4 Inputs

Inputs to the Derwent Estuary include urban and agricultural runoff, sewage and industrial discharges. These inputs can be broadly categorised as point-sources and non-point (or diffuse) sources. Point source discharges to the Derwent Estuary are identified in Figure 17 and include 13 sewage treatment plants (mostly located in the middle estuary) and two major industrial sources: a pulp/newsprint mill (ANM-Boyer) in the upper estuary and a zinc refinery (Pasminco Hobart) on the western shore of the middle estuary.

Other industries which have historically introduced various forms of pollution into the Derwent Estuary include chocolate, textile, ammonia and fertiliser plants, timber mills, abattoirs, etc. These industries are/were mostly located in the middle reaches of the estuary, on the western shoreline. Some of these industries no longer exist; most others (e.g. Cadburys, TIA) now discharge wastewater to municipal sewage treatment plants (STPs).

Inputs from diffuse sources include sediment, organic and nutrient loadings from the Derwent and Jordan Rivers (mostly derived from agriculture and forestry), and urban runoff. Municipal and industrial refuse disposal sites and large industrial stockpiles also contribute significant amounts of contaminants to the Derwent. Other diffuse sources include atmospheric fall-out and pollutants leached from contaminated sediments within the estuary.

This chapter attempts to summarise and quantify pollutant inputs to the Derwent during 1996 on the basis of existing reports and monitoring data. Where possible, estimated inputs from both point- and diffuse-source inputs have been included. However, it should be noted that we were only able to quantify parameters that have been measured; other pollutants undoubtedly are discharged to the estuary as well.

4.1 Sewage treatment plants

Sewage treatment plants collect and treat wastewater using a variety of treatment technologies, depending on wastewater volume and character, costs, and environmental criteria. Effluent from domestic sewage treatment plants usually contains elevated concentrations of total suspended solids (TSS), biological oxygen demand (BOD), nutrients and bacteria. Some treatment plants treat both domestic and industrial wastes (such as the plants at Prince of Wales Bay, Macquarie Point, Selfs Point and Cameron Bay), in which case, industrial contaminants may also be present.

Sewage treatment plants are not normally designed to treat large volumes of stormwater. Diversion of stormwater to sewage treatment plants - whether due to infiltration through cracked sewer mains, historical cross-connections of sewer and storm-water pipes or illegal private connections from roofs and paved areas. - can cause major treatment problems, resulting in the discharge of poorly-treated or untreated sewage to the estuary. Furthermore, it may take some time for operations to return to normal after a major flood event, and effluent quality may continue to be poor during this period. Several treatment plants around the Derwent have recurrent problems with stormwater infiltration: during periods of high runoff; this results in overflows of untreated sewage combined with stormwater to the estuary.

Monitoring requirements

All sewage treatment plants which discharge to the Derwent are required to monitor their effluent on a monthly basis for TSS, BOD and faecal coliforms; many plants also provide data on faecal streptococcus, nutrients and other performance indicators. Maximum permitted levels of BOD, TSS and faecal coliform in treated sewage discharged to Tasmania's inland, estuarine and coastal waters are summarised in Table 11.

Table 11 Sewage treatment plant discharge limits under the Environment Protection (Water Pollution) Regulations, 1974

Receiving Waters	BOD_5 (mg/L)	TSS/ NFR (mg/L)	Faecal coliforms orgs/100 ml	Oil & grease (mg/L)	Ammonia (mg/L)	Nitrate+ nitrite (mg/L)	Total phosp. (mg/L)
Inland waters							
(i)	20	30	200	10	0.5	10	2
(ii)	40	60	200	10	0.5	10	2
Bays and estuaries							
(i)	20	30	1000	10	0.5	10	2
(ii)	40	60	1000	10	0.5	10	2
Coastal waters	N/A	200	N/A	N/A	N/A	N/A	N/A

Notes:
(a) (i) represents where the flow of the receiving waters is <50 times the flow of the emission, and (ii) is where the flow of the receiving waters is > 50 times the flow of the emission;
(b) the oxygen content of the receiving water shall not be reduced below 50% saturation
(c) the effluent should be visually free of grease and oil
(d) where algae are visually detectable in the effluent (i.e. from sewage lagoon systems), thereis no limit on the NFR and the BOD level is increased to 40 mg/L

This data is reported to, and reviewed by, the Division of Environment and Planning/DELM and gives an indication of typical effluent quality. However, since samples are collected independently of the operation of the plant, this data may not reflect unusual conditions (e.g. high rainfall events, spills, etc.) which may have significant effects on the estuary.

Sewage effluent discharges to the Derwent Estuary

In 1996, 13 sewage treatment plants discharged effluent directly to the Derwent (or into tributaries in close proximity to the estuary) at the locations shown in Figure 17. As indicated in Table 12 and Figure 18, average daily flows varied widely from plant to plant, ranging from approximately 200 kL/d at Brighton to 13,000 kL/d at Macquarie Point. The larger treatment plants monitor actual flows; for the smaller lagoon-type systems, flow estimates were provided by local councils. The combined total average daily flow from all 13 plants was approximately 54,000 kL; of this the Macquarie Point, Prince of Wales Bay and Rosny plants contributed 55% - as indicated in Figure 19.

The type and degree of wastewater treatment varied from plant to plant, as is summarised in Table 13, and consequently effluent quality varied as well (see Figure 18, Table 12). Faecal coliform levels were elevated in effluent from several plants around the Derwent on a number of occasions in 1996 - particularly at Rokeby, Brighton, Blackmans Bay and Taroona. In 1996, the Sandy Bay sewage outfall discharged untreated, maccrated sewage to the Derwent at Blinking Billy Point, which contained very high levels of faecal coliform, TSS and BOD. Although the Sandy Bay outfall accounted for only 7% of total sewage flows, it contributed a disproportionally high percentage of the sewage-derived faecal coliform (99.6%), TSS (33%) and BOD (38%).

Annual inputs of TSS, BOD, nutrients and faecal coliform from the 13 sewage treatment plants which discharge to the Derwent were calculated for 1996 on the basis of each plant's average flow rates and effluent concentrations, derived from monthly monitoring records. Results are summarised in Table 12 and relative inputs are shown graphically in Figure 19. Total sewage-derived inputs of TSS and BOD are estimated at 677 and 678 tonnes/year, respectively. Total phosphorus inputs were approximately 142 t/yr, while dissolved inorganic nitrogen was approximately 487 t/yr.

Several small communities adjacent to the estuary are not served by sewers (e.g. Tranmere), relying on individual or community septic systems. Inputs from these areas (not included here due to lack of data) are probably relatively small, but may nonetheless have significant local effects. Sewage may also be discharged directly to the Derwent from recreational vessels, which often lack holding tanks.

Raw sewage discharged as a result of spills or other plant/infrastructure malfunctions is a serious concern, as volumes are difficult to ascertain and raw sewage contains high levels of contaminants. Faecal bacteria numbers, for example are typically over 25,000 times higher in raw sewage than in treated sewage. It is therefore very important to reduce events such as pump station overloads, and the overloading and bypassing of sewage treatment plants during storm events. One major cause of these events is wet weather infiltration through the sewerage systems, often due to roof-top connections to sewer. A recent survey in Glenorchy, for example, indicated that over 50% of homes had illegal stormwater connections to sewer in the surveyed area. During wet weather, stormwater inputs can increase normal sewage flows by 2 to 3 times or more. Plants which have identified significant stormwater problems include Cameron Bay, Blackmans Bay and others. Other causes of raw sewage discharges include the malfunctioning of pumps and other components of sewerage systems.

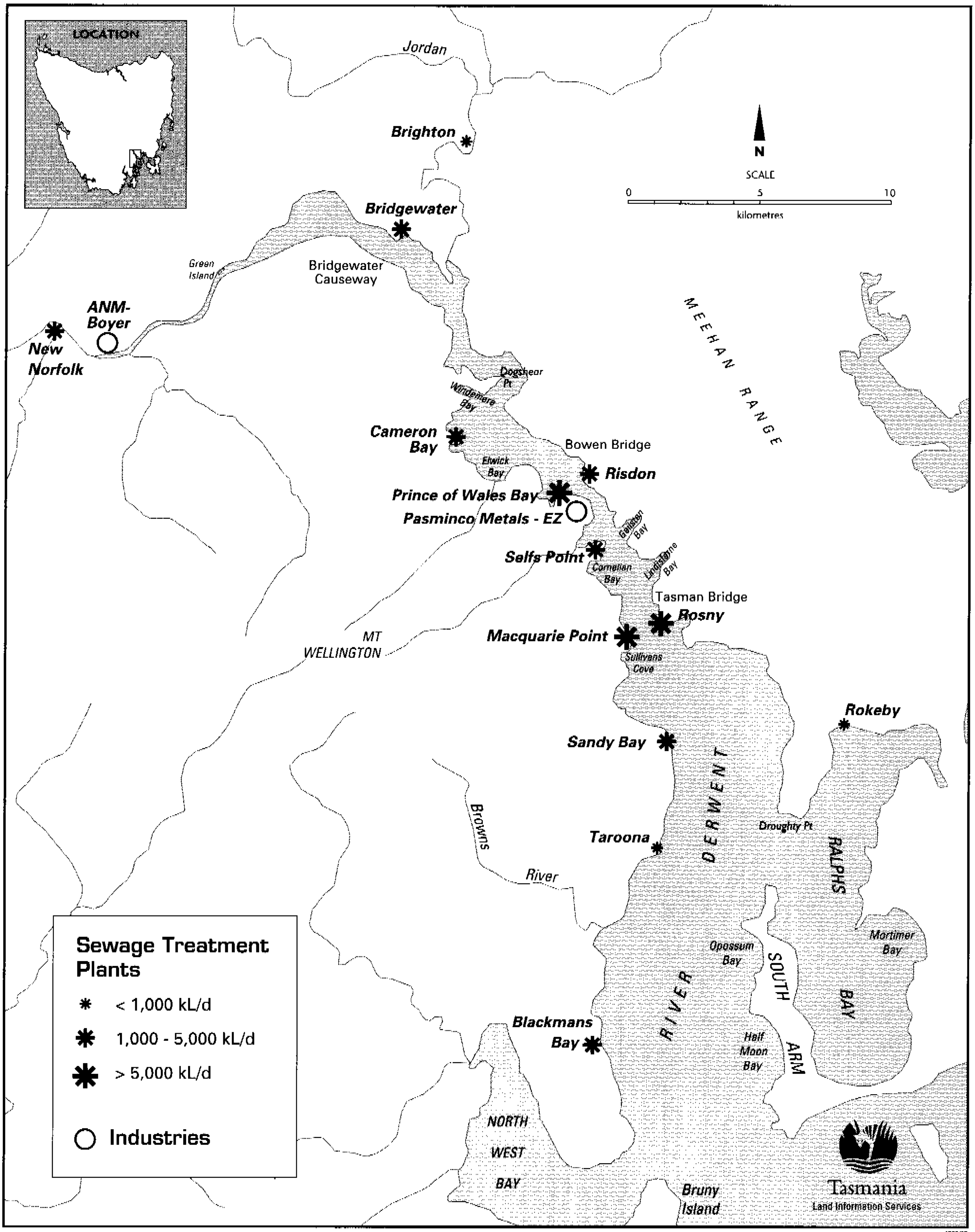


Figure 17 Wastewater discharges

Table 12 Derwent sewage treatment plants - average daily flows, concentrations and annual inputs (1996)

Name	Discharge	KL/d	TSS (NFR)		BOD		Ammonia		Nitrate + nitrite		Total phosphorus		Faecal coliforms**
	Licenced	Avg. 1996	mg/L	t/yr	mg/L	t/yr	mg/L	t/yr	mg/L	t/yr	mg/L	t/yr	No./100ml
New Norfolk*	4,100	2,500	58.0	10.7	17.0	7.7	21.8	24.8	1.9	4.8	8.2	8.1	60
Bridgewater	3,125	2,097	14.0	52.9	10.1	15.5	32.4	19.9	6.3	1.7	10.6	7.4	11
Brighton	200	285	52.5	5.5	34.8	3.6	19.1	2.0	0.5	0.1	9.6	1.0	2365
East Risdon	1,000	2,710	3.9	3.9	6.2	6.1	0.2	0.2	1.3	1.3	5.4	5.3	12
Rokeby	1,330	992	35.0	12.7	27.4	9.9	15.6	5.7	2.5	0.9	9.2	3.3	9670
Rosny	7,500	8,561	32.0	100.0	35.1	109.7	25.2	78.9	3.5	10.8	7.5	23.5	128
Cameron Bay	6,000	4,000	9.6	14.0	22.0	32.1	34.6	50.5	1.6	2.3	9.2	13.4	100
Prince of Wales Bay	9,900	8,000	8.2	23.8	7.5	21.9	23.7	69.1	11.0	32.1	9.2	26.9	15
Sandy Bay	2,700	4,000	155.9	227.6	177.4	259.0	23.8	34.7	0.6	0.9	6.2	9.0	3,244,865
Macquarie Point	18,000	13,000	19.9	94.2	13.8	65.6	10.9	51.9	6.4	30.4	5.2	24.7	17
Selfs Point	6,250	4,000	29.6	43.3	24.1	35.3	7.8	11.4	11.9	17.4	7.6	11.0	56
Blackmans Bay	4,125	3,200	89.1	104.1	80.0	93.4	25.2	29.5	4.1	4.8	8.2	9.6	10634
Taroona	1,150	750	56.9	15.6	95.5	26.1	35.2	9.6	0.6	0.2	9.1	2.5	530
Total	*65,380*	*54,095*		*708*		*686*		*388*		*108*		*146*	*4.8E+16*

