Appendix C – Assessment of Acid and Metalliferous Drainage – Greenbushes Lithium Mine Expansion – 2018 Mining Proposal (GHD 2018) and Talison Leaching Study – Stage 2 AMD Testing Results (GHD 2019)
Executive summary

GHD was engaged by Talison Lithium Australia Pty Ltd to undertake an Acid and Metalliferous Drainage assessment (AMD), to demonstrate the leaching potential of the future tailings and waste rock due to the proposed expansion of the mine - the Greenbushes Lithium Mine, located at Greenbushes Western Australia.

The scope of works for this AMD study included the collation and geo-statistical analysis of Talison’s mineralogical assay data base - for the proposed waste rock and ore, and a review of the body of information relating to previous AMD assessments of the previously mined waste rock and existing tailings facilities.

Given the continuity of mineralogy between the previously mined material and the proposed mined material (waste rock and ore), the findings of previous AMD assessments, relating to the existing waste rock and tailings facilities, are considered reliable indicators of the future AMD risk.

This report is subject to, and must be read in conjunction with, the limitations set out in Section 1.3 and the assumptions and qualifications contained throughout the Report.

Acidic drainage risk

The risk that the tailings (derived from ore processing) will produce adverse quantities of acid is considered low, given the low sulphur content (average 0.04%). In support, a previous assessment of the drainage derived from the existing tailings seepage/dam facility (long term data 1997 to 2014) indicates that the drainage waters are circa neutral and are moderately buffered (bicarbonate). Following the proposed ore processing, the risk of acid production is further reduced given that tailings are subject to the addition of carbonate to lower the pH prior to tailings deposition.

Given the low sulphur content in the proposed waste rock, the risk that the waste will produce adverse quantities of acid is considered low (average sulphur 0.007%). The observed occurrence of carbonate within the proposed waste rock (amphibolite), should be sufficient to neutralise the production of the low quantities of acid which may be produced. The inferred neutralising capacity of the waste rock is supported by previous assessments of the previously mined waste rock, comprising; a): water quality seepage from the existing waste rock facility (16 years), b): long term kinetic testing (7 waste rock samples), and c): static AMD tests (51 waste rock samples).

Metalliferous drainage risk

Acidic conditions, which may cause dissolution and mobilisation of metals should not prevail in the waste rock and ore. A large number of elements analysed within the ore and waste rock (total 25), support that a small number of elements are elevated compared to a standard (GAI) and may present a source of environmental concern, if mobilised during leaching of the waste rock and tailings.

Saline drainage risk

Previous studies relating to long term data (1997 to 2014), indicates that seepage waters derived from the existing tailings storage facilities possess stable major-ion concentrations (and TDS). Given the mineralogical continuity between the previously mined ore and the proposed ore, the risk of elevated concentrations of saline drainage leaching from the future tailings (processed ore), is considered low.

Previous studies relating to seepage/drainage derived from the existing waste rock dump indicates stable EC values from 2,500 to 3,500 $\mu$S/cm, over the long term (1997 to 2013). Given the mineralogical continuity of between the previously mined waste rock and the proposed waste rock, the risk of increased and elevated concentrations of saline drainage leaching from the proposed waste rock dump is considered low.
Summary and recommendations

The risk of adverse AMD impacts derived from the proposed waste rock and tailings is considered low based on previous AMD assessments of previously mined waste rock and ore - which is directly applicable given the continuity of mineralogy (between the previously mined material and the proposed mined material).

The potential risk of adverse AMD impacts derived from the proposed ore/tailings and waste rock is also considered low given the assessment of the elemental data supplied by Talison (eg: low sulphur content). However, as an additional confirmation the following specific AMD laboratory testing is recommended:

- Acid neutralising capacity (ANC)
- Net acid generation (NAG)
- Sulphur speciation
- Metals (testing for comprehensive suite - 52 metals)
- Leach testing (major-ions, pH, EC, metals)
- Gross alpha and beta

The numbers of samples required for specific laboratory analysis should be sufficient to statistically justify conclusions relating to the AMD risk and/or requirements for any additional further AMD testing and analysis (eg: kinetic testing requirements).
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Appendices

Appendix A Plan and cross sections though proposed pit (Figures A0 to A12)
1. Introduction

1.1 Purpose of this report

GHD was engaged by Talison Lithium Australia Pty Ltd to undertake an Acid and Metalliferous Drainage assessment (AMD), to demonstrate the leaching potential of the future tailings storage facilities and waste rock dumps due to the proposed expansion of the mine - the Greenbushes Lithium Mine.

The purpose of this report is to present the findings of an assessment of the geochemical data and information (supplied by Talison) and the risk that acid, metalliferous or saline drainage may leach from the proposed tailings storage facilities and waste rock dumps as a consequence of the proposed mine expansion.

1.2 Outline of mining proposal

Talison Lithium Australia Pty Ltd (Talison) is proposing to expand the existing Greenbushes Lithium Mine, to increase the production of spodumene ore and lithium mineral concentrate from the operation.

The mine is located within the Shire of Bridgetown – Greenbushes immediately south of the Greenbushes town site, approximately 250 km south of Perth and 80 km south east of Bunbury in Western Australia.

The Greenbushes region is recognised as the longest continuously operated mining area in WA, with mining of tin having commenced in 1888. Tin, tantalum and lithium mining have all occurred throughout the history of mining activity in the area. The current Greenbushes Lithium Mine has been operated as a modern open cut, hard rock operation on a continuous basis since 1983, with both tantalum and spodumene (lithium) ores being extracted and processed.

The expansion will increase throughput at the Greenbushes operation from the current approved production rate of 4.7 Mtpa to 9.5 Mtpa of spodumene ore to produce up to 2.3 Mtpa of lithium mineral concentrate. Lithium mineral concentrates from the operation will continue to be transported to the Ports of Bunbury and Fremantle (limited volumes) for export as per current arrangements, and will also supply the Tianqi Lithium Process Plant under construction in Kwinana, and the Albemarle Lithium Process Plant proposed for construction in the Kemerton Strategic Industrial Area north of Bunbury.

