5. Description of the Discharges

5.1 Introduction

Auckland City's drainage system discharges contaminated stormwater to the environment. The processes resulting in these discharges are described in Chapter 3. Chapter 4 describes the general nature and quantity of these discharges with specific reference to the five integrated catchment areas of Auckland City.

This chapter of the report describes in more detail the nature, sources and quality of the Auckland City drainage system discharges. The types and sources of contaminants carried in typical discharges are outlined in Section 5.2. Section 5.3 describes the quality of Auckland stormwater in terms of major contaminants and also provides the findings of toxicity studies carried out on stormwater collected at representative sites in Auckland. Where appropriate, the available local information is compared with stormwater quality data reported for other parts of New Zealand and overseas.

5.2 Types and Sources of Contamination

The quality and quantity of stormwater that is ultimately discharged to the environment generally depends on the nature of land uses within each stormwater catchment. Different catchments and land uses give rise to varying volumes of stormwater and types of contaminants within the stormwater and sediments.

5.2.1 Diffuse Urban Runoff

The majority of stormwater that flows to the Auckland stormwater drainage system is runoff from impermeable and permeable surfaces, roads and land. The principal types and sources of contaminants entering the stormwater drainage system via impermeable surface runoff include:

- Contaminants washed from the atmosphere with rainfall, including particulate material and emission products, principally from road use.
- Products of erosion, including sediments, paint from roofs and building surfaces, rust from metallic building fittings, road aggregate, road-surfacing products (bitumen, asphalt), and paint from road markings.
- Vehicle derived wastes including those from tyre and brake lining wear, and service station forecourt runoff, including oils and greases, petrol spillage, engine and body wear.
- Organic wastes from animals and plant litter.
- Litter.
- Illegally disposed of industrial and commercial waste, including wash down wastes spilt onto impermeable industrial and commercial yards.

Runoff from permeable land (parks, bush, lawns, gardens, and cleared or undeveloped areas) generally results from heavier storm events, when rainfall exceeds the volume readily absorbed by the ground. Permeable surface runoff is typically high in sediments (soils and dust). The runoff may also contain organic contaminants associated with pesticides or fertilisers applied to the land. In areas where land is cleared or undergoing development, land erosion products such as clay, sand or silt and construction materials may enter the stormwater drainage system.

5.2.2 Point Sources

In addition to the general sources of stormwater, other distinct discharges enter the drainage system at various sites and under certain circumstances. These sources are referred to as **point sources** and include any inputs to the drainage system from wastewater system relief overflows, landfill leachate and trade waste overflows.

Wastewater and combined stormwater and wastewater system relief overflows to the stormwater network may occur during heavy rainfall at numerous overflow sites in Auckland City, in particular in integrated catchment areas 1 and 2, where the proportion of catchment served by combined stormwater and wastewater systems is higher. These system relief overflows are intermittent and depend on rainfall duration and intensity.

As described in Chapter 3, the system relief overflows are designed to allow controlled discharge of combined stormwater and wastewater to occur should the pipe network become overloaded. There are approximately 581 designed and pump station overflows in the city. Contaminants from the wastewater and combined pipe networks generally enter the stormwater network at these locations.

5.3 Quality of the Discharges

5.3.1 Introduction

The characterisation of contaminants in urban stormwater is a complex task. The concentrations of the different contaminants in stormwater can vary considerably with different land uses and catchment runoff characteristics. The origin and fate of the contaminants vary both within and between storm events because the frequency and duration of rainfall can vary. "First-flush effects" give rise to higher contaminant concentrations in runoff when the first rain falls, particularly after dry periods (Williamson 1982; NIWA 1993). The quality of stormwater discharged can also be influenced by interactions between different contaminants.

In general, urban stormwater contaminants may include:

- **Suspended sediments** derived from dust deposition, land erosion, land clearance and construction-related sources, road wear and instream erosion.
- **Trace elements** dissolved in the stormwater and bound to suspended sediments; derived from vehicle emissions and wear, road wear, roof and building erosion and runoff, metal fragments.
- **Organic contaminants** such as hydrocarbons and oils, trace organics derived from vehicle emissions, oil and fuel spillages, roading, fertiliser and pesticide use, trade waste overflows.

- **Pathogenic micro-organisms** derived from system relief overflows, animal and bird droppings.
- **Nutrients** derived from organic debris, system relief overflows, animal and bird droppings.
- **Oxygen-demanding substances** derived from soil organic matter and plant detritus, system relief overflows, organic contaminants.
- **Litter** including food, paper, glass, metal, plastics, rubber and organic materials.
- **Bed load contaminants** which are washed down the stormwater system by physical force, including sand, gravels, road chips and their associated contaminants.

5.3.2 Stormwater Quality Information

Stormwater and sediment quality information is limited for Auckland City. Whilst studies have been undertaken in Auckland (listed in Table 5.1), not all contaminant classes were included in each of the studies. Other stormwater quality data have been reported for sites in greater Auckland (Leersnyder 1993, ARC 1994b) and although these data were collected outside of the Auckland City boundaries, the information is considered representative of typical residential, commercial and industrial stormwater and is included in the description of Auckland City stormwater for this reason.

