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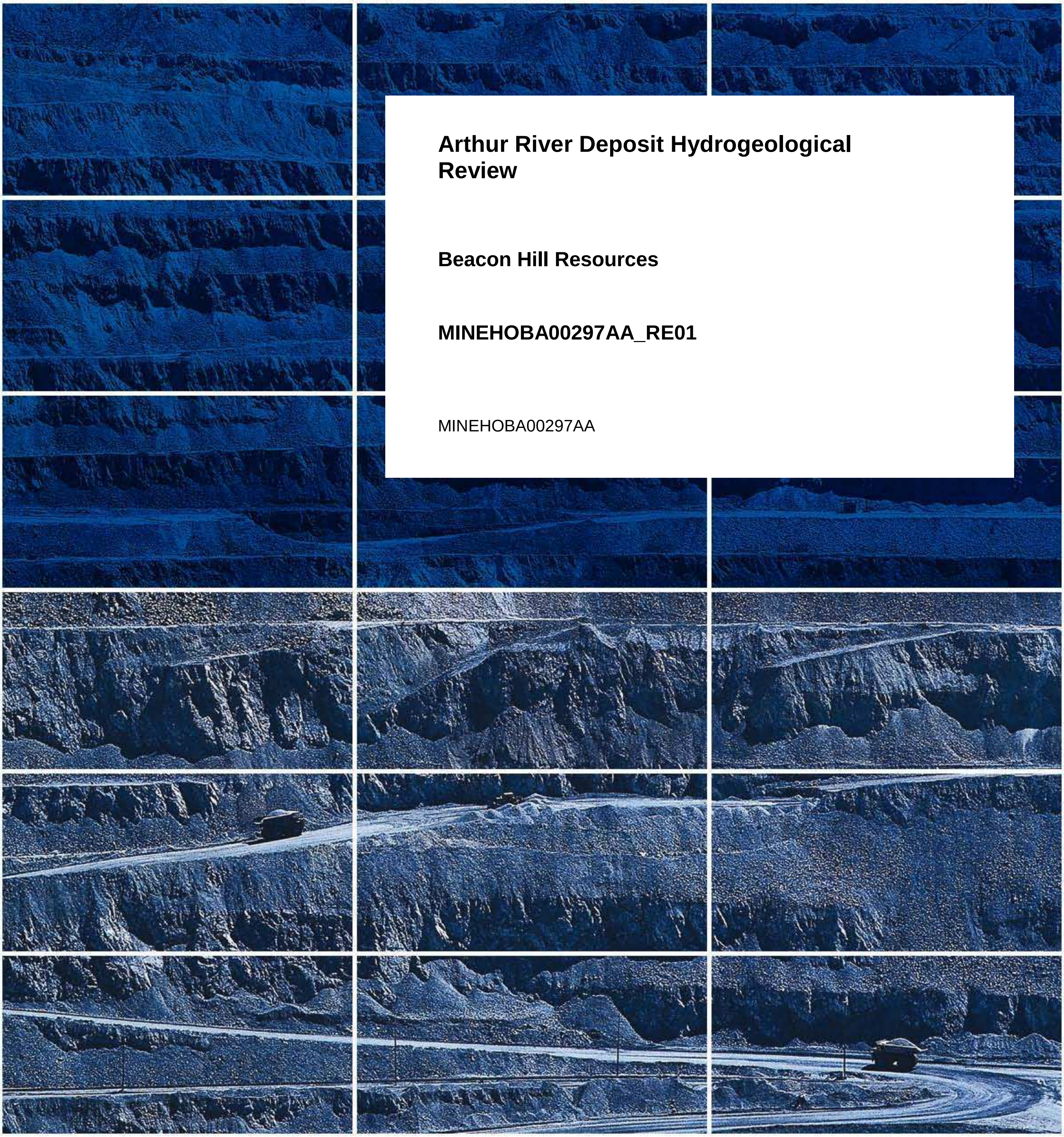

Arthur River Deposit Hydrogeological Review

Beacon Hill Resources

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16 March 2010

Alan Daley
Beacon Hill Resources PLC
Level 6, 22 William Street
Melbourne, Victoria 3000
Australia

Attention: Alan Daley

Dear Alan,

RE: Arthur River Deposit Hydrogeological Review

Please find attached our Arthur River Deposit Hydrogeological Review

For and on behalf of Coffey Mining Pty Ltd

____

Dr Lee Evans
Senior Hydrogeologist

Attachment A: Important Information about your Coffey Report

MINEHOBA00297AA

DOCUMENT INFORMATION

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Document Review and Sign Off

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Senior Hydrogeologist

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Principal Engineer

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EXECUTIVE SUMMARY

This work was commissioned primarily to provide a hydrogeological review of the Tasmanian Magnesite NL Arthur River Deposit to identify and discuss the key risks associated to hydrogeology and hydrology at the site. There has been a significant body of work undertaken in the 1990's on the deposit with the majority of that work focusing on area referred to herein as Pit 1. Based on the previous studies and preliminary site investigations, Coffey Mining believe that the Pit 1 area in the proposed form is high risk, predominantly due to the proximity to the Keith River. That there is an additional proposed mining area available that is well elevated relative to Pit 1, referred to herein as the proposed Pit 2 area, Coffey Mining consider that undertaking a drilling/study program to enable the two areas to be compared would be prudent.

The recommended work plan for the proposed Pit 2 area includes:

- (i) a hydrogeological drilling program parallel to the resource drilling program;
- (ii) undertaking an additional pumping test, modelling exercise and dewatering infrastructure design for the Pit 2 area;
- (iii) incorporating geotechnical logging and analysis into the logging of the resource drilling core (orientated core, therefore inclined holes may will provide additional geotechnical insight, however, vertical holes are more appropriate for hydrogeological testing; as such Coffey recommend any program include both vertical and inclined holes);
- (iv) undertaking geophysical borehole logging including acoustic televiewer imaging and high precision flow meter logging;
- (v) undertaking cross-hole radar at selected locations with identified cavities and large conduits;
- (vi) specific focus on recovering karst sediment during any subsequent drilling potentially through push tubes or triple tube drilling;
- (vii) undertaking geochemical characterisation by sampling both ore and waste core material for discharge water quality prediction;
- (viii) undertaking preliminary geotechnical/hydrological assessments of proposed infrastructure site;
- (ix) upon determining the likely discharge requirements design water settlement, treatment and retaining structures according;
- (x) undertake a detailed risk assessment and pilot testing program for engineering a groundwater retaining structure such as the grout curtain proposed; and
- (xi) undertake a detailed risk assessment and engineering design of any surface water retaining structures;

If the client wishes to pursue the Pit 1 area the recommended work plan includes:

items (iii) to (xi) listed above for the proposed Pit 2 area

1 INTRODCUTION

Coffey Mining were approached to provide a hydrogeological review of the Arthur River Deposit in North Western Tasmania for Beacon Hill Resources PLC (BHR). The scope involved reviewing existing data and a preliminary site visit. The focus was to identify and provide comment on the potential for hydrogeological and hydrological issues to become 'fatal flaws' in both: (i) the mining approach proposed by others (Hatch, 1999), and (ii) the mining approach proposed by BHR (2009). These proposed mining approaches refer to open pits with depths of up to 145 m. BHR (2009) describes the deposit as a large magnesite ($MgCO_3$) body within the north easterly Bowry Formation rocks of the Arthur Metamorphic Complex. The climate is considered wet temperate and mining lease bounds two large rivers the Arthur River and the Keith River.

2 SITE FEATURES AND NOMENCLATURE

The proposed mining site features are presented in Figure 1 (BHR, 2009).

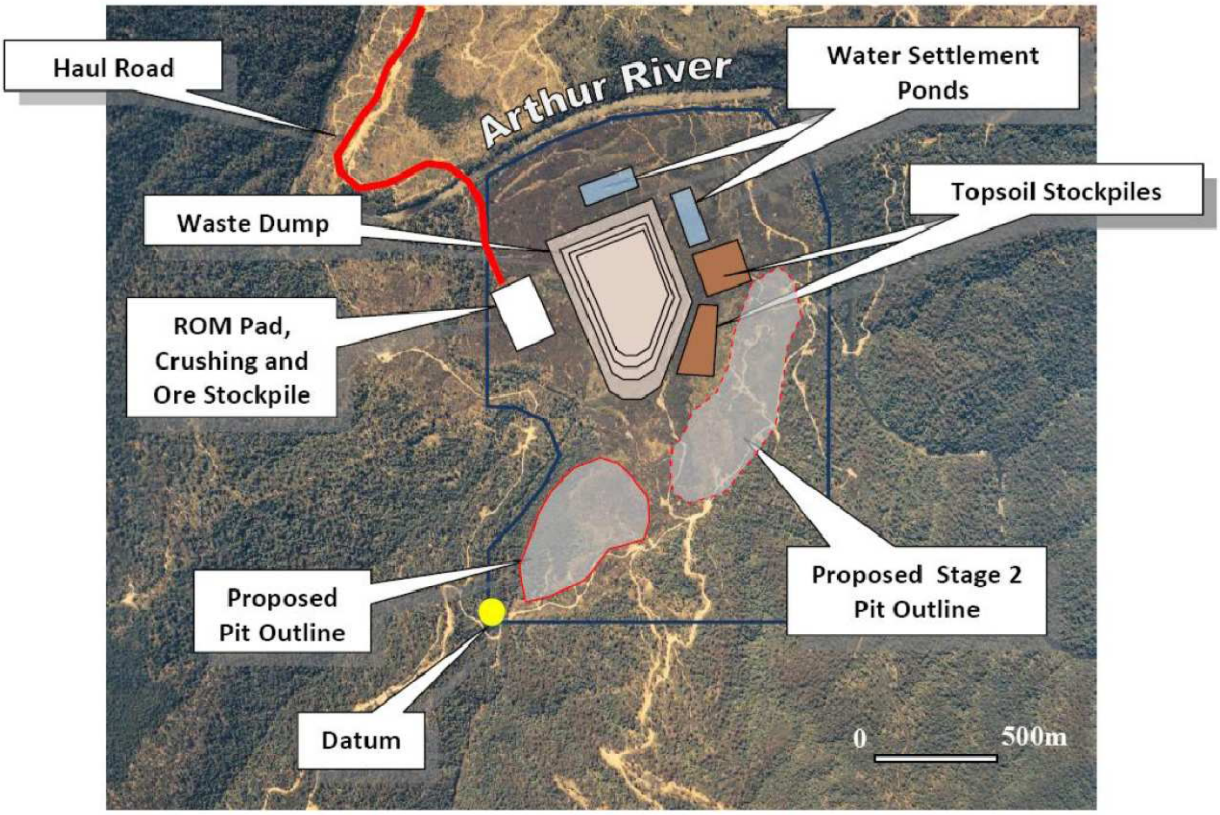

Figure 1 Proposed site mining features and lease boundary (blue) (BHR PLC, 2009)

