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NSW Environment Protection Authority

Subject

Report on practices to manage Lead (Pb) and Lead slag in soil and associated human exposure

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1. SUMMARY

The New South Wales (NSW) Environment Protection Authority (EPA) has sought the services of a consultant to undertake a literature review and prepare a report on practices to manage Lead (Pb) and Lead Slag in Soil and associated human exposure.

There are general principles and accepted practices under NSW and Australian regulations and guidelines noted from the literature on what constitutes a robust 'leading practice' lead remediation and/or management program, and these provided indications on where to look for equivalent investigations and works in the context of lead contamination in the North Lake Macquarie Area (NLMA). Standards and research have also been reviewed as they provide guidance on benchmarks and in some instances an additional level of detail on the significance of some clean up actions and other control measures compared with others. These provide valuable insights which can be applied locally.

The most significant factor contributing to reduced blood lead levels (BLL) in the target age range for children in the NLMA, is the cessation of airborne lead contaminated dust emissions associated with smelter closure. While BLL have dropped below the health investigation level (NH&MRC 2016) there remains a requirement for long term monitoring, not only of BLL, to ensure current control measures are effective and to ensure recontamination does not introduce exposure pathways of significance to human health.

The Lead Abatement Strategy (LAS) undertaken by Pasminco Cockle Creek Smelter (PCCS) with approval from the environmental regulator and planning authority in NSW, differs from overseas leading practice lead cleanup projects in many ways. The LAS was a program of finite duration, with spatial boundaries defined by a grid with lead smelter sourced material exclusions, specifically slag. The LAS focussed only upon cleanup of lead contaminated dust fallout from the smelter on residential properties in close proximity to the source. The PCCS site lies within the LAS grid. Within this site, the lead contaminated materials from residential LAS remediation as well as contaminated materials from within the PCCS site are encapsulated in a new containment cell. Remediation works are currently being undertaken within the PCCS site, by the Deed Administrators for PCCS, Ferrier Hodgson. The company webpage[1] states that the cell contains approximately 1.85 million m^3 of contaminated materials.

Outside the PCCS the long term impacts and responsibility for residual lead contamination has been externalised onto the community and environment. This includes lead contamination of:

- LAS Nominated Properties whose owners chose to participate in the Lead Abatement Program (LAP), and may still contain lead contamination
- LAS Nominated Properties whose owners chose not to participate in the LAP, and
- LAS-excluded areas.

Exclusions are summarised in the report and include those non-residential areas (such as public open space) as well as slag related contamination on the participating properties and impacts beyond the grid which include lead transported via drainage of the PCCS, slag used as construction material and fill in the Lake Macquarie City Council (LMCC) area, and lead contaminated sediments within the Cockle Creek catchment and North Lake Macquarie (NLM).

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[1] www.ferrierhodgson.com/au/industries/property/~/link.aspx?_id=928E96DB30C24B8AAE4B39B74E664602&_z=z

Institutional Control Programs (ICP) are evident to some degree, through the LMCC policies and planning schemes. However, there appears to be no single entity which is resourced to undertake further remediation where required, nor to systematically investigate those areas not included in the LAP. Post LAP cleanup data to demonstrate the performance of the program, as part of that program, are not evident. The auditor's statement was limited to a review, not an audit, due to the absence of a strictly followed regulatory process for the LAS unlike the process currently being applied to the PCCS site remediation.

1.1 Elements of Leading Practice Lead Remediation Programs

Leading practice programs may not have all of the following characteristics, however this list has been developed to summarise what was in evidence within the literature reviewed:

- Clear leadership and resourcing to plan, implement, monitor, engage and manage the cleanup.
- The establishment of lead remediation technical and health monitoring teams, whose role it was, to focus solely on the lead remediation program including long term management and community engagement.
- Responsible Party legislation which enables agreement to be reached between those parties contributing to the contamination and governments to provide resources for project management, cleanup works and ICPs.
- High levels of transparency not only in terms of expenditure but also in providing the evidence for specific actions and to demonstrate exposure reduction.
- Information is accessible to the public with dedicated webpages which pull together all relevant content on lead contamination risks (for that site/area), control measures, the cleanup program itself, good quality spatial data (updated regularly), progress and performance reporting.
- Active and adaptable stakeholder engagement programs throughout the cleanup program.
- Stakeholders include individual residential and commercial property owners, regulatory authorities, local councils (as public land owners and planning authority), state governments, the company(ies) involved, health authorities, catchment managers, developers, and in many instances national governments where funding and other resources have been provided and national governments have also undertaken comprehensive reviews. There are also formalised community and technical expert stakeholder groups which meet regularly as part of the engagement and implementation program.
- A robust data set and knowledge base from which to design the cleanup program.
- Removal of the critical lead contamination source as an effective control measure e.g. shut down of smelter or highly improved smelter technology which greatly reduces lead emissions to the atmosphere.
- In designing programs, recognition that soil outside of the home environment varies with distance from the source of contamination, not property boundaries, and intake estimates should account for soil sources in the immediate neighbourhood and greater community.
- Forensic analysis of emissions and other lead sources (e.g. tailings, slag) to estimate total lead loads to the environment and thereby identify at a coarse level the magnitude of the impact and the scope of the program cleanup to support planning.
- An understanding of the chemical forms of the lead and the bioavailability and bioaccessibility of those forms of lead to inform the risk and control measures that

may enable more advanced health risk assessment to be made taking account of the currently better developed methodologies and guidelines that were not in place when the LAS was first implemented.

- A system for prioritising sites with the aim of timely cleanup for the target demographic.
- Provision of a waste containment site (or multiple sites) with sufficient capacity to meet the requirements of the lead cleanup program now and in the future.
- Sourcing of sufficient clean soil materials for remediation works where contaminated soils need to be replaced, capped or covered.
- Wide age range blood lead level (BLL) screening initially, which is narrowed down to focus on the high risk age range, as the program evolves, based on the data gathered.
- Acceptance that ingestion is the primary exposure pathway according to current (state of the art) health risk assessment methodology and the target demographic is pregnant women and children 0-4 years with some programs highlighting a peak in BLL around 2 years.
- Target BLL < 5 µg/dL according to the NH&MRC (2016) recommendation.
- Appropriate education programs which support the cleanup and BLL screening programs for parents and children.
- Mechanisms to identify and address gaps or inadequacies in cleanup programs that makes use of advances in NSW and Australian formal methodologies for soil contamination.
- Programs apply relevant standards at the time (for BLL, lead in soil, lead uptake modelling methods etc.), and adapt to changing standards over time.
- Multiple sources of data to support BLL screening are used to help interpret the data and define control measures according to the currently accepted enHealth (2012) health risk methodology.
- Testing before and after control measures have been applied to evaluate their effectiveness against objectives and reporting on this.
- Programs which not only address the high priority areas, but then systematically evaluate all possible sources of recontamination.
- Attention to internal house lead dust cleanup as well as external as part of the program.
- In addition to residential yards, programs address garden beds where vegetables are grown (remove contamination from soil or construct raised garden beds with clean soil[2]), neighbouring properties, unsealed roads, road shoulders, railway easements and driveways.
- Also addressed are lead contamination transport mechanisms through geomorphic processes such as wind or water erosion and deposition. Anthropogenic disturbances (e.g. involving excavation of contaminated soils) are managed through planning controls, property owner agreements defined by the ICP.
- Reviews of programs identify that lead contaminated ground and surface water sources can be overlooked or not previously well-understood, so programs need to investigate these pathways and define control measures (e.g. this may require new surface drainage and underground stormwater systems to separate clean from contaminated waters).
- Riverine contamination removal integrated with the program to control further spread of lead in sediments.

[2] see Inner West Council – www.marrickville.nsw.gov.au/en/environment/in-your-home/gardening/

- Aquatic ecosystem bioaccumulation studies where human health impacts are possible through the food chain due to exposure of organisms to lead contaminated waterways (through water, food, sediments etc.) by people in the community as well as taking account of food gathering practices of indigenous people.
- Recontamination risks are clearly understood through systematically addressing the knowledge gaps and evaluating the control measures applied.
- A long term commitment to mitigate lead contamination and recontamination risks through effective ICPs which address all legal, administrative, policy and procedural requirements to ensure the works undertaken are effective and if not, or are disrupted by extreme events or other disturbance, there are appropriate responses, with clear responsibility and resources to address.

1.2 Recommendations

To ensure the lead abatement measures are maintained, it is strongly recommended that LMCC be involved with the recording of the requirement for on-going management of Nominated Properties where lead abatement measures have been implemented.

If not already occurring, LMCC should consider the requirement for a permanent physical barrier to indicate the separation of clean and contaminated materials as part of the ICP.

The remediation of all properties surrounding the smelter site is not yet complete. The responsibility to monitor and manage this appears to have been devolved to property owners under LMCC development and planning controls. Completion of remediation within the LAS area was not validated for soil contamination. Further examination is needed to understand if the works undertaken and institutional controls provide sufficient protection.

Institutional controls appear to be currently separated into different policy documents of LMCC. It would be valuable if the ICP existed in its own right as a point of orientation or 'road map' to all relevant controls. In so doing, a review should be undertaken which identifies any controls which are currently absent but may be needed, based on learnings from leading practice lead cleanup programs elsewhere. The ICP by LMCC, with endorsement of the NSW EPA and NSW Health, will need to ensure those aspects within and excluded from the LAS are addressed as well as:

a. Unsealed roads and road shoulders and railway easements.
b. Flood impacts which could mobilise or expose contaminated materials.
c. Controls over soil and rock removal from the base of hillslopes which could initiate instability. Also the requirement for construction of walls at the base of slopes as part of remediation to avoid sloughing into residential yards re-exposing contaminated soils.
d. Site selection and development of a containment structure for future slag recovered through remediation (and other lead contaminated materials) that can demonstrate, based on leaching property studies, retention of seepage from slag that might enter ground and surface waters.
e. Management of lead contaminated groundwater from interactions with surface water and soils in the vicinity of the former PCCS and interaction with Cockle Creek and Cockle Bay to minimise any effects on the aquatic ecosystem of Lake Macquarie. It should be determined if some aspects of this may be the responsibility of Ferrier Hodgson as part of post-remediation monitoring and maintenance.

f. Contaminated sediments in Cockle Creek and North Lake Macquarie require further assessment.
g. Specific ICP for long term management of the PCCS site, including monitoring that is updated, needs to take account of the current practices set out by enHealth (2012) and the NEPC (2013) for contaminated soil.
h. Should monitoring reveal there is any worsening of the levels of human exposure to lead in specific locations in the future, which cannot be easily remediated, consider some areas currently zoned residential, to be rezoned for a lower risk land use, based on the accepted health risk assessment approach as described above.
i. All recommendations from earlier studies, if not captured already, should be summarised in an overarching document (or web-page). The purpose of this step is intended to bring together all NLM lead contamination knowledge and study recommendations as well as how those recommendations have been implemented. If not implemented, then it should be stated why not. This would enable a proactive and risk-based approach to long term management of lead in NLM. High risk areas and issues could be identified through this process. Lead contamination is a long term issue so systems and personnel need to be focussed on management in the long term. This report identifies some of these risks, but perhaps not all. (During the review it was not easy to find the direct association between recommendations made in specific reports and LMCC policy updates. This does not imply they actions haven't occurred. For example, Douglas Partners' (2010) recommendations on black slag cannot be directly traced to an action plan). With any long life program, recommendations from earlier studies can be lost unless there is a strategic and continuous focus on knowledge management;
j. Good quality spatial data management to enable the superimposition of a range of datasets on the NLMA to inform lead risk management (e.g. Flood levels, acid sulfate soils, and soil lead concentrations).
k. Funding of the ongoing ICP as overseas studies noted that local rates and state taxes may not be enough. The ICP needs to be fully costed in order to evaluate resourcing requirements in the long term. Most programs identified there was no clear end point. A team of people with an appropriate skills set, whose responsibilities are solely focussed on the ICP is likely to be required. A legacy fund in some form is required to sustain the ICP.

High rainfall and flooding related remobilisation risks need to be evaluated to ensure control measures are put in place in high risk areas of the lower Cockle Creek Catchment, Cockle Bay and North Lake Macquarie aquatic ecosystems.

Further studies are required to investigate the pathways through the food chain to humans (via fish and shellfish), that may be current health risks, and also to study if bioaccumulation is a potential health risk to local people gathering local aquatic species as food sources.

The Winding Creek and Lower Cockle Creek floodplain risk management and Plan (WMA Water 2016; final draft, April 2016) should inform an environmental health study to evaluate the risk of lead recontamination. This should address remobilisation locations on the floodplain, banks and bed as well as Cockle Bay sediments and foreshore areas with the aim of quantifying risks for recontamination and applying control measures.

Collating all existing data and knowledge on the lead contaminated zone of Cockle Creek Catchment, Cockle Bay and North Lake Macquarie is an imperative. An

Environmental Management Plan is required for Cockle Creek and Cockle Bay to integrate all knowledge on the status of contamination and risks of recontamination. From this process, knowledge gaps can be more clearly identified. A systematic program of investigation is then required to address knowledge gaps as part of the risk assessment process. This would need to consider all possible lead pathways and human interactions with the river, lake, bed and banks which could remobilise contaminated sediments in order to evaluate human health risks. Then, a management strategy for these contaminated materials can be developed which will highlight areas that need to follow on. It is not clear if these areas are included in the LMCC Environmental Management Plan (EMP). Engagement with relevant stakeholders needs to occur as a matter of course and control measures applied.

Ensuring the maintenance of a centralised Blood Lead Level database by the NSW Health Department is considered necessary so that if future BLL screening requires the relevant historic data, the data can be available and made reference to, when new data are gathered. Planning for future BLL screening to ensure recontamination is not impacting human health is recommended, including in summer instead of winter. The application of BLL measurement was adopted for the Pasminco Boolaroo site before the availability of the accepted enHealth (2012) Australian health risk assessment methodology was in place. Currently BLL is assessed as the exposure step of the enHealth (2012) health risk assessment framework only. However, the hazard identification step considering contamination levels and dose of the health risk assessment framework for the remediated Pasminco smelter site that brings exposure assessment (BLL measurement) together is incomplete. Thus the risk assessment for the remediated Pasminco smelter site, according to current land management practice is not complete.

Site-specific assessment of bioaccessibility for lead as incorporated in the NEPM for contaminated soil by NEPC (2013) should be carried out using in-vitro tests that simulate the gastro-intestinal system such as the physiologically-based extraction test (PBET) in-vitro assay (Ruby et al. 1996) or Unified BARGE Method (UBM) (Denys et al. 2012) by following the accepted practice of the NEPC (2013, Schedule B4). Methods based on gastric-only phase do not simulate intestinal absorption of lead, the key absorption step in humans, and overestimate the prediction of lead bioavailability for human health risk assessment.

Procedures within the LMCC EMP should include a review of the GIS database for the location of lead contamination prior to works being undertaken.

The IEUBK (Integrated Exposure Uptake Biokinetic Model) is useful for validating soil total and bioaccessible-adjusted lead measurements but should not be the sole criterion for estimating health-protective soil concentrations as the input data may not all be correct (as happened at Trail, Canada) and needs to be validated by actual BLL measurement. Geographically complex sites may need improved methods involving GIS techniques that allow spatial relationships between populations and hazards to be examined and a decision making structure that follow the accepted Australian health risk assessment procedures of enHealth (2012). Generally, the surface terrain of the former smelter site is sloping towards Cockle Creek but is not considered to be a complex one. The use of GIS for plotting and comparing BLL with soil lead for NLM also demonstrated that the former smelter site is not a complex terrain (Willmore et al. 2006).

Site specific clean up levels can be derived from IEUBK model and be supported by site-specific measures of bioaccessible lead noting that lead uptake occurs via the intestinal phase and not from the gastric/stomach phase where solubilisation occurs.

In the NLMA there is no single publicly available map outlining areas where cleanup works have been undertaken or where contamination is still known to exist. There should be a collective goal of LMCC and NSW EPA to improve transparency and accessibility of mapped data. Leading practice programs overseas are characterised by such transparency.

Accumulation of lead and other metal levels accumulated in home grown vegetables at Boolaroo and surrounding suburbs has received limited study. This subject needs to be assessed as part of any further health risk assessment of exposure of individuals from soil in gardens of residential houses at Boolaroo.

The groundwater quality objectives for the PCCS site remediation (being undertaken by Ferrier Hodgson) are not within the scope of this review; however, groundwater data, monitoring sites and water quality status before, during and after the remediation should be reviewed. In the absence of this knowledge, groundwater and potential surface water interactions could pose potential risks for recontamination.

The State government should review whether Responsible Party legislation or its equivalent (polluter pays) in NSW or under Australian government legislation is adequate to mitigate the impacts and liabilities for remediation of contamination being externalised onto the community and environment in the future.

1.3 Structure of the report

This report is structured so that the regulatory context for lead contamination and remediation in NSW and NLMA is introduced. Then an overview of the LAS and LAP as implemented by Pasminco, is provided. Recognised frameworks for health risk assessment, contamination guidance, exposure pathways, form and species of lead identified, blood lead measured and prediction, as well as reference to water and sediment quality are then addressed. The report then systematically covers the key areas of focus of the literature review as they relate to ‘reducing human exposure to lead’, namely:

- Remediation and/or management programs that have been undertaken for comparable lead contamination sites and areas, ensuring that specific details regarding the form and species of lead are identified.
- The success of the programs and consideration of ‘best practice’.
- How the success or otherwise of the programs was evaluated or measured.
- The cost of the programs and/or indicative costs associated with management practices and strategies identified.
- Where exposure control was used, the methods used and their effectiveness.
- Where relevant, define and reference the meanings of bioaccessibility, bioavailability and bioaccumulation for consistency in reporting.

Other observations which have been noted during the literature review, largely from NLMA related studies, are summarised toward the end of the report prior to drawing conclusions from the literature review.

2. SCOPE OF WORKS

The New South Wales Environment Protection Authority (EPA) has sought the services of a consultant to undertake a literature review and prepare a report on practices to manage Lead (Pb) and Lead Slag in Soil and associated human exposure.

The objective of the consultancy is to review literature relevant to programs aimed at 'reducing human exposure to lead' and to report on the following key areas:

1. Remediation and/or management programs that have been undertaken for comparable lead contamination sites and areas, ensuring that specific details regarding the form and species of lead are identified.
2. The success of the programs and consideration of 'best practice'.
3. How the success or otherwise of the programs was evaluated or measured.
4. The cost of the programs and/or indicative costs associated with management practices and strategies identified.
5. Where exposure control was used, the methods used and their effectiveness.
6. Where relevant, define and reference the meanings of bioaccessibility, bioavailability and bioaccumulation for consistency in reporting.

Appendix A contains the complete Scope of Works.

2.1 Background Information

The suburbs of Boolaroo, Argenton and Speers Point in the North Lake Macquarie area of NSW, Australia are the subject of a legacy of lead contamination arising from the operation of the former Pasminco Lead and Zinc smelter in the area from 1897 to 2003 (Figures 1 and 2).

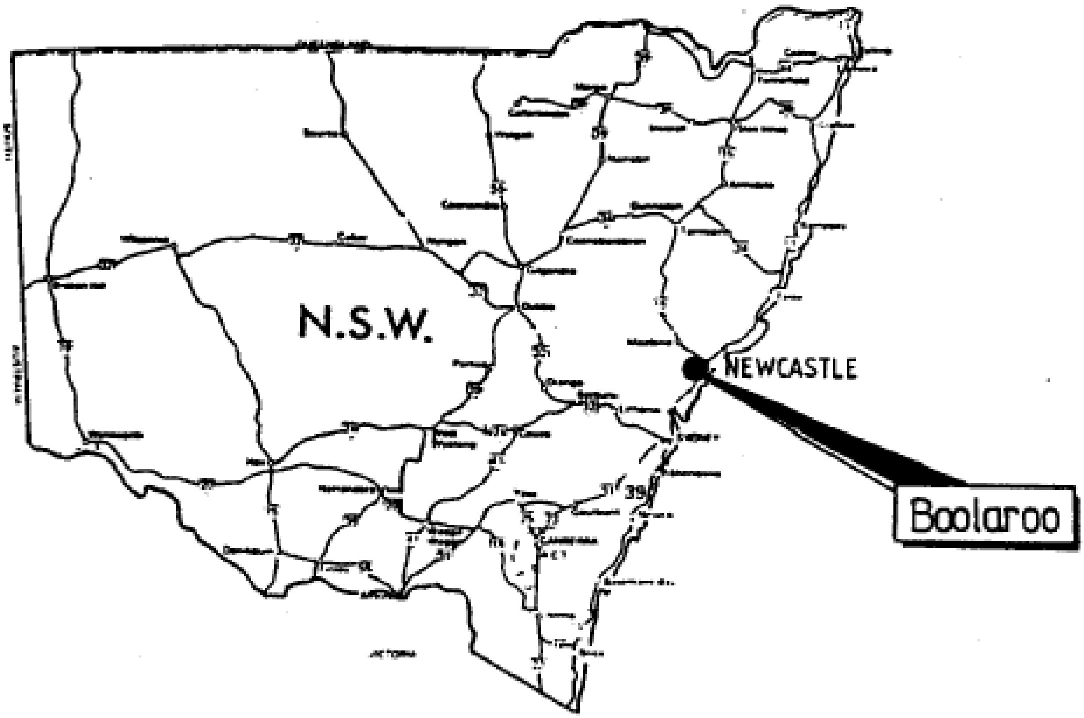


Figure 1 Location of Boolaroo near Newcastle (Environment and Earth Sciences 1993)

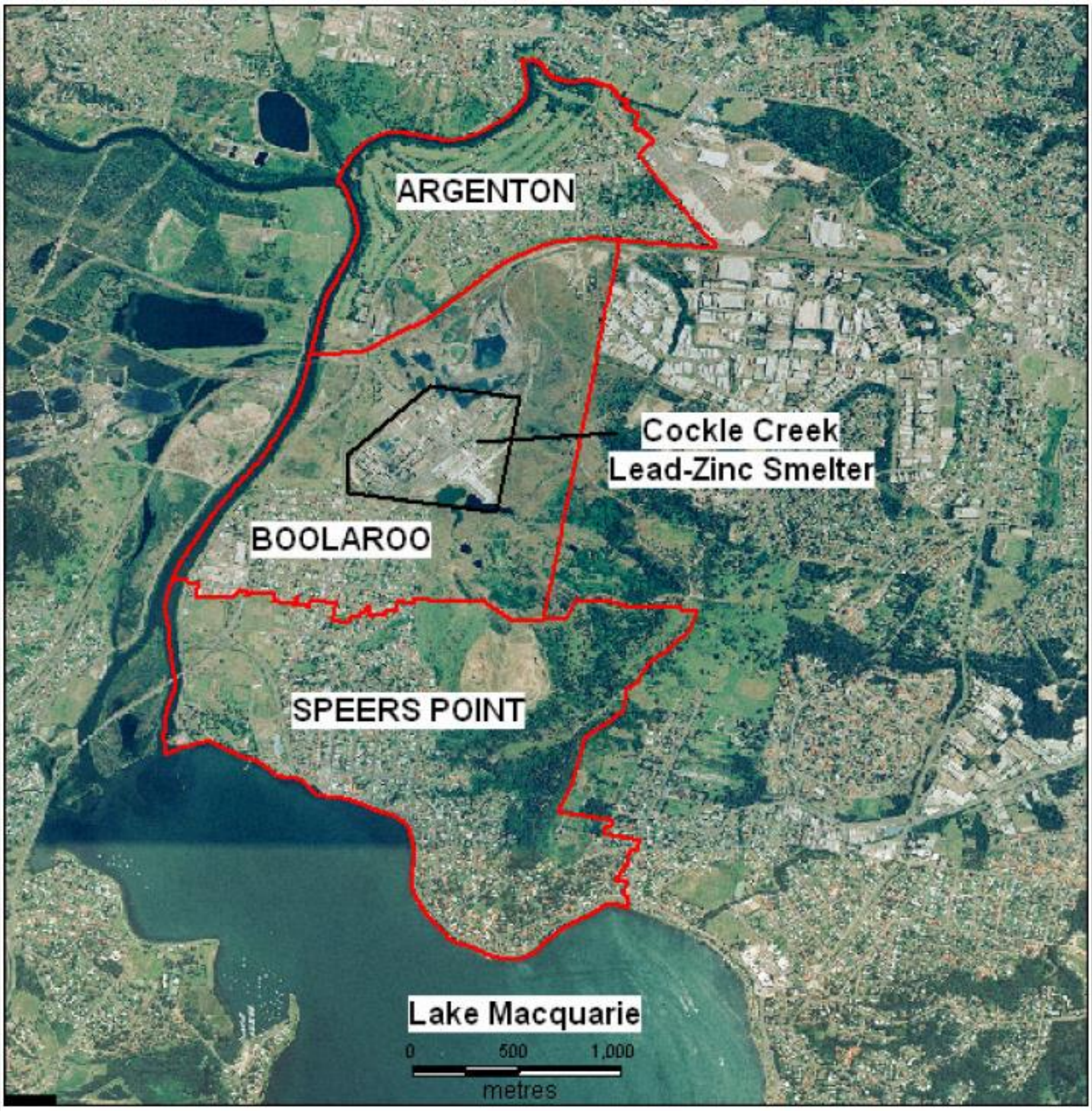


Figure 2 Location of the cockle Creek lead-zinc smelter in relation to the suburbs Boolaroo, Argenton and Speers Point, North Lake Macquarie, NSW, Australia (Willmore et al. 2006)

The original smelter has been demolished and the entire industrial site has been remediated by excavation and placement of contaminated soil in an onsite containment cell. Hence, there are no ongoing smelter emissions; nor should there be any significant lead dust contamination arising from the former smelter site. This should be verified by the current monitoring of the site during remediation, but lies outside the scope of this review. The sources of contamination to be considered by this review are as follows:

- The residual lead contamination in surface soil, roof and wall cavities from point source and fugitive (or fume) emissions associated with former smelting works.
- Lead-slag and lead-slag impacted soil used as imported fill onto properties.

The affected areas of these suburbs are primarily residential (approximately 2,500 residential properties), light commercial/industrial, recreational and parkland over an area of approximately 500 ha excluding the former smelter site. Additionally, the wider Hunter region surrounding the former smelter has been subject to the widespread use of lead-slag from the Pasminco smelter, and other industrial sources (Willmore et al. 2006).

Considerable literature exists relating to the management of contaminated land which resulted from the historical mishandling of lead pollutant sources, and/or lead containing waste streams (Gulson et al. 2004). Additionally, lead is ubiquitous in the urban environment from sources such as mineral processing; lead paint; motor vehicle emissions; battery manufacturing and recycling; rifle ranges and other sources where lead is processed or used in industry (Elias and Gulson 2003, Gulson et al. 1995, Lanphear et al. 2003). Where possible, the literature relevant to this review should be identified as being focused on similar legacy contamination issues or comparable sites/areas to the former Pasminco smelter in NLMA where the lead contamination resulted from point source and fugitive (or fume) emissions associated with smelting works and the widespread use of lead-slag (Morrison 2003).

The Literature Review is being prepared by the EPA to inform the deliberations of the Lead Expert Working Group (LEWG). The purpose of this group is to provide understanding of past actions and to determine those future actions which are required to further address lead contamination in the area, particularly where human exposure pathways are identified.

3. INTRODUCTION TO REVIEW OF LITERATURE

Reports provided by NSW EPA and others for this literature review comprise the following types of documents:

- Scientific papers published in peer reviewed journals (predominantly on soil and blood lead levels, as well as mapping locally and measurement methods globally and review of the Lead Abatement Strategy (LAS);
- Presentations from community meetings;
- Standards and regulatory guidance documents (including Fact Sheets) from Lake Macquarie City Council (LMCC), New South Wales and Australian government, and overseas;
- Company technical reports on environmental studies on the Pasminco refinery site to meet regulatory requirements;
- Government initiated technical studies/reports on the local area and specific materials (e.g. Cockle Creek, Cockle Bay and black slag);
- Lead Abatement Strategy (LAS) project details;
- Lead Expert Working group documents; and
- Overseas Case study reports and published papers.

The review of literature examines published papers and reports that have dealt with lead mining, concentrating and smelting and the specific issue of investigating, identifying and quantifying human exposure to lead at key sites throughout Australia and internationally, particularly in Canada and the USA. All supplied and available reports were read to give familiarity with the contents and enable key details of soil contamination data to be compiled, summarised and interpreted in the context of assessing soil metal contamination against the Australian National Environment Protection Measure (NEPM) for soil contamination (NEPC 2013). Selected other data sources and literature comprising published papers and reports accessible from the internet were also reviewed. Particular attention has been paid to locating literature and report details of remediation and/or management programs that have been undertaken for comparable lead contamination sites which give specific attention to the form and species of lead identified. Key elements of leading practice lead cleanup programs have also been summarised with the aim of indicating opportunities to sustain improvements in lead contamination management in the NLM area.

Focusing questions that can be applied to this study are as follows:

- What are the potential pathways of lead from the rehabilitated smelter area and remnant contamination from lead slag and residual lead contamination in surface soil, roof and cavities from point source and fugitive (or fume) emissions associated with former smelting?
- How does the form of lead in the environment affect its ability to affect human health?
- What is the risk to the Boolaroo population, particularly to young children, from exposure to the residual lead contamination?
- What procedure was used to determine the risk to the health of the Boolaroo population?
- What measures can be taken to reduce the lead risk?
- What would benefit from further examination of lead contamination?
- How will NEPM be applied in this context to bring about good outcomes for human health in an effective manner?

3.1 Regulatory requirements in NSW

Land management of the former Pasminco smelter in NLM falls under the jurisdiction of NSW state and local government agencies.

Lake Macquarie City Council (LMCC 2016) is required to ensure that the use of contaminated land, or suspected contaminated land, occurs by minimising risk to the community and the environment by ensuring compliance with the requirements of the NSW Contaminated Land Management Act 1997 (CLM Act), State Environmental Planning Policy (SEPP) 55 - Remediation of Land and the associated Managing Land Contamination: Planning Guidelines 1998.

The requirements for management of contaminated land in Lake Macquarie City are set out in the CLM Act, SEPP55, Managing Land Contamination: Planning Guidelines 1998, Lake Macquarie LMLEP 2014, and Lake Macquarie LMDCP 2014.

The management of contaminated land is a shared responsibility between the NSW EPA, NSW Department of Planning and Environment (DP&E), and Lake Macquarie City Council.

Under the CLM Act, the NSW EPA regulates contaminated sites that are significant enough to warrant regulation (see Part 3 Division 2 of the CLM Act). The NSW EPA:

- Regulates the appropriate investigation and clean-up of significantly contaminated land;
- Administers the NSW site auditor scheme under Part 4 of the CLM Act;
- Makes or approves guidelines for use in the assessment and remediation of contaminated sites;
- Administers the public record of regulated sites under the CLM Act.

Contaminated or potentially contaminated sites that are not regulated by the NSW EPA are managed by LMCC through land use planning processes i.e., SEPP55 and related guidelines, LEP 2014, DCP 2014, and any other relevant council policies and procedures.

Lake Macquarie City Council has developed a framework to manage those sites, which are contaminated or potentially contaminated, that do not pose an unacceptable risk to human health or the environment under its current or approved use. The planning and development process will determine what remediation or abatement is required to ensure the land is suitable for a different use. This policy is a land-based policy only. Part 7A of the Environmental Planning and Assessment Act 1979 (EP&A Act) provides that planning authorities who act substantially in accordance with SEPP55 and related guidelines, are taken to have acted in good faith when carrying out planning functions.

Note that the regulation of water contamination with lead and associated metals and subsequent uptake by aquatic biota is not dealt with here but may be covered elsewhere under regulations of the NSW EPA. Guidance for contamination of water and sediment is given in the ANZECC/ARMCANZ (2000) decision processes and water quality criteria and may be relevant to potential human health effects via consumption of aquatic species such as fish and shellfish arising from lead dispersion to Upper Lake Macquarie from the former Pasminco smelter site (Section 4.5.8).

Lake Macquarie City Council can also determine if the land is affected by a Policy that restricts the development of the land because of a contamination risk. Notifying restrictions on land use and any other additional information is also applied by Lake Macquarie City Council by using 'Notations' as a component of Section 149(2) planning certificates at Question 7(e) (Council and other public authority policies on hazard risk restrictions) in the following cases:

“Notation 1. Contaminated or potentially contaminated land:

Where land has a previous site history which could have involved contaminants, or is in the vicinity of a contamination source, and is identified in Council’s Database of Contaminated or Potentially Contaminated Land, the following notation will be included:
Lake Macquarie City Council has adopted a policy that may restrict development of Contaminated or Potentially Contaminated land which is implemented when zoning, development, or land use changes are proposed. Consideration of the adopted Policy located in DCP 2014, and the application of provisions under relevant NSW legislation is recommended. Lake Macquarie City Council can provide additional information from its records for this site on request. In particular, this notation applies to a number of properties in the LGA, and also applies where the LAS Program testing shows that lead levels in soil are above the 300 mg/kg HIL Level A threshold for lead (Table 1), and remediation has not been undertaken. When a property participates in the LAS program, Notation 1 will be removed and replaced by Notation 2, i.e. acknowledging site remediation was carried out. If a property has not participated in the LAS, then Notation 1 remains on that property.

Notation 2. Contaminated or potentially contaminated land that has undergone some form of remediation or abatement:

Where land has a previous site history which could have involved contaminants, or is in the vicinity of a contamination source, and the land has undergone some form of remediation or abatement in anticipation of a particular use, or range of uses, the following notation will be included: Lake Macquarie City Council has adopted a policy that may restrict development of Contaminated or Potentially Contaminated land which is implemented when zoning, development, or land use changes are proposed. Consideration of Council’s adopted Policy located in DCP 2014, and the application of provisions under relevant NSW legislation is recommended. Council can provide additional information from its records for this site on request, including details of any remediation works that have occurred. This notation applies where information is provided to Lake Macquarie City Council, being a Site Audit Statement, Site Audit Report, Management order, Voluntary management proposal, Ongoing maintenance order, LAS reports or that slag contamination exists on the site and is encapsulated (covered with acceptable material, or placed under a concrete slab etc.).

Notation 3. Land that has undergone some form of testing (including participation in the Pasminco LAS) and found to be under the threshold level for further investigation:

Where land has a previous site history, which could have involved contaminants, or is in the vicinity of a contamination source, and the results of testing for contaminants are below the level of investigation identified in the NEPM 2013 Guidelines, and SEPP55 guidelines, e.g. less than 300 mg/kg lead in soil for Residential use following HIL Level A (NEPC 2013), the following notation will be included:

Lake Macquarie City Council has adopted a policy that may restrict the development of Contaminated or Potentially Contaminated land. This policy is implemented when zoning, development, or land use changes are proposed. Consideration of the Council's adopted Policy and DCP 2014, and the application of provisions under relevant NSW legislation is recommended.

Lake Macquarie City Council can supply additional information from its records for this site on request, including tests that indicate that the level of certain contaminants is below investigation thresholds.

Notation 4. No clear site history:

Where Lake Macquarie City Council records do not contain a clear site history for the land or there is inadequate knowledge of uses that may have led to contamination or potential contamination, the following notation will be included:

Lake Macquarie City Council has also adopted a policy that may restrict the development of Contaminated or Potentially Contaminated land. This policy is implemented when zoning, development, or land use changes are proposed if Lake Macquarie City Council does not hold sufficient information about previous use of the land to determine whether the land is contaminated. Consideration of Council's adopted Policy located in DCP 2014, and the application of provisions under relevant NSW legislation is recommended. This 'Notation' only applies where Lake Macquarie City Council records do not contain a clear site history, or where there are gaps in that information, so there is not sufficient information to have any certainty.

The following information should be provided on all Section 149(5) Planning Certificates, or provided during any other enquiries made to Lake Macquarie City Council about land, if held in Council's database:

- Any activities listed in Council's DCP 2014, or SEPP55 shown by Council's records as having occurred on the land
- The results of any site investigations held by the Council
- The results of any site abatement
- Any notifications of remediation
- Copies of any site audit statements if held by the Council.

All information recorded and actions taken, such as remediation or abatement, will be held in Lake Macquarie City Council's database in perpetuity as factual information about the land and available to all enquirers.

Other information that may be relevant to an enquirer under Section 149(5) or other enquiries made to Council about land in the CPCL Database should include any of the types of information that may be held by Council as listed in Attachment 1 of this Policy.

