

Review of Schneider et al. (2019) on
the significance of atmospheric metal
contamination from mining activity
adjacent to the Tasmanian Wilderness
World Heritage Area

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ENVIRONMENT PROTECTION AUTHORITY

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I Introduction

A recently published paper by Schneider et al (2019) concludes that there has been metal contamination from mining activity adjacent to the Tasmanian Wilderness World Heritage Area (TWWHA).

The study claims that past mining activities have caused metal contamination within lake sediments in the TWWHA. The authors also calculate sediment enrichment factors that are among the worst in the world, being some of the highest ever reported, and state that the metal contamination might be causing health risks to aquatic ecosystems and humans that feed on them.

Scientific staff of EPA Tasmania have reviewed the paper and the results of recent water sampling in sixteen lakes.

This review finds that the conclusions of the paper are not supported by the data.

2 Review of the Paper

2.1. General comments

The presentation of data and its analysis is potentially confusing, with a mix of discussion of metal concentrations and enrichment factors.

Supplementary tables are used to display key detailed data, which are not available for the reader's consideration in the paper itself.

The authors do not identify that their own data reveals changes in metal concentrations and sedimentation rates occurring outside of the timeframes they chose to focus on in the paper, and particularly in the case of Owen Tarn, this data shows metals concentrations rising from around the 1400s. The changes and the possible mechanisms for those changes across all the lakes studied are not considered in the paper and if they are accounted for in the analysis, it is not discussed.

A key challenge in understanding the data of the paper is the question of uncertainty and statistical variations. Measurement uncertainties are not quoted. Detection limits are also not quoted. The sample size is very limited, and constitutes what might be used in a preliminary investigation rather than in depth research project. There is no discussion provided on how the sub-sample of the cored material, or the cored material of each lake as a whole, may be a representative sample. The impression given is of a level high confidence, which is arguably inconsistent with these limitations.

Other potentially important analytes have not been included, such as tin, which has been mined on Tasmanian west coast. The lack of analysis of sulphur and carbon (both of which can be important in the fixing of metals) also impairs interpretation of the data.

There is a lack of discussion around other potential contaminant sources (either naturally occurring, or man-made), and no control sites were used, creating a high level of uncertainty as to what experimental variables may be present that are uncontrolled. This fact is directly relevant to the issue of rising metals levels prior to the 1800s.

The choice of 1930 as a cut-off date is clearly fundamental to the work, however there appears to be an absence of any data or supposition to support using this date over any other date.

2.2. History of mining and geological setting

The mining activities described by the authors are not supported by the historical record, in particular, the claim that open-cut mining commenced in around 1930, along with the introduction of new mining technology, naming as an example, 'stamper and mills'. The authors' description is inaccurate in places and is not supported by data or references. The authors have highlighted mining activity around Queenstown and Rosebery but have not mentioned the mining activity that occurred in other locations, such as around Zeehan.

It is not clear from the paper if the focus on open-cut mining activities is in order to explore the mechanisms for the entrainment of dust into the air column, and its subsequent transport and deposition into the lakes, or merely as a descriptive tool to indicate an increase in extraction and associated processing activities around that time. In general, dust generated by open-cut mining would generally fallout relatively nearby to the operation, whereas pyrometallurgical processes emit finer particles into the atmosphere.

In any case, sources which document the Tasmanian mining history timeline (Bacon 2013, Blainey 1967) do not describe any particularly large startup or expansion of open-cut mining, or adoption of new technology, in the area around 1930.

For example, the authors imply that active mining has been taking place in Rosebery since 1936. Mining commenced in Rosebery in 1893 and reached full production in 1900, followed by periods of downturn and closure in the early 1900s (Bacon, 2013). It would be correct to state that the Rosebery mine has operated *continuously* since 1936 (MMG, 2016), however the operation is predominantly underground, not open-cut.

The geology of the West Coast mineralised areas is complex, and worthy of discussion in the paper. There is an absence of discussion of the mineralogy, which affects bioavailability and could contribute toward understanding metal sources. For example, isotopic fingerprinting of lead in the samples would provide information on the source of the lead, given that Tasmanian orebodies have characteristic lead isotope signatures.

There is also an absence of discussion of the local geology around the lakes from which sediment samples were collected.

