Hunter Community
Environment Centre

OUT OF THE ASHES II

NSW water pollution and our aging coal-fired power stations

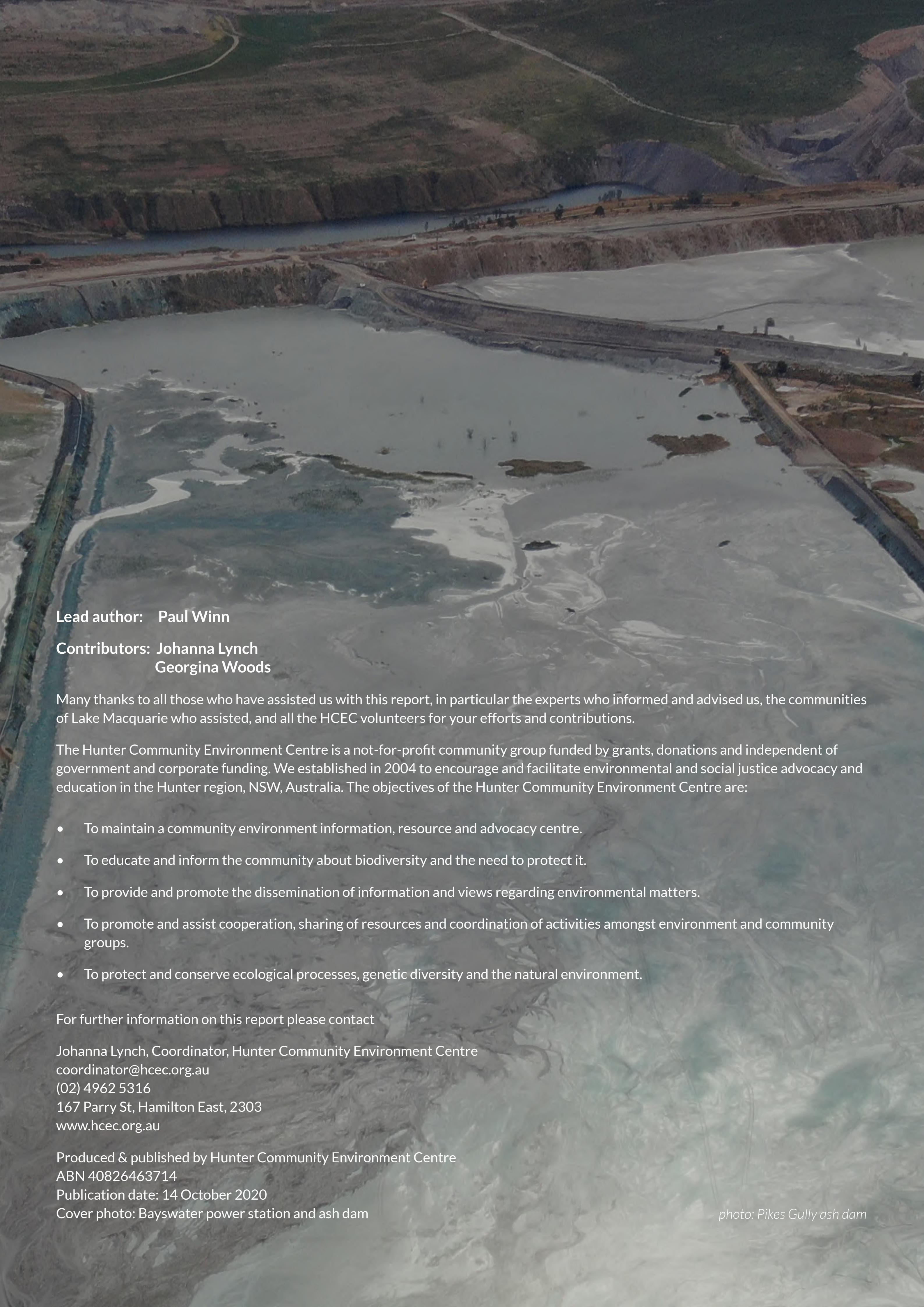

photo: Pikes Gully ash dam

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Many thanks to all those who have assisted us with this report, in particular the experts who informed and advised us, the communities of Lake Macquarie who assisted, and all the HCEC volunteers for your efforts and contributions.

The Hunter Community Environment Centre is a not-for-profit community group funded by grants, donations and independent of government and corporate funding. We established in 2004 to encourage and facilitate environmental and social justice advocacy and education in the Hunter region, NSW, Australia. The objectives of the Hunter Community Environment Centre are:

- To maintain a community environment information, resource and advocacy centre.
- To educate and inform the community about biodiversity and the need to protect it.
- To provide and promote the dissemination of information and views regarding environmental matters.
- To promote and assist cooperation, sharing of resources and coordination of activities amongst environment and community groups.
- To protect and conserve ecological processes, genetic diversity and the natural environment.

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Produced & published by Hunter Community Environment Centre
ABN 40826463714
Publication date: 14 October 2020
Cover photo: Bayswater power station and ash dam

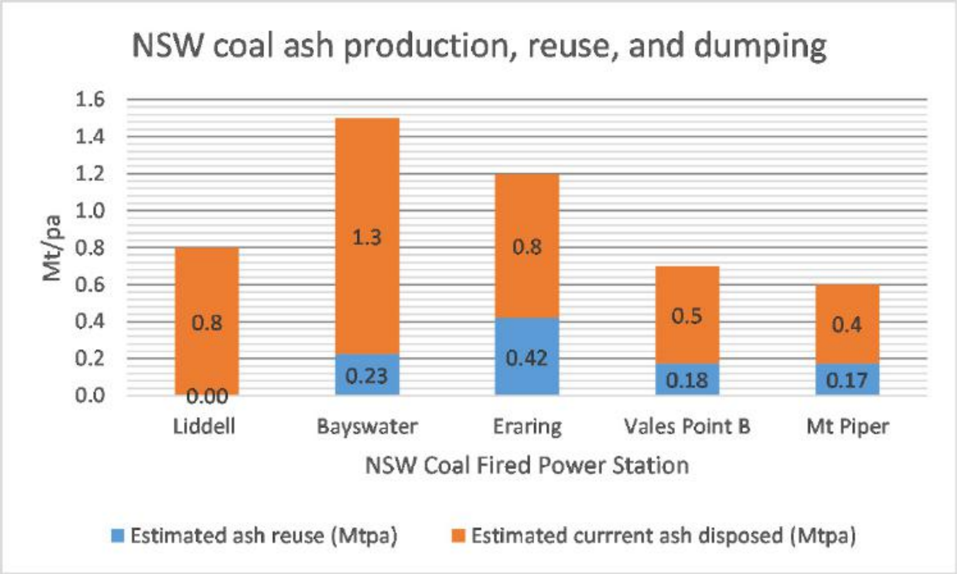
Executive Summary

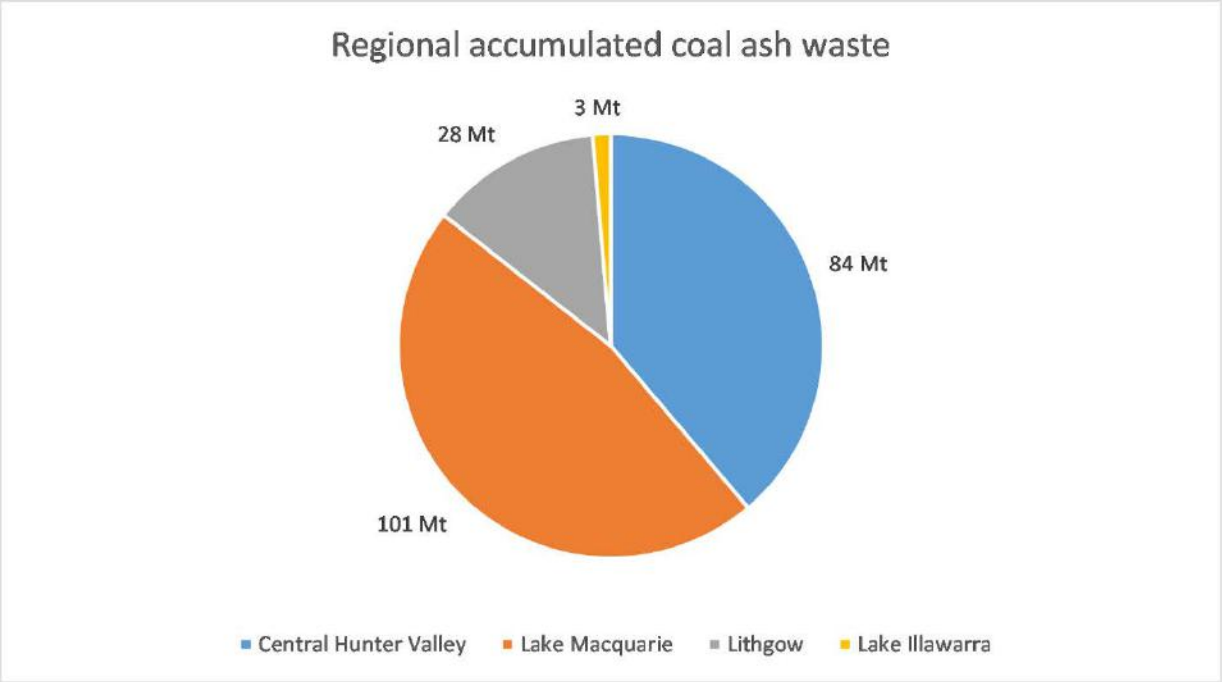
Following from the *Out of the Ashes* report in 2019, this report broadens our investigation into the environmental impacts of seven of the eight coal ash waste dumps in NSW. Our analyses and investigations undertaken over the past two years highlight the inadequacy of the current NSW Environmental Protection Authority (EPA) regulation of the pollution from these massive stores of heavy metals, heavy metals that we demonstrate are causing significant environmental harm and risking human health.

Based on published data, NSW Treasury documents, and our own water and sediment testing, we conclude that the NSW Government is liable for considerable decontamination works at the six active power station ash waste dumps when these facilities are decommissioned, as well as for at least one decommissioned ash waste dump. This work will be necessary to remedy ongoing heavy metal pollution, which demands the Government move quickly to substantially reduce the massive volumes of coal ash dumped annually and accumulated in the State.

We believe the potentially high cost associated with this liability can be substantially reduced by implementing a suite of policies aimed at proactive coal ash reuse, and the implementation of a levy paid by power station operators who dump coal ash waste. These measures would incentivise reuse of the legacy of 50 years of coal ash waste in NSW and reduce the ongoing disposal of coal ash in waste dumps.

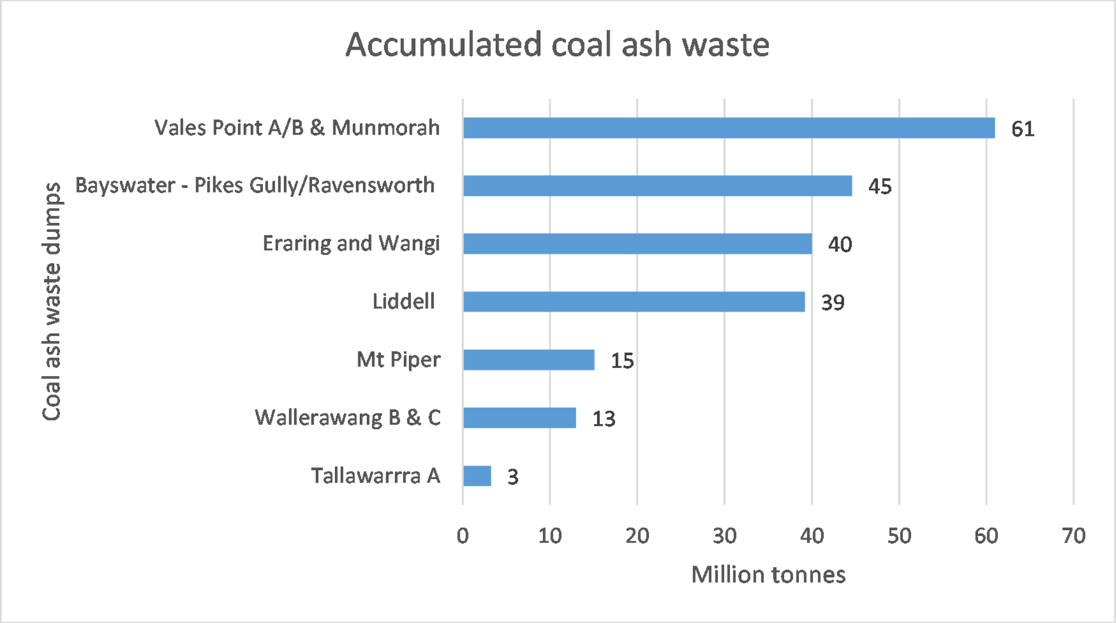
We estimate that the five operating coal-fired power stations in NSW collectively generate about 4.8 million tonnes (Mt) of coal ash a year, and dump about 3.8 Mt a year into on-site ash dams, placement areas, or mine voids, which have now collectively accumulated about 160 Mt of coal ash. Including the decommissioned Wallerawang and Tallawarra ash dams, and the contributions made by the former Munmorah, Wangi, and Vales Point A power stations to the Eraring and Vales Point ash dams, the total coal ash waste accumulated in NSW is about 216 Mt.



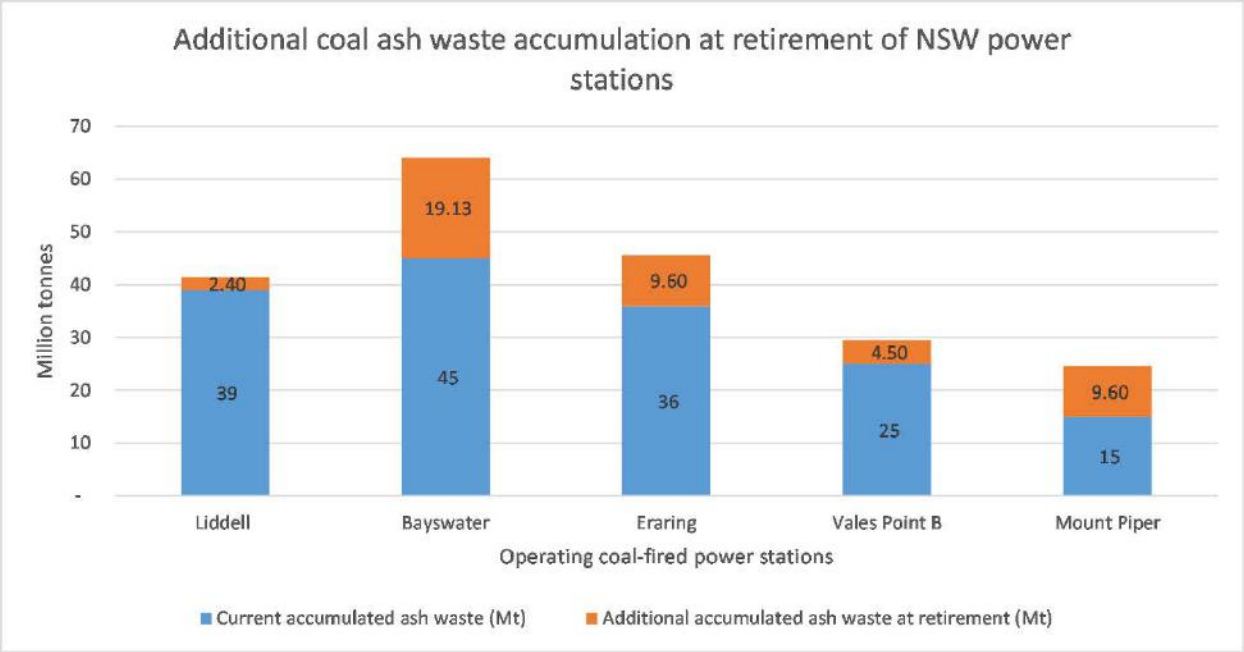


Of this total, Lake Macquarie is burdened with over 100 Mt, the Central Hunter Valley 84Mt, Lithgow 28Mt, and Lake Illawarra 3Mt of ash (See chart above).

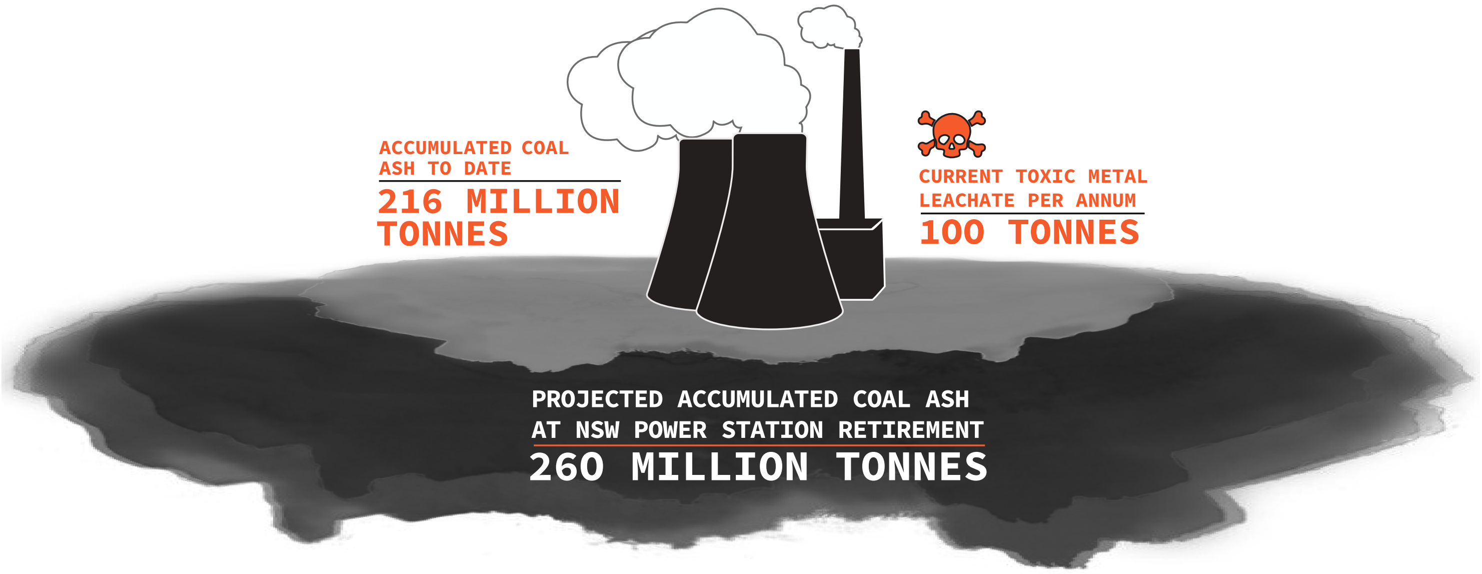
Eight separate coal ash waste dumps exist in NSW (See chart below)

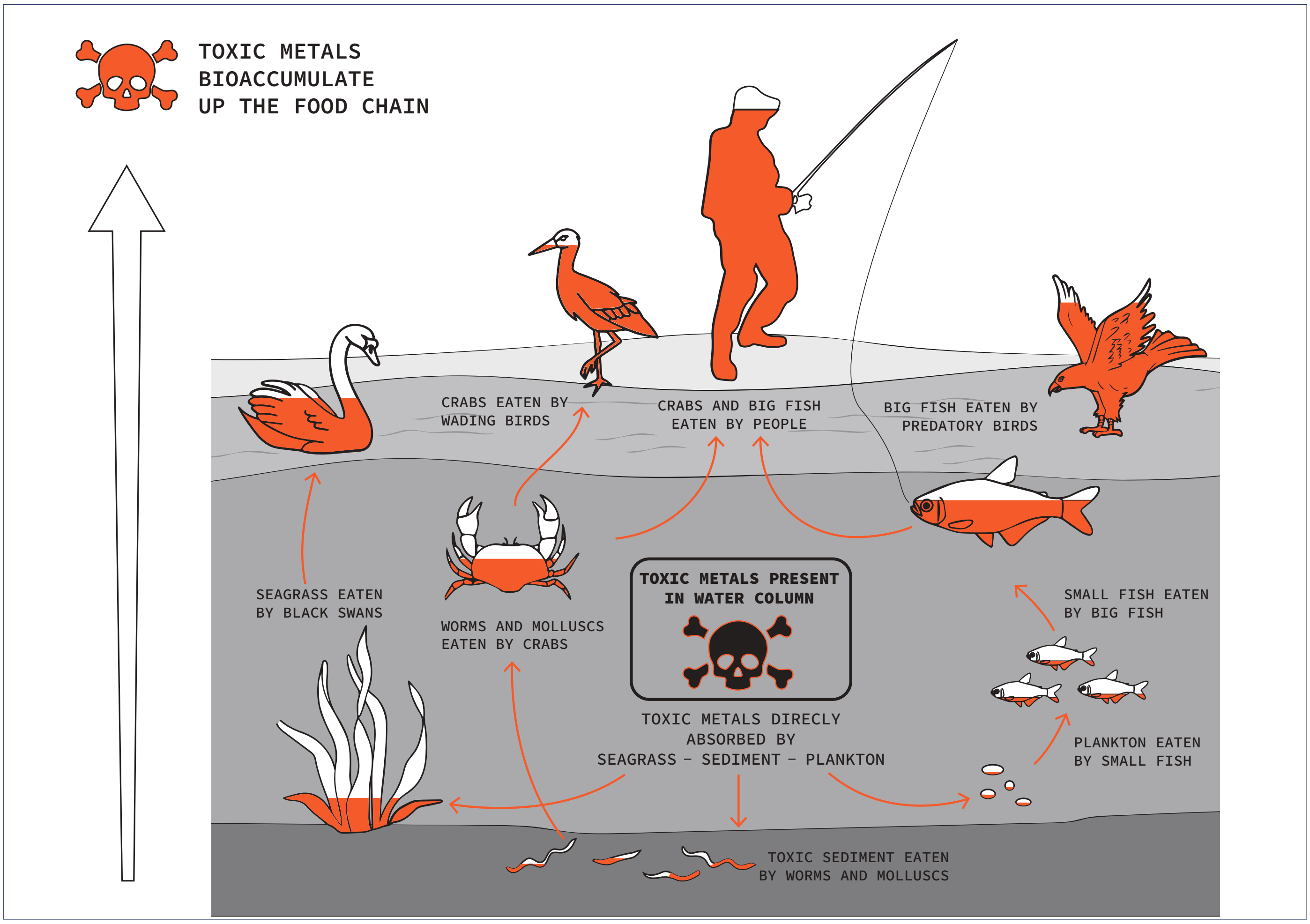


Without any additional coal ash reuse in NSW (or reduction) we estimate over 260Mt of coal ash waste will have accumulated once all five power stations retire (see chart below).



These enormous ash waste dumps contain correspondingly enormous volumes of metals. In 2018/19, over 5,400 tonnes of metals and about 1,300 tonnes of other harmful pollutants were reported to the National Pollutant Inventory (NPI) as “transferred” to on-site ash dumps by NSW power stations. Classifying this dumping as pollution “transfers”, in effect, avoids reporting of water pollution, even though some of the metals contained within the ash will leach into groundwater and ultimately to surface water.


ACCUMULATED COAL ASH TO DATE
216 MILLION TONNES
CURRENT TOXIC METAL LEACHATE PER ANNUM
100 TONNES
PROJECTED ACCUMULATED COAL ASH AT NSW POWER STATION RETIREMENT
260 MILLION TONNES


TOXIC METALS BIOACCUMULATE UP THE FOOD CHAIN
CRABS EATEN BY WADING BIRDS
CRABS AND BIG FISH EATEN BY PEOPLE
BIG FISH EATEN BY PREDATORY BIRDS
SEAGRASS EATEN BY BLACK SWANS
WORMS AND MOLLUSCS EATEN BY CRABS
TOXIC METALS PRESENT IN WATER COLUMN
SMALL FISH EATEN BY BIG FISH
TOXIC METALS DIRECLY ABSORBED BY SEAGRASS – SEDIMENT – PLANKTON
PLANKTON EATEN BY SMALL FISH
TOXIC SEDIMENT EATEN BY WORMS AND MOLLUSCS

Despite significant ground and surface water contamination identified at all eight coal ash waste dumps, no pollution to groundwater was reported to the NPI in 2018/19 by any NSW coal-fired power station.

Heavy metal pollution has likely played an important role in global biodiversity decline. Long-term exposure to metals and metalloids in the environment, even at low doses with chronic exposure, represents a major threat to wildlife populations and biodiversity and can alter the distribution and abundance of wildlife individuals and populations.Indeed, our own research has found high metal concentrations in water birds found at Lake Macquarie and Lake Liddell, which indicates bioaccumulation which may be affecting breeding success.

As far as human health risks are concerned, the consumption of fish and crustaceans is a common pathway for exposure, but swimming in contaminated water can also expose people to metal toxicity. Metal concentrations have been found in commonly caught and consumed seafood from Lake Macquarie above recommended safe levels.

Two main ash types are generated by coal fired power stations. Bottom ash, which is a course material, and fly ash, which is collected by fabric filters or precipitators before entering the smoke stacks. Fly ash makes up about 90 percent of the ash generated and contains far greater concentrations of metals, and is finer and thus leach higher concentrations of metals when it comes into contact with water.

A 2001 ACARP Report[1] on metal leachability from Australian fly ash concludes that tested Australian power station fly ashes pose environmental compliance problems for at least seven metals;

1. boron,
2. copper
3. nickel,
4. molybdenum,
5. selenium,
6. vanadium, and
7. zinc.

Some of the acidic ashes pose additional problems with;

1. arsenic,
2. cadmium,
3. copper,
4. nickel, and
5. zinc.

Delays were found in the appearance of some elements in leachate, particularly

1. arsenic,
2. barium,
3. boron,
4. molybdenum,
5. selenium, and
6. vanadium.

These metals, for some fly ashes, may continue to leach metal concentrations above ecosystem Water Quality Guidelines (WQG) for many decades after the initial spikes in concentrations have flattened.

Using these ash leachate data and published specific NSW fly ash metal concentrations, we estimate about 145 tonnes of metals will leach from about 3.4 Mt of fly ash dumped in NSW each year, including about 73 tonnes of NPI reportable pollutants. We further estimate about 100 tonnes of NPI reportable metals will leach annually from the accumulated coal ash waste in NSW.

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[1] Killingley J, McEvoy S, Kokumcu C, Stauber S and Dale L. 2001. Trace element leaching from fly ash from Australian power stations. ACARP project number C8051. (Table 3.5. Column leach data for 32 elements from 9 power station)s https://www.acarp.com.au/abstracts.aspx?repId=C8051

- **Lake Macquarie catchment** is the worst affected, with an estimated 45 tonnes of NPI reportable metals leaching annually from about 90 million tonnes of accumulated fly ash waste, dumped by three decommissioned and two operating power stations.

- **The Central Hunter River Valley** suffers the effects of 40 tonnes of NPI reportable metals leached annually from 75 million tonnes of accumulated fly ash.

- **The Upper Coxs River**, which forms part of Sydney's drinking water catchments, suffers from an estimated 16 tonnes of NPI metals leached per annum from 25 million tonnes of accumulated fly ash.

- The former Tallawarra A power station dumped an estimated 2.7 million tonnes of fly ash on shores of **Lake Illawarra** up until it retired in 1989. We estimate this leaches about 1 tonne of NPI metals each year.

An additional 45Mt of coal ash waste will have accumulated in NSW when these power stations retire, if no additional reuse occurs. We expected this additional ash will result in the leaching of an additional 1,000 tonnes of NPI reportable metals. The additional NPI reportable metals leached regionally includes;

- 460 tonnes in the Central Hunter Valley,

- 302 tonnes in Lake Macquarie, and

- 206 tonnes in the Upper Coxs River.

If nothing is done to remove this source of contamination, we estimate about 42 additional tonnes of selenium will leach before all the NSW power stations retire. Vales Point power station currently pays a paltry $72 a kilogram fee for its selenium pollution under the NSW Load Based Licence (LBL) scheme. The LBL fee is clearly too low to incentivise pollution reduction, as our research indicates selenium levels are increasing in Vales Point discharge. If all power station operators were forced to pay this fee for their current selenium pollution, the cost to NSW power station operators would be about $3 million. The same fee for all metals leached from this additional coal ash waste would result in $152 million paid by NSW power station operators for their water pollution and the impacts it causes between now and retirement.

If the Vales Point LBL selenium fee were applied to all the metals we estimate are currently leaching from NSW power station ash waste dumps, NSW power station operators would incur a combined pollution bill of about $15 million a year. However, we believe $72 a kilogram is an order of magnitude below what the power station operators should be paying for metal pollution to waterways, given the persistent and accumulating impacts to the environment and human health. Due to the likely high cost of substantially reducing the metal leachate, in order to create an adequate incentive to address the problem we believe NSW power station operators should be paying a combined LBL fee of $150 million a year for the metals leached from coal ash waste dumps.

After the NSW Government built and operated these power stations and their ash dumps for 40 to 80 percent of their design lives, they sold them. The NSW Government therefore retains the liability associated with the coal ash waste dumped up until they changed hands. The current operators are liable for the pollution caused by the additional coal ash waste dumped since purchase and until the facilities are decommissioned.

In 2013, prior to the power station sell-off, Environmental Resources Management Australia P/L (ERM) was engaged by NSW Treasury as Site Contamination Environmental Advisor for the Electricity Generating Assets. ERM produced seven Environmental Site Assessments (ESA) consisting of soil, sediment, surface water and groundwater and assessments of risks to human health and the environment. The ESAs were intended to determine baseline contamination levels. Despite serious deficiencies in the Assessments, including inappropriate and inadequate background samples, restricted and inconsistent metal analyses, as well as an eagerness to downplay the levels of water and soil contamination at the sites, they represent the most comprehensive sets of contamination data on NSW power stations.

The ESAs for all five active NSW power station sites undertaken by ERM conclude that metal contamination from the ash dumps was likely to represent a potential risk to human health and/or the environment. All the ESAs for the five operating power station sites identified significant metal contamination in groundwater surrounding the ash dumps, surface waters draining ash dumps, and in sediment of waterways surrounding the ash dumps. The NSW Government has been aware of this contamination for at least five years, but the assessments have only recently been made accessible to the public via the NSW parliamentary inquiry into the costs of remediating coal ash containment facilities.

Rather than being addressed, the metal pollution from the ever increasing volumes of coal ash waste has continued, and in some cases has increased. Long-term Environmental Protection Licence (EPL) monitoring reveals significant metal pollution from all power station sites is being ignored by the EPA.

Bayswater monitoring shows concentrations of **boron** and **molybdenum** at twice or more the EPL limits and the concentrations of both these metals show an increasing trend.

Similarly at Liddell, **boron** concentrations consistently exceed ANZECC recreational use, and long-term irrigation guidelines. **Selenium** concentrations consistently exceed ANZECC livestock trigger value and long-term irrigation guidelines. Concentrations of **cadmium** and **boron** have been steadily increasing.

Eraring groundwater monitoring shows numerous exceedances of ANZECC and/or NHMRC drinking water guideline (DWG) for **cadmium, copper, manganese, and zinc** and surface water discharge show consistent exceedances for **copper**, consistent exceedances of DWG and ANZECC recreational use guideline for **manganese**, and consistently very high **iron** concentrations five times the ANZECC water quality guidelines (WQG) for recreational use.

Vales Point groundwater monitoring show consistent exceedances of ANZECC and/or NHMRC DWG for **arsenic, copper, iron, lead, manganese, nickel, selenium, and zinc**, and surface water discharge monitoring shows occasional exceedances of ANZECC WQG for **cadmium, copper**, and **lead**, and consistent exceedances of NHMRC WQG for **selenium**. The trend for discharged **selenium** concentrations is increasing with 42 ppb discharged in July 2020.

Mt Piper Power Station has not, until very recently, monitored for any metals in groundwater or surface water discharge.

HCEC has collected water and sediment samples from the waterways draining the five NSW power stations. A summary of our findings is presented below.

Central Hunter River Valley

All samples from Bayswater and Liddell surface drainage exceeded ANZECC and/or NHMRC WQG for pH, EC, **aluminium, boron, copper, iron, nickel, selenium, and/or zinc.**

- Liddell ash dam showed exceedances for EC, **aluminum, boron, copper, iron, nickel, and zinc**.
- Lake Liddell, where both Liddell and Bayswater ash dams drain showed exceedances for EC, **aluminum, boron, copper, Iron, selenium**. Laboratory analyses of the metal load of a black swan feather found on the shore of Lake Liddell shows bioaccumulation of **aluminium, copper, iron, manganese, selenium, and zinc.**
- Drainage from the Bayswater's Pikes Gully Ash Dam revealed exceedances for EC and pH (10.5) **aluminum, copper, iron, and zinc**.
- Sediment samples taken from Liddell and Bayswater ash dam drainage revealed very high **copper** concentrations exceeding ANZECC High Sediment Quality Guideline (SQG) by a factor of 10, and **mercury** exceeding the Low SQG.

Lake Macquarie

Surface water drainage and sediment samples taken by HCEC draining from what we believe is seepage from Eraring and Vales Point ash dumps confirms significant exceedances, including **aluminium**, **arsenic, boron, cobalt, copper, iron, manganese, nickel, and zinc**. A sediment core was taken from Mannering Bay, from which ANSTO identified 15 dates from 1930 to 2019. Laboratory analysis for metals at those identified sediment dates shows the contribution of metal load in Mannering Bay from the sole industrial metal source, the Vales Point Power Station ash dam built in 1962. The time series from 1930 to 1960 shows little or no increases in metal concentrations. However, the next time stamp (1970) shows a substantial increase in metal concentrations in the sediment of Mannering Bay.

Cadmium concentrations have increased by a factor of 15,

1. **copper** by 12,

2. **zinc** by 10,

3. **selenium** by 8 to 10,

4. **lead** by 4,

5. **manganese** by 3,

6. **arsenic** by 2 to 3, and

7. **iron** by 2.

White-faced heron feathers we found in Mannering Bay contained elevated concentrations of **aluminium, boron, chromium, copper, iron, and manganese**, and concentrations of **lead and zinc** above health impact thresholds.

The Vales Point power station operators have retrofitted some new technology and processes to slow the contamination, which has seen reductions in sediment concentrations for a number of metals in Mannering Bay. However, **cadmium and selenium** sediment concentrations remain above recommended ecosystem protection levels.

Vales Point is one of the few power stations in Australia still using wet sluicing ash transport, which agitates the ash pumped from boilers to the ash dump in a slurry of over 90 percent water. Installing dense phase ash transport technology, which uses only 30 percent water, would significantly reduce metal concentrations in leachate that enters Lake Macquarie.

Lithgow

EPL monitoring results for metals at Mt Piper has never been published, but water and sediment samples we took from surface waters near to the Mount Piper power station ash dam, the Wallerawang Power Station ash dam, and Springvale Colliery show a number of very high exceedances of human health, ecological, and agriculture WQG. Metal concentrations of 70 percent of the water samples exceeded WQGs for **aluminium, boron, cadmium, copper, manganese, nickel, and zinc**, as well as pH and EC.

Mount Piper discharge exceeded pH, EC, **aluminium** WQG by a factor of 7 and **copper** by a factor of 2.

Drainage from Mt Piper ash dam exceeded WQG for **aluminum** by a factor of 38, **copper** by a factor 4, and **zinc** by a factor of 2.6.

Water tested downstream the ash dam drainage exceeded WQG for **nickel** by a factor of 3.

Springvale mine discharge exceeded WQG for pH and EC, **aluminium** by a factor 3, **boron** by a factor of 5, **manganese** by a factor of 3, **zinc** by a factor of 15. Sediment samples from Springvale discharge showed substantial exceedances for **cadmium, lead, and nickel, zinc**. Drainage from Wallerawang's ash dump exceeded WQG for pH (4.5), EC, **aluminum** by a factor of 60, **boron** by a factor of 3, **cadmium** by a factor of 13, **copper, manganese** by a factor of 18, **nickel** by a factor of 10, **zinc** by a factor of 260. Sediment samples exceeded guideline values for **arsenic** by 2.5, **nickel** by a factor of 4.

Coxs River samples exceeded WQG for EC, **boron and nickel** by a factor of 5.

Samples from Lake Wallace, into which the Coxs River runs, exceeded WQG for pH (9.1) EC by a factor of 3, **copper** by a factor of 3, and **nickel**. Lake Wallace sediment sample exceeded Guideline values for **lead** by a factor of 5, **nickel, and zinc**.

Clearly, all NSW power station coal ash waste dumps are contaminated sites that must be rehabilitated in a manner that reduces, and ultimately prevents future leaching of metals into groundwater and surface waters. HCEC believes this could be achieved at least cost by providing assistance to companies wishing to produce safe high volume coal ash waste products.

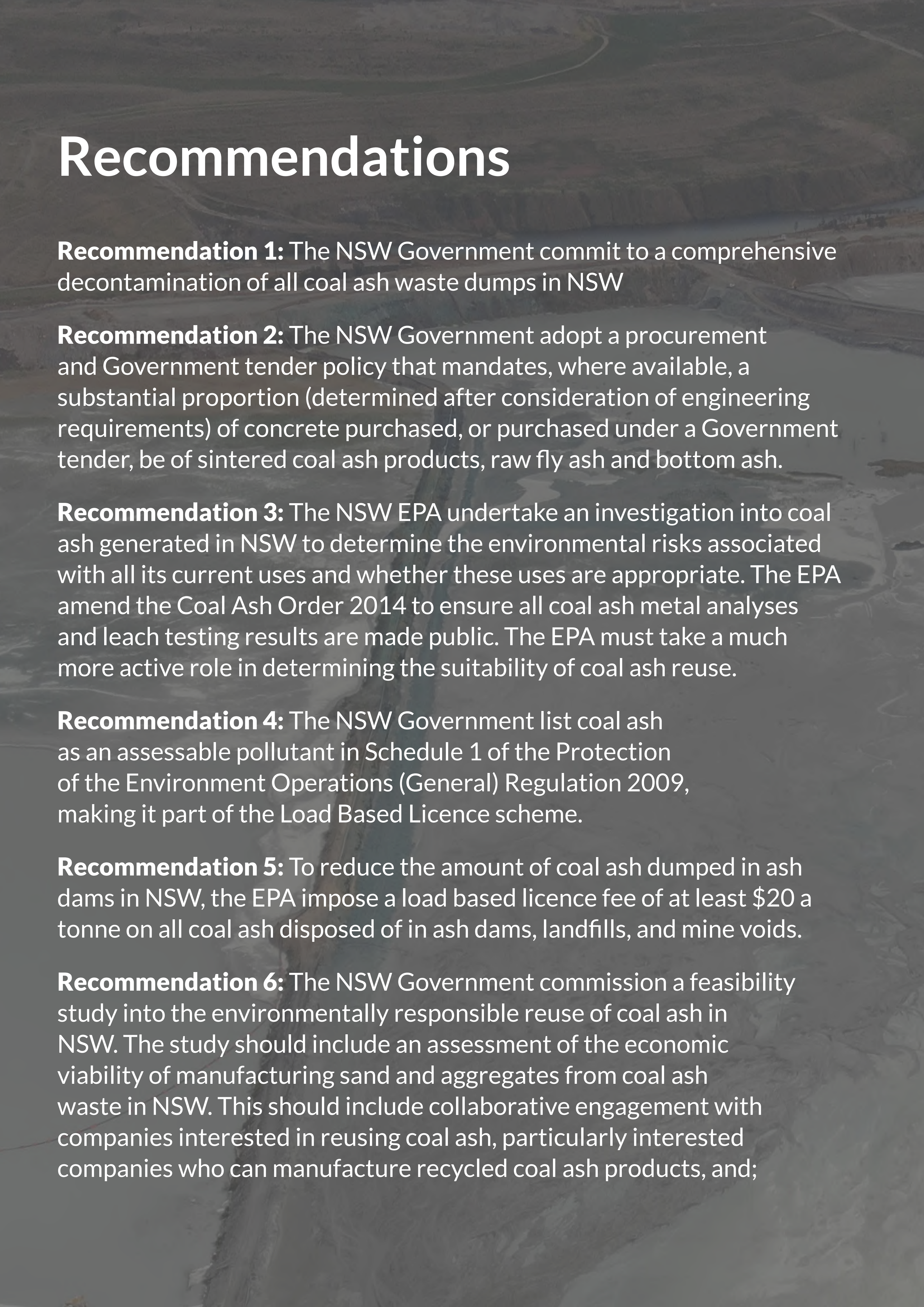
Ridding the State of its coal ash waste burden requires a dramatic increase in its safe beneficial reuse. Far greater incentives must be provided to force power generators to facilitate access to companies wishing to produce safe high volume coal ash products.

To address this damaging pollution problem, the market failure of State's coal ash waste reuse must be addressed. To achieve this, three key Government policy alignments are required.

The listing of coal ash as an assessable pollutant under the *POEO Regulations*, and the imposition of a Load Based Licence fee of at least $20 for every tonne of coal ash waste dumped. This would provide a compelling incentive for power station operators to reduce and eliminate the dumping of ash.

Government assistance in the form of feasibility studies, pilot plants, market appraisals, logistics, engineering specifications and ash suitability studies to support the development of a viable coal ash reuse industry.

A Government procurement policy for a mandated component of coal ash and sintered coal ash products in concrete etc. This will provide a ready market for high volume coal ash products in NSW, and kick start a new industry that will create regional and rural employment.



Recommendations

Recommendation 1: The NSW Government commit to a comprehensive decontamination of all coal ash waste dumps in NSW

Recommendation 2: The NSW Government adopt a procurement and Government tender policy that mandates, where available, a substantial proportion (determined after consideration of engineering requirements) of concrete purchased, or purchased under a Government tender, be of sintered coal ash products, raw fly ash and bottom ash.

Recommendation 3: The NSW EPA undertake an investigation into coal ash generated in NSW to determine the environmental risks associated with all its current uses and whether these uses are appropriate. The EPA amend the Coal Ash Order 2014 to ensure all coal ash metal analyses and leach testing results are made public. The EPA must take a much more active role in determining the suitability of coal ash reuse.

Recommendation 4: The NSW Government list coal ash as an assessable pollutant in Schedule 1 of the Protection of the Environment Operations (General) Regulation 2009, making it part of the Load Based Licence scheme.

Recommendation 5: To reduce the amount of coal ash dumped in ash dams in NSW, the EPA impose a load based licence fee of at least $20 a tonne on all coal ash disposed of in ash dams, landfills, and mine voids.

Recommendation 6: The NSW Government commission a feasibility study into the environmentally responsible reuse of coal ash in NSW. The study should include an assessment of the economic viability of manufacturing sand and aggregates from coal ash waste in NSW. This should include collaborative engagement with companies interested in reusing coal ash, particularly interested companies who can manufacture recycled coal ash products, and;

- Sample ash from all NSW power stations to determine the ideal compositional matrix for the required products and test the products for engineering specification, market feasibility, and human health and environmental safety.
- Design, build, operate, and evaluate a pilot plant.
- Develop a business plan that includes an estimate of final production costs, market appraisals, and transport logistics.
- Identify and amend policy and regulatory barriers, as long as this does not risk negative impacts to the environment or human health.

Recommendation 7: The EPA ensure all NSW power stations operating wet ash dams install appropriate equipment to transport ash in a dense phase to minimise metal mobilisation.

Recommendation 8: The NSW EPA ensure all power station operators estimate and report to the NPI all emissions to land and water from ash dumps.

Recommendation 9: The NSW EPA must strictly enforce the ANZECC water quality guidelines. Where it deviates from these scientifically supported concentration limits, it must be on the basis of site specific biological effects data for at least fifteen species, that clearly shows that allowing discharge and leaching of metals at concentrations above ANZECC/ARMANZC (2000) will not degrade aquatic ecosystems and species, or risk human health. These determinations, and their biological effects justification, must be published on the POEO Public Register.

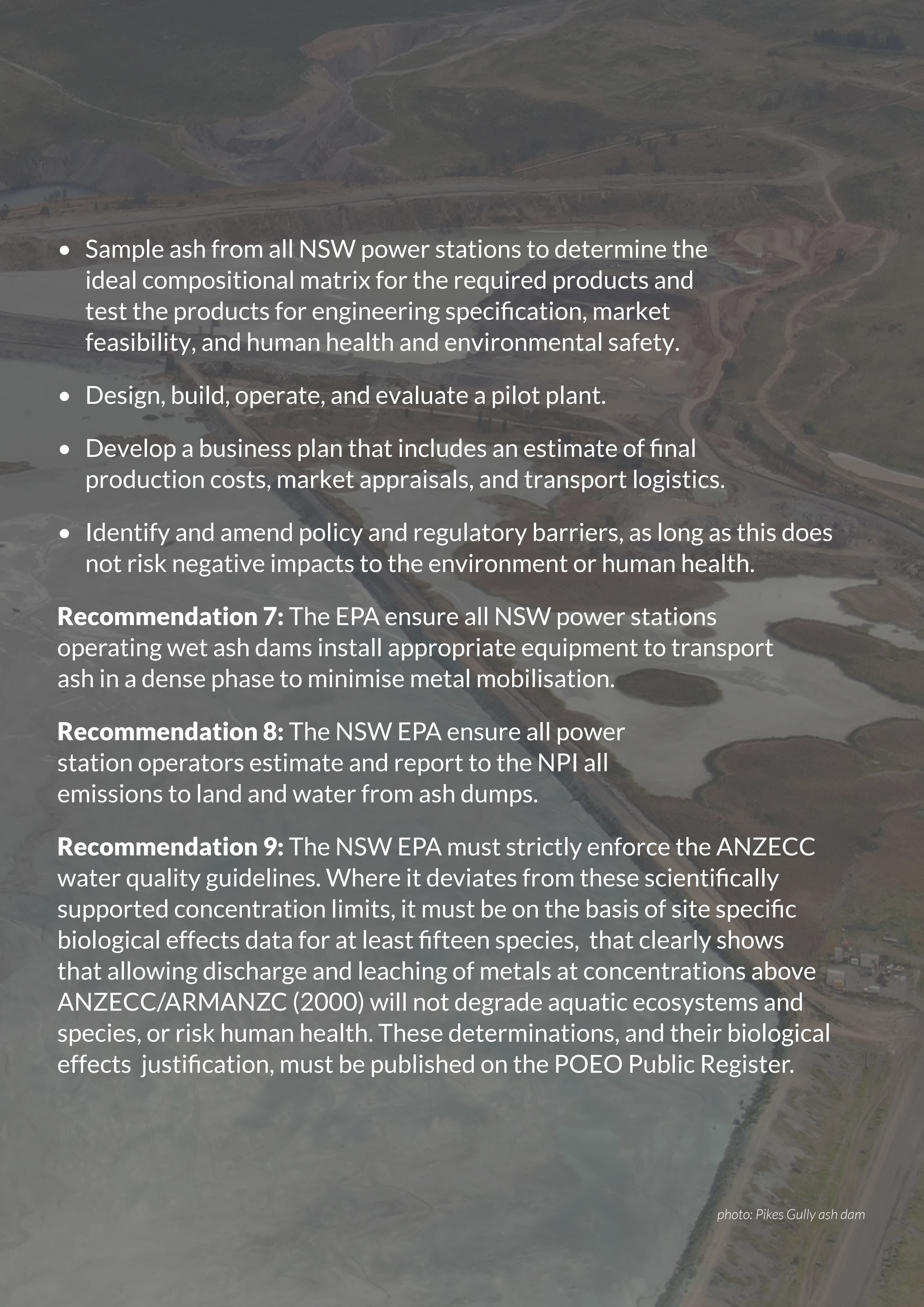


photo: Pikes Gully ash dam

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photo: Energy Australia's Mt Piper power station and ash placement area

Introduction

Coal currently represents 81% of New South Wales (NSW) electricity generation.[2] However, NSW coal-fired electricity generation is expected to end in 2042, when the last of the State's five operating coal-fired power stations (Mount Piper) is set to close. Liddell is the next to close in 2023, Vales Point in 2029, Eraring in 2032, and Bayswater in 2035.

Coal-fired power stations are the major source of at least ten air pollutants in NSW, and we all can look forward to significant staged improvements to air quality as the NSW coal-fired power fleet is progressively retired. Water pollution from coal-fired power stations is also significant but under-reported and even more poorly regulated. Monitoring results required by and reported to the NSW Environmental Protection Authority (EPA) by the power station operators show exceedances of Australian Water Quality Guidelines (WQG) for a dozen heavy metals. Despite this, the only assessable pollutants listed in the *Protection of the Environment Operations Act (POEO Act) Regulations 2009* for coal power stations are selenium, total suspended solids and salt.

Of even greater concern is that two power stations, Mount Piper and Liddell, and until recently, Vales Point, have no regulatory limits listed in their Environmental Protection Licences (EPL) for any of the toxic elements regularly contaminating surrounding waterways as a result of coal ash dumps. However, as Bayswater Power Station EPL concentration limits for two metals have been exceeded in every published monitoring report on AGL's website, imposing limits achieves nothing without EPA enforcement action. Indeed, until very recently, Energy Australia was under no obligation to even monitor for any of the significant number of metals leached and discharged from Mount Piper Power Station.

By far the greatest discharge of water pollutants from coal-fired power stations are toxic metals released from the millions of tons of coal ash waste generated annually by power station boilers and dumped into unprotected landfills and mine voids. We estimate about 40 percent of all the coal ash generated in Australia is from NSW coal-fired power stations - a disproportionate contribution to countries' third largest waste stream which represents 20 percent of all Australia's total waste produced, [3] and a consequence of the high ash content of the NSW bituminous coals.

While pollution control measures have been employed at all NSW operating ash dumps to varying standards and levels of success, none are lined with an impermeable membrane, which is international best practice. The ash dumps therefore leach trace elements to the surrounding groundwater and surface water when water in the ash and rain is allowed to percolate through.

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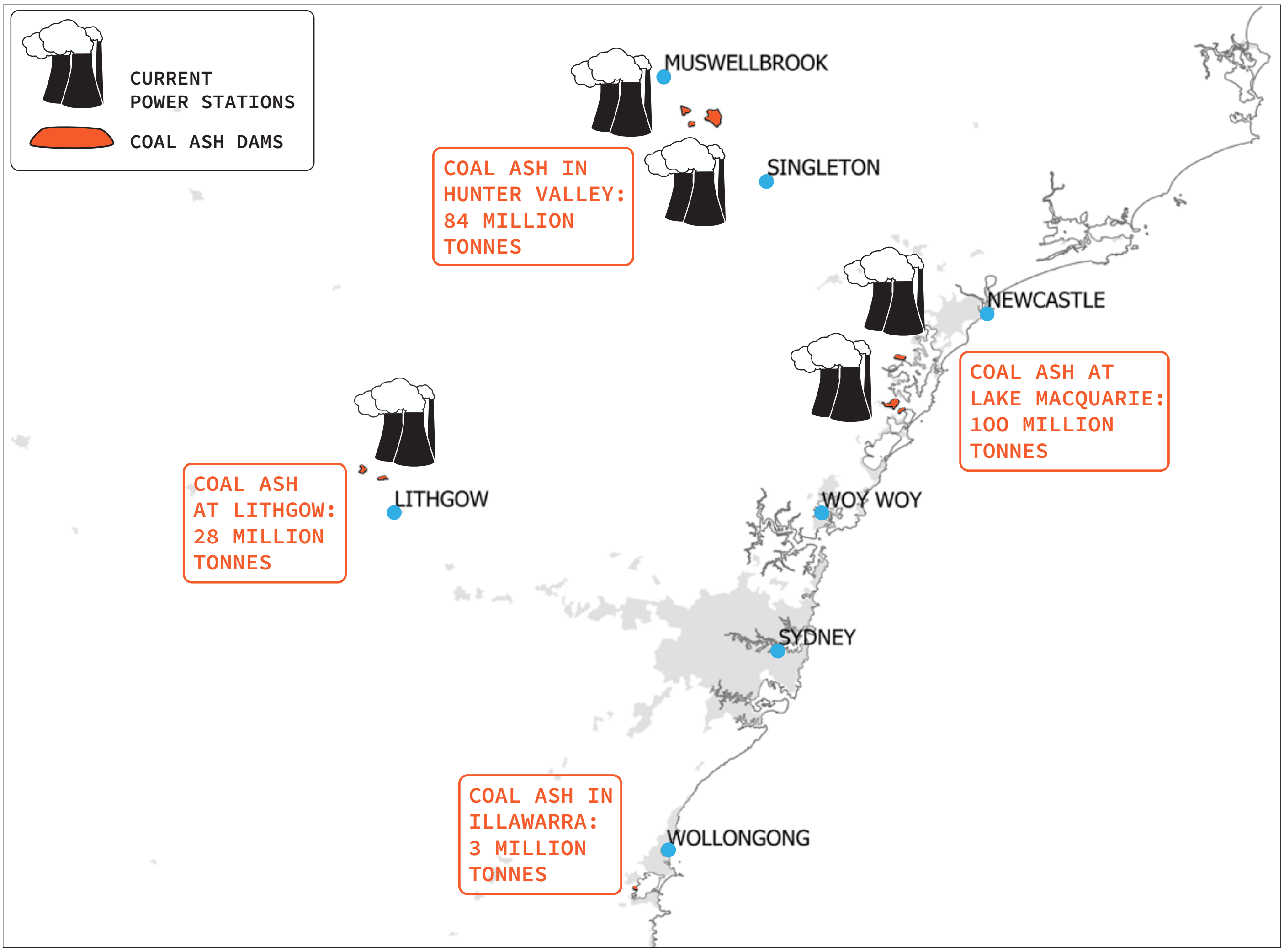
[2] State of NSW and DPIE, 2019.

[3] The Australian Senate Environment and Communications References Committee, 2018.



A recent report for the Federal Department of Environment and Energy (DEE)[1] points out that fly ash is specifically excluded from the relevant National Environment Protection Measure (NEPM) hazardous waste classification. Without the exemption the concentrations of heavy metals in fly ash from coal fired power generation would be sufficient to classify it as hazardous waste. The report noted that:

"Coal fired power generation is slowly declining in Australia. This will create a legacy of large onsite storages of fly ash. The extent to which these storages will be remediated and made safe for the long-term is unclear."

For the past two years, the Hunter Community Environment Centre (HCEC) has been investigating the impacts of Eraring and Vales Point power stations on Lake Macquarie. In March 2019, we released *Out of the Ashes: water pollution and Lake Macquarie's ageing coal-fired power stations* which identified significant contamination of southern Lake Macquarie and its ecosystems with heavy metals and the contribution made to this long-standing issue by the two coal power station ash waste dumps.

Recently, we have reviewed commercial in confidence Environmental Site Assessments (ESA) commissioned by NSW Treasury in preparation for the sale of Eraring, Vales Point, Bayswater, Liddell, and Mount Piper power stations in 2013/14. We have analysed the water quality data, particularly the analyses of groundwater samples collected as part of the ESAs, and other relevant documents provided to the NSW Legislative Council under Standing Order 52. These ESAs provide stark evidence of the significant groundwater contamination beneath NSW coal fired power stations and their ash waste dumps.

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[1] Department of the Environment and Energy & Blue Environment, 2019.

Further, we have reviewed published water quality monitoring required by NSW EPA, which invariably show continuing exceedances of Australian WQG, and in one case consistent exceedances of metal concentration limits imposed by the EPA through its Environmental Protection Licences (EPL).

In addition, we have taken water and sediment samples from waterways around all five power stations and present the laboratory results that reveal significant exceedances of ANZECC & ARMCANZ (2000)[2] guidelines and Australian Drinking Water Guidelines[3] for a number of toxic metals.

Using published data on metal concentrations in Australian and NSW coal ash and derived leachate, we estimate the amount of heavy metals currently leaching from the State's coal ash waste dumps and quantify hidden subsidies in the form of uncosted water pollution by coal-fired electricity generators.

Finally, we offer recommendations for reducing water pollution from coal-fired power stations, recovering the cost associated with these impacts, and identify practical long-term solutions to address this major source of water pollution. Our analysis and investigations highlight the inadequacy of the current EPA regulation of coal ash dumps, which we demonstrate, are causing significant environmental harm and risking human health.

We conclude that the NSW Government will be liable for considerable decontamination works at the five active power station ash dumps, to remedy ongoing heavy metal pollution when these facilities are decommissioned. However, we believe the costs associated with this liability can be substantially reduced by implementing a suit of policies aimed at proactive coal ash reuse, and the implementation of an LBL fee to power station operators who dump coal ash waste. We believe these measures will incentivise the reuse of the legacy of 50 years of coal ash waste dumping in NSW and address the ongoing generation of coal ash waste, which in turn could provide significant regional business and employment opportunities.

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[2] ANZECC & ARMCANZ (2000)

[3] NHMRC, NRMMC, 2011.

photo: Liddell power station ash dam

Estimated coal ash waste generation and accumulation and heavy metal leachate

The five operating coal-fired power stations in NSW collectively generate an estimated 4.8 Mt of coal ash waste a year - about 90 percent fly ash and 10 percent bottom ash. For the past year or so only about 10% of this has been beneficially reused.[4] However, when Bayswater ash reuse starts again, we estimate the five operating power stations will dump about 3.8 Mt a year into on-site ash dams, placement areas, or mine voids, which have collectively accumulated about 160 Mt of coal ash. Including the now decommissioned Wallerawang, Munmorah, and Tallawarra ash dams, and the contributions made by Munmorah and Wangi power stations to the Eraring and Vales Point ash dams, total coal ash accumulation in NSW is about 216 Mt. Table 1 below sets out the figures used for these estimates.

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[4] AGL suspended sales of coal ash in January 2019 and was fined (Enforceable Undertaking) $100,000 by the EPA for supplying coal ash with metal concentrations above that prescribed in the Coal Ash Order 2014.

Table 1: NSW coal-fired power stations. [5]

Facility	Operating						Decomissioned							Combined Total
	Liddell	Bayswater	Eraring	Vales Point B	Mt Piper	TOTALS	Wallerawang C	Wallerawang B	Vales Point A	Munmorah	Wangi	Tallawarrra A	TOTALS	
Licensee	AGL Macquarie		Origin Energy	Sunset Power Int.	Energy Australia NSW		*Energy Australia (Decomissioned)*	*Delta Electricity (Decommissioned)*	*NSW Electricity Commission (Decomissioned)*	*Generator Property Management (Decomissioned)*	*NSW Electricity Commission (Decomissioned)*	*Energy Australia (Decomissioned)*		
LGA	Muswell - brook	Singleton	Lake Macquarie	Central Coast	Lithgow		*Lithgow*	*Lithgow*	*Central Coast*	*Central Coast*	*Lake Macquarie*	*Woolongong*		
Installed	1971	1985	1983	1978	1992		*1980*	*1961*	*1963*	*1969*	*1958*	*1961*		
Expected closure date or decommissioned	2023	2035	2032	2029	2042		*2014*	*1990*	*1989*	*2010*	*1986*	*1989*		
Current age	49	35	37	42	28		*40*	*59*	*57*	*51*	*62*	*59*		
Age at expected closure or decomissioned	52	50	49	51	50		*34*	*29*	*26*	*41*	*28*	*28*		
Plant load factor	0.650	0.7400	0.740	0.656	0.714									
Capacity (MW)	1680	2640	2880	1320	1400		*1000*	*100*	*875*	*1400*	*330*	*320*		
Production (GWh) 2017/18	8,519	15,546	17,186	8,063	7,864									
Estimated Coal consuption (Mtpa) - NGHG emission factors	3.0	5.9	5.0	2.9	2.8	19.6	***2.0***	***0.2***	***1.9***	***3.1***	***0.7***	***0.6***	8.6	
Estimated average ash content (%)	26.0	26.0	23.0	24.0	23.0	24.4	*23.0*	*23.0*	*24.0*	*23*	*23*	*23*	23	
Estimated ash produced (Mtpa)	0.8	1.5	1.2	0.70	0.60	4.8	***0.5***	***0.05***	***0.46***	***0.7***	***0.17***	***0.15***	2.0	
Current ash reuse %	0	15	35	25	29	21								
Estimated ash reuse (Mtpa)	0.00	0.23	0.42	0.18	0.17	1								
Estimated currrent ash disposed (Mtpa)	0.8	1.3	0.8	0.5	0.4	3.8								
Estimated historic reuse %	0	15	20	15	10	12	*10*	*10*	*10*	*10*	*10*	*10*	11	
Estimated historic reuse (Mtpa)	0	0.23	0.24	0.11	0.06	0.63	*0.04*	*0.00*	*0.04*	*0.07*	*0.02*	*0.01*	0.19	
Estimated historic ash disposal (Mtpa)	0.80	1.275	0.96	0.60	0.54	4.17	*0.36*	*0.04*	*0.40*	*0.63*	*0.15*	*0.12*	1.7	5.86
Estimated acumulated ash (Mt)	39	45	36	25	15	159	***12***	***1***	***10***	***26***	***4***	***3***	57	217

Among the operating power stations;

- Bayswater generated the highest volume of ash annually with about 1.5Mt, of which only 0.23Mt is reused.
- Eraring generates about 1.2Mt, of which about 0.42Mt is reused.
- Liddell generates about 0.8Mt of ash with no reuse.
- Vales Point generates about 0.7Mt of ash waste a year, 0.18Mt of which is reused.
- Mt Piper generates 0.6Mt of ash with 0.17Mt reused. In total, about 3.8Mt of coal ash waste is dumped in NSW every year (See Chart 1).

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[5] Coal consumption was calculated using CO2 emissions set out in the Clean Energy Regulator, 2019. Electricity sector emissions and generation data 2017–18 and Department of Environment and Energy, 2017. National greenhouse accounts factors.

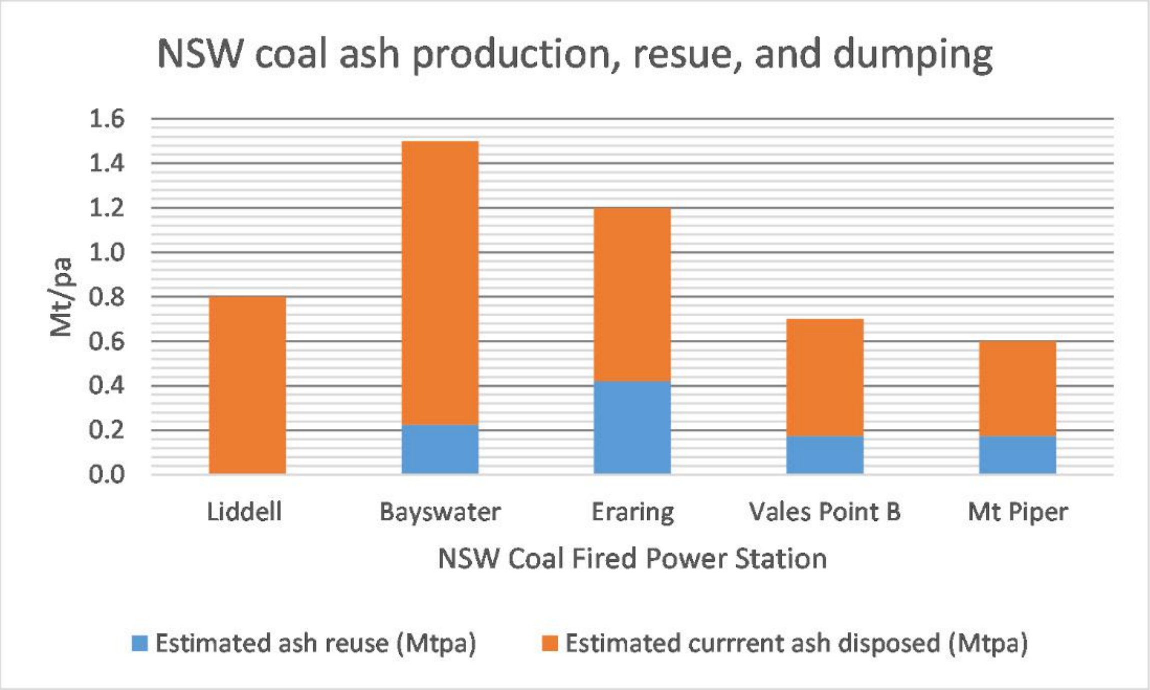


Chart 1: Accumulated coal ash and regional ash dump totals

The Vales Point ash dam is the largest in NSW, holding about 60 Mt (less what was dumped in Munmorah ash dam), Bayswater's Ravensworth Rehabilitation Area, into which AGL dumps fly ash, and the Pikes Gully ash dam collectively hold about 45Mt. The Eraring ash dump holds about 40Mt, and Mount Piper ash dump holds about 15Mt. About 13Mt is held in the decommissioned Wallerawang power station's Kerosene Vale ash dump and the former Tallawarra A ash dump on the shores of Lake Illawarra holds about 3Mt.

About 216Mt of coal ash waste has accumulated in NSW over the past 50 years. Lake Macquarie is burdened with close to half the total at over 100 Mt, the Central Hunter Valley holds 84Mt, Lithgow has 28Mt and Lake Illawarra has 3Mt (See Table 2).

Table 2: Accumulated coal ash and regional ash dump totals

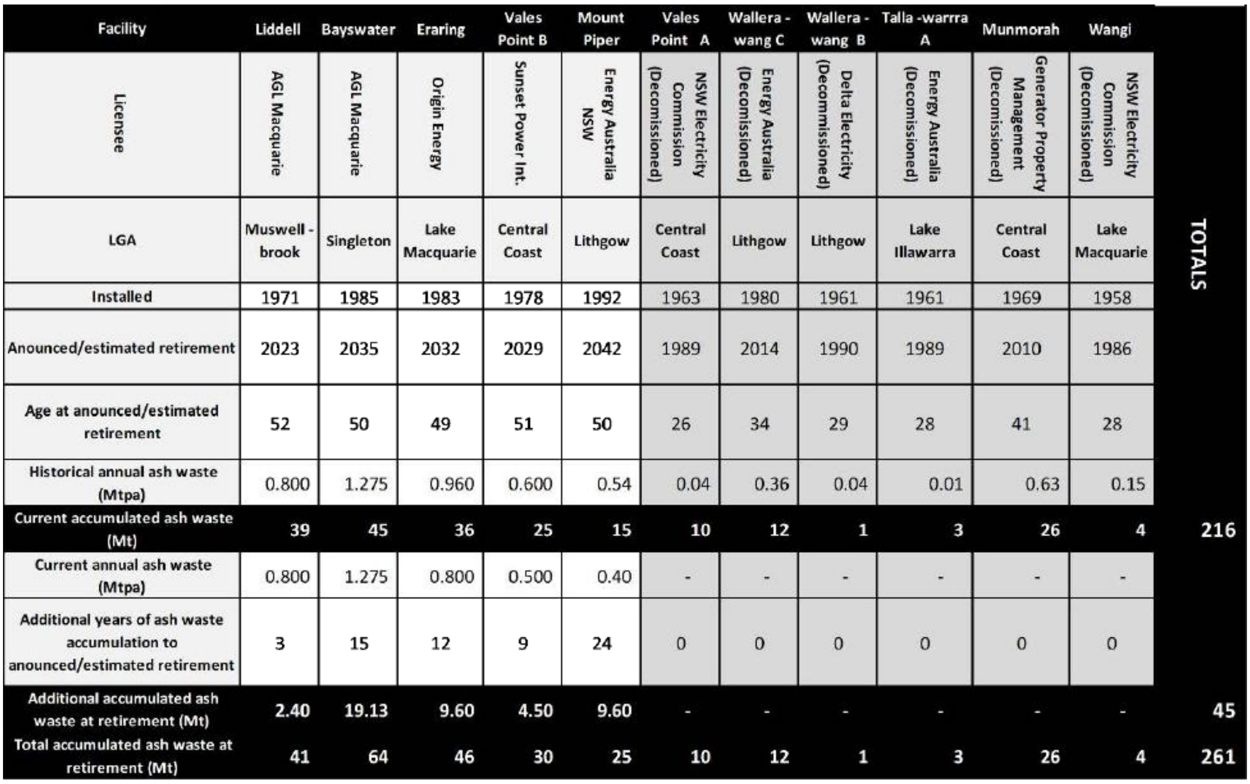
Facility ash dump	Operating ash dumps					*Decomissioned*		Total
	Central Hunter Valley		Lake Macquarie		Lithgow		*Lake Illawarra*	
	Liddell	Bayswater - Pikes Gully and Ravensworth mine rehab.	Eraring and Wangi	Vales Point A/B & Munmorah	Mt Piper	*Wallerawang B & C*	*Tallawarrra A*	
Estimated acumulated ash (Mt)	39	45	40	61	15	*13*	*3*	**216**

As shown in Table 3, based on the announced and expected closure dates for the five operating coal-fired power stations and current reuse rates, an additional 45Mt of coal ash will be disposed of in ash waste dumps in NSW. Including:

- 2.4 Mt at Liddell (2023),
- 4.5 Mt at Vales Point (2029),
- 10 Mt at Eraring (2032),
- 19 Mt at Bayswater (2035), and
- 9.6 Mt at Mt Piper (2042).

Without any additional coal ash reuse in NSW (or reduction) over 260Mt of coal ash waste will have accumulated once all five power stations retire (see table 3 below), a 20 percent increase to the current problem.

Table 3: Additional coal ash waste accumulation till power station retirement



Facility	Liddell	Bayswater	Eraring	Vales Point B	Mount Piper	Vales Point A	Wallera - wang C	Wallera - wang B	Talla -warrra A	Munmorah	Wangi	TOTALS
Licensee	AGL Macquarie	AGL Macquarie	Origin Energy	Sunset Power Int.	Energy Australia NSW	NSW Electricity Commission (Decomissioned)	Energy Australia (Decomissioned)	Delta Electricity (Decommissioned)	Energy Australia (Decomissioned)	Generator Property Management (Decomissioned)	NSW Electricity Commission (Decomissioned)	
LGA	Muswell - brook	Singleton	Lake Macquarie	Central Coast	Lithgow	Central Coast	Lithgow	Lithgow	Lake Illawarra	Central Coast	Lake Macquarie	
Installed	1971	1985	1983	1978	1992	1963	1980	1961	1961	1969	1958	
Anounced/estimated retirement	2023	2035	2032	2029	2042	1989	2014	1990	1989	2010	1986	
Age at anounced/estimated retirement	52	50	49	51	50	26	34	29	28	41	28	
Historical annual ash waste (Mtpa)	0.800	1.275	0.960	0.600	0.54	0.04	0.36	0.04	0.01	0.63	0.15	
Current accumulated ash waste (Mt)	39	45	36	25	15	10	12	1	3	26	4	216
Current annual ash waste (Mtpa)	0.800	1.275	0.800	0.500	0.40	-	-	-	-	-	-	
Additional years of ash waste accumulation to anounced/estimated retirement	3	15	12	9	24	0	0	0	0	0	0	
Additional accumulated ash waste at retirement (Mt)	2.40	19.13	9.60	4.50	9.60	-	-	-	-	-	-	45
Total accumulated ash waste at retirement (Mt)	41	64	46	30	25	10	12	1	3	26	4	261

Coal ash leachate

Coal ash contains toxic metals at various trace concentrations depending on the metal concentrations in the coal burnt, and to a lesser degree the air pollution reduction mechanisms installed at the power station.[6] [7]

The proportion of these metals that will be released from the ash depends largely on the amount of water the ash comes into contact with and the permeability of the settled ash in the dump. Acidity and bonding

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[6] U.S. EPA, 2010; Wadge and Hutton, 1987; Querol, et al, 1996.

[7] USGS, 1997.

between the element in the ash and the physicochemical properties of the water are also important factors determining the proportion of metals that will leach.[8]

Two main ash types are generated by coal fired power stations. Bottom ash, which is a course material, and fly ash, which is collected by fabric filters or precipitators before entering the smoke stacks. Fly ash makes up about 90 percent of the ash generated and contains far greater concentrations of metals, and is finer and thus more likely to leach metals when it comes into contact with water.

Of course, not all this leachate will necessarily escape the ash containment facility. The facility's discharge should be treated before release, and one dump (Eraring) is lined with clay, thus slowing the leachate as it percolates through to the groundwater beneath. However, the Vales Point ash dump was built on the coal ash dumps used by the former Vales Point A and Munmorah Power Stations, and the Eraring ash dump was built on the former Wangi Power Station ash dump. Both these underlying ash dumps are likely to be continuing to leach toxic metals into Lake Macquarie. Eraring, Vales Point, and Mt Piper ash dumps are also built on former coal mine workings, which are likely to provide additional pathways for metal leachate contamination.

Coal ash leachate is, in effect, contaminated water highly detrimental to local water bodies and underground water tables, making the local water unsuitable for drinking.[9] This effect has been seen in many studies on local water quality near ash ponds.[10] Coal ash leachates can be consumed or absorbed by aquatic organisms and cause toxic effects.[11] Bioaccumulation of trace metals from ash storage dams is a concern, as food chain transfer from phytoplankton is the major route of exposure for some metals in aquatic animals.[12]

A number of studies have shown decreased survival and metamorphic success in amphibians exposed to coal ash contaminated sediments.[13] Heavy metal pollution has likely played an important role in global biodiversity decline. Species richness for frogs in Victoria has been shown to correlate negatively with sediment concentrations of copper, nickel, lead, zinc, cadmium and mercury. Distributions of the three commonly-observed frog species were significantly negatively associated with the total level of metal contamination at individual sites, adding to a small but growing body of evidence that heavy metal pollution has contributed to global amphibian decline.[14]

The discharge of metals from ash dumps has also been linked to a number of lethal and sublethal effects on fish species. Populations of fish have decreased in lakes,[15] and growth, male condition factor, and lipid storage were decreased in fish exposed to coal ash contaminated sediments. [16] A number of coal ash trace elements have been found to result in lethal and sublethal decreased growth and condition factors,[17] and fish population and community changes, such as decreased population density, reproductive success, and adult biomass, [18] histopathological abnormalities in somatic and reproductive tissues,[19] and the reduction in fish population fitness through increased susceptibility to disease, predation, and decreased reproductive capacity. [20]

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[8] Fulekar & Dave, 1991; Pandey, 2014.

[9] TGupta et al, 2018.

[10] See for example Chakrabarti et al, 2005; Mudd & Kodikara, 1998.

[11] Bryan & Langston, 1992.

[12] Killingley et al, 2001.

[13] Snodgrass et al, 2004.

[14] Ficken & Byrne, 2013.

[15] See for example Cumbie & VanHorn, 1978; Charlotte et al, 1986; Lemly, 1997.

[16] Rowe, 2003.

[17] Hopkins, 2001.

[18] Garrett & Inman, 1984.

[19] Sorensen, 1988.

[20] Hatcher et al, 1992.

Long-term exposure to heavy metals in the environment represents a major threat to wildlife populations and biodiversity. In the field, metal exposure is generally characterised by low doses and chronic exposures which alters the distribution and abundance of populations.[21]

As far as human health risks are concerned, a common pathway for exposure is the consumption of fish and crustaceans, but swimming in contaminated water can also expose people to metal toxicity (See Appendix 1 for toxicological data on common metals leached from NSW coal ash).

COLUMN LEACH TEST DATA

Leaching of coal ash is a problem that needs very long-term strategies and as such needs to be firmly based on reliable empirical data.[22] Specific coal ash leachability can only be characterised for individual materials with each specific disposal site requiring appropriate material characterisation based on the attributes of that ash and the site conditions.[23] Tests for coal ash leaching are regularly made by those NSW power generators that "sell" ash, to meet obligations under the *NSW Coal Ash Order* (coal ash reuse guidelines).[24] However, none of these are made public, not even to the NSW EPA. Given the seriousness of the coal ash leachate problem in NSW, it is a surprising indictment on the NSW power station operators' lack of diligence and concern for the local environment that site specific leachate data has not been compiled and published.
As we do not have access to trace element analyses of NSW coal ash and reliable leaching characteristics, we have attempted to estimate the amount of toxic metals leaching from NSW coal ash dumps by other means.

Killingley et al (2001)[25] tested the leaching characteristics of fly ash from nine Australian bituminous coal –fired power stations by simulating the leaching of fly ashes in storage dams. A column leach test method is based on the continuous flow of water through a fixed bed of solid ash over a period of some 18 months. It is regarded as the gold standard leaching test,[26] as it is more representative of leachate derived from an ash disposal site which more closely resembled a field situation of the gravity-induced flow of water through an ash dump. The column leach test also provides a liquid to solid ratio that can be used to estimate the time it takes for the metals to leach from the ash until safe concentrations are reached.[27]

The Report concludes that leachates from the tested Australian power station fly ashes pose environmental compliance problems for at least seven metals **- selenium, molybdenum, boron, vanadium, nickel, zinc, and copper**, and that some of the acidic ashes pose additional problems with **cadmium, arsenic, copper, nickel and zinc.**[28]

The column leaching tests recorded delays in the appearance of some elements, particularly **arsenic, barium, boron, molybdenum, selenium and vanadium** which for some fly ashes had maximum leachate concentrations after several liquid to solid volumes had passed through the columns.

Table 4 below sets out the results of these column leaching tests in mean concentrations (ppm) of metals in the nine Australian fly ash samples tested by Killingly et al

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[21] Tovar-Sánchez et al, 2018.

[22] Killingley et al, 2001.

[23] Hassett, 1994.

[24] Resource Recovery Order under Part 9, Clause 93 of the Protection of the Environment Operations (Waste) Regulation 2014 -The Coal Ash order 2014

[25] Killingley et al, 2001.

[26] ibid

[27] Jackson ET AL, 1984.

[28] Killingley, et al, 2001.

(2001), the five NSW fly ash samples tested by Azzi et al (2013), the mean concentrations in derived leachate, and the percentage of initial trace element concentrations in the coal ash found in the leachate. To estimate the concentration of trace elements leached from NSW fly ash, mean concentrations of fly ash from the five NSW coal-fired power stations are also included from Azzi et al (2013). While the individual power stations were not identified, the mean percentage trace elements leached from the tested Australian fly ash, was applied to the mean concentrations of trace elements found in NSW fly ash to estimate the concentrations of trace elements leaching from NSW coal ash waste dumps.

Table 4: Metal concentrations in NSW coal ash and average leachate from Australian coal ash

Metal (mg/k - ppm)		NSW coal-fired power stations[29]						Australian power stations[30]			NSW
		1	2	3	12	13	Mean ppm	Mean ppm (mg/l)	Mean leached ppm (mg/l)	Mean leached %	Mean leached ppm (mg/l)
Arsenic	**As**	12	4	6.6	12	43	15.52	14.4	0.46	3.194	0.496
Boron	**B**	25	56	89	75	80	65	50.9	10.6	20.74	13.481
Barium	**Ba**	393	420	653	393	510	473.8	1465	28	1.9	9.002
Beryllium	**Be**	22	15	4	9	6	11.2	2.8	0.113	3.99	0.447
Cadmium	**Cd**	0.4	0.9	0.25	0.44	0.35	0.468	0.4	0.054	12.52	0.059
Cobalt	**Co**	11	10	6	11	38	15.2	38.1	0.168	0.44	0.067
Chromium	**Cr**	50	40	18	45	72	45	65.7	0.892	1.36	0.612
Copper	**Cu**	52	50	28	47	151	65.6	77.7	0.626	1.36	0.892
Germanium	**Ge**	40	18	5	10	10	16.6	13.7	0.75	5.48	0.910
Mercury	**Hg**	0.02	0.03	0.15	0.12	0.22	0.108	0.1	0.012	10.92	0.012
Lithium	**Li**	180	28	48	58	106	84	72.7	3.29	4.53	3.805
Manganese	**Mn**	88	200	899	321	413	384.2	517	3.24	0.627	2.409
Molybdenum	**Mo**	8	5	5	6	10	6.8	8.5	4.09	48.2	3.278
Nickel	**Ni**	41	30	11	24	70	35.2	77.8	0.456	0.587	0.207
Lead	**Pb**	59	60	48	68	48	56.6	59.2	0.025	0.042	0.024
Antimony	**Sb**	2.9	2.3	3.1	3.9	2.9	3.02	2.5	0.189	7.637	0.231
Selenium	**Se**	5.2	4.7	2.5	3.5	3.7	3.92	2.9	0.686	23.749	0.931
Tin	**Sn**	10	12	6	10	11	9.8	7.3	0.003	0.04	0.004
Vanadium	**V**	128	120	49	109	172	115.6	145	4.16	2.86	3.306
Tungsten	**W**	5	7	6	6	3	5.4	4.8	0.488	10.143	0.548
Zinc	**Zn**	108	86	67	124	142	105.4	145.5	2.18	1.5	1.581
Zirconium	**Zr**	600	440	250	400	450	428	387	0.004	0.001	0.004

Killingley et al (2001) suggest volumes of leachate that were passed through the columns (23 times the volume of ash) represents rainfall equivalents in the order of 20 – 50 years for most of the ashes and ash dam environments. However, for all the 9 fly ash samples most of the metals were leached after between 1 and 8 times the volume of ash in (to solid ratio (L/S)) passed through the ash column - 1 to 15 years.[31] Indeed, the Killingley test shows most metals concentrations at less than ANZECC WQG for irrigation and livestock after just one to two times the volume of water to fly ash (1-5 years).

The average L/S for seven metals was less than 1 (aluminium, beryllium, copper, iron, nickel, uranium, and

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[29] Azzi et al, 2013.

[30] Killingley, 2001.

[31] Killingley, 2001.

zinc). A further five had an average L/S of less than 2 (arsenic, cadmium, cobalt, manganese, mercury), and two (chromium and lithium) had an L/S of less than 4. Boron had an average L/S of 12, and selenium, molybdenum an average of 20, and for lead to leach below ANZECC WQG for irrigation took "less than" the L/S of 23 for the study.