The approved boundary for the mining operation (Mine Development Envelope) will expand from the current 1,591 ha area to 1,989 ha. Approximately 68.5% of the Mine Development Envelope has already been disturbed as a result of the extensive history of mining within the area, as well as forestry, water storage and supply, surrounding agriculture activities and edge effects from the town of Greenbushes. The existing mining operation is located predominately within the Greenbushes State Forest (State Forest 20) with the surrounding region comprising the State Forest, agricultural properties, tree plantations and urban environment (Greenbushes townsite).

The expansion will involve the merging and expansion of three existing open pits, extension of the Floyds waste rock landform, development of additional water catchment dams within the Floyd’s waste rock landform catchment, establishment of a new tailings storage facility to accommodate increased tailings production, and construction and operation of new infrastructure including a new Mine Services Area, explosive storage facilities, a new crushing circuit and two new processing plants.
Talison is seeking environmental approval for the proposed expansion under Parts IV and V of the WA *Environmental Protection Act 1986* and the *Mining Act 1978*, and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

### 1.3 Limitations

This report has been prepared by GHD for Talison Lithium Australia Pty Ltd and may only be used and relied on by Talison Lithium Australia Pty Ltd for the purpose agreed between GHD and the Talison Lithium Australia Pty Ltd as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Talison Lithium Australia Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Talison Lithium Australia Pty Ltd and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

### 1.4 Scope of work

The scope of works for this AMD study included:

- review of existing information;
- collation of the Talison mineralogical assay data;
- geo-statistical analysis of the geochemical data;
- review of previous investigations relating to leaching of the existing facilities; and
- provision of recommendations based on the AMD assessment.
2. **Project geological setting**

2.1 **Regional geological setting**

The lithium hosting ore comprises the Greenbushes pegmatite, which intrudes the granitic rocks located on the western margin of the Yilgarn Craton – recognised as a regionally extensive granitic and greenstone metamorphic terrain. The regional geology is presented in Figure 1.

The Greenbushes pegmatite lies within a 15 to 20 km wide, north to north-west trending lineament, known as the Donnybrook-Bridgetown Shear Zone. A sequence of sheared gneiss, orthogneiss, amphibolite and migmatite outcrops along the shear zone lineament together with syntectonic granitoid intrusives.

The Greenbushes pegmatites were recorded as have been dated at approximately 2,525 million years (Ma) and appear to have been intruded during shearing. However, the pegmatites have been affected by subsequent deformation and/or hydrothermal re-crystallisation, the last episode dated at around 1,100 Ma (Behre Dolbear June, 2011).

2.2 **Local geology and overview of ore mineralogy**

The mineralogy of the pegmatite orebody is well documented and much of what follows is derived from a Technical Report (Behre Dolbear 2011) and conversations with Daryl Baker – Talison Mine Geologist.

The Greenbushes pegmatite body is approximately 100 to 250 meters in width and strikes in a north to north-westerly direction and dips moderately to steeply towards the west-southwest (See Figure 2 and Figure 3).

The main pegmatite is bounded by granofels - which forms the footwall; with amphibolite and dolerite - which forms the hanging wall.

The pegmatite has been intruded by Proterozoic dolerite dykes and sills which generally trend east-west and vary in width from a few centimetres to tens of metres.

The pegmatite bodies of the Greenbushes deposit are generally lenticular in nature and inter-finger along strike and down dip. The pegmatite is mineralogically zoned as follows:

- **The Lithium or Spodumene Zone**: enriched in the lithium-bearing silicate mineral spodumene.
- **Sodium or Albite Zone**: characterized by albite (Na-plagioclase), tourmaline, muscovite and tantalite and cassiterite mineralization.
- **Potassium feldspar Zone**: contains concentrations of microcline and accessory minerals such as apatite, minor beryl and garnet.

Within the amphibolites and dolerites (generally referred to locally as “greenstones”) contain occasional stringers and pods where sulphides are present. The sulphides comprise pyrite, pyrrhotite and chalcopyrite. Arsenopyrite and arsenolamprite (native arsenic) are ubiquitous in some areas, particularly within granofelsic and amphibolitic inliers in the main pegmatite. In addition, within the ore native arsenic is present (Daryl Baker pers.com).

The hanging wall amphibolites also exhibit common carbonate alteration present as veinlets, some 1 to 10 cm thick. Carbonate alteration is not noted within the hanging wall dolerites or the footwall granofels.
2.3 Detail on ore mineralogy

In general, the full width of the pegmatite ore body is excavated and processed, given that the pegmatite comprises economical grades of lithium hosted within spodumene.

Within the hosting pegmatite there are a number of cross-cutting dolerite dykes, which range in width from a few centimetres to a few metres. The dykes have substantially different chemistry to the pegmatites and are basic in composition. Lithium values in the mafic dykes are relatively low and the dykes are identified by significantly higher calcium oxide ("CaO") and Fe₂O₃ values. The dyke material, identified in the drill hole intervals by elevated iron, is manually separated from lithium pegmatite during mining to avoid contamination of the final lithium products.

The approximate abundances of major minerals within the pegmatite are quartz 28%, spodumene 26%, albite 23%, K-feldspar 20%, tourmaline 1%, mica 1% and apatite 0.5%. The chemical formulae of the major minerals and secondary minerals are presented in Table 2-1.

