Supplementary Submission
No 39a

INQUIRY INTO COSTS FOR REMEDIATION OF SITES CONTAINING COAL ASH REPOSITORIES

Organisation: Hunter Community Environment Centre

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Hunter Community Environment Centre.

Legislative Council Public Works Committee
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SUPLEMENTARY SUBMISSION TO:

Inquiry into the costs for remediation of sites containing coal ash repositories

1 SEPTEMBER 2020

Executive Summary

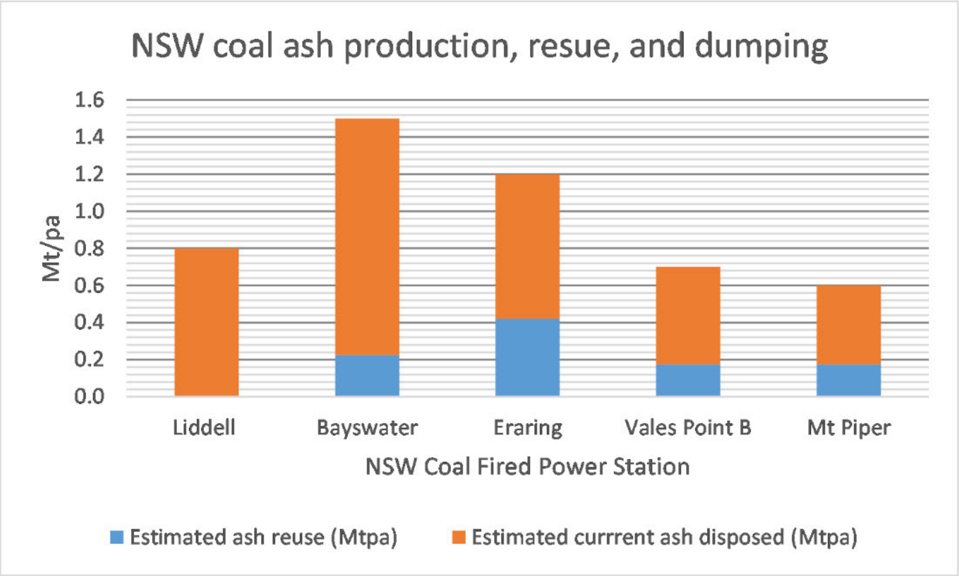
Our analysis and investigations undertaken during the delay in the hearings for the inquiry highlight the inadequacy of the current EPA regulation of coal ash dumps, which we demonstrate is causing significant environmental harm and risking human health.

We conclude that the NSW Government is liable for considerable decontamination works at the five active power station ash dumps to remedy the ongoing heavy metal pollution when these facilities are decommissioned and must move to substantially reduce the volumes of coal ash, particularly fly ash, from which most of the metal leachate is derived.

We believe the costs 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 Load-Based Licencing fee paid by 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 could provide significant regional business and employment opportunities.

We estimate the five operating NSW coal-fired power stations collectively generate 4.8 Mt of coal ash waste a year, and 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, the total coal ash accumulation in NSW is about 216 Mt.

- 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 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).



Coal ash produced by NSW power stations and reuse rates per annum

The Vales Point ash dam is the largest in NSW, holding about 60 Mt (minus what was dumped in Munmorah ash dam), with Bayswater's Ravensworth Rehabilitation Area, into which AGL dumps fly ash, and the Pikes Gulley ash dam collectively holding about 45Mt. The Eraring ash dump holds about 40Mt, and Mt 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, with Lake Macquarie burdened with over 100 Mt, the Central Hunter Valley with 84Mt, Lithgow with 28Mt, and Lake Illawarra with 3Mt (See Table 2).

Accumulated coal ash and regional ash dump totals

	Operating ash dumps					***Decomissioned***		
	Central Hunter Valley		**Lake Macquarie**		**Lithgow**		***Lake Illawarra***	
Facility ash dump	**Liddell**	**Bayswater - Pikes Gulley and Ravensworth mine rehab.**	**Eraring and Wangi**	**Vales Point A/B & Munmorah**	**Mt Piper**	***Wallerawang B & C***	***Tallawarrra A***	**Total**
Estimated acumulated ash (Mt)	39	45	40	61	15	*13*	*3*	**216**
Regional total	**84**		**101**		**28**		**3**	

In 2018/19, over 5,400 tonnes of metals and about 1,500 tonnes of other harmful pollutants were reported to the National Pollutant Inventory as "transferred" to on-site ash dumps by NSW power stations. These transfers are, in effect, avoiding the reporting of water pollution, as some of the metals contained within the ash will leach into groundwater, and ultimately to surface water.

Despite serious contamination of groundwater by coal ash storages found in other parts of the world,[1] - eg 90% of US power plants reported unsafe levels of at least one pollutant derived from coal ash in groundwater,[2] no emissions to groundwater were reported to the NPI in 2018/19 by any NSW coal-fired power station.

Coal ash leachate and ecosystem pollution

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.

The proportion of these metals that will be released from the ash depends largely on the amount of water the ash come into contact and the permeability of the settled ash in the dump. 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. This effect has been seen in many studies on local water quality near ash ponds. Coal ash leachates can be consumed or absorbed by aquatic organisms and cause toxic effects. 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.

The long-term exposure to heavy metals in the environment represents a major threat to wild 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.

Heavy metal pollution has likely played an important role in global biodiversity decline. Species richness for frogs in Victoria has been shown to correlated 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. Our own research has found high metal concentrations in water birds found at Lake Macquarie and Lake Liddell, which indicates bioaccumulation.

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. Metal concentrations have been found in regularly caught and consumed seafood from Lake Macquarie above recommended safe levels.

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[1] US EPA - Environmental Protection Agency, 1999. Report to Congress, Wastes from the Combustion of Fossil Fuels Volume 1 – Executive Summary. https://www.epa.gov/sites/production/ files/2015-08/documents/march_1999_report_to_congress_volumes1and2.pdf; U.S. EPA - Environmental Protection Agency, 2010. Human and Ecological Risk Assessment of Coal Combustion Wastes. Office of Solid Waste and Emergency Response, Office of Resource Conservation and Recovery. Draft EPA document. April 2010. Pp 2-4. https://earthjustice.org/ sites/default/files/library/reports/epa-coal-combustion-waste-risk-assessment.pdf; US EPA -Environmental Protection Agency, 2015. Hazardous and solid waste management system; disposal of coal combustion residuals from electric utilities (Codified at 40 CFR Parts 257 and 261). Fed Reg;80 (74):21302-21501.

[2] Environmental Integrity Project, 2019. Coal's Poisonous Legacy Groundwater Contaminated by Coal Ash Across the U.S. http://www.environmentalintegrity.org/wp-content/uploads/2019/03/National-Coal-Ash-Report-3.4.19-1.pdf

Killingley et al (2001)[3] 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 employed 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,[4] 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.[5] The Report concludes that leachates from the Australian power station fly ashes tested 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**.[6]

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: solid volumes had passed through the columns. These metals may continue to leach metal concentrations above ecosystem WQG for many decades after the initial spikes in concentrations have flattened.

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; 46 tonnes of boron, 8.2 tonnes of manganese, 5.4 tonnes of zinc, 3 tonnes of copper, 3.2 tonnes of selenium, 2 tonnes of chromium, 1.7 tonnes of arsenic, 700 kg of nickel, 200 kg of cadmium, 81 kg of lead, and 40 kg of mercury.

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 NPI pollutants. This includes 2,600 tonnes of boron, 470 tonnes of manganese, 308 tonnes of zinc, 180 tonnes of selenium, 120 tonnes of chromium, 96 tonnes of arsenic, 11 tonnes of cadmium, 4.6 tonnes of lead, and 2.3 tonnes of mercury.

When average 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 - 64 tonnes of boron,11.5 tonnes of manganese, 7.5 tonnes of zinc, 4.5 tonnes of selenium, 4 tonnes of copper, 3 tonnes of chromium, 2.4 tonnes of arsenic, 1 tonne of nickel, 280kg of cadmium, 110 kg of lead, and 56kg of mercury.

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[3] 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

[4] 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

[5] Danny R. Jackson, Benjamin C. Garrett, and Thomas A. Bishop**, 1984. Comparison of batch and column methods for assessing leachability of hazardous waste** *Environmental Science & Technology* **1984** *18* (9), 668-673**.** **https://pubs.acs.org/doi/pdf/10.1021/es00127a007**

[6] 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 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 Cox's River, which forms part of Sydney's drinking water catchments, suffers from an estimated 31 tonnes of metals (16 tonnes of NPI metals) leached 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 Tarawarra 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.

NSW Treasury water pollution reports

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. While ESAs were prepared for Mount Piper, Wallerawang, Eraring, Shoalhaven, Bayswater, Liddell, Vales Point, and the Colongra Power Stations,[7]we only have access to ESAs for the five operating power stations.

Despite serious deficiencies in the Assessments, including inappropriate or inadequate background concentrations, restricted and inconsistent metal analyses, as well 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.

All the ESAs 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 stations sites identified significant metal contamination in groundwater surrounding the ash dumps, surface waters draining ash dumps, and in sediment and waters of surrounding waterways.

The NSW Government has been aware of this contamination for at least seven years. In that time much of this contamination has increased.

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[7] NSW Treasury, 2014.

Environmental Protection Licence (EPL) Monitoring

EPL monitoring reveals significant metal pollution from all power station sites is being ignored by the EPA.

Central Hunter Valley

Bayswater EPL 779

Despite the metal contamination from the Pikes Gulley Ash Dam being highlighted in ERM (2014), no regulated limits on metal concentrations for discharge have been inserted into the EPL by the EPA. While monitoring is required for boron, cadmium, copper, iron, molybdenum, nickel, and silver, AGL claim discharge has never occurred since February 2016.

Nevertheless, licenses discharge point 24 (formerly licenses discharge point 17), does provide regulated limits on the concentrations of boron (810ug/L), cadmium (0.3ug/L), copper (1ug/L), iron (270ug/L), molybdenum (290ug/L), nickel (19ug/L), and silver (0.5ug/L).

Quarterly monitoring from February 2016 to March 2020, shows **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 metals show an increasing trend**.**

Liddell EPL 2122

The EPA for Liddell does not prescribe any concentration limits for any metals. However monitoring data shows **Boron, cadmium, copper and selenium** concentrations consistently exceed ANZECC 95% trigger values.

Boron concentrations also consistently exceed ANZECC recreational use, and long-term irrigation guidelines. Selenium concentrations consistently exceed ANZECC livestock trigger value and long-term irrigation guideline.

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, many metals show either increasing concentrations or at constant levels.

Lake Macquarie

Eraring 1429

The only concentration limits prescribed in the EP for discharge are **copper**, (5ppb), **iron** (300ppb), and **selenium** (2ppb) in the cooling water from the cooling water outlet canal to Myuna Bay. The 5 ppb copper concentration limit is almost 4 times the ANZECC/ARMANZC (2000) marine trigger value for 95% species protection (1.3 ppb) applied in NSW. Biological effects data to substantiate exceeding the 95% trigger value are not publically available, or may not exist.

Groundwater monitoring between October 2016 and April 2020 show numerous exceedances of ANZECC/ARMANZC (2000) and/or NHMRC Drinking Water Guidelines (DWG) for **cadmium, copper, manganese, and zinc.**

Surface water monitoring from May 2012 to July 2019 show consistent exceedances of ANZECC/ARMANZC (2000) 95% trigger value for **copper** (below the 5ppb concentration limit).

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

Vales Point EPL 761

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) at LDP 22 -Discharge of cooling water from the cooling water outlet canal to Wyee Bay. No explanation for selenium concentration being 3ppb higher than Eraring's discharge limit. Biological effects data should be made available by the EPA to substantiate its decision. One explanation is that the operators of Vales Point power station are reluctant or unable to keep selenium concentrations below 5ppb.

EPL groundwater monitoring between October 2016 and April 2020 show consistent exceedances of ANZECC/ARMANZC (2000) and/or NHMRC Drinking Water Guidelines (DWG) for **arsenic, copper, iron, lead, manganese, nickel, selenium, and zinc.**

Published EPL monitoring results for metal concentrations in ash dam water discharged into the cooling water canal shows occasional exceedances of ANZECC/ARMANZC (2000) for **cadmium, copper, and lead**, and consistent exceedances of ANZECC/ARMANZC (2000) and NHMRC DWG for **selenium**. **The trend for discharged selenium concentrations is increasing with 42 ppb discharged in July 2020**

Upper Cox's River

Mount Piper EPL 13007

The previous EPL variation prescribed no monitoring for metals, only for Total Suspended Solids (TSS), pH, and Oil and Grease. The new EPL variation includes a requirement to now monitor for Electrical Conductivity (EC), but **omits to prescribe concentration limits for any metals**, and only very recently, after complaints by the HCEC, has it included any monitoring for metals.

HCEC surface water and sediment testing

Central Hunter Valley - Bayswater and Liddell

HCEC collected 10 water samples and sediment samples from the waterways draining AGL's Bayswater and Liddell ash dumps on 29 July 2020. All samples analysed exceeded ANZECC/ARMANZC (2000) and/or NHMRC DWG for pH, EC, **aluminium, boron, copper, iron, nickel, selenium, and/or zinc.**

Two sites on Bowmans Creek, which drains from the Ravensworth Rehabilitation Project, where AGL dump their Bayswater fly ash, were sampled for dissolved and total metals. Samples from both sites revealed concentrations of;

- **Aluminum** (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.

Tinkers Creek that drains from the Liddell ash dam;

- **EC** levels in excess of ANZECC/ARMANZC (2000) recommended values for species protection.
- **Aluminum** 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.

Lake Liddell, where both Liddell and Bayswater ash dams drain;

- **EC** levels in excess of ANZECC/ARMANZC (2000) recommended values for species protection.
- **Aluminum** 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.

Pikes Gully Creek 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.
- **Aluminum** 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

Sediments

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.

We also had analysed a black swan feather from the shore of Lake Liddell that may show bioaccumulation of aluminium, copper, iron, manganese, selenium, and zinc.

Lake Macquarie- Eraring and Vales Point

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.

The EnviroLab report 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 **aluminum** (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 EPL limit imposed on the Eraring cooling water outlet (2ug/L)

Mannering Bay sediment core sample

To identify the sediment contamination contribution of Vales Point ash dam, 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 for metals shows the contribution of metal load in Mannering Bay from the sole industrial metal source, the Vales Point Power Station ash dam which was built in 1962. The time series shows that from 1930 to 1960, little or no increases in metal concentrations was apparent. However, the next time stamp (1970) shown a substantial increase in metal concentrations in the sediment of Mannering Bay.

We had analysed white faced heron feathers found in Mannering Bay that have high concentrations of a number of metals shown to reduce breeding success, which may indicate bioaccumulation of metals found in the sediments here.

While there have been a number of attempts to retrofit new technology and processes to slow the contamination, which has seen reductions in sediment concentrations for a number of metals, cadmium and selenium concentrations remain above recommended ecosystem protection levels.

The only sure way of stopping the ongoing contamination of the Lake Macquarie ecosystems is to remove the ash.

Upper Cox's River - Mount Piper

Seven unfiltered and 12 field filtered 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. A number of exceedances of human health, ecological, and agriculture guidelines were identified by the laboratory report.

Background concentrations of aluminium, iron, and zinc were above ANZECC (2000) 95% trigger values. The background site was also slightly acidic (6.4 pH) with a conductivity of 190uS/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 - **aluminium, 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;

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

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

- **aluminium** (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.

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

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.

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.

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:

- **aluminum** (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 DGV for arsenic, cadmium, lead, nickel, and zinc, with many above the “High GV”. Background concentrations were all below DGVs..

Springvale LDP6 sediment sample exceeded the DGV for:

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

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.

Sawyers Swamp Creek sediment sample exceeded the DGV for:

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

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)

Recommendations

- **Recommendation 1:** The NSW Government commit to a comprehensive decontamination of Vales Point and Eraring power station sites.
- **Recommendation 2**: The NSW EPA undertake an investigation into coal ash generated in NSW determine the environmental risks associated with all its current uses are whether these uses are appropriate. The EPA amend the Coal Ash Exemption 2014 to ensure all coal ash metal analyses and leach testing results are made public. The EPA must take a much more active role is determining the suitability of coal ash reuse.
- **Recommendation 3:** The NSW Government list coal ash as an assessable pollutant in Schedule 1 of the Protection of the Environment Operations (General) Regulation 2009.
- **Recommendation 4:** 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 5:** 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 fly ash in NSW.

- HCEC recommends the NSW government immediately begin the process of trialling a pilot plant, to capitalise on the benefits that a coal ash re-use industry can offer and avoiding being left with an unmanageable liability. We recommend the following steps be undertaken:
    - *Select interested companies who can manufacture recycled coal ash products, and involve them in one or more stages of the feasibility study.*
    - *Sample ash from all NSW power stations to determine the ideal compositional matrix for the required products and test the products for market suitability and human health and environmental safety.*
    - *With the assistance of the selected interested companies, 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.*

Recommendation 6: The EPA ensure all NSW power station operating wet ash damps install appropriate equipment to transport ash in a dense phase to minimise metal mobilisation.

Recommendation 7: The NSW EPA ensure all power station operators estimate and report to the NPI all emissions to land and water from ash dumps.

Recommendation 8: The NSW EPA publish all site specific biological effects data that establishes that allowing the discharge and leaching of metals at concentrations above ANZECC/ARMANZC (2000) will not degrade aquatic ecosystems and species, as well as data that established that allowing discharge and leaching of metals above NHMRC Health Guidelines will not cause human health impacts.

Contents

1. Introduction

Thank you for the opportunity to make a supplementary Submission to the Public Work's Committee inquiry into the costs for remediation of coal ash repositories in New South Wales.

In this supplementary submission, with the additional time available due to COVID 19, we provide the results of;

- Investigations of the water quality surrounding the five NSW power station ash dumps, as well as Wallerawang decommissioned ash dump.
- Analyses of the Stage 2 Environmental Site Assessments undertaken for the privatisation of coal-fired generators in 2013/14.
- Analyses of all available NSW EPA Environmental Protection Licence water quality monitoring data for the five power stations.

- Estimates of the amount of ash produced and dumped by NSW power stations and the amount of metals leaching from this ash.
- Analyses of the NSW Load Based Licence scheme (LBL) and National Pollutant Inventory (NPI) in relation to the five NSW power stations.

Our analysis and investigations highlight the inadequacy of the current EPA regulation of coal ash dumps, which we demonstrate, is causing significant environmental harm and risking human health.

We conclude that the NSW Government is liable for considerable decontamination works at the five active power station ash dumps, to remedy the 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 a 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 could provide significant regional business and employment opportunities.

NSW coal-fired electricity generation is currently expected to extend out to 2042, when the last of the State's five operating coal-fired power stations (Mount Piper) is set to close. Liddell is due to close in 2023, Vales Point in 2029, Eraring in 2032, and Bayswater in 2035.

Water pollution from coal-fired power stations is significant but under-reported and even more poorly regulated. Paying lip service to the "polluter pays" principle, the NSW pollution Load Based Licence (LBL) fees payed by coal-fired power stations in 2019 amounted to 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 $0.15 million, 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 for a dozen heavy metals, the only assessable pollutants listed in the *Protection of the Environment Operations Act* (POEO Act) Regulations for coal power station are selenium, total suspended solids and salt.

Of even greater concern is that two power stations, Mount Piper and Liddell, have no regulatory limits listed in their Environmental Protection Licences (EPL) for any of the toxicants regularly contaminating surrounding waterways.

The 2016 Issues Paper for the long delayed review of the NSW Load Based Licensing scheme by the EPA,[8] identified 76.4% of 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".

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 4.7 million tonnes of coal ash is generated each year in NSW; 40 percent of all the coal ash generated in Australia. A disproportionate

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[8] NSW EPA, 2016. Review of the Load-based Licensing Scheme Issues paper. https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/licensing/lbl/load-based-licensing-review-issues-paper-150397.pdf

contribution to countries' third largest waste stream which represents 20 percent of all Australia's total waste produced.[9]

In 2018/19, NSW power stations reported 5,400 tonnes of metals in the coal ash dumped in on-site ash dumps. While pollution control measures have been employed at all NSW operating ash dumps to varying standards and levels of success, they are unlined and therefore leach trace elements to the surrounding groundwater and surface water when water in the ash and rain is allowed to percolate through the ash dump.