Table 5: Liquid to solid ratios for column leach test by Killingley et al (2001) adapted from Table 3.6

Australian Fly Ash Sample #		**L/S at ANZECC Guideline**									**Mean L/S**
		23	**22**	**21**	**20**	**19**	**18**	**17**	**16**	**15**	
Sodium	Na		1.7	6.2	6	2.7					**4.2**
Calcium	Ca	<	0.41	0.21	<	<	<	1.1	<		**0.6**
Sulfate	SO2					2.5	<	0.65	0.35	1.4	**1.2**
Metals											
Aluminium	Al	0.8				0.7				0.89	**0.8**
Arsenic	As	0.42	<	<	<	0.1	<	4.4	<	0.56	**1.4**
Beryllium	Be	0.42				0.2	<	<	<	0.2	**0.3**
Boron	B	1.3	21.6	27.5	21.8	2.5	<	11.5	5.4	4.7	**12.0**
Cadmium	Cd	0.55	<	<	<	1.1	<	<	<	1.4	**1.0**
Chromium	Cr	0.42	<	<	<	7.4	<	<	3.7	0.13	**2.9**
Cobalt	Co	0.42	<	<	<	2.8	<	<	<	1.4	**1.5**
Copper	Cu	0.78	<	<	<	0.4	<	<	<	0.6	**0.6**
Iron	Fe	0.42	<	<	<	0.04	<	<	<	0.56	**0.3**
Lead	Pb	<	<	<	<	<	<	<	<	<	
Lithium	Li	0.78	8.1	w	<	1.4	<	1.5	4.4	0.56	**3.8**
Manganese	Mn	0.35	<	<	<	2	<	<	<	1.4	**1.3**
Mercury	Hg	<	<	<	<	<	<	1.1	<	<	**1.1**
Molybdenum	Mo	21	23	13.1	9.1	36	13	20	6.9	35	**19.7**
Nickel	Ni	0.42	<	<	<	1.5	<	<	<	0.9	**0.9**
Selenium	Se	21.2	<	17.9	32	21	4.5	30	2	29	**19.7**
Uranium	U	0.42	0.4	<	<	0.07	<	<	<	<	**0.3**
Vanadium	V	0.42	23	27.5	23	39	15.4	28	0.06	22.3	**20**
Zinc	Zn	0.42	<	<	<	1.2	<	<	<	0.9	**0.8**

As shown in Table 6, virtually all of the elements had been leached below the ANZECC WQG for irrigation and livestock at the end of the experiment (max 23L/S).

The assumptions made in Killingley et al (2001) was that these metals would leach into groundwater and, therefore, WQG for irrigation and livestock watering would be the appropriate WQG to assess concentration levels. However, nearly all surface-water features (streams, lakes, reservoirs, wetlands, and estuaries) interact with groundwater. Pollution of surface water can cause degradation of ground-water quality and conversely pollution of groundwater can degrade surface water. Thus, effective water management requires a clear understanding of the linkages between groundwater and surface water as it applies to any given hydrologic setting.[32]

Taking into account the interactions between groundwater with surface water, leachate concentrations derived by Killingley et al (2001) were well above ANZECC WQG for 95% species protection for seven metals (**aluminium, cadmium, cobalt, copper, mercury, and selenium**). As shown in Table 6, all but cobalt exceeded ANZECC species protection guidelines by at least an order of magnitude after completion of the leachate test. All of these concentrations would have a significant impact on aquatic ecosystems.

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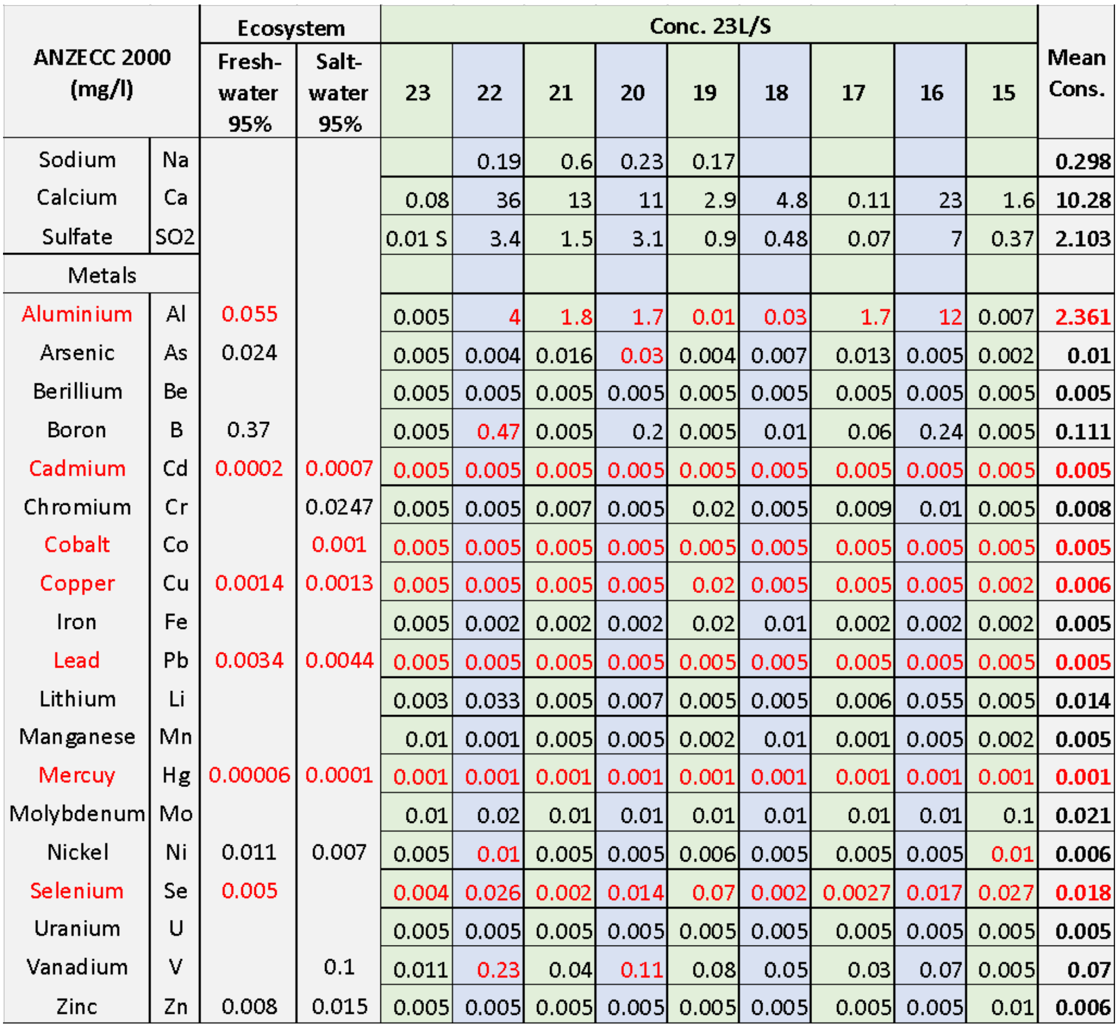
[32] Winter et al, 2013.

Table 6: Leachate from column leach test and Water Quality Guidelines.



ANZECC 2000 (mg/l)		Ecosystem		Conc. 23L/S									Mean Cons.
		Fresh-water 95%	Salt-water 95%	23	22	21	20	19	18	17	16	15	
Sodium	Na				0.19	0.6	0.23	0.17					**0.298**
Calcium	Ca			0.08	36	13	11	2.9	4.8	0.11	23	1.6	**10.28**
Sulfate	SO2			0.01 S	3.4	1.5	3.1	0.9	0.48	0.07	7	0.37	**2.103**
Metals													
Aluminium	Al	0.055		0.005	4	1.8	1.7	0.01	0.03	1.7	12	0.007	**2.361**
Arsenic	As	0.024		0.005	0.004	0.016	0.03	0.004	0.007	0.013	0.005	0.002	**0.01**
Berillium	Be			0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	**0.005**
Boron	B	0.37		0.005	0.47	0.005	0.2	0.005	0.01	0.06	0.24	0.005	**0.111**
Cadmium	Cd	0.0002	0.0007	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	**0.005**
Chromium	Cr		0.0247	0.005	0.005	0.007	0.005	0.02	0.005	0.009	0.01	0.005	**0.008**
Cobalt	Co		0.001	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	**0.005**
Copper	Cu	0.0014	0.0013	0.005	0.005	0.005	0.005	0.02	0.005	0.005	0.005	0.002	**0.006**
Iron	Fe			0.005	0.002	0.002	0.002	0.02	0.01	0.002	0.002	0.002	**0.005**
Lead	Pb	0.0034	0.0044	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	**0.005**
Lithium	Li			0.003	0.033	0.005	0.007	0.005	0.005	0.006	0.055	0.005	**0.014**
Manganese	Mn			0.01	0.001	0.005	0.005	0.002	0.01	0.001	0.005	0.002	**0.005**
Mercuy	Hg	0.00006	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	**0.001**
Molybdenum	Mo			0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.1	**0.021**
Nickel	Ni	0.011	0.007	0.005	0.01	0.005	0.005	0.006	0.005	0.005	0.005	0.01	**0.006**
Selenium	Se	0.005		0.004	0.026	0.002	0.014	0.07	0.002	0.0027	0.017	0.027	**0.018**
Uranium	U			0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	**0.005**
Vanadium	V		0.1	0.011	0.23	0.04	0.11	0.08	0.05	0.03	0.07	0.005	**0.07**
Zinc	Zn	0.008	0.015	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.01	**0.006**

Similar site specific column tests could predict the potential impact of closing an ash dam. Evidence of delayed leachability of elements in a column system may predict what will happen to leachate composition after a fly ash dam is closed and the factors which inhibit or withhold element leachability change after ash dams are decommissioned.[33]

Estimated heavy metal pollution from NSW coal ash dumps

Due to a lack of access to site specific data, we had no choice but to make estimates and apply generalised average leaching percentages from Australian fly ash to available NSW fly ash concentrations. While these

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[33] Killingley et al, 2001.

estimates broadly identify contamination by NSW coal ash dumps, a wide range of concentrations are apparent for the anonymous NSW fly ash site and site specific data must be applied by power station operators and the EPA to determine the actual metal loads and these determinations must be made public, and appropriate measures implemented to ensure our waterways are not further contaminated.

Nevertheless, we applied the mean percentage of metals leached from fly ash generated by nine bituminous coal-fired power stations in NSW, Queensland and Western Australia in laboratory tests reported in Killingly et al (2001), to the mean metal concentrations found in five power station fly ash samples.[34]

With these figures and the estimates of fly ash dumped by NSW power stations set out in Table 1, we have estimated the amount of metals that may be leaching from the NSW coal ash dumped each year in Table 7 below. The estimates for individual metal leaching do not correlate with some of the contamination identified in Chapters 6, 7, and 8. We are, therefore, not confident in the estimates for individual metals. However, we believe the total metals leached are a reasonable estimate that is useful to highlight the scale of the metal pollution from NSW coal ash waste dumps.

Table 7: Estimated metals leached from annual fly ash dumped by NSW power stations applying Killingly et al (2001) to Azzi et al (2013).

Facility			Liddell	Bayswater	Eraring	Vales Pt B	Mt Piper	TOTALS
Licensee			AGL Macquarie		Origin Energy	Sunset Power Int.	Energy Australia NSW	
LGA			Muswell - brook	Singleton	Lake Macquarie	Central Coast	Lithgow	
Est. ash dumped (tpa)			800,000	1,300,000	800,000	500,000	400,000	**3,800,000**
Est. fly ash dumped - 90% total ash (tpa)			720,000	1,170,000	720,000	450,000	360,000	**3,420,000**
METAL/METALOID		leached mg/kg	kg	kg	kg	kg	kg	kg
Antimony	**Sb**	**0.2306**	166	270	166	104	83	**789**
Arsenic	**As**	**0.4957**	357	580	357	223	178	**1,695**
Barium	Ba	9.0022	6,482	10,533	6,482	4,051	3,241	**30,788**
Berillium	**Be**	**0.4469**	322	523	322	201	161	**1,528**
Boron	**B**	**13.4810**	9,706	15,773	9,706	6,066	4,853	**46,105**
Cadmium	**Cd**	**0.0586**	42	69	42	26	21	**200**
Chromium	**Cr**	**0.6120**	441	716	441	275	220	**2,093**
Cobalt	**Co**	**0.0669**	48	78	48	30	24	**229**
Copper	**Cu**	**0.8922**	642	1,044	642	401	321	**3,051**
Gernamium	Ge	0.9097	655	1,064	655	409	327	**3,111**
Lead	**Pb**	**0.0238**	17	28	17	11	9	**81**
Lithium	Li	3.8052	2,740	4,452	2,740	1,712	1,370	**13,014**
Manganese	**Mn**	**2.4089**	1,734	2,818	1,734	1,084	867	**8,239**
Mercuy	**Hg**	**0.0118**	8	14	8	5	4	**40**
Molybdenum	Mo	3.2776	2,360	3,835	2,360	1,475	1,180	**11,209**
Nickel	**Ni**	**0.2066**	149	242	149	93	74	**707**
Selenium	**Se**	**0.9310**	670	1,089	670	419	335	**3,184**
Tin	Sn	0.0039	3	5	3	2	1	**14**
Tungsten	W	0.5477	394	641	394	246	197	**1,873**
Vanadium	V	3.30616	2,380	3,868	2,380	1,488	1,190	**11,307**
Zinc	**Zn**	**1.581**	1,138.32	1,849.77	1,138.32	711.45	569.16	**5,407**
Zirconium	Zr	0.00428	3	5	3	2	2	**15**
Totals			**30,458**	**49,496**	**30,459**	**19,037**	**15,230**	**144,679**
Total NPI reportable metals			**15,442**	**25,093**	**15,442**	**9,651**	**7,721**	**73,348**

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[34] Azzi et al, 2013: Killingley et al, 2001.

We estimate about 145 tonnes of metals will leach from the roughly 3.4 Mt of fly ash dumped in NSW each year, including about 73 tonnes of NPI reportable pollutants.

We can demonstrate that, apart from Mount Piper, the average annual volumes of rainfall catchment at each of the other four ash dumps is greater than the volume of ash each power station dumps each year. This may indicate leachability of coal ash in NSW is more a factor of ash permeability than availability of water. However, we would expect that ash delivered to the dumps by wet sluicing, such as occurs at Vales Point and Liddell, is likely to leach more quickly than denser phase transported ash employed at Bayswater's Ravensworth and Eraring ash dumps as water and ash has been agitated during transport. However, Mount Piper's dry ash placement may be more exposed to rainfall leaching.

The average L/S for seven metals tested by Killingley et al (2001) was less than 1 (**aluminium, beryllium, copper, iron, nickel, uranium, and zinc**). According to Killingley et al (2001) time scale, these metals might leach to below irrigation WQGs in a year or two depending on permeability. A further five had an average L/S of less than 2 (**arsenic, cadmium, cobalt, manganese, mercury**), and two (chromium and lithium) had an L/S of less than 4, which may take five to ten years to leach to irrigation WQG, and **boron, selenium, molybdenum and lead** may take 20 to 50 years.

Killingley et al (2001) found that virtually all of the elements had been leached below the ANZECC WQG for irrigation and livestock at the end of the experiment (23 L/S). However, leachate was well above ANZECC WQG for ecosystem protection for seven metals (**aluminium, cadmium, cobalt, copper, lead, mercury, and selenium**), for all but cobalt by at least an order of magnitude. All of these would have a significant impact on aquatic organisms.These metals may continue to leach metal concentrations above ecosystem WQG for many decades after the initial spikes in concentrations have flattened.

Applying the estimated average metal leachate to our estimates of accumulated fly ash in NSW, we calculate that about 8,200 tonnes of metals has or will leach into groundwater, including about 4,200 tonnes of pollutants reportable under the National Pollutant Inventory (NPI).

Table 8: Estimated metal leaching from fly ash accumulated in NSW coal ash dumps

Facility			Liddell	Bayswater	Eraring	Vales Point B	Mount Piper	Vales Point A	Wallera - wang C	Wallera - wang B	Talla - warrra A	Munmorah	Wangi	Totals
Licensee			AGL Macquarie	AGL Macquarie	Origin Energy	Sunset Power Int.	Energy Australia NSW	NSW Electricity Commission (Decomissioned)	Energy Australia (Decomissioned)	Delta Electricity (Decommissioned)	Energy Australia (Decomissioned)	Generator Property Management (Decomissioned)	NSW Electricity Commission (Decomissioned)	
LGA			Muswell - brook	Singleton	Lake Macquarie	Central Coast	Lithgow	Central Coast	Lithgow	Lithgow	Lake Illawarra	Central Coast	Lake Macquarie	
Current age (age at decomission)			49	35	37	42	28	57	40	59	59	51	62	
Est. accumulated fly ash -90% of ash (Mt)			35	40	32	22	14	11	9	1	3	23	4	195
Metal		mg/kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg
Antimony	Sb	0.2306	8,137	9,263	7,373	5,187	3,139	2,555	2,076	231	692	5,305	923	44,879
Arsenic	As	0.4957	17,489	19,909	15,847	11,149	6,746	5,491	4,461	496	1,487	11,401	1,983	96,458
Barium	Ba	9.0022	317,598	361,551	287,782	202,468	122,502	99,712	81,020	9,002	27,007	207,051	36,009	1,751,701
Berillium	Be	0.4469	15,766	17,948	14,286	10,051	6,081	4,950	4,022	447	1,341	10,278	1,788	86,957
Boron	B	13.4810	475,610	541,431	430,961	303,201	183,449	149,321	121,329	13,481	40,443	310,063	53,924	2,623,212
Cadmium	Cd	0.0586	2,067	2,353	1,873	1,318	797	649	527	59	176	1,348	234	11,401
Chromium	Cr	0.6120	21,591	24,579	19,564	13,764	8,328	6,779	5,508	612	1,836	14,076	2,448	119,087
Cobalt	Co	0.0669	2,360	2,686	2,138	1,504	910	741	602	67	201	1,538	268	13,014
Copper	Cu	0.8922	31,475	35,831	28,521	20,066	12,141	9,882	8,029	892	2,676	20,520	3,569	173,602
Gernamium	Ge	0.9097	32,094	36,535	29,081	20,460	12,379	10,076	8,187	910	2,729	20,923	3,639	177,011
Lead	Pb	0.0238	839	955	760	535	323	263	214	24	71	547	95	4,626
Lithium	Li	3.8052	134,247	152,826	121,645	85,583	51,781	42,148	34,247	3,805	11,416	87,520	15,221	740,438
Manganese	Mn	2.4089	84,987	96,749	77,009	54,179	32,781	26,682	21,680	2,409	7,227	55,405	9,636	468,745
Mercuy	Hg	0.0118	416	474	377	265	160	131	106	12	35	271	47	2,295
Molybdenum	Mo	3.2776	115,634	131,637	104,778	73,717	44,602	36,304	29,498	3,278	9,833	75,385	13,110	637,775
Nickel	Ni	0.2066	7,290	8,299	6,605	4,647	2,812	2,289	1,860	207	620	4,752	826	40,206
Selenium	Se	0.9310	32,844	37,390	29,761	20,938	12,669	10,312	8,379	931	2,793	21,412	3,724	181,152
Tin	Sn	0.0039	138	157	125	88	53	43	35	4	12	90	16	763
Tungsten	W	0.5477	19,324	21,998	17,510	12,319	7,453	6,067	4,929	548	1,643	12,598	2,191	106,579
Vanadium	V	3.30616	116,641	132,784	105,691	74,359	44,990	36,620	29,755	3,306	9,918	76,042	13,225	643,332
Zinc	Zn	1.581	55,778	63,497	50,541	35,558	21,514	17,512	14,229	1,581	4,743	36,363	6,324	307,640
Zirconium	Zr	0.00428	151	172	137	96	58	47	39	4	13	98	17.12	833
TOTALS			1,492,475	1,699,023	1,352,365	951,453	575,669	468,573	380,733	42,304	126,911	972,985	169,215	8,231,704
NPI reportable metals totals			756,648	861,363	685,616	482,363	291,850	237,555	193,022	21,447	64,341	493,280	85,788	4,173,273

As shown in Table 9, when averaged across the age of the ash dumps, we estimate 200 tonnes of metals could be leaching into NSW groundwater each year, including 100 tonnes of NPI reportable metals.

Table 9: Estimated annual leachate from accumulated fly ash in NSW coal ash dumps

Facility			Liddell	Bayswater	Eraring	Vales Point B	Mount Piper	Vales Point A	Wallera - wang C	Wallera - wang B	Talla - warrra A	Munmorah	Wangi	Totals
Licensee			AGL Macquarie	AGL Macquarie	Origin Energy	Sunset Power Int.	Energy Australia NSW	NSW Electricity Commission (Decomissioned)	Energy Australia (Decomissioned)	Delta Electricity (Decommissioned)	Energy Australia (Decomissioned)	Generator Property Management (Decomissioned)	NSW Electricity Commission (Decomissioned)	
LGA			Muswell - brook	Singleton	Lake Macquarie	Central Coast	Lithgow	Central Coast	Lithgow	Lithgow	Lake Illawarra	Central Coast	Lake Macquarie	
			1971	1985	1983	1978	1992	1963	1980	1961	1989	1969	1958	
Age at retirement			52	50	49	51	50	57	40	59	31	51	62	
Est. accumulated fly ash -90% of ash (Mt)			35	40	32	22	14	11	9	1	3	23	4	195
Metal		mg/kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg
Antimony	Sb	0.2306	166	265	199	124	112	45	52	4	12	104.0	15	1,097
Arsenic	As	0.4957	357	569	428	265	241	96	112	8	25	224	32	2,357
Barium	Ba	9.0022	6,482	10,330	7,778	4,821	4,375	1,749	2,025	153	458	4,060	581	42,811
Berillium	Be	0.4469	322	513	386	239	217	87	101	8	23	202	29	2,125
Boron	B	13.4810	9,706	15,469	11,648	7,219	6,552	2,620	3,033	228	685	6,080	870	64,110
Cadmium	Cd	0.0586	42	67	51	31	28	11	13	1	3	26	4	279
Chromium	Cr	0.6120	441	702	529	328	297	119	138	10	31	276	39	2,910
Cobalt	Co	0.0669	48	77	58	36	33	13	15	1	3	30	4	318
Copper	Cu	0.8922	642	1,024	771	478	434	173	201	15	45	402	58	4,243
Gernamium	Ge	0.9097	655	1,044	786	487	442	177	205	15	46	410	59	4,326
Lead	Pb	0.0238	17	27	21	13	12	5	5	0	1	11	2	113
Lithium	Li	3.8052	2,740	4,366	3,288	2,038	1,849	739	856	64	193	1,716	245	18,096
Manganese	Mn	2.4089	1,734	2,764	2,081	1,290	1,171	468	542	41	122	1,086	155	11,456
Mercuy	Hg	0.0118	8	14	10	6	6	2	3	0	1	5	1	56
Molybdenum	Mo	3.2776	2,360	3,761	2,832	1,755	1,593	637	737	56	167	1,478	211	15,587
Nickel	Ni	0.2066	149	237	179	111	100	40	46	4	11	93	13	983
Selenium	Se	0.9310	670	1,068	804	499	452	181	209	16	47	420	60	4,427
Tin	Sn	0.0039	3	4	3	2	2	1	1	0	0	2	0	19
Tungsten	W	0.5477	394	629	473	293	266	106	123	9	28	247	35	2,605
Vanadium	V	3.30616	2,380	3,794	2,857	1,770	1,607	642	744	56	168	1,491	213	15,723
Zinc	Zn	1.581	1,138	1,814	1,366	847	768	307	356	27	80	713	102	7,519
Zirconium	Zr	0.00428	3	5	4	2	2	1	1	0	0	2	0.28	20
TOTALS			30,459	48,544	36,550	22,654	20,560	8,221	9,518	717	2,151	19,078	2,729	201,180
Total NPI reportable metals			15,442	24,610	18,530	11,485	10,423	4,168	4,826	364	1,091	9,672	1,384	101,993

Regional leachate estimates

These staggering figures are even more significant when we focus on the catchments where ash dumps exist. NSW coal-fired power stations are located in three areas; Central Hunter River Valley, southern Lake Macquarie, the Upper Cox's River, and a small decommissioned dump in Lake Illawarra.

Lake Macquarie catchment is the worst affected, with an estimated 80 tonnes of metal (45 tonnes of NPI reportable metals) leaching annually from about 93 million tonnes of accumulated fly ash historically dumped by three decommissioned and two operating power stations. Eraring and Vales Point collectively dump an additional 1.2 million tonnes of fly ash annually from which about an additional 54 tonnes of metals (27 tonnes of NPI reportable metals) will leach.

The central Hunter River Valley suffers the effects of 80 tonnes of metals (40 tonnes of NPI reportable metals) leached annually from 75 million tonnes of accumulated fly ash. Bayswater and Liddell collectively dump a further 1.9 million tonnes of fly ash dumped annually, from which a further 80 tonnes of metals (40 tonnes of NPI reportable metals) will leach.

The Upper Coxs River, which forms part of Sydney's drinking water catchment, suffers from an estimated 31 tonnes of metals (16 tonnes of NPI metals) per annum from 24 million tonnes of accumulated fly ash from 2 former and 1 operating power stations. Mount Piper dumps an additional 0.36 million tonnes of fly ash a year, from which an additional 31 tonnes of metals (16 tonnes of NPI reportable metals) will leach.

While the Tallawarra A power station ceased operating in 1989, we estimate that annually about 2 tonnes of metal (1 tonnes of NPI metals) leach each year from the estimated 3 million tonnes of fly ash historically dumped on its shores.

Table 10 sets out the amount of each metal estimated to leach from fly ash in each of the four regions.

Table 10: Regional estimates of fly ash leachate

Catchments		Central Hunter River Valley			Lake Macquarie			Upper Cox's River			Lake Illawarra	
		Leached from annual fly ash dumped	Leached from accummulated fly ash dumped	Average annual leachate from accumulated fly ash	Leached from annual fly ash dumped	Leached from accummulated fly ash dumped	Average annual leachate from accumulated fly ash	Leached from annual fly ash dumped	Leached from accummulated fly ash dumped	Average annual leachate from accumulated fly ash	Leached from accummulated fly ash dumped	Average annual leachate from accumulated fly ash
Fly ash (Mt)		1.9	75		1.2	93		0.36	24		3	
METAL/METALOID		kg										
Antimony	Sb	436	17,400	431	270	21,342	486	83	5,445	168	692	12
Arsenic	As	937	37,398	926	632	45,871	1,046	178	11,703	361	1,487	25
Barium	Ba	17,014	679,148	16812	11,469	833,022	18,989	3,241	212,524	6,553	27,007	458
Berillium	Be	845	33,714	835	569	41,352	943	161	10,550	325	1,341	23
Boron	B	25,479	1,017,040	25176	17,176	1,247,470	28,436	4,853	318,259	9,813	40,443	685
Cadmium	Cd	111	4,420	109	75	5,422	124	21	1,383	43	176	3
Chromium	Cr	1,157	46,171	1143	780	56,632	1,291	220	14,448	446	1,836	31
Cobalt	Co	126	5,046	125	85	6,189	141	24	1,579	49	201	3
Copper	Cu	1,686	67,307	1666	1,137	82,556	1,882	321	21,062	649	2,676	45
Gernamium	Ge	1,719	68,629	1699	1,159	84,178	1,919	327	21,476	662	2,729	46
Lead	Pb	45	1,793	44	30	2,200	50	9	561	17	71	1
Lithium	Li	7,192	287,074	7106	4,848	352,116	8,026	1,370	89,833	2,770	11,416	193
Manganese	Mn	4,553	181,736	4499	3,069	222,912	5,081	867	56,870	1,754	7,227	122
Mercuy	Hg	22	890	22	15	1,091	25	4	278	9	35	1
Molybdenum	Mo	6,195	247,270	6121	4,176	303,294	6,914	1,180	77,378	2,386	9,833	167
Nickel	Ni	391	15,588	386	263	19,120	436	74	4,878	150	620	11
Selenium	Se	1,760	70,234	1739	1,186	86,147	1,964	335	21,978	678	2,793	47
Tin	Sn	8	296	7	5	363	8	1	93	3	12	0
Tungsten	W	1,035	41,322	1023	698	50,684	1,155	197	12,931	399	1,643	28
Vanadium	V	6,249	249,425	6174	4,212	305,937	6,974	1,190	78,052	2,407	9,918	168
Zinc	Zn	2,988	119,275	2953	2,014	146,298	3,335	569	37,324	1,151	4,743	80
Zirconium	Zr	8	323	8	5	396	9	2	101	3	13	0
Totals		79,954	3,191,497	79002	53,898	3,914,590	89,232	15,230	998,706	30,795	126,911	2151
Total NPI metals		40,535	1,618,011	40,052	27,325	1,984,601	45,238	7,721	506,319	15,612	64,341	1,091

Table 11 shows that the estimated additional 45Mt of fly ash that will accumulate if no additional ash reuse occurs in NSW will result in the leaching of an additional 2000 tonnes of metals, including 970 tonnes of NPI reportable metals. The additional NPI reportable metals leached regionally includes;

- 460 tonnes in the Central Hunter Valley,
- 302 tonnes in Lake Macquarie, and
- 206 tonnes in the Upper Coxs River.

Table 11: Estimates of the additional metal leachate at retirement of the five operating power stations if no increase in reuse occurs.

Facility			**Liddell**	**Bayswater**	**Eraring**	**Vales Point B**	**Mount Piper**	**Totals**
Licensee			**AGL Macquarie**	**AGL Macquarie**	**Origin Energy**	**Sunset Power Int.**	**Energy Australia NSW**	
LGA			**Muswellbrook**	**Singleton**	**Lake Macquarie**	**Central Coast**	**Lithgow**	
Age at retirement			**52**	**50**	**49**	**51**	**50**	
Additional fly ash accumulated at retirement -90% of ash (Mt)			2.4	19.1	9.6	4.5	9.6	**45**
Metal		**mg/kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**
Antimony	**Sb**	**0.2306**	554	4,412	2,214	1,038	2,214	**10,432**
Arsenic	**As**	**0.4957**	1,190	9,483	4,759	2,231	4,759	**22,421**
Barium	**Ba**	**9.0022**	**21,605**	**172,212**	**86,421**	**40,510**	**86,421**	**407,170**
Berillium	**Be**	**0.4469**	1,073	8,549	4,290	2,011	4,290	**20,212**
Boron	**B**	**13.4810**	32,354	257,892	129,418	60,665	129,418	**609,746**
Cadmium	**Cd**	**0.0586**	141	1,121	562	264	562	**2,650**
Chromium	**Cr**	**0.6120**	1,469	11,708	5,875	2,754	5,875	**27,681**
Cobalt	**Co**	**0.0669**	161	1,279	642	301	642	**3,025**
Copper	**Cu**	**0.8922**	2,141	17,067	8,565	4,015	8,565	**40,352**
Gernamium	**Ge**	**0.9097**	**2,183**	**17,402**	**8,733**	**4,094**	**8,733**	**41,145**
Lead	**Pb**	**0.0238**	57	455	228	107	228	**1,075**
Lithium	**Li**	**3.8052**	**9,132**	**72,793**	**36,530**	**17,123**	**36,530**	**172,109**
Manganese	**Mn**	**2.4089**	5,781	46,083	23,126	10,840	23,126	**108,956**
Mercuy	**Hg**	**0.0118**	28	226	113	53	113	**533**
Molybdenum	**Mo**	**3.2776**	**7,866**	**62,700**	**31,465**	**14,749**	**31,465**	**148,246**
Nickel	**Ni**	**0.2066**	496	3,953	1,984	930	1,984	**9,346**
Selenium	**Se**	**0.9310**	2,234	17,809	8,937	4,189	8,937	**42,107**
Tin	**Sn**	**0.0039**	**9**	**75**	**38**	**18**	**38**	**177**
Tungsten	**W**	**0.5477**	**1,315**	**10,478**	**5,258**	**2,465**	**5,258**	**24,773**
Vanadium	**V**	**3.30616**	**7,935**	**63,247**	**31,739**	**14,878**	**31,739**	**149,538**
Zinc	**Zn**	**1.581**	3,794	30,245	15,178	7,115	15,178	**71,509**
Zirconium	**Zr**	**0.00428**	**10**	**82**	**41**	**19**	**41**	**194**
TOTALS			**101,529**	**809,270**	**406,116**	**190,367**	**406,116**	**1,913,397**
NPI reportable metals totals			**51,473**	**410,280**	**205,891**	**96,511**	**205,891**	**970,045**

photo: Vales Point power station ash dam

The National Pollutant Inventory (NPI)

The NPI tracks data on 93 substances that may harm human health and the environment. These substances are chosen by the NPI Review Steering Committee based on recommendations from a Technical Advisory Panel that considers the substance's potential toxicity, human and environmental health effects and the risk of exposure.[35] The categories of emissions are divided into emissions to air, water, and land. Polluting facilities must also report the pollutants in substances transferred in waste streams to designated containment such as a landfill, tailings storage facility, underground injection, or other long term purpose-built waste storage structure. These destinations are considered to be 'final destinations'.

The NPI does not, however, reflect the level of contamination leaching from coal ash in NSW. Leachate is created by introducing water to coal ash, thereby dissolving the metals in solution. We can demonstrate that these dissolved metals leach from ash dumps into underlying groundwater and are discharged into surface water surrounding all five NSW power stations. However, none of these metals emitted from these coal ash waste dumps into surrounding water resources are reported to the NPI.

Groundwater contamination is reported to the NPI as emissions to land. In 20118/19 emissions to land reported from NSW included 344 tonnes of toxic metals. However, no NSW coal-fired power station reported any emissions to land. Table 12 below, sets out reported coal-fired power station emissions as a proportion of total reported NSW Industrial sources of pollution, revealing the very large contribution of coal power to the State's air pollution burden, and the apparent under reporting by the very small contribution to NPI reported water pollution.

The NPI largely relies on facilities estimating their own emissions rather than providing facility monitoring.[36] Cooper, Green, & Meissner (2017) found emissions estimates in the NPI were not accurate and were inconsistent with past data and other sources.[37]

However, emission factors can provide an estimate of emissions when no alternative is available in the form of site specific data. Nevertheless, no emission factors are provided for emissions to land or emissions to water by coal power stations. It is therefore difficult to argue that the NPI is encouraging reporting of this substantial pollution source.

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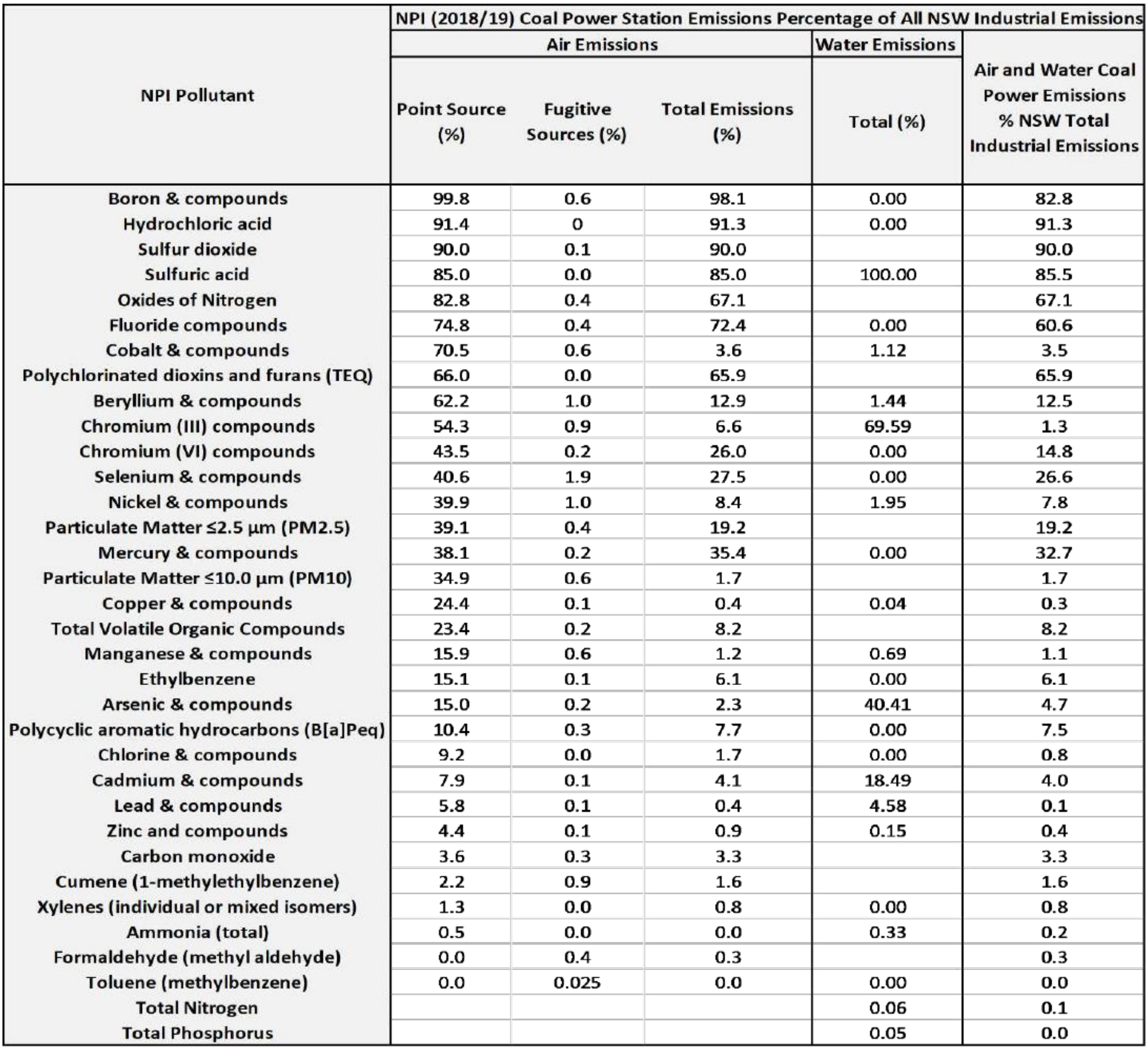
[35] Commonwealth of Australia 2018; Pacey & Back, 2018.

[36] OECD, 2014.

[37] Cooper et al, 2017.

Under the NSW *POEO Regulations* the occupier of a NPI reporting facility is required to provide the EPA with substance identity information and estimated emissions, along with any other information that may be required to assess the integrity of the emission data, among other data. Corporations failing to provide such annual data are liable for a maximum penalty of 40 penalty units.

Table 12: NPI (2018/19) Coal Power Station Emissions as % of all NSW Industries Emissions



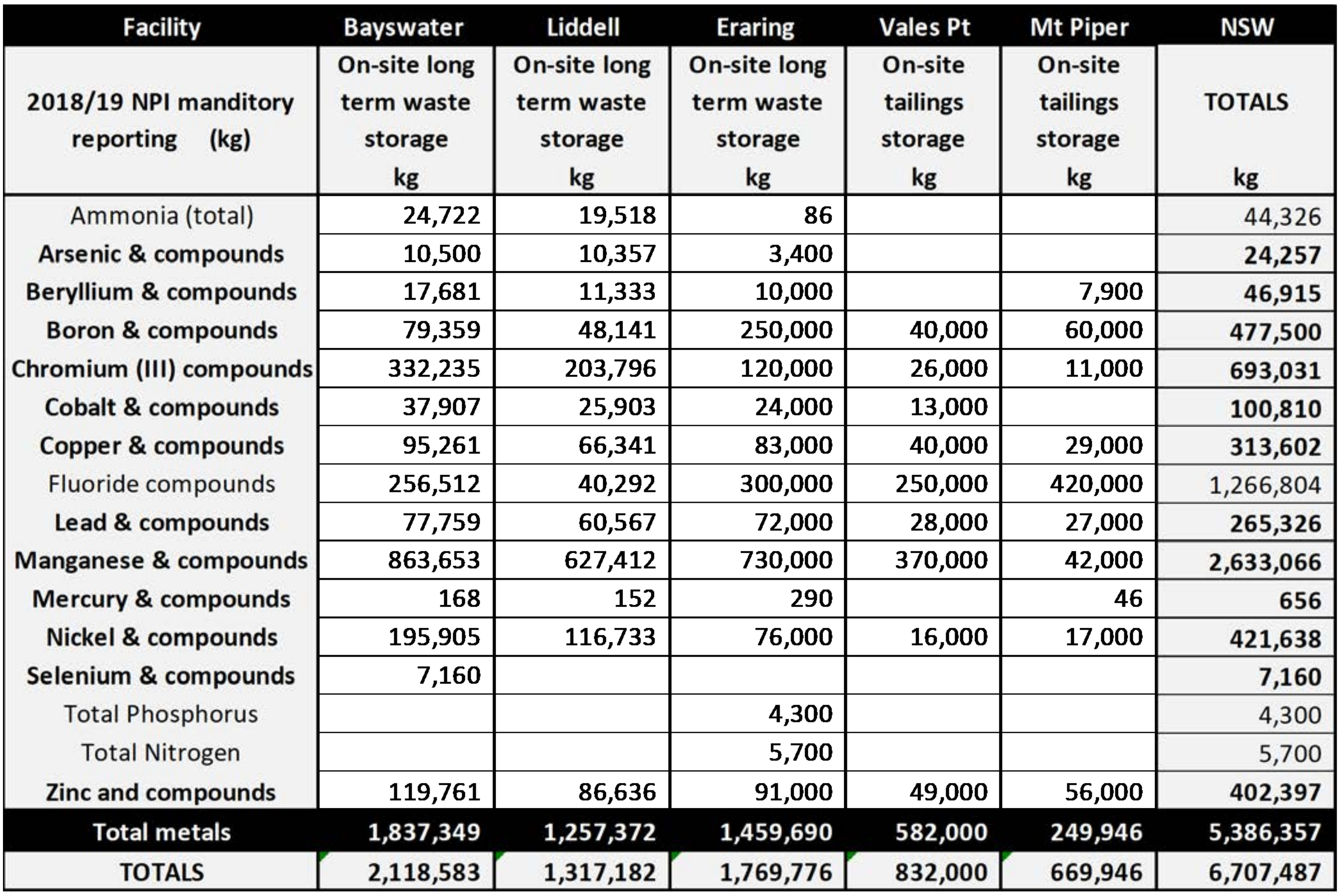
NPI Pollutant	NPI (2018/19) Coal Power Station Emissions Percentage of All NSW Industrial Emissions				
	Air Emissions			Water Emissions	Air and Water Coal Power Emissions % NSW Total Industrial Emissions
	Point Source (%)	Fugitive Sources (%)	Total Emissions (%)	Total (%)	
Boron & compounds	99.8	0.6	98.1	0.00	82.8
Hydrochloric acid	91.4	0	91.3	0.00	91.3
Sulfur dioxide	90.0	0.1	90.0		90.0
Sulfuric acid	85.0	0.0	85.0	100.00	85.5
Oxides of Nitrogen	82.8	0.4	67.1		67.1
Fluoride compounds	74.8	0.4	72.4	0.00	60.6
Cobalt & compounds	70.5	0.6	3.6	1.12	3.5
Polychlorinated dioxins and furans (TEQ)	66.0	0.0	65.9		65.9
Beryllium & compounds	62.2	1.0	12.9	1.44	12.5
Chromium (III) compounds	54.3	0.9	6.6	69.59	1.3
Chromium (VI) compounds	43.5	0.2	26.0	0.00	14.8
Selenium & compounds	40.6	1.9	27.5	0.00	26.6
Nickel & compounds	39.9	1.0	8.4	1.95	7.8
Particulate Matter ≤2.5 µm (PM2.5)	39.1	0.4	19.2		19.2
Mercury & compounds	38.1	0.2	35.4	0.00	32.7
Particulate Matter ≤10.0 µm (PM10)	34.9	0.6	1.7		1.7
Copper & compounds	24.4	0.1	0.4	0.04	0.3
Total Volatile Organic Compounds	23.4	0.2	8.2		8.2
Manganese & compounds	15.9	0.6	1.2	0.69	1.1
Ethylbenzene	15.1	0.1	6.1	0.00	6.1
Arsenic & compounds	15.0	0.2	2.3	40.41	4.7
Polycyclic aromatic hydrocarbons (B[a]Peq)	10.4	0.3	7.7	0.00	7.5
Chlorine & compounds	9.2	0.0	1.7	0.00	0.8
Cadmium & compounds	7.9	0.1	4.1	18.49	4.0
Lead & compounds	5.8	0.1	0.4	4.58	0.1
Zinc and compounds	4.4	0.1	0.9	0.15	0.4
Carbon monoxide	3.6	0.3	3.3		3.3
Cumene (1-methylethylbenzene)	2.2	0.9	1.6		1.6
Xylenes (individual or mixed isomers)	1.3	0.0	0.8	0.00	0.8
Ammonia (total)	0.5	0.0	0.0	0.33	0.2
Formaldehyde (methyl aldehyde)	0.0	0.4	0.3		0.3
Toluene (methylbenzene)	0.0	0.025	0.0	0.00	0.0
Total Nitrogen				0.06	0.1
Total Phosphorus				0.05	0.0

Transfers

Under the NPI transfers are defined as the movement of substances on or off-site. It is mandatory for facilities to report a transfer if NPI substances are transferred in waste streams to designated containment such as a landfill, tailings storage facility, underground injection, or other long-term purpose-built waste storage structure. These destinations are considered to be 'final destinations', although this may not be the case in all situations.

Facilities may also wish to voluntarily report a transfer for reuse, recycling, or reprocessing. Despite historically reusing a small proportion of the ash generated, no NSW power station voluntarily reports these amounts.[38]

Table 13: NPI reported Transfers by NSW power stations in 2018/19



Facility	Bayswater	Liddell	Eraring	Vales Pt	Mt Piper	NSW
2018/19 NPI manditory reporting (kg)	On-site long term waste storage kg	On-site long term waste storage kg	On-site long term waste storage kg	On-site tailings storage kg	On-site tailings storage kg	TOTALS kg
Ammonia (total)	24,722	19,518	86			44,326
Arsenic & compounds	10,500	10,357	3,400			24,257
Beryllium & compounds	17,681	11,333	10,000		7,900	46,915
Boron & compounds	79,359	48,141	250,000	40,000	60,000	477,500
Chromium (III) compounds	332,235	203,796	120,000	26,000	11,000	693,031
Cobalt & compounds	37,907	25,903	24,000	13,000		100,810
Copper & compounds	95,261	66,341	83,000	40,000	29,000	313,602
Fluoride compounds	256,512	40,292	300,000	250,000	420,000	1,266,804
Lead & compounds	77,759	60,567	72,000	28,000	27,000	265,326
Manganese & compounds	863,653	627,412	730,000	370,000	42,000	2,633,066
Mercury & compounds	168	152	290		46	656
Nickel & compounds	195,905	116,733	76,000	16,000	17,000	421,638
Selenium & compounds	7,160					7,160
Total Phosphorus			4,300			4,300
Total Nitrogen			5,700			5,700
Zinc and compounds	119,761	86,636	91,000	49,000	56,000	402,397
Total metals	1,837,349	1,257,372	1,459,690	582,000	249,946	5,386,357
TOTALS	2,118,583	1,317,182	1,769,776	832,000	669,946	6,707,487

Table 13 shows that in 2018/19, about 5,400 tonnes of metals and about 1,300 tonnes of other harmful pollutants were reported as "transferred" to on-site ash dumps by NSW power stations.

Reported transfers of pollutants from NSW power stations are, however, inconsistent and appear significantly under reported. Vales Point and Mount Piper, for example, reportno transfers of ammonia, arsenic, selenium, phosphorus, or nitrogen, and Vales Point reports no transfers of mercury. These transfers, in effect, evade reporting of water pollution, as some of the metals contained within the ash will leach into groundwater, and ultimately to surface water.

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[38] Australian Government, 2009.

Emissions to Land

The NPI Manual identifies that for each NPI substance, which exceeds the Category 1, 1b, 2a, or 2b thresholds for the facility as a whole, the amount of this substance in the discharged leachate must be reported as an emission to land. However, no NSW power station reports any emission to land. Groundwater is included in emissions to land, which are defined as the land on which the facility is located. Emissions to land include slurries and sediments.

The manual lists these emission sources as being broadly categorised as groundwater, surface impoundments of liquids and slurries, and unintentional leaks and spills.

There are currently no emission factors provided for emissions to land, and therefore groundwater. The *NPI Emission Estimation Technique Manual for Fossil Fuel Electric Power Generation* is not much help, recommending direct measurement and mass balance to estimate these emissions, and listing

a lacklustre list of control technologies for waste material and ash (for a coal fired facility) as:

- Utilisation of fly ash for cement products;
- Controlled waste landfill or disposal off-site;
- Wet ash dams (not impacted by wind erosion);
- Twin ash dams (ash disposed to landfill or mine overburden areas); and
- Bunding of oil and chemical storages (reduce the risk of spillage to soil).

Despite serious contamination of groundwater by coal ash storages found in Government commissioned consultant reports, EPA monitoring, and our own water and sediment sampling (see Chapters 6, 7, and 8), as well as in other parts of the world,[39]- eg 90% of US power plants reported unsafe levels of at least one pollutant derived from coal ash in groundwater[40] - no emissions to groundwater were reported to the NPI in 2018/19 by any NSW coal-fired power station.

Emissions to Water

The NPI defines emissions to water as discharges to surface waters such as lakes, rivers, dams and estuaries, coastal or marine waters and storm water runoff.

Table 14 sets out the reported emissions to water by NSW coal power stations. In 2018/19, only three of the five NSW coal power stations reported any emissions to water to the NPI. As a proportion of all NSW industrial water emissions reported in NSW, coal power stations amounted to a mere 0.2% of metals and 0.3% of total emissions to water with only 373 kilograms of metals reported. Of the power stations that did report emissions to water in 2018/19 (Vales point, Eraring, and Liddell), Vales Point failed to report any cobalt, cadmium, beryllium, manganese, or mercury, and Liddell only reported sulfuric acid discharge.

Table 14: NPI (2018/19) Emissions to Water by NSW coal-fired power stations

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[39] US EPA, 1999; U.S. EPA, 2010.

[40] Environmental Integrity Project, 2019.

Facility	Bayswater	Liddell	Eraring	Vales Point	Mount Piper	NSW Power Stations	Total NSW industry	
Emissions to Water (kg)								% NSW Total
Sulfuric acid		58,446				58,446	58,446	100.0
Ammonia (total)			35,000	16,000		51,000	15,398,641	0.3
Total Nitrogen			13,000			13,000	22,952,967	0.1
Total Phosphorus			1,500			1,500	3,003,612	0.0
Manganese & compounds			**130**			**130**	**18,822**	**0.7**
Arsenic & compounds			**41**	**65**		**106**	**262**	**40.4**
Zinc and compounds			**21**	**31**		**52**	**35,426**	**0.1**
Chromium (III) compounds			**9**	**43**		**52**	**74**	**69.6**
Copper & compounds			**9**	**7**		**16**	**36,627**	**0.0**
Nickel & compounds			**8**	**6**		**15**	**744**	**1.9**
Lead & compounds			**1**	**1**		**2**	**34**	**4.6**
Cobalt & compounds			**1**			**1**	**72**	**1.1**
Cadmium & compounds			**0**			**0**	**1**	**18.5**
Beryllium & compounds			**0**			**0**	**12**	**1.4**
Mercury & compounds			**0**			**0**	**38**	**0.0**
Metals Total	0	0	220	153	0	373	163,296	0.228
TOTALS	**-**	**58,446**	**49,720**	**16,153**	**-**	**124,319**	**42,125,294**	**0.295**

No emission factors are included for emissions to water in the *NPI Emission Estimation Technique Manual for Fossil Fuel Electric Power Generation*. However, the manual identifies sources of emissions to water are primarily from steam cycle facilities which can include:

- Ash transport wastewater and discharge from wet ash dams;
- Boiler and cooling tower blowdown;
- Coal stockpile runoff;
- Floor drains;
- Metal and boiler cleaning waste;
- Water treatment facility discharges.[41]

The NPI emission manual cites a number of control technologies for emissions to water that includes controlling ash leachate:

- neutralising acid discharges;
- dense-phase ash transport (no ash transport water to dispose of);
- impoundment of site drainage e.g. settling ponds;
- "zero discharge" operations by evaporating excess water;
- use of marine disposal for saline water;
- control of floor drains discharges via oil and silt interceptors;
- mechanical condenser cleaning systems; and
- chemical substitution e.g. non solvent cleaning techniques.

Only Bayswater (for fly ash to the Ravensworth mine pit dumps) and Eraring utilise dense-phase ash transport. No NSW power station that we know neutralise acid discharge, and none practice zero discharge.

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[41] Australia Government, 2012.

photo: Eraring power station ash dam

Australian Water Quality Framework

Pollution in NSW is regulated by the *Protection of the Environment Operations Act 1997* (POEO Act). The Act specifically prohibits water pollution (s120) and provides for maximum penalties of up to $1,000,000 or 7 years' imprisonment for individuals, and $5,000,000 for a corporation with special executive liability for directors or managers. However, it is a defence against prosecution if the water pollution was regulated by an environment protection licence (EPL) and the conditions of that licence were not contravened.

What constitutes pollution is at issue. The Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand (ANZECC /ARMCANZ, 2000) operate to determine maximum concentrations of pollutants for a variety of water uses, including ecosystem protection. The NSW Water Quality Objectives[42]are the agreed environmental values and long-term goals for NSW surface waters. The Water Quality Objectives for NSW[43]are to maintain or improve the ecological condition of waters and rely on the ANZECC (2000) trigger values to describe the condition and quality of water.

A 1998 Review of ANZECC WQG identified major limitations of the two principal approaches to determining water quality under ANZECC.

The review found that ANZECC WQG did not consider;

1. the toxicity of mixtures,
2. accumulation of toxicant in the animal tissue, and transfer of chemicals between the various compartments of the environment.[44]

Despite failing to address these issues, ANZECC/ARMCANZ (2000) represented a major step forward in water quality assessment and monitoring. Key advances at that time included the adoption of a risk-based approach to water quality management, the notion of different levels of ecosystem condition/protection, new methods for deriving water quality guideline values (GVs; termed trigger values [TVs] in the 2000 Guidelines) for toxicants based on species sensitivity distributions (SSDs), and the promotion of integrated assessment (i.e. assessments combining physicochemical, toxicological and biological indicators). The ANZECC Guidelines (2000) set out values to assess if a water resource is fit for recreation, food production, and aquatic ecosystem health. If the "trigger values" are reached, it may not be safe for that use and management action can be triggered to either more accurately determine whether the water is safe for that use, or to remedy the problem. The guidelines form the central technical reference of the

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[42] NSW Government, 2006.

[43] DEC, 2005.

[44] Warne, 1998.

National Water Quality Management Strategy[45]which the federal and all state and territory governments have adopted for managing water quality. The ANZECC guidelines identify different levels of protection for different water bodies and specify levels of protection corresponding to high conservation value, slightly to moderately disturbed, or highly disturbed ecosystems. The level of protection applied to most waterways in NSW is that suggested for "slightly to moderately disturbed" ecosystems (95% species protection).[46]

While the ANZECC Guidelines suggest a preference for local biological effects data to derive guidelines for ecosystem protection, in the absence of such data, 95% protection levels is the default for slightly to moderately disturbed, with 99% recommended for chemicals that bioaccumulate or for which 95% provides inadequate protection for key test species.

The ANZECC Guidelines are conservative and do not incorporate scientific research on ecotoxicology that has not been confirmed for multiple species. ANZECC therefore omits trigger values for a number of metals based on 'Insufficient Data' (ID). For example, of the 30 metals and metalloids provided with trigger values for freshwater, only 12 have values specified for marine waters.

A further review of ANZECC (2000) documents commenced in 2009. The first major update was approved in 2018 (the current version).[47] The updated online platform still focuses on the derivation of default Guideline Values (GVs), but provides additional guidance, where necessary, for the derivation of regional, site-specific and short-term GVs. The preferred method for GV derivation continues to be based on the use of a species sensitivity distribution (SSD) of chronic toxicity data. The minimum data requirements for using a SSD have not changed from the 2000 Guidelines, that is, toxicity data for at least five species that belong to at least four taxonomic groups. However, using toxicity data from at least eight species is strongly encouraged, and from more than 15 species is considered optimal. Different statistical distributions are fitted to the toxicity data depending on how many species and taxa they belong to, in order to avoid over-fitting the data. [48]

In NSW, the process of deriving site specific toxicity data is not transparent. None are published on the POEO Act Register or the EPA website. However, NSW EPA regularly applies concentration limits to EPL conditions that substantially exceed ANZECC /ARMCANZ (2000) Guidelines without publishing any justification for this deviation.

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[45] Department of Agriculture and Water Resources, 2018.

[46] DEC, 2006.

[47] Australian Government, 2017.

[48] Warne et al, 2018.

photo: Vales Point power station ash dam

photo: Bayswater power station ash dam

Load Based Licence Review

Introduced in 1999, the LBL scheme aims to encourage cleaner industrial production through a “polluter pays” principle defined as “requiring those who generate pollution and waste to bear the cost of containment, avoidance or abatement”.[49] In effect, it requires some environment protection (EPL) licensees to pay part of their licence fees based on the load of pollutants their activities release to the environment.[50]

The scheme is implemented under the *Protection of the Environment Operations Act 1997* (POEO Act), the *Protection of the Environment Operations (General) Regulation* 2009 (POEO Regulation) and the *Load Calculation Protocol* (LCP).[51] However, the scheme is wracked with exemptions and dangerously high thresholds that allow corporate polluters to avoid paying the full costs of their pollution impacts. Indeed, at present, the NSW LBL Scheme is not providing an adequate incentive for polluters to reduce pollution.

The 2016 Issues Paper for the long delayed review of the NSW LBL scheme by the EPA identified 76.4% of NPI reported metals emissions to water in the Hunter Region were from the electricity generation industry [Bayswater, Liddell, Eraring, and Vales Point], citing this as a “significant sources of metals not currently captured under the LBL scheme”.[52]Yet these toxic metals are not assessable pollutants under the NSW LBL.

Under the current POEO Regulation the only metal listed as an assessable pollutant for coal-fired electricity generators is selenium. Of great concern is that two power stations, Mount Piper and Liddell, have no regulatory limits listed in their EPLs for any of the toxicants regularly contaminating surrounding waterways and Vales Point has very recently had such limits introduced. Until very recently, Energy Australia was under no obligation to even monitor for any of the significant number of metals leached and discharged from Mount Piper Power Station.

In 2014, as part of the LBL review, a comparison of load-based licence fees with marginal abatement costs and marginal external costs was undertaken for selected pollutants.[53] The report found that almost all estimates of abatement measure cost and all estimates of externality cost were higher than the level of the corresponding LBL fee, mostly by an order of magnitude.

The LBL scheme needs major reform to meet its stated aims. While stable or declining trends in total loads is reported for the majority of LBL assessable air pollutants from 2003/04 to 2013/14, total loads of assessable pollutants discharged to NSW waterways increased.[54]

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[49] See section 6(2)(d)(i) of the Protection of the Environment Administration Act 1991 (POEA Act).

[50] NSW EPA, 2016.

[51] NSW EPA, 2017a.

[52] NSW EPA, 2016.

[53] ACIL Allen Consulting, 2014.

[54] NSW EPA, 2016.

As part of the NSW LBL review, a comparative review of load-based licensing fee systems was prepared.[55]The comparative review found that:

1. large emission reductions are typically associated with continuous (and correct) measurement of emissions, and

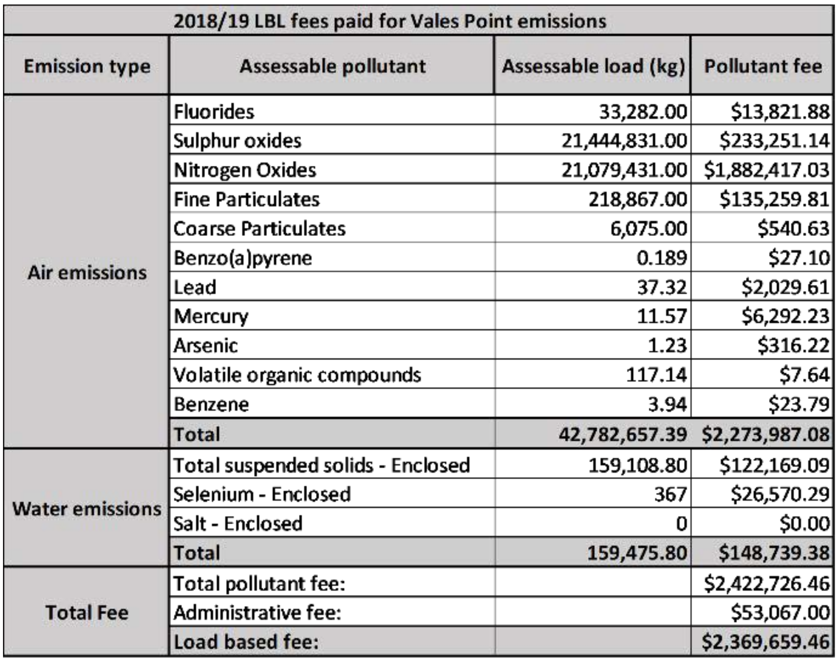
2. Real incentives require fee levels to exceed the cost of emission abatement.

Of the 70 respondents to LBL industrial survey (over 50% of licensees in the scheme), 68% stated that their LBL fees were significantly lower than the cost of upgrading equipment to reduce emissions.[56] An analysis of the financial costs paid by the respondents shows that LBL fees were less than the cost of upgrading equipment in 84% of the cases. On average these LBL fees were just 18% of the cost of equipment upgrades. [57]

Tables 15 sets out the LBL fees paid by NSW power station operators in 2018/19. Paying lip service to the “polluter pays” principle, coal-fired power stations paid a paltry $13.7 million, mostly for their nearly 300,000 tonnes of nitrogen and sulphur oxides, fluorides, and fine particle emissions. The water pollution component of the coal-fired power stations LBL fee was a mere $150,000, paid by just two power stations, Vales Point and Eraring. Far from reflecting the actual level of water pollution, and despite EPA required monitoring showing exceedances of Australian Water Quality Guidelines (WQG) for a dozen heavy metals, the only accessible pollutants listed in the *Protection of the Environment Operations* Regulation for coal power station are selenium, total suspended solids and salt.

This is a major omission, as a number of toxic metals and other pollutants are discharged to NSW waterways from coal-fired power stations (see Chapters 6, 7, and 8). The POEO Regulations list 11 assessable pollutants that iron or steel producers must report - arsenic, cadmium, chromium, copper, lead, mercury, oil and grease, selenium, total suspended solids, and zinc. Indeed, there are a total of 17 assessable water pollutants listed in the *POEO Regulation* for other industries. No valid arguments exist for restrictive application of this scheme given the contamination being caused and the availability of mitigation actions that are not being pursued.

Tables 15: LBL fees paid in 2018/19 by the five operating NSW power stations



2018/19 LBL fees paid for Vales Point emissions			
Emission type	**Assessable pollutant**	**Assessable load (kg)**	**Pollutant fee**
Air emissions	Fluorides	33,282.00	$13,821.88
	Sulphur oxides	21,444,831.00	$233,251.14
	Nitrogen Oxides	21,079,431.00	$1,882,417.03
	Fine Particulates	218,867.00	$135,259.81
	Coarse Particulates	6,075.00	$540.63
	Benzo(a)pyrene	0.189	$27.10
	Lead	37.32	$2,029.61
	Mercury	11.57	$6,292.23
	Arsenic	1.23	$316.22
	Volatile organic compounds	117.14	$7.64
	Benzene	3.94	$23.79
	Total	42,782,657.39	$2,273,987.08
Water emissions	Total suspended solids - Enclosed	159,108.80	$122,169.09
	Selenium - Enclosed	367	$26,570.29
	Salt - Enclosed	0	$0.00
	Total	159,475.80	$148,739.38
Total Fee	Total pollutant fee:		$2,422,726.46
	Administrative fee:		$53,067.00
	Load based fee:		$2,369,659.46

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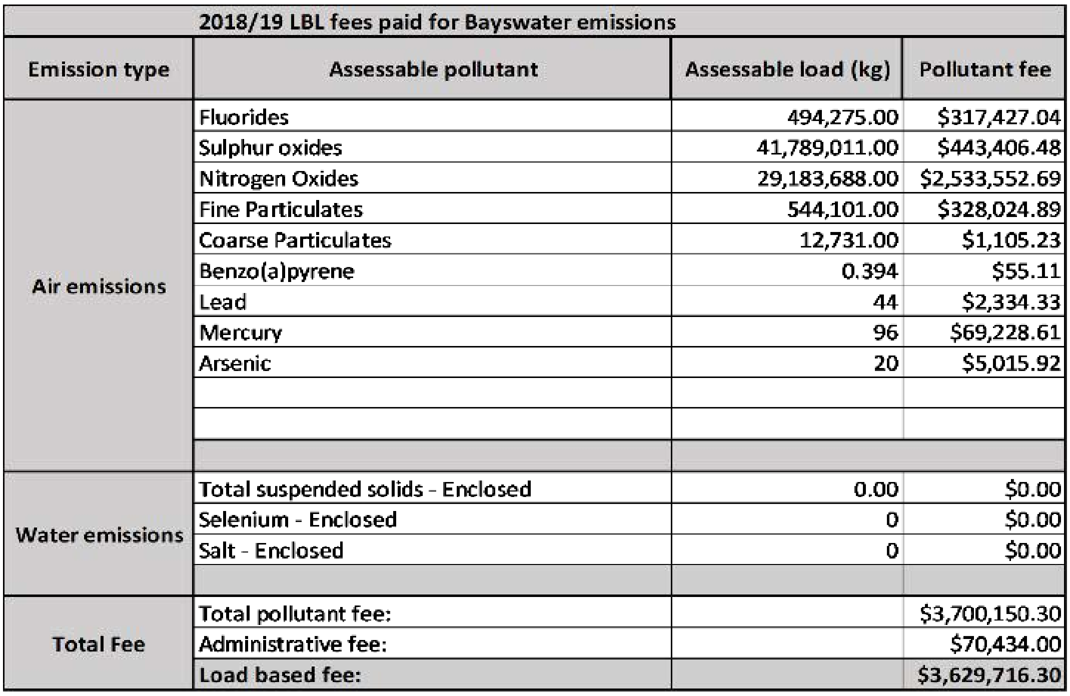
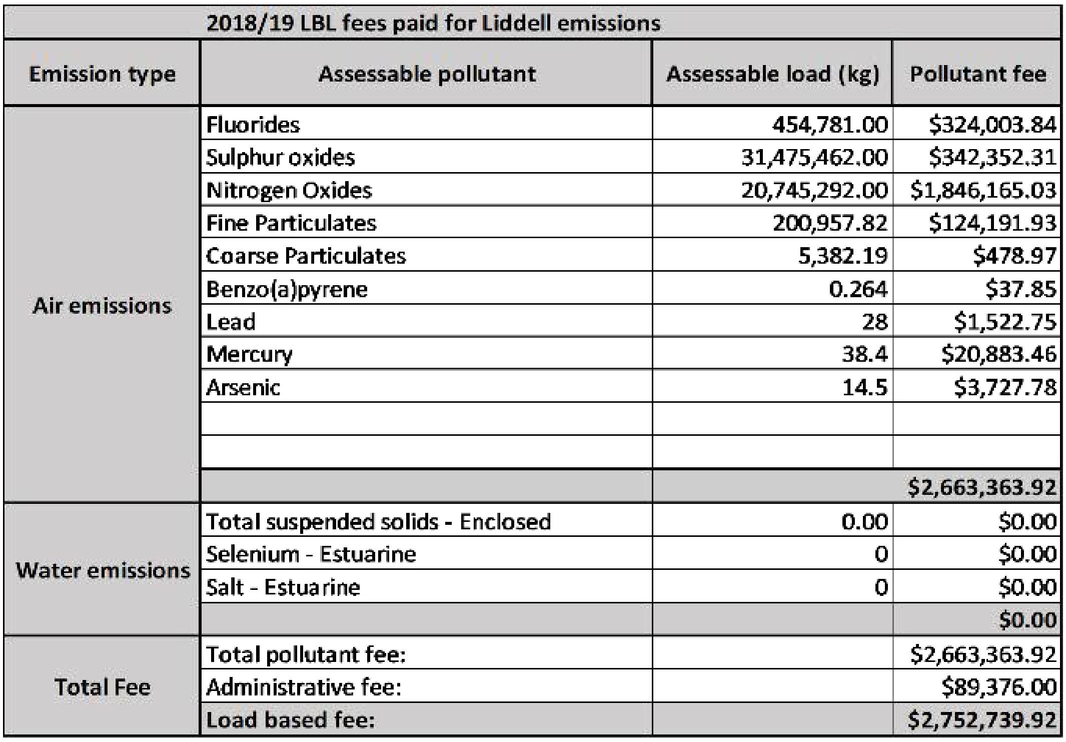
55 BDA Group, 2014.

56 NSW EPA, 2016.

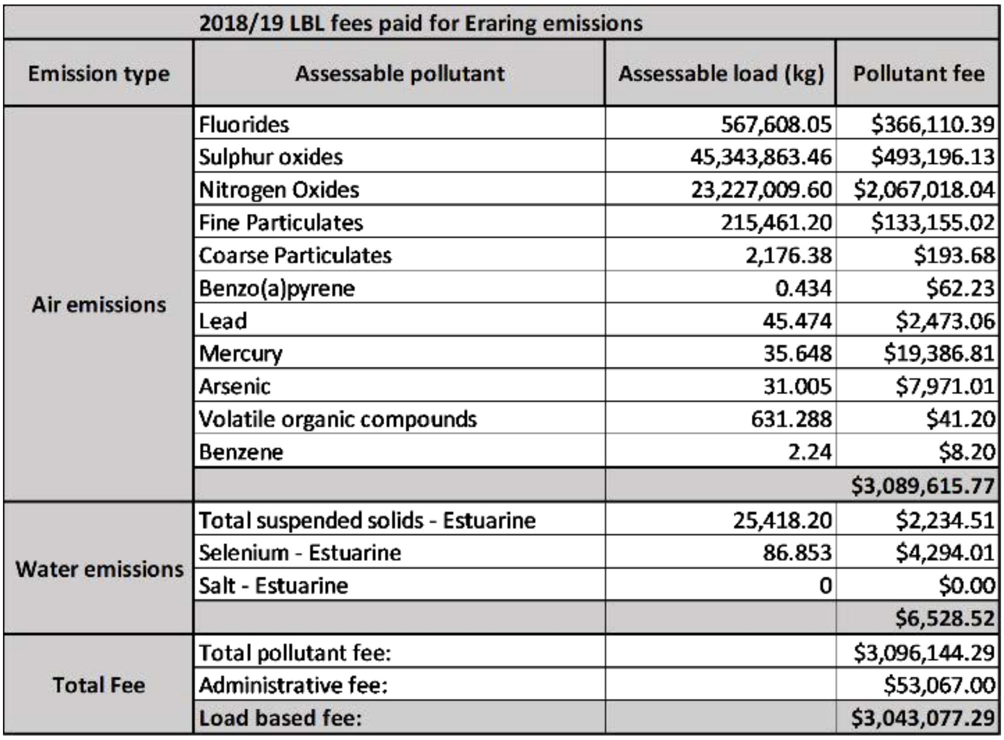
57 Ibid.



2018/19 LBL fees paid for Bayswater emissions			
Emission type	**Assessable pollutant**	**Assessable load (kg)**	**Pollutant fee**
Air emissions	Fluorides	494,275.00	$317,427.04
	Sulphur oxides	41,789,011.00	$443,406.48
	Nitrogen Oxides	29,183,688.00	$2,533,552.69
	Fine Particulates	544,101.00	$328,024.89
	Coarse Particulates	12,731.00	$1,105.23
	Benzo(a)pyrene	0.394	$55.11
	Lead	44	$2,334.33
	Mercury	96	$69,228.61
	Arsenic	20	$5,015.92
Water emissions	Total suspended solids - Enclosed	0.00	$0.00
	Selenium - Enclosed	0	$0.00
	Salt - Enclosed	0	$0.00
Total Fee	Total pollutant fee:		$3,700,150.30
	Administrative fee:		$70,434.00
	Load based fee:		$3,629,716.30

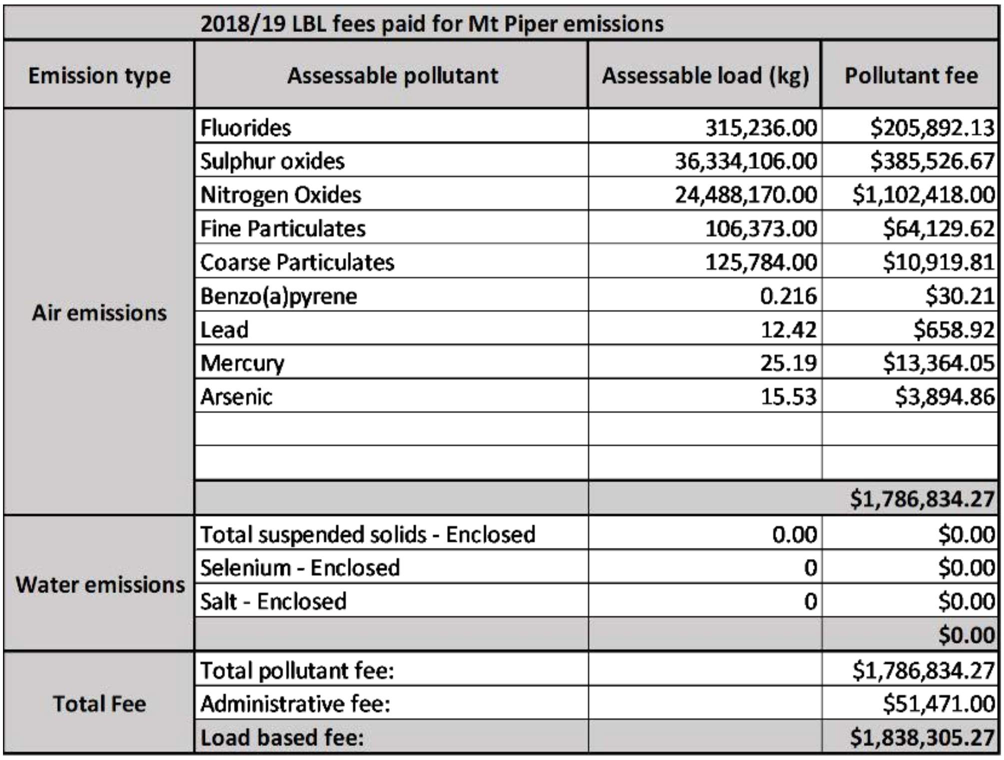


2018/19 LBL fees paid for Liddell emissions			
Emission type	**Assessable pollutant**	**Assessable load (kg)**	**Pollutant fee**
Air emissions	Fluorides	454,781.00	$324,003.84
	Sulphur oxides	31,475,462.00	$342,352.31
	Nitrogen Oxides	20,745,292.00	$1,846,165.03
	Fine Particulates	200,957.82	$124,191.93
	Coarse Particulates	5,382.19	$478.97
	Benzo(a)pyrene	0.264	$37.85
	Lead	28	$1,522.75
	Mercury	38.4	$20,883.46
	Arsenic	14.5	$3,727.78
			$2,663,363.92
Water emissions	Total suspended solids - Enclosed	0.00	$0.00
	Selenium - Estuarine	0	$0.00
	Salt - Estuarine	0	$0.00
			$0.00
Total Fee	Total pollutant fee:		$2,663,363.92
	Administrative fee:		$89,376.00
	Load based fee:		$2,752,739.92



2018/19 LBL fees paid for Eraring emissions

Emission type	Assessable pollutant	Assessable load (kg)	Pollutant fee
Air emissions	Fluorides	567,608.05	$366,110.39
	Sulphur oxides	45,343,863.46	$493,196.13
	Nitrogen Oxides	23,227,009.60	$2,067,018.04
	Fine Particulates	215,461.20	$133,155.02
	Coarse Particulates	2,176.38	$193.68
	Benzo(a)pyrene	0.434	$62.23
	Lead	45.474	$2,473.06
	Mercury	35.648	$19,386.81
	Arsenic	31.005	$7,971.01
	Volatile organic compounds	631.288	$41.20
	Benzene	2.24	$8.20
			$3,089,615.77
Water emissions	Total suspended solids - Estuarine	25,418.20	$2,234.51
	Selenium - Estuarine	86.853	$4,294.01
	Salt - Estuarine	0	$0.00
			$6,528.52
Total Fee	Total pollutant fee:		$3,096,144.29
	Administrative fee:		$53,067.00
	Load based fee:		$3,043,077.29



2018/19 LBL fees paid for Mt Piper emissions

Emission type	Assessable pollutant	Assessable load (kg)	Pollutant fee
Air emissions	Fluorides	315,236.00	$205,892.13
	Sulphur oxides	36,334,106.00	$385,526.67
	Nitrogen Oxides	24,488,170.00	$1,102,418.00
	Fine Particulates	106,373.00	$64,129.62
	Coarse Particulates	125,784.00	$10,919.81
	Benzo(a)pyrene	0.216	$30.21
	Lead	12.42	$658.92
	Mercury	25.19	$13,364.05
	Arsenic	15.53	$3,894.86
			$1,786,834.27
Water emissions	Total suspended solids - Enclosed	0.00	$0.00
	Selenium - Enclosed	0	$0.00
	Salt - Enclosed	0	$0.00
			$0.00
Total Fee	Total pollutant fee:		$1,786,834.27
	Administrative fee:		$51,471.00
	Load based fee:		$1,838,305.27

Due to the high thresholds and low pollutant load fees paid by NSW power generators, the current fees paid cannot incentivise pollution mitigation. We estimate about 4.4 tonnes of selenium is leaching annually from NSW coal ash waste dumps. If the paltry $72 a kilogram paid by Vales Point for just a very small part of its selenium pollution under the NSW LBL scheme were broadly applied, the selenium leachate generated by NSW power stations, would amount to about $320,000 a year in LBL fees. However, NSW power station operators pay a mere $30,000 a year for discharge of selenium. If the same LBL fee was levied on all the metals we estimate is leaching each year from NSW coal ash waste dumps, $14.5 million a year would be paid. However, $72 a kilogram is an order of magnitude below what power station operators should be paying for metal pollution to waterways, given its persistent and accumulating impact to the environment and human health and the availability of mitigation actions that are not being taken. Indeed, for all metal pollution to be priced according to its persistent and cumulative impacts, and at a price point that would actually encourage pollution mitigation, we estimate NSW power station operators should be paying a combined LBL fee of about $150 million a year for the metals leached from coal ash waste dumps.However, the NSW Government sold these power stations in 2013-2015 after building and then operating them and their ash dumps for 40 to 80 percent of their design lives. The NSW Government therefore retained 40 to 80 percent of the liability associated with the coal ash waste dumps when they retire. The current operators are only liable for the pollution caused by the additional coal ash waste dumped since purchase.

Delays in the leaching of certain metals, such as arsenic, boron, molybdenum, selenium, and vanadium (see Chapter 2), complicate this apportionment, which for such metals, may remain the responsibility of the NSW Government.

However, the additional 45Mt of coal ash waste that will accumulate if no additional reuse occurs in NSW would be expected to result in the leaching of an additional 2,000 tonnes of metals. If the LBL scheme levied the same fee levied against Vales Point for selenium for all metals leached from this additional ash dumped, we would expect $144 million would be paid by NSW power station operators for the water pollution and the impacts this causes between now and the plants' retirement.

As most of the metal contamination of groundwater and surface water is leaching from operating coal ash waste dumps, it would be simpler, and perhaps more effective, if the NSW Government listed coal ash itself as an assessable pollutant for coal-fired electricity generation, and applied a fee of at least $20 a tonne for power station operators who dump coal ash. This would result in an annual cost to coal power producers of about $76 million at current ash production and reuse rates, and would substantially reduce the volume of coal ash waste dumped, particularly if it were complemented by Government assistance for the market development of large volume sintered ash products.

Indeed, a 2003 report[58]for the State owned operator of NSW power stations, Pacific Power supported just such a fee, and suggested a levy of $18 to 20 per tonne of waste generated and placed in an ash dam, arguing that; "Such a fee would measurably (and possibly dramatically) increase the avoided cost of dumping coal ash. The result could be a very strong incentive for producers to reduce their rate of ash disposal by subsidising other uses".

The level at which this fee is set, however, should be determined with reference to per tonne reuse costs to avoid repeating the mistake of pricing the pollution fee below the cost of reusing ash and mitigating the water pollution it causes.

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[58] Pacific Power, 2003.

photo: Vales Point power station ash dam

NSW Treasury water pollution reports

The NSW Government sold its NSW power stations to private energy companies between 2013 and 2015. A conditions of the power stations sale included agreements as to the apportionment of liability for decommissioning and rehabilitating the sites. These agreements were made after a set of Environmental Site Assessments (ESA) identified significant contamination of both sites attributed to a number of operational sources including the very large coal ash waste dumps.

Environmental Resources Management Australia P/L (ERM) was engaged by NSW Treasury as Site Contamination Environmental Advisor for the Electricity Generating Assets. ERM produced eight Environmental Site Assessments (ESA) consisting of soil, sediment, surface water and groundwater and assessments of risks to human health and the environment. The ESAs were intended to determine baseline contamination levels. While ESAs were prepared for Mount Piper, Wallerawang, Eraring, Shoalhaven, Bayswater, Liddell, Vales Point, and the Colongra Power Stations.[59] We only have access to ESAs for the five operating power stations.

