Government of South Australia
Primary Industries and Resources SA

WATER MONITORING REPORT FOR THE BRUKUNGA MINE SITE FOR CALENDAR YEARS 2004 AND 2005.

EPA site Licence No. 10577

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Biological monitoring reports prepared by staff of the Australian Water Quality Centre

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Mine Regulation & Rehabilitation Branch
Minerals and Energy Resources Division
Department of Primary Industries and Resources SA

Water Monitoring Report for the Brukunga Mine Site for calendar years 2004 and 2005

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WATER MONITORING REPORT FOR THE BRUKUNGA MINE SITE FOR CALENDAR YEARS 2004 AND 2005

Abstract

The Brukunga mine site is an historic site that was worked from 1955 to 1972 to recover iron sulphide minerals as a source of sulphur that was converted to sulphuric acid, and subsequently used in the manufacture of superphosphate fertiliser. The pyrite and pyrrhotite minerals that occur on site naturally oxidise in air to form acid and the resultant Acid-Rock-Drainage (ARD) subsequently dissolves other minerals creating heavy metal pollution in the local watercourse.

The land is freehold title to the Crown and is managed by the Department of Primary Industries and Resources - Minerals and Energy Resources Division.

The key work undertaken on site is the intercept of acid seepage and the treatment of the acid with lime to prevent acid and metals from entering and polluting the local watercourse. The acid water is neutralised in a plant to remove the soluble heavy metals before the cleaned water is released back to Dawesley Creek. The water-monitoring program undertaken in accordance with conditions of the Environment Protection Agency site licence No.10577 provides a measure of the success of the interception and treatment program.

In 2003 a major improvement in water quality in the creek downstream of the mine site was achieved primarily due to the construction of a 1.7 km creek diversion drain. The water was returned to a condition suitable for livestock and irrigation use for the first time in half a century. The improvements achieved in water quality are evident in the water monitoring results obtained for calendar years 2004 and 2005, which are presented in this report.

1 SUMMARY

The Dawesley Creek which flows north to south through the Brukunga mine site was contaminated by sulphuric acid and soluble heavy metals, shortly after mining commenced in 1955, as the acid drained from the waste rock dumps into the watercourse. In 1972 the mine closed and the sulphide minerals exposed in the rock freshly broken by mining, continued to oxidise to produce acid drainage. After a plea from the company for assistance the government accepted responsibility for the site in August 1977. Government research indicated that a lime neutralisation plant was the best approach to address the problem and a treatment plant was duly commissioned in September 1980. SA Water Corporation was the operator of the plant until it was transferred to PIRSA in January 1998.

Acid drainage from the site is collected from three main sources;

- Seepage from 8M-tonnes of waste rock, in two main dumps,
- Seepage from the toe of the 3.5M-tonne tailings dam; and to a lesser extent
- Seepage from in-situ minerals exposed in the quarry floor.

Fig 1. Collecting acid seepage at the toe of the southern waste rock dump.

Fig 2. Acid seepage collected at the toe of the wall of the tailings storage facility.

During the period that the lime treatment plant operated from 1980 to 2003, the interception system was partially successful and captured only half the pollution from the site. The seepage that escaped to the creek polluted the water up to 22 km downstream of the mine site, making the water unsuitable for livestock or irrigation use.

In 1998 the 'Brukunga Taskforce' and later the 'Brukunga Mine Site Remediation Board' were established to examine the pollution problems and to develop strategies for their remediation. A number of engineering options were developed and several were presented to, and subsequently supported by the Premier and cabinet in 2000 resulting in approval for substantial new capital initiatives.

A major improvement occurred in the quality of creek water in June 2003 when a $M1.9 diversion drain was completed which took the flow of the creek past the mine site, separating it from the main source of pollution. The 1.7 km drain produced an immediate improvement in the quality of water downstream of the mine and the improvements are clearly evident in the water monitoring results presented in this report.

Fig 3. Open section of the diversion drain carrying Dawesley Creek flow past the mine

In May 2005 the second significant improvement was completed with a $M0.8 upgrade to the acid treatment plant, which added a parallel stream of mixing tanks effectively doubling the plant's peak capacity that enabled most of the pollution surges in winter to be processed. The results of this improvement began to have an influence in the latter part of 2005 and should be better reflected in the monitoring results of future years.

Fig 4. New mixing tanks installed next to the original tanks, doubling the plant's peak treatment capacity.

The scope of the water-monitoring program was established by negotiation between the EPA and SA Water Corporation in August 1996. The water monitoring requirements are described in condition 1 of the EPA site licence for Brukunga, number 10577.

Significant improvements achieved in the water quality in Dawesley Creek are now clearly evident in the water monitoring results recorded for calendar years 2004 and 2005, i.e. post-construction of the diversion drain, as compared with results for the years prior to the drain. Soluble metal and sulphate levels in the watercourse downstream of the mine site are now generally at levels, as recommended by ANZECC/ ARMCANZ[1], suitable for livestock and irrigation use, for the majority of the time.

2 BACKGROUND

Historic mining at Brukunga from 1955 to 1972 produced 5.5 million tonnes of iron sulphide ore as a source of sulphur for the manufacture of sulphuric acid. The acid was used to convert phosphate ores into superphosphate fertiliser, crucial to the success of agriculture in SA. Mining ceased in May 1972 on the withdrawal of the Commonwealth production subsidy and no mining has occurred on the site for past 34 years.

Quarrying of the hillside produced approximately 8 million tonnes of broken waste-rock, and ore processing produced 3.5 million tonnes of sand tailings. Both the rock dumps and sand-tailings dam contain randomly distributed low-grade sulphide mineralisation, which continues to oxidise and form leachate.

Mining activity exponentially increased the surface area of the exposed sulphide minerals and the natural oxidisation process produces acid seepage at a rate greatly elevated above natural background rates. A scientific study undertaken by ANSTO[2] in 1993 for PIRSA indicated that the accelerated rate of oxidation is likely to continue as a long-term problem producing at elevated rates for in excess of 240 years.

Pollution control at Brukunga is exacerbated by the flow of Dawesley Creek, passing through the site, and the creek's close proximity to the toe of the waste rock dumps. Acid conditions enable the breakdown of other minerals, which are released creating high levels of soluble heavy metals, e.g. iron and aluminium in the watercourse. The acid seepage escapes into the creek and from there it is carried from the site.

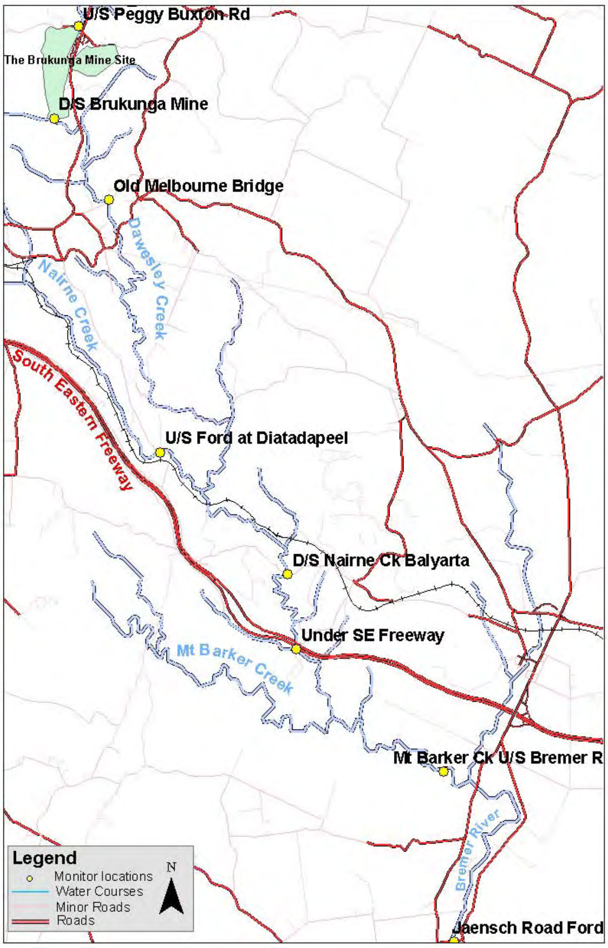

Fig 5. Dawesley Creek flow to the Bremer River and location of monitoring stations.

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[1] ANZECC/ARMCANZ, Australian and New Zealand Environment and Conservation Council, and Agriculture and Resource Management Council of Australia and New Zealand

[2] ANSTO, Australian Nuclear Scientific and Technical Organisation.

The first objective of the Brukunga Board was to restore the water quality in Dawesley Creek downstream of the mine site, to a level that would be suitable for livestock and irrigation use. PIRSA's activities at Brukunga are oriented to intercepting the acid drainage and treating it to neutralise and remove the heavy metals before returning the water to the creek. Considerable work also has been and is continuing to be done towards landscaping the site by progressively planting areas with native vegetation.

The intercepted acid water is treated in an active lime neutralisation plant, which was established on the site in September 1980. Operation of the plant over the initial 25 years had made significant improvement however, despite best efforts until July 2003 the interception program was only able to capture approximately half of the acid seepage generated. The remnant seepage evaded capture and then contaminated the Dawesley watercourse to such an extent that the water downstream of the mine site was not suitable for livestock use.

In June 2003 PIRSA completed the construction of a $1.9 Million large diameter 1.7 km diversion drain. The drain diverts the regular flow of Dawesley Creek past the mine site enabling the remnant acid seepage to be isolated in a section of the creek and collected at a small downstream weir. Diversion of the creek resulted in an immediate and significantly noticeable improvement in water quality in the watercourse and those results are reflected in the values presented in this report.

In addition to the construction of the drain the decision was taken to double the peak treatment capacity of the acid treatment plant so that additional pollution generated during the wet winter period could also be neutralised. A second series of three mixing tanks were installed in June 2005. The upgrade of the plant enabled additional pollution to be treated and reduced the duration and volume of any overflow that may occur during persistent storm events.

3 THE WATER MONITORING PROGRAM

The water-monitoring program consists of three independent strategies that bring a focus on determining the condition on the watercourse.

The three strategies as described in licence condition No.1 are:

1. *Determines the annual and seasonal loads of heavy metals entering Dawesley Creek from the Premises by measuring the stream flow and their concentration upstream and downstream of the Premises;*

2. *Determines the extent of impact of the Premises (the zone of impact) on Dawesley Creek and the Bremer River by undertaking a biological (macro invertebrates) monitoring program at three-monthly intervals; and*

3. *Determines the temporal and spatial variations of pH and heavy metal concentrations within the zone of impact by undertaking a monthly sampling program at a selection of fixed sites within the zone for the purpose of assessing compliance with the water quality guidelines for the protection of the aquatic ecosystem pursuant to the ANZECC Fresh and Marine Water Guidelines.*

The tabulated results and graphic representation for each monitoring strategy is presented as three separate appendixes A, B, and C to this report and a discussion of the results are presented in Section 8 of this report.

4. HYDROLOGY AT BRUKUNGA

Flow in Dawesley Creek is described as intermittent, with small steady flows through most of the year, elevated and flushed during storm events particularly in winter, and in most years in late summer the creek dries to periods of no-flow. High evaporation and low flow in summer concentrates the contaminants with higher levels recorded. In winter with more consistent rain and significant surface run-off the extra water dilutes the contaminant levels lowering recorded concentrations.

Short-lived storm events overflow the diversion drain's capacity resulting in short-term flushes through the old creek, i.e. for a few hours or a few days. The capacity of the diversion drain was selected at a 1 in 1 year average overflow of the system. Any overflow at the upstream weir mixes with polluted water in the isolated section of creek and if the rate of inflow exceed the capacity of the two pumps transferring pollution from the creek to the holding ponds, then a pollution overflow downstream of the mine will occur, in a greatly diluted form.

The variable seasonal effects on; flow rate, temperature and nutrient levels, exerts significant influence on the rates of growth or decline and the distribution of macro-invertebrate communities, and can result in significant natural variations in community health, from year to year and season to season, and hence observed variations cannot necessarily be directly attributed to pollution from the mine site.

Water samples collected for both load and temporal monitoring programs are analysed by the Australian Water Quality Centre, a business unit of the South Australian Water Corporation and a NATA accredited organisation, Corporate accreditation number 1115 for chemical and biological testing.

Biological monitoring is undertaken by employees of the South Australian Water Corporation, a NATA accredited organisation, Corporate accreditation number 1115 for chemical and biological testing.

Flow monitoring and data logging and continuous water sample collection is undertaken by Water Data Services Pty Ltd, a South Australian consultancy based in Adelaide, with NATA certification number 7642-2 (AS/NZS ISO 9001:2000) for: *"Design, construction and installation of water quantity and quality monitoring stations. Provision of environmental and natural resources information services including monitoring of water quality and quantity, data analysis and presentation, monitoring of meteorological sites and data analysis and hydrological studies."*

5 ANNUAL AND SEASONAL CONTAMINANT LOADS

The annual and seasonal contaminant loads are determined for an agreed suite of chemical contaminants as they leave the mine site in the waters of Dawesley Creek.

The volume of flow in Dawesley Creek is determined as it passes over concrete v-notch weirs established in the creek immediately upstream and downstream of the mine site.

Fig 6. Upstream v-notch weir located in Dawesley Creek, for monitoring water flow.

Fig 7. Downstream v-notch weir monitors the volume of water leaving the site.

Flow data logged at the two hydrometric stations enables a water balance for the mine site to be calculated.

The hydrometric stations at Brukunga were established in 1993 by the Department of Engineering & Water Supply (E&WS) as part of a system of automatic logging stations to record creek flows in the Adelaide Hills. In 1998 automatic water sampling facilities were installed at Brukunga and chemical analysis commenced on 3rd February 1998.

The sampling pumps activate automatically at intervals proportional to the flow-rate of the stream. The samples are deposited in a bucket to form a representative composite mix and a sample is sent for analysis approximately every two-weeks, when the buckets are emptied and reset.

Fig 8. Automatic flow data recording and composite water sample collection equipment located in the monitoring huts.

The monitoring equipment is supplied and maintained by contractors *Water Data Services Pty Ltd* (WDS) who provide a full field service sending water samples to the *Australian Water Quality Centre* (AWQC) laboratories for analysis.

The assay results and flow volumes for each two-week period are tabulated and the product of the two values is the load in kilograms of the particular pollutant that leaves the mine site in the water of Dawesley Creek. The flow and assay data is also entered by WDS direct to the Department of Environment *'HYDSYS'* water data archive.

6 EXTENT OF IMPACT BIOLOGICAL MONITORING

Biological monitoring, collecting and identification of macro-invertebrate species living in the watercourse is undertaken by biologists from the *Australian Water Quality Centre* (AWQC) on a quarterly basis during the months of March, June, September and December of each year.

Fig 9. A biologist netting a sample of macro-invertebrates at Peggy Buxton Rd

Biological monitoring in the Dawesley Creek – Bremer River system commenced in September 1996 with the selection of six monitoring sites. The relative heath of the streams influenced by acid drainage can be compared with observations obtained at the two control sites that are not impacted by acid drainage from the mine site, i.e. in Dawesley Creek immediately upstream of the mine site, and in Nairne Creek before it enters Dawesley Creek.

At each monitoring location, AWQC biologists use a 250 µm mesh net to sweep a 10 metre section of the creek using the standard edge habitat method to collect macro-invertebrates in accordance with the standard Monitoring River Health (MRH) technique. The number of different macro-invertebrate animal species is identified and the populations are counted in the laboratory to provide a comparative measure for estimating the relative health of the stream.

7 TEMPORAL AND SPATIAL WATER VARIATION MONITORING

Water samples are taken monthly at eight separate locations, one upstream of the mine site and one in Nairne Creek as control sites. There are four in Dawesley Creek below the mine and Mt Barker Creek and Bremer River. A plan showing the location of the eight sampling stations is presented in Fig 5, page 6. The grab samples are taken at near mid-month for each year.

Fig 10. Grab sampling of creek water for chemical analysis at Melbourne Bridge.

The water samples collected are forwarded to *Australian Water Quality Centre* (AWQC) for chemical analysis for a suite of nine metals, i.e. aluminium, cadmium, chromium, copper, iron, lead, manganese, nickel and zinc and for sulphate, pH, conductivity in μS/cm and Total Dissolved Solids by EC. The acidity of samples as $CaCO_3$ to a pH 9.5 was added to the suite of items from August 2003 for four locations, to provide additional information.

All assay values reported are total samples, i.e. the samples are unfiltered and include values from dissolved metals and from particles in the water. The results are tabulated and when reported values exceeding ANZECC Water Quality Guideline recommenced guidelines for livestock, irrigation and ecosystems are colour coded to provide an enhanced visual recognition of occurring trends. Some graphic representation of data is also presented.

8 DISCUSSION OF MONITORING RESULTS

The 2004 and 2005 water monitoring results for all three monitoring approaches, show pleasing signs that indicate significant improvements in the quality of water leaving the mine site have occurred.

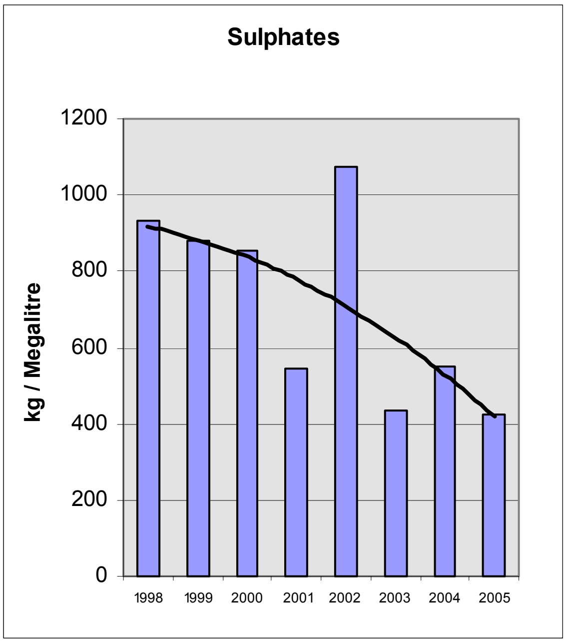

Fig 11. Graph of annual sulphate load leaving the mine site in Dawesley Creek.

Years 2004 and 2005 were both post installation of the diversion drain in Dawesley Creek at Brukunga and the results obtained confirm that the key goal to reduce pollution has been achieved by implementing an engineering solution to more effectively isolate the source of pollution.

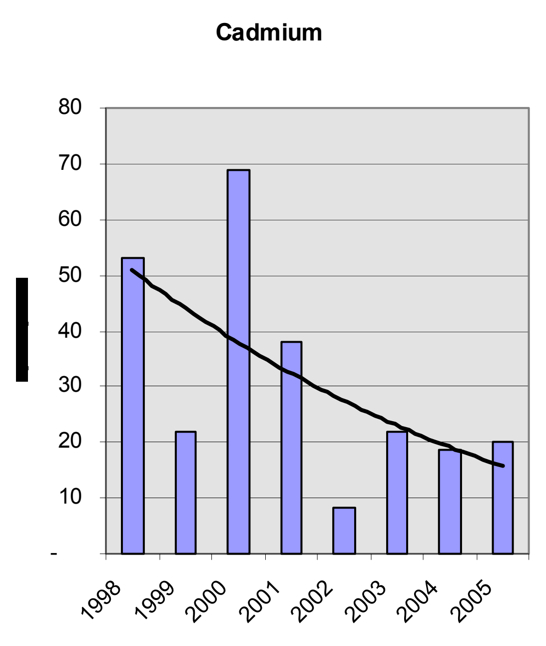

Fig 12. Graph of annual cadmium load in kg/Mega-litre of water leaving the mine site

The ‘annual metal load’ monitoring strategy provides good evidence of the decreasing load of pollutant in water leaving the mine site. The pollutants loads are calculated for each year however large variations in flow, due to drought and flood make direct trend comparisons very difficult. To provide a comparison between years, the results have been normalised by dividing by the annual volume of water. The load graphs for sulphates and cadmium (fig 11 & 12 for example) show the trend of annual load of pollutant reducing over the past eight years.

The graphs are for normalised values in kilograms per mega-litre of water and the trendline is a second order polynomial.

The biological monitoring strategy results also provide indications that significant improvements in water quality have recently occurred. This improvement is demonstrated in the graph of ‘Mean-taxon-richness from 1996 to 2005’ for quarterly biological monitoring of macro-invertebrates. To provide a comparison, the data was separated and plotted into two averages for each of the six monitoring sites, one average for data collected prior to construction of the diversion drain (1996-2002 ‘red’) and the other for data collected post construction (2003-2005 ‘blue’).

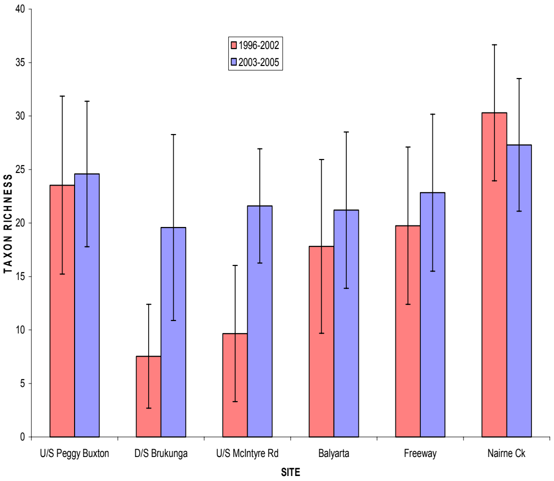

Fig 13. Species richness average value pre and post the diversion drain for locations along the watercourse. Error bars show two standard deviations.

Since March 2003, all sites on Dawesley Creek that are influenced by acid drainage from the mine site have on average supported more macro-invertebrate taxa. The monitoring strategy includes two sites as a control, i.e. two sites not influenced by acid drainage from the mine site, the Peggy Buxton Road site immediately above the mine, and the Nairne Creek site that flows into Dawesley Creek.

The monthly grab sampling strategy records the level of concentrations and spatial variations as the water moves downstream. The levels of a suite of metals are recorded on a spreadsheet for each monitoring location.

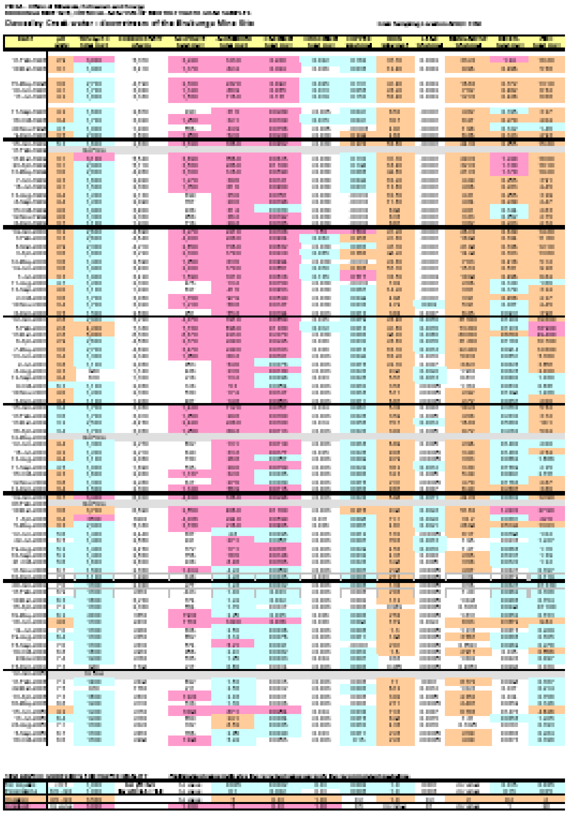

Fig14. Pictorial of spreadsheet recording assay values over past eight years; Note the colour change for 2004 and 2005 towards the bottom.

Values exceeding the ANZECC recommended guidelines are colour coded and each passing year the colours provide a visible indication of the change in pollution level. The figure shows eight years of monitoring results for nine metals and sulphate. Moving down the sheet with each year it is noticeable that the pink exceedance values for sulphate, aluminium and cadmium begin to clear in the last two recorded years i.e. 2004 and 2005.

9 ADDITIONAL MINE SITE MONITORING WORK

9.1 Site rainfall and plant utilisation

The annual rainfall significantly influences the volume of seepage from the waste rock dumps that requires capture and processing. Seasonal variations i.e. wet years or drought years, influence the volume of pollution requiring treatment and the cost of pumping and plant operation. Seepage is greatest in winter when plant utilisation is high with the plant operating 24 hours per day and 7 days per week. Site rainfall is read daily and entered into a spreadsheet.

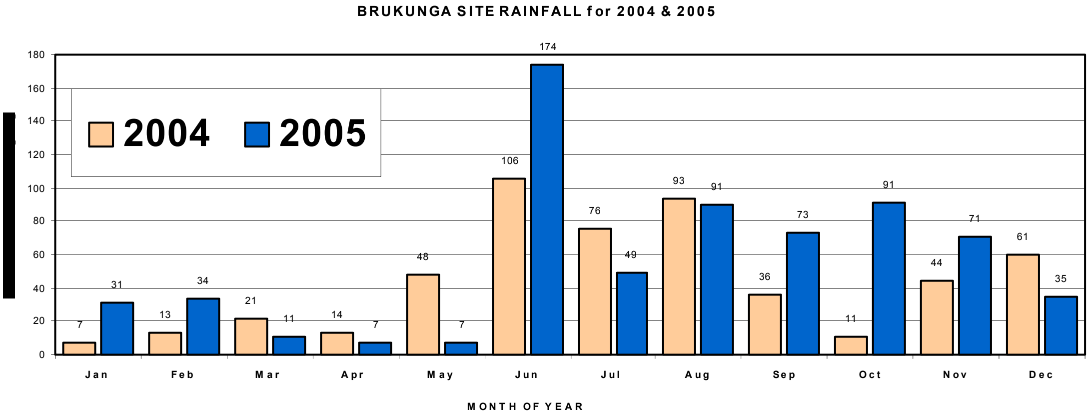

Fig 15. Monthly rainfall (mm) recorded at Brukunga for 2004 and 2005.

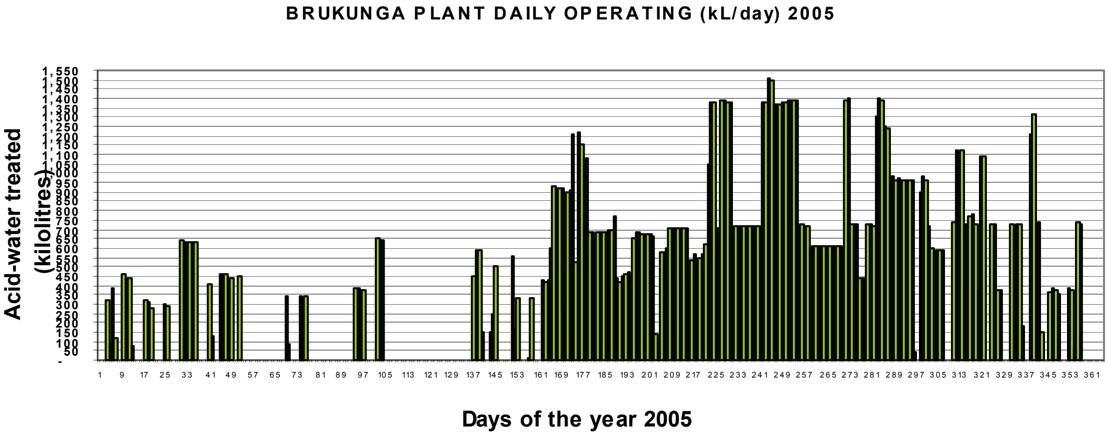

Fig 16. Plant shutdowns and throughput in kilolitres, for each day of 2005.

Year	Plant operation as a percent of available time (i.e. 24/7 > 100%)												Rainfall mm	Kilolitres treated
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
2001	30%	33%	46%	10%	80%	94%	94%	95%	98%	92%	59%	33%	**618**	**106,905**
2002	32%	33%	34%	28%	46%	47%	77%	51%	36%	40%	28%	40%	**392**	**53,472**
2003	27%	25%	10%	25%	47%	89%	100%	100%	100%	76%	80%	10%	**607**	**123,098**
2004	47%	15%	36%	33%	24%	81%	100%	99%	98%	55%	66%	35%	**531**	**115,051**
2005	41%	52%	18%	23%	8%	72%	95%	100%	100%	93%	73%	44%	**673**	**160,797**

Fig 17. Monthly plant operation as a percentage of available time 24/7

9.2 Sand tailings dam monitoring

During mining the treatment of ore to produce a concentrate also produced 3.5Mt of finely ground sand tailings that were deposited in a shallow farm valley. Since 1980 the tailings dam has been progressively covered with native vegetation to rehabilitate the surface. The vegetation cover stabilises the surface from the forces of erosion and reduces the volume of rain that otherwise would percolate deep through the sands and result in acid seepage at the base of the dam. The trees also provides habitat for wildlife.

The effect of the vegetation cover in reducing deep-percolation of rainwater is monitored in two methods;

- A v-notch weir is used to measures the flow of seepage from the base of the dam, and
- Internal measurements are taken to the watertable via boreholes on a monthly basis.

Graphic presentation of annual seepage over thirty years, records the reduction in seepage that has occurred and a graph of the depth to watertable, for each year indicates the amount of internal drying of the tailings dam.

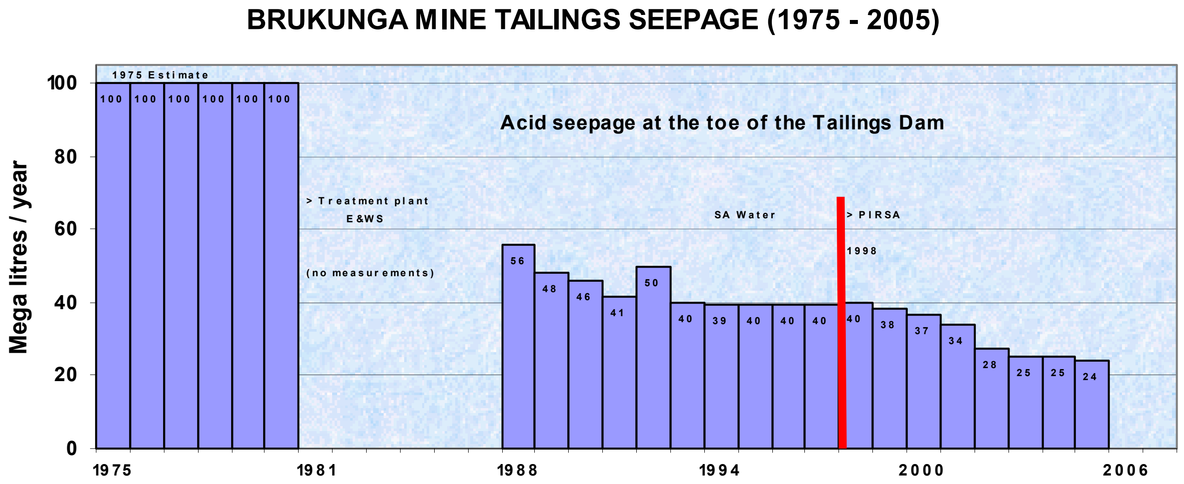

Fig 18. Annual volume of acid seepage from the sand tailings dam as measured at the v-notch

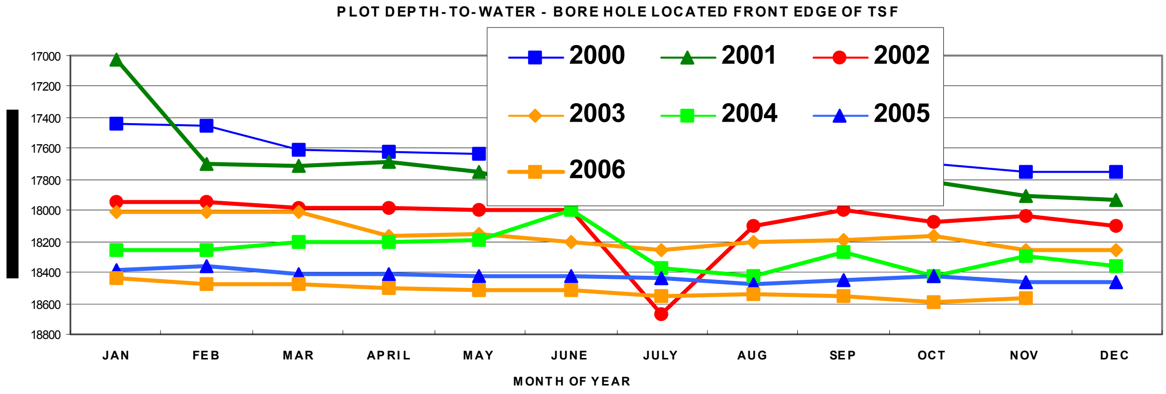

Fig 19. Depth measured to water in a monitoring bore in the tailings dam indicates progressive annual internal drying is being achieved.

9.3 *Water in the holding ponds (feed to the plant)*

Since September 1999 a quarterly sample has been taken from the acid-water holding ponds to provide information on the quality of feed water to the treatment plant (figure 20). Significant fluctuations in the concentration level of sulphate and various soluble metals are noticeable with high values tending during the summer and dryer conditions, and more diluted values occurring in winter.

ACID HOLDING POND (ie. water feed to treatment plant)

DATE	pH	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	IRON mg/l	MANGANESE total mg/l	NICKEL mg/l	ZINC mg/l
10-Mar-04	2.6	10,200	406	0.0555	2,180	117.0	0.6194	23.6
18-Jun-04	2.9	5,470	464	0.3570	445	42.4	1.2220	44.0
15-Sep-04	2.9	6,560	603	0.2739	611	40.8	1.2880	34.9
15-Dec-04	2.8	8,930	768	0.0941	935	76.4	0.2216	40.5
22-Mar-05	2.7	8,110	222	0.0249	2,190	105.0	0.1552	14.8
15-Jun-05	2.9	6,000	485	0.0666	631	55.5	0.7611	23.6
05-Sep-05	2.9	6,860	579	0.1732	517	43.0	0.0476	37.1
15-Dec-05	3.0	10,400	839	0.1805	1,430	97.6	1.3130	47.7

☐ **Indicates corrected potentially spurious reporting by laboratory**

1992 ANZECC RECOMMENDED GUIDELINE VALUES FOR WATER QUALITY

Irrigation	4.5 - 9.0	no value	5	0.01	1	2	0.2	2
Livestock	no value	1,000	5	0.01	no value	no value	1	20

Fig 20. Quarterly assay of acid polluted water collected for feed to the treatment plant.

10 CONCLUSIONS

The completion of new capital works initiatives undertaken by PIRSA in 2003 and 2005 achieved a dramatic improvement in the quality of water in Dawesley Creek downstream of the Brukunga mine site, (Fig C-11 p.109 and Fig C-13 p.111) demonstrate that sulphate and cadmium pollution has been successfully removed from the water.

The improvements recorded in the water monitoring results are more clearly evident when a comparison is made between the data collected before June 2003 and data collected after that date. The improvement is evident in all three monitoring strategies, i.e. the load calculations, biological observations, and monthly chemical concentrations.

The diversion of Dawesley Creek enabled more effective separation and collection of polluted seepage from the mine site, however this also increased the amount of water requiring treatment. Additional plant hours and the purchase of manufactured slaked lime reagent have contributed to a general rise in operating costs from around $550,000 pre 2003, to $725,000 in financial year 2005/06.

The quantity of water requiring treatment is strongly influenced by the seasons with more acid seepage generated in wetter years. The addition of a second treatment stream to the plant, completed in 2005 increased the peak rate of treatment from 0.75 Mega-litres per day to 1.5 Mega-litres per day.

In addition to water capture and treatment PIRSA's two site staff also manage the 123 ha property with activities including; plant maintenance, pest and weed control, maintenance of tracks and firebreaks, drain and fence maintenance, tree planting and routine water sampling.

In July 1998, six months after PIRSA took over operational control of Brukunga the EPA required that signs warning of the pollution be posted along the creek, a notice be placed in the newspapers and letters be sent to residents along the watercourse. Soon after PIRSA agreed to supply those landowners living downstream without an alternate water supply for irrigation and livestock, with deliveries of water. With the improvement in water quality it would appear an appropriate time to meeting with EPA to discuss warning requirements.

Dawesley Creek watercourse was polluted by acid seepage from the mine site, from soon after mining commenced in 1955. With the installation of the diversion drain in 2003, for the first time in nearly 50 years, the water has been returned to a condition suitable for livestock and irrigation use and it is rapidly returning to a condition that will sustain a wide diversity of aquatic ecosystems living in association with the stream.

11 REFERENCE

(ANZECC) Australian and New Zealand Environment and Conservation Council (1992) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Environment Australia Publications.

APPENDIXES

APPENDIX A

ANNUAL LOAD OF HEAVY METALS

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2004 CALCULATED POLLUTION LOAD IN DAWESLEY CREEK

Dawesley Creek up-stream of Brukunga Mine AW426658

2004 DATE	Sulphate kg	Aluminium kg	Cadmium kg	Chromium kg	Copper kg	Iron kg	Lead kg	Manganese kg	Nickel kg	Zinc kg
7-Jan-04	520.446	5.52547	0.003415	0.02732	0.02049	9.562	0.0082	0.357	0.051908	0.12294
21-Jan-04	333.801	2.19024	0.001755	0.01053	0.00702	3.7206	0.00316	0.179	0.030186	0.01755
4-Feb-04	244.454	0.8379	0.001330	0.01330	0.00798	2.17588	0.00346	0.259	0.01729	0.03458
18-Feb-04	315.741	1.89807	0.002265	0.05436	0.01359	4.3488	0.00997	0.239	0.044394	0.03624
3-Mar-04	152.736	0.72594	0.001110	0.00888	0.00666	1.35642	0.00266	0.135	0.01221	0.03774
17-Mar-04	98.982	0.8505	0.000810	0.00486	0.00324	1.28628	0.00146	0.053	0.009558	0.01458
31-Mar-04	781.83	3.57408	0.003285	0.01971	0.00657	6.05754	0.00526	0.240	0.043362	0.02628
14-Apr-04	342.5	0.66856	0.001918	0.00822	0.00274	1.36726	0.00164	0.078	0.014796	0.01096
28-Apr-04	102	0.1725	0.000600	0.00225	0.0075	0.267	0.00068	0.018	0.004875	0.02925
12-May-04	14.9	0.0196	0.000050	0.00030	0.0004	0.0461	0.00005	0.003	0.00059	0.0011
26-May-04	65.79	0.16039	0.000215	0.00344	0.00172	0.24467	0.00026	0.017	0.002107	0.00774
9-Jun-04	260.3	0.48224	0.000685	0.00411	0.00411	0.83296	0.0011	0.079	0.006165	0.01781
23-Jun-04	2635.68	11.18226	0.015504	0.07752	0.0969	18.48852	0.02132	1.089	0.133722	0.27132
7-Jul-04	460.53	1.10295	0.001935	0.01548	0.01548	2.92572	0.00271	0.249	0.024381	0.05418
14-Jul-04	1044.42	8.69011	0.006695	0.06695	0.18746	17.5409	0.01339	0.516	0.077662	0.25441
21-Jul-04	1078.71	2.8064	0.004385	0.02631	0.05262	7.92808	0.00526	0.418	0.047358	0.18417
4-Aug-04	32744.14	1228.3596	0.181710	10.17576	7.99524	2096.933	3.70688	104.919	5.160564	31.981
18-Aug-04	20568.24	422.7916	0.142835	2.85670	3.14237	488.4957	0.85701	35.309	2.028257	11.1411
1-Sep-04	3223.584	9.14004	0.016380	0.09828	0.09828	33.7428	0.02293	2.752	0.127764	0.4914
16-Sep-04	4797.375	29.36575	0.029075	0.17445	0.17445	76.758	0.03489	2.780	0.459385	0.6978
29-Sep-04	1750.782	11.54895	0.009705	0.09705	0.09705	28.3386	0.01747	1.221	0.09705	1.82454
13-Oct-04	1138.32	6.5484	0.00612	0.06120	0.04896	17.9928	0.0257	1.157	0.062424	0.25704
27-Oct-04	642.01	7.1858	0.003534	0.03534	0.02945	12.8402	0.0106	1.280	0.038285	0.25916
10-Nov-04	1128.816	6.23376	0.00648	0.05184	0.03888	12.61008	0.00778	0.441	0.054432	0.1944
24-Nov-04	722.625	6.9085	0.005125	0.03075	0.02050	15.17	0.00513	0.545	0.06765	0.11275
8-Dec-04	169.074	0.86118	0.001116	0.00744	0.01302	1.1346	0.0013	0.137	0.01395	0.09114
22-Dec-04	1247.378	23.064	0.030752	0.09610	0.15376	25.947	0.03075	1.245	0.117242	4.5167
	76,585	**1,793**	**0.48**	**14.03**	**12.2**	**2,888**	**4.80**	**156**	**8.75**	**52.7**

Dawesley Creek down-stream of Brukunga Mine

DATE	Sulphate kg	Aluminium kg	Cadmium kg	Chromium kg	Copper kg	Iron kg	Lead kg	Manganese kg	Nickel kg	Zinc kg
7-Jan-04	2066.4	1018.44	0.512172	0.25092	0.67404	1047.96	0.14465	27.700	0.938244	50.184
21-Jan-04	6132	5.3144	0.017374	0.01533	0.01022	8.1249	0.00256	9.709	0.193669	1.26217
4-Feb-04	5808	6.864	0.02064	0.0144	0.024	10.704	0.0024	12.192	0.1584	1.2192
18-Feb-04	2453.22	10.8108	0.00756	0.0378	0.02268	19.5048	0.00189	3.780	0.099414	0.71064
3-Mar-04	2559.67	10.5524	0.006417	0.02139	0.02852	18.6806	0.00357	3.059	0.158286	0.72013
17-Mar-04	7277.1	25.0974	0.012033	0.01719	0.02865	34.4946	0.00458	5.604	0.13752	1.05432
31-Mar-04	6543.66	45.6108	0.026358	0.03438	0.1719	61.884	0.01719	8.079	0.34953	2.37222
14-Apr-04	4428.34	8.0934	0.013818	0.01974	0.02632	10.5938	0.00329	4.817	0.178976	0.76328
28-Apr-04	12442.5	39.9582	0.034128	0.02133	0.02133	13.5801	0.00356	23.819	0.317106	4.49352
12-May-04	2944.9	14.3639	0	0.0601	0.0601	15.6861	0	4.027	0.2404	1.5025
26-May-04	10877.28	36.3952	0.0688	0	0.0688	23.5984	0	11.834	0.344	4.472
9-Jun-04	7918.4	38.864	0.056	0	0.056	21.336	0	11.200	0.56	6.72
23-Jun-04	44712	2474.685	1.630125	0.6831	2.8566	968.76	0.41918	164.876	9.01692	164.565
7-Jul-04	39072	1176.6	0.82584	0.0888	0.7326	350.76	0.06216	102.564	2.76834	82.14
21-Jul-04	29944.04	881.65	0.182742	0.19236	0.83356	339.836	0.07053	60.914	1.869098	31.515
4-Aug-04	178727.4	19457.328	7.591306	7.3702	21.7421	12492.49	4.64323	725.965	27.343442	851.258
18-Aug-04	123320.4	26351.01	6.020595	15.41505	51.1896	10819.62	3.19935	433.367	35.803635	581.7
1-Sep-04	28827.81	2904.759	0.380952	0.62271	2.49084	904.761	0.20513	45.421	1.827837	39.5604
16-Sep-04	40837.65	7866	0.845595	1.76985	7.14495	2982.525	0.69483	67.517	3.48726	77.349
29-Sep-04	16849.58	3063.56	0.351253	0.18487	0.92435	1140.912	0.23505	29.843	0.541405	57.5738
13-Oct-04	14266.8	21.9286	0.099075	0.03963	0.1321	14.7952	0.00661	34.214	0.544252	6.64463
27-Oct-04	8551.44	31.7016	0.054168	0.03552	0.09768	26.4624	0.00444	17.938	0.384504	3.13464
10-Nov-04	12861.33	48.9873	0.053661	0.05193	0.10386	39.6399	0.00866	33.581	0.349662	3.68703
24-Nov-04	10366.38	31.7106	0.027018	0.04266	0.11376	40.8114	0.00711	31.142	0.399582	3.04308
8-Dec-04	13474.8	160.74	0.108756	0.02736	0.14364	56.8404	0.00889	71.136	1.080036	13.4748
22-Dec-04	11566.08	16.08192	0.08064	0.06912	0.20736	8.15616	0.01152	33.638	1.384704	5.92128
	644,829	**65,747**	**19.0**	**27.1**	**89.9**	**31,473**	**9.76**	**1,978**	**90.5**	**1,997**

