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Water Quality in the Bayswater Main Drain

Swan River Trust
Report No. 4

Water Quality in the Bayswater Main Drain

A working paper for the
Bayswater Integrated Catchment Management
Steering Committee

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Report No. 4

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Chairman's Foreword

The Swan River Trust (and its predecessor the Swan River Management Authority) has been involved in investigating pollution in the Bayswater Main Drain since 1987. During that time the Trust has often had difficulty in determining the sources of various pollutants in the drain.

Increased community concern about the possible impacts on the Swan River encouraged the Trust to look for a new way of tackling the problem of pollution in the Bayswater Main Drain. The establishment of the Bayswater Integrated Catchment Management Steering Committee has facilitated this new approach. This has required a strong commitment by local government and the community.

This is the first time in Western Australia that a coordinated or integrated approach has been used in an urban catchment. The Swan River Trust is pleased to be involved in this process.

As part of the Trust's contribution to Integrated Catchment Management two water quality monitoring programmes were designed to investigate the contribution of pollution from different land use types and soil type mixes within the catchment, and to assess the possible impacts on the river environment.

This report is the first in a series designed to investigate and resolve pollution problems in the Bayswater Main Drain. I encourage all people concerned with this issue to read it and contact the Swan River Trust if further information is required.

Ron Davies AM
Chairman
Swan River Trust

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Maps

Production of maps in colour was prohibitive. However colour maps will be held at the Bassendean Town Council, Bayswater City Council, Stirling City Council, Swan River Trust, Water Authority of W.A. (Whipple St) and the Electoral Office of Dr Judy Edwards for viewing. In addition each Task Group will be supplied with a colour copy of the maps.

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Summary

The Bayswater Main Drain is the largest urban catchment in the Perth metropolitan area. It collects groundwater and surface runoff from a 2700 ha catchment consisting of land zoned for urban residential, commercial and industrial purposes. The total area zoned residential (which includes houses and parks) within the catchment is approximately 2336 ha. The industrial and commercial zonings have approximate areas of 295 ha and 69 ha respectively. The catchment includes the suburbs of Morley and Dianella where market gardens existed prior to urban development.

The catchment is characterised by sandy soils (Bassendean sands) which have a limited ability to adsorb and retain pollutants, and a high water table. A network of drains was constructed to drain the winter waterlogged soils. An efficient drainage network combined with a large number of septic tanks used for the disposal of domestic and industrial wastes means that the Bayswater Main Drain contributes significantly to the total pollutant load entering the Swan River.

The Swan River Trust developed two monitoring programmes associated with the Bayswater Main Drain. The catchment investigation aimed at defining and apportioning the pollutant load derived from different land uses and soil type mixes within the catchment of the Bayswater Main Drain. The investigation in the Swan River aimed at assessing the possible human health risks and environmental damage resulting from the discharge of drainage waters into the river.

Catchment Monitoring

Five sampling sites were selected in the catchment for this investigation. The King William Street Branch Drain, Gummery Street, Walter Road and Redlands St sites all represent subcatchments that are totally residential. The Slade Street site (referred to as the Bayswater Main Drain in the river monitoring section) represents the total input from the catchment (minus the contribution of the King William Branch Drain which discharges downstream of this site) to the Swan River.

Samples were collected on a roughly fortnightly basis from 14 May 1990 to 9 January 1991. Parameters analysed included trace metals (arsenic, cadmium, chromium, iron, lead, nickel, zinc, mercury); pesticides (organochlorines, organophosphates), solvents; nutrients (phosphorus,nitrogen); fluoride; pH; and flow.

Soluble reactive phosphorus concentrations were at or below detection at all sites except the King William St site. Mean total phosphorus concentrations were almost an order of magnitude higher at Slade St than at other sites. Generally the residential subcatchments recorded low levels of total phosphorus, however data did show a trend of increasing phosphorus concentration with increasing density of septic tanks (this does not take into account flow or subcatchment area).

The King William St site recorded the highest levels of nitrate and total nitrogen of the five sites monitored. These results, along with those of soluble reactive phosphorus, were inconsistent with the amount of reticulated sewerage in this subcatchment (90%) and a further investigation was initiated.

Aldrin, chlordane, dieldrin, DDT, heptachlor and lindane residues were all detected during the survey. The most frequently detected organochlorine residues were chlordane and dieldrin, being detected in eight to ten of the samples collected. The remaining four residues were detected twice or less during the survey.

Chlordane levels were generally below the environmental criterion at all sites. All dieldrin levels recorded at all sites were above the environmental criterion. The highest levels were recorded at the King William St site and a further investigation of this subcatchment has been initiated.

All sites exceeded the criteria for chlordane and dieldrin frequently. That is, water from residential areas contained levels of these two organochlorine residues that exceeded the environmental criteria. Therefore, the presence of these elevated levels at the Slade St site cannot be totally attributed to historic or current practices in the industrial area.

Levels of fluoride from the residential catchments were well below the environmental criterion. The highest fluoride levels were recorded at the Slade Street site, although the levels were lower than the six-month mean criterion used for river environments. Levels at the Slade St site reflect the influence of stormwater on fluoride concentrations. When the groundwater contribution is highest, levels of fluoride are also high, linking the fluoride source to groundwater contamination. Fluoride levels decline as rainfall and therefore stormwater contributions increase. No levels above the criterion for single samples were detected.

Arsenic, cadmium, copper and nickel levels were generally below the environmental criteria for single samples at all sites. At all sites lead levels were generally below the single sample criterion, however two single records at the King William St and Slade St sites exceeded this criterion. The most common source of lead in an urban environment is exhaust from motor vehicles using leaded petrol.

River Monitoring

Investigations of pesticides and trace metal levels in the Swan River environment adjacent to the Bayswater Main Drain included sites upstream and downstream of the discharge point. Samples of water biota and sediments were collected.

Residues of aldrin, chlordane, DDT, dieldrin and heptachlor were detected in the waters of the Swan River. Aldrin, chlordane and DDT levels were generally below the environmental criteria. Dieldrin levels on the two sampling occasions were above the environmental criterion. Heptachlor was not detected during the initial sampling in the river. However during the second sampling levels exceeding the environmental criterion were recorded in the Swan River downstream of the drain mouth. This indicates that the Bayswater Main Drain is not the major source of heptachlor in the river.

The levels of dieldrin in water samples taken from the Swan River are cause for concern because they exceed the criterion (0.003 µg/L) recommended by the Environmental Protection Authority for the long term protection of the riverine environment. All dieldrin levels detected in the Bayswater Main Drain (Slade St site) exceeded the recommended criterion for waters of the Swan River, but this was before dilution and mixing with the receiving waters (Section 3.4.1.1). Both dieldrin and aldrin were used in the past for a range of insecticidal purposes and aldrin is readily converted to dieldrin in the environment.

Five organochlorine residues were detected in the sediments of the Swan River in the vicinity of the Bayswater Main Drain (aldrin, chlordane and metabolites,DDT and metabolites, dieldrin and heptachlor). Pesticide levels in the river and mouth of the drain sediments were well within recommended levels for soils. It is believed that these levels do not pose a health or environmental threat, even though it may not be appropriate to use soil criteria for aquatic sediments. However, there are no criteria for river sediments.

Organochlorine levels in fish, shrimp, mussels, crabs and worms were mostly below the health criteria . This means that there is no health risk associated with eating these animals. These low levels are indicative of a low level of environmental contamination generally. It should be noted that health limits for organochlorines in crustaceans (shrimps) and fish are considerably more stringent than for molluscs (mussels).

Trace metals were well below the upper limit recommended for single water samples in the Swan River on both occasions. Copper was the only trace metal detected that exceeded the six-month median limit (5 µg/L). The concentrations of trace metals in river sediments were below acceptable levels for soils, with the exception of chromium and zinc. It is difficult to determine the source of trace metals in sediments as levels may reflect a current or historic source. Therefore it is difficult to determine whether trace metals deposition has been recent or not.

Concentrations of trace metals in the tissues of mussels were well below the health limits . This means that there is no health risk associated with eating these animals although they are not normally eaten as they are very small. Since mussels are filter feeders and thus concentrate metals from the surrounding environment these low levels are indicative of a low level of environmental contamination generally.

Fish samples collected during a survey investigating pesticide contamination within the Swan-Canning estuary are currently being analysed for trace metals. It is expected that concentrations in the fish will be below those found in the mussels.

Conclusion

The levels of pesticides and trace metals detected in Swan River waters and sediments and in tissues of aquatic animals were generally well below human health limits. Based on two sampling occasions, levels of dieldrin, heptachlor, and copper in the Swan River exceeded the respective environmental criteria for the long term protection of the estuarine environment.

Generally, levels of pesticides and trace metals in the Swan River and its biota were below environmental and health criteria. Levels of some pesticides and trace metals are elevated in the Bayswater Main Drain. Dilution and mixing in the Swan River appears to reduce the concentrations of these pollutants and therefore their impact on the ecology of the system.

These results should not lead to complacency. It is important that pollutant loads from the Bayswater Main Drain do not increase. It is also important that pollutant loads to the Swan River generally are reduced. As Perth continues to expand so too will the exportation of pollutants to the river.

The Bayswater Integrated Catchment Management Plan which will be developed by the Bayswater Integrated Catchment Management Steering Committee, is an important part of this process. The overall aim of this project is to identify sources of pollution (both direct and indirect) and to develop actions to control pollution so that the river is maintained as a healthy, functioning system now and into the future.

1.0 Introduction

The processes that occur in catchments that lead to pollutant generation, transport and deposition are variable. Catchment urbanisation results in increased volume and decreased quality of stormwater runoff and groundwater. A number of processes are involved and some of these are outlined below (Australian Environment Council, 1988).

The impervious surfaces (such as roads and roofs) do not enable water to infiltrate into the soil. This leads to increased surface runoff during rainfall. Conventional drainage networks promote rapid and efficient collection and transport of stormwater runoff and intercepted groundwater.

The consequences of increased stormwater volume include increased peak velocities and discharge rates and pollutant transport and possibly increased erosion from the land, drain bed and banks.

Urbanisation increases the range of pollutants available for transportation to waterways. Pollutants can include dust, soil, animal faeces, oil and grease, metal particles from corrosion and abrasion, chemicals used in industry, nutrients from domestic and commercial use, pesticides, and a myriad of chemicals used in residential areas. Sources of these pollutants include industrial practices and wastewater disposal, septic tank seepage, sewage overflows, vehicle service centres, leachate from landfill sites, and historic land use sites such as redeveloped market garden areas (Australian Environment Council, 1988).

Groundwater levels generally rise as a consequence of urbanisation. This is due to many factors including a reduction in trees (from the natural state) which take up groundwater and release it to the atmosphere (a process known as transpiration), and increased watering of gardens and parks. Drainage networks may be designed to intercept groundwater as a means of lowering groundwater levels. This means that pollutants contained in the groundwater will move more rapidly to the receiving waterbody than if the natural flow of groundwater were to continue.

Much of the north-eastern metropolitan region drains into the Swan River between Maylands and Midland. The Swan River in this region has poor exchange with the more marine waters of Melville Water during summer. The excess supply of nutrients leads to the development of very large populations of microscopic plants (phytoplankton blooms). Phytoplankton may consume much of the dissolved oxygen in the water during the night when they are unable to photosynthesise. Very low dissolved oxygen levels have been recorded in this stretch of the Swan River. Poor water quality associated with phytoplankon blooms may cause unpleasant water conditions such as a slimy feel or discolouration and may lead to the death of aquatic animals such as molluscs and fish.

The Bayswater Main Drain is the largest urban catchment in the Perth metropolitan area. It collects groundwater and surface runoff from a 2700 ha catchment consisting of land zoned for urban residential, commercial and industrial purposes. There are two industrial premises licensed under the Environmental Protection Act (1986) to discharge wastewater into the drainage system. The catchment includes the suburbs of Morley and Dianella where market gardens existed prior to urban development.

The catchment is characterised by sandy soils (Bassendean Sands) which have a limited ability to adsorb and retain pollutants, and a high water table. A network of drains was constructed to drain the winter waterlogged soils. An efficient drainage network combined with a large number of septic tanks used for the disposal of domestic and industrial wastes means that the Bayswater Main Drain contributes significantly to the total pollutant load entering the Swan River.

Localised discolouration of water, possible heavy metal and pesticide contamination and potential human health and environmental risks in the Swan River adjacent to the Bayswater Main Drain have raised considerable community concern. This has lead to the formation of the Bayswater Integrated Catchment Management Steering Committee. This Committee consists of representatives from both State and local governments as well as local community representatives. The aim of the Committee is to develop a management plan for the catchment which will both minimise pollution entering the drainage system and improve the local environment.

The issues associated with the Bayswater Main Drain are complicated and diverse. Therefore, to assist the Steering Committee in achieving its aim, five Task Groups have been established. This approach has meant that one complicated issue has been broken down into several more manageable issues. Each Task Group is investigating an issue and has membership from the general community as well as State and local agencies.

1.1 Structure of Report

This report presents the results of the two monitoring programmes conducted from 14 may 1990 to 9 January 1991. Section 2.0 collates the catchment monitoring data collected by the Swan River Trust and also includes some data from the Bayswater City Council's industrial area survey. A limited amount of interpretation has been undertaken on the data presented. This is primarily to enable Task Groups to use the information now rather than waiting until a thorough interpretation of data is complete. Also, Task Groups are collecting information which will assist in the interpretation of the data in this report.

Section 3.0 of the report interprets the data collected by the Swan River Trust on the impact of the drainage waters on the river and its biota. A more detailed interpretation of this data has been undertaken.

1.2 Environmental and Health Criteria

The fate of bio-accumulative pollutants such as organochlorine pesticides and heavy metals in the aquatic environment is highly complex and poorly understood. Environmental scientists must determine what levels of such pollutants are able to be assimilated by receiving waterbodies without leading to potential human health risks or adverse environmental impacts. This section discusses these issues.

Effluent discharge criteria, environmental criteria and human health limits are formulated and applied to industrial effluents, the environment and to potential food for human consumption, in order to meet the stated objectives of healthy people and environments. The relationships between the different types of criteria in the context of effluent discharges, dilution factors and mixing zones are often poorly understood. Figure 1 explains the relationship between these factors.

1.2.1 Industrial effluents

Pollutants such as heavy metals and organochlorine pesticides may be dissolved in an effluent, adsorbed onto or incorporated into organic particles or soil particles. This is represented as the shaded rectangles in the hypothetical effluent represented in Figure 1. The standards for levels of pollutants in effluents are enforced through appropriate discharge limits (effluent criteria) which should ensure that pollutants in effluents do not cause adverse environmental impacts in receiving waterbodies after dilution and mixing have occurred. Discharged effluents may be diluted from between 100 to 1000 times or more depending on the volume of effluent and drain flow. This is represented by a smaller shaded rectangle in the drain water in Figure 1.

When an effluent is discharged into a drain the reduction in water velocity causes much of the suspended solid load to settle. This means that pollutants adsorbed onto particulates become incorporated into the drain sediments (sedimentation).

1.2.2 Environmental criteria

Similar processes of dilution, mixing and sedimentation occur when drain waters enter riverine systems although dilution factors are often considerably greater (10 000 - 1 000 000 times). Figure 1 shows this as a very small shaded rectangles in the riverine waters.

Environmental criteria are selected depending on the beneficial use assigned to a particular river. In the case of the Swan River where aquatic animals are harvested and consumed, stringent criteria (Schedule 3 in DCE Bulletin 103) are appropriate.

1.2.3 Human health criteria

Pollutants may be incorporated into the tissues of animals and plants through a number of mechanisms and may ultimately be ingested by humans. Maximum residue levels (MRL) and maximum permitted concentrations (MPC) of pollutants in foodstuffs are statutory limits enforced by health authorities.

For certain pollutants, the recommended criteria may be slightly below the lower limits of detection of analytical techniques commonly used by chemists. For example, the environmental criterion for DDT in riverine waters is 0.001 µg/L and the lower limit of detection is 0.002 µg/L. This is because the costs associated with analysing for DDT to below 0.002 µg/L are prohibitive, and the analysis might not provide much additional information.

