Aquatic Environmental Values associated with the Crest Magnesite Mining Development, North West Tasmania

Report to Pitt and Sherry, Tasmania

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Introduction

This report described an aquatic biological assessment requested for the DPEMP for the Crest magnesite mining development in north west Tasmania. This project was required to produce the following products:

- an assessment of the current, 'background' biological condition of all streams and rivers relevant to the Crest mine site development;
- a design for an ongoing monitoring program associated with Crest activities, focussing on the potential impacts of changes in chemical and physical water quality on the biological and habitat conditions in rivers downstream of the mine site.

A survey was conducted in March 1999 to assess fish and macroinvertebrate communities and environmental conditions in the Arthur, Keith Rivers and Johnnys Creek in the vicinity of the Crest lease. These data are also designed to form the basis for a pre-post analysis to monitor mining impacts in the future. Only the overall characteristics of the data are described in this report. AUSRIVAS analysis and pre- vs post-mining impact analysis will be conducted as part of future monitoring of Crest activities.

Methods

Eleven sites were identified for sampling - five in the Arthur River, four in the Keith River and two in Johnnys Creek (adjacent to the mine site). Site locations are listed in Table 1. Sites were sampled once in early March 1999 by:

- collecting quantitative and qualitative samples of macroinvertebrates at each site – 10 surber samples (500 micron mesh, pooled) and 1 standard AUSRIVAS kick - live pick sample per site;
- electrofishing for fish species in the Keith River and Johnnys Ck (low flow conditions are required for such a survey, and these conditions in the Arthur River did not occur during the survey period);
- collecting a suite of environmental descriptive data at each sampling site, as well as samples for water quality data (the latter to be analysed as part of Dr L. Koehnken's water quality survey).

Of the macroinvertebrate samples, only the surber samples were processed. Of these, three sites (one site downstream of the mine site in each stream) were identified to species level (for a total of 3 days' work). All samples were processed by calcium chloride flotation, and sub-sampling to 20% using a standard box sub-sampler (Marchant 1991), prior to manual sorting, enumeration and identification of organisms from sub-sample. The remaining samples were identified to family level. Fish surveys were conducted by a standard 2 pass operation with a back-pack electroshocker. All fish were identified, measured and released.

The following environmental variables were measured at each study sites:

- Velocity at riffle sampling location (m/s)
- Algal Cover of riffle substrate%
- Silt Cover of riffle substrate %
- Detritus Cover of riffle substrate %
- Moss Cover of riffle substrate %
- Bedrock as proportion of substrate area for 100 m site %
- Boulder as proportion of substrate area for 100 m site %
- Cobble as proportion of substrate area for 100 m site %
- Pebble as proportion of substrate area for 100 m site %
- Gravel as proportion of substrate area for 100 m site %

- Sand as proportion of substrate area for 100 m site %
- Silt as proportion of substrate area for 100 m site %
- Aquatic vegetation. Rank – 1 = absent, 2 = sparse, 3 = moderate, 4= extensive.
- Overhanging vegetation. Rank - as for aquatic vegetation.
- Trailing vegetation. Rank - as for aquatic vegetation.
- LH Riparian vegetation. Rank - as for aquatic vegetation, left bank, facing upstream.
- RH Riparian vegetation. Rank - as for aquatic vegetation, right bank, facing upstream.
- Temperature (C)
- Conductivity (microS/cm)
- Wetted width (m)
- Bankfull channel width (m)
- Clarity. Rank- 1 = clear, 2 = low turbidity, 3 = moderate turbidity, 4= highly turbid.
- Riffle (broken water) as proportion of 100 m reach %
- Run (smooth water < 1 m deep) as proportion of 100 m reach %
- Pool (water > 1 m depth) as proportion of 100 m reach %
- Snag (woody and log debris) as proportion of 100 m reach %

Statistical analysis

Differences in abundances and number of taxa between groups of sites were evaluated by t-test (after $\log_e(x+1)$ transformation), suing SYSTAT (8.0). Differences in community composition between the Keith and Arthur rivers were assessed using the ANOSIM routine in PRIMER (Clarke and Warwick 1994), after conversion of ln(x+1) transformed data sets into Bray-Curtis similarity matrices. Taxa responsible for differences were evaluated suing the SIMPER routine in PRIMER Sample data was ordinated using the MDS routine in PRIMER, and associations examined using the UPGMA cluster technique CLUSTER in PRIMER.

Data are presented in both tabular form and graphically; the latter in the form of standard box-plots with the median and interquartile range (25 - 75 percentiles) represented by the centre line and box edges. Vertical lines (whiskers) in the box plots extend to the 'inner

fences' at 1.5 times the interquartile range and outliers are indicated as asterisks or circles.

Table 1. Location of study sites Crest aquatic biological survey.

Site	Stream	Location	Easting	Northing
ARF1	Arthur River	u/s Farquhar Rd		
ARF2	Arthur River	u/s Farquhar Rd		
ARF3	Arthur River	u/s Farquhar Rd		
ART	Arthur River	at Tiger Bend		
ARR	Arthur River	at Relapse Ck.		
ARH	Arthur River	at Hilders Br.		
KUS1	Keith River	u/s Farquhar Rd		
KUS2	Keith River	u/s Farquhar Rd		
KDS1	Keith River	d/s Farquhar Rd		
KDS2	Keith River	u/s Arthur R		
JUS	Johnnys Ck	u/s Farquhar Rd		
JDS	Johnnys Ck	u/s Arthur R		

Results and Discussion

River habitats

Details of instream habitats in the Keith River, Arthur River and Johnnys Creek are described in Tables 2 and 3. The Arthur between just upstream of Farquhars Bridge and Hilders Bridge is a substantial west coast stream, typified by well developed wet sclerophyll – rainforest riparian vegetation and cool humic water. In this reach the Arthur is a wide (25 - 50m), moderate gradient stream with an armoured cobble-pebble substrate, little sand or silt deposition within the channel and large quantities of woody debris (representing up to 30% cover within the channel). The sites sampled were predominantly run-riffle reaches, with few pools. Conductivities under low to moderate flows are

relatively high (ca 75 – 100 microS/cm), probably due to sulphate and carbonate (see Koehnken report on water quality). Algal cover in May ranged from low in the vicinity of Farquhars Bridge to high at Relapse Ck and Hilders Bridge, but moss cover was low at all sites. Overall, habitat quality was good at all sites and should support a diverse and abundant fauna.

