supervising scientist report 167

North-west rivers environmental review

A review of Tasmanian environmental quality data to 2001

Graham Green

Natural Heritage Trust
Helping Communities Helping Australia
A Commonwealth Government Initiative

supervising scientist

Tasmania

Environment Australia
Department of the Environment and Heritage

This report was funded by the Natural Heritage Trust, a Commonwealth initiative to improve Australia's environment, as part of the RiverWorks Tasmania program. RiverWorks Tasmania is a joint program managed by the Tasmanian Department of Primary Industries, Water and Environment and the Commonwealth Supervising Scientist Division to improve the environmental quality of Tasmanian estuaries. The primary objectives of RiverWorks Tasmania are:

- to undertake a series of capital works projects designed to reduce or remove significant historical sources of pollution;
- to invest in mechanisms that will provide for sustainable environmental improvement, beyond the completion of the capital works program;
- to develop proactical and innovative mechanisms for improving environmental conditions which can be transferred to other areas of Tasmania and other Australian States;
- to produce public education/information materials.

For further information about this report please contact the Program Manager, RiverWorks, Department of Primary Industries, Water and Environment, GPO Box 44, Hobart 7001.

G Green – Environment Division, Department of Primary Industries, Water and Environment, GPO Box 44, Hobart 7001

This report has been published in the Supervising Scientist Report series and should be cited as follows:

Green G 2001. *North-west rivers environmental review*: *A review of Tasmanian environmental quality data to 2001*. Supervising Scientist Report 167, Supervising Scientist, Darwin.

The Supervising Scientist is part of Environment Australia, the environmental program of the Commonwealth Department of Environment and Heritage.

Supervising Scientist
Environment Australia
GPO Box 461, Darwin NT 0801 Australia

ISSN 1325-1554

ISBN 0 642 24373 5

Cover illustration: e.g. design, Hobart ,Tasmania

Printed in Hobart, Tasmania, by PMP Print P/L

Executive summary

This document provides an environmental review of the rivers, including estuaries, of north-west Tasmania. The document covers the natural environment, human uses and values, and pollution sources such as sewage treatment plants, mines, waste disposal sites, stormwater, industry, agriculture and forestry. An overview of current work and outstanding issues on a catchment by catchment basis is given.

The major river health issues in the region are acid mine drainage, dairy effluent, leachate from past waste disposal sites, and soil loss from agricultural land. Sewage and stormwater systems perform poorly at times with impacts primarily at the coast rather than in the rivers.

Acid mine drainage is a serious issue from old mine sites in the Waratah and Mt Bischoff region. Contaminated drainage has impacted tributaries of the Arthur River and created a 'dead zone' for approximately 20 km downstream in the Arthur. Acid mine drainage is a problem to a lesser extent in the Frankland River (tributary of the Arthur) from old mine workings at Balfour, and in the Forth River from old workings at Round Hill above Lake Cethana.

Agriculture is a major land use across north-west Tasmania. Notable impacts from dairying operations are evident in the far north-west at Edith Creek (tributary of the Duck River) and at Togari (Montagu River catchment). Due to the deep soils across much of the region and generally high rainfall, soil loss is a big issue that affects most rivers, particularly in areas of intensive cropping. The problem manifests in waterways as high turbidity, and high sediment bed load. Waterways that are particularly affected are those with small catchments in the central coast region such as Claytons Rivulet, Buttons Creek, Sulphur Creek and the Don River. These catchments tend to be intensively developed and the streams do not receive high volume flushing flows of clean water from forested or high altitude areas.

Closed waste disposal sites of particular concern in the region are: View Street waste depot in Burnie located in a gully with high water table; Port Sorell waste depot with pulp mill waste leachate to creek and groundwater; industrial waste landfill in Burnie that impacts upon tributaries of the Cam River upstream from a town water supply off-take; and an abattoir waste disposal site in Smithton that leaches to a tributary of the Duck River.

The biggest wastewater problem in the region is cross connections between the sewage and stormwater systems. Influxes of water to the sewer via stormwater connections create problems at sewage pump stations that can at times overflow to rivers. The Mersey estuary is particularly affected by this problem. Additionally stormwater infrastructure is absent in parts of Burnie and Devonport in which case stormwater is either connected to the sewer through lack of an option, or not connected at all.

The water quality of sewage effluent and stormwater is not perceived to be a major concern for river health on the north-west coast as most outfalls are to the ocean. Monthly monitoring data for sewage treatment plants on the north-west coast demonstrates that most plants perform close to or worse than current effluent quality guidelines. There have been no studies undertaken to characterise stormwater quality in the region.

There are many small towns in north-west Tasmania that are not serviced by reticulated sewerage systems and rely on septic tanks or similar systems. Cradle Valley is an area that has a number of individual sewerage systems at numerous locations that collectively may have some impact if not upgraded. Due to the high conservation status of the area and the increasing visitor usage there is an argument for upgrading and centralising the sewage collection and treatment facilities of the area.

Industrial wastewater is not a significant issue for the rivers of north-west Tasmania. Goliath Cement works in the Mersey catchment has a water management plan, and the old Tioxide site on the Blythe estuary has been rehabilitated to minimise off site impacts. The Leven estuary is sometimes affected by pump station overflows resulting from influx of vegetable processing factory effluent.

An assessment of estuaries using physico-chemical criteria, species diversity and level of human disturbance showed that estuaries of the north-west coast are generally degraded. Just the Black River estuary has high conservation significance. Several estuaries (the Welcome, Montagu, West Inlet, East Inlet and Detention) have moderate conservation significance.

Primary identified issues from the review are summarised in the following table.

Summary of primary identified issues

Category of activity	Municipality	Site	Issue	Affected river(s)	Suspected pollutants
Sewage/stormwater	All	All larger towns	Infrastructure cross connections and pump station overflows	Particularly Duck, Emu, Leven, Buttons Ck, Mersey	Bacteria, pathogens, nutrients, BOD
Refuse disposal site	Burnie City	View Street	Leachate	Local stream and groundwater	Metals, hydrocarbons, nutrients
Industrial waste landfill	Burnie City	Mooreville Road	Leachate from pulp mill waste	Cam River	Metals and industrial chemicals
Intensive cropping	Central Coast, Kentish	Widespread	Soil loss	All	Turbidity, suspended solids
Old mine site	Circular Head	Balfour	Acid mine drainage	Frankland, Arthur	Acidity, sulphates, heavy metals
Dairy	Circular Head	Edith Creek	Effluent irrigation and discharge	Edith Creek, Duck	Nutrients, BOD, faecal coliforms
Dairy	Circular Head	Togari	Dairy effluent	Montagu	Nutrients, BOD, faecal coliforms
Abattoir waste disposal	Circular Head	Smithton	Leachate from 50 years of abattoir waste	Duck River	BOD, nutrients, metals
Old mine site	Kentish	Round Hill	Acid mine drainage	Forth	Acidity, sulphates, heavy metals
Refuse disposal site	Latrobe	Port Sorell waste depot	Leachate from site which includes extensive pulp mill waste.	Local creek and groundwater	Metals, hydrocarbons, nutrients
Old mine site	Waratah/ Wynyard	Mt Bischoff area	Acid mine drainage	Waratah, Arthur	Acidity, sulphates, heavy metals

Contents

Tables

Figures

Acknowledgments

The preparation of this report was funded by the Natural Heritage Trust's RiverWorks Tasmania program. Contributions from the following people are acknowledged:

Tony Port	GIS support
Helga Grant	Information on hydro-electricity operations
Chris Bobbi	Hydro Tasmania technical report
Greg Dowson	Technical reports and Mersey WQOs
Kate Berry	State of Rivers progress reports for the Duck, Montagu, Inglis/Flowerdale and Welcome Rivers
Sue Dobson	PEV reports
Mike Askey-Doran	Rivercare reports and information.
Michael Syka	Sewage treatment plant information
R Moore, A Ezzy, M Cummins	Tip site information
Shivaraj Gurung	Acid mine drainage information
Todd Walsh	Giant freshwater lobster information
B Churchill, R Dineen & L Koehnken	Review of draft material
Bill Bourke	Acid mine drainage site information

Acronyms

ANZECC	Australia and New Zealand Environment and Conservation Council
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CWR	Commissional Water Right
DELM	Department of Environment & Land Management (now DPIWE)
DPIWE	Department of Primary Industries, Water & Environment
GIS	Geographic Information System
HEC	Hydro Electric Corporation
ML	Megalitre
MRT	Mineral Resources Tasmania
NFR	Non-filterable Residue
NHT	Natural Heritage Trust
P&WS	Parks and Wildlife Service
PCB	Polychlorinated Biphenyl
PEV	Protected Environmental Value
SPWQM	State Policy on Water Quality Management
STP	Sewage Treatment Plant
TBT	Tributyl-tin
TSS	Total Suspended Solids
UV	Ultraviolet
WQO	Water Quality Objective

1 Introduction

The rivers of north-west Tasmania (from the Arthur in the west to the Rubicon in the central north — figure 1) are characterised by significant diversity in terms of their natural setting, extent of development within their catchments and characteristic water quality. There are very few unimpacted rivers in the region. The Arthur River, draining to the west coast, is a remote wild river with minimal human settlement in its catchment. The Black River, draining to the north coast near Stanley, is relatively unimpacted. The headwaters of the Mersey, Forth and Leven are nearly pristine as they rise in or near the Cradle Mountain Lake St Clair National Park. Catchment development in the region tends to increase progressively towards the coast where the highest density urban development is located. Most of the north-west region away from the coast is sparsely populated with catchment activity dominated by agricultural and forestry practices. Consequently impacts upon rivers of the region are largely related to these activities, although hydro electricity generation has impacted upon the Mersey and Forth Rivers and acid mine drainage is a significant impact in the upper Arthur catchment.

This document has been prepared to assist project proponents and the committees assessing project applications to formulate and prioritise potential projects under the RiverWorks program. RiverWorks Tasmania is a Natural Heritage Trust (NHT) program aimed at assisting the community with the remediation of water pollution sources. The initial phase of RiverWorks funding (1997–1999) focused on the Tamar, Derwent, Huon and King River catchments. The program has now been expanded to encompass all Tasmanian waterways. This document complements an environmental review of the north-east Tasmanian rivers and the previously prepared State of the Derwent Estuary Report (Coughanowr 1997) and State of the Tamar Report (Pirzl & Coughanowr 1997).

The aim of this report is to provide an overview of river condition based upon existing water quality and environmental information, databases held by the Department of Primary Industries, Water and Environment (DPIWE) and information from local councils and community groups. The report covers significant contamination point and diffuse sources in relation to waste disposal sites, industrial operations, agriculture and forestry, urban activity and mining operations. A summary of the status of all major river catchments in the region is given.

1.1 Overview of previous work

Most of the 'river health' work conducted recently in north-west Tasmania has been related to the presence/absence of stream fauna through the Monitoring River Health Initiative. Water quality monitoring undertaken is primarily related to hydro-electric operations, water supply testing, or particular 'State of the River' investigations. Rivercare work such as willow removal and stock access management has gained momentum in the region over the past 5 years. There has been very little work in the region to characterise the impact of sewage and stormwater discharges on river health so currently anecdotal evidence is the best guide. Specific studies/programs across the region are summarised below.

Figure 1 River catchments of north-west Tasmania

1.1.1 Regional studies

The Australia Wide Assessment of River Health program (Krasnicki et al 2001) monitored aquatic invertebrates from all catchments of the region to determine river health according to the presence or absence of particular species.

Most of the rivers of the north-west have been surveyed for the presence of the giant freshwater lobster (*Astacopsis gouldi*), which may be used as an indicator of water quality and habitat health, in a project that commenced in 1997. The lobster is listed as *Vulnerable* under Tasmania's *Threatened Species Protection Act 1995*, and is the largest freshwater invertebrate in the world. Due to over-fishing, slow growth and low reproductive rates, plus their sensitivity to degraded habitat (particularly siltation and enhanced temperature), severe population declines have been recorded over most of their natural distribution. The findings of the study will be available in 2002 in a report published by the Inland Fisheries Service.

The State of the Rivers Program funded jointly by the Commonwealth and Tasmanian Governments is currently underway in several north-west rivers: the Inglis, Duck, Montagu and Welcome. Monthly sampling is conducted at sites throughout the catchments. Water quality parameters monitored are: conductivity, dissolved oxygen, turbidity, pH, total nitrogen and total phosphorus. Progress reports on the water quality are given by Berry (2001). Water quality and identification of key point source impacts have been identified in the Mersey River Experimental Study Technical Reports (DELM 1997).

Erosion and soil loss (related to agricultural practices) and its effect on rivers and water quality has been investigated in catchments of the central coast region (Sims & Cotching 2000).

1.1.2 Regular and ongoing water sampling

Cradle Coast Water (formerly the North West Regional Water Authority) undertakes water quality testing daily for parameters such as colour, turbidity, pH, alkalinity and temperature. Testing 3 times annually is undertaken for most of the parameters in the Australian Drinking Water Guidelines including nutrients, faecal indicators, organics, inorganics, heavy metals, herbicides and pesticides. Water quality testing sites are Lake Barrington and Lake Paloona (Forth River), the Forth River just upstream of Forth township, Lake Isandula (West Gawler River), Leven River, Cam River and Lake Mikany at Smithton (Van Eysden, Cradle Coast Water, pers comm, 2001).

Hydro Tasmania has a water quality monitoring station on the Forth River downstream of Lake Paloona dam. Two Waterwatch groups (Burnie/Wynyard and Five Rivers) sample sites on rivers in the central part of the region between the Inglis and the Mersey River.

