Responses to S92 request for further information – CRC092692

NIWA Client Report: CHC2009-150
September 2009

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Helen Rouse Ton Snelder

1. Introduction

The Christchurch City Council (CCC) recently lodged a resource consent application to discharge water and contaminants to water from various overflow points in the Christchurch wastewater network as a result of wet weather events (Murray and Tipler 2008). Environment Canterbury (ECan) reviewed this application, and required further information under S92 of the RMA before processing the application. In a letter dated 1 May 2009, ECan raised 12 points for further information. This report concentrates on four of these points:

Point 4: Effects in and around local drains

ECan wanted more "*information on the flow rates, durations, volumes and quantity of the proposed indirect discharges via local drainage channels"*. They also wanted an *"assessment of the short and long term effects of the discharges on those channels, their margins, and neighbouring occupied properties"*. While the CCC has good data on sewer overflows in the mainstem of the Avon and Heathcote rivers, the only data available on discharges to the small drains are for Dudley Creek, at the Grassmere St and Slater St sites.

Point 5: Ecological effects in the estuary and short-term effects in the rivers

ECan wanted more "*information on the short and long term ecological effects from the discharge on the estuary…and short term effects of the discharge on the rivers. This information should include further information on ecosystems in the waters and on the margins*".

Point 6: Changes in relative impact of the proposed wastewater discharges in the drains, streams and estuary as stormwater improvements are made

ECan's S92 letter asked for more information regarding potential effects of improvements to stormwater as part of integrated catchment management plans, or removal of the Bromley waste water treatment plant discharge that may result in improvements to water quality in streams and the estuary. ECan contended that such an improvement may mean that the sporadic sewer overflows may have a more detrimental impact than they currently do, as the health of the estuary and rivers improves. ECan also wanted "*further information on what ecological parameters and indices will be appropriate as the water quality is improved*".

Point 8: **Effects on estuary water quality**

ECan wanted "*further information on the short and long-term effects of the proposed discharges on estuary water quality*". Information to answer this point was also considered in information to answer Points 5 and 6.

This report provides new information summarising the effects of the discharges on both the estuary and the rivers. The original AEE submitted to ECan (Murray and Tipler 2008) contained detailed reports summarising investigations of the impacts of the sewer overflows on the ecology of the Avon and Heathcote rivers (Suren et al 2008; McMurtrie and Burdon 2006). However, no specific reports were produced that dealt with the effects of the sewer overflows on the estuary. As such, and following on from ECan's request for further information, we have first summarised salient information about the ecology of the estuary, the nature of contaminants in sewer overflows, and their potential effects on estuarine biota. We have then addressed the issues raised in points 4, 5, 6 and 8 above in specific sections in this report. The relevance of each section to the points raised by ECan is outlined in Table 1.

Table 1: **List of Section 92 points that ECan has raised with the applicant, and our responses to them in this report.**

ECan S92 Point	Refer to section
Point 4: Effects in and around local drains	3.1 Changes in water quality above and below selected sewer overflow points 3.2 Assessment of the degree to which sewer overflows are diluted in rivers 3.3 Estimated concentrations of contaminants from sewer overflows 3.5 Comparison of water quality conditions in the Avon and Heathcote and Styx Rivers 4.1 Instream ecology
Point 5: Ecological effects in the estuary and short-term effects in the rivers	2.3 Contaminant levels in the Avon/Heathcote estuary / Ihutai sediments 3.4 Total mass load of contaminants 4.1 Instream ecology 4.2 Estuarine ecology
Point 6: Changes in relative impact of the proposed wastewater discharges in the drains, streams and estuary as stormwater improvements are made	3.1 Changes in water quality above and below selected sewer overflow points 3.2 Assessment of the degree to which sewer overflows are diluted in rivers 3.4 Total mass load of contaminants 4.1 Instream ecology 4.2 Estuarine ecology
Point 8: Effects on estuary water quality	3.3 Estimated concentrations of contaminants from sewer overflows 3.4 Total mass load of contaminants

2. Summary of estuarine ecology

2.1. Biological communities in the Avon/Heathcote estuary / Ihutai

The Avon-Heathcote estuary / Ihutai comprises four general habitat types: the water column; intertidal areas of sandflat, mudflat, seagrass beds and macroalgal beds; subtidal channels; and fringing vegetation (saltmarshes) (Morrisey 2003, Cawthron 2002). The most extensive habitat type within the estuary is unvegetated sandflats and mudflats.

The intertidal area supports macroalgal beds of *Gracilaria, Ulva* and *Enteromorpha,* and periodic blooms of *Ulva* and *Enteromorpha* may be linked to nutrient inputs from the rivers and the Christchurch wastewater treatment plant. Seagrass (*Zostera novazelandica*) beds cover approximately 14 ha. of tidal flats around the estuary.

A diverse fauna of benthic invertebrates inhabits the Avon-Heathcote / Ihutia estuary, dominated by estuarine species of bivalve and gastropod molluscs, polychaete worms and crustaceans (Gust *et al.* 2004). The species assemblage is typical of east coast estuarine conditions (Knox 1992). Most species are salt tolerant and are characteristic of mudflats where there is no reduction in salinity of the sea water (Knox 1992). The Avon-Heathcote / Ihutai estuary is the largest predominantly muddy-sand estuary in Canterbury, so the benthic invertebrate community is considered to be of regional importance (Sagar and Weatherhead 1999).

Thirty four species of fish have been recorded from the estuary, and due to the diverse species assemblage and large size of the estuary, it is considered to be of regional importance to fish (James 1999). Some notable species such as flounder (*Rhombosolea plebeian, R. leporine*) and yellow eyed mullet (*Aldrichetta forsteri*) use the estuary as a nursery. Others like inanga (*Galaxias maculatus*) breed just above the salt wedge in the Avon/Otakaro and Heathcote/Opawaho Rivers, while eels (*Anguilla australis, A. dieffenbachia*) and lamprey (*Geotria australis*) utilize the estuary as a migratory transition zone between the rivers and the sea.

The estuary and oxidation ponds are recognized as an outstanding wildlife area of national importance (Crossland 1993) due to the presence of a diverse bird fauna (104 species have been recorded since 1980), and are considered internationally important to populations of five wetland species (New Zealand scaup [*Aythya novaseelandiae*], New Zealand shoveler [*Anas rhynchotis*], South Island pied oystercatcher [*Haematopus ostralegus finschi*], eastern bar-tailed godwit [*Limosa lapponica baueri*], and red billed gull [*Larus novahollandiae scopulinus*]). The estuary is an important stopover for many wetland birds during migrations, and is at the southern end of the East Asian Flyway, an international migration route used by birds like the bar-tailed godwit that breed in Siberia and Alaska and spend the non-breeding season in Australasia. Birds utilize a wide range of habitats within the estuary for feeding. Invertebrates within intertidal flats provide food for waders, waterfowl, herons, spoonbills and gulls, and wildfowl graze on seagrass and macroalgae. Fringing vegetation and freshwater wetlands provide important habitat for a range of crustaceans, molluscs, worms and insects that are an important food source for a variety of bird species.

Vegetation fringing the estuary provides valuable habitat for estuarine fauna, particularly on the western margin of the estuary comprising patches of relatively undisturbed native marshland plants (Gust *et al.* 2004, Morrisey 2003).

2.2. Nature of contaminants in wastewater/sewage discharge and potential effects to estuarine biota

Wastewater originating from stormwater and sewage overflow and discharging into the Avon and Heathcote Rivers and the estuary may contain elevated levels of a range of contaminants such as: nitrogen and phosphorous; heavy metals such as copper, lead, chromium, arsenic, mercury and zinc; and a range of organic contaminants including polycyclic aromatic hydrocarbons (PAHs), organochlorines, dioxin, chlorophenols and bichlorinated biphenyls (PCBs). These contaminants originate from a range of sources. Nutrients come mostly from animal faeces, fertilisers, and plant material, while heavy metals and organic chemicals enter waterways via industrial waste streams, and surface run-off carrying by-products of automobile use, and combustion of waste and fuel.

Most of these contaminants are present at measurable levels in urbanized estuaries in New Zealand. Levels of many of these contaminants are decreasing through the phasing out of their use, and the increased regulation of industrial processes in urban areas. However, levels of PAHs and some heavy metals, especially zinc, are expected to rise in some areas as a consequence of urban expansion and increased use of motor vehicles (Mills and Williamson 1999).

Nutrients stimulate growth of algae and other aquatic plants. Over-production of algae results in nuisance blooms which can smother other benthic biota, and subsequent decomposition can create patches of anoxic sediment. Very high ammonia nitrogen levels in water and sediments can be acutely toxic to fish and other aquatic animals.

Heavy metals and organic compounds may be acutely or chronically toxic to animals above particular concentrations, with potential effects ranging from rapid mortality to chronic mild disruption of physiological processes.

Based on toxicological studies, guidelines have been developed for threshold contaminant levels above which adverse biological effects may occur. Previous assessments of effects relating to contaminants in the Avon-Heathcote/Ihutia estuary (e.g. Mills and Williamson 1999, Morrisey 2003) have considered Environment Canada's 'threshold effect levels' (TEL), representing concentrations at which adverse biological effects are expected to occur rarely and 'probable effect levels' (PEL) above which adverse biological effects are expected to occur frequently (Smith *et al.* 1996). Guidelines have also been developed by the Australia and New Zealand Environment and Conservation Council (ANZECC 2000) which provide recommended threshold levels for contaminants in water and sediments beneath which a particular percentage of species are considered to be protected from significant adverse effects.

2.3. Contaminant levels in the Avon/Heathcote estuary / Ihutai sediments

Sediments act as both a source and sink for contaminants in the estuary. Sediments carrying contaminants suspended in runoff enter the estuary from point and diffuse sources, particularly during high rainfall events. Contaminants settle out and accumulate in estuarine sediments.

