

MARDIE PROJECT
GROUNDWATER MONITORING &
MANAGEMENT PLAN
VOA

COMPANY NAME:	Mardie Minerals Pty Ltd (ACN 152 574 457) a wholly owned subsidiary of BCI Minerals Limited (ACN 120 646 924)
STATEMENT No & DATE	(Under assessment)
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This document has been prepared in accordance with *Instructions on how to prepare and Environmental Protection Act 1986 Part IV Environmental Management Plans* (EPA, 2020), and with reference to the associated guidance.

EXECUTIVE SUMMARY

Proposal Name	Mardie Project
Proponent Name	Mardie Minerals Pty Ltd (ACN 152 574 457) a wholly owned subsidiary of BCI Minerals Limited (ACN 120 646 924)
Ministerial Statement No.	<i>Under assessment</i>
Purpose of the EMP	To ensure that indirect impacts to vegetation, ecosystems and pastoral use as a result of changes to groundwater regimes are minimised.
Key environmental factor/s, outcome/s and objective/s	Inland Waters: To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.
Condition clauses	<i>To be issued</i>
Key components in the EMP	Groundwater monitoring network and additional baseline investigations. Groundwater recovery systems.
Proposed construction date	July 2021
EMP required pre-construction?	Yes

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GLOSSARY AND ABBREVIATIONS

Term	Definition/Description
AHD; mAHD	Australian Height Datum; broadly equivalent to mean sea level
AS/NZS ISO14001	Australian Standard for Environmental management systems - Requirements with guidance for use (2016)
BCH	Benthic Community Habitat
BCI	BCI Minerals Limited
Brine	A high concentration of salt in water, from seawater (3.5% salt) to full saturation (typically 26% salt)
Concentrator Pond	The initial series of ponds where seawater is evaporated close to the level of saturation where salt (halite) precipitates
CPT	Cone penetration test
Crystalliser Pond	Ponds where brine is further evaporated to result in the precipitation (crystallisation) of halite and other salts, including SOP
DCP	Deep Cone Penetrometer
DEM	Digital elevation model; a computer simulation of the landscape topography
DWER	Department of Water and Environment Regulation (WA).
EP Act	<i>Environmental Protection Act 1986</i> (WA)
EPA	Environmental Protection Authority (WA)
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i> (Cth.)
ERD	Environmental Review Document
Halite	Sodium chloride salt
KM	Kuruma Mardudhunera People
KTMS	Kainite type mixed salt
Mardie Minerals	A proprietary company (ACN 152 574 457) wholly controlled by BCI Minerals Limited
mbgl	Metres below ground level
mg/L	Milligrams per litre
mRL	Metres Relative Level (elevation, measured in metres above height datum)
MSL	Mean Sea Level
Mtpa	Million tonnes per annum
NaCL	Sodium chloride (salt, halite)
Potash	A salt that contains potassium (element symbol K) in a water-soluble form
PPT or ppt	Parts per thousand; equivalent to grams per litre
SOP	Sulfate of Potash
TDS	Total dissolved salts
YM	Yaburara Mardudhunera People

1 CONTEXT, SCOPE AND RATIONALE

This Groundwater Monitoring and Management Plan (GMMP) describes the monitoring and management measures to be implemented by Mardie Minerals Pty Ltd (Mardie Minerals) during the construction and operation of the Mardie Project (the Proposal) to ensure that residual impacts to groundwater dependent ecosystems and other vegetation are minimised.

1.1 PROPOSAL

The Proposal is a greenfields high quality salt and sulphate of potash (SoP) project and an associated export facility at Mardie, approximately 80 km south west of Karratha, in the Pilbara region of Western Australia (WA) (Figure 1).

The Proposal is an evaporative solar project that utilises seawater to produce raw salts as a feedstock for dedicated processing facilities that will produce high purity salt, fertiliser grade SoP product, and other commercial by-products. Production rates of 4.4 million tonnes per annum (Mtpa) of salt (NaCl), 120 thousand tonnes per annum (ktpa) of SoP are being targeted, sourced from a 150 gigalitres per annum (GLpa) seawater intake. To meet this production, the following infrastructure will be developed:

- Primary seawater intake pump station;
- Concentrator ponds;
- Processing facilities and stockpiles;
- Causeway, trestle jetty and transshipment berth / channel;
- Bitterns disposal pipeline and diffuser;
- Drainage channels and flood protection;
- Administration buildings;
- Accommodation village;
- Access / haul roads;
- Desalination plant for fresh water production;
- Boat launching facility and port stockyard; and
- Associated infrastructure including: power supply, communications, workshop, laydown, landfill facility, sewage treatment plant.

The Development Envelopes and indicative layout of the Proposal are shown in Figure 2 and Figure 3, respectively. The operating life of the Mardie Project is expected to be greater than sixty years.

1.1.1 Pond characteristics

The two priority attributes of the Proposal that are of importance to this GMMP are the predicted salinity (expressed in this document as Electrical Conductivity, or EC, and reported as micro-Siemens per centimetre, which is abbreviated to $\mu\text{S}/\text{cm}$) and typical water level of each pond. Figure 4 maps out the salinity and water level relative to the natural surface for the ponds, as well as for Mardie Pool.

1.1.2 Project schedule

Table 1 shows the development schedule for those activities relevant to the GMMP.

Table 1: Project schedule (indicative)

Project Milestone	Target
Pond construction (Ponds 1-4)	July - Sep 2021
Pond construction (Ponds 5-7)	Oct - Dec 2021
Pond construction (Ponds 8-9)	Jan 2022
Filling of ponds 1-3	Feb - June 2022
Crystalliser construction	April 2022 – July 2023
Filling of ponds 4-9	July – Dec 2022

Project Milestone	Target
Filling of crystallisers	Mar 2023 – Mar 2024

1.2 KEY ENVIRONMENTAL FACTOR

The key environmental factor relevant to this GMMP is Inland Waters. The EPA (2018) defines the factor “Inland Waters” as:

The occurrence, distribution, connectivity, movement, and quantity (hydrological regimes) of inland water including its chemical, physical, biological and aesthetic characteristics (quality).

The EPA objective for Inland Waters is “to maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected” (EPA, 2018). The environmental values that may be impacted by changes to hydrological regimes and the quality of surface and groundwater are groundwater dependent vegetation and ecosystems, as well as vegetation adjacent to ponds that may be sensitive to groundwater mounding.

The Proposal activities that may affect these factors are described in Table 1.

Table 2: Proposal activities that may affect Inland Waters

Key Environmental Factor: Inland Waters	
Proposal activities that may affect this factor	<ol style="list-style-type: none"> 1. Operation of concentration and crystallisation ponds. 2. Stockpiling of salt products. 3. Bitterns storage dams and pipelines.
Environmental values that may be affected	<ul style="list-style-type: none"> • Benthic communities and habitats (BCH), including mangrove, algal mat and samphire communities, as well as the biological systems that they support. • Mardie Pool and associated vegetation and fauna. • Groundwater-dependent terrestrial vegetation growing adjacent to the ponds. • Livestock watering bores.
Ecosystem health condition / sensitive component of the key environmental factor	<ul style="list-style-type: none"> • Groundwater salinity. • Groundwater levels.
Existing and/or potential uses	Pastoral Station (cattle).

1.3 SCOPE AND ASSOCIATION WITH OTHER MANAGEMENT PLANS

This management plan is designed to align with other Proposal management plans and avoid repetition. To that extent, plan provides monitoring and management actions for impacts to groundwater, that have been developed to be closely associated with the monitoring and management actions specified within the Mardie Benthic Communities and Habitat Monitoring and Management Plan (BCHMMP).

1.4 CONDITION REQUIREMENTS

The Ministerial Statement for the Proposal has not yet been issued, therefore this section will be completed once the conditions are released.

1.5 RATIONALE AND APPROACH

1.5.1 Management objectives

The management objectives for groundwater are:

1. Ensure that indirect impacts to vegetation and ecosystems as a result of changes to groundwater regimes are minimised; and

2. Ensure that indirect impacts to groundwater resources used by Mardie Pastoral Lease as a result of changes to groundwater regimes are minimised, or otherwise made good to the satisfaction of the Leaseholder.

1.5.2 Study findings

Groundwater, geotechnical and vegetation studies undertaken by Mardie Minerals over the Proposal area, as well as groundwater studies over the wider region by other parties, have been reviewed by AQ2 (Appendix 1). The main points of the review are summarised below.

Data review

Documents and data relevant to the environmental assessment of the Mardie Project were reviewed as background to this desktop groundwater risk assessment, to summarise key information and findings relevant to groundwater receptors and saline seepage from crystallisation ponds. This summary is provided in Table 3.

