4.0 Environmental impacts

A century of mining development caused substantial disturbances within the Mount Lyell lease site and surrounding areas, downstream riverine systems and Macquarie Harbour. In the initial years, impacts to the environment resulted from mine access, harvesting timber for fuel, mine support and housing, dramatically increased incidence of bushfires, smelter gasses and the discharge of process waste into the Queen and King Rivers system. When operations closed in 1994 an estimated 100 million tonnes of tailings and smelter slag had been discharged into the Queen River with impacts downstream to Macquarie Harbour. Pyritic smelting resulted in an estimated annual discharge of around 200 000 tonnes of sulphur dioxide into the atmosphere. Acidic rainfall, which had a devastating effect on surrounding vegetation, was the direct result of high rainfall of the region, the position of the smelters at the bottom of a steep sided valley, and frequent temperature inversions within the valley. This section summarises the regional and site impacts of the mining operation.

4.1 Land and vegetation disturbance

The lease site contains large open-cut voids, substantial quantities of overburden and unconsolidated waste rock dumps and slag from smelting (figure 3.3). Support infrastructure for mining was installed and included the towns of Linda, Gormanston, Queenstown and Crotty, with associated roads and railways linking this area to the coast and towns to the north. The Lyell highway to Hobart was completed in 1932 and the Murchison highway through to Burnie was completed in 1963. Prior to the completion of the roads the only access to this region was via the rail system from Macquarie Harbour. In 1914 Lake Margaret hydro-electric power station was built to supply the mining operations with power.

Prior to mining, the region supported temperate rainforest dominated by Myrtle (*Nothofagus cunninghammii*), with Sassafras (*Atherosperma moschatum*), Leatherwood (*Eucryphia lucida*) and Celery Top Pine (*Phyllocladus aspleniifolius*) being of secondary importance. At higher altitudes, King Billy Pine (*Athrotaxis selaginoides*) may become a co-dominant species with Huon Pine (*Lagarostrobus franklinii*) dominant in the riverine areas (Kirkpatrick 1977). Temperate rainforest is characterised by a relatively low species diversity and limited understorey, comprising Laurel (*Anopterus glandulosus*), Musk (*Olearia argophylla*), Native Pepper (*Drimys lanceolata*), Waratah (*Telopea truncata*) and Horizontal (*Andopetalum biglandulosum*). Groundcover is typically moss and ferns of which the dominant species is *Dicksonia antarctica*.

Blackwood (*Acacia melanoxylon*) and Eucalyptus species (principally *Eucalyptus obliqua* and *Eucalyptus nitida*) tend to dominate in more frequently disturbed areas, particularly drier ridges subject to fire. Temperate rainforest has not developed the recovery and reproductive features of fire tolerant species and is consequently susceptible to the effects of fire and unable to easily re-establish. A particularly hot burn may destroy the rainforest, particularly at higher altitudes where more fire resistant sclerophyllous and acacia species dominate after burning.

Vegetation coverage has been dramatically altered over large areas in the Queenstown region due to the combined effects of logging, wild fires and sulphur dioxide emissions. Once the vegetation was cleared, the high rainfall and steep topography resulted in the erosion of soil and sub soil horizons. An estimated 10 million tonnes of topsoil has washed from the mine site into the Queen and King Rivers (MLMRCL 1990). The acidic mist formed from sulphur dioxide and the light rains of the region, combined with regular fires and a lack of soil, suppressed regeneration of vegetative cover. Immediately around Mount Lyell, both tree and understorey vegetation was removed, producing a 'lunar landscape' of bare hills displaying the colours of the primary rock and weathered soils. Wood (1991) estimated from aerial photographs that around 15 km^2 were completely devoid of vegetation in the early 1950s with a further 25 km^2 substantially denuded (figure 4.1). The bare hills were vulnerable to erosion and little top soil remains outside valleys today.

