Sediment Quality Survey for Heathcote River Catchment, City Outfall Drain and Estuary Drain

Prepared for Christchurch City Council

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Contents

Tables

Figures

Executive summary

This report describes a survey of stream sediment quality in the Heathcote River, City Outfall Drain / Linwood Canal, and the Estuary Drain. Stream sediments can demonstrate the effects of stormwater discharges as contaminants such as metals and persistent organics accumulate in the sediment over time. Accumulated contaminants can also adversely affect stream biota. The sediment quality was examined at 13 sites across the Heathcote River / Ōpawharo catchment, and one in each of the City Outfall Drain, and the Estuary Drain. Samples were collected from the surface of the stream bed sediment and analysed for metals, PAHs, phosphorus, organic carbon and grain size. This work was carried out to inform the Heathcote, Estuary + Coastal and Avon Stormwater Management Plans (SMPs).

Within the Heathcote River / Ōpawharo catchment, the highest concentrations of metals were measured at sites in upper (but downstream of Curletts Road Drain) and lower reaches; and the lowest concentrations at the most upstream Heathcote River site and at sites in the tributaries Cashmere Stream, Cashmere Brook and Steamwharf Stream. Sites in the middle reaches of the Heathcote River contained moderate metal concentrations compared to other sites in this survey. PAH concentrations showed a similar pattern with the exception of an extremely elevated concentration of total PAHs was measured in the Heathcote River, downstream of Colombo Street (614 mg/kg) and a site in the lower section measuring 77 mg/kg. Sites were ranked for overall sediment quality and the three sites downstream of Aynsley Terrace had the worst overall quality, along with the site downstream of Colombo Street.

The City Outfall Drain (in the Estuary + Coastal SMP area) had among the highest concentrations of metals and was ranked in the bottom three sites for overall sediment quality. The Estuary Drain (in the Avon SMP area) had low to moderate metal concentrations, but had the highest concentrations of phosphorus and arsenic of the sites sampled.

Lead, zinc and PAHs concentrations exceeded ANZECC sediment quality trigger values at 4 – 6 sites, showing these are the major contaminants of concern. One or more trigger value was exceeded at 9 of the 15 sites sampled. There were also two sites where the ISQG-high values were exceeded. The zinc ISQG-high value of 410 mg/kg was exceeded in City Outfall Drain, measuring 450 mg/kg; and the total PAHs ISQG-high value of 40 mg/kg exceeded in the Heathcote River downstream of Colombo Street, measuring 212 mg/kg when normalised to 1% TOC (614 mg/kg in sample). Copper, arsenic, cadmium, chromium and nickel concentrations in the sediment did not exceed their respective trigger values at any sites and were generally well below the guidelines.

A comparison of the present survey results with a prior survey 30 years ago suggested that lead concentrations have decreased; whilst zinc concentrations appear to have increased, at least in some locations. This is in keeping with previous findings for the Heathcote River catchment. For copper, cadmium, chromium and nickel there has been no clear increase or decrease. The survey found the sediment metal concentrations were within the range previously measured in urban stream sediments from elsewhere in Christchurch and around New Zealand.

This report investigated potential influences on sediment quality including soils, landuse, roading materials and earthquake-related liquefaction. The following findings were made:

- The sources of cadmium, copper, lead, and zinc are likely to be the same, and different from that for organic carbon, phosphorus, arsenic, chromium, nickel and PAHs.
- Arsenic, chromium, lead and nickel in sediment are likely to be sourced primarily from soils. Soils contain elevated concentrations of lead compared to outside urban areas as a result of the historical use of lead additives in petrol.
- Rural landuse was associated with lower concentrations of metals in sediment whereas residential and residential/business landuse was associated with somewhat higher copper, lead and zinc concentrations; though this relationship was not statistically significant.
- Elevated PAHs (higher than all other sites and above trigger values) in the Heathcote River downstream of Colombo Street are likely due to historical use of coal tar used as roading material.
- Liquefaction sediments may have influenced the quality of sediments in Steamwharf Stream, however the influence on contaminant concentrations at other locations was not clear.

For stormwater management in the Heathcote River / Ōpawharo catchment, zinc is the primary contaminant of concern. Source control should be considered where possible to reduce inputs, and prevent further increases (particularly in sub-catchments being developed from rural landuse). Further investigations including toxicity testing, targeted stormwater and sediment sampling and dredging of contaminated sediments may be useful to manage contaminants in the City Outfall Drain / Linwood Canal. In addition, although not included in this survey, Haytons Drain and Curletts Road Drain have previously been identified as having poor sediment quality and stormwater management efforts may be more, or equally usefully spent in those areas.

1 Introduction

1.1 Introduction

The Christchurch City Council (CCC) is developing Stormwater Management Plans (SMPs) for Christchurch and these will contribute to catchment-wide applications to Environment Canterbury for consent to discharge stormwater. Background studies are currently being undertaken to provide information for the SMPs and consent application and these studies include the sediment quality of catchment waterways. The study described in this report covers streams located within three SMPs:

- Heathcote River and its tributaries, within the Heathcote River / Ōpawharo SMP;
- City Outfall Drain / Linwood Canal, within the Estuary + Coastal SMP; and

Estuary Drain, within the Avon River / Ōtākaro catchment. This report describes the sediment quality of these waterways which was assessed through field collection of samples and laboratory analysis.

1.2 Project Scope

NIWA was engaged by CCC to report on a survey of sediment quality in the Heathcote River catchment. Sediment samples were collected by a third party (Boffa Miskell), at the same as they conducted an ecological survey in the catchments. Samples were analysed by Hill Laboratories and the data supplied to NIWA for reporting.

The report on sediment quality in the Heathcote River catchment was to be consistent with our previous report on the Avon River sediment survey (Gadd & Sykes, 2014) and include:

- reviewing the two existing sources of information on sediment quality to be provided by CCC;
- undertaking data analyses to assess the current state of sediment quality;
- conducting an assessment of changes in sediment quality compared to the results of previous studies;
- conducting an assessment of variations in sediment quality across the catchment and of the main influences on sediment quality; and
- summarising issues and making recommendations.

1.3 This Report

This report is organised in nine sections (including this introduction) as listed below.

- Section two provides background information on issues influencing the sediment quality of the Heathcote River / Ōpawharo, City Outfall Drain / Linwood Canal and the Estuary Drain, based on previous studies in the catchments and elsewhere in Christchurch.
- Section three describes the methods used in this sediment survey, including field, laboratory and statistical methods used in this report.
- Section four presents the current state of sediment quality in these catchments, including spatial patterns and comparisons with sediment quality guidelines.
- Section five discusses the main influences on sediment quality in the catchments.
- Section six compares the current state of sediment quality in the Heathcote River / Ōpawharo catchment and the City Outfall Drain / Linwood Canal with previously measured data for this catchment to investigate changes over time.
- Section seven compares the current state of sediment quality in the Heathcote River / Ōpawharo catchment and the two drains with other data from around Christchurch and elsewhere in New Zealand.
- Section eight summarises the major findings of this sediment survey.
- Section nine suggests recommendations for management of these catchments.

When reading the report it is important to be aware that, because this survey only collected single samples at each site, statistical comparisons between sampling sites could not be undertaken. Differences described in the text (e.g., higher, lower) are relative differences only based on the single sampling results. Additional sampling of the stream sediments may indicate that differences between sites described in this report are not statistically significant.

2 Review of Existing Information

2.1 Overview of the Heathcote River / Ōpawharo Catchment

The Heathcote River / Ōpawharo is one of two rivers that drain the majority of Christchurch City, with the Avon River / Ōtākaro being the other. The Heathcote River source is to the west of the city and the river then flows in an easterly direction, meandering around the base of the Port Hills before discharging into the south-western part of the Avon-Heathcote Estuary (Figure 2-1).

The Heathcote River is primarily spring-fed and slow-flowing, and becomes tidally influenced around Mackenzie Avenue footbridge (PDP 2007). The total catchment area is 103 km^2, of which approximately one third is the Port Hills area and is mainly in rural landuse (Robb 1988). There is also a significant area of rural landuse in the upper, north and west of the catchment (PDP 2007) though this is rapidly being converted to residential landuse. Cashmere Stream is one of the major tributaries and flows from the rural hills area to join with the Heathcote River main stem near Cashmere and Hoon Hay Roads. Cashmere Stream has several tributaries to the north which drain the flat, rural land, including Dunbars Drain and Ballantines Drain. There are also two tributaries in the north-west of the catchment that join directly with the Heathcote River: Haytons Drain and Curletts Drain. Most of these tributaries have been extensively modified, by straightening, channelizing, lining and reinforcing (for example with wooden boxing).

In addition to the rural and residential landuse, the Heathcote River catchment has considerable industrial landuse (when compared to the Avon River catchment). The industrial land is located in the north-west of the catchment, in the subcatchments of Haytons Drain and Curletts Drain; in the Jacksons Creek subcatchment and in the lower part of the catchment around Woolston and the Woolston Cut. The industrial areas have previously resulted in significant degradation of the Heathcote River (PDP 2007).

Two additional waterways outside of the Heathcote River catchment were included in this sediment survey. The City Outfall Drain is the next waterway to the north. This waterway drains an area of approximately 4.8 km^2, of which the majority is residential, but also includes industrial and commercial land. The Estuary Drain is located in Bexley Reserve and has a very small catchment which is primarily from the reserve and from an upstream residential area. Both waterways discharge directly into the Avon-Heathcote / Ihutai Estuary.

2.2 Previous Sediment Studies in the Catchment

A major survey of sediment quality in the Heathcote River / Ōpawharo catchment was undertaken by the Christchurch Drainage Board (CDB) in 1980/81 (Robb 1988), with sampling at 86 locations from the headwaters to mouth and at multiple locations within tributaries. Samples were also collected from five locations within the City Outfall Drain / Linwood Canal. Samples were analysed for grain size (silt/clay, sands, gravel); and six metals (cadmium, chromium, copper, lead, nickel and zinc) using methods comparable to those in the current survey (see Table 2-1 for a summary of the results compared to ANZECC guidelines). In the same study, samples were also collected from the Avon and Styx River catchments and in the Avon-Heathcote Estuary.

Sediment quality in the Heathcote River was assessed again in 2003, as part of Christchurch City Council's Integrated Catchment Management Planning for South-West Christchurch (Kingett Mitchell 2005). Stream sediment samples were collected from 27 sites, mainly in the upper Heathcote catchment, of which 13 were in tributaries and 14 in the main stem (Kingett Mitchell 2005). A study

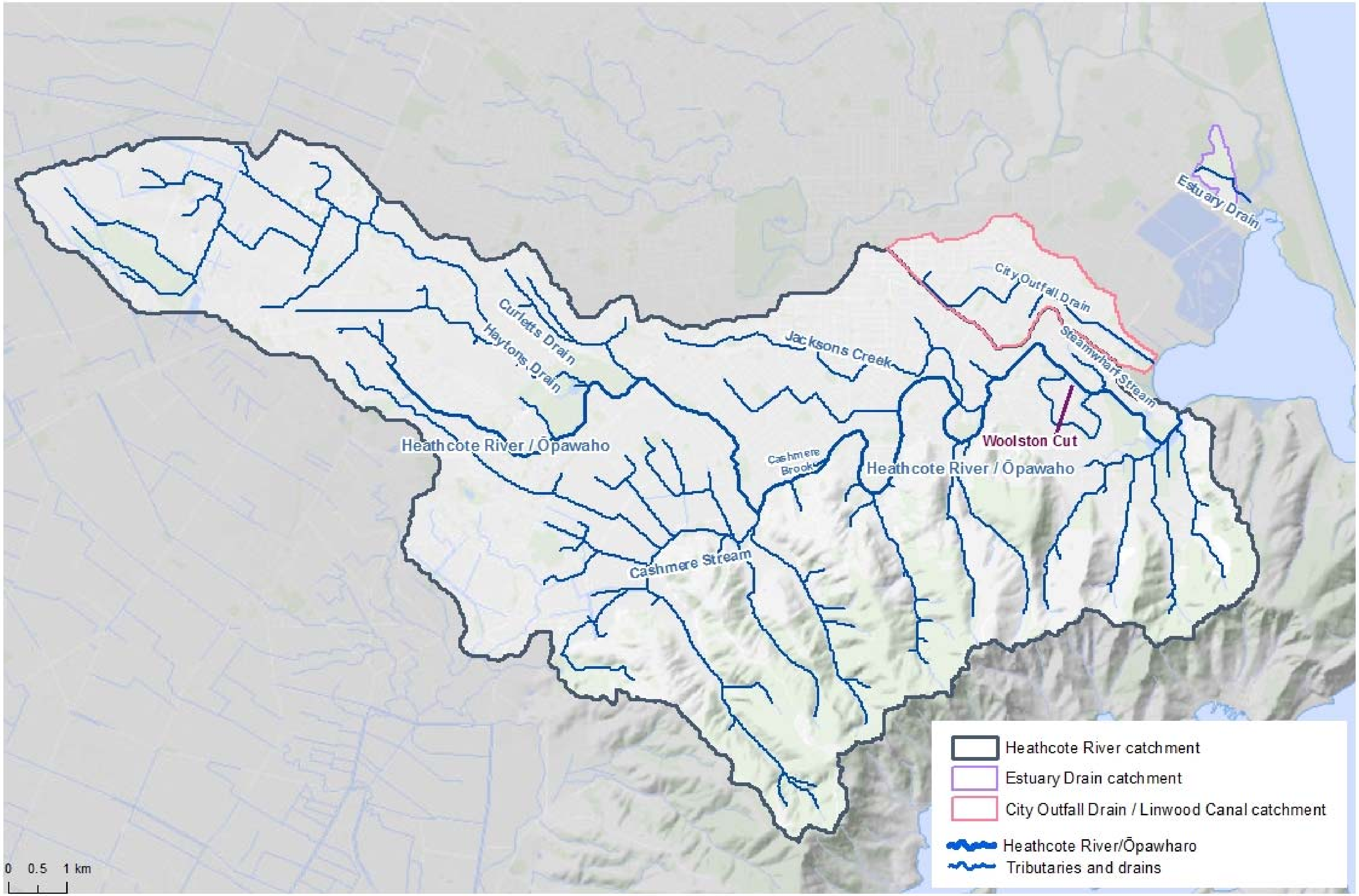

Figure 2-1: The Heathcote River / Ōpawharo indicating major tributaries and approximate catchment boundary; and City Outfall Drain / Linwood Canal and Estuary Drain.

in 2009 of the water quality in Haytons Drain, commissioned by Environment Canterbury and Christchurch City Council also included measurements of sediment quality (Moores et al. 2009). Samples were collected within Haytons Drain and its tributary Pararua Main Drain, and at sites upstream and downstream of Haytons Drain's confluence with the Heathcote River. In 2011, urban stream sediments throughout the Canterbury Region were surveyed (Golder 2012), including four sites in the Heathcote River / Ōpawharo and one in Cashmere Stream. The data from these three studies are summarised in Table 2-1 along with those from the CDB study.

Table 2-1: Summary of metal concentrations in sediments of the Heathcote River / Ōpawharo catchment. Mean concentrations (mg/kg) ± standard deviation. Yellow shading indicates mean exceedance of ANZECC (2000) ISQG-low, red shading indicates exceedance of ANZECC (2000) ISQG-high.

Location	Survey	No. sites	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Cashmere Stream	Robb (1988)	12	0.03 ± 0.02	13 ± 3	9.3 ± 2.6	15 ± 8	9.1 ± 1.8	72 ± 24
	KML (2005)	1	-	-	8	14	-	106
	Golder (2012)	1	0.11	13	9.3	16	11	98
Cashmere Stream tributaries	Robb (1988)	15	0.09 ± 0.08	14 ± 3	16 ± 5	66 ± 51	11 ± 2	163 ± 96
	KML (2005)	8	-	-	22 ± 17	70 ± 63	-	245 ± 163
Curletts & Haytons Drains	Robb (1988)	5	2.2 ± 3.4	22 ± 12	83 ± 99	154 ± 229	7.3 ± 4.1	454 ± 354
	KML (2005)	4	-	-	97 ± 81	152 ± 151	-	736 ± 101
	NIWA (2009)	8	-	-	15 ± 8	32 ± 18	-	492 ± 585
Upper Heathcote	Robb (1988)	14	1.1 ± 1.4	12 ± 3	81 ± 93	70 ± 52	7.2 ± 1.9	173 ± 93
	KML (2005)	7	-	-	50 ± 40	45 ± 16	-	616 ± 295
	NIWA (2009)	2	-	-	34 ± 40	40 ± 31	-	385 ± 106
	Golder (2012)	1 [a]	1.3 ± 0.1	16 ± 1	73 ± 2	31 ± 2	9.6 ± 0.3	393 ± 15
Mid Heathcote	Robb (1988)	7	0.47 ± 0.29	9 ± 2	20 ± 8	80 ± 76	6.8 ± 1.3	156 ± 53
	KML (2005)	2	-	-	30 ± 12	47 ± 29	-	276 ± 16
	Golder (2012)	1	0.45	21	54	50	14	410
Lower Heathcote	Robb (1988)	28	0.41 ± 0.27	77 ± 101	43 ± 29	208 ± 247	12 ± 4	269 ± 130
	KML (2005)	5	-	-	35 ± 18	56 ± 26		380 ± 253
	Golder (2012)	2	0.2 ± 0.2	20 ± 12	16 ± 13	23 ± 18	11 ± 3	161 ± 127
City Outfall Drain	Robb (1988)	5	3.5 ± 6.0	23 ± 8	45 ± 29	234 ± 196	16 ± 2	594 ± 410
Other tributaries	Robb (1988)	5	0.16 ± 0.18	16 ± 8	15 ± 6	143 ± 215	7.5 ± 1.9	221 ± 120
ISQG-Low			1.5	80	65	50	21	200
ISQG-High			10	370	270	220	52	410

Note: [a] One site but three samples collected.

The previous studies indicate that the contaminant of most concern in the catchment is zinc, with many locations where the concentrations exceeded sediment quality guidelines, including the higher level of ISQG-high, above which adverse effects are more likely. Lead concentrations also exceeded guidelines at many locations, especially in the earlier surveys. In general, lead concentrations observed in the more recent surveys appear to be lower than that those observed in 1980/81. Copper and cadmium concentrations exceeded the lower guideline concentrations at a small number of sites, whereas mean chromium and nickel were consistently lower than the guideline concentrations.

The data also suggests that the sediment quality is poorer in Curletts and Haytons Drains than in the main river, and in other tributaries such as Cashmere Stream (and its tributaries). Metal concentrations in the upper and mid reaches of the Heathcote River were generally higher than the lower, tidal reaches.

Mercury concentrations were measured in the Canterbury-wide survey (Golder 2012) and had not previously been regularly measured in sediment surveys. The mercury concentrations in sediments from the Heathcote River (0.043-0.087 mg/kg) and Cashmere Stream (0.065 mg/kg) were mid-range of those found at other locations around Canterbury (0.012-0.17 mg/kg) and were also below the ANZECC (2000) ISQG-low of 0.15 mg/kg.

Polycyclic aromatic hydrocarbons (PAHs) have been measured in Heathcote River catchment sediments in at least three previous studies: the Golder (2012) survey of regional sediment quality; the South-West Christchurch survey (Kingett Mitchell 2003); and much earlier, in a PhD study (Lee 1982). A fourth study of PAHs in Christchurch stream sediments (Depree & Ahrens 2005) also included one site in the lower Heathcote River and two near the river mouth.

The 1982 survey, a PhD thesis, investigated PAHs in the Christchurch urban environment, including sediments from 8 locations in the Heathcote River / Ōpawharo (Lee 1982). In that study, PAHs were lowest at the river source (0.8 mg/kg), increased downstream to a maximum of 40 mg/kg at the Radley St Bridge and then decreased towards the river mouth, where concentrations were 3.6 mg/kg. Atmospheric particulate matter, automobile exhaust particulates and domestic soot particulates were also studied as part of source identification. Lee (1982) found that domestic soot was the primary source of PAHs in stream sediments based on PAH and lead ratios.

PAHs were measured at 12 sites in the South-West Christchurch survey (Kingett Mitchell 2003), all in the upper catchment and including 9 within the tributaries. That study found the highest concentrations in the Heathcote River just downstream of the confluence with Cashmere Stream (49.8 mg/kg), however PAHs were not measured at sites further downstream. The lowest concentration (0.12 mg/kg) was measured in Milnes Drain, a rural tributaries of Cashmere Stream. In contrast to the metal results, Haytons Drain and Curletts Road Drains did not have higher PAH concentrations compared to other locations, measuring 1.8-3.1 mg/kg. Some of the rural tributaries of Cashmere Stream had much higher total PAHs, for example 18 mg/kg in Ballantines Drain.

Depree & Ahrens (2005) reported PAH concentrations in the Heathcote River that were much lower than those measured in the Avon River and its tributaries. In the Avon catchment, total PAH concentrations were between ~50 and 100 mg/kg in St Albans Stream, Dudley Creek and the section of the Avon River / Ōtākaro downstream of these tributaries, whereas the concentrations were less than 20 mg/kg at the Heathcote River site. A follow-up series of studies of the roading material, footpaths and roadside soils, particularly around the central northern suburbs of St Albans and Richmond, identified PAHs at concentrations up to 12,000 mg/kg (Depree 2006; Depree & Olsen 2005a, 2005b). The elevated PAH concentrations were attributed to the use of coal tar, a by-product from gas works, which was used in roading construction up until the 1970s. In locations where coal tar was used in road sealing, the concentrations of PAHs in runoff particulate material ranged from ~20 to 200 mg/kg of PAHs, substantially higher than concentrations in the absence of coal tar.

2.3 Stormwater and Water Quality Studies in the Catchment

Water quality is monitored monthly at 14 sites in the Heathcote River catchment and at one site in the City Outfall Drain / Linwood Canal by Christchurch City Council (Margetts & Marshall 2015). The monitoring includes dissolved copper, lead and zinc, as well as physico-chemical parameters, nutrients and bacteria. The most recent monitoring report summarises the 2014 data and shows that dissolved zinc concentrations were highest in Haytons and Curletts Road Drains compared to other sites in the catchment (Figure 2-2), and when compared to sites in the other monitored rivers. Zinc concentrations at Catherine Street in the lower Heathcote River were lower than this, but higher than other sites in the catchment. Zinc concentrations in the City Outfall Drain / Linwood Canal were lower than these sites but still higher than most other sites in the Heathcote River and in other monitored streams. Cashmere Stream has lower metal concentrations than the main Heathcote River and generally has much better water quality than the main river (Margetts & Marshall 2015; McMurtrie & James 2013). Zinc concentrations in Curletts Road Drain have decreased significantly (by 146%) since monitoring began in 2007, though the reasons for this are not clear. Within the main stem, the highest concentrations were measured at Rose Street, in the upper reaches (downstream of Haytons and Curletts Drain but upstream of the confluence with Cashmere Stream) and at Catherine Street, in the lower, tidal reaches.

Dissolved copper was regularly below the detection limit, except in Haytons Drain and Curletts Road Drain, and in the lower reaches of the main river. The highest concentrations were measured in Curletts Road Drain, with a median of 0.006 mg/L (Margetts & Marshall 2015). This was the highest copper concentration measured at any of the stream sites sampled in the monitoring programme, including sites in the City Outfall Drain, Avon, Halswell, Styx and Ōtukaikino Rivers. The source of this copper was not identified, but as with the zinc, the concentrations have significantly decreased over the monitoring period (38% decrease for copper). Dissolved lead was below detection at almost all sites in the Heathcote River and in the City Outfall Drain, on almost all sampling occasions, with the exception of the most downstream Heathcote River site of Ferrymead Bridge where it was detected several times, with a maximum of 0.0047 mg/L.

The water quality monitoring results indicate similar issues to the sediment quality surveys described above: that is, highest concentrations of metals in the Haytons and Curletts Road Drains, and in the lower reaches of the Heathcote River. Although the City Outfall Drain / Linwood Canal had lower metal concentrations than these sites, it was ranked as the waterway with the worst water quality overall, due to high suspended solids, turbidity and dissolved reactive phosphorus and low dissolved oxygen (Margetts & Marshall 2015).

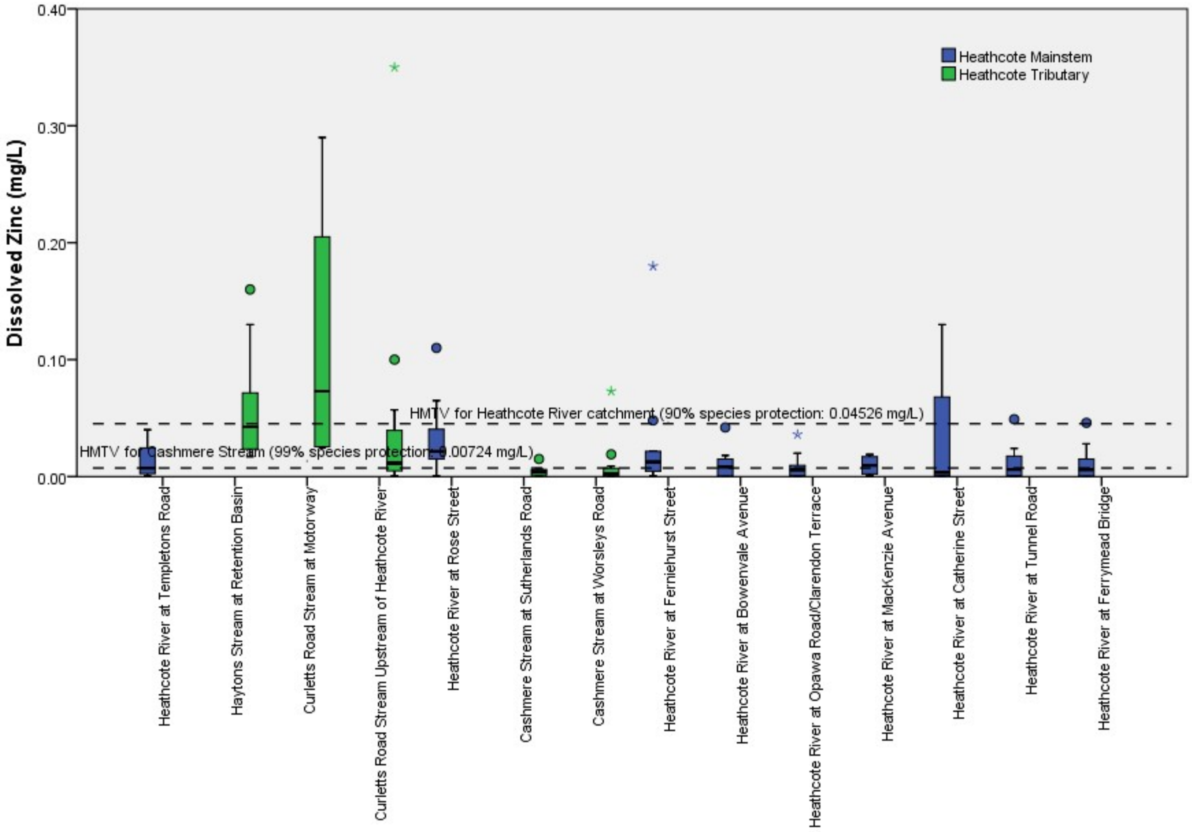

Figure 2-2: Dissolved zinc concentrations in the Heathcote River catchment from January to December 2014. Figure from Margetts and Marshall (2015).

3 Methods Used to Assess Sediment Quality

3.1 Sampling Sites

Eighteen sites were proposed by CCC for the 2015 instream sediment quality survey in the Heathcote River catchment, including two sites outside the catchment in the City Outfall Drain and Estuary Drain. The sites were selected to coincide with long-term aquatic ecology, water quality or sediment monitoring sites; South-West SMP aquatic ecology monitoring sites; and previous surveys of fauna and flora. The full list of proposed sites including map references are tabulated in Appendix A. Three of the proposed sites were not sampled during this survey due to either lack of water (site 3 in the upper Heathcote River, site 11 in Jacksons Creek), or access (site 16 in the lower tidal section of the Heathcote River). Details of the 15 sites sampled are given in Table 3-1.

Table 3-1: Survey site locations for the 2015 instream sediment quality survey.

Site No.	Site Name	Reasoning	Last sediment surveys
1	Cashmere Stream: upstream of Sutherlands Road	Long-term & South-West SMP aquatic ecology site; long-term water quality site; nearby to 1988 sediment quality site	Robb (1988)
2	Cashmere Stream: Penruddock Rise	Long-term & South-West SMP aquatic ecology site; 1988 sediment quality site	Robb (1988)
4	Heathcote River: Canterbury Park/ Showgrounds	Long-term & South-West SMP aquatic ecology site; long-term sediment quality site	Robb (1988) & Kingett Mitchell (2005)
5	Heathcote River: d/s of Spreydon Domain	Long-term & South-West SMP aquatic ecology site; nearby to 1988 sediment quality site	Robb (1988)
6	Heathcote River: Rose Street/ Centennial Park	Long-term & South-West SMP aquatic ecology site; long-term water quality site; nearby long-term sediment quality site	Robb (1988) & Kingett Mitchell (2005)
7	Heathcote River: d/s of Barrington Street	Long-term aquatic ecology site; nearby to 1988 sediment quality site	Robb (1988)
8	Cashmere Brook: Ashgrove Terrace	Long-term aquatic ecology site	Sediment not previously sampled
9	Heathcote River: downstream of Colombo St	Long-term aquatic ecology site; nearby to 1988 sediment quality site	Robb (1988)
10	Heathcote River: d/s of Tennyson Street	Long-term aquatic ecology site; nearby to 1988 sediment quality site	Robb (1988)
12	Heathcote River: Aynsley Terrace	Previous fish survey; nearby to 1988 sediment quality site	Robb (1988)
13	Heathcote River: Catherine Street (tidal site)	Previous biological and botanical survey; long-term water quality site;1988 sediment quality site	Robb (1988)
14	Heathcote River: Tunnel Road (tidal site)	Previous biological and botanical survey; long-term water quality site; 1988 sediment quality site	Robb (1988)
15	Steamwharf Stream	Previous inanga spawning reach severely impacted by sedimentation from earthquakes	Sediment not previously sampled
17	Estuary Drain: Bexley Park [1]	Previous fish survey	Sediment not previously sampled
18	City Outfall Drain: Dyers Road/Linwood Avenue [2]	Previous botanical survey; 1988 sediment quality site	Robb (1988)

Note: 1 This site is within the Estuary + Coastal SMP area. 2. This site is within the Avon River / Ōtākaro SMP area.