Despite serious deficiencies in the assessments, including inappropriate and inadequate background data, restricted and inconsistent metal analyses, as well as an eagerness to downplay the levels of water and soil contamination at these sites, they represent the most comprehensive sets of contamination data on NSW power stations.

The following sections are taken directly from ERM's State 2 Environmental Site Assessments.[60]We were allowed to copy these documents, marked "Commercial in Confidence" as part of documents called for by the Upper House inquiry into the Costs for remediation of sites containing coal ash repositories[61] under NSW Parliamentary Standing Order 52.

All the ESAs undertaken by ERM concluded that the concentrations of metals identified in soil, sediment, surface water and groundwater at the sites were considered likely to represent a potential risk to human health and/or the environment. Of significant interest is that all the power station sites were notable for some very low pH (some wells with such low pH were actually used as background groundwater conditions) which may indicate acidic ash, or acid sulfate soil conditions. Such conditions would be expected to substantially increase the metal leachate emanating from these sites.

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[59] NSW Treasury, 2014.

[60] ERM, 2014a.

[61] https://www.parliament.nsw.gov.au/committees/inquiries/Pages/inquiry-details.aspx?pk=2556

Central Hunter Valley

Liddell (AGL Macquarie)

The groundwater across the site ranged from acidic to slightly alkaline (pH3.4 to 8.9) and brackish to highly saline (114,000 µS/cm) with an average EC of 11,000 µS/cm).

Metals including **arsenic, cadmium, lead, nickel and selenium** were detected at concentrations in excess of the NHMRC drinking water values in groundwater samples collected from various monitoring wells located across the Site. **Lead, selenium and nickel** also exceeded the NHMRC recreational water values in a smaller subset of those locations. Metals including **boron, cadmium, copper, lead, manganese, mercury, nickel, selenium and zinc** were detected at concentrations in excess of the ecological screening values for freshwater environments in groundwater samples collected from various monitoring wells located across the site.

Liddell Power Station is located approximately 1km east of the New England Highway on the shore of Lake Liddell. Existing and former coal mines in the area include Drayton Coal Mine adjacent to the Liddell Ash Dam west of the site, Liddell Colliery approximately 2 km south east of the Liddell Power Station operational area, and the Ravensworth Rehabilitation Area approximately 7 km to the south of the Liddell Power Station operational area, where much of Bayswater's ash is dumped.

The site lies in the Hunter River Valley and its tributaries. Whilst the general slope in the area is towards the Hunter River in the south, the topography is characterised by undulating hills that leads to high variability in slope direction across the Site. The main power block is cut into the slope of the hill exposing natural bedrock (a conglomeratic sandstone). There is evidence to suggest the site level at the boundary with Lake Liddell has been raised over time through in-filling.

In the majority of instances, results from three background monitoring wells located near the north eastern boundary of the Bayswater site on the north eastern side of Lake Liddell, were utilised in establishing background conditions in the absence of suitable locations on the Liddell site. It is noted that low pH was observed in groundwater at one background well (pH 3.4) may have resulted in elevated concentrations of metals at this location and hence data from this well was utilised with caution when assessing results. [Table 16 sets out the background wells and concentrations used for both Bayswater and Liddell ESAs.]

Table 16: Background concentrations used by ERM

Well ID		**BY_MW24**	**BY_MW25**	**BY_MW26**
(pH)		**3.5**	**5.5**	**6.8**
Metal	**EQL**	**µg/L –ppb**		
Arsenic	**0.2**	16.4	1	1
Boron	**5**			
Cadmium	**0.05**	3.06	2.26	0.06
Chromium	**0.2**	10.1		0.3
Cobalt	**0.1**			
Copper	**0.5**	60.1	0.32	13.1
Lead	**0.1**	48.2	37.5	9.7
Manganese	**0.5**			
Mercury	**0.1**			
Nickel	**0.5**	853	195	7
Selenium	**0.2**			
Zinc	**1**	3250	142	32

Liddell Site contamination summary

- **Arsenic** concentrations exceeded health and ecological screening values. Two areas were above the same order of magnitude as background. The more significant exceedances may warrant reporting.

- **Boron** concentrations exceeded ecological value and average background concentration at the ash dam boundary. The remainder of the exceedances are related to wells which are likely to be representative of water with Lake Liddell where exceedances for boron were also noted.

- **Cadmium** concentrations exceeded ecological and drinking water screening values. The majority within an order of magnitude of background concentrations of (3 µg/L). Four areas including the ash dam exceeded background and may warrant reporting.

- [Cobalt not mentioned]

- **Copper** concentrations exceeded ecological screening values. None exceeded background (61µg/L).

- **Lead** concentrations exceeded health and ecological screening values. Several exceeded maximum background (40µg/L) including at the ash dam boundary and may warrant reporting

- **Manganese** concentrations exceeded ecological screening values and above reported background 1,130 µg/L (not reported in background wells).

- **Nickel** concentrations exceeded ecological and drinking water screening values, several above maximum background (195 µg/L) including the ash dam.

- **Selenium** concentrations exceeded ecological and health screening values and above reported background (not detected in background wells). The highest concentrations adjacent to the ash dam.

- **Zinc** concentrations exceeded ecological and health screening values. Several exceeded maximum background (145µg/L) including the ash dam.

Liddell Ash Dam Area of Environmental Concern (AEC LB)

Liddell Ash Dam, located approximately 4 km to the west across the New England Highway, and associated pipelines for carrying ash slurry and return water. It currently accepts about I million cubic metres (m^3) of fly and bottom ash from Liddell per year, along with sand filter backwash and treated water from the sewage treatment plant. Macquarie Generation personnel also indicated that fabric filter bags and bonded asbestos cement pipe sections have previously been disposed of in the ash dam.

There are several potential water discharge points from the ash dam area. These are the Ash Skimmer Dam, seepage through the ash dam wall itself, seepage through the base to groundwater and Tinkers Creek. Tinkers Creek is situated downstream from the ash dam area and acts as a potential contaminant pathway as it flows into Lake Liddell. A settling pond is located between the dam and Tinkers Creek to provide some control on the particulate discharge to the creek.

Based on the topography and available hydrological information, all areas at the site were considered to ultimately discharge to Lake Liddell [assessed in the Bayswater ESA]. It is also important to note that there are also direct and indirect discharges of storm, process and cooling waters to the Lake.

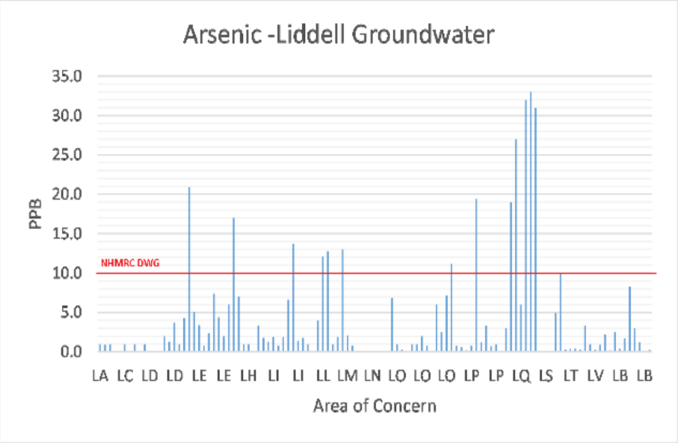
Groundwater data

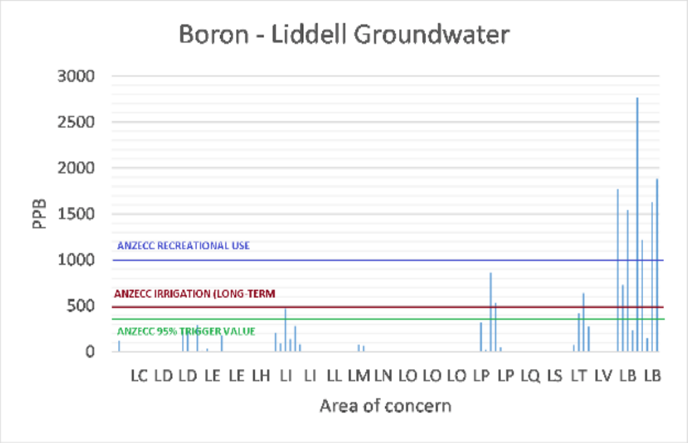
The Liddell site was divided into Areas of Environmental Concern (AEC).

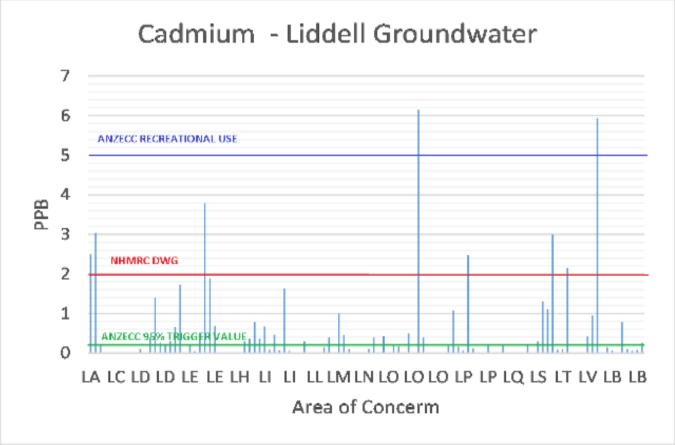
LA - Ammonia plant
LB- Ash Dam
LC - Bulk fuel storage - Light-vehicle refueling area
LD - Bulk fuel storage — Mobile refueling facility
LE - Bulk fuel storage — Fuel oil installation
LF - Bulk fuel storage — Waste oil AST (Transformer Road) and former transformer
LG - Bulk fuel storage — Turbine oil AST
LH - Bulk fuel storage - Waste oil ASTs (liquid alternative fuels) and emergency generator
LI - Current and former coal storage area
LJ - Dangerous goods, flammable Liquids and stares
LK - Former construction workshop and storage
LL - Hunter Valley gas turbines
LM - Machinery graveyard
LN - Oil and grit trap
LO -Former and current maintenance stares, workshops, foam generator and unofficial lay-down areas
LP -Fill material (Site leveling and Shoreline expansion)
LQ -Transformer operations/ transformer road
LR - TransGrid switchyard
LS - Landfills (waste disposal and borrow pit)
LT -Water uptake and pump station
LU -Water treatment plant
LV -Buffer land

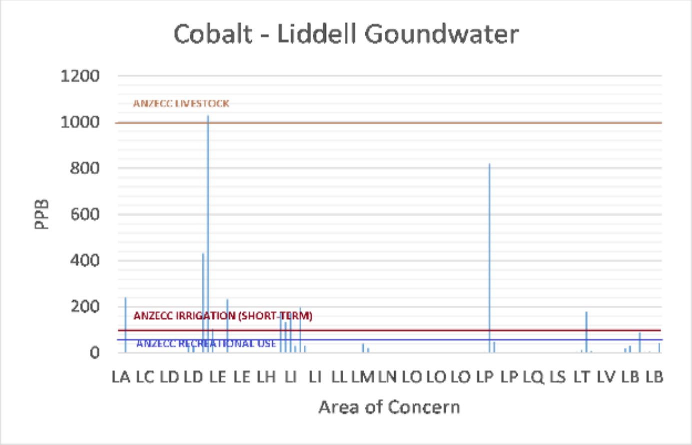
The groundwater results from these areas of concern are displayed below.

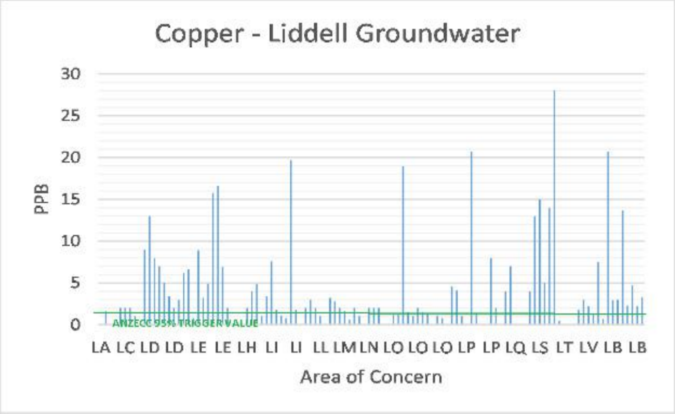
Charts 2: Liddell groundwater exceedances

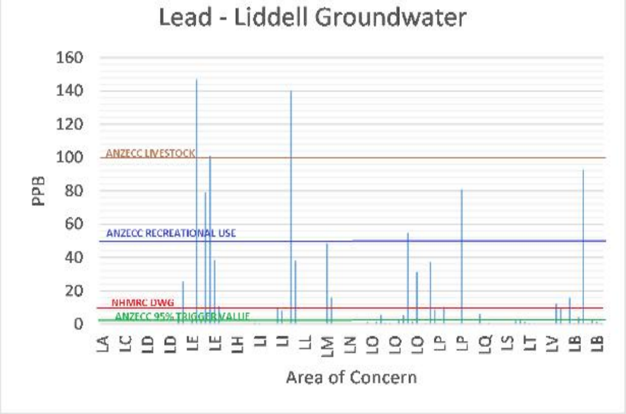


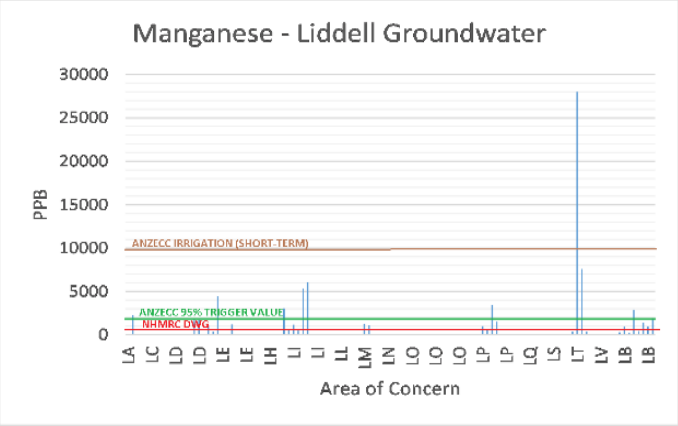


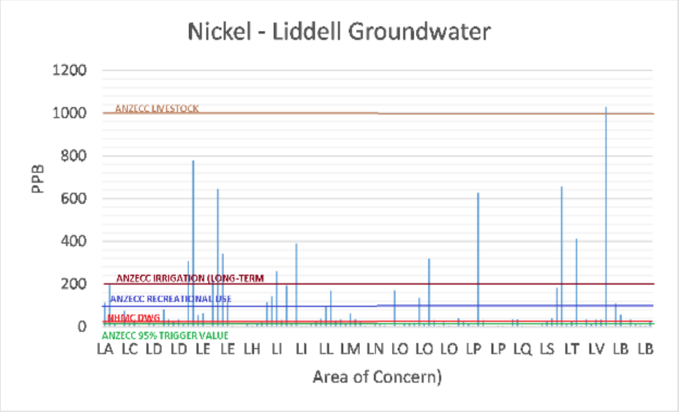


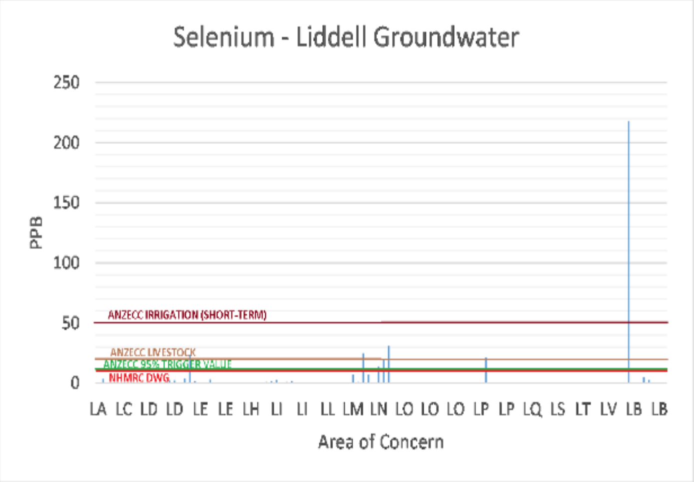


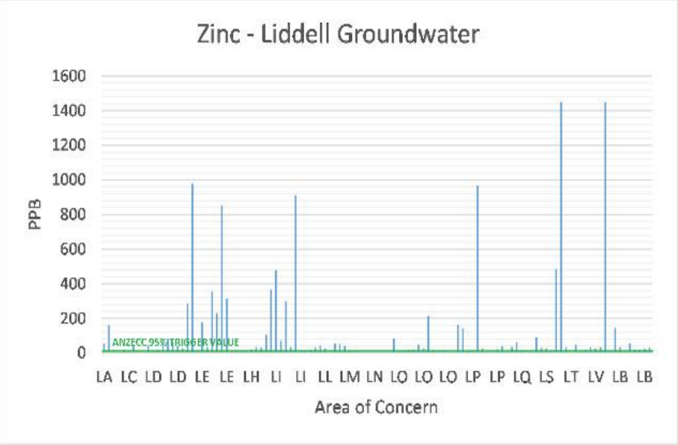












Bayswater (AGL Macquarie)

The Bayswater Power Station site lies within the Hunter River Valley and is approximately 8,300 hectares (ha), including the Ravensworth Rehabilitation Area, Lake Liddell and buffer lands. The power block lies at an elevation of approximately 200 m AHD, dropping to an elevation of approximately 170 m AHD at the northern edge of the coal storage facility. The site generally slopes towards the Hunter River with the Ravensworth Rehabilitation Area [fly ash dump] 5km to the north of the Hunter River.

Ash is dumped in two sites –

1. Pikes Gully Ash Dam, at an elevation of approximately 170 m AHD, with the down gradient Pikes Gully valley sloping towards the east, approximately 200m to the east and associated pipelines for ash slurry and return water,

2. Ravensworth Rehabilitation Area (fly ash disposal), including the former Ravensworth No.2 and Ravensworth South final voids, located approximately 8 km east south-east of the power station and associated ash delivery and return water system. The Ravensworth Rehabilitation Area lies at an elevation of approximately 120 m AHD, with the local topography highly disturbed by former mining operations.

Several local waterways flow from the site:

- Tinkers Creek, which runs along the western boundary of the Bayswater Power Station and flows into Lake Liddell;

- Bayswater Creek and associated tributaries flow into Liddell Ash Dam and into the western arm of Lake Liddell.

- Bayswater Creek then flows south from Lake Liddell, runs along the western boundary of the Ravensworth Rehabilitation Area, and ultimately flows to the Hunter River;

- Foy Creek, which runs along the eastern boundary of the Ravensworth Rehabilitation Area and ultimately joins with the Hunter River,

- Saltwater Creek and Wisemans Creek, flowing to the south into the Plashett Dam;

- the Plashett Dam (also known as Plashett Reservoir), located approximately 6 km to the south-west of the Bayswater Power Station;

- the Freshwater Dam, located adjacent and directly to the west of the Bayswater Power Station;

- the Bayswater Cooling Water Makeup Dam, located directly to the south of the Bayswater Power Station;

- the Pikes Gully Ash Dam; located to the east of the Bayswater Power Station;
- the Brine Concentrator Holding Pond, located approximately 740 m to the south-east of Bayswater Power Station;
- Brine Concentrator Decant Basin, located approximately 1.3 km to the south-west of the Bayswater Power Station; and
- Void 4 at the Ravensworth Rehabilitation Area, which acts as a water management storage system.

Exceedances of Human Health (Drinking Water) or Ecological Screening Value

- **Arsenic -**Drinking water value exceeded. All except those in AEC BF [Coal unloaders, rail infrastructure and coal transfer lines] are however in same order of magnitude as background locations [See Table 16, arsenic background 16.4 µg/L] and exceedances were 465% of guideline of BF [Coal unloaders, rail infrastructure and coal transfer lines] may be required further assessment.
- **Boron -** Ecological value and average background concentration reported in Kellett et al (1987) (170 µg/L) were both exceeded in some locations. It should be noted that the exceedances were in the vicinity of the **Pikes Gully Ash Dam** which is regulated under the Site EPL and is currently subject to a PRP in relation to water management.
- **Cadmium -** Both ecological and drinking water were exceeded. The majority of exceedances were of the same order of magnitude [as background] with the exception of BB_MW04 [Brine concentrator decant basin] and BX_MW03 [switchyard] which may warrant reporting.
- **Chromium -** One isolated exceedance of drinking water screening value was identified at BP_MW04 [Mobile plant workshop and refuelling] and this exceedance was only marginal. Confirmatory sampling could be undertaken to confirm the result and assess the likelihood that the detected concentration will foreseeably remain above the human health (drinking water) screening value. It is also noted that the drinking water screening value is designed to be protective of risks associated with chromium VI, rather than the less toxic chromium III. As such, any confirmatory sampling should include chromium an evaluation of chromium speciation.
- **Copper -** Ecological value exceeded however background concentrations of 0.0131 - 0.0601 mg/L [131 - 601 µg/L] were identified in BY_MW26 and BY_MW2d (respectively)[Buffer lands]. Some results exceed these values and hence may warrant reporting (particularly within AECs BG [Contaminated water treatment plant] and BV [Power block]).
- **Lead** –Both ecological and drinking water values were exceeded however background concentrations of 375 µg/L were Identified in BY_MW26 and BY_MW24 (respectively) [Buffer lands] several results exceeded these values and hence may warrant reporting.
- **Manganese -**Ecological value exceeded, and average background concentration (1,130 µg/L) are lower than the ecological value, hence the noted exceedances may warrant reporting.
- **Mercury -**Two minor exceedances of the ecological value were identified within AEC BV [Power block]. Both results only marginally exceed the guideline and are close to the LOR, therefore suggest confirmatory samples to confirm the result and assess the likelihood that the detected concentrations will foreseeably remain above the ecological screening value.
- **Nickel -**Both ecological and drinking water values were exceeded however background concentration of 195 µg/L was identified in BY_MW25 several results

exceeded this value and hence may warrant reporting (particularly those in AECs BB [Brine concentrator decant basin],
BG [Contaminated water treatment plant], BV [Power Block], and BX [TansGrid switchyard]).

- **Selenium -**Both ecological and drinking water values exceeded, it appears that background concentrations are lower than the screening values, hence the noted exceedances may warrant reporting (particularly within AEC BB [Brine concentrator decant basin]). It should be noted that many exceedances appear to be associated with **Pikes Gully Ash Dam** which is regulated under the Site EPL and is currently subject to a PRP in relation to water management.

- **Zinc -**Ecological and drinking water values were exceeded however background concentrations of 142 µg/L were identified in BY_MW25 (which aligns closely with the literature background value of 150 µg/L). Several results exceed these values and hence may warrant reporting. It should be noted that many exceedances appear to be associated with **Pikes Gully Ash Dam** which is regulated under the Site ERL and is currently subject to a PRP in relation to water management.

Pikes Gully Ash Dam

The Pikes Gully Ash Dam is located approximately 200 m (at its nearest point) to the east/south-east of the Bayswater Power Station and covers an area of approximately 150 ha. The ash dam receives runoff from the sluiceways draining Bayswater Power Station. In addition, sections of fly ash slurry pipes and return water pipes with asbestos containing material (ACM) are reportedly buried in the ash within the dam once a section is decommissioned. The fly ash slurry pipeline and water return water pipeline (with ACM) run along the northern side of the ash dam. The EPL (779) licenses several materials for disposal on site, but does not specify disposal Locations. Macquarie Generation management indicated that the following waste streams may have been disposed of in the ash dam:

- acid solutions or acids in solid form;
- asbestos;
- fly ash and bottom ash;
- waste mineral oils unfit for their original use;
- waste oil / water hydrocarbon / water mixtures or emulsions;
- boiler cleaning residues;
- spent fly ash filter bags; and
- water treatment residues.

As outlined in the Preliminary ESA (ERM, 2013), seepage has been noted at the toe of the dam wall in Pikes Gully. In addition, a report by HLA (HLA, 2004) makes reference to the presence of saline groundwater seepage at and below a small dam Located approximately 250 m from south of the Pikes Gully Ash Dam.

Shallow conductive zones consistent with groundwater with elevated salinity that may have presented preferential pathways of saline groundwater extending towards the south of the ash dam. During ERM's site visit for the Preliminary ESA conducted in August 2013, seepage was also observed on the saddle dam wall on the northern section of the dam. During the Preliminary ESA conducted in August 2013, seepage was also observed on the saddle dam wall on the northern section of the dam.

Seepage from the ash repository has the potential to be saline and contain arsenic and heavy metals (specifically barium, beryllium, boron, cadmium, chromium, cobalt, lead, manganese, mercury, molybdenum, nickel, thallium, selenium and/ or zinc). Parameters historically assessed during groundwater monitoring conducted at the ash dam included EC, pH, hardness, arsenic and metals (including aluminum, copper, iron, lead, manganese, nickel, and selenium) in up to six monitoring wells located downgradient of the ash dam wall.

Available results indicate that analytes exceeding one or more of the guidance criteria (for irrigation and livestock water quality – ANZECC (2000)) for one or more sampling events include nickel, manganese and iron (Macquarie Generation, 2010).

Eleven groundwater monitoring wells were installed around the perimeter of the ash dam. In addition, three existing monitoring wells were gauged and sampled. **Boron, cadmium, copper, lead, manganese, nickel, and zinc** were detected at concentrations in excess of the adopted ecological and/or human health (drinking water) screening values in groundwater samples collected. **Lead and nickel** were reported above the recreational screening values within two monitoring wells.

Groundwater collected from all monitoring wells at the ash dam boundary reported metals concentrations greater than the adopted ecological screening values. The majority of groundwater samples from the Pikes Gully Ash Dam reported **boron, cadmium, copper, lead, manganese, nickel, and zinc** at concentrations in excess of the adopted ecological and/or human health (drinking water) screening values. **Lead and nickel** were reported above the recreational screening values within two monitoring wells.

Given the volume and nature of the ash and water stored within the Ash Dam, it is considered that impacts observed in the other AECs within this catchment would be minor contributors to the overall potential impacts arising from the Ash Dam.

Ravensworth Rehabilitation Site

The Ravensworth Rehabilitation Site is located approximately 8 km east/south-east of the Bayswater Power Station and is currently used for the disposal of fly ash. The Area of Environmental Concern (AEC) is located in the former Ravensworth No. 2 Mine (the location of Void 1 to 4) and a section of the Ravensworth South Mine (the location of Void 5). Both these former mines operated as open cut coal mines.

The surface geology has been extensively disturbed by mining. Much of the former opencast mine workings within this AEC have been backfilled with mine spoil that includes coal from uneconomic seams, and the remnant coal is subject to spontaneous combustion. Part of the Ravensworth No.2 Mine has been backfilled with fly ash (Voids 1 to 3) and coal preparation plant rejects (eastern ramp of Void 4) (Aurecon, 2012). ERM understands that Void 5 is currently being prepared for future fly ash disposal. **The base of the voids is expected to be in contact with regional groundwater flow. Seepage from the ash filled voids has the potential to be saline and contain heavy metals.**

The available groundwater sampling reports state that samples have not been obtained from the Ravensworth Rehabilitation Site during sampling events covering the monitoring period from 2006 to 2010 as underground heat generated from spontaneous combustion did not permit samples to be taken from the available monitoring wells (Macquarie Generation, 2010). Six wells were reportedly installed in this area, but Macquarie Generation has advised that none of the wells are currently useable due to subsidence, being covered by fill material, or being affected by high temperatures from spontaneous combustion.

A comparison of data collected prior to the ash disposal (in Void 4) commencing indicates that **boron and molybdenum** concentrations have increased by approximately a factor of six and an order of magnitude respectively between 1992/1995 and 2012. Monitoring wells installed within the Ravensworth Rehabilitation Area detected metals including **copper, nickel and zinc** exceeding the ecological and/or human health (drinking water) based screening values. Metals including **boron, cadmium, copper, lead, manganese, nickel, selenium and zinc** were detected at concentrations in excess of the adopted ecological screening values in groundwater samples collected from wells within this catchment. **Nickel and cadmium** were detected at concentrations exceeding the adopted human health (recreational) screening, primarily the area surrounding the Brine Concentrator Decant Basin (with one additional exceedance for nickel identified immediately adjacent to Plashett Reservoir.

While the report with the Void 4 monitoring data did not compare the results against guidance criteria, a comparison of data collected prior to the ash disposal commencing indicates that **boron and molybdenum** concentrations have increased by approximately a factor of six and an order of magnitude respectively between 1992/1995 and 2012 (Macquarie Generation, 2012).

The Preliminary ESA (ERM, 2013) concluded that given the lack of groundwater characterisation data coupled with the potential for impact considering the nature of the mine spoils and the ash disposed of at the Ravensworth Rehabilitation Site, further investigation was warranted to assess potential soil and groundwater impacts. Of the trace metals, **arsenic, boron and manganese**, were above the laboratory LOR but below the adopted human health and ecological screening levels in all monitoring wells sampled.

Trace metals that exceeded the adopted screening criteria include **copper** exceeding the ecological based screening criteria in one well, **nickel** exceeding both the drinking water guideline and ecological based screening criteria in two wells, and **zinc** exceeding the ecological based screening criteria in two wells. Note that the concentrations of analytes that have exceeded the adopted screening criteria are lower in downgradient monitoring wells compared to the upgradient monitoring well. The trace metal exceedances of adopted screening criteria are therefore not attributed to the on-site activities at the AEC [Area of Environmental Concern].

Monitoring wells installed within the Ravensworth Rehabilitation Area detected metals including **copper, nickel and zinc** exceeding the ecological and/or human health (drinking water) based screening values.

Plashett Reservoir

Plashett Reservoir groundwater samples reported **boron, cadmium, copper, lead, manganese, nickel selenium and zinc** were detected at concentrations in excess of the adopted ecological screening values. **Nickel and cadmium** were detected at concentrations exceeding the adopted human health (recreational) screening values primarily the area surrounding the Brine Concentrator

Surrounding waterways and Lake Liddell

Lake Liddell, a water storage reservoir for the Power Stations has a surface area of around 1100 ha and is up to 32m deep, supplies cooling water to Liddell Power Station and make-up water for the Bayswater Cooling Water Makeup Dam. It also accepts a range of treated discharges. The Lake is constructed in a natural valley at the confluence of Bayswater, Tinkers and Maidswater Creeks. The lake is dammed on the eastern side and is equipped with a spillway leading to a large holding pond. Water is periodically discharged from Lake Liddell to manage salinity and level. The discharge point is at the dam wall, and discharges flow via Bayswater Creek to the Hunter River, approximately 13 km downstream. Discharges of salt are managed under the Hunter River Salinity Trading Scheme.

A total of 49 sediment and surface water samples were collected to assess potential impacts of discharges from the Liddell Power Station on Lake Liddell.

In surrounding waterways and Lake Liddell, **arsenic, cadmium, chromium, lead, nickel, selenium and zinc** were detected at concentrations in excess of the NHMRC (2011) drinking water values in groundwater samples. **Arsenic, cadmium, lead and nickel** also exceeded the NHMRC (2008) recreational water values in a smaller subset of those locations.

Metals including **boron, cadmium, copper, Lead, manganese, mercury, nickel, selenium and zinc** were detected at concentrations in excess of the ecological screening levels for freshwater environments in groundwater samples collected from various monitoring wells located across the site. **Boron and selenium** are the primary metals of ecological concern in relation to surface water within Lake Liddell.

- **Arsenic** concentrations exceeded the ISQG-Low [Interim Sediment Quality Guidelines] at all but five sediment sampling locations. Arsenic concentration at the reference location was the highest recorded in the lake. The exceedances of the arsenic ISQG-Low are therefore not considered to be a result of site activities.

- **Boron** and **copper** exceeded the ecological screening value in the majority of surface water samples analysed from within Lake Liddell and its tributaries. Boron and copper concentrations in surface water exceeded the adopted ANZECC (2000) screening values for the protection of 95% of freshwater species at most of the locations sampled. The boron concentrations in the unnamed creek to the north of the Pikes Gully Ash Dam spillway were approximately threefold greater than those measured in Lake Liddell. The Pikes Gully Ash Dam is considered a potential source of boron and nickel to the unnamed creek.

- **Copper** exceedances were also commonly measured. There were two exceedances of the copper ISQG-High [Interim Sediment Quality Guidelines], both in the bay north of the Liddell Power Station. The highest copper concentrations were detected in the bay to the north of the Liddell Power Station, potentially resulting from inputs from Tinkers Creek. The highest copper concentrations were measured in the bay north of the Liddell Power Station; however, ISQG-Low exceedances were noted in sediments throughout the AEC. Tinkers Creek may contribute copper to the bay north of the Power Station, however identified copper exceedances in surface water are considered likely to be largely attributable to background conditions.

- One exceedance of the **mercury** ISQG-High, at the sampling location closest to the Power Station. Mercury exceeded the ISQG-High at one location, where coal fines were noted.

- **Selenium** exceeded the ecological screening criteria in surface water samples collected from the unnamed creek to the north of the Pikes Gully Ash Dam spillway and in eight samples from within Lake Liddell. The measured selenium concentrations ranged from I to 45.2 mg/kg, with an average concentration of 6.2 mg/kg. The highest selenium concentrations were measured in samples collected from the bay north of the Liddell Power Station. Water from Tinkers Creek drains into this part of Lake Liddell.

- **Nickel** concentrations exceeded the ISQG-Low [Interim Sediment Quality Guideline] at 14 locations. Nickel exceeded the ecological screening value in the unnamed creek to the north of the Pikes Gully Ash Dam spillway. Nickel exceeded the ISQG-Low, but at a smaller number of sampling locations than arsenic or copper. Nickel exceedances were generally noted in clusters, but there was no overall spatial trend in the distribution of these clusters. The highest nickel exceedances were concentrated in the unnamed creek to the north of the Pikes Gully Ash Dam spillway. Nickel exceeded the ecological screening value in surface water samples collected from the unnamed creek to the north of the Pikes Gully Ash Dam spillway but not in any samples within the lake itself

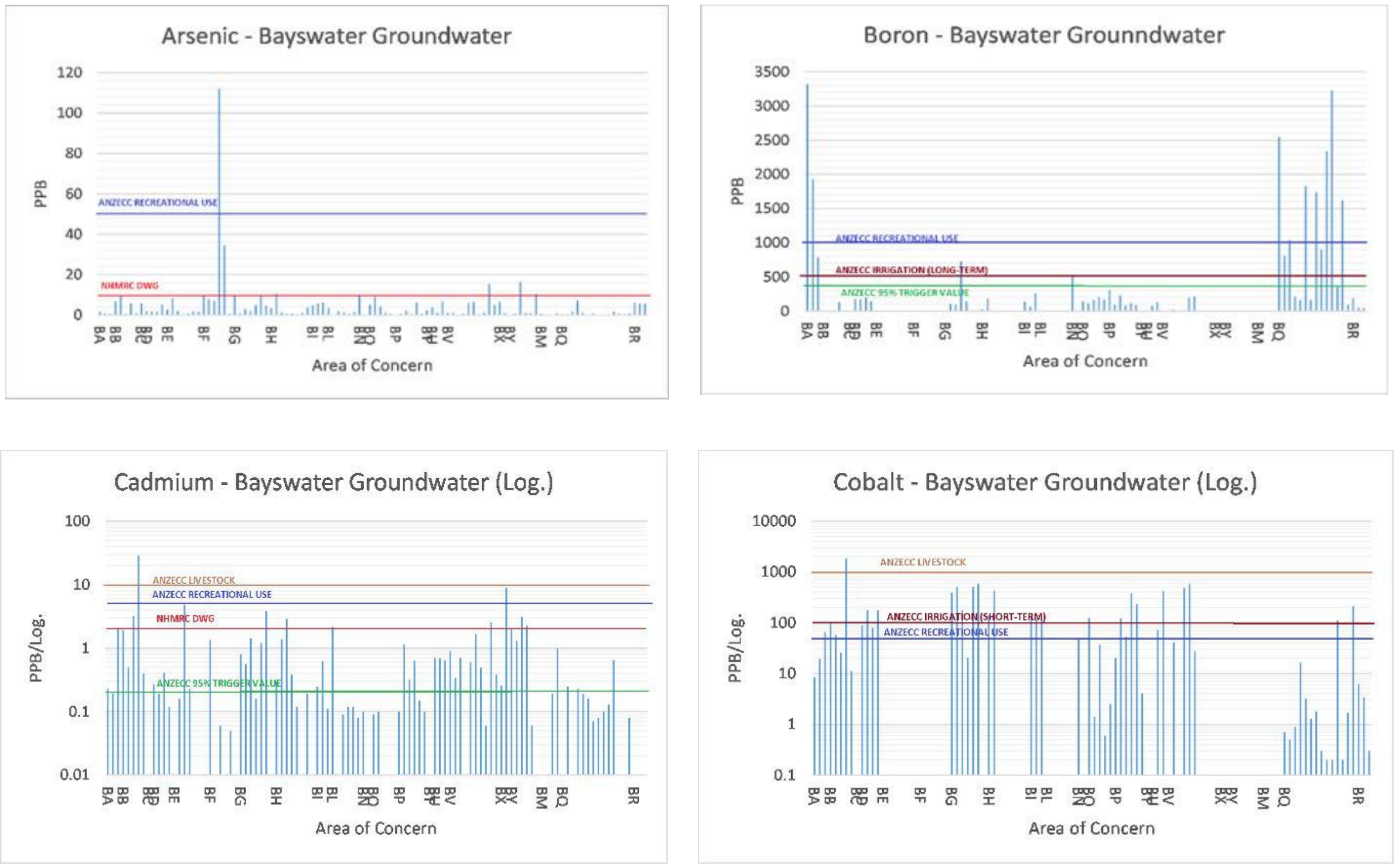
- **Zinc** exceeded the adopted ecological screening criteria in 19 of the surface water samples collected with the highest concentrations detected in samples collected from Tinkers Creek. The zinc exceedances identified were generally within two times the ANZFCC (2000) trigger value and did not show a clear spatial trend, and may be a result of natural variability in zinc concentrations, particularly given that the observed results are also within background ranges identified within Kellet et al (1987)

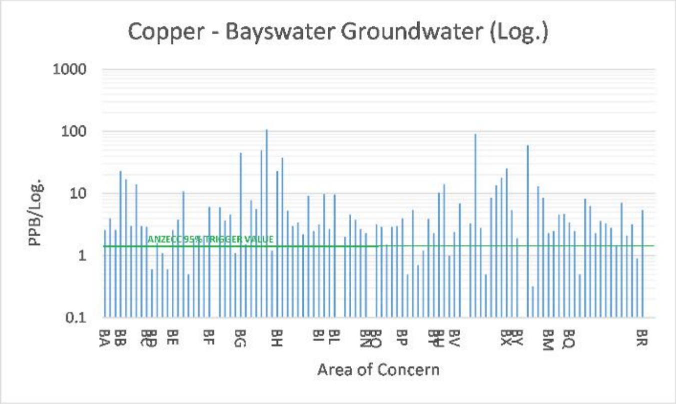
Groundwater data

BA - Brine concentrator holding pond
BB - Brine concentrator decant basin
BC - Fuel oil installation
BD - Vehicle refueling depot
BE - Coal storage area
BF - Coal unloaders, rail infrastructure and coal transfer lines
BG - Contaminated water treatment plant
BH - Cooling water treatment plants
BI - Demineraliser plant
BJ - Former contractor staging area
BK - Former large items assembly area
BL - Generator transformer areas
BM - Landfill
BN - Lime softening plant
BO - Lime softening plant sludge lagoons
BP - Mobile plant workshop and refuelling
BQ - Pikes Gully Ash Dam
BR - Ravensworth Rehabilitation Area
BS - Low pressure pumping station
BT - High pressure pumping station
BU - Main store — dangerous goods storage area
BV – Power Block
BW – **Sediments in Lake Liddell and surrounding waterways**
BX – TansGrid switchyard
BY – Buffer lands

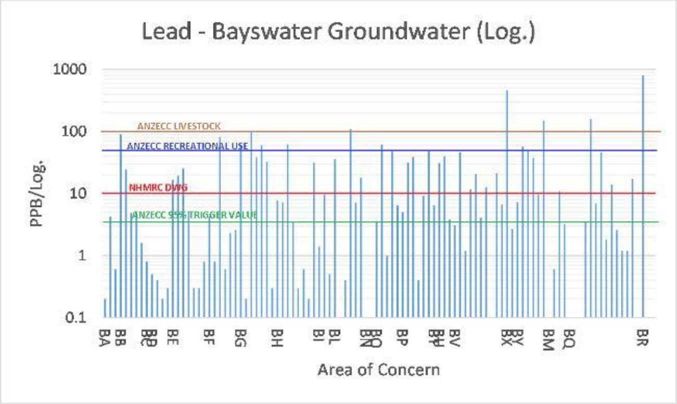
The groundwater results from these areas of concern are displayed below.

Charts 3: Bayswater groundwater exceedances

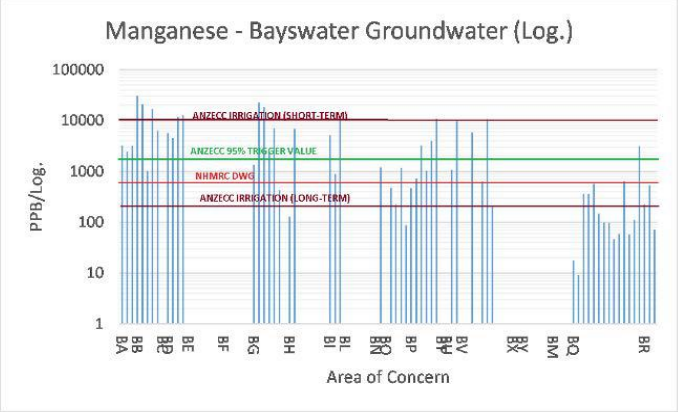




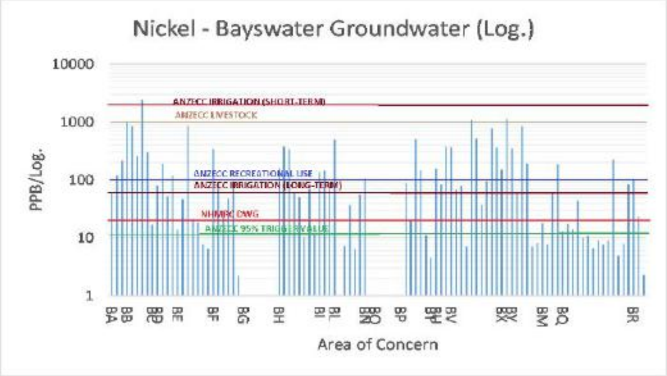
Copper - Bayswater Groundwater (Log.)



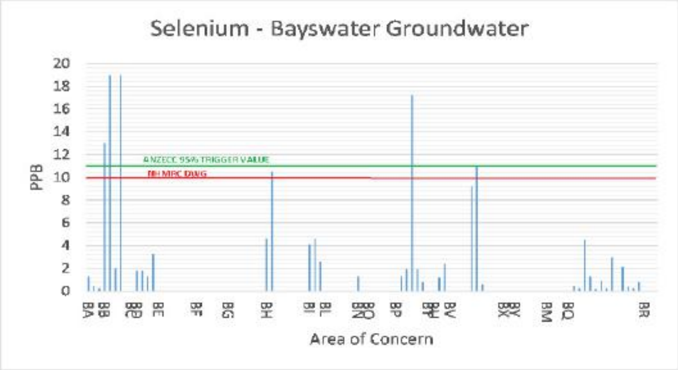
Lead - Bayswater Groundwater (Log.)



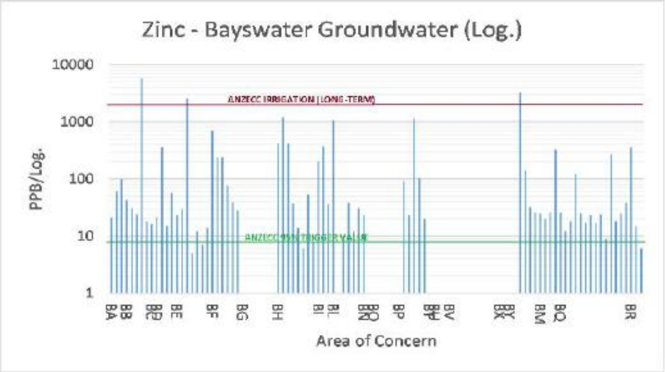
Manganese - Bayswater Groundwater (Log.)



Nickel - Bayswater Groundwater (Log.)



Selenium - Bayswater Groundwater



Zinc - Bayswater Groundwater (Log.)

Lake Macquarie

Vales Point (Sunset International)

The Site is located on the shore of Lake Macquarie, between Wyee Bay and Chain Valley Bay. The Ash Dam has been constructed within a natural valley, from the ridge to the south to the north east, towards Mannering Bay [Lake Macquarie], with a slight incline towards the northwest, where it discharges into Wyee Creek [AND Lake Macquarie].

Prior to Munmorah Power Station ceasing operations, the Vales Point Ash Dam was also used for the storage of fly ash produced at Munmorah Power Station.

Most of the ash produced by Vales Point is transported by wet sluicing via pipelines to the Ash Dam. The northern portion of the Ash Dam (Ponds 1, 2 and 3) have been filled to capacity and rehabilitated. The central areas of the Ash Dam, known as Pond 4, 5A and 5B, are currently active and receiving wet sluice from the Power Station. Ash settles in these upper reaches of the dam and the water is pumped back to the Power Station via ash return water pumps.

Various other solid and liquid wastes are also permitted to be directed to the Ash Dam under the EPL including, ash dam water treatment plant residues, treatment plant discharges, coal mine dewatering discharge etc. Asbestos Containing Material (ACM) was also historically disposed of within the dam.

Intrusive soil and groundwater investigations within the Ash Dam were not considered necessary, as it was already acknowledged that the area was impacted with waste materials (primarily ash). The investigations focused on identifying what may have migrated from the ash dam. Nineteen groundwater monitoring wells were installed around the entire boundary of the Ash Dam, with the exception of an approximately 2 km stretch along the south western side of the Ash Dam where high pressure Jemena gas pipeline prevented their installation.

Groundwater at the ash dam boundary ranged from fresh to highly saline and highly acidic in places (pH of 3.6 to 6.55). Five monitoring wells recorded pH values of less than 4, which ERM suggest as indicative of Acid Sulfate Soil conditions. One of these wells with pH less than 4 is near the Ash Dam toe drain, on the north western boundary of the ash dam, and one near the discharge point for the Ash Dam into Wyee Creek.

The surface water samples collected from within the Ash Dam toe drain reported concentrations of manganese greater than the adopted human health (drinking water) screening values and **cobalt and zi**nc concentrations greater than the adopted ecological screening levels. **Arsenic, nickel and selenium** were in excess of the adopted screening values in groundwater monitoring wells located immediately upgradient of the ash dam toe drain but not within the toe drain. Concentrations of **copper and zinc** in excess of the ecological screening levels were identified in groundwater collected from the ash dam boundary consistent with those measured in monitoring wells up-gradient of the landfills. Groundwater **copper and zinc** concentrations at the ash dam boundary was greater than the adopted ecological screening values.

The concentrations of metals in groundwater equalling or exceeding the maximum background concentrations by a factor of two were considered as potentially indicative of concentrations above background values.

It is noted that a limited number of monitoring wells are available as background monitoring wells and that only one round of data is available for comparison of reported concentrations from these monitoring wells to the rest of the monitoring network established during the Stage 2 ESA. From 117 monitoring wells installed at the Site, three wells identified as up-hydraulic gradient of any identified on-site sources were used as background concentrations. However, two key controls on metal and metalloid solubility are low pH and low oxidation/Reduction Potential (ORP), both increase solubility of metals. The pH and ORP of one background well was as low as 3.8 and -82 m V. Nevertheless, these monitoring wells, at the boundary of the ash dam, were considered as general background data points for the Site.

Arsenic, nickel and selenium were in excess of the adopted screening values in groundwater monitoring wells located immediately upgradient of the ash dam toe drain but not within the toe drain. Concentrations of **copper and zinc** in excess of the ecological screening levels were identified in groundwater collected from the ash dam boundary consistent with those measured in monitoring wells up-gradient of the landfills. Groundwater **copper and zinc** concentrations at the ash dam boundary was greater than the adopted ecological screening values.

- **Arsenic** (max 184 µg/L – mean 5.5 µg/L). Samples from 12 wells equalled or exceeded 10 µg/L (drinking water criteria). Samples with exceedances of the adopted screening values were taken from a number of monitoring wells **downgradient of the ash dam**, and **not considered attributable to background concentrations**.

- **Cobalt** (0.9 µg/L to 169 µg/L – mean 19 ug/) Samples from 58 of 64 monitoring wells exceeding the lowest adopted screening values of 1 µg/L (marine adopted ecological screening values). Two monitoring wells downgradient of the ash dam recorded concentrations of cobalt with a factor of two above the maximum background downgradient of the ash dam and therefore **highly localised to either the coal storage area or the ash dam**.

- **Copper** (4.5 µg/L to 596 µg/L - mean 13 µg/L. Samples from 91 out of 117 monitoring wells equaling or exceeding the lowest adopted screening values of 1.3 pg/L (marine adopted ecological screening values). Eight wells exceeded the maximum reported background concentration by a factor two at the vehicle refuelling depot, the fuel oil installation area **and downgradient of the Ash Dam**.

- **Lead (max** 231 µg/L **-** mean 12 µg/L. Samples from 35 wells equalling or exceeding the lowest adopted screening values of 4.4 ug/ L (marine adopted ecological screening values), in the **vehicle refuelling area, mobile plant maintenance area, Wyee rail coal unloader and at the ash dam** boundary. Eight wells exceeded maximum background concentrations (20µg/L) in the mobile plant maintenance area, the switchyard and **downgradient of the ash dam**.

- **Manganese** (max 17,300 µg/L - mean 1,287 µg/L. Samples from 23 out of 64 wells exceeding the adopted screening values of 500 µg/L (drinking water criteria). Samples with exceedances of the adopted screening values were taken from monitoring located in the Wyee rail coal unloader area, the mobile plant maintenance area, the coal storage area and ash dam. Three wells exceeded maximum background (2290 µg/L) by a factor of two at the mobile plant maintenance area, the coal storage area, and **downgradient of the ash dam**.

- **Nickel** (Max 133 µg/L – mean 15 ug/L). Samples from 32 wells reported concentrations exceeding the lowest adopted screening value of 20 µg/L (drinking water criteria) at the ash dam boundary. Three wells exceeded maximum background concentration (32µg/L) **downgradient of the ash dam.**

- **Selenium** (max 276 µg/L – mean 16 µg/L). Samples from 9 of 63 wells reported concentrations exceeding the screening value of 10 ug/ L (drinking water criteria). Eight wells exceeded the adopted screening values for selenium at the ash dam boundary. Selenium concentrations at eight wells on the **downgradient of the ash dam** exceeded the maximum background concentration (10µg/L) by a factor of two.

- **Zinc** (max 1200 µg/L **-** 63 µg/L). The majority of monitoring wells (108/117) exceeded the adopted screening values of 15 µg/L (marine adopted ecological screening values). One monitoring well, exceeded the maximum background concentration of 116 µg/L **downgradient of the ash dam**.

As historical and current underground coal mining works occur extensively in the area surrounding and underlying the majority of the Site (including the ash dam), the mine works and related subsidence effects (which could enlarge fracture surfaces within bedrock) may further have contributed to elevated metal(loid) concentrations observed in groundwater. **The long term disposal of waste ash materials, which are known sources of metal contaminants, within the Ash Dam, may also have contributed to metal impacts in the underlying groundwater.**

Offsite Sediments and Surface Waters

Cadmium was identified in individual samples collected from within Wyee Creek, the control area and Wyee Bay at concentrations in excess of the ISQG-low value. Two sediment samples collected from within Wyee Bay were in excess of the ISQG-low values.

Exceedances of the adopted **selenium** ecological screening level were identified in numerous sediment samples collected from within the lower reaches of Wyee Creek and within Mannering Bay. The maximum selenium concentration reported in a sediment sample collected from Wyee Creek was 26 mg/kg, with the selenium concentrations measured in sediment samples collected from within Wyee Creek generally increasing along the Creek towards Mannering Bay.

Relatively consistent concentrations of selenium were recorded throughout Mannering Bay, at up to 8 mg/kg.

Copper and cobalt concentrations marginally in excess of the adopted ecological screening levels were identified in a number of surface water samples.

Zinc concentrations exceeded the adopted ecological screening values in approximately 60% of the surface water samples. The samples collected from the upper reaches of Wyee Creek generally demonstrated the highest zinc concentrations, which may reflect a contribution from the Ash Dam.

Acid sulfate soils

The ash dam was built in the course of Mannering Creek and the ash dam deposits are therefore expected to be largely underlain by quaternary alluvial sediments. Disturbance of the sediments during construction of the ash dam and/or infiltration of ash dam water (that would be expected to be largely oxygenated) into the underlying sediments, may have resulted in the creation of acid sulfate soil conditions with naturally occurring sediments contributing to the elevated metal concentrations observed in groundwater. pH values of less than 4 were recorded in monitoring wells five well at the ash dam boundary and near the Ash Dam toe drain, the north western boundary of the Ash Dam, and near the discharge point for the Ash Dam into Wyee Creek, and immediately to the east of the ash dam.

However, acidic groundwater conditions (with pH levels below 4.5) were found in a large number of groundwater monitoring wells across the Site, including a number of monitoring wells installed in the Munmorah Conglomerate and located away from the alluvial sediments (including background monitoring well VU MW17 with a pH of 3.8). Relatively acidic conditions are therefore not restricted to areas where disturbed alluvial sediments may be located, as a result of the construction of the ash dam.

Conversely, based on the approach to assessing background conditions as discussed above, the arsenic exceedances and the majority of selenium exceedances of the assessment criteria cannot be attributed to background conditions. Where concentrations of metal(loids) in groundwater were measured above background values, impact generally appears to be localised in distinct areas of the site with the main potential source areas being the vehicle refuelling depot, the coal storage area and the ash dam.

However, the majority of samples with concentrations reported above the background values were taken from monitoring wells located downgradient of the ash dam. The ash dam appears to present a primary source of arsenic and selenium to groundwater. The data further indicates that the ash dam may act as a secondary source of cobalt, copper, lead, manganese, nickel, and zinc, contributing to metal concentrations that are generally elevated in background conditions.

If disturbed alluvial sediments underlie the ash dam, these sediments may be contributing to elevated metal(loid) concentrations with potential sulfide oxidation In sediments resulting in acid sulfate conditions. As historical and current underground coal mining works occur extensively in the area surrounding and underlying the majority of the Site (including the ash dam), the mine works and related subsidence effects (which could enlarge fracture surfaces within bedrock) may further have contributed to elevated metal(loid) concentrations observed in groundwater. **The long term disposal of waste ash materials, which are known sources of metal contaminants, within the Ash Dam, may also have contributed to metal impacts in the underlying groundwater.**

The long term storage of coal materials within the Coal Storage Area may also have contributed to the observed metal impacts in groundwater in this area.

Metals in Groundwater

Exceedances of the adopted human health (drinking water and recreational) screening levels were reported in groundwater for **arsenic, lead, nickel manganese and seleni**um and exceedances of the adopted ecological screening levels were also reported for **cobalt, copper, lead, nickel, selenium and zinc.**

Where concentrations above background values were found in distinct areas of the site with the main potential source areas being the Vehicle Refuelling Depot (VH), the Coal Storage Area (VJ) and the Ash Dam (VO).

The majority of samples with concentrations reported above the background values were taken from monitoring wells located downgradient of the Ash Dam which appears to be a primary source of arsenic and selenium to groundwater and a secondary source of cobalt, copper, lead, manganese, nickel and zinc.

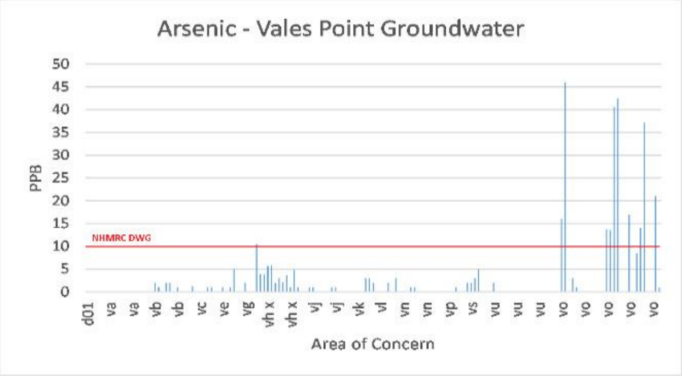
Rural residential and residential communities are located immediately to the north, west and south of the Ash Dam. The extraction of groundwater for potable, domestic, stock watering or commercial purposes in these areas may therefore potentially occur in the future. Risk to human health may be associated with the extraction of groundwater for use in the vicinity of the Ash Dam, particularly if that water were used for domestic purposes, although given the general elevated background metal concentrations measured across the Site, the groundwater beneath the adjacent properties is also likely to be generally unsuitable for potable use.

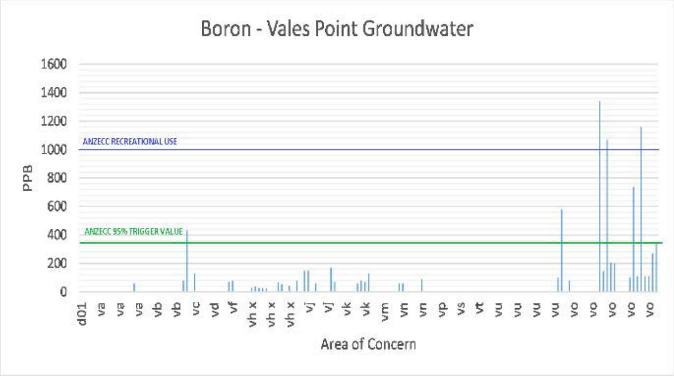
Groundwater data

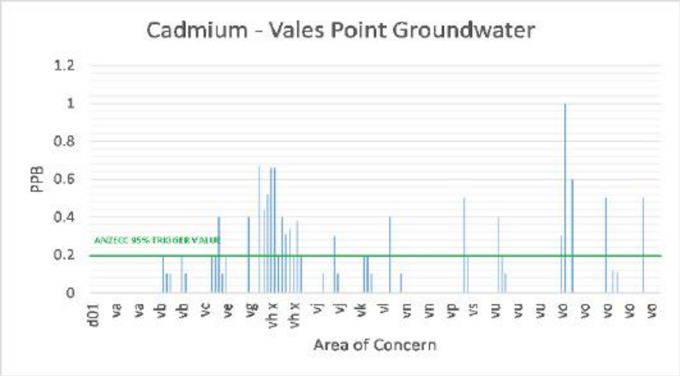
ERM divided the site into 21 individual areas of concern (AECs), according to usage and the presence of potential sources of contamination, as follows;

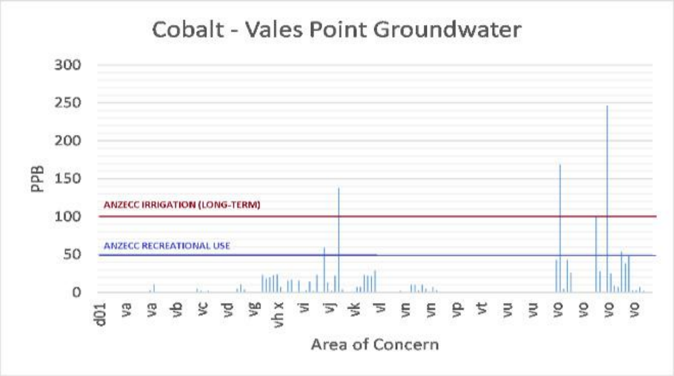
- VA — B Station Operational Area;
- VB — former A Station Demolition Area;
- VC - Transformer Area;
- VD - Main Dangerous Good Store;
- VE-Contaminated Water Treatment Plant;
- VF-Waste Oil Storage Area;
- VG-Fuel Oil Installation;
- VH-Vehicle Refueling Area;
- VI-Water Treatment Area;
- VJ-Coal Storage Area;
- VK-Mobile Plant Area;
- VL-Sewage Treatment Plant;
- VM-Chlorine Plant;
- VN-Wyee Rail Coal Unloader;
- **VO-Ash Dam**;
- VP-Asbestos Landfills;
- VO-Dust Line;
- VR- Wyee Creek and Lake Macquarie Sediments and Surface Waters;
- VS-TransGrid Switchyard;
- VT-Fly Ash Plant
- VU-Site Buffers and Boundaries

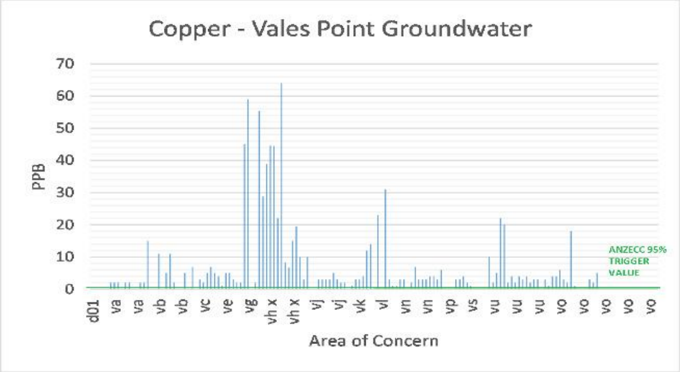
The groundwater results from these areas of concern are displayed below.

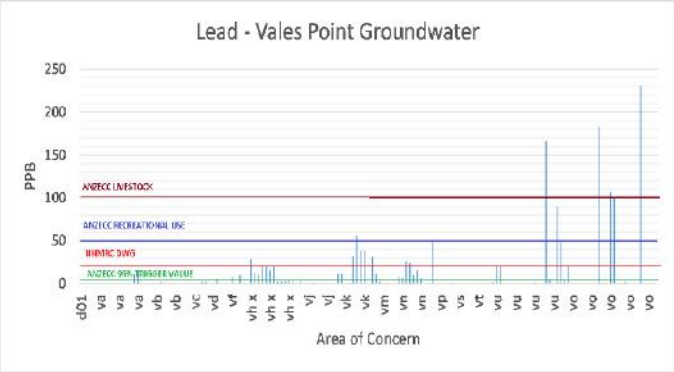


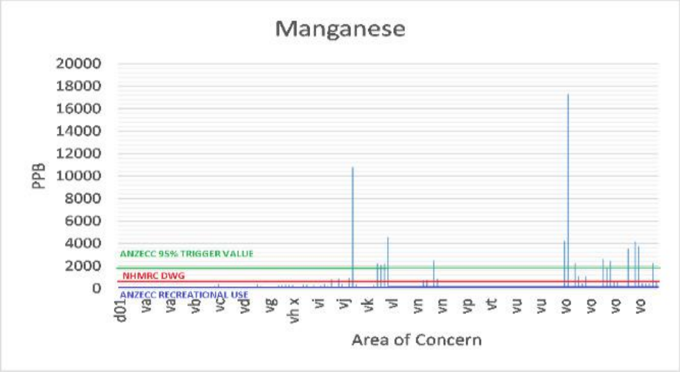


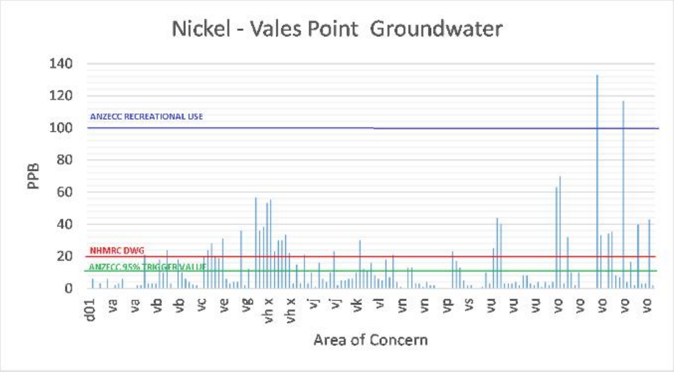


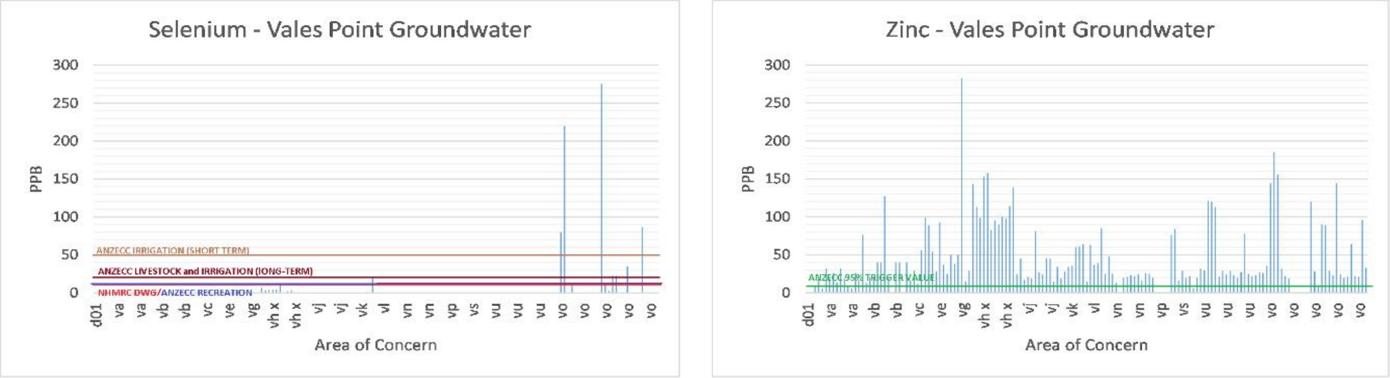












Charts 4: Vales Point groundwater exceedances

Eraring (Origin Energy)

Eraring Power Station is situated adjacent to the western shore of Lake Macquarie, near the township of Dora Creek, southwest of Newcastle, NSW. The total area of the Eraring Power Station is approximately 1147 hectares (ha), including water canals but excluding associated coal mines.

The limited nature of the available groundwater background dataset (consisting of a total of 5 samples) did not facilitate the use of standard statistical methods for the estimation of background concentrations from the Background Monitoring Wells.

A potential risk to the environment from metals concentrations in groundwater at certain site boundaries above ecological screening values;

- Elevated **selenium** concentrations within sediments in offsite surface water bodies down-gradient of the Coal Combustion Products Management Facility (CCPMF)[ash dam] also represent a potential risk to the environment (ecological exposure and ingestion of fish); and

- With regard to groundwater, a duty to report exists for exceedances of drinking water guideline values due to elevated concentrations of **arsenic, nickel, selenium**, benzolalpyrene and vinyl chloride.

A duty to report exists for exceedances of ecological guideline values due to elevated concentrations of **cadmium, copper, lead, nickel, selenium and zinc.**

The following trends were noted.

- Elevated concentrations of **copper, lead and zinc** exceeding the ANZECC criteria were commonly observed immediately surrounding the Attemperation Reservoir.

- Elevated concentrations of **copper, lead and zinc** exceeding the ANZECC criteria were commonly observed immediately surrounding the CCPMF [Ash Dam].

- **Lead and arsenic** concentrations also exceeded the Australia Drinking Water Guidelines.

- Concentrations of suspended solids and selenium regularly exceeded the EPL acceptance limit at surface sampling locations, particularly at the Ash Dam toe drain sampling location, at the Ash Dam return canal sampling location and at the utilisation area sampling point adjacent to the sewerage treatment works.

- **Selenium** concentrations also commonly exceeded the adopted ANZECC criteria and the Australia Drinking Water Screening value, however it is noted that concentrations of selenium decreased from 2006 to 2013.

Groundwater salinity, measured as electrical conductivity, was highly varied across the site ranging from 31µS/cm to 120,500 µS/cm for 2013 sampling and 145 µS/cm to 28,937 µS/cm for 2014 sampling. Groundwater pH measured across the site was varied but predominantly exhibited slightly acidic conditions within the majority of groundwater monitoring wells with some isolated monitoring wells exhibiting low pH in areas down-gradient of the Attemperation Reservoir, the CCPMF [ash dam] and the southern portion of the site.

The evaluation indicates that groundwater flow from the coal storage area and the power station is towards the south south west, with groundwater in this sub-catchment ultimately draining towards Muddy Lake (which then drains into Lake Macquarie). In the sub-catchment within which the CCPMF [ash dam] is located, groundwater flow is to the south towards Myuna Bay from the CCPMF while groundwater in the south western section of this sub-catchment likely flows towards Whiteheads Lagoon. In the southern most sub-catchment indications are that to the south of the Attemperation Reservoir groundwater flows south south east towards Lake Eraring.

Ash Dam (CCPMF)

The CCPMF occupies an area of approximate 150ha. Potentially contaminating activities, include ash slurry, water and fines from the dirty water collection/treatment system, mine water from the adjacent Awaba Mine and overflows from the oil retention lagoon. The eastern portion of the current CCPMF was also previously used as an ash dam for the nearby former Wangi power Station, although it is noted that the surface of the former Wangi Ash Dam was significantly lower than that of the current CCPMF.

Historic investigations have demonstrated that seepage from the CCPMF is saline and contains heavy metals. In particular, **selenium, copper, lead, zinc and arsenic** concentrations in excess of ANZECC (2000) freshwater trigger values and/or NHMRC (2011) ADWG [Australian Drinking Water Guideline] values have been detected in groundwater collected from monitoring wells up, down and cross hydraulic gradient of the CCPMF. **Selenium has also been reported in surface water collected from the CCPMF toe drain and return water canal, although concentrations were noted to have increased between 2011 and 2013 (ERM, 2013a).**

Groundwater pH readings during the 2013 sampling event ranged from 2.71 to 7.87 with pH values <4 reported in two monitoring wells located to the south of the CCPMF. Sulfidic odors were also detected at locations on the western side of the CCPMF and south of the CCPMF. Groundwater pH readings during the 2014 sampling event ranged from 2.82 to 6.39 wit**h pH values <4 reported on the down-gradient of the CCPMF.**

Arsenic, copper, lead, nickel, selenium and zinc were detected at concentrations in excess of the adopted human health and/or ecological screening values in groundwater samples collected from across the ash dam area.

N**ickel, zinc and selenium** results were generally higher than background levels in the monitoring wells located downgradient of the CCPMF. It is likely that the ongoing operation of the CCPMF contributes to these results, although no clear distribution of metal concentrations in groundwater was evident between the various downgradient wells. Detections of selenium in groundwater were limited to 2 monitoring wells and potential acid sulfate soil conditions in the area downgradient of the CCPMF could also have contributed to the mobilisation of metals in groundwater.

Whiteheads Lagoon, Return Water Dam, Crooked Creek, Drainage Channels & Lake Macquarie Sediments & Surface Water (Area EG)

Historic groundwater and surface water monitoring indicates that seepage from the CCPMF is saline and contains elevated concentrations of heavy metals and selenium. It is understood that prior to 1991, CCPMF seepage was discharged directly into the surface water features Crooked Creek and Whiteheads Lagoon. Emergency overflow can still be potentially discharged to Crooked Creek (from the Return Water Dam. The potential also exists for groundwater discharges to affect conditions within offsite surface water bodies.

Arsenic, copper, and zinc concentrations exceeded the ISQG-Low values in nineteen, seven, and eight sediment samples respectively. The nickel concentration exceeded the ISQG-Low in two samples and the ISQG-High in one sample in Whiteheads Lagoon.

The measured selenium concentrations ranged from 0.1 to 42 mg/kg, with an average concentration of 2.4 mg/kg. The highest selenium concentrations of selenium were measured in samples collected from within Crooked Creek and the Return Water Dam.

Copper, lead, nickel, and zinc concentrations exceeded the ANZECC (2000) marine water trigger values in a small number of samples. There were no concentrations reported which exceeded the NHMRC (2008) Guidelines for Managing Risks in Recreational Water.

The ISQG-Low for **arsenic** is 20 mg/kg and the maximum arsenic concentration detected was 33 mg/kg. The highest concentrations exceedances were measured in the distant Myuna Bay samples and the arsenic results in the control samples (Bonnells Bay) were of the same order of magnitude as those measured in Crooked Creek and Whiteheads Lagoon. Similar spatial trends were noted for copper and zinc, with the highest analytical results and greatest concentrations of these metals measured in the Bonnells Bay and distant Myuna Bay samples.

These results suggest that it is unlikely that the elevated arsenic concentrations are linked to historical discharges to Crooked Creek or Whiteheads Lagoon. It is possible that urban and sewage inputs, in addition to outputs from power generation activities, have contributed to the widespread enrichment of sediments throughout this area with heavy metals (Kirby et. al., 2001, Lake Macquarie City Council, 1995). Metal concentrations naturally present in regional soil and groundwater may also contribute to the observed metal impacts in sediment.

The maximum **nickel** concentration of 54 mg/kg measured at the southern end of Whiteheads Lagoon only marginally exceeds the ISQG-High of 52 mg/kg. The other two samples collected at this location (at 0.25 m bgl and 0.75 m bgl) reported nickel concentrations in excess of the ISQG-low values. The other samples collected within Whiteheads Lagoon reported nickel concentrations of a similar order of magnitude to the control locations. **Given that elevated nickel concentrations have been identified in groundwater collected down-gradient of the CCPMF [ash dam], these nickel impacts may be associated with the operation of the CCPMF and/or the historical operation of the Wangi Ash Dam**. These results do not however suggest that historical discharges to Whiteheads Lagoon have resulted in widespread nickel impacts.

As noted in the Preliminary ESA (ERM, 2013a), selenium concentrations in surficial sediments are expected to be related to fly ash from the power station, including the direct release of seepage from the CCPMF into Crooked Creek prior to 1991 (Nobbs et al. 1997, Kirby et. al., 2001, Lake Macquarie City Council, 1995).

Selenium concentrations measured in sediment samples collected from the Return Water Dam (42 mg/kg) were significantly higher than those measured in the other sampling locations. Similarly, the selenium concentrations measured in the sediment samples collected from Crooked Creek (6.3 mg/kg; 18 mg/kg) were generally higher than those measured in other sampling areas.

The Return Water Dam is part of the contaminated water management system at the Site. Emergency overflow from the CCPMF can also be discharged to Crooked Creek via a weir. As such, the return Water Dam and Crooked Creek receive discharges as a part of the licensed contaminated and waste water management system at the Site. On this basis, the Return Water Dam and Crooked Creek are considered likely to be impacted as a result of these licensed operations.

Moderately elevated selenium concentrations were also detected in a number of the sediment samples collected from the southern end of Whiteheads Lagoon (up to 5 mg/kg). Seepage impacts to Crooked Creek and to a lesser extent Whiteheads Lagoon, do not however appear to have translated into elevated selenium concentrations within Myuna Bay, with selenium concentrations measured in Myuna Bay sediment samples being of the same order of magnitude as those measured in the control locations.

Surface Water

Copper was reported at concentrations in excess of the adopted ecological screening level in a number of samples collected from Crooked Creek and the Return Water Dam. However, copper concentrations in surface water in Whiteheads Lagoon and Myuna Bay met the screening values, as did copper concentrations in sediment in Crooked Creek. Copper concentrations in surface water were however generally low, at <5 µg/L in all samples, relative to a screening level of 1.3 µg/L

Zinc concentrations ranged from <5 to 254 µg/L, exceeding the screening level of 15 µg/L in a number of the surface water samples. A large number of zinc exceedances were recorded in Myuna Bay and the zinc concentrations in Myuna Bay were comparable to those at the reference locations in Bonnells Bay. This result is consistent with what was observed in the sediments and suggests that the zinc concentrations measured in Myuna Bay may be representative of conditions throughout the area. The highest surface water zinc concentrations were recorded in Crooked Creek, immediately down-gradient of the CCPMF, which suggests that the operation of the CCPMF [ash dam] may contribute to these impacts. Elevated zinc concentrations have also been recorded in groundwater collected from down- gradient of the CCPMF. Measured zinc concentrations in surface water from the lower reaches of Crooked Creek were however consistent with those in the broader study area.

Nickel exceeded the ecological screening level in one sample, located in Crooked Creek but widespread nickel impacts to surface water were not identified.

The most elevated **selenium** results (up to 94 µg/L) were detected in the surface water samples collected from Crooked Creek and the Return Water Dam, with selenium reported at or near the LOR in the other sampling areas. This result is consistent with what was observed in the sediment results and suggests that selenium seepage impacts to Crooked Creek do not appear to have translated into elevated selenium concentrations within Myuna Bay.

Groundwater

- **Arsenic** (Max 73 µg/L – mean 3.5 ug/ L). Concentrations equalling or exceeding the lowest adopted screening value of 10 µg/L (drinking water criteria) were limited to 9 of the 145 monitoring wells sampled. Samples with exceedances of adopted screening values were taken from monitoring wells located **directly down gradient of the CCPMF**, the operational and decommissioned UST area, the fuel oil installation and AST area and the accessible operational area and non-operational areas. Background concentrations were below the assessment criteria and the elevated arsenic concentrations are therefore **not considered attributable to background concentrations**.

- **Cadmium** (Max 2.8 µg/L- mean 0.14 µg/L). Reported values exceeding the lowest adopted screening value of 0.06 µµµµµµg/L (freshwater ecological screening values) amounted to 137 out of the 145 monitoring wells sampled. Reported concentrations above the maximum reported background concentration were limited to 31 out of 145 monitoring wells. These locations include monitoring wells within the accessible operational areas in the southern part of the power block, non-operational areas, **down gradient of the Return Water Dam and down gradient of the CCPMF**.

- **Copper** (Max 100 µg/L – mean 2.6 µg/L). Concentrations equalling or exceeding 1 µg/L (freshwater ecological screening values) were recorded in samples from 59 of the 145 monitoring wells sampled. Reported concentrations above the maximum reported background concentration were limited to a total of five monitoring wells. These include **down gradient of the CCPMF, down gradient of the Return Water Dam**, adjacent to the Coal Storage Area, and in a non-operational area.

- **Lead** (Max 64 µg/L- mean1.4 µg/L). Concentrations equalling or exceeding the lowest adopted screening values of 1 µg/L (freshwater ecological screening values) were identified in samples from 16 of the 145 monitoring wells sampled. Monitoring wells with samples exceeding the adopted screening values were located predominantly in locations **down gradient of the CCPMF and the Return Water Dam,** in a number of locations in non-operational areas and in operational areas including the operational and decommissioned UST area and the workshop. Reported concentrations above the maximum reported background concentration were limited to a total of six monitoring wells. These include monitoring wells located **down gradient of the CCPMF**, monitoring well located **adjacent to the Return Water Dam**, monitoring well located down gradient of the Return Water Dam, monitoring well located in the downgradient section of the power station, and two monitoring wells located in non- operation areas.

- **Nickel** (Max 254 ug/ L – mean 18µg/L). Concentrations exceeding the lowest adopted screening value of 8 µg/L (freshwater ecological screening values) were identified in samples from 72 of the 145 monitoring wells sampled. Reported concentrations a factor of two above the maximum reported background concentration were limited to 47 out of the 145 monitoring wells sampled. The highest nickel concentrations were reported (226 µg/L) located do**wn gradient of the Return Water Dam** and monitoring wells (131 µg/L) and (114 µg/L) located **down gradient of the CCPMF**.

- **Selenium** (Max 205 µg/L – mean 6.8 µg/L). Concentrations exceeding the screening value of 5 µg/L (freshwater ecological screening values) were identified in samples from 13 of 145 monitoring wells. Monitoring wells with samples that exceeded the adopted screening values were limited to monitoring wells located at the transformer area, the workshops, non-operational areas, locations **down gradient of the CPPMF** (205 ug/ L). Selenium concentrations in the Background Monitoring Wells were all below a laboratory LOR of <10 µg/L and exceedances of the assessment criteria are therefore **not considered attributable to background conditions**.

- **Zinc** (Max 1 050 ug/ L – mean 57 µg/L. The majority of monitoring wells (134/145) exceeded the adopted screening values of 2.4ug/ L (freshwater ecological screening values). Zinc concentrations in the Background Monitoring Wells averaged 37ug/ L, with a maximum reported concentration of 58 µg/L. Reported concentrations above the maximum reported background concentration included samples taken from 27 monitoring wells. These locations including monitoring wells within the accessible operational areas in the southern part of the power block, non-operational areas, **down gradient of the Return Water Dam and down gradient of CCPMF**

Low pH Distribution and Potential Influence of Acid Sulfate Soils

There was a high probability of encountering acid sulfate soils immediately to the south of the Site. Based on a review of aerial photography, these areas had been cleared of vegetation, and exposed soils suggested that earthworks had previously been undertaken in these areas. It is noted that

these activities may have allowed oxidation of potential acid sulfate soil, to create actual acid sulfate soil conditions in these areas.

The pH of groundwater observed across the Site was typically low, and pH values within the nominated background monitoring wells ranged between 3.91 and 6.05 indicating that the groundwater is naturally somewhat acidic. Measured pH levels below 5 across the Site, and the broad site distribution of groundwater with pH below 5, coupled with the pH levels observed in the background monitoring wells indicates that the majority of low pH measurements are attributable to natural conditions. In addition, areas of historical soil disturbance may have led to generation of actual acid sulfate soils (which would typically exhibit a pH level below 4). Measured pH levels below 4 were observed in 11 monitoring wells.