The physiographical and associated hydrological features of the site are summarised in Figure 2. Searchers Folly and Taylors Hill, to the south and south east of the mine lease respectively, are the local topographic high points at 520 and 500 m AHD respectively. The drainage line (Johnnys Creek) between these two features dissects the mine lease flowing north into the Arthur River, one of Tasmania's major water courses. At the western boundary of the mine lease the Keith River also flows north into the Arthur River. The mining lease is bounded to the north by the Arthur River. A number of local features are referred to throughout this report including; and these too are displayed on Figure 2.

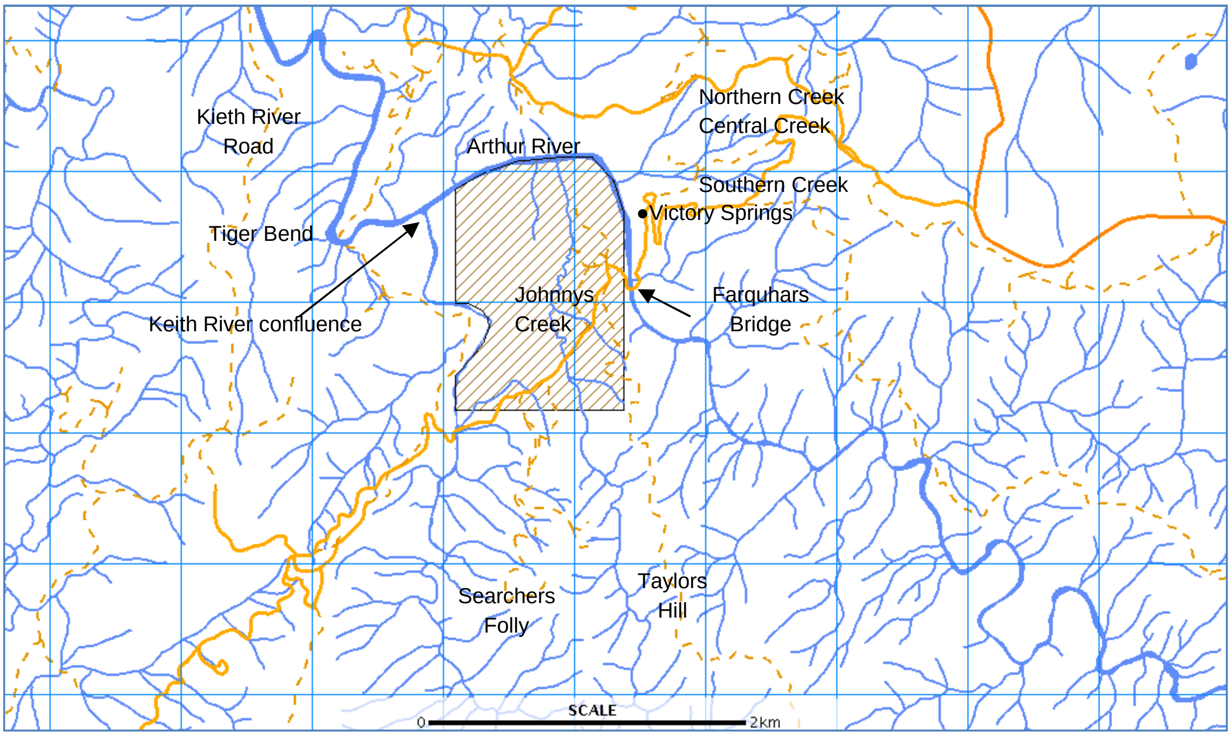

Figure 2 Site features (after The List, 2010); proposed mining lease cross hatched and bounded in black, natural watercourses in blue, roads in orange.

3 PRELIMINARY SITE INVESTIGATION

Three attempts were made to gain access to the mining lease area. On the first two attempts access across the Arthur River was possible, however, not in a location that enabled access to the mining lease. The first attempt was made on foot across the Arthur River at the Keith River confluence and Tiger Bend which did not enable water sampling equipment to be taken due to the depths and flows of the river. The second attempt was on 4WD motorbikes and attempted to work in the Keith River Road and the numerous recreational motorbike tracks throughout the area. The third attempt on foot in March enabled access to the mining lease area.

On the first site inspection seeps were observed precipitating iron oxy-hydroxides and flowing into the Arthur River upstream of Farquhars Bridge (Figure 5). These seeps may provide insight into either the groundwater quality or as hypothesised by Lockley (Lockley, pers. com. 2010) may be related to oxidation of sediments on the banks of the Arthur River sourced from upstream mining operations. These seeps were accessed on the third site visit and sampled to provide potential insight into either groundwater exiting the hangingwall material or river bank sediments.

Weather conditions on all three occasions were variable with intermittent heavy rain and windy conditions. The third occasion on the 9/3/2010 allowed the inspection of the Arthur River after a rainfall event the previous day (Luncheon Hill, 20.4 mm, 8/3/2010, BOM, 2010; Wynyard, 36.4 mm, 8/3/2010, BOM, 2010). These flows were still considered low flow conditions, however, provided insight into the response of the system. Relative to the previous inspections, the Arthur River (Figure 6) was quite turbid after the rainfall event, as was the Keith but to lesser extent (Figure 7). Johnnys Creek was observed and sampled to provide an additional surface water signature for the site (Figure 8).

Monitoring bores dating back to the 1990s were dipped and samples taken for geochemical comparison with previous works. The geochemical results were not available at the time of publication of this draft report. Depths to water were obtained from the monitoring bores MB5, MB4, and MB2 with respective depths of approximately 15.6 m, 17.3 m and <1 m below collar. MB4 was also dipped to full depth (51 m), however, appeared to no longer be functioning and contained no water. Given the logging suggested the hole was totally drilled in the hangingwall ferruginous clays, this is not unexpected after 10 years.

A remnant billabong feature was observed and photographed (Figure 9) and this feature is discussed later in Section 4.3.5

Figure 3 Keith River under low flow conditions from the confluence with the Arthur River (February, 2010)

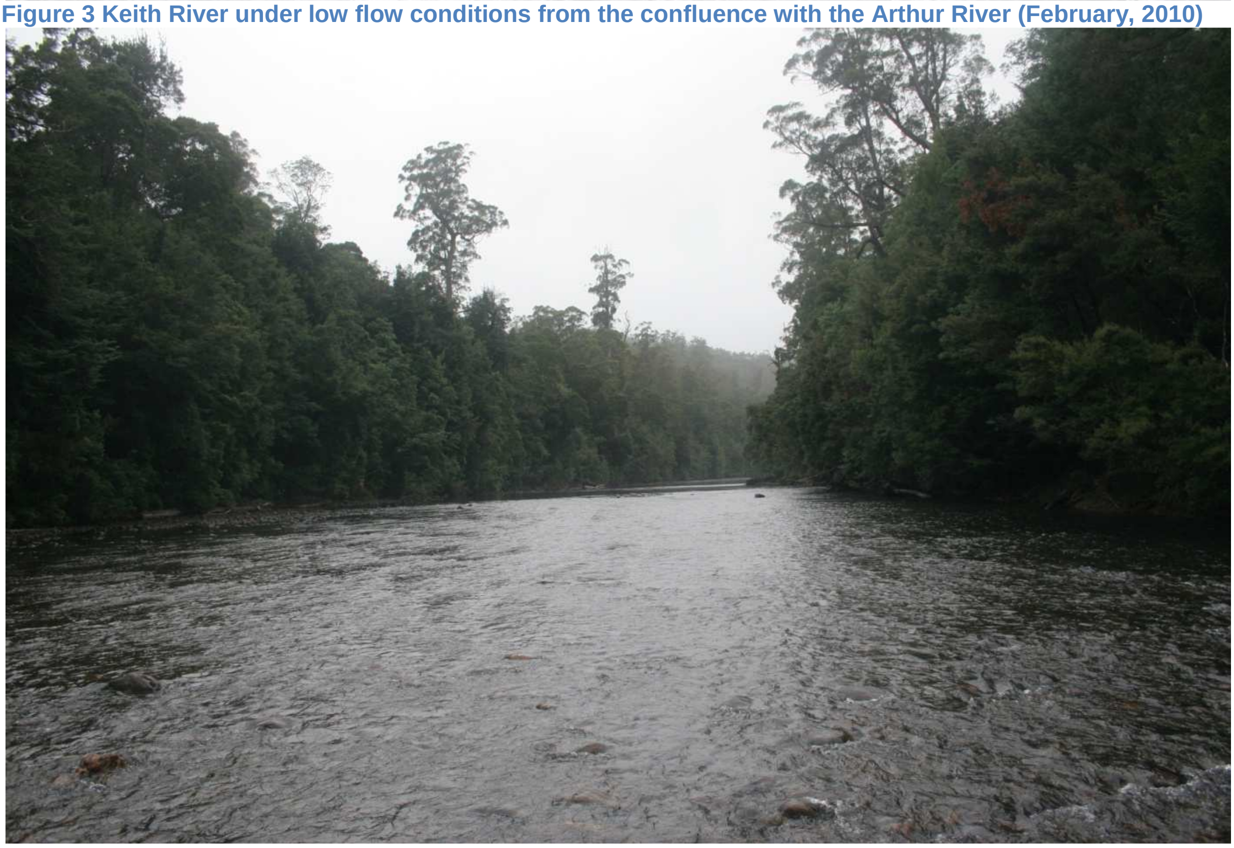

Figure 4 The Arthur River under low flow conditions downstream of the confluence with the Keith River (February, 2010)

Figure 5 Seeps upstream of Farquhars Bridge on the Arthur River bank (February, 2010).

