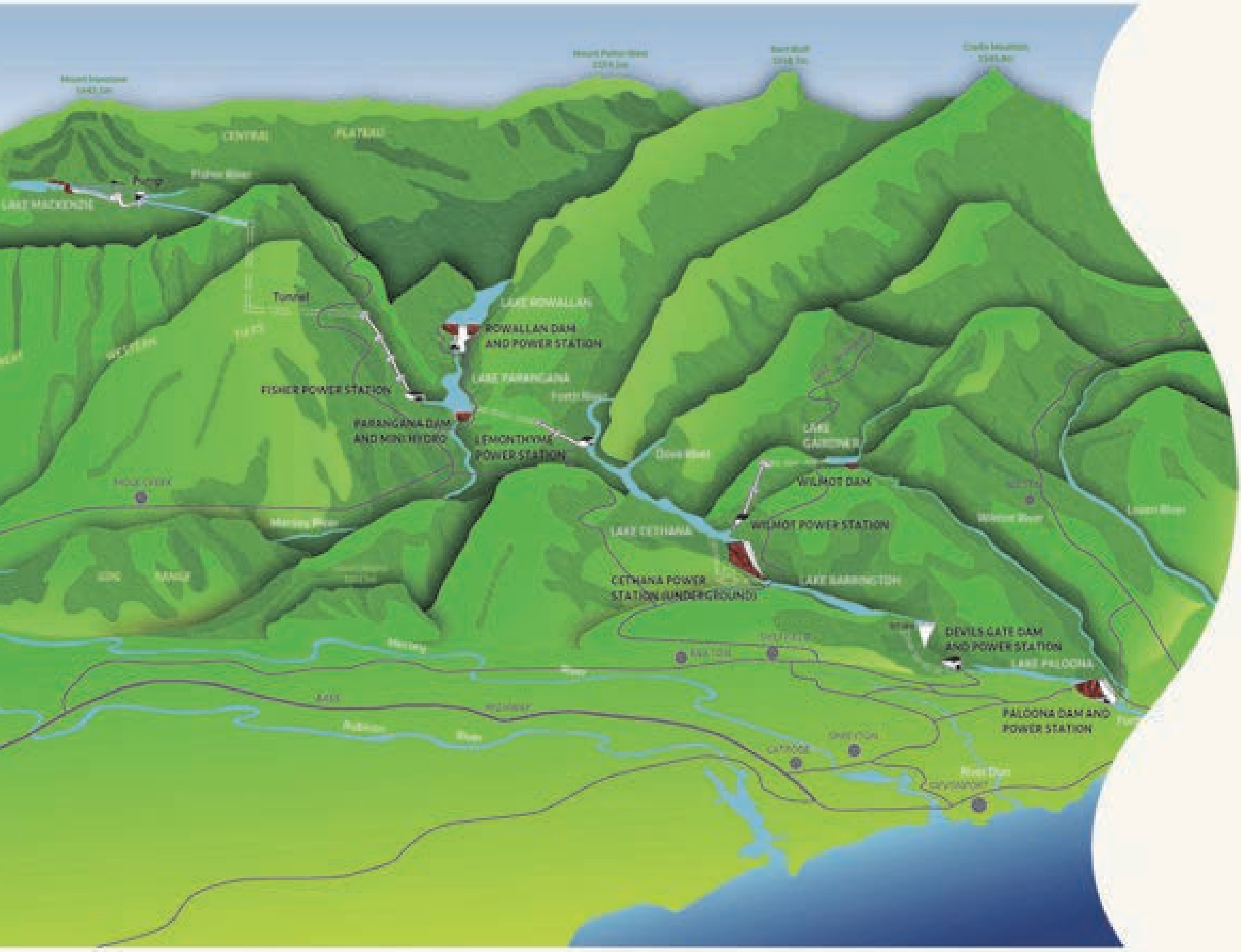
Mersey-Forth Water Management Review

We seek opportunities to enhance environmental and cultural values



Hydro Tasmania

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This Mersey-Forth Water Management Review represents Hydro Tasmania's current knowledge on the Mersey-Forth catchments. It identifies known impacts and issues surrounding Hydro Tasmania's water and land assets, insofar as Hydro Tasmania is aware of these issues at the time of preparing this document.

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Executive Summary

Hydro Tasmania, Australia's largest clean energy generator, is committed to leadership in sustainable management of its operations and water resources. The Mersey-Forth Water Management Review is part of a broader program aimed at reviewing Hydro Tasmania's water and land management activities across the six major hydro-electric catchments in Tasmania. The assessment is done in consultation with stakeholders and in light of present impacts on social, environmental and economic conditions in the catchments.

The Mersey-Forth Power Scheme, in the mid north west of Tasmania, Australia, harnesses the waters of the Mersey, Forth, Wilmot and Fisher Rivers, originating at an altitude of 1120 metres falling to sea level below the last power station. The scheme consists of seven main storages, seven power stations, water diversions and transfer infrastructure. Since its commissioning in the late 1960's and early 1970's Hydro Tasmania's hydro power operations have contributed to the development of an area characterised by forests, agriculture, conservation areas, industry, recreation and urbanisation.

Improving Hydro Tasmania's management activities in the Mersey-Forth catchments, where possible, will be achieved through the fulfilment of four objectives. These are:

1. Consultation with stakeholders to identify values and issues relating to hydropower operation of lakes and rivers in the catchments;
2. Systematic assessment of relevant issues;
3. Evaluation of a series of cost-effective mitigation and management actions to improve management; and
4. Implementation of a program for sustainable management of Hydro Tasmania's water and land resources in the Mersey-Forth catchments, as appropriate and practicable.

This Mersey-Forth Water Management Review report has been prepared to gain greater understanding of the Mersey-Forth catchments and to facilitate engagement with stakeholders. The report outlines the process of the review program and provides information on the catchments. The report includes:

- A brief overview of the environmental and social characteristics of the catchments;
- Available data and information on Hydro Tasmania's assets and infrastructure, system operations, electricity yield and climate change;
- Summaries of water quality, biological and geomorphological aspects of lakes and rivers;
- The multiple uses of Hydro Tasmania's land assets and waterways, and Aboriginal and cultural heritage aspects; and
- Identification of known impacts and issues associated with the waterways.

In consultation with stakeholders, the Mersey-Forth Water Management Review process will contribute to identifying and, where possible, improving water and land management activities to ensure the sustainable management of a vital resource for the benefit of Tasmania.

Acknowledgements

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List of Abbreviations and Acronyms

ACE-CRC	Antarctic Climate and Ecosystem Cooperative Research Centre
ANCOLD	Australian National Committee on Large Dams
ANZECC	Australian and New Zealand Environment and Conservation Council
ASFB	Australian Society for Fish Biology
AUSRIVAS	Australian Riverine Assessment System
Ca^{2+}	Calcium
CAMBA	China-Australia Migratory Bird Agreement
CCM	Climate Change Model
CCRS	Climate Change Response Strategy
CFEV	Conservation of Freshwater Ecosystem Values
CFT	Climate Futures for Tasmania
Chl-a	Chlorophyll-a
Cumec	Cubic metres per second (m^3/s)
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DPI	Dipole mode index
DPIPWE	Department of Primary Industries, Parks, Water and Environment
DPIWE	Department of Primary Industries, Water and Environment
D/S	Downstream
EC	Electrical conductivity
ENSO	El Niño Southern Oscillation
EPBCA	*Environmental Protection and Biodiversity Conservation Act 1999* (Commonwealth)
ESMS	Environment and Sustainability Management System
FSL	Full Supply Level
GCM	Global Climate Model
GWh	Giga Watt hour (Energy)
IFS	Inland Fisheries Service
IPCC	Intergovernmental Panel on Climate Change
K^+	Potassium
kW	Kilowatt
m	Metre
mASL	Metres above sea level
MRWG	Mersey River Working Group
mg/L	Milligrams per litre
ML	Megalitre
Mn^{2+}	Manganese
MW	Megawatt
Na^+	Sodium
NH_3-N	Ammoniacal nitrogen
NMOL	Normal Minimum Operating Level
NO_x-N	Dissolved Nitrogen
NTU	Nephelometric Turbidity Units (measure of turbidity)
NVA	Natural Values Atlas
O/E	Number of observed divided by the number of expected macroinvertebrate taxa
pa	Presence absence for macroinvertebrate data
PEVs	Protected Environmental Values
PWS	Tasmanian Parks and Wildlife Service
RIVPACS	River Invertebrate Prediction and Classification System

rk	Rank abundance for macroinvertebrate data
SAM	Southern Annular Mode index
TAC	Tasmanian Aboriginal Council
TALSC	Tasmanian Aboriginal Land and Sea Council
TKN	Total kjeldahl nitrogen (measure of organic and ammoniacal nitrogen)
TP	Total phosporus
TSPA	*Threatened Species Protection Act 1995* (Tasmania)
TSS	Total suspended solids
TWWHA	Tasmanian Wilderness World Heritage Area
US EPA	United States Environmental Protection Agency
U/S	Upstream
µS/cm	Microsiemen per centimetre (measure of electrical conductivity)

1 Introduction

1.1 Background and Purpose of the Mersey-Forth Water Management Review

For Hydro Tasmania a sustainable future involves the balanced application of economic, environmental and social considerations to business decisions and activities. Hydro Tasmania's core business is the generation and trading of electricity by serving electricity, renewable energy and water management markets nationally and in Tasmania. Hydro Tasmania is Australia's leading renewable energy business.

Hydro Tasmania recognises that its water and land resources are highly valued by a diverse range of stakeholders. A number of values are associated with the water and land resources including electricity generation, agriculture, forestry, manufacturing, domestic water supply, irrigation, recreational use, aesthetics and ecosystem health. Hydro Tasmania's operations therefore need to align with wider state and community economic, environmental and social objectives. As such Hydro Tasmania aspires to continuously improve its practices, and engage with stakeholders with the intent of increasing the value of its resources for the community, while taking into account operational constraints. In a unique position as a hydropower generator and multiple use water resources manager, Hydro Tasmania is committed to sustainable management of its land and water resources.

Hydro Tasmania's Water Management Review Program aims to proactively, and in consultation with stakeholders, assess the impact of current water management activities on social, environmental and economic conditions in Hydro Tasmania's catchments, in order to establish more sustainable practices. Initiated in 1999, it is planned that this process is undertaken catchment by catchment across the six major catchment groups in the hydro-electric generating system, and is consistent with State Government requirements for water management planning.

The Mersey–Forth catchments, in central north western Tasmania, are the focus of the current Water Management Review Program. The objectives of the review are to:

- Consult with stakeholders to identify values and issues relating to hydropower operation in the catchments;
- Systematically assess relevant environmental, social and multiple use issues;
- Evaluate cost effective mitigation and management actions to improve management; and
- Implement a program for sustainable management of Hydro Tasmania's water resources in the Mersey-Forth catchments, as appropriate and practicable.

This Mersey-Forth Water Management Review Report provides an overview of the current knowledge of Hydro Tasmania's assets and operations, and known impacts and issues associated with these assets, within the broader context of environmental conditions and social values within the Mersey–Forth catchments. It has been prepared to initiate the Mersey-Forth Water Management Review process through which Hydro Tasmania intends to systematically assess and improve its management activities, in consultation with stakeholders and communities.

1.2 The Water Management Review Process

The Mersey-Forth Water Management Review process has been designed to follow four stages and take a minimum of three years to complete. These stages are:

- Stage 1: Information Review;
- Stage 2: Stakeholder Consultation;
- Stage 3: Technical Studies; and
- Stage 4: Program Development.

Stage 1 is an information review which involves desktop investigations and the development of this Water Management Review Report. The report consolidates available baseline information of social, environmental and operational activities and issues associated with Hydro Tasmania's water and land assets, as known by Hydro Tasmania at the time of preparing this document. This report is intended to provide stakeholders with information and serve as a basis for discussion in the stakeholder engagement process. The report is available in hard copy and on the website at www.hydro.com.au/MFWMR/

Stage 2 is the stakeholder engagement and consultation process. This process will encourage perspectives to be voiced and will facilitate mutual understanding of values and issues. Information and advice gained through this process will be used to identify priority issues requiring further consideration in Stage 3. While Hydro Tasmania will endeavour to address all issues raised, it reserves the right to focus stakeholder involvement on issues that can reasonably be addressed and that lie within the aims and objectives of the Water Management Review process. The role of stakeholders participating in the engagement process will be of an advisory capacity and not a decision making role.

A Stakeholder Engagement Consultation Report will be published summarising the consultation process detailing findings on values, issues and advice provided. Proposed technical studies and investigations, to be undertaken in Stage 3, will be identified. A stakeholder feedback survey will be distributed with the Stakeholder Engagement Consultation Report to measure the outcomes of Stage 2.

Engagement and consultation with all interested stakeholders is expected to continue throughout the life of the project and not only in this stage.

Stage 3 will involve the commissioning of technical studies to research specific issues, or to assess the feasibility of mitigation opportunities and management options. The time taken to complete the studies will depend on the complexity of the issues. Some technical studies may involve collaboration and participation with stakeholder organisations. Some solutions may not require significant research and development and may be implemented after discussion with stakeholders. Feedback to stakeholders on the status of the technical studies and other measures will be provided throughout the process. Technical reports will be made available to stakeholders upon completion.

Stage 4 is the development of a program of commitments to improve management in the catchments. Informed by an understanding of stakeholder issues and the findings of technical studies, management options proposed in Stage 3 will be prioritised according to benefits and costs, and actions identified for implementation. Commitments emanating from this stage will be consolidated into a Mersey-Forth Summary Report and will conclude the formal water management review process.

The Mersey–Forth Scheme harnesses the waters of the Mersey, Forth, Wilmot and Fisher Rivers. While the Water Management Review will take into consideration the entire Mersey–Forth catchment area, the primary focus will be on the upper catchments which lie within the Local Government Areas of Kentish and Meander Valley. Hydro Tasmania recognises that there are a number of issues that will be raised in the lower parts of the catchments within the context of this review. Currently the lower Mersey catchment, downstream of Lake Parangana, falls under the Mersey Forth Water Management Plan (DPIWE 2005). Any issues pertaining to this area will be referred to the appropriate responsible organisations and opportunities for ongoing collaboration identified.

1.3 Legislative and Policy Framework

Hydro Tasmania exercises its water resource management responsibility within a legislative and policy framework which includes both State and Commonwealth legislation. Hydro Tasmania's rights to use water in Tasmania were originally granted in the *Hydro-Electric Commission Act 1929*. These rights were carried over into the *Water Act 1957* and on its repeal via the *Water Management Act 1999*. Hydro Tasmania holds a Special Licence under the *Water Management Act 1999*. The associated water licence agreement introduced a number of new conditions including monitoring and reporting of water use. Map 1-1 shows the location of all hydro-electric schemes in Tasmania.

Under Hydro Tasmania's Water Licence the *Wesley Vale Pulp and Paper Industry Act 1961* requires operators of upstream dam owners on the Mersey River to make water available to the operators of the Wesley-Vale paper mill during times of drought. In March 2010 the Wesley-Vale paper mill closed down. Hydro Tasmania has agreed to make available a proportion of this water, if required, to the Sassafras Wesley-Vale Irrigation Scheme which is being developed by Tasmanian Irrigation (TI).

The *Water Management Act 1999* brought water management practices in Tasmania into the broader Resource Management and Planning System of Tasmania (1994). This system provides the legislative framework for sustainable use and management of the natural resources, including freshwater. Further it required that state and local bodies, on whom a function is imposed or a power is conferred under the Act, perform the function or exercise the power in such a manner as to further the Act's objectives (Appendix A-1).

The State Policy on Water Quality Management 1997 required the setting of Protected Environmental Values (PEVs) for each waterway and this was completed for the Mersey River in 2001 (DPIWE 2001). The Mersey Water Management Plan (DPIWE 2005) provides a framework for managing the lower Mersey catchments water resources in accordance with the *Water Management Act 1999*. The Water Management Plan area covers the Mersey River catchment below Lake Parangana. It includes environmental, water usage and development and compliance and monitoring objectives. The Water Management Plan also outlines water management provisions and licenses, monitoring of the environmental flow release below Parangana, surface water allocations, metering of water use, management of water storages, water transfers, groundwater licensing and allocation, and restriction management. Hydro Tasmania's voluntary commitment under this Water Management Plan is to maintain an environmental flow from Parangana Dam.

A large portion of the Mersey-Forth catchments (Map 2-4) lie within the Tasmanian Wilderness World Heritage Area (TWWHA). The TWWHA is managed by the Tasmanian Parks and Wildlife Service (PWS) in accordance with the Tasmanian Wilderness World Heritage Area Management Plan 1999 (PWS 1999). Hydro Tasmania is committed to operating its assets in alignment with the TWWHA management objectives.

Map 1-1
Hydro power schemes in Tasmania

Hydro Tasmania's Sustainability Code (Appendix A-2), Hydro Tasmania's Environment Policy (Appendix A-3), and the International Hydropower Association Sustainability Assessment Protocol (IHA 2011) guide the Corporation's commitment to leadership, sustainable management of water resources, and engagement with the Tasmanian community regarding the multiple use of land and water assets under Hydro Tasmania's responsibility.

The Water Management Review Program is a proactive process in support of Hydro Tasmania's legislated and voluntary commitments.

1.4 Report Content

This Mersey-Forth Water Management Review Report provides an overview of the Mersey-Forth catchments. Chapter 2 provides a brief description of the climate, vegetation, geology, local government, catchment land use and environmental values. A description of hydropower infrastructure, an outline of the operation of the Hydro Tasmania generation system, electricity yield, cloud seeding, water use and water releases is in Chapter 3.

Chapter 4 provides a description of current trends and projected changes to rainfall and runoff resulting from climate change. Environmental and social aspects in the Mersey-Forth catchments are covered in Chapters 5 to 9: water quality (Chapter 5), biological (Chapter 6), and geomorphological aspects (Chapter 7). Broader land and multiple use considerations are covered in Chapter 8 and cultural heritage aspects in Chapter 9.

1.5 Opportunities for Involvement

Hydro Tasmania is seeking to better understand the values that the community place on the Mersey-Forth catchments and would like to see the water management review process as a means of gaining that understanding. In the process it is anticipated that existing relationships will be strengthened and new, long term relationships established with the local community, stakeholders and users of the waterways in the Mersey-Forth catchments.

Stakeholders in the Mersey–Forth catchments are encouraged to become involved in the Water Management Review process. Please register your interest by:

1. Contacting the Mersey-Forth Water Management Review Team by phone, letter or email using the contact details provided below; or
2. Filling in the Mersey-Forth Water Management Review Stakeholder Survey, which can be obtained online at: www.hydro.com.au/MFWMR/ or from the Team.

Requests for information, clarification on the report, or the process, can be obtained at:

Hydro Tasmania
For attention: Mersey-Forth Water Management Review Team
Post: GPO Box 355, Hobart, Tasmania 7001, Australia
Email: merseyforth@hydro.com.au
Call: 1300 360 441 (Local call cost Australia-wide)
Web: www.hydro.com.au/MFWMR/

2 Catchments Characteristics

2.1 Overview

The Mersey-Forth catchments are located in the central north west of Tasmania covering a total area of 2,800 km^2. The combined generating capacity of the Mersey-Forth Power Scheme is about 16% of Tasmania's energy needs. The scheme harnesses the waters of the Mersey, Forth, Wilmot and Fisher Rivers, originating at an altitude of 1120 metres on the Great Western Tiers, and falling to sea level after the last power station (Map 2-1).

2.2 Climate

A cool temperate climate is characteristic of the Mersey-Forth catchments. The climate is dominated by a moist, westerly air stream which is generated from the northern edge of the 'Roaring Forties'. Rainfall is highest in winter, with August as being the wettest month and February and March being the driest months. Winter snowfalls are common above 600 m, but may fall at any time of year in the highland areas of the catchments (Richley 1979). Table 2-1 shows the average annual rainfall, and winter and summer temperatures for two representative weather stations in the Mersey-Forth catchments (Australian Bureau of Meteorology 2010); Waldheim in the upper catchments and Devonport airport on the coast.

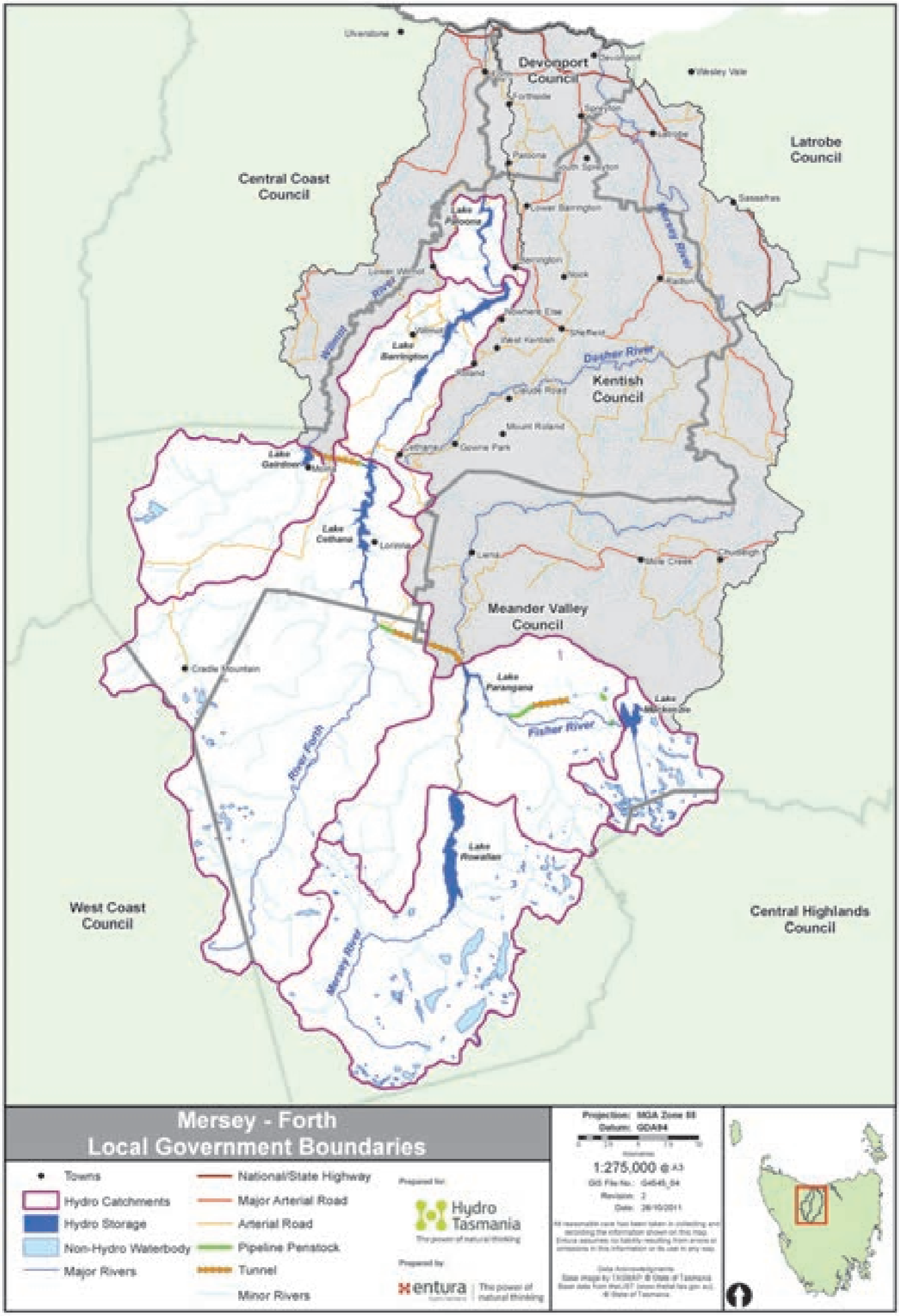
Table 2-1
Mersey-Forth rainfall and average temperatures

BOM Station	**Devonport (Airport) #091126**	**Cradle Valley (Waldheim) #096005**
Annual rainfall (mm)	900	2650
Winter average temperature (°C)	3.7 - 12.2	-0.5 - 4.6
Summer average temperature (°C)	12.0 - 21.3	5.9 - 17.0

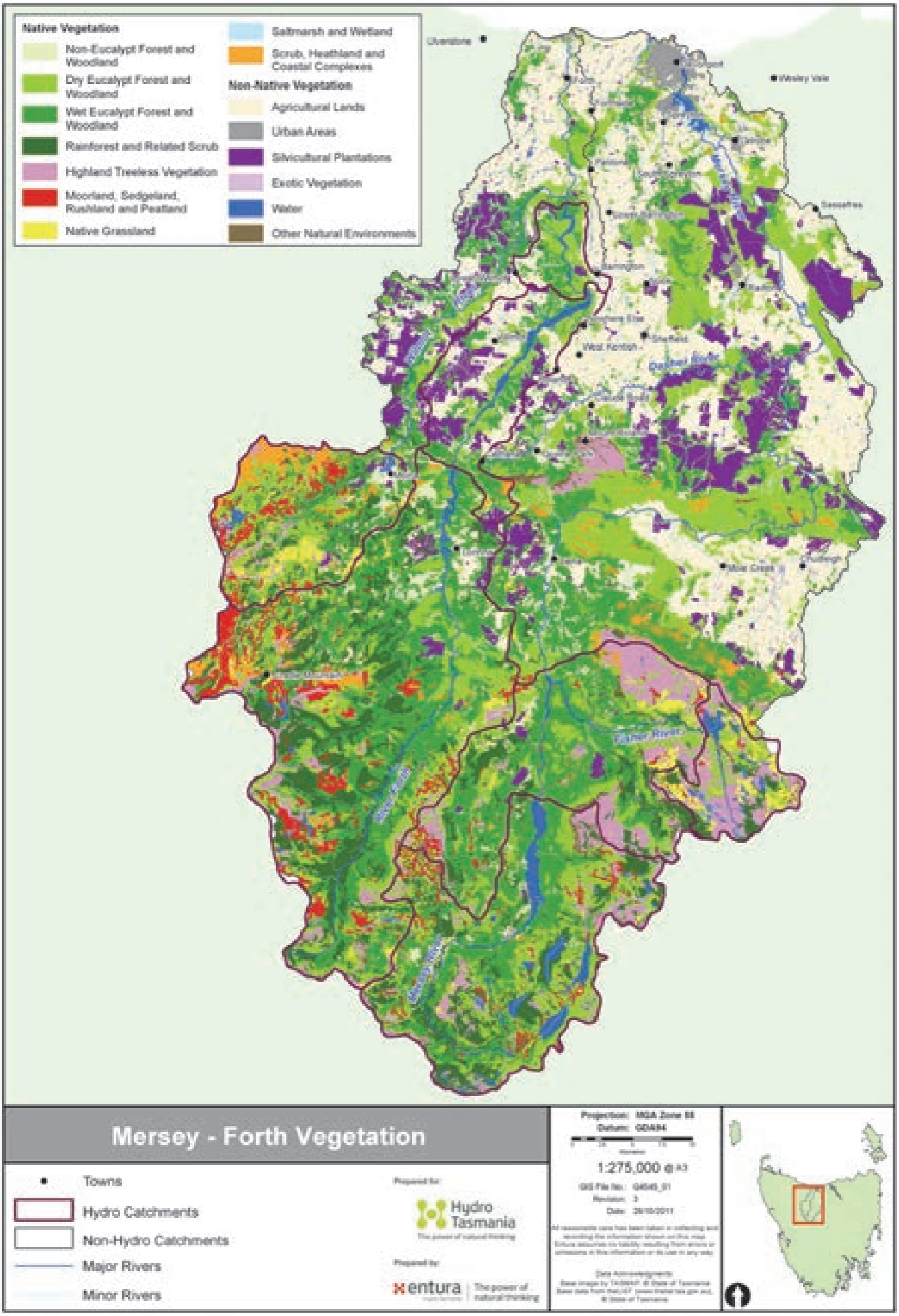
2.3 Vegetation

A map of the major vegetation types and land use in the Mersey-Forth catchments is presented in Map 2-2. Much of the natural vegetation in the lower and middle Mersey catchment has been cleared for agriculture and forestry. Dry sclerophyll forest dominates the remaining natural vegetation in the drier coastal areas, giving way to wet sclerophyll forest, dominated by *Eucalyptus obliqua* in the higher rainfall areas further inland. The middle Mersey catchment is generally covered by wet *Eucalyptus obliqua* forest and significant areas of *Eucalyptus simmondsii* scrub. Pine plantations also cover large areas of the middle catchment. The upper Mersey catchment supports large areas of *Eucalyptus delegantensis* forest, interspersed with grassland, rainforest, montane grassy forest, and alpine and sub-alpine complexes. Most of the riparian vegetation in the upper part of the catchment is still intact.

In the lower Forth catchment, most of the natural vegetation has been cleared for agricultural and forestry use, with occurrences of *Eucalyptus obliqua* wet sclerophyll forest. The middle and upper areas of the Forth catchment support primarily *Eucalyptus obliqua* wet sclerophyll forest. In the upper catchment, areas of scrub and eucalypt forest, button grass moor, rainforest and alpine and sub-alpine complexes also occur.



Map 2-1
Mersey-Forth catchments and local government boundaries



Map 2-2
Mersey-Forth catchments vegetation and land use

2.4 Geology, Topography and Soils

The Mersey-Forth catchments contain outcrops of the Precambrian, Cambrian and Ordovician rocks that are typical of western Tasmania, and the more recent intrusive igneous and sedimentary rocks typical of eastern Tasmania (Map 2-3)

Precambrian metamorphic rocks outcrop in the Mersey catchment in the vicinity of Parangana Dam and in the upper Forth catchment. The soils that develop in these areas are generally yellowish-red and brownish, gravelly and gradational (Richley 1979).

Cambrian rocks, including volcanic and associated rocks, are found in a number of locations in both the Mersey and the Forth catchments, particularly along the middle and lower reaches of the Wilmot River, and in the vicinity of the Minnow and Dasher rivers. In the foothills of Mount Roland, particularly to the north and west, these older rocks are overlain by a sheet of recent sedimentary deposits. Soils with a predominantly gradational profile have developed on the Cambrian rocks.

Predominantly siliceous Ordovician rock sequences are found at a number of locations in the Forth catchment, most notably from Lake Gairdner east through to Mount Roland. The soils that have formed on this material are generally shallow and organic, although in places skeletal and shallow, sandy soils have developed (Richley 1979).

In the middle Mersey River, in the vicinity of Mole Creek, Ordovician sedimentary and limestone is the main bed rock. Limestone is slowly dissolved by rainwater and the resulting countryside has an abundance of caves, underground streams and depressions (dolines) created by the collapse of overlying rocks. The soils that form on the limestone are moderately erodible. Erosion hazards include sheet and gully erosion, and stream bank erosion (Richley 1979).

Devonian granite intruded the overlying sedimentary and other rocks about 400 million years ago. Metal-rich liquids associated with the granite created an array of mineral deposits near Lake Gairdner and around Lake Cethana. The area was extensively mined for tin, tungsten, silver, lead and gold during the late 19th and early 20th centuries.

The south-eastern part of the Mersey-Forth catchments is dominated by the Great Western Tiers. Hard Jurassic dolerite caps the Tiers.

Earthquakes and basaltic volcanoes further shaped the Mersey-Forth catchments during the Tertiary period. Weathering of basalt has produced the deep, fertile soils that characterise north-western Tasmania.

The more recent geology of the Mersey-Forth catchments includes the product of a succession of Ice Ages – glacial deposits, U-shaped valleys and other erosional features.

2.5 Local Government and Catchment Land Use

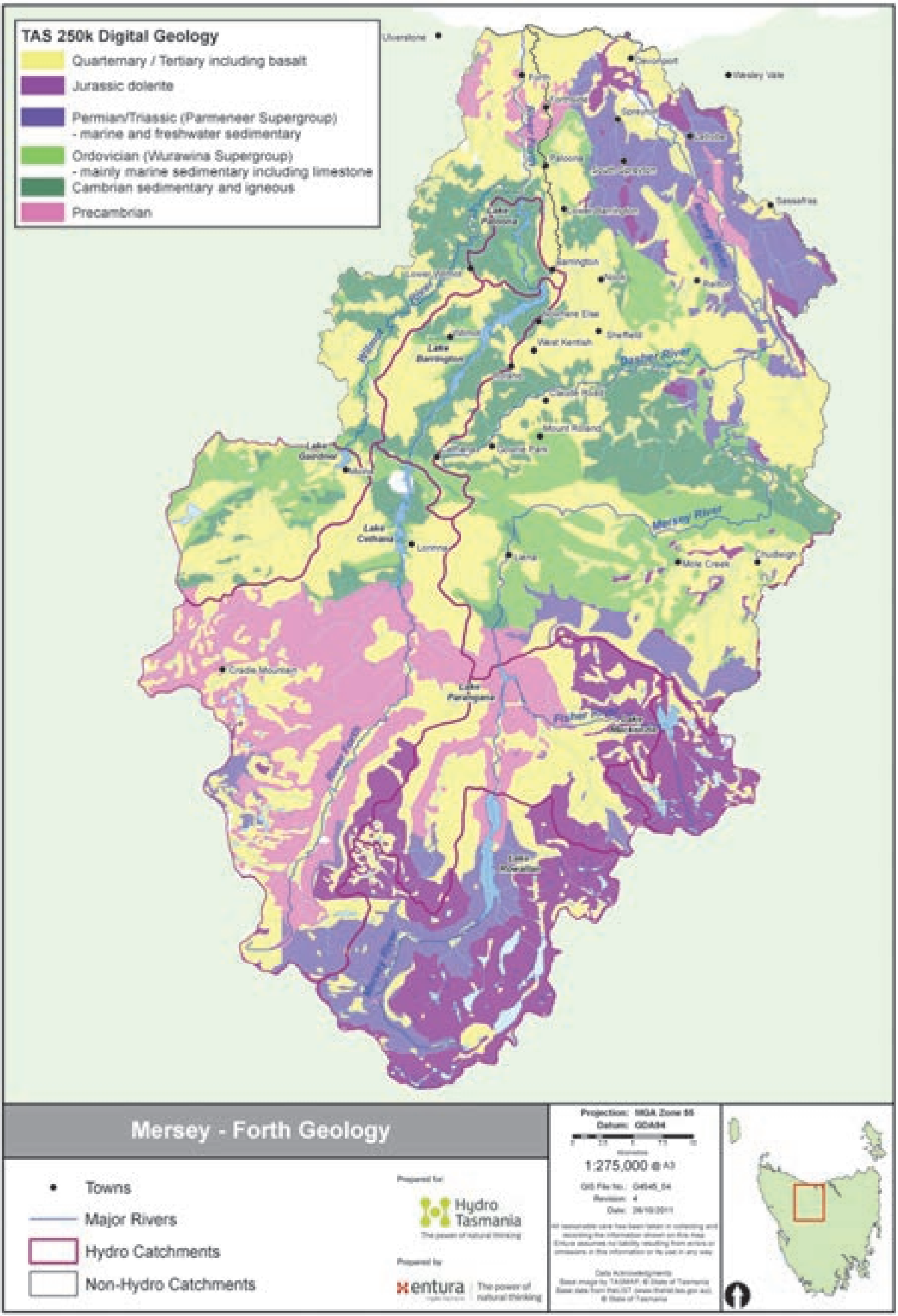
The Mersey-Forth catchments cover a large area comprising seven local government areas (Map 2-1):

- Devonport City Council;
- Kentish Council;
- Central Coast Council;
- Latrobe Council;

- Meander Valley Council;
- Central Highlands Council; and
- West Coast Council.

The main land uses in the Mersey-Forth catchments are agriculture, retail and tourism, manufacturing, mining, hydro power and conservation. Agriculture is diverse and includes farming of beef, dairy, sheep, pigs and cropping. An increasingly important land-use is recreation and tourism. Cradle Mountain, in the west, is a top tourist attraction, and Lake Barrington has a world standard rowing course.

Industries in the catchments include water treatment facilities, quarrying and manufacturing. Manufacturing has for many years been a vitally important activity in the region, and includes activities such as dairy product manufacturing, vegetable processing, textile product manufacturing, saw-milling and wood product manufacturing, cement production and mining equipment manufacturing.



Map 2-3
Mersey-Forth catchments geology

The region is renowned for its unique and diverse environment, including pristine wilderness, rugged mountainous areas, extensive forests, old mining towns and productive agricultural landscapes. A number of areas are designated for conservation or protection purposes. Land tenure in the catchments is shown in Map 2-4.

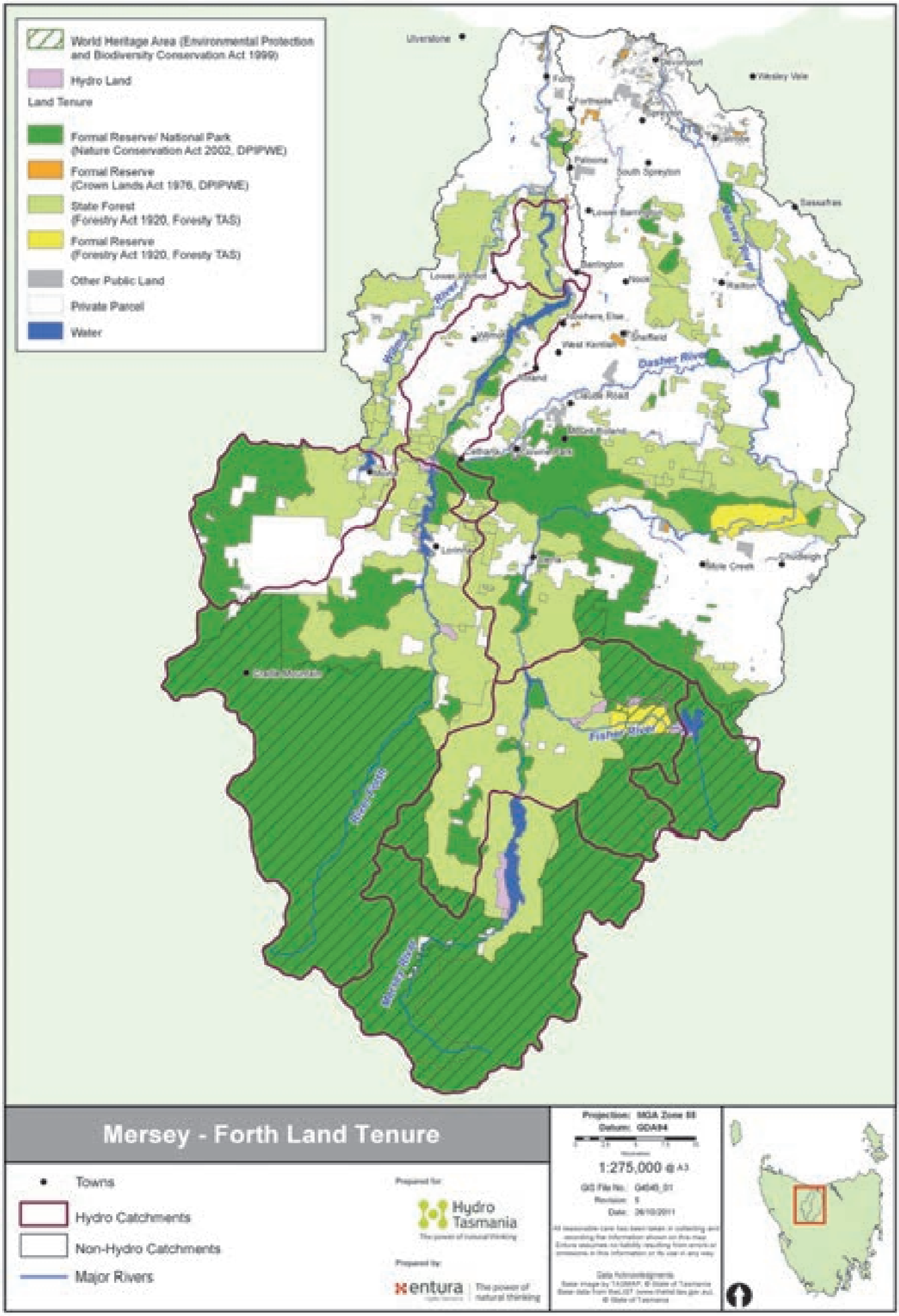
2.6 Protected Environmental Values

In 2001, following community consultation and the identification of community values for the Mersey catchment, Protected Environmental Values (PEVs) were established as part of the DPIWE program setting of environmental management goals for Tasmanian surface waters (DPIWE 2001). These values are summarised in Table 2-2 and a detailed list of community values identified during the consultation process is given in Appendix B.

No PEVs have been identified for the Forth catchment, however, values can be assumed to be similar to those in the Mersey.

Table 2-2
Protected environmental values for the Mersey River catchment (Source: DPIWE 2001)

Value		**Geographical extent of value**			
		Upper	**Middle**	**Lower**	**Coastal**
Fishing for human consumption		✓	✓	✓	✓
Crustacea for human consumption					✓
Recreation	Aesthetic	✓	✓	✓	✓
	Primary contact	✓	✓	✓	✓
	Secondary contact	✓	✓	✓	✓
Irrigation and stock watering		✓	✓	✓	✓
Hydro-electric generation		✓			
Industrial water supply			✓	✓	
Drinking water			✓	✓	
Protection of karst ecosystems			✓	✓	



Map 2-4
Mersey-Forth catchments land tenure

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3 Hydro Tasmania Infrastructure and System Operations

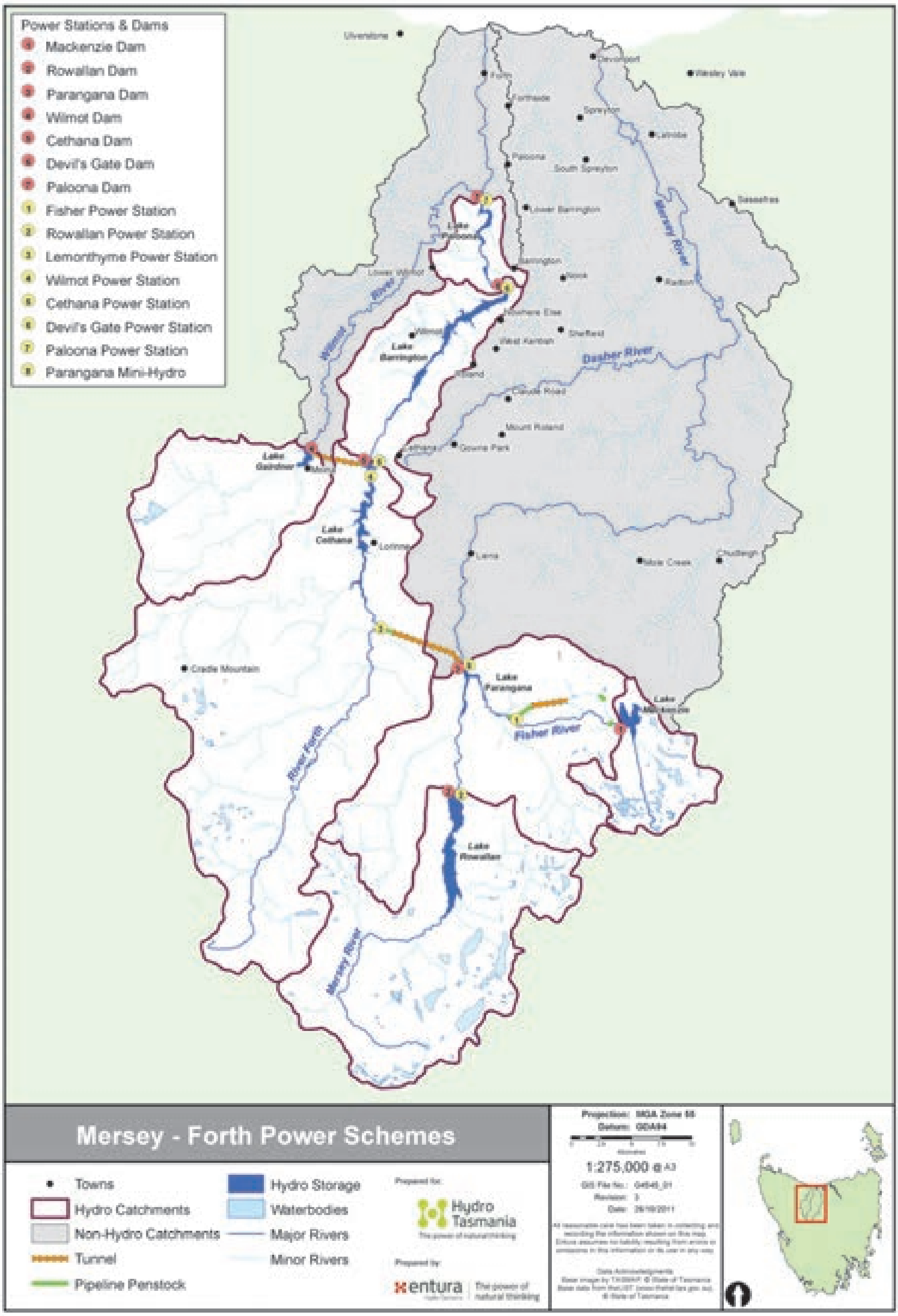
3.1 Overview of the Mersey-Forth Power Scheme

This chapter provides a description of the Mersey-Forth Power Scheme (Map 3-1), its infrastructure and operations, an assessment of river discharges before and after construction, electricity yield, cloud seeding activities, water use and downstream water releases. For general reference Map 3-1 is provided at the back of the report. A generalised relief map of the scheme in the Mersey-Forth catchments is shown on Map 3-2.

The Mersey-Forth Power Scheme was constructed between 1963 and 1973. A mini-hydro power station was later added at Parangana Dam in 2001. The scheme consists of seven lakes and dams, and eight power stations incorporating:

- Lake Rowallan, Rowallan Dam and Rowallan Power Station;
- Lake Mackenzie, Mackenzie Dam and downstream Fisher Power Station;
- Lake Parangana, Parangana Dam and Parangana Power Station (mini-hydro);
- Lake Cethana, Cethana Dam and Lemonthyme, Cethana and Wilmot Power Stations;
- Lake Gairdner and Wilmot Dam;
- Lake Barrington, Devils Gate Dam and Devils Gate Power Station; and
- Lake Paloona, Paloona Dam and Paloona Power Station.

A schematic representation of the Mersey-Forth Scheme is shown in Figure 3-1. Three major tunnels and an inter-catchment diversion of water from the Mersey River catchment, at Parangana Dam, into the catchment of the Forth River is a significant portion of the scheme. Water diversions, weirs and other transfer infrastructure as well as roads, offices, rainfall and water level monitoring devices are also part of the established infrastructure. Appendix C lists Hydro Tasmania's major infrastructure in the Mersey-Forth Power Scheme.



