BRUKUNGA REMEDIATION PROGRAM: WATER MONITORING REPORT 2007

EPA Licence: 10577

Mine Completion Program
Mining Regulation & Rehabilitation
Minerals and Energy Resources Division

Final Report • October 2008

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ACKNOWLEDGMENTS

The biological monitoring component of this report has been prepared by staff of the Australian Water Quality Centre.

EXECUTIVE SUMMARY

The Brukunga pyrites mine operated as an open pit mine from 1955 to 1972 to recover sulphur from iron sulphide minerals. The concentrated ore was converted to sulphuric acid, and subsequently used in the manufacture of superphosphate fertiliser. The pyrite and pyrrhotite minerals that remain 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 has been managed by the Department of Primary Industries and Resources - Minerals and Energy Resources Division since 1998.

The key work undertaken on site is the interception 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. In 2005 upgrading of the lime treatment plant was completed, effectively doubling its capacity. The improvements achieved in water quality since these two capital initiatives are still evident in the water monitoring results obtained for calendar year 2007, 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 and undisturbed areas.

Figure 1. Checking floats and lines on main seepage collection dams.

Figure 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 considered only partially successful as it captured only half the pollution from the site. The seepage that escaped to the creek impacted water quality up to 22 km downstream of the mine site, often meaning the water was 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 continuing improvements are clearly evident in the water monitoring results presented for 2007 in this report.

Figure 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 are reflected in the monitoring results of 2006 & 2007.

Figure 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 to 2007, 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

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

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. More recent investigations on this matter suggest the figure could be in the order of 1000 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.

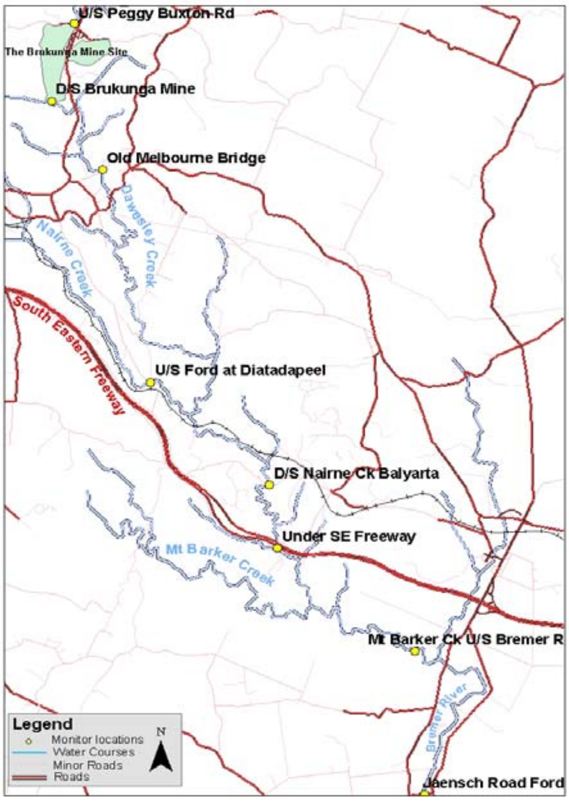


Figure 5: Dawesley Creek flow to the Bremer River and location of monitoring stations.

The 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.

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 impacted water quality within the Dawesley watercourse to such an extent that the water downstream of the mine site was often 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 contaminated water 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

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

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 flat v weirs established in the creek immediately upstream and downstream of the mine site.

Figure 6: Upstream flat v weir located in Dawesley Creek, for monitoring water flow.

Figure 7: Downstream v 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.

Figure 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. 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.

Figure 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. Monitoring of riffle zones commenced in 2006. The relative health 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. The grab samples are taken at near mid-month for each year.

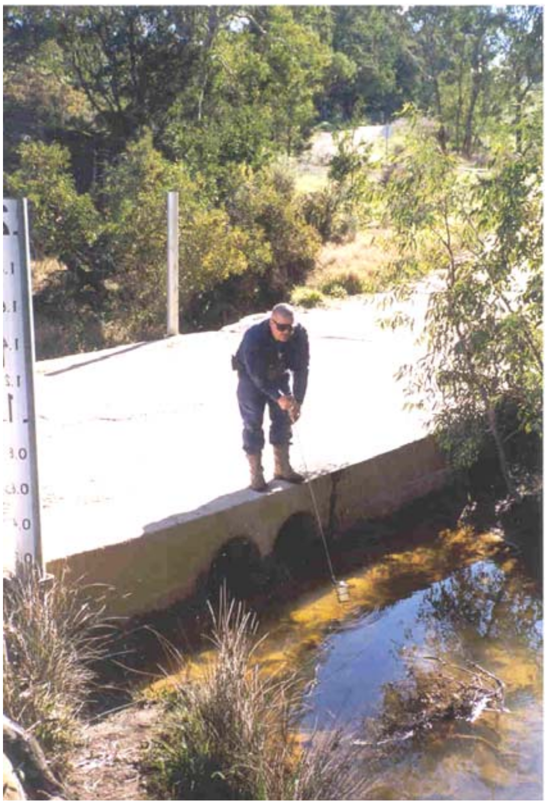


Figure 10. Grab sampling of creek water for chemical analysis at Melbourne Bridge.

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 2007 water monitoring results for the three monitoring strategies (described on page 6), continue to show signs that indicate significant improvements in the quality of water leaving the mine site.

Data for 2004 to 2007 represents post installation of the diversion drain in Dawesley Creek at Brukunga and the results obtained confirm that the key goal to reduce pollution is being achieved following the implementation of this engineering solution to more effectively isolate the source of pollution.

The ‘annual metal load’ monitoring strategy provides good evidence of the decreasing load of pollutant in water leaving the mine site. The pollutant loads are calculated for each year however large variations in flow, due to drought (as in 2007) 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 a general net annual load of pollutant reduction over the past nine years.

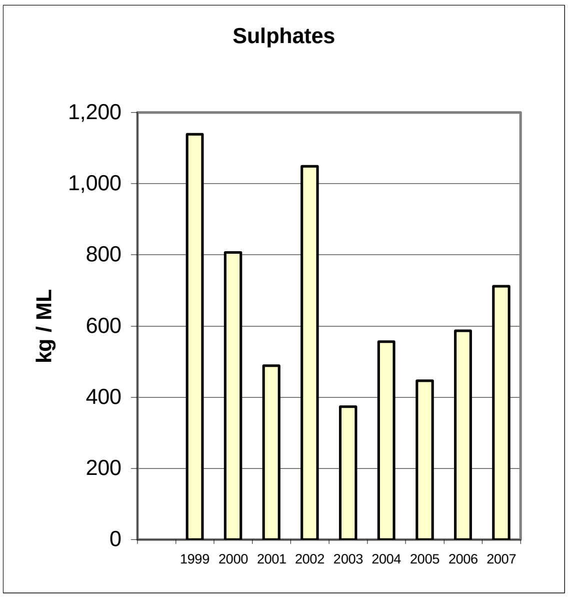


Figure 11. Graph of annual sulphate load in kg/ML of water leaving the mine site in Dawesley Creek.

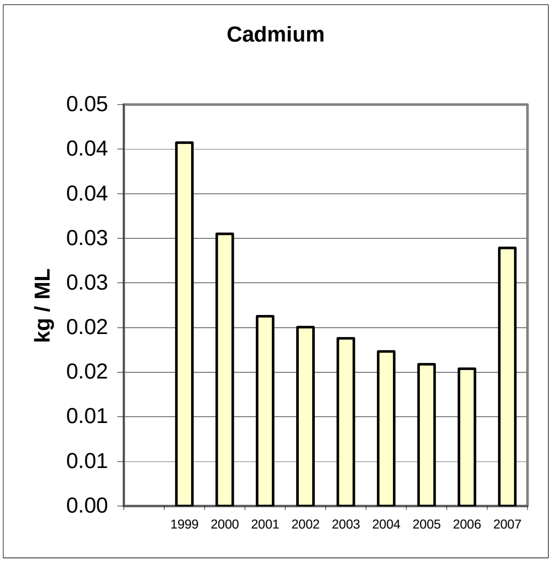


Figure 12. Graph of annual cadmium load in kg/ML of water leaving the mine site

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 2007' 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 (2003-2007'blue').

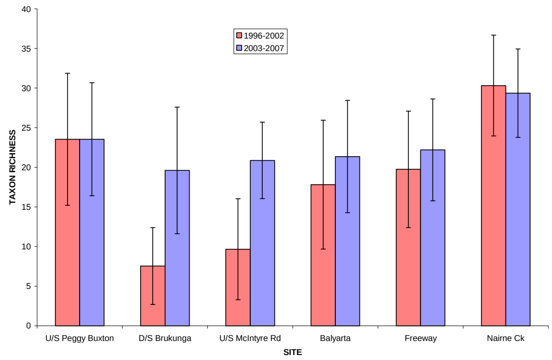


Figure 13. Species richness average value pre and post the diversion drain for locations along the watercourse. Error bars show two standard deviations.

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.

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 ten 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 three recorded years i.e. 2005 to 2007. In 2007 (as in 2006) cadmium levels are below ANZECC guidelines set for irrigation and livestock. In addition 2006 & 2007 pH levels in the Dawesley Creek were compliant with ANZECC recommended guidelines for irrigation and livestock.

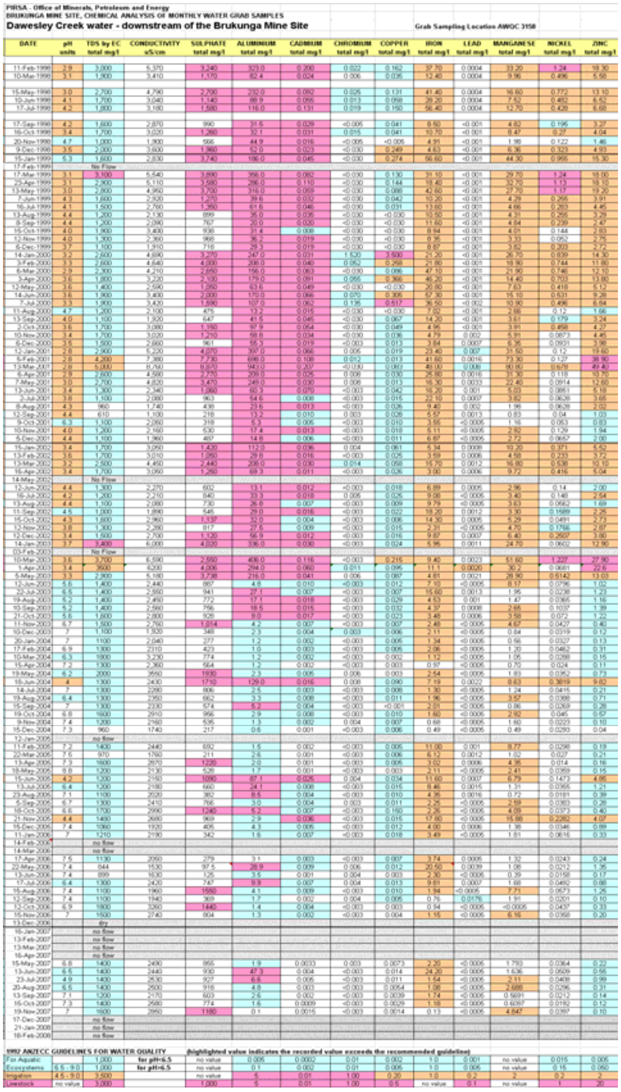

PIRSA - Office of Minerals, Petroleum and Energy
BRUKUNGA MINE SITE, CHEMICAL ANALYSIS OF MONTHLY WATER GRAB SAMPLES
Dawesley Creek water - downstream of the Brukunga Mine Site
Grab Sampling Location AWQC 3158

Figure 14. Pictorial of spreadsheet recording assay values over past ten years; Note the colour change for 2004 - 2007 towards the bottom.

9 ADDITIONAL 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.

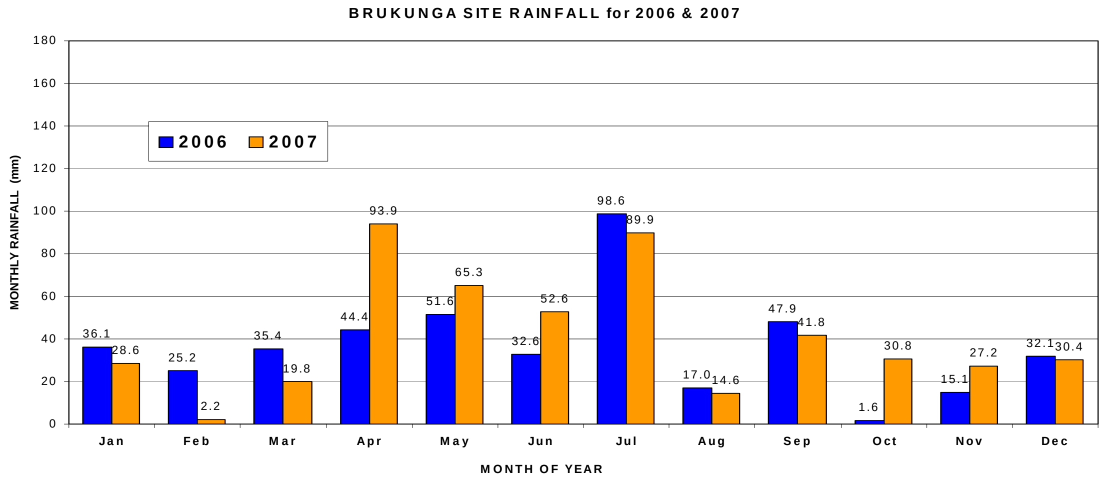


Figure 15. Monthly rainfall (mm) recorded at Brukunga for 2006 and 2007.

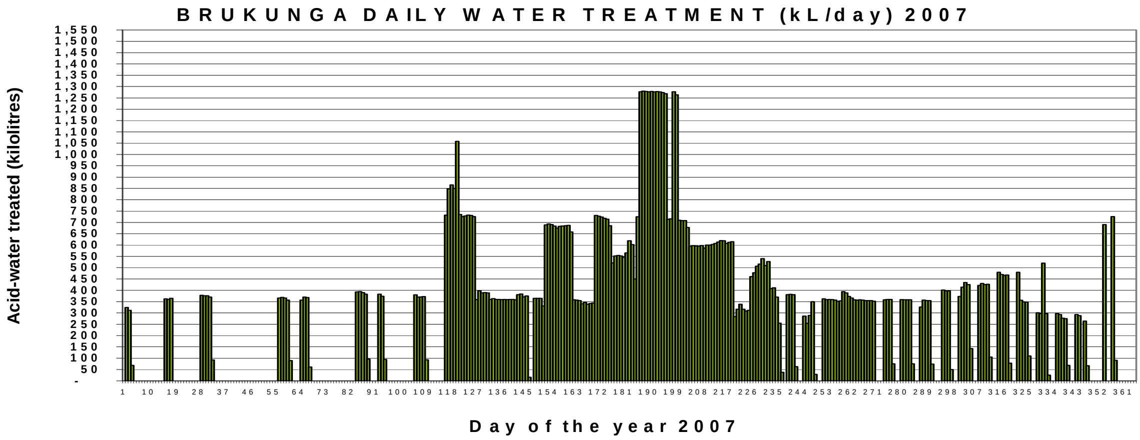


Figure 16. Plant shutdowns and throughput in kilolitres, for each day of 2007.

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		
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**
2006	26%	35%	35%	27%	69%	58%	83%	81%	52%	49%	20%	10%	**438**	**79,565**
2007	26%	15%	28%	38%	94%	100%	99%	91%	77%	56%	62%	31%	**497**	**109,312**

Figure 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.

9.3 Plant Efficiency

Since September 1999 a quarterly sample has been taken from the acid-collection ponds to provide information on the quality of feed water to the treatment plant (figure 20). In May 2007 monitoring was increased to monthly sampling and at the same time monthly sampling of the water leaving the clarifying ponds was also incorporated into the overall monitoring program.

9.4 Load Sampling and Grab Sampling Comparison

A review of water quality data was implemented in July 2007. A comparison of grab and composite sample data (before the sampling point was relocated) suggested that composite samples were not representative of the water quality leaving the lime treatment plant at the mine site. A visual inspection of the sampling point revealed that the sampler intake was located in sludge and precipitates, which was believed to be affecting the amount of contaminants measured in the samples taken. Figure 21 demonstrates the sudden improvement in water quality after September 2007 (when the sampling point was moved). Grab samples taken at various sites around the Brukunga Mine, particularly at AWQC site 3158 (Dawesley Creek D/S Brukunga) re-enforce the issue that the composite sampler was registering higher non-representative readings due to the sampling inlet being

BRUKUNGA MINE TAILINGS SEEPAGE (1975 - 2007)

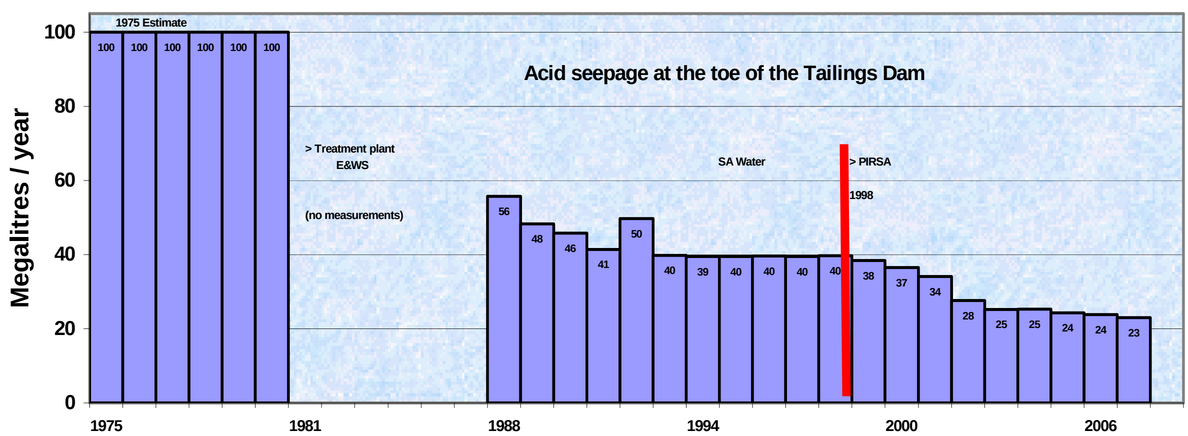


Figure 18. Annual volume of acid seepage from the sand tailings dam as measured at the v-notch

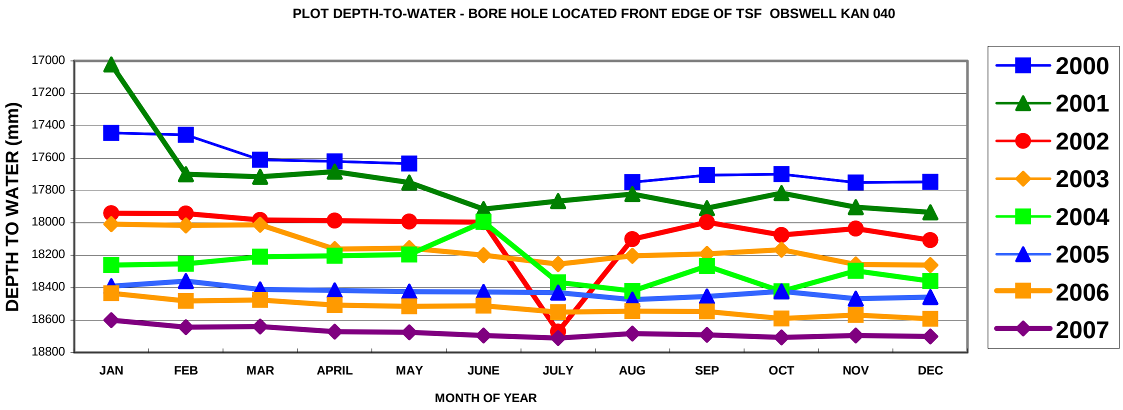


Figure 19. Depth measured to water in a monitoring bore in the tailings dam indicates progressive annual internal drying is being achieved.

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
22/Mar/05	2.7	8,110	222	0.0249	2,190	105	0.155	14.78
15/Jun/05	2.9	6,000	485	0.0666	631	55.5	0.761	23.60
05/Sep/05	2.9	6,860	579	0.1732	517	43	0.048	37.10
15/Dec/05	3.0	10,400	839	0.1805	1,430	97.62	1.313	47.70
14/Mar/06	2.9	13,800	1012	0.1074	2,150	<0.0005	2.002	42.60
13/Jun/06	3	9,510	779	0.0862	1,250	72.02	1.495	31.70
12/Sep/06	3	6,840	548	0.1300	791	43.53	1.016	28.50
13/Dec/06	3	9,390	258	0.0371	2,350	<0.0005	0.520	<0.003
13/Mar/07	2.7	5,760	207	0.0228	1,680	94.7	0.4859	<0.003
13/Jun/07	3	9,510	779	0.0862	1,250	72.02	1.4950	31.70
13/Sep/07	2.8	7,770	575	0.1305	874	49.78	0.8712	32.20
12/Dec/07	2.9	9,150	279	0.0800	2,140	115.7	0.9410	20.66

[box] **Indicates corrected potentially spurious reporting by laboratory**

< values represent detection limits

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

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

submerged in sludge. When the grab and relocated sampler inlet data are compared to the upstream data, similar trends are observed.

Comparison of load calculation data for similar flow years 2006 and 2002 (tables A-2 and A-3) suggests that the creek diversion and treatment plant upgrade are having a significant effect on net pollution from the mine site. Net pollution loads in kg/ML of flow show that sulphate load was approximately 50% less, aluminium load approximately 70% less and cadmium load approximately 50% less in the 2006 calculations.

In July 2007 composite sampling results showed a spike in metal load at the downstream sampling site. These elevated levels, compared with previous and subsequent results, are believed to be caused by the inlet of the composite sampler being submerged in sludge, as discussed; and are as a result of the highest monthly flows in Dawesley Creek occurring during July. The metal load on the stream is the product of metals levels and flow volumes, therefore the buildup of sludge at the sample inlet combined with the high flows in July caused metal loads for that month to reported as high. This, in turn, has caused the annual metal load to be reported as high compared to previous years. This is supported by the grab sample results for July, where all metals levels are significantly lower than for the corresponding composite samples. For example, levels of aluminium were recorded at 6.6mg/L for the grab samples and 106 and 129mg/L for the composite samples.

9.5 Flow Data Issues

Flow monitoring by way of data logging and field gauging is undertaken both upstream and downstream of the site using two V-notch weirs.

Several times in 2007 the data logger upstream and downstream from the Brukunga Mine site failed, and as a result flow data was estimated from the downstream weir.

Recent analysis of the annual flow data identified a discrepancy in both the upstream and downstream flow data, with the volume of water being recorded downstream of the mine less than the volume of water that is being treated by the acid water treatment plant that discharges into the creek. A closer inspection of raw data also revealed a number of months, particularly in 2006 where negative values (difference between downstream and upstream) were apparent.

As a result a thorough review of the historical data was undertaken first by WDS and secondly by Tonkin Consulting in order to provide independent verification. The review was commissioned to identify, analyse and resolve the data discrepancies identified, with a view to confirming or reassessing the annual flow volumes.

Upon completion, rating tables were recalculated resulting in changes made to all flow data recorded since 1999 (table A-2), a number of recommendations were also made to reduce the further possibility of error.

