Lead Pathways Study
Land Report summary

July 2009

Summary of the report *Study of Heavy Metals and Metalloids in the Leichhardt River and Surrounding Locations* by:

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THE UNIVERSITY OF QUEENSLAND AUSTRALIA

SMI CMLR Centre for Mined Land Rehabilitation

entox national research centre for environmental toxicology

MOUNT ISA MINES

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University of Queensland's Centre for Mined Land Rehabilitation (CMLR)

Formally established in 1993, the Centre for Mined Land Rehabilitation (CMLR) at The University of Queensland (UQ) consists of a collaborative and multidisciplinary grouping of research, teaching and support staff and postgraduate students dedicated to delivering excellence in environmental research and education to the Queensland, national and international minerals industry and associated government sectors.

The Centre is widely recognised as the source of quality research and postgraduate students at the cutting edge of issues in mining environmental management and sustainability. It has built a reputation for the provision of the scientific research that is necessary to support and underpin the decisions that need to be made to minimise the environmental risks by the mining and processing of the full spectrum of commodities including coal, gold, bauxite, alumina, base metals, heavy mineral sands and oil, both in Australia and overseas.

The Centre is one of six UQ research centres that make up the Sustainable Minerals Institute (SMI – www.smi.uq.edu.au). The SMI was established in 2001 as a joint initiative of the Queensland Government, UQ and the minerals industry, to provide an over-arching framework for progressing minerals industry research and education, with the purpose of providing knowledge-based solutions to meet the sustainability challenges in the global mining industry.

About the authors

Associate Professor Barry Noller

Associate Professor Noller has a PhD (1978) in Environmental Chemistry from the University of Tasmania. He worked as a Research Fellow at the Australian National University (1978–1980), Senior Research Scientist at the Alligator Rivers Region Research Institute, Jabiru, Northern Territory (1980–1990) and then as Principal Environmental Chemist for the Department of Mines and Energy, Darwin Northern Territory (1990–1998). From 1998–2006 Professor Noller was Deputy Director of the National Research Centre for Environmental Toxicology (EnTox) – The University of Queensland, Coopers Plains, Qld. EnTox has a strong involvement with the utilisation of the risk assessment process to deal with toxicological hazards, including in environmental systems. Since November 2006 Professor Noller has been appointed as Honorary Research Consultant and Principal Research Fellow at the Centre for Mined Land Rehabilitation (CMLR) a centre of the University of Queensland based at St Lucia in Brisbane. The CMLR is part of the Sustainable Minerals Institute.

Associate Professor Noller has been working and publishing in the field of environmental chemistry and industrial toxicology for the past 32 years and has presented over 200 conference papers and published more than 130 papers. His professional activities undertaken at four different centres have covered processes and fates of trace substances in the environment, particularly in tropical environmental systems with special reference to risk management associated with their application and studies of the bioavailability of toxic elements in mine wastes, including waters.

Professor Jack Ng

Professor Ng is a certified toxicologist (DABT – Diplomate of the American Board of Toxicology) and is the Program Manager for Metals and Metalloids (M&M) Research at the National Research Centre for Environmental Toxicology (EnTox). His major research themes include chemical speciation of arsenic species in environmental and biological media, bioavailability in relationship to toxicities using various animal models, carcinogenicity and mechanistic studies of chronic arsenic toxicity in both humans and animals. Other research interests include toxicity of mixed metals, the transfer of heavy metals via the food chain from mine tailings and other mining wastes in addition to study on natural toxins in plants relevant to human health. Jack's projects represent a combination of independent effort as well as linkages through national and international collaboration.

Professor Ng is also the Program Leader for Risk Assessment in the newly established CRC-CARE (Contamination Assessment and Remediation of the Environment). Professor Ng has over 290 publications including journal papers, book chapters and technical reports.

Dr Vitukawalu Matanitobua

Dr Matanitobua has studied environmental chemistry and toxicology at the National Research Centre for Environmental Toxicology (EnTox), the University of Queensland and received his PhD in 2007.