Councils of the region are involved in the bathing water sampling program which involves weekly monitoring over summer months at sites along the north-west coast (mostly coastal rather than river sites). Results are published annually by the Tasmanian Department of Health and Community Services.

1.1.3 Natural resource management

Natural resource management projects received significant funding across the region when funds became available in 1997 through the Natural Heritage Trust. Several projects have been undertaken on the Mersey River — natural resource management plan (Armstrong et al

2000a), Rivercare plans (Armstrong et al 2000b), river styles report (Lampert 2000), and a river flow and catchment assessment (Mersey River Working Group 1998).

Catchment management plans have been completed for the following rivers: Welcome, Montagu, Pet and Guide, and Caroline Creek (Latrobe) and Rivercare plans have been completed for the Welcome, Duck, Inglis/Flowerdale, Leven, Don, Mersey and Rubicon Rivers.

2 Natural environment

2.1 Catchments

The major river catchments (based on area of the river basin) of north-west Tasmania are listed in table 1 together with major tributaries and significant towns in the catchment. More detailed information covering individual catchment characteristics is given in chapter 5.

Table 1 North-west rivers — catchment information

River	Catchment area (km^2)	Significant tributaries	Significant towns
Arthur	2492	Frankland, Rapid, Hellyer	Waratah
Mersey*	1759	Arm, Fisher, Dasher	Devonport, Latrobe, Sheffield, Railton, Mole Ck
Forth**	1126	Dove, Wilmot	Forth, Wilmot
Leven	700	Gawler	Ulverstone
Inglis	505	Flowerdale	Wynyard
Duck	350		Smithton
Black	345	Dip	
Montagu	327		
Welcome	304		
Blythe	277		
Rubicon	263		
Cam	249	Guide	
Emu	243		Burnie
Detention	152		
Don	136		Don
Franklin Rivulet	133		
Claytons Rivulet	75		

* Catchment water yield upstream of Lake Parangana is diverted to the Forth River catchment.
** Receives substantial inter-basin transfer of water from the Mersey River catchment.

2.2 Geomorphology and geology

The topography of north-west Tasmania includes plateau country, high mountains, rolling hills, floodplains, escarpments and coastal plains. North-west Tasmania has been divided into four distinct physiographic zones by Davies (1965). The ‘north-west plateau’ is central to the region with the ‘western ranges’ and ‘high dissected plateau’ lying to the south at the head of the region’s watershed. The north-west corner of the region is defined as ‘coastal platforms’.

The major landforms of the north-west are summarised in table 2.

2.2.1 High dissected plateau

Deep dissection by large valley glaciers characterises the ‘high dissected plateau’ zone which includes Cradle Mountain. Two of the north-west’s major rivers, the Mersey and the Forth, originate in this zone.

Table 2 Summary of the major landforms of the north-west*

Land form	Local relief	% area
Low hills	<100 m	31.0
Mountains	>300 m	19.0
Undulating plains		17.5
Hills	100–300 m	16.5
Flat plains		13.9
Coastal dunes and beaches		2.1

* After Richley (1978)

2.2.2 Western ranges

Precambrian and folded Palaeozoic rocks form the 'western ranges' in which the topography is largely controlled by major structural trends (Davies 1965). Harder quartzite and conglomerate units form a series of dissected mountain ranges including Black Bluff and Mt Roland. The Leven River originates in the 'western ranges'.

2.2.3 North-west plateau

From the 'western ranges' in the south of the region to the north coast is a rolling to hilly plateau known as the 'north-west plateau'. In the west of this zone the major land systems are formed from Pre-Cambrian rocks; east of there is a more rugged area on Permian Upper Carboniferous strata (Richley 1978) occupied by the headwaters of the Arthur River (the north-west region's largest river and fourth longest in Tasmania). Further to the east of the Arthur River headwaters there are extensive areas of tertiary basalt.

Other features of the north-west plateau are the Dip Range, Rocky Cape and Sisters Hills which are resistant ridges of quartzite projecting above the plateau surface. The Dial range running southward from near the coast at Penguin and the prominent St Valentines Peak are other residuals consisting of siliceous conglomerate (Richley 1978).

Typical coastal features along the northern edge of the north-west plateau are scarps, sometimes exceeding 65 m in height, resulting from the sea undercutting basalt (Richley 1978). The coastal plain is characterised by narrow rock benches less than 100 m wide with only scattered small strips of sandy beach. The coastal plain widens around the mouths of major rivers such as the Mersey, Forth, Leven, Emu and Inglis.

2.2.4 Coastal platforms

From about 300 m altitude at the foot of the western ranges the coastal platforms slope westward to end near the coast forming a well defined scarp sometimes 30 m high (Richley 1978). Much of this plateau area is undulating to rolling country which transgresses geological boundaries. The plateau is deeply incised by the Arthur River and, by comparison, all other streams dissecting the plateau are minor.

Siltation of estuaries in the north-west corner of the region followed by emergence resulted in the formation of extensive low coastal plains (Richley 1978). Sand dunes fringe the plain between small basalt-capped hills. Further inland approaching the Arthur River the flat plain gives way to more undulating country developed on gravelly Pre-Cambrian strata (Richley 1978).

2.3 Soils

North-west Tasmania is characterised by two main soil types, yellow podzolic soils and krasnozems. General soil types are mapped by Nicolls and Dimmock (1971) and by Davies (1965).

Krasnozems are deep, well-drained, friable clay soils formed over igneous rock and have little differentiation of the profile into horizons. They are moderately to strongly acid, relatively high in organic matter, and finely coloured red or brown by oxides of iron. Those nearest the coast are usually the reddest. Krasnozems have a high agricultural reputation and are used for dairying and for vegetable cropping. Under natural conditions the soils support wet sclerophyll forest or rainforest.

The yellow podzol soils form over siliceous rock, have greyish A horizons and a strongly acid reaction throughout (Nicolls & Dimmock 1971). In unaltered systems this soil type supports heavy timber.

2.4 Climate

North-west Tasmania experiences a temperate marine climate. Heat absorption and storage by the sea produces much milder winters and cooler summers than in continental climates at the same latitudes. This effect diminishes with altitude and distance from the sea (Richley 1978).

2.4.1 Precipitation

Average annual rainfall along the northern coast of the region is 900 mm. Rainfall steadily increases towards the south of the region to 2000 mm annually over the Arthur River catchment and 2800 mm at Cradle Valley. Rainfall is predominant in the winter with, on average, 25% of the annual rainfall occurring in July and August. January to March is the driest period experiencing, on average, just 15% of the annual rainfall. Irrigation is required in the summer months to support agricultural activities. In higher inland areas of the region snowfalls are fairly common and occur mainly in winter but may fall in any month. There is no permanent snow line within the region, however, above 1300 m altitude snow drifts may persist into summer.

2.4.2 Temperature

It is rare for temperatures over 27°C to be recorded in the region and temperatures over 32°C are very infrequent. At Burnie mean maximum and minimum temperatures for January are 21.5°C and 11.8°C respectively whilst for July they are 12.5°C and 5.4°C respectively. There is a sharp increase in the incidence of frost away from the coast in the region. Coastal areas only receive severe frosts in winter whilst inland areas may experience severe frosts at any time of the year. Cold air drainage down river valleys from higher land results in greater frequency of frosts than might be expected in some centres, notably Wynyard and East Devonport (Richley 1978).

2.4.3 Droughts and floods

One of the region's most severe dry spells occurred in 1888 when Burnie received 60% of its annual rainfall (Richley 1978). Floods occur from time to time but are not a regular event. Disruption to rail and road traffic, and associated damage, was caused by flooding at several centres in 1871, 1910, 1916, 1944 and 1970. The worst floods for the region as a whole happened in 1929, when all streams were affected, eight people were killed and heavy stock losses were reported.

2.5 Vegetation

The vegetation of the north-west is determined principally by climate, soils and fire. In the lower rainfall areas of the zone along the north and west coast sclerophyll eucalypt forest is the climax vegetation community, while rainforest is the climax where the annual rainfall is greater than 1400 mm. In heavy rainfall areas that have been subjected to a high fire frequency, mixed forests of both eucalypt and rainforest species occur together.

Pure rainforests of the region are dominated by myrtle with sassafras, celery-top pine and king-billy pine less common. Typical understorey species include leatherwood, native laurel, musk, mountain pepper, waratah, horizontal scrub and tree ferns.

The eucalyptus forests can be divided altitudinally into two groups. Below 600 m stringy-bark is dominant over most areas with other species, such as black peppermint, Smithton peppermint, white gum, and swamp gum becoming common according to soils and aspect. Above 600 m gum-topped stringy-bark is most common together with mountain white gum, cider gum and Tasmanian snow gum.

In wetter areas over poor soils melaleucas, banksias and tea trees are common as a dense shrub layer beneath the eucalypt canopy. Blackwood may be present in these situations as a secondary tree layer. The Welcome River catchment in the far north-west has an extensive area of melaleuca swamp forest.

There are broad areas of heath and scrub in the north-west corner of the region which is mainly attributable to the low fertility and often sandy soils. In poorly drained or swampy sites at all altitudes sedge-land communities characterised by buttongrass, cord rush, heaths, and cutting grass may be present.

2.6 River fauna

Waterways of north-west Tasmania are habitat for a multitude of species including threatened, rare or endangered fauna such as the giant freshwater crayfish, freshwater snails, the Australian grayling, the Burnie burrowing crayfish, velvet worms and the green and gold frog (Bryant & Jackson 1999). Known aquatic species in the Mersey catchment are listed in table 3.

Table 3 Known aquatic species in the Mersey catchment (Armstrong et al 2000b)

Name	Comments	Species
Australian grayling	Listed as *Vulnerable* under the *Threatened Species Protection Act 1995,* it occurs in clear, gravelly streams with a moderate flow. Prefers deep, slow flowing pools. Threats: habitat loss, overfishing.	*Prototroctes maraena*
Blackfish	This species is dependent on snags in the river for habitat, food and reproduction. It has disappeared from the lower reaches.	*Gadopsis marmoratus*
Climbing galaxias	The largest of the Tasmanian galaxias, they inhabit headwaters of clear bouldery streams with riffles and cascades, under stones. Juveniles in large schools live in lake margins, near tributary mouths.	*Galaxias brevipinnis*
Mud galaxias	Live in marginal swamps and ditches with no noticeable flow. Threatened by drainage and marsh reclamation practices.	*Galaxias cleaveri*
Jollytail	Juveniles form a substantial part of the whitebait runs. They tolerate a wide range of habitat conditions, but prefer the lower reaches of coastal streams and rivers, in still or slow moving water.	*Galaxias maculatus*
Sandy	Occupying both fresh and salt water, they are threatened by loss of instream habitat; stream channel damage from sand and gravel extraction; loss of riparian vegetation; channelisation leading to increased flow velocities.	*Pseudaphritis urvillii*
Tasmanian smelt	Lower reaches of coastal streams probably in slow flowing water with cover provided by logs and aquatic plants. Threatened by loss of instream habitat and predation from introduced species.	*Retropinna tasmanica*
Spotted mountain trout	Riverine populations prefer lower elevation quiet streams in pools with log debris, overhanging banks and boulders.	*Galaxias truttaceus*
Tasmanian whitebait	Were once the basis for commercial fishery and still form a large component of the whitebait run. Prefer lowland estuarine reaches of rivers with suitable spawning habitat.	*Lovettia sealii*
Short-fin eel	Likely to be throughout catchment, but status unknown.	*Anguilla australis*
Long-finned eel	Likely to be in the catchment, but status unknown.	*A. reinhardtii*
Brown trout	A very popular introduced recreational fishing species, it was introduced in the late 1800s and has naturalised, spawning on seasonally inundated gravel (20 mm) point bars.	*Salmo trutta*
Rainbow trout	Another popular introduced recreational fishing species.	*Oncorhynchus mykiss*
Invertebrates		
Giant freshwater lobster	Listed as *Vulnerable* under *Tasmania's Threatened Species Protection Act 1995*, they are the largest freshwater invertebrate in the world. Due to over fishing, slow growth and low reproductive rates, plus their sensitivity to degraded habitat, severe population declines have been recorded over most of their distribution.	*Astacopsis gouldi*
Freshwater lobster	Lives throughout the catchment, preferring undisturbed smaller streams with pools, undercut banks and instream debris.	*Astacopsis franklinii*
Yabbie	Naturalised in farms dams? Presently only reported in one dam.	*Cherax destructor*
Dragonflies	Very diverse and abundant group of species.	*Odonata spp*
Caddisflies, Mayflies and Stoneflies	These three groups of species form the basis for much of the macroinvertebrate communities throughout the catchment. They are indicator species for degraded water quality and habitat.	*Trichoptera, Ephemero-ptera* and *Plecoptera*
Freshwater snail	Rare species found generally in the upland streams.	*Beddomeia* spp

3 Human uses and values

3.1 Population centres

The population of north-west Tasmania is approximately 100 000 (table 4). Approximately 75% of the population reside in the major towns scattered along or near the north coast (table 5). The remainder of the region is sparsely populated.

The distribution of population in north-west Tasmania has implications for water quality in that urban impacts such as sewage and stormwater are largely focused at the coast and river estuaries rather than in the river catchments.