2.3. Modelling

HYSPLIT tracks the movements of individual particles 'released' (numerically) into meteorological fields.

It is not clear if the (hypothetical) particles are released at ground level (or at a 'stack height' if the researchers are considering a smelter). It is also not clear if the topography has been taken into account. For Queenstown, it may be the case that under certain meteorological conditions these emitted particles would not make it out of the valley. If the modelled topography is not a good representation of the actual terrain then the model results may show that more particles escape than actually would do so.

A high-resolution DEM would be required to capture the complex topography around Queenstown, and to an extent, also around Rosebery. It is not clear from the paper if this was used.

The authors provide little detail of the physics of the deposition. They note that precipitation may assist in the process, but otherwise there is little discussion of 'fallout' processes. Providing a likely mechanism for deposition is critical in determining the conclusions of the paper.

The source meteorological data for the HYSPLIT trajectories are from the US NOAA NCAR/NCEP reanalysis. This review has been unable to identify the particular data set from the link in the paper. Some of these (global) reanalyses necessarily have limited spatial resolution, some are around 100 km x 100 km or even more coarse. The authors don't state what grid size was available for the meteorological data. If low spatial resolution meteorological data were used along with a low resolution DEM for the topography it would be difficult to draw meaningful conclusions regarding transport and deposition from the resulting trajectories.

The stated 10 km x 10 km HYSPLIT grid would certainly be too crude for meaningful analysis of transport from Queenstown to Basin Lake and Owen Tarn.

2.4. Analysis and presentation of results

It would have been instructive to provide, in the paper itself, metal analysis of cores by depth and age, and sedimentation rates, to give a general picture of sediment analysis changes. This would illustrate that there are unexplained curiosities in the data. These are not mentioned by the authors, but deserve closer attention.

For example, based on the data provided in Supplementary Table 3, it could be argued that metal concentrations in Owen Tarn have been increasing since the late 1400s, peaking in the mid-1950s, and steeply declining since, to pre-European settlement levels (with the exception of copper). There does not appear to be a precipitous increase in metal concentrations starting in the 1930s.

This was compared to data provided in Table I of the paper itself. Table I removes some of these curiosities from the data, by splitting it into “before mine”, and “mining-peak”. Using Owen Tarn again as an example, the background levels for lead, copper and zinc are given as 10, 5 and 3 mg/kg respectively in Table I. Using an average in this case may be misleading, as these are closer to levels in the 1300s, than in the years prior to mining, and therefore the magnitude of any increase after 1880 may be far less.

Likewise, the paper states that the largest variations in sedimentation rates occurred in the 1930s. This is not supported by the data in Supplementary Table 3, which provides sedimentation rates which are effectively constant throughout the record during European settlement for Lakes Cygnus, Perched and Dobson, or display other features, for example at Lake Dove, the highest sedimentation rate occurs around 1899 to 1901. At Owen Tarn, the rate peaks at 1958, and at Basin Lake in 1947.

Therefore, it is not possible to determine how the authors have drawn the conclusion that sedimentation rates significantly changed in the 1930s. The authors note that sedimentation increased as a result of increased atmospheric inputs, with the details discussed in a separate publication. Details of that publication are not provided.

In summary, the data does show changes in metal concentrations in the lake sediments, however the timeline of those changes does not necessarily support a conclusion that these are due to mining practices beginning in the 1930s.

2.4.1 Review of Table I

Table I appears to contain multiple errors, as follows:

- Fold-increase values appear incorrect for Lake Dobson. These should be 0.3, 0.2, 0.92, 0.0, 1.1, 0.6, n/a, and n/a.
- Other smaller errors in the ‘fold-increase’ values are present across the table, possibly relating to rounding errors.
- It is not clear how the background values given for Owen Tarn relate to the data given in Supplementary Table 3.
- The ‘before’ and ‘mining peak’ values for Al and Fe in Owen Tarn appear to be inconsistent with the data in Supplementary Table 3.

2.4.2 Review of Table 4

Notwithstanding the comments made above regarding Table I, there appear to be errors in the calculations of enrichment factors.

Staff of EPA Tasmania have independently calculated the EFs using the formula given in the paper with the values given in Table I. EFs calculated by EPA Tasmania, as shown in the table below, are substantially lower for Owen Tarn than given in the paper.

