1 Introduction

Over the past century, mining activities in the Mount Lyell region have resulted in considerable impact to the natural environment within and about the mining lease sites, the rivers and Macquarie Harbour. Impacts are related to the general landscape of the Queenstown area, the removal of vegetation and topsoil, changes to hydrology and water quality, and the deposition of tailings and slag in the rivers and harbour. In 1995, the Tasmanian and Federal Governments established a joint program to develop a strategy for remediating the environmental impact of past mining at Mount Lyell. The program was titled 'The Mount Lyell Remediation Research and Demonstration Program'. The authorities coordinating the program comprised the Tasmanian Department of Environment and Land Management's Division of Environmental Management, the Commonwealth Environment Protection Authority's Office of the Supervising Scientist (***oss***) and the Environmental Research Institute of the Supervising Scientist (***eriss***).

The Mount Lyell Remediation Research and Demonstration Program (MLRRDP) is a series of projects to investigate the extent and mechanisms of environmental impacts which have resulted from mining activities (Appendix A). Impacts ranged from acid drainage associated with mining, to the tailings deposits in the Queen and King Rivers, and Macquarie Harbour. The Program forms an important component of a larger and longer term Tasmanian Government program to understand and overcome these environmental impacts.

The MLRRDP includes three related projects dealing with the management of the quantity and quality of effluent from the lease site, the primary source of pollutants into the river and Macquarie Harbour system. These are:

1 a review and presentation of historical literature and data for the characterisation of sources of effluent from the lease site;

2 identification of the potential options for managing effluent water from the lease site and recommendations for construction and operation of demonstration/evaluation trials; and

3 construction and evaluation of test cases.

Project 1, the subject of this report, presents a consolidation of available information. Project 2 builds on this information and identifies options to reduce the emission of acid drainage from the lease site. Project 3 involves the construction and evaluation of some of the options identified in Project 2.

This report provides an introduction to the site with a brief history of the mining and processing operations undertaken over the past century. The environmental impacts resulting from these operations are presented with an overview of available information on the current quantity and quality of effluent water from the lease site.

2 Site location and description

2.1 Location

The area disturbed by mining at Mount Lyell covers approximately 13 km^2. The site is within two kilometres of the township of Queenstown, which is located some 270 km north-west of Hobart and about 25 km from the west coast of Tasmania and the Southern Ocean (figure 2.1). The port of Strahan, located on Maquarie Harbour, was the main supply and export centre for regional mining following its establishment in 1880. Macquarie Harbour has a