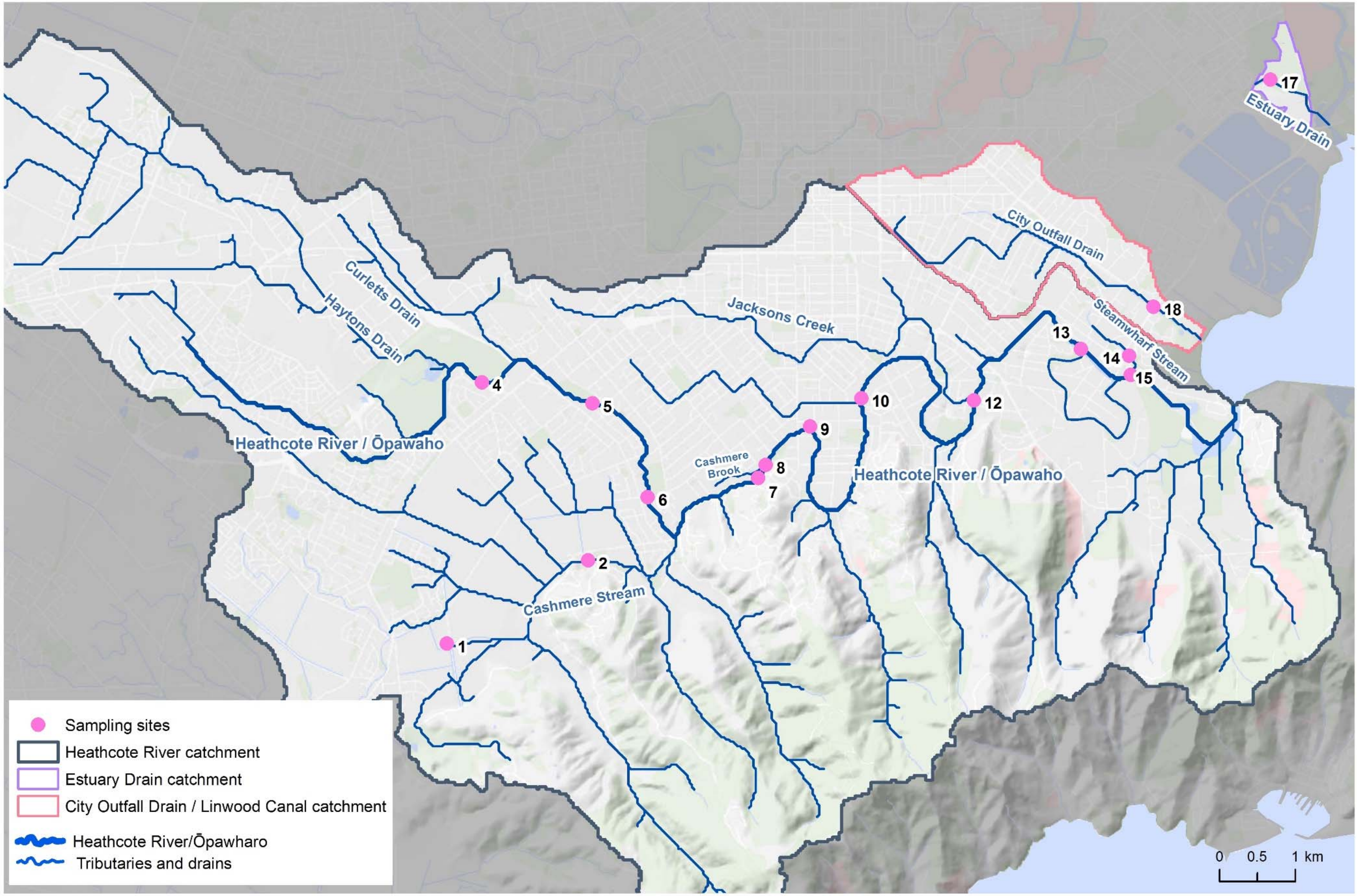

Figure 3-1: Location of sampling sites in the Heathcote River / Ōpawharo, City Outfall Drain / Linwood Canal and Estuary Drain. See Table 3-1 for site names.

3.2 Sampling Methods

Sediments were collected from multiple locations at each site, within a reach of approximately 20 m. The surface sediment (top 3 cm or so) were collected by scraping along the surface of the sediment using a sampling container attached to a mighty gripper. Water was drained off the collected samples either directly from the jars or using a 500 µm mesh sieve. The samples were then transferred to laboratory supplied jars, and stored on ice in a chilli bin until delivery to the laboratory. Single samples were collected at each site and no replicates were collected for this study.

3.3 Analytical Methods

All analyses were conducted by Hill Laboratories in Hamilton. The analyses undertaken are summarised in Table 3-2. Hill Laboratories are IANZ accredited for these tests with the exception of TOC and the grain size analysis.

Table 3-2: Analytes and their analytical methods.

Analytes	Analytical method	Reference
Grain size analysis	Wet sieving, gravimetric analysis	
Total recoverable arsenic, cadmium, copper, chromium, nickel, lead, zinc	Air dried at 35°C and sieved, <2mm fraction. Nitric / hydrochloric acid digestion, ICP-MS, trace level.	US EPA 200.2
Total organic carbon (TOC)	Air dried at 35°C and sieved, <2mm fraction. Acid pretreatment to remove carbonates if present, neutralisation, Elementar Combustion Analyser.	
Total phosphorus (TP)	Air dried at 35°C and sieved, <2mm fraction. Nitric / hydrochloric acid digestion, ICP-MS, screen level.	US EPA 200.2
Polycyclic aromatic hydrocarbons (PAHs)	Air dried at 35°C and sieved, <2mm fraction. Dried at 103°C for 4-22hr, sonication extraction, SPE cleanup, GC-MS SIM analysis.	US EPA 8270
Semi-volatile organic compounds (SVOCs)	Air dried at 35°C and sieved, <2mm fraction. Sonication extraction, SPE cleanup, GC-MS full scan analysis.	US EPA 3540, 3550, 3640 & 8270

3.4 Data Analysis Methods

Statistical comparisons between sites in this sediment survey were not possible as single samples were analysed at each location. Comparisons between sites are made generally, using tables and with maps produced in ArcMap 10. The total PAHs presented in this report represent the sum of the 16 PAHs analysed, which are the PAHs listed as priority pollutants by the USEPA (1982). Where one or more compounds was below the detection limit, half the detection limit was used in the calculation. This is consistent with the approach used in other Christchurch sediment surveys.

Correlations between individual contaminants and between contaminants and mud content were assessed with Pearson's correlation coefficients, which measure the strength and direction of the relationships between each of the two variables. These correlations were undertaken using R (Version 3.1.1). A correlation coefficient greater than 0.7 is considered strong, whereas as a coefficient less than 0.7 is considered weak.

Multivariate analyses of the sediment quality data were undertaken using the statistical package Primer 6 (Version 6.1.5). The correlated variables arsenic, cadmium, chromium and copper were excluded and the analysis was undertaken on mud, TOC, phosphorus, lead, nickel, zinc and total

PAHs. Data were first Log+1 transformed, then normalised and a resemblance matrix was constructed based on Euclidean distances. Non-metric Multi-Dimensional Scaling (NMDS) ordination along with hierarchical cluster analysis was used to investigate overall differences in sediment quality between sites and display site clusters.

Statistical differences between groups based on the catchment landuse were tested using a Kruskal-Wallis rank sum test for the individual contaminant concentrations. This tests for differences in the median of three or more groups. Any significant differences in the median concentrations were further assessed using Wilcoxon rank sum tests to compare between two groups. The overall sediment quality was also compared using the ANOSIM multivariate test (Primer 6) to compare between landuse groups. The ANOSIM was undertaken on a resemblance matrix constructed based on Euclidean distances for transformed and normalised values of mud, TOC, phosphorus, lead, nickel, zinc and total PAHs.

Box plots were used to graphically compare differences in contaminant concentrations in this study with other studies in Christchurch and elsewhere (Section 7). Box plots were produced in R (Version 2.15.0). A line in the middle of the box indicates the median concentration. Top and bottom bounds of the box indicate the 25th (lower) and 75th (upper) percentiles. Whiskers extend to the nearest data points that are within 1.5 times the inter-quartile range (IQR) of the median value. Data points lying outside this range (outliers) are shown as individual points. Wilcoxon rank sum tests were used to test for significant differences between two groups of studies.

Differences in contaminant concentrations between surveys were also compared using multivariate techniques. Only the more recent studies in the Styx and Avon catchments were included as these also measured arsenic, cadmium, chromium and nickel in addition to copper, lead, zinc and PAHs. Correlations between the variables were assessed with Pearson's correlation coefficients, and cadmium was excluded from the analysis due to correlation with copper (correlation coefficient 0.86). The data were then log(x+1) transformed, all variables normalised and a resemblance matrix was constructed based on Euclidean distances. Nonmetric multi-dimensional scaling (NMDS) ordination was used to most effectively display site clusters, followed by Principal Component Analysis (PCA) to demonstrate which variables were most important in differentiating the sites. These variables are plotted as vectors on the PCA plot and the direction of the lines shows the direction of increasing concentration.

4 Current State of Sediment Quality

4.1 Sediment Quality in the Catchment

The concentrations of metals and selected other contaminants in the sediment samples are tabulated in Table 4-1. The full results, including grain size analysis of collected samples and concentrations of individual PAH compounds are included in Appendix B.

The coloured bars in Table 4-1 indicate the relative concentration of each measurement, to enable rapid comparison between sites. Large variations in the size of the data bars indicate large variation in the concentrations between samples, for example, for lead, concentrations range from 4.2 to 136 mg/kg (a 30-fold variation); whereas the bars for nickel are all of similar size and concentrations range from 7 to 13 mg/kg (less than 2-fold variation). The results for tributaries are listed first followed by sites in the main stem of the Heathcote River, from upstream to downstream.

Table 4-1 shows a number of apparent outliers:

- The zinc concentration in the sample from City Outfall Drain (450 mg/kg) was approximately double most measurements in the Heathcote River catchment. Copper and lead were also higher in this location relative to other sites.
- The arsenic concentration in the Estuary Drain (Site 17) was substantially higher (13 mg/kg) than at all other sites (typically 2-4 mg/kg). The phosphorus concentration was also highest at this site compared to others. The high concentration of arsenic may be due to a discharge of groundwater into the stream, and is discussed further below.
- Total PAHs measured 614 mg/kg in the Heathcote River downstream of Colombo Street, much higher than the typical concentrations in the catchment (<10 mg/kg). This is likely to be due to a fragment of coal tar particulates within the sample (discussed further in Section 5.5).

Zinc concentrations were also high (relative to other sites) at two sites in the lower Heathcote River (Sites 12 and 13). While other metals including copper and lead were also relatively high at these two sites, the highest concentrations of copper and lead were measured in the upper and mid-reaches of the river. Copper was highest at Site 5 (39 mg/kg), near Spreydon Domain (downstream of Curletts Road Drain) and also relatively high at Site 6, Centennial Park, 1.6 km downstream (30 mg/kg). Relatively high cadmium concentrations were also measured in samples from these two sites (0.32 mg/kg). Lead concentrations were highest at Centennial Park (Site 6) recorded (136 mg/kg) and Barrington Street (Site 7, also 136 mg/kg), and moderate at Site 5 (24 mg/kg). Metal concentrations appear to be lower in the Heathcote tributaries of Cashmere Stream (both sites), Cashmere Brook and Steamwharf Stream; and in the Estuary Drain.

Sediment concentrations of metals/metalloids were generally in the order cadmium < arsenic < nickel < copper < chromium < lead < zinc. However there were a few sites where this differed, such as those sites mentioned above.

The elevated arsenic concentration in the Estuary Drain may have been caused by a dewatering discharge into the stream during construction of a groundwater well in October 2013. Groundwater can contain elevated arsenic concentrations from the leaching of old marine sediments and weathered rocks, particularly when groundwater is anaerobic. The dewatering discharge contained very high concentrations of iron, as shown by iron flocs forming in the stream, and high iron

Table 4-1: TOC, phosphorus, metals/metalloids, PAHs and mud concentrations in sediment samples collected for this study. All data mg/kg except mud and TOC. Sites ordered from upstream to downstream, with tributaries first.

Site Name	Site No.	Mud (%)	TOC (%)	Phosphorus	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Total PAHs
Cashmere Stream - Sutherlands	1	7	0.4	310	0.6	0.06	8	3	4.2	7	30	0.09
Cashmere Stream - Penruddock	2	38	0.6	480	4.0	0.05	12	6	12	10	52	0.46
Cashmere Brook	8	4	0.9	430	4.0	0.10	11	9	31	9	145	28
Steamwharf Stream	15	11	0.5	390	3.0	0.06	14	6	16	9	93	1.8
Heathcote River - Showgrounds	4	6	1.6	410	2.2	0.19	9	6	12	6	130	0.73
Heathcote River - Spreydon Domain	5	5	1.1	570	3.3	0.32	13	39	24	9	220	3.0
Heathcote River - Centennial	6	7	0.7	500	2.8	0.32	11	30	136	8	183	7.0
Heathcote River - Barrington	7	7	0.8	350	2.2	0.16	11	9	136	8	148	8.2
Heathcote River - Colombo St	9	9	2.9	600	4.2	0.22	12	18	36	9	230	614
Heathcote River - Tennyson St	10	23	2.0	370	2.9	0.15	10	14	21	8	163	6.1
Heathcote River - Aynsley	12	68	2.9	570	6.7	0.39	17	30	45	11	340	8.1
Heathcote River - Catherine (tidal)	13	41	2.5	520	4.6	0.30	22	24	64	12	300	77
Heathcote River - Tunnel (tidal)	14	50	1.6	540	4.4	0.25	25	19	29	12	183	9.2
Estuary Drain	17	15	0.9	890	13.0	0.10	14	10	30	10	165	3.1
City Outfall Drain / Linwood Canal	18	42	1.7	630	4.0	0.20	21	26	57	13	450	3.7

concentrations in groundwater are also often associated with higher arsenic concentrations. As there were no measurements of sediment quality in the Estuary Drain prior to this discharge, or of arsenic in the discharge itself, the groundwater discharge cannot be confirmed as the source.

SVOCs were assessed in all collected samples (Table 4-2) and at least one compound (excluding PAHs) was detected in 10 out of 15 samples. Three types of phthalates were detected in samples. Phthalates are plasticisers and can be expected to be found in urban stream sediments which may have degrading plastic rubbish within them. Carbazole and dibenzofuran were also detected in three samples. These compounds are released into the air during combustion of wood, coal and petroleum products and can be transported from the air to waterways during rain events. There were no SVOCs (excluding the PAHs) detected in samples from Cashmere Stream, Cashmere Brook Steamwharf Stream and the Estuary Drain.

Table 4-2: Semi-volatile organic compounds (excluding PAHs) detected in the sediment samples collected for this study. All data mg/kg. Detected values in bold for clarity. Sites ordered from upstream to downstream, with tributaries first.

Site No.	Site	Bis (2-ethylhexyl) phthalate	Butyl-benzyl phthalate	Di-n-butyl phthalate	Carbazole	Dibenzofuran
1	Cashmere Stream - Sutherlands	< 0.6	< 0.3	< 0.3	< 0.15	< 0.15
2	Cashmere Stream - Penruddock	< 0.7	< 0.4	< 0.4	< 0.17	< 0.17
8	Cashmere Brook	< 0.7	< 0.4	< 0.4	**0.23**	< 0.16
15	Steamwharf Stream	< 0.6	< 0.3	< 0.3	< 0.14	< 0.14
4	Heathcote River - Showgrounds	**2.5**	< 0.7	**2.1**	< 0.4	< 0.4
5	Heathcote River - Spreydon Domain	< 0.6	< 0.3	< 0.3	< 0.14	< 0.14
6	Heathcote River - Centennial	**0.6**	< 0.3	< 0.3	< 0.15	< 0.15
7	Heathcote River - Barrington	< 0.7	< 0.4	**9.4**	< 0.17	< 0.17
9	Heathcote River - Colombo St	**0.8**	< 0.4	< 0.4	**4.5**	**1.86**
10	Heathcote River - Tennyson St	**1.2**	< 0.4	< 0.4	< 0.18	< 0.18
12	Heathcote River - Aynsley	**2.7**	< 0.5	< 0.5	< 0.3	< 0.3
13	Heathcote River - Catherine (tidal)	**3.6**	< 0.5	< 0.5	**0.3**	**2.1**
14	Heathcote River - Tunnel (tidal)	**0.8**	< 0.4	< 0.4	< 0.18	**0.18**
17	Estuary Drain	< 0.7	< 0.4	< 0.4	< 0.17	< 0.17
18	City Outfall Drain / Linwood Canal	**5.3**	**0.5**	< 0.4	< 0.17	< 0.17

4.2 Geographic Analysis of Sediment Quality in the Catchment

The results are also shown in relation to their location within the catchment in Figures 5-1 to 5-5. The particle size distribution of the samples collected is shown in pie charts indicating the amount of gravel, sand, and mud in the samples (Figure 4-1). This shows a relatively high proportion of fine sand and mud in samples from the lower reaches of the Heathcote River and in the City Outfall Drain. The Estuary Drain also had a high proportion of fine sand (78%), though a somewhat lower proportion of mud (15%) compared to the other tidal sites (41-50%). Samples from the upper and mid Heathcote

River had higher proportions of gravels, coarse sand and medium sand. Samples from Cashmere Stream also had very high proportions of fine sand and mud, with less than 5% gravels and coarse sand. This fine sediment has been attributed to residential development in the hill-side suburbs, when large areas of soil were exposed, resulting in substantial erosion and transport of fine sediments into Cashmere Stream (McMurtrie & James, 2013).

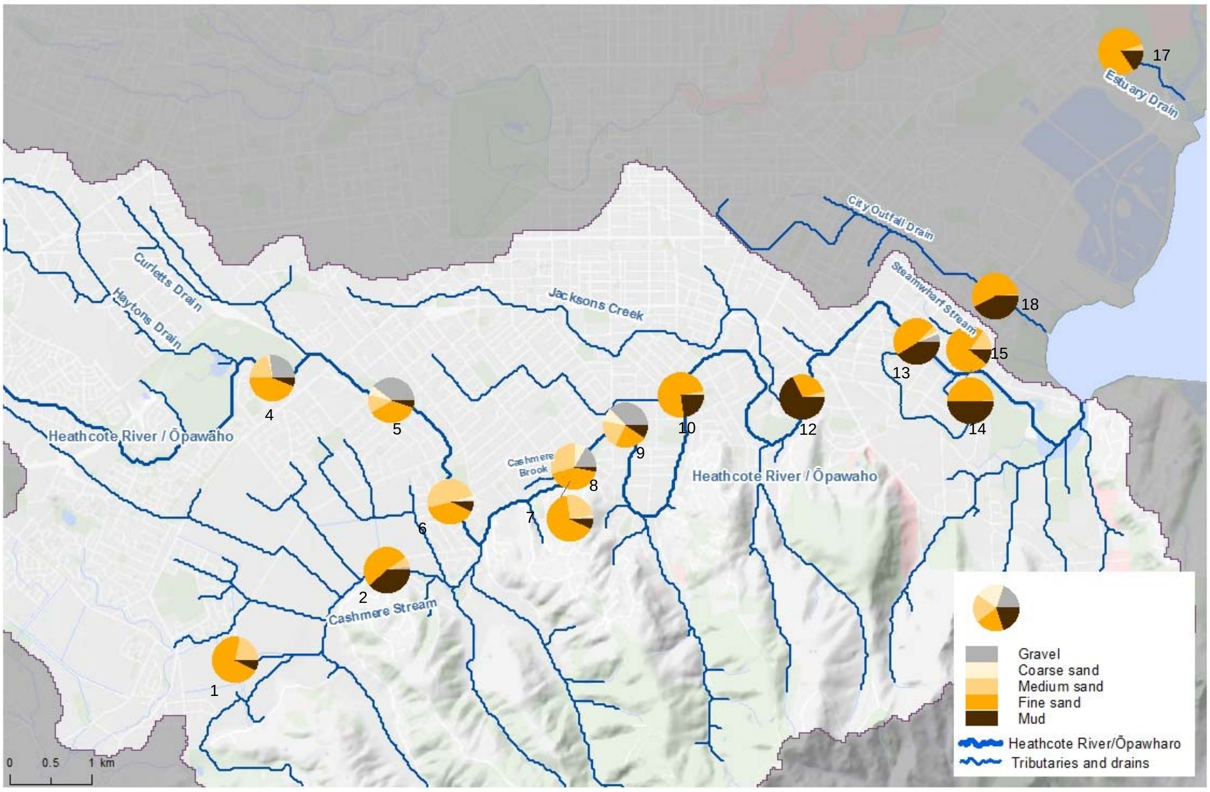

Figure 4-1: Distribution of particle sizes in samples collected from each site in the Heathcote River / Ōpawharo, City Outfall Drain / Linwood Canal and Estuary Drain catchments.

The highest concentrations of lead, copper, cadmium and zinc were measured at sites in the Heathcote River downstream of Curletts Road Drain, and in the lower and tidal reaches; and in the City Outfall Drain (Figure 4-2). As mentioned previously, these metals were at much lower concentrations in Cashmere Stream, Cashmere Brook, the most upstream Heathcote River site and Steamwharf Stream. The Estuary Drain also had lower concentrations of these metals compared to the Heathcote River.

Arsenic, nickel and chromium concentrations at each site are shown in Figure 4-3. The concentrations of these metals (and metalloid) were more similar throughout the sites sampled but with higher concentrations in the downstream sites of the Heathcote River. . The highest concentrations of nickel and chromium were found in the lowest reaches of the Heathcote River and may be partly due to the texture of these samples, which had a much greater proportion of mud compared to upstream sites (see Section 5.1 for further information on the relationship between metals and sediment texture). Arsenic showed a similar pattern, with a few exceptions: highest concentrations in the Estuary Drain and higher concentrations in lower Cashmere Stream (relative to metal concentrations).

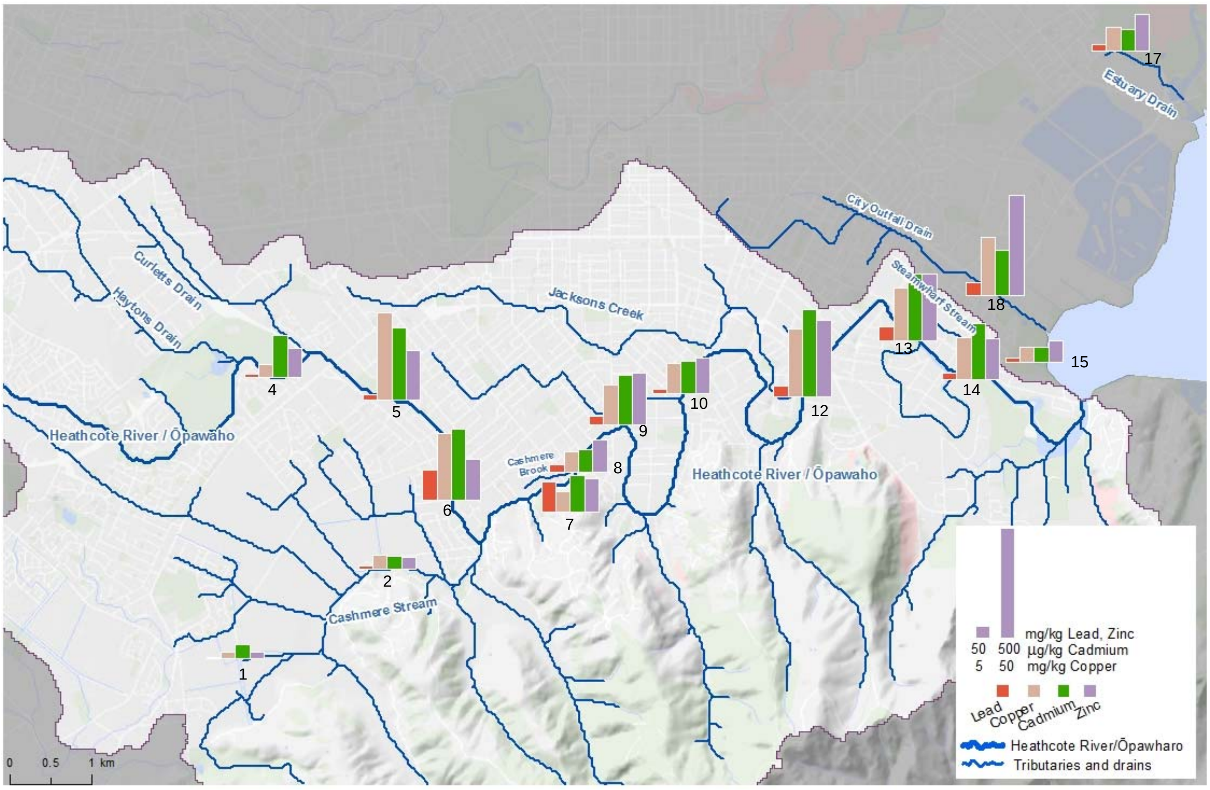

Figure 4-2: Lead, copper, cadmium and zinc at each site in the Heathcote River / Ōpawharo, City Outfall Drain / Linwood Canal and Estuary Drain catchments. Note different scales and units for copper and cadmium, scaled to allow visibility on this map.

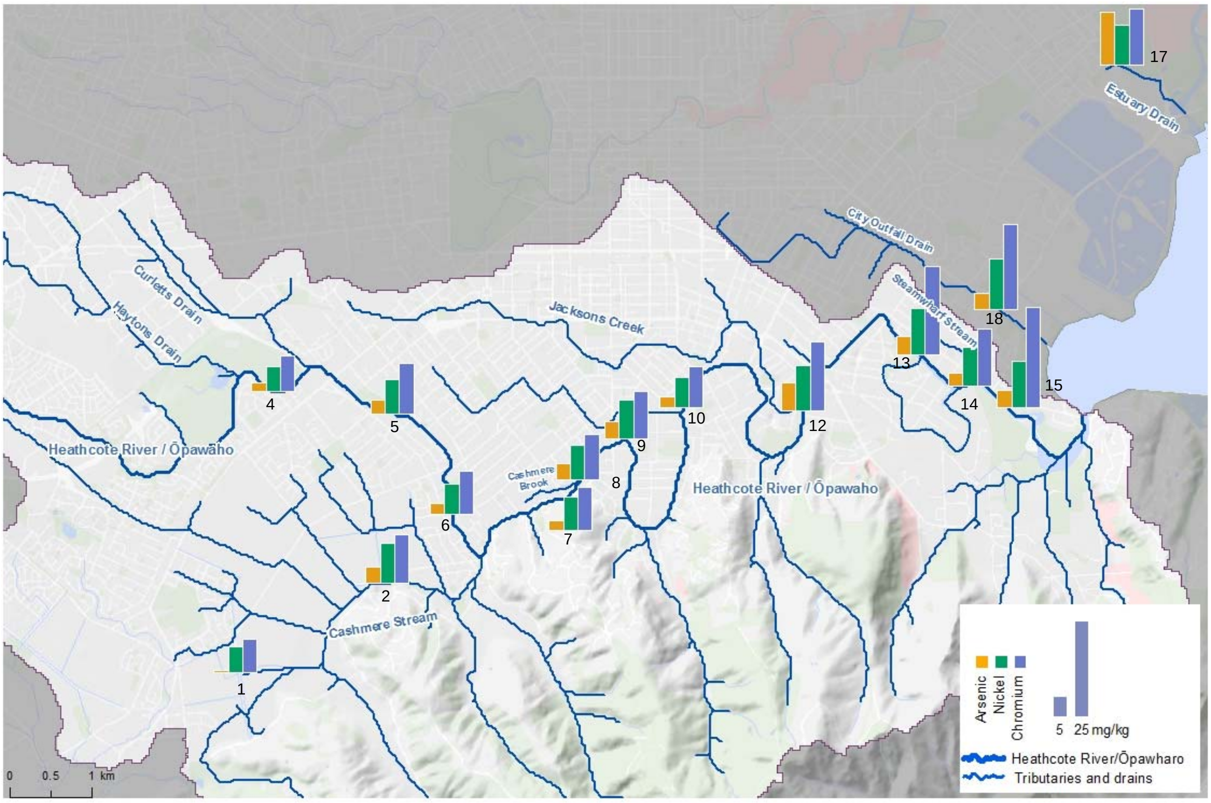

Figure 4-3: Arsenic, nickel and chromium at each site in the Heathcote River / Ōpawharo, City Outfall Drain / Linwood Canal and Estuary Drain catchments.