Independent review process

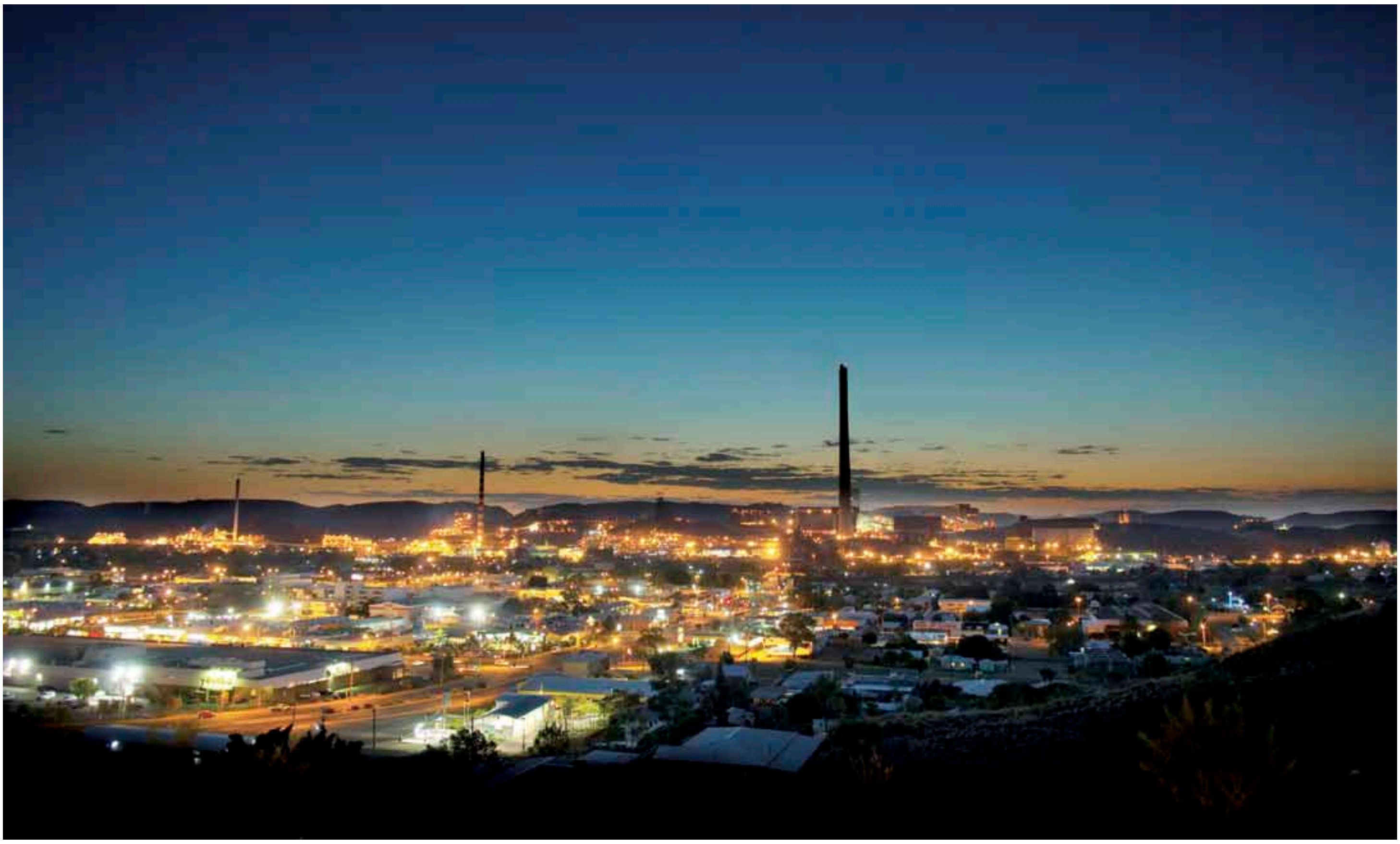
The *Lead Pathways Study* Land Report, *Study of Heavy Metals and Metalloids in the Leichhardt River and Surrounding Locations*, on which this summary report is based was independently reviewed by an environmental soil contamination specialist, Professor Michael J. McLaughlin B.Sc. (Hons) M.Agr.Sc.(Dist.) Ph.D.

Professor McLaughlin is a foundation Director of CSIRO's Centre for Environmental Contaminants Research and also a Professor in the School of Earth and Environmental Sciences at The University of Adelaide. He sits on the Queensland Water Commission Expert Advisory Panel on water recycling, and on the international metals industries' Ecotoxicity Technical Advisory Panel.