10 CONCLUSIONS

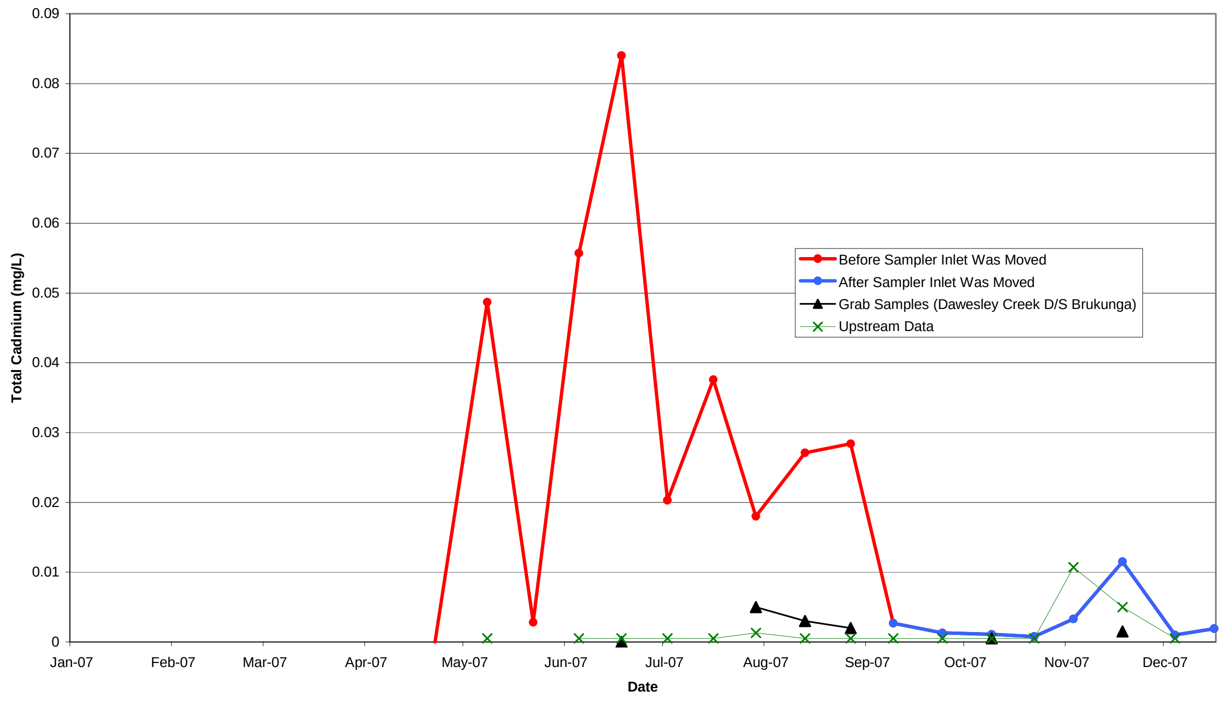
Analysis of 125 years of rainfall data recorded at Nairne, the closest official rain gauge to Brukunga, shows that total rainfall for 2007 of 584mm was well below the long-term average of 680mm. Seven out of twelve months recorded below average rainfall in 2007, with August registering 62mm below the long-term average for the month of August. At the Brukunga site, the total annual rainfall was recorded as 497mm.

The effect of extended dry periods of low flow were considered in the analysis of the 2007 data as drought conditions can negatively impact on water quality readings and macro invertebrate survey data (as recently seen in 2006 and 2007). The 2007 annual flow of 332 ML recorded immediately downstream from the mine site was the lowest annual flow recorded since monitoring began in 1998. Approximately 110 ML of acid water was treated in 2007 with 20% of the acid feed water volume originating from the seepage collected from the tailings dam. The treatment plant ran well under full capacity for the majority of 2007, except for a four month period stretching from May to August (see fig 17), resulting in only minor releases of untreated seepage to the creek.

The completion of new capital works initiatives undertaken by PIRSA in 2003 and 2005 has achieved a dramatic improvement in the quality of water in Dawesley Creek downstream of the Brukunga mine site, (See Fig C-11 and Fig C-13 in Appendix C) demonstrating that sulphate and cadmium pollution is being successfully removed from the water for the majority of the time.

The improvements recorded in the water monitoring results are more clearly evident when a comparison is made between the data collected before the installation of capital works (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.

2007 Composite Water-quality Sampling in Dawesley Creek down-stream of Brukunga Mine (Cadmium)



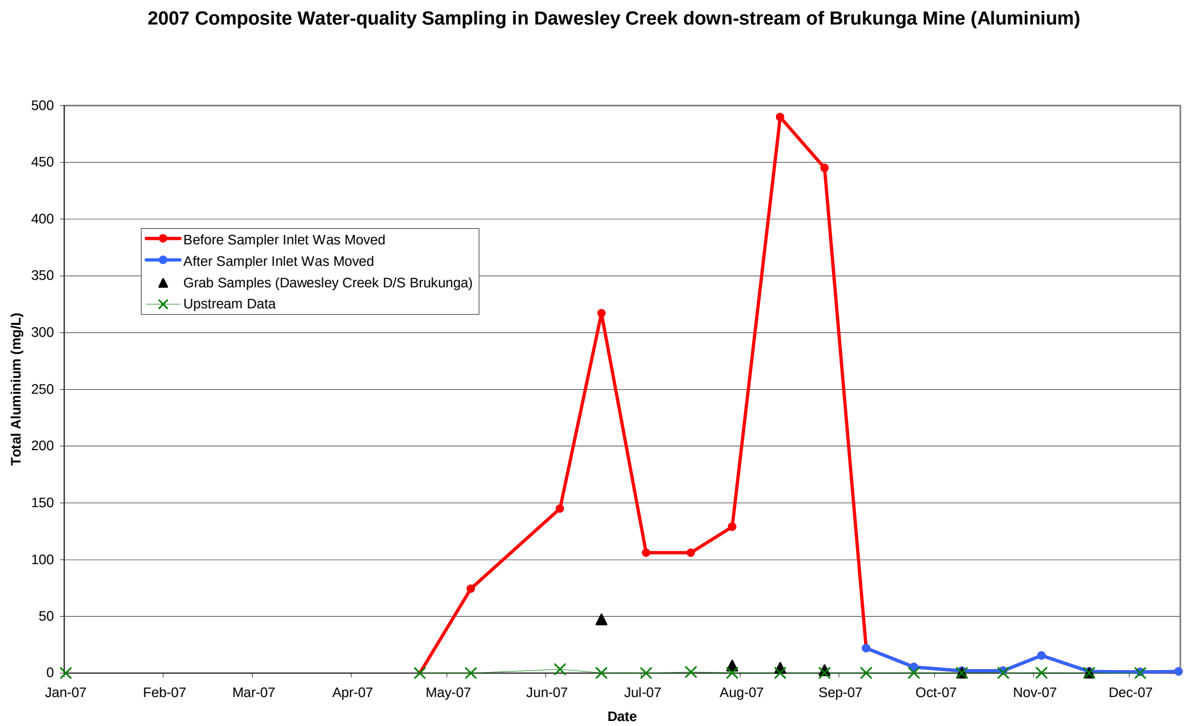


Figure 21. A comparison of contaminant levels before and after the composite sampler inlet was relocated

In general, the AWQC water quality test results of the grab samples taken from around the Brukunga mine site (see Fig 22) demonstrate that the water leaving the lime treatment plant and diversion pipe is of better quality than what was being recorded by the downstream WDS sampler. Water leaving the mine site was expected to be of good quality in 2007 (due to low flows and the treatment plant operating under full capacity).

Location	Site
1	Brukunga Upstream V weir
2	Seepage Pond
3	Tailings Dam
4	Clarified Pond
5	Above Plant Discharge to Creek
6	Discharge to Creek
7	Outlet of Ribloc (Diversion Drain)
8	Upstream from Bottom V weir
9	Brukunga Downstream V weir
10	Old Melbourne Bridge

Figure 22. Grab sample location at the Brukunga Mine Site.

Figure 23 demonstrates the large variation in stream water quality (sulphate) as water travels through the mine site. Extra grab samples were taken in 2007 due to suspect data being collected at the composite sampler site (as the sampler inlet was located in sludge) and to try and determine if any contributing contaminates were being added as water travelled through the mine site (i.e. whether the water quality measured at the bottom weir truly reflects the water quality leaving the plant). It appears that the water in an open stretch of creek upstream from the bottom weir can potentially be exposed to minor metal contamination before the sampling point at the bottom weir.

The following summarises the grab sampling points:

Site 1, the Brukunga Upstream V weir is a control site (even though it receives flows from the Bird In Hand Treatment works located further upstream).

Site 2, the Seepage Pond contains highly acidic seepage from rock waste dumps and the tailings dam (this is pumped into lime treatment plant)

Site 3, the Tailings Dam contains seepage from tailings dam area (contributes to metal loads of seepage pond)

Site 4, Clarified Pond, here water quality improves after treatment in lime plant and is allowed to settle (this measures how well the treatment process is working)

Site 5, Above plant discharge point (water quality in creek above the discharge point)

Site 6, Discharge to Creek is where water quality from treatment plant mixes with creek water

Site 7, Outlet of Ribloc (a dilution effect is seen, as higher quality water from upstream is added from diversion drain)

Site 8, Upstream from Bottom V weir is a length of the stream where the treated water can be potentially be exposed to metals before the sampling at the bottom weir

Site 9, Brukunga Downstream weir composite sampling site for water quality and flow leaving mine site

Site 10, the Old Melbourne Bridge site is the first downstream temporal and spatial sampling site from mine discharge (water quality should improve with dilution effect)

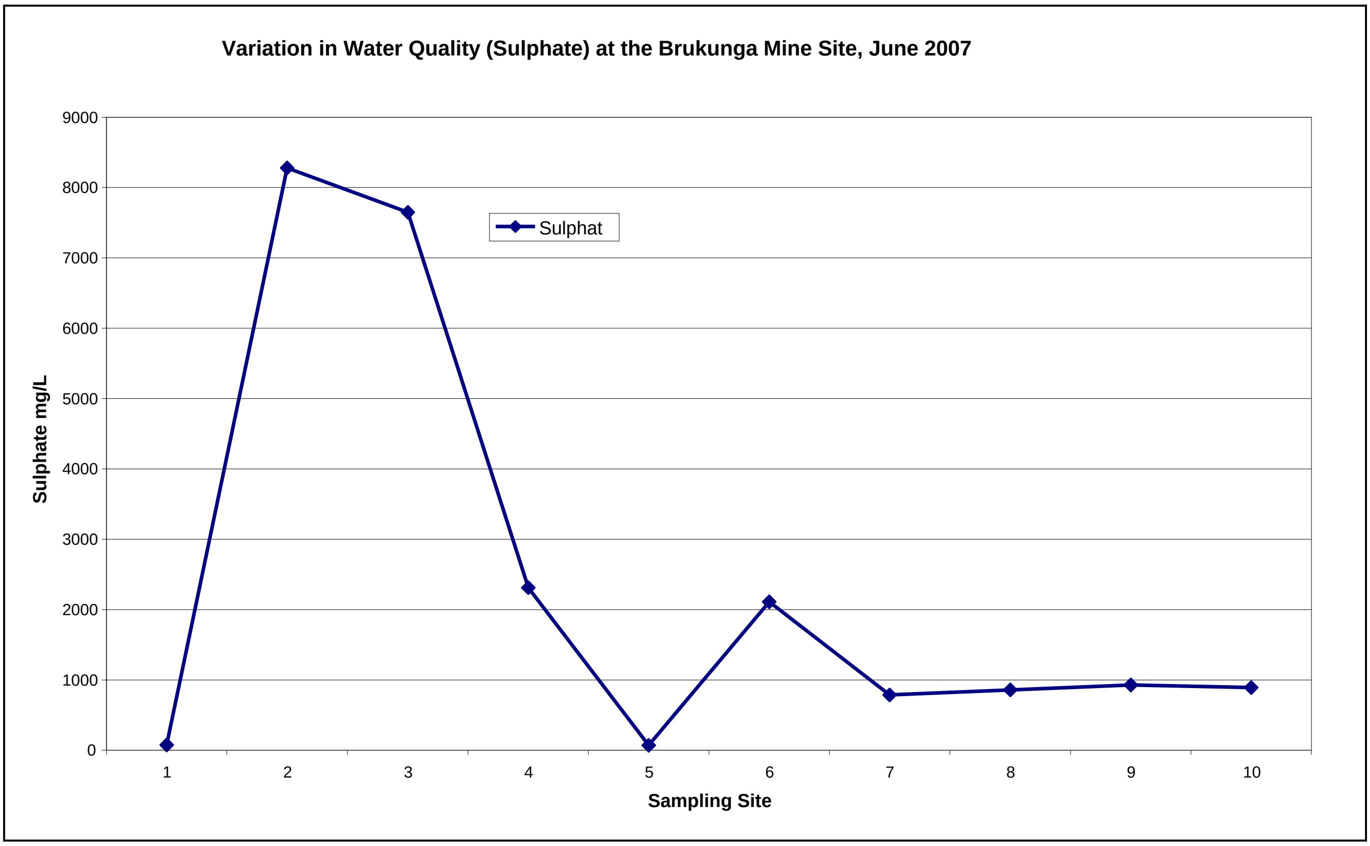


Figure 23. Variation in stream water quality (sulphate) as water travels through the Brukunga Mine site (June 2007 Grab Sample Data)

Composite sampler inlet was submerged in colloidal/metallic sludge until September 2007 (therefore was artificially increasing the recorded contaminant levels).

The macroinvertebrate monitoring studies support that the water quality in the Dawesley creek is improving compared to the conditions prior to the creek diversion. The results continue to show that the positive trend in Mean Taxon Richness since operation of the diversion scheme was most marked at the Brukunga downstream site and the McIntyre road site. These two sites show improvement, and multivariate analysis suggests that they are close to becoming reference site condition. In particular, the Brukunga downstream site was equal to or greater than the Peggy Buxton reference site in 3 out of 4 quarterly surveys (March, June, & September). However, in December, dry conditions resulted in the upstream reference site being reduced to a stagnant pool fed by treatment water. Drought conditions can negatively affect macroinvertebrate survival and can complicate the interpretation of results. Further possible work may be needed to identify invertebrate drift (see Appendix B).

It would seem that the first objective of restoring water quality in the Dawesley Creek to a level that complies with ANZECC 1992 Guidelines for irrigation and livestock, has largely been met.

Metal concentrations in the Dawseley Creek immediately downstream of the mine site were consistently low for the majority of the year. In 2007 cadmium levels in the Dawseley Creek were below the ANZECC recommended guidelines for livestock and irrigation use.

Overall the temporal and spatial metal data, for Strategy 3 of the EPA guidelines, show that the metal levels in the Dawesley Creek system comply with the ANZECC guidelines. The creek system is also returning to a condition suitable for livestock and irrigation usage in addition to supporting a wide diversity of aquatic ecosystems associated with the creek system.

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.

APPENDICES

APPENDIX A - ANNUAL LOAD OF HEAVY METALS

Table A-1 Calculated loads of contaminants in Dawesley Creek at Brukunga Mine site 2007

2007 CALCULATED CONTAMINANT LOAD IN DAWESLEY CREEK

Dawesley Creek Upstream of Brukunga Mine

AW426658

Date	Sulphate kg	Aluminium kg	Cadmium kg	Chromium kg	Copper kg	Iron kg	Lead kg	Manganese kg	Nickel kg	Zinc kg
3-Jan-07	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow
24-Apr-07	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow
10-May-07	2127.96	1.27	0.01	0.08	0.10	25.12	0.01	5.48	0.23	0.61
24-May-07	645.12	28.64	0.00	0.03	0.04	51.07	0.02	1.05	0.06	0.20
7-Jun-07	1528.20	3.65	0.01	0.08	0.11	22.53	0.01	2.07	0.19	1.58
20-Jun-07	961.60	0.81	0.01	0.04	0.04	10.51	0.01	1.97	0.10	0.25
4-Jul-07	754.02	12.89	0.01	0.25	0.15	27.79	0.15	1.58	0.11	0.53
18-Jul-07	4995.60	76.02	0.04	0.29	0.26	123.80	0.04	6.76	0.41	1.74
31-Jul-07	1820.40	7.27	0.02	0.44	0.09	21.16	0.03	4.77	0.16	1.05
15-Aug-07	1493.40	1.87	0.01	0.04	0.02	11.08	0.01	1.13	0.11	0.17
29-Aug-07	1086.40	1.83	0.00	0.03	0.04	9.80	0.00	0.75	0.07	0.29
11-Sep-07	1216.00	2.43	0.00	0.03	0.04	10.36	0.00	0.32	0.08	0.22
26-Sep-07	1342.91	8.49	0.01	0.07	0.04	20.42	0.01	0.54	0.13	0.34
11-Oct-07	419.41	1.21	0.00	0.02	0.03	5.23	0.00	0.27	0.05	0.15
24-Oct-07	614.69	2.27	0.00	0.03	0.02	6.73	0.00	0.50	0.06	0.10
5-Nov-07	379.44	2.28	0.07	0.02	0.16	6.15	0.02	0.50	0.08	0.73
20-Nov-07	262.08	1.05	0.03	0.02	0.29	4.07	0.03	1.08	0.04	0.94
6-Dec-07	108.22	0.18	0.00	0.01	0.01	1.17	0.00	0.40	0.02	0.03
Total Load (kg)	**19755.46**	**152.15**	**0.24**	**1.48**	**1.43**	**356.97**	**0.37**	**29.17**	**1.89**	**8.93**

Dawesley Creek Downstream of Brukunga Mine

AW426659

Date	Sulphate kg	Aluminium kg	Cadmium kg	Chromium kg	Copper kg	Iron kg	Lead kg	Manganese kg	Nickel kg	Zinc kg
03-Jan-07	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow
24-Apr-07	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow
10-May-07	39092.00	2503.91	1.64	0.10	1.58	394.29	0.07	217.84	3.13	138.84
24-May-07	5220.00	13.50	0.02	0.02	0.03	12.96	0.00	19.41	0.16	1.04
07-Jun-07	13127.40	3393.00	1.30	0.37	2.93	2131.74	0.39	92.71	2.29	214.58
20-Jun-07	17463.60	6276.60	1.66	0.48	3.49	2514.60	0.50	50.00	2.12	211.86
04-Jul-07	16758.00	2416.80	0.46	0.07	0.56	1228.92	0.23	62.65	0.80	97.13
18-Jul-07	73848.00	9593.00	3.40	2.26	10.77	5095.15	0.94	249.42	17.75	385.53
31-Jul-07	14145.00	2644.50	0.37	0.49	1.48	1020.90	0.22	37.72	1.69	80.57
15-Aug-07	11709.60	8036.00	0.44	0.90	4.21	1623.60	0.33	39.39	2.34	127.26
29-Aug-07	11942.70	5384.50	0.34	0.15	2.55	1167.65	0.23	44.93	1.90	63.53
11-Sep-07	6169.20	233.20	0.03	0.07	0.08	287.26	0.03	9.30	0.33	3.21
26-Sep-07	11495.70	131.35	0.03	0.07	0.17	141.23	0.01	6.21	0.29	1.93
11-Oct-07	6703.20	29.40	0.02	0.04	0.10	28.08	0.01	6.63	0.25	1.00
24-Oct-07	5654.70	22.25	0.01	0.03	0.04	17.82	0.01	4.03	0.13	0.71
05-Nov-07	6572.70	167.86	0.04	0.03	0.11	40.44	0.01	19.22	0.71	8.67
20-Nov-07	8743.80	17.23	0.14	0.04	0.08	16.40	0.06	15.09	0.27	0.86
06-Dec-07	6477.00	5.92	0.01	0.02	0.08	5.61	0.00	20.99	0.13	0.41
Total Load (kg)	**255122.60**	**40869.01**	**9.91**	**5.14**	**28.27**	**15726.64**	**3.05**	**895.53**	**34.28**	**1337.12**

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

	Sulphate	Aluminium	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
Total Load (kg/yr)	235367.14	40716.85	9.67	3.66	26.84	15369.67	2.68	866.36	32.39	1328.19

Table A-2. Annual net contaminant loads in Dawesley Creek at Brukunga Mine site

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

Year	Water flow	Sulphate	Aluminium	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
	ML	Kg	kg	kg	kg	kg	kg	kg	kg	kg	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	21.9	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
2006	383	211,537	18,236	4.2	1.2	17.4	13,596	1.19	804	15.3	620
2007	332	235,367	40,716	9.7	3.7	26.9	15,369	2.68	866	32.4	1,328

Table A2. Annual net contaminant loads in Dawesley Creek at Brukunga mine site

NET CONTAMINANT LOAD FROM BRUKUNGA MINE SITE (kilograms per megalitre 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
2006	553	48	0.0109	0.0031	0.045	35.500	0.0031	2.099	0.0399	1.619
2007	718	124	0.030	0.011	0.082	46.916	0.008	2.645	0.099	4.054

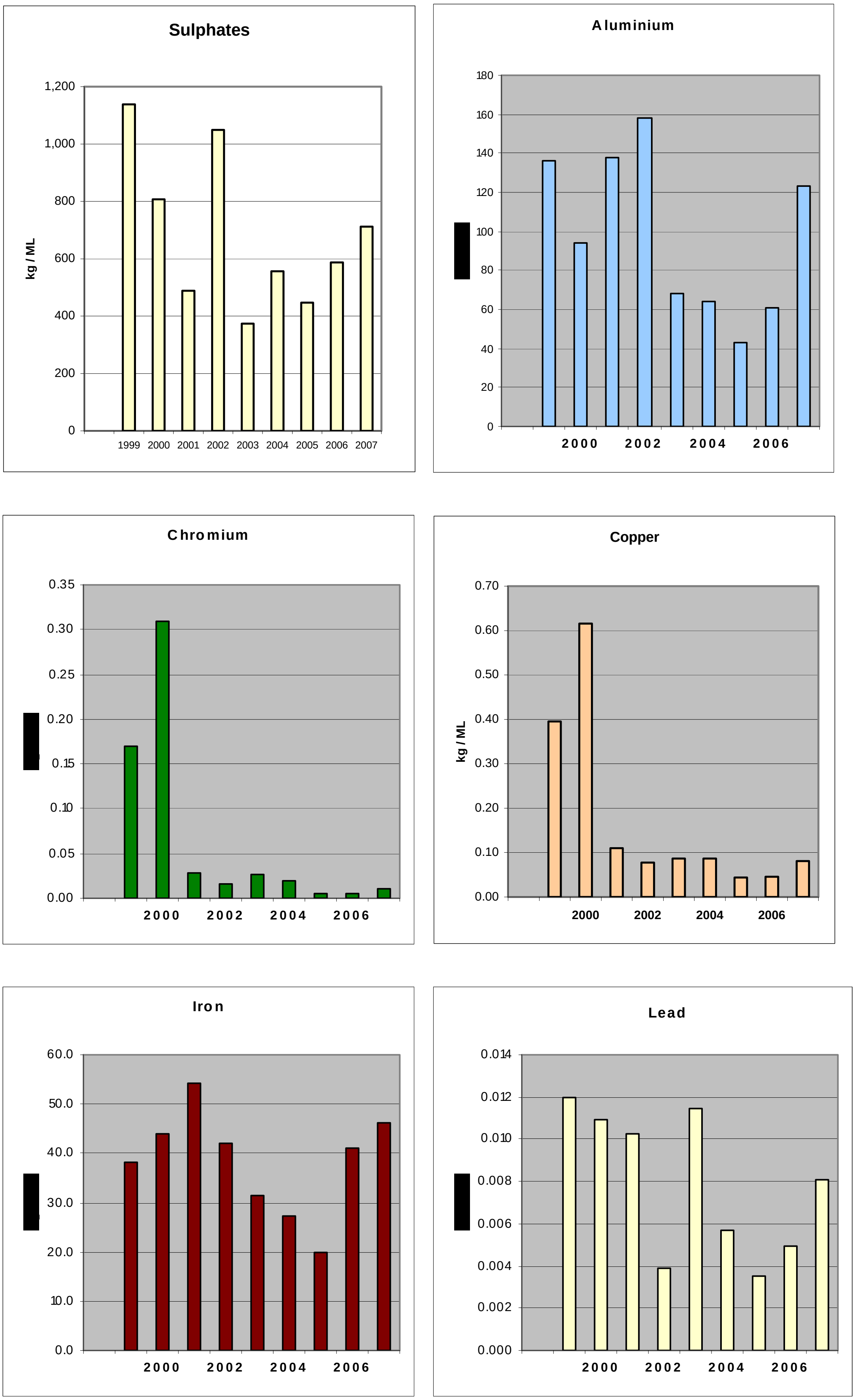


Fig A-1. Graphs of annual load of contaminant in Dawesley Creek 1998 to 2007 (kilograms / megalitre of flow)

APPENDIX B - BIOLOGICAL MONITORING RESULTS

Brukunga Acid Mine Drainage Impact Monitoring Program: Macroinvertebrate Results 2007

Submitted by Australian Water Quality Centre, (compiled by: Darren Hicks) for Primary Industries & Resources, South Australia (PIRSA)

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Tables and Figures

The Brukunga Acid Mine Drainage Impact Monitoring Program

Macroinvertebrate Results 2007

1. Introduction

The Brukunga Acid Mine Drainage Impact Monitoring Program, initiated in the 1996–1997 financial year, includes monitoring macroinvertebrate and chemical parameters at sites on the Dawesley Creek – Bremer River system. The Australian Water Quality Centre (AWQC) has 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 is to investigate the impact of Acid Mine Drainage (AMD) on Dawesley Creek including the downstream extent of the impact and subsequent to the construction of a diversion channel around the mine site to investigate the recovery of Dawesley Creek.