Data on contaminant levels in sediments and shellfish sampled from the Avon-Heathcote estuary showed that parts of the estuary were moderately contaminated with heavy metals and organic compounds (Mills and Williamson 1999). Contaminant levels were greatest in samples from depositional areas near the mouths of the Avon and Heathcote Rivers. Total metal concentrations approached or exceeded lower threshold effect levels (TELs) for copper lead and zinc but probable effect levels (PELs) were not exceeded, and Mills and Willamson (1999) concluded that heavy metals were present at levels below those where impacts to benthic biota would be expected to occur. The same study found that dioxin levels in sediments and cockles at one site exceeded Canadian guidelines for impacts on wildlife which feed on fish (or shellfish), and there is potential for impacts, particularly to wading birds.

Gust *et al.* (2004) sampled shallow and deep sediment cores taken along the route of the Christchurch City Council sewer outfall pipeline crossing the northern portion of the estuary near the mouth of the Avon River. That study found zinc and lead at levels exceeding ANZECC (2000) ISQG (Interim Sediment Quality Guidelines) 'low' trigger values (zinc: 200 mg/kg, lead: 50 mg/kg) in a deep section (1.4 m) of fine sediment from one core, and mercury at levels exceeding those trigger values (mercury: 0.15 mg/kg) within several core samples along the transect. However, levels of heavy metals did not exceed ANZECC (2000) ISQG 'high' threshold concentrations in any of the core samples.

Substantial levels of some contaminants are expected to continue to discharge as stormwater during rainfall events to the Avon and Heathcote Rivers, and accumulate within estuary sediments, especially in depositional zones at the mouths of the rivers. Contaminants associated with motor vehicle usage such as zinc, copper and PAHs have been identified in particular. While the effects from these contaminants are likely to be mitigated to some extent through dilution, adsorption of some contaminants to riverbed sediments, and flushing of others out of the estuary, there remains a potential for significant effects to estuarine biota from contaminants entering the estuary via the rivers, stormwater point sources and surface runoff.

The sewer wastewater overflows will also contribute to mass loading of nutrients, heavy metals and organic contaminants discharging into the Avon and Heathcote Rivers and ultimately reaching the estuary. However, the contaminants of greatest concern identified above, in particular PAHs, zinc and dioxins, all enter waterways predominantly via surface runoff to the stormwater system (Willamson 1993, Suren 2000, Ermens 2007). Wastewater overflows are intermittent, and relatively brief, and their contribution to contaminant loading in the river water that flows into the estuary is likely to be insignificant compared to that from the high volumes of stormwater discharging at the same time.

3. Section 92 responses

Our responses to points 4, 5 6, and 8 raised by ECan in their s92 request have been addressed by the following methodology:

1. examining the changes in water quality above and below selected sewer overflow points, in both the mainstem of the Avon and Heathcote rivers, and in Dudley Creek;

2. assessing the degree to which sewer overflows in the Avon and Heathcote Rivers are diluted;

3. calculating the mass loadings of contaminants (zinc, copper and lead) into the estuary, and the relative loadings of these materials from the wastewater overflows;

4. comparing long-term water quality conditions in the Avon and Heathcote Rivers, which are subject to sewer overflows, to that of water quality conditions in the Styx River, which has no sewer overflows;

5. in view of the above, discussing the effects of the sewer overflows on the instream and estuarine ecological values

3.1. Changes in water quality above and below selected sewer overflow points

Water quality data was obtained from the Christchurch City Council from sites above and below 10 overflow sites in three waterways: the Avon River, Dudley Creek, and the Heathcote River. These 10 sites were chosen as they are the sites for which data is available. Two sites were located in both the Avon River (Fendalton Rd (PS1/16-1 and PS1/16-2) and River Rd (PS1/11)), and Dudley Creek (Grassmere St (PS1/21) and Slater St (PS7/1)). Six sites were located in the Heathcote River: Bowenvale Bridge (PS22/2) - located upstream; Fisher Ave (PS20/4); Tennyson Ave (PS20/3); Waltham Rd (PS20/2); Locarno St (PS20/1)[1]; and Bedford Row (PS19/1) – the most downstream. At each site, samples had been collected at locations above and below of the sewer overflows. The average distance below the overflows was 160m, with a range of 100 – 250 m. This data had been collected from May 2006 until May 2009.

A total of 22 individual overflow events were monitored. All samples were analysed for NH_3, DRP and *E. coli*. Sampling was conducted during individual overflow events, with some monitoring lasting for up to five days. The average and maximum values of NH_3, DRP and *E. coli* during each event were calculated. Use of the average and maximum values of these parameters, rather than the median values, would focus more on the higher values recorded, and thus skew the data. In this way we were presenting a "worse case" scenario rather than if we used the median values. Analysis of Variance (ANOVA) was used to determine whether either nutrients or *E. coli* levels varied between sites within each waterway, and at locations above and below the sewer overflows. If no differences in sites were observed, for clarity we just presented the average data from all sites combined to show the locations above and below the overflows varied over time.

No differences were observed in the average concentrations of DRP or NH_3 at any of the different overflow sites in any of the three waterways, nor at locations above and below the sewer overflows (Figure 1 and 2). Counts of *E. coli* were significantly higher at the River Rd site than the Fendalton Rd site in the Avon River (Figure 3). Counts were also significantly higher at locations below the sewer overflows at both sites (Figure 3). ANOVA showed that *E. coli* counts in the Heathcote River were significantly higher at the Locarno St overflow site (PS20/1) than the other five sites. However, *E. coli* counts were similar for samples collected above and below sewer overflows (Figure 4).

[1] Recent network upgrades in the Heathcote catchment now mean that Lorcano Street is not predicted to overflow.

Examination of maximum loadings in the monitored events showed that concentrations of DRP differed only in the lower Dudley Creek site, where they were higher. No differences existed in the maximum DRP concentrations at locations above and below the overflows in Dudley Creek. DRP concentrations did not differ between sites in either the Avon or Heathcote Rivers, and did not differ between sites above and below the sewer overflows. No differences were observed in maximum concentration of NH_3 between sites within any of the three waterways, or at locations above and below the sewer overflows,. As with the average *E. coli* counts, maximum counts were higher at the River Rd site in the Avon than at the Fendalton Rd site, and also higher at the Locarno St overflow site in the Heathcote than other sites. However, inlike the average *E. coli* counts, we found no differences in maximum counts at locations above and below sewer overflows in any of the sites, or rivers.

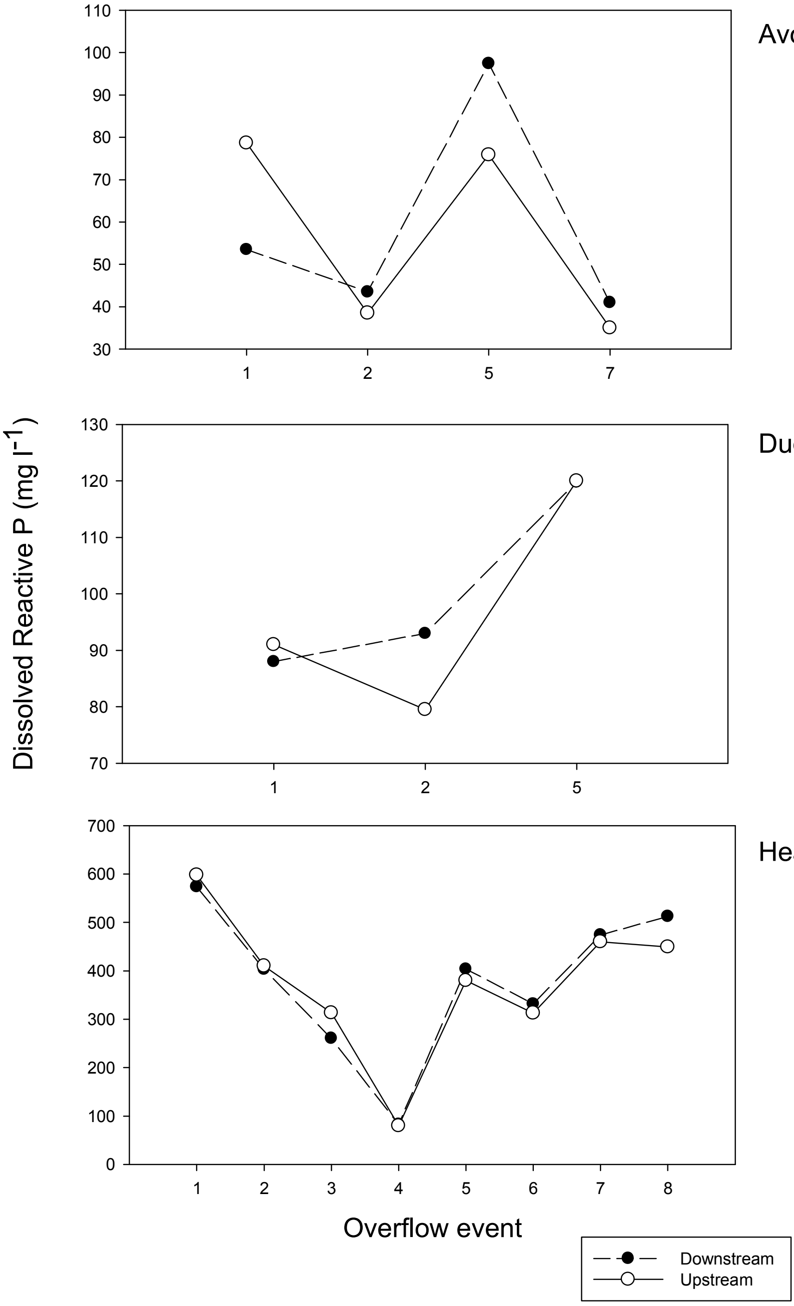

Figure 1: **Average concentration of dissolved reactive phosphorus found at all sewer overflow sites in the Avon, Dudley Creek, or the Heathcote River at locations upstream (open symbols) and downstream (closed symbols) of the overflows over time during 22 monitored overflow events. Note how the x-axis differs in scale, and that many of the individual overflows times are missing from some sites. This reflects the fact that not all sites overflow at the same times during rainfall events.**

