bayswater had an elevated concentration of ethinylestradiol detected on one occasion. Bayswater also had total aluminium concentrations in the surface water which were consistently above Australia and New Zealand Environment and Conservation Council trigger values (ANZECC & ARMCANZ 2000).

The Bibra Lake sump was notable for high concentrations of PAHs, with trigger values exceeded on a number of occasions. Profiles suggest that the source is primarily of pyrogenic origin. This may be from local bushfires or engine combustion of fuels and subsequent settling and runoff into the sump.

Surfactants and metals were consistently detected at all sites. TPH concentrations were highest in sediments at one of the Herdsman Lake sites, Bibra Lake and both the Bickley Brook sites.

The sites monitored in this study were all in drains from catchments that are dominated by industrial land uses. There is a diverse range of industries in each catchment, with different waste and stormwater management practices making it difficult to determine the source(s) of contamination. The Department of Environment (2004a) has published a contaminated sites management series paper on potentially contaminating activities, industries and land uses, which provides useful information on the types of chemicals and waste products likely to be discharged. Potential sources, other than industry, include septic tanks, road runoff, bushfires and fertiliser application on residential properties, parks and reserves.

1 Background

1.1 Background to the project

The Perth region natural resource management group (NRM) is a community-led regional group with responsibility for coordinating and delivering natural resource management in the Swan region of Western Australia. The Perth region NRM plays a key role in implementing the Swan region strategy for natural resource management and managing and administering the distribution of strategic funding in the Perth region (Swan Catchment Council 2004).

Through the Sustainable Production project the Perth region NRM is looking to systematically improve poor environmental practice among small to medium enterprises. There are approximately 110 000 small to medium enterprises throughout the catchment, with varying potential threats impacting on water and land assets as a result of:

- pollutants leaching into the soil and groundwater
- contaminants flowing into rivers and wetlands
- solid waste to landfill (Swan Catchment Council 2004).

The Swan–Canning industry survey report noted discrepancies between the amount of industrial waste generated on premises and the amount recorded; raised concerns for the storage of waste on open sealed or unsealed surfaces; the storage of chemicals on premises without bunding; the disposal of industrial effluent in unacceptable ways; and the improper on-site stormwater treatment facilities of many industries (Swan River Trust 1999).

The Perth region NRM has a suite of pilot projects to encourage small to medium enterprises to adopt best-management practices. To complement these projects, the Water Science Branch from the Department of Water was requested to implement a monitoring program for a select number of industrial zones in the Perth metropolitan area to investigate industrial contaminants. This report discusses the results of the monitoring program and presents information on contaminants in water and sediment samples taken on three occasions within a one-year period at four industrial areas (six sites) in stormwater drains and sumps.

1.2 Scope of the project

The purpose of the sampling was to identify contaminants of concern in stormwater or sediment collected from stormwater drains and sumps downstream from selected industrial areas. The sampling and analyses were undertaken using standard methodologies (ANZECC & ARMCANZ 2000).

1.3 Perth stormwater drains

Catchments within the Perth metropolitan area are drained by a series of main drains and local government drains. Surface water in the drains originates primarily from overland surface flow, especially from hard surfaces such as roads, car parks and footpaths. Surface water in some of the areas may also originate from industrial wastewater discharges, or groundwater where the drains intercept the watertable. Groundwater generally travels through a catchment much more slowly than surface water; and contaminants can persist for longer due to conditions underground (e.g. anoxia, lack of ultraviolet light).

Sediment in the drains may accumulate gradually over time as suspended solids settle out, or it can be deposited suddenly during large storm events. Sediment chemistry involves complex processes which may result in the binding, break down, or release of contaminants. Some of the drains have regular wetting and drying cycles which may influence the fate of contaminants. Chemical processes such as redox conditions, pH and the geochemistry of sediment particles influence contaminant persistence and availability (ANZECC & ARMCANZ 2000).

2 Methodology

2.1 Contaminant selection

A range of chemicals were identified as being typically used or discharged by small to medium industry for industrial purposes. These included nutrients, metals, surfactants, solvents and hydrocarbons. Pesticides, herbicides, most pharmaceuticals and other emerging chemicals were not selected for determination as they are more commonly associated with residential or agricultural land uses. Information on the common chemicals and waste products found in local industries was sourced from the Department of Environment (2004a). Contaminants that were measured, and their limits of reporting, are listed in Appendices A & B.

Some analytes such as major ions, miscellaneous inorganic compounds and surfactants were not analysed in sediment because the laboratory techniques were not readily available. Acid sulphate soil-related parameters were tested in sediment.

The lowest practicable levels of reporting were requested for each analyte. Ideally, the limits of reporting reflected, or were lower, than the ANZECC & ARMCANZ (2000) trigger values for each parameter. However, for the numerous parameters that do not have appropriate guidelines, the limits of reporting were selected to maximise possible detections within reasonable budget constraints.

2.2 Frequency of sampling

The timing of sampling was based on rainfall events, water levels in the stormwater drains and sampling logistics. Where possible, the post-winter flows were captured prior to the drains drying out in the spring and summer months. Three sampling events were conducted spanning a four-month period, on 4–5 October 2007, 18–19 October 2007 and 18 January 2008.

2.3 The sites

There were four industrial areas sampled as part of this monitoring program, as shown in Figure 4. Herdsman Lake and Bickley Brook each had two sample sites; the other two areas had one. The industrial areas were selected based on advice from staff at the Perth Region NRM on their priority areas of interest. Specific site selection was based on site visits, and sites were selected at the bottom of the industrial catchments to capture as broad a range of industrial runoff as possible.



Figure 1 Sampling for a range of contaminants at the Bibra Lake site in October 2007



Figure 2 Sampling for a range of contaminants at the first Bickley Brook site in October 2007



Figure 3 Sediment samples taken from the first Bickley Brook site in October 2007

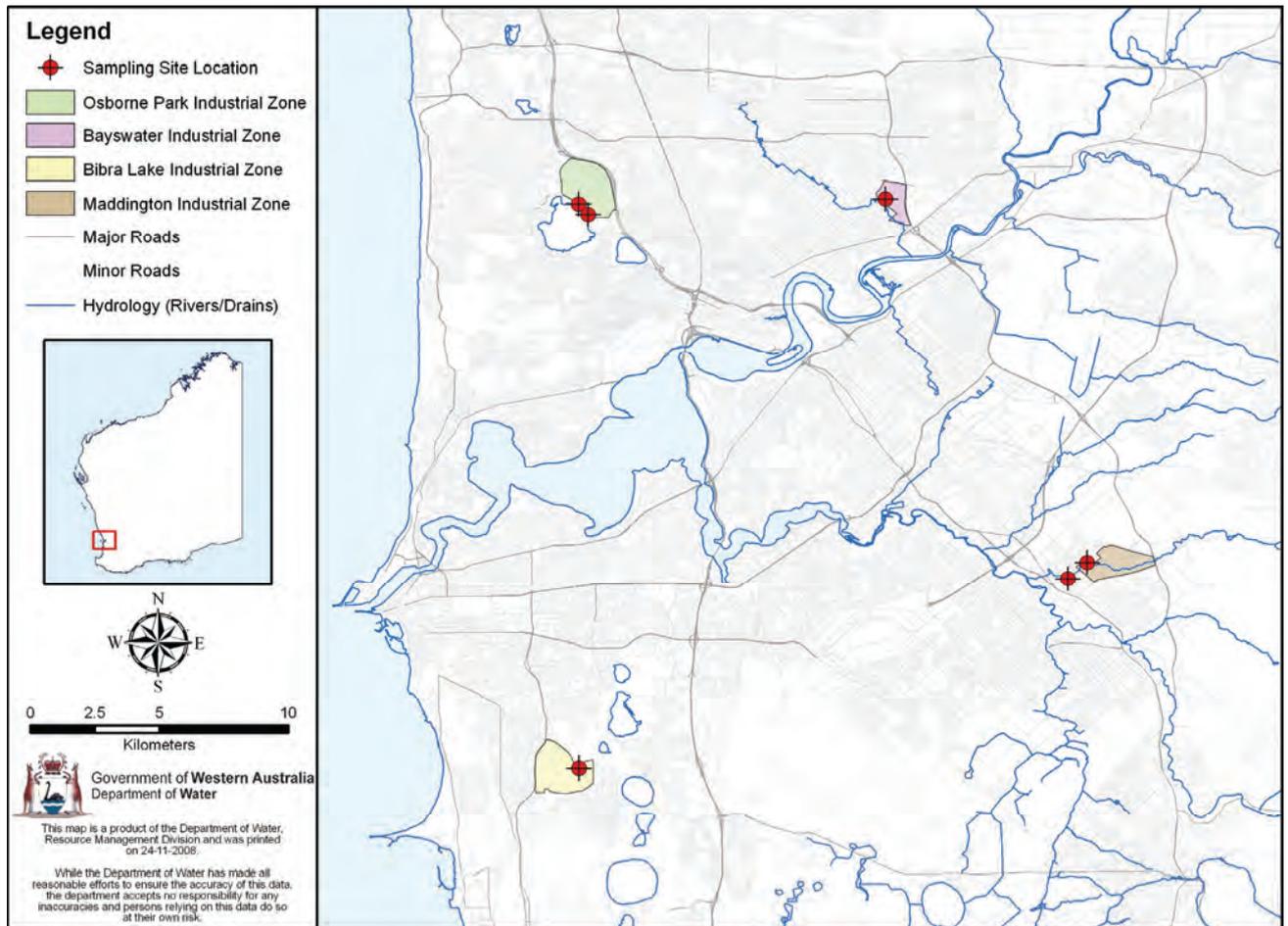


Figure 4 Water and sediment sampling sites and associated industrial areas in the Perth Metropolitan region, Western Australia

Herdsmen Lake

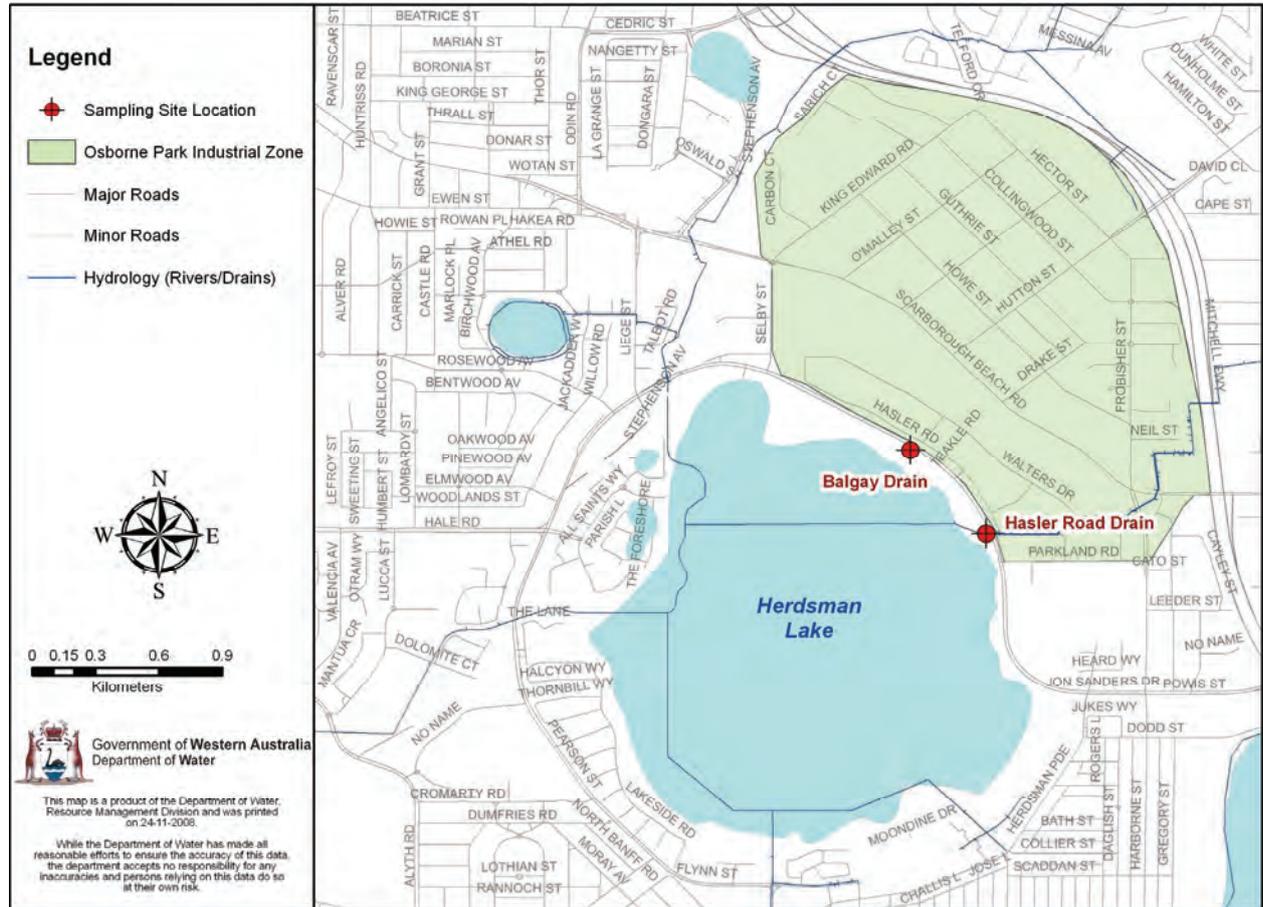


Figure 5 Industrial sampling sites at Herdsman Lake

Site 1 Balgay Drain

The Balgay Drain site is situated on the north side of Herdsman Lake and is accessible from Jon Sanders Drive near the intersection with Parkland Road. Water drains into the Herdsman Main Drain which crosses the lake in a westerly direction and discharges into the Indian Ocean at Floreat Beach. The drain has two large pipes running underneath Jon Sanders Drive draining into a large open drain. On each sampling occasion there was a steady supply of water draining from the industrial area. The open drain contained a dense mat of green algae and prominent orange flocculant each time it was visited.