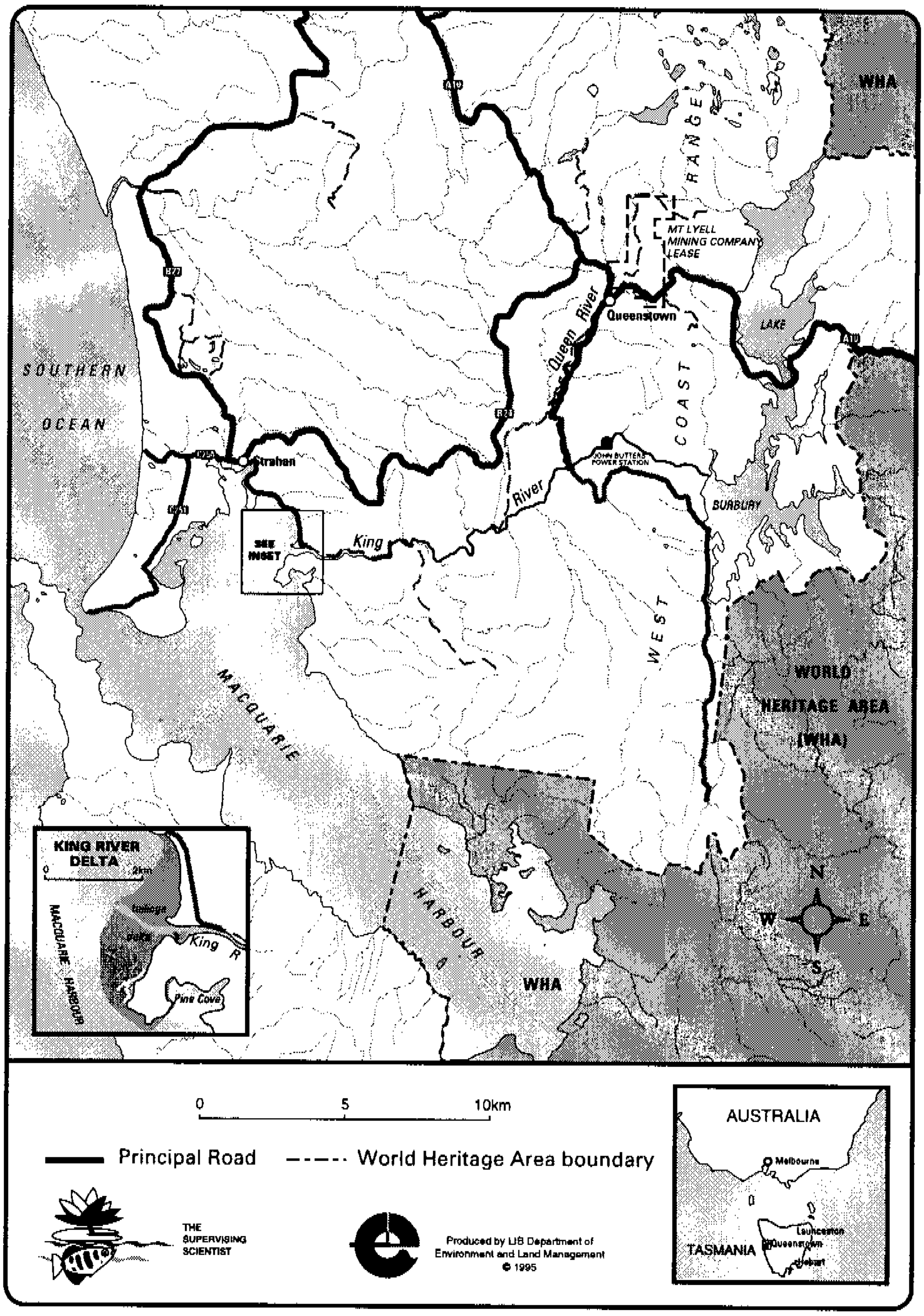

Figure 2.1 Regional map

water surface area of around 275 km^2 and is almost totally landlocked, with a narrow ocean mouth of a few hundred metres known as Hell's Gates (Locher 1995).

Queenstown was developed specifically to serve the Mount Lyell mining field at the turn of the century. The population of Queenstown was approximately 3360 in 1991 but exceeded 5000 in the early 1970s (Australian Bureau of Statistics 1991). The decrease in population reflected the downturn in the mining industry and the lower metal prices during the late eighties. Historically the town has provided housing for the work force and support services for The Mount Lyell

Mining and Railway Company operations, but more recently provides similar services for a number of other mining operations within the district, principally the Henty Gold Project. The town also serves as a regional centre for education, health, and other Government services.

2.2 Topography and drainage

Queenstown is situated in the physiographic region of Tasmania known as the Western Ranges which comprise a series of quartzite and conglomerate units forming dissected mountain ranges (Corbett 1976). Many of the mountains in this region exhibit glacial features including cirque lakes, moraines and glacial erratics. From about 300 m at the foot of the West Coast Range, the Western Coastal Platform slopes westward to end near the coast. The platform is deeply incised by the major west flowing river systems including the King, Queen, Henty and Pieman Rivers.

The mining operations are located within the west coast mountain range with Mount Lyell (920 m), on the Cape Horn Spur, being situated about two kilometres north of the mining field. Philosophers Ridge runs between the spurs of Mount Lyell and Mount Owen (1146 m) forming the eastern border of the West Lyell open-cut (figure 2.2). Gradients of the region are typically one in two to one in four.

Geological control of the topography and drainage is evident, with the resistant Owen Conglomerate generally controlling the drainage pattern. The major rivers are confined to either the underlying or softer overlying formations, particularly the Gordon Limestone. Philosophers Ridge forms the main hydrological divide within the Mount Lyell mining lease area, with water to the east flowing via Lyell–Comstock Creek through the Sedgwick Valley and Linda Creek through the Chamouni Valley to Lake Burbury. On the western side, Conglomerate and Haulage (Glovers) Creeks and the East and West Queen Rivers drain surface runoff into the Queen River which has its confluence with the King River approximately 15km downstream of the mine site. The drainage catchments are illustrated in figure 2.3.

The catchment of the King River is 809 km^2 with an annual discharge of 60.2 m^3/s (South West Tasmania Resources Survey 1980) and its major sub-catchment, the Queen River, is 79.3 km^2 with an annual runoff of 5.2 m^3/s. The elevation at the point where tailings are discharged into Haulage Creek is 200 m (Australian Height Datum, AHD) and falls at an average gradient of 1:90 through the Queen River to the King River. Below this confluence the gradient is a gentler 1:350 to Macquarie Harbour.