Figure 6 Arthur River at Farquhars Bridge looking East (March 2010)

Figure 7 Keith River above the confluence of the Arthur River (March 2010)

Figure 8 Looking downstream along Johnnys Creek at Farquhars Road (March 2010)

Figure 9 Remnant billabong feature in the area designated for mine infrastructure

4 LITERATURE AND DATA REVIEW

4.1 Summary of previous research

Previous research and background information was primarily from four major sources: (i) Mineral Resources Tasmania (MRT) library documents and resources; (ii) unpublished consultant/company reports from previous exploration companies; (iii) local karst literature; and (iv) web based resources referring to magnesite karst systems.

4.1.1 Deposit information

MRT resources relate to four deposits relevant to this report: (i) Keith River Magnesite (Deposit Id. 430), (ii) Keith River Gossan (Deposit Id. 429), (iii) Arthur River Magnesite (Deposit Id. 426), and the Victory Copper Mine (Deposit Id. 414). Deposits within the Lyons River area are also collectively referred to within this report, however, the focus of the report is primarily the Mining Lease (24M/2009) held by Tasmanian Magnesite NL. The alluvial deposit Campbell Hydraulic (Deposit Id. 408) is also found within the mining lease 24M/2009.

A review of these deposits, and associated geological literature (e.g., McNeil, 1961; Nye, 1977; Thomas, 1981; Frost, 1982; Dickson, 1990; Anon, 1991; Gardner, 1993; Turner, 1993; Osborne and Armstrong,1996; Wyatt, 1997; Calver, 1999; Anon, 2000; Tasmania Magnesite NL, 2002; Bacon et al., 2008; MRT, 2009) provided insight into the hydrogeological setting and conceptual hydrogeological conditions.

The four key geological features are:

(i) the alluvial cover;

(ii) a footwall unit (containing sulphide mineralisation) and a weathered hanging wall unit (associated with sulphide weathering);

(iii) the extensively karstified magnesite units (also containing sulphide mineralisation); and

(iv) dolerite intrusion.

The sulphide mineralisation is highlighted above as it may play a role in the pit water chemistry. The chemistry of pit water may affect the management and pumping of pit water as well as the treatment and discharge of water off site. Both pyrite and chalcopyrite are referred to within the local literature. The proximity to the Keith River Gossan may also have implications for background water chemistry.

A report presenting drill core photography (Wyatt, 1997) provided a visualisation of these materials as core, however, there was little karst fill material recovered. The karst features logged as cavities within the magnesite (and alluvials) are extensive and anecdotal evidence (Wyatt, pers. comm., 1999; and Poke pers. comm., 2009) suggests that they are generally filled with alluvial material. Karst features are discussed further in Sections 4.1.3 and 4.1.4; in the database (Section 4.2) and as they have both hydrogeological and geotechnical implications (Section 5.1).

4.1.2 Unpublished consultant/company reports

The project description (BHR, 2009) document provides the summary document for the background of this report. Unpublished consultancy and company reports provide a more specific insight into the hydrology and hydrogeology. The most relevant reports include the draft DPEMP Pitt and Sherry (1999b) and associated documents (e.g., Pitt and Sherry 1999a; Davis and Cook, 1999; and HECEC, 1999), Hatch (1999) and specifically Golder (1999a and 1999b). The specific hydrogeology and hydrology reports by Golder (1999a and 1999b) are discussed separately in Section 4.3.

The unfinished Hatch (1999) mine plan discusses the mine area and infrastructure with reference to a five stage “Pit 1” area and a “Proposed Pit 2” area which coincide broadly to BHR’s (2009) “Proposed Pit Outline” and “Proposed Stage 2 Pit Outline” respectively (Figure 1). These two pits are referred to collectively herein as Pit 1 and Pit 2. The majority of the geological drilling and hydrogeological research has been focussed on the Pit 1 area.

Hatch (1999) also provides drawings for infrastructure including settlement ponds and waste dumps included a cell titled “pyritic overburden encased in 2.8 m of clay envelope” and states that “Footwall material containing disseminated pyrite has been intersected in the resource drilling. This material will be sealed within a clay area within the waste dump.”

A key item in the report by Hatch (1999) is the proposal that the site will be isolated from the Keith River by a 2 m bund 40 m from the eastern edge of the Keith River. The 100 year flood evaluation for the Keith River is stated as R.L. 145 m AHD. The Hatch (1999) report also introduces the concept of a grout curtain to limit water interaction from the Keith River. These two features are discussed in detail in Section 4.3.4 and Section 4.4.2.

4.1.3 Karst Research

Sharples (1997) and Williams (1999) provide descriptions and discussion on the significance of the Central and Southern Creek area, however, given their location north of the mining lease area (Figure 2) these areas are considered beyond the scope of this report. Potential groundwater impacts (related to drawdown) and impacts to surface features (related to site access) in this area may need to be considered in further works, however, were considered beyond the scope of this report. There is also significant reference to Victory Springs in this area. The Victory Springs area may provide future scope for local geochemical analogies for disturbed areas associated to karst features and exposed sulphides.

Williams (1999) provides the most relevant and descriptive of the karst systems in the Keith-Arthur area covered by the mining lease. He refers to deep superficial fill interpreted as a sinkhole from drilling, however, this is not consistent with the lithology logging in the Crest drilling database. There is anecdotal evidence supported by Poke (Poke, pers. comm., 2010) that sinkhole features were observed during the drilling, and provided problematic conditions when drilling using percussion methods. Williams (1999) provides key statements on the area:

(i) “There are no surface outcrops except near water level close to the Keith and Arthur Rivers”

(ii) “It is clear that subsurface karst is well developed in the area, which is not surprising given the proximity of a large river”

(iii) “A warm spring indicates a natural geothermal circulation”; and

(iv) “There are no features of geoconservation significance in the area except for the subsurface cavities, which may prove to be of scientific interest in the event of deep quarrying.”

Dunn (2005) and ANRA (2009) list mining as “wetland threatening processes” for the Keith River magnesite karst system. They (Dunn, 2005 and ANRA, 2009) refer to the system as an inland, subterranean karst wetlands important for maintenance of ecological processes well developed magnesite karst system. The SOE (2009) lists the “Keith and Arthur Rivers Magnesite Karst” in the karst sites listed in the Tasmanian Geoconservation Database which is available as a GIS layer on the The List (2009) website (Figure 10).

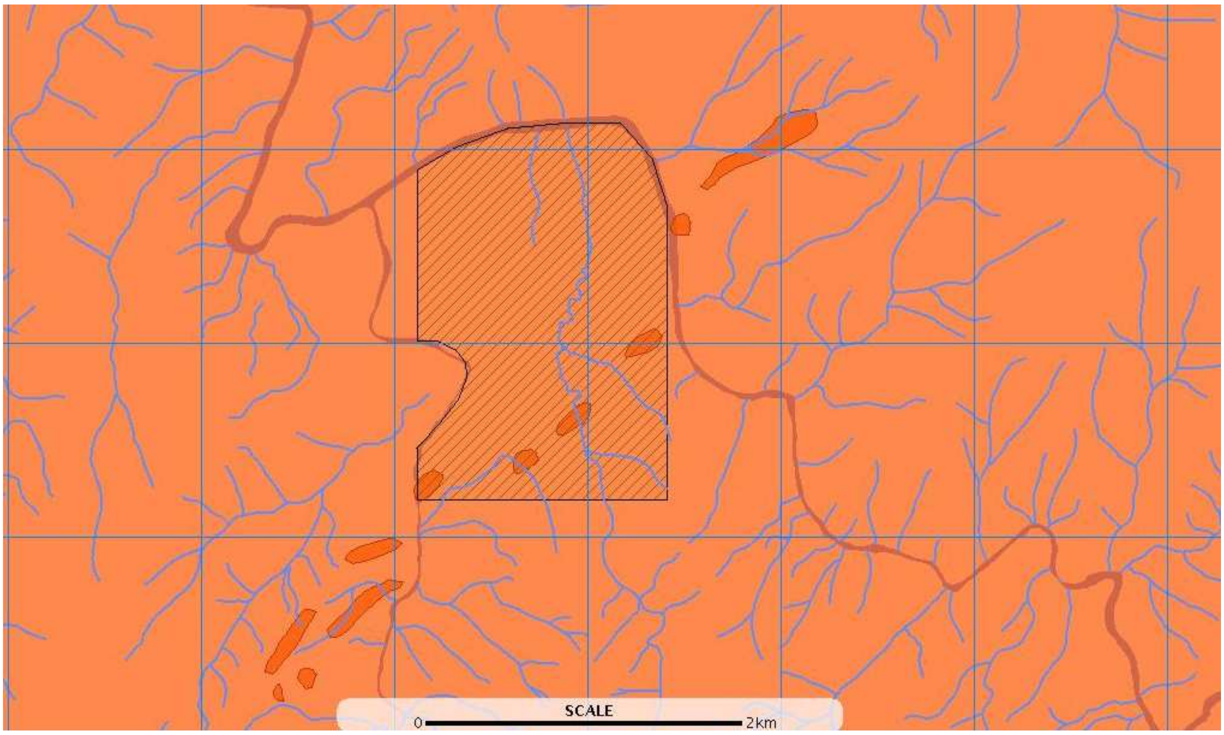

Figure 10 Screen snapshot of the Tasmanian Geoconservation Database (The List, 2009), the proposed mining lease is cross hatched and outlined in black, drainage lines and creeks are in blue, the Keith River and Arthur River in red, the Arthur lineament geoconservation site is in orange and Keith/Arthur Rivers Magnesite Karst geoconservations sites are in bright orange.