Table 3: Relevant findings of AQ2 data review

Report	Key Findings
<i>DFS Factual Geotechnical Report</i> (CMW Geosciences 2020)	Soil permeability was measured via in situ falling head tests and laboratory tests on reconstituted samples. All tests measured permeability on a relatively small scale local to the bore and hence may not represent bulk soil permeability.
<i>Seepage Model Results and Potential Environmental Impacts</i> (Soilwater Group 2019)	Seepage modelling is based on the original Eastern Crystallisers location 250m north of Mardie Pool (since moved to 1000m east). Modelling indicates that downward seepage rate of hypersaline water could vary from 1m/2years to reaching the calcarenite aquifer in 6 months, depending on estimated permeability and seepage rate. Suggested that monitoring bores be installed and seepage capture bores may be required if seepage is detected.
<i>Detailed flora and vegetation survey for the Mardie Project</i> (Phoenix Environmental Services 2020)	34 significant flora species which may potentially occur within the study area: <ul style="list-style-type: none"> • One Threatened Flora species • 33 State-listed Priority Flora Recognised groundwater dependent species identified as associated with Mardie Pool.
<i>"Groundwater enhances aboveground growth in mangroves"</i> (Hayes et al. 2018)	Mangroves use non-saline groundwater and rainwater when available rather than saline water sources. Groundwater flows into the intertidal stimulates organic matter accumulation in above-ground biomass suggesting the availability of non-saline water sources, such as groundwater and rainfall, are important for the growth and productivity of mangrove forests.

Conceptual geological models

The geological model is based on published regional geological and hydrogeological reports, supplemented by recent geotechnical investigations carried out to support the Mardie Project. Soilwater Group (2019) and CMW (2020) provide differing conceptual geology models.

The geological model proposed by Soilwater Group (2019) postulates that the project area is generally underlain by a moderately to highly calcreted shelly calcarenite layer, which dips in a westerly direction (Figure 5). The supratidal flats in the west of the Proposal area occur on top of the calcarenite layer and have formed by prolonged deposition of terrestrial and marine sediments. Depending on the rainfall intensity within the various creek catchments, and the distance from the discharge point, the sediments making-up the Supratidal Flats vary from heavy clays to sands to gravels, with each deposition event interfingering with the last deposition event. To the east of the Supratidal Flats, the calcarenite layer is unconformably overlain by Pleistocene to Holocene aeolian, alluvial and colluvial sediments forming the current surface of the Onslow Land System.

The geological model developed by CMW Geosciences is based on recent geotechnical investigations including a large number of shallow test pits and CPT sites, combined with a small number of widely spaced deeper boreholes. The model proposes a series of six generic sub-horizontal layers, most of which are sub-divided due

to varying composition or geotechnical properties. Not all units are present across the entire site. In order of depth these layers are:

- Unit 1- Surficial clayey sandy gravel
- Unit 2a – Sand and gravel with fines
- Unit 2b – Sand with shells and gravel, medium dense to dense
- Unit 3a – Clay/gravelly clay, very soft to soft
- Unit 3b – Clay/ sandy clay, firm to stiff
- Unit 4a – Clayey gravel/ gravelly clay, dense, cemented in places
- Unit 4b – Coral with sandy clay
- Unit 5 – Very low to medium strength rock with pockets of stiff soil
- Unit 6a – Calcareous conglomerate/ impure calcilutite, low to high strength
- Unit 6b – Impure calcilutite, high to very high strength

Interpreted distribution of these geological units across the site is described by cross sections in CMW(2020). Figure 6 provides a representative geological cross section beneath evaporation ponds (after CMW 2020).

Near the Eastern Crystalliser ponds and Mardie Pool, CMW(2020) proposes the existence of 0.5 to 1.5m of clayey sand (Units 2+3b) over clayey gravel/ gravelly clay (Unit 4). Unit 4 appears to correlate with Soilwater Group's "Calcarenite" layer (Figure 2) which is depicted to extend to basement. Generally, the two models can be considered equivalent near Mardie Pool in that there are no significant differences which may have implications for groundwater flow.

Soilwater Group (2019) proposes the calcarenite unit dipping below the sediments of the supratidal flats to the west, with interfingering alluvial layers overlying. CMW proposes that Units 4a and 5 are continuous and sub-horizontal beneath the evaporation ponds and further to the west. The CMW model is the favoured option for analysis of groundwater flow from beneath evaporation ponds towards the tidal creeks.

Groundwater quality

The quality of groundwater at Mardie is summarised below through several sources. Preston Consulting (2020) states:

- Groundwater within the Supratidal Flats is generally of neutral pH, whilst the groundwater in the calcarenite aquifer is more alkaline, likely reflecting the presence of the calcarenite. The majority of the alkalinity is in the form of Bicarbonate, with minor Carbonate alkalinity;
- Groundwater within the Supratidal Flats is hypersaline, with 2 – 5 times higher salinity than seawater; likely due to its low permeability and resulting evaporative concentration of salts.
- The groundwater in the calcarenite aquifer is brackish to saline with better quality being associated with the Mardie-pool creek line (likely to result from recharge);
- All groundwater is generally classified as NaCl type, although groundwater in the Supratidal Flats may also be considered CaSO₄ type, likely reflecting the formation of gypsum;
- All groundwater in the development envelopes has low to very low nutrient levels; and
- All groundwater in the development envelopes has low levels of measured metals, although some bores contain elevated Zn and minor Cd and Cu.

A landholder bore census was completed by AQ2 in November 2019 including bores relatively close to the crystallisers and Mardie Pool. Bores nearest to Mardie Pool contained water which was brackish (5,800 to 7,700 µS/cm) and slightly alkaline (pH 8.0 to 8.5). Water in bores at the southern end of the project area and closer to the coast was more saline, however still rated as brackish (9,000 to 10,400 µS/cm; pH 8.3 to 8.6). New bores drilled approximately 3 km to the south of Mardie Pool during 2019 yielded 1-2 L/s, indicating some permeability in the shallow aquifer.

Water quality data was acquired by BCI Minerals in April 2019 from a large number of test pits and CPT holes covering the extent of the evaporation ponds on the supratidal flats. Test pit sites near to tidal creeks on the western side of the proposed evaporation ponds produced groundwater in the range 50,000-80,000 µS/cm. This is generally slightly higher than EC for sea water (50,000 µS/cm) and may represent the combination of evapotranspirative concentration and some flushing. Salinity was much higher at test pits further inland on the broad supratidal flats within the bounds of the proposed evaporation ponds. EC here was generally 3-4 times that of sea water (up to 210,000 µS/cm) presumably due to evapo-concentration of stranded sea water and the

absence of regular flushing. These areas are inundated only by peak spring tides, storm surges from ocean side and by flooding during cyclonic events.

Seawater interface

Previous investigations at Mardie have indicated that the sea water interface (SWI) is well inland of the coast. Haig (2009) proposes, from bore water sampling, that the SWI is present east of Mardie Pool in the vicinity of the Secondary Crystalliser. Airborne EM data (Fugro 2010, AQ2 2019) indicates higher conductivity at depths greater than 10 mbgl to the east of Pond 5 which coincide with the boundary of Haig (2009) (Figure 7). It is possible that the SWI is present below and east of the evaporation ponds, however a bore installed in 2019 east of Flynn's bore to 40m depth has provided water at salinity levels suitable for domestic use.

Groundwater Levels and Flow

Figure 9 provides estimated groundwater level across the entire site and indicates that groundwater flow is generally towards and perpendicular to the coastline. Flow gradient is relatively steep beneath the elevated land to the west of the project. The gradient reduces significantly on the flats beneath the proposed evaporation ponds to approximately 2 m in 8 km, or 0.00025. Groundwater passing beneath the evaporation ponds will generally flow directly towards the coast, with local deviations toward tidal creeks where those creeks intercept the SWL. Beneath the evaporation ponds and primary crystalliser across the expanse of the supratidal flats the SWL is generally less than 1m below surface.

Mardie Pool

Mardie Pool is noted to be the only permanent waterhole within the Mardie Project development envelope (Figure 2). Located 3km west of Mardie Homestead, it is seasonally 300-500 m long and 1-20 m wide (Figure 8). Surface water was sampled from the pool in February 2020, and found to be fresh, with EC of 370-960 $\mu\text{S}/\text{cm}$.

The main conservation concern is for Mardie Pool and its associated riparian vegetation. Some of the planned crystallizers are located on sandy substrates with connection to a calcarenite layer, which is more porous than other sedimentary layers and may be hydrologically connected to Mardie Pool. Saline discharge from the ponds to Mardie Pool has the potential to raise the salinity of the groundwater and/or the surface water in the Mardie Pool environment and increase stress on the plant species growing there.

The tolerance to soil water salinity is likely to be variable among the species in the riparian zone of Mardie Pool. The two species most likely to be adversely affected by an increase in salinity in either the soil water or surface water are *Typha domingensis* and *Melaleuca argentea*. Previous studies on *Typha domingensis* indicate that the species is intolerant of large changes in the salinity regime, but the response by *Melaleuca argentea* is uncertain.

Coastal vegetation

Figure 10 displays the mapped extent of mangrove species and algal mats at Mardie (Phoenix, 2020). Proposed ponds are positioned close to, or impinge upon, mangrove habitat at Evaporation Ponds 1 and 2 in the south, and near the primary crystalliser ponds in the north. Evaporation Ponds 3 to 8 are generally greater than 1 km from mangrove areas. Ponds also are proposed to be constructed across large areas of land mapped as algal mats, with remaining areas of algal mat coverage existing to the immediate west of Ponds 2 to 8.