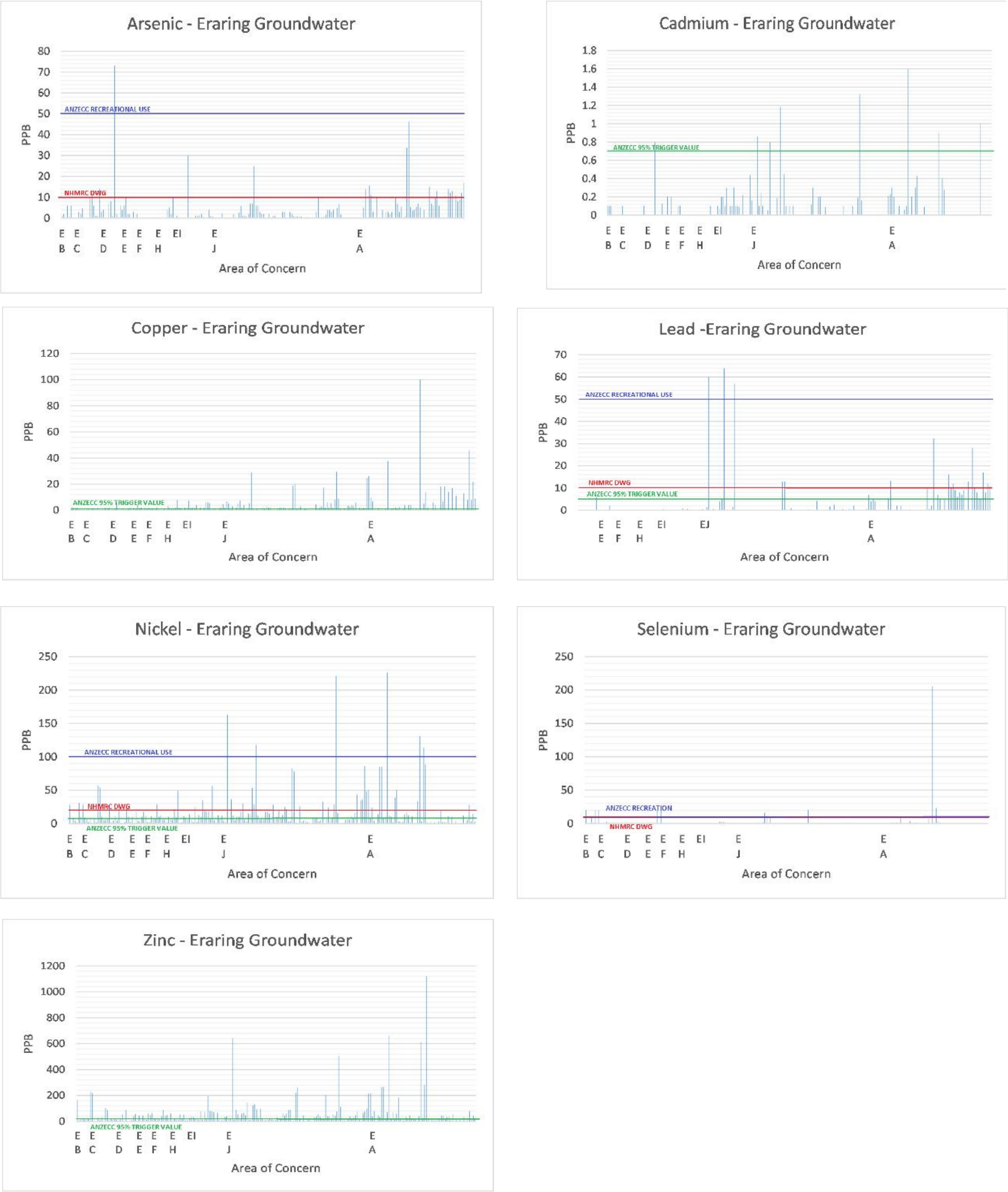
Areas of suspected actual acid sulfate soils include **the Attemperation Reservoir** (and adjacent area) and the areas **between the CCPMF and Myuna Bay**. While actual acid sulfate soils may be contributing to elevated metal and metalloid concentrations in near shore locations underlain by alluvial sediments in the vicinity of the Attemperation Reservoir and between the CCPMF and Myuna Bay, the distribution of elevated metal(loid) concentrations across the site and adjacent to sites sources, suggests that the suspected actual acid sulfate soils in these locations is not the dominant influence on the elevated metal(loid) concentrations. Furthermore, pH levels in groundwater monitoring wells further down-gradient of these two areas (for example adjacent to Muddy Lake or Myuna Bay) suggests the areas of actual acid sulfate soils are spatially limited.

Groundwater data

For the purpose of this assessment, the Site was divided into 12 individual Work Areas, (referred to hereafter as AECS), according to usage and the presence of potential sources of contamination, as follows;

- **EA — Coal Combustion product Management Facility (CCPMF, also known as the ash dam);**
- EB — Transformer Area;
- EC - Fuel oil installation, fuel pipelines
- ED - Operational and Decommissioned Underground Storage Tanks
- EE — Workshops;
- EF — Former Northern Gas Turbine Location (non-operational);
- EG — **Whiteheads Lagoon, Return Water Dam, Crooked Creek, Drainage Channels and Lake**
- Macquarie Sediments and Surface Waters;
- EH - Coal Storage Area;
- EI -Accessible Operational Area;
- EJ -Non-Operational Areas including Non-Operational Lots;

- EK - Coal Haul Road; and
- EL - Asbestos Containing Pipework.



Charts 5: Eraring groundwater exceedances

Upper Coxs River

Mount Piper (Energy Australia)

The site is located 2.5 km west of the Coxs River which runs from north to south. The River was dammed at Lake Wallace and Lake Lyell to provide Delta Electricity with water, and is now used for boating and fishing. The river ultimately flows to Lake Burragorang [Warragamba Dam] which stores much of Sydney's drinking water supply.

Construction of Mount Piper required substantial earthworks to level the land and backfill a former open-cut mine with overburden, indeed the dry ash from Mt Piper is dumped in former open cut mines. The current and historic mining activity has significantly influenced aquifer properties and groundwater flows.

Where underground workings have been left in place, hydraulic conductivities are very high (5 to 50 m/d) in the disturbed coal seams. The hydraulic conductivity of the backfilling material in the open cut mine voids is lower (10^{-1} m/d) and for the Marrangaroo Conglomerate underlying the Lithgow seam even lower (10^{-3} m/d). In addition, two geological faults dissect the northern and southern site boundaries, passing through the former contractors yard and the operational area in the southern portion of the site and the coal storage area in the northern portion of the site.

The ESA identifies that various metals were detected at concentrations above the human health (drinking water) and/or ecological screening values which were not attributable to background conditions in groundwater at a number of locations across the Site.

Ash placement areas

The ash dumps were designed for dry ash placement, with water addition for ash conditioning prior to disposal and dust suppression following disposal. Brine conditioned ash was disposed in a designated area of the ash repository. EC readings indicated that groundwater conditions were fresh in wells on the northern perimeter of the ash repository and saline in wells on the eastern perimeter, adjacent to the Lamberts North Ash Repository. The measured groundwater pH was acidic (pH3.31 to 6.15).

All seven of the groundwater monitoring wells at the older area of the ash dump (area MG) exceeded metals concentrations greater than the adopted human health and/or ecological screening values.

- **Arsenic, boron, cadmium, chromium, copper, lead, manganese, nickel and zinc** concentrations exceeded the adopted ecological screening values in most groundwater samples.
- **Boron, cadmium, lead and manganese** were detected at concentrations in excess of the adopted human health (drinking water).
- **Arsenic and nickel** were detected at concentrations in excess of the adopted human health (drinking water and recreational) screening values.

The newer ash dump (area MH) constructed in 2013 has a 5 m fill layer above the base of a former open cut mine workings, which was in direct contact with groundwater within the Lithgow Seam. The fill material was intended to provide a barrier to groundwater infiltration of the ash, and prevent potential leaching of contaminants from the ash to groundwater. The ash dump receives dry ash with water used for dust control only.

Six existing and three new groundwater monitoring wells on the boundary with the ash repository were sampled. The groundwater was acidic to neutral (pH 4.24 to 6.91) and saline in most locations. Metals were high at the boundary of the area.

- **Arsenic, boron, cadmium, chromium, copper, lead, manganese, nickel, zinc** were detected in groundwater at concentrations in excess of the ecological screening values.
- **Arsenic, lead, manganese and nickel** were detected in groundwater at concentrations in excess of the human health (drinking water) screening values.
- **Manganese and nickel** were detected in groundwater at concentrations in excess of the human health (recreational assessment) criteria.

Lake Lyell and Thompsons Creek Reservoir - MM

The Coxs River was dammed downstream of Lake Wallace to form Lake Lyell in 1982. Lake Lyell has an active capacity of approximately 31 GL, sourced from local runoff. The water is also pumped to off-stream storage at Thompsons Creek, which supplies Mt Piper, or to Lake Wallace, which once supplied Wallerawang Power Station.

There are three local farmers with agreements to agist stock within the buffer lands around Lake Lyell. Lithgow City Council owns a portion of lands adjacent to Lake Lyell, as well as leasing additional lands which are publicly accessible for camping and recreation.

Thompsons Creek Reservoir is located approximately 8 km south-west of the operational area of Mt Piper Power Station. The reservoir was constructed in 1992 on Thompsons Creek to provide off-stream storage for supply of the water to Mt Piper and Wallerawang. Although the surface runoff catchment of Thompson Creek is relatively small, Thompsons Creek Reservoir has a storage capacity of up to 27.5 GL with water routinely pumped from Lake Lyell.

The reservoir is also available to the public for recreational fishing. Surrounding buffer lands are generally vacant vegetated lands, with some areas used for stock grazing by local farmers under agreements with Delta.

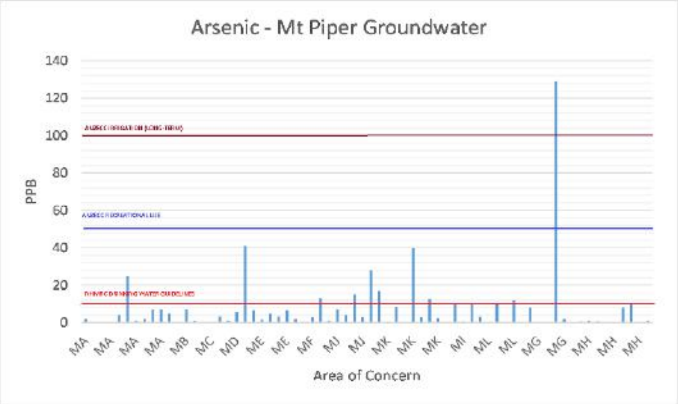
- **Copper** concentrations exceeded the adopted ecological screening values in all surface water samples from Lake Lyell and Thompsons Creek Reservoir.
- **Copper, nickel and zinc** concentrations in sediment at In Lake Lyell, exceeded ANZECC ISQG-Low at one location.
- In Thompsons Creek Reservoir **copper and lead** concentrations exceeded ANZECC ISQG- Low in one location.
- **Zinc** concentration exceeded the adopted ecological screening values in one sample from Thompsons Creek Reservoir.

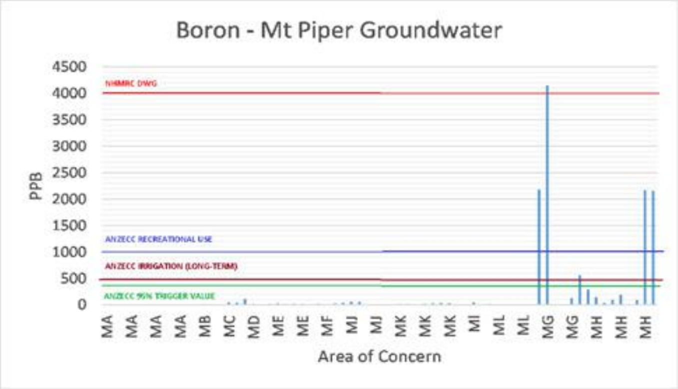
Groundwater data

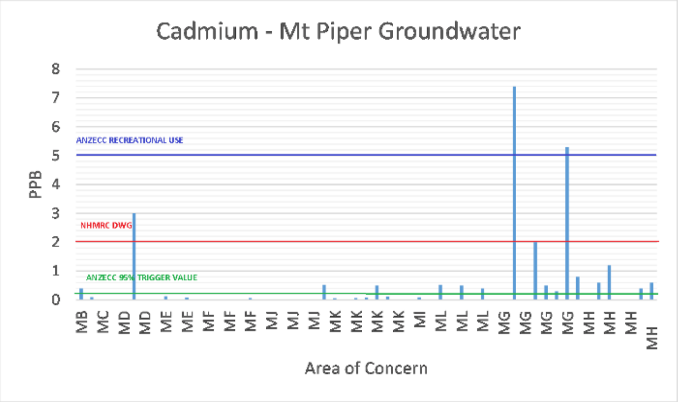
GHD divided the Mt Piper site ha into 13 individual areas of concern according to usage and the presence of potential sources of contaminant, as follows:

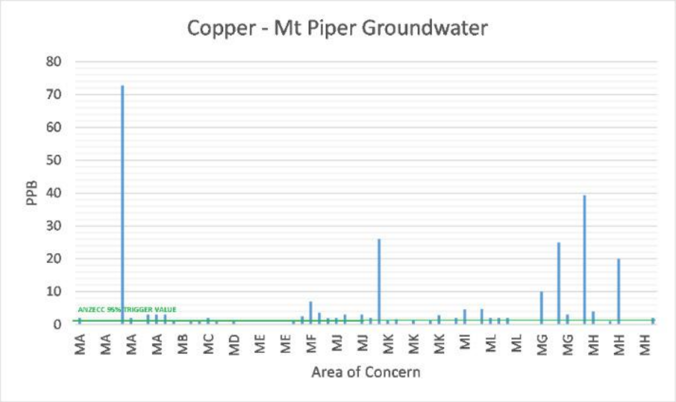
- MA-Former Landfills
- MB-Coal Storage Area
- MC-Electrical Transformers
- MD-Workshops

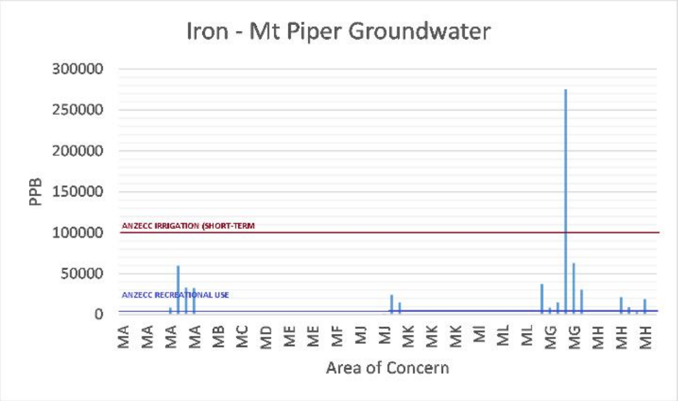
- ME-Mobile Plant Refuelling Area
- MF-Operational ASTS
- **MG -Current Ash Repository (Former Ash Repository)**
- **MH-Lamberts North Ash Repository**
- MI - Water Holding Ponds
- MJ-Operational USTS
- MK-Accessible Operational Areas
- ML-Non Operational Areas (Including Buffer Lands & Former Contractors Yard)
- MM - Water Assets (Lake Lyell And Thompsons Creek Reservoir) And Thompsons Creek Reservoir)

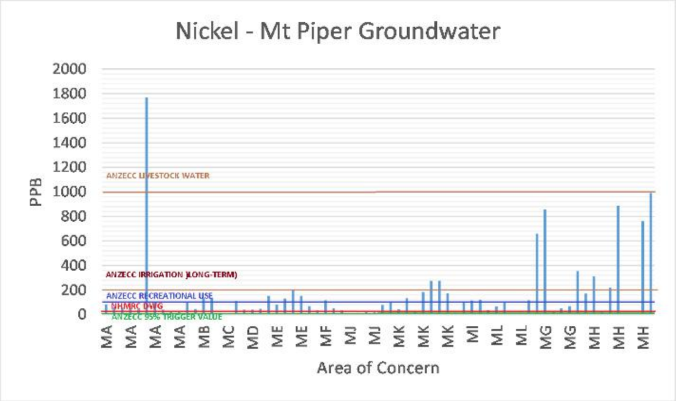


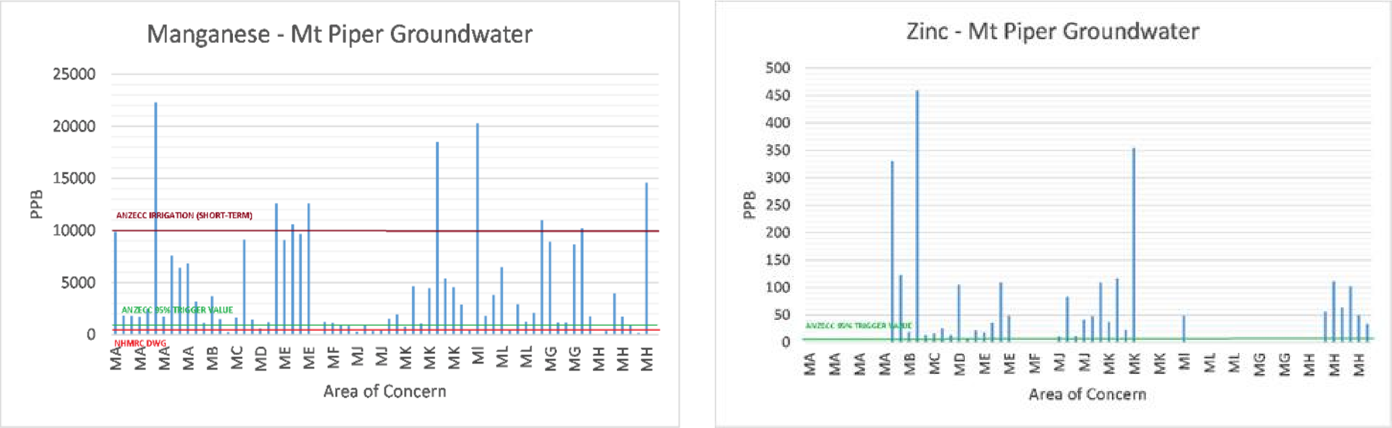












Charts 6: Mount Piper groundwater exceedances

photo: Vales Point power station ash dam rehabilitation

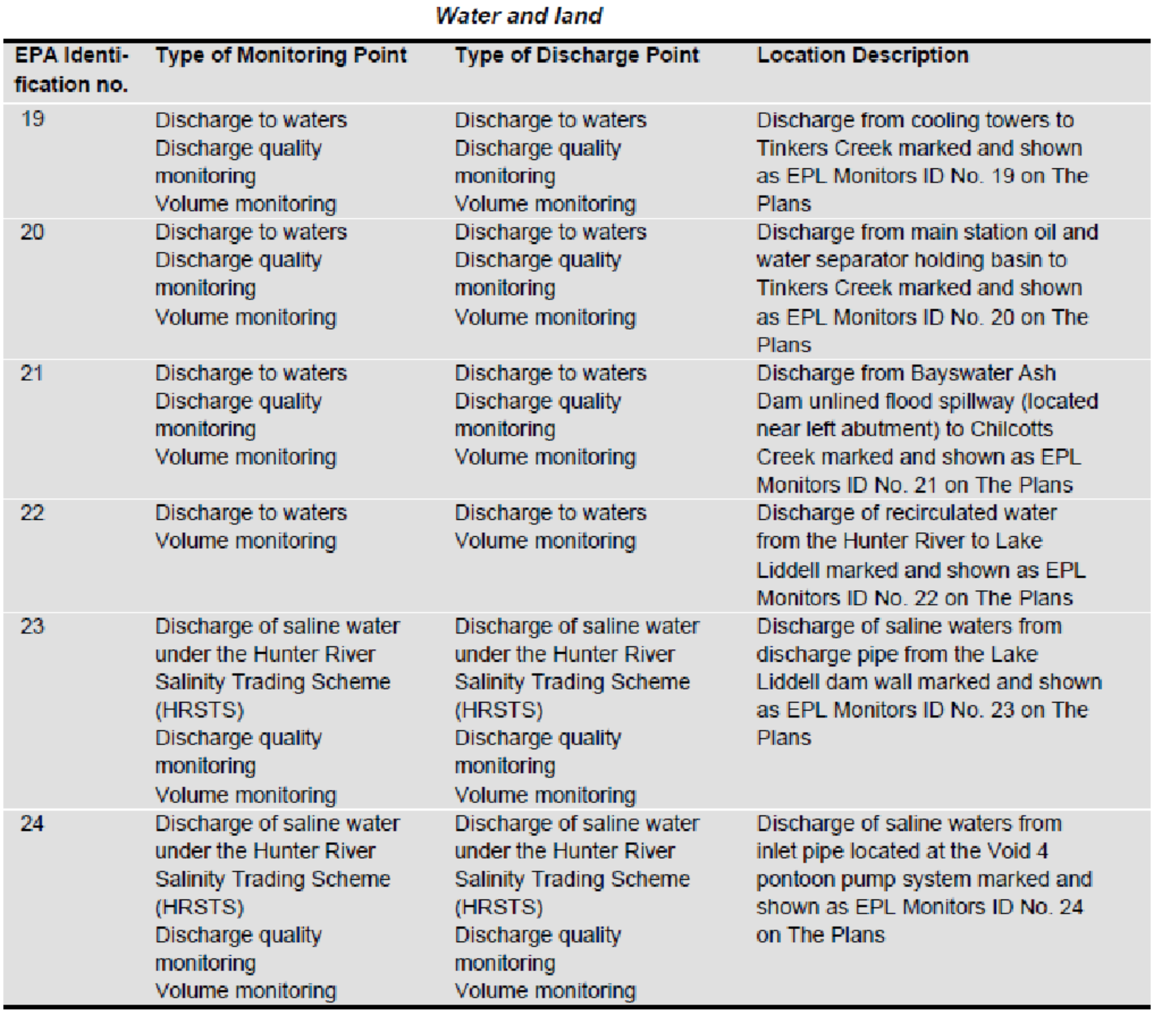
Environmental Protection Licence (EPL) Monitoring

Central Hunter Valley

Bayswater EPL 779

The recently varied (23 July 2020) Bayswater Power Station EPL identifies the discharge to waters at six points set out in the following table. The previous version of the licence (6 February 2020), which had five discharge points, identified the discharge from the Bayswater Ash Dam unlined flood spillway, as monitoring point 18. However, that monitoring location is now designated as point 21.

Table 17: Licenced Monitoring Points Bayswater EPL



Water and land

EPA Identi-fication no.	Type of Monitoring Point	Type of Discharge Point	Location Description
19	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge from cooling towers to Tinkers Creek marked and shown as EPL Monitors ID No. 19 on The Plans
20	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge from main station oil and water separator holding basin to Tinkers Creek marked and shown as EPL Monitors ID No. 20 on The Plans
21	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge from Bayswater Ash Dam unlined flood spillway (located near left abutment) to Chilcotts Creek marked and shown as EPL Monitors ID No. 21 on The Plans
22	Discharge to waters Volume monitoring	Discharge to waters Volume monitoring	Discharge of recirculated water from the Hunter River to Lake Liddell marked and shown as EPL Monitors ID No. 22 on The Plans
23	Discharge of saline water under the Hunter River Salinity Trading Scheme (HRSTS) Discharge quality monitoring Volume monitoring	Discharge of saline water under the Hunter River Salinity Trading Scheme (HRSTS) Discharge quality monitoring Volume monitoring	Discharge of saline waters from discharge pipe from the Lake Liddell dam wall marked and shown as EPL Monitors ID No. 23 on The Plans
24	Discharge of saline water under the Hunter River Salinity Trading Scheme (HRSTS) Discharge quality monitoring Volume monitoring	Discharge of saline water under the Hunter River Salinity Trading Scheme (HRSTS) Discharge quality monitoring Volume monitoring	Discharge of saline waters from inlet pipe located at the Void 4 pontoon pump system marked and shown as EPL Monitors ID No. 24 on The Plans

Despite metal contamination from the Pikes Gully Ash Dam being highlighted by ERM (2014),[62] the EPA requires no groundwater monitoring to be undertaken at this site under its EPL, and sets no regulated limits on metal concentrations that can be discharged. While monitoring is required for boron, cadmium, copper, iron, molybdenum, nickel, and silver, AGL claims discharge has never occurred since February 2016.

Also of concern is that the EPA does not require any groundwater monitoring by AGL.

There are concentration limits imposed on discharge from licensed discharge point 24 (formerly licensed discharge point 17 – "Discharge of saline waters from inlet pipe located at the Void 4 pontoon pump system"), which drains from the Ravensworth Rehabilitation Area. The licence imposes regulated limits on the concentrations in the discharge of boron (810μg/L), cadmium (0.3μg/L), copper (1μg/L), iron (270μg/L), molybdenum (290μg/L), nickel (19μg/L), and silver (0.5μg/L).

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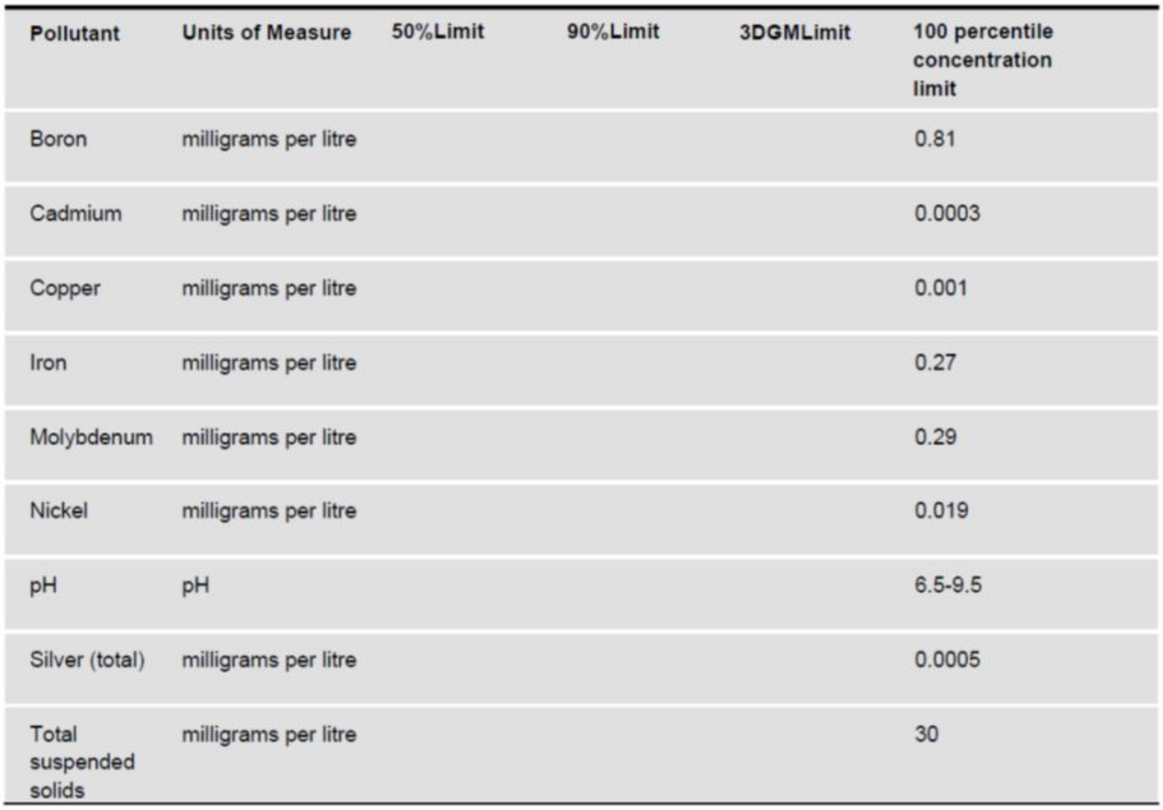
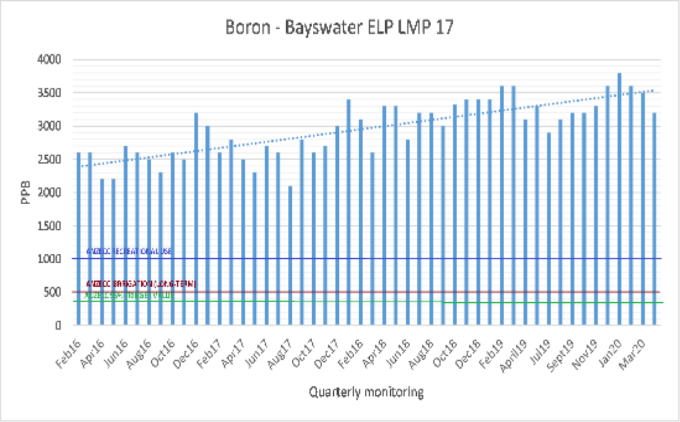
[62] "Metals exceeding the adopted ecological screening values included boron, cadmium, copper, lead, manganese, nickel and zinc. Concentrations of lead and nickel in excess of the adopted human health (drinking water or recreational) screening values were also detected in a number of samples... Given the volume and nature of the ash and water stored within the Ash Dam, it is considered that impacts observed in the other AECs within this catchment would be minor contributors to the overall potential impacts arising from the Ash Dam."

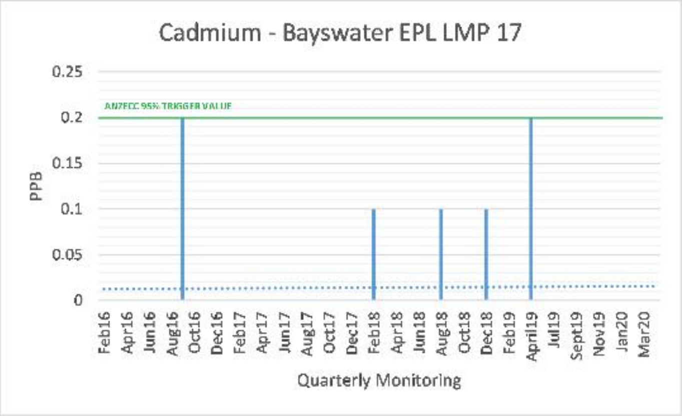
Table 18: Concentration limits for former LMP 17 (now 24) Licenced Monitoring Points Bayswater EPL

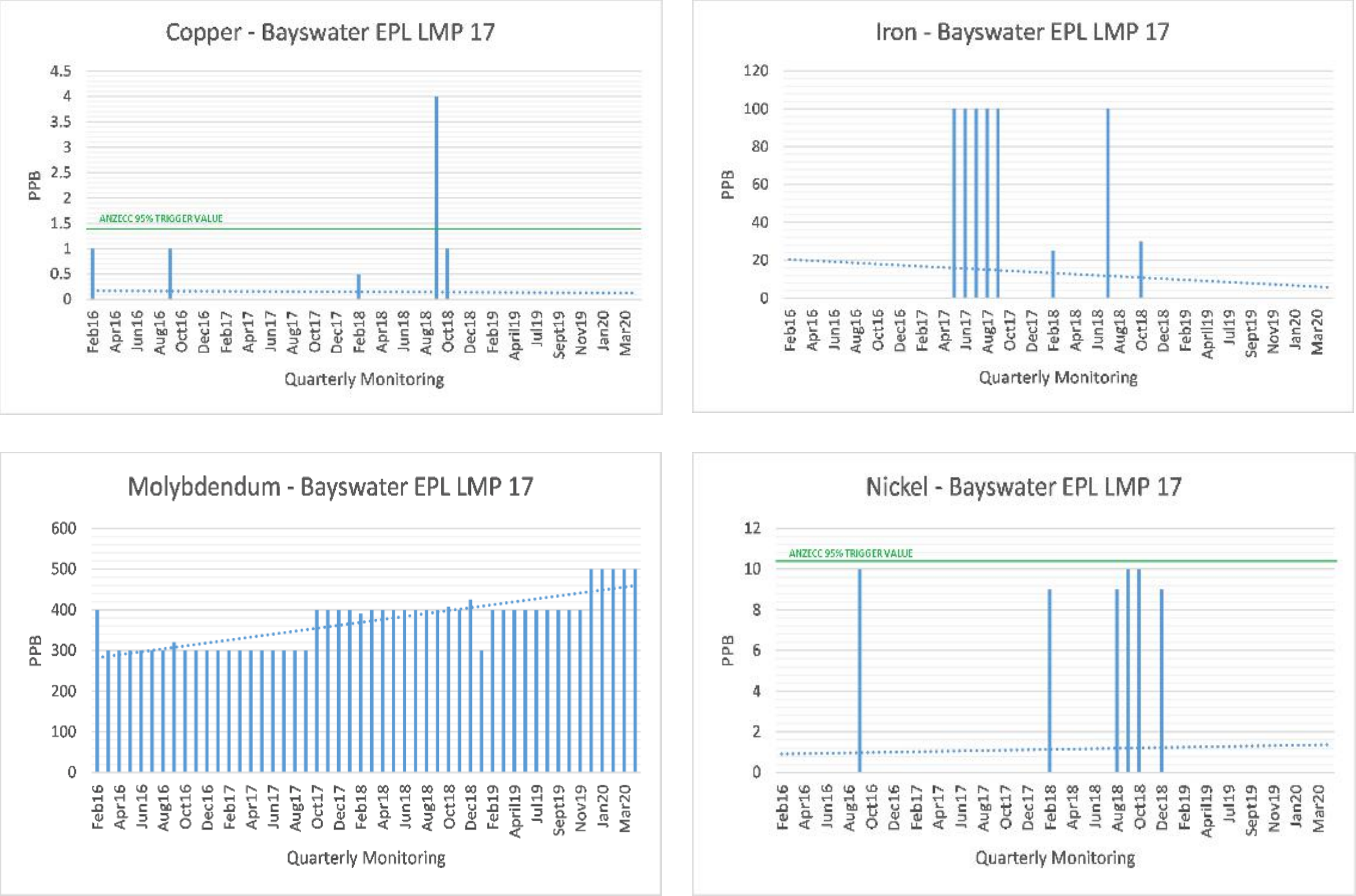


Pollutant	Units of Measure	50%Limit	90%Limit	3DGMLimit	100 percentile concentration limit
Boron	milligrams per litre				0.81
Cadmium	milligrams per litre				0.0003
Copper	milligrams per litre				0.001
Iron	milligrams per litre				0.27
Molybdenum	milligrams per litre				0.29
Nickel	milligrams per litre				0.019
pH	pH				6.5-9.5
Silver (total)	milligrams per litre				0.0005
Total suspended solids	milligrams per litre				30

As shown in the following charts, which represent quarterly monitoring from February 2016 to March 2020, boron (by a factor of 2-3) and molybdenum (by a factor of 2) consistently exceed the EPL regulated limits. Of even more significance is that concentrations of both these metal concentrations show an increasing trend.





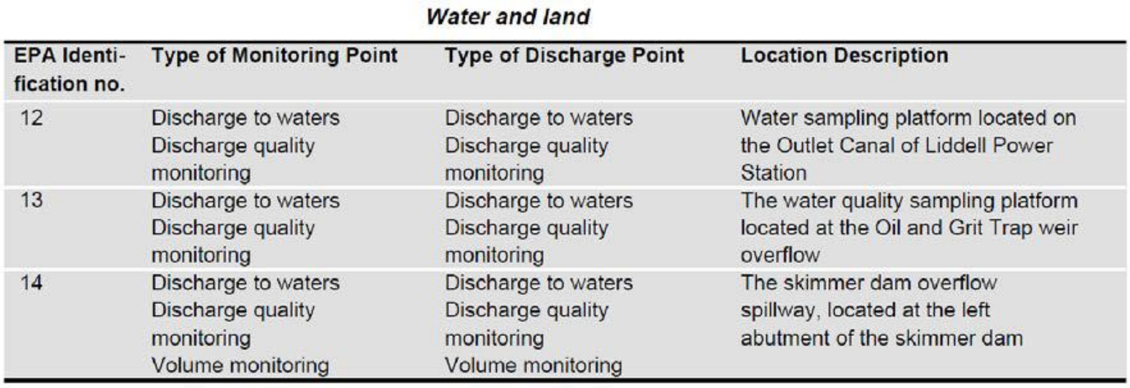


Charts 7: EPL monitoring Bayswater

Liddell EPL 2122

Liddell's EPL was varied in July 2020. An additional monitoring point (19) was added, and changes were made to the existing monitoring point numbers. Former licenced monitoring points (LMP) 12, 13, and 14 are now numbered 16, 17, and 18.

Table 19: Licenced Monitoring Points previous version of Liddell EPL

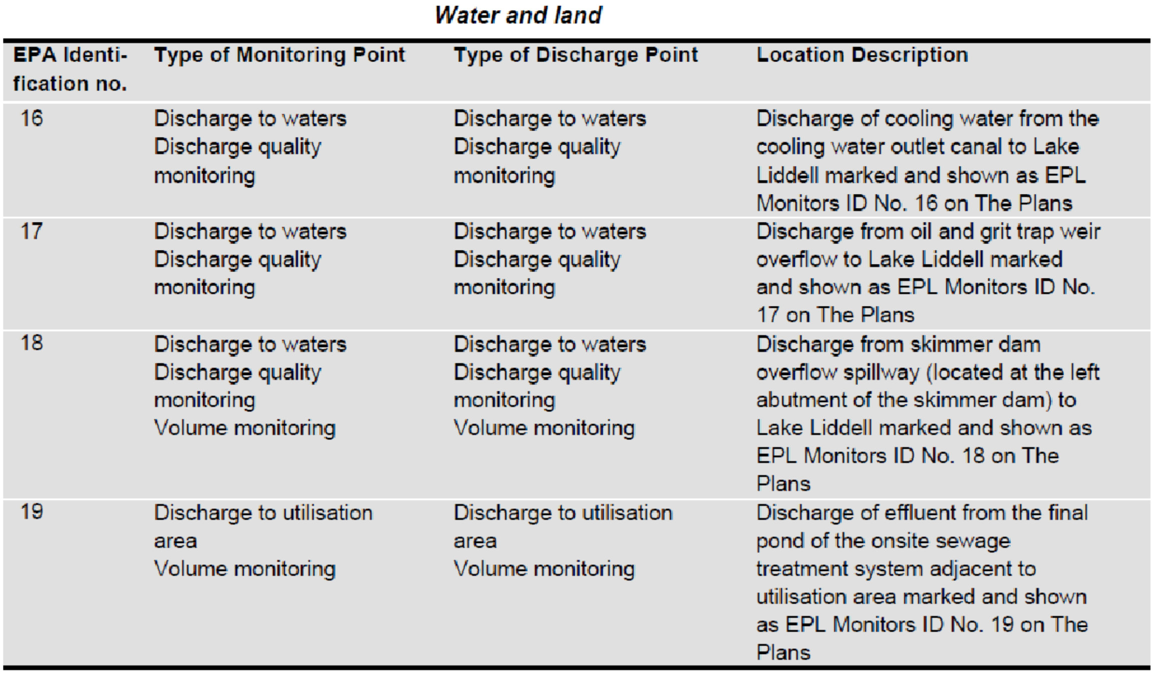


Water and land

EPA Identification no.	Type of Monitoring Point	Type of Discharge Point	Location Description
12	Discharge to waters Discharge quality monitoring	Discharge to waters Discharge quality monitoring	Water sampling platform located on the Outlet Canal of Liddell Power Station
13	Discharge to waters Discharge quality monitoring	Discharge to waters Discharge quality monitoring	The water quality sampling platform located at the Oil and Grit Trap weir overflow
14	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	The skimmer dam overflow spillway, located at the left abutment of the skimmer dam

Liddel's EPL does not prescribe any regulated limits on metal concentrations on any of its four licenced discharge points.

Table 20: New Licenced Monitoring Points Liddell EPL



Water and land

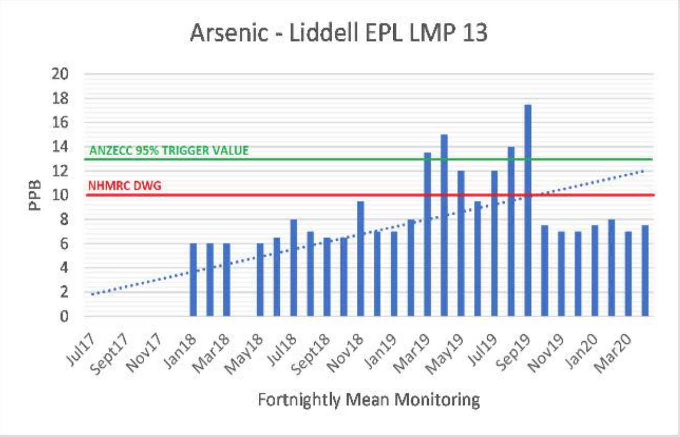
EPA Identification no.	Type of Monitoring Point	Type of Discharge Point	Location Description
16	Discharge to waters Discharge quality monitoring	Discharge to waters Discharge quality monitoring	Discharge of cooling water from the cooling water outlet canal to Lake Liddell marked and shown as EPL Monitors ID No. 16 on The Plans
17	Discharge to waters Discharge quality monitoring	Discharge to waters Discharge quality monitoring	Discharge from oil and grit trap weir overflow to Lake Liddell marked and shown as EPL Monitors ID No. 17 on The Plans
18	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge from skimmer dam overflow spillway (located at the left abutment of the skimmer dam) to Lake Liddell marked and shown as EPL Monitors ID No. 18 on The Plans
19	Discharge to utilisation area Volume monitoring	Discharge to utilisation area Volume monitoring	Discharge of effluent from the final pond of the onsite sewage treatment system adjacent to utilisation area marked and shown as EPL Monitors ID No. 19 on The Plans

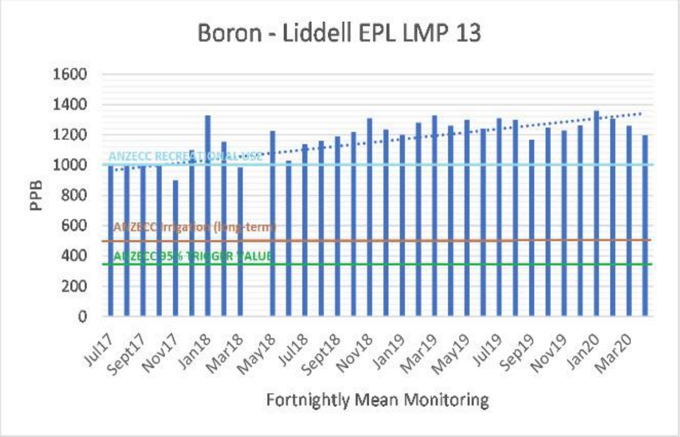
However, fortnightly monitoring is required at points 16 and 17 (formerly 12 and 13) for antimony, arsenic, barium, beryllium, boron, cadmium, chromium (III & VI), cobalt, copper, lead, manganese, molybdenum, mercury, nickel, selenium, tin, vanadium, and zinc. Weekly monitoring is also required during discharge at discharge point 18 (formerly 14) for arsenic, boron, cadmium, chromium (III & VI), copper, lead, mercury, selenium, and zinc.

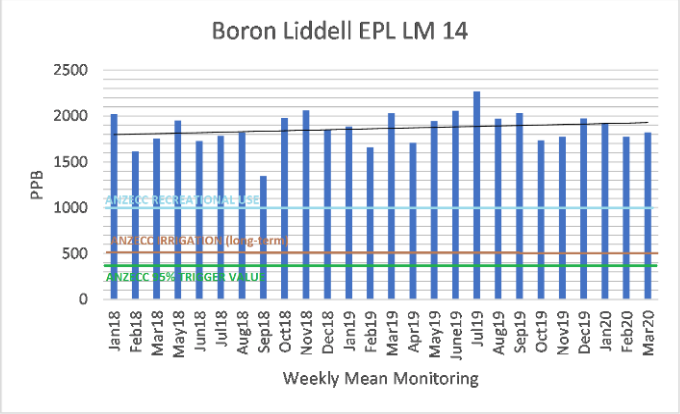
As shown in the following charts, which represent fortnightly monitoring from July 2017 to March 2020, at former monitoring point 13 (now 17), and weekly monitoring at the former monitoring point 14 (now 18), boron, cadmium, copper consistently exceeded ANZECC 95% trigger values during this period, and boron and selenium consistently exceed ANZECC 95% trigger values at former LMP 14.

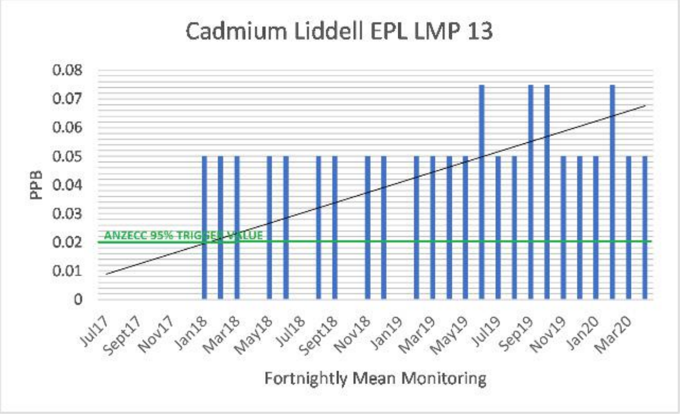
Boron concentrations at former LMP 13 and 14 also consistently exceed ANZECC recreational use, and long-term irrigation guidelines. Selenium concentrations at LMP 14 also consistently exceed ANZECC livestock trigger value and long-term irrigation guidelines.

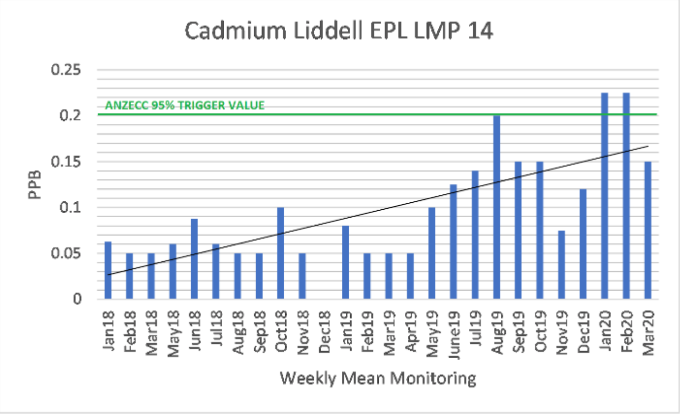
At LMP 13, boron has been steadily increasing, with cadmium at LMP 14 showing a marked increase over time. Indeed, with the possible exception of copper at LMP 14, no metal concentrations at any of the LMPs show improvement under the current regulatory and monitoring program overseen by the EPA

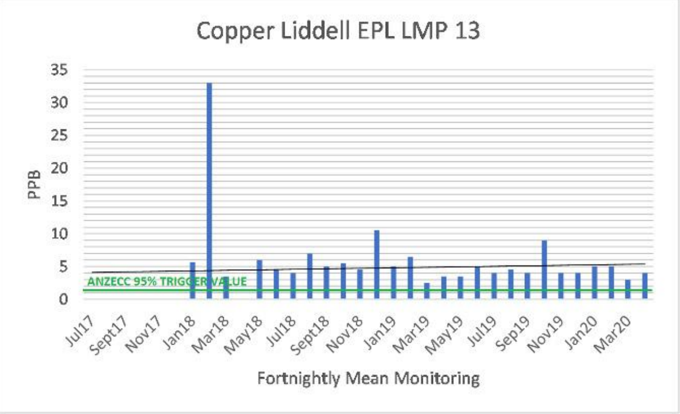












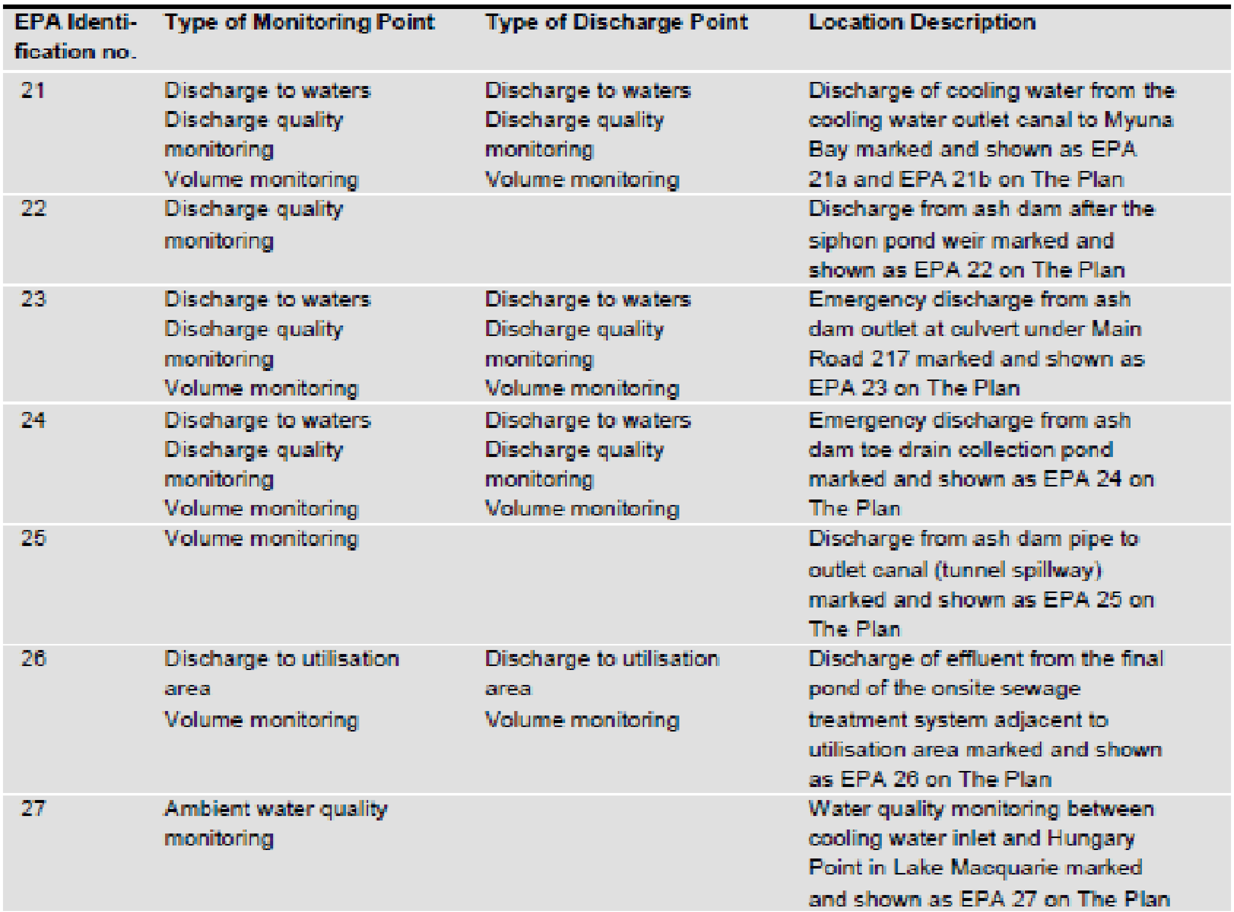
Charts 8: Liddell EPL monitoring results

Lake Macquarie

Eraring 1429

Eraring's EPL was varied in July 2020 which altered the numbers of the 15 monitoring points, including five Licenced Discharge Points (LDP), three groundwater Licenced Monitoring Points (LMP), and five ambient LMPs in Lake Macquarie.

Table 21: New Licenced Monitoring Points Eraring EPL

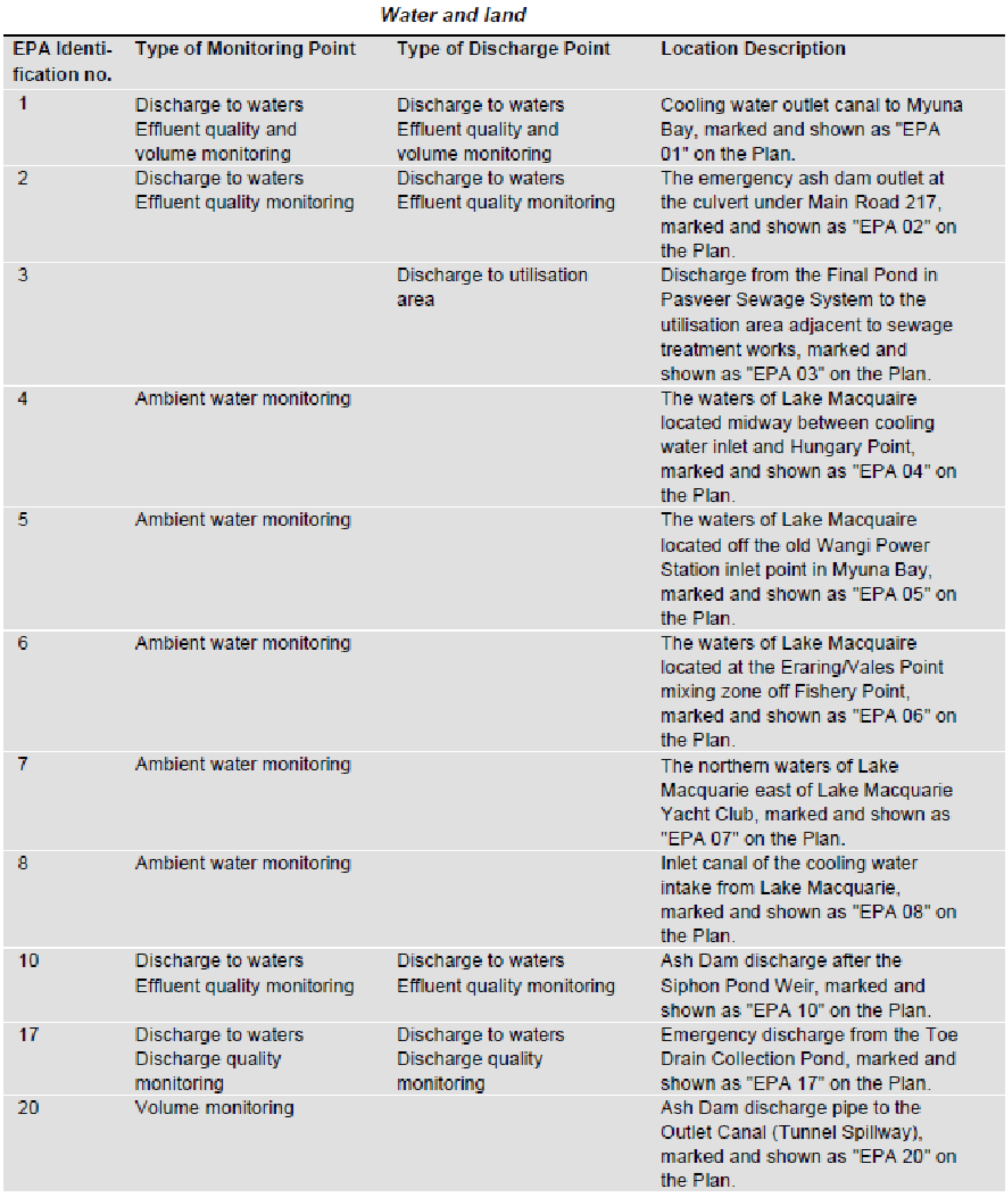


EPA Identification no.	Type of Monitoring Point	Type of Discharge Point	Location Description
21	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge of cooling water from the cooling water outlet canal to Myuna Bay marked and shown as EPA 21a and EPA 21b on The Plan
22	Discharge quality monitoring		Discharge from ash dam after the siphon pond weir marked and shown as EPA 22 on The Plan
23	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Emergency discharge from ash dam outlet at culvert under Main Road 217 marked and shown as EPA 23 on The Plan
24	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Emergency discharge from ash dam toe drain collection pond marked and shown as EPA 24 on The Plan
25	Volume monitoring		Discharge from ash dam pipe to outlet canal (tunnel spillway) marked and shown as EPA 25 on The Plan
26	Discharge to utilisation area Volume monitoring	Discharge to utilisation area Volume monitoring	Discharge of effluent from the final pond of the onsite sewage treatment system adjacent to utilisation area marked and shown as EPA 26 on The Plan
27	Ambient water quality monitoring		Water quality monitoring between cooling water inlet and Hungary Point in Lake Macquarie marked and shown as EPA 27 on The Plan

		utilisation area marked and shown as EPA 26 on The Plan
27	Ambient water quality monitoring	Water quality monitoring between cooling water inlet and Hungary Point in Lake Macquarie marked and shown as EPA 27 on The Plan
28	Ambient water quality monitoring	Water quality monitoring near the old Wangi Wangi Power Station in Lake Macquarie marked and shown as EPA 28 on The Plan
29	Ambient water quality monitoring	Water quality monitoring near the Vales Point and Eraring Power Station mixing zone off Fishery Point in Lake Macquarie marked and shown as EPA 29 on The Plan
30	Ambient water quality monitoring	Water quality monitoring east of the Lake Macquarie Yacht Club in Lake Macquarie marked and shown as EPA 30 on The Plan
31	Ambient water quality monitoring	Water quality monitoring at the inlet canal for the cooling water intake in Lake Macquarie marked and shown as EPA 31 on The Plan
32	Groundwater quality monitoring	Groundwater quality monitoring bore MW01 marked and shown as EPA 32 on The Plan
33	Groundwater quality monitoring	Groundwater quality monitoring bore MW02 marked and shown as EPA 33 on The Plan
34	Groundwater quality monitoring	Groundwater quality monitoring bore MW06 marked and shown as EPA 34 on The Plan
35	Groundwater quality monitoring	Groundwater quality monitoring bore D26 marked and shown as EPA 35 on The Plan

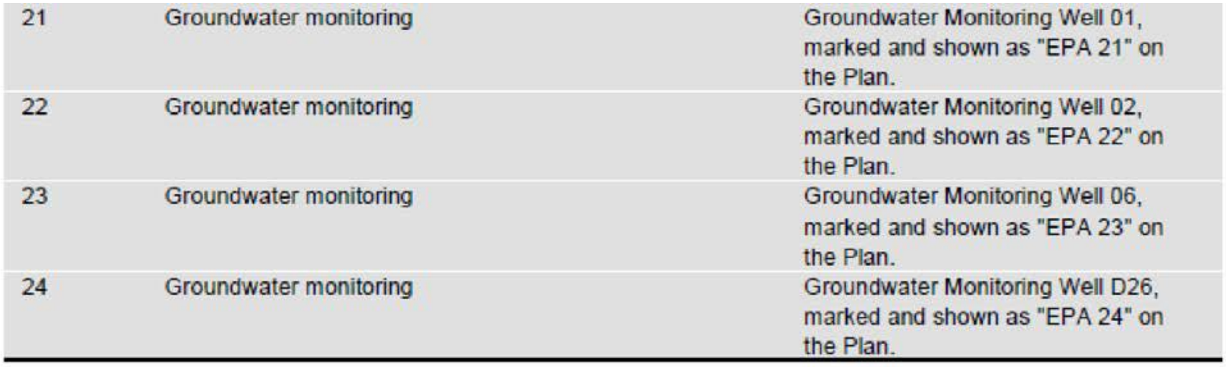
The previous EPL variation identified the same 15 monitoring points, but the identification numbers have subsequently changed.

Table 22: Previous Licenced Monitoring Points Eraring EPL



Water and land

EPA Identification no.	Type of Monitoring Point	Type of Discharge Point	Location Description
1	Discharge to waters Effluent quality and volume monitoring	Discharge to waters Effluent quality and volume monitoring	Cooling water outlet canal to Myuna Bay, marked and shown as "EPA 01" on the Plan.
2	Discharge to waters Effluent quality monitoring	Discharge to waters Effluent quality monitoring	The emergency ash dam outlet at the culvert under Main Road 217, marked and shown as "EPA 02" on the Plan.
3		Discharge to utilisation area	Discharge from the Final Pond in Pasveer Sewage System to the utilisation area adjacent to sewage treatment works, marked and shown as "EPA 03" on the Plan.
4	Ambient water monitoring		The waters of Lake Macquaire located midway between cooling water inlet and Hungary Point, marked and shown as "EPA 04" on the Plan.
5	Ambient water monitoring		The waters of Lake Macquaire located off the old Wangi Power Station inlet point in Myuna Bay, marked and shown as "EPA 05" on the Plan.
6	Ambient water monitoring		The waters of Lake Macquaire located at the Eraring/Vales Point mixing zone off Fishery Point, marked and shown as "EPA 06" on the Plan.
7	Ambient water monitoring		The northern waters of Lake Macquarie east of Lake Macquarie Yacht Club, marked and shown as "EPA 07" on the Plan.
8	Ambient water monitoring		Inlet canal of the cooling water intake from Lake Macquarie, marked and shown as "EPA 08" on the Plan.
10	Discharge to waters Effluent quality monitoring	Discharge to waters Effluent quality monitoring	Ash Dam discharge after the Siphon Pond Weir, marked and shown as "EPA 10" on the Plan.
17	Discharge to waters Discharge quality monitoring	Discharge to waters Discharge quality monitoring	Emergency discharge from the Toe Drain Collection Pond, marked and shown as "EPA 17" on the Plan.
20	Volume monitoring		Ash Dam discharge pipe to the Outlet Canal (Tunnel Spillway), marked and shown as "EPA 20" on the Plan.

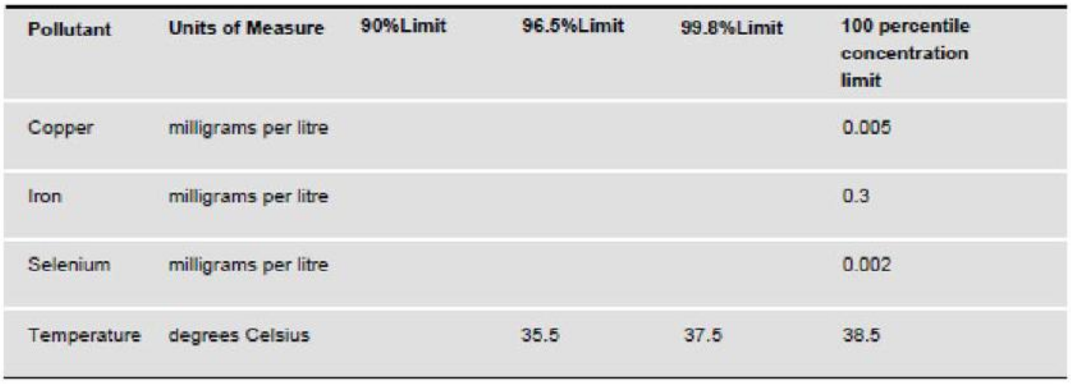


21	Groundwater monitoring	Groundwater Monitoring Well 01, marked and shown as "EPA 21" on the Plan.
22	Groundwater monitoring	Groundwater Monitoring Well 02, marked and shown as "EPA 22" on the Plan.
23	Groundwater monitoring	Groundwater Monitoring Well 06, marked and shown as "EPA 23" on the Plan.
24	Groundwater monitoring	Groundwater Monitoring Well D26, marked and shown as "EPA 24" on the Plan.

The only concentration limits prescribed in the EPL for discharge are copper (5ppb), iron (300ppb), and selenium (2ppb) in the cooling water from the cooling water outlet canal to Myuna Bay. LDP 21 was formerly numbered LDP 1 and its concentration limits are shown below.
The 5 ppb copper concentration limit at this monitoring point is almost 4 times the ANZECC/ARMANZC (2000) marine trigger value for 95% species protection (1.3 ppb) applied in NSW. Data and research to substantiate setting a concentration limit that exceeds the ANZECC (2000) 95% trigger value in terms of its biological effects has not been made available by the EPA or Origin Energy.

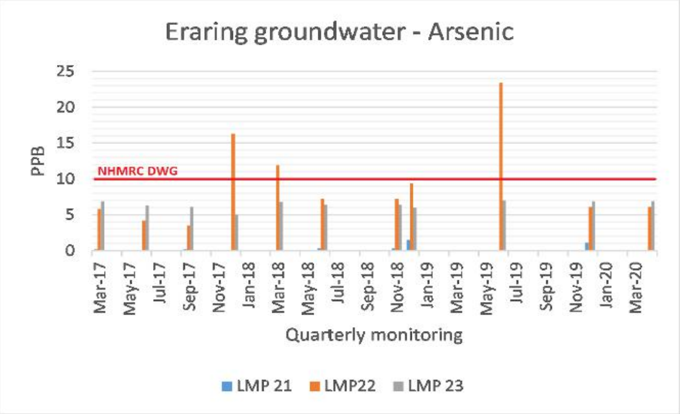
The 2ppb selenium concentration limit is acceptable and accords with the British Columbia WQGs and Lemly (2000).

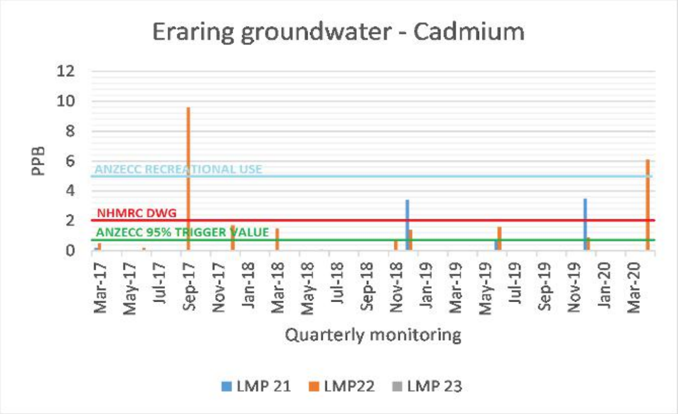
Table 23: Licenced Concentration Limits for Eraring EPL

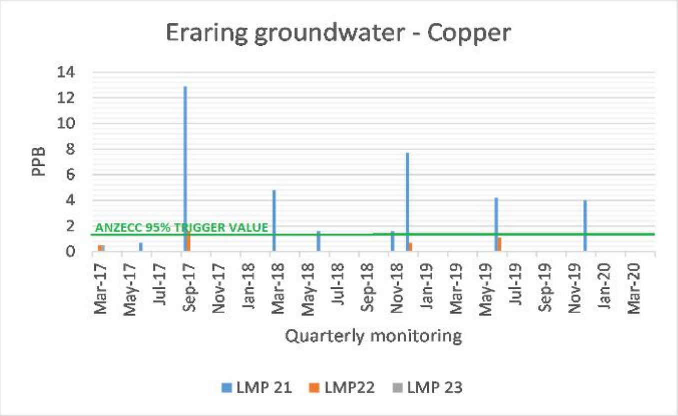


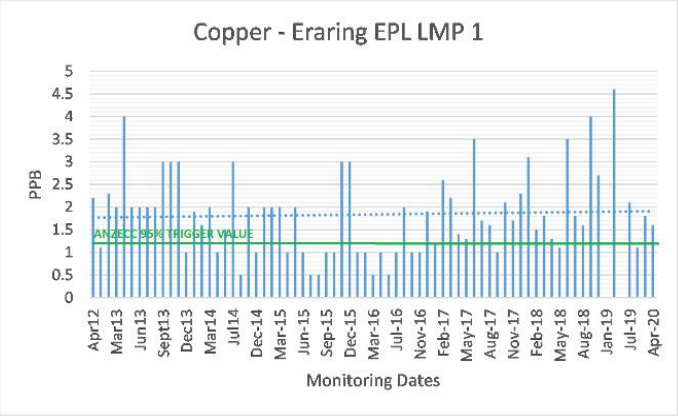
Pollutant	Units of Measure	90%Limit	96.5%Limit	99.8%Limit	100 percentile concentration limit
Copper	milligrams per litre				0.005
Iron	milligrams per litre				0.3
Selenium	milligrams per litre				0.002
Temperature	degrees Celsius		35.5	37.5	38.5

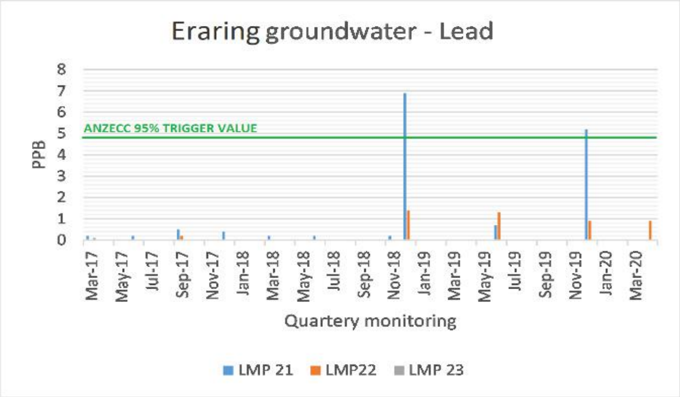
Four groundwater LMPs 32, 33, 34, and 35, were previously numbered 21, 22, 23, and 24. The following charts show concentrations of selected metals from published EPL groundwater monitoring between October 2016 and April 2020 using the old numbering. The charts show numerous exceedances of ANZECC/ARMANZC (2000) and/or NHMRC Drinking Water Guidelines (DWG) for cadmium, copper, manganese, and zinc.

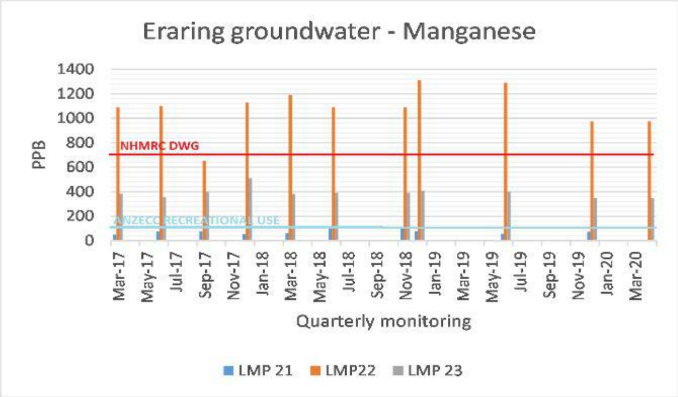

Eraring groundwater - Arsenic
PPB
25
20
15
10
5
0
NHMRC DWG
Mar-17
May-17
Jul-17
Sep-17
Nov-17
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19
Sep-19
Nov-19
Jan-20
Mar-20
Quarterly monitoring
LMP 21
LMP22
LMP 23

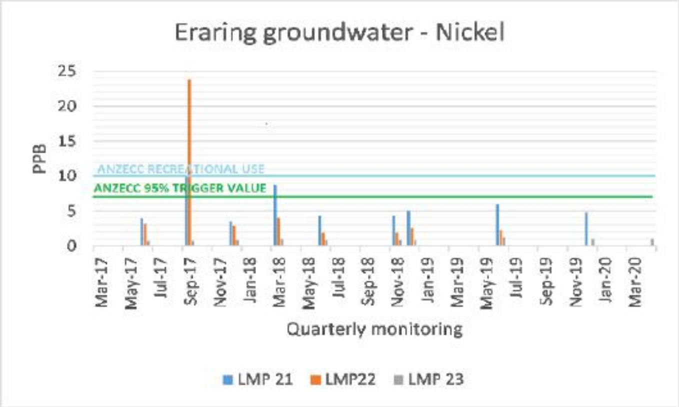

Eraring groundwater - Cadmium
PPB
12
10
8
6
4
2
0
ANZECC RECREATIONAL USE
NHMRC DWG
ANZECC 95% TRIGGER VALUE
Mar-17
May-17
Jul-17
Sep-17
Nov-17
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19
Sep-19
Nov-19
Jan-20
Mar-20
Quarterly monitoring
LMP 21
LMP22
LMP 23

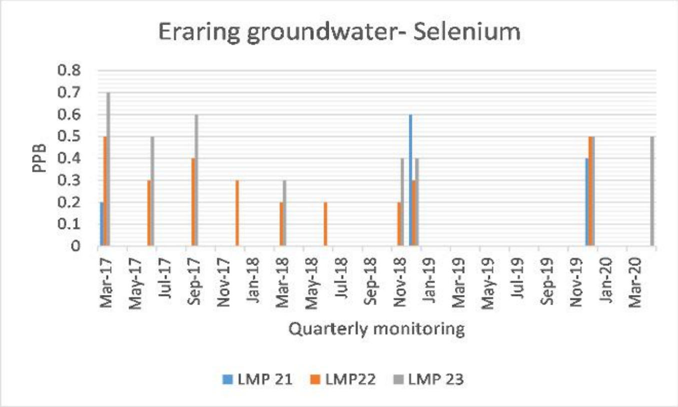

Eraring groundwater - Copper
PPB
14
12
10
8
6
4
2
0
ANZECC 95% TRIGGER VALUE
Mar-17
May-17
Jul-17
Sep-17
Nov-17
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19
Sep-19
Nov-19
Jan-20
Mar-20
Quarterly monitoring
LMP 21
LMP22
LMP 23

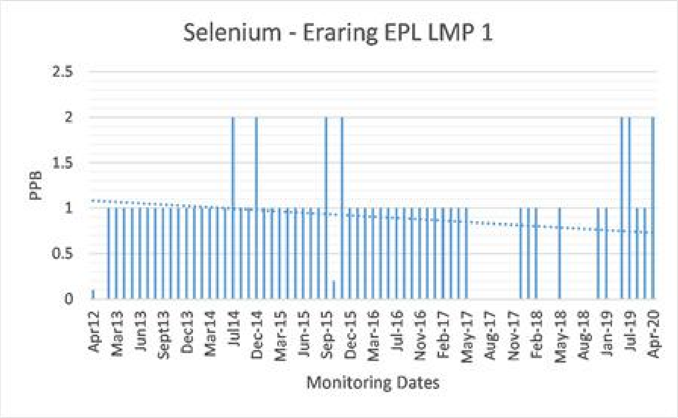

Copper - Eraring EPL LMP 1
PPB
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
ANZECC 95% TRIGGER VALUE
April2
Mar13
Jun13
Sept13
Dec13
Mar14
Jul14
Dec-14
Mar-15
Jun-15
Sep-15
Dec-15
Mar-16
Jul-16
Nov-16
Feb-17
May-17
Aug-17
Nov-17
Feb-18
May-18
Aug-18
Jan-19
Jul-19
Apr-20
Monitoring Dates

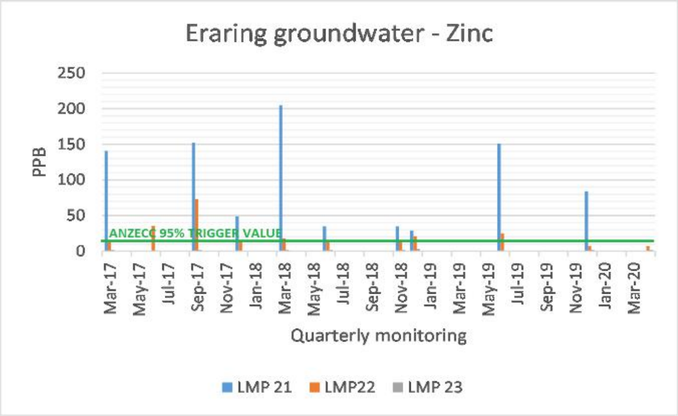

Eraring groundwater - Lead
PPB
8
7
6
5
4
3
2
1
0
ANZECC 95% TRIGGER VALUE
Mar-17
May-17
Jul-17
Sep-17
Nov-17
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19
Sep-19
Nov-19
Jan-20
Mar-20
Quartery monitoring
LMP 21
LMP22
LMP 23


Eraring groundwater - Manganese
PPB
1400
1200
1000
800
600
400
200
0
NHMRC DWG
ANZECC RECREATIONAL USE
Mar-17
May-17
Jul-17
Sep-17
Nov-17
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19
Sep-19
Nov-19
Jan-20
Mar-20
Quarterly monitoring
LMP 21
LMP22
LMP 23


Eraring groundwater - Nickel
PPB
25
20
15
10
5
0
ANZECC RECREATIONAL USE
ANZECC 95% TRIGGER VALUE
Mar-17
May-17
Jul-17
Sep-17
Nov-17
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19
Sep-19
Nov-19
Jan-20
Mar-20
Quarterly monitoring
LMP 21
LMP22
LMP 23

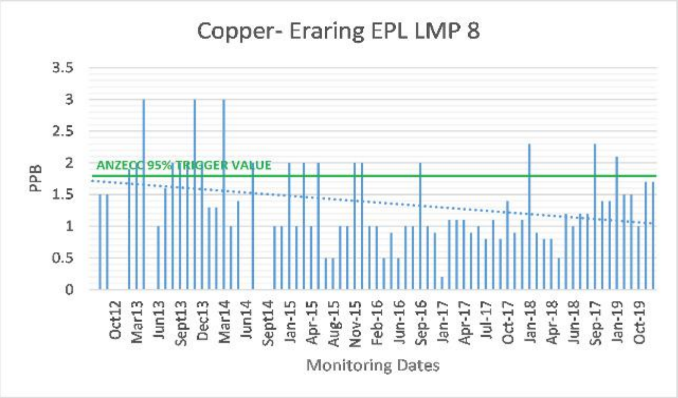

Eraring groundwater- Selenium
PPB
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Mar-17
May-17
Jul-17
Sep-17
Nov-17
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19
Sep-19
Nov-19
Jan-20
Mar-20
Quarterly monitoring
LMP 21
LMP22
LMP 23

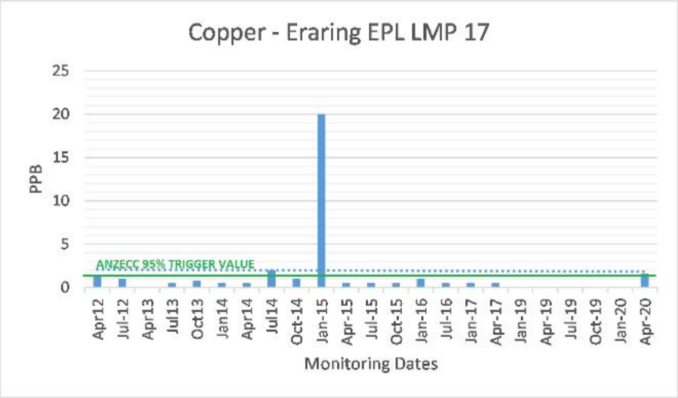


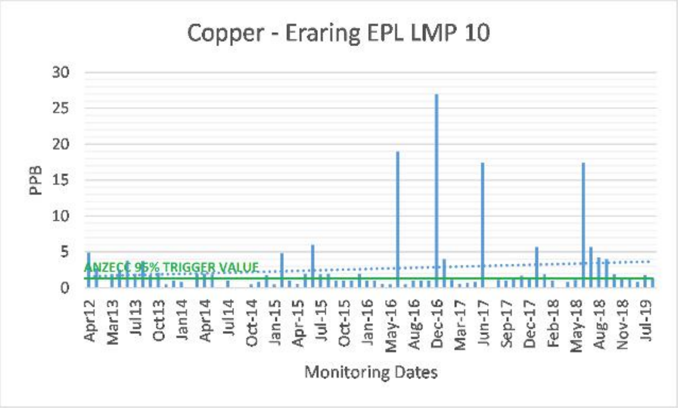


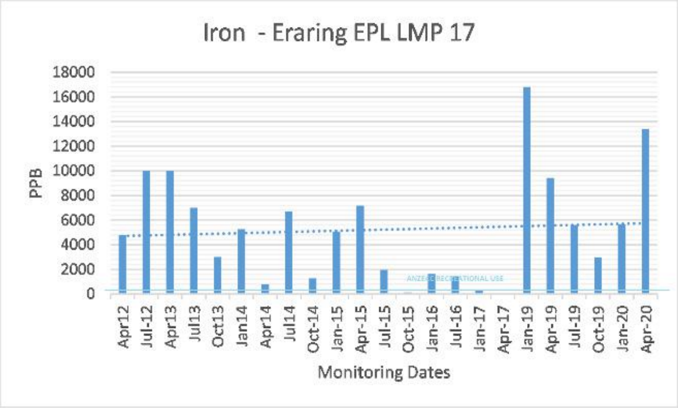
Charts 9: Eraring EPL groundwater monitoring results

The following charts show selected metal concentrations in surface water LMPs and LDPs from May 2012 to July 2019. They show consistent exceedances of ANZECC/ ARMANZC (2000) 95% trigger value for copper (below the 5ppb concentration limit) at LMPs 1, 8, and 10.