Limitations on information in Section 149 certificates Council will specify in a planning certificate any limitations on the information regarding contamination contained in that certificate. Limitations may arise as a result of the purpose for which the information was collected by Council or provided to Council, or the reliability of the source of the information" (LMCC 2016).

3.2 Lead abatement strategy

Pasminco Cockle Creek Smelter (PCCS) under agreement with the administrators developed a Lead Abatement Strategy Implementation document (PCCS 2007). The strategy was developed with input from a lead expert. Nominated properties in the three suburbs (Figure 3) were specified as part of the development consent issued by the government (14 November 1995) following a Commission of Inquiry.

Figure 1

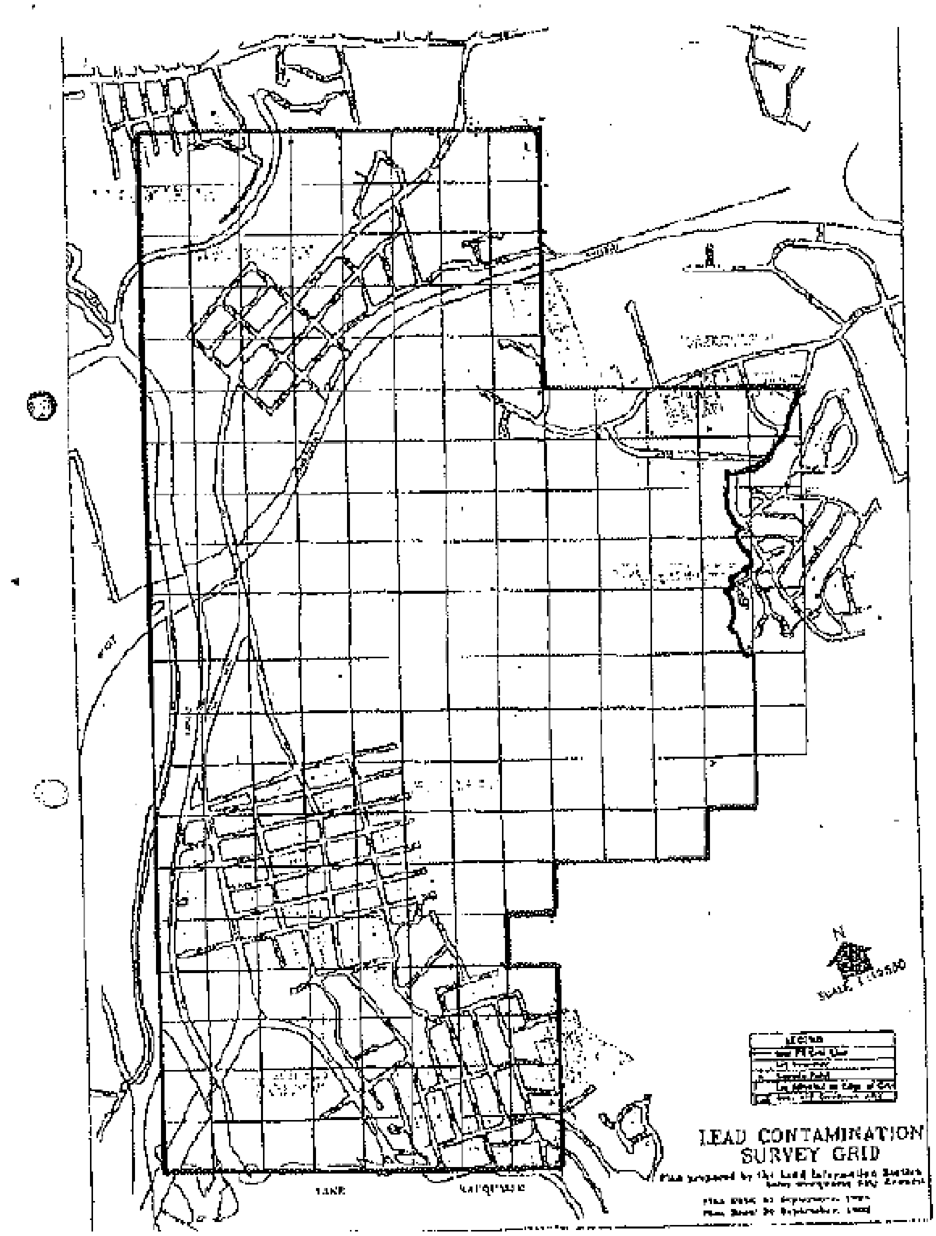


Figure 3 Lead abatement survey grid

‘The Lead Abatement Strategy (LAS) focussed on lead dust deposition not on the presence of lead slag used for fill in a number of properties because slag was used on a voluntary basis whereas dust deposition was not a voluntary action’ (PCCS 2007 p8).

Participation in the LAS was voluntary so not all properties nominated participated. It is difficult to find a map that shows which properties were actually remediated as compared with those identified but not remediated. LMCC may have this data on their database. The Institutional Control Program (ICP) is not clearly identified however it is apparent that LMCC provides planning control and other guidance. This review was not able to ascertain whether the two categories of property are clearly identified.

Because the focus of the LAS was on dust fallout on residential yards within a defined grid there remain questions about other areas and sources. They include garden beds for food growing, driveways and slag.

It is not clear what strategy is in place to evaluate lead risk from these sources. Lead contamination in recreational public space, (land in LMCC's care and control), is addressed in the LMCC Environmental Management Plan (LMCC 2016). Lead slag sources may be mapped on the LMCC database, however it is not clear how well soil lead levels are understood and managed in public open space. Additionally, the complete Cockle Creek bed, banks and floodplain were not included within the LAS. In parts of the grid (Figure 3) where soil sampling was undertaken close to Cockle Creek there are apparent lead hotspots (Figure 6). Questions remain about the human health risks associated with direct ingestion of dust or through the food chain from Cockle Creek Catchment and North Lake Macquarie.

Advice on appropriate barrier construction is given in Fact sheet 12 (LMCC 2015a) and recommends a soil barrier to isolate lead contaminated soils from non-lead contaminated soils. This approach is different to case studies reviewed overseas where a permanent fabric barrier is used (Hilts 2003). It is not clear how, in the NLMA, without a permanent physical barrier to isolate lead contaminated materials from non-contaminated materials within the LAS area, recontamination can be prevented.

Wilmore et al. (2006) set out to determine patterns of childhood lead exposure in a community living near a lead and zinc smelter in NLM, Australia between 1991 and 2002. This was undertaken by analysing serial blood lead levels (BLL) of children less than 13 years of age in NLM participating in voluntary blood lead screening. Distance to the smelter and soil lead concentration of the child's place of residence was calculated. Categorical analysis of BLL by residential distance from smelter, residential soil lead concentration, age and year of sample was calculated. Linear regression models were fitted for blood lead levels against residential distance from smelter, the log of residential soil lead concentration, age and year of BLL sample.

The finding of Wilmore et al. (2006) was that the geometric mean BLLs were statistically significantly higher for distances less than 1.5 kilometres from the smelter and for residential soil lead concentrations greater than 300 mg/kg HIL Level A (Table 1). Yearly BLLs since 1995 were statistically significantly lower than for preceding years, with an average decrease of 0.575 µg/dL per year since 1991. BLLs are statistically significantly higher for children whose age is 1 to 3 years old. Linear regression modelling of BLL predicted a statistically significant decrease in BLL of 3.0831 µg/dL per kilometre from the smelter and a statistically significant increase in BLL of 0.25 µg/dL per log of lead in residential soil. The model explained 28.2% of the variation in BLL.

From this study it was concluded that residential distance to the smelter, log of residential soil lead concentration, child's age and year of BLL sample are statistically significant factors for predicting elevated BLLs in children living near the NLM lead smelter.

The LMCC may have records on the Nominated Properties treated and those where owners chose not to engage with the LAS, however data of this nature was not easily accessible for the purposes of this review. It is not clear what follow up measures are maintained on those Nominated Properties. Because there are a number of policy documents, one centralised ICP may provide easier access to the overall program of long term management.

3.3 Contaminated land auditor on LAS

Evaluation of the LAS did not require the issues of a formal Site Audit Statement. It is noted that not all issues within the LAS study were within the scope of the Site Auditor and are the responsibility of the agencies LMCC & EPA. Bill Ryall, (HLA 2007) undertook the review of the LAS. Bill Ryall is a Site Auditor accredited by the NSW EPA (then part of the Department of environment and Climate Change (DECC)) under the Contaminated Land Management Act 1997. With respect to the type of review required, NSW DECC has advised that:

> "as the sites being dealt with under the LAS are not declared or regulated by the DECC/EPA and there is no formal requirement for auditing of the process of the work, DECC considers that it is neither appropriate nor warranted for a Site Auditor to issue a formal Site Audit Statement on the LAS".

As a consequence of DECC's requirements, only an informal review has been undertaken and no Site Audit Report or Site Audit Statement has been, or will be, issued. The review is considered to be outside of the requirements of the Contaminated Land Management Act 1997 (HLA 2007). The contaminated site auditor for the LAS (HLA 2007) noted the following in his review of the lead abatement strategy report:

- LAS and LAP terminology have been used interchangeably when one is the concept and the other the program of works;
- Some aspects lie outside responsibility of a Site Auditor (and are the responsibility of regulatory authorities);
- LAP was not applied to public open space;
- The report has problems with use of term certifier and auditor; and
- The importance of LMCC being involved in recording the requirement for ongoing management of Nominated Properties where lead abatement measures have been implemented, was emphasised.

In their conclusions (HLA 2007) it was noted that a critical element of the Lead Abatement Program (LAP) is considered to be the management of Nominated Properties after completion of the LAP. To ensure the lead abatement measures are maintained, it is strongly recommended that LMCC be involved with the recording of the requirement for on-going management of Nominated Properties where lead abatement measures have been implemented.

3.4 Environmental Management Plan LMCC

The Environmental Management Plan (EMP) for Contaminated Land in Council's Care and Control v2 24 Feb 2016 (LMCC 2016) states that exposure pathways do not include those pathways via ecosystems/biota, nor does it address bioaccumulation. The scope of this EMP also does not extend to non-land based contamination, or the management of contamination on private land.

Section 2.1 states that while black slag isn't exposed at the surface it is not an environmental and public health hazard. However, this statement does not address the potential interactions of black slag with water (surface and groundwater).

The existence of high lead concentrations in soils at the former Pasminco site is also identified (Harvey et al. 2016). There are also parts of the Cockle Creek flood plain which have not been included in soil lead studies. This may be justified from a human health perspective which has focussed on residential properties, however it poses a knowledge gap around potential contamination where it could be mobilised and create new exposure areas as a consequence of recreational activities or fluvial processes.

Apart from a limited study of cadmium, lead and zinc uptake in home-grown vegetables in gardens at Boolaroo houses (Kachenko and Singh 2004), there appears to have been no comprehensive study of home grown vegetables since that time. The limited results of Kachenko and Singh (2004) showed that predominantly leafy vegetable samples (n=40) exceeded the maximum level (ML) food standard guidelines for cadmium and lead at that time. Thus lead and other metal levels accumulated in home grown vegetables need to be considered as part of any further health risk assessment of residential houses at Boolaroo.

3.5 Recognised Frameworks

The success of programs to control human exposure to lead will be assessed against available data for soil total lead concentration and local population blood lead levels against appropriate guidelines using recognised frameworks. Best practice involves following the risk assessment approach following enHealth (2012) with guidance of NEPM (NEPC 2013) and the NH&MRC (2016).

4.5.1 Risk assessment

The risk assessment procedure for considering the impact of chemicals, which is generally adopted (enHealth 2012), considers the following steps:

- Hazard identification
- Dose response assessment
- Exposure assessment.

Risk characterisation then enables the estimation of any adverse effect and provides a means of devising risk management if appropriate. Risk management can then be applied on the basis of the assessments given below.

Risk assessment is a process that enables management and communication tools to be developed to aid controlling any adverse effects of chemical applications (Ricci 2006). It comprises the discrete steps of identification of source and hazard, dose response, exposure and calculation of risk (ISO 31000 2009). There may be acceptable risk management concepts that will apply to public health and the environment arising from exposure to contaminated materials when applied under controlled conditions as pure or mixed formulations, if the effects of these formulations on public health and the environment are not found to be detrimental.

4.5.2 Health risk assessment

The recognised framework for health risk assessment in Australia is Environmental Health Risk Assessment Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012). The guidelines present a general environmental health risk assessment methodology which has been adopted nationally to evaluate risks and establish standards for the protection of human health and the environment.

Previous studies of dispersion of metal in dusts have indicated that the primary pathways from various sources to the receptors are inhalation and ingestion of materials. Generally, it is recognised that 95% of exposure to dispersed lead material arises from ingestion and 5% from inhalation (Davies et al. 1990). Following enHealth's risk assessment approach (enHealth 2012), a variety of guidelines, standards and procedures can be employed. In cases of minor exceedances of investigation levels or exceedances related to contaminants that have low human toxicity and limited mobility, a qualitative risk assessment may be sufficient. The risk assessment process (enHealth 2012) may lead to the development of site-specific response levels generated by the risk assessment and agreement between the professionals assessing the site and regulatory authorities. The Tier II risk assessment process (see below) described by NEPC (2013) allows for toxicity assessments when HILs for the designated category or land use are exceeded. For example, bioaccessibility giving a simulation of human gastro-intestinal uptake is now accepted by NEPC (2013) to assess lead bioaccessibility to predict bioavailability and gives comparative data for other metals for health risk assessment purposes.

Blood lead measurement for example is the key data item of the 'Exposure assessment' step in the health risk assessment of lead. 'Hazard identification' and 'dose response assessment' are undertaken using data from soil contamination studies and bioavailability measurement by animal uptake experiment or prediction with bioaccessibility measurement.

In the absence of data from the ‘hazard identification’ and ‘dose response assessment’, the health risk assessment (enHealth 2012) is not completed for the particular site.

4.5.3 Soil contamination guidelines

The NEPM (Assessment of Site Contamination) provides the soil guidelines used in Australia to assess health and ecological effects on a site-specific basis (NEPC 2013). A site may be assessed based on investigation levels, or a site-specific assessment can be undertaken. The NEPC provides a framework for investigation levels (NEPC 2013, Schedule B4), which are principally described as ‘Investigation Levels’ or ‘Response Levels’. Soil NEPM can be applied if the contamination of soil by dust fallout is considered to be a health issue as in the case with children who may be exposed to up to 95% of lead in surface dust via ingestion and transfer to the gastro-intestinal system (Davies et al. 1990).

Investigation Levels for human health exposure are generally the Health Investigation Levels (‘HILs’). To accommodate the range of human exposure settings, a number of generic Investigation Levels have been set (NEPC 2013) based on land use and human activity. HILs are defined as “the concentration of a contaminant above which further appropriate investigation and evaluation will be required” (NEPC 2013). HILs are only used for assessing existing contamination and are intended to prompt an appropriate site-specific assessment where levels indicate there is the potential for adverse effects on human health values for that site. The site should be sufficiently characterised to provide a complete hazard assessment according to enHealth (2012) and the designated Investigation Levels to ensure the comparison is meaningful and appropriate; e.g. for houses or recreation activities. Table 1 gives the soil investigation levels for lead (NEPC 2013).

Table 1 NEPM Soil Investigation Levels (HIL = Health Investigation Level) (NEPC 2013)

Metal	Residential			Commercial
(mg/kg)	(HIL Level A)	(HIL Level B)	(HIL Level C)	(HIL Level D)
Lead (Pb)	300	1200	600	1,500

Note:

Level A – Residential with garden/accessible soil (home grown produce <10% fruit and vegetable intake, (no poultry), also includes children’s day care centres, preschools and primary schools.

Level B – Residential with minimal opportunities for soil access includes dwellings with fully and permanently paved yard space such as high-rise buildings and apartments. Level C – Public open space such as parks, playgrounds, playing fields (e.g. ovals), secondary schools and footpaths. This does not include undeveloped public open space where the potential for exposure is lower and where a site-specific assessment may be more appropriate.

Level D – Commercial/industrial includes premises such as shops, offices, factories and industrial sites.

Soil and dust concentrations may be compared against the NEPM criteria (NEPC 2013). The Australian Standard 4482.1 Guide to the investigation and sampling of sites with potentially contaminated soil, Part 1: non-volatile and semi-volatile compounds (Standards Australia 2005) and NSW EPA soil sampling guidelines (DEC NSW 2006) provide guidance for collecting sufficient and reliable information for the assessment of a site potentially contaminated by metals and metalloids.

The human health risk assessment process for contaminated land is undertaken in stages or ‘tiers’ involving progressively more detailed levels of data collection and analysis. In the NEPM guidance is given on the use of the tiers referred to as Tier 1, Tier 2 and Tier 3. The approach provides for assessment at a level of complexity that is appropriate for the problem under consideration; the degree of health protection achieved is equal at each tier (NEPC 2013 Schedule B4) as follows:

- The Tier 1 (or screening level) assessment is the first stage of assessment at the site. It includes a comparison of known site data with published risk-based guidance levels, such as the HILs.

- A Tier 2 assessment is typically required when one or more contaminants are present at the site at levels that significantly exceed Tier 1 guidance criteria, if there are no appropriate Tier 1 criteria, or if there are unresolved and significant uncertainties identified in the Tier 1 assessment. Tier 2 assessment includes a site-specific risk assessment and the development of site-specific target levels for comparison with site data.

- A Tier 3 assessment may be required where exceedance of Tier 2 site-specific target levels is judged to represent a potentially unacceptable risk to human health. The Tier 3 assessment typically focuses on the risk-driving contaminants in more detail, although studies aimed at reducing the uncertainties inherent in the modelling of exposure pathways are also common at Tier 3.

4.5.4 Exposure pathways

Human health risk assessments have found that ingesting soil and dust can be a major route of exposure to immobile soil contaminants. For example, direct correlations between blood lead and children's rates of hand-in-mouth and object-in-mouth behaviours have confirmed the direct relationship between hand-to-mouth activities and blood lead levels. There is also an association between the high contributions of soil or soil-borne materials and high blood lead in children. This is because ingestion via hand to mouth transfer (10 µm to 250 µm size dust) is responsible for up to 95% of exposure.

The inhalation pathway accounts for 5% or less of exposure from dust (Section 4.5.2) and is restricted to fine airborne particulate matter ('PM') that can get into the airways and into the lungs depending on the volume of air breathed in during 1 day. Particulate matter is categorised according to various diameters or sizes based on the physical property of airborne material (NEPC 2002). PM_{10} and $PM_{2.5}$ are mixtures of solid particles and liquid droplets found in the air, with particle size less than 10 µm and 2.5 µm, respectively (NEPC 2002). They pose the greatest problems for human health, because they can penetrate deep into the lung and get into the bloodstream. Fine particles capable of penetration deep into the lung are believed to be completely absorbed into the blood stream. Particles larger than about 7 µm tend to deposit on the walls of the airways (the thoracic region) and become part of the mucus that is moved up to the mouth and then swallowed. $PM_{2.5}$ gives an approximation for fine mode particles, and therefore alveolar deposition, while PM_{10} indicates the thoracic aerosol component.

People may be exposed to contaminants from sources such as food, air and water; collectively this exposure from other sources is termed background exposure. For the majority of contaminants of concern from land contamination, the background exposure will primarily be from food and water. There are three potential exposure pathways to humans, namely dermal, inhalation/ingestion (particle size dependent as discuss before) and oral exposure. Dermal exposure from metals and metalloids in dust is generally considered to be insignificant while dust ingestion is the accepted major pathway of exposure.

The inhalation of dust containing metals and metalloids is an important consideration in lead slag dust dispersion. Larger particles (1 – 5 µm) will usually lodge at different regions along the respiratory pathway during inhalation, and are eventually moved up into the oral cavity and swallowed. Smaller particles (<1 µm) will often lodge as far as the alveoli, and may also be moved out of the lungs and swallowed or alternatively absorbed directly into the lymphatics. Insoluble particles deposited deep within the alveoli may be retained for extended periods.

Oral ingestion is usually the most significant exposure pathway relatively to the dermal or inhalation exposure route. This is particularly true for young children because their incidental ingestion of soil via hand-to-mouth activity is much higher compared to adults both in absolute amount as well as intake per unit body weight.

A detailed review by Ng et al. (2015) as part of the revision of the NEPM in 2013 concluded that physiologically-based extraction procedures were acceptable for use at Tier 2 to estimate the bioaccessibility of lead.

Site-specific assessment of bioaccessibility for lead may be carried out using in-vitro tests such as the physiologically-based extraction test (PBET) in-vitro assay (Ruby et al. 1996) or Unified BARGE Method (UBM) (Denys et al. 2012) (NEPC 2013, Schedule B4).

4.5.5 Management issues

LMCC provides guidance to its personnel and contractors on management of exposure pathways for black slag. Works on contaminated land, owned or managed by Council (LMCC 2016), must consider the exposure to:

1- Members of the community that are currently using Community or Operational land (parks, playgrounds, sporting fields, childcare centres etc.);
2- Members of the community, staff, and contractors during works; and
3- The effect on the environment.

There is a 'standard approach for 'black slag':

> *"Note – Council has received independent advice on Pasminco Black Slag management, and the recommended approach is landscaping, with cover to a depth of 200mm with an appropriate substance (see TRIM D01914557, and D01914565)." (LMCC, 2016)*

The Douglas Partners (2010) report provides this advice. It is stated there that 500 mm provides a high level of protection and makes reference to ANZECC & NH&MRC (1992) and ANZECC (1999) guidelines which were relevant at the time. However, through a process of subjective rationalisation, it is noted that this thickness would require a lot of imported soil. 'A compromise thickness is therefore recommended of 150 mm of imported bulk soil (for example, clay or sandstone) with a topsoil layer of 50 mm and grass seeded or turfed' (Douglas Partners, 2010).

The process diagram 5.2 in LMCC's EMP (2016) does not require that a search of the GIS database be undertaken prior to earthworks/disturbance. Rather it describes what happens when black slag is found during works so that the GIS database is updated. With access to such valuable data there could be a process similar to 'dial before you dig' which ensures that potential contamination is detected prior to earthworks as a mitigating measure. This would be part of the Institutional Control Program. A risk assessment process may have informed this EMP and this is the level at which risk mitigation as well as management should be identified.

This EMP does not appear to adequately address fluvially-active areas associated with runoff to Cockle Creek and Lake Macquarie. Section 6 describes a 'contamination process review or audit' whereby council may commission a 3rd party audit to undertake a review of the remediation process. This implies a review occurs after the work is initiated not at the planning stage, however it is not clear.

4.5.6 Blood lead measurement and prediction

Exposure of the population to lead is assessed directly by measuring blood lead. The NH&MRC (2016) recommends that if a person has a blood lead level greater than 5 µg/dL, the source of exposure should be investigated and reduced, particularly if the person is a child or pregnant woman. Exposure to lead in Australia has dropped significantly over recent decades as a result of measures restricting the use of lead in paint, petrol and consumer goods (Gulson et al. 2014).

As a result, the average blood lead level in Australia is estimated to be less than 5 µg/dL. Investigating the source of exposure where blood lead levels are greater than 5 µg/dL will reduce the risk to individuals, particularly children (NH&MRC 2016).

Measurement of blood lead should be considered when symptoms or health effects associated with lead are present and/or a source of lead exposure is suspected. In the specific case of lead, a risk assessment technique has been developed to assess the uptake of lead into the blood, which effectively applies an a priori uptake factor to an estimated dose to estimate blood lead concentration (NEPC 2013 Schedule B4). The US EPA integrated exposure uptake biokinetic model (IEUBK) for lead in children is widely known and used in this respect (US EPA 2004). This approach, with the appropriate justifications, is considered suitable at Tier 2 for assessing risks from lead. Whilst the USEPA IEUBK model (USEPA 1994) is commonly used to predict blood lead concentration from lead ingestion, it is only applicable to young children (NEPC 2013, Schedule B4).

4.5.7 Water quality guidelines

Lead in water may be a relevant health risk issue if there is a contamination of drinking water situation. The health risk assessment of metals and metalloids in water follows the Australian Drinking Water Quality Guidelines (ADWG 2011) that are applied directly by comparison of total concentrations. Table 2 gives the drinking water quality guideline for lead (ADWG 2011).

Recreational use of water is assessed using the NH&MRC guidance (NH&MRC 2008). Waters contaminated with chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreational purposes. Recreational water should have a pH in the range 6.5–8.5 and dissolved oxygen content greater than 80% (ANZECC/ARMCANZ 2000, NH&MRC 2008). According to the NH&MRC (2008), the trigger value for lead in recreational water quality assessment is 10 times that of the drinking water quality guideline value (Table 2).

Table 2 Drinking water quality guideline for lead (ADWG 2011)

Metal or metalloid	Drinking water guideline (ADWG 2011) (mg/L)
Lead	0.01

The assessment of water quality for protecting the aquatic ecosystem requires a combination of analytical methods based on the decision-tree process for assessing metal and metalloid toxicity in water (ANZECC/ARMCANZ 2000). Whilst ecological effects in the aquatic ecosystem are not directly human health effects, there may be an indication of bioaccumulation if lead in water and sediments affect edible fish and shellfish species.

Table 3 gives the lead water quality trigger values for protection of the freshwater aquatic ecosystem (ANZECC/ARMCANZ 2000). These trigger values can be extremely low and indicate that increased protection is required for more vulnerable aquatic ecosystems. Also, at lower pH the effects on aquatic species are more significant.

Table 3 Water quality values for protection of freshwater aquatic species for lead (ANZECC/ARMCANZ 2000)

Metal or metalloid	Water quality trigger values (µg/L) for protection of marine water aquatic species (ANZECC/ARMCANZ 2000)		
	80% protection of species	90% protection of species	95% protection of species
Lead	12	6.6	4.4

4.5.8 Sediment contamination

Sediment quality of marine and estuarine is assessed by comparing metal concentrations against the interim sediment quality guidelines of ANZECC/ARMCANZ (2000). Sediment is sampled according to ANZECC/ARMCANZ (2000) to give a <63 µm fraction from each whole collected sediment sample and subsequently analysed for lead.

Physical properties of sediment such as grain size and density are important in sedimentation and transport processes. Typically, sediments are characterised as coarse material, clay/silt and sand fractions, on the basis of separations using 2 mm and 63 µm sieves. Particles >2 mm may consist of shells, rocks, wood and other detrital materials, and are usually not a source of bioavailable contaminants. The clay/silt fraction has a high surface area and because of this its surface chemistry is more likely to absorb organic and heavy metal and metalloid contaminants. Particles <63 µm are more commonly found in the gut of sediment-ingesting biota. A significant metal fraction may be present in detrital, mineralized form (i.e. the >2 mm fraction), but this is generally considered of little ecological importance as it is usually unavailable for bioaccumulation (ANZECC/ARMCANZ 2000).

The decision tree for undertaking sediment quality assessment follows that described by ANZECC/ ARMCANZ (2000) with a focus on identifying the issues and protection measures necessary to manage them. The ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines (ISQGs) are trigger values (Table 4) that, if exceeded, prompt further action as defined by the decision tree. The two kinds of trigger levels that are indicated are:

1. ISQG-High, which is defined as the median of effects data from a large sediment toxicity database and represents a concentration above which there is a high probability of biological effects and below which effects are possible.
2. ISQG-Low, which is derived from the lower 10th percentile of toxicity data from a US effects database and represents a concentration below which there is a low probability of effects.

Table 4 Sediment quality values for protection of aquatic species for lead (ANZECC/ARMCANZ 2000)

Metal or metalloid	Interim sediment quality guideline for protection of freshwater aquatic ecosystem (ANZECC/ARMCANZ 2000) (mg/kg)	
	ISQG-low	ISQG-high
Lead	50	220

As a first step, the total lead concentrations are compared with the ISQG-High and ISQG-Low trigger values (Table 3). If the low trigger value is exceeded and the concentration is greater than background levels, then management or remedial action or further investigation is required. Further investigation considers the contaminant that is bioavailable in the <63 µm fraction or can be transformed and mobilised into an ecologically-bioavailable form, allowing comparison of contaminant concentrations adjusted for bioavailability with the ISQG-Low trigger value. In the case of lead, the bioavailable concentration is estimated by extraction with cold 1 molar (M) hydrochloric acid (ANZECC/ARMCANZ 2000). This is considered to be a more meaningful measure than the total contaminant concentration where natural mineralisation in sediment is commonly found (Batley and Maher 2001).

When the ISQG-Low trigger value is exceeded by the concentration after adjustment for predicted bioavailability (by extraction with 1M hydrochloric acid), acute and chronic toxicity testing with aquatic species is undertaken. Toxicity testing enabled the response of the test organism to the bioavailable fraction in sediment to be assessed and was considered to be the most reliable measure of potential effect of lead (ANZECC/ARMCANZ 2000).

4.5.9 Bioaccumulation in aquatic species

An additional risk from particulate matter in sediment is that acute human toxicity from the consumption of fish or other aquatic species if contamination with lead may be possible. The potential risk is assessed by comparing with the maximum levels set by Food Standards of Australia and New Zealand (FSANZ 2010) for fish consumption by children and adults. In general, the liver of the fish or shellfish have higher heavy metal and metalloid concentrations compared to the muscle. Frequent or regular consumption of fish or shellfish that exceed Maximum Levels (MLs) of heavy metals and metalloids is not recommended.

The ANZECC/ARMCANZ (2000) guidelines together with food guidelines permit the evaluation and assessment of impact from lead in terms of human exposure and ecological effects. The Australian New Zealand Food Standards Code (FSANZ 2010) gives the maximum levels of specified metal and metalloid contaminants in foods, including aquatic foods. For lead, this maximum level is **0.5 mg/kg** (FSANZ 2010).

4.6 Form and species of lead identified

A chemical ‘species’ is the specific form of an element defined by its oxidation (valency) state and/or complex or molecular structure. Some of these structural levels are more important for risk assessment than others. In particular, valency state and inorganic and covalent organometallic speciation are of great importance in determining the toxicity of metals and metalloids (WHO 2006). Elements occur in soil in either the solid phase or in the soil solution. In the solid phase, ions can be bound to soil components by means of ion exchange or surface complexes or they can occur as minerals or be co-precipitated as minerals in soil. In the soil solution they can occur as free ions or complexes.

Standard chemical analysis provides a measure of ‘total’ metal in soil, expressed as a concentration of the elemental form. This is not particularly informative as a means of assessing how toxic the soil could be (Section 4.5.3). Further difficulty is introduced because toxicological research rarely focuses on the metal species most likely to be present in soil. Typically, the focus is on the most toxic forms, and on those that are of particular health concern as a result of their presence in food, consumer products or in the workplace. This means that the available metal and metal compounds may significantly overestimate the toxicity of the metals in soil (NEPC 2013 Schedule B4). Figure 4 shows how lead species in various lead compounds and minerals affect lead bioavailability.

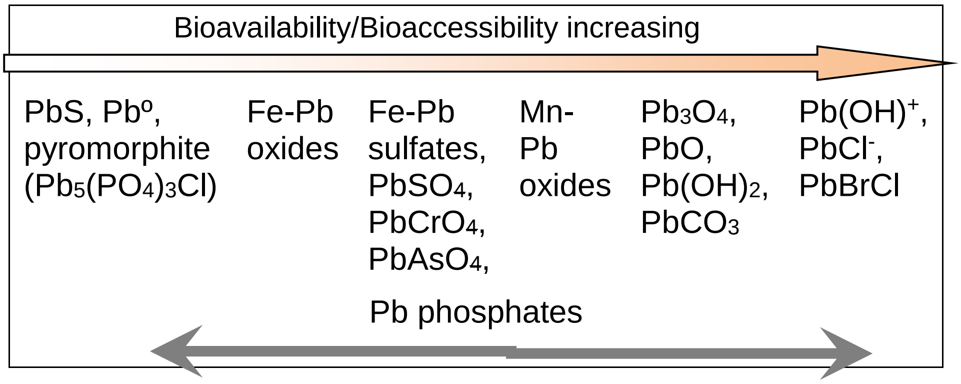


Figure 4 Schematic of how different lead species affect lead bioavailability with constant particle size (modified from Ruby et al. 1999)

Lead chemical form in soils has traditionally been estimated by X-ray diffraction (XRD). However, XRD has limited sensitivity and cannot detect forms of lead below 0.01% or greater than 10,000 mg/kg which is far higher than the NEPM (2013) soil criteria for lead. Selective extraction techniques based on Tessier's and the BCR methods are commonly used to measure 'operationally-defined' lead forms but do not measure the actual chemical form (Ure and Davidson 2002). In addition, techniques based on scanning electron microscopy (SEM) and SEM/EDS can be used to examine and compare mineralogical and morphological characteristics of smelter slag (Morrison et al. 2016). However, there are limitations with distinguishing lead chemical forms when using X-ray techniques.

A convenient technique for determination of lead chemical form in soils and mine waste is synchrotron-induced X-ray absorption spectroscopy (XAS) (Brown et al. 1999). This is a very sensitive technique performed at a synchrotron facility which can detect lead down to environmental concentrations of 0.001-0.002% (10-20 mg/kg), including both crystalline and amorphous forms. The bioavailability of lead changes widely among different lead species in various environmental matrices. Appropriate understanding of the relationship between speciation and bioavailability for human health and environmental risk assessment requires comprehensive identification of lead species in specific environmental media, such as air particulates, dust and mine waste (Brown et al. 1999). Information on the binding environment of heavy metals and metalloids helps to optimise remediation strategies and to assess their potential hazard to humans and other organisms (Brown et al. 1999).

Synchrotron radiation-induced X-ray absorption spectroscopy ('XAS') techniques have been applied extensively to determine the lead speciation at the molecular scale of solid phase samples at contaminated sites (Brown et al. 1999). X-ray absorption spectroscopy is an element-specific, bulk-sensitive and non-destructive method that is able to identify discrete compounds of a particular element, down to trace levels (lead < 20 mg/kg) and enable poorly crystalline and fine-grained amorphous species to be identified. These are likely to control lead bioavailability to biota and mobility in natural systems, but are difficult to characterise using traditional techniques, such as XRD (Brown et al. 1999).

Access to synchrotron radiation-induced X-ray absorption spectroscopy ('XAS') techniques have been made available in Australia with the completion of the Australian Synchrotron facility in Melbourne in 2007.

The literature review follows the key areas of the objectives of the consultancy to review literature relevant to programs aimed at 'reducing human exposure to lead' and to report on the following key areas.

5. REMEDIATION AND/OR MANAGEMENT PROGRAMS

This section addresses Scope of Works 3.1: "Remediation and/or management programs that have been undertaken for comparable lead contamination sites and areas, ensuring that specific details regarding the form and species of lead are identified".

Several former lead mining and smelter sites exist throughout the world with varying degrees of success in terms of remediation effectiveness. There was a particular focus during the last 30 years and the sites that were examined are effectively the benchmarks for the current time. Following extensive remediation programs of Superfund sites in the USA, a symposium was held at Coeur d'Alene, Idaho, USA in May 2000 to review several such sites. The findings of the Coeur d'Alene symposium are presented as a review (Elias and Gulson 2003). Whilst this review draws on the findings from a range other lead smelter remediation projects, the reviewers found that the most comprehensively documented programs from across the range of remediation case studies were primarily focussed on Coeur D'Alene River Basin, Idaho, USA (NRCNA 2005), Trail, British Columbia, Canada (Hilts 2003) and Butte – Silver Bow (BSBHD 2014). Therefore, it is considered useful to examine the findings of these sites. The dispersion of lead throughout the surrounding community is as dust from lead-contaminated soil that becomes mobilised by size-reduction processes. The study sites considered in this paper are closely aligned with those being considered in the current review and therefore it provides a reasonable basis for comparison of remediation issues with the current site.

Remediation plans were considered to cover a range of issues and variables:

- Government policy regarding mechanisms for decisions and supporting funds.
- Company policy / viability to survive the economic impact of remediation cost.
- Community relationship with participation in decision-making and expectation of improvement to living conditions and benefits.
- Topography that will influence the dispersion plume being on flat land, in a valley or a slope.
- Climate whether hot dry or cold wet climate will influence dispersion characteristics.
- Land use whether there is compatibility with the soil lead remediation if they increase human exposure
- Population density - not all residents will receive benefits of remediation.
- Metal species - the finding was that there was some information available about different forms of lead and their harm but the symposium did not have sufficient information to clarify this issue.