Most of the stormwater quality studies demonstrate the conventionally accepted fact that contaminant concentrations are not uniform throughout a stormwater runoff event. Generally, maximum concentrations usually coincide with or precede the period of peak flow. The event-mean-concentration (EMC) is one of the summary statistics commonly used for stormwater quality, up to approximately a one-month storm, because it provides a useful index of total contaminant loading to the final receiving water. Where a large number of storms have been sampled, an overall mean of individual EMCs is a plausible descriptor of stormwater quality at the site. For larger storms EMC is less appropriate as it assumes an infinite quantity of pollutants in catchments.

Studies also demonstrate the large variability in single storm event contaminant EMCs and loads. This variability is readily understood in terms of storm intensity and duration, antecedent rainfall record and predominant land use within the stormwater catchment. In the Auckland region further variability between sites is to be expected from wastewater system relief overflows which exist in many of the integrated catchment areas. For this reason, information on nutrients, oxygen demand and indicator organisms is more relevant than is the case with other urban areas not using combined system and wastewater system relief overflows.

Sites in Table 5.1 labelled CO (combined stormwater and wastewater system relief overflow) sites or WO (wastewater system relief overflow during wet weather) sites indicate that samples were taken directly from a system relief overflow structure. Note also that other stormwater sites may be impacted by wastewater system relief overflows at upstream locations.

Stormwater quality summarised in the following sections for the Carrington, Pacific Steel and Hayman Park sites are representative of untreated runoff from roading (carpark), industrial, and commercial land uses respectively. However, it should be noted that these stormwater samples were collected at the inlets to stormwater treatment facilities at these sites. Therefore,

Table 5.1: **Stormwater quality studies of relevance to the Auckland City area.**

Integrated Catchment Area and Site	Land Use	No. Storms	Study period	Reference
Integrated Catchment Area 1				
Grey Lynn (Hakanoa St)	Residential (CO/WO)	2	1999	Worley (2000)
Integrated Catchment Area 2				
Meadowbank (Temple St)	Residential		1999	City Design (2000b)
Meadowbank (Waiatarua Tunnel)	Residential		1999	City Design (2000b)
Meadowbank (Ngapuhi Rd)	Residential (CO)		1999	City Design (2000b)
Meadowbank (Lucerne Rd)	Residential (CO)	3	1999	City Design (2000b)
Meadowbank (Lucerne Rd)	Residential (CO)	4	1999	Worley (2000)
Integrated Catchment Area 3				
Carrington	Carpark	14	1994	ARC (1994a)
Mt Roskill (Memorial Rd)	Industrial/Residential	3	1999	Worley (2000)
Integrated Catchment Area 5				
Southdown	Industry	6		ARC (1992a)
Kohimarama	Residential			Worley (2000)
Glen Innes (Concorde Pl)	Residential/ Commercial (WO)	2	1999	Worley (2000)
Tamaki (Pilkington Rd)	Industry	3	1999	Worley (2000)
Glendowie (Whitehaven)	Residential	3	1999	Worley (2000)
St Heliers (Vale Rd)	Residential	3	1999	Worley (2000)
Other Information of Interest (not within Auckland City boundaries)				
Pacific Steel (Mangere)	Industry	6	1992	Leersnyder (1993)
Hayman Park (Manukau)	Commercial	4	1992	Leersnyder (1993)
Pakuranga	Residential	27	1988-1992	ARC (1994b)

the actual stormwater quality discharged to the stormwater drainage system after treatment is somewhat improved. It is conceivable that for most modern and future industrial and commercial complexes in Auckland City, stormwater treatment facilities may be required as part of the resource consent process.

Stormwater Sediment and Gutter Dust Studies

Many contaminants entering the stormwater drainage system are not very water soluble and are strongly associated with (that is, bound within or adsorbed to) particulate material and sediment washed into the gutters and stormwater pipe network. Such contaminants include several trace elements and trace element "species" and most of the toxic organic contaminants.

In late 1999 and early 2000, dust and sediments were collected from gutters and roofs in the Meadowbank/Orakei Basin catchments by City Design (2000b) in order to further characterise the physical properties of sediments potentially entering the stormwater system. In addition, stormwater sediment and gutter dust analyses were carried out by ARC (1992a) to indicate the nature of sediments (and associated contaminants) collected on impermeable surfaces within two representative catchments in the greater Auckland area. The gutter dusts were sampled at Southdown (a highly industrial catchment within integrated catchment area 5) and Pakuranga (not within the Auckland City boundaries, but representative of Auckland City catchments of high residential and commercial land use, and very low industrial land use).

The results of these studies are described in the following sections.

5.3.3 Sediment Loading

Urban runoff is not different from storm runoff from pastoral or arable land, in the respect that high concentrations of sediments and associated nutrients, bacteria and organic matter are entrained. However, unlike sediments in stormwater from other land uses, sediments in urban stormwater are often media for the transport of material derived from vehicle and industrial sources (that is, trace element and hydrocarbon contaminants). The sediments and the contaminants which are bound to them are associated with a wide range of potential effects on the receiving environment.