Mining operations have significantly changed the runoff characteristics of the area through the removal of vegetation, the excavation of large open pits, the development of underground workings, placement of mining and processing infrastructure and the development of waste-rock and process waste dumps. The waste rock dumps cover an area of around 90 ha. The six open pits in the area, with a combined surface area of 57 ha (table 2.1), collect and store rainfall, and discharge rainfall/runoff to mine workings or groundwater via adits and fracture systems in the base of the pits. The catchment area of the West Lyell open-cut is increasing in size as the pit walls collapse as a result of underground mining. The surface expression of an extensive fracture system along the south-western and eastern sides, were observed during field visits associated with this project, implies that the actual catchment area is greater than the pit perimeter.

MLMRCL (1994a) noted that the connecting pathways for water between the Comstock open-cut and the underground workings are not well known. Rainwater collected in the southern portion of the West Lyell open-cut drains into the mine workings of Prince Lyell from where it is pumped to the surface and discharged into Haulage Creek. No records of

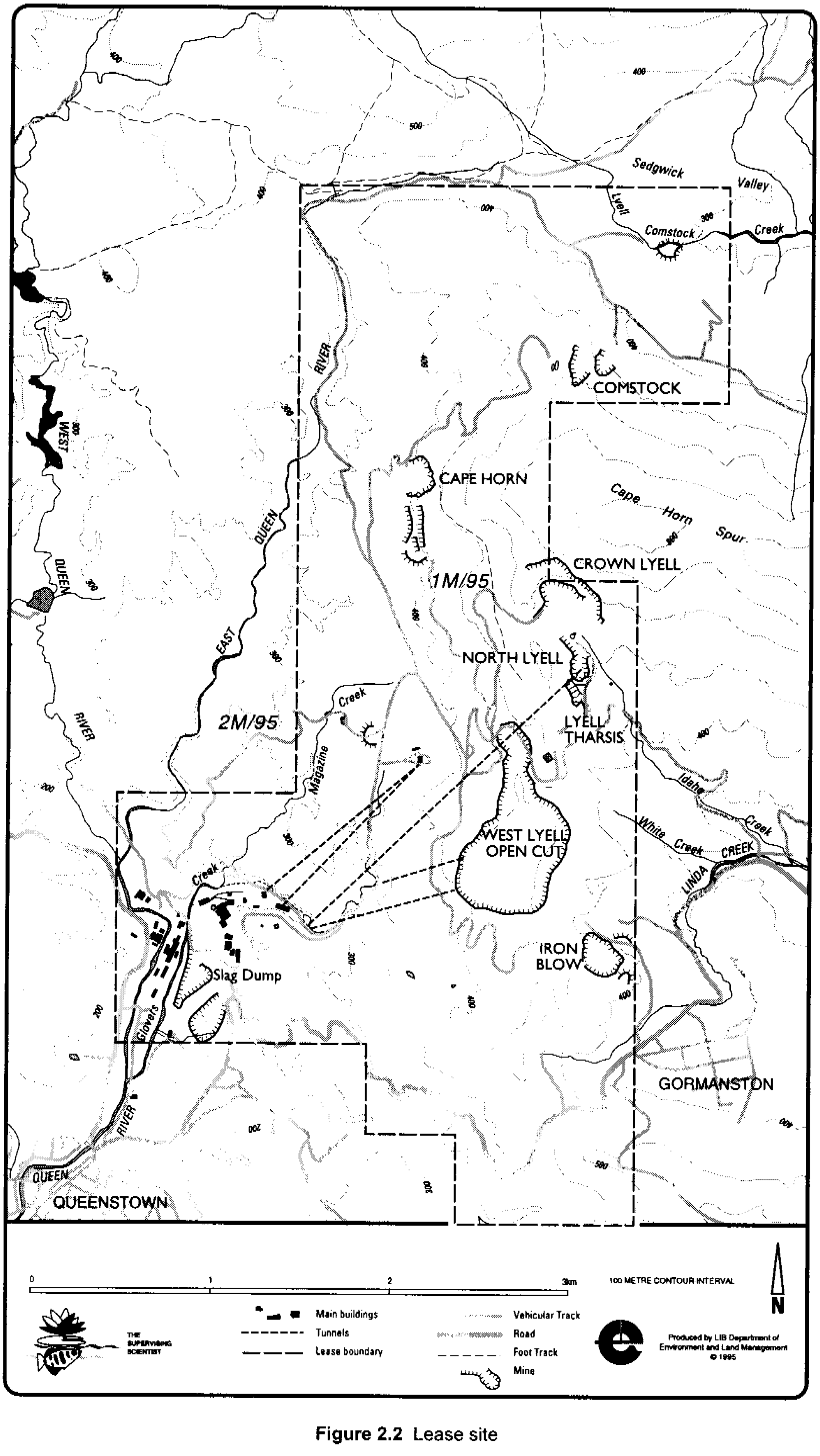

Figure 2.2 Lease site

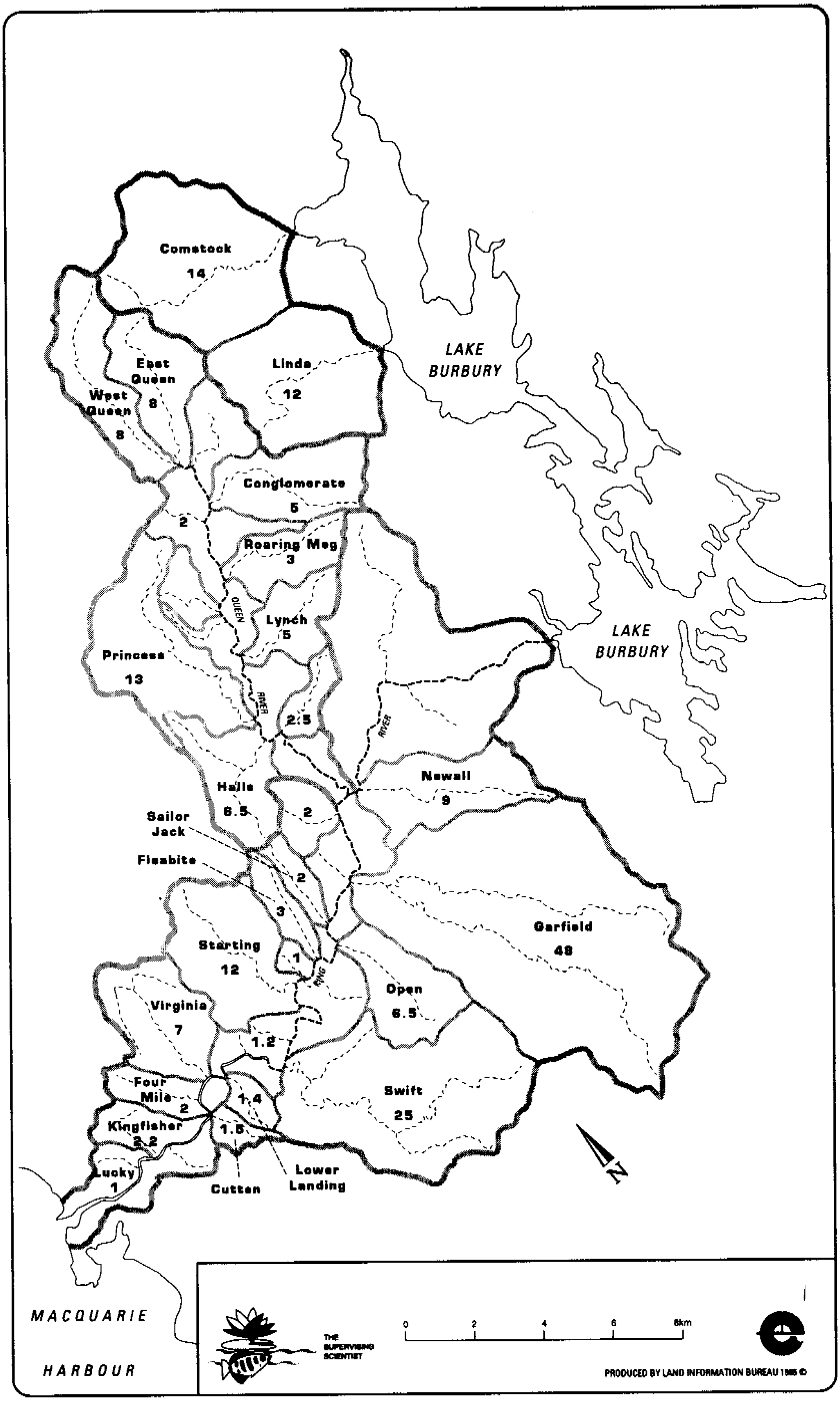

Figure 2.3 Regional surface water drainage network of the Mount Lyell mine and vicinity (modified after Locher 1995)

metered discharge volumes were kept, although some pump hours were documented. An adit in the northern end of the West Lyell open-cut drains this portion of the catchment into the North Tunnel. It is understood that there has been no study of the effects of mining on the local surface and groundwater hydrology.

