An environmental collaborative research programme: Field studies contributing to the sustainability of New Zealand's mineral industry.

PACRIM conference proceedings, Adelaide Australia, September 2004.

*Amanda Black**, *Tony Clemens and Dave Trumm, CRL Energy Ltd.*
*Corresponding author
a.black@crl.co.nz
CRL Energy Ltd
PO Box 29-415
77 Clyde Road, Ilam
Christchurch, New Zealand
Fax: 0064 3 364 2774

Abstract

Adopting environmentally acceptable practices in New Zealand is a crucial requirement for mineral wealth development. Recent planned expansions in the coal and gold industry have increasingly placed mining in the media spotlight. A lack of appropriate standard environmental guidelines has resulted in inconsistent responses and assessments of current and proposed mines. These inconsistencies have lead to delays in decisions on developing economic mineral deposits that may have only minor short-term impacts, and have also allowed unacceptable environmental management practices to continue elsewhere.

A research collaboration between CRL Energy, Landcare Research, University of Canterbury and University of Otago aims to provide regulator groups and the mining industry with a unified approach to the requirements of the Resource Management Act 1991, the legislation that largely drives the nation's environmental policies and guidelines. The tangible outcome of this research programme will be water quality and impact management guidelines integrated into a decision-making framework. The result of this unification will assist in the development of viable mineral deposits and minimise environmental impacts.

The framework will be derived from a synthesis of three objectives. Objective 1 identifies potential water quality impact. This objective is based on a targeted geochemical study of the lithology and waterways of the West Coast and Southland regions. Objective 2 categorises the degree of impacts on the ecology of receiving aquatic ecosystems and determines the processes that drive aquatic ecosystem recovery. Objective 3 identifies best strategies to sufficiently manage impacted ecosystems, and to prevent future unacceptable impacts. Wide consultation with representatives of the mining industry and regulator groups will occur frequently during the development stages of the framework. It is anticipated that this multidisciplinary approach will provide a robust and coherent, standardised system that will assist in achieving industry and environmental targets.

1.0. Introduction

Mining has been an integral part of New Zealand's landscape since the 1800's and has approximately $80 billion in potential wealth in known mineral deposits, comprised mainly of coal, gold, aggregate, and iron sands (NZMIA, 2003). Currently it is predicted that the $1 billion per annum gained from minerals will double within 10 years. This is to be achieved by increasing coal production to 6 million tonnes ($400 million), precious metals production to 3 million ounces ($750 million), aggregate to 37 million tonnes ($700 million) and iron sands to 3.5 million tonnes ($100 million) (NZMIA, 2003).

High profile cases have created a negative public image of mineral extraction. Recent media attention has focused on the both the positive (economics) and negative (environmental) aspects of the coal industry, particularly with the increase in planned coal production to meet the international market demand for low ash and sulphur coal. With the cancellation of the proposed hydro scheme planned for the South Island, coal is being touted as the medium term solution to the country's increasing energy needs (SENZ, 2003). New Zealand's largest coal producer Solid Energy New Zealand Ltd. has committed to improve its environmental management practices, with a statement in the Annual Report of an environmental 'no net negative impacts' goal (SENZ, 2003).

Since the passing of New Zealand's Resource Management Act (RMA, 1991), many industries in New Zealand, including the minerals industry have made major operational and management changes. Prior to 1991, mineral exploration, access and extraction were the primary steps involved in generating mineral wealth. Subsequently, there has been an increasing emphasis on a further step, namely managing the environmental impacts.

While environmental management is an essential part of any development, the lack of standard guidelines coupled with inconsistent procedures among parties has lead to confusion and significant delays in developing economically viable mineral deposits. Often regulators request further information and clarification on the geochemical, remedial and ecological aspects of the management proposal. Since there are no standardized methods of assessing these aspects, interpretations are often subjective.

The successful development of a standard system to provide industry and regulators with a uniform process to base important environmental decisions upon is a key element in cultivating New Zealand's mineral resources. Recognising this, the New Zealand Government, through the Foundation of Science Research and Technology, is financially supporting a research collaboration between CRL Energy Ltd, Landcare Research, University of Canterbury School of Biological Sciences and University of Otago Department of Geology to provide industry and regulators with a standardized decision making framework for the West Coast and Southland Regions.