The following discussion describes the presence and nature of sediments measured in Auckland stormwater. The associated sediment-bound contaminants are discussed in the sections following.

Sediment Sources in Urban Stormwater

Sediments in urban stormwater are derived from a number of sources including roofs, street gutters, street and paved surfaces adjacent to the gutter, and other impermeable and permeable areas channelled to the stormwater pipe network. Sources are listed in Section 5.3.1.

The impermeable surfaces and roofs act as collecting surfaces for particulate material from the atmosphere and other sources (soils, plant debris, litter, surface erosion products). These sediments are quickly mobilised during rainfall events.

If storm events exceed the volume of rainfall easily absorbed by permeable land, such as gardens, parks and urban reserves, surface runoff from these surfaces may channel sediment to the stormwater pipe network.

In areas where new development is occurring, instream erosion is a major source of the sediments ultimately discharged in urban stormwater to the receiving environments (Williamson 1993). In Auckland, the streams have been incorporated into the stormwater drainage system for many years and instream erosion has greatly reduced from what it was at the time of development.

The Physical Nature of Sediments in Urban Stormwater

The physical nature of sediments contained in Auckland stormwater has been assessed by ARC (1992a) and City Design (2000b).

ARC (1992a) reported that the physical nature and composition of the gutter dust entering the stormwater drainage system reflects the density of traffic. In high density traffic areas in both a residential/commercial catchment (Pakuranga) and an industrial catchment (Southdown), 60% of the material was inorganic and comprised soils, materials eroded from other paved and man made surfaces, metal fragments and rust, rubber fragments from tyre and vehicle wear, glass, plastic and litter.

The proportion of organic debris (from adjacent tree, grassed and garden sources) increased from 40% to 85% in a lower density traffic area in Pakuranga.

The material collected in the Pakuranga and Southdown street gutters was generally coarse in nature and predominantly in the particle size range 0.12 – 1 mm (ARC 1992a). The gutter dust collected in the Meadowbank catchment was finer and the mean particle size of the coarse fraction was 1.2 – 1.3 mm. The difference between the two studies is likely to be due to sampling methods, whereby City Design (2000b) vacuumed the samples and hence more of the fine fraction is likely to have been collected than from sweep sampling.

Sediments that were collected in the stormwater pipe network at Pakuranga and Southdown were finer than those in the street gutters and generally particle sizes ranged from less than 0.020 – 0.063 mm. The difference in particle sizes between material collected in the street gutters and that measured in the stormwater itself may be due to the variable mobility of the various particle sizes. Non-buoyant, larger particles do not generally travel as far and settle more quickly within the stormwater pipe network than finer particles which are carried for long distances. The effects of velocity on particle transport are complex. Larger particles are also more likely to be retained by catch-basins, gratings and other "catching" mechanisms along the stormwater pipe network. ARC (1992a) also discussed the limitations of gutter dust sampling, whereby larger material is easily collected and a proportion of finer particles are lost during collection.

Suspended Solids Levels in Urban Stormwater

Information on suspended solids in stormwater in the Auckland City area is presented in Table 5.2. In addition, Williamson (1993) has summarised typical event mean concentrations (EMCs) of suspended solids in urban runoff, as reported in overseas and New Zealand literature. The suspended solids concentrations measured in the Auckland City area (Table 5.2) are within the range of typical EMCs for suspended solids reported by Williamson (1993). These ranged from 50 – 470 g/m^3, with a median of 170 g/m^3. Suspended solids concentrations measured at Southdown and Pakuranga by ARC (1992a) were relatively low as a result of the high proportion of impermeable surface coverage in the catchments assessed.

Table 5.2 summarises the suspended solids concentrations in Auckland City stormwater with different land uses. There is no clear correlation between the land use and suspended solids concentrations in urban stormwater reported in Table 5.2. Williamson (1993) discusses the variation in suspended solids levels and loading in urban runoff with land use and development. Sediment yields from mature urban areas such as Auckland City are not reported as high (in the order of 500 kg/hectare/year) and are similar to those in New Zealand low-lying pastoral and native catchments. It may be concluded from the information presented by Williamson (1993) that sediment yield in urban runoff is a reflection of land development rather than land use.

Table 5.2: **Suspended solids concentrations† measured in Auckland City stormwater.**

Integrated Catchment Area and Site	Land Use*	Suspended solids concentration (g/m³)	Comments
Integrated Catchment Area 1			
Grey Lynn (Hakanoa St)	RES (CO)	104	
Integrated Catchment Area 2			
Meadowbank (Temple St)	RES	166.8	City Design (2000b)
Meadowbank (Waiatarua Tunnel)	RES	19.8	City Design (2000b)
Meadowbank (Lucerne Rd)	RES (CO)	104.4	City Design (2000b)
	RES (CO)	112	Worley (2000)
Integrated Catchment Area 3			
Carrington	Carpark	26	Untreated
		2	Treated by sand filter
Mt Roskill (Memorial Ave)	IND / RES	97.3	
Integrated Catchment Area 5			
Southdown	IND	52	
Kohimarama	RES	32	
Glen Innes (Concorde Pl)	RES/COM (WO)	182	
Tamaki (Pilkington Rd)	IND	253	
Glendowie (Whitehaven)	RES	151	
St Heliers (Vale Rd)	RES	55.1	
Pacific Steel **	IND	123.6	Untreated
		26.9	Treated by wet detention ponds
Hayman Park **	COM	26.6	Untreated
		10.8	Treated by wet detention ponds
Pakuranga **	RES	24.9	

Sources: Provided in Table 5.1.