Total PAHs at each site are presented in Figure 4-4 and indicate a wide variation in concentrations across the sites surveyed. Like other parameters, total PAH concentrations were low in the Cashmere Stream and upper Heathcote River sites, and in Steamwharf Stream. PAHs were at moderate concentrations in Cashmere Brook compared to other sites in the catchment. There were two sites with much higher concentrations of PAHs than all others: Site 9 in Heathcote River, downstream of Colombo Street (614 mg/kg) and Site 13 in the lower section of the Heathcote River (77 mg/kg). Probable sources of elevated PAHs in stream sediments are discussed in Section 5.5.

Sediment TOC and phosphorus concentrations are presented in Figure 4-5 and generally show higher TOC in the lower, tidal reaches of the Heathcote River and in the City Outfall Drain. Phosphorus concentrations were fairly similar throughout the catchment and lower than in the sample collected from the Estuary Drain, which was comparatively elevated.

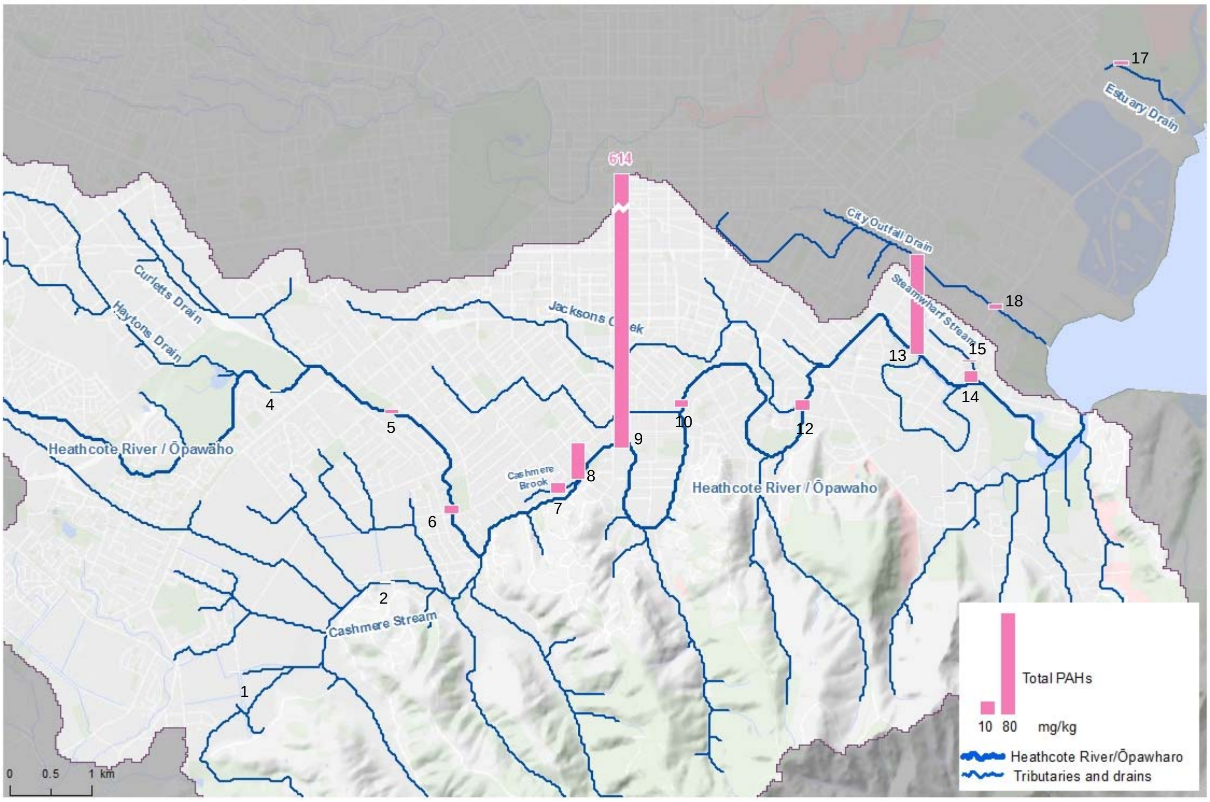

Figure 4-4: Total PAHs at each site in the Heathcote River / Ōpawharo, City Outfall Drain / Linwood Canal and Estuary Drain catchments. Note break in bar for Site 9 where sample measured 614 mg/kg. Concentrations in Cashmere Stream, and Site 4 are too low to be visible on the map.

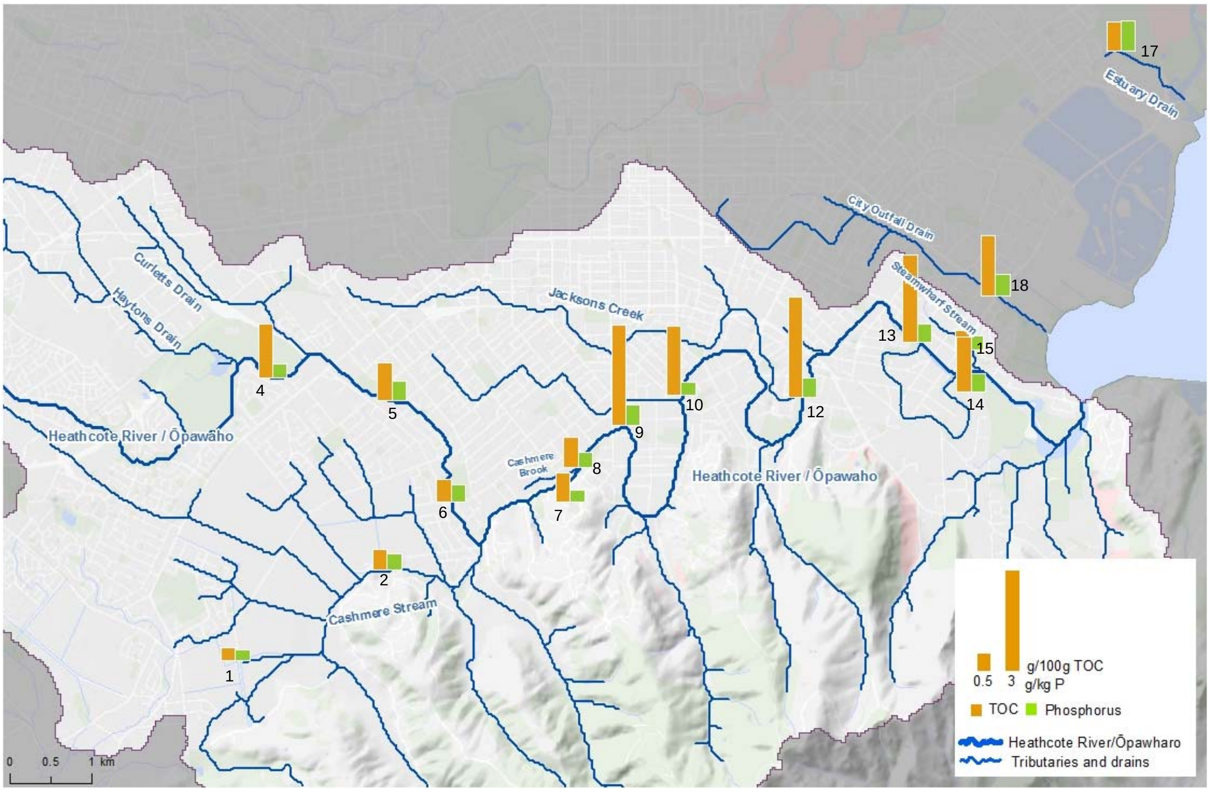

Figure 4-5: TOC and phosphorus concentrations at each site in the Heathcote River / Ōpawharo, City Outfall Drain / Linwood Canal and Estuary Drain catchments. Note units for TOC and phosphorus differ to ensure both are visible in this map.

4.3 Multivariate Analyses of Sediment Quality

The data presented in Table 4-1 suggest that several of the metals are correlated. Correlations between contaminants can indicate common sources, which can assist stormwater managers in their catchment planning. If sources are the same, stormwater mitigation methods may be applied to reduce inputs of several contaminants at once.

Correlations between different contaminants in the sediment samples are examined in Figure 4-6 below. The top right of the plot shows scatter plots for each pair of variables, as indicated at the left hand end of the row of plots and bottom of the column of plots. The bottom left of the plot shows correlation coefficients, with a value close to 1 representing a strong positive correlation between the two variables indicated at the top of the column and the right hand end of the row. Pyrene is used as an indicator for PAHs, as all PAHs are very closely related, with the exception of naphthalene (where concentrations are below the detection limit in 4 out of 15 samples).

The results indicate that cadmium and copper are closely related, as are copper and zinc (correlation coefficient 0.9). Chromium and nickel are also closely correlated (correlation coefficient 0.9). Lead is not as strongly correlated with other metals, as there are two sites where lead is at high concentration relative to other contaminants, suggesting a specific source of this at these sites. Arsenic and phosphorus concentrations are highly correlated, though not to the same extent as the strongest relationships between metals (coefficient 0.8). Pyrene is not highly correlated with the other contaminants but does show some, albeit weaker, relationships with TOC, lead and zinc.

Overall the analysis suggests that the source (or sources) may be the same for cadmium, copper and zinc, and also for lead at most, but not all, sites. It also indicates that sources of chromium and nickel and linked, but that these sources are different from the other metals.

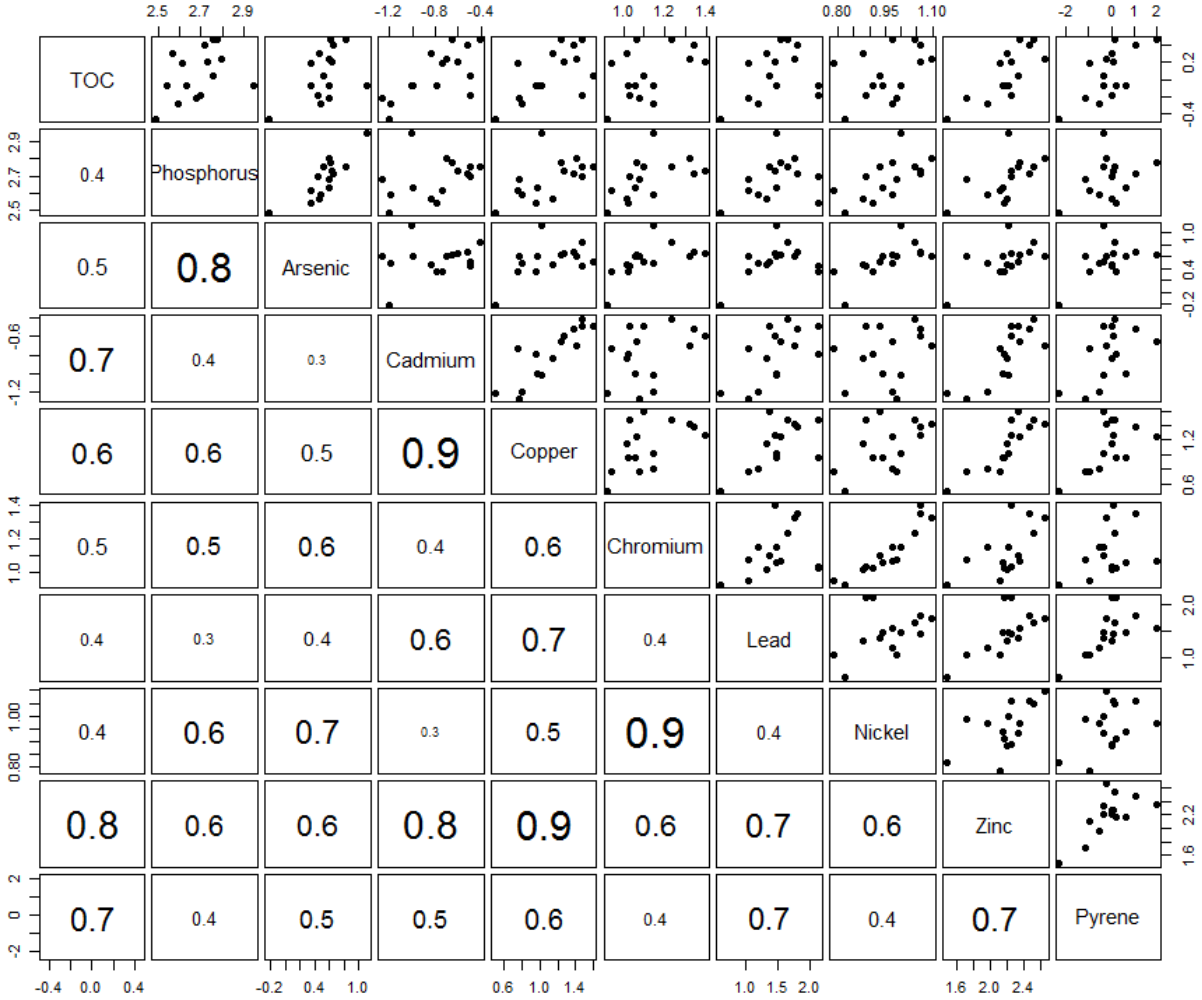

Figure 4-6: Correlations between contaminants in sediment samples. Note: Named variable at left of each row of scatter plots is y-axis. Named variable at bottom of each column of scatter plots is x-axis. All plotted on log10 scale. Correlation coefficients are presented in lower left side of matrix. Font size for correlation coefficient indicates strength of relationship.

Multivariate analyses of the sediment quality data were undertaken using the statistical package Primer 6 (Version 6.1.5). The correlated variables arsenic, cadmium, chromium and copper were excluded and the analysis was undertaken on mud, TOC, phosphorus, lead, nickel, zinc and total PAHs in one collective analysis. Concentrations (except mud) were first Log transformed, then normalised and a resemblance matrix was constructed based on Euclidean distances. Non-metric Multi-Dimensional Scaling (NMDS) ordination along with hierarchical cluster analysis was used to investigate overall differences in sediment quality between sites and display site clusters.

The NMDS plot for all sites (Figure 4-7) shows two main groups of sites (circled in blue) and two sites that plot separately from these clusters (site 1 and 17). The cluster in the middle of the NDMS plot includes several tributaries of the Heathcote River and sites in the upper and middle sections. The second cluster, to the right of the NDMS plot includes sites in the lower Heathcote River the City Outfall Drain and site 9 in the middle Heathcote. Site 9 is shown to be a little different from the other sites in this cluster when a shorter distance is used for the clustering. Figure 4-8 shows the NDMS plot with the plotting symbol size related to the concentration of various sediment contaminants. This shows that sites plotted towards the right side of the plot have higher zinc, and to some extent higher TOC; whereas sites towards the bottom right hand corner have higher PAHs. Site 1 is upstream in Cashmere Stream and had very low concentrations of contaminants. Site 9 is in the Heathcote River downstream of Colombo Street and differed from the other sites in that it had comparatively very high concentrations of PAHs. For the two main groups, the cluster to the right includes those sites that were higher in most metals, whereas the cluster to the left includes the sites with lower metals (see Table 4-1 for raw data).

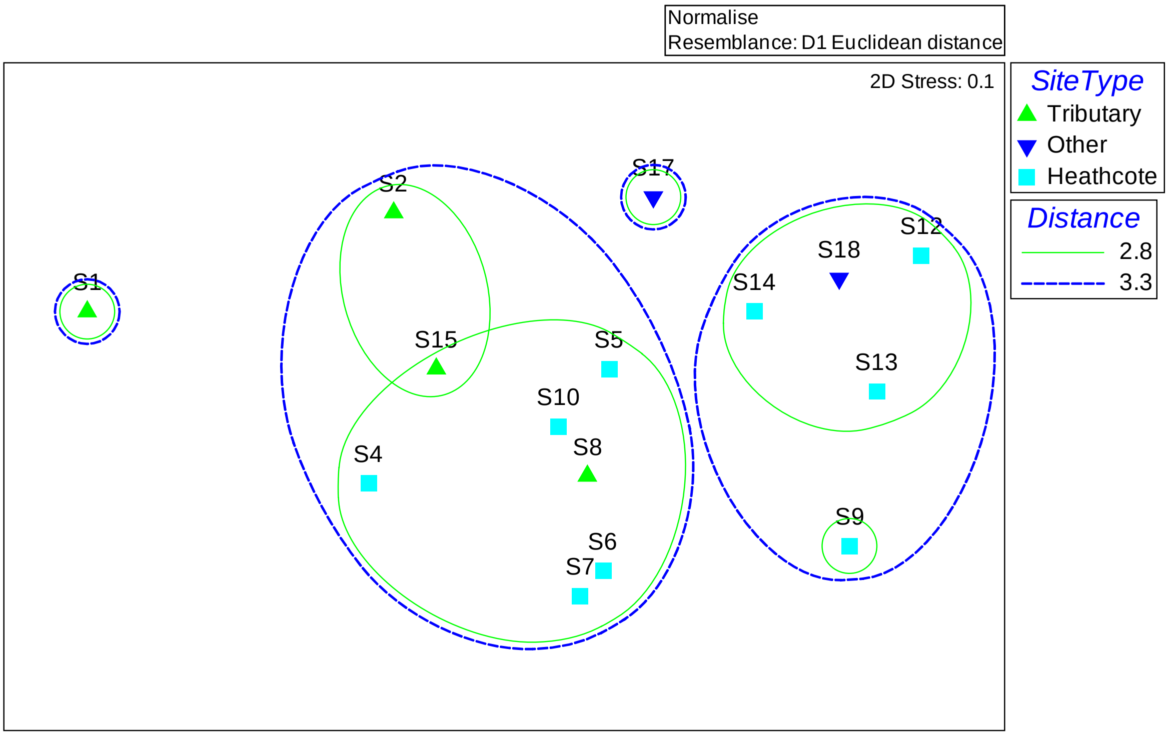

Figure 4-7: NMDS plot of sediment quality at the different sites.

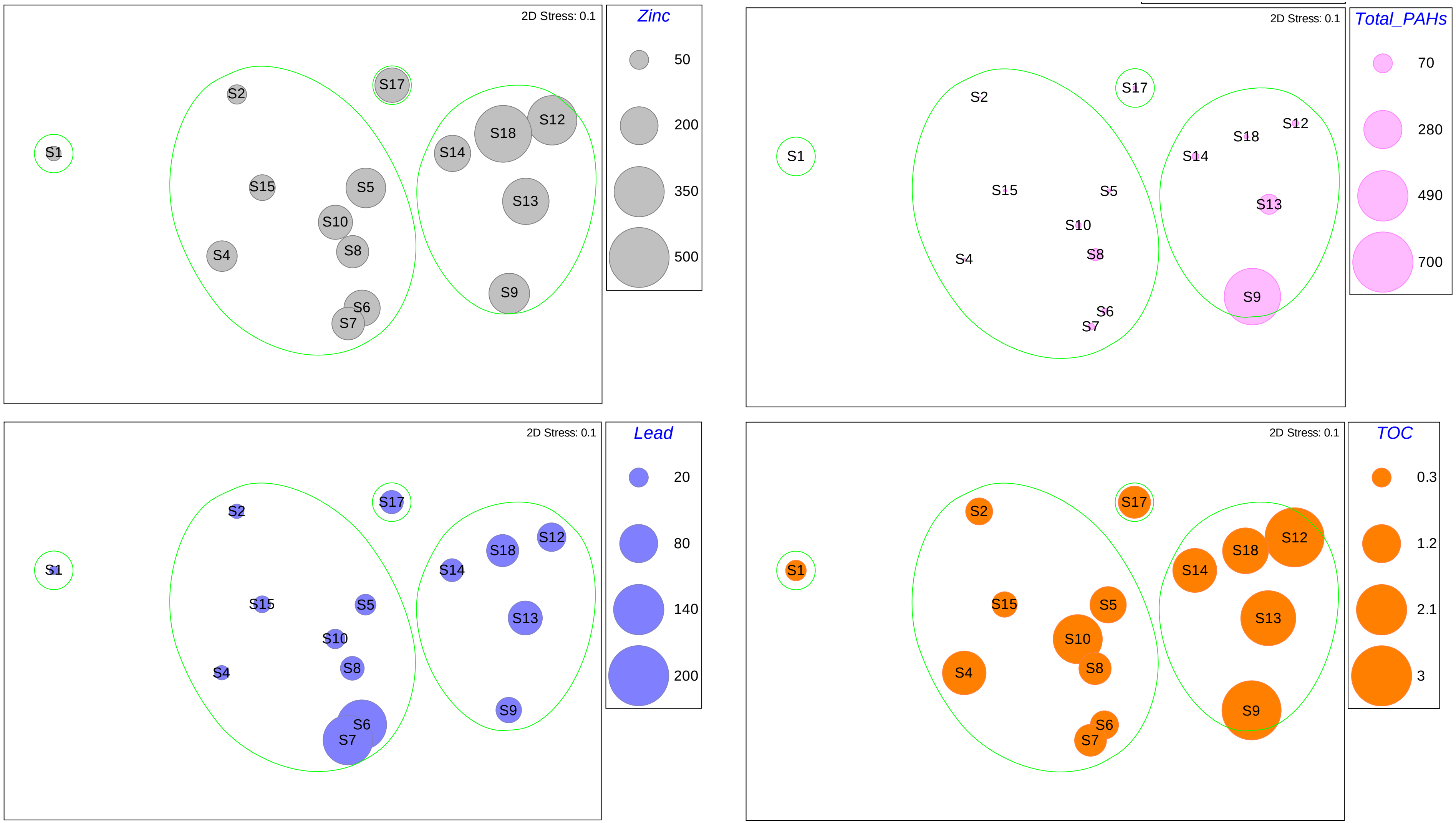

Figure 4-8: NMDS bubble plots of sediment quality at the sites in the Heathcote River catchment, with bubble size indicating concentration (mg/kg for zinc, lead and total PAHs, % for TOC) of specific contaminants.

The sediment contaminant concentrations were ranked from best (1) to worst (15) for each of the contaminants measured, including total PAHs and bis (2-ethylhexyl) phthalate (the most commonly detected SVOC) and an overall rank was calculated from the sum of each rank (Table 4-3). The highest ranked site was the furthest upstream site in Cashmere Stream (S1) which had the lowest concentrations of almost all contaminants. The site further downstream in Cashmere Stream was also highly ranked (3 out of 15). The furthest upstream site in the Heathcote River was ranked second overall, due to the low concentrations of metals at this site. Steamwharf Stream was ranked 4th overall.

The sites ranked 15th and 14th (worst and 2nd worst) differed by only 1 in the sum of ranks and so can almost be considered equal in ranking. These sites were in lower Heathcote River, in the region where the river becomes wider and slower. This is likely to be a depositional zone for sediments, including those generated in upper areas of the catchment. The City Outfall Drain was also in the bottom three of the sites sampled. The overall rankings are shown in Figure 4-9.

Table 4-3: Overall ranking of sediment quality at each site sampled. Based on ranking for each contaminant, then summing to provide overall rank. Rankings are colour coded from best to worst as follows: dark green (1-3); light green (4-6); yellow (7-9); orange (10-12); red (13-15).

Site	Site No.	TOC	Phos-phorus	Arse-nic	Cad-mium	Chro-mium	Cop-per	Lead	Nickel	Zinc	Total PAHs	DEHP	Overall rank
Cashmere Stream: Sutherlands	1	1	1	1	2	1	1	1	2	1	1	5=	**1**
Cashmere Stream: Penruddock	2	3	7	9	1	8	3	3	10	2	2	5=	**3**
Cashmere Brook	8	7	6	9	5	6	6	9	7	5	13	5=	**7**
Steamwharf Stream	15	2	4	6	3	11	4	4	9	3	4	5=	**4**
Heathcote River: Showgrounds	4	9	5	3	8	2	2	3	1	4	3	12	**2**
Heathcote River: Spreydon Domain	5	8	12	7	14	9	15	6	6	11	5	5=	**10**
Heathcote River: Centennial	6	4	8	4	14	5	14	15	4	10	9	5=	**8**
Heathcote River: Barrington	7	5	2	3	7	4	5	15	5	6	11	5=	**5**
Heathcote River: Colombo St	9	15	13	11	10	7	9	10	9	12	15	10=	**12=**
Heathcote River: Tennyson St	10	12	3	5	6	3	8	5	3	7	8	11	**6**
Heathcote River: Aynsley	12	15	12	14	15	12	14	11	12	14	10	13	**15**
Heathcote River: Catherine (tidal)	13	13	9	13	12	14	11	13	14	13	14	14	**14**
Heathcote River: Tunnel (tidal)	14	10	10	12	11	15	10	7	14	10	12	10=	**12=**
Estuary Drain	17	6	15	15	4	11	7	8	11	8	6	5=	**9**
City Outfall Drain / Linwood Canal	18	11	14	9	9	13	12	12	15	15	7	15	13

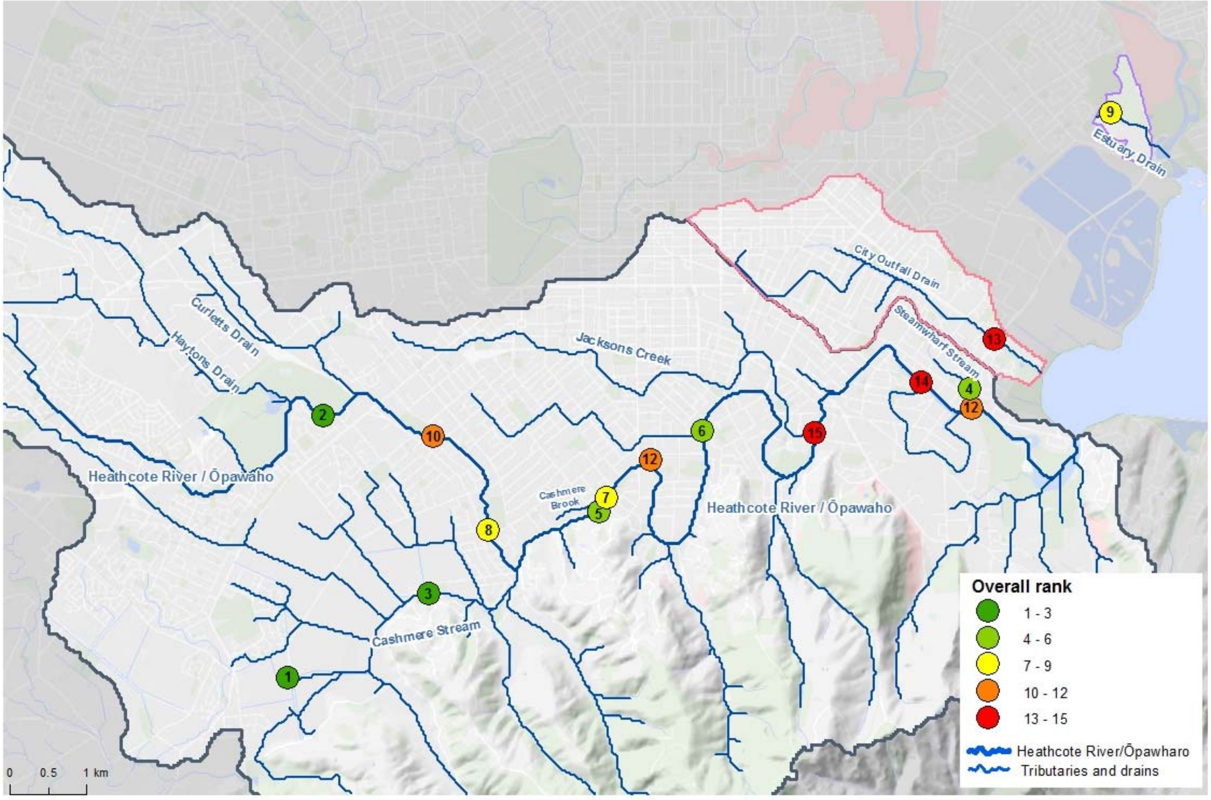

Figure 4-9: Overall ranking of sediment quality in the Heathcote River / Ōpawharo, City Outfall Drain / Linwood Canal and Estuary Drain.

4.4 Current State Compared to Guidelines

The concentrations of key contaminants are compared to ANZECC (2000) sediment quality guidelines in Table 4-4. Sites are shaded yellow where they exceed the ISQG-low and shaded orange where they exceed ISQG-high. Arsenic, cadmium, chromium and nickel are not included in the table as concentrations in all samples were well below sediment quality guidelines of 20, 1.5, 80 and 21 mg/kg respectively (see Table 4-1 for concentrations at each site). All samples were below the guidelines for copper and many were also below the guidelines for lead, zinc and total PAHs.

There were four samples which exceeded the ISQG-low for lead but none that exceeded the ISQG-high. Five samples exceeded the ISQG-low for zinc, of which one also exceeded the ISQG-high, at 450 mg/kg (Site 18). Six samples exceeded the current ISQG-low for total PAHs, of which one also exceeded the ISQG-high (sample from Site 9). New, slightly higher, trigger values for total PAHs have been proposed during the review and update of the ANZECC guidelines (Simpson et al. 2010): ISQG-low of 10 mg/kg; and ISQG-of 50 mg/kg, based on modelling of the toxicity of PAHs (Di Toro & McGrath 2000). Four samples exceed the proposed ISQG-low, though one of these only marginally (measuring 10.6 mg/kg). The sample from Site 9, downstream of Colombo Street, still exceeds the revised ISQG-high. The majority of the exceedances were within the main stem of the Heathcote River, rather than the tributaries, as seen in Figure 4-10.