* 1994 data

** geomean; total represents total number of fcu's discharged from all STPs

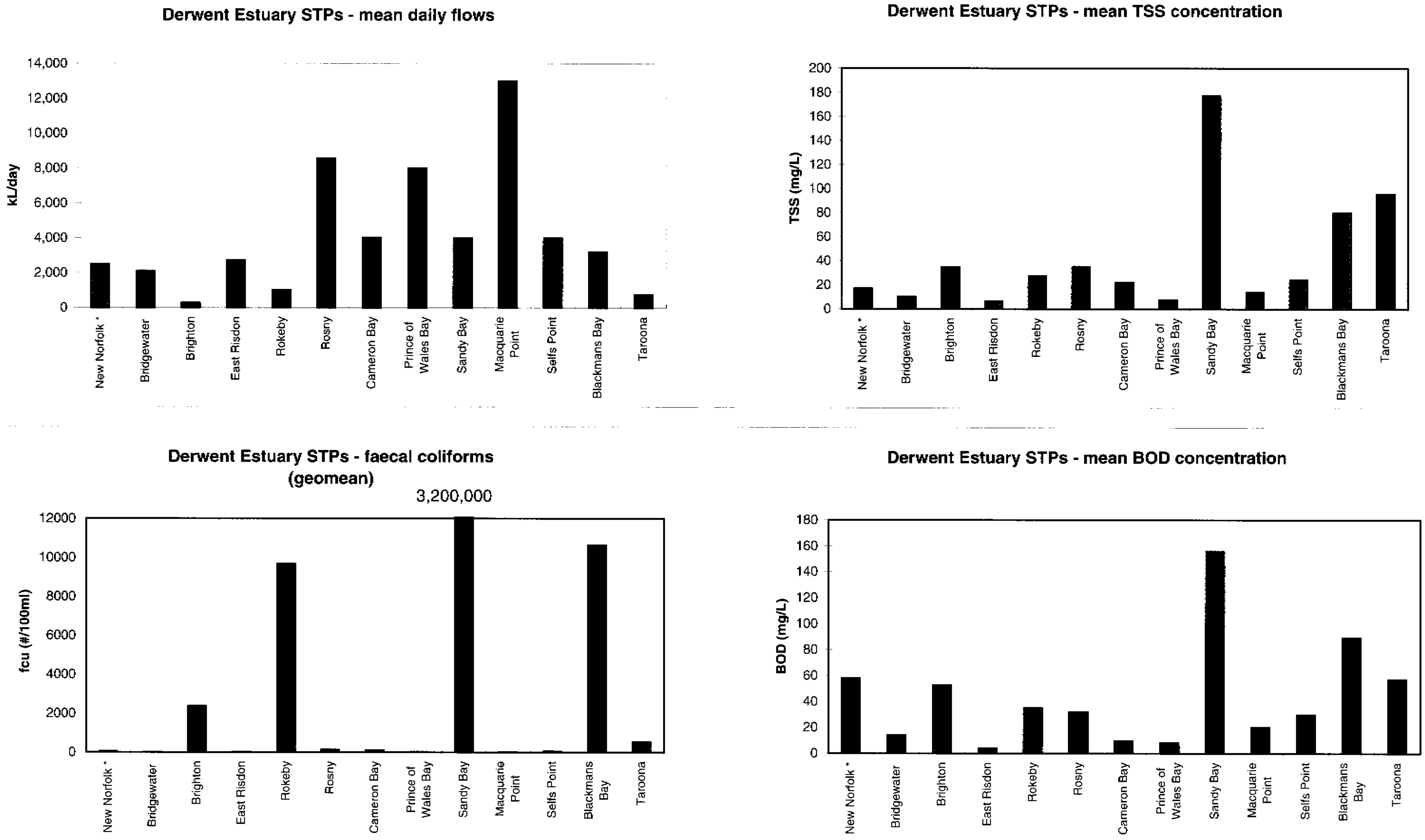


Figure 18 Derwent sewage treatment plants - average daily flows and mean concentrations (1996)

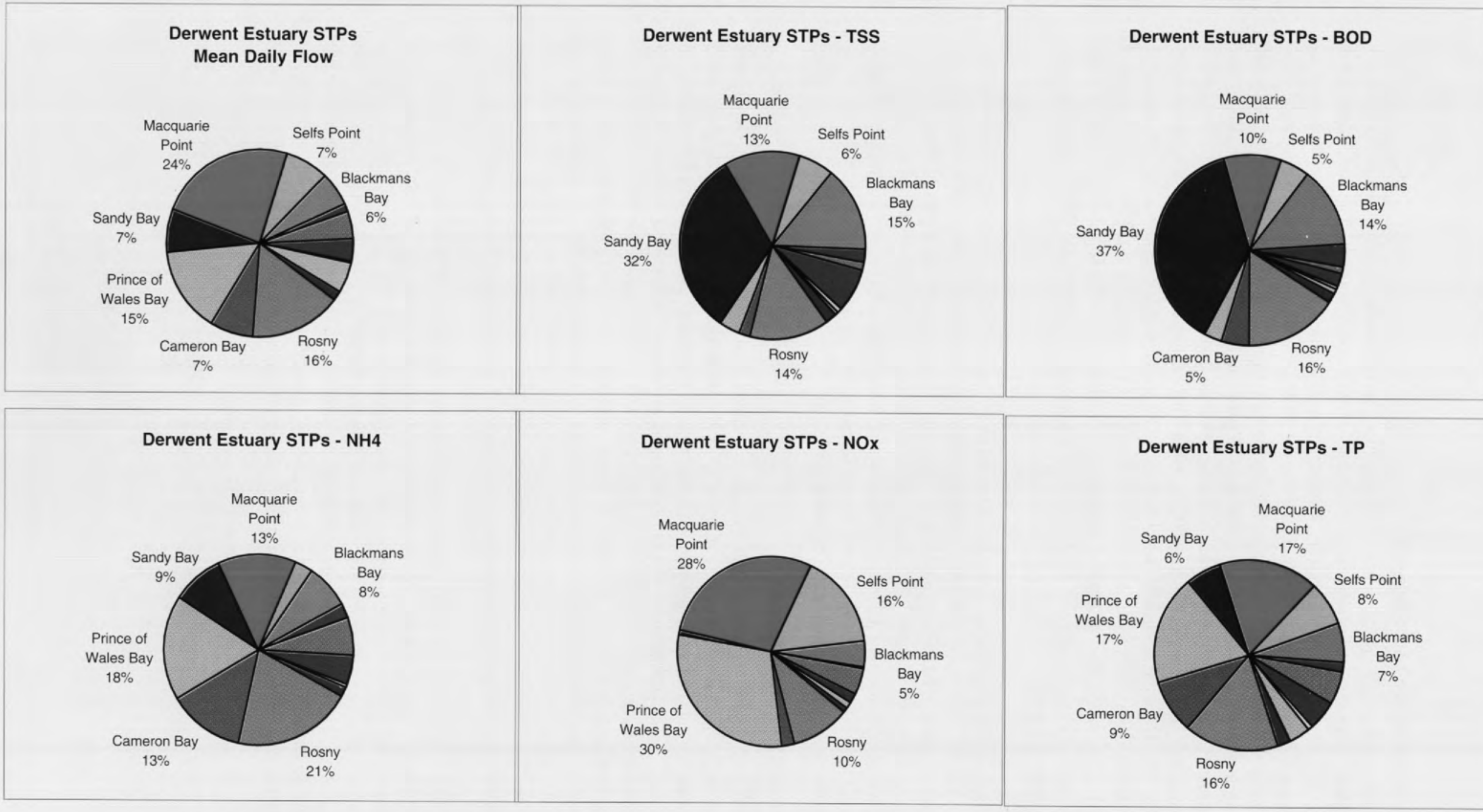


Figure 19 Derwent sewage treatment plants - relative flows and inputs (1996)

Recent and planned improvements

Several important sewage treatment plant upgrades have been completed since 1996, which have resulted in significant reductions in sewage-derived contaminants. The most significant of these is the treatment of Sandy Bay's sewage (piped to Selfs Point for tertiary treatment as of February 1997) - which in 1996 accounted for 99.6% of the sewage-derived bacterial load to the estuary (Figure 20). The Blackmans Bay plant (the second largest contributor of faecal coliform to the estuary in 1996, contributing 0.3% of total inputs) was also upgraded in late 1996/early 1997, significantly reducing bacterial inputs from this source as well. Together, these two changes should result in a 500 to 1000-fold decrease in the reported bacterial load entering the Derwent Estuary from STPs. The next biggest contributor of bacterial contamination via STPs is Rokeby, which is due to be upgraded by 2002. Kingborough Council is installing also telemetry systems and variable speed pump drives to reduce the incidence of accidental sewage discharges and pump station failures (J. Doole, Kingborough Council, pers. Comm.).

As regards nutrients, tertiary treatment of sewage at the new Selfs Point plant is expected to result in a 10% reduction in total sewage-derived nitrogen and phosphorus inputs to the Derwent Estuary. Further reductions in nutrients should result from the planned tertiary treatment plant at Rokeby and from wastewater reuse projects proposed at Brighton, Bridgewater and possibly Clarence. Wastewater reuse commenced at Brighton in August 1997 and very little discharge is anticipated to enter the Derwent from the site in future (J. Parkinson, Brighton Council, pers. comm.).

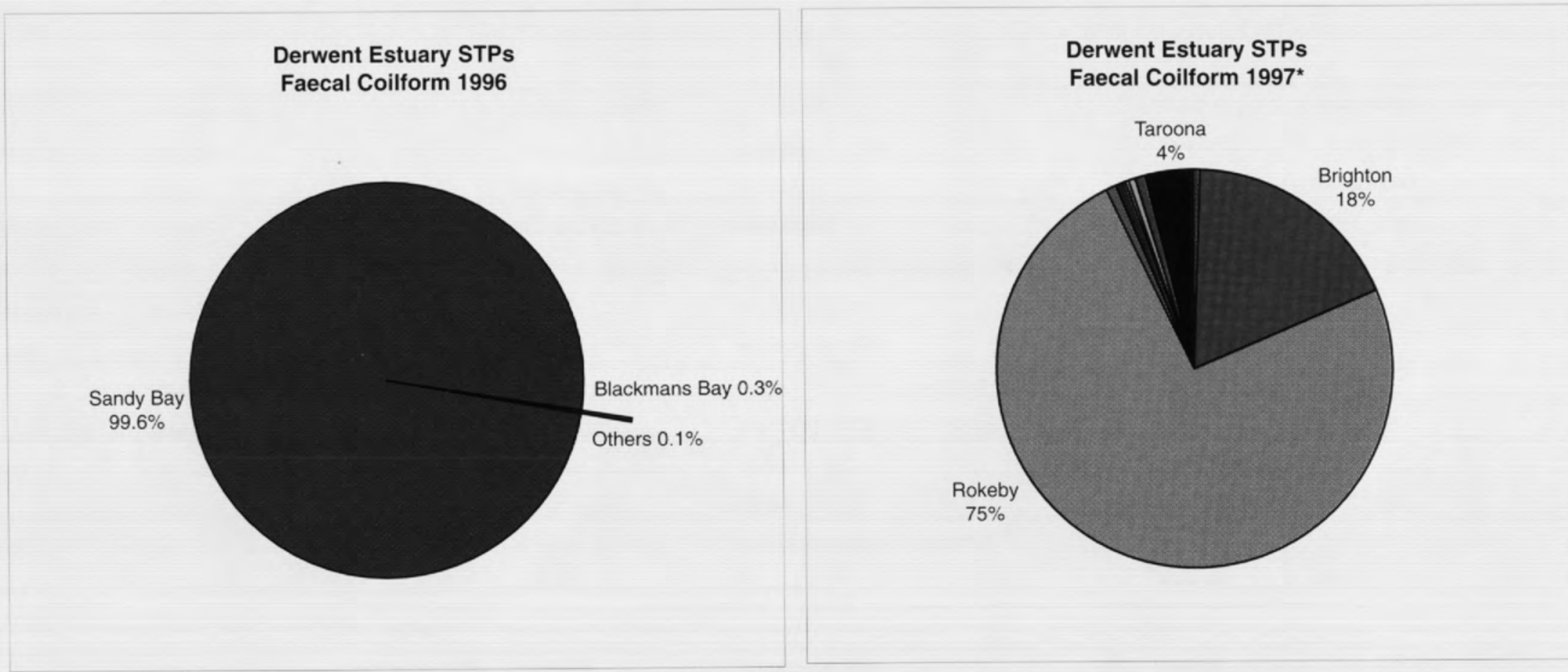
4.2 Industrial discharges

In 1996, two major industries (the Pasminco Hobart Zinc Refinery and the ANM- Boyer Newsprint Mill) and one smaller industry (Textile Industries Australia) discharged treated wastewater to the Derwent Estuary. The location of each of these industries is indicated in Figure 17. In addition to direct discharges of liquid processing wastes, industrial contaminants also enter the estuary via other pathways, including air emissions, windblown dust, ground water seepage, stormwater runoff and spills. Liquid processing wastes from most other industries around the Derwent are sent to municipal WWTPs for treatment before being discharged to the Derwent, however, these smaller industries and storage facilities also undoubtedly contribute contaminants to the estuary via stormwater and spills. For the most part, however, these diffuse sources are not monitored and cannot be readily quantified.