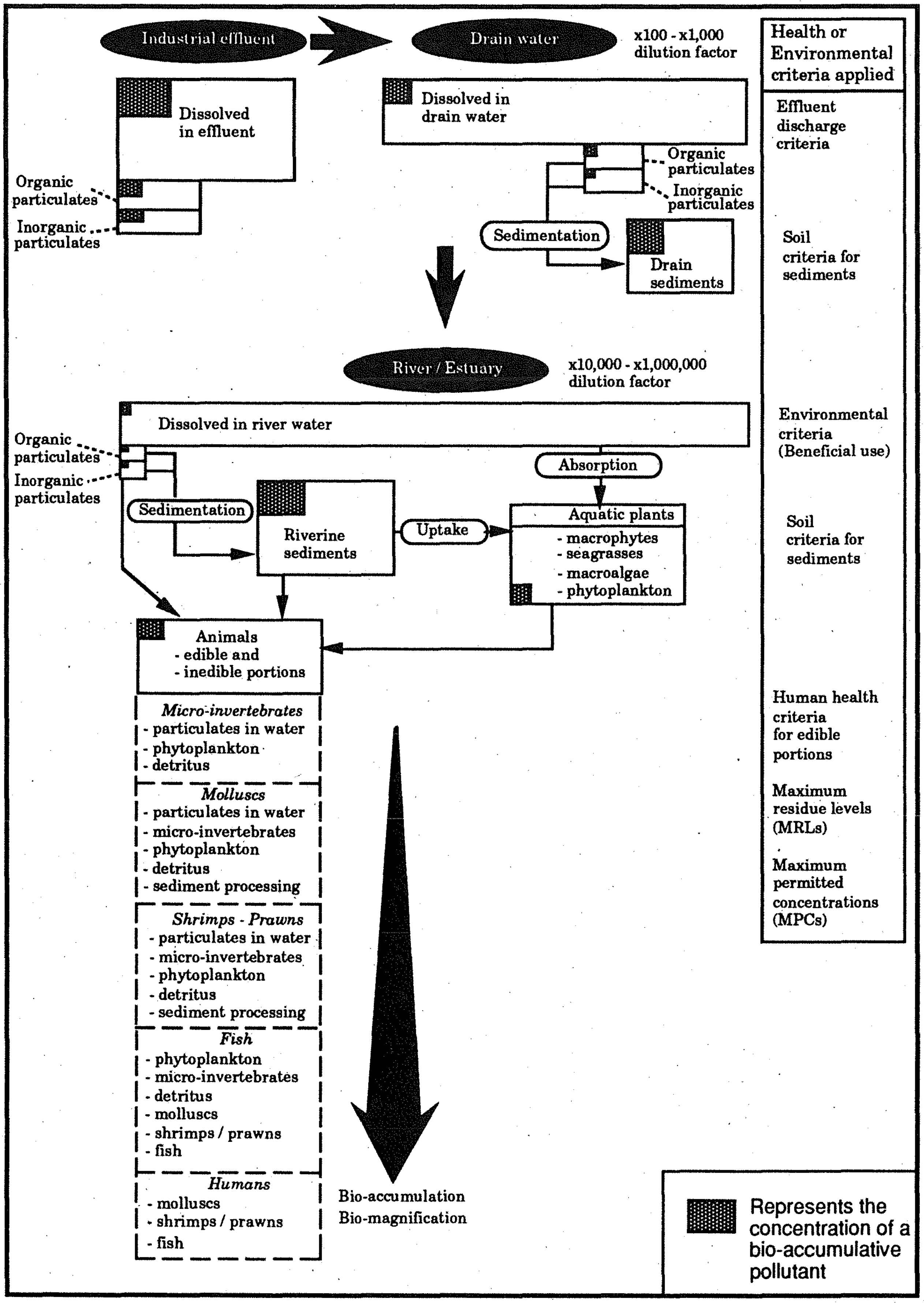


Figure 1 Fate of bio-accumulative pollutants in an industrial effluent

2.0 Catchment Monitoring

2.1 Introduction

The catchment area of the Bayswater Main Drain is 2700 ha and is the largest urban catchment in the Perth metropolitan area. It collects groundwater and surface runoff from land zoned residential, commercial and industrial. The total area zoned residential (which includes houses and parks) within the catchment is approximately 2336 ha. The industrial and commercial zonings have approximate areas of 295 ha and 69 ha respectively.

2.2 Soil Types

Soil types in the catchment include Bassendean sands (deep grey sands), Guildford formation (sand over clay),Tamala limestone sands, swamp deposits (peaty clay) and alluvium(sandy silts) (Map 1). All these soils have very low ability to bind phosphorus (Table 1). The Phosphorus Retention Index (PRI) is a laboratory measurement of the phosphorus retention capacity, or the ability to adsorb phosphorus, of a soil (Allen and Jeffery,1990). PRI is not static and becomes smaller as phosphorus is applied to soils and adsorbing surfaces are used up. Soils with PRIs <10 are characterised as having poor phosphorus retention.

Soil Type	PRI
Bassendean	2 - 5
Guildford	5 - 10
Tamala	5 - 10
Swamps/Peaty sands	<2
Sandy Silt	>5
Alluvium	>100

Table 1. Typical Phosphorus Retention Indices for Soils within the Bayswater Main Drain Catchment (Allen & Jeffery, 1990)

The catchment is dominated by Bassendean and Guildford sands. The surface horizon of these two groups is very coarse silicious sands with very low moisture holding capacity. Pollutants (especially phosphorus) can rapidly move with percolating water into the groundwater.

The surface layer of Guildford formation soils, being Bassendean sands, has a low capacity to retain phosphorus. Below the thin layer of sand (of varying thickness) is a relatively impermeable layer of clay. In this soil type pollutants will move rapidly through the sand layer to the clay. At this point some adsorption of pollutants can occur, however, generally the water carrying the pollutants will move along the top of the clay layer.

Tamala limestone sands have a moderate PRI which is higher than those for Bassendean sands, Guildford sands and swamp soils and have a high permeability and sometimes they contain cavernous limestone. This means that preferred pathways for water movement may prevent pollutants being trapped by this soil's slightly higher retention ability.

The low lying peaty sands are very acidic soils with a high organic matter content. They have a low PRI and in the past were highly prized as horticultural soils because of their high water availability.

Sandy silts are characterised by the fact that they are deposited along creek lines and are therefore a combination of the soils higher up in the catchment. They have a relatively high capacity to bind phosphorus and a higher natural fertility than the other soil types.

Map 1 shows an approximate distribution of the soil groups in the Bayswater Main Drain catchment. The development of the catchment has led to the introduction of fill into the peaty clay and sandy silt soils to enable building above the groundwater level. Therefore the soils in the catchment are likely to be combinations of what is shown in Map 1 and introduced fill of unknown origin and chemical properties.

2.3 Groundwater

Map 2 shows the depth to groundwater. The catchment of the Bayswater Main Drain contains a variety of depths to groundwater. The Redlands Rd subcatchment generally has groundwater depths of less than 3m.

Preliminary flow data from the Slade St monitoring site indicate that in winter approximately 80% of the runoff is groundwater and during summer nearly 100% (subject to summer storms) is derived from groundwater.

2.4 Sewerage

Approximately 40% (1050ha) of the Bayswater Main Drain catchment is sewered (Map 3). The remainder of the catchment relies on septic tank systems for the disposal of household effluent and industrial effluent. The approximate area of the residential zoning that is serviced by reticulated sewerage is 962 ha (or 41% of the residential area). The area within the industrial zoning that is serviced by reticulated sewerage is approximately 30 ha (or only 10% of the industrial area). Approximately 55 ha (or 80%) of the area zoned commercial is serviced by reticulated sewerage.

2.5 Aim of the Study

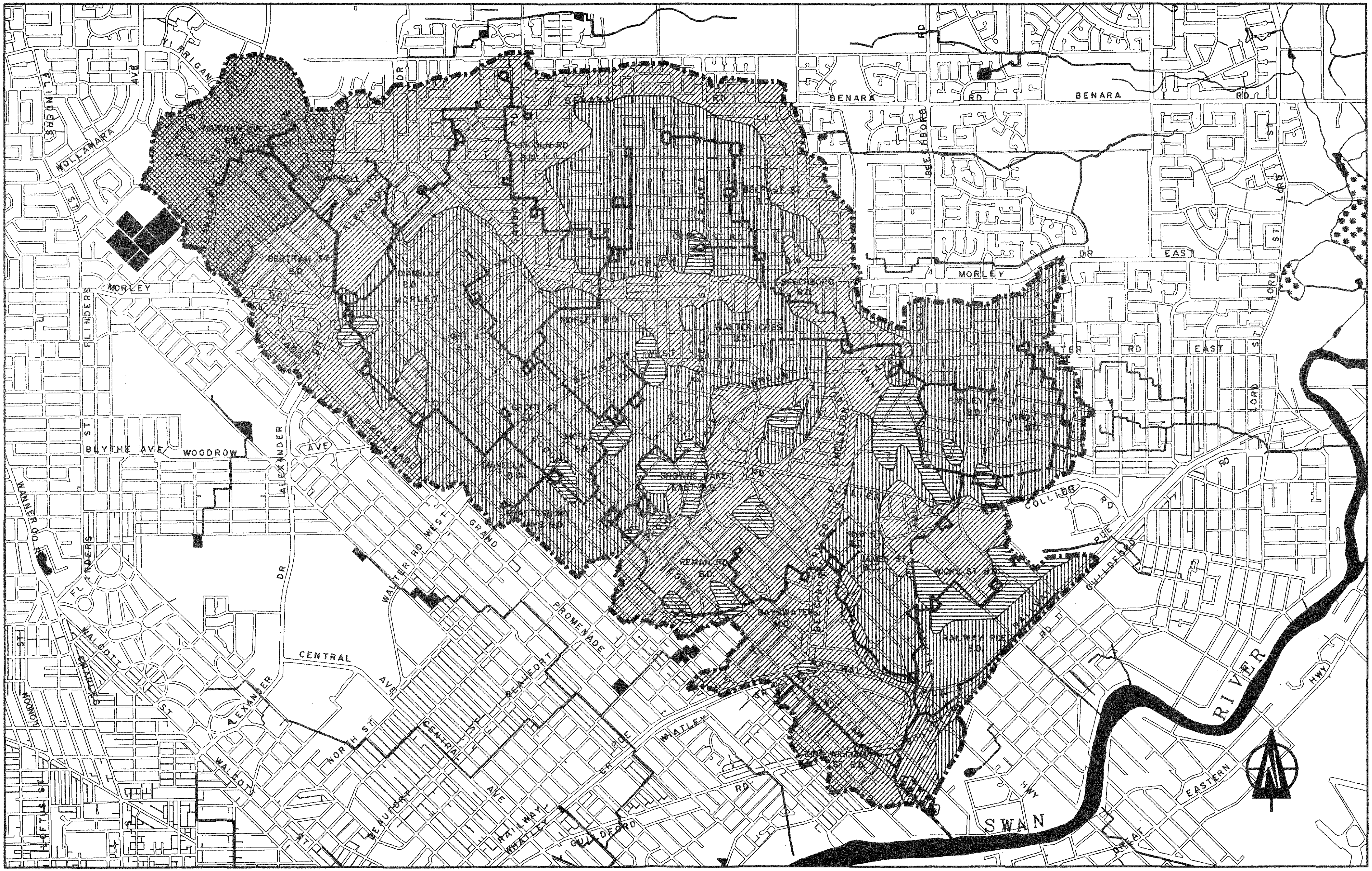
The aim of the catchment investigation was to attempt to define and apportion the pollutant load derived from different land uses and soil type mixes within the catchment.

2.6 Sites and Methods

Five sampling sites were selected in the catchment for this investigation. These included:

King William Street Branch Drain
Gummery Street (near Catherine Street)
Walter Road (between Light and Russell Streets)
Redlands St
Slade Street (referred to as Bayswater Main Drain in Section 3.0)

MAP 1 SOIL TYPES IN THE BAYSWATER M.D. CATCHMENT



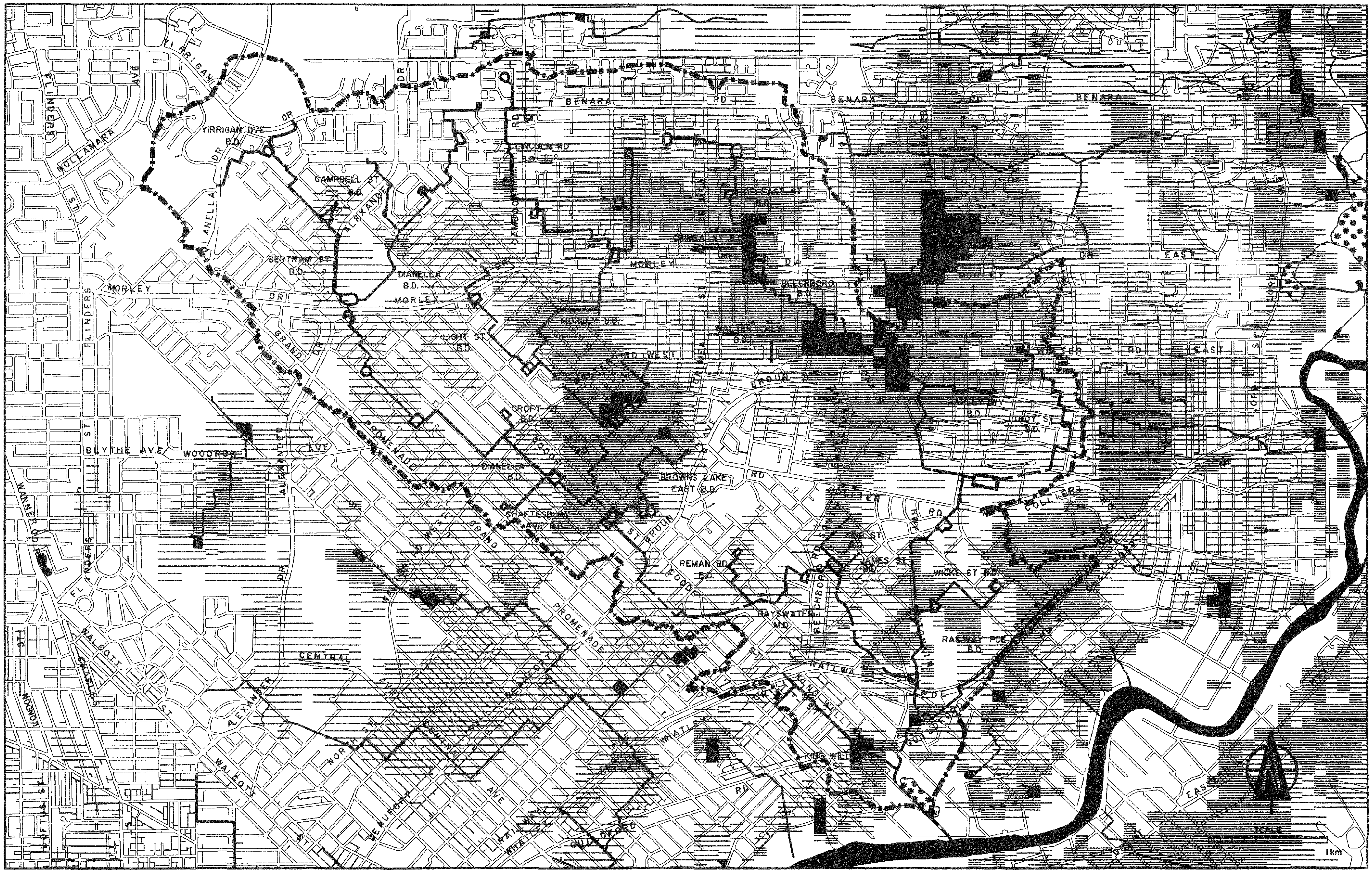
SOIL TYPES

- PEATY CLAY
- GUILDFORD FORMATION
- BASSENDEAN SAND
- TAMALA LIMESTONE
- SANDY SILT
- DRAINAGE CATCHMENT BOUNDARY

SCALE 0 1km

Map produced by Water Authority of Western Australia

MAP 2 DEPTH TO GROUNDWATER IN THE BAYSWATER M.D. CATCHMENT



DRAINAGE CATCHMENT BOUNDARY

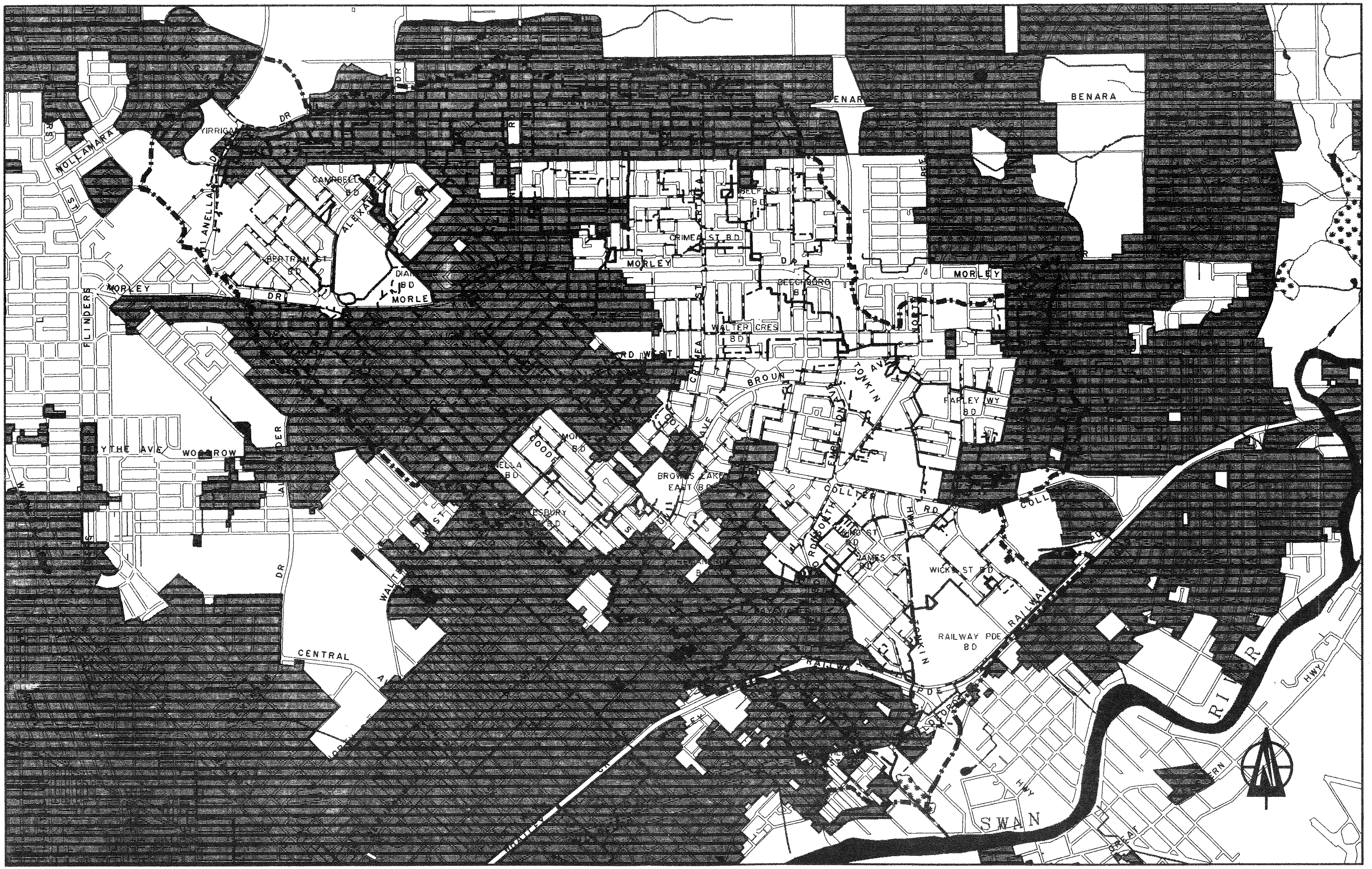
DEPTH TO GROUNDWATER BELOW NATURAL SURFACE

- < 0 m
- 0 - 2 m
- 2 - 3 m
- 3 - 5 m
- > 5 m

NOTE:
DEPTH TO GROUNDWATER BELOW NATURAL SURFACE CALCULATED BY SUBTRACTING THE MAXIMUM GROUNDWATER R.L. ABOVE A.H.D. FROM THE NATURAL SURFACE LEVEL A.H.D.