Professor McLaughlin received his BSc in 1977 (Univ. Ulster), MAgrSc in 1979 (Reading Univ.) and PhD in 1986 (Univ. Adelaide). Before joining CSIRO Land and Water in 1991, he worked as a research scientist at the Soil and Irrigation Research Institute in South Africa dealing with sustainability issues relating to wastewater and sewage biosolid disposal on soils, particularly concerns relating to metals and phosphorus. McLaughlin also worked in CSIRO Plant Industry in Canberra on issues relating to acidic soils and reactions of fertiliser phosphorus and fluoride in soils. From 1988 to 1991 he was Technical Manager of the Australian Phosphate Corporation and Honorary Research Fellow at La Trobe University, Melbourne, responsible for environmental issues relating to fertiliser use in Australia.

Professor McLaughlin's entire research career has focussed on the impacts and chemistry of nutrients and contaminants in soil and food quality, agricultural re-use of wastewaters and solids, and environmental risk assessment, specifically the assessment and remediation of contaminated soils, and the behaviour and toxicity of contaminants in the soil system.

He is a prolific producer of research outputs with more than 191 referred publications and numerous books, book chapters, conference papers and industry publications to date.



Introduction

In late 2006, Xstrata Mount Isa Mines commissioned Associate Professor Barry Noller from the University of Queensland's Centre for Mined Land Rehabilitation (CMLR) to conduct a *Whole of Emissions Study*, which has now evolved into the *Lead Pathways Study*.

This study will enable us to better understand the potential pathways of lead into the Mount Isa community through land, air and water and any potential risk to human and ecological health from our mine operations.

We take the issue of lead levels in the Mount Isa community very seriously and we are committed to ensuring the continued safety of our operations and to raising community awareness about living safely in an environment where there are naturally occurring minerals, including lead.

We understand the mine is an integral part of the community in Mount Isa. More than 4,000 of our people call Mount Isa home and a vast number indirectly rely on the mine for their livelihoods. We are also acutely aware of balancing the economics of our business with our environmental and social responsibilities as an active participant in the Mount Isa community. That is why we commissioned this study and why we continue to keep you informed of its progress.

Even though the CMLR identified the potential risk to human health to be minimal, Xstrata Mount Isa Mines undertook the second stage of the Leichhardt River Remediation Project in May and June 2008 as part of our ongoing commitment to the health and safety of the Mount Isa community. We are committed to undertaking further remediation work if required.

On behalf of the entire team at Xstrata Mount Isa Mines, we would like to thank Associate Professor Noller and his team for his work to date in delivering the first phase of the *Lead Pathways Study*.

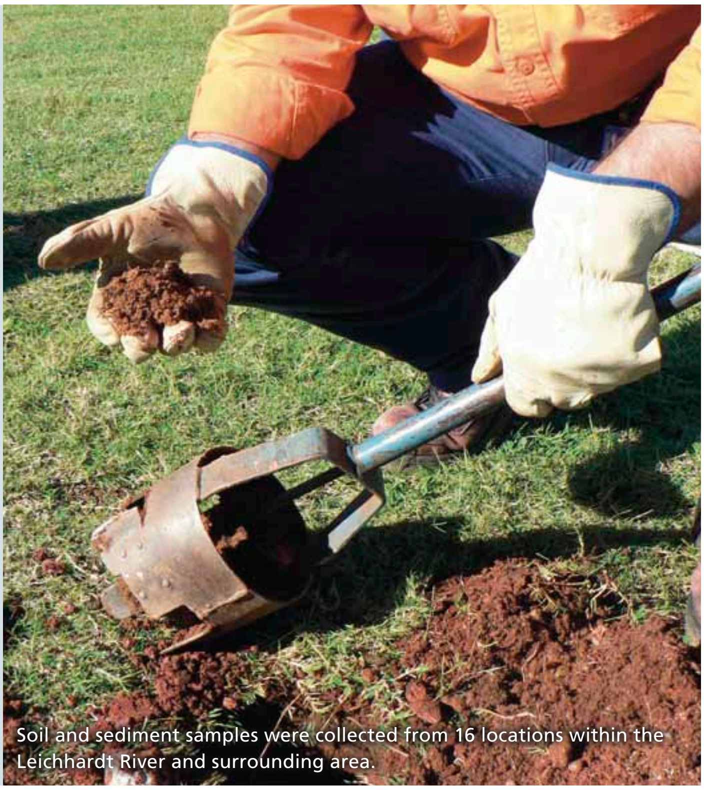
Steve de Kruijff
Chief Operating Officer
Xstrata Copper, North Queensland Division