A recent report for the Federal Department of Environment and Energy[10] (DEE) points out that fly ash is specifically excluded from the relevant National Environment Protection Measure (NEPM) hazardous waste classification.[11] Without the exemption the concentrations of heavy metals in fly ash from coal fired power generation are usually sufficient to classify it as hazardous waste. And 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."[12]

For two years, the Hunter Community Environment Centre has been investigated the impacts that Eraring and Vales Point power stations are having on Lake Macquarie. In March 2019, we released *Out of the Ashes: water pollution and Lake Macquarie's ageing coal-fired power stations* that 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 the Environmental Site Assessments (ESA) commissioned by NSW Treasury in preparation for the sale of Eraring, Vales Point, Bayswater, Liddell, and Mount Piiper power stations in 2013/14. We have analysed the water quality data, particularly the analyses of groundwater samples collected as part of the ESIAs, 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.

Further, we have reviewed the published water quality monitoring required by NSW EPA. These invariably show continued exceedances of Australian Water Quality Guidelines.

In addition, we have taken water and sediment samples from waterways around all five power stations and present the laboratory results revealing significant exceedances of ANZECC and NHMRC Water Quality Guidelines (WQG) for a number of toxic metals.

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[9] The Australian Senate Environment and Communications References Committee, 2018. Never waste a crisis: the waste and recycling industry in Australia.

[10] Department of the Environment and Energy & Blue Environment, 2019. Hazardous Waste in Australia 2019. https://www.environment.gov.au/system/files/resources/b4335773-4e09-4d87-8648-592b2b94d2d9/files/hazardous-waste-australia-2019.pdf

[11] *N150 'fly ash, excluding fly ash generated from Australian coal fired power stations'.*

[12] Department of the Environment and Energy & Blue Environment, 2019. Hazardous Waste in Australia 2019. https://www.environment.gov.au/system/files/resources/b4335773-4e09-4d87-8648-592b2b94d2d9/files/hazardous-waste-australia-2019.pdf

We estimate the amount of heavy metals currently leaching from New South Wales coal ash 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 a major source of water pollution.

2. Estimated coal ash waste generation and accumulation and heavy metal leachate

The five operating NSW coal-fired power stations collectively generate an estimated 4.8 Mt of coal ash waste a year. For the past year only about 10% of this is currently beneficially reused.[13] However, when Bayswater ash reuse starts again, we estimate the five operating powers 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, the total coal ash accumulation in NSW is about 217 Mt. Table 1 below sets out the figures used for these estimates.

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[13] 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. [14]

Facility	Operating						*Decomissioned*						TOTALS	Combined Total
	Liddell	Bayswater	Eraring	Vales Point B	Mt Piper	TOTALS	*Wallerawang C*	*Wallerawang B*	*Vales Point A*	*Munmorah*	*Wangi*	*Tallawarrra A*		
Licensee	AGL Macquarie	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									
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***	57.07	217

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[14] Coal consumption was calculating using CO2 emissions set out in Clean Energy Regulator, 2019. **Electricity sector emissions and generation data 2017–18** **http://www.cleanenergyregulator.gov.au/NGER/Pages/Published%20information/Electricity%20sector%20emissions%20and%20generation%20data/Electricity-sector-emissions-and-generation-data-2017%E2%80%9318-.aspx** and Department of Environment and Energy, 2017. National greenhouse accounts factors. https://www.environment.gov.au/system/files/resources/5a169bfb-f417-4b00-9b70-6ba328ea8671/files/national-greenhouse-accounts-factors-july-2017.pdf

- 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 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).

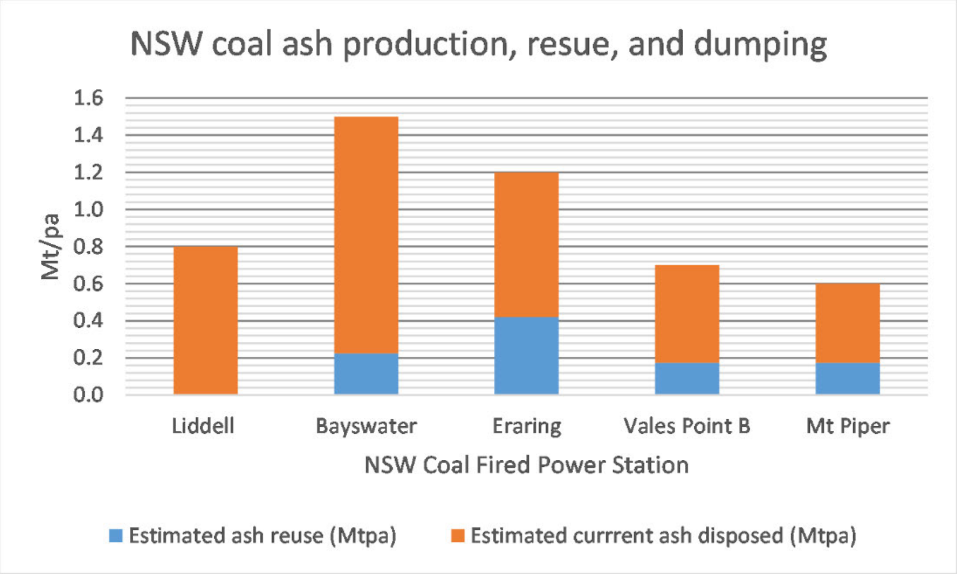

Chart 1: Accumulated coal ash and regional ash dump totals

The Vales Point ash dam is the largest in NSW, holding about 60 Mt (less what was dumped in Munmorah ash dam), with Bayswater's Ravensworth Rehabilitation Area, into which AGL dumps fly ash, and the Pikes Gulley ash dam collectively holding about 45Mt. The Eraring ash dump holds about 40Mt, and Mt 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, with Lake Macquarie burdened with over 100 Mt, the Central Hunter Valley with 84Mt, Lithgow with 28Mt, and Lake Illawarra with 3Mt (See Table 2).

Table 2: Accumulated coal ash and regional ash dump totals

	Operating ash dumps					*Decomissioned*		Total
	Central Hunter Valley		Lake Macquarie		Lithgow		*Lake Illawarra*	
Facility ash dump	Liddell	Bayswater - Pikes Gulley 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**
Regional total	**84**		**101**		**28**		**3**	

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.[15] [16]

The proportion of these metals that will be released from the ash depends largely on the amount of water the ash come into contact and the permeability of the settled ash in the dump. Acidity and bonding 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.[17] Of course, not all this leachate will necessarily escape the ash containment facility. The facility's discharge should be treated before release, and some dumps, Eraring for example, is lined with clay, thus limiting the amount of leachate that will percolate through to the groundwater beneath the ash dump.

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.[18] This effect has been seen in

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[15] U.S. EPA - Environmental Protection Agency, 2010. Human and Ecological Risk Assessment of Coal Combustion Wastes. Office of Solid Waste and Emergency Response, Office of Resource Conservation and Recovery. Draft EPA document. April 2010. Pp 2-4. https://earthjustice.org/ sites/default/files/library/reports/epa-coal-combustion-waste-risk-assessment.pdf; Wadge A and Hutton M, 1987. The leachability and chemical speciation of selected trace elements in fly ash from coal combustion and refuse incineration. Environ Pollut 48:85–99; Querol, X., Juan, R., Lopez-Soler, A., Fernandez-Turiel, J., & Ruiz, C. R., 1996. Mobility of trace elements from coal and combustion wastes. Fuel, 75(7), 821-838

[16] USGS – United States Geological Survey, 1997. Radioactive Elements in Coal and Fly Ash: Abundance, Forms, and Environmental Significance. U.S. Geological Survey Fact Sheet FS-163-97 October, 1997. https://pubs.usgs.gov/fs/1997/fs163-97/FS-163-97.pdf (Accessed 28/6/18).;

[17] Fulekar, M. H., & Dave, J. M., 1991. Release and behaviour of Cr, Mn, Ni and Pb in a fly-ash/soil/water environment: Column experiment. International Journal of Environmental Studies, 38, 281–296.10.1080/00207239108710673; Pandey, S. K., 2014. Coal fly ash: Some aspects of characterization and environmental impacts. Journal of Environmental Science, Computer Science and Engineering & Technology, 3, 921–937

[18] T Gupta, A Miller and M Yellishetty, 2018. Current perspective, challenges and opportunities for fly ash utilisation and pond reclamation in Australian scenario.. Rehabilitation of mining and resources projects as it

many studies on local water quality near ash ponds.[19] Coal ash leachates can be consumed or absorbed by aquatic organisms and cause toxic effects.[20] 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.[21]

The long-term exposure to heavy metals in the environment represents a major threat to wild populations and biodiversity. In the field, metal exposure is generally characterized by low doses and chronic exposures which alters the distribution and abundance of populations.[22]

Heavy metal pollution has likely played an important role in global biodiversity decline. Species richness for frogs in Victoria has been shown to correlated 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.[23]

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.

Column leach test data

Leaching of coal ash is a problem that needs very long-term strategies and as such need to be firmly based on reliable empirical data.**[24]** Specific coal ash leachability can only be characterized for individual materials with, each specific disposal site requiring appropriate material characterization based on the attributes of that ash and the site conditions. [25] Tests for coal ash leaching are regularly made by those NSW power generators that provide access to companies who recycle coal ash, to meet obligations under the NSW Coal Ash Order (coal ash reuse guidelines). However, none of these are made public, not even to the NSW EPA. As we do not have access to trace element analyses of NSW coal ash and reliable

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relates to Commonwealth responsibilities Submission 74 - Supplementary Submission. https://www.aph.gov.au/DocumentStore.ashx?id=8a9e3cf5-2a20-41a4-b6d6-807c5fcc7aa6&subId=515687

[19] See for example Chakrabarti, S., G. Mudd, and J. Kodikara, 2005, Coupled Atmopsheric-Unsaturated Flow Modelling of Leached Ash Disposal in the Latrobe Valley, Australia: 1st International Conference on Engineering for Waste Treatment, p. 8; Mudd, G. M., and J. Kodikara, 1998, Coal Ash Leachability: Detailed Field Studies: Australian Institute of Energy (AIE) - 8TH Australian Coal Science Conference, p. 357-362;

[20] Bryan, G. W., & Langston, W. J., 1992. Bioavailability, accumulation and effects of heavy metals in sediments with special reference to United Kingdom estuaries: a review. Environmental pollution, 76(2), 89-131.

[21] 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. https://www.acarp.com.au/abstracts.aspx?repId=C8051

[22] Tovar-Sánchez, Efraín & Hernández-Plata, Isela & Martínez, Miguel & Valencia-Cuevas, Leticia & Mussali, Patricia. (2018). Heavy Metal Pollution as a Biodiversity Threat. 10.5772/intechopen.74052.

[23] FICKEN, K.L.G. and BYRNE, P.G. (2013), Heavy metal pollution and anuran species richness. Austral Ecology, 38: 523-533. doi:10.1111/j.1442-9993.2012.02443.x

[24] 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

[25] Hassett, D.J. (1994), Scientifically valid leaching of coal conversion solid residues to predict environmental impact, Fuel Processing Technol., 9, 445-459.

leaching characteristics, we have attempted to estimate the amount of toxic metals leaching from NSW coal ash dumps.

Killingley et al (2001)**[26]** 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 employed 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,**[27]** 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.[28]

The Report concludes that leachates from the Australian power station fly ashes tested 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.**[29]**

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: solid volumes had passed through the columns.

Table 3 below sets out the results of these column leaching tests in mean concentrations (ppm) of fly ash, 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 Australian fly ash tested, 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.

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[26] 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

[27] 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

[28] Danny R. Jackson, Benjamin C. Garrett, and Thomas A. Bishop**, 1984. Comparison of batch and column methods for assessing leachability of hazardous waste** *Environmental Science & Technology* **1984** *18* (9), 668-673**.** **https://pubs.acs.org/doi/pdf/10.1021/es00127a007**

[29] 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

Table 3: Metal concentrations in NSW coal ash and average leachate from Australian coal ash

Metal (mg/k - ppm)		NSW coal-fired power stations[30]						Australian power stations[31]			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 represents rainfall equivalents in the order of 20 – 50 years for most of the ashes and ash dam environments, and for all the 9 fly ash samples most of the metals were leached after between 1 and 8 times the volume of ash in water, or liquid to solid ratio (L/S), passed through the ash column.[32] However, in the Killingley test, most metals concentrations were less than ANZECC WQG for irrigation and livestock after just one to two times the volume of water to fly ash.

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[30] Azzi, M, Day, S., French, D., Halliburton, B. Element, A., Farrell, O., Feron, P. (2013): Impact of Flue Gas Impurities on amine-based PCC Plants – Final Report. CSIRO, Australia (Table 3.3) https://www.globalccsinstitute.com/archive/hub/publications/111821/impact-flue-gas-impurities-amine-based-pcc-plants.pdf

[31] 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

[32] 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

Indeed, the average L/S for seven metals was less than 1 (aluminium, beryllium, copper, iron, nickel, uranium, and 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 4: 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	10.1	<	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

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 ground water. Pollution of surface water can cause degradation of ground-water quality and conversely pollution of ground water can degrade surface water. Thus, effective water management requires a clear understanding of the linkages between ground water and surface water as it applies to any given hydrologic setting.[33]

Taking into account the interactions between groundwater with surface water, leachate concentrations derived by Killinhley et al (2001) were well above ANZECC WQG for 95% species protection for seven metals (aluminium, cadmium, cobalt, copper, mercury, and selenium). All but cobalt, by at least an order of magnitude. All of concentrations of which would have a significant impact on aquatic ecosystems.

Table 5: 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 as evidence of delayed leachability of elements in a column system may predict what will happen to leachate

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[33] T.C. Winter, J.W. Harvey, O.L. Franke, and W.M. Alley, 2013. **Ground Water And Surface Water A Single Resource. USGS Circular 1139.** https://pubs.usgs.gov/circ/circ1139/

composition after a fly ash dam is closed and the factors which inhibit or withhold element leachability change after ash dams are decommissioned. [34]

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 generalized average leaching percentages from Australian fly ash to available NSW fly ash concentrations. While these estimates broadly identify contamination by NSW coal ash dumps, 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 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 metal concentrations found in five power station fly ash samples.[35]

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 leached from the NSW coal ash dumped each year in Table 6 below.

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[34] 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

[35] Azzi, M, Day, S., French, D., Halliburton, B. Element, A., Farrell, O., Feron, P. (2013): Impact of Flue Gas Impurities on amine-based PCC Plants – Final Report. CSIRO, Australia (Table 3.3) https://www.globalccsinstitute.com/archive/hub/publications/111821/impact-flue-gas-impurities-amine-based-pcc-plants.pdf: 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

Table 6: Estimated metals leached from 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	
Licensee			AGL Macquarie		Origin Energy	Sunset Power Int.	Energy Australia NSW	TOTALS
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**

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; 46 tonnes of boron, 8.2 tonnes of manganese, 5.4 tonnes of zinc, 3 tonnes of copper, 3.2 tonnes of selenium, 2 tonnes of chromium, 1.7 tonnes of arsenic, 700 kg of nickel, 200 kg of cadmium, 81 kg of lead, and 40 kg of mercury.

Column leach test data shows that most metal concentrations were less than ANZECC WQG for irrigation and livestock after twice the volume of water to ash had passed through the ash column.

We can demonstrate that, apart from Mt Piper, the average annual volumes of rainfall catchment at each of the other four ash dump 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 the ash delivered to the dumps in a wet slurry such as Vales Point are likely to leach more quickly than denser phase transported ash employed at Bayswater, Liddell, and

Eraring as water and ash has been agitated during transport. However, Mt Piper's dry ash placement may make it more permeable and 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). All but cobalt, by at least an order of magnitude. All of which 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 NPI pollutants. This includes 2,600 tonnes of boron, 470 tonnes of manganese, 308 tonnes of zinc, 180 tonnes of selenium, 120 tonnes of chromium, 96 tonnes of arsenic, 11 tonnes of cadmium, 4.6 tonnes of lead, and 2.3 tonnes of mercury.

Table 7: 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	Woollon - gong	Central Coast	Lake Macquari e	
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

When average 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 - 64 tonnes of boron,11.5 tonnes of manganese, 7.5 tonnes of zinc, 4.5 tonnes of selenium, 4 tonnes of copper, 3 tonnes of chromium, 2.4 tonnes of arsenic, 1 tonne of nickel, 280kg of cadmium, 110 kg of lead, and 56kg of mercury.

Table 8: 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	Woollon - gong	Central Coast	Lake Macquarie	
Current age			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**	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) leach 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 Cox's River, which forms part of Sydney's drinking water catchments, 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 Tarawarra 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 9: 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

3. 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.[36] 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 produced 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 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 10, below, sets out coal-fired power station emissions reported as a proportion of total NSW Industrial sources reported, revealing the very large contribution of coal power to the State’s pollution burden.

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[36] Commonwealth of Australia 2018. The Review of the National Pollutant Inventory Discussion Paper. http://www.npi.gov.au/system/files/resources/dcca72a5-be70-4d7a-b2cd-d1e59b6c07e3/files/npi-review-discussion-paper.pdf; Kathryn Pacey, Olivia Back, 2018. Review of the National Pollutant Inventory" Discussion Paper released (Clayton Utz) https://www.claytonutz.com/knowledge/2018/august/review-of-the-national-pollutant-inventory-discussion-paper-released

Table 10: NPI (2018/19) Coal Power Station Emissions as % of all NSW Industries Emissions

NPI Pollutant	Air Emissions			Water Emissions	Total 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

The NPI largely relies on facilities estimating their own emissions rather than providing facility monitoring.[37] Cooper, Green, & Meissner (2017) found emissions estimates in the NPI were not accurate and inconsistent with past data and other sources.[38]

However, emission factors can provide an estimate of emissions when no alternative presents, such as a lack of site specific data. Nevertheless, no emission factors are provided for Emissions to Land or

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[37] OECD, 2014. Guidance Document on Elements of a PRTR : Part 1. (ENV/JM/MONO(2014)33). Paris Retrieved from http://www.oecd.org/env/ehs/pollutant-release-transferregister/publicationsintheseriesonpollutantreleaseandtransferregisters.htm.

[38] Cooper, N.; Green, D.; Meissner, K.J. The Australian National Pollutant Inventory Fails to Fulfil Its Legislated Goals. *Int. J. Environ. Res. Public Health* **2017**, *14*, 478. https://www.mdpi.com/1660-4601/14/5/478#cite

Emissions to Water by coal power stations. It is therefore difficult to argue that the NPI is encouraging reporting of this substantial pollution source.

Under the NSW POEO Regulations the occupier of a NPI reporting facility is 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 is liable for a maximum penalty of 40 penalty units.

Transfers

Under the National Pollutant Inventory (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 substantial proportion of the ash generated, no NSW power station voluntarily reports these amounts.[39]

Table 11: 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**
TOTALS	**2,118,583**	**1,317,182**	**1,769,776**	**832,000**	**669,946**	**6,707,487**

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[39] Australian Government, 2009. NPI Transfer Information Booklet. http://www.npi.gov.au/resource/transfers-information-booklet-version-2

In 2018/19, over 5,400 tonnes of metals and about 1,500 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 station is, however, inconsistent and appears significantly under reported. Vales Point and Mt Piper, for example report no transfers of ammonia, arsenic, selenium, phosphorous, or nitrogen, and Vales Point report no transfers of mercury.

These transfers are, in effect, avoiding the reporting of water pollution, as some of the metals contained within the ash will leach into groundwater, and ultimately to surface water.

The NPI Transfer 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.

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 stormwater runoff.