The Keith between just upstream of Farquhars Road Bridge and the Arthur is an almost pristine west coast stream, with a well developed wet sclerophyll – rainforest riparian vegetation and cool humic water. In this reach the Keith is 8 – 15m wide, moderate gradient stream with a diverse substrate dominated by a cobble-pebble armour layer, but with bedrock outcrops and in-channel sand deposits. No silt deposits were observed. Substantial quantities of woody debris were observed - up to 25% cover within the channel. The sites sampled were predominantly run-riffle reaches, but with up to 30% of the reaches as pools. Conductivities under low to moderate flows are relatively high (ca 75 – 100 microS/cm), probably associated with carbonate (see Koehnken report on water quality). Algal cover in May was extremely low – largely due to heavy shading, and moss cover was essentially absent in riffles. Overall, habitat quality was very good at all sites and the stream should support a diverse and abundant fauna.

Johnnys Creek between just upstream of the Farquhars Road Bridge and the Arthur is an almost pristine small west coast stream, with a well developed wet sclerophyll – rainforest riparian vegetation and cool humic water. In this reach Johnnys Creek has a 3-5 m wide channel, a low to moderate gradient, and a diverse substrate dominated by a gravel-cobble armour layer, but with substantial in-channel sand deposits. No silt deposits were observed. Substantial quantities of woody debris were observed - up to 25% cover within the channel. The sites sampled were predominantly riffle-pool sequences. Conductivities under low to moderate flows are relatively high (ca 75 – 100 microS/cm). At the upstream site (JUS), algal and moss cover in May was very low, but ranged up to 15% at the downstream site (JDS). Overall, habitat quality was good at both sites and the stream should support a diverse and abundant fauna.

Macroinvertebrate fauna

Details of the macroinvertebrate fauna of the Keith River, Arthur River and Johnnys Creek are described in Tables 4 and 5.

The fauna of the Keith River was dominated by leptophlebiid mayflies (mainly of the genus *Nousia*), elmid beetle larvae and adults, baetid mayflies and scirtid beetle larvae. The fauna of the Arthur River was dominated by baetid mayflies, elmid and scirtid beetle larvae. The two downstream sites (ARR and ARH) also had very high densities of simuliid (blackfly) larvae. The fauna of Johnnys Creek was also dominated by leptophlebiid mayflies and elmid beetles with high abundances of amphipods, and at the downstream site of oligochaetes (worms) and midges of the sub-family chironominae.

Inspection of the species composition of the macroinvertebrate fauna (Table 6) revealed a generally diverse fauna at all sites, with *Nousia* sp (Leptophlebiidae), *Genus 2* (Baetidae) and *Taschorema* sp. and *Ethochorema* sp. (Hydrobiosidae), a prominent feature of the fauna.

River:	Arthur R.						Keith R.		
Site:	u/s Farquars 1	u/s Farquars 2	u/s Farquars 3	At Tiger Bend	at Relapse Ck.	At Hilders Br.	u/s Farquars 1	u/s Farquars 2	Mid Site
Date:	03-Mar-99	03-Mar-99	03-Mar-99	03-Mar-99	03-Mar-99	03-Mar-99	02-Mar-99	02-Mar-99	03-Mar-99
Code:	ARF1	ARF2	ARF3	ART	ARR	ARH	KRUS1	KRUS2	KRDS1
Velocity (m/s)	1.25	1	0.6	1	1.7	1.25	1.25	1	0.8
Algal Cover %	20	10	5	5	15	40	3	3	0
Silt Cover %	0	0	0	0	0	0	0	0	0
Detritus Cover %	0	0	0	0	0	0	0	0	0
Moss Cover%	0	0	0	0	2	0	0	0	0
Bedrock %	0	0	0	0	0	0	10	0	10
Boulder %	5	0	0	10	5	15	20	20	5
Cobble %	30	30	25	60	55	40	20	35	35
Pebble %	40	30	40	20	20	20	20	15	20
Gravel %	20	30	30	10	15	15	20	20	20
Sand %	5	10	5	0	5	10	10	10	10
Silt %	0	0	0	0	0	0	0	0	0
Aquatic veg	1	1	1	1	1	1	1	1	1
Overhanging veg	2	2	2	2	2	2	2	3	3
Trailing veg	2	2	2	2	2	2	2	2	2
LH Rip veg	4	4	4	4	4	4	4	4	4
RH Rip veg	4	4	4	4	4	4	4	4	4
Temp (C)	17	17.1	17.1	17.1	16.6	18.7	15.3	15.3	16.8
Conductivity (microS/cm)	73.1	73.1	73	73.2	70.8	74.7	74.5	74.4	80.5
Wetted width (m)	25	24	25	28	50	35	7	6	12
Bankfull width (m)	30	29	26	33	50	40	12	8	12.5
Clarity (Rank)	1	1	1	1	1	1	1	1	4
Riffle %	0	2	0	30	50	40	40	35	10
Run %	100	98	100	55	50	60	30	50	80
Pool %	0	0	0	15	0	0	30	15	10
Snag %	20	25	10	30	2	10	0	10	25

Table 2. Environmental characteristics of each study site in the Arthur and Keith Rivers. See Methods for description of variables.