4.1.4 Karst Development

Williams (1999) and Pitt and Sherry (1999b) provide summaries of karst forming process highlighting that carbonate rocks (including magnesite). Pitt and Sherry (1999b) highlight that "an increase in the concentration CO_2 in groundwater results in an increased dissolution of carbonate rock by water" due to the formation of carbonic acid. Pitt and Sherry (1999b) also provide local comment into karst forming processes through the work of Technical Advice on Water (1999) "from the magnesium concentrations, pH and alkalinity values Ms Koehnken deduced that CO_2 was readily available within the recharge area due to constant replenishment of soil derived CO_2."

Osborne and Armstrong (1996) present in addition the hypothesis that sulphide weathering plays a significant role in the development of karst features in eastern Australia. Clarke (2009) also discusses the concept of sulphides resulting in dissolution in Tasmanian karst systems. "Many significant limestone caves in eastern Australia (particularly New South Wales, Tasmania) are associated with sulfide deposits and other ore bodies. These deposits have a variety of origins (hydrothermal, paleokarst, volcaniclastic). The sulfides weather on exposure to oxygen - rich vadose seepage water, lowering the water pH and releasing sulfate and magnesium which can lead to the deposition of gypsum and aragonite speleothems. Removal of weathered ores and ore - bearing paleokarst sediments in the vadose zone is, in places, an important mechanism for the formation of large caverns."

Pitt and Sherry (1999b) provide comment on this concept relative to the current geochemistry of groundwater stating that "although pyrite rock occurs in the area, there appears little impact on groundwater sulphate concentrations" and that "generally metal concentrations in the groundwater were low". Whilst this may have been the static condition under saturated conditions, the process of pumping groundwater and mining are likely to change conditions and therefore geochemical processes such that this additional factor in karst development, as well as contamination, may become significant.

4.2 Drilling database

4.2.1 Drilling database visualisation

The Crest drilling database was visualised in 3D using the Surpac 6.03 graphical user interface. The lithology codes were coloured to provide insight into the distribution of logged cavities in relation to the geometries of the deposit geology. Figure 11 below provides a perspective view of selected borehole log information.

4.2.2 Drilling database statistics

The Crest database was also analysed statistically in order to gain an appreciation and extent of the cavities in relation to the deposit geology. Table 1 provides the summary statistics of the logged cavities. A total of 342.85 m were logged with the lithology code "Cavity" of a total of 4660.50 drilled representing 7.4% of the rock mass. Of a total of 3650.75 m logged as magnesite and cavity, cavities account for 9.4%.

Table 1 Drilling database cavity analysis

HOLE ID	Logged cavities percentage of hole	Logged cavities percentage of Magnesite intersection	Total length of logged cavities (m)	Median cavity intersection length logged (m)	Minimum cavity intersectio n length logged (m)	Maximum cavity intersection length logged	Number of logged cavities
AR002	4%	8%	9.65	0.50	0.20	2.80	9
AR003	5%	5%	18.50	3.00	1.50	14.00	3
AR006	21%	26%	74.50	29.70	3.60	41.20	3
AR007	11%	12%	24.80	0.40	0.20	3.00	27
AR008	6%	10%	15.90	1.60	0.40	3.20	9
AR009	0%	0%	0.00	0.00	0.00	0.00	0
AR010	1%	1%	2.10	2.10	2.10	2.10	1
AR011	0%	0%	0.00	0.00	0.00	0.00	0
AR013	2%	4%	4.20	0.85	0.10	2.40	4
AR014	8%	13%	10.30	0.40	0.40	3.70	14
AR015	8%	10%	8.80	0.40	0.40	3.40	14
AR016	3%	3%	7.60	0.95	0.40	1.50	8
AR017	10%	12%	18.30	0.90	0.10	3.00	19
AR018	7%	8%	18.20	0.50	0.20	1.80	30
AR019	5%	9%	6.60	0.40	0.20	1.30	13
AR020	12%	15%	30.00	0.50	0.20	4.30	36
AR021	6%	7%	13.80	0.40	0.10	2.40	19
AR022A	3%	4%	7.70	0.60	0.40	2.50	7
AR023	21%	23%	43.70	0.65	0.20	2.80	42
AR024	7%	29%	4.60	1.15	1.00	1.30	4
AR026	8%	8%	19.70	0.70	0.10	2.40	22
MB002	5%	7%	1.40	0.70	0.40	1.00	2
MB004	1%	4%	0.30	0.30	0.30	0.30	1
MB005	5%	4%	2.20	0.90	0.30	1.00	3
MB006	0%	0%	0.00	0.00	0.00	0.00	0
PB002	0%	0%	0.00	0.00	0.00	0.00	0

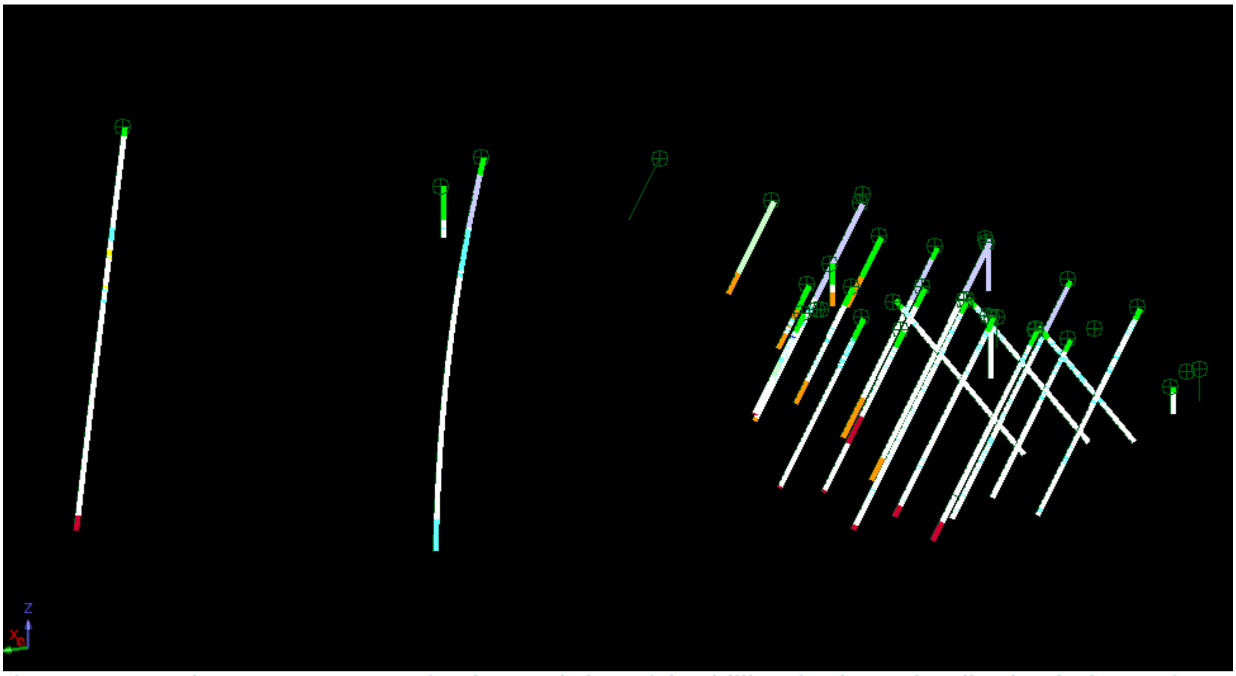

Figure 11 Example output as a rotated orthogonal view of the drilling database visualisation (colours of note are the 'light blue' cavities, 'white' magnesite, 'orange' dolerite, 'green' alluvials, 'red' Footwall and 'purple' Hangingwall).

The conceptual model in Golder (1999b) refers to a 75 m depth where cavities are more likely to occur above, than below. This comment is believed to have originated from comments made by Wyatt (Wyatt, pers. comm., 1999). Coffey believe that the Hatch (1999) report misinterprets this and states that most cavities developed in the magnesite occur within the upper 70 m. The drillhole database indicates that cavities are recorded to be intersected (from) at depths (downhole) of up to approximately 350 m with 95% of cavities intercepted (from) shallower than approximately 200 m (downhole) and 80% of cavities intercepted (from) shallower than approximately 130 m (downhole) (Figure 12). Drillhole database statistics indicate that the median depth of cavities intercepted was approximately 60 m (downhole). These results are further skewed by the number of shallow drillholes. Thus, Coffey believe that it is reasonable to assume that the entire magnesite deposit at depths likely to be mined is karstic and requires management as such. The aforementioned potential misinterpretation has implications in that it appears to form the basis of the conceptual design for the grout curtain discussed in Hatch (1999) which is also discussed later in Section 4.3.4.