Note: †Event-mean-concentrations or means of event-mean-concentrations given. *RES = residential; IND = industrial; COM = commercial; CO = combined stormwater and wastewater system relief overflow site; WO = wastewater system relief overflow site. **Not within the Auckland City boundaries. Information given for comparison.

5.3.4 Trace Elements

Sources of Trace Elements in Urban Stormwater

The predominant source of lead, zinc and copper in urban stormwater, gutter dusts and sediments is vehicle emissions.

Until 1996, lead was used in petrol as an anti-knock additive. Although lead is not currently added to petrol, it may still enter the stormwater drainage system when contaminated sediments are disturbed, and from used oil. Lead may also be associated with paint chips from eroded building surfaces.

Soluble lead in urban runoff is likely to be present as the inorganic complexes $PbCO_3$ and the ionic complex $PbHCO_3^+$. Only a small fraction of the lead is typically present as the Pb^{2+} ion (Kingett Mitchell & Associates Ltd 1988).

Copper is common in urban stormwater and stormwater sediments because of its use in mechanical and electrical engine parts and in many industries. Copper is likely to be primarily in the form of fine metallic particles in urban stormwater (Kingett Mitchell & Associates Ltd 1988).

There are a number of varied sources of zinc in urban stormwater and sediments. Zinc may be bound to particulate material from rubber tyres and metal alloy products. In addition, runoff from galvanised roof surfaces and painted surfaces commonly contain dissolved or sediment-bound zinc.

The most toxic form of zinc in urban runoff is the free Zn^{2+} ion (Timperley 1999). Other less toxic species include $Zn(OH)_2$, $ZnCO_3$ carbonate and the ionic complexes $ZnOH^+$ and $ZnHCO_3$. Larger zinc species are the zinc-organic complexes including simple organic and amino acid complexes with zinc, and the non-toxic zinc-natural organic matter complexes, humic acid and fulvic acid (Kingett Mitchell & Associates Ltd 1988).

Other trace elements which potentially pose a toxic threat to receiving environments include arsenic, mercury, nickel and cadmium, which may be present in urban runoff from catchments associated with heavy industry. Cadmium is often a contaminant in zinc products, however zinc used in New Zealand industry contains much lower cadmium levels than reported overseas (Williamson 1993).

Levels of Trace Elements in Urban Stormwater

Information on trace element concentrations measured in stormwater in the Auckland City area is presented in Table 5.3. In addition, ARC (1992a) has reported trace element levels in stormwater, stormwater sediments and gutter dusts from two representative catchments in Auckland, and Williamson (1993) has summarised information on trace elements in urban runoff, as reported in overseas and New Zealand literature.

Reported concentrations of lead and copper in the Auckland City stormwaters are 60 – 190 g/m^3 and 15-110 g/m^3 respectively. These were generally lower than the median EMCs of 110 g/m^3 and 40 g/m^3 reported by Williamson (1993). The exception was the lead and copper measured in untreated stormwater collected from the Pacific Steel industrial site at Otahuhu.

Zinc concentration at the industrial sites was also at the higher end of the range of typical EMCs for zinc (90 – 800 g/m^3) reported by Williamson (1993). Note that Leersnyder (1993) reported a large reduction (generally > 80%) in trace element concentrations at the outlet of the Pacific Steel and Hayman Park stormwater treatment (wet detention pond) facilities. This brought the trace element levels in the treated stormwater actually entering the stormwater drainage system to concentrations similar to residential stormwater (refer Table 5.4). Similar reductions in trace element concentrations were reported by ARC (1994a) for Carrington carpark runoff treated by an on-site sand filter.

Although the Grey Lynn and Meadowbank areas are primarily residential, high mean EMC of zinc was also measured at these combined stormwater and wastewater system relief overflow sites. Zinc is a common additive to many household products and the concentrations at this site reflect both zinc in wastewater and that transported by stormwater runoff from catchment surfaces.