This report provides a summary of macroinvertebrate results for 2007 and provides comparisons with data from past years. Climatic conditions experienced during 2007 have seen continued low winter rainfall and this is likely to have had an added effect on the composition of macroinvertebrates in the catchment. A recommendation from the 2005 survey was for some sites to have riffle habitats sampled, in the wetter months, to determine if the flowing water habitats and fauna of Dawesley Creek are recovering. Monitoring of riffles in the study area commenced in 2006. As there is no previous site-specific data for use in determining if these riffles are improving after the creek diversion, the 2006 and subsequent results have been used to represent the baseline condition.

Sites

Macroinvertebrate monitoring has been conducted in the system since September 1996. The six sites monitored from 1996 to 2007 are listed in Table 1, the first five are in order of increasing distance down Dawesley Creek; while the Nairne Creek site was selected as another control site which flows into Dawesley Creek upstream of the Balyarta Ford site. 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. 2007	4728
Dawesley Ck. D/S Brukunga	Site 2	Sept. 1996 – Dec. 2007	3158
Dawesley Ck. at McIntyre Rd	Site 3	Sept. 1996 – Dec. 2007	1951
Dawesley Ck. at Balyarta Ford	Site 4	Sept. 1996 – Dec. 2007	1822
Dawesley Ck. at Freeway	Site 5	Dec. 1996 – Dec. 2007	1952
Nairne Ck. at Djatadapeel Ford	Site 6	Sept. 1996 – Dec. 2007	1953

2. 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 sampled at all sites and is the habitat chosen for comparisons of previous macroinvertebrate assemblages across all sites and times.

Riffles were sampled during June and September from Dawesley Creek at Peggy Buxton Rd, Downstream Mine and Balyarta and from Nairne Creek at Djatapeel, as of 2006. 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 had 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.

The spot pH values reported in the results section where measured on site with a calibrated multimeter from YSI incorporated model; YSI 556 MPS.

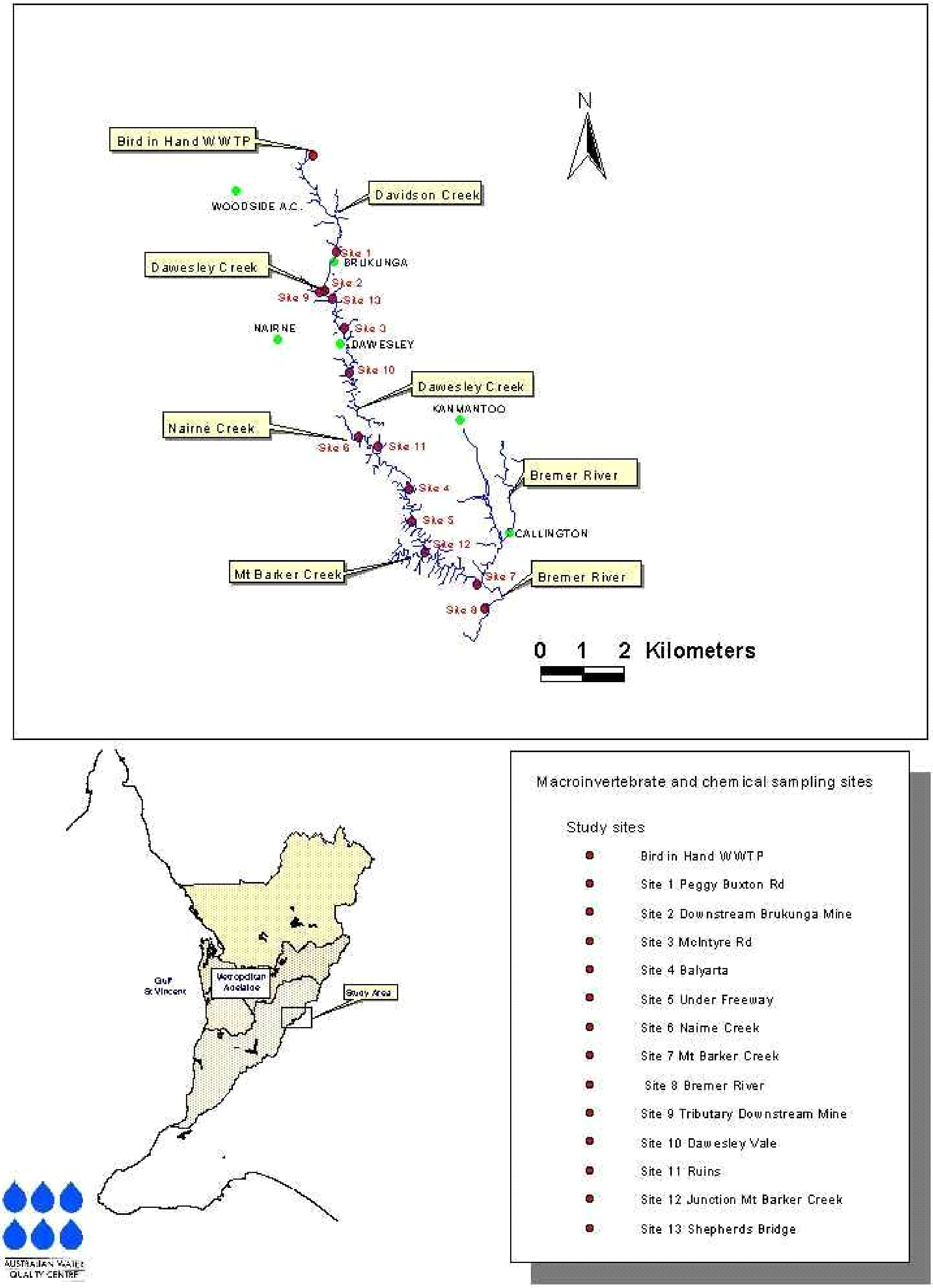

Figure 1. **Location and site map for the Dawesley Creek System.**

Interpretation of Macroinvertebrate Data

Macroinvertebrate data were analysed by several techniques. These were simple indices (taxon richness, abundance); Multivariate analyses (MVA), and AusRivAS predictive models.

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.

MVA are statistical procedures that can detect similarities in biological community data (i.e. the taxa present and their abundance). They 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, and such patterns may not be revealed by simple diversity indices and raw taxon richness and abundance figures. 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 of edge samples to investigate for indications of ecological change after several years of operation of the diversion channel. This was done by comparing rainfall averages for the years 1997 to 2007 for SE Australia and the pattern and number of dry sites each year. From the six complete years of data available (1997-2002), the 2002 data were selected, as the hydrological conditions then most approximated those in 2007.

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. This gave an analysis matrix of 37 samples by 138 taxa. To equalise the relative importance for the analysis of taxa abundance and taxa composition the dataset was transformed, the transformation reduces the weighting any one relatively abundant taxon has on the grouping a site falls within the MVA. The optimum balance between the significance of the two parameters was achieved by performing the 0.3 power transformation. The Bray-Curtis association measure was used on transformed 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 two-dimensional solution was calculated using a maximum of 400 iterations, a random start and a stability criterion of 0.00001. The resulting stress value was 15.23 and the solution was stable after approximately 64 iterations.

The stability criterion was chosen at the very low level of 0.00001 to guarantee the reliability of the ordination solution. The MVA ordination can be set to run an indefinite number of solutions until it finds the solution with the lowest stress (stress between 12 and 19 are considered acceptable) and meeting the stability criterion. In the case of the chosen 400 iterations, if the ordination had not found a solution after 400 attempts which met the stability criterion and with a stress less than 19, it would have reported that no solution had been found. In this case the ordination result is very reliable with the solution resolved with the set stability criterion after 64 attempts in a 2 dimensional plane with a stress of 15.23. If a stress of 20 or over is recorded it means the ordination result could have been arrived at by chance rather that consistent patterns in the data and the program states the results are unreliable.

AusRivAs is the first national biological assessment of river health to be conducted on a continental scale, AusRivAS involved the sampling of macroinvertebrates from over 6000 sites, 650 of them from South Australia. The condition of a river site is determined by comparing it to a reference site, reference sites are considered to be in an undisturbed unimpacted state.

AusRivAS 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 the AusRivAS analysis of 2007 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 Richness

2007 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 level taxonomic 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 to 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 2007

In previous surveys, it has been common for many Dawesley Creek sites to be dry in March. Consistent with these conditions, only three sites held water in March 2007 (Figure 2) and only Nairne Creek was flowing, Dawesley Creek at Peggy Buxton and downstream the mine contained ponded still water. Taxon richness and pH remain relatively unchanged at both Nairne Creek and Peggy Buxton as compared to the same sampling period last year. Brukunga mine however shows a significant increase in taxon richness after its lowest recorded taxon richness result at this time in 2006 (see Figure 8). It has returned to similar levels as in 2004 and 2005, however pH remains relatively low due to absence of flow in Dawesley Creek, the water present at the site in March appeared to be from ground water input from the mine site, which is of low pH.

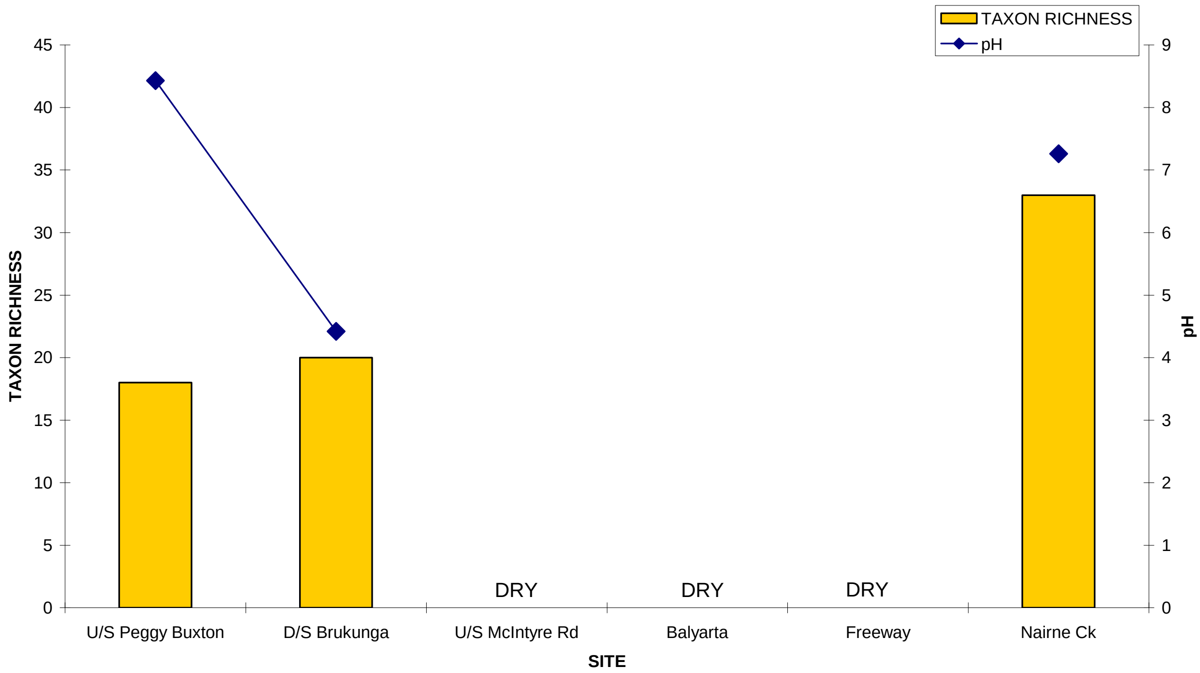

Figure 2. March 2007 taxon richness and pH.

June 2007

Results from the June 2007 samples followed a similar pattern shown in the 2006 winter survey with all sites containing flowing water and, with the exception of Brukunga Mine, all sites had a pH value close to neutral (Figure 3). The spot pH value at Brukunga Mine was 5.3 which is around 1 unit lower than in 2006, however still the second highest pH recorded for June since monitoring began.

Nairne Creek site possessed the highest taxon richness. The lowest taxon richness was seen at the McIntyre Rd and Freeway sites (Figure 3) suggesting the biological communities there were still undergoing the recovery process from the dry spell. The Balyarta site had also been dry during March but showed macroinvertebrate richness comparable to that of the Peggy Buxton Road site (Figure 3), as did the Brukunga Mine site. Macroinvertebrate drift from the nearby confluence with Nairne creek may have contributed to this comparatively rapid recovery at the Balyarta Ford site.

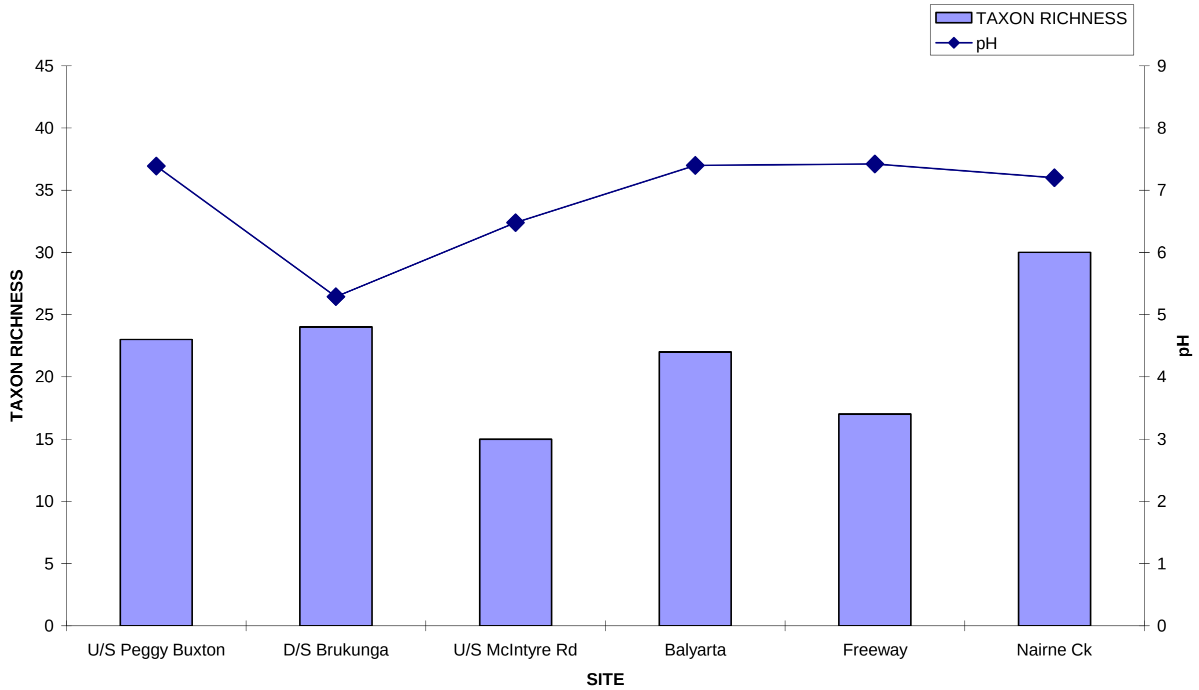

Figure 3. June 2007 taxon richness and pH.

September 2007

Flowing water was again present at all sites in September. The spot values of pH were all above neutral ranging from 7.25 to 8.0 across the sites (Figure 4). The Level of macroinvertebrate richness is variable with Nairne Creek showing the highest value of 33 followed closely by Brukunga mine with 31 (Figure 4). In comparison to samples taken in September 2005 and 2006, Brukunga mine has more or less doubled in taxon richness (Figure 8). September appears to be the month when the lowest macroinvertebrate richness is recorded at Peggy Buxton Road with low figures in September 2005, 2006 and 2007.

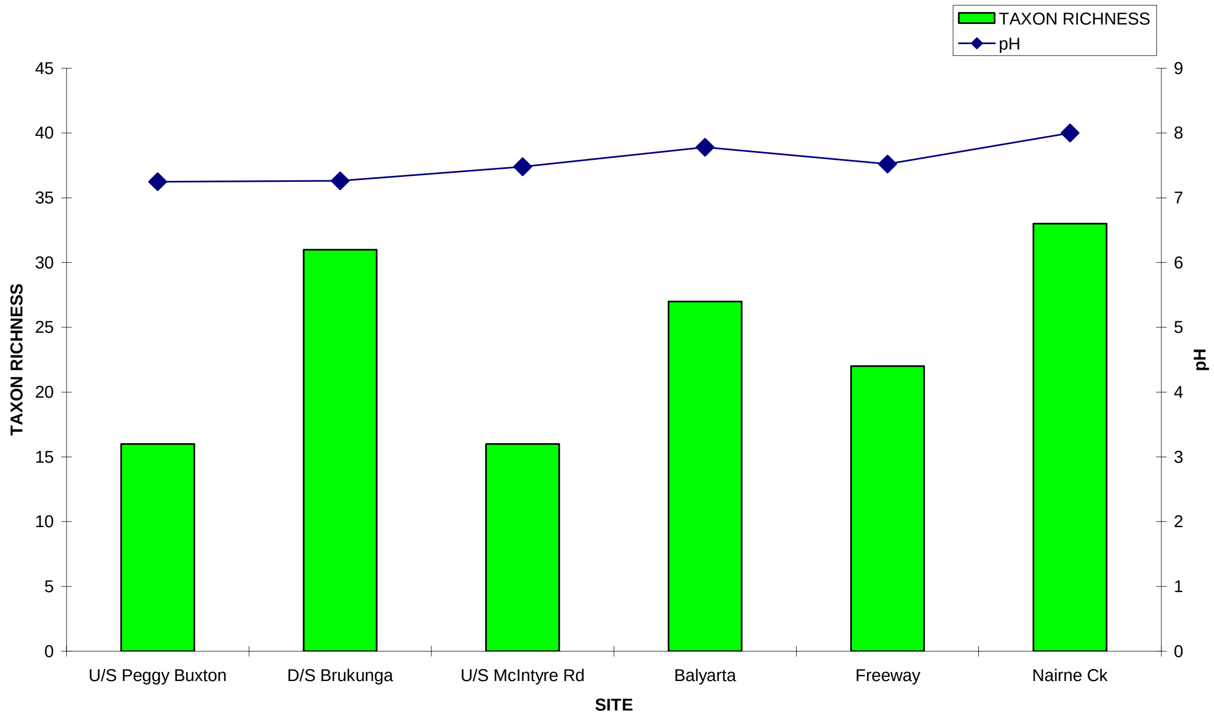

Figure 4. September 2007 taxon richness and pH.

December 2007

An exceptionally dry spring resulted in only 2 sites having surface water which was not flowing when visited in December 2007 (Figure 5). The Brukunga Mine and Balyarta sites were dry during December for the first time in 2006. When visited in December 2007, these two sites were again dry but Nairne creek was also dry for the first time in December since the beginning of the program in 1996. The mine site was dry in December 2007 due to gauge management requiring draining of the gauge pool. The spot pH value and taxonomic richness was significantly lower at McIntyre Rd than it was at the local reference site Peggy Buxton Rd and this is believed to be from low pH ground water infiltration.

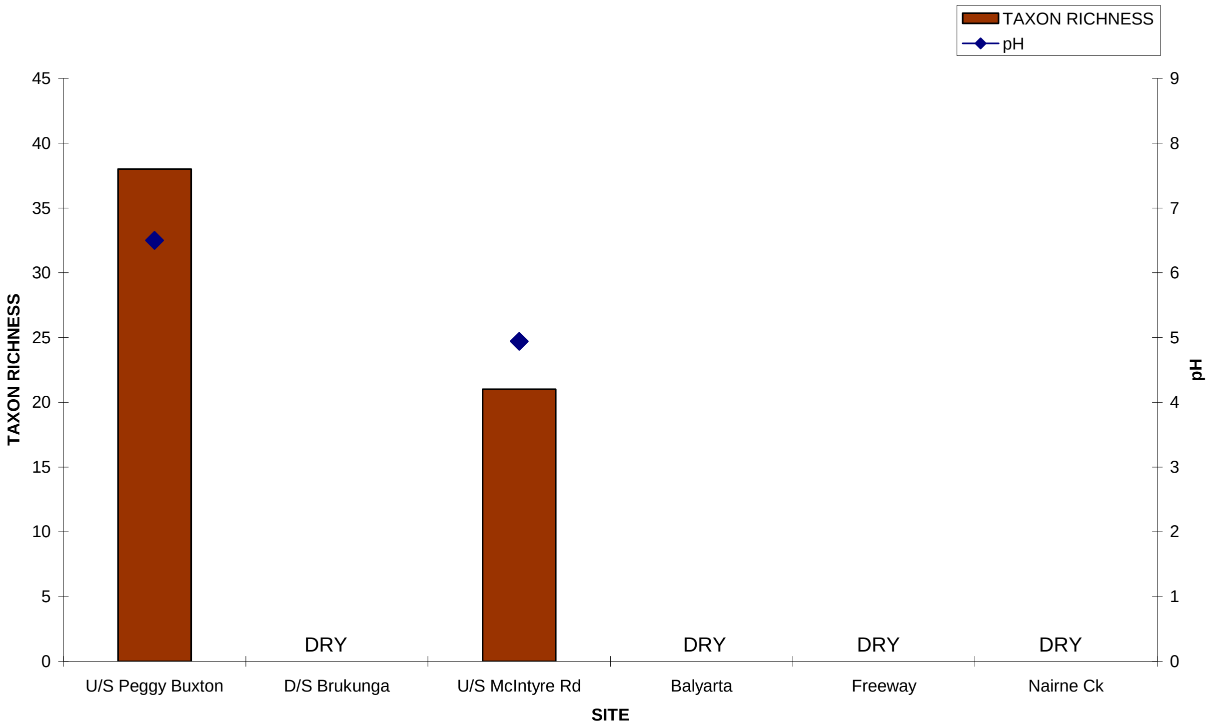

Figure 5. December 2007 taxon richness and pH.