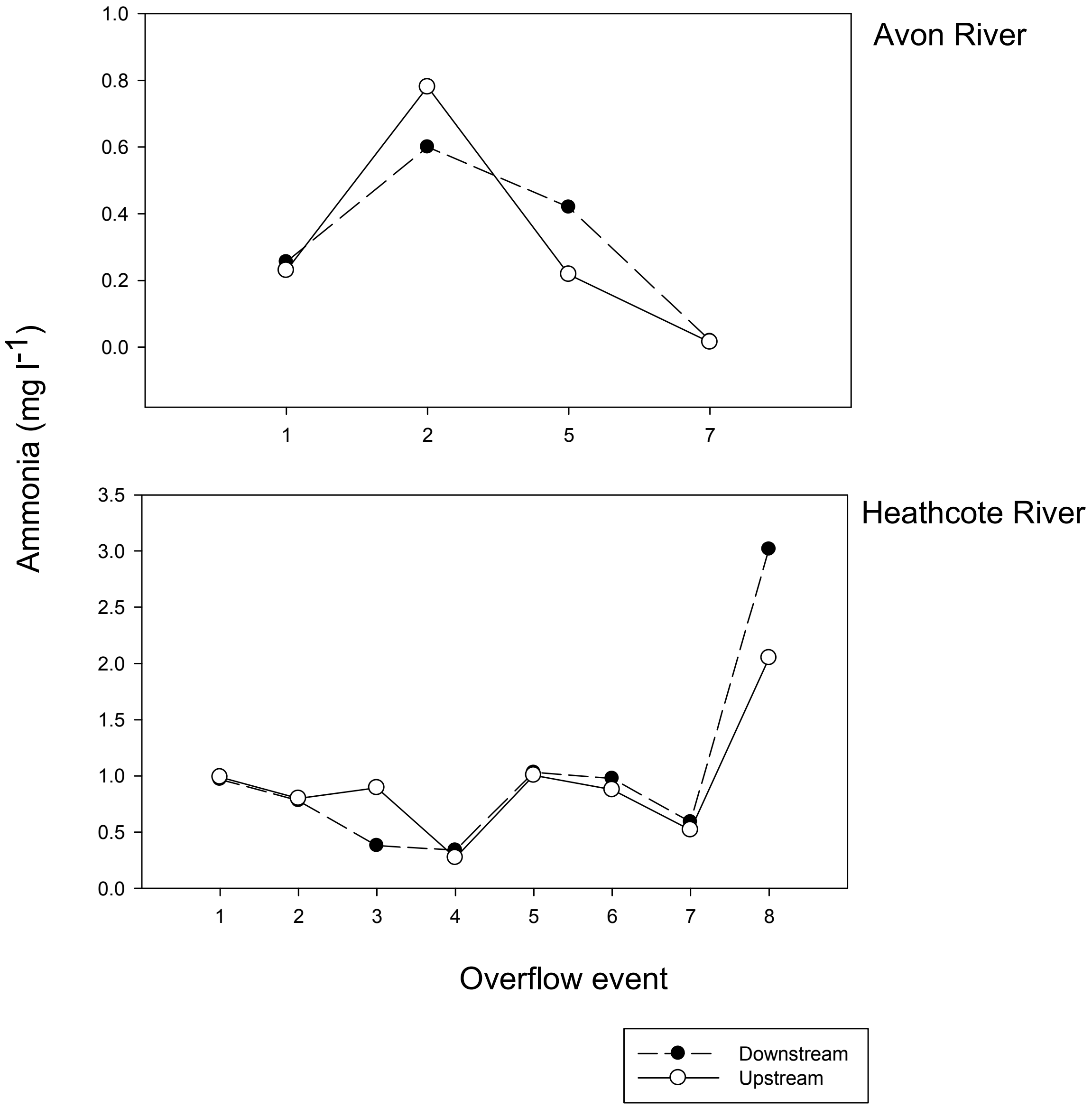

Figure 2: **Average concentration of ammonia found at sewer overflow sites in the Avon, Dudley Creek, or the Heathcote River at locations upstream and downstream of the sewer overflows over time during monitored overflow events (x-axis as in Figure 1)**

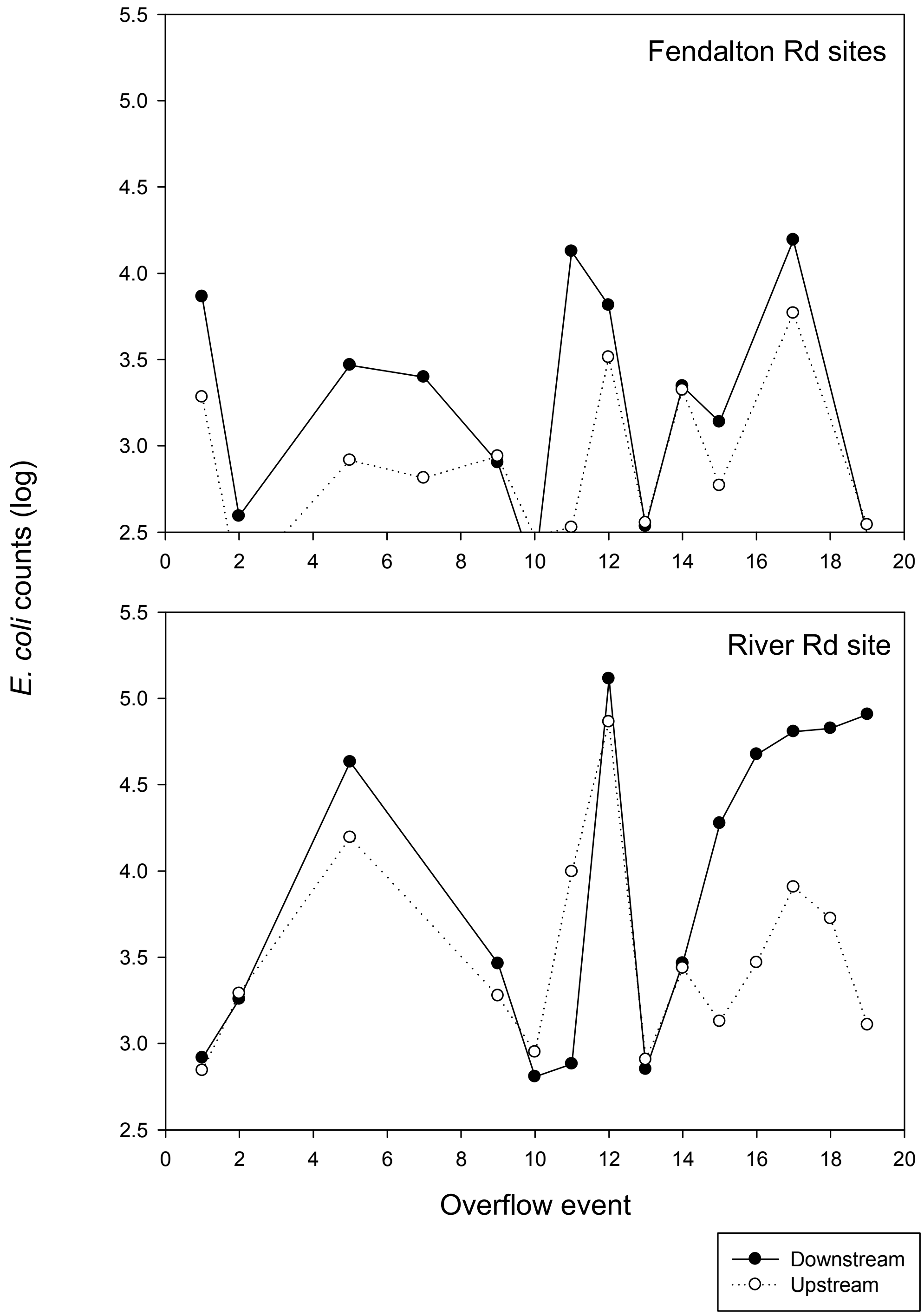

Figure 3: **Average counts of *E. coli* in the Avon River at the upstream Fendalton Rd sites, and the lower River Rd sites at locations upstream and downstream of the sewer overflows over time during monitored overflow events (x-axis as in Figure 1).**