Ecological approaches have been covered briefly but it is identified by Elias and Gulson (2003) that there are processes that can affect biota such as acid mine drainage and lead solubility. During the last decade there has been enhanced development of the methodology for ecological effects assessment from soil contamination. The significance of ecological issues at NLM associated with lead contamination remains an open issue. There are two issues at NLM:

(i) the effects on aquatic biota as part of the ecosystem; and
(ii) occurrence of bioaccumulation of lead in species like fish and shellfish species that may be consumed by the local population (especially indigenous people).

Elias and Gulson (2003) identified the following goals to:

(i) Protect human health, including both children and adults
(ii) Restore the environment
(iii) Retain the social fabric of the community and
(iv) Maintain viability of the industry.

Possible options to consider align with the available examples:

(i) Strategies for remediation discussed were from the key sites considered below, and
(ii) Evaluation of remediation effectiveness considered collective experience.

According to Elias and Gulson (2003) the key statement of measure of remediation success is the reduced risk to lead exposure and this can be assessed in two ways:

1. A reduction in blood lead concentrations of the most susceptible subpopulation of residents (usually children); or
2. A reduction in lead concentration of soil and dust which were the major pathways of lead exposure.

The identified difficulty was that neither of these measures adequately evaluates the long term effectiveness of remediation (see also Section 4.5.2). The issues identified by Elias and Gulson (2003) are identified as important to consider in the review. The concept of markers of remediation effectiveness as measured by specific monitoring activities is given (Elias and Gulson 2003, Table 2 p9). Best practice remediation effectiveness was also discussed and is part of current mine remediation practice (Department of Industry, Innovation and Science, 2016).

A controversial issue raised by Elias and Gulson (2003) was the contribution of emissions from current operations vs historical contamination. The supporting details were as follows:

1. The key sites following will look at a summary of issues for the respective sites.
2. Trail emission reduction with improved smelter operation (Hilts 2003).
3. At Port Pirie, the significance of recent lead fallout from current operations compared with historic fall out was identified (van Alphen 1999).
4. Lake Macquarie despite reductions in emissions, still had exceedance of air concentrations (Morrison 2000).
5. Broken Hill and occurrence of widespread lead contamination in houses (Boreland and Lyle 2014, Jacobs 1992).

Elias and Gulson (2003) also reviewed details of bioavailability of lead mine waste that were identified in the very detailed studies carried out by Casteel and co-workers. Casteel et al. (1997) showed that the bioavailability of lead as galena varied because of differences in particle size with higher bioavailability being observed for smaller particle sizes. This study points to the importance of having bioavailability measurement of lead in actual mine wastes.

Finally, Elias and Gulson (2003) considered the issue: is contamination always a problem? This is not always the case. ‘Living with lead in Broken Hill’ (Jacobs 1992) is a key example that has demonstrated that diligence is required in maintaining awareness within a community with historical lead contamination where blood lead levels remain high. The need for such diligence at Broken Hill is demonstrated by the finding in 2014 that 53% of children have blood lead levels exceeding the 5 µg/L recommended for investigation (NH&MRC 2016).

5.1 Blood lead levels and exposure

The relationship of levels of lead in the blood of people with exposure to various lead sources has been studied at lead smelting sites all over the world (ATSDR 2004). Previous studies reviewed by ATSDR provided evidence of the high risks for children living in the vicinity of a lead smelter from the ingestion or inhalation of lead from airborne emissions, lead-bearing soils, dust (including household dusts, entrained dusts by wind or human-oriented events); water supplies, and food. Studies on high concentrations of lead in the environment resulting from stack emissions, fugitive emissions (Ohmsen 2001), and the use of slag (Morrison 2003) showed that a range of artificial lead compounds may be present in environment close to mine sites and lead processing facilities.

A graph of BLL at various smelters over time has been prepared by Interior Health (2015) to put the Trail BLL in context with other BLL data (Figure 5).

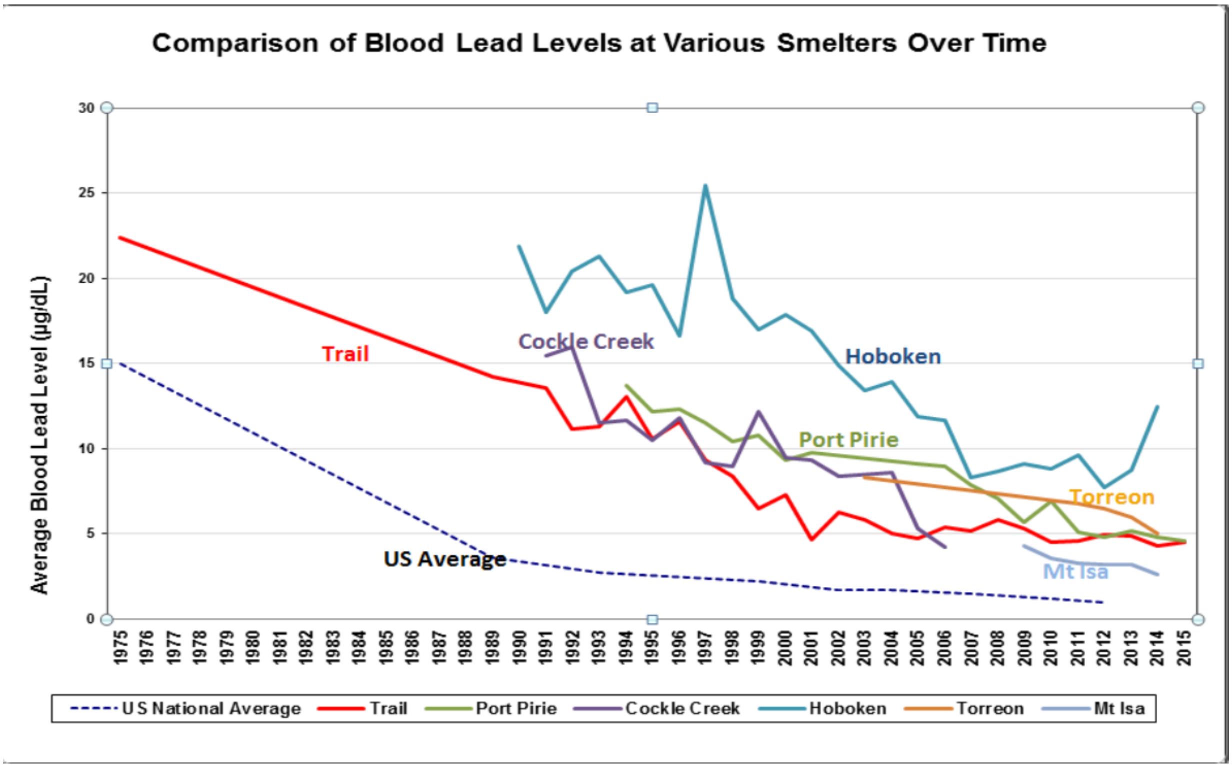


Figure 5 Comparison of BLLs at various smelters over time (Interior Health 2015)

5.1.1 Port Pirie

The primary lead–zinc smelter in Port Pirie, South Australia, currently operated by Nyrstar NV, is the major source of lead contamination in that city (Maynard et al. 2005). The smelter has been operated since 1889 and has the capacity to smelt 300,000 tonnes of ore concentrates annually and to produce approximately 230,000 tonnes of refined lead. Lead levels in airborne materials, dust falls, surface soils, and rainwater tanks were assessed (Wilson et al. 1986, van Alphen 1999). The important factors identified were age, pica habits, ingestion of paint and soil or dust through inhalation pathways, and the success of decontamination programs in some areas in Port Pirie.

Lead exposure and absorption by children in Port Pirie have been reviewed, showing that children, in particular, from the population in Port Pirie have been exposed to lead from several sources and via multiple environmental pathways (Maynard et al. 2005). The highest concentrations of lead in surface soil and air at Port Pirie were found within 2 km of the smelter and the concentration decreased with distance from the smelter (Landrigan 1983). Lead emitted from the smelter reached children at Port Pirie by a variety of pathways. Two major routes were identified: inhalation of airborne lead and ingestion of lead deposited from air in dust and soil (Landrigan 1983). The relative importance of these two routes varied with the age of children. Ingestion was not particular important for older children, whereas younger children, because of their normal hand-to-mouth behaviour, were at risk of exposure by both routes (Landrigan 1983).

The geographic clustering of children with elevated blood lead levels in Port Pirie were closest to the lead smelting facility (Landrigan 1983). This fact, accompanied by elevated lead concentrations in soil (range 4–2100 mg/kg), house dust (mean 4740 mg/kg) and rain water tanks (geometric mean 50 µg/L), strongly indicated that the lead–zinc smelter was the major source of lead contamination at Port Pirie (Landrigan 1983).

Two high volume air sampler monitoring locations monitored airborne particulate lead levels at Port Pirie and showed a decrease from 3.18 µg/m^3 to 0.6 µg/m^3 from 1974 to 1982 at Solomontown 1.8 km from the main smelter stack and lower annual mean concentrations of 0.71–1.43 µg/m3 at Orana, 2.6 km from the stack. Lead concentrations in dust fall in Port Pirie did not decrease appreciably over the previous decade ranging from 6.61 mg/m^2/day 1.4 km from the main smelter stack to 1.4 mg/m2/day 3.0 km from the stack. Thus fallout dust remained a key issue at Port Pirie while airborne lead particulate levels were not excessive.

Thus airborne deposition of lead-contaminated dust appears to be the important pathway of contamination for children in Port Pirie (Maynard et al. 2005, van Alphen 1999). Blood lead levels and spatial air lead distribution between two high-risk sites near the smelter were compared (Calder et al. 1994). Although the results showed a progressive decline in the proportion of children above the recommended blood lead level, an analysis of the blood lead data by risk area in Port Pirie suggested that the reduction in blood lead levels appeared to be greater in the low risk area, farthest from the probable source of continuing contamination, compared with high risk areas in the northern part of Pirie West, relatively close to the smelter (Calder et al. 1994). In addition, the two high risk areas showed different patterns of reduction from each other. Air monitoring data clearly showed that the air lead levels declined rapidly with distance from the smelter and associated works in Port Pirie (Calder et al. 1994). These results indicated the significance and importance of air pathway to the children's blood lead levels in a community near a lead smelter facility. Dust at Port Pirie was transported mainly through wind, primarily re-entrainment, from the lead smelter and new fugitive emissions. Human, vehicle and material handling activities also assisted dust to rise (Maynard et al. 2005).

The prevalence of elevated blood lead levels in children in the 3–5 year age group (16.1% with > 30 µg/dL; mean 22.0 µg/dL) from a total of 1239 children at Port Pirie in 1982 was more than three times higher than for the older 6–14 year age group (5.0% with > 30 µg/dL; mean 17.9 µg/dL) (Landrigan 1983). From a total of 230 children in the 3–5 year age exceeding a blood lead level of 30 µg/dL, the number of children from the high risk area was 32 out of 78 examined (41.0%) compared with 5 out of 152 examined (3.3%) from the other (low risk) areas. Thus there was a clear connection with blood lead > 30 µg/dL from the high risk area.

Positive associations of blood lead levels of two-year-old children with surface soil lead concentrations also suggested a strong influence from ingestion of soil-borne dust on blood lead concentrations in early childhood at Port Pirie (McMichael et al. 1985).

The distribution of elevated soil lead concentrations around the smelter at Port Pirie was roughly concentric. The mean dust lead concentrations in the homes of 23 children with elevated blood lead levels examined in the control case study was 4470 mg/kg (Landrigan 1983). Rainwater tanks had two contributory sources of lead: lead dust and lead paint from roofs and gutters. As many as 47.5 per cent of the rainwater samples collected contained more than World Health Organization's ('WHO') guidelines for lead concentrations in drinking water (0.05 mg/L) (Landrigan 1983).

Lead decontamination programs have been conducted in Port Pirie since 1984. Abatement programs involved identifying children with elevated blood lead levels, decontaminating houses, treating soils, general city greening, family education, and support and community education (Calder et al. 1994). The general strategy developed for the decontamination program was based on the premise that the major source of lead in Port Pirie was a substantial lead sink in the city, from which lead-contaminated dust readily re-entrained, although substantial contributions also came from lead-based paint and contaminated rainwater. The blood lead monitoring program showed the most significant decrease in children's mean blood lead levels were in areas that were remote from the smelter (Calder et al. 1994).

An intensive study of newly borne infants from Port Pirie through to 36 months of age confirmed that ingestion was the most likely route for 95% of the dose of lead based on hand lead load and related measurements compared against BLL (Simon et al. 2007).

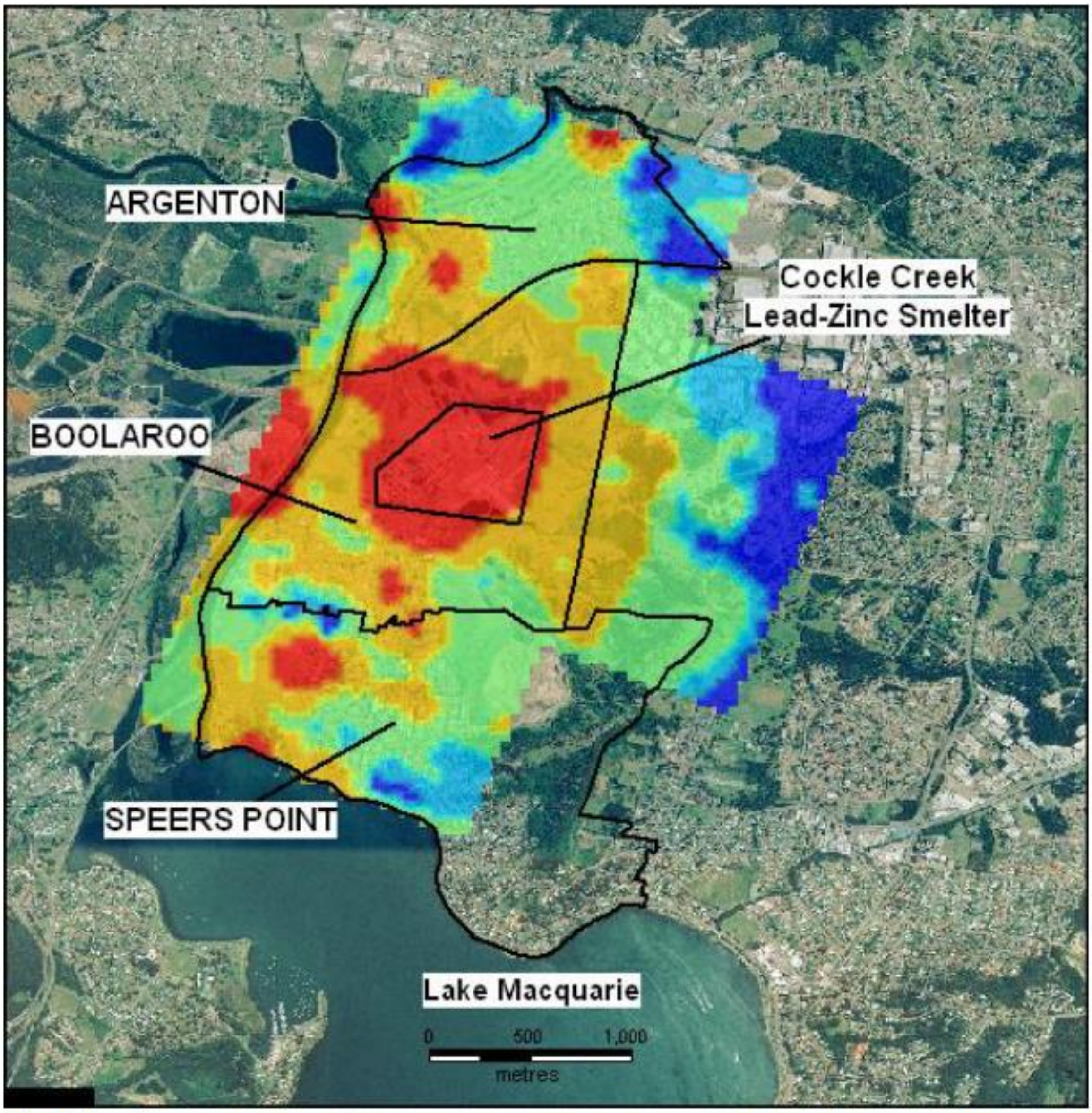
In 2012 an extensive soil sampling survey from 353 sites was undertaken to confirm the historical lead contamination in soil and determine if SA Health abatement program needed to be modified (SA Health 2013). The survey also sought to identify if the gradient of lead concentrations extended across Port Pirie city. The results indicated that the Port Pirie Regional Council's footpath remediation strategy reduced lead contamination of footpaths, SA Health recognised that sites exceeding HIL lead concentrations that are accessible to the public would require further attention. Only total lead concentrations were measured and there was no testing for bioaccessibility (Ng et al. 2015) which is applicable as a step in a Tier 2 assessment (NEPC 2013 Schedule B4). The Port Pirie soil survey demonstrated the applicability of retesting soil lead concentrations to confirm the status of contamination in order to re-assess further need for remedial works.

5.1.2 Blood Lead levels – North Lake Macquarie

Willmore et al (2006) undertook a study using GIS to map soil lead levels and blood lead levels over time within the LAS area. Figure 6 shows the soil lead levels in and around the Boolaroo smelter site in 1992 within which the Nominated Properties are located based on the lead contamination survey grid. Figures 7, 8 and 9 show blood lead levels (BLL) in the Boolaroo area within the LAS grid. They show the overall pattern aligned with emissions from the smelter then improvement in BLL when emissions ceased. These images show the relationship between lead emission distribution from the former smelter and soil lead with BLL and changes over time in BLL associated with the LAS and elimination of emissions due to the shut-down of the smelter. The relative importance of each source of lead cannot be quantified on the basis of these data alone.

Site investigations of soil lead concentrations were undertaken at Boolaroo in 1992 through to 2003.The practice of free access to smelter waste was promoted as it was deemed to be non-hazardous (Greg Piper, MP video 2 December 2015 Boolaroo Cockle Creek Smelter[3]).

[3] www.youtube.com/watch?v=UVNjdnGtHcA



Soil lead: Gridded and imaged 1992 soil lead concentration in the suburbs surrounding the Cockle Creek lead-zinc smelter, North Lake Macquarie, NSW, Australia. Navy: soil lead < 150 ppm, Turquoise: 150 ppm – < 300 ppm, Green: 300 ppm – < 1000 ppm, Orange: 1000 ppm – <4000 ppm, Red: ≥ 4000 ppm

Figure 6 Soil lead concentrations in suburbs near a lead smelter in North Lake Macquarie 1992 (Willmore et al. 2006)

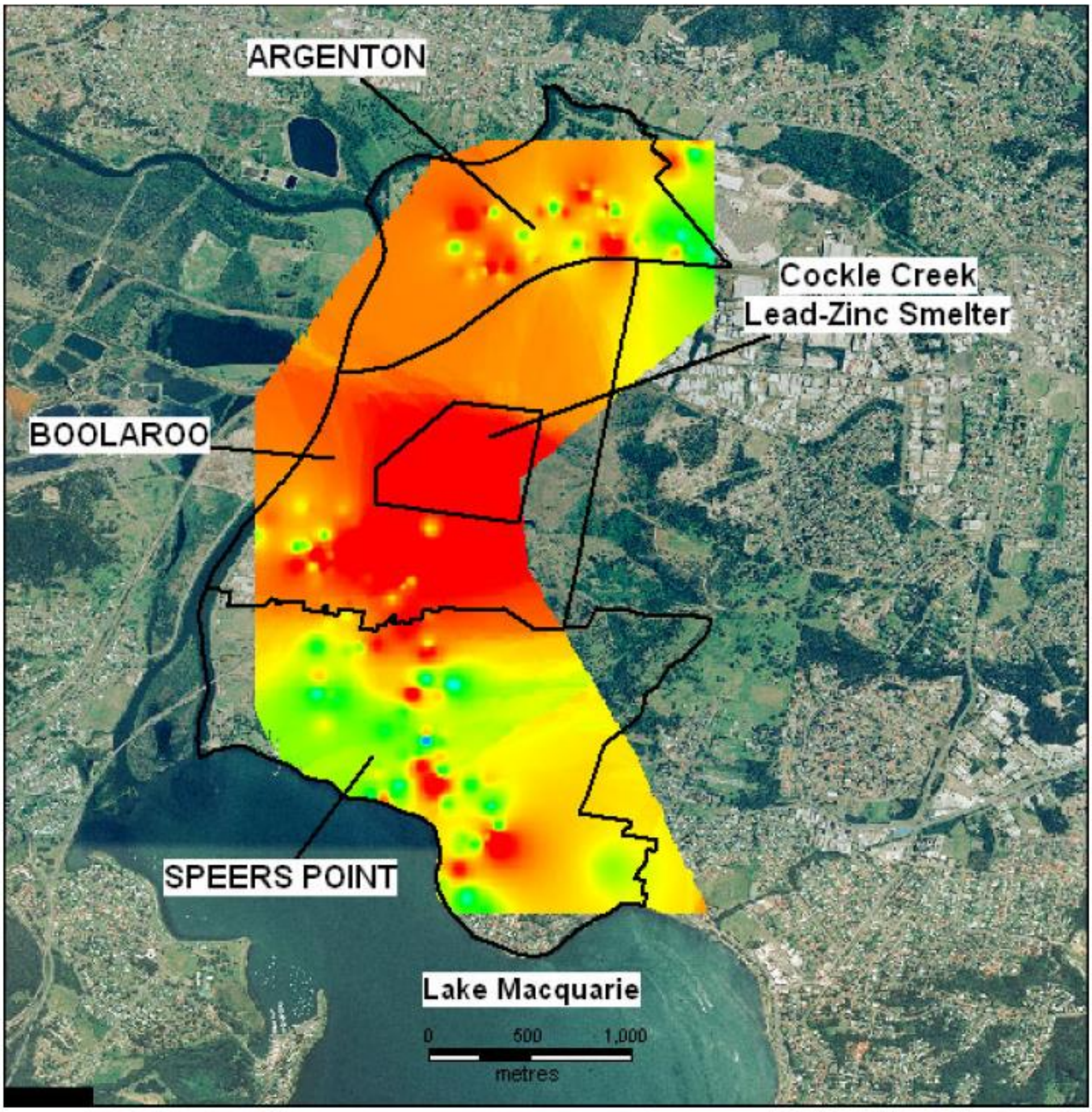


Figure 3
Gridded and imaged 1992 blood lead levels of child residents in the suburbs surrounding the Cockle Creek lead-zinc smelter, North Lake Macquarie, NSW, Australia. Navy: BLL < 5.5 μg/dL, Turquoise: 5.5 μg/dL – < 7.5 μg/dL, Green: 7.5 μg/dL – < 10 μg/dL, Yellow: 10 μg/dL (the NHMRC national level of concern) – < 15 μg/dL, Red: ≥ 15 μg/dL.

Figure 7 Child Blood Lead levels 1992 (Willmore et al. 2006)

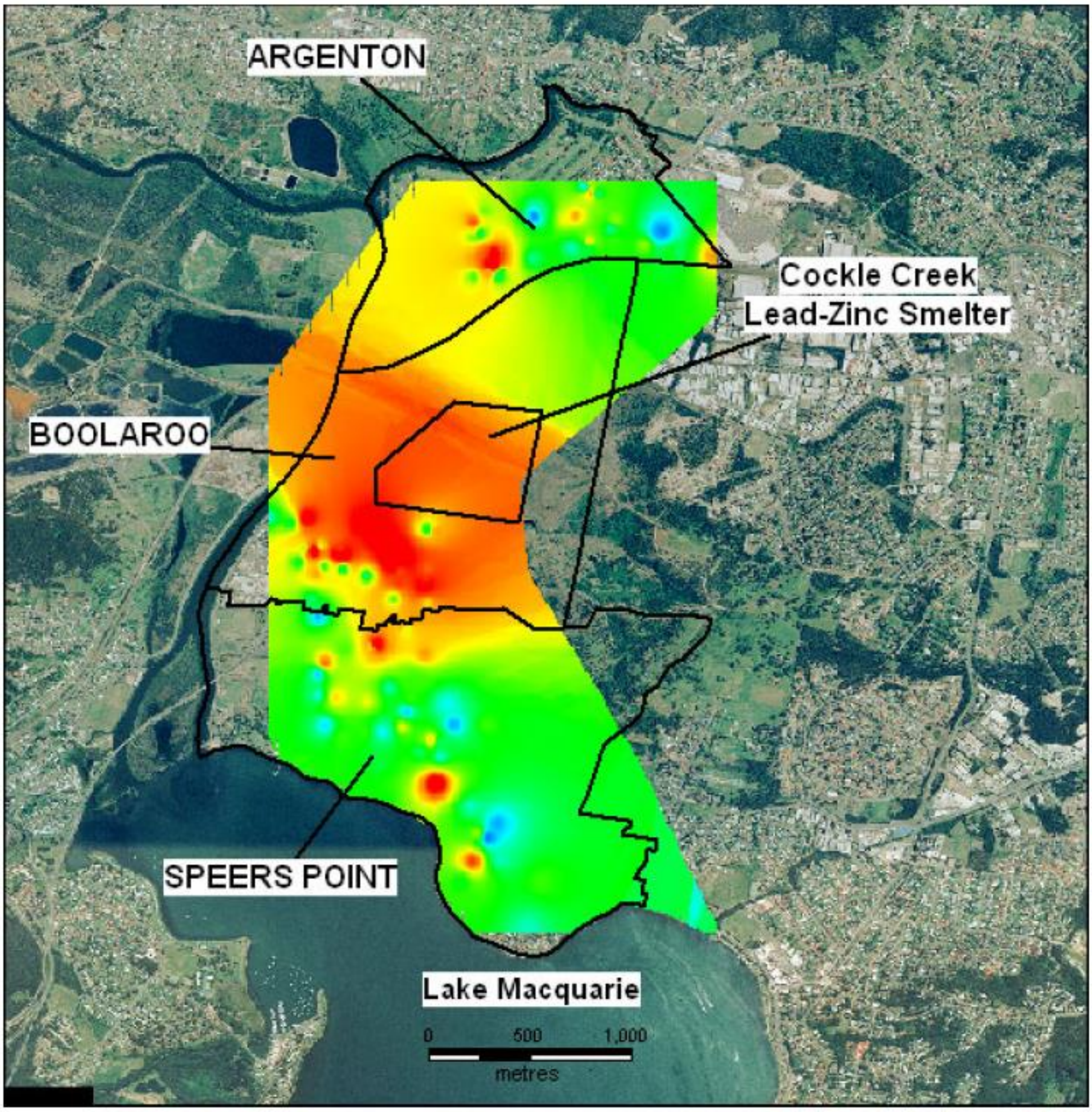
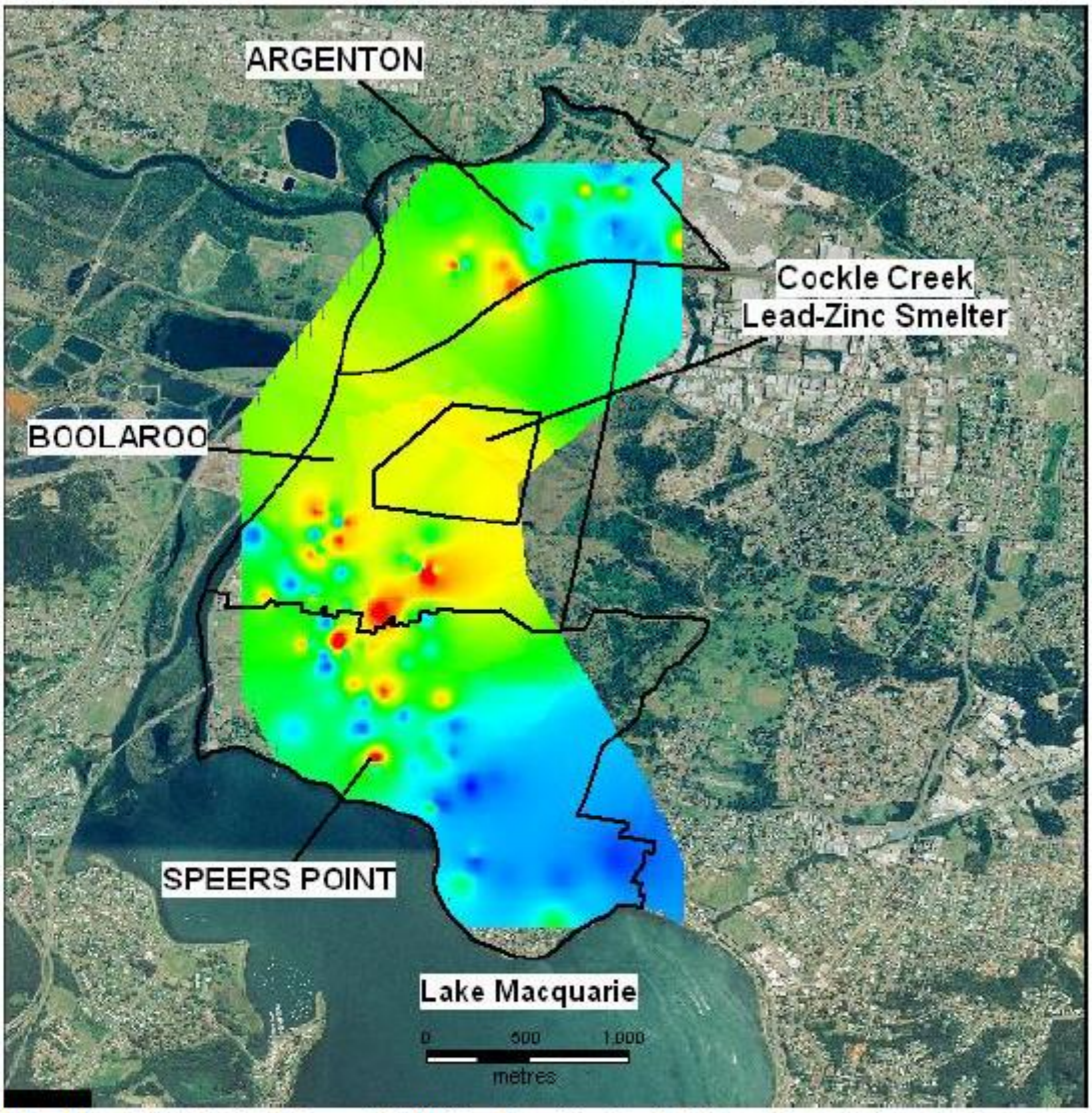


Figure 4

Gridded and imaged 1996 blood lead levels of child residents in the suburbs surrounding the Cockle Creek lead-zinc smelter, North Lake Macquarie, NSW, Australia. Navy: BLL < 5.5 µg/dL, Turquoise: 5.5 µg/dL – < 7.5 µg/dL, Green: 7.5 µg/dL – < 10 µg/dL, Yellow: 10 µg/dL (the NHMRC national level of concern)- < 15 µg/dL, Red: ≥ 15 µg/dL.

Figure 8 Child resident blood lead levels 1996 (Willmore et al. 2006)



Blood lead: Gridded and imaged 2002 blood lead levels of child residents in the suburbs surrounding the Cockle Creek lead-zinc smelter, North Lake Macquarie, NSW, Australia. Navy: BLL < 5.5 µg/dL, Turquoise: 5.5 µg/dL – < 7.5 µg/dL, Green: 7.5 µg/dL – < 10 µg/dL, Yellow: 10 µg/dL (the NHMRC national level of concern)- < 15 µg/dL, Red: ≥ 15 µg/dL. Source: Willmore A, Sladden T, Bates L, Dalton C. Use of geometric information system to track smelter-related lead exposures in children: North Lake Macquarie, Australia, 1991-2002, *International Journal of Health Geographics* 2006 **5**:30 doi:10.1186/1476-072X-5-30. Available at http://www.ij-healthgeographics.com/content/5/1/30

Figure 9 Blood lead levels in children in suburbs near a lead smelter in North Lake Macquarie 2002 (Willmore et al. 2006)

A number of blood lead surveys were accompanied by other studies of soil. In particular, changes in the blood lead levels were apparent following changes in smelter design. The most recent sampling program for North Lake Macquarie (Hunter New England Local Health District (HNELHD 2015) has confirmed the downward trend in BLLs. It is noted that HNE Population Health has reminded GPs servicing this area to continue to check BLL of children less than 5 years of age with factors for lead exposure. It will be important for a centralised BLL database to be maintained into the future. Any future screening to verify that BLL remain below the investigation level should take care to avoid sample bias identified in other studies. For example, a poor voluntary representation from those who perceive the risk to be low not engaging with screening. The timing of the screening is likely to be important (summer versus winter) and the program may need to be mindful of cultural aspects which have led to different results in BLL in indigenous and non-indigenous community members elsewhere.

A study by Ngueta et al. (2014) on cold-to-warmer weather changes in Canada for children's BLL was undertaken and related it to previous blood lead status. The study highlighted "the major influence of previous blood lead concentration in the colder-to-warmer changes in BLLs. The magnitude of increase in BLLs from colder to warmer months is more important in children with BLLs <10 µg/dL during colder months. While not reducing the important role of soil and dust (strongly established in the previous studies), we suspect that the deleterious influence of BLLs on the vitamin D metabolic sites/pathways could explain such observation." This study was undertaken in a cold climate (Canada) so it is not clear if this is relevant to temperate North Lake Macquarie. However, the study noted a number of reasons why there might be seasonal variation with one being increased exposure of children during warmer months.

The 2015 study at North Lake Macquarie (HNELHD 2015) was undertaken on 72 children who were between six months and less than five years of age in winter at a time when there is less outdoor play and less exposure to dust due to moist climate conditions. This was the first cohort of children to be screened who had grown up in the area since the closure of the smelter in 2003. The 2015 study assessment also corresponded with the NH&MRC releasing its advice that adverse conditions can occur in blood lead levels greater than 10 µg/L, but there was insufficient evidence to determine whether health effects occur at levels greater than 5 µg/L but less than 10 µg/L (Section 4.5.5; NH&MRC 2016). It was considered that the basis for the reduction of blood lead level from the previous survey in 2005/2006 was that the closure of the smelter resulted in greater than 80% reduction in lead in air levels between 2002 and 2004.

Lead remediation has been undertaken on 1226 accepted properties with 437 properties recommended for abatement work while 359 have been completed since the closure of the smelter. However, 731 property owners did not accept the offer for testing. Residents need to remain aware that potential sources of lead still exist such as pre-1970 paint which may be a risk during any home renovations (Gulson et al 1995). While the BLLs show no need to investigate further, there may be a need to confirm that BLLs do not increase above the health investigation level in the future, for example in 5 years. The remediation of all properties surrounding the smelter site is not yet complete and further examination is needed to determine if measures are adequate. There is as yet, no completion of remediation that has been validated for soil contamination.

6. CONSIDERATION OF SUCCESS AND 'BEST PRACTICE'

This section addresses Scope of Works 3.2: "The success of the programs and considerations of 'best practice'. The performance evaluation aspects of success will be addressed in Section 6. This section will provide an overview of what is considered best practice.

6.1 Review of Bunker Hill contamination cleanup

The Bunker Hill site comprises 5400 ha in the Silver Valley of the South fork of the Coeur d'Alene River (SFCDR) and includes the 150 abandoned industrial complex of the former Bunker Hill company Lead/zine mine and smelter in Kellogg, Idaho. A US Environmental protection Agency (EPA) plan to clean up this contamination under Superfund proposed spending millions of dollars on contamination clean up in the Coeur d'Alene River basin (NRCNA 2005). More than 7000 people in 5 residential areas. In addition to smelter-related lead contamination there was also mill tailings discharged to the river or confined in piles onsite (adding to the contaminant sources).

The Bunker Hill review (NRCNA 2005) characterised the need for careful design, implementation, and perpetual maintenance of a community-wide lead clean up.

Future action was required on:

- Infrastructure
- Institutional controls for homeowner projects (post-cleanup)
- Erosion control for undeveloped hillsides with potential to impact the developed valley floor
- Drainage improvements and flood control
- Waste piles and increasing the rate at which cleanup proceeds.

Focusing on these areas was considered crucial to minimising recontamination at a large scale lead cleanup.

Studies found that interior dust clean up alone was not effective where, within a year, they were re-contaminated by outdoor sources, (CH2MHill 1991 in Sheldrake and Stifelman 2003) so cleanup efforts were directed toward residential yard soils, commercial properties and rights of way.