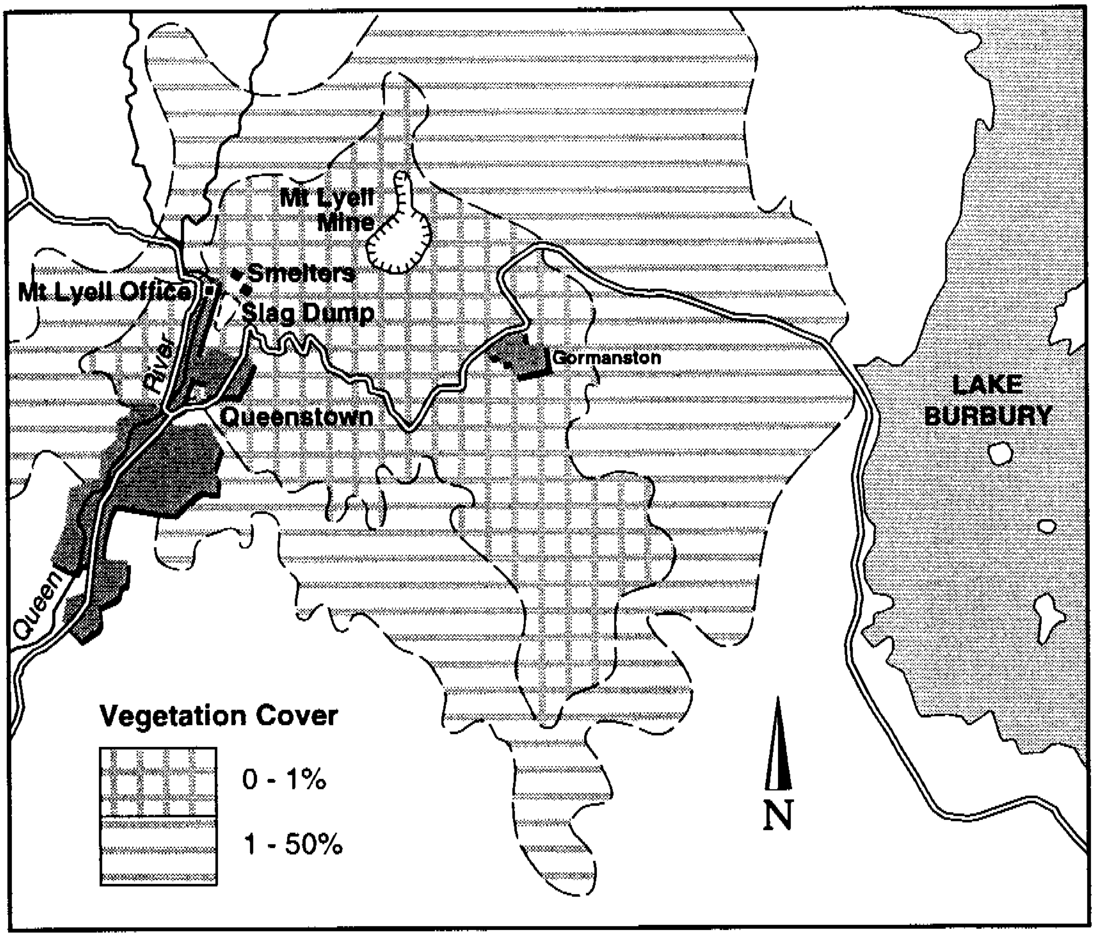

Figure 4.1 The extent of vegetation impact in 1953 (after Wood 1991)

The local community has lived with this environment for many years, in some cases third generations, and feel that the environment has unique aesthetic qualities worthy of preservation. This is reflected in the nominating of the landscape on the interim register of the National Estate as the 'Queenstown Hills Cultural Landscape'. The feeling is so strong that on 14 October 1993, through direct lobbying by the community, the Premier of Tasmania instructed MLMRCL to cease its revegetation program (Hay 1994). MLMRCL Annual Site Plan 1994/95 states that the re-implementation of a revegetation program is imperative to:

- enhance the aesthetics of the lease site environment;
- establish a stable vegetative cover to reduce the potential for pest plant invasion;
- reduce the erosion potential thereby improving the stability of the landscape;
- reduce the long-term sediment loads to the rivers;
- decrease the acid generating potential for diffuse (pyritic outcrop) sources.

Revegetation trials were conducted on the Mount Lyell lease site by MLMRCL together with an assessment of soil condition on the site and its relationship to revegetation. Prescriptions for establishing native species on the site were determined through these trials (MLMRCL

1991), although this is poorly documented. A PhD study assessing soil contamination and researching potential revegetation methods for the lease site is currently being finalised (Dawson submitted) and will provide more scientifically-based prescriptions for revegetation on the lease site.

Over a century of mining, approximately 37 million cubic metres of tailings and slag were discharged into the Queen River. Due to its relatively steep grade of 0.011 the Queen River is essentially a conduit for the transport of tailings to the King River with little or no long-term storage of tailings. This material in-filled the valleys of the King River, to a depth of four metres at Teepookana and nine metres at a location half way between Teepookana and the river mouth giving a total estimated storage of 7–10 million tonnes of mine waste (Locher 1995), and produced a delta-like formation at its mouth. When tailings discharge stopped in 1994, the delta had a surface area of 250 ha above mean sea level in the Harbour (its development is shown in figure 4.2) and is estimated to contain 100 million tonnes of material comprising erosion products and 85% of all mine wastes discharged over its century of operation. The deposited tailings have also reduced the navigability of the King River at its mouth, allowing access only to shallow drafted small boats. This is a significant change from the days when all equipment for the Mount Lyell mining operation was transported by sea going vessels six kilometres up the King River to the port of Teepookana. During the first six months after tailings discharge ceased, most of the tailings in the Queen River were washed into the King River.

The discharge of tailings material also produced point bars and sediment banks along the lower reaches of the King River. Locher (1995) estimated that sediment banks contained 3.5 million tonnes of material in 1993. A large portion of the vegetation of these areas is now dead, as a result of the deposition of sediment. The tailings material also represents a considerable source of leachable copper, iron, aluminium, manganese and zinc. The impact of these metals on aquatic life within the Harbour is being examined through projects 9 and 13 within the MLRRDP (Appendix A).

4.2 Aquatic ecosystem

The undisturbed portions of the Queen and King River catchments support a diversity of organisms including drifting invertebrates. Lake et al (1977), Swain et al (1981) and Fulton (1989) recorded Nematoda, Arachnida, Crustacea and Insecta, 59 taxa of benthic invertebrates, fish and platypus in the King River, upstream of the confluence with the Queen River. All these studies concluded that macro invertebrate fauna were reduced in both diversity and abundance below pollution inputs of Comstock Creek and Linda Creek.

Project 7 (Appendix A) of the MLRRDP program was designed to assess the status of the aquatic ecosystem of the Queen and King Rivers downstream of mining operations. Preliminary surveys have identified extremely limited populations of aquatic invertebrates within areas disturbed by tailings disposal and acid drainage, with only three taxa being identified.

4.3 Water quality

4.3.1 Introduction

This section summarises in tabular form the flow and water quality data available from the mine site, the Queen and King Rivers, and Macquarie Harbour. The data available for each station are listed in Appendix B.