There have been a number of improvements in the treatment of industrial wastewater in recent years. In 1988/90, ANM commenced primary treatment of its effluent, and Pasminco's effluent treatment plant was commissioned in 1991. Since 1994, Cadbury-Schweppes has been diverting its wastewater to the Cameron Bay WWTP, and TIA was connected to Prince of Wales Bay WWTP in April 1996. All industries operate under licences from the Department of Environment and Land Management (DELM) and work to targets and objectives outlined in their Environmental Improvement Programs (EIP).

Table 13 Derwent sewage treatment plants: plant type and improvements

Location	Council	Lic. Discharge kL/d	Outfall	Treatment type	Recent/Planned Improvements
New Norfolk	Derwent Valley	4100	Derwent River	biofiltration	wetland polisher, 1994
Bridgewater	Brighton	3125	Derwent Estuary	activated sludge (biofiltration)	reuse proposed
Brighton	Brighton	200	Jordan River	lagoon system	reuse commenced Aug. 1997
East Risdon	Clarence	1000	Derwent Estuary	oxidation ditch	
Rokeby	Clarence	1330	Ralphs Bay	activated sludge plus lagoons	new plant proposed 1998/9
Rosny	Clarence	7500	Derwent Estuary	biofiltration, solids contact tank	upgraded 1994
Cameron Bay	Glenorchy	6000	Derwent Estuary	activated sludge	upgraded 1994
Prince of Wales Bay	Glenorchy	9900	Derwent Estuary	activated sludge	upgraded 1994
Sandy Bay	Hobart	2700	Derwent Estuary	maceration only, no disinfection	tertiary treatment at Selfs Point, 1997
Macquarie Point	Hobart	18000	Derwent Estuary	biofiltration	
Selfs Point	Hobart	6250	Derwent Estuary	biofiltration	new tertiary STP commissioned Feb. 1997
Blackmans Bay	Kingborough	4125	Derwent Estuary	extended aeration	new clarifier 1995; sludge centrifuge 1996/7
Taroona	Kingborough	1150	Derwent Estuary	biofiltration	upgraded 1994; further improvements planned



* following upgrades to Sandy Bay and Blackmans Bay

Figure 20 Derwent sewage treatment plants - relative faecal coliform inputs (1996 and 1997)

Australian Newsprint Mills (ANM)

The ANM Boyer Mill is located on the northern bank of the Derwent River, approximately 4 km downstream of New Norfolk. The plant has been operating since 1941 and is Australia's largest producer of newsprint, with a total annual capacity of 265,000 tonnes. ANM's 1996 production was 261,000 tonnes.

The ANM Boyer Mill produces newsprint and specialty papers from mechanically produced pulps of eucalypt and pine trees. Eucalypt chips (175,000 t) and radiata pine chips (400,000 t) are converted to pulp using two processes: the cold caustic soda (CCS) pulping process involves the mechanical refining of caustic impregnated eucalypt woodchips, and the thermomechanical pulping (TMP) process uses radiata pine woodchips. The various pulp streams are blended, diluted, cleaned and screened prior to feeding to the paper machines. Fibre and water conservation measures are employed. The main bleaching agent used is hydrogen peroxide. Paper production is followed by customer reel winding, wrapping, warehousing, and rail transport to the Burnie port.

Features of environmental significance include:

- water treatment plant
- wastewater treatment plant
- steam boiler
- industrial stockpiles and solid waste disposal areas

Emissions

Atmospheric emissions are primarily derived from the coal-fired steam boiler (and standby boilers), and to a lesser extent to dust from stockpiles, materials handling and roads.

Liquid emissions from the site include industrial processing water, stormwater and ground-water seepage. ANM's effluent is warm (30°C), highly coloured and contains elevated concentrations of TSS, organic matter (measured as biochemical oxygen demand) and resin acids. Resin acids, produced during the thermomechanical pulping process of pine, are toxic to fish in high concentrations. Nutrients concentrations are generally low. Until the primary treatment plant was constructed in 1988, liquid process emissions were discharged directly to the Derwent River under a Ministerial Exemption. All contaminated process streams now receive primary treatment, comprising coarse and fine screening, chemical dosing, flocculation, and clarification. Primary treatment reduces effluent concentrations of TSS (by 90%), resin acids (by 70%) and BOD (by 15 - 20%). The clarified effluent is discharged to the Derwent approximately 1.35 km downstream of the mill centre, and the solid sludge is processed further prior to disposal at a landfill.

All water used in pulp processing is taken from the Derwent just upstream of New Norfolk at Lawitta. This water is treated and clarified at ANM's water treatment plant, situated at the western settlement area, and resulting sludge is discharged to nearby settling ponds and wetlands. Runoff from these areas is discharged to the Derwent via the Western Drain (licensed).

Sewage effluent In 1990, a package treatment plant (80 kL/d) was commissioned to replace 11 septic tanks on site. Some initial problems with elevated faecal coliform levels have been controlled through improved chlorination

Stormwater runoff from the site can be divided into 3 zones. Runoff from the central mill area and surrounding paved areas is diverted to clarifiers and/or settling ponds in the Eastern Settlement. Runoff from the northern area (log yards, wood mill, car park) is diverted directly to the combined effluent outfall. Site runoff from western areas goes to the wetlands/settling ponds of the Western Settlement. Stormwater quality monitoring was initiated in 1994; initial results suggest elevated TSS, particularly from the landfill area.

Groundwater Several areas of concern have been identified in a site contamination assessment. The decommissioned Chlor Alkali Area (Caustic Chlorine Plant) was found to have elevated levels of mercury, zinc, barium, and sulphur in shallow soils Elevated sulphur levels were also found in soils at ANM's two solid waste disposal areas: the decommissioned boiler ash dump and the wood waste/sludge landfill (located, approximately 400 and 800 m north of the Derwent River). Elevated sulphide levels have also been measured in groundwater adjacent to the Derwent in the Eastern and Western Settlement Areas.

Monitoring

In 1996, ANM's monitoring program included daily or weekly analysis of samples from the combined effluent stream outfall for T, pH, TSS, COD, BOD, TOC and resin acids. Sewage effluent is monitored monthly for faecal coliform. Groundwater from the ash dump and landfill is monitored every six months at two boreholes. Emissions testing is carried out on the boiler every six months (particulates, CO_2). Ambient water quality monitoring is carried out in the upper Derwent approximately every six weeks for temperature, pH, salinity, DO, resin acids, nutrients and light penetration. Recent sediment surveys (1995) have looked at sludge distribution and macrobenthic communities downstream of the outfall (see Section 6.2 for details).

Summary of 1996 emissions

The following mass emissions were calculated for the site for 1996, on the basis of monitoring data and ANM's 1995 EMP:

Table 14 ANM - summary of 1996 mass emissions

	Treated Effluent		Stormwater	Groundwater	Atmosph.
Total Effluent. Volume	61,000 kL/d 22,265 ML		?	?	?
	conc. (mg/L)	mass load tons/yr	mass load tons/yr	mass load tons/yr	mass load tons/yr
TSS/particulates	65	1447	?	?	38 mg/m3
BOD	315	7013	?	?	
resin acids	2.3	51	?	?	
PO_4	0.06	1.32	?	?	
TP	0.36	7.92	?	?	
NO_3	0.01	0.22	?	?	
NH_3	?		?	?	
TN	2.3	51	?	?	

Recent and planned improvements

- 1988/90 - primary effluent treatment plant commissioned (2 clarifiers)
- 1990 - #5 boiler commissioned
- Oct 1993 - chlor alkali plant ceased operating
- 1998/2001 - secondary effluent treatment system (reduction of BOD, resin acids, TSS)

(Sources: ANM, 1995; ANM, 1996; D. Richardson, pers. comm.)

Pasminco Hobart, Risdon Refinery

Pasminco Hobart is situated at Risdon (Glenorchy), on the western shore of the Derwent Estuary. The plant has been operating since 1917 and is one of the world's largest producers of zinc metals and alloys with an annual production of about 210,000 t; 85% of this is exported. Other products include sulphuric acid (370,000 tpa), copper sulphate (3000 tpa), silver-lead residue (30,000 tpa) and cadmium (400 tpa). Zinc is produced through a series of processes including roasting of zinc concentrate (sulphide) to produce zinc oxide (calcine), progressive acid leaching of calcine to produce impure zinc sulphate solution, and purification and electrolysis of this solution to produce zinc and zinc alloys. Jarosite is the major solid waste produced (up to 240,000 tpa) and, until the end of 1997, was disposed of in the ocean 100 km south of Hobart.

Features of environmental significance include;

- wastewater treatment plant
- foreshore gas scrubbers
- other stacks and vents
- industrial stockpiles (zinc concentrate, manganese dioxide)
- Loogana and Inshallah dumps (jarosite, primary leach residue)

Emissions

Atmospheric emissions are derived from stack and vent sources (9 major), fugitive emissions and dust from stockpiles, material handling and roads. Stacks and vents are variously monitored for particulates, sulphur oxides and heavy metals. The foreshore stacks are the main source of SO_2, particulates are derived primarily from steam boilers (when operating) and most metals are emitted from the dross mill, casting baghouse and anode casting areas. Dust inputs are derived from a number of open stockpiles and disposal areas around the site, particularly the concentrate stockpiles at the wharf and the jarosite and primary leach residue (PLR) dumps adjacent to New Town Bay. Mass loads are difficult to quantify, however, a rough estimate derived from dust fall-out data suggests that dust inputs may be of similar or greater magnitude to stack and vent emissions.

Liquid emissions from the site include industrial processing water, stormwater and contaminated groundwater discharge. Liquid emissions from the site contain TSS, SO_4, ammonia, trace metals (particularly Zn, Pb, Cd, Cu, Fe, Hg), As, F and Se. Prior to 1981, liquid emissions from the site were discharged to the Derwent Estuary without treatment. Between 1981 and 1991, the majority of liquid emissions were captured in a Contaminated Water Pond system and recycled within the plant. In 1991, an effluent treatment plant was constructed to treat industrial effluents and approximately 50% of site stormwater. Approximately 750 kL/d of effluent from the Mercury Removal plant plus another 2500 kL/d from the effluent treatment plant are combined with 130,000 kL/d of estuarine water (circulated through the foreshore scrubbers) and discharged through two outfalls at the wharf. Effluent from the Mercury Removal Plant (Mercury Removal Filtrate or MRF) is characterised by elevated concentrations of metals, fluoride and arsenic, while the effluent from the foreshore scrubbers is acidic and contains elevated concentrations of SO_4. (Note: Pasminco's effluent treatment plant also treats the majority of Impact Fertilisers wastewater/stormwater - approx. 50 kL/d, except during major storm events).

Prior to 1993, the site was serviced by approx. 25 septic tanks; these have been progressively replaced with connections to Glenorchy's Prince of Wales Bay WWTP (connections completed in 1995).

Stormwater from catchments A, B and C (which drain the main processing areas - approximately 50% of the site) is diverted to a contaminated water pond and treated at the effluent treatment plant prior to discharge to estuary. This system was designed to collect and treat water from a 1-in-10 year event; during extreme events, overflow is diverted to the Derwent (monitored and reported). In 1996, 2 high rainfall events resulted in diversions, contributing substantial mass loads of zinc (9 t) to the estuary. Stormwater from the remainder of the site enters the Derwent without treatment.