The 1993 Panhandle Health District (PHD) Lead Health Study identified several co-factors which influence the soil/dust pathway and were related to excessive blood lead levels. These included parental income and socioeconomic status, parental education level, home hygiene practices, smokers in the house, nutritional status of the child, use of locally grown produce, exposed soil in the yard, number of hours spent outside, pica behaviour and age (PHD 1986 in Sheldrake and Stifelman 2003).

An extensive database has been maintained by Idaho Department of Health and Welfare which relates BLL, environmental media contaminant concentrations, environmental exposures, health intervention and remedial activities on an individual basis. This is confidential with only summary info released (due to the personal nature of medical records) (Sheldrake and Stifelman 2003)

Responsible Party agreements in 1994 enabled implementation of cleanup in the communities – residential yard soil, well closures in contaminated aquifers, financing an Institutional Control Program, including provision of a disposal area. Priority cleanup for residents was for pregnant women or young children (and those with BLL >10 µg/dL living on yards with soil lead concentrations >1000 mg/kg) who have highest priority needs with at least 30 cm clean soil barrier for yards, and 60cm for garden areas.

Summary features of this project are:

- A durable fabric marker installed where contamination at depth with the ICP ensuring barrier integrity
- 'Responsible Party' agreements ensure residential clean up to be funded (200 residential parcels per year)
- Periodic reviews are needed in perpetuity (due to contamination at depth)
- There is a need to repair after flooding, erosion, or deposition of contaminated soils (this becomes the responsibility of the property owner)
- Record of Decision requires ICP long term stability of barriers and to enforce the property owners' obligations.

Several comments on site characterisation and remedial investigations are provided for Bunker Hill (NRCNA 2005).

6.1.1 The importance of an Institutional Control Program (ICP)

ICP as defined for Superfund sites is as follows:

> "The ICP is a locally adopted set of rules and regulations incorporated into land use and zoning codes to ensure barrier integrity throughout the site. The purpose of the ICP is to protect public health and assist local land transactions within the Superfund site. The ICP has been established to oversee real estate transactions, certify contractors to work safely within the BHSS, to enforce rules and regulations, and to help residents comply with the Institutional Controls" (Sheldrake and Stifelman, 2003).

The ICP enforcement is linked to building departments and land use planning activities and include:

- Contaminant management rules;
- Barrier design and permitting criteria;
- Ordinances requiring Panhandle Health District
- To approve building permits;
- Ordinance amendments to comprehensive plans
- And zoning regulations;
- Model subdivision ordinances;
- Storm water management requirements; and
- Road standards and design criteria.

Sheldrake and Stifelman (2003) analysed the following in their review:

- Blood lead levels;
- House dust lead levels;
- Barrier effectiveness;
- Institutional controls program;
- Fugitive dust;
- Recontamination sources; and
- Infrastructure and disposal.

Sheldrake and Stifelman (2003) found the following:

Education for 2 year olds accounted for a 3.9 µg/dL reduction due to intervention without yard cleanup) in a study of ages kinder to grade 3 (p117). A vacuum cleaner loan program was of value. Improvements to ICP (from surveys) require a closer disposal site and pre-project sampling (p118).

Local zoning laws do not prevent removal of soil/rock from base of slopes – making erosion inevitable (p119 Section 3.6.3). They recommended gabion walls and zoning changes and further, recommended the following Institutional Controls Program (ICP) standards:

- All county and city crews are trained and licensed by the Institutional Controls Program;
- Rock pit operators sample materials that are used at the site;
- Institutional Controls Program implementers go to currently operating rock pits and sample them to supplement owner sampling, if necessary; and
- Material being placed on roads is tested on an intermittent basis.

Throughout the ICP there was an ongoing need for disposal of lead contaminated materials.

6.1.2 Critical deficiencies

Deficiencies identified in this program included lack of drainage maintenance by local entities and need for infrastructure improvements in particular for many areas which had recurrent flooding (Sheldrake and Stifelman 2003).

Lack of road maintenance and need to replace failing road infrastructure (to ensure underlying contamination not exposed) as ‘road sub-grades can be ongoing sources of contamination. Remobilisation observations where water interacted with contaminants:

- The highest concentrations of dissolved metals occur during low-flow events. Therefore, low-flow events have the greatest impact on the aquatic ecosystem.
- The highest suspended sediment loads, which can contain particulate lead and zinc, occur during high-flow events, when the erosive ability of the river is greatest. (Sheldrake and Stifelman 2003, p121)

In summary they noted that:

- A clean soil barrier was an essential part of cleanup,
- House dust was the most significant proximate source of lead exposure for young children (note that at Trail emissions were continuing as distinct from the current North Lake Macquarie situation), and
- Community maintenance and scale present challenges at all stages: funding, planning, construction and maintenance into perpetuity.

7. PROGRAM PERFORMANCE EVALUATION

This section addresses Scope of Works 3.3: 'How the success or otherwise of the programs was evaluated or measured'.

7.1 Bunker Hill and Coer D'Alene River Basin

The National Research Council of the National Academies (NRCNA) in 2005 published the document 'Superfund and mining mega sites, lessons from the Coeur D'Alene River Basin, Committee on Superfund Site assessment and remediation in the Coeur d'Alene river Basin'. In this document the link was made between the introduction of legislation in 1980, that is the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA 1980) in USA and the process of identification of Superfund sites in the USA, of which Bunker Hill was one.

This lessons learned document, found the technical basis for decision making for this project was generally sound. 'However, for EPA's decision making regarding environmental protection, the committee has substantial concerns, particularly regarding the effectiveness and long-term protection of the selected remedy.'

It was also noted that 'characterisation did not adequately address groundwater – the primary source of dissolved metals in surface water – or identify specific locations and materials contributing metals to groundwater' (NRCNA 2005). The review also noted that there were no appropriate repositories to hold the proposed amount of contaminated materials. Reviewers felt that frequent flooding could impact remedial actions and potentially lead to re-contamination.

A positive lesson learned from this project was that there was a sound basis for planning based on the identification of existing knowledge and knowledge gaps:

> 'Overall, EPA's evaluations provide a useful depiction of the location of contaminated soils, sediments, and surface waters over the large spatial scale of the basin. The data have been used to estimate average mass loading of metals in the Coeur d'Alene River and Lake and to provide an adequate description of contaminants moving through much of the system.' (NRCNA 2005).

Figures 10 and 11 show distribution pie charts for the fate of lead contamination from mill tailings, thereby providing valuable knowledge for planning remediation.

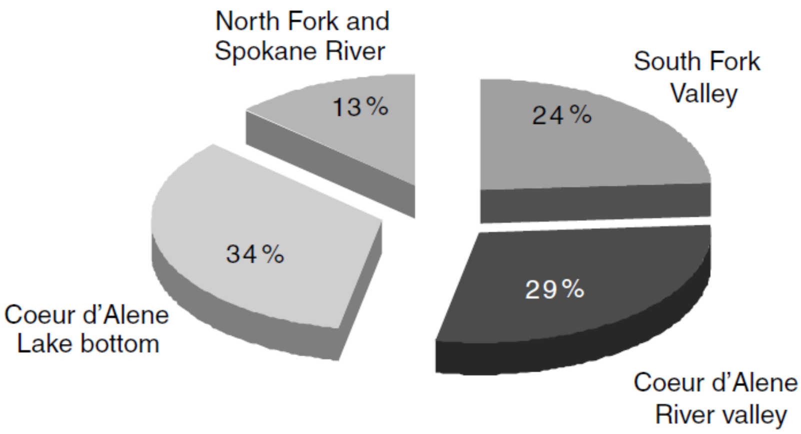


Figure 10 distribution of ~880,000 tons of lead from mill tailings released to streams (Bookstrom et al. 2001 in NRCNA 2005)

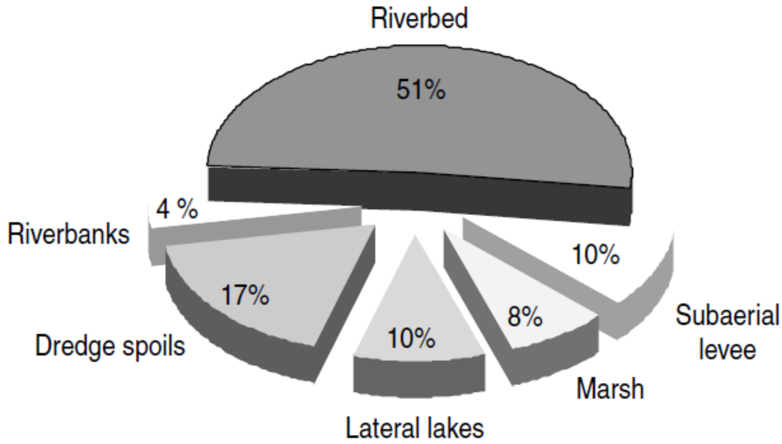


Figure 11 Distribution of lead by depositional environment in the lower reach (Cataldo to Harrison) of the Coeur d'Alene River (Bookstrom et al 2001 in NRCNA 2005)

Also learned was that aggregate data for 0-9 year olds is misleading and underestimates the risk for the target group of the population (NRCNA 2005). This review also highlighted that knowledge gaps existed around the human health impacts of contaminants other than lead; in this instance arsenic and zinc.

NRCNA (2005) also recommended that site specific bioavailability and ingestion rates be used as they, 'would have improved the application of the Integrated Exposure Uptake Biokinetic (IEUBK) model' (USEPA 2007). Other models and epidemiological studies could have helped to assess the reliability of the IEUBK model predictions and better characterise the physical-chemical properties of the exposure source materials. In essence, they noted that IEUBK should not be the sole criterion for estimation for health-protective soil concentrations. Geographically complex sites need improved methods and a decision making structure that follow the appropriate health risk assessment procedures.

NRCNA (2005) recommended long-term support of institutional-control programs (ICP) 'to avoid undue human health risks from recontamination and to maintain the integrity of remedies intended to protect human health'. They also recommended that the 'effectiveness of remedial actions for human health protection needs to be further evaluated. This evaluation should be supported by ongoing environmental and blood lead monitoring efforts'.

7.2 Trail, British Columbia, Canada

Trail BC has been the site of a major lead and zinc smelting facility for over 80 years (Hilts 2003). Following blood lead level monitoring which showed higher than average BLL in Trail and later despite a decline in overall BLLs, there were 39% of the Trail children tested in 1989 above the US EPA's level of no concern of 15 µg/dL. This resulted in the formation of the Trail Community Lead Task Force in 1990.

The apportionment of childhood lead exposure to current and historical sources is an important factor in remedial decision making for sites with active sources of lead dust (Hilts 2003). These findings suggest that increased attention should be paid to the importance of emission reductions at other sites with operating lead smelters. The IEUBK model over-predicted with measured blood lead levels in Trail children when the new smelter started. The only parameter change that brought the predicted blood lead levels in line was a reduction in soil/dust bioavailability from 30% to 10%.

This research emphasises the importance of ‘active sources’ of lead vs soil concentrations.

“The IEUBK (USEPA 2007), with its emphasis on soil concentrations, would not have predicted the dramatic decline in children’s blood lead levels seen in Trail following the reductions in air lead levels but may have been due to inputting less accurate measured data for lead emissions. The Trail experience suggests that increased attention should be paid to the importance of active sources of highly bioavailable and mobile lead bearing dusts.” (Hilts 2003). Figure 12 shows the trends at the time.

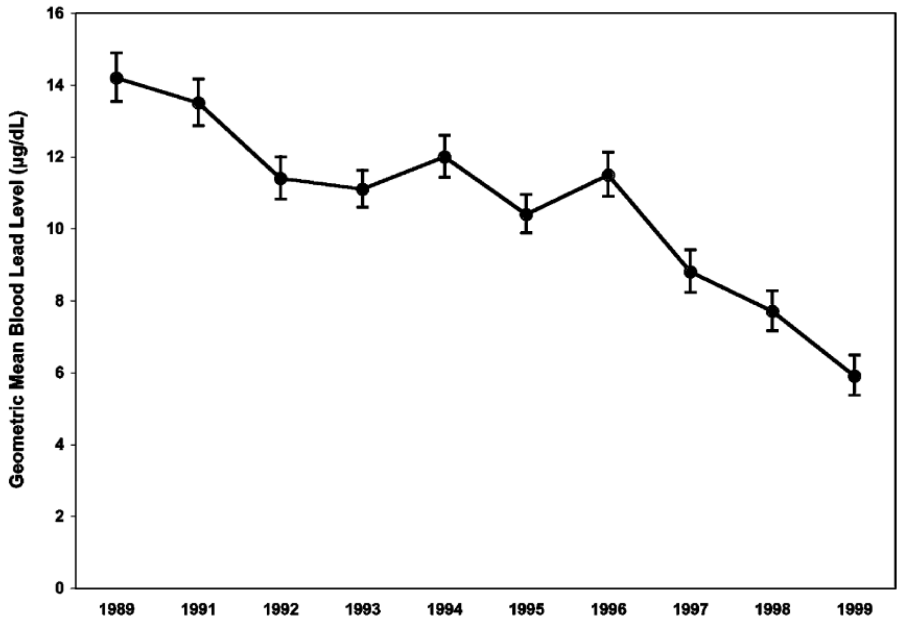


Figure 12 Geometric mean blood lead levels in Trail children (error bars are 95% confidence limits on the geometric means) in Hilts (2003)

More recently updated data from the Trail Area Health and Environment Program (TAHEP) (Trail Area Health and Environment Committee (TAHEC) 2014) shows that the rate of change has reduced in the last few years (Figure 13).

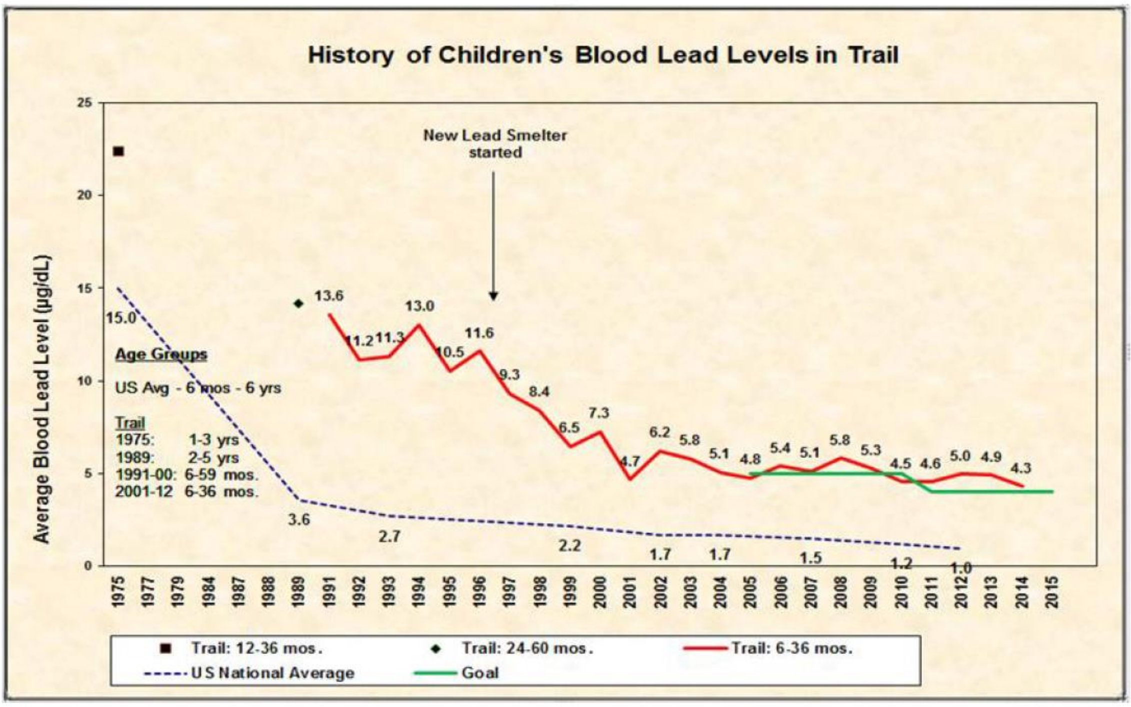


Figure 13 History of children's BLL in Trail, 2014

Progress in reducing lead emissions is shown in Figure 14. The level of lead in community air has averaged around 0.35 µg/m³ in more recent years (TAHEC 2014.)

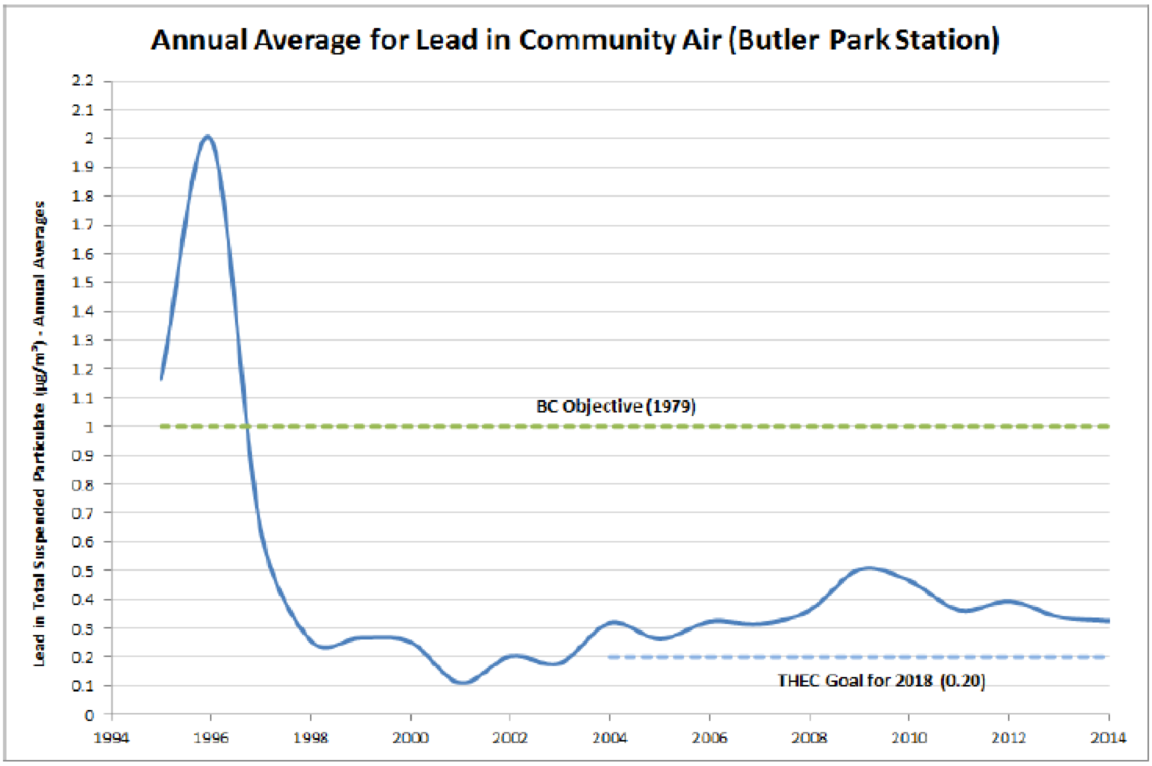


Figure 14 Lead in community air (Butler Park Station) Trail (TAHEC 2014)

The finding that smelter lead emission reductions were associated with large and rapid declines in dust lead levels in Trail (TAHEC 2014, p7) is consistent with the finding by van Alphen (1999) that metal deposition in dust fall containers in Port Pirie, Australia appeared to be derived more from current smelter emissions, than from historical dust lead sinks.

Yard clean up near the Bunker Hill Superfund Site, (BHSS) was found to be an effective tool for reducing house dust lead concentrations (and reduction in children's blood lead levels) (Sheldrake and Stifelman 2003). It was noted that contiguous cleanup of residences has a three times greater reduction of children's blood lead levels versus cleaning neighbouring properties. This highlighted the importance of a community-wide preventative approach to controlling lead contamination in soil and lead dust.

7.3 Butte-Silver Bow, Montana, USA

Butte – Silver Bow, Montana was a large scale mining and mineral processing activity which has experienced 25 years of ongoing remediation efforts and a residential metals abatement program (BSBHD 2014). This program has included BLL monitoring of Butte children, examination of blood lead trends and assessment of the effectiveness of Butte's lead source and exposure reduction measures.

An evaluation study (Schoof et al. 2015) has examined the BLL trends in a total of 2796 Butte children aged 1–5 from 2003–2010 as compared to a reference data set matched for similar demographic characteristics over the same period. Blood lead differences across Butte during the same period were interpreted with respect to effectiveness of remediation and other factors potentially contributing to ongoing exposure concerns.

The BLLs in Butte were higher when tested in summer/fall than in winter/spring for two neighbourhoods, and statistically higher BLLs were found for children in Uptown living in properties built before 1940, probably associated with lead in paint (Schoof et al. 2015). The persistence of greater percentage of high BLLs (45 µg/dL) in certain areas of Butte vs. the reference data set supported the continuation of the home lead abatement program. It was concluded that BLL declines in Butte arose from the cumulative effectiveness of screening efforts, community-wide remediation, and the ongoing metals abatement program in. The Butte abatement programs including home evaluations and assistance in addressing multiple sources of lead exposure were considered to be important complements to community-wide soil remediation activities" (Schoof et al. 2015).

7.4 Implications of lessons learned for North Lake Macquarie

It is in the context of experience and outcomes from the studies cited above that enables the following observations to be made. This comment poses a question for North Lake Macquarie (NLM) on the site specific nature of soil ingestion rates (see von Lindern et al. 2016) and whether there is a probabilistic distribution of BLLs in a population that is sufficiently representative to identify if remedial attention to any site is needed. The Butte evaluation study (Schoof et al. 2015) shows the importance of conducting representative long term evaluation of BLL in children.

In addition to the significance of dust ingestion rates, investigations of a single acidic extraction show that the slag at NLM easily releases lead. This property of slag poses a long term threat because of a lack of inertness of the slag (Morrison and Gulson 2007). An important detail to recognise in the context of understanding population BLL at NLM and soil lead concentration is that gastric-only bioaccessibility measurement will over-predict bioavailability of lead and should be confirmed by using the USEPA IEUBK model to predict blood lead increase from ingestion of slag dust or soil by children. Lead uptake occurs via the intestinal phase and not from the gastric/stomach phase where solubilisation occurs (Section 10.2). Site specific clean up levels can be derived from IEUBK model BLL predictions and be supported by site-specific measures of total and bioaccessible lead.

The concept of a lead budget is posed as a useful tool to estimate the total load to the environment and to map its fate (Figures 10 and 11). As remediation is undertaken the budget can be updated to reflect the removal and safe encapsulation of a proportion of that lead. This could help to quantify the significance of residual un-remediated lead contamination in the environment and whether it requires further investigation to verify its significance from a human health perspective.

A range of data exists in reports concerning the North Lake Macquarie location which could help to develop such a 'lead budget'. One such source is shown in Figure 15 where lead in mass emissions were estimated (EPA 1999, Dames and Moore 1994, PMS 2000 in Morrison 2003).

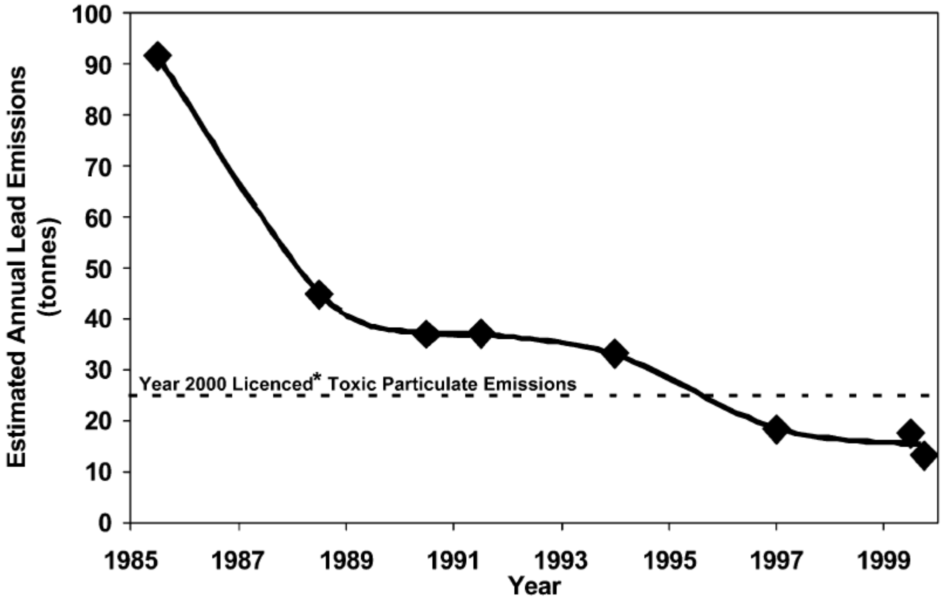


Figure 15 Estimates of smelter lead mass emissions in the period 1985/1986-2000
(EPA 1999, Dames and Moore 1994, PMS 2000. in Morrison 2003)

An estimate of the volume of remaining lead in the environment may be needed in order to deal appropriately for planning and designing future repositories of lead-contaminated materials. There will need to be a plan for a future repository as residual black slag from playing fields, road sides and other locations. This literature review does not report on the progress toward developing such a repository for these wastes; however, planning may well be advanced for this, through the LMCC.

From studies of lead in the aquatic, estuarine and lacustrine sediments, (e.g. MHL 2002) it could be possible to estimate the volumes of lead-contaminated sediments; however, this would require further study and updated data may also be required considering the sediment mobility in Cockle Creek and Bay. Where cores have been taken there are indications of historic contamination with less contaminated sediments overlaid (Figures 16 and 17). Figure 18 indicates the spatial distribution of lead concentration within Lake Macquarie. Figure 19 shows absolute changes in lead concentrations between 1975 and 2003.

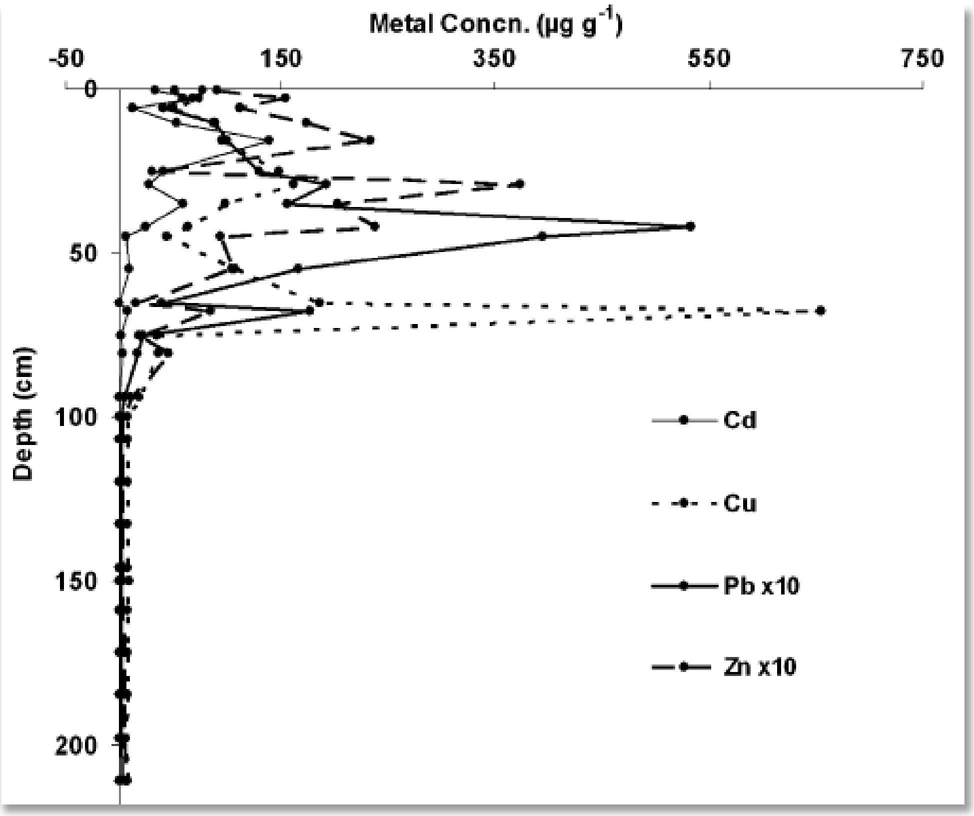


Figure 16 Metal concentrations from Core 3 Cockle Creek (mouth) Olmos et al. (2010)

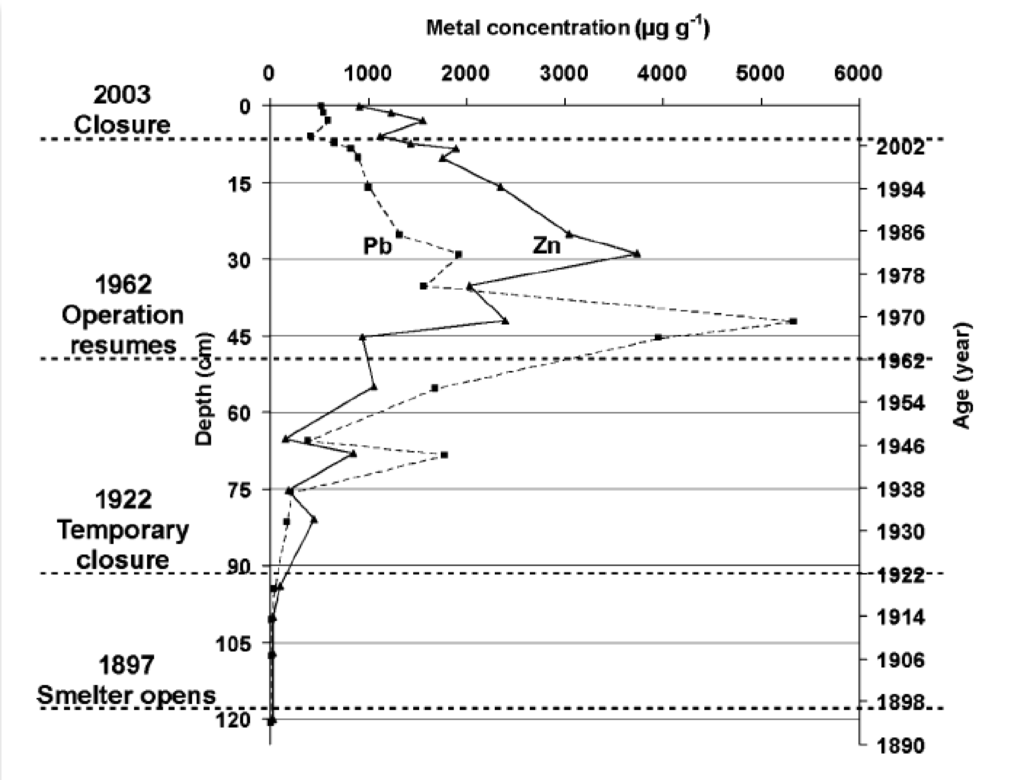


Figure 17 Lead and zinc concentrations in core 3 (Cockle Creek with corresponding ages) Olmos and Birch (2010)

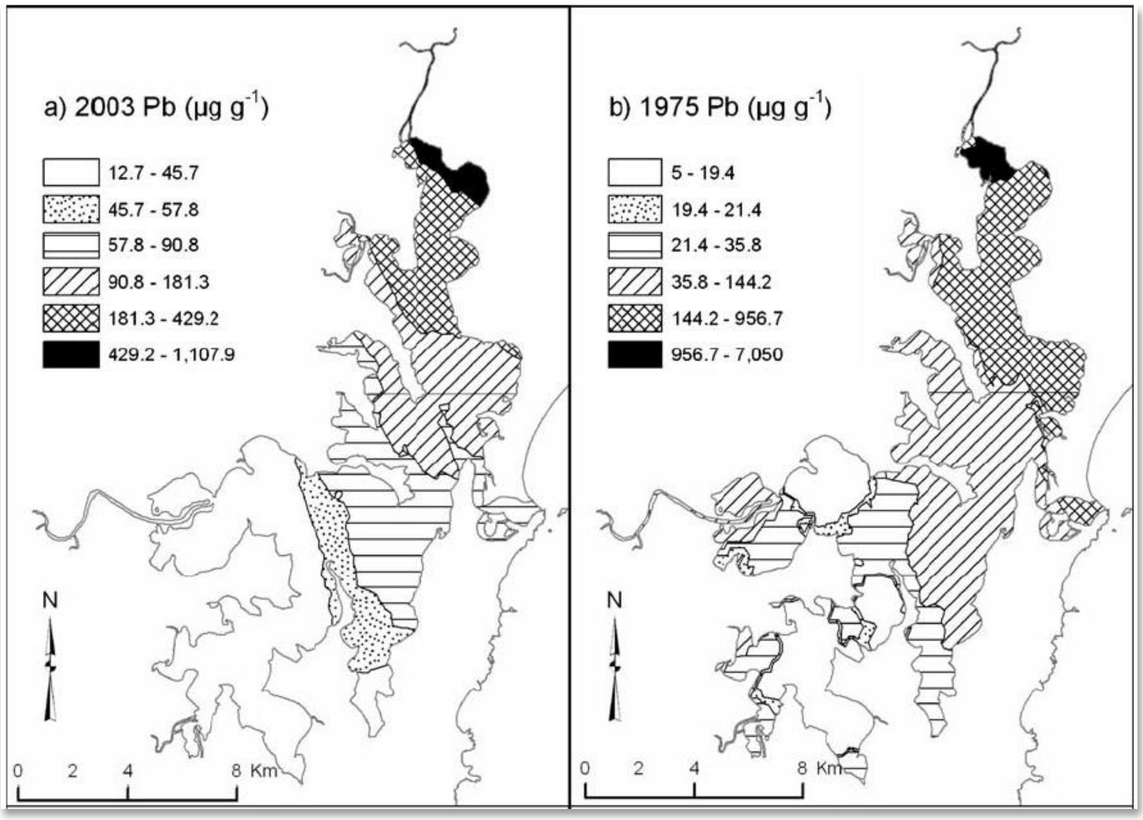


Figure 18 Lead concentrations (µg/g) 2003 and 1975, Olmos and Birch (2010)

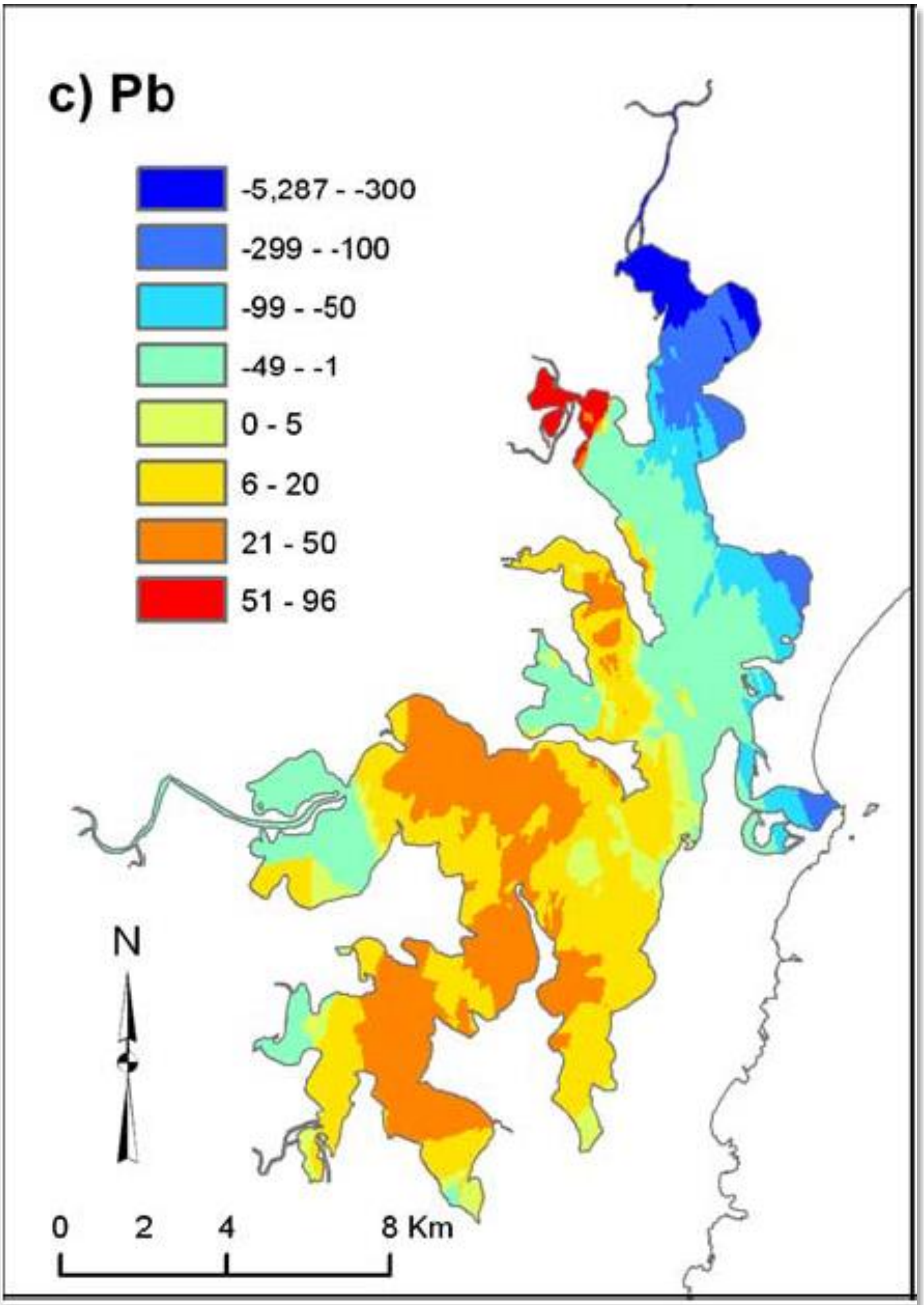


Figure 19 Absolute change (µg/g) in lead concentrations from 1975 to 2003 in Lake Macquarie - Olmos and Birch (2010)

River sediment coring may be required further upstream from Lake Macquarie up into Cockle Creek to define the risk of exposure of contaminated sediments through natural fluvial processes including extreme events. It is not clear if there are institutional controls for lake sediments to minimise their re-disturbance and contamination.