Mean taxon richness 1996-2007

A comparison of the 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, and indicates that continued improvement will give rise to statistically significant differences (Figure 6).

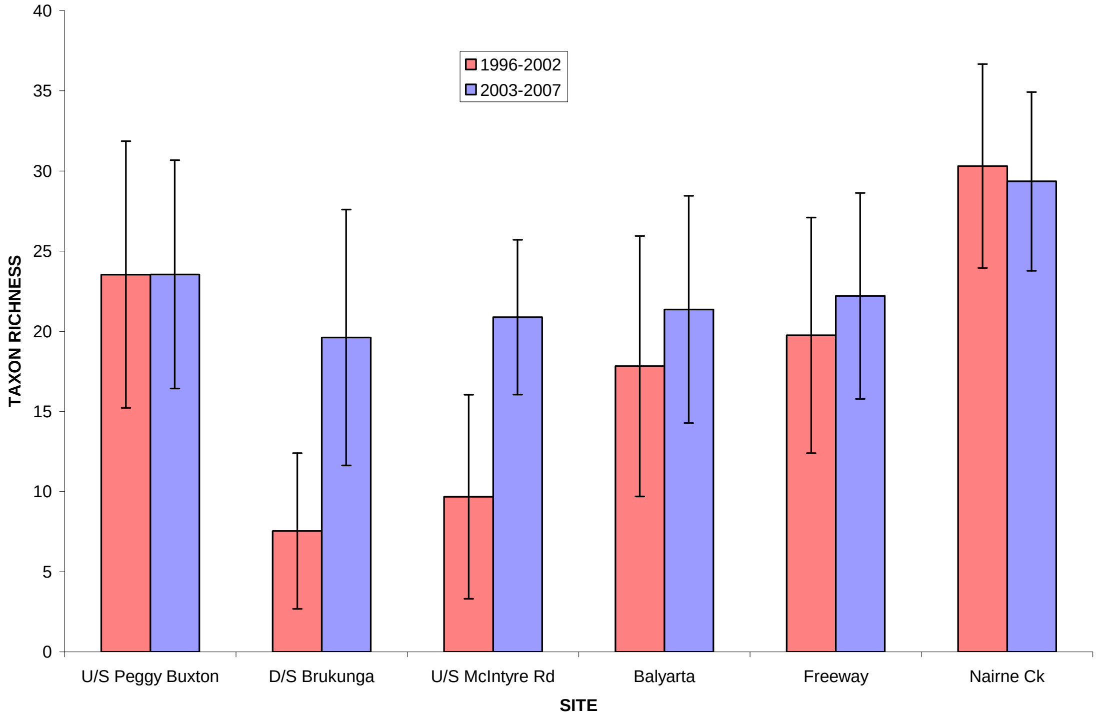

***Figure 6*. Dawesley Creek system: taxon richness at six sites: 1996 – 2002 and 2003 – 2007.** Error bars show two standard deviations.

Temporal Changes at Each Site

At each of the six sites, the data set from March 1998 to December 2007 has been presented (Figures 7-12). This allows the 2007 data to be compared with the findings of earlier years. In all the figures that follow taxonomic richness for the different months is; yellow for March, blue for June, green for September and brown for December.

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 taxon richness. Prolonged periods of normal flow, on the other hand, created favourable conditions for macroinvertebrates which resulted in times of increased taxon richness. Reduced flow due to continued dry conditions throughout winter and spring in 2006 and 2007 resulted in lower taxon richness and a pattern similar to that seen during 2003 (Figure 7), with the exception of the sample taken in December 2007. Taxon richness peaked in 2002 when 42 different taxa were recorded in December. The lowest numbers of taxa were recorded in September 2003 and September 2006 when 13 and 14 taxa were recorded, respectively (Figure 7). Stream spot pH fluctuated over the years from 6 to 8 until December 2006 when it peaked with a value approaching 9.

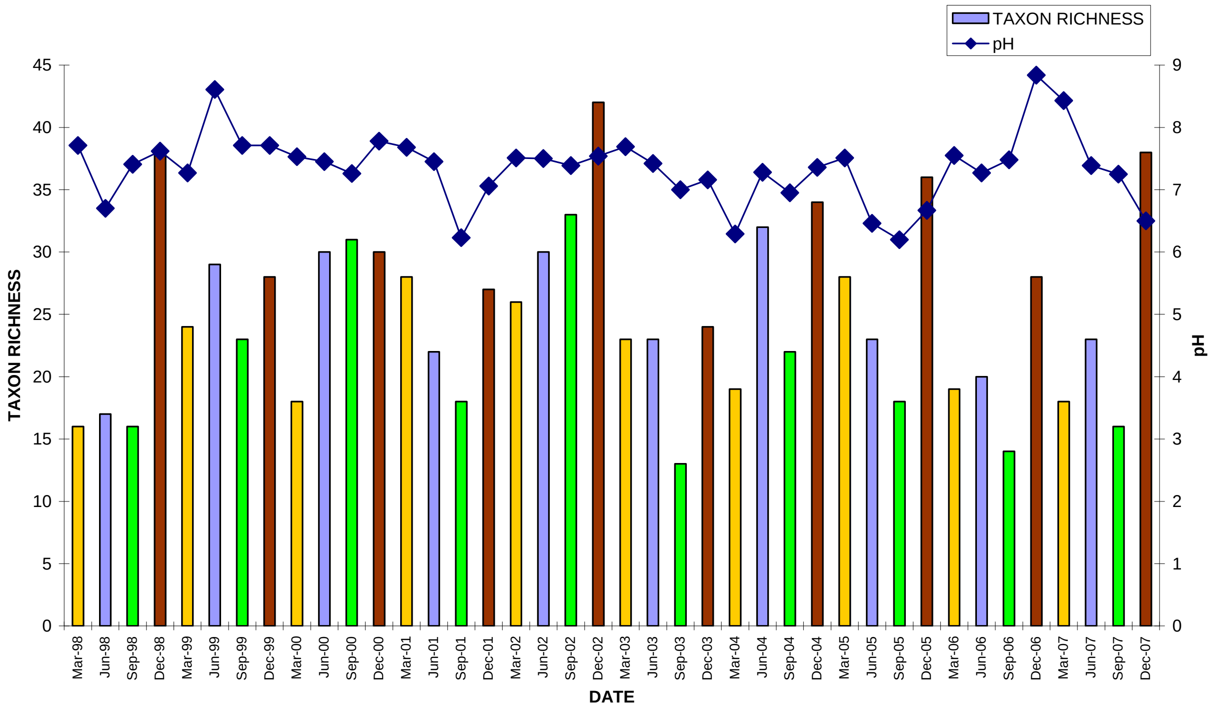

***Figure 7*. Dawesley Creek: Peggy Buxton Road. Taxon richness and pH.**

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, circumneutral conditions in September and December 2004 (Figure 8). In 2007, the maximum taxonomic richness was recorded in September with results in March and June also being relatively high. Similar results to the September richness value has not been seen since December 2003. Since the diversion the pH looks to be fluctuating between 4.3 and 7.5 units. The 2007 results do not vary from this pattern showing pH readings from 4.4 in March to 7.3 in September. The site has now been dry on two occasions, in December 2006 and 2007, since monitoring began due to maintenance of the gauge pool by PIRSA mine rehabilitation.

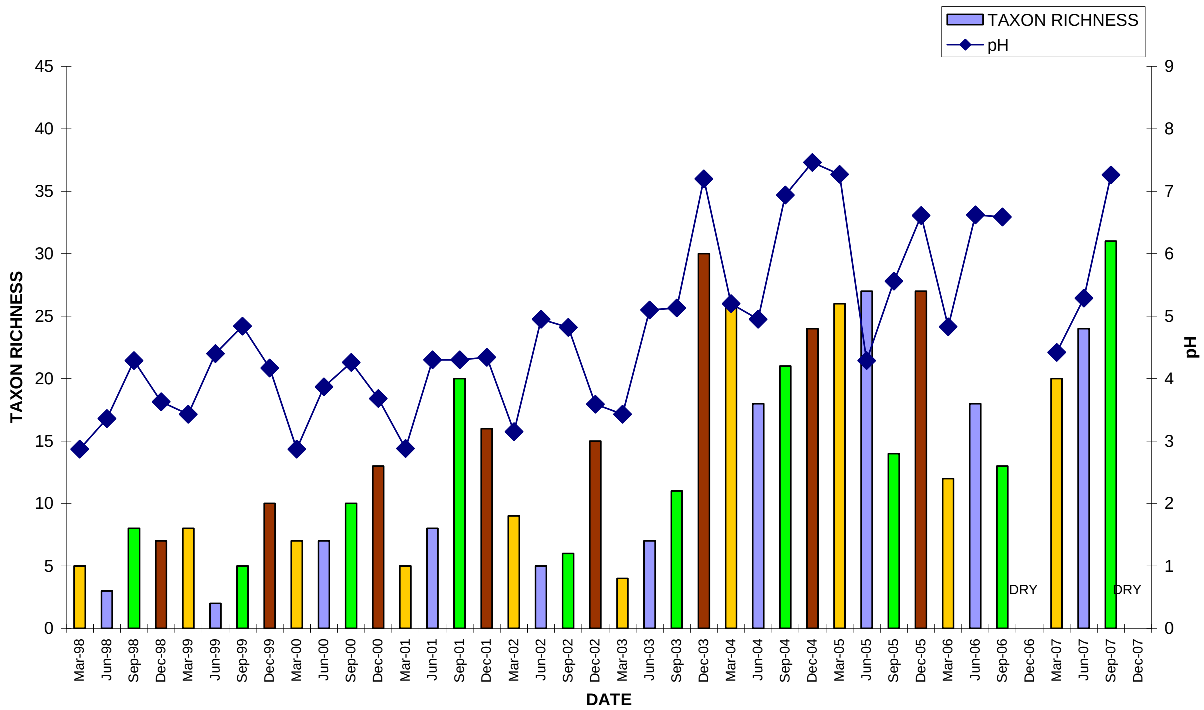

***Figure 8*. Dawesley Creek: Downstream of Brukunga mine. Taxon richness and pH.**

Upstream McIntyre Road

Values of spot pH were quite variable in 2007 (Figure 9). The value rose, not unusually, from June to September but then took a sharp downward turn from September to December. A drop similar to this magnitude has not been detected since 2001. Again no surface water was present in March, and the other months sampled showed richness was not overly dissimilar to the 2006 results. The highest richness ever measured at the site was collected in December 2004.

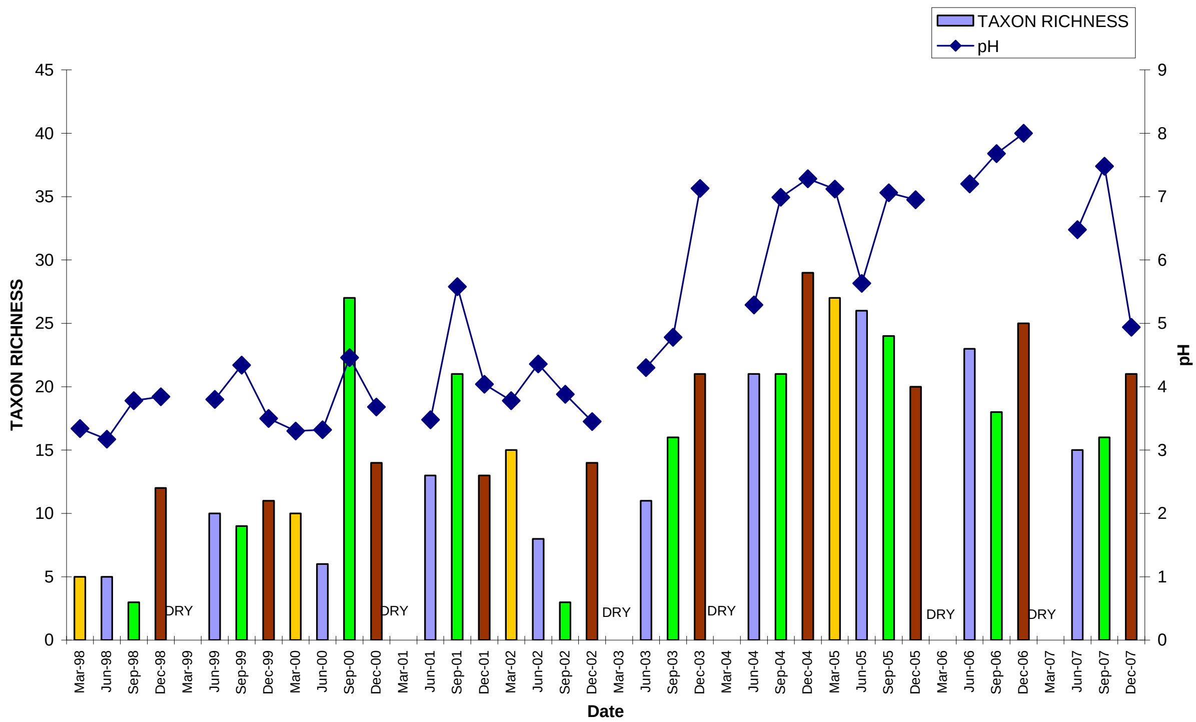

***Figure 9*. Dawesley Creek: McIntyre Road. Taxon richness and pH.**

Balyarta

The section of Dawesley Creek downstream of its confluence with Nairne Creek is usually dry in late summer and early autumn. The 1996/97(no longer on graph) 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). During 2007, richness showed a typical stepping up in June and September following a characteristic dry channel in March (Figure 10). Spot pH values were within the range of previous years. As mentioned above, the site being dry for a second time in December shows the continuing effect of drought conditions.

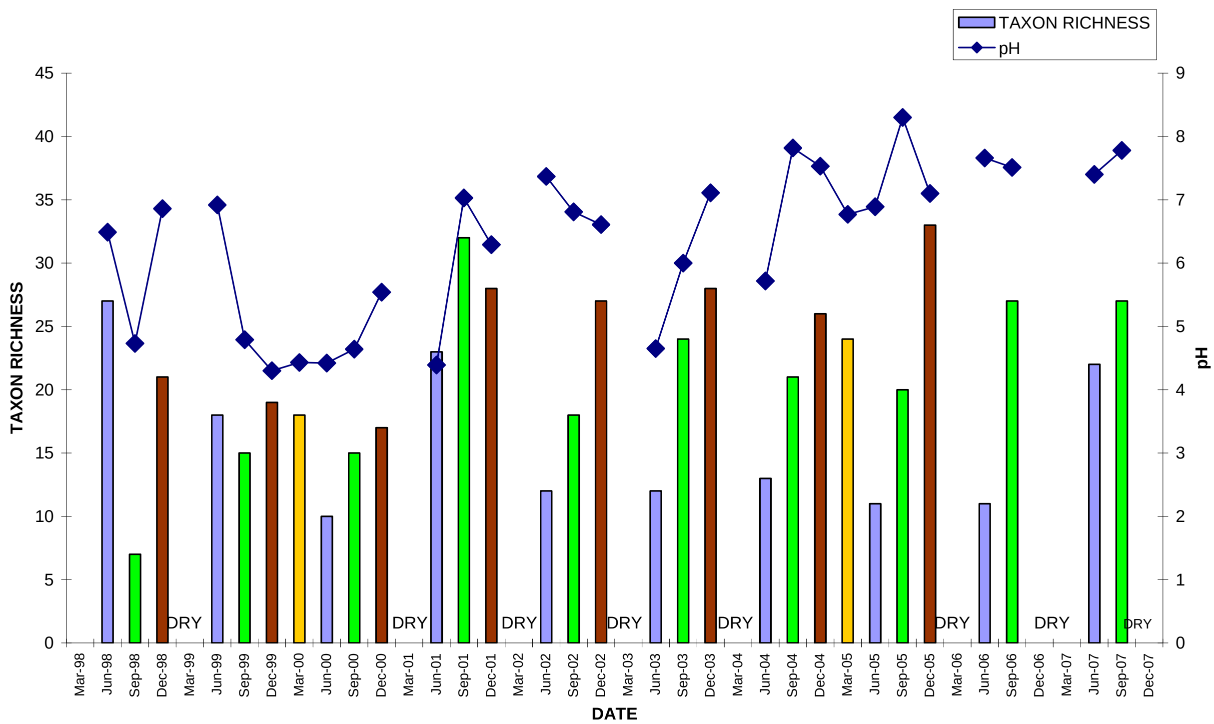

***Figure 10*. Dawesley Creek: Balyarta. Taxon richness and pH.**

Freeway

As this is an intermittently flowing 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 has 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. Results for 2004-2007 were very similar, except for a slight decline in the September taxon richness. During 2004-2007, the pH was alkaline to neutral, which suggests that the AMD influence was subdued or absent at these times.

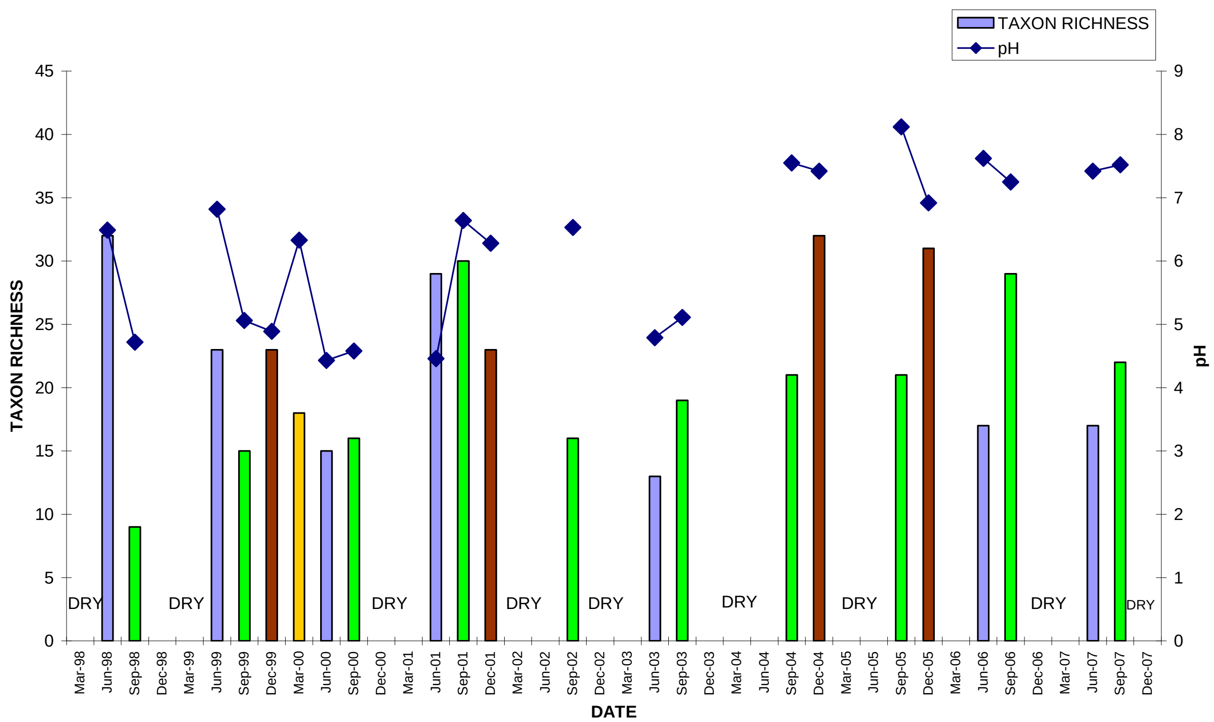

***Figure 11*. Dawesley Creek: Freeway. Taxon richness and pH.**

Nairne Creek

From 1996 to 2003 this local 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. The surface hydrology of Nairne Creek experienced a major change during 2004 and 2005. Consequently, ecological changes occurred. During these two years, the stream was dry in March, and June values of taxon richness and pH were markedly lower than for the previous December (Figure 12). Previous to sampling in June 2007 a ford was constructed at the site where previously the water flowed over a rocky section of road. As a consequence, by September the baseline level of the main pool had dropped by approximately 30 centimetres due to a pipe located at the base of the ford. In December 2007 the site was dry. Apart from the dry periods, in general, pH and taxon diversity has remained relatively consistent at this site.

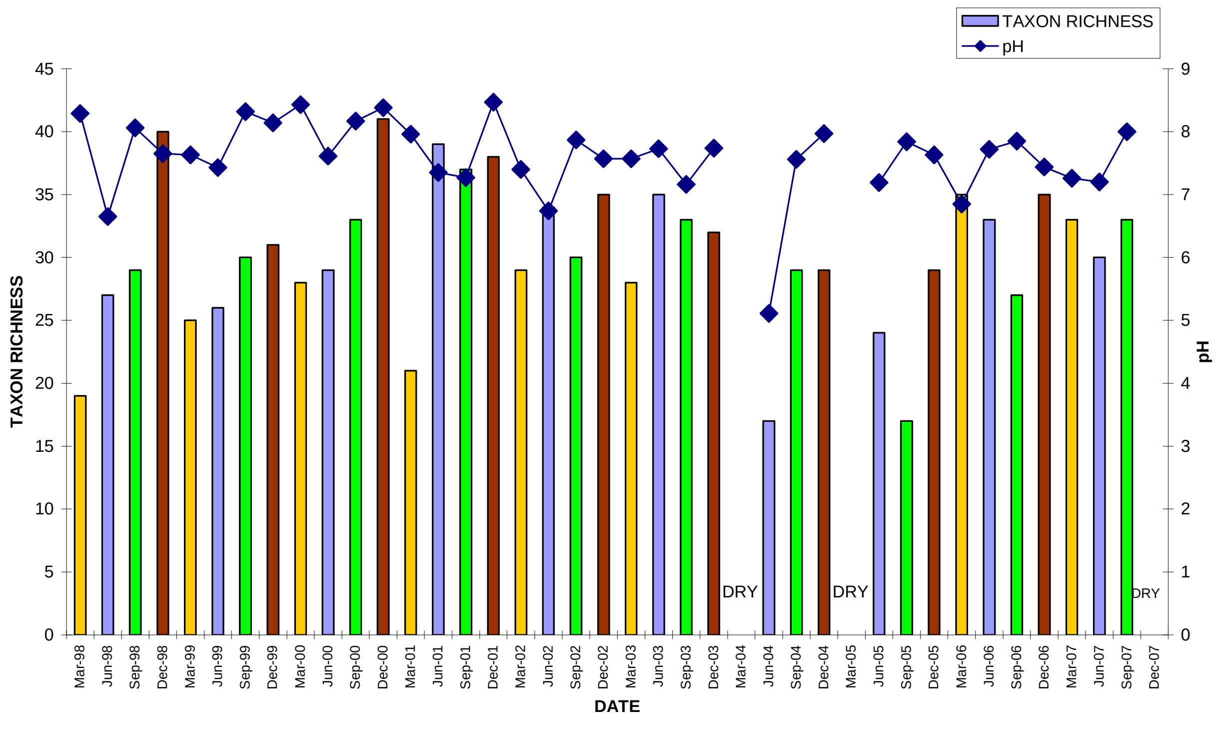

***Figure 12*. Nairne Creek. Taxon richness and pH.**

AusRivAS Results

Six seasonal models were used in this study; the autumn edge and riffle model, spring edge and riffle model and the combined season edge and riffle models. 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 the June and September samples. The riffle samples from June were tested in the autumn riffle model and those from September were tested in the spring riffle model. The combined season riffle model data was produced by summing the abundance of each taxon in the June and September samples. Results from the AusRivAS models for the 2007 data are shown in Table 2.