	FROM PAPER TABLE 1		Enrichment Factors recalculated by eqn at paper section 2.7						
	Al background	Al mining peak	As	Cd	Cu	Fe	Pb	Se	Zn
Owen Tarn	1639	3336	8.2	3.4	21.6	0.8	24.2	2.2	8.4
Basin Lake	4185	8680	5.1	Undefined	24.5	0.7	26.7	0.8	3.5
Lake Dove	39337	55179	2.6	1.4	3.7	0.8	2.4	0.7	1.1
Lake Cygnus	12292	14662	1.1	0.8	5.0	1.3	2.1	6.4	1.7
Lake Dobson	15783	16214	1.6	Undefined	1.0	1.2	12.7	Undefined	2.0
Perched Lake	10362	18360	1.4	1.0	2.2	1.1	8.3	1.1	0.8

2.4.3 Review of Table 5

The heading of Table 5 is confusing. The authors appear to have used the maximum concentration value from Supplementary Table 3. Therefore, the heading should read to the effect of “ratios of maximum concentration in sediments (between 1930 to 1980) from lakes...”. Therefore, the term ‘average’ appears to be used in error.

It would be useful to state the screening values used. The Se comparison in Table 5 appears to contain some errors. It is noted that all values for Se at Lake Dobson are below the detection limit, in Supplementary Table 3, and yet the paper reports a value of 0.6 against the screening value.

2.5. Conclusions regarding Selenium

There is an error in the paper at Section 3.5 comparing Se sediment concentrations between Owen Tarn and a lake in North Carolina, the former is in units of mg/kg while the latter is in mg/g. The units for the North Carolina study should be µg/g (Lemly, 1997). Thus, the paper should state that Se concentrations of between 4 to 12 µg/g were high enough to cause severe reproductive failure and teratogenic deformities in fish in Belew's Lake, North Carolina. The paper goes on to state that 'Owen Tarn organisms 'might be facing health issues due to Se contamination'.

It is acknowledged that that data in Supplementary Table 3 shows Se levels in Owen Tarn sediments as high as 16.78 mg/kg (at 12 cm depth), but these concentrations began rising prior to the 1800s. Se levels in Basin Lake have been within the 4-12 mg/kg range at various times across the entire record, and in Perched Lake since 1821. This has not been addressed.

2.6. Use of Enrichment Factors

Enrichment factors are presented in the paper in a manner that implies they indicate an ongoing environmental concern.

The paper presents metal contamination in two ways; as enrichment factors and as a concentration. The former is a ratio of metal concentration in one part of the sediment cores to other parts of the same core. The latter is the amount of metals per unit mass of the sediments on a dry basis at a location in the core. It is the concentration that is the critical factor in potential environmental impact. If levels of metals are low, which is the case for some parts of the sediment cores, then enrichment factors could be very large whilst not posing any environmental threat.

It is noted that aluminium has been used to calculate the enrichment factor. Aluminium can be mobile in the Tasmanian aquatic environment. For these sediments iron may be a better alternative choice, and would yield lower maximum EF values.

Enrichment factors alone, therefore, should not be associated with potential environmental effects, and do not demonstrate the assertion that the contamination is likely to pose a threat to ecosystem health.

2.7. Environmental Regulation

The authors' claim that had regulations been strictly followed, following the implementation of the *Environment Protection Act 1973*, that metal contamination would have been less, and would have only left a minor legacy. The authors have not provided any analysis of the data to describe what comprises a minor legacy, and how this differs from the data provided.

Ministerial exemptions that existed under the 1973 Act were removed with the introduction of *Environmental Management and Pollution Control Act 1994*. Exemptions were related primarily to emissions to water, not to air.

3 Water Sampling

Department of Primary Industries, Parks, Water and Environment (DPIPWE) staff collected water samples from sixteen natural lakes and artificial impoundments, in western, south-western, and highland Tasmania, in February and March 2019.

- Basin Lake
- Bischoff Reservoir
- Dove Lake
- Great Lake
- Lake Binney
- Lake Bronte
- Lake Burbury
- Lake Dobson
- Lake Lea
- Lake Plimsoll
- Lake Rhona
- Lake St Clair
- Lake Rosebery
- Lake Selena
- Little Pine Lagoon
- Pine Lake

Perched Lake, Lake Cygnus and Owen Tarn (reported in Schneider et al, 2019) were not readily accessible during this sampling campaign.