Groundwater contamination is associated with a number of existing and former stockpiles and solid waste disposal areas on the site; these include the manganese dioxide stockpile (74,000 t), the jarosite dump (120,000 t) and primary leach residue (PLR) dump (560,000 t). Groundwater monitoring has identified a number of areas with low pH and elevated concentrations of metals, orthophosphate, sulphate and fluoride. In particular, the PLR and jarosite dumps at Loogana/Inshallah have resulted in significant contamination of ground water with seepage to the estuary. Mass loading estimates derived from groundwater flow net analysis suggest that mass loading of zinc from groundwater sources are in the order of 80 to 150 tonnes/year. Data for other metals is not available.

Handling of zinc concentrate at the wharf results in some direct losses to the Derwent. These are difficult to quantify, but possibly in the order of 50 to 100 tons per year were lost under and in the immediate vicinity of wharf. Since early 1997, all concentrates have been stored in sheds on the wharf.

Monitoring

In 1996, Pasminco Hobart's monitoring program included monitoring of atmospheric emissions from specific stacks and vents (SO_x, particulates, metals), ambient monitoring at 3 high-volume samplers (particulates) and 17 dust fall-out gauges (particulates, metals). Liquid effluents are monitored at the effluent treatment plant, mercury removal plant, foreshore scrubber outfalls and at the A, B and C drain overflows. Groundwater is monitored at a series of approximately 30 boreholes. Ambient monitoring in the Derwent Estuary includes daily water samples collected at the wharf, monthly monitoring of New Town Bay and an annual survey of metals in shellfish and fish throughout the Derwent.

Summary of 1996 emissions

The following mass emissions were calculated for the site for 1996, on the basis of monitoring data and other recent information provided by Pasminco Hobart:

Table 15 Pasminco Hobart - summary of 1996 mass emissions

	Effluent MRF + ETP	Foreshore Scrubbers	Stormwater overflows*	Ground-water**	Handling losses/spills	Atmosph. /dust***
Volume	3250 kL/d	130,000 kL/d	21,000 kL total	10-20 kL/d		
	Mass load (in tonnes)					
TSS/particulates	0.46	45				20-40
Zinc	11.12		8.86	80-150	50 - 100	5 - 15
Cadmium	0.28		0.07	?	?	?
Copper	0.03		0.18	?	?	?
Mercury	0.01			?	?	?
Lead	1.12		0.05	?	?	1+
Arsenic	4.84			?	?	?
Fluoride	52.38			?	?	?
Iron	3.97			?	?	?
Ammonia		13		?	?	?
SO_4		10,000				
SO_x						200+

* A, B and C catchments only
** estimated 80-150 t from Loogana groundwater, 7 t from remainder of site
*** stacks and vents plus windblown dust

Improvements since 1990

- 1991 - effluent treatment plant commissioned
- 1993 - upgrade/construction of #5 acid unit (reduced SO_2 emissions by 50%)
- 1991/92 - short-term stockpile management plan implemented; longer-term plan initiated
- 1996 - commencement of retreatment of manganese dioxide stockpile (approx. 10 yr. project)
- 1997 - all stockpiles covered or under sheds except jarosite and PLR
- 1997 - cotreatment process to replace ocean-dumping of jarosite. Paragoethite to be shipped to S. Australia for further treatment and recovery of metals.
- 1997 - Loogana/Inshallah rehabilitation commenced. Some jarosite to be dumped at sea according to permit conditions; remainder placed in secure landfill. PLR being shipped to Port Pirie for smelting over 20-yr period.
- 1998 - MRF to be fully treated at effluent treatment plant, once cotreatment starts
- 1997/98 - replacement of gas scrubbers

As a result of recently completed and on-going improvements, substantial decreases in mass emissions are anticipated from Pasminco Hobart within next few years; e.g. from >200 tpa zinc in 1996 to <50 tpa zinc by the Year 2000.

(Sources: PMEZ, 1996a; PMEZ, 1996b, PMEZ, 1996c).

Textile Industries Australia

Textile Industries Australia (TIA) is located in Glenorchy, near Prince of Wales Bay. It was established in 1947 on a site formerly occupied by a wartime munitions complex. The plant is currently used for textile printing and finishing.

Liquid effluent was discharged at Prince of Wales Bay via storm drains from 1947 until April 1996. The effluent was a dilute solution of dyes and other organic compounds used in printing pastes and was monitored for suspended solids, COD, BOD, oil and grease. Since April 1996, TIA's effluent has been pretreated and discharged to the Prince of Wales Bay STP under a Trade Waste Agreement with the Glenorchy Council. During the period from January through April of 1996, TIA discharged approximately 36 t of COD, 5 t of BOD, 4 t of TSS and 2 t of oil and grease to Prince of Wales Bay.

Impact Fertilisers

Impact Fertilisers (previously owned and operated by Pasminco Hobart) is situated immediately to the north of Pasminco Hobart at Risdon. This plant produces approximately 165,000 tonnes of NPK fertilisers per year. Processing effluents from this plant are treated at the Pasminco Hobart effluent treatment plant, as is the majority of stormwater runoff from the fertiliser processing and storage areas. During extreme rainfall events, stormwater overflows are diverted to the estuary; volumes and concentrations are monitored and reported to the Division of Environment and Planning/DELM. During 1996, stormwater overflows were directed to the Derwent on 9 occasions, resulting in inputs of approximately 1 t TSS and 1.6 t phosphorus. Other potential sources of contamination from the site include particulates and nutrients in wind blown dusts from fertiliser raw and finished products and nutrients discharged via groundwater.

Cumulative inputs from ANM, Pasminco Hobart, TIA and Impact Fertilisers are summarised in Table 16.

Other industries

A number of other industries are located immediately adjacent to the Derwent or near rivulets which discharge to the Derwent. The majority of these direct their processing wastes to sewer, however, stormwater runoff and spills from many of these sites may eventually enter the Derwent. In most cases, stormwater inputs are not monitored and cannot be readily quantified. These industries are briefly identified below.

Cadbury Schweppes Australia Ltd

- located in Claremont;
- produces chocolates and other confections;
- trade wastes are pretreated and discharged to Cameron Bay STP (since October 1994);
- site runoff enters Derwent;

Selfs Point Petroleum Tank Farm

- located at Selfs Point (New Town);
- storage facility for petroleum fuels and liquid petroleum gas, also contains a bitumen plant;
- spill prevention methods include bunding around storage tanks;
- site runoff enters Derwent.

Table 16 Summary of estimated industrial inputs to the Derwent Estuary, 1996

Parameter	ANM (1)	Pasminco (3)	Impact Fertilisers (5)	TIA (6)	Total Industries
Total effluent volume (ML)	22,265	47,747	5	53	70,070
Contribution in tonnes					
TSS	1,447	46	1	4	1,497
BOD	7,013	na	<1	5	7,018
COD	na	na	na	36	36
Faecal coliform	negl.	na	na	na	negl.
Ammonia-N	na	13	<1	na	13
Nitrate+nitrite N	<1	na	na	na	na
DIN	na	na	na		na
Total nitrogen	51 (2)	na	na	na	0
Phosphate	1.32 (2)	na	na	na	0
Total phosphorus	7.92 (2)	na	2	na	2
Zinc	na	20 (+ 135 to 265)(4)	na	na	220 (+ or - 60)
Cadmium	na	0.35	<0.01	na	0.4
Copper	na	0.21	<0.01	na	0.2
Lead	na	1.17	<0.01	na	1.2
Iron	na	4.00	na	na	4
Manganese	na	na	0.10	na	na
Mercury	na	0.01	<0.01	na	0.01
Selenium	na	0.01	na	na	0.01
Arsenic	na	4.84	<0.01	na	4.84
Fluoride	na	52	0.2	na	53
Sulphate	na	10,000	na	na	10,000
Oil and grease	na	na	0.02	2	2
Resin acids	51	na	na	na	51
Phenols	na	na	na	na	na
PAHs	na	na	na	na	na

na not analysed
(1) main outfall only
(2) based on occasional monitoring (data not required in licensing conditions)
(3) main outfall + stormwater (50%)
(4) values in parenthesis are estimates of zinc inputs from groundwater, windblown dust and handling losses
(5) During stormwater overflows only; most processing wastes are treated at Pasminco
(6) For period Jan - April only; after April, wastes were discharged to Prince of Wales Bay WWTP

Incat Tasmania Pty Ltd

- located in Derwent Park;
- produces high-speed catamarans;
- site runoff enters Prince of Wales Bay and Derwent.

ACI Glass Factory

- located in Moonah/Derwent Park;
- produces clear glass products;
- trade wastes and some site run-off discharged to sewer;
- remaining site run-off enters Prince of Wales Bay;
- closed in 1997.

National Foods

- located in Lenah Valley;
- processes dairy products;
- trade wastes discharged to sewer;
- site runoff enters New Town Rivulet.

Cascade Brewery Company Pty Ltd,

- located in Casacades/South Hobart;
- produces beer and other beverages;
- trade wastes discharged to sewer;
- site runoff enters Hobart Rivulet.

Cuthbertsons Tannery

- located in South Hobart;
- processes leathergoods;
- trade wastes discharged to sewer;
- site runoff enters Hobart Rivulet.

Tasmanian Board Mills

- located in Austins Ferry;
- processes timber products;
- tradewastes (sawdust) to boilers or council tip;
- site runoff recycled for log spray; excess diverted to settling dam and then to Derwent.

Gunns Ltd.

- located in Austins Ferry;
- processes timber products;
- tradewastes (sawdust) to boilers or council tip;
- site runoff diverted to settling dam, then to Derwent.

Bridgewater Abattoir

- located in Bridgewater;
- processed meat products;
- trade wastes discharged to lagoon system, followed by spray irrigation;
- site runoff entered small creek/Derwent;
- closed 1996.

Gunns Veneers

- located in New Norfolk;
- produces veneers;
- trade wastes discharged to ANM effluent stream via on-site treatment plant;
- site runoff enters Derwent via ANM effluent stream.

Other sites not specifically mentioned here include quarries, concrete batching plants, brick and paver manufacturers, truck and railway depots, small metal foundries, platers and galvanisers, hospitals, vinyards, nurseries, petrol stations, car washes, etc.

4.3 Urban runoff

Urban stormwater runoff is increasingly being recognised as a major source of pollutants entering urban waterways and estuaries. In highly urbanised areas, particularly industrial areas, up to 90% of rainfall may flow into the drainage system as stormwater (Scott, 1996; Commonwealth of Australia, 1996). Urban stormwater typically carries high concentrations of suspended solids (dust and soil) with adsorbed nutrients, heavy metals, hydrocarbons, pesticides, bacteria, litter and other contaminants derived from human activities (CEPA, 1993). Urban runoff contaminants originate not only from land activities in the drainage catchment where runoff is collected, but also from atmospheric deposition (Horner *et al.*, 1994). Contaminants carried by stormwater may exchange with groundwater and can be linked to demonstrable impacts in receiving estuarine or coastal waters. These impacts may include bacterial enrichment, acute and chronic toxicity to biota, oxygen depletion, turbidity, siltation, nutrient enrichment and eutrophication (Scott, 1996; CEPA, 1993). Despite these potential impacts, there is currently little control or treatment of stormwater in Australia.

The pollutant load carried by stormwater is unpredictable and is driven largely by the nature of meteorological events and watershed hydrology. Up to 60% of the insoluble pollutant load, including suspended solids, faecal coliforms and nutrients, may be concentrated in the initial flush ('first flush') or less than 25% of the storm-event water volume (Vorreiter and Hickey, 1994). Stormwater systems have traditionally been constructed with the aim of collecting and removing excess runoff as quickly as possible to avoid flooding during heavy rain. Despite this, flooding often continues to be a problem due to increased peak flows, which are a result of increasing development within urban catchments (Scott, 1996).

Urban runoff and the Derwent Estuary

In conjunction with this report, a map was prepared which delineates all catchments between Bridgewater and Tinderbox/South Arm, which contribute runoff directly to the Derwent Estuary. All stormwater outlets with a diameter of > 30 cm are also shown on this map. In total, there are 5-10 major urbanised rivulets which discharge to the Derwent, along with at least 270 stormwater outlets. See map provided at the back of this report for details.

Few stormwater studies have been conducted in Hobart, with the exception of the following:

- Green (1997) - a three-year study on hydrocarbons and faecal material focusing on four Hobart catchments;
- Blacklow (1985) - a four-month study of microbiological water quality in Hobart Rivulet;
- DELM, 1995 - a one-year study of nutrients in a small residential catchment in Sandy Bay (Waimea);
- Jenkins (1991) - a two-month general study of stormwater quality.