The edge model rated Peggy Buxton Road to be an ‘A’ (same as local reference site) for June and September, while in March it was rated a ‘B’ (slight impairment to ecological health). In December the edge sample was rated ‘X’ (above reference site). The riffle model rated all samples a ‘B’ where the habitat was present in June and September. All Brukunga mine edge habitats received ratings of ‘A’, except for in March when it received a ‘B’ rating. The Brukunga mine showed ‘C’ band ratings (significant impairment to ecological health) to all riffle habitats that were present in June and September. No habitats were present in December. McIntyre Rd received an ‘A’ rating by the edge model for June and a ‘B’ rating for September and December. No riffles were surveyed at McIntyre Rd throughout the survey. Balyarta received an ‘A’ rating from the edge model in June and September. No surface water was present in March or December. Both riffle habitats in June and September received ‘B’ ratings. The Freeway also contained no surface water in March and December. The edge model rated this site as being ‘A’ in June and ‘B’ in September. No riffle habitat was present. Nairne Creek received the highest number of ‘A’ ratings including edge habitats in March, June and September and a riffle habitat in June. The remaining riffle habitat observed was rated ‘B’, however the OE50 score was only 0.03 points away from receiving an ‘A’ rating; making it a relatively healthier riffle than at other sites. The combined season edge model decreased the rating at McIntyre Rd from ‘A’ in June to ‘B’. Decreases in ratings also occurred at Balyarta and the Freeway. Two ‘A’ band edges in June and September were decreased to a ‘B’ rating at Balyarta whilst at the Freeway ‘A’ and ‘B’ band edges were decreased to a ‘C’ band (significant impairment to ecological health). At Nairne Creek however the combined riffle model improved the rating from a ‘B’ in September to an ‘A’ rating (Table 2). All other sites combined model ratings were the same as the individual season (Table 2).

Table 2. AusRivAS results for sites sampled in 2007. A equal to reference sites, B slight impairment to ecological health, C significant impairment to ecological health, X above reference condition

		Peggy Buxton 4728		Brukunga 3158		McIntyre Rd 1951		Balyarta 1822		Freeway 1952		Nairne Creek 1953	
		OE50	Band	OE50	Band	OE50	Band	OE50	Band	OE50	Band	OE50	Band
March	edge	0.74	B	0.5	B	DRY		DRY		DRY		0.83	A
	riffle	Riffle not present		Riffle not present								Riffle not present	
June	edge	0.91	A	1.04	A	1.00	A	0.82	A	0.82	A	1.08	A
	riffle	0.79	B	0.4	C	Riffle not present		0.66	B	Riffle not present		0.95	A
Sept	edge	0.86	A	0.96	A	0.66	B	0.82	A	0.54	B	1.05	A
	riffle	0.7	B	0.51	C	Riffle not present		0.66	B	Riffle not present		0.83	B
Dec	edge	1.22	X	DRY		0.73	B	DRY		DRY		DRY	
	riffle	Riffle not present				Riffle not present							
Combined Jun/Sept	edge	0.91	A	0.89	A	0.54	B	0.69	B	0.49	C	0.91	A
	riffle	Outside experience of mode		0.43	C	Riffle not present		0.5	B	Riffle not present		0.88	A

A feature of the AusRivAS model is the Predicted Taxa output, the model generates a probability value (ranging between 0 and 1) of each family being present in a sample. This is not based on detailed information of the biology of the animals but on statistical relationships between the physical and chemical characteristics of streams and the distribution patterns of families across reference sites. The larger the percentage that a taxa is predicted at a site the more weighting it carries towards the Observed versus Predicted taxa output (OE50), which is the final probability determining the AusRivAS model output rating. Taxa which are considered to be missing from samples are those which are predicted to be at a site with a probability greater than 0.5, but were not collected.

The missing animals of the most concern are those with the highest probability values, particularly if they are absent from a number of samples from a single site or catchment. This being only the second year riffles have been sampled, there is only data from 2006 with which to draw comparisons and comparisons will be made after three years of data collection. It was recommended in the 2005 report that taxa highly predicted by the AusRivAS autumn and spring riffle models be identified and their presence at sites monitored into the future to see if the riffles are approaching reference site condition and thus improving in ecological health.

Table 3 outlines the taxa predicted to be in riffle habitat at the four sites that had riffles sampled in 2007. The light green in Table 3 represents taxa collected with a probability of 0.5 or above, and the dark green represents taxa that were predicted to be collected at a high probability at each site, during the autumn and spring seasons, and were not collected. By observing the figures in Table 3 it is apparent that the Brukunga mine site received a significantly impaired ecological health rating due to the taxa predicted but not collected throughout the surveys. This amounted to 4 of the 11 highly predicted taxa being collected during the autumn and 6 of the 11 highly predicted taxa being collected during spring at this site.

Peggy Buxton and Balyarta received slightly impaired ecological health ratings, having not collected two and four respectively of the highly predicted taxa during autumn and three and five each during spring. Nairne Creek received a rating of ecological health ‘equal to local reference sites’ in autumn and ‘slightly impaired ecological health’ in spring having not collected two highly predicted taxa during both seasons. It should be noted that the OE50 score for Nairne Creek for spring was 0.83 very close to reference condition, while Peggy Buxton and Balyarta had spring OE50 scores of 0.7 and 0.66.

There are some families of macroinvertebrates marked blue in Table 3 that are predicted at a high probability and missing at most AMD affected sites. The return of these macroinvertebrates should be monitored in future surveys to determine if recovery of riffle habitats is occurring.

Table 3. Macroinvertebrate families predicted by the autumn and spring riffle AusRivAS model. >> collected at the site, 0.7 to1.0 predicted at site >70 % and not collected, no colour predicted at a site at between 50 and 69 % and not collected. Note that taxa predicted between 50 and 69% which were not recorded from any site were deleted from the comparison. Cells coloured blue represent macroinvertebrates to look for in future surveys as evidence for improvement in ecological health.

Family	Common name	Balyarta	Nairne	Mine	Peggy Buxton
Autumn Riffle					
Nematoda	Round worm	»0.86	»0.87	0.85	»0.86
Hydrobiidae	Freshwater snail	0.86	»0.88	0.84	0.84
Oligochaeta	Freshwater worm	»0.97	»0.97	»0.98	»0.97
Acarina	Water mite	»0.90	»0.89	»0.82	»0.88
Ceinidae	Scuds	0.77	»0.79	0.81	»0.78
Collembola	Springtails	»0.57	»0.57	»0.56	»0.55
Scirtidae	Marsh beetle	0.55	»0.56	0.56	0.52
Tipulidae	Crane fly	»0.52	»0.49	0.41	0.51
Ceratopogonidae	Biting midge larvae	0.83	0.83	0.84	»0.83
Simuliidae	Black fly larvae	»0.95	»0.95	0.86	»0.93
Tanypodinae	Non-biting midge larvae	0.84	»0.85	0.83	0.83
Orthocladiinae	Non-biting midge larvae	»0.95	»0.96	»0.92	»0.93
Chironominae	Non-biting midge larvae	»0.98	»0.98	»0.98	»0.98
Gripopterygidae	Stonefly	»0.74	»0.78	0.72	0.66
Hydroptilidae	Micro caddis fly	0.68	0.7	0.66	0.65
Hydropsychidae	Net spinning caddis fly	0.5	»0.52	0.49	»0.50
Spring Riffle					
Nematoda	Round worm	»0.97	»0.97	»0.97	»0.98
Hydrobiidae	Freshwater snail	0.88	»0.91	0.87	0.87
Physidae	Freshwater snail	0.43	»0.31	0.46	0.5
Oligochaeta	Freshwater worm	»1.00	»1.00	»1.00	»1.00
Acarina	Water mite	»0.95	»0.96	»0.94	»0.94
Ceinidae	Scuds	0.92	»0.84	0.94	»0.96
Collembola	Springtails	»0.52	»0.48	»0.54	»0.55
Dytiscidae	Predacious diving beetle	»0.52	»0.37	»0.56	0.59
Scirtidae	Marsh beetle	0.57	0.62	0.53	»0.52
Ceratopogonidae	Biting midge larvae	»0.86	»0.88	0.84	»0.84
Simuliidae	Black fly larvae	»0.96	0.96	0.96	0.96
Tanypodinae	Non-biting midge larvae	0.91	»0.92	0.9	»0.90
Orthocladiinae	Non-biting midge larvae	»1.00	»1.00	»1.00	»1.00
Chironominae	Non-biting midge larvae	»0.99	»0.98	»1.00	»1.00
Leptophlebiidae	Mayfly	0.71	»0.79	0.65	0.65
Gripopterygidae	Stonefly	»0.45	»0.56	0.4	0.38

Hydrobiosidae	Clawed caddis fly	0.71	0.81	0.65	0.64
Hydroptilidae	Micro caddis fly	0.69	0.63	0.7	0.73

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 4. About one third of the samples were allocated to Group 1 – which comprised all but one sample from the local reference sites (Table 4). Group 2 contained samples with similar to the reference group taxa composition but lower taxa richness and abundance (Table 5). Apart from a single Peggy Buxton Road sample, Group 2 was represented by samples from improved AMD exposed sites and sites in the downstream section of the study reach (Table 4). Group 3 consisted of a single Brukunga mine sample. The sample was collected in March 2007 when Dawesley Creek ceased to flow and was dominated by temporary water taxa that were uncommon in the data set. Group 4 included samples with relatively low taxa diversity and extremely low abundance. Finally, the samples in Group 5 were collected in 2002 from sites proximal to the AMD discharge point (Table 4).

Table 4. **Group membership of cluster analysis.**

Group	**Designation**	**Sites**	**Years**	**Months**
1	Local reference sites	Nairne Creek	both	All
		Peggy Buxton	2002	All
			2007	March, September, December
2	One Peggy Buxton sample with some common taxa missing.	Peggy Buxton	2007	June
	Some improved AMD-exposed sites.	Brukunga	2007	June, September
		McIntyre Road	2007	September, December
	Most downstream sites		2002	June, December
		Balyarta	2007	All
		Freeway	2007	All
3	One Brukunga mine sample with relatively high number and abundance of uncommon taxa	Brukunga	2007	March
4	Samples with low taxa richness and very low abundance	McIntyre Road	2007	June
		Balyarta	2002	September
		Freeway	2002	September

5	Sites receiving AMD	Brukunga	2002	All
		McIntyre Road	2002	All

***Table 5*. Macroinvertebrate community statistics of cluster analysis groups.**

Group	Sample Number	Taxa Richness			Abundance		
		Min	Max	Mean	Min	Max	Mean
1	14	15	42	29	615	10212	3934
2	11	9	27	20	224	2327	1025
3	1	16	16	16	5111	5111	5111
4	3	14	15	14	37	55	48
5	8	3	14	8	754	25850	9924

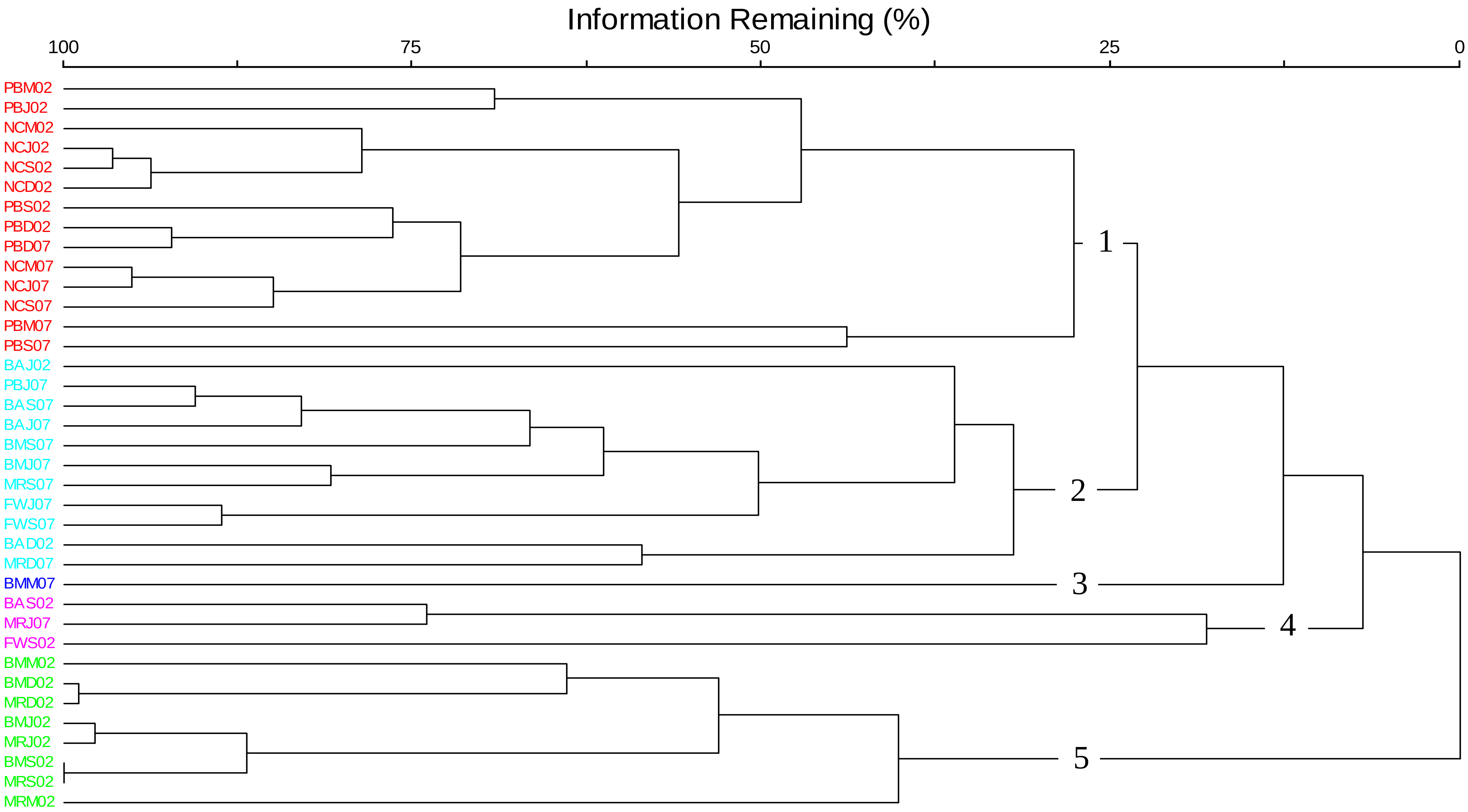

***Figure 13.* Dendrogram of 2002 and 2007 edge samples.** (First two letters designate site. PB = Peggy Buxton Road, BM = D/S Brukunga, MR = McIntyre Road, BA = Balyarta, FW = Freeway, NC = Nairne Creek. Third letter designates month, M = March, J = June, S = September and D = December. Digits indicate year of collection). Interpretation of Groups 1-5 is provided in Table 4.

Ordination 2002, 2007

The NMS ordination in 2 dimensions produced similar groupings to the cluster analysis. Though clearly defined, Groups 1 and 2 shared boundaries (Table 14) emphasising the taxa composition similarity between the reference and moderately impacted sites. The single sample of Group 3 was not associated with any other cluster and was positioned between Groups 2 and 5 (Table 14). The low abundance samples of Group 4 formed an outlier cluster. The AMD impacted samples formed a separate group and were well separated from the rest of the samples.

The taxonomically diverse samples from local reference sites occupy the left side of the ordination plot. Most distant from the local reference sites along the X axis are the species poor 2002 samples from Brukunga Mine and McIntyre Road. The distribution of samples in the direction of the Y axis appears to be determined by the number of individuals. The high abundance samples from both the reference and AMD impacted samples are located at the bottom the plot. The least similar to them are the samples with the lowest abundance in the dataset (Figure 14). The 2007 samples from sites that have been exposed to AMD were positioned close to the cluster of local reference site samples and were at a marked distance from samples from those sites in 2002 (Figure 14). This suggests that between 2002 and 2007, the macroinvertebrate species at McIntyre Road and Brukunga Mine had changed and become more similar to that at local reference sites that have not been exposed to AMD.

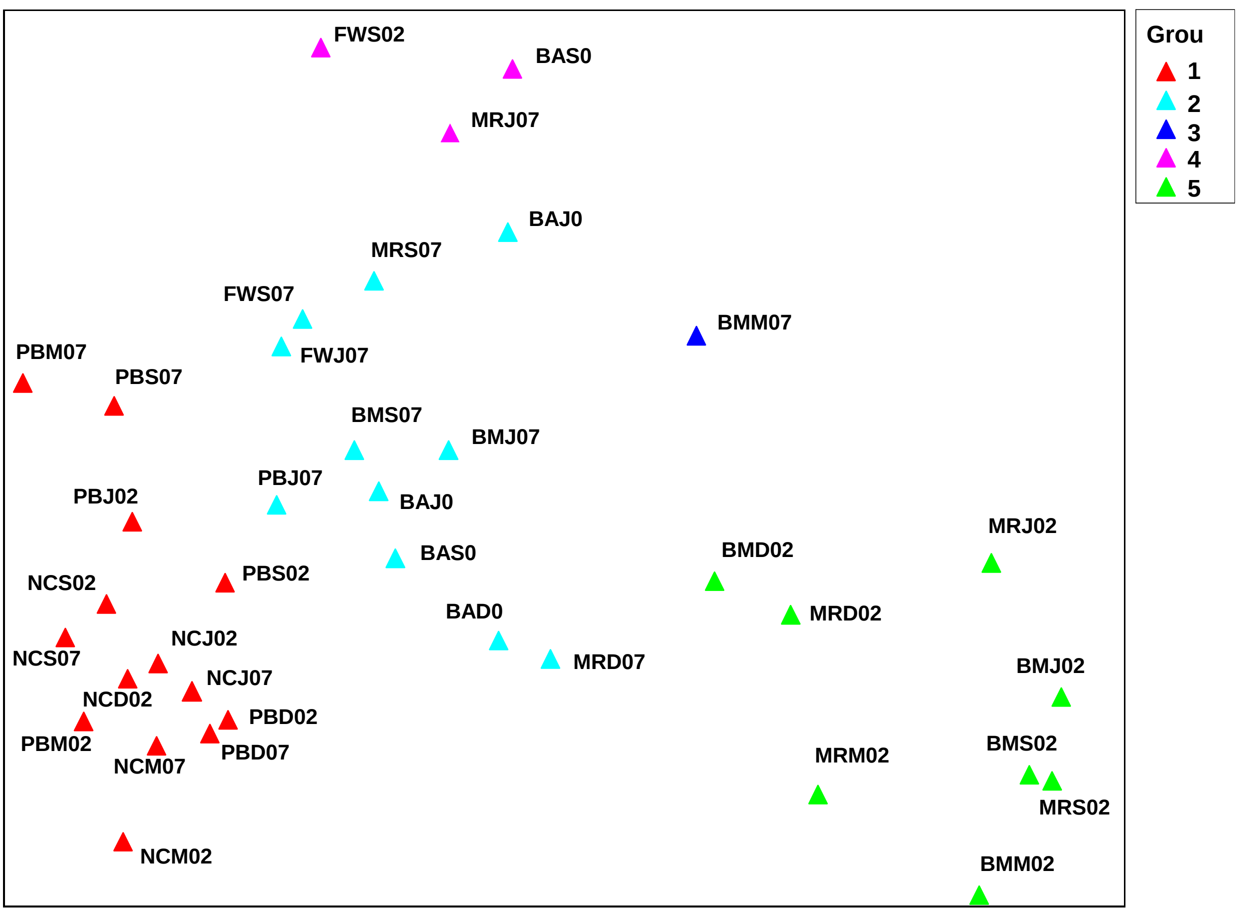

Figure 14. **SSH Ordination of 2002 and 2007 edge samples.** Group numbers are those from the cluster analysis.

4. 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 to an environment that more frequently resembles reference condition as predicted by AusRivAS models. 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 2007 monitoring is that Dawesley Creek is improving compared to the conditions prior to the diversion. Two of the driest winters on record however have contributed independently of AMD to a decline in stream health, taxonomic richness and AusRivAS scores from those recorded in 2004 and 2005.

The occurrence of surface water at the monitoring sites was less frequent than average in 2007; however it was similar to the previous year as well as 2002 which was also characterised by relatively low flow. Macroinvertebrate richness at sites downstream of Brukunga Mine showed variable levels around the local reference sites throughout the survey. When water was present, Nairne Creek always showed the highest number of taxa richness. Peggy Buxton however showed much more variation. On three occasions from four, the Brukunga mine site showed slightly higher taxa richness than Peggy Buxton, with the exception of December when Peggy Buxton showed the highest taxa richness value of any site for the annual survey. This is likely due to an increased concentration of macroinvertebrates at the site as a result of the shrinking pool on this occasion. McIntyre Rd, Balyarta and under the Freeway were variable in taxa richness, however when taxa was relatively lower it is likely that was a result of the sites recovering from having no surface water in March or December or both. Although the degree of variation has been large, the average richness at Dawesley Creek sites downstream of Brukunga Mine since 2003 remains higher than values from the 1996 to 2002 data.

Peggy Buxton received AusRivAS results equal to reference condition in June and September. During these months, this site would usually have the largest proportion of its flow contributed from natural rainfall runoff which improves habitat, making it more favourable to a wider assemblage of macroinvertebrates. The other proportion of water received at this site is treated waste water (WW) from the Bird in Hand waste water treatment plant. During the drier months of March and December the treated WW would usually be the only reason the site has surface water present, providing a refuge for macroinvertebrates, even in the presence of the often eutrophic conditions. The dry conditions during 2007 have altered the percentage of WW in the flows and hence impacted the usual flow regime. The ‘above reference’ condition in December reflects the concentration of macroinvertebrates in a drying pool after the cooler months of autumn and winter. The area was a last refuge for many taxa. In March, however, the ‘slight impairment to ecological health’ is a result of the pool having been a refuge for so long that many taxa would have died due to pressures such as predation, competition and stress due to water condition.

In general, the AMD influenced sites, McIntyre Rd and Balyarta had AusRivAS results indicating slight impairment to ecological health. These sites endured periods of dry conditions which would have resulted in less invertebrate drift, reducing the chances of re-colonisation of macroinvertebrate in the AMD influenced reaches of Dawesley Creek. Brukunga mine received predominately ‘A’ bands from the edge model which is an improvement on the previous year but is not as marked as the improvement shown in 2004 when all sampling occasions showed the site to be ‘equal to reference’ for edge habitats. The Freeway site usually has surface water only in June and September and had ‘equal to reference’ in June and ‘slight impairment’ in September. This Freeway site in the region below the ford where sampling occurs is dominated by the rush *Typha sp.* This rush dies back in the cooler months allowing more light to penetrate into the water and adds decaying organic matter. Both these features provide more energy in the stream at this site and gives greater opportunities for different macroinvertebrates to inhabit the site. During spring the stands of *Typha sp.* recover and form dense cover, increasing shading and taking nutrients from the system, creating less opportunity for different macroinvertebrates to inhabit the site.

For all surveys the AusRivAS results for Nairne Creek were generally favourable. It seems strange that, during our driest years on record, Nairne Creek continued to flow. It was mentioned in the 2005 report that it was our belief from a comment made by the land owner adjacent the Nairne Creek site that the Chapman’s factory contributed significant water to Nairne Creek year round from condensation from many fridges and since the closing of the site the creek has become temporally dry for the first time she could remember. A visit to the old Chapman’s factory site on the 13/3/2007 revealed some abattoir activity at the site. A meeting with the site manager revealed that all internal runoff from abattoir activity is captured by grease traps and flows to a filter plant where greasy residue is filtered and the remaining water pumped to effluent ponds. They are required by law to allow no internal runoff from operations to enter Nairne Creek or leave the site. Runoff from building roofs and outside concreted areas is allowed to flow into Nairne Creek. From this new information the flow in Nairne Creek is most likely from a new or recharged spring contributing water to the Nairne Creek catchment upstream of the site. The construction of the ford at this site has now altered the site to the point that comparisons with past data would be affected and the site should no longer be sampled. The 10 years of macroinvertebrate data for this site will be useful in determining which macroinvertebrates are in the catchment and are likely to populate Dawesley Creek now and into the future.