The water samples were analysed for metals by Analytical Services Tasmania (AST). The results are provided in Appendix I.

All metals concentrations, in all lakes, met the health guideline values of the Australian Drinking Water Guidelines.

The results do not indicate that any ecological values are compromised.

In general, the presence of metals in sediments, particularly if rich in organic matter and with low redox, does not necessarily mean that bioavailable concentrations are present in the water column. Furthermore, it is known that for the waters of the west coast of Tasmania that humic material and dissolved organic matter greatly reduces the bioavailability of aquatic toxicants such as copper and zinc.

As stated above, the water quality analysis results did not indicate that any metals are present at abnormal levels within the water column.

4 Other Comments

EPA Tasmania notes that the media release from The Australian National University which launched the study states that "...Tasmania's concentration levels were one of the highest ever reported". This is not a true reflection of the contents of the paper, which refers to enrichment factors as the highest ever reported, not concentration levels.

EPA Tasmania also notes that the media release stated that "it's even worse with Mercury and Lead...". The paper contains no data and no discussion on Mercury.

5 Conclusion

The data in the paper does suggest that changes in lake sediments have occurred and enhanced metals concentrations in sediments are present in parts of the sediment core, particular in Basin Lake and Owen Tarn, but does not provide strong evidence to support the conclusion that this is due to the increase of open-cut mining techniques in the 1930s.

There are changes in metal concentrations throughout the sediment depth that suggest that alternative hypotheses need to be considered.

Enrichment factors may be high, in some lakes for some metals, however there is no evidence that this contamination is likely to pose any threat to ecosystems or to human health.

There is no data, analysis or discussion in the paper to support the authors' final conclusion that the metals deposited in the sediments are constantly remobilized by redox reactions, wind, catchment activities and activities of microorganisms in the sediment.

The claim that most of the TWWHA has been contaminated by open-cut mining is not supported and there is no compelling evidence provided in the paper that requires a reaction to any historic contamination or that would change the current regulatory framework.

Today's mines operate in accordance with current environmental legislation, and new and existing mining operations employ best practice techniques.

6 References

Bacon, C.A., 2013. *A Tasmanian mining history timeline. Tasmanian Geological Survey Record 2013/10*. Mineral Resources Tasmania, Department of Infrastructure, Energy and Resources, Tasmania.

Blainey, G., 1967. *The Peaks of Lyell*. Melbourne University Press, Carlton, Vic, Australia.

Lemly, A.D., 1996. Ecosystem Recovery Following Selenium Contamination in a Freshwater Reservoir. *Ecotoxicology and Environmental Safety* 36, pp 275 – 281.

MMG. 2016. *Rosebery Fact Sheet*. <http://www.mmg.com/en/Our-Operations/Mining-operations/Rosebery.aspx>

Schneider, L. et al., 2019. How significant is atmospheric metal contamination from mining activity adjacent to the Tasmanian Wilderness World Heritage Area? A spatial analysis of metal concentrations using air trajectories models. *Science of the Total Environment* 656, pp 250 – 260.

7 Appendix I

7.1 Water sampling results

As discussed at Section 3, DPIPWE staff collected water samples from the sixteen natural lakes and artificial impoundments listed below, in western, south-western, and highland Tasmania, in February and March 2019.

- Basin Lake
- Bischoff Reservoir
- Bronte Lagoon
- Great Lake
- Lake Binney
- Lake Burbury
- Lake Dobson
- Lake Dove
- Lake Lea
- Lake Plimsoll
- Lake Rhona
- Lake Rosebery
- Lake Selina
- Lake St Clair
- Little Pine Lagoon
- Pine Lake

For each lake (with the exception of Bronte Lagoon and Lake Rhona) two sets of results are provided, as duplicate samples were taken. Duplicate sample data are not available for Bronte Lagoon or Lake Rhona.

Field data are also shown, where readings were taken, for pH, conductivity and temperature.