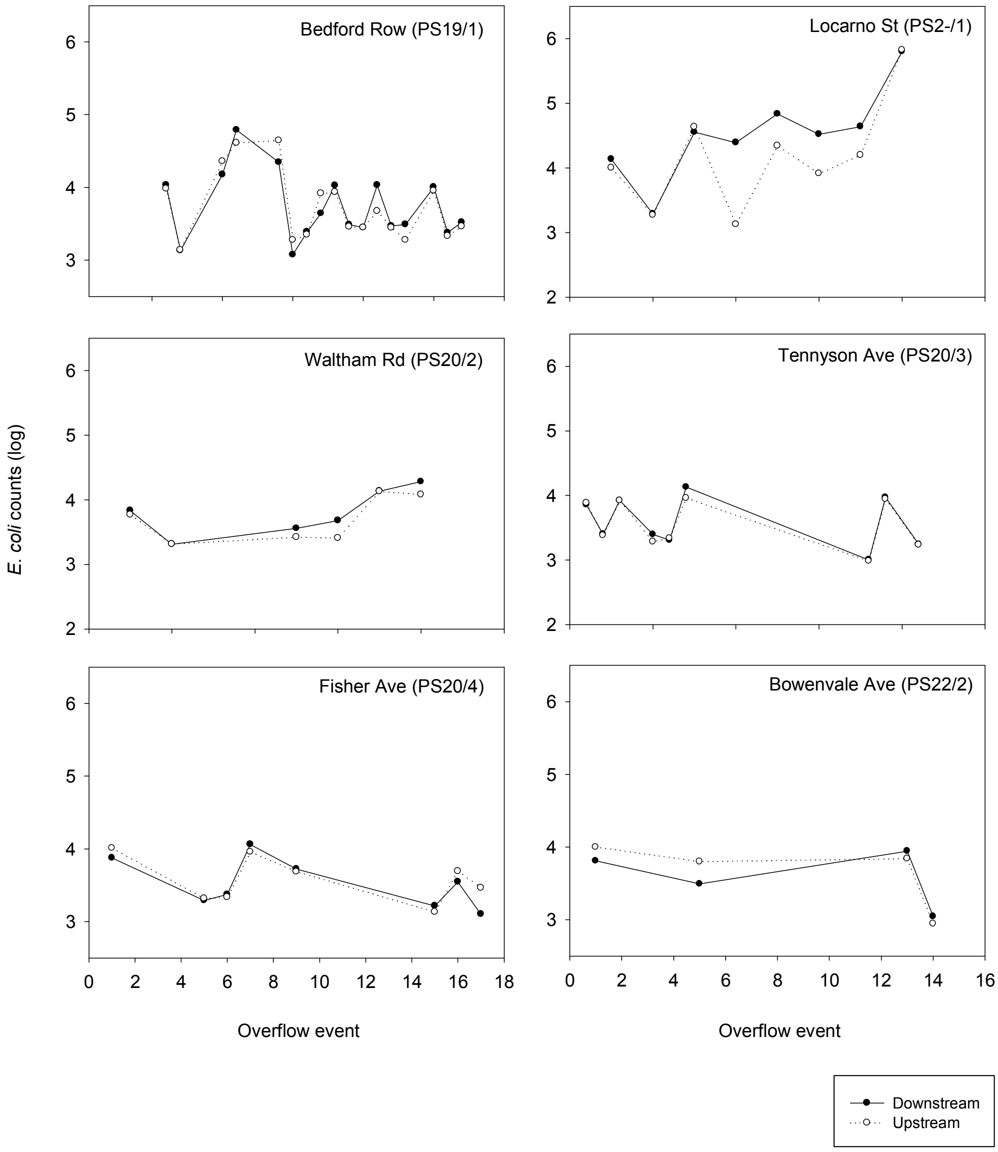

Figure 4: Average counts of *E. coli* in the Heathcote River at the six overflow sites at locations upstream and downstream of the sewer overflows over time during monitored overflow events, (x-axis as in Figure 1).

3.2. Assessment of the degree to which sewer overflows are diluted in rivers

The CCC provided data on start and end times that different sewer overflows discharged into the Avon and Heathcote rivers, and Dudley Creek, as well as the volumes discharged. Instantaneous flow records for the Avon and Heathcote Rivers were obtained and the volume of water flowing in the rivers during the time of the sewer overflows calculated. From this it was possible to determine the degree of dilution of the sewer overflow into the rivers, as well as any relationships between dilution rate and river flow. Unfortunately, no flow records are available for Dudley Creek, so it was not possible to directly estimate dilution rates of the sewer overflows into this smaller waterway, and an alternative approach has been used. This involved calculating the estimated flow for the upstream Grassmere St and downstream Slater St site during different rainfall intensities (a 6 month, and 2 year average return interval) to work out the degree of dilution of the sewer overflows in this waterway.

The results showed that the degree of dilution varied widely between the different sewer overflows, and the different overflow events. Sewer overflows were diluted on average by 1:84 times, with a minimum dilution of only 1:11 times, and maximum dilution of over 1:27,000 times. The median dilution rate of the sewer overflows into the receiving river water was 1:334 times. Such a high dilution rate may explain why the above analysis of differences in water quality parameters showed little differences in water quality above and below the overflows.

Regression analysis showed a significant positive relationship between the volume of sewer overflow and river flow (Figure 4; $r^2 = 0.481$, $F = 46.26$, $P < 0.001$), highlighting the fact that more sewer overflows into the river during times when the river flow was naturally high as a result of rainfall.

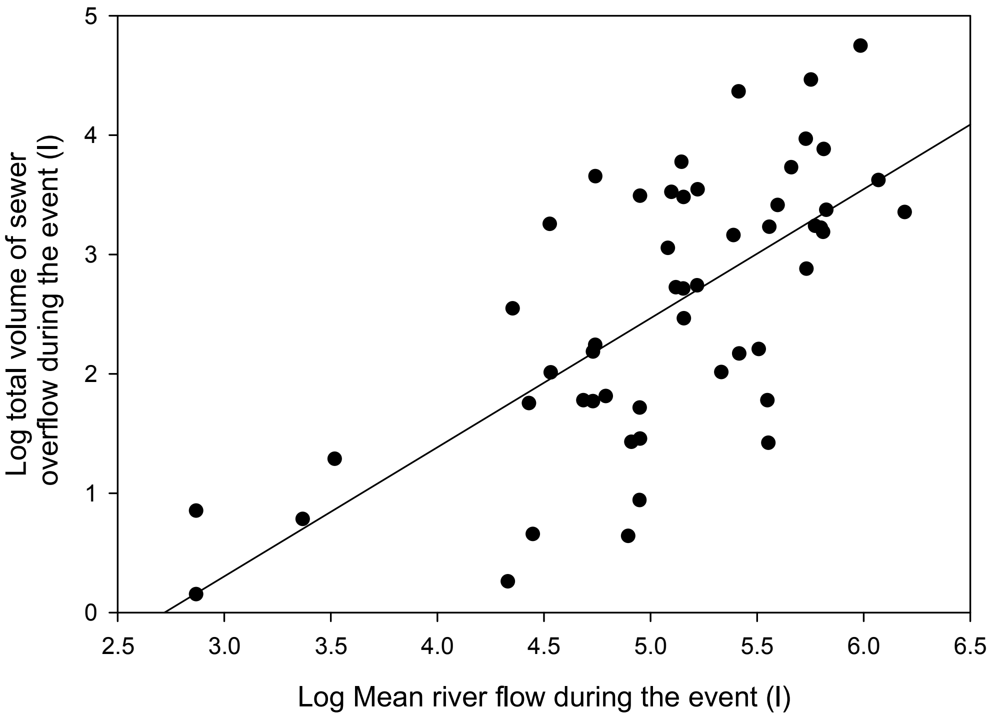

Figure 4: **Relationship between the volume of the sewer overflow entering the Avon and Heathcote Rivers, and river flow.**

Calculations provided to us by Paul Dickson, CCC, showed that the estimated flow for the Grassmere St site was 800 l s^{-1} and 1300 l s^{-1} for a 6 month, and 2 year ARI respectively, while the flow of the lower Slater St site was 1100 ls^{-1} and 1600 ls^{-1} for a 6 month, and 2 year ARI respectively. Data provided by the CCC showed volumes discharged on a single occasion at the Grassmere site, and on three occasions at the Slater St site (Table 2). Given the above flow estimates, and the volumes of discharged from the overflows, it was possible to calculate the overall dilution of the sewer overflows.

This analysis showed that, under a 2 year ARI flow, the average dilution was 1:56 – slightly lower than the average observed in the Avon and Heathcote rivers. The minimum dilution (1:24) was, however, higher than the minimum dilution observed in data from the Avon and Heathcote rivers. The average dilution under a 6-month ARI scenario was 1:39, while the minimum dilution (1:16) was still higher than the minimum dilution observed in the Avon and Heathcote rivers. These results suggest that even in the smaller waterways such as Dudley Creek, the sewer overflows are diluted to a relatively large extent, and are thus unlikely to have significant detrimental impacts on the aquatic ecosystem.

Table 2: Observed volumes of sewer overflows in the Grassmere St and Slater St sites in Dudley Creek, showing the predicted dilution under 2 flow scenarios; a 2 year ARI flow, and a 6 month ARI flow.

	Time details			Estimated flow (m^3)		Estimated dilution	
Site	Overflow Start Date	Time (s)	Volume discharged (m^3)	2 Yr ARI scenario	6 mo ARI scenario	2yr ARI scenario	6mo ARI scenario
Grassmere St	30/07/2007	30600.0	1078	39780	24480	1:37	1:23
Slater St	12/06/2006	21600.0	1457	34560	23760	1:24	1:16
	12/06/2006	17400.0	370.5	27840	19140	1:75	1:52
	30/07/2007	28800.0	482	46080	31680	1:96	1:66

3.3. Estimated concentrations of contaminants from sewer overflows

CCC provided data for heavy metal and nutrient concentrations in raw sewage measured at the inlet to the Bromley oxidation ponds. Based on the analysis of the degree to which the sewer overflows are diluted in rivers (section 3.2), it was possible to assess whether the overflows were likely to exceed ANZECC guidelines. Calculations showed that heavy metal concentrations in the rivers attributable to the sewer overflows, did not exceed ANZECC guidelines for concentrations at which 90% of species are considered to be protected from significant adverse effects (Table 3). However, estimated concentrations of nutrient indicators (total nitrogen and total phosphorous) based on mean nutrient concentrations and the estimated mean dilution rate of overflow discharge into rivers did exceed ANZECC guideline trigger values used to assess risk of nuisance growth of aquatic plants and algae in estuaries (Table 3), and exceeded the trigger value for total phosphorus for the ANZEEC trigger value fro freshwater.

Table 3: ANZECC trigger values for contaminants, and estimated contaminant concentrations in rivers flowing into Avon-Heathcote estuary during sewage overflow events.

	Metals ($\mu g\ L^{-1}$)				Nutrients ($\mu g\ L^{-1}$)	
Guideline standard	**Copper**	**Zinc**	**Lead**	**Mercury**	**TN**	**TP**
ANZECC 90% protect (Freshwater)[a]	1.8	15.0	5.6	1.9	614	33
ANZECC 90% protect (Marine)[b]	3.0	23.0	6.6	0.7		
ANZECC trigger (Estuaries)[c]					300.0	30.0
Estimated conc. in rivers resulting from sewage overflows.[d]	0.49	2.02	0.12	0.01	507.0	89.0

a = ANZECC trigger values for toxicants beneath which 90% of species are protected in freshwater systems.
b = ANZECC trigger values for toxicants beneath which 90% of species are protected in marine systems
c = ANZECC trigger values for main indicators (TN, TP) used to assess risk of nuisance growth of aquatic plants and algae.
d = Calculation based on mean contaminant concentrations in raw sewage (CCC data) and mean dilution rate of overflow discharge into river.