The sampling of riffles for the second time in the study has allowed for a better picture of what riffle taxa can occur at these sites as well as providing a comparison with the previous year so as to evaluate change. Riffles present at Peggy Buxton and Balyarta all had ‘slight impairment to ecological health’. In comparison to the previous year the riffle at Peggy Buxton has shown to contain two more taxa, Acarina (water mites) and *Hydroptilidae* (micro cadis-fly); but also did not contain some true riffle dwellers, *Simuliidae* (black flies) or *Gripoptergidae* (stoneflies) which were present in 2006. The riffles occurring at Brukunga mine are a long way from being near reference site condition. No *Simuliidae* (blackflies), *Gripoptergidae* (stoneflies) or *Ceinidae* (scuds) taxa were collected suggesting that either the riffle habitat is not healthy enough to support these taxa or dispersal of organisms to the habitat is restricted. As at Peggy Buxton, some taxa were collected at the Mine site that were not in 2006 and again included Acarina (aquatic mites) and *Hydroptilidae* (micro cadis-fly). Riffle habitat in AMD effected reaches are still yet to resemble habitat ‘equal to reference’ condition. Riffle habitat at Nairne Ck is generally near or at reference condition and contains a number of true riffle dwelling species (Table 3). *Leptophlebiidae* (mayflies) were collected for the first time, at Nairne Ck, in spring. Also collected were *Physidae* (freshwater snails) resulting in Nairne Ck being the only riffle site to contain Gastropods (aquatic snails). However, interestingly the true riffle specialists Simuliidae (blackflies) and *Hydrobiosidae* (clawed cadis-fly) were not collected in spring. This change in the macroinvertebrate community may be due, in part, to the changed substrate and habitat conditions caused by the construction of the ford at the site. This also may have contributed to a change in normal flow conditions resulting in a less healthy riffle habitat at the time of sampling. Close attention should be paid to the riffle macroinvertebrates marked in blue in Table 3, to determine if the ecological health of the AMD influenced regions of Dawesley Creek are approaching, or equal, to the condition of reference sites.

MVA indicated that the macroinvertebrate samples from the local reference sites were very similar to each other. Closely associated with this collection of the reference site samples were the samples collected in 2007 at Brukunga mine and McIntyre Road and most Balyarta and Freeway samples from both 2002 and 2007. In 2002, the composition of macroinvertebrate samples from sites known to receive AMD had little resemblance to that at the local reference sites. In 2007, both taxonomic composition and abundance of macroinvertebrates in samples from these sites were quite similar to those at the 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 material which makes up their exoskeleton. Macroinvertebrates from these groups are usually recorded in Dawesley Creek at Peggy Buxton Road and Nairne Creek, however records of them in the past from AMD affected regions in Dawesley Creek are very rare. It is very interesting then that for the first time a specimen of *Physidae* (freshwater snail) has been recorded at the Brukunga mine site. Given it has been five years since the diversion around the mine site, and spot pH recordings indicate waters of neutral pH, it is not surprising that *Physidae* (freshwater snail) have been collected finally at this site. It is still however an unanswered question as to why crustaceans and other molluscs have not also 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 via drift or active movement up or down the stream. Previous years' records for molluscs, and this year's *Physidae* recording, from AMD affected waters 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. Minimal molluscs occurring in AMD affected waters may be due to the drought reducing flows within Dawesley Creek, thus causing poor recruitment from population sources in non AMD affected waters.

Three different types of Crustacean taxa were recorded in AMD effected sites in June and September during the survey. One specimen of *Partya australiensis* (freshwater shrimp) was collected from both the Freeway and Balyarta. *Austrochiltonia australis* (scud) were recorded from McIntyre Rd and Brukunga mine collecting two and one respectively. Finally one *Cherax destructor* (yabbie) was collected from Balyarta. Not unusually, many scuds were recorded from Nairne Creek, and slightly less in Peggy Buxton. Shrimps were not recorded in high abundance from any site throughout 2007. As stated above there does not appear to be any significant populations of these Crustaceans in AMD affected waters; their presence in low numbers is most likely due to invertebrate drift and temporary colonisation. Close attention to the distribution of Molluscs and Crustaceans is still required in Dawesley Creek to ascertain if the ecological health of the creek is approaching those of the reference sites in the study.

Recommendations

As discussed with the Project Manager Mine Rehabilitation we recommend that macroinvertebrates be collected from edge and riffles at four sites on Dawesley Creek, these being Peggy Buxton Rd (S#4728); Downstream Mine (S#3158); McIntyre Rd/Old Melbourne bridge (S#1951) and Balyarta/Browns crossing (S#1822) at times when the creek is flowing during autumn (recommended June) and spring (October) only. It is our understanding that Mine Rehabilitation is searching for a stream in the area which has a similar geology and hydrology to Dawesley Creek, for use as a control site for comparison to Dawesley Creek and if such a site is found it also should be included in the study.

If a new study program is accepted by the EPA it is recommended that the area some sites have had macroinvertebrates collected from in the past be moved slightly to incorporate habitat that it more representative of the stream at those sites. This movement of macroinvertebrate sampling areas at sites has not occurred previously at it would make pre and post diversion comparisons difficult to interpret. Future study should also focus on whether sites are returning to a condition that expert macroinvertebrate ecologists believe reflects a balanced macroinvertebrate community with the habitat present.

It is recommended that taxonomic richness graphs at riffles be constructed for comparisons after three years of collection.

As part of a further investigation with the reduced sites visited the highly predicted taxa in edge samples from the AusRivAS model could be isolated, to determine what type of taxa may be contributing to the impairment of ecological health in the study area. The habitat requirements of the missing highly predicted taxa could be identified and possible reasons for their absence in the AMD influenced sites proposed.

Invertebrate drift could be monitored at the outfall of the diversion pipe and downstream of the Nairne Creek site, to determine which macroinvertebrates are moving from the Peggy Buxton Rd site into the downstream mine site and from Nairne Creek into the Balyarta site. The macroinvertebrate assemblages at the two receiving water sites could be compared to the invertebrate drift, to determine what proportion of the macroinvertebrate assemblage at the downstream mine and Balyarta site is from macroinvertebrates moving into the site from upstream or have established populations at the site.

5. References

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APPENDIX C - METAL CONCENTRATION WITHIN THE ZONE OF IMPACT

pages 54-69

Nairne Creek water, upsteam of the ford at Diatadapeel

Grab Sampling Location AWQC 1953

< indicates below 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
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	1.21	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	0.124	<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
11-Jan-2006	7.6	816	1480	84.3	0.082	<0.0005	<0.003	0.0036	0.108	<0.0005	0.0343	0.0053	0.006
14-Feb-2006		no flow											
14-Mar-2006	8.2	594	1080	81	0.125	<0.0005	<0.003	0.0034	0.206	<0.0005	0.003	0.0046	0.008
17-Apr-2006	7.9	572	1040	60.6	0.055	<0.0005	<0.003	0.0029	0.17	<0.0005	0.005	0.0029	0.007
22-May-2006	7.5	567	1030	63.9	0.180	<0.0005	0.006	0.0032	0.43	<0.0005	0.0174	0.0035	0.012
13-Jun-2006	7.8	572	1040	45.9	0.028	<0.0005	0.003	0.0014	0.134	<0.0005	0.0062	0.0024	0.006
17-Jul-2006	7.5	760	1380	69.9	0.137	<0.0005	<0.003	0.0038	0.409	0.0006	0.0242	0.0033	0.023
15-Aug-2006	7.6	720	1300	66	0.079	<0.0005	0.005	0.0035	0.369	<0.0005	0.0133	0.0029	0.014
12-Sep-2006	7.9	570	1040	45.9	0.041	<0.0005	<0.003	0.0025	0.183	<0.0005	0.0062	0.0023	0.006
12-Oct-2006	7.4	690	1260	72.3	0.047	<0.0005	<0.003	0.0027	0.246	<0.0005	0.007	0.0033	0.01
15-Nov-2006	7.5	650	1180	63.6	0.038	<0.0005	<0.003	0.0038	0.148	<0.0005	0.0045	0.0027	0.007
13-Dec-2006	7.5	780	1420	66.6	0.032	<0.0005	<0.003	0.0017	0.231	<0.0005	0.0355	0.0042	0.009
16-Jan-2007		no flow											
13-Feb-2007		no flow											
13-Mar-2007	7.7	730	1320	83.7	0.03	<0.0005	<0.003	0.0013	0.396	<0.0005	0.0046	0.0041	0.008
16-Apr-2007		no flow											
15-May-2007	7.7	610	1110	67.5	0.066	<0.0005	<0.003	0.0025	0.358	<0.0005	0.008	0.0023	0.014
13-Jun-2007	8.1	500	905	41.1	0.077	<0.0005	<0.003	0.0028	0.724	<0.0005	0.0147	0.0018	<0.003
23-Jul-2007	7.8	1000	1830	93.3	0.292	<0.0005	0.003	0.003	1.02	<0.0005	0.0397	0.0032	0.009
20-Aug-2007	7.8	1000	1860	84.3	0.105	<0.0005	<0.003	0.0016	0.673	<0.0005	0.0295/0.0309	0.0023	0.006
13-Sep-2007	8	810	1470	66.6	0.052	<0.0005	<0.003	0.0012	0.539	<0.0005	0.0118	0.0019	0.004
15-Oct-2007		no flow											
20-Nov-2007		no flow											
17-Dec-2007		no flow											

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

	pH	TDS		SULPHATE	ALUMINIUM	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MANGANESE	NICKEL	ZINC
For Aquatic		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	**for pH>6.5**	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

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

Peggy Buxton Road, Dawesley Creek water upstream of the Mine Site

Grab Sampling Location AWQC 4728

< indicates below 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
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	0.009	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	0.003	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	0.001	0.009
18-Oct-2005	7.5	1,000	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	1,020	1850	71.7	0.455	<0.0005	0.004	0.0048	1.01	0.0006	0.1076	0.004	0.014
15-Dec-2005	7.7	1,510	832	45.3	0.455	<0.0005	<0.003	0.0016	1.13	0.0007	0.0645	0.0069	0.027
11-Jan-2006		no flow											
14-Feb-2006		No Flow											
14-Mar-2006		no flow											
17-Apr-2006	7.8	1,130	2050	64.2	0.322	<0.0005	0.003	0.003	1.44	0.0008	0.1756	0.0063	0.014
22-May-2006	7.5	810	1470	44.4	0.356	<0.0005	0.006	0.0026	0.594	<0.0005	0.0262	0.0035	0.009
13-Jun-2006	7.6	849	1540	65.4	0.238	<0.0005	0.004	0.0016	0.519	<0.0005	0.0372	0.004	0.007
17-Jul-2006	7.5	980	1780	59.7	0.149	<0.0005	0.004	0.0031	0.79	0.0005	0.2101	0.0043	0.01
15-Aug-2006	7.4	1,100	1950	81.9	0.341	<0.0005	0.004	0.0014	0.94	<0.0005	0.2892	0.0033	0.005
12-Sep-2006	7.7	850	1540	43.2	0.327	<0.0005	0.004	0.0047	0.805	0.0094	0.0203	0.0032	0.015
12-Oct-2006	7.8	910	1650	52.8	0.457	<0.0005	<0.003	0.0017	0.928	0.0006	0.0281	0.0028	0.007
15-Nov-2006	7.8	1,000	1820	27.9	0.372	<0.0005	0.003	0.0026	1	0.0005	0.0681	0.003	0.007
13-Dec-2006	7.9	1,400	2530	22.2	1.890	<0.0005	0.004	0.003	3.73	0.0017	0.1127	0.0039	0.017
16-Jan-2007		no flow											
13-Feb-2007		no flow											
13-Mar-2007		no flow											
16-Apr-2007		no flow											
15-May-2007	7.4	880	1600	70.5	0.059	<0.0005	<0.003	0.0031	1.04	<0.0005	0.078	0.0093	0.027
13-Jun-2007	7.4	840	1520	77.1	0.084	<0.0005	<0.003	0.0025	1.12	<0.0005	0.2694	0.0062	0.018
23-Jul-2007	7	990	1800	127	0.283	<0.0005	<0.003	<0.0010	1.35	<0.0005	0.4113	0.0068	0.044
20-Aug-2007	7.4	830	1510	93	0.358	<0.0005	<0.003	0.002	0.954	<0.0005	0.0375	0.0071	0.026
13-Sep-2007	7.7	870	1570	58.2	0.362	<0.0005	<0.003	0.0019	1.12	<0.0005	0.0297	0.0067	0.033
15-Oct-2007	7.5	980	1780	52.2	0.203	<0.0005	0.003	0.0016	0.671	<0.0005	0.0359	0.0052	0.014
19-Nov-2007	7.6	990	1800	49.2	0.175	<0.0005	<0.003	0.0021	0.466	<0.0005	0.0655	0.0065	0.011
12-Dec-2007	7.8	1,200	2140	41.4	0.252	<0.005	0.001	<0.005	1.71	<0.01	0.37	0.008	0.013

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

	pH	TDS		SULPHATE	ALUMINIUM	CADMIUM	CHROMIUM	COPPER	IRON	LEAD	MANGANESE	NICKEL	ZINC
For Aquatic		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	**for pH>6.5**	no value	0.100	0.0020	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

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

Dawesley Creek water - downstream of the Brukunga Mine Site

Grab Sampling Location AWQC 3158

< indicates below 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
12-Jan-2005		no flow											
11-Feb-2005	7.2	1400	2440	692	1.5	0.002	<0.003	0.005	11.00	0.001	8.77	0.0298	0.19
22-Mar-2005	7.5	970	1760	211	2.6	0.001	<0.003	0.006	6.12	0.0012	1.02	0.027	0.21
13-Apr-2005	7.3	1600	2870	1220	2.0	0.001	<0.003	0.005	3.02	0.0006	4.35	0.014	0.16
18-May-2005	8.8	1200	2130	528	1.7	0.001	<0.003	0.003	2.11	<0.0005	2.41	0.0359	0.15
15-Jun-2005	4.2	1200	2150	1090	87.1	0.025	0.004	0.034	11.60	0.0007	6.79	0.1473	4.85
13-Jul-2005	6.4	1200	2180	660	24.1	0.008	<0.003	0.015	8.46	0.0015	1.31	0.0355	1.21
23-Aug-2005	7.1	1100	2020	382	8.5	0.004	<0.003	0.010	4.35	0.0016	0.72	0.0181	0.39
5-Sep-2005	6.7	1300	2410	766	3.0	0.004	0.003	0.011	2.25	<0.0005	2.59	0.0383	0.28
18-Oct-2005	6.6	1700	2990	1240	5.2	0.007	<0.003	0.150	2.26	<0.0005	4.09	0.0373	0.40
21-Nov-2005	4.4	1480	2680	969	2.9	0.036	<0.003	0.015	17.80	<0.0005	15.88	0.2282	4.07
15-Dec-2005	7.4	1060	1920	405	4.3	0.005	<0.003	0.012	4.00	0.0006	1.38	0.0346	0.89
11-Jan-2006	7	1210	2190	342	1.6	0.007	<0.003	0.018	3.49	<0.0005	1.81	0.0616	0.33
14-Feb-2006		no flow											
14-Mar-2006		no flow											
17-Apr-2006	7.5	1130	2050	279	3.1	0.003	<0.003	0.007	3.74	0.0005	1.32	0.0243	0.24
22-May-2006	7.4	844	1530	97.5	28.9	0.009	0.006	0.012	20.50	0.0039	1.08	0.0212	1.35
13-Jun-2006	7.4	899	1630	125	3.5	0.001	0.004	0.003	2.30	<0.0005	0.39	0.0158	0.17
17-Jul-2006	6.4	1300	2420	747	9.9	0.007	0.004	0.013	9.81	0.0007	1.68	0.0492	0.88
15-Aug-2006	7.4	1100	1960	1550	4.1	0.009	<0.003	0.010	1.94	<0.0005	7.71	0.0573	1.25
12-Sep-2006	7.4	1100	1940	369	1.7	0.002	0.004	0.005	0.76	0.0176	1.91	0.0201	0.10
12-Oct-2006	6.9	1800	3260	1440	1.4	0.004	<0.003	0.003	0.94	<0.0005	<0.0005	0.0437	0.33
15-Nov-2006	7	1500	2740	804	1.3	0.002	<0.003	0.004	1.15	<0.0005	6.16	0.0358	0.20
13-Dec-2006		no flow											
16-Jan-2007		no flow											
13-Feb-2007		no flow											
13-Mar-2007		no flow											
16-Apr-2007		no flow											
15-May-2007	6.8	1400	2490	855	1.9	0.003	0.003	0.007	2.20	<0.0005	1.793	0.0364	0.22
13-Jun-2007	6.5	1400	2440	930	47.3	0.004	<0.003	0.014	24.20	<0.0005	1.636	0.0509	0.55
23-Jul-2007	4.9	1400	2530	927	6.6	0.005	<0.003	0.011	1.54	<0.0005	2.11	0.0408	0.99
20-Aug-2007	6.5	1400	2500	918	4.8	0.003	<0.003	0.005	1.08	<0.0005	2.688	0.0296	0.31
13-Sep-2007	7.1	1200	2170	603	2.6	0.002	<0.003	0.004	1.74	<0.0005	0.5691	0.0212	0.14
15-Oct-2007	7.3	1400	2580	774	1.6	0.001	<0.003	0.003	1.18	<0.0005	0.6097	0.0192	0.12
19-Nov-2007	7	1600	2850	1180	0.1	0.002	<0.003	0.001	0.13	<0.0005	4.847	0.0397	0.10
17-Dec-2007		no flow											

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

For Aquatic		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	**for pH>6.5**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.050
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.20	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

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

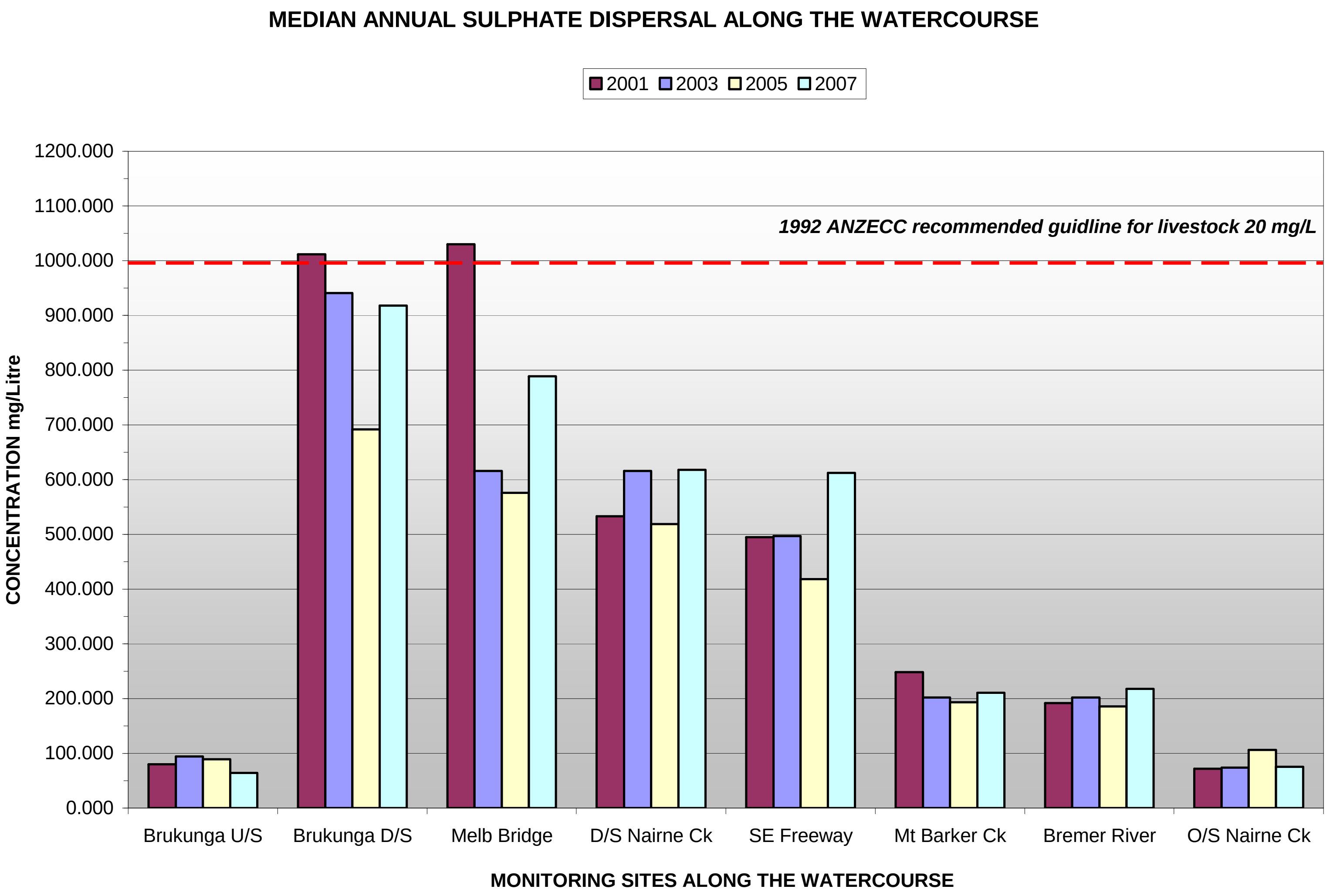

Figure C-1. Sulphate in Dawesley Creek leaving the mine site

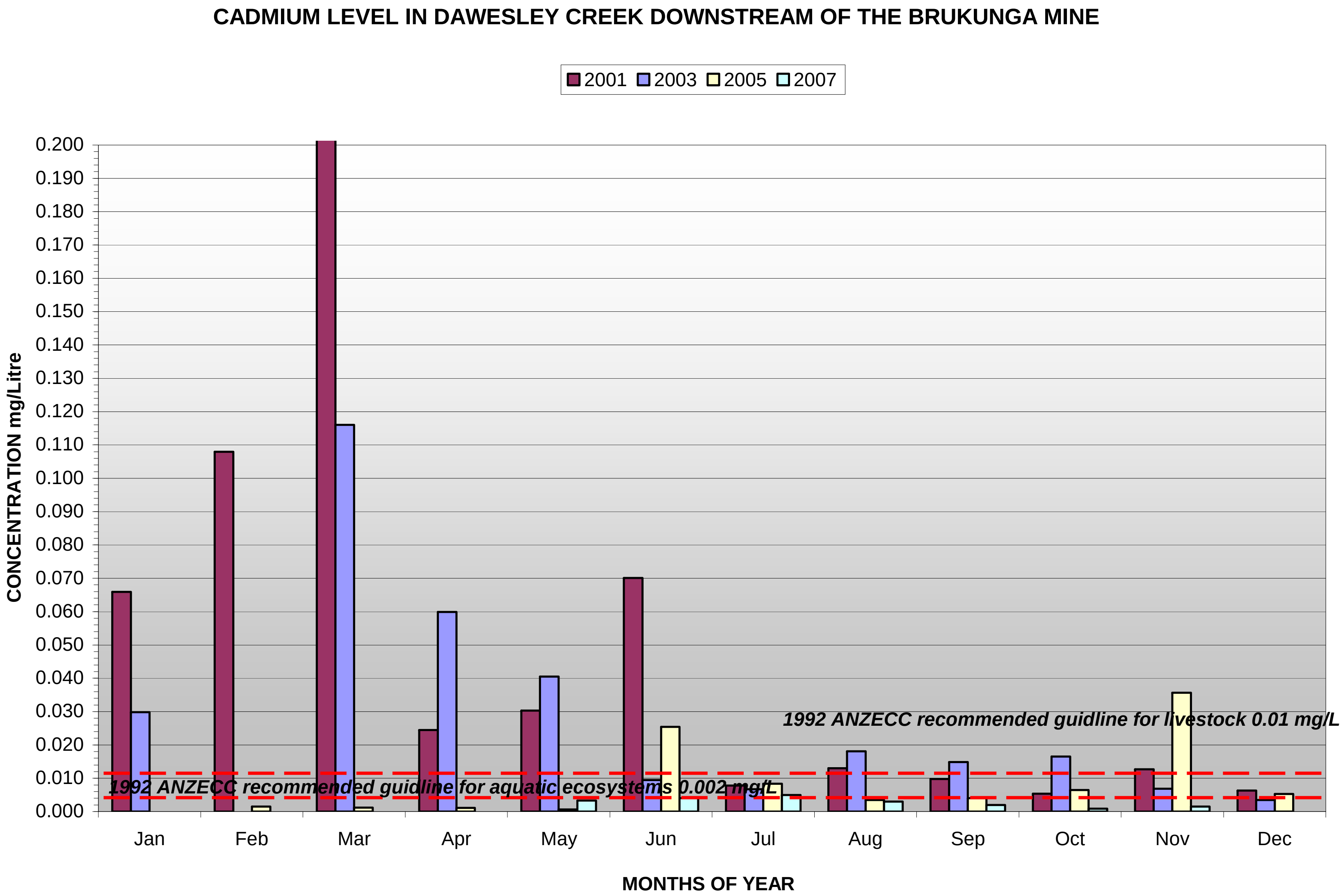

Figure C-2. Cadmium in Dawesley Creek leaving the mine site

Dawesley Creek water - at McIntyre Road (Old Melbourne Bridge)