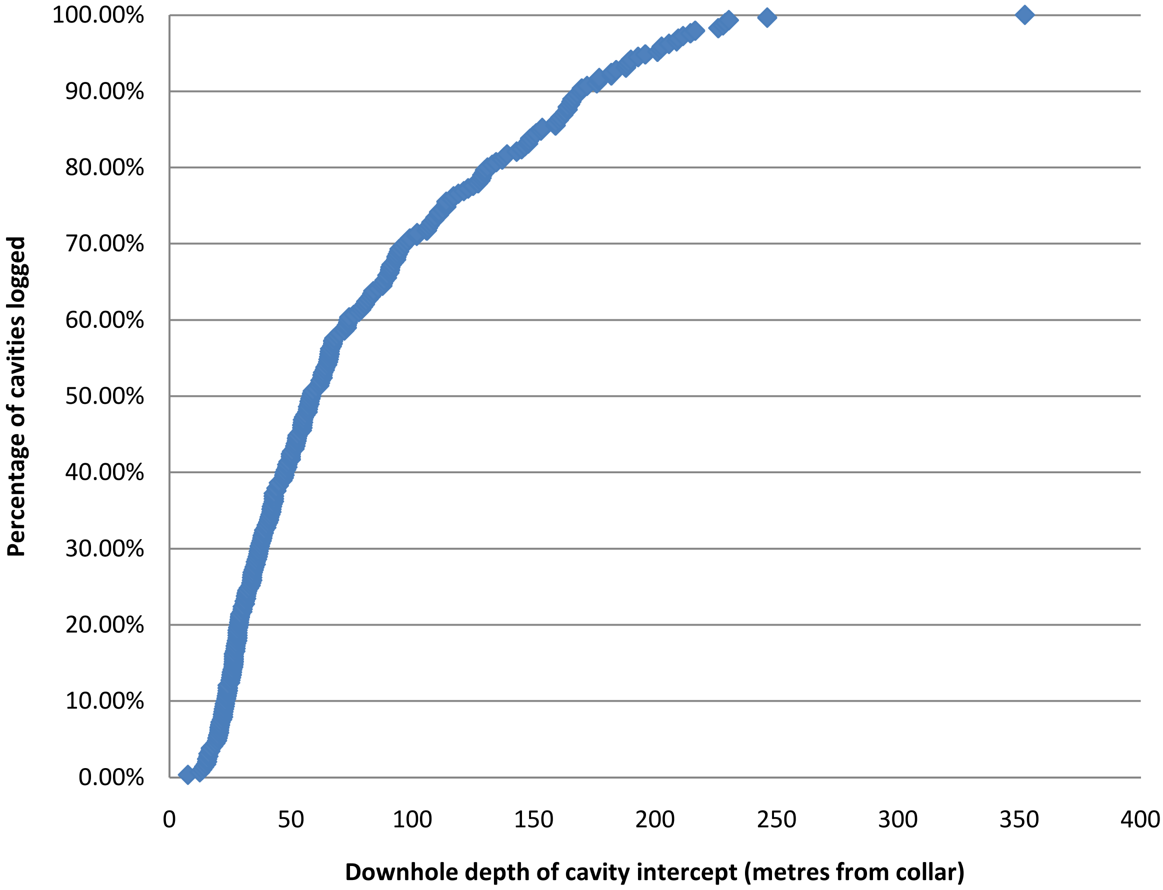

Figure 12 Downhole depths (m) that cavities were intercepted (from) in the drillhole database

4.2.3 Drilling and Karst Connectivity

The visualisation and statistical exercise again highlighted that the karst features were extensive and highly likely to be interconnected especially in the area of the majority of drilling (the Pit 1 area). One of the additional two exploration drillholes in the proposed Pit 2 area highlighted the presence of a very large cavity logged at 41.2 m along the drillhole (AR006) trace. A second cavity of significant length (29.7 m) was also encountered toward the end of AR006 suggesting a different style of karst formation to the much smaller but more frequent cavities observed in the Pit 1 area.

The 26 exploration diamond drill holes (AR*), monitoring bores (MB*) and pumping bores (PB*) that currently intercept the deposit also provide a further conduit mechanism for connectivity between karst features. This is enhanced by the relative competency of the magnesite, however, clay rich magnesite and fill deposits may provide material for blockage of these holes.

4.3 Hydrogeology

4.3.1 Hydrogeological analysis and modelling

The hydrogeology of the proposed pit (Pit 1) area is discussed at length through the analysis of a short term pumping program and subsequent groundwater flow modelling exercise (Golder, 1999a and Golder, 1999b). That the six day test pumping provided relatively uniform draw downs in the karst environment indicates that the system can be validly modelled using the pumping tests as a calibration target.

The test pumping analysis appears to have been analysed with the concept that the system behaves like an equivalent porous media, thus providing valuable input for the groundwater modelling exercise. This approach commonly may be discredited in karst terrain, however, Coffey believes there is merit in approaching the modelling in this manner in this case, especially given the responses that were observed. The test pumping provides valuable information about flows within the karst features and the hydraulic conductivity of the sediments contained in the features in their present form. It should be noted that the model files and calibration information were not provided to Coffey, however, for the purposes of this report it is considered that the Golder (1999b) model provides a reasonable representation of the pump test results.

Coffey believe that the introduction of the materials properties “magnesite barrier” and “magnesite partial barrier” in the computer model (Golder, 1999b) may have been negated by the introduction of a lower permeability material representing the dolerite unit. Dolerite was observed in the drillholes AR002, AR009, AR013, AR014, AR024, AR025, MB004 and presumably AR0012. Depending on the extent and geometry of the dolerite it is expected to behave as a hydraulic barrier and appears as an alternate logical explanation for the limited drawdown observed at MB5 relative to those at MB2 and MB3 (which both would be expected to have lower draw downs than MB5 if influenced by the Keith River and the aquifer was isotropic). The Hatch (1999) report also recognises that the dolerite dyke may provide a hydraulic barrier. Further understanding of the hydraulic barriers such as the dolerite unit may prove beneficial developing an effective mine dewatering strategy.

4.3.2 Pumping requirements

The groundwater pumping rate requirements of 152 L/s as predicted by Golder (1999b) are manageable from a pit dewatering perspective. These volumes could be handled with a primary sump pumping system, however, Coffey would also recommend a second contingency sump pumping system to allow for breakdowns, maintenance and allow for interaction with the active mining area. The concept of multiple sump pumping would require ongoing management and incorporation into the mining method, and in such a climate would be a focal point of the mine design, maintenance and management.

It is worth noting that the BHR (2009) proposal refers to trailer mounted mine dewatering pumps and the Golder (1999a) specifies the additional requirement of floating pumpsets. Whilst trailer mounted (non-floating) would be appropriate for dry conditions and regular pumping of groundwater, they would require significant manning and management during periods of extreme rainfall. It is Coffey's experience that during these periods of extreme weather, manning and moving pit dewatering pumps relative to the pit flooded levels can be a high risk activity. Floating pumpsets in conjunction with associated generators and infrastructure that is designed to be able to be left for significant periods of time in these conditions significantly lowers the risk of: (i) personnel exposed to extreme conditions; (ii) the flooding of the pumps and infrastructure; and (iii) the total flooding of the pit.

Managing incident rainfall (that rain which falls directly into the engineered and limited catchment that contains the mine infrastructure) from storm events is a key challenge in open pits in such environmental settings. The Hatch (1999) and Golder (1999b) discuss the design requirements of pumping and pipework such that most storm runoff be removed from the pit floor within 24 hours for the fully developed stage 3 mine (Pit 1). This increases the sump pumping requirements (including groundwater inflow) by a factor of approximately 3 and over 4 for the fully developed Pit 1. Whilst this is achievable by upscaling pumping capacity and lines there are additional factors which may prevent production resuming within 24 hours of such an event. As such, these design requirements may worth reconsidering based on a cost benefit analysis specific to the mining approach proposed in future works.

The BHR (2009) proposal refers to campaign mining during periods of lower regional rainfall may be more appropriate than aiming to ensure an empty pit in 24 hours. The management of pit dewatering may be altered to align with planned mining campaigns, however, pit dewatering is likely to be a continuous process related to consistent groundwater flow and intermittent rainfall, rather than in planned campaigns.

Managing incident rainfall will be a considerable challenge at the Arthur River Deposit given the setting, however, the capability to manage direct surface water ingress from the Keith or Arthur Rivers is unlikely to be viable with pumping infrastructure. As such mine site designs must ensure that there is a very low risk of water ingress from these surface water features (see Section 5.2.2).

4.3.3 Changes to the groundwater regime

Coffey's experience in mining in karst terrain demonstrates that there can be significant alteration to sediments contained in karst features when subject to nearby blasting, exposure in excavations and high velocity flows related to mine dewatering. Karst features currently filled with sediments could reasonably be expected to flow at higher rates after such events, however, mobilisation of sediments also has implications for pumping. Pumping 'dirty water' can have serious implications on submersible borehole pumps and cause damage to standard dewatering pumps. In addition, the turbidity of discharged water also has implications which are discussed further in Section 4.3.5. Whilst considered valid for the current groundwater regime, the groundwater modelling approach (Golder, 1999b) does not account for, nor could it reasonably be expected to predict these changes in the karst feature sediments related to mining and dewatering.

4.3.4 Engineering features to manage groundwater inflow

The concept of installing a vertical grout curtain to 70 m or solid rock as described in Hatch (1999) is potentially feasible, however, raises a significant number of geotechnical and hydrogeological concerns. These include:

(i) that any engineering attempts to manage flows in the karst features may be complicated by the presence of the sediments within the karst features described above. In contrast, through the use of innovative engineering approaches such as soil mixing/jet grouting with the karst features, the sediments may provide the very medium that ensure the approach is successful. Likewise the mobilisation of the sediments may affect the quality of in-pit water as well as provide issues for the management of the active mining area.