Table 2-1 Pegmatite body minerals and chemical formulae

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Chemical Formulae</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Major pegmatite minerals</strong></td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td>SiO₂</td>
</tr>
<tr>
<td>Spodumene¹</td>
<td>LiAl(SiO₃)₂</td>
</tr>
<tr>
<td>Muscovite</td>
<td>KAl₂(AlSi₃O₁₀)(F,OH)₂</td>
</tr>
<tr>
<td>Albite²</td>
<td>NaAlSi₅O₈</td>
</tr>
<tr>
<td>Microcline²</td>
<td>KAlSi₃O₈</td>
</tr>
<tr>
<td>Perthite²</td>
<td>KAlSi₅O₈ and NaAlSi₅O₈</td>
</tr>
<tr>
<td><strong>Secondary pegmatite minerals</strong></td>
<td></td>
</tr>
<tr>
<td>Lithiophilite</td>
<td>Li(Mn²⁺ Fe²⁺)O₄</td>
</tr>
<tr>
<td>Amblygonite</td>
<td>(Li, Na) AlPO₄(F,OH)</td>
</tr>
<tr>
<td>Holmquisite</td>
<td>Li(Mg, Fe²⁺)₂Al₂ Si₆ O₁₂(OH)₂</td>
</tr>
<tr>
<td>Lepidolite</td>
<td>K(Li, Al)₂(Si, Al)₄O₁₆(OH)²</td>
</tr>
<tr>
<td>Tourmaline</td>
<td>(Ca,K,Na,)₃(Al,Fe,Li,Mg,Mn)₃(Al,Cr, Fe,V)⁵(BO₃)₃(Si,Al,B)₆O₁₈(OH,F)⁴</td>
</tr>
<tr>
<td>Columbo-Tantalite</td>
<td>(Mn,Fe,Mg)(Nb,Ta)₂O₆</td>
</tr>
<tr>
<td>Cassiterite</td>
<td>SnO₂</td>
</tr>
<tr>
<td>Fluorapatite</td>
<td>Ca₅(PO₄)₃F</td>
</tr>
</tbody>
</table>

¹ includes varieties of Spodumene: kunzite and hiddenite (Fe, Mn and Cr inclusions in Spodumene)
² may contain up to 10% anorthite (CaAl₂Si₂O₆)
2.4 Ore processing

The ore is separated into two grades for processing:

- Technical grade plant, comprising >3.8% Li$_2$O (i.e. >47% spodumene) makes a variety of products for ceramic and glass manufacturing applications.
- Chemical grade plant, comprising >0.7% Li$_2$O (i.e. >8% spodumene) and typically 2% Li$_2$O concentrate feedstock for battery manufacture.

The ore processes are similar for both the Technical and the Chemical Grade – and both tails contain Na$_2$CO$_3$, oleic acid, and frother as part of fatty acid flotation process.

In addition, during ore processing the ore is treated with the addition of sulfuric acid (H$_2$SO$_4$), and following the removal of lithium, the pH is adjusted with the addition of sodium carbonate (NaHCO$_3$) to increase the residue to a pH of about 8 before being deposited as a slurry in the tailings storage facilities.

Given that tailings are co-disposed within the tailings storage facilities, for the purposes of this AMD assessment the technical and the chemical grade tailings are characterised together.

2.5 Proposed waste rock and ore tonnages

The proposed ore and waste rock tonnages are presented in Table 2-2. The Table also shows the number of elemental analysis results undertaken by Talison, and the recommend sampling requirements based on guidelines.

The Table indicates that density of samples numbers (obtained by Talison) is over and above that required to satisfy the requirements to characterise the ore and waste rock.

Table 2-2 Rock type – proposed mined tonnages and assay sample numbers

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>Proposed mined mass (Mt)</th>
<th>No. of samples with elemental* analysis</th>
<th>No. of samples recommended (based on Mt, &amp; QLD EPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphibolite waste</td>
<td>202</td>
<td>1,951</td>
<td>330</td>
</tr>
<tr>
<td>Dolerite waste</td>
<td>57</td>
<td>967</td>
<td>180</td>
</tr>
<tr>
<td>Granofels waste</td>
<td>63</td>
<td>1,022</td>
<td>188</td>
</tr>
<tr>
<td>Mafic clay waste</td>
<td>38</td>
<td>353</td>
<td>150</td>
</tr>
<tr>
<td>Pegmatite waste</td>
<td>185</td>
<td>7,577</td>
<td>310</td>
</tr>
<tr>
<td>Pegmatite ore</td>
<td>175</td>
<td>20,790</td>
<td>290</td>
</tr>
</tbody>
</table>

* Al$_2$O$_3$, As$_2$O$_3$, BaO, CaO, Cs$_2$O, Fe$_2$O$_3$, K$_2$O, Li$_2$O, MgO, MnO, Na$_2$O, Nb$_2$O$_5$, NiO, P$_2$O$_5$, PbO, Rb$_2$O, Sb$_2$O$_3$, SnO$_2$, SO$_3$, SrO, Ta$_2$O$_5$, TiO$_2$, ZnO and ZrO$_2$
Simplified Regional Geology

(Reproduced from Ingham et al, 2011)
Simplified Local Geology

Assessment of acidic metalliferous drainage

Figure 2

(Reproduced from Ingham et al, 2011)

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Schematic Cross Section
(reproduced from Ingham et al, 2011)

Talison Lithium Limited
Assessment of acidic
metalliferous drainage.

Figure 3

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3. Geochemical data and information inputs

3.1 Talison mineralogical assay and drill hole database

Talison provided GHD a Drill hole database, which included a record of mineralogical assay data and drill hole survey information, undertaken during drilling programs completed between 1979 and 2017.

The database includes a total of 1073 collar locations of which 1058 have assay records. The total dataset includes a record of around 75,000 assay samples.

The Talison laboratory analysis was undertaken using XRF and Atomic Absorption Spectroscopy (AAS) methods, and the concentrations were reported in their oxide form as percent, with level of reporting ranging from 0.002 to 0.005%.

The mineralogical assay data includes the in-house analysis for the following parameters: Al₂O₃, As₂O₃, BaO, CaO, Cs₂O, Fe₂O₃, K₂O, Li₂O, MgO, MnO, Na₂O, Nb₂O₅, NiO, P₂O₅, PbO, Rb₂O, Sb₂O₃, SiO₂, SnO₂, SO₃, SrO, Ta₂O₅, TiO₂, ZnO and ZrO₂.