Figure 6 Balgay Drain, sample site one at Herdsman Lake

Site 2 Hasler Road Drain

This site is situated on the north side of Herdsman Lake accessible from Jon Sanders Drive near the intersection with Teakle Road. Water drains to Herdsman Lake, and the drain had ceased flowing after the first visit. When the drain was not flowing, water backed up from Herdsman Lake itself so the drain remained permanently inundated and stagnant.



Figure 7 Hasler Road Drain, sample site two at Herdsman Lake

Both drains capture stormwater from the Osborne Park industrial area and Herdsman Lake Business Park to the north. The industrial area contains mixed small to medium industries such as car wreckers, engineering companies, automotive electricians, service stations, tyre service centres, sand blasting facilities, welding facilities, steel shops, paint shops, printing companies, and transmission and radiator repairers. The business park contains primarily warehouses, office complexes, showrooms and a newspaper company.

Herdsman Lake receives drainage waters from both the regional and local drainage systems. The sites were suggested by the Perth Region NRM to provide information for future urban drainage planning. In the past, areas of Herdsman Lake have been used for rubbish disposal, sanitary landfill and agriculture. At the beginning of the 20th century, market gardeners used the swampland with its peaty soils and abundant freshwater to grow vegetables commercially. Osborne Park gradually transformed into a residential suburb in the years following World War II. By the 1980s, industry had become dominant in most of Osborne Park (Conservation Commission of WA 2004). The industrial area is still largely unsewered and effluent is generally treated by septic tank systems.

Despite the development around Herdsman Lake it remains an important wetland on the Swan Coastal Plain, as it supports a wide diversity of wildlife species, serves as an important bird breeding ground and is a summer refuge for migratory birds (Conservation Commission of WA 2004).

Bayswater

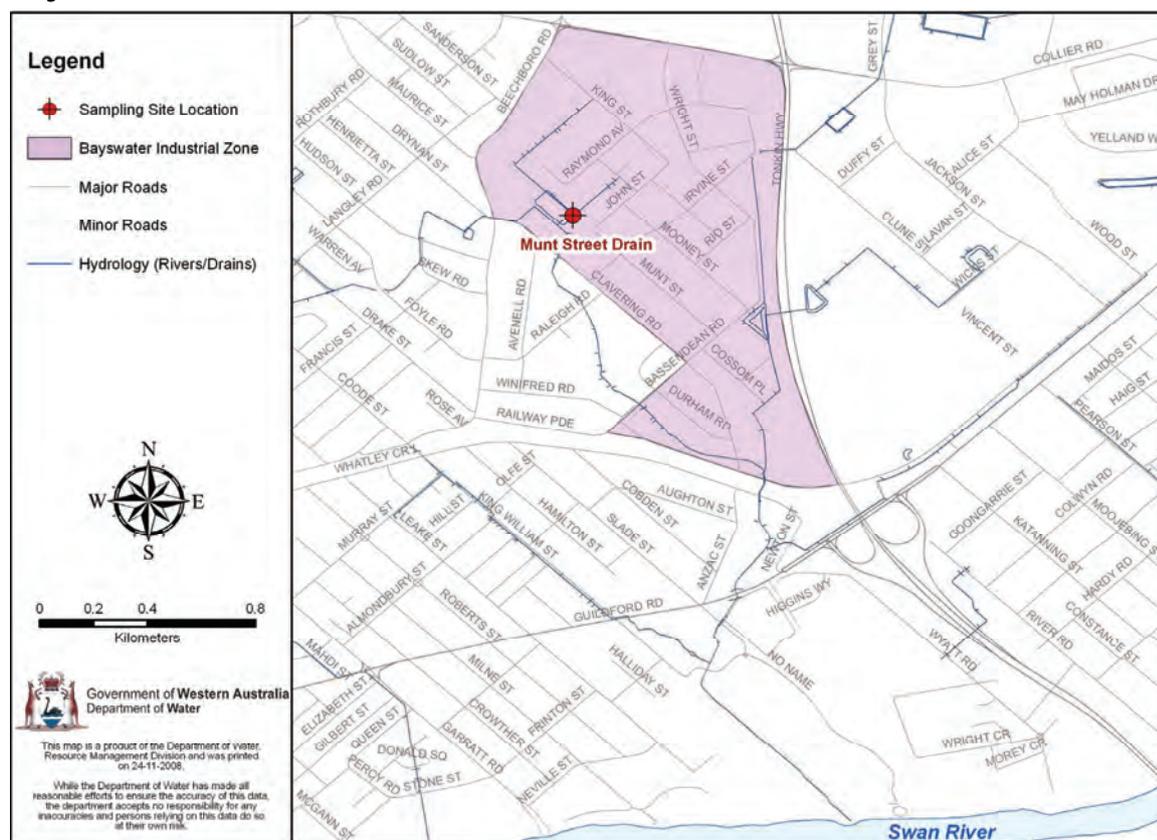


Figure 8 Sampling site at Bayswater

Site 3 Munt Street

The Munt Street site is situated near the end of Munt Street in Bayswater and is accessible from Clavering Road. The site is at the confluence of two stormwater drains which capture water from the northern part of the Bayswater industrial area. The drain then enters the Bayswater Main Drain and flows into the Swan River.

This site was selected after discussions with the North Metropolitan Catchment Group. High pollutant concentrations were observed in 2007 sampling. The drain had the most coarse, sandy sediment of all the sites. There were a number of pipes from individual premises that discharge upstream of the site and in mid-October milky white water was observed flowing from a nearby pipe.

Bayswater Main Drain was constructed by the Water Corporation in the 1960s and was developed from what was once an extensive wetland system, which has since been significantly modified to provide land for development. The Main Drain drains groundwater to prevent flooding of low lying areas and also receives stormwater via the large catchment area from numerous local government stormwater drains. Some sections of the drain flow all year round, while other areas flow intermittently.

Industry was introduced into the eastern district of Bayswater in the 1920s (City of Bayswater 2008). The Bayswater industrial centre has small to medium industries including car wreckers, automotive electricians, building product supplies, mechanical repair workshops, printing companies, cabinet makers, tyre repairers, service stations, battery suppliers, radiator specialists, gas suppliers, cleaning supplies, fridge and washer suppliers, panel and paint facilities, sheet metal and fabrication facilities, aluminium and chrome product

suppliers, plasterers, sand blasting facilities, tile supplies and engineering companies. The industrial area is still largely unsewered.



Figure 9 Bayswater industrial stormwater drain

Bibra Lake

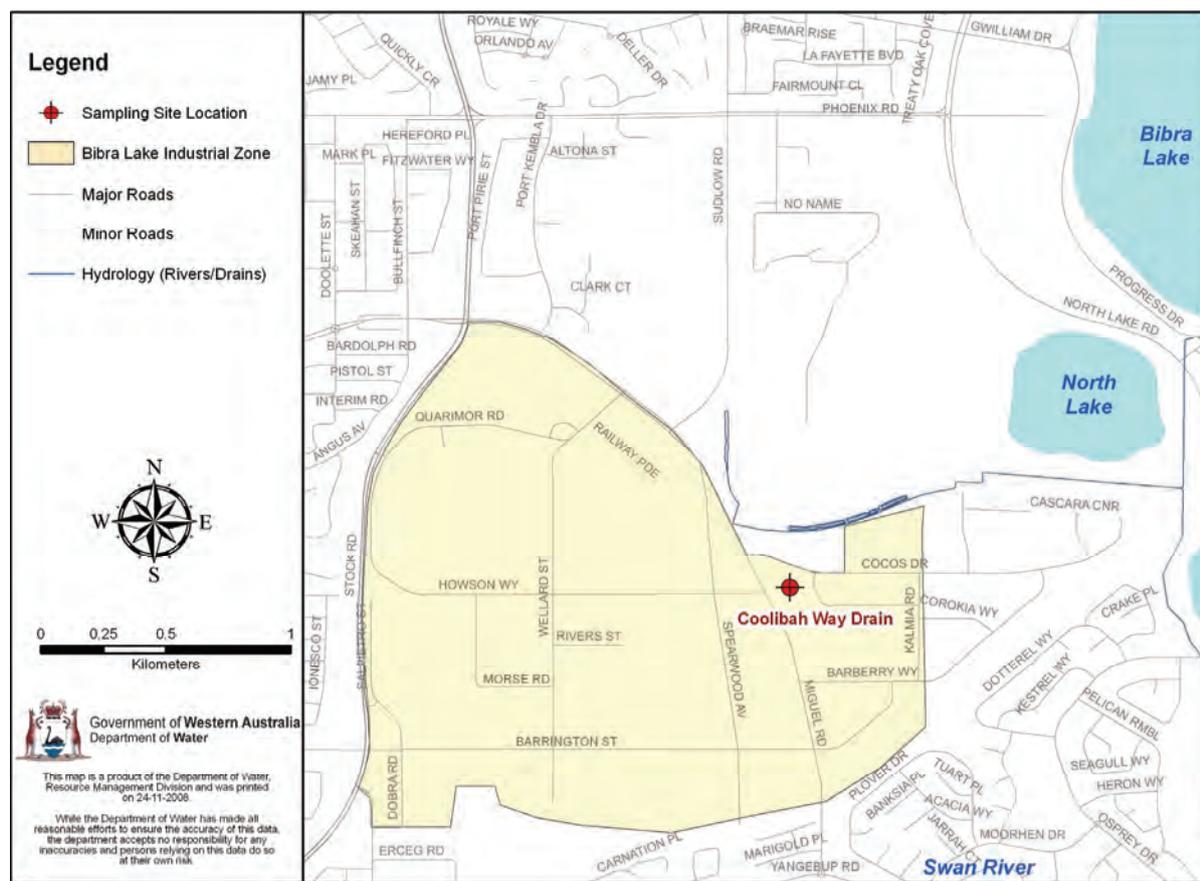


Figure 10 Sampling site in Bibra Lake

Site 4 Coolibah Way

The Coolibah Way site is a sump situated on Coolibah Way near the intersection with Cocos Drive in Bibra Lake. It drains a number of premises in the surrounding industrial area with the stormwater draining to groundwater. The sump is dry for most of the year, but contained water on the two occasions it was sampled in October 2007. Soils in the area are generally quite sandy but the sediment in the sump is fine grey clay, resulting from years of suspended solid deposition into the sump.

Urban and industrial development in Bibra Lake became established in the 1970s (City of Cockburn 2008). The [Beeliiar regional park](#), incorporating South Lake, Bibra Lake, Little Rush Lake and Yangebup Lake, runs in a line to the east of the sample site. The majority of the suburb, which is not part of the [Beeliiar regional park](#), contains small to medium industry within the Bibra Lake industrial area and Hamilton commercial centre. The industrial area includes industries such as green recycling, welders, paper suppliers, limestone suppliers, a concrete plant, a steel shop, metallurgical testing, asphalt and concrete pipe suppliers, mining products, spray painters, cabinet makers and a dredging company. The industrial area is still largely unsewered and effluent is generally treated by septic tank systems.