3.4. Total mass load of contaminants

Mills and Williamson (1999) calculated approximate mass loadings of zinc, copper, lead and PAHs discharged to Christchurch waterways from urban stormwater (Table 4). Using 59 records provided by CCC for total volumes discharged from different sewage overflows during heavy rainfall events between 2005 and 2009, and mean concentrations of those contaminants in sewage effluent, a range of values were calculated to estimate annual mass loads from sewage overflows (Table 4). Estimates of annual mass load from overflows were calculated using median, mean and maximum values from the 59 records of discharge volume measured at various overflow sites during high rainfall events, and assumed two such events per year. This is the average recurrence interval of the wastewater discharges sought under the current resource consent application. These estimates indicated that the annual mass load of heavy metal contaminants entering the rivers and estuary from wastewater overflows was negligible compared to contaminant loading entering via surface runoff and stormwater (Table 4).

Table 4: Estimated annual mass loading of contaminants from stormwater (Mills and Willamson 1999), and from sewage overflows discharging from the Avon and Heathcote rivers into the estuary in the vicinity of Christchurch City.

Parameter	Mass load from stormwater (kg)	Mass load from sewage overflows[1] (kg)		
		Median	Mean	Max
Zinc	7500	3.1	21.3	380
Copper	900	1.1	6.6	116.7
Lead	2000[a]	0.2	1.1	20.3
PAHs	50	Not available	Not available	Not available

[a]Lead loads now are much less than in 1995 reflecting the removal of lead from fuel

Within Christchurch, stormwater is conveyed via roadside gutters and catchpits (i.e., drain inlets) to the reticulated pipe network and on to streams, and the Avon/Heathcote estuary. Roadside gutters and catchpits therefore represent an obvious point at which to intercept and remove contaminants, and there are products on the market which can be installed in existing catchpits. An example of this is the EnviroPod – a filter bag that can be readily inserted into catchpits and later removed for cleaning. Trials suggest they can trap up to 80% of TSS (e.g., ARC 2003), although they are designed neither to trap fine particles (<100 microns) nor treat dissolved metals. However, studies internationally and in New Zealand have shown that a substantial proportion of metals in stormwater are attached to finer particulate matter or are in dissolved form, so the 80% figure is regarded as being very conservative. Recent studies have shown that use of a combination of Enviro-Pods, and Stormfilter vaults fitted with cartridges made of zeolite, perlite and granular activated carbon (ZPG) can remove over 40 -

60% of copper, lead and zinc, the principle heavy metals of concern (http://www.enviropod.com/index.asp?s1=case%20studies&s2=Sylvia%20Park%20Treatment%20Train).

Given this, we were able to use the data presented above to calculate the annual mass loadings of stormwater into the Avon and Heathcote rivers if all stormwater was treated to achieve a 60% reduction in heavy metals (Table 5). From this, we see that the mean and median contribution of the wastewater overflows to the total loading was still very minor (generally < 1%), except for the maximum estimated loadings that would occur only very rarely. Note also that this calculation assumes that all stormwater in the entire catchment draining into the rivers would be treated, and to a level to remove 60% of total contaminant loadings. Such a degree of spatial treatment and such a consistently high efficiency is unlikely. These estimates are therefore very conservative, and likely to be much lower. Furthermore, the CCC has no funding in the 10 year 09/19 LTCCP for such work, although it is possible that consideration may be given to these types of facilities in subsequent LTCCP's.

Table 5: Estimated annual mass loading of contaminants from stormwater given an optimal 60% extraction efficiency from best practice wastewater treatment devices, and the calculated percentage contribution from sewage overflows.

			% contribution from sewage overflows[1])		
Parameter	**Mass load from stormwater (kg)**	**After 60% removal (kg)**	**Median**	**Mean**	**Max**
Zinc	7500	3000	0.1	0.7	12.7
Copper	900	360	0.3	1.8	32.4
Lead	2000[a]	800	0.0	0.1	2.5

Finally, even if such removal rates were achieved, there is still a legacy of heavy metal contamination in the rivers and estuary that is likely to exert an effect on instream and estuarine communities.

3.5. Comparison of water quality conditions in the Avon and Heathcote and Styx Rivers

The CCC provided water quality sampling data from four catchments: the Avon River (14 sites), the Heathcote River (16 sites), the Otukaikino Stream (6 sites), and the Styx River (11 sites). Both the Avon and Heathcote Rivers have sewer overflows, while the

Styx River has not. This meant that it was possible to determine whether water quality differed between rivers with and without sewer overflows. Such information is helpful to put into context the effect of the sewer overflows on water quality conditions of the Avon and Heathcote Rivers

The number of sampling occasions at the sites differed greatly, so the data were simplified by selecting catchments where most monitoring had been done. This gave us seven sites in the Avon catchment, and five sites in the Heathcote and Styx catchments. These sites had been sampled between 28 and 30 occasions. Examination of this data showed that a number of different waterways had been sampled within each catchment. It was assumed that there could be a large degree of variability between sites of different waterways, so all data were grouped according to particular waterways within each catchment. This gave us three waterways in the Avon (the Avon mainstream, Waimairi Stream and Wairarapa Stream), two waterways in the Heathcote (with the Heathcote mainstem, and Cashmere stream), and three waterways in the Styx (the Styx mainstem, Smacks Creek and Kaputone stream. This arrangement of individual waterways within separate catchments was ideal for analysis of water quality data by a nested analysis of variance (ANOVA).

A total of 18 water quality metrics were selected for this analysis. These included five nutrient parameters (ammonia, nitrate, nitrite, soluble P, total P), four bacterial parameters (BOD5, *E. coli*, *Enterococci*, and faecal coliforms), seven physical parameters (conductivity, dissolved oxygen (both ppm and %), pH, suspended solids, temperature and turbidity), and two metals (copper and zinc). The statistical distribution of these parameters was investigated, and either log or fourth root transformation was used where the data was not normally distributed (Table 6).

Table 6: list of water quality parameters, and the transformation used to make the data normally distributed prior to analysis.

	Transformation used to obtain normally distributed data		
Parameter	**None**	**Logged**	**Fourth Root**
Ammonia			✓
BOD_5			✓
Conductivity		✓	
Copper			✓
Dissolved oxygen (ppm)	✓		
Dissolved oxygen (% saturation)	✓		
E. coli		✓	
Enterococci		✓	
Faecal coliforms		✓	
Nitrate			✓
Nitrite			✓
Nitrate-Nitrite			✓
Ph	✓		
Soluble P			✓
Suspended sediments			✓
Temperature			✓
Total P			✓
Turbidity			✓
Zinc			✓

Nested ANOVA of the appropriately transformed data showed that the Heathcote catchment had the highest concentrations of 11 parameters, including all five nutrient parameters (Figure 5), three physical parameters (conductivity, suspended solids and turbidity), and zinc and BOD_5 (Figure 6). Of these parameters, only ammonia, BOD_5, and total P could be attributed to sewer overflows. All the other parameters most likely reflected inputs of stormwater. Many of the nutrient parameters in all three catchments were also higher than the ANZEEC (2000) guidelines values designed to minimize adverse effects of nutrients on lowland rivers (Figure 5). Dissolved Zinc was below the recommended trigger value for Zinc for the protection fo 90% of aquatic species in the Styx River, but above this recommended level in the Avon and Heathcote (Figure 6).

Counts of *E. coli* differed between the three catchments, and were highest in the Styx catchment (Figure 7), despite this river having no sewer overflows. Biological oxygen demand (BOD_5) was highest in the Heathcote catchment. Neither *Enterococci* or faecal coliform counts were significantly different between the three catchments, suggesting that the sewer overflows in the Avon and Heathcote were not necessarily resulting in higher bacterial loadings than in catchments without the sewer overflows. The Avon had the highest dissolved oxygen of all three waterways, suggesting that any bacteriological contamination of this river was not resulting in a significantly high BOD5.

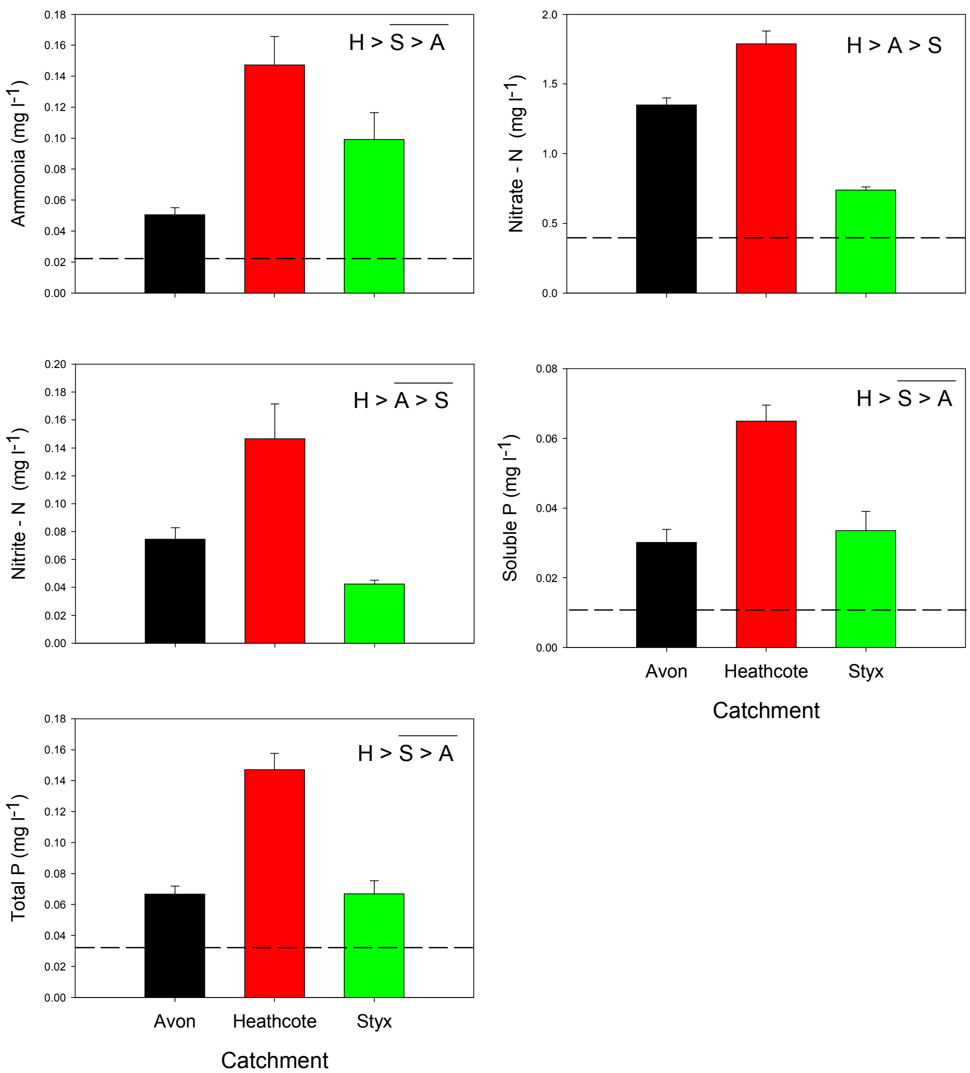

Figure 5: **Mean concentrations (± 1 SE) of nutrients in the Avon (A), Heathcote (H) and Styx (S) catchments, showing the higher nutrient concentrations in the Heathcote. Each graph shows results of post-hoc means testing, with means not significantly different to each other joined by a line. Dashed line indicates relevant ANZEEC (2000) guideline values to minimize adverse effects due to nutrients for lowland rivers.**