Table 4-4: Comparison of major contaminant[a] concentrations in sediment to ANZECC sediment quality guidelines. All data mg/kg. Yellow shading indicates exceedance ISQG-low, orange ISQG-high.

Site No.	Site Name	Copper	Lead	Zinc	Sum PAHs [b,c]	Sum PAHs [b,d]
	ISQG-Low [c]	65	50	200	4	10
	ISQG-High [c]	270	220	410	45	50
1	Cashmere Stream - Sutherlands	3.1	4.2	30	0.3	0.3
2	Cashmere Stream - Penruddock	5.9	11.5	52	0.8	0.8
8	Cashmere Brook	9.2	31	145	32.5	32.5
15	Steamwharf Stream	6.3	15.6	93	3.4	3.4
4	Heathcote River - Showgrounds	5.7	11.5	130	0.5	0.5
5	Heathcote River - Spreydon Domain	39	24	220	2.7	2.7
6	Heathcote River - Centennial	30	136	183	10.6	10.6
7	Heathcote River - Barrington	9	136	148	9.8	9.8
9	Heathcote River - Colombo St	17.5	36	230	212	212
10	Heathcote River - Tennyson St	13.9	21	163	3.1	3.1
12	Heathcote River - Aynsley	30	45	340	2.8	2.8
13	Heathcote River - Catherine	24	64	300	30.9	30.9
14	Heathcote River - Tunnel	18.5	29	183	5.7	5.7
17	Estuary Drain	10.4	30	165	3.7	3.7
18	City Outfall Drain	26	57	450	2.1	2.1

Note: [a] Arsenic, cadmium, chromium and nickel are not included in the table as concentrations in all samples were well below sediment quality guidelines of 20, 1.5, 80 and 21 mg/kg respectively . [b] Sample concentrations normalised to 1% total organic carbon, as recommended in ANZECC (2000). [c] Guidelines from ANZECC (2000). [d] Proposed new guidelines for total PAHs from Simpson et al. (2013).

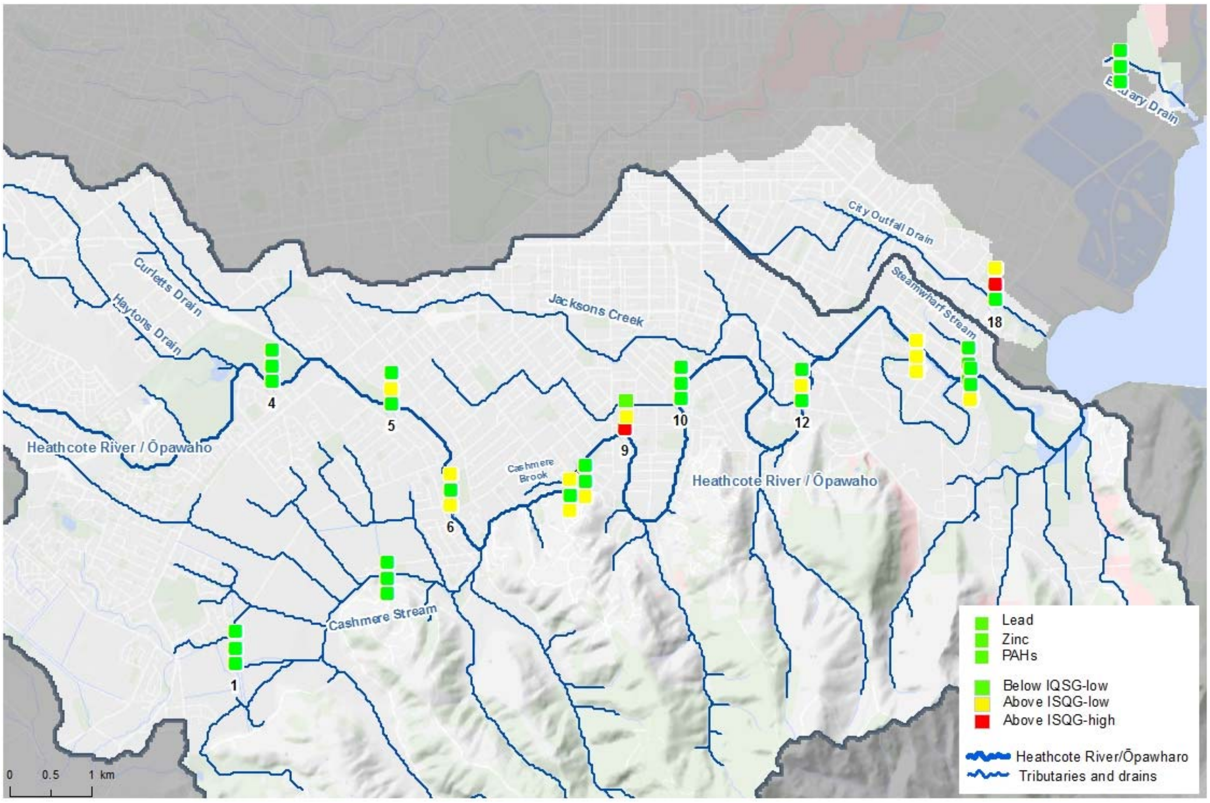

Figure 4-10: Comparison of lead, zinc and PAHs to ANZECC sediment quality guidelines. Sites numbered (see Table 3-1 for key). Boxes at each site from top to the bottom represent lead, zinc and PAHs. Traffic lights are green when below ISQG-low, yellow if above ISQG-low and red if above ISQG-high.

The comparison of sediment quality to trigger values (based on current trigger values for PAHs) is summarised in Table 4-5 and shows that at least one of the trigger values was exceeded at nearly two-thirds of the sites sampled. This does not necessarily imply that there will be adverse effects on biota, but should trigger further monitoring and investigations (ANZECC 2000).

Table 4-5: Summary of the exceedance of trigger values in the Heathcote River / Ōpawharo catchment, City Outfall Drain / Linwood Canal and Estuary Drain.

	Total number of sites (%)
No exceedance of any trigger value	6 (40%)
Exceeds 1 trigger value	4 (27%)
Exceeds 2 trigger values	4 (27%)
Exceeds 3 trigger values	1 (7%)
Exceeds 4 trigger values	0

The total PAH concentration at site 9 was very high and well in excess of the ANZECC ISQG-high. Toxicity testing on sediment samples with concentrations up to 72 mg/kg, due to the incorporation of coal tar fragments, have previously shown chronic effects on aquatic biota (Ahrens et al.; 2007). Based on this, the concentrations in the sample from downstream of Colombo Street can be expected to pose a risk to aquatic organisms.

5 What are the Main Influences on Heathcote Sediment Quality?

5.1 Sediment Grain Size

Metal contaminants are usually found at higher concentration in sediment samples with higher mud content, as the greater surface area of mud-sized particles increases adsorption. Consequently when comparing between sediment samples from different locations or different years, it is important to also compare the mud content, as higher metal concentrations at one site may be purely due to a higher proportion of fine particles. There was a wide range in mud content of the samples collected in this survey, from 3 to 68%. All metals showed a positive correlation with the proportion of mud in the sediment samples (Figure 5-1), however the relationship was weak for all but chromium and nickel as R-values were below 0.7 (see Section 3.4 for details of statistical analysis). This indicates that concentrations of metals, other than chromium and nickel, in the samples do not only reflect the proportion of mud in the samples, but are also influenced by additional site-specific factors, such as stormwater inputs. In contrast, any differences observed in concentrations of chromium and nickel between sites may be purely due to differences in the sediment grain size of each sample.

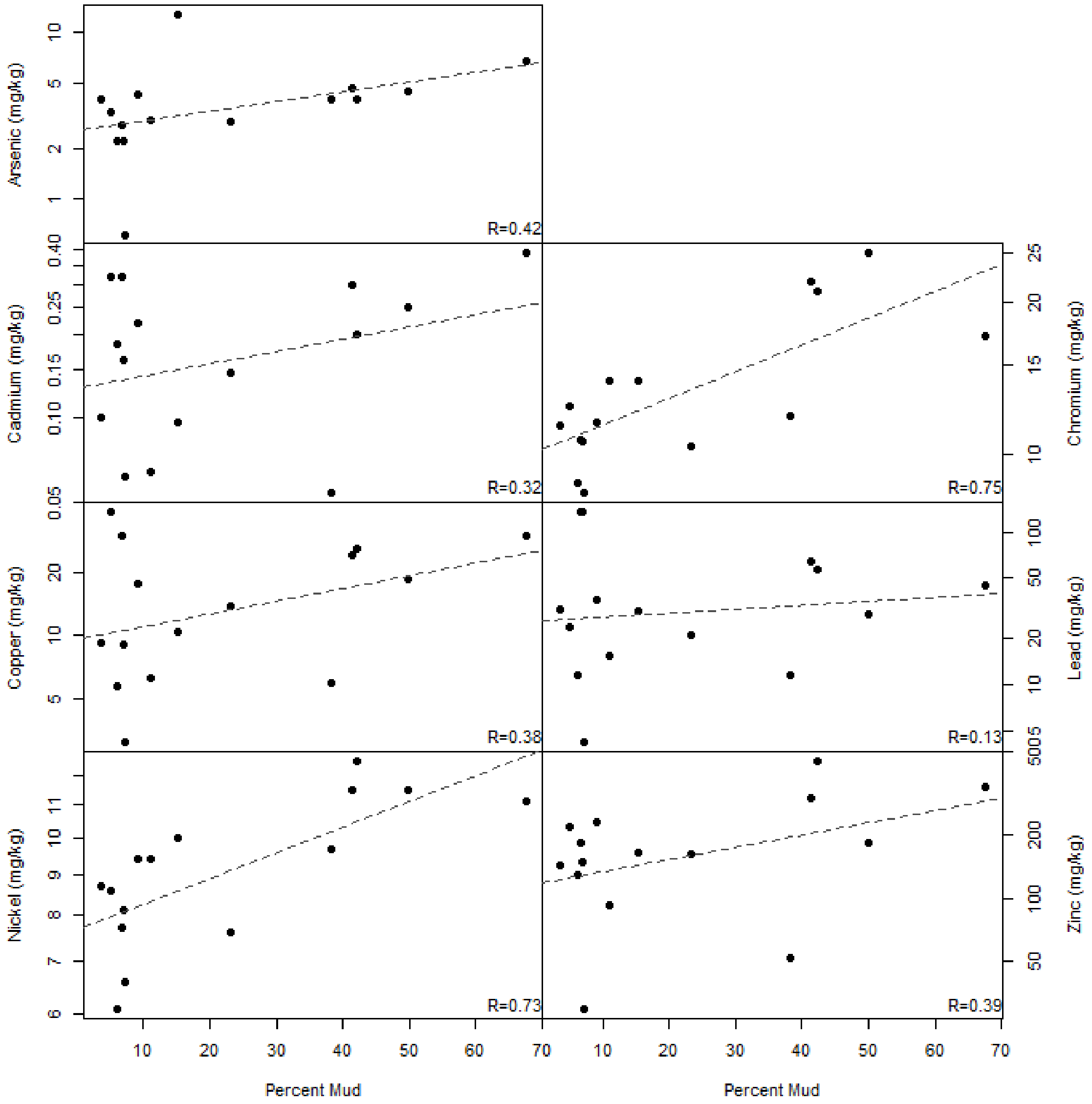

Figure 5-1: Relationship between metals/metalloids and percent mud in Heathcote River sediments. Note: Metals plotted on log scale.

5.2 Catchment Soils

In the absence of anthropogenic influences, the concentration of metals in stream sediments would be expected to reflect concentrations in the catchment soils, which differ according to soil type. Figure 5-2 compares metal concentrations in the sediment samples from each site with 'level 1 background' soil concentrations for the dominant soil type in the catchment at the point of sampling (mapped in Figure C-1 in Appendix C). The 'level 1 background' concentration is the maximum recorded concentration in the data set, excluding outliers, as determined through a survey of 17 sites in Christchurch by Tonkin & Taylor (2006; 2007). This comparison shows that arsenic, chromium and nickel were generally around the same concentration as the soils, whereas cadmium and copper concentrations were often slightly higher (up to 2x soil concentrations), and lead and zinc concentrations were well above soil concentrations at some sites (4-7x soil concentrations). This indicates that there are other sources of cadmium, copper, lead and zinc in addition to soil.

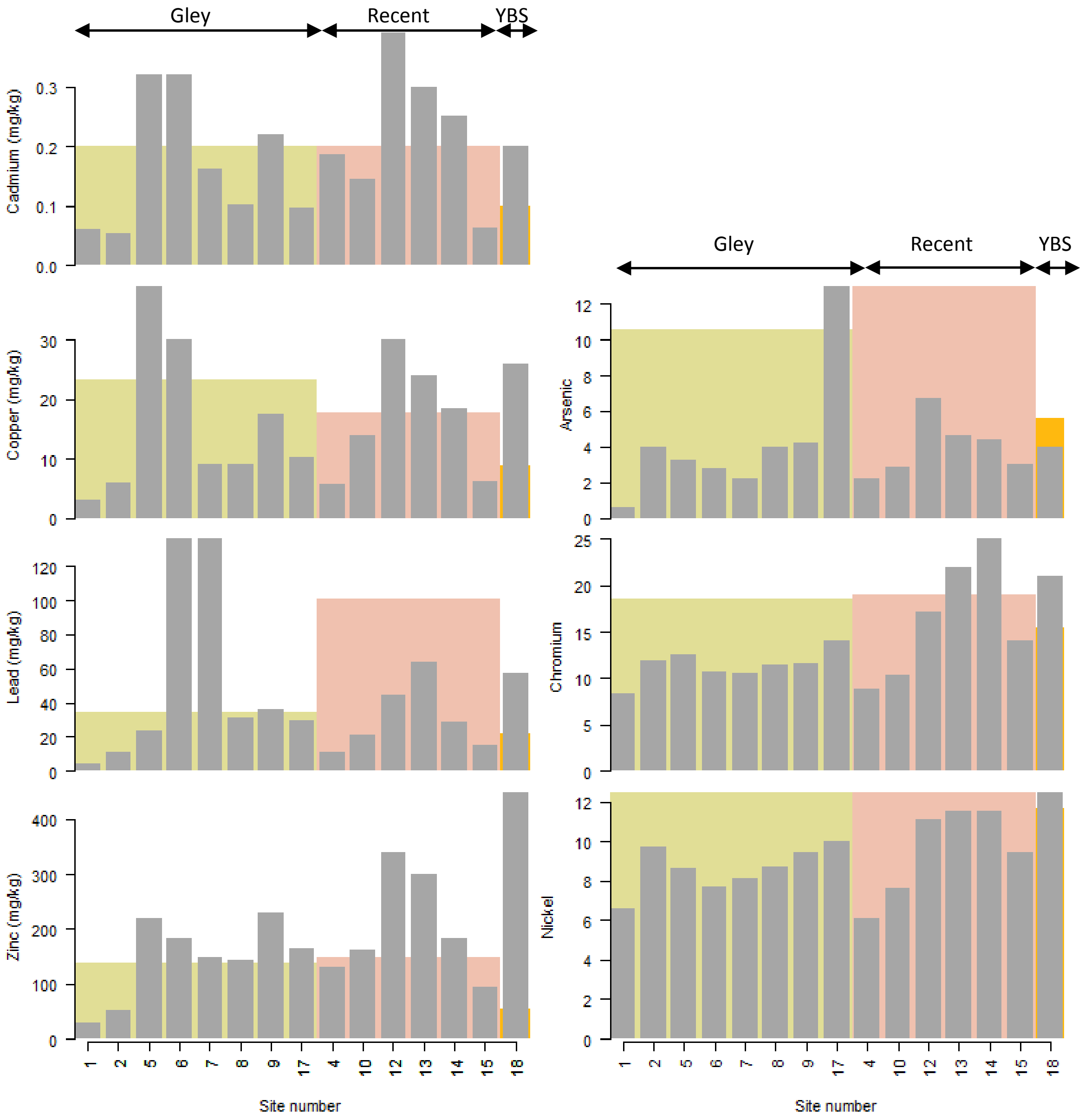

Figure 5-2: Comparison of sediment metal/metalloids at each site with "background" soil concentrations for gley, recent and yellow brown sand soils shown as coloured background, in green, pink and orange respectively. Note: Soil concentrations from Tonkin & Taylor (2007).

5.3 Catchment Landuse and Stormwater Quality

A major influence on stream sediment quality is the quality of the water entering the stream, which is itself influenced by the land the water is running off, and the activities undertaken on that land. The predominant landuse in the Heathcote River catchment is residential, particularly around the main stem of the river and in the mid to lower reaches. The planning zones for the catchment are shown in Figure 5-3.

There are some areas of other landuses: rural land dominates the catchment of Cashmere Stream and most of its tributaries, although the area of residential land has increased in recent years in this subcatchment; industrial landuse dominates the catchments of Curletts Drain and parts of Haytons Drain; and there is a significant area of industrial landuse in the lower Heathcote catchment around Woolston. There are also considerable areas of conservation land on the slopes of the Port Hills but the tributaries that drain these areas are ephemeral and were not sampled. The catchment of the City Outfall Drain is predominantly in residential landuse, however there is industrial or commercial landuse in the upper part of the catchment. The Estuary Drain catchment landuse is mainly open space (Bexley Park) and conservation (land near the wastewater oxidation ponds), but there is also a minor portion of residential area of Aranui within the catchment.

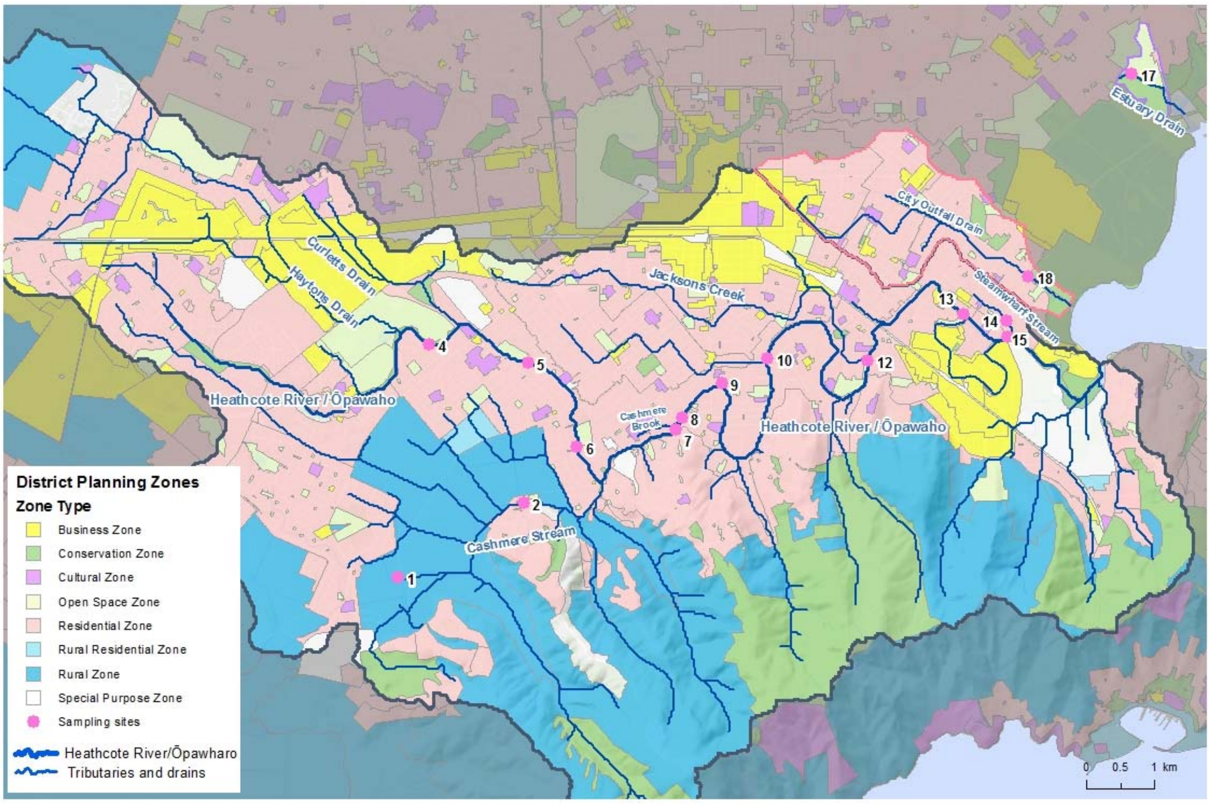

Figure 5-3: CCC planning zones in the catchments. Note: zoning map from Canterbury Maps (http://canterburymaps.govt.nz/).

The dominant landuse of the catchment upstream of each site was identified based on the zoning map and aerial photographs (tabulated in Table C-2 in Appendix C). This information was used to assess whether sediment quality was related to catchment landuse, for both individual sediment contaminants and overall quality, using the multivariate analysis described previously (Section 3.4 and 4.3).

For individual contaminants, there were some differences in the concentrations between three landuse categories of rural/open space, residential and residential with business (Figure 5-4). There was a significant difference in the median concentration (p-value < 0.05 in Kruskal-Wallis test for differences between medians) for total PAHs (p-value 0.038) and cadmium (0.043) but not for other contaminants including copper, lead and zinc (complete statistics are presented in Table C-3 in Appendix C of this report). Wilcoxon rank sum tests were used to further examine the statistical differences for cadmium and PAHs and found these were due to differences between the rural and residential landuse groups (p-value 0.024 for both), suggesting PAHs and cadmium are lower in streams with rural landuse in the catchment. There were no significant differences between the residential and business grouping with either rural or residential (p-values >0.05).

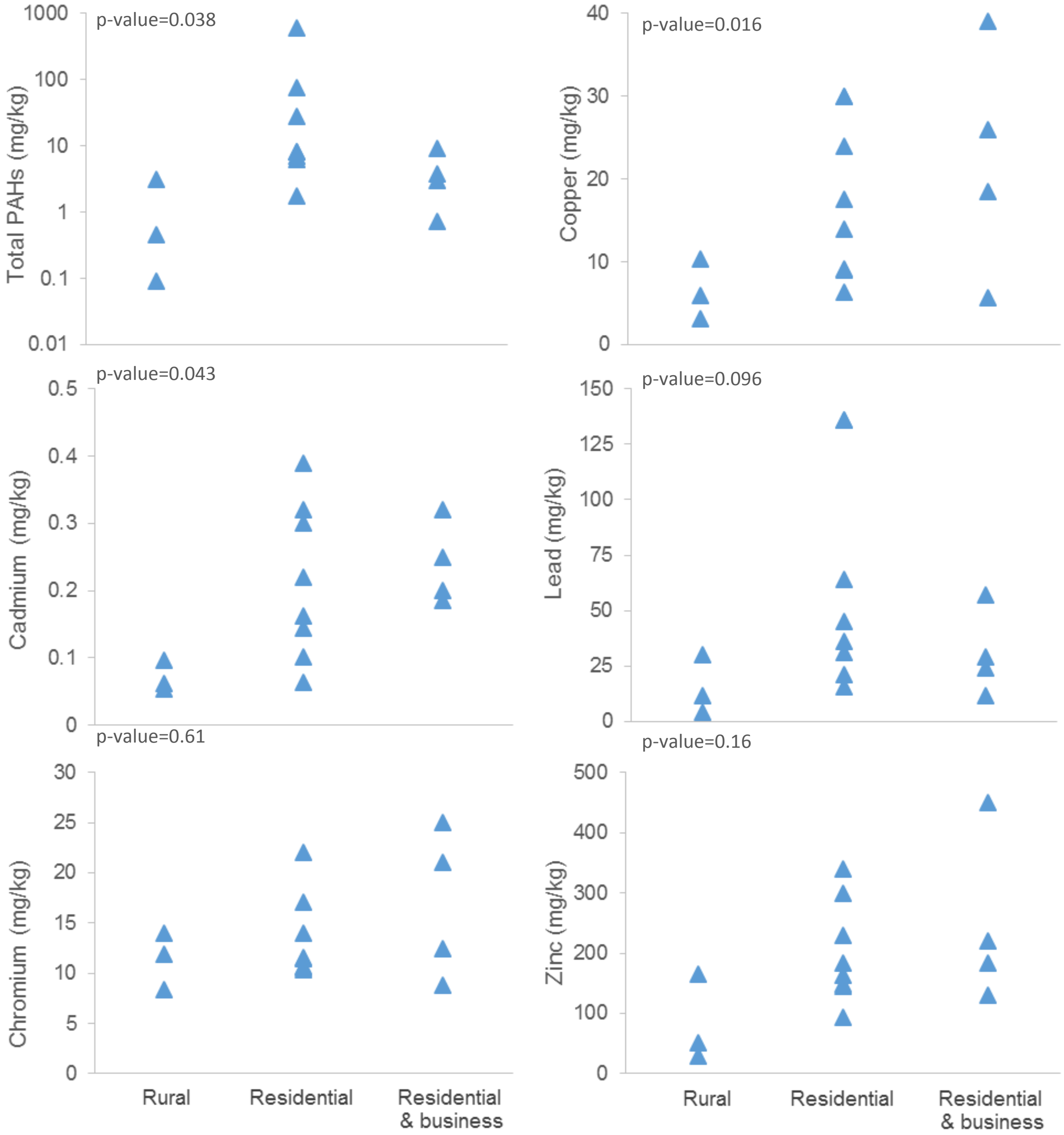

Figure 5-4: Comparison of contaminant concentrations in sediments by different landuses.

When multiple contaminants are considered together using the NMDS plot (Figure 5-5) some differences in sediment quality due to landuse can be observed. Samples from sites with rural landuse or open-space in the catchment are located towards the top of the plot, which indicates lower concentrations of most contaminants (see Section 4.3). However they are not clustered together (clusters are shown by blue and green circles), indicating that factors other than land use are more important in influencing the clustering of sites. Similarly, those sites with business landuse (commercial or industrial) within their catchments are not clustered together, again indicating drivers other than landuse affect the sediment concentrations.

Multivariate tests for differences between the groups based on landuse as a factor (ANOSIM) showed no significant differences in sediment quality based on landuse. Lack of statistical difference between the sites is not particularly surprising as there are few samples, with only three in the rural group and four in the residential/business group; and there was significant variation in the sediment quality within groups. Furthermore, there are other factors that influence sediment quality, and these may operate at a site-specific level, rather than a catchment level, such as the effect of roading material.

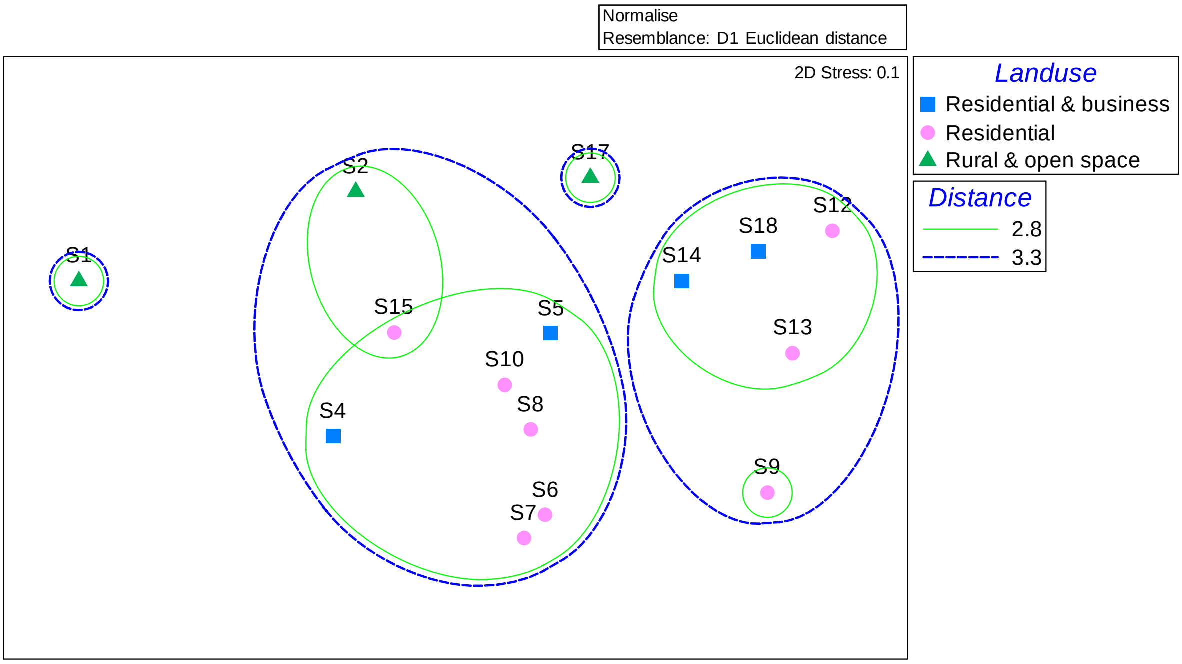

Figure 5-5: NDMS plot of sediment quality with the symbols for each site coded by dominant landuse in the catchment.