The review found some studies of the food chain about 13 years ago (Batley 1992) and occasional examination of lead and other metal accumulation in fish and other aquatic species (Alquezar et al. 2006, Roach et al. 2008). From five fish species collected in Lake Macquarie, higher lead concentrations were found in samples from Cockle Bay when compared to reference estuaries (Roach et al. 2008). In addition, the magnitude of the lead bioaccumulation was greatest in bottom-dwelling species that burrow into the sediment seeking food. Further studies are required to investigate the pathways through the food chain to humans (via fish and shellfish) and also to study bioaccumulation. An adaptive management approach as a whole to ensure links between management objectives, management options, performance benchmarks and quantitative monitoring indicators for habitats and ecological communities.

Earlier it was noted (Section 4.5.4) that there is a need to quantify groundwater (potential primary source of dissolved metals in surface water and precipitated metals in sediments) to define the extent of contamination of the groundwater aquifer, the dynamics of groundwater movement and the complex relationship between surface water and groundwater including Cockle Creek. This would need to take account of the recent remediation program on the Pasminco site.

In addition, an understanding of speciation of metals essential to characterise risk more effectively and ascertain the effectiveness of potential remedial actions '*Speciation information should be collected and examined to elucidate the potential for metal transport and the effect of transformation processes on the fluxes and bioavailability of metals*.' (NRCNA 2005).

8. COST OF PROGRAMS AND MANAGEMENT PRACTICES

This section addresses the Scope of Works Item 3.4 'The costs of the programs and/or indicative costs associated with management practices and strategies identified'.

8.1 Introduction

Remediation costs for programs of remediation work overseas can be insightful in terms of:

- How the work has been planned, undertaken and monitored;
- Line items for expenditure;
- Duration of expenditure required for monitoring and other ICP (after works have been completed);
- Gaining an indication of the proportion of work carried out by governments versus contractors (and industry if the company still has a presence); and
- To gain orders of magnitude costs for various tasks.

However, because each lead contaminated site is unique in terms of nature and distribution of the contamination as well as the social context, and local capacity to undertake the works, it would be very difficult to transfer those costs directly to the northern Lake Macquarie context. Another critical aspect to consider is whether contaminants other than lead, are present which require additional or alternative treatment methods.

Investigation Levels for human health exposure are generally the Health Investigation Levels ('HILs') which are site specific. To accommodate the range of human exposure settings, a number of generic Investigation Levels have been set (NEPC 2013) based on land use and human activity (Section 4.5.3). HILs are only used for assessing existing contamination and are intended to prompt an appropriate site-specific assessment where levels indicate there is the potential for adverse effects on human health values for that site. The site should be sufficiently characterised and realistic Investigation Levels selected, to ensure the comparison is meaningful and appropriate; e.g. for houses or recreation activities. This information would then provide a more accurate basis for assessing remediation costs.

8.2 Bunker Hill, Idaho, USA

The Bunker Hill cleanup up remedy is estimated to cost approximately $360 million (see Table 5). The selected remedy is described in four parts in Section 12, Part 2 of the ROD (EPA 2002 in NRCNA 2005):

Protection of human health in the community and residential areas of the upper, middle, and lower basins

1. Environmental protection in the upper, middle, and lower basins
2. Lake Coeur d'Alene
3. Spokane River.

Table 5 (Table 8-6 in NRCNA 2005) shows the break-down of estimated costs.

Table 5 Estimated cost of the selected remedy (NRCNA 2005)

Area	Selected Remedy	Estimated Total Cost
Human health protection in the community and residential areas of the upper basin and lower basin	Full remedy, including soil and house dust, including yards, infrastructures, repositories, rights-of-way, commercial properties, and recreation areas	$92,000,000 Including:
	Alternatives S4 (information and intervention and partial removal and barriers) and D3: (information and intervention, vacuum loan program/dust mats, interior source removal, and capping/more extensive cleaning)	$89,000,000[a]
	Drinking water: Alternative W6 (public information and multiple alternative sources)	$2,200,000
	Aquatic food sources: Alternative F3 (information and intervention and monitoring)	$910,000
Ecologic protection in the upper basin and lower basin	Approximately 30 years of prioritized actions	$250,000,000 Including:
	Upper basin tributaries	$100,000,000
	Lower basin riverbanks and bed	$71,000,000
	Lower basin floodplains	$81,000,000
Lake Coeur d'Alene	Not included in the selected remedy	
Spokane River	Combination of elements of Spokane River Alternative 3, 4, and 5	$11,000,000
Monitoring	Basin-wide monitoring	$9,000,000
Total Cost		$360,000,000

NOTE: costs are rounded to two significant figures.
[a]Includes costs for residential soil, street rights of way, commercial properties, and common areas, 31 recreational areas in the lower basin, and house dust.
SOURCE: Adapted from EPA 2002, Table 12.0-1.

8.3 Butte, Montana, USA

In 1983, Butte, Montana was declared a federal Superfund Site. Mine tailings deposits through the area of Silver Bow Creek/Butte contain elevated metals from a century of mining and smelting in Butte and Anaconda, Montana.

Soil abatement of residential yards located in the Butte Priority Soils Operable Unit (when soil lead concentrations exceed 1200 mg/kg or arsenic concentrations exceed 250 mg/kg) as well as clean up works for attic dust, interior dust and paint removals (lead, arsenic and mercury) have been undertaken by the Residential Metals Abatement Program (RMAP) within the Butte-Silver Bow Health Department (BSBHD) during the 2013 financial year (BSBHD 2014). In summary the program completed:

- **113** projects consisting of **33** soil abatement projects including **one** storm water project, **76** residential attics and **4** interior living space dust abatements. All abatement projects were completed due to lead levels ≥1200 mg/kg and/or arsenic ≥ 250. Children were living at or frequently visited the majority of the residences where abatement activities occurred, and

- **208** environmental assessments. The data obtained from the environmental assessments would be used to develop a list of potential abatement projects for the 2014 construction season (BSBHD 2014).

The RMAP purchases and provides much of the materials to ensure compliance with EPA requirements and the contractors use these materials (BSBHD 2014). The attic dust, interior dust and lead-based paint abatements are conducted by RMAP staff.

Table 6 RMAP expenditure 2013 (BSBHD 2014)

January 1, 2013 – December 31, 2013 Detail of Expenditures

Salaries	$	358,621.16
Employee Benefits	$	161,153.30
Payroll / Personnel Expenses	$	6,082.45
Supplies	$	144,561.56
Fixed Assets	$	7,157.48
Postage	$	608.07
Publicity / Media	$	1,000.00
Rent	$	10,718.81
Printing and Duplicating	$	1,037.00
Utilities	$	2,597.67
Repair and Maintenance Services	$	3,786.00
Training	$	5,135.00
Professional Services	$	47,852.00
Contract Services	$	182,336.45
Insurance	$	6,769.25
Computer Charges	$	3,690.00
PBX Charges	$	2,713.56
Machinery and Equipment	$	111,977.72
TOTAL EXPENSES	**$**	**1,058,988.18**

A complete summary of costs for the total program would require a review of a number of documents. It is apparent that there was also a redevelopment program following the groundwater treatment program 'Butte treatment lagoons'. There is also evidence of storm water system improvements including installation of hydrodynamic devices as well as new ordinances, protocols and permit requirements to ensure public education public involvement, illicit discharge detection and elimination, stormwater runoff controls during and after consultation and robust operations and maintenance program.

By 15 October 2014, since 1995, 2595 properties were sampled, 820 properties abated; 450 years; 370 attics with an annual scope of 240 properties to sample, 30 yards abated and 30 attics. From the perspective of works done and works yet to be done, it is possible to freely access maps of these areas.

The same is not true for the North Lake Macquarie area where there is no single publicly available map outlining areas where works have been undertaken or where contamination is still evident. There is a high degree of transparency in these Superfund projects. Figure 20 shows an example of the level of data on a range of actions, as well as the transparency of known contamination for the project and community.

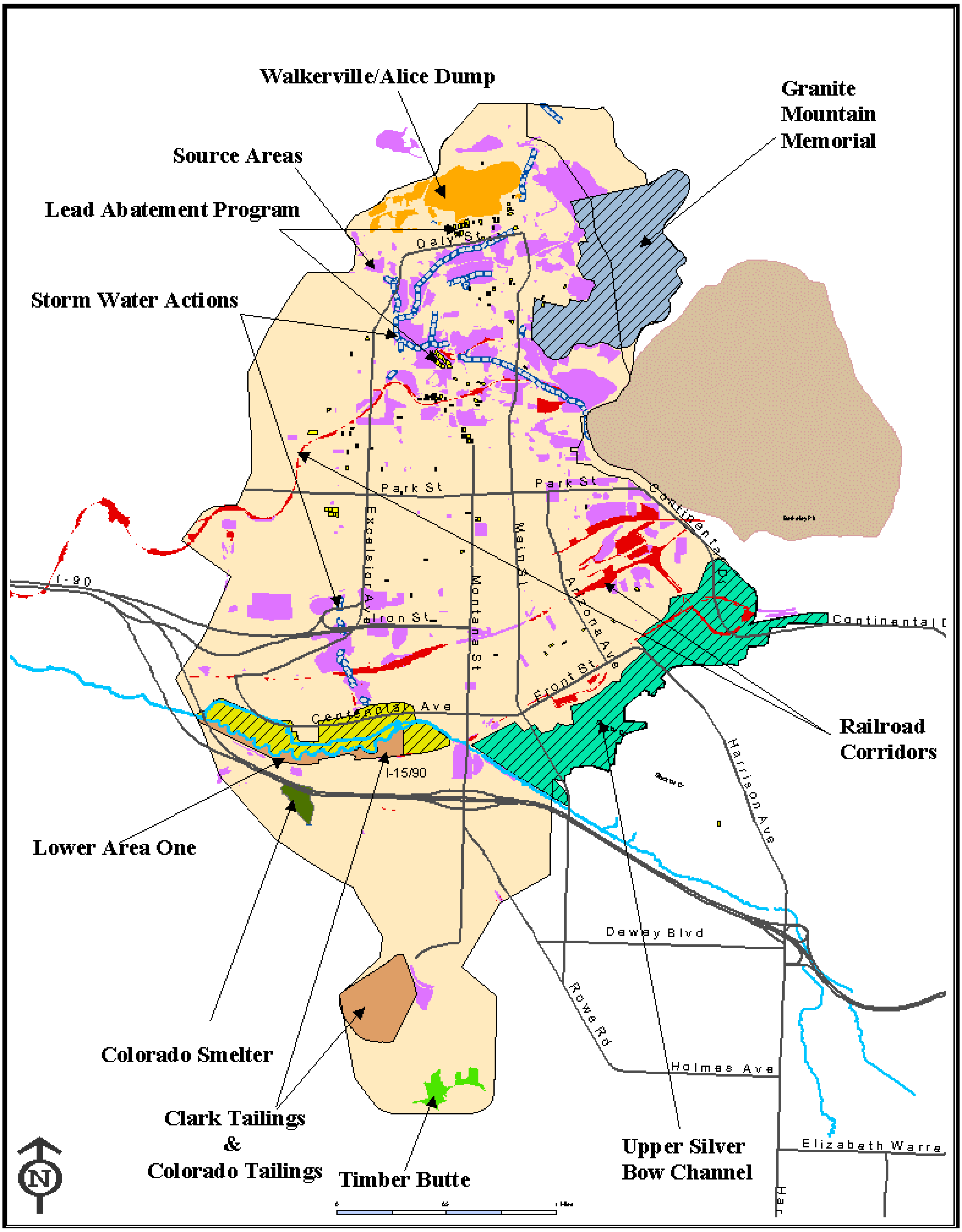


Figure 20 Major works in program/ongoing Butte Silver Bow - 2014
Source: Butte Silver Bow Council Presentation “Butte Priority Soils” Cleanup – 10-15-14

8.4 Trail lead program, British Columbia, Canada

The Trail lead program was introduced in Section 7.2. Information on costs have been located in documents from the Trail Community Lead Task Force in 1990 and subsequent research (Hilts 2003).

The Task Force estimated the cost of residential soil replacement in Trail proper alone at over $55,000,000 (Hilts, 2003) however there were significant concerns about this approach. The following estimates were made in 2000 and it is important to note that emissions were continuing at this stage however there were targets for reduced emissions from the Company (Cominco).

Estimated costs of remedial options (based on 2000 dollars) included:

- Blood testing - $30,000 /year (p73)
- Case management - $20,000/year (p75) with assumption about BLL's and anticipated decline over time
- Community an early childhood education - $25,000/year
- Dust control in unpaved alleys - $8,000/year
- Greening of public areas (company undertook)
- Loan of HEPA vacuum cleaners - $1,000/ year for maintenance, parts and supplies
- Provision of nutrition counselling and foods - $1,000-2,000/year (~50 families in 1999)
- Financial assistance for relocation – ~$15,000/ year (where no response in BLLs)
- Buffer zone expansion $300,000 +?
- Changes in zoning – no cost for rezoning except impact on property values, $85,000 - $125,000 per property if demolition of homes occurs
- Soil remediation by provision of materials - $30,000 /year based on 30 properties
  - Soil mixing above a specified level of lead contamination $2,500- $20,000 (per property)
  - Chemical soil treatment (not fully explored or costed)
  - Phyto-extraction (not fully explored or costed)
  - Soil removal and placement above a specified lead level (top 30cm and replace with 'clean' soil i.e. <100ppm) $13,000 to $47,000 per property
- House dust remediation - $37,500/year (for 150 houses) plus purchase of HEPA vacuum cleaners for 6 day-care centres $8,000
- Comprehensive house de-dusting (removal of carpets etc.) $1,500 (Toronto) and $700 (Port Pirie) per home
- Lead-based paint abatement - $200/property $1,000-$3,000 up to $3,000/property ($9,000-$15,000 year).

Estimated costs for soil remediation are shown in Figure 21.

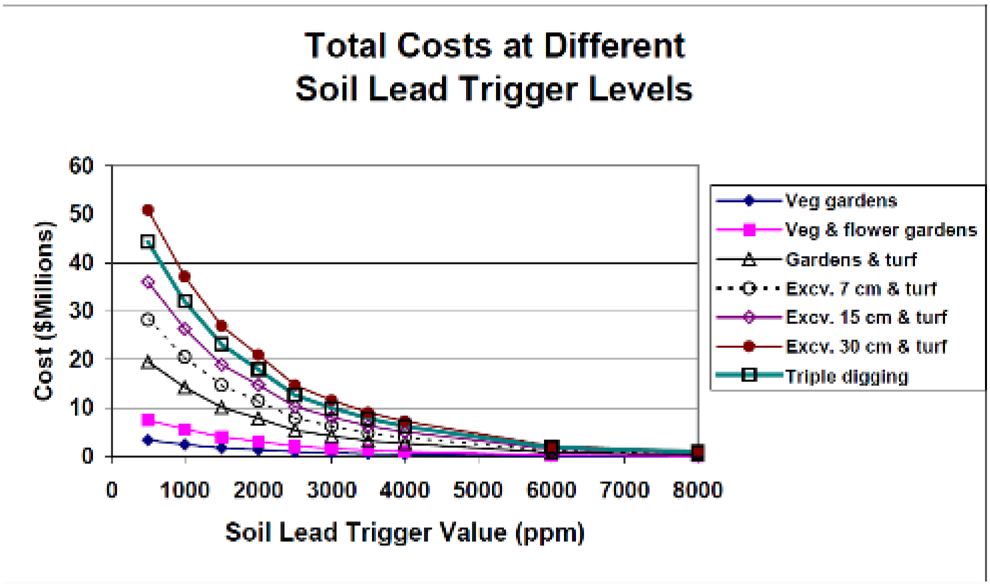


Figure 21 Soil remediation cost comparison Trail, BC (Hilts, White and Yates 2001)

There are costs, other than soil remediation, predicted in this review of remediation options, however further investigation would be required to find how much it actually cost and align that with what works were undertaken.

A newspaper article dated January 28,2016 notes that Teck Metals were to plead guilty to 15 charges over pollution in Trail, BC. While that article notes considerable investment in plant improvements there are a number of unresolved legacy issues (legacy dumps and groundwater contamination). Contemporary independent sources of data would be needed to verify costs associated with implemented interventions.

9. METHOD AND EFFECTIVENESS OF EXPOSURE CONTROL

This section addresses the Scope of Works item 3.5 ‘Where exposure control was used, the method used and their effectiveness’.

Hence, as a measure of remediation success, the reduced risk to lead exposure can be assessed in two ways:

1. A reduction in blood lead concentrations of the most susceptible subpopulation of residents (usually children); or
2. A reduction in lead concentration of soil and dust, which were the major pathways of lead exposure.

The difficulty identified by Elias and Gulson (2003) means that neither of these measures adequately evaluates the long-term effectiveness of remediation. This may arise from deficiencies in the program through not undertaking complete health risk assessment (Section 4.5.2).

Table 7 aims to summarise key elements of two of the leading practice case studies, Trail and Bunker Hill, and provide a comparison with the PCCS Lead Abatement Strategy.

A further summary is given in Table 8 for key items identified for lead smelter site remediation and abatement that in addition to Port Pirie, Trail and Bunker Hill includes summary details of Noyelles-Godault (Pas-de-Calais, France (Declercq et al. 2006, Douay et al. 2008, Ettler 2016, Lorenzana et al. 2003), Rouyn-Noranda, Quebec, Canada (Ettler 2016, Lorenzana et al. 2003), Flin Flon, Manitoba, Canada (Franzin et al., Henderson, P.J. 1998 and Pip 1991), San Potosi, Morales, Mexico (Carrizales et al. 2006 and Diaz-Barriga et al. 1993) and Butte-Silver Bow USA (BSBHD 2014, Schoof et al.2015). Many observational features of lead smelter operation and remediation are common to all, and justify limiting the detailed evaluation of this report to those sites having the most comprehensive detail.

Table 7 Summary table of lead exposure control programs: Bunker Hill, Idaho, USA, Trail, British Columbia, Canada and NLM PCCS LAS

	Remediation programs		
Control measure for contaminant source pathway	**Bunker Hill Superfund Site (BHSS), northern Idaho, USA (Source: Sheldrake and Stifelman 2003 unless otherwise noted)**	**Trail, British Columbia, Canada (Source: Hilts 2003, unless otherwise noted)**	**Lead Abatement Strategy by Pasminco Cockle Creek Smelter, Northern Lake Macquarie (Source: PCCS 2007 unless otherwise noted)**
Data sources			
Dust for lead in air and dustfall	Dust lead concentrations greater than 1000 mg/kg will be evaluated for interior cleanup following completion of the soil cleanup (EPA, 1991 in Sheldrake and Stifelman 2003) 1996 study of adjacent areas found similar associations with BLLs	Collected for 24 h every 6 days using HVA samplers (Hilts 2003) Decline in smelter emissions was accompanied by a 50% reduction in fine, mobile dust lead loadings on exterior and interior surfaces.	'>90% reduction in dust levels due to smelter closure' (not verified in PCCS, 2007). Reduction post-smelter closure noted elsewhere (Morrison 2003) EPA presentation to Lead Expert Working Group (29 Jan 2015) on actions to reduce exposure of children to lead. History, regulatory context and actions. http://www.epa.nsw.gov.au/resources/epa/lewg-meeting2-presentation.pdf
Lead in soil, interior floor dust, street dust and interior dustfall	Links outdoor contamination to indoor re-contamination within a year, (1990 CH2MHill, 1991 in Sheldrake and Stifelman 2003) Vacuum cleaner load Parental counselling on personal hygiene Following closure of the smelter, residual contamination in community soils and dusts was identified as primary source of lead exposure to children. Co-factors identified; parental income and socio-economic status, parental education level, smokers in home, nutritional status of the child, use of home grown produce, exposed soil in yard, hours spent outside, pica behaviour and age (Panhandle Health District 1986 in Sheldrake and Stifelman 2003)	Quarterly sampling network of 32 'sentinel homes' 1994-1999 Soil sampling top 2-3 cm of soil profile dried and passed through 180µm screen Floor dust used 'microvac' method (Que Hee et al, 1985 in Hilts 2003) and subset of 8 homes, whole-house HEPA vacuum method (Hilts et al, 1995 in Hilts 2003) Loan scheme for HEPA vacuum cleaners Street samples, 25 cm x 25 cm areas brushed, dried and passed through 180µm screen Indoor dustfall 20 cm x 20 cm x 7 cm jars on top of furniture (rinsed with distilled water and dried) Sampling of the Sentinel Homes had slight declines in soil and floor dust lead concentrations but these were not statistically significant	Zonal remediation commenced in December 1998 (Morrison 2003) An alternative method applied by Warner-Smith and Hancock (in Elias and Gulson 2003) included a qualitative evaluation via survey of the householder's satisfaction with residential lead abatement. This was polarised and linked to perceived quality of remediation performed. 'unlikely to be chicken runs' (PCCS 2007) no evidence provided) Port Pirie 2005 report highlighting target demographic as infants and toddlers, used as primary reason why the LAS focusses on residential properties and not public open spaces. LAS only addressed topsoil in yards. Provided advice on other aspects but not works i.e. Consultation to provide advice on lead dust in roofs or cavity walls of building or in garden beds to property owners and LMCC and Department of health on how to address during and after the duration of the LAS program Sampling will generally be undertaken at 5 locations across accessible parts of each property and the lead concentration measured directly in the top 50mm of the surface soil at each of the five locations
Database maintenance	Confidential DB maintained by IDHW relates children's BLLs, media contaminant concentrations, environmental exposures, health intervention and remedial activities on an individual basis. Summary data only, released.	Ongoing by Trail Area Health and Environment Program http://www.thep.ca/ Smelter company also maintains databases (likely to include different content – further review would be required)	~2500 private properties were offered testing ~1230 accepted 44 Cat 1, 560 Cat 2, 116 Cat 3, 77 Cat 4, 18, Cat 5, zero Cat 6, 7 not eligible due to slag content Abatement works offered to 437 residential properties (359 had works done), 784 received educational materials Source: EPA presentation 2015

	Remediation programs		
Control measure for contaminant source pathway	**Bunker Hill Superfund Site (BHSS), northern Idaho, USA (Source: Sheldrake and Stifelman 2003 unless otherwise noted)**	**Trail, British Columbia, Canada (Source: Hilts 2003, unless otherwise noted)**	**Lead Abatement Strategy by Pasminco Cockle Creek Smelter, Northern Lake Macquarie (Source: PCCS 2007 unless otherwise noted)**
			http://www.epa.nsw.gov.au/resources/epa/lewg-meeting2-presentation.pdf Full records will be kept which can be audited by DECC or LMCC as per agreement between the Deed Administrator and the stakeholder authorities. (Not able to be verified as part of this review)
Included sources other than dust			
Other lead sources - if/how they were included in remediation	Tailings in the riverine environment: flood plain and river	Delineation of contamination undertaken as part of risk assessment and provided in THEC, 2014 Section A-6. Slag was used as a source of fill in downtown Trail and has a separate risk-based investigation underway as part of SGM program. Deposition of dust fall is the main focus of this program.	Slag not included as this was considered to be used on a voluntary basis (PCCS 2007)
Consultation			
Duration – one off or continual		Trail community lead Task force, Trail Area health and Environment Committee Teck's Environment and Community Feedback line 25-year Task Force duration (2014 TAHEC) industry (Cominco, Teck), government health and other community representatives	Initial consultation period will not exceed 6 months, with further consultation planned during Implementation

Exposure assessment			
Blood lead testing	Wider age range screened early, narrowed down to target age range based on data In 1994, high risk was reduced to 6 years of age in line with EPA guidance Children with > 10 µg/dl BLL are given a high priority for yard soil testing and replacement. Residents with pregnant women or young children can request priority clean up during the summer. Comprehensive health study, 1983 (Federal, state and local) (Panhandle Health District 1986 in Sheldrake and Stifelman 2003) 80% of children had BLLs > 10 µg/dl Objective: < 5% of children with BLLs of 10 µg/dl or greater; and < 1% of children > 15 µg/dl. LeadCare capillary levels reported higher results than LeadCare venous levels (differences < 0.5 µg/dL) Selection bias may have influenced results in either direction, but limited due to participation of >50%. 2 year olds exhibited highest BLL in recent sampling – needs to continue to be closely monitored	High participation rates; from 1989-199 ranged from 75-85% of eligible children. Those testing low earlier, tended not to return for subsequent years' testing. Wider age range screened early, narrowed down to target age range based on data Trail: 1975 BLL 22 µg/dL in children 12-36 months (Neri et al. 1978 in Hilts 2003) 1989 13.1 µg/dL (2-5 years) geometric mean BLL (Hertzman et al 1991) Triggered comprehensive lead exposure prevention program; • Annual BLL screening 6-60 months • Case management • Education programs (early childhood focus) • Community dust abatement • Exposure pathway studies and intervention trials 1983-1993 mean BLL decreased by about 70% due to combination of education and soil removal from 1985 (Techagraphics Environmental Engineering, 1993 in Hilts, White and Yates 2001) [new lead smelter in 1997, Hilts 2003] 1990 Follow up testing of children with 15 µq/dl or higher in 1989 2001 BL testing 6-36 months Primary exposure risk children < 3 years of age (TAHEC 2014)	From Hunter New England Local Health District webpage: http://www.hnehealth.nsw.gov.au/hneph/EnvironmentalHealth/Pages/testing-2015.aspx Studies from 1991 onwards found elevated blood lead levels in children who lived within several kilometres of the smelter. In 1991, 84% of children aged one to four years in Boolaroo and Argenton had blood lead levels of 10 micrograms per decilitre (µg/dL) or above, a level at which learning and behavioural problems may occur. From 1998 to 2001 a household abatement program provided carpet and ceiling vacuuming, removal of visible slag and top dressing of soil. There was however no appreciable reduction in children's blood lead levels as a result. After the smelter's closure, average blood lead levels in children under five years of age steadily declined from 9.6 µg/dL in 2003/04 to 6.8 µg/dL in 2004/05 and to 4.5 µg/dL in 2005/06. The proportion of children in this age group with lead levels greater than 10 µg/dL also declined from 40% in 1997 to 26% in 2004, 17% in 2005 and 7% in 2006 2015 screening: Between 29 June and 17 July 2015, HNE Health screened 72 children aged from six months to five years of age and eight pregnant women living in Boolaroo, Argenton and Speers Point. The screening involved a single finger prick and families were given the results immediately. In this most recent screening program, no one returned a blood lead level greater than 5 µg/dL. The machine used for testing can detect blood lead levels as low as 3.3 µg/dL. Levels below this display on the machine as 'low' and of the 72 children tested, 63 (88%) returned a 'low' reading. (HNELHD 2015) http://www.hnehealth.nsw.gov.au/hneph/EnvironmentalHealth/Documents/blood-lead-screening-2015.pdf
Modelling – Integrated Biokinetic Update Model for lead (IEUBK)	First site where IEUBK was applied to determine risk-based cleanup criteria. Modelling and multiple regression analyses suggested lead exposure for children is comprised of 40% house dust, 30% community	IEUBK, with its emphasis on soil concentrations, would not have predicted the decline in BLL in Trail, following reductions in air lead levels (Hilts, 2003) Model recommended 42% lung absorption (US EPA, 1994 in Hilts 2003)	No evidence of this forming part of the LAS, but perhaps used in subsequent research Not clear how NSW health interacted with the planning for LAS

	soil and 30% from the neighbourhood (with 200-foot radius of child's home and yard) Lessons learned: IEUBK model would have benefited from greater collection and use of additional site-specific information (NRCNA 2005)	Maternal contribution 4 µg/dL (based on umbilical cord samples from 60 babies born 1993-94, Trail hospital) IEUBK over-predicted BLL until the bioavailability was adjusted from 30% to 10% (which related to the significance of current emissions vs the historic store of lead)	
Hazard assessment - Bioavailability/ bioaccessibility	Recommendations made on how to improve on IEUBK (in Lessons Learned) (NRCNA 2005)	Highlighted need for more data to accurately predict. Smelter emissions known to be major contributor (TAHEC 2014)	No evidence of evaluation at the time of the LAS

Residential dust/soil clean up			
Residential soil containing lead	Yard soil cleanup program each summer since 1989 under Superfund From 1989-1993 homes of pregnant women and children <12 were targeted. Highest priority residential yards receive clean soil barrier of at least 30 cm throughout the yard and 60 cm deep in garden areas. Commercial property soils exceeding 1000 mg/kg lead are excavated to 15 cm or 30 cm depending upon lead concentration and intended use Objective: clean up of yards with lead concentrations > 1000 mg/kg Achieve geometric mean; • yard soil lead concentration < 350 mg/kg for each community in the site • house dust lead levels of < 500 mg/kg for each community in the site, with no house dust level exceeding 1000 mg/kg. BHSS average 2-year-old (Terra Graphics, 2000 in Sheldrake and Stifelman 2003) will have reduction of; • 1.7 µg/dL in BLL due to cleanup of the child's residential yard; and • 5.6 µg/dL due to cleanup of the neighbourhood and greater community (via subsequent declines in house dust lead concentration).	Soil remediation and options for mixing and replacement (chemical treatment and phyto-extraction not fully explored). Reviews by Hilts, 2003 revealed no known reports of testing or use of soil mixing to reduce the surface concentration of lead at any sites where human health is a concern From 1974 remedial action included soil replacement, resodding, paving, street washing and some relocation of families Remediation involves removal to 30 cm depth, installation of demarcation layer (visual barrier fabric) and replacement of at least 30 cm of approved fill material. Vegetable gardens; metal levels > 1000 mg/kg lead are offered remediation. Soil removal to a depth of 60 cm and replacement of at least 60 cm of soil	LAS initiated as part of the approval from the Minister for Planning under part 3A of the EP&A Act 1979. The LAS was linked to the PCCS site remediation. LMCC defined all Nominated Properties (s.149 certificate notation) Condition to undertake annual lead survey per property per year if request by owner, will lapse when LAS is implemented (Condition 42). If lead concentration was >300 ppm then PCCS should monitor that property annually (Condition 43) Condition 44 – not known – considered lapsed in 2007 LAS implementation document The strategy will not remediate lead slag (or lead paint) but they will be 'noted for the owner's benefit' but the strategy will not include any actions to address lead exposure from these sources Not sampled as part of LAS; • Garden beds as they are 'expected to produce a lower lead result than from unremediated lawn areas' (not verified or tested?) • Council owned land at the front of the property • Areas < 2 m from a building or fence • Areas where car maintenance or car activity could have resulted in increased lead levels • Areas where slag is evidence on the property Portable hand-held XRF used to identify potential lead hot spots including downpipe discharge to topsoil No mention of sieving samples Sampling of top 50 mm for initial assessment Reference is made to QA/QC samples (not clear where the data are) Abnormally high lead result coupled with other low results is assumed to indicate slag has been used for fill (not clear if this has been verified by testing and analysis) Categories and criteria use NSW EPA 1994 lead management. plan 'similar to' US EPA Criteria for remediation treatment: very complex from implementation strategy) and in practice perhaps unrealistically precise: Category 1 <300 mg/kg no lead abatement action

			Category 2 >300 but < 1000 mg/kg (options a-c based on grass cover, no action if grass cover Category 3 >1000 ppm but < 1500 mg/kg (already grassed, add 25 mm of topsoil, otherwise 25 mm soil plus turn. If in shade with low grass ad 40 mm topsoil and mulch) Category 4 >1500 ppm but <2500 mg/hg (a, already grassed, ad 50 mm topsoil, b, not covered by grass, add 50 mm soil and mulch, c. in shady and low grass cover add 50 mm topsoil and mulch cover Category 5 >2500 mg/kg but <5000 mg/kg (a. excavate 50 mm topsoil and replace with 50 mm new topsoil, replace grass cover (if suitable lead content) or apply new turf. b, as above new turf, c. as above plus mulch) Category 6 >5000 investigate soil profile vertically to determine level of excavation required (expect 100 mm max) and then excavate reinstate with new top soil and apply new turf, maintain practical levels for particular site or mulch as above. Remediation didn't address food growing beds and driveways. No follow up audit to confirm effectiveness of LAS due to it not being declared under legislation - only an auditors review (HLA 2007).
Physical barriers	A durable fabric marker is installed as a visual marker if contamination remains at depth	Upper cap concentration, set out in Protocol 11 of the BC Ministry of Environment, contaminated sites Regulation. (TAHEC 2014). 5,000 mg/kg lead in soil is action level and from 2014 4,000 mg/kg will be offered remediation retroactively. http://www.thep.ca/upload/resources/80/THEP_FINAL_Sept_9_2014_With_THEC_signatures_FINAL_original.pdf	Clean soil replaced on participating properties to variable depth depending upon lead levels measured, grass cover and shade conditions (see section above on the depths of cover) but no permanent visible barrier to delineate the boundary between remediated and unremediated soils.
Audit statement – standard verification (QA/QC) & Performance reporting	Several 5-year review reports are available Follow up monitoring has analysed recontamination risks to inform the ICP Data derived on the value of cleanup of individual residential yards and houses with and without neighbouring area cleanup. Lessons learned: Because of the long term and uncertain nature of the project, a phased approach to cleanup with defined goals, monitoring and evaluation criteria (an adaptive management approach) is warranted. Concerns were raised about whether the Superfund governance process could apply sufficient flexibility to address all the problems at such sites, effectively and efficiently (National Academy of Sciences & US EPA 2005)	Regular program reporting through the Trail Area Health and Environment Committee http://www.thep.ca/upload/resources/80/THEP_FINAL_Sept_9_2014_With_THEC_signatures_FINAL_original.pdf	'Sites were not declared or regulated by DECC/EPA' (HLA 2007) Auditor undertook an informal review however the LAS evaluation did not require a formal Site audit Statement. Not all issues were within the scope of SA and are responsibility of LMCC and EPA LMCC database records where lead in soil >300mg/kg and remediation not undertaken (Notation 1 of Sect 149(2) planning certificates) LMCC database records where LAS (and other) remediation has been undertaken (Notation 2) LMCC database where testing has found soil lead to be <300mg/kg (Notation 3) Where no clear site history/inadequate knowledge LMCC may restrict development (Notation 4) There was an agreed standard at the time, however this standard may not meet the requirements of the future. Future ICP to address as well as; BLL studies and other monitoring/investigations may be required

Hygiene education	30% of population below poverty line Program included cooperative effort of multiple agencies. In addition to BLL screening, school visits, physician awareness for early diagnosis of problem lead exposures, and kindergarten activities (doll house puppet show on household sources of lead, 'glow germs' on spreading of lead etc.)	Education programs established and ongoing through the Trail Area Health and Environmental Program http://www.thep.ca/pages/about-the-program/ webpage indicates all aspects addressed: family health, air quality emissions reduction, home and garden, parks and wildlands, property development Case management, community and early childhood education, nutrition counselling and foods	During the LAS there were educational materials provided to the other 784 participants with lower lead levels (EPA 2015) Awareness raising devolved to local GPs and ensuring they are tuned in to blood lead health impacts – not clear if hygiene education continues.
Boundary definition			
Transparent process to determine boundaries of remediation	Initially targeted houses with children and pregnant women, then later, in 1994 the program expanded to cleanup contiguous parcels of land regardless of high risk occupancy in addition to the high risk yard program. Commercial properties cleaned up at a rate of 10% /year Important observation that 'The importance of soil outside of the home environment varies with distance, not property boundaries, and intake estimates should account for soil sources in the immediate neighbourhood and greater community." (von Lindern et al. 2016)	Remedial options paper addresses data and options plus options selection process (Hilts White and Yates 2001) Boundaries based on types of risks, e.g. human health vs ecological and types of risk management activities (e.g. to address air quality, children's exposure, ecological impacts etc.) (TAHEC 2014)	Not entirely clear how boundaries of the LAS grid were determined – appear to be strongly influenced by residential settlement and wind direction, but contamination extends beyond grid boundary – not clear how boundary was agreed. Reviewers were unable to find a source to verify how the boundary for the LAS was chosen. No final audit on process to the same standard expected today. (HLA 2007 audit review)

Public & undeveloped areas and transport corridors			
Open space, playgrounds and playing fields	Some city parks and playgrounds were cleaned up in 1986 Program expanded in 1994 to include all public properties Parks had similar results to residential yards, post remediation indicating minor contamination migration above clean backfill levels. Potential mechanisms; 1. Vehicle tracking during and after cleanup 2. Barrier disturbance (e.g. utility work); or 3. Other undefined sources.	Trail Area Health and Environmental Program http://www.thep.ca/pages/about-the-program/ webpage indicates all aspects addressed: family health, air quality emissions reduction, home and garden, parks and wildlands, property development Funding set aside for greening of public space	LAS Did not apply to public open space Outside the area of interest for LAS
Foreshore, creek bank, wetlands	More detail in those reports focussed on the Coeur d'Alene River	Public open space included in TAHEP (in TAHEC 2014)	Outside the area of interest for LAS
Unsealed roads and road shoulders of sealed roads & Railway easements/lines	Soil and gravel soft shouldered rights of ways along public roads have demonstrated significant and variable levels of recontamination. (TerraGraphics 1999e, 2000 in Sheldrake and Stifelman 2003) Higher concentrations found on 1989, 1990 and 1991 rights of way remediated compared with more recent remediation with 32% > 1000 mg/kg compared with 13% at the 0-2.5cm depth. Slow rate of remediation and vehicles tracking between cleaned and un-cleaned areas (including driveways) may be important mechanism for recontamination. Union Pacific Railroad right of way soil and gravel sampling indicated there was a need for better access control and careful oversight and scheduling of ICP projects. Commercial property soil lead levels indicated that vehicle tracking was a mechanism for recontamination. 'Soft barriers on commercial properties will require ongoing sampling.'	Funding allocated to road shoulder remediation as part of the program	LMCC is aware of some areas of slag on road shoulders however it is not clear from the review of literature how detailed or complete this data set is. LMCC indicated (pers comm July 2016 LMCC review of draft final report) that the data are incomplete as sites are added to the database as they are identified during maintenance and construction work, or through community reports. This practice has been in place only since the database was established and the EMP adopted It is not clear from the literature review if lead in soil (apart from slag, which is visibly easier to identify) has been sampled for road shoulders or unsealed roads within the North Lake Macquarie area. LMCC (pers comm, review of draft final report July 2016) indicate that road reserves and recreation areas within the LAS have been sampled, and where exceedances of the HIL occur, have been added to the database. Found no evidence of the railway corridor having been sampled as part of the LAS The reviewers did not access the LMCC database or maps of land tenure, use and ownership within the LAS. These aspects are needed to inform elements of lead recontamination risk, however, this was not possible within the scope of this review.