In addition, councils occasionally monitor stormwater quality in several rivulets around Hobart and Glenorchy. Very little data is available for less urbanised areas (e.g. Clarence, Brighton, New Norfolk), although faecal coliform, nutrients and turbidity are monitored at several sites along Browns River (J. Doole, Kingborough Council. pers. comm.).

Faecal contamination

In urban catchments, the bacterium *E. coli* is found in the faeces of humans, dogs, cats, birds, wildlife and other animals, and in manure used as garden fertiliser. *E. coli* contributions from human faeces may enter stormwater drainage systems through septic systems that are not operating optimally or through direct illegal connection of household sewage to stormwater drains. Leachate of faecal material from septic tanks, sewer overflow points and damaged sewers may also enter stormwater drains through cracks, poor joins, holes, or by infiltration.

Faecal content in Hobart stormwater

Faecal coliform counts measured in urban runoff at several sites around Hobart are summarised in Table 17. Values have been found to range from 30 - 25,000 colony forming units (cfu)/100 ml in Hobart Rivulet over a period of several years (Blacklow, 1995, HCC, 1990-93). In a more intensive 18-month study of the fully-piped Derwent Park catchment, counts ranged from 3,000 - 50,000 (Green, 1997). All recorded levels were well above recommended guidelines for primary and secondary contact recreation (150 cfu/100 ml and 1,000 cfu/100 ml, respectively) and demonstrate that stormwater is potentially a major contributor to faecal pollution in the Derwent Estuary. In Kingborough, faecal coliform levels monitored at the mouth of Browns River have consistently exceeded levels recommended for recreational contact for the past 3 years (J. Doole, Kingborough Council, pers. comm.). Bacterial levels in Hobart stormwater samples were generally lower than those recorded in Sydney and Melbourne studies.

Table 17 Faecal coliform counts in stormwater

Study site	Comments	# Faecal coliforms (cfu/100 ml)	Reference
Hobart			
Derwent Park	range - all conditions	3,000 - 50,000	Green (1997)
Hobart Rivulet	dry weather	30 - 25,000	Blacklow (1995)
	wet weather	2,500 - 10,000	Blacklow (1995)
	Council data 1990 (mean)	8,300	Blacklow (1995)
	Council data 1991 (mean)	4,000	Blacklow (1995)
	Council data 1992 (mean)	4,200	Blacklow (1995)
	Council data 1993 (mean)	5,000	Blacklow (1995)
Sydney	dry weather max.	1,000,000	Rowlands *et al.*, (1992)
	wet weather max.	9,000,000	Rowlands *et al.*, (1992)
Melbourne	Yarra River	200 - 17,000	Melbourne Water (1992)
	street runoff	30,000 - 1,800,000	Melbourne Water (1992)

Sources of faecal contamination in Hobart stormwater

Green (1997) used a faecal tracer known as *coprostanol* (a sterol) to identify human faecal material in stormwater, and found that human faecal matter was a minor component of total faecal content in Hobart stormwater except during very wet periods. This finding supported findings from elsewhere in Australia, where sewage contamination in stormwater is a common occurrence during heavy rain (Linforth *et al.*, 1994; Ngo *et al.*, 1992). Low levels of human faecal pollution were detected in storm drains during dry weather suggesting a few direct sewer connections (Green, 1997). The microbiological study of Hobart Rivulet by (Blacklow, 1995) also suggested that sewage-contaminated soils were a contributor to faecal contamination of the rivulet during dry weather.

During wet weather, Blacklow (1995) concluded that the high coliform loads carried in stormwater of Hobart Rivulet are derived from dispersed animal faeces. Green (1997) also identified dog faeces as the major contributor to faecal contamination in Hobart's stormwater for the following reasons:

- a similarity in analysed chemical sterol profiles of dog faeces and stormwater samples;
- low levels or absence of sterol chemical markers for other sources of faeces;
- high bacterial levels bearing only low correlation to levels of the human faecal biomarker coprostanol;
- the fact that up to 10 tonnes of dog faeces are deposited in Hobart every day.

During periods of prolonged wet weather, however, there was a significant rise in faecal bacterial counts in stormwater samples, together with a rise in the concentration of coprostanol. This indicated an inflow to stormwater of human faecal contamination from the sewerage system, which is believed to become overtaxed in some areas during heavy rain (Green, 1997).

Impact of faecal contamination in urban runoff

The predominant concern with microbiological contamination of waterways is public health. Together with traditional bacterial indicators, stormwater has been shown to contain significant concentrations of pathogenic microorganisms, viruses and protozoa that exceed ANZECC guidelines for recreational purposes (Geldreich *et al.*, 1968). As a result, there is exposure risk and implications for human health at virtually all stormwater outfalls, even at high dilution ratios.

The studies of Green (1997) and Blacklow (1995) showed that stormwater in Hobart carries bacterial levels in excess of those discharged by most of the sewage treatment plants on the Derwent Estuary (Green, 1997). The total faecal coliform discharge from the Derwent Park catchment was estimated at 3.8×10^{14} cfu per annum or *$8.5x10^{11}$ cfu/hectare annually* and approximately *$3.4x10^{11}$ cfu/hectare annually* from the Hobart Rivulet catchment.

Hydrocarbons

Sources

Sources of hydrocarbons in stormwater vary between study sites and include vehicle exhaust emissions, used sump oil, diesel, compounds from pavement attrition and tar-based pavement sealants, industrial discharges, fuel oils, as well as wood smoke and other atmospherically transported particulates. Some naturally occurring hydrocarbons, believed to be derived from plant wax components, are also sometimes detected in urban stormwater, particularly in undeveloped areas (Fam *et al.*, 1987).

Polycyclic aromatic hydrocarbons (PAHs), some of which are highly toxic and carcinogenic, are present in fresh oil, and to a greater extent in used oil. PAHs are produced during the incomplete burning of fossil fuels or organic-rich materials. The major sources of PAHs in urban runoff are: those adsorbed to atmospheric dust, industrial wastewater, disposal of used oils, automotive oils and greases, and road wear particles (Hoffman *et al.*, 1984). Aside from oil and combustion sources, several PAHs, such as perylene and retene, are naturally occurring (Hoffman *et al.*, 1984). However, environmental concentrations of PAHs due to natural processes are usually low compared to PAHs originating from anthropogenic (human) sources (Witt, 1995).

Hydrocarbons and PAHs in Hobart stormwater samples

In a recent study of Hobart stormwater, hydrocarbons were readily detectable in samples collected under all types of flow conditions and in all seasons (Green, 1997). The mean concentration of hydrocarbons in stormwater collected from a catchment containing a range of land-use types was 2.88 mg/L, which is within the range reported from stormwater studies elsewhere (Table 18). However, the maximum recorded hydrocarbon level in the study of 22.7 mg/L at the peak flow of a short summer storm, was comparatively high (Table 18) and equivalent to a discharge rate of 178 g/s of hydrocarbons into the Derwent Estuary (Green, 1997).

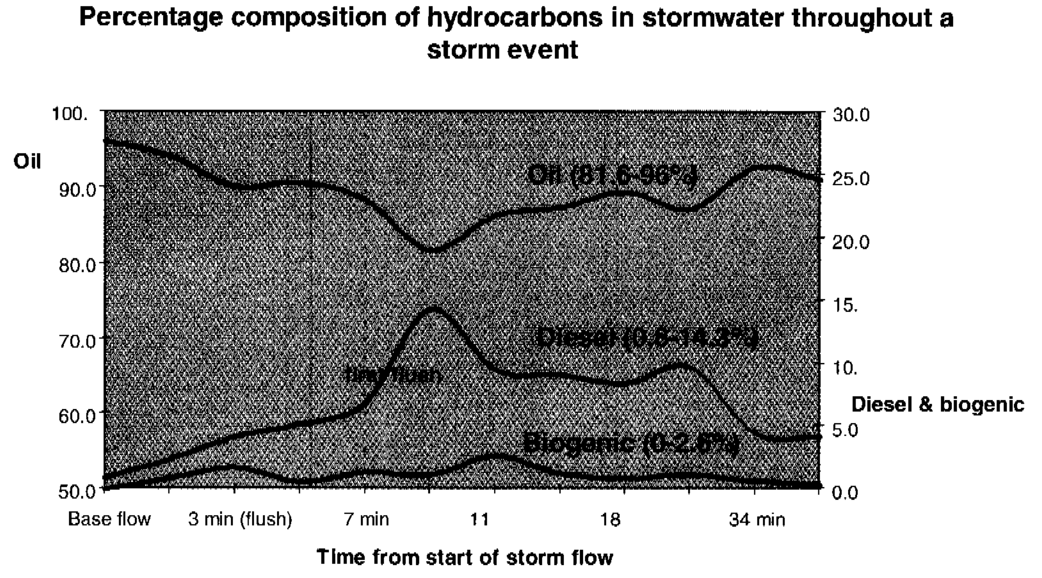
Table 18 Concentrations of hydrocarbons and PAHs in urban runoff

Location	PAH	Aliphatic hydrocarbons	Reference
	Total PAH		
Sydney, Australia *	0.2 - 41.3 ng/l *	0.6 - 21 μG/L *	Nichols *et al., (1993)*
Hobart, Australia	**0.19 - 5.35 μg/l**	**0.26 - 22.7 mg/l**	**Green 1997**
Madrid, Spain	15.1 - 35.5 μg/l	0.47 - 2.18 mg/l	Bomboi & Hernandez, (1991)
Philadelphia, USA	0.68 - 1.72 mg/l	1.50 - 3.58 mg/l	Hunter *et al.*, (1979)
Los Angeles, USA	1.6 mg/l	11.5 mg/l	Eganhouse & Kaplan, (1981)
San Francisco, USA	0.40 - 3.53 mg/l	0.28 - 29.7 mg/l	Fam *et al.*, (1987)
Seattle, USA		0.2 - 7.50 mg/l	Wakeham, (1977)
Narragansett Bay, USA		0.98 - 2.15 mg/l	Hoffman *et al.*, (1982)
	Individual PAH compounds		
Sydney, Australia	0.001 - 9.24 μg/l		Rowlands *et al.*, (1982)
London, England	0.8 - 74 μg/l	5.8 - 18.2 mg/l	Gavens *et al.*, (1982)

* Collected during dry weather (base level flow)

PAH concentrations in Hobart stormwater ranged from 0.19 to 5.35 μg/L (Green, 1997). Many of the PAH levels were above the recommended Australian guidelines of 3 μg/L, which is believed to be the threshold for the protection of aquatic life in marine and fresh waters (ANZECC, 1992), but were generally less than 1% of total hydrocarbons and lower than most other published values for PAHs in stormwater (Table 18).

Green (1997) found that lubricating oils comprised the largest fraction of hydrocarbons in urban runoff throughout most storm events in Hobart. Diesel fuel was the second largest identifiable contributor, reaching levels of 14% of total hydrocarbons, followed by biogenic hydrocarbons derived from plant waxes at 0-2.6% (Figure 21). Automobile sump oil, rather than unused lubricating oils, was identified as the major component of the oil in Hobart stormwater (often greater than 90%). Additionally, vehicle exhaust, was identified as a major contributor in two of the four catchments studied.



Samples collected at Prince of Wales Bay outfall on the Derwent Estuary, 23/9/95 (Green, 1997)

Figure 21 Composition of hydrocarbons in stormwater

Nutrients

Sources of nutrients (nitrogen and phosphorus) in stormwater runoff include sewage overflows, animal wastes, garden fertilisers and soils, detergents, and other materials in surface runoff from municipal and industrial areas. Nutrients in urban stormwater may also originate from decaying plant material and from the atmosphere (Snelder and Trueman, 1995).

A study of nutrient inputs to the Derwent Estuary over a one-year period from a small (28 ha), medium density, residential catchment (Waimea catchment) was conducted in 1993-1994 (DELM, 1995). The nitrate and total phosphorus generation rates for the Waimea catchment appeared to be high relative to studies from elsewhere, and were higher than typical concentrations for commercial, industrial, carpark and highway sites (see Table 19). This was possibly due to unusually dry conditions experienced during the sampling period.

Stormwater quality was monitored in three Hobart catchments (Goulburn, Warwick and McRobies Gully) in 1991 by Jenkins (1991). Among the parameters measured were nitrate (NO_3^-) and phosphate (PO_4^{3-}). Nitrate and phosphate concentrations measured over the duration of the study period were 0.45-0.85 mg/L and 0.03-0.13 mg/L, respectively. The major findings of the work by Jenkins (1991) were that nitrate and phosphate levels in urban runoff tended to be diluted in stormflow from high baseline levels. The McRobies Gully refuse disposal site was identified as a potential site for significant leaching of nutrients to the urban drainage system.