(ii) it appears likely that the karst system is well connected with the Keith and Arthur Rivers (Golder, 1999b and Williams, 1999) and that there is likely to be connection within the karst system to considerable depth;

(iii) a high differential in pressure gradient will be established over a small distance with waters on the west of the grout curtain having a hydraulic head in the order of 139 to 142 m and on the pit side having hydraulic heads at the dewatered pit level. The resultant response may be unplanned relief of higher pressure water (and sediment) in the pit floors and walls. Pit wall and pit floor stability may become an issue if grout curtain is too close to the pit wall;

(iv) in general difficult to test and predict the "quality" and success of a grout curtain in karst. Quality control must be extensive is such terrain to ensure that karst conduits once intercepted by mining will not yield high groundwater flow;

(v) there is potential that although a successfully installed grout curtain will more than likely limit flows through the upper pit walls, which may also assist with geotechnical issues, there will likely be an increased flow (due to differences in pressure gradients) beneath the grout curtain and into the lower slopes. Not only could this encourage high flow rates and sediment displacement within karst features, given adequate connectivity the grout curtain may not lower the overall inflow into the pit significantly.

4.3.5 Water discharge

Managing the ongoing pumping requirements is a matter of correct sizing of equipment and sumps along with ongoing maintenance; however, managing the discharge water is a discipline of a different complexity. Pumping infrastructure can be designed and maintained to perform under most of the likely chemistry and physical properties of water that are likely to occur, however, predicting the chemistry and physical properties of the pit discharge water determines the design of the storage and treatment system, settlement, and quality of the water that is likely to be discharged into the receiving environment.

Hatch (1999) and Golder (1999a) focussed on the collection of suspended solids through the use of settlement ponds. The draft conceptual drainage design document (Golder, 1999a) clearly identifies that it does not address some of the issues of water quality for discharge from the site. These issues include turbidity, dissolved constituents, hydrocarbons (Golder, 1999a). Of these, the dissolved iron content was also identified at the time of the pumping test to likely be problematic for discharge waters. Groundwater pumped and discharged into the Keith River during the test was observed to precipitate large iron oxy-hydroxides and filamentous algae. The pumped groundwater was also said to have a H_2S smell and a "pearly" appearance (Golder, 1999b).

Whilst there is a perception that mining a carbonate orebody will result in alkaline discharge water, the processes associated with acid mine drainage still require consideration from a contamination perspective. The sulphide contents of the Footwall, Hangingwall, magnesite and dolomite will need be quantified and managed accordingly in order to minimise issues associated to acid mine drainage processes. It is assumed that all deposit units will need to be analysed for their potential contaminant contents as well as acid generating and neutralising capacities in order to produce a mine plan which incorporates environmental management (and water management) to a contemporary standard.

Additional mine planning analysis is required to confirm any preliminary hypotheses, however, it is proposed that as the footwall rocks have a high pyrite content, there may be a significant cost benefit in not mining the entire deposit with pit walls extending into in the footwall, thus leaving a buffer of magnesite in the pit walls to minimise the exposure of pyrite. The motivation for such an approach is to initially minimise the potential for acid mine drainage processes as well as the extent and cost of acid mine drainage management infrastructure and long term management required.

The likely contemporary water discharge property requirements for the mining operation need to be determined as part of the DPEMP process and the site water management infrastructure designed accordingly. Both the proposed minesite layouts (Hatch, 1999 and BHR, 2009) allow only a minimal percentage of the available area for the storage (and treatment) of water relative to the available area available and that assigned for mine waste material (Figure 1).

Two preliminary concepts for water infrastructure have been established: (i) a series of cells occupying future areas allocated for waste dumps; and (ii) the strategic use of a low lying remnant billabong feature. It is proposed that a staged modular approach may be beneficial with water settling, treatment and retaining structures initially large occupying areas ultimately designated for future stockpiles. Such an approach provides the 'real estate' or area required to enable a lower risk management of discharge water quality. As the processes are refined and discharge water quality can be assured, less area may be required for water management enabling these areas to be subsequently assigned back to waste dumps. The water retaining structures could then proxy for runoff control bunds around waste rock material. The remnant billabong feature may provide a strategic natural feature that limits the amount of earthworks required in creating water management infrastructure. Coffey consider it appropriate to consider these two new options alongside the Hatch (1999) and BHR (2009) proposals in any future feasibility assessments.

4.4 Hydrology

4.4.1 Rainfall intensity analysis

Pitt and Sherry (1999b) provide an analysis of rainfall intensity based on local and nearby data. Such analysis should be applied dynamically to the surface area of numerous stages of the mine development. This approach was undertaken by Golder (1999a) and can be applied at further stages in the mine design development. There is also application for the developed algorithms to be routinely applied by mine site personal to predict and observe pit water levels associated to specific events further calibrating these models.

Local data as the mine develops will also aid in the hydrological understanding and as such as soon as there is a constant personnel presence on the mine site a local meteorological observation program should be incorporated either into the daily responsibilities or logged automatically with instrumentation.

4.4.2 Surface water flow analysis

Pitt and Sherry (1999b) refer to flood frequency undertaken by HECEC Australia Pty Ltd (1999) with a 1 in 100 year event predicted to a height of 142 m adjacent to the Keith River. It is assumed that the 145 m AHD 100 year event flood level discussed by Hatch (1999) relates to this analysis undertaken by HECEC (1999), although it unclear why the numbers differ other than assuming that there is a 3 m factor of safety. Whilst there is scientific merit in the approach undertaken by HECEC (1999), there is a large element of uncertainly in these levels that present a high risk if the mining operation is reliant on them. These uncertainties include:

(i) the “marked flood level” ascertained by Pitt and Sherry (presumably observed from recent pre1999 flood debris) are “relatively higher than the predicted 100 year flood event” (Pitt and Sherry, 1999b);

(ii) that the calculations were based on distant data sources as there were “no rainfall monitoring or stream flow sites, on either the Arthur or Keith River, in close proximity to the mine site location” (Pitt and Sherry, 1999b);

(iii) that the calculations were justified by the conclusion “that the observed debris level may be due either to log jams and/or a narrower river cross section downstream” suggesting that there are additional factors which could result in higher levels which in turn pose may a high risk to the mining operation; and simply

(iv) that the area is described as “flood prone” (Woodward, pers. comm.,1999).

Additional flood analysis is expected to be required for the Arthur River if not already covered by the HECEC (1999) report.

5 HAZARDS

Whilst geotechnical issues are not the focus of this report, they can rarely be treated in isolation from hydrogeological and hydrological issues, especially in karst settings. As such, geotechnical issues feature prominently in the following discussion.

5.1 Karst features as hazards

5.1.1 Mine infrastructure

Karst features pose geotechnical hazards to mine infrastructure through the potential development of sinkholes and dolines. These problems are enhanced where a veneer of alluvial deposits overlie and mask the karst features as is the case over much of the Arthur River area.

Sinkholes can result in sudden failure whereas dolines are generally associated with large scale depressions. Both features however can be predicted and monitored, lowering the risk of damage to mine infrastructure. It is anticipated that both invasive geotechnical drilling and non-invasive methods (such as geophysics, e.g. ground penetrating radar) will be required for all proposed mine infrastructure locations.

5.1.2 Pit wall and floor stability

The Hatch (1999) study presents Pit 1 walls with batter angles at 40°, 55°, and 65° with 5m catch berms. The Hatch (1999) proposal states that “all open pit faces will be excavated and dressed to reduce erosion” and refers to the potential use of ground support through including fibrecrete and “concrete grouted bird-caged bolts or cablebolts”. A key feature in the Stage 1 mine design for Pit 1 that hatch present is that the highwall is within 50 m of the Keith River.

Coffey has not seen any detailed geotechnical analysis or logging of the core recovered at the Arthur River deposit. Based on the preliminary observation of the core photography and core Coffey believes that any open pit in this material will require considerable geotechnical consideration. In practise it is likely that the geometry and extent of karst features, as well as the weaker units, will influence the achievable pit wall angles. As such mining will be required to be adaptable to both the mapped and unaccounted karst features. The geotechnical properties of karst fill material are likely to be very poor and may be of a similar nature to the alluvials described in Pitt and Sherry (1999).

Mining in karst environments in similar climates is achieved elsewhere and is also analogous to open pit mining in areas containing historical underground workings with poorly understood geometries. There are opportunities for incorporating karst feature identification into the mining process to lower the exposure to hazards associated with them. These include: systematic analysis of blast hole drilling penetration rates (pit floor and wall); systematic analysis of depressurisation drilling (pit wall); routine bench scale non-invasive methods (such as geophysics, e.g. ground penetrating radar, cross hole radar); as well as detailed geotechnical drilling. Monitoring of pit wall and floor movement, pressures and overall stability is anticipated to require significant attention in any pit developed within the deposit.

Karst features also present significant issues in the mining environment related to blasting and placement of explosives. Blasting using standard liquid explosives may not be appropriate over much of the deposit as there is potential for explosive loss, mobilisation and dispersion in karst voids. This has resulted in overblasting, and unsuccessful blasting in other operations. Solid, or encapsulated explosives may provide alternatives for blasting where karst voids are problematic.

5.1.3 Water inrush issues

Karst features and their infill are likely to have varied geometries and properties which determine the water or sediments they both contain and can transmit. Upon exposure or from latter disturbance through the mining process there is a risk associated with sudden water ingress into the pit from karst voids. This risk is elevated where large pressure gradients occur over short distances for example surface water features connected to karst features adjacent to a dewatered pit.

5.2 Climate as a hazard

The climate and specifically high rainfall presents a two-fold hazard to the mining operation: (i) as incident rainfall; and (ii) as surface water flow in the natural watercourse.