Table 12 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. The 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 12: NPI (2018/19) Emissions to Water by NSW coal-fired power stations

Facility	**Bayswater**	**Liddell**	**Eraring**	**Vales Point**	**Mount Piper**	**NSW Power Station Total**	**Total industry NSW**	
Pollutant	**Water Emissions (kg)**	**Water Emissions (kg)**	**Water Emissions (kg)**	**Water Emissions (kg)**	**Water Emissions (kg)**	**Water Emissions (kg)**	**Water Emissions (kg)**	**% NSW Total**
Sulfuric acid		58446				58446	58446	100.0
Ammonia (total)			35000	16000		51000	15398641	0.3
Total Nitrogen			13000			13000	22952967	0.1
Total Phosphorus			1500			1500	3003612	0.0
Manganese & compounds			130			130	18822	0.7
Arsenic & compounds			41	65		106	262	40.4
Zinc and compounds			21	31		52	35426	0.1
Chromium (III) compounds			8.8	43		51.8	74	69.6
Copper & compounds			9.1	6.7		15.8	36627	0.0
Nickel & compounds			8.4	6.1		14.5	744	1.9
Lead & compounds			0.75	0.79		1.54	34	4.6
Cobalt & compounds			0.81			0.81	72	1.1
Cadmium & compounds			0.2			0.2	1	18.5
Beryllium & compounds			0.17			0.17	12	1.4
Mercury & compounds			0.0002			0.00017	38	0.0
Metals Total	**0**	**0**	**220**	**153**	**0**	**373**	**163296**	**0.2**
Toatl Industrial emissions	**0**	**58446**	**49720**	**16153**	**0**	**124319**	**42125294**	**0.3**

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 (gas and water sides); and
- Water treatment facility discharges.[40]

The NPI Emission manual cites a number of control technologies for emissions to water including:

- 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.

Emissions to Land

NSW Power station operators failed to report any Emissions to Land to the NSW EPA. 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, by recommending direct measurement and mass balance to estimate these emissions, and lists a lackluster 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).

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[40] Australia Government, 2012. National Pollutant Inventory Emission estimation technique manual for Fossil Fuel Electric Power Generation Version 3.0 January 2012. http://www.npi.gov.au/system/files/resources/d3fd3837-b931-e3e4-e105-98a9f7048ac6/files/elec-supply.pdf

Despite serious contamination of groundwater by coal ash storages found in other parts of the world,[41] - eg 90% of US power plants reported unsafe levels of at least one pollutant derived from coal ash in groundwater,[42] no emissions to groundwater were reported to the NPI in 2018/19 by any NSW coal-fired power station.

4. Load Based Licence Review

Introduced in 1999, The LBL scheme aims to encourage cleaner production through a ‘polluter pays’ principle defined as ‘requiring those who generate pollution and waste to bear the cost of containment, avoidance or abatement’.[43] 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.[44]

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). The scheme sets limits on some pollutant loads emitted by EPL holders and links licence fees to pollutant emissions.

However, the Scheme is wracked with exemption and thresholds that allow corporate polluters to avoid paying the full costs of their pollution impacts. The NSW LBL Scheme, cannot, therefore provide an adequate incentive for polluters to reduce the pollution

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.[45] 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.

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[41] US EPA - Environmental Protection Agency, 1999. Report to Congress, Wastes from the Combustion of Fossil Fuels Volume 1 – Executive Summary. https://www.epa.gov/sites/production/ files/2015-08/documents/march_1999_report_to_congress_volumes1and2.pdf; U.S. EPA - Environmental Protection Agency, 2010. Human and Ecological Risk Assessment of Coal Combustion Wastes. Office of Solid Waste and Emergency Response, Office of Resource Conservation and Recovery. Draft EPA document. April 2010. Pp 2-4. https://earthjustice.org/ sites/default/files/library/reports/epa-coal-combustion-waste-risk-assessment.pdf; US EPA -Environmental Protection Agency, 2015. Hazardous and solid waste management system; disposal of coal combustion residuals from electric utilities (Codified at 40 CFR Parts 257 and 261). Fed Reg;80 (74):21302-21501.

[42] Environmental Integrity Project, 2019. Coal’s Poisonous Legacy Groundwater Contaminated by Coal Ash Across the U.S. http://www.environmentalintegrity.org/wp-content/uploads/2019/03/National-Coal-Ash-Report-3.4.19-1.pdf

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

[44] NSW EPA, 2016. Review of the Load-based Licensing Scheme Issues paper. https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/licensing/lbl/load-based-licensing-review-issues-paper-150397.pdf

[45] ACIL Allen Consulting, 2014. Load-Based Licence Fee Comparison: Comparison of Load-Based Licence Fees with Marginal Abatement Costs (Mac) and Marginal External Costs (Mec) for Selected Pollutants. https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/licensing/lbl/load-based-licensing-acil-allen-fee-comparison.pdf?la=en&hash=6DE3947ADBEDC81723072D236B92A8EBAD5BB663#page=19&zoom=100,242,76

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 over the same period.

The 2016 Issues Paper for the long-delayed review of the LBL scheme found significant emissions reported to the NPI that are either not required to be reported or do not require fees to be paid under an LBL. For example 'electricity generation' reports significant emissions of cadmium to water (48%), lead to water (16%), chromium to water (15%), arsenic to water (21%) to the NPI,[46] yet these toxic metals are not assessable pollutants under the NSW LBL.

As part of the NSW LBL review, a comparative review of load-based licensing fee systems was prepared.[47] 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 licencees in the scheme), 68% stated that their LBL fees were significantly lower than the cost of upgrading equipment to reduce emissions.[48] 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.[49]

Paying lip service to the "polluter pays" principle, the NSW pollution Load Based Licence (LBL) fees payed by coal-fired power stations in 2019 amounted to 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 $0.15 million, 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 for a dozen heavy metals, the only assessable pollutants listed in the *Protection of the Environment Operations Act* (POEO Act) Regulations 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. For example, the regulations list 11 assessable pollutants that Iron or steel producers must apply - arsenic, cadmium, chromium, copper, lead, mercury, oil & grease,

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[46] NSW EPA, 2016. Review of the Load-based Licensing Scheme Issues paper. https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/licensing/lbl/load-based-licensing-review-issues-paper-150397.pdf

[47] BDA Group, 2014. Comparative review of load-based licensing fee systems. https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/licensing/lbl/load-based-licensing-bda-group-comparative-review.pdf?la=en&hash=BBCBB6245A4D0B8C284C63C85ACDD02150F19A35

[48] NSW EPA, 2016. Review of the Load-based Licensing Scheme Issues paper. https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/licensing/lbl/load-based-licensing-review-issues-paper-150397.pdf

[49] NSW EPA, 2016. Review of the Load-based Licensing Scheme Issues paper. https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/licensing/lbl/load-based-licensing-review-issues-paper-150397.pdf

selenium, total suspended solids, and zinc. Indeed, there are 17 assessable water pollutants listed in the POEO Regs.

As metal contamination of groundwater and surface water from coal ash, particularly fly ash, leaching is well documented, we believe that the NSW Government should list coal ash as an assessable pollutant for coal-fired electricity generation, and applying a fee of at least $20 a tonne for power station operators who dump coal ash.

5. NSW Treasury water pollution reports

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. While ESAs were prepared for Mount Piper, Wallerawang, Eraring, Shoalhaven, Bayswater, Liddell, Vales Point, and the Colongra Power Stations,[50]we only have access to ESAs for the five operating power stations.

Despite serious deficiencies in the Assessments, including inappropriate or inadequate background concentrations, restricted and inconsistent metal analyses, as well 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 from ERM's State 2 Environmental Site Assessments.[51] 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[52] under NSW Parliamentary Standing Order 52.

All the ESAs undertaken by ERM conclude that while the sites were being used as power stations, most of the impacts identified in soil, sediment, surface water and groundwater at the sites were not considered likely to represent a potential risk to human health and/or the environment. The notable exceptions to this were heavy metals.

Central Hunter Valley

Liddell (AGL Macquarie)

The groundwater across the site ranged from acidic to slightly alkaline (3.4 to 8.9) and brackish to highly saline (114,000 uS/cm) with an average EC of 11,000 uS/cm).

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[50] NSW Treasury, 2014.

[51] ERM, 2014a. Project Symphony – Mt Piper. Stage 2 Environmental Site Assessment. August 2014; ERM, 2014. *Project Symphony – Vales Point Power Station. Stage 2 Environmental Site Assessment. Final:* ERM, 2015. *Project Symphony – Eraring Power Station Stage 2 Environmental Site Assessment. Final v05.*

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

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, including 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 characterized 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 (BY_MW24 – 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 13: Background concentrations used by ERM

Well ID		**BY_MW24**	**BY_MW25**	**BY_MW26**
(pH)		**3.5**	**5.5**	**6.8**
Metal	**EQL**	**ug/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 Ash Dam

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 (m3) of fly and bottom ash from the 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.

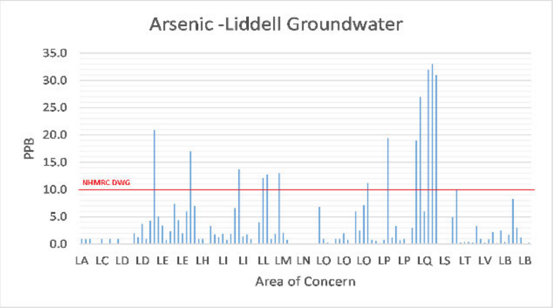
Based on the topography and available hydrological information, all areas at the Site were considered to ultimately discharge to Lake Liddell. It is also important to note that there are also direct and indirect discharges of storm, process and cooling waters to the Lake.

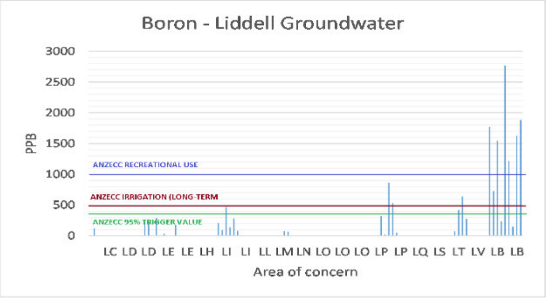
- **Arsenic** concentrations exceeded health and ecological screening values. Two areas were above the same order of magnitude as background. The more significant exceedances may warrant reporting.
- **Boron** concentrations exceeded ecological value exceeded and average background concentration at the ash dam boundary. The reminder 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 ug/L BYMW24). Four areas including the ash dam exceeded background and may warrant reporting.
- [Cobalt not mentioned]
- **Copper** concentrations exceeded ecological screening values. None exceeded background (61ug/L at BYMW24).
- **Lead** concentrations exceeded health and ecological screening values. Several exceeded maximum background (40ug/L at BYMW24) including at the ash dam boundary and may warrant reporting
- **Manganese** concentrations exceeded ecological screening values and above reported background 1.13mg/L. (not reported in background wells)
- **Nickel** connotations exceeded ecological and drinking water screening values, several above maximum background (195 ug/L at BYMW25) 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 (145ug/L BYMW25) including the ash dam.

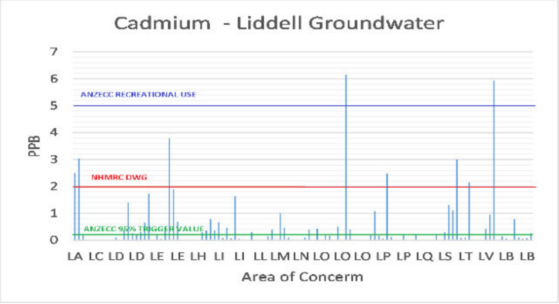
Groundwater data

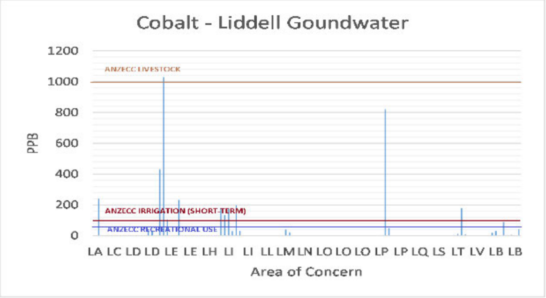
The Liddell site was divided into Areas of Environmental Concern (AEC).

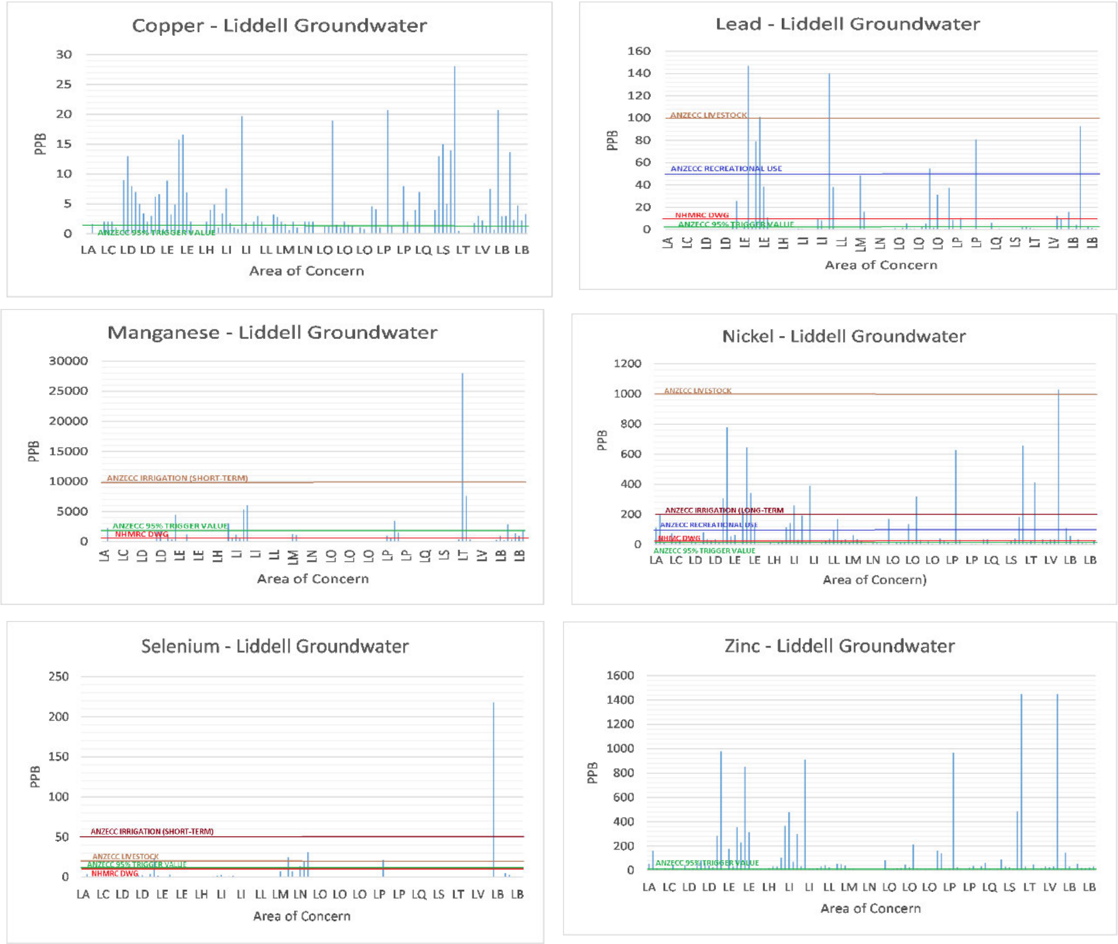
LA - Ammonia plant
LB- Ash Dam
LC - Bulk fuel storage - Light-vehicle refueling area
LD - Bulk fuel storage — Mobile refueling facility
LE - Bulk fuel storage — Fuel oil installation
LF - Bulk fuel storage — Waste oil AST (Transformer Road) and former transformer
LG - Bulk fuel storage — Turbine oil 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











Charts 2: Liddell groundwater exceedances

Bayswater AGL Macquarie)

The Bayswater Power Station site is 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 general slopes towards the Hunter River with the Ravensworth Rehabilitation Area 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.

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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 six 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.

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 are 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.

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 freafrnent 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. 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 Gulley 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

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.

Boron, cadmium, copper, lead, manganese, nickel, and zinc were detected at concentrations in excess of the adopted ecological screening values in groundwater samples collected from the majority of the wells within this catchment. Lead and nickel have also been detected at concentrations exceeding the human health (recreational) guidelines in two 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 in BY MW12 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 AFC.

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

Platshett Resovoir 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

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 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, 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. 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 collected from within Lake Liddell. 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.

Nickel concentrations exceeded the ISQG-Low at 14 locations. Nickel exceeded the ecological screening value in BW SS07 through BW SS10 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)

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

Arsenic -Drinking water value exceeded. All except those in AEC BF arc however in same order of magnitude as background locations and exceedances were 465% of guideline of BF MWC3 and MW05 may be required further assessment.

Boron -Ecological value and average background concentration reported in Kellett et al (1987) (0.17 mg/L) were both exceeded in some locations. It should he 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, however background concentrations of 0.002 0.003 mg/ L were recorded in BY_MW2S and BY_MW24 respectively. The majority of exceedances were of the same order of magnitude with the exception of BB_MW04 and BX_MW03 which may warrant reporting.

Chromium -One isolated exceedance of drinking water screening value was identified at BP_MW04 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 Ill. 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 were identified in BY_MW26 and BY_MW2d (respectively). Some results exceed these values and hence may warrant reporting (particularly within AECs BG end BV).

Lead –Both ecological and drinking water values were exceeded however background concentrations of ().0375 - mg/L were Identified in BY_MW26 and BY_MW24 (respectively) several results exceed these values and hence may warrant reporting.

Manganese -Ecological value exceeded, and average background concentration (1.13 mg/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. Both results only marginally exceed the guideline and are close to the LOR, therefore suggest confirmatory samples to confirm result and assess the likelihood that the detected concentrations will foreseeably remain above the ecological screening value.

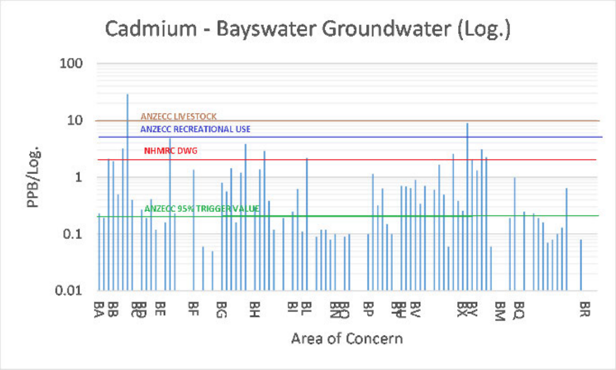
Nickel -Both ecological and drinking water values were exceeded however background concentration of 0.195 mg/L was identified in BY_MW25 several results this value and hence may warrant reporting (particularly those in ABCs BB, EG, BV, BX).

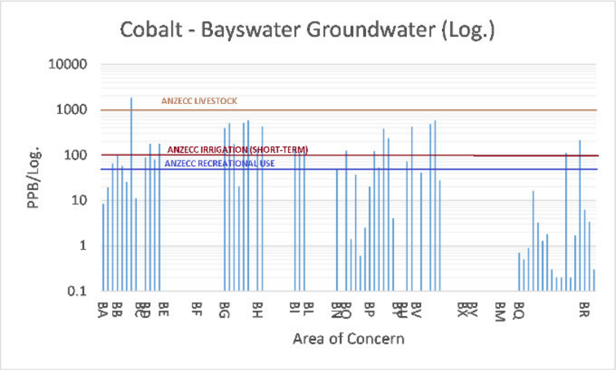
Selenium -Both ecological and drinking water values exceeded, it appears that background concentrations are lower than the screening values, hence the noted exceedances may warrant reporting (particularly within AEC BB). It should be noted that many exceedances appear to associated with Pikes Gully Ash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

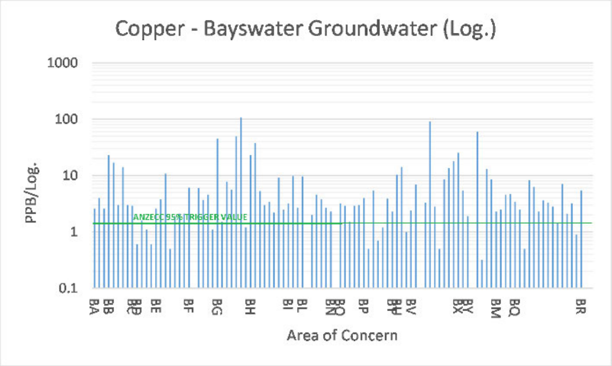
Zinc -Ecological and drinking water values were exceeded however background concentrations of 0.142 mg/L were identified in BY_MW25 (which aligns closely with the literature background value of 0.15 mg/L). Several results exceed these values and hence may warrant reporting. It should be noted that many 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.