The analytical results are shown on the following pages. Tables are shaded where data are not available

Analyte	Units	Basin Lake		Bischoff Res		Bronte Lagoon		Great Lake	
		17/02/2019 14:00	65	19/02/2019 11:30	11:30	24/02/2019 13:25	13:25	20/02/2019 13:30	13:30
Al Dissolved	µg/L	62	65	<8	<8	29		<8	<8
Al Total	µg/L	73	72	28	31	201		47	45
As Dissolved	µg/L	<1	<1	<1	<1	<1		<1	<1
As Total	µg/L	<1	<1	<1	<1	<1		<1	<1
Ba Dissolved	µg/L	<1	<1	<1	<1	1		<1	<1
Ba Total	µg/L	1	<1	<1	<1	2		1	1
Ca Dissolved	mg/L	0.2	0.19	1.05	1.08	1.38		1.01	1.02
Ca Total	mg/L	0.21	0.21	1.12	1.11	1.48		1.07	1.07
Cd Dissolved	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Cd Total	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Co Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
Co Total	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
Cr Dissolved	µg/L	<1	<1	<1	<1	<1		<1	<1
Cr Total	µg/L	<1	<1	<1	<1	<1		<1	<1
Cu Dissolved	µg/L	<1	<1	<1	<1	<1		<1	<1
Cu Total	µg/L	2	1	<1	<1	<1		<1	<1
Fe Dissolved	µg/L	362	371	202	202	106		<20	<20
Fe Total	µg/L	511	512	459	466	369		60	58
Hg Dissolved	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05
Hg Total	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05
K Dissolved	mg/L	0.22	0.21	0.29	0.29	0.09		0.19	0.17
K Total	mg/L	0.22	0.22	0.31	0.31	0.11		0.2	0.18
Mg Dissolved	mg/L	0.65	0.65	1.34	1.37	0.87		0.57	0.57
Mg Total	mg/L	0.68	0.67	1.42	1.41	0.92		0.61	0.60
Mn Dissolved	µg/L	2	2	<1	<1	2		<1	<1
Mn Total	µg/L	2	2	51	51	15		34	33
Mo Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
Mo Total	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
NPOC	mg/L	7	7.1	1.9	1.9	4.1		3	2.9
NPOC Dissolved	mg/L	6.7	6.7	1.9	1.8	3.5		2	2
Na Dissolved	mg/L	5.69	5.63	6	6.13	3.19		1.74	1.74
Na Total	mg/L	5.92	5.8	6.41	6.42	3.37		1.83	1.8
Ni Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
Ni Total	µg/L	<0.5	<0.5	<0.5	1.3	<0.5		<0.5	<0.5
Pb Dissolved	µg/L	0.7	0.7	<0.5	<0.5	<0.5		<0.5	<0.5
Pb Total	µg/L	1	1	<0.5	<0.5	<0.5		<0.5	<0.5
Se Dissolved	µg/L	<2	<2	<2	<2	<2		<2	<2
Se Total	µg/L	<2	<2	<2	<2	<2		<2	<2
Zn Dissolved	µg/L	<2	<2	<2	<2	<2		<2	<2
Zn Total	µg/L	<2	<2	<2	<2	3		<2	<2
pH (laboratory)									
Conductivity (laboratory)	µS/cm								
Field Measurement									
pH (field)		4.57		6.68				7.15	
Conductivity (field)	µS/cm	50.7		49.4				19.6	
Temperature	°C	15.4		16.9				14.9	