Assay analysis is undertaken at the greatest frequency on those lithologies identified as pegmatite i.e. it is targeting the ore body. Within these zones, a near continuous assay record is available (i.e. assay sampling at least every 1 metre). In non-ore zones the assay record is more infrequent, and it is common to undertake 1 metre assays at 10 metre intervals (eg: see Figures A1 to A12, Appendix A).

The density of the collar locations/drill holes with schematic sulphur assay data locations (blue trace) are shown on Figure 4.
3.1.1 **Clipping of assay data within proposed pit**

The Talison assay data and drill holes were "clipped" to exclude zones which are not to be mined (areas beneath proposed pit shell) and zones which have been previously mined (within current pit shell).

A schematic cross section of the existing and proposed pit is shown below in Figure 5, which highlights the clipping of the following drill holes.

- outside of the proposed mining pit boundary (type A);
- beneath the proposed mining pit (type B, D and G); or
- already mined, i.e historic Drillholes (type E, F and G).

The clipped mineralogical assay data resulted in a total of 755 collar locations with assay data within the proposed mining zone. Within these collar locations, a total of around 40,000 assay samples are available. This subset of the mineralogical assay database forms the primary dataset that will be assessed for the purposes of AMD (hanging wall and ore zones).

Figure 4  Sample locations (based on Sulfur assay data – see blue trace)
LEGEND: Types of Drillhole with assay data
- Assay data within mine proposal
- Assay data outside of mine proposal
A: All assay data outside of mine proposal area
B: All assay data beneath mine proposal area
C: All assay data within mine proposal area
D: Part of assay data within mine proposal area, part beneath
E: All assay data in area already mined
F: Part of assay data within mine proposal area, part already mined
G: Part of assay data within mine proposal area, part already mined, part beneath pit

Figure 5  Drillhole locations clipping detail
### 3.2 Previous relevant AMD studies

#### 3.2.1 Introduction

A summary of the previous studies which have been completed on the previously mined and existing waste rock dump (Floyds Dump) and tailings (TSF2) are presented in Table 3-1.

The results of previous AMD studies, are considered relevant to this study, given that the mining proposal comprises development and extension along geological strike and depth of the previously mined ore body and waste rock. The findings are discussed in detail in the following Section, 3.2.2.

#### Table 3-1 Previous relevant studies

<table>
<thead>
<tr>
<th>Study ID</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graeme Campbell &amp; Assc., 2000a</td>
<td>Static testing of 51 waste rock samples to quantify the acid formation potential. Testing included Acid Neutralising Capacity (ANC), total sulphur/sulphate and Net Acid Generation (NAG), and pH/EC.</td>
</tr>
<tr>
<td>Graeme Campbell &amp; Assc., 2000b</td>
<td>Multi element laboratory analysis of 53 waste rock samples, comprising 34 elements.</td>
</tr>
<tr>
<td>Maree, 2015</td>
<td>Kinetic testing of five waste rock samples, including sulphur and Acid Neutralising Capacity (ANC).</td>
</tr>
<tr>
<td>GHD 2014</td>
<td>Characterisation of geochemistry of process/tailings waters, coupled with assessment of impacts to groundwater derived from process/tailings waters.</td>
</tr>
<tr>
<td>GHD 2016</td>
<td>Preliminary assessment of AMD risk from the Tailings Storage Facility 2 (TSF2), through assessment of elemental data (eg: metals and sulphur).</td>
</tr>
<tr>
<td>GHD 2017</td>
<td>Updating of kinetic testing with additional data for the five waste rock samples (see Maree 2015)</td>
</tr>
</tbody>
</table>

#### 3.2.2 Previous study results and summary

**Graeme Campbell & Assc., 2000a**

**Scope:** Static testing of 51 waste rock samples to quantify the acid formation potential (26 amphibolite, 17 granofels, 6 dolerite, and 2 pegmatite).

The waste rock samples were considered suitable with which to characterise the waste rock, given that the samples were randomly gathered from the base of the Cornwall Pit and from drill hole cuttings.

Static testing included 51 samples for Acid Neutralising Capacity (ANC), total sulphur/sulphate, pH/EC and 15 samples for Net Acid Generation (NAG).
**Results:** The geochemical testing indicated the following:

- The maximum sulphur content is 1.3% as S, with an average of 0.14% as S (median 0.1% S).
- A total of 46 waste rock samples were deemed Non-Acid Forming, based on the excess of ANC (which exceeded potential acid production).
- Of the 51 samples, 15 samples with relatively elevated sulphur content (eg: >0.13%) and which were tested for NAG, indicted a total of five of these samples were deemed as PAF.
- Four of the five sample which we deemed as PAF, were derived from granofels (foot wall), while the remaining sample was derived from weathered dolerite.

**Conclusions:** Graeme Campbell concludes that where total sulphur values are less than 0.3% “Buffering by ferro-magnesian silicates (principally hornblende and biotite) ensures that the acid produced from weathering of the pyrite is effectively neutralised.” Where total sulphur is greater than 0.3%, the author recommends that the material is selectively handled and encapsulated.

**Graeme Campbell & Assc., 2000b**

**Scope:** Multi element laboratory analysis of 53 waste rock samples (collected during Graeme Campbell, 2000a), comprising 34 elements (NATA accredited laboratories).

To identify elements of concern which may pose an adverse risk (eg: leaching), the multi elemental analysis results were compared to a Geochemical Abundance Index (GAI).

**Results:** As, Sb and Li generally were enriched while elements Ta, Cd, Sn, Se, Tl, Bi, and B were slightly enriched (compared to the GAI).

In general, greater enrichment of As, Sb and Li occurred within the granofels - particularly As where the occurrence was associated with arsenopyrite.