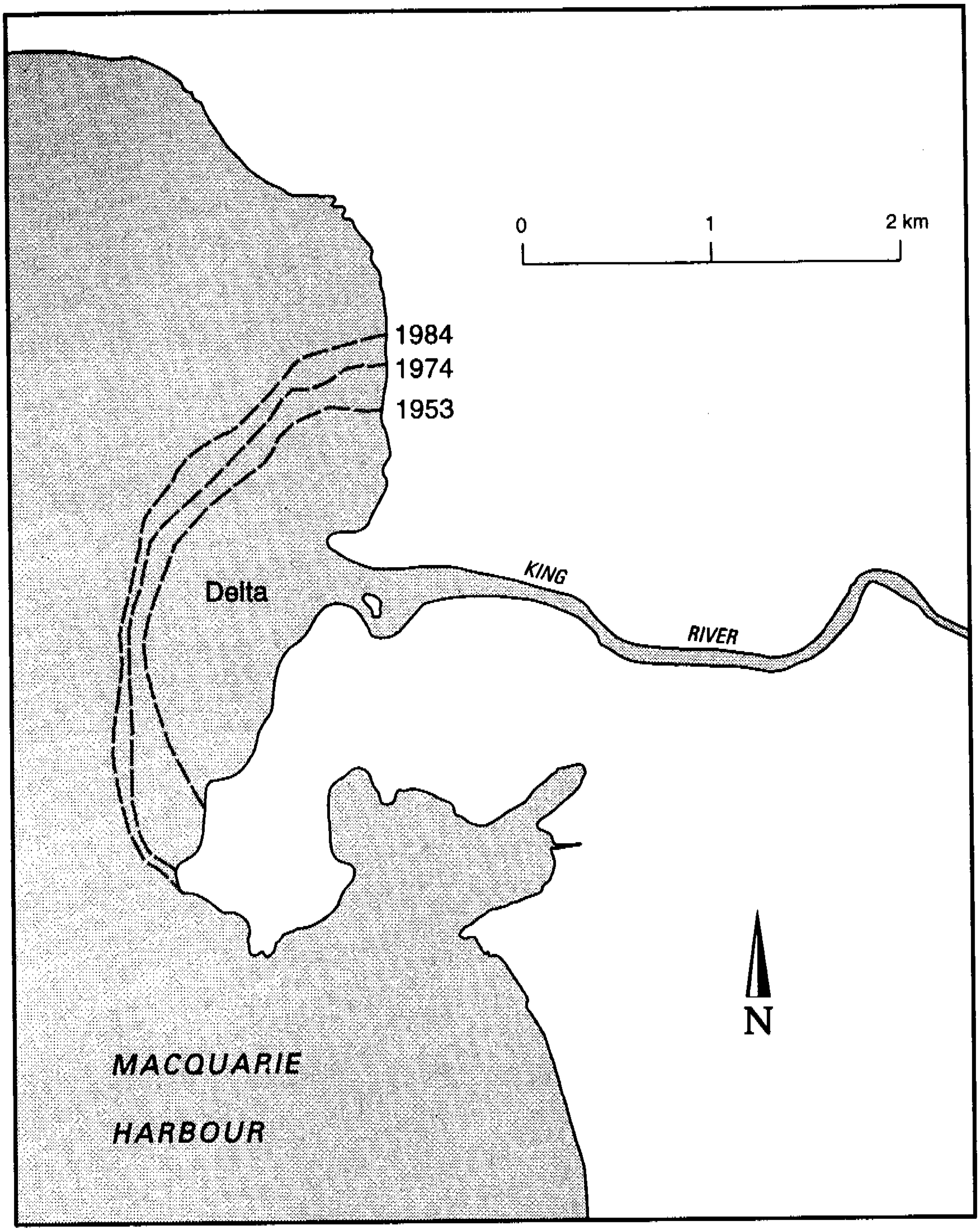

Figure 4.2 Delta development over a thirty year period (after EGI 1993)

The water quality in streams draining undisturbed catchments of the region is slightly acidic within the range pH 4.5–5.5, with a low alkalinity, very low soluble salts, low metals, suspended solids and sulphate, and a high organic content that gives the water a brown coloration, like tea. Water quality data for the King River above Comstock Creek prior to any contamination from mining activity, and the Upper Southwell River to the north, are representative of catchments free of mining activities and are presented in table 4.1. Only analysis for total metal concentrations are available for the King River above Comstock, however, in these undisturbed catchments it is likely that total and dissolved metal concentrations are generally similar. Comparisons by the HEC indicate 90% of the total metal is in the dissolved state (Mounter 1993).

Table 4.1 Typical water quality for streams draining undisturbed catchments (derived from HEC and DELM data)

Parameter	King above Comstock (total metal–mg/L)			Upper Southwell River (dissolved metal–mg/L)		
	Mean	Max	Min	Mean	Max	Min
Copper	0.002	0.005	<0.001	<0.0005	0.0006	<0.0005
Iron	0.2	0.35	0.07	0.16	0.25	0.06
Sulphate	<1	2	<1	<2	5	<2
Zinc	0.002	0.003	0.001	<0.02	0.09	<0.02
Manganese	0.015	0.018	0.003	<0.03	0.08	<0.03
Lead		0.005	<0.001	0.003	0.01	0.001
Suspended solids	2	5	1	4	7	2.5
pH	6.4	7.3	5.9	6.9	7.9	6.1
Conductivity (µS/cm)	39	64	29	45	56	28

The Mount Lyell mining operation has had a dramatic impact on the water quality of both the mine area and catchments downstream of the mine. Effluent that discharges from the mine site consist of discrete point sources and diffuse surface contributions to runoff and can be generally grouped into the following categories:

- abandoned underground and surface mine workings;
- drainage from waste rock dumps;
- mine dewatering from the active Prince Lyell Mine;
- tailings discharge; and
- miscellaneous point sources such as sewage, and waste disposal sites.

Apart from tailings and the few miscellaneous sources, most of the effluent sources have a pH ranging between 2.5 and 3.5 with elevated concentrations of toxic heavy metals, particularly aluminium and copper. If concentrations of metals are not reduced, they will continue to impede the establishment of aquatic ecosystems in the downstream river system.

Of interest in determining the potential for recovery of the affected catchments is the maximum concentrations of toxicants and the period that concentrations of contaminants exceed toxic threshold limits for aquatic organisms. Total loads of contaminants to the river–harbour system are also an indicator of the potential continuing threat to this system and is discussed in section 4.3.4.

4.3.2 Flow data

Both the local and regional hydrology have been altered by mining within the Queenstown area, in particular, land clearance which created the greatest impact on the local hydrography. Less water is retained in the catchment to infiltrate into the soils. The increased runoff has greater erosive energy and is able to carry greater suspended loads than storm runoff events prior to land clearance and mining.

On a regional scale the environmental impacts of the increased water runoff are expected to be small. The disturbed area of around 50 km^2 represents approximately 40% of the Queen River catchment and less than five percent of the King River catchment (area above confluence with Sailor Jack Creek).

Two hydro-electric power schemes have been constructed in the area which also influence regional hydrology. Lake Margaret was constructed on the Yolande River in 1914 to power mining and processing operations at Mount Lyell. Water is periodically directed to the West Queen mill supply dams from Lake Margaret in times of drought.

Modifications to the flows in the King River have occurred through by construction of the Crotty Dam to create Lake Burbury in 1991. The King River power scheme provides power to the Tasmanian grid which is generated at John Butters Power Station. The Power Station generally releases water during daylight hours at an optimum rate of between 70 and 80 m^3/s.