Table 2.1 Catchment areas of the open-cuts

Open-cut	Catchment area (ha)	Open-cut	Catchment area (ha)
West Lyell[1]	37	Crown Lyell	7
Iron Blow	5	Lyell Tharsis	2
Cape Horn	2	Comstock	4

1 The catchment area is continuing to increase with the failure of the pit walls

In the Comstock Valley, the hydrology has been altered by drainage works designed to minimise pollutant loads to Lake Burbury, a site for recreational fishing. A proportion of runoff from mine disturbed areas has been redirected into the East Queen River, but, without planned maintenance it is uncertain how long these strategies will remain effective. These diversion works include:

- from July 1991, acid discharge from the Comstock open-cut and Comstock 5 level adit was diverted from the Lyell–Comstock Creek to the East Queen River just below the mine water intake pump station;
- also in July 1991, a rock-filled embankment was constructed at the Crown Lyell open-cut to divert runoff from the Linda catchment to Haulage Creek via the North Lyell underground workings;
- the Tharsis adit was initially sealed on 23 October 1992, in order to redirect drainage out of the Linda catchment back through the old mine workings to Haulage Creek via the North Lyell Tunnel. In late November 1992, the plug was found to have failed and was re-grouted in May 1993. During a site visit in May 1995, water was being allowed to freely drain from the adit through a pipe and valve system installed through the base of the concrete plug;
- following the completion of mining at the Iron Blow, the open-cut was flooded, and water now drains this pit into the headwaters of Linda Creek via an adit.

The depletion of high grade ore suitable for pyritic smelting and the depletion of firewood supplies close to Queenstown as a result of large scale clearing, required an additional energy source for the smelters and mining operations. To the north of Queenstown in 1914, The Mount Lyell Mining and Railway Company Limited constructed Margaret Dam on the Yolande River, forming Lake Margaret (the Lake Margaret power development was later sold to the HEC in 1985). In 1991, the HEC completed a second major hydro-electric scheme with the construction of the Crotty Dam on the King River and the Darwin Dam at Andrews Divide, forming Lake Burbury. The HEC controls the water release from these dams to provide electricity into the Tasmanian power grid.

Three minor dams located on the West Queen River retain water which is directed to the processing area for the mill water supply. The water is pumped to the mill-head tanks and overflow from the processing area enters Haulage Creek. The West Queen dams are filled with water from Lake Margaret in times of low water supply. Mine water is pumped from the East Queen River to head tanks above the Prince Lyell Shaft, eventually discharging via the Conveyor Tunnel to Haulage Creek.

2.3 Climate

The climate of the west coast region is classified as temperate maritime. Queenstown is 25 km from the Southern Ocean, thus heat absorption and storage by the sea produces much milder winters and cooler summers than in continental climates of the same latitudes, although this effect diminishes with altitude and distance from the coast.

Situated between latitudes 40°S and 45°S, Tasmania is under the influence of a broad band of westerly winds known as the 'Roaring Forties'. These prevailing winds produce a marked west to east variation in cloudiness and rainfall across the State. Characteristically high rainfall occurs in the mountainous western half of the State where elevated regions induce orographic rainfall from the passage of frontal systems embedded in the dominant westerly airstream (figure 2.4). Queenstown receives rainfall on approximately 240 days of the year and the region receives the least amount of sunshine in Australia.