**Conclusions:** Graeme Campbell concludes, “The results indicated that the waste rock of the Cornwall Pit have concentrations of the most environmentally significant elements, either below or close to those typically recorded for un-mineralised zones…However, all litho-types are variously enriched in As, Sb and Li”.

The author (GC) recommended that given elevated concentrations of arsenopyrite within the granofels material - proximal to ore body, the granofels may require selective handling and burial to prevent drainage waters impacted by low pH and high As (and sulphate).

**Graeme Campbell & Assc., 2014**

**Scope:** The scope comprised the assessment of surface water quality derived from seepage emanating from Floyds waste rock dump (one surface water location). The water quality parameters assessed included major ions, pH/EC, and Li, measured monthly over a 16 year period (1997 to 2013).

**Results:** The waste rock dump drainage exhibited the following surface water/seepage drainage water quality:

- Relatively stabilised pH over the long term, circa 7.5 (exhibits seasonal variations evident).
- EC values from 2,500 to 3,500 uS/cm, dominated by sulphate>chloride>carbonate.
The relatively elevated sulphate (~1,000 mg/L) supports derivation from sulphide oxidation of the waste rock.

The dissolved carbonate (50 to 150 mg/L) is considered to reflect dissolution of calcite (buffering)

The Li concentrations are low, and have stabilised at a concentration of close to 1.5 mg/L.

**Conclusions:** Graeme Campbell concludes that the detailed monitoring of drainage-water quality from the Floyds waste rock dump provides invaluable empirical data, derived from a “whole-dump-scale” and reflects a long-term leaching assessment (16 years).

In addition, the author concluded that the “buffering by calcite - bearing amphiboles has the dual benefit of curtailing sulphate oxidation rates (via promoting surface-armouring [of sulphides with Fe oxides]), and instantly neutralising the acidity generated from sulphide oxidation.”

**GHD 2017 (review of Maree, 2015)**

**Scope:** Long term kinetic testing of seven waste rock samples (2 ½ years).

The scope included column leach testing and laboratory analysis of the leach waters (USEPA method 1627), together with sulphur analysis (MPA) and ANC.

**Results:** The neutralising capacity (ANC) and potential acidity (MPA) results indicated that there is large excess of acid neutralisation capacity (carbonates) compared to potential acid production (sulphide oxidation). Based on these results (elevated ANC:MPA ratios, >2), the guidelines indicate that there is a high probability that the waste rock material will remain circa-neutral pH (AMIRA 2002).

After an initial period of rapid sulphate production derived from granofels rock type, the column leach tests indicated that for the representative waste rock types (granofels, dolerite and amphibolite) the rates of sulphur oxidation and bicarbonate production were stable, which resulted in a circa neutral pH.

**Conclusions:** The large excess of carbonate (confirmed through ANC tests) appears to be adequate in neutralising the acid produced by sulphide weathering, resulting in a stable and near neutral pH within the seven column leach tests over the long term (2 ½ years).

**GHD 2014**

**Scope:** Characterisation of geochemistry of process/tailings waters (coupled with assessment of impacts to groundwater derived from process/tailings waters).

Following slurry style deposition of the tailings onto the storage facility (TSF2), discharging seepage is captured by drains excavated into the toe of tailings facility. The seepage is directed/pumped to holding dams – and together make up the water circuit and supply for ore processing and slurry deposition. The tailings circuit waters are actively managed to pH 8-8.5 with addition of sodium carbonate to prevent metal mobilisation.

The geochemical characterisation included an assessment of the seepage water quality derived from the tailings seepage (four locations, TSF1 and TSF2) and holdings dams (four dams) for major-ions, metals and physio-chemical parameters, with monthly data from 1997 to 2014.

**Results:** The assessment of the tailings seepage/dam waters (GHD 2014) indicates that the drainage waters are circum neutral and are moderately buffered (bicarbonate), likely due to the
addition of sodium carbonate during ore processing. The chloride concentrations are stable (~300 to 350 mg/L).

The metal laboratory analysis, restricted to selected metals – indicates a small number of metals appear elevated above that of background (e.g. arsenic, lithium). The presence of these elevated metals in the tailings drainage/circuit waters indicates that either, leaching is occurring from the tailings during weathering processes, and/or liberation of the metals occurs during ore processing.

**GHD 2016**

**Scope**: Preliminary assessment of AMD risk from the Tailings Storage Facility 2 (TSF2), through collation of elemental assay data from the ore and the tailings.

**Results**: The buffering capacity (ANC) of the material was not calculated, given that carbonate assay data was not available, and that the calcium assay data cannot be solely or partially attributed to calcite (eg: calcium in tourmaline). As a consequence, the maximum potential acidity calculations are based solely on the sulphur values.

The data assessed indicates that based on the average sulfur concentrations (99%UCL), the calculated values of Maximum Potential Acid (MPA) are as follows:

- Tailings: 0.12 kg H₂SO₄ / tonne *(based on 1932 samples)*
- Ore: 0.04 kg H₂SO₄ / tonne *(based on 591 samples)*

The slightly elevated sulfur content within the tailings material, compared to the ore is likely to reflect the residual sulfur (as sulfate), following the addition of sulphuric acid during ore processing.

The assay data indicates there are a total of 10 metals at elevated concentrations (above the average crustal abundance), within the ore (As, Al, Bi Co, Cs, Hf, Li, Nb, Pb, Rb, Sb, Sn, Ta, Th, Ti, U and W) and 5 metals within the tailings (As, Cs, Li, Rb, and W), which if liberated from the tailings storage facilities may be also deemed “metals of concern”.

**Conclusions**: Given the very low sulfur values (close to zero), the classification of the ore and tailings is considered reflective of a “Non-Acid Forming” despite the absence of data supporting buffering capacity.
4. AMD assessment results

4.1 Spatial presentation of mineralogical and assay data

A plan showing drill hole locations, schematic sulphur concentrations, and cross section traces is presented as Figure A0 in Appendix A. Cross sections are presented in Figures A1 to A12 (Appendix A), which show the drill hole traces, pit outlines and lithium and sulphur concentrations.