Table 5.3: **Trace element concentrations† measured in Auckland City stormwater.**						
Integrated Catchment Area and Site	**Land Use ‡**	**Comment**	**Total Lead * (mg/m³)**	**Total Copper * (mg/m³)**	**Total Zinc * (mg/m³)**	**Total Cadmium * (mg/m³)**
Integrated Catchment Area 1						
Grey Lynn (Hakanoa St)	RES	CO / WO		20	900	0
Integrated Catchment Area 2						
Meadowbank (Lucerne Rd)	RES	CO (City Design 2000b)		20	250	
Meadowbank (Lucerne Rd)	RES	CO (Worley 2000)		30	400	0
Meadowbank (Waiatarua Tunnel)	RES	(City Design 2000b)		9	42	
Meadowbank (Temple St)	RES	(City Design 2000b)		9	42	
Integrated Catchment Area 3						
Carrington	Carpark	Untreated	21 Tot	8 Tot	35 Tot	
			1.6 Sol	2.7 Sol	14.5 Sol	
		Treated by sand filter	1.5 Tot	2 Tot	7.5 Tot	
			0.9 Sol	1.3 Sol	3.3 Sol	
Mt Roskill (Memorial Ave)	RES			27	223	nd
Integrated Catchment Area 5						
Southdown	IND		82	42	466	
Glen Innes (Concorde Pl)	RES	WO		40	150	0
Tamaki (Pilkington Rd)	IND			46	438	nd
Glendowie (Whitehaven)	RES			10	110	nd
St Heliers (Vale Rd)	RES			nd	128	21
Pakuranga **	RES	High density traffic	55 AS	15 AS	444 AS	
			<22 Dis	7 Dis	238 Dis	
		Low densty traffic	86 AS	13 AS	330 AS	0.056 AS
			0.21 Dis	3.2 Dis	170 Dis	0.018 Dis
Pacific Steel **	IND	Untreated	226	75	2,785	
		Treated by wet detention pond	65	6	230	
Hayman Park **	COM	Untreated	50	16	278	
		Treated by wet detention pond	ND	ND	29	

Sources: Provided in Table 5.1.

Notes: †Event-mean-concentrations or means of event-mean-concentrations given. ‡RES = residential; IND = industrial; COM = commercial; CO = combined stormwater and wastewater system relief overflow site; WO = wastewater system relief overflow site. *Total (TOT) trace element concentrations given unless specified: Sol = Soluble trace element concentration; AS = Acid soluble concentration; Dis = dissolved concentration. **Not within the Auckland City boundaries. Information given for comparison. nd = not detected.

Table 5.4: **Trace element removal efficiency of the (sand filter) stormwater treatment facility at Carrington.**			
Parameter	**Mean Concentration Reduction %**	**Average EMC Reduction %**	**Sum of Loads Reduction %**
Total Lead	94.5	92.9	97.6
Soluble Lead	56.3	20.2	79.3
Total Copper	81.1	69.3	90.8
Soluble Copper	59.3	35.9	71.4
Total Zinc	81.7	77.6	93.2
Soluble Zinc	80.3	76.7	90.5

Source: After ARC (1994a).

A large proportion of trace elements in sediment-rich stormwater is often bound within sediments or adsorbed to the surface of sediments and therefore, trace elements measured in stormwater and sediments are not always readily available to ecological systems in the receiving environments. Concentrations of trace elements measured in Auckland stormwater were correlated with suspended solids concentrations in ARC's (1992a) study. Total dissolved concentrations do not include measurements of contaminants bound within sediments and are therefore closer estimates of bio-available contaminant levels. However, total contaminant concentrations can also affect or limit biodiversity.

Dissolved trace element concentrations have been measured at two of the stormwater sites described in Table 5.2 – at the Carrington carpark (ARC 1994a) and in the residential Pakuranga catchment (ARC 1992a). Both sources of dissolved and total trace element information indicate that soluble trace elements make up approximately half or less than half of the total trace element concentrations. This has been supported by the integrated catchment study undertakn by City Desgin in the Meadowbank catchment.

Leersnyder (1993) also reported the relative proportions of trace element contaminants in the dissolved and particulate form for the untreated (and treated) stormwater from the Pacific Steel and Hayman Park sites. Dissolved lead and copper concentrations were not detected and dissolved zinc made up approximately 13% and 65% of the mean total zinc concentrations in the untreated Pacific Steel and Hayman Park runoff respectively. Leersnyder (1993) reported large reductions (>85%) in the average zinc EMCs at the outlet of the Pacific Steel and Hayman Park stormwater treatment ponds (refer Table 5.3).

5.3.5 Hydrocarbons and Organic Contaminants

The main source of hydrocarbons and organic contaminants in urban stormwater is vehicle emissions. Other sources include atmospheric deposition, the redistribution of chemicals washed off roads and roadside garages, petrol stations and land with a history of contamination. Less commonly, illegal discharges or disposal of oils, paints, household or industrial chemicals and the incorrect usage of pesticides/herbicides also contribute (ARC 1992a).

Hydrocarbon contaminants measured in urban stormwater include oils and grease, total hydrocarbons, alkane hydrocarbons and polycyclic aromatic hydrocarbons (PAHs). As with the trace element contaminants discussed above, hydrocarbons, including alkane hydrocarbons and PAHs, are typically strongly bound to suspended solids (particulate matter) in urban runoff.

Information on organic contaminants in New Zealand stormwater is limited. ARC (1992a) have measured a range of organic contaminants in gutter dusts collected at two representative sites in greater Auckland, Southdown and Pakuranga. The gutter dust data are outlined in the following sections, with comparative overseas information on organic contaminants in urban runoff described where this is available (from Williamson 1993).