1.5.3 Key assumptions and uncertainties

Key assumptions and uncertainties that have been identified to date are:

- The hydrogeological model lacks certainty on groundwater conditions in the deeper substrates, particularly to the west of the project.
- It is assumed that changes to groundwater levels and quality can be detected and responded to effectively before an ecological impact occurs.
- The level of reliance on, or sensitivity to, 'fresh' groundwater by the various benthic primary producer communities at Mardie, including mangroves, samphire wetlands and algal mats, over various timeframes is not known with certainty.
- The ecological water requirements of Mardie Pool are not known with certainty.
- The extents, severity and impact on vegetation of potential groundwater mounding from the ponds and stockyard is not able to be predicted, owing to the scale of the project and surrounding substrate materials.

- The potential for groundwater in underlying calcareous sediments (eg calcarenite) to become saline, impacting beneficial uses, has only been estimated.
- The action triggers provided in this GMMP are preliminary only.
- It is assumed that brine losses to the environment as seeps and leaks will diminish over time, due to geological and biological processes reducing infiltration rates through the clay floors and walls.

The strategies in place to address these uncertainties are listed in Table 4.

1.5.4 Rationale for choice of indicators and/or management actions

The indicators chosen for the GMMP are linked directly to the plan's management objectives and align with the environmental risk pathways.

The management actions that will be triggered by the results of the monitoring program are based on reliable techniques that are known to achieve the required outcomes in a timely manner, and whose secondary impacts can be managed appropriately.

Table 4: Strategy to address identified knowledge gaps and verify assumptions

Item	Assumption/ Uncertainty	Strategy to address uncertainty	Timing
1.	The hydrogeological model lacks certainty on groundwater conditions in the deeper substrates, particularly to the west of the project.	<ul style="list-style-type: none"> Installation of bores to enable monitoring of the vertical distribution of salinity near mangrove stands, algal mats and samphire communities to determine water quality and the existence (or not) of fresh groundwater flow through the root zones. This may also assist in locating the seawater interface. Hydraulic testing programme to determine in-situ permeability of gravelly clay layers and potential for transportation of hypersaline seepage from the ponds to BC and Mardie Pool. Install multiple monitoring bores (screened within the rooting depths) and surface samplers along lateral BCH transects established as part of the BCHMMP. Intensive monitoring over the first 2-3 years will characterise the surface and groundwater salinity and inundation/level regimes. Subsequent monitoring will align with the quarterly BCH condition monitoring program. 	Bores will be installed and testing completed prior to July 2021.
2.	Changes to groundwater levels and quality can be detected and responded to effectively before an ecological impact occurs.	<ul style="list-style-type: none"> Complete 3-D density-dependent flow modelling to inform and confirm the design and placement of groundwater monitoring bores, estimate worse-case seepage rates, and to test the efficacy of proposed management responses. Consideration of the effects of brine salinity on modelling (density-coupled modelling) of seepage and groundwater flow. 	Modelling will be completed and reported prior to the filling of Pond 4.
3.	The level of reliance on 'fresh' groundwater by the various benthic primary producer communities at Mardie, including mangroves, samphire wetlands and algal mats over various timeframes is not known with certainty.	<ul style="list-style-type: none"> Ensure the groundwater investigation and monitoring network is capable of providing sufficient information to quantify the use of fresh groundwater by BCH, so that response triggers can be optimised to suit the GMMP's objectives. 	Prior to the filling of Pond 4.
4.	The ecological water requirements of Mardie Pool are not known with certainty.	<ul style="list-style-type: none"> Investigate the true groundwater dependence and salt tolerance of the various vegetation species surrounding Mardie Pool, including <i>Typha domingensis</i> and <i>Melaleuca argentea</i>. Use outputs in the development of triggers and thresholds in the GMMP. 	Prior to the filling of the crystallisers.
5.	The extents, severity and impact on vegetation of potential groundwater mounding from the ponds and stockyard is not able to be predicted with reliability, owing to the scale of the project.	<ul style="list-style-type: none"> Ensure the monitoring and investigations described in (2) include transects perpendicular to the ponds and stockyard. 	Bores will be installed and testing completed prior to July 2021.
6.	The potential for groundwater in underlying calcareous sediments (eg calcarenite) to become saline, impacting beneficial uses, has only been estimated.	<ul style="list-style-type: none"> Ensure the investigations and modelling described in (1) includes deep bores, including sites on the intertidal islands, which should also form part of the ongoing monitoring program. 	Bores will be installed and testing completed prior to July 2021.

Item	Assumption/ Uncertainty	Strategy to address uncertainty	Timing
7.	The action triggers provided in this GMMP are preliminary only.	<ul style="list-style-type: none"> Ensure the groundwater investigation and monitoring network is capable of providing sufficient information to quantify the use of fresh groundwater by BCH, so that response triggers can be optimised to suit the GMMP's objectives. 	Prior to filling of Pond 4.
8.	Brine losses to the environment as seeps and leaks will diminish over time, due to geological and biological processes reducing infiltration rates through the clay floors and walls.	<ul style="list-style-type: none"> This assumption may be able to be confirmed through the monitoring described above. Additional investigations would be required for ponds where seepage losses have become an issue. 	Ongoing. A precautionary approach will be taken until demonstrated otherwise.

2 EMP COMPONENTS

2.1 EXPANSION OF BASELINE INVESTIGATIONS TO ADDRESS KNOWLEDGE GAPS

Mardie Minerals will undertake and complete the additional works and studies listed in Table 4, in accordance with the timeframes specified. The outcomes of the studies will be used to revise this GMMP, as well as the BCHMMP, if relevant. The revisions to the GMMP will be reviewed by an independent hydrologist to ensure the EMP components adequately and correctly address the study outcomes, and are sufficient to achieve the GMMP's objectives with confidence.

2.2 INTEGRATED MONITORING PROGRAM

2.2.1 Approach

Mardie Minerals will implement the following groundwater management plan, which has been designed to integrate with the BCH monitoring program set out in the BCHMMP. The emphasis will be on the measurement and collection of electronic records (standing water level and electrical conductivity) that can be stored and managed as part of the Proposal's process control systems. Electronic measurements will be routinely verified and instruments calibrated in line with the manufacturer's guidance.

2.2.2 Monitoring locations

Generally, the monitoring bores will be established along transects, perpendicular to the ponds and crystallisers, and aligned towards the nearest sensitive receptors. These transects will align with BCH monitoring transects, where present. Bores will be nested to ensure the different aquifers are monitored separately. The spacing of bores along each transect will depend on the proximity to the pond, with spacing being smaller close to the wall, and increase with distance. Additional bores can be installed if a trigger event occurs, to increase the resolution of the groundwater data.

A series of control bores will also be installed to the south and north of the Proposal and will be monitored at the same frequency as the detection bores.

2.2.3 Schedule

Owing to accessibility issues associated with the intertidal flats, all monitoring bores will be fitted with conductivity- temperature-depth (CTD) loggers, that will take a measurement every 15-minutes¹. These loggers will be downloaded and checked monthly; however, key monitoring bores, including any where a groundwater trigger has been exceeded, will include telemetry, so groundwater indicators can be tracked in real-time.

2.3 MANAGEMENT RESPONSES

Trigger values for groundwater levels and conductivity are still to be finalised, using data collected from the investigations and baseline monitoring program described in Table 4. Preliminary triggers are provided in Table 5, but will be revised in consultation with relevant stakeholders, prior to the filling of Pond 4 (where pond salinity potentially exceeds groundwater salinity), and again prior to the filling of the crystallisers, which are considered a potential risk to Mardie Pool.

The management responses outlined in Table 5 are consistent with the GMMP's management rationale (section 1.5.4), and generally follow the process below:

- verify the monitoring records to confirm the validity of the trigger alert;
- increase the frequency and/or scope of monitoring;
- determine the cause of the trigger alert;

¹ Note that CTD loggers will also be installed in a number of above-ground locations and tidal creeks to maintain a record of tidal and storm surge water levels. Barometric loggers are included as part of the network (north and south).

- implement the appropriate management response – if the cause of the trigger alert is associated with a management response that has already been implemented, then a thorough review will be conducted to identify and resolve any issues; and
- ensure any potential impacts from the management response are avoided or minimise wherever possible (including the use of supplementation to ensure ecological or social water requirements are maintained).

Project management requirements related to the necessary monitoring and inspection of the integrity of the pond walls or the identification of excessive losses of brine through seepage are not included in this GMMP; however, should any such processes identify a potential issue or incident, the GMMP may need to be reviewed to ensure the management objectives are still able to be met.

3 ADAPTIVE MANAGEMENT AND REVIEW OF EMP

3.1 ADAPTIVE MANAGEMENT

Mardie Minerals is committed to improving environmental results and management practices throughout the implementation of the Proposal and therefore will use an adaptive management approach for this GMMP. Adaptive management practices will include:

- Annual review of monitoring data and information gathered;
- Annual evaluation of monitoring and management outcomes against management targets and the objectives of this GMMP; and
- Review of management actions throughout the implementation of the Proposal, and identification of potential new management measures and technologies that may be more effective.