Grab Sampling Location AWQC 1951

< indicates below 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
12-Jan-2005		no flow											
11-Feb-2005	6.9	1,100	2050	479	0.95	0.0014	<0.003	0.006	4.37	<0.0005	2.88	0.029	0.11
22-Mar-2005	7.1	1,200	2240	576	0.12	<0.0005	<0.003	0.003	1.66	<0.0005	0.29	0.017	0.02
13-Apr-2005	7	1,400	2500	725	0.18	<0.0005	<0.003	0.002	1.73	<0.0005	0.05	0.013	0.02
18-May-2005	7.4	1,200	2190	449	0.26	<0.0005	<0.003	0.002	0.81	<0.0005	3.44	0.011	0.01
15-Jun-2005	6.9	900	1630	542	3.11	0.0016	<0.003	0.005	2.32	<0.0005	2.66	<0.0005	0.40
13-Jul-2005	6.1	1,200	2220	585	2.42	0.0071	<0.003	0.009	1.55	<0.0005	2.04	0.059	0.95
23-Aug-2005	7.4	1,000	1860	293	3.43	0.0018	<0.003	0.006	3.00	0.0006	0.68	0.016	0.19
05-Sep-2005	7.3	1,300	2310	652	1.06	0.0031	<0.003	0.006	1.90	<0.0005	3.64	0.042	0.16
18-Oct-2005	6.5	1,600	2870	1200	0.47	0.0100	<0.003	0.007	1.21	<0.0005	4.04	0.080	1.15
21-Nov-05	6.6	1,360	2450	666	0.18	0.0087	<0.003	0.004	1.08	<0.0005	8.00	0.090	0.68
15-Dec-05	7.5	1,090	1980	441	0.36	0.0011	<0.003	0.007	1.39	<0.0005	1.99	0.036	0.20
11-Jan-06	7.3	1,240	2250	417	0.23	<0.0005	<0.003	0.003	3.76	<0.0005	2.23	0.019	0.10
14-Feb-06		No Flow											
14-Mar-06		Dry											
17-Apr-06	7.5	1,180	2140	282	1.25	0.0021	<0.003	0.006	4.31	<0.0005	1.07	0.018	0.13
22-May-06	7.5	988	1790	237	1.07	0.0013	0.005	0.003	2.23	<0.0005	0.65	0.019	0.12
13-Jun-06	7.4	1,210	2190	519	4.39	0.0013	0.003	0.003	1.44	<0.0005	1.12	0.023	0.14
17-Jul-06	7.2	1,300	2410	678	0.47	0.0035	0.003	0.004	1.08	<0.0005	1.95	0.043	0.28
15-Aug-06	6.9	1,500	2720	903	0.07	0.0042	0.004	0.003	0.37	<0.0005	2.58	0.045	0.43
12-Sep-06	7.7	1,000	1900	289	0.34	0.0005	<0.003	0.004	0.75	<0.0005	0.40	0.018	0.05
12-Oct-06	7.1	1,400	2580	792	0.13	0.0008	<0.003	0.002	0.58	<0.0005	0.85	0.014	0.06
15-Nov-06	7.4	1,100	2050	282	0.10	<0.0005	<0.003	0.003	0.86	<0.0005	0.20	0.010	0.01
13-Dec-06	7.5	1,500	2690	537	0.05	<0.0005	<0.003	<0.0010	0.42	<0.0005	<0.0005	0.010	0.02
16-Jan-07		Dry											
13-Feb-07		Dry											
13-Mar-07		Dry											
16-Apr-07		Dry											
15-May-07	6.5	1600	2820	1110	0.568	0.0208	<0.003	0.0137	1.06	<0.0005	5.242	0.0702	1.49
13-Jun-07	7	1400	2480	891	0.408	0.007	<0.003	0.0011	0.47	<0.0005	0.1726	0.0051	0.072
23-Jul-07	5.7	1400	2450	825	0.507	0.0097	0.003	0.0062	0.39	<0.0005	2.523	0.0481	1.35
20-Aug-07	6.5	1300	2400	753	0.49	0.0062	<0.003	0.0053	0.32	<0.0005	2.218	0.0361	0.399
13-Sep-07	7.3	1100	2080	435	0.561	0.0025	<0.003	0.0052	0.78	<0.0005	0.6006	0.0201	0.121
15-Oct-07	7.1	1200	2160	435	0.256	0.0011	<0.003	0.0044	0.91	<0.0005	0.437	0.0164	0.09
19-Nov-07	7	1300	2340	642	0.029	0.0012	<0.003	0.0036	0.13	<0.0005	0.847	0.017	0.076
12-Dec-07	6.6	1800	3320	1110	2.57	<0.005	0.002	0.008	4.82	<0.01	3.22	0.023	0.129

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

For Aquatic		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	**for pH>6.5**	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

Table C-4. Dawesley Creek downstream at Melbourne Bridge

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

Grab Sampling Location AWQC 1822

< indicates below 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
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	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	1.2	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	0.002	<0.003	0.005	0.455	<0.0005	0.92	0.0247	0.114
21-Nov-2005	7	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
11-Jan-2006		no flow											
14-Feb-2006		no flow											
14-Mar-2006		no flow											
17-Apr-2006	7.5	1430	2590	444	0.041	0.0011	<0.003	0.004	0.143	<0.0005	0.2529	0.0097	0.055
22-May-2006	7	1610	2900	783	0.711	0.003	0.007	0.0033	1.18	0.0006	1.648	0.0259	0.284
13-Jun-2006	7.6	1070	1930	360	0.063	<0.0005	<0.003	0.0022	0.241	<0.0005	0.044	0.008	0.034
17-Jul-2006	5.4	1100	1980	474	2.12	0.0107	<0.003	0.0087	0.191	<0.0005	2.585	0.065	1.18
15-Aug-2006	7.4	1300	2320	570	0.081	0.001	0.003	0.0025	0.241	<0.0005	0.6463	0.0169	0.075
12-Sep-2006	7.5	1100	1940	408	0.098	<0.0005	<0.003	0.0032	0.221	<0.0005	0.1097	0.0087	0.025
12-Oct-2006	7.2	1300	2390	507	0.224	0.0005	<0.003	0.0019	0.475	0.0008	<0.0005	0.0075	0.044
15-Nov-2006		no flow											
13-Dec-2006		no flow											
16-Jan-2007		no flow											
13-Feb-2007		no flow											
13-Mar-2007		no flow											
16-Apr-2007		no flow											
15-May-2007	7.2	980	1780	250	1.72	0.0031	0.003	0.0109	2.13	0.0005	0.8708	0.0258	0.38
16-Jun-2007	7.4	1300	2310	633	0.102	0.0018	<0.003	0.0066	0.554	<0.0005	0.9541	0.0311	0.303
23-Jul-2007	6.9	1200	2170	603	0.218	0.0117	0.007	0.006	0.293	<0.0005	2.233	0.0704	1.11
20-Aug-2007	7.1	1300	2280	549	0.204	0.0023	<0.003	0.0021	0.302	<0.0005	0.5472	0.0214	0.167
13-Sep-2007	6.9	1500	2740	723	0.1	0.0026	<0.003	0.0013	0.498	<0.0005	1.306	0.0222	0.184
15-Oct-2007	6.3	1600	2960	786	0.034	<0.0005	<0.003	<0.0010	0.43	<0.0005	1.124	0.0174	0.112
20-Nov-2007		No Flow											
17-Dec-2007		dry											

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

	pH	TDS	Conductivity	Sulphate	Aluminium	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
For Aquatic		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	**for pH>6.5**	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

Table C-5. Dawesley Creek upstream of the mine site

Dawesley Creek water, under the SE Freeway

Grab Sampling Location AWQC 1952

< indicates below 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
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
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
05-Sep-2005	7.1	1200	2140	475	0.228	0.0026	<0.003	0.005	0.476	<0.0005	1.47	0.029	0.202
18-Oct-2005	6.7	1100	1960	332	0.243	0.002	<0.003	0.006	0.207	<0.0005	0.473	0.0258	0.152
21-Nov-2005	6.8	1100	2000	411	0.085	0.002	<0.003	0.0044	0.211	<0.0005	1.497	0.0231	0.178
15-Dec-2005	7.1	1180	2140	426	0.113	0.005	<0.003	0.0026	0.562	<0.0005	0.6377	0.0157	0.083
11-Jan-2006		no flow											
11-Feb-2006													
14-Mar-2006		no flow											
17-Apr-2006		no flow											
22-May-2006	7	1330	2400	456	0.051	0.001	0.005	0.0052	0.126	<0.0005	0.0264	0.0065	0.049
13-Jun-2006	7.3	1240	2250	531	0.189	0.001	<0.003	0.0047	0.368	<0.0005	0.0847	0.0082	0.078
17-Jul-2006	6.1	980	1780	441	0.387	0.0082	<0.003	0.0055	0.052	<0.0005	1.974	0.0521	0.94
15-Aug-2006	6.8	1200	2220	534	0.037	0.0027	<0.003	0.0048	0.073	<0.0005	0.6577	0.0159	0.169
12-Sep-2006	7.4	1200	2090	453	0.064	0.0005	<0.003	0.0039	0.169	<0.0005	0.0709	0.0086	0.032
12-Oct-2006	6.9	1200	2160	450	0.025	0.0008	<0.003	0.0032	0.152	<0.0005	0.3395	0.0051	0.047
25-Nov-2006		no flow											
13-Dec-2006		no flow											
16-Jan-2007		dry											
13-Feb-2007		dry											
13-Mar-2007		dry											
16-Apr-2007		dry											
15-May-2007	6.7	1000	1830	369	<0.020	0.0008	<0.003	0.0083	0.265	<0.0005	0.6318	0.0124	0.052
13-Jun-2007	7.1	1200	2220	624	0.058	0.0018	<0.003	0.0049	0.387	<0.0005	0.3017	0.0154	0.24
23-Jul-2007	6.5	1200	2180	600	0.053	0.0049	<0.003	0.0039	0.112	<0.0005	1.08	0.032	0.772
20-Aug-2007	6.6	1300	2280	570	0.104	0.0021	<0.003	0.0033	0.131	<0.0005	0.1286/0.1412	0.0154	0.184
13-Sep-2007	6.5	1500	2640	642	0.057	0.002	<0.003	0.0036	0.383	<0.0005	0.3854	0.016	0.165
15-Oct-2007	6.8	1600	2940	759	0.054	0.001	0.003	0.0033	0.289	<0.0005	0.5559	0.011	0.132
20-Nov-2007		No Flow											
17-Dec-2007		no flow											

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

For Aquatic		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	**for pH>6.5**	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

Table C-6. Dawesley Creek d/s at Sth East Freeway (~ 22 km)

Mt Barker Creek water, before the confluent with the Bremer River (Loc 6)

Grab Sampling Location AWQC 1807

< indicates below 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
12-Jan-2005		no flow											
11-Feb-2005		no flow											
22-Mar-2005	8	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	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	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	0.19	<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		0.0075	
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
11-Jan-2006		no flow											
11-Feb-2006													
14-Mar-2006	7.9	1770	3190	121	0.174	<0.0005	<0.003	<0.0010	0.176	<0.0005	0.5408	0.0041	0.008
17-Apr-2006		no flow											
22-May-2006	7.5	1010	1830	309	0.182	0.0007	0.005	0.0035	0.249	<0.0005	0.0757	0.0048	0.031
13-Jun-2006	7.7	1230	2220	274	0.088	<0.0005	0.003	<0.0010	0.191	<0.0005	0.0687	0.0033	0.019
17-Jul-2006	7.7	1400	2560	218	0.143	<0.0005	<0.003	0.003	0.249	0.0006	0.141	0.007	0.083
15-Aug-2006	7.8	1500	2710	212	0.057	<0.0005	0.004	0.0021	0.141	<0.0005	0.0955	0.0032	0.03
12-Sep-2006	7.8	1000	1850	197	0.091	<0.0005	<0.003	0.0018	0.12	0.0005	0.0492	0.0032	0.022
12-Oct-2006	7.9	1100	1970	175	0.268	<0.0005	<0.003	0.0011	0.381	0.0008	0.261	0.0029	0.021
15-Nov-2006			no flow										
13-Dec-2006	7.9	1700	2990	144	0.084	<0.0005	<0.003	<0.0010	0.18	<0.0005	0.5885	0.0034	0.081
16-Jan-2007			no flow										
13-Feb-2007			no flow										
13-Mar-2007	8.3	2500	4490	151	0.13	<0.0005	<0.003	<0.0010	0.23	<0.0005	0.202	0.0041	0.005
16-Apr-2007			no flow										
15-May-2007	7.5	1200	2250	263	0.127	0.0019	<0.003	0.0036	1.03	0.0008	1.065	0.0222	0.559
13-Jun-2007	7.6	1100	2050	217	0.79	0.0005	<0.003	0.0022	0.646	<0.0005	0.1759	0.0059	0.135
23-Jul-2007	7.4	1300	2380	217	0.218	<0.0005	<0.003	0.0025	0.612	<0.0005	0.1128	0.0054	0.079
20-Aug-2007	7.4	1300	2430	204	0.125	<0.0005	<0.003	0.0016	0.38	<0.0005	0.0992/0.1069	0.0036	0.051
13-Sep-2007	7.7	1100	2060	151	0.081	<0.0005	<0.003	0.0012	0.427	<0.0005	0.0982	0.0029	0.036
15-Oct-2007	7.5	1300	2300	199	0.044	<0.0005	0.003	0.0011	0.362	0.0012	0.1543	0.0027	0.019
20-Nov-2007		no flow											
12-Dec-2007	7.7	1500	2790	296	0.056	<0.005	<0.001	<0.005	0.339	<0.01	0.505	0.005	0.014

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

	pH	TDS	Conductivity	Sulphate	Aluminium	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Zinc
For Aquatic		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	**for pH>6.5**	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

Table C-7. Mount Barker Creek

Bremer River water, at Jaensch Road ford (Loc 8)

Grab Sampling Location AWQC 1824

< indicates below 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
12-Jan-2005		no flow											
11-Feb-2005		no flow											
22-Mar-2005	8	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	2500	4410	322	0.426	0.0006	<0.003	0.004	0.22	<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
5/09/2005	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	0.27	<0.0005	<0.003	0.003	0.137	<0.0005	0.1459	0.0071	0.021
21-Nov-2005	7.6	1150	2090	154	2.19	0.0012	0.007	0.0078	3.22	0.0043	0.6598	0.0168	0.124
15-Dec-2005	8	1280	2320	172	0.24	<0.0005	<0.003	0.0014	0.346	<0.0005	0.3475	0.0072	0.074
11-Jan-2006		No Flow											
11-Feb-2006		No Flow											
14-Mar-2006	8	2400	4300	152	0.142	<0.0005	<0.003	<0.0010	0.222	<0.0005	0.5902	0.0025	0.006
17-Apr-2006		no flow											
22-May-2006	7.5	844	1530	117	2.271	0.0006	0.009	0.005	2.41	0.0025	0.406	0.0062	0.094
13-Jun-2006	7.6	1270	2300	300	0.186	<0.0005	<0.003	<0.0010	0.206	<0.0005	0.1324	0.0029	0.011
17-Jul-2006	7.4	1500	2770	235	0.183	<0.0005	0.005	0.0027	0.308	0.0006	0.1387	0.0058	0.046
15-Aug-2006	8	1500	2680	205	0.093	<0.0005	0.004	0.0023	0.185	<0.0005	0.0942	0.003	0.018
12-Sep-2006	7.8	1400	2560	194	0.551	<0.0005	<0.003	0.0049	0.732	0.0012	0.084	0.004	0.037
12-Oct-2006	8.8	1200	2230	174	0.101	<0.0005	<0.003	0.0013	0.174	<0.0005	0.1485	0.0021	0.011
15-Nov-2006		No Flow											
13-Dec-2006	8.1	2100	3840	148	0.042	<0.0005	0.003	<0.0010	0.101	<0.0005	0.1978	0.0018	0.005
16-Jan-2007		No Flow											
13-Feb-2007		No Flow											
13-Mar-2007	8.2	2400	4350	188	0.042	<0.0005	<0.003	<0.0010	0.166	<0.0005	0.4881	0.0016	0.005
16-Apr-2007		No Flow											
15-May-2007	7.4	1200	2110	283	0.186	0.0008	<0.003	0.0036	0.602	0.0005	0.4128	0.0087	0.13
13-Jun-2007	7.5	1000	1830	225	0.143	<0.0005	<0.003	0.0026	0.56	<0.0005	0.1081	0.0053	0.068
23-Jul-2007	7.6	1300	2410	211	0.329	<0.0005	<0.003	0.0023	0.625	<0.0005	0.0679	0.0043	0.064
20-Aug-2007	7.5	1400	2560	227	0.195	<0.0005	<0.003	0.0017	0.38	<0.0005	0.0937/0.0995	0.0034	0.034
13-Sep-2007	7.8	1400	2600	197	0.154	<0.0005	<0.003	0.0014	0.351	<0.0005	0.1475	0.0028	0.028
15-Oct-2007	7.7	1300	2400	230	0.058	<0.0005	<0.003	<0.0010	0.194	<0.0005	0.1037	0.0019	0.007
20-Nov-2007		No Flow											
12-Dec-2007	7.7	1600	2970	126	0.036	<0.005	<0.001	<0.005	0.439	<0.01	0.222	<0.005	0.006

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

For Aquatic		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	**for pH>6.5**	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

Table C-8. Bremer River at Jaensch ford

ALUMINIUM DISPERSED ALONG THE WATERCOURSE 2001/2003/2005/2007

Date	U/S Brukunga	D/S Brukunga	Old Melb. Bridge	D/S Nairne Ck	SE Freeway	Mt Barker Creek	Bremer River	O/S Nairne Creek
2001								
12-Jan-2001	0.433	397.0	125.00			0.614	0.509	0.280
5-Feb-2001	0.281	698.0	217.00			0.573	0.819	0.458
13-Mar-2001	0.799	943.0				0.650	0.452	0.362
6-Apr-2001	0.562	209.0	313.00			0.846	0.604	0.807
7-May-2001	0.332	249.0	271.00			0.635	0.342	0.294
13-Jun-2001	0.880	60.3	74.50	30.70	24.90	0.354	0.795	0.267
2-Jul-2001	0.461	54.6	55.10	30.80	25.30	0.345	0.310	0.315
8-Aug-2001	0.590	23.6	40.00	15.30	15.10	0.305	0.176	0.563
12-Sep-2001	0.821	13.2	9.91	5.54	7.28	4.850	3.300	0.687
9-Oct-2001	0.548	5.3	2.06	3.15	5.88	0.427	0.326	0.295
14-Nov-2001	0.543	17.4	46.10	0.208	0.29	0.089	0.231	0.115
5-Dec-2001	0.846	14.8	18.70	0.347	0.25	0.231	0.205	0.109
Max	0.880	943.000	313.000	30.800	25.300	4.850	3.300	0.807
Min	0.281	5.270	2.060	0.208	0.250	0.089	0.176	0.109
Median	**0.555**	**57.45**	**55.1**	**5.54**	**7.28**	**0.5**	**0.397**	**0.305**
2003								
14-Jan-2003	1.180	336.0				0.567	0.602	0.140
03-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	11.80	16.20	5.60	1.140	2.340	0.397
22-Jul-2003	0.169	27.1	5.18	7.21	0.98	0.039	0.402	0.259
19-Aug-2003	0.209	17.1	18.30	3.98	5.18	0.433	<0.020	0.398
10-Sep-2003	0.748	18.5	1.91	0.80	1.72	0.514	0.507	0.421
21-Oct-2003	0.355	9.0	2.73	0.181	0.189	0.341	0.417	0.293
11-Nov-2003	0.609	4.2	0.32	0.165	0.116	0.056	0.69	0.069
10-Dec-2003	1.09	2.3	0.26	0.036		0.207	0.14	0.193
Max	1.180	406.000	18.300	16.200	5.600	1.140	2.340	0.421
Min	0.169	2.280	0.259	0.036	0.116	0.039	0.140	0.069
Median	**0.482**	**18.5**	**2.73**	**0.8**	**1.35**	**0.341**	**0.462**	**0.259**
2005								
12-Jan-2005								
11-Feb-2005	0.336	1.5	0.95					
22-Mar-2005	0.307	2.6	0.12	0.194		0.241	0.182	
14-Apr-2005	0.532	2.0	0.18					
02-May-2005	0.187	1.7	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	1.2	0.558	0.081	0.189	0.198
23-Aug-2005	0.556	8.5	3.43	0.507	0.328	0.139	0.212	0.439
05-Sep-2005	0.353	3.0	1.06	0.331	0.228	0.19	0.356	0.170
18-Oct-2005	0.373	5.2	0.47	0.319	0.243	0.138	0.27	0.112
21-Nov-2005	0.455	2.9	0.18	0.317	0.085	0.488	2.19	0.124
15-Dec-2005	0.455	4.3	0.36	0.181	0.113	0.297	0.24	0.035
Max	2.720	87.100	3.430	1.200	0.558	0.488	2.190	0.694
Min	0.187	1.520	0.118	0.181	0.085	0.081	0.182	0.035
Median	**0.455**	**2.960**	**0.466**	**0.325**	**0.236**	**0.207**	**0.255**	**0.184**
2007								
16-Jan-2007								
13-Feb-2007								
13-Mar-2007						0.13	0.042	0.03
16-Apr-2007								
15-May-2007	0.059	1.890	0.568	1.720	<0.020	0.127	0.186	0.066
13-Jun-2007	0.084	47.300	0.408	0.102	0.058	0.79	0.143	0.077
23-Jul-2007	0.283	6.600	0.507	0.218	0.053	0.218	0.329	0.292
20-Aug-2007	0.358	4.760	0.490	0.204	0.104	0.125	0.195	0.105
13-Sep-2007	0.362	2.570	0.561	0.100	0.057	0.081	0.154	0.052
15-Oct-2007	0.203	1.600	0.256	0.034	0.054	0.044	0.058	
19-Nov-2007	0.175	0.081	0.029					
12-Dec-2007	0.252		2.570			0.056	0.036	
Max	0.362	47.300	2.570	1.720	0.104	0.790	0.329	0.292
Min	0.059	0.081	0.029	0.034	0.053	0.044	0.036	0.030