The assessment of the mineralogical data base and drill hole information indicates the following:

- The Figures (A0 to A12) show that spatial characterisation of the ore body and waste rock has been achieved by completing mineral resource drill holes, which are based close to a 50 metre grid. The drill holes are generally inclined and intersect the hanging wall, ore zone and foot wall.
- The Figures A1 to A12 show that location of elevated sulphur concentrations appear to be generally associated with the contacts of the pegmatite and the waste rock.
- The Table 2-2 indicates the numbers of mineralogical assays within the hanging wall, ore zone and foot wall is over and above that required to satisfy the guideline requirements.
- The mineralogical assays comprise analysis (as oxide) for 25 elements comprising common rock forming elements and metals. (Al, As, Ba, Ca, Cs, Fe, K, Li, Mg, Mn, Na, Nb, Ni, P, Pb, Rb, Sb, Si, Sn, S, Sr, Ta, Ti, Zn and Zr)

Given the above information, it is considered that there is sufficient spatial, mineralogical and elemental data to adequately characterise the initial AMD potential and risks associated with the ore and waste rock.

4.2 Acidic Drainage

4.2.1 Ore assessment

Sulphide occurrence in ore

The mineralogy of the ore is presented in Section 2.3. The description of the ore mineralogy indicates that sulfur is not observed within the ore as potentially acid generating minerals (sulphides) and sulfur is not present as non-acid generating sulfur minerals (e.g. gypsum). Trace sulphides are however, noted where inclusions of footwall dolerite occur as pods within the pegmatite material (Behre Dolbear, 2011), although this material will be separated from the ore and included in the waste stream.

The ore elemental assay data have been presented as a statistical summary as Table 4-1. In addition, a cumulative frequency histogram for sulfur (as S% values) for the ore is presented in Figure 6.

As a conservative assumption, the sulphur is deemed present as sulphides.

Data for the ore (Table 4-1 and Figure 6) indicates that sulfur is detected at concentrations generally below the level of reporting (0.001%), with an average concentration of 0.007%. The data shows that of the 20,790 samples with sulfur data, 57% of the sulfur concentrations were measured below the level of reporting 0.001%.
The tabulated data indicate that the average concentrations of sulfur in the ore (0.007%) are lower than the average crustal composition of 0.035%, and as a consequence do not exceed the GAI (GAI greater than 3 indicates enrichment).

The Geochemical Abundance Index (GAI) is a measure to compare the elemental concentration of a sample (e.g. waste rock) to that of the median abundance in the most relevant background media (soils, crustal abundance etc.). The purpose of the GAI is to provide a relative indication of any elemental enrichment that may be of environmental importance/concern. The GAI is considered as an indicator of elements to be assessed in more detail (e.g. leaching studies).

**Carbonate occurrence within ore**

Carbonate assay data is not available for ore. In addition, the occurrence of calcium within the assay data cannot be solely, or partially, attributed to calcium carbonate, given that calcium is present within the minerals which make up the ore (e.g. feldspars, tourmaline, fluorapatite).

The mineralogy (Section 2.3) indicates that carbonate minerals have not been identified within the ore as primary or secondary minerals (e.g. calcite and/or dolomite). Anecdotal evidence (Daryl Baker Pers.com) supports the occurrence of carbonates within some fractures and joints within the ore body, but carbonate is not considered associated with the major deformation and mineralisation event. As a consequence, carbonate is not deemed a significant or measurable constituent of the ore body.

**Acid base accounting of the ore**

Based on the statistical average of sulfur concentrations (see Section 4.2.1), the calculated values of Maximum Potential Acid (MPA) of the ore is 0.19 kg H₂SO₄ / tonne.

For the purposes of this study the carbonate occurrence of the ore is deemed as negligible, and as a consequence, the neutralising capacity (ANC) is also deemed as zero.

Given the Equation 1 below (AMIRA 2002), the Net Acid Production Potential (NAPP) equates 0.19 kg H₂SO₄/tonne ore. Despite the low concentration of sulfur, which support that the risk of adverse impacts from acid leaching is low, according to the guidelines (AMIRA 2002), the AMD classification of the material is indicated as “Uncertain”, given that buffering capacity of the material from carbonate is deemed as negligible (zero).

\[
\text{Equation 1: NAPP} = \frac{\text{MPA} \times \% \text{Total S} \times 30.6}{1 + \text{ANC} \times (\% \text{CaO} \times 17.5 + \% \text{MgO} \times 24.3)}
\]

4.2.2 Waste rock assessment

**Sulphide occurrence within waste rock**

The mineralogy of the waste rock is consistent with generalised descriptions of dolerite, amphiboles and granofels (Daryl Baker mine geologist pers. comm). Sulphide is not noted within the waste rock excluding relatively minor amounts associated with the contacts of the waste rock with the ore body or where inclusions of dolerite occur as pods within the pegmatite material.

The waste rock elemental assay data have been presented as a statistical summary in Table 4-2. In addition, a cumulative frequency histogram for sulfur (as S% values) for the waste rock is presented in Figure 7.

Data for the waste rock (Table 4-2 and Figure 7) indicates that sulfur is detected at concentrations generally below level of reporting (0.001%), with an average concentration of 0.04%. The data shows that of the 12,072 samples with sulfur data, 37% were measured below
the level of reporting, at 0.001%. The tabulated data indicate that the concentrations of sulfur (0.04%) marginally exceeded the average crustal composition of 0.035%, and as a consequence do not exceed the GAI index.

**Carbonate occurrence within waste rock**

Carbonate assay data is not available for the waste rock. In addition, the calcium assay data cannot be solely or partially attributed to calcium carbonate, given that calcium is present within the minerals which make up the amphiboles and dolerites (eg: feldspars).

Observations and field testing, however, indicates the common occurrence of carbonates within fractures and joints hosted within the amphibolite waste rock, within the hanging wall. The carbonate observations and field testing plan is presented in Figure 8 and Figure 9 (supplied by Talison geologist).