5.4 Liquefaction

Liquefaction has the potential to affect the sediment quality by adding sediments from underlying geological material. These sediments are expected to be lower in metals than the resident stream sediments (see Zeldis et al. (2011)). Burial of existing sediments with 'cleaner' liquefaction-sourced sediment would result in lower concentrations of metals being measured in streams compared to those that would have been sampled prior to the earthquakes. Whilst dredging stream sediments removes sediment, rather than adding, it may have a similar effect, in removing contaminated surface sediments and exposing less contaminated stream bed sediments.

Information on liquefaction within the Heathcote River, City Outfall Drain and Estuary Drain catchments was obtained from the Canterbury Maps GIS portal, based on liquefaction mapping from aerial and satellite photos and site visit data following the Christchurch Earthquakes (see Brackley (compiler) (2012) for details). This data is shown Figure 5-6 below and indicates that there was substantial liquefaction, or flooding of sediment throughout the three catchments. Of most interest is the liquefaction immediately adjacent to the waterways, which is particularly apparent in the lower reaches of the Heathcote River and in Jacksons Creek and Steamwharf Stream. Photographs of the Steamwharf Stream taken during an ecological survey in 2011 to examine earthquake effects (Taylor & Blair 2011) show severe slumping of the stream banks and collapse into the stream bed. Dredging of the bed was recommended to restore fish habitat (Taylor & Blair). Although information on stream dredging throughout the three catchments was sought from the Drainage Department of Christchurch City Council, this was not made available for this project.

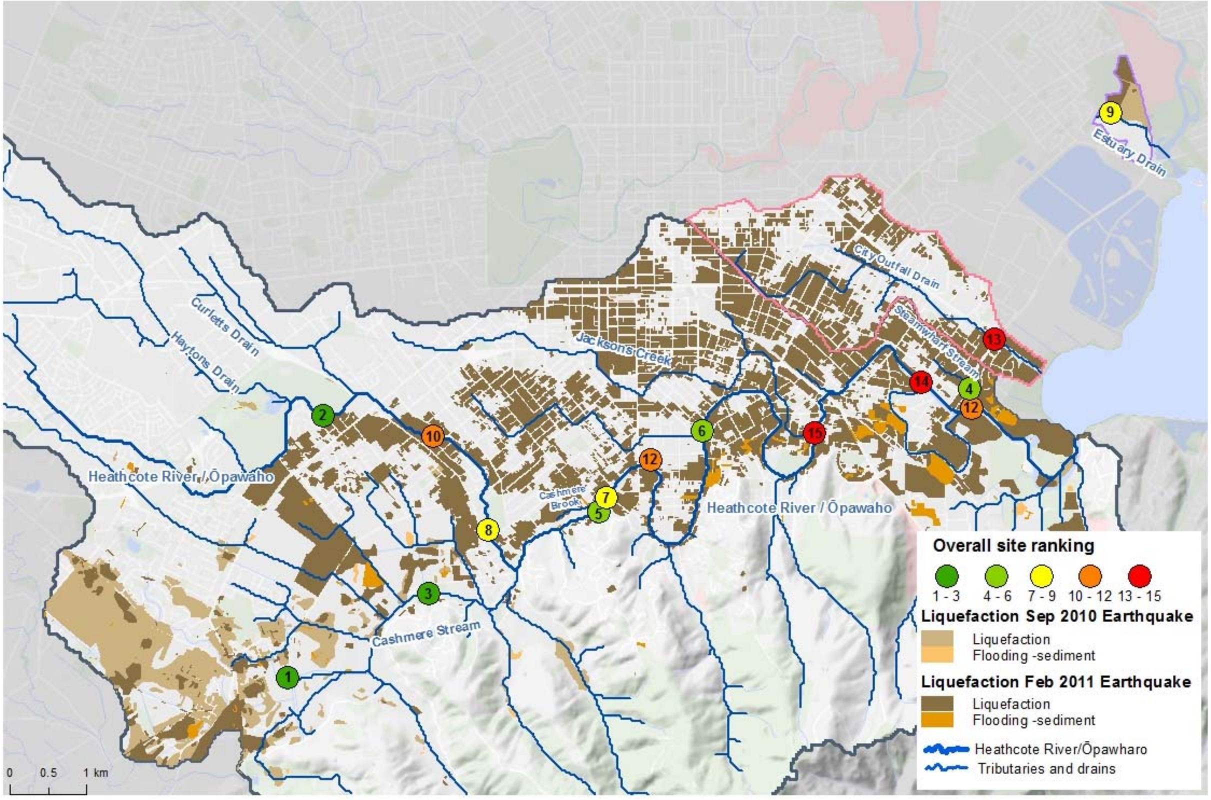

Figure 5-6: Location of liquefaction and flooding with sediments after the September 2010 and February 2011 earthquakes. Note: Liquefaction data from Canterbury Maps http://canterburymaps.govt.nz/

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A high proportion of the Steamwharf Stream catchment, and the stream itself, was affected by liquefaction and thus the sample collected may have been derived from soils from the stream banks that have fallen into the stream, or from liquefaction sediments, rather than from stormwater-derived sediments. This theory is supported by the very high proportion of fine sand in the sediment sample collected. These reasons could explain the relatively good sediment quality at this site (overall site ranking of 4) compared to others with residential land use, being more similar to sites with rural or open space landuse, as shown by the grouping in Figure 5-5. However, this conjecture cannot be confirmed as there is no previous sediment quality data (pre-earthquake) for this site to compare with.

Approximately half of the Estuary Drain catchment was affected by liquefaction, however this does not appear to have affected the stream sediment quality. Although metal concentrations were relatively low compared to other sites in this study, this probably also reflects landuse in the catchment (see Section 5.3). Furthermore, the concentrations of arsenic and phosphorus were very high at this site compared to others, which would not be expected if stream sediments were largely comprised of liquefaction sediments.

Equally, the City Outfall catchment had extensive liquefaction, however the sampled sediments contained elevated metals compared to other sites in this study, suggesting that although there may have liquefaction in the catchment, it did not significantly affect the stream sediment quality, or if it did, this was only in the short-term.

5.5 Historic Roading Materials

As described in Section 2.2, the use of coal tar in roading materials has been identified as a major source of PAHs, particularly in older areas of Christchurch (Depree and Ahrens 2005). There was one site in this study (Heathcote River, downstream of Colombo Street) where PAHs were extremely elevated, measuring 614 mg/kg, well above that measured at other sites in this study and previously in Heathcote River sediments (Kingett Mitchell 2005; Moores et al. 2009; Golder 2012). A similarly high concentration was measured in the Avon River catchment sediment survey, with 506 mg/kg measured in a sample from Dudley Creek. That was attributed to a small fragment of coal tar from roading material being included in the sediment analysed by the laboratory.

Although coal tar usage has not been identified in this area of Christchurch previously, it is highly unlikely that such a high result could be due to stormwater, as PAHs are usually at much lower concentrations than this in stormwater particulates (Depree & Olsen 2005a) or roadside gutter debris (Kennedy & Gadd 2003), where concentrations are usually less than 5 mg/kg. Lower concentrations are even present in sediments collected from stormwater treatment devices (e.g., 11-13 mg/kg in the Grafton Gully sediment retention tank; Depree & Ahrens 2007) or catchpits on industrial sites excluding that from a service station (Gadd et al. 2009). Other sources such as wood/coal soot from domestic combustion also could not readily account for the concentration of PAHs found in the Heathcote River. For example, soot contains PAH concentrations of around 1000 mg/kg, so the sediment sample would need to contain around 60% soot – which is highly unlikely to be the case.

It is estimated that up to 50% of Christchurch's urban roads still have coal tar in subsurface layers. Frittering of the seal edge (roads and footpaths) enables these subsurface seal layers (containing between 7,000 and 12,000 mg/kg) to be subject to weathering and abrasion and subsequently transported into streams through the stormwater system (Depree & Ahrens 2005). This wear could have been accelerated in locations where the Canterbury earthquakes caused additional breakup of the road surface, however it is not known if there was such damage to roading in this area of Christchurch.

6 Has the Sediment Quality Changed Over Time?

Trends of increasing concentrations of contaminants within the stream sediments are of importance to stormwater managers: over time an increasing number of such sites will exceed guideline concentrations. On that basis, the more widespread application of stormwater treatment may be required to reduce contaminant inputs and steady any increase. Conversely, decreasing concentrations over time or the presence of contaminants at relatively constant, low concentrations can indicate areas where additional management interventions may be of lower priority, or where existing management methods are working effectively.

Landuse changes in the catchment can be expected to have resulted in changes to sediment quality. Approximately 500-600 ha of rural land in the upper Heathcote River catchment has been converted to residential land since the previous major survey in the catchment in 2003 (Kingett Mitchell 2005) and this is likely to have affected sediment quality in the upper reaches of the Heathcote River main stem, and tributaries of the Cashmere Stream such as Dunbars Drain and Hendersons Road Drain. Residential landuse typically increases the amount of contaminants transported into streams due to the additional sources (for example zinc roofing, traffic on roads), additional impervious surfaces and changes in stormwater management (e.g., from open drains, overland flow and infiltration to piped systems).

However, although there have been a number of surveys of sediment quality in the Heathcote River catchment (see Section 2.2), these studies have involved sample collection at different groups of sites. This means that, unfortunately, there are no long-term records of sediment quality from repeatedly sampled sites, which would have allowed trend analysis. Nevertheless, sampling has been undertaken on two or more occasions at a number of sites (or closely located sites), allowing the results of this study to be compared with those of previous surveys.

Of the 15 sites sampled in this current study, 12 were located at or near to sites previously measured by Christchurch Drainage Board (Robb 1988). Both studies measured a similar suite of contaminants, (excluding arsenic and PAHs) and used similar methods. Eight of the sites were also near locations sampled in the 2003 survey of South-West Christchurch, in which copper, lead, zinc and PAHs were measured (Kingett Mitchell 2003); and a further five were near sites sampled in the 2011 survey of sediments throughout the region (Golder 2012). In all surveys, only single samples from each site were analysed. This lack of replication prevents any statistical comparisons on a site-by-site basis. However, it is possible to make a qualitative comparison of the concentrations at sites sampled in this study, with those measured previously at the same or nearby sites. In addition, it is possible that liquefaction affected the sediment quality at some of these sites, making comparisons between the surveys even more problematic (see Section 5.4).

6.1 Metals

The concentrations of lead, copper and zinc measured in each survey at these locations are compared in Figure 6-1. This does not show a consistent trend over time for any of these metals.

Kingett Mitchell (2003) reported a general increase in zinc concentrations in the catchment, based on comparison of 2003 and 1980/81 data. Likewise, the current survey also suggests higher concentrations of zinc at several sites compared to 1980/81. However, the data does not indicate that zinc concentrations have increased further since 2003, at least not at those sites that have been resampled. The 2015 concentrations were lower than 2003 concentrations, and at some sites, lower than 1980/81. This is despite the change in landuse in the upper catchment as described above, which would be expected to further increase metal concentrations.

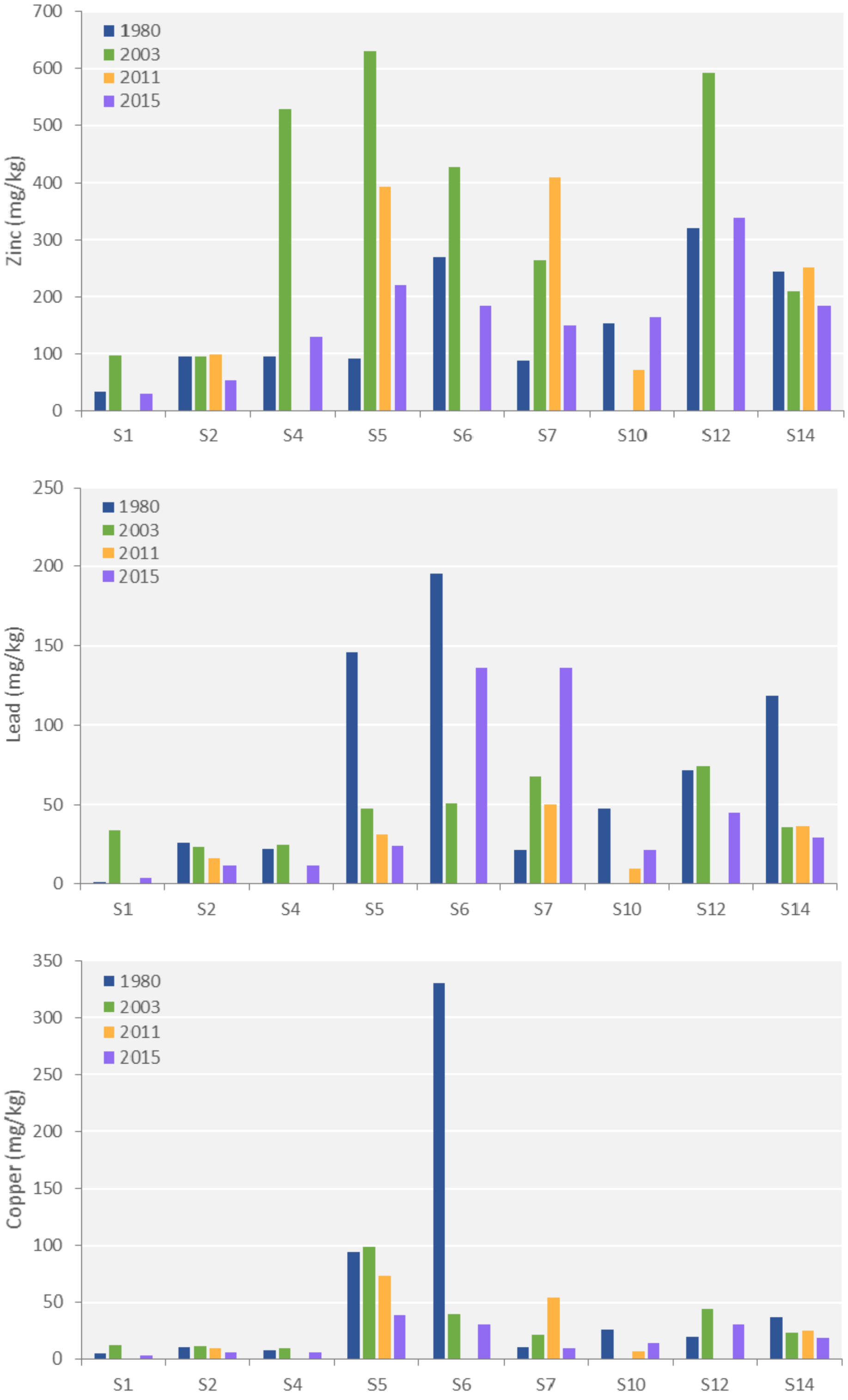

Figure 6-1: Lead, copper and zinc concentrations at sites measured in the current and previous surveys in the catchment.

For lead, the concentrations in 1980/81 were often much higher than in the more recent surveys; however they do not appear to have decreased further since 2003, with concentrations varying in the more recent surveys. Copper concentrations do not show any consistent pattern – with lower concentrations in recent surveys at some sites, and higher concentrations at others.

For cadmium, chromium and nickel (Figure 6-2) there was very little difference in the concentrations between years, with the exception of a substantial difference in cadmium at site 6. The small differences observed are likely to be due to the natural heterogeneity of sediment samples or from differences in sample texture (i.e., the proportion of fine particles), as shown in Figure 6-2.

Though this comparison does not provide any definitive answer as to changes in sediment metal concentrations over time, the amalgamation of the data sets provides greater evidence that metal concentrations are lower at sites in Cashmere Stream and the upper Heathcote, and moderate to high (and extremely variable) concentrations at sites in the middle and lower reaches.

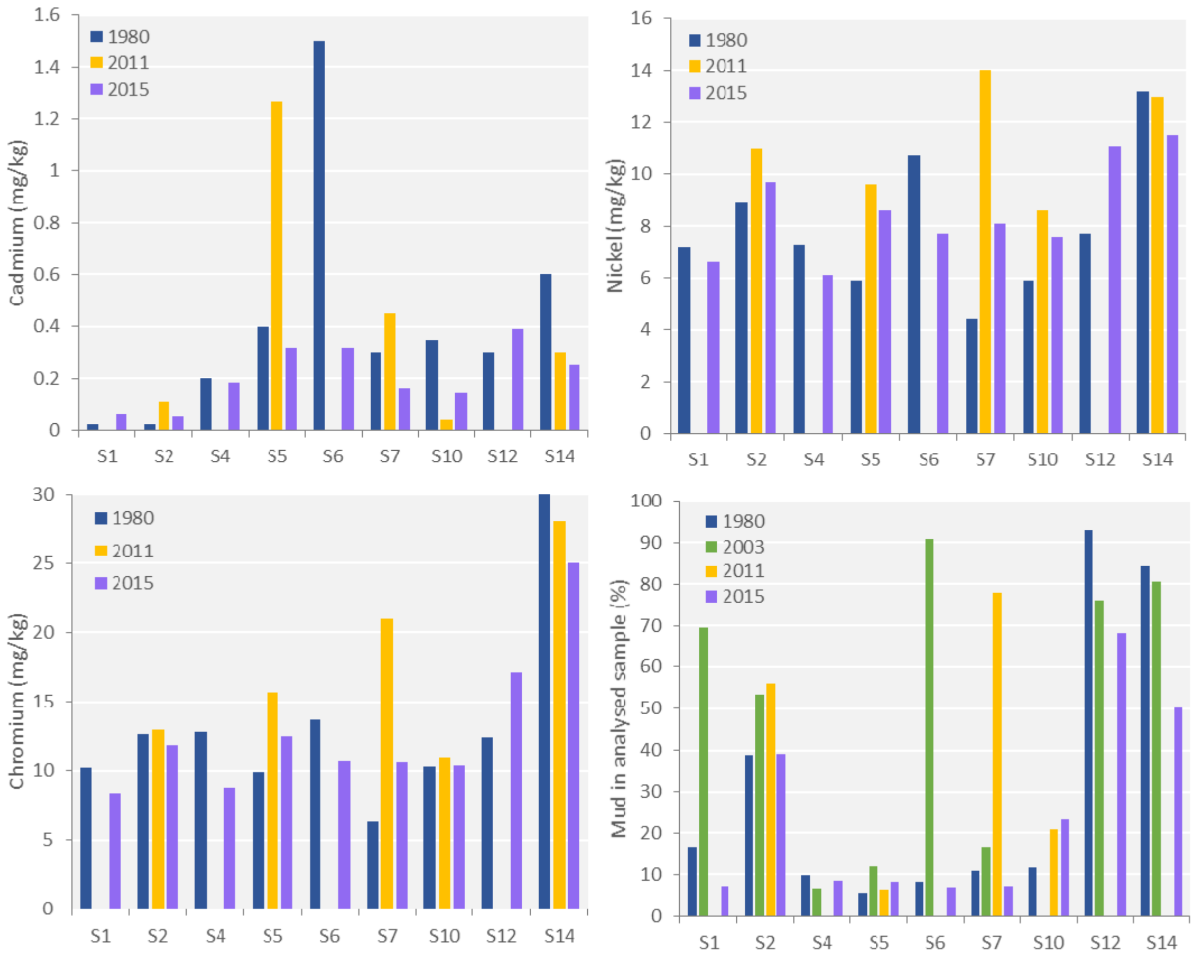

Figure 6-2: Cadmium, chromium and nickel concentrations, and mud content of samples from sites measured in the current and previous surveys in the catchment.

Table 6-1 compares metal concentrations in samples collected in this survey with those collected in the 1980/81 survey. This comparison provides the best indication of long-term changes because these two surveys have the most overlap in terms of the location of sites sampled. The comparison indicates that zinc concentrations have increased at four sites (all in the upper catchment), decreased at two sites and are unchanged at six sites. However, when the mud content of the analysed sample is taken into account, by normalising the metal concentration with the proportion of mud in the sample (adopting the same approach as that in Gadd & Sykes, 2014), the number of sites with a higher zinc concentration in the 2015 survey increases to six, with only two sites measuring lower concentrations in 2015.

Copper concentrations were lower at seven sites in 2015 and higher at only one site compared to the 1980/81 survey. Once normalised for mud content, this changes to five sites with lower concentrations and three with higher concentrations. The change in lead concentrations is more consistent, with 10 out of 12 sites having lower lead concentrations in 2015 than in 1981/81. This change in lead concentrations was also noted in Kingett Mitchell (2003) and is most likely due to the decrease of lead from petrol in the period between these surveys (banned in 1996). When normalised concentrations were considered, the change was slightly less strong, with seven of the 12 sites showing a reduction in lead concentrations.

Table 6-1: Comparison of metal concentrations in the Heathcote River / Ōpawharo catchment and the City Outfall Drain / Linwood Canal between 1980 and 2015. Arrows indicate direction of change, where the difference between years was more than 30%.

	Zinc				Copper				Lead			
Site No.	1980	2015	Change	Change in mud normalised conc.	1980	2015	Change	Change in mud normalised conc.	1980	2015	Change	Change in mud normalised conc.
1	35	30	→	↑	5	3.1	↓	↑	1	4.2	↑	↑
2	95	52	↓	↓	10	5.9	↓	↓	26	12	↓	↓
4	95	130	↑	↑	7	5.7	→	→	22	12	↓	↓
5	92	220	↑	↑	95	39	↓	↓	146	24	↓	↓
6	269	183	↓	→	330	30	↓	↓	195	136	↓	→
7	87	148	↑	↑	11	9	→	↑	21	136	↑	↑
9	172	230	↑	↑	18	18	→	→	88	36	↓	↓
10	152	163	→	↓	26	14	↓	↓	48	21	↓	↓
12	320	340	→	↑	19	30	↑	↑	72	45	↓	→
13	367	300	→	→	50	24	↓	↓	1250	64	↓	↓
14	244	183	→	→	37	19	↓	→	119	29	↓	↓
18	410	450	→	N/A *	27	26	→	N/A *	135	57	↓	N/A *

Note: * No texture data provided by Robb (1988) for City Outfall Drain sample, so normalised zinc concentration could not be calculated.

6.2 PAHs

PAHs have been measured in Heathcote River catchment sediments in at least three previous studies: the Golder (2012) survey of regional sediment quality; the South-West Christchurch survey (Kingett Mitchell 2003); and much earlier, in a PhD study (Lee 1982). As each of these studies has used a different group of sites, only 7 of the sites in the current survey (of total 15) have previously been sampled (see Table 6-2). Furthermore, for the 1982 study, a different suite of PAH compounds was analysed, only 7 of which are the same as the current survey. PAHs had not been measured in the City Outfall Drain / Linwood Canal or Estuary Drain prior to the current survey.

The data is not sufficient to assess changes over time in the concentration of PAHs, but it does provide confirmation of the patchiness of the concentrations measured in the current survey. As in the current survey, there was a wide range in the concentrations of total PAHs from < 1 mg/kg to more than 40 mg/kg at some sites. However, there were no sites examined in the previous surveys that had PAH concentrations as high as those measured at site 9, of 614 mg/kg (including results for sites that are not tabulated in Table 6-2, because they were not located near sites used in the current survey). The highest concentration previously reported was 45.2 mg/kg reported in 2003 at HE29 (Kingett Mitchell 2003) in the Heathcote River downstream of the confluence with Cashmere Stream (similar location to site 7 in this survey). This high concentration was not confirmed in more recent sampling at similar sites, with 2.7 mg/kg measured in 2011 and 8.2 mg/kg in this 2015 survey.

The within-site heterogeneity of PAH concentrations was assessed through the analysis of three samples collected by Golder (2012) at the site near Spreydon Domain, where three replicates measured 1.1, 2.4 and 5.4 mg/kg. This range in concentrations was similar to that noted between years for many of the sites, but a much smaller range than the differences at Site 7, suggesting the presence of influences additional to the inherent variability in site sediment quality.

Table 6-2: Comparison of PAH concentrations (mg/kg) in 1982, 2003, 2011 and 2015 at sites in the Heathcote River catchment.

Site No.	Site Name	Sum of PAHs *				Sum of 7 PAHs	
		2015	2011	2003	1982	2015	1982
S1	Cashmere Stream: Sutherlands	0.09		2.8			
S2	Cashmere Stream: Penruddock	0.46	0.83				
S4	Heathcote River: Showgrounds	0.73					
S5	Heathcote River: Spreydon Domain	3.0	3.0	1.6	2.7	1.4	1.8
S6	Heathcote River: Centennial	7.0					
S7	Heathcote River: Barrington	8.2	2.7	45.2		3.8	3.0
S8	Cashmere Brook	27.9					
S9	Heathcote River: Colombo St	614					
S10	Heathcote River: Tennyson St	6.1	1.1		7.1	3.1	4.3
S12	Heathcote River: Aynsley	8.1					
S13	Heathcote River: Catherine (tidal)	77.2			40.3	34.9	20.6
S14	Heathcote River: Tunnel (tidal)	9.2	12.4		17	5.2	9.5

Note: For 2015, 2011 and 2003, the value represents the sum of 16 priority pollutant PAHs as listed by USEPA (1982); whereas the total for 1982 represents the sum of 20 PAH compounds measured.

7 This Study Compared to Elsewhere in Christchurch or NZ

Figures 7-1 to 7-4 compare contaminant concentrations in the sediments from the Heathcote River / Ōpawharo catchment measured in this study, and those in the two drains (Estuary Drain and City Outfall Drain) with those previously measured in urban stream sediments from elsewhere in Christchurch (i.e., Avon, Heathcote, Halswell, Haytons and Styx River catchments), around Canterbury and around New Zealand. The figures also indicate the ANZECC (2000) sediment quality guideline concentrations (background colour) to provide context for interpreting the measured concentrations. It should be noted that the current survey did not include some sites on tributaries of the Heathcote which had the highest metal concentrations in previous studies. The 2003 survey focused on the upper Heathcote and the upper tributaries (including Haytons Drain, Curletts Drain and Cashmere Stream) and five sites in the tidal reach. In contrast, current survey did not sample Haytons or Curletts Drains and did include sites throughout the middle reaches. The 2003 study data are shown separately in the plots below to provide an indication of how the sediment quality in the current study compares with that in the upper part of the Heathcote catchment.

Zinc concentrations measured in the current survey of Heathcote River catchment sediments were very similar to concentrations recently measured in the Avon River / Ōtākaro catchment survey and in the Canterbury-wide survey. Although the median zinc concentration in the Styx catchment survey was higher than that in this Heathcote River catchment survey, and exceeded the zinc ISQG-low, there was a wide spread in the Styx data. There were no statistically significantly differences between median concentrations for any of these surveys. Zinc concentrations in the current survey were lower than in the previous survey in the Heathcote River catchment (statistically significant p-value 0.0019 using Wilcoxon rank sum test); the survey of Haytons Drain catchment (p-value 0.017); and the data from Auckland (p-value 0.003). The median zinc concentrations in these three studies were above the ISQG-low, unlike the median for the current survey. Zinc concentrations in the Heathcote River catchment were higher than those measured in the Tauranga surveys (p-value 0.0016) and the predominantly rural Halswell catchment, however for the latter the difference was not statistically significant.

The zinc concentrations in the City Outfall Drain and Estuary Drain were higher than the Halswell, Avon and Styx surveys, but similar to or slightly lower than the Haytons Drain study or the previous Heathcote survey. No statistical analyses could be undertaken for these two sites.

The copper concentrations measured in the current survey of Heathcote River catchment sediments were very similar to concentrations recently measured in the Avon River / Ōtākaro catchment survey, the Styx survey and in the Canterbury-wide survey and there were no statistically significantly differences between median concentrations for any of these surveys (note, no statistical analyses were undertaken for the two drains). As for zinc, the copper concentrations in this study were also lower than the previous survey in the Heathcote River catchment (p-value 0.017) and the Auckland data (p-value <0.0001), but not lower than the concentrations measured in the Haytons Drain catchment. Note that the lower zinc and copper concentrations in the current survey compared to the 2003 survey does not demonstrate changes in concentration over time, but could be a result of the different sites measured in each survey. Copper concentrations were higher in the Heathcote catchment than in Halswell and Tauranga, but this was significant only for Tauranga (p-value 0.005). For all studies, most values were below the ISQG-low for copper. As for the Heathcote River catchment, the copper concentrations measured in the drain sediments were similar to those measured in the Avon River / Ōtākaro catchment, the Styx, Haytons Drain and in the Canterbury-wide surveys; and slightly lower than previous survey in the Heathcote River catchment and the Auckland data.

The lead concentrations measured in the current survey of Heathcote River catchment sediments were similar to concentrations in the Styx survey and in the Canterbury-wide survey and the Halswell catchment, with no statistically significant differences recorded. Median lead concentrations for the drains were slightly higher than these surveys (no statistical analyses undertaken). Unlike the copper and zinc data, the lead concentrations in the Heathcote River catchment in this study were somewhat lower than those recently measured in the Avon River / Ōtākaro catchment survey, where many samples exceeded the ISQG-low (however this difference was not statistically significant). The data for the two drains were very similar to that for the Avon River catchment and the previous Heathcote River catchment survey; and lower than the concentrations measured in Auckland. As for copper and zinc, lead concentrations in this survey of the Heathcote River catchment were again lower than in the previous survey but this difference was not statistically significant, albeit close to being so (p-value 0.050). Concentrations in the current Heathcote catchment survey were much lower than those measured in Auckland (p-value 0.0003), where the median concentration was well over the ISQG-low and many samples exceeded the ISQG-high.