Oils and Grease

Oil and grease are common contaminants washed off streets, carparks and petrol station forecourts during rainfall events. Generally these oils and greases are not in high concentrations and most of the by-products associated with the oils and greases are not toxic (Williamson 1993), other than PAHs in engine oil.

ARC (1992a) reported oil and grease levels in stormwater from Southdown and Pakuranga. Oil and grease concentration in two samples were 3.14 and 6.77 g/m^3 for the industrial Southdown catchment and 1.89 and 8.31 g/m^3 for a representative catchment in Pakuranga.

Polycyclic Aromatic Hydrocarbons (PAHs) and Total Hydrocarbons

PAHs emissions are derived from the incomplete thermal combustion of fuel and are very common in smoke and vehicle exhausts and consequently urban runoff. As discussed earlier, PAH compounds are also components in engine and lube oil, in particular used or "old" oil, and may enter the stormwater drainage system through oil puddles and spills washed off roads and carparks during storm events. PAHs are known to cause potentially toxic effects on aquatic organisms in the receiving environments.

PAH and other hydrocarbon contaminants are not generally soluble and are predominantly bound within or adsorbed to particulate matter in urban runoff. Hydrocarbon and PAH concentrations in stormwater sediments in the Southdown and Pakuranga catchments were reported by ARC (1992a). Pyrene, chrysene (benz(a)anthracene), fluoroanthene and benzo(g,h,i)perylene were the dominant PAH compounds in the stormwater sediments. All PAH compounds were present at higher concentrations in the finest silts <0.047 mm. Based upon the measured suspended solids concentrations in the stormwaters sampled, ARC (1992a) estimated that total PAH levels in the stormwater were approximately 27.1 $\mu g/m^3$ in the industrial Southdown catchment and approximately 62.2 $\mu g/m^3$ in the residential Pakuranga catchment.

Williamson (1993) provides a discussion on the toxicity of PAH compounds. The most toxic PAH compounds are generally those of low molecular weight such as naphthalene and phenanthrene and their alkyl derivatives. These low molecular weight PAH compounds (or "LPAH") are sufficiently soluble in water to be bioavailable (and present acute toxic effects) on biota. LPAH compounds are generally very volatile and rapidly biodegrade such that they are not typically present at high concentrations in urban stormwater or receiving environment sediments. Occasionally petrol spills in industrial or motor accidents may result in these LPAH compounds entering the stormwater drainage system.

Higher molecular weight PAH compounds (or "HPAH") are more stable, however they pose a risk of potential chronic toxic effects on benthic biota and bottom dwelling fish.

ARC (1992a) noted that PAH concentrations were a small proportion of the total hydrocarbons measured in the gutter dusts and stormwater suspended sediments sampled. Alkane hydrocarbons made up a significant proportion of the total hydrocarbon concentrations measured in the Pakuranga stormwater suspended sediments (ARC 1992a). Concentrations of all hydrocarbon types generally increased with decreasing particle size in the suspended sediment particle range. For instance, most (77.3%) of the total hydrocarbons measured were associated with particles smaller than silt size (<0.063 mm).

ARC (1992a) estimated a total hydrocarbon concentration of 0.2 g/m^3, based upon the measured suspended solids concentrations in the stormwater collected at the residential Pakuranga catchment. Even in Pakuranga, which indicated higher levels of PAH than the industrial Southdown catchment, the level of total hydrocarbons is well below the range of total hydrocarbon concentrations (1 – 5 g/m^3) in typical urban stormwater reported by Williamson (1993).

Organochlorine Contaminants

Organochlorine contaminants have also been reported in Auckland stormwater sediments and gutter dusts (ARC 1992a), including polychlorinated biphenyls (PCBs), DDT and its breakdown products, and other pesticide and fertiliser products. Although these contaminants are not currently manufactured or used, Auckland has a widespread history of their usage. These contaminants are highly persistent in the environment and may enter the stormwater drainage system after atmospheric deposition or redistribution of local soils and sources (ARC 1992a).

PCBs were manufactured up until the late 1970s for a variety of uses including capacitors, pumps and oils. The PCB congeners containing five to seven chlorine atoms are particularly common and ubiquitous in the environment. PCB concentrations were estimated by ARC (1992a) at approximately 4.98 $\mu g/m^3$ in the industrial Southdown catchment and approximately 0.5 $\mu g/m^3$ in the residential Pakuranga catchment (based upon the measured suspended solids concentrations in the stormwater). These estimated PCB concentrations are relatively low when compared to typical PCB levels in urban runoff (0.014 – 890 $\mu g/m^3$) as reported by Williamson (1993).

DDT was widely used as a pesticide in New Zealand until 1970. Current insecticide products may still contain DDT as an ingredient. DDT and its breakdown products DDD and DDE are often measured in residual concentrations in soils and marine and freshwater sediments in Auckland.