5.2.1 Incident rainfall

Incident rainfall requires management in both the pit and throughout the mining area. The hazards include not only total pit flooding but also local flooding affecting geotechnical stability and conditions in the active mine area. Coffey believe that pit surface drainage should be incorporated into the pit geometry design to ensure that it is accounted for at an early stage. Due to the site location, climate and karst features Coffey envisage every bench and every haul road may require space to be allowed for open channel drainage, ultimately reporting to the working sumps. As such the benches should be designed with a fall for drainage. The standard design concept sequence of “batter, bench, haul road, windrow, batter” would therefore be replaced with “batter, drain, bench, batter, drain, haul road, windrow, batter, drain etc…”. Examples of other drainage elements to be included in the drainage design include:

(i) Significant drainage on all service roads

(ii) allowance for diversion of fresh water runoff around the entire pit boundary; and

(iii) incorporate and allow for drainage (including saturated karst features) and sumps into geotechnical designs.

5.2.2 Natural surface watercourses as hazards

Flood vulnerability from interaction with the natural surface water courses is of specific importance as it is assumed that due to the high predicted volumes of the local rivers in such events, if there were a breach of infrastructure allowing direct surface water inflow into the pits, that the proposed pumping systems would not be capable of managing such flows. Such pumping systems could be designed to handle such volumes, however, they are likely to be viable. As such, the factors of safety and confidence incorporated into the design of flood protection should be significant and should be clearly documented. Likewise any mine features that have the potential to impact on flood protection (i.e. a nearby highwall) should have similar factors of safety and confidence incorporated into their design.

Although the Arthur River was only observed under low flows (Figure 4) anecdotal observations of flow over and damage to the Arthur River Bridge or Farquhar's Bridge presents an clear indication of the hydrological risk the Arthur River presents to infrastructure under peak flows. The Keith River was also observed in low flow conditions (February, 2010), however, given its large catchment area and the local environment it is likely that it too could present a significant hydrological risk to the site. Although the Johnnys Creek catchment is of a significantly smaller size than the Keith and Arthur Rivers it is likely that diversions works would be required if any infrastructure were designed to be placed along its course. The location specific hazards and risks of each of the proposed pits are discussed further in Section 5.3.

5.3 Location specific hazards and risks

5.3.1 Pit 1 location

The current "Proposed Pit Outline" (BHR, 2009) referred as "Pit 1" (Hatch, 1999) presents a high risk due to its location immediately adjacent to the Keith River. Due to the Stage 1 of the Pit 1 development starting with a highwall 50 m from the Keith River these high risk elements are exposed from the start of mining through to Stage 5.

These hazards include:

(i) karst conduits with the potential of connecting the proposed pit to highly permeable river bed sediments of the Keith River and surrounds resulting in large pit groundwater and karst sediment inflows, as either long term or sudden events;

(ii) alluvial deposits with unfavourable geotechnical properties, potentially covering as yet identified karst features;

(iii) limitations of engineering solutions for mitigating groundwater flows from the Keith River.

(iv) a low elevation of the pit boundary relative to the Keith River and potential flood elevations;

(v) a limited area for engineering solutions for mitigating potentially sudden surface water flows into the pit from peak flows in the Keith River;

(vi) an increased risk of water management engineering solutions interacting and potentially contaminating (e.g. grout, polymers) the Keith River;

(vii) a limited area to identify (and treat) long term contamination and discharge from the pit prior to it reaching the receiving environment

(viii) discharge of mine water to the receiving environment that does not meet water quality criteria, specifically during extreme weather conditions;

(ix) a likely long term closure scenario of a surface water feature (flooded pit lake) in connection with the river system.

The constructed bund (levee) featured in the Hatch (1999) report would require significant engineering works to be effective (including being incorporated into the grout curtain design proposed in the same document). The levee is proposed to be located in an area predominantly mapped as alluvials at a distance of 40 m from the Keith River making it extremely close to the highwall. The Pitt and Sherry (1999a) report describes these alluvial materials and provides reports of instability in the sediments. Woodward (Woodward pers. comm., 1999) describes the instability observed in the sediments as “spectacular”. As such, it is assumed that any levee would be required to be keyed into competent material below the alluvials to lower the risk of settlement and failure when functioning as a water retaining structure during periods of high rainfall. levee material selection would require careful consideration and engineering to ensure problems associated with water retaining structures such as scouring and piping failure do not occur at critical times when under flooded conditions.

The concept of a levee, on an alluvial setting with a karst basement, immediately adjacent to a pit boundary (and highwall) raises numerous concerns. Designs for such structures need to be according to applicable Australian and international standards for dam/levee design and incorporate numerous factors such as implications of failure, piping, earthquakes, liquefaction etc. The risks associated with the river and such a structure include:

(i) that the structure may be inadequate to prevent flood waters and sediments entering the pit;

(ii) that the structure may be damaged by flood waters and sediments resulting in failure;

(iii) that the alluvials may be reworked damaging or undercutting the structure;

(iv) that saturated karst features with a significantly higher hydrostatic head than the dewatered pit induce pressures and resultant pit inflows (of both sediment and water) either through the pit walls or beneath/around/through a grout curtain

The grout curtain feature has been previously discussed in Section 4.3.4. The limited area available based upon the current Pit 1 designs highlights concerns already raised associated to such a structure. The location of the leaves little room for monitoring such a structures performance or providing contingency if the structure is observed to be underperforming.

5.3.2 Proposed Pit 2 location

The proposed Pit 2 also has risks associated to its location, the lack of information and proposed geometry. The key risk is the lack of geological and thus hydrogeological information, relative to the Pit 1 area. Coffey considers that any additional resource drilling in this area should be accompanied by a hydrogeological program on a similar scale to that undertaken previously at the Pit 1 site. Additional risks include:

(i) that the proposed Pit 2 geometry intersects Johnnys Creek;

(ii) that the Pit 2 geometry is likely to have more interaction with the Arthur River than Pit 1 due to is location; and

(iii) that very large karst features were interpreted in this area specifically in drillhole AR006.

The proposed Pit 2 is likely to have a low point in the pit boundary with an elevation of approximately 160 m AHD in the Johnnys Creek area, but well above the Arthur River elevation. Dependant on resource drilling it may be appropriate to consider a modified Pit 2 to the east of Johnnys Creek (and west of the ridge adjacent to the Arthur River) as a lower risk initial pit option.

5.3.3 Waste dumps and topsoil stockpiles locations

Topsoil stockpiles in high rainfall environments often require significant encapsulation to: (i) maintain the stockpiles form; and (ii) to ensure that topsoil is not eroded in storm events. It should also be noted that the two proposed topsoil stockpile locations are sited on Johnny's Creek. The location of these in any further design work will need to consider the potential for interaction with surface water features.

The geotechnical implications of the geochemistry of topsoil stockpiles and waste dumps may also require consideration. Soil high in available CO_2 may also present a localised problem for the dissolution of the footing below stockpiles. Likewise, oxidising high sulphide waste material may present similar engineering problems. Timeframes in which such dissolution could occur in relation of the life of mine requires further assessment.

5.3.4 Closure

Given the setting and high rainfall, the closure approach that the pit could be flooded to natural water table (BHR, 2009) would likely result in a flooded pit which periodically overflows to the receiving environment at a decant point. This "natural water table" may not reflect the pre-mining water table.

Engineering a decant point that has some distance to travel prior to entering receiving waters may provide an opportunity to treat (potentially passively) discharged pit waters, further endorsing a modified Pit 2 as a lower risk initial option. Long term treatment of mine water after mine decommission (like the operational treatment of pit dewatering) often requires significant relatively flat lying 'real estate' or area. Given the 'alluvial terrace' nature of the northern part of the mine lease, this area may be available for such a use. Depending on the closure strategies adopted there is potential to develop this area as, for example, an engineered passive treatment wetland to provide filtration of the mine water prior to it entering the receiving environment.

5.3.5 Fauna and flora

To date much of the local reference to karst fauna (Suter, and Richardson, 1977 and Richardson and Doran, 1998; Beacon Hill Resources NL, 2009) have related to troglobites. Stygofauna has not as yet been discussed in the literature relating to the mining proposal. Humphreys (2006) provides a summary paper on stygofauna titled "Groundwater fauna" where defines them simply as "animals that live in underground water". The karst features and associated aquifer on the site may provide a suitable habitat for stygofauna and Coffey recommend that sampling be considered to determine or exclude their presence at an early stage in the project.

5.3.6 Impact on surface water features

Predicting the changes of water flow in the creeks adjacent to the mine site over the mine life remains a significant unknown for any excavation at the proposed Pit 2 location. The Golder (1999b) modelling on Pit 1 predicts the decrease in flows in the Keith River will be significant. The requirements for maintaining flows both in the Arthur River and Keith River need to be determined through consultation with the relevant authorities. This was considered beyond the scope of the current report, as were determining the contemporary requirements for discharging water.

Predicting the discharge water chemistry over the mine life remains a significant unknown for both pits and requires a number of additional areas of study. These include but may not be limited to:

(i) a review of the wholerock and mineral geochemistry of both waste and ore;

(ii) further review of groundwater and surface water quality;

(iii) predictive modelling of the development of mine water chemistry over time;

(iv) determining the requirements for discharge quality; and

(v) providing engineering designs for water treatment/settlement infrastructure with the aim of discharging water of a quality that conforms to contemporary requirements.

6 SUMMARY OF RECOMMENDATIONS AND PROPOSED WORK PROGRAM

Based on the previous studies and preliminary site investigations, Coffey Mining believe that the Pit 1 shell in the proposed form is high risk, predominantly due to the proximity to the Keith River. That there is an additional proposed mining area available that is well elevated relative to Pit 1, referred to herein as the proposed Pit 2 area, Coffey Mining consider that undertaking a drilling/study program to enable the two areas to be compared would be prudent.