Map produced by Water Authority of Western Australia

MAP 3 SEWERED AREAS IN THE BAYSWATER M.D. CATCHMENT



DRAINAGE CATCHMENT BOUNDARY
WAWA MAIN DRAIN (PIPED)
WAWA OPEN MAIN DRAIN
LOCAL AUTHORITY DRAIN (PIPED)

SEWERED AREAS

SCALE
0 1km

Map produced by Water Authority of Western Australia

Map 4 shows the location of the Swan River Trust monitoring sites within the Bayswater Main Drain catchment. It also shows the locations of monitoring sites used by the Bayswater City Council as part of its industrial area investigation.

The King William Street Branch Drain, Gummery Street, Walter Road and Redlands St sites all represent subcatchments that are totally residential. The Slade Street site represents the total input from the catchment (minus the contribution of the King William Branch Drain which discharges downstream of this site) to the Swan River. Downstream of the Slade Street site the drain is subjected to tidal influence. That is, during a high tide water will bank-up in this part of the drain and flow will be reduced or cease.

Samples were collected on a roughly fortnightly basis from 14 May 1990 to 9 January 1991. Appendix 1 contains the sampling dates. Parameters analysed included trace metals (arsenic, cadmium, chromium, iron, lead, nickel, zinc, mercury), pesticides (organochlorines, organophosphates), solvents; nutrients (phosphorus,nitrogen), fluoride; pH, and flow.

After Three sampling runs were completed the programme was reviewed to determine whether any analyses were unnecessary so that resources were not being wasted. The review concluded that mercury was at concentrations below the limit of detection (0.0005 mg/L). The environmental criteria for mercury is 0.00014 mg/L. Therefore as levels were below the detection limit it was concluded that mercury sampling should discontinue.

Samples for pesticides, trace metals and solvents were collected in bottles prepared by the Chemistry Centre of W.A. All water samples were submitted to the Chemistry Centre for analysis.

Flow measurements were made using standard stream gauging techniques. Water depth was measured using Westdata Model 389 data loggers with Westdata Capacitance type Water Level Probes installed at Gummery Street, Walter Road, and Redlands Street. The Slade Street site uses a Unidata Starlog Data Logger with a Unidata Shaft Encoder water level measuring instrument. These loggers interrogate the probe every 30 seconds and every 5 minutes average the previous 5 minutes of interrogations and record the average water level height. To relate water depth, stream velocity and flow volume instantaneous gaugings using Hydrological Services or Ott Pygmy current meters were made. Rating curves are prepared using these data and physical measurements such as cross sections. Hydraulic control at the sites is provided by existing features such as broad crest weirs or culverts. The data collected by the above techniques are processed to daily flow and daily load figures using HYDSYS (a dedicated time series data processing package) running on a Promax 368 P.C (courtesy of WAWA).

The criteria used to assess the levels of pollutants at the five sites are from Schedule 7(3) DCE (1981). Normally these criteria are for estuarine waters and are not normally applied to drainage waters, however they are used in this report as a guide to the level of pollutants within the catchment.

2.7 Results and Discussion

At the time of preparation of this report information relating to flow was unavailable, therefore no loads have been calculated and only concentrations have been presented. A note of caution is necessary here. High concentrations of nutrients do not necessarily correlate with a high load. The load of nutrients is dependent on the volume of water leaving a catchment area. Therefore a small catchment with high concentrations and small flow may have a lower load contribution than a small catchment with low concentrations and a large flow.

Table 2 presents information on the subcatchments of the Bayswater Main Drain that were monitored during this survey.

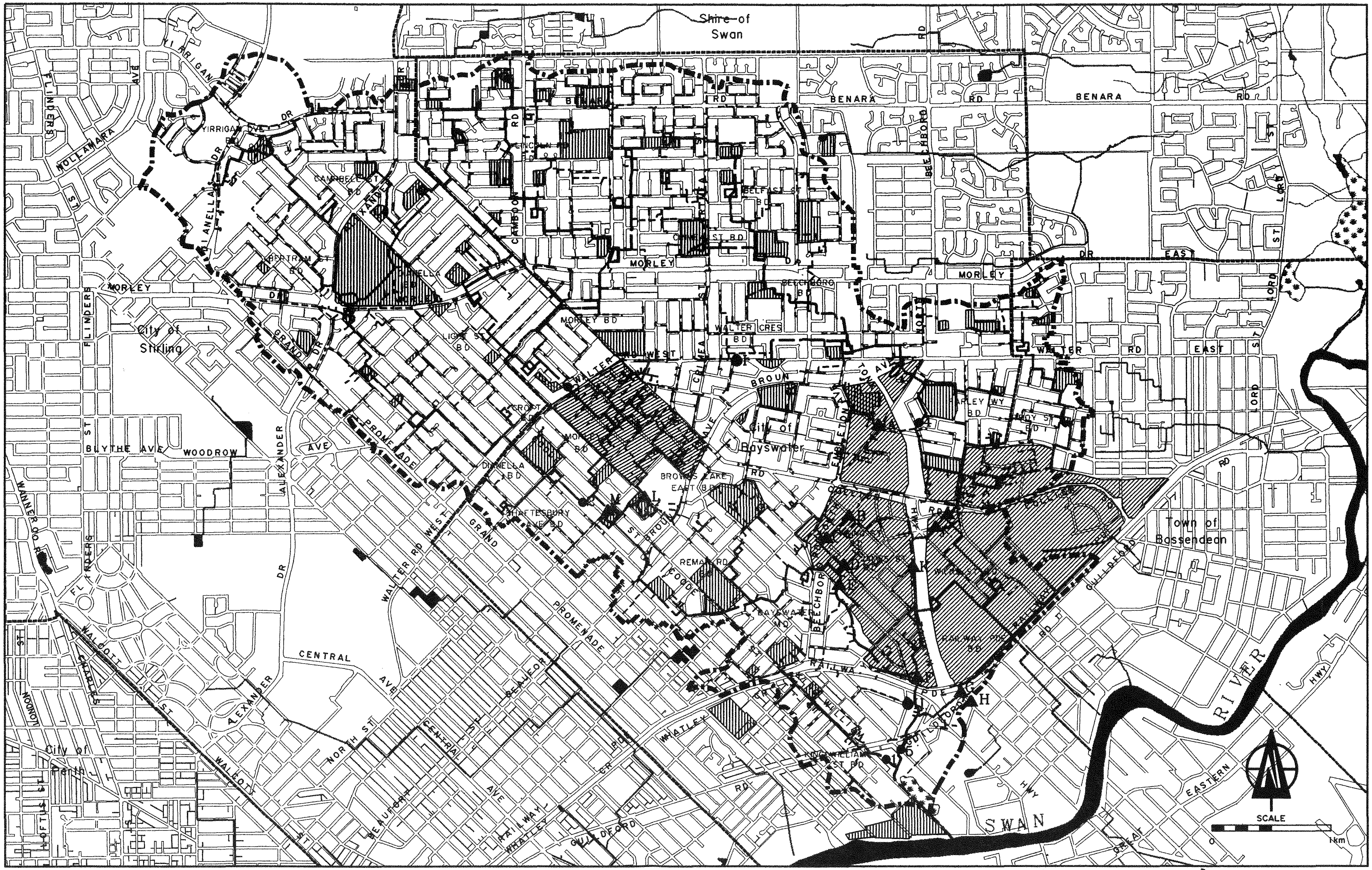
Subcatchment	Subcatchment Area (hectares)	Area Sewered (hectares)	% Subcatchment Sewered	Soil Types (decreasing dominance)
Gummery St	725	362	50	Bassendean over Guildford sands, Bassendean, peaty clay
Walter Rd	394	315	80	Bassendean, Bassendean/ Guildford,peaty clay
Redlands St	501	50	10	Bassendean, Bassendean/ Guildford, Tamala limestone, peaty clay
King William St	81	73	90	Bassendean, peaty clay, sandy silt
Other Areas	990	250	25	Bassendean, Bassendean/ Guildford,peaty clay
Total Area	2700	**1050**	39	

Table 2. Characteristics of the Subcatchments Sampled within the Bayswater Main Drain Catchment (Estimated reticulated sewerage in June 1991 - source WAWA).

Data have been presented in two ways. Firstly a summary of the monitoring results for nutrients, trace metals and pesticides has been tabulated. This includes for each site the mean (average) of all results collected between May 1990 and January 1991, the standard deviation for each mean, and the range of concentrations recorded. In addition time series graphs have been prepared to show the variations in concentrations that occurred during the survey. The raw data is contained in Appendix 2.

Data interpretation is not complete and the purpose of Section 2.0 of this report is to present the data in a usable form so that Task Groups can use them in their investigations of issues. However, care must be taken in using the nutrient data until the flow information becomes available.

Map 4 Monitoring Sites, Land Uses & Local Authority Boundaries in the Bayswater M.D. Catchment



Water Authority of Western Australia

Map produced by R King, Surface Water Branch Aug. 1991.

LEGEND

- INDUSTRIAL AREA
- PARKS & RECREATION
- LIGHT INDUSTRIAL
- DRAINAGE CATCHMENT BOUNDARY
- LOCAL GOVERNMENT AUTHORITY
- WAWA MAIN DRAIN (PIPED)
- WAWA OPEN MAIN DRAIN
- LOCAL AUTHORITY DRAIN (PIPED)

BAYSWATER CITY COUNCIL SAMPLING SITES

- A WOTTON ST
- B KING ST
- C BEECHBORO/MAURICE ST
- D CLAVERING RD - UPPER DRAIN
- E CLAVERING RD - MAIN DRAIN
- F RAILWAY PDE - ADACENT TO BRADYS
- G RAILWAY PDE - GAS VALVE - CSBP
- H RIVER RD/GOONGARRIE ST
- I JACKSON ST/NON FERROUS - INLET
- J JACKSON ST/NON FERROUS - OUTLET
- K CULLEN ST
- L DRAKE WY - LAKE
- M COODE ST - LAKE

SWAN RIVER TRUST SAMPLING SITES:

- 1 GUMMERY ST
- 2 WALTER RD
- 3 REDLANDS ST
- 4 SLADE ST
- 5 KING WILLIAM ST B.D.

WATER AUTHORITY OF W.A. SAMPLING SITES:

- I SILVERWOOD ST/WALTER RD WEST
- II ANZAC ST

2.7.1 Nutrients

2.7.1.1 Introduction

Phosphorus and nitrogen are essential to aquatic life. They are the two main nutrients needed for plant growth and are necessary for both plant and animal metabolisms. Plant growth is limited by the amount of nitrogen and phosphorus available, which are usually low in most waters. Phosphorus and nitrogen become stored in the sediments of waterbodies. Any free phosphorus or nitrogen is rapidly taken up by algae (phytoplankton and macroalgae) and other larger aquatic plants (e.g. seagrasses).

Nutrient input from catchments results in a shift in the nutrient balance of a waterbody. Major disruption of this balance by large nutrient inputs is known as eutrophication. Eutrophication is enrichment of waters with phosphorus and nitrogen , mostly as a consequence of human activity - disturbance of land and vegetation, input of industrial wastes and human wastes (e.g. septic tanks). Fertilisers containing phosphorus and nitrogen (used on suburban lawns for example) can be transported to waterways via surface runoff after rains and in groundwater.

Eutrophication can result in large algal blooms which as they decompose give off obnoxious odours and remove oxygen from the water and in severe cases this may lead to fish deaths. Another consequence of eutrophication is a reduction in the diversity of organisms living in the waterbody.

2.7.1.2 Results

Soluble Reactive Phosphorus represents the 'plant available' phosphorus in the water, that is phosphorus that is dissolved in the water rather than bound to particles suspended in the water. Total Phosphorus is the sum of dissolved, organic and soil bound phosphorus in water. Estuaries in the south-west of Western Australia are generally phosphorus limited. This means that there is sufficient nitrogen available for plant growth but inadequate levels of phosphorus.

Nitrate and ammonia are the forms of nitrogen that are dissolved in water, and form part of Total Nitrogen. Nitrate and ammonia are readily available for plant growth. Total Nitrogen is the sum of nitrate, ammonia and organic nitrogen. Organic nitrogen is less available for plant growth and must be converted to nitrate and/or ammonia by microbial activity before it is available for plant growth.

Table 3 presents the data for Soluble Reactive Phosphorus (SRP), Total Phosphorus,

Nitrate-N, Ammonia-N and Total Nitrogen for the five sites within the Bayswater Main Drain Catchment.

Nutrients (mg/L)	Statistics	Slade St	Gummery St	Walter Rd	Redlands St	King William St
Soluble Reactive Phosphorus	Mean	0.010	0.010	0.010	0.010	0.024
	SD					0.019
	Range	<0.010 - 0.010	<0.010 - 0.010		<0.010 - 0.020	0.010 - 0.060
Total Phosphorus	Mean	0.230	0.031	0.022	0.049	0.069
	SD	0.200	0.020	0.015	0.049	0.079
	Range	0.09 - 0.650	0.016 - 0.070	0.010 - 0.050	0.010 - 0.160	0.020 - 0.260
Nitrate - N	Mean	0.562	0.208	0.365	0.758	1.372
	SD	0.118	0.191	0.151	0.249	0.293
	Range	0.4 - 0.71	0.03 - 0.62	0.15 - 0.55	0.42 - 1.10	0.65 - 1.70
Ammonia - N	Mean	0.494	0.116	0.218	0.163	0.134
	SD	0.234	0.117	0.161	0.09	0.086
	Range	0.28 - 0.95	0.02 - 0.40	0.05 - 0.46	0.04 - 0.29	0.05 - 0.29
Total Nitrogen	Mean	1.925	1.0	1.187	1.56	2.162
	SD	0.328	0.427	0.497	0.341	0.58
	Range	1.4 - 2.8	0.3 - 1.9	0.70 - 2.3	0.95 - 1.8	0.95 - 2.8

Table 3. Nutrient Levels (mg/L) at Sampling sites within the Bayswater Main Drain Catchment (May 1990 to January 1991).

The Vollenweider and Kerekes (1980) eutrophication classification based on mean annual nutrient and chlorophyll 'a' concentrations (Table 4) can be used as a guide for assessing the level of nutrient enrichment in the Bayswater Main Drain catchment. However, these criteria are not normally applied to drain water.

Water States	Mean Total Phosphorus (mg/L)	Mean Total Nitrogen (mg/L)
Oligotrophic	0.008	0.66
Mesotrophic	0.026	0.75
Eutrophic	0.084	1.88

Table 4. Classification for the Assessment of Trophic State (Vollenweider and Kerekes, 1980).

2.7.1.3 Phosphorus

Data contained in Table 3 show that concentrations of Soluble Reactive Phosphorus (SRP) are at or below the detection limit. The exception is King William Street Branch Drain. The mean SRP level at this site is more than double the levels at the other four sites. Figure 2 shows the variation in SRP levels at the five sites monitored. This figure clearly demonstrates the variability in SRP results at the King William St site. This variability is inconsistent with the amount of sewerage in the subcatchment (90% sewered). An investigation of this subcatchment has been initiated in June 1991 to identify the possible sources of this variability.