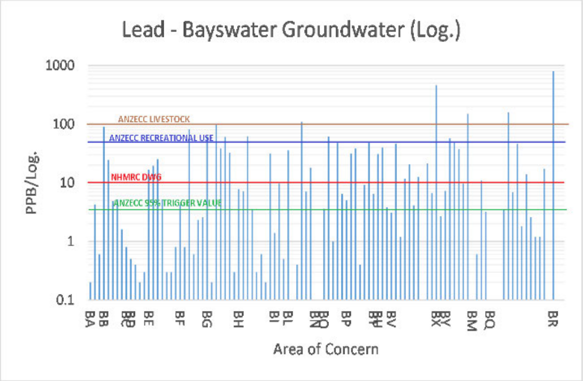
Groundwater data

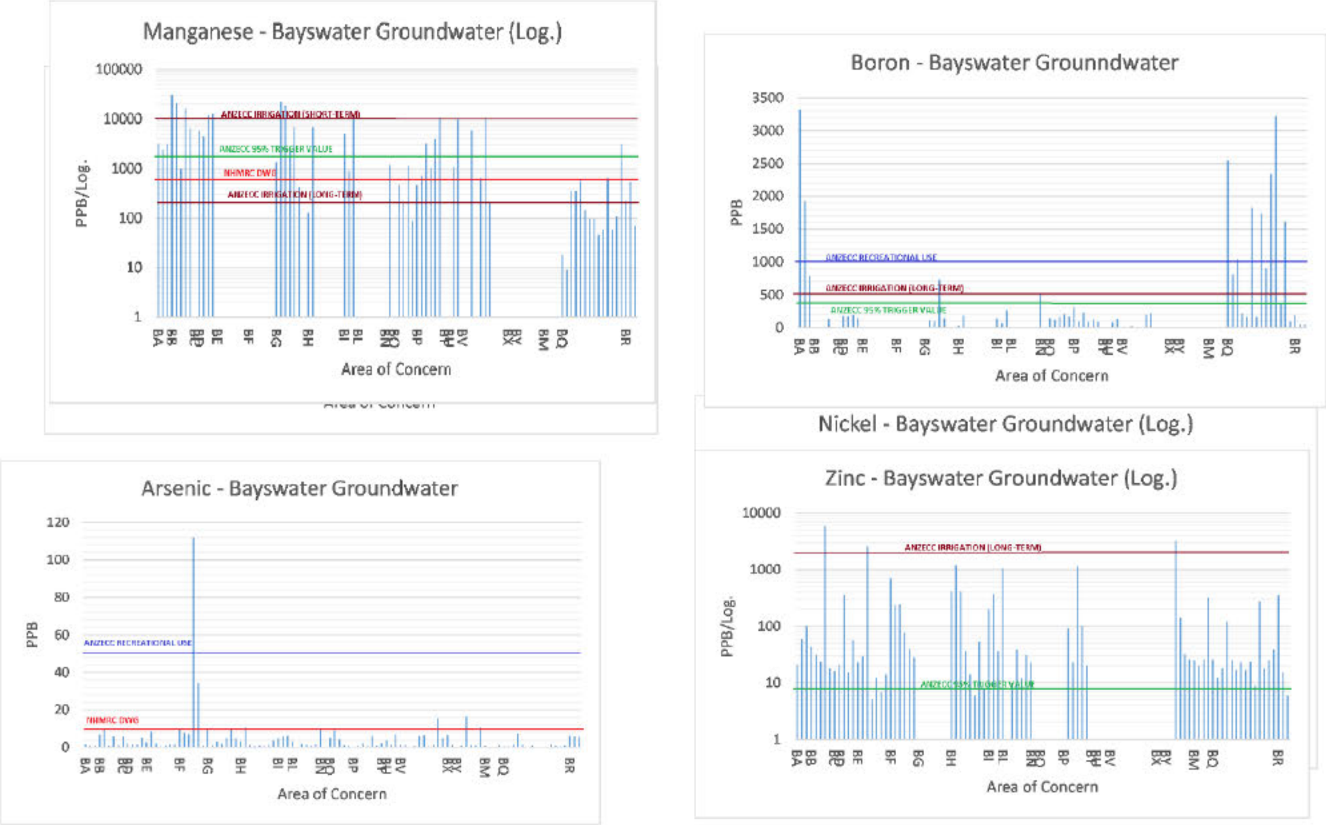
BA - Brine concentrator holding pond
BB - Brine concentrator decant basin
BC - Fuel oil installation
BD - Vehicle refuelling depot
BE - Coal storage area
BF - Coal unloaders, rail infrastructure and coal transfer lines
BG - Contaminated water treatment plant
BH - Cooling water treatment plants
BI - Demineraliser 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











Charts 3: Bayswater groundwater exceedances

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.

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 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 zinc concentrations greater than the adopted ecological screening levels.

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 is low pH and low ORP, both increase solubility of metals. The pH and ORP of 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 and are referred to as the Background Monitoring Wells in the ESA.

- 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 boundary of the Ash Dam, 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 is low pH and low ORP, both increase solubility of metals. The pH and Oxidation/Reduction Potential (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.

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, which is 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 zinc 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.

Arsenic (max 184 ug/L – mean 5.5 ug/L). Samples from 12 wells equalled or exceeded 10 ug/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 ug/L to 169 ug/L – mean 19 ug/) Samples from 58 of 64 monitoring wells exceeding the lowest adopted screening values of 1 ug/L (marine adopted ecological screening valuest). 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 ug/L to 596 ug/L - mean 13 ug/L. Samples from 91 out of 117 monitoring wells equalling 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 ug/L - mean 12 ug/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 (20ug/L) in the mobile plant maintenance area, the switchyard and **downgradient of the ash dam**.

Manganese (max 17,300 ug/L - mean 1,287 ug/L. Samples from 23 out of 64 wells exceeding the adopted screening values of 500 ug/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 ug/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 ug/L – mean 15 ug/ L). Samples from 32 wells reported concentrations exceeding the lowest adopted screening value of 20 ug/L (drinking water criteria) at ash dam boundary. Three wells exceeded maximum background concentration (32ug/L) **downgradient of the ash dam.**

Selenium (max 276 ug/L – mean 16 ug/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 (10ug/L) by a factor of two.

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

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.

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 reached 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% 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.

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.

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 refueling 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.

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 reached 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% 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.

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 selenium 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).

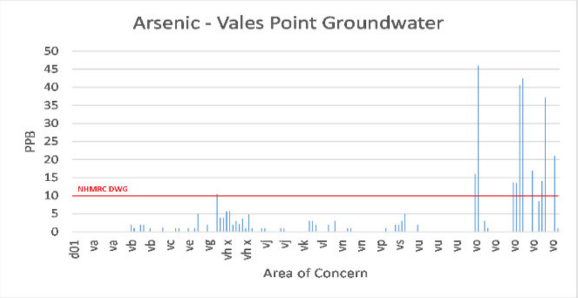
The majority of samples with concentrations reported above the background values were taken from monitoring wells located downgradient of the Ash Dam which appears to be a primary source of arsenic and selenium to groundwater and a secondary source of cobalt, copper, lead, manganese, nickel and zinc.

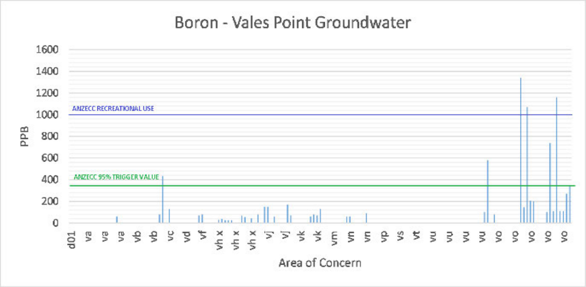
Rural residential and residential communities are located immediately to the north, west and south of the Ash Dam. The extraction of groundwater for potable, domestic, stock watering or commercial purposes in these areas may therefore potentially occur in the future. Risk to human health may be associated 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

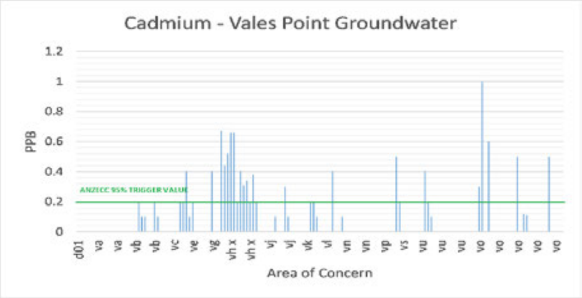
Groundwater data

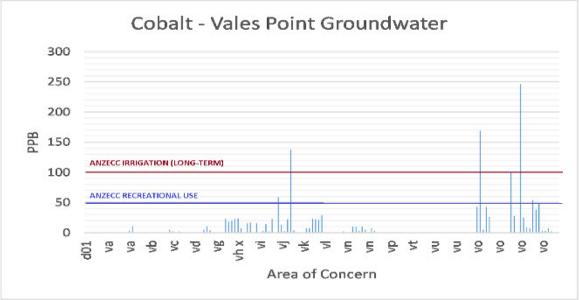
ERM divided the site into 21 individual areas of concern (AECs), according to usage and the presence of potential sources of contamination, as follows;

- 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









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 31uS/cm to 120,500 uS/cm for 2013 sampling and 145 US/cm to 28,937 uS/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.

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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 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 &creased between 211b 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 odours 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 with 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 reporting 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, 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 ug/ L in all samples, relative to a screening level of 1.3 ug/ L

Zinc concentrations ranged from <5 to 254 ug/ L, exceeding the screening level of 15 ug/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 may contribute to these impacts. Elevated zinc concentrations have also been recorded in groundwater collected from down- gradient of the CCPMF (Section 55.1). 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 ug/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 ug/L – mean 3.5 ug/ L). Concentrations equalling or exceeding the lowest adopted screening value of 10 ug/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 ug/L- mean 0.14 ug/L). Reported values exceeding the lowest adopted screening value of 0.06 ug/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 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 the CCPMF**.

Copper (Max 100 ug/L – mean 2.6 ug/ L). Concentrations equalling or exceeding I ug/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 ug/L- mean1.4 ug/ L). Concentrations equalling or exceeding the lowest adopted screening values of 1 ug/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 18ug/L). Concentrations exceeding the lowest adopted screening value of 8 Ug/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 pg/L) located do**wn gradient of the Return Water Dam** and monitoring wells (131 ug/L) and (114ug/L) located **down gradient of the CCPMF**.

Selenium (Max 205 ug/L – mean 6.8 ug/L). Concentrations exceeding the screening value of 5 ug/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 ug/L and exceedances of the assessment criteria are therefore **not considered attributable to background conditions**.

Zinc (Max 1 050 ug/ L – mean 57 ug/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 ug/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.

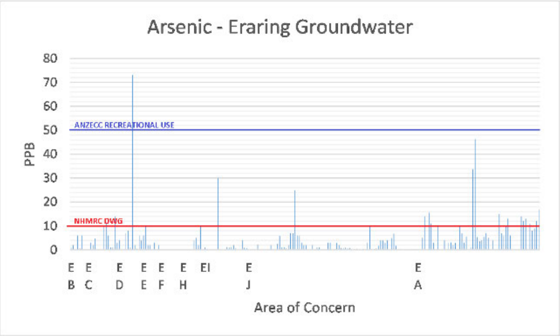
The pH of groundwater observed across the Site was typically low, and pH values within the nominated background monitoring wells ranged between 3.91 and 6.05 indicating that the groundwater is naturally somewhat acidic. Measured pH levels below 5 across the Site, and the broad site distribution of groundwater 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.

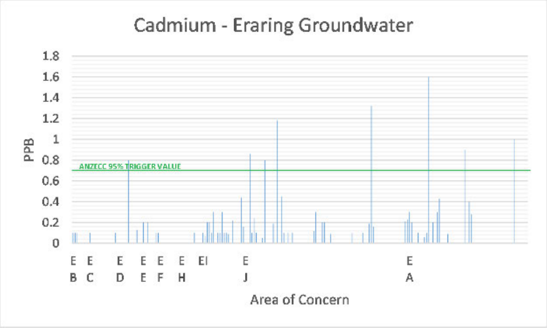
Areas of suspected actual acid sulfate soils include the Attemperation Reservoir (and adjacent area) and the areas **between the CCPMF and Myuna Bay**. While actual acid sulfate soils may be contributing to elevated metal and metalloid concentrations in near shore locations underlain by alluvial sediments 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 site 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 Cox’s 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 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 significant influenced aquifer properties and groundwater flows.

Where underground workings have been left in place, hydraulic conductivities is 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.

The ash dumps was 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 (3.31 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.

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.

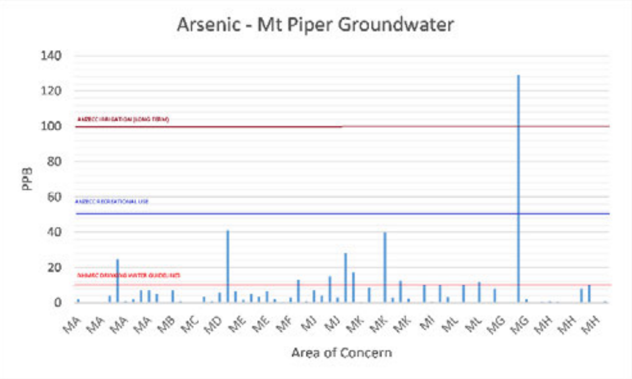
- **Copper** concentrations exceeded the adopted ecological screening values in all surface water samples from Lake Lyell and Thompsons Creek Reservoir.
- **Copper, nickel and zinc** concentrations in sediment at In Lake Lyell, exceeded ANZECC ISQG-Low at one location.
- In Thompsons Creek Reservoir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

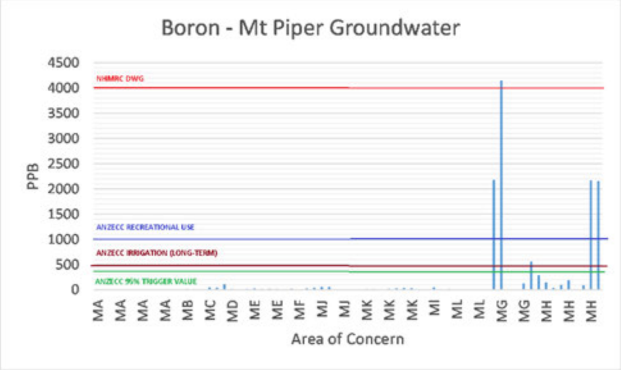
Groundwater data

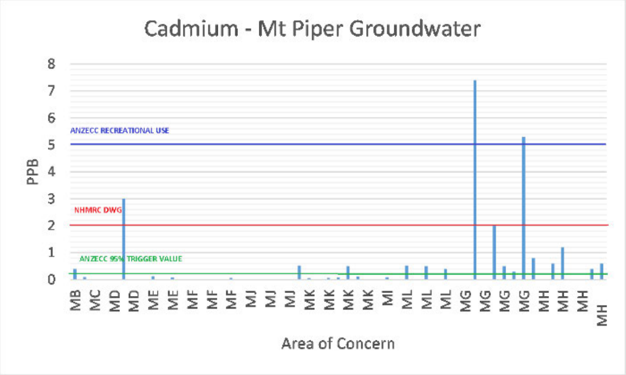
GHD divided the Mt Piper site ha into 13 individual areas of concern according to usage and the presence of potential sources of contaminant, as follows:

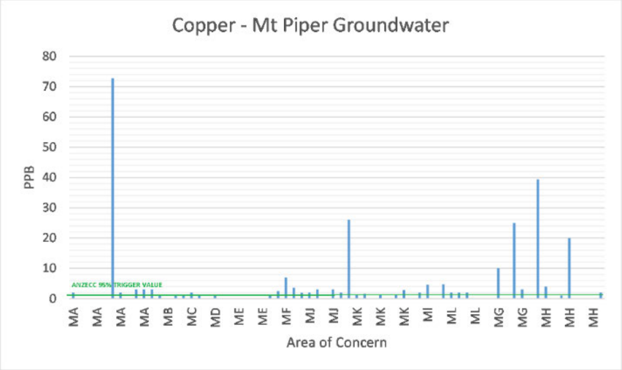
- MA-Former Landfills
- MB-Coal Storage Area
- MC-Electrical Transformers
- MD-Workshops
- ME-Mobile Plant Refuelling Area
- MF-Operational ASTS
- **MG -Current Ash Repository (Former Ash Repository)**
- **MH-Lamberts North Ash Repository**
- Ml - Water Holding Ponds
- MJ-Operational USTS
- MK-Accessible Operational Areas

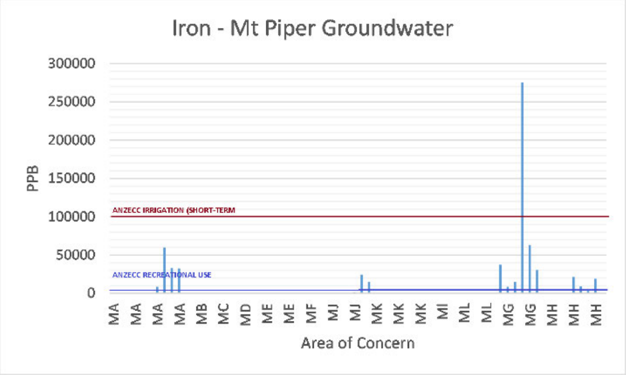
- ML-Non Operational Areas (Including Buffer Lands & Former Contractors Yard)
- MM - Water Assets (Lake Lyell And Thompsons Creek Reservoir)