Manganese - Eraring EPL LMP 10

Manganese - Eraring EPL LMP 17

Selenium - Eraring EPL LMP 8

Selenium - Eraring EPL LMP 10

Zinc - Eraring EPL LMP 17

Zinc - Eraring EPL LMP 10

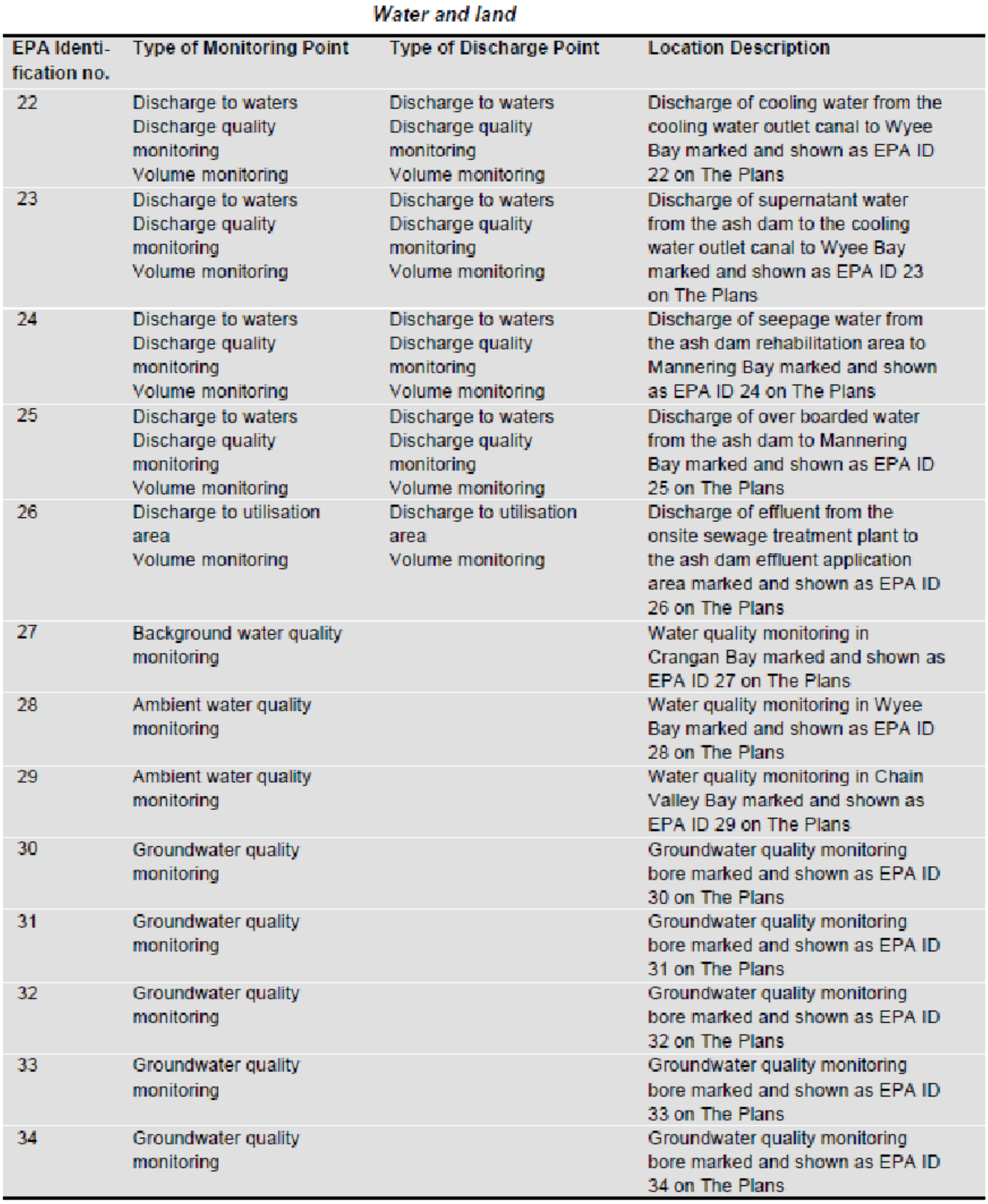
Charts 10: Eraring discharge monitoring results

The chart for LMP 17 - "Emergency discharge from ash dam toe drain collection pond" shows consistent exceedances of NHMRC DWG and ANZECC/ARMANZC (2000) recreational use guideline for manganese. LMP 17 shows consistently very high iron concentrations (>16000 ppb) well above the 300ppb recommended by ANZECC/ARMANZC (2000) for recreational use.

Vales Point EPL 761

Vales Point EPL was varied in July 2020 to add new concentration limits on discharge at the cooling water outlet to Lake Macquarie, require more monitoring, and alter the numbers labeling the 13 Licenced Monitoring Points (LMP), including five Licenced Discharge Points (LDP), five groundwater Licenced Monitoring Points (LMP), and three ambient LMPs. Prior to this variation, the monitoring requirements imposed by the EPA on this power station were woefully inadequate to identify water pollution from the site. While monitoring of the existing LMPs is a step forward, our own sampling program has identified high concentrations of metals, where official monitoring does not occur, draining into Mannering Bay from the base of the northern ash dam spillway (see chapter 6).

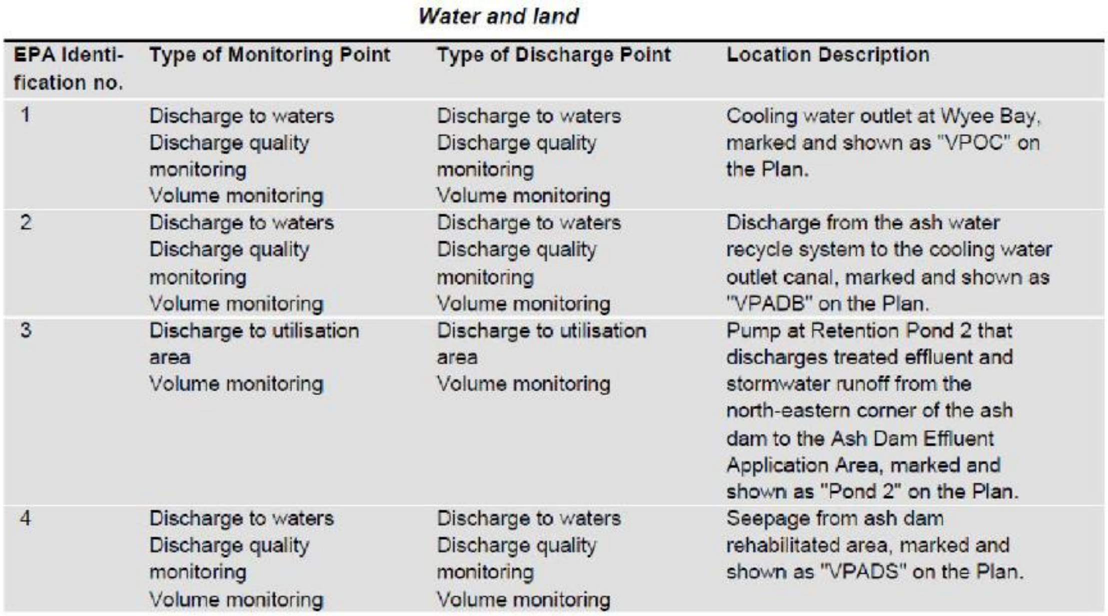
Table 24: New Licenced Monitoring Points for Vales Point EPL



Water and land

EPA Identi-fication no.	Type of Monitoring Point	Type of Discharge Point	Location Description
22	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge of cooling water from the cooling water outlet canal to Wyee Bay marked and shown as EPA ID 22 on The Plans
23	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge of supernatant water from the ash dam to the cooling water outlet canal to Wyee Bay marked and shown as EPA ID 23 on The Plans
24	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge of seepage water from the ash dam rehabilitation area to Mannering Bay marked and shown as EPA ID 24 on The Plans
25	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge of over boarded water from the ash dam to Mannering Bay marked and shown as EPA ID 25 on The Plans
26	Discharge to utilisation area Volume monitoring	Discharge to utilisation area Volume monitoring	Discharge of effluent from the onsite sewage treatment plant to the ash dam effluent application area marked and shown as EPA ID 26 on The Plans
27	Background water quality monitoring		Water quality monitoring in Crangan Bay marked and shown as EPA ID 27 on The Plans
28	Ambient water quality monitoring		Water quality monitoring in Wyee Bay marked and shown as EPA ID 28 on The Plans
29	Ambient water quality monitoring		Water quality monitoring in Chain Valley Bay marked and shown as EPA ID 29 on The Plans
30	Groundwater quality monitoring		Groundwater quality monitoring bore marked and shown as EPA ID 30 on The Plans
31	Groundwater quality monitoring		Groundwater quality monitoring bore marked and shown as EPA ID 31 on The Plans
32	Groundwater quality monitoring		Groundwater quality monitoring bore marked and shown as EPA ID 32 on The Plans
33	Groundwater quality monitoring		Groundwater quality monitoring bore marked and shown as EPA ID 33 on The Plans
34	Groundwater quality monitoring		Groundwater quality monitoring bore marked and shown as EPA ID 34 on The Plans

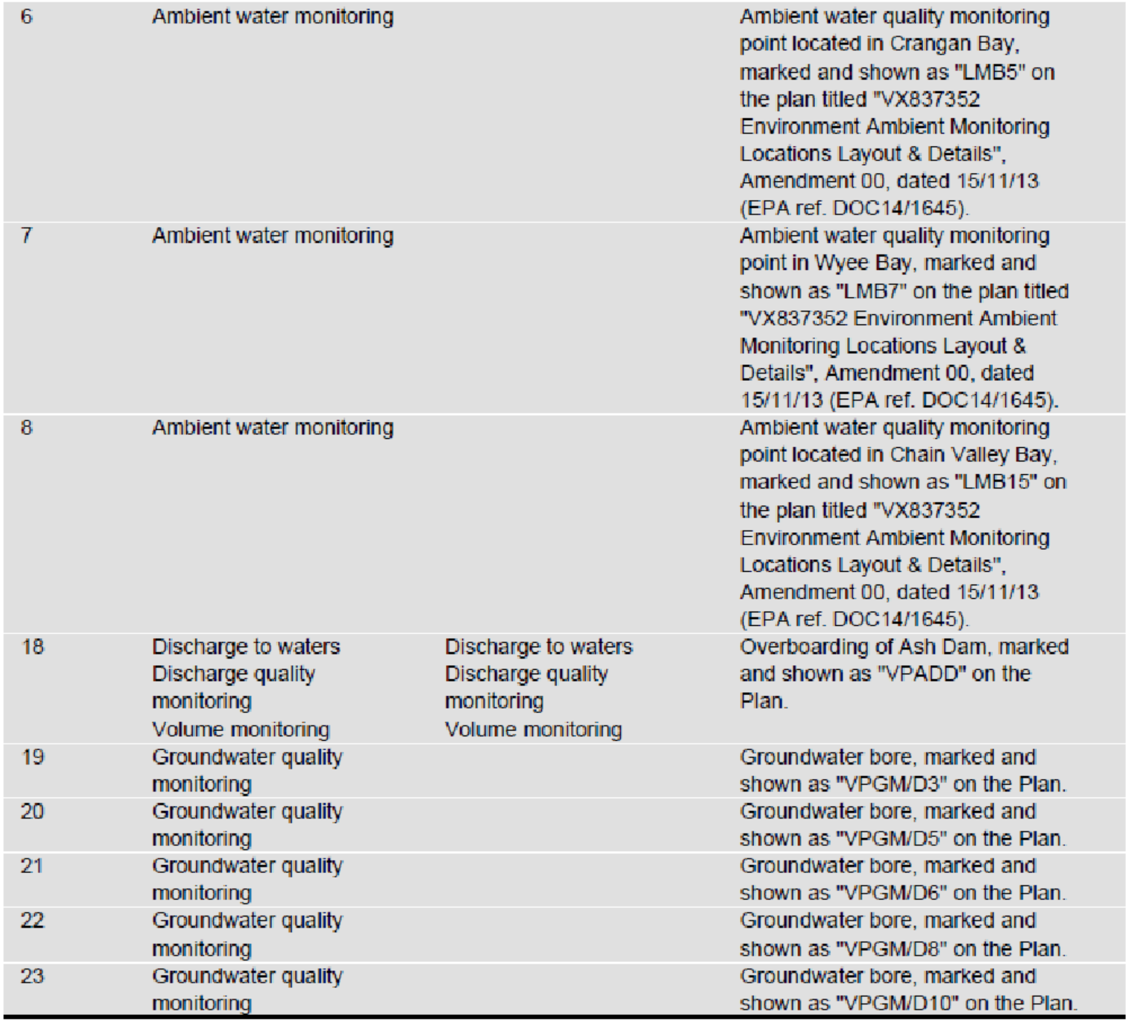
The previous EPL variation identified 13 Licenced Monitoring Points (LMP), including five Licenced Discharge Points (LDP), five groundwater LMPs, and three ambient LMPs.



Water and land

EPA Identi-fication no.	Type of Monitoring Point	Type of Discharge Point	Location Description
1	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Cooling water outlet at Wyee Bay, marked and shown as "VPOC" on the Plan.
2	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge from the ash water recycle system to the cooling water outlet canal, marked and shown as "VPADB" on the Plan.
3	Discharge to utilisation area Volume monitoring	Discharge to utilisation area Volume monitoring	Pump at Retention Pond 2 that discharges treated effluent and stormwater runoff from the north-eastern corner of the ash dam to the Ash Dam Effluent Application Area, marked and shown as "Pond 2" on the Plan.
4	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Seepage from ash dam rehabilitated area, marked and shown as "VPADS" on the Plan.

Table 24: Previous Licenced Monitoring Points for Vales Point EPL



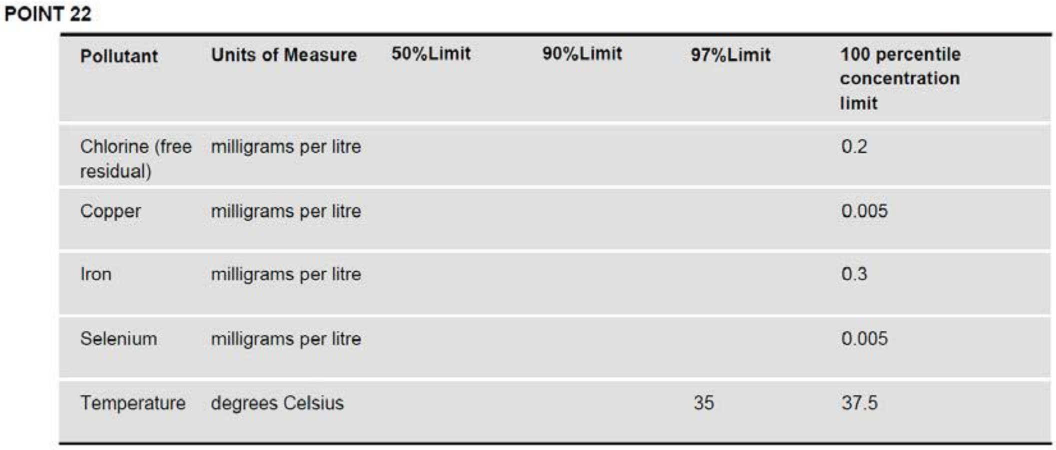
6	Ambient water monitoring		Ambient water quality monitoring point located in Crangan Bay, marked and shown as "LMB5" on the plan titled "VX837352 Environment Ambient Monitoring Locations Layout & Details", Amendment 00, dated 15/11/13 (EPA ref. DOC14/1645).
7	Ambient water monitoring		Ambient water quality monitoring point in Wyee Bay, marked and shown as "LMB7" on the plan titled "VX837352 Environment Ambient Monitoring Locations Layout & Details", Amendment 00, dated 15/11/13 (EPA ref. DOC14/1645).
8	Ambient water monitoring		Ambient water quality monitoring point located in Chain Valley Bay, marked and shown as "LMB15" on the plan titled "VX837352 Environment Ambient Monitoring Locations Layout & Details", Amendment 00, dated 15/11/13 (EPA ref. DOC14/1645).
18	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Overboarding of Ash Dam, marked and shown as "VPADD" on the Plan.
19	Groundwater quality monitoring		Groundwater bore, marked and shown as "VPGM/D3" on the Plan.
20	Groundwater quality monitoring		Groundwater bore, marked and shown as "VPGM/D5" on the Plan.
21	Groundwater quality monitoring		Groundwater bore, marked and shown as "VPGM/D6" on the Plan.
22	Groundwater quality monitoring		Groundwater bore, marked and shown as "VPGM/D8" on the Plan.
23	Groundwater quality monitoring		Groundwater bore, marked and shown as "VPGM/D10" on the Plan.

: Condition L7 specifies the limit conditions specific to discharges from Monitoring and Discharge Point 18.

Since July 2017 ash dam seepage (discharge at LDP4 – to Mannering Bay) has been captured and pumped back to the ash dam. There has been no licence 'discharge to waters' (i.e. to Mannering Bay) reported by Vales Point under its EPL since July 2017.

LDP 18 – "Overboard from ash dam" only reported discharge in July and August 2013 and May 2015.

Up until July 2020, Vales Point's EPL did not prescribe any metal concentration limits for any of its five discharge points. The latest variation prescribes free residual chlorine (200ppb) copper (5ppb), iron (300ppb), selenium (5ppb), and temperature (37.7C) limits at LDP 22 (formerly LDP 1 -Discharge of cooling water from the cooling water outlet canal to Wyee Bay).

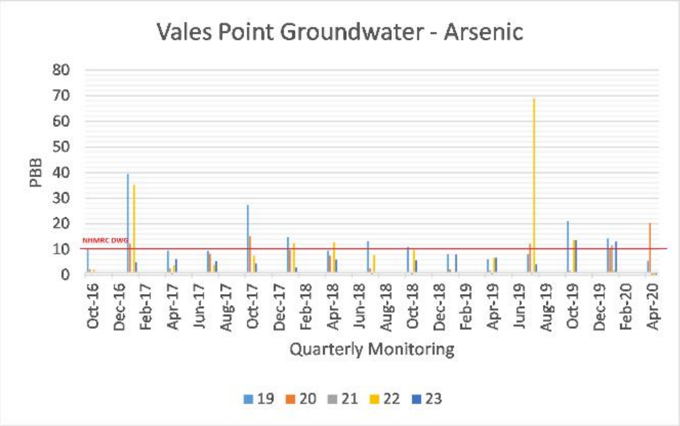


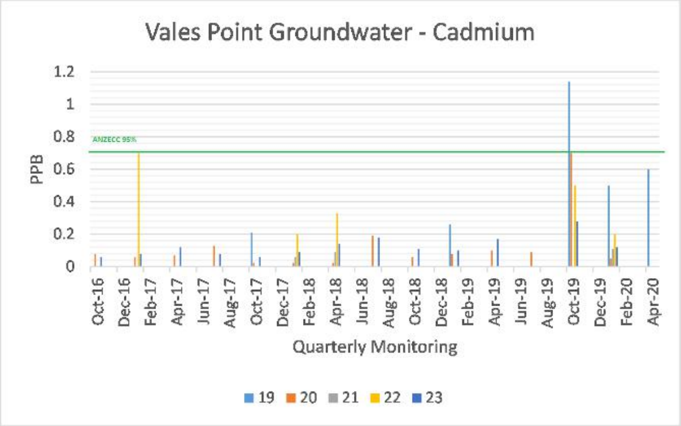
POINT 22

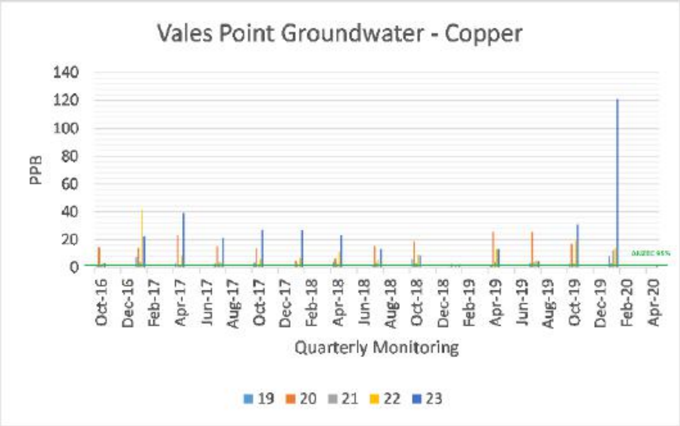
Pollutant	Units of Measure	50%Limit	90%Limit	97%Limit	100 percentile concentration limit
Chlorine (free residual)	milligrams per litre				0.2
Copper	milligrams per litre				0.005
Iron	milligrams per litre				0.3
Selenium	milligrams per litre				0.005
Temperature	degrees Celsius			35	37.5

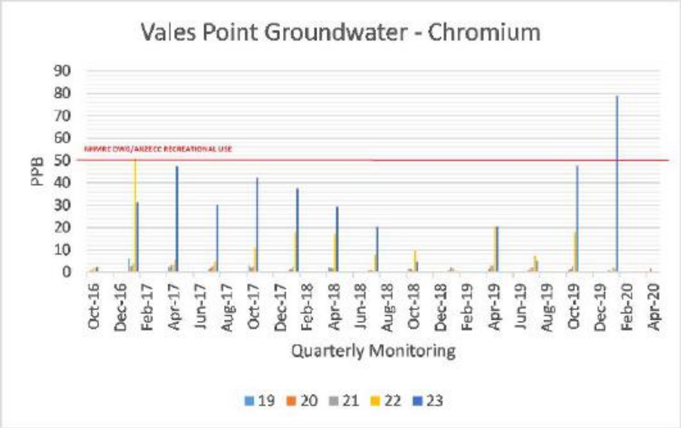
Table 25: New concentration limits for Point 22 (formerly LDP 1) for Vales Point EPL

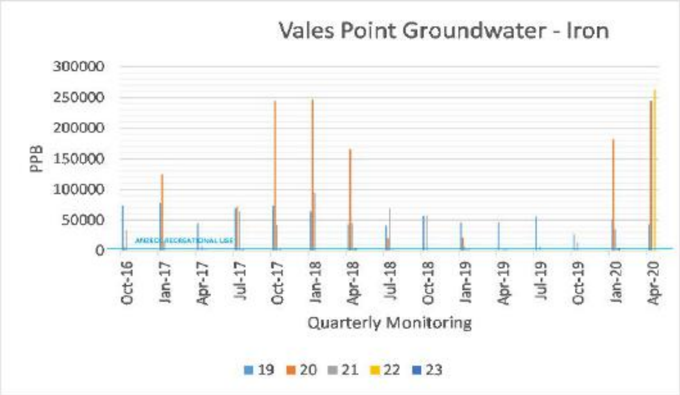
The following charts show concentrations of selected metals from published EPL groundwater monitoring results for Vales Point between October 2016 and April 2020. The charts show consistent exceedances of ANZECC/ARMANZC (2000) and/or NHMRC Drinking Water Guidelines (DWG) for arsenic, copper, iron, lead, manganese, nickel, selenium, and zinc.

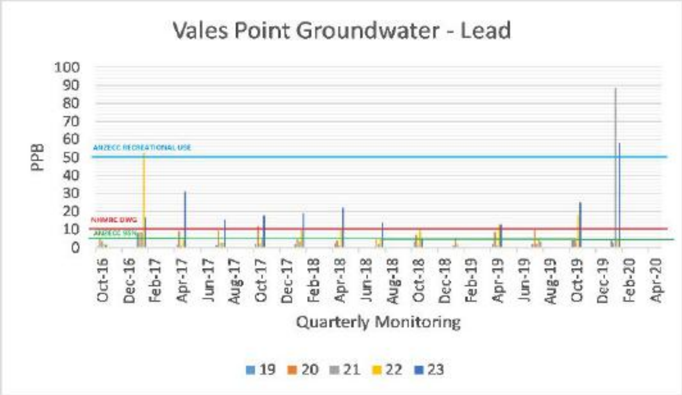

Vales Point Groundwater - Arsenic
PBB
0
10
20
30
40
50
60
70
80
NHMRC DWG
Oct-16
Dec-16
Feb-17
Apr-17
Jun-17
Aug-17
Oct-17
Dec-17
Feb-18
Apr-18
Jun-18
Aug-18
Oct-18
Dec-18
Feb-19
Apr-19
Jun-19
Aug-19
Oct-19
Dec-19
Feb-20
Apr-20
Quarterly Monitoring
19
20
21
22
23

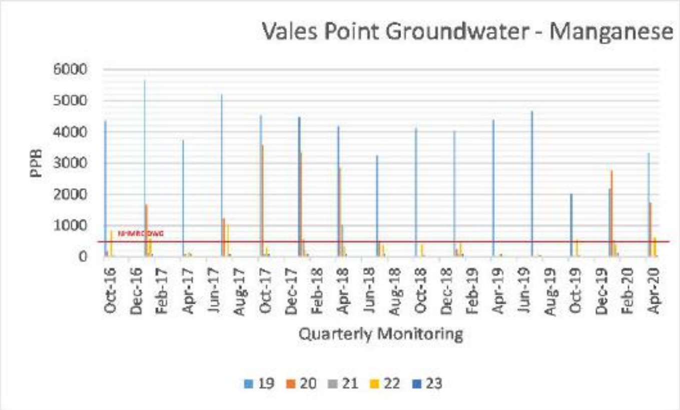

Vales Point Groundwater - Cadmium
PPB
0
0.2
0.4
0.6
0.8
1
1.2
ANZECC 95%
Oct-16
Dec-16
Feb-17
Apr-17
Jun-17
Aug-17
Oct-17
Dec-17
Feb-18
Apr-18
Jun-18
Aug-18
Oct-18
Dec-18
Feb-19
Apr-19
Jun-19
Aug-19
Oct-19
Dec-19
Feb-20
Apr-20
Quarterly Monitoring
19
20
21
22
23

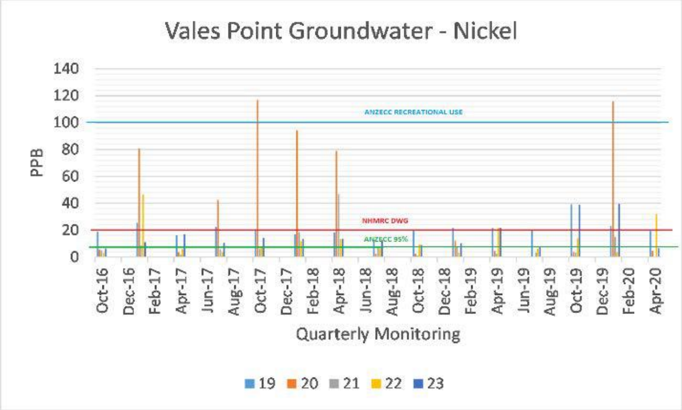

Vales Point Groundwater - Copper
PPB
0
20
40
60
80
100
120
140
ANZECC 95%
Oct-16
Dec-16
Feb-17
Apr-17
Jun-17
Aug-17
Oct-17
Dec-17
Feb-18
Apr-18
Jun-18
Aug-18
Oct-18
Dec-18
Feb-19
Apr-19
Jun-19
Aug-19
Oct-19
Dec-19
Feb-20
Apr-20
Quarterly Monitoring
19
20
21
22
23

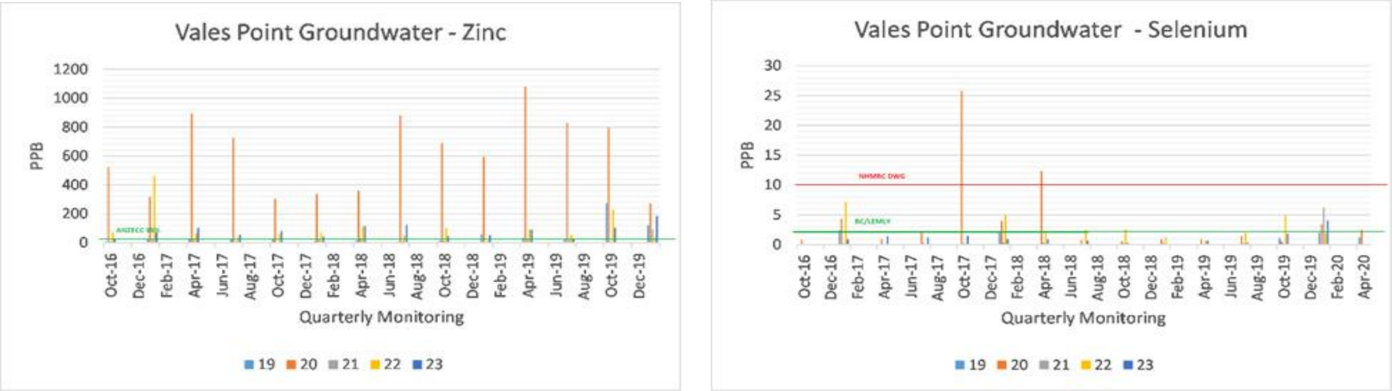

Vales Point Groundwater - Chromium
PPB
0
10
20
30
40
50
60
70
80
90
NHMRC DWG/ANZECC RECREATIONAL USE
Oct-16
Dec-16
Feb-17
Apr-17
Jun-17
Aug-17
Oct-17
Dec-17
Feb-18
Apr-18
Jun-18
Aug-18
Oct-18
Dec-18
Feb-19
Apr-19
Jun-19
Aug-19
Oct-19
Dec-19
Feb-20
Apr-20
Quarterly Monitoring
19
20
21
22
23


Vales Point Groundwater - Iron
PPB
0
50000
100000
150000
200000
250000
300000
ANZECC RECREATIONAL USE
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Apr-20
Quarterly Monitoring
19
20
21
22
23


Vales Point Groundwater - Lead
PPB
0
10
20
30
40
50
60
70
80
90
100
ANZECC RECREATIONAL USE
NHMRC DWG
ANZECC 95%
Oct-16
Dec-16
Feb-17
Apr-17
Jun-17
Aug-17
Oct-17
Dec-17
Feb-18
Apr-18
Jun-18
Aug-18
Oct-18
Dec-18
Feb-19
Apr-19
Jun-19
Aug-19
Oct-19
Dec-19
Feb-20
Apr-20
Quarterly Monitoring
19
20
21
22
23


Vales Point Groundwater - Manganese
PPB
0
1000
2000
3000
4000
5000
6000
NHMRC DWG
Oct-16
Dec-16
Feb-17
Apr-17
Jun-17
Aug-17
Oct-17
Dec-17
Feb-18
Apr-18
Jun-18
Aug-18
Oct-18
Dec-18
Feb-19
Apr-19
Jun-19
Aug-19
Oct-19
Dec-19
Feb-20
Apr-20
Quarterly Monitoring
19
20
21
22
23

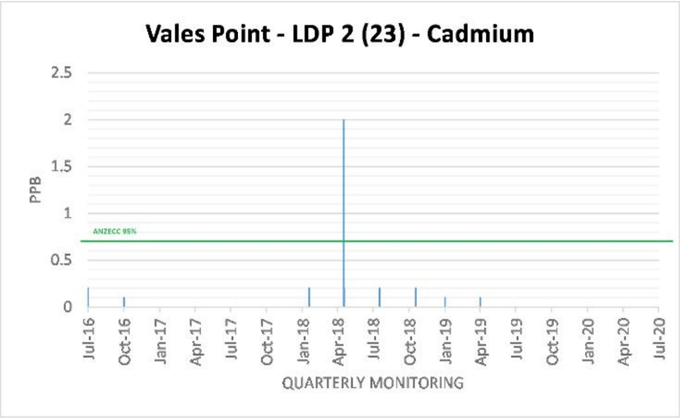

Vales Point Groundwater - Nickel
PPB
0
20
40
60
80
100
120
140
ANZECC RECREATIONAL USE
NHMRC DWG
ANZECC 95%
Oct-16
Dec-16
Feb-17
Apr-17
Jun-17
Aug-17
Oct-17
Dec-17
Feb-18
Apr-18
Jun-18
Aug-18
Oct-18
Dec-18
Feb-19
Apr-19
Jun-19
Aug-19
Oct-19
Dec-19
Feb-20
Apr-20
Quarterly Monitoring
19
20
21
22
23

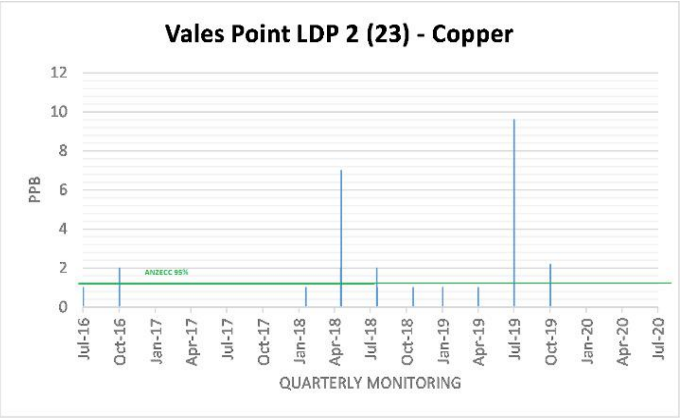


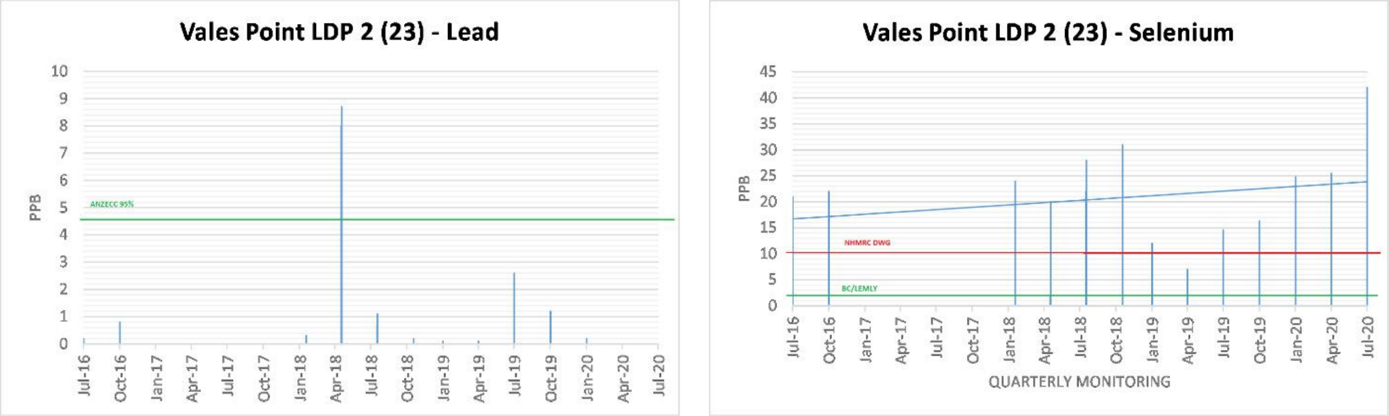
Charts 11: Vales Point groundwater monitoring results

The following charts show published EPL monitoring results for selected metal concentrations in ash dam water discharged into the cooling water canal (LDP 23 – formerly LDP 2).

The charts shows occasional exceedances of ANZECC/ARMANZC (2000) for **cadmium, copper, and lead,** and consistent exceedances of NHMRC DWG for **selenium**. The trend for discharged **selenium** concentrations is increasing with 42 ppb discharged in July 2020 into the cooling water outflow.







Charts 12: Vales Point EPL discharge monitoring results

Upper Coxs River

Mount Piper EPL 13007

The Mount Piper EPL was varied in August 2020 to include substantial changes to water quality monitoring. The new Licence identifies 14 Licenced Monitoring Points, including nine groundwater LMPs, three surface water quality LMPs, and one LDP.

Table 26: New Licenced Monitoring Points for Mount Piper EPL

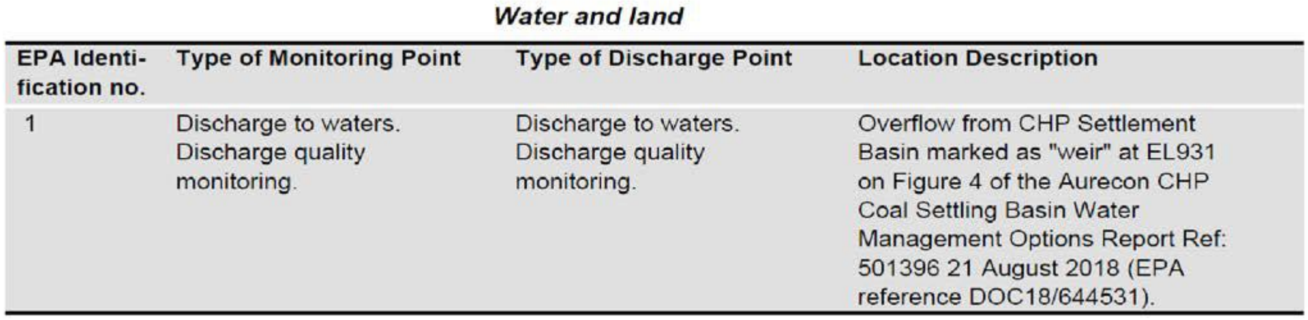
Water and land

EPA Identi-fication no.	Type of Monitoring Point	Type of Discharge Point	Location Description
12	Discharge to waters Discharge quality monitoring Discharge volume monitoring	Discharge to waters Discharge quality monitoring Discharge volume monitoring	Overflow from CHP Settlement Basin marked as "weir" at EL931 on Figure 4 of the Aurecon CHP Coal Settling Basin Water Management Options Report Ref: 501396 21 August 2018 (EPA reference DOC18/644531).
13	Groundwater quality monitoring		Groundwater monitoring point D10 as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)
14	Groundwater quality monitoring		Groundwater monitoring point D102 as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)
15	Groundwater quality monitoring		Groundwater monitoring point D103 as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)
16	Groundwater quality monitoring		Groundwater monitoring point D104 as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)
17	Groundwater quality monitoring		Groundwater monitoring point D105 as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)
18	Groundwater quality monitoring		Groundwater monitoring point D106 as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)

19	Groundwater quality monitoring	Groundwater monitoring point D107 as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)
20	Groundwater quality monitoring	Groundwater monitoring point D113 as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)
21	Groundwater quality monitoring	Groundwater monitoring point D3 as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)
22	Surface water quality monitoring	Surface water monitoring point C as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)
23	Surface water quality monitoring	Surface water monitoring point E as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)
24	Surface water quality monitoring	Surface water monitoring point F as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)
25	Surface water quality monitoring	Surface water monitoring point G as shown on figure Groundwater and Surface Water Sampling Location ERM letter dated 21 November 2018 received by the EPA on 23 November 2018 (DOC19/854888)

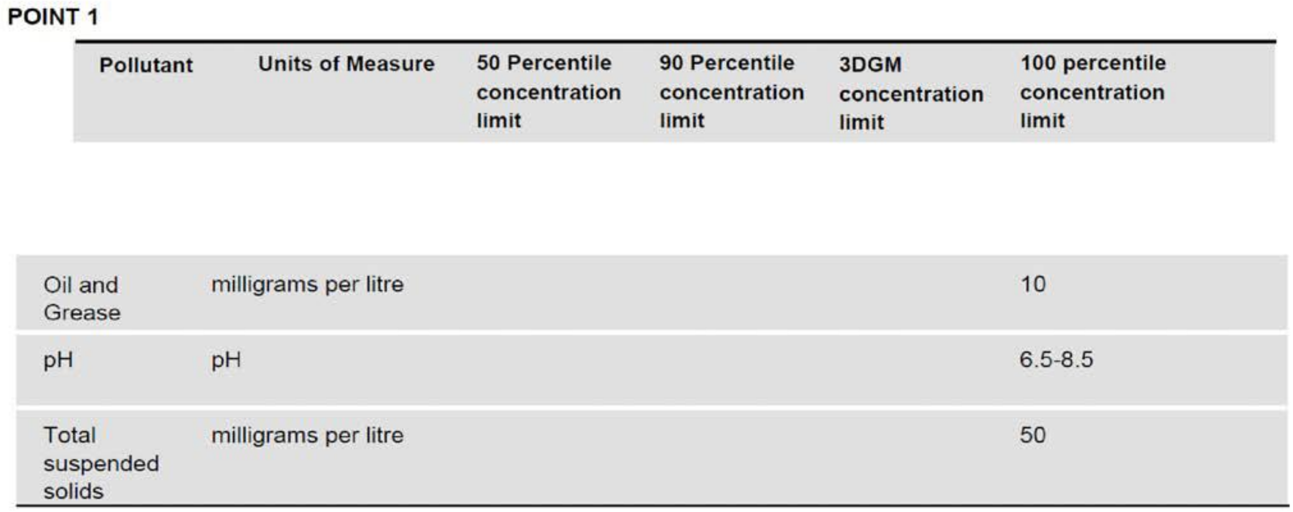
Previously, the EPL prescribed no monitoring for metals, only for Total Suspended Solids (TSS), pH, and Oil and Grease. Following the variation, the EPL now requires extensive monitoring of metals at 13 locations comprising nine groundwater and four surface water LMPs. However, the EPL still fails to set any concentration limits for metals at all discharge points.

Table 27: Concentration limits for former Point 1 (now 12) under the previous variation of Mount Piper EPL



Water and land

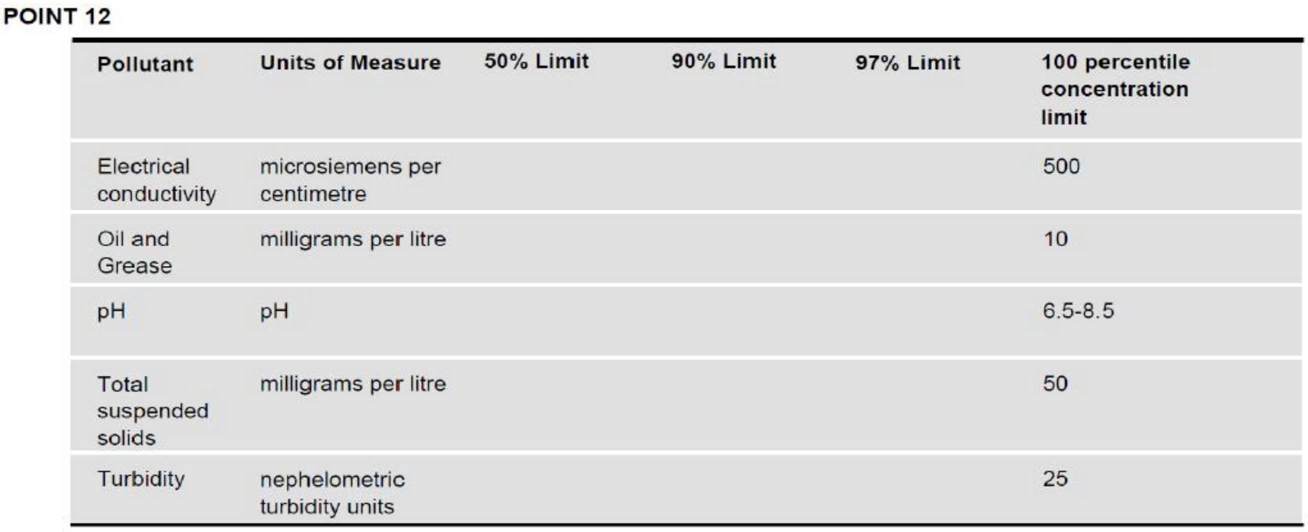
EPA Identi-fication no.	Type of Monitoring Point	Type of Discharge Point	Location Description
1	Discharge to waters. Discharge quality monitoring.	Discharge to waters. Discharge quality monitoring.	Overflow from CHP Settlement Basin marked as "weir" at EL931 on Figure 4 of the Aurecon CHP Coal Settling Basin Water Management Options Report Ref: 501396 21 August 2018 (EPA reference DOC18/644531).



POINT 1

Pollutant	Units of Measure	50 Percentile concentration limit	90 Percentile concentration limit	3DGM concentration limit	100 percentile concentration limit
Oil and Grease	milligrams per litre				10
pH	pH				6.5-8.5
Total suspended solids	milligrams per litre				50

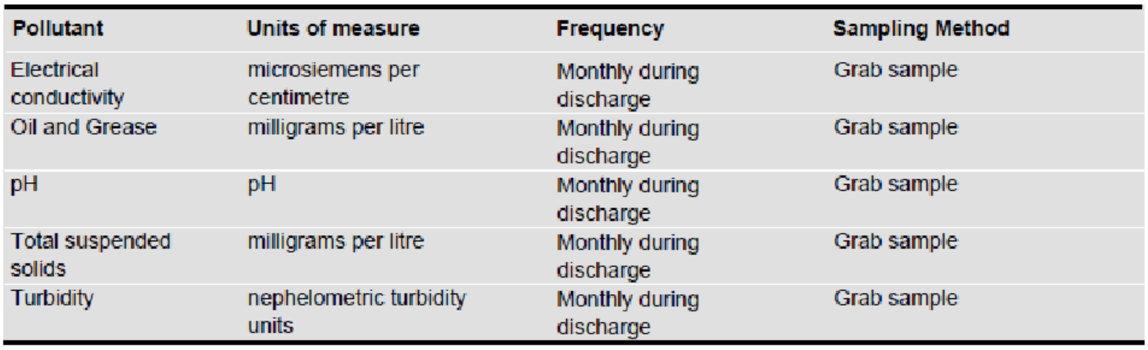
Table 28: Concentration limits for new Point 12 (former LMP 1) under the new variation of Mount Piper EPL



POINT 12

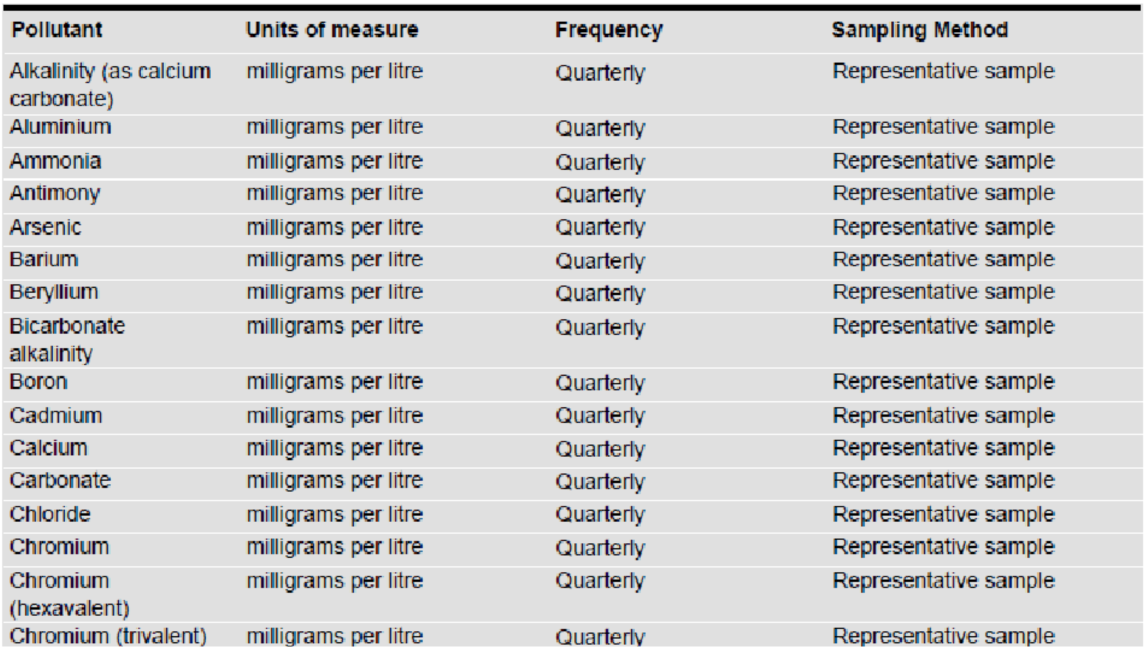
Pollutant	Units of Measure	50% Limit	90% Limit	97% Limit	100 percentile concentration limit
Electrical conductivity	microsiemens per centimetre				500
Oil and Grease	milligrams per litre				10
pH	pH				6.5-8.5
Total suspended solids	milligrams per litre				50
Turbidity	nephelometric turbidity units				25

Table 29: Monitoring parameters under the new variation of Mount Piper EPL



Pollutant	Units of measure	Frequency	Sampling Method
Electrical conductivity	microsiemens per centimetre	Monthly during discharge	Grab sample
Oil and Grease	milligrams per litre	Monthly during discharge	Grab sample
pH	pH	Monthly during discharge	Grab sample
Total suspended solids	milligrams per litre	Monthly during discharge	Grab sample
Turbidity	nephelometric turbidity units	Monthly during discharge	Grab sample

POINT 13,14,15,16,17,18,19,20,21



Pollutant	Units of measure	Frequency	Sampling Method
Alkalinity (as calcium carbonate)	milligrams per litre	Quarterly	Representative sample
Aluminium	milligrams per litre	Quarterly	Representative sample
Ammonia	milligrams per litre	Quarterly	Representative sample
Antimony	milligrams per litre	Quarterly	Representative sample
Arsenic	milligrams per litre	Quarterly	Representative sample
Barium	milligrams per litre	Quarterly	Representative sample
Beryllium	milligrams per litre	Quarterly	Representative sample
Bicarbonate alkalinity	milligrams per litre	Quarterly	Representative sample
Boron	milligrams per litre	Quarterly	Representative sample
Cadmium	milligrams per litre	Quarterly	Representative sample
Calcium	milligrams per litre	Quarterly	Representative sample
Carbonate	milligrams per litre	Quarterly	Representative sample
Chloride	milligrams per litre	Quarterly	Representative sample
Chromium	milligrams per litre	Quarterly	Representative sample
Chromium (hexavalent)	milligrams per litre	Quarterly	Representative sample
Chromium (trivalent)	milligrams per litre	Quarterly	Representative sample

Copper	milligrams per litre	Quarterly	Representative sample
Dissolved Oxygen	milligrams per litre	Quarterly	Representative sample
Electrical conductivity	microsiemens per centimetre	Quarterly	Representative sample
Iron	milligrams per litre	Quarterly	Representative sample
Lead	milligrams per litre	Quarterly	Representative sample
Magnesium	milligrams per litre	Quarterly	Representative sample
Manganese	milligrams per litre	Quarterly	Representative sample
Mercury	milligrams per litre	Quarterly	Representative sample
Molybdenum	milligrams per litre	Quarterly	Representative sample
Nickel	milligrams per litre	Quarterly	Representative sample
Nitrate	milligrams per litre	Quarterly	Representative sample
Nitrate + nitrite (oxidised nitrogen)	milligrams per litre	Quarterly	Representative sample
Nitrite	milligrams per litre	Quarterly	Representative sample
pH	pH	Quarterly	Representative sample
Potassium	milligrams per litre	Quarterly	Representative sample
Selenium	milligrams per litre	Quarterly	Representative sample
Silver	milligrams per litre	Quarterly	Representative sample
Sodium	milligrams per litre	Quarterly	Representative sample
Standing Water Level	metres	Quarterly	In situ
Sulfate	milligrams per litre	Quarterly	Representative sample
Sulfur	milligrams per litre	Quarterly	Representative sample
Total dissolved solids	milligrams per litre	Quarterly	Representative sample
Vanadium	milligrams per litre	Quarterly	Representative sample
Zinc	milligrams per litre	Quarterly	Representative sample

POINT 22,23,24,25

Pollutant	Units of measure	Frequency	Sampling Method
Alkalinity (as calcium carbonate)	milligrams per litre	Monthly	Grab sample
Aluminium	milligrams per litre	Monthly	Grab sample
Ammonia	milligrams per litre	Monthly	Grab sample
Antimony	milligrams per litre	Monthly	Grab sample
Arsenic	milligrams per litre	Monthly	Grab sample
Barium	milligrams per litre	Monthly	Grab sample
Beryllium	milligrams per litre	Monthly	Grab sample
Bicarbonate alkalinity	milligrams per litre	Monthly	Grab sample
Boron	milligrams per litre	Monthly	Grab sample
Cadmium	milligrams per litre	Monthly	Grab sample
Calcium	milligrams per litre	Monthly	Grab sample
Chloride	milligrams per litre	Monthly	Grab sample
Chromium	milligrams per litre	Monthly	Grab sample

Cobalt	milligrams per litre	Monthly	Grab sample
Copper	milligrams per litre	Monthly	Grab sample
Dissolved Oxygen	milligrams per litre	Monthly	Grab sample
Electrical conductivity	microsiemens per centimetre	Monthly	Grab sample
Iron	milligrams per litre	Monthly	Grab sample
Lead	milligrams per litre	Monthly	Grab sample
Magnesium	milligrams per litre	Monthly	Grab sample
Manganese	milligrams per litre	Monthly	Grab sample
Mercury	milligrams per litre	Monthly	Grab sample
Molybdenum	milligrams per litre	Monthly	Grab sample
Nickel	milligrams per litre	Monthly	Grab sample
Nitrate	milligrams per litre	Monthly	Grab sample
Nitrate + nitrite (oxidised nitrogen)	milligrams per litre	Monthly	Grab sample
Nitrite	milligrams per litre	Monthly	Grab sample
pH	pH	Monthly	Grab sample
Potassium	milligrams per litre	Monthly	Grab sample
Selenium	milligrams per litre	Monthly	Grab sample
Silver	milligrams per litre	Monthly	Grab sample
Sodium	milligrams per litre	Monthly	Grab sample
Sulfate	milligrams per litre	Monthly	Grab sample
Sulfur	milligrams per litre	Monthly	Grab sample
Total dissolved solids	milligrams per litre	Monthly	Grab sample
Vanadium	milligrams per litre	Monthly	Grab sample
Zinc	milligrams per litre	Monthly	Grab sample

photo: Vales Point power station ash dam rehabilitation

HCEC surface water and sediment testing

Central Hunter Valley

Bayswater and Liddell

HCEC collected water and sediment samples from the waterways draining AGL's Bayswater and Liddell ash dumps on 29 July 2020. These included:

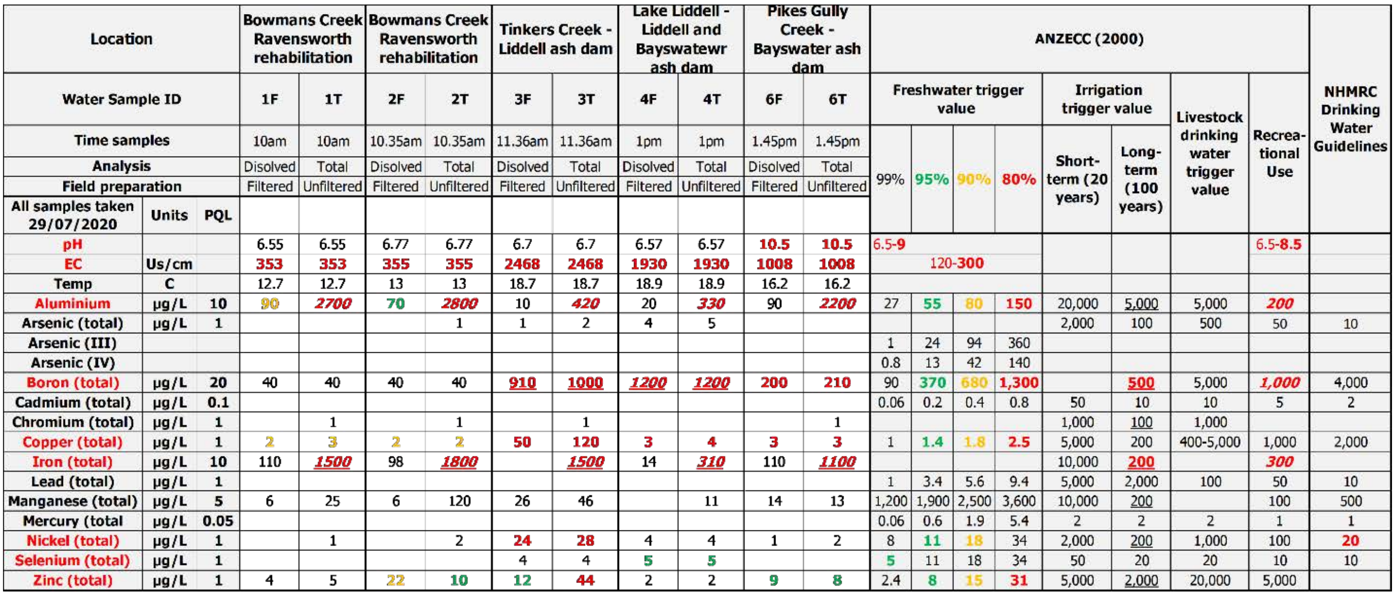
- Site 1 and 2. Two sites on Bowmans Creek, which drains from the Ravensworth Rehabilitation Project, where AGL dump their Bayswater fly ash;
- Site 3. Tinkers Creek that drains from the Liddell ash dam;
- Site 4. Lake Liddell, where both Liddell and Bayswater ash dams drain;
- Site 6. Pikes Gully Creek which drains seepage from the Bayswater Ash Dam were found to contain.

All samples analysed exceeded ANZECC/ARMANZC (2000) and/or NHMRC DWG for **pH, EC, aluminium, boron, copper, iron, nickel, selenium, and/or zinc.**

Figure 1: Central Hunter River Valley including Lake Liddell, Liddell and Bayswater Power Stations and ash dumps

WATER SAMPLES

Table 30: Results of HCEC's Central Hunter Valley water sampling



Location			Bowmans Creek Ravensworth rehabilitation		Bowmans Creek Ravensworth rehabilitation		Tinkers Creek - Liddell ash dam		Lake Liddell - Liddell and Bayswatewr ash dam		Pikes Gully Creek - Bayswater ash dam		ANZECC (2000)								NHMRC Drinking Water Guidelines
Water Sample ID			1F	1T	2F	2T	3F	3T	4F	4T	6F	6T	Freshwater trigger value				Irrigation trigger value		Livestock drinking water trigger value	Recrea-tional Use	
Time samples			10am	10am	10.35am	10.35am	11.36am	11.36am	1pm	1pm	1.45pm	1.45pm	99%	95%	90%	80%	Short-term (20 years)	Long-term (100 years)			
Analysis			Disolved	Total	Disolved	Total	Disolved	Total	Disolved	Total	Disolved	Total									
Field preparation			Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered									
All samples taken 29/07/2020	Units	PQL																			
pH			6.55	6.55	6.77	6.77	6.7	6.7	6.57	6.57	**10.5**	**10.5**	6.5-**9**							6.5-**8.5**	
EC	Us/cm		**353**	**353**	**355**	**355**	**2468**	**2468**	**1930**	**1930**	**1008**	**1008**	120-**300**								
Temp	C		12.7	12.7	13	13	18.7	18.7	18.9	18.9	16.2	16.2									
Aluminium	µg/L	10	**90**	***2700***	**70**	***2800***	10	***420***	20	***330***	90	***2200***	27	**55**	**80**	**150**	20,000	5,000	5,000	***200***	
Arsenic (total)	µg/L	1				1	1	2	4	5							2,000	100	500	50	10
Arsenic (III)													1	24	94	360					
Arsenic (IV)													0.8	13	42	140					
Boron (total)	µg/L	20	40	40	40	40	**910**	**1000**	***1200***	***1200***	**200**	**210**	90	**370**	**680**	**1,300**		**500**	5,000	***1,000***	4,000
Cadmium (total)	µg/L	0.1											0.06	0.2	0.4	0.8	50	10	10	5	2
Chromium (total)	µg/L	1		1		1		1				1					1,000	100	1,000		
Copper (total)	µg/L	1	**2**	**3**	**2**	**2**	**50**	**120**	**3**	**4**	**3**	**3**	1	**1.4**	**1.8**	**2.5**	5,000	200	400-5,000	1,000	2,000
Iron (total)	µg/L	10	110	***1500***	98	***1800***		***1500***	14	***310***	110	***1100***					10,000	**200**		***300***	
Lead (total)	µg/L	1											1	3.4	5.6	9.4	5,000	2,000	100	50	10
Manganese (total)	µg/L	5	6	25	6	120	26	46		11	14	13	1,200	1,900	2,500	3,600	10,000	200		100	500
Mercury (total	µg/L	0.05											0.06	0.6	1.9	5.4	2	2	2	1	1
Nickel (total)	µg/L	1		1		2	**24**	**28**	4	4	1	2	8	**11**	**18**	34	2,000	200	1,000	100	**20**
Selenium (total)	µg/L	1					4	4	**5**	**5**			**5**	11	18	34	50	20	20	10	10
Zinc (total)	µg/L	1	4	5	**22**	**10**	**12**	**44**	2	2	**9**	**8**	2.4	**8**	**15**	**31**	5,000	2,000	20,000	5,000	

Red – Parameters that exceed at least one WQG

Two sites on Bowmans Creek (1 and 2) were sampled for dissolved and total metals. Samples from both sites revealed concentrations of;

- **Aluminium** (total) that exceeded ANZECC/ARMANZC (2000) Recreational Use Guideline, and 95% species protection Trigger Value (total and dissolved).
- **Copper** that exceeded ANZECC/ARMANZC (2000) 95% species protection Trigger Value (total and dissolved).
- **Iron** (total) that exceeded ANZECC/ARMANZC (2000) Long-Term Irrigation Trigger Values and Recreational Use Guidelines.
- At one site, **zinc** (total and dissolved) exceeded ANZECC/ARMANZC (2000) 95% species protection Trigger Value.

Samples from Tinkers Creek (site 3) that drains from the Liddell ash dam revealed;

- EC levels in excess of ANZECC/ARMANZC (2000) recommended values for species protection.
- **Aluminium** concentrations (total) well in excess of ANZECC/ARMANZC (2000) Recreational Use Guidelines, and 80% species protection Trigger Value.
- **Boron** (total and dissolved) in excess of ANZECC/ARMANZC (2000) 90% species protection and Long-Term Irrigation Trigger Values.
- **Copper** (total -120ppb, and dissolved -50ppb) at very high concentrations that exceeded ANZECC/ARMANZC (2000) 80% Trigger Value.
- **Iron** (total) in excess of ANZECC/ARMANZC (2000) Long-Term Irrigation Trigger Value and Recreational Use Guidelines.
- **Nickel** (total and dissolved) in excess of ANZECC/ARMANZC (2000) 90% species protection Trigger Value, and NHMRC DWG.
- **Zinc** (total and dissolved) in excess of 95% and 80% species protection Trigger Values.

Samples taken from Lake Liddell (4), where both Liddell and Bayswater ash dams drain, revealed;

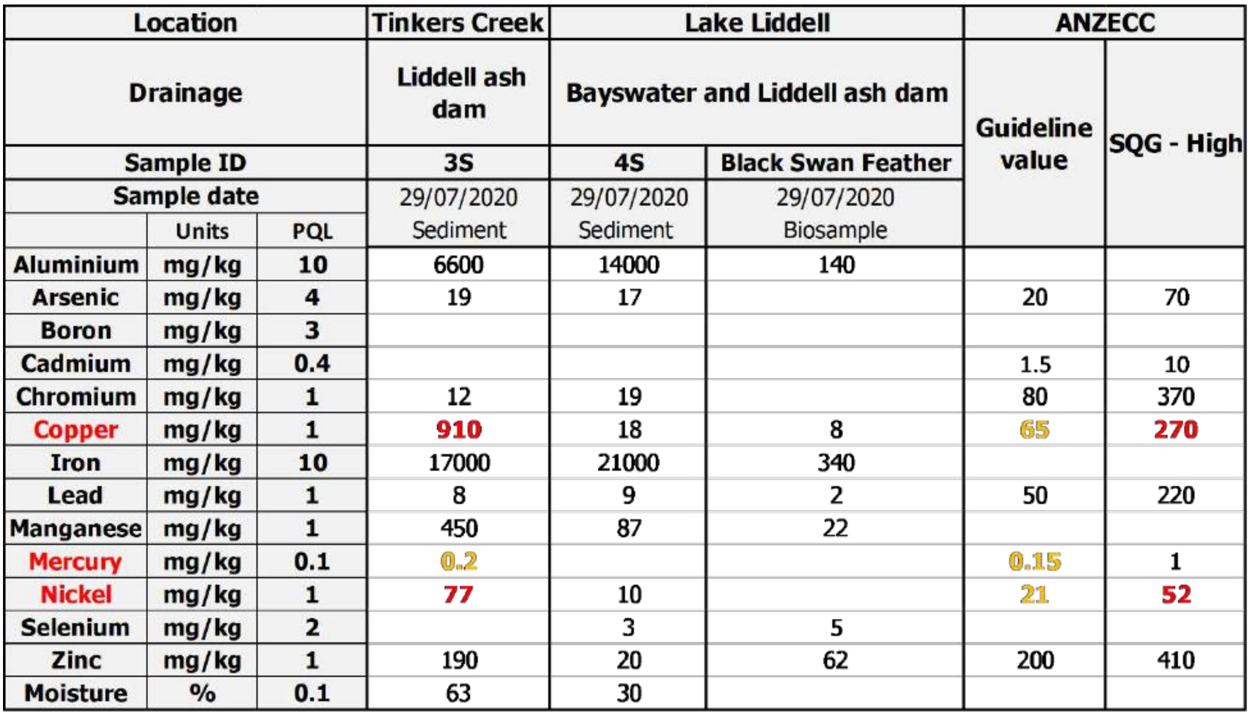
- EC levels in excess of ANZECC/ARMANZC (2000) recommended values for species protection.
- **Aluminium** concentrations (total) in excess of ANZECC/ARMANZC (2000) Recreational Use Guidelines.
- **Boron** (total and dissolved- 1200 ppb) in excess of ANZECC/ARMANZC (2000) 80% species protection, Long-Term Irrigation Trigger Values, and Recreational Use Guidelines.
- **Copper** (total and dissolved) concentrations that exceeded ANZECC/ARMANZC (2000) 80% Trigger Value.
- **Iron** (total) in excess of ANZECC/ARMANZC (2000) Long-Term Irrigation Trigger Value, and Recreational Use Guideline.
- **Selenium** concentrations at the 95% species protection Trigger Value.

Samples taken from Pikes Gully Creek (6) which drains seepage from the Bayswater Ash Dam, were found to contain:

- EC and pH (10.5) well above ANZECC/ARMANZC (2000) recommended levels for all uses.
- **Aluminium** concentrations (total) well in excess of ANZECC/ARMANZC (2000) Recreational Use Guidelines, and 80% species protection.
- **Copper** at very high concentrations that exceeded ANZECC/ARMANZC (2000) 80% Trigger Value.
- **Iron** (total) in excess of ANZECC/ARMANZC (2000) Long-Term Irrigation Trigger Value, and Recreational Use Guidelines.
- **Zinc** (total and dissolved) in excess of 95% species protection Trigger Value.

SEDIMENT SAMPLES

Table 31. Results of HCEC's Central Hunter Valley sediment sampling



Location			Tinkers Creek	Lake Liddell		ANZECC	
Drainage			Liddell ash dam	Bayswater and Liddell ash dam		Guideline value	SQG - High
Sample ID			3S	4S	Black Swan Feather		
Sample date			29/07/2020	29/07/2020	29/07/2020		
	Units	PQL	Sediment	Sediment	Biosample		
Aluminium	mg/kg	10	6600	14000	140		
Arsenic	mg/kg	4	19	17		20	70
Boron	mg/kg	3					
Cadmium	mg/kg	0.4				1.5	10
Chromium	mg/kg	1	12	19		80	370
Copper	mg/kg	1	910	18	8	65	270
Iron	mg/kg	10	17000	21000	340		
Lead	mg/kg	1	8	9	2	50	220
Manganese	mg/kg	1	450	87	22		
Mercury	mg/kg	0.1	0.2			0.15	1
Nickel	mg/kg	1	77	10		21	52
Selenium	mg/kg	2		3	5		
Zinc	mg/kg	1	190	20	62	200	410
Moisture	%	0.1	63	30			

Red – Parameters that exceed at least one WQG

Significant metal enrichment was discovered in a sediment sample taken from Tinkers Creek with;

- **Copper** (910 ppm) and **nickel** (77 ppm) concentrations exceeding ANZECC/ARMANZC (2000) SQG – High.
- **Mercury** in excess of ANZECC/ARMANZC (2000) sediment Guideline Value.

Laboratory analysis of a black swan feather taken from the shore of Lake Liddell shows bioaccumulation of **aluminium, copper, iron, manganese, selenium, and zinc**.

Lake Macquarie

We took six water samples and three sediment samples from three locations near to Eraring and Vales Point ash dams on 23 April 2020. The results confirmed previous identification of high metal concentrations near to these locations.

- Site 1 – Crooked Creek flowing past the now abandoned Myuna Bay Sport and Recreation Centre
- Site 2 – Crooked Creek at the base of the Eraring ash dam and upstream from #1.
- Site 3 – Drainage from ash dam seepage flowing into the southern tip of Mannering Bay.

The Envirolab report analyzing these samples (Annex 2) reveals significant exceedances of ANZECC Marine 95% Trigger Values (MTV) and Recreational Use Guidelines (RUG), as well as NHMRC Drinking Water Guidelines (DWG).

The exceedances include(exceeded WQG are in parenthesis) **aluminium** (RUG), **arsenic** (DWG), **boron** (RUG), **cobalt** (MTV), **copper** (MTV), **iron** (RUG), **manganese** (RUG/DWG), **nickel** (MTV/DWG), and **zinc** (MTV). All sites sampled were acidic with pH below recommended by ANZECC for marine waters. All three sites drained from the ash dam and well above any tidal influence, yet recorded electrical conductivities measured were greater than 4000, the upper threshold of the recording unit used.

Selenium concentration in the unfiltered sample also slightly exceeded the EPL limit imposed on the Eraring cooling water outlet (2μg/L).

Table 32. Results of HCEC's Lake Macquarie water sampling

Sample location				Eraring ash dam overflow Crooked Creek				Vales Point ash dam seepage		ANZECC (2000) Marine trigger value				ANZECC (2000) Recreational Use	NHMRC Drinking Water Guidelines
Sample ID				1wt	1wd	2wt	2wd	3wt	3wd	99%	95%	90%	80%		
Field Prep.				TOTAL	DISOLVED	TOTAL	DISOLVED	TOTAL	DISOLVED						
Type of sample				Water	Water	Water	Water	Water	Water						
Date Sampled				23/5/20	23/5/20	23/5/20	23/5/20	23/5/20	23/5/20						
pH.				5.9		4.1		4.5		7-8.5					
EC		uS/CM		>3999											
Metal/metaloiid		**Units**	**PQL**												
Aluminium	Al	µg/L	10	330	290	16000	15000	81000	75000					200	
Arsenic	As	µg/L	1	2	1	8	4	**43**	**43**					50	**10**
Boron	Bo	µg/L	20	1900	1900	1800	1800	100	100					1,000	4,000
Barium	Ba	µg/L	1	190	250	100	100	230	200					1,000	
Cadmium	Cd	µg/L	0.1	0.3	0.3	0.1	0.1	0.1	0.2	0.7	0.7	14	36	5	2
Cobalt	Co	µg/L	1	**4**	**4**	**18**	**19**	**59**	**60**	0.005	**1**	**14**	150		
Chromium	Cr	µg/L	1			5								50	50
Copper	Cu	µg/L	1	**2**		**3**				0.3	**1.3**	**3**	8	1,000	2,000
Iron	Fe	µg/L	10	11000	11000	43000	6400	1700	1700					300	
Lead	Pb	µg/L	1			3		2	2	2.2	4.4	20	85	50	10
Manganese	Mn	µg/L	5	**1600**	**1900**	**5600**	**5900**	**8600**	**8600**					100	**500**
Molybdenum	Mo	µg/L	1	3	2	4									
Mercury	Hg	µg/L	0.05							0.1	0.4	0.7	1.4	1	1
Nickel	Ni	µg/L	1	6	**7**	**21**	**22**	**36**	**36**	7	**7**	200	560	100	**20**
Selenium	Se	µg/L	1			**3**								10	
Thallium	Th	µg/L	1												
Vanadium	V	µg/L	1			13				50	100	160	280		
Zinc	Zn	µg/L	1	**46**	**53**	**49**	**45**	**130**	**130**	7	**15**	23	**43**	5,000	

Figure 2. Results for all sample sites

Eraring

Figure 3. HCEC water sampling sites at Eraring

Vales Point

Figure 4. HCEC sample sites at Vales Point

MANNERING BAY SEDIMENT CORE SAMPLE

Numerous studies have been published on the elevated heavy metal concentrations in southern Lake Macquarie sediment. The two ash dams are probably the greatest contributors to the problem, with coal mines supplying the power stations also making a contribution. Leaching of metals from the ash dams to the underlying mines working may also be taking place, particularly from the Eraring ash dam into former workings of Centennial’s Mandalong mine.

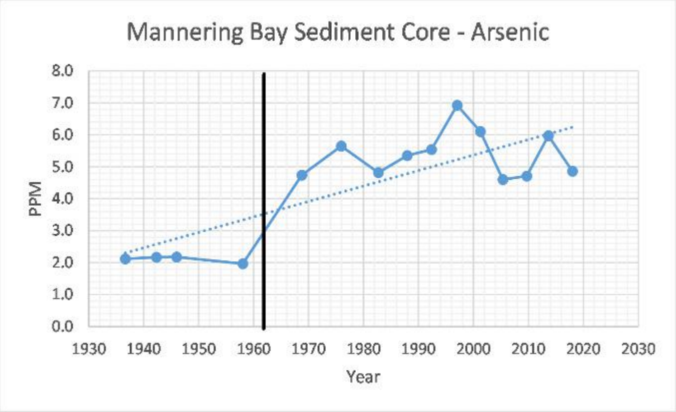
It is unlikely that the former Pasminco smelter at Cockle Creek in the very north tip of the Lake has contributed, given its distance to the north, the prevailing Lake currents and separated low tidal influences, and the imposition of Wangi Wangi Point which effectively divides the Lake in two.

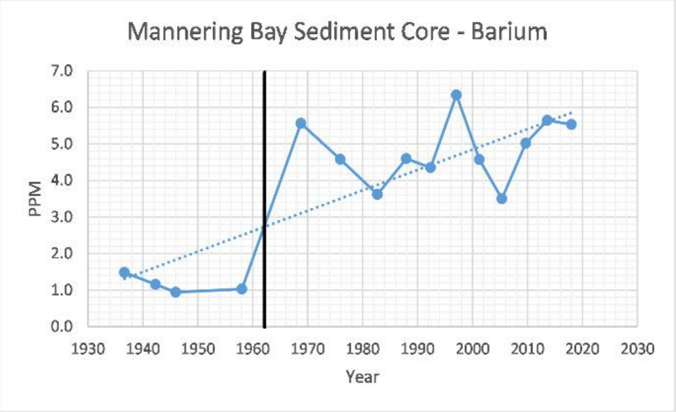
To identify the contribution Vales Point ash dam makes to the elevated metal concentrations found in Lake Macquarie sediment, we took a 30cm sediment core from Mannering Bay and asked ANSTO to provide a lead 210 isotopic dating analysis. ANSTO identified 15 dates from 1930 to 2019. Laboratory analysis of the sediment samples taken from these timestamps, shows a substantial increase in metal concentrations between 1960 and 1970; Coal ash waste was first dumped in Vales Point ash dam in 1962. The time series also shows that from 1930 to 1960 little increase in metal concentrations was apparent. However, the next time stamp (1970), a substantial increase in metal concentrations in the sediment of Mannering Bay;

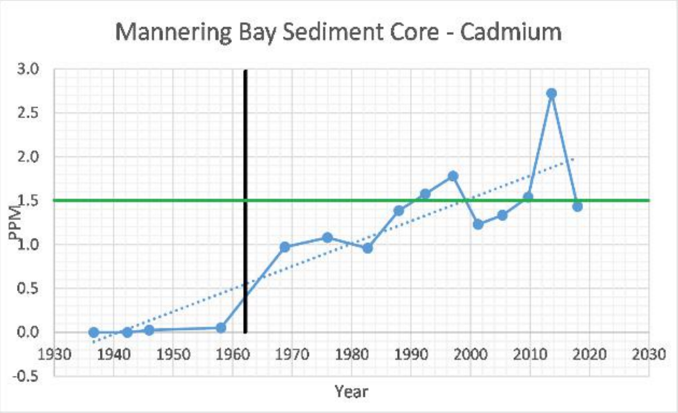
1. **Cadmium** concentrations have increased by a factor of 15,
2. **copper** by 12,
3. **zinc** by 10,
4. **selenium** by 8 to 10,
5. **lead** by 4,
6. **manganese** by 3,
7. **arsenic** by 2 to 3, and
8. **iron** by 2.

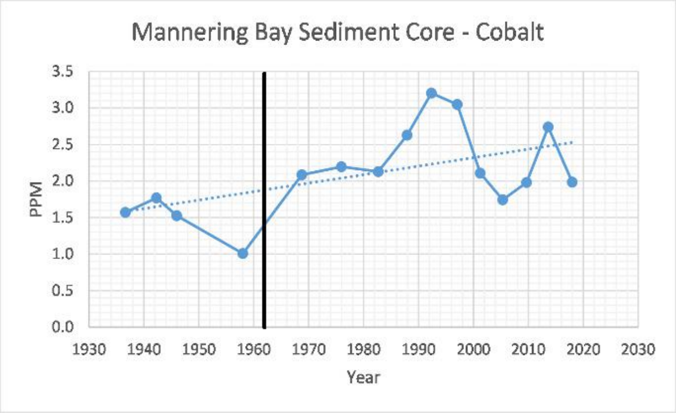
In 1995, Vales Point installed new ash handling procedures, which saw reductions in sediment concentrations for a number of metals. Despite these attempts, however, cadmium and selenium concentrations in sediment laid down recently remain above recommended ecosystem protection levels (shown as a green horizontal line on charts below) and some metal concentrations, such as copper, continue to increase.

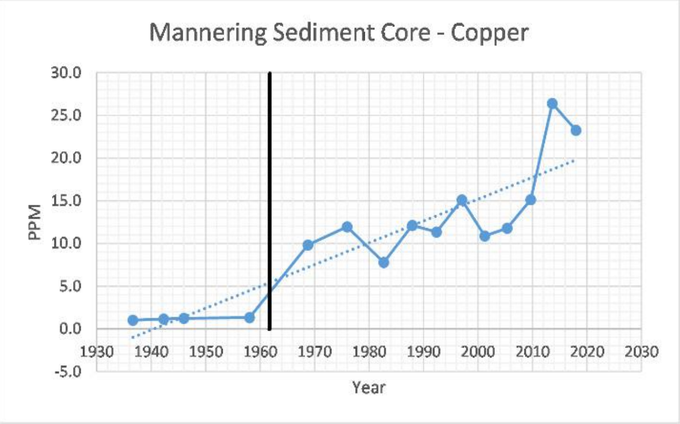
The only sure way of stopping the ongoing contamination of the Lake Macquarie ecosystems is to remove the ash. However, Vales Point power station operator can do more to reduce the leachate concentrations. Currently, the power station employs outdated wet sluicing (about 90% water/10% ash) to pump ash from boilers to the ash dump. Dense phase ash transport (30% water/70% ash) results in far less leachate as less water comes into contact with the ash during transport.

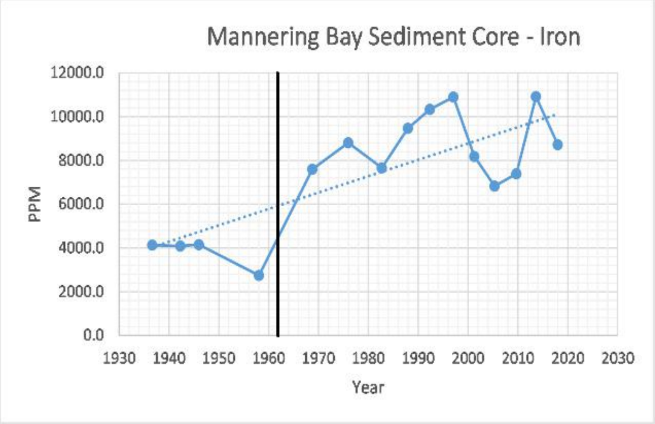


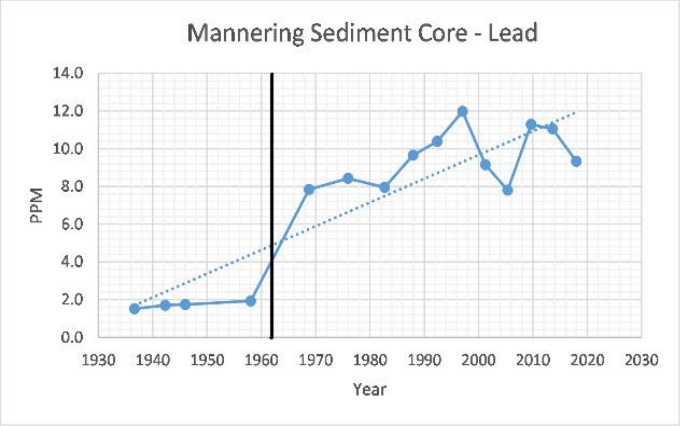


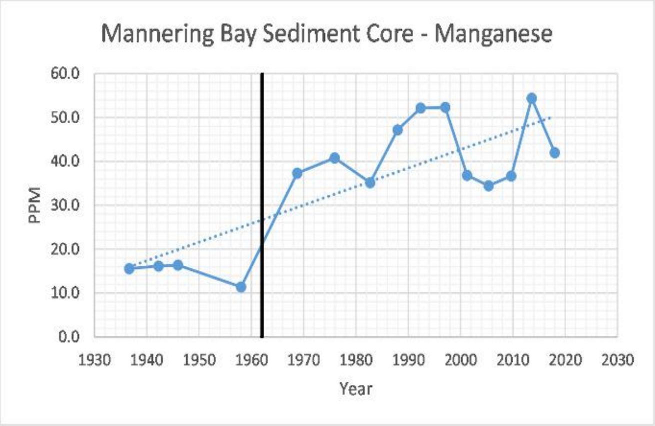


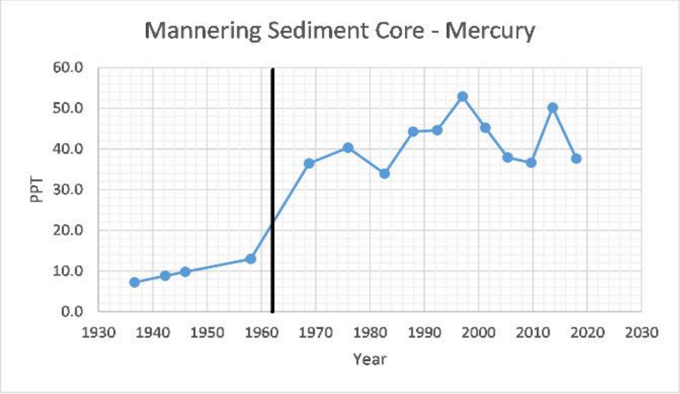


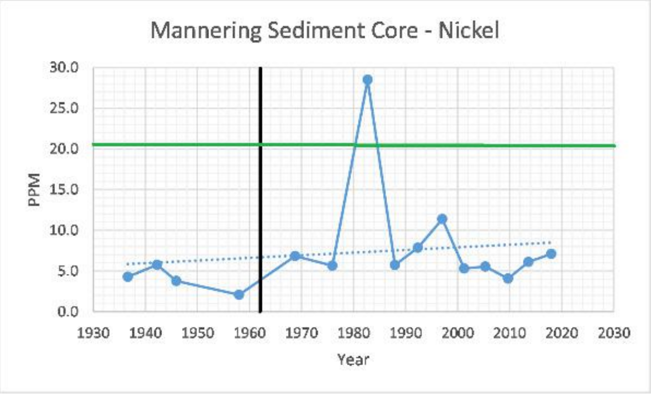

Mannering Sediment Core - Copper
PPM
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
Year

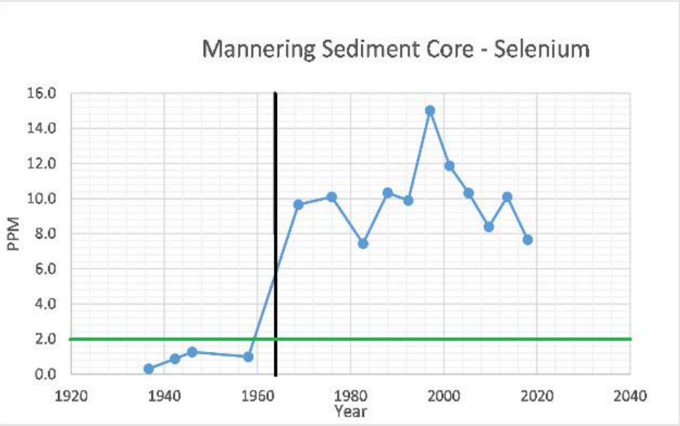

Mannering Bay Sediment Core - Iron
PPM
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
Year

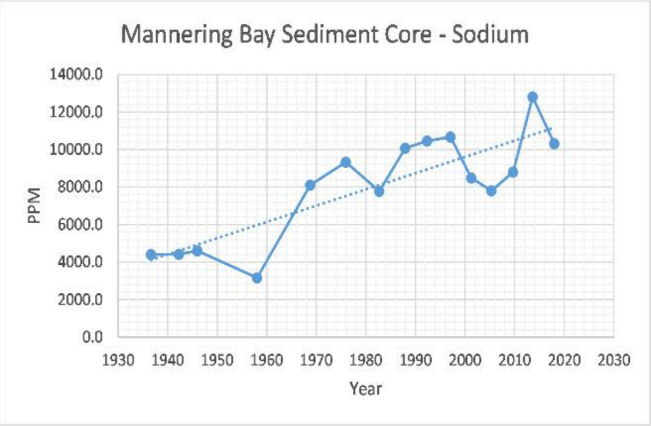

Mannering Sediment Core - Lead
PPM
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
Year

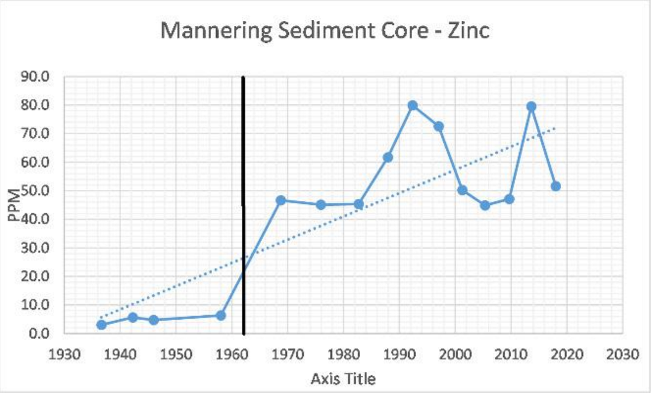

Mannering Bay Sediment Core - Manganese
PPM
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
Year


Mannering Sediment Core - Mercury
PPT
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
Year


Mannering Sediment Core - Nickel
PPM
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
Year


Mannering Sediment Core - Selenium
PPM
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1920
1940
1960
1980
2000
2020
2040
Year


Mannering Bay Sediment Core - Sodium
PPM
14000.0
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
Year



Charts 13: Mannering Bay sediment metal/metalloid concentrations 1930 to 2019. Black line indicates commissioning of Vales Point A.