This programme has been awarded NZ$475,000 per annum for six years (July 2004-June 2010). The goal of this programme is to reduce impacts from current and future mining operations, minimise environmental degradation and to facilitate processes involved in developing mineral wealth and environmental sustainability. A decision-making framework will be the overall outcome of this collaborative research programme and will be derived from three objectives that focus on establishing effects-based water quality threshold targets and management strategies

During the first 3 years a targeted detailed study of the West Coast and Southland region will occur. These investigations will identify the likelihood of water quality impacts by examining the geochemical characteristics of the mineral deposits. Impacts on the receiving ecosystems will be categorised according to their degree of disturbance and thresholds of tolerance and processes that drive ecosystem recovery will be determined. This programme will also identify strategies to mitigate such impacts and expand on remediation techniques that have already been tested at an historic site on the West Coast (Trumm et al., 2003).

A programme governance panel, comprised of key strategic individuals, will provide feedback and help to ensure that the framework is sound and will be adopted by the identified end users.

2.0. Research methodology

This research is focused primarily on determining and managing the likelihood of water quality impacts to be incorporated into the decision-making framework. The research has been divided among three objectives:

1. Establishing a baseline of water quality and rock geochemistry to determine the likelihood of impacts from mine related disturbances.
2. Categorising the degree of ecological impact on algal and macro-invertebrate communities through ecotoxicity studies to develop water quality threshold limits,
3. Identifying the most appropriate impact management strategy to remediate impacted ecosystems.

The sites chosen for this study are constrained within the West Coast and Southland regions of the South Island, New Zealand (Figure 1), where much of the growth in coal and gold mining is planned.

2.1. Determining potential impacts

In the West Coast region, acid mine drainage (AMD) from coal mining is one of the main sources of aquatic ecosystem degradation (Trumm et al., 2003). Historic and current coal mining operations have resulted in a legacy of impacted streams around the northern part of the region, namely catchments within the acid producing Brunner Coal Measures (James, 2003). To date, very little AMD or mine related environmental data is available from the Southland region.

While gold mining has also been documented as a producer of AMD in New Zealand and Internationally (Morell, et al., 1995; Ritchie, 1993), it does not have any reported occurrences in the South Island. Gold mining does however cause an increase in bioavailability of trace elements in the streams (Webster-Brown & Craw, 2004).

The South Island's geology, ecology, climate and topography vary considerably from region to region (Black et al., 2004). As a result, mines in different areas have different discharge water quality and environmental impacts. The impact of pH and dissolved trace elements from various mine discharges can range from minor to severe, with the presence of environmentally significant trace elements varying from site to site (Harding, 2004).

While the science behind the geochemical processes of acid generation and consequent contaminant problems is well understood (Gray, 1997), the extent of the likelihood of environmental impacts from different lithologies in the targeted regions of New Zealand remains largely undefined. A significant body of rock (geochemical) and water data (quality, flow, rainfall) already exists for some of the South Island's regions (Black 1999, 2000, 2001; Craw et al. 2000; Campbell 2001; Craw & Pacheo, 2002; James, 2003), and this information will be collated into a consistent format.

Rock units containing economic amounts of coal and gold from up to six new sites in the West Coast and Southland regions will be geochemically assessed to determine the potential for environmental impacts through mine drainage. The collation of existing data and geochemical assessments will lead to identification of areas that have the potential for "high", "medium" or "low" risk to water quality. The critical factor is to select appropriate sites and design an adequate spatial and temporal sampling regime. It is planned that a geochemical GIS map and database of the regions will be developed once all required information has been collated.

2.2. Identifying the impacts on the aquatic ecosystem

Impacts of AMD on stream systems are well documented (Bradley, 2003). However, much of this research has focused on assessing the ecology of macro-invertebrate communities rather than determining the mechanisms responsible for the impacts, or the processes that drive the recovery of impacted systems (Harding et al 1998; 1999; 2000; 2003; Stark 2001).

Aquatic ecosystem community recovery includes a complex set of scenarios that require more than just correcting the physico-chemical parameters (O'Halloran, 1998; 1999, 2001; Eason 1999, Cussins 2000; Harding, 2004). It is necessary to identify the biological factors that drive the recovery of impacted streams so that methods designed to assess site-specific effects are transferable to other areas.