Kevin Hendry
Executive General Manager
Xstrata Zinc, Mount Isa Operations

Summary of findings relating to human health

As part of the *Lead Pathways Study* Land Report a human health risk assessment was undertaken in order to understand the potential impact of historical mine sediments found in the Leichhardt River and surrounding area on the Mount Isa community. This assessment found that:

- **Soils sampled in this study are unlikely to cause acute or sub-chronic lead or arsenic toxicity in adults or children**
- **Chronic lead toxicity is unlikely to occur in adults**
- **Chronic lead toxicity is unlikely to occur in children as a result of activities undertaken in recreational areas**
- **Chronic arsenic toxicity is unlikely to occur in adults or children**
- **The bioaccessibility of lead in soils sampled in this study ranged from less than one percent to 24 percent. The bioavailability of lead in these samples will generally be much lower than these estimates.**



Soil and sediment samples were collected from 16 locations within the Leichhardt River and surrounding area.

Background

The *Lead Pathways Study* is a comprehensive research program being conducted by the University of Queensland's Centre for Mined Land Rehabilitation (CMLR) in collaboration with the National Research Centre for Environmental Toxicology (EnTox).

Commissioned by Xstrata Mount Isa Mines in late 2006, the study is assessing potential pathways of lead and other heavy metals into the Mount Isa community and any associated risks to human and ecological health.

The study has been divided into three investigation phases:

- Land Report
- Water Report
- Air Report.

All three phases of the *Lead Pathways Study* will be independently peer reviewed.

This summary report presents the key findings of the *Lead Pathways Study* Phase One report, *Study of Heavy Metals and Metalloids in the Leichhardt River and Surrounding Locations,* and has been developed as a companion document to this scientific report. Both reports are available online at www.xstrata.com/operation/mountisa/publications/

Purpose

The purpose of the Land Report was to assess historical heavy metal and metalloid contamination within the Leichhardt River, the swimming pool area and Kruttschnitt oval to determine the effectiveness of previous remedial works conducted on these areas and any potential risk to human and ecological health. The previous remedial works were undertaken between 1991 and 1994 to remove mine-related sediments left over from historical mining practices of the 1940s and 1950s.

Between April and August 2007, 21 soil and sediment samples were collected from 16 locations within the Leichhardt River and surrounding area (refer to Figure 1 and Table 1). The samples were analysed in order to:

- understand the distribution of historical contamination within an area previously known to be contaminated;
- determine the bioaccessibility of heavy metals in the soil and sediment samples as an estimate of bioavailability;
- complete a human health risk assessment to determine the potential site specific risk from heavy metal and metalloid contamination; and
- compare sediment results against sediment quality guidelines prepared by the Australian and New Zealand Environmental Conservation Council (ANZECC 2000) to measure any potential ecological toxicity.

Definitions:

Metalloid: a nonmetallic element that has some of the same properties as a metal. Arsenic is an example of a metalloid.

Bioaccessibility: is the predicted amount of a contaminant that is absorbed into the body following skin contact, ingestion, or inhalation as measured through tests outside of an organism (eg) using laboratory equipment to simulate the gastro-intestinal tract. Bioaccessibility is a scientifically recognised method of predicting bioavailability.

Bioavailability: is the actual amount of a contaminant that is absorbed into the body following skin contact, ingestion, or inhalation.

Acute exposure: exposure to a chemical for 14 days or less.

Sub-chronic exposure: repeated exposure to a chemical for a period of one to three months.

Chronic exposure: repeated exposure to a chemical for a period of three months or more.

Soil sampling in the Leichhardt River.

Human health risk assessment

The first step in the human health risk assessment was to compare the total concentrations of heavy metals and arsenic in samples taken from the Leichhardt River and surrounding area against the National Environmental Protection (Assessment of Site Contamination) Measures (NEPMs) soil guidelines.

The NEPM soil guidelines were developed by the National Environmental Protection Council (NEPC) for the assessment of site contamination in Australia and provide generic soil guidelines to assess health based and ecological effects on a site specific basis.

The guidelines include Health Investigation Levels (HILs) and Ecological Investigation Levels (EILs) which are used for assessing existing contamination and are intended to prompt an appropriate site-specific investigation where there are exceedances of investigation levels.