NET CONTRIBUTION FROM THE BRUKUNGA MINE SITE (kilograms per annum)

2004	Sulphate	Aluminium	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
kilograms	568,244	63,954	18.5	13.1	77.7	28,584	4.96	1,822	81.7	1,944

Table A.1 Calculated loads of pollution in Dawesley Creek at Brukunga mine site 2004

2005 CALCULATED POLLUTION LOAD IN DAWESLEY CREEK

Dawesley Creek up-stream of Brukunga Mine **A4260658**

DATE	**Sulphate kg**	**Aluminium kg**	**Cadmium kg**	**Chromium kg**	**Copper kg**	**Iron kg**	**Lead kg**	**Manganese kg**	**Nickel kg**	**Zinc kg**
4-Jan-05	0	0	0	0	0	0	0	0.000	0	0
18-Jan-05	0	0	0	0	0	0	0	0.000	0	0
2-Feb-05	2858.436	162.1452	0.02786	1.22584	0.8358	295.8732	0.495908	22.555	0.729932	3.12032
16-Feb-05	1627.2	2.2032	0.0072	0.1152	0.072	17.568	0.01872	2.514	0.08352	0.3024
2-Mar-05	1107.72	5.60376	0.00543	0.0543	0.03258	18.0276	0.009774	1.598	0.052128	0.13032
16-Mar-05	743.6	7.0928	0.003575	0.0286	0.03575	17.6605	0.012155	3.220	0.04576	0.17875
30-Mar-05	799.14	4.92102	0.015422	0.02804	0.02804	13.2489	0.007711	5.838	0.044864	0.98841
13-Apr-05	716.42	6.5302	0.00317	0.02536	0.02536	15.0258	0.00951	4.292	0.020922	0.10778
27-Apr-05	949.62	5.0673	0.00399	0.02394	0.03192	10.0548	0.005586	3.663	0.030324	0.62244
11-May-05	354.64	7.4932	0.00143	0.02574	0.01716	10.868	0.007722	1.017	0.00143	0.09152
25-May-05	14.76	0.2496	0.00006	0.0006	0.00072	0.4872	0.00024	0.031	0.00006	0.00348
8-Jun-05	976.8	2.72505	0.00333	0.01665	0.0222	6.438	0.003885	0.569	0.01554	0.17205
22-Jun-05	4280.4	126.936	0.0246	0.1476	0.246	156.948	0.10332	5.540	0.03936	0.8856
6-Jul-05	3344.841	176.3946	0	0.33282	0.27735	174.7305	0.094299	4.981	0.05547	0.83205
20-Jul-05	1504.735	46.9025	0.000000	0.0771	0.08995	56.026	0.021845	2.038	0.02056	0.29555
3-Aug-05	1584.152	13.1083	0	0	0.05578	33.7469	0	1.919	0.016734	0.22312
17-Aug-05	3515.784	28.0728	0	0	0.04456	47.2336	0	3.338	0	0.40104
31-Aug-05	4918.902	104.7093	0	0.32468	0.24351	107.1444	0.056819	6.453	0.097404	1.05521
13-Sep-05	11189.18	237.3462	0	1.17936	0.7371	427.518	0.250614	23.528	0	3.24324
28-Sep-05	2587.4	49.98	0	0.204	0.136	114.58	0.0578	5.620	0.0204	0.816
13-Oct-05	7416.192	119.616	0	0.45568	0.45568	307.584	0.182272	10.777	0.5696	1.93664
26-Oct-05	43699.81	6368.593	0.967582	0	1.90344	3172.4	0.333102	237.137	3.085159	198.275
9-Nov-05	11931.26	463.9936	0	0.82856	0.952844	907.2732	0.393566	39.025	1.201412	3.93566
23-Nov-05	3546.855	19.2465	0	0.38493	0.291447	319.767	0.153972	10.443	0.269451	1.26477
7-Dec-05	1637.064	79.6484	0	0.24804	0.22048	199.81	0.129532	4.953	0.212212	1.12996
21-Dec-05	1140.96	244.831	0.014262	0.4754	0.432614	701.215	0.361304	9.033	0.337534	2.44831
	112,446	**8,283**	**1.08**	**6.2**	**7.2**	**7,131**	**2.71**	**410.1**	**6.95**	**222.5**
	If detetion levels used		**1.71**	**10.8**			**4.19**		**9.29**	

DATE	**Sulphate kg**	**Aluminium kg**	**Cadmium kg**	**Chromium kg**	**Copper kg**	**Iron kg**	**Lead kg**	**Manganese kg**	**Nickel kg**	**Zinc kg**
Dawesley Creek down-stream of Brukunga Mine					**A4260659**					
4-Jan-05	0	0	0	0	0	0	0	0	0	0
18-Jan-05	0	0	0	0	0	0	0	0	0	0
2-Feb-05	22518.84	599.748	0.486588	0.90528	1.18818	436.2318	0.463956	138.0552	3.28164	52.6194
16-Feb-05	13874.36	33.8551	0.031155	0.06231	0.12462	106.9655	0.016616	94.62812	0.365552	3.1155
2-Mar-05	9721.74	36.0003	0.018249	0.04977	0.11613	69.3462	0.009954	47.4474	0.3318	2.43873
16-Mar-05	3055.99	23.7804	0.014602	0	0.05215	45.6834	0.008344	13.3504	0.232589	1.61665
30-Mar-05	3494.4	22.776	0.0104	0	0.0416	51.272	0.00936	14.872	0.16432	1.7888
13-Apr-05	6049.5	17.658	0.00981	0	0.0545	41.638	0.00872	18.203	0.18312	1.3734
27-Apr-05	6704.76	22.1598	0.00947	0.02841	0.04735	64.0172	0.006629	67.8052	0.226333	1.87506
11-May-05	1306.26	12.8781	0.00369	0.01107	0.02583	22.6197	0.004059	5.3136	0.085239	0.87822
25-May-05	3798	4.176	0.00396	0.0054	0.0108	27.72	0.0009	53.46	0.19728	1.908
8-Jun-05	12075.6	35.0817	0.024984	0.03123	0.05205	75.5766	0.005205	129.084	0.404949	4.33056
22-Jun-05	84088.8	5515.236	2.901888	0.74196	4.61664	2291.832	0.469908	596.0412	11.599308	327.2868
6-Jul-05	83981.6	9364.32	3.716	2.15528	14.93832	4912.552	0.601992	572.264	17.011848	386.464
20-Jul-05	29246.8	5499.67	1.001385	1.01728	3.36974	2511.41	0.397375	136.0612	4.367946	211.7214
3-Aug-05	28324.8	4552.2	1.07904	0	3.0348	2485.164	2.151336	206.7036	2.920152	202.6572
17-Aug-05	36927.72	3807.597	1.111506	0.32151	2.34243	2007.141	0.174534	221.3826	6.554211	161.6736
31-Aug-05	16864	7310.544	1.534624	1.2648	6.23968	3524.576	0.657696	193.0928	8.819872	235.2528
13-Sep-05	71725.46	5570.328	1.961594	1.34766	5.39064	2545.58	0.419272	362.3708	12.57816	215.6256
28-Sep-05	35417.25	4550.58	0.828549	0.21465	1.33083	1850.283	0.266166	135.6588	1.446741	110.3301
12-Oct-05	61378.03	6177.064	1.819093	0.78522	5.2348	2656.661	0.314088	260.4313	11.359516	222.479
26-Oct-05	5419.56	203.4712	0	0.38032	0.38032	420.2536	0.152128	21.58316	0.608512	3.61304
9-Nov-05	74509.92	6903.744	2.631	2.52576	9.092736	4651.608	0.778776	405.174	13.89168	347.292
23-Nov-05	41238	1085.934	0.996585	0.20619	1.683885	629.5668	0.06873	308.73516	4.515561	133.3362
7-Dec-05	1902.888	1054.378	0.773396	0	0.728884	650.988	0.08346	124.52232	2.534402	101.2648
21-Dec-05	11926.74	175.9058	0.138873	0	0.419342	167.7368	0.035399	57.31915	0.923097	12.77087
	665,551	**62,579**	**21.11**	**12.05**	**60.5**	**32,246**	**7.10**	**4,183.6**	**104.60**	**2,743.7**
	If detetion levels used		**21.23**	**12.39**		Missing values taken as the average of the two adjacent values				

NET CONTRIBUTION FROM THE BRUKUNGA MINE SITE (kilograms per annum)

2006	**Sulphate**	**Aluminium**	**Cadmium**	**Chromium**	**Copper**	**Iron**	**Lead**	**Manganese**	**Nickel**	**Zinc**
kilograms	**553,105**	**54,296**	**20.0**	**5.9**	**53.3**	**25,115**	**4.39**	**3,773**	**97.7**	**2,521**

Table A-2 Calculated loads of pollution in Dawesley Creek at Brukunga mine site for 2005

NET POLLUTION LOAD FROM THE BRUKUNGA MINE SITE (kilograms per annum)

Year	Water flow M-litres	Sulphate kg	Aluminium kg	Cadmium kg	Chromium kg	Copper kg	Iron kg	Lead kg	Manganese kg	Nickel kg	Zinc kg
1998	696	649,219	108,376	53.0	29.0	127.0	46,485	10.00	3,832	224.0	2,995
1999	904	796,743	81,642	22.0	76.0	187.0	19,576	7.00	4,668	211.0	3,054
2000	2,180	1,866,054	231,425	69.0	603.0	1,221.0	111,028	24.00	12,816	507.0	8,689
2001	1,703	932,150	24,496	38.0	47.0	185.0	91,724	17.00	5,815	146.0	5,247
2002	416	447,016	71,368	8.4	9.1	35.4	18,869	1.96	2,460	78.6	1,761
2003	1,179	511,087	75,991	21.88	32.3	103.2	37,626	13.79	2614	119.8	2,604
2004	**1,032**	**568,244**	**63,954**	**18.5**	**13.1**	**77.7**	**28,584**	**4.96**	**1,822**	**81.7**	**1,944**
2005	**1,258**	**533,105**	**54,296**	**20.0**	**5.9**	**53.3**	**25,115**	**4.39**	**3,773**	**97.7**	**2,521**

Table A-3. Annual net pollution loads in Dawesley Creek at Brukunga mine site

NET POLLUTION LOAD FROM BRUKUNGA MINE SITE (kilograms per Mega-litre of flow)

YEAR	Sulphate kg/Ml	Aluminium kg/Ml	Cadmium kg/Ml	Chromium kg/Ml	Copper kg/Ml	Iron kg/Ml	Lead kg/Ml	Manganese kg/Ml	Nickel kg/Ml	Zinc kg/Ml
1998	933	156	0.0761	0.0417	0.182	66.789	0.0144	5.506	0.3218	4.303
1999	881	90	0.0243	0.0840	0.207	21.646	0.0077	5.162	0.2333	3.377
2000	856	106	0.0317	0.2766	0.560	50.930	0.0110	5.879	0.2326	3.986
2001	547	14	0.0223	0.0276	0.109	53.860	0.0100	3.415	0.0857	3.081
2002	1076	172	0.0201	0.0220	0.085	45.402	0.0047	5.919	0.1892	4.237
2003	434	64	0.0186	0.0274	0.088	31.919	0.0117	2.218	0.1016	2.209
2004	**551**	**62**	**0.0179**	**0.0127**	**0.075**	**27.698**	**0.0048**	**1.766**	**0.0792**	**1.884**
2005	**424**	**43**	**0.0159**	**0.0047**	**0.042**	**19.964**	**0.0035**	**2.999**	**0.0777**	**2.004**

Table A-4. Annual net pollution loads at Brukunga normalised for annual flow quantity

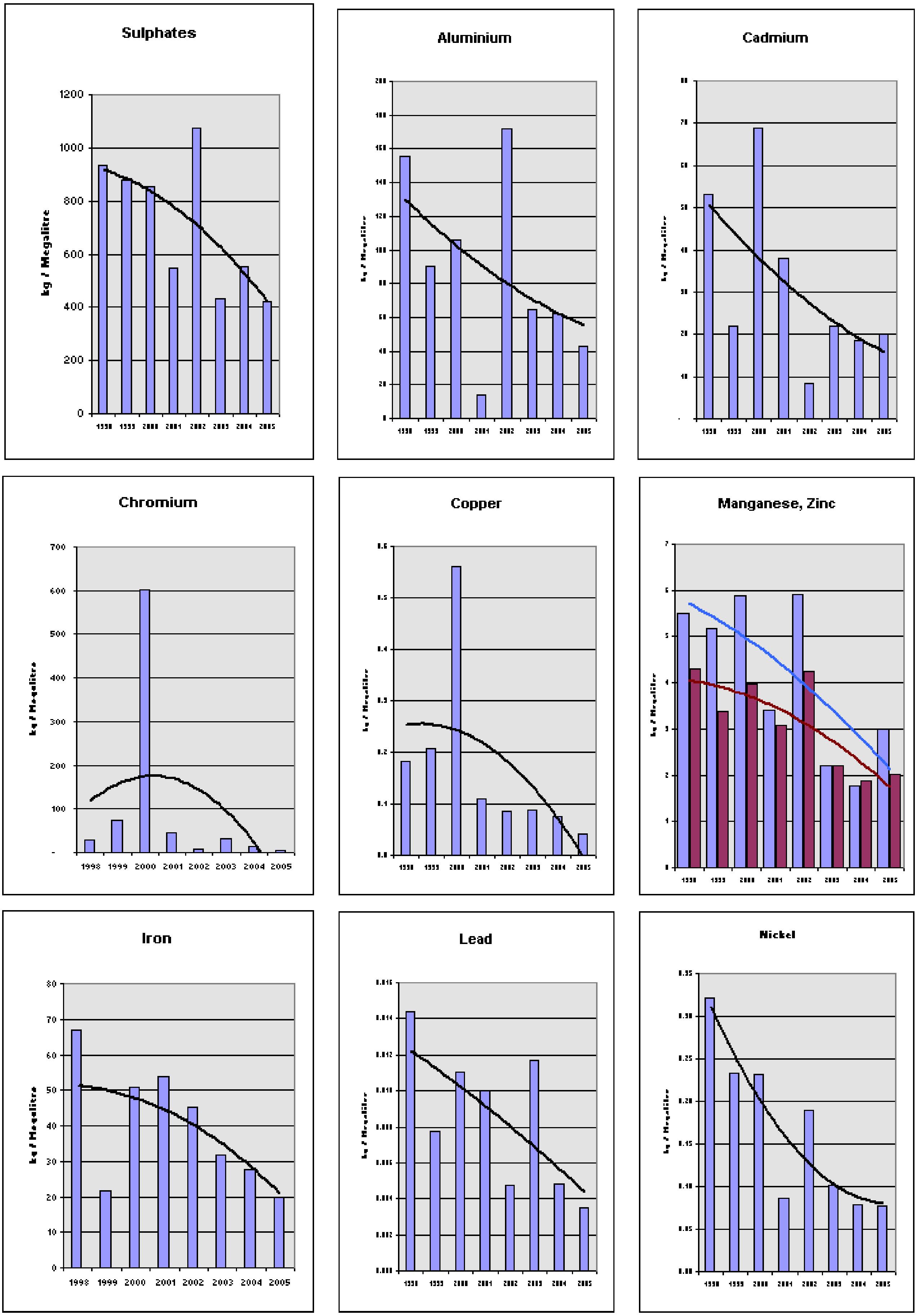

Fig A-4. Graphs of annual load of pollutant in Dawesley Creek 1998 to 2005 (kilograms / Mega-litre of flow)

APPENDIX B

BIOLOGICAL MONITORING RESULTS

- **Macro-invertebrate Results 2004** pages 23 - 71

  (followed by Macro-invertebrate Results for 2005)

Brukunga Acid Mine Drainage Impact Monitoring Program: Macroinvertebrate Results 2004

Submitted by Australian Water Quality Centre, (compiled by: Sally Maxwell and Scott Howell)
for Primary Industries & Resources, South Australia (PIRSA)

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Tables and Figures

1. Introduction

The Brukunga Acid Mine Drainage Impact Monitoring Program, initiated in the 1996–1997 financial year, involved monitoring macroinvertebrate and chemical parameters at sites on the Dawesley Creek – Bremer River system. The Australian Water Quality Centre (AWQC) conducted biological monitoring for Primary Industries & Resources SA subject to an Environment Protection Authority licence agreement for management of the disused Brukunga pyrites mine. The principal aim of the monitoring program was to investigate the impact of Acid Mine Drainage (AMD) on Dawesley Creek including the downstream extent of the impact. This report provides a summary of macroinvertebrate results for 2004 and provides comparisons with data from past years.

2. Methods

Macroinvertebrate Sampling Method

All macroinvertebrate sampling was conducted with sweep nets (250 μm mesh) and conformed to the Australian Rivers Assessment System (AusRivAs) standard protocol, where a 10 metre section of stream is sampled (Anon. 2001). Edge habitat was chosen because it is the only habitat present at the range of flows experienced at the sites, and thus it permits a fair comparison to be made across all sites and times. The South Australian AusRivAs laboratory scoring protocol was used to process samples. The protocol involves counting all organisms in a randomly chosen 10% of the sample from a Marchant sub-sampler (Marchant 1989). Sub-sampling continued until a minimum of 200 animals ha been identified; for the purposes of obtaining a representative sample. Identification was taken to the lowest practical level using the latest keys (Hawking 2000) and the AWQC voucher collection. Identification was carried out at family level or lower in all groups except Turbellaria, Nematoda and some Oligochaeta (where they were identified at the levels stated). Most Insecta and Mollusca were taken to species. The Dipteran families Ceratopogonidae, Tipulidae, Psychodidae, Stratiomyidae and Simuliidae were taken to species or morpho-species and the Culicidae were taken to genus. The Chironomidae were taken to genus where possible (and in some cases to species) and other dipteran families were not identified below family.

Sites

Regular macroinvertebrate monitoring has been conducted in the system since September 1996. The six sites monitored in 2002, 2003 and 2004 are listed in Table 1, in order of increasing distance down the catchment. These sites were sampled quarterly (in March, June, September and December). The duration of monitoring at each site is included. Figure 1 is a map of the streams showing all sites that have been sampled during the project.

Table 1. **Macroinvertebrate sites, and monitoring duration.**

Site Name	Label	Monitoring Duration	AWQC Location Code
Dawesley Ck. at Peggy Buxton Rd	**Site 1**	Sept. 1996 – Dec. 2004	4728
Dawesley Ck. D/S Brukunga	Site 2	Sept. 1996 – Dec. 2004	3158
Dawesley Ck. at McIntyre Rd	Site 3	Sept. 1996 – Dec. 2004	1951
Dawesley Ck. at Balyarta Ford	Site 4	Sept. 1996 – Dec. 2004	1822
Dawesley Ck. at Freeway	Site 5	Dec. 1996 – Dec. 2004	1952
Nairne Ck. at Djatadapeel Ford	Site 6	Sept. 1996 – Dec. 2004	1953

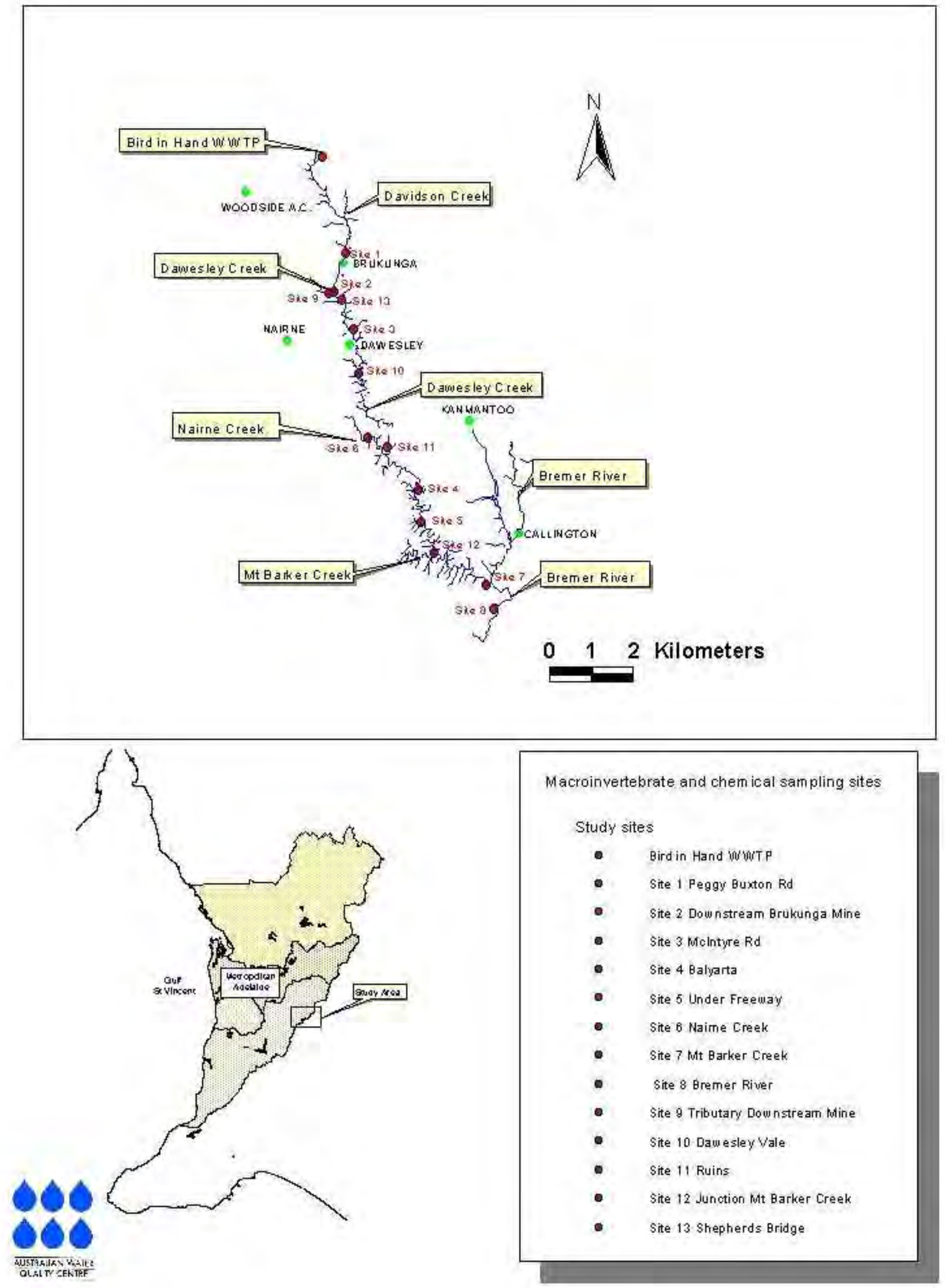

Figure 1. **Location and site map Dawesley Creek System**

Interpretation of Macroinvertebrate Data

Species richness, which reflects the number of different types of macroinvertebrates identified in a sample, can be used to estimate the health of a stream. In this report, the term taxon richness is used - as not all the taxa that were counted are species. As detailed in the previous section, some taxa were only identified to family, some to genus and others to species. The taxa present in each sample and the abundance of each taxon reflects the differences between sites, habitats and conditions prior to the date of sampling. There are no simple rules for interpreting these complex data sets. Variation due to factors such as extreme flow events, time of day, chance colonisation by rare taxa, and weather conditions is always present in addition to the variation due to water quality, season, habitat variability, ambient temperature and plant productivity. Statements regarding abundance in this report refer to the abundance within the sub-sampled portions of each collection.

As indicated in the 2003 report, multivariate analyses (MVA) were used to interpret all the data from 2002 to 2004 (inclusive). Upon recommendation from the 2003 report 2002 to 2004 data were combined to observe patterns and changes over these years. MVA are statistical procedures that can detect similarities in biological community data. MVA are a broad set of objective tools that can be used to seek and reveal structure within complex data sets avoiding investigator subjectivity. Ordination and classification of macroinvertebrate community data (i.e. the taxa present and their abundance) provide an assessment of how similar or dissimilar samples are. Both spatial and temporal patterns can be detected which simple diversity indices and raw taxon richness and abundance figures may not reveal. When two different MVA methods detect the same pattern the degree of confidence in the validity of the pattern is increased.

The statistical package PATN was used to carry out both classification (Flexible UPGMA) and ordination (SSH multidimensional scaling). The Bray-Curtis association measure was used on untransformed abundance data for both methods.

AusRivAS can provide additional information. It uses family level data to compare a sample with the community found at best available reference sites with similar environmental characteristics. It produces a rating that is a guide to the level of any impact and also calculates the probability of each family occurring in a sample. These outputs are useful to determine the effectiveness of the rehabilitation of the creek by comparing the fauna to reference sites. The results from AusRivAS analysis of 2004 data are included in this report.

The AusRivAS models function by using chemical and physical variables to classify a sample and then predict the families that should be present in that sample if it were from a reference site based on the classification group probabilities. This predicted (or "***Expected***") number of families is then compared with the number of families collected (or "***Observed***") in the sample. The comparison is in the form of a ratio of the Observed: Expected number of families – or OE in AusRivAS. The models make frequent use of a 50% probability of taxon occurrence at a site. This is because those taxa with a > 50% chance of occurring are considered the most useful for detecting a real decline in the number of taxa (Coysh *et al.* 2000). The AusRivAS output used in this report is the OE50 which is the observed: expected ratio for families predicted at greater than 50% probability for a sample. The OE50 ratio can be simplified to a band. Band ratings are X (higher than expected observed number of taxa), A (equivalent to reference), B (reduced number of families and therefore significantly impaired), C (severely impaired) and D (extremely impaired). The probabilities which determine the boundaries between bands may be different for each model season, as they are based on percentiles.

3. Results

Macroinvertebrate Diversity Results 2004 Surveys

The primary results consist of a list of the taxa recorded at each site and the abundance estimate of each taxon. To ensure the greatest compatibility between data sets generated at different times by different operators, only the highest taxonomic level data were used for Oligochaeta and aquatic mites. In order to ensure the most accurate representation of taxon richness results where both adult and immature specimens of the same taxon were present in the sample, the data were combined. In this report only the taxon richness is discussed in detail. Richness is a measure of the diversity of the macroinvertebrate community. A higher number of taxa generally indicates a more natural site with less human-induced stress. It is also accepted that a more diverse community will recover more quickly from both natural and human-induced stresses compared with a community with low diversity.

In the graphs that summarise the macroinvertebrate data, the pH measured in the field at the time of sample collection have been added to indicate the major differences in water chemistry at different sites and times. Even though a clear correlation between taxa and pH is evident, causality is not implied. There are many differences in the chemistry of low pH AMD and higher pH (neutral or alkaline) streams. The reduced diversity is not simply attributable to increased acidity.

March 2004

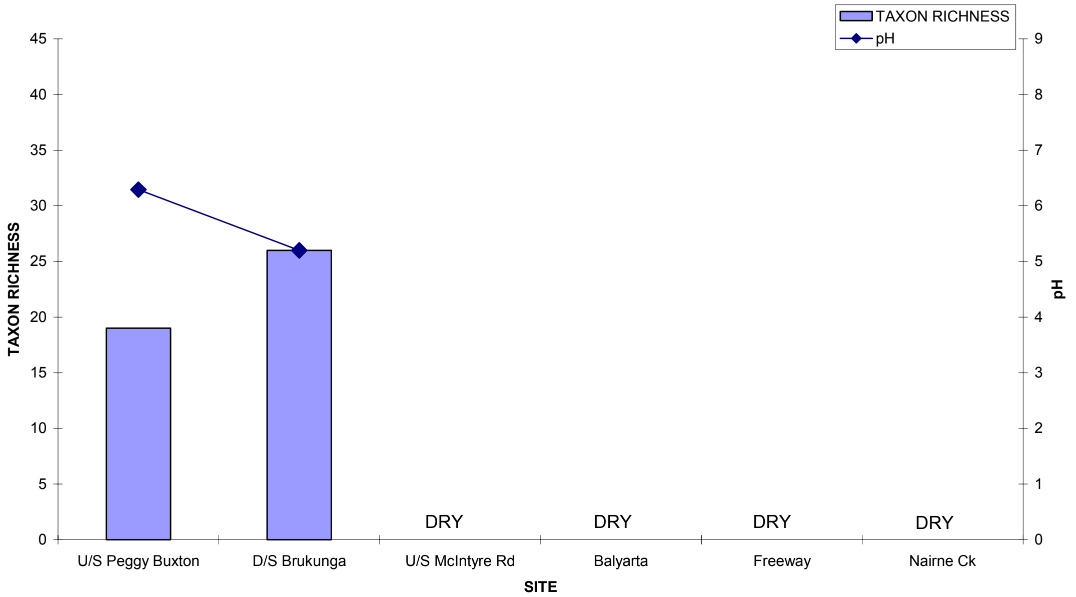

***Figure 2*. March 2004 taxon richness and pH.**

In previous years Dawesley Creek sites have commonly been dry in March and 2004 was no exception (Figure 2). Only two sites held water in March 2004 – Peggy Buxton Road and Dawesley Creek, downstream of the mine. Nairne Creek was dry in March for the fist time throughout the monitoring duration. This is thought to be a result of the closure of the Chapmans Smallgoods factory. Local property owners suggested that condensation from large refrigerated cool rooms had previously been a major contributor to flow in Nairne Creek.

June 2004

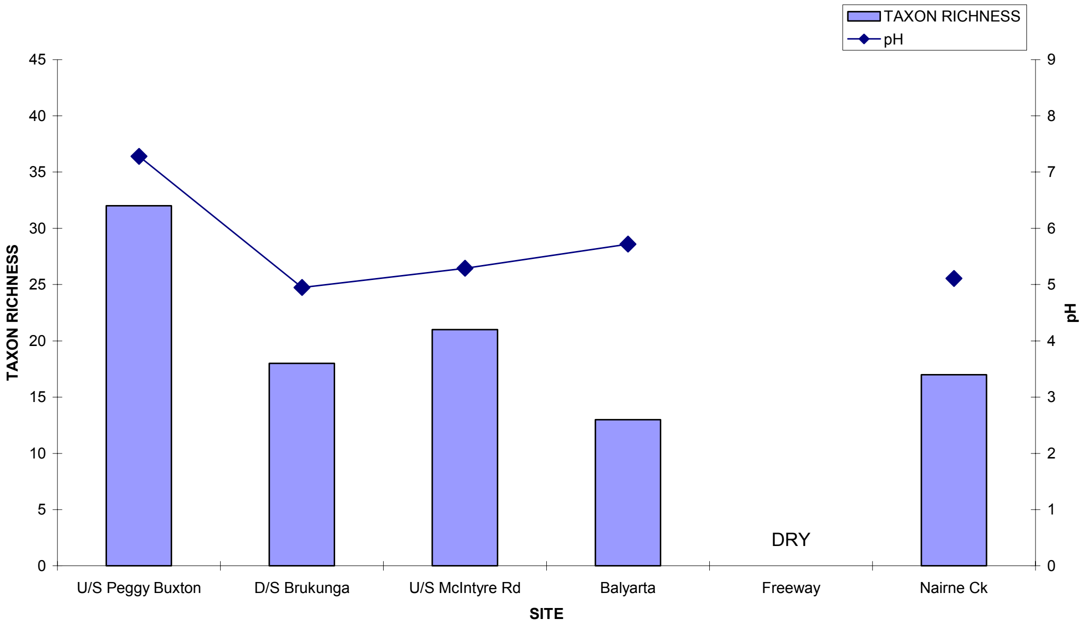

***Figure 3*. June 2004 taxon richness and pH.**

The June sampling results (Figure 3) repeated the typical pattern shown in past years (see Figure 6); that of lower diversity and lower pH at sites downstream of the mine. Peggy Buxton Road had the highest taxon richness with 32 taxa collected including four species of Crustacea. Balyarta had the lowest number of taxa collected and the lowest abundance of individuals. The sample contained 13 taxa and had very low abundance (30% had to be processed to meet the minimum of 200 specimens in a sample). Only 17 taxa were collected at Nairne Creek compared with 35 in June 2003. The reduction in taxa is likely a result of the change in site flow characteristics from permanent water to an ephemeral pool.

September 2004

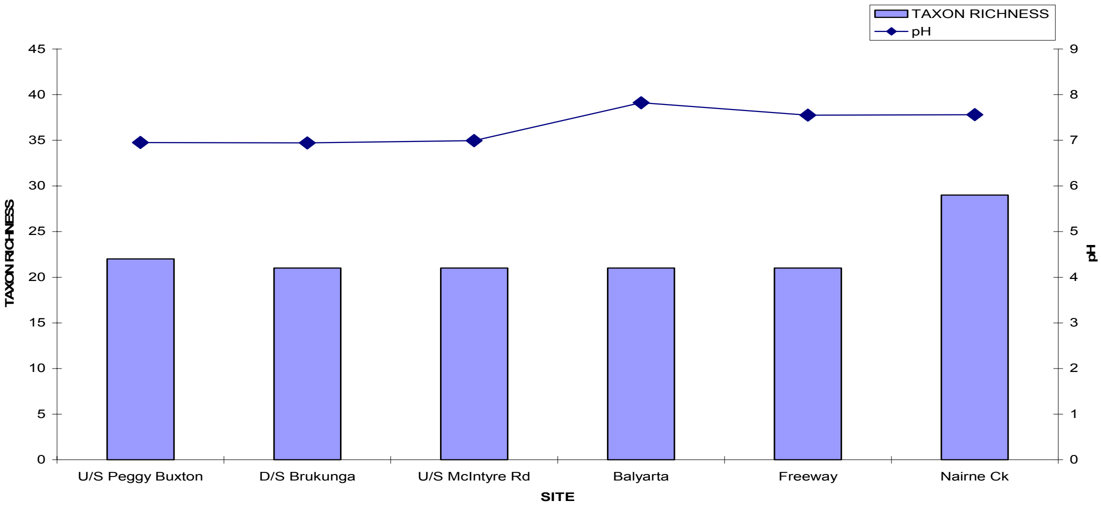

***Figure 4*. September 2004 taxon richness and pH.**

The September data showed circum neutral pH levels at all sites and the taxon richness in the Dawesley Creek sites were equivalent to that recorded at Peggy Buxton Road and approaching the richness recorded at Nairne Creek (Figure 4). At Dawesley Creek under the freeway excess gravel from the service road had washed into the creek possibly creating some disturbance in the system.

December 2004

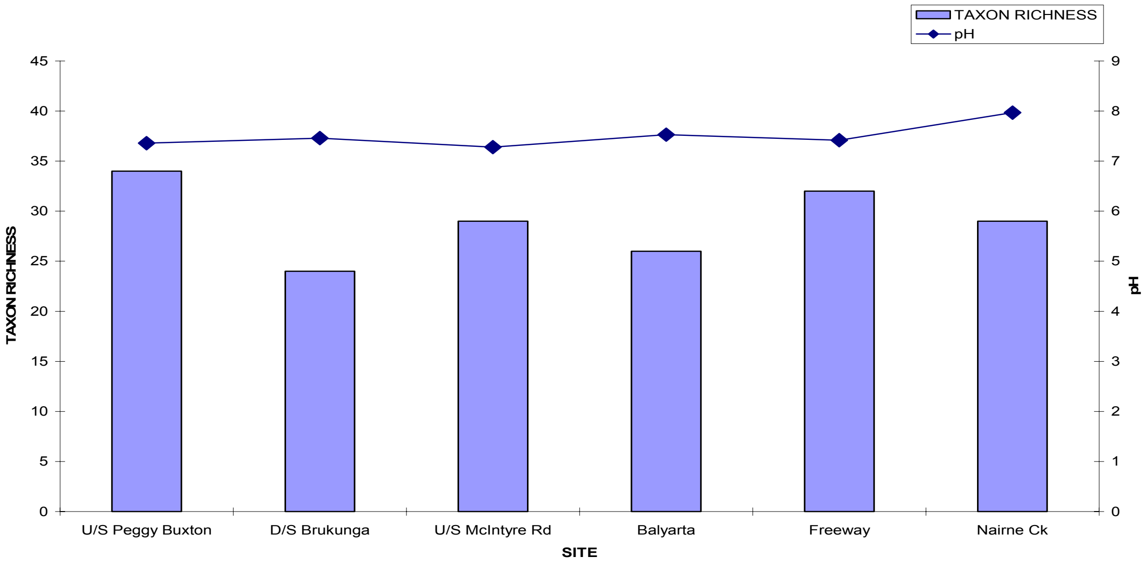

***Figure 5*. December 2004 taxon richness and pH.**

A pH between seven and eight was observed at all sites during 2004 and importantly pH neutral was recorded at the d/s mine site, as in December 2003. Due to recent rain in the Dawesley creek catchment, the site under the freeway was flowing; an unusual occurrence for that time of year. The December results followed the same pattern shown in 2003. Neutral pH levels were recorded at all sites and the taxon richness in most Dawesley Creek sites downstream of the mine were close to that recorded at Peggy Buxton Road and in Nairne Creek. Riffle habitat was again observed d/s of the gauge at Peggy Buxton Road and colonisation of macrophytes was also recorded.

Mean taxon richness 1996-2004

Figure 6 shows the mean taxon richness and standard deviation at each site, in all samples from 1996 to 2004, arranged in order along the stream. Although Peggy Buxton Road on Dawesley Creek is upstream of the Brukunga mine and is unaffected by AMD it is not necessarily a good measure of an un-impacted site. This is because the Bird in Hand Wastewater Treatment Plant is at the headwaters of Dawesley Creek causing Peggy Buxton Road to be eutrophic at times. Nairne Creek is a better reference site for this study since it is only slightly eutrophic as well as not impacted by AMD.

In 2003 the mean results clearly show the impact of the AMD on Dawesley Creek - reducing the taxon richness downstream of the site on Peggy Buxton Road. The AMD impact prior to 2003 had been highest at the site downstream of the mine but in 2003 the taxon richness at this site was on average much higher than that at McIntyre Road, which was the most heavily affected site for that year. On average, through all the years, the site downstream of the mine did appear to have the lowest richness but due to high variation in the data this does not seem significant. McIntyre road could be said to be on average equally as impacted as the mine site.

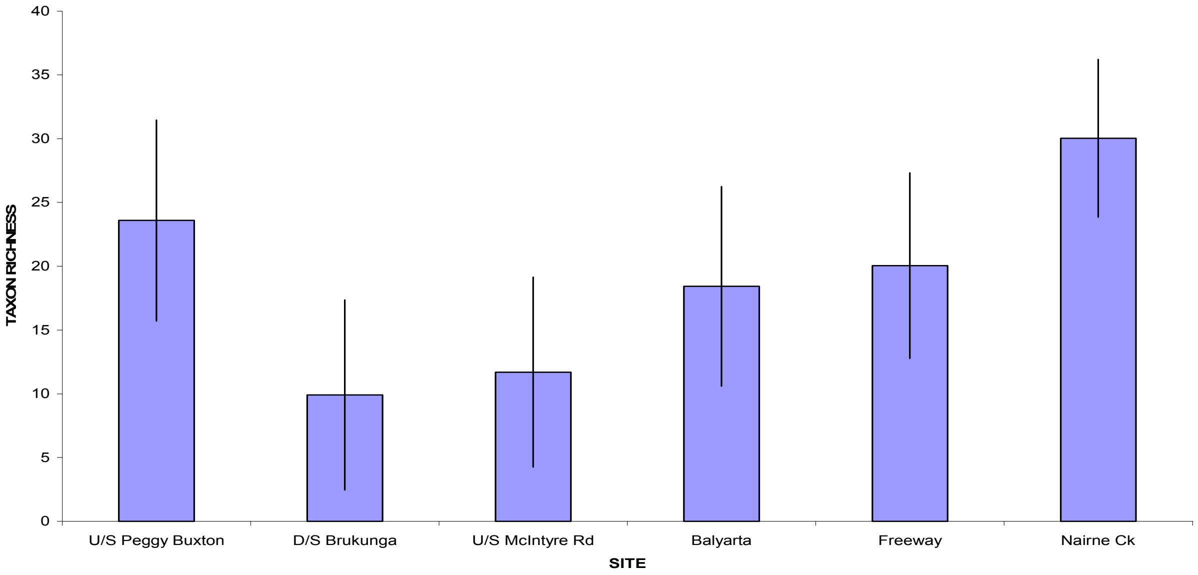

***Figure 6*. Dawesley Creek system: taxon richness six sites: 1996 - 2004.**

(bars represent standard deviation)

Temporal Changes at Each Site

At each of the six sites the full data set from September 1996 to December 2004 has been presented in a series of graphs (Figures 7-12). This allows the 2004 data to be compared with the findings of earlier years.

Peggy Buxton Road (immediate upstream of the Mine Site)

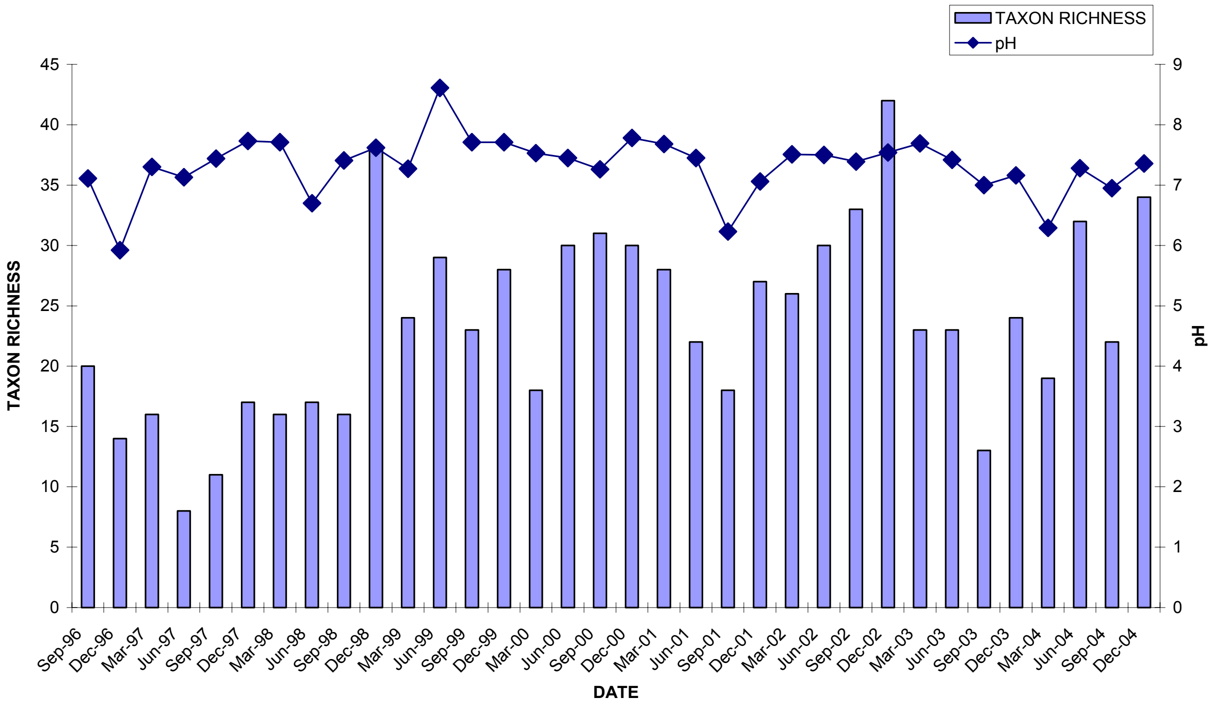

Figure 7. **Dawesley Creek: Peggy Buxton Road. Taxon richness and pH.**

Water discharged from the Bird in Hand Wastewater Treatment Plant was found to affect conditions at Peggy Buxton Road. Macroinvertebrate species richness was depressed at times due to eutrophic conditions (Figure 7). Flow levels were variable and often ceased in autumn but the pools remained and a macroinvertebrate community was always present. Both floods and periods of ceased flow impacted the community causing reduction in species richness. Prolonged periods of normal flow, on the other hand, created favourable conditions for macroinvertebrates which resulted in increased taxon richness. The species richness was usually much higher than that found immediately downstream where AMD enters the creek. Taxon richness peaked in 2002 when 42 different taxa were recorded in December. The lowest numbers of taxa were recorded in June 1997 and September 2003 when 7 and13 taxa were recorded, respectively. Stream pH fluctuated over the years from 6 to 8.