From existing data on water quality, stream ecology and ecotoxicity studies for the West Coast and Southland, a draft set of water quality thresholds will be formulated. Extensive algal surveys in a range of impacted systems will be used to identify impact tolerance levels. Experiments designed to identify conditions limiting microbial processes will also be conducted and ecotoxicological data on a representative range of endemic invertebrate taxa will establish pH and metal tolerances. From these results the levels of ecosystem recovery will identify thresholds for water quality parameters.

The effect of mine drainage on aquatic taxa in West Coast systems is complicated by the fact that many West Coast species are highly endemic tolerate a wide range of pH and metals (Bradley, 2003). This suggests an adaptation to naturally acidic streams on the West Coast (Winterbourne et al., 2000)

2.3. Managing the risk

Based on findings from existing work at a historic West Coast coal mine site (Lindsay et al., 2001; Black et al., 2003; O'Halloran et al., 2003; Trumm et al., 2003) a methodology to determine strategies for minor, moderately and severely impacted sites will be formulated. Small-scale trial remediation systems using passive remediation techniques will be trialled at other minor and moderately impacted historic coalmine sites. The results of these trials and previous research will be used to develop, an impact management strategy and its success measured against the water quality and ecological threshold limits developed in Objectives 1 and 2.

Ultimately the best methods of managing the potential and actual impacts is to either prevent or treat mine discharge so that the physico-chemical parameters of the receiving water do not exceed any ecological thresholds. The level of treatment required will depend on the amount and duration of discharge in combination with the natural background characteristics of the receiving water.

2.4. Building the framework

The purpose of the framework is to provide appropriate water quality and impact management guidance, which will allow environmentally responsible extraction of mineral resources. These guidelines will be designed to compliment existing policies and generic guidelines currently used by regulators and industry, particularly in the preparation of an assessment of environmental effects, which accompanies resource consents (as required under the New Zealand RMA, 1991).

Consultation with end users in industry and regulatory organisations to discuss optimal ways of combining the results from the three objectives into a useable framework will occur on a regular basis. An evaluation of the various types of frameworks and best management practices from other countries will provide the initial structure (Cavanagh et al., 2003). This will be trialled by end users at sites within the West Coast and Southland regions. Modifications to improve the framework will occur as required once the results of trials and feedback from end users is collected.

The framework is initially envisaged as a comprehensive document, containing a series of feedback loops between the three main research themes. The initial output will be a document detailing the rationale of the framework as well as milestones answered in objectives 1-3. Although the framework will be built with water quality impacts from coal and gold mine drainage, the process developed should be applicable to the aggregate industry.

An effective decision-making framework must be based upon a thorough scientific understanding of geochemistry and ecosystem interactions and its response to natural and anthropogenic induced stress and remediation techniques. It is anticipated that recommendations will be developed to help guide future work in a number of areas of potential extraction sites and environmental sustainability.

3.0. Concluding summary

The strategic objective of this research is to provide a unified decision process to meet the requirements of the RMA and to promote sound environmental practices in the mining industry. Current guidelines require mining operations be completed in an environmentally responsible way. However, it is recognized that temporary localized adverse effects may be unavoidable during mining and that management and operational practices need to ensure that long-term there are no net negative environmental impacts.

Responding to regulatory and public concerns, the New Zealand mining industry has improved environmental management practices over the last 10 years. Management of the environmental effects of mining in New Zealand has become more publicised as a result of the increase in developments. Mining in New Zealand, particularly for coal has a negative image, despite the economic reliance on coal as an export commodity and a energy source. In part, this image is understandable because some historic sites still noticeable and significantly impact on water quality in streams (Trumm et al., 2003).

The final framework, incorporating the geochemical information, ecosystem recovery threshold targets and management strategies for the West Coast and Southland regions will be completed and in place by June 2010.

4.0. Acknowledgements

The authors would like to thank the Foundation for Research, Science and Technology for investment in this new contract and to also thank Solid Energy New Zealand Ltd, for financial support and encouragement of this new initiative.