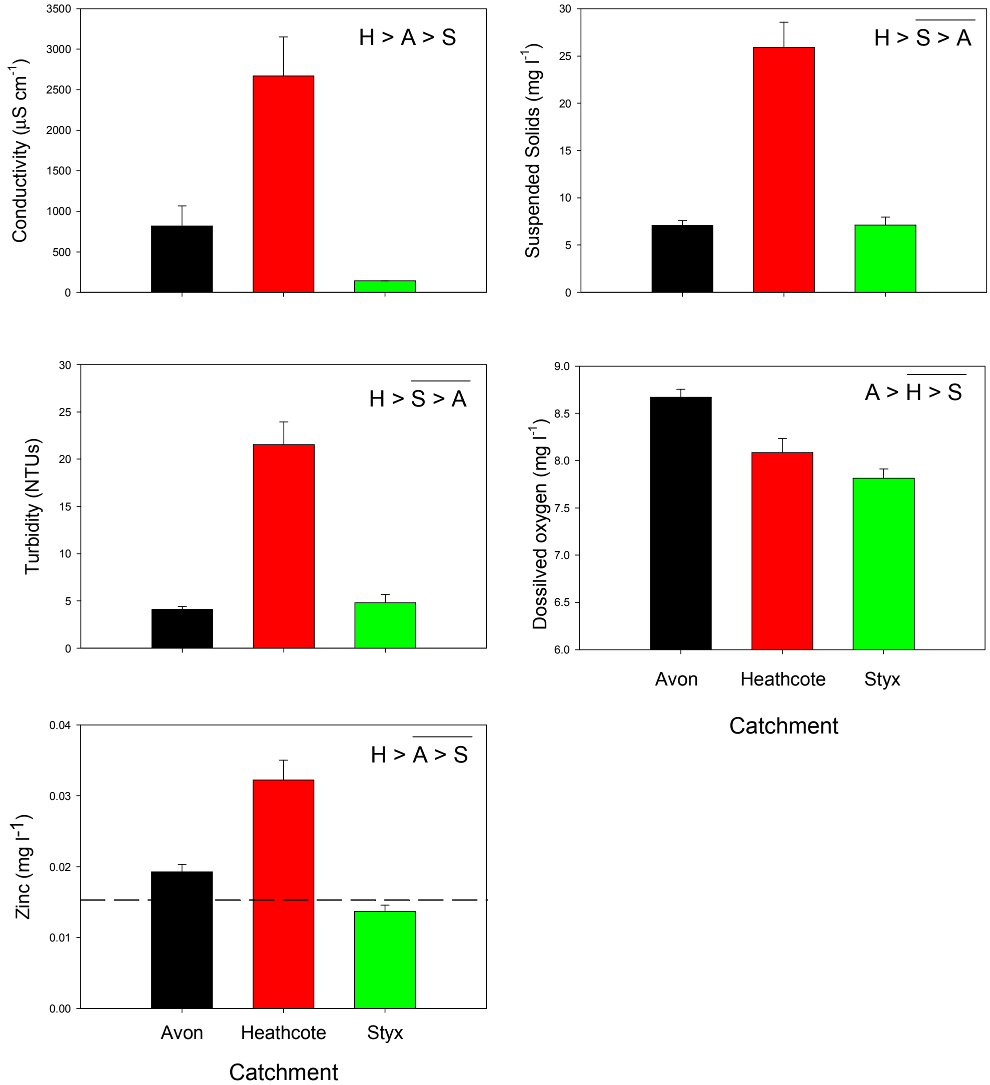

Figure 6: **Mean values (± 1 SE) of physical parameters (conductivity, suspended solids, turbidity and Biological Oxygen Demand (BOD_5)), and dissolved Zinc in the Avon, Heathcote and Styx catchments. Conventions as per Figure 5. . Dashed line indicates relevant ANZEEC (2000) guideline values for Zinc beneath which 90% of species are protected in freshwater systems.**

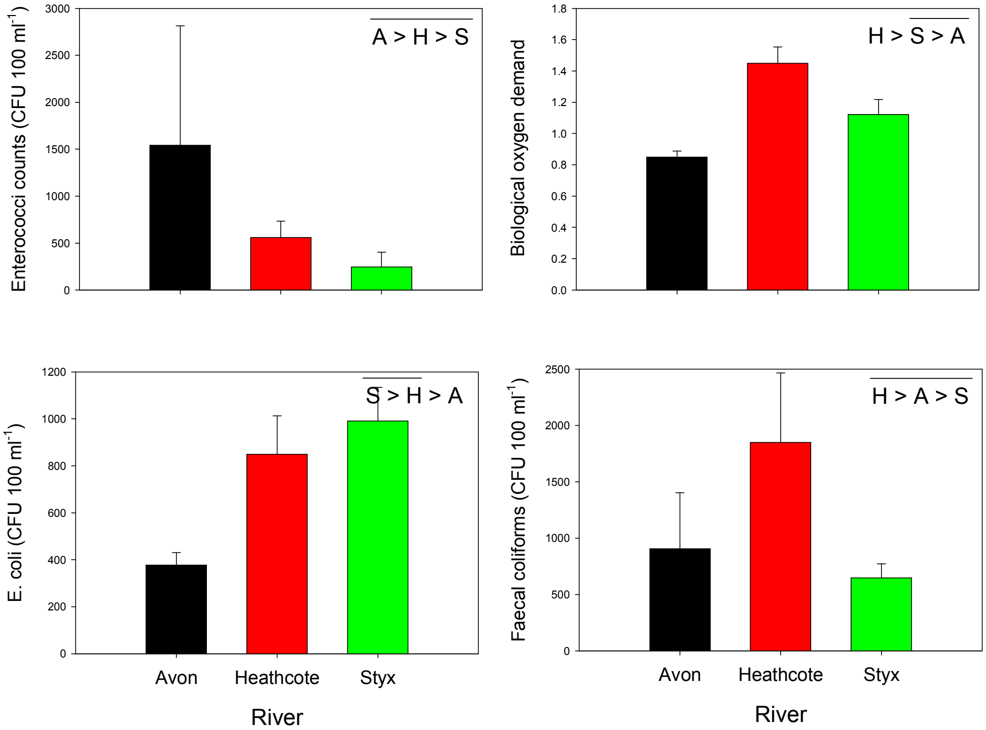

Figure 7: **Mean values (+ 1 SE) of bacterial contamination, and dissolved oxygen levels in the Avon, Heathcote and Styx Rivers. Conventions as per Figure 5.**

Examination of differences between each waterway within three catchments revealed some interesting patterns. In the Avon catchment, the Avon mainstem had higher values of four nutrient parameters (ammonia, soluble phosphorus, nitrate, and total phosphorus), four physical parameters (turbidity/suspended solids, pH and conductivity), and BOD_5. Of interest was the finding that *E. coli* counts did not differ between the Avon mainstem and either Waimairi or Wairarapa Stream, while Waimairi stream had the highest enterococci counts, and Wairarapa Stream the highest faecal coliform counts. The high bacterial counts in these two streams were unexpected given the fact that sewer overflows do not occur in these small tributaries.

The mainstem of the Heathcote River has high concentrations of three nutrients (ammonia, soluble phosphorus, and total phosphorus) as well as higher turbidity/suspended sediments and conductivity than Cashmere stream. Cashmere stream had higher dissolved and saturated oxygen concentrations. Bacterial loadings in both the Heathcote and Cashmere stream were similar.

Within the Styx catchment, the Kaputone Stream had the highest levels of four nutrients (ammonia, nitrate, nitrate-nitrite, soluble and total phosphorus), as well as the highest faecal coliform counts, and BOD5. Both Kaputone Stream and the Styx River had the highest nitrate-nitrite concentrations, suspended sediments/turbidity, and

E. coli counts. The high nutrient concentrations, and *E. coli* counts in Kaputone stream may reflect inputs from the Belfast freezing works, but the high *E. coli* counts in the Styx are unexplained, but are not related to the presence of sewer overflows.

These results suggest that the presence of sewer overflows in the Avon and Heathcote Rivers did not have demonstrably clear and consistent effects in overall water chemistry. The finding that bacterial loadings in waterways without sewer overflows in them were at times greater than the loadings in waterways with the sewer overflows suggests that there must be other transport mechanisms for bacteriological contamination of urban streams to occur. The most likely mechanisms for this would be a mixture of stormwater run-off, as well as contamination from animals. Indeed, recent studies by ESR showed that *E. coli* contamination into parts of the Avon River came from either birds, or from dog faeces that was washed into the stormwater system. Presence of sewer overflows in the Avon and Heathcote Rivers consequently does not necessarily result in increased bacterial loadings over and above what is happening already.