The total annual discharge for the King River has remained about the same (56 m^3/s), however, controlled discharges from Lake Burbury have modified the flow duration characteristics of the King River downstream of Crotty Dam. Flow duration information calculated at the Sailor Jack Creek monitoring station on the King River is presented in figure 4.3. The data comprise of four years prior to construction of Crotty Dam and six years post construction. Although the period of record is short and therefore unlikely to demonstrate the true magnitude of the change, the data show that the minimum flow rate increased (from around 1 m^3/s to 3 m^3/s) and the period of high flows decreased (flows greater than 1000 m^3/s have reduced from 0.3% to 0.1% of the period of record). Flood frequency data for Crotty prior to the dam construction are provided in figure 4.4.

The Queen River is the largest sub-catchment of the King River with a mean annual discharge of 5.2 m^3/s. Based on six years of data from the Queen River, five kilometres south of Queenstown, the 1:5 year flood is around 100 m^3/s and the 1:100 year flood is between 100 and 300 m^3/s (confidence intervals for the relationship are wide due to the limited data).

Until 1993, there was no continuous measurement of the flow rate within the Queen River catchment on the mine lease site. Previously, MLMRCL obtained visual estimates for flow on a monthly basis for a number of sites (see figures 4.5 and 4.6), although the accuracy of this method is limited. In 1993, the HEC (on behalf of MLMRCL) installed flow monitors at four sites comprising Haulage Creek, above the West Lyell Tunnel (station 5); East Queen River, above West Queen River (station 11); Haulage Creek, below Magazine Creek and prior to tailing discharge (station 9a); and West Lyell Tunnel (station 7). Flow monitoring was undertaken at these sites by MLMRCL until mine closure in December 1994 and subsequently continued by DELM and CMT.

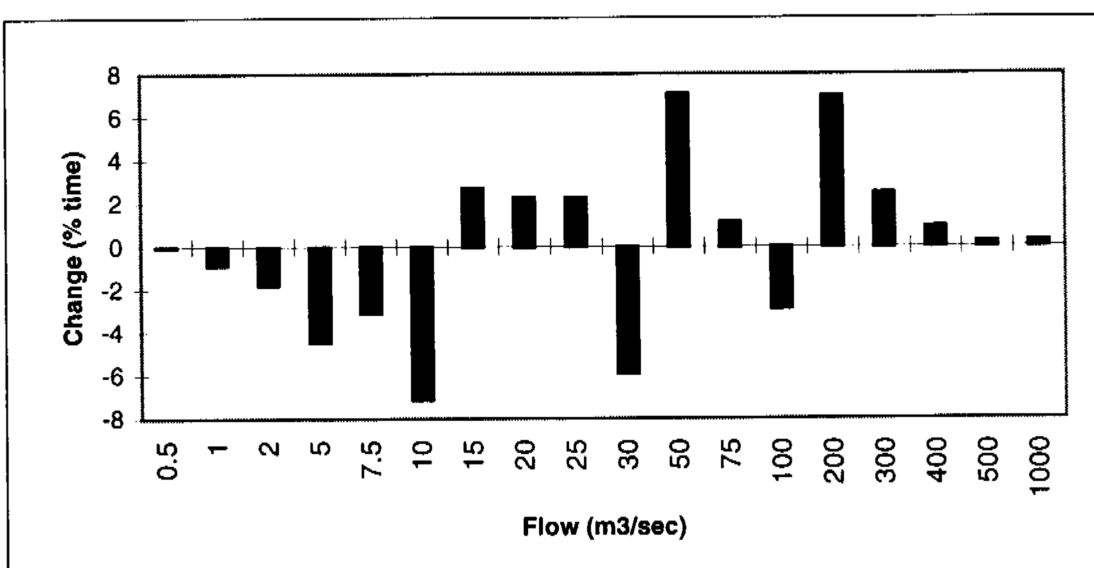

Figure 4.3 Difference in percentage of time that flow was within a given range (pre-construction minus post-construction data) at Sailor Jack Creek (HEC supplied data)

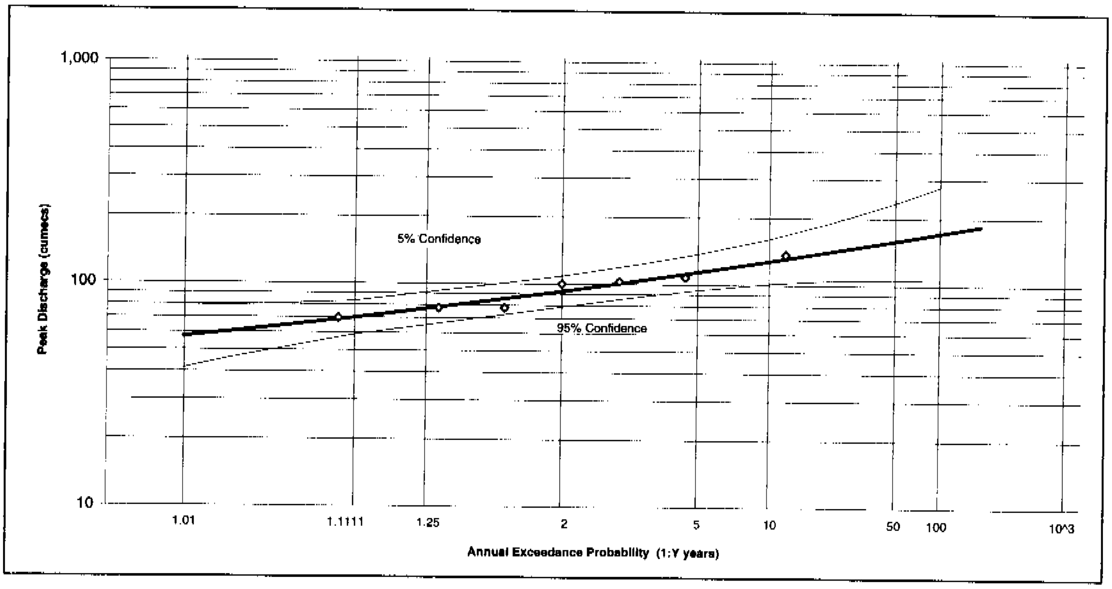

Figure 4.4 Flood frequency curve for the King River at Crotty, prior to dam construction (HEC supplied data)

Of these continuously monitored stations, a generally reliable dataset has been established with the exception of station 9a, one of the most important stations in respect to determining mass load contributions to the Queen River. The HEC recorded median flow for station 9a is 397 L/s (8/93–8/95), but this figure may be an over-estimate, as the actual flow derived from totalling respective inputs into Haulage Creek at this site gives a median value of 225 L/s (table 4.2).