Water			
Surface water (and storm water systems)	Drainage improvements identified as part of the next stage to maintain cleanup goals (remediation was not completed at the time of Sheldrake and Stifelman 2003 paper)	Under Soil and Groundwater Management Program (see below)	Outside the area of interest for LAS
Groundwater	Well closures in contaminated aquifers after 1994 when the program expanded Lessons learned: EPA's site characterisation did not adequately address groundwater – the primary source of dissolved metals in surface water- or identify specific locations and materials contributing metals to groundwater. The sources of lead contamination to ground and surface water need to be identified and priorities set for their cleanup. (NRCNA 2005)	Under development is a Soil and Groundwater Management Program to address groundwater migration and localised ecological impact in Columbia River. Operational site issues are separate from THEP. (TAHEC, 2014) Studies/reports initiated by company.	Groundwater does not appear to have been part of the LAS
Extreme events (e.g. flooding)	Following clean up, recontamination due to extreme events becomes the responsibility of the property owner. Lessons learned: long term effectiveness of proposed remedial actions is severely limited by frequent flooding events in the basin and their potential to recontaminate remediated areas with contaminated sediments. Flooding received little attention in the selection of remedies. (NRCNA 2005)	Possibly addressed by LCEMP (TAHEC 2014)	It may be clear to LMCC who is responsible, but it was not identified in any LMCC documents who would be responsible for recontamination after extreme events (i.e. Cockle Creek catchment, bed, bank and delta sediments and North Lake Macquarie foreshore, banks and bed sediments)
Lacustrine and fluvial processes – remobilisation, transportation and deposition	Following clean up, recontamination due to erosion or deposition events becomes the responsibility of the property owner Lessons learned: downstream transport of lead contaminated sediments can only be addressed by removing or stabilising contaminated sediments in the river basin. (NRCNA 2005)	Lower Columbia Ecosystem Management Program (LCEMP) – collaborative approach to assess, rehabilitated, conserve and enhance land-based wildland (including wetland and riverbank/creek bank) (TAHEC, 2014). Teck initiated and tied to company commitments but also involves collaboration. Has steering committee.	Outside the area of interest for LAS Evidence of Landcare being involved in riverbank erosion stabilisation but few details provided (2016 flood study) LMCC (pers comm, review of draft final report, July 2016) noted that the bank stabilisation program along Cockle Creek is primarily delivered by LMCC, with support from Landcare volunteers.
Ecological health	Gained some analysis/review	Aquatic Receiving Environment Monitoring Program (AREMP) described in (THEC, 2014) as a condition for Trail Operations ongoing effluent discharge. Aquatic issues are addressed by Teck directly with BC MoE Environmental Protection.	Outside the area of interest for LAS

Remediation Institutional control program (ICP)			
Resourcing of remediation and ICP	Financing of ICP after 1994 through RP agreements The value of long term staff members is noted as a contributing factor to the success of the ICP Overall rate and scope of the cleanup affects its permanence and effectiveness	Strong evidence that ongoing controls are in place by both company and community, government	Not addressed by PCCS – they planned to prepare documentation to hand over to LMCC (no apparent ongoing funding) Preparation of documentation for the property owner(s) and the authorities identifying the property status following implementation of the LAS
Long term requirements for ICP	Long term support of ICPs must be provided (NRCNA 2005)	Active program in place for more than 25 years. Not entirely clear what happens post-smelter closure, however most of the remediation is being undertaken through collaborative arrangements during operations and being reported on progressively. Community program office on behalf of Teck Metals Ltd delivers the Property Development Program.	Finite time period for responsibility of implementation (2007). After the 2 years it appears that all long term aspects default to Local government LMCC. Participants had 1 month in which to respond after the initial Consultation Period. However, withdrawal from the LAS was possible at any stage.
Disposal area	Creation of disposal area after 1994 Limited disposal areas due to the confined topography of the valley Lessons learned: there are no appropriate repositories to hold proposed amounts of excavated materials (NRCNA 2005)	Reference is made to a designated disposal area (THEC, 2014) http://www.thep.ca/upload/resources/80/THEP_FINAL_Sept_9_2014_With_THEC_signatures_FINAL_original.pdf	The Pasminco Containment cell was available for local residents in the GRID under the LAS for self-clean up until closure in 2015. Subsequently the nearest restricted solid waste landfill is Kemps Creek in Sydney. (EPA and LMCC are working on a local solution.)
Roles and responsibilities	Durable fabric marker to separate contamination from remediated soils is enforced through the ICP to ensure barrier integrity (local government) Periodic reviews of the clean up's effectiveness will be needed in perpetuity One-time installation of barriers on residential and commercial properties (Record of Decision, Region 10 EPA 1991). Following cleanup, operation and maintenance including repair of recontamination by events, such as flooding, erosion or deposition of contaminated soils, becomes the responsibility of the property owner. ICP is a locally adopted rules and regulations incorporated into land use and zoning codes to ensure; • Barrier integrity throughout the site, • Education, • Sampling assistance,	Clear identification of roles and responsibilities evolved over 27-year program and continuing. It is not known if there is a post-smelter closure plan for long term management. http://www.thep.ca/upload/resources/80/THEP_FINAL_Sept_9_2014_With_THEC_signatures_FINAL_original.pdf	Auditor emphasised importance of LMCC recording the requirement for ongoing mgmt. of Nominated Properties where LAS applied (HLA 2007). [reviewers not able to verify whether this occurred based on the content of this literature review]

	• Clean soils and soil removal for small projects, • Provide disposal site • To protect public health • Assist local land transactions, • Oversee real estate transactions, • Certify contractors to work safety within the BHSS, • Enforce rules and regulations, • Links to local building departments for storm water management, road design, barrier design etc., and • To help residents comply with the ICP.		
Responsible Parties	Agreed to remediate 200 residential parcels per year until all home yards, commercial properties and rights of way with lead contaminated soils > 1000 mg/kg have been remediated	Active site so company continues to be involved.	No evidence of. Specific agreement for LAS tied to smelter plans for closure and remediation
Constraints to complete remediation	Sourcing sufficient clean soil to use as replacement for contaminated soils as part of remediation program Large volume of materials Depths difficult to remove in residential settings	Ongoing impacts and management due to smelter still operating within a context of continual improvement and progressive remediation (TAHEC 2014)	2-year time period, limited in area and applicable to volunteer property owners within the Nominated Property grid [need to compare plan with actual program]
Overall planning and accountability - Legal identification/ declaration of site	Site added to Superfund National Priorities List (NPL) in 1983 after smelting ceased in 1981 Intervention program and cleanup commenced by Panhandle Health District and EPA respectively as negotiations with BHSS Responsible Parties (RPs) were undertaken. In 1994 agreements were reached with several RP. Program extended after 1994 Formalised program with people and resources to manage both the remediation and long term management	There are active programs and processes, with information readily available to the public outlining how governments and the company are progressively working toward reduced lead contamination and lower BLL objectives as smelting continues	It may be clear to Ferrier Hodgson what was and is required to meet their remediation obligations under current regulatory frameworks and processes, for the PCCS (within its operational boundaries), however this was not the focus of this literature review. The LAS for residential properties was not declared or regulated by the DECC/EPA and there were no formal requirements for auditing of the process of the work, DECC considered that it was not appropriate nor warranted for a Site Auditor to issue a formal Site Audit Statement on the LAS. As a consequence, only an informal report was undertaken by an Auditor. (HLA 2007) LMCC has policies in place to address ongoing responsibility for management of lead on public and private land in the NLMA. It is not clear how these polices encourage further investigation and study of lower Cockle Creek and NLM in a proactive manner in order to understand risks associated with contaminated sediments and the food chain, or whether policies simply address risks when works are proposed which will create disturbance.

			The literature review did not identify the ICP for the PCCS itself and how this interacts with surrounding areas. This may be particularly relevant to groundwater aspects of remediation and potential ongoing drainage of this area of residual sub-surface lead contamination. It is not clear if Ferrier Hodgson will maintain the site and its offsite impacts in perpetuity. The review did not reveal a program of work with a team of people within LMCC who are solely focussed on the ICP and investigating knowledge gaps to progressively improve certainty regarding lead risk exposure; at least for the first few years after PCCS remediation is completed to verify that appropriate control measures are in place.
Liability accounting/ estimated costs	$359 million over 30 years (NRCNA 2005)	Annual costs provided as well as options costed	$3 million Australian for remaining zonal remediation as at March 2001 (in Morrison 2003) based on 1000 properties in the zone if they were all remediated.
Identification of potential recontamination sources	Fugitive dust needs to be controlled as part of clean-up plans. Sources included; • hillsides, • waste piles, & • uncapped commercial properties	Systematic evaluation of recontamination sources and consideration of options Greening of public areas active program	Apart from soils at depth, not subject to remediation, the subject of LMCC control measures; other sources of recontamination do not appear to have been addressed as part of LAS but may have been by subsequent LMCC planning controls (e.g. to prevent hillside sloughing in new housing development areas)
Land use zoning (future)	Reference to land use zoning not easily found, but may exist	Changes in zoning to reduce risks in key areas. some residents given financial assistance to relocate. Considerations on buffer zone expansion [as part of planning]	Not fully within this scope - warrants further review. Particularly sites within the grid, which weren't remediated being rezoned for other purposes
Knowledge sharing	Lessons learned document in particular provides an objective review of the overall program for the BHSS Superfund project, making those findings available to all. In addition, there are a range of peer reviewed technical papers on various aspects as well as some addressing more complete program detail	Abundant program details through webpages and supporting reports on various aspects of the program.	LAS implementation document October 2007 (PCCS) was available in public domain until 2015. No evidence of independent review of the whole program (as is evidenced in Superfund sites) however there are a range of peer reviewed papers which address various aspects of this program. There is also the Lead Expert Working Group who are involved in review of a range of technical content.

Table 8 Summary table of key items identified for lead smelter site remediation and abatement

Location of smelter	Significant aspects of abatement
Port Pirie, Australia	• Attention to emission reductions gave reduced BLL • Focused soil lead sampling program assessed 3 risk areas to categorise most significant exposure source linked to ingestion
Noyelles-Godault, Pas-de-Calais, France	• Extensive and repeated BLL surveys conducted prior to shut down showed key role of soil and house dust • Bioavailability and bioaccessibility measured in soils • Persistence of soil pollution remained the key factor and pointed to need for better knowledge of lead transfer from the smelter • Replacement of garden soil used as a remediation technique showed clear improvement for extensive contaminated garden soil
Rouyn-Noranda, Quebec, Canada	• Largest copper smelter in world with significant lead emissions • Soil intervention was associated with reduced BLLs • Seasonality did not contribute to reductions in BLLs
Flin Flon, Manitoba, Canada	• Copper smelter with significant lead emissions • Limited BLL survey data available. • Significant risks from exposure to arsenic, cadmium and lead emissions, and from eating fish from lakes contaminated with mercury. • Organic matter in soils retains lead and other metals. • Significant soil contamination and effects on terrestrial species. • Vegetable gardens show high leaf concentrations. In some cases, existing soil was replaced with uncontaminated soil for garden cultivation.
San Luis Potosi, Morales, Mexico	• BLL survey data available • Bioavailability and bioaccessibility measured in soils
Trail, Canada	• Comprehensive remediation program • Using specific air quality objectives Company reduction in emissions using improved smelter technology concurrent with community abatement program to give significant BLL reduction. • Publicly accessible project expenditure
Bunker Hill, USA	• Comprehensive remediation program • Included comprehensive fate of lead in the environment prediction and investigation due to lead dust deposition as well as tailings disposal in a riverine context • Publicly accessible project expenditure
Butte-Silver Bow, Montana USA	• Separation of storm water contamination • Publicly accessible project expenditure • Comprehensive spatial data on contaminant sources • BLL declines achieved by community-wide abatement programs including home evaluations

10. APPLICABILITY OF BIOACCESSIBILITY, BIOAVAILABILITY AND BIOACCUMULATION

This section addresses the Scope of Works item 3.6 'Where relevant, define and reference the meanings of bioaccessibility, bioavailability and bioaccumulation for consistency in reporting'.

10.1 Bioavailability

Bioavailability is one of the essential tools in pharmacokinetics because bioavailability must be considered when calculating dosages for non-intravenous routes of administration. Bioavailability is 'the amount of a contaminant that is absorbed into the body following skin contact, ingestion, or inhalation' (Ng et al., 2015). This definition, under the clinical setting, has since been widely adopted by various environmental jurisdictions. There are many definitions of bioavailability (NRC, 2003).

Taking into consideration the multiple exposure pathways, bioavailability is defined by this project as the amount of a contaminant that is absorbed into the systemic circulation of the body following skin contact, ingestion, or inhalation.

More specific definitions for bioavailability (NRC, 2003) include:

i. ***Absolute bioavailability*** is the fraction or percentage of a compound that is ingested, inhaled, or applied to the skin that actually is absorbed and reaches systemic circulation.

ii. ***Relative bioavailability*** is referred to the comparative bioavailability of different forms of a chemical or for different exposure media containing the chemical and is expressed as a fractional relative absorption factor. In the context of environmental risk assessment, relative bioavailability is the ratio of the absorbed fraction from the exposure medium in the risk assessment (e.g. soil) to the absorbed fraction from the dosing medium used in the critical toxicity study.

Bioavailability is determined using living organisms. Because of the ethical issues of using people, most of the tests to determine bioavailability of samples of lead-containing materials (such as dirt and dusts) are carried out using animal test subjects.

10.2 Bioaccessibility

Bioaccessibility refers to 'the fraction of a compound that is soluble in the gastrointestinal tract and is therefore available for absorption – which is specifically referred to when in vitro assessment models are used' (Ng et al., 2015). Bioaccessibility data are specifically determined in a test-tube environment (in vitro) and represent the fraction of contaminant available for absorption by the gastrointestinal tract or lung prior to the blood stream (U.S. EPA, 1994). Reliable analysis of the potential hazard to children of ingesting lead from environmental media depends on accurate information on a number of key parameters, including the rate and extent of lead absorption from each (U.S. EPA, 2007). When reliable data on the bioavailability of lead and other heavy metals and metalloids in soil, dust, air particulates or other waste materials at a site are available, this information can be used to improve the accuracy of exposure and risk assessment at specific geographic locations (Ruby et al., 1999).

The concept of bioaccessibility was developed as a predictive tool for estimation of bioavailability. The in-vitro BAc assay reduces the need to use living animals once the former has been validated against an animal model. In-vitro BAc methods (arsenic and lead) have been adopted by NEPC as a tier-two site contamination assessment in Australia (NEPC, 2013).

The bioaccessibility of lead is determined using a simulated digestive system, mimicking the chemical environment in the stomach and intestines, or a simulated lung system, mimicking the fluids found in lungs. One such test is the 'physiologically-based extraction test' ('PBET') (Ruby et al. 1999). Results from these bioaccessibility tests tend to be higher than from absolute bioavailability (ABA) tests (Bruce et al. 2007, Diacomanolis et al. 2007, Ng et al. 2015).

Whilst the reference to bioaccessibility is to simulate the human gastro-intestinal tract, there is a strong focus on restricting the simulation to gastric only by using an acidic solution with the comment that the intestinal phase is less significant because the pH is much higher (up to 7). In addition, animal uptake measurement of bioavailability often shows lower values compared with bioaccessibility which imply that whole of animal models is not corresponding to gastric phase only simulation. The same situation will apply with IEUBK prediction of blood lead in children if gastric-only bioaccessibility is inputted as the prediction of bioavailability.

The pH values selected reflect those used by Ruby et al. (1996), and are based on the "fasting", "average" and "fed" pH states (pH 1.3, 2.5, 4.0) of a human stomach, and pH 7 reflects the intestinal pH in humans. Bruce et al. (2007) tested all pH states (1.3, 2.5, 4.0) during PBET analyses of the waste material, to maximise the potential to correlate bioaccessibility results with in vivo bioavailability results.

In contrast to gastric-only bioaccessibility based on a single pH, an average pH provides an intermediate pH for testing in the complete gastro-intestinal simulation of bioaccessibility such as with the PBET (Ruby et al. 1996) or IVG tests and represents a nutritional status intermediate between fasting and fed states. Because the use of fasting state alone using PBET overestimates the bioavailability of lead (Bruce et al. 2007), it is clear that gastric-only bioaccessibility based on a single pH increases the overestimation of bioavailability prediction and will show a greater difference with measured bioavailability from animal uptake models.

Food in the stomach and intestine is a very important factor in lead absorption. Following solubilisation in the stomach lead is transferred with nutrients from food to the intestine whether absorption and uptake occur. Previous studies evaluated lead isotope absorption by volunteers who were fed lead with meals or specific foods, or on fasting. For the volunteers who were fasting, as much as 71 per cent of soluble lead was absorbed (Heard et al. 1983). However, when the lead was ingested with a meal, absorption fell to a range of 3–7 per cent of the dose (Heard et al. 1983, James et al. 1985, Maddaloni et al. 1998). Calcium and phosphorus were mainly responsible for reducing the gastrointestinal absorption of lead in human subjects. The effect of calcium was greater than phosphorus on gastrointestinal absorption (Blake and Mann 1983). Calcium competes with lead absorption by a calcium-transport protein in the small intestine, but also to form co-precipitates with phosphate and lead (Heard et al. 1983). This explains why the measured bioavailability from animal uptake models is much lower than found with simulated in vitro bioaccessibility tests (Diacomanolis et al. 2007).

10.3 Bioaccumulation

Bioaccumulation is the process of uptake of lead by aquatic or terrestrial species where a lower member of the food chain is consumed by a higher member. In the context of food chain and human food intake bioaccumulation may result is transfer of lead from water and sediment via species such as fish and shellfish that are consumed (ANZECC/ARMCANZ 2000). The water and sediment guidelines (Tables 3 and 4) give some indication of the potential for lead bioaccumulation to occur.

Bioaccumulation of trace metals, including lead has been observed at Lake Macquarie (Dames and Moore 1994):

"Trace metals can be readily taken up by biological organisms and can accumulate in specific parts or organs. They can be toxic to the organism or to humans via consumption. Batley (1987) measured trace metals in samples of seagrass, green algae and bivalve molluscs including the hairy mussel and the cockle. Furner (1979) reported by Batley (1987) had previously observed high levels of lead in the two bivalve species from the lake. Measurements on seagrasses from the northern lake showed roots and rhizomes to contain nine times more zinc and 32 times more lead than samples from the southern lake sites.

Measurements of metals in tissues of the two bivalve species showed accumulation of lead, zinc, copper, cadmium and selenium at levels which present a health risk if consumed by humans (Batley, 1985). The observed concentrations were lower than the earlier measurements of Furner (1979)… little is known of the relative uptakes from sediments or the water column".

Ground and surface water interactions with lead through rainfall runoff, groundwater flows, as well as contaminated river and lake sediments in the North Lake Macquarie area are aspects worthy of further review. These risks were not specifically the subject of this literature review as part of the Scope of Works provided by the NSW EPA (Appendix A), however some aspects are highlighted here as they raise some uncertainty about current and future re-contamination through ecological pathways to humans.

10.4 Groundwater contributions to the contaminant load

During the Environmental Impact Statement for plant upgrading at the Pasminco site a number of groundwater studies were initiated. These studies and subsequent monitoring of groundwater may have implications for groundwater interacting with surface waters as well as Cockle Creek and subsequently Cockle Bay. Cockle Creek has been identified as a contaminated site and consequently the potential for update of metals by organisms and subsequent bioaccumulation exists.

10.5 Groundwater observations

Groundwater draining from Munibung Hill flows in a westerly direction through the Incitec and Pasminco sites into Cockle Creek after passing through an open paddock owned by Pasminco in the Southwest and an industrial area to the northwest of the plant." (Environmental and Earth Sciences 1992) Groundwater recharge results from infiltration of Munibung Hill runoff as well as from a number of surface ponds and dams located throughout the site.' Shallow groundwater flow beneath the site is controlled in part by the original topography which has been altered by cut and filling operations and service corridors. Site personnel have reported that during the redevelopment of the plant in the late 1950s, sand and crushed conglomerate was used as fill beneath all pads to depths up to 0.5 m thick. In addition, slag with a texture of coarse sand was also used extensively as fill and backfill around pipes in service corridors.

Following the installation of 17 initial groundwater bores and sampling program it was reported that:

- Groundwater leaving the INCITEC site exceeds Schedule 2 of the Regulations of the Clean Waters Act for fluoride, sulfate, lead, zinc, cadmium, iron and manganese;
- Groundwater leaving the Pasminco site exceeds Schedule 2 for all of the above parameters as well as chloride, nitrate and ammonia. It is important to note that not all bore waters exceed the criteria for the complete range of parameters and that sulfate, fluoride and chloride may be exempt if discharging into saline water. (Environmental and Earth Sciences 1992).

A supplementary study was undertaken (Environmental and Earth Sciences 1993) to define the background water quality above INCITEC's plan, to define groundwater quality leaving the site in areas other than current and former gullies, to evaluate quality in the supplementary bores, soil and bedrock permeability in the vicinity of all bores to estimate groundwater flows, and to interpret the results in terms of state and federal guidelines.

Whilst groundwater flows were predicted to be very slow through the natural sediments (non-gully between BH1 and BH14) approximately 0.00002m/day, 'poor quality groundwater is channelled into current and former gullies from whence it discharges off site' (Environmental and Earth Sciences 1993).

Figure 22 shows the location of boreholes from the first study in 1992 (Environmental and Earth Sciences 1992) and highlights the historic 'gully Cockle Creek alluvium' drainage area from which it was noted that groundwater velocities were much higher than through the bedrock. Figure 23 shows the general groundwater flow paths including the flows toward the gully area.

Figure 22 also highlights the large pipe corridors (Sewer 0.3m and water pipe 1.8 m diameter) said to be backfilled with slag materials. Acid water was discharged from the sewer at the time and was believed to be related to the backfill materials (Environmental and Earth Sciences 1992) however the notion of this coming from the acid plant or any other source was not discussed.

Figure 24 shows a map following further groundwater investigations (Environmental and Earth Sciences 1993) after installation and sampling of additional bores. New bores were installed upstream of the plant site to identify more accurately, background water quality, and additional bores were installed downstream as well. The 1993 bores are marked with a full black circle to distinguish them from the 1992-installed bores. The buried pipelines and porous drainage area are not marked on this updated figure (as they were in Figure 22). It is not clear why this important information on potential contamination sources and flow paths has been omitted in the latter report (Environmental and Earth Sciences 1993).

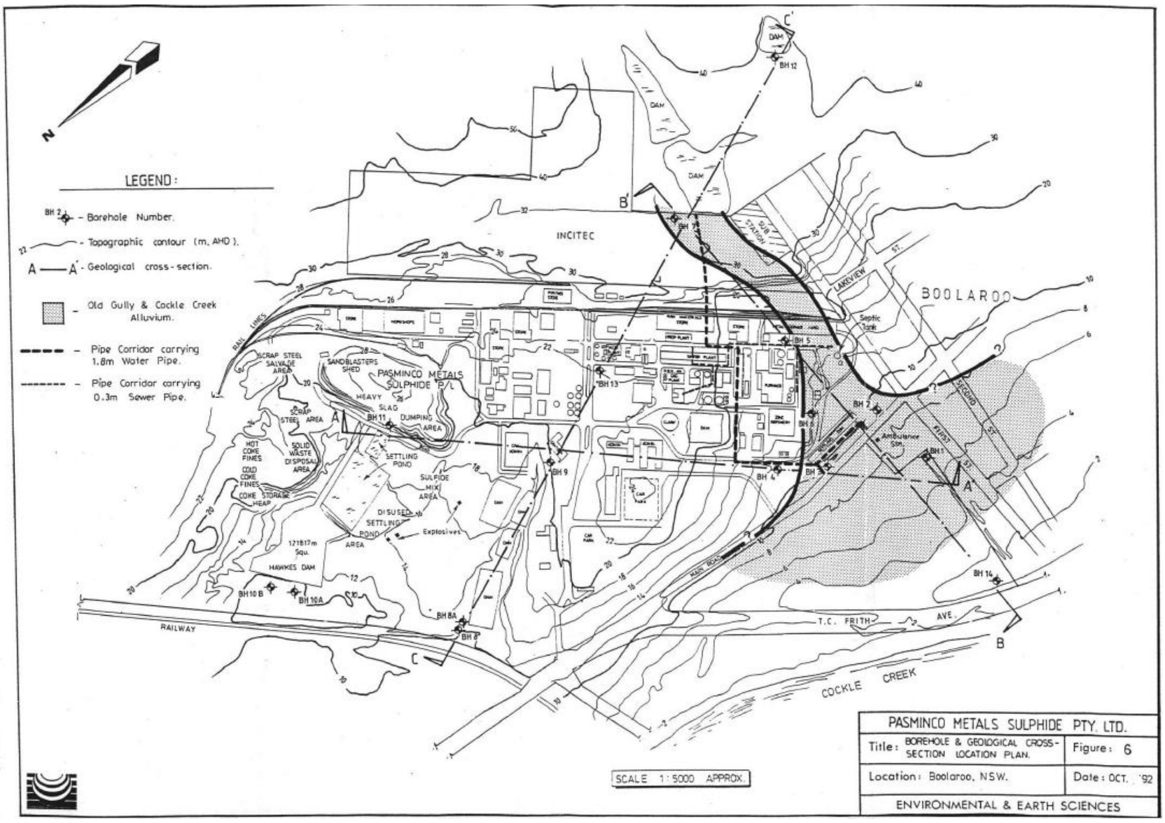


Figure 22 Borehole and geological cross-section location plan (Environmental and Earth Sciences1992)

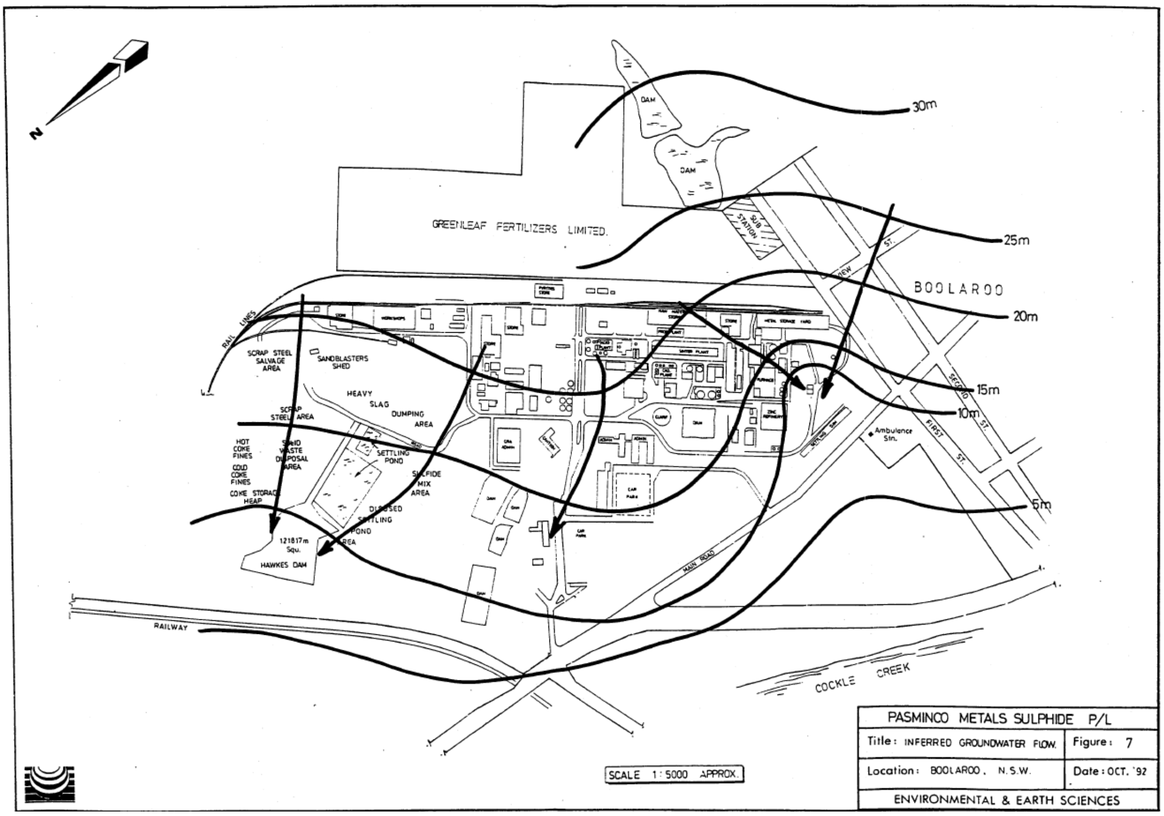


Figure 23 Inferred groundwater flow (Environmental and Earth Sciences1992)

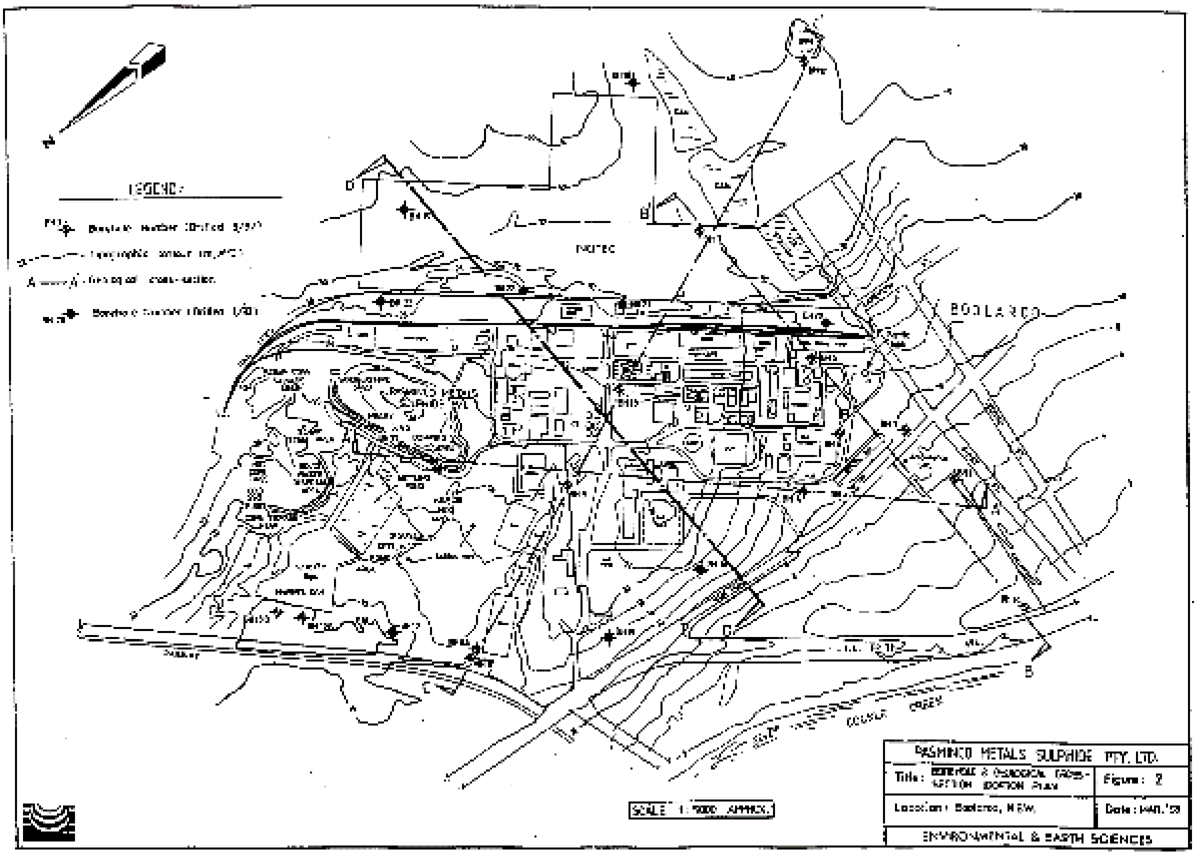


Figure 24 Borehole and geological cross-section location plan (Environmental and Earth Sciences 1993)

Table 9 highlights the bore water quality which exceeded standards. At that time bores downgradient of the plant site had lead concentrations which exceeded standards. More recent monitoring data are required to evaluate how this has changed over time and whether groundwater concentrations meet current standards. The ICP will need to consider whether further investigation is required to understand if there is a risk of higher lead in groundwater coming in contact with surface waters, taking account of remediation works which have recently been undertaken or are still in progress.