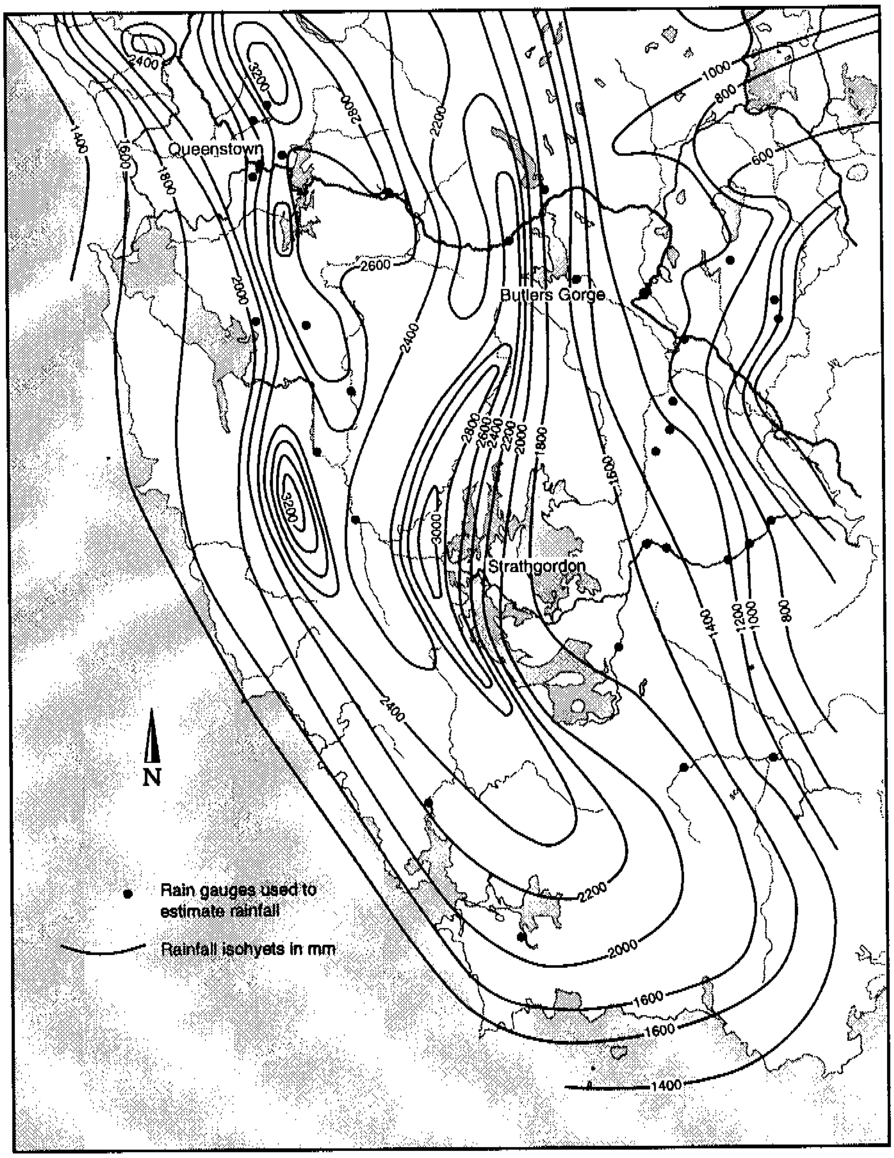

Figure 2.4 Regional annual rainfall

Throughout the west coast region, rainfall generally exceeds the effective rainfall (that required to initiate and maintain plant growth above the wilting point) in all months except January. Annual average rainfall for Queenstown is 2400 mm and 2520 mm for Mount Lyell (calculated from 30 years of data to 1993 recorded at station 097034 located in the township of Queenstown, and 87 years of data to 1993 recorded at station 097008 located on the mine site of Mount Lyell, respectively). The general rainfall statistics are provided in table 2.2. Because Mount Lyell is slightly higher than Queenstown, it receives slightly higher rainfall in the summer months.

Table 2.2 Rainfall statistics for stations 097008 (Mount Lyell) and 097034 (Queenstown)

Month	Mean rainfall (mm)		Median rainfall (mm)		Number of rain days	
Station	Mount Lyell	Queenstown	Mount Lyell	Queenstown	Mount Lyell	Queenstown
January	151	148	146	136	16	17
February	122	101	111	83	13	13
March	163	144	160	143	17	17
April	224	209	215	202	19	21
May	244	242	227	227	21	22
June	234	219	228	197	19	21
July	260	269	265	267	22	24
August	264	264	264	261	23	24
September	247	246	247	261	21	23
October	228	210	222	182	21	22
November	200	181	202	193	19	19
December	184	172	175	166	18	19
Total	2517	2394	2473	2412	229	242