The recommended work plan for the proposed Pit 2 area includes:

(xii) a hydrogeological drilling program parallel to the resource drilling program;

(xiii) undertaking an additional pumping test, modelling exercise and dewatering infrastructure design for the Pit 2 area;

(xiv) incorporating geotechnical logging and analysis into the logging of the resource drilling core (orientated core, therefore inclined holes may will provide additional geotechnical insight, however, vertical holes are more appropriate for hydrogeological testing; as such Coffey recommend any program include both vertical and inclined holes);

(xv) undertaking geophysical borehole logging including acoustic televiewer imaging and high precision flow meter logging;

(xvi) undertaking cross-hole radar at selected locations with identified cavities and large conduits;

(xvii) specific focus on recovering karst sediment during any subsequent drilling potentially through push tubes or triple tube drilling;

(xviii) undertaking geochemical characterisation by sampling both ore and waste core material for discharge water quality prediction;

(xix) undertaking preliminary geotechnical/hydrological assessments of proposed infrastructure site;

(xx) upon determining the likely discharge requirements design water settlement, treatment and retaining structures according;

(xxi) undertake a detailed risk assessment and pilot testing program for engineering a groundwater retaining structure such as the grout curtain proposed; and

(xxii) undertake a detailed risk assessment and engineering design of any surface water retaining structures;

If the client wishes to pursue the Pit 1 area the recommended work plan includes:

(i) items (iii) to (xi) listed above for the proposed Pit 2 area.

7 REFERENCES

Report References

Anon, 2000, Annual Report covering March 1999 - March 2000. Arthur River Magnesite Project RL8718 - West Takone Crest Magnesium NL 00-4416

Anon, 1991, Preliminary Study Into the Mining of the Lyons River Magnesite Deposit Tasmania, CRA Exploration Proprietary Limited, Savage Resources Limited, RL17/1987, RL18/1987 91-3270

ANRA, 2009, Wetland values Australian Natural Resources Atlas, Biodiversity Assessment – King http://www.anra.gov.au/topics/vegetation/assessment/tas/ibra-kin-wetland-values.html 26/11/2009

Bacon C A, C R Calver, and J Pemberton, 2008, The industrial Mineral deposits of Tasmania, Mineral Resources of Tasmania 13

BHR (Beacon Hill Resources Plc) 2009, Tasmanian Magnesite NL, Mining Lease Application Arthur River Project Description, November, 2009

Calver, C. R., 1999, Tasmanian magnesite resources: a summary. Record Tasmanian Geological Survey 1999/07.

Clarke, A. 2009, Southern Tasmanian Caverneers AN INTRODUCTION TO CAVE PROCESSSES, CAVE RESEARCH & CAVE FAUNA IN TASMANIA By Arthur Clarke http://www.lmrs.com.au/stc/research.htm%2027/11/2009

Davies P.E. and L.S.J. Cook, 1999, Aquatic Environmental Values associated with the Crest Magnesite Mining Development, North West Tasmania

Dickson, T. W., 1990, Arthur River and Lyons River magnesite deposits, in: Hughes, F. E. (ed.). Geology of the mineral deposits of Australia and Papua New Guinea. Monograph Serial Australasian Institute of Mining and Metallurgy 14:1181–1183.

Dunn H., 2005, Assessing the Condition and Status of Tasmania’s Wetlands and Riparian Vegetation Nature Conservation Branch Technical Report 02/09 Revised March 2005

Frost, M. T., 1982, The magnesite deposit at Main Creek, Savage River, Tasmania. Economic Geology 77:1901–1911.

Gardner, D., 1993, Keith River Relinquishment Report and Annual Report - December 1992 to December 1993, Peko Exploration Limited, EL40/1989 93_3529

Golder Associates Pty Ltd (Golder), 1999, Draft report on Preliminary Groundwater Study Crest – Multiplex Magnesite Project, Submitted to Pitt & Sherry, June, 1999

Golder Associates Pty Ltd (Golder), 1999, Draft report on Conceptual Drainage Design Crest – Multiplex Magnesite Project, Submitted to Hatch Australia Pty Ltd, May 1999

Hatch Australia Pty Ltd, 1999, Mine Plan Crest – Multiplex Magnesite Project, May, 1999

Humphreys, W. 2006, Groundwater fauna' paper prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/emerging/fauna/index.html>.

Kiernan, K., 1995, An Atlas of Tasmanian Karst. Research Report No 10 Tasmanian Forest Research Council Inc.

McNeil, R.D., 1961, Geological Reconnaissance of part of the Arthur River Area TR5_46_60

MRT (Mineral Resources Tasmania), 2009, Tiger Database www.mrt.tas.gov.au

Nye, 1977, Progress Reports on Exploration on E.L. 43/70, Arthur River, Tasmania During 1974-1977 Mineral Holdings Australia Proprietary. Limited 78-1243

Osborne, R. and Armstrong L, 1996, Vadose weathering of sulfides and limestone cave development, evidence from eastern Australia Helictite http://www.caves.org.au/helictite/contents3.html

Pitt & Sherry, 1999a Magnesite Mine Overburden Investigation, report prepared for Hatch Australia Pty Ltd

Pitt & Sherry, 1999b Crest – Multiplex Magnesite Mine Arthur-Keith Rivers, Development Proposal & Environmental Management Plan.

Richardson, A. M.M. and Doran, N. E., 1998, Fauna of magnesite karst : field report and scientific assessment, Unitas Consulting

Sharples, C., 1997, Karst geomorphology and values of the Tarkine : limestone, dolomite and magnesite karst systems of the Arthur-Pieman Region of Tasmania : a report to the Australian Heritage Commission and the Tasmanian Conservation Trust Inc.

SOE (State of the Environment), 2009 Karst sites listed in the Tasmanian Geoconservation Database http://soer.justice.tas.gov.au/2009/table/481/index.php 23/11/2009

Suter, P.J. and Richardson A.M.M., 1977, The biology of two species of Engaeus (Decapoda: Parastacidae) in Tasmania. Habitat, food, associated fauna and distribution. Australian Journal of marine and Freshwater Research 28: 95-103

Tasmania Magnesite NL, 2002, Arthur River Magnesite Project RL 8718 Annual Report for the Period April 2001 to March 2002 Tasmania Magnesite NL

Technical Advice on Water, 1999 Crest Magnesium Project: Water quality and water quality issues for Pitt & Sherry

The List, 2009, Tasmanian Geoconservation Database v6.0 (2008)

Thomas, N.M., 1981, Quarterly Report on Exploration Licence 43/70 North-Western Tasmania. Longworth and McKenzie Proprietary Limited, Mineral Holdings Australia Proprietary. Limited., EL43/1970 81-1663

Turner, N.J., 1993, Geological/Geomorphological Aspects of the Wilderness Societys September 1992 Proposal for a World Heritage Area in the North West Forests. UR1993_04

Williams, P. W., 1999, Report on the geoconservation values of the magnesite karst in northwest Tasmania Dept. of Geography, University of Auckland, Auckland, N.Z.

Wyatt, J. D., 1997, Summary report on the Arthur/Lyons River magnesite resource northwestern Tasmania. Geological Investigations Pty Ltd [TCR 99-4309].

Wyatt, J.D., 1997, Report Diamond Drill Investigation - RL 8717 and RL 8718, Arthur River Magnesite Deposit. Geological Investigations Proprietary Limited, Mineral Holdings Australia Proprietary. Limited., Tasmania Magnesite NL, RL17/1987, 99_4309

Additional literature reviewed for relevant data

Gazette, 2009 Commonwealth of Australia Gazette No. S212, Friday, 11 December 2009 http://www.ema.gov.au/portal/govgazonline.nsf/03375D69AE6A3516CA25768900087DD7/$file/S212.pdf

ACF - The Tarkine in Brief http://www.acfonline.org.au/news.asp?news_id=412 23/11/2009

Wetland threatening processes, Australian Natural Resources Atlas, Biodiversity Assessment – King http://www.anra.gov.au/topics/vegetation/assessment/tas/ibra-kin-wetland-threats.html 23/11/2009

Tarkine National Coalition, 2009, TNC - Welcome! - Tarkine Wilderness Protection in North West Tasmania http://www.tarkine.org/caves.php 23/11/2009

Tarkine wilderness Tasmania | Tarkine Trails http://www.tarkinetrails.com.au/the-tarkine%2023/11/2009

The Examanier, 1998, Crest's billion dollar hope FRAN VOSS 02 Dec, 1998 10:47 AM

Western Tasmania A Place of Outstanding Universal Value Proposed extensions to the Tasmanian Wilderness World Heritage Area Geoff Law - September 2009

Matthew Campbell-Ellis A multi-sector approach to developing sustainable competitive advantage in the Tarkine Applying a Regional Development Platform Method to develop Tarkine Regional Innovation Systems May 2008

Forestry Tasmania 2002, Tasmanian Karst Atlas v.2.0, GIS layer - superceded by v.3.0.

Clark, A 1998, New Mine for Magnesite Karst - Tasmania. NEWCAVES CHRONICLES No. 11, July 1998

Pemberton, M. 2007, A Brief Consideration of Geodiversity and Geoconservation, Michael Pemberton, Department of Primary Industries and Water, Tasmania

Coffey Mining, 2009, Arthur-Lyons River Magnesite Project Competent Persons Report prepared on behalf of Beacon Hill Resources PLC, Astaire Securities PLC MINEWPER00714AC

Ford, D and P. Williams 1989 Karst Geomorphology and Hydrology, Chapman and Hall, pp 601

Waltham A.C. and P.G. Fookes, 2003, Engineering classification of karst ground conditions Quarterly Journal of Engineering Geology and Hydrogeology 2003; v. 36; p. 101-118

Additional unpublished reports not reviewed

Household, I. Calver, C and Sharples, C.S. Magnesite karst in northwest Tasmania – geology, geomorphology and hydrology. Report to Tasmanian Department of State Development.

HECEC Australia Pty Ltd (1999) Keith and Arthur Rivers: Hydrology and Flood Frequency Report prepared for Pitt and Sherry

Additional public literature not yet reviewed

Gray, Lyndsey (Ed), 1999 Tasmania Underground Series No. 2: The Magnesite Caves of Keith River Savage River Caving Club