Map 3-1
Mersey-Forth power schemes

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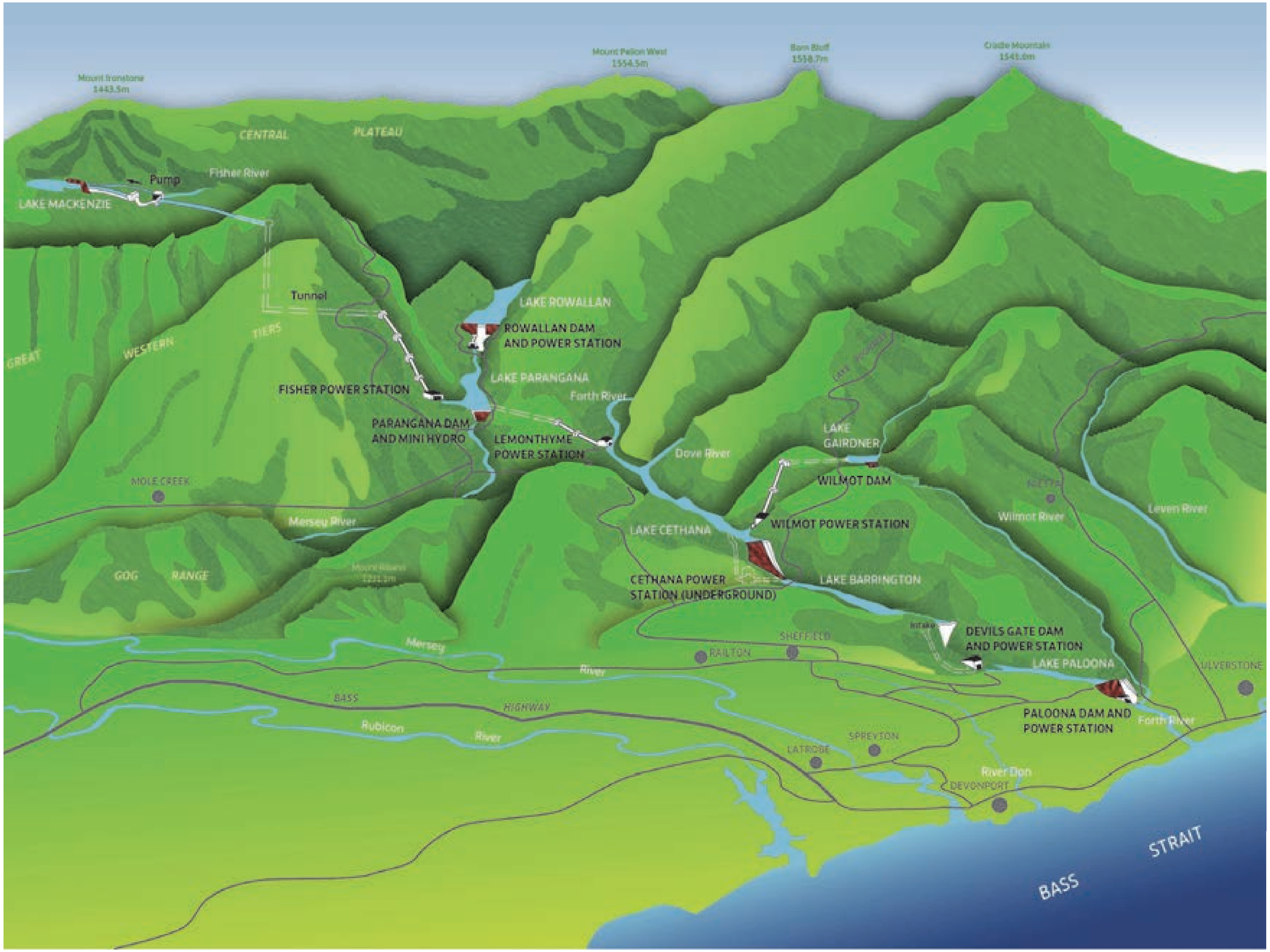


Map 3-2
Generalised relief map of the Mersey-Forth power scheme

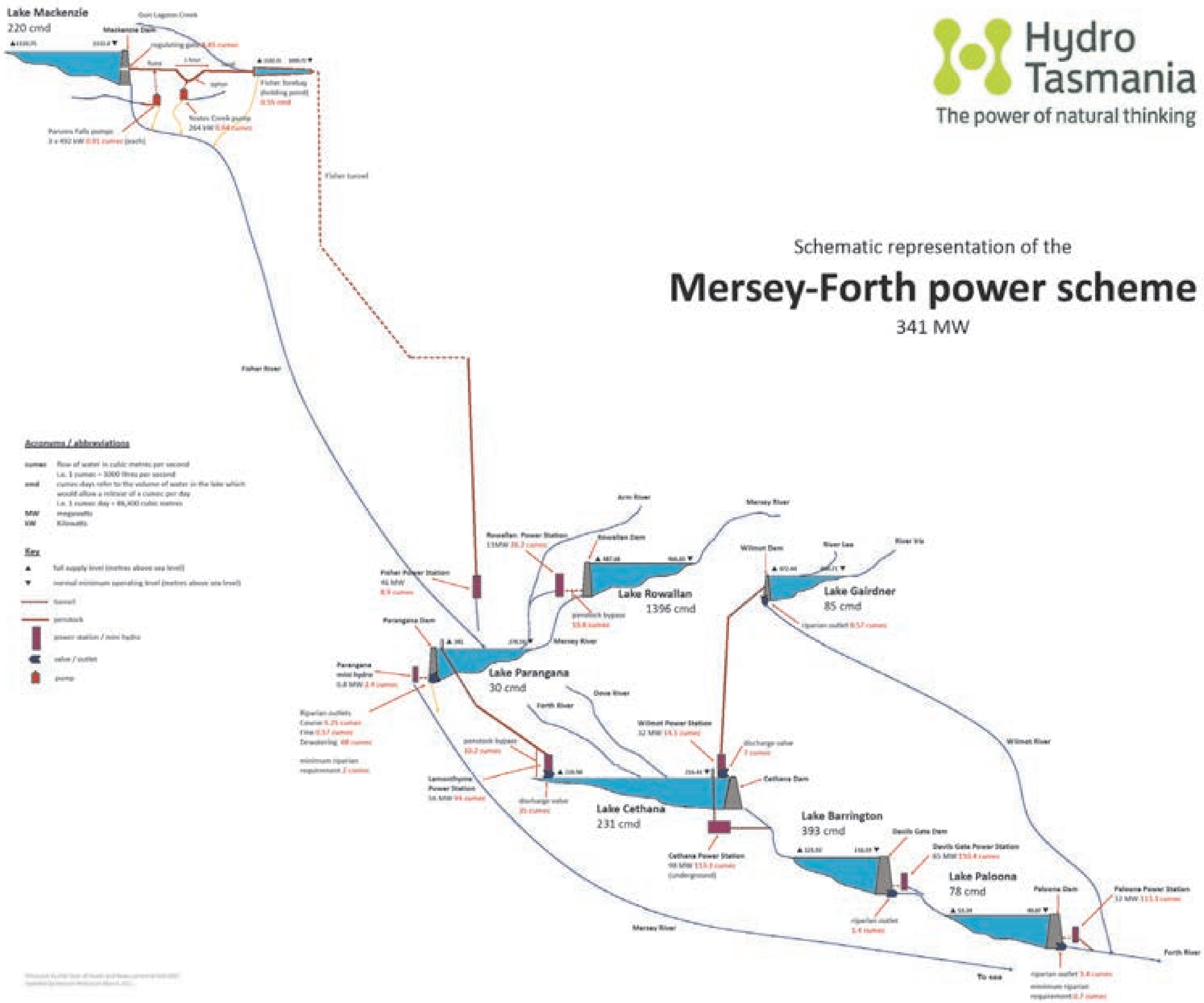


Figure 3-1
Schematic representation of the Mersey-Forth power scheme

3.2 Infrastructure in the Mersey-Forth Power Scheme

3.2.1 Mersey River

Lake Rowallan (Photograph 3-1) is the main headwater storage in the Mersey-Forth scheme. The Mersey River is the primary inflow to Lake Rowallan but the lake also receives water from a number of small streams. Under high inflow conditions, typically at least once a year, the lake spills over the spillway on Rowallan Dam into the Mersey River.

The water from Lake Rowallan passes through Rowallan Power Station into the Mersey River and on to Lake Parangana, which is impounded by Parangana Dam (Photograph 3-1). Other inflows to Lake Parangana are from Lake Mackenzie via the Fisher Power Station. The majority of the water inflow to Lake Parangana is diverted into the Forth catchment via the 6.5 km long Lemonthyme Tunnel into the Lemonthyme Power Station.

Photograph 3-1
Lake Rowallan (top left), Rowallan Dam (top right), Lake Parangana (bottom left) and Parangana spillway (bottom right), October 2010

Hydro Tasmania releases an environmental flow into the Mersey River below the Parangana Dam via the Parangana mini-hydro power station (see section 3.9.1). The flow release is the lesser of 2 cumecs or 8.25 times the flow as measured at the Arm River above Mersey flow monitoring station. At times of high flows water spills over the Lake Parangana spillway into the lower Mersey River.

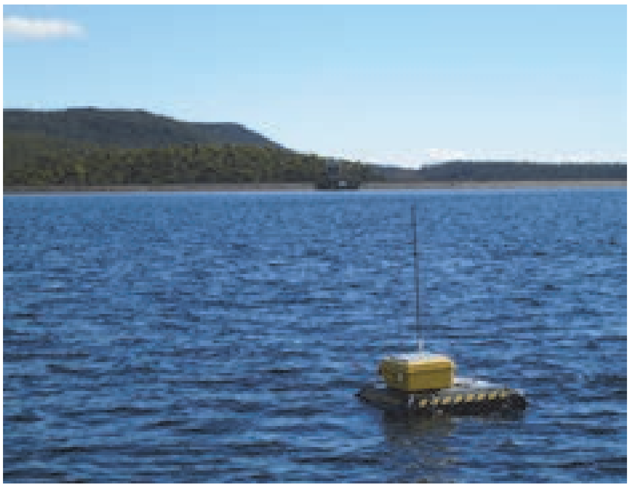
3.2.2 Fisher River

The construction of Lake Mackenzie dam (Photograph 3-2) resulted in the inundation of two natural lakes, Lake Mackenzie and Sandy Lake, and the Pine Marsh wetland. The main inflows into Lake Mackenzie are Fisher River and Explorer Creek. The main outflow is via Fisher Canal and Fisher Tunnel to the Fisher Power Station (Photograph 3-2). The lake spills over the Mackenzie spillway into the Fisher River which then flows into Lake Parangana. Map 3-3 gives a spatial overview of the infrastructure at Lake Mackenzie.

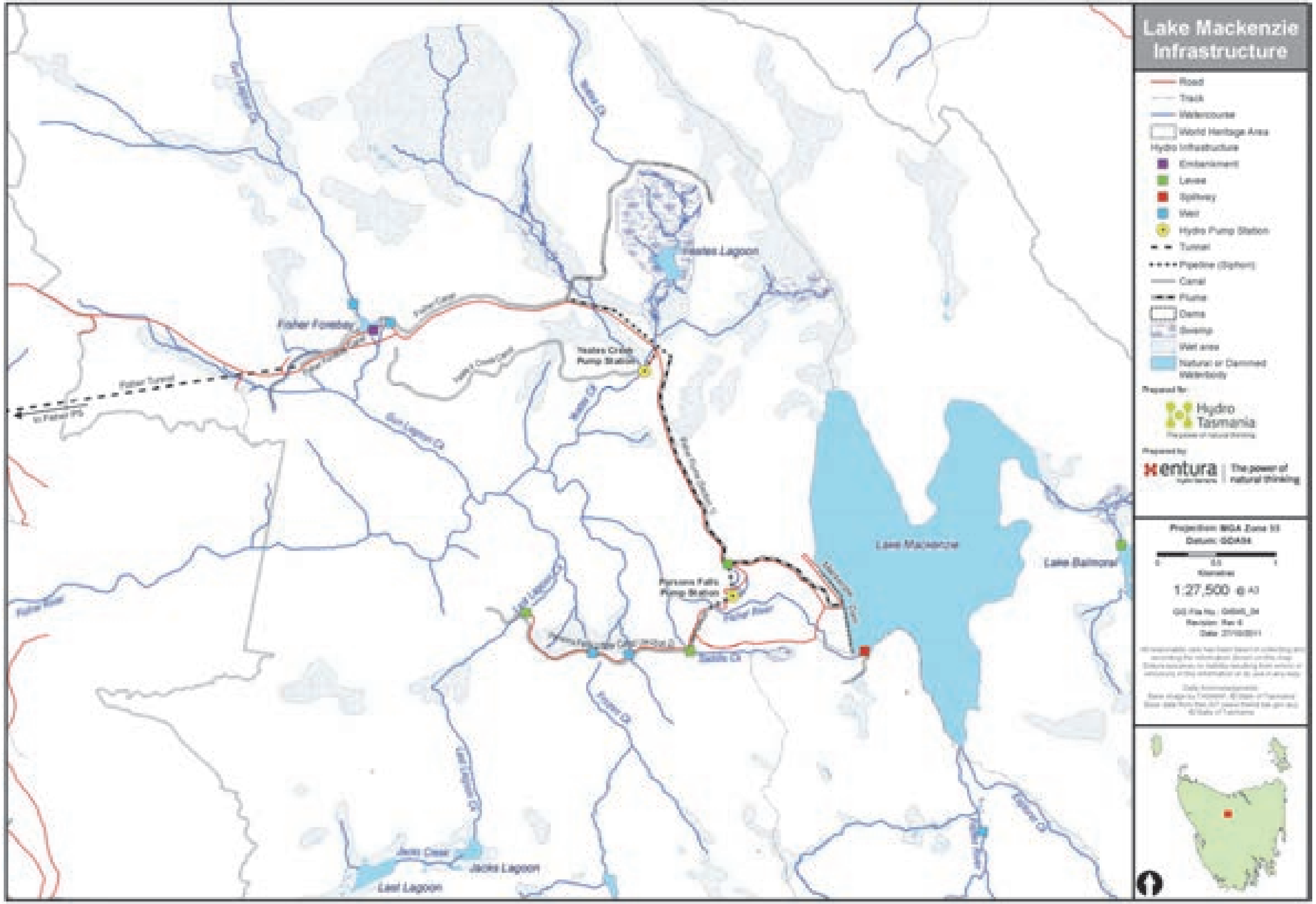
Below Lake Mackenzie, a canal picks up Saddle, Steep, Frozen and Last Lagoon Creeks. A siphon transfers this water into a pump pond where the Parsons Falls Pump Station, with three pumps, transfers the water into the flume section of Fisher Canal. The 6.4 km long Fisher Flume consists of two canal sections, two flume sections, and a pipeline/siphon under Yeates Creek. The open sections pick up a significant amount of run-off from the buttongrass moorland that borders the canal.

Yeates Creek is pumped into Fisher Canal by Yeates Creek pump station, downstream of Parsons Falls pump station. Gunn Lagoon Creek is also diverted into Fisher Canal, downstream of Yeates Canal.

The Fisher River below Lake Mackenzie has been largely dewatered. The Fisher Power Station discharges water back into the Fisher River which then flows into Lake Parangana.



Photograph 3-2
Lake Mackenzie, water quality raft and dam wall in the background (left, March 2011) and Fisher Power Station and Penstock (right, October 2010)



Map 3-3
Infrastructure at Lake Mackenzie

3.2.3 Wilmot River

Lake Gairdner (Photograph 3-3) was created by the construction of Wilmot Dam on the Wilmot River, which is a tributary of the Forth River. The lake receives water from the upper Wilmot River and the local catchment. The main outflow from the lake is via a tunnel and penstock, through Wilmot Power Station and into Lake Cethana. This enables the water to be used at Wilmot, Cethana, Devils Gate and Paloona Power Stations. The diversion generally results in no flow, apart from occasional spill over the dam, in the section of the Wilmot River immediately downstream of the dam.

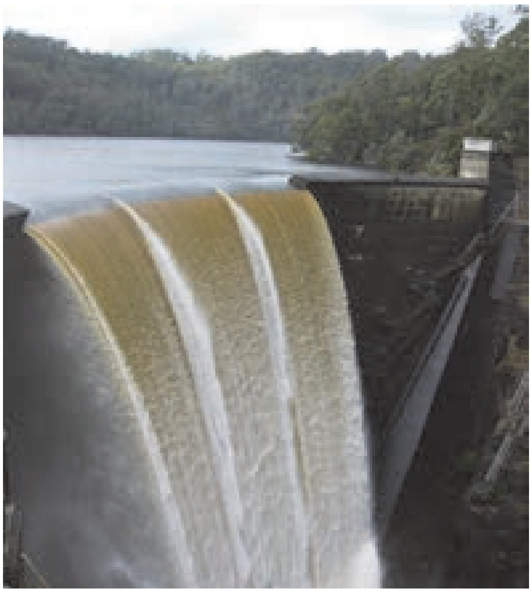
Photograph 3-3
Lake Gairdner (October 2010)

3.2.4 Forth River

Lake Cethana is a long narrow lake which lies in a steep valley of the Forth River behind Cethana Dam (Photograph 3-4). It is the first of three instream impoundments on the Forth River, and receives water from the Forth and Dove Rivers, the upper Mersey catchment via Lemonthyme Power Station, and from Lake Gairdner via Wilmot Power Station. The main outflow of water is through a tunnel to the underground Cethana Power Station. Under high inflow conditions the lake may spill into Lake Barrington over the spillway on Cethana Dam.

Lake Barrington is the second of three impoundments on the Forth River. Again, it is a long, narrow, deep lake, impounded by the Devils Gate Dam (Photograph 3-4) in a steep valley of the Forth River. The main outflow from Lake Barrington is through Devils Gate Power Station, which discharges water into Lake Paloona. Lake Barrington may spill over Devils Gate Dam and into Lake Paloona.

Lake Paloona is the last storage before the coast in the Mersey-Forth system (Photograph 3-4). It flooded a steep, densely forested valley of the Forth River. The outflow from Lake Paloona is through Paloona Power Station, via the spillway on Paloona Dam and the riparian outlet, all of which flow into the lower Forth River almost at sea level.



Photograph 3-4
Cethana Dam (top left, October 2010), Paloona Dam (top right, October 2010) and Lake Barrington and Devils Gate Dam on spill (bottom, August 2010)

3.2.5 Telemetered Monitoring of Flow, Water Quality and Rainfall

Hydro Tasmania actively monitors flows, water quality and rainfall in the Mersey-Forth catchments via its telemetered hydrometric network. Appendix D shows the location of the various hydrometric monitoring sites currently operational in the Mersey-Forth catchments. Remote monitoring is primarily undertaken by Hydro Tasmania to assess inflows to power generation storages, and for compliance, environmental, dam safety, flood forecasting, recreational and community purposes. Data from remote monitoring sites is transmitted automatically, via telemetry, in either real time or at periodic intervals to Hydro Tasmania's Hobart databases. Entura and Hydro Tasmania manage the operation, maintenance, and data collection and distribution services for the hydrometric network.

3.2.6 Dam Maintenance

Hydro Tasmania's approach to dam safety is in accordance with the requirements of the Tasmanian Dam Safety Regulator and ANCOLD (Australian National Committee on Large Dams), and is consistent with contemporary best practice in Australia. Routine surveillance is undertaken at all dams as often as three times weekly. More detailed engineering inspections are done annually to ensure the safety of the dams. Comprehensive surveillance reviews, which assess the performance of the dams and review their operation, maintenance and hazard categories, are generally completed every five years. Dam safety reviews, which are full design reviews against current engineering standards, are undertaken when required. Cethana, Devils Gate, and Paloona Dams have undergone significant upgrades as a result of these assessments. The last dam safety review of Lake Rowallan identified potential improvements which are currently the subject of more detailed assessment.

3.3 Storage Operations

The primary purpose of water releases from all storages in the Mersey-Forth system is power generation. The actual power output for any year varies according to many factors including rainfall patterns, plant outages, electricity demand and transmission constraints. Water releases are also provided for water supply, irrigation, recreation and environmental purposes. Table 3-1 shows operational characteristics of the Mersey-Forth storages. All storages are operated according to Hydro Tasmania's Storage Operating Rules.

Lake levels are controlled between the Full Supply level (FSL) and the Normal Minimum Operating Level (NMOL). The differences in operating ranges vary from 21 metres in Lake Rowallan to 2.5 metres in Lake Parangana. Lake Rowallan has the largest fluctuations in lake level of all the Mersey-Forth lakes because of its role as a seasonal headwater storage. All storages can, at times, be drawn below NMOL. This is normally done to facilitate maintenance outages. Lakes will exceed their FSL during a spill event.

Duration curves for the lakes are included in Appendix E. The average monthly lake levels for the Mersey-Forth lakes are shown in Appendix F. Time series plots over the entire period of operation are provided for each of the seven Mersey-Forth lakes in Appendix G.

Table 3-1
Operational characteristics of storages in the Mersey-Forth Power Scheme

Storage	Operating Range (m)	Power Conversion Factor (kW/cumec)	FSL (mASL)	NMOL (mASL)	Surface Area at FSL (km^2)	Intake Depth (m below FSL)	Storage Type
Lake Rowallan	21	325	487.68	466.65	8.85	32.0	Head Storage - inter-seasonal
Lake Mackenzie	9.8	5344	1120.75	1111.00	2.96	11.5	Head storage
Lake Parangana	2.5	1277	381.00	378.56	1.14	6.6	Run-of-river
Lake Gairdner	11.7	1936	472.44	460.71	0.97	16.2	Run-of-river
Lake Cethana	4.6	778	220.98	216.41	4.74	12.9	Run-of-river
Lake Barrington	5.4	544	121.92	116.59	6.67	11.7	Run-of-river
Lake Paloona	4.3	263	53.34	49.07	1.76	11.4	Run-of-river

3.3.1 Headwater Storages

Lake Rowallan is the primary headwater storage for the Mersey-Forth Power Scheme. It is operated as a seasonal storage and the lake level is drawn down over the drier summer and autumn months to meet hydro-generation (Appendix F; Figure F-2, Appendix G; Figure G-2). In the wetter winter and spring the lake refills as the run-of-river storages are more independent, receiving higher inflows from their own catchments. Lake Rowallan may be operated below its NMOL during a prolonged drought or if infrastructure maintenance is required.

Lake Mackenzie shows some seasonal variance in lake levels, tending to be highest in winter and spring and lowest in autumn (Appendix F; Figure F-1).

3.3.2 Run-of-River Storages

Parangana, Cethana, Gairdner, Barrington and Paloona are all run-of-river storages.

While Lake Parangana shows little seasonal variance (Appendix F; Figure F-3) water levels in the lake fluctuate rapidly (Appendix G; Figure G-3) illustrating the operation of Lemonthyme Power Station responding quickly to changes in electricity demand.

Lake Cethana and Lake Gairdner show little seasonal variation in lake level (Appendix F; Figure F-4, Appendix F; Figure F-5), however, water levels in both lakes fluctuate in response to varying inflows and generation requirements (Appendix G; Figure G-4, Appendix G; Figure G-5). Lake level fluctuations are relatively large in Lake Gairdner with annual changes in excess of 10 m common (Appendix G; Figure G-5).

Lake Barrington shows a small seasonal pattern in water levels (Appendix F; Figure F-6). Water levels in Lake Barrington are generally maintained between 120.5 and 121.5 mASL (Appendix G; Figure G-6), reflecting its use for rowing and other recreational activities.

Lake Paloona does not show any clear seasonal patterns in water level (Appendix F; Figure F-7). Lake Paloona water levels tend to fluctuate rapidly within a narrow band between 51 and 53 mASL (Appendix G; Figure G-7) responding to changes in hydro-generation requirements without causing large short-term fluctuations in downstream flows.

Major maintenance within the Mersey-Forth system tends to be coordinated across the whole of the storage chain occurring mainly in January to March, and less frequently in December and April.

3.3.3 Lake Level Agreements

Of the seven storages in the Mersey-Forth catchments Lake Barrington is the only one where operations are regularly modified to meet recreational requirements. Hydro Tasmania may be requested by the Tasmanian Rowing Council (and its affiliated organisations) to keep the level of Lake Barrington high for a period of days for rowing events. Hydro Tasmania endeavours to meet these requests but this may not always be possible due to operational requirements.

3.4 Power Station Operation

Table 3-2 lists the discharge from the power stations when operating at efficient load and full gate, assuming that the lakes are at full supply level. At efficient load, a power station machine uses the optimal flow of water necessary to generate power. The maximum flow through a turbine is referred to as full gate flow.

Table 3-2
Discharge from Mersey-Forth Power Stations at efficient load and full gate at full supply levels

Power Station	Discharge at Efficient Load (cumecs)	Discharge at Full Gate (cumecs)
Rowallan	19.2	26.9
Fisher	5.8	8.5
Lemonthyme	35.0	44.1
Wilmot	13.6	14.4
Cethana	91.0	109.0
Devils Gate	92.0	115.0
Paloona	50.0	120.9
Parangana Mini Hydro	-	2.5

Rowallan Power Station is typically operated on 'base' load, generating a reasonably steady output all day. It is run fairly continuously throughout the drier period of the year and it is usually shut down in wetter periods, in winter and spring, when other dams downstream are on spill. The power station may also be turned off in the summer when downstream maintenance is being carried out to prevent unnecessary spill at downstream dams or simply to conserve water for later use.

For the safety of people who use the river downstream of Rowallan Power Station the station undertakes a start-up regime. The station is stepped up gradually rather than turned on to efficient load immediately. The station is run on zero load for two hours, one megawatt for one hour and 2 megawatts for one hour. The turbine can then be loaded as required. This is intended to provide a warning to river users that flows are about to increase and that they should move out of the river channel. There are also warning signs on all rivers stating that water levels can increase at any time.

Fisher Power Station is operated at full gate if there is a high risk of spill at Lake Mackenzie. The station generates a fairly consistent base load over winter and spring. During the summer the small capacity in Lake Mackenzie only allows Fisher Power Station to provide electricity at peak times.

The other power stations in the Mersey-Forth system are run-of-river power stations.

To address downstream safety considerations downstream of Paloona Dam, a slow, stepped start up regime is used. The machine is initially loaded to two MW and then increased over a 20 minute period to seven MW which is maintained for two hours. The generator load may then be increased to the required load at rate of four MW per five minute interval.

3.5 River Discharge Alteration Before and After Dam Construction

Appendix H shows discharge duration curves for pre- and post-development periods, downstream of Fisher Power Station, Parangana Dam and Paloona Power Station. These curves show the frequency of occurrence of specific flows below identified major structures, and indicate the biggest changes to natural flow regimes as a result of hydro-generation development in the Mersey-Forth catchments.

While the Fisher River immediately below the dam is dewatered, due to the diversion of water from Lake Mackenzie to Fisher Power Station, maximum flows (occurring less than 1% of the time) in the Fisher River downstream of Fisher Power Station have only been slightly reduced post-development (Appendix H; Figure H-1). The median flows (exceeded 50% of the time) have increased from 3.5 to 7.7 cumecs. This is due to the controlled release of stored water from Lake Mackenzie for power generation. Overall, post-development flows in the Fisher River downstream of Fisher Power Station are less frequently in the >15 cumecs range and more frequently in the <15 cumecs range. This is due to the regulation of river flows to manage power generation providing more consistent, smaller releases of water compared to natural flows.

Flows in the Mersey River at Liena (Appendix H; Figure H-2) have been significantly reduced by development of the Mersey Power Scheme and the transfer of water from Lake Parangana into the Forth catchment. Post-development, river flows are lower at least 95% of the time than under natural conditions by up to 75 cumecs. Median flows have been reduced from 17 to 1 cumec and the frequency of flows greater than 200 cumecs has been reduced.

Although the magnitude of high-flow events in the Forth River (those occurring less than 5% of the time) downstream of Paloona Power Station has decreased post-development, flows have generally increased compared to natural conditions (Appendix H; Figure H-3). The median flow has increased from approximately 19 to 54 cumecs, with post-development flows significantly exceeding natural flows from 10 to 75% of the time, reflecting the diversion of flows from the upper Mersey and Wilmot Rivers into the lower Forth River.

3.6 Electricity Yield

The water available for both hydropower generation and other uses in the Mersey-Forth catchments is affected by rainfall and the amount of runoff into the waterways. The amount of water available in the future will also be influenced by annual variability in rainfall and the impacts of climate change (Chapter 4).

Hydro Tasmania calculates yield based on the amount of energy that could be generated with the available water. Analysis of modelled yield trends for the Mersey-Forth catchments has identified a downward trend over the period from 1924-2010. While the yield in the Mersey-Forth catchments are naturally variable, the magnitude of the trend amounts to approximately 2.4% reduction in yield per decade (Figure 3-2).

In response to the recent period of prolonged low rainfall, and climate change projections (see Chapter 4 Climate Change) Hydro Tasmania has revised the target yields for the Mersey-Forth Power Scheme from a modelled long term mean yield of 1524 GWh to 1393 GWh.

Hydro Tasmania will continue to update its long term analysis on inflows as more data is accumulated.

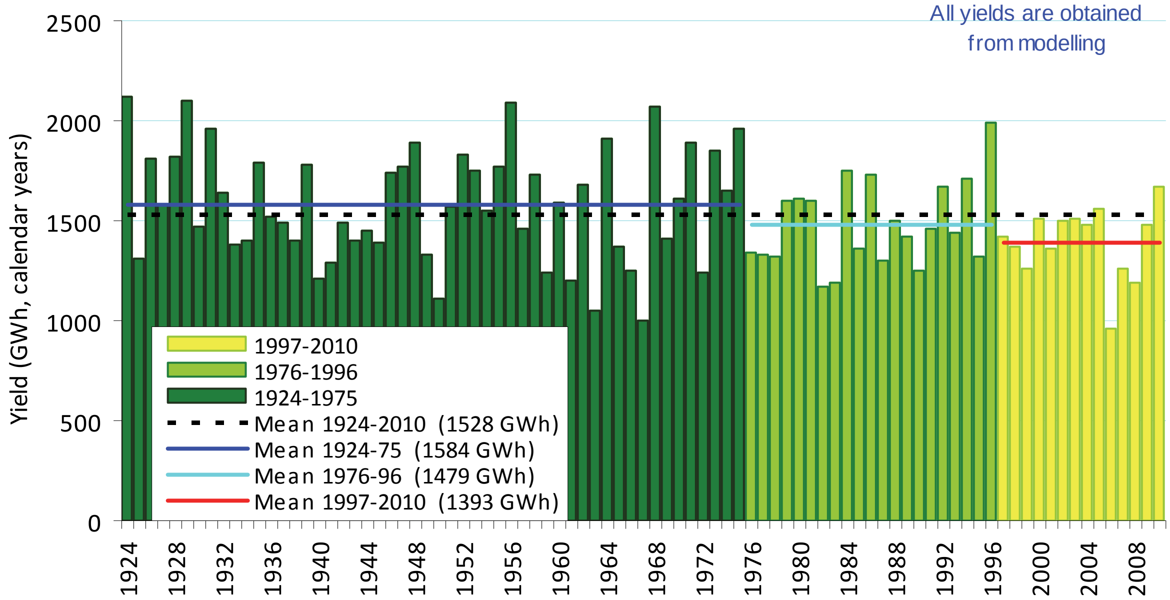


Figure 3-2
Modelled electricity yield from the Mersey-Forth Power Scheme

3.7 Cloud Seeding

In times of low precipitation, between April and October, Hydro Tasmania conducts cloud seeding operations which target, amongst other areas, the upper Mersey-Forth catchments (Hydro Tasmania 2007). The Mersey-Forth was cloud seeded six times in 2007, and five, one and four times in 2008 to 2010 respectively.

3.8 Irrigation and Industry Water Use

The greatest demands on water into the future, for other uses than hydro generation, are likely to come from irrigation for agricultural purposes. Increased levels of heavy industry in the catchments may also place demands on water.

Currently there are no formal irrigation schemes in the Mersey-Forth catchments, however, irrigators along the Mersey, and to a lesser extent the Forth, do extract water for irrigation purposes. A number of irrigation developments are expected to draw water from the Mersey-Forth: the Sassafras-Wesley Vale Irrigation Scheme and the planned Forth Irrigation Scheme being two notable examples.

3.9 Downstream Water Releases for Water Supply, Environmental Flow and Recreation Arrangements

3.9.1 Obligatory Water Releases

Forth River: Water Release for Urban Water Use

Hydro Tasmania maintains a minimum flow of 0.71 cumecs at the Forth River below Paloona Power Station for town water supplies.

Mersey River: Industrial Releases

Under the *Wesley Vale Pulp and Paper Industry Act 1961* Hydro Tasmania was obliged to make water available during periods of naturally low flows for the Wesley-Vale paper mill. As the mill closed in 2010 a proportion of this water has been made available, if required, to irrigators in the Sassafras-Wesley Vale Irrigation Scheme.

Mersey River: Environmental Flow

"Environmental flows" are river flows or flow regimes which are managed to achieve specific environmental goals, for example, maintenance of a water quality objective, or maintenance of a particular biological community in terms of species diversity and abundance. Environmental flows are released where there is an identified impact arising from altered flow regimes.

During the 1990's Hydro Tasmania participated in the Mersey River Working Group, which investigated several flow options below Parangana Dam to increase usable habitat area and flow for fish and macroinvertebrates in the Mersey River. The Working Group included representatives from the Department of Primary Industries and Fisheries, Department of Environmental and Land Management, the Inland Fisheries Service and the local community. The resulting report included the key recommendation to maintain a year-round flow of 2 cumecs below the Parangana Dam in order to restore in-stream habitat for aquatic biota (MRWG 1998).

Since 1999 Hydro Tasmania has endeavoured to maintain a flow in the Mersey River below Parangana Dam of the lesser of 2 cumecs or 8.25 times the flow as measured at the Arm River above Mersey flow monitoring station. This flow is delivered via the Parangana mini-hydro power station which is attached to the riparian outlet in the bottom of Parangana Dam.

Refer to Chapter 6.5 for information on environmental monitoring as part of the Mersey River Environmental Flows assessment.

3.9.2 Voluntary Water Releases

Hydro Tasmania voluntarily meets requests for water releases for canoeing and rafting events, when possible, but reserves the right to cancel releases at any time.

Over an 18 month period (January 2010 and July 2011), Hydro Tasmania received approximately 350 requests for recreational water releases. Seventy eight per cent of these requests were associated with the Mersey-Forth catchments and were for releases at Lakes Rowallan and Paloona. Hydro Tasmania was able to meet approximately 70% of total requested releases in the Mersey-Forth catchments. Due to unexpected high/low flows, or outages, the business was not able to provide 20% of the requests made and another 10% of requests were cancelled by the stakeholders.

Situations where voluntary water releases are being provided by Hydro Tasmania are explained below.

Mersey River: Water Release for Canoeing and Rafting

A white water canoe and raft course has been constructed in the Mersey River between Lakes Rowallan and Parangana. A typical flow requested is between 24 and 27 cumecs.

Fisher River: Water Release for Canoeing

There are occasional requests to canoe the Fisher River below Fisher Power Station. The typical flow requested is around 8.5 cumecs which requires operating the power station at full gate.

Forth River: Water Release for Canoeing

A canoe course exists downstream of Paloona Dam. The typical flow requested is 34 cumecs.

4 Climate Change

The El Niño Southern Oscillation (ENSO) is a climatic phenomenon which influences rainfall over Australia's eastern states. El Niño events are usually associated with lower than average rainfall over parts of eastern Australia. La Niña events are usually associated with above average rainfall over parts of eastern Australia. The patterns of rainfall and runoff in the Mersey-Forth catchments are influenced by the ENSO during autumn and summer. Other climate drivers which affect rainfall in the Mersey-Forth catchments are the Blocking Index in autumn, and the Southern Annular Mode Index (SAM) and Dipole Mode Index (DPI) in spring and summer (Grose *et al.* 2010).

Hydro Tasmania has been pursuing greater insight into the potential impacts of climate change on its operations and has supported research activities in this area. Hydro Tasmania has been a partner in the Climate Futures for Tasmania (CFT) project which was undertaken by the Antarctic Climate and Ecosystem Cooperative Research Centre (ACE-CRC) from 2007-2010.

4.1 Climate Change Projections

The Climate Futures for Tasmania project was developed to provide information on predicted climate change impacts at a local scale by downscaling Global Climate Models (GCMs), with a scale of 120 - 150 km per grid cell, to a local scale of 10-15 km grid cells. Climate Futures for Tasmania has recently released results from downscaling six global climate models, analysing the trends in climatic and hydrological variables under a range of climate change scenarios (Bennett *et al.* 2010). Interpreting these can present difficulties since the six climate model projections are considered equally likely to occur and can give a wide spread of results. There is most confidence in the relatively large regional and seasonal changes on which these models show strong agreement (Bennett *et al.* 2010). It is the implications of these projections for the Mersey-Forth catchments that are presented in this chapter.

Results from the modelling indicate that natural variability is likely to play a greater role than anthropogenic climate change in influencing runoff for the near future (2010-2039) and medium-term future (2040-2069). However, the strength of the effects of anthropogenic climate change is expected to increase throughout the 21st century (Bennett *et al*. 2010).

4.1.1 Projected Annual Rainfall

Nationwide, there are several research initiatives on the impacts of climate change on water availability. Grose *et al.* (2010) found that annual state-wide rainfall over Tasmania will not change significantly over the next century. Figure 4-1 presents the projected precipitation based on six GCM's, with the Intergovernmental Panel on Climate Change (IPCC) A2 Emissions Scenario which is a multi-model approach for developing a carbon dioxide emission scenario. The range of model predictions (indicated by the pink minimum and maximum lines) shown together with the mean (red line) and actual (black line) of the six models. While there seems to be little predicted change in total annual precipitation state-wide, the spatial and temporal variation of rainfall is projected to change (Grose *et al.* 2010).

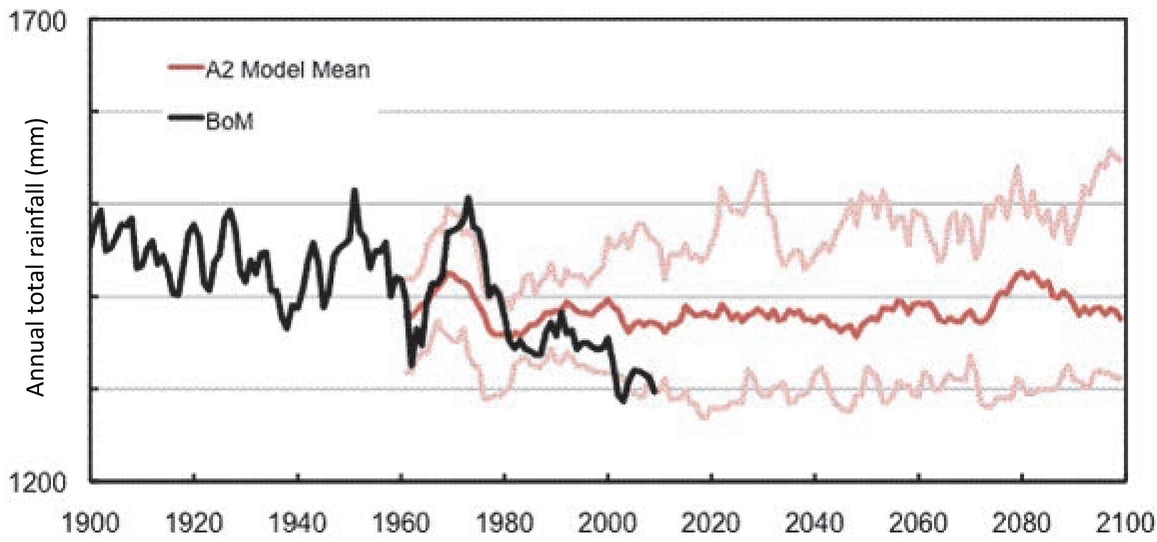


Figure 4-1
Tasmania state-wide precipitation (Grose *et al.* 2010). Dark pink line represents model mean from the six GCMs. Lighter pink lines represent the maximum and minimum for each year from the six GCMs.

4.1.2 Projected Runoff

Recent modelling by the CFT project predicts decadal variations in runoff across the state. Summer runoff in the northwest is projected to decrease throughout the 21st century, culminating in decreases of more than 20% for much of the north-west. By 2100, it is projected that much of the State will experience decreased or little-changed frequency of lower runoff events, and increases to higher runoff events. This suggests changes in the character of stream flows: hydrographs may rise faster, to higher peaks, and drop more quickly (Bennett *et al.* 2010). Projected changes to annual inflows and runoff into the Mersey-Forth catchments are presented in Figure 4-2

The impacts of historical and projected variability on the aquatic environment are not fully understood. Hydro Tasmania will continue to participate in State and Federal Government initiatives to understand the potential impacts of climate change on the aquatic and terrestrial environment. From this, opportunities for adaptation will be identified.

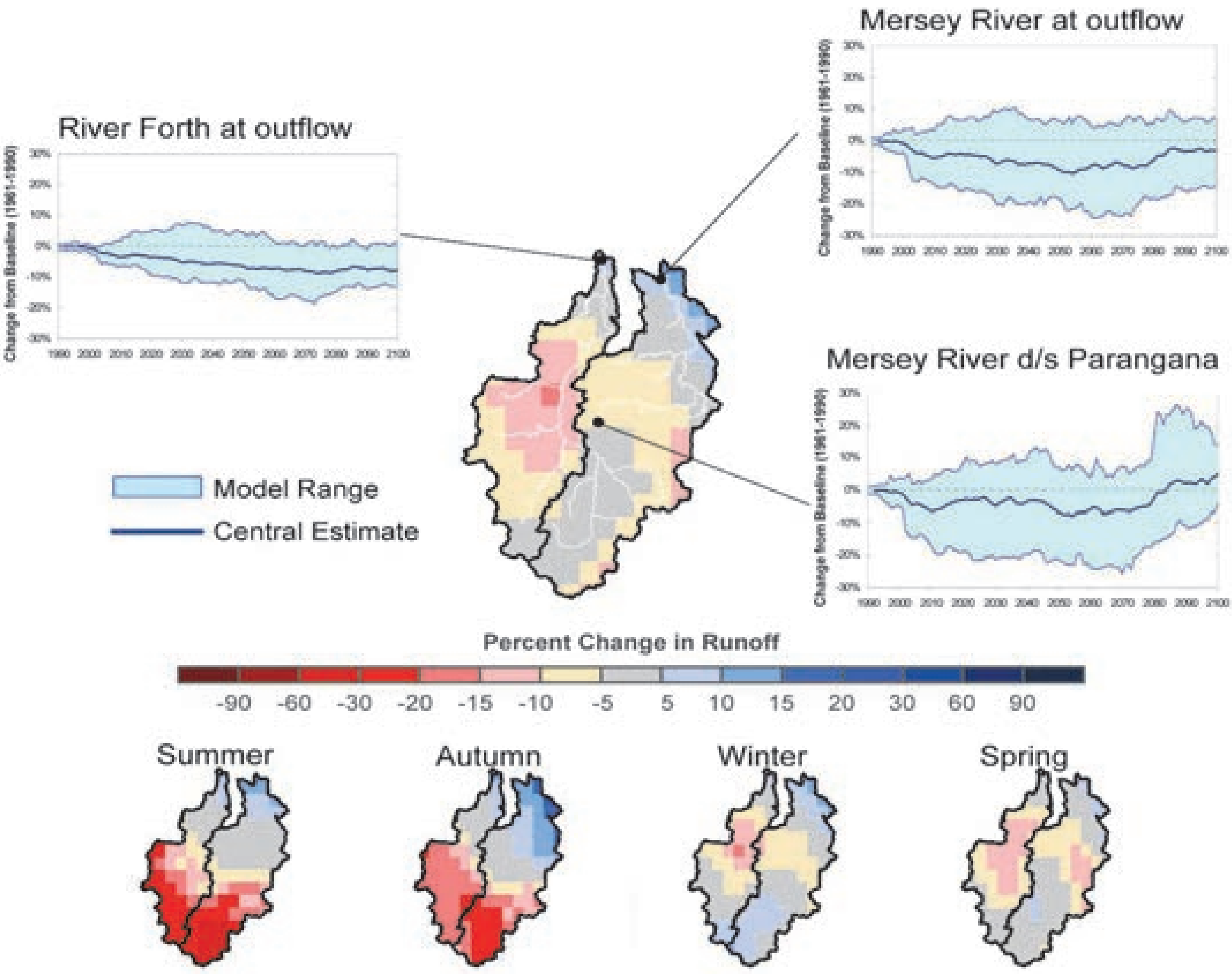


Figure 4-2
Seasonal inflow and runoff change in the Mersey-Forth catchments 2070-2099 versus 1961-1990
(Bennett *et al*. 2010)

5 Water Quality

This chapter presents a summary of the findings of water quality monitoring (Photograph 5-1) in the rivers and lakes of the Mersey-Forth Power Scheme. Waterways and years of monitoring are listed in Appendix I. The data presented and analysed in this section has been obtained from all of the lakes and rivers sites monitored for at least one year between 1974 and 2010 in the Mersey-Forth catchments. Water quality statistics were compared against guideline values (ANZECC & ARMCANZ 2000) for the ecosystem protection of freshwater lakes, reservoirs and rivers in Tasmania/south-eastern Australia (Appendix J; Table J-1). Cyanobacterial biovolumes were assessed against National Health and Medical Research Council (NHMRC 2008) alert levels (Appendix J; Table J-2).

Photograph 5-1
Water quality monitoring in a Mersey-Forth river (left, Peter Harding,) and lake (right, Kristin Schumann and Peter Harding), October 2010

5.1 Monitoring of Lakes and Rivers

All seven Mersey-Forth lakes have been monitored for physico-chemical parameters, total and soluble nutrients and selected metals (Appendix D). Summary statistics are presented in Appendix K. Water column physico-chemical profiling (Appendix L) and algal sampling (Appendix M) were also completed as part of a bi-monthly sampling program in 2010/11.

Nine river sites have been monitored for water quality (Appendix N). Water quality statistics are provided where there are more than 10 samples on record for physico-chemical parameters (Appendix N; Table N-1), but where there are less, the individual records are tabulated (Appendix N; Table N-2).

5.2 Mersey-Forth Lakes

The waters of the Mersey-Forth lakes are clear and fresh, indicated by low turbidity and low conductivity, but tend to be rich in oxidised nitrogen (NO_x-N; 80th percentiles exceeding ANZECC guidelines) particularly in the lakes lower in the catchments (Appendix K).

5.2.1 Temperature

Maximum depths (at the dam wall) for the Mersey-Forth lakes range between 14 m (Lake Mackenzie) and 110 m (Lake Cethana) (Appendix C). Temperature profiles plotted for the deepest sites in each of the lakes, measured at approximately 1 m intervals through the water column, show that all lakes except Lake Mackenzie (not shown) were thermally stratified to some extent in 2010-11 (Appendix L; Figure L-1). In the deepest lakes (Cethana and Barrington) stratification started to develop in spring. The thermoclines established at a depth of approximately 20 m were then not broken down until winter, and surface water temperatures were around 5 to 15 degrees warmer than bottom waters. The shallower lakes (Paloona, Gairdner, Rowallan and Parangana) showed some signs of stratification but to a lesser extent and for shorter periods of time.

Lake Mackenzie may be susceptible to seasonal ice formation (depending on wind conditions) due to its high elevation and water temperatures recorded below 4^{o}C (20th percentile = 3.26^{o}C).

5.2.2 Dissolved Oxygen

The 20th percentile of dissolved oxygen (per cent saturation) samples was below ANZECC triggers for five of the seven lakes in the Mersey-Forth catchments (Appendix J) for surface water measurements. However, dissolved oxygen concentration (mg/L) was often not as depleted as the per cent saturation data would suggest. This may be due to calibration issues as altitude effects the solubility of oxygen in water. There are times when the surface waters of five of the lakes (Rowallan, Parangana, Cethana, Barrington and Paloona) have been oxygen depleted.

Seasonal dissolved oxygen stratification occurred to some degree in all of the Mersey-Forth Lakes in 2010/11 (Appendix L; Figure L-2) except Lake Mackenzie (not shown). Profiles for Lakes Rowallan, Parangana and Gairdner (down to a depth of 20 to 25 m) showed some degree of oxygen depletion in bottom waters in summer, but dissolved oxygen concentrations were predominantly within ANZECC guidelines. Profiles for Lakes Cethana and Barrington showed oxyclines at around 20 m, particularly in summer and autumn. Below the oxycline dissolved oxygen concentrations were well below the lower ANZECC guideline of 90% saturation. Profiles for Lake Paloona down to a depth of 25 m indicate stratification in summer, but dissolved oxygen concentrations were low (80%) throughout the water column and remained low (less than the ANZECC guideline of 90%) in autumn and winter.

5.2.3 Conductivity

Electrical conductivity (EC) of the water in all of the Mersey-Forth lakes was consistent with the guidelines at the 20th percentile (Appendix K). Only at Lake Gairdner does EC exceed the guideline at the 80th percentile (38.25 μs/cm).

5.2.4 Turbidity

Turbidity for all lakes was within ANZECC guidelines (Appendix K). However, at low lake levels, Lake Mackenzie and Lake Gairdner may be susceptible to wind resuspension of sediments.

5.2.5 pH

The pH of the water in the lakes was generally neutral (median 6.5 to 7.0) (Appendix K). However, pH in Lakes Mackenzie, Cethana, Gairdner and Paloona was more acidic than the minimum guideline (i.e. <6.5) at the 20th percentile.

5.2.6 Nutrients and Productivity

Total phosphorus (TP), filterable reactive phosphorus (FRP) and total nitrogen (TN) were within ANZECC guideline values at the 80th percentiles for all lakes (Appendix K). Filterable reactive phosphorus concentrations were mostly low and near the detection limit of the assay.

The concentration of nitrogen as ammonia (NH_3-N) was within ANZECC guidelines for most of the Mersey-Forth lakes except Lakes Gairdner and Paloona which exceeded guidelines (0.010 mg/L) at the 80th percentile. Concentrations of nitrogen as nitrate + nitrite (NO_x-N) exceeded the ANZECC guidelines at the 80th percentile for all lakes except Lake Mackenzie and could stimulate primary production.

Chlorophyll-*a* concentration is an indicator of the algal biomass in the water and tends to fluctuate seasonally. Six of the seven lakes have recorded maximum chlorophyll *a* values higher than the ANZECC trigger level (Appendix K). Lake Gairdner is the exception. The 80th percentiles for all lakes were below the ANZECC trigger level, suggesting none of the lakes have prolonged high algal biomass.

Algal species density data was collected in 2010/11 and it appears that diverse algal communities were present in many of the lakes in summer. Cyanobacteria were not detected in August, October or December 2010, but were present in April and June 2011 and were a significant component of phytoplankton in February 2011. Cyanobacterial biovolumes were below the NHMRC surveillance alert level throughout the period (Appendix M).

5.2.7 Metals

Concentration data for iron (Fe^{2+}), manganese (Mn^{2+}) and aluminium (Al^{3+}) from water samples is summarised in (Appendix K). Manganese concentrations in all lakes were well below the ANZECC and there are no ANZECC triggers for iron.

Aluminium concentrations exceeded the ANZECC guideline trigger (0.055 mg/L). The toxicity of aluminium to biota varies depending on the pH of the water and the ANZECC guideline trigger of 0.055 mg/L for aluminium applies to waters with pH>6.5. The guideline trigger falls to 0.0008 mg/L for water with pH<6.5 and is considered less reliable, as there is insufficient data available to assess the toxicity of aluminium at low pH (ANZECC & ARMCANZ 2000). All of the lakes in the Mersey-Forth catchments have recorded pH above and below 6.5. Therefore it is difficult to assess the significance of aluminium concentrations in these lakes. Only Lake Mackenzie has a median aluminium concentration below 0.055 mg/L.

5.3 Mersey River and Tributaries

There is a substantial record of water quality measurements in the Mersey River at Liena and Kimberley. Water quality statistics (Appendix N) indicate that water quality in the headwaters of the Mersey River is excellent. EC tends to increase lower in the catchment (exceeding the Tasmanian rivers median of 90 µS/cm indicated by ANZECC for the Mersey River at Kimberley), below the diversion to the Forth River. pH of the water has a wide range (6.31 – 9.24 at Kimberley and 5.50 – 9.65 at Liena). However, the extremes of this range are infrequent, reflected in narrow ranges for pH for the 20th and 80th percentiles: 7.51 – 8.29 at Kimberley and 7.13 – 7.55 at Liena.

There is much less data available for the Fisher and Arm Rivers (Appendix N; Table N-1). Water quality in the Fisher and Arm Rivers is generally very good with EC and turbidity consistently below the minimum ANZECC guideline values, reflecting the near-pristine condition of this headwater catchment. However, the pH of the Fisher River varies over a wide range (4.95 – 8.40) and the source(s) and pattern(s) of this fluctuation have not been clearly identified, nor has their impact on the receiving waters of Lake Mackenzie.

5.4 Forth River and Tributaries

There is a substantial record of water quality measurements for the Forth River below Wilmot River and below Lake Paloona (Appendix N; Table N-1). Water quality below Paloona is good. Conductivity, dissolved oxygen and turbidity were within ANZECC guidelines, but pH was more acidic than the guideline at the 20^{th} percentile. Conductivity, turbidity and nutrient concentrations at sites downstream of Paloona were higher than those at sites in the upper catchments.