Downstream Brukunga (immediate downstream of the mine site)

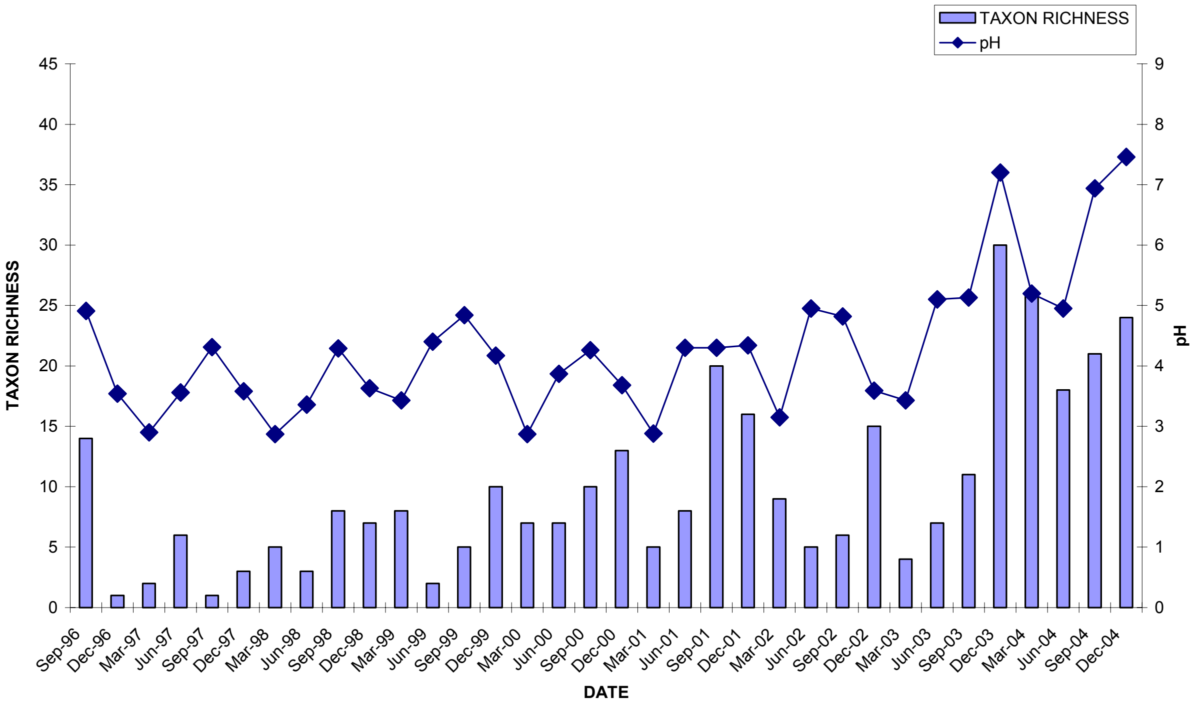

***Figure 8*. Dawesley Creek: Downstream of Brukunga mine. Taxon richness and pH.**

The pH measurement in December 2003 was the first recorded above 7 since the diversion became operational.

Measurements in 2004 followed this trend showing the highest recorded pH for March and June since 1996 and again, circumneutral conditions in September and December 2004 (see Figure 8).

In 2004, the maximum taxonomic richness was recorded for all seasons except for December where it was marginally higher in 2003.

Upstream McIntyre Road (~2 km downstream of the mine site)

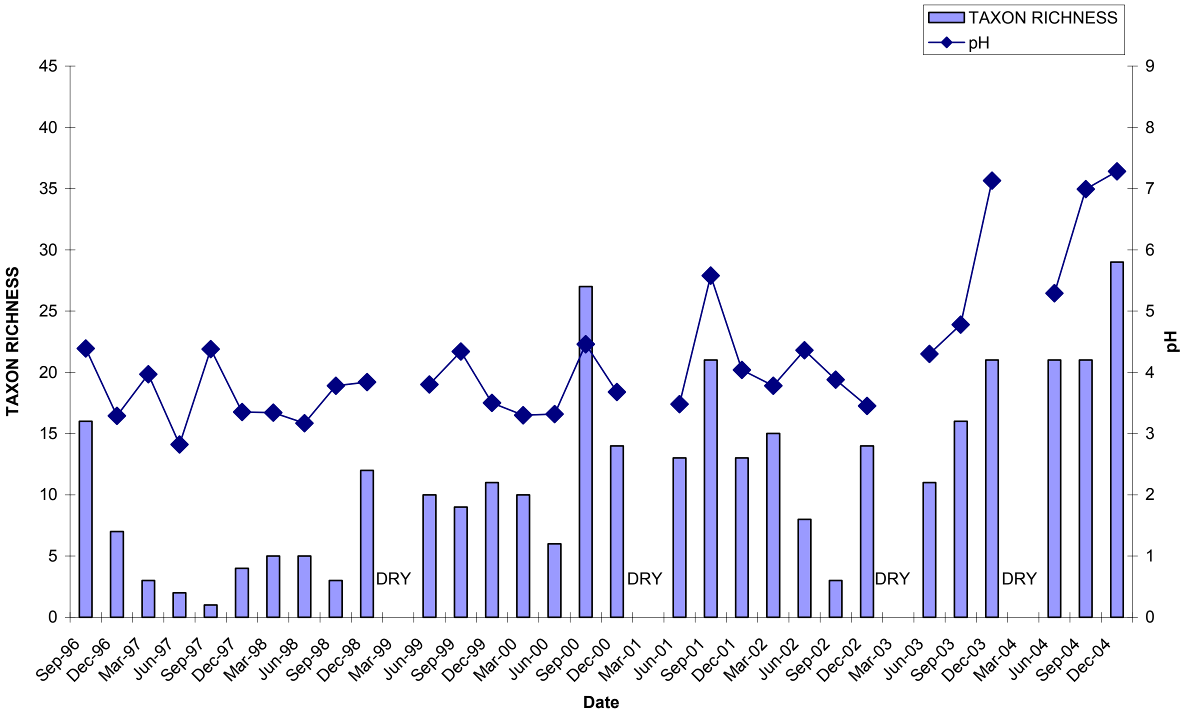

***Figure 9*. Dawesley Creek: McIntyre Road. Taxon richness and pH.**

The 2004 data showed the highest pH levels recorded for the site at all sampling dates since 1996 (Fig. 9).

The taxon richness was the highest recorded for all seasons except September and the samples showed less dominance by *Tanytarsus fuscithorax,* indicating reduced impact of AMD.

This site has showed a general improvement over the years in terms of pH and consequently taxon richness.

December 2004, the last date to be sampled, showed the highest richness ever measured at the site.

Balyarta

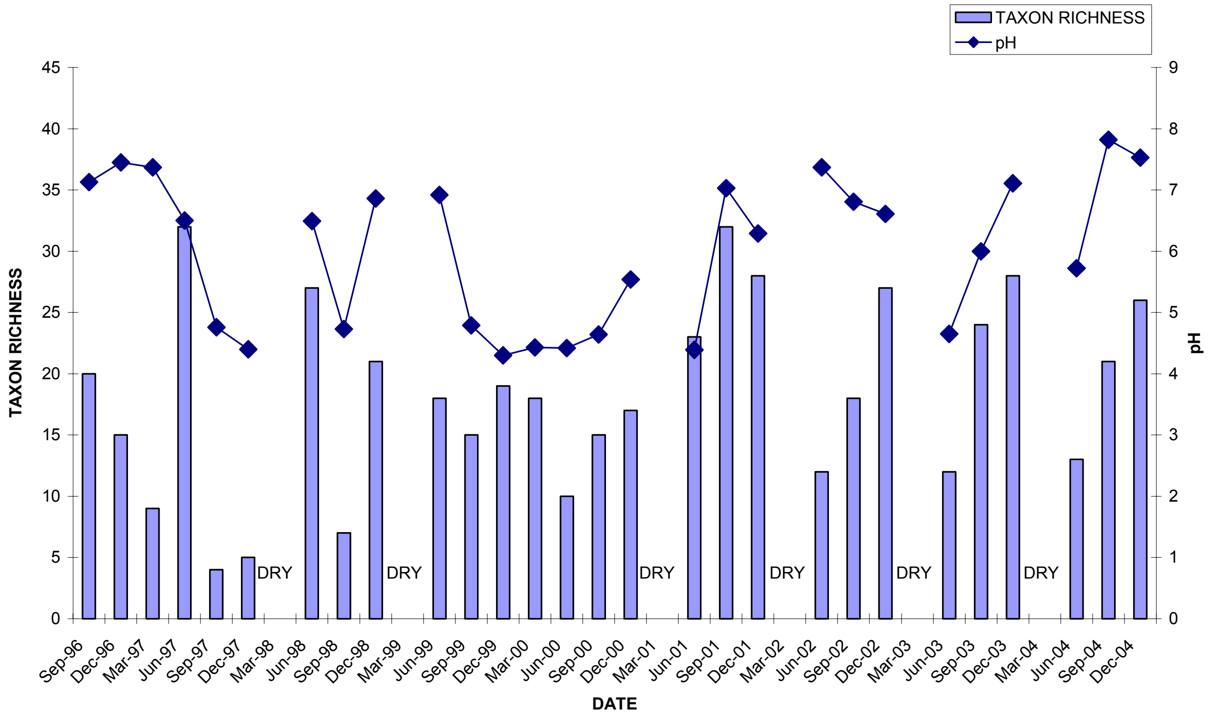

***Figure 10*. Dawesley Creek: Balyarta. Taxon richness and pH.**

The section of Dawesley Creek downstream of its confluence with Nairne Creek was usually dry in late summer and early autumn. There was variation from year to year in the degree of effect of low pH water from the mine at this site. These year to year variations are dependent on the amount of rainfall and flow.

The 2004 data followed the pattern shown in most years since 1997, i.e. the taxon richness decreased when the AMD influence extended downstream (Fig. 10).

The stream pH in 2004 showed similar seasonal trends to most years since 2000; however the values were noticeably higher at all sample dates.

In 2003, AMD impact on the macroinvertebrate community of the Balyarta site appeared to have been reduced and this trend continued in 2004.

Freeway

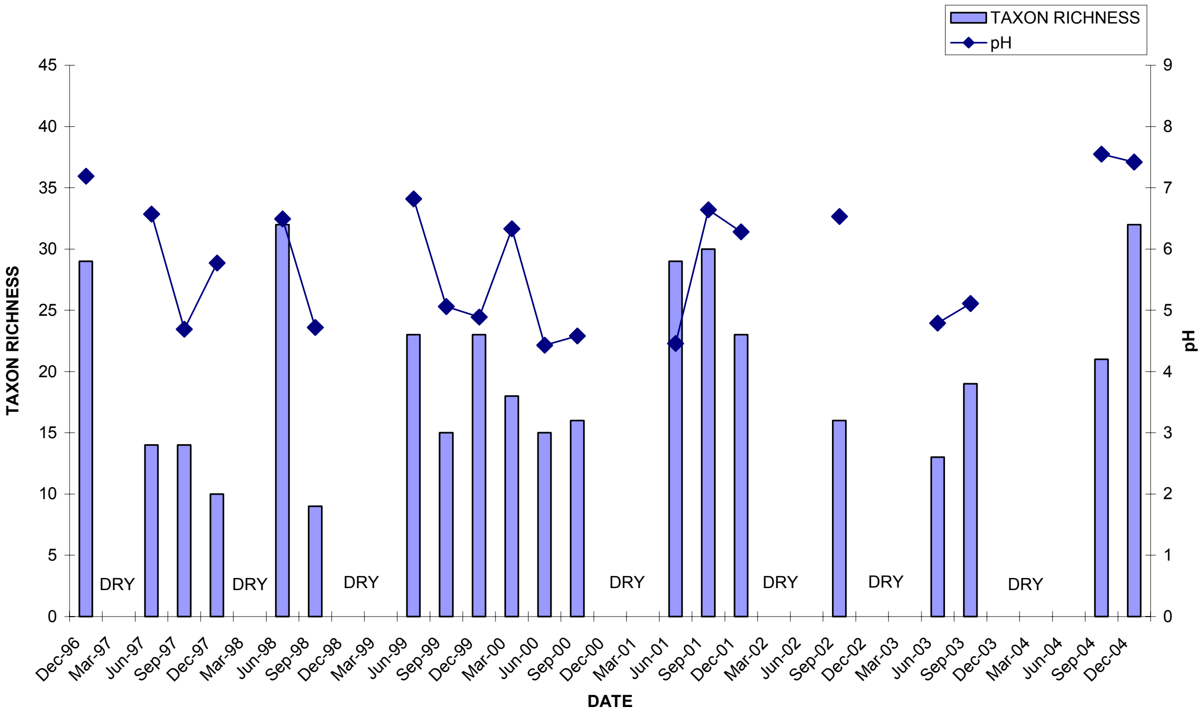

***Figure 11*. Dawesley Creek: Freeway. Taxon richness and pH.**

The Freeway site was sampled just twice in 2004 and 2003 (September and December) and (June and September) respectively and only once in 2002 (June) (Figure 11). As an intermittent site the taxon richness has been variable over the years of monitoring (Fig.11).

Simply by chance, sampling may have taken place a few days, a few weeks or a few months after the site was wetted. Consequently, the time for the community to establish at the site before sampling occurred also varied. In some cases the time was sufficient for a diverse community to establish but at other times there may have been only a short time between inundation and sampling.

The samples from 2003 were thought to be affected somewhat by AMD as the pH was about 5 on each sampling occasion.

Of the two records in 2004 the pH was relatively close to neutral, which suggests that the AMD influence was subdued or absent at these times.

In 2004 this site appeared to be in a phase of recovery with higher than average taxon richness.

Nairne Creek (a control site not influenced by AMD)

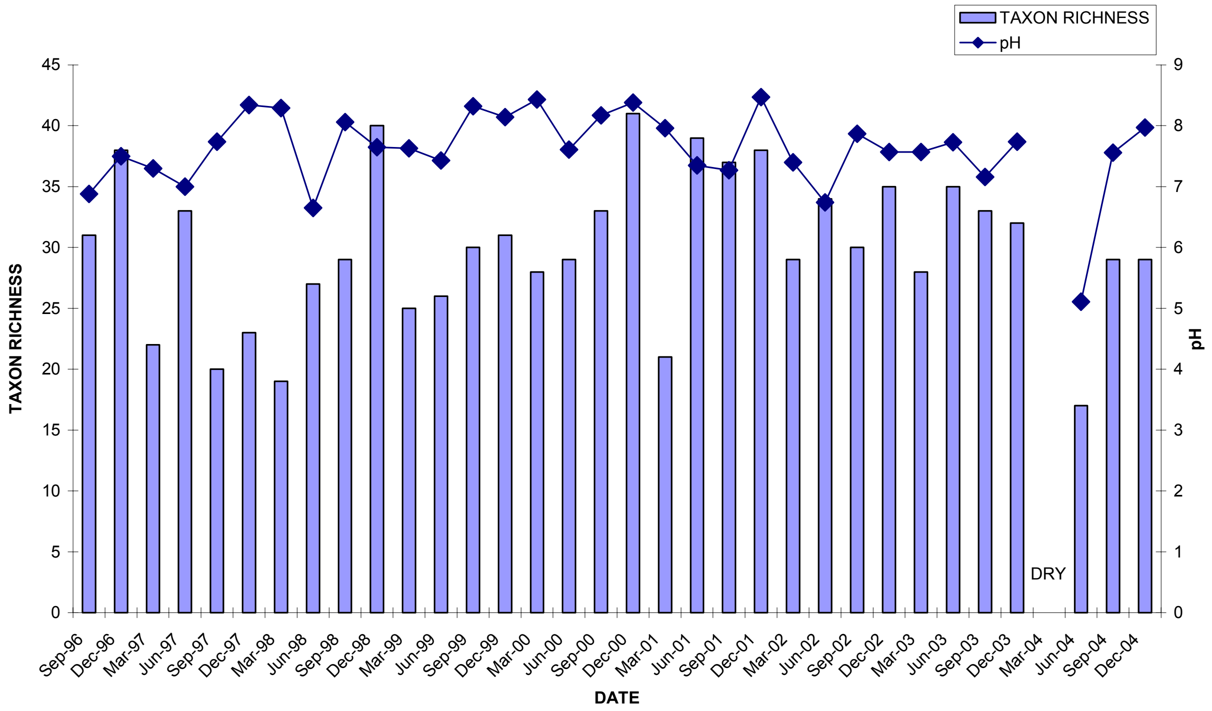

***Figure 12*. Nairne Creek. Taxon richness and pH.**

From 1996 to 2003 this control site was slightly eutrophic but had a taxon richness and pH that was comparable to other Mount Lofty Ranges streams with reasonable water quality (Figure 12).

It reflected the condition expected to prevail in Dawesley Creek if AMD and treated wastewater from the Bird-in-Hand WWTP were not present, with highest taxon richness in winter and spring.

However, in March 2004, it was dry for the first time on record and pH surprisingly dropped to five in June. The explanation for this is unclear but could suggest the groundwater entering Nairne Creek is acidic. Taxon richness was the lowest ever recorded in this month reflecting the water quality change.

Richness in September and December were also the lowest ever recorded for these months, even though pH had recovered to usual levels. The changes at this site are thought to reflect the shift from a permanent to an intermittent stream following the closure of the Chapman's Smallgoods factory located upstream. Local land owners' report that the creek now rarely flows in summer as Chapman's no longer discharge condensation from their refrigerators and freezers into the creek.

Unseasonable rain in Late November/December caused the flow in December and also accounts for the low taxon richness recorded as the community was re-establishing.

AusRivAS Results

Three seasonal models were used in this study, the Autumn edge model, Spring edge model and the Combined season edge model. The samples from March and June were tested in the Autumn edge model and the samples from September and December were tested in the Spring edge model. The Combined season edge model data was produced by summing the abundance of each invertebrate family in June and December samples. Results from the AusRivAS models in 2004 are shown in Table 2.

In 2003, the OE50 scores and resultant bands showed that Peggy Buxton Road and Nairne Creek were expectedly the best sites and those downstream of the mine on Dawesley Creek were impaired to more or less degrees. Peggy Buxton Road was equivalent to reference (Band A) in most results and Nairne Creek was the same except for December. Sites that rated as severely impaired (Band C) were downstream of Brukunga in March and McIntyre Road in June, which were the samples with the lowest taxon richness in 2003. All scores for McIntyre Road and the Freeway were Band B (significantly impaired) or lower. The Brukunga Mine and Balyarta sites were Band B or C except in December when they were rated as equivalent to reference.

For the 2004 data the OE50 scores and corresponding bands showed that Balyarta and the Freeway were significantly impaired (B) throughout 2004. McIntyre Road was also significantly impaired in June and September but was equivalent to reference in December (A). No site score was significantly impaired (Band C) in 2004. Nairne Creek was dry in March and was significantly impaired during June and September. However it had recovered to reference condition by December. Peggy Buxton Road was equivalent to reference (Band A) in most results and importantly the Brukunga Mine site was equivalent to reference in all results.

In the Combined season model for 2003 the sites at McIntyre Road and Balyarta were rated as significantly impaired and the other sites as equivalent to reference. These results contrast with 2004 where the sites at Nairne Creek and Balyarta were rated as significantly impaired and the other sites were equivalent to reference. The Freeway site was not used in the combined season model in 2004 as it was dry in June.

Table 2. **AusRivAS results for sites sampled in 2004.**

		Peggy Buxton	**Brukunga Mine site**	**McIntyre Road**	**Balyarta**	**Freeway**	**Nairne Creek**
		4728	**3158**	**1951**	**1822**	**1952**	**1953**
March	**OE50**	0.73	1.12	DRY	DRY	DRY	DRY
	Band	B	A				
June	**OE50**	0.87	0.93	0.72	0.5	DRY	0.65
	Band	A	A	B	B		B
September	**OE50**	0.71	0.83	0.59	0.63	0.55	0.78
	Band	B	A	B	B	B	B
December	**OE50**	1.05	0.88	1.06	0.68	0.78	0.82
	Band	A	A	A	B	B	A
Combined Season Jun/Dec	**OE50**	1.01	0.88	0.94	0.64	DRY	0.79
	Band	A	A	A	B		B

Multivariate Analysis Results

Cluster analysis

Results of the cluster analysis produced a dendrogram (Figure 13), which grouped samples with similar macroinvertebrate communities. For the year 2004 data there were three groups in the dendrogram (marked with rings) as in 2003 (Brukunga Report 2003) and 2002 (Figure 31, Randall and Cox, 2003). However, the group membership of sites changed considerably over the years.

The dendrogram for 2002 could be simplified by saying that the sites that were repeatedly affected by AMD (D/S Brukunga and McIntyre Road) were grouped together and the sites unaffected by AMD (Peggy Buxton Road and Nairne Creek) were grouped together. The sites sometimes affected by AMD (Balyarta and the Freeway) formed an intermediate group.

Similarly, it was observed in 2003 that the group in best condition included all Peggy Buxton Road and Nairne Creek samples but differed from 2002, as it also included the September and December samples from the downstream Brukunga mine site. These sites all had a reasonably even distribution of taxa i.e. no particular species dominated the total abundance of invertebrates.

The intermediate group in 2003 included McIntyre Road and the Freeway in June and September and Balyarta from September. These sites were all similar in that they had a community that was dominated by one or two highly abundant taxa. In most cases these were springtails, but the prevalence of nematodes and *Tanytarsus fuscithorax* were also recorded. The group of poorest quality sites included the site downstream of the mine in March and June and McIntyre Road in December. These samples were characterised by having a community dominated by *Tanytarsus fuscithorax* (at least 83% of abundance), which is the characteristic effect of AMD contamination in Dawesley Creek.

In 2004 there was less separation observed between sites exposed and not exposed to AMD.

In the dendrogram Group 1 and 2 are part of a bigger supra group and include samples from all sites except for Balyarta Ford (Figure 13). The most distinct group (Group 3) is made up of the samples from Balyarta Ford, Nairne Creek (September and June) and the Brukunga Mine samples taken in June and September. These samples were all dominated by Hypogastruridae. Also the characteristic dominance of *Tanytarsus fuscithorax* in AMD affected sites was not observed.

The likely reason for the changes in Nairne creek is the closure to the Chapman's Factory, influencing flow levels and making it more like Balyarta, which is consistently dry in March.

Group 2 contains sites from the Brukunga Mine in March and December, the Freeway and McIntyre Rd in December and June. These sites as in 2003 were dominated by one or two abundant taxa. Generally they contained fairly high numbers of chironomids with one sample, McIntyre Rd (June) containing high numbers of *Tanytarsus* sp. suggesting possible impact of AMD. However the dominance of this group was not too great with 22 other taxa recorded. Group 1 contains all samples taken from Peggy Buxton Rd, which were characterised by high numbers of *Austrochiltonia australis*, Olilgochaeta and to a lesser extent *Heterias pusilla*.

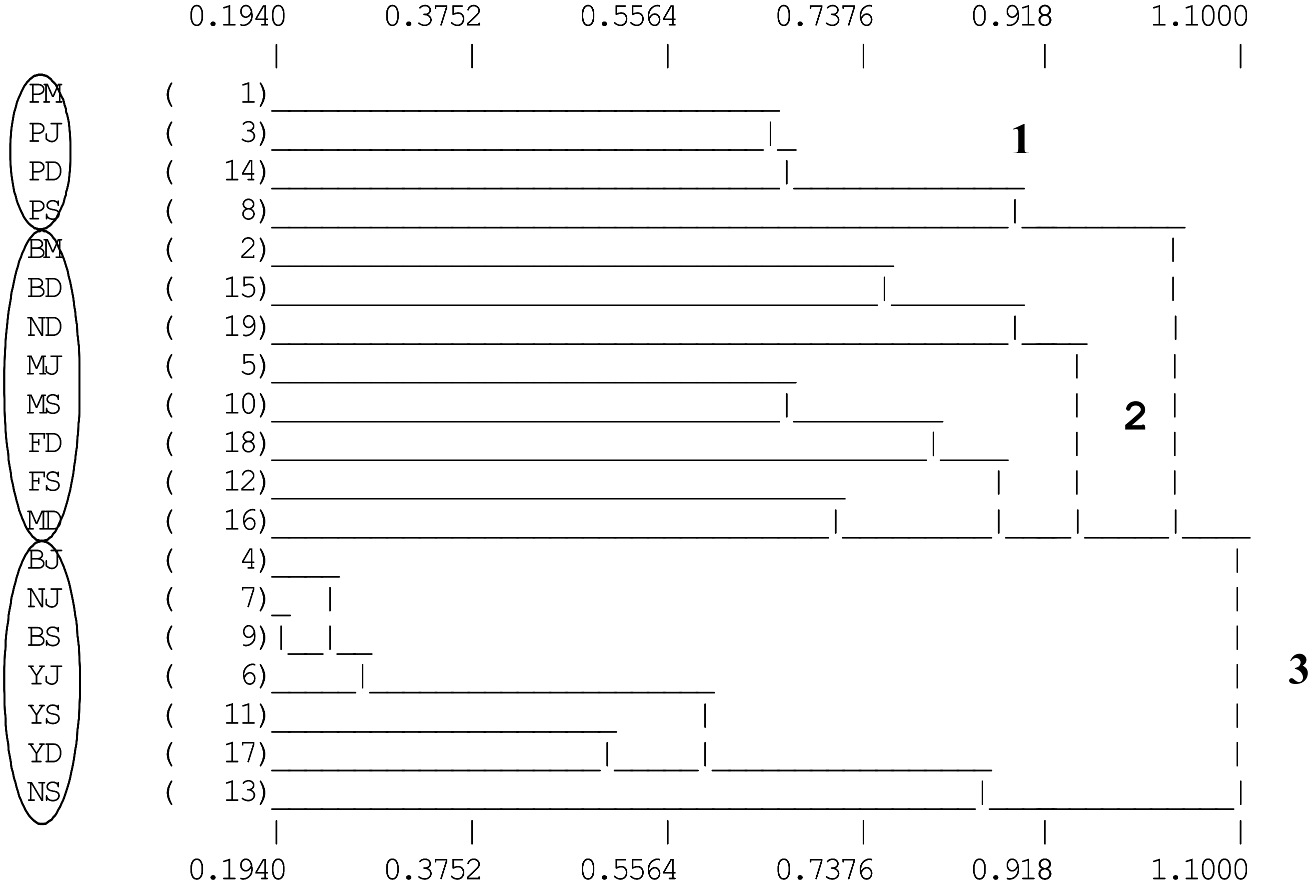

Figure 13. **Dendrogram 2004 samples.**

<u>First letter designates site</u>.

P = Peggy Buxton Road,
B = D/S Brukunga,
M = McIntyre Road
Y = Balyarta,
F = Freeway,
N = Nairne Creek.

<u>Second letter designates month</u>

M = March
J = June
S = September
D = December

Ordination 2004

The SSH ordination in 3 dimensions produced a similar grouping of sites as the classification. In Figure 14, a letter designating the month of collection has been used to label each sample. The groups from the classification have been superimposed on the ordination plot. The sites at Peggy Buxton Rd separate from all other sites along axis 2 and 3. Regardless of season these site were different from all others (Group 1). Balyarta ford and Freeway sites have all seasons in the one group however they are also clustered with other samples from the same season. Importantly, Brukunga mine and Nairne creek sites group more based on season than site, particularly at the Brukunga mine where June and September samples are placed in Group 3 and December and March show quite different placing along axis 2 and 3 and are placed in Group 2. September and June samples form Nairne Creek are also in Group 3 where as the sample from December are placed in Group 2.

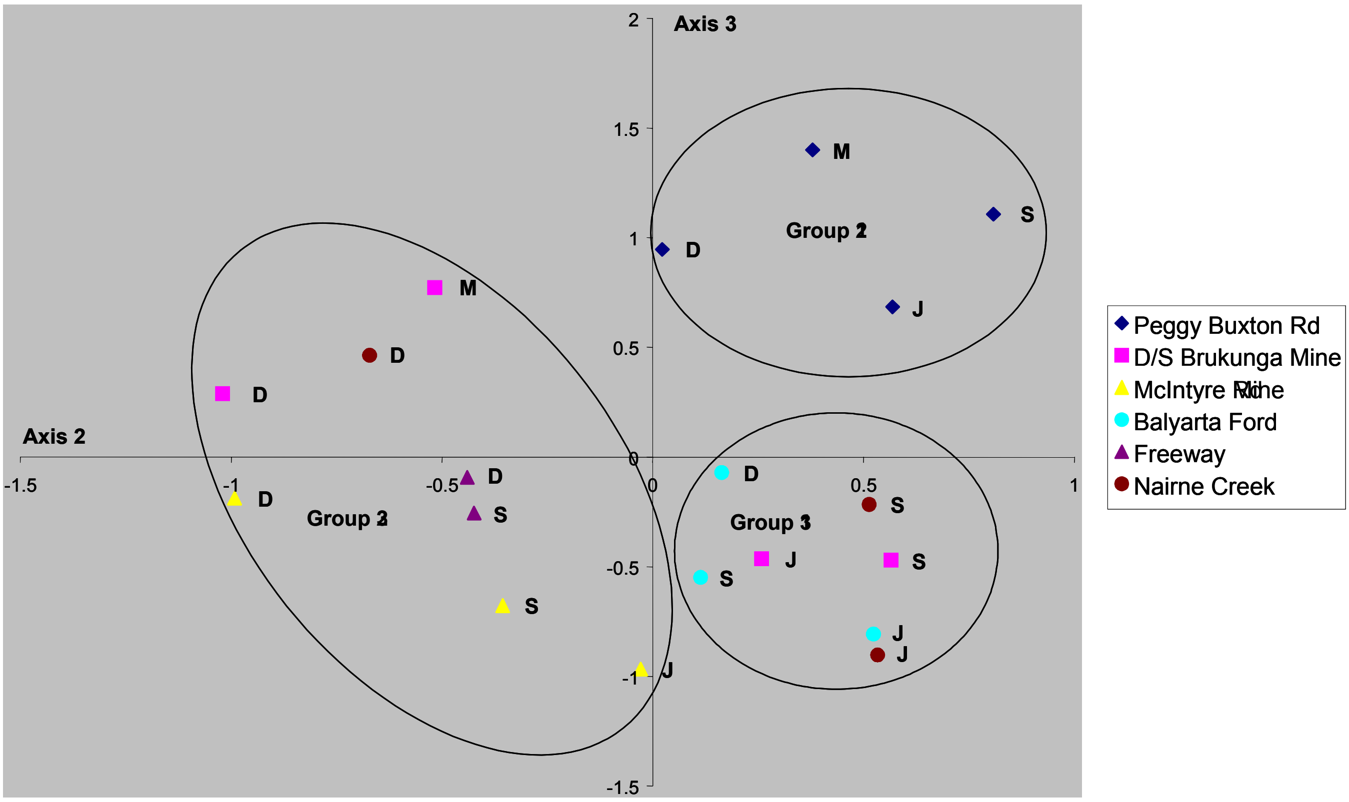

Figure 14. **SSH Ordination of 2004 samples.**
(M = March, J = June, S = September and D = December)

Combined Ordination

It was recommended in 2003 that the 2004 report should include MVA of all data from 2002 to 2004 (rather than for just a single year) to identify if the changes recorded continued and if the improvement was evident at all times of the year. Figure 15 is the resultant ordination and shows that Peggy Buxton Rd and Nairne Creek, unaffected by AMD, are positioned on the left side of the plot in a fairly tight cluster, spread along axis 3. The two sites closest to the impact of the mine, Brukunga D/S and McIntyre Rd are spread along axis 1. On closer inspection of the points it can be observed that there is a separation relating to sampling year where those samples from 2002 are generally placed furthest along axis 1 and there is a general shift toward the left in latter years. This places those samples taken in later years closer to those un-impacted and suggests a recovery. This pattern is observed in most months. Interestingly Nairne Creek and Balyarta in June 2004 are very closely aligned, separated from other Nairne Creek sites. This identifies the change from permanent water to an intermittent stream at Nairne Creek in 2003. The corresponding dendrogram can be viewed in appendices.

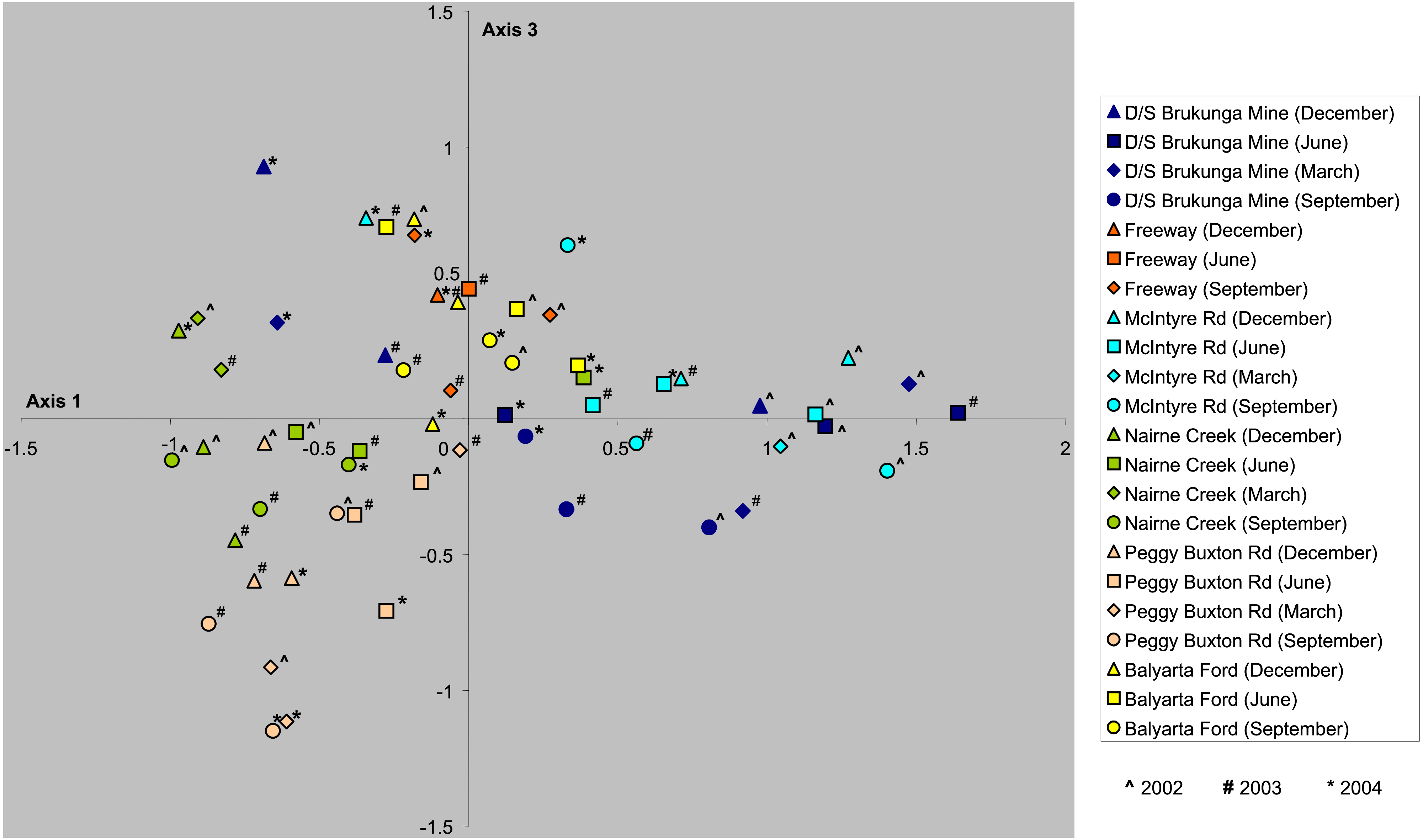

Figure 15. **SSH Ordination of combined samples 2002 - 2004.**

4. Discussion and Conclusions

Despite the collection and extensive treatment of as much ground water from the mine site as possible, early monitoring showed the water in Dawesley Creek to be acidic and unsuitable as habitat for most macroinvertebrates. Gradual improvement has occurred since and most sites downstream of the mine have shown a trend towards reference condition.

The construction of the diversion around the mine site in 2003 was intended to isolate the mine and prevent much of the contamination (Randall and Cox, 2003). The main impact of this construction, based on monitoring in 2003, was that the site immediately downstream of the diversion (D/S Brukunga) had a more diverse macroinvertebrate fauna after the diversion came into operation in June, compared with samples taken in March and June in previous years. This may have been the effect of dilution from water flowing past Peggy Buxton Road. However, the AMD impact was still obvious at McIntyre Road and further downstream at Balyarta and the Freeway as indicated by pH measurements and macroinvertebrate results. In contrast 2004 showed improvement at Brukunga downstream of the mine which was recorded at reference condition for both December and in the combination of all months. The Freeway also showed improvement with higher taxon richness than in 2003. Balyarta Ford was the only site to be recorded as significantly impaired (Band B) but encouragingly the pH was nearer to normal levels and subsequent improvement in macroinvertebrate richness can be expected.

The seasonal fluctuation of flow in Dawesley Creek produces a seasonal fluctuation in the pH and the macroinvertebrate community downstream of the confluence with Nairne Creek. At low flow, especially early in each year, Nairne Creek contributes most of the flow in this section or dilutes any discharge from Dawesley Creek so the sites at Balyarta and the Freeway have a community and pH that resemble that in Nairne Creek. This occurs during late autumn, early winter and through summer in most years. This pattern was also present in 2003 and 2004 with the site at Balyarta showing a relatively diverse community in December but lower taxon richness in June and September.

Over the sampling years there was a clear correlation between pH and the diversity of the macroinvertebrate community, lower pH was associated with a reduced diversity. As indicated earlier this association is obvious but not necessarily causal. Both the taxon richness data and the MVA analysis show that the macroinvertebrate community was different in the AMD affected section of Dawesley Creek compared with Nairne Creek and Peggy Buxton Road upstream of the AMD inputs.

The 2003 report produced by AWQC noted that there was some improvement in the diversity of the macroinvertebrate community at sites downstream of the Peggy Buxton Road diversion since it became operational in June 2003. The greatest improvement was at the site immediately downstream of the mine; however other sites further downstream were still influenced by AMD and did not show as great improvement. Despite the increased diversity, there were many taxa that were rare or absent in Dawesley Creek such as molluscs, crustaceans, mayflies and stoneflies which are common in the adjacent Nairne Creek. Up until 2002 there were several taxa that were only found at Peggy Buxton Road and Nairne Creek. These include baetid mayflies and caddis-flies. In December 2003 these taxa were collected at all sites that were sampled. Several taxa were only ever found in Nairne Creek including stoneflies, leptophlebiid and caenid mayflies. These families are regarded as more sensitive to environmental disturbance than the others collected during monitoring and were missing from all sites in the 2004 sampling. Some other taxa that are not regarded as generally sensitive but are known to be particularly excluded by AMD are molluscs and crustaceans. Both molluscs and crustaceans were commonly found at Peggy Buxton Road and Nairne Creek. During 2003, only one specimen of each of these groups was collected at the sites downstream of the mine in Dawesley Creek. This pattern was similar in previous years. Notably, crustaceans were not recorded at Nairne Creek in 2004. However in 2004 *Cherax destructor* were found at the site downstream of the mine as were *Physa acuta* one record of a hydrobid snail ina sample. Notably crustaceans were not recorded at Nairne Creek in 2004.

In all years the impact of AMD was less downstream of the confluence of Dawesley Creek and Nairne Creek. This pattern was emphasised by both combined MVA results where the reference sites, Nairne Creek and Peggy Buxton Road, group together distant from the AMD affected sites of downstream Brukunga and McIntyre Road. The two Dawesley Creek sites downstream of Nairne Creek, Balyarta and at the Freeway were recorded as intermediate.

The closure of the Chapmans' small good Factory in 2003 had considerable impacts on the site at Nairne Creek. For the first time it did not score at reference condition in the AusRivAS analysis for combined seasons and was placed in the intermediate and more impacted groups in the 2004 ordination. The removal of permanent water diminished the diversity and impacted on water quality reducing the pH to around five in June. The reason for this is unclear but could be due to the impact of regional acidic ground water. Nairne creek is now intermittent and is perhaps a more representative control for the more temporary sites. In the ordination in June, Nairne Creek and Balyarta occupied almost the same space. This indicates that they are now very similar in community composition. Through the changes observed at Nairne Creek the importance of flow can also be recognised.

Another artefact of water entering a system in relatively large volumes is invertebrate drift. This is where, due to the flow of water, animals are mobilised in the water column and subsequently transported downstream. The release of water from the waste water treatment plant may be affecting the drift of animals from Peggy Buxton Rd to the site immediately downstream of the mine. This could also be influencing the apparent return to reference condition at this site as field observations recorded that large amounts of silt were present in 2004. Although PIRSA recorded that silt had been cleared in February (PIRSA 2004) it had redeposited at this site upstream of the gauge when the March 2004 sampling was conducted. The presence of such a large amount of silt would commonly be expected to reduce macroinvertebrate diversity but this was not recorded. It may therefore be because of invertebrate drift from Peggy Buxton Rd that the Brukunga mine site recorded such good diversity. To test this phenomenon the AWQC recommends drift sampling where the animals mobilised in the water column are collected over an hour period. This would then determine what animals are drifting and subsequent monitoring should show whether these animals are persisting.

In conclusion, there appears to be some improvement in the composition of the macroinvertebrate community at sites downstream of the diversion since it became operational in June 2003. All the types of analysis (taxon richness, AusRivAS and multivariate analysis) indicate this and therefore multiple lines of evidence support this conclusion. The improvement has been greatest at the site immediately downstream of the mine and to a lesser extent at McIntyre Road and the Freeway. The other sites further downstream are not as different after the completion of the diversion and perhaps are still influenced by AMD through groundwater entry. Further improvement of the richness of taxa was recorded in 2004 and trend towards reference condition continued.

Future monitoring will be able to show if these taxa return after consistent flows along the diverted stream. The diversion seemed to have improved conditions in 2003 at the site immediately downstream of the mine and this continued in 2004. AusRivAS monitoring indicated a further shift towards reference condition in the survey for 2004.