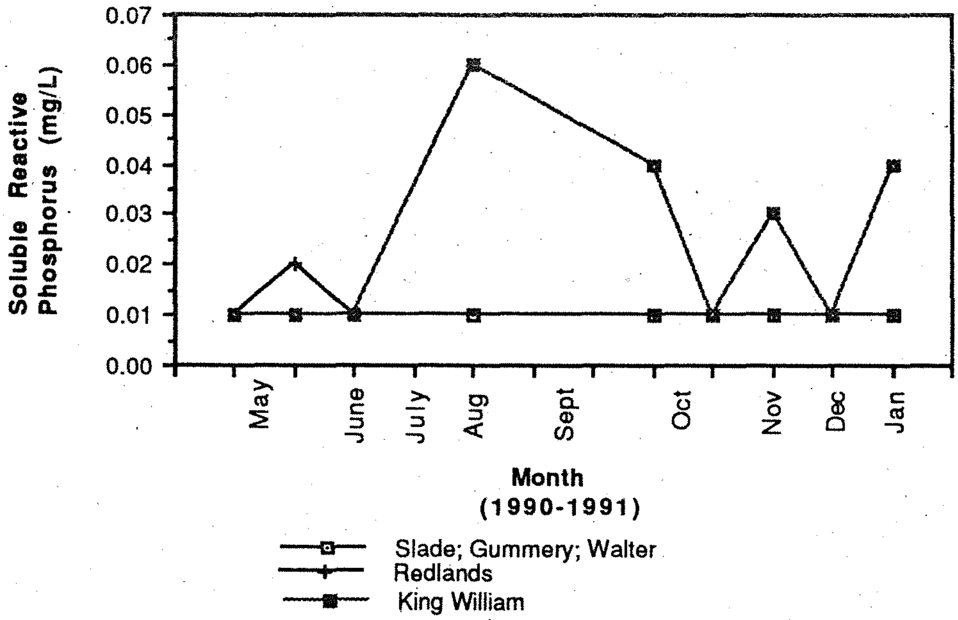


Figure 2. Soluble Reactive Phosphorus Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Note: 1. Results from Slade St, Gummery St and Walter Rd were the same and have been plotted as one line

The Total Phosphorus mean for the Slade St Site approaches an order of magnitude higher than the totally residential subcatchment sites. Table 5 shows a trend of increasing mean phosphorus concentration with increasing density of septic tanks. However, flow data and the size of the subcatchment area have not been used in determining this trend. An investigation by WA Water Authority (Tan, 1991) sampled subsoil drainage (groundwater) from low lying Bassendean sands in a sewered and an unsewered catchment during a peak storm flow event. This investigation found higher average phosphorus and nitrogen concentrations and estimated annual loads coming from the unsewered catchment.

The King William St subcatchment does not conform to this trend even though 90% of the catchment is sewered. An investigation of this subcatchment was initiated in June 1991.

Mean Total Phosphorus results (Table 3) for all sites were in the mesotrophic to eutrophic range (Table 4).

Site	% Sewered	Average TP conc (mg/L)
Walter Rd	80	0.022
Gummery St	50	0.031
Redlands Rd	10	0.049

Table 5. Area Sewered and Average Total Phosphorus Concentrations within Residential Subcatchments.

Figure 3 shows the variability between the five sites. Generally the residential subcatchments recorded low levels of Total Phosphorus (there are elevated levels on occasions). It is interesting to note that initially Total Phosphorus levels were high coinciding with the first flush effect. Then as winter and rainfall continued these levels gradually decreased.

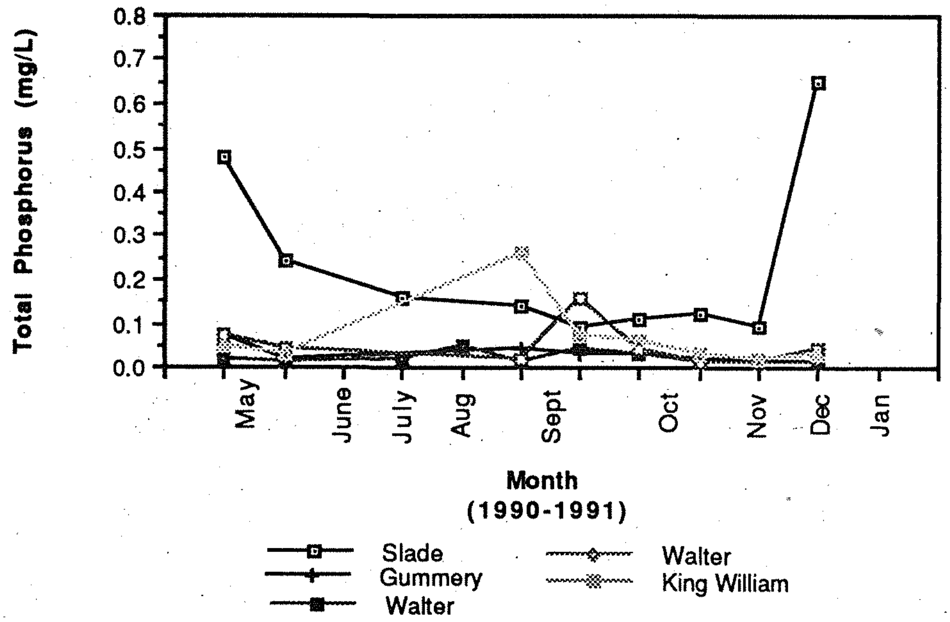


Figure 3. Total Phosphorus Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

2.7.1.4 Nitrogen

The highest mean nitrate level was recorded at the King William St site (Table 3). These results, as with the SRP results, are inconsistent with the amount of reticulated sewerage in this subcatchment (90%) and a further investigation of possible sources was initiated in June 1991. The mean result from the Redlands St site is more consistent with the amount of sewerage in the subcatchment (10%) and reflects the possibility of septic tank leachate reaching the drainage network. Figure 4 shows the variability of results between the five sites. The highest concentrations of nitrate consistently occur at the King William St site.

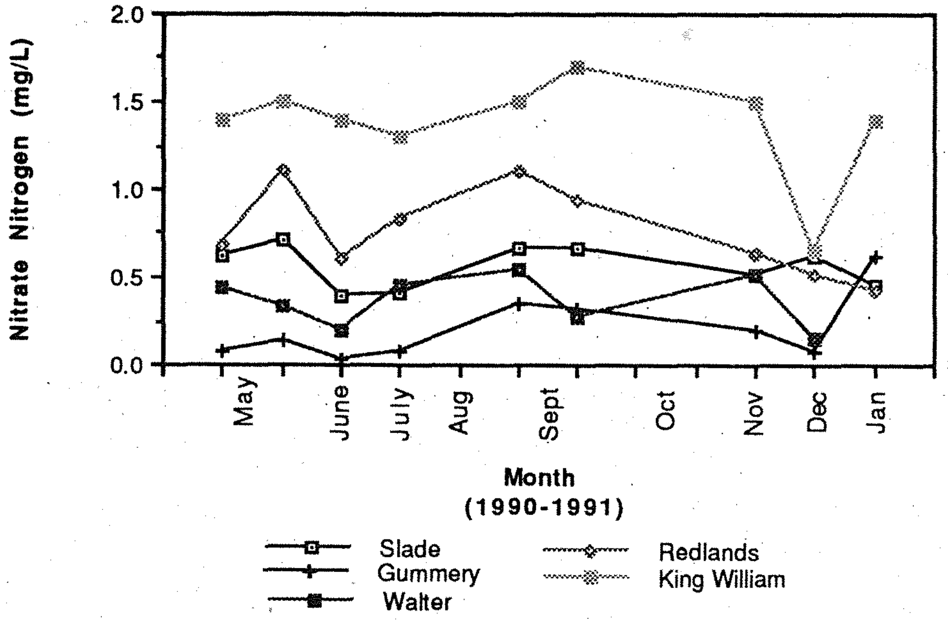


Figure 4. Nitrate-Nitrogen Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Mean ammonia levels were highest at the Slade St site (Table 3). Results from the residential subcatchment sites were similar. Figure 5 shows the variability in ammonia results at each site.

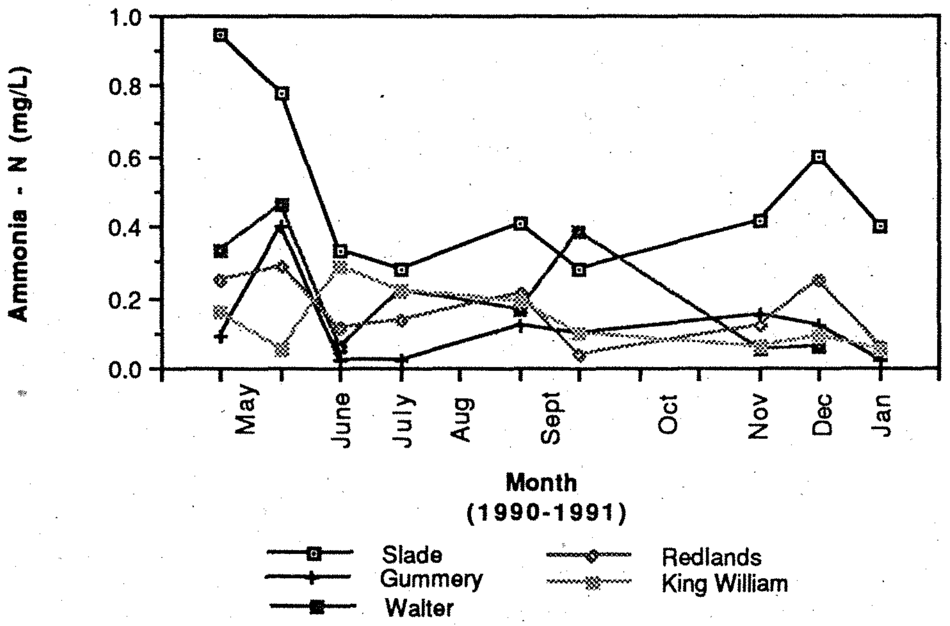


Figure 5. Ammonia-Nitrogen Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Mean Total Nitrogen levels were again highest at the King William St site (Table 3) and the investigation initiated in June 1991 will include this parameter. The meam levels at all sites were within the range considered to be eutrophic (Table 4). Figure 6 shows that although the mean Total Nitrogen levels is highest at King William St, the levels are similar to other sites.

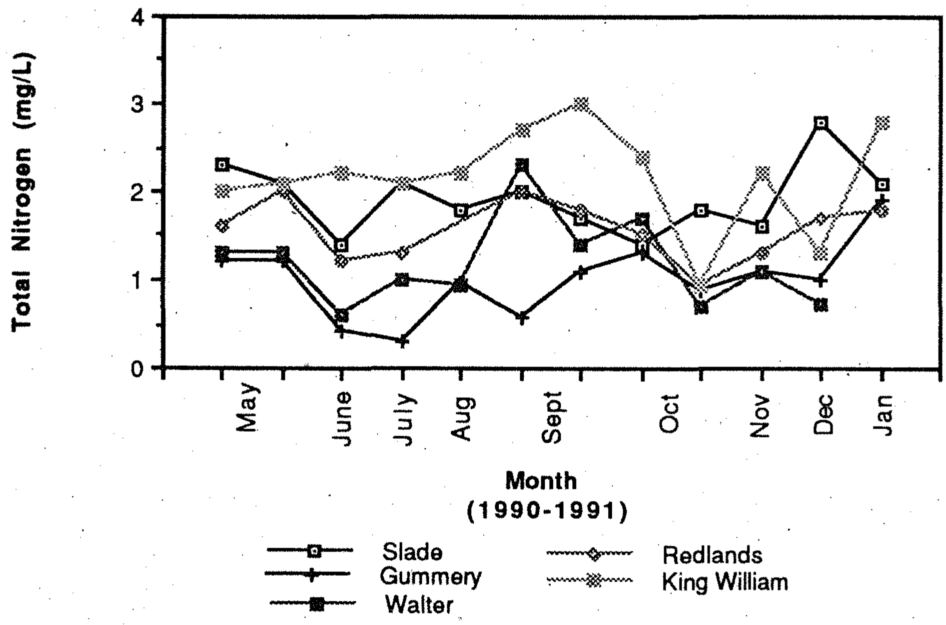


Figure 6. Total Nitrogen Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

2.7.1.5 Industrial Survey Results.

Bayswater City Council conducted analyses for Total Phosphorus and Total Nitrogen on two occasions, July 1990 and May 1991. Levels of Total Phosphorus were generally within the range recorded at the Swan River Trust's sites. However, in July 1990 the elevated levels recorded adjacent to the CSBP site suggested the movement of groundwater from the site into the drainage system (Bayswater City Council, 1991).

Total Nitrogen levels in the industrial area were significantly higher than levels recorded at the five Swan River Trust sites (Bayswater City Council, 1991).

2.7.2 Pesticides

2.7.2.1 Introduction

Two major groups of pesticides were investigated: organophosphates and organochlorines. Organophosphate pesticides have gradually replaced organochlorine compounds in agriculture and urban use (Derache, 1977). Organophosphate pesticides are chemically unstable and have a shorter residual life (5-10 years compared to 50 years for organochlorine residues) (Public Health Department, 1983). They have toxicity levels equal to or higher than the organochlorine compounds and are more mobile in the environment, and constant use may lead to higher chronic environmental levels.

In June 1987, all organochlorine pesticides were de-registered for all agricultural uses. Urban use of organochlorine was restricted to the use of aldrin, dieldrin, chlordane and heptachlor for termite pre-treatment of house pads. The on-going restriction of organochlorine pesticide use means that, over time, it can be expected that levels of these chemicals will decrease in the environment generally. As soil bound organochlorines gradually decompose, so the store of these chemicals will decrease in the environment, albeit slowly.

Organophosphate pesticides are less persistent in the environment than organochlorine pesticides and are more difficult to detect. The detection limit for organophosphate chemicals in water is below the environmental criterion for the maintenance of aquatic ecosystems. No organophosphate pesticides were detected in any samples collected during this investigation.

2.7.2.2 Results

Table 6 presents the statistical data for pesticides from the five sites. Six organochlorine pesticides were detected throughout the survey. These were aldrin, chlordane and metabolites, dieldrin, DDT and metabolites, heptachlor and lindane.

Twelve samples for organochlorine analysis were collected from each site. Organochlorine pesticide residues were not detected on all occasions (Table 6). The most frequently detected organochlorine residues were chlordane and dieldrin, being detected in between eight and ten of the samples collected. The remaining four organochlorine residues were detected twice or less during the survey.

Aldrin residues were detected in only two samples from each site and all results were below the environmental criterion (Table 6).

Pesticide (µg/L)	Statistics	Slade Street	Gummery St	Walter Rd	Redlands St	King William St	Environ-mental Criterion
Aldrin	Mean						0.003
	SD						
	Range	0.002	0.002	0.002	0.002	0.002	
	% > crit.	0/2	0/2	0/2	0/2	1/2	
Chlordane	Mean	0.003	0.004	0.004	0.003	0.003	0.004
	SD	0.002	0.002	0.003	0.002	0.003	
	Range	0.002 - 0.007	0.002 - 0.007	0.002 - 0.009	0.002 - 0.007	0.002 - 0.004	
	% > crit.	1/8	2/10	2/7	1/8	1/8	
Dieldrin	Mean	0.013	0.010	0.005	0.005	0.028	0.003
	SD	0.005	0.004	0.002	0.002	0.012	
	Range	0.008 - 0.018	0.005 - 0.018	0.002 - 0.008	0.002 - 0.008	0.019 - 0.060	
	% > crit.	9/9	9/9	8/9	8/9	10/10	
DDT & Metabolites	Mean						0.001
	SD						
	Range	0.002 - 0.005	0.002 - 0.010	0.005	0.002	0.002	
	% > crit.	2/2	2/2	1/1	2/2	2/2	
Heptachlor	Mean						0.001
	SD						
	Range	0.002	0.002	0.002	0.002 - 0.003	0.002 - 0.004	
	% > crit.	2/2	2/2	2/2	2/2	2/2	
Lindane	Mean			ND			0.004
	SD						
	Range	0.002	0.002		0.003	0.002	
	% > crit.	0/1	0/1		0/1	0/1	

Table 6. Mean and Range Pesticide Results (µg/L) From Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

ND Not Detected

% > crit. 1/8 = 1 = 1 > criteria and

8 = 8 detections from 12 samples

Note: 1. A missing number means there were insufficient data for statistical analyses.

2. Limit of detection for organochlorine pesticide residues is 0.002 µg/L

Chlordane was detected between seven and ten times from the five sites (Table 6). On the majority of occasions the levels were below the environmental criterion. Exceedences were generally less than twice the criterion (Figure 7).