Table 4 Population distribution in north-west Tasmania

Municipality	Population (1998)*
Devonport City	24 667
Central Coast	21 122
Burnie City	19 665
Waratah/Wynyard	13 954
Circular Head	8 450
Latrobe	7 947
Kentish	5 468
Total	101 273

* Derived from the *Tasmanian Year Book 2000* (Australian Bureau of Statistics)

Table 5 Major population centres in north-west Tasmania

Town	Population (approx)
Devonport	22 600
Burnie–Somerset	20 700
Ulverstone	10 050
Wynyard	4 700
Smithton	3 500
Penguin	2 800
Latrobe	2 600
Port Sorell	1 170
Sheffield	930
Railton	900
Turners Beach	900
Stanley	570
Total	71 420

3.2 Land tenure and use

The primary land tenure categories in north-west Tasmania are private property, forestry and reserves (refer to table 6 and figure 2).

Table 6 North-west Tasmania land tenure*

Tenure	Area (km^2)	% area
Private Property	5 026	47%
State Forest	3 336	31%
Nature Recreation Area Game Reserve Conservation Area Regional Reserve	966	9%
National Park State Reserve Nature Reserve Historic Site	627	6%
Forest Reserve	543	5%
Unallocated Crown Land	63	
Public Reserve	53	
Hydro Electric Corporation	26	
Total	10 640	

* Area covered is by river catchment from the Arthur through to the Rubicon

3.2.1 Agriculture

The combination of high rainfall and fertile soils makes north-west Tasmania one of the most important agricultural regions in the State. Farming activities include grazing of beef cattle, dairies and intensive cropping. The area in the lower catchments contains some of the best agricultural land in Tasmania. Red krasnozem soils are a feature of the area. These soils which form over basalt are the most productive in the State and are capable of supporting up to 3 crops per year (DPIWE 2001a). Crops include onions, carrots, potatoes, peas, beans, brassicas, sweet corn, poppies, pyrethrum and cereals (DPIWE 2001a).

3.2.2 Forestry

The second major land use of north-west Tasmania is forestry, both State and private. Clear-felling of native forests for export woodchips is the primary forestry activity; selective logging of some of the higher-altitude forests and drier forests is also carried out. Trees for chipping and pulping are sourced primarily from wet sclerophyll eucalypt forest and pure rainforest. In the region, logs are primarily processed at the Hampshire woodchip mill and exported from the port of Burnie. Approximately 25% of the native forest timber harvested in the region is processed at local sawmills, however, two-thirds of this volume ends up as residue and is woodchipped. A minor component of the forestry industry in the region is selective logging of rainforest timbers for specialty uses (furniture, craft and boat building). Whole log exports, primarily of plantation origin, are also a major product of the forestry industry in the region. Local processing of plantation logs is carried out in local sawmills and by the small pulp mill at Wesley Vale.

Figure 2 Land tenure of north-west Tasmania

A current significant land use issue in the north-west is the use of prime agricultural land for forestry plantation development. Agricultural land and communities are currently being displaced across the region as plantations based on the fast growing mainland blue gum (*Eucalyptus nitens*) are being established. An associated issue during plantation establishment is the use of herbicides and pesticides which are potentially mobilised to the waterways of the region (refer to section 4.2.3). Additionally, clear-fell forest harvesting is known to result in increased sedimentation in waterways and altered catchment water balance.

(Note: the Burnie paper mill, which used to process local logs, now uses imported pulp after the Burnie pulp mill closed down in 1998.)

3.2.3 Other land uses

Other land uses in the region include hydro-electricity production, mineral exploration and mining, conservation and recreation. Marine farming is a growing industry in some estuarine areas around the coast (DPIWE 2000a). More detailed land tenure descriptions are given in sections covering individual catchments (chapter 5).

3.3 Water allocation and uses

3.3.1 Circular Head and Waratah/Wynyard

An estimated 6000 town water supply connections are served for domestic and industrial purposes with an annual water use of approximately 1.5 million ML. Treated town water is supplied at Smithton, Wynyard, Somerset, Waratah and Yolla. There are 474 Commissional Water Rights (CWRs) allocated in the Circular Head and Waratah/Wynyard municipal areas which are summarised in table 7. The CWRs are primarily for irrigation with a small number being for other industrial purposes.

Table 7 Main water allocations for Circular Head and Waratah/Wynyard

Catchment	CWRs	Yearly use (ML)
Arthur	5	22 016
Welcome	5	298
Montagu	13	788
Duck	76	3 526
Cam	41	1 252
Black/Detention	61	5 135
Inglis/Flowerdale	113	4 060

From DPIWE (2000a)

3.3.2 Central Coast region

Cradle Coast Water collects, treats and supplies bulk drinking water supplies to the Central Coast, Devonport, Latrobe and Kentish Councils from the Cam, Leven, Gawler and Forth Rivers. Burnie City Council takes water for drinking water supply from the Pet and Guide Rivers for treatment and distribution within its municipality (DPIWE 2001a). There is no direct abstraction of town drinking water from the Mersey River.

Hydro Tasmania is the major water user in the upper Mersey catchment with the majority of the water transferred to the Forth River basin and used to generate electricity (section 3.4).

Water licences are allocated to extract water for irrigation, commercial and industrial use. The largest industrial consumer in the area is the Wesley Vale pulp mill which uses approximately 30 ML per day. Vegetable processing factories are other significant industrial water users. Major water allocations for the central coast area are shown in table 8.

Table 8 Main water allocations for central coast area

Catchment	CWRs	Yearly use (ML)
Emu/Blythe/Leven	160	43 588
Mersey	137	17 500*

* Based on maximum daily extraction of 50 ML

3.4 Hydro-electricity power generation

3.4.1 Description of the Mersey–Forth power scheme

Hydro Tasmania has significant controlling influence over water flows and catchment yields in two of the region's major catchments, the Mersey and the Forth. The Mersey–Forth Power Scheme harnesses the waters of the Mersey, Forth, Wilmot, and Fisher Rivers (figure 3) and generates 15.8% of the State's electricity. The scheme consists of seven storages (Lake Mackenzie, Lake Rowallan, Lake Parangana, Lake Cethana, Lake Gairdner, Lake Barrington, Lake Paloona); seven power stations (Rowallan, Fisher, Lemonthyme, Cethana, Wilmot, Devils Gate, Paloona); seven large dams (Mackenzie, Rowallan, Parangana, Cethana, Wilmot, Devils Gate, Paloona) and three major tunnels (Fisher, Lemonthyme, Wilmot).

The Mersey–Forth Power Scheme involves a major diversion of water from the Mersey River catchment, at Parangana Dam, into the catchment of the Forth River. There is also other water diversion and transfer infrastructure in the catchment, including three small diversions in the upper catchment near Lake Mackenzie (small streams).

There are two in-stream storages on the Mersey River. Lake Rowallan is the most upstream storage and is the headwater storage for the Mersey–Forth Power Scheme. From Lake Rowallan, water is directed through the Rowallan Power Station, which discharges into the Mersey River below the dam. Lake Parangana is the second (and last) storage on the Mersey River. Lake Parangana receives water from the Mersey and from the Lake Mackenzie diversion.

Lake Mackenzie was formed by the construction of Mackenzie Dam across the Fisher River (the rising waters inundated 2 natural lakes — Lake Mackenzie and Sandy Lake). Water is diverted from Lake Mackenzie via the Fisher Canal and Fisher Tunnel to the Fisher Power Station, which discharges into Lake Parangana. Spills from Lake Mackenzie go down the Fisher River (natural watercourse) and flow into Lake Parangana.

From Lake Parangana, water is diverted into the Forth catchment, via the Lemonthyme Tunnel to the Lemonthyme Power Station, which discharges into Lake Cethana.

Lake Gairdner (Wilmot River catchment) is also diverted into Lake Cethana. Lake Gairdner is an in-stream storage on the Wilmot River. The water is diverted via a tunnel, through the Wilmot Power Station, which discharges into Lake Cethana (approximately 28 km upstream from Wilmot River confluence with Forth River). Spills from Lake Gairdner at Wilmot Dam pass down the Wilmot River (natural waterway) and flow into the Forth River.

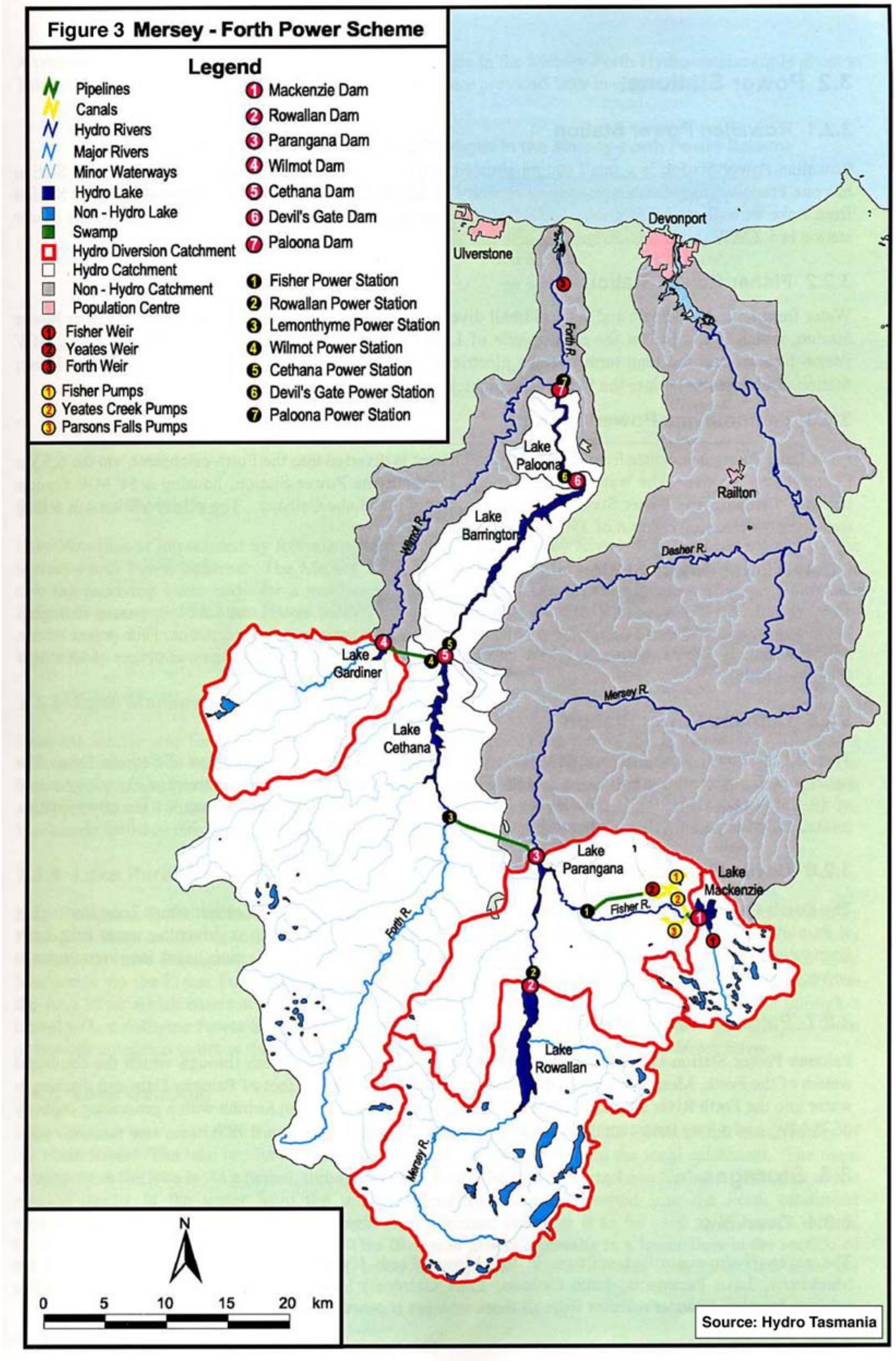

Figure 3 Mersey–Forth power scheme

There are three in-stream storages on the Forth River. The most upstream of these is Lake Cethana (which, as mentioned, also receives water from the Mersey and Wilmot diversions). Water is directed out of the lake via the Cethana Power Station and into Lake Barrington.

Lake Barrington, the second in-stream storage on the Forth River was created by Devils Gate Dam. Water is directed via Devils Gate Power Station into Lake Paloona, the last in-stream storage on the Forth River. Water is directed from Lake Paloona *via* the Paloona Power Station and into the remaining reach of the Forth River. Spills from these three storages go over the respective dams and into the storage/river below.

4 Overview of pollution sources

4.1 Regional point sources

The waterways of north-west Tasmania are affected by municipal, industrial, mining and agricultural inputs. Point source activities that are licenced by DPIWE under the *Environmental Management and Pollution Control Act 1994* are identified in figure 4.

4.1.1 Sewage

There are 16 sewage treatment plants (STPs) in the north-west. Currently effluent from 4 of these plants is discharged to inland waterways. The STPs are summarised in table 9 with effluent quality from the past 5 years presented in table 10.