3.2 REVIEW REQUIREMENTS

The GMMP will be reviewed annually through the construction phase and every two years during operation. It will also be updated based on review outcomes. The review will take into account whether management targets are being achieved or are likely to be achieved and will identify any updates required to realise the targets.

3.3 APPROVAL REQUIREMENTS FOR REVISED GMMP

This GMMP has been developed as part of the response to submissions that were made to the EPA. It is anticipated that the requirement for the GMMP will be included within the Ministerial Conditions for the Proposal. Therefore, formal approval will be sought from DWER for any significant revisions to the GMMP as a result of information gained through adaptive management.

3.4 ROUTINE AND REACTIVE MONITORING

The GMMP incorporates routine monitoring and management actions groundwater, to be carried out over various timelines outlined in Section 2.2. In addition to these routine events, reactive monitoring and management is proposed in response to a trigger event, which may include but is not limited to:

- a wall breach;
- a toxicant spill;
- monitoring data, including from other plans such as the BCHMMP, suggests a significant change; and
- after cyclones, if warranted.

Implementation of reactive monitoring and management will allow Mardie Minerals to respond to unforeseen potential impacts to groundwater and groundwater receptors and therefore have improved success in achieving the management objectives of the GMMP.

3.5 EARLY RESPONSE INDICATORS, CRITERIA AND ACTIONS

This GMMP includes early response indicators and actions regarding impacts to groundwater, with the intent of making design or operational changes as soon as practicable, before significant indirect impacts occur.

4 STAKEHOLDER CONSULTATION

4.1 RECORD-KEEPING

As part of its ESMS, the Company records and retains all stakeholder consultation activities, including meetings and written correspondence, as well as the resultant actions and/or outcomes. For consultation regarding matters addressed in the GMMP, an extract of those records is appended (Appendix 2), and will be updated with each revision of the plan.

4.2 EIA PROCESS

The Mardie Project has undergone a 10 week public environmental review (June - September 2020), in which a number of submissions relating to groundwater issues were received from the public and also from WA government departments, including DWER, DAWE and DBCA. As a consequence, this GMMP was prepared and subsequently distributed to those agencies for feedback and assessment. The main points arising from these processes have been included in the consultation outcomes table.

4.3 INCIDENTS, REPORTS AND COMPLAINTS

On-site incidents and near-misses that have the potential to impact on groundwater are captured through the project's ESMS, and responded to in accordance with system procedures. All complaints received from the public and other sources through the Company's formal grievance mechanisms are also managed as incidents, through the ESMS. Likewise, directions, warnings and appropriate recommendations received from government agencies, community organisations or arising from consultant's reports are all managed as incidents through the ESMS. This ensures that they are recorded, investigated and acted on, if necessary, with the outcomes of the process communicated to the originator.

4.4 GROUNDWATER USERS

The Mardie project is situated adjacent to a working pastoral lease, which relies on numerous groundwater bores to supply drinking water for stock (cattle). The Company maintains an access agreement with the station lease holder (PMPL), which includes regular stakeholder meetings.

Groundwater dewatering by Citic Pacific operations may result in impacts to vegetation or declines in groundwater levels, particularly in alluvial aquifers associated with the Fortescue River delta. The Company will consult with CP if such effects are noticed and cannot be attributed solely to the Mardie operations.

4.5 TRADITIONAL OWNERS

The Company maintains Cultural and Heritage Management Plans and formal working agreements with the YM and KM traditional owner groups. Through these avenues, operational matters and environmental monitoring information is reported to the members; who may also ask specific questions or raise concerns.

5 REFERENCES

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- EPA, 2020. *Preparation of Management Plans*
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- Fugro Airborne Surveys, 2010. *Interpretation of Airborne EM, Magnetic and Falcon Gravity Gradiometer Data, Pilbara Coast, Western Australia*. Prepared for Department of Water, Government of WA.
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- Hayes MA, Jesse A, Welte N, Tabet B, Lockington D, Lovelock CE. Groundwater enhances aboveground growth in mangroves. *J Ecol*. 2019;107:1120–1128. <https://doi.org/10.1111/1365-2745.13105>
- Phoenix Environmental Services, 2020. *Detailed flora and vegetation survey for the Mardie Project*. Prepared for BCI Minerals Ltd, June 2020.
- Preston Consulting, 2020. *Mardie Project Environmental Review Document (Final)*.
- Soilwater Group, 2019. *Mardie Salt and SOP Project – Seepage Model Results and Potential Environmental Impacts*. Prepared for BCI Minerals Ltd, November 2019.

TABLES

Table 5: Groundwater monitoring, triggers and management actions

EPA Factor and Objectives:	Inland Waters: To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.			
Outcomes:	No decrease in environmental condition (i.e. extent, diversity, structure, cover, resilience) of groundwater-dependent vegetation and ecosystems as a result of any impacts to groundwater from the Mardie Project.			
Key Environmental Values:	<ul style="list-style-type: none"> Mardie Pool and the groundwater-dependent ecosystems it supports. Intertidal benthic communities and habitats, namely samphire and mangrove vegetation. 			
Key Impacts and Risks:	<ul style="list-style-type: none"> Potential mounding and surface expression of groundwater inland of the ponds, impacting vegetation through waterlogging. Seepage from ponds and channels resulting in elevated salinity in underlying groundwater. Transport of hypersaline groundwater towards potential groundwater dependent ecosystems, such as Mardie Pool, coastal mangroves and algal mats (note that the monitoring and management of the condition of benthic communities and habitats is addressed in a separate environmental management plan). 			
Criteria	Response Actions	Monitoring	Schedule	Reporting
<p>Trigger:</p> <p>Groundwater levels exceed previous maxima over a continuous 96-hour period.</p> <p>Groundwater salinity exceed the 80%-ile value of the baseline or control site records.</p> <p>Threshold:</p> <p>Groundwater levels exceed previous maxima over a continuous 14-day period.</p> <p>Groundwater salinity exceed the 95%-ile value of the baseline or control site records.</p>	<p>Trigger level actions:</p> <ul style="list-style-type: none"> Investigate reasons for elevated groundwater levels. If associated with seepage salt ponds, develop interception and recovery program. Increase data recovery to 48-hourly. Advise as an incident and action trigger for BCHMMP. <p>Threshold contingency actions:</p> <ul style="list-style-type: none"> Implement groundwater recovery program. Increase data recovery to continuous telemetry. 	<p>Indicators: Groundwater SWL & EC.</p> <p>Methodology: Network of permanently deployed groundwater level/Temp/EC loggers.</p> <p>Location: Transects of nested piezometers aligned towards coast and focused on sensitive receptors (including control sites).</p>	<p>15-minute readings, downloaded fortnightly.</p>	<p>Agency reporting on exceedance of threshold criteria and contingency actions.</p> <p>Annual review to stakeholders, prepared by an appropriate, external consultant, and covering patterns and trends in monitoring results, and a review of exceedances and management responses.</p>

Criteria	Response Actions	Monitoring	Schedule	Reporting
<p>Trigger: Groundwater salinity exceed the 80%-ile value of the baseline or control site records.</p> <p>Threshold: Groundwater salinity exceed the 95%-ile value of the baseline or control site records.</p>	<p>Trigger level actions:</p> <ul style="list-style-type: none"> Investigate reasons for elevated groundwater levels. If associated with seepage salt ponds, develop interception and recovery program. Increase data recovery to 48-hourly. Advise as an incident and action trigger for BCHMMP. <p>Threshold contingency actions:</p> <ul style="list-style-type: none"> Implement groundwater recovery program. Increase data recovery to continuous telemetry. 	<p>Indicators: Groundwater SWL & EC.</p> <p>Methodology: Network of permanently deployed groundwater level/Temp/EC loggers.</p> <p>Location: Transects of nested piezometers aligned towards Mardie Pool (including control sites).</p>	15-minute readings, downloaded monthly.	As above
<p>Trigger: >80% of 'No effect level' for pond riparian vegetation (to be determined prior to filling crystallisers).</p> <p>Threshold: >'No effect level' for pond riparian vegetation. >5,000 $\mu\text{S}/\text{cm}$ (80% of 'No Effect Level' for cattle).</p>	<p>Trigger level actions:</p> <ul style="list-style-type: none"> Review groundwater monitoring record or groundwater recovery system operation. If groundwater recovery is not underway, implement a recovery program, including pond supplementation if necessary, to the satisfaction of DWER. <p>Threshold contingency actions:</p> <ul style="list-style-type: none"> Review and expand, if necessary, the groundwater recovery program. Abstract salty pool water from the base of the pool and supplement with appropriate quality groundwater. 	<p>Indicators: Pool SWL & EC.</p> <p>Methodology: Two permanently deployed groundwater level/Temp/EC loggers.</p> <p>Location: One logger in the deepest section of Mardie Pool, the other at the surface.</p>	15-minute readings, telemetered to operations.	