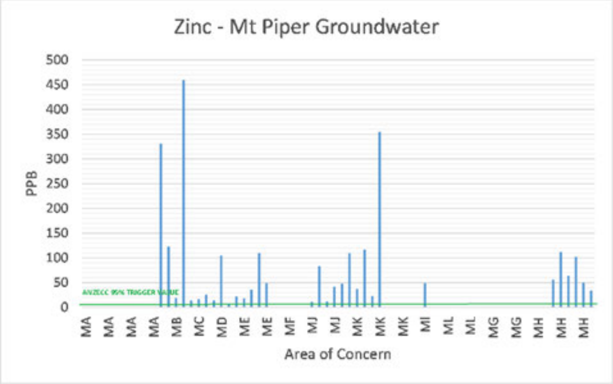


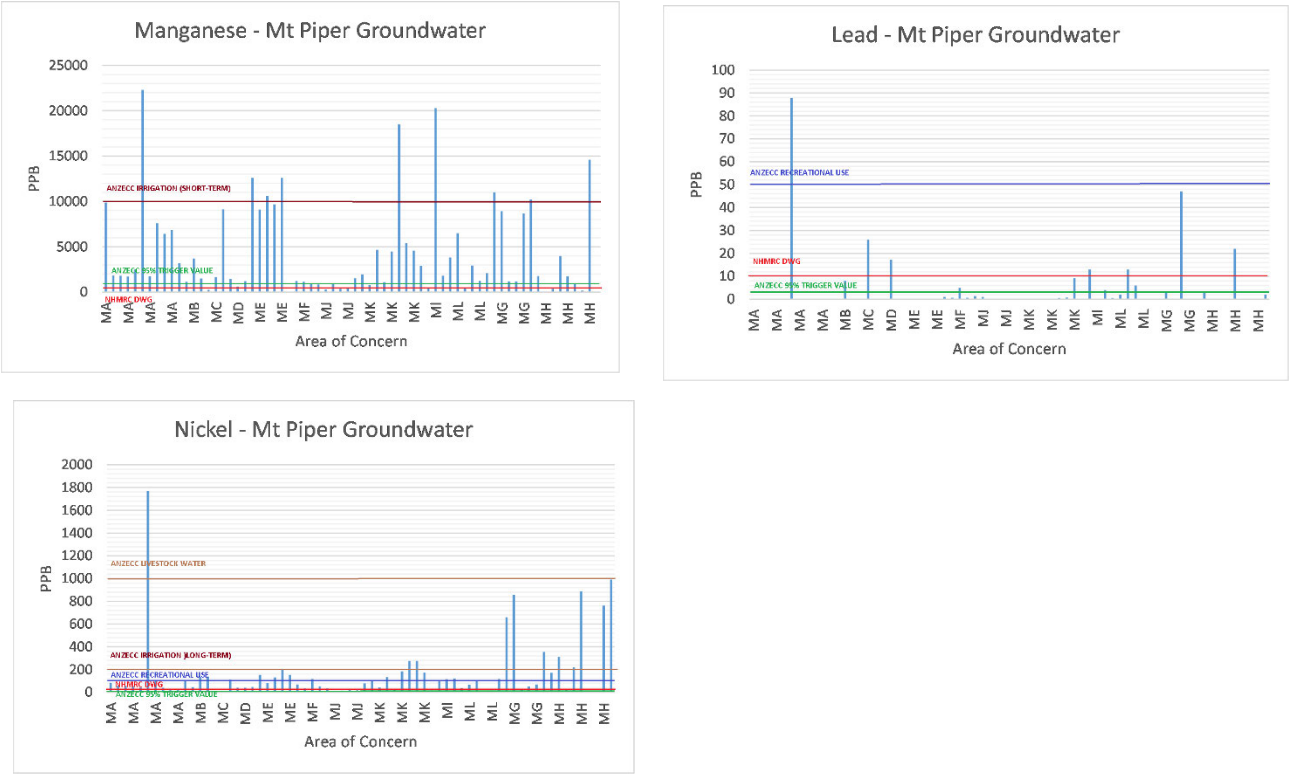












Charts 5: Mount Piper groundwater exceedances

6. Environmental Protection Licence (EPL) Monitoring

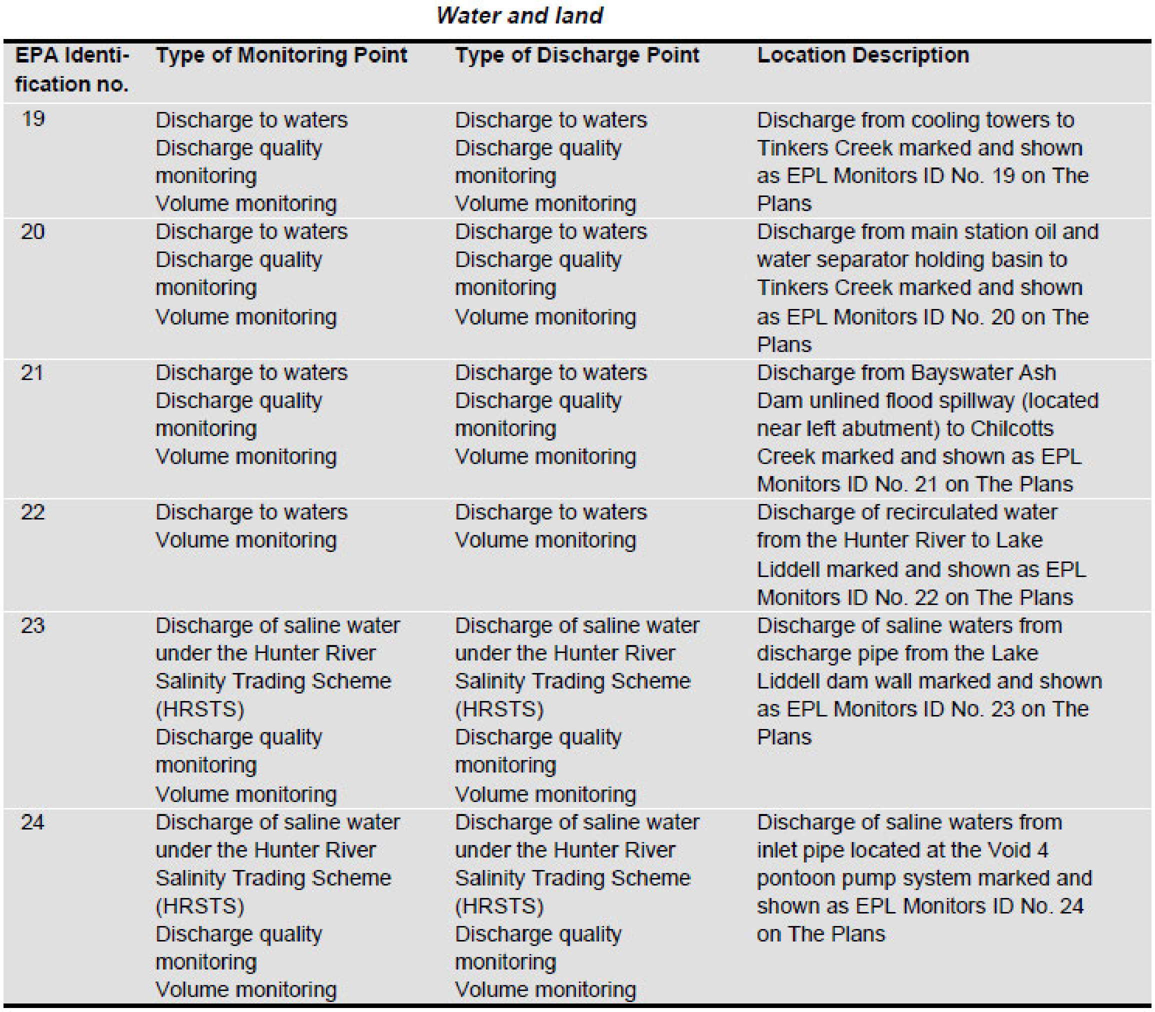
Indeed, recent field evaluation by HCEC staff revealed a pH of 10.5 in Pikes Gully Creek, downstream from the Pike Gulley Ash Dam.

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 (6 February 2020), which identified five discharge points, identifies the discharge from the Bayswater Ash Dam unlined flood spillway, as point 18. However, the number of the same point is now 21.

Table 14: 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 the metal contamination from the Pikes Gulley Ash Dam being highlighted in ERM (2014),[53] no regulated limits on metal concentrations have been inserted into the EPL by the EPA. While monitoring is required for boron, cadmium, copper, iron, molybdenum, nickel, and silver, AGL claim discharge has never occurred since February 2016.

Nevertheless, licenses discharge point 24 (formerly licenses discharge point 17), does provide regulated limits on the concentrations of boron (810ug/L), cadmium (0.3ug/L), copper (1ug/L), iron (270ug/L), molybdenum (290ug/L), nickel (19ug/L), and silver (0.5ug/L).

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

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[53] “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.”

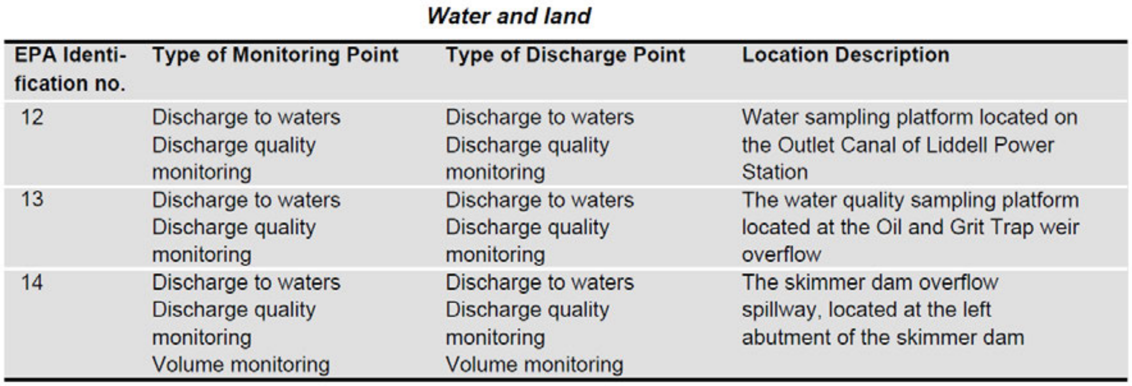
regulated limits. Of even more significance is that concentrations of both these metal concentrations show an increasing trend.

Charts 6: EPL monitoring Bayswater

Liddell EPL 2122

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

Table 15: Licenced Monitoring Points previous version of Liddell EPL

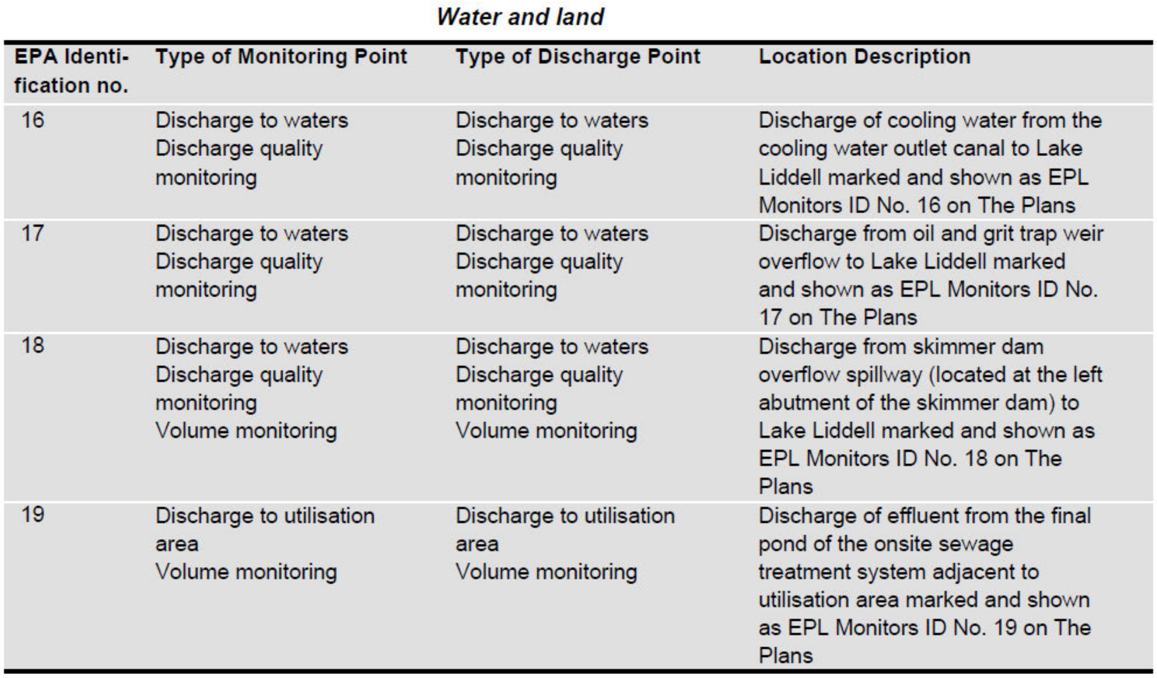


Water and land

EPA Identi-fication no.	Type of Monitoring Point	Type of Discharge Point	Location Description
12	Discharge to waters Discharge quality monitoring	Discharge 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 prescibe any regulated limits on metal concentrations on any of its four licenced discharg points.

Table 16: New Licenced Monitporing Points Liddell EPL



Water and land

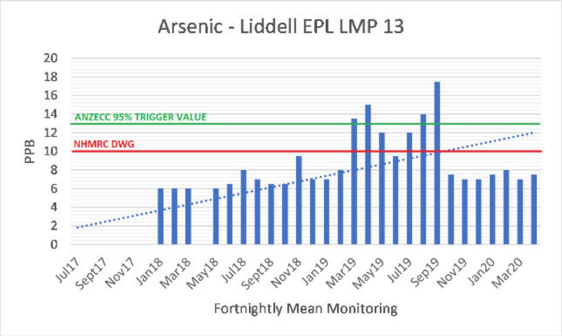
EPA Identi-fication no.	Type of Monitoring Point	Type of Discharge Point	Location Description
16	Discharge to waters Discharge quality monitoring	Discharge to waters Discharge quality monitoring	Discharge of cooling water from the cooling water outlet canal to Lake Liddell marked and shown as EPL Monitors 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

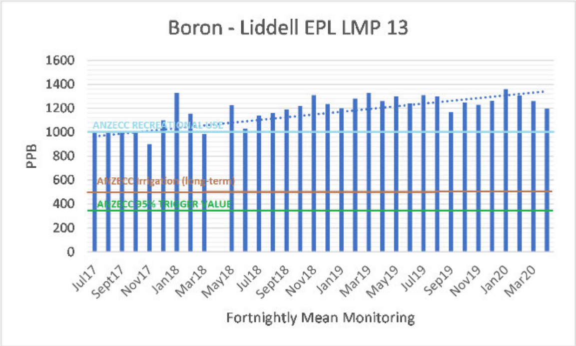
However, fortnightly monitoring is required at points 16 and 17 (formerly 12 and 13) for antimony, arsenic, barium, beryllium, boron, cadmium, chromium (III & VI), cobalt, copper, lead, manganese, molybdenum, mercury, nickel, selenium, tin, vanadium, and zinc. Weekly monitoring is also required during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

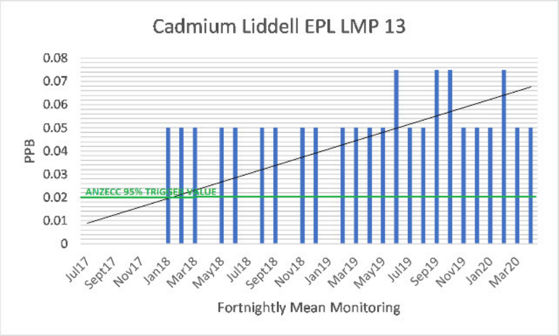
As shown in the following charts, which represent fortnightly monitoring from July 2017 to March 2020, at former monitoring point 13 (now 17), and weekly monitoring at the former monitoring point 14 (now 18), boron, cadmium, copper consistently exceeded ANZECC 95% trigger values, and boron and selenium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

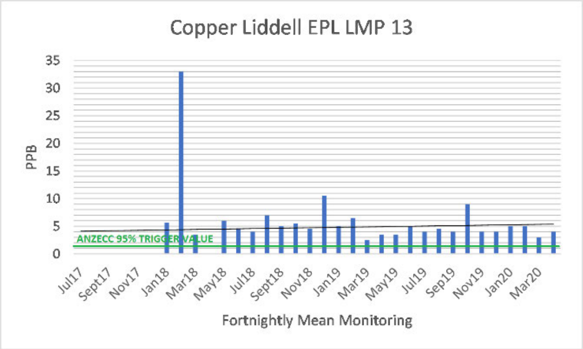
Boron concentrations at both former LMP 13 and 14 also consistently exceed ANZECC recreational use, and long-term irrigation guidelines. Selenium concentrations at LMP 14 also consistently exceed ANZECC livestock trigger value and long-term irrigation guideline.

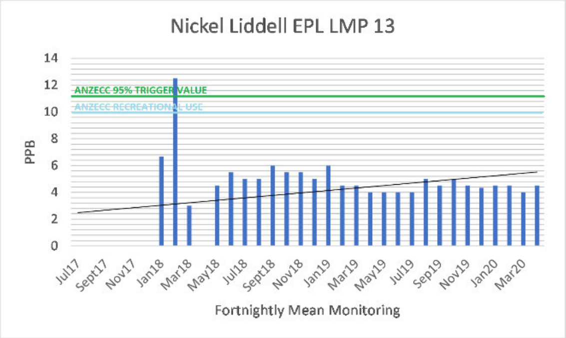
At LMP 13, boron has been steadily increasing, with cadmium at LMP 14 showing a marked increase over time. Indeed, with the possible exception of copper at