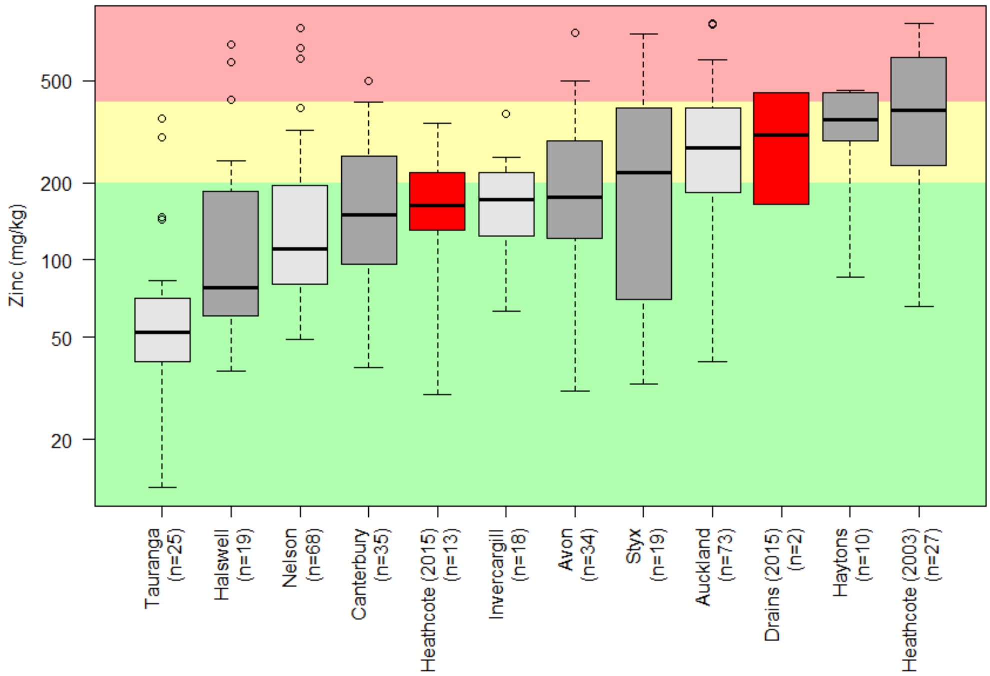

Figure 7-1: Zinc concentrations in the Heathcote River catchment and City Outfall Drain and Estuary Drain sediments in this study (red) compared to the Heathcote 2003 study and other locations around Canterbury (darker grey) and New Zealand (light grey). Note: Y-axis plotted on log10 scale. Background colours represent sediment quality guidelines (green below ISQG-low; yellow above ISQG-low; pink above ISQG-high). Top and bottom bounds of the box indicate the 25th (lower) and 75th (upper) percentiles, line in the middle of the box indicates the median. Whiskers extend to the nearest data points that are within 1.5 times the inter-quartile range (IQR) of the median value. Data points lying outside this range (outliers) are shown as individual points.

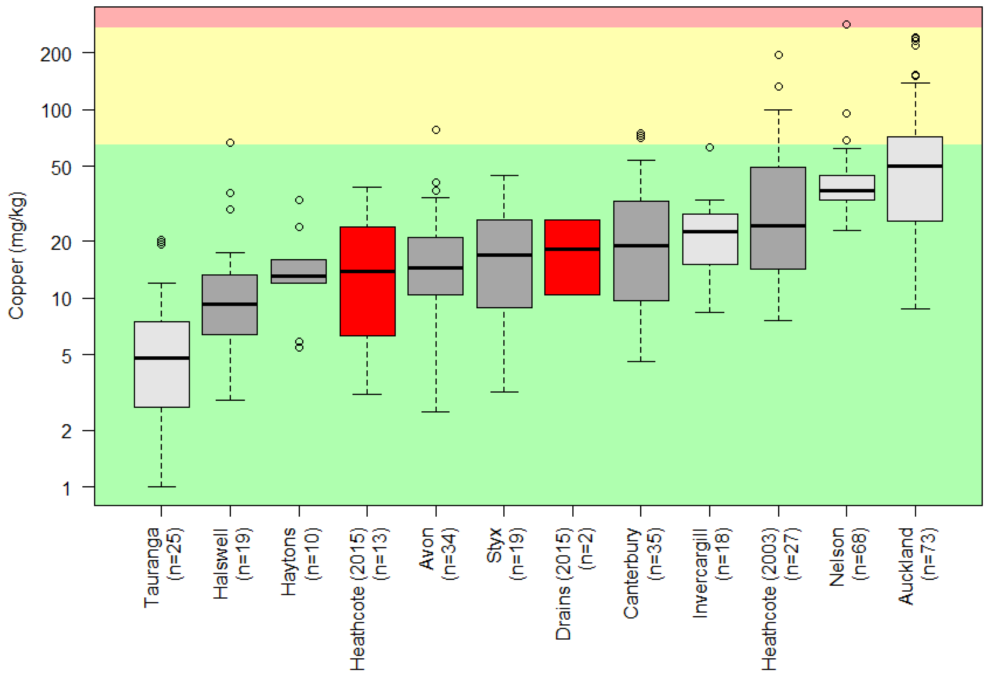

Figure 7-2: Copper concentrations in the Heathcote River catchment and City Outfall Drain and Estuary Drain sediments in this study (red) compared to the Heathcote 2003 study and other locations around Canterbury (darker grey) and New Zealand (light grey). Note: Y-axis plotted on log10 scale. Background colours represent sediment quality guidelines (green below ISQG-low; yellow above ISQG-low; pink above ISQG-high).

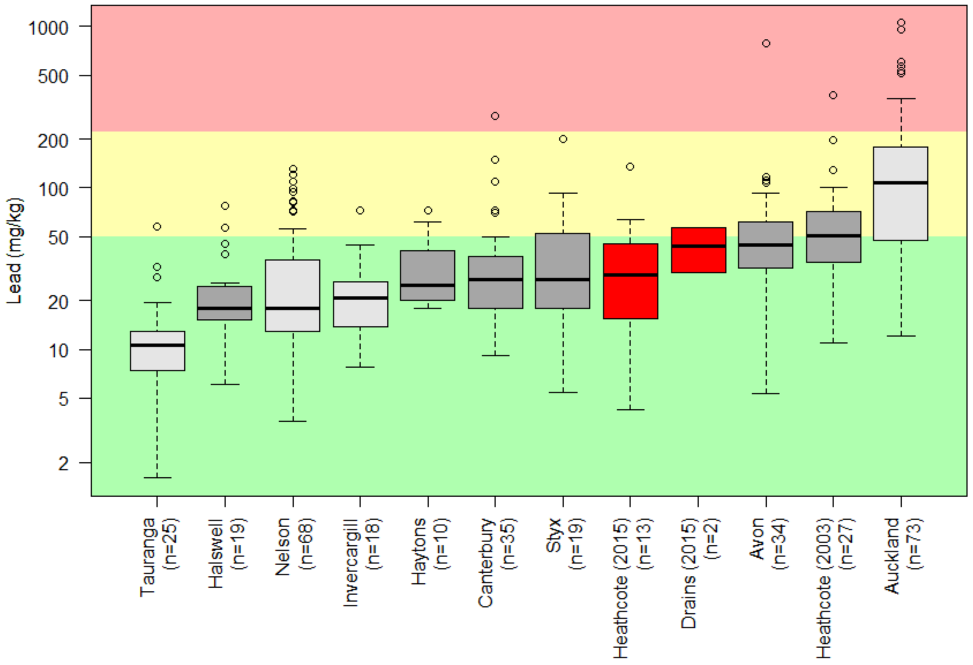

Figure 7-3: Lead concentrations in the Heathcote River catchment and City Outfall Drain and Estuary Drain sediments in this study (red) compared to the Heathcote 2003 study and other locations around Canterbury (darker grey) and New Zealand (light grey). Note: Y-axis plotted on log10 scale. Background colours represent sediment quality guidelines (green below ISQG-low; yellow above ISQG-low; pink above ISQG-high).

Arsenic, cadmium, chromium and nickel have been measured in fewer surveys (Figure 7-4) than copper, lead and zinc. The median concentrations of chromium and nickel in the Heathcote River catchment sediments were lower than at most other locations, whereas median arsenic and cadmium concentrations were similar, at least to most other data from Canterbury. Arsenic, chromium and nickel concentrations in the Heathcote sediments were lower than those from the Styx River (p-values all <0.05), but no different to those from the Avon River (p-values ≥0.05). There was no difference in the cadmium concentrations between surveys. For the City Outfall and Estuary Drains, the concentrations were also similar to those measured previously, and were close to the range of values measured in the Styx River catchment. For these metals/metalloids, almost all samples from all studies were below their ISQG-low trigger values.

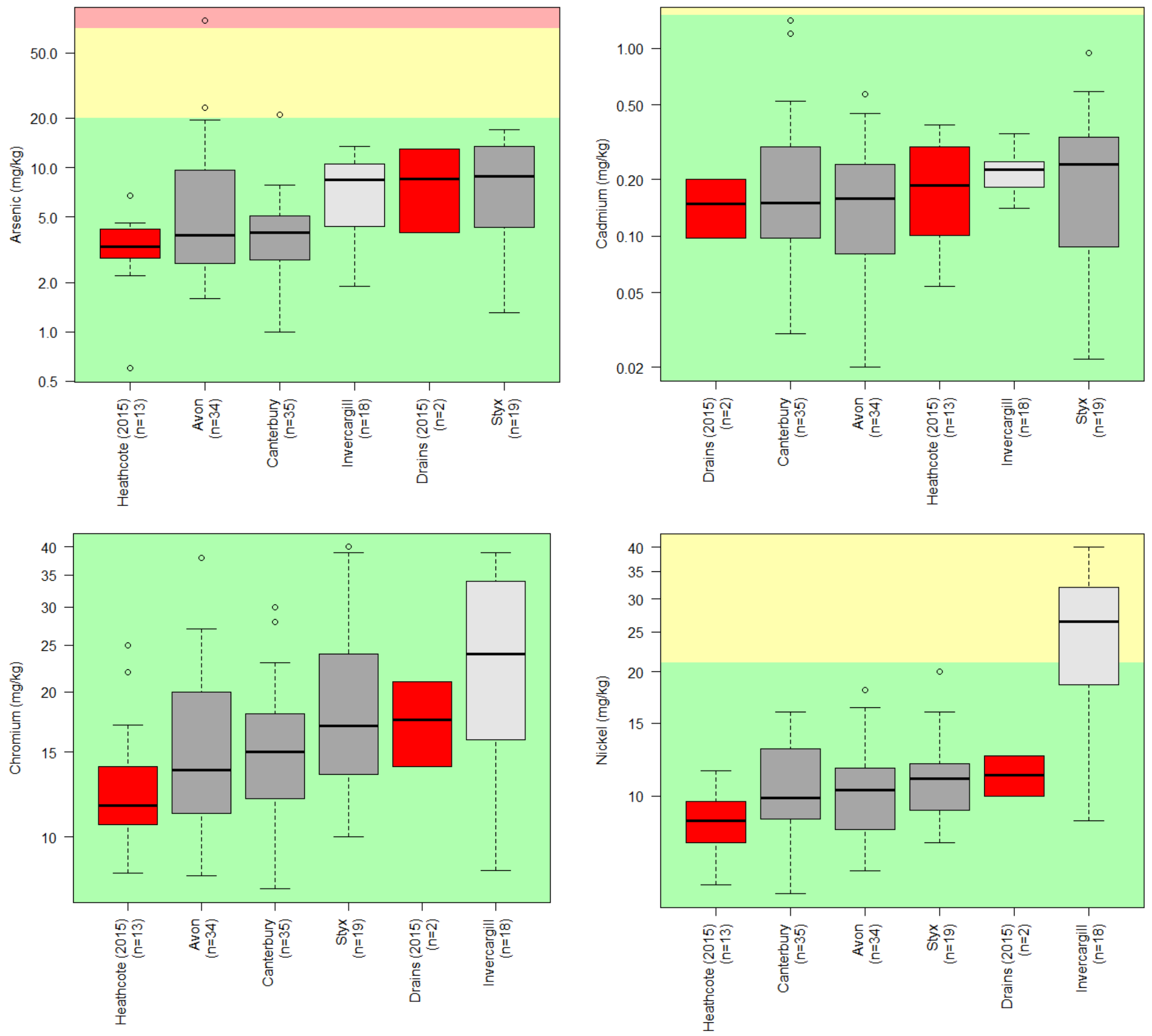

Figure 7-4: Arsenic, cadmium, chromium and nickel concentrations in the Heathcote River catchment and City Outfall Drain and Estuary Drain sediments in this study (red) compared to other locations around Canterbury (darker grey) and New Zealand (light grey). Note: Y-axis plotted on log10 scale. Background colours represent sediment quality guidelines as described previously.

PAHs have been measured in all the recent studies of Christchurch and Canterbury urban streams, along with studies in Auckland (Figure 7-5). The concentrations in the Heathcote River / Ōpawharo catchment sediments are very similar to those from the Avon River and about the same as those in Auckland, where coal tar has also been used in roading material. Total PAH concentrations in the Heathcote catchment were significantly higher than in the Haytons Drain (p-value 0.005) and Halswell surveys (0.004), and somewhat, but not significantly higher than in the Styx and Canterbury-wide surveys. PAHs in the drains were within the range previously measured in the Styx, Avon and Heathcote River catchments and in the regional survey, but, as for the current Heathcote survey results, somewhat higher than measured in the Haytons and Halswell catchments.

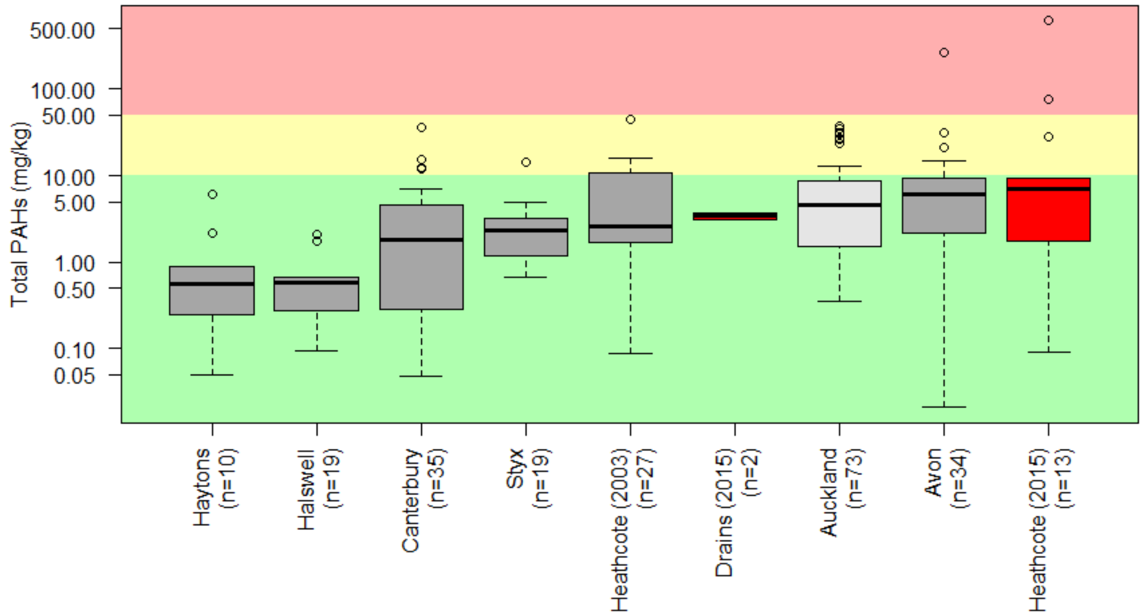

Figure 7-5: Total PAHs concentrations in the Heathcote River catchment and City Outfall Drain and Estuary Drain sediments in this study (red) compared to the Heathcote 2003 study and other locations around Canterbury (darker grey) and New Zealand (light grey). Note: Y-axis plotted on log10 scale. Background colours represent sediment quality guidelines as described previously.

The overall quality of the Heathcote River sediments compared to other surveys was compared using multivariate techniques as described in Section 3.4. This included only the more recent studies in the Styx and Avon catchments which measured arsenic, cadmium, chromium and nickel in addition to copper, lead, zinc and PAHs. The PCA plot (Figure 7-6) displays site clusters with the variables included in the analysis plotted as vectors to demonstrate which variables were most important in differentiating the sites. The direction of the vector lines shows the direct of increasing concentration (i.e., total PAH concentrations increase towards the top and nickel and chromium concentrations increase towards the bottom)

This analysis did not show any distinctive clustering based on the catchment, although to some extent the sites in the Styx catchment were distributed around the lower part of the plot (corresponding to higher concentrations of nickel, arsenic and chromium) and the site from the Heathcote River were distributed around the upper part of the plot (corresponding to higher concentrations of the PAHs, lead, zinc and copper). Sites in the Avon River catchment overlapped both groups. This, along with the box plots shown previously, demonstrates the wide variation in sediment quality within each catchment, where landuse, roading materials and liquefaction at a site-based level are of more influence than any catchment-wide factors.

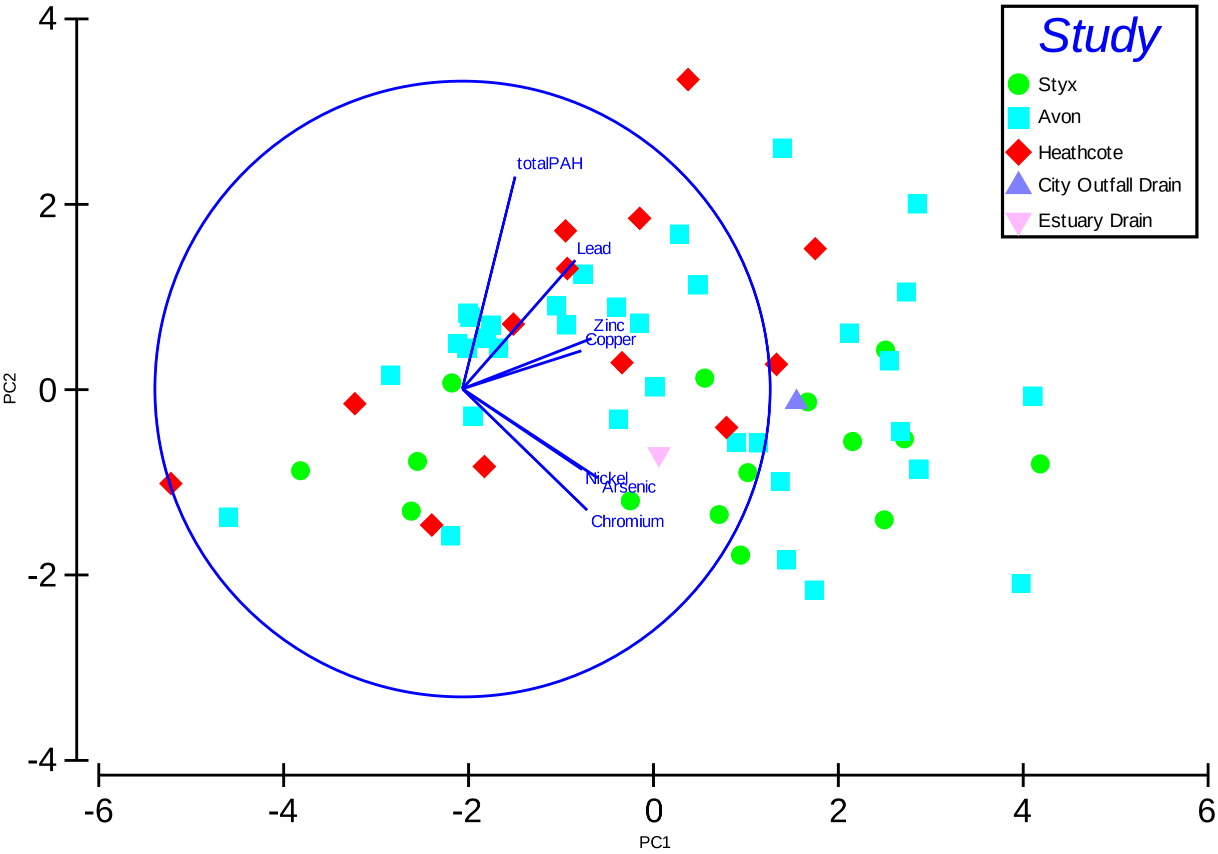

Figure 7-6: Multivariate analysis of sediment quality in the Heathcote River catchment and City Outfall Drain (COD in plot) and Estuary Drain sediments in this study compared to the Styx and Avon River. Note: PCA analysis of arsenic, chromium, copper, lead, zinc and PAHs after transformation (log(x+1)) and normalisation. Cadmium excluded from analysis due to strong correlation with copper (0.86).

8 Summary of Sediment Quality, Changes Over Time and Influences

8.1 Sediment Quality

The survey of sediment quality in the Heathcote River / Ōpawharo catchment has shown that lead, zinc and PAHs concentrations were variable in samples collected across the catchment; with a 10-20x difference between the lowest and highest concentrations measured. By contrast, there was less variation in the concentrations of copper and arsenic and very little variation between sites for chromium, nickel and phosphorus. The sediment texture was also variable, with samples from sites in the lower, tidal reaches and in Cashmere Stream dominated by mud and fine sand; whereas sites in the upper and middle reaches had significant proportions of gravel and coarse sand. In general, higher concentrations of metals were measured in the middle and lower reaches of the Heathcote River and in the City Outfall Drain / Linwood Canal. Metal concentrations were usually lower in the Heathcote River headwaters, Cashmere Stream, Steamwharf Stream and the Estuary Drain. Table 8-1 summarises the key findings for each contaminant, including their concentrations, guideline exceedances, trends and major sources.

8.2 Changes in Sediment Quality Over Time

Comparison of the metal concentrations from the 1980/81 study suggests that lead concentrations in sediments at most sites are now considerably lower than they were in the 1980s, as can be expected due to the removal of lead additives from petrol. For zinc there appears to be an increase in concentration between the surveys, based on analysis of mud-normalised metal concentrations. For copper there was no clear difference between the surveys, with increases observed at 3 sites, decreases at 5 sites and no change at 4 sites. There was little difference between the cadmium, chromium, nickel or PAH concentrations in the current survey and in earlier surveys from 1980-82.

8.3 Influences on Sediment Quality

Correlations between contaminants in the sediment samples indicated that the sources of cadmium, copper, lead, and zinc may be the same. The correlations also suggested that this source is different from that for organic carbon, phosphorus, arsenic, chromium, nickel and PAHs.

Metals are naturally-occurring in soils though their concentrations can be somewhat different between soils. Soils in the catchment are predominantly recent, with some small patches of gley and organic. For arsenic, chromium, lead and nickel the sediment concentrations are similar to the soil concentrations. Lead concentrations in the soils of urban Christchurch are higher than outside the urban centre as a result of lead additives in petrol. These historically contaminated soils are likely to be the primary source of lead on a catchment-wide basis. For cadmium, copper and zinc, many of the sediment concentrations were higher than the soils, suggesting that these metals are influenced by factors other than soil.

Urban land use is a major influence on sediment quality identified in other studies, as is impervious surface cover to a lesser extent. For sites in the Heathcote River / Ōpawharo catchment, lower concentrations of contaminants were found at the sites with a rural catchment, compared to those with catchments dominated by residential and residential / business land uses. The input of

Table 8-1: Summary of sediment contaminants.

Contaminant	Measured conc. (mg/kg)	Exceedance of sediment quality guidelines	Change since previous survey	Likely sources	Urban stormwater as major source?
PAHs	0.09 - 614 mg/kg	6 sites exceed ISQG-low (4 mg/kg) 1 site (212 mg/kg, normalised for TOC) exceeds ISQG-high (45 mg/kg)	No evidence of change	Coal tar in roading materials	Likely through transport of coal tar residues in road material and roadside soils
Zinc	30 - 450 mg/kg	5 sites exceed ISQG-low (200 mg/kg) 1 site exceeds ISQG-high (410 mg/kg)	Higher at some sites, no change at most	Urban stormwater	Likely
Lead	4.2 - 136 mg/kg	4 sites exceed ISQG-low (50 mg/kg) No sites exceed ISQG-high (220 mg/kg)	Lower at most sites	Legacy, contaminated soils	Likely through transport of legacy contaminated soils
Copper	3 - 39 mg/kg	No sites exceed ISQG-low (65 mg/kg)	Not clear	Urban stormwater and soils	Likely, as concentrations closely correlated to zinc
Arsenic	0.6 - 13 mg/kg	No sites exceed ISQG-low (20 mg/kg)	No historical data for comparison	No contamination noted	Unlikely
Cadmium	0.05 – 0.39 mg/kg	No sites exceed ISQG-low (1.5 mg/kg)	No change	Urban stormwater	Likely as concentrations closely correlated to copper and zinc
Chromium	8 - 25 mg/kg	No sites exceed ISQG-low (80 mg/kg)	No change	Soils, with generally similar concentrations	Unlikely, concentrations related to sediment grain size
Nickel	7 - 13 mg/kg	No sites exceed ISQG-low (21 mg/kg)	No change	Soils, with generally similar concentrations	Unlikely, concentrations related to sediment grain size
Phosphorus	310 - 890 mg/kg	Not applicable	No historical data to compare to	Mixture	Unlikely

contaminated sediments conveyed in urban stormwater is the most likely explanation for these differences. However, there was considerable overlap in the metal concentrations between land uses and, for the most part, differences were not statistically significant.

A hotspot of PAH contamination was found in the Heathcote River, downstream of Colombo Street. This is likely to be derived from coal tar residues that were used for roading materials in this part of Christchurch, and in other areas. These types of residues are less bioavailable and are less toxic than fresh tars but are likely to cause toxicity at the concentrations found at that site.

The Canterbury earthquakes of 2010 and 2011 resulted in large amounts of liquefaction around the Heathcote River / Ōpawharo catchment, and some of these sediments may have entered the river and its tributaries. These sediments are expected to have lower concentrations of contaminants than stormwater derived sediments and may be the cause of lower than expected metal concentrations in Steamwharf Stream.

Based on the results from this, and previous studies, a range of recommendations for stormwater contaminant catchment management are presented in the next section.

9 Recommendations for Stormwater Management and Monitoring

9.1 Recommendations for Stormwater Management

This sediment quality survey has identified zinc, lead and PAHs as the primary contaminants of concern due to a number of locations where guidelines were exceeded. Whilst lead concentrations are an issue at a small number of locations, the concentrations of lead in the sediment are lower than when measured in the 1980s and they are expected to decline further due to lead being removed from petrol. Therefore there are no recommendations for dealing specifically with lead.

The likely source of the extremely elevated PAHs in sediments at one site is roading materials and roadside soils rather than vehicle or combustion sources. The concentrations in the sediments are at levels that can be expected to cause chronic effects on aquatic life and as such these results should be confirmed through additional sampling. Ideally this would be conducted both at the site, and at multiple distances upstream and downstream to quantify the extent of the contamination. If these results confirm the very high concentrations then toxicity testing may be useful. Chronic toxicity testing on sediment samples collected at this location would be undertaken with a suitable aquatic organism. This information can then be combined along with the ecological survey data using a weight-of-evidence approach (e.g., Chapman et al. 2002) to provide a robust assessment of the ecological risk of coal-tar contaminated sediments.

Locations where zinc concentrations exceeded guidelines were not confined to a single part of the catchment, being in the upper, mid and lower Heathcote River, as well as the City Outfall Drain. This suggests a catchment-wide approach is needed to manage sediment zinc concentrations, particularly to prevent further increases, and further exceedances of the ISQG-high. One such method may be promoting the use of low zinc yielding materials when replacing roofs in existing developed areas, especially in industrial areas.

Stormwater management could focus on newly developing areas as they are converted from rural to urban landuse, to prevent the overall catchment contaminant loads from increasing significantly. Source control methods, again, such as promoting the use of low zinc yielding materials would be of most benefit in maintaining zinc concentrations. In addition, water sensitive design would reduce the overall concentrations of contaminants reaching the streams.

The City Outfall Drain / Linwood Canal was ranked amongst the worst sites for sediment quality measured in this study. There may be greater potential for remediation of the sediment in this waterway due to the smaller and more confined catchment, compared to the other lowly ranked sites, located in the lower reaches of the Heathcote River. The City Outfall Drain was the only site where the ISQG-high guideline was exceeded by zinc (or any other metal). This survey did not include sites identified in previous studies as having poorest sediment quality, that is, Haytons Drain and Curletts Road Drain. Stormwater management efforts may be more, or equally usefully spent in those areas.

For these three sub-catchments, it may be useful to include the following actions:

1. **Sediment toxicity testing to elucidate whether current concentrations are resulting in adverse effects on biota:** This would provide evidence as to whether sediment quality, or other factors (water quality, habitat) are causing deterioration in the ecological communities in these locations. This would be most easily undertaken by collecting a large sediment sample at each site and submitting to an appropriate laboratory for chronic (>4 days) toxicity testing with a New Zealand invertebrate or fish species.

2. **Remediation of the sediments:** If toxicity testing shows that sediment is a major factor in limiting the biota at these sites, dredging to remove the contaminated sediment may be an option to reduce the metal concentrations. There are however several issues that need to be considered in relation to this: a) the adverse effect of the dredging process on the in-stream biota; and b) whether this will have a long-term beneficial effect or not. To ensure that dredging will mitigate this issue, the contaminant sources need to be identified and managed otherwise contaminants may accumulate to toxic concentrations again.