Upper Coxs River

Mount Piper

Seven unfiltered and 12 field filtered (0.45µM) water sample and five sediment samples were taken from surface waters near to the Mt Piper power station ash dam, the Wallerawang power station ash dam, and Springvale Colliery on 24 and 25 March and 27 and 28 April, 2020.

The samples were analysed for total metals/metalloids by Envirolabs Sydney (See Appendix 2). A number of substantial exceedances of human health, ecological, and agriculture guidelines were identified, and we are now aware that Energy Australia has admitted to the EPA that their Mount Piper ash dam is contaminating groundwater.[63]

Figure 1 and 2 below sets out the sample locations.

- Site 2 - surface drain flowing from Mt Piper power station LDP1.
- Site 3 - mine discharge from the Springvale mine LDP6 that flows into Neubecks Creek.
- Site 4 – Neubecks Creek, upstream from #3.
- Site 5 - Sawyers Swamp Creek which flows from the Kerosene Vale ash dam into the Coxs River.
- Site 7 - Coxs River, 200m downstream from the confluence of Sawyers Swamp Creek.
- Site 8 - western shore of Lake Wallace, into which the Coxs River flows.
- Site 9 – background from Coxs River about 4.5 km upstream from any ash dam drainage confluence.
- Site 10 - natural drain flowing from the Mt Piper ash dam into Neubecks Creek.
- Site 11 – western shore of Lake Lyall, below Lake Wallace.

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[63] EA Lithgow CCC Meeting Notes

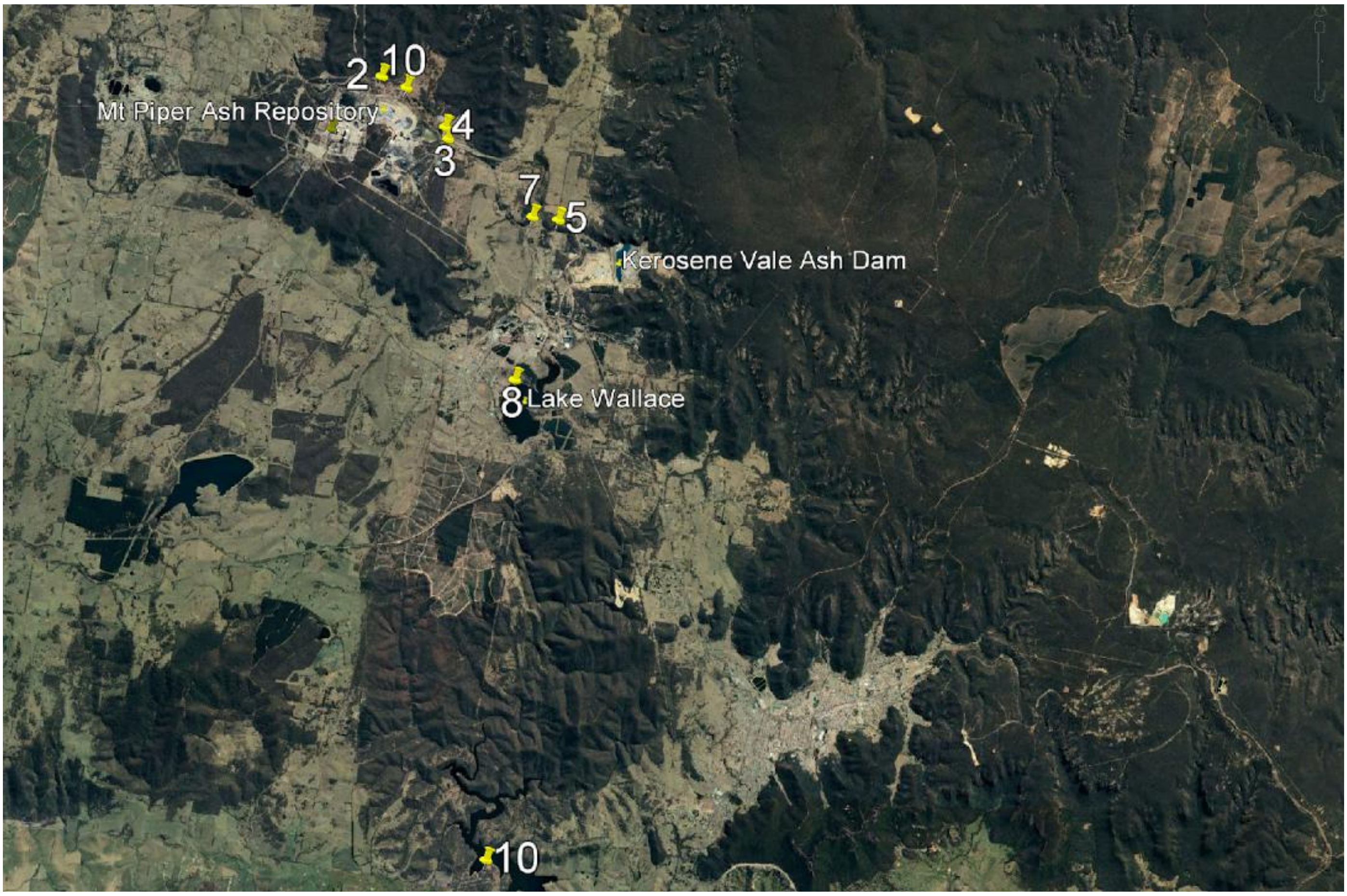


Figure 5: All locations of HCEC sampling in Upper Cox's River

Figure 6: Sample locations at Mt. Piper

SURFACE WATER SAMPLES

Location			**Background (upper Coxs River)**			**Mt Piper -LDP1**		**Springvale – LDP6**				**Newbecks Creek**	**Sawyers Swamp Creek**				**Coxs River**	**Lake Wallace**		**Mt Piper ash dam drainage**	**Lake Lyall**	**ANZECC (2000)**				**NSW EPA**
Sample ID			**9**	**9A**	**9B**	**2**	**2**	**3**	**3A**	**3B**	**3C**	**4**	**5**	**5A**	**5B**	**5C**	**7**	**8**	**8**	**10**	**11**	**Freshwater trigger value**				**EPL 3607 limits LDP9**
Sample date			25-Mar	27-Apr	28-Apr	24-Mar	27-Apr	24-Mar	27-Apr	28-Apr	28-Apr	28-Apr	24-Mar	27-Apr	28-Apr	28-Apr	24-Mar	24-Mar	27-Apr	25-Mar	27-Apr					
Sample type			Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	99%	95%	90%	**80%**	
Field preparation			TOTAL	DISOLVED	DISOLVED	TOTAL	DISOLVED	TOTAL	DISOLVED	DISOLVED	DISOLVED	DISOLVED	TOTAL	DISOLVED	DISOLVED	DISOLVED	TOTAL	TOTAL	DISOLVED	TOTAL	DISOLVED					
Parameter	**Units**	**PQL**	unfiltered	filtered	filtered	unfiltered	filtered	unfiltered	filtered	filtered	filtered	filtered	unfiltered	filtered	filtered	filtered	unfiltered	unfiltered	filtered	unfiltered	filtered					
pH			6.4			6.2		5.7					4.5				6.8	9.1		6.5		6.5-9				
EC	µS/cm		197			**389**		**7,400**					**1,850**				**1,717**	**915**				120-**300**				1200
Silver	µg/L	1																				0.02	0.05	0.1	0.2	
Aluminium	µg/L	10	90	20	30	**400**		**190**			20		**3,300**	**1600**	**1600**	**1600**	250*	60	10	**2,100**	20	27	55	80	**150**	450
Arsenic	µg/L	1											2					7	5	2	3					24
Arsenic (III)	ug/l																					1	24	94	360	
Arsenic (IV)	µg/L																					0.8	13	42	140	
Boron	µg/L	20	20			70	100	**2,100**	**1400**	**1400**	**1400**	200	1,000	200	200	200	460	200	200	30	70	90	370	680	**1,300**	370
Cadmium	µg/L	0.1						0.1					**2.7**	0.7	0.7	0.6						0.06	0.2	0.4	**0.8**	
Cobalt	µg/L	1	7	3	2			78	70	70	67	4	850	44	44	41	4			2						
Chromium	µg/L	1																		2						
Chromium (III)	µg/L																									
Chromium (VI)	µg/L																					0.01	1	6	40	
Copper	µg/L	1				**3**	**3**						2	2	1	1		**3**		**6**		1	1.4	1.8	**2.5**	7
Iron	µg/L	10	500	500	230	320	16	10,000	2000	2500	3300	23	19,000	190	290	170	700	86	25	1,300	12					400
Lead	µg/L	1											2							1		1	3.4	5.6	9.4	
Manganese	µg/L	5	850	370	210	140	60	**6,900**	**5000**	**5200**	**5300**	850	**35,000**	1800	1800	1800	540	72	25	270		1,200	1,900	2,500	**3,600**	1700
Mercury	µg/L	0.05																								
Mercury (organic)	µg/L																					0.06	0.6	1.9	5.4	
Nickel	µg/L	1	2	2	2	5	10	**360**	**330**	**340**	**330**	34	**1,100**	**83**	**86**	**84**	**60**	12	12	9	3	8	11	18	**34**	47
Selenium	µg/L	1				1	1															5	11	18	34	
Thallium	µg/L	1						1																		
Vanadium	µg/L	1																		4						
Zinc	µg/L	1	14	17	21	12	29	**120**	**85**	**84**	**80**	7	**2,100**	**200**	**200**	**200**	28	3		21		2.4	8	15	**31**	50

Table 33: Surface water laboratory results and ANZECC (2000) ecological protection concentrations and EPL limits

Table 33 sets out the results of the laboratory analyses of the water sample compared to ANZECC (2000) trigger values.

Background (site 9) concentrations of aluminum, iron, and zinc were above ANZECC (2000) 95% trigger values. The background site was also slightly acidic (6.4 pH) with a conductivity of 190μS/cm.

Thirteen of the 16 non-background water samples significantly exceeded background levels, as well as significantly exceeding ANZECC (2000) trigger values for concentrations of seven metals - **aluminum, boron, cadmium, copper, manganese, nickel, and zinc**, as well as pH and EC.

Samples from site 2 (Mount Piper LDP1), exceeded ANZECC (2000) trigger values for pH, EC, as well as the 95% trigger value for;

- **aluminum** (unfiltered) by a factor of 7,
- **copper** (both filtered and unfiltered) by a factor of 2.

Samples from site 3 (Springvale LDP6), exceeded ANZECC (2000) trigger values for pH (5.7) and EC (7,400 μS/cm), as well as the 95% trigger value for:

- **aluminum** (unfiltered) by a factor 3,
- **boron** (unfiltered) by a factor of 5, with the 3 filtered samples exceeding by a factor of 3,
- **manganese** (unfiltered) by a factor of 3, with the 3 filtered samples by a factor of 2,
- **zinc** (unfiltered) by a factor of 15, with the 3 filtered samples by a factor of 10.

Samples from site 4 (Nuebecks Creek upstream from LDP6) exceeded ANZECC 95% trigger values for **nickel** by a factor of 3.

Samples from site 5 (Sawyers Swamp Creek) exceeded ANZECC (2000) trigger values for pH (4.5) and conductivity by a factor of 6, as well as 95% trigger values for:

- **aluminum** (unfiltered) by a factor of 60, with the 3 filtered (dissolved) samples exceeding by a factor of 30,
- **boron** (unfiltered) by a factor of 3,
- **cadmium** (unfiltered) by a factor of 13, with the 3 filtered (dissolved) samples exceeding by a factor of 3,
- **copper** (unfiltered) and copper (filtered) exceeded slightly,
- **manganese** (unfiltered) by a factor of 18,
- **nickel** (unfiltered) by a factor of 10, with the 3 filtered (dissolved) samples by a factor of 5 to 8,
- **zinc** (unfiltered) by a factor of 260, with the 3 filtered (dissolved) samples by a factor of 25.

Sample from site 7 (Coxs River downstream of Sawyers Swamp Creek) exceeded the ANZECC (2000) trigger vale for conductivity, as well as the 95% trigger value for:

- **boron** (unfiltered) slightly, and
- **nickel** (unfiltered) by a factor of 5.

Samples from site 8 (Lake Wallace) exceeded the ANZECC trigger values for pH (9.1) and conductivity (950uS/cm) by a factor of 3, as well as the 95% trigger value for:

- **copper** (unfiltered) by a factor of 3, and
- **nickel** (both filtered and unfiltered) slightly.

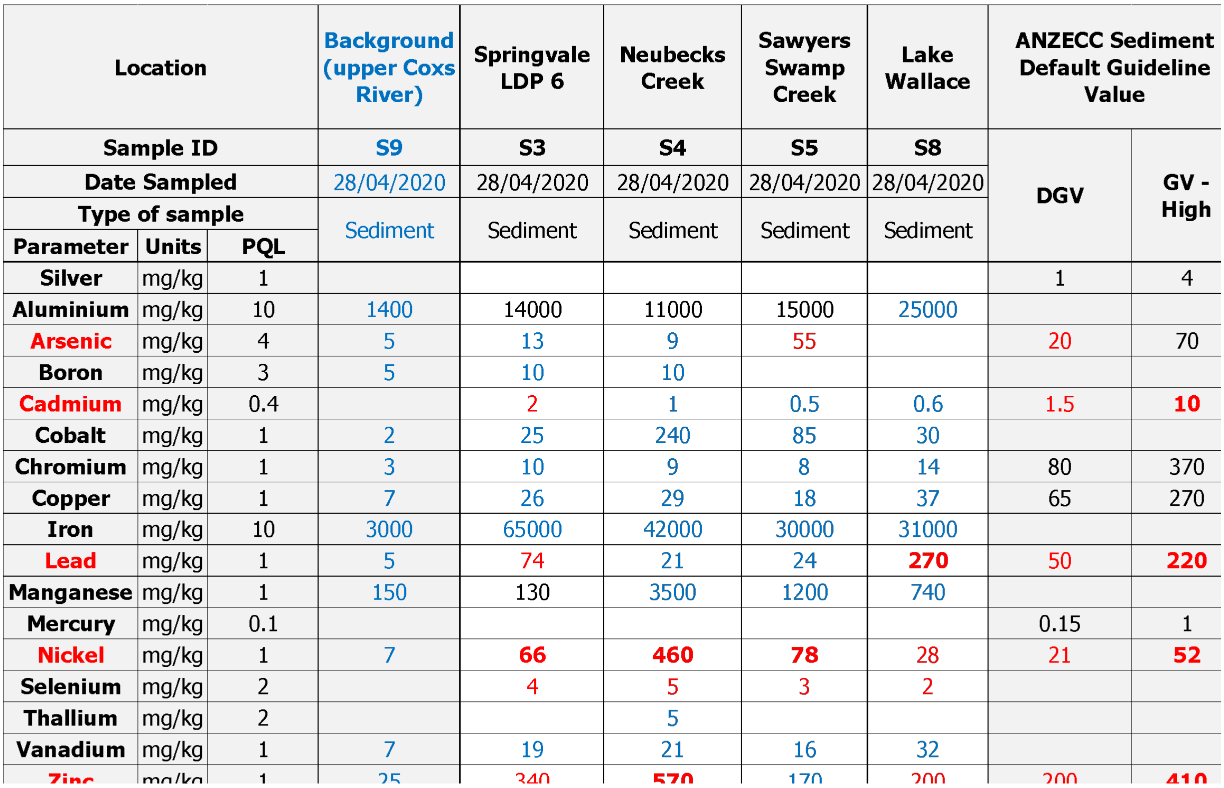
Sample from site 10 (natural drainage from Mt Piper ash dam) exceeded the 95% trigger value for:

- **aluminium** (unfiltered) by a factor of 38,
- **copper** (unfiltered) by a factor 4, and
- **zinc** (unfiltered) by a factor of 2.6.

SEDIMENT SAMPLES

All 4 non-background sediment samples exceeded the ANZECC Default Guideline Value (DGV) for **arsenic, cadmium, lead, nickel, and zinc**, with many above the “High GV”. Background concentrations were all below DGVs. Table 34 sets out the laboratory results compared to ANZECC sediment DGVs.

Table 34: Laboratory results of sediment samples compared to ANZECC DGVs.



Location			**Background (upper Coxs River)**	**Springvale LDP 6**	**Neubecks Creek**	**Sawyers Swamp Creek**	**Lake Wallace**	**ANZECC Sediment Default Guideline Value**	
Sample ID			**S9**	**S3**	**S4**	**S5**	**S8**	**DGV**	**GV - High**
Date Sampled			28/04/2020	28/04/2020	28/04/2020	28/04/2020	28/04/2020		
Type of sample			Sediment	Sediment	Sediment	Sediment	Sediment		
Parameter	**Units**	**PQL**							
Silver	mg/kg	1						1	4
Aluminium	mg/kg	10	1400	14000	11000	15000	25000		
Arsenic	mg/kg	4	5	13	9	55		20	70
Boron	mg/kg	3	5	10	10				
Cadmium	mg/kg	0.4		2	1	0.5	0.6	1.5	**10**
Cobalt	mg/kg	1	2	25	240	85	30		
Chromium	mg/kg	1	3	10	9	8	14	80	370
Copper	mg/kg	1	7	26	29	18	37	65	270
Iron	mg/kg	10	3000	65000	42000	30000	31000		
Lead	mg/kg	1	5	74	21	24	**270**	50	**220**
Manganese	mg/kg	1	150	130	3500	1200	740		
Mercury	mg/kg	0.1						0.15	1
Nickel	mg/kg	1	7	**66**	**460**	**78**	28	21	**52**
Selenium	mg/kg	2		4	5	3	2		
Thallium	mg/kg	2			5				
Vanadium	mg/kg	1	7	19	21	16	32		
Zinc	mg/kg	1	25	340	**570**	170	200	200	**410**

Site 3 (Springvale LDP6) sediment sample exceeded the DGV for:

- **cadmium** slightly,
- **lead** by a factor of 1.5,
- **nickel** by a factor of 3, and GV High by 20%, and
- **zinc** by a factor of 1.5.

Site 4 (Neubecks Creek) sediment sample exceeded the DGV for:

- **nickel** by a factor of 20, and the GV High by a factor of 9,
- **zinc** by a factor of 2.8, and GV High by 1.4.

Site 5 (Sawyers Swamp Creek) sediment sample exceeded the DGV for:

- **arsenic** by 2.5,
- **nickel** by a factor of 4,

Site 8 (Lake Wallace) sediment sample exceeded the DGV for:

- **lead** by a factor of 5, and GV High by 12%,
- **nickel** by 20%, and
- **zinc** (at the DGV

Location			**Background (upper Coxs River)**			**Mt Piper - LDP1**		**Springvale - LDP6**				**Neubecks Creek**	**Sawyers Swamp Creek**				**Coxs River**	**Lake Wallace**		**Mt Piper ash dam drainage**	**Lake Lyall**	**ANZECC (2000) Recreational Use**	**NHMRC Drinking Water Guidelines**
Sample ID			**9**	**9A**	**9B**	**2**	**2**	**3**	**3A**	**3B**	**3C**	**4**	**5**	**5A**	**5B**	**5C**	**7**	**8**	**8**	**10**	**11**		
Sample date			25-Mar	27-Apr	28-Apr	24-Mar	27-Apr	24-Mar	27-Apr	28-Apr	28-Apr	28-Apr	24-Mar	27-Apr	28-Apr	28-Apr	24-Mar	24-Mar	27-Apr	25-Mar	27-Apr		
Sample type			Water TOTAL	Water DISOLVED	Water DISOLVED	Water TOTAL	Water DISOLVED	Water TOTAL	Water DISOLVED	Water DISOLVED	Water DISOLVED	Water DISOLVED	Water TOTAL	Water DISOLVED	Water DISOLVED	Water DISOLVED	Water TOTAL	Water TOTAL	Water DISOLVED	Water TOTAL	Water DISOLVED		
Field preparation																							
Parameter	**Units**	**PQL**	unfiltered	filtered	filtered	unfiltered	filtered	unfiltered	filtered	filtered	filtered	filtered	unfiltered	filtered	filtered	filtered	unfiltered	unfiltered	filtered	unfiltered	filtered		
pH			6.4			6.2		5.7					4.5				6.8	9.1		6.5		6.5-8.5	
EC	μS/cm		197			389		7,400					1,850				1,717	915					
Silver	μg/L	1																				50	100
Aluminium	μg/L	10	90	20	30	400		190			20		3,300	1600	1600	1600	250*	60	10	2,100	20	200	
Arsenic	μg/L	1											2					7	5	2	3	50	10
Arsenic (III)	ug/l																						
Arsenic (IV)	μg/L																						
Boron	μg/L	20	20			70	100	2,100	1400	1400	1400	200	1,000	200	200	200	460	200	200	30	70	1,000	4,000
Cadmium	μg/L	0.1						0.1					2.7	0.7	0.7	0.6						5	2
Cobalt	μg/L	1	7	3	2			78	70	70	67	4	850	44	44	41	4			2		50	
Chromium	μg/L	1																		2			
Chromium (III)	μg/L																						
Chromium (VI)	μg/L																						50
Copper	μg/L	1				3	3						2	2	1	1		3		6		1,000	2,000
Iron	μg/L	10	500	500	230	320	16	10,000	2000	2500	3300	23	19,000	190	290	170	700	86	25	1,300	12	300	
Lead	μg/L	1											2							1		50	10
Manganese	μg/L	5	**850**	370	210	140	60	**6,900**	**5000**	**5200**	**5300**	850	**35,000**	**1800**	**1800**	**1800**	**540**	72	25	270		100	**500**
Mercury	μg/L	0.1																				1	1
Mercury (organic)	μg/L																						
Nickel	μg/L	1	2	2	2	5	10	**360**	**330**	**340**	**330**	34	**1,100**	83	86	84	60	12	12	9	3	**100**	20
Selenium	μg/L	1				1	1															10	
Thallium	μg/L	1						1															
Vanadium	μg/L	1																		4			
Zinc	μg/L	1	14	17	21	12	29	120	85	84	80	7	2,100	200	200	200	28	3		21		5,000	

Table 34. Surface water laboratory results and ANZECC (2000) recreational use and NHMRC drinking water concentrations

Location		Background (upper Coxs River)			Mt Piper -LDP1		Springvale – LDP6				Neubecks Creek	Sawyers Swamp Creek				Coxs River	Lake Wallace		Mt Piper ash dam drainage	Lake Lyall	ANZECC		
Sample		9	9A	9B	2	2	3	3A	3B	3C	4	5	5A	5B	5C	7	8	8	10	11	Irrigation trigger value		Livestock drinking water trigger value
Date Sampled Type of sample		25-Mar Water	27-Apr Water	28-Apr Water	24-Mar Water	27-Apr Water	24-Mar Water	27-Apr Water	28-Apr Water	28-Apr Water	28-Apr Water	24-Mar Water	27-Apr Water	28-Apr Water	28-Apr Water	24-Mar Water	24-Mar Water	27-Apr Water	25-Mar Water	27-Apr Water	Short-term (20 years)	Long-term (100 years)	
Sample Treatment		TOTAL unfiltered	DISOLVED filtered	DISOLVED filtered	TOTAL unfiltered	DISOLVED filtered	TOTAL unfiltered	DISOLVED filtered	DISOLVED filtered	DISOLVED filtered	DISOLVED filtered	TOTAL unfiltered	DISOLVED filtered	DISOLVED filtered	DISOLVED filtered	TOTAL unfiltered	TOTAL unfiltered	DISOLVED filtered	TOTAL unfiltered	DISOLVED filtered			
pH		6.4			6.2		5.7					4.5				6.8	9.1		6.5				
EC	µS/cm	197			389		7,400					1,850				1,717	915						
Silver-Total	µg/L																						
Aluminium-Total (<6.5pH)	µg/L	90	20	30	400		190			20		3,300	1600	1600	1600	250*	60	10	2,100	20	20,000	5,000	5,000
Arsenic-Total	µg/L											2					7	5	2	3	2,000	100	500
Arsenic (III)	ug/l																						
Arsenic (IV)	µg/L																						
Boron-Total	µg/L	20			70	100	**2,100**	**1400**	**1400**	**1400**	200	**1,000**	200	200	200	460	200	200	30	70		**500**	5,000
Cadmium-Total	µg/L						0.1					2.7	0.7	0.7	0.6						50	10	10
Cobalt-Total	µg/L	7	3	2			78	70	70	67	4	**850**	44	44	41	4			2		100	**50**	1,000
Chromium-Total	µg/L																		2		1,000	**100**	1,000
Chromium (III)	µg/L																						
Chromium (VI)	µg/L																						
Copper-Total	µg/L				3	3						2	2	1	1		3		6		5,000	200	400 - 5,000
Iron-Total	µg/L	500	500	230	320	16	**10,000**	**2000**	**2500**	**3300**	23	**19,000**	190	**290**	170	**700**	86	25	**1,300**	12	**10,000**	**200**	
Lead-Total	µg/L											2							1		5,000	2,000	100
Manganese-Total	µg/L	850	370	210	140	60	**6,900**	**5000**	**5200**	**5300**	**850**	**35,000**	**1800**	**1800**	**1800**	**540**	72	25	**270**		**10,000**	**200**	
Mercury-Total	µg/L																				2	2	2
Mercury (organic)	µg/L																						
Nickel-Total	µg/L	2	2	2	5	10	**360**	**330**	**340**	**330**	34	1,100	83	86	84	60	12	12	9	3	2,000	**200**	1,000
Selenium-Total	µg/L				1	1															50	20	20
Thallium-Total	µg/L						1																
Vanadium-Total	µg/L																		4		100	50	
Zinc-Total	µg/L	14	17	21	12	29	120	85	84	80	7	**2,100**	200	200	200	28	3		21		5,000	**2,000**	20,000

Table 35: Surface water laboratory results and ANZECC (2000) agricultural guidelines

photo: Eraring power station ash dam

US Coal Ash Rule and Effluent Guidelines

After extensively studying the effects of coal ash on the environment and public health, the US EPA oversaw the introduction of new technical requirements for coal ash landfills and surface impoundments in 2015.

The new rule regulates the disposal of coal ash from coal-fired power stations. The regulations are aimed at addressing the risks from coal ash disposal, specifically:

- leaking of contaminants into groundwater,
- blowing of contaminants into the air as dust, and
- the catastrophic failure of coal ash surface impoundments.[64]

At the time, the regulations for effluent discharge from coal power stations did not adequately address toxic metal discharges, as it had focused on the settling out of particulates in sediments, rather than dissolved pollutants. In 2015, the US EPA strengthened effluent limits and substantially reduced the amount of toxic metals and other harmful pollutants that power stations can legally discharge into waterways. The rule (40 CFR Part 423),[65] was projected to reduce the annual amount of toxic metals, nutrients, and other pollutants coal-fired power stations discharge by 635,000 million tonnes and reduce water use by 15 billion litres[66] The annual compliance costs for the final rule was estimated at $480 million, with benefits associated with the rule estimated at $451 to $566 million.

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[64] US EPA, 2020.

[65] Title 40, USC, Part 423.

[66] US EPA, 2015.

Reducing NSW metal leachate

The key to addressing metal leachate from coal ash disposal sites is reducing the amount of water that comes into contact with the ash. With the exception of Mount Piper, NSW power stations currently dispose of ash by pumping a slurry to a disposal site adjacent to the power station.[67]Mount Piper uses a dry method for ash disposal.[68]So-called "dry ash" management for transport and disposal typically involves the addition of 20 to 25 percent water to suppress dust, with additional water using sprinklers or water trucks to control dust and improve compaction.[69]Origin Energy and AGL use 'lean phase' fly ash placement at Eraring[70]and Bayswater's Ravensworth mine voids[71] (30% fly ash and 70% water) with Liddell, Bayswater's Pikes Gully ash dam, and Vales Point[72]still using outdated wet sluicing to transport coal ash to their ash dumps, typical with a ash -to-water ratio between 1:10 to 1:15.[73]

However, all ash dumps must be watered to reduce wind blow and none can prevent rainfall from collecting in the dump. Indeed, one research paper points out that absolute containment of a coal ash waste and its leachate is impossible.[74] Water will inevitably come into contact with the ash. The only way to stop metals polluting groundwater is to stop burning coal, reuse the ash produced, or install water treatment, such as reverse osmosis, to reduce metal concentrations in leachate and affected groundwater to safe levels.

Furthermore, the market failure of coal ash reuse in Australia must be addressed. Far greater incentives must be provided to compel power generators to open their gates to companies wishing to produce safe high volume coal ash products.

A 2003 report[75]for the State owned operator of NSW power stations, Pacific Power, identified a fee of $18 to 20 per tonne of waste generated and placed in an ash dam could be introduced identifying that "Such a fee would measurably (and possibly dramatically) increase the avoided cost of dumping coal ash. The result could be a very strong incentive for producers to reduce their rate of ash disposal by subsidising other uses."

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[67] NSW EPA, 2017.

[68] SKM, 2010.

[69] Timmons, 2015.

[70] Eraring Energy, 2007.

[71] Ward et al, 1999.

[72] Delta Electricity, 2017.

[73] Tobias Lutzl, Uli Freitag, 2017.

[74] Hassett, 1994.

[75] Pacific Power, 2003.

Similar types of fees apply to ash disposed of in some US states, where the practice of placing ash into any landfill, whether on site or otherwise, can attract a charge of 50 to 60 USD per ton.[76]Similarly in Europe, taxes are levied on waste disposed, at rates between 10 and 60 Euro per tonne depending on the country concerned.[77]Such taxes strongly encourage recycling initiatives.

HCEC believes the simplest method for New South Wales would be to list fly ash as an assessable pollutant under Schedule 1 of the *POEO Regulations* and impose a LBL fee of at least $20 a tonne to all coal ash dumped into the five operating coal ash waste containment facilities.

These sites are contaminated and must be rehabilitated in a manner that reduces, and ultimately eliminates, future leaching of metals into groundwater and surface waters. HCEC believes this could be achieved at least cost by providing assistance to companies wishing to produce safe high volume coal ash waste products.

Ridding the state of its coal ash waste burden requires a dramatic increase in safe beneficial reuse of the material. To achieve this, three key policy alignments are required:

1. The listing of coal ash as an assessable pollutant under the POEO Regulations, and the imposition of a Load Based Licence fee of at least $20 for every tonne of all coal ash waste dumped. This would provide a compelling incentive for power station operators to reduce and eliminate the dumping of ash.

2. Government assistance in the form of feasibility studies, pilot plants, market appraisals, logistics, and engineering specifications and ash suitability studies to support the development of a viable coal ash reuse industry.

3. A Government procurement policy for a mandated component of coal ash and sintered coal ash products in concrete etc. This will provide a ready market for high volume coal ash products in NSW, and kick start a new industry that will create regional and rural employment.

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[76] Pacific Power, 2003.

[77] Pacific Power, 2003.

photo: Bayswater power station ash dam

Conclusion

Significant metal contamination has been identified by Government consultants, EPA monitoring, and our own water and sediment sampling at all New South Wales' coal ash waste dumps.

EPA monitoring by power station operators shows continued unacceptable metal contamination, some of which is increasing. The EPA has been slow to respond to power station operator prevarication on Pollution Reduction Programs and failing to meet coal ash reuse targets, and may indeed have helped maintain silence and inaction over this substantial water pollution source. Regulation of coal ash waste dumps is clearly inadequate and is not preventing or addressing heavy metal pollution from these facilities.

NSW Treasury received its Stage 2 Environmental Site Assessments that set contamination baselines, prior to power station selloffs, between 2013 and 2015. While these assessments have not been made publically available, the level of ongoing contamination was made clear to the NSW Government more than five years ago. Indeed, metal contamination of southern Lake Macquarie, from Eraring and Vales Point ash dumps, was identified many decades ago but no action has been taken to remove the ash that is the source of this contamination, despite the availability of recycling options.

These power stations were built and operated by the NSW Government and sold to private enterprises at the end of their design lives. The Government therefore retains liability for most of the decontamination at these sites. In the absence of any clear policy response, the NSW Government is now liable for considerable decontamination works at the six active – and already two decommissioned - coal ash waste dumps, when these facilities are decommissioned. The Government must move now to remedy the ongoing heavy metal pollution by quickly and substantially reducing the volumes of coal ash dumped and accumulated.

We believe the costs associated with this liability can be substantially reduced by implementing a suite of policies aimed at proactively increasing coal ash reuse, and the implementation of a Load-Based Licencing fee paid by power station operators who fail to adequately facilitate and actively promote the reuse of their coal ash waste. We believe these measures will incentivise the reuse of 50 years of accumulated coal ash waste and address the ongoing practice of dumping coal ash waste.

photo: Vales Point power station ash dam

Recommendations

Recommendation 1: The NSW Government commit to a comprehensive decontamination of all coal ash waste dumps in NSW

Recommendation 2: The NSW Government adopt a procurement and Government tender policy that mandates, where available, a substantial proportion (determined after consideration of engineering requirements) of concrete purchased, or purchased under a Government tender, be of sintered coal ash products, raw fly ash and bottom ash.

Recommendation 3: The NSW EPA undertake an investigation into coal ash generated in NSW to determine the environmental risks associated with all its current uses and whether these uses are appropriate. The EPA amend the *Coal Ash Order 2014* to ensure all coal ash metal analyses and leach testing results are made public. The EPA must take a much more active role in determining the suitability of coal ash reuse.

Recommendation 4: The NSW Government list coal ash as an assessable pollutant in Schedule 1 of the *Protection of the Environment Operations (General) Regulation 2009*, making it part of the Load Based Licence scheme.

Recommendation 5: To reduce the amount of coal ash dumped in ash dams in NSW, the EPA impose a load based licence fee of at least $20 a tonne on all coal ash disposed of in ash dams, landfills, and mine voids.

Recommendation 6: The NSW Government commission a feasibility study into the environmentally responsible reuse of coal ash in NSW. The study should include an assessment of the economic viability of manufacturing sand and aggregates from coal ash waste in NSW. This should include collaborative engagement with companies interested in reusing coal ash, particularly interested companies who can manufacture recycled coal ash products, and;

- Sample ash from all NSW power stations to determine the ideal compositional matrix for the required products and test the products for engineering specification, market feasibility, and human health and environmental safety.

- Design, build, operate, and evaluate a pilot plant.

- Develop a business plan that includes an estimate of final production costs, market appraisals, and transport logistics.

- Identify and amend policy and regulatory barriers, as long as this does not risk negative impacts to the environment or human health.

Recommendation 7: The EPA ensure all NSW power stations operating wet ash dams install appropriate equipment to transport ash in a dense phase to minimise metal mobilisation.

Recommendation 8: The NSW EPA ensure all power station operators estimate and report to the NPI all emissions to land and water from ash dumps.

Recommendation 9: The NSW EPA must strictly enforce the ANZECC water quality guidelines. Where it deviates from these scientifically supported concentration limits, this must only be done on the basis of site specific biological effects data that clearly shows that allowing discharge and leaching of metals at concentrations above ANZECC/ARMANZC (2000) will not degrade aquatic ecosystems and species, or risk human health.

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Appendix 1 – Toxicology

Aluminium (Al)

Aluminum (Al) is the most abundant metal in the earth's crust, comprising about 7% of its mass.[78]The concentration of aluminum in natural waters (e.g., ponds, lakes, streams) is generally below 0.1 mg/L (ppm) or 100 µg/L (ppb).[79]

Human health

NHMRC (2011) DWG is set at 200 ug/L.

Traditionally, aluminium has been not been considered toxic to humans, but recently aluminium toxicity has been linked to multiple neurological diseases such as Parkinson's disease, amyotrophic lateral sclerosis and Alzheimer disease.[80] [81]

The World Health Organisation (WHO) suggests that there is little indication that orally ingested aluminium is acutely toxic to humans despite the widespread occurrence of the element in foods, drinking-water and many antacid preparations. It has been hypothesized that aluminium exposure is a risk factor for the development or acceleration of onset of Alzheimer disease in humans.

The 1997 WHO Environmental Health Criteria document for aluminium concludes that the relationship between aluminium in drinking-water and Alzheimer disease, which was demonstrated in several epidemiological studies, cannot be totally dismissed. However, strong reservations about inferring a causal relationship are warranted in view of the failure of these studies to account for demonstrated confounding factors and for total aluminium intake from all sources. Taken together, the relative risks for Alzheimer disease from exposure to aluminium in drinking-water above 100 µg/l (100ppb) are low. But, because the risk estimates are imprecise for a variety of methodological reasons, a population-attributable risk cannot be calculated with precision.[82]

A health-based value derived from the Joint FAO/WHO Expert Committee on Food Additives provisional tolerable weekly intake (PTWI) would be 0.9 mg/l (900 ppb) based on an allocation of 20% of the PTWI to drinking water and assuming a 60 kg adult drinking 2 litres of water per day.[83]

Aquatic life

ANZECC (2000) set the Freshwater Trigger Value (95% species protection) at 55µg/L at a pH >6.5.

High concentration of Al in water has strong correlation, particularly in low pH water, with Al accumulation in

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78Barakat, 2010.
79ATSDR, 2008; Berntssen et al, 1997.
80Milind et al, 2012.
81ATSDR. 2007.
82WHO, 2011.
83WHO, 2011.

fish organs such as kidney, skeleton and gills. It has also found in the brain and heart due to causing a distinct neuropathology in the brain.[84] It mainly reduces the number of skin mucous cells associated with the overall mucification of skin and gills and finally reduces the activities of gill enzymes leading to osmoregulatory failure.[85]

Though Al accumulates in different organs of the body mentioned above, it has profound effects on the gills, the most sensitive organ; and three main consequences of toxic effects on fish can be documented,[86]as:

Respiratory disturbances due to interlamellar mucous clogging, Al precipitation and reduced membrane fluidity;

Osmoregulatory disturbances due to net loss in ion uptake (Na+, Cl-and Ca2+) caused by Al binding to gill surface, intracellular Al accumulation, increased membrane permeability and damage of epithelium; and

Circulatory disturbances characterized by very high levels of hematocrit due to reduced blood plasma volume, erythrocyte swelling, and release from spleen.

The US EPA sets a maximum concentration criteria for aluminium in waterways at 750 ppb for pH between 6.5 and 9 and a continuous concentration criteria of 87 ppb in water with a pH between 6.5 and 9 to protect aquatic life.

Plants and crop

ANZECC (2000) set the Long-Term irrigation (up to 100 years) Trigger Vale at 5000 µg/L and Short Term irrigation (up to 20 years) Trigger Value at 20,000 µg/L.

In simple nutrient solutions concentrations of aluminium can begin to inhibit root growth within 60 min.[87]Aluminium is toxic to many plants when the concentration is greater than 2000–3000 ppb with a soil pH < 5.5.[88] Aluminium has been found to suppress the growth of rice seedlings and concentrations of 500 and at 2000 ppb and appears to be lethal to young rice plants. [89] Aluminum toxicity symptoms in rice starts with interveinal orangish mottling, leaving the veins green. Then the interveins turn yellow, and brown spots appear, gradually developing into necrotic streaks. The symptoms generally occurred first in the lower leaves, and in severe cases the lower leaves turned light brown and die. [90] Excess Al also induces iron (Fe) deficiency symptoms in rice (Oryza sativa L.), sorghum and wheat. [91] [92] [93]

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[84] Exley, 1996.
[85] Rosseland, et al, 1990.
[86] Rosseland & Staurnes, 1994; Havas & Rosseland, 1995.
[87] Delhaize& Ryan, 1995.
[88] Balsberg Pahlsson, 1990.
[89] Thawornwong & Van Diest, 1974.
[90] Tanaka & Navasero, 1966.
[91] Clark et al, 1981.
[92] Foy & Fleming, 1982.
[93] Furlani & Clark, 1981.

Arsenic (As)

Arsenic levels in natural waters generally range between 1 and 2 µg/l (1-2 ppb), although concentrations may be elevated (up to 12,000 ppb) in areas containing natural sources.[94]

Human health

NHMRC (2011) set the DWG at 10µg/L.

The WHO provisional guideline value for arsenic in drinking water is 10µg/L.[95]Arsenic is highly toxic to humans. Inorganic arsenic is absorbed readily from the human gastrointestinal tract, the lungs, and to a lesser extent from the skin, and becomes distributed throughout the body tissues and fluids.[96]

Inorganic arsenic compounds are classified by the International Agency for Research on Cancer as a Group 1 carcinogen (carcinogenic to humans).[97]The International Programme on Chemical Safety (IPCS) concluded that long-term exposure to arsenic in drinking-water is causally related to increased risks of cancer in the skin, lungs, bladder and kidney, as well as skin changes, such as hyperkeratosis and pigmentation changes.[98] Increased risks of lung and bladder cancer and of arsenic-associated skin lesions have been reported to be associated with ingestion of drinking-water at concentrations below 50 µg/l.[99]

Characteristic effect of long-term oral exposure to inorganic arsenic include patches of darkened skin and the appearance of small "corns" or "warts" on the palms, soles, and torso, and are often associated with changes in the blood vessels of the skin. Skin cancer may also develop. Swallowing arsenic has also been reported to increase the risk of cancer in the liver, bladder, and lungs. [100]

Although chronic As toxicity produces varied nonmalignant manifestations as well as cancer of skin and different internal organs, dermal manifestations such as hyperpigmentation and hyperkeratosis are diagnostic of chronic arsenicosis.[101] The pigmentation of chronic As poisoning commonly appears in a finely freckled, “raindrop” pattern of pigmentation or depigmentation that is particularly pronounced on the trunk and extremities and has a bilateral symmetrical distribution. [102] Other indicators of chronic arsenicosis are weakness, anemia, peripheral neuropathy, hepatomegaly with portal zone fibrosis (with/without portal hypertension), chronic lung disease and peripheral vascular disease.[103]

Chronic exposure of humans to inorganic arsenic in the drinking water has also been associated with excess incidence of miscarriages, stillbirths, preterm births, and infants with low birth weights. [104] Arsenic has been found in the milk of cows drinking arsenic contaminated water. One study found arsenic concentrations in water drunk by dairy cattle above 150 µg/l, which bio transferred to their milk which had arsenic concentrations of 0.5 to 7.8 µg/l . The bio transfer factor (BTF) for milk has been found to range from 1.5×10^{-5} to 4.3×10^{-4}.[105]

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[94] WHO, 2011.
[95] WHO, 2011.
[96] Sollman, 1957.
[97] IARC, 2020.
[98] WHO, 1981.
[99] WHO, 2011.
[100] ATSDR, 2007.
[101] Mazumder et al, 2000.
[102] Mazumder et al, 2000.
[103] Mazumder et al, 2000
[104] ATSDR, 2007.
[105] Perez-Carrera et al, 2009.

Although there is a substantial database on the association between both internal and skin cancers and the consumption of arsenic in drinking-water, there remains considerable uncertainty over the actual risks at low concentrations. In its updated evaluation, the United States National Research Council concluded that "the available mode-of-action data on arsenic do not provide a biological basis for using either a linear or nonlinear extrapolation". The maximum likelihood estimates, using a linear extrapolation, for bladder and lung cancer for populations in the USA exposed to arsenic at concentrations of 10 μg/l in drinking-water are, respectively, 12 and 18 per 10 000 population for females and 23 and 14 per 10 000 population for males. The actual numbers indicated by these estimated risks would be very difficult to detect by current epidemiological methods.

Aquatic life

Concentrations of arsenic in open seawater are typically less than 2 ppb.[106] Although some fish and shellfish take in arsenic, which may build up in tissues, most of this arsenic is in an organic form called arsenobetaine (commonly called "fish arsenic") that is much less harmful.[107]

Continuous exposure of freshwater organisms including fish to low concentrations of arsenic results in bioaccumulation, notably in liver and kidney. As a consequence, arsenic induces hyperglycemia, depletion of enzymatic activities, various acute and chronic toxicity, and immune system dysfunction.[108]

The risk associated with arsenic from seafood is based on the inorganic arsenic component with organic arsenic generally considered to be non-toxic. Concentrations of inorganic arsenic in marine fish are normally very low (<0.005 ppm), although shellfish and some seaweeds may contain higher levels.[109]While some seaweeds and bivalves have been identified as potential exposure risks for inorganic arsenic, data indicates that toxicity at high concentrations of some species of organic arsenic compounds in seafood may be occurring.[110]

Arsenobetaine (AB), the major organic arsenic species in most fish, is considered non-toxic and not metabolised. However, other more complex organic arsenic compounds in the form of arsenosugars and arsenolipids are also present at significant quantities in some types of seafood, and have been shown to be taken up and metabolised in humans.[111] Indeed, recent findings have shown that some forms of organic arsenic and their intermediate metabolites display cytotoxicity in cell cultures.[112]

Plants and crops

Inorganic arsenic disrupts plant metabolism through disrupting phosphate metabolism and transport proteins, leading to imbalances in phosphate supply. [113]

106Ng, 2005.
107ATSDR, 2007.
108Kumari et al, 2017.
109European Food Safety Authority (EFSA), 2009.
110Taylor et al, 2017.
111ibid
112Leffers et al, 2013; Meyer et al, 2014; Meyer et al, 2015.
113Finnegan & Chen, 2012.

Boron (B)

Human Health

No data are available on adverse effects of high boron intakes from food or water. [114]Symptoms associated with accidental consumption of boric acid or borax (sodium borate), contained in some household cleaning products and pesticides, include nausea, gastrointestinal discomfort, vomiting, diarrhea, skin flushing, rash, excitation, convulsions, depression, and vascular collapse.[115] The amount of boron consumed in people who accidentally consumed boron ranged from 18 to 9,713 mg, and most were children younger than 6 years.[116]. Boron toxicity can also cause headache, hypothermia, restlessness, weariness, renal injury, dermatitis, alopecia, anorexia, and indigestion. In infants, high boron intakes have caused anemia, seizures, erythema, and thin hair.[117]Extremely high doses of boron can be fatal; for example, 15,000 to 20,000 mg can cause death in adults.[118]

Aquatic life

The acute toxicity of boron to various fish has been the focus of a number of studies.[119] The most sensitive freshwater fish identified thus far is the rainbow trout (Oncorhynchus mykiss). Initial studies in reconstituted water indicated a lowest observed effect concentration (LOEC) of 0.1 mg/L. The LOEC is the lowest observed concentration at which there is a significant increase in the frequency of an adverse reproductive or developmental effect in comparison to a control group.[120]

Subsequent tests in natural waters (with boron amendments), however, indicated that the LOEC ranged from 1.1 to 1.73 mg/L. Major trout hatcheries commonly use waters containing up to 1 mg/L boron with no apparent problems (Butterwick et al., 1989; Howe, 1998).

Arecent study by Pillard et al. (2002) evaluated the toxicity of boron to the mysid shrimp (*Americamysis bahia*) in saline water. This species was chosen because it is the most common marine invertebrate required in whole-effluent toxicity (WET) tests and it has proven to be more sensitive to ion toxicity than other WET organisms. Pillard et al. (2002) observed a no-observed-adverse-effect level (NOAEL) of 275 mg/L boron in water with a salinity of 10 ppt (parts per thousand) and 170 mg/L boron in water with a salinity of 20 ppt (Pillard et al., 2002). The NOAEL is the highest concentra-tion at which there is not a significant increase in the frequency of an adverse reproductive or developmental effect in comparison to a control group. (TheNOAEL can differ significantly from the LOEC, depending on the magnitude of the concentrations tested.)

Plants and crops

Bradford (1966)[121] in a review of boron deficiencies and toxicities stated that when the boron concentration in irrigation waters was greater than 750 µg/L, some sensitive plants such as citrus began to show injury. Biggar and Fireman (1960[122]) showed that with neutral and alkaline soils of high absorption capacities

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[114] Institute of Medicine, 2001.
[115] Nielsen, 2012.
[116] Litovitz, et al, 1988.
[117] Uluisik et al, 2018.
[118] ibid
[119] Parks & Edwards, 2005
[120] Parks & Edwards, 2005
[121] Bradford, 1966.
[122] Biggar and Fireman, 1960.

water containing 2000 µg/L boron might be used for some time without injury to sensitive plants. The criterion of 750 µg/L is thought to protect sensitive crops during long-term irrigation.

Cadmium (Cd)

Human health

The WHO sets 3 µg/l as a limit for safe exposure in drinking water.[123]The WHO identifies that cadmium accumulates primarily in the kidneys and has a long biological half-life in humans of 10–35 years. [124] There is evidence that cadmium is carcinogenic by the inhalation route, and IARC has classified cadmium and cadmium compounds in Group 2A (probably carcinogenic to humans). However, there is no evidence of carcinogenicity by the oral route and no clear evidence for the genotoxicity of cadmium.[125] The kidney is the main target organ for cadmium toxicity.[126]

Eating food or drinking water with very high cadmium levels severely irritates the stomach, leading to vomiting and diarrhea, and sometimes death. [127] Eating lower levels of cadmium over a long period of time can lead to a build-up of cadmium in the kidneys. If the build-up of cadmium is high enough, it will damage the kidneys. Exposure to lower levels of cadmium for a long time can also cause bones to become fragile and break easily. [128] Cadmium is found in breast milk and a small amount will enter the infant's body through breastfeeding. The amount of cadmium that can pass to the infant depends on how much exposure the mother may have had. [129] Similarly, consuming milk of animals that drink cadmium contaminated water, will similarly pass on cadmium.

Prolonged inhalation or ingestion exposure of humans to cadmium at levels causing renal dysfunction can lead to painful and debilitating bone disease in individuals with risk factors such as poor nutrition; the occurrence of these bone effects in elderly Japanese women exposed to high levels of cadmium in rice and water was referred to as Itai-Itai disease. [130]

The US EPA has determined that exposure to cadmium in drinking water at a concentration of 400 ppb for up to 10 days is not expected to cause any adverse effects in children. The EPA has determined that lifetimeexposure to 5 µg/l (ppb) cadmium in drinking water is not expected to cause any adverse effects. [131]

Aquatic life

Aquatic organisms will accumulate cadmium, possibly entering the food supply. Cadmium concentrates in freshwater and marine animals to concentrations hundreds to thousands of times higher than in the water. Reported bioconcentration factors (BCFs) range from 3000 to 4,190 for fresh water aquatic organisms.[132]

People who regularly consume shellfish and fish organ meats (liver and kidney) may have increased cadmium

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[123] ATSDR, 2012a.
[124] WHO, 2011. p 327
[125] ibid
[126] WHO, 2011. p 327
[127] ATSDR, 2012a. p 5.
[128] ibid
[129] Ibid. p 3.
[130] ATSDR, 2012a.
[131] ATSDR, 2012a.
[132] ATSDR, 2012a.

exposure.[133] People who fish in local waters as a means of food should be cautious and abide by any advisories. ATSDR reports: "Recreational and subsistence fishers that consume appreciably higher amounts of locally caught fish from contaminated waterbodies may be exposed to higher levels of cadmium associated with dietary intake (EPA 1993a). Cadmium contamination has triggered the issuance of several human health advisories.[134]

The *Water Quality and Fish Health* Technical Paper by the European Inland Fisheries Advisory Commission state that: "…very small concentrations of cadmium may produce specific effects after a long exposure period. Chief among these specific effects are those exerted on the reproductive organs. An adverse influence of long exposure to cadmium upon the maturation, hatchability and development of larvae in rainbow trout was recorded at concentrations as low as 2 ppb[1]….For salmonids, the maximum admissible cadmium concentration in water is 0.0002 mg per litre, and for cyprinids 1ppb.[135]The US EPA recommends 1.8ppb acute and 0.72 ppb chronic criteria for healthy freshwater aquatic life.[136]

Plants and crops

Cadmium is a non-essential element that negatively affected plant growth and development. Stomatal opening, transpiration and photosynthesis has been reported to be affected by cadmium, as has iron, nitrate and phosphorous deficiencies. Chlorosis, leaf roll and stunting are the main visible symptoms of cadmium toxicity in plants.[137]

Cobalt (Co)

Human health

Cobalt is not regulated by the US EPA, as it is not currently considered toxic to humans, the environment or crops. However, recent research suggests that absorbing large amounts of cobalt over longer periods of time can lead to serious health problems and that cobalt poisoning that occurs from constant contact with your skin will likely cause irritation and rashes that go away slowly. Swallowing a large amount of absorbable cobalt at one time is very rare and is likely not very dangerous. It may cause nausea and vomiting.

Copper (Cu)

Cu naturally occurs in the aquatic environment in low concentrations. Major aquifers of the U.S. have Cu concentrations less than 10 ppb total Cu (Lee and Helsel 2005), while Canadian freshwaters have 1-8 ppb Cu (ATSDR 1990), and streams in Bristol Bay have 0.04-5.60 ppb Cu (Zamzow 2011). Seawater Cu concentrations are generally less than 1 ppb (Nordberg et al. 2007).

133ATSDR, 2012a.
134ATSDR, 2012a.
135Svobodová, et al, 1993.
136US EPA, 2017.
137Benavides et al, 2005.

Human health

Copper is an essential trace metal necessary for growth and metabolism of all living organisms; humans need approximately 1-2.5 mg daily (Nordberg et al. 2007).

Cu is toxic at higher concentrations and mammals (including humans) evolved efficient Cu regulatory systems for uptake, distribution, storage and excretion (Nordberg et al. 2007). In mammals, excess Cu is generally absorbed into gastrointestinal cells and excreted when cells slough (Eisler 2000). Overdoses of Cu are documented and symptoms in humans for 44 mg/L and less include gastrointestinal distress, nausea, vomiting, headache, dizziness, and metallic taste in mouth; higher doses can cause coma and death (NAS 2000). Humans afflicted with Wilson's disease, children under one year, people with liver damage, chronic disease, and diabetes are more susceptible to Cu poisoning (Nordberg et al. 2007)

Birds and mammals, when compared to lower forms, are relatively resistant to copper. But diets containing elevated concentrations of copper are sometimes fatal to ducklings (Wood and Worden 1973) and livestock when fed for extended periods. Domestic sheep (Ovis aries) are the most susceptible farm animals to chronic copper poisoning and effects include liver damage, impaired reproduction, reduced resistance to diseases, jaundice, and death (Gopinath and Howell 1975; Higgins 1981; Bires et al. 1993)

Aquatic species

Copper is among the most toxic of the heavy metals in freshwater and marine biota (Schroeder et al. 1966; Betzer and Yevich 1975), and often accumulates and causes irreversible harm to some species at concentrations just above levels required for growth and reproduction (Hall et al. 1988).

Cu is acutely toxic (lethal) to freshwater fish in soft water at low concentrations ranging from 10 – 20 part per billion (NAS 1977) and most invertebrates are highly sensitive to copper. In one study, larvae acclimated to copper exposure more quickly than juvenile and adult fish and had better survival (Sellin et al. 2005). In some fish species, younger fish are more resistant to copper toxicity than older fish; in others, the reverse is true (Howarth and Sprague 1978; Pickering and Lazorchak 1995; Furata et al. 2008).

Copper will damage a number of organs and systems, including the gills, liver, kidney, immune system, and nervous system (Cardeilhac and Whitaker 1988). Gills appear to be the most affected organ during acute toxicity, and will become blunt and thickened and lose ability to regulate body fluid ion concentrations. Copper also suppresses immune system function, and can affect the lateral line of fish. Prolonged copper exposure also may result in reduced growth (Wong et al. 1999). During toxicity, in addition to general signs of distress (e.g., increased respiration), fish may display darkening and behavioral abnormalities: lethargy, incoordination, problems with posture and balance, and, eventually, death (Cardeilhac and Whitaker 1988).

Plants and crops

Copper toxicosis in terrestrial higher plants is rare but occurs on mine spoils and where copper-rich manures or fungicides are used excessively (Schroeder et al. 1966; NAS 1977; Alva et al. 1995; Arduini et al. 1995).

Chromium (Cr)

The levels of chromium in U.S. fresh waters typically range from less than 1 to 30µg/L, with a mean concentration of 10µg/L.[138] Average concentrations of total chromium (including Cr(III) and Cr(VI) in dissolved and particulate phases) in uncontaminated surface and marine waters of Canada are generally below 1 µg/l.[139]

The two naturally occurring forms of chromium are chromium(III), and chromium(VI). Between 10% and 60% of the total chromium content in Canadian rivers may be present as dissolved Cr(VI).[140] Soluble chromium(VI) may persist in some bodies of water, but will eventually be reduced to chromium(III) by organic matter or other reducing agents in water. [141]

The residence times of chromium (total) in lake water range from 4.6 to 18 years, with the majority of the chromium in lakes and rivers ultimately deposited in the sediments. [142]

Human health

The WHO provisional guideline value for total chromium in drinking water is 50 µg/L.

Small amounts of chromium (III) are needed for human health, but some critics question its essentiality.[143]

In humans and animals, high levels of chromium (VI) in drinking water has been found to cause tumors in the stomach.[144] The US EPA has classified chromium (VI) as a Group A, known human carcinogen,[145] and the International Agency for Research on Cancer has listed chromium (vi) compounds as [146]Group 1 – carcinogenic to humans.

Absorbed chromium distributes to nearly all tissues, with the highest concentrations found in kidney and liver. Bone is also a major depot and may contribute to long-term retention kinetics of chromium. Absorbed chromium can be transferred to fetuses through the placenta and to infants via breast milk.

The higher toxic potency of chromium (VI) compared to chromium (III) is complex. Chromium (VI) enters cells by facilitated uptake, whereas chromium (III) crosses cell membranes by simple diffusion; thus, cellular uptake of chromium (VI) is more effective than the uptake of chromium (III). Furthermore, in biological systems, reduction of chromium (VI) to chromium (III) results in the generation of free radicals, which can form complexes with intracellular targets.

The primary effects associated with exposure to chromium (VI) compounds are respiratory, gastrointestinal, immunological, hematological, reproductive, and developmental. In addition, dermal and ocular irritation may occur from direct contact. Based on available dose-response data in humans and animals, the most sensitive non cancer effects of chromium (VI) compounds are respiratory (nasal and lung irritation, altered pulmonary function), gastrointestinal (irritation, ulceration and nonneoplastic lesions of the stomach and small intestine), hematological (microcytic, hypochromic anemia), and reproductive (effects on male reproductive organs, including decreased sperm count and histopathological change to the epididymis).[147]

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[138] ATSDR, 2012b.
[139] Erickson & Fowler, 1987: Mayer, 1988: Rossmann & Barres,1988.
[140] Canada Health, 2015.
[141] Cary, 1982: US EPA. 1984a: Lide, 1998.
[142] Schmidt & Andren, 1984.
[143] ATSDR, 2012b.
[144] Dayan & Paine, 2001.
[145] US EPA, 1999.
[146] IARC, 2012.
[147] ATSDR, 2012b.

Accidental or intentional ingestion of extremely high doses of chromium (VI) compounds by humans has resulted in severe respiratory, cardiovascular, gastrointestinal, hematological, hepatic, renal, and neurological effects leading to death or in patients who survived because of medical treatment. [148]

Aquatic organisms

The aquatic toxicology of Cr depends on both biotic and abiotic factors. The biotic factors include the type of species, age and developmental stage. The temperature, concentration of Cr, oxidation state of Cr, pH, alkalinity, salinity, and hardness of water constitute the abiotic factors. Moreover, lethal and sub-lethal concentrations of the metal and its speciation also determine the sensitivity of the individual organism.[149]

Lethal concentrations (96h-LC_{50}) of chromium ranges from 40 to 120 mg/l (ppm) depending on the species affected. Sub-lethal acute effects on various species, such as reduced fertility and systemic disruption, ranges from 5μg/L (ppb) to 120 mg/l (ppm). [150]

Continual exposure to Chromium changes various enzyme activities in kidney, brain, and liver. Chronic exposure to Chromium may also induce irregular behavioral responses in various species of fish. Chromium concentrations leading to chronic effects in freshwater fish ranges generally begins to take effect at concentrations as low as 7.5μg/L (ppb) for Cr (vi) to 100 μg/L for Cr(iii), for certain freshwater species.[151] In Chinook salmon, for example, physiological modifications as well as DNA damages occurred at a concentration of 24 μg/L.[152]

Plants and crops

Cr accumulation in plants causes high toxicity in terms of reduction in growth and biomass accumulation, and Cr induces structural alterations. Cr interferes with photosynthetic and respiration processes, and water and minerals uptake mechanism. Various enzymatic activities related to starch and nitrogen metabolism are decreased by Cr toxicity either by direct interference with the enzymes or through the production of reactive oxygen species. Cr causes oxidative damage by destruction of membrane lipids and DNA damage. Cr may even cause the death of plant species. Few plant species are able to accumulate high amount of Cr without being damaged.[153]

Reduced productivity of some tomato species have been found after irrigated with 5–10 mg/l (ppm) Cr (VI). [154] However, several studies have also reported that Cr (III) exposure induces oxidative damage in plants resulting in growth inhibition. [155]

Iron (Fe)

The median iron concentration in rivers has been reported to be 700ppb In anaerobic groundwater where iron is in the form of iron (II), concentrations will usually be 500 – 10,000 ppb but concentrations up to

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[148] ATSDR, 2012b.
[149] Velma, 2009.
[150] Velma, 2009.
[151] Velma, 2009.
[152] Aslam & Yousafzai, 2017.
[153] Singh et al, 2013.
[154] Singh et al, 2013.
[155] Singh et al, 2013.

50,000 ppb can sometimes be found (6). Concentrations of iron in drinking-water are normally less than 300 ppb but may be higher in countries where various iron salts are used as coagulating agents in water-treatment plants and where cast iron, steel, and galvanized iron pipes are used for water distribution.[156]

Human health

Anaerobic groundwater may contain ferrous iron at concentrations up to several milligrams per litre without discoloration or turbidity in the water when directly pumped from a well. On exposure to the atmosphere, however, the ferrous iron oxidizes to ferric iron, giving an objectionable reddish-brown colour to the water. Iron also promotes the growth of “iron bacteria”, which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on the piping. At levels above 300 ppb, iron stains laundry and plumbing fixtures. There is usually no noticeable taste at iron concentrations below 300ppb although turbidity and colour may develop. No health-based guideline value is proposed for iron.[157]

Aquatic life

Iron has also been found to be toxic to some aquatic life. Warnick and Bell (1969) obtained 96-hour LC50[158] values of 320 µg/L for mayflies, stonefies, and caddisflies; all are important fish food organisms. Brandt (1948) found iron toxic to carp, *Cyprinus carpio*, at concentrations of, 900 µg/L when the pH of the water was 5.5. Pike, *Esox lucius*, and trout (species not known) died at iron concentrations of 1000 to 2000 µg/L(Dudoroff and Katz,1953). In an iron polluted Colorado stream, neither trout nor other fish· were found until the waters were diluted or the iron had precipitated to effect a concentration of less than 1000 µg/L even though other water quality constituents measured were suitable for the presence of trout (FWPCA. 1967). The European Inland Fisheries Advisory Commission (19154) recommended that iron concentrations not exceed 1000 µg/L in waters to be managed for aquatic life.

The European Inland Fisheries Advisory Commission (19154) recommended that iron concentrations not exceed 1000 ppb in waters to be managed for aquatic life.

Plant and crop

Although iron is an essential nutrient for plants, its accumulation within cells can be toxic.[159] Iron toxicity is a major nutritional disorder in irrigated and rain fed waterlogged rice.[160] Soluble iron present in the soil solution under waterlogged conditions is absorbed by roots and accumulates in leaves, causes poor growth and tillering and severe yield reductions, associated with leaf discoloration.[161]

Iron toxicity leads to increased polyphenol oxidase activity, leading to the production of oxidized polyphenols. It also causes leaf bronzing and reduced root oxidation power and can act catalytically via the Fenton reaction to generate hydroxyl radicals, which can damage lipids, proteins and DNA.[162]

The bronzing symptoms start in fully developed older source leaves with the occurrence of tiny brown spots that spread from the leaf tip to the base. In the further development of the symptom, the leaf tips become orange-yellow and dry up in some rice varieties. These symptoms are particularly developed in older leaves having higher

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156WHO, 1996.
157WHO, 2011.
158LC50 is the concentration of the chemical in the air or water that will kill 50% of the test animals with a single exposure.-
159Connolly & Guerinot, 2002.
160Stein ET AL, 2014.
161Audebert & Sahrawat, 2000.
162Connolly & Guerinot, 2002.

transpiration rates.[163] Eventually, the entire transpiring leaf becomes orange to rusty brown, or purple brown when toxicity is extremely severe.[164] Iron toxicity remains an important constraint to rice production, and together with Zn deficiency, it is the most commonly observed micronutrient disorder in wetland rice. The Fe2+ concentrations in the soil solution that reportedly affect lowland-rice yields can range from as low as 10,000 ppb.[165]

Average reported yield losses due to iron toxicity are in the range of 12%–35%. [166]However, toxicity at seedling and early vegetative stages can strongly affect plant growth and result in a complete crop failure.[167]

Lead (Pb)

Lead is a naturally occurring metal found in the Earth's crust at about 15–20 mg/kg (15-20ppm). [168] On average rivers contain between 3 and 30ppb and seawater contains trace amounts (2-30ppt),[169] with drinking water generally containing less than about 5μg/L.[170]

Human health

The WHO states in its Drinking Water Guidelines[171]that exposure to lead is associated with a wide range of effects, including various neurodevelopmental effects, mortality (mainly due to cardiovascular diseases from increased blood pressure.), impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes.

Impaired neurodevelopment in children is generally associated with lower blood lead concentrations than the other effects. Infants and children are considered to be the most sensitive subgroups of the population. [172] The *Toxicological Profile for Lead* by the US Agency for Toxic Substances and Disease Control[173]warns that, in general, if adults and children swallow the same amount of lead, a bigger proportion of the amount swallowed will enter the blood in children than in adults with children absorb about 50% of ingested lead and that no safe blood lead level in children has been determined. Based on the dose-response analyses, 0.025mg/l of lead to 1kg body weight is associated with a decrease of at least 3 intelligence quotient (IQ) points in children and an increase in systolic blood pressure of approximately 3 mmHg (0.4 kPa) in adults.[174]

For adults who had just eaten, the amount of lead that enters the blood from the stomach is only about 6% of the total amount taken in. In adults who had not eaten for a day, about 60–80% of the lead from the stomach got into their blood. In general, if adults and children swallow the same amount of lead, a bigger proportion of the amount swallowed will enter the blood in children than in adults. Children

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[163] Yamanouchi & Yoshida, 1981.
[164] Fairhurst & Witt, 2002.
[165] Becker and Asch, 2005.
[166] Lantin & Neue, 1989.
[167] Abifarin, 1988.
[168] ATSDR, 2007. p 19.
[169] Lenntech Water Treatment Solutions.
[170] See WHO, 2011.
[171] WHO, 2011. p 384.
[172] Ibid
[173] ATSDR, 2007a. p 10.
[174] WHO, 2011. p 384.

absorb about 50% of ingested lead. No safe blood lead level in children has been determined. [175]

Lead exposure may also cause weakness in fingers, wrists, or ankles. Lead exposure also causes small increases in blood pressure, particularly in middle-aged and older people. Lead exposure may also cause anemia. At high levels of exposure, lead can severely damage the brain and kidneys in adults or children and ultimately cause death. In pregnant women, high levels of exposure to lead may cause miscarriage. High level exposure in men can damage the organs responsible for sperm production.[176] Lead can be transferred from the mother to the fetus and also from the mother to infants via maternal milk.[177]Evidence has also been shown for transfer of lead to milk and edible tissue in cattle poisoned by licking the remains of storage batteries burned and left in a pasture. The highest lead level found in the milk of these cows studied for 18 weeks was 0.22 mg/kg (220 ppb). [178]

US EPA Red Book states that "As far as is known, lead has no beneficial or desirable nutritional effects. Lead is a toxic metal that tends to accumulate in the tissues of man and other animals. Although seldom seen in the adult population, irreversible damage to the brain is a frequent result of lead intoxication in children. The major toxic effects of lead include anemia, neurological dysfunction, and renal impairment. The most common symptoms of lead poisoning are anemia, severe intestinal cramps, paralysis of nerves (particularly of the arms and legs), loss of appetite and fatigue; the symptoms usually develop slowly. High levels of exposure produce severe neurologic damage, often manifested by encephalopathy and convulsions; such cases frequently are fatal. Lead is strongly suspected of producing subtle effects (ie effects due to low level or long term exposures insufficient to produce overt symptoms), such as impaired neurologic and motor development and renal damage in children. "

Aquatic life

Lead is toxic to all aquatic biota, and organisms higher up in the food chain may experience lead poisoning as a result of eating lead-contaminated food.[179]Older organisms tend to contain the greatest body burdens with lead concentrations usually highest in benthic organisms and algae, and lowest in upper trophic level predators (e.g., carnivorous fish).[180]Bio-concentration factors for aquatic biota are: 42 for fish, 536 for oysters, 500 for insects, 725 for algae, and 2,570 for mussels.[181] The European Inland Fisheries Advisory Commission set a maximum admissible lead concentration in water of 0.004 to 0.008 mg per liter for salmonids and 0.07 mg per liter for cyprinids.[182]The US EPA National Recommended Aquatic Life Criteria for freshwater are 0.065 mg/l (acute) and 0.0025 μg/L (chronic).[183]

Plants and crops

Excess lead causes a number of toxicity symptoms in plants e.g. stunted growth, chlorosis and blackening of root system and inhibits photosynthesis, upsets mineral nutrition and water balance, changes hormonal status and affects membrane structure and permeability.[184]

175ATSDR, 2007a.
176ATSDR, 2007a. pp 8-9.
177ATSDR, 2007a. pp 156.
178ATSDR, 2007a. p 340.
179ATSDR, 2007a. p 322.
180ATSDR, 2007a. p 321.
181ibid
182Svobodová et al, 1993.
183US EPA, 2016.
184Sharma & Dubey, 2005.

Manganese (Mn)

In natural waterways manganese is rarely found at concentrations above 1000 μg/l.

Human health

Manganese is an essential nutrient, and eating a small amount of it each day is important to stay healthy. While the WHO does not set a safe drinking water level for manganese, and deems it "not of health concern at levels found in drinking-water,"[185]the US Agency for Toxic Substances and Disease Registry state that: "Manganese has been shown to cross the blood-brain barrier and a limited amount of manganese is also able to cross the placenta during pregnancy, enabling it to reach a developing fetus. Nervous system disturbances have been observed in animals after very high oral doses of manganese, including changes in behavior. Sperm damage and adverse changes in male reproductive performance were observed in laboratory animals fed high levels of manganese. Impairments in fertility were observed in female rodents provided with oral manganese before they became pregnant. Illnesses involving the kidneys and urinary tract have been observed in laboratory rats fed very high levels of manganese. These illnesses included inflammation of the kidneys and kidney stone formation. The US EPA concluded that existing scientific information cannot determine whether or not excess manganese can cause cancer.

Very large doses of ingested manganese can cause some disease and liver damage. However, only a few manganese toxicity problems have been found throughout the world and these have occurred under unique circumstances, i.e., a well in Japan near a deposit of buried batteries. [186]

The US EPA has established that exposure to manganese in drinking water at concentrations of 1000 μg/l for 1 or 10 days is not expected to cause any adverse effects in a child and has established that lifetime exposure to 300 μg/l manganese is not expected to cause any adverse effects.

Studies in children have suggested that extremely high levels of manganese exposure may produce undesirable effects on brain development, including changes in behavior and decreases in the ability to learn and remember. In some cases, these same manganese exposure levels have been suspected of causing severe symptoms of manganism disease (including difficulty with speech and walking). We do not know for certain that these changes were caused by manganese alone. We do not know if these changes are temporary or permanent. We do not know whether children are more sensitive than adults to the effects of manganese, but there is some indication from experiments in laboratory animals that they may be.[187]

Consumer complaints arise when manganese exceeds a concentration of 150 μg/L in water supplies (Griffin, 1960). These complaints are concerned "primarily with the brownish staining of laundry and objectionable tastes in beverages. It is possible that the presence of low concentrations of iron may intensify the adverse effects of manganese. Manganese at concentrations of about 10 to 20 μg/L is acceptable to most consumers. A criterion for domestic water supplies of 50 μg/L should minimize the objectionable qualities.

Aquatic life

The tolerance values of aquatic organisms is reported to range from 1.5 mg/l to over 1,000 mg/l . [188]

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[185] WHO, 2011. p 387.
[186] McKee & Wolf, 1963. (1976 reprint)
[187] ATSDR, 2012c. p6
[188] McKee & Wolf, 1963.

McKee and Wolf (1963) summarized data on toxicity of manganese to aquatic marine life. Ions of manganese are found rarely at concentrations above 1000 µg/L. The tolerance values reported range from 1500 µg/L to over 1,000,000 µg/L. [189]

Manganese is rapidly assimilated and bio-concentrated into nodules that are deposited on the sea floor. The major problem with manganese may be concentration in the edible portions of mollusks, as bioaccumulation factors as high as 12,000 have been reported.[190] In order to protect against a possible health hazard to humans by manganese accumulation in shellfish, a criterion of 100 µg/l is recommended for marine water.[191]

Plants and crops

At concentrations of slightly less than 1000 µg/L to a few milligrams per liter, manganese may be

Problems may develop with long-term (20 year) continuous irrigation on other soils with water containing about 10,000 µg/l of manganese.[192] In select areas, and where acidophilic crops are cultivated and irrigated, a criterion of 200 µg/l is suggested for consideration. [193]

Nickel (Ni)

Human health

The WHO guidelines for Nickel in drinking water is 70 µg/L (ppb).

The most common harmful health effect of nickel in humans is an allergic skin reaction. A person can become sensitive to nickel when nickel is in direct and prolonged contact with the skin.[194]

Aquatic life

Nickel is highly toxic to fish and other aquatic species at concentrations as low as 0.01mg/l.[195]The US EPA recommend a maximum of 0.47mg/l for acute and 0.052mg/l for chronic concentrations for healthy freshwater aquatic life.[196]

Nickel does not appear to concentrate in fish.[197] However, to protect fresh water fish species, the FAO (1984) suggested an average concentration of nickel should not exceed 0.01 mg/l and the 95 percentile should not exceed 0.03 mg/l in soft water (20 mg/l as CaCO3). In hard water (320 mg/l as CaCO3), the corresponding concentrations of nickel should be 0.04 and 0.12 mg/L respectively.[198]

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[189] McKee & Wolf, 1963. (1976 reprint). 548 p.
[190] National Academy of Sciences, National Academy of Engineering, 1972.
[191] US EPA, 1976.
[192] National Academy of Sciences, National Academy of Engineering, 1972.
[193] US EPA, 1976.
[194] ATSDR, 2005. p 6.
[195] Grimwood & Dixon, 1997.
[196] US EPA, 2017.
[197] ATSDR, 2005. p 227
[198] FOA, 1984. p 15.

Plants and crops

Studies show that some plants can take up and accumulate nickel. [199]As with other heavy metals, excess concentrations of Ni in plants cause chlorosis and necrosis, due to disruption of Fe uptake and metabolism.[200] Elevated concentrations of Ni can inhibit cell division at root meristems in non-tolerant plants and decrease plant growth.[201]

Selenium (Se)

Selenium is present in Earth's crust, often in association with sulfur-containing minerals. Most drinking-water contains concentrations of selenium that are much lower than 10 ppb, except in certain seleniferous areas. [202] [203]

Human health

The WHO sets a provisional guideline of 40 ppb for safe drinking water, which is lower than the US EPA drinking water standard of 50ppb.[204]

Selenium is an essential trace element, and foodstuffs such as cereals, meat and fish are the principal source of selenium for the general population. Levels in food also vary greatly according to geographical area of production. However, even in high selenium areas, the relative contribution of selenium from drinking-water is likely to be small in comparison with that from locally produced food. [205]

Selenium is considered toxic to people. Symptoms appear similar to those of arsenic poisoning.[206] Ingestion of selenium in amounts as low as .07 mg per .day has been shown to give rise to signs of selemium toxicity, selenium concentrations above 10 μg/L should not be permitted in drinking water.[207] Chronic oral intake of very high levels of selenium (10–20 times more than normal,[208]can produce selenosis in humans, the major effects of which are dermal and neurological and causes diseased nails, skin and hair loss, as well neurological problems, including unsteady gait and paralysis.[209]

The primary adverse effects in laboratory animals exposed to selenium are cardiovascular, gastrointestinal, hematological, hepatic, dermal, immunological, neurological, and reproductive, although doses causing these effects are generally at least 5 times higher than normal daily selenium intake. A condition (syndrome) referred to as "blind staggers" has been repeatedly observed in cattle feeding off vegetation in areas with high selenium content in the soil. [210]

High intakes of selenium are associated with a number of specific diseases and the potential for adverse effects, but seems to be strongly influenced by other factors. Symptoms in people with

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[199] ATSDR, 2005. p 3.
[200] De kock, 1956.
[201] Bhalerao et al, 2015.
[202] WHO, 2011. p 413.
[203] ATSDR, 2003. p 3.
[204] WHO, 2017.
[205] WHO, 2011. p 413.
[206] Kehoe ET AL, 1944.
[207] Smith & Westfall,1937.
[208] In the USA the average daily intake without supplements is 108 ug per day see U.S. DAARS, 2012.
[209] ATSDR, 2003. p 15.
[210] Ibid. p 16.

high urinary selenium levels included gastrointestinal disturbances, discoloration of the skin, decayed teeth, hair or nail loss, nail abnormalities and changes in peripheral nerves.. [211]

Chronic oral intake of very high levels of selenium (10–20 times more than normal) can produce selenosis in humans, the major effects of which are dermal and neurological and causes diseased nails, skin and hair loss, as well neurological problems, including unsteady gait and paralysis.[212]Very high amounts of selenium have caused decreased sperm counts, increased abnormal sperm, changes in the female reproductive cycle in rats, and changes in the menstrual cycle in monkeys. [213]

The average dietary intake that is associated with selenosis has been found to be in excess of 900 µg/day. As selenium is an essential element, various national and international organizations have established recommended daily intakes of selenium. A joint FAO/WHO consultation recommended intakes of 6–21 µg of selenium per day for infants and children, according to age, 26 and 30 µg of selenium per day for adolescent females and males, respectively, and 26 and 35 µg of selenium per day for adult females and males, respectively. Because of concern about the adverse effects resulting from exposure to excessive levels of selenium, various national and international organizations have established upper limits of exposure for selenium. FAO/WHO established an upper tolerable limit for selenium of 400 µg/day. [214]

Aquatic life

Selenium in water can be concentrated from 100 to more than 30,000 times in the food organisms eaten by fish and wildlife, which exposes them to a highly concentrated dietary source of contamination.[215]

Selenium can also cause developmental abnormalities and reproductive failure in fish and wildlife.[216]Waterborne concentration of selenium of 0.0027 mg/l has been found to result in 20-30% total fish population mortality a year for of two species.[217]In 2016, the US EPA introduced a recommended a 30 day chronic concentration of between 0.0015 mg/l and 0.0031mg/l for healthy freshwater organisms. [218]

A significant portion of the selenium consumed by wildlife is passed to their offspring in eggs, where it can kill developing embryos outright or induce a variety of lethal or sublethal teratogenic deformities.[219]However, parents can consume a selenium-laden diet and experience partial or complete reproductive failure without exhibiting symptoms of selenium toxicosis themselves. [220] Moreover, aquatic food organisms of wildlife strongly bioaccumulate selenium—hundreds to thousands of times the waterborne concentration—but are unaffected by tissue residues that are high enough to cause reproductive failure when consumed by fish and aquatic birds.[221] Thus, bioaccumulation in aquatic food chains, and dietary transfer to eggs cause otherwise innocuous concentrations of waterborne selenium to become toxic.[222]

Selenium is a well-documented contaminant in coal ash wastewater and it can cause developmental abnormalities and reproductive failure in fish and wildlife.[223] The US EPA sets a water quality criterion of 5 µg/l for freshwater aquatic life. However, Lemly (2013) [224] found waterborne concentration of selenium of 2.7 µg/l resulted

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211WHO, 2011. p 413.
212ATSDR, 2003. p 15.
213ATSDR, 2003. p 7.
214WHO, 2011. p 413.
215Lemly, 1998.
216Lemly, 2002.
217Lemly, 2013.
218US EPA, 2016.
219Lemly, 1993.
220Lemly, 1999.
221Lemly, 1998.
222Lemly, 1993b.
223Lemly, 2002a.
224Lemly, D., 2013.

in 20-30% total population mortality a year for of two species and suggest that an ecologically appropriate standard should be in the 1.5-2.0 µg/l range, as has been recommended in the scientific literature.