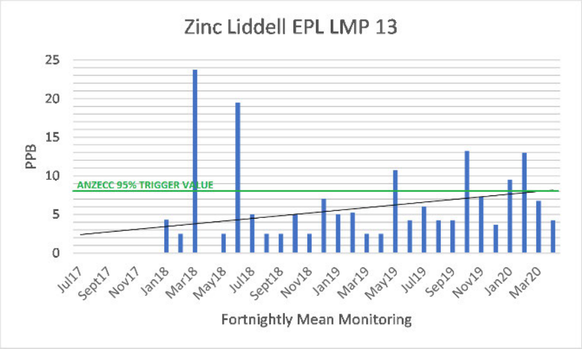


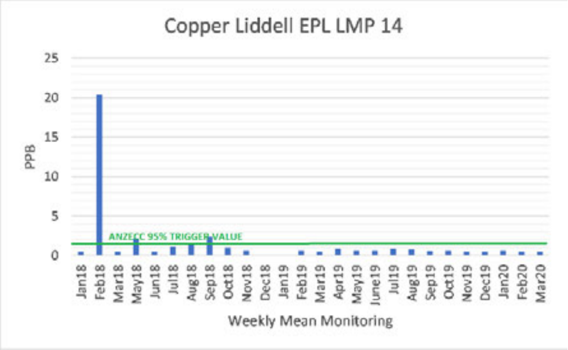


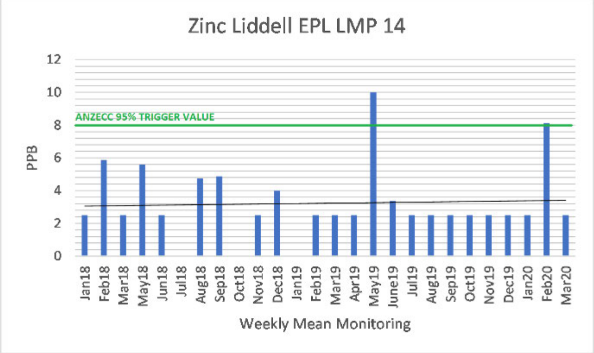


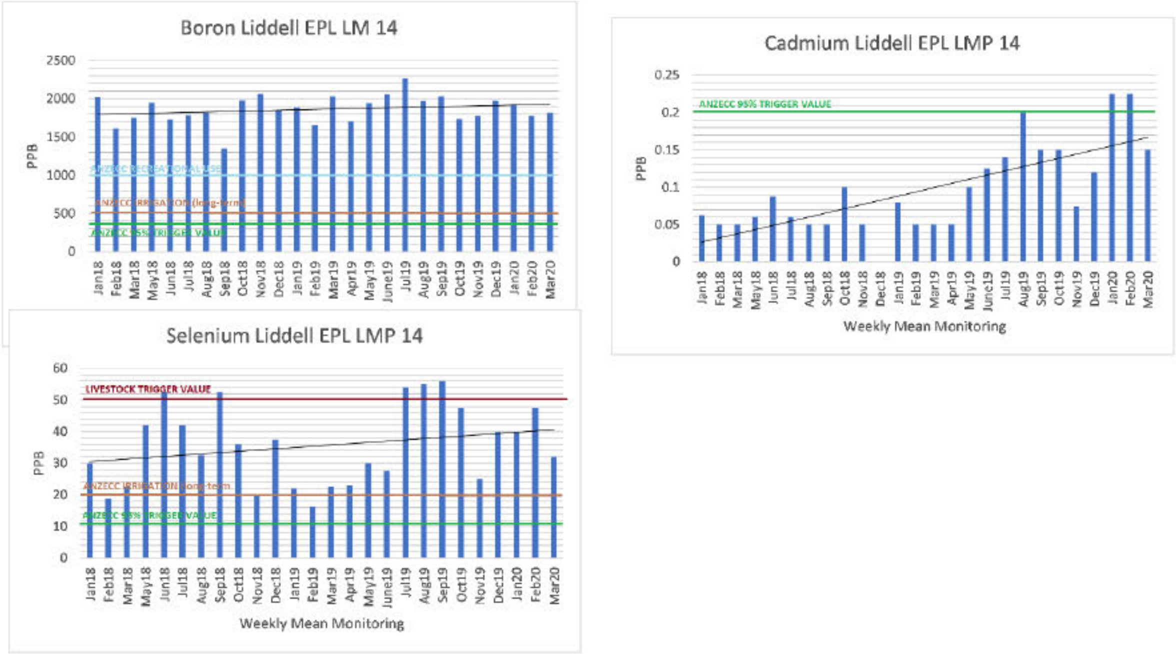










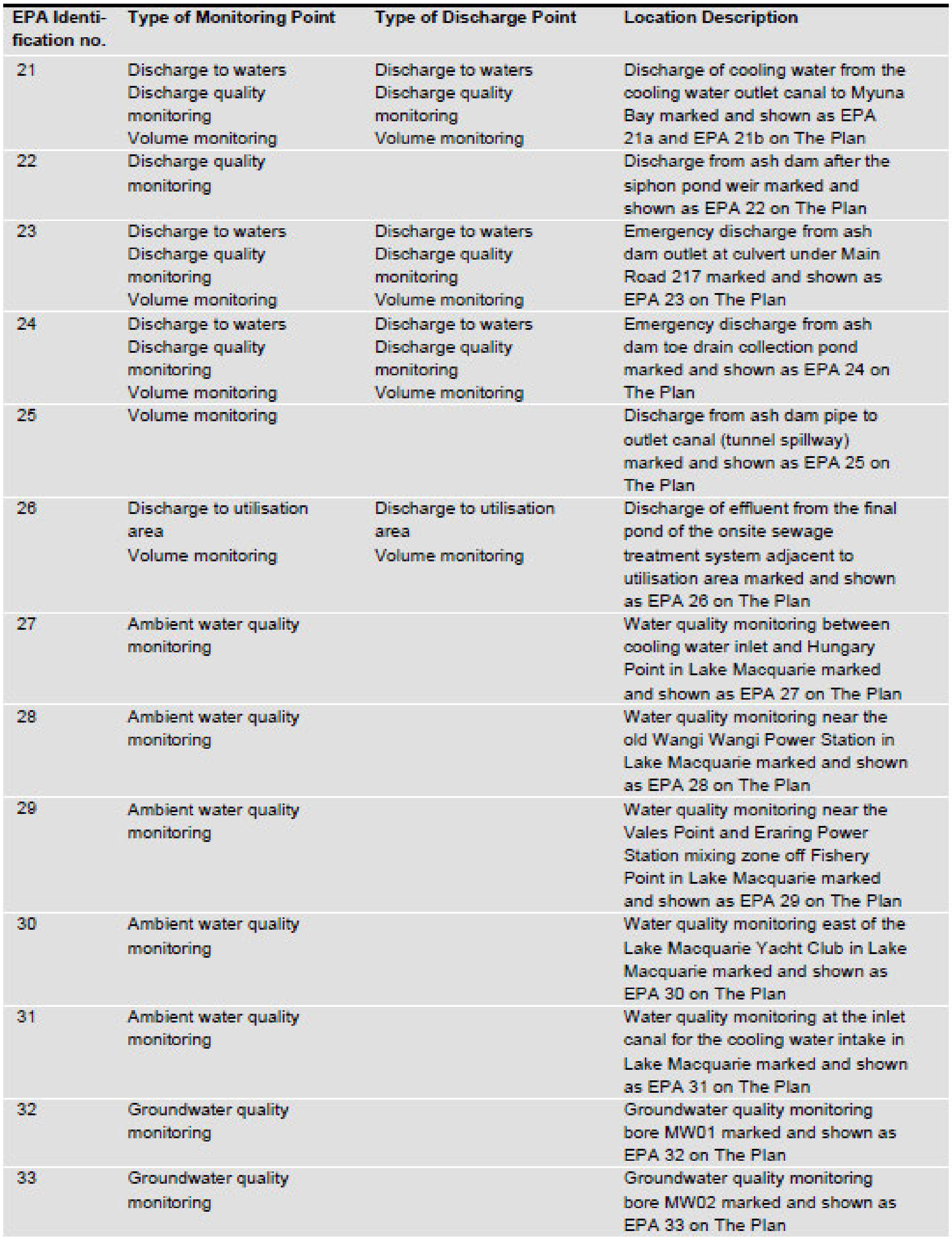


Charts 7: Liddell EPL monitoring

Lake Macquarie

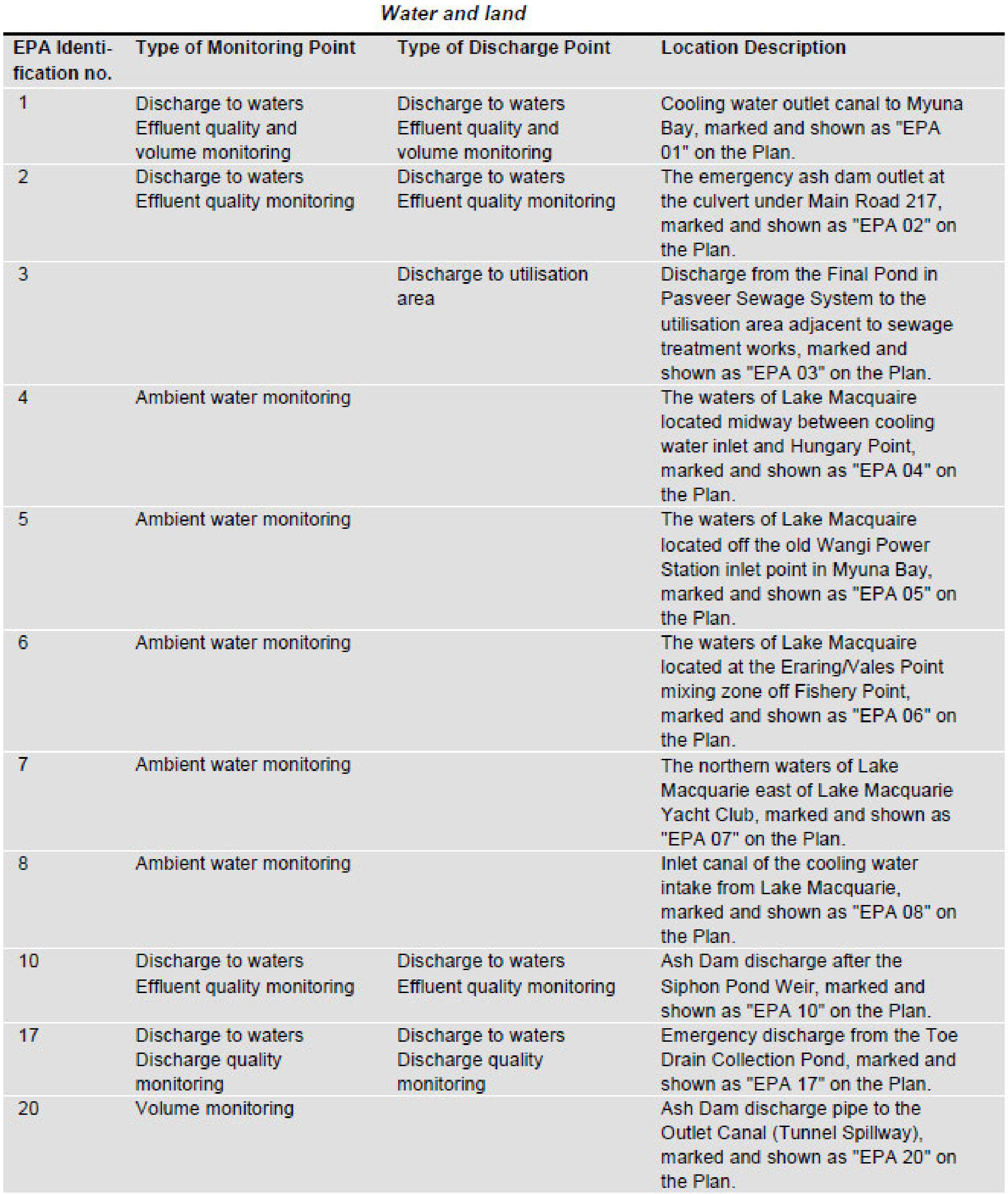
Eraring 1429

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.



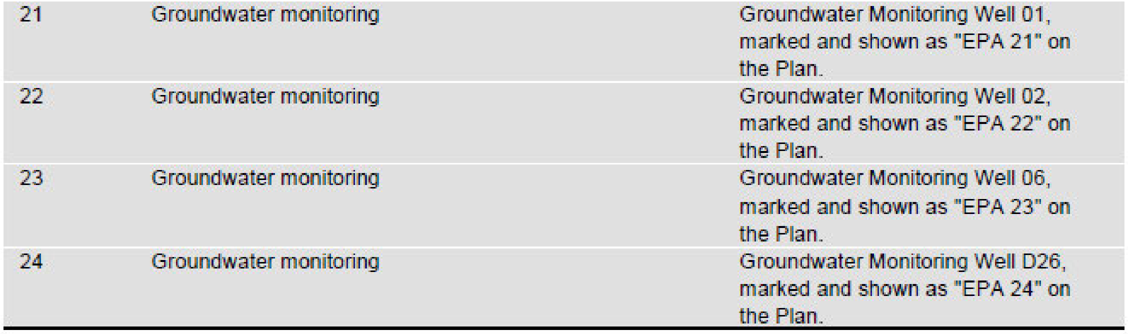

EPA Identi-fication no.	Type of Monitoring Point	Type of Discharge Point	Location Description
21	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge to waters Discharge quality monitoring Volume monitoring	Discharge of cooling water from the cooling water outlet canal to Myuna 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
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.



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.

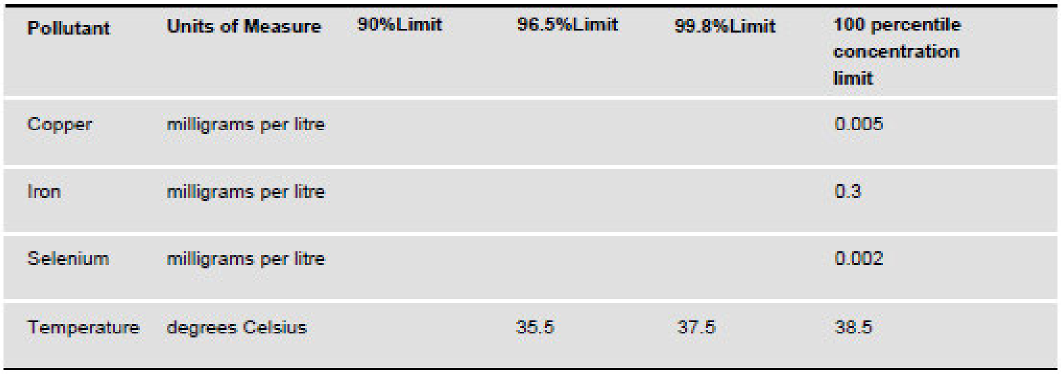


21	Groundwater monitoring	Groundwater Monitoring Well 01, marked and shown as "EPA 21" on the Plan.
22	Groundwater monitoring	Groundwater Monitoring Well 02, marked and shown as "EPA 22" on the Plan.
23	Groundwater monitoring	Groundwater Monitoring Well 06, marked and shown as "EPA 23" on the Plan.
24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

The only concentration limits prescribed in the EP 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. The 5 ppb copper concentration limit is almost 4 times the ANZECC/ARMANZC (2000) marine trigger value for 95% species protection (1.3 ppb) applied in NSW. Biological effects data to substantiate exceeding the 95% trigger value is not publically available.

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

POINT 21



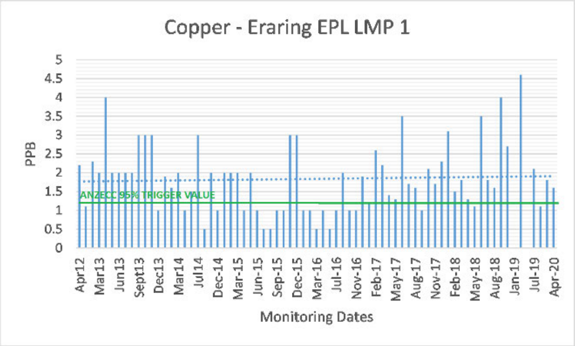
Pollutant	Units of Measure	90%Limit	96.5%Limit	99.8%Limit	100 percentile concentration limit
Copper	milligrams per litre				0.005
Iron	milligrams per litre				0.3
Selenium	milligrams per litre				0.002
Temperature	degrees Celsius		35.5	37.5	38.5

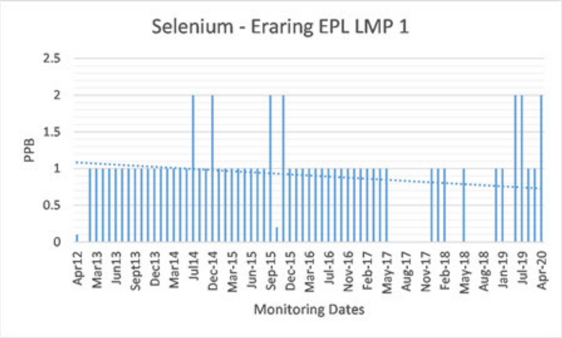
Four groundwater LMPs 32, 33, 34, and 35, were previously numbered 21, 22, 23, and 24. The following charts show concentrations of selected metals from published EPL groundwater monitoring between October 2016 and April 2020. The charts show numerous exceedances of ANZECC/ARMANZC (2000) and/or NHMRC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

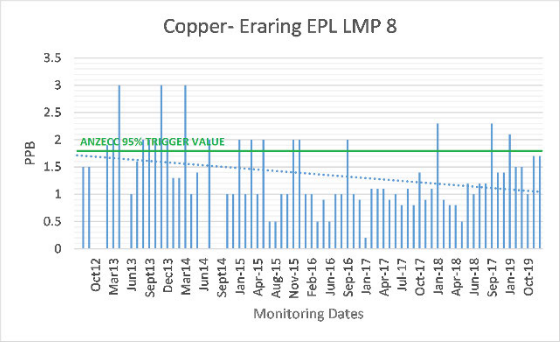
Charts 7: Eraring EPL groundwater monitoring

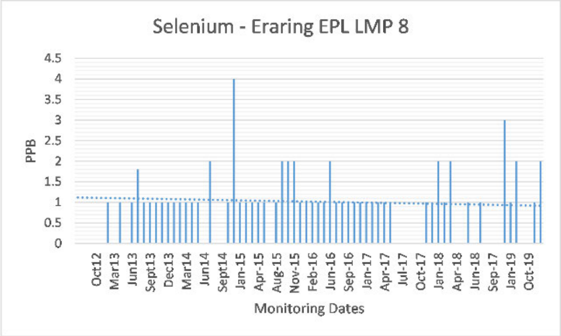
The following charts show selected metal concentrations in surface water LMPs and LDPs from May 2012 to July 2019. They show consistent exceedances of ANZECC/ARMANZC (2000) 95% trigger value for copper (below the 5ppb concentration limit) at LMPs 1, 8, and 10.

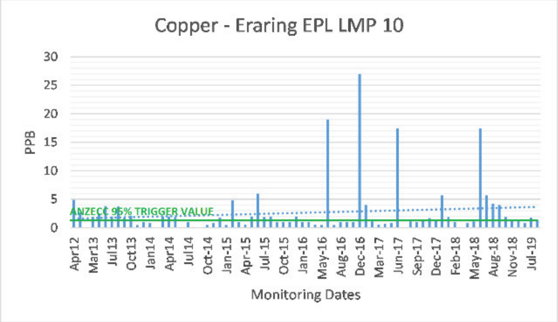
Discharge from LMP10 (now) - Emergency discharge from ash dam outlet at culvert under Main Road- show consistent exceedances of ANZECC/ARMANZC (2000) 95% trigger value for copper.

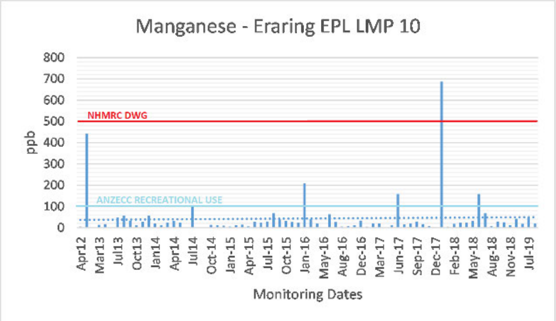


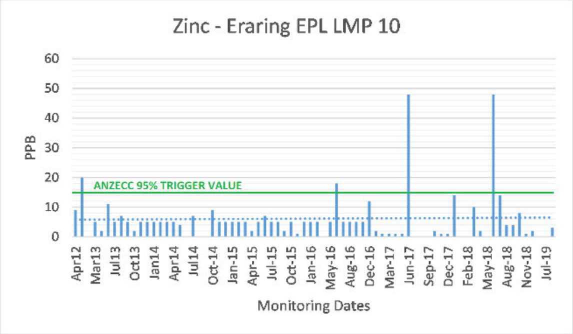


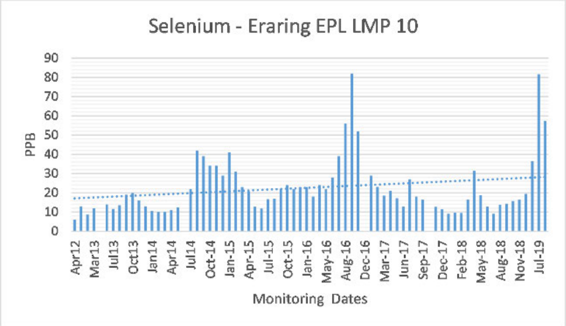


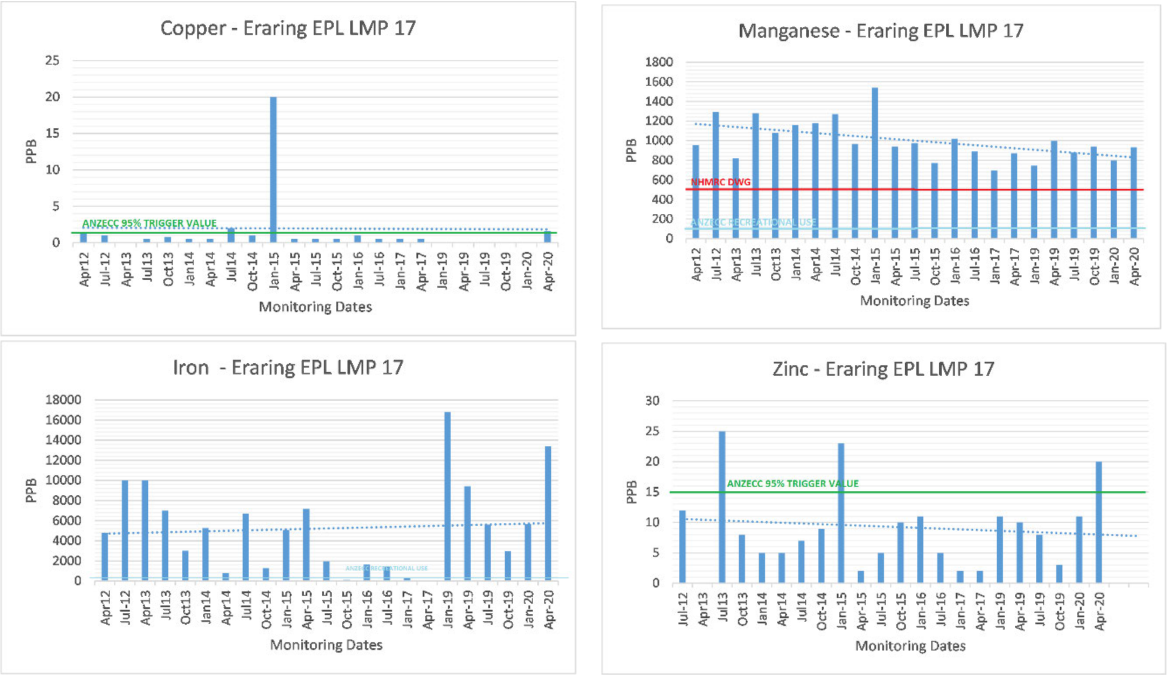












Charts 8: Eraring discharge monitoring

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, alter the numbers of the 13 Licenced Monitoring Points (LMP), including five Licenced Discharge Points (LDP), five groundwater Licenced Monitoring Points (LMP), and three ambient LMPs. As well as requiring more comprehensive monitoring, particularly metals, which was previously woefully inadequate to identify water pollution from the power station site. While monitoring of the existing LMPs is a step forward, we have identified high concentrations of metals, where monitoring does not occur, draining into Mannering Bay from the base of the northern ash dam spillway (see chapter 6).