3.6. Contaminant levels in rivers flowing into the estuary – water quality

Examination of water quality data from the Avon and Heathcote Rivers allowed us to compare nutrient levels to ANZECC (2000) guidelines. Average nutrient levels in the rivers often exceeded ANZECC thresholds above which excessive plant growth may occur). Copper and zinc concentrations measured in both rivers exceeded ANZECC (2000) recommended threshold levels for contaminants in water and sediments beneath which a 90% of species are considered to be protected (copper: 1.8, zinc: 15 µg/l) from significant adverse effects on several occasions in 2008 and in 2009. No data was available for levels of PAHs or other organic contaminants. This data came from routine water quality monitoring of the Avon and Heathcote Rivers. Examination of flow data from these rivers on the days of sampling showed that the average flows when water quality samples were taken were less than the long-term average flow. This means that neither the Avon nor the Heathcote would have been receiving inputs from sewer overflows, which only occur during times of prolonged rainfall and high river flows. These results highlight the fact that Christchurch's urban waterways are most likely impacted by lower intensity, but more frequent stormwater runoff that flows into them instead of the infrequent sewer inputs.

4. Synopsis of effects

Based on the above analyses, we can summarise what effects the sewer overflows are likely to have on the ecology of the Avon and Heathcote Rivers, and of the estuary. However, before this summary, it is important to consider that the above sewage discharges are currently occurring at a recurrence interval of ca. 6 months. ECan note (Point 6 in the s92 letter) that if the proposal is consented at a six month ARI then there will be more frequent overflows into lower dilution storm flows than those that were to occur at the currently consented 2 year ARI. However, the sewer overflows are currently occurring at a six-month ARI or more frequently at some sites, so the proposed activity will not increase the frequency of existing discharges. Furthermore, discussions with the CCC indicate that the current frequency and quantity of sewer overflows in both the Avon and Heathcote Rivers will decrease from the current situation, with the planned works in the LTCCP. As such, the contention by ECan that there will be more frequent overflows into a lower dilution of storm flows is not correct.

Based on our analyses presented in section 3, we have shown that the sewer overflows had little or no effect on water quality at sites above and below the overflows, even at a 6 month ARI. The only exception to this was the higher *E. coli* counts in the lower Avon River site below the overflow. Our results also showed that high degree that the sewer overflows are diluted to; under both a 2 year and 6 month ARI. We also showed that stormwater contributes a far greater mass load of heavy metal contaminants entering the rivers and estuary than the sewer overflows. In the earlier reports, McMurtrie et al (2006) and Suren et al (2008) found no demonstrable impacts from the sewer overflows on either the benthic invertebrate, or fish communities in waterways exposed to sewer overflow discharges. If no effects were observed in waterways currently exposed to a 6-month ARI, then it is highly unlikely that any demonstrable improvement to the ecological communities would result by reducing the discharge to a 2-year ARI.

4.1. Instream ecology

Our analysis shows that the combined sewer overflows did not result in higher nutrients or *E. coli* counts in either the Avon or Heathcote Rivers, nor in Dudley Creek, with the exception of a slight increase in the average *E. coli* counts in the Avon River below the sewer overflows. Although there was an increase in *E. coli* counts at sites further downstream in the Avon, and to a lesser extent the Heathcote River, this could not be attributable solely to the impacts of the sewer overflows, as these downstream sites would undoubtedly receive more stormwater from the urban catchment, and so be exposed to a higher contaminant loading. Furthermore, our analysis of dilution rates within the Avon and Heathcote rivers showed a very high degree of dilution of the sewer overflows when mixed with the receiving river water, with a median rate of 1:334 times. Such a high dilution rate may explain why the analysis of differences in water quality parameters showed few differences in water quality above and below the overflows. Moreover, the calculated annual mass loadings of contaminants from the sewer overflows when compared to stormwater inputs were negligible. Finally, analysis of overall water chemistry from the Avon, Heathcote, and Styx Rivers showed few consistent differences in water chemistry that could be related to the effects of the sewer overflows. Many of the differences between rivers could be attributed to the inputs of stormwater run-off from the surrounding urban catchments, and not to the presence of sewer overflows. The finding that the Styx River had higher *E. coli* counts, and similar faecal coliform counts, as the Avon and Heathcote Rivers suggests that the presence of sewer overflows does not necessarily result in high bacterial loadings.

Given the lack of increases in nutrients below the overflows, the high degree of dilution to the overflow discharge, and the fact that discharges only happen during times when the rivers are naturally in high flow, then it is highly unlikely that any biological effects would be detected below the overflows, as was observed by both McMurtrie et al (2008) and Suren et al 2009 in the initial AEE. This contention is further reinforced by examination of the invertebrate communities in the Avon and Heathcote rivers, and in Dudley Creek, which are typical of those normally found in urban streams. This community is dominated by oligochaetes, the amphipod *Paracalliope*, the snail *Potamopyrgus*, midges and the small bivalve *Sphaerium*. These invertebrates are highly tolerant of degraded conditions, and are unlikely to be affected by short-term discharges of sewage that may flow into the rivers occasionally, and become highly diluted.

The invertebrate communities in waterways in the Avon and Heathcote catchment are faced with multiple stressors, including:

1. alterations to their physical and hydrological habitat conditions;
2. inputs of stormwater;
3. loss of connectivity between upstream and downstream areas;
4. occasional sewer overflows.

Prior to urbanisation, it is highly likely that the streambed in these rivers was dominated by cobbles and gravel. Such streambeds are still found in many of the non-urban streams to the north of Christchurch, such as the head reaches of the Styx River, and the Otukaikino. Many waterways within the Avon and Heathcote catchments have streambeds dominated by fine silts. These have smothered what presumably was a coarser substrate, resulting in a reduction of habitat quality for many invertebrates. Furthermore, many of the banks have been modified and replaced with gabion, concrete, or wood lined banks. Riparian conditions have also changed considerably, with much of the native overhanging vegetation now replaced by exotic vegetation (Suren *et al.* 2005). These changes to the physical habitat conditions would have had profound influences on the invertebrate communities.

The second major stressor facing invertebrate communities in waterways throughout Christchurch is from stormwater discharges. Stormwater inputs contain quantities of heavy metals, sediments, nutrients, organic compounds and pathogens (Williamson 1993, Williamson *et al.* 1999, Suren 2000, Ermens 2007), and urban run-off represents a widespread, chronic stress on aquatic ecosystems. This explains the commonly observed degradation of stream health in urbanised catchments (Walsh 2000, Paul & Meyer 2001, Walsh *et al.* 2005). Although stormwater inputs may result in concentrations of metals, toxicants and nutrients exceeding ANZECC (2000) guidelines for the protection of aquatic health, there is also the issue that much of this material is combined into the sediments so that sentiment concentrations often exceed ANZECC (2000) guidelines, and have detrimental impact on aquatic species. Moreover, recent surveys of metal contamination of biofilms coating cobbles in Christchurch streams have shown that they also contain high levels of heavy metals (Suren & Elliot 2004). Recent experiments have shown that these metal contaminated biofilms result in increased mortality of grazing invertebrate such as the mayfly Deleatidium (A. Suren unpublished data). Although algal biofilms may be washed from streams during floods, new growth is also expected to be contaminated as well, reflecting its close association with sediments.

Another stressor facing stream invertebrate communities involves a loss of connectivity between upstream and downstream areas. Blakely & Harding (2005) and Blakely *et al.* (2006) found that road culverts act as significant barriers to the upstream flying behaviour of adult caddisfly species. They found that streams with suitable egg laying habitat such as coarse cobbles or boulders were not utilised if these areas were upstream of low road culverts through which adults would not fly. The implications of this finding is that many sections of streams in urban environments become increasingly isolated to many aquatic insects species, and become dominated only by a fauna that can both persist in the habitat conditions, and that can colonise these areas.

As a result of these multiple large-scale stressors, the composition of the invertebrate communities in waterways of Avon and Heathcote catchments has been altered from that prior to urban development. All taxa intolerant of these altered conditions would have disappeared, leaving behind only tolerant taxa. It is very unlikely that these remaining taxa would be sensitive to the occasional sewer overflows, particularly when these occur only during periods of high river flow, and thus become well diluted.

It is our opinion that the freshwater biota of these waterways is more likely constrained by other pressures associated with urbanisation such as sedimentation, loss of instream and riparian habitat and loss of connectivity than it is by occasional sewer overflows. Furthermore, the high degree to which stream sediments and biofilms are contaminated by heavy metals represents a long lasting legacy that will always exert a constraining influence on invertebrate communities, even with improvements to stormwater quality. Even if stormwater treatment did improve its quality, our calculations showed that the percentage contribution of the sewer overflows to annual loadings of heavy metals even after treatment would still be negligible. Furthermore, any reduction in the frequency of overflows from a 6-month ARI to a 2-year ARI is also highly unlikely to have a demonstrable impact to the ecological values of Christchurch's waterways. It is our opinion that the biota of waterways within the Avon and Heathcote catchments is constrained by other stressors, and not by the occasional sewer overflows.

4.2. Estuarine ecology

The sewer wastewater overflows will contribute to mass loading of nutrients, heavy metals and organic contaminants discharging into the Avon and Heathcote Rivers and ultimately reaching the estuary. However, the contaminants of greatest concern, particularly zinc, lead, copper, PAHs, and dioxins, all enter the waterways predominantly via surface runoff to the stormwater system. The estimated contribution of contaminants from 6-monthly ARI sewer discharge to the river water that flows into the estuary is negligible compared to that from the higher volumes of stormwater discharged.

Estimated concentrations of heavy metals resulting from sewer overflow discharged into river waters are below ANZECC (2000) guideline values for protection of 90% of species. Estimated mean concentrations of some nutrients (total nitrogen and total phosphorous) discharging from sewer overflows into rivers exceeded ANZECC guideline trigger values used to assess risk of nuisance growth of aquatic plants. However, contaminated river water would be further diluted once it has entered the estuary, lessening the likelihood of nuisance plant growth or harmful effects to estuarine biota. Thus, any small reduction in estuarine water quality attributable to the sewer overflows is unlikely to cause significant adverse ecological effects to the estuary, especially when considering the high degree to which the sewer overflows are diluted, and the much greater impacts from contaminants in stormwater.