Plants and crops

At elevated levels selenium is toxic to most plants. When plants are exposed to high concentrations of selenium in their root medium, they may exhibit stunting of growth, chlorosis, withering and drying of leaves, decreased protein synthesis, and premature death of the plant.[225]

Vanadium (V)

The US EPA does not regulate Vanadium, nor does it recommend maximum concentrations.

Based on occupational exposure studies, human experimental studies, and studies in laboratory animals, the respiratory tract following inhalation exposure and the gastrointestinal tract, hematological system, and developing organism following oral exposure are the primary targets of toxicity

Zinc (Zn)

Zinc occurs in small amounts in almost all igneous rocks. The principal zinc ores are sulfides, such as sphalerite and wurzite.[226] The natural zinc content of soils is estimated to be 1–300 mg/kg.[227]In natural surface waters, the concentration of zinc is usually below 10 µg/l, and in groundwaters, 10– 40 µg/l.[228]

Human health

Zinc is an essential trace element. However, manifest copper deficiency is the major consequence of the chronic ingestion of zinc. [229] Impairment of the copper status of volunteers by dietary intake of 18.5 mg of zinc per day has been reported.[230]

The antagonistic effects of zinc on the toxic effects of other metals, including cadmium, lead, and nickel, is also reports.[231]

Aquatic life

Toxic concentrations of zinc compounds cause adverse changes in the morphology and physiology of

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[225] Zayed et al, 2000.
[226] Elinder 1986.
[227] Nriagu, 1980.
[228] WHO, 2003.
[229] Cousins & Hempe, 1990.
[230] Festa et al, 1985.
[231] Reddy et al, 1987: Waalkes et al, 1985: Hietanen et al, 1982.

fish. Acutely toxic concentrations induce cellular breakdown of the gills, and possibly the clogging of the gills with mucous. Chronically toxic concentrations of zinc cause general enfeeblement and widespread histological changes to many organs of fish, but not to gills and growth and maturation are retarded.[232] Toxicity appears to be determined by the concentrations of calcium carbonate (CaCO3) (ie hard water).

The toxicity of zinc compounds to aquatic animals is modified by several environmental factors, particularly hardness (CaCO3), dissolved oxygen, and temperature. [233] Acute toxicity of zinc in fish (LCD50) has been found as low as 10µg/L (ppb) in the presence of CaCO3 concentrations of 1700 µg/L (ppb).[234] At concentrations of 20 mg/L (ppm) calcium the LC5O was found at zinc concentrations of 870 µg/L (ppb), and at 360 mg/l CaCO3 it was 33,000 µg/L (ppb). At 14 mg/l CaCO3, the incipient lethal level of zinc , the level beyond which the organism can no longer survive, was found to be 420 µg/L.[235] In water with a total hardness of 200 mg/L CaC03, 180 µg/L zinc caused an 83 percent reduction in eggs produced, in chronic tests. [236]

Toxic concentrations of zinc compounds cause adverse changes in the morphology and physiology of fish. Acutely toxic concentrations induce cellular breakdown of the gills, and possibly the clogging of the gills with mucous. Chronically toxic concentrations of zinc compounds, in contrast, cause general enfeeblement and widespread histological changes to many organs, but not to gills. Growth and maturation are retarded.

Using dilution water with calcium of 1700 µg/L, Affleck (1952) found a 54 percent mortality (>LC50) of rainbow trout fry in 28 days in a zinc concentration of 10 µg/L. Pickering and Henderson (1966) determined the 96-hour LC5O of zinc for fathead minnows, *Pimephales Rromelas*, and bluegills, *Lepomis macrochirus*, using static test conditions. For fathead minnows in soft water (20 mg/L CaC03) the LC5O was 870 µg/L, and in hard water (360 mg/l CaCOJ) it was 33,000 µg/L. Bluegills were more resistant in both waters. Similarly, the lethal threshold concentration was 3 or 4 times as high for coarse fish as for trout, *Salvelinus fontinalis*, (Ball, 1967).

The Atlantic salmon, Salmo salar, was tested in a 168-hour continuous-flow bioassay at 17° C in water with a total hardness of 14 mg/l CaCO3. The incipient lethal level, the level beyond which the organism can no longer survive, was 420 µg/L of zinc (Sprague and Ramsay, 1965).

Brungs (1969) found that in water with a total hardness of 200 mg/L CaC03, 180 µg/L zinc caused an 83 percent reduction in eggs produced by the fathead minnow, *Pimephales promelas*, in chronic tests. The tests lasted 10 months and the control test water contained 30 µg/L zinc. The 96-hour continuous-flow TLm was determined to be 9,200 µg/L zinc.

The 48-hour LC50 for *Daphnia magna* (a small freshwater planktonic crustacean) in soft water with a hardness of 45 nWl CaC03 and an alkalinity of 42 mg/L has been found to be 100 µg/L; in 70 µg/L zinc, there was a 16 percent reproductive impairment in a 3-week chronic test (Biesinger and Christensen, 1972).Toxicities of zinc in nutrient solutions have been demonstrated for a number of plants. Hewitt (1948) found that zinc at 16 to 20 mg/L produced iron deficiencies in sugar beets. Hunter and Vergnano (1953) found toxicity to oats at 25 mg/L. Millikan (1947) found that 2.5 mg/L produced iron deficiency in oats. Early (1943) found that the Peking variety of soybeans was killed at 0.4 mg/L, whereas the Manchu variety was killed at 1.6 mg/L zinc.

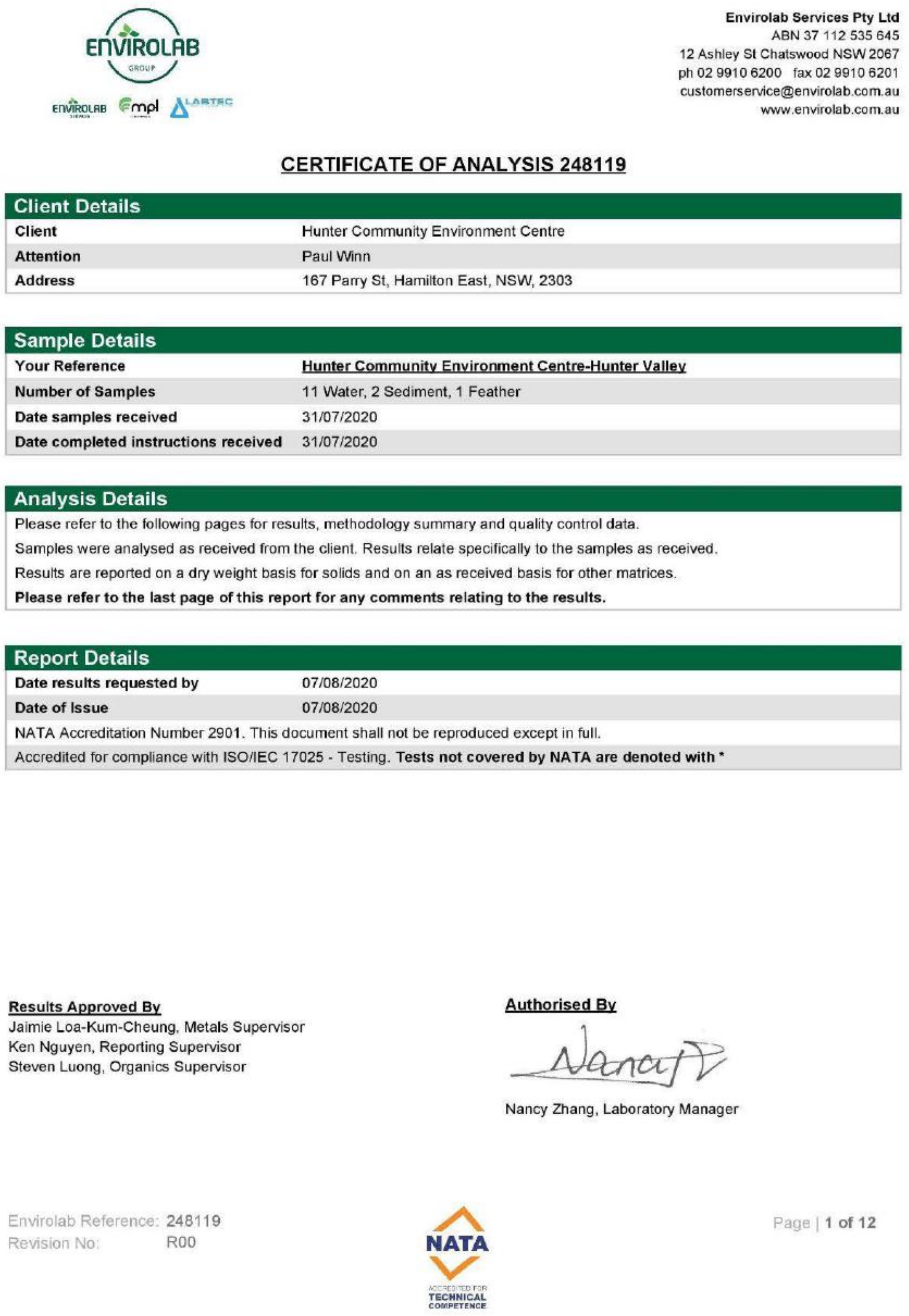
Plants and crops

The toxicities of zinc has been demonstrated for a number of plants at concentrations of between 16 to 20 mg/l (ppm) which produced iron deficiencies in sugar beets, and oats at 25 mg/l ,[237] and soybeans.

232Pickering & Henderson, 1966.
233Skidmore, 1964.
234Pickering & Henderson, 1966.
235Sprague & Ramsay, 1965.
236Brungs, 1969.
237Hewitt, 1948.

Appendix 2: Laboratory Reports

Bayswater and Liddell



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CERTIFICATE OF ANALYSIS 248119

Client Details

Client	Hunter Community Environment Centre
Attention	Paul Winn
Address	167 Parry St, Hamilton East, NSW, 2303

Sample Details

Your Reference	Hunter Community Environment Centre-Hunter Valley
Number of Samples	11 Water, 2 Sediment, 1 Feather
Date samples received	31/07/2020
Date completed instructions received	31/07/2020

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Please refer to the last page of this report for any comments relating to the results.

Report Details

Date results requested by	07/08/2020
Date of Issue	07/08/2020

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Results Approved By
Jaimie Loa-Kum-Cheung, Metals Supervisor
Ken Nguyen, Reporting Supervisor
Steven Luong, Organics Supervisor

Authorised By

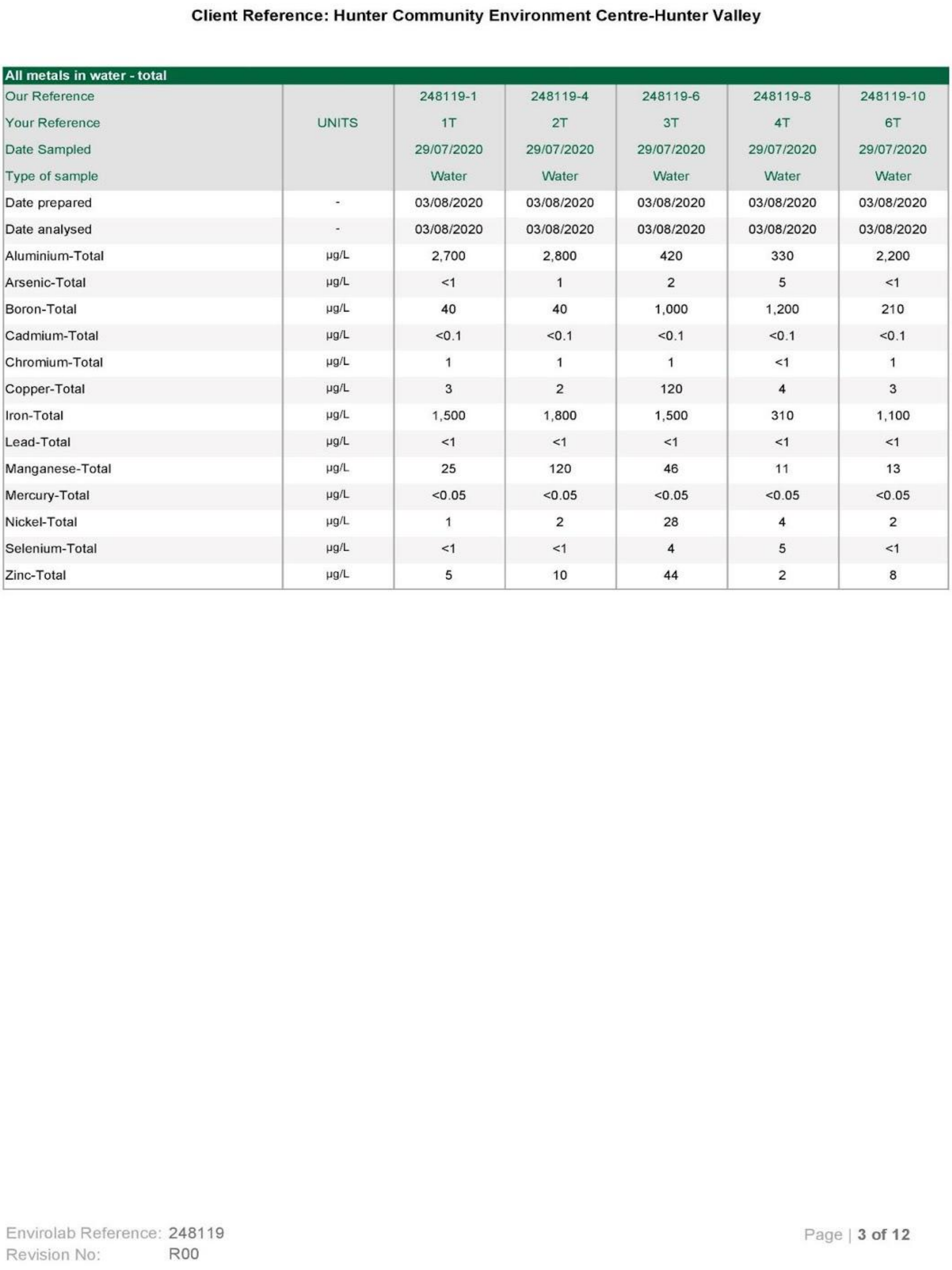
Nancy Zhang, Laboratory Manager

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Client Reference: Hunter Community Environment Centre-Hunter Valley

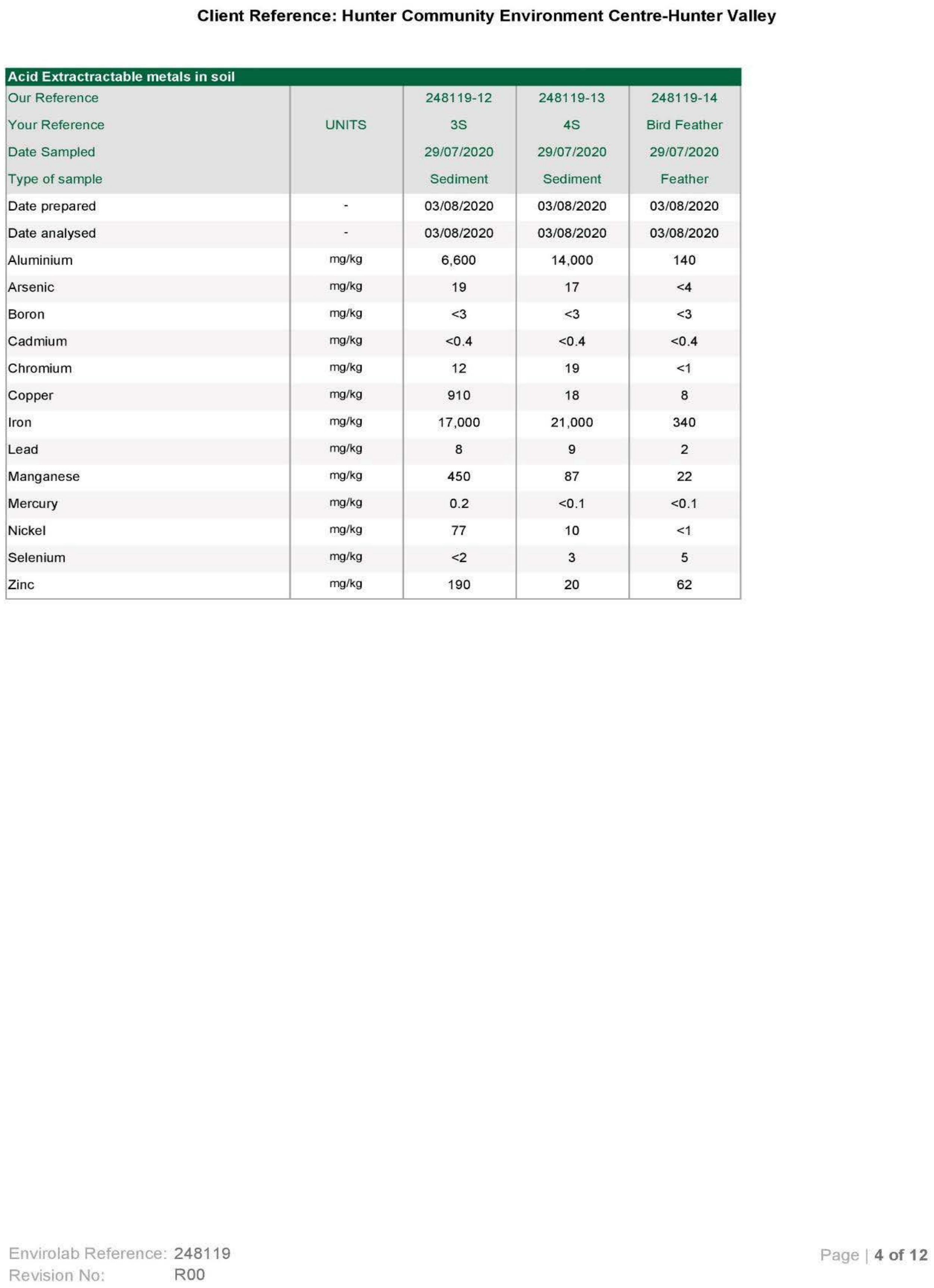
All metals in water-dissolved

Our Reference		248119-2	248119-5	248119-7	248119-9	248119-11
Your Reference	UNITS	1F	2F	3F	4F	6F
Date Sampled		29/07/2020	29/07/2020	29/07/2020	29/07/2020	29/07/2020
Type of sample		Water	Water	Water	Water	Water
Date prepared	-	03/08/2020	03/08/2020	03/08/2020	03/08/2020	03/08/2020
Date analysed	-	03/08/2020	03/08/2020	03/08/2020	03/08/2020	03/08/2020
Aluminium-Dissolved	μg/L	90	70	10	20	90
Arsenic-Dissolved	μg/L	<1	<1	1	4	<1
Boron-Dissolved	μg/L	40	40	910	1,200	200
Cadmium-Dissolved	μg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium-Dissolved	μg/L	<1	<1	<1	<1	<1
Copper-Dissolved	μg/L	2	2	50	3	3
Iron-Dissolved	μg/L	110	98	<10	14	110
Lead-Dissolved	μg/L	<1	<1	<1	<1	<1
Manganese-Dissolved	μg/L	6	6	26	<5	14
Mercury-Dissolved	μg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel-Dissolved	μg/L	<1	<1	24	4	1
Selenium-Dissolved	μg/L	<1	<1	4	5	<1
Zinc-Dissolved	μg/L	4	22	12	2	9



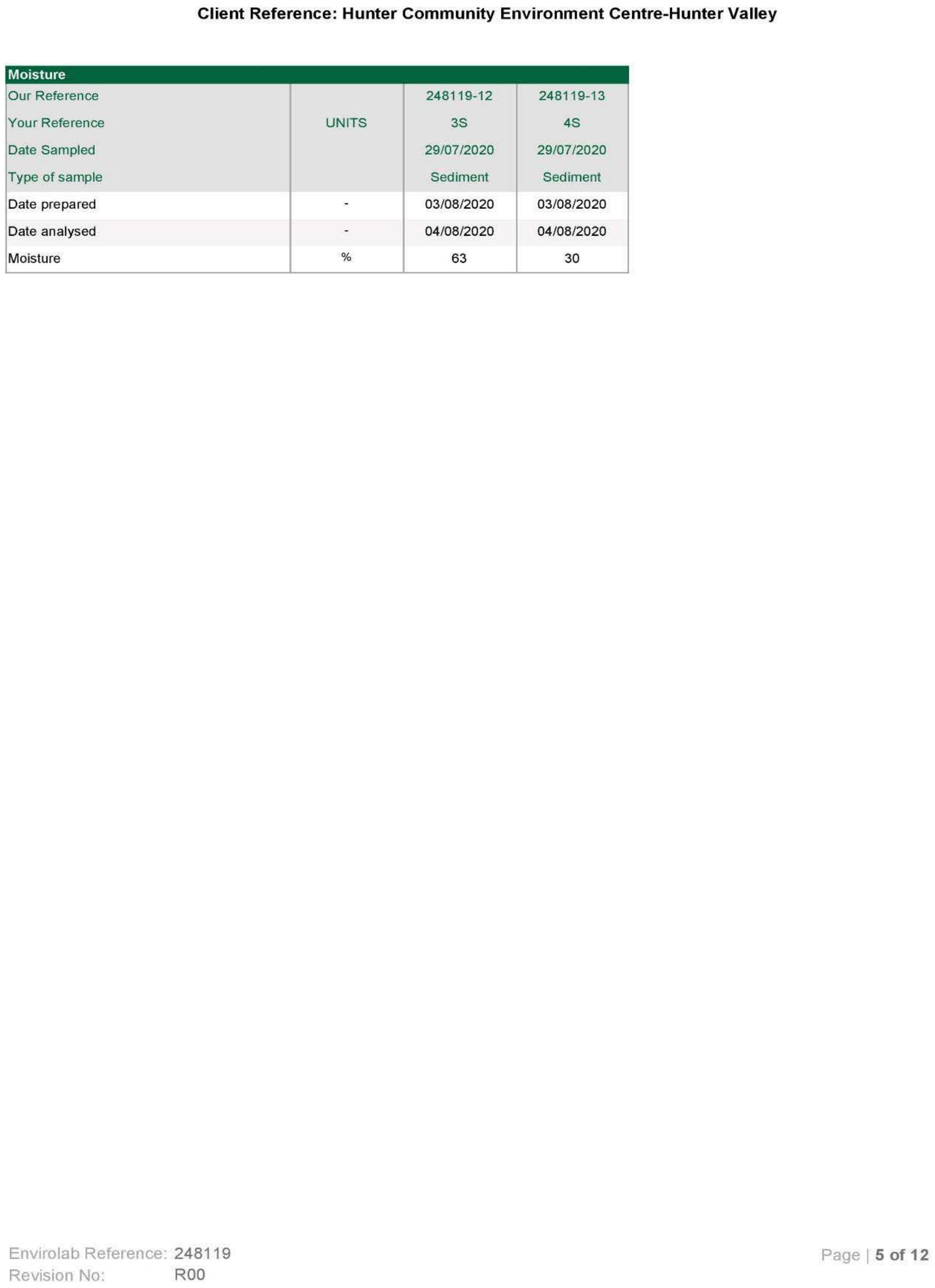
Client Reference: Hunter Community Environment Centre-Hunter Valley

All metals in water - total						
Our Reference		248119-1	248119-4	248119-6	248119-8	248119-10
Your Reference	UNITS	1T	2T	3T	4T	6T
Date Sampled		29/07/2020	29/07/2020	29/07/2020	29/07/2020	29/07/2020
Type of sample		Water	Water	Water	Water	Water
Date prepared	-	03/08/2020	03/08/2020	03/08/2020	03/08/2020	03/08/2020
Date analysed	-	03/08/2020	03/08/2020	03/08/2020	03/08/2020	03/08/2020
Aluminium-Total	μg/L	2,700	2,800	420	330	2,200
Arsenic-Total	μg/L	<1	1	2	5	<1
Boron-Total	μg/L	40	40	1,000	1,200	210
Cadmium-Total	μg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium-Total	μg/L	1	1	1	<1	1
Copper-Total	μg/L	3	2	120	4	3
Iron-Total	μg/L	1,500	1,800	1,500	310	1,100
Lead-Total	μg/L	<1	<1	<1	<1	<1
Manganese-Total	μg/L	25	120	46	11	13
Mercury-Total	μg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel-Total	μg/L	1	2	28	4	2
Selenium-Total	μg/L	<1	<1	4	5	<1
Zinc-Total	μg/L	5	10	44	2	8



Client Reference: Hunter Community Environment Centre-Hunter Valley

Acid Extractactable metals in soil				
Our Reference		248119-12	248119-13	248119-14
Your Reference	UNITS	3S	4S	Bird Feather
Date Sampled		29/07/2020	29/07/2020	29/07/2020
Type of sample		Sediment	Sediment	Feather
Date prepared	-	03/08/2020	03/08/2020	03/08/2020
Date analysed	-	03/08/2020	03/08/2020	03/08/2020
Aluminium	mg/kg	6,600	14,000	140
Arsenic	mg/kg	19	17	<4
Boron	mg/kg	<3	<3	<3
Cadmium	mg/kg	<0.4	<0.4	<0.4
Chromium	mg/kg	12	19	<1
Copper	mg/kg	910	18	8
Iron	mg/kg	17,000	21,000	340
Lead	mg/kg	8	9	2
Manganese	mg/kg	450	87	22
Mercury	mg/kg	0.2	<0.1	<0.1
Nickel	mg/kg	77	10	<1
Selenium	mg/kg	<2	3	5
Zinc	mg/kg	190	20	62

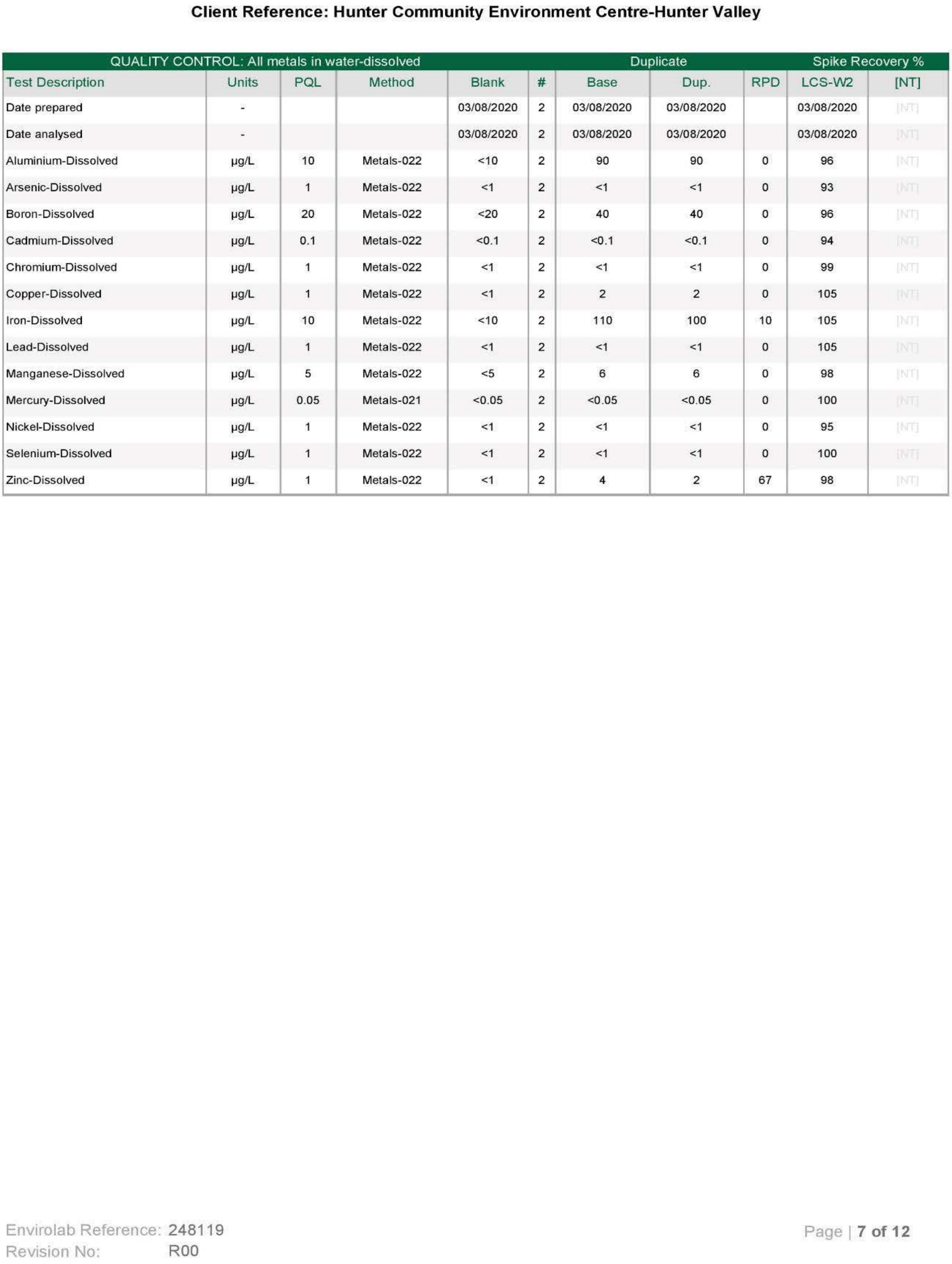


Client Reference: Hunter Community Environment Centre-Hunter Valley

Moisture			
Our Reference		248119-12	248119-13
Your Reference	UNITS	3S	4S
Date Sampled		29/07/2020	29/07/2020
Type of sample		Sediment	Sediment
Date prepared	-	03/08/2020	03/08/2020
Date analysed	-	04/08/2020	04/08/2020
Moisture	%	63	30

Client Reference: Hunter Community Environment Centre-Hunter Valley

Method ID	Methodology Summary
Inorg-008	Moisture content determined by heating at 105+/-5 °C for a minimum of 12 hours.
Metals-020	Determination of various metals by ICP-AES.
Metals-021	Determination of Mercury by Cold Vapour AAS.
Metals-022	Determination of various metals by ICP-MS.

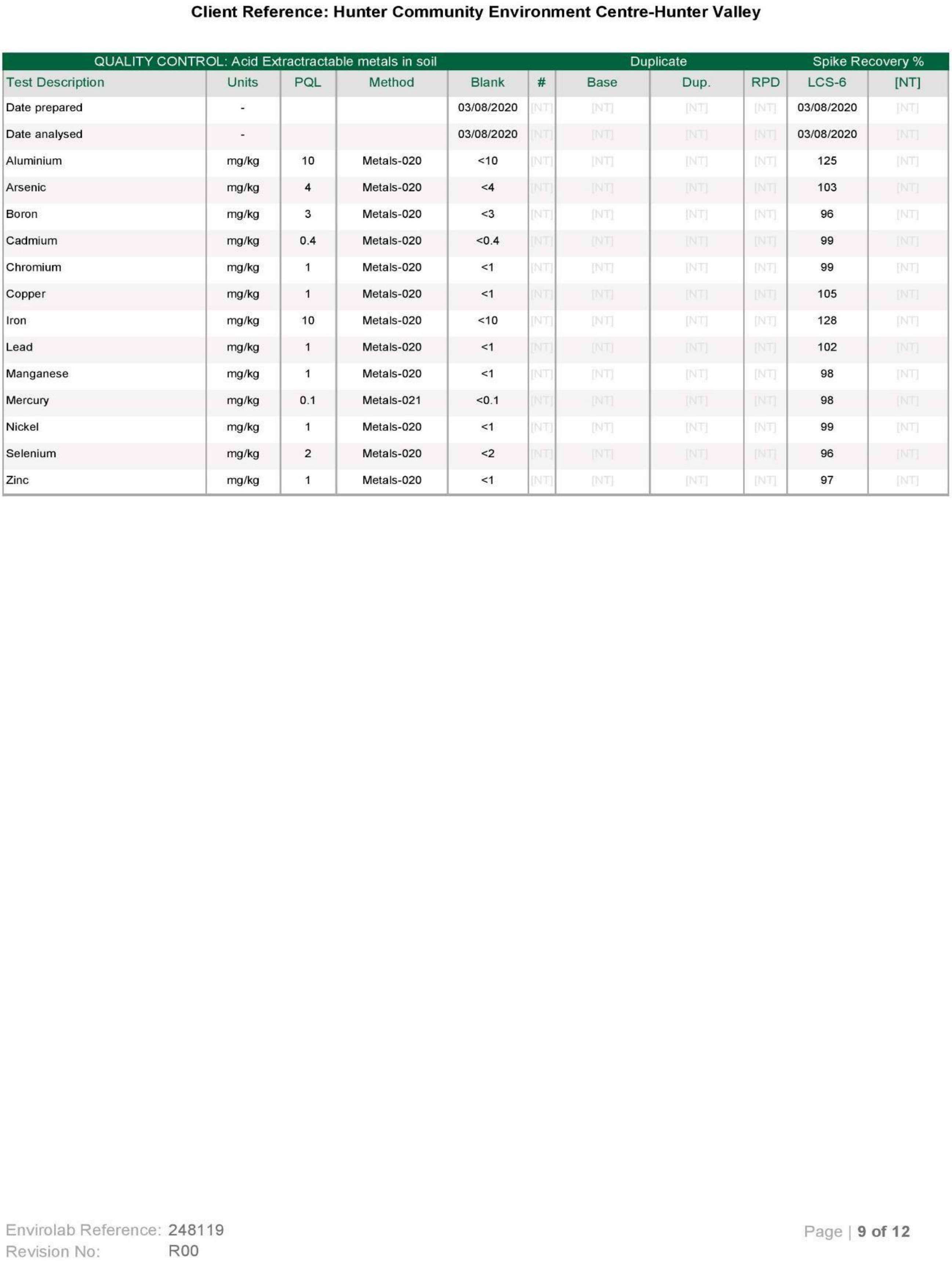


Client Reference: Hunter Community Environment Centre-Hunter Valley

QUALITY CONTROL: All metals in water-dissolved					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W2	[NT]
Date prepared	-			03/08/2020	2	03/08/2020	03/08/2020		03/08/2020	[NT]
Date analysed	-			03/08/2020	2	03/08/2020	03/08/2020		03/08/2020	[NT]
Aluminium-Dissolved	µg/L	10	Metals-022	<10	2	90	90	0	96	[NT]
Arsenic-Dissolved	µg/L	1	Metals-022	<1	2	<1	<1	0	93	[NT]
Boron-Dissolved	µg/L	20	Metals-022	<20	2	40	40	0	96	[NT]
Cadmium-Dissolved	µg/L	0.1	Metals-022	<0.1	2	<0.1	<0.1	0	94	[NT]
Chromium-Dissolved	µg/L	1	Metals-022	<1	2	<1	<1	0	99	[NT]
Copper-Dissolved	µg/L	1	Metals-022	<1	2	2	2	0	105	[NT]
Iron-Dissolved	µg/L	10	Metals-022	<10	2	110	100	10	105	[NT]
Lead-Dissolved	µg/L	1	Metals-022	<1	2	<1	<1	0	105	[NT]
Manganese-Dissolved	µg/L	5	Metals-022	<5	2	6	6	0	98	[NT]
Mercury-Dissolved	µg/L	0.05	Metals-021	<0.05	2	<0.05	<0.05	0	100	[NT]
Nickel-Dissolved	µg/L	1	Metals-022	<1	2	<1	<1	0	95	[NT]
Selenium-Dissolved	µg/L	1	Metals-022	<1	2	<1	<1	0	100	[NT]
Zinc-Dissolved	µg/L	1	Metals-022	<1	2	4	2	67	98	[NT]

Client Reference: Hunter Community Environment Centre-Hunter Valley

QUALITY CONTROL: All metals in water - total					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W2	248119-4
Date prepared	-			03/08/2020	1	03/08/2020	03/08/2020		03/08/2020	03/08/2020
Date analysed	-			03/08/2020	1	03/08/2020	03/08/2020		03/08/2020	03/08/2020
Aluminium-Total	µg/L	10	Metals-022	<10	1	2700	2600	4	108	[NT]
Arsenic-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	92	[NT]
Boron-Total	µg/L	20	Metals-022	<20	1	40	40	0	111	[NT]
Cadmium-Total	µg/L	0.1	Metals-022	<0.1	1	<0.1	<0.1	0	95	[NT]
Chromium-Total	µg/L	1	Metals-022	<1	1	1	1	0	104	[NT]
Copper-Total	µg/L	1	Metals-022	<1	1	3	2	40	106	[NT]
Iron-Total	µg/L	10	Metals-022	<10	1	1500	1500	0	102	[NT]
Lead-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	107	[NT]
Manganese-Total	µg/L	5	Metals-022	<5	1	25	25	0	97	[NT]
Mercury-Total	µg/L	0.05	Metals-021	<0.05	1	<0.05	<0.05	0	101	100
Nickel-Total	µg/L	1	Metals-022	<1	1	1	1	0	94	[NT]
Selenium-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	100	[NT]
Zinc-Total	µg/L	1	Metals-022	<1	1	5	4	22	104	[NT]

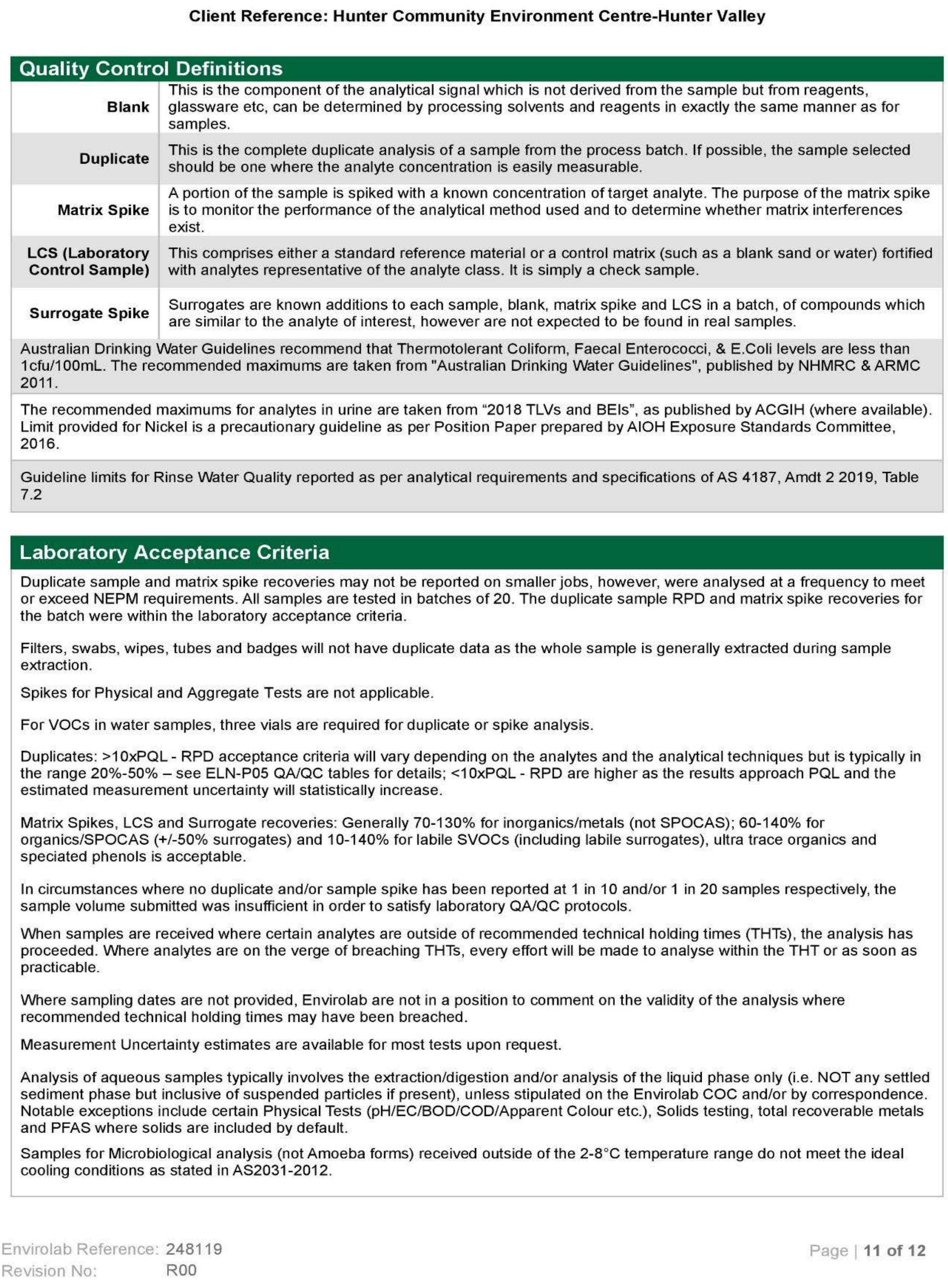


Client Reference: Hunter Community Environment Centre-Hunter Valley

QUALITY CONTROL: Acid Extractractable metals in soil					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-6	[NT]
Date prepared	-			03/08/2020	[NT]	[NT]	[NT]	[NT]	03/08/2020	[NT]
Date analysed	-			03/08/2020	[NT]	[NT]	[NT]	[NT]	03/08/2020	[NT]
Aluminium	mg/kg	10	Metals-020	<10	[NT]	[NT]	[NT]	[NT]	125	[NT]
Arsenic	mg/kg	4	Metals-020	<4	[NT]	[NT]	[NT]	[NT]	103	[NT]
Boron	mg/kg	3	Metals-020	<3	[NT]	[NT]	[NT]	[NT]	96	[NT]
Cadmium	mg/kg	0.4	Metals-020	<0.4	[NT]	[NT]	[NT]	[NT]	99	[NT]
Chromium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	99	[NT]
Copper	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	105	[NT]
Iron	mg/kg	10	Metals-020	<10	[NT]	[NT]	[NT]	[NT]	128	[NT]
Lead	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	102	[NT]
Manganese	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	98	[NT]
Mercury	mg/kg	0.1	Metals-021	<0.1	[NT]	[NT]	[NT]	[NT]	98	[NT]
Nickel	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	99	[NT]
Selenium	mg/kg	2	Metals-020	<2	[NT]	[NT]	[NT]	[NT]	96	[NT]
Zinc	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	97	[NT]

Client Reference: Hunter Community Environment Centre-Hunter Valley

Result Definitions	
NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported



Client Reference: Hunter Community Environment Centre-Hunter Valley

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.

The recommended maximums for analytes in urine are taken from “2018 TLVs and BEIs”, as published by ACGIH (where available). Limit provided for Nickel is a precautionary guideline as per Position Paper prepared by AIOH Exposure Standards Committee, 2016.

Guideline limits for Rinse Water Quality reported as per analytical requirements and specifications of AS 4187, Amdt 2 2019, Table 7.2

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals (not SPOCAS); 60-140% for organics/SPOCAS (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

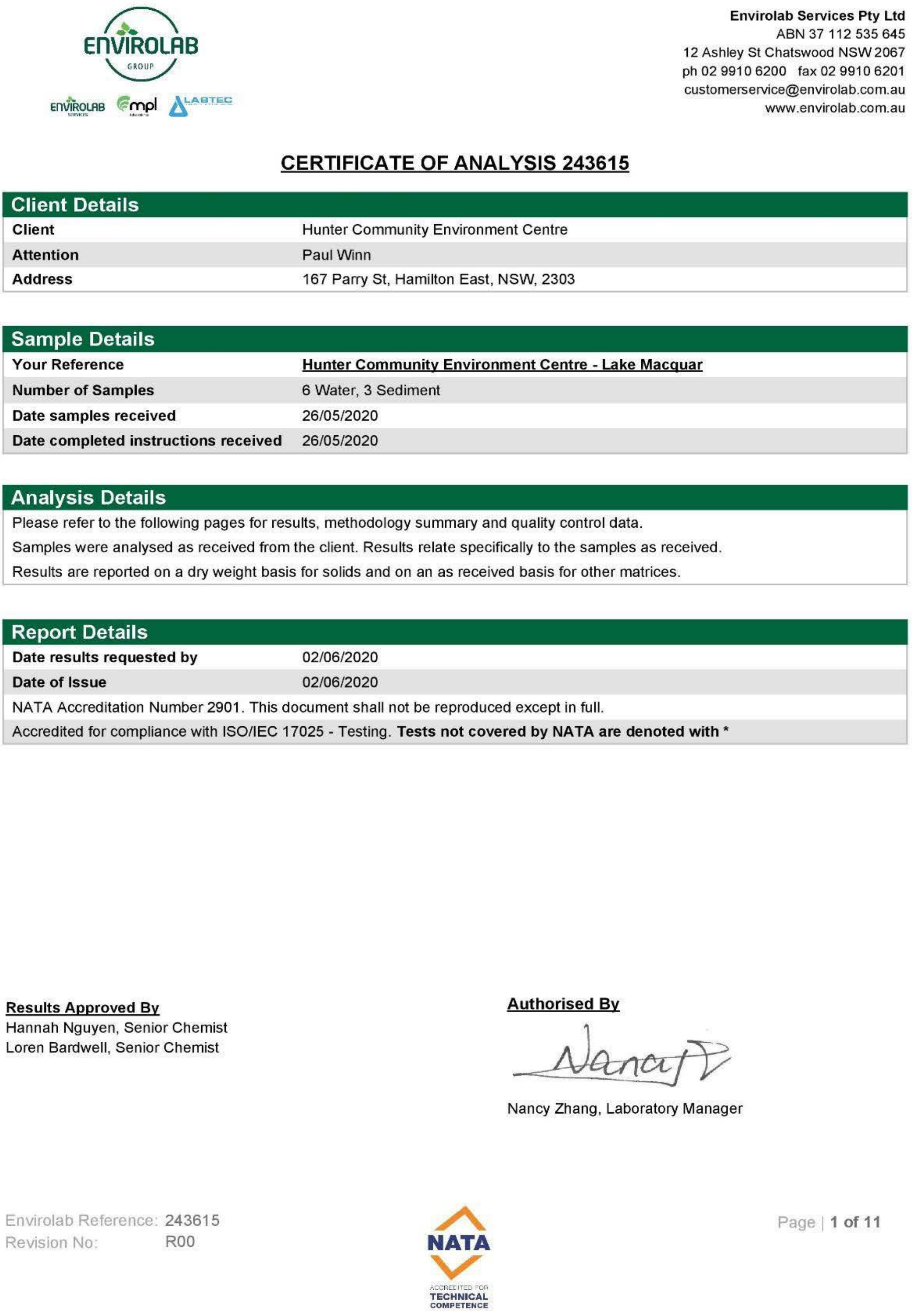
Analysis of aqueous samples typically involves the extraction/digestion and/or analysis of the liquid phase only (i.e. NOT any settled sediment phase but inclusive of suspended particles if present), unless stipulated on the Envirolab COC and/or by correspondence. Notable exceptions include certain Physical Tests (pH/EC/BOD/COD/Apparent Colour etc.), Solids testing, total recoverable metals and PFAS where solids are included by default.

Samples for Microbiological analysis (not Amoeba forms) received outside of the 2-8°C temperature range do not meet the ideal cooling conditions as stated in AS2031-2012.

Client Reference: Hunter Community Environment Centre-Hunter Valley

Report Comments
In theory the total metal content should be higher than the dissolved metal content. However, in some samples this is not the case. The sample has been re-analysed for both Total and Dissolved and results have been confirmed.

Vales Point & Eraring



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www.envirolab.com.au

CERTIFICATE OF ANALYSIS 243615

Client Details

Client	Hunter Community Environment Centre
Attention	Paul Winn
Address	167 Parry St, Hamilton East, NSW, 2303

Sample Details

Your Reference	Hunter Community Environment Centre - Lake Macquar
Number of Samples	6 Water, 3 Sediment
Date samples received	26/05/2020
Date completed instructions received	26/05/2020

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date results requested by	02/06/2020
Date of Issue	02/06/2020

NATA Accreditation Number 2901. This document shall not be reproduced except in full.

Accredited for compliance with ISO/IEC 17025 - Testing. **Tests not covered by NATA are denoted with ***

Results Approved By
Hannah Nguyen, Senior Chemist
Loren Bardwell, Senior Chemist

Authorised By

Nancy Zhang, Laboratory Manager

Envirolab Reference: 243615
Revision No: R00

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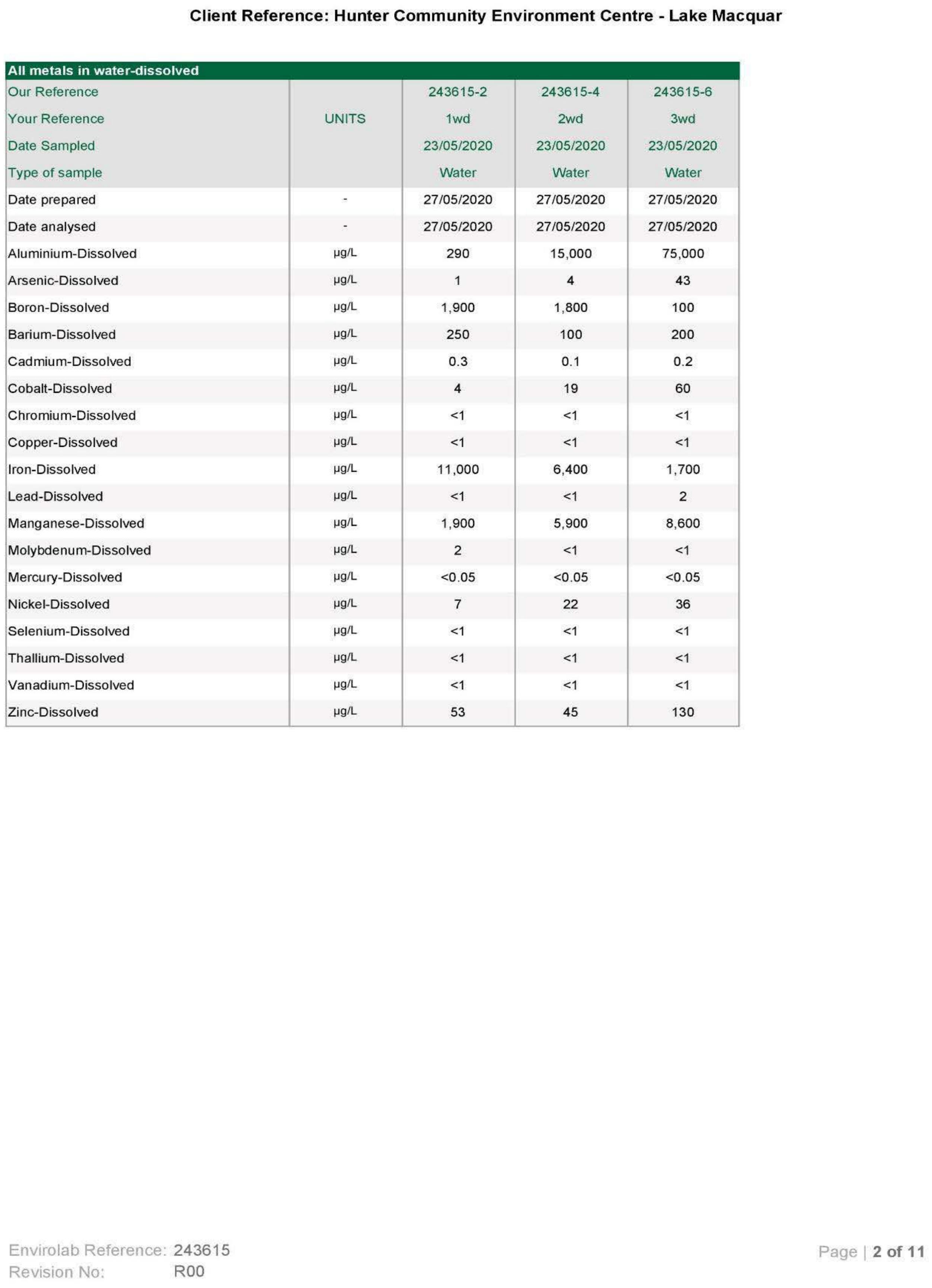
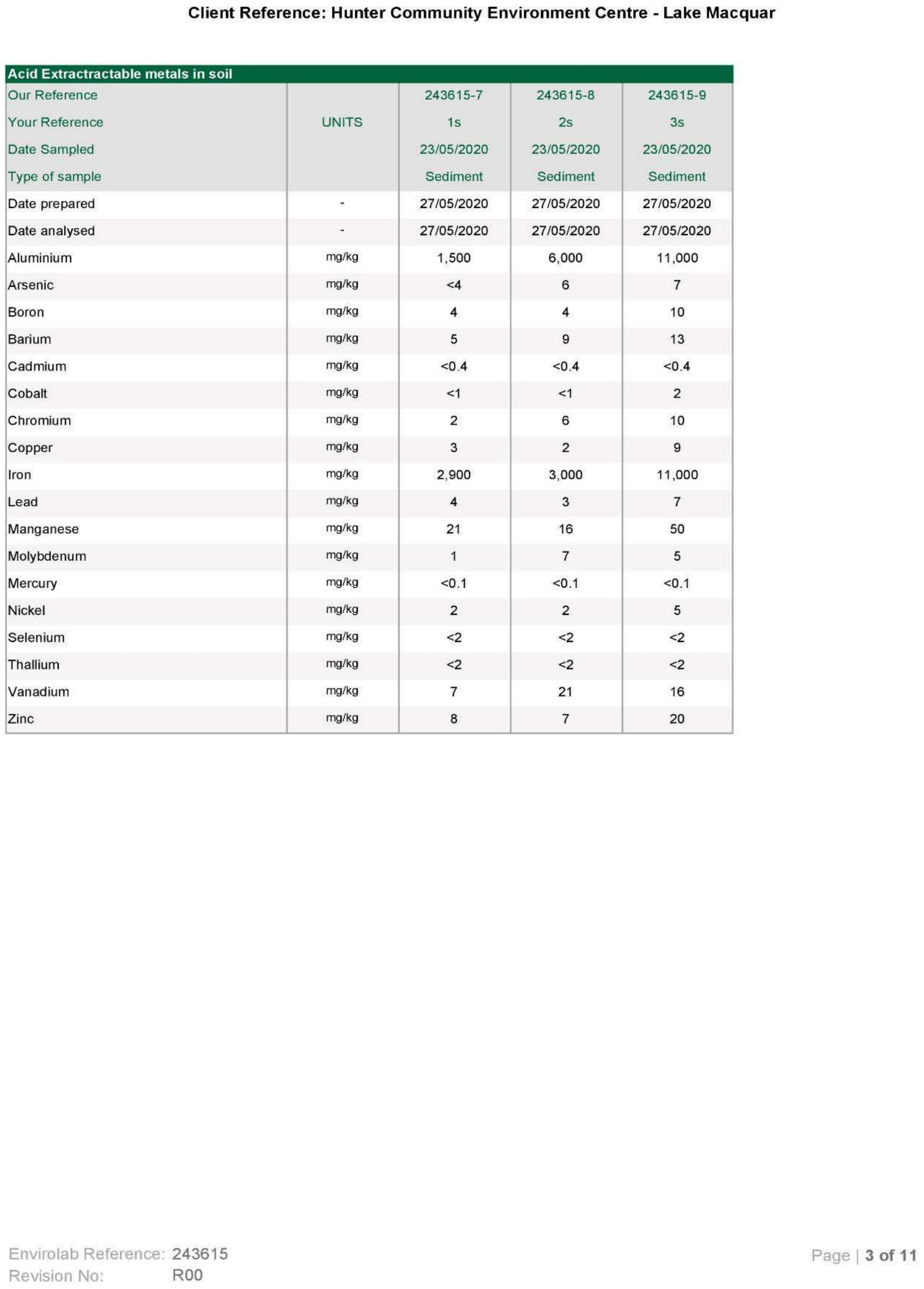


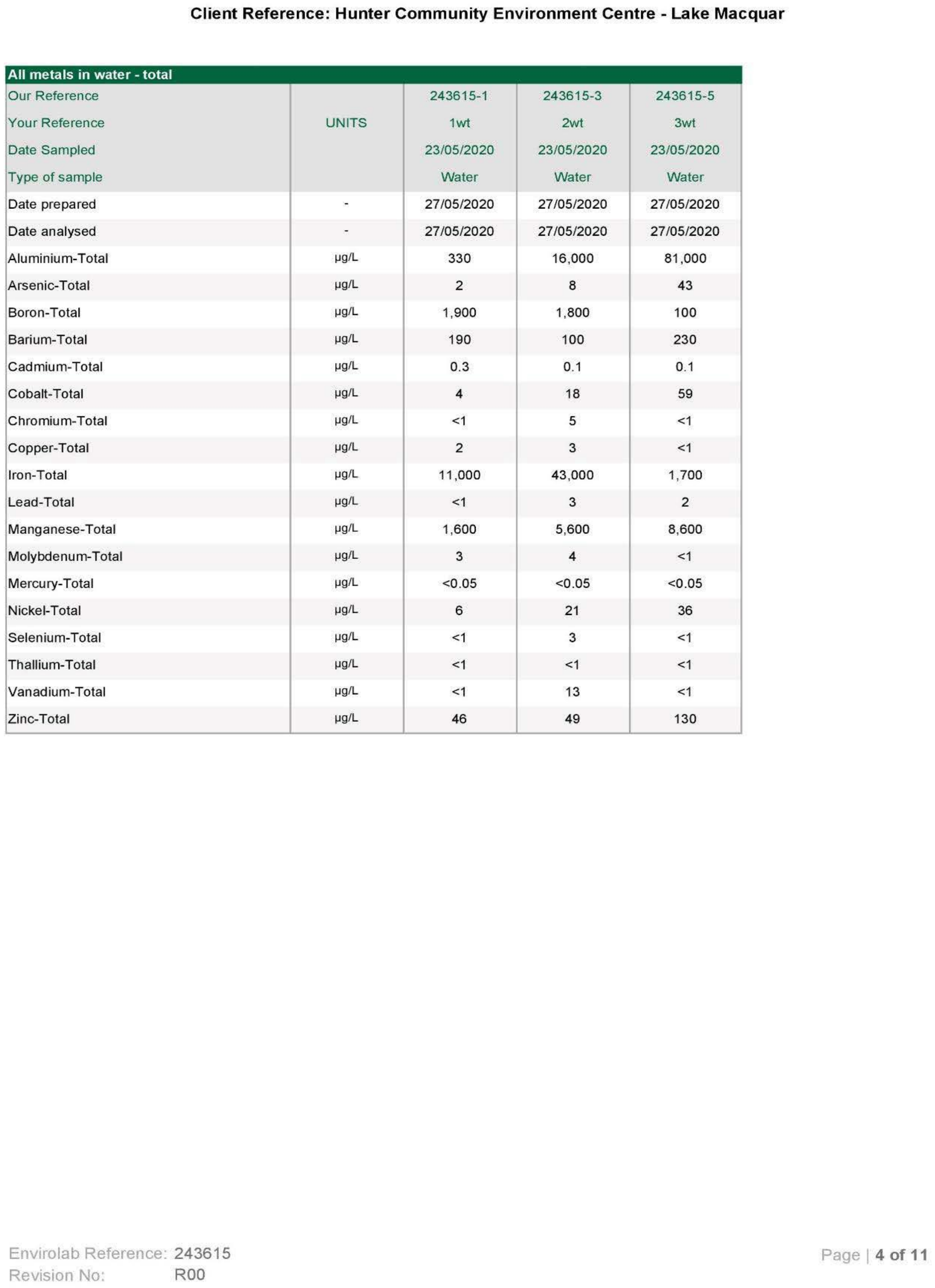
Client Reference: Hunter Community Environment Centre - Lake Macquar

All metals in water-dissolved				
Our Reference		243615-2	243615-4	243615-6
Your Reference	UNITS	1wd	2wd	3wd
Date Sampled		23/05/2020	23/05/2020	23/05/2020
Type of sample		Water	Water	Water
Date prepared	-	27/05/2020	27/05/2020	27/05/2020
Date analysed	-	27/05/2020	27/05/2020	27/05/2020
Aluminium-Dissolved	µg/L	290	15,000	75,000
Arsenic-Dissolved	µg/L	1	4	43
Boron-Dissolved	µg/L	1,900	1,800	100
Barium-Dissolved	µg/L	250	100	200
Cadmium-Dissolved	µg/L	0.3	0.1	0.2
Cobalt-Dissolved	µg/L	4	19	60
Chromium-Dissolved	µg/L	<1	<1	<1
Copper-Dissolved	µg/L	<1	<1	<1
Iron-Dissolved	µg/L	11,000	6,400	1,700
Lead-Dissolved	µg/L	<1	<1	2
Manganese-Dissolved	µg/L	1,900	5,900	8,600
Molybdenum-Dissolved	µg/L	2	<1	<1
Mercury-Dissolved	µg/L	<0.05	<0.05	<0.05
Nickel-Dissolved	µg/L	7	22	36
Selenium-Dissolved	µg/L	<1	<1	<1
Thallium-Dissolved	µg/L	<1	<1	<1
Vanadium-Dissolved	µg/L	<1	<1	<1
Zinc-Dissolved	µg/L	53	45	130



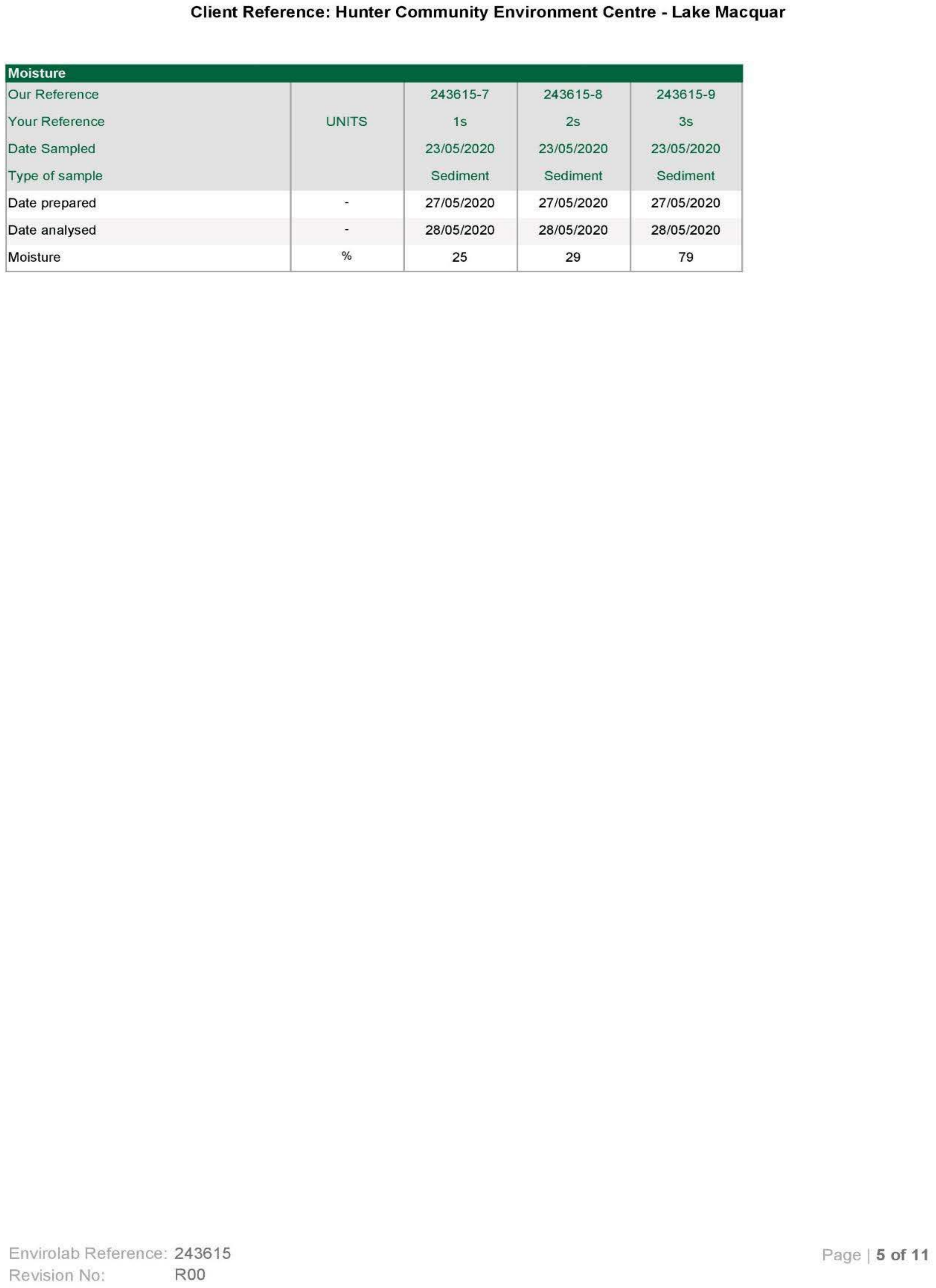
Client Reference: Hunter Community Environment Centre - Lake Macquar

Acid Extractractable metals in soil				
Our Reference		243615-7	243615-8	243615-9
Your Reference	UNITS	1s	2s	3s
Date Sampled		23/05/2020	23/05/2020	23/05/2020
Type of sample		Sediment	Sediment	Sediment
Date prepared	-	27/05/2020	27/05/2020	27/05/2020
Date analysed	-	27/05/2020	27/05/2020	27/05/2020
Aluminium	mg/kg	1,500	6,000	11,000
Arsenic	mg/kg	<4	6	7
Boron	mg/kg	4	4	10
Barium	mg/kg	5	9	13
Cadmium	mg/kg	<0.4	<0.4	<0.4
Cobalt	mg/kg	<1	<1	2
Chromium	mg/kg	2	6	10
Copper	mg/kg	3	2	9
Iron	mg/kg	2,900	3,000	11,000
Lead	mg/kg	4	3	7
Manganese	mg/kg	21	16	50
Molybdenum	mg/kg	1	7	5
Mercury	mg/kg	<0.1	<0.1	<0.1
Nickel	mg/kg	2	2	5
Selenium	mg/kg	<2	<2	<2
Thallium	mg/kg	<2	<2	<2
Vanadium	mg/kg	7	21	16
Zinc	mg/kg	8	7	20



Client Reference: Hunter Community Environment Centre - Lake Macquar

All metals in water - total				
Our Reference	UNITS	243615-1	243615-3	243615-5
Your Reference		1wt	2wt	3wt
Date Sampled		23/05/2020	23/05/2020	23/05/2020
Type of sample		Water	Water	Water
Date prepared	-	27/05/2020	27/05/2020	27/05/2020
Date analysed	-	27/05/2020	27/05/2020	27/05/2020
Aluminium-Total	µg/L	330	16,000	81,000
Arsenic-Total	µg/L	2	8	43
Boron-Total	µg/L	1,900	1,800	100
Barium-Total	µg/L	190	100	230
Cadmium-Total	µg/L	0.3	0.1	0.1
Cobalt-Total	µg/L	4	18	59
Chromium-Total	µg/L	<1	5	<1
Copper-Total	µg/L	2	3	<1
Iron-Total	µg/L	11,000	43,000	1,700
Lead-Total	µg/L	<1	3	2
Manganese-Total	µg/L	1,600	5,600	8,600
Molybdenum-Total	µg/L	3	4	<1
Mercury-Total	µg/L	<0.05	<0.05	<0.05
Nickel-Total	µg/L	6	21	36
Selenium-Total	µg/L	<1	3	<1
Thallium-Total	µg/L	<1	<1	<1
Vanadium-Total	µg/L	<1	13	<1
Zinc-Total	µg/L	46	49	130



Client Reference: Hunter Community Environment Centre - Lake Macquar

Moisture				
Our Reference		243615-7	243615-8	243615-9
Your Reference	UNITS	1s	2s	3s
Date Sampled		23/05/2020	23/05/2020	23/05/2020
Type of sample		Sediment	Sediment	Sediment
Date prepared	-	27/05/2020	27/05/2020	27/05/2020
Date analysed	-	28/05/2020	28/05/2020	28/05/2020
Moisture	%	25	29	79

Envirolab Reference: 243615
Revision No: R00

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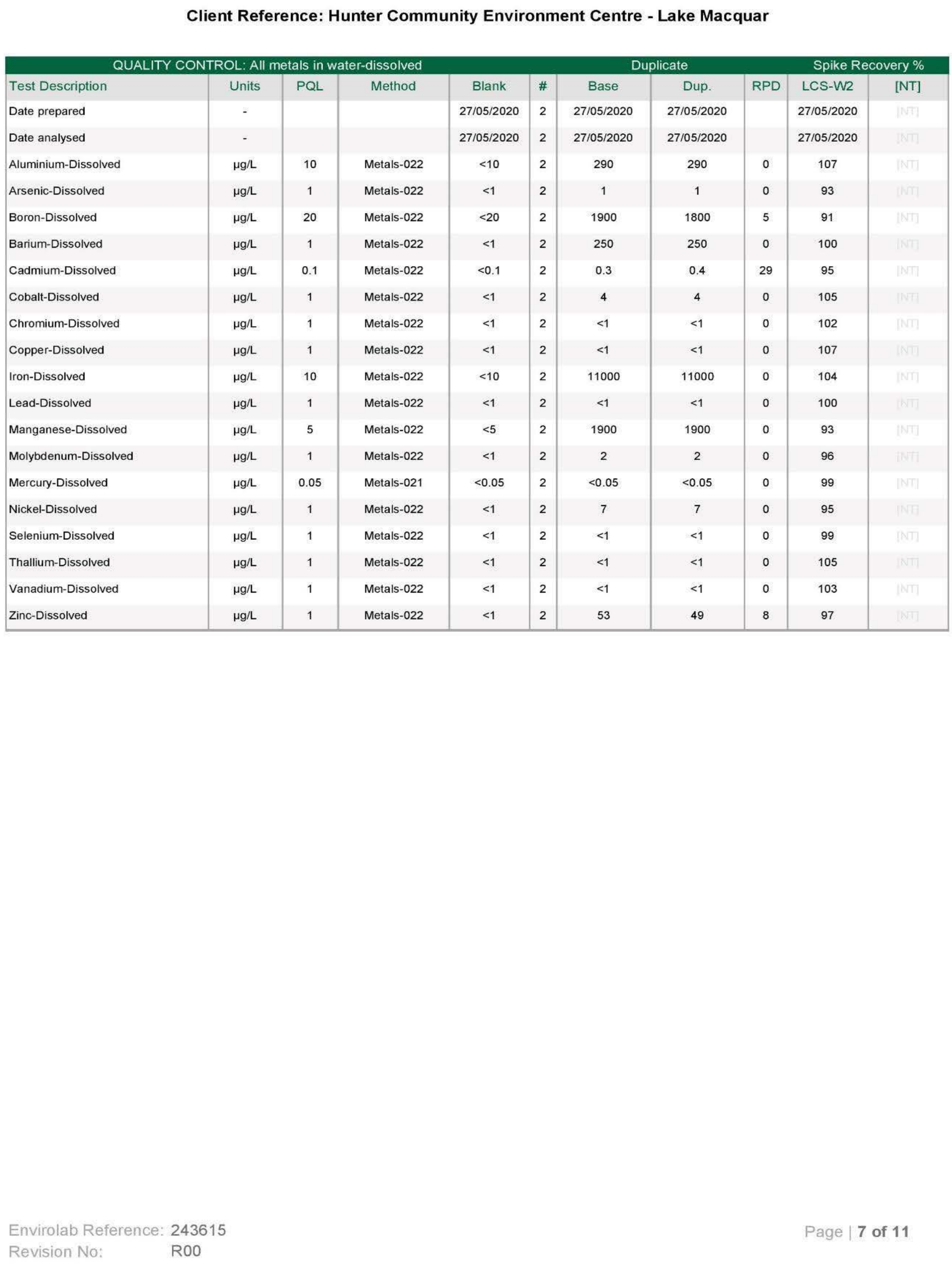
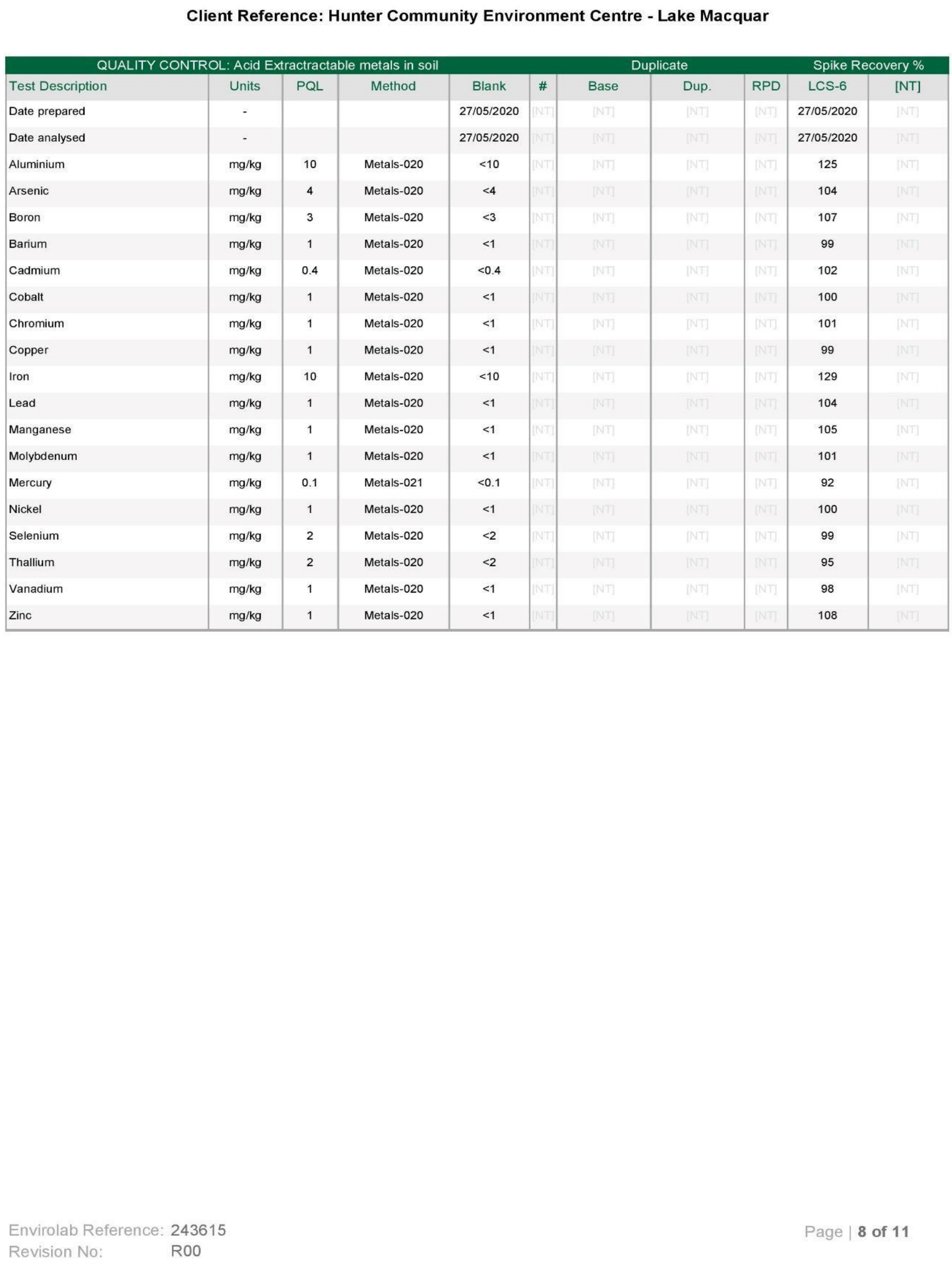
Client Reference: Hunter Community Environment Centre - Lake Macquar

Method ID	Methodology Summary
Inorg-008	Moisture content determined by heating at 105+/-5 °C for a minimum of 12 hours.
Metals-020	Determination of various metals by ICP-AES.
Metals-021	Determination of Mercury by Cold Vapour AAS.
Metals-022	Determination of various metals by ICP-MS.