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5. Appendices

dendrogram combined

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          0.0599      0.3519      0.6439      0.9360      1.2280      1.5200
               |           |           |           |           |           |
PM02    (    1)____________
PM04    (   41)___________|_________________
PJ03    (   24)_________________           |
PD03    (   36)________________|______     |
PJ04    (   43)______________________|_____|_________
PS03    (   30)________________                     |
BS03    (   31)_______________|__________________   |
NS04    (   53)_________________________________|___|_
NM02    (    4)_____________________________________ |
NJ02    (    9)___________________                 | |
NS02    (   15)__________________|_______          | |
NM03    (   23)_________________________|___       | |
ND02    (   20)________________________    |       | |
NJ03    (   29)____________________   |    |       | |
ND03    (   40)___________________|___|____|____   | |
PD02    (   16)________________________        |   | |
PD04    (   54)_______________________|__      |   | |
ND04    (   59)_________________________|______|   | |
PS02    (   10)__________________              |   | |
NS03    (   35)_________________|___________   |   | |
PS04    (   48)____________________________|___|___|_|____
YD02    (   19)__________________                        |
YD03    (   39)_________________|______                  |
PM03    (   21)_______________________|___________       |
YJ03    (   27)____________________              |       |
FS04    (   52)___________________|_______       |       |
BD03    (   37)______________________    |       |       |
MD04    (   56)_____________________|____|_______|__     |
BM04    (   42)__________________________________  |     |
MS04    (   50)_______________________          |  |     |
BD04    (   55)______________________|_________ |  |     |
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PJ02    (    5)__________________                                       |
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YS03    (   33)____________         |                                   |
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YJ02    (    8)________                 |                               |
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YS02    (   13)_________           |    |                               |
YJ04    (   46)________|_          |    |                               |
MJ03    (   26)______   |          |    |                               |
NJ04    (   47)_____|__ |          |    |                               |
BS04    (   49)_______| |          |    |                               |
BJ04    (   44)_______|_|______    |    |                               |
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FS02    (   14)______________________|__|_______________________________|___
BM02    (    2)____                                                        |
MD02    (   18)___|_________                                               |
BJ03    (   25)____________|__________________________                     |
MM02    (    3)_______________                       |                     |
BS02    (   11)_____         |                       |                     |
MD03    (   38)____|___      |                       |                     |
MS02    (   12)___    |      |                       |                     |
BD02    (   17)__|____|______|_______________        |                     |
BJ02    (    6)_                             |       |                     |
MJ02    (    7)|__________                   |       |                     |
BM03    (   22)_________ |                   |       |                     |
MJ04    (   45)________|_|____________       |       |                     |
MS03    (   32)______________________|______|________|_____________________|
               |           |           |           |           |           |
          0.0599      0.3519      0.6439      0.9360      1.2280      1.5200
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The Brukunga Acid Mine Drainage Impact Monitoring Program Macroinvertebrate Results 2005

6. Introduction

The Brukunga Acid Mine Drainage Impact Monitoring Program, initiated in the 1996–1997 financial year, involved monitoring macroinvertebrate and chemical parameters at sites on the Dawesley Creek – Bremer River system. The Australian Water Quality Centre (AWQC) conducted biological monitoring for Primary Industries & Resources SA subject to an Environment Protection Authority licence agreement for management of the disused Brukunga pyrites mine.

The principal aim of the monitoring program was to investigate the impact of Acid Mine Drainage (AMD) on Dawesley Creek including the downstream extent of the impact. This report provides a summary of macroinvertebrate results for 2005 and provides comparisons with data from past years.

Sites

Macroinvertebrate monitoring has been conducted in the system since September 1996.

The six sites monitored from 1996 to 2005 are listed in Table 1, in order of increasing distance down the catchment.

These sites were sampled quarterly (in March, June, September and December). Figure 1 is a map of the streams showing all sites that have been sampled during the project.

***Table 1.* Macroinvertebrate sites monitored quarterly since 1996, and period of entire data record.**

Site Name	Label	Monitoring Duration	AWQC Location Code
Dawesley Ck. at Peggy Buxton Rd	**Site 1**	Sept. 1996 – Dec. 2005	4728
Dawesley Ck. D/S Brukunga	Site 2	Sept. 1996 – Dec. 2005	3158
Dawesley Ck. at McIntyre Rd	Site 3	Sept. 1996 – Dec. 2005	1951
Dawesley Ck. at Balyarta Ford	Site 4	Sept. 1996 – Dec. 2005	1822
Dawesley Ck. at Freeway	Site 5	Dec. 1996 – Dec. 2005	1952
Nairne Ck. at Djatadapeel Ford	Site 6	Sept. 1996 – Dec. 2005	1953

7. Methods

Macroinvertebrate Sampling

All macroinvertebrate sampling was conducted with sweep nets (250 µm mesh) and conformed to the Australian Rivers Assessment System (AusRivAs) standard protocol, where a 10 metre section of stream is sampled (Anon. 2001). Edge habitat was chosen because it is the only habitat present at the range of flows experienced at the sites, and thus it permits a fair comparison to be made across all sites and times.

The South Australian AusRivAs laboratory scoring protocol was used to process samples. The protocol involves counting all organisms in a randomly chosen 10% of the sample from a Marchant sub-sampler (Marchant 1989). Sub-sampling continued until a minimum of 200 animals ha been identified; for the purposes of obtaining a representative sample.

Identification was taken to the lowest practical level using the latest available keys and the AWQC voucher collection. Identification was carried out at family level or lower in all groups except Turbellaria, Nematoda and some Oligochaeta (where they were identified at the levels stated). Most Insecta and Mollusca were taken to species.

The Dipteran families Ceratopogonidae, Tipulidae, Psychodidae, Stratiomyidae and Simuliidae were taken to species or morpho-species and the Culicidae were taken to genus. The Chironomidae were taken to genus where possible (and in some cases to species) and other dipteran families were not identified below family.

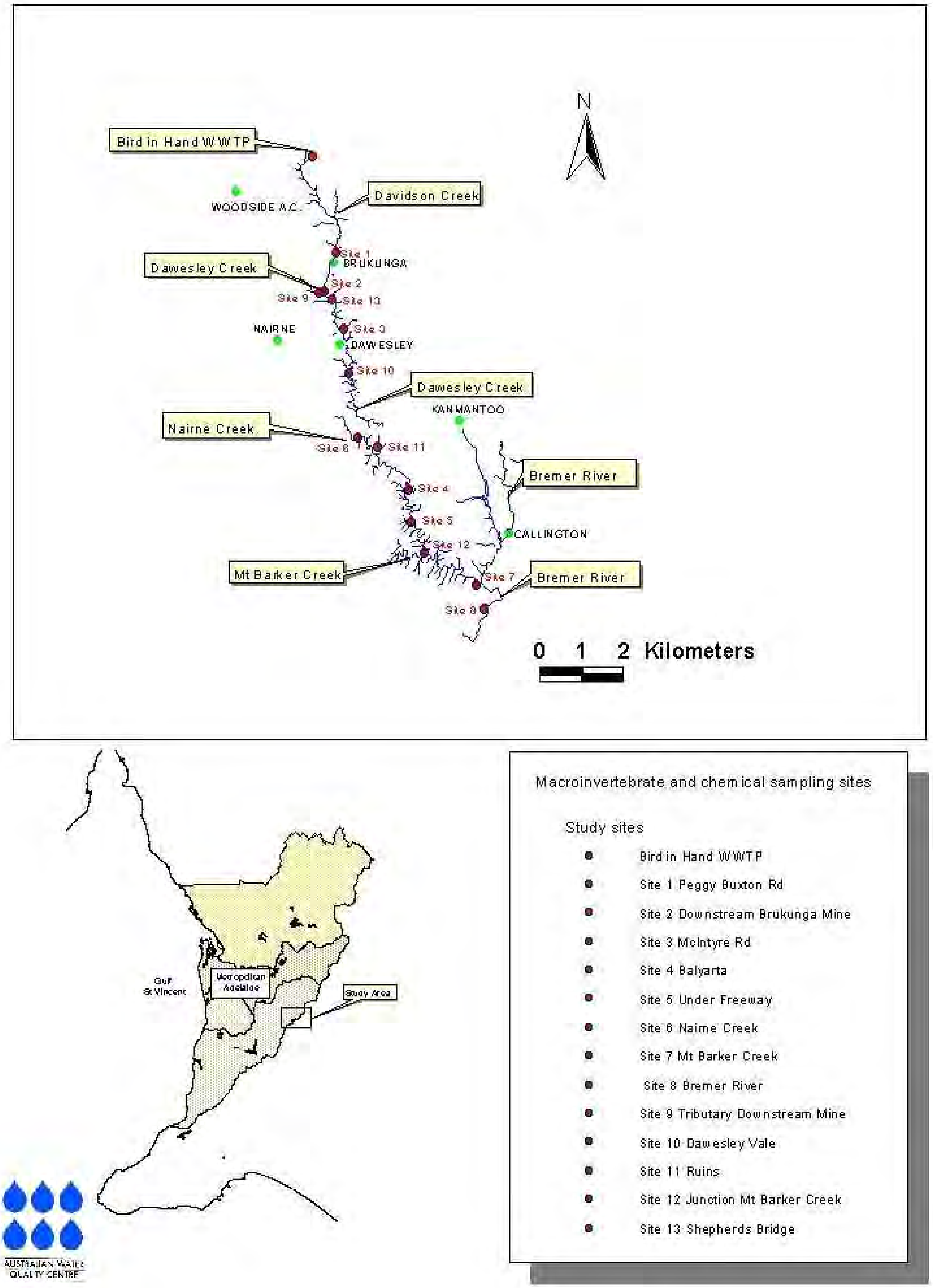

Figure 1. **Location and site map for the Dawesley Creek System**

Interpretation of Macroinvertebrate Data

Species richness, which reflects the number of different types of macroinvertebrates identified in a sample, can be used to estimate the health of a stream. In this report, the term taxon richness is used - as not all the taxa that were counted are species. As detailed in the previous section, some taxa were only identified to family, some to genus and others to species.

The taxa present in each sample and the abundance of each taxon reflects the differences between sites, habitats and conditions prior to the date of sampling. There are no simple rules for interpreting these complex data sets.

Variation due to factors such as extreme flow events, time of day, chance colonisation by rare taxa, and weather conditions is always present in addition to the variation due to water quality, season, habitat variability, ambient temperature and plant productivity. Statements regarding abundance in this report refer to the abundance within the sub-sampled portions of each collection.

Multivariate analyses (MVA) are statistical procedures that can detect similarities in biological community data (i.e. the taxa present and their abundance). MVA are a broad set of objective tools that can be used to seek and reveal structure within complex data sets avoiding investigator subjectivity.

Ordination and classification of macroinvertebrate community data provide an assessment of how similar or dissimilar samples are. Both spatial and temporal patterns can be detected which simple diversity indices and raw taxon richness and abundance figures may not reveal.

When two different MVA methods detect the same pattern the degree of confidence in the validity of the pattern is increased. This is the approach that was followed, by comparing classification and ordination analyses.

In this assessment, MVA were used to conduct a ‘before and after’ comparison to investigate for indications of ecological change after several years of operation of the diversion channel. From the six complete years of data available (1997-2002), the 1997 data were selected, as the hydrological conditions then most approximated those in 2005.

The statistical package PCORD was used to carry out both classification (Group Average UPGMA) and ordination (NMS non-metric multidimensional scaling). Data were grouped at a range of levels, but were predominantly at the genus and species level. No separation of the different life stages or sexes of species was included in the data tested. This gave an analysis matrix of 44 samples by 103 taxa. The Bray-Curtis association measure was used on untransformed abundance data for both methods.

Classification was run with the Groups\Cluster Analysis menu in PCORD. The classification was a hierarchical method run with the group average linkage method. To aid interpretation, a small number of groups were defined by the software. A five group level was chosen, as membership of groups did not change greatly at higher-level groupings.

Ordination was run with the Ordination\NMS menu in PCORD. The Suggested Procedure of McCune and Mefford (1999, p. 114) was followed to determine the final analysis options. A three-dimensional solution was calculated using a maximum of 200 iterations, a random start and a stability criterion of 0.00046. The resulting stress value was 14.92 and the solution was stable after approximately 55 iterations, dropping to a slightly lower stable value after about 150 iterations

AusRivAS can provide additional information. It uses family level data to compare a sample with the community found at best available reference sites with similar environmental characteristics. It produces a rating that is a guide to the level of any impact and also calculates the probability of each family occurring in a sample. These outputs are useful to determine the effectiveness of the rehabilitation of the creek by comparing the fauna to reference sites. The results from AusRivAS analysis of 2005 data are included in this report.

The AusRivAS models function by using chemical and physical variables to classify a sample and then predict the families that should be present in that sample if it were from a reference site based on the classification group probabilities. This predicted (or "***E****xpected*") number of families is then compared with the number of families collected (or "***O****bserved*") in the sample. The comparison is in the form of a ratio of the Observed: Expected number of families – or OE in AusRivAS. The models make frequent use of a 50% probability of taxon occurrence at a site. This is because those taxa with a > 50% chance of occurring are considered the most useful for detecting a real decline in the number of taxa (Coysh *et al.* 2000).

The AusRivAS output used in this report is the OE50 which is the observed: expected ratio for families predicted at greater than 50% probability for a sample. The OE50 ratio can be simplified to a band. Band ratings are X (higher than expected observed number of taxa), A (equivalent to reference), B (reduced number of families and therefore significantly impaired), C (severely impaired) and D (extremely impaired). The probabilities which determine the boundaries between bands may be different for each model season, as they are based on percentiles.

8. Results

Macroinvertebrate Diversity Results

2005 Surveys

The primary results consist of a list of the taxa recorded at each site and the abundance estimate of each taxon. To ensure the greatest compatibility between data sets generated at different times by different operators, only the highest taxonomic level data were used for Oligochaeta and aquatic mites.

In order to ensure the most accurate representation of taxon richness, in cases where records of both adult and immature specimens of the same taxon were present in the sample, the data were combined.

In this report only the taxon richness is discussed in detail. Richness is a measure of the diversity of the macroinvertebrate community. A higher number of taxa generally indicates a more natural site with less human-induced stress. It is also accepted that a more diverse community will recover more quickly from both natural and human-induced stresses compared with a community with low diversity.

In the graphs that summarise the macroinvertebrate data, the pH measured in the field at the time of sample collection have been added to indicate the major differences in water chemistry at different sites and times. It is referred to as spot pH. Even though a clear correlation between taxa and pH is evident, causality is not implied. There are many differences in the chemistry of low pH AMD and higher pH (neutral or alkaline) streams. The reduced diversity is not simply attributable to increased acidity.

March 2005

In previous surveys, it has been common for several Dawesley Creek sites to be dry in March. Conditions in March 2005 were wetter and macroinvertebrate assemblages were present at sites which have been dry in previous autumns.

Samples from McIntyre Road and Balyarta possessed a richness similar to that of the local reference site at Peggy Buxton Road (Figure 2).

Spot samples of stream pH were circum-neutral (Figure 2).

The possibility that flows of Nairne Creek have decreased since 2004 was strengthened with a repeat of the March 2004 record of no flow in March 2005 (Figure 2). All monitoring data prior to 2004 had suggested that the site experienced permanent flow.

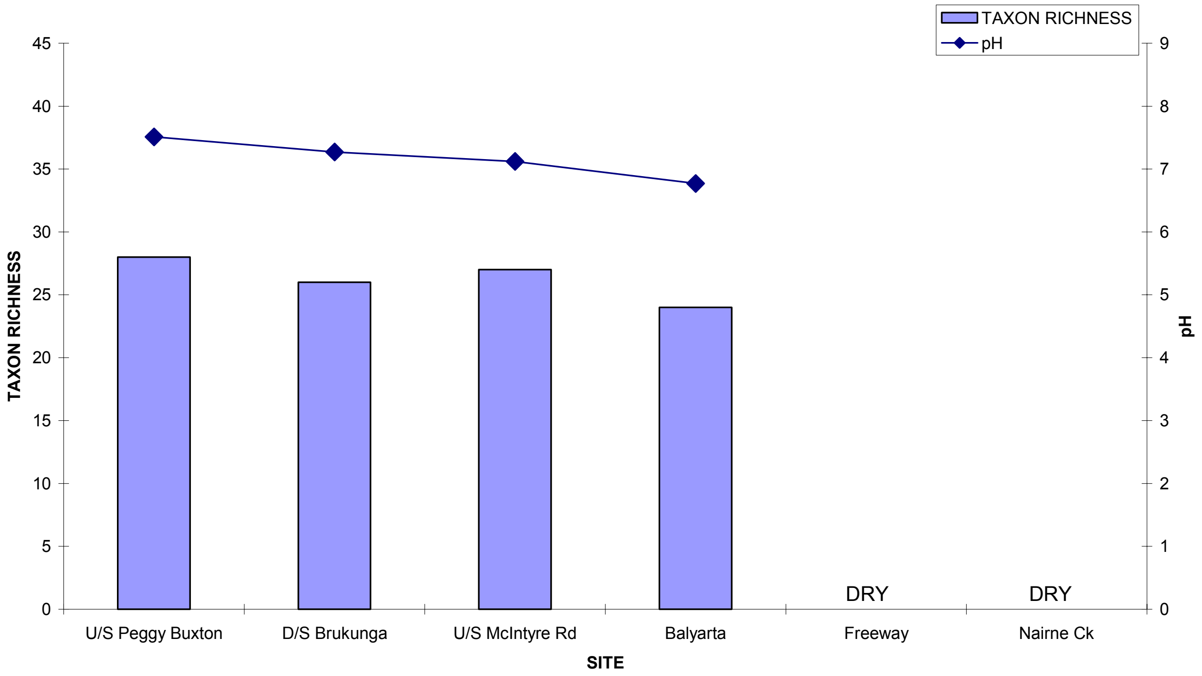

***Figure 2*. March 2005 taxon richness and pH.**

June 2005

Results from the June 2005 samples differed from the pattern commonly present by previous winter surveys.

Spot pH at Brukunga Mine and McIntyre Road were 1-2 units lower than at Peggy Buxton Road; however, levels of macroinvertebrate richness at these sites were comparable to each other (Figure 3) and to values in March (Figure 2).

At Balyarta, the biological community had apparently undergone disturbance during the interval between sampling; macroinvertebrate richness was approximately half of what it had been in March (Figures 2, 3).

Surface water was present in Nairne Creek, and the biological and chemical conditions present mirrored those at Peggy Buxton Road (Figure 3).

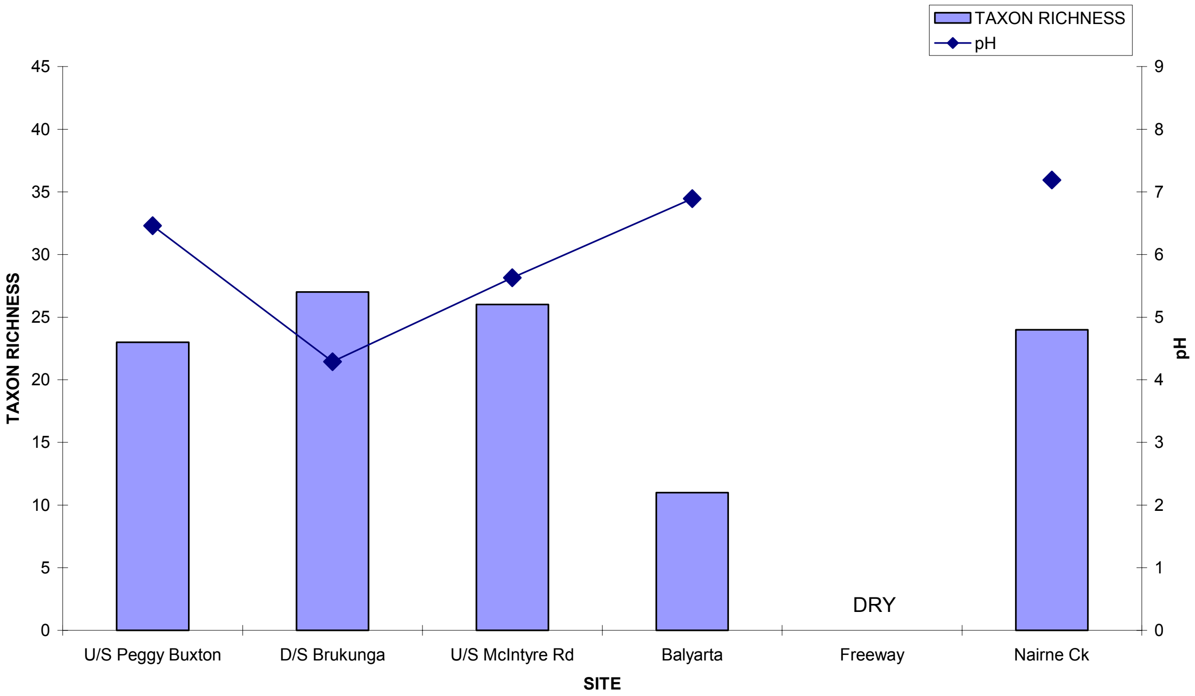

Figure 3. **June 2005 taxon richness and pH.**

September 2005

Surface water was present at the Freeway site in September.

Spot values of pH across the sites were in the range of 6-8 (Figure 4).

Levels of macroinvertebrate richness were generally lower than they had been in June samples (Figures 3, 4). An exception to this was for the Balyarta sample, which did not indicate disturbance – being of a similar richness to other samples (Figure 4).

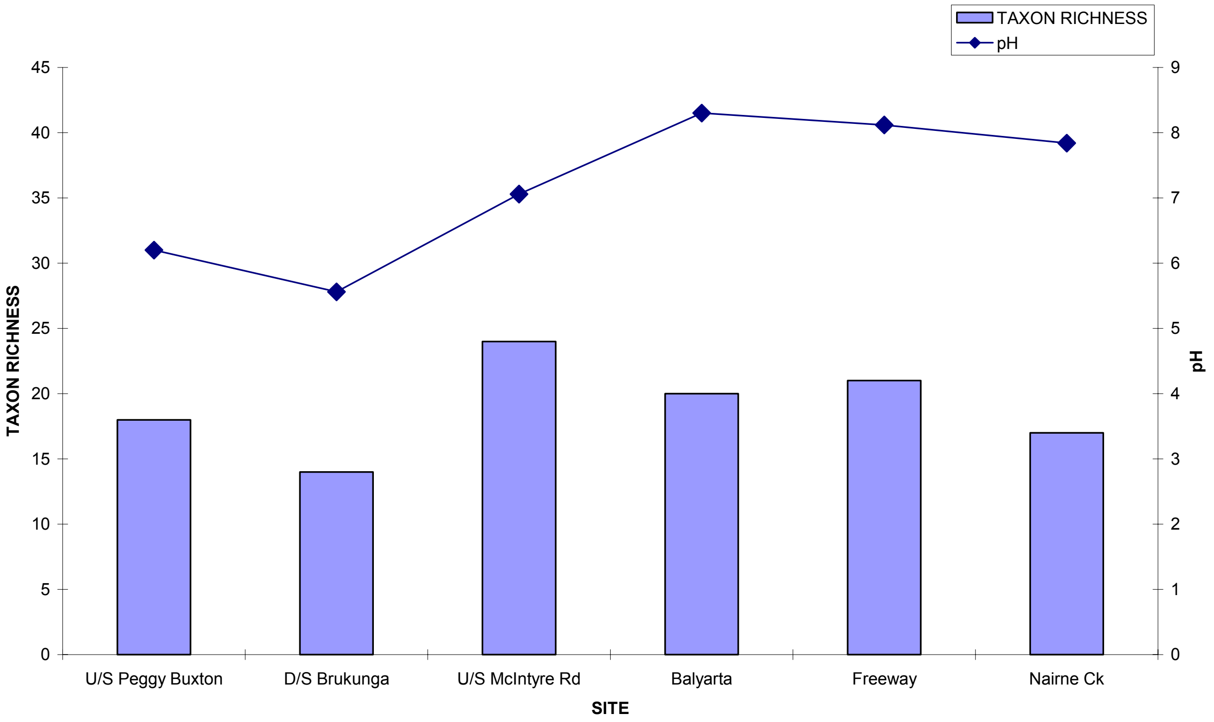

***Figure 4*. September 2005 taxon richness and pH.**

December 2005

Results for this season had the greatest resemblance to the patterns shown for 2004.

A spot pH of between 6.5 and 8 was observed at all sites (Figure 5).

Macroinvertebrate richness at most sites increased when compared to the September values and lay in the range of 25 to 30 taxa (Figures 4, 5).

In contrast, richness at McIntyre Road was similar to the value in September (Figures 4, 5).

A significant biological record was the presence of the isopod crustacean species *Heterias pusilla* at Balyarta. Though frequently at the local reference sites in the Dawesley Creek system, this species has not been detected in the AMD affected reach for many years.

Since September 2000, this species has not been collected in Dawesley Creek downstream of Peggy Buxton Road.

It is likely that improved water quality conditions at Balyarta was the primary factor influencing the occurrence of this crustacean there in 2005.

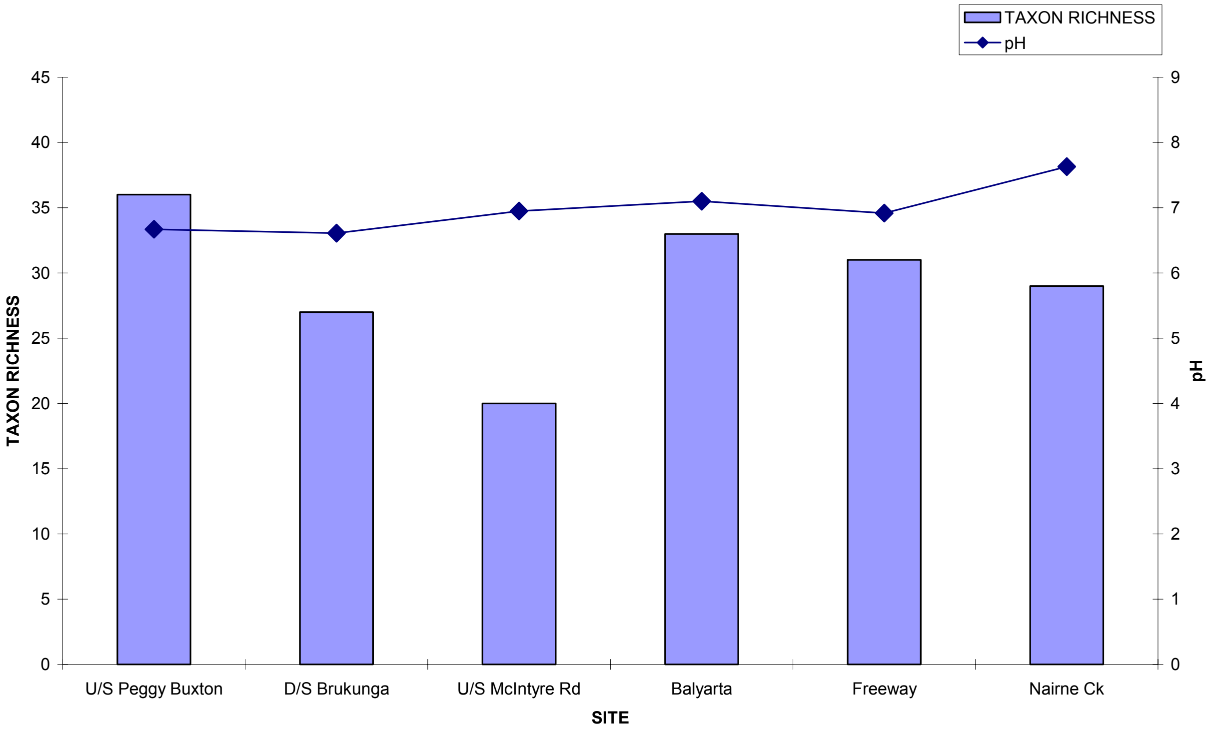

***Figure 5*. December 2005 taxon richness and pH.**

Mean taxon richness 1996-2005

A comparison of macroinvertebrate taxonomic richness prior to and since operation of the diversion scheme is presented in Figure 6.

Since March 2003, all sites on Dawesley Creek that have been exposed to AMD have on average supported more macroinvertebrate taxa (Figure 6).

This trend of improved ecological health was most marked at the Brukunga and McIntyre Road sites, which indicate that continued improvement will give rise to statistically significant differences (Figure 6).

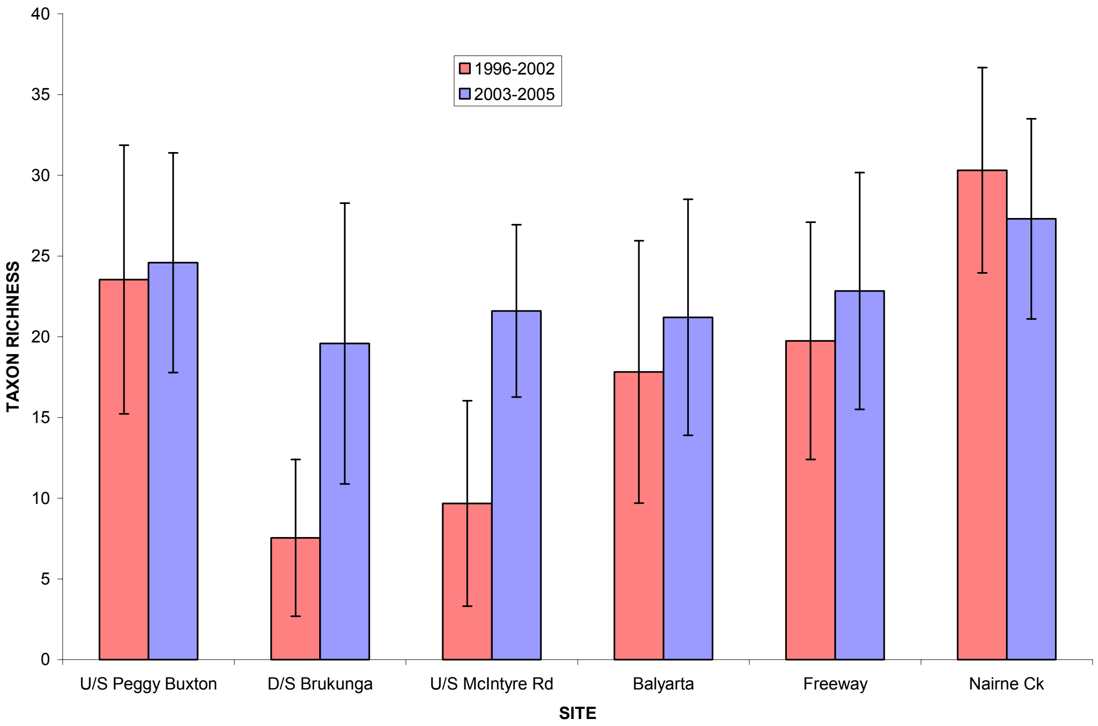

***Figure 6*. Dawesley Creek system: taxon richness at six sites: 1996 – 2002 and 2003 – 2005.** Error bars show two standard deviations.

Temporal Changes at Each Site

At each of the six sites the full data set from September 1996 to December 2005 has been presented in a series of graphs (Figures 7-12). This allows the 2005 data to be compared with the findings of earlier years.

Peggy Buxton Road

Water discharged from the Bird in Hand Wastewater Treatment Plant was found to affect conditions at Peggy Buxton Road. Macroinvertebrate species richness was depressed at times due to eutrophic conditions (Figure 7).

Flow levels were variable and often ceased in autumn but the pools remained and a macroinvertebrate community was always present. Both floods and periods of ceased flow impacted the community causing reduction in species richness. Prolonged periods of normal flow, on the other hand, created favourable conditions for macroinvertebrates which resulted in increased taxon richness. December 2005 would appear to be an example of this pattern. The species richness was usually much higher than that found immediately downstream where AMD has entered the creek.

Taxon richness peaked in 2002 when 42 different taxa were recorded in December. The lowest numbers of taxa were recorded in June 1997 and September 2003 when 7 and 13 taxa were recorded, respectively.

Stream pH fluctuated over the years from 6 to 8.

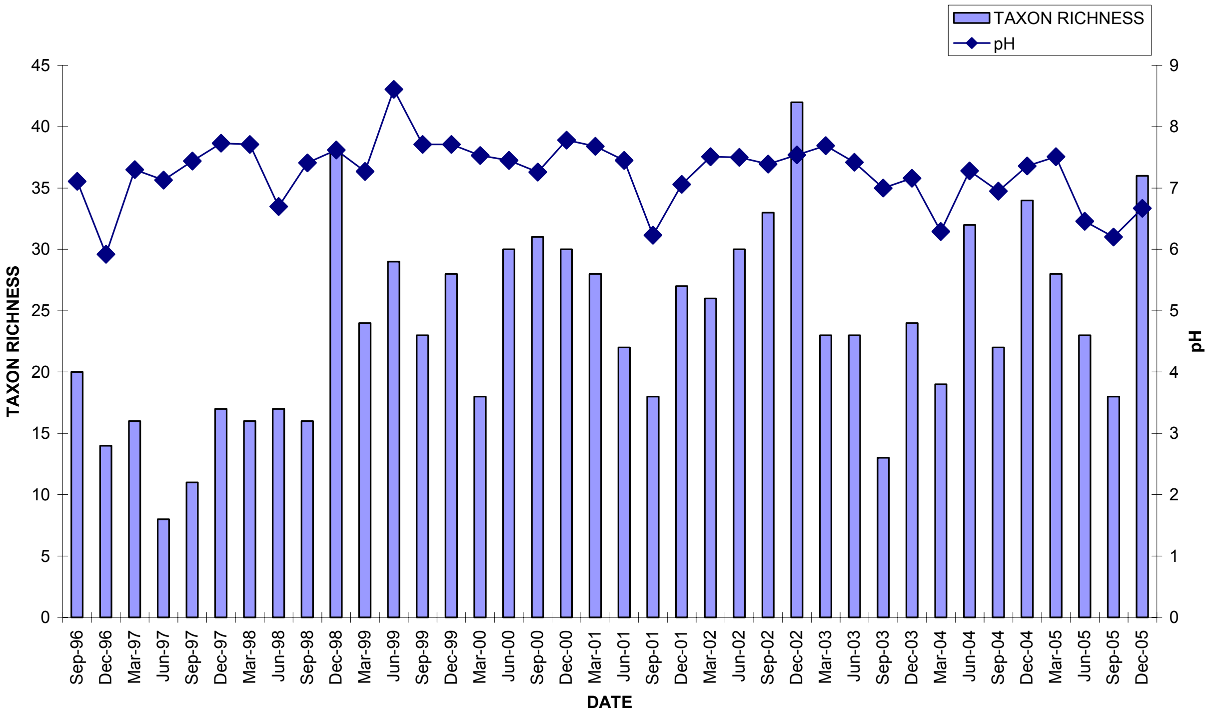

Figure 7. **Dawesley Creek: Peggy Buxton Road. Taxon richness and pH.**

Brukunga Mine

The pH measurement in December 2003 was the first recorded above 7 since the diversion became operational. Measurements in 2004 followed this trend showing the highest recorded pH for March and June since 1996 and again, circum-neutral conditions in September and December 2004 (see Figure 8).

In 2004, the maximum taxonomic richness was recorded for all seasons except for December where it was marginally higher in 2003.

Richness for most of the 2005 samples resembled that of 2004. Low richness in September may have been associated with a pulse of acidity detected in June (Figure 8).

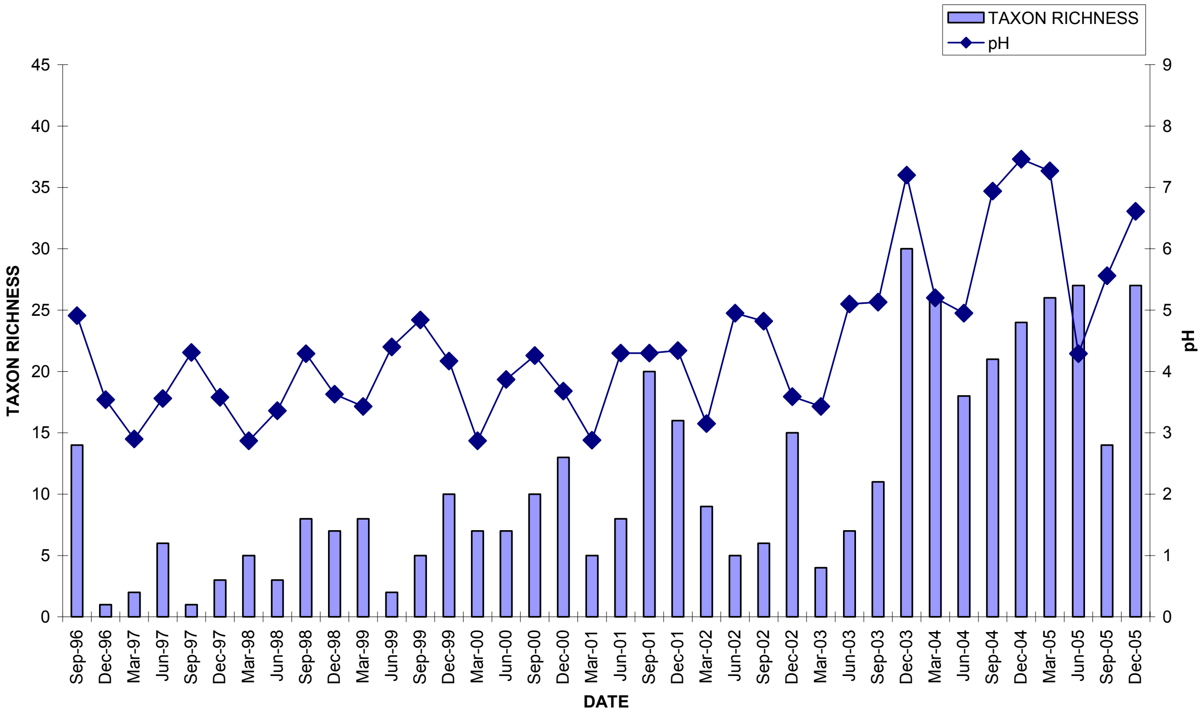

Figure 8. **Dawesley Creek: Downstream of Brukunga mine. Taxon richness and pH.**

Upstream McIntyre Road

Values of pH were within the range of the previous year, with the annual minimum also in June.

December 2004 showed the highest richness ever measured at the site.

In 2005, richness was similar to or greater than that in June and September of 2004 (Fig. 9).

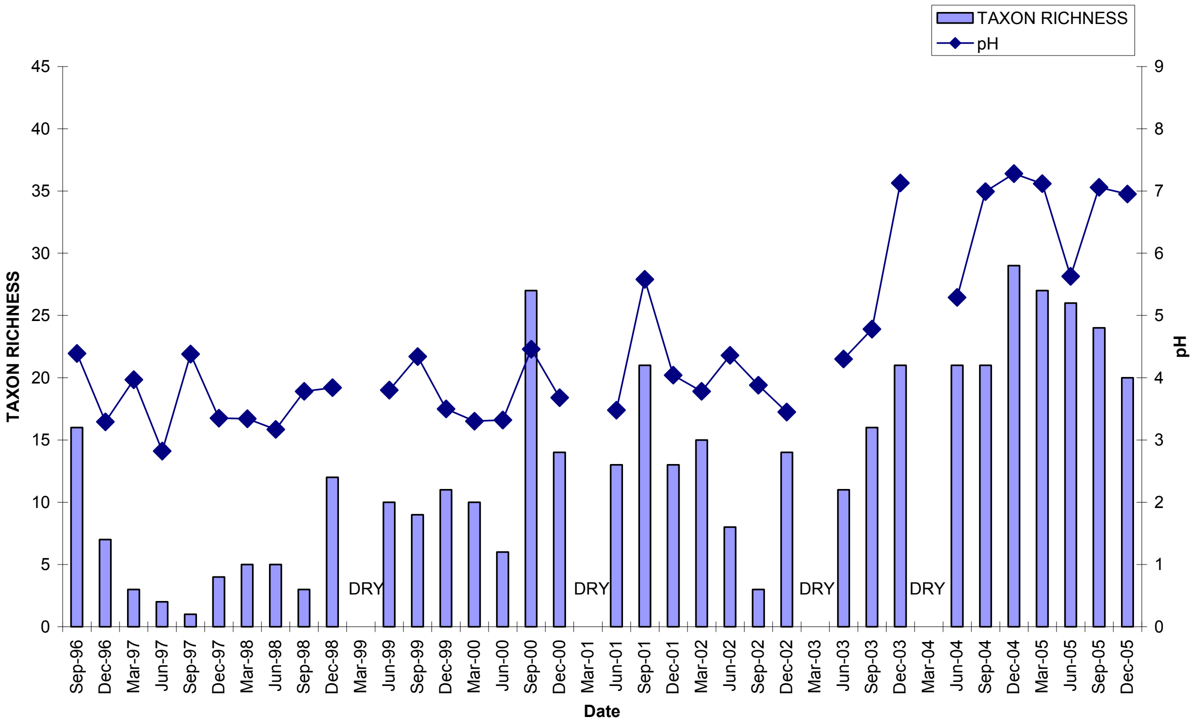

***Figure 9*. Dawesley Creek: McIntyre Road. Taxon richness and pH.**

Balyarta

The section of Dawesley Creek downstream of its confluence with Nairne Creek was usually dry in late summer and early autumn.

The 1996/97 and 2004/05 summers were wetter, and drying of the stream was not observed (Figure 10).

There was variation from year to year in the degree of effect of low pH water from the mine at this site. These year to year variations are dependent on the amount of rainfall and flow. The 2005 data followed the pattern shown in most years since 1997, i.e. the taxon richness decreased when the AMD influence extended downstream (Figure 10).

The stream pH in 2005 provided four consecutive values higher than 6, the first occurrence in the dataset (Figure 10).

A pH of 8.3 in September 2005 eclipsed the previous highest measurement recorded at the site in the previous September (Figure 10).

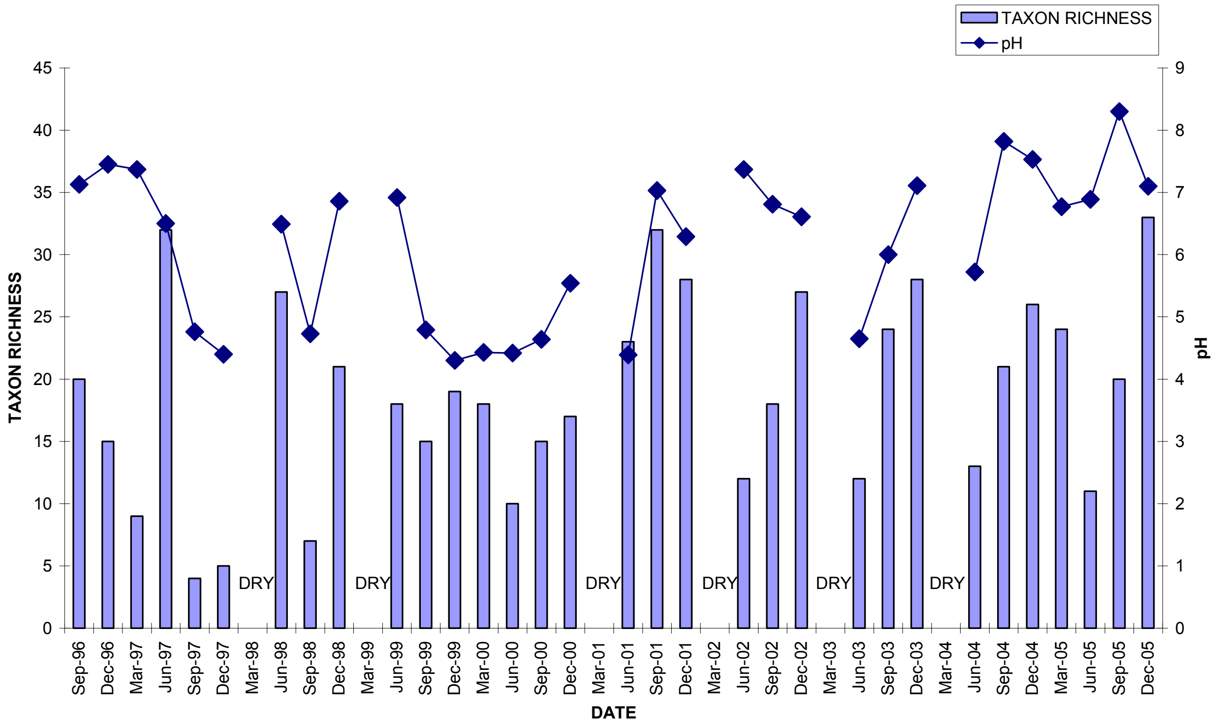

***Figure 10*. Dawesley Creek: Balyarta. Taxon richness and pH.**

Freeway

As an intermittent site the taxon richness has been variable over the years of monitoring (Figure 11).