Table 9 Bore water concentrations that exceed Schedule 2 of the Clean Waters Act

BORE	pH*	Cl+ (mg/l)	F+ (mg/l)	NO_3 (mg/l)	SO_4+ (mg/l)	NH_4 (mg/l)	Pb (mg/l)	Zn (mg/l)	Cd (mg/l)	Fe (mg/l)	Mn (mg/l)
NSW SCH 2	6-8	250	1.5	10	250	0.5	0.05	1	.01	1	.05
Background											
BH12	5.3	-	-	-	-	-	-	-	-	-	-
BH12**	-	-	-	-	-	-	-	-	-	4.1	0.21
BH18	4.9	-	-	-	560	-	-	-	-	-	0.17
BH19	-	770	-	-	-	-	-	-	-	-	0.84
Onto the Site											
BH7	3.6	-	32	-	400	-	.87	-	.03	26	.8
BH7**	3.4	-	35	-	540	-	2.2	19	0.28	-	1.9
BH20	-	260	1.6	-	1,800	1	.14	1.5	.12	-	3.5
BH21	4.6	520	3.4	16	1,900	-	1.4	106	1.1	-	20
BH22	4.9	-- 320	-	67	770	-	0.26	4.5	.07	-	0.36
BH23	4.7	3,700	-	-	610	-	0.36	1.4	.05	6	.65
On the Site (a) Main Plant											
BH5	-	-	-	-	-	2.8	-	2.3	.08	-	.49
BH6	-	300	-	-	430	-	.06	1.2	.02	1.1	5
BH9	5.1	-	-	-	690	-	.2	-	-	-	.07
BH11	5.8	330	-	-	1,200	-	.6	37	-	.81	1.1
BH13	3.4	4,900	-	-	1,100	-	1	8.4	.14	240	2.7
(b) West of Main Road											
BH1	4.7	460	6.4	-	730	2	-	12	.74	-	2.6
Off the Site (a) Main Plant											
BH2	4	680	-	-	590	-	.17	1.1	.02	-	.31
BH2**	5.0	680	-	-	540	-	-	1.7	-	7.0	0.7
BH3d	5.7	-	-	-	-	-	-	-	-	1.6	.43
BH3d**	5.8	-	-	-	-	-	-	-	-	1.1	0.93
BH3s	4.9	-	1.9	22	630	1.4	.15	50	2	-	7.3
BH3s**	4.4	-	1.8	67	800	-	0.3	56	2.5	-	8.6
BH4	-	-	-	-	800	-	-	13	.32	-	3.7
BH8s	4.5	350	-	-	-	-	-	-	-	-	-
BH8s**	4.5	370	-	-	-	-	0.1	-	0.08	-	0.5
BH8d	3.5	1,000	-	-	-	-	.81	8.6	.15	5.5	1.9
BH8d**	3.7	7,900	-	-	-	6.9	0.5	11	0.1	54	1.4
BH10A	5.3	2,600	-	-	-	-	.1	21	-	1.4	4.9
(b) West of Main Road											
BH14	3.4	1,300	9.4	-	1,600	-	.69	2.3	-	67	3.9
BH14**	3.5	1,300	5.1	-	1,400	-	.42	2.1	.02	82	4.2

- Indicates analysis below Schedule 2
* Indicates NSW EPA Criteria
+ Exempt for saltwater
** Sampled on 10 November 1992

All other Bores Numbered 1 to 14 sampled on 31 July 1992; Bores 5 to 23 sampled on the 22 January 1993.

(After Environmental and Earth Sciences 1993)

Flow test analysis found that the permeability of the natural sediments is too low for contaminated groundwater from the Incitec site to have reached BH14 (near Cockle Creek) yet this bore water has a chemical fingerprint similar to that found discharging from Incitec.' (Environmental and Earth Sciences 1993). This may imply that there is a 'shortcut' which groundwater may be making via coarse bedding materials (slag) around pipelines and also the gully and Cockle Bay alluvial material.

Contemporary data on groundwater as well as an understanding of how groundwater contamination has been managed during the plant remediation process, are required to understand the current lead in water risks.

It will be important to confirm that lead-contaminated water cannot surface express and contaminate uncontaminated surface materials or re-contaminate remediated surface soils by interacting with soils and surface waters, particularly where housing exists or is planned, as well as to quantify the impacts of lead in groundwater discharges to Cockle Creek. The ICP for managing lead in the environment may need to put in place monitoring and corrective actions if there are any risks from these pathways.

Review of the current remediation strategy for the PCCS site is not within the scope of this review. The authors do not have this information nor any associated audit reports. It is not known how ponds, dams, subsurface drainage, buried pipes and slag used as pipe bedding etc. have been addressed as part of the remediation program. The groundwater quality objectives are not known to the reviewers. Groundwater data, monitoring sites and water quality status before, during and after the remediation are also not known. A holistic lead management program would address all potential sources, ensuring control measures are informed by evidence. The review of Bunker Hill cleanup program noted the inadequate attention to groundwater.

10.6 Sediment contamination

Dames and Moore (1993) undertook a number of studies of the sediment in Cockle Creek to determine:

- The existing levels of contamination and depth of contamination in the sediments of Cockle Creek;
- Whether sediment contamination is increasing or decreasing following Pasminco's effluent treatment procedures; and
- Background levels of heavy metal contaminants in selected biota such as seagrass leaves and rhizomes; and filter feeding molluscs, such as *Trichomya hirsute* and *Anadara trapezia.*

Dames and Moore (1994) within the Environmental Impact Statement for Pasminco report that for aquatic ecology, seagrass roots and rhyzomes had nine times more zinc and 32 times more lead than samples from the southern lake sites.

For protection of aquatic ecosystem, the ANZECC/ARMCANZ (2000) ISQGs apply (Table 4). For lead ISQG high is 220 mg/kg ISQG low is 50 mg/kg. Even the Northern end sediments exceed ISQG high for lead. Therefore, the aquatic system in Cockle Creek connecting to Lake Macquarie is contaminated with respect to aquatic ecosystem and the aquatic species will be affected. Extraction concentrations (Batley, 1987 in Dames and Moore1993), including at all depths, are high for the Northern end of Lake Macquarie. There is potential for bioaccumulation of lead by shell fish including oysters and fish; however, it's not clear if this has been properly assessed.

Sites used for a monitoring program for water quality in Cockle Creek and Cockle Bay in the northern part of Lake Macquarie for 1991-1992 (Dames and Moore 1994) are shown in Figure 12. Water quality showed generally high background concentrations of cadmium, lead and zinc at all samplings, sites with the highest concentrations usually at Site 10 (effluent drain). Mean lead and discharges at the discharge point are below the figures of 0.4 and 0.5 mg/L reported in June 1984 (Batley 1987 in Dames and Moore 1994) with the exception of zinc in April 1992, where an abnormally high value of 3.24 mg/L was observed. Upstream of the discharge point there were some spatially and temporally inconsistent peaks in concentrations that exceeded (by a factor of >10) the recommended receiving water guidelines for the protection of aquatic ecosystems, (ANZECC & NH&MRC 1992). For lead, they were at; Site 15, Sites 17-21, and on three occasions Sites 19-21 (Dames and Moore 1994).

From this study it appears that lead in water impacted the upper reaches of a tributary of Cockle Creek which poses questions on sediment quality in the upper reaches (which was not the focus of subsequent studies, MHL 2002) and the fate of that lead.

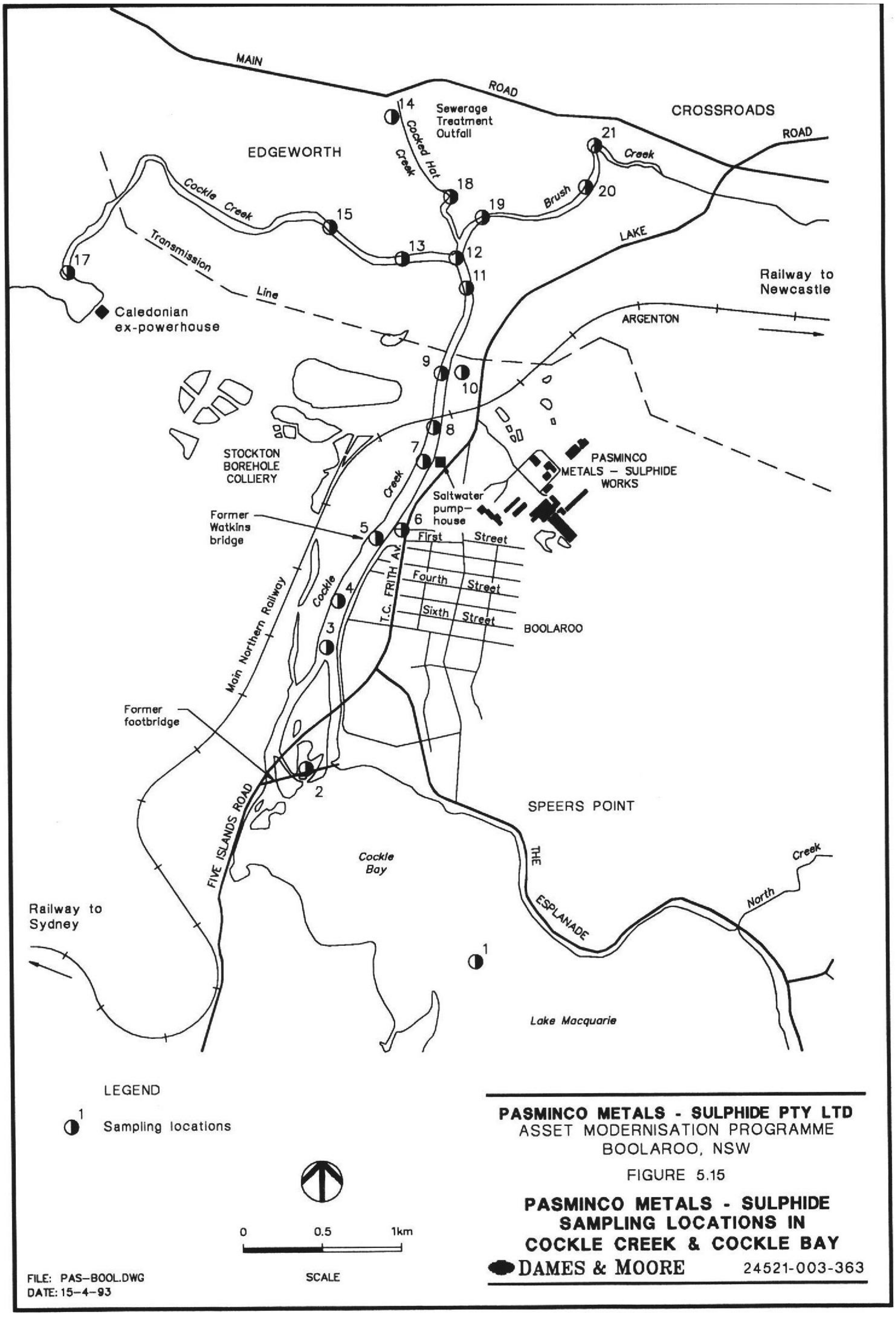


Figure 25 Sampling locations in Cockle Creek & Cockle Bay (Dames and Moore 1994)

11. OTHER OBSERVATIONS

In the process of undertaking the literature review some observations have been made which may be peripheral to the focus of the Scope of works from EPA, however are considered to be relevant to future management of lead in the North Lake Macquarie area, at least in this review.

11.1 Psychological stress

Psychological stress impacts on mental health was not considered but there was increased stress on communities once the Bunker Hill area became a Superfund site (NRCNA 2005). Anecdotally, similar comments have been made (Martin, 2016 pers comm) about residents living within the grid (Willmore et al, 2006) near the Pasminco Smelter site. Because there are areas of interest beyond the immediate locality due to the use of black slag beyond the 'grid' within the LMCC area, the discussion has shifted to moving away from using this boundary or label for the community.

11.2 Indigenous vs non-indigenous children BLLs

It is apparent that a review of Australian literature on BLLs in children that there is a difference between indigenous and non-indigenous exposure to lead. The following observations are noted. Boreland et al (2014) noted that in the Broken Hill area, aboriginal children had consistently higher lead levels which were 2-3µg/dL higher than the non-aboriginal population and were twice as likely to have blood lead levels that exceed 10 µg/dL.

The following is from Lake Macquarie history webpage on 'Aboriginal people in Lake Macquarie':

> *"LMCC is part of the traditional country of the Awabakal people. Some families who are descendants of the Awabakal people continue to live in the City. However, as is the case for most Australian cities, the majority of the contemporary Aboriginal population of the City are from families whose traditional country is elsewhere in NSW.…The Aboriginal population of LMCC has grown strongly over the last decade. The City has the second largest Aboriginal population in NSW (DEWR 2007: web site) LGAs with the largest Indigenous population in NSW.*
>
> 1. *Blacktown 7058*
> 2. *Lake Macquarie 5593*
> 3. *Penrith 4085*
> 4. *Dubbo 3909*
> 5. *Wyong 3798*
>
> *The Aboriginal population comprises 2.2 per cent of the total population of Lake Macquarie. This is a significant increase in recent years. In 2001, approximately 1.9 per cent of the population of Lake Macquarie identified themselves as Aboriginal people. Aboriginal people also comprise approximately 1.8 per cent of the population of adjoining Newcastle City Council".*

There has been a steady decline in blood lead levels in the North Lake Macquarie area and during the last blood lead level screening program all children sampled were below or equal to 5 µg/dL (HNELHD 2015). The survey doesn't distinguish between aboriginal and non-aboriginal children so it is not known if there is any difference in BLL between the two groups. As all BLL are below the required trigger level for investigation, this may not be important.

11.3 Subsidence from underground mining

In the North Lake Macquarie Area, there are potential impacts on groundwater, surface water flows and sediments due to underground mine subsidence exist. Subsidence impacts have been measured in lake bed monitoring (MHL2002, LMCC 2014). Boolaroo lies within the Lake Macquarie mine subsidence district with the Killingworth-Wallsend district adjacent west of Cockle Creek (**Figure 26**). The long term stability of the new impoundment on the PCCS site in the context of subsidence due to mining will be the responsibility of the EPA as regulator of the current remediation. These aspects lie outside the scope of the literature review.

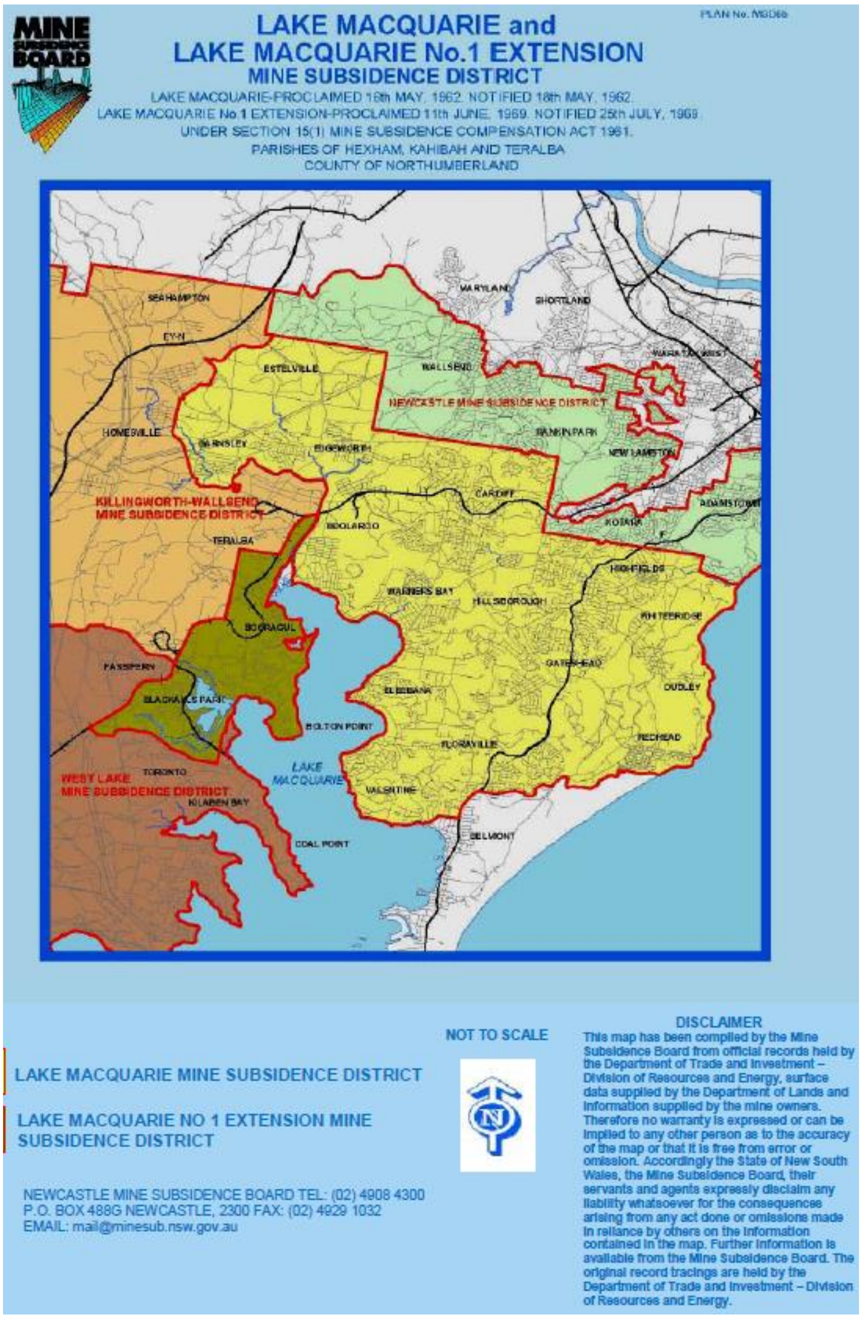


Figure 26 Lake Macquarie and Lake Macquarie No 1 Extension Mine Subsidence district.

11.4 Rainwater tanks

This review has not found any reference to the use of rainwater tanks for water consumption within the NLMA which could pose another pathway if they exist. LMCC would need to confirm whether this issue is relevant as a human health risk in the NLM area with reference to the relevant health guidance on the use of rainwater tanks (enHealth, 2010).

11.5 Lead contaminated Cockle Creek and Cockle Bay sediments

A comprehensive series of investigations by the NSW Department of Public Works and Services Manly Hydraulics Laboratory (MHL 2002) identified the significance of the sediment load from Cockle Creek into Lake Macquarie as well as the degree of lead (and other metal) contamination of sediments. This study preceded the recognition and declaration by NSW EPA of contamination of Cockle Creek Bed and Cockle Bay Sediments (Box 1).

Box 1: Declaration of remediation site under the Contaminated Land Management Act 1997

N.S.W. EPA
Environment Protection Authority

DECLARATION OF REMEDIATION SITE UNDER THE CONTAMINATED LAND MANAGEMENT ACT 1997

The Environment Protection Authority (EPA) declares the following land to be a remediation site under the Contaminated Land Management Act 1997 ("the Act"):

- Lot 201 DP 805914 in the Local Government Area of Lake Macquarie known locally as the Pasminco Cockle Creek Smelter located in Boolaroo, New South Wales ("Pasminco site"); and
- That part of the bed sediments of the southern part of Cockle Creek in line with the northern boundary of the Pasminco Cockle Creek Smelter (Lot 201/DP805914) and continuing south to Cockle Bay ("the Cockle Creek Site"); and
- The bed sediments of Cockle Bay in North Lake Macquarie extending from Cockle Creek and enclosed by a straight line from the public wharf marked in dark brown on the DLWC map and the foreshore of Cockle Bay at the end of Aspinall Street, Booragul ("the Cockle Bay site").

A copy of the DLWC map (Department of Land and Water Conservation land information map for North Lake Macquarie/Cockle Bay area (reference "Date of Status 4 July 2001, prepared by Virginia Gray") is available for inspection at the EPA Offices at 59-61 Goulburn Street, Sydney.

The EPA has considered the matters in Section 9 of the Act and has found that metal contamination (in particular lead, cadmium and zinc) at the Pasminco Site and in the sediments of Cockle Creek and Cockle Bay poses a significant risk of harm. There is a risk that harm is being caused to the biota that is in contact with the contaminated sediments and groundwater, and a risk of harm to human health from off-site movement of airbourne contamination from the Pasminco site.

Measures have been put in place to manage potential health impacts to local residents through implementation of a community based lead abatement program, and pollution reduction program which Pasminco is obliged to meet.

Making the declaration is the first step in a process to develop and implement an overall remediation strategy that will aim to redress the risk of harm posed to human health and the environment.

Making the declaration does not prevent the carrying out of voluntary remediation of the site in accordance with section 26 of the Act. Any person may submit to the EPA a voluntary remediation proposal prepared under the Act.

Obtaining a copy of the Declaration

A copy of the declaration is published in the NSW Government Gazette on 13 September 2002 Gazette number 144 at pages 8122 and 8123. The public may inspect a copy of the declaration free of charge at the EPA, Level 15, 59-61 Goulburn Street, Sydney. Copies of the declaration may be purchased for $12.00 by contacting the EPA's Pollution Line on 131 555 (8.30am to 5pm weekdays).

Submissions may be made:

The Public may make written submissions to the EPA on whether the EPA should proceed to issue a remediation order in relation to the site or on any other matter concerning the site. Submissions should be made in writing to:

Director Contaminated Sites
Environment Protection Authority
P.O. Box A290, Sydney South NSW 1232
or faxed to: 02 9995 5999
by no later than 11 October 2002

The EPA will consider these submissions and remediation of the site may then be required.

Carolyn Strange
A/Director Contaminated Sites
Environment Protection Authority

GA1/676472

These sediments remain declared contaminated sites under the Act however it is not clear what this means in terms of human interactions with this area. For example, people fish in Cockle Creek and there do not appear to be signs indicating any warnings relating to consumption of animals from this ‘contaminated site’. There is little contemporary evidence of ecological or human health studies related to consumption of organisms from Cockle Creek or Cockle Bay.

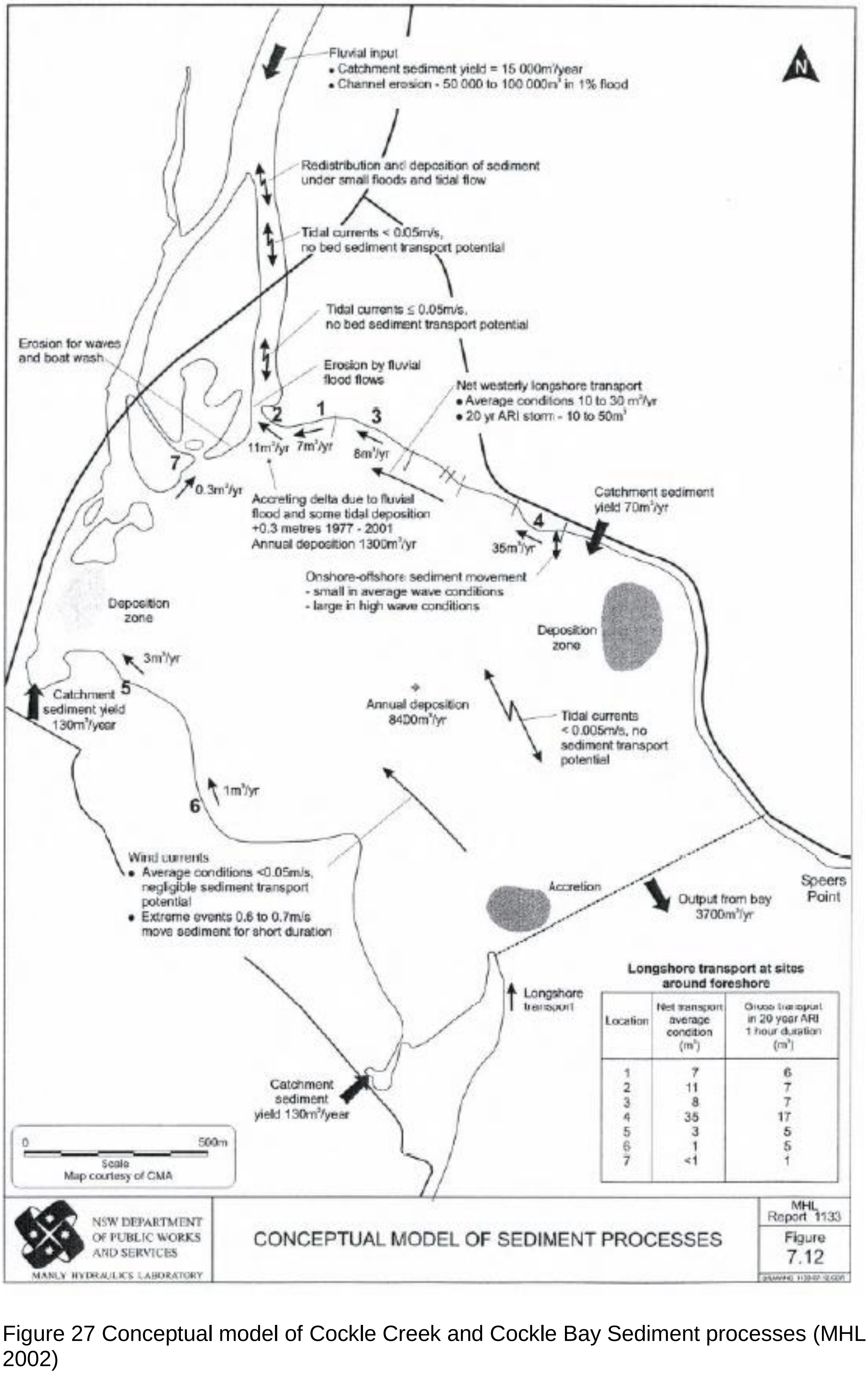
Whilst remediation of the Pasminco Smelter Site is underway and nearing completion, there has not been any documentation to show how the sediments have been remediated.

The 2002 study (MHL 2002) found that:

- The sediment yield from Cockle Bay is 44% of that for the whole of Lake Macquarie, (estimated at 17,500 to 23,500 tonnes/year with constructed traps containing <5% of this yield);
- Annual sedimentation rates on the delta at the entrance of Cockle Creek estimated at 6 mm (within 300 m of Cockle Creek entrance), 3 mm (within 1,100 m of CC entrance) and 2 mm (accurate to +/- 1mm within 2,200 m of CC entrance);
- The sediments of Cockle Creek and Cockle Bay contain metal concentrations 1-2 orders of magnitude greater than in sediments from other parts of Lake Macquarie;
- There is concern that boating activities can disturb contaminated sediments leading to pollution of lake water;
- Foreshore erosion has been observed at Speers Point and Marmong Point and sections of the foreshore have been reclaimed;
- No information on rates of foreshore erosion was found in the literature;
- Estimated flood flows up to 3.9m/s at the Cockle Creek entrance have been provided
- The 1% flood can yield sediment of 20,000 t/y with 14,500 t/y deposition in Cockle Bay and the rest further out in the Lake;
- Evidence from metal concentrations that mixing occurs in the top 20cm of sediment in Cockle Bay;
- Contaminated sediments (at levels above ANZECC/ARMCANZ (2000) guidelines for protection of aquatic ecosystems) occur in the top 0.6 m of Lower Cockle Creek;
- The rate of input of contamination input to the creek sediments has decreased in the last 15-20 years (i.e. prior to 2002) with lower levels of metals in the top 20 cm than deeper down, in the vicinity of the Pasminco Smelter;
- Tidal currents are too small to move sediments in the Cockle Bay or to cause bed sediment transport in Cockle Creek;
- Unprotected foreshores of Cockle Bay are eroding due to direct wave attack or longshore sediment movement;
- Mine subsidence affects the bed level of Cockle Bay;
- Downstream from the smelter, in Cockle Creek, there is a gradual increase in levels of lead and zinc from upstream to downstream (in the top 5-10 cm of creek bed sediment);
- In the North Arm immediately upstream of the Five Island Bridge, lead and zinc level at 40cm depth are similar or greater than overlying sediments;
- A study in the mid-1970s found impacts across Cockle Bay to a depth of 500 mm (elevated metal levels). The 1980’s and early 1990s show elevated heavy metal levels in deeper sediments;
- With the current rate of sediment infilling of Cockle Bay of 5-6 mm/year the upper thickness range is likely to be 600-700 mm;
- There are important fresh water wetlands in the Cockle Bay catchment (not entirely clear to reviewers where they are);
- Noted bank erosion in Cockle Creek and work by the Lake Macquarie catchment coordinator;

- Landcare have done streambank revegetation works; and
- Insufficient data exist on:
    - Sediment properties;
    - Rates of foreshore erosion and sediment transport;
    - Whether levels of contaminants in fish are due to bioaccumulation or intake of sediments;
    - The degree of disturbance of sediments from recreation/commercial boat use,
    - The value of sediment for heavy metals from dredging;
    - The process by which contaminants are absorbed by most species of biota;
    - The contribution sediments are making to heavy metal concentrations in the water column;
    - The toxicology, including bioavailability of metals in the sediments;
    - The extent that bioturbation alters the sediment profile and vertical distribution of contaminants; and
    - Effects of metal contamination on higher trophic level such a birds from consumption of contaminated prey.

From this study a conceptual model of sediment processes was developed (Figure 27).



Longshore transport at sites around foreshore

Location	Net transport average condition (m^3)	Gross transport in 20 year ARI 1 hour duration (m^3)
1	7	6
2	11	7
3	8	7
4	35	17
5	3	5
6	1	5
7	<1	1

Figure 27 Conceptual model of Cockle Creek and Cockle Bay Sediment processes (MHL 2002)

11.6 Removal of sediment from Cockle Creek delta

Within the MHL (2002) study of Cockle Bay as part of a feasibility study for environmental improvements and management, dredging of the Cockle Creek Delta was discussed. Feedback from the EPA as part of the stakeholder engagement process deemed this not feasible due to the contaminated sediments present within the delta.

'Living Lake Macquarie' (LM Catchment Coordinator, April 2005) showed the Cockle Creek Groyne under construction and described the planned removal of the entrance spit. Clarification is needed on the works undertaken and if contaminated (and benign) sediments were removed how they were managed treated and disposed.

11.7 Bioavailability of lead in black slag

A report on slag affected sites in LMC Area was prepared for LMCC (Project 43095.01, Sept 2010 Douglas Partners). Black slag exposure scenarios include (and were found at all locations inspected):

- Child play areas
- Playing fields
- Land stabilisation
- Foreshore
- Creek bank
- Stormwater systems
- Wetlands
- Commercial premises.

The presence of black slag triggers a detailed Stage 2 contamination investigation. Recommendations were made to:

- Establish a register to record the presence of black slag on Council owned sites.
- Develop a priority listing (risk matrix) of public sites based on both human and environmental exposure parameters.
- Implement phased remediation program.
- Undertake a review of environmental factors when planning remediation particularly when in or adjacent to environmentally sensitive areas and especially when the project would be Cat1 under SEPP55.
- Develop a short and long term management plan (before and after remediation).
- Keep stakeholders informed of progress on the management of the slag issue.
- Adjustments should be made to Council's DA process to provide more information on the issues relating to slag on private property and the process for investigation, remediation, validation and auditing of affected sites.
- Investigate the potential for environmental exposure to slag through surface water and groundwater impacts on selected sites.
- Review and where necessary, amend Council's existing Safe Work Method Statements for council workers.

The LAS grid was the focus of historic and recent (Harvey et al, 2016) soil lead (dust) sampling not areas where slag is located. Fact Sheet 12A (LMCC, 2015b) states that black slag is a low health risk if the slag is covered and an adequate barrier is in place to prevent exposure yet the photo in the fact sheet shows exposed black slag.

Whilst the council GIS spatial data base may contain valuable content on the location and volumes of black slag, this information is not accessible for the review. LMCC (*pers comm*, July 2016) indicate that the database contains limited information as it is only the sites that LMCC is made aware of. In most cases, there is no record of the sites at which black slag was applied.

Slag produced by Pasminco was described by the company in its community newsletter as having a ‘lead sulphide content of about 0.7% …with lead bound up in a glass-like structure that would not leach out’ (LMCC 1992). LMCC’s Planning and Environment Committee, sought advice from a Consultant to verify claims by Pasminco, on leaching risks, and gained advice on management of slag with topdressing. Council decided to write to Pasminco suggesting the need for the Company to be more active in publicising the safe handling procedures for the slag, throughout the entire distribution region and the advice be used to identify parks or playing fields which may need to be top dressed (LMCC 1992). Subsequently the slag was shown to be leachable by dilute hydrochloric acid (Morrison and Gulson 2007) indicating that release of lead could occur in acidic soil.

11.8 Flood study

The “Winding Creek and Lower Cockle Creek Floodplain Risk Management Study and Plan draft report)” (WMA Water 2016) is available for consultation on the LMCC webpage. The report comprises four parts with submissions closing 25 July 2016. This represents the most up to date flood study of relevance to NLM superseding the 2004 flood study (LMCC 2004). Section 7.4 ‘Options to mitigate flooding impacts on future development’ specifically Section 7.4.1 ‘Former Pasminco site at Boolaroo’ is very brief. It doesn’t effectively describe the contamination risks beyond the PCCS site with respect to water interactions. Section 2.6.2 notes the contaminated sediments in Cockle Creek. As this report provides options for flood mitigation earthworks such as deepening channels in places and raising floodplains in specific reaches there is an opportunity to use this report to inform an environmental health study to evaluate recontamination risks from flooding.

Figure 28 shows the Lower Cockle Creek flood extents (WMA Water 2016) with flood levels for 50% Annual Exceedance Probability (AEP), 1% and Probable Maximum Flood. The NSW Floodplain Development Manual requires a focus on the 1% AEP (LMCC, *pers comm*, July 2016). These events have the potential to interact with residential and other known contaminated soils on the floodplain when compared with mapped soil contamination (Figure 6). This flood study can be used to inform the potential remobilisation of lead contaminated soils and also to highlight areas of potential future disturbance for flood mitigation works.

The report states that best practice Water Sensitive Urban Design (WSUD) should be applied to the former PCCS site development (WMA Water 2016). WSUD encourages infiltration of rainfall in preference to runoff. There is no discussion in this report, on whether this approach is compatible with a site where lead contamination remains at depth. These specific details lie outside the scope of this review, yet highlight the importance of integrating knowledge between different planning activities within the same local government area. To provide adequate protection from recontamination requires a multi-disciplinary and cross-functional approach within and between agencies and functions. In leading practice lead remediation programs overseas specific personnel with appropriate expertise within government, have as their sole focus, the management of lead remediation works and ICPs.