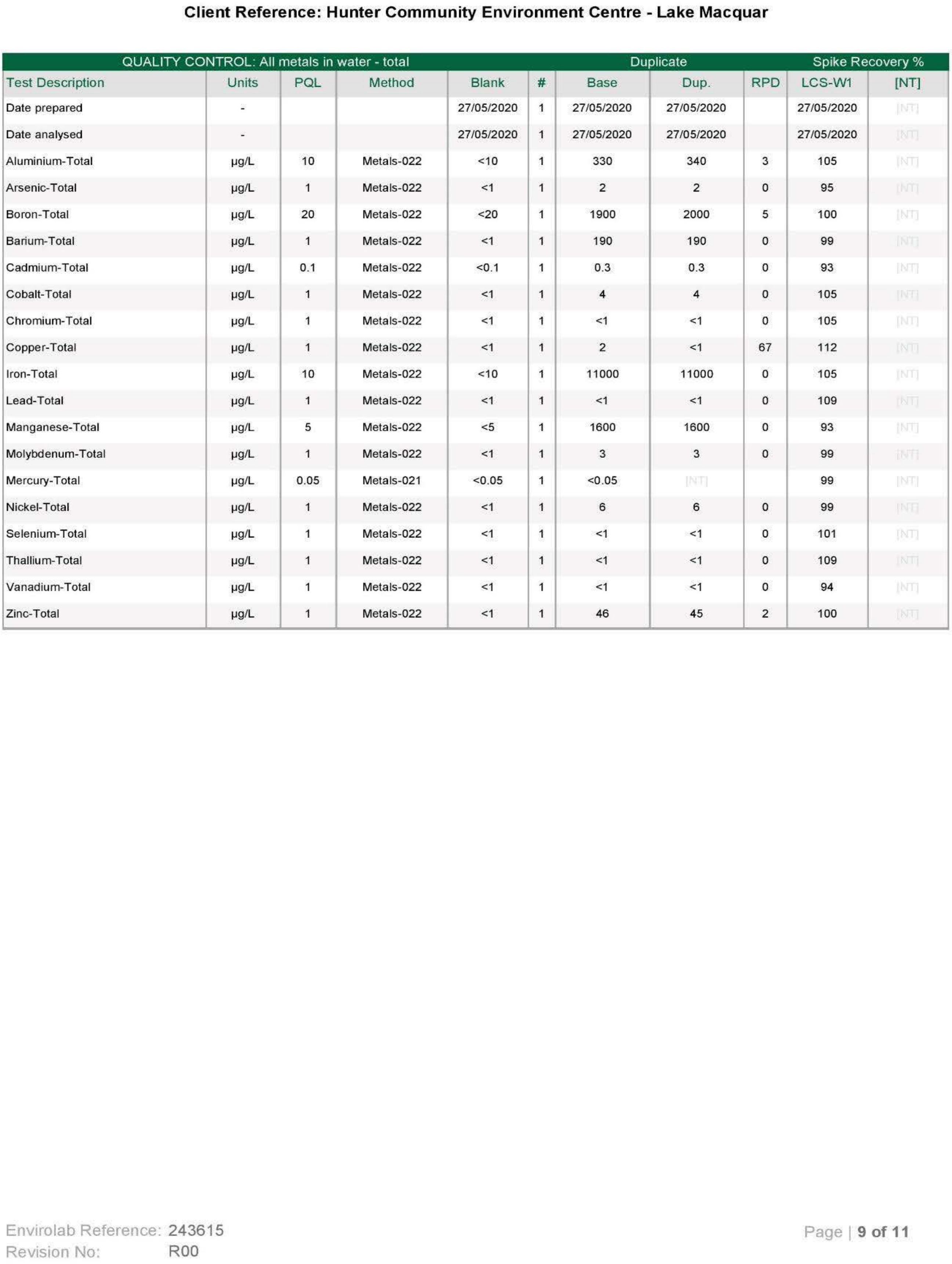
Client Reference: Hunter Community Environment Centre - Lake Macquar

QUALITY CONTROL: All metals in water-dissolved					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W2	[NT]
Date prepared	-			27/05/2020	2	27/05/2020	27/05/2020		27/05/2020	[NT]
Date analysed	-			27/05/2020	2	27/05/2020	27/05/2020		27/05/2020	[NT]
Aluminium-Dissolved	µg/L	10	Metals-022	<10	2	290	290	0	107	[NT]
Arsenic-Dissolved	µg/L	1	Metals-022	<1	2	1	1	0	93	[NT]
Boron-Dissolved	µg/L	20	Metals-022	<20	2	1900	1800	5	91	[NT]
Barium-Dissolved	µg/L	1	Metals-022	<1	2	250	250	0	100	[NT]
Cadmium-Dissolved	µg/L	0.1	Metals-022	<0.1	2	0.3	0.4	29	95	[NT]
Cobalt-Dissolved	µg/L	1	Metals-022	<1	2	4	4	0	105	[NT]
Chromium-Dissolved	µg/L	1	Metals-022	<1	2	<1	<1	0	102	[NT]
Copper-Dissolved	µg/L	1	Metals-022	<1	2	<1	<1	0	107	[NT]
Iron-Dissolved	µg/L	10	Metals-022	<10	2	11000	11000	0	104	[NT]
Lead-Dissolved	µg/L	1	Metals-022	<1	2	<1	<1	0	100	[NT]
Manganese-Dissolved	µg/L	5	Metals-022	<5	2	1900	1900	0	93	[NT]
Molybdenum-Dissolved	µg/L	1	Metals-022	<1	2	2	2	0	96	[NT]
Mercury-Dissolved	µg/L	0.05	Metals-021	<0.05	2	<0.05	<0.05	0	99	[NT]
Nickel-Dissolved	µg/L	1	Metals-022	<1	2	7	7	0	95	[NT]
Selenium-Dissolved	µg/L	1	Metals-022	<1	2	<1	<1	0	99	[NT]
Thallium-Dissolved	µg/L	1	Metals-022	<1	2	<1	<1	0	105	[NT]
Vanadium-Dissolved	µg/L	1	Metals-022	<1	2	<1	<1	0	103	[NT]
Zinc-Dissolved	µg/L	1	Metals-022	<1	2	53	49	8	97	[NT]



Client Reference: Hunter Community Environment Centre - Lake Macquar

QUALITY CONTROL: Acid Extractractable metals in soil					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-6	[NT]
Date prepared	-			27/05/2020	[NT]	[NT]	[NT]	[NT]	27/05/2020	[NT]
Date analysed	-			27/05/2020	[NT]	[NT]	[NT]	[NT]	27/05/2020	[NT]
Aluminium	mg/kg	10	Metals-020	<10	[NT]	[NT]	[NT]	[NT]	125	[NT]
Arsenic	mg/kg	4	Metals-020	<4	[NT]	[NT]	[NT]	[NT]	104	[NT]
Boron	mg/kg	3	Metals-020	<3	[NT]	[NT]	[NT]	[NT]	107	[NT]
Barium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	99	[NT]
Cadmium	mg/kg	0.4	Metals-020	<0.4	[NT]	[NT]	[NT]	[NT]	102	[NT]
Cobalt	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	100	[NT]
Chromium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	101	[NT]
Copper	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	99	[NT]
Iron	mg/kg	10	Metals-020	<10	[NT]	[NT]	[NT]	[NT]	129	[NT]
Lead	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	104	[NT]
Manganese	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	105	[NT]
Molybdenum	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	101	[NT]
Mercury	mg/kg	0.1	Metals-021	<0.1	[NT]	[NT]	[NT]	[NT]	92	[NT]
Nickel	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	100	[NT]
Selenium	mg/kg	2	Metals-020	<2	[NT]	[NT]	[NT]	[NT]	99	[NT]
Thallium	mg/kg	2	Metals-020	<2	[NT]	[NT]	[NT]	[NT]	95	[NT]
Vanadium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	98	[NT]
Zinc	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	108	[NT]



Client Reference: Hunter Community Environment Centre - Lake Macquar

QUALITY CONTROL: All metals in water - total						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W1	[NT]
Date prepared	-			27/05/2020	1	27/05/2020	27/05/2020		27/05/2020	[NT]
Date analysed	-			27/05/2020	1	27/05/2020	27/05/2020		27/05/2020	[NT]
Aluminium-Total	µg/L	10	Metals-022	<10	1	330	340	3	105	[NT]
Arsenic-Total	µg/L	1	Metals-022	<1	1	2	2	0	95	[NT]
Boron-Total	µg/L	20	Metals-022	<20	1	1900	2000	5	100	[NT]
Barium-Total	µg/L	1	Metals-022	<1	1	190	190	0	99	[NT]
Cadmium-Total	µg/L	0.1	Metals-022	<0.1	1	0.3	0.3	0	93	[NT]
Cobalt-Total	µg/L	1	Metals-022	<1	1	4	4	0	105	[NT]
Chromium-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	105	[NT]
Copper-Total	µg/L	1	Metals-022	<1	1	2	<1	67	112	[NT]
Iron-Total	µg/L	10	Metals-022	<10	1	11000	11000	0	105	[NT]
Lead-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	109	[NT]
Manganese-Total	µg/L	5	Metals-022	<5	1	1600	1600	0	93	[NT]
Molybdenum-Total	µg/L	1	Metals-022	<1	1	3	3	0	99	[NT]
Mercury-Total	µg/L	0.05	Metals-021	<0.05	1	<0.05	[NT]		99	[NT]
Nickel-Total	µg/L	1	Metals-022	<1	1	6	6	0	99	[NT]
Selenium-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	101	[NT]
Thallium-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	109	[NT]
Vanadium-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	94	[NT]
Zinc-Total	µg/L	1	Metals-022	<1	1	46	45	2	100	[NT]

Client Reference: Hunter Community Environment Centre - Lake Macquar

Result Definitions	
NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
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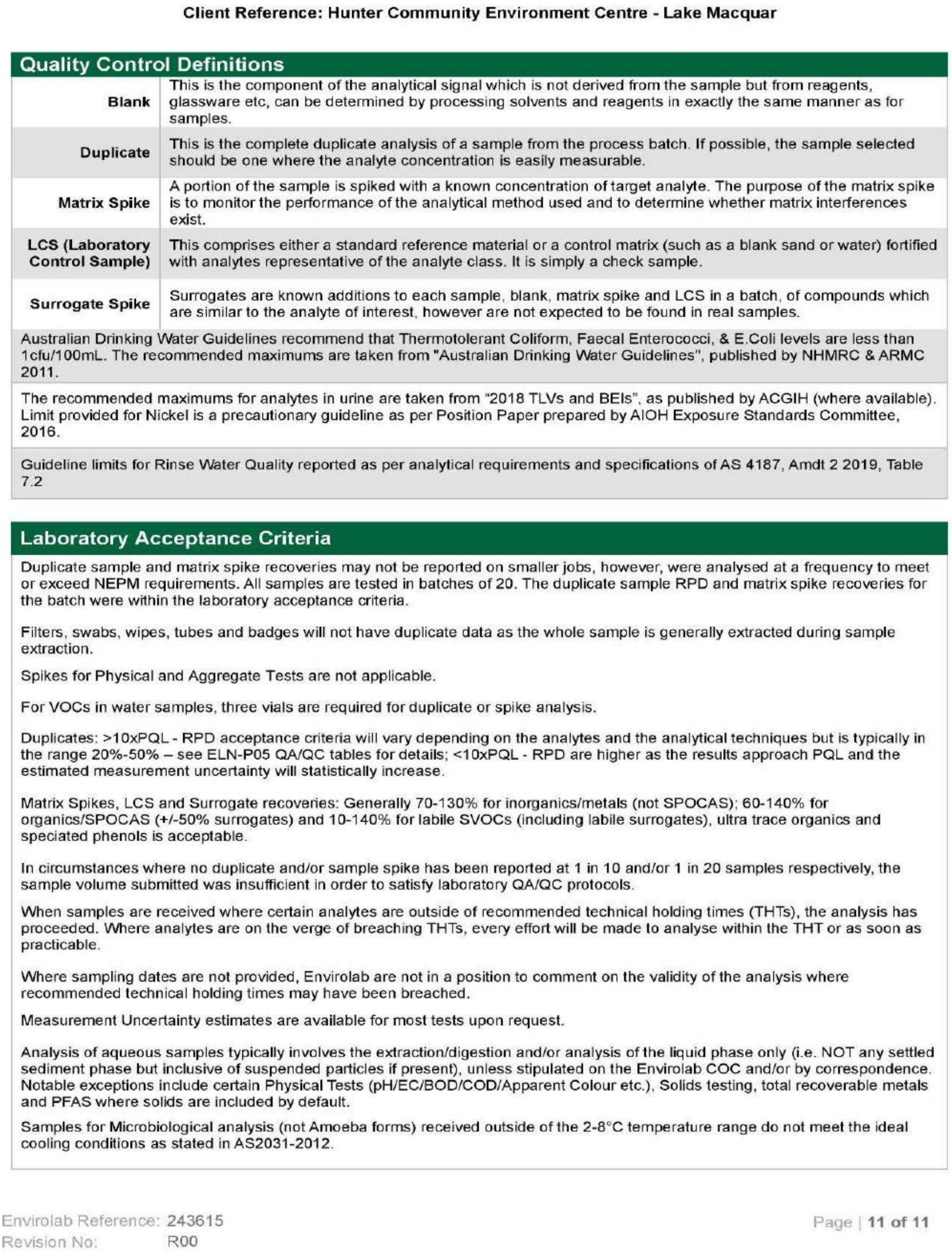
NEPM	National Environmental Protection Measure
NR	Not Reported



Client Reference: Hunter Community Environment Centre - Lake Macquar

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.

The recommended maximums for analytes in urine are taken from "2018 TLVs and BEIs", as published by ACGIH (where available). Limit provided for Nickel is a precautionary guideline as per Position Paper prepared by AIOH Exposure Standards Committee, 2016.

Guideline limits for Rinse Water Quality reported as per analytical requirements and specifications of AS 4187, Amdt 2 2019, Table 7.2

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals (not SPOCAS); 60-140% for organics/SPOCAS (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

Analysis of aqueous samples typically involves the extraction/digestion and/or analysis of the liquid phase only (i.e. NOT any settled sediment phase but inclusive of suspended particles if present), unless stipulated on the Envirolab COC and/or by correspondence. Notable exceptions include certain Physical Tests (pH/EC/BOD/COD/Apparent Colour etc.), Solids testing, total recoverable metals and PFAS where solids are included by default.

Samples for Microbiological analysis (not Amoeba forms) received outside of the 2-8°C temperature range do not meet the ideal cooling conditions as stated in AS2031-2012.

Envirolab Reference: 243615
Revision No: R00

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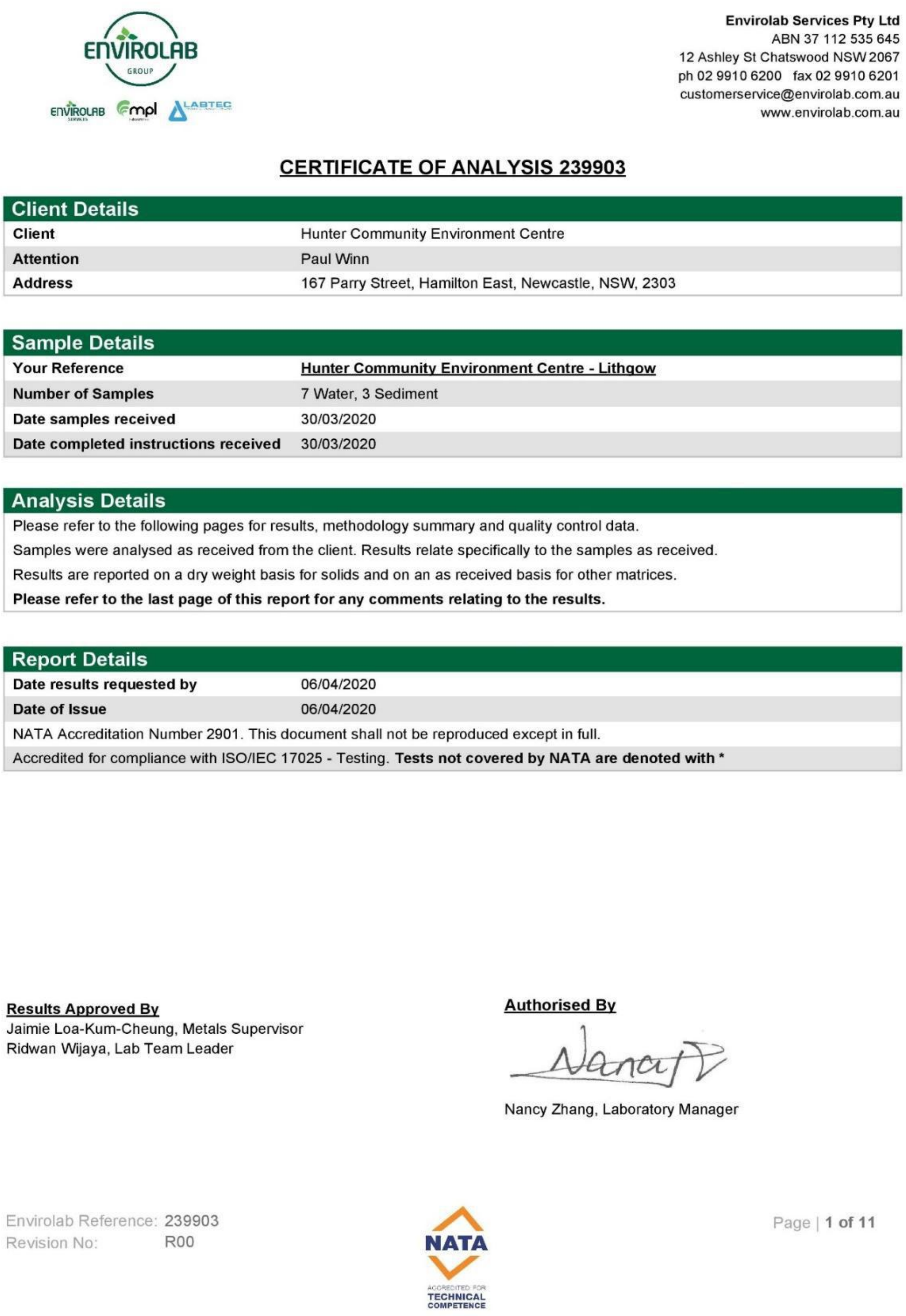
Mount Piper



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CERTIFICATE OF ANALYSIS 239903

Client Details

Client	Hunter Community Environment Centre
Attention	Paul Winn
Address	167 Parry Street, Hamilton East, Newcastle, NSW, 2303

Sample Details

Your Reference	Hunter Community Environment Centre - Lithgow
Number of Samples	7 Water, 3 Sediment
Date samples received	30/03/2020
Date completed instructions received	30/03/2020

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Please refer to the last page of this report for any comments relating to the results.

Report Details

Date results requested by	06/04/2020
Date of Issue	06/04/2020

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Results Approved By
Jaimie Loa-Kum-Cheung, Metals Supervisor
Ridwan Wijaya, Lab Team Leader

Authorised By
Nancy
Nancy Zhang, Laboratory Manager

ACCREDITED FOR TECHNICAL COMPETENCE

Client Reference: Hunter Community Environment Centre - Lithgow

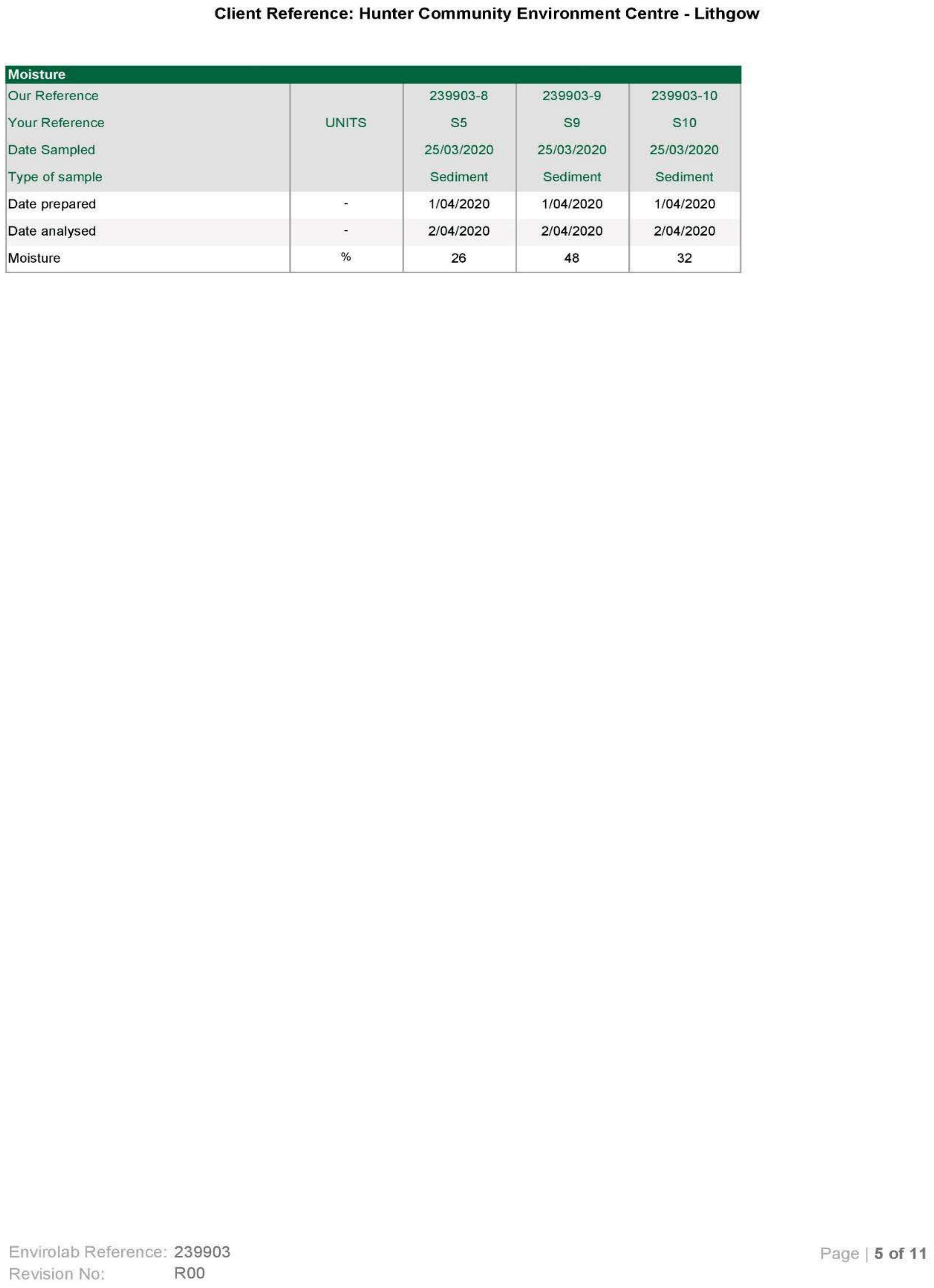
All metals in water - total						
Our Reference		239903-1	239903-2	239903-3	239903-4	239903-5
Your Reference	UNITS	W2	W3	W5	W7	W8
Date Sampled		24/03/2020	24/03/2020	24/03/2020	24/03/2020	24/03/2020
Type of sample		Water	Water	Water	Water	Water
Date prepared	-	01/04/2020	01/04/2020	01/04/2020	01/04/2020	01/04/2020
Date analysed	-	01/04/2020	01/04/2020	01/04/2020	01/04/2020	01/04/2020
Silver-Total	µg/L	<1	<1	<1	<1	<1
Aluminium-Total	µg/L	400	190	3,300	250	60
Arsenic-Total	µg/L	<1	<1	2	<1	7
Boron-Total	µg/L	60	2,100	1,000	460	200
Cadmium-Total	µg/L	<0.1	0.1	2.7	<0.1	<0.1
Cobalt-Total	µg/L	<1	78	850	4	<1
Chromium-Total	µg/L	<1	<1	<1	<1	<1
Copper-Total	µg/L	3	<1	2	<1	3
Iron-Total	µg/L	320	10,000	19,000	700	86
Lead-Total	µg/L	<1	<1	2	<1	<1
Manganese-Total	µg/L	140	6,900	35,000	540	72
Mercury-Total	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel-Total	µg/L	5	360	1,100	60	12
Selenium-Total	µg/L	1	<1	<1	<1	<1
Thallium-Total	µg/L	<1	1	<1	<1	<1
Vanadium-Total	µg/L	<1	<1	<1	<1	<1
Zinc-Total	µg/L	13	120	2,100	28	3

Client Reference: Hunter Community Environment Centre - Lithgow

All metals in water - total			
Our Reference		239903-6	239903-7
Your Reference	UNITS	W9	W10
Date Sampled		25/03/2020	25/03/2020
Type of sample		Water	Water
Date prepared	-	01/04/2020	01/04/2020
Date analysed	-	01/04/2020	01/04/2020
Silver-Total	µg/L	<1	<1
Aluminium-Total	µg/L	90	2,100
Arsenic-Total	µg/L	<1	2
Boron-Total	µg/L	20	30
Cadmium-Total	µg/L	<0.1	<0.1
Cobalt-Total	µg/L	7	2
Chromium-Total	µg/L	<1	2
Copper-Total	µg/L	<1	6
Iron-Total	µg/L	500	1,300
Lead-Total	µg/L	<1	1
Manganese-Total	µg/L	850	270
Mercury-Total	µg/L	<0.05	<0.05
Nickel-Total	µg/L	2	9
Selenium-Total	µg/L	<1	<1
Thallium-Total	µg/L	<1	<1
Vanadium-Total	µg/L	<1	4
Zinc-Total	µg/L	14	21

Client Reference: Hunter Community Environment Centre - Lithgow

Acid Extractractable metals in soil				
Our Reference		239903-8	239903-9	239903-10
Your Reference	UNITS	S5	S9	S10
Date Sampled		25/03/2020	25/03/2020	25/03/2020
Type of sample		Sediment	Sediment	Sediment
Date prepared	-	01/04/2020	01/04/2020	01/04/2020
Date analysed	-	02/04/2020	02/04/2020	02/04/2020
Silver	mg/kg	<1	<1	<1
Aluminium	mg/kg	6,300	24,000	7,100
Arsenic	mg/kg	<4	<4	14
Boron	mg/kg	5	<3	<3
Cadmium	mg/kg	<0.4	1	<0.4
Cobalt	mg/kg	20	68	6
Chromium	mg/kg	2	11	19
Copper	mg/kg	3	14	8
Iron	mg/kg	3,600	130,000	27,000
Lead	mg/kg	7	18	14
Manganese	mg/kg	610	2,800	280
Mercury	mg/kg	<0.1	<0.1	<0.1
Nickel	mg/kg	23	26	14
Selenium	mg/kg	<4	<4	<2
Thallium	mg/kg	<2	3	<2
Vanadium	mg/kg	7	24	32
Zinc	mg/kg	64	120	55

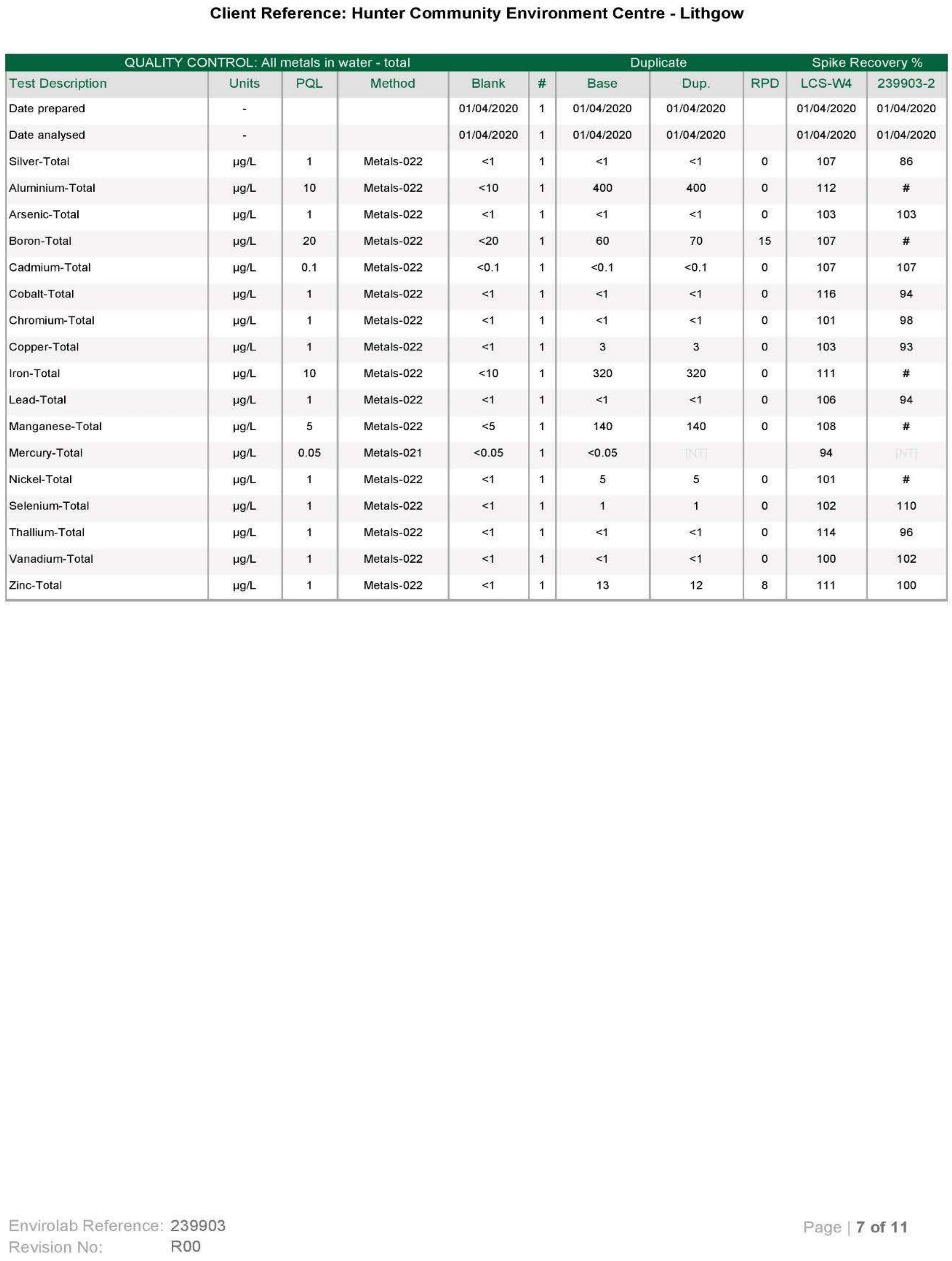


Client Reference: Hunter Community Environment Centre - Lithgow

Moisture				
Our Reference		239903-8	239903-9	239903-10
Your Reference	UNITS	S5	S9	S10
Date Sampled		25/03/2020	25/03/2020	25/03/2020
Type of sample		Sediment	Sediment	Sediment
Date prepared	-	1/04/2020	1/04/2020	1/04/2020
Date analysed	-	2/04/2020	2/04/2020	2/04/2020
Moisture	%	26	48	32

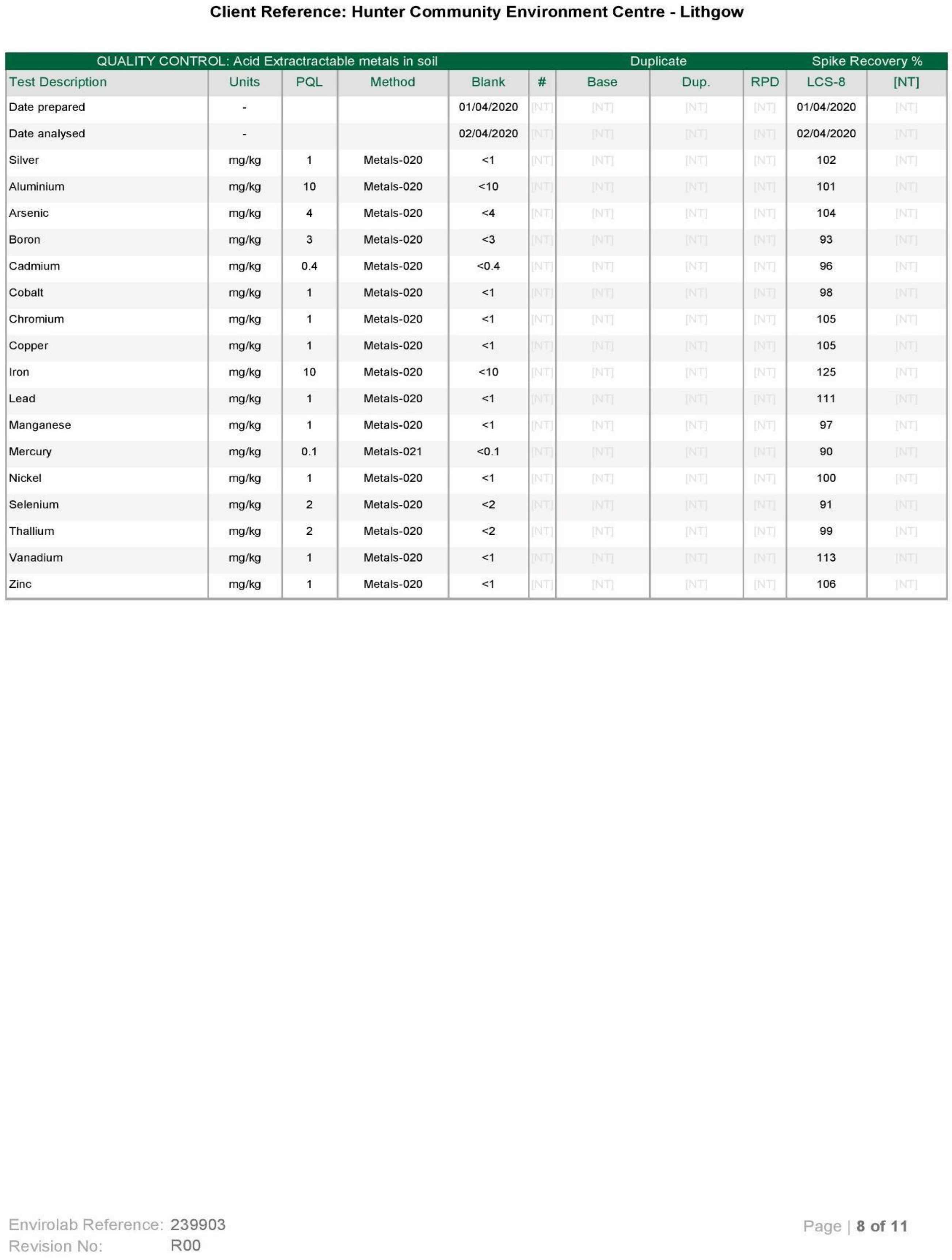
Client Reference: Hunter Community Environment Centre - Lithgow

Method ID	Methodology Summary
Inorg-008	Moisture content determined by heating at 105+/-5 °C for a minimum of 12 hours.
Metals-020	Determination of various metals by ICP-AES.
Metals-021	Determination of Mercury by Cold Vapour AAS.
Metals-022	Determination of various metals by ICP-MS.



Client Reference: Hunter Community Environment Centre - Lithgow

QUALITY CONTROL: All metals in water - total					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W4	239903-2
Date prepared	-			01/04/2020	1	01/04/2020	01/04/2020		01/04/2020	01/04/2020
Date analysed	-			01/04/2020	1	01/04/2020	01/04/2020		01/04/2020	01/04/2020
Silver-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	107	86
Aluminium-Total	µg/L	10	Metals-022	<10	1	400	400	0	112	#
Arsenic-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	103	103
Boron-Total	µg/L	20	Metals-022	<20	1	60	70	15	107	#
Cadmium-Total	µg/L	0.1	Metals-022	<0.1	1	<0.1	<0.1	0	107	107
Cobalt-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	116	94
Chromium-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	101	98
Copper-Total	µg/L	1	Metals-022	<1	1	3	3	0	103	93
Iron-Total	µg/L	10	Metals-022	<10	1	320	320	0	111	#
Lead-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	106	94
Manganese-Total	µg/L	5	Metals-022	<5	1	140	140	0	108	#
Mercury-Total	µg/L	0.05	Metals-021	<0.05	1	<0.05	[NT]		94	[NT]
Nickel-Total	µg/L	1	Metals-022	<1	1	5	5	0	101	#
Selenium-Total	µg/L	1	Metals-022	<1	1	1	1	0	102	110
Thallium-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	114	96
Vanadium-Total	µg/L	1	Metals-022	<1	1	<1	<1	0	100	102
Zinc-Total	µg/L	1	Metals-022	<1	1	13	12	8	111	100



Client Reference: Hunter Community Environment Centre - Lithgow

QUALITY CONTROL: Acid Extractractable metals in soil					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-8	[NT]
Date prepared	-			01/04/2020	[NT]	[NT]	[NT]	[NT]	01/04/2020	[NT]
Date analysed	-			02/04/2020	[NT]	[NT]	[NT]	[NT]	02/04/2020	[NT]
Silver	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	102	[NT]
Aluminium	mg/kg	10	Metals-020	<10	[NT]	[NT]	[NT]	[NT]	101	[NT]
Arsenic	mg/kg	4	Metals-020	<4	[NT]	[NT]	[NT]	[NT]	104	[NT]
Boron	mg/kg	3	Metals-020	<3	[NT]	[NT]	[NT]	[NT]	93	[NT]
Cadmium	mg/kg	0.4	Metals-020	<0.4	[NT]	[NT]	[NT]	[NT]	96	[NT]
Cobalt	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	98	[NT]
Chromium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	105	[NT]
Copper	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	105	[NT]
Iron	mg/kg	10	Metals-020	<10	[NT]	[NT]	[NT]	[NT]	125	[NT]
Lead	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	111	[NT]
Manganese	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	97	[NT]
Mercury	mg/kg	0.1	Metals-021	<0.1	[NT]	[NT]	[NT]	[NT]	90	[NT]
Nickel	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	100	[NT]
Selenium	mg/kg	2	Metals-020	<2	[NT]	[NT]	[NT]	[NT]	91	[NT]
Thallium	mg/kg	2	Metals-020	<2	[NT]	[NT]	[NT]	[NT]	99	[NT]
Vanadium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	113	[NT]
Zinc	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	106	[NT]

Client Reference: Hunter Community Environment Centre - Lithgow

Result Definitions	
NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Client Reference: Hunter Community Environment Centre - Lithgow

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
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When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

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Analysis of aqueous samples typically involves the extraction/digestion and/or analysis of the liquid phase only (i.e. NOT any settled sediment phase but inclusive of suspended particles if present), unless stipulated on the Envirolab COC and/or by correspondence. Notable exceptions include certain Physical Tests (pH/EC/BOD/COD/Apparent Colour etc.), Solids testing, total recoverable metals and PFAS where solids are included by default.

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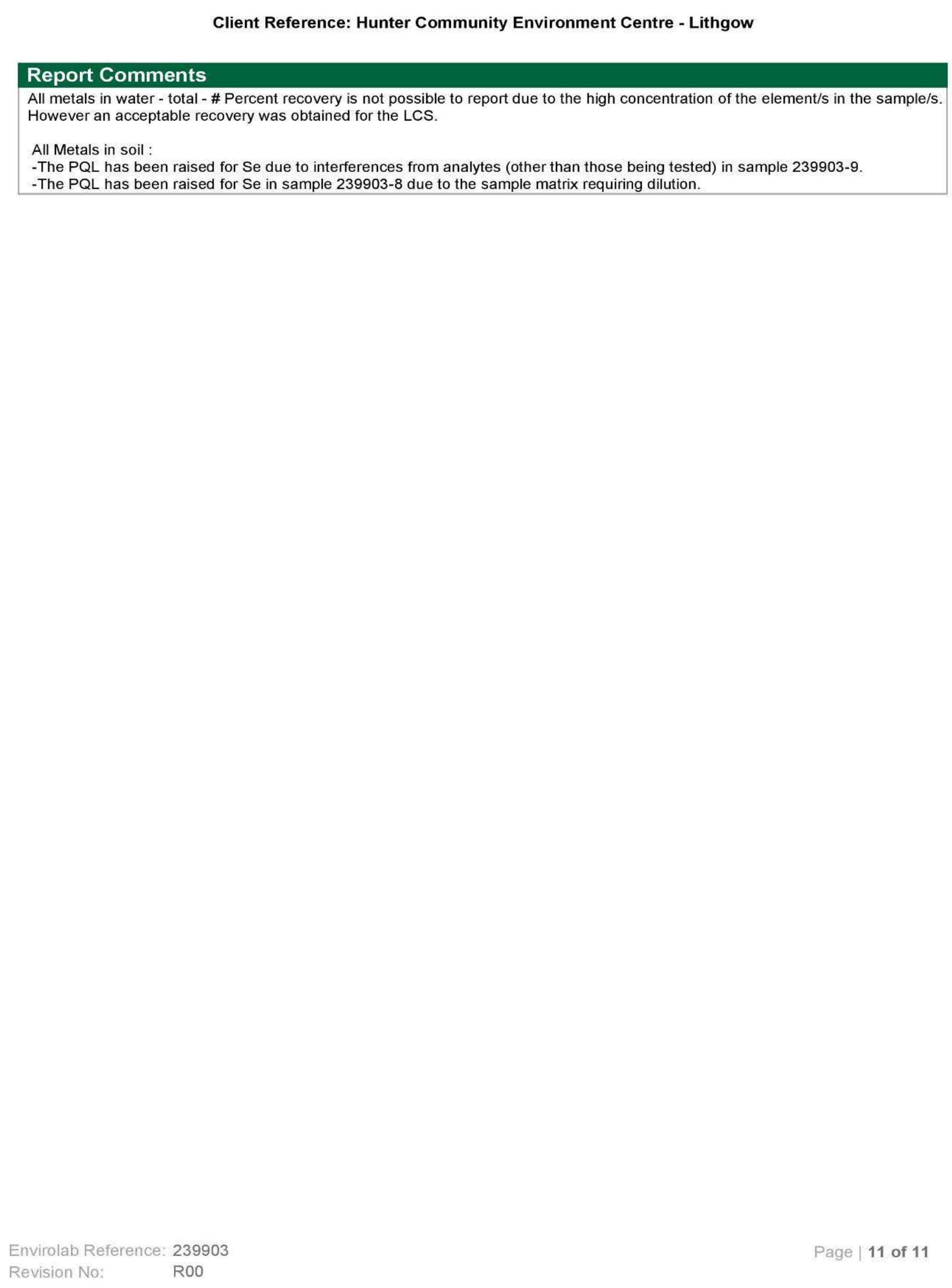
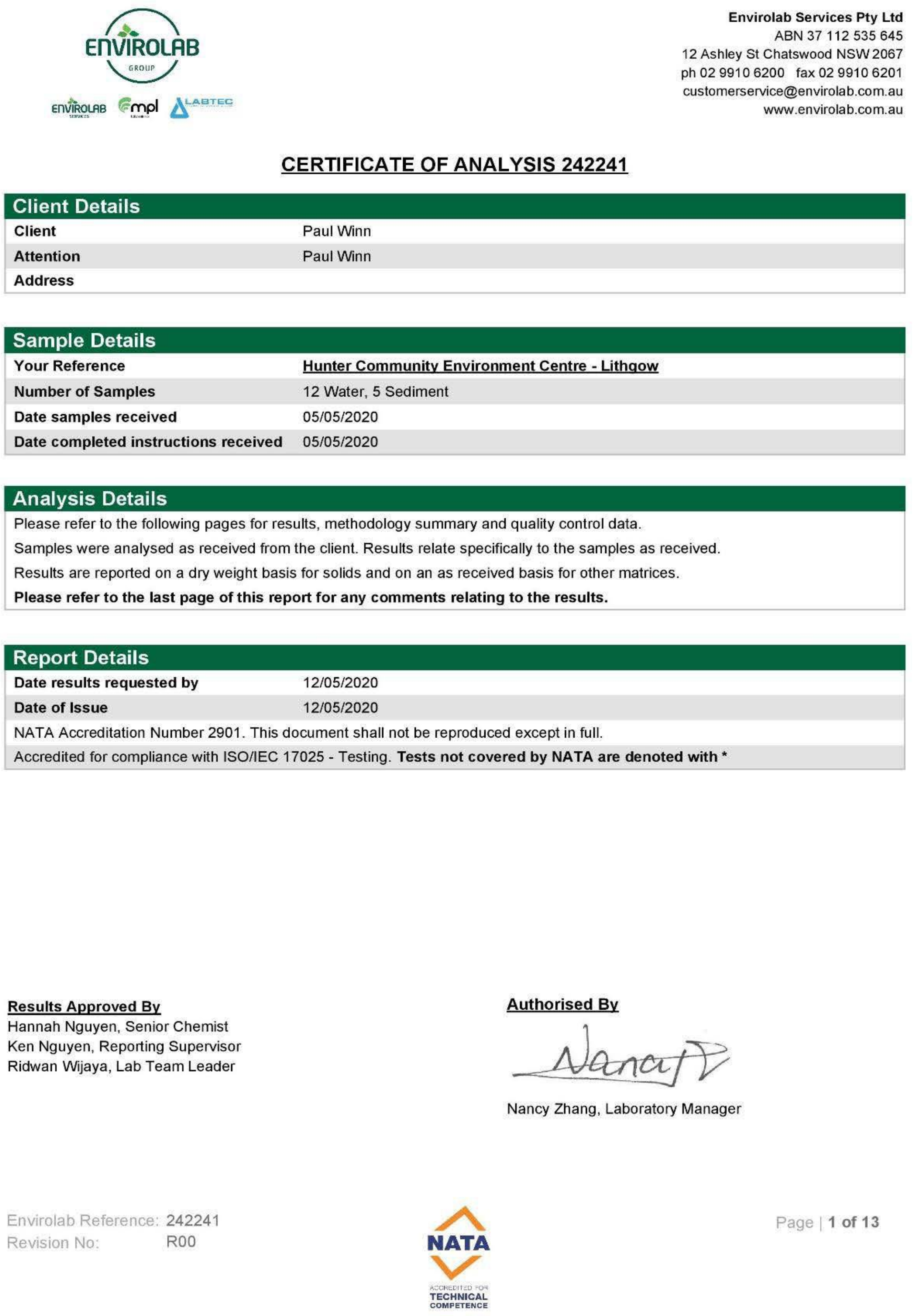


Client Reference: Hunter Community Environment Centre - Lithgow

Report Comments
All metals in water - total - # Percent recovery is not possible to report due to the high concentration of the element/s in the sample/s. However an acceptable recovery was obtained for the LCS. All Metals in soil : -The PQL has been raised for Se due to interferences from analytes (other than those being tested) in sample 239903-9. -The PQL has been raised for Se in sample 239903-8 due to the sample matrix requiring dilution.

Mount Piper 2



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CERTIFICATE OF ANALYSIS 242241

Client Details

Client	Paul Winn
Attention	Paul Winn
Address	

Sample Details

Your Reference	Hunter Community Environment Centre - Lithgow
Number of Samples	12 Water, 5 Sediment
Date samples received	05/05/2020
Date completed instructions received	05/05/2020

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Please refer to the last page of this report for any comments relating to the results.

Report Details

Date results requested by	12/05/2020
Date of Issue	12/05/2020

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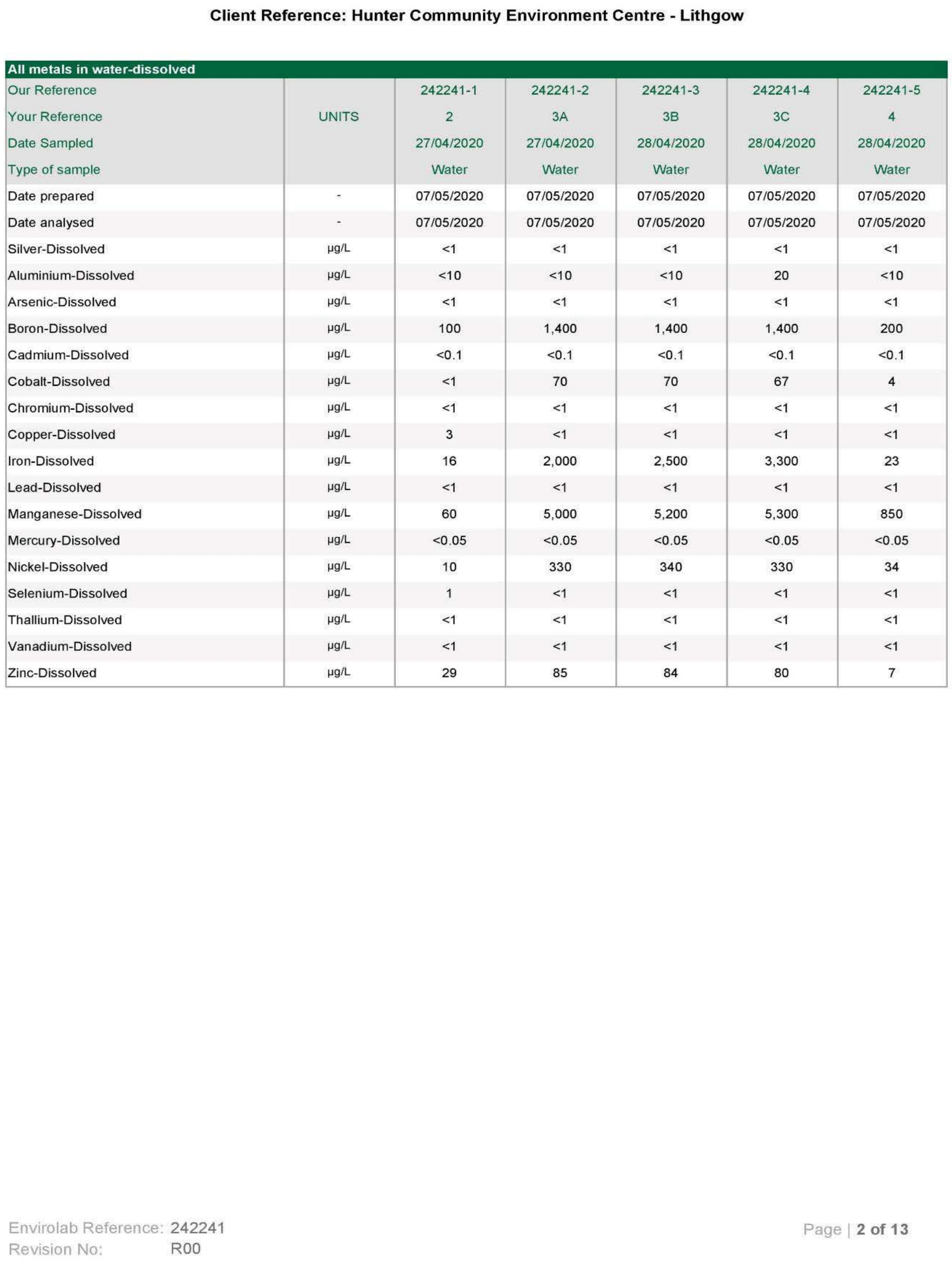
Results Approved By
Hannah Nguyen, Senior Chemist
Ken Nguyen, Reporting Supervisor
Ridwan Wijaya, Lab Team Leader

Authorised By

Nancy Zhang, Laboratory Manager

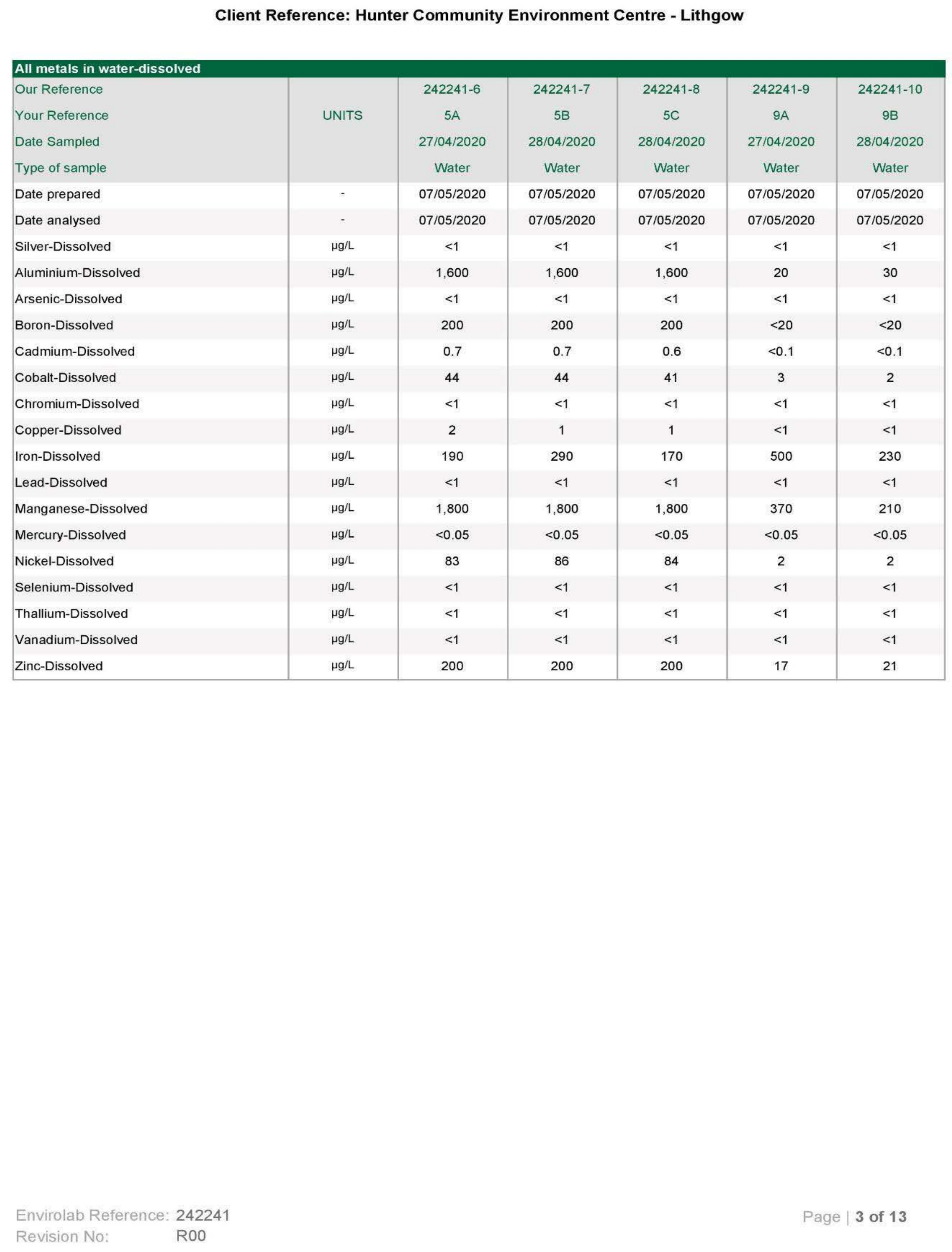
NATA
ACCREDITED FOR TECHNICAL COMPETENCE



Client Reference: Hunter Community Environment Centre - Lithgow

All metals in water-dissolved

Our Reference		242241-1	242241-2	242241-3	242241-4	242241-5
Your Reference	UNITS	2	3A	3B	3C	4
Date Sampled		27/04/2020	27/04/2020	28/04/2020	28/04/2020	28/04/2020
Type of sample		Water	Water	Water	Water	Water
Date prepared	-	07/05/2020	07/05/2020	07/05/2020	07/05/2020	07/05/2020
Date analysed	-	07/05/2020	07/05/2020	07/05/2020	07/05/2020	07/05/2020
Silver-Dissolved	µg/L	<1	<1	<1	<1	<1
Aluminium-Dissolved	µg/L	<10	<10	<10	20	<10
Arsenic-Dissolved	µg/L	<1	<1	<1	<1	<1
Boron-Dissolved	µg/L	100	1,400	1,400	1,400	200
Cadmium-Dissolved	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt-Dissolved	µg/L	<1	70	70	67	4
Chromium-Dissolved	µg/L	<1	<1	<1	<1	<1
Copper-Dissolved	µg/L	3	<1	<1	<1	<1
Iron-Dissolved	µg/L	16	2,000	2,500	3,300	23
Lead-Dissolved	µg/L	<1	<1	<1	<1	<1
Manganese-Dissolved	µg/L	60	5,000	5,200	5,300	850
Mercury-Dissolved	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel-Dissolved	µg/L	10	330	340	330	34
Selenium-Dissolved	µg/L	1	<1	<1	<1	<1
Thallium-Dissolved	µg/L	<1	<1	<1	<1	<1
Vanadium-Dissolved	µg/L	<1	<1	<1	<1	<1
Zinc-Dissolved	µg/L	29	85	84	80	7

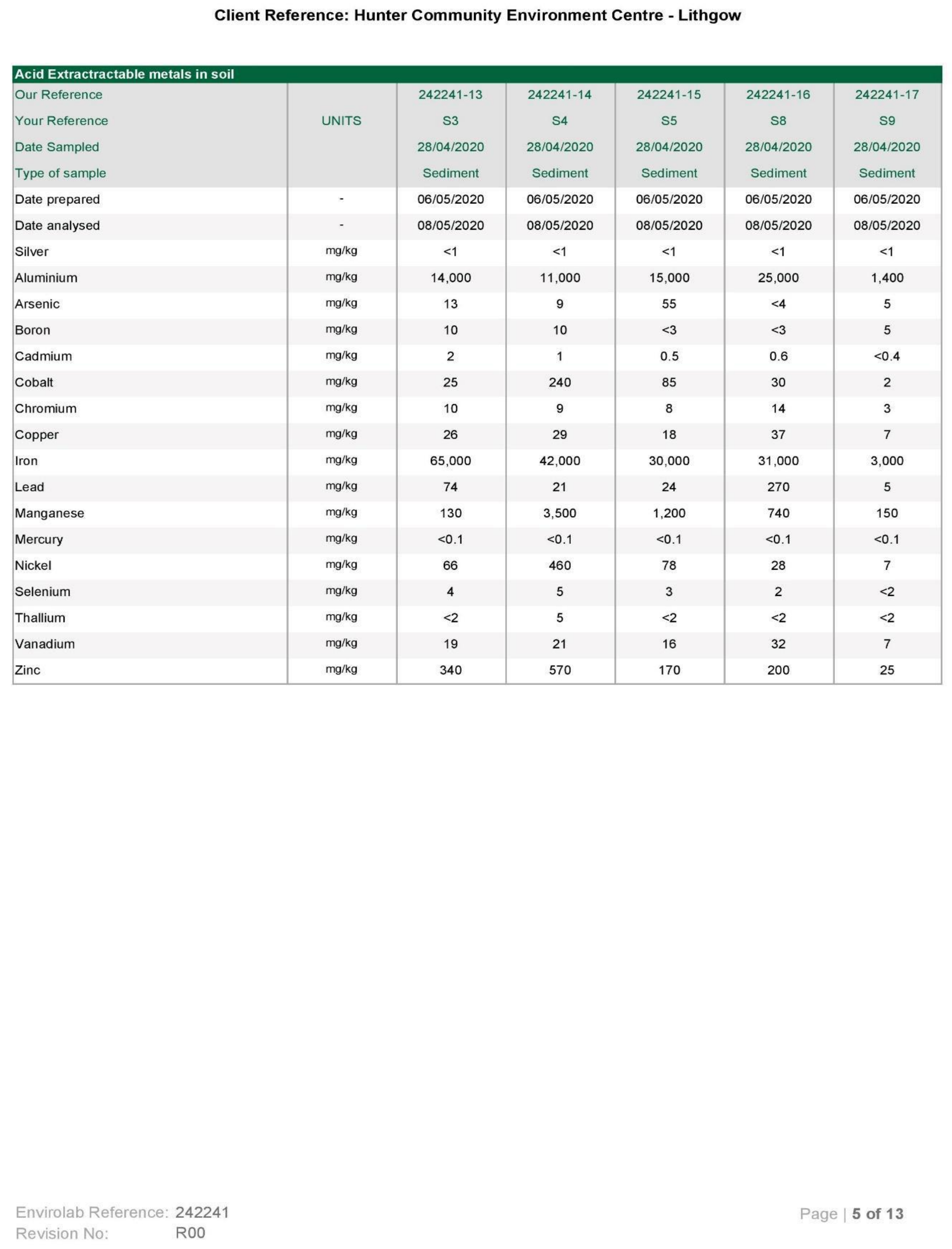


Client Reference: Hunter Community Environment Centre - Lithgow

All metals in water-dissolved						
Our Reference	UNITS	242241-6	242241-7	242241-8	242241-9	242241-10
Your Reference		5A	5B	5C	9A	9B
Date Sampled		27/04/2020	28/04/2020	28/04/2020	27/04/2020	28/04/2020
Type of sample		Water	Water	Water	Water	Water
Date prepared	-	07/05/2020	07/05/2020	07/05/2020	07/05/2020	07/05/2020
Date analysed	-	07/05/2020	07/05/2020	07/05/2020	07/05/2020	07/05/2020
Silver-Dissolved	μg/L	<1	<1	<1	<1	<1
Aluminium-Dissolved	μg/L	1,600	1,600	1,600	20	30
Arsenic-Dissolved	μg/L	<1	<1	<1	<1	<1
Boron-Dissolved	μg/L	200	200	200	<20	<20
Cadmium-Dissolved	μg/L	0.7	0.7	0.6	<0.1	<0.1
Cobalt-Dissolved	μg/L	44	44	41	3	2
Chromium-Dissolved	μg/L	<1	<1	<1	<1	<1
Copper-Dissolved	μg/L	2	1	1	<1	<1
Iron-Dissolved	μg/L	190	290	170	500	230
Lead-Dissolved	μg/L	<1	<1	<1	<1	<1
Manganese-Dissolved	μg/L	1,800	1,800	1,800	370	210
Mercury-Dissolved	μg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel-Dissolved	μg/L	83	86	84	2	2
Selenium-Dissolved	μg/L	<1	<1	<1	<1	<1
Thallium-Dissolved	μg/L	<1	<1	<1	<1	<1
Vanadium-Dissolved	μg/L	<1	<1	<1	<1	<1
Zinc-Dissolved	μg/L	200	200	200	17	21

Client Reference: Hunter Community Environment Centre - Lithgow

All metals in water-dissolved			
Our Reference		242241-11	242241-12
Your Reference	UNITS	8	11
Date Sampled		27/04/2020	27/04/2020
Type of sample		Water	Water
Date prepared	-	07/05/2020	07/05/2020
Date analysed	-	07/05/2020	07/05/2020
Silver-Dissolved	µg/L	<1	<1
Aluminium-Dissolved	µg/L	10	20
Arsenic-Dissolved	µg/L	5	3
Boron-Dissolved	µg/L	200	70
Cadmium-Dissolved	µg/L	<0.1	<0.1
Cobalt-Dissolved	µg/L	<1	<1
Chromium-Dissolved	µg/L	<1	<1
Copper-Dissolved	µg/L	<1	<1
Iron-Dissolved	µg/L	25	12
Lead-Dissolved	µg/L	<1	<1
Manganese-Dissolved	µg/L	25	<5
Mercury-Dissolved	µg/L	<0.05	<0.05
Nickel-Dissolved	µg/L	12	3
Selenium-Dissolved	µg/L	<1	<1
Thallium-Dissolved	µg/L	<1	<1
Vanadium-Dissolved	µg/L	<1	<1
Zinc-Dissolved	µg/L	<1	<1



Client Reference: Hunter Community Environment Centre - Lithgow

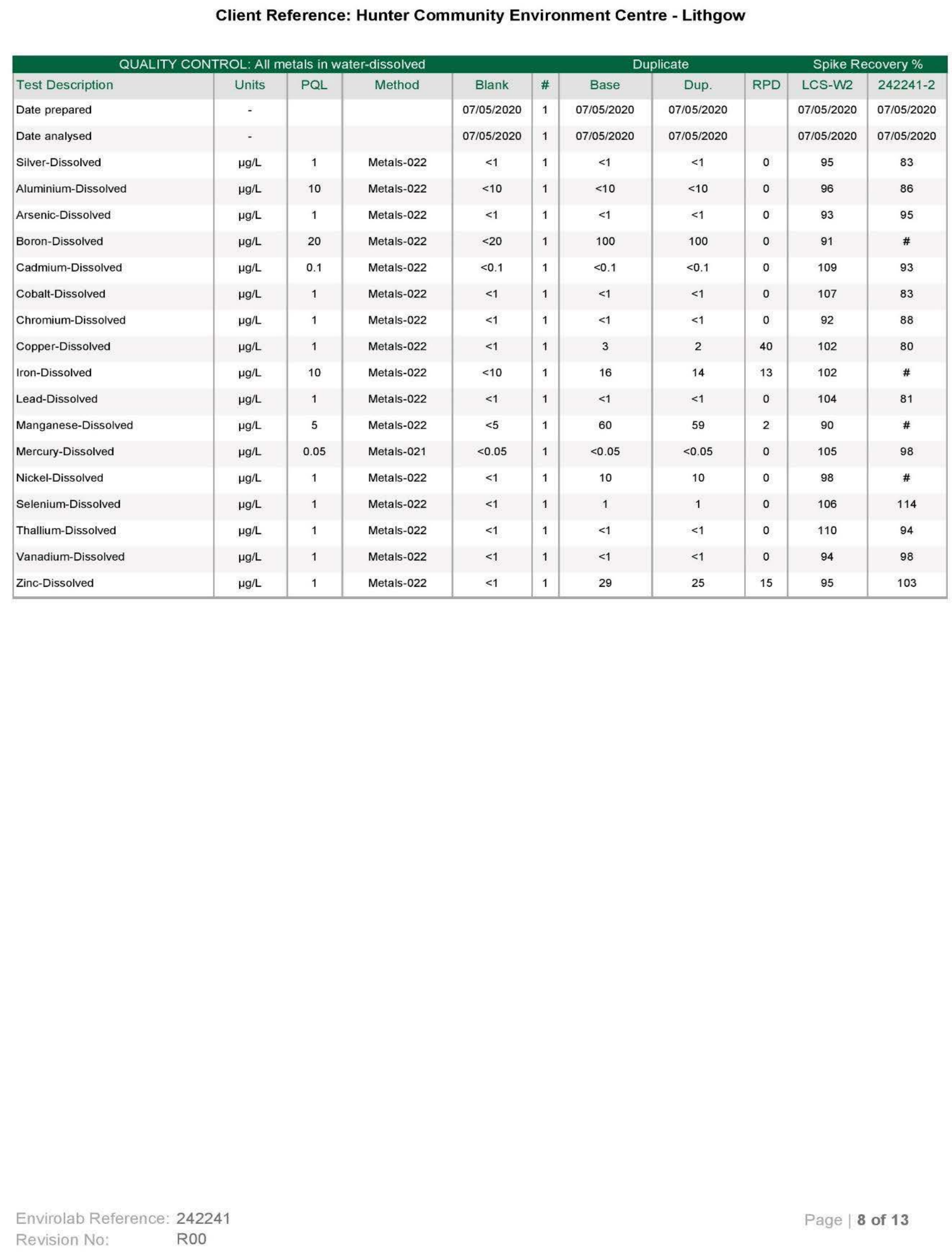
Acid Extractractable metals in soil						
Our Reference		242241-13	242241-14	242241-15	242241-16	242241-17
Your Reference	UNITS	S3	S4	S5	S8	S9
Date Sampled		28/04/2020	28/04/2020	28/04/2020	28/04/2020	28/04/2020
Type of sample		Sediment	Sediment	Sediment	Sediment	Sediment
Date prepared	-	06/05/2020	06/05/2020	06/05/2020	06/05/2020	06/05/2020
Date analysed	-	08/05/2020	08/05/2020	08/05/2020	08/05/2020	08/05/2020
Silver	mg/kg	<1	<1	<1	<1	<1
Aluminium	mg/kg	14,000	11,000	15,000	25,000	1,400
Arsenic	mg/kg	13	9	55	<4	5
Boron	mg/kg	10	10	<3	<3	5
Cadmium	mg/kg	2	1	0.5	0.6	<0.4
Cobalt	mg/kg	25	240	85	30	2
Chromium	mg/kg	10	9	8	14	3
Copper	mg/kg	26	29	18	37	7
Iron	mg/kg	65,000	42,000	30,000	31,000	3,000
Lead	mg/kg	74	21	24	270	5
Manganese	mg/kg	130	3,500	1,200	740	150
Mercury	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel	mg/kg	66	460	78	28	7
Selenium	mg/kg	4	5	3	2	<2
Thallium	mg/kg	<2	5	<2	<2	<2
Vanadium	mg/kg	19	21	16	32	7
Zinc	mg/kg	340	570	170	200	25

Client Reference: Hunter Community Environment Centre - Lithgow

Moisture						
Our Reference		242241-13	242241-14	242241-15	242241-16	242241-17
Your Reference	UNITS	S3	S4	S5	S8	S9
Date Sampled		28/04/2020	28/04/2020	28/04/2020	28/04/2020	28/04/2020
Type of sample		Sediment	Sediment	Sediment	Sediment	Sediment
Date prepared	-	06/05/2020	06/05/2020	06/05/2020	06/05/2020	06/05/2020
Date analysed	-	07/05/2020	07/05/2020	07/05/2020	07/05/2020	07/05/2020
Moisture	%	73	82	55	65	63

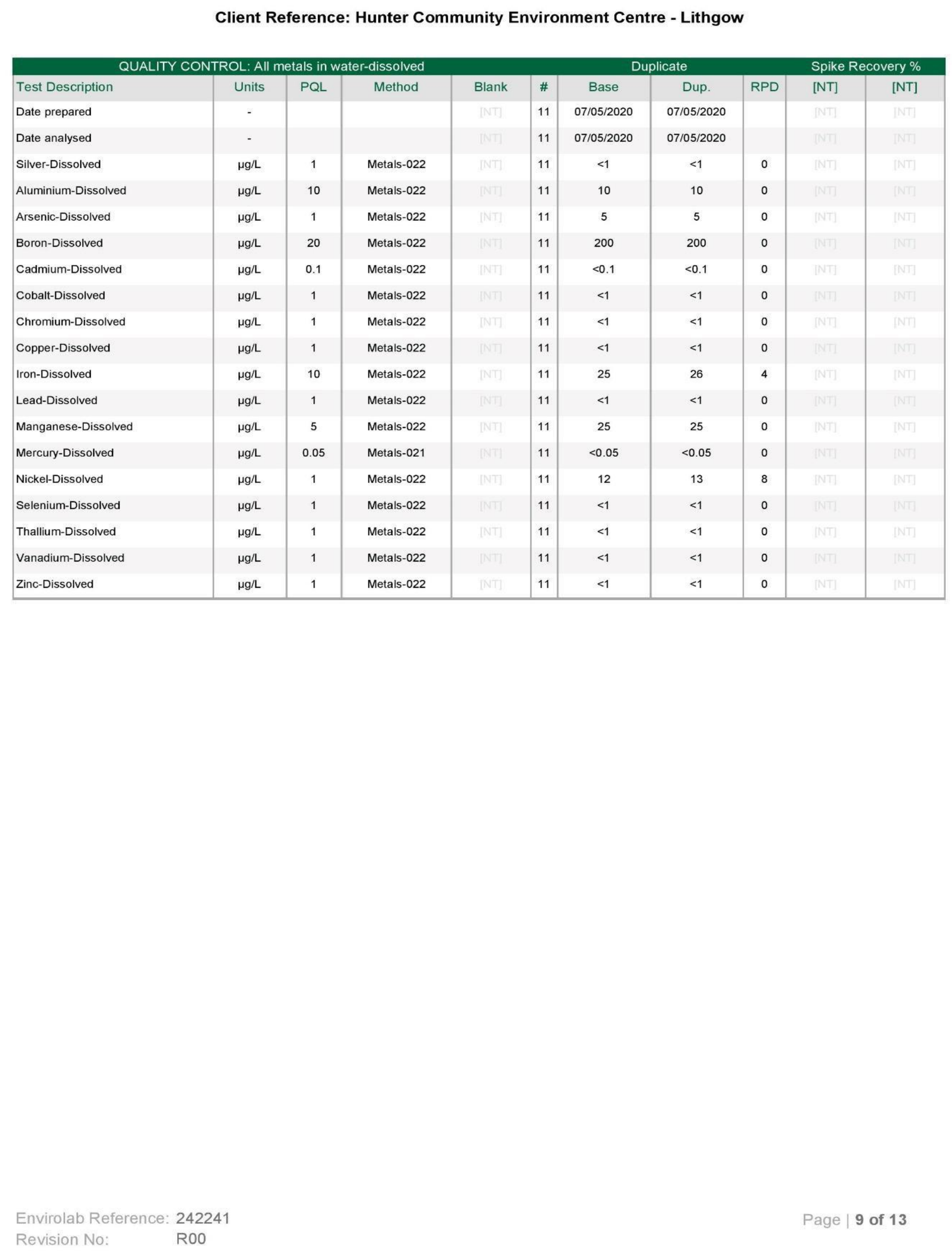
Client Reference: Hunter Community Environment Centre - Lithgow

Method ID	Methodology Summary
Inorg-008	Moisture content determined by heating at 105+/-5 °C for a minimum of 12 hours.
Metals-020	Determination of various metals by ICP-AES.
Metals-021	Determination of Mercury by Cold Vapour AAS.
Metals-022	Determination of various metals by ICP-MS.



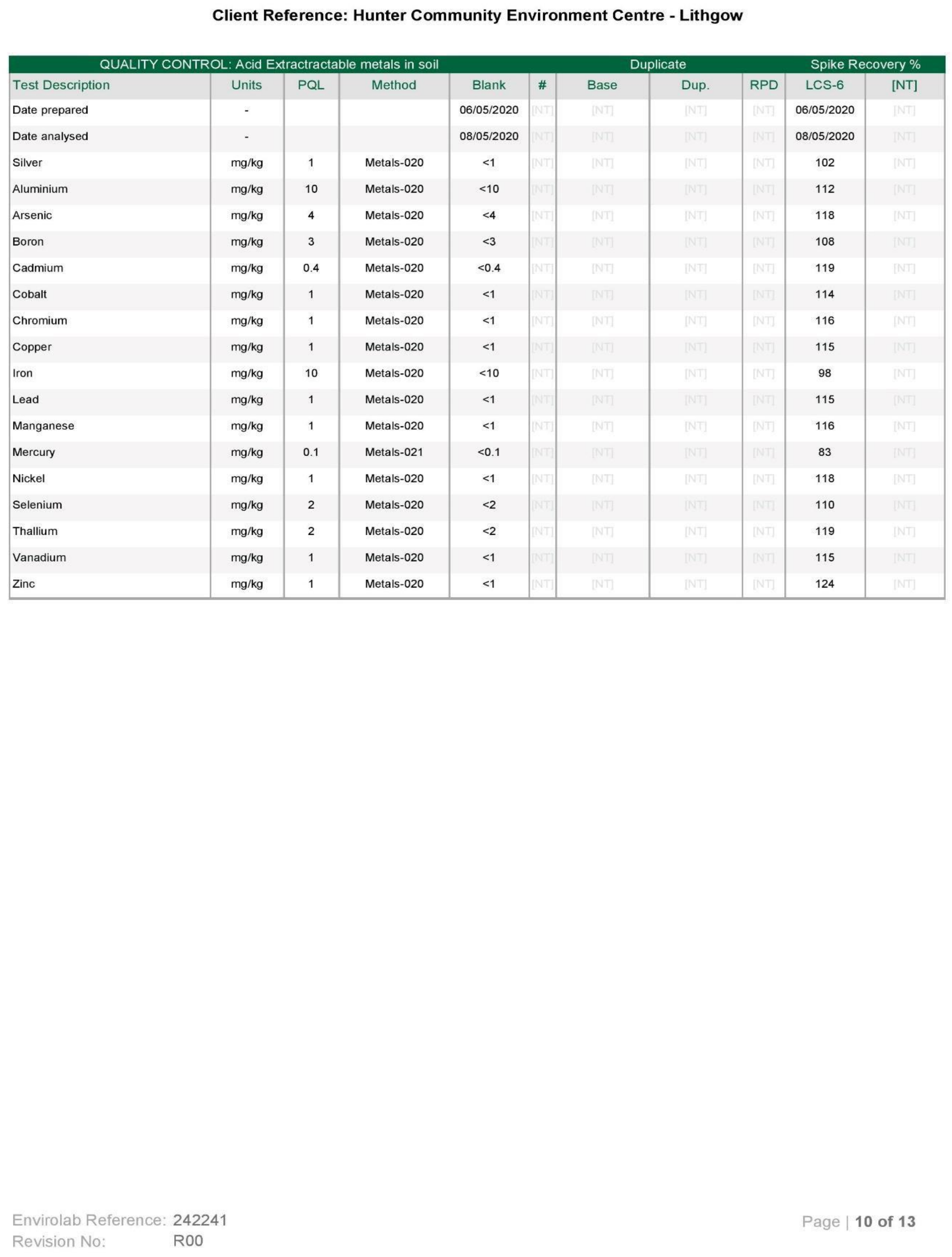
Client Reference: Hunter Community Environment Centre - Lithgow

QUALITY CONTROL: All metals in water-dissolved					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W2	242241-2
Date prepared	-			07/05/2020	1	07/05/2020	07/05/2020		07/05/2020	07/05/2020
Date analysed	-			07/05/2020	1	07/05/2020	07/05/2020		07/05/2020	07/05/2020
Silver-Dissolved	µg/L	1	Metals-022	<1	1	<1	<1	0	95	83
Aluminium-Dissolved	µg/L	10	Metals-022	<10	1	<10	<10	0	96	86
Arsenic-Dissolved	µg/L	1	Metals-022	<1	1	<1	<1	0	93	95
Boron-Dissolved	µg/L	20	Metals-022	<20	1	100	100	0	91	#
Cadmium-Dissolved	µg/L	0.1	Metals-022	<0.1	1	<0.1	<0.1	0	109	93
Cobalt-Dissolved	µg/L	1	Metals-022	<1	1	<1	<1	0	107	83
Chromium-Dissolved	µg/L	1	Metals-022	<1	1	<1	<1	0	92	88
Copper-Dissolved	µg/L	1	Metals-022	<1	1	3	2	40	102	80
Iron-Dissolved	µg/L	10	Metals-022	<10	1	16	14	13	102	#
Lead-Dissolved	µg/L	1	Metals-022	<1	1	<1	<1	0	104	81
Manganese-Dissolved	µg/L	5	Metals-022	<5	1	60	59	2	90	#
Mercury-Dissolved	µg/L	0.05	Metals-021	<0.05	1	<0.05	<0.05	0	105	98
Nickel-Dissolved	µg/L	1	Metals-022	<1	1	10	10	0	98	#
Selenium-Dissolved	µg/L	1	Metals-022	<1	1	1	1	0	106	114
Thallium-Dissolved	µg/L	1	Metals-022	<1	1	<1	<1	0	110	94
Vanadium-Dissolved	µg/L	1	Metals-022	<1	1	<1	<1	0	94	98
Zinc-Dissolved	µg/L	1	Metals-022	<1	1	29	25	15	95	103



Client Reference: Hunter Community Environment Centre - Lithgow

QUALITY CONTROL: All metals in water-dissolved					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	[NT]	[NT]
Date prepared	-			[NT]	11	07/05/2020	07/05/2020		[NT]	[NT]
Date analysed	-			[NT]	11	07/05/2020	07/05/2020		[NT]	[NT]
Silver-Dissolved	µg/L	1	Metals-022	[NT]	11	<1	<1	0	[NT]	[NT]
Aluminium-Dissolved	µg/L	10	Metals-022	[NT]	11	10	10	0	[NT]	[NT]
Arsenic-Dissolved	µg/L	1	Metals-022	[NT]	11	5	5	0	[NT]	[NT]
Boron-Dissolved	µg/L	20	Metals-022	[NT]	11	200	200	0	[NT]	[NT]
Cadmium-Dissolved	µg/L	0.1	Metals-022	[NT]	11	<0.1	<0.1	0	[NT]	[NT]
Cobalt-Dissolved	µg/L	1	Metals-022	[NT]	11	<1	<1	0	[NT]	[NT]
Chromium-Dissolved	µg/L	1	Metals-022	[NT]	11	<1	<1	0	[NT]	[NT]
Copper-Dissolved	µg/L	1	Metals-022	[NT]	11	<1	<1	0	[NT]	[NT]
Iron-Dissolved	µg/L	10	Metals-022	[NT]	11	25	26	4	[NT]	[NT]
Lead-Dissolved	µg/L	1	Metals-022	[NT]	11	<1	<1	0	[NT]	[NT]
Manganese-Dissolved	µg/L	5	Metals-022	[NT]	11	25	25	0	[NT]	[NT]
Mercury-Dissolved	µg/L	0.05	Metals-021	[NT]	11	<0.05	<0.05	0	[NT]	[NT]
Nickel-Dissolved	µg/L	1	Metals-022	[NT]	11	12	13	8	[NT]	[NT]
Selenium-Dissolved	µg/L	1	Metals-022	[NT]	11	<1	<1	0	[NT]	[NT]
Thallium-Dissolved	µg/L	1	Metals-022	[NT]	11	<1	<1	0	[NT]	[NT]
Vanadium-Dissolved	µg/L	1	Metals-022	[NT]	11	<1	<1	0	[NT]	[NT]
Zinc-Dissolved	µg/L	1	Metals-022	[NT]	11	<1	<1	0	[NT]	[NT]



Client Reference: Hunter Community Environment Centre - Lithgow

QUALITY CONTROL: Acid Extractractable metals in soil					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-6	[NT]
Date prepared	-			06/05/2020	[NT]	[NT]	[NT]	[NT]	06/05/2020	[NT]
Date analysed	-			08/05/2020	[NT]	[NT]	[NT]	[NT]	08/05/2020	[NT]
Silver	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	102	[NT]
Aluminium	mg/kg	10	Metals-020	<10	[NT]	[NT]	[NT]	[NT]	112	[NT]
Arsenic	mg/kg	4	Metals-020	<4	[NT]	[NT]	[NT]	[NT]	118	[NT]
Boron	mg/kg	3	Metals-020	<3	[NT]	[NT]	[NT]	[NT]	108	[NT]
Cadmium	mg/kg	0.4	Metals-020	<0.4	[NT]	[NT]	[NT]	[NT]	119	[NT]
Cobalt	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	114	[NT]
Chromium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	116	[NT]
Copper	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	115	[NT]
Iron	mg/kg	10	Metals-020	<10	[NT]	[NT]	[NT]	[NT]	98	[NT]
Lead	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	115	[NT]
Manganese	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	116	[NT]
Mercury	mg/kg	0.1	Metals-021	<0.1	[NT]	[NT]	[NT]	[NT]	83	[NT]
Nickel	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	118	[NT]
Selenium	mg/kg	2	Metals-020	<2	[NT]	[NT]	[NT]	[NT]	110	[NT]
Thallium	mg/kg	2	Metals-020	<2	[NT]	[NT]	[NT]	[NT]	119	[NT]
Vanadium	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	115	[NT]
Zinc	mg/kg	1	Metals-020	<1	[NT]	[NT]	[NT]	[NT]	124	[NT]

Client Reference: Hunter Community Environment Centre - Lithgow

Result Definitions	
NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Client Reference: Hunter Community Environment Centre - Lithgow

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.

The recommended maximums for analytes in urine are taken from “2018 TLVs and BEIs”, as published by ACGIH (where available). Limit provided for Nickel is a precautionary guideline as per Position Paper prepared by AIOH Exposure Standards Committee, 2016.

Guideline limits for Rinse Water Quality reported as per analytical requirements and specifications of AS 4187, Amdt 2 2019, Table 7.2

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals (not SPOCAS); 60-140% for organics/SPOCAS (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

Analysis of aqueous samples typically involves the extraction/digestion and/or analysis of the liquid phase only (i.e. NOT any settled sediment phase but inclusive of suspended particles if present), unless stipulated on the Envirolab COC and/or by correspondence. Notable exceptions include certain Physical Tests (pH/EC/BOD/COD/Apparent Colour etc.), Solids testing, total recoverable metals and PFAS where solids are included by default.

Samples for Microbiological analysis (not Amoeba forms) received outside of the 2-8°C temperature range do not meet the ideal cooling conditions as stated in AS2031-2012.

Client Reference: Hunter Community Environment Centre - Lithgow

Report Comments

All metals in water-dissolved - # Percent recovery is not possible to report due to the high concentration of the element/s in the sample/s. However an acceptable recovery was obtained for the LCS.


Hunter Community
Environment Centre