Simply by chance, sampling may have taken place a few days, a few weeks or a few months after the site was wetted. Consequently, the time for the community to establish at the site before sampling occurred also varied. In some cases the time was sufficient for a diverse community to establish but at other times there may have been only a short time between inundation and sampling.

The samples from 2003 were thought to be affected somewhat by AMD as the pH was about 5 on each sampling occasion.

As for the previous year, in 2005 the pH was alkaline to neutral, which suggests that the AMD influence was subdued or absent at these times.

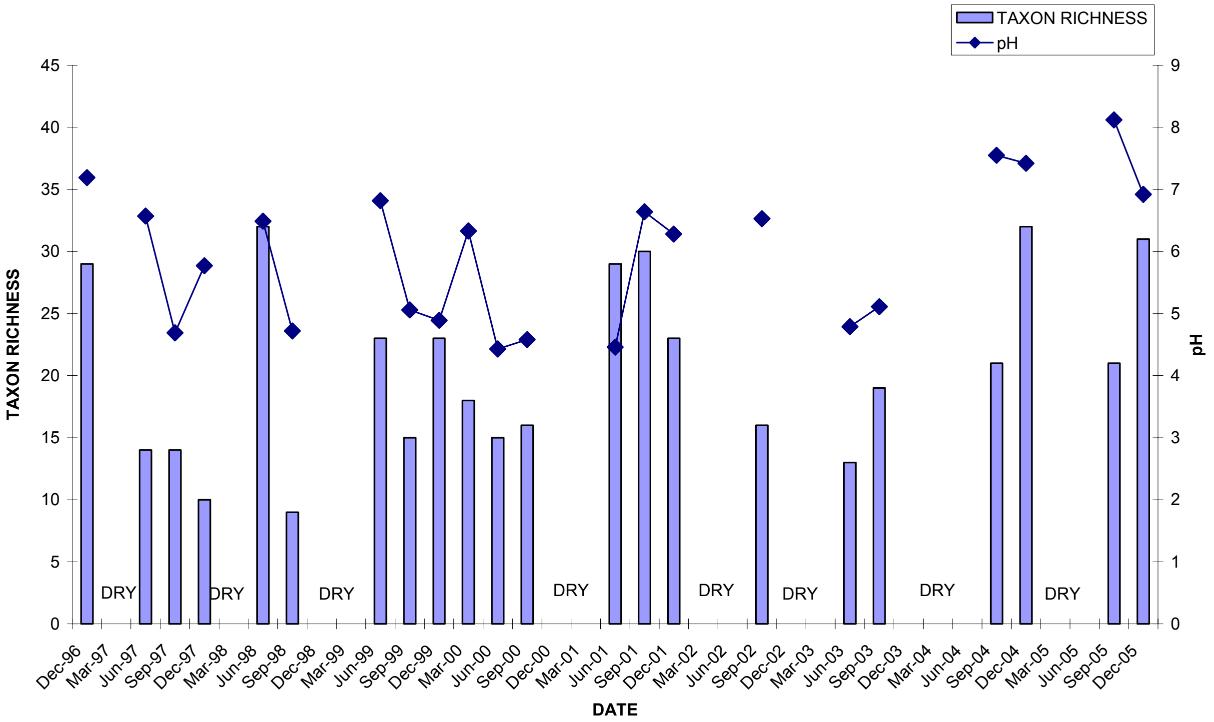

Figure 11. **Dawesley Creek: Freeway. Taxon richness and pH.**

Nairne Creek

From 1996 to 2003 this local reference site was slightly eutrophic but had a taxon richness and pH that was comparable to other Mount Lofty Ranges streams with reasonable water quality (Figure 12). It reflected the condition expected to prevail in Dawesley Creek if AMD and treated wastewater from the Bird-in-Hand WWTP were not present, with highest taxon richness in winter and spring.

The surface hydrology of Nairne Creek appears to have undergone a major change since 2004. Consequently, ecological changes have occurred.

In the most recent two years, the stream has been dry in autumn, and subsequently both pH and taxon richness has stepped up (Figure 12) to levels comparable with those present at Peggy Buxton Road.

Presently, taxon richness in Nairne Creek does not resemble that of other Mount Lofty Ranges streams, but is similar to that in Dawesley Creek at Balyarta and McIntyre Road (see Figures 9 and 10).

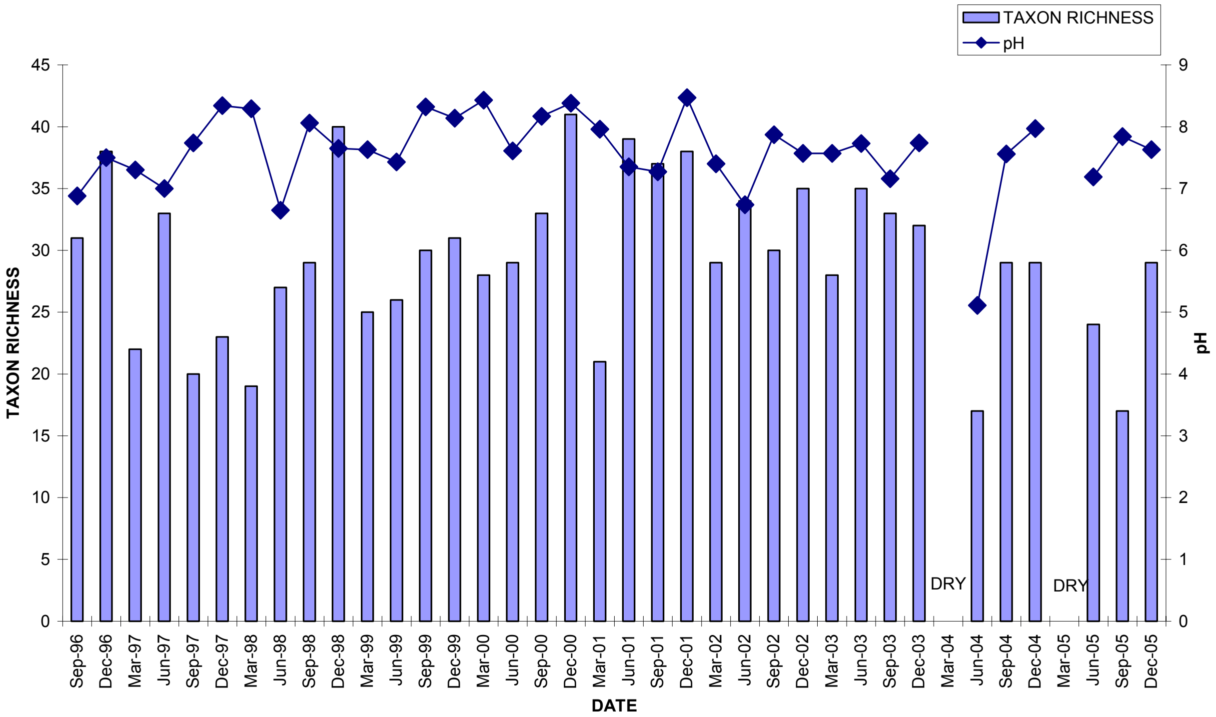

Figure 12. **Nairne Creek. Taxon richness and pH.**

AusRivAS Results

Three seasonal models were used in this study, the Autumn edge model, Spring edge model and the Combined season edge model. The samples from March and June were tested in the Autumn edge model and the samples from September and December were tested in the Spring edge model.

The Combined season edge model data was produced by summing the abundance of each invertebrate family in June and December samples. Results from the AusRivAS models in 2005 are shown in Table 2.

All results for the sites that have not been exposed to AMD **(Peggy Buxton Road and Nairne Creek, or the *local reference sites*) were assessed as being in reference condition (Band A)** during March and December (Table 2).

Note there was no rating for Nairne Creek in March as it was dry. In June and September, macroinvertebrates at these same sites were indicative of a slight impairment of ecological health (Table 2).

Macroinvertebrate richness at Balyarta followed the same trend as Peggy Buxton Road and Nairne Creek (Table 2) and was therefore interpreted as being uninfluenced by AMD.

Macroinvertebrate samples from Brukunga Mine were rated the same as the local reference sites in December, but had lower health than those sites in March (Table 2).

McIntyre Road did not conform to the pattern of the local reference sites in either March or December (Table 2).

The combined season model was not useful in interpreting patterns, as all sites scored similarly.

Table 2. **AusRivAS results for sites sampled in 2005.**

SEASON		**Peggy Buxton 4728**	**Brukunga Mine 3158**	**McIntyre Rd 1951**	**Balyarta 1822**	**Freeway 1952**	**Nairne Creek 1953**
March	**OE50**	0.97	0.74	0.76	0.94	DRY	DRY
	Band	**A**	**B**	**B**	**A**		
June	**OE50**	0.76	1.00	0.73	0.59	DRY	0.77
	Band	**B**	**A**	**B**	**B**		**B**
September	**OE50**	0.62	0.69	0.66	0.5	0.54	0.67
	Band	**B**	**B**	**B**	**B**	**B**	**B**
December	**OE50**	1.1	0.88	0.55	0.92	0.72	1.13
	Band	**A**	**A**	**B**	**A**	**B**	**A**
Combined Season Jun/Dec	**OE50**	0.89	0.88	0.83	0.86	DRY	0.91
	Band	**A**	**A**	**A**	**A**		**A**

Multivariate Analysis Results

Cluster analysis

Results of the cluster analysis are presented in a dendrogram (Figure 13) which shows the grouping of samples with similar macroinvertebrate assemblages.

For the purpose of interpretation, five groups were identified from the dendrogram. These groups are labelled 1-5 in Figure 13 and the group membership is listed in Table 3.

Most of the samples were allocated to Group 1, and most of the 2005 samples were contained in this group.

The macroinvertebrates present at the local reference sites were similar to each other in 2005 and to Nairne Creek samples from 1997.

Notably, 10 of the 14 samples from the Dawesley Creek sites downstream of the diversion in 2005 were placed in the same group as the local reference sites (Figure 13, Table 3).

Group 2 samples came from both years and a range of sites. Interpretation of this set of samples was not simple, though samples from March and September featured prominently.

Groups 3, 4 and 5 contained samples from 1997 collected at sites that received AMD (Figure 13, Table 3). As noted in Table 3, the low richness of many of these samples may have contributed to them having greater similarity with each other.

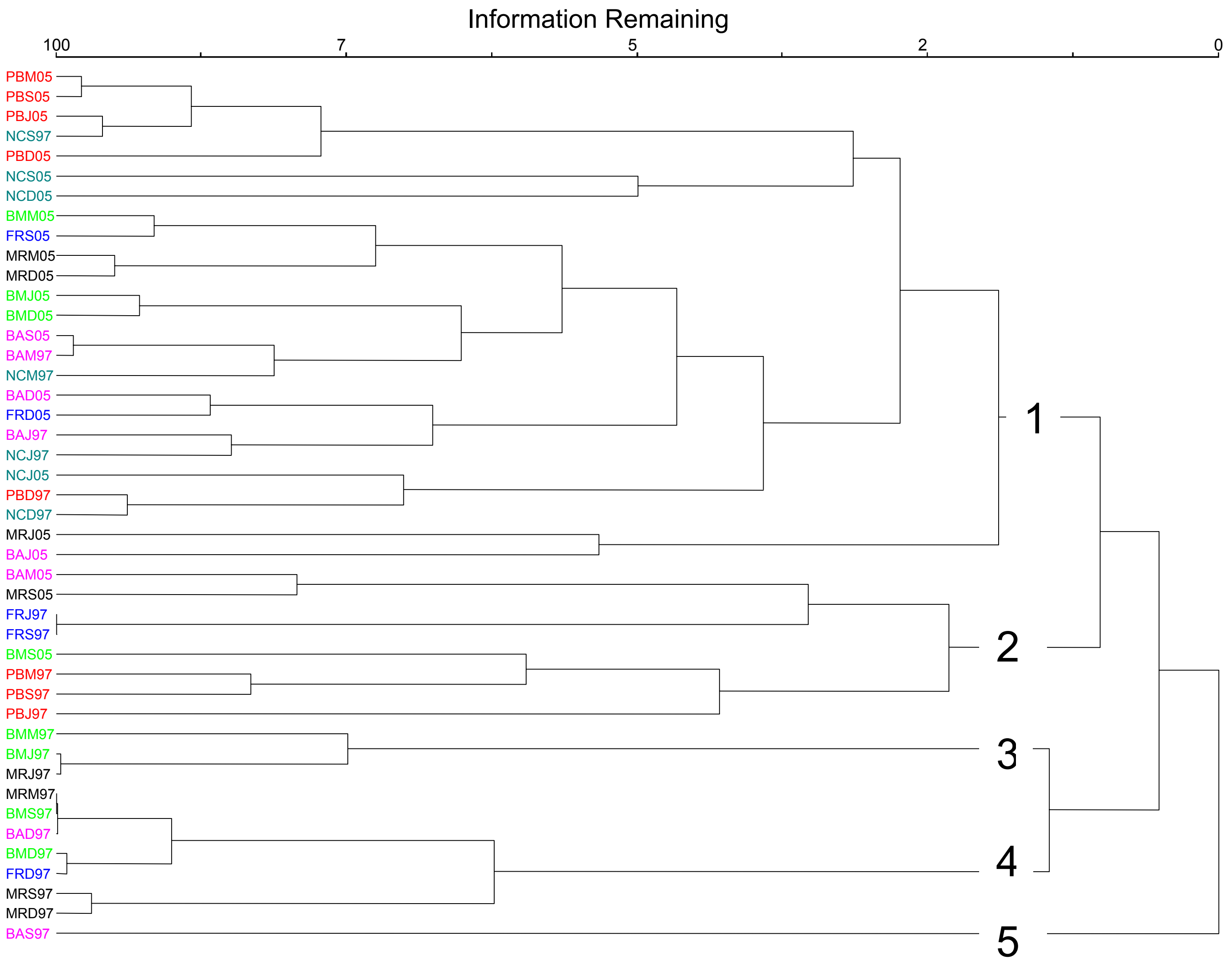

Figure 13. **Dendrogram of 1997 and 2005 samples. (First two letters designate site. PB = Peggy Buxton Road, BM = D/S Brukunga, MR = McIntyre Road, BA = Balyarta, F = Freeway, NC = Nairne Creek. Third letter designates month, M = March, J = June, S = September and D = December. Digits indicate year of collection). Interpretation of Groups 1-5 is provided in Table 3.**

Table 3. **Group membership of cluster analysis.**

Group	Designation	Sites	Years	Seasons
1	**Local reference sites and improved AMD-exposed sites (but mixed)**	Peggy Buxton, Nairne Creek	2005	All
		Peggy Buxton	1997	December
		Nairne Creek	1997	All
		Balyarta	**2005**	**June-December**
		Balyarta	1997	March, June
		Freeway	**2005**	**September, December**
		McIntyre Road	**2005**	**March, June, December**
		Brukunga	**2005**	**March, June, December**
2	No clear commonality; March and September samples	Peggy Buxton	1997	March-September
		Freeway	1997	June, September
		Balyarta	2005	March
		McIntyre Road	2005	September
		Brukunga	2005	September
3	Samples with very few taxa	Brukunga	1997	March, June
		McIntyre Road	1997	June
4	Samples with very few taxa	McIntyre Road	1997	March, September, December
		Brukunga	1997	September, December
		Balyarta	1997	December
		Freeway	1997	December
5	Very few taxa	Balyarta	1997	September

Ordination 1997, 2005

The NMS ordination in 3 dimensions did not confirm all of the cluster groupings to be significant. Primarily, Groups 1 and 2 were not clearly distinguishable from each other (Figure 14). In contrast, Groups 3 and 4 were clearly defined in the ordination space (Figure 14).

The same ordination data are presented with each site and year labelled in Figure 15. Because samples from local reference sites were spread along axis 2 of the plot (Figure 15), this axis is interpreted as representing differences in macroinvertebrate composition attributable to the time of collection alone.

The positioning of samples from local reference sites on the left of axis 1 suggest that this axis reflects differences in macroinvertebrate composition attributable to AMD effects. The trend was for samples from McIntyre Road and Brukunga Mine in 2005 to be located further to the left of Figure 15 than samples from these sites in 1997.

This is indicative of a shift in the composition of macroinvertebrates present towards that observed at the local reference sites.

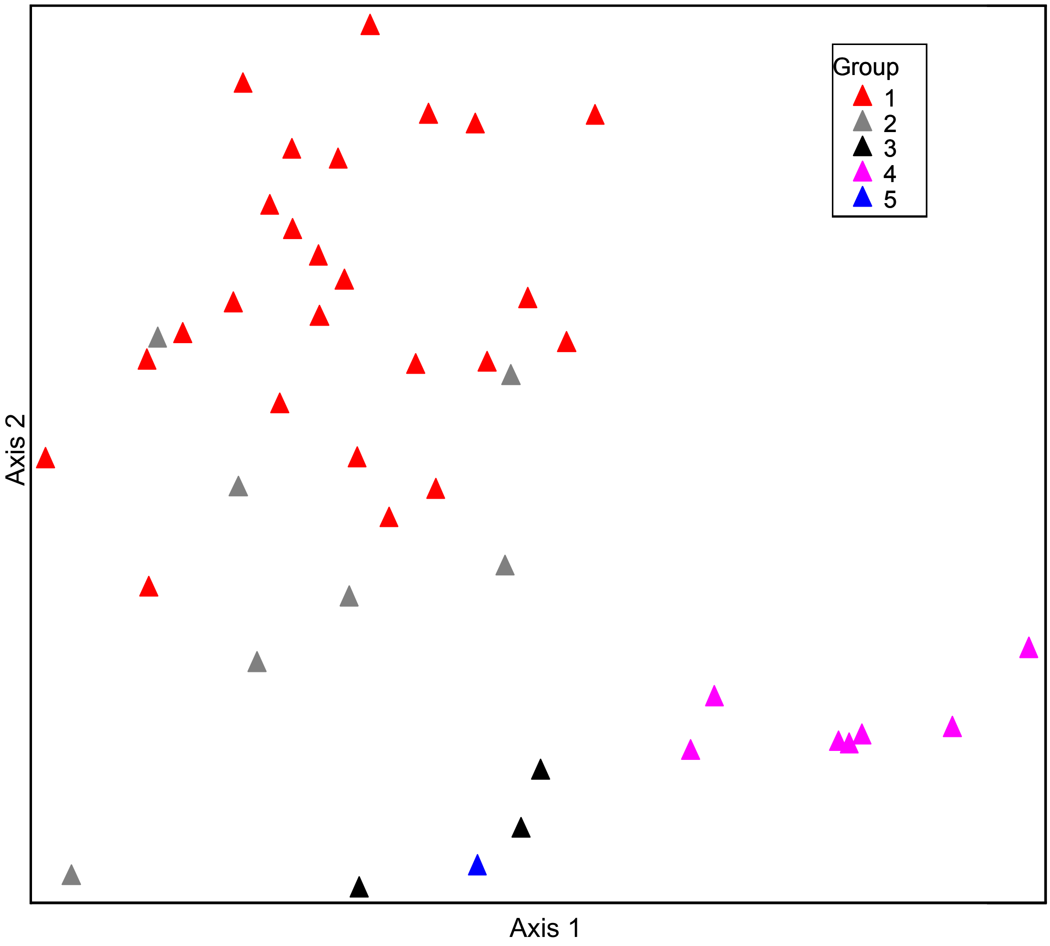

***Figure 14.* SSH Ordination of 1997 and 2005 samples.** Group numbers are those from the cluster analysis.

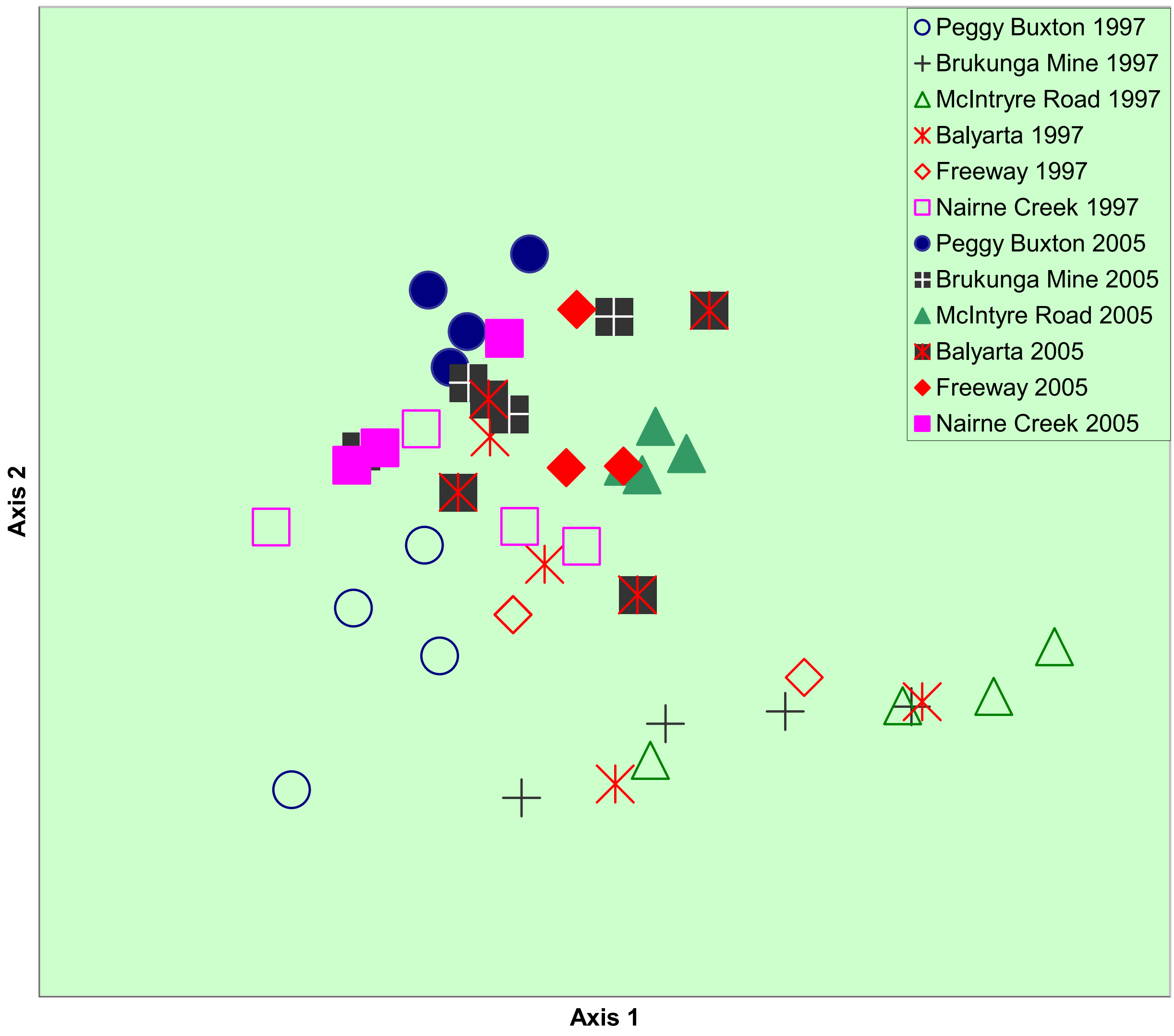

Figure 15. **SSH Ordination of 1997 and 2005 samples.** Samples from the same site have the same symbol shape; 1997 samples have unshaded symbols and 2005 samples have solid symbols.

9. Discussion and Recommendations

During this monitoring program, the water in Dawesley Creek has altered from an acidic state that was unsuitable as habitat for most macroinvertebrates and more frequently resembles reference condition. **The construction of the diversion around the mine site in 2003 was intended to isolate the mine and prevent much of the contamination** (Randall and Cox, 2003). **The indications from the 2005 monitoring are that considerable progress towards that objective has been made.**

The occurrence of surface water at the monitoring sites was higher than average in 2005 and the most similar year of flow during the duration of monitoring was considered to be 1997.

Macroinvertebrate richness at sites downstream of Brukunga Mine resembled levels at the local reference sites on most occasions. Although the degree of variation has been large, the average richness at Dawesley Creek sites downstream of Brukunga Mine since 2003 has been consistently higher than values from the 1996 to 2002 data.

The AusRivAS results for the local reference sites in June and September were not rated as representative of reference site conditions. For this reason, comparison of AusRivAS results between sites was confined to the March and December scores only. Half of the possible total of six assessments for the test sites (March and December at Balyarta and December at Brukunga Mine) were equivalent to AusRivAS reference condition. A similar frequency of Band A scores were recorded for the 2004 data but in that survey, Brukunga Mine was most similar to the local reference sites, with Balyarta least similar and McIntyre Road intermediate.

MVA indicated that the macroinvertebrate samples from the local reference sites were similar to each other, even for data collected in different years. Grouped with this collection of most of the reference site samples was 11 samples from the Dawesley Creek sites downstream of the mine. Ten of these samples were collected in 2005, and only one was collected in 1997. In 1997, sites known to receive AMD had macroinvertebrate assemblages that were more similar to each other than they were to the local reference sites. **In 2005, macroinvertebrates at these sites were equally similar to each other and to local reference sites.**

Macroinvertebrates from the Class Crustacea and the Phylum Mollusca are particularly sensitive to water of low pH. Low pH water affects the ability of these organisms to secrete the calcareous shell which makes up their exoskeleton. Macroinvertebrates from these groups are usually recorded in Dawesley Creek at Peggy Buxton Road and Nairne Creek; records of them in the past from AMD affected regions in Dawesley Creek are very rare.

It has been two years since the diversion around the mine site; spot pH recordings indicate waters of neutral pH; so why have the crustaceans and molluscs not returned to the AMD affected waters of Dawesley Creek? Close attention for the return of these macroinvertebrates will be given to determine if conditions in Daweseley Creek are approaching reference condition.

Unlike many of the macroinvertebrates in the stream that recolonise/repopulate streams via the air (as flying adults), crustaceans and molluscs migrate through the water either through drift or active movement up or down the stream. So far records for molluscs have been from Dawesley Creek at the mine and at Balyarta, both these sites are close to a population source from where these molluscs could have migrated or drifted from; a similar pattern for the few crustaceans recorded in the AMD reaches of Dawesley Creek also occurs.
Recommendations

The macroinvertebrates sampled for the last 10 years have come from pool habitats within the study area. Prior to the operation of the diversion, little information about the biological state of Dawesley Creek would have been obtained by sampling macroinvertebrates from riffle habitats, due to the highly impacted nature of the stream. Now that spot pH recordings in the AMD affected regions of Dawesley Creek are usually neutral, the riffle habitat of Dawesley Creek may be recovering and specialist riffle macroinvertebrates may have returned.

There is sufficient riffle habitat in Dawesley Creek at Peggy Buxton Road, McIntyre Road and Balayarta for populations of riffle animals to establish and it is recommended that these riffle habitats be included in future monitoring. The AUSRIVAS model assesses riffle habitats and will predict which macroinvertebrates should be in Dawesley Creek riffles. This can then be compared to the current condition to see if the riffle habitat is functional and of reference condition.

10. References

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APPENDIX B

BIOLOGICAL MONITORING RESULTS

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- **Macro-invertebrate Results 2005**

Impact Monitoring Program

Macroinvertebrate Results 2005

11. Introduction

The Brukunga Acid Mine Drainage Impact Monitoring Program, initiated in the 1996–1997 financial year, involved monitoring macroinvertebrate and chemical parameters at sites on the Dawesley Creek – Bremer River system. The Australian Water Quality Centre (AWQC) conducted biological monitoring for Primary Industries & Resources SA subject to an Environment Protection Authority licence agreement for management of the disused Brukunga pyrites mine.

The principal aim of the monitoring program was to investigate the impact of Acid Mine Drainage (AMD) on Dawesley Creek including the downstream extent of the impact. This report provides a summary of macroinvertebrate results for 2005 and provides comparisons with data from past years.

Sites

Macroinvertebrate monitoring has been conducted in the system since September 1996.

The six sites monitored from 1996 to 2005 are listed in Table 1, in order of increasing distance down the catchment.

These sites were sampled quarterly (in March, June, September and December). Figure 1 is a map of the streams showing all sites that have been sampled during the project.

***Table 1*. Macroinvertebrate sites monitored quarterly since 1996, and period of entire data record.**

Site Name	Label	Monitoring Duration	AWQC Location Code
Dawesley Ck. at Peggy Buxton Rd	**Site 1**	Sept. 1996 – Dec. 2005	4728
Dawesley Ck. D/S Brukunga	Site 2	Sept. 1996 – Dec. 2005	3158
Dawesley Ck. at McIntyre Rd	Site 3	Sept. 1996 – Dec. 2005	1951
Dawesley Ck. at Balyarta Ford	Site 4	Sept. 1996 – Dec. 2005	1822
Dawesley Ck. at Freeway	Site 5	Dec. 1996 – Dec. 2005	1952
Nairne Ck. at Djatadapeel Ford	Site 6	Sept. 1996 – Dec. 2005	1953

12. Methods

Macroinvertebrate Sampling

All macroinvertebrate sampling was conducted with sweep nets (250 µm mesh) and conformed to the Australian Rivers Assessment System (AusRivAs) standard protocol, where a 10 metre section of stream is sampled (Anon. 2001). Edge habitat was chosen because it is the only habitat present at the range of flows experienced at the sites, and thus it permits a fair comparison to be made across all sites and times.

The South Australian AusRivAs laboratory scoring protocol was used to process samples. The protocol involves counting all organisms in a randomly chosen 10% of the sample from a Marchant sub-sampler (Marchant 1989). Sub-sampling continued until a minimum of 200 animals ha been identified; for the purposes of obtaining a representative sample.

Identification was taken to the lowest practical level using the latest available keys and the AWQC voucher collection. Identification was carried out at family level or lower in all groups except Turbellaria, Nematoda and some Oligochaeta (where they were identified at the levels stated). Most Insecta and Mollusca were taken to species.

The Dipteran families Ceratopogonidae, Tipulidae, Psychodidae, Stratiomyidae and Simuliidae were taken to species or morpho-species and the Culicidae were taken to genus. The Chironomidae were taken to genus where possible (and in some cases to species) and other dipteran families were not identified below family.

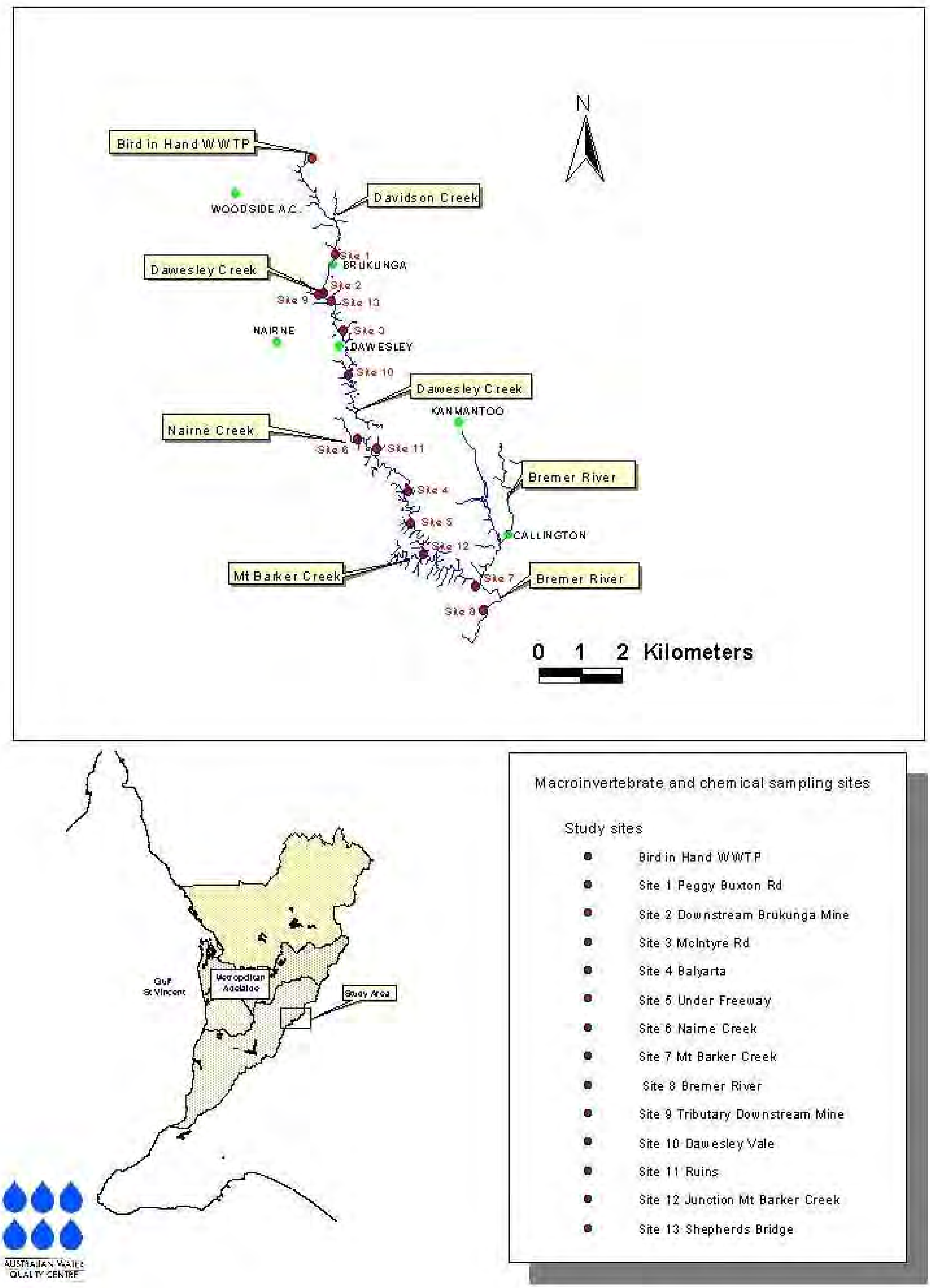

Figure 1. **Location and site map for the Dawesley Creek System**

Interpretation of Macroinvertebrate Data

Species richness, which reflects the number of different types of macroinvertebrates identified in a sample, can be used to estimate the health of a stream. In this report, the term taxon richness is used - as not all the taxa that were counted are species. As detailed in the previous section, some taxa were only identified to family, some to genus and others to species.

The taxa present in each sample and the abundance of each taxon reflects the differences between sites, habitats and conditions prior to the date of sampling. There are no simple rules for interpreting these complex data sets.

Variation due to factors such as extreme flow events, time of day, chance colonisation by rare taxa, and weather conditions is always present in addition to the variation due to water quality, season, habitat variability, ambient temperature and plant productivity. Statements regarding abundance in this report refer to the abundance within the sub-sampled portions of each collection.

Multivariate analyses (MVA) are statistical procedures that can detect similarities in biological community data (i.e. the taxa present and their abundance). MVA are a broad set of objective tools that can be used to seek and reveal structure within complex data sets avoiding investigator subjectivity.

Ordination and classification of macroinvertebrate community data provide an assessment of how similar or dissimilar samples are. Both spatial and temporal patterns can be detected which simple diversity indices and raw taxon richness and abundance figures may not reveal.

When two different MVA methods detect the same pattern the degree of confidence in the validity of the pattern is increased. This is the approach that was followed, by comparing classification and ordination analyses.

In this assessment, MVA were used to conduct a 'before and after' comparison to investigate for indications of ecological change after several years of operation of the diversion channel. From the six complete years of data available (1997-2002), the 1997 data were selected, as the hydrological conditions then most approximated those in 2005.

The statistical package PCORD was used to carry out both classification (Group Average UPGMA) and ordination (NMS non-metric multidimensional scaling). Data were grouped at a range of levels, but were predominantly at the genus and species level. No separation of the different life stages or sexes of species was included in the data tested. This gave an analysis matrix of 44 samples by 103 taxa. The Bray-Curtis association measure was used on untransformed abundance data for both methods.

Classification was run with the Groups\Cluster Analysis menu in PCORD. The classification was a hierarchical method run with the group average linkage method. To aid interpretation, a small number of groups were defined by the software. A five group level was chosen, as membership of groups did not change greatly at higher-level groupings.

Ordination was run with the Ordination\NMS menu in PCORD. The Suggested Procedure of McCune and Mefford (1999, p. 114) was followed to determine the final analysis options. A three-dimensional solution was calculated using a maximum of 200 iterations, a random start and a stability criterion of 0.00046. The resulting stress value was 14.92 and the solution was stable after approximately 55 iterations, dropping to a slightly lower stable value after about 150 iterations

AusRivAS can provide additional information. It uses family level data to compare a sample with the community found at best available reference sites with similar environmental characteristics. It produces a rating that is a guide to the level of any impact and also calculates the probability of each family occurring in a sample. These outputs are useful to determine the effectiveness of the rehabilitation of the creek by comparing the fauna to reference sites. The results from AusRivAS analysis of 2005 data are included in this report.

The AusRivAS models function by using chemical and physical variables to classify a sample and then predict the families that should be present in that sample if it were from a reference site based on the classification group probabilities. This predicted (or "***Expected***") number of families is then compared with the number of families collected (or "***O****bserved*") in the sample. The comparison is in the form of a ratio of the Observed: Expected number of families – or OE in AusRivAS. The models make frequent use of a 50% probability of taxon occurrence at a site. This is because those taxa with a > 50% chance of occurring are considered the most useful for detecting a real decline in the number of taxa (Coysh *et al.* 2000).

The AusRivAS output used in this report is the OE50 which is the observed: expected ratio for families predicted at greater than 50% probability for a sample. The OE50 ratio can be simplified to a band. Band ratings are X (higher than expected observed number of taxa), A (equivalent to reference), B (reduced number of families and therefore significantly impaired), C (severely impaired) and D (extremely impaired). The probabilities which determine the boundaries between bands may be different for each model season, as they are based on percentiles.

13. Results

Macroinvertebrate Diversity Results

2005 Surveys

The primary results consist of a list of the taxa recorded at each site and the abundance estimate of each taxon. To ensure the greatest compatibility between data sets generated at different times by different operators, only the highest taxonomic level data were used for Oligochaeta and aquatic mites.

In order to ensure the most accurate representation of taxon richness, in cases where records of both adult and immature specimens of the same taxon were present in the sample, the data were combined.

In this report only the taxon richness is discussed in detail. Richness is a measure of the diversity of the macroinvertebrate community. A higher number of taxa generally indicates a more natural site with less human-induced stress. It is also accepted that a more diverse community will recover more quickly from both natural and human-induced stresses compared with a community with low diversity.

In the graphs that summarise the macroinvertebrate data, the pH measured in the field at the time of sample collection have been added to indicate the major differences in water chemistry at different sites and times. It is referred to as spot pH. Even though a clear correlation between taxa and pH is evident, causality is not implied. There are many differences in the chemistry of low pH AMD and higher pH (neutral or alkaline) streams. The reduced diversity is not simply attributable to increased acidity.

March 2005

In previous surveys, it has been common for several Dawesley Creek sites to be dry in March. Conditions in March 2005 were wetter and macroinvertebrate assemblages were present at sites which have been dry in previous autumns.

Samples from McIntyre Road and Balyarta possessed a richness similar to that of the local reference site at Peggy Buxton Road (Figure 2).

Spot samples of stream pH were circum-neutral (Figure 2).

The possibility that flows of Nairne Creek have decreased since 2004 was strengthened with a repeat of the March 2004 record of no flow in March 2005 (Figure 2). All monitoring data prior to 2004 had suggested that the site experienced permanent flow.

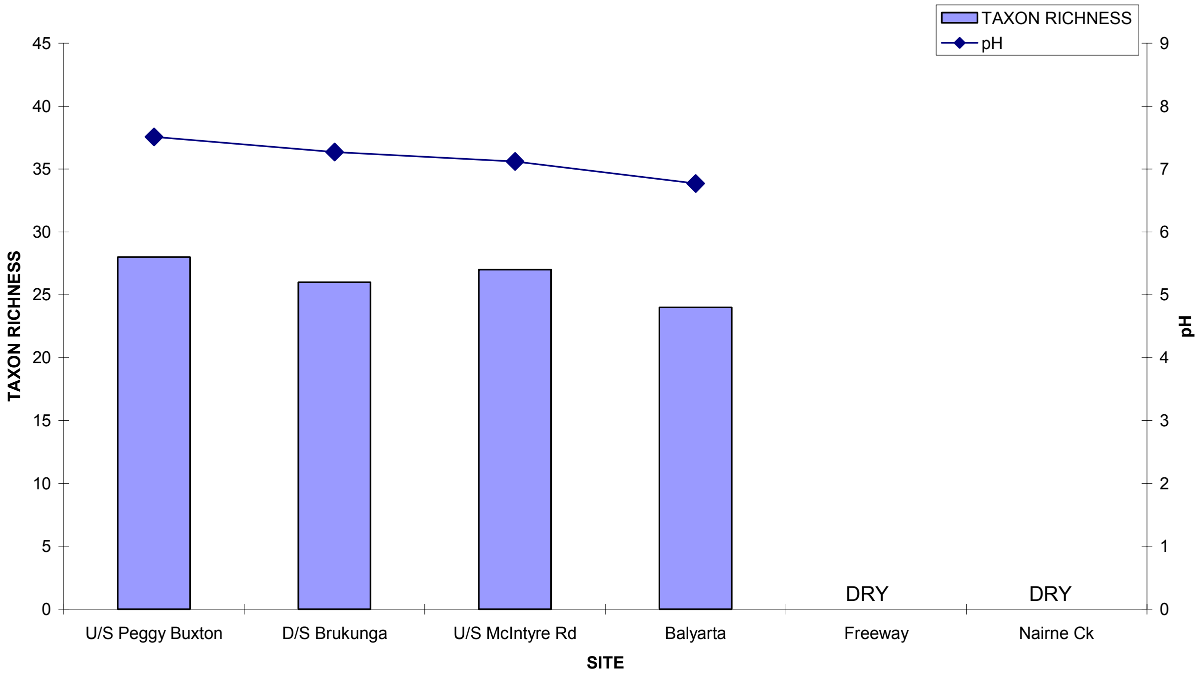

***Figure 2*. March 2005 taxon richness and pH.**

June 2005

Results from the June 2005 samples differed from the pattern commonly present by previous winter surveys.

Spot pH at Brukunga Mine and McIntyre Road were 1-2 units lower than at Peggy Buxton Road; however, levels of macroinvertebrate richness at these sites were comparable to each other (Figure 3) and to values in March (Figure 2).

At Balyarta, the biological community had apparently undergone disturbance during the interval between sampling; macroinvertebrate richness was approximately half of what it had been in March (Figures 2, 3).

Surface water was present in Nairne Creek, and the biological and chemical conditions present mirrored those at Peggy Buxton Road (Figure 3).