Figure 11 Sampling site on Coolibah way in Bibra Lake

Bickley Brook

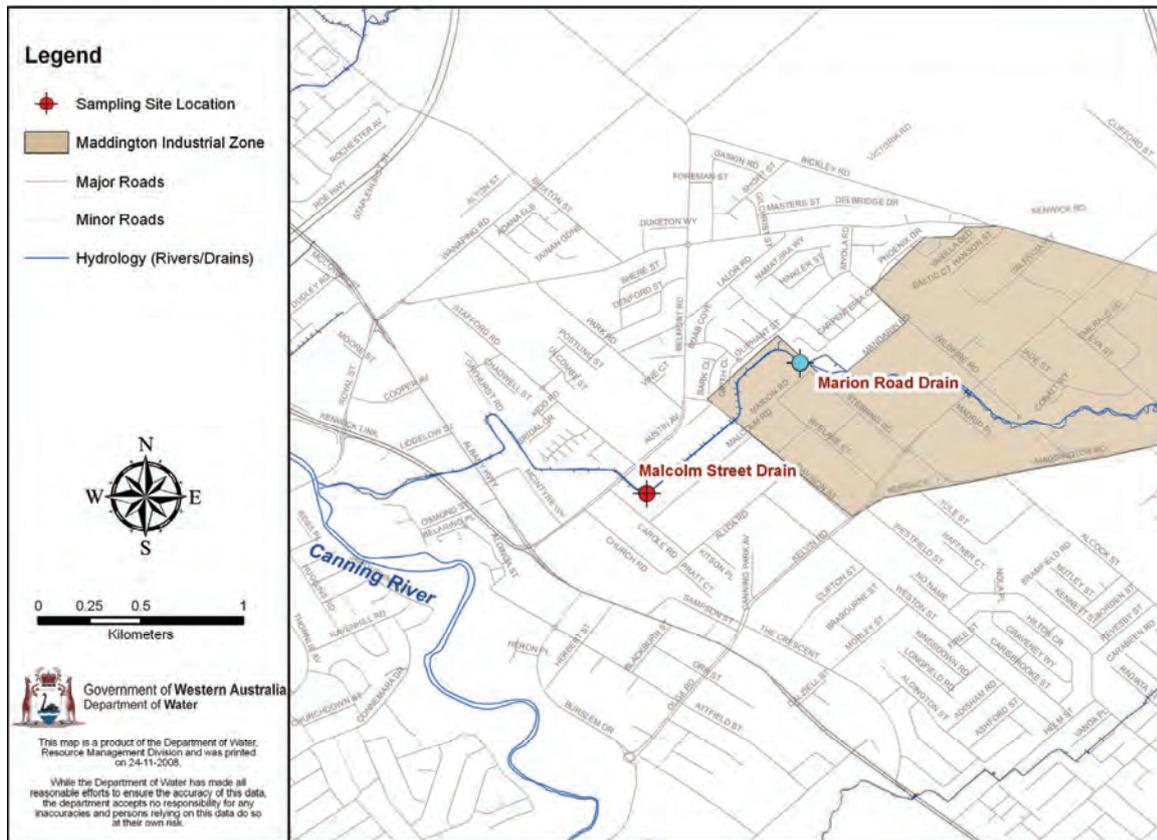


Figure 12 Sampling sites in Bickley Brook

Site 5 Marion Road

The Marion Road site is situated within a park at the corner of Marion Road and Stebbing Road in Maddington. Bickley Brook drains a number of industrial premises within the Davison industrial area as well as premises further upstream.



Figure 13 Bickley Brook near Marion Road

Site 6 Malcolm Street

The Malcolm Street site is situated off Malcolm Road in Maddington. The drain enters Bickley Brook and captures water from the Davison industrial area.



Figure 14 Bickley Brook near Malcolm Street

Both sites were selected after discussions with the South East Regional Centre for Urban Landcare. They were found to have high pollutant concentrations in 2006 sampling. After the initial sampling occasion, water levels were lower on each subsequent sampling occasion. The first site had a noticeable shiny, slick on the water surface in mid-October. The second site was dry in January 2008, so samples could not be collected on this occasion, but water was flowing at all other times.

Bickley Brook is a tributary of the Canning River, located approximately 6 km upstream of the Kent St Weir (Water and Rivers Commission 2002). Its catchment stretches from the Canning River in Kenwick, to the Darling Scarp in the suburbs of Orange Grove, Lesmurdie and Carmel. The catchment has been predominantly cleared, originally for agriculture, and now comprises a mix of semi-rural, residential and light industry. Below Tonkin Highway, Bickley Brook has very little remnant vegetation and now takes the form of an incised trapezoidal drain for much of the lower catchment.

Industry within Maddington commenced in the early 1960s. The Davison industrial area now incorporates small to medium industries including car wreckers, glass suppliers, chemical

suppliers, road building contractors, powder coaters, scaffolding suppliers, concrete tank suppliers, a service station, panel and paint facilities, timber suppliers, sign writers, plastic supplies, sand and soil supplies, cardboard box supplies, aluminium product supplies, cleaning services, smash repairers and radiator specialists. The industrial area is still largely unsewered and effluent is generally treated by septic tank systems.

2.4 Quality control

Field sampling techniques were developed to minimise the potential for cross contamination and unrepresentative samples. New, clean sample containers were sourced from the laboratory prior to sampling. The snapshot nature of the project meant field sample replication was not carried out. Sampling protocols are outlined in more detail in the sampling and analysis plan and follow methods described in the Standard methods for the examination of water and wastewater (APHA 1998). Samples taken in the drains were accompanied by field observation and chain-of-custody forms.

Chemical analysis was conducted by the National Measurement Institute, a NATA accredited laboratory, which has an established quality assurance program. Each batch of samples includes one duplicate sample in every 10 (randomly selected) and one blank matrix test per batch of samples (method test).

2.5 Data analysis and presentation

All data was managed by the water information branch of the Department of Water. Data was compiled in tabular form for each site and individual data compared across sampling runs.

2.6 Application of guidelines

Environmental values for the drains have not yet been determined and agreed upon between all key stakeholders as envisaged in the national water quality management strategy (ANZECC & ARMCANZ 2000) and associated guidelines. To provide a general frame of reference as to the state of water quality in the drains, this report compares the data with those guidelines which the Department of Water considers applicable to these water bodies.

In the absence of specific guidelines for stormwater and associated sediments, guidelines are provided for a range of environmental values including aquatic ecosystems, contaminated sites, primary industries, drinking water, recreation and aesthetics (ANZECC & ARMCANZ 2000, and NEPC 1999). The aquatic system guidelines recognise three levels of protection for aquatic ecosystems, being areas with high conservation value, slightly to moderately disturbed ecosystems and highly disturbed ecosystems. Exceeding the trigger value provided in the ANZECC & ARMCANZ (2000) guidelines indicates that there is the potential for an impact to occur and should trigger a management response such as further investigation or adaptation of the guidelines according to local conditions (ANZECC & ARMCANZ 2000). An exceedance does not indicate that a standard has been exceeded, but rather that further investigation of the site should occur.

The drains in this study are highly modified ecosystems in an industrial catchment where the risk of contamination is high and current environmental value is low. However, the drains ultimately discharge into wetlands, the Swan and Canning rivers, the Swan Estuary or the ocean, where environmental values are high. For this reason the contaminant results are compared to the trigger values for a 95 per cent protection level applicable to slightly to moderately disturbed ecosystems. Nutrient concentrations and physical results are

compared to the statistically derived default trigger values for slightly disturbed ecosystems of south-west Australia (baseflow only) (ANZECC & ARMCANZ 2000).

It is important to note that due to the snapshot nature of this study, water samples were not filtered and, as such, total metals are presented in this report. While this is consistent with the ANZECC guidelines (ANZECC & ARMCANZ 2000), care needs to be taken in interpreting the results as bio-availability, uptake and toxicity also need to be considered.

Trigger values for chromium, copper, lead, nickel and zinc in water require adjustment for hardness to reach a site specific hardness modified trigger value (HMTV). These have been calculated according to ANZECC guidelines and are presented in Appendix D. As total chromium was analysed it was not deemed appropriate to use a HMTV; instead the more conservative guideline for chromium VI is used here, which probably overestimates toxicity.

As this study investigates a diverse range of industrial chemicals, a large number of them are not covered by Australian guidelines. Where this is the case, international guidelines have been sought; these are cited where they are applied.

From a human use perspective, industrial stormwater drains are not a source of drinking water but may be accessed by the public for recreational activities. Therefore, it is reasonable to compare the concentration of contaminants to recreational guidelines, which take into account risks to public health (Department of Environment 2003a).

The concentrations of pollutants in the drain sediments are compared to the interim sediment quality guidelines, where both low and high trigger values are reported (ANZECC & ARMCANZ 2000). Where concentrations are between the low and high values, background concentrations should be investigated. If the results exceed the high guidelines or are above the background concentrations, a further assessment of the bio-availability of the pollutant may be required.

3 Results

3.1 Rainfall

The rainfall records described below were taken at the weather stations at Mount Lawley and Perth Airport, and field observations were taken from the sampling sites.

4–5 October 2007 sampling event: no rainfall during the preceding three days. There had been consistent rainfall up to a daily maximum of 8.4 mm throughout the prior week. Water levels were generally at their highest during this sampling period and the drains were all flowing rapidly. There was also water filling the sump in Bibra Lake caused by the recent rains.

18–19 October 2007 sampling event: 1mm of rainfall was recorded on 18 October. There was also consistent rainfall up to a daily maximum of 10.8 mm throughout the prior week. Water levels were marginally lower than the early October sampling. The drains were all flowing rapidly with the exception of the second Herdsman Lake site which appeared stagnant. The water level in the Bibra Lake sump was high.

18 January 2008 sampling event: there was no rainfall recorded throughout January. Water levels in all drains were significantly lower than the October sampling events and flows were greatly reduced. Both the Bibra Lake sump and site two at Bickley Brook were dry.

3.2 Non detections

Appendix C shows those contaminants that were investigated in the stormwater drains and sump, but not reported at any site on any occasion. This may suggest that the contaminants were not being discharged into the environment in these areas, or were being discharged at very low concentrations, below the limit of reporting used by the laboratory.

3.3 Physical results

Water temperatures at all sites were higher in January than October. The temperatures ranged between 24.8°C at site two at Herdsman Lake in January and 15.6°C at site one at Bickley Brook in mid-October.

The aquatic trigger value for specific conductivity in upland and lowland rivers of south west Australia is 0.12 to 0.3 mS/cm (ANZECC & ARMCANZ 2000). Specific conductivity exceeded the upper trigger value at all sites except for Bibra Lake in the second sampling run.

The trigger values for dissolved oxygen in lowland rivers of south west Australia are 80 per cent (lower limit) and 120 per cent (upper limit) respectively (ANZECC & ARMCANZ 2000). Dissolved oxygen was consistently below the lower limit at all the sites except the two Bickley Brook sites. Site two at Bickley Brook in particular had elevated dissolved oxygen levels peaking at 248 per cent.

The trigger values for pH in lowland rivers of south-west Australia are 6.5 (lower limit) and 8.0 (upper limit) respectively (ANZECC & ARMCANZ 2000). The Bayswater site was below the lower limit on all three occasions. The Bibra Lake site and site two at Bickley Brook exceeded the upper trigger value.

3.4 Water results

All contaminants that were over the limit of reporting in water are summarised in Appendix D. The key results are outlined below.

The two natural hormones 17 β -estradiol and estrone, and the synthetic hormone ethinylestradiol were detected at site two in Herdsman Lake. Ethinylestradiol was detected at the second Herdsman Lake site and Bayswater in early October.

Metals detected above guideline levels were aluminium, chromium, copper and zinc. Water from the Bayswater site had a pH below 6.5 so the trigger value of 0.055 mg/L for aluminium applies at this site (ANZECC & ARMCANZ 2000). On all three occasions the concentrations of aluminium exceeded the trigger value, reaching a high of 0.67 mg/L in Bayswater. Chromium exceeded the trigger value at Bayswater on each sampling occasion and at Bibra Lake and once at each of the Bickley Brook sites on separate occasions. Copper exceeded the trigger value at Bibra Lake and the Bickley Brook sites. Zinc exceeded the trigger value at site two at Herdsman Lake and both Bickley Brook sites on one occasion.

The TPHs C10–C14 were detected at Bibra Lake, site two at Bickley Brook and on one occasion at site two at Herdsman Lake. The TPHs C15–C28 were detected at site two at Herdsman Lake, Bayswater, Bibra Lake and both Bickley Brook sites. The TPHs C29–C36 were detected on one occasion at both site two at Herdsman Lake and Bibra Lake. There are currently no guideline values available for TPHs.

Anionic surfactants were detected at all sites on all occasions. Concentrations ranged between 0.05 mg/L at the Herdsman Lake sites and 0.76 mg/L at Bibra Lake. Non-ionic surfactants were detected at site one at Herdsman Lake, Bayswater and site one at Bickley Brook. There are currently no guideline values available for surfactants.

Phenol and the combined 3- and 4- methylphenol isomers were recorded at Bayswater and site two at Herdsman Lake respectively. The detection for phenol at Bayswater did not exceed the trigger value of 0.32 mg/L (ANZECC & ARMCANZ 2000). There is no guideline value for 3- & 4- methylphenol.

Total nitrogen levels exceeded the guidelines at all sites except at site one at Bickley Brook on one occasion and site two at Bickley Brook on two occasions. Figure 15 shows the proportion of the different forms of nitrogen that comprise the total nitrogen concentration. Site one at Herdsman Lake and the Bayswater site have a large proportion of oxidised nitrogen, whereas the other sites have a greater proportion of total organic nitrogen.