Table 4.2 Water balance for Haulage Creek

Monitoring station	Median Flow (L/s)
Haulage Creek above tunnels (st 5)	54[1]
West Lyell Tunnel (st 6)	4[2]
North Lyell Tunnel (st 7)	56[3]
Conveyor Tunnel (st 8a)	92[4]
Magazine Creek	19[5]
Haulage Creek below Tunnels (st 9a)	225[6]

1 median flow from continuous record (5/93–10/94)
2 median of visually estimated MLMRCL flow data; flow is consistently low with little variation
3 median flow from continuous record (5/93–10/94)
4 continuous record (4/95–10/95)
5 EGI flow determined from catchment area
6 derived from sum of all median flow inputs listed above

GH&D (1994) estimated the median flow for Haulage Creek at station 9a to be 227 L/s, which is calculated by subtracting the contribution of tailings discharge (177 L/s) from the recorded median flow between May 1993 and October 1993 (404 L/s). However, this figure is in fact under-estimated because tailings were actually discharged into Haulage Creek below station 9a and thus the tailings discharge value should not have been subtracted from the recorded value. Coincidentally, the altered median flow of 227 L/s approximates to the flow estimated from totalling respective inputs into Haulage Creek.

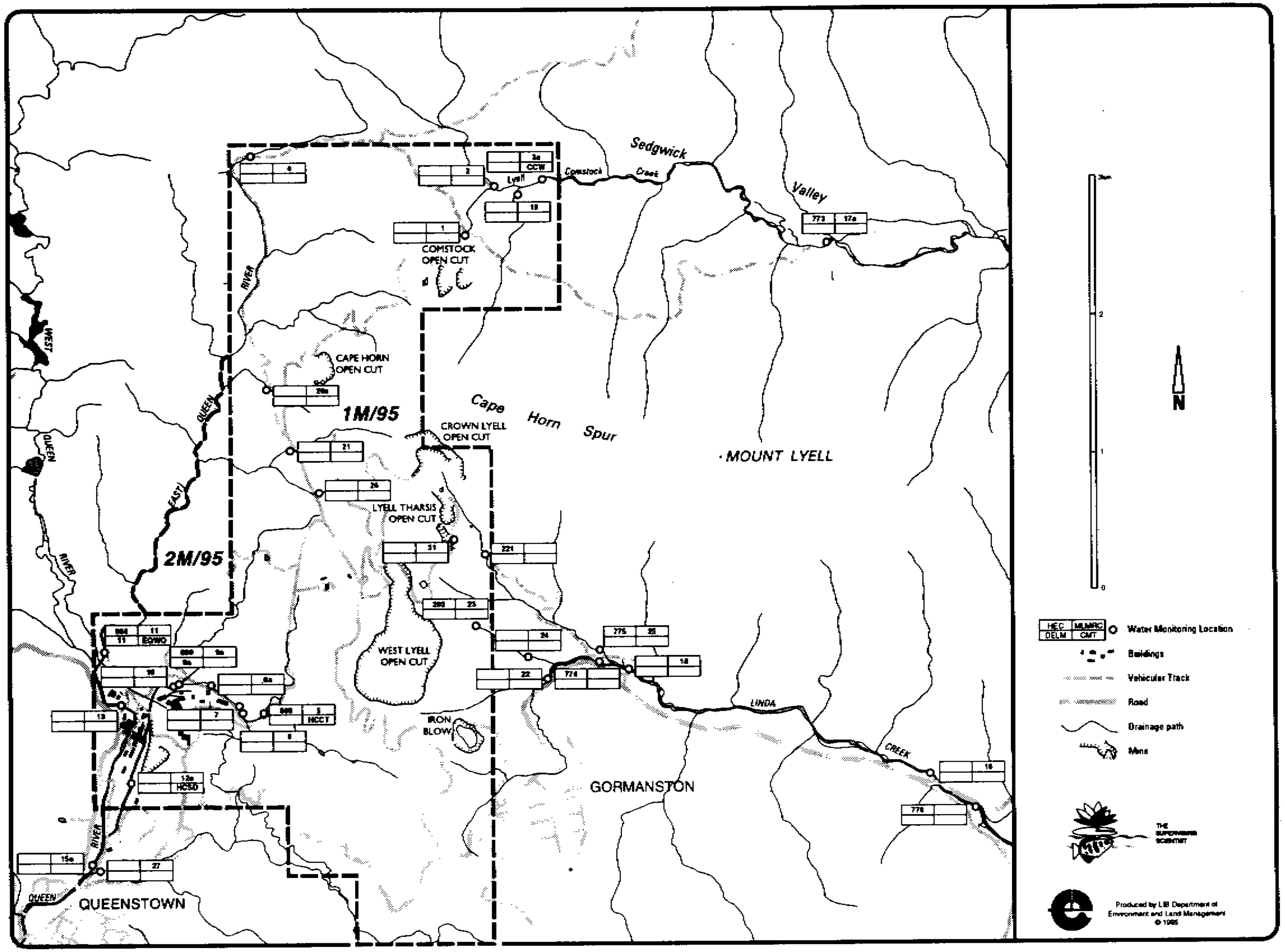

Figure 4.5 Monitoring stations in the Queenstown area

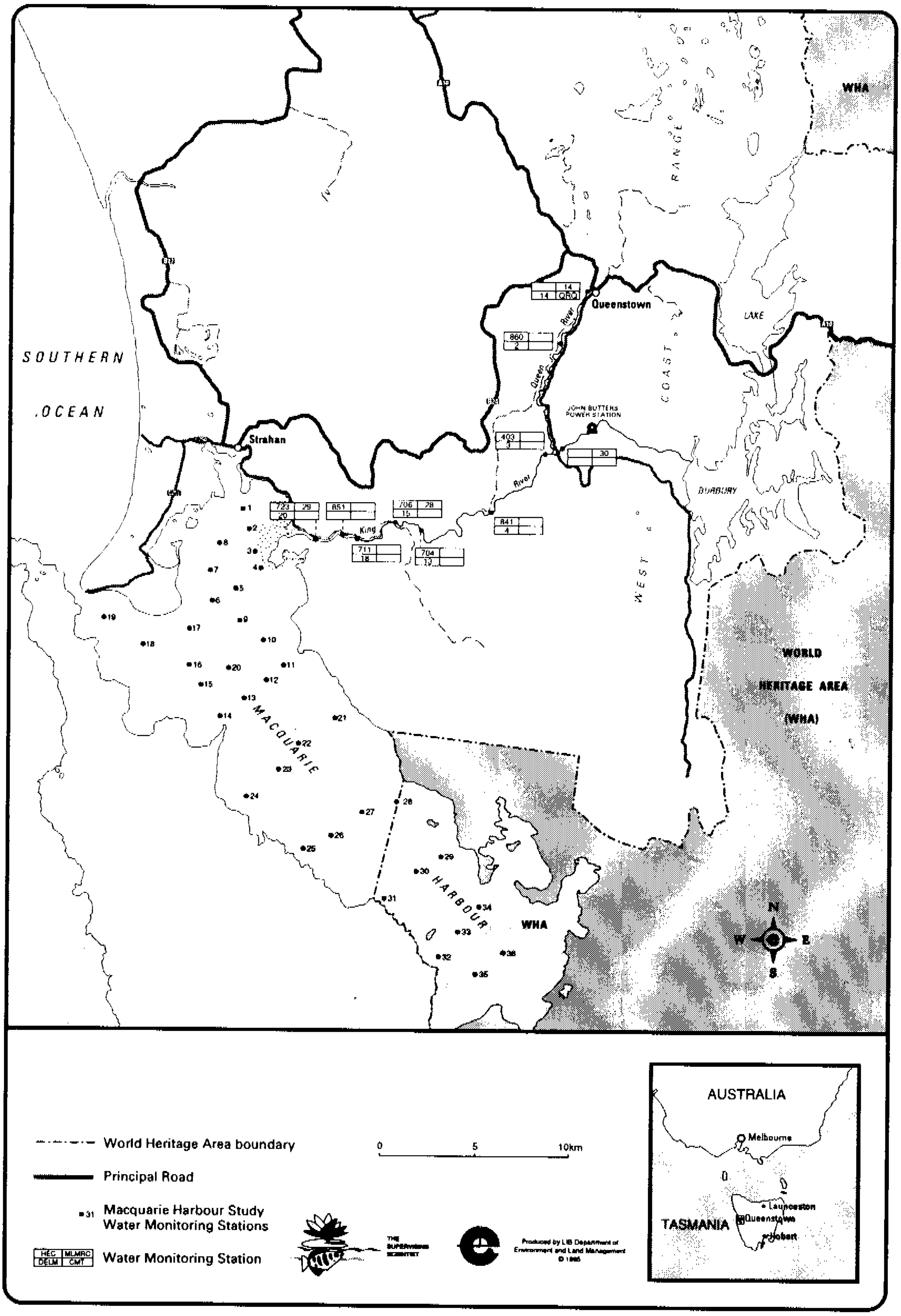

Figure 4.6 Regional water monitoring stations

Given the discrepancy in the flow rates for station 9a, the HEC Water Resources Department conducted a water balance on Haulage Creek in order to recalibrate the flow monitoring stations. This balance is reproduced in table 4.3. The recordings verify that the record at station 9a is reading approximately half the existing rating. It has been suggested that flow readings at station 9a have been consistently difficult to quantify due to the high velocities in the discharge pipe and the possible diversion of drains in the catchment.

Table 4.3 HEC water balance for Haulage Creek (October 1995)

Monitoring station	HEC station number	Flow (L/s)	Flow (%)
Haulage Creek above tunnels (st 5)	669	29	12