Table 6: EMP Changes

Complexity of changes: Minor revisions <input type="checkbox"/> Moderate revisions <input type="checkbox"/> Major revisions <input type="checkbox"/>				
Number of Key Environmental Factors: 1				
Date revision submitted to EPA:				
Proponent's operational requirement timeframe for approval of revision: < One Month <input type="checkbox"/> < Six Months <input type="checkbox"/> > Six Months <input type="checkbox"/> None <input type="checkbox"/>				
Reason for Timeframe:				
Item	Section	Page	Summary of change	Reason for change

FIGURES

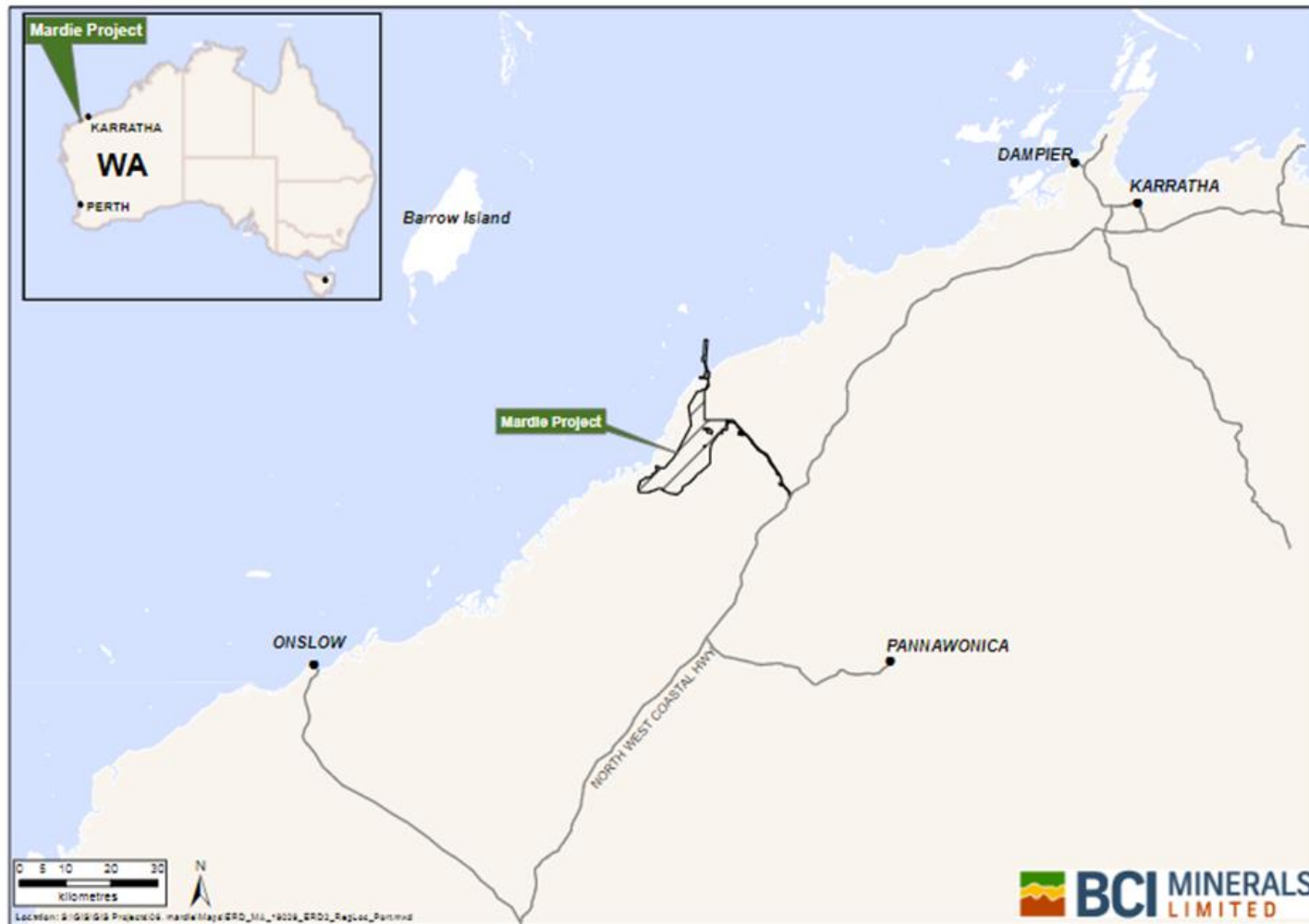


Figure 1: Regional Location of the Proposal

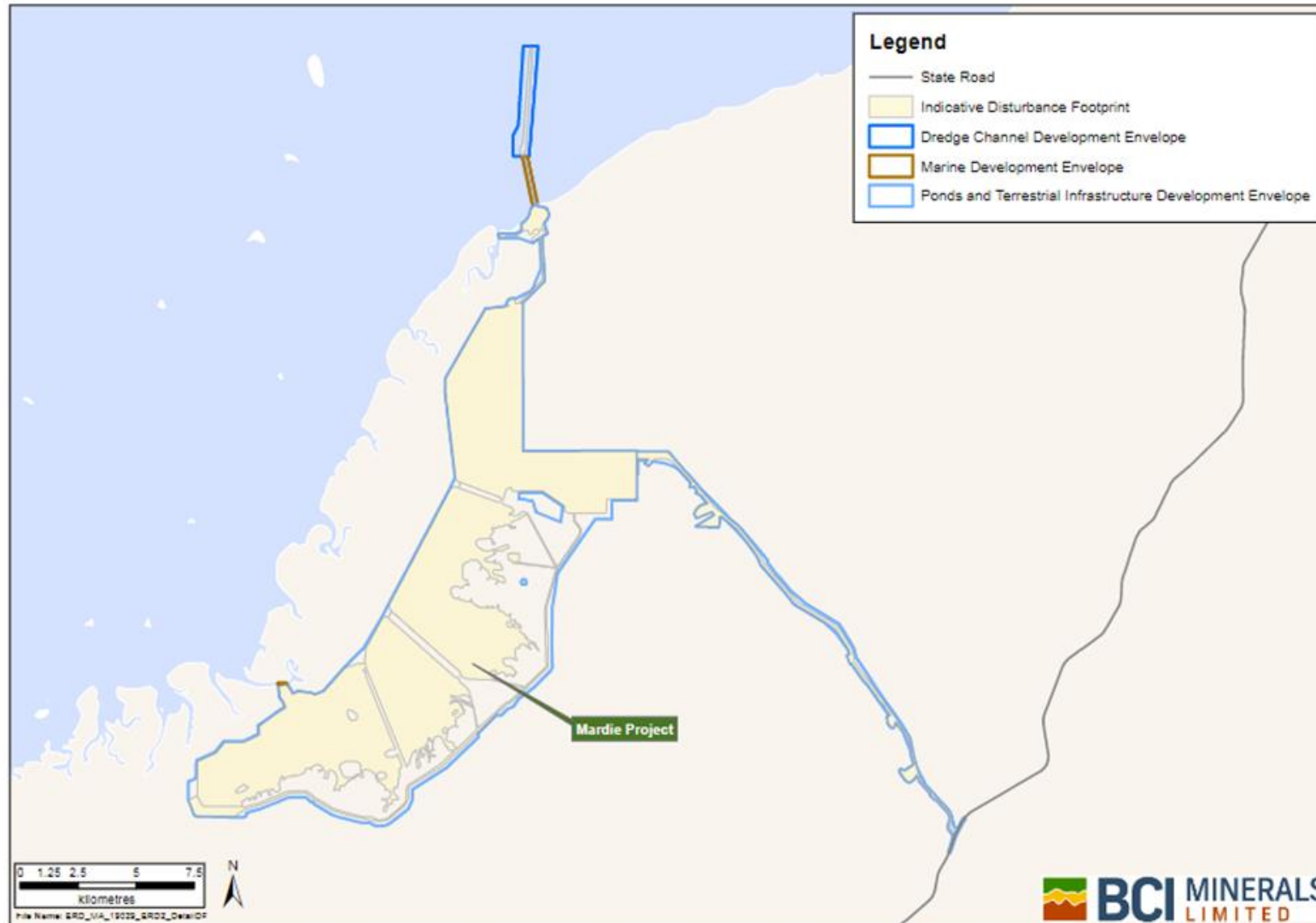


Figure 2: Proposal Development Envelopes and Indicative Disturbance Footprint

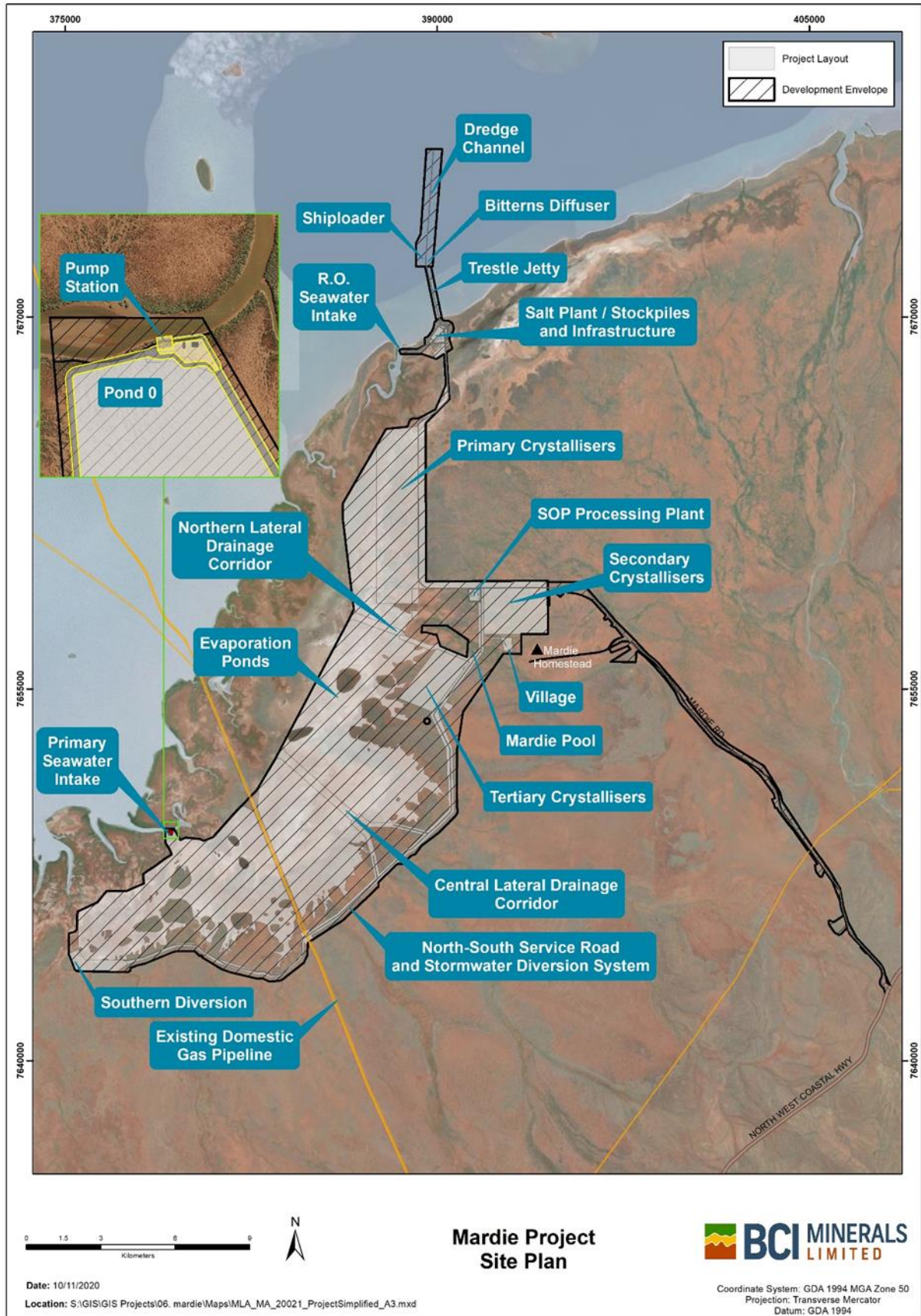


Figure 3: Indicative location of ponds and infrastructure