Based on the Figures and the following reasonable assumptions, the volume of calcite equates to approximately 1,000,000 BCM, or close to 0.5% of the total waste rock mass (~0.3% as CaO):

- The volume of amphibolite is 37% of waste rock volume (Table 2-2)
- Figure 8 indicates at least a 1 cm thick and assumed vertically continuous carbonate veins every 30 cm, resulting in an estimated 0.03 m3/m3 (3%)
- Approximately half the volume of the amphibolite is inferred to possess carbonate veining (Figure 9).
- The carbonate veining, observed in the walls of Cornwall Pit (Figure 8 and Figure 9) is inferred to occur at similar volumes within the amphibolite throughout the new zones of proposed mining.

**Acid base accounting of the waste rock**

Based on the statistical average of sulfur concentrations (Section 4.2.2), the calculated values of MPA of the waste rock is 1.08 kg H2SO4 / tonne.

For the purposes of this study, the carbonate concentrations are estimated at 0.5% within the waste rock (~0.3% as CaO), based on the observations and assumptions presented above (Section 4.2.2).

Given the Equation 1 below (AMIRA 2002), the NAPP equates to - 4.2 H2SO4/tonne. Based on the negative NAPP value, according to the guidelines the AMD classification the waste rock is deemed as “Non - Acid forming”.

\[
\text{Equation 1: NAPP (kg H}_2\text{SO}_4 / \text{tonne)} = \text{MPA } \% \text{ Total S } * 30.6] - \text{ANC } [(\% \text{CaO } * 17.5) + (\% \text{MgO } * 24.3)]
\]
## Table 4-1 Ore elemental assay statistics

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Notes:
1: where below level of reporting, the minimum is assigned as half the level of reporting:
2 assumes normal distribution
Yellow highlights indicates elevated GAI (above or close to 3)
No elemental data for: Ag, Bi, Be, Ce, Cd, Co, Cr, Cu, F, Hf, Hg, Ga, Ge, La, Ln, Mo, Re, Sc, Se, Th, Te, U, V, W, Y
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Notes:
1: where below level of reporting, the minimum is assigned as half the level of reporting
2 assumes normal distribution

Yellow highlights indicates elevated GAI (above >3)

No elemental data for: Ag, B, Bi, Be, Ce, Cd, Co, Cr, Cu, F, Hf, Hg, Ga, Ge, La, Ln, Mo, Re, Sc, Se, Th, Te, U, V, W, Y
Figure 6   Histogram of sulfur content (%) Ore

Figure 7   Histogram of sulfur content (%) Waste rock
Figure 8  Observed carbonate veining in amphibolite waste rock at the former Cornwall pit (source Talison)

Figure 9  Sketch plan indicating extent of carbonate veining at the former Cornwall pit (source Talison)
4.3 Metalliferous drainage

The generalised understanding of the risk associated with metalliferous drainage is based on the following:

- the total concentration of metals/elements within the waste rock and tailings (or ore) against the GAI (index relative to the average crustal abundance), and
- the leachable concentrations of metals/element emanating from the waste rock or tailings.

The current understanding of the metalliferous drainage at Talison is discussed below.

Concentration of metals/elements

The laboratory analysis results of the proposed waste rock and ore, were converted from their reported oxide form as percent, to the elemental forms and expressed as percent.

Statistics were subsequently completed on each element (count, minimum, median, mean, maximum, 99% UCL - assumes normal distribution), the results of which have been presented in Table 4-1 and Table 4-2.

The Ore assay and elemental results (Table 4-1) show the following:

- Of the 25 elements analysed, a total of seven metals were relatively enriched - exceeded the GAI, and include: As, Cs, Li, Rb, Sb, Sn, and Ta.
- A total of 26 elements were not analysed and the concentrations of these elements within the proposed ore is not determined (Ag, Au, Be, Co, Cr, Cu, F, Hf, Hg, Ga, Ge, La, Ln, Mo, Re, Sc, Se, Th, Te, U, V, W, Y)

The waste rock assay and elemental results show the following:

- Of the 25 elements analysed, a total of seven metals were relatively enriched and exceeded the GAI, and include: As, Cs, Li, Rb, Sb, Sn, and Ta.
- A total of 26 elements were not analysed in the proposed waste rock (Ag, Au, Bi, Be, Ce, Cd, Co, Cr, Cu, F, Hf, Hg, Ga, Ge, La, Ln, Mo, Re, Sc, Se, Th, Te, U, V, W, Y)

However, as part of a previous study of previously mined waste rock (GCA 2000) a number of these elements were analysed (Ag, Cd, Cr, Co, Th, U, V, Bi, Se, Mo, B, F). The study found the elements of concern included As, Sb and Li, which were generally enriched, while elements Ta, Cd, Sn, Se, Ti, Bi, and B were slightly enriched (compared to the GAI).

Leachable concentrations of metals/elements

The information presented in Section 4.2 indicates that acidic conditions, which may promote the dissolution and mobilisation of metals, should not prevail in the waste rock and ore.

Specific studies have not been undertaken on the proposed waste-rock and ore (eg: kinetic column leach testing), which relate to assessment of the leachable concentrations of the elements of environmental importance/concern.

4.4 Saline Drainage

Specific studies have not been undertaken on the proposed waste-rock and ore (eg: column leach testing), which relate to assessment of the saline drainage.

However, the information presented in Section 4.2 and Section 2.3 indicates that adverse quantities of saline drainage are not anticipated based on the following:
- Given the low concentrations of sulphides within the waste-rock (which will be buffered by calcite), the contribution from both dissolved sulphate and carbonate should be commensurately low in concentrations.
- Readily dissolvable constituents; (eg: halite, gypsum), which may contribute to saline drainage are not recognised in the ore and waste-rock mineralogy.
5. **Assessment of AMD risk and recommendations**

5.1 **Assessment of ore/tailings**

**Acidic drainage risk (ore/tailings)**

The initial assessment (elemental assay data) indicates that the average sulphur concentration of the ore is low (0.007%, No. of samples 20,790), which supports that the risk of adverse impacts from acid leaching is low (Max. Potential Acidity = 0.19 kg H₂SO₄ / tonne).