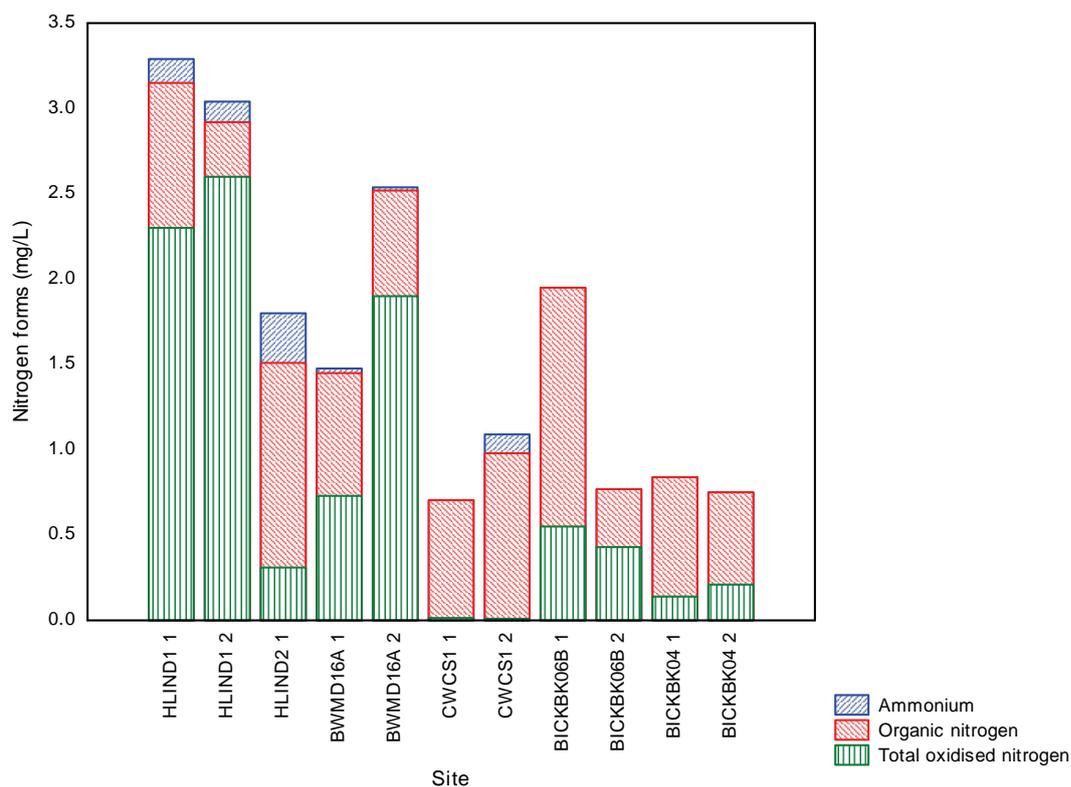


Figure 15 Proportion of different forms of nitrogen in industrial stormwater drains in the Perth region

Total phosphorus exceeded the guideline at the second Herdsman Lake site in mid-October 2007 and on both occasions at Bibra Lake. The filterable reactive component of the total phosphorus was below the limit of reporting or very low for all sites.

Total organic carbon ranged between 2 mg/L at the first Herdsman Lake site and 18 mg/L at the second Herdsman Lake site. The dissolved organic carbon component of the total was high for all sites.

Bromide, calcium, chloride, magnesium, sulfate and thiocyanate ions were detected at every site on at least one occasion. Hardness ranged between 76 mg/L at Bibra Lake and 230 mg/L at both Bickley Brook sites. Total suspended solids ranged between below the limit of reporting (<1 mg/L) at the Bayswater site and 23 mg/L at the second Bickley Brook site. The chemical oxygen demand ranged between the limit of reporting (<5 mg/L) at the first Herdsman Lake and Bickley Brook sites and 37 mg/L at Bibra Lake.

3.5 Sediment results

All detections of contaminants in sediment are summarised in Appendix E. The key results are outlined below.

The PCB Aroclor 1254 was detected on two occasions at the second Herdsman Lake site with the highest concentration being 0.63 mg/kg. Aroclor 1260 was detected at the same site on one occasion at a concentration of 0.08 mg/kg. There are no individual guideline values for PCBs although a trigger value of 23 mg/kg applies for total PCBs (ANZECC & ARMCANZ 2000).

Bibra Lake had detections of PAHs for which analysis was specified, whereas the Bayswater site had no detections. The Herdsman Lake and Bickley Brook sites had intermittent detections. Bibra Lake exceeded the lower level trigger values for acenaphthene, fluorene, pyrene, benz(a)anthracene, chrysene, benzo(a)pyrene and dibenz(ah)anthracene (ANZECC & ARMCANZ 2000).

Metals detected above guideline levels were copper, arsenic, lead and zinc. Copper exceeded the low level trigger value on both sampling occasions at site two at Herdsman Lake and on one occasion at site two at Bickley Brook. Lead exceeded the lower level trigger value on one occasion at site two at Herdsman Lake, Bibra Lake and site two at Bickley Brook. Zinc exceeded the lower level trigger value at site two at Herdsman Lake, Bibra Lake and on one occasion at site two at Bickley Brook. Further, zinc exceeded the high level trigger value at both Herdsman and Bibra Lake on one of the sampling occasions.

The TPH C10–C14 were detected at the second Herdsman Lake site and Bibra Lake. The TPHs C15–C28 and C29–C36 were both detected at site two at Herdsman Lake, Bibra Lake and both Bickley Brook sites. There are currently no guideline values available for TPHs in sediment.

Total nitrogen and total phosphorus concentrations exceeded recommended trigger values at Bibra Lake, with maximum concentrations of 1900 mg/kg and 250 mg/kg respectively. Total organic carbon levels in sediment exceeded one per cent at site two at Herdsman Lake, Bibra Lake and both Bickley Brook sites.

Two phthalates were detected in the sampling program. Dimethylphthalate was reported at Bibra Lake in mid-October at a concentration of 0.48 mg/kg. Bis(2-ethylhexyl)phthalate was reported at site two at Herdsman Lake and Bibra Lake on each occasion and site one at Bickley Brook in January. There are currently no guidelines available for phthalates.

Dichloromethane was detected in mid-October at site one at Herdsman Lake, Bayswater and Bibra Lake. Thiocyanate was detected at all sites with the highest recorded concentration being 4.5 mg/kg at site two at Bickley Brook. There are currently no guidelines available for either of these analytes.

Formation of actual acid sulfate soil usually results in a pH <4. The average pH of sediments across the sites was above pH 4, suggesting that on-site acidification (without further oxidation of these sediments) has not occurred.

The chromium reducible sulphur analysis (Scr) determines the reduced inorganic sulphur (sulfides and elemental sulfur) content of a sediment sample (Ahern et al. 2004). Reduced sulfides produce acid if oxidised, so Scr values can be related to the acid-generating potential of a site if the sediment were to undergo extreme oxidation. Site two at Herdsman Lake had the highest Scr value of 0.25 per cent. The acid neutralising capacity (ANC) is the

intrinsic ability of the sediment to maintain a neutral pH by buffering any acidification that occurs. The net potential acidity is the difference between the acid generating capacity of the sediment (from Scr) and the acid neutralising capacity of the sediment. Sites above the conservative trigger value of 0.03 per cent sulphur are considered to pose an environmental risk if the sediment were to undergo complete oxidation (Department of Environment 2004b). The only site where this was the case was at site two at Herdsman Lake.

4 Discussion

In this study, a range of contaminants were detected in drains of Perth's industrial areas. Appendix F contains more detailed descriptions of those contaminants. Perhaps most notable were the detections of PCBs at Herdsman Lake and the synthetic hormone ethinylestradiol at both Herdsman Lake and Bayswater. TPHs and metals including aluminium, copper, chromium, lead and zinc were also detected at a range of sites in concentrations above trigger values.

The results of this snapshot survey reflect the highly variable nature of stormwater runoff. There was no obvious temporal variability in the data from the limited sampling events that were conducted. Some chemicals, such as hormones and surfactants, were detected in surface waters but not sediment. Other chemicals, such as PCBs and PAHs, were only found in the sediment due to their low water solubility, hydrophobic nature and propensity to adsorb to particulate matter.

A large number of chemicals known to be commonly used for industrial purposes were selected for determination. Many of these chemicals including benzene, toluene, ethylbenzene and xylenes (BTEX), most of the volatile and semi-volatile organic compounds, the phenolic compounds, ethylene glycol, acetone and cyanide were not detected. While this finding suggests that these chemicals are not being discharged into the environment, it should be regarded with some caution. BTEX, the short-chained petroleum hydrocarbons and the volatile and semi-volatile organic compounds may be volatilising prior to reaching the sampling points. Additionally, the limits of reporting for some chemicals may not be sensitive enough to pick up low but potentially toxic levels of chemicals. Ethylene glycol, for example, is a common car radiator coolant and is considered to be harmful at low levels but was analysed in the laboratory to a relatively high limit of reporting of 10 mg/L (ANZECC & ARMCANZ 2000).

Many of the PAHs detected within the study may pose a contamination risk that has not been highlighted due to a lack of guidelines for the contaminant. There are also no guidelines available for TPHs. Most petroleum hydrocarbon detections were in the C10–C14 and C15–C28 fractions. Sources may include vehicle or machinery use, disposal of used oil and transmission fluids or industrial discharges (Department of Water 2007). The shorter chain fraction C6–C9 incorporates the BTEX compounds, all of which are particularly volatile and are likely to have been lost from the system. The longer chain lengths are less soluble in water and less likely to be transported in surface water.

The metals aluminium, chromium, copper, zinc, nickel, lead and arsenic were all detected above guideline levels at certain sites. Many of these metals are common in the environment, but they may also be derived from other anthropogenic sources such as industrial activities. The sources of metal contamination in stormwater in this study are therefore difficult to trace. Aluminium and arsenic often occur naturally in stormwater because of leaching from soils and can be mobilised under acidic conditions. Chromium is a component of stainless steel; copper and zinc are common in all brass products; copper and nickel can be used in metal plating processes; and zinc is found in all galvanised products. Roofs, pipes, fittings, scrap metal, vehicles and machinery are all potential sources. Metals such as lead have also been used as constituents of petrol, oil, grease and paints. Chromium and zinc have historically been used as anti-corrosives in air conditioning systems. Chromium and arsenic are used as wood preservatives.

Metal concentrations in this study are from an unfiltered sample, so metals bound to solids were dissolved when acidified in the laboratory analysis. As such, concentrations reported in this study give an indication of the 'worst case scenario' of metal concentrations that could possibly become bio-available if conditions were favourable. The use of unfiltered water samples for analysis was considered appropriate in a snapshot study of this type. However, for many metals in aquatic systems it is the free ionic form which is believed to be responsible for toxicity (McGeer et al. 2004). For example Cu^{2+} has been directly linked to toxicity in fish and invertebrates, while copper complexed by dissolved organic matter does not induce toxicity to the same degree because bio-availability for uptake is reduced (McGeer et al. 2004). Future targeted studies should assess bio-available metals to determine their likely impacts on organisms in the receiving environments.

As with metals, tracing the sources of other types of contaminants in the stormwater is difficult without a thorough assessment of land uses and environmental management practices in the catchments. For example, surfactants were common at all sites, with anionic surfactants more prevalent than non-ionic surfactants. Typically anionic surfactants are used in detergents, soaps, shampoos and fabric softeners. Non-ionic surfactants are found in foods and drinks, pharmaceuticals and skin-care products and are common wetting agents used in pesticide mixes. Both are used by industry, particularly in cleaning and wash-down processes.

Dichloromethane was detected at three sites on only one occasion. Dichloromethane is a common industrial solvent (e.g. degreaser; paint stripper); but is also used as a solvent in the laboratory and the detections may represent contamination from laboratory processes. Phthalates are found widely in plastics; which are ubiquitous in the environment. They are also present in the laboratory where contamination may occur inadvertently.

Each site is examined below in detail, with a summary of the main contaminants found at the site and consideration of the potential sources of the contaminants.

Herdsman Lake

Balgay Drain is the more eastern of the two drains sampled near Herdsman Lake. This drain comprises an enclosed concrete pipe for a large section upstream of the sample site. The highest concentrations of iron in surface water were in this drain. Low oxygen conditions in enclosed pipes can promote soluble ferrous ions and complexes to predominate over ferric ions. Once oxygen is reintroduced, the iron tends to drop out of solution. There was evidence that this was occurring at this site with iron flocculations being observed. Ammonium concentrations were also comparatively high at this site, which is a common observation in piped systems.

Both anionic and non-ionic surfactants were detected in samples at Herdsman Lake. Sources of these surfactants are difficult to determine but may include service stations, automotive repair shops and any other industry where detergents and soaps are used for cleaning.