Analyte	Units	Lake Binney		Lake Burbury		Lake Dobson		Lake Dove	
		24/02/2019 13:35		17/02/2019 12:00		22/02/2019 10:50		28/02/2019 16:10	
Al Dissolved	µg/L	9	9	98	96	24	24	101	100
Al Total	µg/L	99	124	143	146	30	29	111	121
As Dissolved	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
As Total	µg/L	<1	<1	<1	1	<1	<1	<1	<1
Ba Dissolved	µg/L	1	1	5	5	<1	<1	2	2
Ba Total	µg/L	2	2	5	5	<1	<1	2	2
Ca Dissolved	mg/L	1.64	1.67	2.17	2.19	3.93	3.94	0.24	0.23
Ca Total	mg/L	1.67	1.68	2.23	2.26	3.93	3.94	0.24	0.26
Cd Dissolved	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cd Total	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Co Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Co Total	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cr Dissolved	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Cr Total	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Cu Dissolved	µg/L	<1	<1	9	9	<1	<1	<1	<1
Cu Total	µg/L	<1	<1	11	11	<1	<1	<1	<1
Fe Dissolved	µg/L	40	39	293	292	<20	<20	36	35
Fe Total	µg/L	217	270	483	487	22	22	57	59
Hg Dissolved	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Hg Total	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
K Dissolved	mg/L	0.15	0.15	0.26	0.26	0.12	0.12	0.15	0.15
K Total	mg/L	0.16	0.16	0.27	0.27	0.12	0.12	0.15	0.17
Mg Dissolved	mg/L	0.98	0.99	1	1.02	1.90	1.89	0.38	0.37
Mg Total	mg/L	1	1	1.04	1.04	1.94	1.91	0.38	0.39
Mn Dissolved	µg/L	<1	<1	67	68	<1	<1	8	8
Mn Total	µg/L	17	21	87	89	2	3	9	9
Mo Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Mo Total	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
NPOC	mg/L	2.7	2.8	4.5	4.5	2.0	2.0	4.1	4.1
NPOC Dissolved	mg/L	2.5	2.5	4.3	4.4	2.0	2.0	4.1	4.1
Na Dissolved	mg/L	2.74	2.76	5.18	5.21	2.67	2.66	2.00	2.00
Na Total	mg/L	2.8	2.79	5.36	5.36	2.73	2.72	2.04	2.12
Ni Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ni Total	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Pb Dissolved	µg/L	<0.5	<0.5	0.9	0.9	<0.5	<0.5	<0.5	<0.5
Pb Total	µg/L	<0.5	<0.5	1.7	1.7	<0.5	<0.5	<0.5	<0.5
Se Dissolved	µg/L	<2	<2	<2	<2	<2	<2	<2	<2
Se Total	µg/L	<2	<2	<2	<2	<2	<2	<2	<2
Zn Dissolved	µg/L	<2	<2	7	7	<2	<2	<2	<2
Zn Total	µg/L	2	<2	9	9	<2	<2	<2	2
pH (laboratory)								5.5	5.4
Conductivity (laboratory)	µS/cm							12	10
Field Measurement									
pH (field)				6.82					
Conductivity (field)	µS/cm			48.6					
Temperature	°C			18.3					

Analyte	Units	Lake Lea		Lake Plimsoll		Lake Rhona		Lake Rosebery	
		20/02/2019 8:00	17/02/2019 16:00	17/02/2019 16:00	17/02/2019 16:00	15/02/2019 15:30	15/02/2019 15:30	17/02/2019 17:45	17/02/2019 17:45
Al Dissolved	µg/L	189	188	145	149	72		157	158
Al Total	µg/L	243	233	202	199	85		213	182
As Dissolved	µg/L	<1	<1	<1	<1	<1		<1	<1
As Total	µg/L	<1	<1	<1	<1	<1		<1	<1
Ba Dissolved	µg/L	2	2	7	6	<1		5	5
Ba Total	µg/L	2	2	9	8	<1		6	6
Ca Dissolved	mg/L	0.25	0.23	1.37	1.38	0.16		1.62	1.61
Ca Total	mg/L	0.27	0.26	1.42	1.4	0.17		1.65	1.68
Cd Dissolved	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Cd Total	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Co Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
Co Total	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
Cr Dissolved	µg/L	<1	<1	<1	<1	<1		<1	<1
Cr Total	µg/L	<1	<1	<1	<1	<1		<1	<1
Cu Dissolved	µg/L	<1	<1	<1	<1	<1		<1	<1
Cu Total	µg/L	<1	<1	1	1	<1		<1	<1
Fe Dissolved	µg/L	294	293	378	377	128		144	141
Fe Total	µg/L	396	378	612	608	193		223	226
Hg Dissolved	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05
Hg Total	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05
K Dissolved	mg/L	0.3	0.24	0.37	0.41	0.60		0.31	0.32
K Total	mg/L	0.32	0.27	0.4	0.41	0.65		0.32	0.33
Mg Dissolved	mg/L	0.57	0.56	0.93	0.94	0.42		0.81	0.81
Mg Total	mg/L	0.59	0.59	0.99	0.97	0.43		0.83	0.84
Mn Dissolved	µg/L	10	10	27	27	3		22	20
Mn Total	µg/L	11	10	29	29	3		25	22
Mo Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
Mo Total	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
NPOC	mg/L	12	12	8.8	9	4.4		6.4	6.5
NPOC Dissolved	mg/L	11	12	8.7	8.8	4.0		6.4	6.4
Na Dissolved	mg/L	3.75	3.78	5.73	5.79	3.14		4.37	4.4
Na Total	mg/L	3.87	3.92	6.04	6.07	3.25		4.46	4.55
Ni Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
Ni Total	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
Pb Dissolved	µg/L	<0.5	<0.5	1.1	1.2	<0.5		0.7	0.5
Pb Total	µg/L	0.5	0.6	1.9	1.8	<0.5		1.1	0.8
Se Dissolved	µg/L	<2	<2	<2	<2	<2		<2	<2
Se Total	µg/L	<2	<2	<2	<2	<2		<2	<2
Zn Dissolved	µg/L	<2	<2	<2	2	<2		10	10
Zn Total	µg/L	<2	<2	2	3	<2		11	11
pH (laboratory)									
Conductivity (laboratory)	µS/cm								
Field Measurement									
pH (field)		4.76		5.61				6.35	
Conductivity (field)	µS/cm	33.6		48.6				39.2	
Temperature	°C	9.5		16.9				18.7	