There is no specific Health Investigation Level for assessing potential contamination of soil in riverbeds and it would not generally be expected that children would have regular contact with soil in these locations. However, as a conservative measure Health Investigation Level E was selected for this study as it is the designated level for assessing parks, recreational open space and playing fields, including secondary schools.

The initial comparison of the heavy metal concentrations in the soil samples from the Leichhardt River and surrounding area against the NEPM HIL Level E assumed that the metals were 100 percent bioavailable. That is, it was assumed that all of the metals contained within the samples could be absorbed by the human body. Under this scenario a number of sites exceeded the NEPM HIL Level E criteria and therefore required further investigation.

Extensive scientific research demonstrates that the bioavailability of metals and metalloids in soil is usually only a fraction of 100 percent. That is, if a person ingested the soil only a small portion of the heavy metal or metalloid would actually be absorbed by the body.

As bioavailability can only be measured directly using animal or human dosing experiments, a well recognised scientific approach is to simulate the human gastro-intestinal tract (using laboratory equipment) to estimate the amount of metals or metalloids that can be absorbed by the body (ie) bioaccessibility.

In this study a test known as PBET (physiologically-based extraction test) was used to measure the bioaccessibility of lead and other metals in the soil samples taken from the Leichhardt River and surrounding area. The PBET testing determined that the bioaccessibility of lead and other metals in the soil samples was less than 100 percent. For lead in soil the maximum bioaccessibility identified was 24 percent.

However, bioaccessibility has been found through a number of scientific studies to over-estimate bioavailability. Therefore the bioavailability of lead in the soil samples is likely to be even lower than the bioaccessibility estimates used in this study (refer to Table 2).

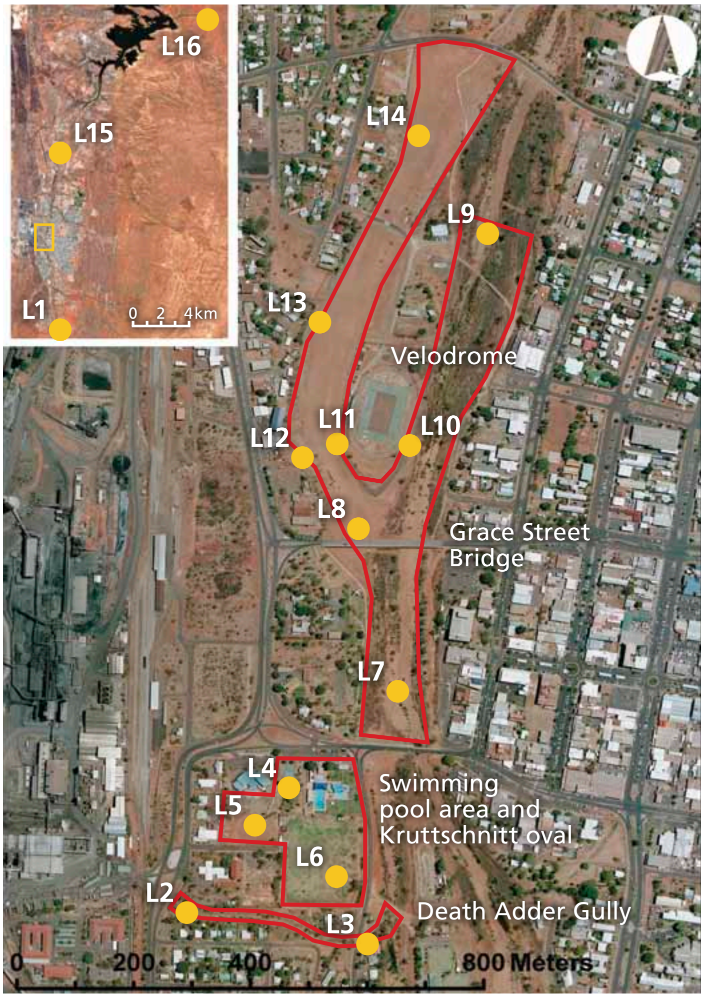


Figure 1: Sampling locations within the Leichhardt River and surrounding area and (map insert) upstream and downstream sampling points.