Table 19 Nutrient generation rates and land-use types

	Location	Nitrate-N kg/ha/yr	Total phosphorus kg/ha/yr
Hobart studies			
Coughanowr, 1995	Hobart	3.9	2.1
General urban runoff			
Graham, 1898	Melbourne	2.7	
Young *et al.*, 1995	SE Australia		1
Young *et al.*, 1995	W Australia		0.4
Young *et al.*, 1995	N. America		1.2
Highway runoff			
Pitt, 1991	N. America	1.7	1.01
Horner, 1992	N. America		1.1
Commercial			
Pitt, 1991	N. America	2.1	1.68
Horner, 1992	N. America		0.8
Industrial			
Pitt, 1991	N. America	0.2	1.46
Residential (low density)			
Pitt, 1991	N. America	0.02	0.05
Horner, 1992	N. America		0.55
Residential (med. density)			
Pitt, 1991	N. America	0.56	0.56
Horner, 1992	N. America		0.59
Residential (high density)			
Pitt, 1991	N. America	0.9	1.12
Horner, 1992	N. America		0.65
Carpark			
Pitt, 1991	N. America	2.2	0.78
Construction			
Pitt, 1991	N. America		90

Suspended solids

In urban stormwater, suspended solids are derived from streambank erosion, from soil particles washed off construction sites, road works, gardens, road grit and dust (including air-borne pollutants) washed out of the atmosphere (Snelder and Trueman, 1995). Construction activities, involving the stripping of vegetation and topsoil and recontouring of the land, results in large quantities of soil being washed off slopes as stormwater runoff. Suspended solid loads recorded in Hobart stormwater are shown in Table 20. The loads (8 - 5650 mg/L) are comparable to those recorded in North America; e.g. 2 - 2890 mg/L in general urban runoff (Horner *et al.*, 1994). The highest levels of suspended solids measured in Hobart stormwater are from rivulets (during flood conditions) rather than from piped catchments (Table 20). This suggests that streambank erosion may be a major contributor to the suspended solids load from urban rivulets in Hobart. Catchments subjected to major land disturbance such as the refuse disposal area at McRobies Gully may also contribute high levels of suspended solids to stormwater during rainfall events (Table 20).

Table 20 Suspended solids loads in Hobart stormwater

Sample site	Date	Comments	Suspended solids mg/L	Reference
New Town Rivulet	27/10/1994	base flow	10	Green (unpublished)
	07/04/1995	high flow	133	Green (unpublished)
	19/12/1995	flood	1970	DELM (unpublished)
	09/02/1996	flood	5650	DELM (unpublished)
Hobart Rivulet	07/04/1995	high flow	247	Green (unpublished)
	19/12/1995	flood	452	DELM (unpublished)
	09/02/1996	flood	1440	DELM (unpublished)
Sandy Bay Rivulet	09/02/1996	flood	1180	DELM (unpublished)
Prince of Wales Bay	1995 - 96	base flow	22 - 81	Green (unpublished)
(Springfield catchment)	1995 - 96	range - all conditions	15 - 570	Green (unpublished)
	1995 - 96	mean - all conditions	107	Green (unpublished)
Waimea catchment	07/04/1995	high flow	59	Green (unpublished)
	06/08/1995	light rain	23 - 33	Green (unpublished)
	19/12/1995	flood	196	DELM (unpublished)
Goulburn catchment	1991	base flow	8 - 15	Jenkins (1991)
	1991	storm events	10 - 220	Jenkins (1991)
Warwick catchment	1991	base flow	9 - 18	Jenkins (1991)
McRobies catchment	1991	base flow	26 - 35	Jenkins (1991)
	1991	storm event	850 - 2200	Jenkins (1991)

Heavy metals

Heavy metals in urban runoff are of particular interest because of their potential for toxicity to humans and to aquatic life. Heavy metals that almost always occur in stormwater include lead (Pb), zinc (Zn) and copper (Cu). Road transport is a major source of metals to the aquatic environment, contributing lead from vehicle emissions, and copper and zinc from vehicle component wear. These metals are discharged into the atmosphere or directly onto the road from where they become entrained in stormwater (Snelder and Trueman, 1995).

The Derwent Estuary has come under close scrutiny for high concentrations of heavy metals, however, there have been very few measurements made of heavy metals in urban runoff in Hobart. The study of Jenkins (1991) included an investigation of zinc and lead in three storm events from three catchments. Results from this study are summarised in Table 21 and compared to mean heavy metal concentrations in urban runoff reported from North America.

Table 21 Heavy metal concentrations in stormwater

Catchment	Comments	Zn^{2+} (μg/l)	Pb^{2+}(μg/l)
Hobart			
(Jenkins, 1991)			
Goulburn	base flow	170	14
	storm event	300 - 1800	25 - 90
	storm event	200 - 2800	12 - 50
Warwick	base flow	130	
McRobies	base flow	100	
	storm event	100 - 250	
Overseas			
(Horner *et al.*, 1994)			
N. America	general urban runoff (mean)	160	140

Other contaminants

Herbicides and insecticides are common in urban stormwater (Snelder & Trueman, 1995) and are commonly used to control plant growth along roads and stormwater drains. Herbicides commonly used in urban situations include organophosphates such as glyphosate and triazines such as atrazine. Results from toxicity studies on animals and plants suggest that in most situations, their presence in stormwater poses little threat to the aquatic environment because lethal concentrations are about 1000 times greater than concentrations in runoff (Snelder & Trueman, 1995).

Organochlorine insecticides are not readily broken down and represent a significant threat to the aquatic environment, particularly insecticides such as chlordane, dieldrin, DDT and lindane (Snelder & Trueman, 1995). Although the use of these chemicals is now banned , they may be washed into the aquatic environment, adsorbed to particulate material, long after application.

Polychlorinated biphenyls (PCBs) are another set of organochlorines that are environmentally persistent and toxic. These are an industrial chemical widely used in the past and their residues still contaminate soil in urban areas (Snelder & Trueman, 1995).

There have been no studies of herbicides, pesticides or PCBs in urban runoff in Hobart.

Estimated inputs of contaminants from urban runoff to the Derwent

In the absence of more site-specific data, a very rough estimate of urban runoff inputs to the Derwent is presented here. These values are based on an estimated total urban area of 50 km^2 (1993/94 Landsat data) and pollutant loading values either derived from Hobart-specific studies or adopted from the literature. The results - presented in Table 22 - obviously require further refinement, but may be useful as a "first cut" estimate.

Table 22 Estimated inputs from urban runoff - Derwent Estuary

Contaminant	kg/ha	t/yr
TSS	322	1610
BOD	30	150
TP	0.65	3
TN	5.8	29
Dissolved inorganic N (NH_3+NO_X)	3.1	16
Pb	0.1	0.5
Zn	0.22	1.1
Cu	0.3	1.5
FC (# of organisms)	2.6E+10	1.3E+14

Notes urban area is estimated at 50 km^2, predominantly high density, residential land use
most pollutant loading rates are derived from Horner (1992)- median values
* BOD and dissolved inorganic N rates are from Horner *et al.*, 1994 (Table 23)
** loading rate for faecal coliform is from Horner (1992) - used maximum value to reflect high values observed in Hobart stormwater.

Summary

Faecal contamination has been the most extensively studied parameter to date in Hobart stormwater catchments. From the studies undertaken (Blacklow, 1995; Green, 1997) it appears that faecal input from dogs is potentially the highest contributor to the bacterial contamination in stormwater, however, human inputs can become considerable during periods of prolonged heavy rain or at times when sewage pump stations malfunction. There is also an impact from aging sewer and stormwater infrastructure, leading to cross contamination in many areas. Significant discharge of hydrocarbons, including some toxic PAHs, to the Derwent Estuary from stormwater have been recorded (Green, 1997), particularly from highly urbanised and industrial catchments. These hydrocarbons were demonstrated to be derived primarily from automobile sump oil.

Nutrient generation rates (kg/ha/yr) in the Hobart urban area appear to be higher than recorded in urban areas from elsewhere. Further work is currently under way to estimate the annual nutrient discharge from the Hobart urban area and to assess whether urban runoff may be a significant contributor to the total nutrient budget of the Derwent Estuary. Suspended solids levels in urban runoff from Hobart are comparable to levels recorded from elsewhere and suggest that catchment and rivulet management practices are required to reduce high sediment yields particularly during flood conditions and from areas subject to land disturbance such as landfill areas. There have been no published studies of pesticides, herbicides or PCBs in stormwater in Hobart.

4.4 Refuse disposal sites

Refuse disposal sites (RDSs) may contribute pollutants to water bodies in the form of leachate, surface runoff and wind-blown rubbish. Sites must meet specified licence conditions, which usually require leachate management, and monitoring of leachate, groundwater and nearby waterways. Parameters which are commonly monitored include nitrate, ammonia, phosphate, pH, BOD, COD, total coliforms, faecal coliforms, metals and organic contaminants. Leachate quality varies from site to site depending on the refuse composition, water content, stage of decomposition, temperature and oxygen availability. Some contaminants which may be present in leachate are hazardous even in very low concentrations. These include chlorinated hydrocarbons, aromatic solvents, phenolic compounds, pesticides and herbicides and metals such as cadmium, mercury and lead. In general these pollutants are associated with the uncontrolled landfills of the past, particularly those with commercial and industrial catchments and associated wastes. Municipal solid waste is less likely to contain material which gives rise to such contaminants in the leachate. Appropriate licence conditions and proper management of RDSs help to minimise the risks of such contaminants escaping into the environment.

Licensed municipal RDSs in the vicinity of the Derwent Estuary are shown in Figure 22. There are 4 active sites at Peppermint Hill (New Norfolk), Jackson Street (Glenorchy), McRobies Gully (Hobart) and Lauderdale (Clarence). McRobies Gully (89 ha) is by far the largest of these, followed by Jackson Street (23 ha). Leachate from these two sites is collected and diverted to sewage treatment plants, however, overflows could potentially enter the Derwent via Hobart and Humphries Rivulets, respectively. The Peppermint Hill site also has a retaining bund and leachate collection ponds; overflows could enter the Derwent via a small stream to the east of the RDS. The Lauderdale RDS (23 ha) is located in former wetlands within 100 m of Ralphs Bay. This site has no containment bunding or leachate ponds, however, groundwater is being monitored in and around the site.

In addition to licensed, active sites, approximately 10 old tips are known to exist along both sides of the estuary (Tamvakis, 1994). Some of these sites (New Town Bay, Prince of Wales Bay, Geilston Bay, Lindisfarne Bay and Kangaroo Bay) were former tidal flats/wetlands at the heads of bays, which were used as rubbish tips. Most former tip sites are now reclaimed as parks, playing fields or wharves. A few are monitored/managed; most are not. Groundwater leaching from some of these tips may be contaminated.

A number of industrial landfills and stockpiles are also present around the Derwent, particularly in the vicinity of Pasminco Hobart and ANM. The Lagoona/Inshallah dumps, located along the northern shoreline of New Town Bay, are the most significant of these in terms of soil and groundwater contamination. See Section 4.2 for further discussion.

According to the Division of Environment and Planning's *Register of Contaminated Sites*, no major contaminated sites have been identified in the vicinity of the Derwent Estuary. Given the urban and industrial history of the area, however, a number are likely to exist.