There is limited water quality data available for the headwaters of the Forth River above Lemonthyme Power Station. Water in these headwaters is generally considered pristine as the catchments lie within the Tasmanian Wilderness World Heritage Area, and the occasional measurements taken indicate good water quality (Appendix N; Table N-1).

There is also little data for the Wilmot River. Conductivity and NO_x-N at the Spellmans Bridge site exceeded the guidelines for four of the six samples, but the other parameters were within the ANZECC guidelines (Appendix N; Table N-1).

5.5 Summary of Water Quality Issues

Water quality related issues that have been identified in the Mersey-Forth catchments are summarised for lakes (Table 5-1) and river sites (Table 5-2) and include the following:

- Stratification in storages and implications for nutrient and metals cycling;
- Possible release of oxygen depleted water from stratified lakes that could impact on downstream biota;
- Oxygen depletion in the lakes of the Forth River (Lakes Cethana, Barrington and Paloona);
- Elevated NOx-N concentrations in lakes that may promote algal growth;
- Elevated aluminium concentrations may present a risk to biota. However, the toxicity of aluminium to biota is complex, dependent on the chemistry of the water and the pH of the water body;
- Limited data is available for rivers in the catchments; and
- Wind-induced resuspension of sediments may occur in Lakes Mackenzie and Gairdner when water levels are low. The extent to which current operations may allow this to occur and any resultant affects on water quality has not been quantified.

Table 5-1
Water quality issues summary by lake

Lake / Issue	Thermal stratification*	Oxygen depleted hypolimnion*	Oxygen depleted surface waters	Elevated nutrients	Acidity	Elevated Aluminium	Wind-induced resuspension of sediments
Lake Mackenzie	None	No	No	No	Yes	No	Yes
Lake Rowallan	Summer	Yes	Yes#	Yes	No	Yes	No
Lake Parangana	Summer, autumn	Yes	Yes#	Yes	No	Yes	No
Lake Gairdner	No data for summer	Yes	No	Yes	Yes	Yes	Yes
Lake Cethana	Summer, autumn, winter	Yes	Yes	Yes	No	Yes	No
Lake Barrington	Summer, autumn, winter	Yes	Yes	Yes	No	Yes	No
Lake Paloona	Summer	Yes	Yes	Yes	Yes	Yes	No

* deep water measurements from bimonthly depth profile data August 2010 to June 2011
# from historic data only, not observed in 2010-11

Table 5-2
Water quality issues summary by river site

River / Issue	Elevated EC	Oxygen depleted	Elevated Turbidity	Elevated nutrients	Acidity
Mersey River at Liena	No	-	No	-	No
Mersey River at Kimberley	Yes	No	No	-	-
Fisher River upstream Lake Mackenzie	No^	-	No^	No^	No^
Forth River upstream Lemonthyme	No^	No^	No^	-	No^
Forth River at Wilmot	No	No	No	Yes^	No
Forth River upstream Sayers Hill Weir	Yes^	-	-	Yes^	-
Forth River upstream Forth Bridge	-	No^	-	-	-
Arm River at road bridge	No^	No^	No^	No^	No^
Wilmot River at Spellmans Bridge	Yes^	No^	No^	Yes^	No^

^ limited data available, – no data available

6 Biological Aspects

The aquatic ecosystems within the Mersey-Forth catchments support many biological values including threatened species and species with high conservation value. Known biological values and the issues affecting them are presented in this chapter.

6.1 Threatened Waterway Dependent Species

Waterway dependent species (for the purposes of this review) are those that are dependent on aquatic ecosystems (rivers and lakes) or habitats that are associated with aquatic environments (riparian zones, lagoons, swamps, drains and wetlands, both partially or entirely inundated) for either all, or part of their life cycle. According to the Natural Values Atlas (NVA) online database (DPIPWE 2010) there are 41 waterway dependent fauna and flora species within the Mersey-Forth catchments which are listed as rare, vulnerable, endangered or critically endangered under the Tasmanian *Threatened Species Protection Act 1995* (TSPA) and/or the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBCA).

6.1.1 Fauna

Of the fifteen threatened waterway dependent fauna species recorded from the Mersey-Forth catchments only three have been recorded from within Hydro Tasmania managed catchments (Table 6-1; Map 6-1). Information on the three species is provided below.

6.1.1.1 Green and Gold Bell Frog

Green and Gold Bell Frog (*Litoria raniformis*), listed as vulnerable under the EBPCA and TSPA, has been reported from wetlands near Wilmot in the Forth catchment. Very little is known about the ecology and population biology of the species. The decline in Tasmania has been attributed to wetland drainage, lowering of the water table and associated removal of native vegetation, and the destruction of wetlands by cattle grazing, particularly in the north west of the state (DEWHA 2007).

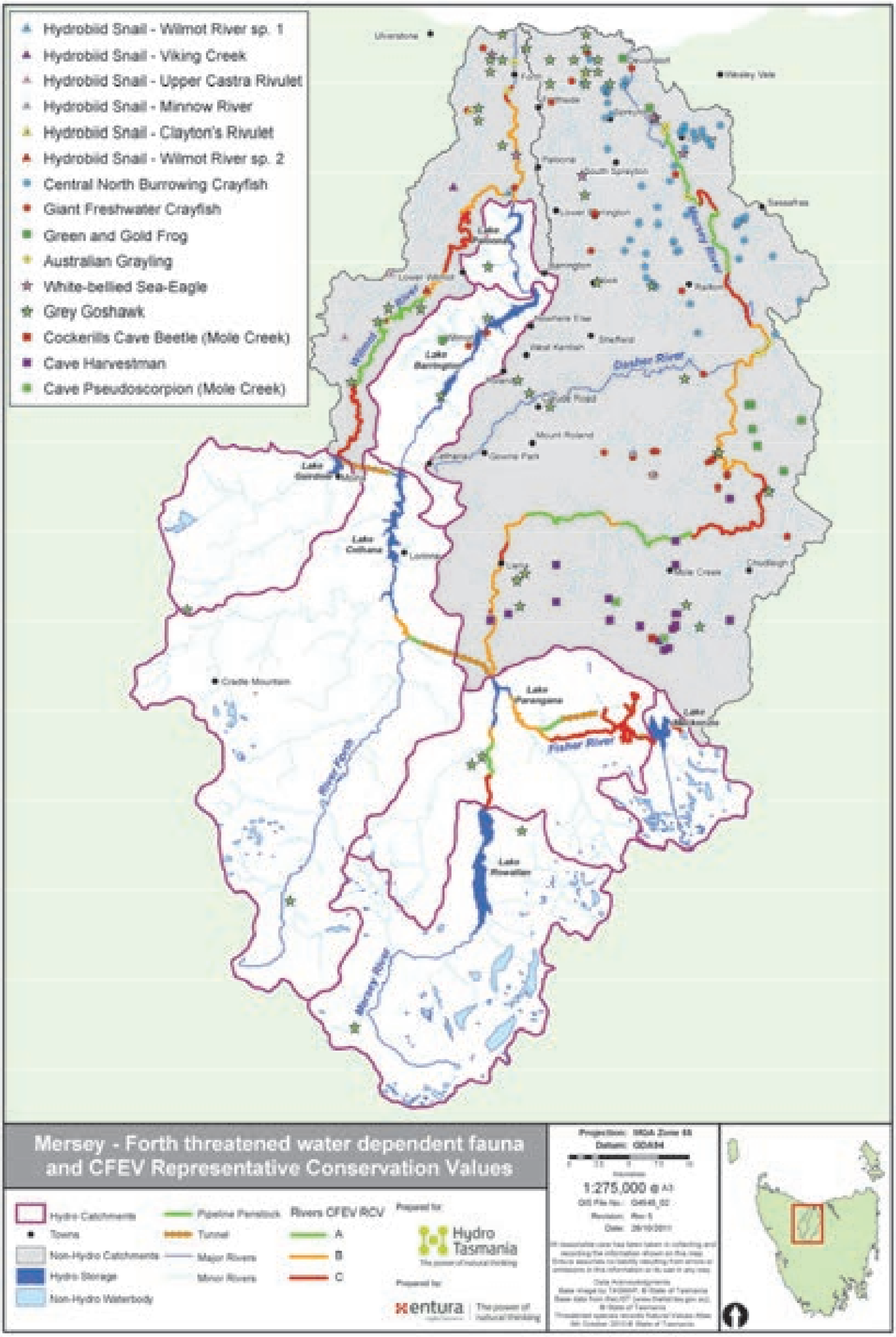
6.1.1.2 Grey Goshawk

Grey Goshawk (*Accipiter novaehollandiae*), listed as endangered under the TSPA, has been identified near the Mersey-Forth rivers and their tributaries. Much of the Mersey-Forth catchments occur within an area identified as core Grey Goshawk habitat by the Forest Practices Authority (FPA 2002). Nesting habitat is critical for their survival and occurs along watercourses in wet forest, with old growth or regrowth older than 50 years, particularly where blackwood (*Acacia melanoxylon*) occurs. Away from the swamp forests most nests are in riparian areas, but nests may occasionally be up to 100 m from a watercourse.

Table 6-1
Conservation status of threatened waterway dependent fauna in the Mersey-Forth catchments
(Source: NVA, DPIPWE 2010)

Common name	**Scientific name**	**Habitat**[##]	**Listing***		**NVA records from within Hydro Tasmania managed catchments**
			TSPA (1995)	**EPBCA (1999)**	
Green and Gold frog	*Litoria raniformis*	Wetlands	V	V	Yes - at Wilmot, Lake Barrington catchment
Grey Goshawk	*Accipiter novaehollandiae*	Water courses in wet forest	E	Not listed	Yes- in all catchments except Lake Mackenzie catchment
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	Coastal, mature forest near water-bodies	V	M CAMBA[#]	No - unconfirmed observations only, but critical habitat present. (DPIPWE 2006a)
Australian Grayling	*Prototroctes maraena*	Aquatic	V	V	No
Central North Burrowing Crayfish	*Engaeus granulatus*	Seeps, wetlands stream banks	E	E	No
Giant Freshwater Crayfish	*Astacopsis gouldi*	Aquatic	V	V	Yes - at Lake Barrington
Hydrobiid Snail (Clayton's Rivulet)	*Beddomeia waterhouseae*	Aquatic	E	Not listed	No
Hydrobiid Snail (Minnow River)	*Beddomeia turnerae*	Aquatic	R	Not listed	No
Hydrobiid Snail (Upper Castra Rivulet)	*Beddomeia lodderae*	Aquatic	V	Not listed	No
Hydrobiid Snail (Viking Creek)	*Beddomeia hermansi*	Aquatic	E	Not listed	No
Hydrobiid Snail (Wilmot River)	*Beddomeia forthensis*	Aquatic	R	Not listed	Yes – in river reaches downstream of dams
Hydrobiid Snail (Wilmot River)	*Beddomeia wilmotensis*	Aquatic	R	Not listed	Yes – in river reaches downstream of dams
Cockerills Cave Beetle (Mole Creek)	*Tasmanotrechus cockerilli*	Cave	R	Not listed	No
Cave Harvestman	*Hickmanoxyomma gibbergunyar*	Cave	R	Not listed	No
Cave Pseudoscorpion (Mole Creek)	*Pseudotyrannochthonius typhlus*	Cave	R	Not listed	No

* Endangered, Vulnerable, Rare, Migratory; [#] China-Australia Migratory Bird Agreement; [##] Entura unpublished data.



Map 6-1
Threatened aquatic fauna and CFEV representative conservation values[1]

[1] The conservation value of a river reach is expressed as the relative importance of the most important physical or ecological class for that reach. 'A' is of highest value, 'B' is intermediate, and 'C' is of least value

6.1.1.3 Giant Freshwater Cayfish

Giant Freshwater Crayfish (*Astacopsis gouldi*), listed as vulnerable under the EBPCA and TSPA, have been reported at Lake Barrington. Habitat requirements for healthy populations include waterbodies with good water quality and stable low water temperatures, as well as complex structure (including snags, pools and undercut banks) and an extensive cover of riparian vegetation to provide shading, nutrients, energy inputs and structure (DPIPWE 2006b).

6.1.2 Flora

Twenty six threatened water dependent flora species have been recorded from the Mersey-Forth catchments but only ten of these have been found in the vicinity of Hydro Tasmania managed lakes and rivers (Table 6-2; Map 6-2).

6.2 Conservation of Freshwater Ecosystem Values

The Conservation of Freshwater Ecosystems Values (CFEV) (DPIW 2008) is a spatial database tool that provides an evaluation of Tasmania's freshwater ecosystems for their conservation value and management priority. A CFEV assessment provides information about the biophysical character and condition of freshwater-dependant ecosystems.

The CFEV project developed a number of conservation criteria including 'naturalness' (N) when compared to pre-European condition, 'representativeness' (R) of the biophysical character of a spatial unit (i.e. lake or river segment) when compared with other spatial units, and 'distinctiveness' (D) of a rare biophysical character and other special values such as listed threatened species and species/communities with high conservation value (DPIW 2008). For the purposes of this report, the Representative Conservation Value (RCV) is considered to be the most useful as it represents the conservation value of a river reach when compared to the rest of Tasmania, based on the important biophysical values of the reach and the current condition. This information has not been verified in the field, but is presented for completeness and is intended only to give a high level overview and to assist with prioritisation of river reaches that may need further assessment.

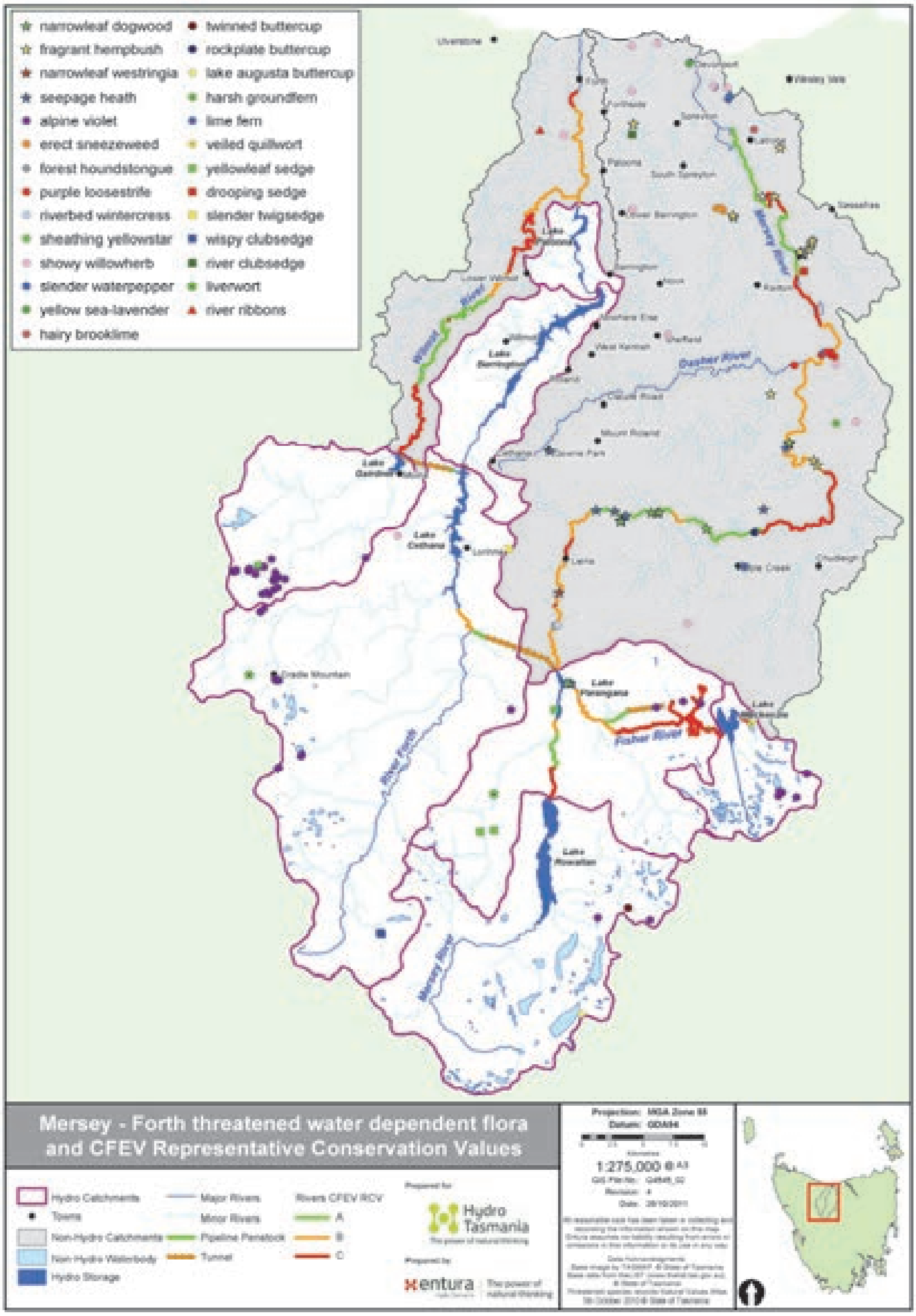
Identified CFEV RCV for the rivers in the Mersey-Forth catchments are included in Map 6-1 and Map 6-2. The CFEV database identified a number of species and communities, in addition to threatened species, with high conservation significance associated with aquatic and riparian reaches of the Mersey-Forth catchments. These include two fish species, a freshwater snail, platypus and five flora communities (Table 6-3).

Table 6-2
Conservation status of threatened water dependent flora in the Mersey-Forth catchments (Source: NVA, DPIPWE 2010)

Common name	Scientific name	Habitat#	Listing*		NVA records from within Hydro Tasmania managed catchments
			TSPA (1995)	EPBCA (1999)	
alpine violet	*Viola cunninghamii*	Terrestrial, soaks, depressions	R	Not listed	Yes- all catchments
drooping sedge	*Carex longebrachiata*	Terrestrial, soaks, depressions, riverine, riparian	R	Not listed	No
erect sneezeweed	*Centipeda cunninghamii*	Soaks, depressions, intermittent wetlands	R	Not listed	No
forest houndstongue	*Austrocynoglossum latifolium*	Riverine, riparian	R	Not listed	No
fragrant hempbush	*Gynatrix pulchella*	Riverine, riparian	R	Not listed	No
hairy brooklime	*Gratiola pubescens*	soaks, depressions, intermittent wetlands	V	Not listed	No
harsh groundfern	*Hypolepis muelleri*	Riverine, riparian	R	Not listed	No
lake augusta buttercup	*Ranunculus collicola*	Intermittent wetlands	R	Not listed	Yes – Lake Rowallan catchment
lime fern	*Pneumatopteris pennigera*	Soaks, depressions, riverine, riparian	E	Not listed	No
liverwort	*Pseudocephalozia paludicola*	Soaks, depressions	V	Not listed	Yes – Lake Parangana and Cethana catchments
narrowleaf westringia	*Westringia angustifolia*	Terrestrial, riverine, riparian	R	Not listed	No
purple loosestrife	*Lythrum salicaria*	Intermittent wetlands, riverine, riparian	V	Not listed	No
river clubsedge	*Schoenoplectus tabernaemontani*	Intermittent wetlands, riverine, riparian	R	Not listed	No
river ribbons	*Vallisneria australis*	Aquatic	R	Not listed	No
riverbed wintercress	*Barbarea australis*	Riverine, riparian	E	CE	No
rockplate buttercup	*Ranunculus sessiliflorus var. sessiliflorus*	Terrestrial	R	Not listed	No
seepage heath	*Epacris moscaliana*	Soaks, depressions, intermittent wetlands, riverine, riparian	R	Not listed	No
sheathing yellowstar	*Hypoxis vaginata var. brevistigmata*	Terrestrial, soaks, depressions	R	Not listed	Yes – Lake Gairdner catchment
showy willowherb	*Epilobium pallidiflorum*	Soaks, depressions, intermittent wetlands, riverine, riparian	R	Not listed	Yes – Lake Cethana catchment
slender twigsedge	*Baumea gunnii*	Wetlands soaks depressions, riverine, riparian	R	Not listed	Yes- Lake Cethana catchment
slender waterpepper	*Persicaria decipiens*	Riverine, riparian	V	Not listed	No
twinned buttercup	*Ranunculus jugus*	Soaks, depressions, intermittent wetlands, riverine, riparian	R	Not listed	Yes – Lake Rowallan catchment
veiled quillwort	*Isoetes humilior*	Aquatic	R	Not listed	Yes – Lake Mackenzie catchment

Common name	Scientific name	Habitat#	Listing*		NVA records from within Hydro Tasmania managed catchments
			TSPA (1995)	EPBCA (1999)	
wispy clubsedge	*Isolepis habra*	Wet riparian	R	Not listed	Yes – Lake Cethana catchment
yellow sea-lavender	*Limonium australe*	Saltmarsh, saline mudflats	R	Not listed	No
yellowleaf sedge	*Carex capillacea*	Terrestrial, soaks, depressions	R	Not listed	Yes - Lake Parangana catchment

* Critically Endangered, Endangered, Vulnerable, Rare; #Entura unpublished data



Map 6-2
Threatened aquatic flora and CFEV representative conservation values[2]

[2] The conservation value of a river reach is expressed as the relative importance of the most important physical or ecological class for that reach. ‘A’ is of highest value, ‘B’ is intermediate, and ‘C’ is of least value

Table 6-3
CFEV (Conservation of Freshwater Ecosystems Values) rivers ecosystem special value fauna and flora communities in reaches of the Mersey-Forth catchments

Species or Community	**CFEV Non-legislated value***	**River Reach**
Big-headed Gudgeon *Philypnodon grandiceps*	Priority fauna species	Mersey River - Parangana Dam to coast
Whitebait (northern stock) *Lovettia sealli sp. nov. A*	Priority fauna species	Forth River - Paloona Dam to coast Mersey River - Parangana Dam to coast
Freshwater snail *Austropyrgus solitarius*	Priority fauna species	Mersey River - Parangana Dam to coast
Platypus *Ornithorynchus anatinus*	Phylogenetically distinct fauna species	Fisher River - Lake Mackenzie to Lake Parangana Forth River - Paloona Dam to coast Mersey River - Parangana Dam to coast Mersey River - Rowallan Dam to Lake Parangana inflow Wilmot River - Lake Gairdner to Forth River confluence
Highland grassland *Poa*	Priority flora communities	Fisher River - Lake Mackenzie to Lake Parangana
Coastal swamp forest *Melaleuca ericifolia*	Threatened flora communities	Mersey River - Parangana Dam to coast
Riparian	Priority flora communities	Forth River - Paloona Dam to coast Mersey River - Parangana Dam to coast Wilmot River - Lake Gairdner to Forth River confluence
Sedgy fern bog	Priority flora communities	Fisher River - Lake Mackenzie to Lake Parangana Mersey River - Rowallan Dam to Lake Parangana inflow
Shrubby forest *Eucalyptus ovata*	Threatened flora communities	Mersey River - Parangana Dam to coast

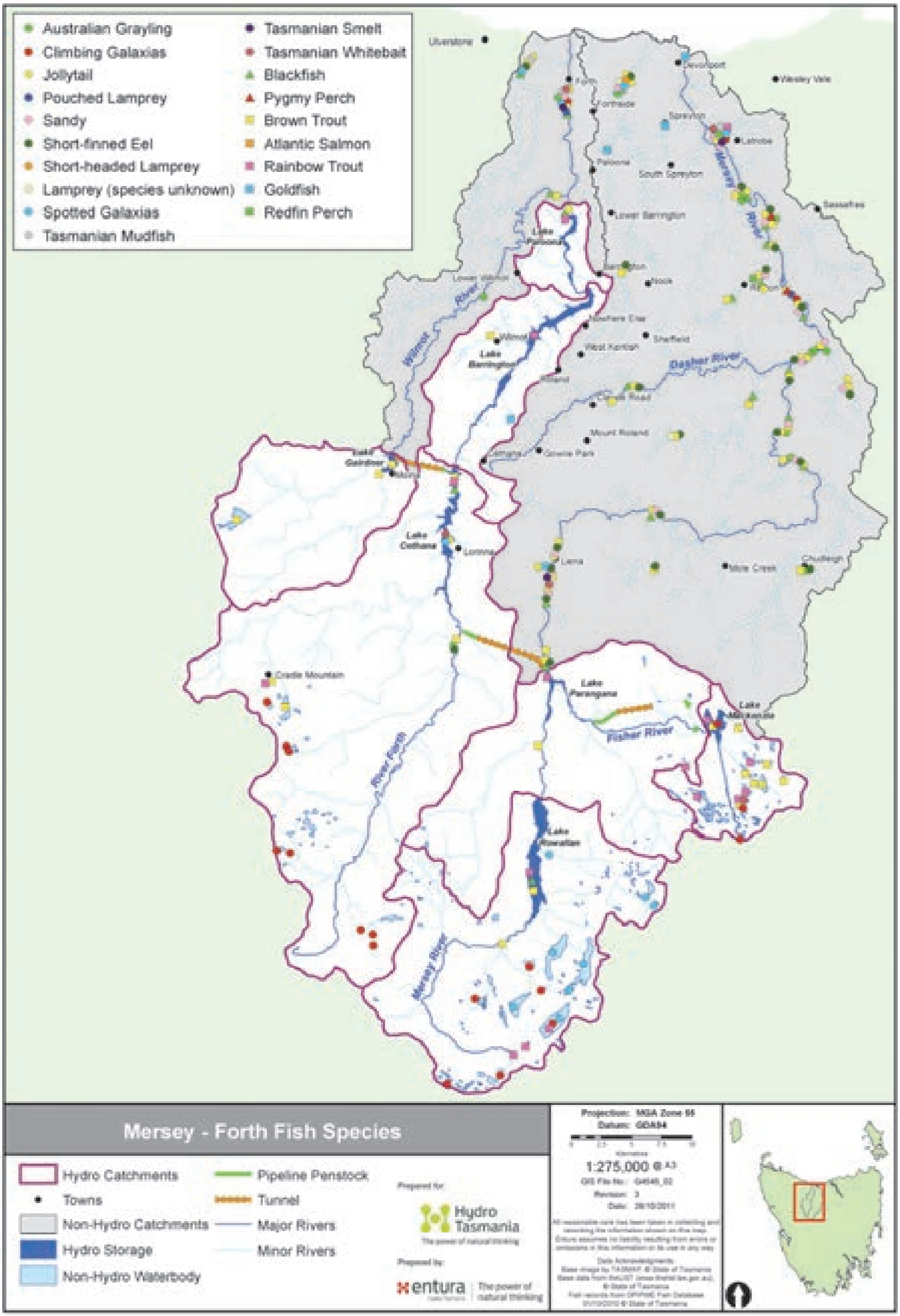
*Where priority fauna species are those that are considered important and have a limited distribution but have not been formally listed under TSPA (1995).

6.3 Fish

Eighteen fish species have been recorded for the Mersey-Forth catchments based on catch records from 1905 to 2009 (DPIPWE 2010). These include thirteen native species, three introduced angling species (Table 6-4; Map 6-3) and the introduced pest species Redfin Perch and Goldfish. Threats to the sustainability of native and introduced angling species are highlighted in Table 6-4.

Table 6-4
Threats to native and introduced angling fish species in the Mersey-Forth catchments (Source: IFS 2006)

Common name	**Scientific name**	**Threats**
Diadromous native species		
Australian Grayling	*Prototroctes maraena*	• Loss of access to salt water interferes with lifecycles • In-stream barriers prevent migration and dispersal • Loss of riparian and instream habitat and drainage of large areas of swamp and wetlands • Stream channel damage from sand and gravel extraction, including stream siltation from erosion • River regulation, including channelisation, loss of dry weather flow, suppression of minor flooding and elevated temperatures during low flows • Predation by introduced species, particularly salmonids • Contaminants entering waterway • Over fishing (eels, whitebait)
Climbing Galaxias	*Galaxias brevipinnis*	
Jollytail	*Galaxias maculatus*	
Pouched Lamprey	*Geotria australis*	
Sandy / Freshwater Flathead	*Pseudaphritis urvillii*	
Short-finned Eel	*Anguilla australis*	
Short-headed Lamprey	*Mordacia mordax*	
Spotted Galaxias	*Galaxias truttaceus*	
Tasmanian Mudfish	*Neochanna cleaveri*	
Tasmanian Smelt	*Retropinna tasmanica*	
Tasmanian Whitebait	*Lovettia sealii*	
Non-diadromous native species		
Blackfish	*Gadopsis marmoratus*	• Loss of instream habitat, particularly woody debris • Habitat fragmentation • River regulation, through increased water flows and reduced water temperatures during spawning seasons • Extensive stream siltation from erosion • Predation by introduced species
Pygmy Perch	*Nannoperca australis*	
Introduced angling species		
Atlantic Salmon	*Salmo salar*	• Loss of instream habitat • Erosion leading to increased sedimentation smothering spawning habitat • Low flows prior to juveniles emerging from gravel nests • Over fishing
Brown Trout	*Salmo trutta*	
Rainbow Trout	*Oncorhynchus mykiss*	



Map 6-3
Mersey-Forth Fish Species

6.3.1 Diadromous Native Species

Diadromous fish migrate between freshwater and saltwater habitats at different stages in their lifecycle. Eleven diadromous native fish species have been recorded from the Mersey-Forth catchments (Table 6-4). Diadromous fish can be separated into three groups depending on the migration strategy:

- Anadromous fish live in saltwater but migrate into freshwater to breed. Anadromous species recorded from the Mersey-Forth are Pouched Lamprey (*Geotria australis*), Short-headed Lamprey (*Mordacia mordax*), Tasmanian Smelt (*Retropinna tasmanica*) and Tasmanian Whitebait (*Lovettia sealii*).
- Catadromous fish live in freshwater but migrate to saltwater to breed. The Short-finned Eel (*Anguilla australis*) is the only truly catadromous fish found in the Mersey-Forth, however the Sandy (*Pseudaphritis urvillii*) migrates downstream to estuarine waters to breed, and can also be considered catadromous.
- Amphidromous fish move between fresh and salt water during their life cycle, but not to breed. Australian Grayling (*Prototroctes maraena*) spend the majority of their life in freshwater. Adults spawn in freshwater and the larvae are washed out to sea. The juveniles return to fresh water. The Climbing Galaxias (*Galaxias brevipinnis*), Jollytail (*Galaxias maculatus*), Spotted Galaxias (*Galaxias truttaceus*) and Tasmanian Mudfish (*Neochanna cleaveri*) are all considered amphidromous although land-locked populations of Climbing Galaxias, Jollytail and Spotted Galaxias have been recorded in Tasmania, indicating that these species can complete their life cycles within fresh waters where migration is not possible.

Adult Short-finned Eels live in freshwater and migrate to the ocean to spawn. Eel larvae return to estuarine areas via oceanic currents and juvenile eels (elvers) move into freshwater, slowly making their way upstream. Dams are a barrier to migration of both adult and juvenile eels. Adult eel passage downstream of dams is generally only possible via spillway flows as survival of eels passing through power station turbines is minimal. Survival is influenced by power station head and turbine type, and is greatest for low head power stations utilising Kaplan turbines.

Paloona Power Station utilises a Kaplan turbine, but Paloona Dam is the most significant barrier to diadromous species in the Mersey-Forth catchments. Its location in the lower reaches of the Forth River means that migrating elvers cannot proceed very far upstream. Similarly, Tasmanian Whitebait, Australian Grayling and Pouched Lamprey cannot migrate upstream of this structure.

Whitebait kills have been documented at the non-Hydro Tasmania weir downstream of Paloona Power Station and Hydro Tasmania has been criticised for causing these kills. An investigation in 2008 showed that although Hydro Tasmania's operations contributed to the problem through reduction of flows, there were also other factors, in particular the structure of the weir and the nature of the river immediately downstream.

The occurrence of multiple dams (i.e. Paloona, Devils Gate and Cethana Dams on the Forth River) presents particular difficulties in developing strategies for facilitating fish migration. The Wilmot River joins the Forth River below Paloona Dam and provides some alternative habitats for diadromous species up to Wilmot Dam, at Lake Gairdner.

Parangana Dam presents a barrier to migration in the mid reaches of the Mersey River. The Lake Rowallan eel population in the upper reaches of the Mersey River is supplemented by elver restocking undertaken during the elver migration season as part of Hydro Tasmania's restocking agreement with IFS.

Whilst dams present obvious barriers to native fish movements other barriers to fish movement may result from altered flow regimes or water quality. High river flows, such as below power stations, may impose a water 'velocity barrier' against which fish cannot swim. Reduced flows, such as in the lower Mersey River, may lower water levels such that small barriers become insurmountable or the depth of water available for fish passage is not adequate. Low dissolved oxygen levels, or high or low water temperatures may pose a barrier through which fish may not migrate. Occurrences of this nature have not been documented in the Mersey catchment. Consequently, most issues relating to native fish dispersal relate to the barriers presented by instream structures and the associated changes in channel hydrology. Little is known about barriers presented by other levees, weirs and culverts within the Mersey catchment.

6.3.2 Non-Diadromous Native Species

Non-diadromous native species remain in fresh water throughout their lifecycle, but may undertake extensive migrations within river systems to feed and reproduce. The primary impacts of dam operations on non-migratory fish are due to the reduction in availability of suitable in-stream habitats, siltation or erosion, and a lack of synchronicity in the timing of high and low flows with the habitat requirements for spawning and the survival of larvae and juveniles. Strandings may occur as a result of high rates of change in flow, as well as extremely low flows with concomitant poor water quality in remnant pools or shallow reaches. Cold water releases from dams in summer may inhibit the spawning of some species. Lake level fluctuations or altered river flows could disrupt spawning and dispersal migrations within lake and lake drainage systems. Artificial barriers may also restrict access to spawning sites or separate populations of rare fish such that genetic viability within the separated populations is compromised.

Blackfish (*Gadopsis marmoratus*) and Pygmy Perch (*Nannoperca australis*) are the only two non-diadromous native fish species in the Mersey-Forth catchments (Source: DPIPWE 2010) (Table 6-4; Map 6-3). The natural range of these species overlaps with a number of Hydro Tasmania dams and, therefore, some fragmentation of the populations of these fish is likely to occur. It is not known to what extent habitat modifications associated within the Mersey-Forth Scheme has affected either of these species. However, habitat modification and siltation are contributing factors in the decline of Blackfish in the lower Mersey River. Habitat modification is also an issue for Pygmy Perch which is restricted to macrophyte beds in low velocity areas. Stable water levels and temperatures are required by Pygmy Perch for spawning and adult rearing habitat (Davies and Humphries 1996).

6.3.3 Introduced Angling Fish

Atlantic Salmon (*Salmo salar*), Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) have been introduced to Tasmanian catchments for recreational fishing, and artificial stocking is undertaken by IFS to maintain their populations. Atlantic Salmon was recorded for the first and only time, in 2006, in the Forth-Wilmot catchments which is consistent with a stocking event. Both Brown Trout and Rainbow Trout are widely dispersed within the Mersey-Forth catchments and are important to recreational fishing. Information on angling fish catch is provided in section 8.2.

Brown Trout and Rainbow Trout are anadromous species, migrating into freshwater habitats to spawn, however, landlocked populations of both these species have been recorded. It is not known if Brown Trout have established breeding populations within the Mersey-Forth catchments, however, this species is known to breed in Tasmanian waters, whereas Rainbow Trout are not known to reliably breed in Tasmanian waters.

6.3.4 Pest Fish

Goldfish (*Carrasius auratus*) have been recorded sporadically in the Mersey-Forth catchments, but have not been recorded since 1996. It is thought that permanent populations are breeding in small farm dams and it is likely that some of these fish enter the river systems during flood. Goldfish may constitute a threat to native fish fauna and introduced angling species due to competition for resources.

Redfin Perch (*Perca fluviatilis*) were observed within the Mersey Catchment at Redwater Creek, Railton in 1998. This was thought to be the sole population of Redfin within the Mersey-Forth catchment until IFS received a report from an experienced angler of a sighting of Redfin in the Lower Mersey at Bells Road, Latrobe, in 2010 (John Diggle, Inland Fisheries Service, pers. comm. 28 Feb 2011). This has yet to be confirmed. Redfin are piscivorous and constitute a threat to native fauna and introduced angling species due to competition for resources and direct predation.

6.4 Macroinvertebrates and River Health

RIVPACS (River Invertebrate Prediction and Classification System) river health assessments are based on aquatic macroinvertebrate community and habitat data (Appendix O). Invertebrates occur in most if not all aquatic habitats and are an important component of the food chain. Aquatic macroinvertebrates are a highly diverse group including sponges, worms, molluscs, crustacea, springtails and insects (i.e. stonefly larvae) (Photograph 6-1). Macroinvertebrates are widely used as biological indicators of river health as macroinvertebrate assemblages can be altered by the type of habitat present and water quality.

Macroinvertebrate communities from water bodies with complex habitats are generally diverse providing a range of food sources for a range of consumers and predators and the greater the abundance of these the more consumers/predators can be supported. RIVPACS condition scores are generated from diversity data (indicated by presence or absence of taxa) and community composition (indicated by rank abundance of family taxa). A brief overview of RIVPACS scoring and condition bands is provided in Appendix O.

Photograph 6-1
Macroinvertebrate sampling (left, Brad Smith, October 2010) and stonefly nymph (right)

Fifteen river health monitoring sites have been sampled in the Mersey-Forth catchments including eight test sites and seven reference sites (Appendix D; Appendix P). The sites have been monitored under a number of projects and have therefore been sampled at different frequencies.

The most recent assessments of river health for each site are presented in Table 6-5 and are described in the following sections. Condition score plots and tables are provided in Appendix P for all sampling occasions.

Table 6-5
River health condition scores spring, autumn and combined season using biodiversity and community composition scores data (up to June 2011)

Type	River Site	No. of Years with data	Most recent year assessed	Biodiversity (O/E presence absence)			Community Composition (O/E rank abundance)		
				Spring	Autumn	Combined Season	Spring	Autumn	Combined season
Test	Fisher River 1.3 km downstream Lake Mackenzie	1	2010/11	0.68	0.55	0.79	0.66	0.79	0.91
Test	Fisher River 400 m downstream Fisher Station	3	2010/11	1.12	1.09	0.94	1.18	1.05	0.91
Test	Forth River downstream Wilmot River (Control Riffle)*	2	2010/11	0.37	1.26		0.29	0.89	
Test	Mersey River upstream Arm Island Bend	1	2010/11	1.21	0.86	0.9	1.11	0.58	0.75
Test	Mersey River downstream Parangana**	6	2008/09			0.84			0.99
Test	Wilmot River 500 m downstream Lake Gairdner	1	2010/11	0.67	0.83	0.64	0.59	0.57	0.62
Test	Wilmot River at Alma Reserve*	9	2009/10	0.81	0.95		0.68	0.89	
Test	Wilmot River at Spellmans Rd	4	2010/11	0.97	0.96	1.1	1.02	0.93	1.04
Ref	Arm River upstream Mersey River	1	2010/11	1.21	1.32	1.17	1.23	1.22	1.13
Ref	Fish River at Mersey Forest Rd	14	2010/11	1.18	1.21	1.08	1.18	1.12	1.09
Ref	Fisher River upstream Fisher Power Station	2	2010/11	1.23	1.00	1.14	1.21	1.12	1.01
Ref	Forth River at Pallawah Rd	2	2010/11	0.78	1.32	1.17	0.65	1.29	1.12
Ref	Forth River downstream Wolfram Mine	1	1998	0.83	1.24	1.24	0.75	1.24	1.16
Ref	Little Fisher River upstream lowest Rd crossing	2	2010/11	1.35	1.11	1.15	1.35	1.13	1.1
Ref	Mersey River downstream Lake Rowallan	14	2010/11	1.39	1.33	1.14	1.39	1.22	1.16

Key	Condition band identifier Condition band name	X Richer than reference	A Equivalent to reference	B Significantly impaired	C Severely impaired

Note: Condition band boundaries vary for each analysis. *Combined season scores could not be included as they were consistently outside model parameters. **Combined season scores only available.

6.4.1 Fisher River

The condition of the Fisher River downstream of Lake Mackenzie was significantly impaired for both biodiversity and community composition in 2010/11, possibly due to reduced flows. Further downstream at the sites upstream and downstream of the Fisher Power Station the condition was equivalent to reference or better. An earlier study by Davies *et al*. (1999) found similar results from sites on the Fisher River downstream of the Fisher Power Station. There is limited long term data for these sites.

6.4.2 Wilmot River

The Wilmot River site downstream Lake Gairdner was significantly impaired for both biodiversity and community composition in 2010/11 (Table 6-5) but its condition improved downstream. In the mid reaches (Wilmot River at Spellmans Road) condition scores indicated the site was equivalent to reference for biodiversity and community composition. This site was first assessed in 1994/95 and has scored equivalent to reference condition on all four sampling occasions (Appendix P; Figure P-1). River condition in the lower reaches (Wilmot River at Alma Reserve) is also typically equivalent to reference, but scored lower (significantly impaired) in spring 2007 and 2008 (Appendix P; Table P-2). This decline is likely to be due to spring flash floods and its condition had returned to equivalent to reference when last assessed in spring 2009 and autumn 2010 (Appendix P; Table P-2).

6.4.3 Forth River

The condition of the Forth River site downstream of Wilmot River (downstream of Lake Paloona) was significantly impaired for biodiversity and severely impaired for community composition in spring 2010, but its condition in autumn 2011 was equivalent to reference. Davies *et al*. (1999) assessed a site on the Forth River downstream of the Paloona Dam and Power Station, but upstream of its confluence with the Wilmot River, and found the communities to be highly modified.

6.4.4 Mersey River

The test site on the Mersey River downstream of Lake Parangana was equivalent to reference condition when last assessed in 2008/09.

Only a few sites have sufficient data for any assessment of trends in condition over time. The condition of the Mersey River site downstream of Lake Parangana has been assessed approximately every two years and has varied between significantly impaired and equivalent to reference condition overall. There has been improvement in condition particularly with respect to rank abundance scores, since 2001-02 (Appendix P; Table P-1).

Davies *et al*. (1999) also found that the communities from sites in the Mersey River reaches, immediately downstream of Rowallan and Parangana Dams, were significantly impaired, but sites further downstream were essentially unimpaired until the effects of land use became significant.

Habitat condition scores for all sites assessed in 2010-11 were excellent and long term habitat assessments for the Mersey River downstream of Lake Parangana have been good to excellent since first assessed in 2000 (Appendix Q; Table Q-1).

6.4.5 River Health Reference Sites

The reference sites were generally equivalent to reference or better. However, community composition scores in the upper Forth River reference sites, downstream of Wolfram Mine and at Palwallah Road, fell in the significantly impaired band in spring (Table 6-5).

6.5 Environmental Flow

Flow is a key driver of ecosystem processes in rivers. Whether the flow regime is driven by rainfall events in the catchments or regulated flows from dams it will have an impact on macroinvertebrate communities. Some macroinvertebrate taxa are adapted to high flows and others to low flows. Recovery of communities at a site following a disturbance is facilitated by its connection to a range of habitats including those that provide refuge against adverse conditions and sources of colonists from less impacted areas. The longitudinal improvement in river condition for the Mersey-Forth rivers is consistent with Davies *et al.* (1999) who demonstrated that Hydro Tasmania managed rivers recovered rapidly downstream of dams due to catchment inflows.

The Mersey River environmental water release (see section 3.9.1) was implemented to address issues related to poor water quality and low baseflows in the lower Mersey River. Preliminary studies by Davies *et al*. (1997) recommended that a minimum flow release of two cumecs from Parangana Dam would provide environmental benefit by improving the condition of macroinvertebrate and fish communities downstream. The aims of this release were to restore in-stream habitat and food supply for aquatic biota in the middle reaches of the Mersey River, and to restore Brown Trout (*Salmo trutta*) and Blackfish (*Gadopsis marmoratus*) fisheries.

The Mersey River Flow Release Monitoring Program (MRFRMP), conducted from 1999 to 2009, was a collaborative effort between the Department of Primary Industries, Parks, Water and Environment, IFS and Hydro Tasmania with significant input into the program by Freshwater Systems. Hydro Tasmania supported the program financially and through the provision of flow and water quality data (DPIW 2009). The program included detailed assessments of hydrology, instream habitat, water quality and macroinvertebrate assemblages (abundance, diversity, community composition, functional feeding groups and AUSRIVAS results) as well as fish assemblages and dietary analysis of Brown Trout. Pre-release monitoring was conducted over three years and then monitoring continued for five years following the implementation of the two cumecs minimum environmental flow below Parangana Dam in 2000. The program concluded that the increased baseflow was of significant benefit to the fish population, increasing the abundance of Brown Trout and the standing stock of macroinvertebrates. There was also some evidence that it benefited native fish.

6.6 Weeds

The following waterway dependent weeds have been identified as the targets of control programs within the Mersey-Forth catchments:

- Weeping willow (*Salix x sepulcralis*, *Salix babylonica*);
- Crack willow (*Salix fragilis*);
- Reed sweet grass (*Glyceria maxima*, *Poa aquatica*);
- Cumbungi bullrush (*Typha latifolia*); and
- Rice grass (*Spartina anglica*).

Willows (*Salix* spp.), except weeping, pussy or sterile pussy willows, are classified as Weeds of National Significance and are declared weeds in Tasmania (Tasmanian Planning Commission 2009). Willows are widespread along water courses in cleared catchments. All willows will propagate vegetatively. Crack willow, in particular, is notorious for infesting downstream areas via fragile twigs that are broken off during floods, high winds or even stream rehabilitation work.

Willows exclude native riparian vegetation through competition and alteration of habitat. Willow encroachment into river channels, particularly in areas with reduced flows, can lead to channel braiding, log jams, localised flooding and excessive erosion in areas of diverted channel flow. High rates of sedimentation are apparent in areas of dense willow infestation leading to burial of riparian plant communities. High seasonal leaf drop from willows, during autumn, is foreign to Australian aquatic communities that are adapted to a more constant nutrient input throughout the year (Parker and Bower 1996) and the chemical composition of willow leaf litter is different to that of leaf litter from native vegetation (Zukowski and Gawne 2006).

The introduced bullrush cumbungi *(Typha latifolia*) is not a declared weed, but is found throughout Tasmania and is spreading. It is a large bullrush that thrives in slow flowing, nutrient rich water and tends to form dense monocultures further restricting flow in waterways. The introduced cumbungi can be confused with native broadleaf cumbungi *(T. orientalis*) and narrowleaf cumbungi *(T. domingensis*).

Reed sweet grass (*Glyceria maxima*, *Poa aquatica*) is not a declared weed in Tasmania but is considered a 'troublesome aquatic weed'. Like cumbungi, it is capable of forming large infestations in a short period of time and produces an extensive network of underground stems and roots dense beds. It is found throughout Tasmania and prefers well aerated water. *Glyceria* accumulates toxic levels of hydrocyanic acid which has resulted in cattle deaths from cyanide poisoning.

Rice grass (*Spartina anglica*) is an introduced intertidal salt marsh plant that causes large infestations in estuaries and is a problem in many of Tasmania's estuaries, but not in inland waters.

The aquatic weed Canadian pondweed (*Elodea canadensis*) is a declared weed. Although it is not currently recorded in the Mersey-Forth catchments, it is present in a number of catchments in Tasmania and is easily spread. Its absence cannot be guaranteed.

6.7 Aquatic Pests and Pathogens

6.7.1 Types of Aquatic Pests and Pathogens

The following aquatic pests and pathogens have been confirmed in the Mersey-Forth catchments (Allan and Gartenstein 2010):

- Root-rot/dieback mould (*Phytophthora cinnamomi*);
- Chytrid frog fungus (*Batrachochytrium dendrobatidis*); and
- Platypus mucor fungus (*Mucor amphibiorum*)

Phytophthora is an introduced water mould that can cause plant disease and death in native Tasmanian vegetation. It poses a serious threat to susceptible plant species found in open vegetation in lowland environments (below 700 m) such as moorlands, heathlands and dry eucalypt forests where rainfall is greater than 600 mm. Phytophthora has the potential to significantly change the ecology of these vegetation types and some threatened plant species are declining as a result of Phytophthora. It does not threaten grasslands, agricultural crops or pasture (Allan and Gartenstein 2010).

Chytrid fungus is an introduced primitive fungus that infects the skin of frogs, destroying structure and function, and resulting in death in most cases. The Tasmanian climate provides ideal conditions for chytrid fungus to spread. Two endemic frog species, the Tasmanian Froglet (*Crinia tasmaniensis)* and the Tasmanian Tree Frog (*Litoria burrowsae*), and one threatened frog species, the Green and Gold Frog (*Litoria raniformis*), occur in the Mersey-Forth catchments and are potentially under threat from the Chytrid fungus (Allan and Gartenstein 2010).

Platypus mucor is a native Australian fungus that has spread widely in northern Tasmania since 1992. The fungus causes deadly ulcerative infection and is the most significant disease threat to platypuses. The fungus may also cause deaths to frogs in captivity and to wild frog populations. However, a 2008-09 survey indicated that the prevalence of the disease has declined since the mid to late 1990s (Allan and Gartenstein 2010).

6.7.2 Field Hygiene Protocols for Aquatic Pests and Pathogens

Freshwater pests and pathogens are spread to new areas when contaminated water, mud, gravel, soil and plant material or infected animals are moved between sites. Contaminated materials and animals are commonly transported on boots, equipment, vehicles tyres and during road construction and maintenance activities. Once a pest pathogen is present in a water system it is usually impossible to eradicate.

Hygiene protocols have been developed for Tasmania (Allan and Gartenstein 2010) to prevent the spread of pests and pathogens. These hygiene protocols can be applied to the three aquatic pests and pathogens detailed above.

6.8 Summary of Biological Issues

There are a number of biological issues that have been identified in the Mersey-Forth catchments that require consideration.

Flow modification is an issue in rivers downstream of dams. The timing and magnitude of flow releases will affect biological communities and could include:

- Possible impact on reproductive success of Pygmy Perch and Blackfish through changed flow regime during the spawning season;
- Possible impact on threatened snail species due to changes in flow and modification of habitat; and
- Alteration to river bed and channel morphology with prolonged low velocity flows causing siltation and smothering of habitat, and prolonged high velocity flows causing scouring and erosion.