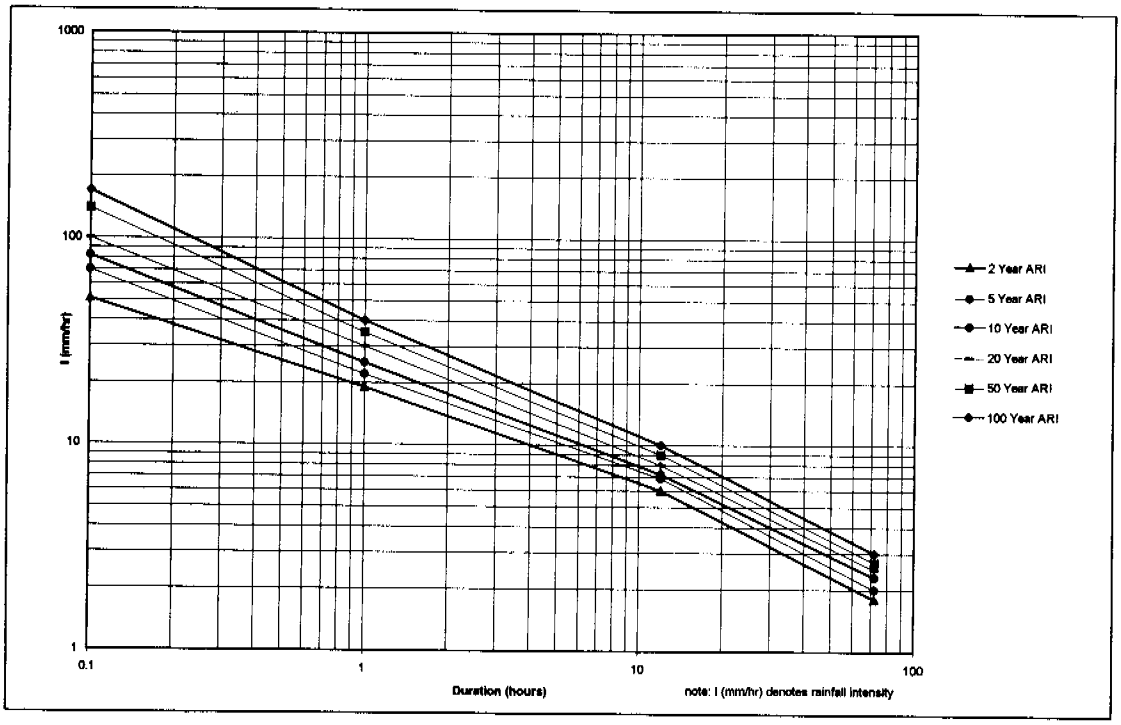

Figure 2.5 Annual recurrence interval intensity/duration chart for Queenstown (Pilgrim 1987)

Rainfall usually occurs as light rain or as a mist interspersed with less frequent heavier rain; winter rainfall generally exceeds summer rainfall. For an annual recurrence interval of two years, the one hour duration storm has an intensity of around 18 mm/h. The annual recurrence interval intensity/duration chart for Queenstown is shown in figure 2.5.

The pan evaporation record for the district is poor, providing only a few good years of continuous record; based on these data annual average pan evaporation is estimated to be around 750 mm, with daily evaporation ranging from less than 0.5 mm in June/July to 3.5 mm in January/February. Evaporation may exceed precipitation for only one or two months in the year. Annual potential evaporation of the region is considerably less than the annual rainfall with excess water being lost to groundwater or surface water discharging via the surface drainage network to Macquarie Harbour.

Although rainfall is the principal means of precipitation, snow and hail frequently occur above the 600 m level. Snow mainly falls in winter but may occur in any month at altitude. At lower elevations snow rarely persists, and there is no permanent snowline.

2.4 Geology

The host rocks of the Mount Lyell ore field lie towards the southern end of a 10–15 km wide belt of volcanic rocks which extends in a north-south direction from Hellyer in the north to South Darwin Peak about 25 km south of Queenstown (figure 2.6). This belt, known as the Mount Read Volcanics, is altered, folded and cleaved to varying degrees and comprises predominantly rhyolites, dacites and andesites, with basalts being relatively rare. The volcanic belt hosts not only the disseminated to massive copper rich ore bodies at Mount Lyell but also the massive polymetallic sulphide ore bodies at Hellyer, Que River, Rosebery and Hercules. Although relatively small in area, the high grade ores of the major deposits in the Mount Read volcanic belt make this belt one of the richest provinces of its type in the world.

The geology of the Queenstown area is dominated by feldspar–phyric lavas, and intrusive rhyolite and dacite of the Mount Read Volcanics. Several lenses of shale, sandstone and tuff are present, the largest being about 80 m thick (Corbett 1981). Overlying the groups of the Mount Read Volcanics are the siliciclastics of the Owen Conglomerate and the Gordon Limestone, periodically outcropping in the vicinity of Mount Lyell and Mount Owen.

The Mount Lyell ore field lies north-east of Queenstown in a complex sequence of felsic lava, breccias and tuff which are strongly altered and cleaved. The ore field is defined by a zone of sericitic and chloritic alteration and is up to 800 m thick (Soloman and Carswell 1989). There are several main ore types in the Mount Lyell ore field, including:

- disseminated pyrite and chalcopyrite in a silicate assemblage of mainly quartz, sericite, and chlorite;
- massive pyrite and chalcopyrite;
- lenses of pyrite, sphalerite, galena and chalcopyrite;
- bornite, chalcopyrite, chalcocite and phyllosilicate replacement; and
- native copper in goethite and clays.