River:	Johnnys Ck	
Site:	u/s Farquars	d/s site
Date:	01-Mar-95	03-Mar-95
Code:	JUS	JDS
Velocity (m/s)	0.7	0.5
Algal Cover %	2	15
Silt Cover %	0	0
Detritus Cover %	0	0
Moss Cover%	0	10
Bedrock %	0	10
Boulder %	0	5
Cobble %	20	40
Pebble %	20	30
Gravel %	40	10
Sand %	20	5
Silt %	0	0
Aquatic veg	1	1
Overhanging veg	3	4
Trailing veg	3	3
LH Rip veg	4	4
RH Rip veg	4	4
Temp (C)	14.3	13.6
Conductivity (microS/cm)	78.8	81.4
Wetted width (m)	1	1.5
Bankfull width (m)	5	3
Clarity (Rank)	1	1
Riffle %	70	100
Run %	0	0
Pool %	30	0
Snag %	10	10

Table 3. Environmental characteristics of each study site in Johnnys Creek. See Methods for description of variables.

		River:	Arthur R.					
		Site:	u/s Farquars 1	u/s Farquars 2	u/s Farquars 3	At Tiger Bend	At Relapse Ck.	At Hilders Br.
		Date:	03-Mar-99	03-Mar-99	03-Mar-99	03-Mar-99	03-Mar-99	03-Mar-99
		Code:	ARF1	ARF2	ARF3	ART	ARR	ARH
Class	Order	Family						
Platyhelminthes	Turbellaria						1	2
Nematoda				1			2	
	Gastropoda	Hydrobiidae						
	Oligochaeta		4	1	6	11	2	19
Arachnida	Hydracarina		2		3	3	1	
Crustacea	Amphipoda	Paramelitidae						
		Eusiridae						1
Insecta	Plecoptera	Eusthenidae	1			2	4	1
		Austroperlidae						
		Gripopterygidae		2		2	9	
		Notonemouridae			3			
	Ephemeroptera	Leptophlebiidae	7	1	12	5	14	26
		Baetidae	72	37	54	11	56	38
	Odonata	Aeshnidae						
Diptera	Chironomidae	Chironominae	2	3	162	10		9
		Orthocladiinae	4	9	6	8	20	4
		Podonominae	1					
		Tanypodinae						
		Aphroteniinae						1
		Simuliidae	8	5	1	6	278	216
		Tipulidae	1	2	2			1
		Athericidae						
		Blephariceridae					2	
		Ceratopogonidae			2			
		Empididae			1	1		
		Unid. pupae	1	1	3	3	3	
	Trichoptera	Calocidae/Helicpphidae		1		1	14	2
		Conoesucidae	3	4		4	7	
		Ecnomidae	1		14	1	1	
		Glossomatidae						
		Helicopsychidae			1			
		Hydrobiosidae	2		5	3	8	6
		Hydropsychidae	1		1		18	7
		Hydroptilidae						
		Leptoceridae		2	4	10	38	6
		Philopotamidae						1
		Philorheithridae	1	1	3		2	4
		Polycentropodidae						
		Unid. pupae		2	1		5	
	Coleoptera	Adult Elmidae	16	17	7	7	70	18
		Larvae Elmidae	115	122	42	33	42	74
		Scirtidae	44	15	62	42	79	83
		Psephenidae		1				
Nematomorpha		Gordiidae						
		Ntaxa	19	19	22	19	23	20
		Total Abundance	286	227	395	163	676	519

Table 4. Macroinvertebrate fauna (at family level) observed in surber samples at sites in the Arthur River, March 1999.

		River:		Keith R.				Johnnys Ck	
		Site:	At Hilders Br.	u/s Farquars 1	u/s Farquars 2	Mid Site	At Arthur R.	u/s Farquars	d/s site
		Date:	03-Mar-99	02-Mar-99	02-Mar-99	03-Mar-99	03-Mar-99	02-Mar-99	04-Mar-99
		Code:	ARH	KRUS1	KRUS2	KRDS1	KRDS2	JUS	JDS
Class	Order	Family							
Platyhelminthes	Turbellaria		2				1	2	
Nematoda					1				
	Gastropoda	Hydrobiidae			1				1
	Oligochaeta		19	3	15	10	14	30	53
Arachnida	Hydracarina			1	4	2	1		
Crustacea	Amphipoda	Paramelitidae			2		4	29	76
		Eusiridae	1						
Insecta	Plecoptera	Eustheniidae	1	4	9	4		12	
		Austroperlidae			2	1		12	
		Gripopterygidae		6	23	1		24	1
		Notonemouridae					1	1	
	Ephemeroptera	Leptophlebiidae	26	33	38	38	82	63	33
		Baetidae	38	24	46	62	8	1	1
	Odonata	Aeshnidae					1	1	
Diptera	Chironomidae	Chironominae	9	1	1	1		3	19
		Orthocladiinae	4	3	15	4	2	12	
		Podonominae		2	4	2	6		
		Tanypodinae							1
		Aphroteniinae	1	1					
		Simuliidae	216	3	16	4	4	5	5
		Tipulidae	1	1					
		Athericidae		1			7		
		Blephariceridae			2				1
		Ceratopogonidae							
		Empididae			1	2		1	
		Unid. pupae		2	4	2	2		4
	Trichoptera	Calocidae/Helicpphidae	2			3	4		5
		Conoesucidae		1	1				1
		Ecnomidae				1	2		
		Glossomatidae							1
		Helicopsychidae							
		Hydrobiosidae	6	6	4	4	5	9	9
		Hydropsychidae	7	2	6			3	
		Hydroptilidae							5
		Leptoceridae	6	5	9	1	20		5
		Philopotamidae	1	1					3
		Philorheithridae	4			5	2		
		Polycentropodidae						1	1
		Unid. pupae			3		1	3	1
	Coleoptera	Adult Elmidae	18	29	19	31	53	16	50
		Larvae Elmidae	74	26	49	53	42	9	28
		Scirtidae	83	31	8	36	45	6	4
		Psephenidae		2	9	1	1	1	
Nematomorpha		Gordiidae						1	
		Ntaxa	20	23	26	22	23	23	23
		Total Abundance	519	188	292	268	308	245	308

Table 5. Macroinvertebrate fauna (at family level) observed in surber samples at sites in the Keith River and Johnnys Creek, March 1999.