Total nitrogen and total phosphorus levels were both detected in the Balgay Drain at levels that exceed trigger values. The most likely source of nutrients is from fertiliser use and septic tanks in the catchment, but other sources may contribute.

The sediment in this drain is most likely to have accumulated over a long period. As water exits the piped section, flow rates decline and solids drop out of solution. There would rarely be enough flow to scour out the drain and the drain does not get regular cleaning. While

there is potential for contaminants to accumulate in the sediments, no guidelines were exceeded. A range of PAHs were detected, however, all high molecular weight (HMW) hydrocarbons which are typically less toxic than the LMW hydrocarbons. The dominance of the HMW hydrocarbons suggests that weathering of petroleum products has occurred in the sediment. There may also be pyrogenic source of PAHs such as bushfires and engine combustion (Vo et al. 2004).

Hasler Road Drain had the lowest dissolved oxygen levels and high total organic carbon levels. Consistent with these observations it was also the only site with mean net potential acidity above 0.03 per cent suggesting it is a reducing environment. If disturbed, the sediments could release acidity and previously bound metals into the water. Arsenic concentrations in the sediment exceeded the trigger values. Arsenic compounds are common and naturally occurring in many Perth soils. All these conditions are typical of many wetlands on the Swan coastal plain where organic materials have been able to accumulate as peat over long periods.

Ethinylestradiol was detected in surface water at a concentration of 0.013 mg/L. Detection of this synthetic hormone, which is found in the birth control pill, suggests that there may be human sewage inputs into the drain. Large sections of the industrial area do not have deep sewerage so it is possible that waste from septic tanks is leaching through the groundwater. Ethinylestradiol is less easily biodegraded than the naturally produced hormones (WERF 2006) and was only detected in one sample.

On the final sampling occasion, natural hormone samples were collected to determine the 17 β -estradiol and estrone levels. The detection of these natural hormones is of concern as they have been shown to cause physiological effects at concentrations close to those reported here. Shore and Shenesh (2003) found that the lowest observable effect level for fish is about 10 ng/L; slightly higher than concentrations found in this study. While the detections may be associated with sewage they could also be derived from domestic or wild animals in the catchment.

The PCBs Aroclor 1254 and Aroclor 1260 were detected in the sediment in the Hasler Road Drain. The importation of PCBs was banned in Australia in the 1970s, with management plans for the phase out and destruction of all PCBs endorsed in 1993 (Environmental Protection and Heritage Council 2003). In the past, these have been commonly used in transformers as an insulating fluid. With historic usage of the Herdsman Lake area for rubbish disposal, sanitary landfill and agriculture, PCBs may be a legacy of this activity. The anoxic conditions and high carbon content of the sediment in the drain is likely to slow the breakdown of the PCBs, which will stay tightly bound and immobile under reducing conditions.

Longer chain length petroleum hydrocarbons were detected in both the water and sediment in the Hasler Road Drain. These petroleum hydrocarbons may be associated with kerosene, diesel and crude oils. The hydrocarbons will degrade over time by microbiological activity in the presence of oxygen; however, the anoxic conditions in the drain will slow this process dramatically. Elevated concentrations suggest that petroleum hydrocarbons are being discharged in the catchment. Petrol stations are a common source of petroleum hydrocarbons, but road runoff and a wide variety of industries are also potential sources.

3- & 4- methylphenol, also known as m- & p- cresols, were detected in the sediment of this drain. A potential natural source may be from micro-organisms breaking down organic materials in the soil. Anthropogenic sources include industrial uses as a solvent, [disinfectant](#), [deodouriser](#) and pesticide.

Of the metals sampled in Hasler Road Drain, zinc exceeded trigger values in water; and copper and lead were above trigger values in the sediment. These types of metals may be coming from a range of sources, including industry. Car wreckers, service stations, welding facilities and automotive repair shops are all potential sources. The metals may also be coming from road or roof runoff in the catchment. The presence of lead in the sediment may be a legacy of the use of lead-based fuels.

Bayswater

The water in the Bayswater drain was clear and had the lowest pH of all the sites – ranging between 6 and 6.5. Aluminium and chromium exceeded trigger values in the water. In low pH conditions, aluminium may be leaching into the water from natural deposits in the soil.

Aluminium and chromium are also widely used in different industries. In Bayswater these industries may include car wreckers, building product suppliers, automotive repair shops, sheet metal and fabrication facilities and aluminium and chrome product suppliers.

Ethinylestradiol was detected in the drain at a concentration of 0.1 ug/L. Detection of this hormone suggests that there may be human sewage inputs into the drain. Large sections of the industrial area do not have deep sewerage, so it is possible that waste from septic tanks is leaching through the groundwater. The hormone was only detected in the drain on one of the three occasions it was sampled. Investigation of the local drainage revealed a badly damaged manhole nearby covering a sewer pipe and it is possible there was leakage from this sewer into the stormwater drain. This was reported to the Water Corporation.

Total nitrogen also exceeded trigger values in the Bayswater drain. The nitrogen was largely in the oxidised and organic forms suggesting that the system is well-oxygenated. Likely sources of anthropogenic nitrogen in the system are from septic tanks and fertiliser application on parks, lawns and gardens within the catchment.

Anionic surfactants and phenol were other contaminants detected in the stormwater within the Bayswater drain. These contaminants are used in a range of industries; for instance, the anionic surfactants are used as cleaning agents and phenol can be used in herbicides.

Sediment at the Bayswater site contained comparatively low concentrations of contaminants. This may be a consequence of the sediment type, which was fairly coarse and sandy and had relatively low total organic carbon content. Sandy sediment does not have the same amount of binding sites available to adsorb contaminants that fine clay and rich organic sediments contain. Contaminants that commonly bind to sediment such as PAHs may therefore move through the system into the downstream environment more rapidly than at other sites.

Bibra Lake

The site at Bibra Lake was within a sump that captures stormwater and allows it to filter slowly into groundwater. The sump drains only a limited catchment. The sediment contained a surface layer of fine silt which is likely to have accumulated as a consequence of years of deposition of suspended sediments. Chromium and copper exceeded the trigger values in the water; and lead and zinc exceeded the trigger values in the sediment. Metal concentrations are likely to have built up over time in the sump. The hydraulic cycle can also cause metals to be released from the sediment back into the water column under certain conditions. Sources of these metals may include any of the local industries that store and use metals, such as welders, steel shops, metallurgical testing and mining product suppliers.

The site had high concentrations of total nitrogen and total phosphorus in the water and sediment. Most of the nitrogen was in an organic form, so it may be from natural sources such as leaf litter. The phosphorus was largely bound to sediment and so is not readily bio-available. The carbon content and fine silty sediment in the sump is likely to strongly bind a high proportion of the phosphorus preventing it from leaching into groundwater.

The highest concentrations of anionic surfactants were detected at this site. As in other catchments, the source of the anionic surfactants is likely to be industries where soaps and detergents are used in cleaning activities.

TPHs were detected both in the water and sediment. Longer chain TPHs were predominant suggesting that the source may be diesel, kerosene or heavy oils from leaks, or spills from storage tanks or vehicles and machinery. It may also be possible that the short chain hydrocarbons have degraded.

PAHs were prominent in the sediment. The silty sediment at this site is likely to strongly adsorb PAHs (ANZECC & ARMCANZ 2000). Almost all of the selected PAHs were detected at this site. Concentrations exceeded guidelines for acenaphthene, fluorene, pyrene, benz(a)anthracene, chrysene, benzo(a)pyrene and dibenz(ah)anthracene. Profiles suggest that the PAHs result from weathering of petroleum. Pyrogenic sources may also be contributing. Used crank case oil and asphalt contain significant amounts of PAHs, which have a mix of petrogenic and pyrogenic characteristics and may have contributed to the totals.

Dimethylphthalate and bis(2-ethylhexyl)phthalate were also detected at this site in the sediment. The phthalates are most commonly used as plasticisers for softening plastics. As plastics are so widely used it is not uncommon for these chemicals to be detected in environmental samples.

Bickley Brook

Bickley Brook flows through a large catchment containing a wide range of industries. Some premises have stormwater systems that discharge water directly into the brook. Physical characteristics of sediments in the brook are spatially variable and include sands, silts and organic materials.

Sampling site one at Bickley Brook exceeded guideline levels for chromium, copper, and zinc in water. As with other sites these metals may be arriving in the brook through stormwater runoff from local industries. The types of local industries may include car wreckers, panel beaters, smash repairers and radiator specialists.

Total nitrogen exceeded trigger values in this Bickley Brook drain. The nitrogen consists almost entirely of oxidised and organic forms suggesting that the system is well-oxygenated. Surfactants were also detected in the surface water.

The sediment was quite variable in consistency and had the highest total organic carbon of any of the sites and highest total nitrogen levels. A variety of PAHs were detected in the sediment, with the HMW compounds pyrene and benzo(ghi)perylene being found the most regularly. Bis(2-ethylhexyl)phthalate, a commonly used plasticiser, was detected on one occasion. TPHs C15–C28 and C29–C36 were also detected in the sediment and are associated with diesel, kerosene and the heavy oils.

Compared to other sites, the second site at Bickley Brook had hard water (e.g. high calcium and magnesium concentrations). Sulphate levels were also high compared to other sites.

The drain also had relatively alkaline water with pH readings up to 9.5. These conditions may result largely from local groundwater influences; however, industrial discharges may also play a role.

Dissolved oxygen concentrations, chemical oxygen demand, total organic carbon and dissolved organic carbon values were all high at the second sampling site. The drain was very shallow, warm and had dense benthic macrophyte growth. The observed hypersaturation of oxygen was most likely due to photosynthetic production. It is evidently a productive system and likely to have significant diurnal dissolved oxygen variations. Nitrogen in the system was largely in oxidised and organic forms. Nitrogen exceeded recommended trigger values for total nitrogen and total oxidised nitrogen in the sediment.

Chromium, copper and zinc exceeded trigger values in water; and copper, lead, nickel and zinc exceeded trigger values in sediment. These metals may be entering the drain in stormwater from industries similar to those described for site one.

Petroleum hydrocarbons were detected in both the water and sediments. The PAHs pyrene and benzo[ghi]perylene were detected in sediment. Anionic surfactants and the highest thiocyanate concentration were also detected at this site. Sources of all these contaminants are difficult to determine, but may be from a variety of the industries in the catchment.

5 Conclusions and recommendations

This study has identified and quantified a range of contaminants in surface water and sediment of stormwater drains in industrial catchments in Perth, including ethinylestradiol and natural hormones, PCBs, PAHs, TPHs, metals and surfactants. As only limited temporal and spatial monitoring was undertaken, it is by no means a comprehensive assessment of the degree of contamination at each location. The information provided in this report is simply a first step in determining potential impacts the contaminants are having on the receiving environment downstream. Contaminants originating from industrial premises and other anthropogenic sources are evident at all the monitoring sites. Assuming that the trend of contamination is the same for similar industrial areas around Perth, there is a continuing need for education of managers of small to medium-sized industries in relation to proper environmental management systems and in particular stormwater, wastewater and waste management.

A number of recommendations can be made as a result of this study.

- An assessment of industries and their environmental management practices be taken within each specific catchment to identify possible sources of contamination.
- Local governments should assess local industrial stormwater quality and consider the associated environmental impacts in urban stormwater management planning.
- Follow-up investigations should include analysis to determine bioavailability of contaminants, such as physical characteristics of sediments and concentrations of filtered rather than total metals.
- Whole sediment toxicity studies should be considered where highly contaminated sediments have been identified, to determine the intensity and extent of any effects on biota.
- Further education of managers of small to medium-sized industry take place in relation to proper environmental management systems and in particular stormwater, wastewater and waste management. The Sustainable Production project at the Perth Region NRM is valuable in this regard.
- Finally, facility managers in particular, need to be made aware of the possible environmental regulations, including legal obligations under the Environmental Protection Act 1986, Unauthorised Discharge Regulations and the Contaminated Sites Act 2003.