The nature and levels of DDT compounds were assessed in gutter dusts in the Southdown and Pakuranga catchments by ARC (1992a). The dominant DDT isomer in the gutter dusts was p,p' DDT, particularly in particles less than 0.047mm. The source of the DDT is not known, although the dominance of the DDT isomer suggests that the DDT has not degraded in the dust and soils collected in the gutters. Like other organic contaminants assessed, all DDT compounds were present at higher concentrations in the finest silts <0.047 mm.

Based upon the measured suspended solids concentrations in the stormwaters sampled, ARC (1992a) estimated that total DDT levels in the stormwater were approximately 0.9 µg/m^3 in the industrial Southdown catchment and approximately 0.42 µg/m^3 in the residential Pakuranga catchment.

Other organochlorine compounds measured by (ARC 1992a) included the pesticides chlordane, lindane, dieldrin and heptachlor. Dieldrin was measured at relatively high concentrations (3.94 – 44.66 ng/g, dry weight) in the industrial Southdown catchment. Levels at Pakuranga were lower and similar to chlordane concentrations (4 – 7 ng/g). The chlordane level estimates (approximately 0.0002 – 0.00054 mg/m^3, based on upon corresponding suspended solids concentrations), were below the concentration range of chlordane reported in overseas urban runoff (0.01 – 10 mg/m^3), as reported by Williamson (1993).

Lindane and heptachlor concentrations were low in the gutter dusts assessed by ARC (1992a).

5.3.6 Microbiological Quality

Generally human enteric micro-organism numbers are low in urban stormwater (Williamson 1993). Another common source of microbiological contaminants to the stormwater drainage system is bird and animal droppings washed from the surfaces and gutters in the urban catchment.

Information on levels of the microbiological indicator organisms faecal coliform and *Enterococci*, measured in stormwater in the Auckland City area, is summarised in Table 5.5. The microbiological quality of stormwater, stormwater sediments and gutter dusts in two representative catchments in Auckland has also been reported by ARC (1992a).

As expected, the highest levels of enteric bacteria were recorded at the combined wastewater and stormwater system relief overflow sites at Grey Lynn (CO), Meadowbank (CO) and Glen Innes (WO). Clearly, the dilution of wastewater by stormwater is lowest at the separated wastewater system relief overflow in Glen Innes.

Worley (2000) also reported fluoride concentrations at several sites to indicate the level of potable water in the stormwater samples (and hence an indication of the level of system relief overflows to the stormwater pipe network). From this information (presented in Table 5.5), higher bacteria levels appear to correlate with higher levels of potable water (as indicated by fluoride concentrations). This suggests that the primary source of bacteria in the stormwater drainage system is from wastewater and combined wastewater and stormwater system relief overflows and pumping station overflows.

5.3.7 Nutrients and Oxygen Demanding Substances

A number of sources contribute nutrients to urban stormwater, including dust, wastewater and combined system relief overflows, animal waste, plant and lawn debris, organic litter and fertilisers (ARC 1992a).

Oxygen demanding contaminants may be present in stormwater from anaerobic water (for example, catchpit waters) and plant and organic matter inputs to the stormwater drainage system (e.g., wastewater, plant litter).

Integrated Catchment Area and Site	Land Use *	Faecal coliforms (cfu/100 mL)	*Enterococci* (cfu/100 mL)	Fluoride (g/m^3)
Integrated Catchment Area 1				
Grey Lynn (Hakanoa St)	RES (CO/WO)	$5.9x10^5$	$8.6x10^4$	0.12
Integrated Catchment Area 2				
Meadowbank (Temple St)	RES (CO)		$5.7x10^3$	
Meadowbank (Ngapuhi Rd)	RES (CO)		$1.4x10^5$	
Meadowbank (Lucerne Rd)	RES (CO)		$1.8x10^5$	
Meadowbank (Lucerne Rd)	RES (CO)	$2x10^6$	$1.7x10^5$	0.14
Integrated Catchment Area 3				
Carrington	Carpark			
Mt Roskill (Memorial Ave)	IND / RES	$1.02x10^4$	$1.8x10^3$	0.15
Integrated Catchment Area 5				
Southdown	IND	$5x10^3$		
Kohimarama	RES	$1x10^5$	532	
Glen Innes (Concorde Pl)	RES (WO)	$1.1x10^6$	$1.1x10^6$	0.18
Tamaki (Pilkington Rd)	IND	$4x10^4$	$5.7x10^3$	0.13
Glendowie (Whitehaven)	RES	$8x10^3$	$6.5x10^3$	0.08
St Heliers (Vale Rd)	RES	$8x10^3$	$4x10^3$	
Pakuranga **	RES	$1.7x10^4$		

Table 5.5 **Microbiological quality† of Auckland City stormwater.**

Sources: Provided in Table 5.1.

Note: †Event-mean-concentrations or medians of event-mean-concentrations given. *RES = residential; IND = industrial; COM = commercial; CO = combined stormwater and wastewater overflow site; WO = wastewater system relief overflow site. **Not within the Auckland City boundaries. Information given for comparison.

The available information on oxygen demanding contaminants and nutrients in Auckland stormwater is presented in Table 5.6. Chemical oxygen demand (COD) and nutrient concentrations are highest at the wastewater system relief overflow sites. This information suggests that the primary sources of oxygen demanding contaminants and nutrients in the Auckland stormwater are from wastewater system relief overflows.