5.0. References

Black, A. & Craw, D. 1999. Environmental effects of open cast coal mining and the *insitu* processes of natural remediation: Wangaloa open cast mine, South Otago, New Zealand. *The Australasian Institute of Mining and Metallurgy New Zealand Branch 32nd Annual Conference: 121-130.*

Black, A. & Craw, D. 1999. Seasonal variation in arsenic, copper and zinc in surrounding streams and wetlands receiving coalmine drainage, Wangaloa open cast mine, southeast Otago. *The 8th New Zealand Coal Conference Proceedings*: *263-267.*

Black, A. & Craw, D. 2000. A preliminary environmental impact assessment on historic coal mining in Reefton, West Coast, New Zealand. *Earth Science Research Report 00/01, Department of Geology, University of Otago. 44pp.*

Black, A. & Craw, D. 2001. Arsenic, copper and zinc occurrence at the Wangaloa coal mine, southeast Otago, New Zealand. *International Journal of Coal Geology 45: 181-193*

Black, A. Craw, D. Youngson, J & Karubaba, J. 2004. Natural rehabilitation of historic mine tailings discharged into a river system, Shag River, east Otago, New Zealand. *Journal of Geochemical Exploration. In Press.*

Black, A. Trumm, D.T. Cavanagh, J. Harding, J., de Joux, A. Moore, T.A. & O'Halloran, K. (2003). Developing remediation strategies for New Zealand sites impacted by Acid Mine Drainage (AMD). A case study, Sullivan Mine, West Coast, New Zealand. *Sixth International Symposium on Environmental Geochemistry, 7-11 September 2003, Edinburgh.*

Black, A. Trumm, D. & Lindsay, P. 2004. Coal mining in New Zealand and impacts on water quality: case studies from West Coast and Otago. *In Metal Contaminants in New Zealand: From sources and transport to effects on ecology and human health. Eds T.A. Moore, A. Black, J.A. Centeno, J.S. Harding, D.A. Trumm (in press).*

Bradley, A. 2003. Stream communities in acid mine drainages: investigating longitudinal recovery and remediation possibilities. *Thesis for Master of Science in Zoology, University of Canterbury, Christchurch, New Zealand.*
Cavanagh J.E. & O'Halloran, K. 2003: International legislative frameworks for managing contaminated land – derivation and application of numeric values. Landcare Research Contract report: LC0203/110, 40p

Campbell, R.N., Lindsay, P & Clemens, A.H. 2001. Acid generating potential of waste rock and coal ash in New Zealand coal mines. *International Journal of Coal Geology 2001: 163.*

Craw, D. Chappell, D. Reay, A. & Walls, D. 2000. Mobilisation and attenuation of arsenic around gold mines, east Otago, New Zealand. *New Zealand Journal of. Geology and. Geophysics. 43: 373-383.*

Craw, D. & Pacheco, L. 2002. Mobilisation and bioavailability of arsenic around mesothermal gold deposits in a semiarid environment, Otago, New Zealand. *Scientist. World Journal. 2: 308-319.*

Cussins, T., O'Halloran, K., Lilburne, L., Cochrane, P., Hickey, C., Sheppard, D., Gough, J., Wickstrom, M., Eason, C. & Phillips, C. 2000. Ecological risk assessment at contaminated sites in New Zealand. In: Johnston, C.D. *ed.* Contaminated site remediation: from source zones to ecosystems*: Proceedings of the 2000 Contaminated Site Remediation Conference, 4–8 Dec 2000, Melbourne, Australia, pp. 17-24.*

Eason, C., Svendsen, C., O'Halloran, K. & Weeks, J.M. 1999: An assessment of the lysosomal neutral red retention test and immune function assay in earthworms (*Eisenia andrei*) following exposure to chlorpyrifos, benzo-a-pyrene (BaP) and contaminated soil. *Pedobiologica 43: 641-645.*

Gray, N. F., 1997. Environmental impact and remediation of acid mine drainage: a management problem. *Environmental Geology: 30. (1/2) 62-71.*

Harding J.S. 2003. Historic deforestation and the fate of endemic species in streams. *NZ Journal of Marine & Freshwater Research 37: 333-345*

Harding, J.S. 2004. Impacts of metals and mining on stream communities. *In Metal Contaminants in New Zealand: From sources and transport to effects on ecology and human health. Eds T.A. Moore, A. Black, J.A. Centeno, J.S. Harding, D.A. Trumm (in press).*

Harding, J.S., Quinn, J.M. & Hickey, C.W. 2000. Effects of mining and forestry production. *In*: New Zealand stream invertebrates: ecology and implications for management. Eds. Collier, M.J. & Winterbourn, M.J. New Zealand Limnological Society, Christchurch, New Zealand.