Table 9 North-west sewage treatment plant treatment summary

Municipality	Premises	Treatment plant type	Outfall
Burnie	Round Hill	Primary clarifier & cold sludge digestion	Ocean
Burnie	Ridgley	Pasveer ditch, 2 polishing lagoons, chlorination	Pet River
Burnie	Cooee Point	Primary clarifier, dissolved air flotation & sludge digester	Ocean
Central Coast	Ulverstone	Primary screens, oxidation ditch & sludge composting	Ocean
Central Coast	Turners Beach	Divided primary lagoon & secondary lagoon (3 cells)	Forth Estuary
Central Coast	Penguin	Two Pasveer ditches	Ocean
Circular Head	Stanley	Primary & secondary 2-cell lagoon system	Ocean
Circular Head	Smithton	Aerated primary lagoons and passive secondary lagoons (7 cell)	Duck Bay
Devonport	Pardoe Downs	Primary fine screening & clarifiers, biosolid reuse proposed	Ocean
Kentish	Sheffield	Primary & secondary 2-cell lagoon system	Dodder Ck
Kentish	Railton	Primary & secondary 2-cell lagoon system	Redwater Ck
Kentish	Cradle Mt Lodge	Activated sludge, nutrient removal, UV treatment	Pencil Pine Ck
Latrobe	Port Sorell	Divided lagoon (2 cells). Being upgraded.	Ocean
Latrobe	Latrobe	Primary clarifier, secondary trickling filter, just upgraded to tertiary. Some effluent reuse planned.	Ocean
Waratah/Wynyard	Somerset	Two Pasveer ditches	Ocean
Waratah/Wynyard	East Wynyard	Two Pasveer ditches	Ocean

Emission Limit Guidelines

Under the *State Policy for Water Quality Management 1997*, draft emission limit guidelines for new sewage treatment plants have been set together with interim discharge requirements for existing plants (timeframes for upgrades are case specific). Maximum permitted levels of BOD, TSS, nutrients and faecal coliforms in treated sewage discharged to Tasmania's fresh and marine waters under these guidelines are summarised in table 11.

Figure 4 Location of potential point source impacts on north-west Tasmania

Table 10 North-west sewage treatment plants effluent quality indicators

Municipality	Premises	Permit Flow (Kl/day)	BOD* mg/l	NFR* mg/l	Total N* mg/l	Total P* mg/l	Faecal coliforms* cfu/100 ml
Burnie	Round Hill	8 000	180	98			
Burnie	Ridgley	110	6	14			1 475
Burnie	Cooee Point	1 900	100	50			
Central Coast	Ulverstone	7 500	1100	525			
Central Coast	Turners Beach	400	23	62		10	160
Central Coast	Penguin	730	30	21			
Circular Head	Stanley	276	25	50	14	10	700
Circular Head	Smithton	5 200	12	13	13	7	205
Devonport	Pardoe Downs	14 000	460	255	40	9	7
Kentish	Sheffield	324	18	55	16	3	2 600
Kentish	Railton	600	8	24	8	3	500
Latrobe	Port Sorell	961	61	80	28	8	32 000
Latrobe	Latrobe	924	44	40	22	6	220 000
Waratah/Wynyard	Somerset	1 200	7	6			
Waratah/Wynyard	East Wynyard	2 900	3	6			

* Results are 50th percentile for 1996–2001 and are derived from results reported monthly to DPIWE.

Notes: Ulverstone and Devonport plants produce very high BOD and NFR but discharge to ocean.

Latrobe and Port Sorell plants historically discharge very high faecal coliform levels although both plants are being upgraded and now have ocean outfalls.

Table 11 Sewage treatment plant discharge limits

	BOD (mg/L)	TSS/ NFR (mg/L)	Faecal coliforms orgs/100 ml	Oil & grease (mg/L)	pH	Total residual chlorine	Total nitrogen (mg/L)	Total phosph (mg/L)
A) Interim discharge requirements for existing plants	5–20*	5–20*	1000	10	6.5–8.5	1	5–40*	0.5–15*
B) Draft Emission Limit Guidelines for Sewage Treatment Plants								
50% ile	10	10	200	1			5	1
90% ile	15	20	500	2			10	3
maximum	20	30	750	5	6.5–8.5		15	5

* Value dependent upon plant type.

Based on the guidelines presented in table 11 most of the STPs of north-west Tasmania are performing at below the expectations of the interim discharge requirements relative to their monthly monitoring data presented in table 10.

Reported sewage and related incidents

Sewage spill incidents that are reported to DPIWE are presented in table 12. Note that these are reported incidents and may not be an accurate indication of the actual number of incidents.

Table 12 Sewage incidents 1/1/97–17/7/01

Municipality	Premises	Pump station overflows	Sewage spill	Sewer leak
Burnie	Cooee Point	1	3	
Central Coast	Ulverstone	26	2	3
Central Coast	Turners Beach	4		
Central Coast	Penguin	20		
Circular Head	Smithton	5	5	
Devonport	Pardoe Downs	77	14	1
Kentish	Sheffield	25	2	
Kentish	Railton	1	1	
Latrobe	Port Sorell	5		
Latrobe	Latrobe		1	
	Total	164	28	4

Notes: Devonport pump station overflows are all to the Mersey Estuary, 95% of the incidents are caused by power outages rather than stormwater infiltration.

Pump station overflows are a problem at Ulverstone. A station on the Leven River fails regularly due to effluent from the Simplot vegetable processing factory (J McNeill, Central Coast Council, pers comm).

Septic tank effluent is a problem for Claytons Rivulet near Ulverstone.

Cradle Valley area

The Cradle Valley area at the head of the Dove River (Forth catchment) has a network of sewage treatment facilities. Cradle Mountain Lodge has a high standard sewerage scheme that operates under licence to DPIWE. Monitoring has indicated that the plant system functions in accordance with the licence conditions. Other existing facilities at the entrance to and inside the National Park employ a diversity of on-site sewage management options including septic tanks and composting systems. Proposed tourist developments are likely to place more pressure on the area's capability to handle human waste and it is likely that an upgraded system will be required. Refer to Johnstone (2000) for details on wastewater infrastructure and options in the Cradle Valley area.

4.1.2 Stormwater

Infrastructure cross connections

The main issue with stormwater systems in north-west Tasmania is infrastructure inadequacy rather than water quality, although there has been little specific stormwater water quality monitoring in the region. The most significant and almost universal issue is infiltration of stormwater into the sewerage system which can cause treatment and/or overflow problems. Sewage pump station overflows often end up in the stormwater system and in some cases affect the rivers or estuaries of the region. Anecdotal information and reported incidents suggest that sewage overflows to the stormwater system are a significant problem in the Mersey estuary.

A related stormwater management issue is that there is no stormwater infrastructure in some areas of Devonport and Burnie (which is only 60% reticulated). In unreticulated areas stormwater either infiltrates or is connected to the sewer.

Stormwater reuse

There is either no market or a very limited market for stormwater reuse in north-west Tasmania. This is primarily due to the fact that the region has a high rainfall and pumping (with associated expense) is an issue due to steep terrain. It has also been argued that major population centres have convenient disposal of stormwater to the ocean at present and that stormwater impact upon waterways tends to be localised and in most cases minimal.

Management

- Central Coast Council has had a long-term strategy to prevent stormwater infiltration to sewer, and Burnie City Council has conducted an infiltration survey.
- Gross and fine solids traps for West Beach, Burnie.
- First flush interceptors at trucking yards in Burnie.
- Trade waste agreements with level 1 (council regulated industires) premises.
- Major centres have street cleaning and stormwater pit cleaning programs and an annual budget allocated to stormwater system maintenance.

4.1.3 Industrial sites/discharges

Industrial effluent 'hot spots' for the region are as follows:

- Vegetable processing factory effluent at Ulverstone is an issue. The factory discharges 5 ML of effluent per day (as opposed to 3 ML for the whole town of Ulverstone) that flows untreated to the ocean via Ulverstone's sewage outfall. The factory effluent is high in BOD and has a temperature in excess of 30°C. There is potential for effluent reuse as well as an energy efficiency program to utilise the heat in the wastewater.
- A mineral processing operation has significant discharges of silica sand to the lower Blythe River on the central coast.
- The former Tioxide Australia industrial site (closed 1995) on the Blythe River is currently being rehabilitated by the company. Three sludge dams from the former Tioxide operations are located within the Minna Creek catchment which joins the Blythe about 1 km upstream from the river mouth. An industrial dump site together with the old sludge dams creates local water quality problems (particularly pH, iron, manganese, zinc and copper). Leachate from the site is now treated through a series of reduction cells (to extract iron and manganese) and a wetland that has been constructed on Minna Creek. Treated water is piped out to sea.
- The Emu River received discharges from the Burnie pulp mill during its operation. There is also an industrial dump site on the river that is known to leach to the river (D Zeven, DPIWE, pers comm).
- The cheese factory at Edith Creek township in the Duck River catchment produces 170 000–350 000 L/day of effluent which is used to irrigate a small lot (approx 1 hectare). Overflow of the irrigated effluent goes to Edith Creek and some direct discharges have been reported at times. Effluent is now supposed to be trucked away from the site. Edith Creek has real problems with organic rich sediments, high BOD and low dissolved oxygen (D Zeven, DPIWE, pers comm).

4.1.4 Acid mine drainage

There are over 1200 metal-related abandoned mines in Tasmania. Most base-metal abandoned mine sites in Tasmania are potential point and diffuse sources of acid mine drainage. Several abandoned mine sites in Tasmania have acute acid drainage problems and therefore need immediate remediation measures to avoid costly future liabilities. The heavy metals Cd (cadmium), Cu (copper), Pb (lead) and Zn (zinc) are the principle pollutants in acid drainage waters (Gurung 2001).

Current Natural Heritage Trust funded research into acid mine drainage in Tasmania is being conducted by Mineral Resources Tasmania. The objectives of this work are to:

- provide an inventory of the sources and the environmental impact of acid drainage from historic abandoned mines in Tasmania;
- create an acid drainage database and GIS maps that can be used as screening tools for scoping impacted watersheds; and
- develop management strategies for remediation of problem sites.

Major acid mine drainage ‘hot-spots’ identified in north-west Tasmania are Mt Bischoff and surrounding mines, Balfour, Round Hill (above Lake Cethana on the Forth River) and Mella (west of Smithton). Gurung (2001) identified Mt Bischoff and surrounding workings as a priority site for mine rehabilitation works in order to address impacts upon the upper Arthur River and tributaries (refer to section 5.1.1 for more detail on this site). In addition, the abandoned mine site at Balfour contributes poor quality acidic water (particularly high in copper) to the Frankland River which is a tributary of the lower Arthur River (B Bourke, DPIWE, pers comm).

Acid mine drainage from Round Hill has more of a social, rather than wilderness, impact, particularly as the Forth River catchment is a primary source of drinking water for the region’s population centres.

Another acid drainage site identified by Gurung (2001) is at Mella west of Smithton where all field pH sites sampled returned values of less than pH 3. Acid drainage from this area has the potential to affect water quality in the Duck River. The acid sulphate soils of far north-west Tasmania are subject to acid leaching when disturbed by agriculture or by alterations to the groundwater table.

4.1.5 Refuse and industrial waste disposal sites

Refuse and industrial waste disposal sites can cause significant water quality problems, particularly as many older sites are located adjacent to watercourses or used to fill gullies and bays. Many historic sites were also commissioned with no consideration to leaching of hazardous material off site or to groundwater. Additionally, until recently, there was no regulation of materials that could be placed in the landfill site and they thus became a repository for hazardous materials such as PCBs, pesticides, oil and heavy metals. Current and closed waste disposal sites in north-west Tasmania are listed in tables 13, 14 and 15.

The sites of most concern in north-west Tasmania are:

- View Street waste depot in Burnie due to high content of vegetable waste and location in a gully with high water table — now closed (table 14);
- Port Sorell waste depot due to high content of pulp mill waste with impact on creek and groundwater (A Ezzy, MRT, pers comm) — now closed (table 14);
- Industrial waste landfill on Mooreville Road Burnie. Leachate enters tributaries of the Cam River upstream from a town water supply off-take (table 16);
- Abattoir waste disposal site in Smithton which has received piggery and abattoir waste for over 50 years with an estimated 500 000 tonnes of material. Leachate to Coventry Creek, a tributary of the Duck River (table 16).