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

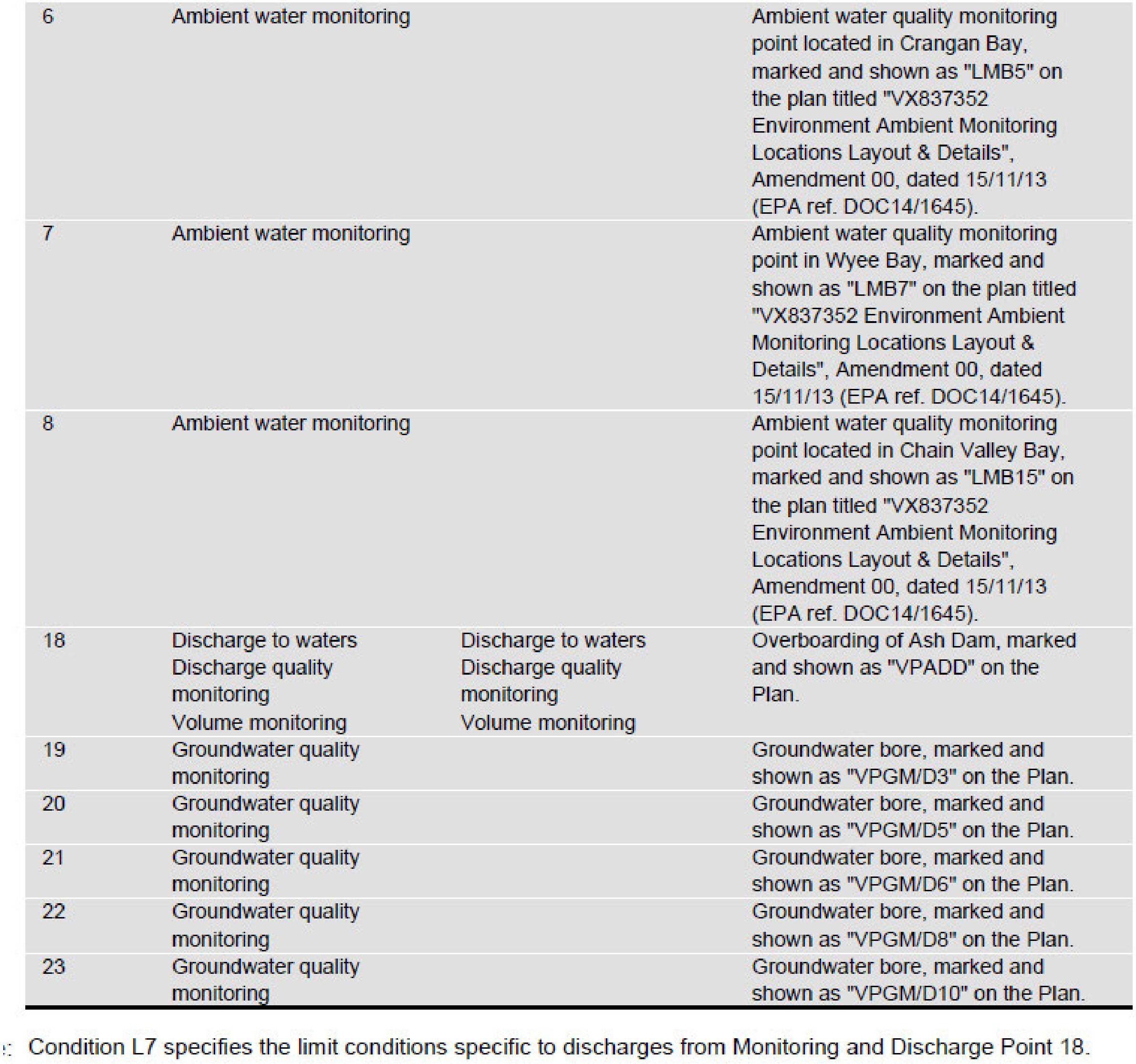
The previous EPL variation identified 13 Licenced Monitoring Points (LMP), including five Licenced Discharge Points (LDP), five groundwater LMPs, and three ambient LMPs.

Water and land

EPA Identification 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.

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



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.

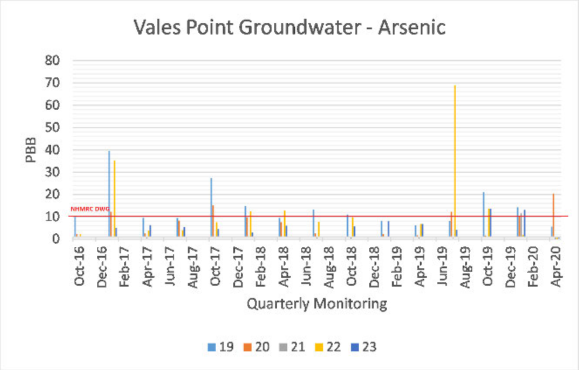
Condition L7 specifies the limit conditions specific to discharges from Monitoring and Discharge Point 18.

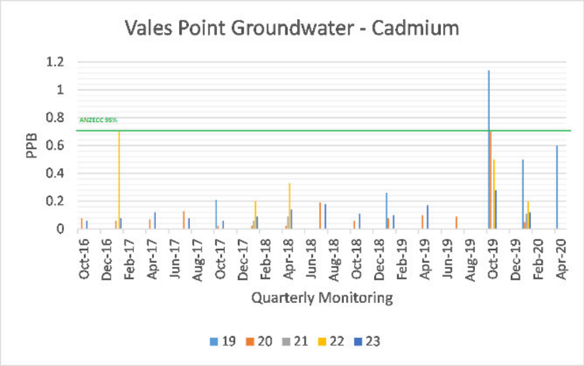
Since July 2017 ash dam seepage (discharge at LDP4 – to Mannering Bay) is captured and pumped back to the ash dam. There was no licence 'discharge to waters' (i.e. to Mannering Bay) since July 2017.

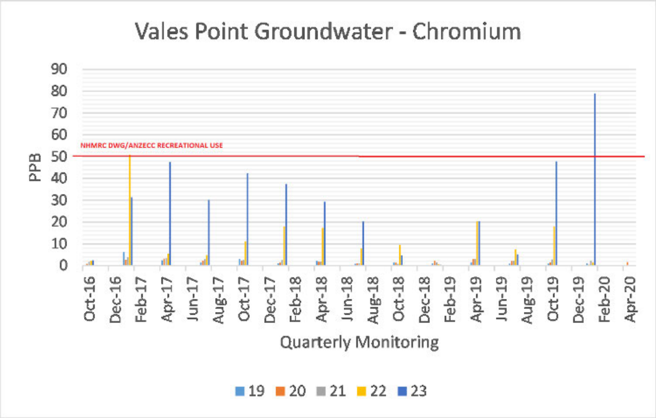
LDP 18 – Overboard from ash dam has only discharge in July and August 2013 and May 2015.

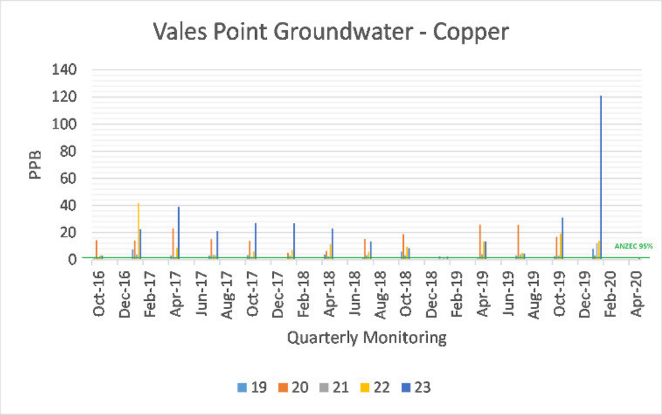
Up until July 2020, Vales Point’s EPL did not prescribe any metal concentration limits for any of its five discharge points. The latest variation prescribes free residual chlorine (200ppb) copper (5ppb), iron (300ppb), selenium (5ppb), and temperature (37.7C) at LDP 22 (formerly LDP 1 -Discharge of cooling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

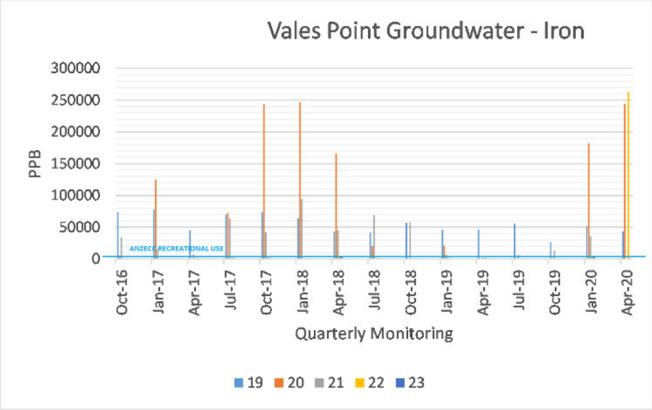
The following charts show concentrations of selected metals from published EPL groundwater monitoring between October 2016 and April 2020. The charts show consistent exceedances of ANZECC/ARMANZC (2000) and/or NHMRC Drinking Water Guidelines (DWG) for arsenic, copper, iron, lead, manganese, nickel, selenium,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

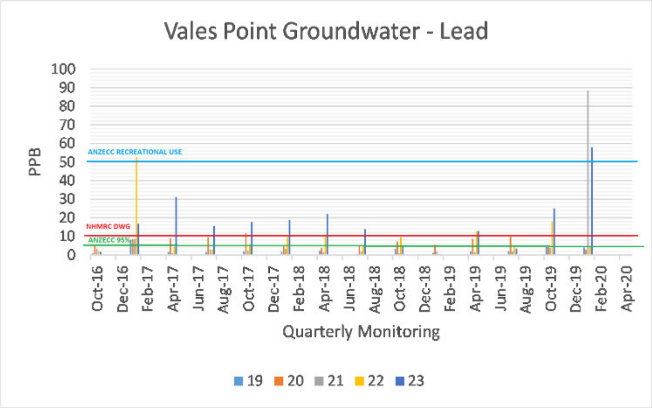

Vales Point Groundwater - Arsenic

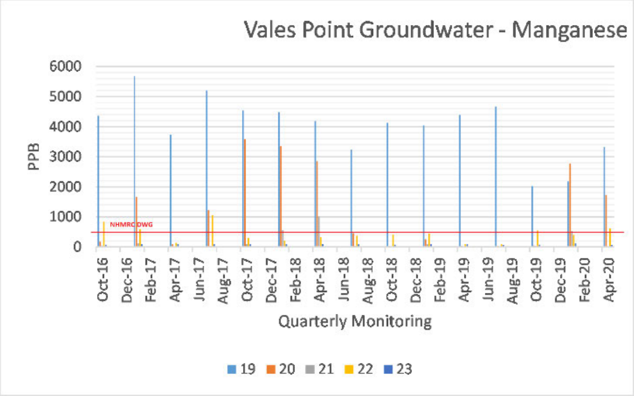

Vales Point Groundwater - Cadmium

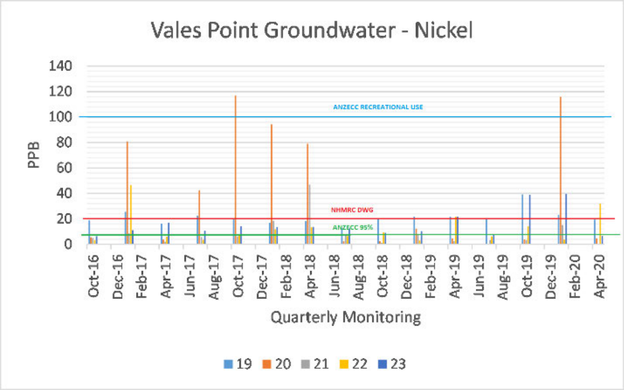

Vales Point Groundwater - Chromium

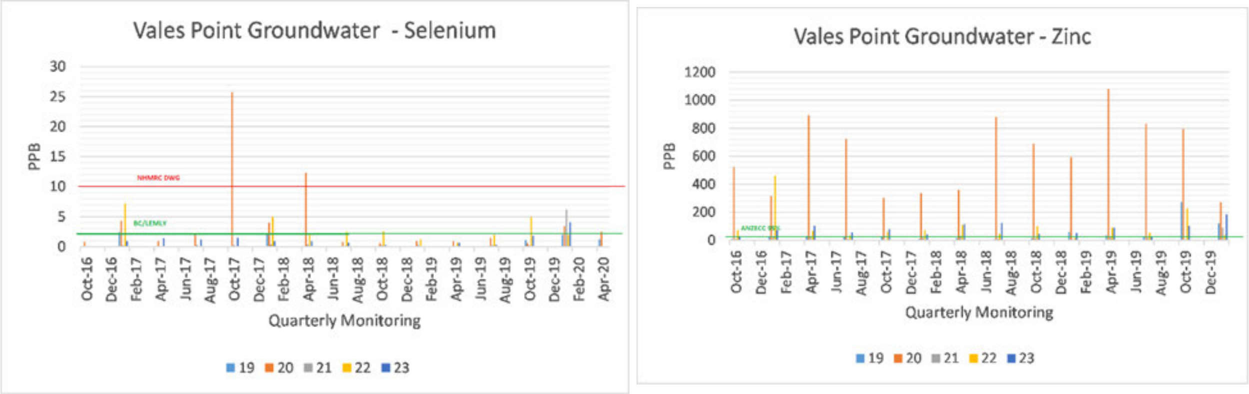

Vales Point Groundwater - Copper


Vales Point Groundwater - Iron


Vales Point Groundwater - Lead


Vales Point Groundwater - Manganese

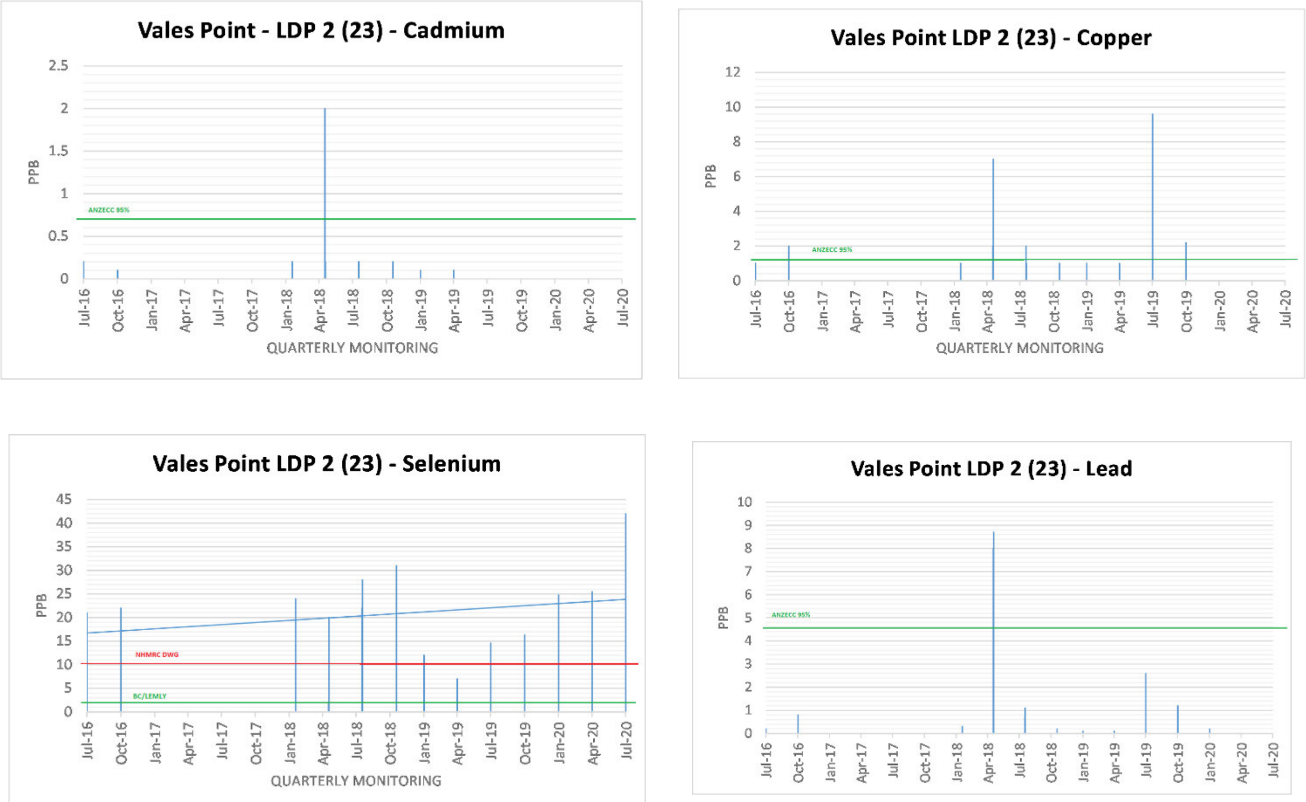

Vales Point Groundwater - Nickel



Charts 9: Vales Point groundwater monitoring

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 ANZECC/ARMANZC (2000) and NHMRC DWG for selenium. The trend for discharged selenium concentrations is increasing with 42 ppb discharged in July 2020.



Charts 10: Vales Point EPL discharge monitoring

Upper Cox’s River

Mount Piper EPL 13007

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

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)

The previous EPL variation prescribed no monitoring for metals, only for Total Suspended Solids (TSS), pH, and Oil and Grease. The new EPL variation includes a requirement to now monitor for Electrical Conductivity (EC), but omits to prescribe concentration limits for any metals, and only very recently, after complaints by the HCEC.

Water and land

EPA Identification 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

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

7. HCEC surface water and sediment testing

Central Hunter Valley

Bayswater and Liddell

HCEC collected 10 water samples and sediment samples from the waterways draining AGL's Bayswater and Liddell ash dumps on 29 July 2020. 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 14: 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	

Two sites on Bowmans Creek, which drains from the Ravensworth Rehabilitation Project, where AGL dump their Bayswater fly ash, 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 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, 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 Gulley Creek 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 15. 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			

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.

We also had analysed a black swan feather from the shore of Lake Liddell that may show 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.

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

The Envirolab report (Annex 1) reveals significant exceedances of ANZECC Marine 95% Trigger Values (MTV) and Recreational Use Guidelines (RUG), as well as NHMRC Drinking Water Guidelines (DWG).