				River:	Arthur R.	Keith R.	Johnnys Ck.
				Site:	Tiger Bend	Mid Site	d/s site
				Date:	03-Mar-99	03-Mar-99	04-Mar-99
				Code:	ART	KRDS1	JDS
Order	Class	Family	Species				
	Gastropoda	Hydrobiidae					1
	Oligochaeta				11	10	53
Arachnida	Hydracarina				3	2	
Crustacea	Amphipoda	Paramelitidae					76
Insecta	Plecoptera	Eusthenidae	*Eusthenia costalis*		2	1	
			Eusthenia spectabilis			3	
		Austroperlidae	*Tasmanoperla thalia*			1	
		Gripopterygidae	*Trinotoperla zwicki*		2	1	1
	Ephemeroptera	Leptophlebiidae	*Nousia spAV4*			3	
			Nousia spAV5		2	37	
			Nousia spAV7		1	9	33
			Nousia spAV9		1		
			Tillyardophlebia rufosa		1	7	
			Austrophlebioides sp AV7			2	
		Baetidae	*Baetid Genus 2 MVsp3*		5	62	1
			Baetid Genus 2 MVsp6		6		
Diptera	Chironomidae	Chironominae			10	1	29
		Orthocladiinae			8	4	19
		Podonominae				2	
		Tanypodinae					1
		Simuliidae	*Austrosimulium furiosum*		6	4	5
		Blephariceridae					1
		Empididae			1	2	
		Unid. pupae			3	2	4
	Trichoptera	Calocidae/Helicophidae	*Caloca sp*		1		
			Tamasia variegata			3	5
		Conoesucidae	*Conoesucus sp AV2*		2		
			Costora delora		2		
			Conoesucus nepotulus				1
		Ecnomidae	*Ecnomina E sp AV1*		1		
			Ecnomus sp			1	
		Glossomatidae	*Agapetus sp AV1*				1
		Hydrobiosidae	*Taschorema asmanum*		2	2	1
			Genus Hydb B sp AV1		1		
			Taschorema sp AV2			1	
			Taschorema apobamum			1	
			Ethochorema nesydrion				1
			Taschorema sp AV4				2
			Ethochorema hesperium				1
			Koetonga clivicola				4
		Hydroptilidae	*Hellyethira basilobata*				5
		Leptoceridae	*Notalina sp*		10		3
			Russobex sp			1	
			Triplectides proximus				1
			Oecetis sp				1
		Philopotamidae	*Hydrobiosella sp AV10*				3
		Philorheithridae	*Tasmanthrus angustipennis*			5	
		Polycentropodidae	*Plectrocnemia sp AV1*				1
		Unid. pupae					1
	Coleoptera	Adult Elmidae			7	31	50
		Larvae Elmidae	*Austrolimnius sp*		33	49	26
			Simsonia wilsoni			4	2
		Scirtidae			42	36	4
		Psephenidae	*Sclerocyphon aquaticus*			1	
		Ntaxa (SPECIES)			**25**	**30**	**31**
		Ntaxa (FAMILY)			**19**	22	**23**

Table 6. Macroinvertebrate fauna (at species level) observed in surber samples at three sites in the Arthur and Keith Rivers and Johnnys Creek, March 1999.

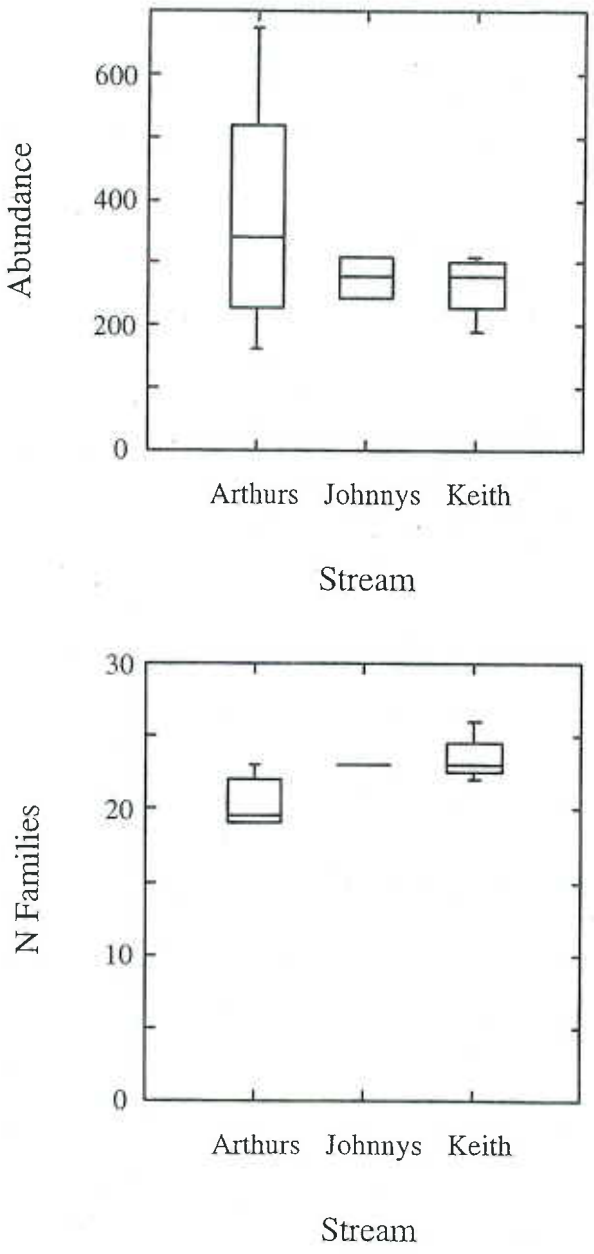

Figure 1. Box plots of total abundance and number of taxa (families) of macroinvertebrate in riffle habitats at all sites in the Arthurs and Keith Rivers and Johnnys Creek, March 1999.