Table 13 Summary details of active refuse disposal sites in north-west Tasmania

Council / Municipality	Site location	Historical issues	Engineering designed infrastructure	Hydrogeological setting	Number of current bores installed	Known major groundwater pollutants	Suspected other major groundwater pollutants	Potential for groundwater contamination
Burnie	Mooreville Road waste depot Burnie	Opened in 1984	Storm water collection system beneath a clay liner, Clay liner with no record of permeability or quality control. Limited leachate collection system.	Local/regional discharge point of unconfined fractured basaltic aquifer. High water table.	Several bores installed, Some MRT monitoring data.	Iron, nitrate.	Metals, hydrocarbons and nutrients	High
Central Coast	Penguin waste depot	Historical mine site	Sleeved storm water pipe with no leachate pond.	Unconfined aquifer connected to filled drainage line.	One - only for water supply not designed for environmental monitoring.	Nil	Metals, hydrocarbons and nutrients	High
Central Coast	Preston waste depot	Nil	Nil	Cambrian fractured aquifer.	Nil	Nil	Metals, hydrocarbons and nutrients	Moderate
Circular Head	Port Latta regional hazardous waste depot	Started operation in 1994	Leachate clay liner, sub liner beneath landfill liner (contaminated). Leachate collection system and ponds. Storm water diversion system and settling ponds.	All surface run off enters un named drainage line (Western Creek) that enters Bass Strait on the eastern side of the Port Latta Pelletising plant.	Nil	Nil	Metals, hydrocarbons and nutrients	Moderate
Latrobe	Dulverton regional waste depot	Opened in 1994 as northern regional site for four Councils	Storm water perimeter drains and settling ponds, Leachate collection system and HDPE lined leachate ponds. Compacted clay liner.	Fractured aquifer believed to exit beneath the site at some unknown (most likely moderate) depth.	Extensive bore network installed and monitored	Nil	To be determined	Low

Information compiled by Andrew Ezzy (MRT)

Table 14 Summary details of closed refuse disposal sites in north-west Tasmania

Council / Municipality	Site location	Historical issues	Engineering designed infrastructure	Hydrogeological setting	Number of current bores installed	Suspected major groundwater pollutants	Potential for groundwater contamination
Burnie	Veiw street waste depot Burnie	Closed 1984. Contains a large quanity of vegetables disposed of after fire in Burnie dock warehouses.	Storm water piped throughout landfill internal structure, pipes of questionable integrity	Local/regional discharge point of unconfined fractured basaltic aquifer. High water table.	Nil	Metals, hydrocarbons and nutrients	High
Central Coast	Castra closed waste depot	Nil	Nil	To be determined	Nil	Metals, hydrocarbons and nutrients	To be determined
Central Coast	South Riana closed waste depot	Closed in 1999	Leachate pond	Cambrian fractured aquifer	Nil	Metals, hydrocarbons and nutrients	High
Central Coast	Ulverstone closed waste depot	Closed approx 1995	Rehabilitation plan nearing completion	Cambrian fractured aquifer	Nil	Metals, hydrocarbons and nutrients	Extreme
Circular Head	Sundown closed waste depot- P&WS	Operated for over forty years, closed in 1995	Nil	Quaternary aquifer. Leachate canal that discharges into Sundown Creek.	Nil	Metals, hydrocarbons and nutrients	Extreme
Circular Head	Marrawah closed waste depot	Closed approx 1995	Nil	Quaternary aquifer	Nil	Metals, hydrocarbons and nutrients	Extreme
Circular Head	Mawbanna closed waste depot	Closed approx 1995	Nil	Fractured Cambrian aquifer	Nil	Metals, hydrocarbons and nutrients	High
Circular Head	Togari closed waste depot	Closed approx 1995	Nil	Quaternary aquifer	Nil	Metals, hydrocarbons and nutrients	Extreme
Circular Head	Smithton Duck River historical waste depot	Nil	Clay capping	Quaternary aquifer next to the Duck River	Nil	Metals, hydrocarbons and nutrients	High
Circular Head	Smithton closed waste depot - Montagu Rd	Closed approx 1995	Capping	Quaternary aquifer	Nil	Metals, hydrocarbons and nutrients	Extreme
Circular Head	Stanley closed waste depot	Nil	Nil	Quaternary aquifer	Nil	Metals, hydrocarbons and nutrients	High
Devonport	Spreyton closed waste depot	Closed approx 1995	Rehabilitation program in progress	Quaternary aquifer next to Mersey River	Nil	Metals, hydrocarbons and nutrients	Extreme
Kentish	Sheffield closed waste depot	Nil	Nil	Unconfined aquifer	Nil	Metals, hydrocarbons and nutrients	High
Latrobe	Port Sorell closed waste depot	Over 80 000 tonnes of waste from Wesley Vale pulp paper plant and extensive amounts of liquid waste from various sources	Nil	Unconsolidated aquifer overlying fractured aquifer. Creek enters site from the north west. Discharge from site passes residential area to the east. Extensive groundwater contamination plume expected to the north east and east.	4 historical holes drilled to the north (2 dry), and one dry bore to the west (Q30 Card 44).	Metals, hydrocarbons, nutrients and any others related to waste streams from the Wesley Vale pulp mill	Extreme
Waratah-Wynyard	Wynyard closed waste depot	Closed in 1995. Cemetery next to landfill has high water table. School next to site.	Storm water pipes past through landfill	Landfill rests on the river gravels (flood plain) of the Inglis River, 1.8 km before the Inglis River discharges into Bass Strait.	Nil	Metals, chloride, hydrocarbons, bacteria and nutrients	High
Waratah-Wynyard	Waratah closed waste depot	To be determined	To be determined	To be determined.	To be determined	To be determined	To be determined

Information compiled by Andrew Ezzy (MRT)

Table 15 Summary details of other waste disposal sites in north-west Tasmania

Category of activity	Council / Municipality	Site location	Historical issues	Engineering designed infrastructure for BPEM	Hydrogeological setting	Number of current bores installed	Known major groundwater pollutants	Suspected other major groundwater pollutants
Abattoir waste disposal	Circular Head	Blue Ribbon Meats, Smithton	Abattoir waste buried for over fifty years. Estimated volume of 500 000 tonnes of material	Nil	Unconfined unconsolidated aquifer overlying dolomitic aquifer. Springs beneath landfill footprint. Disposal site next to Coventry Creek, which discharges into the Duck River 1 km down stream. The Duck River enters Duck Bay 5km down stream.	Nil	Nil	COD, BOD, nutrients and metals
Solid waste disposal sites	Burnie	West Mooreville road Brambles industrial waste landfill - Burnie	Unlined basalt quarry filled with waste stream from Burnie pulp mill. DPIWE historical photos indicated very poor management practices.	Storm water/leachate ponds. Limited capping.	Three fractured aquifers with a main north/south fracture orientation. Leachate spring discharge into a north west tributary and main spring discharge into a northern tributary. Both tributaries join and discharge into the Cam River above a town water off take point.	24 bores. Reported on in 1997 Environmental Management Plan.	Sodium and iron	Metals and industrial chemicals
Solid waste disposal sites	Burnie	Brickport Road closed industrial waste landfill - Burnie	Closed in 1980's	Nil	Tertiary basalt and Precambrian aquifers next to Cooee Creek.	Nil	Nil	Metals and industrial chemicals
Solid waste disposal sites	Devonport	Gunn's unlicensed waste depot - Devonport	To be determined	To be determined	To be determined	To be determined	To be determined	To be determined

Information compiled by Andrew Ezzy (MRT)

4.2 Regional diffuse sources

4.2.1 Soil erosion

The krasnozem (red ferrosol) soils that characterise the north-west coast are vulnerable to severe sheet and rill erosion as a result of their landscape position, frequent intense rainfall events, the fine nature of seed-beds produced for cropping and the lack of vegetative cover during the early stages of crop growth. The study of Sims and Cotching (2000) confirmed that in intensively cropped catchments on the north-west coast of Tasmania erosion is being accelerated by unsustainable farming practices. The erosion of farmland results in off-site water quality problems such as high water turbidity and total suspended solids (TSS) in most of the streams in the area (Sims & Cotching 2000).

High sediment loads in streams impact upon aquatic life by reducing photosynthesis and bottom temperatures. The effects of particulate matter can be directly lethal to aquatic life, while also causing the water to be unsuitable for human and stock consumption and irrigation (Sims & Cotching 2000). Silt bed-load in streams is a major threat to the giant freshwater crayfish which is listed as *Vulnerable* (refer section 2.6).

Soil loss in north-west Tasmania is estimated to be 10 to 142 t/ha/rainfall event which greatly exceeds the rate of soil formation of 0.39 to 0.68 t/ha/year (Sims & Cotching 2000). The majority of this erosion is caused by uncontrolled movement of surface water across bare soil, particularly during paddock preparation and in the early stages of crop establishment. Cultivated gully lines are particularly vulnerable to rill erosion as water is concentrated in these areas. Runoff from roads also poses a major problem as road culverts concentrate water onto cropping paddocks causing rill erosion (Sims & Cotching 2000).

Riparian (streamside) vegetation plays an important role in buffering soil runoff from land and the riverine environment. Additionally, riparian vegetation stabilises river banks that can be a significant source of erosion and sedimentation if not protected. Unfortunately many agricultural practices have resulted in the clearance of native riparian vegetation. As a consequence, siltation arising from the loss of riparian vegetation combined with land clearing for agriculture and forestry is having substantial impacts on the environmental health of rivers downstream. The presence of unnatural levels of siltation and the loss of shade in riparian zones results in temperatures rising in waterways to the extent that in the late summer waterway temperatures can reach lethal levels for aquatic fauna, particularly for the vulnerable giant freshwater crayfish (refer section 2.6).

Management

To prevent and reduce soil erosion, an active soil conservation program has been run by DPIWE over the past ten years. The soil erosion control methods include grassed irrigation runs, contour drains, cut off drains, grassed waterways and cover cropping (Sims & Cotching 2000). To date, only a minority of farmers has adopted the conservation strategies recommended by DPIWE. Some landholders use their land beyond its capability with long crop rotations, poor soil management practices and riparian zone management with consequent environmental degradation (Sims & Cotching 2000).

The erosion of the fertile krasnozem soils has implications for long-term land use as well as for short-and long-term off-site environmental effects. Current environmental regulations allow for control of off-site effects and need to be fully implemented to ensure good water quality.

Sustainable land and water management practices are taught and encouraged through property management planning courses and recently introduced quality assurance programs in the vegetable industry. The continuation of these two approaches is critical to lessening the impact of agriculture on the environment in north-west Tasmania (Sims & Cotching 2000).

4.2.2 Other agricultural runoff

Dairies and stock access to streams

Runoff from dairies is a widespread problem across north-west Tasmania. Uncontrolled dairy effluent can cause bacterial contamination, high BOD, elevated turbidity and nutrient enrichment in streams, particularly during and after rain. The influx of nutrients to streams from these sources has the greatest impact on streams with low flows. High levels of nutrients can lead to algal blooms (given coinciding ideal temperature and light conditions), growth of algae on rocks and depressed dissolved oxygen concentrations.

Some work is being conducted in the region by local government to assess dairy effluent problems, for example nearly 200 dairies have been surveyed in the Circular Head municipality.

Unrestricted access to streams by stock is a common problem that can cause localised erosion, muddying and faecal contamination. Contamination by microorganisms such as bacteria and viruses from faecal material can be hazardous to the health of humans. This problem is currently being addressed at many sites across the region through Landcare and Rivercare projects that involve, for example, fencing riparian zones and provision of alternative stock watering points.

Agricultural chemicals

Cradle Coast Water, the primary water supply authority of the north-west, undertakes extensive water quality testing, including testing for agricultural and forestry chemicals such as herbicides and pesticides, three times annually and also after known events such as spraying programs in water supply catchments or burst farm dams. No test results have detected herbicides or pesticides above detection limits in water samples (Van Eysden, Cradle Coast Water, pers comm).

4.2.3 Forestry operations

Forestry operations are another source of enhanced soil and sediment flow to waterways, particularly during clear-felling and plantation establishment. Unsealed forest roads are a significant source of excess runoff and sediment in forestry areas as they can efficiently direct runoff and sediment to the natural drainage system. The Forest Practices Code sets out prescriptions and guidelines to protect water quality during forest operations. These include watercourse protection through streamside reserves and guidelines for timber harvesting in town water supply catchments.

A concern in relation to water quality is the use of herbicides and pesticides during plantation establishment. Strict procedures apply to the use of herbicides and pesticides to ensure that water quality is maintained (Forestry 1999). Periodic monitoring of water quality may be undertaken to test whether management practices are effective. Water testing is carried out only after broad-acre spraying and three samples are taken: one prior to spraying, one within four hours of spraying, and one following significant rain over the spraying site (Brian Hodgson, Forestry Tas, pers comm).

Herbicides used by Forestry Tasmania are Glyphosate (spiked with Brush-off) prior to planting and Eucmix (does not affect seedlings) after planting (B Hodgson, Forestry Tas, pers comm). Insecticide use in Forestry plantations is minimal. There have been no positive test results for herbicides and pesticides in water sampling undertaken by Forestry Tasmania in the Mersey Forest District (B Hodgson, Forestry Tas, pers comm).

In addition to water quality, timber harvesting affects the quantity of water flowing in streams, with an increase immediately after harvesting, and a decrease when a new forest is establishing.

5 Catchment overview

Water quality across the region varies depending upon local catchment geology, vegetation, rainfall and human impacts. The Arthur River, for example, can be naturally high in tannins due to the organic rich and peat soils within the catchment. Catchments draining to the north coast of the region have been influenced primarily by the broad impacts of agricultural and forestry activities and, nearer to the coast, by more localised urban impacts such as sewage, stormwater, industrial effluent, and contaminated site leachate.

The current state of knowledge of water quality in the region is presented below on a catchment by catchment basis.

5.1 Arthur River catchment

The Arthur River catchment is the largest catchment of the region at approximately 2500 km^2. There are no major towns in the catchment and few roads. The headwaters of the Arthur lie in private land and there is extensive forestry activity throughout the catchment. Part of the recently proclaimed Savage River National Park (Gazetted 30/4/99) lies within the catchment as does the Hellyer River State Reserve.

The historic tin mine at Mt Bischoff, Waratah, is believed to have created significant water quality pollution in the upper Arthur tributaries. This mine operated between 1878 and 1945 and now has significant acid mine drainage problems (DPIWE 2000a) (refer section 5.1.1). There are other abandoned mines in the Arthur River catchment of which the disused site at Balfour is known to create water quality problems at times in the lower catchment.

5.1.1 Acid mine drainage in the Arthur River catchment

Historical information

The Mt Bischoff ore body was discovered in 1871 and at one point became the world's largest tin producer. Early development consisted of open cut and alluvial mining, concentrating on the freely available oxidised ore. Sulphide ore was either left *in situ* or dumped into tributaries of the Waratah River (which flows to the Arthur) to be displaced by stream-flow to the North Valley area.

By 1937, 7 500 000 tonnes of ore had been extracted by open cut mining. At this stage the nature of operations moved to underground mining of discrete pockets of high grade ore.