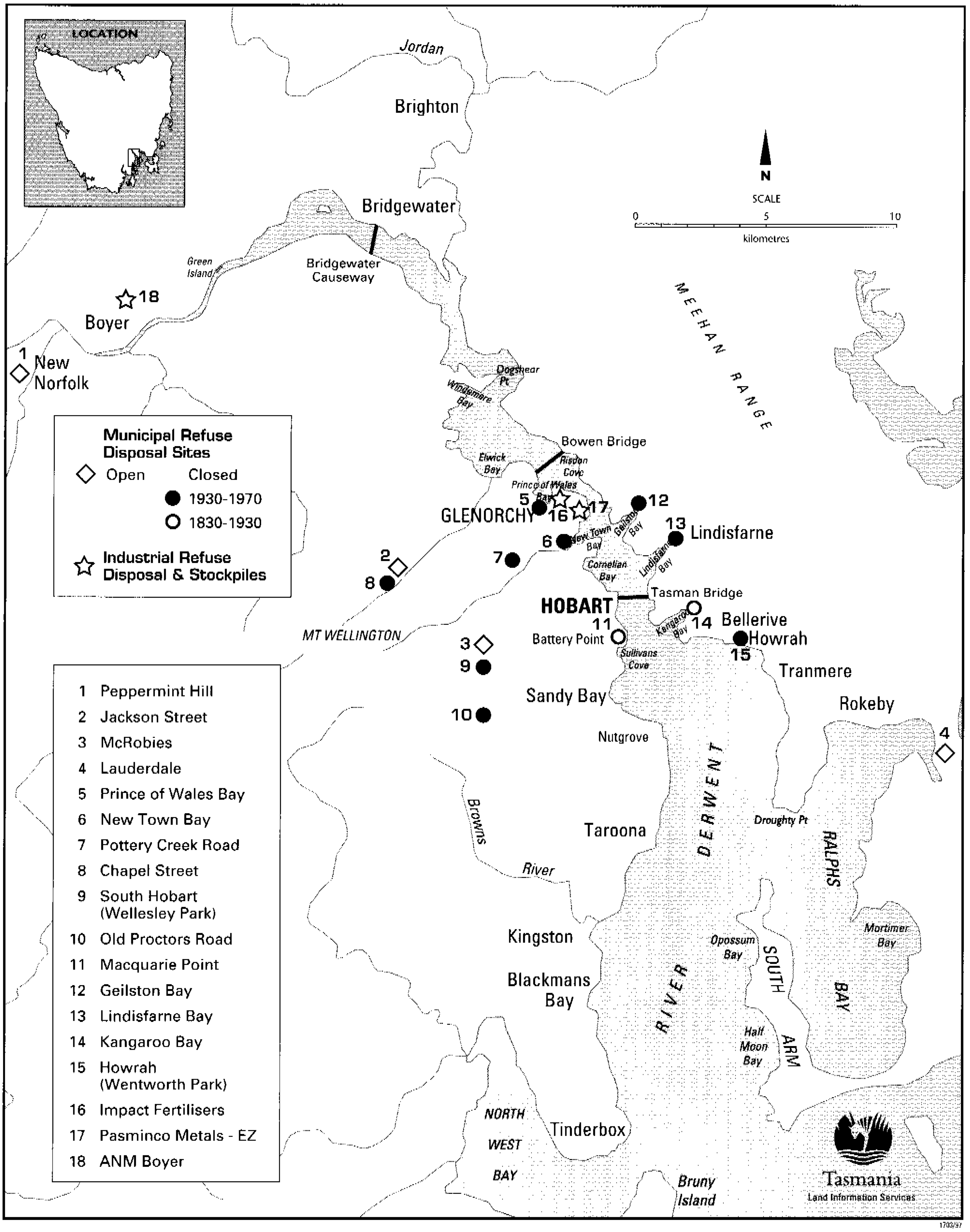


Figure 22 Refuse disposal sites and industrial stockpiles

Summary of Figure 22

1. Peppermint Hill, New Norfolk
1977 - present
•The lifespan of the current tip site at New Norfolk was extended for five years in 1994.
•Filling rate limit is 15,000 cubic metres per annum.
•The tip has surface diversion of water flow, a retaining bund, leachate collection ponds and quarterly sampling of surface and groundwater.

2. Jackson Street, Glenorchy
1986 - present 23 ha
•Previously a quarry site. Council will progressively rehabilitate the site to urban bushland. Expected life of the tip is 29 years.
•Estimated filling rate at this site is 120,000 cubic metres per annum.
•Perimeter drains divert surface runoff away from the tip site. Stormwater pipes at the tip site are directed to a leachate pond which is connected to sewer. The pond overflows to stormwater during heavy rain. Surface water is monitored every 6 months at the site, groundwater every 3 months and leachate every month.
•Tip leachate has been recognised as having elevated levels of ammonia, nutrients, BOD, salinity and zinc.

3. McRobies Gully, South Hobart
1975 - present 89 ha
•Bushland, previously zoned as recreational land, was purchased by council in 1967 for the purpose of developing a long term and controlled disposal area.
•Estimated filling rate of 120,000 cubic metres per annum.
•A leachate pond is constructed to bedrock depth below the tip site from where it is re-routed to a sewage drain. An overflow pipe is connected to stormwater. Groundwater monitoring routinely undertaken.

4. Lauderdale
1970 - present 23 ha
•Expected closure of site in December 2001. Site to be rehabilitated as a passive recreation facility.
•Licensed filling rate currently 24 tonnes per annum.
•No containment bunding or leachate ponds.
•Leachate is monitored every six months from 16 bore sites on and around the site.

5. Prince of Wales Bay, Derwent Park
1920 - 1964
•First used as an illegal dump site then taken over by council as a municipal tip.
•Previously Derwent Estuary tidal flats, now softball and hockey playing fields.

6. New Town Bay
1920 - 1963
•First used as an illegal dump site then taken over by council as a municipal tip.
•Previously Derwent Estuary tidal flats, now rugby fields.

7. Pottery Creek Road, New Town
1961 - 1967 32 acres
•Site earmarked for a municipal tip by council.
•Previously urban bushland, now parkland.

8. Chapel Street, Glenorchy
1971 - 1987 9 ha
•Site earmarked for municipal tip by council for land reclamation.
•Previously a quarry site. Site is being rehabilitated as urban bushland and a neighbourhood park.
•Estimated filling rate at this site was 80,000 cubic metres per annum.
•A leachate pond was established at the site. This has subsequently been filled in with site runoff now diverted to sewer. Site leachate is tested quarterly together with groundwater levels from eight sites at the tip.
•Leachate considered to be of poor quality with salinity, ammonia, hardness, Fe, Zn and organic carbon all elevated.

9. South Hobart
1960 - 1967 5 acres
•First used as an illegal dump site then taken over by council as a municipal tip.
•Previously a quarry site, now soccer and playing fields.

10. Old Proctors Road, Mt. Nelson
1967 - 1974 1.7 ha
•Site earmarked for municipal tip by council for land reclamation.
•Previously a quarry site now school playing fields.
•Estimated filling rate at this site was 90,000 cubic metres per annum.
•Has a leachate pond and a runoff collection pond. This was the first Hobart tip to have such a facility. Leachate has been tested regularly by council since 1977.

11. Macquarie Point, Hobart
1830 - 1938
•Large, organised, council operated site.
•Previously part of the Derwent River, now a wharf site.

12. Geilston Bay
1966 - 1970
•First used as an illegal dump site then taken over by council as a municipal tip for land reclamation.
•Previously Derwent Estuary tidal flats, now recreation area including parkland.

13. Lindisfarne Bay
1950 - 1964
•First used as an illegal dump site then taken over by council as a municipal tip for land reclamation.
•Previously Derwent Estuary tidal flats, now playground and parkland.

14. Kangaroo Bay, Bellerive
1920 - 1975
•First used as an illegal dump site then taken over by council as a municipal tip.
•Previously Derwent Estuary tidal flats, now parkland.

15. Wentworth Park, Howrah
1962 - 1969
•Site earmarked for municipal tip by council for land reclamation.
•Previously mined sand dunes, now playing fields, parks and playgrounds.

16. Impact Fertilisers
•Large phosphate rock stockpile

17. Pasminco Hobart
•Large areas of industrial landfills and stockpiles
•Groundwater monitoring
•Loogana/Inshallah sites being rehabilitated

18. ANM Boyer
•Large areas of industrial landfills and stockpiles
•Groundwater monitoring

4.5 Major tributaries

Pollutant inputs from land uses within the catchment of a given tributary can be estimated by monitoring concentrations in receiving streams, and by multiplying these concentrations by stream discharges. Using hydrographic and water quality data collected over a 12-month study period (1993/1994), nutrient and TSS inputs were calculated from the Derwent River catchment area above New Norfolk and from the Jordan River catchment area above Mauriceton. Based on this approach, total nutrient loadings from the catchments above these points were estimated as 100 tonnes nitrate+nitrite, 35 tonnes ammonia, 3.5 tonnes orthophosphate and 17.5 tonnes total phosphorus over the one-year monitoring period.

Annual TSS inputs were in the order of 10,000 tonnes. Although the Jordan River has relatively high nutrient and TSS concentrations due to heavy agricultural use, this river has a very low annual discharge, and inputs from the Jordan River comprised less that 1% of the total tributary loadings. It should be noted, however, that values for both tributaries probably underestimate actual inputs, as water samples were not systematically collected during high discharge conditions (particularly during peak events in late December/early January), when the majority of sediment and nutrient transport tend to occur. Inputs of BOD and other parameters from the Derwent and Jordan Rivers have not been monitored.

4.6 Estuarine sediments

Many contaminants have an affinity with particulate material, therefore sediments are often a reservoir of pollutants. While contaminants associated with sediments may be relatively immobile, chemical and physical changes may result in them being released back into the environment and they may thus enter the ecosystem.

Information concerning the physical and chemical characteristics of Derwent sediments and associated contaminants is patchy and incomplete and it is difficult to speculate on the significance of Derwent sediments as a source of contaminants. In highly polluted areas of the estuary, such as near Risdon, it is possible that zinc, cadmium, lead, mercury and copper may be released into the water column. Disturbance of sediments by wind-induced resuspension or dredging could also result in remobilisation of contaminants from sediments to the water column.

4.7 Coastal waters

The coastal waters of southeastern Tasmania may constitute a significant source of nutrients to the Derwent Estuary. It is not possible to quantify the relative contribution of nutrients from coastal waters without a complete data set on nutrient levels in coastal waters and further information on contributions from sediments and anthropogenic sources. However, it appears that marine-derived, "background" nutrient levels in the estuary may range from 0 to 50 μg N/L nitrate+nitrite, <5 to 20 μg N/L ammonia, and <2 to 15 μg P/L orthophosphate. These nutrient concentrations fluctuate seasonally, in response to variations in offshore oceanic currents.

4.8 Atmospheric inputs

Substantial quantities of pollutants can enter estuaries directly in the form of precipitation or as dry fall-out from the atmosphere. Atmospheric inputs are derived from a variety of sources, such as emissions from vehicles, industry and wood heaters. The atmosphere has been found to contribute a substantial proportion of pollutants to many urbanised estuaries. In Port Phillip Bay, for example, atmospheric inputs of inorganic nitrogen contribute approximately 800 to 1300 tonnes of nitrogen to the system each year, accounting for 10 to 20% of total nitrogen inputs (Carnovale *et al.*, 1992; Harris *et al.*, 1996).

Most monitoring of atmospheric pollution focuses on contaminants which represent a risk to human health, such as ozone, carbon monoxide, nitrogen oxides, sulfur dioxide, particulates, lead and other air toxics. Compounds which are most likely to affect estuarine water quality include nutrients (particularly ammonia and nitrate-N), cadmium, lead, zinc and other heavy metals, and air toxics such as PAHs and phenolics.

The main sources of atmospheric pollution in the Derwent region are:

- urban inputs (traffic, wood heaters);
- industries;
- other (e.g. bushfires).

Specific data on air quality in the Derwent region are limited. In the Hobart area, monitoring of particulates has been carried out at one to two sites since 1981 (Carnovale, 1997). Some industries, specifically Pasminco Hobart and ANM, routinely monitor stack emissions (for particulates, nitrogen oxides, sulphur oxides and heavy metals). Pasminco Hobart also monitors ambient air quality and dust fall-out (particulates, metals and phosphorus) as part of their licence conditions - see Section 4.2 for details).

Airborne contaminants of particular concern with respect to the Derwent Estuary would include ammonia and nitrate, phosphorus, heavy metals, PAHs and phenolics. The degree of atmospheric fallout will depend largely on local meteorological conditions. This may be estimated through the collection and analysis of representative rainwater samples at sites immediately adjacent to or over the estuary. This type of monitoring has not been done in the Derwent region.

4.9 Spills and other incidents

Spills and other incidents reported to DELM are routinely recorded and categorised in a database which is maintained by the Division of Environment and Planning. A review of this database indicated that in 1996, a total of approximately 50 incidents were reported which affected water quality in the Derwent Estuary or in rivulets and creeks which enter the Derwent. These included spills of hydrocarbons, sewage, chemicals and other substances. The majority of these were relatively minor, however, some larger spills occurred, including a 2000 L diesel spill to Hobart Rivulet (largely contained and cleaned up within the rivulet), several acid spills to the estuary at Risdon and a number of sewage overflows/spills.

In 1975, the vessel *Lake Illawarra* struck the Tasman Bridge and sank to the bottom of the Derwent, along with its cargo of zinc concentrate. The vessel and its cargo were never recovered and remain at the bottom of the estuary in approximately 40 m of water, just south of the Tasman Bridge. Several surveys were carried out in mid/late 1970s to measure heavy metal concentrations in the vicinity of the wreck - no evidence of increased levels was found. No specific surveys have been done since.

4.10 Summary

Table 23 attempts to summarise cumulative inputs to the Derwent from industries, sewage treatment plants, urban runoff and the Derwent River catchment. Relative inputs from each of these sources are further illustrated as pie charts for specific contaminants in Figure 23.