Dams are a barrier to fish passage and the sustainability of populations of migratory fish needs to be considered. It is not known if populations of threatened Australian Grayling can be recovered in the Mersey-Forth Hydro managed catchments and the impact of Hydro Tasmania's operations on other populations of threatened fauna and flora, and protected habitats, is not well understood.

Canals, pipelines and penstocks provide dispersal mechanisms that did not exist naturally. The transfer of aquatic pests and pathogens, pest weeds, introduced fish, and the distribution of native fish to areas where they originally did not exist can pose a threat to existing endemic and threatened species.

Management of weeds on Hydro Tasmania land continues to be an issue.

7 Geomorphological Aspects

7.1 Introduction

Geomorphology is the study of land surfaces and the processes that create them. Hydro Tasmania has modified the natural processes that operate in waterways through flow and sediment regulation, contributing to geomorphic change. This geomorphic change may take a number of forms including river bank erosion, channel changes, sedimentation, vegetation loss or encroachment, and lake shoreline destabilisation and erosion.

This chapter discusses identified geomorphological impacts of Hydro Tasmania operations on the waterways in the Mersey-Forth catchments. The information contained in this chapter is derived from a desktop survey of available information and discussions with geomorphologists and geologists familiar with the region. Available information includes geomorphic mosaics developed for Tasmania as part of the CFEV database (Jerie *et al.* 2003), the Tasmanian Geo-heritage database, a River Styles Report for the Mersey catchment (Lampert 2000), an investigation of the fluvial geomorphology of the Mersey River downstream of Parangana Dam (North Barker & Associates 2003), and discussions with karst experts and geologists working in the region.

7.2 Geomorphic Overview of the Mersey-Forth Catchments

As part of the CFEV (DPIW 2008) project, Jerie *et al.* (2003) developed a map of landscape components, or 'mosaics' in Tasmania, which identify areas with similar physical and environmental controls (geology, topography, climate, earth history). A map showing the distribution of these mosaics within the Mersey-Forth river catchments is shown in Appendix R. The mosaics reflect a highly complex region of Tasmania. The underlying geology includes dolerite, quartzite and karst units with glacial, periglacial, fluvial and dissolution processes having all contributed to the present landscape.

In the Mersey-Forth catchments, the headwaters rise in high plateaus consisting of dolerite or quartzite, with some but not all of the area altered by glacial processes. Glacially carved quartzite valleys and gorges are common, with erosional (relict) surfaces common in the Forth catchment. Periglacial processes acting on the steep Central Plateau have lead to scree slopes in the middle Mersey catchment. Both high relief and low relief karstic areas are present in the Mersey-Forth catchments, which affect the regional hydrology of the area. In the lower reaches of the Mersey catchment, rolling basalt hills and alluvial valleys are present. Towards the coast, finely dissected surfaces and coastal sediments are common in both catchments, and the Don which is sandwiched between the two.

The downstream sequence of geomorphic units in the Mersey-Forth catchments do not occur elsewhere in the State, and combined these catchments comprise a unique river type in Tasmania (DPIW 2008).

7.3 Geomorphic Context of Hydro-Electric Development

The Mersey–Forth Power Scheme reflects the geology of the catchments, with Lake Mackenzie situated on the surface of the Central Plateau and lakes Rowallan, Parangana and Cethana occupying glacially carved valleys. The power stations fed by these impoundments harness the steep relief of the Central Plateau escarpment to provide the hydraulic head for power generation. The downstream lakes Barrington and Paloona are located in the narrow and steep fluvial cut valleys which were created by rivers draining off the plateau. Similar to Lake Mackenzie, Lake Gairdner is located on a relict erosional surface (remnant plateau), although at a lower altitude when compared to the Central Plateau.

7.3.1 Significant Geomorphic Features in the Mersey-Forth Catchments

A number of significant geomorphic and geologic features in the Mersey–Forth region are included in the DPIPWE Geo-conservation – The List database (TASMAP 2010). The distribution of these features is shown in Map 7-1. The features range in significance from ‘local’ to ‘world’, with the latter category associated with glacial features which reflect a significant period in the earth’s history and contribute to the natural values for which the World Heritage Area was listed.

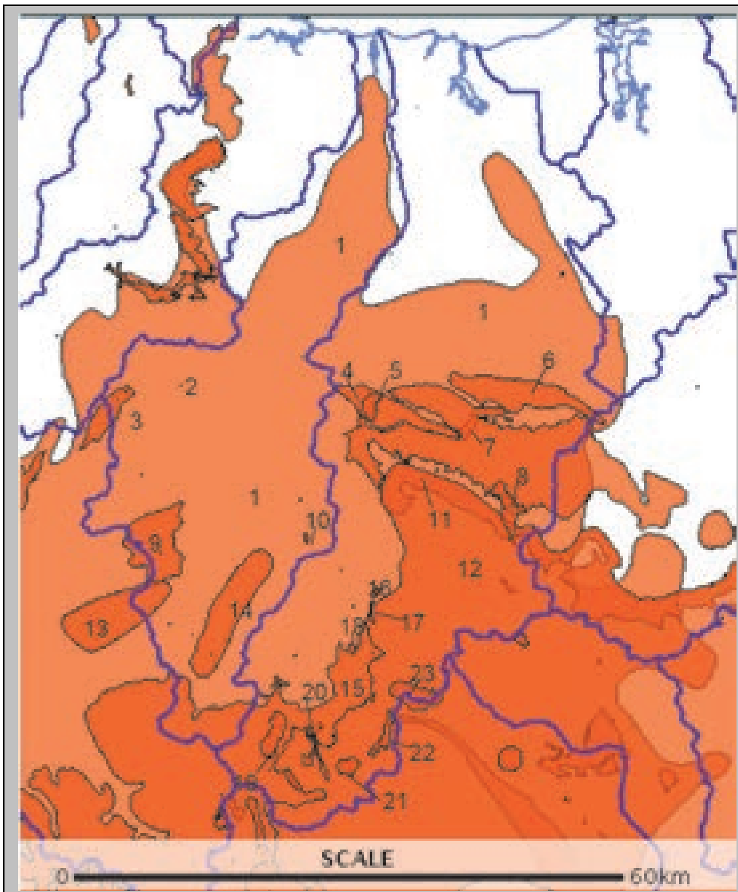
Most of the Mersey-Forth catchments area lies within the Central Highlands Cainozoic Glacial Area, a region which reflects the extensive (~6,000 km^2) glacial activity which occurred in the late Pliocene or early Pliestocene (Kiernan 1990). As evident in Map 7-1 numerous specific glacial features have been identified within the Central Highlands Cainozoic Glacial Area as being significant, including glacial valleys and deposits (moraines), an ice spill-over area, an ice window, a nunatak (exposed ridge or peak not covered by ice) and glacial rock lakes and basins. Karst areas which are considered of significance include the Mole Creek karst system in the Mersey catchment and the Vale of Belvoir in the western Forth catchment. Erosional / depositional features include the Fish River alluvial fan, the Lea River fossil site and Great Western Tier escarpment.

7.3.2 River Styles Investigation

Lampert (2000) completed a river styles investigation of the Mersey catchment downstream of the Parangana Dam. The study examined the main stream lines in the catchment and developed the River Styles map shown in Map 7-2. No systematic River Styles investigations have been completed for the Forth or Wilmot River catchments.

Downstream of Parangana Dam, the Mersey River is characterised by gorge reaches and partly confined bedrock reaches with discontinuous floodplain pockets. In the reach below these sections, approximately 15 km downstream of the dam, there is a reach of low sinuosity gravel bed. In the same area, the first major tributaries enter the Mersey River. The map shows that, with distance downstream, the occurrence of gravel beds increases and a long reach near the mouth is subject to tidal influences.

Site specific investigations are generally required to accurately identify the distribution and range of geomorphic impacts associated with flow regulation, but very limited site-specific information is available for the Mersey–Forth region.



Light orange (1) shows extent of Central Highlands Cainozoic Glacial Area. Large dark orange area (12) indicates extent of Central Plateau Terrain. Other dark orange or red outlined areas show smaller features as indicated by the numbers.

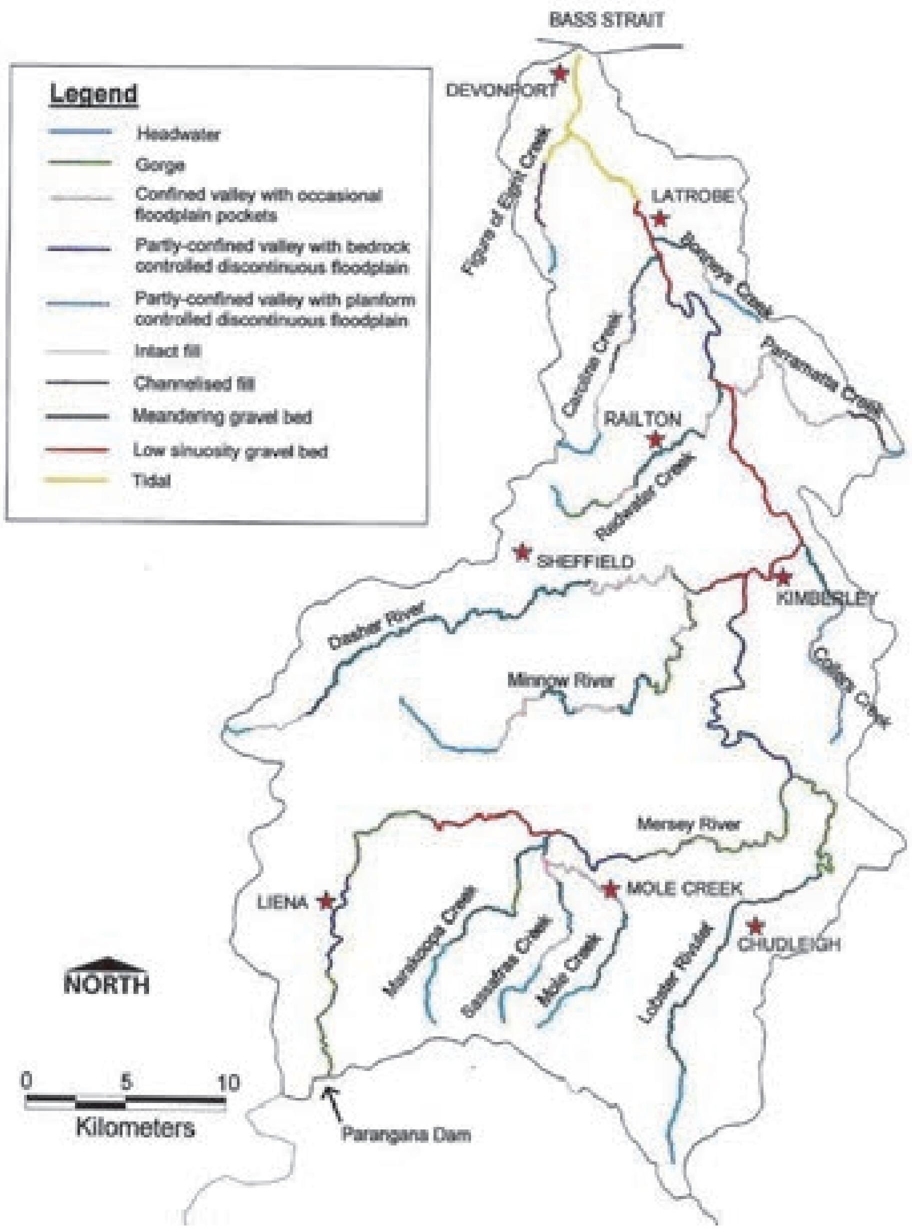
Geoconservation Features (Significance)

1. Central Highlands Cainozoic Glacial Area (Aus)
2. Lea River Oligocene Plant Fossil site (Aus)
3. Vale of Belvoir (Aus)
4. Standard Hill Residual Strike Ridge (Regional)
5. Standard Hill Gorge Structures (Reg)
6. Gog Range Strike Ridge (Reg)
7. Mole Creek Karst (Aus)
8. Lobster Riv Ice Spillover (Tas)
9. Cradle Mtn Glacial Features (Aus)
10. Borradaile Plains Basalt mass movement (Tas)
11. Great Western Tiers Escarpment (Tas)
12. Central Plateau Terrain (World)
13. Barn Bluff-Mt Inglis Glacial Valley (Aus)
14. Forth Valley Glacial Trough (Reg)
15. Upper Mersey-King William Range Terrain (Aus)
16. Dublin Bog Palynological site (Tas)
17. Mersey Valley Latero-terminal moraine (Local)
18. Fish River Alluvial Fan (Tas)
19. Lees Plain Glacial Valley Profile (Tas)
20. Cloister Lagoon-Chapter Lake-Chalice Lake Rock Basin (Reg)
21. Mt Rogoona Nunatak (Reg)
22. Lake Adelaide Glacial Rock Basin Lake (Aus)
23. Walls of Jerusalem Glacial Ice Window (Aus)

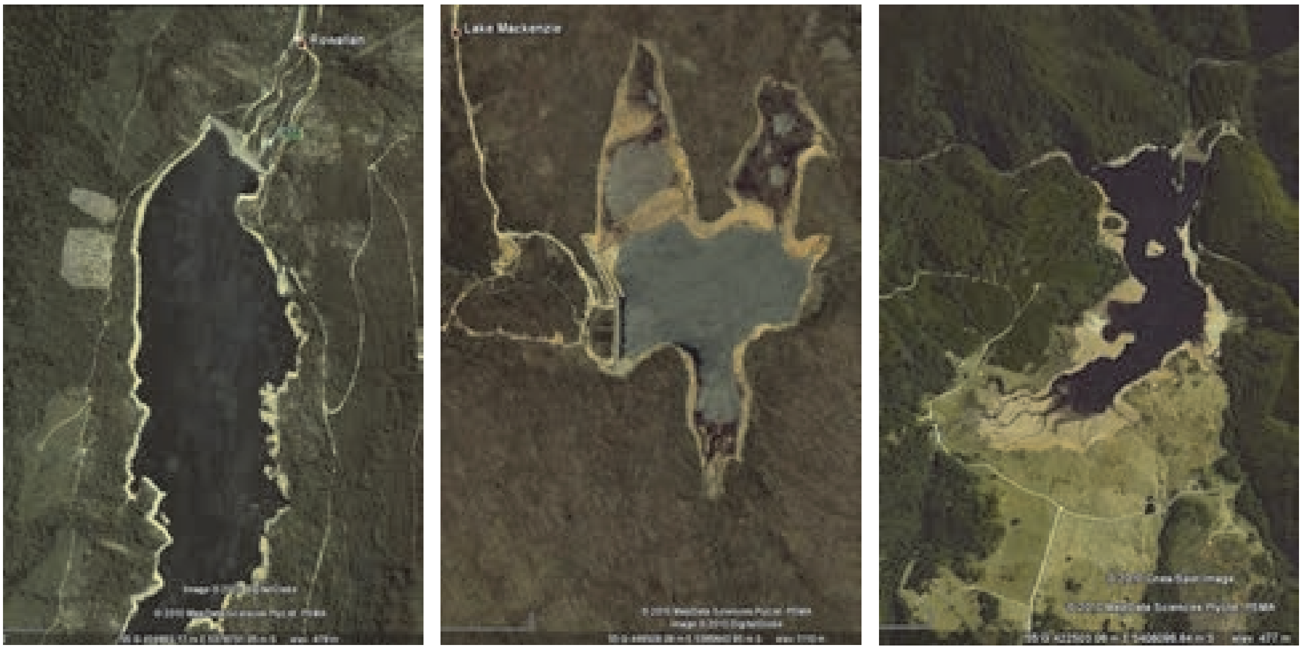
Map 7-1
Map of geoconservation sites in Mersey-Forth catchments as listed in DPIPWE Geoconservation - The List database

7.4 Lakes

The soils and vegetation surrounding all lakes is susceptible to erosion, but there is variable susceptibility to erosion of the underlying geology. Lake Mackenzie with its doleritic geology, and Lake Parangana with its metamorphic rocks, are likely to have relatively erosion-resistant shoreline geology. The geology of the shorelines of Lake Gairdner (unconsolidated sediments), Lake Barrington (predominantly siliceous sediments), Lake Cethana (pockets of unconsolidated sediments, calcareous sediments, and Cambrian acid volcanics) and Lake Paloona (siliceous sediments) may be more susceptible to erosional change. No site specific investigations of these impoundments have been completed.



Map 7-2
Summary of river styles by Lampert (2000)



Photograph 7-1
Google Earth image of the northern end of Lake Rowallan (left), Lake Mackenzie (middle) and Lake Gairdner (right) showing exposed shorelines in March 2007

The typical operating range in Lakes Parangana, Cethana, Barrington and Paloona is small in comparison to Lakes Rowallan, Mackenzie and Gairdner (Appendix F). However, when lake levels are low, shoreline erosion has occurred through inundation, water-logging and erosion of vegetation and soils. This is evident in Lake Mackenzie which is situated in a low relief area, so small changes in water level can expose or inundate large surface areas (Photograph 7-1).

Lake Gairdner is situated on a low-lying karstic region and some of the surrounding area has been developed for agriculture. Shoreline erosion associated with inundation, water logging and wave energy has been observed when the lake level was low (Photograph 7-1).

Limestone is present in the vicinity of Lake Gairdner and the karstic area is characterised by a large number of collapsed or collapsing sink holes which appear to be recent features (A. Slee, Forest Practices Authority, pers. comm. 2010). The relationship between the hydrology of the lake and hydrology of the karst areas is unknown, but raising the regional water table may affect karst stability and processes in the area. The karst in the area is not considered to be of high conservation value.

7.5 Rivers

7.5.1 Mersey River

The hydrology of the lower Mersey River has been significantly altered due to the diversion of the waters from the Mersey River into the Forth catchment. The environmental flow of 2 cumecs from Parangana Dam is improving the biological condition of the river, but part of that requirement included a flow provision sufficient to transport fine-grained material which was 'clogging' the river channel.

In 2003, geomorphic field investigations of the Mersey River downstream of Parangana Dam were completed by North Barker & Associates who identified a range of vegetation and channel changes associated with the altered flow and sediment regime.

In the first three kilometres of river downstream of the dam, there are no major tributary inflows and the reach is starved of both organic and inorganic sediment due to trapping by the dam. The channel has widened through bank scour associated with the infrequent very high flow events, and there is a complete absence of fine-grained material on bedrock, bars, or in the channel due to the lack of sediment supply. Although the channel has widened, rainforest species have encroached onto lateral bars due to a reduction in the frequency of moderate flow events, and vegetation has established on mid-stream, lateral and point bars. This vegetation is poorly anchored due to the lack of fine sediments in the reach and is susceptible to erosion during the infrequent high flow events.

For approximately the next 7 km downstream, evidence of flood impacts and sediment starvation remained, but in 2003 there were also indications that scouring of the channel was incomplete, with the continued presence of fine-grained deposits supporting thick vegetation on the downstream end of higher point bars, and in some protected areas at the downstream end of the bars. These higher deposits were suggested as possibly being pre-dam in origin and the lower material derived from inflows downstream of the dam. It is unknown if these deposits are still present in the river.

Between Liena and the confluence of Lobster Creek numerous tributaries enter the Mersey River. The region has been modified by agricultural and forestry activities and some of the tributaries have been degraded by land use practices. In this reach of the Mersey, low lying, fine-grained flood plain pockets supporting vegetation older than 30 years in age were present at the base of 'older' banks. These were interpreted as post-dam flood deposits, with the sediments derived from the tributary catchments. Impacts of low sediment input and erosion from high flows continued to be present, with the erosion of alluvial banks in high energy positions (outside bends), erosion of vegetation from mid-stream bars, armoured bars and bed, and a lack of fine-grained deposits at the base of vegetation.

7.5.2 Mole Creek Karst Region

Karst regions can be sensitive to regional hydrologic changes due to the linkages between surface and ground water movements. The Mole Creek karst, in the central Mersey River valley, has been and continues to be investigated by DPIPWE (R. Eberhard, DPIPWE, pers. comm. 2010). The agency has gained an understanding of the surface – ground water interactions in the karst, and uses this information for land use planning and management in the area. Water from the Mersey River does not enter the karst, but rather the river serves as a base level for water draining from the karst unit. Due to this relationship, at the present, there is not believed to be any direct alteration to the karst attributable to Hydro Tasmania's operations in the catchment.

7.5.3 Fisher River

The hydrology of the Fisher River has been modified both upstream and downstream of Fisher Power Station. Upstream of the power station, river flow has been reduced due to the creation of Lake Mackenzie and other water diversions which direct water to the Fisher Power Station. Downstream of Fisher Power Station, the channel is likely to have been altered due to changes in flow patterns from the power station, and a reduction in sediment due to storage in Lake Mackenzie. However, the nature and extent of downstream alterations to natural flows have not been ascertained and little is known about the Fisher Rivers sediment characteristics.

7.5.4 Forth River

The Forth River has been highly modified through the creation of the run-of-river impoundments, and the large diversion of water into the catchment via Lemonthyme and Wilmot Power Stations. The Forth River downstream of the final impoundment (Lake Paloona), receives less sediment but more water when compared to the upper Mersey, Fisher and Wilmot rivers due to the sediment-capture of the upstream storages and flow diversions. Sediment regimes in this river have not been investigated.

The geology of the Forth River below Paloona Power Station consists of a small pocket of metamorphic rocks immediately below the power station and a predominance of alluvial and aeolian sediments extending to the mouth of the river. The Forth River discharges into the Forth Estuary**,** which exhibits tidal variations in flow strength and direction. However, little is known regarding the change in the amount of sediment input from the Forth River into the estuary.

7.5.5 Wilmot River

The Wilmot Dam on Lake Gairdner and the diversion of water from the upper Wilmot River into the Forth catchment, have resulted in reduced flows in the Wilmot River downstream of the dam. Only the largest high flow events pass over the dam as spill (Appendix G; Figure G-5). It is likely that this altered flow regime has resulted in channel widening due to scour, the absence of fine-grained sediments in the channel, the encroachment of rainforest into the old riparian zone, and the establishment of new vegetation in the channel and on lateral bars (Photograph 7-2).

Photograph 7-2
Wilmot River downstream of Wilmot Dam (October 2010)

The geology downstream of Wilmot Dam is characterised by predominantly siliceous sediments, with small pockets of unconsolidated sediments, basalt, Cambrian acid volcanics, and glacial and periglacial features. Thus the planform of the Wilmot River may be susceptible to erosion and large scale change, but no investigations of this have been carried out to date.

7.6 Summary of Geomorphological Issues

The recognised and potential geomorphic impacts in the Mersey-Forth catchments attributable to the Mersey-Forth Power Scheme are summarised in Table 7-1.

Most of the identified geomorphic changes associated with the Mersey-Forth Power Scheme affect sediments, soils and vegetation along, or inundated by, the lakes or in the river channels and previous riparian zone. The karstic area surrounding Lake Gairdner may be one area where the underlying geology is also susceptible to hydrologic change.

In the late 1990s, the Mersey River downstream of Parangana Dam (Davies *et al*. 1997) was identified as being degraded in a biological and geomorphic context and an environmental flow was implemented. Aside from investigations associated with the environmental flow, there have not been any detailed investigations of the impact the flow changes have had on the river system, and no other issues have been publicly identified.

Table 7-1
Summary of geomorphic impacts associated with the Mersey-Forth Power Scheme

Alteration	Impact/Potential Consequence
Development of impoundments in river channels	• Drowning of river valleys • Erosion of soils and riparian vegetation through inundation and water logging • Sediment trapping • Reduced and variable flow regimes
Diversion of water out of catchments	• Reduction in low and medium flows - encroachment of vegetation into channels • Maintenance of some very high flows • Reduction in sediment availability • Channel widening through scour • Channel widening through sediment starvation • Changes to ground water
Diversion of water into catchments	• Increase in median flows • Large reduction in sediment availability • Channel widening through increase in median flows • Erosion of soils and loss of riparian vegetation through channel widening • Channel widening through sediment starvation

8 Hydro Tasmania's Land Assets and Multiple Use

This chapter presents the multiple uses of Hydro Tasmania land and water in the Mersey-Forth catchments (Photograph 8-1). Hydro Tasmania manages and operates land and water, often in environmentally sensitive locations, with the aim of promoting sustainable land management policies and practices.

Maps showing land owned by Hydro Tasmania in the Mersey-Forth catchments are provided in Appendix S (Maps A to G). The land owned by Hydro Tasmania was acquired for the construction and on-going management and operation of the Mersey-Forth Power Scheme.

8.1 Hydro Tasmania's Land Assets

With the exception of Gowrie Park and some lake access roads, the majority of Hydro Tasmania's infrastructure assets are along the shorelines of its lakes and along the upper Fisher, Mersey and Forth rivers. This land predominantly provides flood level protection. More substantial land parcels are owned around the power stations, particularly Lemonthyme, Fisher and Wilmot. They serve operational purposes and provide safety buffers for the public around energy production assets.

8.2 Multiple Values and Uses of Hydro Tasmania Land and Waterways

Hydro Tasmania acknowledges that tourism and recreational activities on Hydro Tasmania's lakes and land in the Mersey-Forth catchments have been a catalyst for economic development and are a significant value to the regional communities. Hydro Tasmania endeavours to minimise its operational impact on multiple use values and supports utilisation of its waterways where activities do not conflict with hydro-generation and can be conducted safely with minimal impact on the environment. Changes have been made to power generation operations to accommodate canoeing and rafting below the Rowallan and Paloona dams and Fisher Power Station (section 3.9.2). Generation at Paloona and Rowallan Power Stations is initiated slowly to ensure the downstream safety of recreational users. There are signs on all rivers alerting users to the fact that the water levels can rise at any time.

Hydro Tasmania recognises that an integrated approach to managing increased recreational use within the Mersey-Forth catchments is required and is committed to working with water and land users to develop a sustainable framework that balances operational and economic feasibility with social and environmental sustainability.

Hydro Tasmania is represented on a steering group as part of the Lake Barrington Recreational Framework to manage recreational, environmental, safety and infrastructure values of the Lake Barrington Precinct (Inspiring Place 2010). The steering group includes members from: Sport and Recreation Tasmania, Forestry Tasmania, Parks and Wildlife Service, Inland Fisheries Service, Kentish Council, Marine and Safety Tasmania and Cradle Coast Water.

Photograph 8-1
Tourists and canoeist at Lake Rowallan (October 2010)

Lake Barrington is the site of a world class rowing course, which has been the venue for a number of national and international regattas. On requests from the Tasmanian Rowing Council Hydro Tasmania adjusts the water level of Lake Barrington to facilitate rowing events. Canoeing is also popular on Lake Barrington.

White water courses for kayaking and canoeing exist in the Mersey River between Lakes Rowallan and Parangana, downstream of Lake Paloona and the Fisher River below Fisher Power Station.

Water skiing and boating occurs on Lakes Barrington and Parangana and deep water diving takes place on Lake Cethana. No specific conditions apply to the operational level of the storages associated with these activities.

Lake Paloona is accessible by Hydro Tasmania personnel only, and as such, there are no recreation related activities associated with this lake. Restricted access is enforced at Lake Paloona as it is situated directly upstream of town drinking water supply.

The upper Mersey River has been rated as a 'premium river fishery' with Brown Trout stocked in the Mersey River (IFS 2008). Since the environmental flow release below Parangana, it appears that trout populations have increased (DPIW 2009) and that the lower Mersey is becoming popular with anglers (Table 8-1). The Forth River is also an important trout fishery.

In 2009, Hydro Tasmania, Marine and Safety Tasmania (MAST) and the IFS undertook an assessment of public boat launching facilities on inland waters in Tasmania including the Mersey-Forth catchments (MAST *et al*. 2010). The plan details current condition of existing facilities, and provides information on the maintenance of each facility, short term priorities and potential future developments.

Table 8-1
Number of anglers and fish catch in the Mersey-Forth lakes and rivers from the IFS Annual Report 2009-10 (IFS 2010)

Lake / River	Angler Effort	Angler Numbers	Harvest (Brown Trout)	Harvest (Rainbow Trout)
Lake Mackenzie	815	320	309	112
Lake Rowallan	2 136	640	3 710	646
Lake Parangana	899	142	871	84
Lake Cethana	675	284	927	28
Lake Gairdner	169	106	56	0
Lake Barrington	5 368	1 744	1 040	2 923
Lake Paloona	0	0	0	0
Mersey River	14 361	3 025	17 902	2 192
Forth River	3 991	783	3 091	506

8.3 Land and Multiple Use Issues

The Lake Barrington Recreational Management Framework (Inspiring Place 2010) identifies that a number of the favoured recreational activities at Lake Barrington also represent the greatest health and safety risks. The framework provides recommended options and actions on how to reduce safety risks at Lake Barrington. Safety on Hydro Tasmania land and water in the wider Mersey-Forth catchments requires a co-ordinated management approach to ensure ongoing issues are addressed.

Camping and caravanning without chemical toilets has been identified as having the greatest impact on both public and Hydro Tasmania land and represents a significant risk to water quality and environmental health. In the Mersey-Forth catchments this is particularly the case for the areas between Lakes Rowallan and Parangana. The recreational use of Hydro Tasmania sites are not well understood, nor are the environmental impacts associated with that use.

A growing problem is the occurrence of illegal structures and developments on Hydro Tasmania land and waterways, particularly those that may impact on natural values and multiple uses. At Lake Barrington, illegal structures and developments range from large scale reclamation of the lake for skiing facilities, substantial wharf structures, pontoons, boat ramps, and long term camping (Inspiring Place 2010). Recommended actions for the removal of illegal or unauthorised pontoons/structures and other developments exist for Lake Barrington (Inspiring Place 2010).

9 Cultural Heritage

Land owned or managed by Hydro Tasmania contains a variety of Aboriginal and industrial heritage values. Hydro Tasmania manages cultural heritage assets through its Cultural Heritage Program and its Environment and Sustainability Management System (ESMS).

9.1 Aboriginal Cultural Heritage

The term 'Aboriginal cultural heritage' encompasses all places and items of significance to the Aboriginal community, and in many instances, to the broader community. These include archaeological sites, natural resources (such as plants known to have been used by Aboriginal people in the past), traditional practices and spiritual values. Maintaining the integrity of Aboriginal values is important for two main reasons: the significance of the physical place or item, and the cultural and historical information that may be contained within the site. There are also legal obligations to protect Aboriginal cultural heritage in accordance with the *Aboriginal Relics Act 1975*.

Sites at high risk from Hydro Tasmania activities are those located on lake shorelines and stream banks in areas where erosion may occur due to low water levels, wave action or scouring flows. Sites may also be subject to periodic wetting and drying due to fluctuations in water levels. Risks to artefacts include erosion, exposure and translocation. Siltation of sites may also be an issue for inundated sites and sites on lake shorelines. In addition, impacts may also occur in areas adjacent to ongoing human activity, such as camping or fishing, where inadvertent disturbance from vehicles or boats is likely.

Aboriginal heritage values are identified and managed in consultation with the Aboriginal community and Aboriginal Heritage Tasmania. Survey and management of Aboriginal heritage sites is carried out by Hydro Tasmania Cultural Heritage Program staff or approved consultants with prior agreement of the Tasmanian Aboriginal Land and Sea Council (TALSC), Tasmanian Aboriginal Centre (TAC) and Aboriginal Heritage Tasmania. This is facilitated by information provided on Hydro Tasmania's Geographic Information System which indicates the probability of finding Aboriginal heritage sites on Hydro Tasmania land. Each site is investigated case by case and no information is available about general management of Aboriginal heritage values in the Mersey-Forth catchments.

Much of the archaeological research undertaken within and adjacent to the Mersey-Forth catchments does not discuss management options for Aboriginal cultural heritage values.

9.2 Industrial Cultural Heritage

From 2004-2007, Hydro Tasmania assessed the heritage value of all its assets throughout the state for each catchment. Levels of significance were established according to the criteria in the *Historic Cultural Heritage Act 1995*.

Cethana Dam has been awarded an Engineering Heritage Australia plaque (Engineering Heritage Australia 2011) and is the most significant industrial heritage site in the area.

The following assets have also been assessed through the Cultural Heritage Program as having heritage significance:

- Mackenzie Dam spillway
- Parsons Falls rising main
- Parsons Falls forebay and siphon

- Fisher flume
- Fisher Power Station penstock and tunnel
- Parangana Dam spillway
- Wilmot hilltop valve
- Devils Gate Dam wall

The heritage significance for these assets is generally attributed to technological achievement. Many Hydro Tasmania assets were at the forefront of technological achievement for their time.

Heritage Impact Assessments are required for works (other than routine maintenance) for all assets that have heritage significance. Heritage Impact Assessment requires specific management measures depending on the significance of the site and the nature of the work being undertaken using the Burra Charter principle of "do as much as necessary but as little as possible" for guidance (Australia ICOMOS 1999).

10 Summary and Conclusion

Hydro Tasmania has voluntarily committed to undertake a Water Management Review Program in its catchments to show leadership in sustainable water resource management. The aim of the program is to proactively and systematically, in consultation with stakeholders, assess and modify, as practicable, Hydro Tasmania's water management activities in light of their present impacts on social, environmental and economic conditions.

To initiate the Water Management Review in the Mersey-Forth catchments this report has been produced, consolidating current knowledge of the catchments, waterways and hydro power operations, with the intention of obtaining greater understanding and facilitating stakeholder engagement in the review process. The Water Management Review process will include stakeholder engagement and community consultation culminating in the identification of priority issues to be addressed. Investigations into the feasibility of mitigation and management options will be carried out and a program of commitments to improve Hydro Tasmania's water management in the Mersey-Forth catchments will be developed. The process is intended to take a minimum of three years to complete.

The Water Management Review Report provides information on characteristics and known social and environmental values of the Mersey-Forth catchments. An overview of Hydro Tasmania's infrastructure, and system operations for seven lakes and eight power stations are provided. Electricity yield, water use and downstream water releases for recreation, water supply and environmental flow commitments are discussed.

The most recent climate change predictions have been included. Projections indicate that it is possible that the seasonal and geographic distribution of rainfall will change in Tasmania. Run-of-river storages which dominate the Mersey-Forth Power Scheme are particularly vulnerable to a seasonal variation of rainfall, since they are not designed to store large volumes of water for release during drier periods.

With regards to aquatic ecosystem values, historical and recent water quality data from lakes and key rivers have been assessed with results showing that conditions range from excellent in the headwaters to good in the lower catchments. Thirteen species of waterway dependant flora and flora species, listed as threatened, have been recorded in the Mersey-Forth catchments with habitat destruction and flow modification common threats to many of these species. Consideration of geomorphological aspects of the catchments are summarised highlighting that little is known about erosion in the rivers and lakes of the area.

Hydro Tasmania's management of its land assets and the multiples uses of the waterways are identified. The rivers and lakes of the Mersey-Forth catchments are popular for recreational activities including rowing, boating, kayaking, canoeing, water skiing, diving, and recreational fishing.

Aboriginal heritage values are managed in consultation with the Aboriginal community and Aboriginal Heritage Tasmania. Industrial heritage values, associated Hydro Tasmania assets that were at the forefront of technological achievement for their time, have been identified. Cethana Dam is considered to be of high industrial cultural heritage value.

Known impacts and issues associated with the waterways are identified in each relevant chapter. Overall the main issues of concern include:

- Competing multiple uses of waterways including water based sports with associated health and safety concerns, camping facilities and illegal structures;
- The social and environmental impact of low lake levels and rapid fluctuations in river flows;

- Fish kills as a result of rivers being dewatered or through releases of anoxic water;
- Barriers to fish passage and the sustainability of populations of migratory fish;
- Translocation of pests and diseases through interbasin transfer; and
- Downstream erosion, channel constriction and sediment transport issues.

This document aims to contribute to facilitating an increased understanding of hydropower operations and the values of the Mersey-Forth catchments and community. Its compilation is the first step in a process of evaluating current practices and, where possible, enhancing the management of lakes and rivers in the Mersey-Forth catchments.

11 Glossary

Term	Definition
Anoxic	Absence or deficiency of oxygen.
Biological indicator	A species or organism which is used to grade environmental quality or change.
The Burra Charter	The Burra Charter defines the basic principles and procedures to be followed in the conservation of Australian heritage places.
Chlorophyll-*a*	A green pigment present in algae responsible for photosynthesis. The concentration can be measured by spectrophotometer and is used as a surrogate to estimate the amount of algae present in a water sample.
Conductivity	A measure of the ability of a substance to conduct electricity. In water analysis, it indicates the amount of ions present in the water. Also known as electrical conductivity. Measured in µS/cm.
Cyanobacteria	Blue green algae.
Diadromous	Migration of fish between marine and fresh waters as part of its life history cycle.
Ecosystem	A community of interdependent organisms together with the environment they inhabit and with which they interact, and which is distinct from adjacent communities and environments.
Electrical conductivity	See conductivity.
Endemic	Organism having a distribution limited to a particular geographical area such as an island. The isolation of islands has led to the evolution of endemic forms.
Environmental Flow	Water which has been provided or released for the benefit of the downstream aquatic ecosystem and broader environment.
Exotic	Introduced organisms or species.
Galaxiid(s)	Fish that are members of the Family Galaxiidae (includes the genera *Galaxias*, *Galaxiella* and *Paragalaxias*).
Geomorphology	The study of the earth's shape or configuration.
Habitat	Part of the environment which is occupied by an organism (plant or animal). A habitat supplies the organism's basic life requirements for survival (e.g. food, cover, water).
Hypolimnion	Bottom layer of water in a thermally-stratified lake, below the thermocline.
Macroinvertebrate	A term used to group invertebrates in aquatic ecology, usually refers to animals that are greater than 2 mm in size when fully developed. Includes but is not limited to, the larvae of flying insects (caddisflies, dragonflies, mayflies, chironomids), as well as beetles, worms, sponges, molluscs, crustaceans, mites.
Oxycline	The boundary in a stratified water body at which dissolved oxygen rapidly declines with depth.
Periglacial	Applied to the area surrounding the limit of glaciation and subject to intense frost action, and to the living organisms typical of such areas.
pH	Measure of acidity or alkalinity of a solution. A neutral solution that is neither acidic nor alkaline and has a pH of 7. Increasing alkalinity is indicated by pH's 7 to 14 and increasing acidity is indicated by pH's 7 to 0. pH is measured on a logarithmic scale.

Term	Definition
Phytoplankton	Microscopic plants (algae) which are found in water. The basis of aquatic food chains.
Referable	A dam is a referable dam if in the event of a dam failure people are at risk.
Species	A population or group of individual flora or fauna which interbreed to produce fertile offspring or which possess common characteristics derived from a common gene pool.
Taxon/taxa	A taxonomic category or group, such as a phylum, order, family, genus, or species.
Thermal stratification	Change in temperature profiles over the depth of a water column.
Thermocline	The boundary in a thermally stratified body of water which separates warmer surface water from cold deep water and in which temperature decreases rapidly with depth.
Total Kjeldahl Nitrogen (TKN)	A measure of total nitrogen, one of the plant nutrients. High levels in water have been associated with algal blooms.
Turbidity	The cloudiness in a fluid caused by the presence of finely divided, suspended material. Measured using nephelometric turbidity units (NTU).

12 References

Allan, K & Gartenstein, S 2010, *Keeping it Clean*: *A Tasmanian field hygiene manual to prevent the spread of freshwater pests and pathogens*. NRM South, Hobart, Tasmania. Viewed 7 October 2011, <http://www.nrmsouth.org.au/uploaded/287/15130802_52keepingitcleanspreadswe.pdf>

ANCOLD 2003, *Guidelines on Dam Safety Management*, Australian National Committee on Large Dams.

ANZECC and ARMCANZ 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand*, Canberra, ACT.

Australia International Council on Monuments and Sites (ICOMOS) 1999 *The Burra Charter; The Australia ICOMOS Charter for Places of Cultural Significance, 1999*, viewed 6 October 2011, <http://australia.icomos.org/wp-content/uploads/BURRA_CHARTER.pdf>

Australian Bureau of Meteorology (ABOM) 2010, *Climate Data Online*, viewed 6 September 2011, <http://www.bom.gov.au/climate/data/>

Bennett, J, Ling, F & Graham, B 2010, *Climate Futures for Tasmania*. Technical Report. Water and Catchments, Hobart, Tasmania.

Davies, PE 2002, *Development of a Single Season RIVPACS Model for River Bioassessment in Tasmanian Hydro Catchments*, Hydro Technical Report, Hydro Tasmania, Hobart, Tasmania.

Davies, PE, Cook, LSJ & McKenny CEA 1999, *The influence of changes in flow regime on aquatic biota and habitat downstream of hydro-electric dams and power stations in Tasmania*, Hydro Technical Report Project No. 95/034, Hydro Tasmania, Hobart, Tasmania.

Davies, PE & Humphries P 1996, *An Environmental Flow Study of the Meander, Macquarie and South Esk Rivers, Tasmania*, Department of Primary Industries and Fisheries, Hobart, Tasmania.

Davies, PE, McKenny, C & Cook, L 1997, *Mersey River Environmental Flow Study: Pilot study to determine environmental benefits of flow releases from Parangana Dam to the middle Mersey River*, Freshwater Systems, Hobart, Tasmania.

Department of Environment Water Heritage and Arts (DEWHA) 2007, *The Action Plan for Australian Frogs Recovery Outline No. 8: Southern Bell Frog Wildlife Australia, updated 9 February 2007*, viewed 18 October 2011, <http://www.environment.gov.au/biodiversity/threatened/publications/action/frogs>

Department of Primary Industries and Water (DPIW) 2008, *Conservation of Freshwater Ecosystem Values (CFEV) Project Technical Report*, Conservation of Freshwater Ecosystem Values Program, DPIW, Hobart, Tasmania.

Department of Primary Industries and Water (DPIW) 2009, *An Evaluation of the Environmental Water Release from Parangana Dam to the Lower Mersey River - 1999 to 2009*, DPIW, Hobart, Tasmania.

Department of Primary Industries, Parks, Water and Environment (DPIPWE) 2006a, *Threatened Tasmanian Eagles Recovery Plan 2006-2010*. Threatened Species Section, DPIPWE, Hobart, Tasmania.

Department of Primary Industries, Parks, Water and Environment (DPIPWE) 2006b, *Giant Freshwater Lobster Astacopsis gouldi Recovery Plan 2006-2010*, Threatened Species Section, DPIPWE, Hobart, Tasmania.

Department of Primary Industries, Parks, Water and Environment (DPIPWE) 2010, *Natural Values Atlas*, DPIPWE, Hobart, Tasmania, viewed 6 September 2011, <https://www.naturalvaluesatlas.tas.gov.au/pls/apex/f?p=200:101:4299525931613181>

Department of Primary Industries, Water and Environment (DPIWE) 2001, *Environmental Management Goals for Tasmanian Surface Waters*. Mersey River Catchment, DPIWE, Hobart, Tasmania, viewed 6 September 2011, <http://www.environment.tas.gov.au/index.aspx?base=183>

Department of Primary Industries, Water and Environment (DPIWE) 2005, *Mersey Water Management Plan*, DPIWE, Hobart, Tasmania, viewed 6 September 2011, <http://www.dpiw.tas.gov.au/inter.nsf/WebPages/JMUY-6GM3WP?open>

Engineering Heritage Australia 2011, *Engineering Heritage Recognition Program*, Engineers Australia, viewed 6 September 2011, <http://www.engineersaustralia.org.au/ieaust/index.cfm?3B9DB6F6-B245-C1D9-2EAB-14E0E6D9A73C>

Forest Practices Authority (FPA) 2002, *Threatened Fauna Manual for Production Forests in Tasmania: Grey Goshawk Accipiter novaehollandiae*, Forest Practises Authority, Hobart, Tasmania.

Grose, MR, Barnes-Keoghan, I, Corney, SP, White, CJ, Holz, GK, Bennett, JC, Gaynor, SM & Bindoff, NL 2010, *Climate Futures for Tasmania: General Climate Technical Report*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

Hydro Tasmania 2007, *Cloud Seeding – some facts*, Hydro Tasmania, Hobart, Tasmania, viewed 6 September 2011, <http://www.hydro.com.au/about-us/news/2007-05/cloud-seeding-%E2%80%93-some-facts>

Hydro Tasmania Consulting 2010, *Inflows to Power Stations – 2009 Update*, Technical Report P501132, Hobart, Tasmania.

Inland Fisheries Service (IFS) 2006, *Freshwater Fish Fact Sheets*, updated 31/7/2006, viewed 6 September 2011, <http://www.ifs.tas.gov.au/ifs/fisherymanagement/tasmanianfishfacts/freshwater-fish-fact-sheets>

Inland Fisheries Service (IFS) 2008, *Tasmanian Inland Recreational Fishery Management Plan 2008-2018*, IFS, Hobart, Tasmania, viewed 6 September 2011, <http://www.ifs.tas.gov.au/ifs/fisherymanagement/publications>

Inland Fisheries Service (IFS) 2010, *Annual Report 2009-10*, Hobart, Tasmania, viewed 6 September, 2011, <http://www.ifs.tas.gov.au/ifs/fisherymanagement/publications/Inland%20Fisheries%20Service%20Annual%20Report%202009-2010%20Final.pdf>

Inspiring Place 2010, *Lake Barrington Recreation Management Framework*, Department of Economic Development, Tourism and the Arts, Hobart, Tasmania, viewed 6 September 2011, <http://www.development.tas.gov.au/__data/assets/pdf_file/0003/39432/LakeBarringtonFramework.pdf>

International Hydropower Association (IHA) 2011, *Hydropower Sustainability Assessment Protocol*, viewed 6 September 2011, < http://hydrosustainability.org/>

Jerie, K, Household, I & Peters, D 2003, *Tasmania's river geomorphology: stream character and regional analysis, volume 1 and 2*, Nature Conservation Report 03/5, Nature Conservation Branch, Department of Primary Industries, Water and Environment, Hobart, Tasmania.

Kiernan, K 1990, The Extent of the Late Cainozoic Glaciations in the Central Highlands of Tasmania, *Australia Arctic & Alpine Research*, vol. 22, no.4, pp. 341-354.

Lampert, G 2000, *River Styles Report: North West Tasmania, Mersey Catchment.* DPIWE, Hobart, Tasmania.

Marine and Safety Tasmania, Hydro Tasmania & Inland Fisheries Service 2010*, Inland Waters Boating Infrastructure Draft Plan*, Tasmania, viewed 6 September 2011, <http://www.ifs.tas.gov.au/ifs/newsitems/newsflash/draft-boating-infrastructure-plan-for-comment/>

Mersey River Working Group (MRWG) 1998, *Mersey River Flow and Catchment Assessment: Report and Recommendations on Catchment and Flow Management*. MRWG/DELM/DPIF/HEC/IFC, Hobart, Tasmania.

National Health and Medical Research Council (NHMRC) 2008, *Guidelines for Managing Risks in Recreational Waters.* Australian Government, February 2008.

North Barker & Associates 2003, *Geomorphic Response of the Mersey River and Population Response of Epacris aff. Exserta (Union Bridge) to Flow Regulations,* DPIWE, Hobart, Tasmania.

Parker, G & Bower, D 1996, *Willow Management Guidelines*, Landcare Tasmania, Hobart, Tasmania.

Plafkin, JL, Barbour MT, Porter KD, Gross SK, & Hughes RM 1989, *Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish.* U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C. EPA 440-4-89-001.

Richley, LR 1979, *Land Systems of Tasmania - Region 3,* Department of Agriculture, Hobart, Tasmania.

Schofield, NJ & Davies, PE 1996, '*Measuring the Health of Our Rivers' Water*, vol. May/June, viewed 6 September 2011, <http://www.environment.gov.au/water/publications/environmental/rivers/nrhp/health-river.html>

Tasmanian Parks and Wildlife Service (PWS) 1999, *Tasmanian Wilderness World Heritage Area Management Plan 1999*, DPIWE, Hobart, Tasmania, viewed 18 October 2011, <http://www.parks.tas.gov.au/index.aspx?base=673>

Tasmanian Planning Commission 2009, *State of the Environment Report 2009*, The Commission, Hobart, Tasmania, viewed 6 September 2011, <http://soer.justice.tas.gov.au/2009/indicator/49/index.php>

TASMAP 2010*, DPIPWE Geo-conservation – The List database*, viewed 6 September 2011, <http://www.thelist.tas.gov.au/listmap/listmapstart.jsp>

Water Management Act 1999, Parliament of Tasmania, Hobart, Tasmania, viewed 13 October 2010, <http://www.austlii.edu.au/au/legis/tas/consol_act/wma1999166/>

Wright, JF, Moss, D, Armitage, PD & Furse, MT 1984, 'A Preliminary Classification of Running-Water Sites in Great Britain based on Macro-invertebrate Species and the Prediction of Community Type using Environmental Data', *Freshwater Biology*, vol. 14, no. 3, pp. 221-256.

Zukowski, S & Gawne, B 2006, *Potential Effects of Willow (Salix spp.) Removal on Freshwater Ecosystem Dynamics. A Literature Review*, Report for the North East Catchment Management Authority, Murray-Darling Freshwater Research Centre, Wodonga, Victoria.

Appendices

A Legislation and policy framework

The legislative framework and Hydro Tasmania policy commitments that underpin the Water Management Review Program are provided.

A-1 Water Management Act 1999

The objectives of the *Water Management Act 1999* are to:

(a) promote sustainable use and facilitate economic development of water resources;

(b) recognise and foster the significant social and economic benefits resulting from the sustainable use and development of water resources for the generation of hydro-electricity and for the supply of water for human consumption and commercial activities dependent on water;

(c) maintain ecological processes and genetic diversity for aquatic and riparian ecosystems;

(d) provide for the fair, orderly and efficient allocation of water resources to meet the community's needs;

(e) increase the community's understanding of aquatic ecosystems and the need to use and manage water in a sustainable and cost-efficient manner; and

(f) encourage community involvement in water resource management.

A-2 Hydro Tasmania's Sustainability Code

Hydro Tasmania's Sustainability Code underpins the aims and approach of the Water Management Review Program.