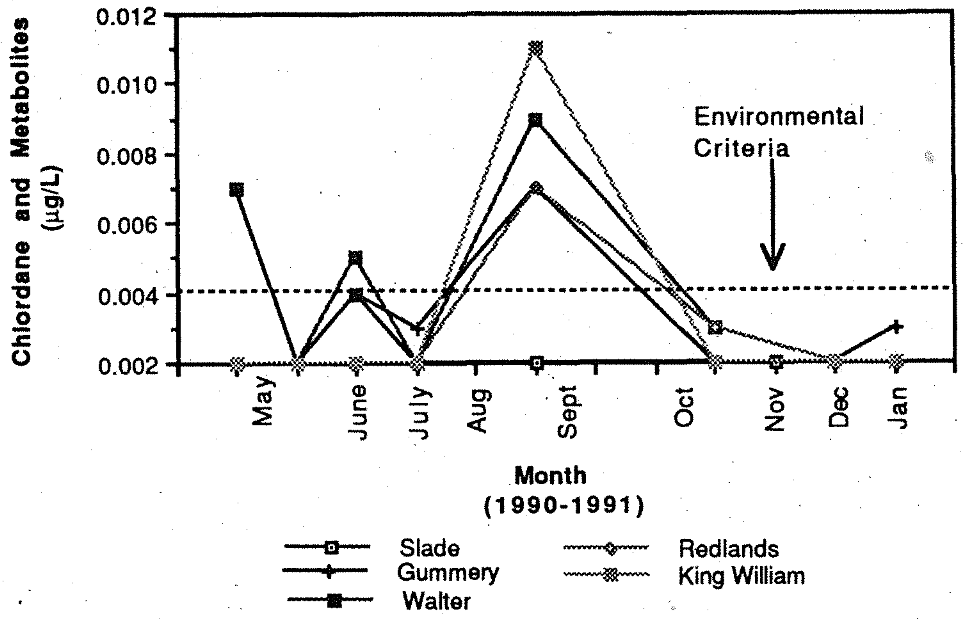


Figure 7. Chlordane Levels (µg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Note: 1. Env. Crit. = Environmental Criterion, Chlordane 0.004 µg/L; DCE, 1981, Schedule 7(3)

Dieldrin was the most consistently detected organochlorine residue and on the majority of detections exceeded the environmental criterion (Table 6). Figure 8 shows the time series graph for dieldrin. This shows that with the exception of the King William St site, levels are comparable between sites. The results from the King William St site are unusual and an investigation of possible sources in the subcatchment was initiated in June 1991.

It is interesting to note that all sites exceeded the criteria for chlordane and dieldrin frequently. That is, water from residential areas contains levels of these two organochlorine residues that exceed the environmental criteria. Therefore, the presence of these elevated levels at the Slade St site cannot be totally attributed to historic or current practices in the industrial area.

The remaining organochlorine residues were not detected frequently enough, or at sufficient concentrations, to cause concern.

No organophosphate pesticide residues were detected.

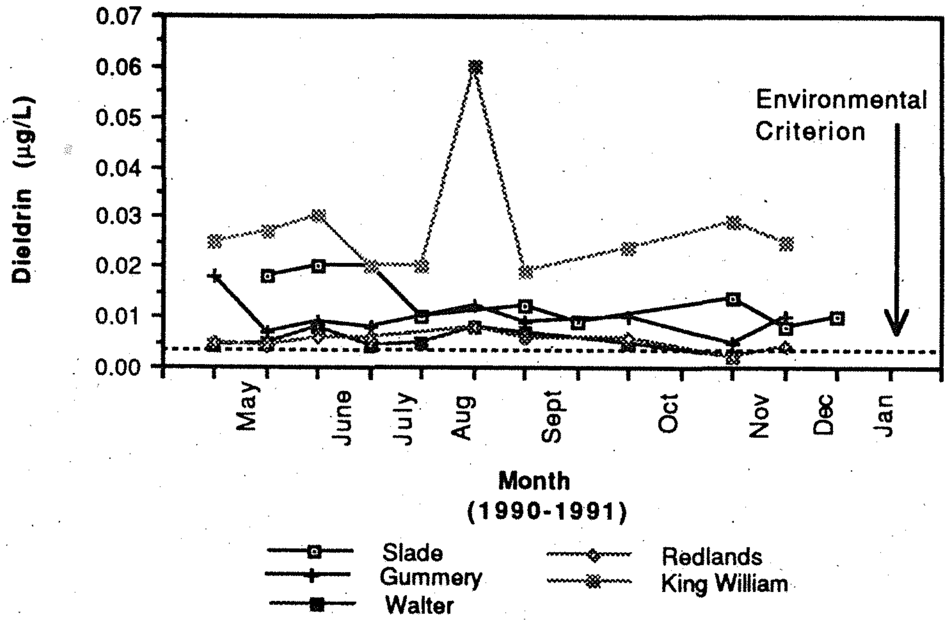


Figure 8. Dieldrin Levels (µg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Note: 1. Env. Crit = Environmental Criterion, Dieldrin **0.003** µg/L ;DCE, 1981, Schedule 7(3)

2.7.2.3 Industrial Area Survey Results

Bayswater City Council conducted analyses for pesticides on three occasions during 1990. Three organochlorine pesticides were detected: aldrin, dieldrin and heptachlor. Dieldrin was the most consistently detected organochlorine residue and results exceeded the environmental criteria at all sites (generally on two occasions). The concentrations recorded in the Bayswater City Council's survey were within the ranges recorded at the five sites monitored by the Swan River Trust (Bayswater City Council, 1991).

Aldrin and heptachlor results were all below the detection limit on all occasions at all sites (Bayswater City Council, 1991).

2.7.3. Trace Metals and Fluoride

2.7.3.1 Introduction

Trace metals may enter the environment naturally as a result of geological phenomena such as weathering of rocks, leaching or degassing. Humans release trace metals into the environment in many ways including burning fossil fuels (e.g. leaded petrol), mining, smelting, discharging industrial, agricultural and domestic waste and by deliberate application of pesticides and fertilisers. Once in the environment, trace metals are not readily removed and therefore accumulate (Duffus, 1980).

Some sources of trace metals in the Bayswater Main Drain catchment include, current and historic industrial activity (e.g. metal platers), old land use such as market gardens, septic tank leachate, runoff from roads and other impermeable surfaces, applications of pesticides and fertilisers in the catchment, air conditioner waste (chromium, zinc), landfill sites and electroplaters.

2.7.3.2 Results

Table 7 presents a summary of results from the five sites.

Trace Metals and Fluoride (mg/L)	Statistics	Slade Street	Gummery St	Walter Rd	Redlands St	King William St	Environ mental Criteria[a]
Fluoride F	Mean	0.9	0.1	0.1	0.1	0.142	
(mg/L)	SD	0.48				0.123	
	Median	0.85	0.1	0.1	0.1	0.1	2.0
	Range	0.20 - 1.80	0.1	0.1	0.1	0.1 - 0.5	(10)
Arsenic As	Mean	0.007	0.005	0.005	0.005	0.005	
	SD	0.004					
	Median	0.008	0.005	0.005	0.005	0.005	0.008
	Range	0.005 - 0.015	0.005	0.005	0.005	0.005	(0.5)
Cadmium Cd	Mean	0.002	0.001	0.001	0.001	0.001	
	SD	0.001	0.006	0.006	0.006	0.001	
	Median	0.003	0.001	0.001	0.001	0.001	0.003
	Range	0.001 - 0.005	0.001 - 0.003	0.001 - 0.003	0.001 - 0.003	0.001 - 0.005	(0.008)
Iron Fe	Mean	5.79	0.542	0.67	0.542	0.531	
	SD	2.78	0.272	0.57	0.348	0.387	
	Median	6.00	0.600	0.55	0.450	0.500	
	Range	2.2 - 10.0	0.4 - 1.1	0.3 - 0.75	0.18 - 1.5	0.2 - 1.7	
Lead Pb	Mean	0.050	0.050	0.0270	0.052	0.051	
	SD	0.059	0.031	0.012	0.040	0.084	
	Median	0.030	0.040	0.025	0.035	0.010	0.008
	Range	0.02 - 0.07	0.03 - 0.13	0.01 - 0.044	0.01 0.071	0.006 - 0.27	(0.200)
Copper Cu	Mean	0.022	0.005	0.004	0.004	0.004	
	SD	0.018	0.003	0.004	0.004	0.005	
	Median	0.020	0.006	0.005	0.004	0.003	0.005
	Range	0.005 - 0.070	0.001 - 0.010	0.001 - 0.014	0.001 - 0.015	0.001 - 0.020	(0.040)
Nickel Ni	Mean	0.010	0.004	0.004	0.003	0.007	
	SD	0.005	0.002	0.002	0.001	0.006	
	Median	0.010	0.005	0.005	0.005	0.005	0.020
	Range	0.005 - 0.018	0.002 - 0.005	0.001 - 0.005	0.001 - 0.005	0.001 - 0.020	(0.450)
Zinc Zn	Mean	0.196	0.070	0.022	0.028	0.034	
	SD	0.043	0.034	0.009	0.018	0.027	
	Median	0.200	0.070	0.025	0.020	0.026	0.020
	Range	0.16 - 0.23	0.02 - 0.120	0.002 - 0.030	0.01 - 0.08	0.015 - 0.110	(0.200)

Table 7 Trace Metal and Fluoride Results (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Environmental Criteria[a] = Upper limit for six-monthly mean concentrations in river water samples. Value in brackets is the upper limit for a single sample (DCE, 1981 Schedule 7(3))

Levels of fluoride from the residential catchments were well below the environmental criterion (Table 7). The highest fluoride levels were recorded at the Slade Street site, although these were lower than the six-month median criterion used for river environments. CSBP is located upstream of this sampling site. Groundwater under this site is contaminated with fluoride and is a possible source of the increased levels in the drainage water. Figure 9 shows a time series plot of the data collected between May 1990 and January 1991. Levels at the Slade St site reflect the influence of stormwater on fluoride concentrations. When the groundwater contribution is highest, levels of fluoride are also high, linking the fluoride source to groundwater contamination. Fluoride levels decline as rainfall and therefore stormwater contributions increase. No levels above the criterion for single samples were detected.

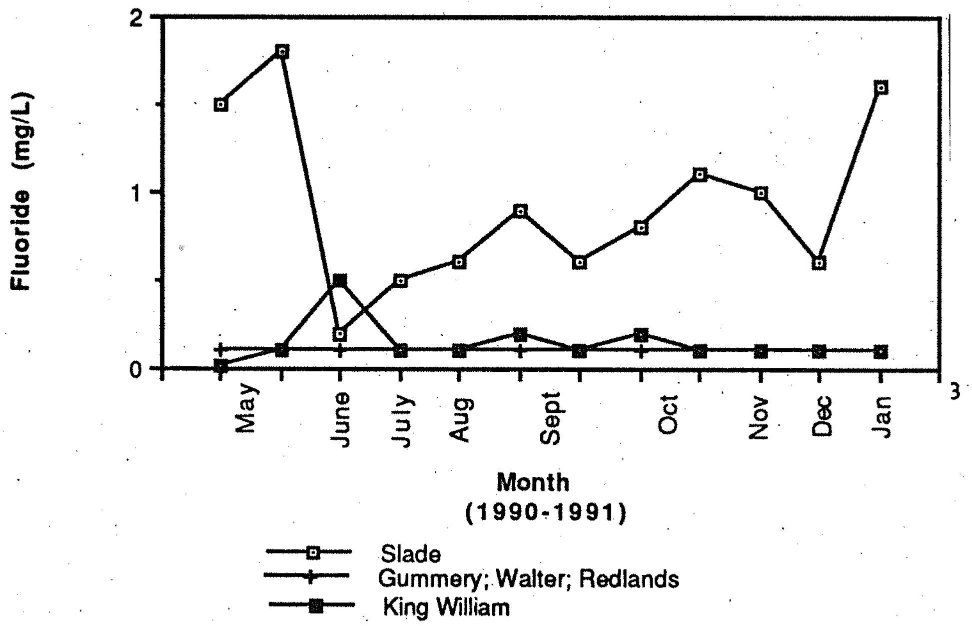


Figure 9. Fluoride Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Note: 1. Results from Gummery St, Walter Rd and Redlands Rd were the same and have been plotted as one line

2. Single Sample Criterion: upper concentration limit for a single sample Fluoride 10 mg/L; DCE,1981 Schedule 7(3)

Mean arsenic levels were at or below the environmental criterion at all sites (Table 7). Highest levels were recorded at the Slade St site. Figure 10 presents a time series plot for the arsenic results collected during this survey. All reults were below the criterion for single samples. Possible sources could be current and historic industrial practices within the industrial area.

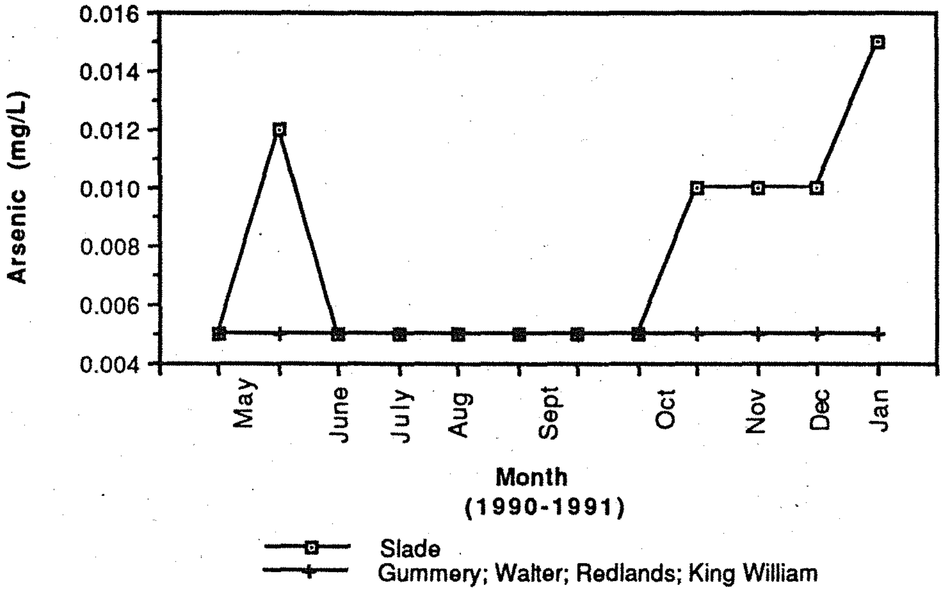


Figure 10. Arsenic Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Note:

1. Results from Gummery St, Walter Rd, Redlands Rd and King William St were the same and have been plotted as one line

2. Single Sample Criterion: upper concentration limit for a single sample for Arsenic **0.5 mg/L**; DCE, 1981 Schedule 7(3)

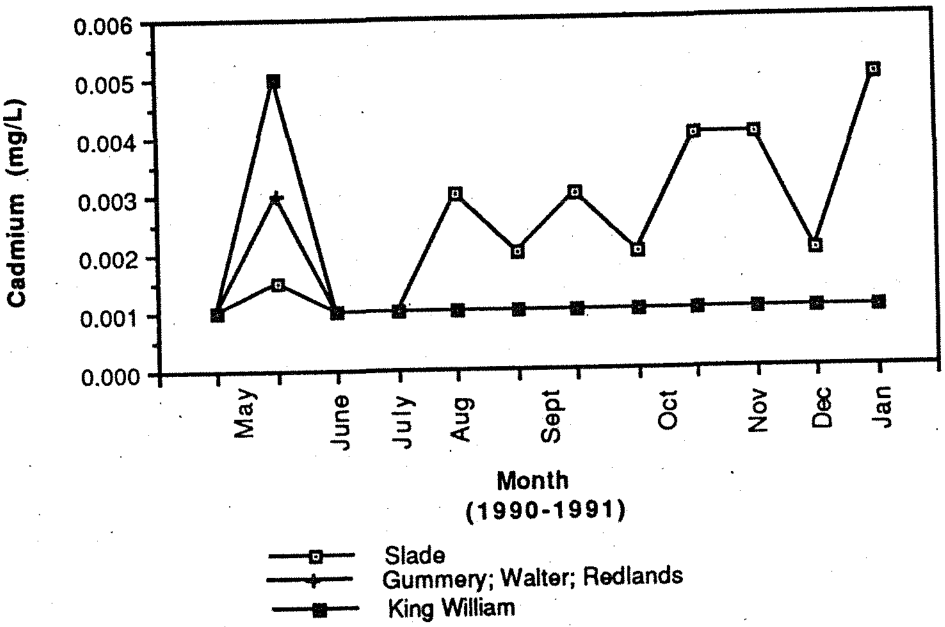


Figure 11. Cadmium Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Note: 1. Results from Gummery St, Walter Rd and Redlands Rd were the same and have been plotted as one line

2. Single Sample Criterion: upper concentration limit for a single sample for Cadmium 0.008 mg/L; DCE, 1981 Schedule 7(3)

Mean cadmium levels were at or below the six-month median criterion at all sites (Table 7). Figure 11 shows the results over time showing that no results exceeded the upper limit for single samples (0.008 mg/L).

Copper results were at or below the six-month median criterion at all residential sites and were elevated at the Slade St site (Table 7). Results plotted in Figure 12 show a gradual increase in copper levels at the Slade St site. This may be due to increased leaching and transportation with storm and ground waters. One sample from the Slade St site exceeded the single sample criterion.