Some sulphide ore was processed throughout the life of the mine by 'splitting' the cassiterite from the sulphide mass by crushing and grinding, recovering the cassiterite concentrate and disposing of the sulphide tailings to the nearest convenient waterway. This kind of mining became the dominant type of production in the late 1930s and disposal of tailings and waste rock in this manner was acceptable practice in those times. The treatment of Mt Bischoff ore in this manner has resulted in significant degradation of waterways for a considerable distance downstream of Waratah.

Mining at Mt Bischoff of any serious magnitude ceased at the end of World War II, however, detailed exploration of the ore body was carried out in the late 1970s. In an area targeted by Lynch Mining, 4 700 000 tonnes of tin oxide were proven to exist.

Recent findings

In current acid mine drainage work that is being conducted statewide (Gurung 2001), Mt Bischoff and surrounding workings were identified as a priority site for mine rehabilitation works in order to address impacts upon the upper Arthur River and tributaries.

- Impacts from the mining area on the Arthur River are not well understood and this needs to be the next stage of the work (S Gurung, MRT, pers comm).
- Drainage waters from Mt Bischoff are a hazard. If consumed, the waters are toxic enough to kill wildlife (S Gurung).
- Flood events are the big danger to the Arthur River system due to the rapid influx of highly acidic water into the system (S Gurung).
- Acid mine drainage problems are immediately evident at North Valley below the Mt Bischoff workings (W Bourke, DPIWE, pers comm).
- Cadmium, zinc, lead, arsenic, iron and manganese are present in significant quantities in the Mt Bischoff ore body (W Bourke, DPIWE).
- Sediment is actively eroding from exposed work faces at Mt Bischoff and tailings are being remobilised from deposit sites along the Waratah River (W Bourke, DPIWE).

Water quality indicators

Data presented by Lynch Mining indicates very poor water quality in the Mt Bischoff area. Low pH, high levels of sulphate and heavy metals clearly indicate acid drainage from the old workings as the cause of poor water quality. In most cases, levels of metals in water samples from the area exceed regulation standards by considerable margins as shown in table 16**.**

Water quality downstream in the Arthur River catchment is indicated by the presence of aquatic invertebrates. Monitoring of giant freshwater lobster in the Arthur has shown a 'dead zone' downstream from Mt Bischoff for at least 20 km where none of these invertebrates are found (T Walsh, IFS, pers comm).

Suggested studies and potential rehabilitation projects (W Bourke, DPIWE)

- The magnitude of the impact of Mt Bischoff on the Arthur River system should be established through a comprehensive water quality monitoring program.
- Locate underground discharge points of AMD from Mt Bischoff.
- Locate points at which contaminants enter the Waratah River from the Mt Bischoff workings.

Effective rehabilitation of the site will require earthworks on a massive scale. Issues to be considered in rehabilitation planning should include:

- Encapsulation of waste rock and exposed rock of high net acid producing potential with unmineralised rock;
- Drainage interception and control;
- Prevention of water entry to underground workings.

Acid mine drainage is also a problem at other sites in north-west Tasmania. These are summarised in section 4.1.4.

Table 16 Heavy metal concentrations, acidity, sulphate and pH for surface water in the Mt Bischoff region

Sampling Date	Comments	Site	pH	AlK (mg CaCO3 /l)	Acidity (mg CaCO3/l)	SO_4^{2-} (mg/l)	Al_D (ug/l)	As_D (ug/l)	Cd_D (ug/l)	Co_D (ug/L)	Cu_D (ug/l)	Fe_D (ug/l)	Mn_D (ug/l)	Ni_D (ug/L)	Pb_D (ug/l)	Zn_D (ug/l)	Al_T (ug/l)	Cu_T (ug/l)	Source
19-Dec-00		Arthur River (AR) at Rubber Rd 1			6	32											503	13	IFS
19-Dec-00		AR Wandle			< 1	13											96	3	IFS
02-Oct-01		Warratah River (WR) above AR		< 1	6	15	320	12	< 1	1	47	2180	64	2	< 5	54	414	59	DPIWE
02-Oct-01		AR above WR		4	< 1	38	237	< 5	< 1	< 1	2	1250	150	< 1	< 5	268	331	3	DPIWE
03-Sep-01		AR below Tinstone Ck (Av.)	6.4		6	16											375	5	IFS
03-Sep-01		AR - "up" Tinstone Ck (Av.)	6.9		2	< 2.85											69	9	IFS
03-Sep-01		Tinstone Ck (TC) (Av.)	3.3		52	< 125											1785	30	DPIWE
02-Oct-01		TC below Bischoff Unplugged		< 1	258		6140	126	11	17	68	56800	3940	22	31	4060	8820	98	DPIWE
02-Oct-01		Bischoff Unplugged (main adit entering TC		< 1	786		12000	347	23	35	133	152000	7900	43	49	8330	22300	264	DPIWE
17-Feb-00		Bischoff mine adit (Average)	2.59	1	2820	12333	30700	32	5		618	513333	10610		24	6647	30433	607	MRT
3 Sept, 2 Oct /01		Magnet Ck (MC) above AR (Av.)	6.8	19	< 1	6	43	< 5	2	< 1	< 1	133	39	< 1	14	337	54	1	DPIWE
3 Sept, 2 Oct /01	Possible reference site	AR above MC (Av.)		4	< 1	1.75	81	< 5	< 1	< 1	< 1	133	< 5	< 1	< 5	3	110.5	1	DPIWE
	Freshwater trigger values for further investigation or remedial action with sufficient information	ANZWQG Physico-chemical and Toxicants(95% level o species protection) or site specific trigger values (TV)	6.5-7.5			Tox work for Mt Lyell concluded a TV for SO4 of 40 mg/L for macro-invertebrates and fish	IWL 0.8 (pH<6.5) 55 (pH >6.5)	As (III) 24 As(V) 13	0.2	Low Reliability TV using AF = 1.2	Cu 1.4	IWL 300	1700	11	3.4	8	Tox work for Mt Lyell concluded a TV for Total Al of 350ug/L for macro-invertebrates and fish	Tox work for Mt Lyell concluded a TV for Total Cu o 35ug/L for macro invertebrates and fish	
	Conclusions (IWL = interim indicative working level)		pH > 6.5 except fo TC, Bishoff adits and immediately ds of TC in AR	Elevation of alkalinity in Magnet Ck	Elvation in acidity due to AMD from Mt Bischoff	AMD from Bishoff elevating total SO4 levels above background in most streams and above Mt Lyell TV of 40mg/L in TC	AMD from Bishoff area elevating dis. A levels above background and above TV of 55 ug/L in TC, WR and AR.	AMD from Bishoff area elevating dis. As levels above TV of 13 ug/L i TC.	AMD from Bishoff area elevating dis. Cd levels above background an TV of 0.2 ug/L in TC and MC.	AMD from Bishoff elevating dis Co levels above background an TV of 1.2 ug/L in TC.	AMD from Bishoff elevating dis. Cu levels above background an TV of 1.4 ug/L in TC, WR and AR.	AMD from Bishoff elevating dis. Fe levels above background an IWL TV of 300 ug/L in TC, WR and AR.	AMD from Bishoff elevating dis. Mn levels above TV of 1700 ug/L in TC.	AMD from Bishoff elevating dis. Ni levels above TV of 11 ug/L i TC.	AMD from Bishoff Area elevating dis. Pb levels above TV of 3.4 ug/L in TC and MC.	AMD from Bishoff area elevating dis.Zr levels above background an TV of 8 ug/L in TC, AR, WR and MC.	AMD from Bishoff area elevating tot. A levels above background an Mt Lyell TV of 350 ug/L in TC AR, and WR.	AMD from Bishoff area elevating tot. Al levels above Mt Lyell TV of 35 ug/L in TC and WR.	
	Trigger Value Exceedence Issues		Issue for TC		Issue for TC	Issue for TC	Issue for TC, WR and AR	Issue for TC	Issue for TC and MC	Issue for TC	Issue for TC,WR, and AR	Issue for TC,WR, and AR	Issue for TC	Issue for TC	Issue for TC and MC	Issue for TC,WR, MC, and AR	Issue for TC,WR, and AR	Issue for TC and WR	

Compiled by G Dowson (DPIWE)

5.2 Welcome River catchment

The Welcome River catchment (304 km^2) covers the low-lying country of the north-west corner of Tasmania. Land tenure in the Welcome catchment is primarily allocated to agriculture and forestry. The main agricultural activities are an intensive dairy industry and sheep grazing. A natural feature of the catchment is one of the most extensive and best preserved examples of mature *Melaleuca ericifolia* swamp forest of any river system in Australia (M Askey-Doran, DPIWE, pers comm).

A catchment management plan has been prepared for the Welcome River in association with the Welcome River Catchment Management Group (Thompson & Brett 1999). The management plan primarily covers land drainage issues as the middle catchment has been extensively modified by drainage works. A current Rivercare plan for the catchment proposes further drainage, channelisation and sediment retention works.

The main water quality monitoring program in the catchment has been through the 'State of the Rivers' Program run by DPIWE through which monitoring has occurred monthly since February 1999. The main findings to date are that the catchment waters experience high salinity and very low dissolved oxygen levels. It is believed that these findings are related in part to the recent low summer river flows. Monitoring has also shown that total nutrient concentrations exceed ANZECC trigger levels at times. The Monitoring River Health Initiative has detected impacts on the macroinvertebrate communities at sites in the lower catchment (DPIWE 2000a).

A geomorphological survey of the Welcome River demonstrated that the river has been partially degraded through sediment inputs, and possibly acid sulphates, from surrounding agricultural drainage schemes which have largely been developed in the last 25 years. Acid sulphate soils are sediments that contain sulphide minerals (predominantly pyrite) formed under estuarine conditions. Many coastal floodplains and swamp sediments commonly contain pyrite that can produce acid drainage when exposed to oxidising conditions as a result of disturbance from agricultural practices and by earth moving and mining activities. Acid drainage can mobilise toxic levels of dissolved metals which can seriously impact water quality and aquatic life in the drainage system (Gurung 2001).

5.3 Montagu River catchment

The Montagu River catchment (327 km^2) is sparsely populated with agriculture and forestry the main land tenure zones within the area. The only reserves within the catchment are Forest Reserves. High intensity agriculture occurs in some parts of the catchment, especially around the Togari and Brittons drainage areas. Most of the tributaries on the Montagu River have been cleared and straightened and utilised as drainage channels for neighboring land. A catchment management plan recently developed for the Montagu River addresses several catchment water resource issues (SKM 1999).

Water quality data collected as part of the State of the Rivers Program (Berry 2001) found high nutrients in several sites around the Montagu catchment and average turbidity higher than the recommended ANZECC trigger level. Dairy effluent containing nitrate, bacteria and fats is a significant problem affecting waterways in the catchment. Snap-shot records of aquatic macroinvertebrates as part of the Monitoring River Health Initiative found that communities were degraded. This is possibly due to habitat loss and poor water quality (DPIWE 2000a).

There are currently five marine farms in the Montagu estuary which have the potential to be affected by catchment water quality, particularly high faecal coliform counts.

5.4 Duck River catchment

Forestry and agriculture are the primary land uses within the Duck River catchment which covers an area of approximately 350 km^2. The lower Duck River catchment has been extensively drained to improve land for agriculture (DPIWE 2000a).

Water quality in some areas of the Duck catchment has been affected by intensive agriculture, particularly dairies and associated effluent runoff. The Edith Creek tributary is particularly impacted by cheese factory effluent causing high BOD and low dissolved oxygen (refer section 4.1.3 & 4.2.2). Abbatoir waste disposal leachate, high in COD, BOD and nutrients, affects Coventry Creek, a tributary of the Duck River.

Recent water quality monitoring as part of the ‘State of the Rivers’ Program (Berry 2001) has shown that areas of the Duck catchment are subject to high nutrient levels, low dissolved oxygen at times, generally high turbidity, occasional elevated salinity levels in tributaries of the river and high faecal bacteria counts (DPIWE 2000a).

Snap-shot macroinvertebrate information obtained through the Monitoring of River Health Initiative indicated that aquatic communities at the four study sites were impacted. This has probably resulted from both water quality and habitat changes in the catchment. Willow infestation on the Duck River and its tributaries is a significant water resource issue for the catchment (DPIWE 2000a). Willow degrades natural habitat, impacts upon water quality and impacts upon environmental flows during the summer months.

In the past, catchment activities appear to have impacted upon water quality in Duck Bay, particularly high faecal coliform counts, where there are currently three marine farms (DPIWE 2000a). This may be partly attributable to urban runoff from Smithton.

The Duck River Rivercare plan has recently been completed and was produced by the Circular Head Council in conjunction with Duck River Catchment Landcare Group. The primary issues for action in the Rivercare plan are willow management, car body removal and fencing of riparian areas.

5.5 Black and Detention River catchments

The Black and Detention River catchments cover a combined area of approximately 500 km^2. Forestry and agriculture are the primary land tenure categories in the catchments and there are only small population centres. There are no drainage or river improvement schemes within the area and little water quality information is available. The Monitoring of River Health Initiative (Krasnicki et al 2001) showed that an aquatic invertebrate community in the upper Detention catchment was healthy.

The Black River estuary has been identified by Edgar et al (1999) as having ‘critical conservation significance’. The Black is the only estuary on the north-west coast to be given this ‘Class A’ rating and gives a positive indication of catchment and river health in the area.

5.6 Inglis/Flowerdale River catchment

The Inglis/Flowerdale catchment (505 km^2) has forestry and agriculture as the main land tenure classifications. Wynyard (population 4700) is situated at the mouth of the Inglis River whilst the catchment contains just small population centres.