Harding, J.S., Young, R.G., Hayes, J.W., Shearer, K.A. & Stark, J.D. 1999. Changes in agricultural intensity and river health along a river continuum. *Freshwater biology 42: 345-357.*

Harding, J.S., Benfield, E.F., Bolstad, P.V., Helfman, G.S. & Jones E.B.D. 1998: Stream biodiversity: the ghost of land-use past. *Proceedings of the National Academy of Sciences 95(25)*: *14843-14847.*

James, T., 2003. Water quality of streams draining various coal measures in the North-central West Coast. *36th annual AusIMM conference, held on 3-5 September 2003 in Greymouth, New Zealand.*

Lindsay, P., Mowatt, C. & Trumm, D. 2001. Proposed remediation of contaminated sites using zeolites. *Engineering & Development in Hazardous Terrain, New Zealand Geotechnical Society Symposium, University of Canterbury, 24-25 August 2001.*

Morell, W.J. Gregg, P.E.H. Stewart, R.B. Bolan, N & Horne, D. 1995. Potential for revegetating base metal tailings at the Tui Mine site, Te Aroha, New Zealand. *PACRIM Conference Proceedings, pp. 395-400.*

NZMIA, 2003. New Zealand Minerals Association website: www.minerals.co.nz.

O'Halloran, K., Black, A., Bradley, A., Cavanagh, J., Harding, J., de Joux, A., Moore, T., & Trumm, D. 2003. Assessment and remediation of A New Zealand West Coast Acid Mine Drainage (AMD) site. *Society for Environmental Toxicology and Chemistry, September 28 - 1 Oct, 2003, Landcare Research, New Zealand.*

O'Halloran, K. 2001: Ecotoxicity thresholds for hazardous waste. Landcare Research Contract Report LC0001/66.

O'Halloran, K. & Booth, L.H. 2001 Terrestrial toxicity tests for soil fauna and flora. *In:* Kookana, Sadler, Sethunathan and Naidu *eds* Organic contaminants. New Delhi, IBH Oxford. *pp. 55-74.*

O'Halloran, K., Booth, L.H., Hodge, S., Thomsen, S. & Wratten, S.D. 1999. Biomarker responses of the earthworm *Aporrectodea caliginosa* to organophophates: Hierarchical tests. *Pedobiologia 43: 646-651.*

O'Halloran, K., Ahokas, J.T. & Wright, P.F.A. 1998. Response of fish immune cells to *in vitro* organotin exposures. *Aquatic Toxicology 40: 141–156.*

O'Halloran, K., Ahokas, J.T. & Wright, P.F.A. 1998. The adverse effects of aquatic contaminants on fish immune responses. *Australasian Journal of Ecotoxicology 4: 9–28.*

Ritchie, A.I.M. 1993. Waste rock dump geochemistry. *Proceedings of the Symposium of the Management and Rehabilitation of Waste Rock Dumps,* Ed. Riley, S.J. Waggitt, P.W. & McQuade, C. pp 69 –90

Stark, J.D., Boothroyd, I.K., Harding, J.S. Maxted, J.R. & Scarsbrook, M.R. 2001. Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report No. 1. Ministry for the Environment, Wellington. 57 pp.

SENZ (Solid Energy New Zealand Limited). 2003. Annual Report pp: 47.

Trumm, D.T., Black, A., Cavanagh, J., Harding, J., de Joux, A., Moore, T.A. & O'Halloran, K. 2003. Developing assessment methods and remediation protocols for New Zealand sites impacted by Acid Mine Drainage (AMD). *Sixth International Conference on Acid Rock Drainage, 12-18 July 2003, Cairns, Australia.*

Trumm, D.A., Black, A. & Gordon, K. 2003. Remediation strategies for acid mine drainage (AMD) at Sullivan Mine, West Coast, New Zealand. *AUSIMM conference, 2-5 September 2003, Greymouth, New Zealand.*

Webster-Brown & Craw, 2004. Examples of trace metal mobility around historic and modern metal mines in New Zealand. *In Metal Contaminants in New Zealand: From sources and transport to effects on ecology and human health. Eds T.A. Moore, A. Black, J.A. Centeno, J.S. Harding, D.A. Trumm (in press).*

Winterbourne, M.J., McDiffet, W.F. & Eppley, S.J. 2000. Aluminium and iron burdens of aquatic biota in New Zealand streams contaminated by acid mine drainage: effects of trophic level. *The Science of the Total Environment 254: 45-54*

Figure captions:

Figure 1. The locality of the West Coast and Southland regions, South Island, New Zealand.