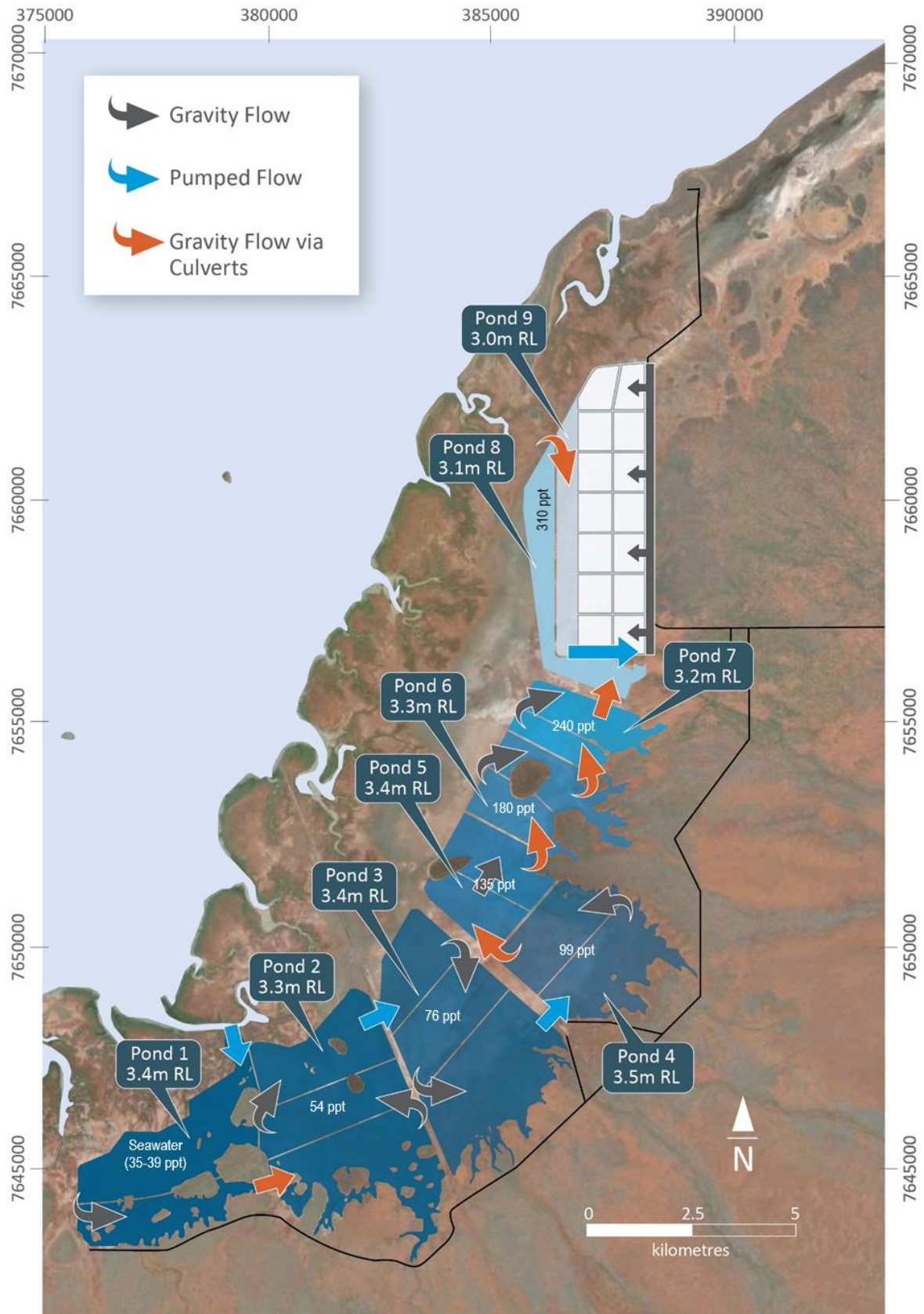


Figure 4: Target salinities and water levels for each pond

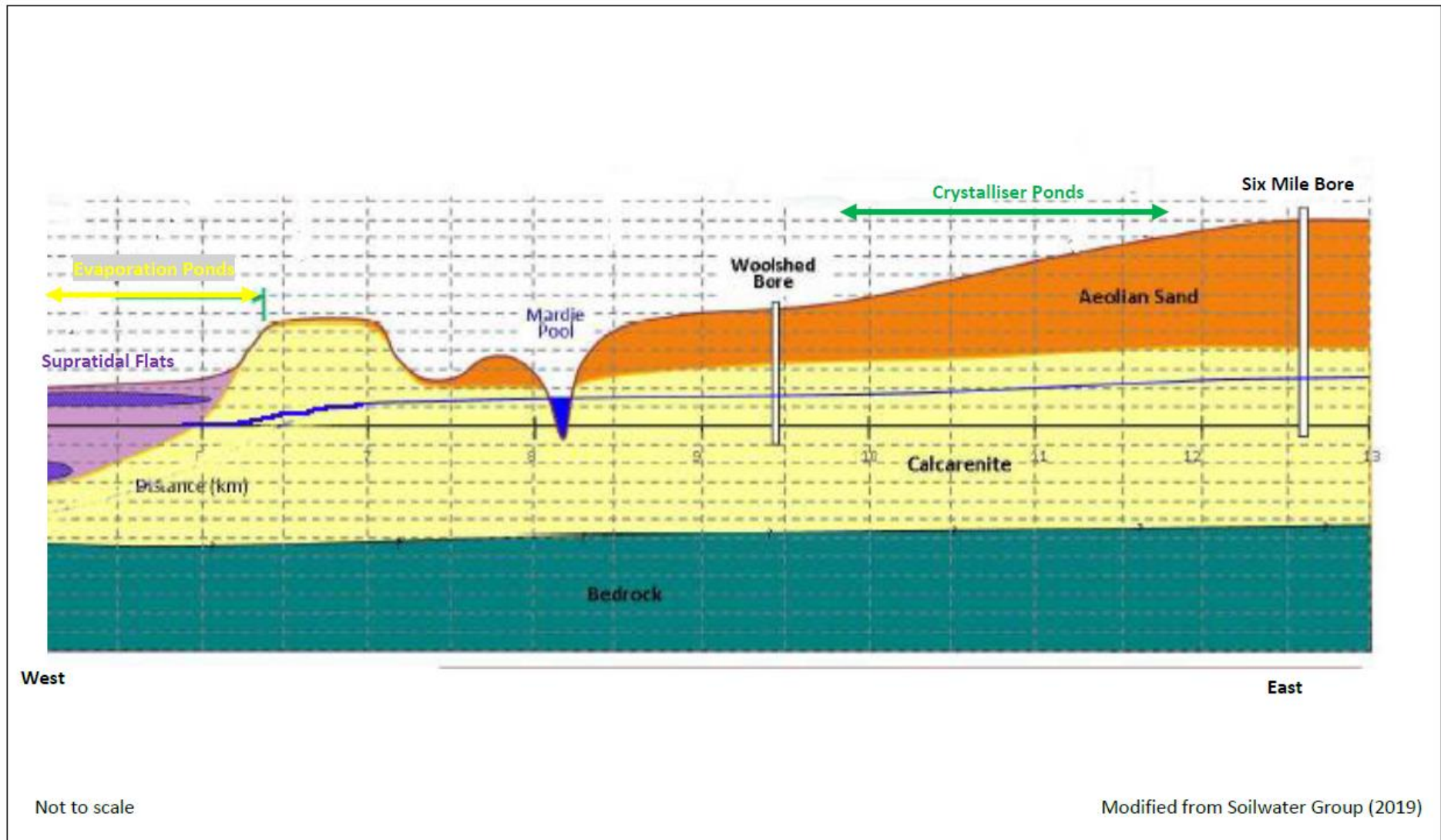


Figure 5: Conceptual Geological Profile – Mardie Pool Area

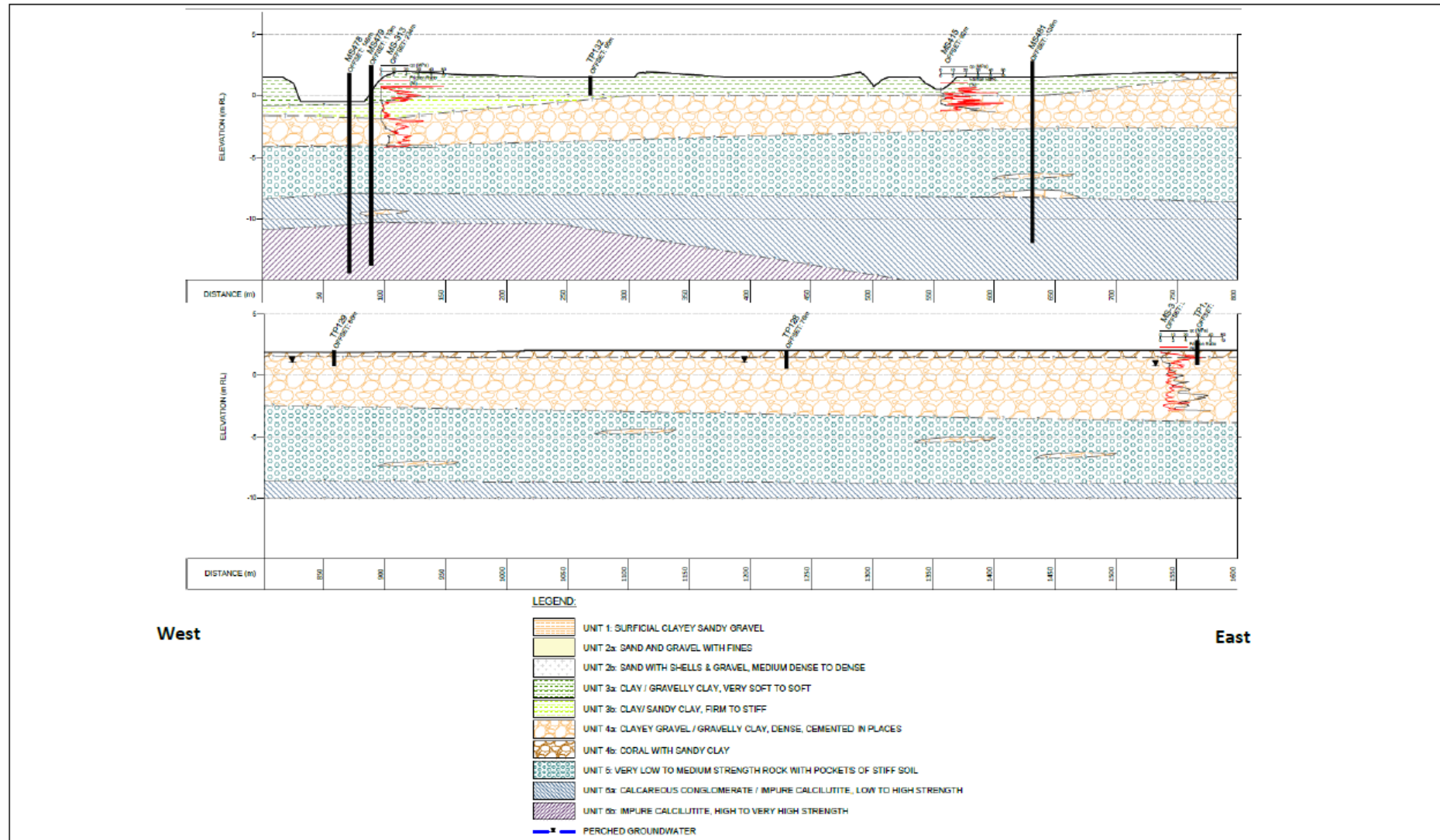


Figure 6: Representative Geological Cross Section Beneath Evaporation Ponds (after CMW 2020)

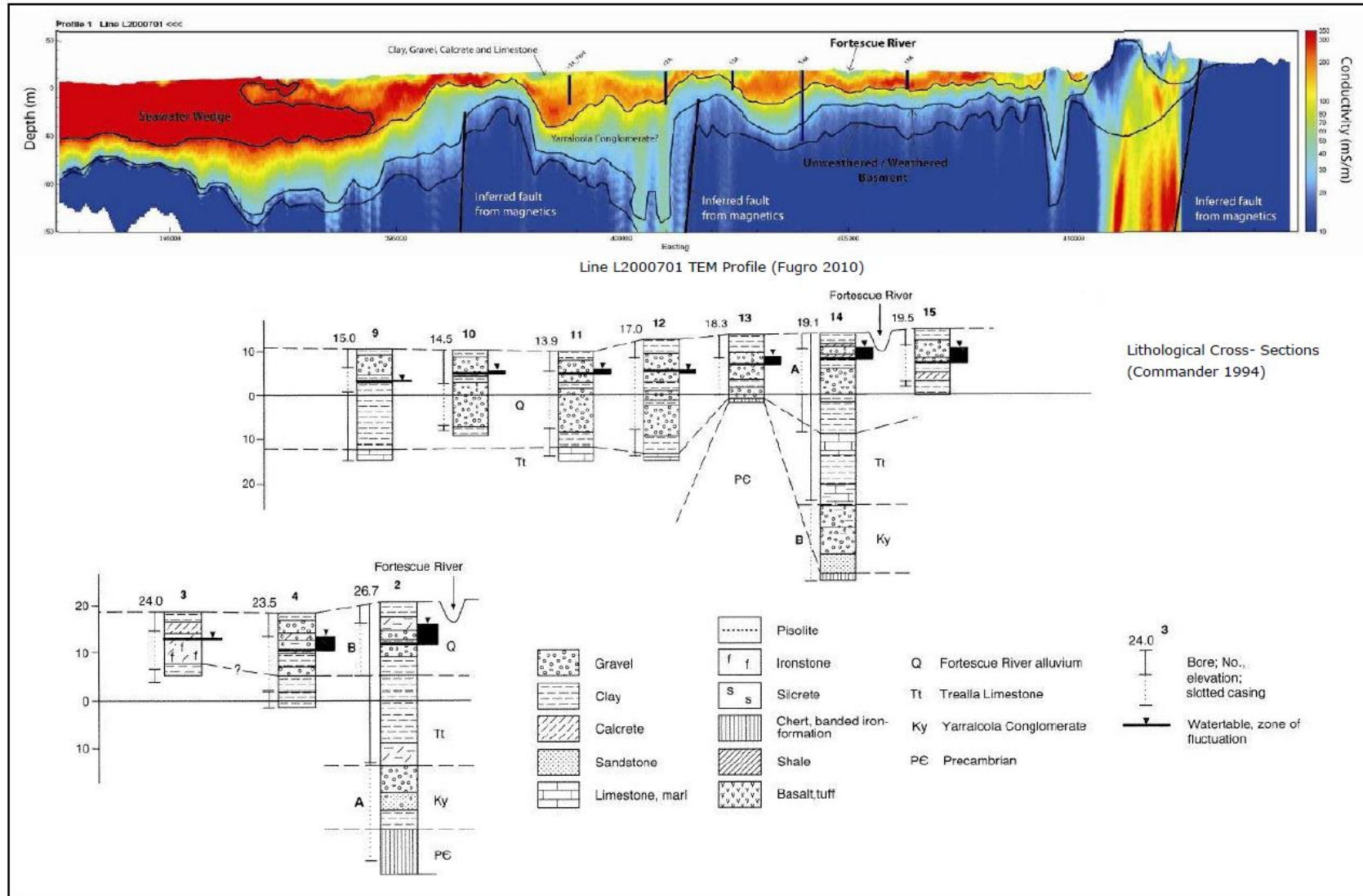


Figure 7: Conceptualisation of the Mardie seawater interface (after Haig, 2009)