Hydro Tasmania Sustainability Code

Our Sustainability Vision

Hydro Tasmania's vision is to be Tasmania's world renowned renewable energy business. Underpinning our vision is our commitment to create a sustainable future.

For Hydro Tasmania, a sustainable future involves the transparent and balanced application of economic, environmental and social considerations to business decisions and activities. Hydro Tasmania believes that these considerations enable the business to address community and stakeholder expectations and ensure long-term business success.

Our Commitments

Hydro Tasmania is committed to applying our Sustainability Principles to our business activities, decision-making processes and performance reporting. We externally benchmark our sustainability performance against international best practice, and review our policy and program every three years.

Our Sustainability Principles

Governance

We govern the business with processes that ensure integration and implementation of our Sustainability Code. We make ethical decisions through the application of our Values and Code of Ethics within a public reporting framework. We comply with relevant legislative requirements and other commitments.

Assets and Resource Use

We use resources efficiently and maintain our energy system, including assets, for the long-term. We ensure new developments meet our Sustainability Code.

Economic Performance

We ensure our financial practices promote long-term prosperity and enhancement of the business. We keep abreast of demand for our products and services. We develop new products and services, as well as adapt and change our current ones, to ensure flexibility in the marketplace and sustainability.

Employees

We offer opportunities for employees to grow and develop, ensuring the capability of our people and encouraging innovation, learning and research. We ensure a diverse and equitable workforce, and support and respect the protection of internationally proclaimed human rights. We are committed to a safe and healthy workplace.

External Stakeholders

We endeavour to gain respect and trust through active engagement with the community and stakeholders. We are committed to sharing information, building community capability and providing for multiple-use of our land and water assets. We encourage our suppliers, customers, partners and industry peers to be sustainable.

Ecosystems and Heritage

We operate our business to provide future generations with a clean and healthy environment. We minimise our environmental impacts and protect heritage as we look towards the future.

Roy Adair
Chief Executive Officer
Hydro Tasmania

Hydro Tasmania
The power of natural thinking

(This code was approved as at 1 August 2008)

Hydro Tasmania
The power of natural thinking

A-3 Hydro Tasmania's Environmental Policy

Hydro Tasmania's Environment Policy also underpins the aims and approach of the Water Management Review program.

B Community values for the Mersey catchment

Community values for the Mersey River and its tributaries were identified as part of the development of Protected Environmental Values (PEVs) for the Mersey catchment, and the environmental management goals for Tasmanian surface waters (DPIWE 2001). This list of values was developed through community consultation carried out by DPIWE and has been reproduced from the original report (DPIWE 2001).

Table B-1
Community values for the Mersey River and its tributaries (from DPIWE 2001)

Aquatic ecosystem / general river health	Recreational	Aesthetic	Consumptive and non-consumptive uses	Other
Giant freshwater crayfish (all streams under 400m)	Fishing (entire river length), with catch safe to eat	Healthy waterways to allow bird-watching	Town water supply: Mole Creek and Latrobe (via Forth River)	Cultural aspects of Kimberly Hot Springs
Environmental flows	Rafting in upper catchment	Attractive waterways to allow painting, sketching and for tourism (including scenic driving)	Drinking water (individual users, unboiled)	Port of Devonport: shipping requirements for non-silted basins
Regionally representative macroinvertebrate communities	Canoeing (downstream of Lake Rowallan)	Alum cliffs area for tourism viewing	Any private water supplies	Port of Devonport. Ballast water for ships
Low nutrient levels	Scuba diving at estuary mouth	Healthy waterways to support platypus populations	Homestead use – domestic water, non-drinking	Archaeological and Aboriginal sites of significance along river
Good quality water	Duck shooting (with dogs)	Maintain native riparian vegetation: widespread weed infestation (willows) destroying aesthetic appeal	Mitchell lime-works	Waterway used to get rid of effluent from sewage treatment plants
Healthy, self-sustaining aquatic ecosystems	Camping/BBQ/picnic king on waterways across catchment (Farrell Park and Myrtle Hole specifically)	Series of parkland/reserve environments along river	Wesley Vale Mill off-take	Stormwater disposal from city, roads, factories and subdivisions
Values associated with karst system around Mole Creek	Horse riding through river (i.e. Horsehead Creek)	Hot springs at Kimberly	Stock watering	
Unimpeded fish migration	Mountain biking through river	Karst system caves at Mole Creek	Ensure supply for emergency use (fire fighting) – all catchments, access required	
Healthy wetlands (including marsh areas in upper catchment World Heritage Area)	Swimming across catchment (various locations specified)	Tree debris detracts from visual values of estuary at low tide	Horticultural use	

Aquatic ecosystem / general river health	**Recreational**	**Aesthetic**	**Consumptive and non-consumptive uses**	**Other**
Maintain native riparian vegetation; widespread weed infestation (willows) limiting bird nesting, chocking waterways, taints water and restricts caddis food supply – control infestation of weeds and willows	Rowing, yachting, sailing, wind surfing, jet skiing, water skiing and kayaking in estuary		Supply for bottled water at Mole Creek Springs	
Healthy environment for trout	Ship watching in estuary		Realistic water allocation for new sub-division use	
Maintaining trout free areas for native species (Fisher System/Lake Adelaide and Lake Radle/Walls of Jerusalem)	Boating wherever possible across catchment (i.e. Apex Regatta, Power Boat Club)		Having existing water rights tied to land ownership	
Whitebait habitat (i.e. Bells Parade)	On-dam recreation – rowing, power boats		Hydro-generation	
Whitebait habitat: estuary marsh areas. Two species use logs and shingles. Galaxias use holes and creeks further upstream. *Galaxias maculatus* use marshes to lay eggs during spring tides	Surfing at estuary mouth		Private generation of hydro-electricity	
Minimise silt load problems at Latrobe, minimise siltation from upper catchment	Photography, painting and sketching		Eel farming	
Commercial eel fishing	Recreational eel fishing		Possible use of lower reaches for oyster spat collection	
Water quality to sustain edible fish	Upper Mersey rainbow trout fishery (exclude brown trout)		Dairying use	
Minimise bank erosion	Platypus watching		Agricultural irrigation	
Maintain healthy habitat for birds (i.e.. sea eagles, albatross, pelican, oyster catcher, heron and swamp harrier in estuarine area)	Hot springs bathing at Kimberly – State Reserve		Clements and Marshalls agricultural processing	
Healthy habitat for crustacean in estuary (i.e. mud crabs)	Bird/sea eagle watching		Agricultural water extraction for processing and washing	
Improve water quality in estuary so shell fish are suitable for consumption	Children paddling (entire length)			
Maintain instream habitat including macrophytes and large woody debris	Dog exercising – especially in estuary area			
Maintain and protect habitat for *Hydrobiid* species (freshwater snails) – generally sheltered, inaccessible habitats under rock slabs in streams	Tourism			
Protect habitat for Australian grayling (*Prototroctes maraena*) – preferred habitat for the adult is deep slow-flowing pools	Cycling/driving beside river			

C Hydro Tasmania infrastructure in the Mersey-Forth catchments

Table C-1
Technical information for Hydro Tasmania structures

Waterway	Structure	Crest Length (m)	Height (m)	Construction	Referable*	Outlet Capacity (m^3/s)	Spillway Capacity (m^3/s)	Storage	Effective storage capacity ($10^6 m^3$)	Power Station	Date Commissioned	Turbine	Generation capacity (MW)
N/A	Mackenzie Levee	50	2.5	Concrete	No			Lake Mackenzie			1972		
Fisher River	Mackenzie Dam	975	14	Bituminous concrete-faced rockfill	Yes	11.3	515		18.975	Fisher	1973	1 Pelton	46
	Fisher Canal Weir	9.9	1.2	Concrete	No						1972		
	Fisher Tailrace weir	5.2	1	Concrete	No						1972		
	Fisher Intake Levee	330	9	Earthfill	No						1972		
	Parsons Weir	15	4	Earthfill	No						1972		
	Saddle Creek Weir	53	0.5	Earthfill	No						1972		
	Last Lagoon Weir	44	0.4	Earthfill	No						1972		
	Frozen Creek Weir	87	0.1	Earthfill	No						1972		
	Steep Creek Weir	30	0.4	Earthfill	No						1972		
	Yeates Creek Weir	30	2.5	Rockfill with membrane	No						1972		
Mersey River	Rowallan Dam	578	43	Rockfill with impervious core	Yes	21.24	665	Lake Rowallan	120.64	Rowallan	1968	1 Francis	11
	Parangana Dam	189	53	Clay-cored rockfill	Yes	2.4	2093	Lake Parangana	2.601	Parangana mini hydro	2001	1 Francis	0.8
						5.9				Lemonthyme	1969	1 Francis	54

Waterway	Structure	Crest Length (m)	Height (m)	Construction	Referable*	Outlet Capacity (m^3/s)	Spillway Capacity (m^3/s)	Storage	Effective storage capacity ($10^6 m^3$)	Power Station	Date Commissioned	Turbine	Generation capacity (MW)
Wilmot River	Wilmot Dam	138	34	Concrete-faced rockfill	Yes	0.78	1104	Lake Gairdner	7.389	Wilmot	1971	1 Francis	32
Forth River	Cethana Dam	213	110	Concrete-faced rockfill	Yes	141.58	1980	Lake Cethana	19.989	Cethana	1971	1 Francis	100
	Devil's Gate Dam	134	84	Double-curvature concrete arch	Yes	226.53	2040	Lake Barrington	33.949	Devil's Gate	1969	1 Francis	63
	Paloona Dam	171	43	Concrete-faced rockfill	Yes	3.43	2040	Lake Paloona	6.755	Paloona	1972	1 Kaplan	30
Mersey-Forth								***Total***	***210.3***			***Total***	***336.8***

*A notable dam requiring a moderate to high level of scrutiny/surveillance to ensure public safety (ANCOLD 2003)

Hydro Tasmania
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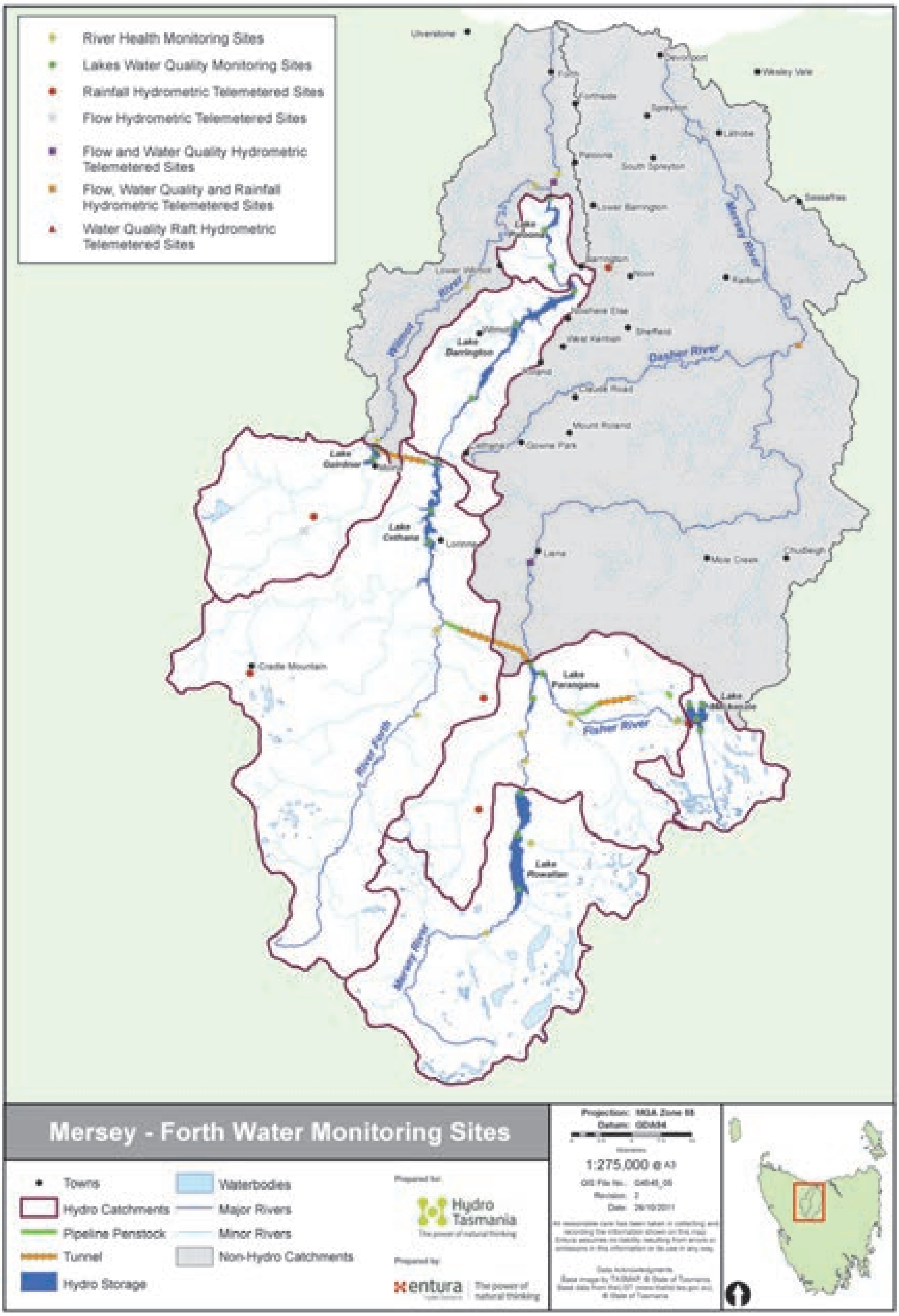
D Mersey-Forth Water Monitoring sites



Hydro Tasmania
The power of natural thinking

E Lake level duration curves for Hydro Tasmania lakes in the Mersey-Forth catchments

For each lake water level duration curves (E-1 to E-7) were obtained by performing percentile calculation on daily time series data extracted from Hydro Tasmania's Hydstra TSM database. Lake level duration curves show the frequency of occurrence of specific lake levels during the period of record. The *y*-axis shows the range of lake levels (expressed as elevation in metres above sea level (mASL) and the *x*-axis shows the percentage of time a particular lake level is exceeded. The plots all have the Normal Minimum Operating Level (NMOL) and full supply level (FSL) marked on the plot.

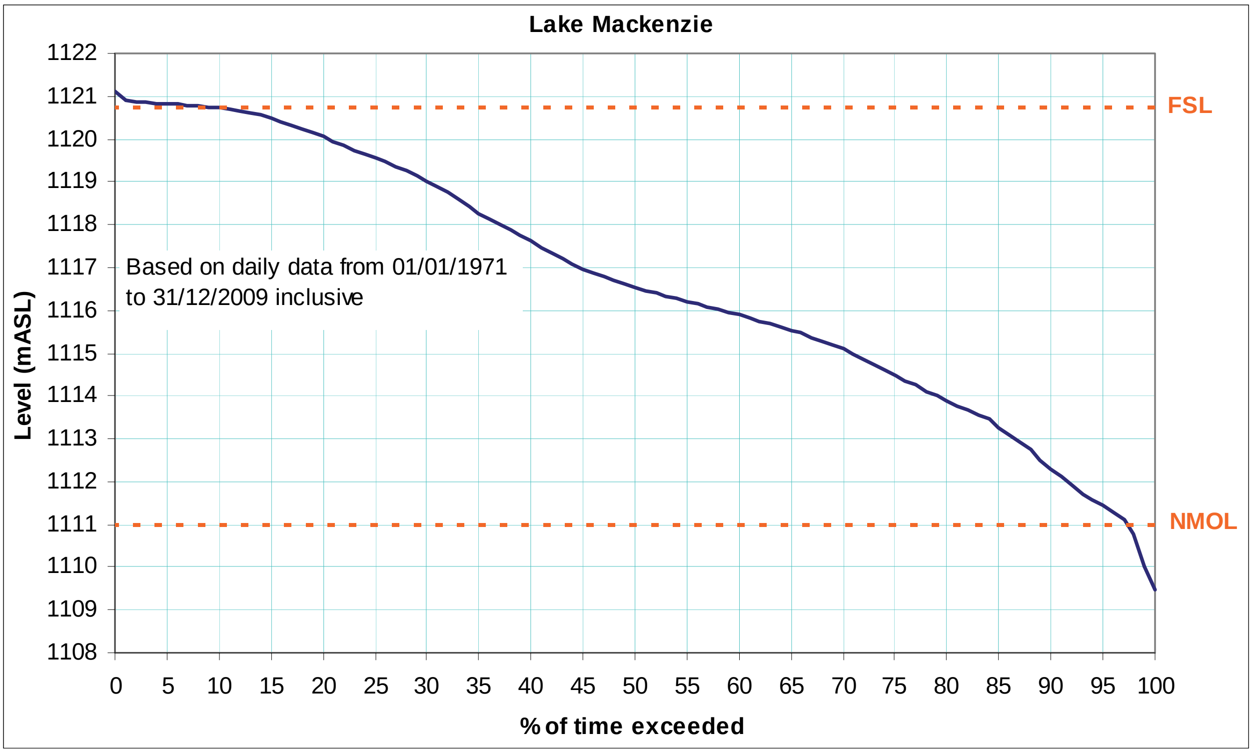


Figure E-1
Lake Mackenzie lake level duration curve

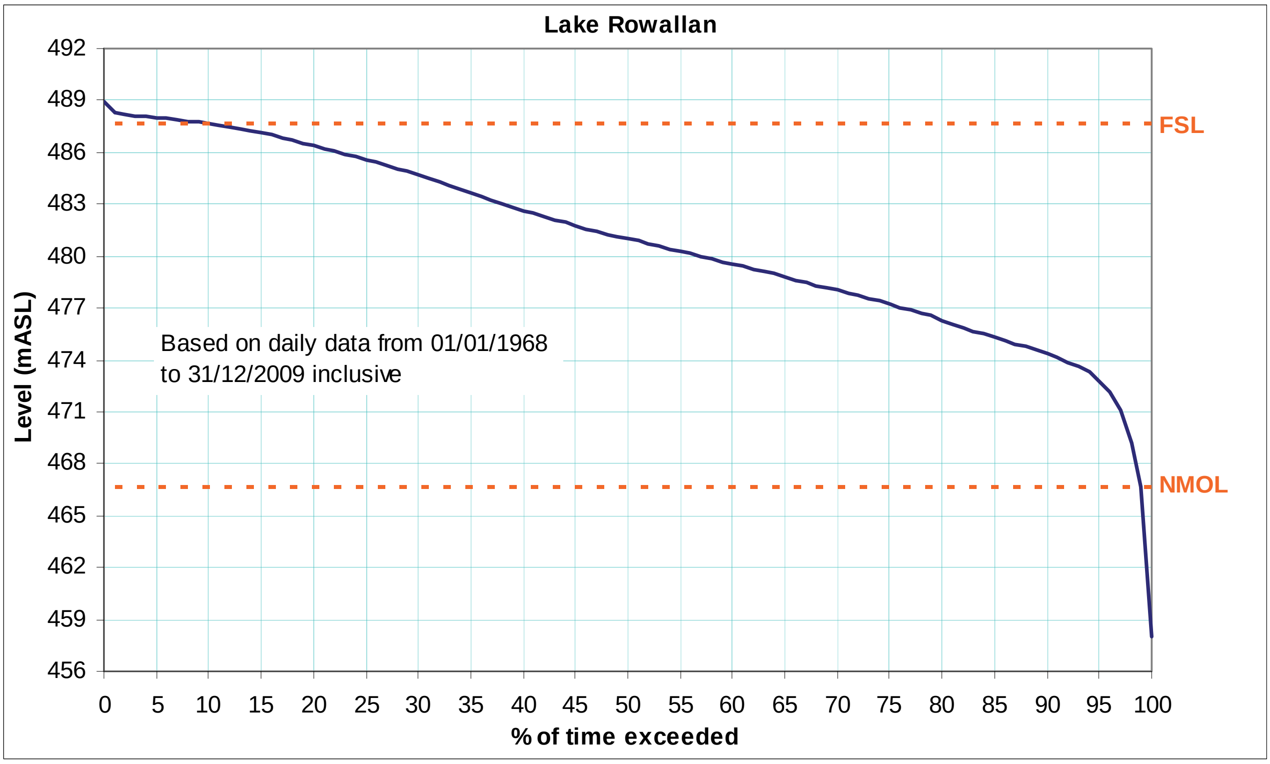


Figure E-2
Lake Rowallan lake level duration curve

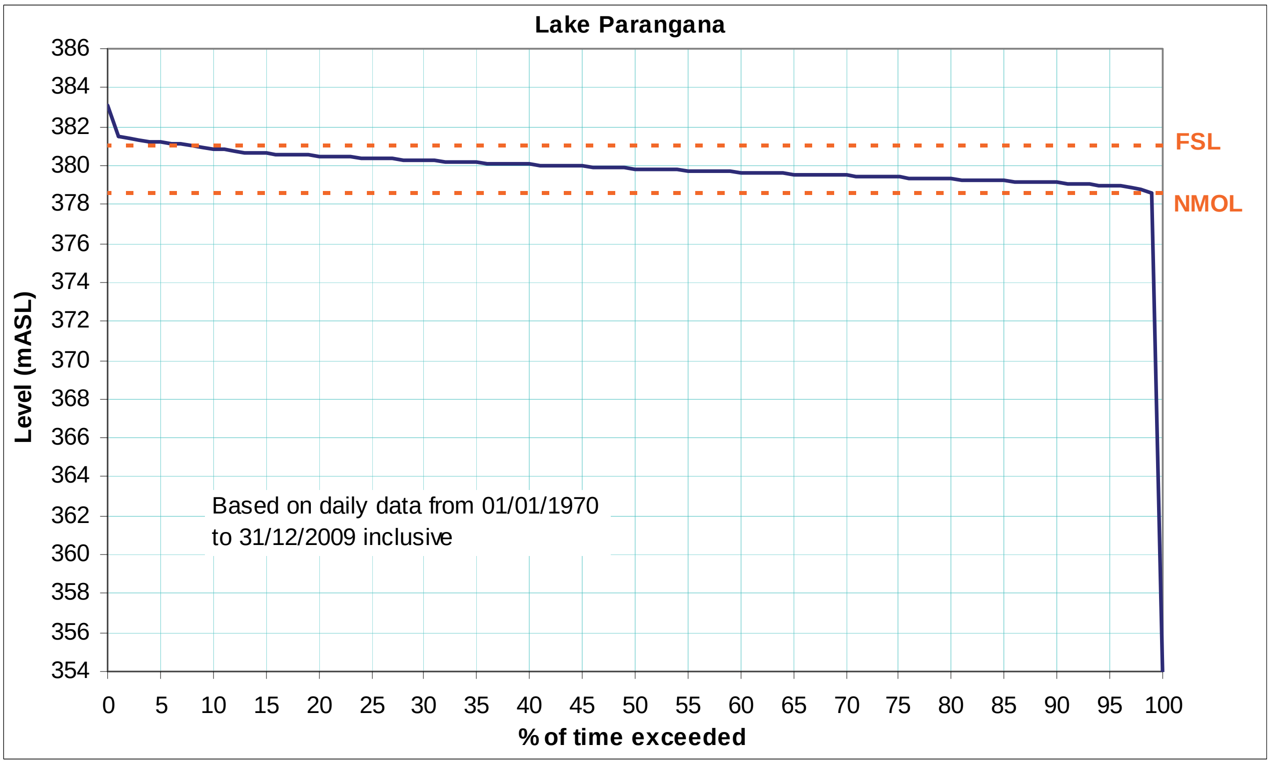


Figure E-3
Lake Parangana lake level duration curve

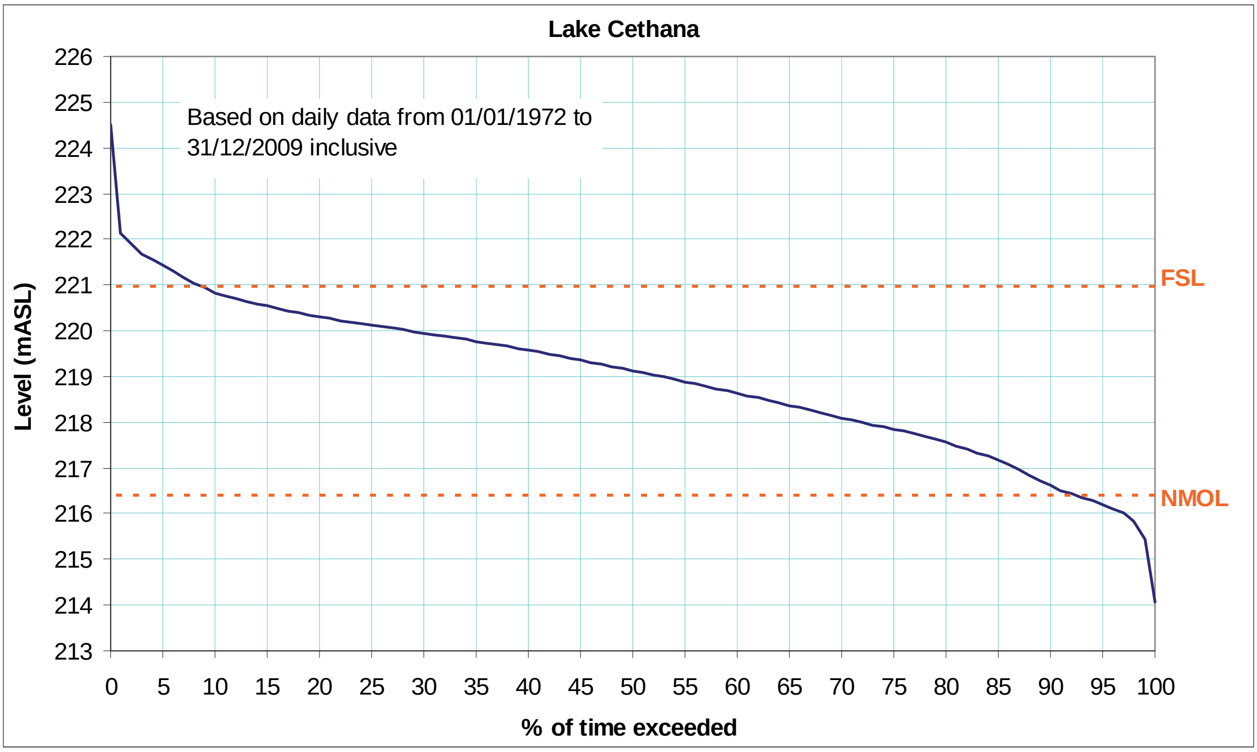


Figure E-4
Lake Cethana lake level duration curve

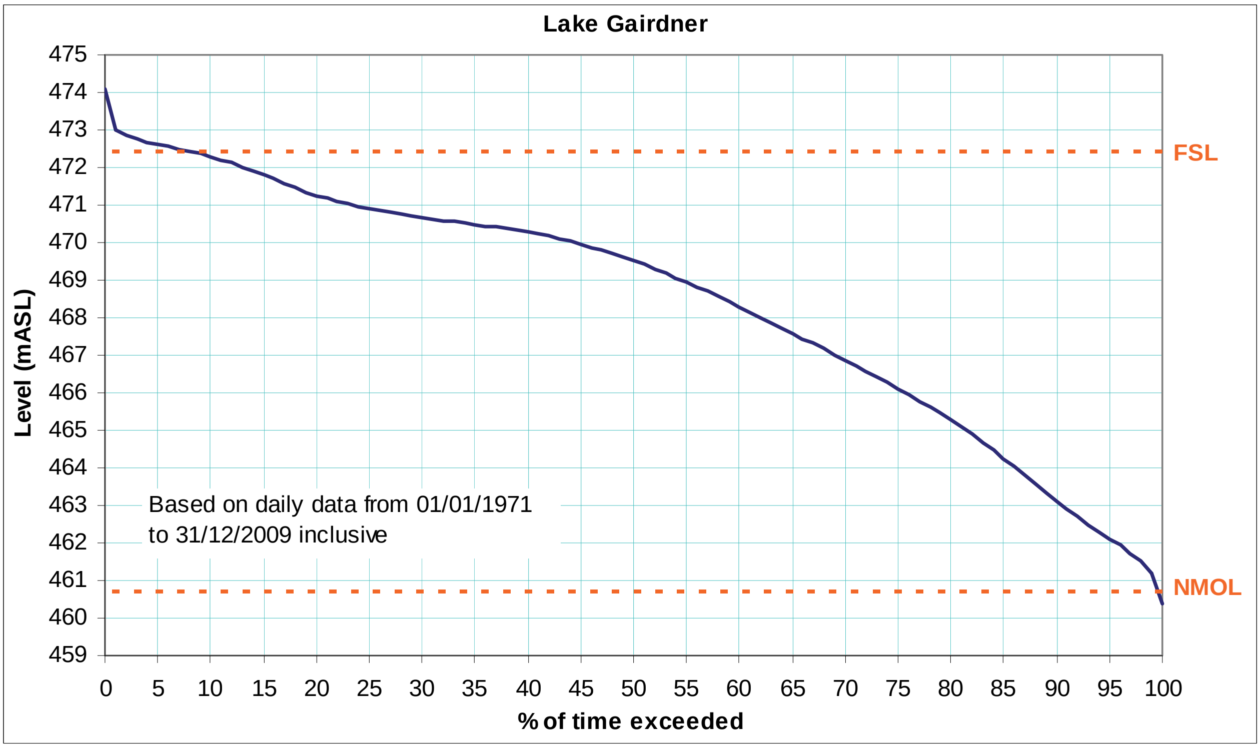


Figure E-5
Lake Gairdner lake level duration curve

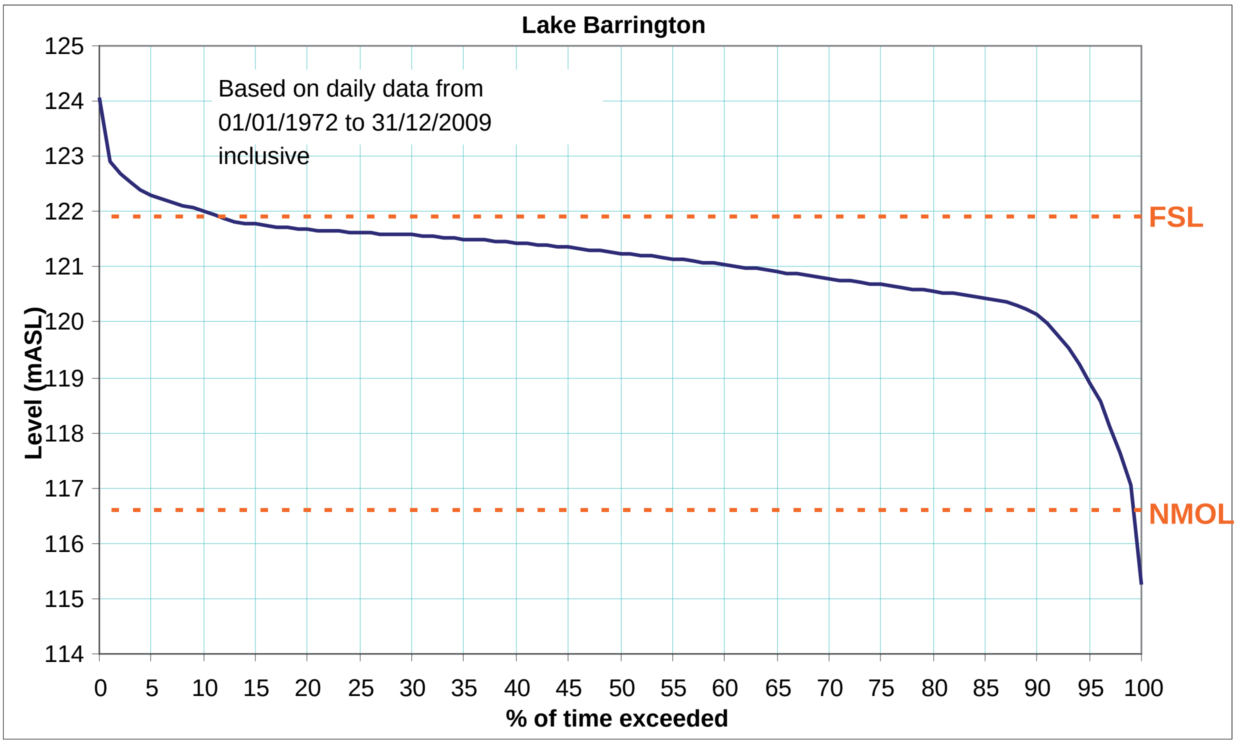


Figure E-6
Lake Barrington lake level duration curve

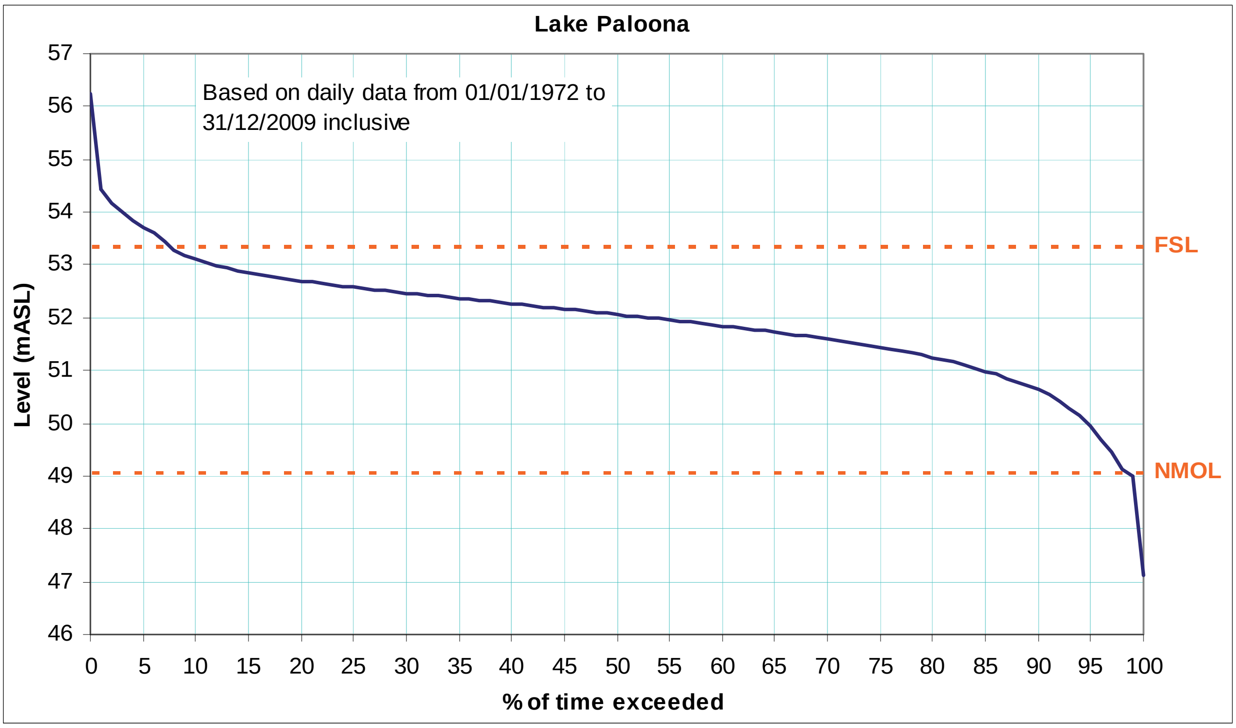


Figure E-7
Lake Paloona lake level duration curve

F Average monthly lake levels for Hydro Tasmania lakes in the Mersey-Forth catchments

The monthly lake level plots (F-1 to F-7), showing the average maximum and minimum lake levels, were plotted by calculating the monthly lake levels from the daily time series data extracted from Hydro Tasmania's 'Hydstra TSM' database (ensuring full calendar years were covered). The *x*-axis indicates the months and the *y*-axis indicates the lake level in mASL. The mid-point for each month is the median value, using all values obtained in a given month over the entire period of record. The minimum and maximum values for each month were obtained by taking the highest and lowest single values for each month over the entire period of record. A maximum value above FSL indicates that the lake is spilling.

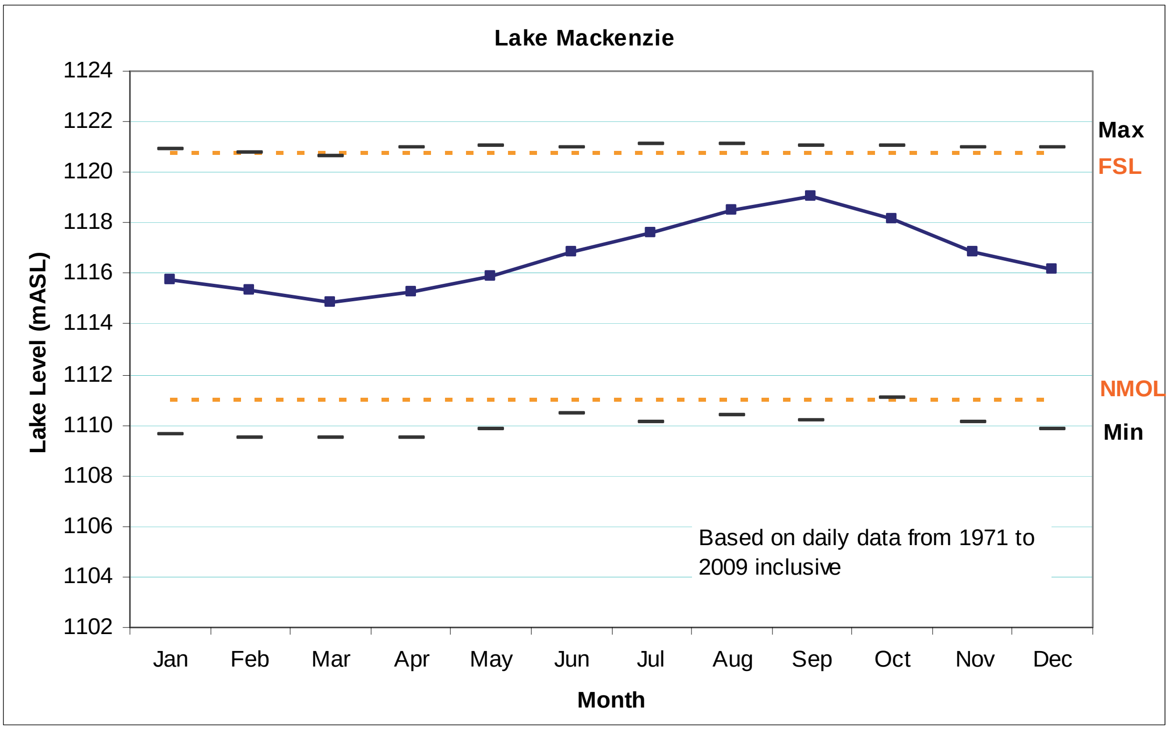


Figure F-1
Lake Mackenzie average monthly lake level

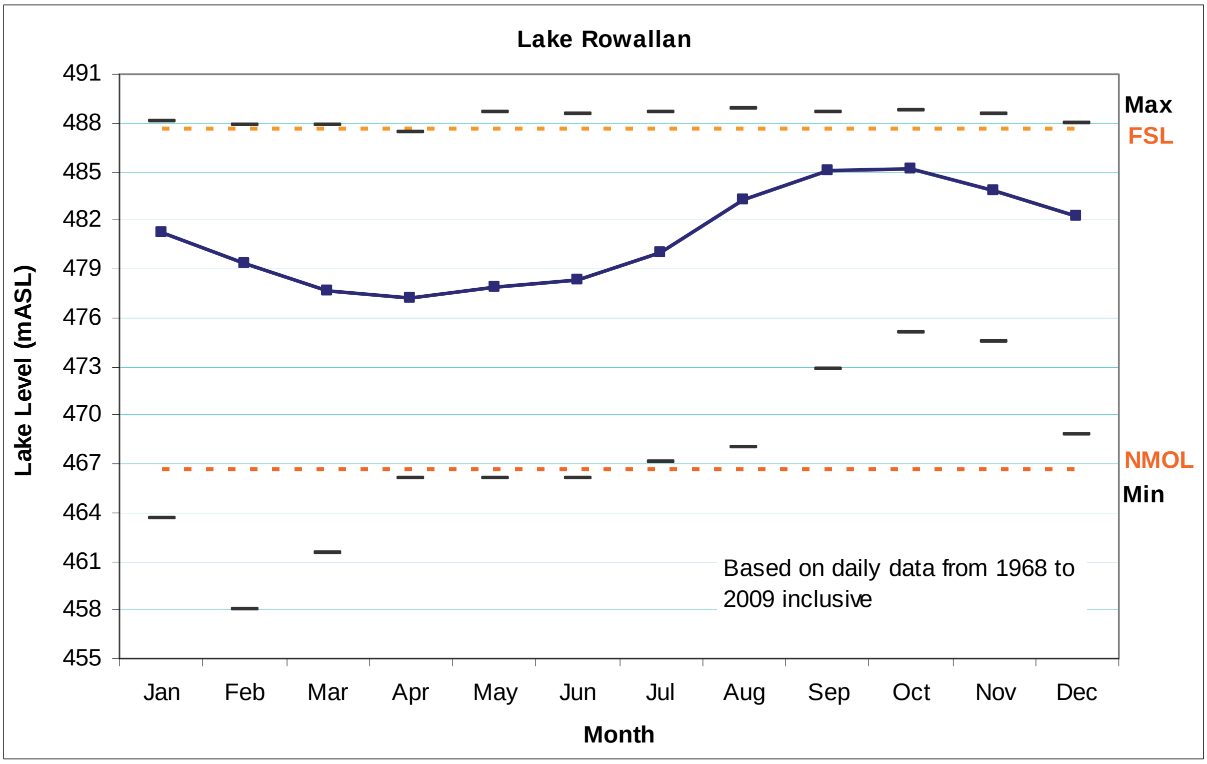


Figure F-2
Lake Rowallan average monthly lake level

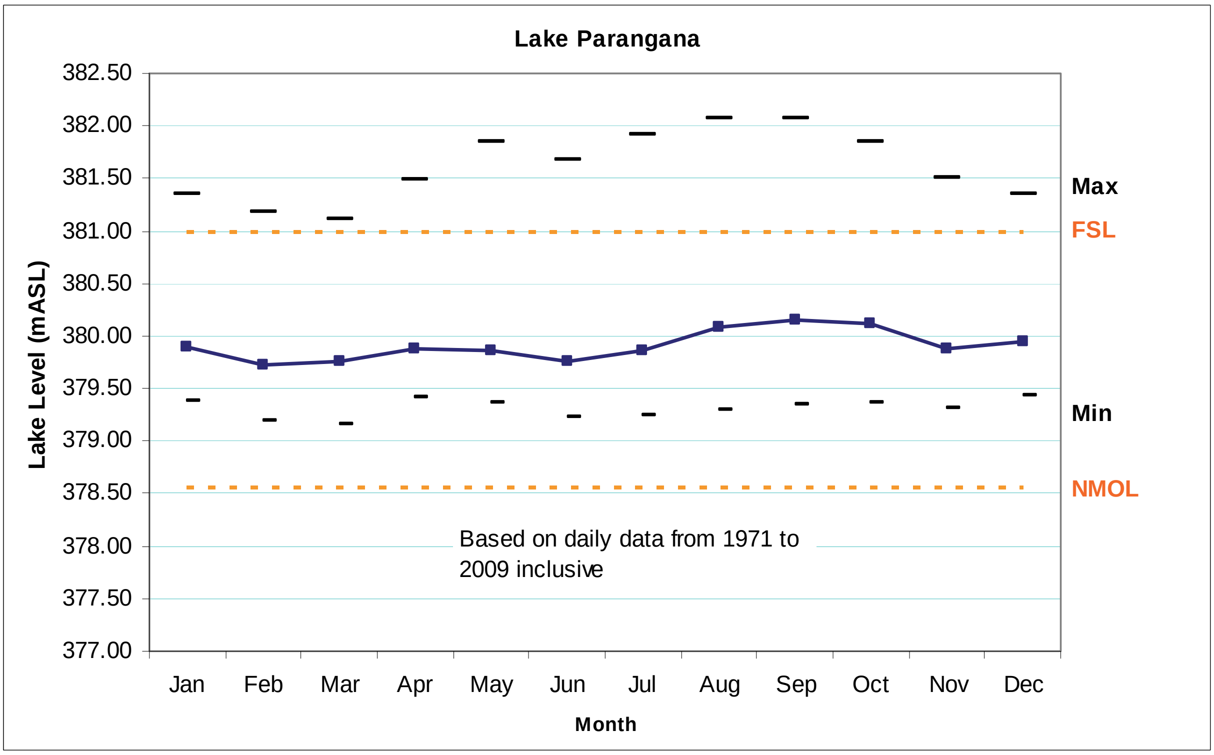


Figure F-3
Lake Parangana average monthly lake level

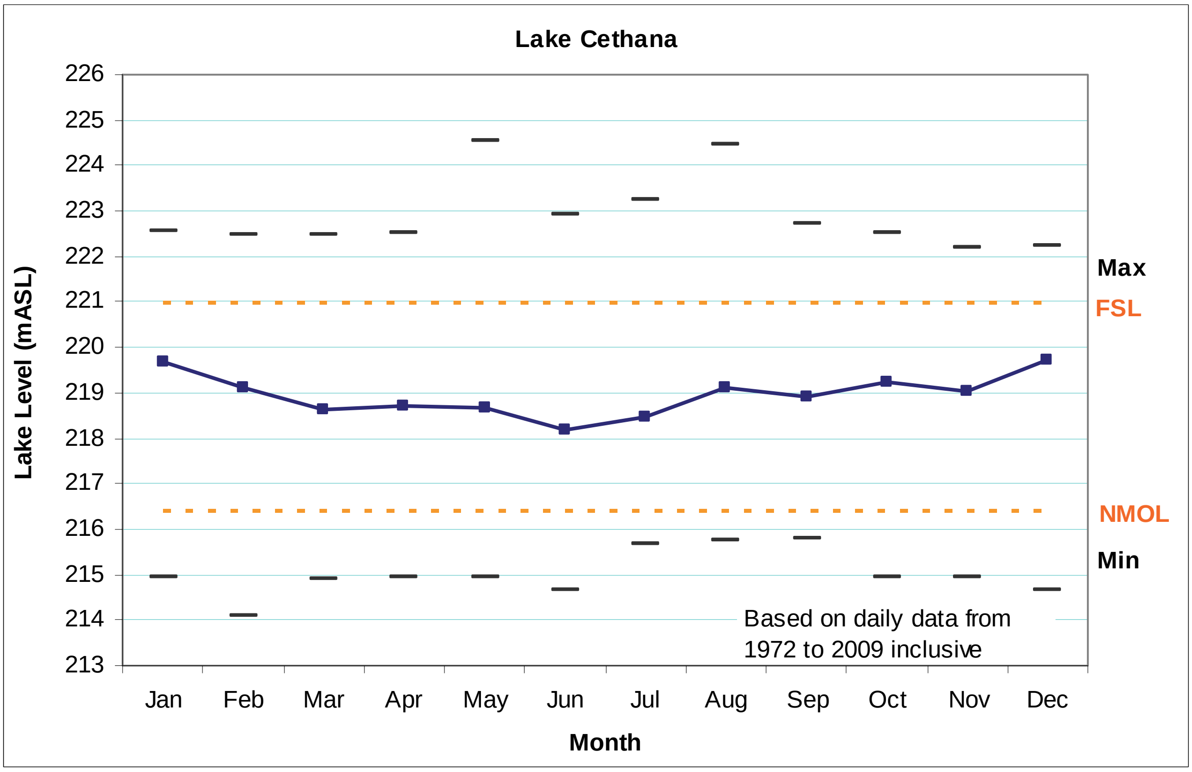


Figure F-4
Lake Cethana average monthly lake level

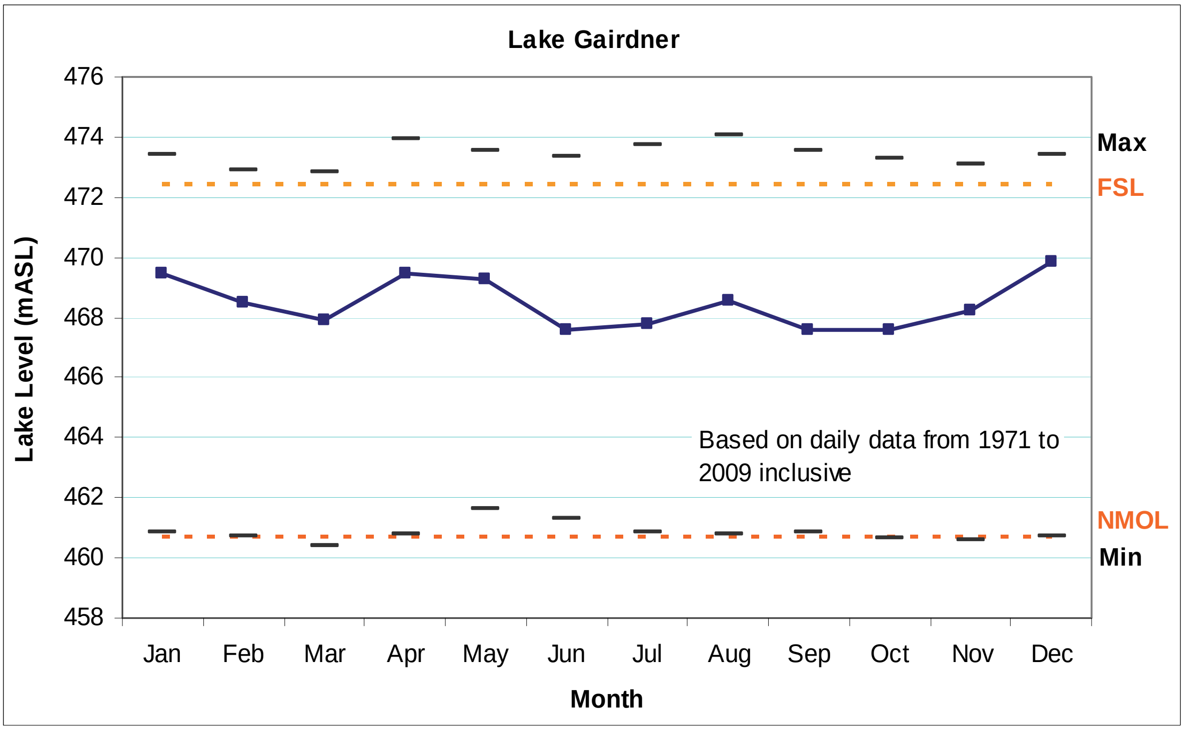


Figure F-5
Lake Gairdner average monthly lake level

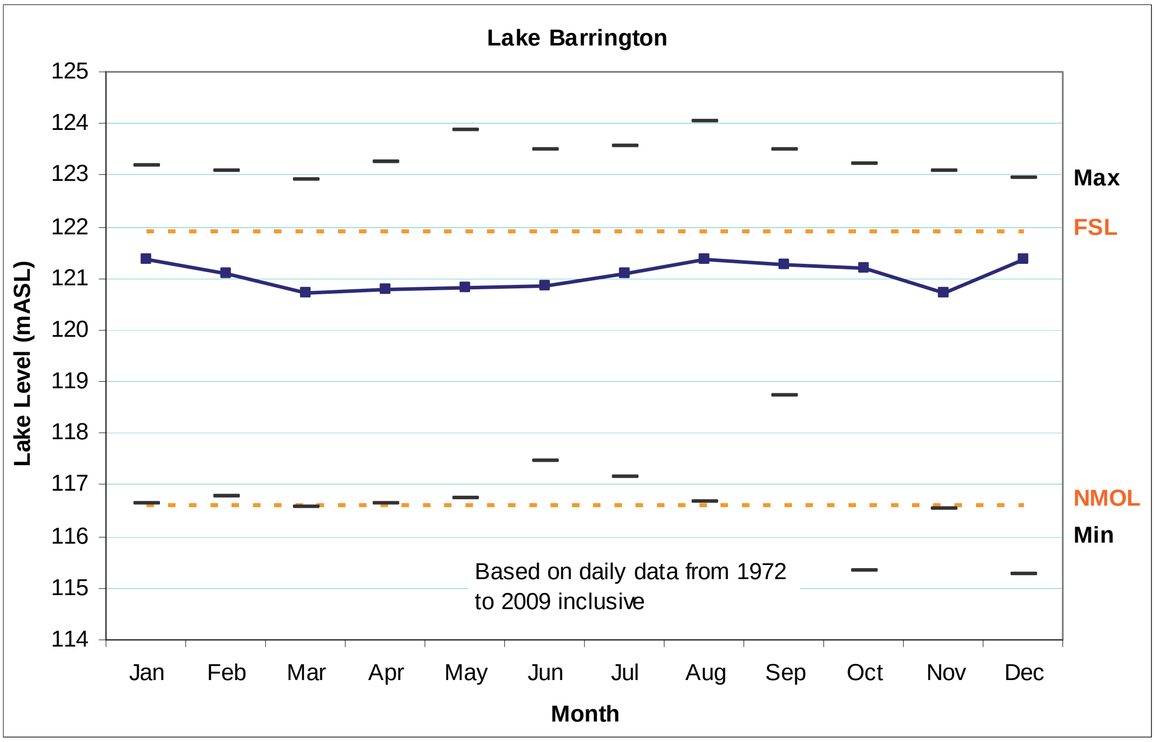


Figure F-6
Lake Barrington average monthly lake level

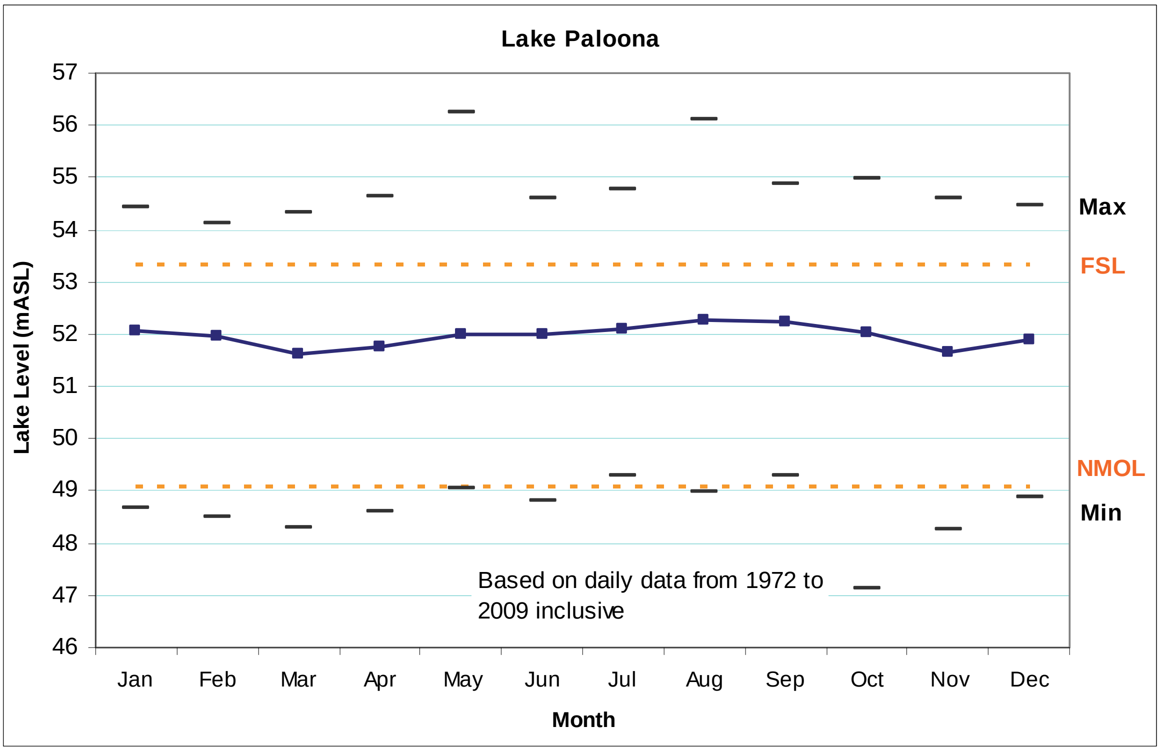


Figure F-7
Lake Paloona average monthly lake level

G Mersey-Forth lake levels 1972 to 2009

The time series plots of water level for each lake were produced by plotting the daily lake level readings obtained from Hydro Tasmania's 'Hydstra TSM' database. The plots were generated for full calendar years covering the period since impoundment of the lakes. The plots also indicate the Normal Minimum Operating Level (NMOL) and the Full Supply Level (FSL).