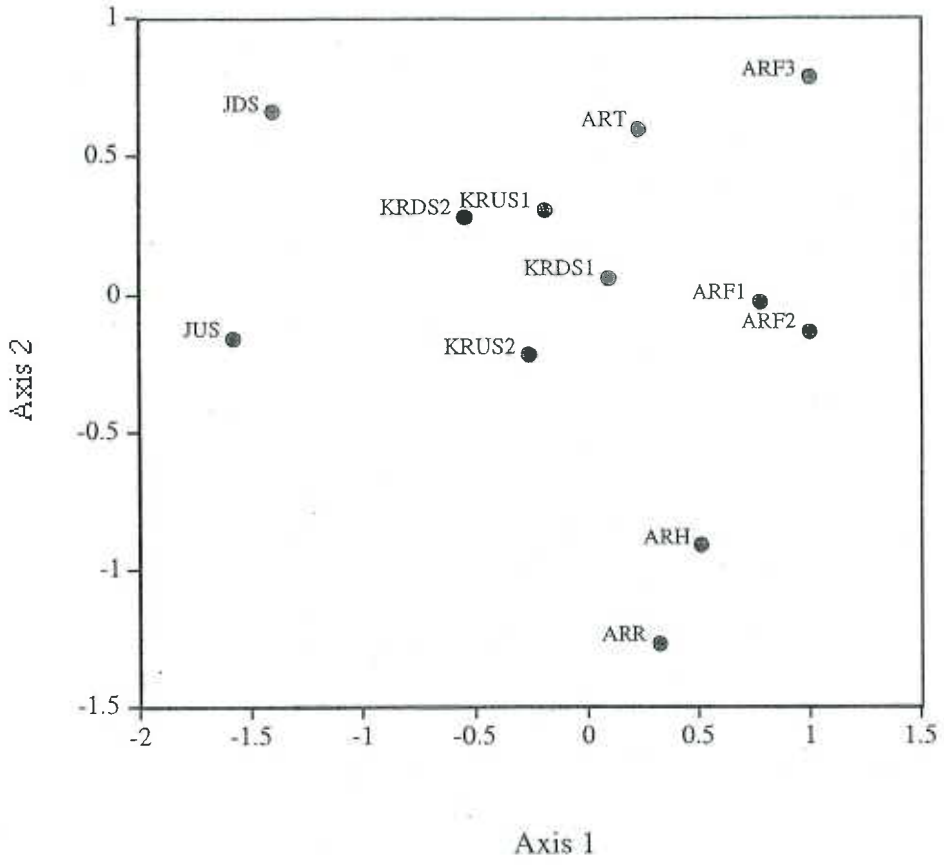

Figure 2. Ordination of macroinvertebrate communities in all sites studied. A= Arthur, K = Keith, J = Johnnys Ck. See Table 1 for site codes.

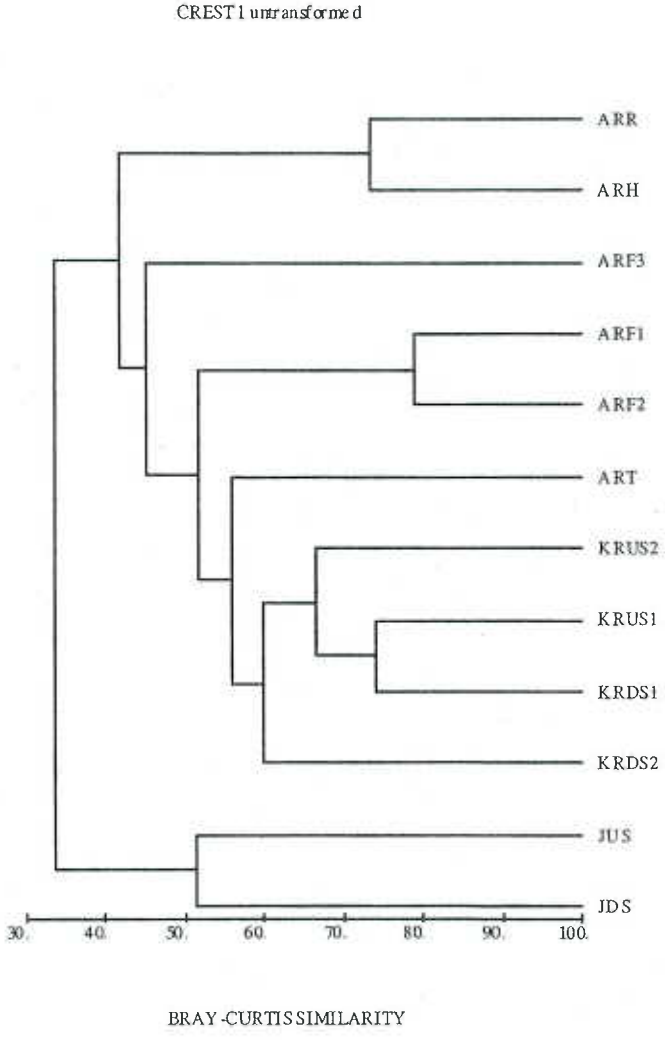

Figure 3. UPGMA cluster dendrogram of macroinvertebrate samples from sites in the Arthur, Keith Rivers and Johnnys Creek, March 1999. Analysis done at family level, data untransformed.