West Lyell Tunnel (st 6)	10670	5	2.1
North Lyell Tunnel (st 7)	670	63	26.1
Conveyor Tunnel	11670	99	41.1
Magazine Creek		14	5.8
Leakage and Pickup (estimated)		20	8.3
Unaccounted		11	4.4
Haulage Creek below tunnels (st 9a)	680	241	100

A continuous flow record was established at the Conveyor Tunnel (station 8a) by the HEC on behalf of CMT in April 1995. This has provided the most accurate quantification of underground mine water discharges to date. The median and mean flows have been calculated at 92 L/s (4/95–10/95) and 81 L/s (4/95–6/95) (CMT 1995). Although the period of record is short, these figures provide the most accurate representation of the actual flow from the Conveyor Tunnel. The fluctuating flow is buffered by a 4 ML storage tank on mining level 18. The storage tank is serviced by three pumps, usually only two of which are operational.

Previously, MLMRCL flow values from the Conveyor Tunnel were estimated from limited pump operational times and the likely pump rates. The latter could vary between 120 L/s and 70 L/s depending on the period since the pumps were last overhauled. MLMRCL records since 1990 suggest an average pump rate of 40 L/s. EGI (1993) and GH&D (1994) both estimated 50 L/s as the median discharge from the Conveyor Tunnel while a mean discharge rate of 83 L/s has been noted by MLMRCL (1994a).

Flows from the Conveyor Tunnel are typically a function of a number of variables including:

- period since pump overhaul and pumping efficiency;
- frequency of mud displacement;
- duration of pump downtime; and
- period of single or dual pump operation.

As a result of the above variables and the short record of accurate monitoring, a typical flow for this station is difficult to quantify.

The Hydro-Electric Commission installed continuous flow recorders at key sites within the Linda, Comstock and King River catchments in 1986. These sites comprise:

- station 775, Idaho Creek above Linda Creek;
- station 773, Comstock Creek above King River;
- station 776, Linda Creek above King River; and
- station 781, King River above Comstock.