Appendix A - Analytes measured in water from industrial drains in Perth

Analytes	Analysis method	Limit of reporting (mg/L)	Variations (mg/L)
Total nitrogen	Persulphate digestion method 4500-N C. (APHA 1998), and the automated cadmium reduction method 4500-NO3- F (APHA 1998).	0.025	
Ammonia and ammonium	Automated phenate method 4500-NH3 G. (APHA 1998).	0.01	
Oxidised nitrogen	Automated cadmium reduction method 4500-NO3- F (APHA 1998).	0.01	
Dissolved organic nitrogen	DON is calculated by analysing TN in a filtered sample and then subtracting the NH ₃ -N/ NH ₄ -N and NO _x -N result.	0.025	
Total phosphorus	Persulphate digestion method 4500-P B.5. (APHA 1998), and the automated ascorbic acid reduction method 4500-P F. (APHA 1998).	0.005	
Filterable reactive phosphorus	Automated Ascorbic Acid Reduction method 4500-P F. (APHA 1998).	0.005	
Total metals	Total unfiltered metals can be analysed by fully digesting the sample using a concentrated nitric/hydrochloric acid to an unfiltered water sample prior to analysis. Metals in water by ICP-MS or ICP-AES (see 3010 A., and 3120 B. APHA 1998).	0.001	Aluminium = 0.005, Iron = 0.005, Mercury = 0.0001, Molybdenum = 0.005, Lead = 0.01, Selenium = 0.002
Bromide	Measured by ion chromatography method 4110 (APHA 1998).	0.01	
Chloride	Measured by ion chromatography method 4110 (APHA 1998).	10.0	
Sulphate	Measured by ion chromatography method 4110 (APHA 1998).	2.0	
Thiocyanate	WL 196	0.1	
Total suspended solids	Basis of the method is gravimetry (APHA 1998; USEPA 1983; AS 1990). The water sample is filtered through a glass fibre (GF/C) filter of 0.45 µm pore size. For TSS: The filters used are dried at 103–105°C and weighed to determine the amount of total suspended solids in mg L ⁻¹ of sample.	1.0	
Total water hardness	Measured by computing it from the results of separate determinations of calcium and magnesium.	1.0	
Chemical Oxygen Demand	Open reflux method procedure 5220B.4b.	5.0	
Dissolved oxygen	Measured in the field using a calibrated Quanta or YSI probe (Oxygen electrode method, APHA 1998).		
pH	Measured in the field using a calibrated Quanta or YSI probe (Electrometry method, APHA 1998).		
Conductivity	Measured in the field using a calibrated Quanta or YSI probe (Instrumental measurement method, APHA 1998). Conductivity is reported at a standard temperature of 25.0° C; this is the specific conductivity.		
Anionic surfactants	PEI – 029 MBAS	0.05	
Non-ionic Surfactants	PEI – 030	0.1	

Analytes	Analysis method	Limit of reporting (mg/L)	Variations (mg/L)
Nonylphenol and octylphenol	NGCMS_1119	0.001	
Phenols	The 4-aminoantipyrine colorimetric method.	0.002	2,4-Dichlorophenol, 2,6-Dichlorophenol, 2-Chlorophenol, o-Cresol{2-methylphenol}, Phenol = 0.001
Halogenated aliphatic compounds	Analysis of volatile organic compounds by the purge and trap technique 6040 C, 6200 (APHA 1998).	0.001	Hexachloroethane = 0.01
Chlorinated benzenes and naphthalenes	NGCMS_1120	0.001	
BTEX	USEPA 5030 purge and trap technique for extraction, with subsequent analysis by GC-FID or GC/PID in accordance with USEPA 8020.	0.001	Xylenes = 0.002
Total petroleum hydrocarbons	USEPA 5030 purge and trap technique for extraction, with subsequent analysis by GC-FID or GC/PID in accordance with USEPA 8020.	0.025	C15-C28 and C29-C36 = 0.1
Polycyclic aromatic hydrocarbons	GC-MS, GC-ECD analysis (USEPA 8080/8140/1996e; APHA 1998).	0.0001	Benzo(b,k)fluoranthene = 0.0002
Phthalates	NGCMS_1111	0.01	Bis(2-ethylhexyl)phthalate = 0.02
Polychlorinated biphenyls	GC-MS, GC-ECD analysis (USEPA 8080/8140; 1983 1996e; APHA 1998).	0.00001	
Ethylene glycol	NGCMS_1122	10.0	
Ethinylestradiol, 17Beta-Estradiol and Estrone	NGCMS_1124	0.000005	
Dissolved organic carbon	Total organic carbon by high temperature combustion and IR detection, method 5310 (APHA 1998).	1.0	
Total organic carbon	Total organic carbon by high temperature combustion and IR detection, method 5310 (APHA 1998).	1.0	
Total cyanide	WL181WL183	0.01	

Appendix B - Analytes measured in sediment from industrial drains in Perth

Parameter	Analysis method	Limit of reporting (mg/kg)	Variations (mg/L)
Total nitrogen	Persulfate digestion method 4500-N C and the cadmium reduction method 4500-NO3- F (APHA 1998).	50.0	
Total phosphorus	Persulfate digestion method 4500-P B.5. and the automated ascorbic acid reduction method 4500-P F. (APHA 1998).	5.0	
Total organic carbon	NW_S15		
Total metals	Metals in water by ICP-MS or ICP-AES (see 3010 A., and 3120 B. APHA 1998).	0.5	cadmium, mercury = 0.1
Halogenated aliphatic compounds	NGCMS_1111	5.0	
BTEX	WL230	0.5	Xylene = 1.0
Phthalates	NGCMS_1111	1.0	Bis(2-ethylhexyl)phthal = 2.0
Ethylene glycol	NGCMS_1122	10.0	
Phenols	NGCMS_1111	1.0	3+4-Methylph {m+p-Cres}, 2,4,6-trichlorophenol, 2,4,5,-trichlorophenol, 2,3,4,6-tetrachloropheno l, Pentachloro Phen = 2.0
Total petroleum hydrocarbons	NGCMS_1121	100	C6-C9 = 25 and C10-C14 = 50
Polycyclic aromatic hydrocarbons	GC-MS, GC-ECD analysis (USEPA 8080/8140/1996e; APHA 1998).	0.01	Benzo(b)&(k)fluoranthene = 0.02
Polycyclic biphenyls	GC-MS, GC-ECD analysis (USEPA 8080/8140; 1983 1996e; APHA 1998).	0.1	
Chlorinated benzenes/naphthalenes	NGCMS_1122	2.0	
Chromium reducible sulphur suite	WL261-19A2 = ANC, WL170 = Moisture, WL281-23A = pH, and WL281-22B = Scr		ANC = 0.05 Scr = 0.01

Appendix C - List of contaminants that did not exceed the limit of reporting from the laboratory analysis

Water	Sediment
Most phenolic compounds – 2-methylphenol, 2-chlorophenol, 2,4-dichlorophenol, 3- & 4- methyl phenol, 2,6-dichlorophenol, 2-nitrophenol, 4-chloro-3-methylphenol, 2,4,6-trichlorophenol, 2,4,5-trichlorophenol, 2,3,4,6-tetrachlorophenol, pentachlorophenol, 2-ethylphenol, 2,4-dimethylphenol, 4-nitrophenol, nonylphenol, octylphenol.	Phenolic compounds – phenol, 2-chlorophenol, 2-methylphenol, 2,4-dichlorophenol, 3- & 4-methyl phenol, 2,4-dimethylphenol, 2,6-dichlorophenol, 2-nitrophenol, 4-chloro-3-methylphenol, 2,4,6-trichlorophenol, 4-nitrophenol, 2,4,5-trichlorophenol, 2,3,4,6-tetrachlorophenol, pentachlorophenol.
Phthalates – dimethylphthalate, diethylphthalate, di-n-butylphthalate, benzybutylphthalate, bis(2-ethylhexyl)phthalate, di-n-octylphthalate.	Phthalates – diethylphthalate, di-n-butylphthalate, benzybutylphthalate, di-n-octylphthalate.
PCBs – Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, Aroclor 1260.	PCBs – Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, Aroclor 1260.
BTEX - benzene, toluene, ethylbenzene, m- & p-xylenes, o-xylene.	BTEX – benzene, toluene, ethylbenzene, m- & p-xylenes, o-xylene
TPH C6-C9	TPH C6-C9
Volatile organic compounds and semi volatile organic compounds - chloromethane, chloroethane, bromomethane, vinyl chloride, trichlorofluoromethane, trichloroethene, 1,2-dibromoethane, 1,1-dichloroethene, dibromomethane, 1,2-dichloroethane, tetrachloroethene, 1,1,-dichloroethane, 2,2-dichloropropane, 1,1,1-trichloroethane, carbon tetrachloride, dichloromethane, trans-1,2-dichloroethene, cis-1,2-dichloroethene, bromochloromethane, 1,1-dichloropropene, 1,2-dichloropropane, cis-1,3-dichloropropene, trans-1,3-dichloropropene, 1,1,2-trichloroethane, 1,3-dichloropropane, 1,1,2,2-tetrachloroethane, 1,2,3-trichloropropane, 1,2-dibromo-3-chloropropane, hexachlorobutadiene, chloroform, bromodichloromethane, dibromochloromethane, bromoform, vinylacetate, 2-butanone, 4-methyl-2-pentanone, 2-hexanone, hexachlorocyclopentadiene, hexachloroethane, hexachloro-1,3-butadiene, 2-chlorotoluene, 4-isopropyltoluene, 1,1,1,2-tetrachloroethane, carbon disulfide, styrene.	Volatile organic compounds and semi volatile organic compounds – chloromethane, vinyl chloride, bromomethane, chloroethane, trichlorofluoromethane, 1,1-dichloroethane, trans-1,2-dichloroethene, 1,1-dichloroethene, 2,2-dichloropropane, cis-1,2-dichloroethene, bromochloromethane, 1,1,1-trichloroethane, carbon tetrachloride, 1,1-dichloropropene, 1,2-dichloroethane, trichloroethene, 1,2-dichloropropane, dibromomethane, cis-1,3-dichloropropene, trans-1,3-dichloropropene, 1,1,2-trichloroethane, 1,3-dichloropropane, 1,2-dibromoethane, 1,1,2,2-tetrachloroethane, 1,2,3-trichloropropane, 1,2-dibromo-3-chloropropane, hexachlorobutadiene, chloroform, bromodichloromethane, dibromochloromethane, bromoform, styrene, 4-isopropyltoluene, 2-chlorotoluene, 4-chlorotoluene, 2-butanone, 2-hexanone, 4-methyl-2-pentanone, vinylacetate, carbon disulfide, 2-chloronaphthalene, hexachloroethane, hexachlorocyclopentadiene, hexachloro-1,3-butadiene.
Chlorinated benzenes - bromobenzene, chlorobenzene, 1,3-dichlorobenzene, 1,2,3-trichlorobenzene, 1,2-dichlorobenzene, isopropylbenzene tert-butylbenzene, 1,3,5-trimethylbenzene, hexachlorobenzene, 1,2,4-trimethylbenzene, 1,4-dichlorobenzene, sec-butylbenzene, 1,2,4-trichlorobenzene, n-propylbenzene, n-butylbenzene. Chlorinated naphthalenes - 2-chloronaphthalene	Chlorinated benzenes - 1,1,1,2-tetrachloroethane, n-butylbenzene isopropylbenzene tert-butylbenzene chlorobenzene a-propylbenzene bromobenzene sec-butylbenzene 1,2-dichlorobenzene 1,3-dichlorobenzene hexachlorobenzene 1,2,4-trichlorobenzene 1,2,3-trichlorobenzene 1,4-dichlorobenzene 1,3,5-trimethylbenzene 1,2,4-trimethylbenzene.
Ethylene glycol	Ethylene glycol
Metals – cadmium, cobalt, mercury, selenium.	Metals – cadmium, mercury, selenium.

Water	Sediment
Acetone	Acetone
Cyanide	Cyanide
PAHs – naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b)&(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(ah)anthracene, benzo(ghi)perylene.	