3. **Further investigations to identify contaminant sources:** These should include sediment and stormwater quality measurements and reconnaissance surveys. Measurement of sediment quality at additional locations in the City Outfall Drain could confirm the results found in this current survey and provide greater information to localise the sources of contaminants. Event-based water sampling for metals at multiple locations, including within the stormwater network as well as the streams, would provide information on the on-going sources at different locations. Reconnaissance surveys in these catchments may identify sites that are contributing excessive loads of contaminants (some of this information may be available already through HAIL studies).

4. **On-site stormwater management to prevent on-going degradation:** If sources of contaminants can be identified through the further investigations outlined above, then stormwater management options could be implemented to reduce contaminant inputs. These may include on-site management practices within industrial sites to reduce spills and improve stormwater quality being discharged, or installing stormwater treatment devices at key locations.

The survey showed that contaminants were generally at lower concentrations in the sediments of Cashmere Stream and previous ecological surveys have shown high value ecological communities in this stream (McMurtrie & James 2013). Stormwater management in the Cashmere Stream and tributary catchments should focus on ensuring sediment quality does not degrade to levels in the remainder of Heathcote River catchment and that the stream can continue to support relatively well-functioning ecosystems. To achieve this, stormwater management should include source control, to reduce the sources of the contaminants, particularly zinc; and water sensitive design, to reduce the transport of contaminants to the stream. Any future urban development in these catchments, including greenfields development of the rural areas at the top of the catchment, should incorporate such stormwater management methods.

9.2 Recommendations for Future Monitoring

Stormwater managers are very interested in understanding whether metal concentrations in stream sediments have changed over time. However, this is difficult to assess based on the data collected for this study. This sediment survey, and others in Christchurch streams, have shown that sediment quality is inherently variable in streams, due to catchment and reach-scale differences. Furthermore the sediment texture of samples can vary markedly from one survey to the next, and consequently metal concentrations vary too. Despite these complications, decreases have been noted between recent and historical sediment lead concentrations; and some studies have found increases in zinc concentrations. However, the significance of such changes depends on factors such as how widespread they are across the catchment and the magnitude of any changes. There is much greater uncertainty over apparent changes that occur only within individual tributaries or sub-catchments. This may be of particular importance in locations or subcatchments where stormwater managers wish to assess the effectiveness of any stormwater management initiavies.

We suggest that the methodology for future studies is amended to include analysis of 3-5 replicates at a fixed subset of sites where change over time is to be assessed. This could comprise of five sites distributed throughout the catchment, for example in the lower reaches of the Cashmere Stream, the upper Heathcote (upstream of Haytons and Curletts Drains), two sites in the middle reaches and a site at the Heathcote River mouth. Replication at these sites would enable statistical comparisons between sampling years and trend analysis, which would enable stormwater managers to have more confidence in the results.

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Appendix A List of Sites

Table A-1: Survey site locations for the 2015 instream sediment quality survey.

Site No.	Catchment	Site Name	Easting	Northing	Reasoning	Last Sediment surveys
1	Heathcote River	Cashmere Stream: upstream of Sutherlands Road	2476053	5735601	Long-term & South-West SMP aquatic ecology site; long-term water quality site; nearby to 1988 sediment quality site	Robb (1988) - Site 26 (nearby)
2	Heathcote River	Cashmere Stream: Penruddock Rise	2477914	5736703	Long-term & South-West SMP aquatic ecology site; 1988 sediment quality site	Robb (1988) - Site 42
3	Heathcote River	Heathcote River: at Templetons Road	2475917	5738512	South-West SMP aquatic ecology site; 1988 sediment quality site	Robb (1988) - Site 83
4	Heathcote River	Heathcote River: Canterbury Park/Showgrounds	2476513	5739053	Long-term & South-West SMP aquatic ecology site; long-term sediment quality site	Robb (1988) & Kingett Mitchell (2005) - Site 90/HE22
5	Heathcote River	Heathcote River: downstream of Spreydon Domain	2477972	5738777	Long-term & South-West SMP aquatic ecology site; nearby to 1988 sediment quality site	Robb (1988) - Site 102 (nearby)
6	Heathcote River	Heathcote River: Rose Street/Centennial Park	2478700	5737538	Long-term & South-West SMP aquatic ecology site; Long-term water quality site; nearby to long-term sediment quality site	Robb (1988) & Kingett Mitchell (2005) - Site 115/HE27 (nearby)
7	Heathcote River	Heathcote River: downstream of Barrington Street	2480159	5737791	Long-term aquatic ecology site; nearby to 1988 sediment quality site	Robb (1988) - Site 124 (nearby)
8	Heathcote River	Cashmere Brook: Ashgrove Terrace	2480258	5737964	Long-term aquatic ecology site	Sediment not previously sampled
9	Heathcote River	Heathcote River: downstream of Colombo Street	2480841	5738474	Long-term aquatic ecology site; nearby to 1988 sediment quality site	Robb (1988) - Site 127 (nearby)
10	Heathcote River	Heathcote River: downstream of Tennyson Street	2481520	5738845	Long-term aquatic ecology site; nearby to 1988 sediment quality site	Robb (1988) - Site 138 (nearby)
11	Heathcote River	Jacksons Creek: Cameron Reserve	2481211	5739629	Long-term aquatic ecology site	Sediment not previously sampled
12	Heathcote River	Heathcote River: Aynsley Terrace	2482928	5738430	Previous fish survey; nearby to 1988 sediment quality site	Robb (1988) - Site 147 (nearby)
13	Heathcote River	Heathcote River: Catherine Street (tidal site)	2484415	5739494	Previous biological and botanical survey; long-term water quality site;1988 sediment quality site	Robb (1988) - Site 164
14	Heathcote River	Heathcote River: Tunnel Road (tidal site)	2485076	5739154	Previous biological and botanical survey; long-term water quality site;1988 sediment quality site	Robb (1988) - Site 179

Site No.	Catchment	Site Name	Easting	Northing	Reasoning	Last Sediment surveys
15	Heathcote River	Steamwharf Stream	2485052	5739405	Previous inanga spawning reach severely impacted by sedimentation from earthquakes	Sediment not previously sampled
16	Heathcote River	Heathcote River: Ferrymead Bridge (tidal site)	2486494	5738760	Previous biological and botanical survey; long-term water quality site; long-term sediment quality site	Robb (1988) & Kingett Mitchell (2005) - Site 190/HE34
17	Estuary Drain (within Estuary SMP area)	Estuary Drain: Bexley Park	2486914[1]	5743051	Previous fish survey	Sediment not previously sampled
18	City Outfall Drain/Linwood Canal (within Estuary SMP area)	City Outfall Drain/Linwood Canal: Dyers Road/Linwood Avenue	2485373	5740054	Previous botanical survey; 1988 sediment quality site	Robb (1988) - Site OD8

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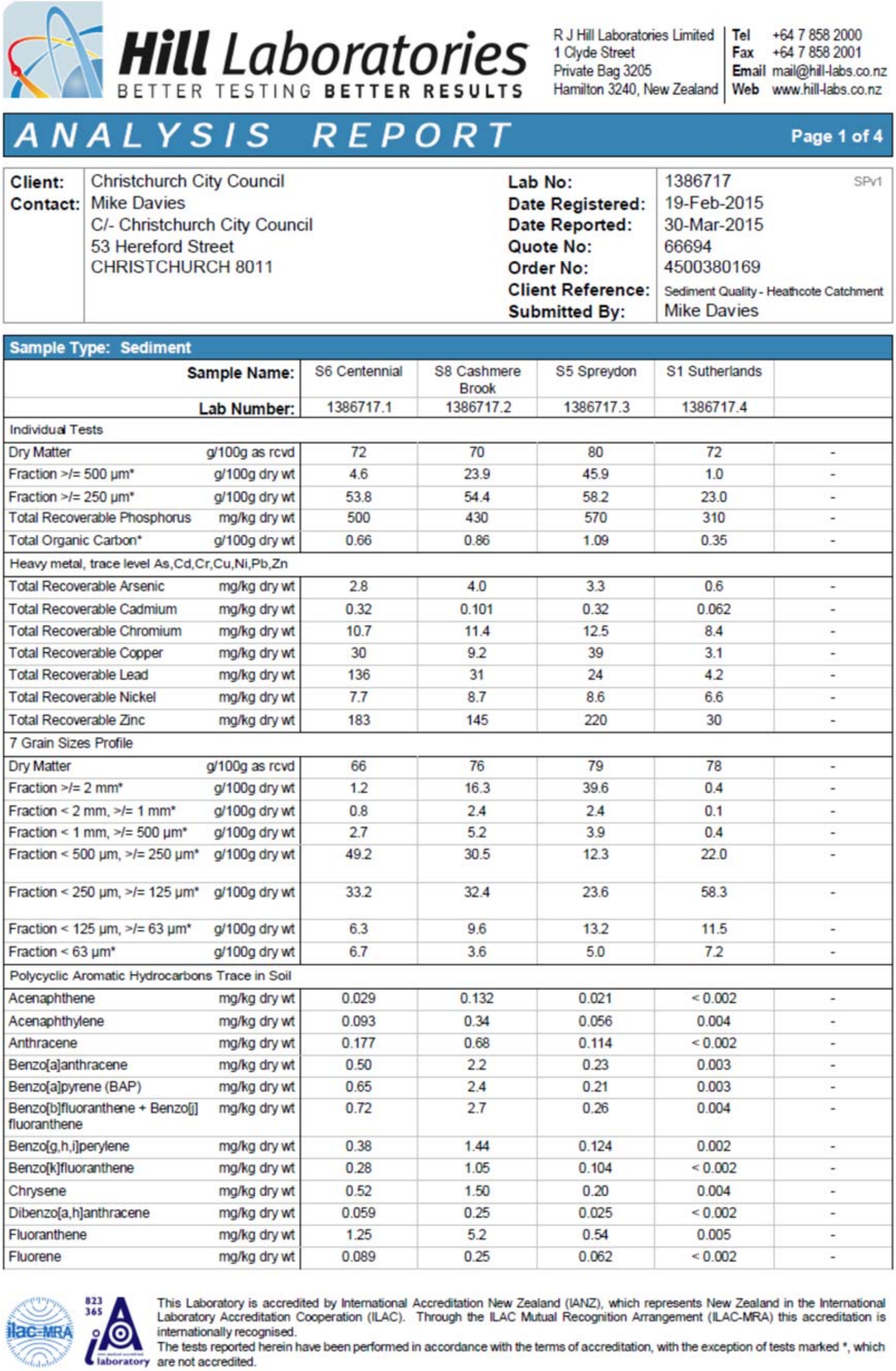
[1] Exact location and coordinates to be confirmed by aquatic ecology surveyors

Appendix B Analytical Results



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ANALYSIS REPORT

Page 1 of 4

Client:	Christchurch City Council	**Lab No:**	1386717 SPv1
Contact:	Mike Davies	**Date Registered:**	19-Feb-2015
	C/- Christchurch City Council	**Date Reported:**	30-Mar-2015
	53 Hereford Street	**Quote No:**	66694
	CHRISTCHURCH 8011	**Order No:**	4500380169
		Client Reference:	Sediment Quality - Heathcote Catchment
		Submitted By:	Mike Davies

Sample Type: Sediment

Sample Name:		S6 Centennial	S8 Cashmere Brook	S5 Spreydon	S1 Sutherlands	
Lab Number:		1386717.1	1386717.2	1386717.3	1386717.4	
Individual Tests						
Dry Matter	g/100g as rcvd	72	70	80	72	-
Fraction >/= 500 µm*	g/100g dry wt	4.6	23.9	45.9	1.0	-
Fraction >/= 250 µm*	g/100g dry wt	53.8	54.4	58.2	23.0	-
Total Recoverable Phosphorus	mg/kg dry wt	500	430	570	310	-
Total Organic Carbon*	g/100g dry wt	0.66	0.86	1.09	0.35	-
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	2.8	4.0	3.3	0.6	-
Total Recoverable Cadmium	mg/kg dry wt	0.32	0.101	0.32	0.062	-
Total Recoverable Chromium	mg/kg dry wt	10.7	11.4	12.5	8.4	-
Total Recoverable Copper	mg/kg dry wt	30	9.2	39	3.1	-
Total Recoverable Lead	mg/kg dry wt	136	31	24	4.2	-
Total Recoverable Nickel	mg/kg dry wt	7.7	8.7	8.6	6.6	-
Total Recoverable Zinc	mg/kg dry wt	183	145	220	30	-
7 Grain Sizes Profile						
Dry Matter	g/100g as rcvd	66	76	79	78	-
Fraction >/= 2 mm*	g/100g dry wt	1.2	16.3	39.6	0.4	-
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.8	2.4	2.4	0.1	-
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	2.7	5.2	3.9	0.4	-
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	49.2	30.5	12.3	22.0	-
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	33.2	32.4	23.6	58.3	-
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	6.3	9.6	13.2	11.5	-
Fraction < 63 µm*	g/100g dry wt	6.7	3.6	5.0	7.2	-
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Acenaphthene	mg/kg dry wt	0.029	0.132	0.021	< 0.002	-
Acenaphthylene	mg/kg dry wt	0.093	0.34	0.056	0.004	-
Anthracene	mg/kg dry wt	0.177	0.68	0.114	< 0.002	-
Benzo[a]anthracene	mg/kg dry wt	0.50	2.2	0.23	0.003	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.65	2.4	0.21	0.003	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.72	2.7	0.26	0.004	-
Benzo[g,h,i]perylene	mg/kg dry wt	0.38	1.44	0.124	0.002	-
Benzo[k]fluoranthene	mg/kg dry wt	0.28	1.05	0.104	< 0.002	-
Chrysene	mg/kg dry wt	0.52	1.50	0.20	0.004	-
Dibenzo[a,h]anthracene	mg/kg dry wt	0.059	0.25	0.025	< 0.002	-
Fluoranthene	mg/kg dry wt	1.25	5.2	0.54	0.005	-
Fluorene	mg/kg dry wt	0.089	0.25	0.062	< 0.002	-

Sample Type: Sediment

Sample Name:		S6 Centennial	S8 Cashmere Brook	S5 Spreydon	S1 Sutherlands	
Lab Number:		1386717.1	1386717.2	1386717.3	1386717.4	
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.37	1.91	0.137	0.002	-
Naphthalene	mg/kg dry wt	0.047	0.074	0.011	< 0.010	-
Phenanthrene	mg/kg dry wt	0.76	3.1	0.44	0.004	-
Pyrene	mg/kg dry wt	1.10	4.7	0.45	0.005	-
Haloethers Trace in SVOC Soil Samples by GC-MS						
Bis(2-chloroethoxy) methane	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
Bis(2-chloroethyl)ether	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
Bis(2-chloroisopropyl)ether	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
4-Bromophenyl phenyl ether	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
4-Chlorophenyl phenyl ether	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
Nitrogen containing compounds Trace in SVOC Soil Samples, GC-MS						
3,3'-Dichlorobenzidine	mg/kg dry wt	< 0.8	< 0.8	< 0.7	< 0.8	-
2,4-Dinitrotoluene	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
2,6-Dinitrotoluene	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Nitrobenzene	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
N-Nitrosodi-n-propylamine	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
N-Nitrosodiphenylamine	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Organochlorine Pesticides Trace in SVOC Soil Samples by GC-MS						
Aldrin	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
alpha-BHC	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
beta-BHC	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
delta-BHC	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
gamma-BHC (Lindane)	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
4,4'-DDD	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
4,4'-DDE	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
4,4'-DDT	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Dieldrin	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
Endosulfan I	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Endosulfan II	mg/kg dry wt	< 0.5	< 0.5	< 0.5	< 0.5	-
Endosulfan sulphate	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Endrin	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Endrin ketone	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Heptachlor	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
Heptachlor epoxide	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
Hexachlorobenzene	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
Polycyclic Aromatic Hydrocarbons Trace in SVOC Soil Samples						
Acenaphthene	mg/kg dry wt	< 0.10	0.18	< 0.10	< 0.10	-
Acenaphthylene	mg/kg dry wt	0.13	0.33	< 0.10	< 0.10	-
Anthracene	mg/kg dry wt	0.23	0.85	< 0.10	< 0.10	-
Benzo[a]anthracene	mg/kg dry wt	1.15	4.4	0.13	< 0.10	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	1.20	4.7	0.14	< 0.15	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	1.52	5.5	0.19	< 0.15	-
Benzo[g,h,i]perylene	mg/kg dry wt	0.84	3.1	< 0.14	< 0.15	-
Benzo[k]fluoranthene	mg/kg dry wt	0.57	2.1	< 0.14	< 0.15	-
2-Chloronaphthalene	mg/kg dry wt	< 0.10	< 0.10	< 0.10	< 0.10	-
Chrysene	mg/kg dry wt	0.95	3.8	0.11	< 0.10	-
Dibenzo[a,h]anthracene	mg/kg dry wt	0.26	0.94	< 0.14	< 0.15	-
Fluoranthene	mg/kg dry wt	2.4	10.2	0.21	< 0.10	-
Fluorene	mg/kg dry wt	< 0.10	0.30	< 0.10	< 0.10	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.68	2.4	< 0.14	< 0.15	-
2-Methylnaphthalene	mg/kg dry wt	< 0.10	< 0.10	< 0.10	< 0.10	-
Naphthalene	mg/kg dry wt	< 0.10	< 0.10	< 0.10	< 0.10	-
Phenanthrene	mg/kg dry wt	1.22	5.7	< 0.10	< 0.10	-
Pyrene	mg/kg dry wt	2.0	8.8	0.20	< 0.10	-

Sample Type: Sediment

Sample Name:		S6 Centennial	S8 Cashmere Brook	S5 Spreydon	S1 Sutherlands	
Lab Number:		1386717.1	1386717.2	1386717.3	1386717.4	
Phenols Trace in SVOC Soil Samples by GC-MS						
4-Chloro-3-methylphenol	mg/kg dry wt	< 0.5	< 0.5	< 0.5	< 0.5	-
2-Chlorophenol	mg/kg dry wt	< 0.2	< 0.2	< 0.2	< 0.2	-
2,4-Dichlorophenol	mg/kg dry wt	< 0.2	< 0.2	< 0.2	< 0.2	-
2,4-Dimethylphenol	mg/kg dry wt	< 0.4	< 0.4	< 0.4	< 0.4	-
3 & 4-Methylphenol (m- + p-cresol)	mg/kg dry wt	< 0.4	< 0.4	< 0.4	< 0.4	-
2-Methylphenol (o-Cresol)	mg/kg dry wt	< 0.2	< 0.2	< 0.2	< 0.2	-
2-Nitrophenol	mg/kg dry wt	< 0.4	< 0.4	< 0.4	< 0.4	-
Pentachlorophenol (PCP)	mg/kg dry wt	< 6	< 6	< 6	< 6	-
Phenol	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
2,4,5-Trichlorophenol	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
2,4,6-Trichlorophenol	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Plasticisers Trace in SVOC Soil Samples by GC-MS						
Bis(2-ethylhexyl)phthalate	mg/kg dry wt	0.6	< 0.7	< 0.6	< 0.6	-
Butylbenzylphthalate	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Di(2-ethylhexyl)adipate	mg/kg dry wt	< 0.2	< 0.2	< 0.2	< 0.2	-
Diethylphthalate	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Dimethylphthalate	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Di-n-butylphthalate	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Di-n-octylphthalate	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Other Halogenated compounds Trace in SVOC Soil Samples by GC-MS						
1,2-Dichlorobenzene	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
1,3-Dichlorobenzene	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
1,4-Dichlorobenzene	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Hexachlorobutadiene	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
Hexachlorocyclopentadiene	mg/kg dry wt	< 0.8	< 0.8	< 0.7	< 0.8	-
Hexachloroethane	mg/kg dry wt	< 0.3	< 0.4	< 0.3	< 0.3	-
1,2,4-Trichlorobenzene	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
Other SVOC Trace in SVOC Soil Samples by GC-MS						
Benzyl alcohol	mg/kg dry wt	< 1.5	< 1.6	< 1.4	< 1.5	-
Carbazole	mg/kg dry wt	< 0.15	0.23	< 0.14	< 0.15	-
Dibenzofuran	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-
Isophorone	mg/kg dry wt	< 0.15	< 0.16	< 0.14	< 0.15	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment

Test	**Method Description**	**Default Detection Limit**	**Sample No**
Individual Tests			
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-4
Dry Matter (Env)	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) , gravimetry. US EPA 3550. (Free water removed before analysis).	0.10 g/100g as rcvd	1-4
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-4
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-4
Total Organic Carbon*	Acid pretreatment to remove carbonates if present, neutralisation, Elementar Combustion Analyser.	0.05 g/100g dry wt	1-4
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1-4
7 Grain Sizes Profile*		-	1-4
Polycyclic Aromatic Hydrocarbons Trace in Soil	Sonication extraction, SPE cleanup, GC-MS SIM analysis US EPA 8270C. Tested on as received sample [KBIs:5784,4273,2695]	0.002 - 0.010 mg/kg dry wt	1-4

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Semivolatile Organic Compounds Trace in Soil by GC-MS	Sonication extraction, GPC cleanup, GC-MS FS analysis. Tested on as received sample	0.10 - 6 mg/kg dry wt	1-4
7 Grain Sizes Profile			
Dry Matter	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-4
Fraction < 2 mm, >/= 1 mm*	Wet sieving, 2.00 mm and 1.00 mm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4
Fraction < 1 mm, >/= 500 µm*	Wet sieving, 1.00 mm and 500 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4
Fraction < 500 µm, >/= 250 µm*	Wet sieving, 500 µm and 250 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4
Fraction < 250 µm, >/= 125 µm*	Wet sieving, 250 µm and 125 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4
Fraction < 125 µm, >/= 63 µm*	Wet sieving, 125 µm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4
Fraction < 63 µm*	Wet sieving, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental Division

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ANALYSIS REPORT

Client:	Christchurch City Council	**Lab No:**	1384614 SPv1
Contact:	Mike Davies C/- Christchurch City Council 53 Hereford Street CHRISTCHURCH 8011	**Date Registered:**	14-Feb-2015
		Date Reported:	24-Mar-2015
		Quote No:	66694
		Order No:	4500380169
		Client Reference:	Sediment Quality - Heathcote Catchment
		Submitted By:	Mike Davies

Sample Type: Sediment

	Sample Name:	S7	S4	S10	S9	
	Lab Number:	1384614.1	1384614.2	1384614.3	1384614.4	
Individual Tests						
Dry Matter	g/100g as rcvd	73	37	70	64	-
Fraction >/= 500 µm*	g/100g dry wt	2.8	29.1	1.6	46.9	-
Fraction >/= 250 µm*	g/100g dry wt	27.6	49.5	3.5	67.0	-
Total Recoverable Phosphorus	mg/kg dry wt	350	410	370	600	-
Total Organic Carbon*	g/100g dry wt	0.84	1.57	2.0	2.9	-
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	2.2	2.2	2.9	4.2	-
Total Recoverable Cadmium	mg/kg dry wt	0.162	0.185	0.145	0.22	-
Total Recoverable Chromium	mg/kg dry wt	10.6	8.8	10.4	11.6	-
Total Recoverable Copper	mg/kg dry wt	9.0	5.7	13.9	17.5	-
Total Recoverable Lead	mg/kg dry wt	136	11.5	21	36	-
Total Recoverable Nickel	mg/kg dry wt	8.1	6.1	7.6	9.4	-
Total Recoverable Zinc	mg/kg dry wt	148	130	163	230	-
7 Grain Sizes Profile						
Dry Matter	g/100g as rcvd	73	62	61	52	-
Fraction >/= 2 mm*	g/100g dry wt	1.1	27.1	0.6	36.9	-
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.4	0.6	0.4	3.6	-
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	1.3	1.4	0.7	6.4	-
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	24.8	20.4	1.9	20.0	-
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	49.2	38.9	22.6	18.0	-
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	16.3	5.5	50.6	5.9	-
Fraction < 63 µm*	g/100g dry wt	7.0	6.1	23.2	9.1	-
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Acenaphthene	mg/kg dry wt	0.029	0.006	0.023	5.4	-
Acenaphthylene	mg/kg dry wt	0.084	0.018	0.081	3.9	-
Anthracene	mg/kg dry wt	0.171	0.015	0.126	21	-
Benzo[a]anthracene	mg/kg dry wt	0.59	0.056	0.49	39	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.65	0.059	0.51	43	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.70	0.088	0.63	44	-
Benzo[g,h,i]perylene	mg/kg dry wt	0.45	0.046	0.34	26	-
Benzo[k]fluoranthene	mg/kg dry wt	0.30	0.031	0.24	17.1	-
Chrysene	mg/kg dry wt	0.54	0.061	0.46	35	-
Dibenzo[a,h]anthracene	mg/kg dry wt	0.083	0.008	0.061	3.9	-
Fluoranthene	mg/kg dry wt	1.76	0.116	1.12	128	-
Fluorene	mg/kg dry wt	0.055	0.007	0.042	8.1	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.44	0.046	0.35	27	-
Naphthalene	mg/kg dry wt	0.015	< 0.03	0.013	0.89	-

Sample Type: Sediment						
	Sample Name:	S7	S4	S10	S9	
	Lab Number:	1384614.1	1384614.2	1384614.3	1384614.4	
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Phenanthrene	mg/kg dry wt	0.78	0.055	0.57	103	-
Pyrene	mg/kg dry wt	1.57	0.107	1.06	109	-
Haloethers Trace in SVOC Soil Samples by GC-MS						
Bis(2-chloroethoxy) methane	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
Bis(2-chloroethyl)ether	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
Bis(2-chloroisopropyl)ether	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
4-Bromophenyl phenyl ether	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
4-Chlorophenyl phenyl ether	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
Nitrogen containing compounds Trace in SVOC Soil Samples, GC-MS						
3,3'-Dichlorobenzidine	mg/kg dry wt	< 0.9	< 1.7	< 0.9	< 1.0	-
2,4-Dinitrotoluene	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
2,6-Dinitrotoluene	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Nitrobenzene	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
N-Nitrosodi-n-propylamine	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
N-Nitrosodiphenylamine	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Organochlorine Pesticides Trace in SVOC Soil Samples by GC-MS						
Aldrin	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
alpha-BHC	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
beta-BHC	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
delta-BHC	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
gamma-BHC (Lindane)	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
4,4'-DDD	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
4,4'-DDE	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
4,4'-DDT	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Dieldrin	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
Endosulfan I	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Endosulfan II	mg/kg dry wt	< 0.5	< 0.7	< 0.5	< 0.5	-
Endosulfan sulphate	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Endrin	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Endrin ketone	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Heptachlor	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
Heptachlor epoxide	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
Hexachlorobenzene	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
Polycyclic Aromatic Hydrocarbons Trace in SVOC Soil Samples						
Acenaphthene	mg/kg dry wt	< 0.10	< 0.17	< 0.10	1.42	-
Acenaphthylene	mg/kg dry wt	0.10	< 0.17	< 0.10	2.4	-
Anthracene	mg/kg dry wt	0.22	< 0.17	0.12	31	-
Benzo[a]anthracene	mg/kg dry wt	1.15	< 0.17	0.71	64	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	1.25	< 0.4	0.81	58	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	1.54	< 0.4	1.04	60	-
Benzo[g,h,i]perylene	mg/kg dry wt	0.88	< 0.4	0.61	39	-
Benzo[k]fluoranthene	mg/kg dry wt	0.54	< 0.4	0.37	23	-
2-Chloronaphthalene	mg/kg dry wt	< 0.10	< 0.17	< 0.10	< 0.10	-
Chrysene	mg/kg dry wt	1.02	< 0.17	0.64	43	-
Dibenzo[a,h]anthracene	mg/kg dry wt	0.25	< 0.4	0.17	5.1	-
Fluoranthene	mg/kg dry wt	2.7	0.16	1.57	188	-
Fluorene	mg/kg dry wt	< 0.10	< 0.17	< 0.10	3.5	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.67	< 0.4	0.47	33	-
2-Methylnaphthalene	mg/kg dry wt	< 0.10	< 0.17	< 0.10	0.13	-
Naphthalene	mg/kg dry wt	< 0.10	< 0.17	< 0.10	0.31	-
Phenanthrene	mg/kg dry wt	1.47	< 0.17	0.76	133	-
Pyrene	mg/kg dry wt	2.4	0.21	1.43	146	-
Phenols Trace in SVOC Soil Samples by GC-MS						
4-Chloro-3-methylphenol	mg/kg dry wt	< 0.5	< 0.7	< 0.5	< 0.5	-