Figure 8: Aerial photo of Mardie Pool (Oct, 2019)

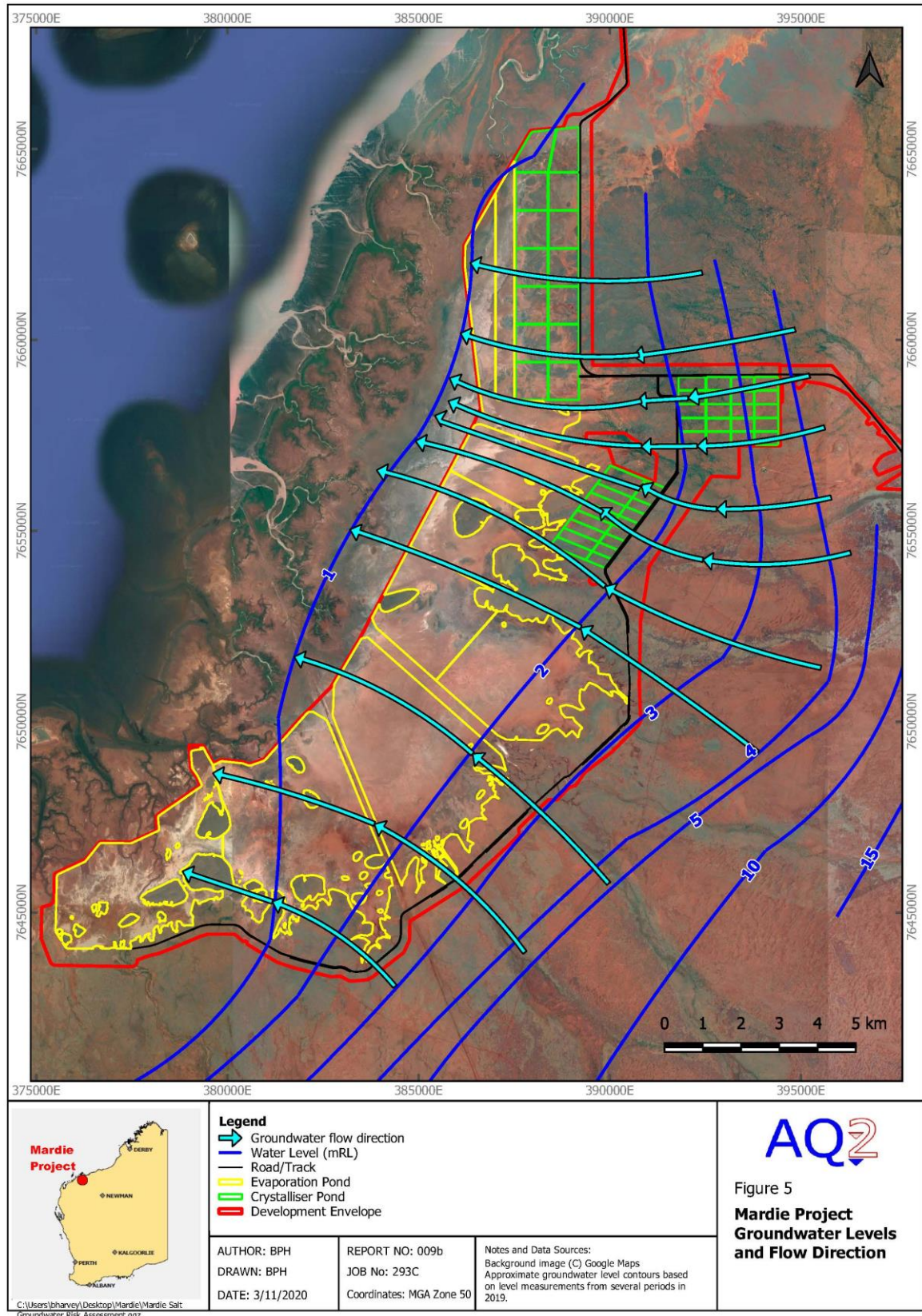


Figure 9: Simplified groundwater contours (AQ2, 2020)

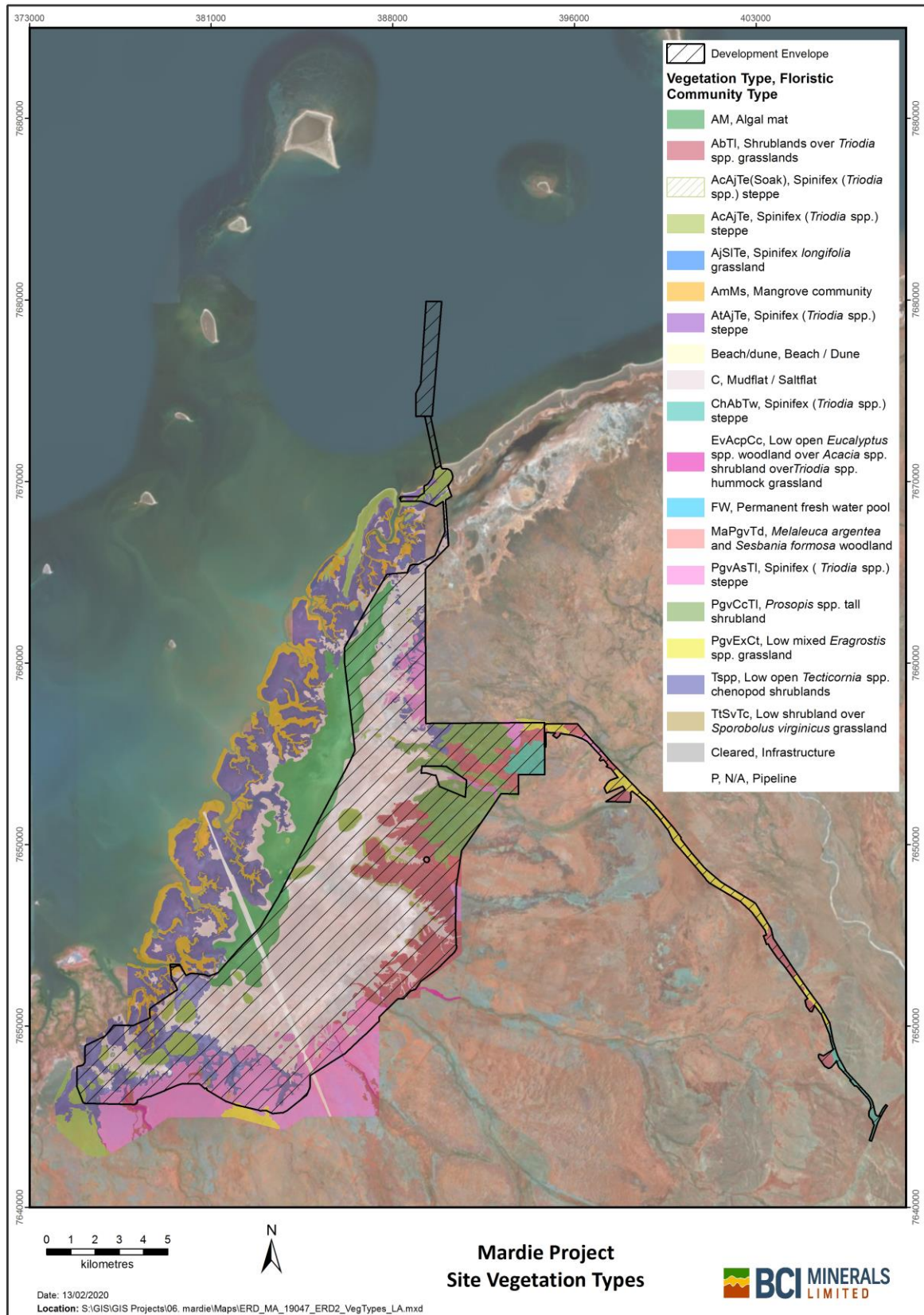


Figure 10: Vegetation map for the Mardie Project (Phoenix, 2020)

APPENDICES

Appendix 1: Groundwater Review and Action Plan (AQ2, 2020)

Appendix 2: Consultation Register

Appendix 3: Mardie Bore Register