The minerals in the ore field are believed to represent two main periods of mineralisation, Cambrian and post-Cambrian. Cambrian mineralisation probably resulted from fluids circulating at the junction of two major fault systems (Great Lyell Fault and Linda Fault Zone). Post-Cambrian mineralisation is believed to have been derived from solutions more

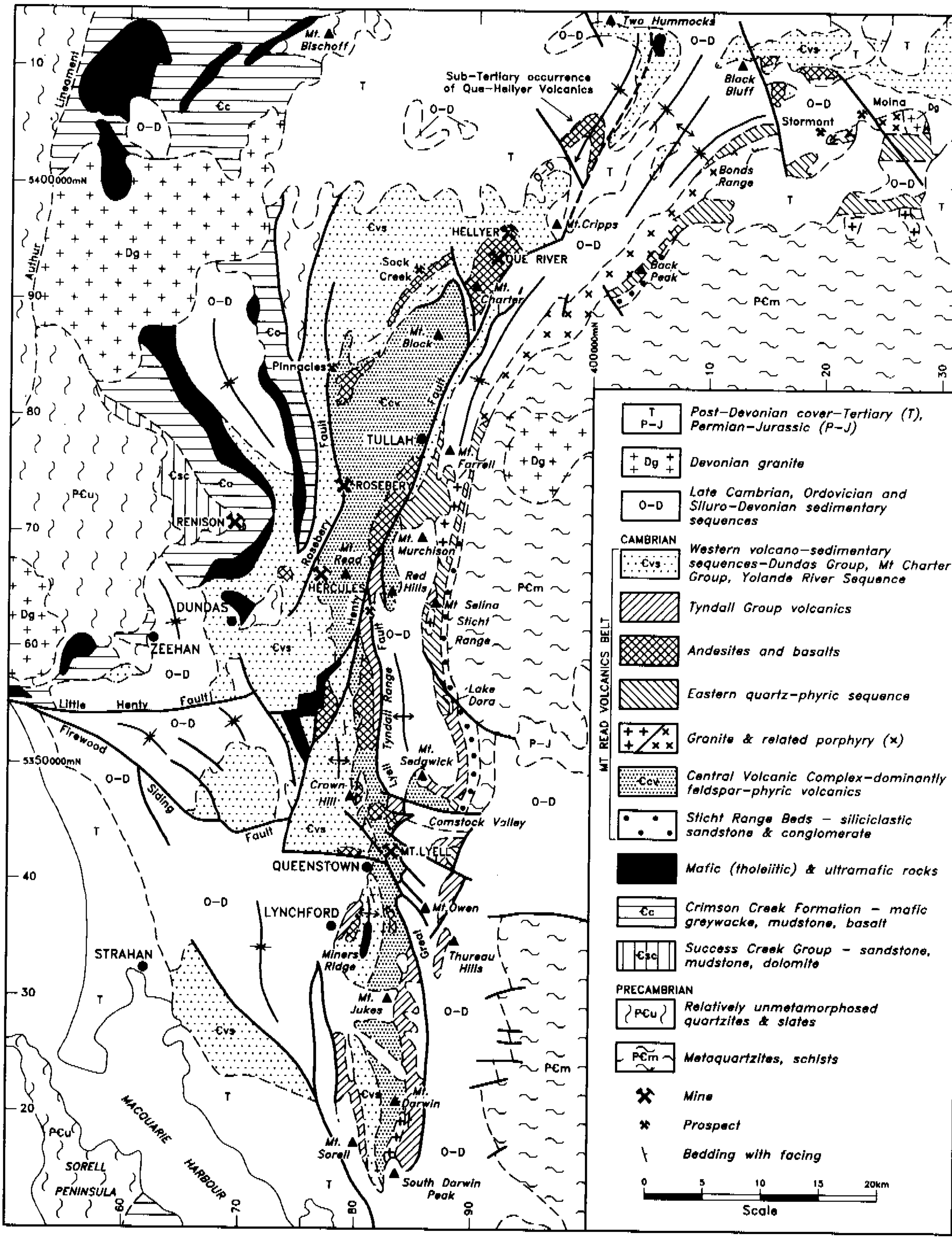

Figure 2.6 Geological setting of the Mount Lyell mining region (after Corbett and Soloman 1989) (reproduced with permission of the Geological Society of Australia Inc)

acidic and oxidised than those forming the Cambrian ores. The acid oxidising fluids are thought to be Devonian in age and are believed to have selectively dissolved copper from the Cambrian sulphide assemblages of the Mount Read Volcanics.

Some of the mineralised zones at Mount Lyell contain up to 49% pyrite. The high sulphidic nature of the mineralised assemblages represents a source of short and long-term environmental impact as a consequence of oxidation and acidic leaching.