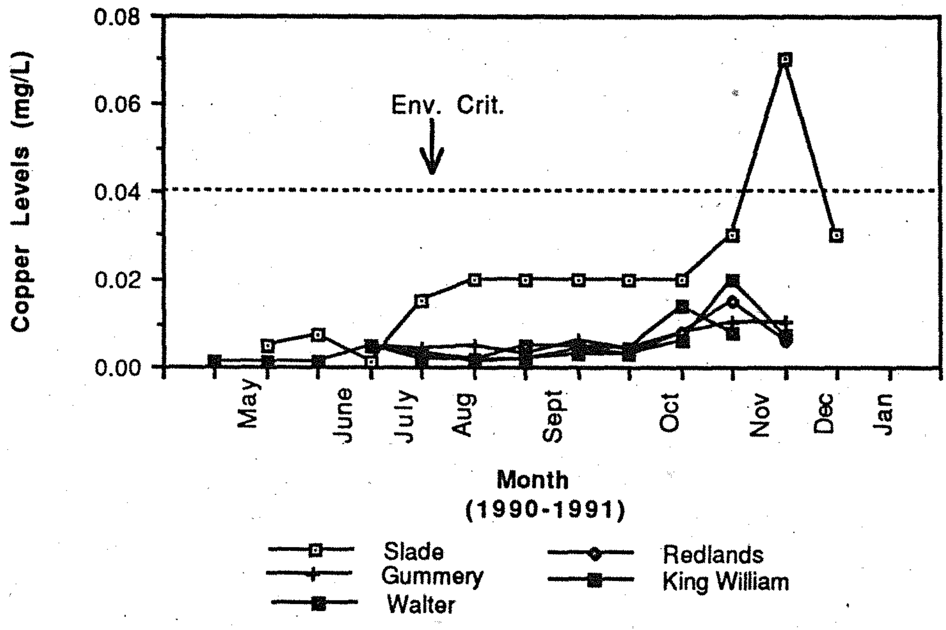


Figure 12. Copper Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Note: 1. Single Sample Criterion: upper concentration limit for a single sample for Copper 0.04 mg/L; DCE, 1981 Schedule 7(3)

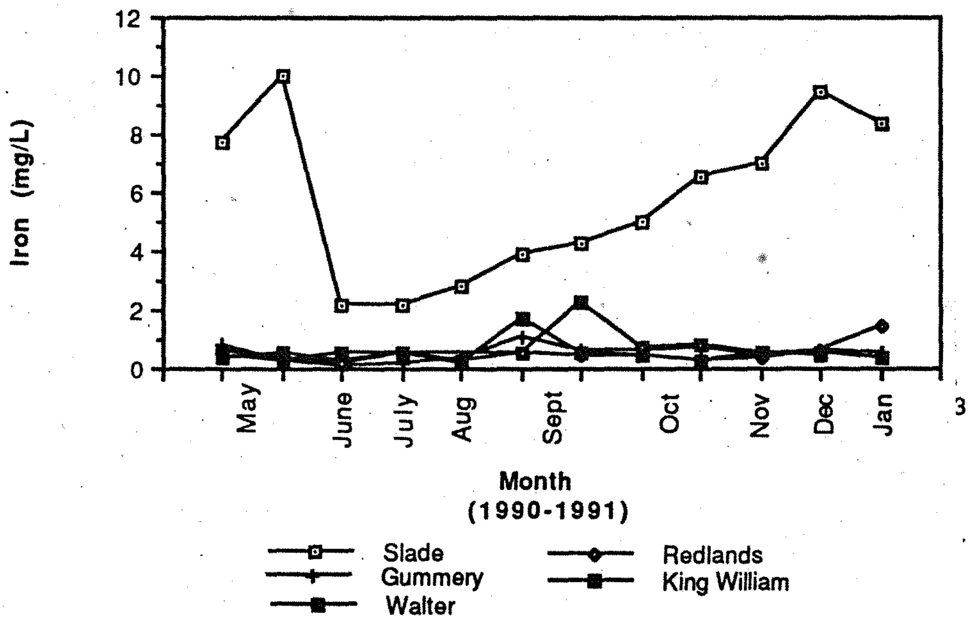


Figure 13. Iron Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Note: 1. No environmental criterion are available for iron

There is no environmental criterion established for iron. Results in Table 7 show that the highest levels were recorded at the Slade St site. Levels from the residential sites were similar. Figure 13 highlights the groundwater contribution of iron. During peak flow periods iron levels decrease at the Slade St site. As stormwater flow decreases iron levels begin to increase reflecting the increased dominance of groundwater in the drain. Bassendean sands contain naturally acidic groundwater and high iron levels.

Median lead levels at all sites exceeded the six-month median criterion (Table 7). Figure 14 shows that on most occasions all sites have lead levels below the single sample criterion, except single records at the King William St and Slade St sites. The most common source of lead in an urban environment is exhaust from motor vehicles using leaded petrol.

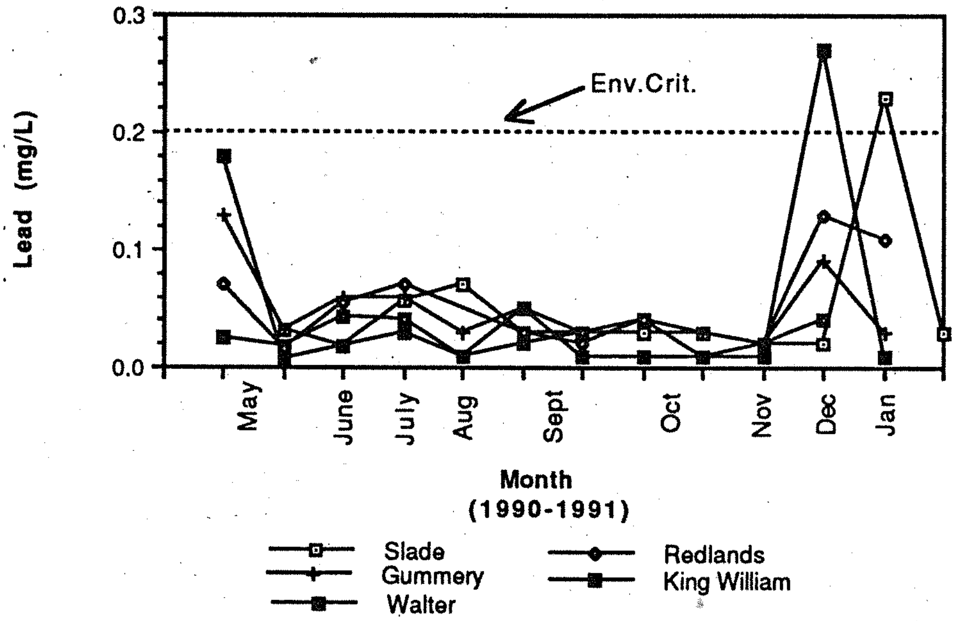


Figure 14. Lead Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Note: 1. Single Sample Criterion: upper concentration limit for a single sample for Lead **0.2 mg/L**; DCE, 1981 Schedule 7(3)

Mean nickel levels were below the six-month median criterion (Table 7) and results in Figure 15 show that all samples were below the criterion for single samples.

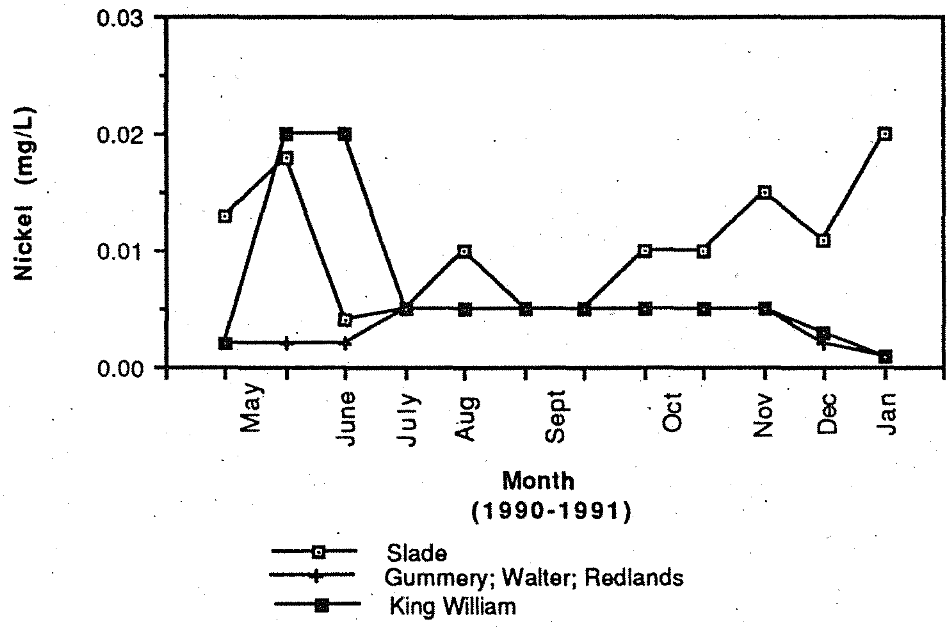


Figure 15. Nickel Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Note:

1. Results from Gummery St, Walter Rd and Redlands Rd were the same and have been plotted as one line

2. Single Sample Criterion: upper concentration limit for a single sample for Nickel 0.45 mg/L; DCE, 1981 Schedule 7(3)

Mean Zinc levels at all sites (except Redlands Rd) exceeded the six-month median criterion (Table 7), the variation above the criterion being greatest at the Slade St site. Figure 16 shows that although the median criterion was exceeded at all the residential sites (except Redlands Rd) the single sample criterion was not. Samples from the Slade St site exceeded the single sample criterion on four occasions.

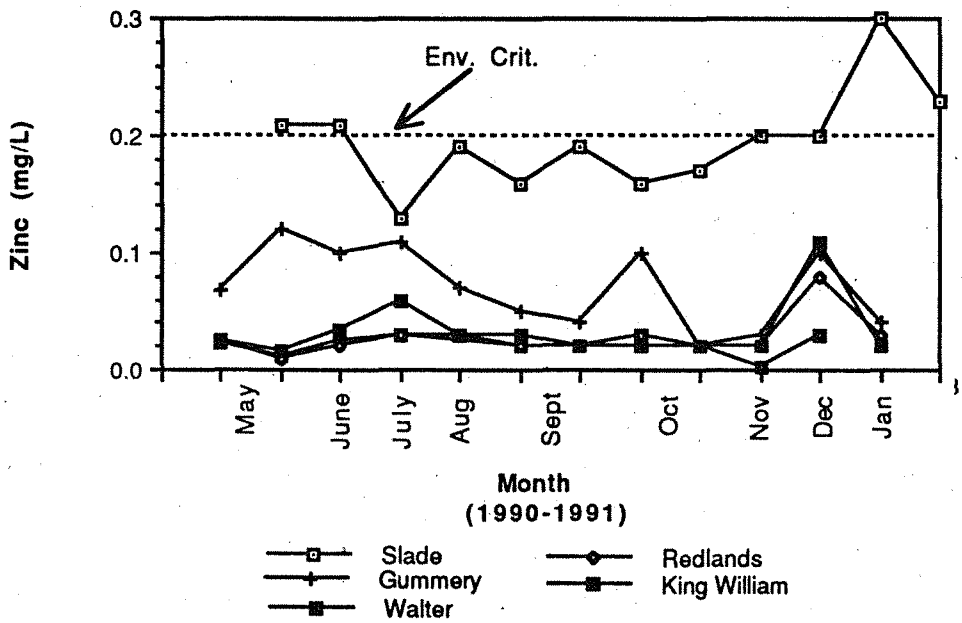


Figure 16. Zinc Levels (mg/L) from Five Sites in the Bayswater Main Drain Catchment (May 1990 to January 1991).

Note: 1. Single Sample Criterion: upper concentration limit for a single sample for Zinc 0.2 mg/L; DCE, 1981 Schedule 7(3)

2.7.3.3 Industrial Survey Results

Trace metal samples collected by the Bayswater City Council in the industrial area generally had levels above the single sample criteria for zinc and lead. These levels were similar in range to those recorded at Slade St (Table 7). Cadmium and copper were generally below the single sample criteria. Other trace metal results (arsenic, chromium, mercury) were below the single sample criteria.

3.0 River Monitoring

3.1 Introduction

The Bayswater Main Drain discharges into the Swan River and is one of 34 main drains with the potential to contribute pollutants such as nutrients, pesticides and trace metals. Excessive levels of these pollutants may cause unacceptable damage to the riverine environment. Trace metals and organochlorine pesticides may be stored and accumulated in the tissues of aquatic animals including edible species. Concerns regarding human health arise when the tissues of contaminated aquatic species are eaten.

3.2 Aim

The aim of this investigation was to assess the possible human health risks and environmental damage resulting from the discharge of drainage waters into the Swan River.

3.3 Methods

Investigations of pesticide and heavy metal levels in the Swan River adjacent to the Bayswater Main Drain were undertaken in March 1990 and November 1990. Samples of water, biota (excluding fish) and sediments were collected on both occasions. Table 8 shows which analyses were performed on the samples and Figure 17 shows the location points and the sampling strategy. Fish samples collected in March 1990 indicated that fish were safe for human consumption. On this basis it was decided that separate sampling for fish was not warranted for this project and samples could be used which were collected for another programme investigating the level of organochlorines in edible fish collected from the entire estuarine system. Samples adjacent to the Bayswater Main Drain are also being analysed for trace metals. These results were not available when this report was prepared.

All samples were submitted to the Chemistry Centre of W.A. for analysis.

Medium	Site	Analysis
Water	BMD, SRD, SRU	Pesticides, Metals
Sediments	SRD, SRU	Pesticides, Metals
Mussels [a]	SRD, SRU	Metals
Shrimp [a]	SRD, SRU	Metals
Fish [a]	SRD, SRU	Pesticides, Metals
Worms	SRD, SRU	Pesticides, Metals

Table 8. Medium Sampled, Sample Sites and Analysis Performed in River Monitoring

Note: [a] Analyses performed on edible portions only

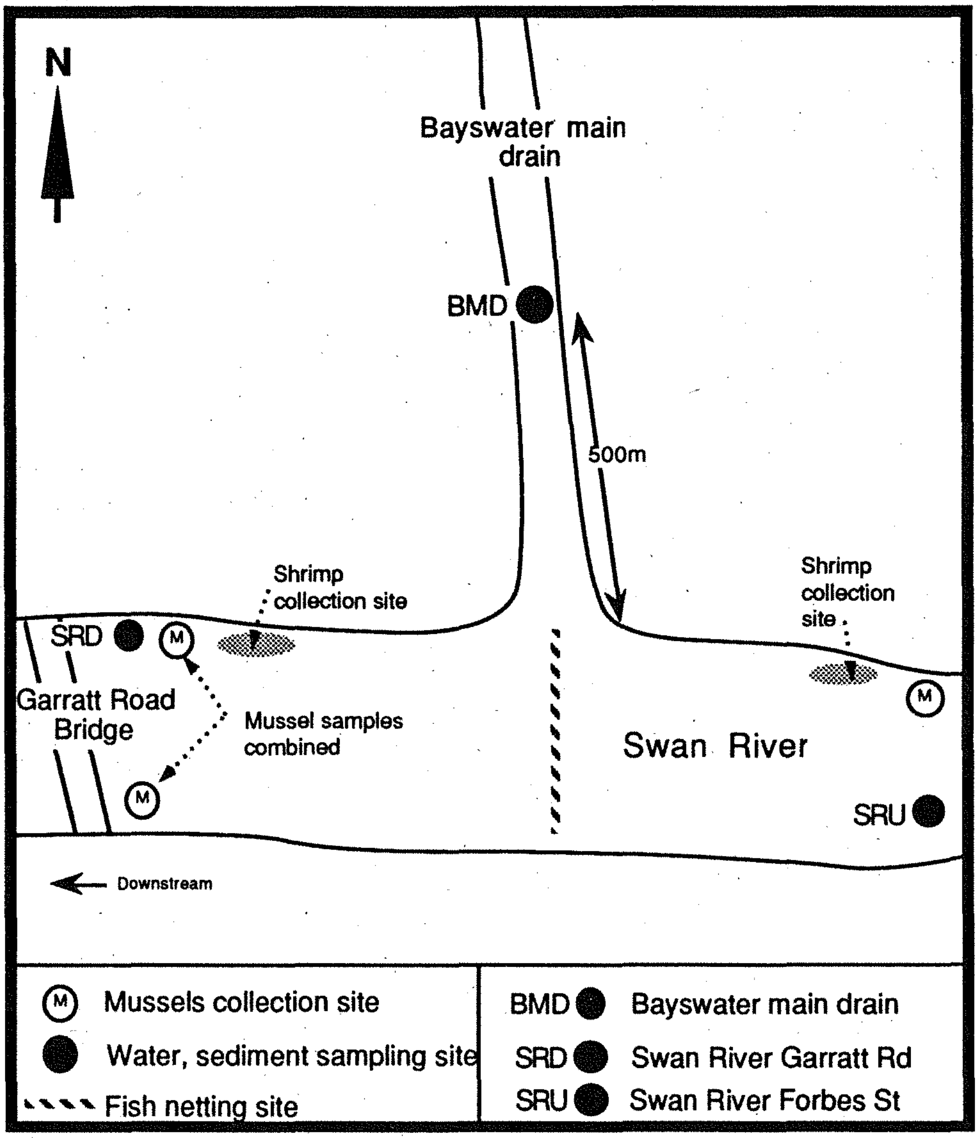


Figure 17. Location of study area and sample sites

3.4 Results and Discussion

3.4.1 Pesticides

Organophosphate compounds are cholinesterase inhibitors. Cholinesterase is an important enzyme at nerve synapses, maintaining the flow of nerve impulses along nerve fibres (Ware, 1986).