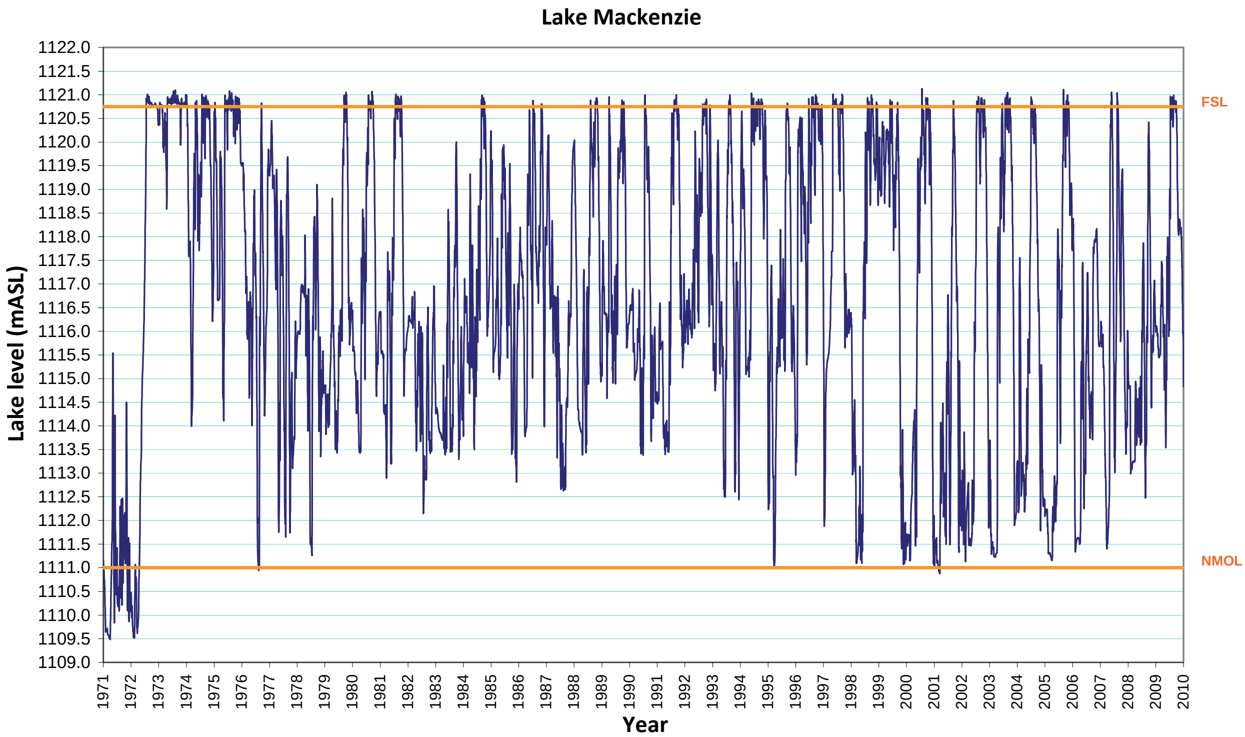


Figure G-1
Lake Mackenzie

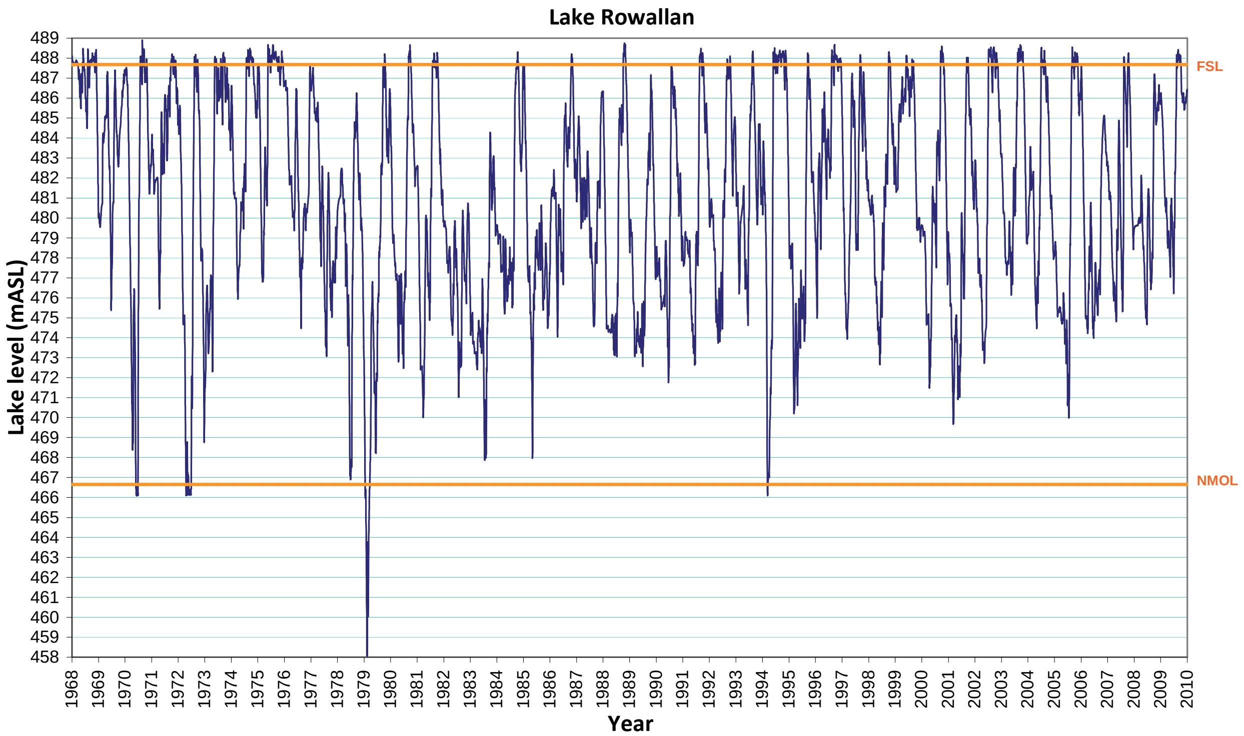


Figure G-2
Lake Rowallan

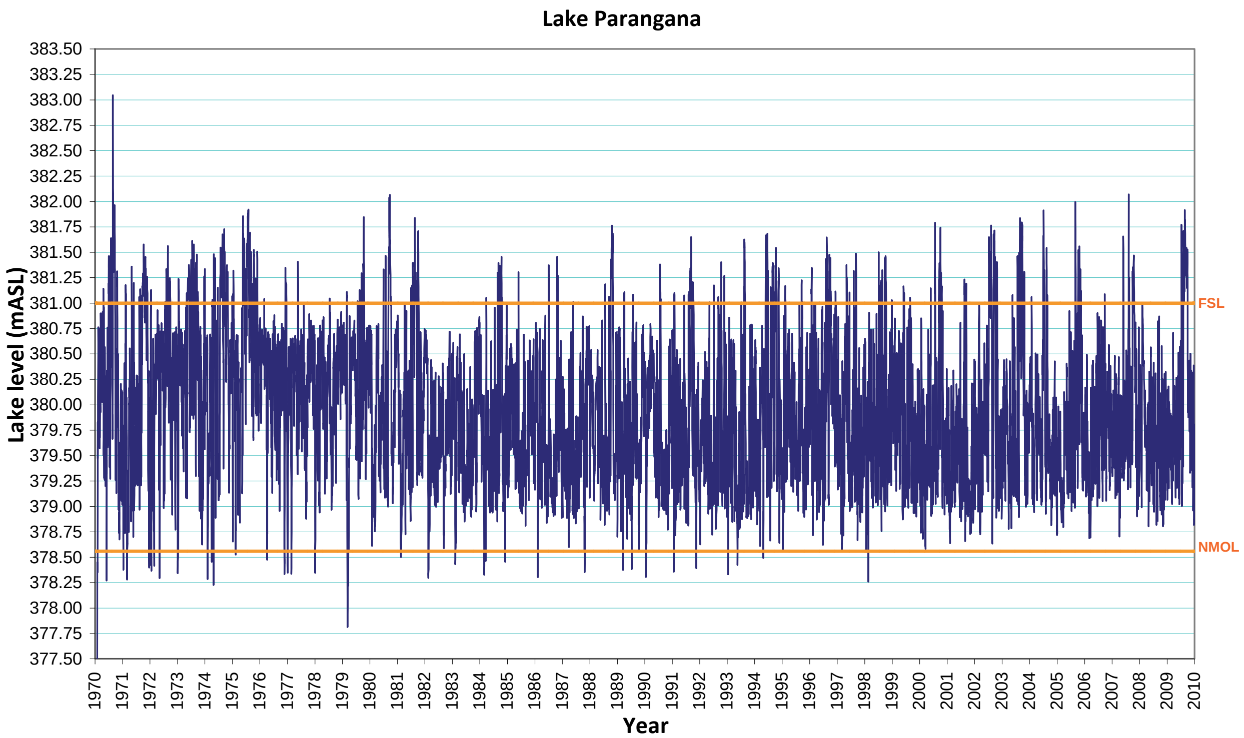


Figure G-3
Lake Parangana

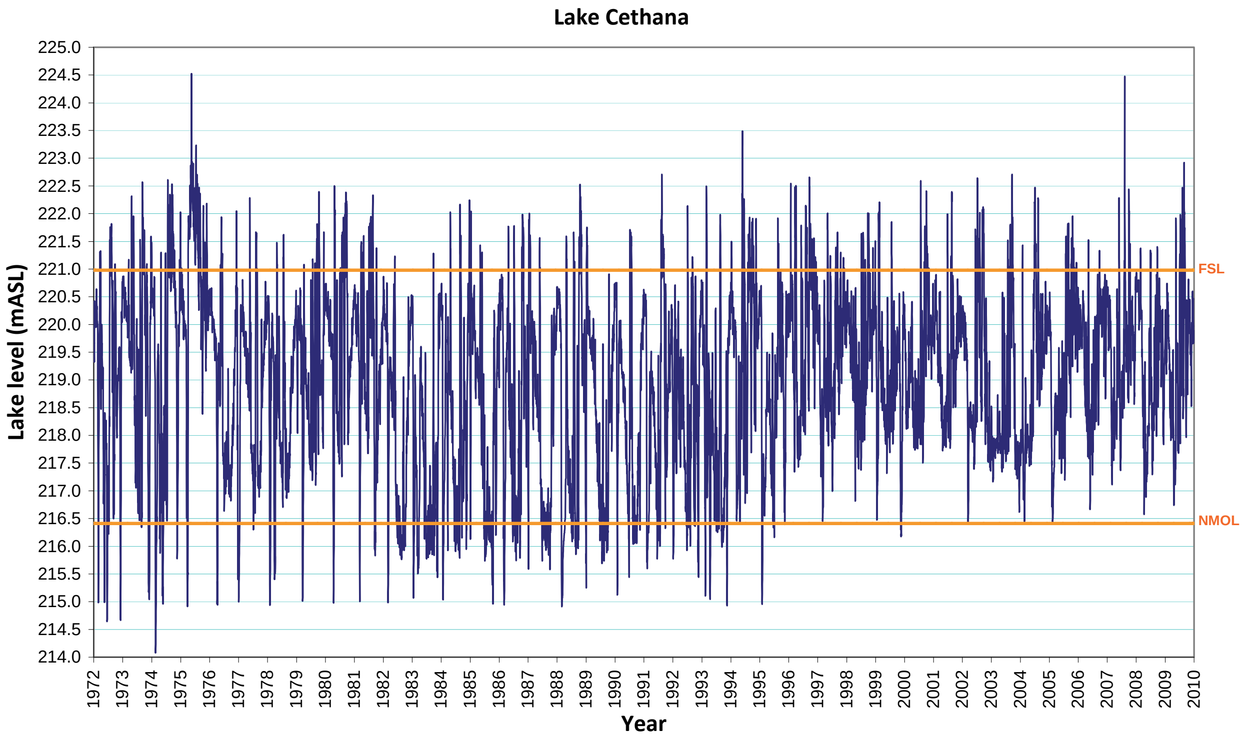


Figure G-4
Lake Cethana

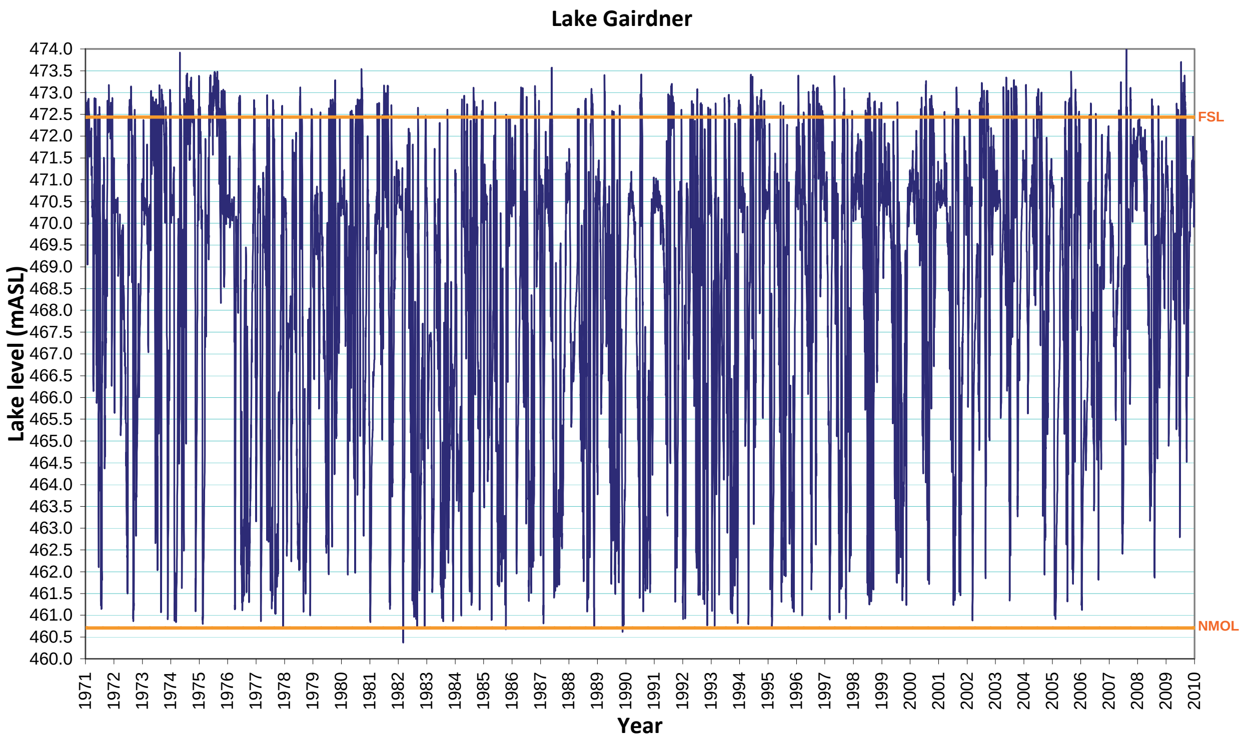


Figure G-5
Lake Gairdner

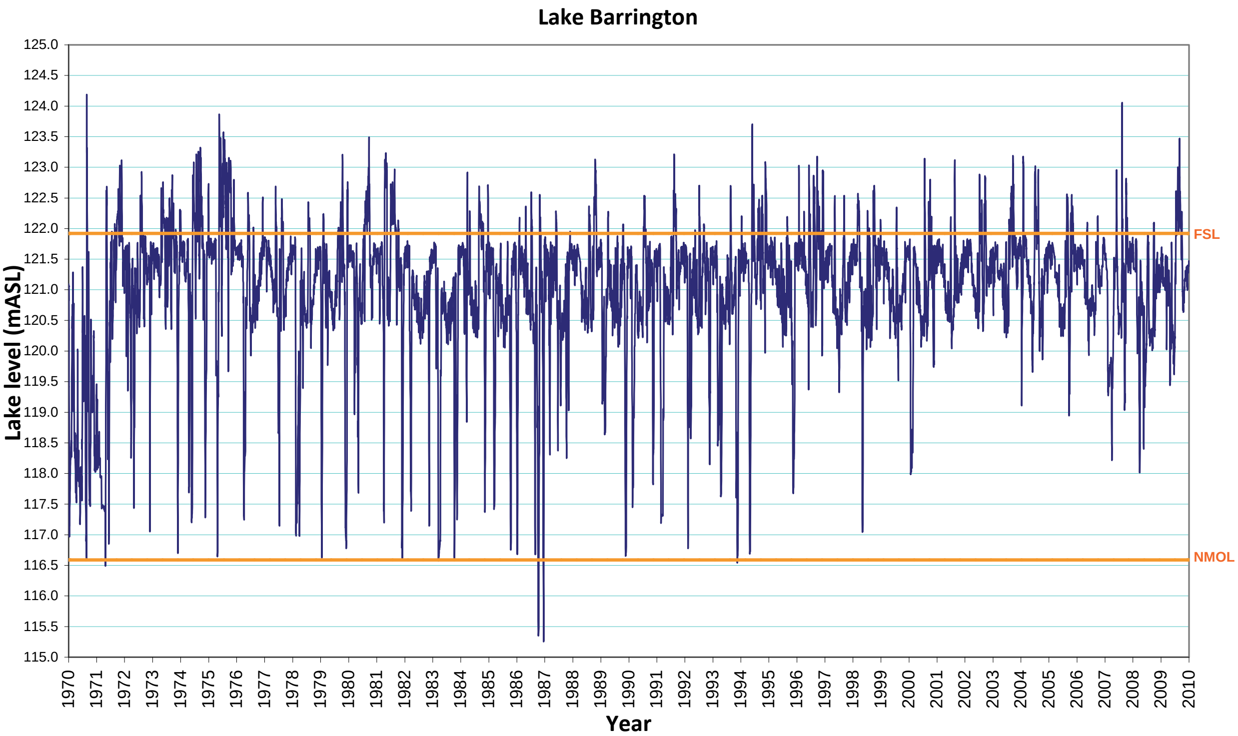


Figure G-6
Lake Barrington

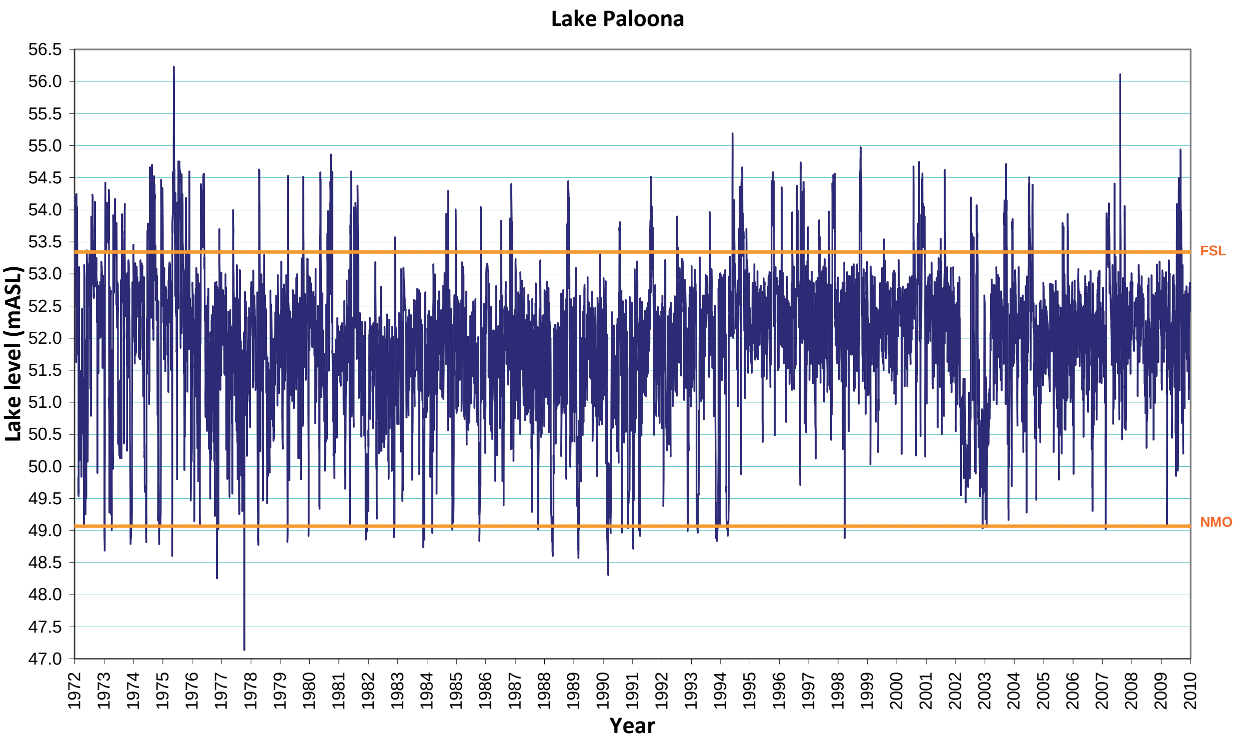


Figure G-7
Lake Paloona

H Natural and post-development flow duration curves for the Fisher, Forth and Mersey rivers

The plots (Figures H-1 to H-3) show the frequency of occurrence of specific flows, in cumecs, below the major structures of Fisher Power Station, Parangana Dam and Paloona Power Station, and indicate changes to the natural flow regime as a result of hydro-electric developments. The y-axis shows the range of discharges in cumecs and the x-axis shows the percentage of time a particular discharge is exceeded. The blue plotted line indicates natural discharges and the red line indicates discharges post-development.

The natural flow curve was calculated by estimating the natural yield based on change in lake volume and power station discharge. The post-development curve is the sum of power station discharge and spill.

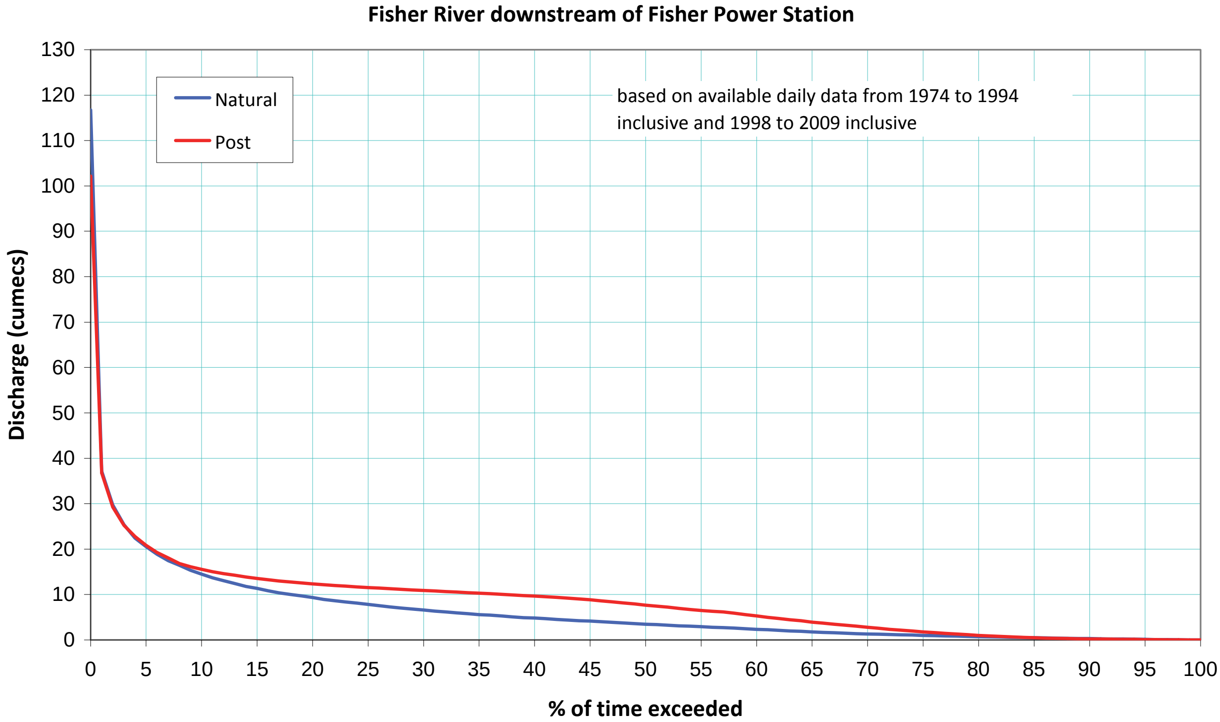


Figure H-1
Natural and post-development flow in the Fisher River downstream of Fisher Power Station

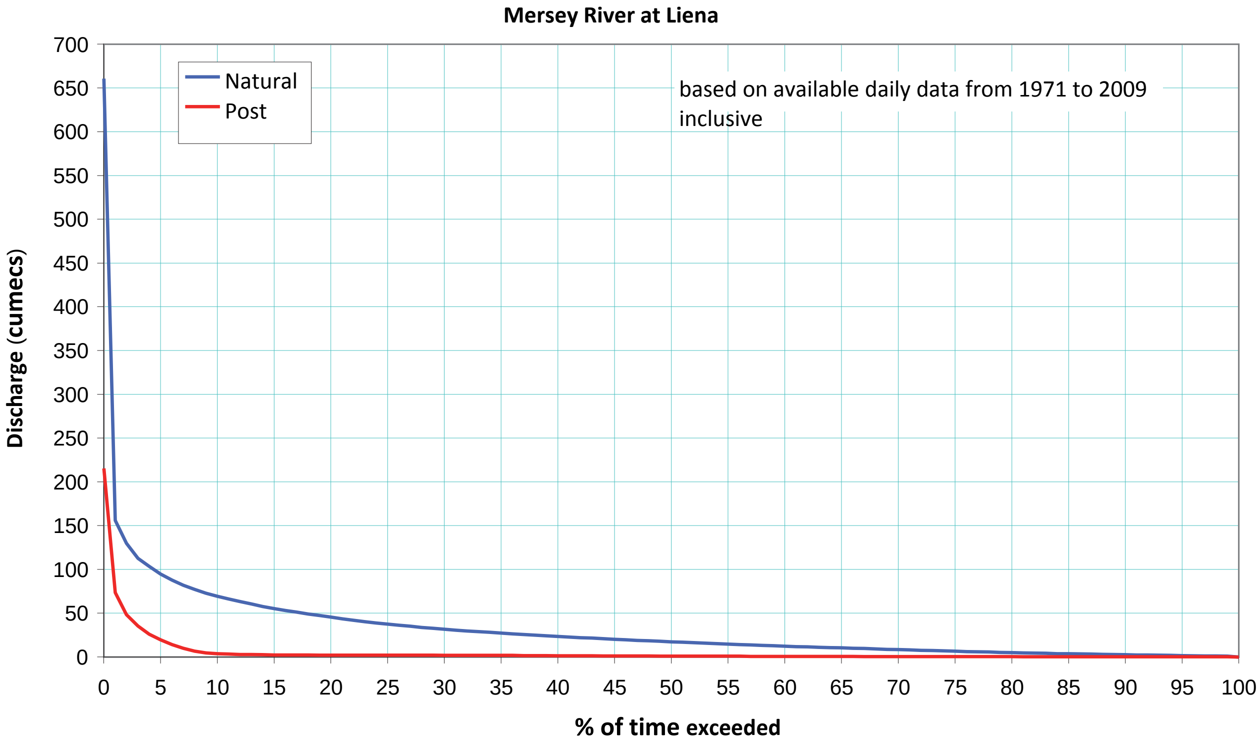


Figure H-2
Natural and post-development flow in the Mersey River downstream of Parangana Dam

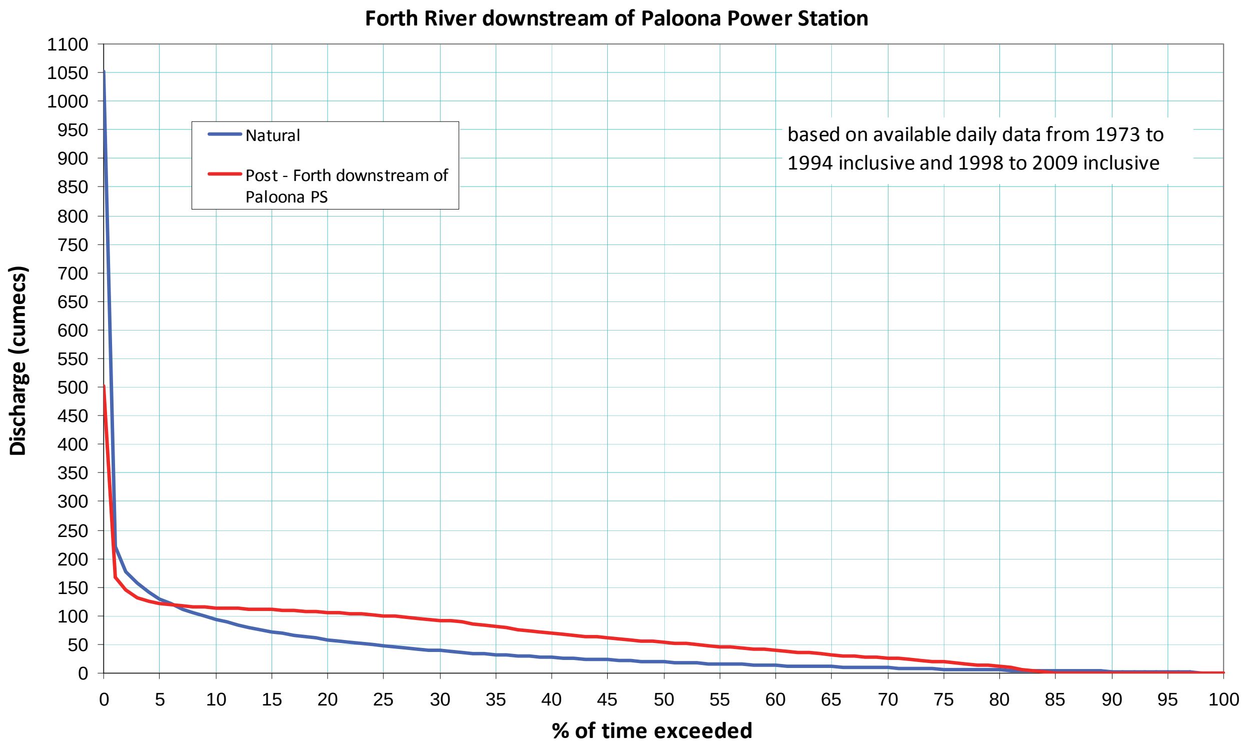


Figure H-3
Natural and post-development flow in the Forth River downstream of Paloona Power Station

I Water quality monitoring undertaken by Hydro Tasmania in the Mersey-Forth catchments

Table I-1
Water quality monitoring undertaken by Hydro Tasmania in the Mersey-Forth catchments

Waterway		Years when monitoring was undertaken
Lakes	Lake Mackenzie	1991-1992, 1995, 1997-1999, 2001-2004, 2010
	Lake Rowallan	1992-1993, 1995-1996, 2001-2004, 2010
	Lake Parangana	2001-2004, 2010
	Lake Cethana	2001-2004, 2010
	Lake Gairdner	1993-1994, 1995-1995, 2001-2004, 2010
	Lake Barrington	1992-1993, 1995-1996, 2001-2004, 2010
	Lake Paloona	2001-2004, 2010
River Sites	Fisher River 400 m downstream of power station	1974-1988, 1994-1995, 2001-2004, 2010
	Fisher River 1.3 km below Mackenzie Dam	2010
	Arm River	1974, 1976, 1986, 1990, 2001-2004
	Mersey River above Arm (Island Bend)	2010
	Mersey River at Liena	Continuous since 1996
	Mersey River at Kimberley	Continuous since 2000
	Forth River above Lemonthyme	1965, 1967-1969, 1976-1978, 1980-1981, 1984, 1986, 1990
	Wilmot River 500 m below dam	2010
	Wilmot River at Spellman's Road	1999-2000, 2010
	Forth River below Wilmot River	1976-1978, 1983, 1986, 1990, 2010
	Forth River upstream of Sayers Hill Weir	1974-1982
	Forth River above Forth Bridge	1979-1980

J Water quality guidelines for Tasmanian lakes and rivers

Table J-1
Water quality trigger levels for Tasmania (ANZECC & ARMCANZ guidelines 2000)

Parameter/Ecosystem Type	Upland Rivers (Elevation >150 m)	Lowland Rivers (Elevation <150 m)	Lakes and Reservoirs
EC (µS/cm)	90 (Tas)	90 (Tas)	30 (Tas)
Turbidity (NTU)	25	50	20
DO (% saturation)	<90 or >110	<90 or >110	<90 or >110
pH [#]	<4.0 or >8.5	<4.0 or >8.5	<4.0 or >8.5
Total N (mg/L)	0.48	0.5	0.35
NH_4^+-N (mg/L)	0.013	0.02	0.01
NO_x-N (mg/L)	0.19	0.04	0.01
Total P (mg/L)	0.013	0.05	0.01
FRP (mg/L)	0.005	0.02	0.005
Chl *a* (µg/L)	NA	5	3

Table J-2
NHMRC* Cyanobacteria alert levels for recreational water

Mode	Biovolume Trigger	Prescribed tier of monitoring actions
Surveillance	>0.04 to <0.4 mm^3/L	Routine sampling
Alert	>0.4 to <4 mm^3/L	Increased sampling to assess risk to users and investigation of cause
Action	4 mm^3/L where known toxin producing cyanobacteria dominate by volume	Local government and health warning water unsuitable for recreational use

*National Health and Medical Research Council, 2008.

[#] Guideline range 6.5 to 8.0 for Tasmanian lakes and rivers unless humic rich, in which case the range is 4.0 to 6.5.

K Water quality statistics for Hydro Tasmania lakes in the Mersey-Forth catchments

Table K-1
Descriptive statistics for water quality parameters, in Mersey-Forth catchments lakes, of samples taken from surface waters to a depth not exceeding 1 m. Values in red have exceeded the ANZECC & ARMCANZ (2000) guidelines (Hydro Tasmania 'Hydstra TSM' database)

Site	Temp	EC	DO	DO	Turb	pH	Chl *a*	NH_3-N	NO_x-N	TN	TP	FRP	Fe^{2+}	Mn^{2+}	Al^{3+}	DOC
	°C	µS/cm	% sat	mg/L	NTU	units	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC (2000) lakes guidelines	***NA***	***3***	***90 - 110***	***NA***	***<20***	***6.5 – 8.0***	***3***	***0.010***	***0.010***	***0.350***	***0.010***	***0.005***	***NA***	***1.9***	***0.055 at pH >6.5***	***NA***
Lake Mackenzie (HT TSM site ID 629): 06/11/1991 – 23/6/2011																
Max	20.00	27.50	102.50	12.32	16.10	7.43	*5.58*	*0.095*	*0.013*	*0.552*	*0.031*	*0.005*	1.500	0.230	*0.085*	22.600
Min	0.70	5.00	*80.50*	7.85	0.00	*5.80*	0.00	0.001	0.001	0.041	0.002	0.001	0.020	0.005	0.020	0.300
Median	7.10	11.00	96.30	10.27	0.90	6.54	0.93	0.004	0.003	0.116	0.006	0.002	0.057	0.012	0.050	1.500
20th percentile	2.83	9.00	*85.00*	9.02	0.53	*6.25*	0.51	0.002	0.001	0.091	0.005	0.001	0.021	0.005	0.039	0.700
80th percentile	12.70	13.04	99.36	11.51	1.80	6.86	2.13	0.009	0.006	0.198	0.008	0.002	0.144	0.024	*0.055*	2.100
n	*71*	*70*	*45*	*64*	*69*	*63*	*93*	*38*	*38*	*39*	*43*	*38*	*44*	*44*	*32*	*11*
Lake Rowallan (HT TSM site ID 562): 05/11/1992 – 22/6/2011																
Max	22.90	28.60	103.70	12.66	7.10	7.50	*6.66*	*0.012*	*0.043*	0.210	*0.017*	*0.040*	0.190	0.040	*1.060*	20.000
Min	4.15	19.00	*80.10*	8.20	0.00	*6.38*	0.00	0.002	0.001	0.051	0.004	0.001	0.020	0.003	0.020	0.600
Median	13.00	25.00	90.70	9.65	0.87	6.90	1.09	0.005	0.003	0.120	0.005	0.002	0.070	0.009	*0.081*	2.500
20th percentile	6.35	23.00	*87.00*	8.56	0.69	6.73	0.41	0.003	0.001	0.091	0.005	0.001	0.0459	0.005	0.041	1.620
80th percentile	17.5	27.00	97.48	10.90	1.35	7.15	2.31	0.006	*0.013*	0.170	0.007	0.002	0.100	0.01	*0.129*	4.58
n	*61*	*61*	*47*	*52*	*82*	*57*	*75*	*31*	*31*	*31*	*31*	*30*	*30*	*30*	*18*	*12*
Lake Parangana (HT TSM site ID 594): 20/01/1997 – 22/6/2011																
Max	19.230	*40.00*	103.00	13.20	10.80	7.50	*5.60*	*0.010*	*0.057*	0.210	0.010	0.003	0.135	0.022	*0.131*	6.500
Min	3.30	12.00	*73.00*	8.10	0.10	*6.40*	0.00	0.002	0.002	0.067	0.005	0.002	0.031	0.005	0.029	0.700
Median	10.42	25.00	94.00	10.12	0.88	7.01	0.50	0.003	0.007	0.120	0.005	0.002	0.071	0.007	*0.065*	2.050
20th percentile	6.00	22.200	*89.32*	8.96	0.66	6.74	0.22	0.002	0.003	0.088	0.005	0.002	0.042	0.005	0.043	1.360
80th percentile	16.11	28.60	99.50	11.63	1.40	7.18	1.87	0.006	*0.018*	0.168	0.007	0.002	0.088	0.010	*0.077*	3.04
n	*57*	*57*	*57*	*57*	*86*	*57*	*46*	*17*	*17*	*17*	*17*	*17*	*16*	*16*	*16*	*10*
Lake Cethana (HT TSM site ID 625): 19/07/2001 – 26/06/2011																
Max	21.18	*31.00*	107.40	11.92	9.00	7.37	*4.50*	*0.013*	*0.040*	*0.360*	*0.011*	0.003	0.298	0.013	*0.271*	6.700
Min	5.88	22.00	*82.00*	8.00	0.30	*5.75*	0.00	0.002	0.001	0.105	0.005	0.002	0.074	0.006	*0.065*	1.700
Median	13.16	27.00	97.00	9.73	1.09	6.92	0.68	0.006	*0.011*	0.180	0.005	0.002	0.112	0.008	*0.144*	NA
20th	6.91	25.00	90.42	9.23	0.84	*6.48*	0.17	0.002	0.003	0.126	0.005	0.002	0.085	0.007	*0.0763*	NA

Site	Temp	EC	DO	DO	Turb	pH	Chl *a*	NH_3-N	NO_x-N	TN	TP	FRP	Fe^{2+}	Mn^{2+}	Al^{3+}	DOC
	°C	µS/cm	% sat	mg/L	NTU	units	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC (2000) lakes guidelines	***NA***	***3***	***90 - 110***	***NA***	***<20***	***6.5 – 8.0***	***3***	***0.010***	***0.010***	***0.350***	***0.010***	***0.005***	***NA***	***1.9***	***0.055 at pH >6.5***	***NA***
percentile																
80th percentile	17.36	28.60	101.04	11.38	2.04	7.14	1.54	0.006	*0.030*	0.240	0.008	0.002	0.167	0.011	*0.179*	NA
n	*37*	*37*	*37*	*37*	*37*	*37*	*28*	*11*	*11*	*11*	*11*	*11*	*10*	*10*	*10*	*4*
Lake Gairdner (HT TSM site ID 613): 22/01/1975 - 20/06/2011																
Max	22.77	*48.00*	*110.60*	12.40	15.20	7.41	2.60	*0.024*	*0.053*	*0.400*	*0.013*	*0.007*	0.580	0.080	*0.341*	33.000
Min	4.00	20.30	*77.00*	7.40	0.30	*6.00*	0.00	0.004	0.001	0.014	0.003	0.001	0.130	0.005	*0.113*	1.800
Median	11.44	29.40	94.00	9.83	1.84	6.67	0.53	0.007	0.006	0.180	0.007	0.002	0.260	0.010	*0.147*	NA
20th percentile	5.80	26.60	91.40	9.30	1.45	*6.46*	0.18	0.004	0.003	0.131	0.005	0.001	0.172	0.010	*0.37*	NA
80th percentile	15.90	*37.58*	100.00	11.46	2.501	7.02	1.21	*0.016*	*0.012*	0.277	0.008	0.002	0.415	0.031	*0.241*	NA
n	*46*	*44*	*26*	*42*	*51*	*41*	*43*	*21*	*21*	*21*	*21*	*21*	*22*	*24*	*8*	*4*
Lake Barrington (HT TSM site ID 604): 05/11/1992 – 21/06/2011																
Max	23.00	*34.50*	109.20	12.40	9.00	7.33	*27.21*	*0.012*	*0.068*	*0.660*	0.016	0.004	0.360	0.029	*0.266*	6.000
Min	6.00	19.00	*77.50*	7.73	0.56	*5.97*	0.00	0.002	0.001	0.069	0.004	0.001	0.020	0.005	0.020	1.400
Median	13.80	28.00	93.90	9.880	1.45	6.59	1.18	0.006	0.010	0.172	0.005	0.002	0.170	0.010	*0.140*	3.700
20th percentile	7.26	26.00	*88.10*	8.99	1.12	6.39	0.24	0.003	0.005	0.110	0.005	0.001	0.119	0.009	*0.111*	1.900
80th percentile	17.68	30.00	99.82	11.06	2.33	6.96	2.35	0.009	*0.031*	0.226	0.008	0.002	0.218	0.018	*0.157*	5.500
n	*69*	*68*	*54*	*59*	*96*	*64*	*80*	*30*	*30*	*30*	*30*	*30*	*29*	*29*	*17*	*11*
Lake Paloona (HT TSM site ID 627): 19/09/1973 – 23/06/2011																
Max	20.34	*31.00*	102.30	12.00	8.30	7.72	*7.57*	*0.014*	*0.069*	*0.390*	*0.034*	*0.005*	0.650	0.050	*0.275*	42.000
Min	6.60	21.00	*68.50*	7.84	0.60	*5.68*	0.00	0.003	0.001	0.083	0.005	0.002	0.070	0.005	*0.056*	1.500
Median	11.16	28.00	92.50	9.47	1.371	6.60	0.93	0.009	0.015	0.198	0.008	0.002	0.216	0.018	*0.167*	3.900
20th percentile	7.50	27.00	*81.10*	8.56	1.04	*6.23*	0.19	0.004	0.006	0.144	0.005	0.002	0.123	0.008	*0.096*	2.300
80th percentile	16.00	29.00	97.00	11.20	1.98	6.83	2.20	*0.011*	*0.048*	0.276	*0.011*	0.003	0.267	0.027	*0.185*	4.700
n	*76*	*56*	*56*	*56*	*86*	*56*	*45*	*17*	*17*	*17*	*17*	*17*	*20*	*20*	*15*	*10*
Paloona Power Station (North West Regional Water Authority data): 01/12/90- 01/09/97																
Max		35.00			1.90	7.90					0.012		2.690	0.107	*0.170*	5.400
Median		28.00			1.50	6.90					0.006		0.160	0.016	*0.130*	4.600
Min		27.00			1.10	*6.20*					0.005		0.080	<0.005	*0.060*	2.900
n		*20*			*9*	*20*					*9*		*20*	*20*	*10*	*6*