Although contaminants from sewer overflows are unlikely to cause toxic effects within the estuarine water column, persistent contaminants such as heavy metals and some organic toxins entering waterways via sewage effluent may accumulate and remain for long periods within estuarine sediments. While Mills and Willamson (1999) concluded that heavy metals were present within estuarine sediments at levels below those where impacts to benthic biota would be expected to occur, continued accumulation of some heavy metals such as copper and zinc, and organic contaminants such as PAHs and dioxin, could raise concentrations within sediments to toxic levels. However, our analysis has shown that the relative contribution from sewer overflows to contamination of estuarine sediments and associated potential adverse impacts to estuarine biota is minor when compared to that from stormwater.

4.3. Responses to ECan's S92 request

Point 4: Effects in and around local drains

From the results of sections 3.1, 3.2, 3.3, and 3.5, we can make the following conclusions about the sewer overflows:

- There are no significant differences in *E. coli* counts above or below sewer overflows in Heathcote or Dudley Ck. Counts of *E. coli* were significantly higher at sites below the sewer overflows only in the Avon River;
- There is a high dilution rate of the sewer overflow when it enters the receiving water;
- Even in the smaller waterways such as Dudley Creek, the sewer overflows are diluted to a relatively large extent, and are thus unlikely to have significant detrimental impacts on the aquatic ecosystem;
- Estimated heavy metal concentrations in the rivers attributable to the sewer overflows, did not exceed ANZECC guidelines for concentrations at which 90% of species are considered to be protected from significant adverse effects;
- Annual mass load of heavy metal contaminants entering the rivers and estuary from wastewater overflows was negligible compared to contaminant loading entering via surface runoff and stormwater;
- The presence of sewer overflows in the Avon and Heathcote Rivers did not have demonstrably clear and consistent effects in overall water chemistry.

Bacterial loadings in waterways without sewer overflows in them were at times greater than the loadings in waterways with the sewer overflows.

McMurtrie et al (2006) surveyed invertebrate communities at sites above and below the Locarno Street sewer overflow point in the Heathcote River five days after a record overflow event. Despite the short time between the overflow event and sampling occurring, they found no clearly discernible effects of the Locarno Street overflow on the benthic invertebrate communities. Suren et al (2008) surveyed both fish and invertebrate communities in the Avon River and Dudley Creek at sites above and below sewer overflows. This study was not done immediately following a discharge event, but was done to determine whether any long-term chronic effects on the extreme biota were apparent. They found little demonstrable impact on either fish or invertebrate communities in the Avon River and Dudley Creek as a result of the sewer overflow discharges. Both these ecological studies also concluded that the ecological communities in Christchurch of waterways are constrained more by changes to physical habitats, and by long-term chronic stormwater inputs than a by the occasional sporadic sewer overflows.

Multiple values exist for the waterways throughout Christchurch, including ecology, recreation, aesthetic, historical, cultural, and drainage. Studies by McMurtrie et al (2006) and Suren et al (2008) clearly showed that the sewer overflows do not adversely affect the ecological values of the waterways. The sewer overflows only happen during times of high rainfall when the rivers are at high flow. During such times, recreational use of the waterways may be lower than would occur when the rivers are not in flood. Many of the smaller creeks such as Dudley Creek are not particularly visible to neighbouring properties as they are often confined to incised channels and flow along margins of properties which are commonly fenced. In some waterways, the CCC has undertaken a considerable amount of riparian enhancements, including provision of walking tracks along the river margin. However, in many cases this planting hides a view of the stream water, so that only glimpses can be seen (Suren 2009). Dudley Creek is an example of this, whereby the walking track along it only provides occasional glimpses of the water (A. Suren pers. obs.). As such, any visual effects of the sewer overflows are likely to be minor, especially given the fact that the only occur during times of high flow, when many of the waterways are naturally turbid as a result of stormwater inputs, and when the numbers of people out walking are likely to be low.

Point 5: Ecological effects in the estuary and short-term effects in the rivers

From sections 2.3, 3.4, 4.1 and 4.2 we can make the following observations. The estuary supports a diverse fauna of benthic invertebrates, and fish. It is also recognized as an outstanding wildlife area of national importance. Wastewater originating from stormwater and sewage overflow and discharging into the Avon and Heathcote Rivers and the estuary may contain elevated levels of a range of contaminants such as: nitrogen and phosphorous; heavy metals such as copper, lead, chromium, arsenic, mercury and zinc; and a range of organic contaminants including polycyclic aromatic hydrocarbons (PAHs), organochlorines, dioxin, chlorophenols and bichlorinated biphenyls (PCBs). However, wastewater overflows are intermittent, and relatively brief, and their contribution to contaminant loading in the river water that flows into the estuary is likely to be insignificant compared to that from the high volumes of stormwater discharging at the same time. Consequently, we predict that the effects of the sewer overflows to the biota of the estuary are minor when compared to that from stormwater. This contention is for both short, and long-term effects of the sewer overflows.

As far as "*further information on ecosystems in the waters and on the margins*", refer to the response to Point 4 (above).

Point 6: Changes in relative impact of the proposed wastewater discharges in the drains, streams and estuary as stormwater improvements are made

From sections 3.4, 4.1 and 4.2 we are able to state confidently that even if all stormwater were treated with best management practice treatment devices capable of achieving a 60% reduction in heavy metals, then the mean and median contribution of the wastewater overflows to the total loading would still be very minor (generally < 1%). Such a degree of spatial treatment and such a consistently high efficiency is unlikely, so the actual reduction in contaminant loads is likely to be less. Notwithstanding this, even if such removal rates were achieved, the instream and estuarine communities are still likely to be limited by overarching effects such as the legacy of heavy metal contamination and habitat alteration following 160+ years of urban development.

ECan also wanted "*further information on what ecological parameters and indices will be appropriate as the water quality is improved*". Under the Proposed NRRP (ECan 2009), ECan has recognized seven major river types, each with their own water quality characteristics and management objectives. As part of this, each river type has specific water quality standards (Schedule WQL1 Water

Quality Classes). For the Urban Class (Class 2.6), ECan has recommended 14 specific standards, of which three are of direct relevance to this investigation:

- (f) The average annual concentration of: (i) soluble inorganic nitrogen shall not be increased by 0.02 milligrams per litre; or (ii) soluble reactive phosphorus shall not be increased by exceed 0.002 milligram per litre.

- (j) The concentration of total ammonia shall not exceed: (i) 0.1 milligram of nitrogen per litre, the average result of ten samples taken every third day; and (ii) 0.9 milligram of nitrogen per litre for a single sample.

- (m) The concentration of any toxicant listed in Table WQL 19 in Part 2 of this Schedule, measured as the total fraction, shall not exceed the concentration specified for the 90 percent level of protection for that toxicant.

Monitoring selected water chemistry parameters above and below individual sewer overflows (section 3.1) showed no consistent differences in overall water chemistry that could be attributable solely to the effects of the sewer discharges. Lack of such effects most likely reflects the high degree of dilution to the sewer overflow upon entering the receiving water (section 3.2). Furthermore, we showed that the annual mass load of heavy metals entering the rivers and estuary from wastewater overflows was negligible compared to contaminant loading entering via surface runoff and stormwater (section 3.4). Water quality monitoring of Avon and Heathcote (section 3.5 and 3.6) showed that these rivers often have high nutrient and metal loads, many of which exceeded ANZECC (2000) guidelines. Much of the water quality sampling was during times when flows in the Avon and Heathcote were less than the long term averages, when no sewer overflows would be occurring. This lead us to conclude that even if the sewer overflows could be completely eliminated, water chemistry within the Avon and Heathcote rivers is unlikely to improve greatly, given the large degree of stormwater that is generated from the impervious areas within their catchments. This means that there is unlikely to be any significant improvement to water quality within the catchments even if all sewer overflows could be stopped. We thus suggest that the current proposed water quality standards for the Urban Class are unlikely to be affected by the occurrence (or not) of occasional sewer overflows.

Point 8: Effects on estuary water quality

This has been covered in sections 3.3 and 3.4, and in our commentary above.

5. Summary

In their S92 request, ECan raised four particular issues which are dealt with in this report including; the effects of the sewer overflows on the ecology of the Avon-Heathcote estuary/Ihutai, and the effects of any changes in the relative impact of the proposed wastewater discharges in the drains, streams and estuary as stormwater improvements are made. We have addressed these issues by describing the baseline ecological conditions of the estuary, and summarising the present contaminants, which arise from a variety of sources including stormwater, sewer overflows, and the Bromley wastewater treatment plant – although the discharge from this is expected to cease shortly.

We examined water quality conditions above and below overflow sites in the Avon and Heathcote rives, and in Dudley Creek. We found no differences in average nutrient concentrations above and below the sewer overflows, and no differences in *E. coli* counts above and below the overflows in the Heathcote River and Dudley Creek. *E. coli* was higher below the overflows only in the Avon River. We showed that the sewer overflows are diluted to a high degree by river flow, with a median dilution of 1:334 times. We also showed that the contribution of contaminants from the sewer overflows was negligible when compared to that from stormwater. Finally, we showed that the sewer overflows did not result in huge differences in water quality in the Avon and Heathcote Rivers when compared to the Styx River, which does not receive such overflows.

The freshwater communities in the Avon and Heathcote Rivers are faced with multiple stressors, including at least a 100 year exposure to stormwater runoff, habitat alteration, and loss of connectivity. Considering the huge impacts that these stressors would have had on freshwater ecosystems, then the impact of occasional sewer overflows would be negligible, especially given the degree to which they are diluted. The communities in the estuary have also faced similar pressures in terms of historic stormwater inputs, and habitat alteration arising from sedimentation. Calculations have shown that annual mass loadings of the key contaminants of concern into the estuary from sewage overflows are extremely small when compared to those from stormwater, even if these loadings could be reduced by best management practices.

Given the above, we regard the ecological effects of occasional sewer overflows on the ecological values of the Avon and Heathcote Rivers and estuary / Ihutai as minor.

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