Organochlorine pesticides are chemically stable and persist in soil, aquatic environments, animal and plant tissues over a long time (Ware, 1986). Organochlorines vary widely in toxicity but are generally considered to be highly toxic, aldrin, heptachlor and dieldrin being most toxic. Organochlorines affect the central nervous system by inhibiting transmission of nerve impulses in both insects and mammals, although the mode of action is unclear. Other effects of organochlorines include reduced fecundity (ability to reproduce), lesions (skin damage), general environmental stress or even death (Thurlow et al., 1986).

Organochlorine pesticides are highly soluble in animal and plant fats and weakly soluble in water. Due to their persistence in the environment organochlorines can be accumulated at all trophic levels. Organochlorines are not readily broken down by microorganisms, enzymes, heat or ultra-violet light (Ware, 1986), so, once ingested, an organism can not eliminate them from its system thus resulting in accumulation. If these organisms are consumed the organochlorines will be passed onto the next trophic level. The amount of residues in an organism is a function of the level and duration of exposure, the species exposed, route of exposure, nature of the organochlorine pesticide and the ability of the organism to metabolise and/or excrete the compound.

3.4.1.1 Pesticide Residues in Waters

No organophosphate residues were detected in the waters of the Swan River and the Bayswater Main Drain.

Residues of five organochlorine residues were detected in the waters of the Swan River and the Bayswater Main Drain. These were aldrin, chlordane, DDT and metabolites, dieldrin and heptachlor (Table 9).

The concentrations of aldrin in the river were all below the environmental criterion (Table 9). Aldrin was only detected on two occasions at the Slade St site (representing the total input from the Bayswater Main Drain catchment)and both were below the environmental criterion (Section 2.7.2.2). Aldrin is metabolised to dieldrin, so the low levels may not be indicative of its initial concentrations.

Chlordane was detected eight times during the catchment monitoring survey (Table 6). The mean concentration was below the environmental criterion and one result was elevated above this criterion (Section 2.7.2.2). Results from the two river samples at both sites were below the detection limit and not of environmental concern. Dilution of the drain water with river water would lead to lower levels in the river.

Organochlorine Residue (µg/L)	Bayswater Main Drain	Swan River Downstream			Swan River Upstream		Environmental Criterion
	(catchment monitoring data)	Surface	Surface	Bottom	Surface	Surface	(DCE, 1981)
		8.3.90	1.11.90	1.11.90	8.3.90	1.11.90	
Aldrin	mean < 0.002	ND	<0.002	<0.002	ND	<0.002	0.003
Chlordane and Metabolites	mean 0.003	<0.002	<0.002	<0.002	<0.002	<0.002	0.004
DDT and Metabolites	mean 0.013	<0.002	<0.002	<0.002	<0.002	<0.002	0.001
Dieldrin	range 0.002 -0.005	0.007	0.007	0.006	0.005	0.004	0.003
Heptachlor	< 0.002	ND	0.003	0.004	ND	<0.002	0.001

Table 9. Organochlorine Pesticide Levels (µg/L) in Water Samples Collected from the Swan River.

Note: The limit of detection for pesticides is **0.002** µg/L (Chemistry Centre of W.A.).

DDT and metabolites levels were below the limit of detection in the river and were detected on only two occasions in the Bayswater Main Drain (Slade St) (Table 9).

The levels of dieldrin in water samples taken from the Swan River are cause for concern because they exceed the criterion (0.003 µg/l) recommended by the Environmental Protection Authority for the long term protection of the riverine environment (Table 9). All dieldrin levels detected in the Bayswater Main Drain (Slade St site) exceeded the recommended criterion for waters of the Swan River, but this was before dilution and mixing with the receiving waters (Section 2.7.2.2). Both dieldrin and aldrin were used in the past for a range of insecticidal purposes and aldrin is readily converted to dieldrin in the environment.

Heptachlor was not detected during the initial sampling in the river (Table 9). However during the second sampling, levels exceeding the environmental criterion were recorded at the Swan River Downstream site. This may reflect the increased reliance on this chemical for the control of termites. Heptachlor was only detected on two occasions (from twelve samples collected) at the Slade St site (Section 2.7.2.2). This indicates that the Bayswater Main Drain is not the major source of heptachlor in the river.

Measuring the total amount of organochlorine pesticide in water samples may not give a reliable indication of potential human health risks. Organochlorine pesticides are highly insoluble in water and are strongly and rapidly adsorbed by particles of soil or organic matter. This means that much of the chemical detected in water samples may be associated with fine particulates and not readily able to enter the tissues of aquatic animals. Fine particles of soil and organic matter containing organochlorines may settle and be incorporated into the sediments. Organochlorine pesticides are highly persistent (10-50 years), and the activity of animals feeding in the sediments may reintroduce them into the the food chain.

3.4.1.2 Pesticide Residues in Sediments

The mobility of pesticides and heavy metals in aquatic sediments and their impact on the environment is influenced by the type of sediments, the form of the pollutants in the sediments and the level of biological activity within the sediments. No environmental criteria are available for the determination of the level of contamination of aquatic sediments.

Draft Australian guidelines for the assessment and management of contaminated sites have been used as an indication of the level of contamination of sediments in the Swan River.

Five organochlorine residues were detected in the sediments of the Swan River in the vicinity of the Bayswater Main Drain (aldrin, chlordane and metabolites,DDT and metabolites, dieldrin and heptachlor). No other common organochlorine pesticides were detected. Pesticide levels in the river and mouth of the drain sediments were well within recommended levels for soils (Table 10). It is believed that these levels do not pose a health or environmental threat, even though it may not be appropriate to use soil criteria for aquatic sediments.

Organochlorine Residue (mg/kg)	Bayswater Main Drain	Swan River Downstream		Swan River Upstream	Soil Criteria[a]
	1.11.90	8.3.90	1.11.90	1.11.90	
Aldrin	<0.002	ND	0.004	<0.002	
Chlordane and Metabolites	<0.002	<0.002	0.004	<0.002	1.00
DDT and Metabolites	0.002	0.002	0.008	0.002	<0.97
Dieldrin	0.005	0.003	0.008	0.003	<0.05
Heptachlor	<0.002	ND	<0.002	<0.002	

Table 10. Organochlorine Pesticides Levels (mg/kg dry basis) Detected in Sediment Samples Collected in the Vicinity of the Bayswater Main Drain.

Soil Criteria[a] = Acceptable levels suggested in the Australian Guidelines for Management of Contaminated Soils (ANZEC NH&MRC 1990)

ND = Not Detected.

Note: Limit of detection 0.002 mg/kg

3.4.1.3 Pesticide Residues in Biota

Four organochlorine pesticides were detected in biota collected in the vicinity of the Bayswater Main Drain. These were chlordane, DDT and metabolites, dieldrin and heptachlor.

All organochlorine levels in shrimp, mussels, and worms were below the health criteria (Table 11). This means that there is no health risk associated with eating these animals even though they are not normally eaten. Levels in the Blue Manna Crab were also below the health criteria. These low levels are indicative of a low level of environmental contamination generally. It should be noted that health limits for organochlorines in crustaceans (shrimps) and fish are considerably more stringent than for molluscs (mussels).

Orgaonchlorine Residue (mg/kg)	Shrimp		Mussels		Worms		Blue Manna Crab	MPA[a]
	SRU	Forbes	SRU	Forbes	SRU	Forbes	Garratt Rd 12/3/91	
Chlordane & Metabolites	<0.002	<0.002	<0.002	0.004	<0.002	0.004	ND	0.005
DDT & Metabolites	<0.002	<0.002	0.004	0.005	<0.002	0.011	<0.01	1.00
Dieldrin	0.007	0.016	0.018	0.029	0.012	0.049	<0.01	0.10
Heptachlor	<0.002	<0.002	<0.002	<0.002	0.004	<0.002	ND	

Table 11. Organochlorine Pesticide Residues (mg/kg wet basis) Detected in Flesh of Worms, Shrimp, Mussels and the Blue Manna Crab in the Vicinity of the Bayswater Main Drain

MPA[a] = Maximum Permitted Concentration,Health Act 1911, Health (foodstuffs) (general) Regulations 1987 Section A12

ND = Not Detected

SRU = Swan River Upstream

The levels of organochlorine residues in five fish species caught in the vicinity of the Bayswater Main Drain were mostly below the health limits (Table 12). The exception was the yellow-eye mullet (*Aldrichetta forsteri*) which exceeded the Health Criteria by two times. Fish collected on the 12.3.91 were collected as part of a programme that is investigating the levels of pesticides in fish throughout the entire estuarine system. Samples from adjacent to the Bayswater Main Drain are currently being analysed for trace metals levels as well.

Organochlorine Pesticide Residues (mg/kg)	Yellow-tail Grunter *Amniataba caudavittatus*	Sea Mullet *Mugil cephalus*		Tailor *Pomatomus saltatrix*	Yellow-eye Mullet *Aldrichetta forsteri*	Bar-tailed Flathead *Phlatycephalus endrachtensis*	MPA[a]
	8.3.90	8.3.90	12.3.91	8.3.90	8.3.90	12.3.91	
Chlordane and metabolites	<0.003	<0.003	ND	<0.003	0.010	ND	0.005
DDT and metabolites	0.013	0.005	0.02	<0.003	0.023	<0.01	1.0
Dieldrin	0.003	0.007	0.03	<0.003	0.032	<0.01	0.1

Table 12. Organochlorine Pesticide Residues (mg/kg wet basis) Detected in Fish Flesh Caught in the Swan River in the Vicinity of the Bayswater Main Drain.

MPA[a] = Maximum Permitted Concentration, Health Act 1911, Health (foodstuffs) (general) Regulations 1987 Section A14

ND = Not Detected.

One difficulty in interpreting results from fish is that they do not remain within restricted areas of the estuary as do mussels and shrimp. Instead fish are mobile and may move throughout the estuarine system depending on food availability and breeding activity. This means that levels of pesticides (and other pollutants) may have been accumulated from other areas within the estuary. The fish species collected for analysis have differing habitats within the estuary. It is important to consider this information in addition to the analytical results.

Yellow tail grunter (*Amniataba caudavitatus*) can spend its entire life within the estuarine system. It is an omnivore and lives on the bottom in both shallow and deep waters throughout the entire estuarine system. The sea mullet (*Mugil cephalus*) uses the estuary as a nursery habitat, is a detritivore and lives in shallow (<2 m) waters throughout the entire estuarine system. Tailor (*Pomatomus saltatrix*) also uses the estuary as a nursery habitat, it is carnivorous and lives in both shallow and deep water throughout the estuary. Yellow-eye mullet (*Aldrichetta forsteri*) also uses the estuary as a nursery habitat. It is omnivorous and lives on the shallow (<2 m) bottom throughout the entire estuary. The bar-tailed flathead (*Platycephalus endrachtensis*) also uses the estuary as a nursery habitat. It is a carnivore and lives on the bottom in both shallow and deep water throughout the estuary.

3.5.1 Trace Metals and Fluoride

As with organochlorine pesticides, trace metals create problems in aquatic environments. After being ingested it is difficult for organisms to eliminate trace metals from their systems. Once assimilated trace metals are accumulated into all trophic levels of food webs. Accumulation of trace metals may be evident in liver, gills and pancreas of organisms and may lead to acute or chronic effects. These effects include reduced fecundity (ability to reproduce), lesions (skin damage) and general environmental stress in organisms (Chegwidden, 1980; Thurlow et al., 1986).

Fluoride is considered to be an acute pollutant in the aquatic environment. It is readily accumulated in bone tissue and also in some soft tissue at slower rates. Its uptake by organisms is directly correlated with environmental concentrations and exposure time. Effects of exposure vary between different organisms and at high levels enzyme inhibition appears to be the effect (Pankhurst et al., 1980). Environmental criteria for marine and estuarine waters for the maintenance of aquatic systems are 6 month median not to exceed 2 mg/l and no single reading to exceed 10 mg/l (DCE, 1981).

3.5.1.1 Trace Metals and Fluoride in Waters

Heavy metals were well below the upper limit recommended for single water samples in the Swan River on both occasions (Table 13). A more stringent set of environmental criteria is recommended for longer term average (6 month median) metal concentrations in river water. Copper was the only heavy metal detected that exceeded this limit (5 µg/L).

When a drain carrying pollutants discharges into a large receiving waterbody such as the Swan River, there is a considerable reduction in the concentration of pollutants because of mixing and dilution and precipitation in the higher pH waters of the river.

Mean levels of copper, lead, and zinc in the Bayswater Main Drain exceeded the six-month mean criteria before dilution with the Swan River (Table 13). Copper and zinc levels did exceed the upper limit for single sample criteria on one and four occasions respectively (Section 2.7.3.2). This is before mixing and dilution have taken place, and means that there is little likelihood of heavy metal contamination of the river environment.

No fluoride samples were collected during the November sampling run. Fluoride levels recorded during the March survey were well below the environmental criterion and no cause for concern. Mean fluoride levels at Slade St were below the six-month mean criterion and no levels exceeded the single sample criterion (Section 2.7.3.2).

Trace Metals and Fluoride (mg/L)	Bayswater Main Drain (catchment monitoring median	Swan River Downstream			Swan River Upstream			Environmental Criteria[a]
		Surface	Surface	Bottom	Surface	Surface	Bottom	
		8.3.90	1.11.90	1.11.90	8.3.90	1.11.90	1.11.90	
Arsenic As	0.008	ND	<0.005	<0.005	ND	<0.005	<0.005	0.008 (0.005)
Cadmium Ca	0.003	<0.001	0.001	0.001	<0.001	0.001	0.001	0.003 (0.008)
Chromium Cr^b	NA	0.001	0.002	0.002	0.001	0.002	0.002	0.002 (0.007)
Copper Cu	0.020	0.004	0.015	0.010	0.007	0.010	0.010	0.005 (0.040)
Lead Pb	0.030	<0.002	<0.010	<0.010	<0.002	<0.010	<0.010	0.008 (0.200)
Mercury Hg	NA	<0.0005			<0.0005			0.00014 (0.003)
Nickel Ni	0.010	0.005	0.001	0.001	0.008	0.001	0.001	0.020 (0.450)
Zinc Zn	0.200	0.007	0.020	0.020	0.006	0.020	0.020	0.020 (0.200)
Fluoride F (mg/L)	0.9	0.6			0.6			2 (10)

Table 13. Trace Metals (mg/L) and Fluoride (mg/L) Concentrations in Waters Collected in the Vicinity of the Bayswater Main Drain

Environmental Criteria[a]	= Upper limit for six-monthly mean concentrations in river water samples. Value in brackets is the upper limit for a single sample. DCE, 1981
Cr^b	= Total Chromium (Cr^{+3} and Cr^{+6})
ND	Not Detected
NA	Not Analysed

3.5.1.2 Trace Metals in Sediments

The concentrations of heavy metals in river sediments were below acceptable levels for soils, with the exception of chromium, lead and zinc (Table 14). The elevated levels of the trace metals may have originated from electroplaters in the area.

Results from the sediments from the mouth of the drain were all below the acceptable levels for soils.

It is difficult to determine the source of trace metals in sediments as levels may reflect a current or historic source. Therefore it is difficult to determine whether trace metals deposition has been recent or not.

Trace Metals (mg/kg)	Bayswater Main Drain	Swan River Downstream		Swan River Upstream		Soil Criteria[a]
	1.11.90	8.3.90	1.11.90	8.3.90	1.11.90	
Arsenic Ar	16		5.8		5.5	
Cadmium Cd	0.28	0.6	0.52	0.8	0.4	3
Chromium Cr[b]	8.2	90	140	120	88	100
Copper Cu	39	90	86	70	92	170
Lead Pb	40	50	100	50	110	100
Nickel Ni	5.0	24	48	34	34	100
Zinc Zn	41	360	220	160	280	350

Table 14. Trace Metals Concentrations (mg/kg) detected in Sediment Samples Collected in the Vicinity of the Bayswater Main Drain.

Soil Criteria[a] = Upper limits suggested in Australian Guidelines for management of contaminated soils above which further investigations should be initiated (ANZEC NH&MRC,1990).

Cr[b] = Total Chromium (Cr^{+3} and Cr^{+6})

3.5.1.3 Trace Metals in Biota

Concentrations of trace metals in the tissues of mussels were well below the health limits (Table 15). This means that there is no health risk associated with eating these animals although they are not normally eaten. Since mussels are filter feeders and thus concentrate metals from the surrounding environment these low levels are indicative of a low level of environmental contamination generally.

Trace Metals (mg/kg)	Swan River Downstream		Swan River Upstream		Maximum Permitted Concentration[a]
	8.3.90	1.11.90	8.3.90	1.11.90	
Arsenic Ar	NA	0.65	NA	0.7	
Cadmium Cd	0.5	1.0	0.9	0.12	2.0
Chromium Cr[b]	0.4	0.2	0.4	0.4	NL
Copper Cu	4.2	3.8	4.9	3.7	70
Lead Pb	0.4	0.4	0.4	0.5	2.5
Nickel Ni	0.2	0.2	0.2	0.2	NL
Zinc Zn	14	20	16	NR	1000

Table 15. Trace Metal Levels (mg/kg wet basis) Detected in Mussels (*Xenostrobus securis*) Collected in the Vicinity of the Bayswater Main Drain.

Maximum Permitted Concentration[a] = Health Act 1911, Health (foodstuffs) (general) Regulations 1987 Section A12;

NL = No Limit.