L Water temperature and dissolved oxygen depth profiles for Mersey-Forth lakes

Bi monthly water temperature and dissolved oxygen depth profiles data, collected in 2010-2011, plotted for Hydro Tasmania Mersey-Forth lakes deeper than 10 m (Hydro Tasmania 'Hydstra TSM' database)

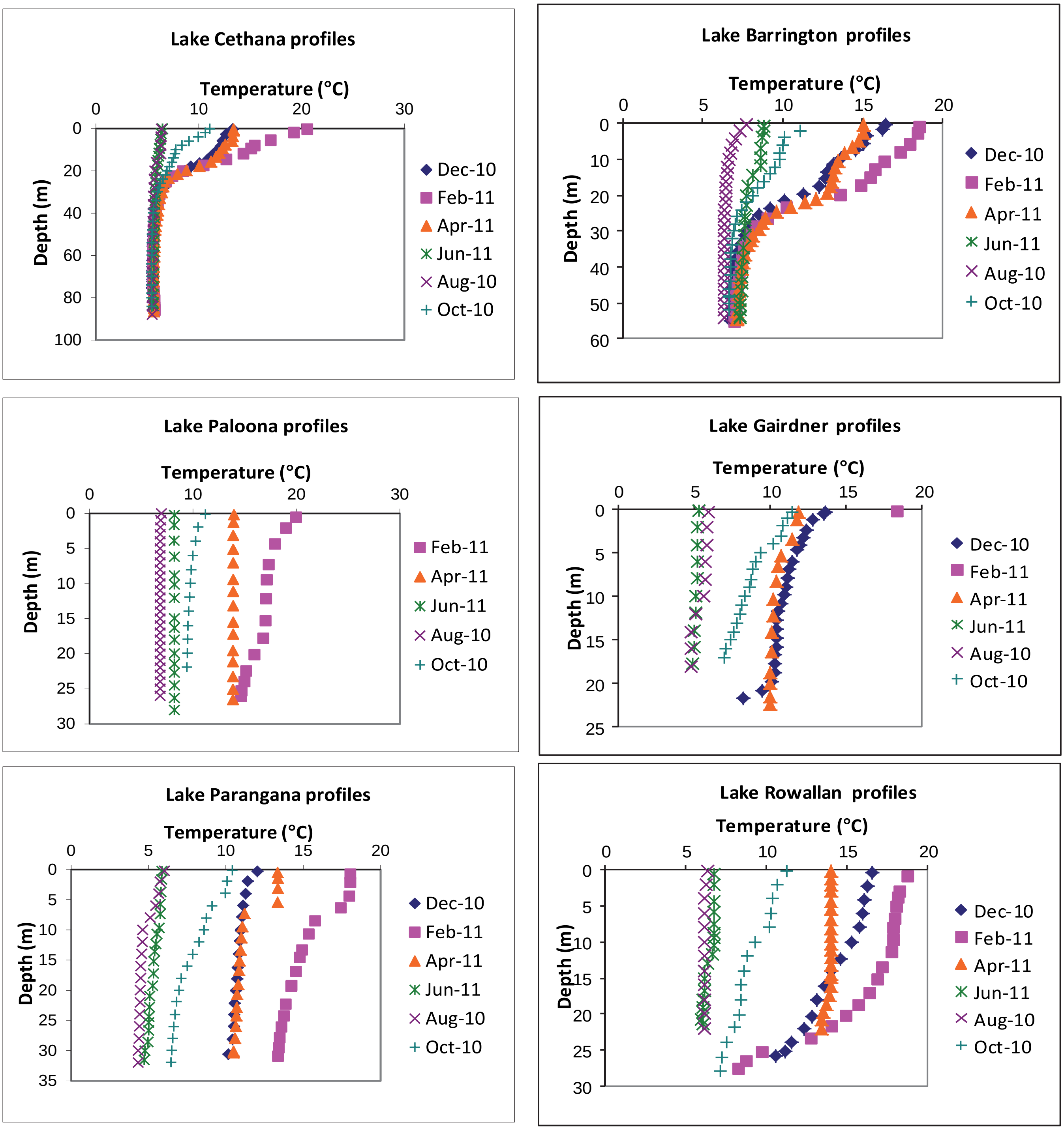


Figure L-1
Water temperature profiles for Lakes Cethana, Barrington, Paloona, Gairdner, Rowallan and Parangana

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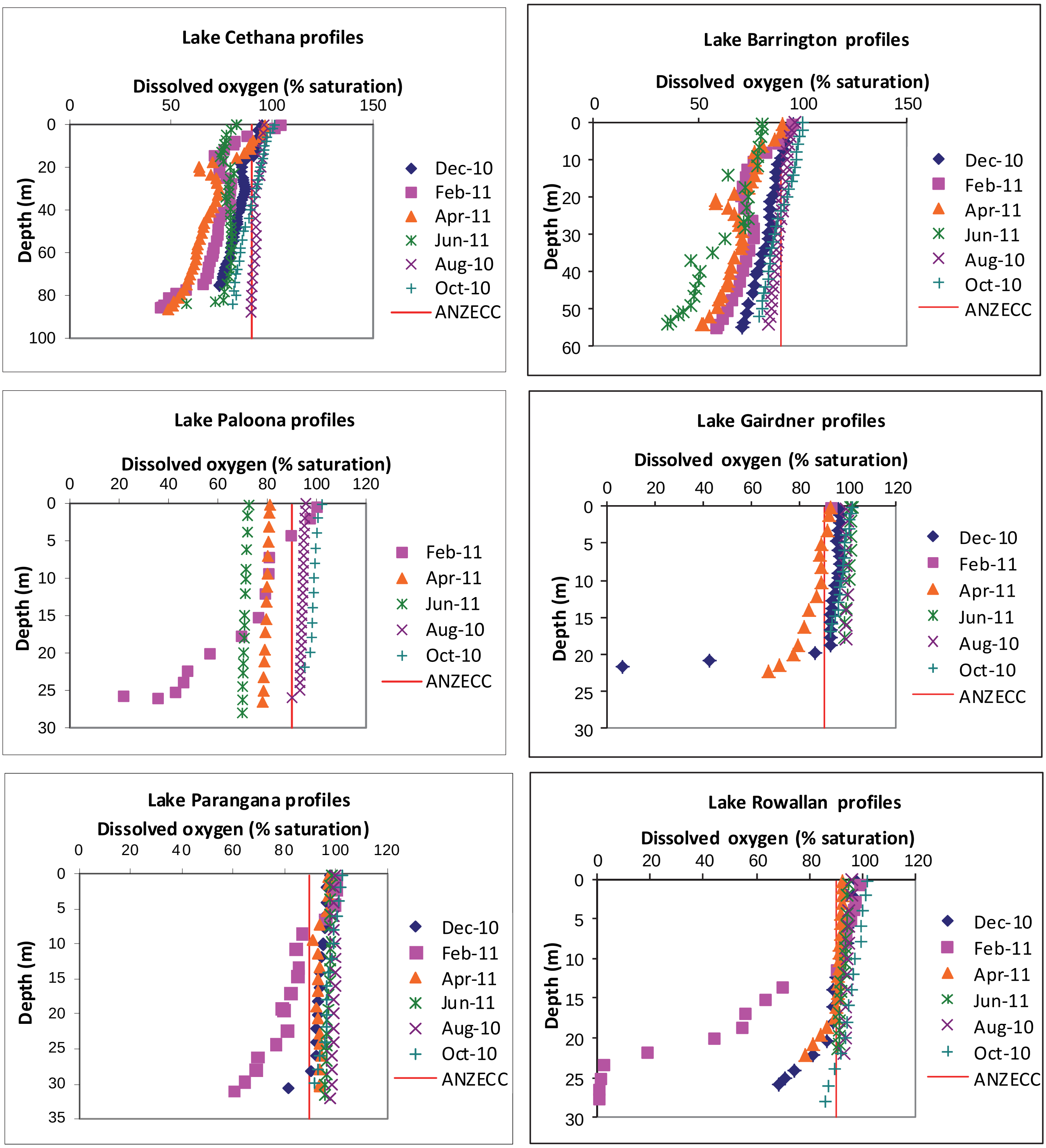

Figure L-2
Dissolved oxygen (% saturation) profiles for Lakes Cethana, Barrington, Paloona, Gairdner, Rowallan and Parangana with ANZECC (2000) guidelines-minimum DO (90%) indicated.

M Cyanobacteria data for Mersey-Forth lake and river sites monitored in 2010-11

Table M-1
Cyanobacteria species, density and biovolume

Sampling Month Year	Lake or River	Waterbody Name	Site	Dominant Cyanobacteria spp	Density (cells /mL)	Biovolume (mm^3/L)
Aug-10	Lake	Barrington	Dam	None	N/A	N/A
Aug-10	Lake	Cethana	Dam	None	N/A	N/A
Aug-10	Lake	Parangana	Dam	None	N/A	N/A
Aug-10	Lake	Rowallan	Dam	None	N/A	N/A
Aug-10	Lake	Mackenzie	Mid	None	N/A	N/A
Aug-10	Lake	Gairdner	Intake	None	N/A	N/A
Aug-10	Lake	Paloona	Dam	None	N/A	N/A
Aug-10	River	Wilmot	Spellmans	None	N/A	N/A
Aug-10	River	Wilmot	Downstream Lake Gairdner	None	N/A	N/A
Aug-10	River	Mersey	Downstream Lake Rowallan	None	N/A	N/A
Aug-10	River	Fisher	Downstream Fisher Power Station	None	N/A	N/A
Aug-10	River	Fisher	Downstream Lake Mackenzie	None	N/A	N/A
Aug-10	River	Forth	Downstream Lake Paloona	None	N/A	N/A
Oct-10	Lake	Barrington	Dam	None	N/A	N/A
Oct-10	Lake	Cethana	Dam	None	N/A	N/A
Oct-10	Lake	Parangana	Dam	None	N/A	N/A
Oct-10	Lake	Rowallan	Dam	None	N/A	N/A
Oct-10	Lake	Mackenzie	Mid	None	N/A	N/A
Oct-10	Lake	Gairdner	Intake	None	N/A	N/A
Oct-10	Lake	Paloona	Dam	None	N/A	N/A
Oct-10	River	Wilmot	Spellmans	None	N/A	N/A
Oct-10	River	Wilmot	Downstream Lake Gairdner	None	N/A	N/A
Oct-10	River	Mersey	Downstream Lake Rowallan	None	N/A	N/A
Oct-10	River	Fisher	Downstream Fisher Power Station	None	N/A	N/A
Oct-10	River	Fisher	Downstream Lake Mackenzie	None	N/A	N/A
Oct-10	River	Forth	Downstream Lake Paloona	None	N/A	N/A
Dec-10	Lake	Barrington	Dam	None	N/A	N/A
Dec-10	Lake	Cethana	Dam	None	N/A	N/A
Dec-10	Lake	Parangana	Dam	None	N/A	N/A
Dec-10	Lake	Rowallan	Dam	None	N/A	N/A
Dec-10	Lake	Mackenzie	Mid	None	N/A	N/A
Dec-10	Lake	Gairdner	Intake	None	N/A	N/A
Dec-10	Lake	Paloona	Dam	None	N/A	N/A
Feb-11	Lake	Barrington	Dam	*Aphanothece* sp.	220	N/A
Feb-11	Lake	Barrington	Luttrels Point	None	N/A	N/A
Feb-11	Lake	Barrington	Upstream Kellys Creek	None	N/A	N/A
Feb-11	Lake	Cethana	Dam	*Aphanothece* sp.	1100	0.0017
Feb-11	Lake	Cethana	Dam	*Rhabdogloea* sp.	100	N/A
Feb-11	Lake	Cethana	Dam	*Snowella* sp.	64	N/A
Feb-11	Lake	Cethana	Off Bulls Creek	*Aphanothece* sp.	2200	0.0033
Feb-11	Lake	Cethana	Off Bulls Creek	*Rhabdogloea* sp.	76	N/A
Feb-11	Lake	Cethana	Off Lorinna	*Aphanothece* sp.	5200	0.0078
Feb-11	Lake	Cethana	Off Lorinna	*Rhabdogloea* sp.	64	N/A
Feb-11	Lake	Cethana	Off Lorinna	*Snowella* sp.	72	N/A
Feb-11	Lake	Parangana	Dam	*Aphanothece* sp.	360	N/A
Feb-11	Lake	Parangana	Dam	*Rhabdogloea* sp.	120	N/A
Feb-11	Lake	Parangana	Dam	*Snowella* sp.	58	N/A
Feb-11	Lake	Parangana	Colorado Creek	*Aphanothece* sp.	240	N/A
Feb-11	Lake	Parangana	Colorado Creek	*Rhabdogloea* sp.	88	N/A
Feb-11	Lake	Parangana	Colorado Creek	*Snowella* sp.	16	N/A
Feb-11	Lake	Parangana	Sugar Loaf	*Aphanothece* sp.	24	N/A
Feb-11	Lake	Parangana	Sugar Loaf	*Rhabdogloea* sp.	140	N/A
Feb-11	Lake	Rowallan	Dam	*Aphanothece* sp.	410	0.0006
Feb-11	Lake	Rowallan	Dam	*Rhabdogloea* sp.	770	N/A
Feb-11	Lake	Rowallan	Dam	*Snowella* sp.	1300	0.0334
Feb-11	Lake	Rowallan	Below Fish River	*Aphanothece* sp.	670	N/A
Feb-11	Lake	Rowallan	Below Fish River	*Rhabdogloea* sp.	770	N/A
Feb-11	Lake	Rowallan	Below Fish River	*Snowella* sp.	420	N/A
Feb-11	Lake	Rowallan	Below Stretcher Creek	*Aphanothece* sp.	2400	0.0036
Feb-11	Lake	Rowallan	Below Stretcher Creek	*Rhabdogloea* sp.	900	N/A
Feb-11	Lake	Rowallan	Below Stretcher Creek	*Snowella* sp.	720	N/A
Feb-11	Lake	Mackenzie	Mid	None	N/A	N/A
Feb-11	Lake	Mackenzie	Fisher Inflow	None	N/A	N/A
Feb-11	Lake	Mackenzie	Sandy Bay	None	N/A	N/A

Sampling Month Year	Lake or River	Waterbody Name	Site	Dominant Cyanobacteria spp	Density (cells /mL)	Biovolume (mm^3/L)
Feb-11	Lake	Mackenzie	Pines	None	N/A	N/A
Feb-11	Lake	Gairdner	Intake	*Pseudanabaena* sp.	0, P	N/A
Feb-11	Lake	Paloona	Dam	None	N/A	N/A
Feb-11	Lake	Paloona	Ingram Creek	None	N/A	N/A
Feb-11	Lake	Paloona	Upstream Kellys Creek	None	N/A	N/A
Apr-11	Lake	Barrington	Dam	None	N/A	N/A
Apr-11	Lake	Cethana	Dam	*Rhabdogloea* sp.	69	N/A
Apr-11	Lake	Parangana	Dam	*Rhabdogloea* sp.	190	N/A
Apr-11	Lake	Rowallan	Dam	*Rhabdogloea* sp.	160	N/A
Apr-11	Lake	Mackenzie	Mid	*Rhabdogloea* sp.	24	N/A
Apr-11	Lake	Gairdner	Intake	None	N/A	N/A
Apr-11	Lake	Paloona	Dam	None	N/A	N/A
Jun-11	Lake	Barrington	Dam	None	N/A	N/A
Jun-11	Lake	Cethana	Dam	None	N/A	N/A
Jun-11	Lake	Parangana	Dam	*Anabaena* sp	0,P	N/A
Jun-11	Lake	Rowallan	Dam	None	N/A	N/A
Jun-11	Lake	Mackenzie	Mid	*Anabaena* sp.	2	N/A
Jun-11	Lake	Mackenzie	Mid	*Planktothrix* sp.	2	N/A
Jun-11	Lake	Mackenzie	Mid	*Pseudanabaena* sp.	1	N/A
Jun-11	Lake	Gairdner	Intake	*Anabaena* sp.	1	N/A
Jun-11	Lake	Paloona	Dam	None	N/A	N/A

* biovolume calculated for cell densities >1000 cells/mL; N/A indicates not applicable

N Water quality statistics for Mersey-Forth rivers

Table N-1
Descriptive statistics for water quality parameters in upland and lowland river sites in Mersey-Forth catchments where greater than ten samples on record

Values in red italics have exceeded the ANZECC & ARMCANZ (2000) guideline values (Hydro Tasmania Hydstra TSM database). N/A indicates not applicable and - indicates no data

Upland River Sites >150 mASL

Site	Temp	EC	DO	Turb	pH	TSS
	(°C)	(µS/cm)	mg/L	NTU	(units)	mg/L
ANZECC Guideline	***N/A***	***median 90 (Tas)***	***N/A***	***< 25***	***4.0 - 8.5***	***N/A***
Mersey River at Liena (HT site 60). Elevation: 283 m						
Max	27.72	*148.70*	14.89	*133.64*	*9.65*	-
Min	2.68	15.21	0.09	0.00	5.50	-
Median	10.00	42.15	10.35	2.08	7.41	-
20th percentile	6.43	36.81	9.13	0.64	7.13	-
80th percentile	14.37	53.02	11.64	3.26	7.75	-
n	*58461**	*13358*	*48223*	*38060*	*40502*	-
Start Date	13/06/1984	22/11/1995	01/04/1999	28/01/1997	13/06/1984	-
End Date	01/07/2010	01/07/2010	01/07/2010	01/07/2010	01/07/2010	-
Fisher River upstream Lake Mackenzie (HT site 16201). Elevation: 1140 m						
Max	23.00	*115.00*	11.20	-	8.40	-
Min	1.00	6.20	8.60	-	4.95	-
Median	8.00	11.00	9.30	-	6.50	-
20th percentile	4.00	9.00	8.88	-	5.87	-
80th percentile	14.00	16.40	10.18	-	7.20	-
n	*86*	*19*	*10*	-	*83*	-
Start Date	05/06/1974	02/05/1985	14/11/1979	-	29/08/1974	-
End Date	15/09/1995	29/06/1995	17/03/1982	-	06/04/1995	-
Forth River above Lemonthyme (HT site 450). Elevation: 225 m						
Max	21.50	-	-	-	7.20	-
Min	3.80	-	-	-	5.50	-
Mean	10.61	-	-	-	6.61	-
Median	11.20	-	-	-	6.60	-
20th percentile	5.64	-	-	-	6.50	-
80th percentile	13.40	-	-	-	6.80	-
n	*27*	-	-	-	*25*	-
Start Date	24/08/1965	-	-	-	22/06/1965	-
End Date	06/09/1990	-	-	-	16/09/1990	-

Site	Temp	EC	DO	Turb	pH	TSS
	(°C)	(µS/cm)	mg/L	NTU	(units)	mg/L
ANZECC Guideline	***N/A***	***median 90 (Tas)***	***N/A***	***< 25***	***4.0 - 8.5***	***N/A***
Arm River WHMS at road Bridge (HT site 624). Elevation: 404 m						
Max	12.80	49.00	11.86	1.81	7.83	-
Min	2.50	15.00	9.20	0.35	5.00	-
Mean	7.55	33.09	10.87	0.86	7.07	-
Median	6.30	35.00	11.03	0.72	7.15	-
20th percentile	5.00	29.00	10.32	0.42	6.73	-
80th percentile	11.58	36.00	11.74	1.43	7.53	-
n	*20*	*11*	*12*	*16*	*18*	-
Start Date	10/12/1974	18/07/2001	18/07/2001	18/07/2001	10/12/1974	-
End Date	17/05/2004	17/05/2004	17/05/2004	17/05/2004	17/05/2004	-

* Continuous Data Logger

Lowland River Sites (<150 mASL)

Site	Temp	EC	DO	Turb	pH	TSS
	(°C)	(µS/cm)	mg/L	NTU	(units)	mg/L
ANZECC guidelines:	***N/A***	***median 90 (Tas)***	***N/A***	***< 50***	***6.5 - 8.0***	***N/A***
Mersey River at Kimberley (HT site 22) Elevation: 50 m						
Max	26.75	*213.88*	15.08	*501.38*	*9.24*	24.00
Min	2.41	39.26	3.67	0.00	*6.31*	0.80
Mean	13.20	*140.21*	10.05	6.65	7.90	7.11
Median	12.67	*144.39*	10.25	4.31	7.90	4.30
20th percentile	7.98	*116.07*	8.56	1.85	7.51	1.16
80th percentile	18.74	*164.49*	11.59	7.71	*8.29*	9.08
n	*45782**	*13387*	*3547*	*50539*	*45975*	*10*
Start Date	01/11/1976	23/05/2007	08/12/1976	01/12/1996	01/04/1999	07/09/1976
End Date	01/07/2010	1/07/2010	26/09/2010	01/07/2010	01/07/2010	18/06/1977
Forth River below Wilmot River (HT site 665). Elevation: 28 m						
Max	26.19	*183.22*	16.67	*153.23*	*8.80*	-
Min	3.89	8.58	4.61	0.12	*5.20*	-
Mean	12.90	41.21	9.95	3.09	6.75	-
Median	12.60	34.33	9.73	1.94	6.61	-
20th percentile	8.11	29.05	8.63	1.46	*6.39*	-
80th percentile	17.64	49.85	11.35	3.69	7.11	-
n	*43108**	*42547*	*40896*	*38509*	*39208*	-
Start Date	10/03/1976	13/07/1999	01/07/1999	01/07/1999	10/03/1976	-
End Date	01/07/2010	01/07/2010	01/07/ 2010	01/07/2010	01/07/2010	-

* Continuous Data Logger

Table N-2
Raw data for water quality parameters in river sites in Mersey Forth catchments where less than ten samples on record

Values in red italics have exceeded the ANZECC & ARMCANZ (2000) guideline values (Hydro Tasmania Hydstra TSM database). N/A is not applicable and - indicates no data.

Upland River Sites (>150 mASL)

Site	Temp	EC	DO	Turb	pH	NH_3-N	NOx-N	TN	TP	Fe^{2+}	Mn^{2+}	Ca^{2+}	Na^{+}	K^{+}	TSS
	(°C)	(uS/cm)	mg/L	NTU	(units)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC guidelines:	***N/A***	***Median 90 (Tas)***	***N/A***	***< 25***	***4.0 - 8.5***	***0.013***	**0.190**	***0.480***	***0.013***	***N/A***	***1.9***	***N/A***	***N/A***	***N/A***	***N/A***
Fisher River upstream Lake Mackenzie (HT site 16201). Elevation: 1140 m															
12/03/1981	-	-	-	-	-	*0.280*	-	-	0.010	0.250	0.040	-	-	-	-
05/06/1980	-	-	-	-	-	0.020	-	-	0.011	0.090	0.028	-	-	-	-
04/11/1986	-	-	-	0.40	-	-	-	-	-	-	-	-	-	-	-
08/01/1987	-	-	-	0.40	-	-	-	-	-	-	-	-	-	-	-
08/03/1988	-	-	-	0.60	-	-	-	-	-	-	-	-	-	-	-
11/01/1988	-	-	-	0.30	-	-	-	-	-	-	-	-	-	-	-
Forth River above Lemonthyme (HT site 450). Elevation: 225 m															
22/06/1965	-	-	-	-	-	-	-	-	-	-	-	1.20	2.60	0.20	8.80
24/08/1965	-	-	-	-	-	-	-	-	-	-	-	1.20	2.80	0.20	1.20
01/10/1965	-	-	-	-	-	-	-	-	-	-	-	1.60	4.80	0.50	0.00
01/03/1966	-	-	-	-	-	-	-	-	-	-	-	2.20	3.80	0.40	-
06/04/1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.00
09/01/1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.50
27/10/2010	9.9	33.00	11.25	0.1	7.2	-	-	-	-	-	-	-	-	-	-
11/03/2011	14.3	33.00	-	0.81	7.3	0.003	0.007	0.17	0.005	0.108	0.046	-	-	-	-
Arm River WHMS at road Bridge (HT site 624). Elevation: 404 m															
27/10/2010	7.6	41.00	11.81	0.4	7.6	-	-	-	-	-	-	-	-	-	-
11/03/2011	13.3	42.00	-	1.39	7.6	0.004	0.024	0.2	0.006	0.057	0.0043	-	-	-	-

Lowland River Sites (< 150 mASL)

Site	Temp	EC	DO	Turb	pH	NH_3-N	NO_x-N	TN	TP	Fe^{2+}	Mn^{2+}	Ca^{2+}	Na^+	K^+	TSS
	(°C)	(uS/cm)	mg/L	NTU	(units)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC guidelines:	***N/A***	***Median <90 (Tas)***	***N/A***	***< 50***	***6.5 - 8.0***	***0.020***	***0.040***	***0.500***	***0.050***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***
Forth River below Wilmot River (HT site 665). Elevation: 28 m															
27/10/1999	-	-	-	-	-	0.005	*0.135*	-	0.008	0.19	0.011	-	-	-	-
15/12/1999	-	-	-	-	-	0.007	0.015	-	0.005	0.13	0.018	-	-	-	-
10/02/2000	-	-	-	-	-	0.017	0.009	-	0.005	0.18	0.030	-	-	-	-
04/04/2000	-	-	-	-	-	*0.034*	0.010	-	0.005	0.21	0.075	-	-	-	-
27/10/2010	10.8	29.00	11.34	1.25	6.67	0.007	0.039	0.18	0.005	0.128	0.006	-	-	-	-
11/03/2011	6.8	38.00	8.77	2.5	6.8	0.006	*0.056*	0.36	0.009	0.248	0.0498	-	-	-	-
Wilmot River @ Spellmans Bridge (HT site 2454). Elevation: 110 m															
27/10/1999	12.00	76.00	11.95	1.36	7.30	0.010	*0.220*	0.420	0.008	0.017	0.310	-	-	-	-
15/12/1999	21.70	*106.00*	10.20	2.30	8.20	0.018	*0.062*	0.282	0.009	0.024	0.280	-	-	-	-
10/02/2000	20.20	*147.00*	8.40	3.10	7.70	*0.068*	0.039	0.069	0.012	0.130	0.390	-	-	-	-
04/04/2000	13.60	*128.00*	11.25	1.84	7.90	0.002	0.020	0.170	0.009	0.041	0.230	-	-	-	-
27/10/2010	13.34	81.00	11.59	1.34	7.65	0.006	*0.15*	0.41	0.008	0.264	0.008	-	-	-	-
11/03/2011	18.5	*93.00*		1.1	7.60	0.004	*0.172*	0.35	0.009	0.155	0.0093	-	-	-	-
Forth River upstream Sayers Hill Weir (HT site 1167). Elevation: <50m															
27/02/1974	-	*291.00*	-	-	-	-	-	-	-	-	-	-	-	-	-
18/07/1974	-	*316.00*	-	-	-	-	-	-	-	-	-	-	-	-	-
22/08/1974	-	*308.00*	-	-	-	*0.160*	-	-	0.010	0.360	-	2.00	3.00	0.20	-
06/11/1974	-	*626.00*	-	-	-	-	-	-	-	-	-	-	-	-	-
19/02/1975	-	*303.00*	-	-	-	-	-	-	-	-	-	-	-	-	-
27/11/1975	-	-	-	-	-	0.020	-	-	0.010	0.400	-	1.60	2.00	0.35	-
23/06/1976	-	-	-	-	-	*0.080*	-	-	0.001	0.290	-	2.00	2.20	0.30	-
10/03/1977	-	-	-	-	-	*0.160*	-	-	0.010	0.140	-	1.40	2.70	0.25	-

Site	Temp	EC	DO	Turb	pH	NH_3-N	NO_x-N	TN	TP	Fe^{2+}	Mn^{2+}	Ca^{2+}	Na^{+}	K^{+}	TSS
	(°C)	(uS/cm)	mg/L	NTU	(units)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC guidelines:	***N/A***	***Median <90 (Tas)***	***N/A***	***< 50***	***6.5 - 8.0***	***0.020***	***0.040***	***0.500***	***0.050***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***	***N/A***
09/11/1978	-	-	-	-	-	0.020	-	-	0.002	0.100	0.020	1.60	2.40	0.17	-
16/08/1979	-	-	-	-	-	*0.140*	-	-	0.010	0.480	0.028	1.40	2.10	0.19	-
04/06/1980	-	-	-	-	-	*0.160*	-	-	0.011	0.300	0.033	3.40	2.50	0.19	-
11/03/1981	-	-	-	-	-	*0.170*	-	-	0.010	0.220	0.038	2.40	2.90	0.23	-
Forth River above Forth Bridge (HT site 1177). Elevation: <50m															
16/07/1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.90
21/08/1979	8.00	-	9.40	-	-	-	-	-	-	-	-	-	-	-	2.30
18/09/1979	7.50	-	12.00	-	-	-	-	-	-	-	-	-	-	-	2.20
30/10/1979	13.00	-	9.00	-	-	-	-	-	-	-	-	-	-	-	5.30
20/11/1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.50
10/12/1979	16.00	-	8.90	-	-	-	-	-	-	-	-	-	-	-	2.90
22/01/1980	17.00	-	5.50	-	-	-	-	-	-	-	-	-	-	-	1.90
16/04/1980	15.50	-	7.60	-	-	-	-	-	-	-	-	-	-	-	1.40
10/06/1980	7.50	-	9.80	-	-	-	-	-	-	-	-	-	-	-	1.90

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O Hydro Tasmania RIVPACS model scoring

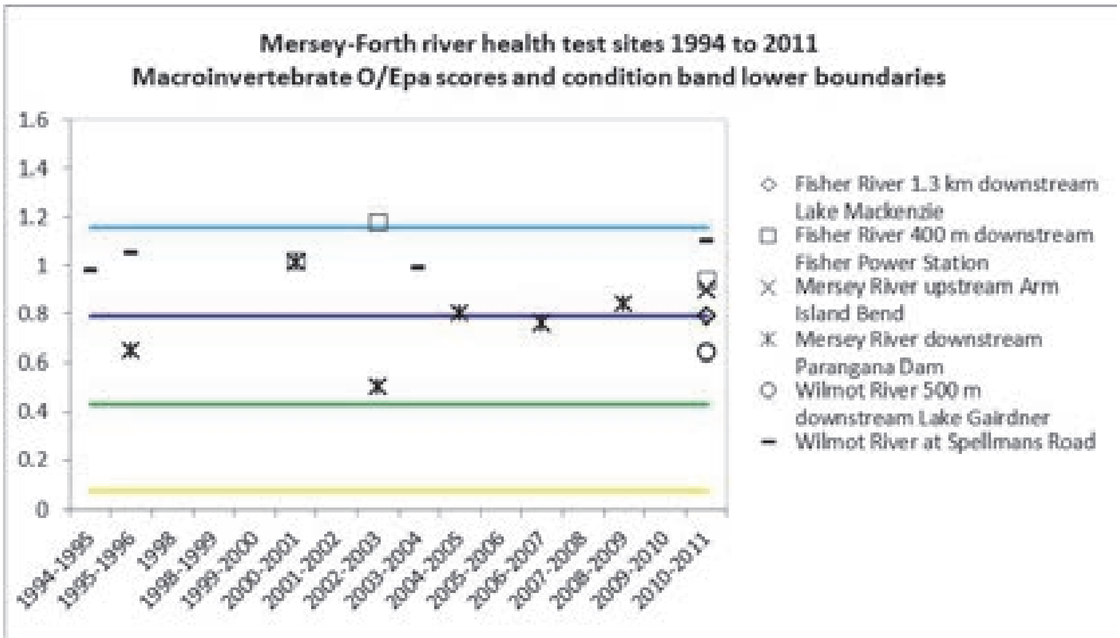
Hydro Tasmania River Invertebrate Prediction and Classification System (RIVPACS) models (Davies *et al*. 1999, Davies 2002) are routinely used for river health assessments in Hydro Tasmania catchments.

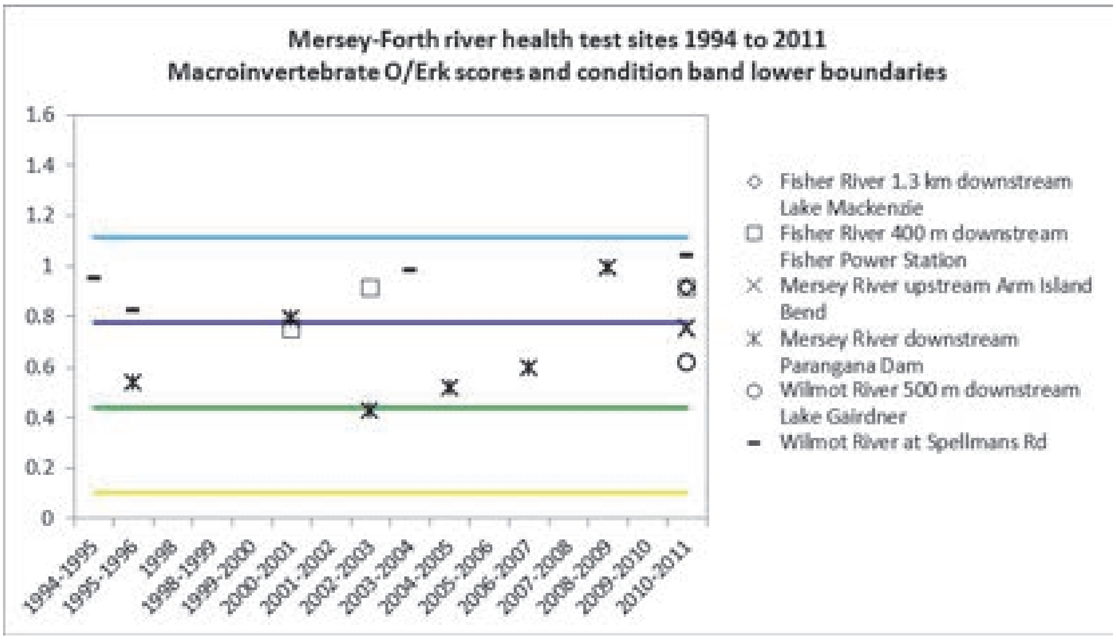
The RIVPACS model produces an O/E score by comparing the ratio of the observed family taxa (O) at a chosen test site with the expected family taxa (E) from a range of pre-selected and sampled reference sites. The model chooses the most appropriate reference sites using predictor habitat and landscape variables (i.e. predictor variables) recorded from the test site (Schofield and Davies 1996, Wright *et al*. 1984). The RIVPACS model outputs are assigned to one of five condition bands. These bands have been standardised to AUSRIVAS terminology and colour coded for ease of interpretation. This model and method has provided a consistent approach for Hydro Tasmania's river health monitoring since its inception and its outputs continue to be refined as knowledge of the system improves.

Table O-1
Hydro Tasmania RIVPACS model condition bands (source: Davies et al. 1999, Davies 2002)

Band	Band Name	Range	Comments
X	Richer than reference	>90th percentile of reference site O/E scores	More families than expected, indicates biodiverse site or possible mild organic enrichment
A	Equivalent to reference	10th to 90th percentile of reference site O/E scores	Equivalent number of families compared with reference sites
B	Significantly impaired	10th percentile of reference site O/E scores minus the range of band A	Fewer families than expected, indicates potential mild to moderate impact on water and/or, habitat quality resulting in loss of families
C	Severely impaired	From the lower bound of band B minus the range of band A	Considerably fewer families than expected, indicates moderate to severe impact on water and/or habitat quality resulting in loss of families
D	Impoverished	From the lower bound of band C to D.	Very few families collected, indicates highly degraded ecosystem with very poor water and/or habitat quality

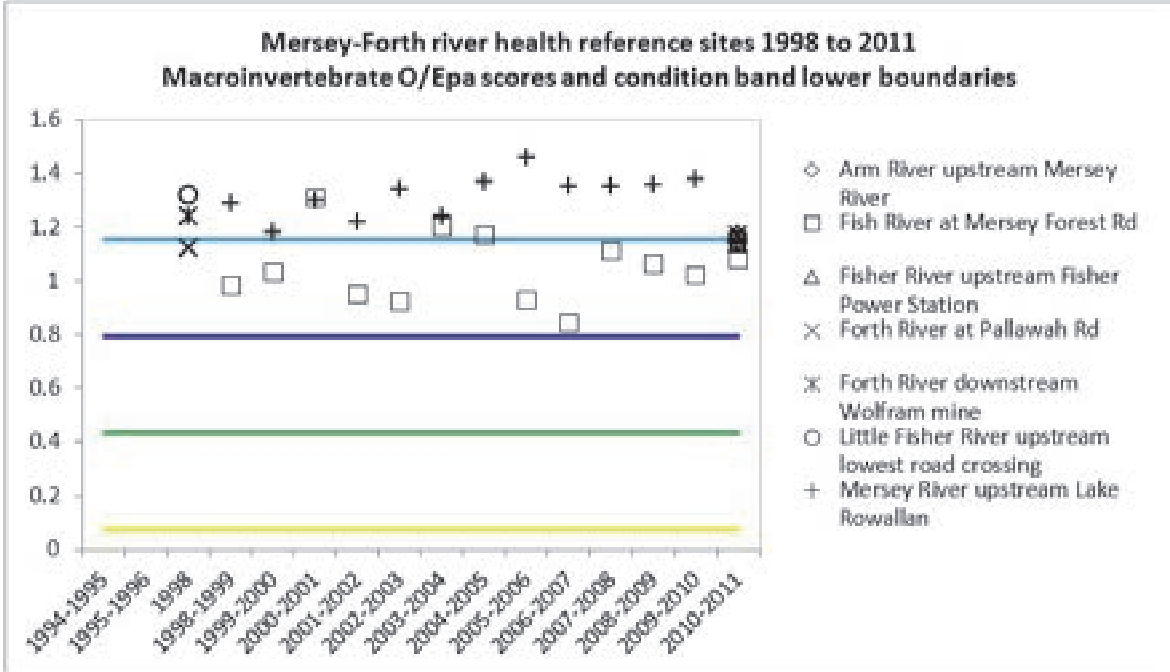
P Hydro Tasmania RIVPACS river health scores 1994 to 2011

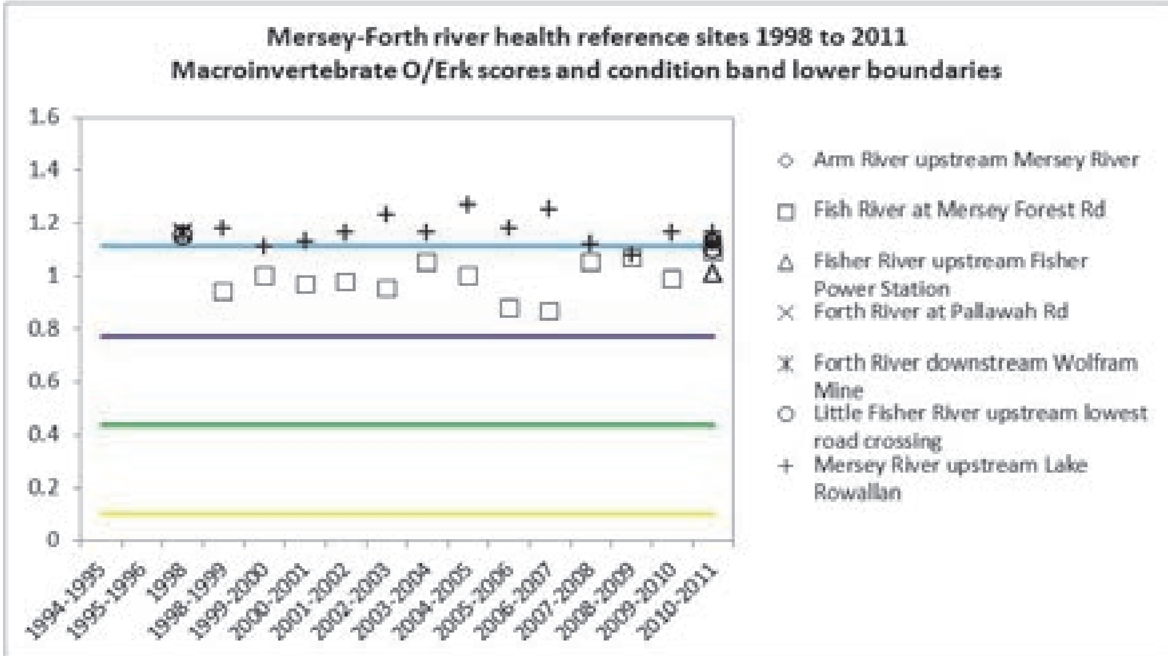




Key	Condition Band Identifier Condition Band Name	X Richer than reference	A Equivalent to reference	B Significantly impaired	C Severely impaired

Figure P-1
Mersey-Forth test site Hydro Tasmania RIVPACS combined season (spring and autumn) scores for biodiversity (top) and community composition (bottom)





Key	Condition Band Identifier Condition Band Name	X Richer than reference	A Equivalent to reference	B Significantly impaired	C Severely impaired

Figure P-2
Mersey-Forth reference site Hydro Tasmania RIVPACS combined season (spring and autumn) scores for biodiversity (top) and community composition (bottom)

Table P-1
Hydro Tasmania RIVPACS model - overall scores for macroinvertebrate biodiversity

Combined Season Presence Absence (pa) Data

Hydro RIVPACS Type	Site	1994-1995	1995-1996	1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011
Reference	Arm River upstream Mersey River	-															1.17
Reference	Fish River at Mersey Forest Rd				0.98	1.03	1.31	0.95	0.92	1.2	1.17	0.93	0.84	1.11	1.06	1.02	1.08
Reference	Fisher River upstream Fisher Power Station																1.14
Reference	Forth River at Pallawah Rd			1.12													1.17
Reference	Forth River downstream Wolfram Mine			1.24													
Reference	Little Fisher River upstream lowest Rd crossing			1.32													1.15
Reference	Mersey River upstream Lake Rowallan				1.29	1.18	1.3	1.22	1.34	1.24	1.37	1.46	1.35	1.35	1.36	1.38	1.14
Test	Fisher River 1.3 km downstream Lake Mackenzie																0.79
Test	Fisher River 400 m downstream Fisher Power Station						1.02		1.18								0.94
Test	Forth River downstream Wilmot River (Control Riffle)									N/A							N/A
Test	Mersey River upstream Arm Island Bend																0.9
Test	Mersey River downstream Lake Parangana		0.65				1.01		0.5		0.8		0.76		0.84		
Test	Wilmot River 500 m downstream Lake Gairdner																0.64
Test	Wilmot River at Alma Reserve	N/A	N/A							N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Test	Wilmot River at Spellmans Rd	0.98	1.05							0.99							1.1

Condition Band Key Combined Season Presence Absence Scores	X Richer than reference >1.15	A Equivalent to reference 0.79 to 1.15	B Significantly impaired 0.43 to 0.79	C Severely impaired 0.07 to 0.43

N/A indicates that the combined season model could not be used due to large seasonal differences

Table P-2
Hydro Tasmania RIVPACS model - overall scores for macroinvertebrate community composition

Combined Season Rank Abundance (rk) Data

Hydro RIVPACS Type	Site	1994-1995	1995-1996	1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011
Reference	Arm River upstream Mersey River																1.13
Reference	Fish River at Mersey Forest Rd				0.94	1.00	0.97	0.98	0.95	1.05	1.00	0.88	0.87	1.05	1.07	0.99	1.09
Reference	Fisher River upstream Fisher Power Station																1.01
Reference	Forth River at Pallawah Rd			1.16													1.12
Reference	Forth River downstream Wolfram Mine			1.16													
Reference	Little Fisher River upstream lowest Rd crossing			1.15													1.1
Reference	Mersey River upstream Lake Rowallan				1.18	1.11	1.13	1.16	1.23	1.16	1.27	1.18	1.25	1.12	1.08	1.16	1.16
Test	Fisher River 1.3 km downstream Lake Mackenzie																0.91
Test	Fisher River 400 m downstream Fisher Power Station						0.75		0.91								0.91
Test	Forth River downstream Wilmot River (Control Riffle)									N/A							N/A
Test	Mersey River upstream Arm Island Bend																0.75
Test	Mersey River downstream Lake Parangana		0.54				0.79		0.43		0.52		0.6		0.99		
Test	Wilmot River 500 m downstream Lake Gairdner																0.62
Test	Wilmot River at Alma Reserve	N/A	N/A							N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Test	Wilmot River at Spellmans Rd	0.95	0.82							0.98							1.04

Condition Band Key Combined Season Rank Abundance Scores	X Richer than reference >1.11	A Equivalent to reference 0.78 to 1.11	B Significantly impaired 0.44 to 0.78	C Severely impaired 0.10 to 0.44

N/A indicates that the combined season model could not be used due to large seasonal differences

Table P-3
Hydro Tasmania RIVPACS model - seasonal scores for macroinvertebrate biodiversity

Single Season Presence Absence (pa) Data Autumn and Spring

Hydro RIVPACS Type	Site	Autumn 1995	Autumn 1996	Autumn 1998	Autumn 1999	Autumn 2000	Autumn 2001	Autumn 2002	Autumn 2003	Autumn 2004	Autumn 2005	Autumn 2006	Autumn 2007	Autumn 2008	Autumn 2009	Autumn 2010	Autumn 2011
Reference	Arm River upstream Mersey River																1.32
Reference	Fish River at Mersey Forest Rd			1.09	1.1	1.1	1.1	1.1	1.03	1.1	1.1	1.1	0.97	1.16	1.1	1.24	1.21
Reference	Fisher River upstream Fisher Power Station																1.00
Reference	Forth River at Pallawah Rd			1.29													1.32
Reference	Forth River downstream Wolfram Mine			1.24													
Reference	Little Fisher River upstream lowest Rd crossing			1.1													1.11
Reference	Mersey River upstream Lake Rowallan			1.33	1.21	1.24	1.11	1.24	1.29	1.33	1.28	1.24	1.27	1.33	1.28	1.24	1.33
Test	Fisher River 1.3 km downstream Lake Mackenzie																0.55
Test	Fisher River 400 m downstream Fisher Power Station						0.96		1.09								1.09
Test	Forth River downstream Wilmot River (Control Riffle)									0.88							1.26
Test	Mersey River upstream Arm Island Bend																0.86
Test	Wilmot River 500 m downstream Lake Gairdner																0.83
Test	Wilmot River at Alma Reserve	1.19	1.19							1.31	1.2	1.07	0.84	0.95	1.2	0.95	
Test	Wilmot River at Spellmans Rd	1.24	1.15							1.07							0.96

Hydro RIVPACS Type	Site	Spring 1994	Spring 1995	Spring 1998	Spring 1999	Spring 2000	Spring 2001	Spring 2002	Spring 2003	Spring 2004	Spring 2005	Spring 2006	Spring 2007	Spring 2008	Spring 2009	Spring 2010	
Reference	Arm River upstream Mersey River															1.21	
Reference	Fish River at Mersey Forest Rd			1.01	1.21	1.02	1.02	1.11	1.21	1.19	1.11	1.01	0.95	0.84	1.1	1.18	
Reference	Fisher River upstream Fisher Power Station															1.23	
Reference	Forth River at Pallawah Rd			1.35												0.78	
Reference	Forth River downstream Wolfram Mine			0.83													
Reference	Little Fisher River upstream lowest rd crossing			1.23												1.35	
Reference	Mersey River upstream Lake Rowallan			1.07	1.39	1.17	1.16	1.28	1.23	0.93	1.22	1.43	1.41	1.29	1.45	1.39	
Test	Fisher River 1.3 km downstream Lake Mackenzie															0.68	
Test	Fisher River 400 m downstream Fisher Power Station					0.94		1.1								1.12	
Test	Forth River downstream Wilmot River (Control Riffle)								0.55							0.37	
Test	Mersey River upstream Arm Island Bend															1.21	
Test	Wilmot River 500 m downstream Lake Gairdner															0.67	
Test	Wilmot River at Alma Reserve	1.36	0.96						1.2	1.21	1.23	1.23	0.62	0.5	0.81		
Test	Wilmot River at Spellmans Rd	0.61	1.1	0.9					0.98							0.97	

Condition Band Key Single Season Presence Absence Scores	Autumn Spring	X Richer than reference	A Equivalent to reference	B Significantly impaired	C Severely impaired
	Autumn	>1.17	0.84 to 1.17	0.50 to 0.84	0.16 to 0.50
	Spring	>1.16	0.73 to 1.16	0.29 to 0.73	0.00 to 0.29

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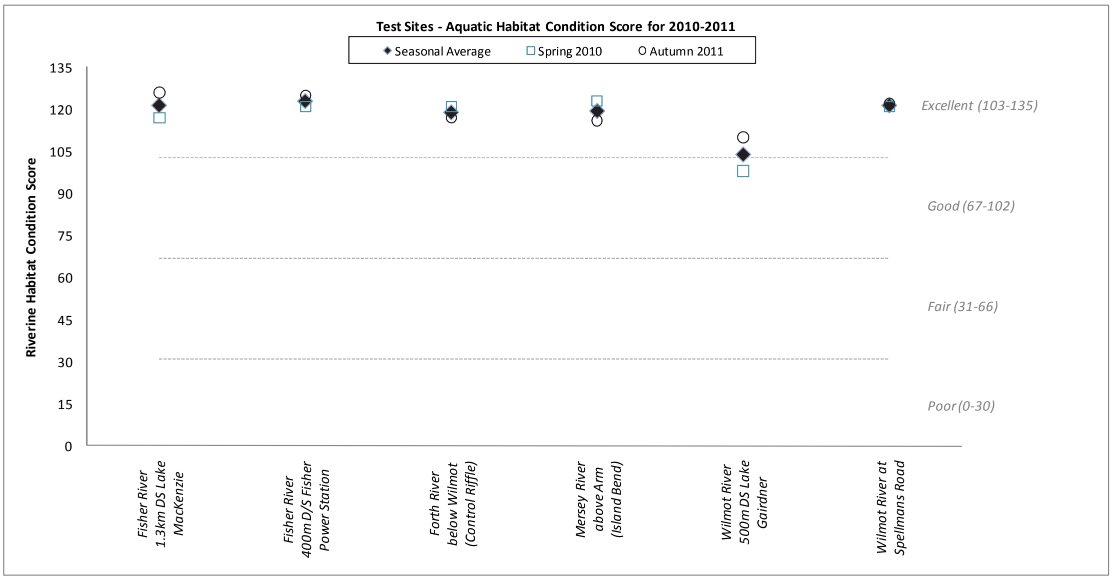
Table P-4
Hydro Tasmania RIVPACS model - seasonal scores for macroinvertebrate community composition