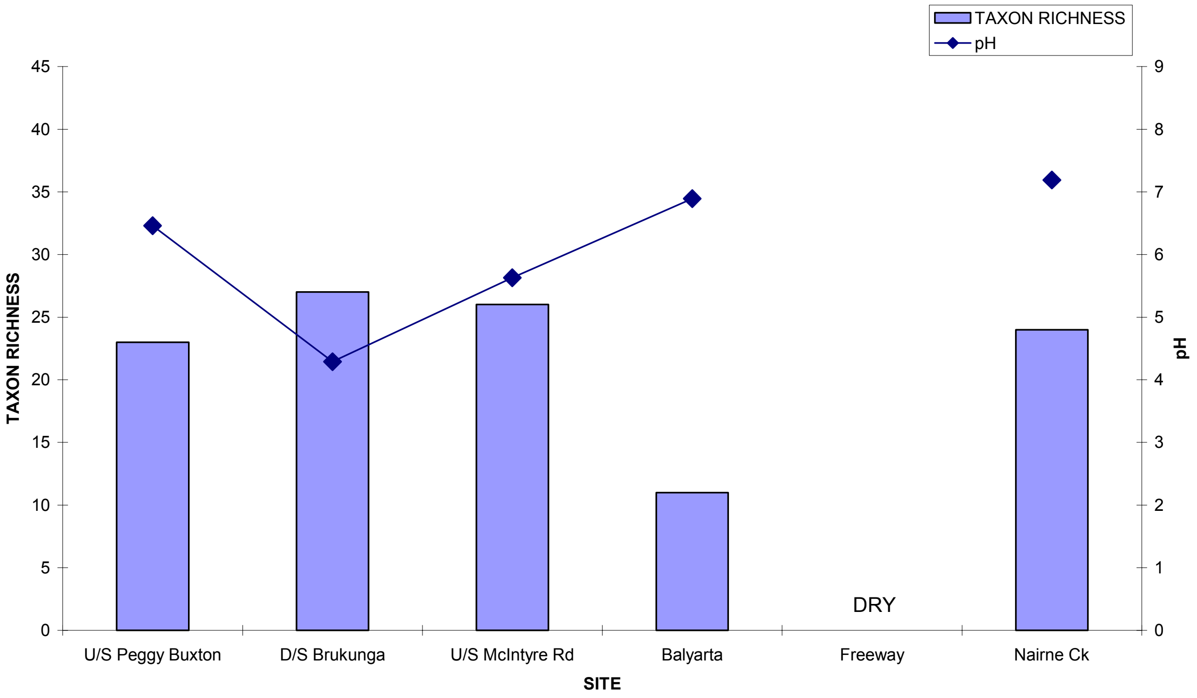

Figure 3. **June 2005 taxon richness and pH.**

September 2005

Surface water was present at the Freeway site in September.

Spot values of pH across the sites were in the range of 6-8 (Figure 4).

Levels of macroinvertebrate richness were generally lower than they had been in June samples (Figures 3, 4). An exception to this was for the Balyarta sample, which did not indicate disturbance – being of a similar richness to other samples (Figure 4).

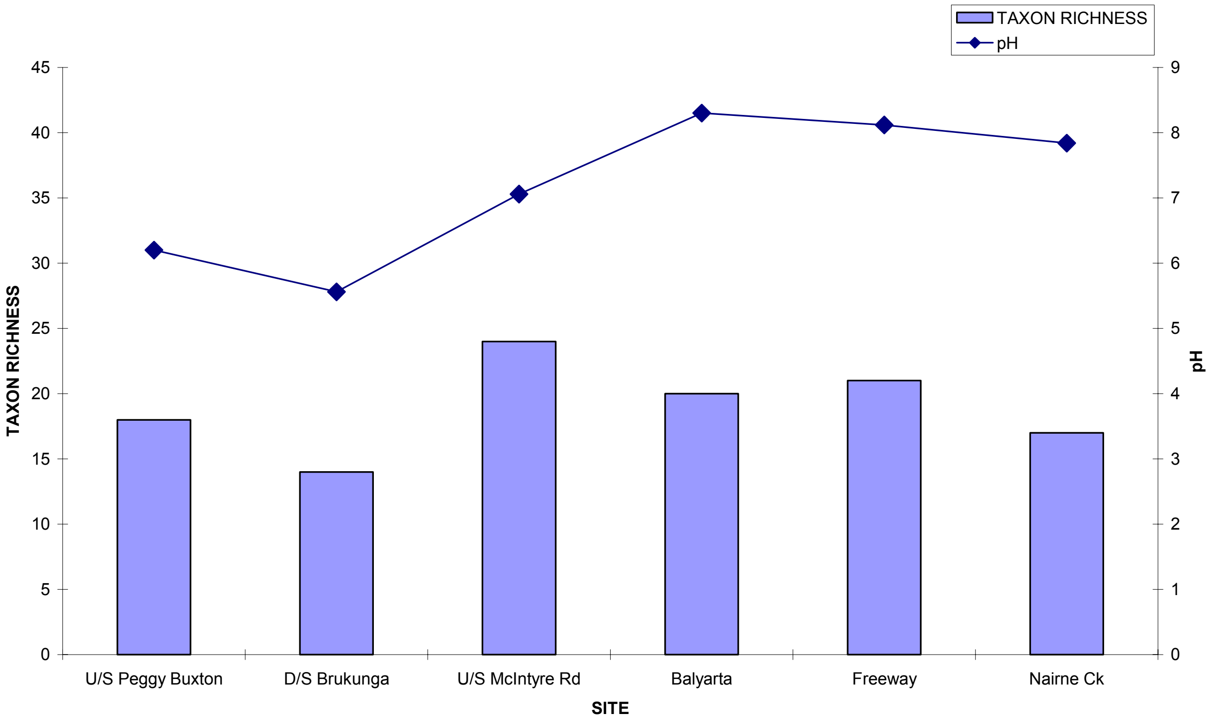

***Figure 4*. September 2005 taxon richness and pH.**

December 2005

Results for this season had the greatest resemblance to the patterns shown for 2004.

A spot pH of between 6.5 and 8 was observed at all sites (Figure 5).

Macroinvertebrate richness at most sites increased when compared to the September values and lay in the range of 25 to 30 taxa (Figures 4, 5).

In contrast, richness at McIntyre Road was similar to the value in September (Figures 4, 5).

A significant biological record was the presence of the isopod crustacean species *Heterias pusilla* at Balyarta. Though frequently at the local reference sites in the Dawesley Creek system, this species has not been detected in the AMD affected reach for many years.

Since September 2000, this species has not been collected in Dawesley Creek downstream of Peggy Buxton Road.

It is likely that improved water quality conditions at Balyarta was the primary factor influencing the occurrence of this crustacean there in 2005.

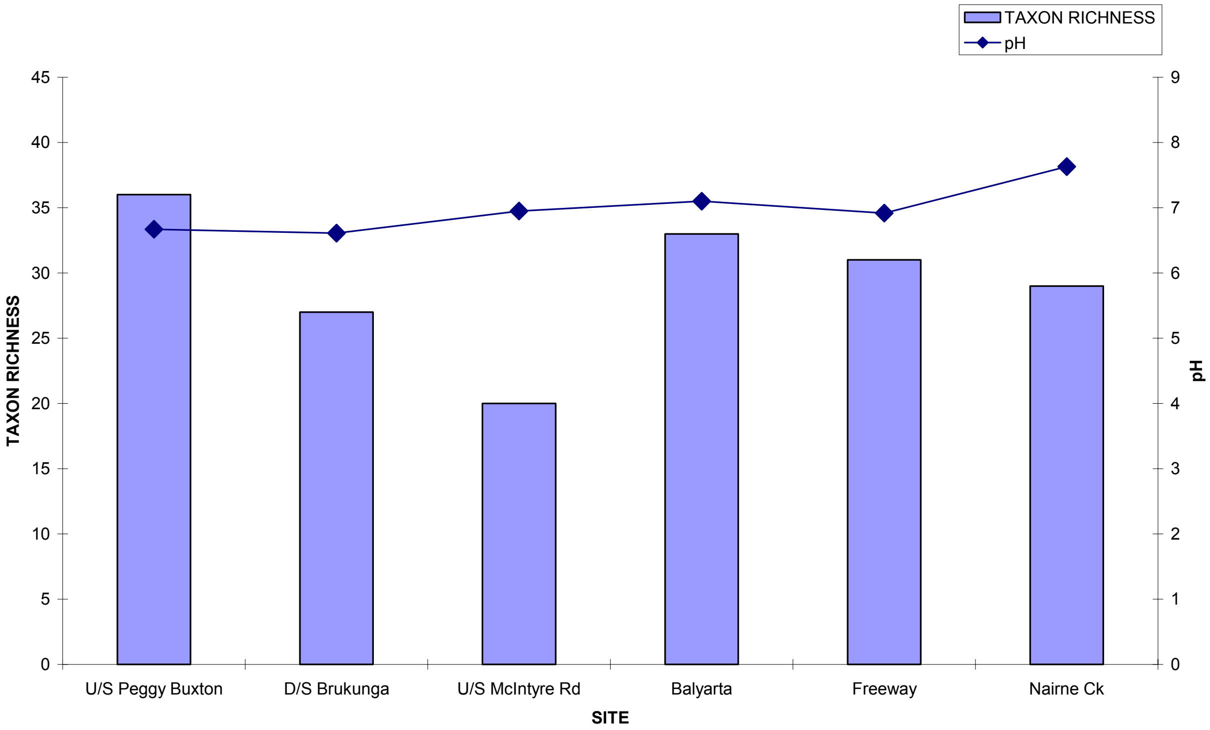

***Figure 5*. December 2005 taxon richness and pH.**

Mean taxon richness 1996-2005

A comparison of macroinvertebrate taxonomic richness prior to and since operation of the diversion scheme is presented in Figure 6.

Since March 2003, all sites on Dawesley Creek that have been exposed to AMD have on average supported more macroinvertebrate taxa (Figure 6).

This trend of improved ecological health was most marked at the Brukunga and McIntyre Road sites, which indicate that continued improvement will give rise to statistically significant differences (Figure 6).

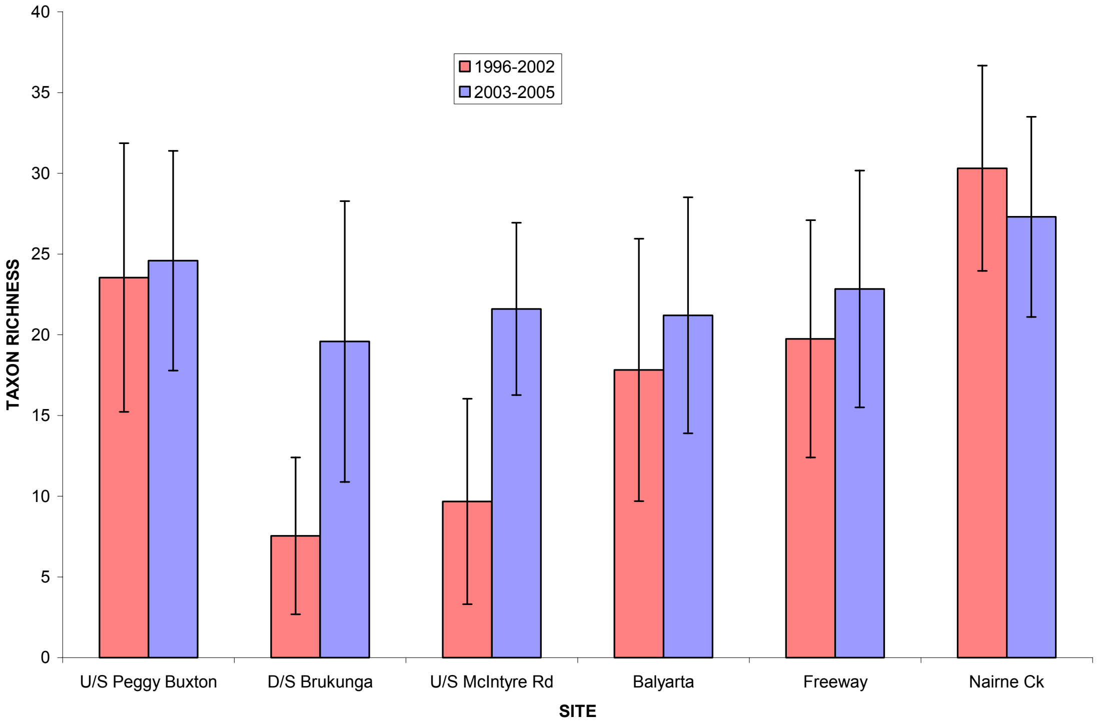

Figure 6. **Dawesley Creek system: taxon richness at six sites: 1996 – 2002 and 2003 – 2005.** Error bars show two standard deviations.

Temporal Changes at Each Site

At each of the six sites the full data set from September 1996 to December 2005 has been presented in a series of graphs (Figures 7-12). This allows the 2005 data to be compared with the findings of earlier years.

Peggy Buxton Road

Water discharged from the Bird in Hand Wastewater Treatment Plant was found to affect conditions at Peggy Buxton Road. Macroinvertebrate species richness was depressed at times due to eutrophic conditions (Figure 7).

Flow levels were variable and often ceased in autumn but the pools remained and a macroinvertebrate community was always present. Both floods and periods of ceased flow impacted the community causing reduction in species richness. Prolonged periods of normal flow, on the other hand, created favourable conditions for macroinvertebrates which resulted in increased taxon richness. December 2005 would appear to be an example of this pattern. The species richness was usually much higher than that found immediately downstream where AMD has entered the creek.

Taxon richness peaked in 2002 when 42 different taxa were recorded in December. The lowest numbers of taxa were recorded in June 1997 and September 2003 when 7 and 13 taxa were recorded, respectively.

Stream pH fluctuated over the years from 6 to 8.

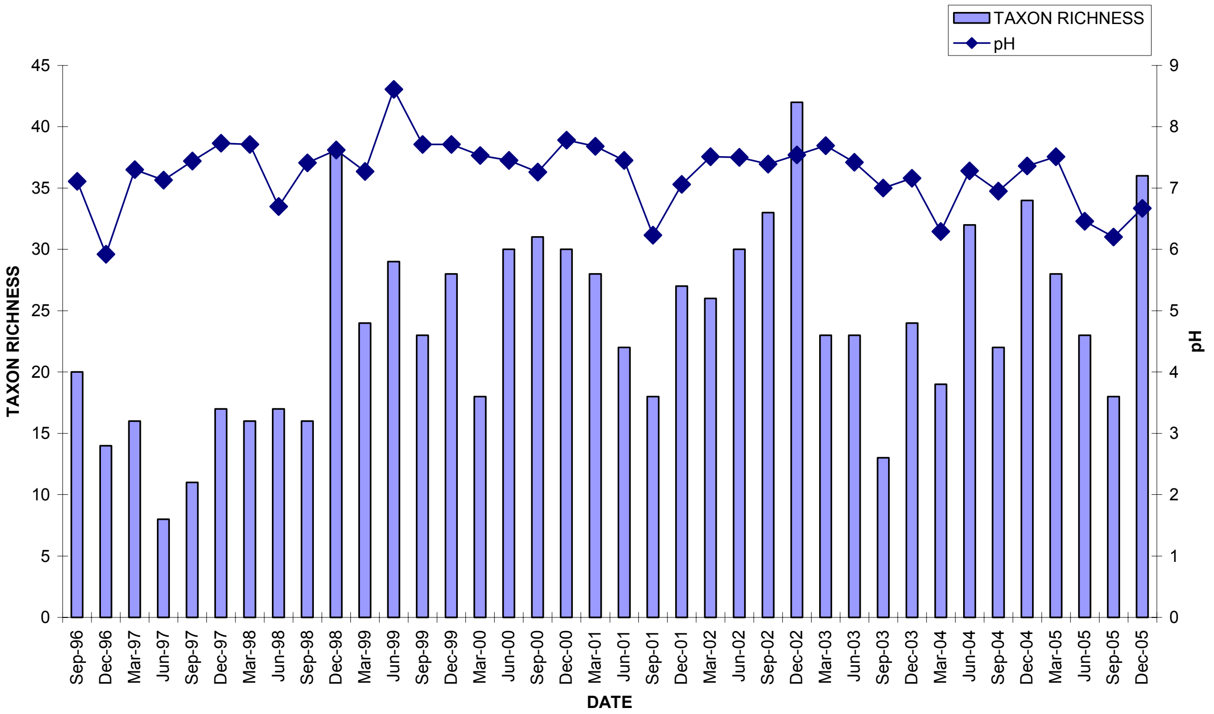

Figure 7. **Dawesley Creek: Peggy Buxton Road. Taxon richness and pH.**

Brukunga Mine

The pH measurement in December 2003 was the first recorded above 7 since the diversion became operational. Measurements in 2004 followed this trend showing the highest recorded pH for March and June since 1996 and again, circum-neutral conditions in September and December 2004 (see Figure 8).

In 2004, the maximum taxonomic richness was recorded for all seasons except for December where it was marginally higher in 2003.

Richness for most of the 2005 samples resembled that of 2004. Low richness in September may have been associated with a pulse of acidity detected in June (Figure 8).

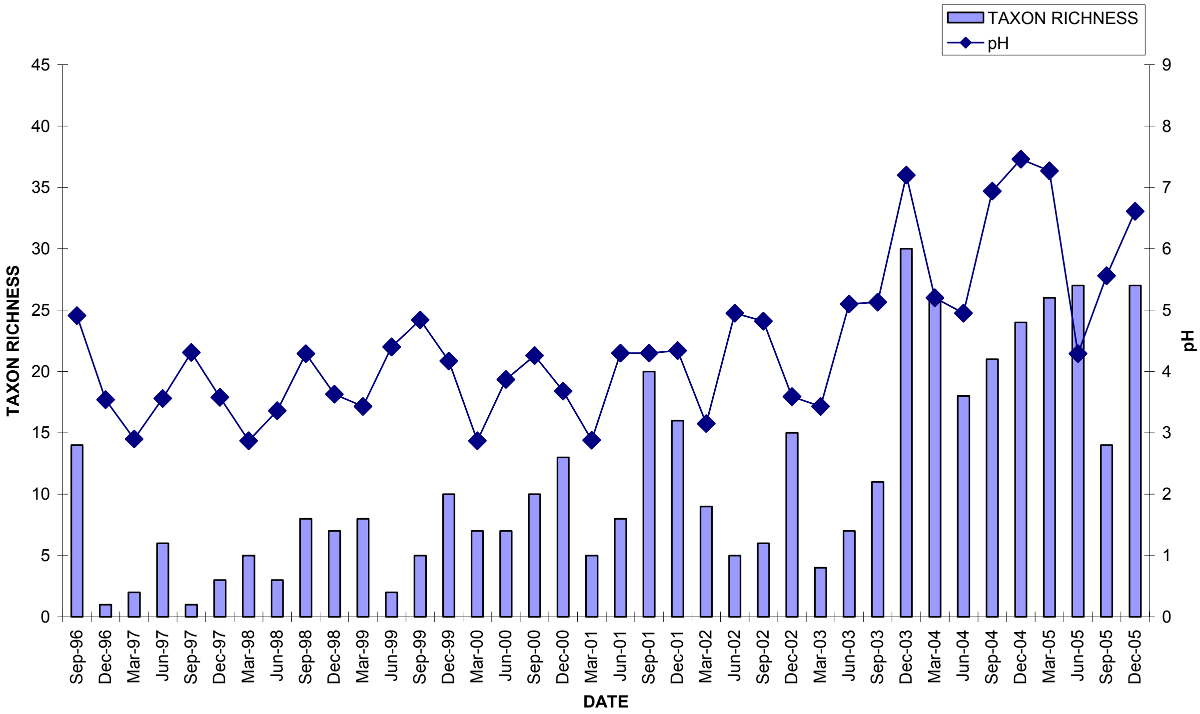

Figure 8. **Dawesley Creek: Downstream of Brukunga mine. Taxon richness and pH.**

Upstream McIntyre Road

Values of pH were within the range of the previous year, with the annual minimum also in June.

December 2004 showed the highest richness ever measured at the site.

In 2005, richness was similar to or greater than that in June and September of 2004 (Fig. 9).

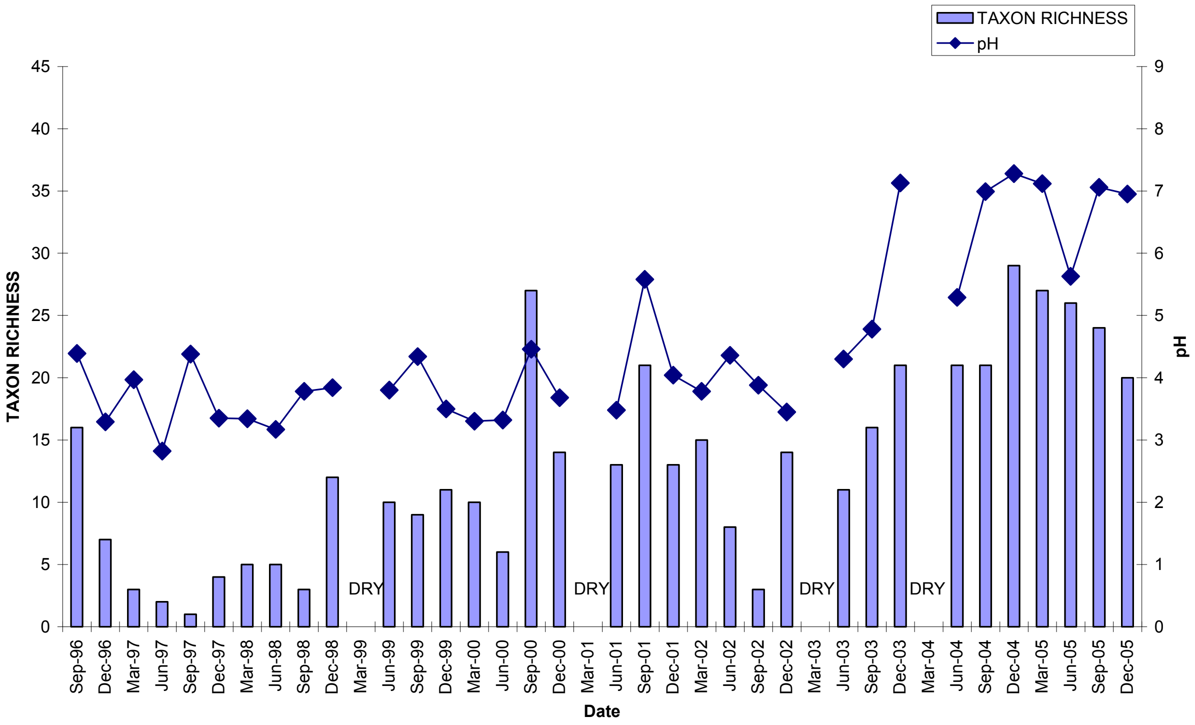

***Figure 9*. Dawesley Creek: McIntyre Road. Taxon richness and pH.**

Balyarta

The section of Dawesley Creek downstream of its confluence with Nairne Creek was usually dry in late summer and early autumn.

The 1996/97 and 2004/05 summers were wetter, and drying of the stream was not observed (Figure 10).

There was variation from year to year in the degree of effect of low pH water from the mine at this site. These year to year variations are dependent on the amount of rainfall and flow. The 2005 data followed the pattern shown in most years since 1997, i.e. the taxon richness decreased when the AMD influence extended downstream (Figure 10).

The stream pH in 2005 provided four consecutive values higher than 6, the first occurrence in the dataset (Figure 10).

A pH of 8.3 in September 2005 eclipsed the previous highest measurement recorded at the site in the previous September (Figure 10).

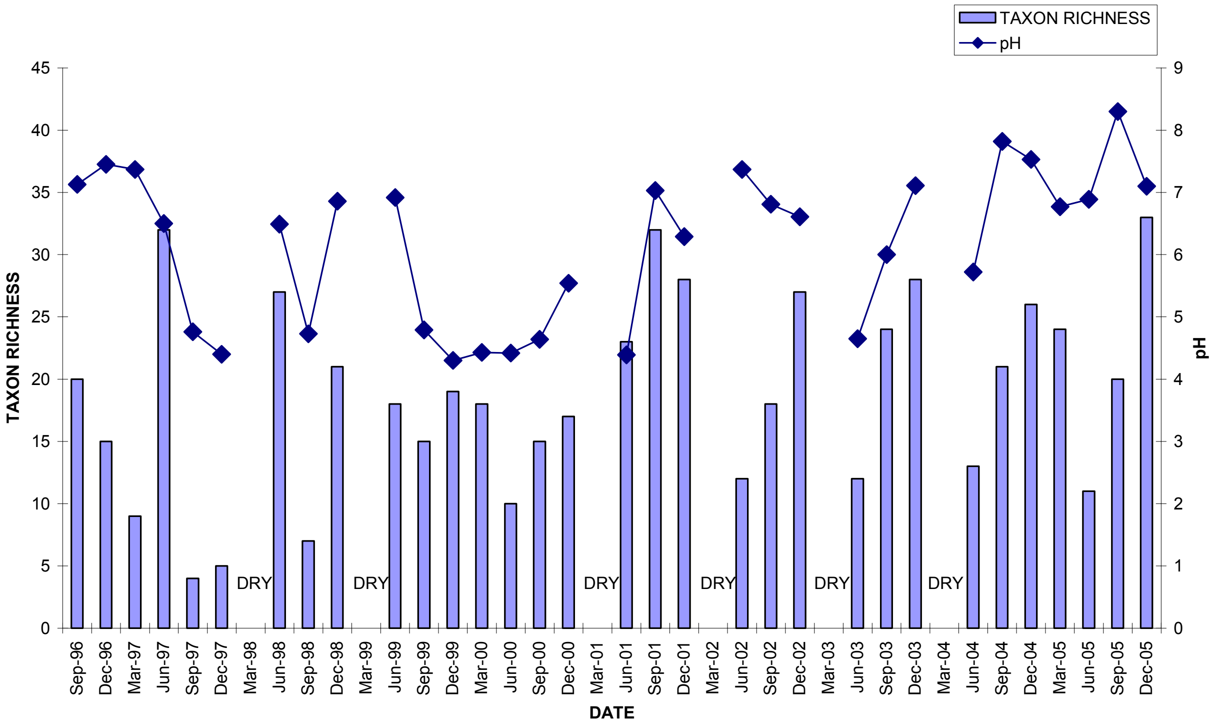

Figure 10. **Dawesley Creek: Balyarta. Taxon richness and pH.**

Freeway

As an intermittent site the taxon richness has been variable over the years of monitoring (Figure 11).

Simply by chance, sampling may have taken place a few days, a few weeks or a few months after the site was wetted. Consequently, the time for the community to establish at the site before sampling occurred also varied. In some cases the time was sufficient for a diverse community to establish but at other times there may have been only a short time between inundation and sampling.

The samples from 2003 were thought to be affected somewhat by AMD as the pH was about 5 on each sampling occasion.

As for the previous year, in 2005 the pH was alkaline to neutral, which suggests that the AMD influence was subdued or absent at these times.

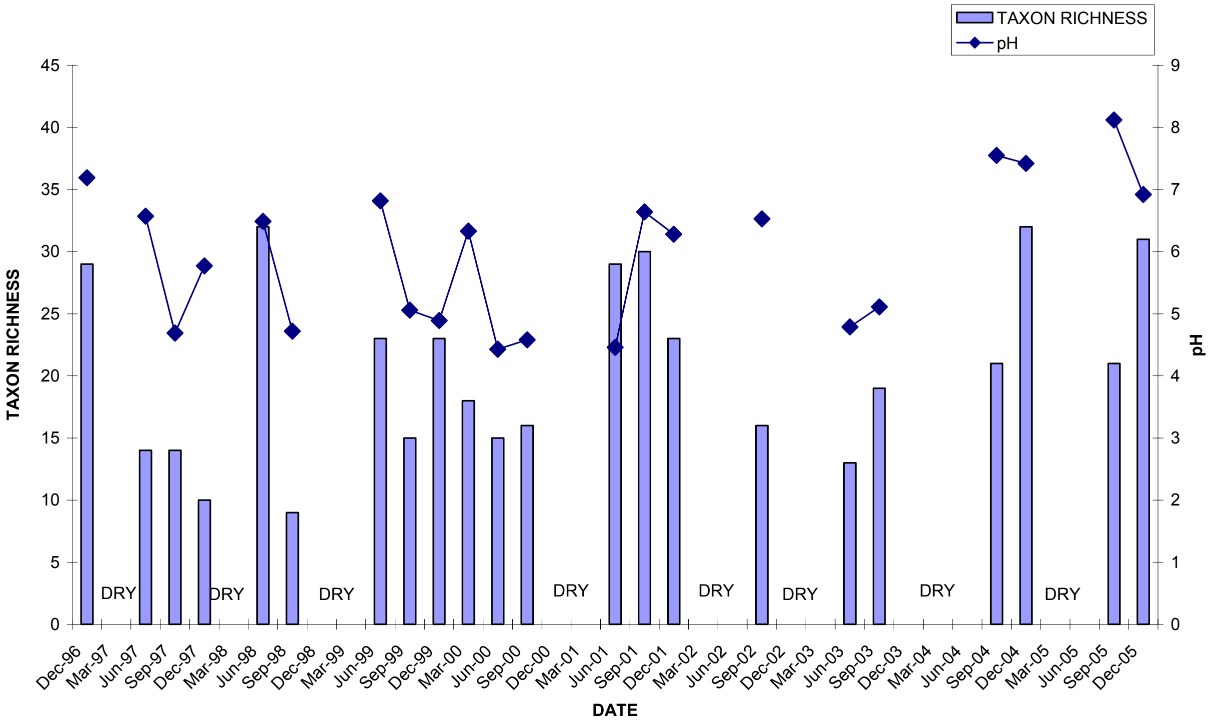

Figure 11. **Dawesley Creek: Freeway. Taxon richness and pH.**

Nairne Creek

From 1996 to 2003 this local reference site was slightly eutrophic but had a taxon richness and pH that was comparable to other Mount Lofty Ranges streams with reasonable water quality (Figure 12). It reflected the condition expected to prevail in Dawesley Creek if AMD and treated wastewater from the Bird-in-Hand WWTP were not present, with highest taxon richness in winter and spring.

The surface hydrology of Nairne Creek appears to have undergone a major change since 2004. Consequently, ecological changes have occurred.

In the most recent two years, the stream has been dry in autumn, and subsequently both pH and taxon richness has stepped up (Figure 12) to levels comparable with those present at Peggy Buxton Road.

Presently, taxon richness in Nairne Creek does not resemble that of other Mount Lofty Ranges streams, but is similar to that in Dawesley Creek at Balyarta and McIntyre Road (see Figures 9 and 10).

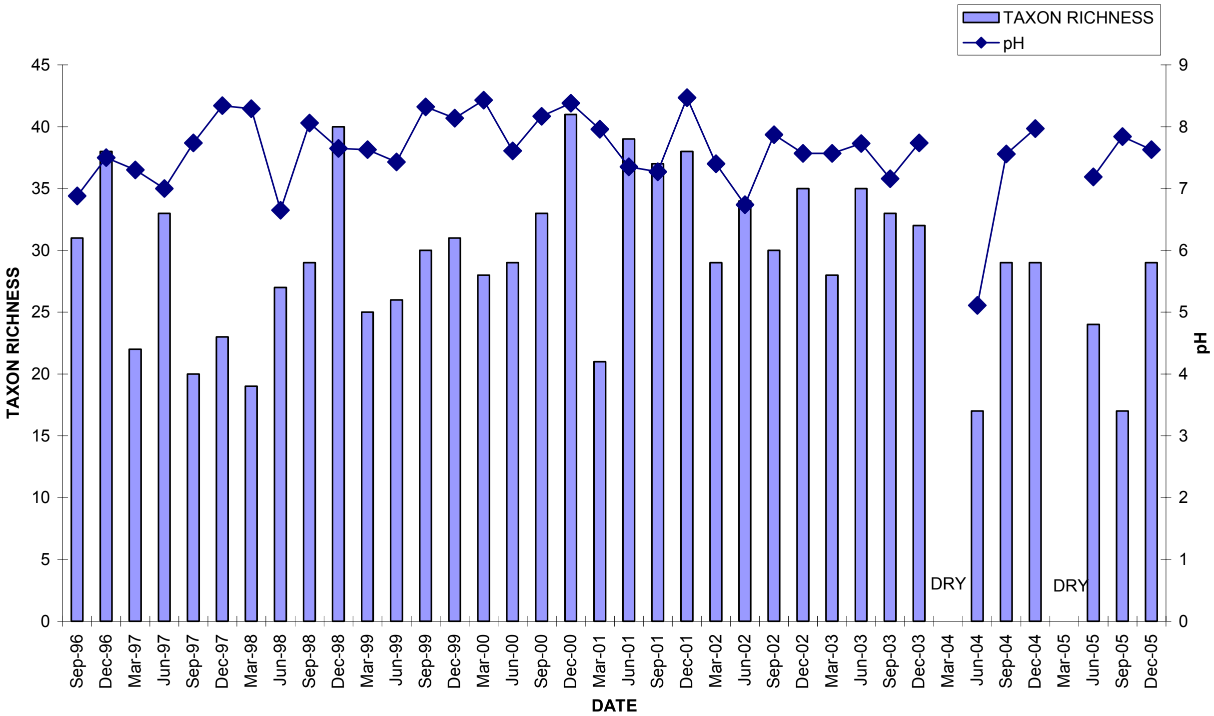

Figure 12. **Nairne Creek. Taxon richness and pH.**

AusRivAS Results

Three seasonal models were used in this study, the Autumn edge model, Spring edge model and the Combined season edge model. The samples from March and June were tested in the Autumn edge model and the samples from September and December were tested in the Spring edge model.

The Combined season edge model data was produced by summing the abundance of each invertebrate family in June and December samples. Results from the AusRivAS models in 2005 are shown in Table 2.

All results for the sites that have not been exposed to AMD **(Peggy Buxton Road and Nairne Creek, or the *local reference sites*) were assessed as being in reference condition (Band A)** during March and December (Table 2).

Note there was no rating for Nairne Creek in March as it was dry. In June and September, macroinvertebrates at these same sites were indicative of a slight impairment of ecological health (Table 2).

Macroinvertebrate richness at Balyarta followed the same trend as Peggy Buxton Road and Nairne Creek (Table 2) and was therefore interpreted as being uninfluenced by AMD.

Macroinvertebrate samples from Brukunga Mine were rated the same as the local reference sites in December, but had lower health than those sites in March (Table 2).

McIntyre Road did not conform to the pattern of the local reference sites in either March or December (Table 2).

The combined season model was not useful in interpreting patterns, as all sites scored similarly.

***Table 2.* AusRivAS results for sites sampled in 2005.**

SEASON		**Peggy Buxton 4728**	**Brukunga Mine 3158**	**McIntyre Rd 1951**	**Balyarta 1822**	**Freeway 1952**	**Nairne Creek 1953**
March	**OE50**	0.97	0.74	0.76	0.94	DRY	DRY
	Band	**A**	**B**	**B**	**A**		
June	**OE50**	0.76	1.00	0.73	0.59	DRY	0.77
	Band	**B**	**A**	**B**	**B**		**B**
September	**OE50**	0.62	0.69	0.66	0.5	0.54	0.67
	Band	**B**	**B**	**B**	**B**	**B**	**B**
December	**OE50**	1.1	0.88	0.55	0.92	0.72	1.13
	Band	**A**	**A**	**B**	**A**	**B**	**A**
Combined Season Jun/Dec	**OE50**	0.89	0.88	0.83	0.86	DRY	0.91
	Band	**A**	**A**	**A**	**A**		**A**

Multivariate Analysis Results

Cluster analysis

Results of the cluster analysis are presented in a dendrogram (Figure 13) which shows the grouping of samples with similar macroinvertebrate assemblages.

For the purpose of interpretation, five groups were identified from the dendrogram. These groups are labelled 1-5 in Figure 13 and the group membership is listed in Table 3.

Most of the samples were allocated to Group 1, and most of the 2005 samples were contained in this group.

The macroinvertebrates present at the local reference sites were similar to each other in 2005 and to Nairne Creek samples from 1997.

Notably, 10 of the 14 samples from the Dawesley Creek sites downstream of the diversion in 2005 were placed in the same group as the local reference sites (Figure 13, Table 3).

Group 2 samples came from both years and a range of sites. Interpretation of this set of samples was not simple, though samples from March and September featured prominently.

Groups 3, 4 and 5 contained samples from 1997 collected at sites that received AMD (Figure 13, Table 3). As noted in Table 3, the low richness of many of these samples may have contributed to them having greater similarity with each other.

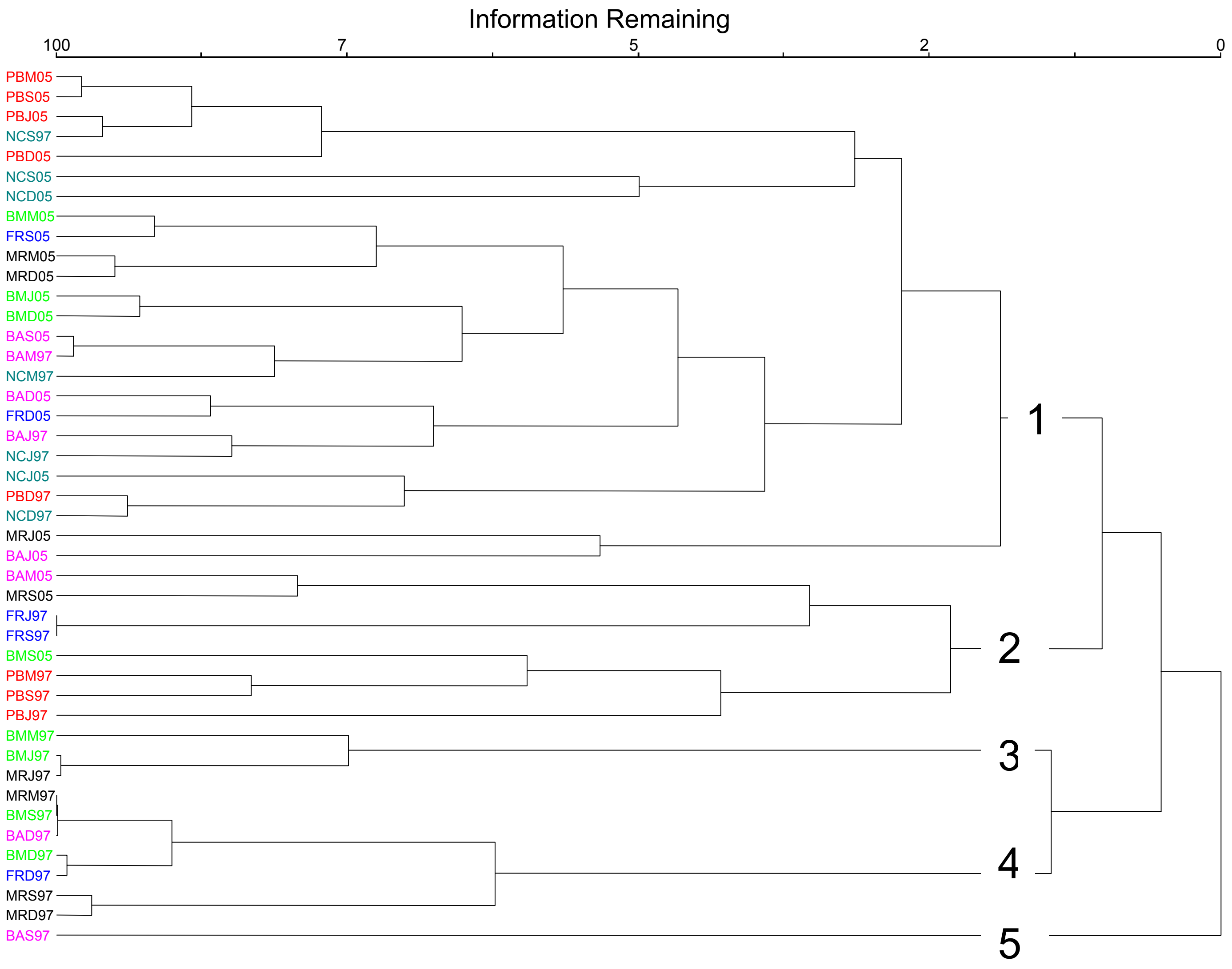

***Figure 13*. Dendrogram of 1997 and 2005 samples.** **(First two letters designate site. PB = Peggy Buxton Road, BM = D/S Brukunga, MR = McIntyre Road, BA = Balyarta, F = Freeway, NC = Nairne Creek. Third letter designates month, M = March, J = June, S = September and D = December. Digits indicate year of collection). Interpretation of Groups 1-5 is provided in Table 3.**

Table 3. **Group membership of cluster analysis.**

Group	Designation	Sites	Years	Seasons
1	**Local reference sites and improved AMD-exposed sites (but mixed)**	Peggy Buxton, Nairne Creek	2005	All
		Peggy Buxton	1997	December
		Nairne Creek	1997	All
		Balyarta	**2005**	**June-December**
		Balyarta	1997	March, June
		Freeway	**2005**	**September, December**
		McIntyre Road	**2005**	**March, June, December**
		Brukunga	**2005**	**March, June, December**
2	No clear commonality; March and September samples	Peggy Buxton	1997	March-September
		Freeway	1997	June, September
		Balyarta	2005	March
		McIntyre Road	2005	September
		Brukunga	2005	September
3	Samples with very few taxa	Brukunga	1997	March, June
		McIntyre Road	1997	June
4	Samples with very few taxa	McIntyre Road	1997	March, September, December
		Brukunga	1997	September, December
		Balyarta	1997	December
		Freeway	1997	December
5	Very few taxa	Balyarta	1997	September

Ordination 1997, 2005

The NMS ordination in 3 dimensions did not confirm all of the cluster groupings to be significant. Primarily, Groups 1 and 2 were not clearly distinguishable from each other (Figure 14). In contrast, Groups 3 and 4 were clearly defined in the ordination space (Figure 14).

The same ordination data are presented with each site and year labelled in Figure 15. Because samples from local reference sites were spread along axis 2 of the plot (Figure 15), this axis is interpreted as representing differences in macroinvertebrate composition attributable to the time of collection alone.

The positioning of samples from local reference sites on the left of axis 1 suggest that this axis reflects differences in macroinvertebrate composition attributable to AMD effects. The trend was for samples from McIntyre Road and Brukunga Mine in 2005 to be located further to the left of Figure 15 than samples from these sites in 1997.

This is indicative of a shift in the composition of macroinvertebrates present towards that observed at the local reference sites.