Sample category	Sample code
Soil (<2mm)	L1, L2, L3, L4, L5, L6, L8, L10, L11, L13, L14
Sediment (<63µm)	L1, L7, L9, L12, L15, L16

Table 1: Category of samples taken as part of the Land Report.

Figure 2: Sites exceeding NEPM Health Investigation Level E when adjusted for bioaccessibility factors – the metals which are in exceedance are noted at each location.

Soil Sample	Lead Total Concentration mg/kg	Bioaccessibility Factor %	Lead Concentration Adjusted for Bioaccessibility mg/kg	NEPM Level E HIL Exceedances HIL 600 mg/kg
L1	5.0	<1	0.1	No
L2	2,171.8	14	304.1	No
L3	2,462.8	12	295.5	No
L4	66.7	1	0.7	No
L5	339.5	8	27.2	No
L6	290.1	11	31.9	No
L8	25,009.8	16	4,001.6	Yes
L10	6,601.2	17	1,122.2	Yes
L11	6,710.4	16	1,073.7	Yes
L13	41,886.4	24	10,052.7	Yes
L14	292.6	20	58.5	No
L15	187.2	5	9.4	No
L16	31.5	<1	0.3	No

Table 2: Total lead concentrations and bioaccessibility adjusted concentrations of soil samples taken from the Leichhardt River and surrounding area.

When the bioaccessibility of lead and other metals for the samples was taken into account, the number of sites exceeding the NEPM HIL Level E criteria was reduced. However, the area of the Leichhardt River known to be impacted by historical contamination, between Grace Street Bridge and downstream of the Velodrome, continued to show exceedances for lead, copper, cadmium and zinc. There was also an exceedance for copper at one site located in the Death Adder Gully area. These sites are presented in Figure 2.

In order to understand the potential impact of these historical mine sediments on the Mount Isa community, a desktop human health risk assessment was undertaken focussing on two key contaminants, lead and arsenic.

The risk assessment considered the ways in which people could potentially be exposed to soils containing lead and arsenic including skin contact, ingestion and inhalation. The assessment took into account a person's potential daily intake of lead and arsenic through these exposure routes as well as the intake of lead and arsenic through a person's normal daily diet and drinking water. The results of the health risk assessment were compared with the metal and metalloid concentration and bioaccessibility data from the Leichhardt River and surrounding area to understand the site specific risk.

Through the desktop human health risk assessment it was determined that oral exposure (ie) hand to mouth activity resulting in ingestion was the most likely means of human exposure to both lead and arsenic in the Leichhardt River setting. The risk assessment also determined that:

- Soils sampled in this study are unlikely to cause acute or sub-chronic lead or arsenic toxicity in adults and children
- Chronic lead toxicity is unlikely to occur in adults
- Chronic lead toxicity is unlikely to occur in children as a result of activities undertaken in recreational areas
- Chronic arsenic toxicity is unlikely to occur in adults or children.

The risk assessment determined that in some instances the ingestion of soil with elevated lead concentrations and high bioavailablity, in addition to the normal dietary intake of lead, could result in a lead intake higher than the acceptable daily intake for young children. This could potentially occur if the soil had a lead concentration greater than 2,400 milligrams/kilogram (mg/kg) and the bioavailability of lead was greater than 10 percent or where the lead concentration was greater than 1,200 mg/kg and the bioavailablity of lead was greater than 20 percent. Over a prolonged period of time, a daily lead intake that continued to exceed the acceptable daily intake could have the potential to cause chronic lead toxicity in children.

However, the soil and sediment samples investigated in this study were taken from the Leichhardt River and recreational areas where the potential exposure time is limited. Therefore, it is unlikely that chronic lead toxicity could occur in children as a result of activities undertaken in these areas. The potential risk is reduced even further given that the bioavailability of lead in these samples will generally be much lower than the bioaccessability estimate which is used in this study.

Ecological risk assessment

The ecological risk assessment undertaken in this study involved two separate processes for the assessment of soils and sediments.

The NEPM Ecological Investigation Levels were used for the assessment of soils and were only applicable to samples from the swimming pool and Kruttschnitt oval area. The assessment of this area determined that there was no ecological health risk and therefore no further investigation was required.

The ecological risk assessment for sediments from the Leichhardt River involved the comparison of the heavy metal and arsenic concentrations in the sediment samples with the Australian and New Zealand Environmental Conservation Council's (ANZECC) Interim Sediment Quality Guidelines (ISQGs).