The flow data from these sites have been used to derive a median flow catchment area relationship in the Comstock and Linda sub-catchments (equation 1 and figure 4.7).

$$\text{FLOW} = (19.3+5.4\times\log \text{AREA}) \times \text{AREA} \qquad \text{Equation 1}$$

where FLOW is in L/s and AREA in km^2

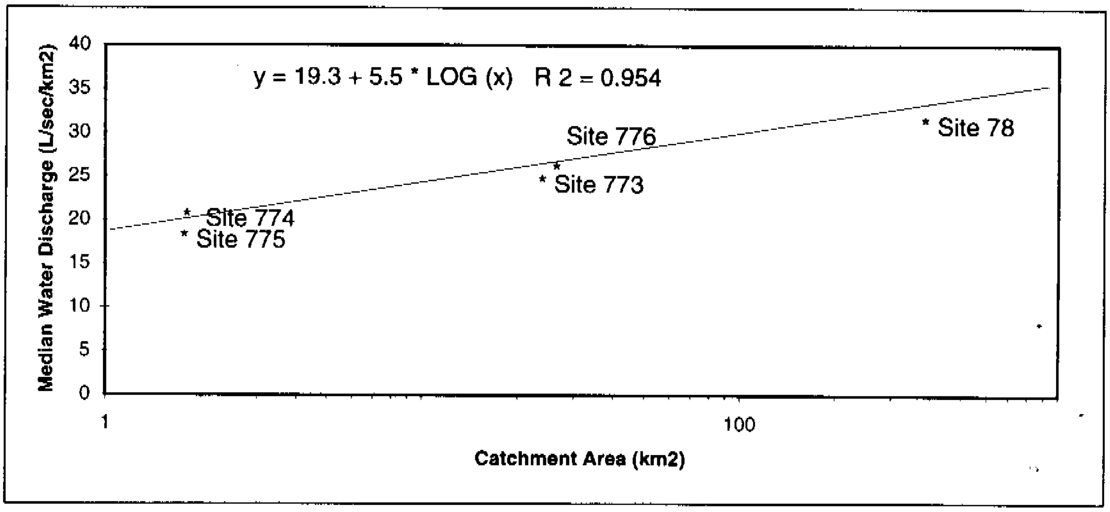

Figure 4.7 Catchment area versus median water discharge for the King River and its tributaries

The relationship indicates that as the catchment area increases the normalised median water discharge increases. In applying this relationship to catchments of the Queen River, it has been assumed that the runoff and rainfall characteristics of the King River sub-catchments are relatively consistent throughout the King River catchment. All flow data recorded by the HEC can be considered reliable and of good quality for the Comstock and Linda catchments, although the period of record is short.

The sub-catchment areas on the mine lease site were re-mapped for this study to take account of roads and drains directing water outside their topographic divides. These sub-catchments are presented in figure 4.8. The HEC flow equation mentioned above was applied to these sub-catchments and the calculated flows compared with other flow estimates (table 4.4).

Based on the size of each sub-catchment and assuming an annual rainfall of 2500 mm and 100% runoff, EGI (1993) estimated mean stream flows from each sub-catchment within the Comstock–Linda–King River system and the Haulage–Queen River system. Using a conversion factor of 0.33 (EGI 1993), the mean flows were converted to median flows. Given that discharges from adits and tunnels are not directly related to rainfall events and are more a function of groundwater inflows and pumping rates underground, EGI assumed that median flows from underground sources are the same as the mean measured flow. EGI developed this flow derivation method in response to the uncertainty associated with the existing MLMRCL data and the lack of data for some major input streams into the Haulage Creek–Queen River system

Table 4.4 shows a combination of mean and median flow values. Median flow represents the central value of a ranked flow dataset. Where the dataset has a limited number of values, the median value is not affected to the same degree as the mean value by the addition of an extremely low or high value to the dataset. However, where the dataset is non-Gaussian, the median value is not particularly useful in that it cannot be used to calculate total flow.