Analyte	Units	Lake Selina		Lake St Clair		Little Pine Lagoon		Pine Lake	
		17/02/2019 16:45	17/02/2019 16:45	17/02/2019 10:00	17/02/2019 10:00	20/02/2019 14:30	20/02/2019 14:30	20/02/2019 12:30	20/02/2019 12:30
Al Dissolved	µg/L	74	72	44	45	30	27	55	59
Al Total	µg/L	89	80	54	55	60	63	80	87
As Dissolved	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
As Total	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Ba Dissolved	µg/L	7	6	2	2	<1	<1	<1	<1
Ba Total	µg/L	7	7	2	2	1	<1	1	1
Ca Dissolved	mg/L	0.74	0.66	1.07	1.07	1.92	1.88	0.70	0.70
Ca Total	mg/L	0.83	0.68	1.09	1.09	1.95	1.98	0.72	0.73
Cd Dissolved	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cd Total	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Co Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Co Total	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cr Dissolved	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Cr Total	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Cu Dissolved	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Cu Total	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Fe Dissolved	µg/L	149	151	<20	23	151	146	<20	<20
Fe Total	µg/L	211	196	23	23	272	274	35	37
Hg Dissolved	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Hg Total	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
K Dissolved	mg/L	0.5	0.15	0.11	0.11	<0.08	<0.08	0.11	0.12
K Total	mg/L	0.56	0.16	0.11	0.11	<0.08	<0.08	0.11	0.12
Mg Dissolved	mg/L	0.66	0.65	0.65	0.65	1.18	1.16	0.42	0.42
Mg Total	mg/L	0.71	0.66	0.66	0.67	1.2	1.23	0.43	0.43
Mn Dissolved	µg/L	9	8	2	2	<1	<1	2	3
Mn Total	µg/L	10	9	3	3	18	18	6	8
Mo Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Mo Total	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
NPOC	mg/L	8.6	8.5	2.4	2.5	4.3	4.5	4	4.2
NPOC Dissolved	mg/L	8.6	8.2	2.4	2.4	4.2	4.2	4.1	4
Na Dissolved	mg/L	4.98	4.72	2.53	2.58	2.99	2.91	1.68	1.7
Na Total	mg/L	5.41	4.84	2.58	2.65	3.1	3.12	1.76	1.77
Ni Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ni Total	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Pb Dissolved	µg/L	0.6	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Pb Total	µg/L	0.9	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Se Dissolved	µg/L	<2	<2	<2	<2	<2	<2	<2	<2
Se Total	µg/L	<2	<2	<2	<2	<2	<2	<2	<2
Zn Dissolved	µg/L	3	<2	<2	<2	<2	<2	<2	<2
Zn Total	µg/L	3	<2	<2	<2	<2	<2	<2	<2
pH (laboratory)									
Conductivity (laboratory)	µS/cm								
Field Measurement									
pH (field)		5.21		6.92		8.46		6.75	
Conductivity (field)	µS/cm	36.4		25.0		34.3		16.3	
Temperature	°C	16.0		16.0		14.5		12.4	



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