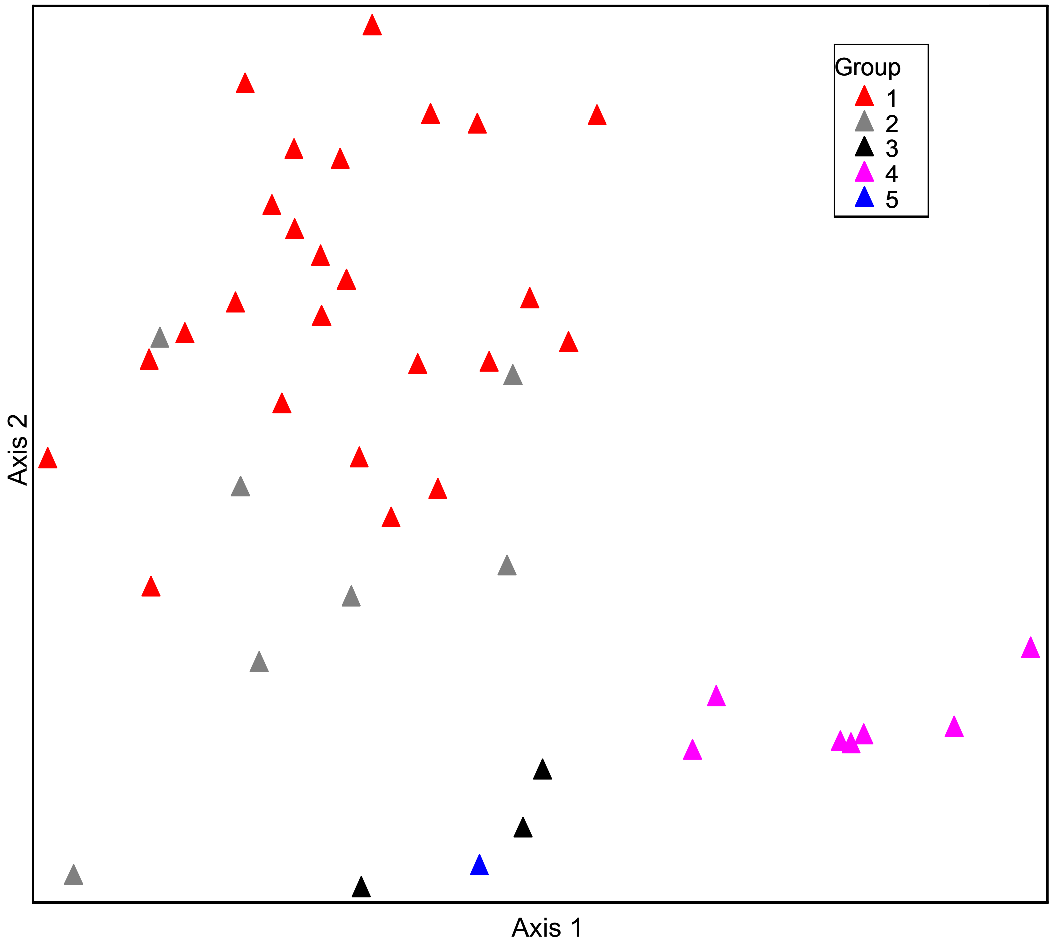

Figure 14. **SSH Ordination of 1997 and 2005 samples.** Group numbers are those from the cluster analysis.

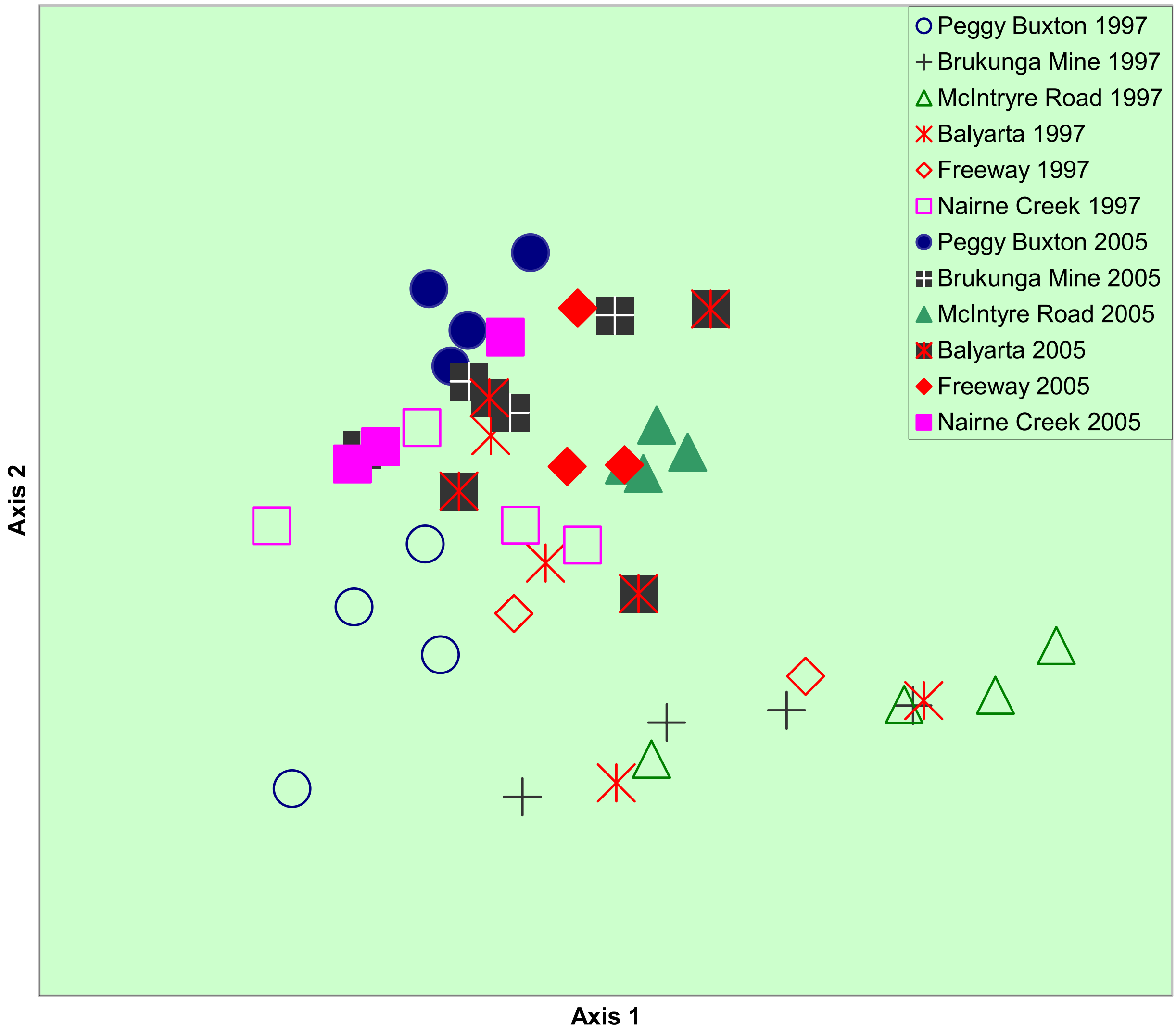

Figure 15. **SSH Ordination of 1997 and 2005 samples.** Samples from the same site have the same symbol shape; 1997 samples have unshaded symbols and 2005 samples have solid symbols.

14. Discussion and Recommendations

During this monitoring program, the water in Dawesley Creek has altered from an acidic state that was unsuitable as habitat for most macroinvertebrates and more frequently resembles reference condition. **The construction of the diversion around the mine site in 2003 was intended to isolate the mine and prevent much of the contamination** (Randall and Cox, 2003). **The indications from the 2005 monitoring are that considerable progress towards that objective has been made.**

The occurrence of surface water at the monitoring sites was higher than average in 2005 and the most similar year of flow during the duration of monitoring was considered to be 1997.

Macroinvertebrate richness at sites downstream of Brukunga Mine resembled levels at the local reference sites on most occasions. Although the degree of variation has been large, the average richness at Dawesley Creek sites downstream of Brukunga Mine since 2003 has been consistently higher than values from the 1996 to 2002 data.

The AusRivAS results for the local reference sites in June and September were not rated as representative of reference site conditions. For this reason, comparison of AusRivAS results between sites was confined to the March and December scores only. Half of the possible total of six assessments for the test sites (March and December at Balyarta and December at Brukunga Mine) were equivalent to AusRivAS reference condition. A similar frequency of Band A scores were recorded for the 2004 data but in that survey, Brukunga Mine was most similar to the local reference sites, with Balyarta least similar and McIntyre Road intermediate.

MVA indicated that the macroinvertebrate samples from the local reference sites were similar to each other, even for data collected in different years. Grouped with this collection of most of the reference site samples was 11 samples from the Dawesley Creek sites downstream of the mine. Ten of these samples were collected in 2005, and only one was collected in 1997. In 1997, sites known to receive AMD had macroinvertebrate assemblages that were more similar to each other than they were to the local reference sites. **In 2005, macroinvertebrates at these sites were equally similar to each other and to local reference sites.**

Macroinvertebrates from the Class Crustacea and the Phylum Mollusca are particularly sensitive to water of low pH. Low pH water affects the ability of these organisms to secrete the calcareous shell which makes up their exoskeleton. Macroinvertebrates from these groups are usually recorded in Dawesley Creek at Peggy Buxton Road and Nairne Creek; records of them in the past from AMD affected regions in Dawesley Creek are very rare.

It has been two years since the diversion around the mine site; spot pH recordings indicate waters of neutral pH; so why have the crustaceans and molluscs not returned to the AMD affected waters of Dawesley Creek? Close attention for the return of these macroinvertebrates will be given to determine if conditions in Daweseley Creek are approaching reference condition.

Unlike many of the macroinvertebrates in the stream that recolonise/repopulate streams via the air (as flying adults), crustaceans and molluscs migrate through the water either through drift or active movement up or down the stream. So far records for molluscs have been from Dawesley Creek at the mine and at Balyarta, both these sites are close to a population source from where these molluscs could have migrated or drifted from; a similar pattern for the few crustaceans recorded in the AMD reaches of Dawesley Creek also occurs.

Recommendations

The macroinvertebrates sampled for the last 10 years have come from pool habitats within the study area. Prior to the operation of the diversion, little information about the biological state of Dawesley Creek would have been obtained by sampling macroinvertebrates from riffle habitats, due to the highly impacted nature of the stream. Now that spot pH recordings in the AMD affected regions of Dawesley Creek are usually neutral, the riffle habitat of Dawesley Creek may be recovering and specialist riffle macroinvertebrates may have returned.

There is sufficient riffle habitat in Dawesley Creek at Peggy Buxton Road, McIntyre Road and Balayarta for populations of riffle animals to establish and it is recommended that these riffle habitats be included in future monitoring. The AUSRIVAS model assesses riffle habitats and will predict which macroinvertebrates should be in Dawesley Creek riffles. This can then be compared to the current condition to see if the riffle habitat is functional and of reference condition.

15. References

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APPENDIX C

METAL CONCENTRATION WITHIN THE ZONE OF IMPACT

Nairne Creek (*Control)*, upsteam of the ford at Diatadapeel

Sample Location AWQC 1953

< - indicates level less than analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
14-Jan-2003	7.5	970	1750	33.5	0.140	<0.0005	<0.003	0.002	0.906	<0.0005	0.0535	0.0033	0.006
11-Feb-2003	7.7	900	1630	46.4	0.396	<0.0005	<0.003	0.006	0.827	0.0011	0.0297	0.0040	0.024
10-Mar-2003	7.7	760	1380	73.2	0.136	<0.0005	<0.003	0.001	0.491	<0.0005	0.0313	0.0030	0.004
01-Apr-2003	7.4	690	1250	74.0	0.248	<0.0005	<0.003	0.005	0.478	0.0006	0.0170	0.0031	0.011
05-May-2003	7.3	630	1150	60.4	0.208	<0.0005	<0.003	0.003	0.260	<0.0005	0.0047	0.0034	0.009
12-Jun-2003	7.7	670	1220	68.9	0.397	<0.0005	<0.003	0.005	0.762	<0.0005	0.0106	0.0077	0.013
22-Jul-2003	7.5	840	1520	82.6	0.259	<0.0005	<0.003	0.003	0.423	<0.0005	0.0139	0.0045	0.015
19-Aug-2003	7.9	890	1610	84.4	0.398	<0.0005	<0.003	0.005	0.803	0.0006	0.0142	0.0035	0.018
10-Sep-2003	8.1	1100	1910	105	0.421	<0.0005	<0.003	0.005	0.747	0.0006	0.0254	0.0061	0.024
21-Oct-2003	7.7	950	1730	104	0.293	<0.0005	<0.003	0.005	0.338	<0.0005	0.0104	0.0061	0.008
11-Nov-2003	7.7	820	1490	79.5	0.069	<0.0005	<0.003	0.005	0.202	<0.0005	0.0056	0.0047	0.006
10-Dec-2003	7.7	720	1300	83.4	0.193	<0.0005	<0.003	0.005	0.196	<0.0005	0.0063	0.0043	0.009
20-Jan-2004	7.6	710	1300	118	0.090	<0.0005	<0.003	0.002	0.495	0.0007	0.0689	0.0052	0.006
17-Feb-2004		no flow											
10-Mar-2004		no flow											
15-Apr-2004		no flow											
19-May-2004		no flow											
18-Jun-2004	7.6	460	830	106	2.16	<0.0005	0.007	0.009	2.260	0.0029	0.0656	0.0073	0.069
14-Jul-2004	7.7	700	1280	114	0.441	<0.0005	<0.003	0.007	0.637	<0.0005	0.0102	0.0077	0.049
19-Aug-2004	7.9	1000	1820	123	0.667	<0.0005	<0.003	0.007	1.020	0.0006	0.0531	0.0062	0.046
15-Sep-2004	7.9	1100	2024	138	0.15	<0.0005	<0.003	<0.001	0.540	<0.0005	0.0783	0.0069	0.029
19-Oct-2004	9	1700	3120	268	0.031	<0.0005	0.004	0.004	0.438	<0.0005	0.0861	0.0072	0.008
9-Nov-2004	8	1000	1850	117	0.234	<0.0005	0.005	0.004	0.554	<0.0005	0.0321	0.0058	0.019
15-Dec-2004	8	720	1310	99.0	0.063	0.0006	<0.003	0.005	0.552	<0.0005	0.0249	0.0060	0.014
12-Jan-2005		no flow											
11-Feb-2005		no flow											
7-Mar-2005		no flow											
13-Apr-2005		no flow											
02-May-2005	7.4	770	1390	160	0.255	<0.0005	<0.003	0.011	0.503	<0.0005	0.0186	0.0047	0.031
15-Jun-2005	7.7	630	1150	122	0.694	<0.0005	<0.003	0.013	1.210	0.0019	0.1095	0.0009	0.036
13-Jul-2005	7.6	870	1570	105	0.198	<0.0005	<0.003	0.005	0.239	<0.0005	0.0085	0.0022	0.033
23-Aug-2005	8.1	580	1050	71.8	0.439	<0.0005	<0.003	0.004	0.523	0.0006	0.0075	<0.0005	0.016
05-Sep-2005	8.3	860	1550	115	0.170	<0.0005	0.004	0.005	0.334	<0.0005	0.0095	0.0024	0.021
18-Oct-2005	7.9	930	1690	107	0.112	<0.0005	<0.003	0.006	0.287	<0.0005	0.0204	0.0071	0.022
21-Nov-2005	7.8	871	1580	99.0	0.124	<0.0005	<0.003	0.0053	0.366	<0.0005	0.0236	0.0056	0.016
15-Dec-2005	8.2	799	1450	83.1	0.035	<0.0005	<0.003	0.0043	0.124	<0.0005	0.0041	0.0069	0.009

1992 ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic	less 6.5	1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**pH>6.5 < 9.0**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-1. Nairne Creek (control, not influenced by mine drainage)

Peggy Buxton Road, upstream of the Mine Site
Sample Location AWQC 4728

< - indicates level less than analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
14-Jan-2003	7.7	1200	2240	42.0	1.180	<0.0005	<0.003	0.003	1.04	0.0012	0.1048	0.0049	0.011
03-Feb-2003		No Flow											
10-Mar-2003	7.8	1600	2850	255.0	0.272	<0.0005	0.004	0.004	1.67	0.0007	0.4504	0.0129	0.018
01-Apr-2003	7.5	1400	2500	74.5	0.339	<0.0005	<0.003	0.001	1.01	0.0005	0.0459	0.0084	0.004
05-May-2003		No Flow											
12-Jun-2003	7.6	870	1570	85.9	1.160	<0.0005	0.004	0.003	1.55	0.0009	0.0362	0.0088	0.012
22-Jul-2003	7.9	730	1330	99.4	0.169	<0.0005	<0.003	0.003	0.531	<0.0005	0.021	0.0056	0.023
19-Aug-2003	7.0	910	1650	93.6	0.209	<0.0005	<0.003	0.003	<0.030	<0.0005	0.1001	0.0051	0.037
10-Sep-2003	7.5	1000	1840	95.6	0.748	<0.0005	<0.003	0.002	1.93	0.0008	0.1915	0.0063	0.069
21-Oct-2003	7.5	1200	2180	124.0	0.355	<0.0005	0.004	0.005	0.758	0.0007	0.0479	0.006	0.019
11-Nov-2003	7.5	1100	1970	98.2	0.609	<0.0005	<0.003	0.003	1.05	0.0007	0.0678	0.0054	0.007
10-Dec-2003	7.2	870	1580	90.7	1.090	<0.0005	<0.003	0.003	2.22	0.0011	0.0601	0.0053	0.038
20-Jan-2004	7.7	970	1760	88.7	0.570	<0.0005	<0.003	0.002	0.921	0.0013	0.0423	0.007	0.008
17-Feb-2004	7.7	1000	1870	62.7	0.510	<0.0005	0.005	0.005	0.815	0.0010	0.0706	0.0059	0.010
10-Mar-2004	7.7	1100	1940	64.2	0.338	<0.0005	<0.003	<0.001	0.727	0.0006	0.0605	0.0042	<0.003
15-Apr-2004	7.8	1000	1830	135.0	0.319	<0.0005	<0.003	0.001	0.446	<0.0005	0.0209	0.0036	0.003
19-May-2004	7.7	1300	2380	153.0	0.373	<0.0005	0.008	0.004	0.569	0.0006	0.0389	0.0049	0.018
18-Jun-2004	7.7	970	1760	101.0	1.050	<0.0005	0.004	0.003	1.46	0.0007	0.0435	0.0049	0.012
14-Jul-2004	7.6	790	1430	78.0	0.649	<0.0005	0.005	0.014	1.31	0.0010	0.0385	0.0058	0.019
19-Aug-2004	7.3	950	1720	85.1	0.421	<0.0005	<0.003	0.004	1.11	0.0007	0.0874	0.0037	0.024
15-Sep-2004	7.5	940	1700	81.7	0.440	<0.0005	<0.003	0.003	1.2	0.0009	0.0661	0.0059	0.012
19-Oct-2004	8.0	1200	2100	104.0	0.273	<0.0005	0.004	0.004	0.792	0.0007	0.1003	0.0052	0.013
09-Nov-2004	7.8	870	1580	63.8	0.848	<0.0005	0.006	0.004	1.59	0.0011	0.0642	0.0045	0.013
15-Dec-2004	7.7	840	1530	54.6	0.827	<0.0005	<0.003	0.002	1.01	<0.0005	0.0328	0.0040	0.005
12-Jan-2005		no flow											
11-Feb-2005	7.5	930	1680	114.0	0.336	<0.0005	<0.003	0.004	1.77	0.0012	0.1829	0.0067	0.015
22-Mar-2005	7.6	910	1650	111.0	0.307	<0.0005	<0.003	0.003	2.11	0.0009	1.342	0.0090	0.011
14-Apr-2005	7.6	950	1720	116.0	0.532	<0.0005	<0.003	0.004	1.65	0.0009	0.663	0.0036	0.012
02-May-2005	8.6	970	1760	140.0	0.187	<0.0005	0.004	0.002	0.484	<0.0005	0.1953	0.0030	0.007
15-Jun-2005	7.6	860	1550	99.9	2.720	<0.0005	0.01	0.007	3.42	0.0022	0.2992	0.0030	0.015
13-Jul-2005	7.4	820	1490	62.6	0.460	<0.0005	<0.003	0.003	0.77	<0.0005	0.1406	0.0021	0.008
23-Aug-2005	7.3	880	1600	73.9	0.556	<0.0005	0.003	0.006	0.937	0.0007	0.1063	0.0142	0.028
05-Sep-2005	7.4	900	1640	82.5	0.353	<0.0005	0.005	0.003	1.04	<0.0005	0.2021	0.0010	0.009
18-Oct-2005	7.5	1000	1810	89.4	0.373	<0.0005	<0.003	0.003	1.10	0.0007	0.2176	0.0049	0.009
21-Nov-2005	7.5	1020	1850	71.7	0.455	<0.0005	0.004	0.0048	1.01	0.0006	0.1076	0.0040	0.014
15-Dec-05	7.7	832	1510	45.3	0.455	<0.0005	<0.003	0.0016	1.13	0.0007	0.0645	0.0069	0.027

ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic	less 6.5	1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**pH>6.5 < 9.0**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-2. Dawesley Creek upstream of the mine site

Dawesley Creek - downstream of Brukunga Mine Site

Sample Location AWQC 3158

< - indicates level less than analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l	Acidity as $CaCO_3$
14-Jan-2003	3.7	3,400	6,000	4,020	336.0	0.0298	<0.003	0.024	5.95	0.0011	24.70	0.0602	12.90	
03-Feb-2003		No Flow												
10-Mar-2003	3.6	3,700	6,590	2,550	406.0	0.1160	<0.003	0.215	9.40	0.0023	51.60	1.2270	27.90	
1-Apr-2003	3.4	3500	6200	4,006	294.0	0.0599	0.011	0.095	11.10	0.0020	30.2	0.0681	22.6	
5-May-2003	3.3	2,900	5,180	3,738	216.0	0.0405	0.006	0.087	4.81	0.0021	28.90	0.5142	13.03	
12-Jun-2003	5.6	1,400	2,440	887	4.8	0.0095	<0.003	0.012	7.10	<0.0005	8.17	0.0796	1.02	
22-Jul-2003	6.5	1,400	2,550	941	27.1	0.0067	<0.003	0.007	15.6	0.0013	1.95	0.0238	1.227	
19-Aug-2003	5.2	1,400	2,450	772	17.1	0.0181	<0.003	0.029	4.53	0.0010	1.47	0.0365	1.16	68.8
10-Sep-2003	5.2	1,400	2,560	756	18.5	0.0148	<0.003	0.032	4.37	0.0008	2.65	0.1037	1.39	61.4
21-Oct-2003	5.6	1,600	2,800	928	8.98	0.0165	<0.003	0.023	3.48	0.0006	3.58	0.0720	1.22	15.5
11-Nov-2003	6.7	1,500	2,760	1,014	4.22	0.0069	<0.003	0.007	2.48	<0.0005	4.67	0.0427	0.397	15.3
10-Dec-2003	7.0	1,100	1,920	348	2.28	0.0035	0.003	0.006	2.11	<0.0005	0.84	0.0319	0.119	26.3
20-Jan-2004	7.0	1100	2,040	277	1.23	0.0022	<0.003	0.005	1.34	<0.0005	0.56	0.0327	0.1330	920
17-Feb-2004	6.9	1300	2310	423	1.00	0.0030	<0.003	0.005	2.06	<0.0005	1.20	0.0462	0.308	93.0
10-Mar-2004	6.3	1800	3,230	774	1.24	0.0020	<0.003	0.002	1.12	<0.0005	1.045	0.0288	0.154	96.5
15-Apr-2004	7.2	1300	2,360	564	1.15	0.0017	<0.003	0.003	0.969	<0.0005	0.7038	0.0240	0.1100	58.0
19-May-2004	6.2	2000	3550	1930	2.25	0.0050	0.006	0.003	2.54	<0.0005	1.831	0.0352	0.733	62.0
18-Jun-2004	4.0	1300	2430	1710	129.0	0.0161	0.008	0.090	7.19	0.0022	8.63	0.3819	9.82	807
14-Jul-2004	7.0	1300	2280	806	2.50	0.0026	<0.003	0.008	1.30	<0.0005	1.238	0.0415	0.209	100
19-Aug-2004	6.4	1300	2350	662	3.34	0.0076	<0.003	0.011	1.96	<0.0005	3.567	0.0388	0.705	68.7
15-Sep-2004	7.0	1300	2330	574	5.21	0.0041	<0.003	<0.001	2.01	<0.0005	0.8591	0.0269	0.278	
19-Oct-2004	6.8	1600	2910	956	2.91	0.0082	<0.003	0.010	1.60	<0.0005	2.917	0.045	0.566	153
9-Nov-2004	7.4	1200	2160	535	1.25	0.0023	0.004	0.007	0.68	<0.0005	1.602	0.0223	0.097	163
15-Dec-2004	7.3	960	1740	217	0.60	0.0014	<0.003	0.006	0.485	<0.0005	0.4852	0.0293	0.039	81.0
12-Jan-2005		no flow												
11-Feb-2005	7.2	1400	2440	692	1.52	0.0015	<0.003	0.005	11.00	0.001	8.772	0.0298	0.187	93.8
22-Mar-2005	7.5	970	1760	211	2.58	0.0012	<0.003	0.006	6.12	0.0012	1.023	0.027	0.214	102
13-Apr-2005	7.3	1600	2870	1220	2.03	0.0011	<0.003	0.005	3.02	0.0006	4.350	0.014	0.158	101
18-May-2005	8.8	1200	2130	528	1.70	0.0006	<0.003	0.003	2.11	<0.0005	2.407	0.0359	0.146	25.1
15-Jun-2005	4.2	1200	2150	1090	87.1	0.0254	0.004	0.034	11.60	0.0007	6.786	0.1473	4.846	578
13-Jul-2005	6.4	1200	2180	660	24.1	0.0084	<0.003	0.015	8.46	0.0015	1.31	0.0355	1.205	15.8
23-Aug-2005	7.1	1100	2020	382	8.54	0.0035	<0.003	0.010	4.35	0.0016	0.7225	0.0181	0.393	81.1
5-Sep-2005	6.7	1300	2410	766	2.96	0.0040	0.003	0.011	2.25	<0.0005	2.59	0.0383	0.284	67.0
18-Oct-2005	6.6	1700	2990	1240	5.24	0.0065	<0.003	0.150	2.26	<0.0005	4.09	0.0373	0.398	73.9
21-Nov-05	4.4	1480	2680	969	2.87	0.0357	<0.003	0.0152	17.8	<0.0005	15.88	0.2282	4.07	85.9
15-Dec-05	7.4	1060	1920	405	4.25	0.0053	<0.003	0.0115	4.00	0.0006	1.375	0.0346	0.886	43.5

1992 ANZECC GUIDELINES FOR WATER QUALITY (highlighted value indicates the recorded value exceeds the recommended guideline)

For Aquatic	less 6.5	1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**pH>6.5 < 9.0**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-3. Dawesley Creek leaving the Brukunga mine site

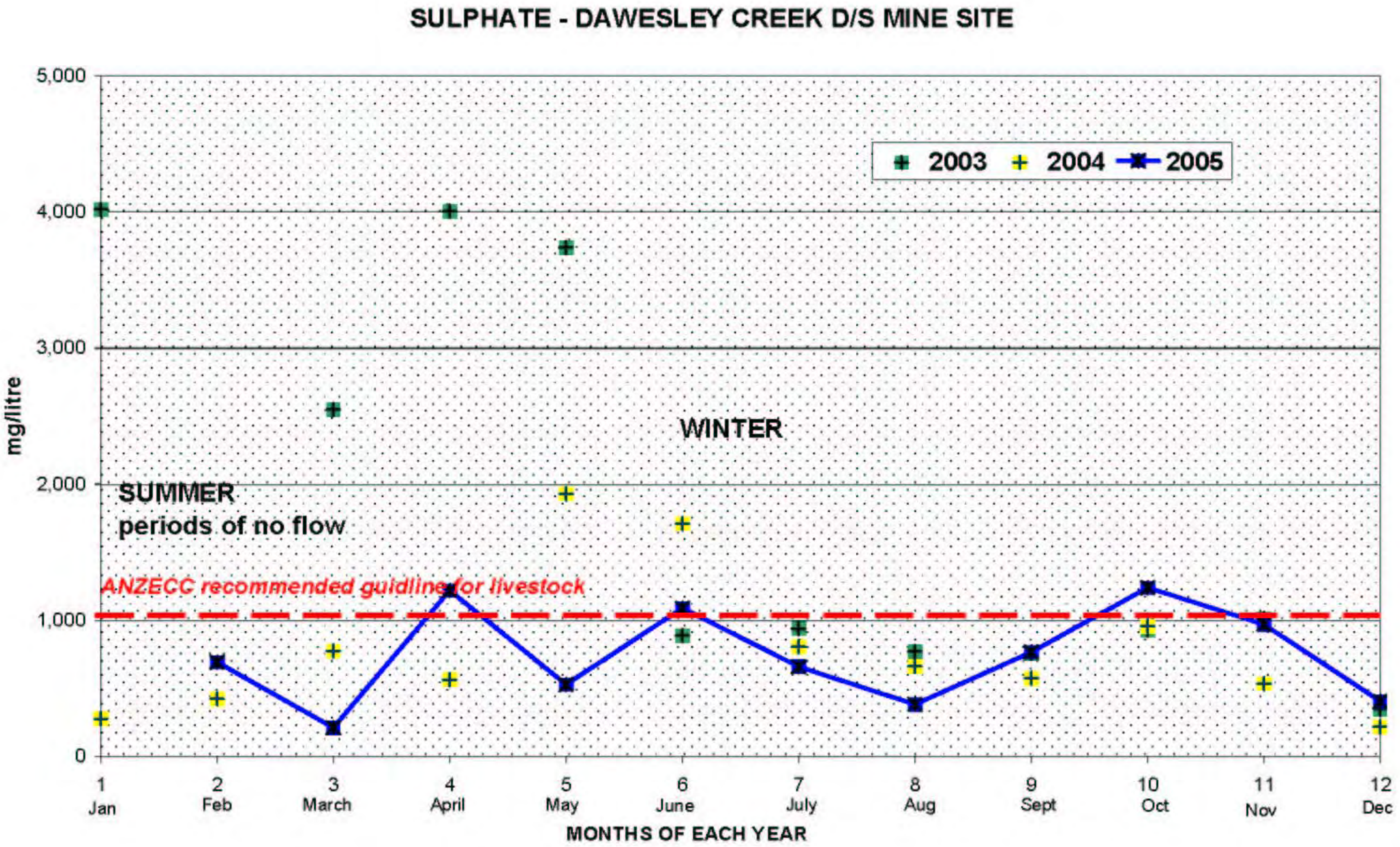


Fig C-4. Sulphate in Dawesley Creek leaving the mine site

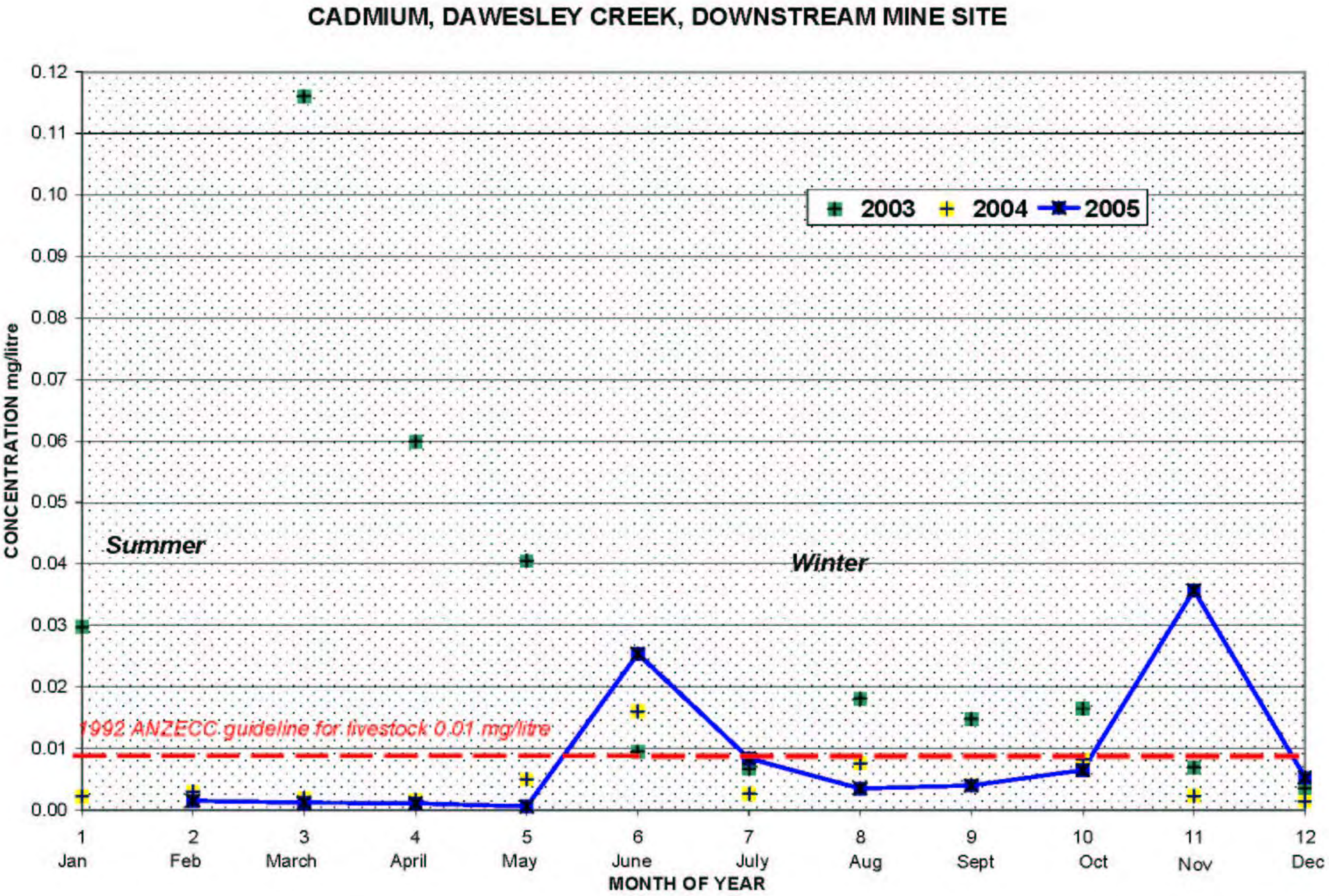
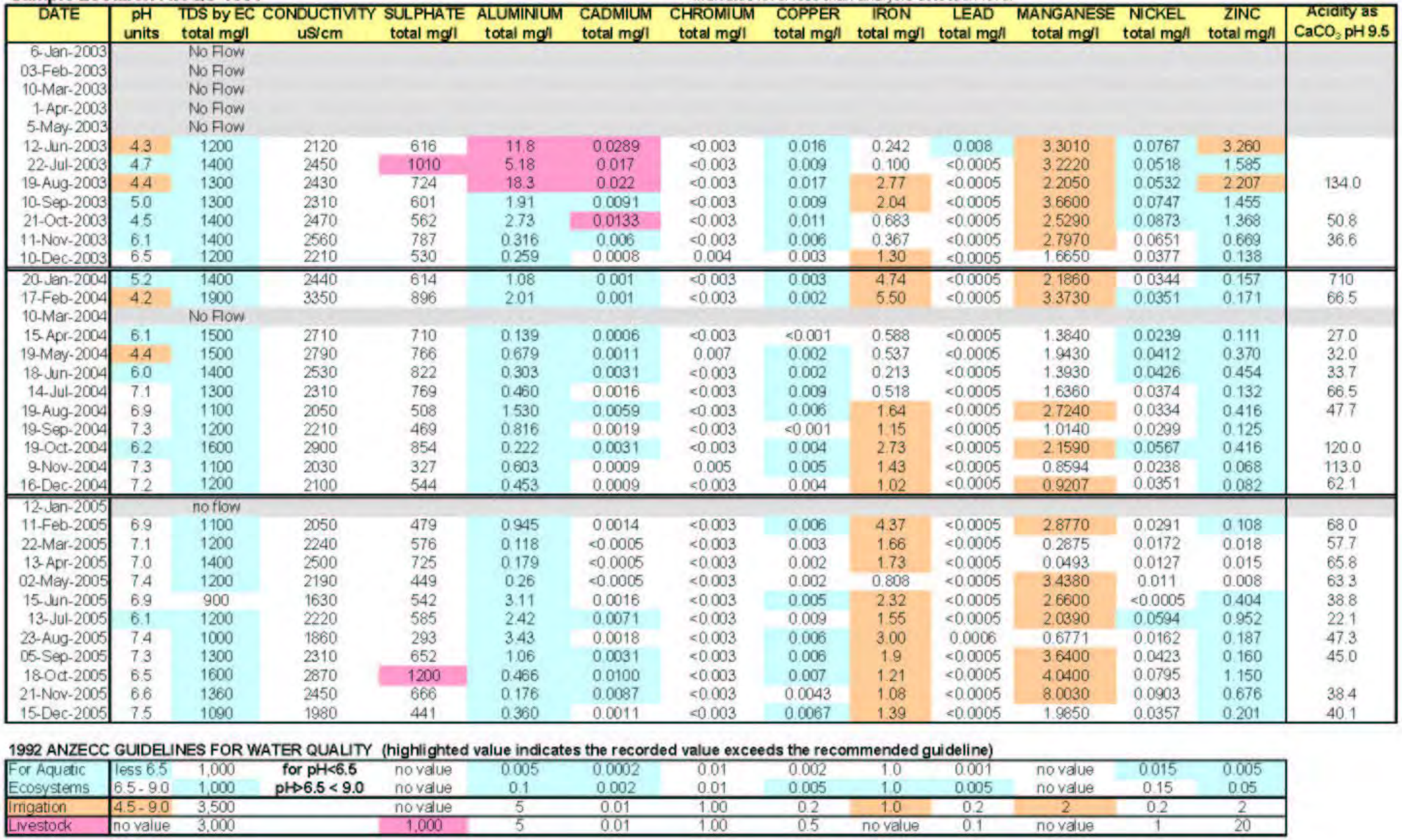


Fig C-5. Cadmium in Dawesley Creek leaving the mine site

Dawesley Creek, at McIntyre Road (Old Melbourne Bridge)

Sample Location AWQC 1951

< - indicates level less than analysis detection level



DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l	Acidity as $CaCO_3$ pH 9.5
6-Jan-2003		No Flow												
03-Feb-2003		No Flow												
10-Mar-2003		No Flow												
1-Apr-2003		No Flow												
5-May-2003		No Flow												
12-Jun-2003	4.3	1200	2120	616	11.8	0.0289	<0.003	0.016	0.242	0.008	3.3010	0.0767	3.260	
22-Jul-2003	4.7	1400	2450	1010	5.18	0.017	<0.003	0.009	0.100	<0.0005	3.2220	0.0518	1.585	
19-Aug-2003	4.4	1300	2430	724	18.3	0.022	<0.003	0.017	2.77	<0.0005	2.2050	0.0532	2.207	134.0
10-Sep-2003	5.0	1300	2310	601	1.91	0.0091	<0.003	0.009	2.04	<0.0005	3.6600	0.0747	1.455	
21-Oct-2003	4.5	1400	2470	562	2.73	0.0133	<0.003	0.011	0.683	<0.0005	2.5290	0.0873	1.368	50.8
11-Nov-2003	6.1	1400	2560	787	0.316	0.006	<0.003	0.006	0.367	<0.0005	2.7970	0.0651	0.669	36.6
10-Dec-2003	6.5	1200	2210	530	0.259	0.0008	0.004	0.003	1.30	<0.0005	1.6650	0.0377	0.138	
20-Jan-2004	5.2	1400	2440	614	1.08	0.001	<0.003	0.003	4.74	<0.0005	2.1860	0.0344	0.157	710
17-Feb-2004	4.2	1900	3350	896	2.01	0.001	<0.003	0.002	5.50	<0.0005	3.3730	0.0351	0.171	66.5
10-Mar-2004		No Flow												
15-Apr-2004	6.1	1500	2710	710	0.139	0.0006	<0.003	<0.001	0.588	<0.0005	1.3840	0.0239	0.111	27.0
19-May-2004	4.4	1500	2790	766	0.679	0.0011	0.007	0.002	0.537	<0.0005	1.9430	0.0412	0.370	32.0
18-Jun-2004	6.0	1400	2530	822	0.303	0.0031	<0.003	0.002	0.213	<0.0005	1.3930	0.0426	0.454	33.7
14-Jul-2004	7.1	1300	2310	769	0.460	0.0016	<0.003	0.009	0.518	<0.0005	1.6360	0.0374	0.132	66.5
19-Aug-2004	6.9	1100	2050	508	1.530	0.0059	<0.003	0.006	1.64	<0.0005	2.7240	0.0334	0.416	47.7
19-Sep-2004	7.3	1200	2210	469	0.816	0.0019	<0.003	<0.001	1.15	<0.0005	1.0140	0.0299	0.125	
19-Oct-2004	6.2	1600	2900	854	0.222	0.0031	<0.003	0.004	2.73	<0.0005	2.1590	0.0567	0.416	120.0
9-Nov-2004	7.3	1100	2030	327	0.603	0.0009	0.005	0.005	1.43	<0.0005	0.8594	0.0238	0.068	113.0
16-Dec-2004	7.2	1200	2100	544	0.453	0.0009	<0.003	0.004	1.02	<0.0005	0.9207	0.0351	0.082	62.1
12-Jan-2005		no flow												
11-Feb-2005	6.9	1100	2050	479	0.945	0.0014	<0.003	0.006	4.37	<0.0005	2.8770	0.0291	0.108	68.0
22-Mar-2005	7.1	1200	2240	576	0.118	<0.0005	<0.003	0.003	1.66	<0.0005	0.2875	0.0172	0.018	57.7
13-Apr-2005	7.0	1400	2500	725	0.179	<0.0005	<0.003	0.002	1.73	<0.0005	0.0493	0.0127	0.015	65.8
02-May-2005	7.4	1200	2190	449	0.26	<0.0005	<0.003	0.002	0.808	<0.0005	3.4380	0.011	0.008	63.3
15-Jun-2005	6.9	900	1630	542	3.11	0.0016	<0.003	0.005	2.32	<0.0005	2.6600	<0.0005	0.404	38.8
13-Jul-2005	6.1	1200	2220	585	2.42	0.0071	<0.003	0.009	1.55	<0.0005	2.0390	0.0594	0.952	22.1
23-Aug-2005	7.4	1000	1860	293	3.43	0.0018	<0.003	0.006	3.00	0.0006	0.6771	0.0162	0.187	47.3
05-Sep-2005	7.3	1300	2310	652	1.06	0.0031	<0.003	0.006	1.9	<0.0005	3.6400	0.0423	0.160	45.0
18-Oct-2005	6.5	1600	2870	1200	0.466	0.0100	<0.003	0.007	1.21	<0.0005	4.0400	0.0795	1.150	
21-Nov-2005	6.6	1360	2450	666	0.176	0.0087	<0.003	0.0043	1.08	<0.0005	8.0030	0.0903	0.676	38.4
15-Dec-2005	7.5	1090	1980	441	0.360	0.0011	<0.003	0.0067	1.39	<0.0005	1.9850	0.0357	0.201	40.1

1992 ANZECC GUIDELINES FOR WATER QUALITY (highlighted value indicates the recorded value exceeds the recommended guideline)

For Aquatic	less 6.5	1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**pH>6.5 < 9.0**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-6. Dawesley Creek downstream at Melbourne Bridge

Dawesley Creek, downstream Nairne Creek (Bremer SVY LOC 5A)