This assessment involved a comprehensive multi-stepped testing process in which the results of each test determined the direction of the investigation.

As part of the investigation, sediment toxicity testing was undertaken using aquatic test organisms. This testing was conducted by Ecotox Services Australasia, a NATA (National Association of Testing Authorities) accredited laboratory specialising in this type of work.

The ecological risk assessment found that sediments from two sites (L9 and L12) exhibited significant ecological toxicity when tested using aquatic macroinvertebrate test organisms and, therefore, require further investigation. In addition further investigation of all sites using a broader range of test organisms may be desirable. These findings are not applicable to human health.

Aquatic test organisms Ceriodaphnia cf dubia (left) and Corophium spp. used for sediment toxicity testing.

Acid generation assessment

As part of the study, samples from two locations east (L10) and west (L11) of the Velodrome were also assessed to determine their acid generating potential. These samples came from waste rock that had been placed in the area historically to prevent erosion. The likelihood of future acidification of the rock material due to oxidation and exposure to water, resulting in the release of heavy metals, was measured and assessed to be low.

Recommendations and actions resulting from the study

This study highlights the value of integrating human health and ecological health risk-based approaches to assess the significance of heavy metal and metalloid contamination. Recommendations based on the findings and observations from the study are outlined below. The findings presented in this study resulted in further remediation work to remove historical mine sediments from the Leichhardt River. The Leichhardt River Remediation Project Stage 2 was completed in June 2008 (refer to case study over page).

Recommendations	Actions
Verification sampling should be undertaken to confirm the success of the subsequent Leichhardt River Remediation Project in removing the contamination.	Xstrata Mount Isa Mines will undertake ongoing verification sampling of the project area following each wet season until 2011. Any remaining historical mine sediments, with the potential to contribute to elevated lead levels, will be remediated.
An investigation should take place into the cause of ecological toxicity adjacent to the Velodrome.	Further investigations into the cause of the ecological toxicity have been incorporated into the *Lead Pathways Study* Water Report to be undertaken by the CMLR.
Confirm sites requiring further detailed ecological risk assessment using a broader range of test organisms.	Further investigations have been incorporated into the *Lead Pathways Study* Water Report to be undertaken by the CMLR.
A more detailed assessment of bioavailability of heavy metals, particularly lead, using animal uptake studies should be undertaken to give a more refined human health risk assessment and to verify the predictive potential of bioaccessibility as a measure of bioavailability.	As part of *Lead Pathways Study* Air Report, animal uptake tests are being undertaken by the CMLR and EnTox to assess the bioavailability of heavy metals in the Mount Isa samples, including Leichhardt River samples from this study.
Further develop knowledge on heavy metal pathways that may have the potential to impact on human health.	The CMLR is continuing to investigate heavy metal pathways and the potential risk to human and ecological health as part of the *Lead Pathways Study* Water and Air Reports.

The Leichhardt River Remediation Project area during the 2008–2009 wet season.

Around 120,000 tonnes of material was removed from the Leichhardt River during remediation works conducted in May and June 2008.

In preparation for the Leichhardt River Remediation Project Stage 2, depth sampling was undertaken to further define the areas requiring remediation.

Leichhardt River Remediation Project Stage 2

The Leichhardt River Remediation Project Stage 2 was undertaken in May and June 2008 in response to the initial findings of the *Lead Pathways Study* Land Report.

The results indicated that previous remedial works of the Leichhardt River completed between 1991 and 1994 to remove historical mine sediments had been successful and the potential risk to human health was assessed to be minimal. However, natural river erosion had uncovered areas of additional mine related sediments. These findings were made available to the Mount Isa community in November 2007 and were reported in the 2007 Xstrata Mount Isa Mines Sustainability Report.

Even though the CMLR identified the potential risk to human health to be minimal, Xstrata Mount Isa Mines undertook the second stage of the Leichhardt River Remediation Project at a cost of around $1.5 million.

The Stage 2 remediation works covered a long stretch of the Leichhardt River from the Isa Street Bridge (south) to the Rugby Park (north). Around 120,000 tonnes of material was removed and safely disposed of on the Xstrata Mount Isa Mines lease. Ongoing sampling and analysis of the area will be conducted after each wet season until 2011.

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Updated and reprinted 2012
D10_XCU1981A_08/12

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