Single Season Rank Abundance (rk) Data Autumn and Spring

Hydro RIVPACS Type	Site	Autumn 1995	Autumn 1996	Autumn 1998	Autumn 1999	Autumn 2000	Autumn 2001	Autumn 2002	Autumn 2003	Autumn 2004	Autumn 2005	Autumn 2006	Autumn 2007	Autumn 2008	Autumn 2009	Autumn 2010	Autumn 2011
Reference	Arm River upstream Mersey River																1.22
Reference	Fish River at Mersey Forest Rd			0.86	1.05	1.13	1.13	1.1	1.04	1.13	1.02	0.95	0.87	0.85	1.22	1.13	1.12
Reference	Fisher River upstream Fisher Power Station																1.12
Reference	Forth River at Pallawah Rd			1.23													1.29
Reference	Forth River downstream Wolfram Mine			1.24													
Reference	Little Fisher River upstream lowest Rd crossing			1.29													1.13
Reference	Mersey River upstream Lake Rowallan			1.27	1.1	1.22	1.29	1.2	1.19	1.28	1.32	1.26	1.27	1.25	1.25	1.19	1.22
Test	Fisher River 1.3 km downstream Lake Mackenzie																0.79
Test	Fisher River 400 m downstream Fisher Power Station						0.93		1.07								1.05
Test	Forth River downstream Wilmot River (Control Riffle)									0.82							0.89
Test	Mersey River upstream Arm Island Bend																0.58
Test	Wilmot River 500 m downstream Lake Gairdner																0.57
Test	Wilmot River at Alma Reserve	1.15	0.96							1.27	1.08	0.89	0.83	0.95	1.02	0.89	
Test	Wilmot River at Spellmans Rd	1.09	1.0							1.06							0.93
Hydro RIVPACS Type	**Site**	**Spring 1994**	**Spring 1995**	**Spring 1998**	**Spring 1999**	**Spring 2000**	**Spring 2001**	**Spring 2002**	**Spring 2003**	**Spring 2004**	**Spring 2005**	**Spring 2006**	**Spring 2007**	**Spring 2008**	**Spring 2009**	**Spring 2010**	
Reference	Arm River upstream Mersey River															1.23	
Reference	Fish River at Mersey Forest Rd			0.96	1.14	0.96	0.97	0.97	1.16	1.11	1.13	0.96	0.98	0.81	1.04	1.18	
Reference	Fisher River upstream Fisher Power Station															1.21	
Reference	Forth River at Pallawah Rd			1.39												0.65	
Reference	Forth River downstream Wolfram Mine			0.75													
Reference	Little Fisher River upstream lowest Rd crossing			1.24												1.35	
Reference	Mersey River upstream Lake Rowallan			1.10	1.41	1.22	1.21	1.32	1.21	0.91	1.10	1.42	1.27	1.19	1.45	1.39	
Test	Fisher River 1.3 km downstream Lake Mackenzie															0.66	
Test	Fisher River 400 m downstream Fisher Power Station					1.14		0.9								1.18	
Test	Forth River downstream Wilmot River (Control Riffle)								0.5							0.29	
Test	Mersey River upstream Arm Island Bend															1.11	
Test	Wilmot River 500 m downstream Lake Gairdner															0.59	
Test	Wilmot River at Alma Reserve	1.37	1.01						1.2	1.25	1.13	1.26	0.56	0.45	0.68		
Test	Wilmot River at Spellmans Rd	0.55	1.02	0.87					1.04							1.02	

Condition Band Key Single Season Rank Abundance Scores		X Richer than reference	A Equivalent to reference	B Significantly impaired	C Severely impaired
	Autumn	>1.20	0.81 to 1.20	0.42 to 0.81	0.03 to 0.42
	Spring	> 1.20	0.78 to 1.20	0.36 to 0.78	0.00 to 0.36

Q Aquatic habitat condition scores for Mersey-Forth Rivers



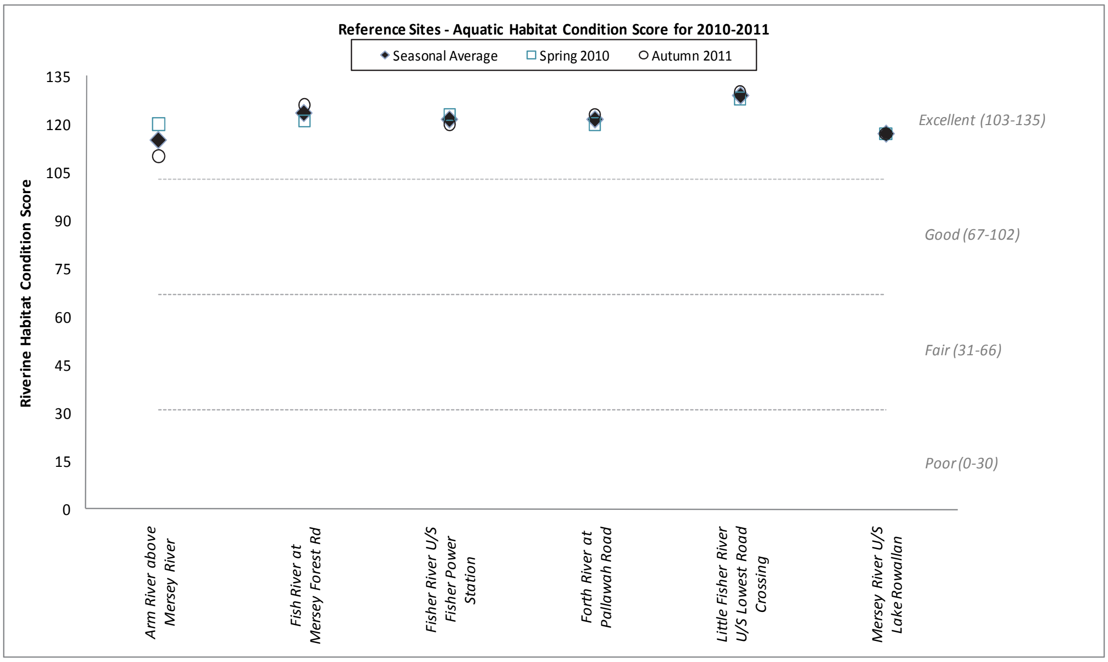


Figure Q-1
Aquatic habitat condition scores for test sites (top) and reference sites (bottom) assessed in 2010-11

Table Q-1
Mersey River downstream Parangana Dam macroinvertebrate habitat assessment condition score and category 2000 to 2009

Year	**Spring**		**Autumn**	
	Score*	**Category**	**Score***	**Category**
2000-2001	106	Excellent	102	Good
2002-2003	112	Excellent	105	Excellent
2004-2005	104	Excellent	101	Good
2006-2007	123	Excellent	129	Excellent
2008-2009	125	Excellent)	126	Excellent

*USEPA RBA protocols (Plafkin *et al*. 1989). Score out of a possible 135
(where excellent equates to 103 to 135 and good equates to 66 to 102)

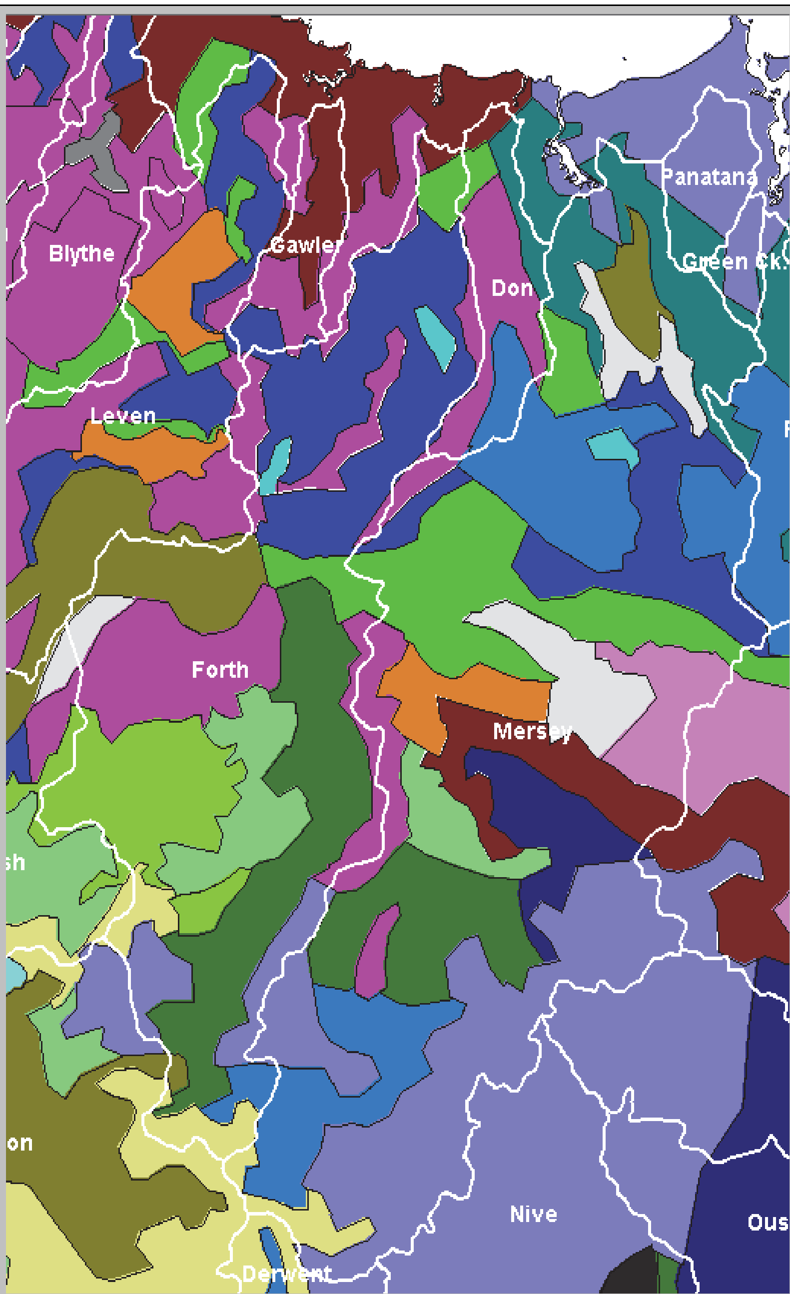
Table Q-2
Instream habitat percentage cover including algal cover and biomass data for the Mersey River downstream of Parangana

Year	Mean % Cover (3 transects, 7 replicate samples)							Phytoplankton Algal Biomass Estimate
	Peri-phyton	Filamentous algae	Woody debris	Macro-phytes	Moss	Bare	Total	Chl-*a* (µg/L)
2001	76.9	4.5	1.4	0.2	0	16.9	100	14.97
2003	85.2	1.2	0.2	0.5	0.2	12.6	100	20.90
2005	60.5	1.4	0.5	0	0	37.6	100	56.48
2007	80.2	6.7	0	0	1.4	11.7	100	46.94
2009	No data	No data	No data	No data	No data	No data	No data	58.33

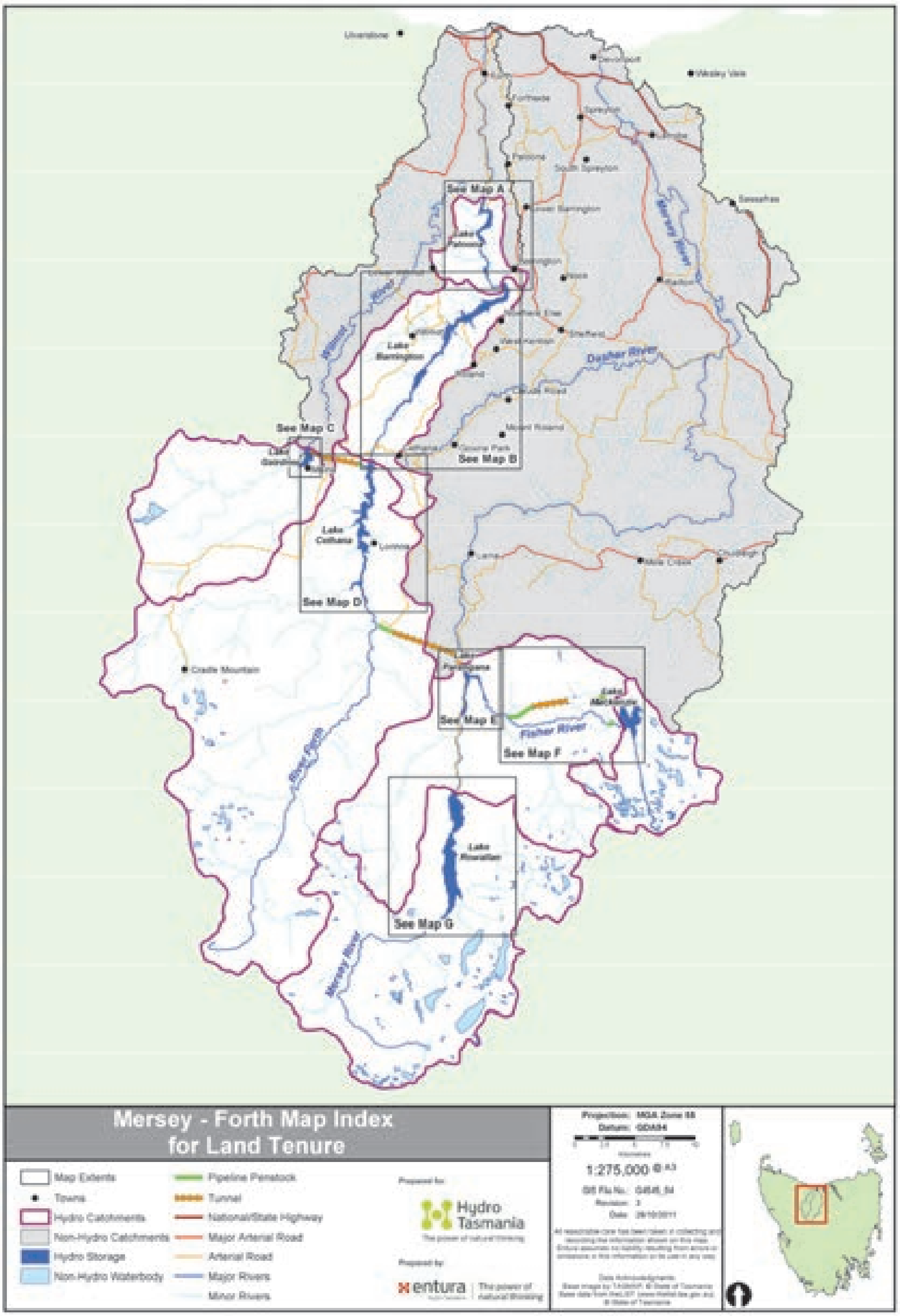
R Geomorphic mosaics in the Mersey-Forth catchments

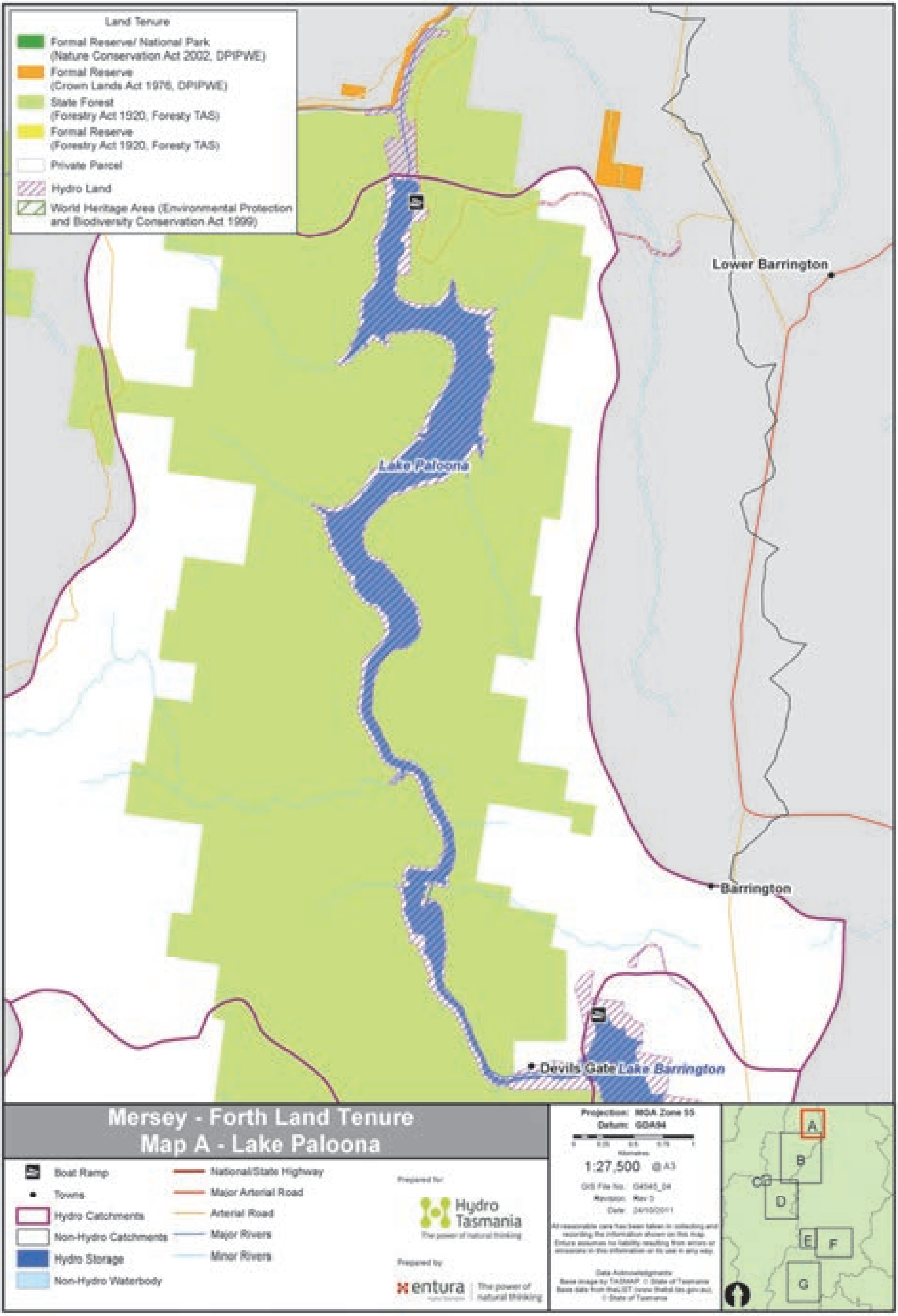
Table R-1
Geomorphic mosaics in the Mersey-Forth catchments (Jerie *et al*. 2003)

	Strongly glaciated plateau
	Glaciated dolerite valleys
	Glaciated quartzite valleys
	Northern relict surfaces
	Southwestern quartzite valleys
	High altitude dolerite plateau
	Steep dolerite scree
	Western Tiers basins and fans
	Northern steep quartzite ridges and scree
	Northern valleys
	Northern rolling basalt hills and alluvial basins
	Glacially dissected quartzite plateau
	Northern karst basin
	Northern high relief karst
	Northern quartzite gorges
	Northern quartzite ridges, hills and valleys
	Finely dissected northern surface and coastal sediments
	Moderate rainfall northern dolerite and Parmeener hills
	Northern Tertiary basins and coastal sediments



S Mersey–Forth catchment land tenure maps for land adjacent to Hydro Tasmania lakes




Land Tenure
Formal Reserve/ National Park (Nature Conservation Act 2002, DPIPWE)
Formal Reserve (Crown Lands Act 1976, DPIPWE)
State Forest (Forestry Act 1920, Foresty TAS)
Formal Reserve (Forestry Act 1920, Foresty TAS)
Private Parcel
Hydro Land
World Heritage Area (Environmental Protection and Biodiversity Conservation Act 1999)
Lower Barrington
Lake Paloona
Barrington
Devils Gate
Lake Barrington
Mersey - Forth Land Tenure
Map A - Lake Paloona
Boat Ramp
Towns
Hydro Catchments
Non-Hydro Catchments
Hydro Storage
Non-Hydro Waterbody
National/State Highway
Major Arterial Road
Arterial Road
Major Rivers
Minor Rivers
Prepared for
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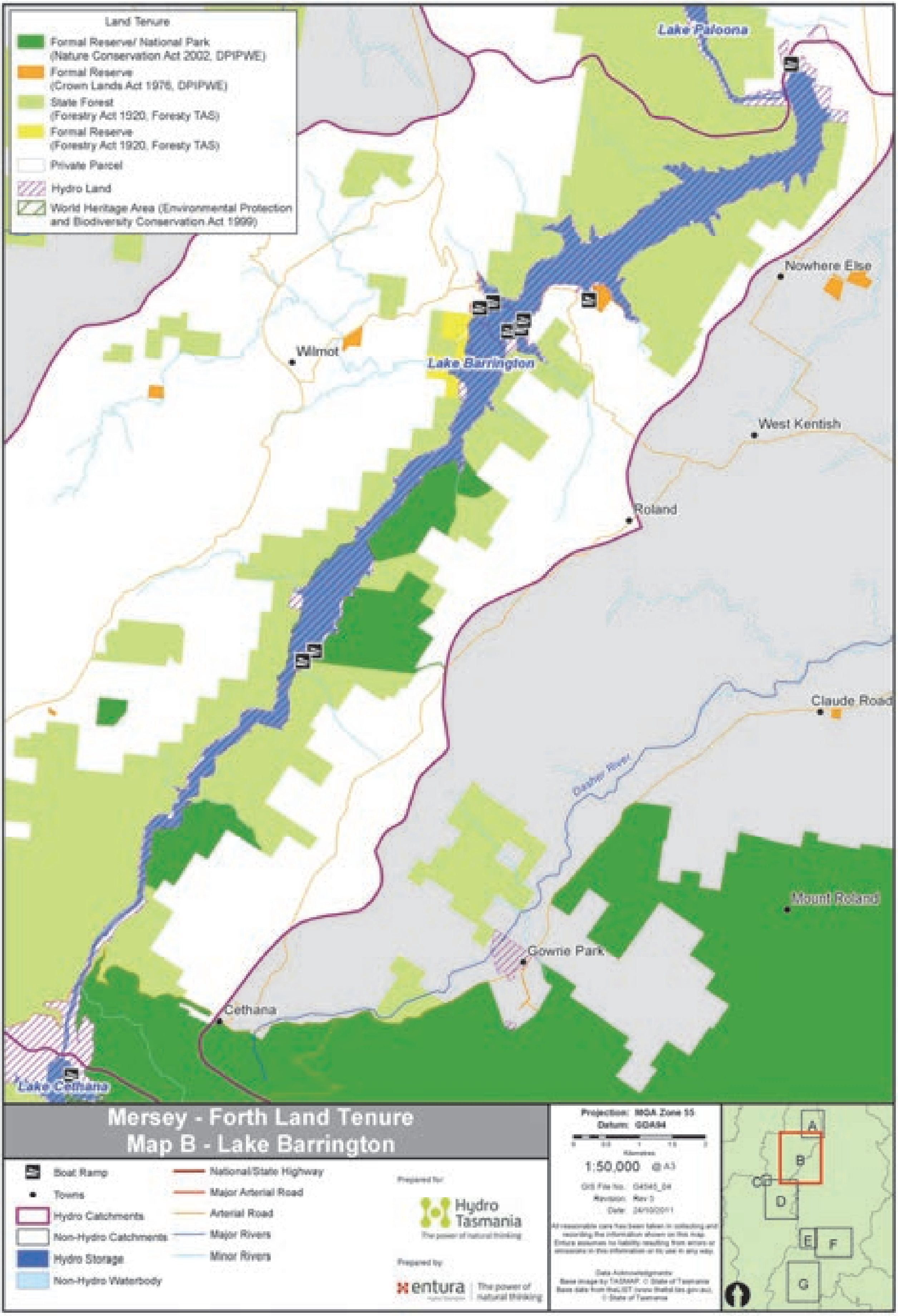

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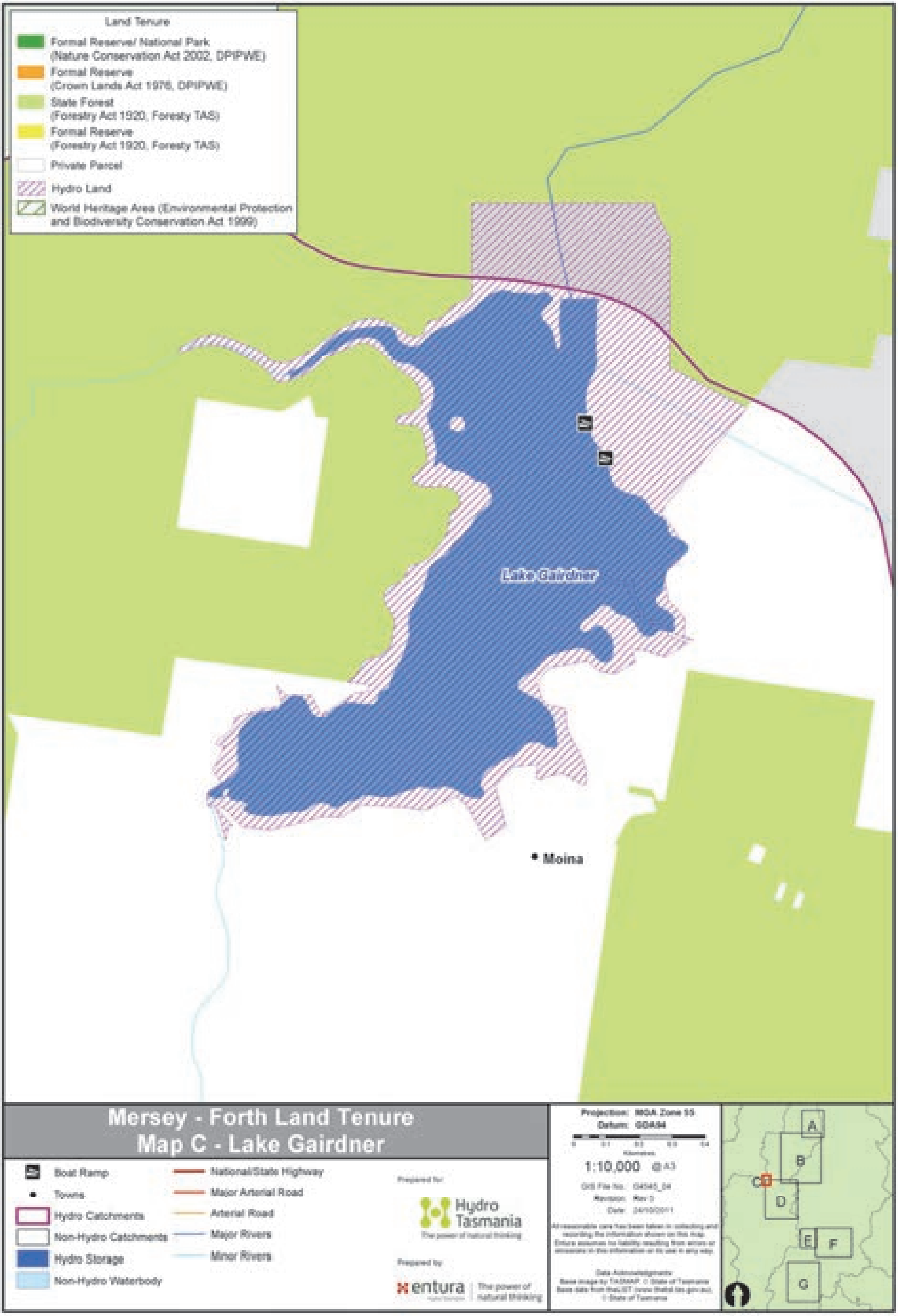
Land Tenure
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Formal Reserve (Crown Lands Act 1976, DPIPWE)
State Forest (Forestry Act 1920, Foresty TAS)
Formal Reserve (Forestry Act 1920, Foresty TAS)
Private Parcel
Hydro Land
World Heritage Area (Environmental Protection and Biodiversity Conservation Act 1999)
Lake Gairdner
Moina
Mersey - Forth Land Tenure
Map C - Lake Gairdner
Boat Ramp
Towns
Hydro Catchments
Non-Hydro Catchments
Hydro Storage
Non-Hydro Waterbody
National/State Highway
Major Arterial Road
Arterial Road
Major Rivers
Minor Rivers
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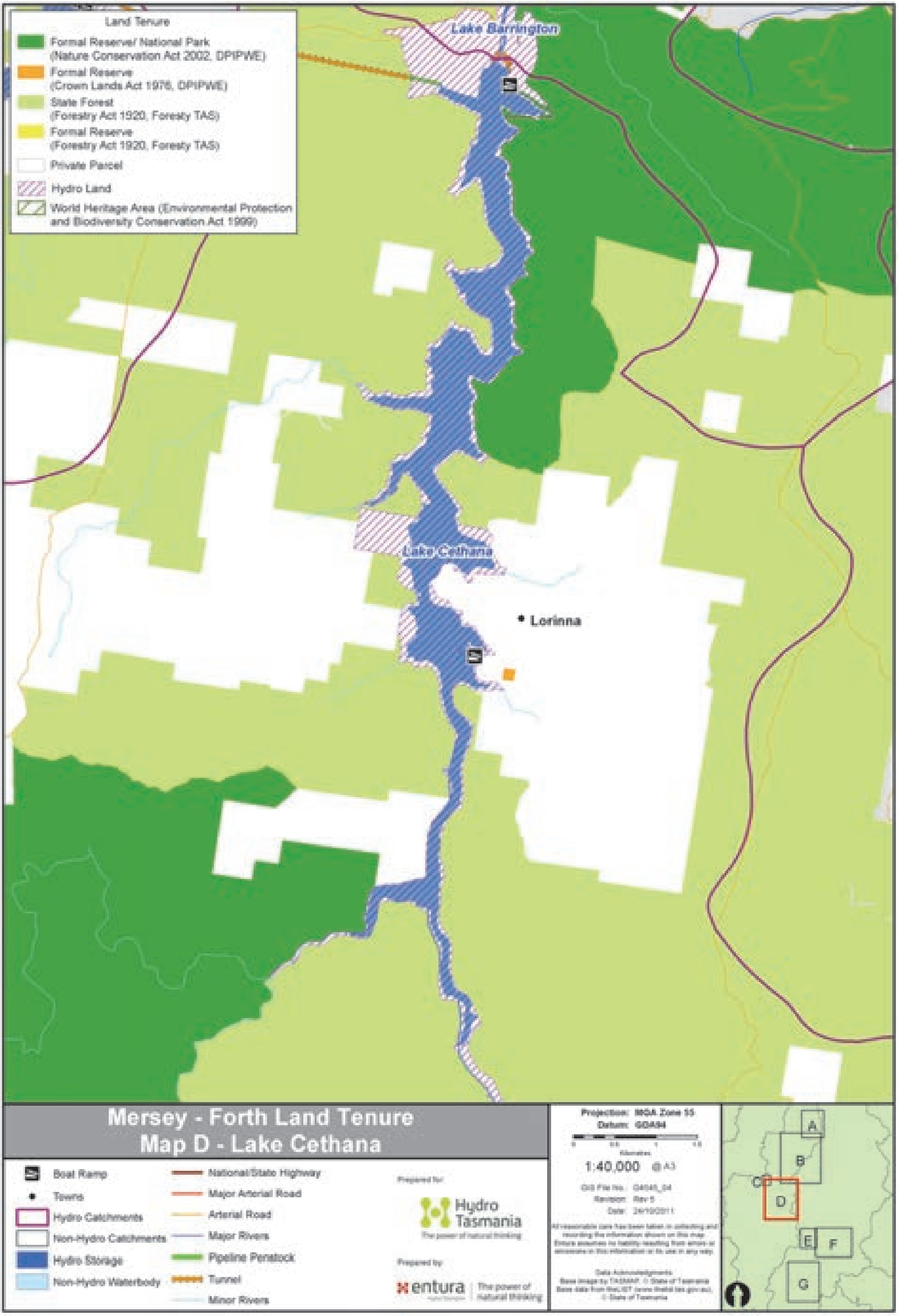

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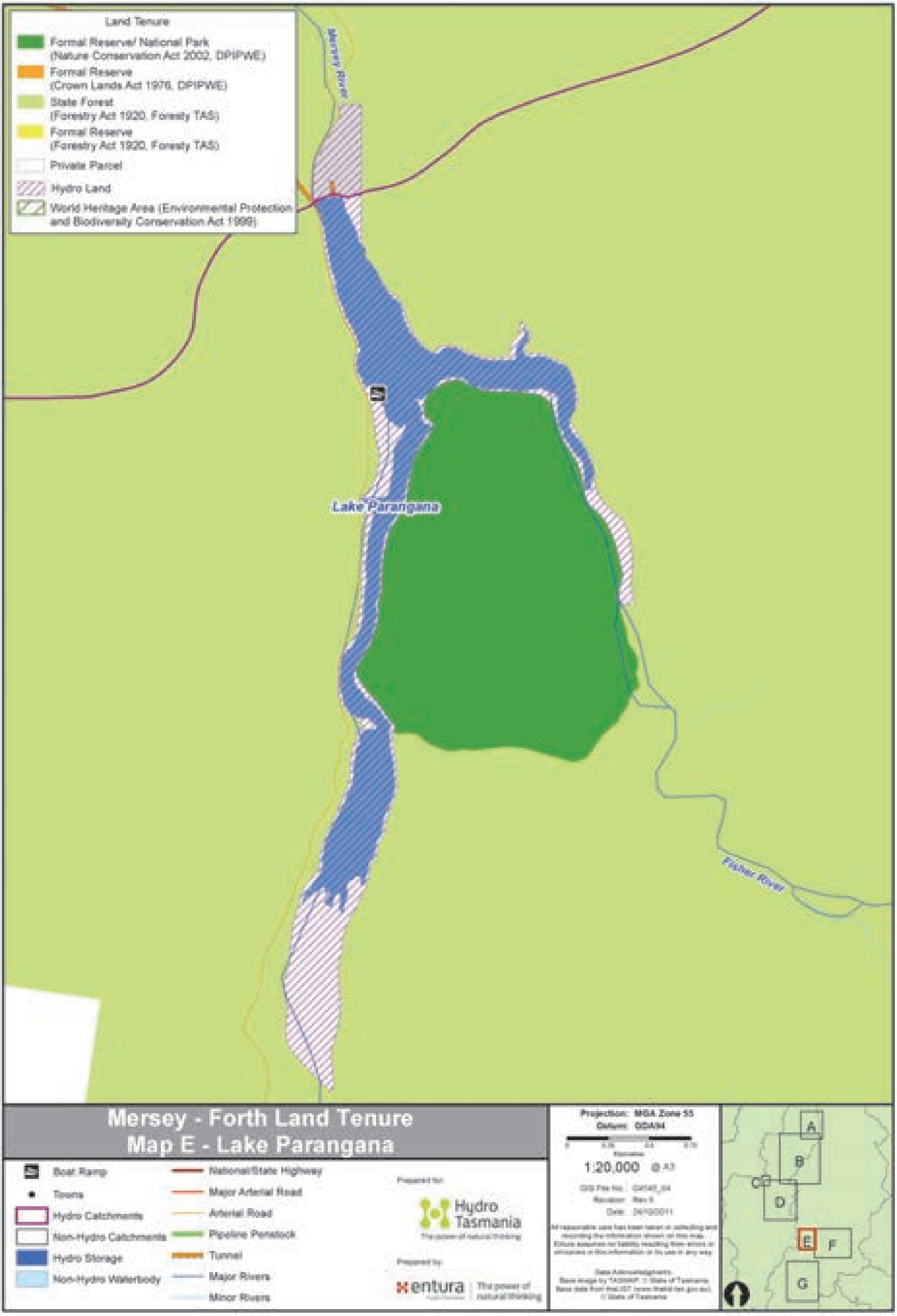
Land Tenure
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Formal Reserve (Crown Lands Act 1976, DPIPWE)
State Forest (Forestry Act 1920, Forestry TAS)
Formal Reserve (Forestry Act 1920, Forestry TAS)
Private Parcel
Hydro Land
World Heritage Area (Environmental Protection and Biodiversity Conservation Act 1999)
Mersey River
Lake Parangana
Fisher River
Mersey - Forth Land Tenure
Map E - Lake Parangana
Boat Ramp
Towns
Hydro Catchments
Non-Hydro Catchments
Hydro Storage
Non-Hydro Waterbody
National/State Highway
Major Arterial Road
Arterial Road
Pipeline Penstock
Tunnel
Major Rivers
Minor Rivers
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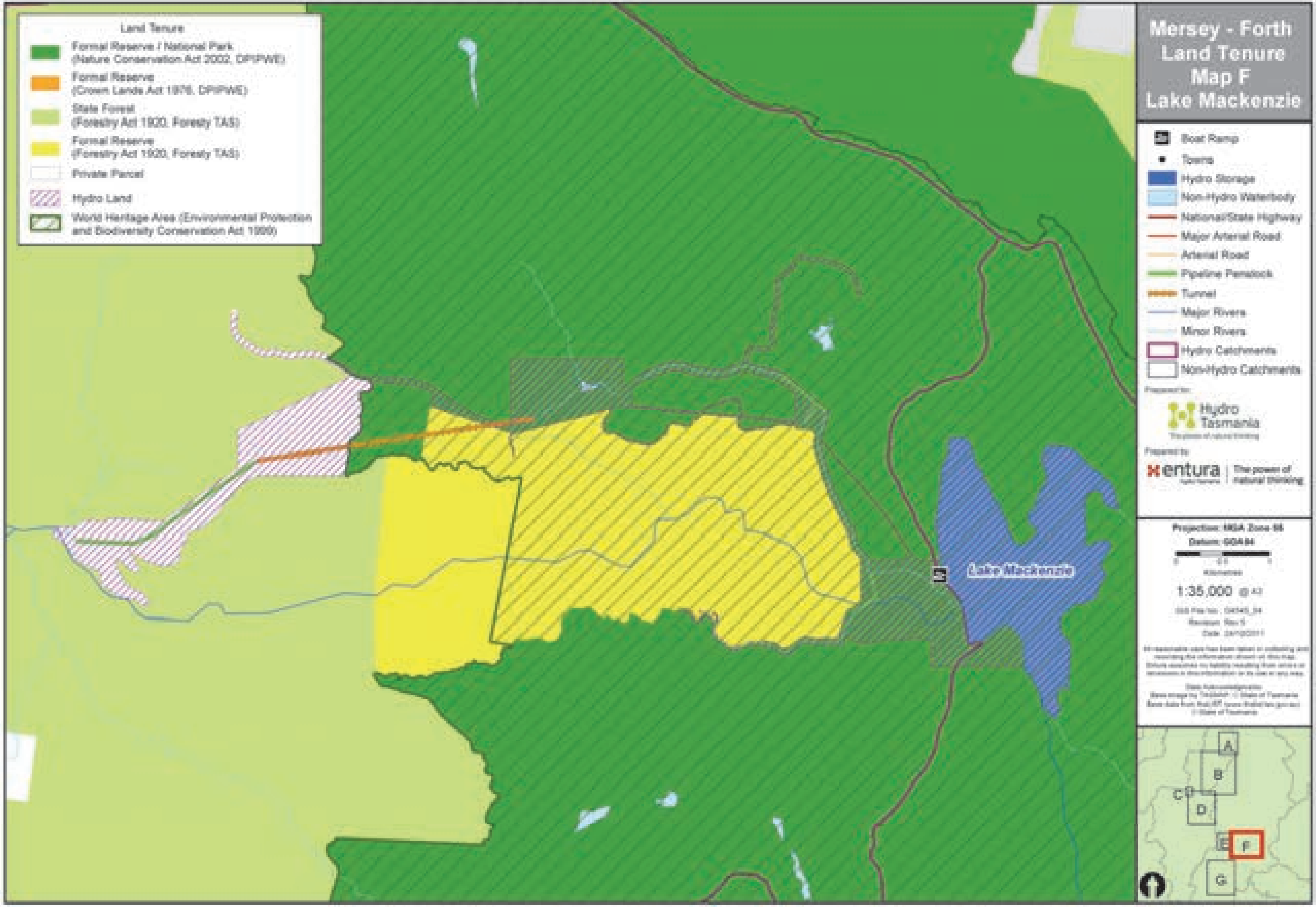

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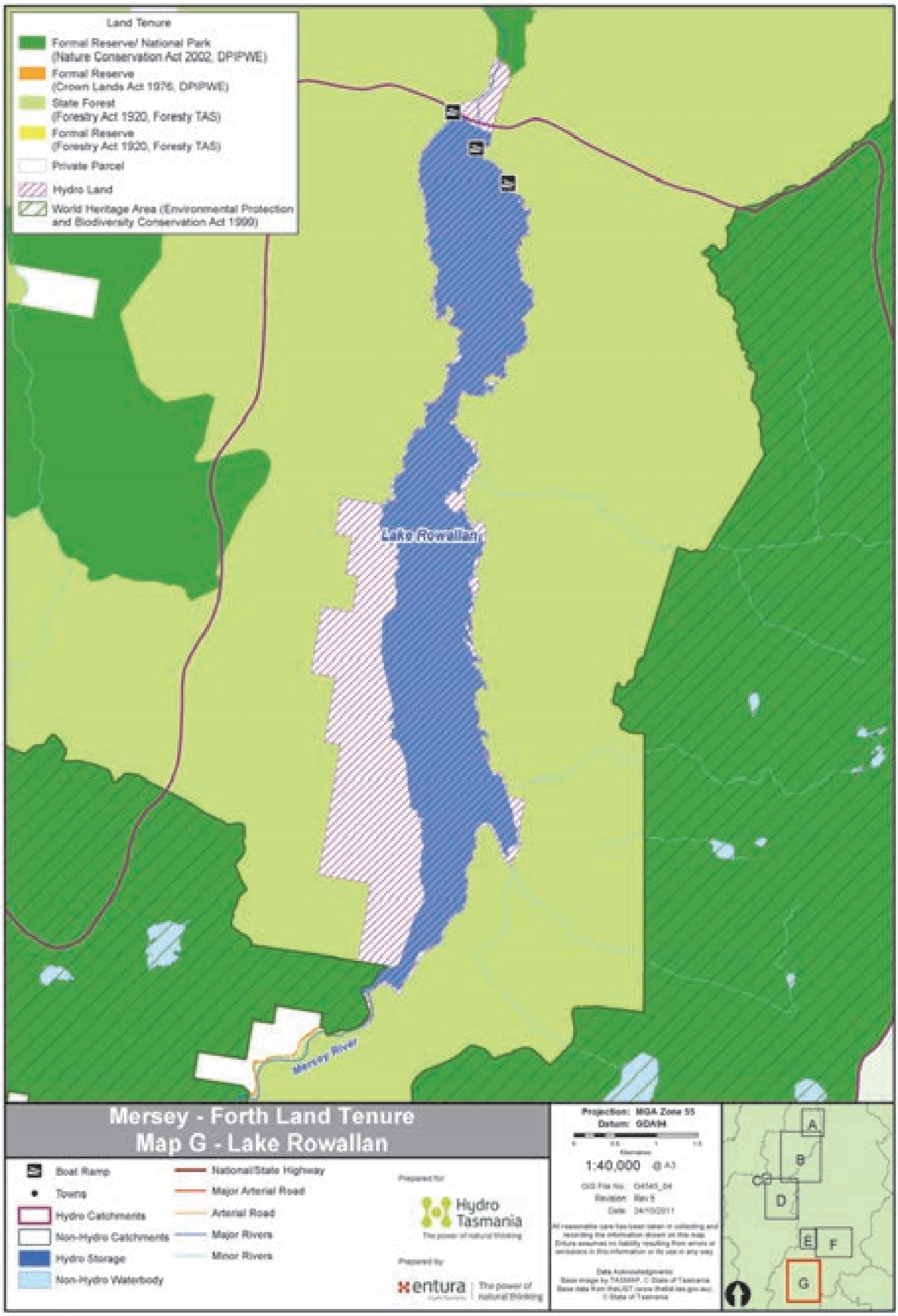
Land Tenure
Formal Reserve/ National Park (Nature Conservation Act 2002, DPIPWE)
Formal Reserve (Crown Lands Act 1976, DPIPWE)
State Forest (Forestry Act 1920, Forestry TAS)
Formal Reserve (Forestry Act 1920, Forestry TAS)
Private Parcel
Hydro Land
World Heritage Area (Environmental Protection and Biodiversity Conservation Act 1999)
Lake Rowallan
Mersey River
Mersey - Forth Land Tenure
Map G - Lake Rowallan
Boat Ramp
Towns
Hydro Catchments
Non-Hydro Catchments
Hydro Storage
Non-Hydro Waterbody
National/State Highway
Major Arterial Road
Arterial Road
Major Rivers
Minor Rivers
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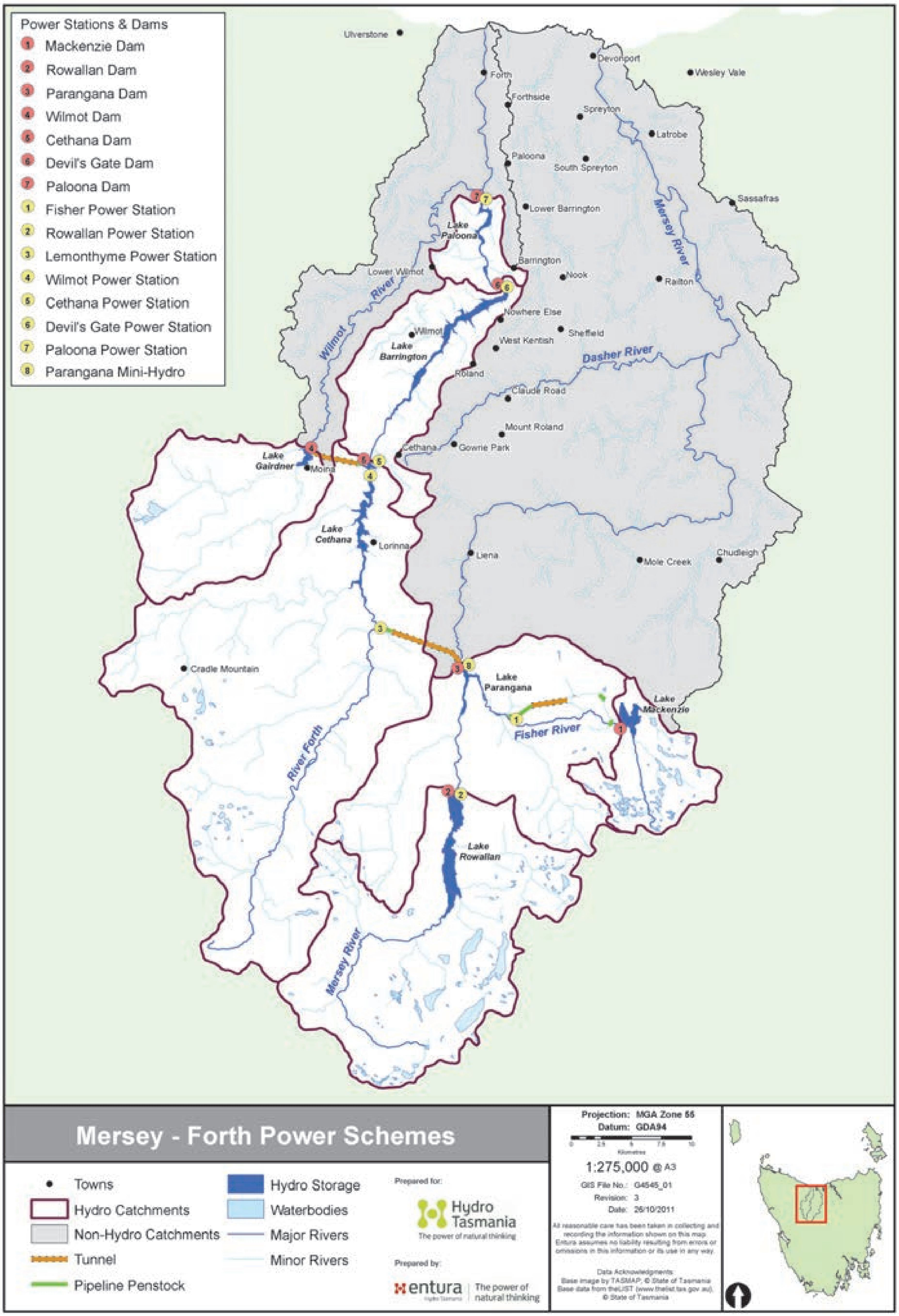
Power Stations & Dams
1 Mackenzie Dam
2 Rowallan Dam
3 Parangana Dam
4 Wilmot Dam
5 Cethana Dam
6 Devil's Gate Dam
7 Paloona Dam
1 Fisher Power Station
2 Rowallan Power Station
3 Lemonthyme Power Station
4 Wilmot Power Station
5 Cethana Power Station
6 Devil's Gate Power Station
7 Paloona Power Station
8 Parangana Mini-Hydro
Ulverstone
Devonport
Forth
Wesley Vale
Forthside
Spreyton
Latrobe
Paloona
South Spreyton
Sassafras
Lower Barrington
Mersey River
Lake Paloona
Barrington
Lower Wilmot
Nook
Railton
Wilmot River
Nowhere Else
Wilmot
Sheffield
West Kentish
Lake Barrington
Dasher River
Roland
Claude Road
Mount Roland
Cethana
Gowrie Park
Lake Gairdner
Moina
Lake Cethana
Lorinna
Liena
Mole Creek
Chudleigh
Cradle Mountain
Lake Parangana
Lake Mackenzie
Fisher River
River Forth
Lake Rowallan
Mersey River
Mersey - Forth Power Schemes
Towns
Hydro Catchments
Non-Hydro Catchments
Tunnel
Pipeline Penstock
Hydro Storage
Waterbodies
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Revision: 3
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