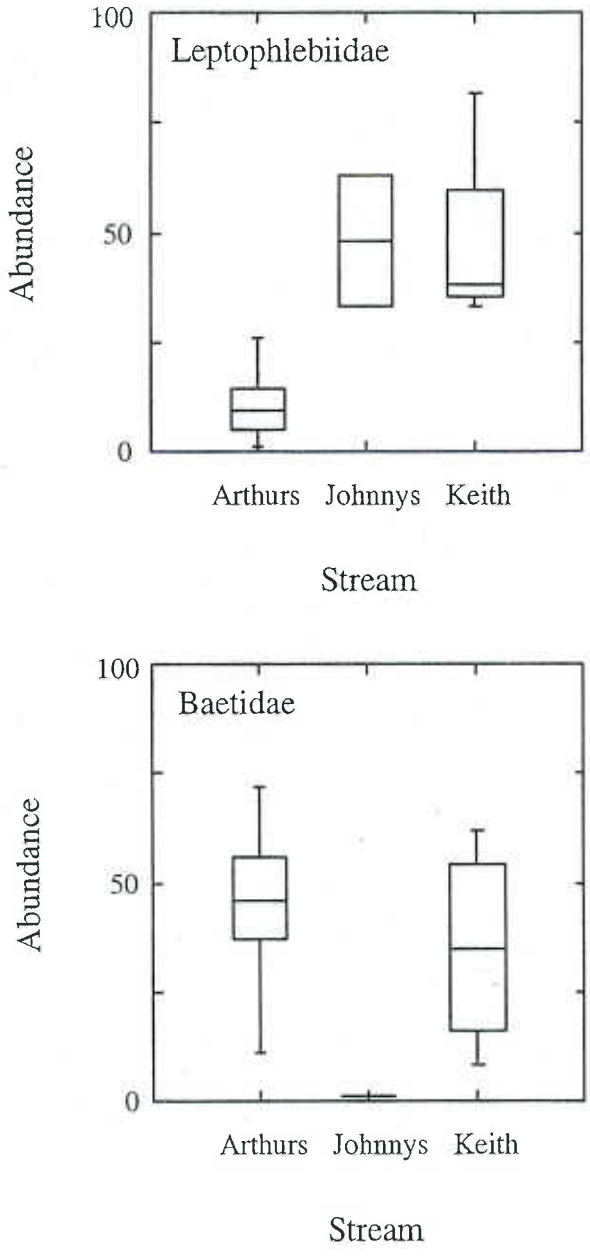

Figure 4. Box plots of total abundance of leptophlebiid and baetid mayflies in riffle habitats at all sites in the Arthurs and Keith Rivers and Johnnys Creek, March 1999.

Comparison between streams and sites

Inspection of the MDS ordination plot (Figure 2) and UPGMA cluster dendrogram (Figure 3) shows that the community composition in Johnnys Creek is markedly different to either community found in the Keith or the Arthurs. The type of fauna in Johnnys Creek is typical of many smaller, lower gradient West Coast streams, with:

- high abundances of parameletid amphipods, leptophlebiid mayflies (genus *Nousia*), oligochaetes and adult elmid beetles;
- high diversities of leptocerid and hydrobiosid caddis larvae (trichoptera);
- lower abundances of leptophlebiids and grypopterygid stoneflies and higher abundances of chironomids and oligochaetes at the downstream, low gradient site.

Differences between the upstream and downstream sites in Johnnys Creek are related to the change in stream gradient, with increases in sand deposition, channel width and organic material deposition, at the downstream site.

There was no evidence of impact in the lower Keith or Johnnys Creek due to current Crest activities, though periods of elevated turbidity were noted during field sampling at KRDS1, believed to be associated with drilling activities.

The riffle macroinvertebrate fauna of the Keith River is more diverse than that of the Arthur, with an average of three more macroinvertebrate families (by t-test, $p < 0.02$). Thus diversity was higher in the Keith than the Arthurs River (Figure 1), although abundance was not significantly different (Figure 1). Both the Keith River and Johnnys Creek had high abundances of leptophlebiid mayflies compared to Arthurs River, which in turn had higher abundances of baetid mayflies (Figure 4).

There was also a statistically significant difference ($p < 0.001$ by ANOSIM) in macroinvertebrate community composition between the Keith River and Arthur River (see Figure 2). Analysis of taxa responsible for those differences (using the SIMPER routine in PATN) showed that 50% of the difference was due to differences in the

abundance of nine taxa (Table 7). Most notable are the lower abundances of leptophlebiid mayflies, eusthenid and gripopterygid stoneflies and podonomiid midges, and the elevated abundances of scirtid beetle larvae and baetid mayflies in the Arthur compared with the Keith River. These differences are consistent with and indicative of:

- high habitat and water quality in the Keith River;
- poorer water quality in the Arthur River;
- changes in community composition consistent with mild acidification in the Arthur River, and possibly metal contamination. These changes are consistent with those described as being associated with mild metal/AMD contamination (elevated metals, sulphate) both in western Tasmania and elsewhere (e.g. Davies et al. 1996).

Table 7. Taxa responsible for 50% of the mean difference in community composition between all Keith and Arthur River sites (derived from SIMPER analysis) in order of decreasing importance.

Taxon	Keith R	Arthur R	%	Cum %
	Mean Abundance			
Leptophlebiidae	47.8	10.8	6.1	6.1
Chironominae	0.8	31.0	6.1	12.2
Simuliidae	6.8	85.7	5.7	17.8
Podonominae	3.5	0.2	4.7	22.6
Gripopterygidae	7.5	2.2	4.6	27.2
Leptoceridae	8.8	10.0	4.2	31.4
Eusthenidae	4.3	1.3	3.8	35.1
Hydropsychidae	2.0	4.5	3.8	38.9
Psephenidae	3.3	0.2	3.7	42.6
Conoesucidae	0.5	3.0	3.6	46.3
Calocidae/Helicophidae	1.8	3.0	3.3	49.6

Water quality assessment of the Keith and Arthur Rivers (Koehnken, this study) showed elevated zinc levels in the Arthur River of between 20 and 50 µg/l compared to < 1 µg/l in the Keith. In addition, sulphate concentrations in the Arthur River were approximately twice those in the Keith (in the range 3-6 mg/l).