However, despite the low concentrations of sulphur within the ore, the classification of the material is indicated as “Uncertain” (AMIRA), given that buffering capacity of the ore is deemed negligible (calcium carbonate data is not available, nor inferable for the ore).

During processing, and following the removal of lithium, the pH or the residual material (tailings) is adjusted with the addition of sodium carbonate (Na₂HCO₃) to increase the pH to~ 8 and buffer the material before being deposited as a slurry in the tailings storage facilities.

Previous studies of long term data (1997 to 2014) indicates that seepage waters derived from the existing tailings storage facilities are circa neutral and are moderately buffered (GHD 2014).

Given that the ore has low sulphur content (assumed as sulphides), and that the observations support that the drainage from the existing tailings facilities are circa neutral (buffered during processing), the risk that the future tailings will generate adverse quantities of acid is considered negligible.

**Metalliferous drainage risk (ore/tailings)**

A large number of elements within the ore has been assessed (total 25), which support that a small number of elements may present a source of environmental concern if mobilised during leaching of the tailings (As, Cs, Li, Rb, Sb, Sn, and Ta).

Specific leaching studies have not been undertaken on the proposed ore or tailings to assess the leachable concentrations of the elements of environmental concern, (eg: kinetic column leach testing).

**Saline Drainage risk (ore/tailings)**

Although, specific saline drainage studies have not been undertaken on the proposed ore/tailings (eg: kinetic column leach testing), previous studies relating to long term data (1997 to 2014), indicates that seepage waters derived from the existing tailings storage facilities possess stable TDS and major-ion concentrations (GHD 2014). As a consequence, the risk of elevated concentrations of saline drainage leaching from the proposed tailings is considered low.

5.2 **Assessment of waste rock**

**Acidic drainage risk (waste-rock)**

The initial assessment (elemental assay data) indicates that the average sulphur concentration of the proposed waste rock is low (0.04%. No. of samples 12,072). Based on field testing/observations and broad assumptions, calcite may comprise as much as 0.5% of the proposed waste rock, which if geochemically available for dissolution should result in excess Acid Neutralising Capacity.
Previous investigations into the acid producing potential of the previously mined waste rock indicate the following (See Section 3.2.2):

- Static AMD testing of waste-rock indicated a low number of samples (5 of the 51) were deemed Potentially Acid Forming (PAF). Where total sulphur is greater than 0.3%, the study indicated that the material may require selectively handling to prevent impacts to drainage waters.
- Assessment of the waste-rock drainage waters, collected over a 16 year period (Floyds dump) supports buffering by calcite bearing amphiboles, with a stable pH (circa 7.5)
- Kinetic column testing of seven waste rock samples (Maree, 2015/GHD 2017), indicates that the large excess of carbonate (confirmed through ANC tests) appears to be adequate in neutralising the acid produced by sulphide weathering, resulting in a near neutral pH within the seven column leach tests over the long term (2 ½ years).

Based on the sulphur values and occurrence of calcite, the classification the proposed waste rock is “Non - Acid forming” (AMIRA, 2002), and together with the previous static, kinetic and waste rock drainage studies, supports that the risk that the waste rock will leach adverse quantities of acid is low.

**Metalliferous drainage risk (waste-rock)**

A large number of elements within the proposed waste rock has been assessed (total 25), which support that a small number of elements may present a source of environmental concern if mobilised during leaching of the tailings occurs (As, Cs, Li, Rb, Sb, Sn, and Ta).

The previous assessment indicated that the previously mined waste rock of the Cornwall Pit have concentrations of the most environmentally significant elements, either below or close to those typically recorded for un-mineralised zones. However, all litho-types are variously enriched in As, Sb and Li.

**Saline Drainage risk (waste-rock)**

Specific saline drainage studies have not been undertaken on the proposed waste-rock (eg: kinetic column leach testing). Previous studies relating to long term data (1997 to 2013) of drainage derived from the existing waste rock dump (Floyds dump) indicates stabilised EC values from 2,500 to 3,500 uS/cm (TDS ~1700 to ~2,500 mg/L).

The risk of more elevated concentrations of saline drainage from the proposed waste rock, at concentrations greater than that observed, is considered low.

### 5.3 Summary and recommendations

The risk of adverse AMD impacts derived from the proposed waste rock and tailings is considered low based on previous AMD assessments of previously mined waste rock and ore - which is directly applicable given the continuity of mineralogy (between the previously mined material and the proposed mined material)

The potential risk of adverse AMD impacts derived from the proposed ore/tailings and waste rock is also considered low given the assessment of the elemental data supplied by Talison (eg: low sulphur content). However, as an additional confirmation, the following specific AMD laboratory testing is recommended:

- Acid neutralising capacity (ANC)
- Net acid generation (NAG)
- Sulphur speciation
- Metals (testing for comprehensive suite - 52 metals)
- Leach testing (major-ions, pH, EC, metals)
- Gross alpha and beta

The numbers of samples required for specific laboratory analysis should be sufficient to statistically justify conclusions relating to the AMD risk and/or requirements for any additional further AMD testing and analysis (e.g., kinetic testing requirements).
6. References


GHD 2014, Stage 3 Integrated Geophysics and Hydrogeological Investigation, Interpretation of Geochemical Data. Report for Talison Lithium Australia (61/30220)

GHD 2016 Characterisation of Acid Metalliferous Drainage potential from Tailings Storage Facility 2 (TSF2) (61/33295)


National guidelines on Acid Metalliferous Drainage (DITR 2007),


USEPA, 2011, Method 1627: Kinetic test method for the prediction of mine drainage quality (December 2011).