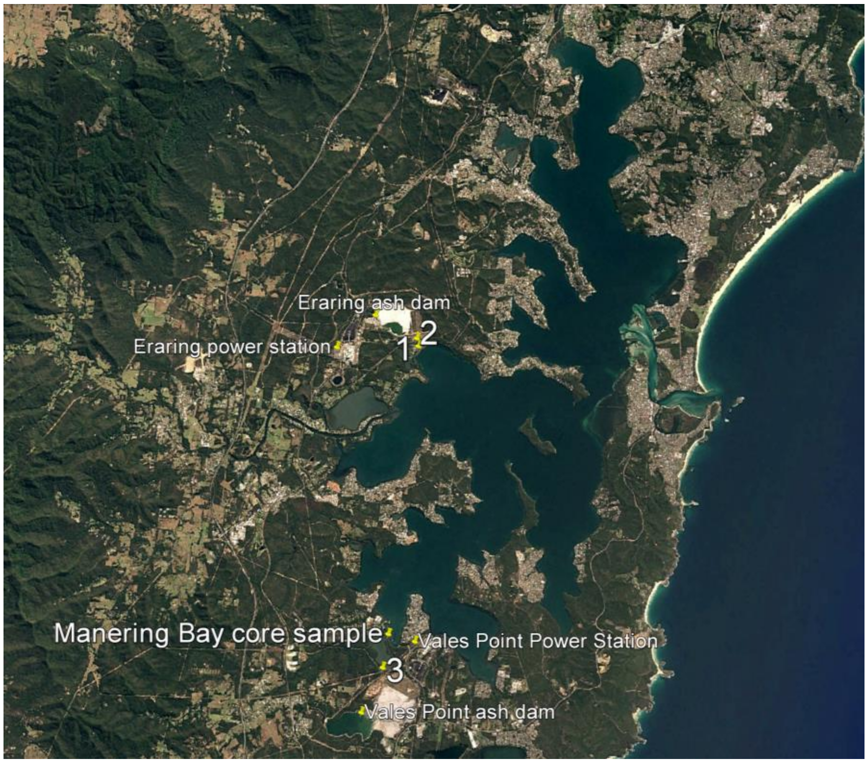
The exceedances include aluminium (RUG), arsenic (DWG), boron (RUG), cobalt (MTV), copper (MTV), iron (RUG), manganese (RUG/DWG), nickel (MTV/DWG), and zinc (MTV). All sites sampled were acidic with pH below recommended by ANZECC for marine waters. All three sites drained from the ash dam and well above 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 EPL limit imposed on the Eraring cooling water outlet (2ug/L).

Table 16. 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. All sample sites



Eraring

Figure 3. HCEC water sampling sites at Eraring

Vales Point

Figure 4. HCEC sample sites at Vales Point

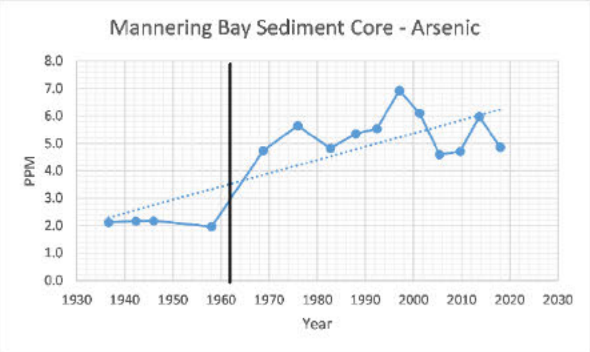
Mannering Bay sediment core sample

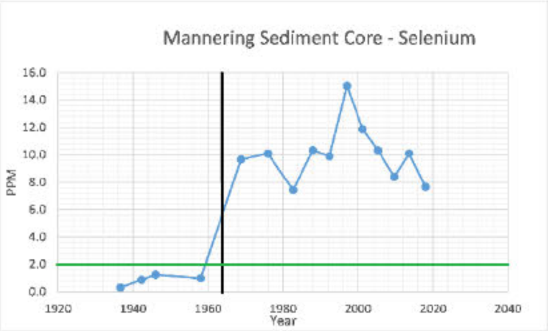
Numerous studies have been published on the elevated heavy metal concentrations in southern Lake Macquarie sediment. The two ash dams are probably the greatest contributors to the problem, with coal mines supplying the power stations also making a contribution. Leaching of metals from the ash dams to 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 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.

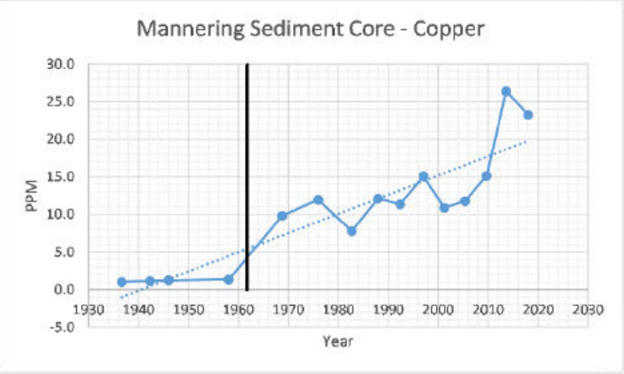
To identify the sediment contamination contribution of Vales Point ash dam, we took a 30cm sediment core from Mannering Bay and asked ANSTO to provide a lead 210 isotopic dating analysis. ANSTO identified 15 dates from 1930 to 2019. Laboratory analysis for metals shows the contribution of metal load in Mannering Bay from the sole industrial metal source, the Vales Point Power Station ash dam which was built in 1962. The time series shows that from 1930 to 1960, little or no increases in metal concentrations was apparent. However, the next time stamp (1970) shown a substantial increase in metal concentrations in the sediment of Mannering Bay.

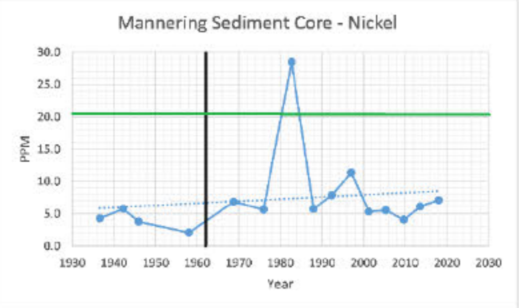
While there have been a number of attempts to retrofit new technology and processes to slow the contamination, which has seen reductions in sediment concentrations for a number of metals, cadmium and selenium concentrations remain above recommended ecosystem protection levels (shown as a green horizontal 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









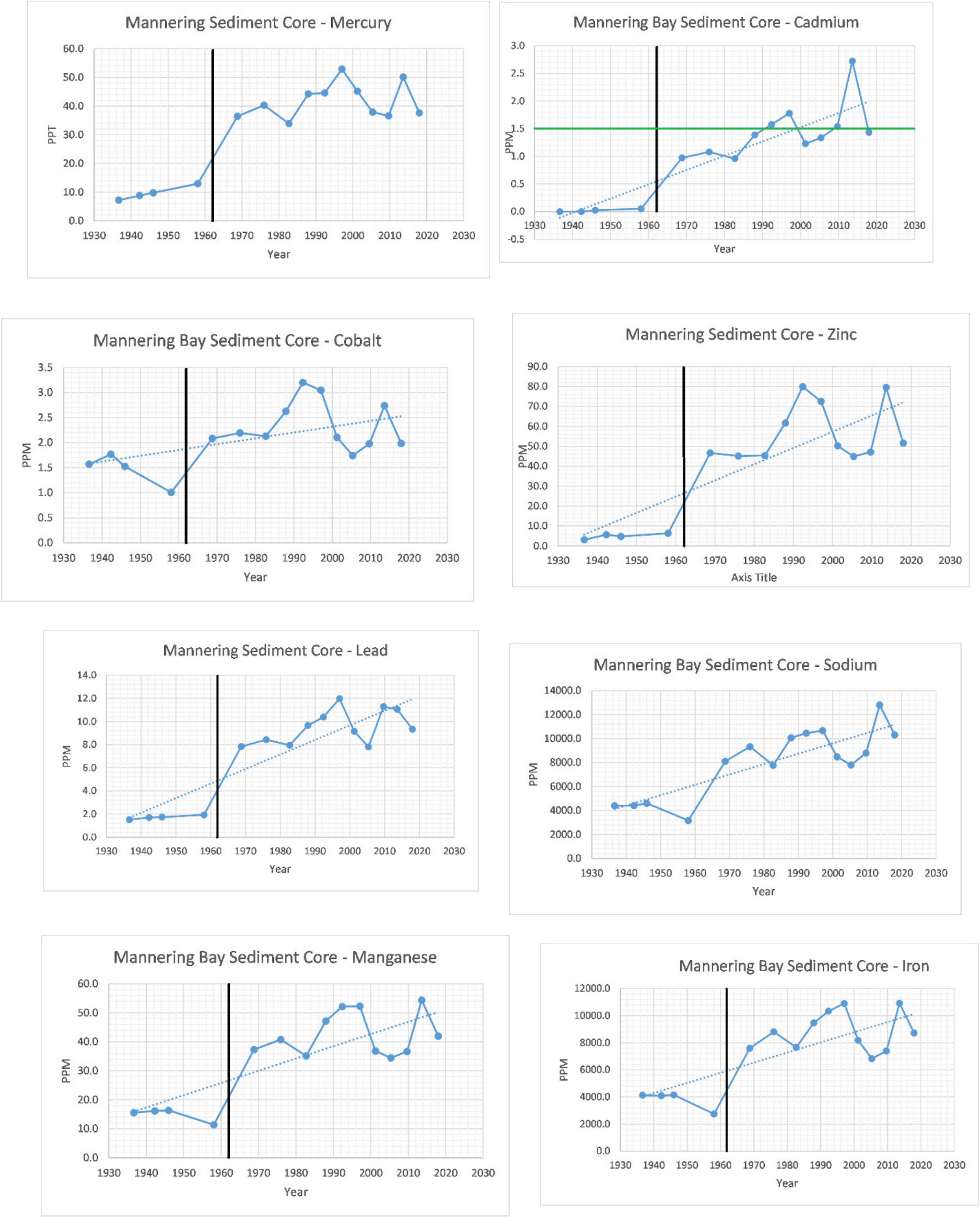


Figure 5: Mannering Bay sediment metal/metalloid concentrations 1930 to 2019. Black line indicates commissioning of Vales Point A.

Upper Cox’s River

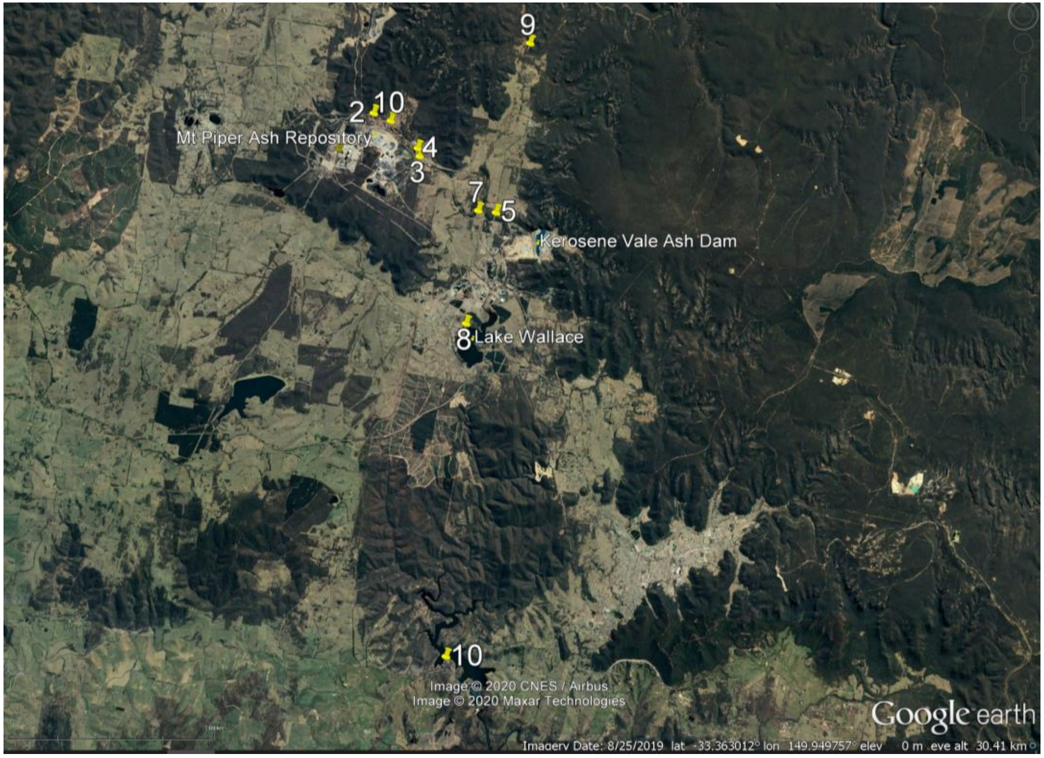
Mount Piper

Seven unfiltered and 12 field filtered (0.45uM) 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 exceedances of human health, ecological, and agriculture guidelines were identified by the laboratory report, and we are now aware that Energy Australia has admitted to the EPA that their Mount Piper ash dam is contaminating groundwater.[54]

Figure 1 and 2 below sets out the sample locations.

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



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[54] EA Lithgow CCC Meeting Notes

Figure 6: All locations of HCEC sampling in Upper Cox's River

Figure 7: Sample locations at Mt. Piper

Surface Water Samples

Table 17: Surface water laboratory results and ANZECC (2000) ecological protection concentrations and EPL limits

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

Background (#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 190uS/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 uS/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 DGV for arsenic, cadmium, lead, nickel, and zinc, with many above the “High GV”. Background concentrations were all below DGVs. Table 2 sets out the laboratory results compared to ANZECC sediment DGVs.

Table 18: 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 1.5,
- nickel by 3, and GV High by 20%, and
- zinc by 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)

Table 19. 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 (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	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water		
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		6.5-8.5	
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 20: Surface water laboratory results and ANZECC (2000) agricultural guidelines

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		
																					Irrigation trigger value		Livestock drinking water trigger value
Sample		9	9A	9B	2	2	3	3A	3B	3C	4	5	5A	5B	5C	7	8	8	10	11	Short-term (20 years)	Long-term (100 years)	
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			
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

8. US Coal Ash Rule and Effluent Guidelines

After extensively studying the effects of coal ash on the environment and public health by the US EPA, new technical requirements for coal ash landfills and surface impoundments were introduced 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.[55]

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),[56] 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[57] The annual compliance costs for the final rule was estimate at $480 million, with benefits associated with the rule estimated at $451 to $566 million.

9. Reducing NSW metal leachate

The key to reducing leachate of metals from coal ash disposal sites is reducing the amount of water that comes into contact with ash. With the exception of Mount Piper, NSW power stations currently dispose of ash by pumping a slurry to a disposal sites adjacent to the power station.[58] Mt Piper uses a dry method for ash disposal.[59] 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.[60] Origin Energy and AGL use ‘lean phase’ fly ash

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[55] https://www.epa.gov/coalash/coal-ash-rule

[56] https://www.ecfr.gov/cgi-bin/text-idx?SID=6b51273d47e8dc451e0aac10f60cdfee&mc=true&node=pt40.31.423&rgn=div5

[57] US EPA, 2015. Final Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Industry. https://www.epa.gov/sites/production/files/2015-10/documents/steam-electric-final-rule-factsheet_10-01-2015.pdf

[58] NSW EPA, 2017. Environment Compliance Report: Coal ash dams and emplacements. https://www.epa.nsw.gov.au/-/media/F296D19215D348A8BC16DEB4D2021A52.ashx

[59] SKM, 2010. Environmental Assessment Mt Piper Power Station Ash Placement Project. https://www.energyaustralia.com.au/sites/default/files/2017-03/Part%201.pdf

[60] Timmons D., 2015. Dense Slurry Coal Ash Management: How Water and Additive Concentrations Affect Environmental Performance. World of Coal Ash (WOCA) Conference in Nasvhille, TN - May 5-7, 2015. http://www.flyash.info/2015/004-timmons-2015.pdf

placement at Eraring[61] and Bayswater[62] (30% fly ash and 70% water) with Liddell and Vales Point power stations[63] still using outdated wet sluicing to transport coal ash to their ash dumps, typical with a solid-to-water ratio between 1:10 to 1:15.[64]

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.[65] 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 installing 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 waste reuse in Australia must be addressed. Far greater incentives need to directed to power generators to force them to overturn the restrictive contracts with cement companies currently in place, and open their gates to companies wishing to produce safe high volume coal ash products.

HCEC believes the simplest method would be to list fly ash as an assessable pollutant under the POEO Regulations and impose a LBL fee of $20 a tonne to all fly 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 removes, 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.

Reducing and eliminating the dumping of ash, and providing industry assistance aimed at dramatically increasing in the safe and beneficially reuse of coal-ash across the state, calling for cooperation between the ash reuse industries, Government, the NSW EPA and power station operators to initiate the necessary upscaling of the industry.

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[61] Eraring Energy, 2007. Environmental Assessment Upgrade and Expansion of the Coal Combustion Product Management System, Eraring Power Station November 2007. https://majorprojects.accelo.com/public/26ea1d60a546826f1a4ce395bdd7dcb0/Eraring%20Power%20Station%20CCP%20-%20Environmental%20Assessment.pdf

[62] A. Ward, T. Bunn & J. Chambers (1999) The Bayswater Fly Ash Transportation System, Coal Preparation, 21:1, 125-147. https://www.tandfonline.com/doi/abs/10.1080/07349349908945613

[63] https://www.de.com.au/environment/ash-management

[64] Tobias Lutzl, Uli Freitag, 2017. How Dense Slurry Fly Ash Disposal helped Europe's largest Brown Coal Power Station to reduce its Water Consumption by over 90%. 2017 World of Coal Ash (WOCA) Conference in Lexington, KY - May 9-11, 2017. http://www.flyash.info/2017/081-Broedel-woca2017p.pdf

[65] Hassett, D.J. (1994), Scientifically valid leaching of coal conversion solid residues to predict environmental impact, Fuel Processing Technol., 9, 445-459.

10. Conclusion

Our analysis and investigations highlight the inadequacy of the current EPA regulation of coal ash dumps, which we demonstrate is causing significant environmental harm and risking human health.

We conclude that the NSW Government is liable for considerable decontamination works at the five active power station ash dumps to remedy the ongoing heavy metal pollution when these facilities are decommissioned and must move to substantially reduce the volumes of coal ash, particularly fly ash, from which most of the metal leachate is derived.

Significant metal contamination has been identified from all operating power station ash dumps since NSW Treasury received its Stage 2 Environmental Site Assessments in 2013/14. In southern Lake Macquarie, metal contamination from Eraring and Vales Point was identified many decades ago.

Monitoring by power station operators shows continued unacceptable metal contamination, some of which is increasing. The EPA have been slow to respond to power station operator prevarication on Pollution Reduction Plans and failure to meet coal ash reuse targets.

The fact that these power stations were operated by the NSW Government for most of their lives and sold to private enterprise at the end of their design lives, means that most of the liability for any coal ash dam decontamination lies with the Government. NSW EPA have helped maintain the silence and inaction over the heavy metal contamination of groundwater and surface water by coal ash dumps. The level of contamination was made clear to the NSW Government in 2014, when the Environmental Site Assessments were completed to set contamination baselines prior to power station selloffs.

We believe the costs 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 Load-Based Licencing fee paid by 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 could provide significant regional business and employment opportunities.

Recommendations

- **Recommendation 1:** The NSW Government commit to a comprehensive decontamination of Vales Point and Eraring power station sites.
- **Recommendation 2**: The NSW EPA undertake an investigation into coal ash generated in NSW determine the environmental risks associated with all its current uses are whether these uses are appropriate. The EPA amend the Coal Ash Exemption 2014 to ensure all coal ash metal analyses and leach testing results are made public. The EPA must take a much more active role is determining the suitability of coal ash reuse.
- **Recommendation 3:** The NSW Government list coal ash as an assessable pollutant in Schedule 1 of the Protection of the Environment Operations (General) Regulation 2009.
- **Recommendation 4:** 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 5:** 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 fly ash in NSW.
    - HCEC recommends the NSW government immediately begin the process of trialling a pilot plant, to capitalise on the benefits that a coal ash re-use industry can offer and avoiding being left with an unmanageable liability. We recommend the following steps be undertaken:
        - *Select interested companies who can manufacture recycled coal ash products, and involve them in one or more stages of the feasibility study.*
        - *Sample ash from all NSW power stations to determine the ideal compositional matrix for the required products and test the products for market suitability and human health and environmental safety.*
        - *With the assistance of the selected interested companies, 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.*

Recommendation 6: The EPA ensure all NSW power station operating wet ash damps install appropriate equipment to transport ash in a dense phase to minimise metal mobilisation.

Recommendation 7: The NSW EPA ensure all power station operators estimate and report to the NPI all emissions to land and water from ash dumps.

Recommendation 8: The NSW EPA publish all site specific biological effects data that establishes that allowing the discharge and leaching of metals at concentrations above ANZECC/ARMANZC (2000) will not degrade aquatic ecosystems and species, as well as data that established that allowing discharge and leaching of metals above NHMRC Health Guidelines will not cause human health impacts.