Leersnyder (1993) reported some reduction in COD and phosphorus concentrations at the outlets of the Pacific Steel and Hayman Park stormwater treatment ponds. However, the reduction efficiency of the treatment ponds was low for ammonia and nitrate (refer Table 5.6).

5.3.8 Stormwater Toxicity Studies

Stormwater samples from three of the sites listed in Table 5.1 (Pacific Steel, Haymans Park, Pakuranga) were tested in 1993 for aquatic toxicity using a standard suite of test organisms (NIWA 1993). All samples demonstrated a slight but measurable toxicity; this could be ranked in terms of catchment type. Industrial and commercial stormwater exhibited similar toxicity, and both exhibited greater toxicity than residential stormwater. A noteworthy feature of all samples was the presence of petroleum hydrocarbon surface films and these needed to be removed to prevent the death of the test organisms.

Table 5.6: Concentrations† of nutrients and oxygen demanding substances measured in Auckland City stormwater.

Integrated Catchment Area and Site	Land Use *	Comment	Chemical Oxygen Demand (COD) (g/m^3)	Phosphorus (g/m^3) Dissolved Reactive Phosphorus (DRP)	Phosphorus (g/m^3) Total Phosphorus (TP)	Nitrogen (g/m^3) Ammonical Nitrogen (NH_4-N)	Nitrogen (g/m^3) Nitrate Nitrogen (NO_3-N)	Nitrogen (g/m^3) Total Kjendahl Nitrogen (TKN)
Integrated Catchment Area 1								
Grey Lynn (Hakanoa St)	RES	CO / WO				0.93		24.3
Integrated Catchment Area 2								
Meadowbank (Lucerne Rd)	RES	CO				5.0		9.73
	RES	CO				7.1		17.2
Integrated Catchment Area 3								
Mt Roskill (Memorial Ave)	IND / RES					0.07		1.07
Integrated Catchment Area 5								
Southdown	IND		43.9	0.019	0.192	0.138	0.981	
Glen Innes (Concorde Pl)	RES /COM	WO			4.8		15.8	
Tamaki (Pilkington Rd)	IND				0.07		0.94	
Glendowie (Whitehaven)	RES				0.03		0.98	
St Heliers (Vale Rd)	RES				0.03		0.59	
Pakuranga **	RES		25.7	0.023	0.098	0.024	0.606	
Pacific Steel **	IND	Untreated	61	0.04	0.447	0.015	0.167	
		Treated by wet detention pond	51.2		0.110	0.019	0.031	
Hayman Park **	COM	Untreated	35.2	0.015	0.131	0.183	0.380	
		Treated by wet detention pond	18.2		0.094	0.150	0.341	

Sources : Provided in Table 5.1.

Notes: †Event-mean-concentrations or means of event-mean-concentrations given. *RES = residential; IND = industrial; COM = commercial; CO = combined stormwater and wastewater overflow site; WO = wastewater system relief overflow site. **Not within the Auckland City boundaries. Information given for comparison. nd = not detected.

Two further series of tests were performed in 1995 (one storm event) and 1997 (three storm events) with samples from the Pacific Steel and Carrington carpark sites, both of which have stormwater detention ponds. These series included both acute and chronic toxicity tests (NIWA 1997). Although the water quality data indicated that both the untreated and treated stormwater for both sites may result in acute and chronic effects (according to USEPA (1999) criteria), the actual acute and chronic toxicity of the stormwater samples was found to be low, particularly after treatment. NIWA (1997) concluded that much of the contaminants present were not in a form readily bioavailable to the test organisms.

5.4 Summary

The quality and quantity of contaminants in Auckland City discharges were compared with EMCs from studies elsewhere, including New Zealand and overseas information summarised by Williamson (1993). The results can be summarised as follows:

- There is limited information available regarding suspended solid concentrations in the Auckland City integrated catchment areas but measurements taken from similar catchment types have indicated that suspended solid concentrations are relatively low.
- Concentrations of lead and copper in stormwater are low throughout the five integrated catchment areas relative to the other areas reported by Williamson (1993).
- Zinc concentrations from industrial areas were relatively high in comparison to the concentrations found by Williamson (1993).
- Hydrocarbon concentrations in stormwater are relatively low in comparison to typical urban stormwater concentration levels reported by Williamson (1993).
- Some organochlorine contaminants were measured in relatively low concentrations (PCB, Lindane, Chlordane) while Dieldrin was relatively high compared to those reported in Williamson (1993).
- The microbiological quality of stormwater varied between and within catchments but a significant increase in bacteria levels was measured during stormflows.
- Acute toxicity levels in stormwater were found to be relatively low, chronic toxicity was demonstrated in the samples taken from detention pond outlets.

The preceding discussion has described the quality and quantity of discharges from Auckland's drainage system. The following two chapters outlines Auckland City's environment and provide the base of information used to assess the effects of the drainage system discharges on the receiving environment in Chapter 8.