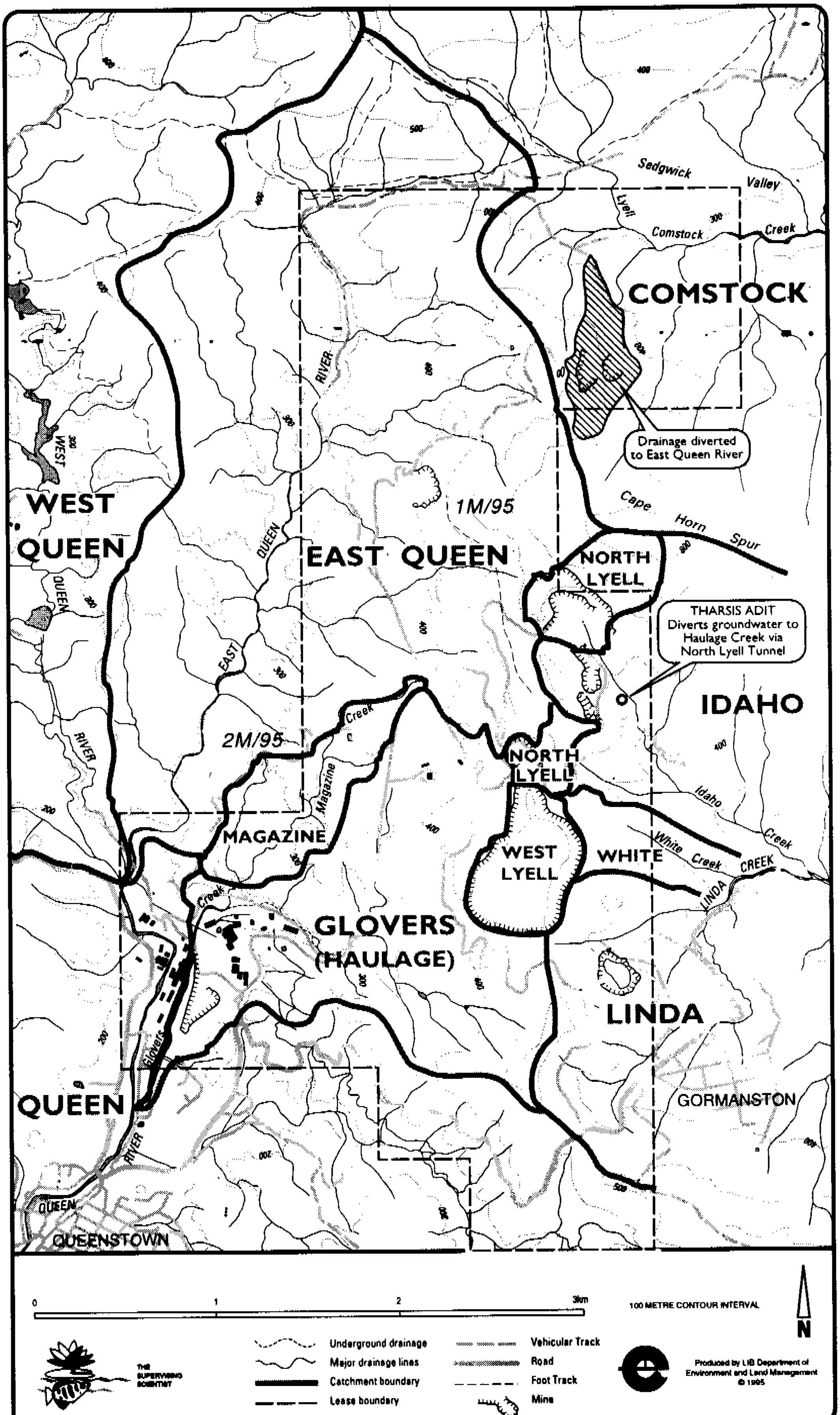

Figure 4.8 Sub-catchments of Mount Lyell

Table 4.4 Flows from sub-catchments on the Mount Lyell mining area

Sub-catchment	Area (km2)	Estimated mean flow[2] (L/s)	Estimated median flow[3] (L/s)	Estimated median flow[4] (L/s)	Measured mean flow[5] (L/s)
Linda Creek above Idaho Creek (774)	2.3	170	57	50	184
Idaho Creek above Linda Creek (st 775)	2.3	182	60	50	150
Linda Creek	14.73 14.40[6]	1165 1140	390 380	375 365	975
Lyell–Comstock Creek above King River (st 773)	13.80 13.58[6]	1095 1075	365 360	350 335	1310
Haulage Creek at Queen River	2.87	225	75	65	
East Queen River (before Comstock diversion)	8.35	660	220	200	
East Queen River (after Comstock diversion) (st 11)	8.56[6]	680	225	210	268
Haulage Creek at tailings discharge point, surface catchment (st 9a)	1.92	150	50	40	
Haulage Creek at tailings discharge point, effective catchment[1]	3.32				
Magazine Creek	0.58	58	19	10	
Haulage Creek above West Tunnel (st 5)	1.67	120	40	35	54

1 includes redirected drainage to the North and West Tunnels and Conveyor Tunnel but excludes the water sourced from the mine header tanks (30 L/s)

2 estimated flow, assuming annual rainfall of 2500 mm and 100% runoff (EGI 1993)

3 estimated mean flow divided by 3 (EGI 1993)

4 estimated from HEC FLOW equation

5 HEC installed flow monitors

6 area post Comstock diversion

EGI (1993) used median flow values on the basis that '...in terms of water quality within a river system, it is often median flow, rather than mean flow, that is more important'. It is assumed by this statement that EGI has taken the median value to represent the 'typical flow'.

Flow duration analysis data for HEC station 773 (table 4.5) was taken from Mounter (1992). These data were used to calculate median and mean flow values for the HEC stations in the Comstock valley. The following techniques were used to calculate median and mean flow values:

- median: percentage of time in each range was cumulated over the ranked ranges and the central value of the range associated with 50% of time was selected as the median value; and
- mean: the central value of the range was multiplied by the percentage of total time within the range to give a total discharge for the range. The total discharge for each range were summed and divided by 100 to give the mean.

Comparisons of median and mean flow values are found in table 4.6

The data in table 4.5 show that the flow distributions are right skewed with half of the total flow occurring in about 80% of the time. Based on these data, total flows calculated from median values would underestimate the actual total flow by up to 500%. The percentage of time in a flow range and the total flow within each range for the HEC station 775 are presented in figure 4.9.

Table 4.5 Flow duration analysis data for HEC station 773 (after Mounter 1992)

Flow range (L/s)	Flow value (L/s)	Time (%)	Cumulative time (%)	Total flow (L)	
0–30	15	2.31	2.31	35	
30–50	40	1.72	4.03	69	
50–70	60	5.22	9.25	313	
70–100	85	7.41	16.66	630	
100–150	125	10.15	26.81	1268	
150–200	175	7.72	34.53	1351	
200–300	250	10.94	45.46	2734	
300–400	350	6.88	52.34	2408	Median
400–600	500	8.45	60.80	4227	
600–800	700	5.59	66.39	3914	
800–1000	900	4.19	70.58	3774	Mean
1000–2000	1500	12.70	83.28	19053	
2000–3000	2500	6.55	89.83	16363	
3000–5000	4000	5.82	95.65	23292	
5000–7000	6000	2.20	97.85	13212	
7000–10000	8500	1.28	99.13	10880	
10000–15000	12500	0.64	99.78	8050	
15000–20000	17500	0.14	99.91	2380	
			Total	114000	

Table 4.6 Median and mean flow values for the HEC stations 773, 774 and 775

Station	Description	Catchment area (km^2)	Median flow (L/s)	Mean flow (L/s)
773	Comstock above King	14.0	350	1100
774	Linda above Idaho	2.3	50	150
775	Idaho above Linda	2.3	35	200

4.3.3 Water chemistry data

Water chemistry datasets were provided for this study by the HEC, DELM and MLMRCL. The data vary widely between datasets in terms of size, locations sampled, analytical techniques used and parameters analysed.

In its investigations for the construction of the King River Power Station, the HEC undertook detailed investigations of water quality and metal loads that would enter Lake Burbury from the Comstock and Linda Creeks. Parameters analysed by the HEC vary from station to station with generally only the major elements being analysed. There is a lack of detailed analysis of some key parameters including calcium, magnesium, sodium, potassium, aluminium and total organic carbon (TOC), all of which influence water chemistry.

The DELM data involve two discrete sets of data: one from The Macquarie Harbour–King River Study (Koenken in press) and the Mount Lyell Shutdown Intensive Monitoring Program (DELM 1995).