Sample Location AWQC 1822

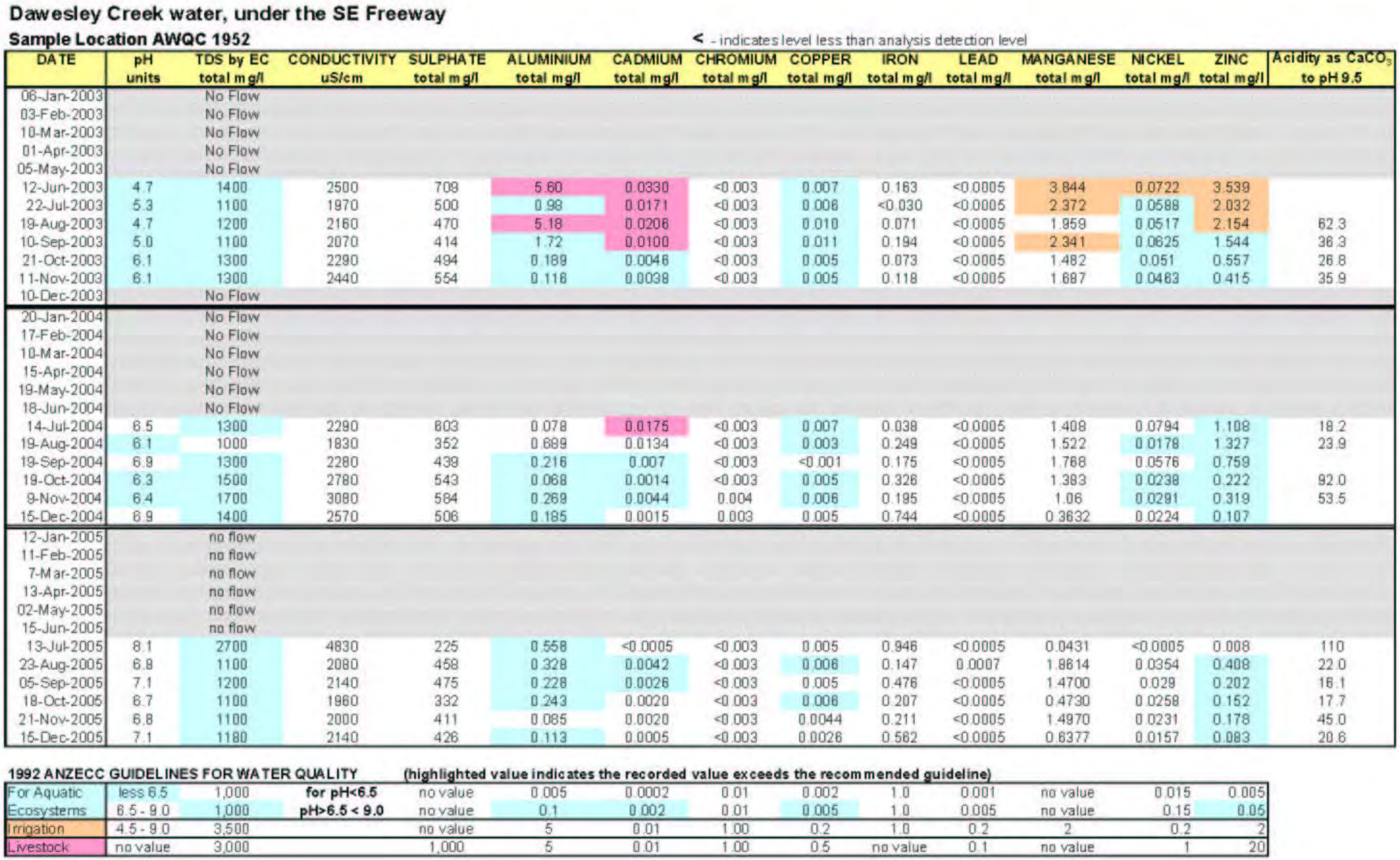
< - indicates level less than analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
06-Jan-2003		No Flow											
03-Feb-2003		No Flow											
10-Mar-2003		No Flow											
01-Apr-2003		No Flow											
05-May-2003		No Flow											
12-Jun-2003	4.4	1,500	2630	812	16.200	0.0352	<0.003	0.011	0.266	<0.0005	4.600	0.0844	3.990
22-Jul-2003	4.6	1200	2140	616	7.210	0.0300	<0.003	0.010	0.092	<0.0005	3.331	0.0570	2.827
19-Aug-2003	4.8	1200	2120	406	3.980	0.0190	<0.003	0.01	0.095	<0.0005	1.866	0.0527	2.036
10-Sep-2003	6.3	1200	2110	418	0.800	0.0076	<0.003	0.007	0.309	<0.0005	2.109	0.0563	1.221
21-Oct-2003	7.2	1300	2340	463	0.181	0.0041	<0.003	0.005	0.257	<0.0005	1.794	0.0583	0.422
11-Nov-2003	6.7	1400	2550	628	0.165	0.0039	<0.003	0.003	0.362	<0.0005	2.547	0.0671	0.694
10-Dec-2003	6.5	1800	3200	667	0.036	0.0008	0.004	0.001	0.952	<0.0005	2.753	0.0293	0.092
20-Jan-2004		No Flow											
17-Feb-2004		No Flow											
10-Mar-2004		No Flow											
15-Apr-2004		No Flow											
19-May-2004		No Flow											
18-Jun-2004	7.0	790	1430	266	1.730	0.0041	0.004	0.009	1.68	0.0017	0.3913	0.0168	0.256
14-Jul-2004	5.4	1300	2370	730	1.630	0.0222	<0.003	0.009	0.146	<0.0005	2.281	0.0843	1.889
19-Aug-2004	6.1	1100	1900	368	2.010	0.0154	<0.003	0.017	0.492	<0.0005	1.713	0.0884	1.554
19-Sep-2004	7.4	1300	2360	394	0.289	0.0045	<0.003	<0.001	0.304	<0.0005	1.141	0.0379	0.361
19-Oct-2004	6.7	1600	2830	546	0.113	0.0024	<0.003	0.006	0.513	<0.0005	1.075	0.0353	0.294
9-Nov-2004	7.2	1700	3000	527	0.349	0.0018	0.005	0.006	0.672	<0.0005	0.6175	0.0226	0.114
15-Dec-2004	7.0	1600	2880	665	0.258	0.0014	<0.003	0.003	0.557	<0.0005	0.1818	0.0272	0.087
12-Jan-2005		no flow											
11-Feb-2005		no flow											
22-Mar-2005	6.6	1700	3120	770	0.194	<0.0005	<0.003	0.003	0.691	<0.0005	3.032	0.017	0.036
13-Apr-2005		no flow											
02-May-2005		no flow											
15-Jun-2005	7.0	1600	2920	675	0.394	0.0058	<0.003	0.006	0.298	<0.0005	1.673	0.0266	0.445
13-Jul-2005	5.6	1500	2750	775	1.200	0.0087	<0.003	0.009	0.293	<0.0005	4.100	0.0674	1.271
23-Aug-2005	7.5	1000	1900	376	0.507	0.0019	<0.003	0.005	0.452	<0.0005	1.74	0.0237	0.112
05-Sep-2005	7.3	1200	2170	486	0.331	0.0016	<0.003	0.005	0.722	<0.0005	1.62	0.0276	0.141
18-Oct-2005	7.2	1100	2080	386	0.319	0.0020	<0.003	0.005	0.455	<0.0005	0.92	0.0247	0.114
21-Nov-2005	7.0	1140	2060	426	0.317	0.0021	<0.003	0.0034	0.719	<0.0005	1.879	0.0298	0.203
15-Dec-2005	6.9	1380	2490	552	0.181	0.0006	<0.003	0.0011	0.688	<0.0005	1.892	0.0311	0.095

1992 ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline**

For Aquatic	less 6.5	1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**pH>6.5 < 9.0**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-7. Dawesley Creek upstream of the mine site



Dawesley Creek water, under the SE Freeway

Sample Location AWQC 1952

< - indicates level less than analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l	Acidity as $CaCO_3$ to pH 9.5
06-Jan-2003		No Flow												
03-Feb-2003		No Flow												
10-Mar-2003		No Flow												
01-Apr-2003		No Flow												
05-May-2003		No Flow												
12-Jun-2003	4.7	1400	2500	709	5.60	0.0330	<0.003	0.007	0.163	<0.0005	3.844	0.0722	3.539	
22-Jul-2003	5.3	1100	1970	500	0.98	0.0171	<0.003	0.006	<0.030	<0.0005	2.372	0.0588	2.032	
19-Aug-2003	4.7	1200	2160	470	5.18	0.0206	<0.003	0.010	0.071	<0.0005	1.959	0.0517	2.154	62.3
10-Sep-2003	5.0	1100	2070	414	1.72	0.0100	<0.003	0.011	0.194	<0.0005	2.341	0.0625	1.544	36.3
21-Oct-2003	6.1	1300	2290	494	0.189	0.0046	<0.003	0.005	0.073	<0.0005	1.482	0.051	0.557	26.8
11-Nov-2003	6.1	1300	2440	554	0.118	0.0038	<0.003	0.005	0.118	<0.0005	1.687	0.0463	0.415	35.9
10-Dec-2003		No Flow												
20-Jan-2004		No Flow												
17-Feb-2004		No Flow												
10-Mar-2004		No Flow												
15-Apr-2004		No Flow												
19-May-2004		No Flow												
18-Jun-2004		No Flow												
14-Jul-2004	6.5	1300	2290	603	0.078	0.0175	<0.003	0.007	0.038	<0.0005	1.408	0.0794	1.108	18.2
19-Aug-2004	6.1	1000	1830	352	0.689	0.0134	<0.003	0.003	0.249	<0.0005	1.522	0.0178	1.327	23.9
19-Sep-2004	6.9	1300	2280	439	0.216	0.007	<0.003	<0.001	0.175	<0.0005	1.768	0.0576	0.759	
19-Oct-2004	6.3	1500	2780	543	0.068	0.0014	<0.003	0.005	0.326	<0.0005	1.383	0.0238	0.222	92.0
9-Nov-2004	6.4	1700	3080	584	0.269	0.0044	0.004	0.006	0.195	<0.0005	1.06	0.0291	0.319	53.5
15-Dec-2004	6.9	1400	2570	506	0.185	0.0015	0.003	0.005	0.744	<0.0005	0.3632	0.0224	0.107	
12-Jan-2005		no flow												
11-Feb-2005		no flow												
7-Mar-2005		no flow												
13-Apr-2005		no flow												
02-May-2005		no flow												
15-Jun-2005		no flow												
13-Jul-2005	8.1	2700	4830	225	0.558	<0.0005	<0.003	0.005	0.946	<0.0005	0.0431	<0.0005	0.008	110
23-Aug-2005	6.8	1100	2080	458	0.328	0.0042	<0.003	0.006	0.147	0.0007	1.8614	0.0354	0.408	22.0
05-Sep-2005	7.1	1200	2140	475	0.228	0.0026	<0.003	0.005	0.476	<0.0005	1.4700	0.029	0.202	16.1
18-Oct-2005	6.7	1100	1960	332	0.243	0.0020	<0.003	0.006	0.207	<0.0005	0.4730	0.0258	0.152	17.7
21-Nov-2005	6.8	1100	2000	411	0.085	0.0020	<0.003	0.0044	0.211	<0.0005	1.4970	0.0231	0.178	45.0
15-Dec-2005	7.1	1180	2140	426	0.113	0.0005	<0.003	0.0026	0.562	<0.0005	0.6377	0.0157	0.083	20.6

1992 ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic	less 6.5	1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**pH>6.5 < 9.0**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-8. Dawesley Creek d/s at Sth East Freeway (~ 22 km)

Mt Barker Creek, above confluence with Bremer River

Sample Location AWQC 1807

< - indicates level less than analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
14-Jan-2003	7.9	1,500	2770	276	0.567	<0.0005	<0.003	0.001	0.475	0.0012	0.3973	0.0048	0.023
03-Feb-2003		No Flow											
10-Mar-2003	7.9	1,900	3490	234	0.126	<0.0005	<0.003	<0.001	0.224	<0.0005	0.3386	0.0071	0.005
07-Apr-2003		No Flow											
05-May-2003		No Flow											
12-Jun-2003	7.4	990	1800	199	1.140	<0.0005	<0.003	0.003	1.22	0.0016	0.1715	0.0077	0.055
22-Jul-2003	8.0	4,800	8410	542	0.039	0.0006	<0.003	0.003	0.221	<0.0005	0.012	0.0047	<0.003
19-Aug-2003	7.6	1,400	2500	193	0.433	0.0011	<0.003	0.003	0.789	0.0013	0.1089	0.0094	0.127
10-Sep-2003	7.8	980	1770	194	0.514	0.0027	<0.003	0.004	0.436	0.0017	0.3244	0.0194	0.214
21-Oct-2003	7.8	1,500	2780	202	0.341	0.0006	<0.003	0.002	0.436	0.0008	0.2826	0.0091	0.033
11-Nov-2003	7.8	4,000	7100	365	0.056	0.0007	<0.003	<0.001	0.247	<0.0005	0.0273	0.0048	<0.003
10-Dec-2003	7.6	1,600	2850	153	0.207	<0.0005	<0.003	<0.001	0.372	<0.0005	0.3431	0.0073	0.018
20-Jan-2004		No Flow											
17-Feb-2004		No Flow											
10-Mar-2004	7.8	2100	3830	190	0.096	<0.0005	<0.003	<0.001	0.177	<0.0005	0.4532	0.0061	<0.003
15-Apr-2004		No Flow											
19-May-2004		No Flow											
18-Jun-2004	7.6	600	1090	82.2	1.29	0.0006	0.004	0.004	1.44	0.0024	0.0775	0.0047	0.065
14-Jul-2004	8.4	8800	1520	868	0.058	<0.0005	0.004	0.004	0.156	<0.0005	0.0227	0.0048	<0.003
19-Aug-2004	7.8	1600	2870	149	0.063	<0.0005	0.006	0.004	0.14	<0.0005	0.0062	0.0028	<0.003
15-Sep-2004	7.6	1200	2130	264	0.116	0.0015	<0.003	0.004	0.175	<0.0005	0.2856	0.0152	0.106
19-Oct-2004	8.1	3900	6920	325	0.063	<0.0005	0.004	0.005	0.426	<0.0005	0.0416	0.0052	0.007
09-Nov-2004	8.1	4500	8020	390	<0.020	0.0010	0.005	0.004	0.457	<0.0005	0.0398	0.005	0.007
15-Dec-2004	7.7	1300	2360	275	0.163	0.0008	0.004	0.002	0.292	<0.0005	0.3755	0.0071	0.014
12-Jan-2005		no flow											
11-Feb-2005		no flow											
22-Mar-2005	8.0	3400	5990	375	0.241	<0.0005	<0.003	0.002	0.166	<0.0005	0.1764	0.0062	0.006
13-Apr-2005		no flow											
02-May-2005		no flow											
15-Jun-2005	7.6	1300	2370	252	0.223	<0.0005	<0.003	0.002	0.275	<0.0005	0.0759	0.0045	0.029
13-Jul-2005	8.0	2800	4950	234	0.081	<0.0005	<0.003	0.004	0.147	<0.0005	0.0121	<0.0005	0.005
23-Aug-2005	8.0	1500	2770	129	0.139	<0.0005	<0.003	0.003	0.290	<0.0005	0.0076	0.0012	0.004
05-Sep-2005	7.7	1200	2200	120	0.190	<0.0005	0.004	0.003	0.220	<0.0005	0.1782	0.0073	0.036
18-Oct-2005	7.8	1600	2890	114	0.138	<0.0005	0.004	0.005	0.36	<0.0005	0.0249	0.004	0.004
21-Nov-2005	7.4	1150	2090	153	0.488	<0.0005	0.003	0.004	0.805	0.0011	0.2408	0.0075	<0.003
15-Dec-2005	7.6	1260	2280	244	0.297	<0.0005	<0.003	<0.0010	0.454	<0.0005	0.4166	0.0071	0.016

1992 ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic	less 6.5	1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**pH>6.5 < 9.0**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-9. Mt Barker Creek

Bremer River, Jaensch Road ford (Loc 8)

Sample Location AWQC 1824

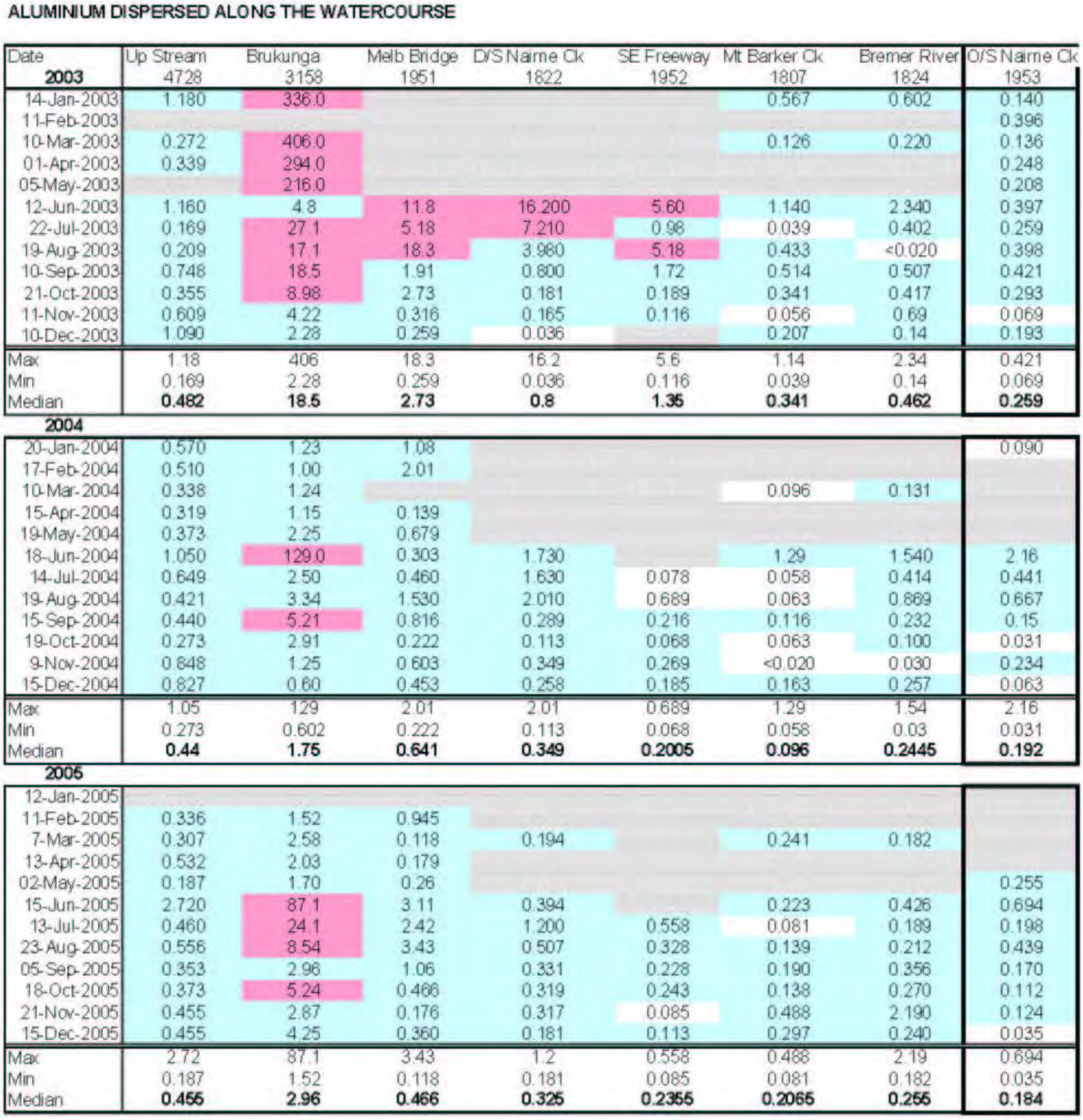
< - indicates level less than analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
14-Jan-2003	7.9	1,900	3,450	151	0.602	<0.0005	<0.003	<0.001	0.647	0.001	0.392	0.0056	0.024
03-Feb-2003		No Flow											
10-Mar-2003	8.1	2,200	4,010	204	0.220	<0.0005	<0.003	0.001	0.314	0.0009	0.317	0.0060	0.025
01-Apr-2003		No Flow											
05-May-2003		No Flow											
12-Jun-2003	7.4	780	1,420	118	2.340	<0.0005	0.003	0.007	2.060	0.0021	0.102	0.0171	0.049
22-Jul-2003	7.1	1,100	1,910	178	0.402	0.0011	<0.003	0.003	0.534	0.0008	0.115	0.0086	0.088
19-Aug-2003	7.7	2,400	4,360	206	<0.020	<0.0005	<0.003	0.003	0.073	<0.0005	0.004	0.0020	0.006
10-Sep-2003	7.7	1200	2170	182	0.507	0.0011	<0.003	0.004	0.461	0.001	0.201	0.013	0.102
21-Oct-2003	7.9	1400	2610	217	0.417	<0.0005	<0.003	0.003	0.465	0.0006	0.2901	0.0089	0.027
11-Nov-2003	8.2	1300	2420	202	0.69	0.0009	0.004	0.003	0.706	0.0009	0.3392	0.0075	0.035
10-Dec-2003	7.7	1700	3140	204	0.14	<0.0005	<0.003	0.001	0.254	<0.0005	0.2447	0.0067	0.008
20-Jan-2004		No Flow											
17-Feb-2004		No Flow											
10-Mar-2004	8.0	2400	4360	188	0.131	<0.0005	<0.003	<0.001	0.193	<0.0005	0.3195	0.0052	0.009
15-Apr-2004		No Flow											
19-May-2004		No Flow											
18-Jun-2004	7.5	570	1040	78	1.540	<0.0005	0.005	0.004	1.730	0.0023	0.054	0.0048	0.049
14-Jul-2004	7.6	1100	2020	196	0.414	<0.0005	0.003	0.008	0.427	0.0006	0.065	0.0064	0.047
19-Aug-2004	7.6	1100	1970	178	0.869	0.002	<0.003	0.006	0.393	0.0009	0.3072	0.0183	0.259
19-Sep-2004	7.8	1300	2340	210	0.232	0.0008	<0.003	0.003	0.285	<0.0005	0.1735	0.0104	0.052
19-Oct-2004	8.0	1700	3010	229	0.100	<0.0005	<0.003	0.003	0.174	<0.0005	0.2855	0.0057	0.017
9-Nov-2004	7.9	1500	2680	160	0.030	0.0006	0.005	0.003	0.168	<0.0005	0.0836	0.0057	0.015
15-Dec-2004	7.8	1200	2140	114	0.257	0.0008	0.005	0.003	0.311	<0.0005	0.2663	0.0065	0.014
12-Jan-2005		no flow											
11-Feb-2005		no flow											
22-Mar-2005	8.0	2600	4570	179	0.182	<0.0005	<0.003	0.002	0.238	<0.0005	0.2711	0.0047	0.013
13-Apr-2005		no flow											
02-May-2005		no flow											
15-Jun-2005	8.0	2500	4410	322	0.426	0.0006	<0.003	0.004	0.220	<0.0005	0.0717	0.0029	0.035
13-Jul-2005	7.8	1900	3450	287	0.189	0.0015	<0.003	0.004	0.239	<0.0005	0.1632	0.011	0.14
23-Aug-2005	7.9	1500	2710	192	0.212	<0.0005	<0.003	0.003	0.238	<0.0005	0.0499	0.0043	0.032
5-Sep-2005	7.8	1300	2290	199	0.356	<0.0005	0.004	0.003	0.557	0.0006	0.1397	0.0048	0.029
18-Oct-2005	7.8	1100	2040	142	0.270	<0.0005	<0.003	0.003	0.137	<0.0005	0.1459	0.0071	0.021
22-Nov-2005	7.6	1150	2090	154	2.190	0.0012	0.007	0.0078	3.220	0.0043	0.6598	0.0168	0.124
15-Dec-2005	8.0	1280	2320	172	0.240	<0.0005	<0.003	0.0014	0.346	<0.0005	0.3475	0.0072	0.074

1992 ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic	less 6.5	1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**pH>6.5 < 9.0**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-10. Bremer River at Jaensch ford



ALUMINIUM DISPERSED ALONG THE WATERCOURSE

Date	Up Stream	Brukunga	Melb Bridge	D/S Nairne Ck	SE Freeway	Mt Barker Ck	Bremer River	O/S Nairne Ck
2003	4728	3158	1951	1822	1952	1807	1824	1953
14-Jan-2003	1.180	336.0				0.567	0.602	0.140
11-Feb-2003								0.396
10-Mar-2003	0.272	406.0				0.126	0.220	0.136
01-Apr-2003	0.339	294.0						0.248
05-May-2003		216.0						0.208
12-Jun-2003	1.160	4.8	11.8	16.200	5.60	1.140	2.340	0.397
22-Jul-2003	0.169	27.1	5.18	7.210	0.98	0.039	0.402	0.259
19-Aug-2003	0.209	17.1	18.3	3.980	5.18	0.433	<0.020	0.398
10-Sep-2003	0.748	18.5	1.91	0.800	1.72	0.514	0.507	0.421
21-Oct-2003	0.355	8.98	2.73	0.181	0.189	0.341	0.417	0.293
11-Nov-2003	0.609	4.22	0.316	0.165	0.116	0.056	0.69	0.069
10-Dec-2003	1.090	2.28	0.259	0.036		0.207	0.14	0.193
Max	1.18	406	18.3	16.2	5.6	1.14	2.34	0.421
Min	0.169	2.28	0.259	0.036	0.116	0.039	0.14	0.069
Median	**0.482**	**18.5**	**2.73**	**0.8**	**1.35**	**0.341**	**0.462**	**0.259**
2004								
20-Jan-2004	0.570	1.23	1.08					0.090
17-Feb-2004	0.510	1.00	2.01					
10-Mar-2004	0.338	1.24				0.096	0.131	
15-Apr-2004	0.319	1.15	0.139					
19-May-2004	0.373	2.25	0.679					
18-Jun-2004	1.050	129.0	0.303	1.730		1.29	1.540	2.16
14-Jul-2004	0.649	2.50	0.460	1.630	0.078	0.058	0.414	0.441
19-Aug-2004	0.421	3.34	1.530	2.010	0.689	0.063	0.869	0.667
15-Sep-2004	0.440	5.21	0.816	0.289	0.216	0.116	0.232	0.15
19-Oct-2004	0.273	2.91	0.222	0.113	0.068	0.063	0.100	0.031
9-Nov-2004	0.848	1.25	0.603	0.349	0.269	<0.020	0.030	0.234
15-Dec-2004	0.827	0.60	0.453	0.258	0.185	0.163	0.257	0.063
Max	1.05	129	2.01	2.01	0.689	1.29	1.54	2.16
Min	0.273	0.602	0.222	0.113	0.068	0.058	0.03	0.031
Median	**0.44**	**1.75**	**0.641**	**0.349**	**0.2005**	**0.096**	**0.2445**	**0.192**
2005								
12-Jan-2005								
11-Feb-2005	0.336	1.52	0.945					
7-Mar-2005	0.307	2.58	0.118	0.194		0.241	0.182	
13-Apr-2005	0.532	2.03	0.179					
02-May-2005	0.187	1.70	0.26					0.255
15-Jun-2005	2.720	87.1	3.11	0.394		0.223	0.426	0.694
13-Jul-2005	0.460	24.1	2.42	1.200	0.558	0.081	0.189	0.198
23-Aug-2005	0.556	8.54	3.43	0.507	0.328	0.139	0.212	0.439
05-Sep-2005	0.353	2.96	1.06	0.331	0.228	0.190	0.356	0.170
18-Oct-2005	0.373	5.24	0.466	0.319	0.243	0.138	0.270	0.112
21-Nov-2005	0.455	2.87	0.176	0.317	0.085	0.488	2.190	0.124
15-Dec-2005	0.455	4.25	0.360	0.181	0.113	0.297	0.240	0.035
Max	2.72	87.1	3.43	1.2	0.558	0.488	2.19	0.694
Min	0.187	1.52	0.118	0.181	0.085	0.081	0.182	0.035
Median	**0.455**	**2.96**	**0.466**	**0.325**	**0.2355**	**0.2065**	**0.255**	**0.184**

Fig C-11. Aluminium dispersion in watercourses 2003 to 2005

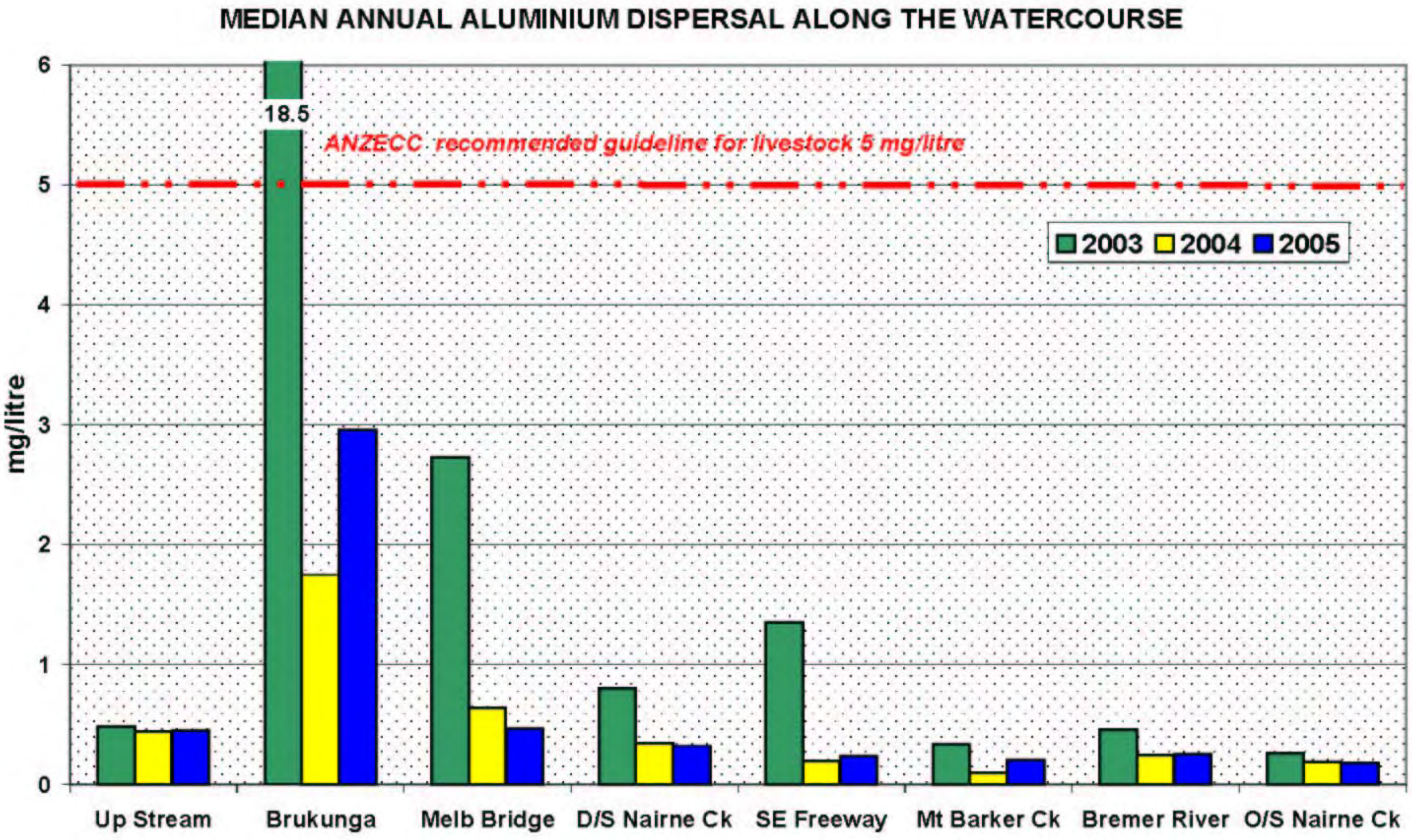
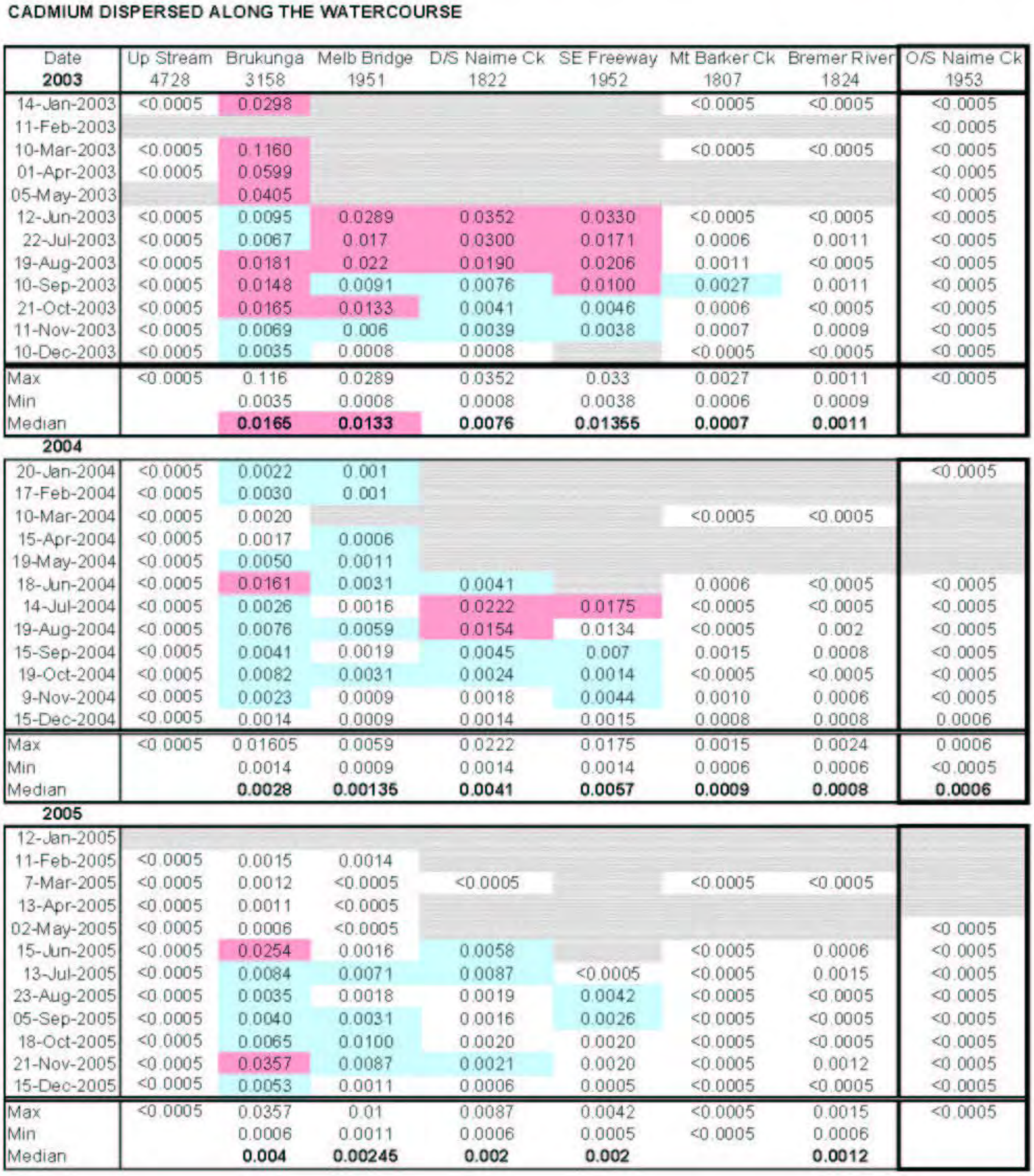


Fig C-12. Plot of median Aluminium dispersion in watercourses 2003 to 2005



CADMIUM DISPERSED ALONG THE WATERCOURSE

Date **2003**	Up Stream 4728	Brukunga 3158	Melb Bridge 1951	D/S Naime Ck 1822	SE Freeway 1952	Mt Barker Ck 1807	Bremer River 1824	O/S Naime Ck 1953
14-Jan-2003	<0.0005	0.0298				<0.0005	<0.0005	<0.0005
11-Feb-2003								<0.0005
10-Mar-2003	<0.0005	0.1160				<0.0005	<0.0005	<0.0005
01-Apr-2003	<0.0005	0.0599						<0.0005
05-May-2003		0.0405						<0.0005
12-Jun-2003	<0.0005	0.0095	0.0289	0.0352	0.0330	<0.0005	<0.0005	<0.0005
22-Jul-2003	<0.0005	0.0067	0.017	0.0300	0.0171	0.0006	0.0011	<0.0005
19-Aug-2003	<0.0005	0.0181	0.022	0.0190	0.0206	0.0011	<0.0005	<0.0005
10-Sep-2003	<0.0005	0.0148	0.0091	0.0076	0.0100	0.0027	0.0011	<0.0005
21-Oct-2003	<0.0005	0.0165	0.0133	0.0041	0.0046	0.0006	<0.0005	<0.0005
11-Nov-2003	<0.0005	0.0069	0.006	0.0039	0.0038	0.0007	0.0009	<0.0005
10-Dec-2003	<0.0005	0.0035	0.0008	0.0008		<0.0005	<0.0005	<0.0005
Max	<0.0005	0.116	0.0289	0.0352	0.033	0.0027	0.0011	<0.0005
Min		0.0035	0.0008	0.0008	0.0038	0.0006	0.0009	
Median		**0.0165**	**0.0133**	**0.0076**	**0.01355**	**0.0007**	**0.0011**	
2004								
20-Jan-2004	<0.0005	0.0022	0.001					<0.0005
17-Feb-2004	<0.0005	0.0030	0.001					
10-Mar-2004	<0.0005	0.0020				<0.0005	<0.0005	
15-Apr-2004	<0.0005	0.0017	0.0006					
19-May-2004	<0.0005	0.0050	0.0011					
18-Jun-2004	<0.0005	0.0161	0.0031	0.0041		0.0006	<0.0005	<0.0005
14-Jul-2004	<0.0005	0.0026	0.0016	0.0222	0.0175	<0.0005	<0.0005	<0.0005
19-Aug-2004	<0.0005	0.0076	0.0059	0.0154	0.0134	<0.0005	0.002	<0.0005
15-Sep-2004	<0.0005	0.0041	0.0019	0.0045	0.007	0.0015	0.0008	<0.0005
19-Oct-2004	<0.0005	0.0082	0.0031	0.0024	0.0014	<0.0005	<0.0005	<0.0005
9-Nov-2004	<0.0005	0.0023	0.0009	0.0018	0.0044	0.0010	0.0006	<0.0005
15-Dec-2004	<0.0005	0.0014	0.0009	0.0014	0.0015	0.0008	0.0008	0.0006
Max	<0.0005	0.01605	0.0059	0.0222	0.0175	0.0015	0.0024	0.0006
Min		0.0014	0.0009	0.0014	0.0014	0.0006	0.0006	<0.0005
Median		**0.0028**	**0.00135**	**0.0041**	**0.0057**	**0.0009**	**0.0008**	**0.0006**
2005								
12-Jan-2005								
11-Feb-2005	<0.0005	0.0015	0.0014					
7-Mar-2005	<0.0005	0.0012	<0.0005	<0.0005		<0.0005	<0.0005	
13-Apr-2005	<0.0005	0.0011	<0.0005					
02-May-2005	<0.0005	0.0006	<0.0005					<0.0005
15-Jun-2005	<0.0005	0.0254	0.0016	0.0058		<0.0005	0.0006	<0.0005
13-Jul-2005	<0.0005	0.0084	0.0071	0.0087	<0.0005	<0.0005	0.0015	<0.0005
23-Aug-2005	<0.0005	0.0035	0.0018	0.0019	0.0042	<0.0005	<0.0005	<0.0005
05-Sep-2005	<0.0005	0.0040	0.0031	0.0016	0.0026	<0.0005	<0.0005	<0.0005
18-Oct-2005	<0.0005	0.0065	0.0100	0.0020	0.0020	<0.0005	<0.0005	<0.0005
21-Nov-2005	<0.0005	0.0357	0.0087	0.0021	0.0020	<0.0005	0.0012	<0.0005
15-Dec-2005	<0.0005	0.0053	0.0011	0.0006	0.0005	<0.0005	<0.0005	<0.0005
Max	<0.0005	0.0357	0.01	0.0087	0.0042	<0.0005	0.0015	<0.0005
Min		0.0006	0.0011	0.0006	0.0005	<0.0005	0.0006	
Median		**0.004**	**0.00245**	**0.002**	**0.002**		**0.0012**	

Fig C-13. Cadmium dispersion in watercourses 2003 to 2005

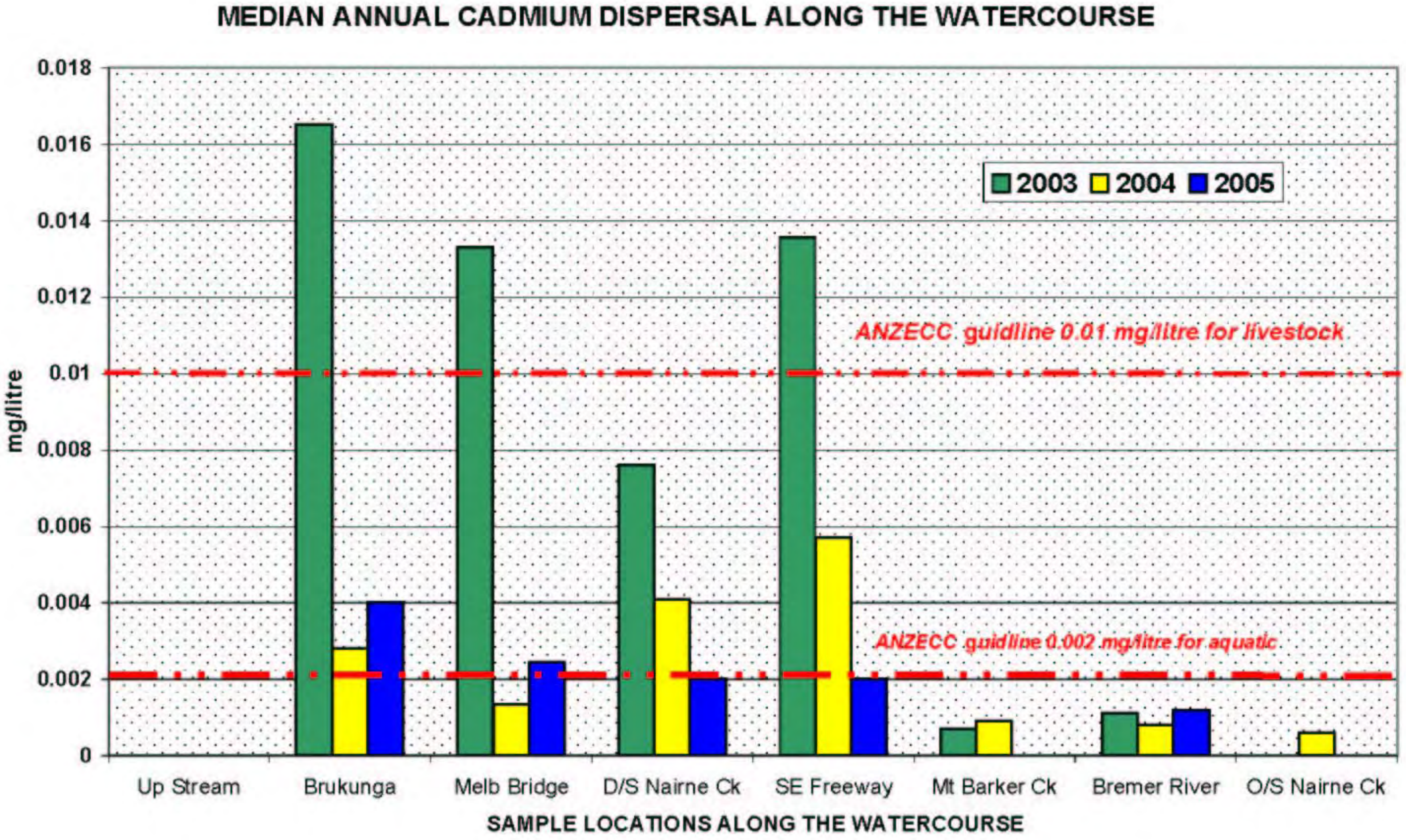


Fig C-14. Plot of median Cadmium dispersion in watercourses 2003 to 2005