Table C-9. Aluminium dispersion in watercourses 2001/2003/2005/2007

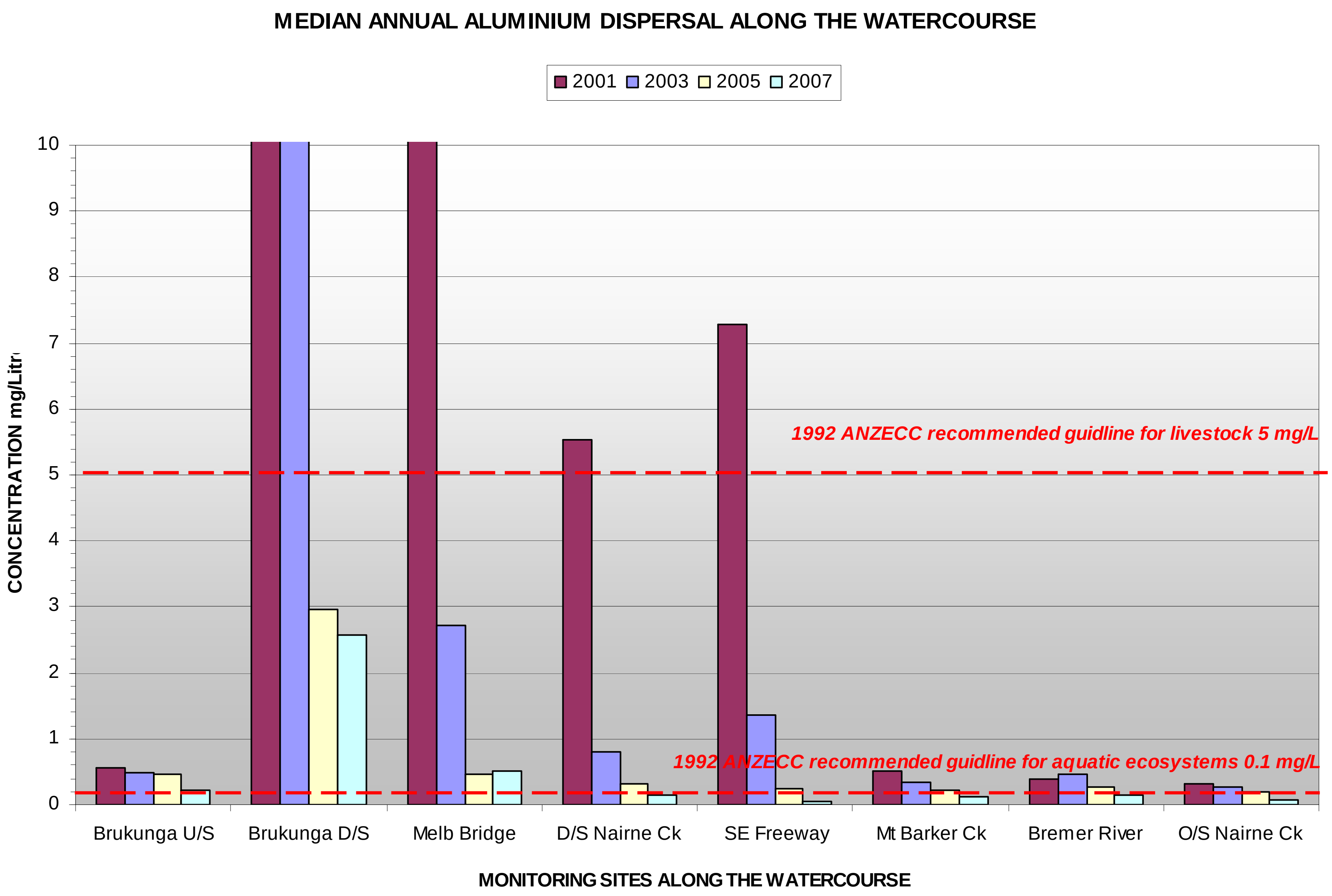

Figure C-3 Plot of median Aluminium dispersion in watercourses 2004 to 2007

CADMIUM DISPERSED ALONG THE WATERCOURSE 2001/2003/2005/2007

Date	U/S Brukunga	D/S Brukunga	Old Melb. Bridge	D/S Nairne Ck	SE Freeway	Mt Barker Creek	Bremer River	O/S Nairne Creek
2001								
12-Jan-2001	<0.0005	0.066	0.0193			0.0006	0.0007	<0.0005
5-Feb-2001	<0.0005	0.108	0.0140			<0.0005	0.0006	<0.0005
13-Mar-2001	<0.0005	0.207				<0.0005	<0.0005	<0.0005
6-Apr-2001	<0.0005	0.025	0.1050			<0.0005	<0.0005	<0.0005
7-May-2001	<0.0005	0.030	0.0684			0.0050	<0.0005	<0.0005
13-Jun-2001	<0.0005	0.070	0.0758	0.0495	0.0552	0.0107	0.0013	<0.0005
2-Jul-2001	<0.0005	0.008	0.0097	0.0164	0.0177	0.0100	0.0025	<0.0005
8-Aug-2001	<0.0005	0.013	0.0124	0.0118	0.0137	0.0040	0.0024	<0.0005
12-Sep-2001	0.0006	0.010	0.0081	0.0037	0.0056	0.0141	0.0042	<0.0005
9-Oct-2001	<0.0005	0.005	0.0035	0.0095	0.0068	0.0016	0.0007	<0.0005
14-Nov-2001	<0.0005	0.013	0.0252	0.0048	0.0034	0.0050	<0.0005	<0.0005
5-Dec-2001	<0.0005	0.006	0.0063	0.0042	0.0018	0.0006	<0.0005	<0.0005
Max	0.001	0.207	0.105	0.050	0.055	0.014	0.004	0.001
Min	0.001	0.005	0.004	0.004	0.002	0.001	0.001	0.001
Median	**0.001**	**0.019**	**0.014**	**0.010**	**0.007**	**0.005**	**0.001**	**0.001**
2003								
6-Jan-2003	<0.0005	0.030				<0.0005	<0.0005	<0.0005
03-Feb-2003								<0.0005
10-Mar-2003	<0.0005	0.116				<0.0005	<0.0005	<0.0005
1-Apr-2003	<0.0005	0.060						<0.0005
5-May-2003		0.041						<0.0005
12-Jun-2003	<0.0005	0.010	0.0289	0.0352	0.0330	<0.0005	<0.0005	<0.0005
22-Jul-2003	<0.0005	0.007	0.0170	0.0300	0.0171	0.0006	0.0011	<0.0005
19-Aug-2003	<0.0005	0.018	0.0220	0.019	0.0206	0.0011	<0.0005	<0.0005
10-Sep-2003	<0.0005	0.015	0.0091	0.0076	0.0100	0.0027	0.0011	<0.0005
21-Oct-2003	<0.0005	0.017	0.0133	0.0041	0.0046	0.0006	<0.0005	<0.0005
11-Nov-2003	<0.0005	0.007	0.0060	0.0039	0.0038	0.0007	0.0009	<0.0005
10-Dec-2003	<0.0005	0.004	0.0008	0.0008		<0.0005	<0.0005	<0.0005
Max	0.001	0.116	0.029	0.035	0.033	0.003	0.001	0.001
Min	0.001	0.004	0.001	0.001	0.004	0.001	0.001	0.001
Median	**0.001**	**0.017**	**0.013**	**0.008**	**0.014**	**0.001**	**0.001**	**0.001**
2005								
12-Jan-2005								
11-Feb-2005	<0.0005	0.002	0.0014					
22-Mar-2005	<0.0005	0.001	<0.0005	<0.0005		<0.0005	<0.0005	
13-Apr-2005	<0.0005	0.001	<0.0005					
18-May-2005	<0.0005	0.001	<0.0005					<0.0005
15-Jun-2005	<0.0005	0.025	0.0016	0.0058		<0.0005	0.0006	<0.0005
13-Jul-2005	<0.0005	0.008	0.0071	0.0087	<0.0005	<0.0005	0.0015	<0.0005
23-Aug-2005	<0.0005	0.004	0.0018	0.0019	0.0042	<0.0005	<0.0005	<0.0005
05-Sep-2005	<0.0005	0.004	0.0031	0.0016	0.0026	<0.0005	<0.0005	<0.0005
18-Oct-2005	<0.0005	0.007	0.0100	0.002	0.002	<0.0005	<0.0005	<0.0005
21-Nov-05	<0.0005	0.036	0.0087	0.0021	0.002	<0.0005	0.0012	<0.0005
15-Dec-05	<0.0005	0.005	0.0011	0.0006	0.005	<0.0005	<0.0005	<0.0005
Max	0.001	0.036	0.010	0.009	0.005	0.000	0.002	0.001
Min	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
Median	**0.001**	**0.004**	**0.002**	**0.002**	**0.003**	**0.001**	**0.001**	**0.001**
2007								
16-Jan-07								
13-Feb-07								
13-Mar-07						<0.0005	<0.0005	<0.0005
16-Apr-07								
15-May-07	<0.0005	0.0033	0.0208	0.0031	0.0008	0.0019	0.0008	<0.0005
13-Jun-07	<0.0005	0.004	0.007	0.0018	0.0018	0.0005	<0.0005	<0.0005
23-Jul-07	<0.0005	0.005	0.0097	0.0117	0.0049	<0.0005	<0.0005	<0.0005
20-Aug-07	<0.0005	0.003	0.0062	0.0023	0.0021	<0.0005	<0.0005	<0.0005
13-Sep-07	<0.0005	0.002	0.0025	0.0026	0.002	<0.0005	<0.0005	<0.0005
15-Oct-07	<0.0005	0.0009	0.0011	<0.0005	0.001	<0.0005	<0.0005	
19-Nov-07	<0.0005	0.0015	0.0012					
12-Dec-07	<0.005		<0.005			<0.005	<0.005	
Max	0.001	0.005	0.021	0.012	0.005	0.002	0.001	0.001

Table C-10. Cadmium dispersion in watercourses 2001/ 2003/ 2005/ 2007

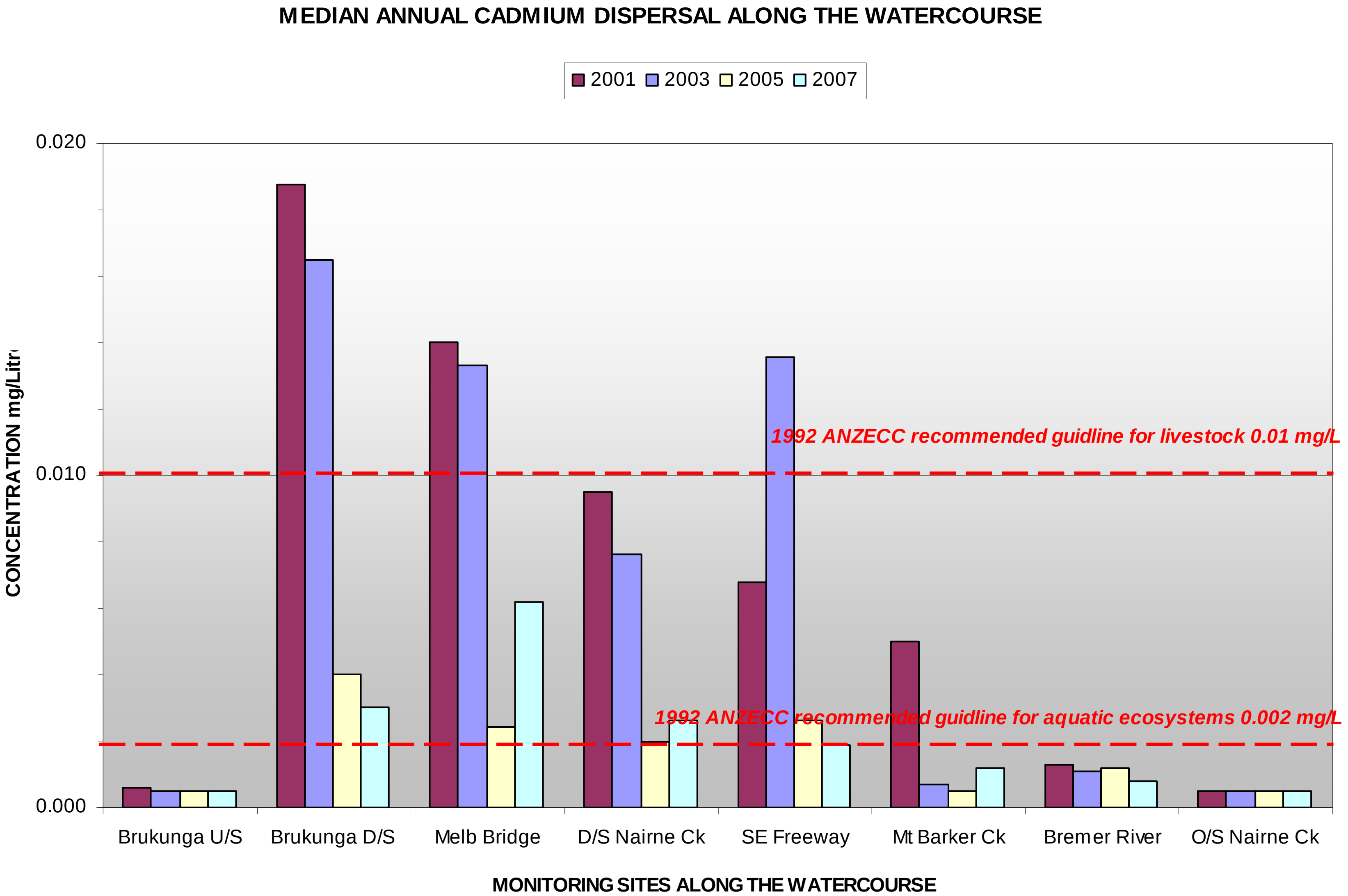

Figure C-4. Plot of median Cadmium dispersion in watercourses 2004 to 2007

ZINC DISPERSED ALONG THE WATERCOURSE 2001/2003/2005/2007

Date	U/S Brukunga	D/S Brukunga	Old Melb. Bridge	D/S Nairne Ck	SE Freeway	Mt Barker Creek	Bremer River	O/S Nairne Creek
2001								
12-Jan-2001	0.016	19.60	6.70			0.026	0.032	0.013
5-Feb-2001	0.004	38.90	9.36			0.013	0.036	0.009
13-Mar-2001	0.011	49.40				0.028	0.018	0.009
6-Apr-2001	0.022	10.70	22.40			0.031	0.260	0.034
7-May-2001	0.012	12.60	17.20			0.182	0.017	0.015
13-Jun-2001	0.025	5.18	5.85	4.180	4.560	1.440	0.354	0.017
2-Jul-2001	0.014	3.65	5.00	4.990	4.650	1.127	0.420	0.016
8-Aug-2001	0.018	2.02	3.40	2.890	3.460	0.502	0.188	0.014
12-Sep-2001	0.097	1.03	0.82	0.394	0.532	1.600	0.511	0.043
9-Oct-2001	0.009	0.83	0.52	1.290	1.700	0.166	0.053	0.012
14-Nov-2001	0.010	1.94	3.72	0.753	0.506	<0.003	0.011	0.005
5-Dec-2001	0.031	2.00	2.49	1.270	0.539	0.027	0.017	0.021
Max	0.097	49.400	22.400	4.990	4.650	1.600	0.511	0.043
Min	0.004	0.831	0.522	0.394	0.506	0.013	0.011	0.005
Median	**0.015**	**4.416**	**5.000**	**1.290**	**1.700**	**0.166**	**0.045**	**0.015**
2003								
6-Jan-2003	0.011	12.90				0.023	0.024	0.006
03-Feb-2003								0.024
10-Mar-2003	0.018	27.90				0.005	0.025	0.004
1-Apr-2003	0.004	22.6						0.011
5-May-2003		13.03						0.009
12-Jun-2003	0.012	1.02	3.26	3.990	3.539	0.055	0.049	0.013
22-Jul-2003	0.023	1.23	1.59	2.827	2.032	<0.003	0.088	0.015
19-Aug-2003	0.037	1.16	2.21	2.036	2.154	0.127	0.006	0.018
10-Sep-2003	0.069	1.39	1.46	1.221	1.544	0.214	0.102	0.024
21-Oct-2003	0.019	1.22	1.37	0.422	0.557	0.033	0.027	0.008
11-Nov-2003	0.007	0.40	0.67	0.694	0.415	<0.003	0.035	0.006
10-Dec-2003	0.038	0.12	0.14	0.092		0.018	0.008	0.009
Max	0.069	27.900	3.260	3.990	3.539	0.214	0.102	0.024
Min	0.004	0.119	0.138	0.092	0.415	0.005	0.006	0.004
Median	**0.019**	**1.223**	**1.455**	**1.221**	**1.788**	**0.033**	**0.027**	**0.011**
2005								
12-Jan-2005								
11-Feb-2005	0.015	0.19	0.11					
22-Mar-2005	0.011	0.21	0.02	0.036		0.006	0.013	
13-Apr-2005	0.012	0.16	0.02					
18-May-2005	0.007	0.15	0.01					0.031
15-Jun-2005	0.015	4.85	0.40	0.445		0.029	0.035	0.036
13-Jul-2005	0.008	1.21	0.95	1.271	0.008	0.005	0.14	0.033
23-Aug-2005	0.028	0.39	0.19	0.112	0.408	0.004	0.032	0.016
05-Sep-2005	0.009	0.28	0.16	0.141	0.202	0.036	0.029	0.021
18-Oct-2005	0.009	0.40	1.15	0.114	0.152	0.004	0.021	0.022
21-Nov-05	0.014	4.07	0.68	0.203	0.178		0.124	0.016
15-Dec-05	0.027	0.89	0.20	0.095	0.083	0.016	0.074	0.009
Max	0.028	4.846	1.150	1.271	0.408	0.036	0.140	0.036
Min	0.007	0.146	0.008	0.036	0.008	0.004	0.013	0.009
Median	**0.012**	**0.393**	**0.187**	**0.128**	**0.165**	**0.006**	**0.034**	**0.022**
2007								
16-Jan-07								
13-Feb-07								
13-Mar-07						0.005	0.005	0.008
16-Apr-07								
15-May-07	0.027	0.22	1.49	0.38	0.052	0.559	0.13	0.014
13-Jun-07	0.018	0.55	0.072	0.303	0.24	0.135	0.068	<0.003
23-Jul-07	0.044	0.99	1.35	1.11	0.772	0.079	0.064	0.009
20-Aug-07	0.026	0.31	0.399	0.167	0.184	0.051	0.034	0.006
13-Sep-07	0.033	0.14	0.121	0.184	0.165	0.036	0.028	0.004
15-Oct-07	0.014	0.12	0.09	0.112	0.132	0.019	0.007	
19-Nov-07	0.011	0.10	0.076					
12-Dec-07	0.013		0.129			0.014	0.006	
Max	0.044	0.992	1.490	1.110	0.772	0.559	0.130	0.014
Min	0.011	0.101	0.072	0.112	0.052	0.005	0.005	0.004
Median	**0.022**	**0.224**	**0.125**	**0.244**	**0.175**	**0.044**	**0.031**	**0.008**

Table C-11. Zinc dispersion in watercourses 2001/ 2003/ 2005/ 2007

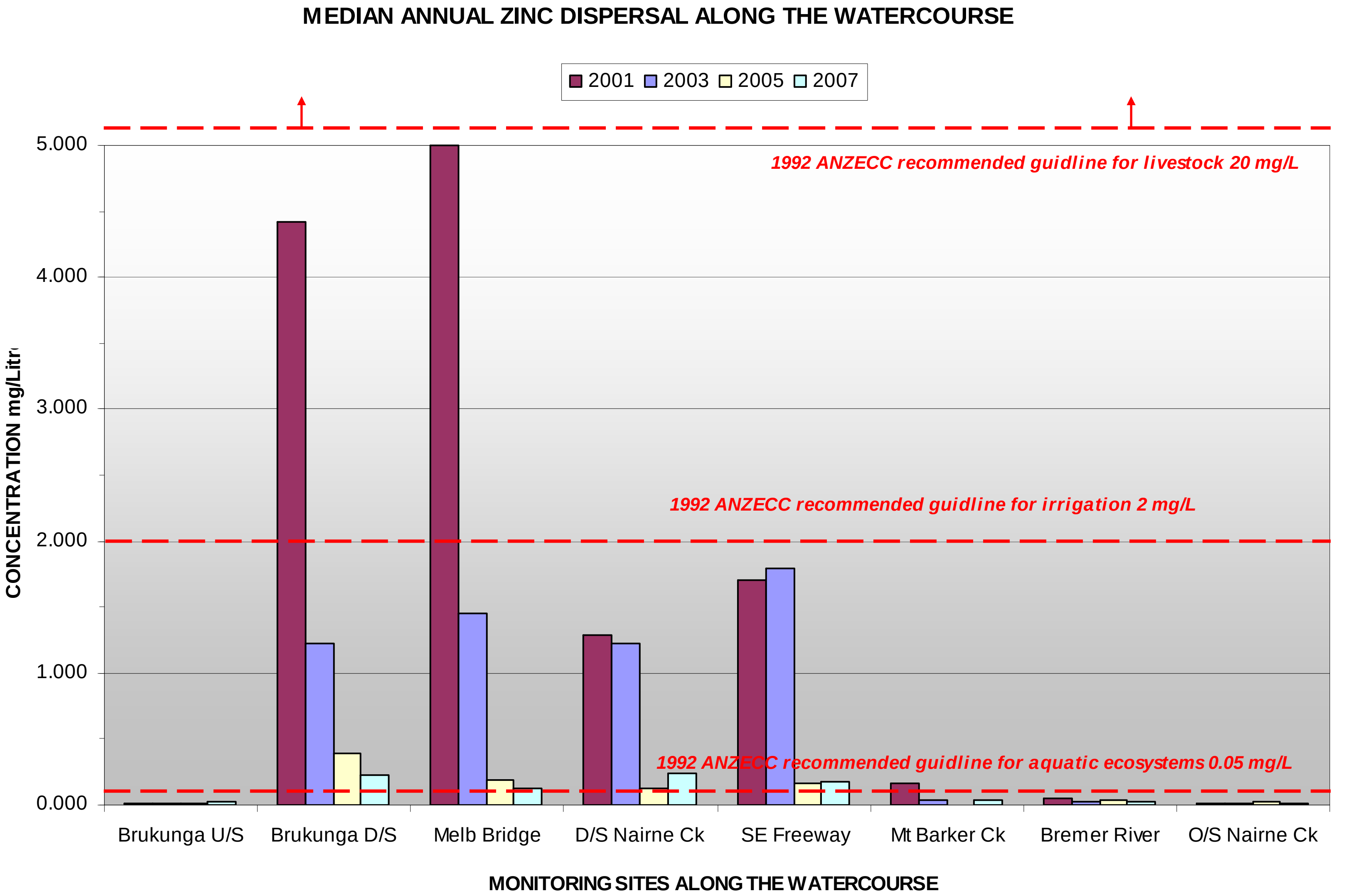

Figure C-5. Plot of median Zinc dispersion in watercourses 2001/ 2003/ 2005/ 2007