Cr[b] = Total Chromium (Cr^{+3} and Cr^{+6})

NA = Not Analysed

Fish samples collected during a survey investigating pesticide contamination within the Swan-Canning estuary are currently being analysed for trace metals. It is expected that concentrations in the fish will be below those found in the mussels.

4.0 Conclusion

Generally, levels of pesticides and trace metals in the Swan River and its biota were below environmental and health criteria. Based on two sampling occasions, levels of dieldrin, heptachlor, and copper in the Swan River exceeded the respective environmental criteria for the long term protection of the estuarine environment.

Levels of some pesticides and trace metals are elevated in the Bayswater Main Drain and this drain contributes the largest load of pesticides, trace metals and nutrients from urban Perth to the Swan River. Dilution and mixing in the Swan River appear to reduce the concentrations of these pollutants and therefore their impact on the ecology of the system.

These results should not lead to complacency. It is important that pollutant loads from the Bayswater Main Drain do not increase. It is also important that pollutant loads to the Swan River generally are reduced. As Perth continues to expand so too will the exportation of pollutants to the river.

The Bayswater Integrated Catchment Management Plan which will be developed by the Bayswater Integrated Catchment Management Steering Committee is an important part of this process. The overall aim of this project is to identify sources of pollution (both direct and indirect) and to develop solutions to control pollution so that the river is maintained as a healthy, functioning system now and into the future.

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Appendix 1 Sample Dates, Bayswater Catchment Monitoring (May 1990 to January 1991).

Sample Number	Sample Date
1	14/05/90
2	25/05/90
3	06/06/90
4	16/07/90
5	14/08/90
6	12/09/90
7	26/09/90
8	10/10/90
9	24/10/90
10	13/11/90
11	04/12/90
12	09/01/91

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Appendix 2 Data from Gummery St, Walter Rd, Redlands Rd, Slade St and King William St Sampling Sites within the Bayswater Main Drain Catchment.

Key to Tables

As	Arsenic
Cd	Cadmium
Fe	Iron
Pb	Lead
Ni	Nickel
Zn	Zinc
SRP	Soluble Reactive Phosphorus
TN	Total Nitrogen
TP	Total Phosphorus
NO3-N	Nitrate-Nitrogen
NH4-N	Ammonia-Nitrogen

Gummery St Site

	A	B	C	D	E	F	G	H	I
1	Date	Fluoride	As	Cd	Fe	Pb	Cu	Ni	Zn
2	900514	0.1	0.005	0.001	0.82	0.13	0.001	0.002	0.068
3	900525	0.1	0.005	0.003	0.31	0.032	0.001	0.002	0.12
4	900606	0.1	0.005	0.001	0.13	0.058	0.001	0.002	0.099
5	900717	0.1	0.005	0.001	0.19	0.06	0.005	0.005	0.11
6	900810	0.1	0.005	0.001	0.4	0.03	0.004	0.005	0.07
7	900912	0.1	0.005	0.001	1.1	0.05	0.005	0.005	0.05
8	900926	0.1	0.005	0.001	0.6	0.03	0.003	0.005	0.04
9	901010	0.1	0.005	0.001	0.6	0.04	0.006	0.005	0.1
10	901024	0.1	0.005	0.001	0.7	0.03	0.004	0.005	0.02
11	901113	0.1	0.005	0.001	0.45	0.02	0.008	0.005	0.03
12	901204	0.1	0.005	0.001	0.67	0.09	0.01	0.002	0.1
13	910109	0.1	0.005	0.001	0.54	0.03	0.01	0.002	0.04
14									
15	Date	SRP	TN	TP	NO3-N	NH4-N			
16	900514	0.01	1.2	0.07	0.08	0.09			
17	900525	0.01	1.2	0.02	0.13	0.4			
18	900606	0.01	0.43		0.03	0.02			
19	900717		0.3		0.07	0.02			
20	900810	0.01	0.97						
21	900912		0.58	0.04	0.35	0.12			
22	900926		1.1	0.03	0.32	0.1			
23	901010	0.01	1.3	0.03					
24	901024	0.01	0.88	0.016					
25	901113	0.01	1.1		0.19	0.15			
26	901204	0.01	1	0.01	0.08	0.12			
27	910109	0.01	1.9		0.62	0.02			

	J	K	L	M	N	O	P
1	Date	Chlordane	Dieldrin	Aldrin	Heptachlor	DDT	LIndane
2	900514	0.007	0.018				
3	900525	0.002	0.007				
4	900606	0.004	0.009				
5	900717	0.003	0.008				
6	900810						
7	900912	0.007	0.012	0.002	0.002		
8	900926		0.009		0.002		
9	901010						
10	901024	0.002	0.01				
11	901113						
12	901204	0.002	0.005	0.002		0.002	
13	910109	0.003	0.01			0.01	0.002
14							
15							
16							
17							
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21							
22							
23							
24							
25							
26							
27							

Walter Rd Site

	A	B	C	D	E	F	G	H	I
1	Date	Fluoride	As	Cd	Fe	Pb	Cu	Ni	Zn
2	900514	0.1	0.005	0.001	0.4	0.024	0.001	0.002	0.023
3	900525	0.1	0.005	0.003	0.57	0.018	0.001	0.002	0.011
4	900606	0.1	0.005	0.001	0.25	0.044	0.001	0.002	0.024
5	900716	0.1	0.005	0.001	0.53	0.04	0.005	0.005	0.03
6	900810	0.1	0.005	0.001	0.3	0.01	0.002	0.005	0.03
7	900912	0.1	0.005	0.001	0.5	0.02	0.002	0.005	0.02
8	900926	0.1	0.005	0.001	2.3	0.03	0.005	0.005	0.02
9	901010	0.1	0.005	0.001	0.75	0.04	0.005	0.005	0.03
10	901024	0.1	0.005	0.001	0.8	0.01	0.004	0.005	0.02
11	901113	0.1	0.005	0.001	0.55	0.02	0.014	0.005	0.002
12	901204	0.1	0.005	0.001	0.42	0.04	0.008	0.001	0.03
13	910109								
14									
15	Date	SRP	TN	TP	NO3-N	NH4-N			
16	900514	0.01	1.3	0.02	0.44	0.33			
17	900525	0.01	1.3	0.01	0.34	0.46			
18	900606	0.01	0.6		0.19	0.06			
19	900716		1	0.02	0.46	0.22			
20	900810	0.01	0.93	0.05					
21	900912		2.3	0.01	0.55	0.17			
22	900926		1.4	0.04	0.27	0.39			
23	901010	0.01	1.7	0.03					
24	901024	0.01	0.7	0.01					
25	901113	0.01	1.1		0.52	0.05			
26	901204	0.01	0.73	0.01	0.15	0.06			
27	910109								

Walter Rd Site

	J	K	L	M	N	O	P	Q	R
1	Date	Chlordane	Dieldrin	Aldrin	Heptachlor	DDT	Lindane		
2	900514	0.002	0.004						
3	900525	0.002	0.005						
4	900606	0.005	0.008						
5	900716	0.002	0.004						
6	900810		0.005						
7	900912	0.009	0.008	0.002	0.002				
8	900926		0.007		0.002				
9	901010								
10	901024	0.003	0.005						
11	901113								
12	901204	0.002	0.002	0.002		0.005			
13	910109								
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									

Redlands Rd Site

	A	B	C	D	E	F	G	H	I
1	Date	Fluoride	As	Cd	Fe	Pb	Cu	Ni	Zn
2	900514	0.1	0.005	0.001	0.64	0.071	0.001	0.002	0.026
3	900525	0.1	0.005	0.003	0.37	0.017	0.001	0.002	0.01
4	900606	0.1	0.005	0.001	0.18	0.055	0.001	0.002	0.02
5	900716	0.1	0.005	0.001	0.52	0.07	0.005	0.005	0.03
6	900810								
7	900912	0.1	0.005	0.001	0.55	0.03	0.002	0.005	0.02
8	900926	0.1	0.005	0.001	0.45	0.02	0.002	0.005	0.02
9	901010	0.1	0.005	0.001	0.45	0.04	0.004	0.005	0.03
10	901024	0.1	0.005	0.001	0.3	0.01	0.003	0.005	0.02
11	901113	0.1	0.005	0.001	0.35	0.02	0.008	0.005	0.02
12	901204	0.1	0.005	0.001	0.65	0.13	0.015	0.002	0.08
13	910109	0.1	0.005	0.001	1.5	0.11	0.006	0.001	0.03
14									
15	Date	SRP	TN	TP	NO3-N	NH4-N			
16	900514	0.01	1.6	0.07	0.68	0.25			
17	900525	0.02	2	0.04	1.1	0.29			
18	900606	0.01	1.2		0.6	0.11			
19	900716		1.3		0.84	0.14			
20	900810								
21	900912		2	0.02	1.1	0.21			
22	900926		1.8	0.16	0.94	0.04			
23	901010	0.01	1.5	0.04					
24	901024	0.01	0.95	0.01					
25	901113	0.01	1.3	0.01	0.63	0.12			
26	901204	0.01	1.7	0.04	0.51	0.25			
27	910109	0.01	1.8		0.42	0.06			

Redlands Rd Site

	J	K	L	M	N	O	P	Q	R
1	Date	Chlordane	Dieldrin	Aldrin	Heptachlor	DDT	Lindane		
2	900514	0.002	0.005						
3	900525	0.002	0.004						
4	900606	0.002	0.006						
5	900716	0.002	0.006						
6	900810								
7	900912	0.007	0.008	0.002	0.002				
8	900926		0.006		0.003				
9	901010								
10	901024	0.003	0.006						
11	901113								
12	901204	0.002	0.002	0.002		0.002			
13	910109	0.002	0.004			0.002	0.003		
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									

	A	B	C	D	E	F	G	H	I
1	Date	Fluoride	As	Cd	Fe	Pb	Cu	Ni	Zn
2	900514	1.5	0.005	0.001	7.7	0.032	0.005	0.013	0.21
3	900525	1.8	0.012	0.0015	10	0.018	0.007	0.018	0.21
4	900606	0.2	0.005	0.001	2.2	0.056	0.001	0.004	0.13
5	900716	0.5	0.005	0.001	2.2	0.07	0.015	0.005	0.19
6	900814	0.6	0.005	0.003	2.8	0.03	0.02	0.01	0.16
7	900912	0.9	0.005	0.002	3.9	0.03	0.02	0.005	0.19
8	900926	0.6	0.005	0.003	4.3	0.03	0.02	0.005	0.16
9	901010	0.8	0.005	0.002	5	0.03	0.02	0.01	0.17
10	901024	1.1	0.01	0.004	6.5	0.02	0.02	0.01	0.2
11	901113	1	0.01	0.004	7	0.02	0.03	0.015	0.2
12	901204	0.6	0.01	0.002	9.5	0.23	0.07	0.011	0.3
13	910109	1.6	0.015	0.005	8.4	0.03	0.03	0.02	0.23
14									
15	Date	SRP	Tn	Tp	NO3-N	NH4-N			
16	900514	0.01	2.3	0.48	0.62	0.95			
17	900525	0.01	2.1	0.24	0.71	0.78			
18	900606	0.01	1.4		0.4	0.33			
19	900716		2.1	0.16	0.41	0.28			
20	900814	0.01	1.8						
21	900912		2	0.14	0.67	0.41			
22	900926		1.7	0.09	0.66	0.28			
23	901010	0.01	1.4	0.11					
24	901024	0.01	1.8	0.12					
25	901113	0.01	1.6	0.09	0.51	0.42			
26	901204	0.01	2.8	0.65	0.62	0.6			
27	910109	0.01	2.1		0.46	0.4			

Slade St Site

Slade St Site

	J	K	L	M	N	O	P	Q	R
1	Date	Chlordane	Dieldrin	Aldrin	Heptachor	DDt	Lindane		
2	900514	0.007	0.018						
3	900525	0.002	0.02						
4	900606	0.004	0.02						
5	900716	0.002	0.01						
6	900814								
7	900912	0.002	0.012	0.002	0.002				
8	900926		0.009		0.002				
9	901010								
10	901024								
11	901113	0.002	0.014						
12	901204	0.002	0.008	0.002		0.002			
13	910109	0.002	0.01			0.005	0.002		
14									
15									
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17									
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19									
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22									
23									
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25									
26									
27									

King William St Site

	A	B	C	D	E	F	G	H	I
1	Date	Fluoride	As	Cd	Fe	Pb	Cu	Ni	Zn
2	900514	0.01	0.005	0.001	0.49	0.18	0.001	0.002	0.026
3	900525	0.1	0.005	0.005	0.26	0.006	0.001	0.02	0.015
4	900606	0.5	0.005	0.001	0.53	0.018	0.001	0.02	0.035
5	900716	0.1	0.005	0.001	0.56	0.03	0.005	0.005	0.06
6	900810	0.1	0.005	0.001	0.2	0.01	0.003	0.005	0.03
7	900912	0.2	0.005	0.001	1.7	0.05	0.001	0.005	0.03
8	900926	0.1	0.005	0.001	0.5	0.01	0.002	0.005	0.02
9	901010	0.2	0.005	0.001	0.45	0.01	0.003	0.005	0.02
10	901024	0.1	0.005	0.001	0.3	0.01	0.003	0.005	0.02
11	901113	0.1	0.005	0.001	0.5	0.01	0.006	0.005	0.02
12	901204	0.1	0.005	0.001	0.56	0.27	0.02	0.003	0.11
13	910109	0.1	0.005	0.001	0.33	0.01	0.007	0.001	0.02
14									
15	Date	SRP	TN	TP	NO3-N	NH4-N			
16	900514	0.01	2	0.05	1.4	0.16			
17	900525	0.01	2.1	0.03	1.5	0.05			
18	900606	0.01	2.2		1.4	0.29			
19	900716		2.1		1.3	0.22			
20	900810	0.06	2.2						
21	900912		2.7	0.26	1.5	0.19			
22	900926		3	0.07	1.7	0.1			
23	901010	0.04	2.4	0.06					
24	901024	0.01	0.95	0.03					
25	901113	0.03	2.2	0.02	1.5	0.06			
26	901204	0.01	1.3	0.03	0.65	0.09			
27	910109	0.04	2.8		1.4	0.05			

	J	K	L	M	N	O	P	Q	R
1	Date	Chlordane	Dieldrin	Aldrin	Heptachlor	DDT	Lindane		
2	900514	0.002	0.025						
3	900525	0.002	0.027						
4	900606	0.002	0.03						
5	900716	0.002	0.02						
6	900810		0.02						
7	900912	0.011	0.06	0.03	0.004				
8	900926		0.019		0.002				
9	901010								
10	901024	0.002	0.024						
11	901113								
12	901204	0.002	0.029	0.002		0.002			
13	910109	0.002	0.025			0.002	0.002		
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Appendix 3. Six-month Median Calculation for Trace Metals from Gummery St, Walter Rd, Redlands Rd, Slade St and King William St Sampling Sites within the Bayswater Main Drain Catchment.

Trace Metal	Six Month Period	Slade St	Gummery St	Walter Rd	Redlands St	King William St
Fluoride F	May - Oct	0.8	0.1	0.1	0.1	0.1
	June - Nov	0.7	0.1	0.1	0.1	0.1
	July - Dec	0.7	0.1	0.1	0.1	0.1
	Aug - Jan	0.85	0.1	0.1	0.1	0.1
Arsenic As	May - Oct	0.005	0.005	0.005	0.005	0.005
	June - Nov	0.005	0.005	0.005	0.005	0.005
	July - Dec	0.005	0.005	0.005	0.005	0.005
	Aug - Jan	0.008	0.005	0.005	0.005	0.005
Cadmium Cd	May - Oct	0.002	0.001	0.001	0.001	0.001
	June - Nov	0.002	0.001	0.001	0.001	0.001
	July - Dec	0.002	0.001	0.001	0.001	0.001
	Aug - Jan	0.003	0.001	0.001	0.001	0.001
Iron Fe	May - Oct	4.3	0.60	0.53	0.45	0.49
	June - Nov	4.1	0.52	0.54	0.45	0.50
	July - Dec	4.6	0.60	0.54	0.45	0.50
	Aug - Jan	6.0	0.60	0.55	0.45	0.48
Lead Pb	May - Oct	0.03	0.040	0.024	0.035	0.010
	June - Nov	0.03	0.035	0.025	0.030	0.010
	July - Dec	0.03	0.035	0.025	0.030	0.010
	Aug - Jan	0.03	0.030	0.020	0.030	0.010
Copper Cu	May - Oct	0.020	0.004	0.002	0.002	0.002
	June - Nov	0.020	0.004	0.004	0.003	0.003
	July - Dec	0.020	0.005	0.005	0.004	0.003
	Aug - Jan	0.020	0.006	0.005	0.004	0.003
Nickel Ni	May - Oct	0.010	0.005	0.005	0.005	0.005
	June - Nov	0.075	0.005	0.005	0.005	0.005
	July - Dec	0.010	0.005	0.005	0.005	0.005
	Aug - Jan	0.010	0.005	0.005	0.005	0.005
Zinc Zn	May - Oct	0.190	0.070	0.023	0.020	0.026
	June - Nov	0.180	0.060	0.022	0.020	0.025
	July - Dec	0.190	0.060	0.025	0.020	0.025
	Aug - Jan	0.195	0.045	0.020	0.020	0.020