The Wynyard Landcare Group produced a Rivercare Plan in 1999 covering the Inglis River, Flowerdale River, Blackfish Creek and Seabrook Creek. The primary issues expressed by the Landcare Group and local community include:

- flooding of grazing lands;
- loss of land to willow infestations;
- expected spread of willow;
- stream bank erosion;
- loss of natural habitat in the riparian zone;
- loss of waterway based recreational activities;
- poor water quality;
- loss of habitat for giant freshwater crayfish and platypus.

Following production of the Rivercare Plan, large scale willow removal works were commenced during 1999 and continued into 2000. Protection of remnant native vegetation and promotion of regeneration is the current focus of the Wynyard Landcare Group. The Rivercare technical team of DPIWE is assisting with river restoration in the area and have documented project priorities (DPIWE 2001b).

According to the 'State of the Rivers' (DPIWE), water quality in the catchment may be described as good for all parameters measured, although Blackfish Creek exhibited consistently high turbidity. A snap-shot assessment of macroinvertebrates in the mid-catchment indicated that communities were moderately to severely impacted (DPIWE 2000a).

Siltation from excessive erosion is recognised as a problem for water quality in the catchment. Erosion and siltation problems from past and present gravel pit operations may be significant at times (DPIWE 2000a). Gravel extraction occurs at a number of sites along the Inglis and there are currently 10 active level 1 pits (regulated by local government).

5.7 Central Coast catchments (Cam, Emu, Blythe, Leven, Forth, Don)

The Forth River catchment at 1126 km^2 is the third largest in north-west Tasmania and originates in the Tasmanian Wilderness World Heritage Area at Cradle Mountain Lake St Clair National Park. The Leven, which has its headwaters in the Black Bluff Range at the northern edge of the Cradle Mountain Lake St Clair National Park, is the second major river draining to the central coast region. Smaller rivers draining to the coast in the region are the Cam, Emu, Blythe, Gawler (drains to the Leven estuary) and Don. The Wilmot River is a significant tributary of the Forth.

The major land tenure within the central coast catchments is private property (much of which has been cleared for agriculture) followed by State Forest. Major reserves in the region are the northern edge of Cradle Mountain Lake St Clair National Park, Black Bluff Nature

Recreation Area, Leven Canyon Regional Reserve, Blythe River Conservation Area and Forest Reserves.

Agricultural land of the central coast catchments is used to grow a wide range of commercial crops including potatoes, carrots, brassicas, onions, poppies, peas, beans and pyrethrum. In some catchments the majority of the land is under permanent pasture for dairy or beef production. Many of the steeper sites are planted with fast growing eucalypts, the Tasmanian blue gum *Eucalyptus globulus* and the mainland species *Eucalyptus nitens,* to supply the export woodchip market. Only a small portion of the land remains as remnant or re-growth native vegetation.

Water is used extensively for irrigation in the central coast catchments. In this region Cradle Coast Water collects water from the Cam, Leven, Gawler and Forth Rivers and supplies bulk drinking water to the councils of the central coast region. A major industrial use for fresh water in the region is for the production of paper products at Burnie. North Forest Products utilise some water in their woodchip mill at Hampshire.

5.7.1 Water quality — general

Small rivers and streams of the central coast region are the most impacted in terms of water quality due to their lower water discharge and greater catchment development. Claytons Rivulet and Buttons Creek are particularly impacted by agriculture and septic tank leachate (J McNeill, Central Coast Council, pers comm). The Emu River has a siltation problem (D Williams, Burnie City Council, pers comm). The mouth of the Blythe River is impacted by current and past industrial operations (refer section 4.1.3). Leachate from an industrial waste landfill in Burnie enters tributaries of the Cam River upstream from a town water supply off-take (refer section 4.1.5).

Specific water quality data for the region is available from Five Rivers Waterwatch and also Central Coast Council. Cradle Coast Water monitor their drinking water catchments on a regular basis (refer section 1).

5.7.2 Water quality — Forth River

Hydro Tasmania has a monitoring station on the Forth River downstream of Paloona Power Station in the lower catchment. Data show that there is a clear seasonal pattern for dissolved oxygen, conductivity and water temperature, with higher concentrations of oxygen and dissolved salts and lower water temperature during winter months, when the power station is virtually in continuous operation (Bobbi et al 2000). During the summer period, power station shutdowns have a significant impact on all these parameters, with increased variability in all three parameters as local climatic conditions influence conditions in the river. During some periods daily changes in dissolved oxygen as large as 4 mg/L are seen, while temperatures as high as 22.5^{o}C also occur, mimicking variations in air temperature (Bobbi et al 2000). When the power station is turned on during the summer period, the result is a corresponding drop in conductivity and dissolved oxygen (which drops down to as low as 5 mg/L). These drops in oxygen may result from intake of oxygen depleted water from Lake Paloona, and its discharge may have implications for the environment downstream.

Turbidity peaks at the monitoring station give evidence of the impact local runoff has on the turbidity of water in Lake Paloona and hence on downstream conditions. The Forth River carries a high sediment load due to agricultural soil loss in its tributaries (refer section 4.2.1) and flow fluctuations due to hydro-electric generation in the catchment.

Macroinvertebrate sampling on the Forth downstream of Paloona power station reflects both riffle and edge-water communities that are greatly impacted (Bobbi et al 2000). Although dissolved oxygen at this site may undergo short-term dramatic changes, it is more likely that the severe changes in river flows at this site are the main influence on the macroinvertebrate communities (Bobbi et al 2000).

5.8 Mersey River catchment

5.8.1 General

The headwaters of the upper Mersey River catchment lie within the Tasmanian World Heritage Area comprising parts of the Cradle Mountain Lake St Clair National Park and the Walls of Jerusalem National Park. Most of the remainder of the upper catchment is State Forest. The upper catchment drainage has been modified by hydro-electric development with a majority of the water diverted from Lake Parangana to the Forth River catchment (refer to section 3.4). Major tributaries of the upper Mersey catchment are the Fish, Fisher and Arm Rivers.

The middle Mersey catchment is primarily private freehold land with substantial areas of State Forest. The Alum Cliffs State Reserve covering spectacular gorge country is a feature of the middle catchment along with several karst reserves near Mole Creek. The middle catchment supports extensive agricultural activities such as grazing, piggeries, dairying, and commercial cropping. Major tributaries of the middle Mersey catchment are Lobster Rivulet, Minnow River, Dasher River and Coilers Creek.

The lower Mersey catchment is characterised by more intensive human settlement (towns of Sheffield, Railton and Latrobe) and activity (agricultural, forestry and industry). Major tributaries of the lower Mersey catchment are Redwater, Parramatta, Caroline and Bonneys Creeks. The Mersey estuary is flanked by low density urban development (Spreyton area) and high density urban (City of Devonport).

The geomorphology of the Mersey catchment and estuary is covered in some detail by Lampert (2000) who identified ten ‘river styles’ within the catchment.

5.8.2 Natural resource management in the catchment

Working Group and Steering Committee

The Mersey River Working Group was set up in 1996 in response to concerns about river flows and a range of other catchment issues. The Working Group negotiated a minimum environmental flow release with the Hydro Electric Corporation in 1998 and recommended a review of other catchment issues leading to the formation of the Mersey Catchment Steering Committee. This committee was involved in the preparation of a natural resource management plan (Armstrong et al 2000a), a geomorphological study (Lampert 2000) and Rivercare plans (Armstrong et al 2000b) for the Mersey catchment. The approach used in the preparation of these documents was the assessment of the geomorphic condition of the river in order to identify and prioritise river conservation and rehabilitation strategies as listed below:

- maintain or improve the geomorphic condition of near-intact reaches (upper reaches of primary tributaries and the main river (down to the Alum Cliffs);
- prevent zones of geomorphic instability from extending further into the catchment;

- minimise land-use and management practices that promote or extend further destabilisation of river courses;
- develop a continuous riparian corridor where practicable;
- frame all rehabilitation strategies within a catchment perspective.

Caroline Creek Catchment Management Plan

The Caroline Creek Catchment Management Plan arose out of concerns of the Latrobe Landcare Group over the degenerated condition of the Mersey River (pollution and a critical reduction in volume) at Railton. Caroline Creek, one of the last tributaries of the Mersey, has changed from being a clear stream to a generally turbid stream whose intermittent flow is no longer either reliable or clear enough for domestic use (Steane 1996). Major identified factors of degradation (after Steane 1996):

- Forest clearing, burning and conversion to pasture — loss of deeper roots and organic matter from the soil, less water infiltration, shorter seasonal flow.
- Clearing and draining of swamps and marshes.
- Lack of riparian reservation and stock access to streams.
- On-stream dams for water storage.
- Poor forest management, particularly short forestry rotations and clear felling of large coups.
- Mineral extraction, quarries, sand, gravel and clay pits — often sited on steep slopes, lack of measures to control runoff, inadequate site rehabilitation.
- Intermittent problems with Goliath Cement's clay storage dump and Dulverton Landfill area.

5.8.3 Water use in the catchment

Hydro Tasmania is a major water user in the upper Mersey catchment (refer to section 3.4). Construction of the Parangana Dam is estimated to have reduced median and mean flow in the Mersey downstream at Liena by ten-fold with consequent reduction in annual flood flows (DPIWE 2000b).

There are 137 licences currently allocated for water extraction for irrigation or commercial use in the catchment. Peak water use is approximately 50 ML per day over the summer months (DPIWE 2000b). Drinking water for the major population centres of the region is supplied by Cradle Coast Water. This water is piped from the Forth River and there is no direct abstraction of town drinking water from the Mersey. The town of Mole Creek draws drinking water from a tributary of the Mersey (DPIWE 2000b).

There are eight industrial water users drawing upon Mersey River water. The largest of these is the Wesley Vale pulp mill (located outside the catchment) which uses approximately 30 ML per day. The remaining industrial water users total just 3 ML per day (DPIWE 2000b).

5.8.4 Potential water quality impacts

There are several point sources that potentially impact upon water quality in the Mersey River catchment. Sewage treatment works are located at Devonport (coastal discharge), Sheffield (discharge to Dodder Rivulet), Railton (Redwater Creek), and Latrobe (Mersey River). In addition, the townships of Liena, Mole Creek, Chudleigh and Kimberley are all on septic tanks. There are an estimated 1085 premises in the catchment with septic tank systems.

Intensive agriculture is the most significant environmentally relevant activity in the region, three piggeries and 24 dairies were identified in the region (DELM 1997).

The Dulverton regional landfill located in the lower reaches of the Mersey catchment (Caroline Ck Catchment) utilises a range of runoff control measures to minimise off-site impacts. Old landfill sites at Railton, Sheffield and Spreyton are currently being rehabilitated (DPIWE 2000b). Regional landfill impacts are identified in section 4.1.5. Goliath Cement Works, also located on Caroline Creek, has a water management plan to minimise impacts on water quality.

5.8.5 Water quality

The environmental quality of water in the Mersey catchment was examined in a series of catchment-wide surveys carried out during the spring and summer 1996–97 (DELM 1997). The document also provides a review of monitoring data for the catchment.

Water quality monitoring results for the Mersey show that conditions in the river at present and in the recent past are good, however, there is a general decline in water quality on moving downstream (DELM 1997). Additionally, there is a general loss of macroinvertebrate species sensitive to water pollution down the length of the Mersey.

Compared with the main river, the water quality of Mersey tributaries is much more degraded. The worst of these are Coilers Creek and Redwater Creek in the middle of the catchment where nutrient levels are sufficient to cause algal blooms at times. The elevated nutrient levels appear to be related to intensive animal industries and wastewater effluent (DELM 1997). Parramatta and Kings Creeks in the lower catchment also suffer from water quality degradation, particularly low dissolved oxygen and lack of macroinvertebrate fauna, however, the causes are more complex due to the increased variety of catchment activities. Refer also to Caroline Creek catchment management plan above.

The microbiological quality of rivers in the catchment is variable with conditions in tributaries generally found to be worse than in the main stream. Of 18 sites sampled for bacterial water quality, six exceeded the ANZECC (1992) guidelines for primary contact with water (DELM 1997).

Turbidity measurements indicated that the greatest soil loss in the catchment is occurring in the sub-catchments of Mole Creek, Lobster Rivulet, Minnow River and Dasher River (DELM 1997).

Two factors have been identified as possible causes of degradation of the macroinvertebrate communities in the Mersey: Parangana Dam (due to flow and habitat alteration) and degraded water quality in the lower catchment. Water quality, habitat degradation from both forestry and agricultural practices, and Parangana Dam are considered the main impacts within the Mersey catchment that affect macroinvertebrate communities (DELM 1997).

Other water quality information for the Mersey and nearby rivers is available from Five Rivers Waterwatch who monitor water quality at 50 sites.

5.9 Port Sorell catchment (Rubicon/Franklin)

The Port Sorell catchment is primarily a modified landscape with rural and forestry land uses predominant. The major reserve in the catchment is part of the Asbestos Range National Park which lies along the north-east coast of the area.

Population centres are small in the Port Sorell catchment although, at the coast, the town of Port Sorell is a popular holiday area. The Wesley Vale pulp mill is the major industrial complex in the catchment. The major source of pollution leachate to Port Sorell is the closed waste depot which contains a high content of pulp mill waste and has groundwater leachate problems (refer section 4.1.5).

The major stream in the Port Sorell catchment is the Rubicon River which rises in low-lying rural country near Elizabeth Town. The other significant stream in the area, Franklin Rivulet, has a catchment characterised by State Forest. The Port Sorell waterway is the largest estuary of the north-west coast.