It should be noted that the above data is limited in extent, and that pulses of higher zinc concentrations may occur at ranges that may exert toxicological effects on macroinvertebrates (ANZECC 1992, Davies et al. 1996). While the Arthur has elevated alkalinity, the recorded levels of $CaCO_3$ (in the range 10-20 mg/l) are not high enough to markedly reduce the toxicity of dissolved metals.

Fish fauna

The fish fauna of Keith River (Table 8) was typical of most mid-catchment west coast Tasmanian stream sites (Davies 1989, Fulton 1990, Davies et al. 1996, Davies and Cook 1998). Both sites sampled were dominated by the native blackfish (*Gadopsis marmoratus*) and the introduced brown trout (*Salmo trutta*). A total of six fish species were observed in the Keith, including the migratory shortfinned eel (*Anguilla australis*), sandy (*Pseudaphritis urvillii*) and juveniles of the pouched lamprey (*Geotria australis*), as well as the common jollytail (*Galaxias maculatus*). None of these species are considered rare or threatened. Johnnys Creek contained a depauperate fish fauna, with only brown trout recorded. Freshwater lobster were recorded in both streams (see below).

Table 8. Summary of fish captures in the Keith River and Johnnys Creek. All numbers are totals from 2-pass electrofishing operations.

River:	Keith R.		Johnnys Ck.	
Site:	u/s Farquars	at Arthur jctn	u/s Farquars	downstream
Date:	09-Mar-99	09-Mar-99	10-Mar-99	10-Mar-99
Code:	KRUS2	KRDS2	JUS	JDS
Length of stream fished (m):	120	110	105	130
Salmo trutta	14	9	15	33
Gadopsis marmoratus	14	11	0	0
Anguila australis	4	1	0	0
Pseudaphritis urvillii	6	8	0	0
Galaxias maculatus	0	2	0	0
Lamprey ammoecete	0	2	0	0

Threatened species

None of the aquatic insects listed in the TSA (1995) were found in the Keith, Arthur or Johnnys Creek samples. Only two taxa relevant to the Threatened Species Act (TSA 1995) were observed.

The giant freshwater lobster, *Astacopsis gouldi* was found at several sampling sites. These records fall within the known distribution for this species, which includes streams of the Arthur catchment (Horwitz 1994, Lynch and Bludhorn 1997), though this is the first formal recording of the species in the Keith River and in Johnnys Creek. The species is listed under both the Commonwealth Endangered Species Protection Act (1992) and the Tasmanian Threatened Species Act (1995). It is listed as vulnerable under the TSA, and is the subject of an active ongoing Recovery Plan (Bludhorn 1997), due to be endorsed by the Commonwealth in mid-late 1999. Currently, the primary threatening process to the species is habitat degradation. In order to be consistent with the requirements of the recovery Plan and TS Act, alterations to water quality, sediment characteristcis and riparian vegetation in both the Keith and Arthur Rivers should be avoided.

One other taxon of interest, found in the Keith River and Johnnys Creek, was a hydrobiid snail of the genus *Beddomeia*. While formal identification of the species found in these streams has yet to take place, it falls within the taxon groups 4C or 5A, as described by

Ponder et al. (1993), which includes 11 known species (all of which are listed under the TSA 1995), and an indeterminate number of undescribed species. None of the described species have been recorded from the Keith River to date, nor from the Arthur River. Specimens from this study have been submitted for formal identification (which can require electron-microscopy) to Dr W. Ponder (Australian Museum, Sydney).

Both *A. gouldi* and the *Beddomeia* snail group receive special protection under the Special provisions of the Forest Practices Code (1993). The Forest Practices Board's Threatened Fauna Manual (Jackson and Munks 1998) describes the following requirements:

- *retain riparian vegetation along Class 4 streams (streams with catchment areas < 50 ha);*
- *maintain water quality by following the Forest Practices Code prescriptions for stream protection.*

In addition, small streams which contain suitable habitat for *A. gouldi* are required to have a 10 m riparian buffer to protect instream habitat for juveniles, under additional special provisions put in place by the Forest Practices Board (S Munks FPB, pers.comm.). Tasmanian research on the impact of land clearing (forestry) activities on stream habitat and fauna indicates that a minimum riparian buffer of 30 m is required to protect instream stream values. Buffer widths may minimise impacts on water quality, especially for clay-rich and highly erodible soils.

In summary, since both *A. gouldi* and endemic snails of the genus *Beddomeia* have been found in Johnnys Creek and the Keith River, and since *A. gouldi* is known from the Arthur River, the following recommendations are made:

- all streams (drainage with defined channels, whether flow is perennial or ephemeral) will have a 30 m buffer of riparian vegetation maintained, regardless of size. No machinery is to enter these buffers, and no waste or drainage waters are to passed across or through them unless specifically approved.

- all drainage lines will have a 10 m riparian buffer, and crossings will be minimised.
- road drainage will be consistent with prescriptions of the Forest Practices Code (1993).

Monitoring Program

A design is required for future monitoring of stream biological condition associated with Crest activities. A design is proposed which incorporates relevant control and reference sites in the Arthur and Keith Rivers, and Johnnys Ck. The design will also be consistent with requirements of both a quantitative program and the AUSRIVAS (AUStralian RIVer Assessment Scheme) bioassessment framework, and allow both types of reporting outputs. Thus it will allow reporting of biological condition using both the existing AUSRIVAS reporting indices and quantitative reporting on biodiversity, abundance and community composition of invertebrates and fish. It will allow detection of impacts associated with Crest activities in the Keith-Arthur River catchments with definable sensitivity and power.

Overall design

The proposed design will have a quantitative component, with determined power and sensitivity, and a semi-quantitative component to allow broad comparison with other rivers across Tasmania.

Quantitative

The overall design will conform to a 'Beyond BACI' (Before After Control Impact') design, *sensu* Underwood (1992). Thus, several control sites, unaffected by potential mining impacts, are selected within the streams associated with and in close proximity to the Crest lease. A number of potentially impacted 'test' sites are also selected. All sites are sampled on several occasions prior to the commencement of major mining development. This represents the 'pre-impact' period and data set.