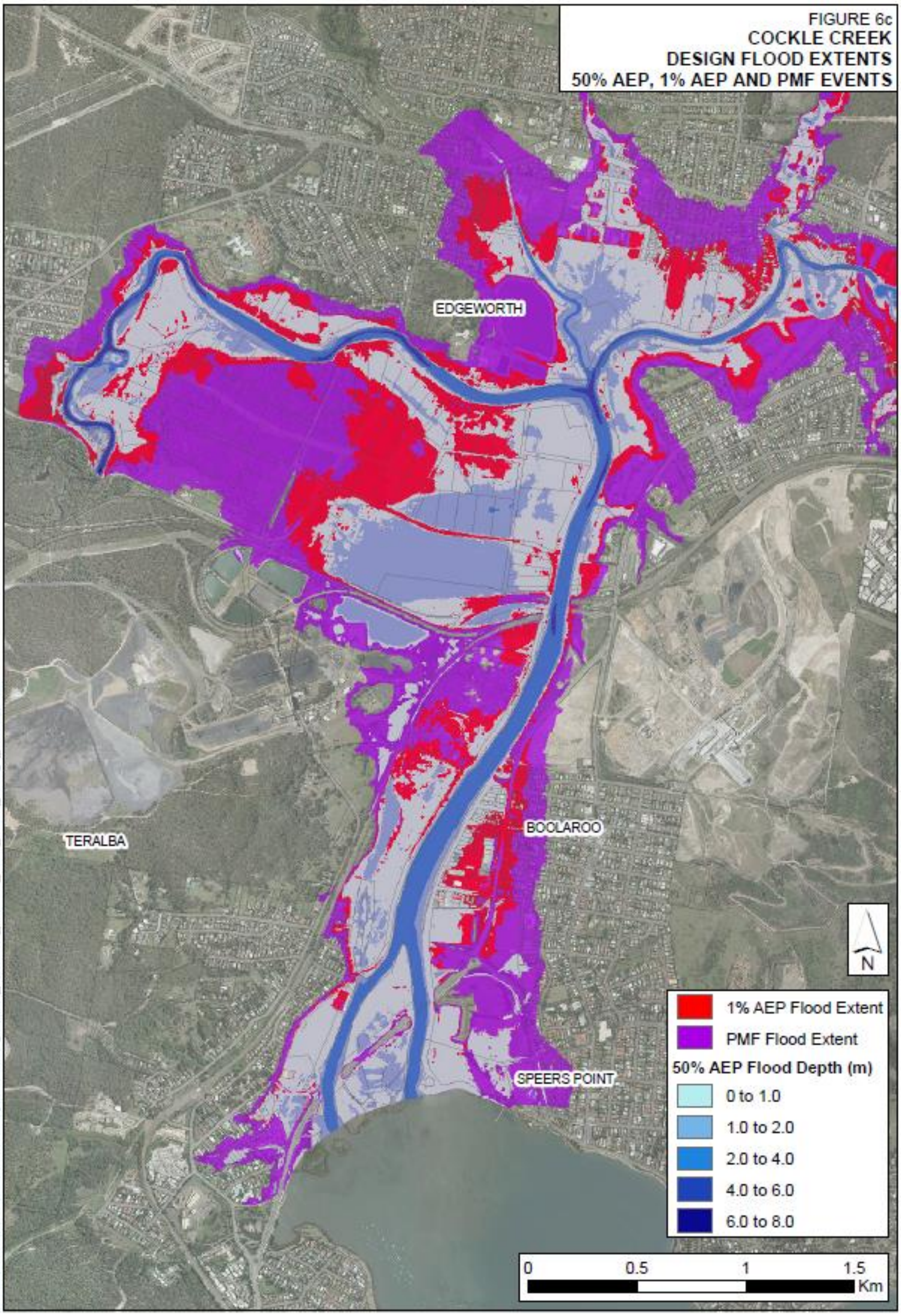


Figure 28 Cockle Creek Design flood extents, 50% AEP, 1% AEP and PMF events (WMA Water 2016)

The discussion section (WMA Water 2016) describes the need for dredging to reduce the flood levels, however it also acknowledges that this is an unsustainable practice. It is noted that an environmental impacts statement would be required prior to dredging. The report notes that dredging has occurred in the past in the vicinity of the mouth of Cockle Creek. Historic photos of Cockle Creek flooding are shown in Photo 1 (WMA Water 2016).

Photo 1: Selection of photographs of Cockle Creek from Council's web site

An Environmental Management Plan is required for Cockle Creek and Cockle Bay to integrate all knowledge on the status of contamination and risks of recontamination. From this process, knowledge gaps can be more clearly identified. A systematic program of investigation is then required to address knowledge gaps as part of the risk assessment process. This would need to consider all possible lead pathways and human interactions with the river, lake, bed and banks which could remobilise contaminated sediments in order to evaluate human health risks.

11.9 Acid Sulfate Soils (ASS)

Indicative acid sulfate soils (ASS) maps are provided by the LMCC (2014, 2.1.10 acid sulfate soils). Figure 28 shows the North Lake Macquarie ASS map where it outlines that more accurate planning maps are available at council. This highlights the risk of acidification of water and sediments if acid sulfate soils are disturbed and exposed to the atmosphere as they are sufficiently acidic to leach slag. Guidance from LMCC (2014) refers to the importance of ensuring slag does not come in contact with ASS.

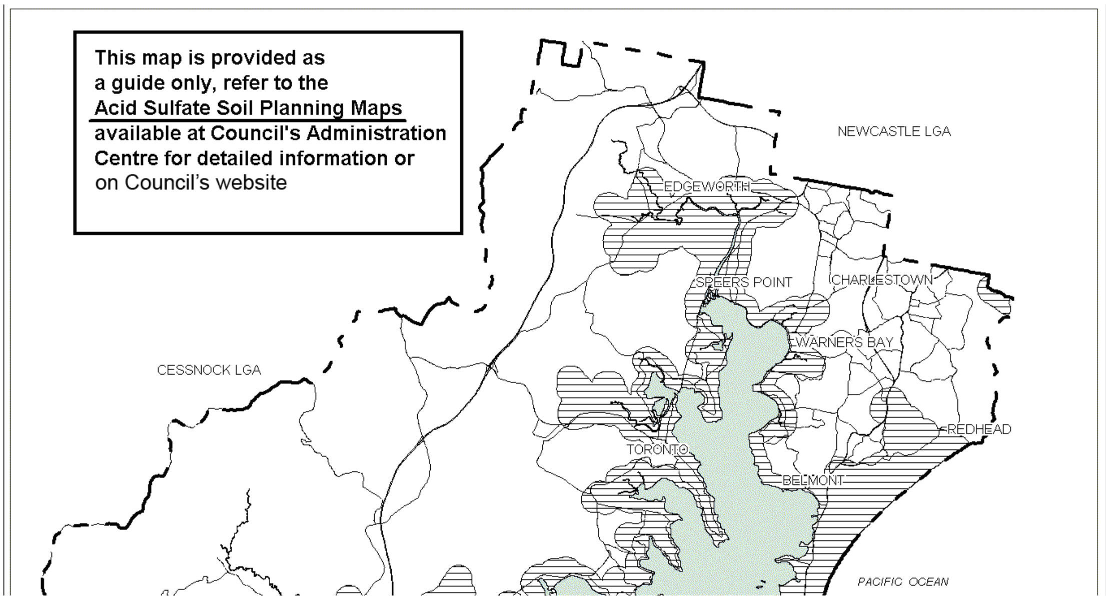


Figure 29 Indicative ASS map North Lake Macquarie (LMCC 2014)

A report on slag affected sites (Douglas Partners 2010) refers to the ASS risk map for Wallsend (DLWC) 9232 S3 sheet which shows high acid sulfate soil potential and severe environmental risk if the bottom sediments of Cockle Bay are disturbed. The presence of slag for land reclamation in lake edges at Eleebana and Warners Bay strongly increases the potential for heavy metal desorption at these locations, particularly if sediments are disturbed.

The combined impacts of acid sulfate soils, flooding, and uncertain additional exposures of lead (as shown on the western margin of the soil lead grid) as well as known contaminated sediments (and declared contaminated site) pose questions about long term management in the form of an ICP of Cockle Creek and Cockle Bay.

As part of the ICP, an overlay of risk factors for re-contamination of areas due to exposure and disturbance should be addressed. A specific environmental management plan for this corridor/zone may be required to adequately define what is known and where the knowledge gaps exist so that effective risk management systems can be applied through the ICP to ensure lead cannot be remobilised. There remains a question about the ‘hot spot’ on the edge of the LAS grid, near Cockle Creek (Figure 6).

11.10 Databases and knowledge management

LMCC ‘Council’ maintain their “Database of Contaminated or Potentially Contaminated Land”. According to Council Policy, the database includes only those properties that are known to Council, including details of site remediation or “abatement” that has been undertaken and the associated validation records. So – it will contain not only known slag locations, but also any properties abated under the LAP. The reviewers have not had access to this database so cannot comment on it.

12. CONCLUSIONS AND RECOMMENDATIONS

The New South Wales (NSW) Environment Protection Authority (EPA) has sought the services of a consultant to undertake a literature review and prepare a report on practices to manage Lead (Pb) and Lead Slag in Soil and associated human exposure.

There are general principles and accepted practices under NSW and Australian regulations and guidelines noted from the literature on what constitutes a robust 'leading practice' lead remediation and/or management program, and these provided indications on where to look for equivalent investigations and works in the context of lead contamination in the North Lake Macquarie Area (NLMA). Standards and research have also been reviewed as they provide guidance on benchmarks and in some instances an additional level of detail on the significance of some clean up actions and other control measures compared with others. These provide valuable insights which can be applied locally.

The most significant factor contributing to reduced blood lead levels (BLL) in the target age range for children in the NLMA, is the cessation of airborne lead contaminated dust emissions associated with smelter closure. While BLL have dropped below the health investigation level (NH&MRC 2016) there remains a requirement for long term monitoring, not only of BLL, to ensure current control measures are effective and to ensure recontamination does not introduce exposure pathways of significance to human health.

The Lead Abatement Strategy (LAS) undertaken by Pasminco Cockle Creek Smelter (PCCS) with approval from the environmental regulator and planning authority in NSW, differs from overseas leading practice lead cleanup projects in many ways. The LAS was a program of finite duration, with spatial boundaries defined by a grid with lead smelter sourced material exclusions, specifically slag. The LAS focussed only upon cleanup of lead contaminated dust fallout from the smelter on residential properties in close proximity to the source. The PCCS site lies within the LAS grid. Within this site, the lead contaminated materials from residential LAS remediation as well as contaminated materials from within the PCCS site are encapsulated in a new containment cell. Remediation works are currently being undertaken within the PCCS site, by the Deed Administrators for PCCS, Ferrier Hodgson. The company webpage[4] states that the cell contains approximately 1.85 million m^3 of contaminated materials.

Outside the PCCS the long term impacts and responsibility for residual lead contamination has been externalised onto the community and environment. This includes lead contamination of:

- LAS Nominated Properties whose owners chose to participate in the Lead Abatement Program (LAP), and may still contain lead contamination
- LAS Nominated Properties whose owners chose not to participate in the LAP, and
- LAS-excluded areas.

Exclusions are summarised in the report and include those non-residential areas (such as public open space) as well as slag related contamination on the participating properties and impacts beyond the grid which include lead transported via drainage of the PCCS, slag used as construction material and fill in the Lake Macquarie City Council (LMCC) area, and lead contaminated sediments within the Cockle Creek catchment and North Lake Macquarie (NLM).

Institutional Control Programs (ICP) are evident to some degree, through the LMCC policies and planning schemes. However, there appears to be no single entity which is resourced to undertake further remediation where required, nor to systematically investigate those areas not included in the LAP.

[4] www.ferrierhodgson.com/au/industries/property/~/link.aspx?_id=928E96DB30C24B8AAE4B39B74E664602&_z=z

Post LAP cleanup data to demonstrate the performance of the program, as part of that program, are not evident. The auditor's statement was limited to a review, not an audit, due to the absence of a strictly followed regulatory process for the LAS unlike the process currently being applied to the PCCS site remediation.

12.1 Elements of Leading Practice Lead Remediation Programs

Leading practice programs may not have all of the following characteristics, however this list has been developed to summarise what was in evidence within the literature reviewed:

- Clear leadership and resourcing to plan, implement, monitor, engage and manage the cleanup.
- The establishment of lead remediation technical and health monitoring teams, whose role it was, to focus solely on the lead remediation program including long term management and community engagement.
- Responsible Party legislation which enables agreement to be reached between those parties contributing to the contamination and governments to provide resources for project management, cleanup works and ICPs.
- High levels of transparency not only in terms of expenditure but also in providing the evidence for specific actions and to demonstrate exposure reduction.
- Information is accessible to the public with dedicated webpages which pull together all relevant content on lead contamination risks (for that site/area), control measures, the cleanup program itself, good quality spatial data (updated regularly), progress and performance reporting.
- Active and adaptable stakeholder engagement programs throughout the cleanup program.
- Stakeholders include individual residential and commercial property owners, regulatory authorities, local councils (as public land owners and planning authority), state governments, the company(ies) involved, health authorities, catchment managers, developers, and in many instances national governments where funding and other resources have been provided and national governments have also undertaken comprehensive reviews. There are also formalised community and technical expert stakeholder groups which meet regularly as part of the engagement and implementation program.
- A robust data set and knowledge base from which to design the cleanup program.
- Removal of the critical lead contamination source as an effective control measure e.g. shut down of smelter or highly improved smelter technology which greatly reduces lead emissions to the atmosphere.
- In designing programs, recognition that soil outside of the home environment varies with distance from the source of contamination, not property boundaries, and intake estimates should account for soil sources in the immediate neighbourhood and greater community.
- Forensic analysis of emissions and other lead sources (e.g. tailings, slag) to estimate total lead loads to the environment and thereby identify at a coarse level the magnitude of the impact and the scope of the program cleanup to support planning.
- An understanding of the chemical forms of the lead and the bioavailability and bioaccessibility of those forms of lead to inform the risk and control measures that may enable more advanced health risk assessment to be made taking account of the currently better developed methodologies and guidelines that were not in place when the LAS was first implemented.
- A system for prioritising sites with the aim of timely cleanup for the target demographic.
- Provision of a waste containment site (or multiple sites) with sufficient capacity to meet the requirements of the lead cleanup program now and in the future.

- Sourcing of sufficient clean soil materials for remediation works where contaminated soils need to be replaced, capped or covered.
- Wide age range blood lead level (BLL) screening initially, which is narrowed down to focus on the high risk age range, as the program evolves, based on the data gathered.
- Acceptance that ingestion is the primary exposure pathway according to current (state of the art) health risk assessment methodology and the target demographic is pregnant women and children 0-4 years with some programs highlighting a peak in BLL around 2 years.
- Target BLL < 5 µg/dL according to the NH&MRC (2016) recommendation.
- Appropriate education programs which support the cleanup and BLL screening programs for parents and children.
- Mechanisms to identify and address gaps or inadequacies in cleanup programs that makes use of advances in NSW and Australian formal methodologies for soil contamination.
- Programs apply relevant standards at the time (for BLL, lead in soil, lead uptake modelling methods etc.), and adapt to changing standards over time.
- Multiple sources of data to support BLL screening are used to help interpret the data and define control measures according to the currently accepted enHealth (2012) health risk methodology.
- Testing before and after control measures have been applied to evaluate their effectiveness against objectives and reporting on this.
- Programs which not only address the high priority areas, but then systematically evaluate all possible sources of recontamination.
- Attention to internal house lead dust cleanup as well as external as part of the program.
- In addition to residential yards, programs address garden beds where vegetables are grown (remove contamination from soil or construct raised garden beds with clean soil[5]), neighbouring properties, unsealed roads, road shoulders, railway easements and driveways.
- Also addressed are lead contamination transport mechanisms through geomorphic processes such as wind or water erosion and deposition. Anthropogenic disturbances (e.g. involving excavation of contaminated soils) are managed through planning controls, property owner agreements defined by the ICP.
- Reviews of programs identify that lead contaminated ground and surface water sources can be overlooked or not previously well-understood, so programs need to investigate these pathways and define control measures (e.g. this may require new surface drainage and underground stormwater systems to separate clean from contaminated waters).
- Riverine contamination removal integrated with the program to control further spread of lead in sediments.
- Aquatic ecosystem bioaccumulation studies where human health impacts are possible through the food chain due to exposure of organisms to lead contaminated waterways (through water, food, sediments etc.) by people in the community as well as taking account of food gathering practices of indigenous people.
- Recontamination risks are clearly understood through systematically addressing the knowledge gaps and evaluating the control measures applied.
- A long term commitment to mitigate lead contamination and recontamination risks through effective ICPs which address all legal, administrative, policy and procedural requirements to ensure the works undertaken are effective and if not, or are disrupted by extreme events or other disturbance, there are appropriate responses, with clear responsibility and resources to address.

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[5] see Inner West Council – www.marrickville.nsw.gov.au/en/environment/in-your-home/gardening/

12.2 Recommendations

To ensure the lead abatement measures are maintained, it is strongly recommended that LMCC be involved with the recording of the requirement for on-going management of Nominated Properties where lead abatement measures have been implemented.

If not already occurring, LMCC should consider the requirement for a permanent physical barrier to indicate the separation of clean and contaminated materials as part of the ICP.

The remediation of all properties surrounding the smelter site is not yet complete. The responsibility to monitor and manage this appears to have been devolved to property owners under LMCC development and planning controls. Completion of remediation within the LAS area was not validated for soil contamination. Further examination is needed to understand if the works undertaken and institutional controls provide sufficient protection.

Institutional controls appear to be currently separated into different policy documents of LMCC. It would be valuable if the ICP existed in its own right as a point of orientation or 'road map' to all relevant controls. In so doing, a review should be undertaken which identifies any controls which are currently absent but may be needed, based on learnings from leading practice lead cleanup programs elsewhere. The ICP by LMCC, with endorsement of the NSW EPA and NSW Health, will need to ensure those aspects within and excluded from the LAS are addressed as well as:

a. Unsealed roads and road shoulders and railway easements.
b. Flood impacts which could mobilise or expose contaminated materials.
c. Controls over soil and rock removal from the base of hillslopes which could initiate instability. Also the requirement for construction of walls at the base of slopes as part of remediation to avoid sloughing into residential yards re-exposing contaminated soils.
d. Site selection and development of a containment structure for future slag recovered through remediation (and other lead contaminated materials) that can demonstrate, based on leaching property studies, retention of seepage from slag that might enter ground and surface waters.
e. Management of lead contaminated groundwater from interactions with surface water and soils in the vicinity of the former PCCS and interaction with Cockle Creek and Cockle Bay to minimise any effects on the aquatic ecosystem of Lake Macquarie. It should be determined if some aspects of this may be the responsibility of Ferrier Hodgson as part of post-remediation monitoring and maintenance.
f. Contaminated sediments in Cockle Creek and North Lake Macquarie require further assessment.
g. Specific ICP for long term management of the PCCS site, including monitoring that is updated, needs to take account of the current practices set out by enHealth (2012) and the NEPC (2013) for contaminated soil.
h. Should monitoring reveal there is any worsening of the levels of human exposure to lead in specific locations in the future, which cannot be easily remediated, consider some areas currently zoned residential, to be rezoned for a lower risk land use, based on the accepted health risk assessment approach as described above.
i. All recommendations from earlier studies, if not captured already, should be summarised in an overarching document (or web-page). The purpose of this step is intended to bring together all NLM lead contamination knowledge and study recommendations as well as how those recommendations have been implemented. If not implemented, then it should be stated why not. This would enable a proactive and risk-based approach to long term management of lead in NLM. High risk areas and issues could be identified through this process. Lead contamination is a long term issue so systems and personnel need to be

focussed on management in the long term. This report identifies some of these risks, but perhaps not all. (During the review it was not easy to find the direct association between recommendations made in specific reports and LMCC policy updates. This does not imply they actions haven't occurred. For example, Douglas Partners' (2010) recommendations on black slag cannot be directly traced to an action plan). With any long life program, recommendations from earlier studies can be lost unless there is a strategic and continuous focus on knowledge management;

j. Good quality spatial data management to enable the superimposition of a range of datasets on the NLMA to inform lead risk management (e.g. Flood levels, acid sulfate soils, and soil lead concentrations).
k. Funding of the ongoing ICP as overseas studies noted that local rates and state taxes may not be enough. The ICP needs to be fully costed in order to evaluate resourcing requirements in the long term. Most programs identified there was no clear end point. A team of people with an appropriate skills set, whose responsibilities are solely focussed on the ICP is likely to be required. A legacy fund in some form is required to sustain the ICP.

High rainfall and flooding related remobilisation risks need to be evaluated to ensure control measures are put in place in high risk areas of the lower Cockle Creek Catchment, Cockle Bay and North Lake Macquarie aquatic ecosystems.

Further studies are required to investigate the pathways through the food chain to humans (via fish and shellfish), that may be current health risks, and also to study if bioaccumulation is a potential health risk to local people gathering local aquatic species as food sources.

The Winding Creek and Lower Cockle Creek floodplain risk management and Plan (WMA Water 2016; final draft, April 2016) should inform an environmental health study to evaluate the risk of lead recontamination. This should address remobilisation locations on the floodplain, banks and bed as well as Cockle Bay sediments and foreshore areas with the aim of quantifying risks for recontamination and applying control measures.

Collating all existing data and knowledge on the lead contaminated zone of Cockle Creek Catchment, Cockle Bay and North Lake Macquarie is an imperative. An Environmental Management Plan is required for Cockle Creek and Cockle Bay to integrate all knowledge on the status of contamination and risks of recontamination. From this process, knowledge gaps can be more clearly identified. A systematic program of investigation is then required to address knowledge gaps as part of the risk assessment process. This would need to consider all possible lead pathways and human interactions with the river, lake, bed and banks which could remobilise contaminated sediments in order to evaluate human health risks. Then, a management strategy for these contaminated materials can be developed which will highlight areas that need to follow on. It is not clear if these areas are included in the LMCC Environmental Management Plan (EMP). Engagement with relevant stakeholders needs to occur as a matter of course and control measures applied.

Ensuring the maintenance of a centralised Blood Lead Level database by the NSW Health Department is considered necessary so that if future BLL screening requires the relevant historic data, the data can be available and made reference to, when new data are gathered. Planning for future BLL screening to ensure recontamination is not impacting human health is recommended, including in summer instead of winter. The application of BLL measurement was adopted for the Pasminco Boolaroo site before the availability of the accepted enHealth (2012) Australian health risk assessment methodology was in place. Currently BLL is assessed as the exposure step of the enHealth (2012) health risk assessment framework only.

However, the hazard identification step considering contamination levels and dose of the health risk assessment framework for the remediated Pasminco smelter site that brings exposure assessment (BLL measurement) together is incomplete. Thus the risk assessment for the remediated Pasminco smelter site, according to current land management practice is not complete.

Site-specific assessment of bioaccessibility for lead as incorporated in the NEPM for contaminated soil by NEPC (2013) should be carried out using in-vitro tests that simulate the gastro-intestinal system such as the physiologically-based extraction test (PBET) in-vitro assay (Ruby et al. 1996) or Unified BARGE Method (UBM) (Denys et al. 2012) by following the accepted practice of the NEPC (2013, Schedule B4). Methods based on gastric-only phase do not simulate intestinal absorption of lead, the key absorption step in humans, and overestimate the prediction of lead bioavailability for human health risk assessment.

Procedures within the LMCC EMP should include a review of the GIS database for the location of lead contamination prior to works being undertaken.

The IEUBK (Integrated Exposure Uptake Biokinetic Model) is useful for validating soil total and bioaccessible-adjusted lead measurements but should not be the sole criterion for estimating health-protective soil concentrations as the input data may not all be correct (as happened at Trail, Canada) and needs to be validated by actual BLL measurement. Geographically complex sites may need improved methods involving GIS techniques that allow spatial relationships between populations and hazards to be examined and a decision making structure that follow the accepted Australian health risk assessment procedures of enHealth (2012). Generally, the surface terrain of the former smelter site is sloping towards Cockle Creek but is not considered to be a complex one. The use of GIS for plotting and comparing BLL with soil lead for NLM also demonstrated that the former smelter site is not a complex terrain (Willmore et al. 2006).

Site specific clean up levels can be derived from IEUBK model and be supported by site-specific measures of bioaccessible lead noting that lead uptake occurs via the intestinal phase and not from the gastric/stomach phase where solubilisation occurs.

In the NLMA there is no single publicly available map outlining areas where cleanup works have been undertaken or where contamination is still known to exist. There should be a collective goal of LMCC and NSW EPA to improve transparency and accessibility of mapped data. Leading practice programs overseas are characterised by such transparency.

Accumulation of lead and other metal levels accumulated in home grown vegetables at Boolaroo and surrounding suburbs has received limited study. This subject needs to be assessed as part of any further health risk assessment of exposure of individuals from soil in gardens of residential houses at Boolaroo.

The groundwater quality objectives for the PCCS site remediation (being undertaken by Ferrier Hodgson) are not within the scope of this review; however, groundwater data, monitoring sites and water quality status before, during and after the remediation should be reviewed. In the absence of this knowledge, groundwater and potential surface water interactions could pose potential risks for recontamination.

The State government should review whether Responsible Party legislation or its equivalent (polluter pays) in NSW or under Australian government legislation is adequate to mitigate the impacts and liabilities for remediation of contamination being externalised onto the community and environment in the future.

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14. APPENDICES

Appendix A – Scope of Work from Request for Quotation

Request for Quotation

QUOTATION CONDITIONS
STATEMENT OF REQUIREMENTS and
RESPONDENT QUOTATION

Report on practices to manage Lead (Pb) and Lead slag in soil and associated human exposure

EPA-1-2016

Issue Date: 6 January 2016

Closing Date: Friday 29 January 2016

Closing Time: 10:00am

Lodgement: *https://tenders.nsw.gov.au/epa/*

PART B - STATEMENT OF REQUIREMENTS

LITERATURE REVIEW OF PRACTICES TO MANAGE LEAD (Pb) AND LEAD SLAG IN SOIL AND ASSOCIATED HUMAN EXPOSURES.

1. Terms of reference

The New South Wales Environment Protection Authority (EPA) is seeking the services of a consultant to undertake a literature review and prepare a report on practices to manage Lead (Pb) and Lead Slag in Soil and associated human exposure.

2. Background Information

The suburbs of Boolaroo, Argenton and Speers Point in the North Lake Macquarie area are the subject of a legacy of lead contamination arising from the operation of the former Pasminco Lead and Zinc smelter in the area from 1897 to 2003. The original smelter has been demolished and the entire industrial site has been remediated by excavation and placement of contaminated soil in an onsite containment cell. Hence, there are no ongoing smelter emissions; nor is there any significant lead dust contamination arising from the former smelter site. Hence, the sources of contamination to be considered by this review are as follows:

- The residual lead contamination in surface soil, roof and wall cavities from point source and fugitive (or fume) emissions associated with former smelting works.
- Lead-slag and lead-slag impacted soil used as imported fill onto properties.

The affected areas of these suburbs are primarily residential (approximately 2,500 residential properties), light commercial/industrial, recreational and parkland over an area of approximately 500 ha excluding the former smelter site. Additionally, the wider Hunter region surrounding the former smelter has been subject to the widespread use of lead-slag from the Pasminco smelter, and other industrial sources.

Considerable literature exists relating to the management of contaminated land which resulted from the historical mishandling of lead pollutant sources, and/or lead containing waste streams. Additionally, lead is ubiquitous in the urban environment from sources such as mineral processing; lead paint; motor vehicle emissions; battery manufacturing and recycling; rifle ranges and other sources where lead is processed or used in industry. Where possible, the literature relevant to this review should be identified as being focused on similar legacy contamination issues or comparable sites/areas to the former Pasminco smelter in North Lake Macquarie where the lead contamination resulted from point source and fugitive (or fume) emissions associated with smelting works and the widespread use of lead-slag.

The Literature Review is being prepared by the EPA to inform the deliberations of the Lead Expert Working Group (LEWG). The purpose of this group is to understand past actions and to determine those future actions which are required to further address lead contamination in the area, particularly where human exposure pathways are identified.

A blood lead screening program was carried out in Boolaroo, Argenton and Speers Point in July 2015. The program ran for three weeks and 73 children (less than five years of age) and eight pregnant women were tested. This represents approximately 20% of children less than five years of age residing in the area. Results indicated that 88% of those tested were below the detection limit of 3.3 µg/dL and 12% between 3.3 and 4.7 µg/dL. The Chief Health Officer's Lead Reference Panel Report can be made available to provide detailed information about the blood lead screening program.

The functions of the LEWG are to:

- Consider actions taken to date to limit exposure of children to lead in the Boolaroo area and surrounding suburbs if appropriate, including the actions and outcomes of the Lead Abatement Strategy.
- Respond to the outcomes of the 2015 blood lead monitoring program, being planned by the Department of Health, on options for further lead management, should the need be identified.

The LEWG is responsible for:

- Providing advice and guidance to the EPA and government on measures to protect the local community from ongoing risks associated with legacy contamination.
- Addressing any issues that may arise as a result of new information becoming available related to the issue.
- Reconciling differences in opinion and approach, and resolving disputes arising from them.

NSW EPA seeks to gather comprehensive knowledge about current management practices and strategies for reducing or mitigating human exposure to lead and lead slag in soil. Management practices and strategies may include standard remediation techniques such as capping or removal. Other measures or strategies that rely on engineering, scientific, economic, education or regulatory measures proposed to achieve a desired outcome may also be reviewed where relevant.

The EPA proposes to commission a literature review to identify measures of control to reduce human exposure to lead and lead-slag in soil for comparable sites/areas.

The proposed literature review will be one of the matters considered by the LEWG in providing advice and guidance to the EPA and government broadly.

It is important to note that the consideration of best practice in the context of this review is based on the achievement of improved public health and environmental outcomes, and the reduction of human exposure to lead.

It is acknowledged that other sites in the world may have involved greater expenditure on control of human exposure, a more comprehensive removal of source contamination or a different form of ongoing exposure prevention. The focus of this review needs to be on whether these alternative strategies have been more effective in reducing human exposure, and whether such strategies could have relevance to the North Lake Macquarie context, having regard to the site specific constraints involved.

3. Scope of work

The objective of the consultancy is to review literature relevant to programs aimed at 'reducing human exposure to lead' and to report on the following key areas

3.1. Remediation and/or management programs that have been undertaken for comparable lead contamination sites and areas, ensuring that specific details regarding the form and species of lead are identified.

3.2. The success of the programs and consideration of 'best practice'.

3.3. How the success or otherwise of the programs was evaluated or measured.

3.4. The cost of the programs and/or indicative costs associated with management practices and strategies identified.

3.5. Where exposure control was used, the methods used and their effectiveness.

3.6. Where relevant, define and reference the meanings of bioaccessibility, bioavailability and bioaccumulation for consistency in reporting.

4. Outputs

Draft and final reports covering all points defined in the scope of work.

5. Timeframes and payment schedule

The duration of the project is 8 weeks.

The project will have three stages linked to payments, as follows:

Stage 1
- Agreement on scope of analysis and detailed project plan within 1 week of project commencement
- 50% progress payment of contract sum

Stage 2
- Delivery of draft report addressing scope of work within 6 weeks of project commencement
- 25% progress payment of contract sum

Stage 3
- Acceptance of final report to the satisfaction of EPA within 8 weeks of project commencement
- 25% final payment of contract sum.

The final report must address all aspects of the scope of work.

Electronic reports need to be submitted in Microsoft Word /Microsoft Excel compatible format.

The study must be completed by 29 April 2016.

A budget of up to $25,000 (including GST) is anticipated.

6. Contract

The successful consultant will be required to sign a standard NSW EPA consultancy contract.

7. Submission of Tenders

Tenders must include in their submission:
- A brief summary of your relevant experience in this area.
- A project plan including discussion of the approach to the study and methods that will be used.
- Work plans including timetables for delivering outputs.
- Proposed budget.
- Short CV(s) for the consultant(s) who would undertake the work.
- Names of relevant referees and their contact details.
- Declaration of any conflict of interest or risk of conflict of interest.

8. Evaluation Criteria

The selection criteria used to award this consultancy will be:

- Quality of the proposed method and approach to the project.
- Experience, relevant expertise and demonstrated capacity to undertake the consultancy.
- Ability to perform the work within the timeframe.
- High level of report writing and communications skills.
- Value for money.

9. Lodgement of Proposal

Via EPA eTender Website: *https://tenders.nsw.gov.au/epa/*

Proposals must be received by no later than 10:00 am on Friday 29 January 2016.

10. Contact / Further Information

Enquiries about this consultant's brief should be made to:

Niall Johnston
Contaminated Land Section
Environment Protection Authority (NSW)
Ph: 02 9995 5651
niall.johnston@epa.nsw.gov.au

1. Standards, Licences & Approvals

Appendix B – Experience of Consultants

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 newly created 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 has been 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 Consultant and Associate Professor at the Centre of Mined Land Rehabilitation (CMLR) a centre of the University of Queensland based at St Lucia. The CMLR is part of the Sustainable Minerals Institute.

Professor Noller has been working and publishing in the field of environmental chemistry and industrial toxicology for the past 40 years and has presented 360 conference papers and published 198 papers. His professional activities undertaken at 4 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. He has undertaken a number of consulting activities in Queensland, Tasmania, New South Wales, Western Australia and the Northern Territory and has undertaken a number of investigations at the Metropolitan Colliery since 2007. He was appointed in 2007 as Lead Author of the Australian Government Leading Practice Sustainable Development Program for the Mining Industry Handbook on Cyanide Management and was Project Leader for the Lead Pathways Study conducted at Mount Isa on behalf of Glencore Xstrata 2007-2013.

Corinne Unger is an environmental scientist with more than 30 years' experience in land and mine rehabilitation in Australia and overseas. She has a Bachelor's degree in earth sciences, Diploma of Education and Post-Graduate Diploma in Geoscience (Applied Geomorphology) from Macquarie University. Following her role of Soil Conservationist for the NSW government in southern NSW, Ms Unger moved to a role in the mining sector in the Northern Territory. Here she managed mine rehabilitation and research at ERA's Ranger Mine for 10 years. Later she was appointed Senior Environmental Officer in an environmental regulatory role in Central Queensland for the Department of Mines and Energy, then Project Manager, Mount Morgan Mine Rehabilitation Project for 5 years. In 2003 Ms Unger and her team produced the rehabilitation plan for the historic Mount Morgan Mine, the largest legacy mine in Queensland. For the last 11 years she has been a self-employed consultant specialising in mine rehabilitation and closure planning based in Brisbane, Queensland. In 2009 Ms Unger was awarded a Churchill Fellowship to undertake research overseas on 'Leading practice abandoned mine rehabilitation and post-mining land use'. Since 2011 she has been a part-time Senior Research Officer at The University of Queensland's Sustainable Minerals Institute undertaking research on jurisdictional maturity of abandoned mine programs in Australia, hosting a multi-stakeholder 'Managing Mining Legacies' forum in 2012. More recently, Ms Unger has been Chief Investigator for coal mine rehabilitation and closure knowledge management projects funded by ACARP (Australian Coal Association Research Program). She was also the inaugural Chair of the AusIMM's Community and Environment Society (2013-2015) and is now a member of AusIMM's Board of Chartered Professionals. Ms Unger joined the Technical Review Board of the Department of Economic Development, Jobs Transport and Resources for the Victorian government, in September 2015.

Key projects of relevance to this review task include closure planning for two lead and zinc mines in New South Wales, which involved the integration of multi-disciplinary requirements into a framework to meet the range of objectives to ensure safe, stable, non-polluting landforms with appropriate land uses. The heritage listing of these sites clearly elevates the need for community access within an industrial context. The identification of knowledge needs and knowledge gaps in order to bring about effective remediation is also within Corinne's experience. This included a review of one company's Port Pirie lead monitoring program in the context of interacting activities in close proximity to identify priorities for ongoing management to mitigate impacts on the local community. Having managed rehabilitation and research at an active uranium mine also means that Corinne has a multi-disciplinary understanding of the issues which need to be considered as part of controlling and rehabilitated potential sources of pollution. As Project Manager for Mount Morgan mine, Corinne coordinated more than 50 studies over 5 years as well as the finalisation of the rehabilitation plan for this site (2003). Corinne is familiar with how contamination is mitigated, managed and remediated in a mining context to reduce or eliminate human exposure to metals in the environment. Subsequent project management support for the former uranium and copper mine (Rum Jungle Northern Territory) also involved the comprehensive understanding of soil contamination, surface and groundwater impacts from acid and metalliferous drainage in order to facilitate the development of the holistic conceptual rehabilitation plan for Rum Jungle – a project requiring multiple consultancies, disciplines and stakeholders.

Centre for Mined Land Rehabilitation (CMLR)

CMLR (www.cmlr.uq.edu.au)
At the forefront of research, education and technical expertise, the Centre for Mined Land Rehabilitation (CMLR) is leading the way we think about mining environmental management.

CMLR is involved in a broad range of research and training projects with mining companies, industry bodies and government departments from across Australia and the world.

As a part of one of the largest universities in the world, the CMLR has a team of highly skilled professionals focusing on the key issues facing modern mining and minerals processing industries.

A member of the Sustainable Minerals Institute (previously the Sir James Foots Institute of Mineral Resources), the Centre was established at The University of Queensland in 1993 and has built on more than twenty years involvement with the mining and minerals industries.
CMLR and the Sustainable Minerals Institute (www.smi.uq.edu.au)

The Sustainable Minerals Institute (SMI) was established in 2001 as a joint initiative between the Queensland Government, The University of Queensland and the Minerals Industry. The proposed development was to build upon the existing expertise within the various centres and departments and provide and over-arching framework for progressing Minerals Industry Research, Education and Training activities.

The CMLR is the sole provider of environmental mining management within the University and has established for itself and the SMI a reputation of national and international significance.
Our Location

The CMLR is situated on the 5th floor of the Sir James Foots Building (No 47A) at the University of Queensland, St Lucia campus (www.uq.edu.au).