Significant works have occurred in the catchment of the Rubicon over the past century which have altered the natural drainage patterns. Many flats have been drained for development of pasture and natural stream-beds have been straightened and de-snagged aiming to facilitate drainage capacity and to reduce flooding. The river works have created many problems, for example, in many cases, native vegetation was not re-established along the channels and erosion of channel banks and beds developed. Additionally, the river works created enhanced flooding in some areas and siltation in others which reduced channel capacity and promoted in-stream vegetation growth (Armstrong 2000c).

In the 1990s a river improvement Trust was established on the Rubicon River. The major focus of the Trust was removal of willows and realignment of the stream. The Greater Rubicon Catchment Group was established in 1998 and completed a Rivercare Plan in 2000 (Armstrong 2000). The plan proposes actions to address the following main issues of concern:

- stream-bank and bed erosion, particularly in straightened channels;
- control of invasive weeds, particularly willows;
- poor water quality;
- deterioration of the aquatic and riparian environment which restricts the habitat of native species, particularly the giant freshwater crayfish (*Astacopsis gouldi*).

6 Estuary health

6.1 General

Estuaries are semi-enclosed or periodically closed coastal bodies of water with unique and highly variable environments that represent the major interface between land based processes within the catchment and the marine environment (Edgar et al 1999). The primary estuaries of north-west Tasmania from west to east are the Arthur, Welcome, Montagu, Duck, West Inlet, East Inlet, Black, Detention, Crayfish, Inglis, Cam, Blythe, Emu, Leven, Forth, Don, Mersey and Port Sorell. Much of north-west Tasmania's urban development is located on estuaries and they are arguably the most degraded part of the river systems in the region.

Edgar et al (1999) identified nine major threats to Tasmanian estuaries: i) increased siltation resulting from land clearance and urban and rural runoff; ii) increased nutrient loads resulting from sewage and agricultural use of fertilisers; iii) urban effluent; iv) foreshore development and dredging; v) marine farms; vi) modification to water flow through dams and weirs; vii) acidification of rivers and heavy metal pollution from mines; viii) the spread of introduced pest species; and ix) long-term climate change.

The effects of introduced marine pests is increasing and appears largely uncontrollable at present. Once established, introduced marine species can be extremely difficult, often impossible, to eradicate, and can result in severe consequences to the marine environment, acquaculture and public health. Marine pests typically reproduce rapidly and tend to prey on or out-compete the native flora and fauna. Temperate southern hemisphere estuaries are susceptible to pest invasions from northern temperate areas as they provide comparable conditions for these species to thrive, but may lack their natural predators to control their populations.

Edgar et al (1999) found two common pests in estuarine sampling in Tasmania: the green crab *Carcinus maenas* and the gastropod *Potamopyrgus antipodarum.* The threat posed by these and other species (including seastars *Asterias amurensis* and *Patiriella regularis*, the molluscs *Musculista senhousia, Crassostrea gigas, Maoricolpus roseus, Theora fragilis* and *Corbula gibba*, the polychaete *Sabella spallanzani* and the ricegrass *Spartina anglica*) is extremely high.

Edgar et al (1999) assessed the conservation significance of Tasmanian estuaries using physico-chemical criteria, species diversity, level of human disturbance (using population density data) and proportion of catchment area under statutory protection. The estuaries of the north-west coast did not rate well in the assessment. Just the Black River estuary was rated as Class A (critical conservation significance). Several estuaries (the Welcome, Montagu, West Inlet, East Inlet and Detention) were rated as Class C (moderate conservation significance). All remaining estuaries, primarily in the central coast region, were classified as either degraded (Class D) or badly degraded (Class E).

These classifications reflect the degree of human disturbance related to the impacts mentioned above. Consequences include: decline in fish stocks, siltation, loss of seagrass beds, spread of introduced marine pests and nutrient enrichment with associated stimulation of primary production (algal growth).

Another research project investigating the health status of Tasmanian estuaries was commenced by the Tasmanian Aquaculture and Fisheries Institute in 1999 and is scheduled to run for two years. Estuaries of the north-west being surveyed under the project are the Duck, East Inlet, Black, Don, Mersey, Port Sorell and Arthur.

The aim of the Natural Heritage Trust funded project is to expand knowledge of the characteristics and health of Tasmanian estuaries and to identify estuarine types, or regions, particularly at risk from human impacts. Physical (sediment type), chemical (nutrients, chlorophyll *a* and turbidity) and biological data (macroinvertebrate distribution) are being collected at each estuary. Based on these data, the health status of each estuary is assessed. A detailed report on the state of the surveyed estuaries will be produced and data therein will provide a baseline for future reassessments of estuarine health.

6.2 The Mersey Estuary

The Mersey Estuary has a host of problems as can be expected in an urban area and industrial port. The lower Mersey Estuary adjacent to the City of Devonport has been completely modified for port development and there is no remaining natural foreshore. The lower Mersey Estuary is regularly dredged and is flanked at the mouth by seawall groynes.

The Port of Devonport Corporation has a permit for sea disposal of dredge spoil from the Harbour area downstream of Victoria Bridge. Tributyl-tin (TBT) and heavy metals are present in the dredged material, and sampling indicates that this contamination is getting worse (Armstrong et al 2000b). The TBT is sourced from the port slip-way, and plans are underway to address this through a Slip-way Environmental Management Plan (Armstrong et al 2000b).

General catchment and stormwater impacts on the Mersey Estuary are high, both from upstream and in the local catchment — refer to stormwater and sewage (section 4.1). The Latrobe sewage treatment plant has caused significant water quality problems in the past, however, effluent outflow is currently being diverted from the Mersey to the Devonport ocean outfall (refer section 4.1).

Tidal reaches of the Mersey Estuary still have fringing remnant native vegetation in places, but are heavily impacted by urbanisation, industry, clearing and grazing. Rehabilitation of these reaches is problematic as they receive sediment from upstream reaches, overflows from the Latrobe sewage treatment plant (refer section 4.1), industry and stormwater.

A number of creeks flow to the Mersey Estuary all of which are known to be badly degraded — Kings Creek, Horsehead Creek, Cockers Creek and Figure of Eight Creek. Willows line all the waterways of the upper Mersey Estuary. Horsehead Creek has substantial areas of intact native vegetation.

Local efforts to remove willows and a weir at Pig Island have been successful in uncovering shingle and deepening the river, and improving the connection between the river and some backwaters that are important for fish breeding. This work has been based on the Latrobe Landcare Group's documentary evidence of the state of the river and banks in the 1940s and 50s, when shingle banks, fish recruitment, the giant freshwater lobster and invertebrates were common.

7 Environmental planning and benchmarks

7.1 Environmental management goals for Tasmanian surface waters

7.1.1 Protected Environmental Values

The first step in the implementation of the State Policy on Water Quality Management 1997 is the identification of Protected Environmental Values (PEVs). PEVs are the current values and uses of a water body for which water quality should be protected. The main PEV categories for consideration in each water body are:

a) Protection of Aquatic Ecosystems;

b) Recreational Water Quality and Aesthetics;

c) Raw Water for Drinking Supply;

d) Agricultural Water Uses;

e) Industrial Water Supply.

PEVs for water bodies of north-west Tasmania have been identified for most catchments and compiled for catchments in the Circular Head & Waratah/Wynyard municipalities (DPIWE 2000), the Mersey River catchment (DPIWE 2000a), and North Central Coast (DPIWE 2001). The PEVs for north-west Tasmania were determined in consultation with the community by the Board of Environmental Management, Councils, and the Tasmanian Parks and Wildlife Service.

7.1.2 Water Quality Objectives

The next stage in the development of the State Policy on Water Quality Management 1997 is to specify a range of Water Quality Objectives (WQOs). WQOs will be designed to ensure the quality of water in each water body is maintained at a level which will allow the chosen PEVs to be protected. A case study has been developed by DPIWE for the Mersey River to provide a basis for determining the methodology for setting WQOs.

Mersey WQO case study

The draft WQOs for the Mersey River catchment were set by taking into account the major catchment land uses in the upper, middle and lower catchment. In the upper catchment the key indicators reflect water quality issues associated with the operation of the dams and with production logging. In the middle catchment the indicators reflect a wide range of land use and activities including recreational water use at many local swimming holes. In the lower catchment the indicators reflect high intensity agriculture and urban inputs at the estuary. The lack of water quality data at the Mersey estuary necessitated the adoption of national Water Quality Guidelines. The draft WQOs for the Mersey River system are detailed in DPIWE (2000b).

Monitoring is an important component of the WQO framework. Specific monitoring requirements for the Mersey catchment are yet to be determined and should be consistent with the Draft State Water Quality Monitoring Strategy.

References

Armstrong, Attwater C & Ecosynthesis 2000a. *Natural resource management plan for the Mersey catchment.* Armstrong Agricultural Services Pty Ltd, Launceston.

Armstrong, Attwater C & Ecosynthesis 2000b. *Rivercare plans for the Mersey River: 1 Upper Mersey; 2 Dasher Minnow; 3 Middle Mersey; 4 Lower Mersey*. Armstrong Agricultural Services Pty Ltd, Launceston.

Armstrong 2000. *Rivercare plan for the Rubicon River and tributaries*. Armstrong Agricultural Services Pty Ltd, Launceston.

ANZECC 1992. *Australian water quality guidelines for fresh and marine waters*. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council, Canberra.

Berry K 2001. *Progress reports for State of the rivers reporting*. DPIWE, Hobart.

Bobbi C, Gamble S & Peterson J 2000. *Waterway health monitoring program annual report 1999–2000*. Hydro Tasmania, Hobart.

Bryant S & Jackson J 1999. *Tasmania's threatened fauna handbook*. Parks & Wildlife Service, Hobart.

Coughanowr C 1997. *State of the Derwent Estuary: A review of environmental quality data to 1997*. Supervising Scientist Report 129, Supervising Scientist, Canberra.

Davies JL 1965. *Atlas of Tasmania*. Lands and Surveys Department, Hobart.

DELM 1997. *Mersey River experimental study technical reports,* incorporating *State of the river reports*. Tasmanian state government –(DELM, DPIF, HEC & IFS), Hobart.

DPIWE 2000a. *Environmental management goals for Tasmanian surface waters. Catchments within the Circular Head and Waratah/Wynyard municipal areas*. Department of Primary Industries, Water & Environment, Hobart.

DPIWE 2000b. *Environmental management goals for Tasmanian surface waters. Mersey River catchment*. Department of Primary Industries, Water & Environment, Hobart.

DPIWE 2000c. Case study: *Water Quality Objectives for the Mersey River Catchment, Draft for Discussion.* Department of Primary Industries, Water & Environment, Hobart.

DPIWE 2001a. *Environmental management goals for Tasmanian surface waters. Catchments draining into the north-central coast and the greater Rubicon catchment*. Department of Primary Industries, Water & Environment, Hobart.

DPIWE 2001b. *Restoration priorities and tasks for riparian areas previously vegetated with crack willow (Salix fragilis). Inglis River and adjoining catchments*. Rivercare Technical Team, Department of Primary Industries, Water & Environment, Hobart.

Edgar G, Barrett N & Graddon D 1999. *A classification of Tasmanian estuaries and assessment of their conservation significance: an analysis using ecological and physical attributes, population and land use*. Ocean Rescue 2000, Marine Protected Area Program, Parks & Wildlife Service, DPIWE, Hobart.

Forestry Tasmania 1999. *Mersey Forest District: Forest management plan*. Forestry Tasmania, Hobart.

Gurung S 2001. *Tasmanian acid drainage reconnaissance. Acid drainage from abandoned mines in Tasmania.* Bureau of Mineral Resources, Tasmanian Geological Survey Report 2001/5, Hobart.

Johnstone C & Associates 2000. *Cradle Mountain National Park and Pencil Pine tourist zone: Wastewater strategy*. Report prepared for Kentish Council by C Johnstone and Associates P/L, Hobart.

Krasnicki T, Pinto R & Read M 2001. *Australia wide assessment of river health, Tasmania program*. DPIWE, Hobart, Tasmania.

Lampert G 2000. *Mersey catchment river styles report*. Completed for Mersey Catchment Steering Committee and DPIWE, Hobart.

Mersey River Working Group 1998. *Mersey River flow and catchment assessment: Report and recommendations on catchment and flow management issues in the Mersey and its tributaries*. DELM, DPIF, HEC, IFC, Hobart.

Nicolls KD & Dimmock GM 1971. *Soils*. In *Tasmanian Year Book 1971*, Commonwealth Bureau of Census and Statistics, Hobart, p 45.

Pirzl H & Coughanowr C 1997. *State of the Tamar Estuary: A review of environmental quality data to 1997*. Supervising Scientist Report 128, Supervising Scientist, Canberra.

Richley L 1978. *Land systems of Tasmania region 3*. Department of Agriculture, Hobart, Tasmania.

Sims C & Cotching W 2000. Turbidity and sediment loads from selected catchments in north-west Tasmania. *Natural Resource Management* 3, 1–7.

SKM 1999. *Montagu River Catchment Management Plan*. Montagu River Landcare Group and Sinclair Knight Merz, Hobart.

Steane D & Associates 1996. *Caroline Creek catchment management plan*. Prepared for the Latrobe Landcare Group by David Steane and Associates, Hobart.

Thompson & Brett 1999. *Welcome River catchment management plan*. Thompson & Brett, Willing & Partners Consulting Group, Hobart.