The available data suggest that STPs contributed the majority of nutrients and faecal indicator bacteria to the estuary in 1996. The Derwent River constitutes the largest freshwater flow to the system by far and contributes the major sediment load. Urban runoff probably contributes the second largest sediment load and also carries a substantial hydrocarbon and faecal bacteria load. Since improvements to sewage treatment at Sandy Bay and Blackmans Bay were completed in late 96/early 97, urban runoff now appears to dominate bacterial inputs (see Figure 24). The contribution by stormwater to the annual bacterial load delivered to the Derwent Estuary is now probably in the vicinity of 50-75%. As sewage treatment in Hobart continues to be upgraded, there will be an expected continued decrease in bacterial loads to the Derwent Estuary from sewage treatment plants. Hence the relative proportion of faecal pollution that stormwater conveys to the Derwent Estuary will continue to increase in the future, unless stormwater management practices are implemented.

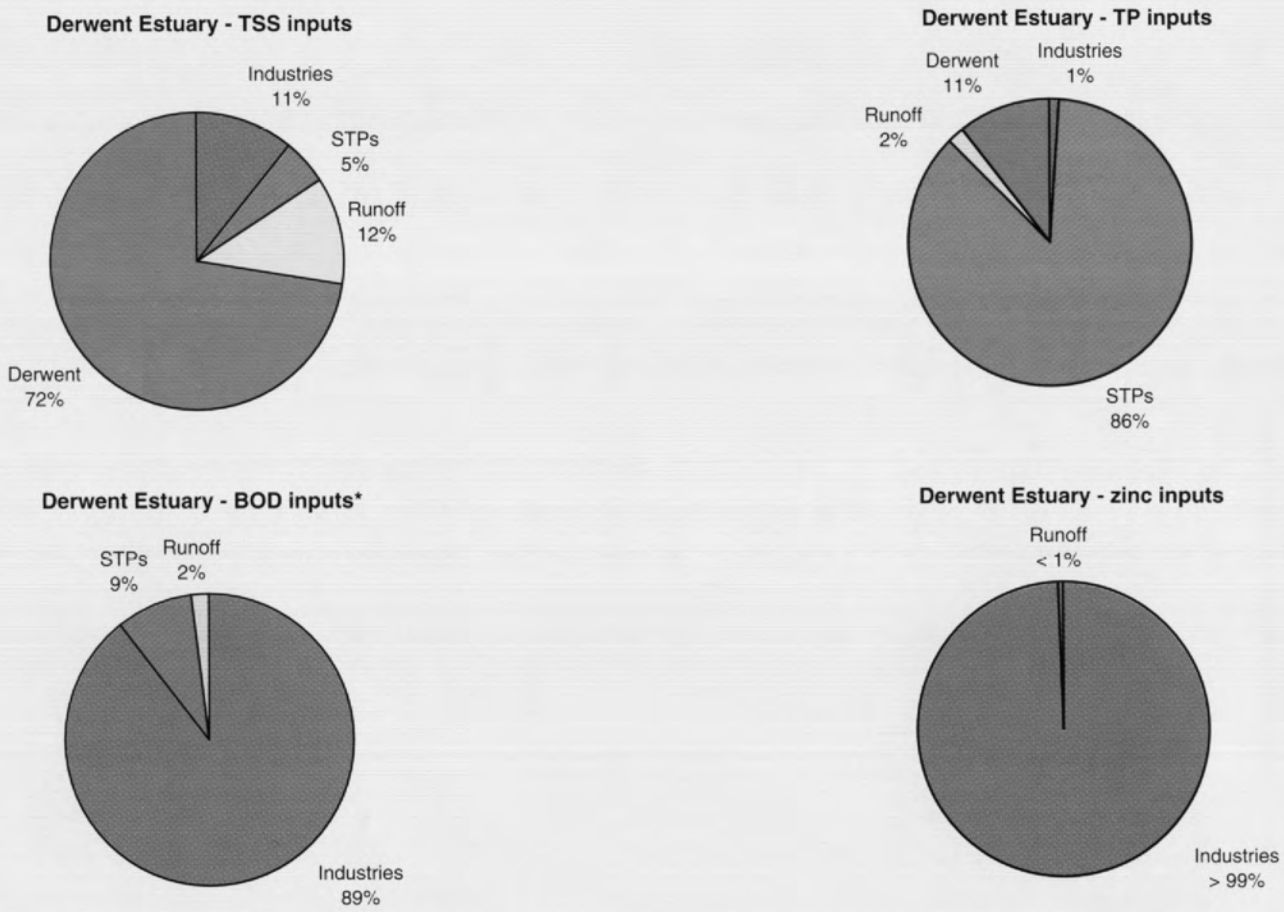
Industries still contribute substantial loads of pollutants to the Derwent via both point and diffuse sources. For example, a single point source discharge at ANM-Boyer accounts for 89% of the anthropogenic BOD load to the estuary, and also contributes substantial amounts of suspended solids and resin acids. In contrast, the majority of heavy metal inputs from Pasminco Hobart in 1996 were derived from diffuse sources, particularly contaminated ground water, handling losses at the wharf and wind-blown dust. Pasminco Hobart thus contributed over 99% of zinc loads to the estuary in 1996, primarily from diffuse source emissions. It is anticipated that, with the construction of new storage and handling facilities at the wharf in early 1997, zinc inputs will be reduced by approximately 30 - 40%.

Table 23 is limited in its usefulness, however, as the full range of parameters has not been measured for most sources; thus, cumulative inputs cannot be accurately determined and intercomparisons are of questionable value. Inputs of nutrients, TSS and BOD from tributaries, for example, are poorly defined. Some pollutants, such as hydrocarbons, PAHs, pesticides, phenolics, PCBs and other organic compounds have been rarely or never monitored in wastewaters discharging to the Derwent or in the Derwent itself. Furthermore, inputs from municipal and industrial sources have undoubtedly been underestimated, as most of these values were based on monitored end-of-pipe liquid emissions, and do not include diffuse sources (e.g. air emissions, groundwater inputs, spills and sewage overflows). In highly contaminated areas of the estuary, sediments may also be an internal source of contaminants, particularly for metals. Table 24 provides an alternative, qualitative overview of inputs from all sources, both diffuse and point.

Table 23 Summary of cumulative inputs to the Derwent Estuary 1996

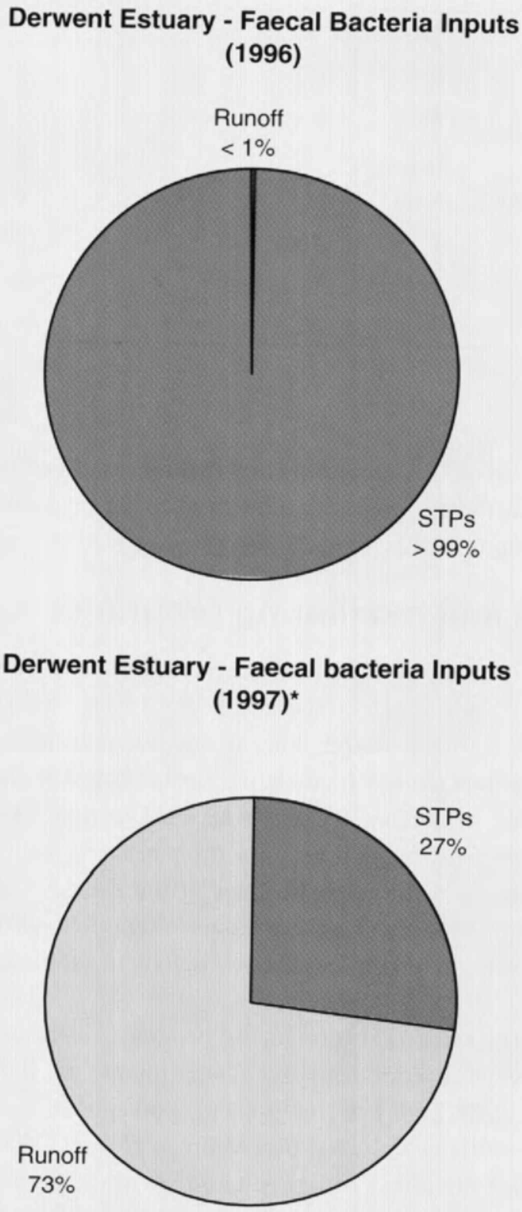
Parameter	Total (1) Industries	Sewage (3) Treatment STPs	Urban (4) Runoff	River (5) Derwent
Total effluent volume (ML)	70,070	19,714	?	3,784,320
Contribution in tonnes				
TSS	1,497	677	1,610	10,000
BOD	7,018	678	150	na
COD	36	na	na	na
Faecal coliform	negl	4.75E+16	1.30E+14	na
Ammonia-N	13	380		35
Nitrate+nitrite N	na	104		100
DIN	0	484	16	135
Total nitrogen	51	na	29	na
Phosphate	0	na		4
Total phosphorus	2	142	3	18
Zinc (2)	220	na	1	na
Cadmium	0.4	na	na	na
Copper	0.2	na	2	na
Lead	1.2	na	<0.5	na
Iron	4.0	na	na	na
Manganese	0.1	na	na	na
Mercury	0.0	na	na	na
Selenium	0.0	na	na	na
Arsenic	5	na	na	na
Fluoride	53	na	na	na
Sulphate	10,000	na	na	na
Oil and grease	2	na	na	na
Resin acids	51	na	na	na
Phenols	na	na	na	na
PAHs	na	na	na	na

na not available
(1) Mostly based on end-of-pipe emissions from ANM, PMEZ, Impact Fertilisers, TIA (except zinc)
(2) Rough estimate of all zinc inputs, both end-of-pipe and diffuse sources
(3) Includes all STPs which discharge directly to Derwent, plus Brighton STP
(4) Based on typical contaminant generation rates (kg/ha) from the literature; some Hobart-specific data
(5) Based on (mean TSS concentration x mean flow); actual value probably higher



* anthropogenic inputs only - no data available for Derwent River BOD

Figure 23 Relative inputs of TSS, BOD, TP and zinc to the Derwent - 1996



* following commissioning of new Selfs Point STP,
treatment of Sandy Bay outfall and upgrading of Blackmans Bay STP

Figure 24 Relative inputs of faecal coliform to the Derwent - 1996 and 1997

Table 24 Pollution sources and pollutants - qualitative assessment of inputs

Source	TSS	BOD	Nutrients	Bacteria	Metals	HC
STPs	M	M	L	L	S	?
Industry - metals	S	S	S	S	L	?
Industry - pulp	L	L	S	S	S	?
Derwent River	L	M/L?	M	S	S	?
Urban air pollution	S	S	S/M?	na	S/M	?
Estuarine sediments	?	?	?	?	?	?
Urban Runoff	L	S	S	L	S	L

L Large
M Medium
S Small

On the basis of this initial review, it is recommended that all input estimates be progressively reviewed and refined. Monitoring programs may need to be upgraded and expanded - at least for a short time - to better quantify inputs.

5 Previous studies and monitoring programs

Environmental quality monitoring has been carried out intermittently in the Derwent by a variety of organisations and individuals since the early 1970s, when the well-publicised illness caused by eating oysters from Ralphs Bay raised awareness about the contaminated status of the estuary. The earliest studies focused primarily on heavy metal concentrations in waters, sediments and biota. In the late 1980s, a serious episode of sludge rafting in the upper estuary spawned further investigations, this time relating to the characteristics and distribution of paper mill sludge in the upper reaches of the estuary. Over the past 5 years, monitoring programs have looked more closely at bacteriological levels near bathing beaches, nutrients, chlorophyll *a* and phytoplankton, and heavy metals in sediments and biota.

Only two relatively consistent long-term monitoring programs have been maintained: semi-annual water quality surveys carried out by Department of the Environment (now E&P/DELM) from 1971 - 1988 and 1993 to present, and annual surveys of heavy metal concentrations in fish and shellfish conducted by Pasminco Hobart (1972 to present). CSIRO has also recently studied and modelled the circulation of the Derwent Estuary. The most pertinent studies of environmental quality in the Derwent are identified below:

- Department of the Environment, 1972 - 1988: semi-annual surveys (2 - 5/yr) of surface water quality throughout the Derwent. Monitored 14 sites for physical parameters, heavy metals and faecal indicator bacteria;
- Pasminco Hobart, 1972 - present: annual survey of heavy metal concentrations in oysters, mussels and flathead from 25 sites;
- Bloom, 1975: snapshot survey of entire estuary for heavy metals in waters, sediments and biota (50-140 sites);
- Local councils/DCHS/DELM, 1987 to present: bacteriological surveys of bathing beaches at 30 sites (weekly during summer months);
- ANM, 1988 - present: fortnightly water quality surveys at 12 sites in upper estuary;