Appendix D - Concentrations of contaminants in water samples collected

Parameter	Water	Guideline ANZECC 2000	LOR	Herdsman Lake 1		Herdsman Lake 2		Bayswater		Bibra Lake		Bickley Brook 1		Bickley Brook 2			
				4 & 5 Oct 2007	18 & 19 Oct 2007	18 Jan 2008	4 & 5 Oct 2007	18 & 19 Oct 2007	18 Jan 2008	4 & 5 Oct 2007	18 & 19 Oct 2007	18 Jan 2008	4 & 5 Oct 2007	18 & 19 Oct 2007	18 Jan 2008	4 & 5 Oct 2007	18 & 19 Oct 2007
Physicals	Temperature (°C)			19.35	19.62	22.67	19.36	24.78	22.1	19.36	22.18	18.68	20.94	17.16	23.12	26.2	21.18
	Specific conductivity (mS/cm)	0.12 - 0.3		0.746	0.768	0.756	0.756	0.781	0.687	0.682	0.704	0.309	0.222	0.643	1.437	1.248	1.299
Phenols	Dissolved oxygen (mg/L)			7.76	6.7	5.45	3.12	1.59	6.35	3.99	2.64	3.83	2.39	12.24	9.63	20.01	12.04
	pH	6.5 - 8.0		6.92	7.06	7.03	6.95	7.33	6.07	6.36	6.43	8.22	8.33	8.49	7.56	9.54	8.24
Hormones	Phenol (ug/L)	0.32	<0.1	<LOR	<LOR	<LOR	<LOR	<LOR	0.2	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
	3&4 Methylphenol (ug/L)		<0.2	<LOR	<LOR	<LOR	0.84	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Petroleum Hydrocarbons	17Beta-estradiol (ug/L)		<0.005	NS	NS	<LOR	NS	0.007	NS	NS	<LOR	NS	NS	NS	NS	NS	NS
	Ethinylestradiol (ug/L)		<0.005	NS	NS	<LOR	NS	0.007	NS	NS	<LOR	NS	NS	NS	NS	NS	NS
Metals	TPH C6-C9 (ug/L)		<25	<LOR	<LOR	<LOR	0.013	<LOR	0.1	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
	TPH C10-C14 (ug/L)		<25	<LOR	<LOR	<LOR	45	<LOR	<LOR	<LOR	<LOR	140	<LOR	<LOR	<LOR	<LOR	<LOR
	TPH C15-C28 (ug/L)		<100	<LOR	<LOR	<LOR	1200	<LOR	160	<LOR	<LOR	830	<LOR	<LOR	<LOR	<LOR	<LOR
	TPH C29-C36 (ug/L)		<100	<LOR	<LOR	<LOR	240	<LOR	<LOR	<LOR	<LOR	260	<LOR	<LOR	<LOR	<LOR	<LOR
	Al (tot) (mg/L)	0.055	<0.001	0.065	0.077	0.078	0.01	0.039	0.13	0.67	0.11	0.068	0.18	0.086	0.07	0.073	0.10
	Sb (tot) (mg/L)		<0.001	0.001	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	0.002	<LOR	<LOR	<LOR	<LOR	<LOR
	As (tot) (mg/L)	0.024 or 0.013	<0.001	0.005	0.005	0.005	0.005	0.007	0.001	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
	Cr (tot) (mg/L)	0.001*	<0.001	<LOR	<LOR	<LOR	<LOR	<LOR	0.001	0.001	0.003	<LOR	0.001	<LOR	<LOR	<LOR	<LOR
	Co (tot) (mg/L)		<0.001	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
	Cu (tot) (mg/L)	0.0014	<0.001	0.001	0.001	<LOR	<LOR	<LOR	0.001	0.0001	<LOR	0.001	0.002	0.001	0.001	0.002	0.003
	Cu (tot) HMTV (mg/L)		<0.001	0.006	0.006	0.006	0.007	0.007	0.004	0.004	0.005	0.004	0.003	0.004	0.004	0.008	0.008
	Fe (tot) (mg/L)		<0.001	3	3.9	3.5	1.1	2	0.19	0.17	0.33	0.28	0.36	0.57	0.75	1.4	0.81
	Pb (tot) (mg/L)	0.0034	<0.001	<LOR	<LOR	<LOR	<LOR	9.81E-05	8.24E-06	1.99E-05	<LOR	<LOR	1.99E-05	<LOR	<LOR	0.0002	0.0004
	Pb (tot) HMTV (mg/L)			0.033	0.028	0.031	0.035	0.035	0.018	0.016	0.020	0.015	0.011	0.016	0.016	0.045	0.045
	Mn (tot) (mg/L)	1.9	<0.001	0.032	0.021	0.024	0.065	0.043	0.014	0.007	0.022	0.025	0.028	0.026	0.033	0.51	0.027
	Mo (tot) (mg/L)		<0.001	0.002	0.001	0.004	<LOR	<LOR	0.002	0.002	<LOR	0.003	0.002	<LOR	<LOR	<LOR	<LOR
	Ni (tot) (mg/L)	0.011	<0.001	<LOR	<LOR	<LOR	0.001	<LOR	0.004	0.002	0.003	0.001	0.001	0.001	0.004	0.001	<LOR

Below limit of reporting (<LOR); not sampled (NS); green shading (equal to or exceeds guidelines); red shading (exceeds guidelines by 10x) for those contaminants for which guidelines are available. * Guideline used for total chromium is for (CrVI), as detailed in Methodology section.

Concentrations of contaminants in water samples collected

Parameter	Water	Guideline ANZECC 2000	Herdsmans Lake 1		Herdsmans Lake 2		Bayswater		Bibra Lake		Bickley Brook 1		Bickley Brook 2			
			4 & 5 Oct 2007	18 & 19 Oct 2007	4 & 5 Oct 2007	18 Jan 2008	4 & 5 Oct 2007	18 Oct 2007	18 Oct 2007	18 Oct 2007	18 Oct 2007	18 Oct 2007	18 Jan 2008	4 & 5 Oct 2007	18 & 19 Oct 2007	4 & 5 Oct 2007
Analyte	Ni (tot) HMTV (mg/L)		0.050	0.046	0.053	0.053	0.033	0.031	0.030	0.024	0.031	0.062	0.031	0.062	0.058	0.062
	Zn (tot) (mg/L)	0.008	0.004	0.005	0.061	0.004	0.003	0.003	0.001	0.003	0.002	0.012	0.002	0.003	0.005	0.013
Major Ions	Zn (tot) HMTV (mg/L)	0.008	0.037	0.033	0.038	0.024	0.022	0.026	0.022	0.018	0.022	0.045	0.022	0.045	0.042	0.045
	Bromide (mg/L)		0.3	0.32	NS	0.25	0.27	NS	0.11	0.11	0.62	NS	0.83	0.95	0.53	0.53
	Calcium (mg/L)		51	<LOR	59	31	<LOR	35	30	<LOR	20	68	20	46	<LOR	<LOR
	Chloride (mg/L)		110	120	NS	110	90	NS	20	20	120	NS	130	240	250	250
	Hardness (mg/L)		180	160	190	110	100	120	97	76	100	230	100	210	230	230
	Magnesium filterable (mg/L)		12	NS	11	7	NS	8	3	NS	12	13	12	22	NS	NS
	Sulfate as SO4-S (mg/L)		19	19	7	24	17	NS	3	3	12	NS	12	21	20	20
Nutrients	Thiocyanate (mg/L)		0.1	0.12	NS	0.2	0.19	NS	0.2	0.2	0.2	NS	0.1	0.2	0.2	0.2
	Total nitrogen (mg/L)	1.2	3.3	3.2	NS	1.5	2.9	NS	1.4	1.3	1.9	NS	0.83	NS	0.87	0.93
	Total oxidised nitrogen (mg/L)	0.15	2.3	2.6	NS	0.73	1.9	NS	0.015	0.01	0.55	NS	0.43	0.14	0.21	0.21
	Organic nitrogen (mg/L)		0.85	0.32	1.2	0.72	0.62	NS	0.69	0.97	1.4	NS	0.34	0.7	0.54	0.54
	Ammonia (mg/L)	0.08	0.14	0.12	NS	0.027	0.018	NS	<LOR	0.11	<LOR	NS	<LOR	<LOR	<LOR	<LOR
	Total phosphorus (mg/L)	0.065	0.051	0.068	NS	0.02	0.024	NS	0.13	0.065	0.022	NS	0.026	<LOR	0.041	0.041
	Filterable reactive phosphorus (mg/L)	0.04	<LOR	<LOR	NS	<LOR	0.008	NS	<LOR	0.009	<LOR	NS	<LOR	<LOR	<LOR	<LOR
	Dissolved organic carbon (mg/L)		4	2	16	11	11	NS	10	11	4	NS	3	13	14	14
	Total organic carbon (mg/L)		5	2	18	12	12	NS	13	12	4	NS	3	14	14	14
Chemical Oxygen Demand	Chemical oxygen demand (mg/L)		9	<LOR	24	27	22	NS	37	36	12	NS	<LOR	23	24	24
Total Suspended Solids	Total suspended solids (mg/L)		8	11	5	<LOR	1	NS	5	2	3	NS	2	5	23	23
Surfactants	Anionic surfactants (mg/L)		0.09	0.07	0.11	0.25	0.09	0.65	0.76	0.42	0.28	0.1	0.23	0.3	0.3	0.3
	Non-ionic Surfactants (mg/L)		<LOR	0.98	<LOR	<LOR	<LOR	1.1	<LOR	<LOR	0.3	NS	<LOR	<LOR	<LOR	NS

Below limit of reporting (<LOR); not sampled (NS); green shading (exceeds guidelines); red shading (exceeds guidelines by 10x) for those contaminants for which guidelines are available.

Appendix E - Concentration of contaminants in sediment samples collected from various stormwater drains

Parameter	Sediment	Guideline ANZECC 2000 Low	Guideline ANZECC 2000 High	Herdsmans Lake 1		Herdsmans Lake 2		Bayswater		Bibra Lake		Bickley Brook 1		Bickley Brook 2	
				4 & 5 Oct 2007	18 & 19 Oct 2007	18 Jan 2008	4 & 5 Oct 2007	18 Jan 2008	4 & 5 Oct 2007	18 & 19 Oct 2007	4 & 5 Oct 2007	18 & 19 Oct 2007	4 & 5 Oct 2007	18 & 19 Oct 2007	4 & 5 Oct 2007
PAHs	Naphthalene (mg/kg)	0.16	2.1	<LOR	<LOR	<LOR	<LOR	<LO R	<LO R	0.029	0.018	<LOR	<LOR	<LOR	<LOR
	Acenaphthylene (mg/kg)			<LOR	<LOR	<LOR	<LOR	<LO R	<LO R	0.006	0.052	<LOR	<LOR	<LOR	<LOR
	Acenaphthene (mg/kg)	0.016	0.5	<LOR	<LOR	<LOR	<LOR	<LO R	<LO R	<LOR	0.057	<LOR	<LOR	<LOR	<LOR
	Fluorene (mg/kg)	0.019	0.54	<LOR	<LOR	<LOR	<LOR	<LO R	<LO R	0.02	0.02	<LOR	<LOR	<LOR	<LOR
	Phenanthrene (mg/kg)	0.24	1.5	<LOR	<LOR	<LOR	<LOR	<LO R	<LO R	0.028	0.032	<LOR	<LOR	<LOR	<LOR
	Anthracene (mg/kg)	0.085	1.1	<LOR	<LOR	<LOR	<LOR	<LO R	<LO R	0.01	0.076	<LOR	<LOR	<LOR	<LOR
	Fluoranthene (mg/kg)	0.6	5.1	<LOR	0.03	<LOR	<LOR	<LO R	<LO R	0.064	0.4	<LOR	0.009	<LOR	<LOR
	Pyrene (mg/kg)	0.665	2.6	<LOR	0.066	<LOR	<LOR	<LO R	<LO R	0.1	0.762	0.008	0.019	0.024	0.018
	Benz(a)anthracene (mg/kg)	0.261	1.6	<LOR	<LOR	<LOR	<LOR	<LO R	<LO R	0.022	0.267	<LOR	<LOR	<LOR	<LOR
	Chrysene (mg/kg)	0.384	2.8	<LOR	0.031	<LOR	0.028	<LO R	<LO R	0.048	0.524	<LOR	0.007	<LOR	<LOR
	Benzo(b,k)fluoranthene (mg/kg)			<LOR	<LOR	<LOR	0.021	<LO R	<LO R	0.067	0.952	<LOR	<LOR	<LOR	<LOR
	Benzo(a)pyrene (mg/kg)	0.43	1.6	<LOR	0.036	<LOR	0.01	<LO R	<LO R	0.03	0.524	<LOR	<LOR	<LOR	<LOR
	Benzo(ghi)perylene (mg/kg)			<LOR	0.046	<LOR	<LOR	<LO R	<LO R	0.039	0.476	<LOR	0.015	<LOR	0.021
	Indeno(1,2,3-cd)pyrene (mg/kg)			<LOR	0.026	<LOR	<LOR	<LO R	<LO R	0.018	0.41	<LOR	<LOR	<LOR	<LOR
	Dibenz(a,h)anthracene (mg/kg)	0.063	0.26	<LOR	<LOR	<LOR	<LOR	<LO R	<LO R	0.005	0.076	<LOR	<LOR	<LOR	<LOR
Phthalates	Dimethylphthalate (mg/kg)		<1	<LOR	<LOR	<LOR	<LOR	<LO R	<LO R	<LOR	0.476	<LOR	<LOR	<LOR	<LOR
	Bis(2-ethylhexyl)phthalate (mg/kg)		<2	<LOR	<LOR	<LOR	3.727	<LO R	<LO R	2.758	5.238	<LOR	<LOR	<LOR	<LOR
PCBs	Aroclor 1254 (mg/kg)		<0.1	<LOR	0.627	<LOR	0.292	<LO R	<LO R	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
	Aroclor 1260 (mg/kg)		<0.1	<LOR	<LOR	<LOR	0.076	<LO R	<LO R	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
	TPH C10-C14 (mg/kg)		<50	<LOR	<LOR	<LOR	83	<LO R	<LO R	160	77	<LOR	<LOR	<LOR	<LOR
	TPH C15-C28 (mg/kg)		<100	<LOR	3600	<LOR	5900	<LO R	<LO R	1300	1700	460	260	510	210
				<LOR	<LOR	<LOR	<LOR	<LO R	<LO R	5900	1700	460	260	510	480

Below limit of reporting (<LOR); not sampled (NS); green shading (exceeds guidelines by 10x) for those contaminants for which guidelines are available.