Sample Type: Sediment

Sample Name:		S7	S4	S10	S9	
Lab Number:		1384614.1	1384614.2	1384614.3	1384614.4	
Phenols Trace in SVOC Soil Samples by GC-MS						
2-Chlorophenol	mg/kg dry wt	< 0.2	< 0.4	< 0.2	< 0.2	-
2,4-Dichlorophenol	mg/kg dry wt	< 0.2	< 0.4	< 0.2	< 0.2	-
2,4-Dimethylphenol	mg/kg dry wt	< 0.4	< 0.4	< 0.4	< 0.4	-
3 & 4-Methylphenol (m- + p-cresol)	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
2-Methylphenol (o-Cresol)	mg/kg dry wt	< 0.2	< 0.4	< 0.2	< 0.2	-
2-Nitrophenol	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Pentachlorophenol (PCP)	mg/kg dry wt	< 6	< 7	< 6	< 6	-
Phenol	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
2,4,5-Trichlorophenol	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
2,4,6-Trichlorophenol	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Plasticisers Trace in SVOC Soil Samples by GC-MS						
Bis(2-ethylhexyl)phthalate	mg/kg dry wt	< 0.7	2.5	1.2	0.8	-
Butylbenzylphthalate	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Di(2-ethylhexyl)adipate	mg/kg dry wt	< 0.2	< 0.4	< 0.2	< 0.2	-
Diethylphthalate	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Dimethylphthalate	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Di-n-butylphthalate	mg/kg dry wt	9.4	2.1	< 0.4	< 0.4	-
Di-n-octylphthalate	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Other Halogenated compounds Trace in SVOC Soil Samples by GC-MS						
1,2-Dichlorobenzene	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
1,3-Dichlorobenzene	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
1,4-Dichlorobenzene	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Hexachlorobutadiene	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
Hexachlorocyclopentadiene	mg/kg dry wt	< 0.9	< 1.7	< 0.9	< 1.0	-
Hexachloroethane	mg/kg dry wt	< 0.4	< 0.7	< 0.4	< 0.4	-
1,2,4-Trichlorobenzene	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-
Other SVOC Trace in SVOC Soil Samples by GC-MS						
Benzyl alcohol	mg/kg dry wt	< 1.7	< 4	< 1.8	< 1.9	-
Carbazole	mg/kg dry wt	< 0.17	< 0.4	< 0.18	4.5	-
Dibenzofuran	mg/kg dry wt	< 0.17	< 0.4	< 0.18	1.86	-
Isophorone	mg/kg dry wt	< 0.17	< 0.4	< 0.18	< 0.19	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-4
Dry Matter (Env)	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) , gravimetry. US EPA 3550. (Free water removed before analysis).	0.10 g/100g as rcvd	1-4
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-4
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-4
Total Organic Carbon*	Acid pretreatment to remove carbonates if present, neutralisation, Elementar Combustion Analyser.	0.05 g/100g dry wt	1-4
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1-4
7 Grain Sizes Profile*		-	1-4
Polycyclic Aromatic Hydrocarbons Trace in Soil	Sonication extraction, SPE cleanup, GC-MS SIM analysis US EPA 8270C. Tested on as received sample [KBIs:5784,4273,2695]	0.002 - 0.010 mg/kg dry wt	1-4

Sample Type: Sediment

Test	**Method Description**	**Default Detection Limit**	**Sample No**
Semivolatile Organic Compounds Trace in Soil by GC-MS	Sonication extraction, GPC cleanup, GC-MS FS analysis. Tested on as received sample	0.10 - 6 mg/kg dry wt	1-4
7 Grain Sizes Profile			
Dry Matter	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-4
Fraction < 2 mm, >/= 1 mm*	Wet sieving, 2.00 mm and 1.00 mm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4
Fraction < 1 mm, >/= 500 µm*	Wet sieving, 1.00 mm and 500 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4
Fraction < 500 µm, >/= 250 µm*	Wet sieving, 500 µm and 250 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4
Fraction < 250 µm, >/= 125 µm*	Wet sieving, 250 µm and 125 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4
Fraction < 125 µm, >/= 63 µm*	Wet sieving, 125 µm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4
Fraction < 63 µm*	Wet sieving, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-4

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

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ANALYSIS REPORT

Client:	Christchurch City Council	**Lab No:**	1393602 SPv1
Contact:	Mike Davies	**Date Registered:**	06-Mar-2015
	C/- Christchurch City Council	**Date Reported:**	17-Apr-2015
	53 Hereford Street	**Quote No:**	66694
	CHRISTCHURCH 8011	**Order No:**	4500380169
		Client Reference:	Sediment Quality - Heathcote Catchment
		Submitted By:	Belinda Margetts

Sample Type: Sediment

	Sample Name:	S15 Steam Wharf 02-Mar-2015	S13 Catherine 04-Mar-2015	S12 Aynsley 04-Mar-2015	S17 Estuary 04-Mar-2015	S14 Tunnel 03-Mar-2015
	Lab Number:	1393602.1	1393602.2	1393602.3	1393602.4	1393602.5
Individual Tests						
Dry Matter	g/100g as rcvd	76	53	45	66	62
Fraction >/= 500 µm*	g/100g dry wt	1.2	8.1	2.7	1.8	1.5
Fraction >/= 250 µm*	g/100g dry wt	15.8	12.6	5.3	6.0	2.7
Total Recoverable Phosphorus	mg/kg dry wt	390	520	570	890	540
Total Organic Carbon*	g/100g dry wt	0.53	2.5	2.9	0.85	1.60
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	3	4.6	6.7	13	4.4
Total Recoverable Cadmium	mg/kg dry wt	0.064	0.30	0.39	0.097	0.25
Total Recoverable Chromium	mg/kg dry wt	14.0	22	17.1	14.0	25
Total Recoverable Copper	mg/kg dry wt	6.3	24	30	10.4	18.5
Total Recoverable Lead	mg/kg dry wt	15.6	64	45	30	29
Total Recoverable Nickel	mg/kg dry wt	9.4	11.5	11.1	10.0	11.5
Total Recoverable Zinc	mg/kg dry wt	93	300	340	165	183
7 Grain Sizes Profile						
Dry Matter	g/100g as rcvd	71	54	49	61	69
Fraction >/= 2 mm*	g/100g dry wt	0.2	5.9	1.0	1.1	0.9
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.2	1.0	0.7	0.2	0.2
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	0.7	1.2	1.0	0.5	0.4
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	14.7	4.5	2.6	4.2	1.3
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	53.3	23.7	8.8	56.1	16.1
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	19.9	22.5	18.3	22.6	31.2
Fraction < 63 µm*	g/100g dry wt	11.0	41.3	67.6	15.3	49.9
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Acenaphthene	mg/kg dry wt	0.005	2.0	0.049	0.019	0.072
Acenaphthylene	mg/kg dry wt	0.017	1.34	0.115	0.063	0.141
Anthracene	mg/kg dry wt	0.026	3.7	0.177	0.071	0.25
Benzo[a]anthracene	mg/kg dry wt	0.168	5.8	0.48	0.25	0.63
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.174	5.6	0.75	0.31	1.02
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.23	5.6	0.74	0.32	0.77
Benzo[g,h,i]perylene	mg/kg dry wt	0.117	3.3	0.49	0.21	0.67
Benzo[k]fluoranthene	mg/kg dry wt	0.086	2.4	0.27	0.149	0.32
Chrysene	mg/kg dry wt	0.171	4.3	0.57	0.23	0.83
Dibenzo[a,h]anthracene	mg/kg dry wt	0.017	0.81	0.102	0.041	0.145
Fluoranthene	mg/kg dry wt	0.23	10.5	1.29	0.44	1.20
Fluorene	mg/kg dry wt	0.010	2.2	0.090	0.031	0.100
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.101	4.2	0.55	0.23	0.74

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The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Sediment

Sample Name:		S15 Steam Wharf 02-Mar-2015	S13 Catherine 04-Mar-2015	S12 Aynsley 04-Mar-2015	S17 Estuary 04-Mar-2015	S14 Tunnel 03-Mar-2015
Lab Number:		1393602.1	1393602.2	1393602.3	1393602.4	1393602.5
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Naphthalene	mg/kg dry wt	< 0.010	4.2	0.036	0.101	0.40
Phenanthrene	mg/kg dry wt	0.134	9.7	0.97	0.21	0.70
Pyrene	mg/kg dry wt	0.29	11.5	1.39	0.44	1.21
Haloethers Trace in SVOC Soil Samples by GC-MS						
Bis(2-chloroethoxy) methane	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
Bis(2-chloroethyl)ether	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
Bis(2-chloroisopropyl)ether	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
4-Bromophenyl phenyl ether	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
4-Chlorophenyl phenyl ether	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
Nitrogen containing compounds Trace in SVOC Soil Samples, GC-MS						
3,3'-Dichlorobenzidine	mg/kg dry wt	< 0.7	< 1.1	< 1.2	< 0.9	< 0.9
2,4-Dinitrotoluene	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
2,6-Dinitrotoluene	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Nitrobenzene	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
N-Nitrosodi-n-propylamine	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
N-Nitrosodiphenylamine	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Organochlorine Pesticides Trace in SVOC Soil Samples by GC-MS						
Aldrin	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
alpha-BHC	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
beta-BHC	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
delta-BHC	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
gamma-BHC (Lindane)	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
4,4'-DDD	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
4,4'-DDE	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
4,4'-DDT	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Dieldrin	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
Endosulfan I	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Endosulfan II	mg/kg dry wt	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Endosulfan sulphate	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Endrin	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Endrin ketone	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Heptachlor	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
Heptachlor epoxide	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
Hexachlorobenzene	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
Polycyclic Aromatic Hydrocarbons Trace in SVOC Soil Samples						
Acenaphthene	mg/kg dry wt	< 0.10	2.7	< 0.12	< 0.10	0.11
Acenaphthylene	mg/kg dry wt	< 0.10	1.20	< 0.12	< 0.10	< 0.10
Anthracene	mg/kg dry wt	< 0.10	4.7	0.15	< 0.10	0.23
Benzo[a]anthracene	mg/kg dry wt	0.12	8.3	0.78	0.19	0.82
Benzo[a]pyrene (BAP)	mg/kg dry wt	< 0.14	7.7	0.9	0.21	0.93
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.17	7.1	1.1	0.26	1.04
Benzo[g,h,i]perylene	mg/kg dry wt	< 0.14	5.2	0.8	0.19	0.80
Benzo[k]fluoranthene	mg/kg dry wt	< 0.14	2.9	0.4	< 0.17	0.34
2-Chloronaphthalene	mg/kg dry wt	< 0.10	< 0.11	< 0.12	< 0.10	< 0.10
Chrysene	mg/kg dry wt	0.10	5.4	0.65	0.16	0.62
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.14	1.5	< 0.3	< 0.17	0.19
Fluoranthene	mg/kg dry wt	0.26	15.1	1.66	0.32	1.51
Fluorene	mg/kg dry wt	< 0.10	2.6	< 0.12	< 0.10	0.14
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	< 0.14	4.6	0.6	< 0.17	0.59
2-Methylnaphthalene	mg/kg dry wt	< 0.10	3.3	< 0.12	< 0.10	0.30
Naphthalene	mg/kg dry wt	< 0.10	6.0	< 0.12	< 0.10	0.59
Phenanthrene	mg/kg dry wt	0.12	15.1	0.95	0.13	0.91
Pyrene	mg/kg dry wt	0.26	13.8	1.75	0.33	1.66
Phenols Trace in SVOC Soil Samples by GC-MS						

Sample Type: Sediment

Sample Name:		S15 Steam Wharf 02-Mar-2015	S13 Catherine 04-Mar-2015	S12 Aynsley 04-Mar-2015	S17 Estuary 04-Mar-2015	S14 Tunnel 03-Mar-2015
Lab Number:		1393602.1	1393602.2	1393602.3	1393602.4	1393602.5
Phenols Trace in SVOC Soil Samples by GC-MS						
4-Chloro-3-methylphenol	mg/kg dry wt	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
2-Chlorophenol	mg/kg dry wt	< 0.2	< 0.3	< 0.3	< 0.2	< 0.2
2,4-Dichlorophenol	mg/kg dry wt	< 0.2	< 0.3	< 0.3	< 0.2	< 0.2
2,4-Dimethylphenol	mg/kg dry wt	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
3 & 4-Methylphenol (m- + p-cresol)	mg/kg dry wt	< 0.4	< 0.5	< 0.5	< 0.4	< 0.4
2-Methylphenol (o-Cresol)	mg/kg dry wt	< 0.2	< 0.3	< 0.3	< 0.2	< 0.2
2-Nitrophenol	mg/kg dry wt	< 0.4	< 0.5	< 0.5	< 0.4	< 0.4
Pentachlorophenol (PCP)	mg/kg dry wt	< 6	< 6	< 6	< 6	< 6
Phenol	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
2,4,5-Trichlorophenol	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
2,4,6-Trichlorophenol	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Plasticisers Trace in SVOC Soil Samples by GC-MS						
Bis(2-ethylhexyl)phthalate	mg/kg dry wt	< 0.6	3.6	2.7	< 0.7	0.8
Butylbenzylphthalate	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Di(2-ethylhexyl)adipate	mg/kg dry wt	< 0.2	< 0.3	< 0.3	< 0.2	< 0.2
Diethylphthalate	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Dimethylphthalate	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Di-n-butylphthalate	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Di-n-octylphthalate	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Other Halogenated compounds Trace in SVOC Soil Samples by GC-MS						
1,2-Dichlorobenzene	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
1,3-Dichlorobenzene	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
1,4-Dichlorobenzene	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Hexachlorobutadiene	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
Hexachlorocyclopentadiene	mg/kg dry wt	< 0.7	< 1.1	< 1.2	< 0.9	< 0.9
Hexachloroethane	mg/kg dry wt	< 0.3	< 0.5	< 0.5	< 0.4	< 0.4
1,2,4-Trichlorobenzene	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18
Other SVOC Trace in SVOC Soil Samples by GC-MS						
Benzyl alcohol	mg/kg dry wt	< 1.4	< 3	< 3	< 1.7	< 1.8
Carbazole	mg/kg dry wt	< 0.14	0.3	< 0.3	< 0.17	< 0.18
Dibenzofuran	mg/kg dry wt	< 0.14	2.1	< 0.3	< 0.17	0.18
Isophorone	mg/kg dry wt	< 0.14	< 0.3	< 0.3	< 0.17	< 0.18

Sample Name:		S2 Cashmere Penruddock 05-Mar-2015	S18 Outfall 04-Mar-2015			
Lab Number:		1393602.6	1393602.7			
Individual Tests						
Dry Matter	g/100g as rcvd	63	66	-	-	-
Fraction >/= 500 µm*	g/100g dry wt	3.2	0.7	-	-	-
Fraction >/= 250 µm*	g/100g dry wt	10.9	2.0	-	-	-
Total Recoverable Phosphorus	mg/kg dry wt	480	630	-	-	-
Total Organic Carbon*	g/100g dry wt	0.60	1.74	-	-	-
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	4	4	-	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.054	0.20	-	-	-
Total Recoverable Chromium	mg/kg dry wt	11.9	21	-	-	-
Total Recoverable Copper	mg/kg dry wt	5.9	26	-	-	-
Total Recoverable Lead	mg/kg dry wt	11.5	57	-	-	-
Total Recoverable Nickel	mg/kg dry wt	9.7	12.5	-	-	-
Total Recoverable Zinc	mg/kg dry wt	52	450	-	-	-
7 Grain Sizes Profile						
Dry Matter	g/100g as rcvd	60	57	-	-	-
Fraction >/= 2 mm*	g/100g dry wt	2.4	0.1	-	-	-
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.3	< 0.1	-	-	-

Sample Type: Sediment

	Sample Name:	S2 Cashmere Penruddock 05-Mar-2015	S18 Outfall 04-Mar-2015			
	Lab Number:	1393602.6	1393602.7			
7 Grain Sizes Profile						
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	0.5	0.5	-	-	-
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	7.6	1.4	-	-	-
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	29.4	21.8	-	-	-
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	21.3	34.0	-	-	-
Fraction < 63 µm*	g/100g dry wt	38.3	42.2	-	-	-
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Acenaphthene	mg/kg dry wt	< 0.003	0.010	-	-	-
Acenaphthylene	mg/kg dry wt	0.010	0.065	-	-	-
Anthracene	mg/kg dry wt	0.011	0.066	-	-	-
Benzo[a]anthracene	mg/kg dry wt	0.048	0.24	-	-	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.050	0.39	-	-	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.038	0.33	-	-	-
Benzo[g,h,i]perylene	mg/kg dry wt	0.031	0.30	-	-	-
Benzo[k]fluoranthene	mg/kg dry wt	0.016	0.157	-	-	-
Chrysene	mg/kg dry wt	0.040	0.28	-	-	-
Dibenzo[a,h]anthracene	mg/kg dry wt	0.006	0.052	-	-	-
Fluoranthene	mg/kg dry wt	0.074	0.61	-	-	-
Fluorene	mg/kg dry wt	0.004	0.022	-	-	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.029	0.30	-	-	-
Naphthalene	mg/kg dry wt	< 0.011	0.020	-	-	-
Phenanthrene	mg/kg dry wt	0.029	0.28	-	-	-
Pyrene	mg/kg dry wt	0.071	0.59	-	-	-
Haloethers Trace in SVOC Soil Samples by GC-MS						
Bis(2-chloroethoxy) methane	mg/kg dry wt	< 0.17	< 0.17	-	-	-
Bis(2-chloroethyl)ether	mg/kg dry wt	< 0.17	< 0.17	-	-	-
Bis(2-chloroisopropyl)ether	mg/kg dry wt	< 0.17	< 0.17	-	-	-
4-Bromophenyl phenyl ether	mg/kg dry wt	< 0.17	< 0.17	-	-	-
4-Chlorophenyl phenyl ether	mg/kg dry wt	< 0.17	< 0.17	-	-	-
Nitrogen containing compounds Trace in SVOC Soil Samples, GC-MS						
3,3'-Dichlorobenzidine	mg/kg dry wt	< 0.9	< 0.9	-	-	-
2,4-Dinitrotoluene	mg/kg dry wt	< 0.4	< 0.4	-	-	-
2,6-Dinitrotoluene	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Nitrobenzene	mg/kg dry wt	< 0.17	< 0.17	-	-	-
N-Nitrosodi-n-propylamine	mg/kg dry wt	< 0.4	< 0.4	-	-	-
N-Nitrosodiphenylamine	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Organochlorine Pesticides Trace in SVOC Soil Samples by GC-MS						
Aldrin	mg/kg dry wt	< 0.17	< 0.17	-	-	-
alpha-BHC	mg/kg dry wt	< 0.17	< 0.17	-	-	-
beta-BHC	mg/kg dry wt	< 0.17	< 0.17	-	-	-
delta-BHC	mg/kg dry wt	< 0.17	< 0.17	-	-	-
gamma-BHC (Lindane)	mg/kg dry wt	< 0.17	< 0.17	-	-	-
4,4'-DDD	mg/kg dry wt	< 0.17	< 0.17	-	-	-
4,4'-DDE	mg/kg dry wt	< 0.17	< 0.17	-	-	-
4,4'-DDT	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Dieldrin	mg/kg dry wt	< 0.17	< 0.17	-	-	-
Endosulfan I	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Endosulfan II	mg/kg dry wt	< 0.5	< 0.5	-	-	-
Endosulfan sulphate	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Endrin	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Endrin ketone	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Heptachlor	mg/kg dry wt	< 0.17	< 0.17	-	-	-
Heptachlor epoxide	mg/kg dry wt	< 0.17	< 0.17	-	-	-
Hexachlorobenzene	mg/kg dry wt	< 0.17	< 0.17	-	-	-

Sample Type: Sediment						
	Sample Name:	S2 Cashmere Penruddock 05-Mar-2015	S18 Outfall 04-Mar-2015			
	Lab Number:	1393602.6	1393602.7			
Polycyclic Aromatic Hydrocarbons Trace in SVOC Soil Samples						
Acenaphthene	mg/kg dry wt	< 0.10	< 0.10	-	-	-
Acenaphthylene	mg/kg dry wt	< 0.10	< 0.10	-	-	-
Anthracene	mg/kg dry wt	< 0.10	< 0.10	-	-	-
Benzo[a]anthracene	mg/kg dry wt	0.38	0.32	-	-	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.34	0.35	-	-	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.36	0.45	-	-	-
Benzo[g,h,i]perylene	mg/kg dry wt	0.24	0.39	-	-	-
Benzo[k]fluoranthene	mg/kg dry wt	< 0.17	< 0.17	-	-	-
2-Chloronaphthalene	mg/kg dry wt	< 0.10	< 0.10	-	-	-
Chrysene	mg/kg dry wt	0.29	0.29	-	-	-
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.17	< 0.17	-	-	-
Fluoranthene	mg/kg dry wt	0.50	0.70	-	-	-
Fluorene	mg/kg dry wt	< 0.10	< 0.10	-	-	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.19	0.25	-	-	-
2-Methylnaphthalene	mg/kg dry wt	< 0.10	< 0.10	-	-	-
Naphthalene	mg/kg dry wt	< 0.10	< 0.10	-	-	-
Phenanthrene	mg/kg dry wt	0.12	0.33	-	-	-
Pyrene	mg/kg dry wt	0.54	0.73	-	-	-
Phenols Trace in SVOC Soil Samples by GC-MS						
4-Chloro-3-methylphenol	mg/kg dry wt	< 0.5	< 0.5	-	-	-
2-Chlorophenol	mg/kg dry wt	< 0.2	< 0.2	-	-	-
2,4-Dichlorophenol	mg/kg dry wt	< 0.2	< 0.2	-	-	-
2,4-Dimethylphenol	mg/kg dry wt	< 0.4	< 0.4	-	-	-
3 & 4-Methylphenol (m- + p-cresol)	mg/kg dry wt	< 0.4	< 0.4	-	-	-
2-Methylphenol (o-Cresol)	mg/kg dry wt	< 0.2	< 0.2	-	-	-
2-Nitrophenol	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Pentachlorophenol (PCP)	mg/kg dry wt	< 6	< 6	-	-	-
Phenol	mg/kg dry wt	< 0.4	< 0.4	-	-	-
2,4,5-Trichlorophenol	mg/kg dry wt	< 0.4	< 0.4	-	-	-
2,4,6-Trichlorophenol	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Plasticisers Trace in SVOC Soil Samples by GC-MS						
Bis(2-ethylhexyl)phthalate	mg/kg dry wt	< 0.7	5.3	-	-	-
Butylbenzylphthalate	mg/kg dry wt	< 0.4	0.5	-	-	-
Di(2-ethylhexyl)adipate	mg/kg dry wt	< 0.2	< 0.2	-	-	-
Diethylphthalate	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Dimethylphthalate	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Di-n-butylphthalate	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Di-n-octylphthalate	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Other Halogenated compounds Trace in SVOC Soil Samples by GC-MS						
1,2-Dichlorobenzene	mg/kg dry wt	< 0.4	< 0.4	-	-	-
1,3-Dichlorobenzene	mg/kg dry wt	< 0.4	< 0.4	-	-	-
1,4-Dichlorobenzene	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Hexachlorobutadiene	mg/kg dry wt	< 0.4	< 0.4	-	-	-
Hexachlorocyclopentadiene	mg/kg dry wt	< 0.9	< 0.9	-	-	-
Hexachloroethane	mg/kg dry wt	< 0.4	< 0.4	-	-	-
1,2,4-Trichlorobenzene	mg/kg dry wt	< 0.17	< 0.17	-	-	-
Other SVOC Trace in SVOC Soil Samples by GC-MS						
Benzyl alcohol	mg/kg dry wt	< 1.7	< 1.7	-	-	-
Carbazole	mg/kg dry wt	< 0.17	< 0.17	-	-	-
Dibenzofuran	mg/kg dry wt	< 0.17	< 0.17	-	-	-
Isophorone	mg/kg dry wt	< 0.17	< 0.17	-	-	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-7
Dry Matter (Env)	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) , gravimetry. US EPA 3550. (Free water removed before analysis).	0.10 g/100g as rcvd	1-7
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-7
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-7
Total Organic Carbon*	Acid pretreatment to remove carbonates if present, Elementar Combustion Analyser.	0.05 g/100g dry wt	1-7
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1-7
7 Grain Sizes Profile*		-	1-7
Polycyclic Aromatic Hydrocarbons Trace in Soil	Sonication extraction, SPE cleanup, GC-MS SIM analysis US EPA 8270C. Tested on as received sample [KBIs:5784,4273,2695]	0.002 - 0.010 mg/kg dry wt	1-7
Semivolatile Organic Compounds Trace in Soil by GC-MS	Sonication extraction, GPC cleanup, GC-MS FS analysis. Tested on as received sample	0.10 - 6 mg/kg dry wt	1-7
7 Grain Sizes Profile			
Dry Matter	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-7
Fraction < 2 mm, >/= 1 mm*	Wet sieving, 2.00 mm and 1.00 mm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-7
Fraction < 1 mm, >/= 500 µm*	Wet sieving, 1.00 mm and 500 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-7
Fraction < 500 µm, >/= 250 µm*	Wet sieving, 500 µm and 250 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-7
Fraction < 250 µm, >/= 125 µm*	Wet sieving, 250 µm and 125 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-7
Fraction < 125 µm, >/= 63 µm*	Wet sieving, 125 µm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-7
Fraction < 63 µm*	Wet sieving, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-7

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

Appendix C Supporting Information

Soils Information

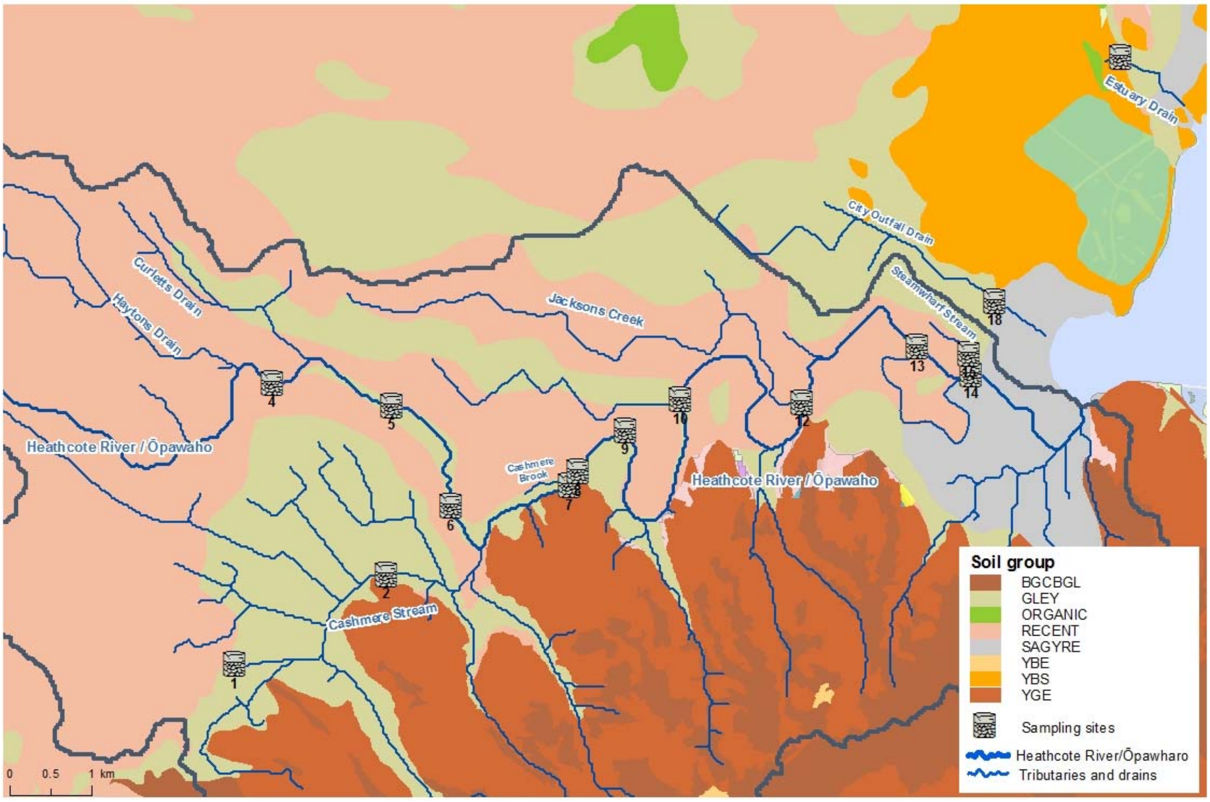

Figure C-1: Soil groups in the Heathcote River, City Outfall Drain and Estuary Drain catchments. Soil map layer from Canterbury Maps portal.

Table C-1: Background concentrations of trace elements in Christchurch urban soils.

	Soil concentrations (mg/kg)						
Soil type	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Zn**
Level 1							
Gley	10.6	0.2	18.5	23.3	34.9	15.6	138
Recent	15.3	0.2	19.0	17.7	101	16.6	149
Yellow Brown Sand	5.6	0.1	15.4	8.8	22.3	11.7	54.9

Landuse

Table C-2: Dominant landuses for catchment upstream of each sampling site. Based on CCC GIS zoning.

Site No.	Stream	Dominant catchment landuse
1	Cashmere Stream - Sutherlands	Rural / open space
2	Cashmere Stream - Penruddock	Rural / open space
4	Heathcote River - Showgrounds	Residential & business
5	Heathcote River - Spreydon Domain	Residential & business
6	Heathcote River - Centennial	Residential
7	Heathcote River - Barrington	Residential
8	Cashmere Brook	Residential
9	Heathcote River - Colombo St	Residential
10	Heathcote River - Tennyson St	Residential
12	Heathcote River - Aynsley	Residential
13	Heathcote River - Catherine (tidal)	Residential
14	Heathcote River - Tunnel (tidal)	Residential & business
15	Steamwharf Stream	Residential
17	Estuary Drain	Rural / open space
18	City Outfall Drain / Linwood Canal	Residential & business

Table C-3: Summary of differences in sediment contaminants based on landuse.

Contaminant	P-value
Total PAHs	0.038
Cadmium	0.043
Lead	0.096
TOC	0.13
Zinc	0.16
Copper	0.16
Phosphorus	0.53
Chromium	0.61
Nickel	0.90
Mud	0.96
Arsenic	0.98