All sites are sampled periodically following the commencement of major mining or mine development operations (as part of a routine monitoring program), at roughly the same seasonal timing and frequency as conducted during the pre-impact period. This represents the 'post-impact' data set.

Formal statistical evaluation of the degree of impact at each test site is conducted using analysis of variance (ANOVA), with time (pre vs post) and space (control vs test) as factors. Formal identification of a statistically detectable impact is performed by inspecting the space * time interaction term in the ANOVA. This controls for differences between sites which occurred prior to impact commencing, and is based on the assumption that the degree of change in the differences between sites between the pre and post impact period may be assigned to the mining activity (in this case). Both Type I (alpha) and Type II (beta) levels should be agreed on and defined prior to reporting the impact.

This process identifies statistically detectable changes due to mining activities. It does not assess the conservation or environmental significance of those changes. This must also be done, either post hoc or a priori by all parties agreeing on specific environmental thresholds.

The variables to be assessed using this design should include:

- total abundance of macroinvertebrates and fish;
- diversity (as taxon richness) of macroinvertebrates and fish;
- community similarity (using a similarity index) of macroinvertebrates.

Semi-quantitative

In addition it is proposed that assessment be conducted using the semi-quantitative, but nationally standardised AUSRIVAS bioassessment procedure. Thus all sites selected above would be also sampled semi-quantitatively for macroinvertebrates, and a suite of additional reference sites (four additional to the control sites already selected) would be sampled. All site data would then be analysed using the AUSRIVAS procedure (Schofield and Davies 1996), to allow reporting to be consistent with state-wide bioassessment reporting as conducted by DPIWE. This has the major advantage of reporting the Crest site condition in a manner entirely consistent (in output and scale) with all other sites

assessed using the AUSRIVAS procedure (e.g. in State of the Rivers surveys). The variable reported form this component would be the AUSRIVAS bioassessment O/E (observed/expected) index and its associated band.

The addition of the semi-quantitative component to the formal quantitative monitoring bioassessment program incurs little extra cost, as sample collection is rapid (kick sampling with live-picking on site), and inexpensive.

Management objectives to be addressed

It is recommended that management objectives for the streams associated with the Crest lease site be developed. Examples of these could include, for sites downstream of Crest operations:

1. No change in stream macroinvertebrate diversity by more than 20%;
2. No change in AUSRIVAS band assignment;
3. No loss of fish species or life history stages;
4. *Astacopsis gouldi* and *Beddomeia* to be present at all locations at which they were observed prior to mining operations commencing.

Monitoring should report against these objectives.

Sample sites

Control and test sites for quantitative monitoring

The following sites are recommended as control sites for quantitative monitoring:

ARF1, ARF2, ARF3, KRUS1, KRUS2, JUS.

The following sites are recommended as test sites for quantitative monitoring:

ART, ARR, ARH, KRDS1, KRDS2, JDS.

Reference sites for semi-quantitative monitoring.

Four reference sites already sued within the Tasmanian AUSRIVAS models should be used as additional sites for AUSRIVAS bioassessment. They should be selected from the same biological group as the Keith and Arthur Rivers.

Sampling and sample processing – macroinvertebrates

Sampling is to be conducted twice yearly in spring (October-November) and autumn (March to May).

All sites should be sampled as follows:

1. 10 surber samples, 500 micron mesh, pooled, of riffle habitat. Samples to be preserved.
2. 1 kick sample with AUSRIVAS net (250 Micron mesh, picked on site using standard AUSRIVAS protocol.

All surber samples to be sub-sampled to 20%, and sorted and identified to family level. All AUSRIVAS samples to be identified to 'family' level (standard AUSRIVAS taxonomic level).

Sampling and sample processing – fish

Sampling to be conducted once a year in autumn (March-April).

Only the sites selected above for quantitative sampling are to be sampled. Each sites to be electrofished using back-pack shockers in a two-pass operation. Arthur River sites will require two teams working in parallel and sampling may be restricted to riffle-run habitats. All fish to be measured and identified prior to release.

Data analysis

Quantitative

All data to be analysed using ANOVA of appropriately transformed variables. Variables to include:

1. total abundance of macroinvertebrates and fish;
2. diversity (as taxon richness) of macroinvertebrates and fish;
3. community similarity (using Bray Curtis similarity index) of macroinvertebrates.

For 1 and 2 above, ANOVA is to use time * space as factors and the significance of the interaction term will be reported. For 3 above, ANOVA is for time only (pre- vs post-) and the significance of that term will be reported.

For this analysis to be effective, at least two sampling events should take place during the pre-impact period to provide temporal replication. Additional sampling is therefore recommended for spring 1999.

Semi-quantitative

All macroinvertebrate live-kick sample data to be analysed using the standard AUSRIVAS predictive models, (alpha set) situated on the AUSRIVAS server (University of Canberra), and accessed via the AUSRIVAS website. Paired t-test should be performed on differences between pre- and post- O/E values. Site band assignments should also be reported.

Overall Conclusions

Then Keith and Arthur Rivers and Johnnys Creek. contain biological diverse communities in good condition. A slight impact of metal contamination may be occurring in the Arthur River, both upstream and downstream of the Crest lease site, reflected in the macroinvertebrate community. *Astacopsis gouldi* (freshwater lobster) was observed at several sites in the Arthur and Keith Rivers and Johnnys Creek, as were snails of the *Beddomeia* genus. Both of these taxa require protection from declining water quality and stream habitat conditions (*A. gouldi* is listed in the Tasmanian Threatened Species Act 1995). Riparian buffers are recommended for this purpose, and water quality deterioration should be kept to a minimum.

A biological monitoring program conforming to the 'Beyond-BACI' design is recommended. At least one additional round of 'pre-impact' sampling should be conducted to form a sound statistical basis for assessing future impacts of Crest operations in the Arthur catchment.

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