Concentration of contaminants in sediment samples collected from various stormwater drains

Parameter	Sediment Analyte	Guideline ANZECC 2000 Low	Guideline ANZECC 2000 High	Alternate Guideline Value	Herdsman Lake 1		Herdsman Lake 2		Bayswater			Bibra Lake		Bickley Brook 1		Bickley Brook 2	
					4 & 5 Oct 2007	18 Jan 2008	4 & 5 Oct 2007	18 Jan 2008	4 & 5 Oct 2007	18 & 19 Oct 2007	18 & 19 Oct 2007	4 & 5 Oct 2007	18 & 19 Oct 2007	4 & 5 Oct 2007	18 & 19 Oct 2007	4 & 5 Oct 2007	18 Jan 2008
VOC	TPH C29-C36 (mg/kg)				<100	<LOR	<LOR	1200	<LO	<LO	<LO	1600	1600	480	150	360	370
	Dichloromethane (mg/kg)				<1	<LOR	<LOR	<LOR	2.5	105	4.2	<LOR	<LOR	<LOR	1.2	<LOR	1.8
Metals	Aluminium (mg/kg)					1400	1110	3460	0	0	4440	7090	4440	2020	3390	10500	10400
	Antimony (mg/kg)	2	25		<0.5	<LOR	<LOR	0.86	<LO	<LO	1.4	1.6	1.4	<LOR	<LOR	<LOR	<LOR
	Arsenic (mg/kg)	20	70		<0.5	8.2	12	21	<LO	<LO	4.5	5.2	4.5	0.57	<LOR	<LOR	8.2
	Chromium (mg/kg)	80	370			8.4	3.8	28	5.8	5.3	19	38	19	5.4	6.3	16	28
	Cobalt (mg/kg)				<0.5	0.59	0.63	0.64	<LO	<LO	2.4	4.1	2.4	1.4	2	7.5	15
	Copper (mg/kg)	65	270			5.8	6.1	6.1	2.5	1.5	29	54	29	9.5	20	19	110
	Iron (mg/kg)					8610	9890	10100	610	810	6430	24500	6430	7680	8970	24900	32900
	Lead (mg/kg)	50	220			26	18	180	6.6	3.5	27	60	27	16	9.5	25	180
	Manganese (mg/kg)					16	12	28	4.2	2	64	120	64	15	27	50	93
	Molybdenum (mg/kg)				<0.5	0.93		<LOR	<LO	<LO	1.1	2.3	1.1	0.65	0.62	0.89	2.1
	Nickel (mg/kg)	21	52			0.62	2.3	7.9	0.68	1.3	10	20	10	2.2	3.4	9.3	22
	Zinc (mg/kg)	200	410			70	72	1050	17	14	340	790	340	77	43	120	450
Nutrients	TN (mg/kg)			500	<50	220	210	NS	150	96	1900	1000	1900	600	920	NS	790
	TP (mg/kg)			150	<5	130	30	NS	96	69	250	160	250	110	100	NS	66
	TOC (mg/kg)					3000	3900	4700	170	130	21000	33000	21000	18000	14000	14000	11000
Major Ions	TOC (%)			1		0.3	0.39	2.5	0.17	0.13	2.1	3.3	2.1	1.8	1.4	1.4	0.45
	Thiocyanate (mg/kg)				<0.5	0.6		NS	0.6	0.2	0.4	1.8	0.4	<LOR	3.2	NS	<LOR
Chromium																	
Reducible Sulfur Suite	ANC (%)				<0.05	1.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Mean net potential acidity			<0.03		0.026	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	pH kcl			<4		8.4	NS	NS	6.8	NS	NS	9	NS	6.5	NS	NS	NS
	Scr (%)				<0.01	0.05	NS	NS	0.03	NS	NS	0.02	NS	0.02	NS	NS	0.01

Below limit of reporting (<LOR); not sampled (NS); green shading (equal to or exceeds guidelines); red shading (exceeds guidelines by 10x) for those contaminants for which guidelines are available.

Appendix F - Summary of contaminants found in this study

Ethinylestradiol

Ethinylestradiol is the active ingredient in oral contraceptive pills and hormone replacement therapy. It imitates the effects of a natural estrogen in the body and is an endocrine disrupting compound (EDC). EDCs are chemicals that may alter the endocrine [system](#) (consisting of glands, hormones and cellular receptors that [control](#) the body's internal [functions](#)) and may cause developmental or reproductive disorders (ANZECC & ARMCANZ 2000). In the environment it degrades more slowly than natural hormones. Sources of ethinylestradiol include leaking sewerage systems, septic tanks, or indirect runoff into water. Aguayo et al. (2004) found that biological effects including endocrine disruption and genotoxicity have been demonstrated at concentrations as low as 0.0003 ug/L. Nash et al. (2004) found that only 0.1 ng/L of ethinylestradiol induces the egg yolk precursor protein vitellogenin in male fish.

Polychlorinated biphenyls

PCBs comprise a group of 209 individual compounds in 10 homologous groups which were produced commercially in large quantities up until the late 1970s (National Advisory Body on Scheduled Wastes 1998). PCBs are listed in the Stockholm Convention on persistent organic pollutants as one of the so-called 'dirty dozen chemicals'. PCBs have been widely used as dielectric fluids for capacitors and transformers, as heat transfer fluids, plasticisers, lubricant inks, fire retardants, organic chemical solvents, paint additives, immersion oils, sealing liquids, adhesives, laminating agents, waxes and dust removers (ANZECC & ARMCANZ 2000). PCBs are among a broader group of organochlorine chemicals which persist in the environment due to their ability to resist chemical and physical breakdown. They bio-accumulate through the food chain. PCBs are stored in body fat and persist in this fat for many years after exposure has ceased (ANZECC & ARMCANZ 2000).

Polycyclic aromatic hydrocarbons

PAHs are formed during incomplete combustion of organic material. The principle sources of PAHs are the incomplete combustion of fossil fuels or wood (pyrogenic sources) and spilt oil or petroleum products (petrogenic sources). Petroleum will alter in its chemical composition as it resides in the environment. Evaporation, dissolution and biodegradation processes (i.e. weathering) will remove the low molecular weight (LMW) compounds from the petroleum in preference to high molecular weight (HMW) compounds.

Pyrogenic sources may be depleted in low molecular weight (LMW) 2–3 ring PAHs and enriched in high molecular weight (HMW) 4–6 ring PAHs leading to LMW/HMW ratios <1. Petrogenic sources are dominated by LMW PAHs and have LMW/HMW ratios >1 (Vo et al. 2004). Additionally, if the phenanthrene to anthracene ratio is less than 10 it may suggest that a greater proportion of the PAH contamination originates from pyrogenic sources (Wilson et al. 2003). Anthracene is not usually found in petroleum, but it is found in residues from fires. It is an indicator that pyrogenic sources have contributed to the PAHs in the sample. If anthracene is absent, it is most likely a petrogenic source.

PAHs are used in dyes, plastics and pesticides. They will break down slowly under microbial action and are considered to be moderately persistent chemicals, particularly when the sediment is characterised by low oxygen and high organic carbon content (Vo et al. 2004).

They do not dissolve easily in water and tend to adsorb to particulate matter and settle to the bottom of waterways. PAHs have moderate to high acute and chronic toxicity to aquatic life. LMW PAHs (e.g. phenanthrene) are acutely toxic and many HMW PAHs (e.g. benzo(a)pyrene) are mutagenic and carcinogenic (Boonchan et al. 2000).

Total petroleum hydrocarbons

TPH analysis is a non-specific laboratory method that detects a broad range of organic compounds within certain boiling ranges. Hydrocarbons are of prime economic importance because they encompass the constituents of the major [fossil fuels](#) and [plastics](#), [waxes](#), [solvents](#) and oils. Attention is focused on petroleum hydrocarbon contamination derived from petrol and diesel. HMW hydrocarbons are less available to organisms because they are less soluble in water and are more likely to adsorb onto the soil. While petroleum hydrocarbons may bio-concentrate to a limited extent, many organisms will readily metabolise petroleum hydrocarbons (EPHC 2003). Toxic effects have appeared over a large range of TPH concentrations (EPHC 2003). The low molecular weight aromatic component is likely to be a significant contributor to the toxicity of these mixtures (ANZECC & ARMCANZ 2000). Tsvetnenko (1998) provided an advisory water quality criterion to protect warm water marine organisms from unacceptable levels of ambient petroleum hydrocarbons. This value was calculated as 0.007 mg/L using water soluble fractions.

Metals

Metals are naturally occurring and also used in a diverse range of industries. Organisms have always been exposed to metals and in many incidences have developed means of responding to their presence (McGeer et al. 2004). Trace elements such as cobalt, copper, iron, manganese, selenium, molybdenum and zinc are necessary for the normal development of animals (Kapusta et al. 2004). The risk metals present to humans and ecological receptors is dependant upon metal speciation and the consequent bio-availability. Excess amounts of certain metal species are potentially toxic when they interact with certain biomolecules in an organism. Metals also persist as inorganic forms in environmental sinks and are cycled through the biotic components of an ecosystem. In many situations, metals bio-accumulate within organisms (Kapusta et al. 2004). Cadmium, lead, mercury and arsenic are also suspected endocrine disrupting chemicals.

Surfactants

Surfactants are wetting agents that lower the [surface tension](#) of a liquid, allowing easier spreading and mixing. Certain surfactants are known to be toxic to animals. Surfactants are usually categorised into three groups; anionic, non-ionic and cationic. Anionic surfactants comprise such common groups as linear alkylbenzene sulfonates (LAS) and alkyl ethoxylated sulfates (AES). Typically anionic surfactants include detergents, soaps, shampoos and fabric softeners. Non-ionic surfactants include alcohol ethoxylates (AE) and alkylphenol ethoxylates (APE). Non-ionic surfactants are found in foods and drinks, pharmaceuticals and skin-care products and are common wetting agents used in pesticide mixes. Cationic surfactants comprise quaternary ammonium compounds. Toxicities of detergents can vary widely with species and chemical (ANZECC & ARMCANZ 2000).

Phenolic compounds

Phenol, also known as carbolic acid, is a toxic, colourless [crystalline solid](#) with a sweet odour. Phenol has [antiseptic](#) properties and it is used in the production of drugs, [herbicides](#)

and [synthetic resins](#). 3- & 4- methylphenol are also known as m-cresol and p-cresol respectively and are widely occurring natural and manufactured chemicals. Cresols are used as solvents, [disinfectants](#), [deodourisers](#) and pesticides and are found in foods, wood, [tobacco smoke](#), [crude oil](#), [coal tar](#) and wood [preservatives](#). Small organisms in soil and water produce cresols when they break down organic materials. When cresols are breathed, ingested, or applied to the [skin](#) at high levels they can be harmful (ANZECC & ARMCANZ 2000).

Nutrients

Concentrations of nutrients, especially nitrogen and phosphorus usually determine the maximum biological productivity of an aquatic system. Excess levels of nutrients can stimulate the growth of plants and algae to the extent that they begin to dominate an aquatic system. Natural sources of nutrients are weathering of rock, animal waste, fixation of atmospheric nitrogen by some plants and decomposition of biological material. Human sources include fertiliser application, septic tanks, sewage outfalls, , detergents and industrial effluent.

Phthalates

Phthalates are organic compounds commonly added to [plastics](#) to increase their flexibility. The phthalates show low water solubility, high oil solubility and low volatility. Phthalates are used in [nail polish](#), [adhesives](#), [paint](#) pigments and a wide range of other products. Phthalates are suspected of being endocrine disrupting compounds (ANZECC & ARMCANZ 2000).

Dichloromethane

Dichloromethane is a colourless, volatile liquid used widely as a solvent. It is commonly used as a [paint stripper](#), for metal cleaning, pharmaceuticals, aerosols and acetate films. In the [food industry](#), it is used to [decaffeinate coffee](#) and to prepare extracts of [hops](#) and other [flavourings](#). Dichloromethane is the least [toxic](#) of the simple chlorohydrocarbons, but it is not without its health risks. Dichloromethane is metabolised by the body to [carbon monoxide](#) and it is a suspected carcinogen (Pankow & Cherry 1996).

Acid sulphate soils

Acid sulphate soils are soils containing iron sulfides after being disturbed and exposed to air produce sulfuric acid, which may leach toxic quantities of aluminium, arsenic and other metals from the soil (Department of Environment 2004b).

Thiocyanate

Thiocyanate may be present in herbicides, gasworks and photography industries. Cyanide is usually converted to thiocyanate by the addition reaction of sulfur. Forms of cyanide such as thiocyanate and cyanate do not form free cyanides (except for thiocyanate in acidic media) and hence are much less toxic (ANZECC & ARMCANZ 2000). Many natural waters contain thiocyanate from organic decomposition products and wastewater discharges. Some industrial wastes, such as those from the steel industry, petroleum refining and coal gasification may also contribute significant concentrations of thiocyanate.

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